SCIENCE, STATE-FORMATION AND DEVELOPMENT: THE ORGANISATION OF NUCLEAR RESEARCH IN INDIA 1938-1959

A Thesis
Presented to
The Academic Faculty

By

Jahnavi Phalkey

In Partial Fulfilment
Of the Requirements for the Degree
Doctor of Philosophy in History of Science and Technology

Georgia Institute of Technology

December 2007

SCIENCE, STATE-FORMATION AND DEVELOPMENT:
THE ORGANISATION OF NUCLEAR RESEARCH IN INDIA
1938-1959

September 12, 2007

John Krige (Advisor)
Kranzberg Professor
School of History, Technology and Society
Georgia Institute of Technology
Atlanta

Alice Bullard
Associate Professor
School of History, Technology and Society
Georgia Institute of Technology
Atlanta

Hanchao Lu
Associate Professor
School of History, Technology and Society
Georgia Institute of Technology
Atlanta

Steven Usselman
Associate Professor
School of History, Technology and Society
Georgia Institute of Technology
Atlanta

Itty Abraham (External examiner)
Director and Associate Professor
Centre for South Asia Studies and School of Government
University of Texas at Austin
Austin

ACKNOWLEDGEMENTS

I want to thank my supervisor John Krige, in the first instance for making a historian out of a social scientist, and then again, for our discussion on how durable politics can be accomplished through historical scholarship. I am also grateful to him for his confidence in the importance of my research. Alice Bullard has given me intellectual support through the years and I wish to thank for her continuing belief in my work. I am also thankful to Bruce Hevly, for his kind generosity in spending extensive time discussing my regrettably incomplete drafts during his sabbatical year in Trondheim.

Research on this thesis was made possible through two major grants: a Junior Research Fellowship from the American Institute of Indian Studies (2003-2004) for research in India and a Dissertation Research Improvement Grant from the National Science Foundation (2005-2007) for research in the United States and Europe. Research grants from the California Institute of Technology Archives, Centre for the History of Physics at the American Institute of Physics, Niels Bohr Archives at the Institute for Theoretical Physics, Copenhagen, Denmark, and the Department of History, Norwegian University of Science and Technology, Trondheim, Norway, have made possible further archival research.

This thesis has travelled far too much. I would like to thank the following institutions for hosting my work: Centre for Studies in Social Sciences, Calcutta, India (2003-2004), Prof. Hans-Jörg Rheinberger and Department III at the Max Planck Institute for the

History of Science, Berlin, Germany (Summer 2004) and finally Prof. Håkon With Andersen and the Department of History at the Norwegian University of Science and Technology, Trondheim, Norway (2004-2007).

Many have helped my work beyond the call of duty. I express my deep-felt gratitude to the archivists who have provided indispensable help and support. I am grateful to Anil Kakodkar, Chairman, Atomic Energy Commission of India, for access to documents relating to the meeting of August 1964. I am grateful to R. K. Ramanathan in Bangalore for kindly sharing with me his father's (R. S. Krishnan) papers and photographs. Late Santimay Chatterjee and Enakshi Chatterjee, Calcutta, Indira Chowdhury, Tata Institute of Fundamental Research, Bombay, David DeVorkin, Air and Space Museum, Smithsonian Institution, Washington DC, Deepak Kumar and Ravi Shukla, Jawaharlal Nehru University, Delhi, Atri Mukhopadhyay, Saha Institute of Nuclear Physics, Calcutta and Rajinder Singh, Carl von Ossietzky University, Oldenburg, helped me access archival material also from their personal collections. I wish to also thank Patrick Carroll, University of California at Davis, for sending me a copy of his new book.

I have benefited immensely from interviews and correspondence with physicists and technical staff retired from or working with the Indian Institute of Science, Bangalore, the Saha Institute for Nuclear Physics, Calcutta and the Tata Institute of Fundamental Research, Bombay, who spared time and memories without which it would have been considerably more difficult to make sense of archival documents. I also remain surprised by and indebted to the following who tenaciously trudged through this thesis or parts of it out of sheer generosity: Indira Chowdhury, Jacob Darwin Hamblin, Roderick Home, Lise Kvittingen, Thomas Lassman, Hanchao Lu, György Péteri, Revati Phalkey, and Roland Wittje.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

All photographs are reproduced with permission.

LIST OF ABBREVIATIONS

JDB: John Desmond Bernal

HJB: Homi Jehangir Bhabha

SSB: Shanti Swarup Bhatnagar

PMSB: Patrick Maynard Stuart Blackett

JDC: John Douglas Cockcroft

JCG: Jnan Chandra Ghosh

FJC: Frederic Joliot-Curie

KSK: Kariamanikkam Krishnan

RSK: Rappal Sangameswara Krishnan

EOL: Ernest Orlando Lawrence

BDN: Basanti Dulal Nagchoudhuri

JN: Jawaharlal Nehru

MLEO: Mark Oliphant

MNS: Meghnad Saha

JRDT: Jehangir Rustom Dorab Tata

AECI: Atomic Energy Commission of India (I have avoided using IAEC and Indian Atomic Energy Commission, because the Israeli Atomic Energy Commission uses the same acronym)

AERC: Atomic Energy Research Committee (1946-1948)

BRAE: Board of Research on Atomic Energy (1946-1948)

BSIR: Board of Scientific and Industrial Research, India
CSIR: Council of Scientific and Industrial Research, India

DSIR: Department of Scientific and Industrial Research, United Kingdom

USAEC: Atomic Energy Commission, United States of America

SUMMARY

This thesis is a history of the beginnings of nuclear research and education in India, between 1938 and 1959, through the trajectories of particle accelerator building activities at three institutions: the Department of Physics, Indian Institute of Science, Bangalore, the Palit Laboratory of Physics, University Science College, Calcutta, later (Saha) Institute of Nuclear Physics, and the Tata Institute of Fundamental Research, Bombay. The two main arguments in this thesis are: First, the beginnings of nuclear research in India were rooted in the "modernist imperative" of the research field. However, post-war organisation of nuclear research came to be inextricably imbricated in processes of state-formation in independent India in a manner such that failure to actively engage with the bureaucratic state implied death of a laboratory project or constraints upon legitimately possible research. Second, state-formation, like the pursuit of nuclear research in India for the period of my study, became about India's participation and claim upon the universal. State-formation was equally a modernist imperative. Powerful sections of the nationalist bourgeoisie in India understood "Science" and the "State" as universals in World History, and India, they were convinced, had to confirm its place in history as an equal among equals. These two arguments combined explain how nuclear research came to be established, transformed, and extended through the gradual assembly of material infrastructure to realistically enable the new country take a capable decision on the nuclear question.

PREFACE

The “Peaceful Nuclear Explosions” (PNE’s) carried out at Pokharan, (Rajasthan) in May 1974 announced India’s claim to belong to the ranks of the five nuclear powers. India, with a history of less than twenty-five years since the end of formal imperial control, was the first developing country that realised a nuclear research infrastructure able to realistically support any decision on the establishment of a nuclear program and the direction it would take. Following the use of atomic bombs at the end of WWII, it was impossible not to connect nuclear research/ the atom with global power and weaponry, even when seen critically. Unlike the United Kingdom or the USSR, the realisation of a nuclear program was a remote possibility for the interim political government on the Indian sub-continent. There was the atomic bomb, and there was wishful thinking. For that reason, what many in and outside India have considered an outstanding technological and scientific accomplishment, has cast a rather long shadow on the history of physics, especially nuclear physics practice in India in the mid-twentieth century. The PNE’s have imposed a teleological meta-narrative within which the history of nuclear physics in India is embedded and written. This, more than anything else, has proved to be an obstacle towards understanding the tenuous emergence of the necessary infrastructure, and the various alternatives considered in the period between 1947 and 1959, that in the first instance made the PNE’s imaginable and later possible.

A strange historical coincidence underpins this narrative. Formal decolonisation of India came two years after the terrific demonstration of the power of the atom in a volatile international order. A self-aware community of physicists and scientist statesmen saw the conjuncture of the arrival of the nuclear age, with the departure of the British, as a unique opportunity to promote their physics, themselves and their country. In this thesis, I have teased out the possible paths available to and considered by physics practitioners between the late 1930s and 1950s in India. The end of WWII coincided with accelerated plans for transfer of power to India and the next three years saw contest, bitter struggle, disappointment and perplexity. Neither the exact form of the new state nor the shape of post-war nuclear research was self-evident. It was imperative that the scientific community in India find ways of continuing research and producing credible science in a shifting local and international political context. I have traced the gradual consolidation of these paths in contest, collaboration and within constraints, through the motivations of and strategies employed by those desirous of establishing, sustaining and extending nuclear physics as a research field in India. In doing so, I have, like my historical actors, purposefully crossed the historiographic boundary of 1947. It becomes increasingly clear that their activities were not dominated by the desire to build "a bomb", certainly not at the outset, and only tenuously for at least a decade after 1945. It is in hindsight that their decisions prove crucial for making the political decision that India could and should conduct a nuclear test in 1974.

In this preface, I want to briefly explore four specific features of the history of physics in India, and comment on the organisation of my study. First, apart from being a history of a rather small elite, my stories necessarily revolve around "a few great men". I have chosen to write about nuclear education and research focusing upon leadership and laboratory activities specifically of particle accelerator building. These were led by Chandrasekhara Venkata Raman and Rappal Sangameswara Krishnan (Indian Institute of Science, Bangalore), Meghnad Saha and Basanti Dulal Nagchoudhuri ([Saha] Institute of Nuclear Physics, Calcutta) and Homi Jehangir Bhabha and D. Y. Phadke (Tata Institute of Fundamental Research, Bombay) as well as Shanti Swarup Bhatnagar (Council for Scientific and Industrial Research of India). After the Subaltern turn in history writing, especially on the sub-continent, as well as the critical reevaluation of the "heroic lone genius" in the historiography of science, this historiographic approach demands explanation. In the first instance, this is a function of available sources, themselves determined by the fact that there were a rather small number of men involved with *nuclear research in universities and national laboratories* for the period of my study (I have come across but one female nuclear physicist in my research). In addition, the absence of robustly documented histories of nuclear research in India made it imperative that I fully comprehend the implications of those choices that are accessibly documented. I became more convinced of this approach when I found that the absence of established state organisations to take over the task of nuclear research on an unprecedented scale, demanding highly specialised skilled personnel was not unique to the Indian context. Individuals thus came to enjoy a large and significant role in the shaping of nuclear research after WWII. A completely different approach to the subject, like for example a study of thorium mining or plutonium processing, would potentially enable a more inclusive history but that is not the focus of my study.

A second important dimension of this thesis is the negotiation between two registers, the political administrative, and laboratory practice. One the one hand we have the place of nuclear research in free India, the attitudes of Nehru's administration, and how they thought about the future, and how they presented this elite scientific project to the larger constituency at home and to the world at large. On the other hand, we have the register of scientific practice in the laboratory, of what it meant to build or want to build particle accelerators within the Nehruvian project - under circumstances of scarce funding, unavailability of materials, inadequate training, and the denial of sharing nuclear knowledge internationally. In negotiating the two dimensions, my study departs from the mainstream scholarship on history of science in India. In prioritising scientific practice without losing sight of the place of science in the *planning* (more than imagining) of independent India, this thesis seeks to shift the terrain of discussion from one that stresses the role of the ideology and the "authority of science" towards one that focuses on practice and material culture of science in India. As but one way of marking this departure, I have insisted upon working with the vocabulary of my historical actors. I have preferred the use of "imperial India" and "free or independent India" as descriptive terms, instead of colonial and post-colonial India except when the discussion is historiographic. If material culture is the physical world shaped by people and artefacts through intention and action in a society, the particle accelerators in this study embody aspirations, positions, negotiations, and the efforts of their patrons, mentors, builders and users. The embodiment is at once scientific and political. The accelerators thus provide a tangible anchor to trace linkages between scientists, technicians, the state, funding agencies, industry, as well as local and international politics, and therefore to write about processes that contribute to the culture of scientific practice.

That brings us to the third dimension of this thesis – of nuclear research technology. Beginning in the early 1930s, the focus in physics research had shifted towards the atomic nucleus, facilitated in part by the feasibility of particle accelerators as large experimental apparatuses for smashing atoms. A section of the community continued to work with cosmic ray physics. By the late 1930s, physicists from India, like their colleagues the world over, began to take an active interest in nuclear physics, the most ‘modern’ branch of the subject. One option available to physicists in India was enrolment in the life of the leading centres in Western Europe and North America. But the four leading actors in my study were convinced of the imperative to create *in India,* facilities and capabilities to participate in nuclear physics research as an international activity. With the end of the war and Indian independence, the nuclear imperative was recast in national-statist terms, a choice that was increasingly buttressed by yet another constraint: that of the significantly altered nature and scale of nuclear research technologies. Indians, like Europeans, including Britain, framed and confronted the problem in the same terms when they began to pose the question in the mid-1940s. The choice between creating a “top class” research facility with comprehensive provision for time and resource intensive nuclear research was *necessarily* weighed against the choice of continuing support for university teaching and nuclear research with lower intensity on a long term basis, with comprehensive provision for physics research on a broad spectrum. Only the United States had resources to invest in several facilities for nuclear research, some of which had begun work before 1939, work which was only intensified during the war. By the early 1950s even in the United States, the technology was affordable and feasible only in collaboration, as seen with the group of universities pooling their resources for the establishment of the Brookhaven National Laboratory. The European answer was the establishment of CERN.

Where were the solutions then, for a (not yet and later) newly independent country with limited resources, a small number of university laboratories, a small number of skilled nuclear researchers and a fragile position in world politics? This brings us to the fourth dimension of this thesis, the spectre of the atomic bomb. I began research on this thesis as a recovery of the material pre-history of India's nuclear capability. This history is crucial and becomes increasingly relevant because contemporary political regimes in India have now claimed possession of nuclear weapons and aspire to belong to the nuclear club. When writing this thesis, I have tried to bracket this contemporary turn in Indian history in order to recover alternative paths, considered and taken, in the pursuit and organisation of nuclear research in India, sometimes sotto voce, during a rather tumultuous period in Indian and arguably world history. But at the same time, there is no forgetting Hiroshima and Nagasaki. History of nuclear research after 1945 cannot escape the connotations of warfare and aspirations of global power. Nuclear researchers in the post-war period could hardly claim innocence of the possible meanings of their work, and there are no better reasons for a historian to claim such a privilege. However, a historian must be cautious of the meanings one can attribute to the early period of nuclear research in India: the question of organising nuclear research towards a weapons program as early as the years 1945 to 1947 does not have much meaning because the necessary apparatus, skills, materials and more so, political sovereignty and therefore political will were not consolidated. After formal independence, political will may have been a possibility but a political decision required sufficient manpower willing to participate in the mandate, and the material infrastructure to support such a decision. The technology also structured the horizons of possibility: the skills required for the peaceful and wartime use of nuclear technology were mutually exchangeable. Apart from a complete refusal to participate in nuclear research on moral or political-economic grounds, this threshold of skills and infrastructure would have to be reached before any decision could be meaningfully taken.

The implications of such a mandate in terms of power and therefore access to resources was obvious to political leaders and scientific statesmen alike, but what was it that they exactly could and did do with these resources, and to what effect? As this thesis shows, earlier research agendas, including those of training students, contributions to medical physics, and the quest for the discovery of sub-atomic particles proved significant in shaping the strategies, devices and interests in nuclear research of the small but eminent physics community in India.

Histories of nuclear research in India are necessarily trans-national. As Charles Withers asserts, a thesis like mine is written "*above national context* in which the exchange of scientific and commercial information can be read as international, trans-national and between particular individuals and institutions, and *by a concern to explore the local nature and site of scientific knowledge*". [1] The meanings and significance of nuclear research in India was never separate from its larger meanings globally, even prior to 1945. I am acutely aware that this may amount to a denial of the specific circumstances of its configuration in India, but that is not my intention. Physics laboratories on the sub-continent were connected into a network of laboratories and people internationally, as well as with each other. The exchanges between them involved students, experts as well as artefacts. The nation, the

[1] Charles WJ Withers, *Geography, Science and National Identity: Scotland since 1520* (Cambridge: Cambridge University Press, 2001): 14-15 Emphasis added.

nation-state and the world system of nation-states as frames of reference were gradually introduced in a decisive manner for scientific practice during this period, even as they remained deeply contentious arguments on the Indian sub-continent. I have shown how this framing at the intersection of national-state in the context of international politics eventually transformed equipment, research agendas and expertise in the three laboratories.

Given the claim that I wish to explore the local nature and site of scientific knowledge in reference to its intersections with international history, it would be fair to ask if is this history of particle accelerators alone or are their trajectories a means to tell another story? While I would like to claim that this narrative goes in and out of the laboratory precisely to meaningfully implicate the larger context, at the same time I would like to insist on the special nature of the apparatus. This aspect of the history of modern India cannot be told through dams or steel plants, but at the same time cannot be told through narratives of reactor building, thorium mining or plutonium processing. In the period of my study and the facilities I study, the scale of the particle accelerators was far larger than any equipment procured by those physics departments before then. But it was still possible to argue for particle accelerators in the university setting. Particle accelerators in the 1930s and early 1940s were equipment of basic research in nuclear physics that had roots and connections with the university laboratory and were perceived to be legitimately so by the physics community. The end of the war convinced increasingly many physicists that the apparatus would only get bigger and this justified the need to locate them in national laboratories instead. By the early 1950s such an argument would become more and more impossible to make.

The chapters in this thesis are organised chronologically. A thematic organisation of the study may have allowed for a synthetic narrative on the development of the nuclear field in India, but it would also have resulted in a compromise on the details of laboratory work and scientific practice. In decentering "science" as well as India's "nuclear program", I have instead explored a range of trajectories of (largely) men and machines that move across the laboratory and the emerging national-statist space from their local context, the site of their scientific practice. The chapters, therefore, unfold locally and chronologically, but with significant overlap. Two of the three histories were set in motion in 1938. The quest to establish nuclear physics at the Indian Institute of Science, Bangalore began in 1938 and was resolutely truncated in July 1947. Efforts at the University Science College Calcutta also began in 1938 and building work on the cyclotron was effectively completed in 1954. Bombay was the last of the three to enter the field (1944), and the particle accelerator building groups were more or less dissolved by 1959. I begin with the history in Bangalore because even though it began the same time as Calcutta, the story stops in 1947. The history of Calcutta facility continues on to 1954, and Bombay being the last one to join in, was the last to wrap up particle accelerator building activities in 1959.

I realise that placing the history of the facility in Bombay as the last empirical chapter, even though chronologically justified, can have the effect of privileging the facility, thereby supporting the teleological bias evident in current nuclear histories of India. However, by concentrating on the declining fortunes of particle accelerator builders in Bombay, within the ambiguous mandate of the "centralised national facility" for nuclear research, I hope to have shown the similarity of their reduced conditions with other builders, especially those in Calcutta. Scientific practice, even in a privileged national facility was eventually subject to the shifting paradigms of national development and national security.

Finally, this thesis is an account of eminent political leaders, industrial leaders and physicists in India, brought together in conflict, collaboration and contest by their shared concerns to establish institutions and extend nuclear research in India in acute awareness of, and in conjunction with, the world at large. By the end of the narrative, I hope to have shown how difficult, and yet remarkable this accomplishment was, even as its moral implications may remain troubling and deeply disturbing.

CHAPTER 1: AT HOME IN THE WORLD: SCIENCE, STATE AND NATION IN INDIA

> "The absence of an adequately detailed narrative of the Indian nuclear program's evolution has consequences. It has impaired the Indian polity's capacity to debate with adequate knowledge what has been done in the nuclear field, by whom, for what reasons, and at what costs."[2]
>
> George Perkovich, (1999): 11

> "All historiography rests upon acts of choice. No historiography can ever be a neutral enterprise: an enquiry into any given aspect of the past necessarily derives from some evaluation in the present. And, in the end, or rather in the beginning, all such choices are not simply historiographic, but political."[3]
>
> T. G. Ashplant and Adrian Wilson, (1988): 274

This thesis will attempt a recovery of the early history of Indian engagement with the nuclear. This is my contribution to knowledge of what has been done in the nuclear field in India, between 1938 and 1959, "by whom, for what reasons, and at what costs". As such then, my thesis asks questions and explores histories that open the field for further inquiry and comment. Nuclear matters today, in India and elsewhere, are far from trivial concerns. Like all acts of recovery, my concerns for writing this history are contemporary but I wish to avoid an overwhelmingly presentist investment in the historical explanations of what happened, how and why, or for that matter in making decisions on who were a part of making nuclear history in India.

---

[2] George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999), 11.

[3] T. G. Ashplant and Adrian Wilson, "Present-centered History and the Problem of Historical Knowledge," *Historical Journal* 31, (1988): 274; quoted in Jeff Hughes, "Whigs, Prigs and Politics: Problems in the Historiography of Contemporary Science," in Thomas Söderqvist, ed., *The Historiography of Contemporary Science and Technology* (Amsterdam: Harwood Academic Publishers, 1997), 19-38.

My thesis forwards two main arguments: First, the beginnings of nuclear research in India were rooted in the "modernist imperative" of the research field.[4] However, post-war organisation of nuclear research came to be inextricably imbricated in processes of state-formation in independent India in a manner such that failure to actively engage with the bureaucratic state implied death of a laboratory project or constraints upon legitimately possible research. Second, state-formation, like the pursuit of nuclear research in India for the period of my study, became about India's participation and claim upon the universal. State-formation was equally a modernist imperative. Powerful sections of the nationalist bourgeoisie in India understood "Science" and the "State" as universals in World History, and India, they were convinced, had to confirm its place in history as an equal among equals. These two arguments combined explain how nuclear research was established, transformed, and extended through the gradual assembly of material infrastructure to realistically enable the new country take a capable decision -any decision- on the nuclear question.

The histories of India, as well as those of the founding moment of organising nuclear research in this period, are both best characterised by transition. This was the moment of transition of three orders: of India from imperial rule towards independence; of experimental nuclear physics from "wax and string" set ups towards electronics and

[4] Jeff Hughes, "Radioactivity and Nuclear Physics," in Mary Jo Nye, ed., *The Modern Physical and Mathematical Sciences,* The Cambridge History of Science IV (Cambridge: Cambridge University Press, 2003), 369. It is almost impossible to use Hughes phrase "modernist imperative" as a historian of India without a footnote, much as I wish I could use it with the same lightness of meaning as he proposes. Modern and modernity as analytic concepts have been "endlessly patient of interested interpretation" in social theory and history, especially in the post-war period. I understand Hughes use of the phrase to mean nuclear physics was the problem of the time, the frontier of physics inquiry and as such then, physicists were drawn into this inquiry to remain competent, competitive and in conversation with their colleagues.

complex instrument systems; and the organisation of nuclear research from the university laboratory onto national-state agenda and international politics; and finally the transition of the world order from one led in imperialism largely by Britain (in India's case) and Europe towards the Cold War increasingly to be led by the USA and the USSR. This introductory chapter therefore begins with an overview on science under imperial rule, and is focused especially on the institutionalisation of physics research in India by mid-twentieth century. The following section discusses the processes of decolonisation and state-formation, and the emergence of "scientific industrialism" as an overarching purpose of the Indian state.[5] Section three discusses the arrival of the nuclear as a political imperative in 1945, and the subsequent recasting of processes of state formation and nuclear research in India. The last section spells the organisation of this thesis, and historiographic and methodological concerns that inform my writing.

1.1 Science Under Imperial Rule - The Not-so-long History of Physics in India

> "The development of the physical science in India has not, like that of the other sciences, a long history".[6]
>
> Meghnad Saha, (1938): 674

The study of science under colonialism as a field of inquiry is now firmly established within history of science and history of colonialism both. Indicative is the recent Focus

[5] Pratik Chakrabarti, *Western Science in Modern India: Metropolitan Methods, Colonial Practices* (Delhi: Permanent Black, 2004), 298-300.

[6] Meghnad Saha, "Progress of Physics in India during the Past Twenty-Five Years," in Baini Prashad, ed., *The Progress of Science in India During the Past Twenty-Five Years* (Calcutta: The Indian Science Congress Association, 1938), 674.

section on colonial science in *Isis* (2005), journal for the History of Science Society (HSS).[7] As the editor of the section Londa Schiebinger notes, the historiographic essays are complementary to an earlier volume edited by Roy MacLeod for *Osiris* (2000)*,* the other publication related to HSS.[8] The previous year had already seen an issue of *Science Technology and Society* edited by Michael A. Osborne addressing the "social history of science, technoscience and imperialism".[9] But this by no means implies that there is scholarly agreement on just what the term 'colonial science' can definitively explain. Mark Harrison's useful genealogy of the term begins by tracing it back to the repeatedly and obligatorily discredited George Basalla.[10] Harrison argues that Basalla has to be understood as a part of the modernisation theory complex where his "universal model for the diffusion of science" makes sense. Colonial science for Basalla was characterised by dependence, and in the backlash that followed against modernisation theory and politics of the early Cold War, colonial science came to be characterised as a "tool of empire". Dependency theorists of the 1970s, while continuing to work with Basalla's chronology,

---

[7] Londa Schiebinger, ed., Focus section *Isis* 96, no.1 (2005), contains the following essays: Mark Harrison, "Science and the British Empire," Jorge Cañizares-Esguerra, "Iberian Colonial Science," Steven J. Harris, "Jesuit Scientific Activity in the Overseas Missions, 1540–1773," and Michael Osborne, "Science and the French Empire".

[8] Roy MacLeod, ed., "Nature and Empire: Science and the Colonial Enterprise," *Osiris* 15*,* (2000).

[9] Michael A. Osborne, ed., "The Social History of Science, Technoscience and Imperialism," *Science, Technology and Society* 4, no. 2, (1999). Apart from historians of science, scholars engaged in postcolonial science studies are equally committed to understanding colonial science. Similarly suggestive are the following special issues: Itty Abraham and Paula Chakravarty (issue organizers), "The Contradictory Spaces of Postcolonial Technoscience," *Economic and Political Weekly* 41, no.3 (2006); Maureen McNeil, ed., "Postcolonial Technoscience," *Science as Culture* 14, no. 2 (2005); and Warwick Anderson, ed., "Postcolonial Technoscience," *Social Studies of Science* 32, no.5/6 (2002). Postcolonial science studies is more of an approach to study scientific practices in historical contexts of colonial rule or those transformed by colonial rule, to study periods beginning with colonialism into periods following decolonisation as well.

[10] Mark Harrison, "Science and the British Empire," *Isis* 96, no.1 (2005): 56-63; George Basalla, "The Spread of Western Science," *Science* 156, (1967): 611-622. The following paragraph is based on Harrison's essay.

framed the question on colonial science through a critique of colonial enterprise itself. Colonial science thus seen was an instrument of imperial rule, functioning within the binary of "centre/ metropolis and periphery". In the 1980's Roy MacLeod's concept of the "moving metropolis" signalled that historians were willing to allow for dynamism in scientific practice at the periphery.[11] Others began to lay stress on the cultural authority of science in colonial contexts following theoretical questions raised by the works of Michel Foucault and Edward Said.[12] Historians of India continue to engage with extensions of some of these questions, and current scholarship particularly converges upon the relationship between colonialism, science and Indian modernity.

Recent scholarship on the response to, and establishment of Western scientific practice in India has now firmly recognized the centrality of "science" in understanding the history of modern India, and its inseparability from the history of imperialism.[13] History of science in India thus framed cannot be understood except as a part of colonial history and

---

[11] Roy MacLeod, "On visiting the 'Moving Metropolis: Reflections on the Architecture of Imperial Science," in Nathan Reingold and Marc Rothenberg, eds., *Scientific Colonialism: A Cross-Cultural Comparison* (Washington DC: Smithsonian Institution Press, 1987), 217-249.

[12] Edward W. Said, *Orientalism* (New York: Penguin, 1978); Michel Foucault, "Governmentality," in Graham Burchell et.al. eds., *The Foucault Effect: Studies in Governmentality* (Chicago: University of Chicago Press, 1991), 87-104.

[13] See Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Scientific Knowledge in South Asia and Europe, 17th and 19th Centuries* (New Delhi: Permanent Black, 2006); Dhruv Raina and S. Irfan Habib, *Domesticating Modern Science: A Social History of Science and Culture in Colonial India* (New Delhi: Tulika Books, 2004); Pratik Chakrabarti, *Western Science in Modern India: Metropolitan Methods, Colonial Practices* (Delhi: Permanent Black, 2004); John Lourdusamy, *Science and National Consciousness in Bengal, 1870-1930* (New Delhi: Orient Longman, 2004); David Arnold, *Science, Technology an Medicine in Colonial India* The New Cambridge History of India III, 5. (Cambridge: Cambridge University Press, 2000); Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton: Princeton University Press, 1999); Zaheer Baber, *The Science of Empire: Scientific Knowledge, Civilisation and Colonial Rule in India* (New Delhi: Oxford University Press, 1998); Deepak Kumar, *Science and the Raj, 1857-1905* (New Delhi: Oxford University Press, 1995); Deepak Kumar, ed., *Science and Empire: Essays in Indian Context* (New Delhi: Anamika Publications, 1991).

all the contingent alliances that shaped this history up until Indian independence when it became possible to think of India otherwise.[14] The first academic histories of colonial science in India came from Deepak Kumar and his colleagues at the Jawaharlal Nehru University, New Delhi, followed closely by two historians Dhruv Raina and S. Irfan Habib at the National Institute for Science, Technology and Development Studies (NISTADS), again in Delhi. Deepak Kumar's first book, even with its recent revised edition with two extra chapters, remains the authoritative chronicle of British colonial scientific enterprise in India. New entrants to the field have found thesis topics embedded in the footnotes, a testimony to his extensive archival research in India and Britain. Raina and Habib have over the years engaged with the question of domestication of modern science in India in an episodic exploration of the history and historiography of science in India.[15] The field of history of science in India then, is relatively young.

Two books that have made a major impact on the understanding of the place of science under colonialism in the history of modern India are those by Gyan Prakash (1999) and David Arnold (2000). Both cover the same time period but are remarkably different in their approach. Gyan Prakash writes of science as a cultural discourse in colonial India.

[14] As a part of nationalist history writing, the Indian National Science Academy (INSA) constituted a board to commission a history of science in India (1959). Leading the committee was the physicist Debendra Mohan Bose, (Jagdish Chandra Bose's nephew), and the book was published in 1970 (D. M. Bose, B. V. Subbarayappa, and S. N. Sen, *A Concise History of Science in India* (Delhi: INSA, 1970). The Academy also began publishing the *Indian Journal for History of Science* beginning 1966. On the other hand, the Needhamian Abdur Rahman's efforts led to the establishment of the National Institute for Science, Technology and Development Studies (NISTADS) in the early 1980's as a laboratory under the Council for Scientific and Industrial Research, dedicated to science policy related research. Rahman was a prolific writer and worked closely with UNESCO, a tradition that continues to date with other academic historians of science in India. See Dhruv Raina, *Images and Contexts: The Historiography of Science and Modernity in India* (New Delhi: Oxford University Press, 2003), especially Chapter 5, "Science, Scientists, and the History of Science in India, 1966-94".

[15] See Kumar, (1995) and Raina, and Habib, (2004).

He argues that even as the cultural authority of science constituted and informed strategies of control for imperial rule, it also held the promise of "liberty, progress and universal reason" for the Indian nationalist bourgeoisie and those doubtful of the colonial enterprise. Modern India, he proffers, was shaped within this contradiction. Prakash does not want to look at colonial science in its connection to political ideologies and institutional structures that colonialism put in place, but rather scientific practices themselves as constituting colonialism's political ideology and institutional structure. Scientific practice was not a mere tool of empire, he argues, because it was inextricably implicated in the very making and meaning of empire.

David Arnold's work is concerned with things he considers missing in Prakash. Prakash's book does not tell us, Arnold writes, "about how science was constituted, disciplined and institutionalised, even what science *was*, in the rapidly changing context of nineteenth and early twentieth century India".[16] Prakash in turn looks at David Arnold's Cambridge history volume as offering no interpretive breakthrough in the field but most certainly "an authoritative interpretation" of existing scholarship on science in colonial India.[17] Having synthesised the wide-ranging scholarship on science, technology and medicine in India, Arnold agrees with Prakash, that science was never a mere tool of empire. British authorities drew upon Indian intellectual traditions in uneven ways and even when they did employ "science" for political purposes, they did not necessarily possess resources or

[16] David Arnold, "Review of Gyan Prakash (1999) Another Reason: Science and the Imagination of Modern India," *The Journal of Imperial and Commonwealth History* 28, no. 2 (2000): 163.

[17] Gyan Prakash, "Review of David Arnold (2000) Science, Technology and Medicine in Colonial India," *Victorian Studies,* (Autumn Issue, 2002): 149-151.

even enough mastery over scientific matters to maintain it as a tool of control. Arnold then identifies three characteristics that can illustrate the history of science in colonial India. First was the continuing presence of variegated traditions of India's own sciences and their legacy for imperial rule. Second, the social and intellectual impact of colonial science and its relationship to the imperial regime in India as well as European science, and finally, the authority of science, technology and medicine as central attributes of India's modernity, drawing upon both Indian and Western sources.

Imperialism's scientific authority was fragile because "the cultural voice of science was being trained in Europe when it was first heard in India".[18] But the fragility did not register symmetrically in the colonial setting because establishment of scientific practice was not separate from establishment of political authority. Colonial scientific practice was not an autonomous activity when most funding, at least up until the late nineteenth century came from the colonial state. Governmental agencies continued to function with racial privilege and Indian practitioners rarely acquired leadership positions. It also meant that disciplines considered useful for maintaining colonial rule such as medicine, botany, zoology and geology were institutionalised unlike mathematics, physics and chemistry.[19] What this provided was an opportunity for some "to transcend, through a dual dedication

---

[18] Roy MacLeod, "Review of Gyan Prakash, Another Reason: Science and the Imagination of Modern India," *American Historical Review%*, (2000): 1720-1721.

[19] Even though chemistry was not institutionalised in company science, it became important by 1900 in response to the "blue terror" of synthetic indigo developed in Germany. In 1916, Thomas Holland, earlier with the Indian Geological Survey of India, led the Indian Industrial Commission and asserted the importance of supporting researches in chemistry. Plans to institute an Indian Chemical Service in 1920 were opposed strongly by among others Prafulla Chandra Ray, leading the 'School of Indian Chemistry' and founder of Bengal Chemical and Pharmaceutical Works (1899) in Calcutta. See P. C. Ray, *Life and Experiences of a Bengali Chemist* (Calcutta: Chukerverity, Ghattesjee and Co, 1932) and Arnold, (2000): 163-166.

to science and nation, the prejudices and pettinesses of the colonial world".[20] Physics research in early twentieth century was rarely funded by the colonial state.[21] The physics community in India was thus born extraneous to and not dominated by the logic of colonial rule.

The physicist Jagdish Chandra Bose is credited not only with establishing physics research in Calcutta in the late nineteenth century but also to have "invented national science for India as laboratory science in contrast to the observational and field sciences that had been dominated by Europeans in India".[22] Bose's work on electromagnetic waves continues to be recognised as innovative leading up to, among others, the work of Marconi. Lord Kelvin, Bose's sponsor at the Royal Society in London where he presented his work to the British scientific community, asked the [British] Government of India to provide for a laboratory for Bose's research in Calcutta. No state support was forthcoming. The schism between the goals of the [British] Government of India and collegiality, when present, between the British scientific community and its counterpart in India continued to characterise imperial rule even in the late colonial period. Driven by

---

[20] Arnold, (2000): 155.

[21] Exceptions to this rule came with university departments that were established in the 1920s, where salaries for physics teaching came partially from the state. However, there was hardly any research funding available for university professors. Most of them relied on nationalist philanthropy and large foundations from the United States as well, for funds to conduct research, travel aboard for conferences and spend time in European and American laboratories. Applied physics research during the Second World War most certainly received funding from the late colonial state, but this was not the case at the nascence of this community or even up until 1940 in an institutionalised manner.

[22] Arnold, (2000): 166. See also: Visvapriya Mukerjee, "Some Historical Aspects of Jagdish Chandra Bose's Microwave Research During 1895-1900," *Indian Journal for History of Science* 14, (1979): 87-104; Deepak Kumar, "The "Culture" of Science and Colonial Culture, India, 1820-1920," *British Journal for History of Science* 29, (1996): 195-209; and Patrick Geddes, *An Indian Pioneer of Science: The Life and Work of Sir Jagadis C. Bose* (London: Longmans, Green, and Co, 1920).

an inconsistent practice of 'government', it was not even underscored by racialism in all instances. Ronald Ross of the Indian Medical Service had already warned at the turn of the century, "the [British] Government of India is a mule as regards science … it won't do anything unless it is driven".[23]

The absence of an institutional framework for physics meant its practice also escaped a colonial framing of its relevance, status and research agenda. Many physicists benefited financially from local and nationalist associations dedicated to the "cultivation" of science, established through local philanthropy. Some did not even require funding and continued to work in the tradition of gentlemen scientists. Jagdish Chandra Bose and others like him never became colonial scientists, established their own research agenda in response to international physics, and most of them construed their scientific belongings within the international scientific community. As Arnold notes;

> "Until the 1900's there were few opportunities to take higher degrees and pursue research in Indian universities. Travelling abroad, usually to Britain, gave Indian students not only a superior training to any they could receive at home, but also the sense, hard to attain in India at the time, of belonging to an international scientific community - being part of the latest research activity, mixing on more equal terms than was ever likely in India with leading scientists, gaining access to a scientific domain that was not bounded by Britain alone but embraced France, Germany and the United States as well."[24]

---

[23] See Kumar, (1995): 176. Surgeon Major Ronald Ross was a member of the Indian Medical Service beginning 1881. His research in India confirmed Charles Louis Alphonse Laveran and Sir Patrick Manson's hypothesis that mosquitoes were connected with the propagation of malaria. He returned to Britain in 1899 and was awarded the Nobel Prize in physiology / medicine in 1902 for his work on malarial epidemiology. He continued his work on malaria and later also worked in West Africa. See *Nobel Lectures, Physiology or Medicine 1901-1921* (Amsterdam: Elsevier Publishing Company, 1967), and Ronald Ross, *Memoirs* (London: John Murray, 1923).

[24] Arnold, (2000): 155.

Being a part of an international physics community also brought with it a regulated rigour of practice – not all inquiry into physical phenomena qualified as physics. When J. C. Bose turned to work on questions inspired by a metaphysical quest for the unity of life, he was accused of having given in to oriental fantasy. Bose was trying to draw similarity patterns of responses in the "living and non-living". His demonstration of a suffering cabbage [stimulated by a high-voltage electric current] moved George Bernard Shaw to tears. Some theologians, romanticists, Indian nationalists as well as some scientists in India and abroad applauded what appeared to them a revolutionary claim. Leading physicists and phytologists, in India and abroad, responded less enthusiastically.[25] Evaluating the accomplishments of Indian physics in 1938, Meghnad Saha, an astrophysicist and a student of J. C. Bose, credited Bose for having made "from the Indian point of view, … the first contribution to physics to receive attention in Europe". Saha closed the paragraph with a cryptic lament: "Unfortunately these investigations were not continued, as Sir Jagadish's [sic] attention was diverted to other channels".[26] Those abroad drove home the point more directly: "In the less genial climate of England drooping shots do not erect themselves… Neither can little boys ascend unattached ropes

[25] For responses to Bose's later work see: Subrata Dasgupta, *Jagadis Chandra Bose and the Indian Response to Western Science* (New York: Oxford University Press, 2000). Among Bose's critics was Chandrasekhara Venkata Raman, who was awarded the Nobel Prize for physics in 1930, the first Asian to be thus recognised. Raman apparently called Bose's later work in biophysics as "mumbo-jumbo". See Krishna Dutt and Andrew Robinson, *Rabindranath Tagore: The myriad minded man* (New York: St. Martin's Press, 1996), 129 cited in Arnold, (2000): 167. For an evaluation of Bose's work as an 'epistemic of alternate Indian science' see: Ashis Nandy, *Alternative Sciences: Creativity and Authenticity in Two Indian Scientists* (Delhi: Oxford University Press, 1995) and Ashis Nandy, "Defiance and Conformity in Science: The Identity of Jagadis Chandra Bose," *Science Studies* 2, no.1 (1972): 31-85.

[26] Saha, (1938): 675.

before the eyes of hypnotised beholders".[27] A real physicist could no longer be seen doing hybrid science.[28]

Gyan Prakash has evoked a very specific use of the term hybrid in the context of scientific activity in India. Hybridization for him refers to "the undoing of dominance that is entailed in dominance's establishment…. To situate science in a language of the other (translation) was to hybridise its authority, to displace it's functioning as a sign of colonial power. Hybridisation, therefore served as a counter-hegemonic ground upon which the elite pressed their entitlement to modernity even as they misrecognised their

---

[27] W. O. James, "Review of Life Movements in Plants, Sir J. C. Bose and others [Transactions of the Bose Research Institute, VI, London: Longmans, Green, and Co]," *New Phytologist* 30, no. 2 (1931): 142-144. For a good many years, James complains, Bose has played "*le Jongleur de Notre Dame*" [sic]. For a superbly readable account on the legend of the Indian rope trick and its relation to the idea of the "mystic east" see Peter Lamont, *The Rise of the Indian Rope Trick: The Biography of a Legend* (London: Little Brown, 2004). It is important to note here that it was *no longer* possible to carry out this inquiry legitimately as physics, but this was not the case at the turn of the century. To cite an example from the community that had earlier recognised Bose's work, the British physicist Oliver Lodge continued to believe in the existence of the ether and was drawn into questions of psychophysics and the paranormal. David Edwards notes; "Oliver Lodge's reputation has been sullied in the eyes of many of the scientific community by his advocacy of spiritualism. Many eminent nineteenth century scientists were interested in, and indeed researched into the paranormal – Sir William Crookes, Lord Rayleigh, and J. J. Thomson to name a few. […] Lodge had the misfortune to live on into a more rational era which ridiculed or, at best, ignored such work, so he got the reputation of being somewhat of a crank. Nobody called J. J. Thomson a crank for once holding similar views". See David Edwards, "The Victorian Polymath," in Peter Rowlands and J. Patrick Wilson, eds., *Oliver Lodge and the Invention of Radio* (Liverpool: PD Publications, 1994), 19-38.

[28] Hybrid as an analytical construct has been repeatedly evoked to explain the condition of intercultural interaction, especially that between the West and the rest. As a concept, it is worn-out from being dragged around to explain anything that falls between from syncretism to social change evoking responses ranging from the celebratory to those of lament. I use the term hybrid only to remain in conversation with existing scholarship. My use of the term hybrid here means the pursuit of scientific inquiry with questions that were informed by concerns other than those the physics community came to, even if eventually, agree upon. In that sense, I could be held responsible for unwittingly positing that there exists a physics that is not informed by "external questions". That is not what I mean. I do wish to privilege though, the community of physicists for their priority to, if not in the first instance, *even if eventually come to agree upon* what constitutes legitimate scientific inquiry into physical phenomena. Prakash's definition of the term is distant from its more general use to signal "cultural syncretism, mixture or pluralism" but his employment of the term often corresponds to such meanings as well, see especially his discussion of medicine.

aspirations for power as imitation and loyalism".[29] Prakash has claimed that the introduction of scientific practice in India allowed physicists, and other elite, to lay claim upon modernity, and in claiming so, destabilise the authority of Western modernity. This complicated reading of late nineteenth and early twentieth century scientific practice in India is compelling, but it becomes increasingly difficult by the late 1920s to evenly extend this understanding of hybridisation as a dominant reading of how scientific practice was understood by the physics community. I am convinced the physics community, most certainly by the 1930s, would neither "misrecognise" their scientific practice as anything but a self conscious claim upon universalism, nor characterise their *scientific practice* as counter hegemonic to the authority of Western science. Not all of them (even though some would) would perceive their practice as advancing "the claim of the elite as a modern representative of indigenous traditions".[30] On the contrary, they gradually identified their interest in the consolidation of the authority of science precisely over indigenous traditions. A distinction, I believe, necessarily needs to be made in this period between the cultural authority of Western modernity and the cultural authority of science, most certainly for practising scientists, and especially for those working outside the colonial scientific edifice. Scientific authority, credibility and legitimacy, and political authority, credibility and legitimacy, under colonial rule was not *in everyday practice* conflated for those doing physics and mathematics, *in the same manner* as it was their colleagues practicing zoology, metrology, botany, medicine, or anthropology within

[29] Prakash, (1999): 84.

[30] Prakash, (1999): 84.

colonial establishments.[31] As Prakash would remind us, Western modernity was a force to contend with, authority of science, a force to lay claim upon.

Such a distinction or decoupling is important to make also because it is highly problematic, especially for the interwar period, to presume blanket congruence between science and modernity, however understood. The debate was rather fragile. Within India, reactions against modern science came not only from Gandhi's increasing influence upon nationalist politics in India, but also from "repulsion at the mechanised barbarity of the First World War". A section of practising scientists like Prafulla Chandra Ray and Pramatha Nath Bose sought to reconstitute an understanding of science that would counter the cultural authority of western modernity. But such a tendency was not seen dominantly among the physicists and their commitment to cosmopolitan science only grew stronger with the next generation of scholars, most notable among them being Meghnad Saha. Even as they battled "anti-intellectualism" and "anti-scientific" attitudes at home,[32] most of them were well aware of similar debates abroad, especially in Germany.[33] The physicist Shanti Swarup Bhatnagar wrote in 1941, "The fate of the

---

[31] Furthermore, even for those working within the colonial establishment, as David Arnold has argued in the case of medical practitioners, syncretism was not a "politically or professionally acceptable" option for personnel of the Indian Medical Services. Their fears were attached to state funding and professional status, and fear of ostracism from their colleagues. Arnold, (2000): 185.

[32] Arnold, (2000): 190.

[33] Debendra Mohan Bose was with Erich Regener's laboratory in Berlin during the First World War, Meghnad Saha spent a year in Walther Nernst's laboratory in Berlin in 1921-22, and Satyendranath Bose spent a year with Einstein in Berlin in 1925-1926. The debate came with German scientists visiting India too. Arnold Sommerfeld visited India in the mid 1920s, the 1930s saw Max Born teaching in India, and Erwin Schrödinger was offered a position in Allahabad. The active engagement with ideas coming up in Germany was seen in Meghnad Saha's discussion of Oswald Spengler in the very first editorial (1934) of his journal *Science and Culture.* For discussions on the problematic of science and modernity in the interwar period see among others: Paul Forman, "Scientific Internationalism and the Weimar Physicists: The Ideology and its Manipulation in Germany after WWI," *Isis* 64**,** (1973): 151-180; Jonathan Harwood,

Jewish scientific workers in Germany, is one out of the many glaring examples of the fact that science is not allowed to live up to its reputation as a profession of seekers after knowledge and truth, owing to the comparatively lower degree of growth of the moral side of our modern civilisation."[34] Bhatnagar was quite clear that science and modernity could not be unproblematically conflated – if only to say something we would now consider equally problematic, that science was more modern than modernity itself.

In any case, as the physicist Meghnad Saha commented, the establishment of research and education in the physical sciences in India were a rather recent history".[35] Saha locates the institutionalisation of physics research in India with the establishment of the Indian Association for the Cultivation of Science (IACS, 1876), and the institutionalisation of advanced physics teaching with the establishment of the University Science College (USC, 1916), both in Calcutta.[36] Chandrasekhara Venkata Raman was appointed the first Palit Professor of Physics at the USC (1917) and in his person was the bridge between the IACS and the USC. In 1926, Raman began editing the *Indian Journal of Physics* representing both institutions. After educational reforms (1921), more

---

"Weimar Culture and Biological Theory: A Study of Richard Woltereck (1877-1944)," *History and Science* 34, (1996): 345; and Herbert Mehrtens, *Moderne Sprache, Mathematik: Eine Geschichte des Streits um die Grundlagen der Disziplin und des Subjekts formaler Systeme* (Frankfurt am Main: Suhrkamp, 1990), especially Introduction.

[34] Shanti Swarup Bhatnagar, "The Ordeal through which Science is Passing," *The Hindusthan Times* Annual Edition, 1941. Reprinted in V. V. Krishna, ed., *S. S. Bhatnagar on Science, Technology and Development, 1938-1954* (New Delhi: Riley Eastern Ltd, 1993), 44.

[35] Meghnad Saha, (1938): 674.

[36] Saha, (1938) and K. R. Ramanathan, (1938) "On India's Contribution to Modern Physics" in *Sri Ram Krishna Centenary Volume* Calcutta, quoted in Saha, (1938). I have not found (easily) research in English on the establishment of scientific education and research in regions other than Bengal. Most academic histories of science in India accept Bengal but moreover Calcutta as the centre for the early institutionalisation of science in India.

institutions and departments took up graduate teaching and research in the physical sciences. All of these and more were established with patronage from various princely states of India or endowments from nationalist or reformist associations.[37] The following table (Table 1.1) places the establishment of advanced science teaching in selected Indian universities firmly in the early twentieth century.[38]

[37] The importance of scientific research for purposes of war and government was recognised following the First World War quite decisively in Britain and led to the establishment of the Department of Scientific and Industrial Research in 1916. In the context of changing perceptions on scientific and industrial research at home and increasing demands in India, the [British] Government of India appointed the Holland Commission or the Industrial Commission of India. Even if its recommendations were largely ignored, it served to reinforce nationalist demands for industrialisation of India. It also led to the first recurring grant from the government to the Indian Association for the Cultivation of Science in 1922. See Prakash, (1999): 175-178 and Arnold, (2000): 164.

[38] Science teaching, and sporadic research, sometimes for a master's degree, was conducted in prominent colleges like for example the Presidency College, Calcutta and Elphinstone College, Bombay.

Table 1.1: The founding of science departments at selected Indian Universities[39]

University	Departments Physics	Chemistry	Mathematics	Botany	Geology	Zoology
Aligarh (1920)	1920	1920	1920	1920	1950	1932
Allahabad (1887)	1922	1922	1922	1922	-	1922
Andhra (1926)	1932	1932	1932	1945	1941	1947
Annamalai (1929)	1929	1929	1929	1931	1953	1931
Indian Institute of Science Bangalore (1911)	1933	1911	1956	n.a.	n.a.	n.a.
Benares (1916)	1917	1917	1917	1919	1921	1919
Bombay (1857)	1971	1967	1963	-	-	-
Royal Institute of Science, Bombay (1920)	1920	1920	1920	1923	n.a	1920
Calcutta (1857)	1916	1915	1916	1918	1928	1919
Dhaka (1921)	1921	1921	n.a	n.a	n.a	n.a
Lahore (1882)	1951	1923	1882	1924	1951	n.a
Forman Christian College, Lahore (1865)	n.a	n.a	n.a	n.a	n.a	n.a
Lucknow (1921)	1921	1921	1921	1921	1951	1921
Madras (1857)	1952	1933	1927	1933	1952	1933
Osmania (1918)	1928	1918	1918	1924	1945	1924

[39] This is a modified version of Arnold's table. See Arnold, (2000): 191. Arnold's table is based upon U. Sen et. al., *Scientific Research in Indian Universities* (New Delhi: CSIR, 1965). In my version, I have included information from Arnold, (2000); Sen, (1965); Saha, (1938) and other sources. This cannot be taken as a comprehensive listing of institutions engaged in *research* in the physical sciences because it does not include institutions like for example the Indian Association for the Cultivation of Science, or the Royal College of Science in Baroda.

I have thus far shown that the belongings of the physics community in India were far from integrated into the core of colonial ambition or the colonial state. But this does not locate the institutionalisation of physics outside the logic of colonial science. The most coveted scientific recognition was after all election to a Fellowship of the Royal Society of London and the Nobel Prize. An election to the Royal Society called for discussions not only on scientific credibility but of political implications as well. Meghnad Saha's election to the Royal Society (1927) was heavily debated not with doubts about his scientific achievements, but rather his political affiliations with Indian nationalists. He was accused of having sheltered a nationalist charged with sedition by the [British] Government of India. Barely three years later, C. V. Raman required that the [British] Government of India grant him a passport for his journey to Stockholm to receive the Nobel Prize. The British representative in Stockholm requested an inquiry into Raman's political activities. He did not want to be embarrassed by a critic of the empire. His fears were assuaged by the inquiry – Raman, he was told, was not interested in politics. In fact, hosting a congratulatory dinner for Raman would give the empire a good face. He did just that and reported back to his colleagues in India – Raman apparently broke down into tears at the award ceremony and that could be explained in only one way - the amount of money he was awarded was too much for an Indian to have ever seen. Prakash puts it eloquently when he says, "You could not simply wish away empire when it formed the setting in which the members of colonising and colonised cultures met".[40] Saha was

[40] Gyan Prakash, "Inevitable Revolutions," *The Nation* (April 30, 2007). The quote continues as follows: 'To claim otherwise would amount to a claim that empire can permit "easy relationships" between cultures, that human exchanges can occur outside history. Not now, not then.'

nonetheless elected a fellow and Raman was granted a passport and a dinner. They may have escaped integration into the colonial scientific edifice, but they were subjects of colonial rule based upon the confidence in Britain's right to conquer and rule, and that left them vulnerable to other affects of empire.

Nascent as the physics community in India was then, its members had accumulated significant international credibility and visibility by 1930. One of them had won the Nobel Prize and another had been nominated for the same.[41] And then came the "happy thirties".[42] The 1930s can be called the decade when nuclear physics as a field came into its own. The year 1932 is now routinely cited as the "annus mirabilis" of nuclear physics. It was the year, the physicist Victor Weisskopf remembered, as "the year nuclear physics was born or really took a strong momentum […] the great year when the neutron was discovered, accelerators were built, the deuteron was discovered…. This is only true […]

[41] Saha was nominated twice for the Nobel Prize, once by the physicist Arthur Holly Compton (1930) and another time in the early 1950s, by the Indian physicist Sisir Kumar Mitra. Saha was never awarded the Nobel Prize. Robert Marc Friedman argues that astrophysics was marginalised in Swedish physics during this period, which ended in the exclusion of the field from the Nobel Prizes. "If the Nobel institution was to benefit Swedish physics, the number of specialties and individuals having access to the funds would have to be limited. They [Carl Wilhelm Oseen, Manne Siegbahn, and Svante Arrhenius] had reason to appreciate astrophysics and broader cosmical physics as a threat to their own priorities…. During the next few decades, leading astrophysicists who were nominated were summarily dismissed: Hans Bethe, Ira Bowen, Arthur Eddington, Edwin Hubble, Meghnad Saha, Henry Norris Russell. The committee noted that regardless of how important the astrophysicists' achievements might be for the specialty field of astrophysics, these did not have sufficient significance for the field of physics in general (as the committee defined it) to warrant a Nobel Prize [Even though] Work by Saha and Bethe […] certainly could not justifiably be dismissed as being solely significant for astrophysics divorced from a mainstream of physics." It was finally in 1967 that Bethe was awarded the Nobel Prize after a change in the Committee and much lobbying by prominent physicists. See Robert Marc Friedman, *The Politics of Excellence: Behind the Nobel Prize in Science* (New York: Henry Holt and Company, 2001), 150-151.

[42] See Hans A. Bethe, "The Happy Thirties," in Roger H. Stuewer, ed., *Nuclear Physics in Retrospect* (Minneapolis: University of Minnesota Press, 1979), 11-31.

in a restricted sense".[43] Weisskopf and his colleagues, who met at the American Institute of Physics to explore the history of nuclear physics, agreed that while it was not easy to set a date for when nuclear physics was born, 1932 was momentous enough to make the year remarkably significant for the history of the field. Major conferences addressed these developments and regular international meetings had begun to reorient their questions towards nuclear physics. Notable among these were the Rome conference organised by Enrico Fermi (1931), the Solvay conference in Brussels (October 1933), the large International Conference on Physics dedicated to nuclear physics in London (1934), and most certainly the annual informal physics conference in Copenhagen (1936).[44] Meghnad Saha and the young Indian physicist Homi Jehangir Bhabha, fresh with a doctoral degree from the University of Cambridge (1935), were present at the 1936 meeting. This was clearly the emerging frontier for physics research. By the late 1930s, key institutions and people had reoriented their institutions and research agendas towards the new field.[45] Significant among them was the Institute of Theoretical Physics in Copenhagen led by Niels Bohr.[46] If research questions in physics of the 1920s came from

---

[43] See "Session I: The Initiation of Nuclear Physics as a Major Research Field," in Charles Weiner and Elspeth Hart, eds., *Exploring the History of Nuclear Physics* (New York: American Institute of Physics, 1972), 5-40. For a history of just how the phrase annus mirabilis of nuclear physics came to be associated with the year 1932, see Jeff Hughes, "1932: The *Annus Mirabilis* of Nuclear Physics," *Physics World* 13, no.7 (July 2000): 43-48.

[44] See Finn Aaserud, *Redirecting Science: Niels Bohr, Philanthropy and the Rise of Nuclear Physics* (Cambridge: Cambridge University Press, 1990), 49, 59, 152, and 235-237. For the London conference see J. H. Awbery, *International Conference on Physics, London 1934: A Joint Conference organized by the International Union of Pure and Applied Physics and The Physical Society: Papers & Discussions* (London: The Physical Society, 1935).

[45] For an account of the emergence of nuclear physics as a field of study in the early 1930s, see Jeff Hughes, "The Social Origins of Nuclear Physics," in *The Radioactivists: Community, Controversy and the Rise of Nuclear Physics* (PhD Dissertation: University of Cambridge, 1993), 350-374.

[46] See Aaserud, (1990), Chapter 2. See also Jeff Hughes, "'Modernists with a Vengeance': Changing Cultures of Theory in Nuclear Science, 1920-1930," *Studies in the History and Philosophy of Modern Physics* 29, no.3, (1998): 339-367.

quantum mechanics and spectroscopy, then Raman with the Nobel Prize award for his work in spectroscopy was proof that the physics community in India was working at the frontiers of science. With reorientation of the discipline, it was professionally desirable that the Indian community engage with new questions.

Prof. M.N. Saha in Europe on Carnegie Trust Fellowship
International Conference on Nuclear Physics, Copenhagen, Denmark, 1936
Sitting, Front Row (L to R) : Prof. W. Pauli, Prof. Jordan, Prof. W. Heisenberg, Prof. Max Born, Prof. Lise' Meitner, Prof. Otto Stern, Prof. J Franck.
Sitting, Second Row (L to R) : -, Prof. M Oliphant, Prof. M.N. Saha, -, -, Prof. R Openheimer
Sitting, Fourth Row, (behind Prof. Openheimer) : Prof. H. J. Bhabha,
Standing, First from left : Prof. Niels Bohr

Figure 1.1: Meghnad Saha and Homi Jehangir Bhabha at the 1936 informal meeting on Nuclear Physics, Institute for Theoretical Physics, Copenhagen, Denmark.
Reproduced with permission from the Meghnad Saha Archives, Saha Institute of Nuclear Physics, Calcutta.

Ernest Rutherford, one of the world's most eminent experimental nuclear physicists and director of the Cavendish Laboratory, was to address the Indian Science Congress on January 3, 1938. Unfortunately, he died on October 15, 1937 – but he had already written his address to the Congress a couple of months before his death. In the second section of the address, he wrote on the "transmutation of matter" detailing the history of scientific inquiry towards and into the nucleus of matter. The individual physicist could do simpler experiments, but the nature of experimental physics was changing. Rutherford had to give in to the arrival of machines and electrical engineering into the Cavendish Laboratory. The change was dramatic – and Rutherford captured beautifully the arrival of "big-science" as it came to be called in the later post-war period.[47]

> "I cannot but reflect on the amazing contrast between my first experiment on the transmutation of nitrogen in the University of Manchester in 1919 and the large scale experiments on transmutation which are now in progress in many parts of the world. In the one case, imagine an observer in a dark room with very simple apparatus painfully counting with a microscope a few faint scintillations originating from the bombardment of nitrogen by a source of α particles. Contrast this with the large-scale apparatus now in use for experiments on transmutation in Cambridge. A great hall contains massive and elaborate machinery, rising tier on tier, to give a steady potential of about two million volts. Nearby is the tall accelerating column with a power station on top, protected by great corona shields – reminding one of a photograph in the film of Wells' "*Things to Come"* […] Here is a band of investigators using complicated electrical devices for counting automatically the multitude of fast particles from the transformation of the target element or photographing with an expansion chamber, automatically controlled, the actual tracts of particles from exploding atoms. To examine the effect of still faster particles, a cyclotron is installed in another large room […] A power

[47] For an overview on the genealogy and usefulness of the term big-science, see James H. Capshew and Karen A. Rader, "Big Science: Price to the Present," in Arnold Thackray, ed., "Science After '40," *Osiris* 7, (1992): 3-25. See also Peter Galison and Bruce Hevly, eds., *Big Science: The Growth of Large Scale Research* (Stanford CA: Stanford University Press, 1992). Derek J. de Solla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963) revised edition as *Little Science, Big Science - and Beyond* (New York: Columbia University Press, 1986) and Alvin Weinberg, *Reflections on Big-Science* (Cambridge MA: MIT Press, 1967).

> station nearby is needed to provide current to excite the electromagnet […] Such a comparison illustrates the remarkable changes in the scale of research that have taken place in certain branches of Pure Science within the last twenty years […] important problems arise which can only be solved by use of large powers (sic) and complicated apparatus, requiring the attention of a team of research workers."[48]

The formidable shape of things to come was not lost on his audience. They had traversed the path towards the change, some of them with Rutherford's help. Among the very first Indian physicists to engage with radioactivity research was Ruchi Ram Sahni of the Forman Christian College, Lahore, who came to the discipline following graduate studies with Rutherford at the Manchester University (1912-1914). The next decade though saw several more Indians at various European laboratories engaged in radioactivity and later nuclear physics research. Satyendranath Bose from the Dhaka University worked with Marie Curie in Paris (1924-25).[49] Another physicist from the Dhaka University, Rajendra Lal De worked both with Marie Curie and with Otto Hahn in Berlin. He claimed the discovery of an element and called it *Daccinum* after the city of his origins (later proved erroneous). Debendra Mohan Bose had worked first at the Cavendish, and later with Erich Regener in Berlin (1919), developing on could chamber techniques. Once back in India, he continued with cosmic ray research and later also turned to work with transuranic elements.

---

[48] Ernest Rutherford played an outstanding role in the history of nuclear physics. Under his leadership, the Cavendish Laboratory had become probably the most important laboratory for experimental nuclear physics in the 1930s. See Ernest Rutherford, "Researches in India and in Great Britain," reprinted in *The Shaping of Indian Science: Indian Science Congress Association Presidential Addresses, 1914-1947* (Hyderabad: Universities Press (India), 1938), 436-437.

[49] S. N. Bose is known for his collaboration with Albert Einstein (Bose-Einstein statistics).

The Indian Science Congress Association published a collection of essays for the Indian Science Congress meeting in Calcutta evaluating a quarter century of scientific research in India.[50] The collection poses two important questions for the story I have written thus far. First is the question of locating physicists among the Indian scientific community at large. How peculiar was the status of physics in India? Were there others from different disciplines equally engaged in prominent researches and participating in their respective fields internationally? It is not an easy question to answer without looking at the history of fields other than physics and unfortunately, not much research is available. But if one begins with indicators of international prominence like fellowships of the Royal Society, and the Nobel Prize, then the strength of physics community is obvious. Physicists dominated the list among Indians elected to the Royal Society. Of the ten fellows elected between 1918 and 1947, six were physicists and among those remaining was a statistician initially trained as a physicist at Cambridge.[51]

[50] Baini Prashad, *The Progress of Science in India during the Past Twenty-five Years* (Calcutta: The Indian Science Congress Association, 1938).

[51] I do not wish to offer the list as an unproblematic representation of the community's prominence. It can be well argued that the dominant numbers of physicists could explain the priorities of the Royal Society, and more generally reflect the prominence of physics in British scientific research. More simply, it is also explained by the nature of nominating fellows. Following his prominence in the field, CV Raman nominated three successful fellows in physics (K. S. Krishnan, H. J. Bhabha and S. Chandrasekhar); he also nominated B. Sahni. Raman had also nominated R. S. Krishnan and S. Bhagavantam in 1944, but they were not elected. The elections need to be contextualised, but it appears to me reasonable to say that the Indian physics community came to be internationally recognised in this period.

Table 1.2: Indian fellows of the Royal Society, 1918-1947[52]

Date elected	*Fellows*	**Principle field of research**
1918	Srinivasa Ramanujan	Mathematics
1920	Jagdish Chandra (J. C.) Bose	Physics, plant physiology
1924	Chandrasekhara Venkata (C. V.) Raman	Physics
1927	Meghnad Saha	Astrophysics
1936	Birbal Sahni	Palaeobotany
1940	Kariamanikkam S. (K. S.) Krishnan	Physics
1941	Homi Jehangir Bhabha	Cosmic ray physics
1943	Shanti Swarup Bhatnagar	Physical chemistry
1944	Subrahmanyan (S.) Chandrasekhar	Astrophysics
1945	Prasanta Chandra Mahalanobis	Statistics

The other troubling question would be - what could it mean to talk of an *Indian* scientific community in this period. Meghnad Saha like others writing for the collection wrote a review essay on physics taking the South Asian sub-continent as a self-evident unit of representation for 'India'.[53] He discussed the departments of Dhaka, Lahore, Allahabad, Calcutta and Bangalore, and their research activities in physics. His colleagues writing reviews for the other sciences did no different. As is quite clear, writing in 1938, Dhaka, Lahore, Bangalore all more or less qualified as India. A tentative national framework for the Indian scientific community had emerged first with the establishment of the Indian Science Congress (1914). From deliberations in the Indian Science Congress emerged

[52] This table has been borrowed from Arnold, (2000), 194.

[53] Meghnad Saha, (1938), 674-741.

two contesting organisations wanting to represent the scientific community of the subcontinent: the Indian Academy of Science in Bangalore (1934) and the National Academy of Science in Allahabad (1934). By the early 1940s however, it would no longer be possible to presume a sub-continental expanse of "India".

The outbreak of WWII in 1939 recast the framework of scientific practice for the Indian scientific community. The first institution towards organisation of scientific and industrial research aimed at war effort was organised by the [British] Government of India. The physical chemist Shanti Swarup Bhatnagar was appointed Director of Scientific and Industrial Research for war related research in 1940.[54] In the next couple of years, national life got more hectic. Mohandas Gandhi launched the "Quit India" movement in August 1942, even as the Japanese occupied Burma the same year. Exclusion of the Indian scientific community from coordinated British scientific war efforts became a hugely embarrassing matter following the Japanese occupation of Burma. Efforts at fortifying scientific research for war effort on the Eastern front began in earnest with the creation of a South East Asia Command (SEAC) led by Louis Mountbatten.[55] A young scientist from the Cavendish, already working with the Middle

[54] Shanti Swarup Bhatnagar studied Chemistry with F. G. Donnan at the University College London. Bhatnagar work was based in the laboratory for industrial chemistry at the department of physics, Punjab University in Lahore. He was appointed as director of the Board for Scientific and Industrial Research (BSIR) in 1940, on the strength of his work as well as his favour with the imperial order. His work for a British oil company had earlier earned him knighthood.

[55] Studies of SEAC thus far have been written largely from a political, military or diplomatic history approach but I have failed to find studies that foreground scientific war-effort. Among others see P. Dennis, *Troubled Days of Peace: Mountbatten and South East Asia Command, 1945-46* (New York: St. Martin's Press, 1987); S.R. Ashton, "Mountbatten, the Royal Family, and British Influence in Post-Independence India and Burma," *The Journal of Imperial & Commonwealth History* 33, no. 1 (January 2005): 73 – 92; Christopher Baxter, "In Pursuit of a Pacific Strategy: British Planning for the Defeat of Japan, 1943–45," *Diplomacy and Statecraft* 15, no. 2 (June 2004): 253 – 277; Nicholas Tarling, "Some Rather Nebulous Capacity: Lord Killearn's Appointment in Southeast Asia," *Modern Asian Studies* 20, no. 3 (1986): 559-

Eastern Command in Cairo, John Cowdery Kendrew, was sent as scientific advisor to the Allied Air Commander in Chief at Delhi, and he soon shifted work to Colombo with Mountbatten's arrival. The Council for Scientific and Industrial Research (CSIR) of India was established in late 1942 to consolidate research in civilian settings for war purposes.[56] The [British] Government of India soon approved the deputation of the physiologist Archibald Vivian Hill to India. He arrived in India in late 1943 to survey scientific research establishments in India towards their capacity to serve war effort against the Japanese, advise SEAC and at the same time reassure the Indian scientific community of Britain's commitment to Indian independence despite Winston Churchill's roaring denials.[57] It was finally important even for those in London that given the nature of [British] Indian Government, "there wasn't the slightest possibility of any positive contribution from India for the war-effort" in the near future unless serious efforts were taken.[58] Additionally, there were good reasons to jealously guard imperial preference in the shadow of rising American power in international politics.[59]

600; John J. Sbrega, "Anglo-American Relations and the Selection of Mountbatten as Supreme Allied Commander, South East Asia," *Military Affairs* 46, no. 3 (Oct. 1982): 139-145; Lord Zuckerman, "Earl Mountbatten of Burma, K. G., O. M. 25 June 1900-27 August 1979," *Biographical Memoirs of Fellows of the Royal Society* 27, (Nov. 1981): 354-364; Richard M. Leighton, "Allied Unity of Command in the Second World War: A Study in Regional Military Organization," *Political Science Quarterly* 67, no. 3 (September,1952): 399-425.

[56] V. V. Krishna, "Organisation of Industrial Research: The Early History of CSIR, 1934-1947," in Roy MacLeod and Deepak Kumar, eds., *Technology and the Raj: Western Technology and Technical Transfers to India, 1700-1947* (New Delhi: Sage Publications, 1995).

[57] Hill's visit to India is discussed in detail in Chapter 2 of this thesis.

[58] John Desmond Bernal, scientific advisor to Louis Mountbatten, Commander in Chief of the South East Asia Command, in *India Visit: Notes on the Indian Situation*, December 1944, Folder B4.47: Box: 52, JDB Papers.

[59] See among others: Kenton J. Clymer, *Quest for Freedom: The United States and India's Independence* (New York: Columbia University Press, 1995); Gary R. Hess, *America Encounters India, 1941-1947* (Baltimore: the Johns Hopkins Press, 1971).

As Indian independence and partition of the sub-continent became imminent, the idea of building national institutions increasingly began to take priority among varying sections of the Indian bourgeoisie. Bhatnagar left his laboratory and home in Lahore to lead the CSIR during the war and despite family and property, like many others, remained in Delhi after partition. He began planning for the establishment of several large laboratories for scientific and industrial research. The framework for "national laboratories" in India, and they were called "national" even under the late colonial state, began to be nurtured in the colonial incubator. But "[f]or most practical purposes India ha[d] never come into the war".[60]

1.2 Can the Administrative State become a Civilising State?

> "In short, there is a shift from a diffuse symbolic capital, resting solely on collective recognition to an objectified symbolic capital codified, delegated and guaranteed by the state, in a word, *bureaucratised*."[61]
>
> Pierre Bourdieu, (1994): 11

John Darwin, political scientist, has proposed, "if we could generalize about the causes of imperial failure at the colonial periphery, and weigh them against domestic and international constraints upon the behaviour of the colonial powers during and after the Second World War, we might advance the historiography of decolonization beyond the

[60] John Desmond Bernal, (1944) *India Notes*, op. cit.

[61] Pierre Bourdieu, "Rethinking the State: Genesis and Structure of the Bureaucratic Field," *Sociological Theory* 12, no.1 (1994): 11, emphasis added.

crude and generalized level at which it now rests".[62] Postcolonial scholarship has already drawn attention to the need for analytical separation between the formal moment of decolonisation and the long-drawn out process of decolonisation itself. This important insight requires fine-tuning in two senses. First, the significance of the formal transformation of the relationship between coloniser and colonised cannot be underestimated. As the colonizing power Britain had to begin to stop thinking like an empire, it opened formal spaces for the nationalist bourgeoisie in India to no longer frame themselves as subjects of imperial rule.[63] The struggle against subjugation was an omnipresent dimension of colonial rule itself: empires *are* unstable, and colonial administrations constantly have to redefine and reaffirm the modalities of their power through time. However, the historical weight of resistance became more significant as London itself began to lose grip on its hegemonic power. Second, the struggle to define and debate a new sense of what India was, and would become began long before the formal transfer of power from London to Delhi. The formality of decolonisation lent political credibility to these forces already in the making. From the Indian perspective, a strong case can be made that the formal process of decolonisation began in the 1930s and more decisively in 1939 with the outbreak of WWII. The political and economic demands of a brutal war against European fascism saw both Indian independence movements and the [British] Indian government (despite being at war) planning and imagining a new India. Imperial ambition demanded that decolonisation had to be accomplished in such a manner that it did not imply for Britain a complete abdication of moral, political, cultural

---

[62] John Darwin, "What was the late colonial state?" *Itinerario*, 3, no. 4 (1999): 73-82.

[63] See Frederick Cooper, *Colonialism in Question: Theory, Knowledge, History* (Berkeley: University of California Press, 2005).

and scientific leadership in the post-war era at the same time that it implied for India the gradual affirmation of political autonomy, the redefinition of identity and increasingly the need to reinvent scientific industrialism in the project of shaping a national culture.

If anti-colonial nationalisms had informed the struggle for self-rule, it was increasingly becoming apparent at the moment of decolonisation that nationalism as ideology could not provide a coherent national identity. Jawaharlal Nehru's *Discovery of India* written in prison during the last three years of WWII, ends with a deep anxiety about what the idea of India could contain, and for how long. "The discovery of India – what have I discovered? […] Today she is four hundred million separate individual men and women, each differing from the other, each living in a private universe of thought and feeling."[64] These doubts were not new for Nehru but he had earlier found enough faith in the idea to argue for the "unity" of India.[65] His shaky belief in this unity was now based upon "invisible threads". "India is a geographical and economic entity," he continued to argue, "a cultural unity amidst diversity, a bundle of contradictions held together by strong but invisible threads."[66] Having led various anti-colonial struggles successfully under the banner of the Indian National Congress, the challenge for the nationalist bourgeoisie of the new country lay in their ability to articulate and mobilise, even create precisely these invisible threads of belonging. They would find the answer in the formation of a bureaucratic state.

---

[64] Jawaharlal Nehru, *The Discovery of India* (New Delhi: Oxford University Press, 1946, 2003), 562.

[65] Jawaharlal Nehru, *The Unity of India: Collected Writings 1937-40* (London: Lindsay Drummond, 1941).

[66] Nehru, (1946, 2003), 562.

The political, administrative and territorial entity of India that was created in the aftermath of partition and integration of princely states had never before existed as a single state. Upon decolonisation a majority of Indian citizenry thus begotten, was "unaware of its own national and later constitutional subjectivity – about what it meant to give themselves a republican, democratic and secular political authority".[67] Even in the early nineteenth century, most observers of Indian politics would have located the state as a 'curious marginality' to everyday life in Indian society. Sudipta Kaviraj, an important theorist of the state in India has argued that pre-colonial state in India was characterised by exteriority; "as long as the rent was extracted, the political regime did not arrogate to itself the right to rearrange productive or more generally ordinary social relations". If British imperial government acted within general rules of marginality and majesty as a successor to the Mughal state in the early phase of colonial rule, at the height of imperial hegemony it was characterised by reorganisation of social and economic life, encouragement of social reform and a discourse on political morality of imperial authority. It managed to thus generate a debate on the morality of its own political authority, which finally contributed to anti-colonial nationalism. Political mastery though was never really a matter of debate alone and "as the British used barbarism to deal with the 'barbarians', … they also undercut the very ideals of civilisation and progress that legitimised their power".[68] The practice of colonial rule undid its own foundations.

---

[67] Sudipta Kaviraj, "The Modern State in India," in Martin Doornbos, and Sudipta Kaviraj, eds., *Dynamics of State Formation: India and Europe Compared* (New Delhi: Sage Publications, 1997), 230.

[68] Prakash, (1999), 47.

Partha Chatterjee, one of the most important political theorists of anti-colonial nationalism in India, has argued that ideas of difference and particularity were foregrounded in the shaping of Indian national identity and culture, what he calls nationalism's 'spiritual domain'. But he argues further that 'difference was not a viable criterion in the domain of the material' sphere of national life, which included matters of science, technology and the state.[69] This claim has been criticised first and foremost for rendering 'western modernity' singular, as well as for drawing an unsustainable distinction between the spiritual and material domain of nationalism in India.[70] In my reading, Chatterjee would have not a problem denying variegated interests and uneven affects of colonialism. What he and other post-colonial scholars wish to remember though are the political dangers of missing the framework of imperialism as mastery. The colonial encounter was managed, policed and represented in and through mastery. The colonial project may not have been implemented or experienced evenly but it was informed by a shared sanctimonious belief in Britain's right to conquer and rule in this case India. The expanse of colonial interests be they mercantile, religious, political, scientific or adventure – and therefore necessarily differently configured - were still not mere contagion. In rendering colonialism effortlessly fragmented, there is an inherent danger of neglecting the historically constructed hierarchy between cultures and races, and the violence employed to enforce them.[71] Anti-colonial nationalisms were responses

---

[69] Partha Chatterjee, *The Nation and its Fragments: Colonial and Postcolonial Histories* (Princeton: Princeton University Press, 1994), 9.

[70] Among others, see Cooper, (2005); 140, Prakash, (1999); 158 and Sugata Bose, "Nation as Mother," in Bose and Jalal, eds., *Nationalism, Democracy and Development: State and Politics in India* (New Delhi: Oxford University Press, 1996), 76-103.

[71] The nature of British colonialism in India is a matter of strong debate among the Cambridge School, the Chicago led North American Schools, and the Subaltern School of historiography of the Indian sub-

to the foundations, assumptions and workings of this mastery, and to use a very very old phrase, *using the very tools of the master*.

Chatterjee's other claim though, of the separation of nationalism's spiritual and material domain is historically less sustainable. Even if the spiritual domain was made inaccessible to the transformations of Western modernity, however understood, the very act of making it so is out of step in disallowing public life to inform 'private' life. One good question to ask would be if it were even possible to create such a disjunction. If this was affected even rhetorically, a robust history of its meanings for India's various regions and populations is not possible within the scope of this thesis. It should suffice to say that this claim is not evenly true for practicing scientists and political leaders among the nationalist bourgeoisie I study. But Chatterjee's work remains important because even if one were to *entirely* deny his theorisation of the national domain, his characterisation of nationalist reconfiguration of what he calls the material domain continues to be useful. More recently, Chatterjee outlined the strategies of modernisation followed by the nationalist elite:

> "Is it possible to accept western modernity without its colonialism? And I think that has been a fundamental strategy of elite nationalism, which is to take the position that there are good things about western modernity and there are bad things about western modernity, but it is possible to accept and adopt

continent. For the debate see among others Partha Chatterjee, *The Nation and its Fragments* (Princeton: Princeton University Press, 1994), Chapter 2; David Washbrook, "Progress and Problems: South Asian Economic and Social History, c. 1720-1860," *Modern Asian Studies* 22, no.1 (1988): 57-96; David Ludden, "Introduction" in Ludden, ed., *Reading Subaltern Studies: Critical History, Contested Meaning, and the Globalisation of South Asia* (New Delhi: Permanent Black, 2001) and Sugata Bose, "Post-Colonial Histories of South Asia: Some Reflections," *Journal of Contemporary History* 38, no. 1 (2003): 135-136.

> and learn the good things of western modernity without accepting colonialism. Right?"[72]

Nationalist imagination in India actively sought to reorder the material domain –i.e. the state, and industrial development but this reorganisation would not proceed by invoking the indigenous, difference or particularity. By the mid twentieth century, they were convinced of their engagement in adopting the nation-state, science and technology as the good things of Western modernity, and this faith was further emboldened when the struggle against colonialism appeared to have finally succeeded. What is clear from Chatterjee's argument is the need to rethink *just what the nationalist elite thought they were doing* when they accepted or rejected ideas or processes introduced by the colonial encounter. Chatterjee's is but one attempt to theorise what anti-colonial nationalism wanted to accomplish. Gyan Prakash offers yet another reading, that Indians received modernity (and science) in translation, and this translation hybridised or led to the undermining of its cultural authority. If Indians could understand and practice science, they could now counter the hegemony of colonial rule on its own terms and lay claim upon modernity.[73] In either case, what Chatterjee and Prakash discuss is the *manner of reception and negotiation* of modernity by the nationalist bourgeoisie. A more interesting question, to my mind, is to move back from the manner and instead begin again with the pragmatic *content* of modernity that the nationalist bourgeoisie agreed *had* to be appropriated.

---

[72] "Interview: Partha Chatterjee in conversation with Anuradha Dingwaney Needham," *Interventions* 1, no. 3 (1999): 422.

[73] Prakash, (1999).

By 1945, Nehru was leading the elite nationalist coterie that confronted at least two legitimately authorising power structures towards independence. The first was the bureaucratic and discursive apparatus of the colonial state with its history of repression of those in whose name it was now sovereign. The second was the amorphous Indian National Congress, a 'triumphant national movement' whose history was one of challenging that very state apparatus. In the very first instance, the nationalist leaders had to decide if their goal was to establish "an untrammelled version of the Western state, a purer form of Western modernity than colonialism had permitted", or in recognition of its inherently flawed morality in making political subjection feasible, and as Mohandas Gandhi continued to insist –abandon that ideal.[74] Would anti-colonial nationalism civilise the state, or was the administrative state to be transformed into a civilising state?[75] The answer lay in the Congress' own understanding of power: were they going to subject the modern state to its own [nationalist] civilising impulses, or were they going to subject an already established subject population to a nationalist version of a civilising mission – a *more true* universal modernity?

Mohandas Gandhi claimed that Indian nationalism could make a choice and not accept "western modernity" as something good for the majority of India. The nationalist bourgeoisie led by among others Subhash Chandra Bose, Jawaharlal Nehru and

[74] Kaviraj, (1997): 234.

[75] For a comprehensive argument on the inseparability of state-formation in Western Europe from its self-understanding of the "civilising process", see Norbert Elias, *The Civilising Process* (Oxford: Basil Blackwell, 1978 [1939]). I propose the idea of a "civilising state" with a sense of irony informed by Elias' understanding of the civilising process and state formation in Western Europe. To begin with, the state makers had to and in part wanted to, accomplish the affects of Elias' civilising process in India. At the same time though, state makers in independent India had inherited and come to participate in the attributes of a similarly misplaced and indefensible earnestness of the European civilising mission.

nationalist scientists like Meghnad Saha argued strongly against Gandhi and accepted economic determinism as a guarantee of political autonomy. "And in that area the choice had already been made – Elsewhere, by History, by 'the spirit of the age' […] An economy based on cottage and small scale industries was "doomed to failure" because it could only 'fit in with the world framework' as a 'colonial appendage'.[76] The universalised configuration of the modern state (and science) as proposed by History and introduced into India by the colonial project would lead the way to progress and sovereignty.[77]

And what was this thing called universal modernity at the end of WWII when Europe had diverged, contested and sought settlement through violence and fascism? Sudipta Kaviraj raises an important question of how *the content of modernity* was pragmatically determined in the process of state formation. [78] How did the nationalist bourgeoisie led by Nehru perceive the corpus of: "capitalist industrialisation, the increasing centrality of the state in social order, urbanisation, sociological individuation, secularisation in politics and ethics, creation of a new order of knowledge, vast changes in the organisation of family and intimacy, and finally changes in artistic and literary culture?"[79] The answer lies in how Nehru and the nationalist bourgeoisie understood the relationships between

---

[76] Partha Chatterjee, *Nationalist Thought and the Colonial World: A derivative discourse?* (New Delhi: Oxford University Press, 1985), 144. Chatterjee is quoting from Nehru's *Discovery of India*.

[77] For a controversial but interesting take on "westernisation" of political system in the world as "modernisation of the world order" see Bertrand Badie, *The Imported State: The Westernisation of Political Order* [Translated by Claudia Royal] (Stanford: Stanford University Press, 2000).

[78] See Sudipta Kaviraj, "An Outline of a Revisionist Theory of Modernity," *Arch. European Sociology* 46, no. 3 (2005): 497-526.

[79] Kaviraj, (2005): 508.

these various components into which the history of European modernity was rendered "analytically decomposable". Indian nationalist elite, not unlike European intellectuals of the time, ascribed simultaneity, and symmetrical interdependence to all these processes. The link between them was the overarching logic of increasing rationalisation of public life and bureaucratisation of state practice. This Weberian reading of European modernity proved crucial in their imagination in the first instance of how Europe became modern.[80] It also strengthened the nationalist bourgeoisie's claims on state formation by packaging modernity as an expressive totality.

In accepting simultaneity as against a "sequential" development of European modernity, Nehru and the nationalist bourgeoisie explicitly rejected any contradiction between capitalism and democracy.[81] Given that they had accepted economic growth as a guarantee of political autonomy, and political autonomy was a moral assertion against the despotism of the colonial state – suggesting or accepting that capitalism historically developed or can develop in the absence of democracy was discomfited. The economic logic of capitalism, and the political logic of democracy and social justice, had to appear congruent. If British failure to develop or allow the development of India was ground for discontent, how could the Indian nationalist bourgeoisie now propose economic growth without political freedom and undermine their own legitimacy to hold power? There was of course the added difficulty of reading the emergence of modernity historically and

---

[80] Ibid.

[81] Capitalism stood in for economic growth and this was acceptable to the large interests represented in the Indian National Congress – be it as a historically necessary stage (for the left) or a desirable goal (the liberals and centrists). This agreement began to disaggregate in the mid 1940s with big business and industrial interests becoming concerned as well as vocal about what form of economic growth was desirable. One such expression was the Bombay Plan (1944).

therefore differentially in Britain, Germany, Italy, France and so on – to decide which one was more acceptable, and then arrive at the particular sequence of the corpus of processes therein. Allowing for such a specific reading would perhaps also lead to an introduction of the role of religion in social order. The nationalist bourgeoisie in India was confronted the task of state-formation, and the state would have to, single handed, accomplish the establishment of the varied processes that legitimated itself and the secular modernity, they were convinced, it should symbolise. Simultaneous and symmetrical was a pragmatic reading that best served their purposes. Informed by this structural reading then, the nationalist bourgeoisie "deliberately attempted to advance all these processes simultaneously in the hope that they would support each other, or fall together in the face of resurgence of tradition".[82]

The formal decisions on what a new Indian polity, or at least a new state would look like were deliberated upon in the Constituent Assembly of India between 1945 and 1950. The immediate context was no less important in shaping these deliberations than were the larger political and moral concerns with universal modernity that informed anti-colonial nationalism. The immediacy was compounded by the fact that the Constituent Assembly of India also happened to be carrying out the day-to-day functions of government as a provisional parliament.[83] The overwhelmingly immediate problems were those of maintaining law and order following the violence of partition, establishing the territorial

---

[82] Kaviraj, (2005): 519-520. Kaviraj argues that at the time of independence, "it was simply taken for granted that the symmetrical-functionalist reading of Western modernity was correct; indeed, there was no competing hypothesis about how to read that history".

[83] See Granville Austin, *Working a Democratic Constitution: The Indian Experience* (New Delhi: Oxford University Press, 1999).

integrity of "India", and transforming an anti-colonial nationalism into a politics of self-government. The period between 1945 and 1950 is most crucial for understanding the imperatives of state-formation in India.

It is only recently that some attention has been devoted to study the partition of the sub-continent. Quite understandably, much of it is focused on religious nationalism and the violence of partition. The decolonisation of British India resulted in severe political instability on the sub-continent. The partition of territory into India, and East and West Pakistan resulted in serious law and order disturbances. Boundaries were drawn and like most boundaries, these did not correspond to the realities of belonging for the people it sought to distribute over landscapes. Millions migrated across the borders in a matter of months and the "refugees" confronted the new governments with infrastructural problems. Religious strife complicated matters and the most urgent problem that challenged the new governments was that of controlling violence and maintaining law and order on the streets. The urgency hardly allowed the privilege to think in terms of the viability of continuing government with colonial police and military apparatus. It was not the case though, that the privilege when available led to different conclusions. The highhanded integration of princely states into Indian Territory in the first years of independence is witness to nationalist investment in the continuation of a centralised colonial state apparatus.[84]

---

[84] See Barbara Ramusack, *The Indian Princes and their States* New Cambridge History of India III/6 (Cambridge: Cambridge University Press, 2004) and Manu Bhagavan, *Sovereign Spheres: Princes, Education and Empire in Colonial India* (Oxford: Oxford University Press, 2003). The territory of British India did not include the 552 princely states of India. Of these, 216 were merged into former British provinces, and another 275 were combined to form five new states: Rajasthan; Saurashtra; Patiala and East Punjab States Union (PEPSU); Madhya Bharat and Vindhya Pradesh. The four largest units – Mysore; Travancore-Cochin; Hyderabad; and Jammu Kashmir were retained without substantial changes. [Note

Other material affects of partition, specifically addressing scientific practice have not been studied at all. Each of the departments mentioned in Table 1.1 was favourably profiled in the international scientific community. The departments were engaged in similar international networks and there was traffic of people, ideas and instruments between them. Of these, after partition, the Punjab University was divided into the Punjab University, Pakistan and Panjab University, India. Several colleges affiliated with the Calcutta University fell in East Pakistani territory, affecting among other things the university's income from examination fees. The universities of Dhaka and Lahore were completely in Pakistani territory and those in Aligarh, Delhi, Calcutta and Allahabad (at least) saw significant and painful demographic reconfigurations. With the territorial integrity of the sub-continent in question, there were no easy answers towards establishing national frameworks.

With independence, the overarching rationale of anti-colonial nationalism was no longer binding even the Indian National Congress. First and foremost, there were those that no longer identified with Nehru's continuing support for secular politics in the wake of partition. The more left leaning members of the Congress also began to move away from what they perceived as Nehru's liberalism and socialism. As an umbrella organisation, the Congress had allowed for panoply of interests to converge on two broad issues: the

---

from Francine Frankel, *India's Political Economy, 1947-2004: The Gradual Revolution*, 2nd ed. (New Delhi: Oxford University Press, 2005), 74.

issue of Indian independence and scientific industrialism.[85] What exactly was scientific industrialism? Pratik Chakrabarti has proposed but not sufficiently developed upon the idea of "scientific industrialism" in the short conclusion to his recent book.[86] Orientalist imagination, particularly of the eighteenth and nineteenth century, had overwhelmingly stressed mysticism and spiritual aspects of the Indian civilisation, and some Europeans and some Indians often used that as an explanation for the lack of "material development" in India to varying degrees, in varying significance, and in different contexts. Beginning late nineteenth century, "scientific industrialism" was co-produced as an ideology around the need to restore or establish material development of the Indian sub-continent *through industrialisation*, where industrialisation came to mean the development of science-based-industry. The inspiration came from various meanings science came to occupy in its representation of man's triumph over nature intellectually, but also in its consequences for the betterment of living conditions. The ontology of Western science promised a new social and economic order, *in relation to the essential materialism that India lacked or lost*.[87]

Science, Chakrabarti claims, was eventually "practiced and adopted in colonial India with a faith in its superior ontology". Indian scientists especially the generation after the physicist Jagdish Bose and the chemist Prafulla Ray had come to accept the ontology of

---

[85] See among others, Paul R. Brass, *The Politics of India since Independence* (Cambridge: Cambridge University Press, 1990); Rajni Kothari, *Politics in India* (Delhi: Orient Longman, 1970), especially Chapter 5; Stanley A. Kochanek, *The Congress Party of India* (Princeton: Princeton University Press, 1968) and Myron Weiner, *Party Building in a New Nation: The Indian National Congress* (Chicago: University of Chicago Press, 1967).

[86] Chakrabarti, (2004), 298-300.

[87] Chakrabarti, (2004), 299.

Western science, perhaps also with a faith in its superiority although such a claim is bound to be heavily contested by post-colonial scholarship. Scientific industrialism grew out of the accommodation of this *acceptance* within the struggle against subject status and defiance of alien rule. Though never used by the historical actors in this thesis, the term is perhaps useful to map the corpus of thoughts and beliefs of a select nationalist bourgeoisie for purposeful organisation of scientific activity on the national scale.

Shiv Visvanathan, sociologist of science, has provided a useful history of what he calls "scientized technology", a term that has significant overlap with Chakrabarti's "scientific industrialism". Visvanathan traces the roots of "scientized technology" with the establishment of the Indian Association for the Cultivation of Science (IACS) in Calcutta (1876).[88] Mahendra Lal Sircar, founder and promoter of the IACS was convinced that scientific education "must permeate the country before technical education is even possible".[89] Nationalist press supportive of Sircar's ambitions laid out the message for Bengal's English speaking audiences:

> "that between scientific knowledge and its application to the practical pursuit of these industries in India, there is a gulf fixed, and this gulf is due to conditions which mere science is powerless to remove, which are indeed the despair alike of Savant and Statesman. In the vast majority of cases, the application of science to industry or art is not a simple operation which can be performed either by the man of science or man of practice, even by both together, but an extremely difficult operation in which success implies long patient and costly experiment…"[90]

---

[88] Shiv Visvanathan. *Organising for Science* (New Delhi: Oxford University Press, 1985), 1-132.

[89] Mahendra Lal Sircar, "Secretary's Address," *IACS Annual Report*, (1888): 18.

[90] Excerpt from the *Hindu Patriot*, in *IACS Annual Report,* (1891): xiii-xxxiv.

At the turn of the century, Sircar would finally argue, "It is through the laboratory that starvation may be eventually turned to plenty".[91] Visvanathan traces the historical trajectory of a more or less coherent "scientized technology" beginning with the *Swadeshi* movement (1905),[92] following through WWI, and the establishment of an Indian Industrial Commission to finds ways of reducing Indian dependence on exported goods (1918), compounded with an admiration for Soviet path to industrialisation (1920s) - all of which discursively culminated in the idea that planned industrial development based upon goal oriented scientific research or industrial research, was the most correct path towards progress. The argument was nationalist in spirit but the *employment of scientific knowledge towards practical pursuits* could hardly appear anachronistic - as historians of colonial science have shown, most scientific institutions established under colonial rule were after all engaged with imperial ambitions in the least with those of trade, survival in the tropics and territorial control. This perspective on scientific inquiry combined with the critical engagement of Indians with scientific research beginning the late nineteenth century, were escorted increasingly by the later reductionisms of the editors of science popularisation journals like *Current Science* and *Science and Culture* in English as well as vernacular press. By the 1930s, the necessity of material development of India also drew in varied sources like New Deal America, Soviet planning and industrialisation, reconstruction in Nazi Germany and American philanthropic

---

[91] Mahendra Lal Sircar, "Secretary's Address," *IACS Annual Report*, (1901): 27.

[92] *Swadeshi* literally translates to "of one's own nation". For a history of the partition of Bengal and the *Swadeshi* movement see: Sumit Sarkar, *The Swadeshi Movement in Bengal, 1903-1908* (Delhi: People's Publishing House, 1973).

foundations.[93] Visvanathan's history is useful, but "scientized technology" fails to capture the purposeful enrolment of scientific research for material development, of the faith in science-based-industrialisation to advance the modernisation of India. This faith in industrialisation, in the final instance, became the core of a secular ideology – and it could be called "scientific industrialism" - that provided the scaffolding of a free India. There remained though, a significantly influential section of the Congress led by Mohandas Gandhi that did not support the necessity of large-scale industrialisation throughout the first half of the twentieth century, but a majority of the various shades of nationalist leadership had not rejected the India produced by "colonial governmentality".[94]

> "I was agreeably surprised at the large measure of unanimity achieved by us in spite of the incongruous elements in our [National Planning] Committee. The big business element was the largest single group and in its outlook on many matters… was definitely conservative. Yet the urge for rapid progress, and the conviction that only thus could we solve our problems of poverty and unemployment, were so great that all of us were forced out of our grooves and compelled to think on new lines… To me the spirit of co-operation of the members of the Planning Committee was peculiarly soothing and gratifying, for I found it a pleasant contrast to the squabbles and conflicts of politics. We knew our differences and yet we tried and often succeeded, after discussing

---

[93] Most historians of science have attributed the crystallisation of scientific industrialism in India to the debates generated by and in the pages of *Science and Culture*, launched in 1934 and led by Meghnad Saha and his colleagues at the Indian Association for the Cultivation of Science and University College of Science, Calcutta. See among others Prakash, (1999) and Chakrabarti, (2004). I would suggest that journals like *Current Science* launched in Madras (1932) contributed similarly and equally to the debate but in this case the southern regions of India. Meghnad Saha in Calcutta and Mokshagundam Visvesvaraya in Madras were but two that vociferously argued for depoliticised industrial growth. For an overview on ideas for developing India for the period between 1930 and 1950, see Benjamin Zachariah, *Developing India: An Intellectual and Social History* (New Delhi: Oxford University Press, 2005).

[94] For colonial governmentality, see David Scott, "Colonial Governmentality," *Social Text* 43, (Spring 1995): 191-220.

> every point of view, *in arriving at an integrated conclusion which was accepted by all of us, or most of us*."[95]

Colonial rule had not made India productive enough.[96] The nationalist elite had to take responsibility of leadership. They were the legitimate agents who would better perform the task of making India productive. The integrated conclusions found within the National Planning Committee debates were a welcome change for Nehru from the troubling debates in politics. Planning was not to be about politics, but about making a task list for the new state. In this manner, NPC also managed to place debates on the future of India outside politics, in the hands of experts and (therefore) beyond contest, and therefore accountability for development was now outside the purview of exactly those whose future was being discussed. The arguments were well ensconced in economic nationalism of the turn of the century – colonialism had rendered India unproductive and poor. The path to increasing production, economic growth and therefore to progress was through industrialisation but also of increasing rationalisation of public life. The "Note for the Guidance of Sub-Committee's of the National Planning

---

[95] Nehru, (1946, 2003), 399-401. The period between 1938 and 1947 saw very systematic expressions of the consensus on scientific industrialism of which Soviet inspired planned development was an important aspect. First was the appointment of a National Planning Committee by the Indian National Congress Ministries in 1938. Soon followed the communist "Peoples Plan" (1943), the Bombay Plan proposed by industrial leaders (1944) and Mohandas Gandhi's 'Constructive Program" (revised 1943) based on his ideas of rural development and village republics.

[96] For an argument prioritising political economy as an explanation over modular nationalism in the making of India as a productive space and a discussion of late nineteenth century economic nationalism see Manu Goswami, *Producing India: From Colonial Economy to National Space* (Chicago: The University of Chicago Press, 2004), Chapters 2 and 7.

Committee" clearly laid out the priorities on this path and especially marked the "Russian Plan" as the "model of Priorities hitherto found".[97]

> "It is essential that much greater attention should be paid to *making scientific and technical research as an integral part of planned economy*. Universities and research institutions should be organised to permit of fundamental and basic applied research on the widest possible basis being undertaken in the country. Further, industrial research should be comprehensively planned and linked with the development of industries, and industrial research organisations created, best suited to the needs of individual industries. To put further research actively on a proper basis, highly trained personnel with first-class scientific ability in progressively growing numbers will be needed. To produce these workers, two things require to be done; (1) to build up as rapidly as possible institutions in India which can give the highest type of scientific training of the most varied type and (2) to have men trained abroad to meet the scientific and industrial needs of the country in the very immediate future".[98]

Thus, the nationalist conception of the state *embodied the technological imperative* in the co-production of scientific industrialism, and this was most explicitly expressed in the establishment and mandate of the National Planning Committee of the Indian National Congress.[99] Independence of India accomplished, Congress nationalist government strategy then, was to strengthen scientific industrialism as an overarching purpose of the state – a talisman to hold up against resurgence of religious and other nationalisms, and to fortify redress of uneven development under imperialism, should the left ever manage to deliver a politically destabilising critique. There was also the question of princely states where government was legitimated by ascribed power. State formation has been

[97] K. T. Shah, "Appendix III- Note for the Guidance of Sub-Committee's of the National Planning Committee," *Report of the National Planning Committee*, (New Delhi: The National Planning Committee of the Indian National Congress, 1938), 65. Emphasis added.

[98] Shah, (1938), 61.

[99] Zachariah, (2005).

characterised with the concentration of power, necessarily through marginalisation and dispossession of other power wielding or potentially power holding processes and structures.[100] A centralising impulse thus executed in the name of making India productive, and therefore autonomous and sovereign, could potentially inscribe legitimate political authority of the Indian state in a territory acquiesced, acquired and annexed from varying sources of power – something the evocation or imagination of a primordial belonging to nation could far from achieve at this moment. Science also appeared to suggest as Yaron Ezrahi has argued, "*a cultural strategy for depersonalising authority through the free operation of a voluntary, self-regulating community which evolves universally valid standards*".[101] Scientific industrialism was made into a secular ideology "to buttress the centralising project of a post-colonial nation-state".[102]

The new state had effectively emerged as an agent of social change in two ways. The Indian National Congress had emerged not only as leaders of government in independent

[100] Max Weber accounts for the state-formation as successful monopolisation of physical violence over a definite territory, and over the totality of the corresponding population. Norbert Elias accounts for state formation on similar lines but as more than monopolisation of physical violence and as a part of the larger "civilising process" of Western Europe. See Max Weber, *Economy and Society: An Outline of Interpretive Sociology* I. (Berkeley: University of California Press, 1978); Norbert Elias, *State Formation and Civilisation* (Oxford: Basil Blackwell, 1982 [1939]). For more recent accounts see Quentin Skinner, "The State," in Terence Ball, James Farr, and Russell L. Hanson, eds., *Political Innovation and Conceptual Change* (Cambridge: Cambridge University Press, 1989), 90-131; Charles Tilly, *Coercion, Capital and European States, AD 990-1990* (Oxford: Basil Blackwell, 1990). I have found very useful Bourdieu's argument of the genesis of the state as concentration and increasing bureaucratisation of both symbolic and physical power. See Bourdieu, (1994).

[101] Yaron Ezrahi, "Science and the Problem of Authority in Democracy" in *Transactions of the New York Academy of Sciences* 39, (1980): 44.

[102] Bose, (2003). In calling for a "dynamic conception of religion and its changing meanings in the precolonial ecumene and colonial and postcolonial public sphere", Sugata Bose is convincing when he argues that "The field [of South Asian Studies] is in need of a historiography that knows how to distinguish between religious sensibility and religious bigotry as well as between secularism as a system of values and secularism as an ideology to buttress the centralising project of a post-colonial nation-state".

India but also as a moral alternative to colonial rule, and in that, personified the new state. The promise to build a nation, the Congress would now have to deliver as a state. No less important was the consensus on making India productive - the development of India. [103] Given then, the urgency of law and order problems coupled with that the Nehru led nationalist coterie was increasingly facing opposition from both within and without the nationalist movement, the provisional government came to rely heavily upon existing bureaucratic procedure for effective government. Even if independence meant that bureaucratic leadership was now committed to transforming the state, because this was still a largely unreconstructed colonial bureaucracy, "local administration was inseparable from local power" structures. A strong bureaucratic state resting precariously upon local power structures thus began to emerge in the early years of Indian independence as a promise of an alternative to nationalist politics, a guarantor of freedom and citizenship, and as an agent of development.[104] The significance therefore, of nationalism's *explanatory potential* for history of this period can sometimes be overestimated.

1.3 The Future Shape of Things - Nuclear Physics, State Formation and Development in India, 1945-1959

> "Presently, we may have to follow other countries in having a great atomic energy research institute also, not to make bombs, I hope; I do not see how we can lag behind in this very important matter, because atomic energy is

[103] See among others Chatterjee, (1993), 205, and Itty Abraham, *Science, Secrecy and the Post-colonial State: The Making of the Indian Atomic Bomb* (London: Zed Books, 1998), 25-26.

[104] See especially Sudipta Kaviraj, (1997); see also Frankel, (2005), Chapter 3 and Lloyd I. Rudolph and Susanne Hoeber Rudolph, *In Pursuit of Lakshmi: The Political Economy of the Indian State* (Chicago: University of Chicago Press, 1987), Chapter 2.

going to play a vast and dominating part, I suppose, in the future shape of things."[105]

Jawaharlal Nehru, (January 1947).

The most dramatic technological imperative –the nuclear - presented itself to Indian state makers with the end of WWII. The nature of Japan's defeat in the war was spectacular beyond contemporary imagination. The end of WWII also coincided with accelerated plans for transfer of power to India and the next three years saw contest, bitter struggle, disappointment and perplexity. Neither the exact form of the new state nor nationalisms' place therein, or the shape of post-war nuclear research were self-evident. In the period between 1945 and 1948, the Constituent Assembly of India debated the future of nuclear weapons in free India, secrecy surrounding nuclear research, and regulation of mining and trade of fissile materials found in India, *in conjunction with* debates on making a correct national-state framework for the baffling entity called India that was coming into being.

Nuclear research was not a matter for the state to legislate upon anywhere in the world before WWII. It certainly became one after the end of the war. Following the use of atomic weapons, atomic and nuclear research became inextricably intertwined with warfare, and like other matters of international warfare, it became the business of states. *And an Indian state was in the making*. Nehru and the nationalist bourgeoisie realised the importance of nuclear pursuits also as a potential energy source but this dual imperative was equally obvious to the physics community in India. The use of atomic bombs recast

[105] Jawaharlal Nehru, "The Necessity of Atomic Research," Extracts from a speech after laying the foundation stone of the National Physical Laboratory at New Delhi on January 4, 1947; Reproduced in *Pandit Jawaharlal Nehru on Atomic Energy* (Bombay: Bhabha Atomic Research Centre, 1989).

the relevance of nuclear physics research for the physics community the world over and in India. There was no escaping the redefinition of their status, but also the changing nature and scale of physics practice. Both, the nationalist bourgeoisie along with those engaged with nuclear research held stakes in the shape of things to come and it was in the convergence of the interests of these two sets of actors that nuclear history of India took shape.

The discovery of nuclear fission, in the year WWII broke out, confirmed the potential of nuclear energy for the scientific community. How this could be utilised for war purposes became clear only with the end of the war, but the use of nuclear power for peaceful purposes, including the production of energy, remained far from clear and largely utopian even towards the end of the decade. Nuclear research as a field was radically transformed under wartime scientific effort, and the priority to understand this transformation has framed the history of nuclear physics as a field even for the interwar period. Jeff Hughes in his essay on radioactivity and nuclear physics in the Cambridge History of Modern Science contends, "The nuclear age is only now coming to be understood as a contingent accomplishment rather than an inevitable outcome of scientific activity."[106] Historiography of nuclear physics has been plagued by teleological reconstructions of its historical past, particularly for the period prior to WWII, with preference given to those events that became significant for weapons making during and after the war. In this process canonical nuclear history, particularly for the period prior to WWII is guilty of

[106] Hughes, (2003): 352.

"its implicit naturalistic justification of the creation of nuclear weapons".[107] It is important to write the history of nuclear physics as an emerging field in the 1930s when physicists justified their interest as one of the need "to participate in the most 'modern' branch of the subject". They were driven by what Hughes calls the modernist imperative of nuclear physics.[108]

The Indian physics community was indeed drawn into nuclear physics as a modernist imperative. The modernist imperative in the late 1930s meant first and foremost, the establishment of capabilities to pursue nuclear physics: one option was the development of infrastructure for participating in nuclear physics research as an international activity. Another option was that of participating in study and research at the leading centres in Western Europe and North America. The Cavendish Laboratory at Cambridge University, England, was the leading laboratory for experimental nuclear physics until the mid 1930s. Moreover, it was a laboratory for the Empire with an established tradition of training Indian students. The Radiation Laboratory at the University of California Berkeley had come into the fray with its successful implementation of the cyclotron principle in 1933, and increasingly took lead through building larger accelerators with higher energies. In 1938, two of India's prominent scientists, Chandrasekhara Venkata Raman and Meghnad Saha sent a student each, Rappal Sangameswara Krishnan to the Cavendish, and Basanti Dulal Nagchoudhuri to the Radiation Laboratory, respectively, with the explicit purpose of training to come back and establish nuclear physics in India.

---

[107] Hughes, (2003): 373.

[108] Hughes, (2003): 369.

The physicist Walther Bothe in Germany was working towards acquiring a cyclotron around the same time. In December 1938, he found the following distribution of cyclotrons in the world (in his order of preference):[109]

Table 1.3: The World of Cyclotrons in 1938

Location	Number of Cyclotrons	Laboratory/ Leading Mentors
USA	9 completed 27 under construction	
England	2 completed	-Cavendish Laboratory, Cambridge University [John D. Cockcroft] -Department of Physics, Liverpool University [James Chadwick]
Japan	2 completed	Institute of Physical and Chemical Research (Riken), Tokyo [Yoshio Nishina]
Denmark	1 completed	Institute for Theoretical Physics, Copenhagen [Niels Bohr]
Sweden	1 under construction	-Research Institute for Physics (also called the Nobel Institute) Stockholm [Manne Siegnahn]
Switzerland	1 under construction	*-Physikalisches Institut der Eidgenössische Technischen Hochschule*, (ETH) Zurich [Paul Scherrer]
France	1 under construction	-*College de France*, Paris [Joliot Curie]
Russia	1 under construction	-Leningrad [Rukavichnikov]

109 See Mark Walker, *German National Socialism and the Quest for Nuclear Power, 1939-1949* (Cambridge: Cambridge University Press, 1993), 173. I have developed table 1.3 beginning with Bothe's survey, and added detail on the laboratories and physicists involved in each case. I do not offer this table as a decisive historical overview on the cyclotrons in 1938, but as an example of what the physics community knew about cyclotron projects in the world. Dating a "good external beam" and therefore to declare cyclotron 'functioning" is far from an undisputed matter. Bothe's survey does not appear to be grossly off the mark.

It is useful in the first instance to outline how the modernist imperative for nuclear physics presented itself to the Indian physics community for the period prior to 1945. This enables me to write a history of nuclear physics without prioritising a trajectory that establishes the inevitability and naturalness of an Indian nuclear weapons or energy program. The history of Indian nuclear physics, I will argue, goes beyond the history of the Indian nuclear program in both, her weapons or nuclear energy capability. Decisive action towards entering the field of experimental nuclear physics research by Raman and Saha was contemporaneous with many others, as Bothe's survey shows. In 1936, Meghnad Saha was impressed by the "atom-smasher" [cyclotron] at the Radiation Laboratory in Berkeley, and convinced of its dual importance for medical treatment and nuclear physics research. He wanted to build one in India because the atom-smasher would elevate the status of his laboratory as one possessing the most recent equipment for cutting edge scientific research. He also perceived his efforts in building infrastructure for science as inseparable from his efforts at nation building. His arguments must have convinced Jawaharlal Nehru, who not only supported Saha's quest for funds from industry led philanthropic foundations, but also followed the developments on this first Indian cyclotron while imprisoned.

In the case of C. V. Raman who wanted to establish nuclear physics at the Indian Institute of Science, Bangalore, he argued that nuclear physics was "the [research] problem of the time". He saw the necessity for the establishment of nuclear physics to retain the prestige of the Institute as India's foremost scientific research institute. A cyclotron should be built, he said, no less because, “Almost every civilised country, barring India, had one”.[110] Homi J. Bhabha, the youngest and the only one of the three to have studied abroad (Cambridge), saw advantages in the pursuit of nuclear physics to further his research interests in cosmic ray physics. In India during the war, he became aware of the strength of his industrial and scientific network and led the establishment of an institution dedicated to fundamental research in the physical sciences. The Tata Institute of Fundamental Research was established by June 1945, but particle accelerator building activity began in 1951-52. Bhabha argued for the establishment of an “outstanding school of physics” (not for the introduction of a new field within an existing institution), to train young scientists, who could become experts on nuclear energy matters – discussions on which he had witnessed in Copenhagen at the 1933 and 1936 conferences. This was not only one’s duty to his country, Bhabha argued but also one necessary towards advising industrial development of India.

Raman at the Department of Physics, Indian Institute of Science, Bangalore, Saha at the Department of Physics, University College of Science, and Bhabha towards the Tata Institute of Fundamental Research, Bombay, all argued for the establishment of nuclear physics before August 1945, on different scales and with varying ambitions. In the modernising of their discipline, they also found connections with the broader agreement on scientific industrialism. Nuclear physics was necessary for building a nation, as a sign of civilisation and for advising on India’s industrial productivity respectively. Before August 1945, the nationalist bourgeoisie accepted the logic of building nation,

[110] News Clipping, “Key to the Universe: The Discovery of Cyclotron, Sir C. V. Raman’s Tribute to Prof. Lawrence” most likely from the daily *The Hindu* (January 7, 1940), RSK Papers.

civilisation and training of expertise, but as a part of the larger commitment to promoting scientific education and research and necessary for developing India. There was no reason to prioritise nuclear physics, no case to be made for nuclear exceptionalism. That changed with the use of atomic weapons at the end of WWII. Nuclear physics now became uniquely important to the state. It was no longer possible to think about nuclear research on the same lines as thinking about building dams or planning heavy industrial development. For the first, as a future source of energy it provided the very basis for the hope of an accelerated industrial development of India. It was now well imaginable as essential to industrial development. But this was also the period of India's decolonisation. It was no less frightening that not possessing nuclear knowledge could leave India unable to participate in international politics as a sovereign nation-state. Would the inability to master nuclear science and technology mean the loss of sovereignty yet again?

> "It can hardly be challenged that, in the context of the modern world, no country can be politically and economically independent, even within the framework of international interdependence, unless it is highly industrialised and has developed its powers to the utmost. Nor can it achieve or maintain high standards of living and liquidate poverty without the aid of modern technology in almost every sphere of life. *An industrially backward country will continually upset the world's equilibrium and encourage the aggressive tendencies of more developed countries*."[111]

If national-state formation was an imperative, and state formation meant mastery over territory and resources as well as monopoly of political power, then the nuclear presented itself as a scientific and technological challenge that had to be mastered on the path towards the making of a sovereign state. On the scale of funding and complexity, nuclear

[111] Nehru, (1946, 2003), 413. Emphasis added. The conflation of the national development and national security concerns is discussed in Abraham, (1998): 11-15.

research now was a much larger enterprise than it was within the university laboratory. Even if this change had begun before the war, its significance now was important enough that ways would have to be found by those concerned with the state and those already engaged with nuclear physics to continue and expand this research field.

Raman, Saha and Bhabha were under spotlights. The research field they wanted to promote was transformed in significance but also in scale and the very nature of its experimental practice. Nuclear research was on state agenda and feasible perhaps only with state funding. Laboratories would have to be readjusted to these new parameters, re-equipped, and newer networks and alliances would have to be built in order to ensure the survival of the nuclear physics laboratory in the university and research institutions. The three laboratories were now in competition for state resources but increasingly also for priority. Given scarce resources, they could compete, or specialise and collaborate, but both Bhabha and Saha came to see centralisation and the comprehensive provision of research equipment within a single facility as a requisite condition for the progress of nuclear research. Moreover, in the prevailing circumstances of scarcity, they saw little sense in separating fundamental research in nuclear physics from nuclear energy research. With the exception of the United States, others in the field including Britain were confronted with a similar problem.[112] A strategy of concentration and nomination was also the preferred method of statist organisation – the coincidence would not be

[112] For the British debate between John D. Cockcroft arguing for centralisation and James Chadwick arguing for equipment in university laboratories, see Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy, 1945 -1952, Policy Execution II* (London: Macmillan, 1974), Chapter 2 "Labour's Machinery of Government," and Chapter 18 "Research: Harwell's Role." See also Jean Bocock, Lewis Baston, Peter Scott, and David Smith, "American influence on British Higher Education: Science, Technology, and the Problem of University Expansion, 1945-1963," *Minerva* 41, (2003): 327-346. I discuss this problem in Chapter 3 of this thesis.

missed. The tentative convergence of interests and anxieties of the two communities, nationalist political leadership and nuclear researchers, recast the nuclear field for free India most decisively in the period between 1945 and 1948, within the larger project of state formation. It was in their ideas of making of the state that the physicists sought to make feasible their reformed research agenda. In the emerging rhetoric of what the new state would look like lay the constraints on legitimately possible research pursuits. If Nehru and the political leadership had found in this community the expertise to work the technological challenge presented by the nuclear, Raman, Saha, Bhabha, and their colleagues and students knew more than ever before, the support their proposals would now enjoy with the new government. The importance of co-production of the state and the nuclear physics community in independent India cannot be overstressed.

If the state were to be the agent of social change and development, and to take charge of reorganising science towards this goal, certain infrastructures and mechanisms would have to be put in place. This had already begun with the coordination of scientific war effort under the late colonial state.[113] We have seen how and why colonial state structures continued into independent India. The Council for Scientific and Industrial Research [CSIR of India] was one of them. Shanti Swarup Bhatnagar was leading the scientific research for war effort beginning 1940. The CSIR coordinated industrial and fundamental

---

[113] The late colonial state makes for an interesting concept in itself. Concerned with issues that did not register earlier with the colonial state but began to take precedence and weight under the shadow of impending decolonisation, the late colonial state took on a near complete different character of government. As regards development, the first Colonial Development Act came as early as 1928 and another relevant act came in 1940. These did not however concern India as much as they did the African colonies but the point here is the acknowledgement by Britain of the need for development work in the colonies. For an argument on the concept, see John Darwin, (1999). For an overview on how development became a concern for the late colonial state, especially in the case of Africa, see Sabine Clark, *Experts, Empire and Development: Fundamental Research for the British Colonies* (Doctoral Thesis, University of London, 2005).

research for war purposes, and worked as a centralised organisation. The organisation and its leader were retained in free India, reincarnated without ceremony as a coordinating state department for building national laboratories.[114] In 1946, the Atomic Energy Research Board of India led by Homi J. Bhabha was established under the CSIR. In the period between 1946 and 1948, Bhatnagar played an important role in ensuring that one laboratory emerged as *the central laboratory* of nuclear research in India, within the reigning CSIR logic of developing one good laboratory dedicated to one purpose – in fact the logic of the state, of concentration and nomination. Moreover, this was increasingly the more convincing manner for organising nuclear research technology for many, and not just in India. Nation building cannot be conflated with national-state framework: Bhatnagar's work involved the establishment of laboratories for India within a national-state framework. But the nature of his efforts were distinct from Meghnad Saha's or Homi J. Bhabha's enterprise, or for that matter even Raman's efforts to build a nuclear physics laboratory. Unlike Bhatnagar, their efforts were argued as a part of nation building efforts linking themselves with nationalist politics (Saha), with national identity (Bhabha) or universal modernity and civilisation (Raman). Bhatnagar's efforts were at the outset bureaucratic. His first task at the national scale, if it could be called that, was the coordination of scientific and industrial research for war-purposes of the colonial state. Bhatnagar continued to organise and coordinate scientific research for the state, after independence, towards the realisation of autonomy and self-sufficiency.

[114] See V. V. Krishna, (1995).

While most historians and social scientists agree on the importance of science as a metonym for modernity and development within the Nehruvian project, there is far too little social history of the foundational moments of state formation in India. There is however a significant and rich body of literature critically exploring the connections between the state in independent India and its role as an agent of development. [115] In these studies, science is evoked in the context of state led technological projects like large dams where science stands in for the violence of modernisation. Ashis Nandy's landmark volume, *Science Hegemony and Violence* is one such important critique of the Nehruvian state.[116] Scholars have also written stringent moral critiques of the nuclear research imperative and national security concerns, but very few examine its history within the larger processes of the transformation of India.[117] Newer histories and social studies mapping the transformation of the state in independent India have no chapters on scientific practice, institutions or scientific statesmen.[118]

---

[115] See among others Amita Baviskar, *In the Belly of the River: Tribal Conflicts over Development in the Narmada Valley* (New Delhi: Oxford University Press, 2004); Akhil Gupta, *Postcolonial Developments: Agriculture in the Making of Modern India* (Durham: Duke University Press, 1998); Satyajit Singh, *Taming the Waters: The Political Economy of Large Dams in India* (New Delhi: Oxford University Press, 1997).

[116] Ashis Nandy is at the Centre for Studies in Developing Societies, New Delhi (CSDS), an autonomous social science research institution established in 1963. The writings of scholars like Rajni Kothari, D. L. Sheth and Ashis Nandy from the CSDS have become "a point of reference for various attempts from the South to question the global establishment view of democracy". The centre's most widely representative statement on the place of science in independent India is Ashis Nandy, *Science, Hegemony and Violence: A Requiem for Modernity* (New Delhi: Oxford University Press, 1988), see Shiv Visvanathan, "On the Annals of the Laboratory State", 262-278.

[117] See M. V. Ramana and Zia Mian, *Prisoners of a Nuclear Dream* (New Delhi: Orient Longman, 2003); Praful Bidwai and Achin Vanaik, *South Asia on a Short Fuse: Nuclear Politics and the Future of Global Disarmament* (New Delhi: Oxford University Press, 1999) and Praful Bidwai and Achin Vanaik, "A Very Political Bomb," *Bulletin of Atomic Scientists* (July-August 1998).

[118] See for example Francine R. Frankel, Zoya Hasan, Rajeev Bhargava, and Balveer Arora, *Transforming India: Social and Political Dynamics of Democracy* (New Delhi: Oxford University Press, 2000); Partha Chatterjee, *State and Politics in India* (New Delhi: Oxford University Press, 1998); Sudipta Kaviraj, *Politics in India* (New Delhi: Oxford University Press, 1997).

The Indian state is also studied by another group of scholars who want to understand the nature of the "post-colonial state". Ethnographic studies of the "everyday state" focus upon the affects of a centralised powerful state at the local level, upon a populace earlier habituated to "polity" [marginal political authority].[119] Driven by a theoretical mood to behead the king and notice the undoing of the state in governmentality,[120] anthropologists of the state in India have studied how the state is experienced daily through its agents like the police, schools, local government and so on. This is a tremendously important evaluation of power in social order, yet I want the king to have his head back because it could have meaning only along with the rest of the body politic. I want to understand how the Indian state was realised in the expectations of the nationalist bourgeoisie, and not undermine their determination for sovereignty as an expression *also* of freedom and power, and not of power, law or prohibition alone. Moreover, I also want to understand how the state was realised in scientific practice, and given the nature of nuclear research, how increasingly difficult this conjoined exercise came to be in the context of the Cold War.

---

[119] See for example Thomas Blom Hansen, *Wages of Violence: Naming and Identity in Postcolonial Bombay* (Princeton: Princeton University Press, 2001); Veronique Benei and Chris Fuller, *The Every day State and Modern Society in India* (London: Hurst and Co, 2001); Thomas Blom Hansen and Finn Stepputat, eds., *States of Imagination: Ethnographic Explorations of the Postcolonial State* (Durham: Duke University Press, 2001).

[120] Michel Foucault is credited to have called for a revised political philosophy that was not centred on sovereignty. "Sovereign law and prohibition formed a system of representation of power which was extended during the subsequent era by the theories of right: political theory has never ceased to be obsessed with the person of the sovereign. Such theories continue to busy themselves with the problem of sovereignty. What we need, however, is a political philosophy that isn't erected around the problem of sovereignty nor therefore around the problems of law and prohibition. We need to cut off the king's head: in political theory it still needs to be done". See Michel Foucault, "Truth and Power," (p. 121) in Colin Gordon, ed., *Power/ Knowledge: Selected Interviews and Other Writings*, *1972-1977* (New York: Pantheon, 1976), 109-133.

Jeremi Suri and Odd Arne Westad have reopened the debate on the nature of Cold War to establish the 'third world" not as a subject of super-power rivalry alone, but of resolute actors who shaped the 'global cold war" in definite ways. Westad argues that leaders in colonial and newly independent countries actively negotiated super-power intervention to ensure "lucrative" foreign support and assurances against "less favourable external interference". This was possible also because the leaders were familiar with the rhetoric, ideas and resources from dominant international institutions, where they were often educated. If modernisation was offered as a promise by the United States and the USSR, it soon became a claim-making device in the hands of leaders in the third world. Westad also makes the rather important observation as to how the Cold War brought together varied countries in Asia, Africa and Latin America through the idealism of freedom, the epitome of which was the Bandung Conference of 1955. Jeremi Suri is convincing when he argues, "If the forces of modernisation turned 'peasants into Frenchmen' before the First World War, the pressures of Cold War politics turned former colonial subjects into global activists at mid-twentieth century".[121] And global activists indeed some of the actors in this thesis became, Jawaharlal Nehru most obviously, but also Homi J. Bhabha most decisively through the Atoms for Peace meeting in Geneva (1955).

John Krige and Kai Henrik Barth have on the other hand reminded us of the centrality of the nuclear question and *yet again, not of nuclear weapons alone* during the early Cold

[121] Jeremi Suri, "The Cold War, Decolonisation, and Global Social Awakenings: Historical Intersections" in *Cold War History* 6, no. 3 (August 2006): 356.

War, in its implications for international affairs.[122] The novelty of Krige and Barth's volume is not only in their timely reconsideration of the nuclear question, but also in the global scope of the volume. Even more so for my thesis, the essays in the volume make connections between decolonisation, development, and science and technology – connections that have been largely ignored by both diplomatic historians and historians of science but long obvious to development studies scholars and historians of the "third world".[123] While a significant number of histories of nuclear physics – as histories of science, also especially dealing with particle accelerator development, exist for the United States and also Western Europe, there is little work done on the history of nuclear physics in other parts of the world. Japan is perhaps the only exception.[124]

There is also no study on the establishment of nuclear physics research and education in India, although histories of the nuclear energy and weapons program of India tend to

---

[122] John Krige and Kai Henrik Barth, "Introduction: Science Technology and International Affairs," *Osiris* 21, (2006a): 1-21. Not too long ago, *Social Studies of Science* carried a special issue on 'Science in the Cold War' and the implications thereof for scientific practice - decentring the nuclear, but seeking nonetheless to explain 'Science and the State during the Cold War'. The glaring omission in the discussion was the use of science and technology by the state to further Cold War politics. See Mark Solovey, "Science and the State during the Cold War: Blurred Boundaries and Blurred Legacy," *Social Studies of Science* 31, no.2 (2001), Special Issue: Science in the Cold War: 165-170. For an overview on the "Global Cold War see Odd Arne Westad, *The Global Cold War: Third World Interventions and the Making of Our Times* (Cambridge: Cambridge University Press, 2006) and Jeremi Suri, *Power and Protest: Global Revolution and the Rise of Détente* (Cambridge, MA; Harvard University Press, 2003)

[123] For an authoritative interpretation of Cold War politics in relation to "third world" development, see Arturo Escobar, *Encountering Development: The Making and Unmaking of the Third World* (Princeton: Princeton University Press, 1995). See also David Engerman, Nils Gilman, Mark H. Haefele, and Michael Latham, *Staging Growth: Modernisation, Development and the Global Cold War* (Boston: University of Massachusetts Press, 2003).

[124] Another notable exception is a recent volume of the *Historical Studies in the Physical Sciences* edited by Roderick Home on particle accelerator laboratories outside of Western Europe and Northern America. See Rod W. Home, Ana M. Riberio De Andrade, and Carlos D. Galles, eds., *Historical Studies In The Physical Sciences* 36, no. 2 (2006). The volume carries papers on Argentina, Australia, Brazil, Japan, and Mexico.

comment especially on the Tata Institute of Fundamental Research, Bombay, for the period after 1945. In contrast to the rich body of scholarship on science in colonial India, there is relatively little work on the history of scientific practice in independent India. The scholarship on colonial science provides for a rich context leading into the "idea of modern India" at the threshold of independence, but that is where most current literature stops. Most histories of science in India dedicate their last chapter to address the period immediately leading up to 1947, and bring in the discussion on the nation and state as ideas – and drop it there. The impact of atomic weapons and the establishment of Atomic Energy Research Committee (1946) are seldom discussed as a part of this history. There are however scholars from other disciplines, who offer important insights into the discussion on scientific practice in independent India, but not all of them make explicit connections to the Cold War. Of these, I will first discuss two that deal directly with the actors in this thesis.

Robert S. Anderson, then a graduate student at the University of Chicago was among the very first to study the Tata Institute of Fundamental Research, Bombay and the Saha Institute of Nuclear Physics, Calcutta in the late 1960s. His ethnographic study of the two laboratories, using methods characteristic of area studies at the University of Chicago, resulted in the publication of a monograph in 1975.[125] Both the thesis and the monograph

---

[125] See all by Robert S. Anderson, *Building scientific institutions in India: Bhabha and Saha* (Montreal: Centre for Developing Area Studies, 1975); - *The Life of Science in India: a comparative ethnography of two research institutes* (Doctoral Thesis, Department of Anthropology, University of Chicago, 1971) [One of Anderson's letters of recommendation came from Edward Shils, the founder of *Minerva* (1962)]. See also – "Cultivating Science as Cultural Policy: A Contrast of Agricultural and Nuclear Science in India," in Lloyd I. Rudolph, ed., *Cultural Policy in India* (Delhi: Chanakya Publications, 1984), 43-58 and – "The Government of Scientific Institutions: Case Studies of Two Research Laboratories in the late 1960s," *Contributions to Indian Sociology* 11, no.1 (1977): 137-168.

are not explicitly concerned with studying the nuclear field in India and therefore Anderson is not concerned with Raman's efforts at establishing nuclear physics in Bangalore. Nonetheless, Anderson's work, especially his thesis remains a landmark in the study of the two laboratories precisely because his research was carried out before the first "peaceful nuclear explosion" in India (1974) and he does not frame the comparative study of the laboratories in terms of a nuclear weapons or energy program. Anderson's thesis was concerned with the establishment of scientific practice in modern laboratory spaces in a developing country. The monograph looks at the two laboratories as Saha and Bhabha's efforts at building modern institutions of science in India. Anderson's rich description of life in the two laboratories is very useful for understanding contemporary concerns of their employees. His larger argument is that the difference in the nature of the two institutions can be attributed to the social status (ascribed and achieved), social networks and a class-based vision of their mentors. But Saha and Bhabha's social backgrounds, I will argue, cannot be imposed onto political positions in any straightforward fashion and political positions cannot be unproblematically offered as explanations for shaping their scientific practice. The context of their scientific practice and the larger national-statist and international concerns require attention. Given that I am concerned with the history of nuclear physics in India, I remain engaged with Anderson's question of the differing fortunes of the two laboratories. But I am not interested in institution building per se, certainly not in the same way as Anderson, and therefore I also discuss other laboratories in India who were competing, collaborating or benefiting from the expertise and resources in Bombay and Calcutta.

More recently, Itty Abraham's work has contributed to the history of the nuclear field in India. Abraham's work began in political science, political history, and science studies but his more recent work is actively engaged with history of science.[126] In his book, *The Making of India's Atomic Bomb,* Abraham covers the period roughly between 1945 and 1974, to examine the meanings of atomic research in India and makes an explicit connection between the post-colonial state, development and the nuclear energy and weapons program in India. Bringing together political history, security studies, and South Asian studies, Abraham's was the first study of the nuclear field to make a connection between crises of political legitimacy and the place of nuclear research in independent India. The founding moment for his work is the formation of the Atomic Energy Commission in India (1948), although he does go back in time to discuss Homi J. Bhabha as a colonial scientist. The study follows the trajectory of reactor building efforts in India, and therefore the research agenda of the Atomic Energy Commission of India.

Abraham's explanations of the origins of India's nuclear program are centred largely on Bhabha and Nehru's understanding of the nuclear, and Meghnad Saha is discussed in his role as a critic of India's emerging nuclear field, but not as someone leading a potentially competing laboratory. Given that Abraham's concerns are of explaining how India grew to love and come to make the atomic bomb in the Cold War context, his work does not

---

[126] See all by Itty Abraham, "Rare Earths: Travancore in the Annals of the Cold War, 1945-47", Paper presented at the *Bodies, Networks, Geographies* Workshop*,* Eindhoven, 2007; - "The Ambivalence of Nuclear Histories" *Osiris* 21, (2006a): 49-65; - "The Contradictory Spaces of Postcolonial Techno-science," *Economic and Political Weekly*, (January 21, 2006b): 210-217; - Postcolonial Science, Big-Science and Landscape" in Roddy Reid and Sharon Traweek, eds., *Doing science + culture* (New York: Routledge, 2000); - *The Making of the Indian atomic bomb: Science, Secrecy and the Postcolonial State* (London: Zed Books, 1998); - "Science and Secrecy in Making of Postcolonial State," *Economic and Political Weekly* 32, (August, 1997): 2136 –2146; - "Science and Power in the Postcolonial State," *Alternatives* 21, (1996): 321-339.

engage with the question of how Homi J. Bhabha came to lead, but rather with how he shaped the nuclear field. His work then provides the essential context for the later half of my work, the spectre of urgency under which the particle accelerator groups at the Institute for Nuclear Physics, Calcutta and the Tata Institute of Fundamental Research, Bombay worked beginning 1948 up until 1959.[127]

Dhruv Raina and Ashok Jain, and Shiv Visvanathan, have discussed more specifically the broader field of scientific and industrial research in independent India.[128] In their essay on big science and funding for higher education in India, Raina and Jain argue that scientific research, especially state funded "big-science" was established outside the academic setting. The infrastructure that emerged after independence allowed for two ways to participate in cutting edge scientific research: the industrial research imperative (CSIR) or the nuclear research imperative (Atomic Energy Commission of India) leaving advanced teaching and especially scientific research in the universities starving for funds and prestige. The priority of the two structures, they argue, was premised on the promise of concomitant economic progress. While the argument deserves to be empirically investigated for exactly how the marginalisation of universities came about, historians of science working on India would agree with Raina and Jain's broad conclusions. My thesis partially addresses their argument on the nuclear research imperative in showing

[127] George Perkovich's excellent and detailed history of the Indian nuclear energy and weapons program has been a very useful reference for the later half of my work. However his concerns as a diplomatic historian are framed by debates on proliferation and hence the focus of attention are the tests of 1974, far ahead in the future as far as my study is concerned. See George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999).

[128] Dhruv Raina and Ashok Jain, "Big Science and the University in India" in John Krige and Dominique Pestre, eds., *Science in the Twentieth Century* (Amsterdam: Harwood Academic Publishers, 1997), 859-878 and Shiv Visvanathan, (1985).

how university and institutes of advanced research were marginalised in favour of supporting national laboratories. Even more so, my study also shows how the nuclear research imperative was in the first instance incubated within the industrial research imperative – as an agenda for the CSIR. It was later separated from the CSIR by the logic of nuclear exceptionalism and Bhabha's ambitions to morph into its own orbit within the state system. Finite resources meant the establishment of priorities and priorities were negotiated against historical conjuncture.

Shiv Visvanathan's ethnographic study of the CSIR's National Physical Laboratory, New Delhi (NPL) focuses on the Indian response to the industrial research imperative. The German industrial research laboratory at the turn of the century was successful in binding together science, technology and industry, without excluding the university laboratory. This was the framework for the establishment of the National Physical Laboratory in England, which in turn informed the establishment of a similar laboratory with the same name under the CSIR in India (1947). "The sociology of a science laboratory in India", Visvanathan is convinced "has to be an intrinsic part of the sociology of a developing society" [129] - it is only in this larger context that issues like transfer of technology take meaning allowing for a richer analysis than can be accomplished through institutional history or organisational theory. The first 130 pages are devoted to a useful spelling of the content of what he calls "scientized technology" - not different from scientific industrialism - as it emerged in colonial and later independent India. Visvanathan concludes that this consensus was not adequate to bridge the "disjunction between

[129] Visvanathan, (1985): 1.

science and technology" in practice to help establish industrial research as the key to progress in India. This disjunction, he believes, was in fact present in the very understanding of scientific industrialism in the mid-twentieth century. The industrial research laboratory was organised like university laboratories, and physicists had to find a way to connect their science to possible applications and their commercialisation. Visvanathan contends that physicists accepted the "scientisation of industry" in principle but the "industrialisation of their science" caught them unawares. Missing was the entrepreneurial element and active networking environment required to sustain an industrial research complex, which resulted in the NPL constantly trying to withdraw into a shell of a university-like laboratory instead of taking head on the tasks of innovation and standards-testing functions it was meant to perform.

Visvanathan's examination of the NPL makes a tremendously important argument about the organisation of scientific research in independent India. First, he lays into relief how industrial and nuclear research emerged as the two necessary priorities of scientific research in independent India. Second, he has shown why scientific practice as a metonym for modernity and therefore for development was an *intellectual accomplishment* of the national bourgeoisie under colonial rule, which proved entirely inadequate in practice as seen in the case of the NPL (and arguably extendable to the CSIR). It was one thing to share the pride of accomplishment in science as a national bourgeoisie (linked into political and industrial leadership), and for this the university was an adequate site; but it was quite another thing to "deliver progress" in real terms required by the national-state, working with a miserably inadequate industrial, intellectual and economic infrastructure.[130]

For my study, Visvanathan's argument about the apparent failure of the industrial research imperative becomes useful in complicating the *apparent success* of the nuclear research imperative in delivering to the national-state's expectations. Right at the outset, the nuclear research imperative came very close to the promise of industrial growth and it had *already overcome* the disjunction between science and technology in its specific promise as an energy source. Moreover, it had also bridged the concerns of development with national security. No other research agenda of the physics community or the scientific community at large could have accomplished such preciousness with such good timing. Itty Abraham has shown how the Atomic Energy Commission of India's (AECI) research establishment managed to partially overcome the disjunction *in practice* through purchase, import and reengineering of technologies from Britain, Canada and the United States. He has also shown us how the remainder was managed in the last instance with the peaceful nuclear explosions. In its accomplishment of the tests, the AECI managed to rely upon the *other measure* for its success – instead of asking to be judged for provision of an energy source towards accelerated industrialisation i.e. for its contribution to national development, the tests became a measure of its national security potential. Given the period of my study however, I do not discuss the peaceful nuclear explosions (1974)

[130] If the Gandhian critique of industry led modernisation was strong within the nationalist movement, a strong intellectual critique of Nehruvian modernity was well established by the early 1960s. Scholars at the CSDS mentioned earlier (among others) argued that the demands and goals of the Indian state were misguided. It was only in the early 1970s though that a strong nation wide political critique of the Nehruvian project was expressed. See among others Achin Vanaik, *A Painful Transition: Bourgeois Democracy in India* (London: Verso, 1990).

or nuclear power plants, or research reactors built during this period. I study, first and foremost, the establishment of advanced teaching and research in nuclear physics (1938-1945), followed by an argument on its reconstruction beginning August 1945 towards an autonomous nuclear field (1945-1948) and its impact again for laboratory practice of nuclear physics (1948-1959). Visvanathan allows me to better answer four important questions: first, what was the promise of the nuclear physics educators and laboratory leaders to the national-state project or where did they imagine their projects within the larger consensus on scientific industrialism between 1938 and 1945? Second, how did their contribution relate to the newfound nuclear research imperative of the newly founded national-state (1945-1948)? How did the research laboratories I study perceive the disjunction between science and technology? And finally, can we extend the apparent success of the nuclear research imperative to research laboratories outside the AECI's research agenda for the period between 1948 and 1959?

1.4 The Prospectus - Organisation of Nuclear Research in India, 1938-1959

> "To endeavour to think the state is to take the risk of taking over (or being taken over by) a thought of the state, i.e. applying to the state categories of thought produced and guaranteed by the state and hence to misrecognise its most profound truth."[131]
>
> Pierre Bourdieu (1994: p. 1)

Newer histories of nuclear science and technology focusing away from weapons related research, map its intersections with and relations to other scientific disciplines, academia,

[131] Pierre Bourdieu, "Rethinking the State: Genesis and Structure of the Bureaucratic Field," *Sociological Theory* 12, no.1 (1994): 1.

industry, the modern state, medicine, the military, the media, and the public.[132] "Rather than taking them as self-evidently significant", these studies look at nuclear physicists "as having actively to justify their own work to one another and their collective efforts to other scientists and to the wider polity".[133] Within these new histories of nuclear physics then, this thesis, first and foremost, is a history of efforts to establish three low-energy particle accelerators for nuclear physics research and education in pre and post-war/ Cold War India. It is a history of what it has meant to establish, maintain and extend the discipline of nuclear physics in India before and under the spectre of the bomb. In doing so, this study will address one glaring limitation in history of science scholarship as of yet not satisfactorily addressed: the field shows a remarkable disconnect from the larger context of its significance and affects, especially in the context of the non-West. Colonial science on the one hand and post-colonial state formation on the other have been objects of studies in the recent past. But not much analytical sophistication is available to borrow for understanding post-colonial practice of modern science *as a part of the larger history of science in the later half of the twentieth century*. This study will participate in the field of history of physics by extending the boundaries of inquiry, *within the same analytic frame*,[134] beyond the much-studied American and West European contexts.[135] The goal is

---

[132] Among others see Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (Cambridge: The MIT Press, 1998); Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993); Jeff Hughes, *The Radioactivists: Community, Controversy and the Rise of Nuclear Physics* (PhD Dissertation in History and Philosophy of Science, University of Cambridge, 1993).

[133] Hughes, (2003): 351-352.

[134] I have borrowed this phrase from Warwick Anderson, "Postcolonial Technoscience," *Social Studies of Science* 32, no. 5/6 (2002): 643-658; who in turn takes it from Ann Stoler and Frederick Cooper, "Between Metropole and Colony: Rethinking a Research Agenda," in F. Cooper and A. Stoler, eds., *Tensions of Empire: Colonial Cultures in a Bourgeois World* (Berkeley: University of California Press, 1997), 4.

to arrive at a more complete picture of the ethos of big-science and the nature of scientific internationalism from the inter-war period up until the early Cold War. Margaret Gowing summed it most succinctly for this period when she submitted: "Nuclear physics was posing more and more new questions about Government endowment of science, about institutions and academic and international co-operation. The subject cut increasingly deeply into university structure."[136] My study is an attempt to unravel what nuclear history looks like, in its form as a history of university education and research, in India between 1938 and 1959. This thesis is an *empirical intervention*, connecting history of science, especially history of physics, with historiography of South Asia to write an enriched history of modern India.

As a history of modern India, this thesis is about the specific intersection of nuclear physics and state formation in India. In prioritising the study of scientific practice as opposed to an analysis of perceptions of science, I hope to recover variegated interests and intentions for the establishment of nuclear physics in India. I do not centre the narratives on institutions or individuals alone, but on their particle accelerator building activities for nuclear physics research and education. If material culture is the physical world shaped by people and artefacts through intention and action in a society, the particle accelerators in this study embody aspirations, positions, negotiations, and efforts

---

[135] Among others see Alvin Weinberg, *Reflections on Big-science* (Cambridge: Cambridge University Press, 1967); Galison and Hevly, eds., (1992), Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993); Armin Hermann, John Krige, Ulrike Mersits, and Dominique Pestre, eds., *History of CERN I: Launching the European Organization for Nuclear Research* (Amsterdam: North-Holland, 1987).

[136] Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy, 1945 -1952, Policy Execution* II (London: Macmillan, 1974), 226.

of their patrons, mentors, builders and users. The embodiment is at once scientific and political. The accelerators thus provide a tangible anchor to trace linkages between scientists, technicians, the state, funding agencies, industry, as well as local and international politics, and therefore to write about processes that contribute to the culture of scientific practice.[137]

One set of actors in this study are a section of the nationalist bourgeoisie in India who were connected into colonialism, nationalism, and state processes through privilege and power, which makes their experience unique. Studying their ambitions and anxieties allows me to crack open and lay threadbare the workings of the nationalist and state edifice. It also allows me to take seriously the issue of leadership in both science and politics, which has for some time not enjoyed much attention in Indian historiography following especially the subaltern turn.[138] If Subaltern Studies have produced an immensely rich understanding of the political field with histories from 'below', "the costs have been heavy. Political history has been neglected – the doings of the state, of its elites, and of the many significant individuals in India's twentieth century history. Whatever political history has been written has remained imprisoned by the imperial

---

[137] Langdon Winner, "Do Artifacts Have Politics?" in Donald McKenzie and Judy Wajcman, eds., *The Social Shaping of Technology* (London: Open University Press, 1999); Bernward Joerges, "Do Politics have Artifacts?" *Social Studies of Science* 29, no. 3 (1999): 411-431; Steve Woolgar and Geoff Cooper, "Do Artefacts Have Ambivalence? Moses' Bridges, Winner's Bridges and Other Urban Legends in S&TS", *Social Studies of Science* 29, no. 3 (1999): 433-449.

[138] For a critical reading of the Subaltern Studies project especially on the matter of leadership see K. Balagopal, "Drought and TADA in Adilabad," *Economic and Political Weekly* 24, no. 47 (November 25, 1989): 2587-91, reprinted in David Ludden, ed., *Reading Subaltern Studies: Critical History, Contested Meaning, and the Globalisation of South Asia* (New Delhi: Permanent Black, 2001), 343-357. For an overview on Subaltern Studies see (http://www.lib.virginia.edu/area-studies/subaltern/ssallau.htm). See also Ranajit Guha, *A Subaltern Studies Reader, 1986-1995* (Minneapolis: University of Minnesota Press, 1997).

mode of administrative history or, in its post-1947 analogue, diplomatic history, or has been repetitious nationalist hagiography. *The attempt to see the larger picture through new eyes has rarely been risked*".[139] Under no circumstances do I wish to suggest a revival of imperial or nationalist historiography, or for that matter a study of the anxieties of leadership alone. But I am also not invested in the recovery of resistance alone to these processes. I have instead chosen to follow particle accelerator *building activities* in my stories to show precisely that not every one involved in these facilities was necessarily concerned with state formation or for that matter, building nation or resisting the processes *in the same manner* even when *their activities are historically inseparable from each other*. The other set of actors in my study then are students, technical physicists and laboratory technicians engaged in the everyday practice of science. The larger contexts of political history, and the scientific and political ambitions of leadership are indispensable to understand this history. Decisions on the pursuit of scientific practice were also taken increasingly outside the laboratory, more so, in the name of the nation, by the state-in-making.

The thesis is therefore not organised as a grand narrative of the "national-statist organisation of nuclear research in India". Instead, it tells three distinct but connected contemporary stories about how different actors sought to further their ambitions of establishing nuclear physics in India in relation to the other two and how the national-state was *realised* in their scientific practice. Charles Withers has argued that scholars especially in the history of science can be "insensitive to the problematic notion of the

[139] Sunil Khilnani, *The Idea of India* (New Delhi: Penguin, 1997), 2-3.

nation itself, and to the historical construction of ideas of national identity".[140] The tendency, Withers argues, is one of assuming the nation as a frame of reference, the "spatial scale" within which scientific practice somehow emerges and is to be understood. It is exactly this tendency that I wish to overcome in my study. Mid-twentieth century India offers an historian no chance of taking the Indian nation, or the Indian national-state for granted. It is precisely the moment of transition that makes this period rather exciting to study. A conscious decision to stay away from a teleological nationalist grand narrative brings into history the activities of others involved in the day-to-day practice of science. Not everyone in history was building nation-making state, *even when their scientific practices most certainly contributed to realising the state.* Their practices, I will argue, were informed by their own motivations - which may well be those of building nation, (the national by no means was a proprietary intellectual project of the elite) - but at the same moment affects of the ambitions and anxieties of those leading the projects consciously within the process of state formation.

How do I draw out the historical connection between these three stories? Pierre Bourdieu has outlined "a model for the emergence of the state" to systematically account for the "historical logic" of the processes that have instituted the state. The state, for Bourdieu, is the "culmination of a process of concentration of different species of capital" in which the species of capital are not a priori givens but constructed within the process of

---

[140] Charles W. J. Withers, *Geography, Science and National Identity: Scotland since 1520* (Cambridge: Cambridge University Press, 2001), 14-15.

culmination.[141] State formation in India was realised in a process of concentration. The specificity for this thesis is that the formation of a national state, and the nuclear question as state agenda, emerged contemporaneously in Indian history. The logic of nuclear research technology was also increasingly becoming one of concentration precisely in this period. As a result, because of the priority of nuclear research, and its initial incubation in the wartime CSIR, the organisation of scientific research in India per se, came to be increasingly shaped within the historical logic of state formation. Taken over by the thought of the state, scientific and industrial researches and the nuclear field were instituted as a process of concentration, in the collective accomplishment of dispossessing and marginalising domestic competitors of the instruments of scientific and nuclear research and of the rights to use them. This cannot be different from showing that "the state could not have succeeded in progressively establishing its monopoly over violence without dispossessing its domestic competitors of instruments of physical violence and of the right to use them, thereby contributing to the emergence of one of the most essential dimensions of the "civilising process".[142] The question was not "what could India do for science" or for that matter, "what could science do for India": it was rather – how was India as both nation and state, realised in this case through the practice of science. The

[141] Pierre Bourdieu, (1994): 3-4. Bourdieu is quite obviously discussing Western Europe and I am aware of the problems (historically) and politics (of Eurocentric social scientific knowledge) in employing his work to discuss Indian history. But I have certainly found use for Bourdieu's understanding of the state in my work. More actively, I am not convinced that the historical trajectory of state formation can be analysed using concepts that can somehow arise only internally to Indian politics. The historical actors I study had formulated useful and pragmatic understandings of history and politics towards state formation as a critique of the colonial state within their understanding of European modernity, as such state formation in Europe was already one of their referents.

[142] Bourdieu, (1994): 5.

three individual stories empirically substantiate the implications of this larger process for laboratory practice in nuclear physics.

The thesis is organised as follows: Chapter two maps the arrival of the nuclear question within the debates on science and scientific industrialism, in processes of decolonisation and war effort (1938-1947). Given that scientific industrialism arose as a secular nationalist ideology, it was ironic that the first purposeful attempt at its accomplishment on a national-scale was the establishment of the Board of Scientific and Industrial Research (1940) and soon the Council for Scientific and Industrial Research (1942) *by the [British] Government of India* as wartime exigency. An editorial of the *Journal of Scientific and Industrial Research* confirmed; "It is the responsibility of every modern State to promote industrial progress with the help of scientific discovery."[143]

The subsequent three chapters explore three specific stories of attempts at the establishment of nuclear physics education and research, through building particle accelerators at the Indian Institute of Science, Bangalore, Institute of Nuclear Physics (later Saha Institute of Nuclear Physics) Calcutta and the Tata Institute of Fundamental Research, Bombay, between 1938 and 1959. These stories do not qualify as institutional histories because I focus on the stories of accelerator building groups within departments of physics. While the institutions undeniably form part of the context, the narrative by no means is exhaustive of institutional history in each case. As a brief concluding essay, I will bring together the thematic of transition through a wider discussion on development

[143] Editorial, "Protection of Inventions in Free India" *Journal of Scientific and Industrial Research* V, no. 3, (September 1946).

in India, of the nuclear physics laboratory and the world order as seen empirically through the three laboratories.

I do not wish to *a priori* insist upon retrieval of historical difference, but allow the place and meaning of scientific practice in mid twentieth century India to emerge as experienced by the historical actors I study. This of course, in no way means that I will uncritically accept their self-representation or for that matter argue that there is no specificity to Indian history. Scientists do science and they do politics. They also accomplish politics with science, but that cannot amount to saying that scientists do science motivated by politics alone. Nuclear researchers in India promoted their field, they also argued for and accomplished nation building and state formation, but that cannot amount to saying that their scientific practice was motivated by reasons of nation and state *alone*. So what is demanded of a critical history of nuclear physics education and research in India is not "an account of the development of the subject that preferentially emphasi[ses] those elements that would become important in the making of state, or for that matter purposes of state in the nuclear field, those of nuclear weapons or energy programs".[144] What is needed is an assessment of the political implications of specific choices, and specific instances of the exercise of power and agency by those engaged in and affecting nuclear research in colonial and independent India. As such then, this study is a conscious attempt to move away from what Jeff Hughes calls a teleological bomb historiography.

[144] Hughes, (2003): 351.

I am well aware that the scientists in this study are but one section of the vast array of nationalist imaginations of the state in the period covered by this thesis. Jonathan Sadowsky, historian of medicine has argued, "One of the greatest dangers in historical research is overestimating the significance of one's data." [145] In my study, this would mean suggesting that state-making activities of nuclear scientists exemplify a 'post-colonial condition'. I will argue instead that their experiences cannot be understood except as a part of the transition of India from empire to an independent country, but also that they were not typical experiences of this transition. Moreover, even their own experiences of this process were not uniform. The significance of nuclear research in India for the period between 1938 and 1959 changed more than once. It was imperative that the community found ways of continuing research and producing credible science in a shifting local and international political context to determine (at home), and participate (abroad) in the shape of things to come. Nuclear scientists were not even representative of scientists in India generally but some of them became exceptional in a number of respects. This thesis narrates three stories that will substantiate who became exceptional, who did not – and how and why they became so.

[145] Jonathan Sadowsky, *Imperial Bedlam: Institutions of Madness in Colonial Southwest Nigeria* (Berkeley: University of California Press, 1999).

CHAPTER 2: *GIVE SCIENCE A CHANCE*[*] - SCIENCE IN PLANNING FOR INDEPENDENT INDIA, 1938-1947

> "India – like radium – had been 'discovered' by the Europeans; […] this was finally what separated Aadam Aziz from his friends, this belief of theirs that he was somehow the invention of their ancestors."[146]
>
> Salman Rushdie, (1981:11)

The Indian Science Congress celebrated its twenty-fifth anniversary in the year 1938. The occasion was special also because this was a joint meeting with the British Association for the Advancement of Science (BAAS), which was meeting in India for the very first time. The meeting was momentous enough to merit the presence of the Viceroy General of India, Lord Linlithgow.[147] Ernest Rutherford was to chair the meeting, as we saw in the previous chapter, but his death three months before the meeting meant that James Jeans, vice president of the Royal Society, read his address to the Congress. The address was entitled *Researches in India and in Great Britain* – it was now possible to juxtapose the two locations.[148] The scientific community of India had come of age. The metropolis visited the periphery in an acknowledgement of the commonwealth of science. It would

---

[*] Shanti Swarup Bhatnagar's presidential address to the Indian Science Congress of 1945 in Nagpur was entitled "Give Science a Chance".

[146] Salman Rushdie (1981) *Midnight's Children* London: Jonathan Cape Ltd., p. 11.

[147] The Viceroy General of India was the highest political office in British India. He was the representative of the British Crown in India, often with a career holding important military offices before being sent to India. As Viceroy, he was also the de facto chancellor of all the universities in India. This did not mean much for the day-to-day administration of universities, but meant much in ceremonial matters and especially during the convocation or ceremonies of confirming degrees. Linlithgow was India's longest reigning viceroy (seven years).

[148] Lord (born Ernest) Rutherford, *Researches in India and Great Britain*, Presidential Address written for the Indian Science Congress Meeting, 1938. Reprinted in *The Shaping of Indian Science: Indian Science Congress Association, Presidential Addresses, 1914-1947*, I (Hyderabad, Universities Press, 2003), 421-440.

take another five years, and the exigencies of war coupled with intensified nationalist demand for free India, that the imperial crown of the commonwealth of science, the Royal Society itself would hold an extraordinary meeting in Delhi, an event without precedent in its history. But that would be another occasion.

2.1 Scientific Industrialism at the Outbreak of War

The silver jubilee celebrations of the Indian Science Congress (ISC) called for a review of scientific activity in India – moreover, it called for an assessment of the place of scientific research in modern India.[149] Those addressing the Congress gave ample attention to the two questions. The three prominent groups present at the meeting were delegates from the BAAS, representatives of the viceroyalty in India, and scientists from the universities and colonial scientific establishments in India. Discussions and addresses to the meeting would soon reveal that there was no significant disagreement among them that science would lead the "progress" of India. They all strived simultaneously though, to argue for the correctness of their understanding of what a "real India" and the "real Indian" looked like, and what was required for their progress. The one strong dissenting voice regularly identified among the Indian nationalist bourgeoisie was that of Mohandas Gandhi (himself not present at the Congress) and other Gandhians who proffered the ideal of self-sufficient village republics as the obvious political choice for free India. They did not imagine the need for heavy industrialisation in India. The scientific

[149] The Indian Science Congress Association published a collection of essays for the occasion. See Baini Prashad, (1938).

community respected Gandhi for his political leadership of anti-colonial nationalism, but his ideas on science and industry did not find complete resonance with this group.[150] The [British] Government of India for its part had begun reluctantly encouraging industrial development in India beginning the period after WWI. The presence of leading British scientists from Britain as well as Europe (the German physicist Walther Bothe, and the Danish physicist Niels Bohr were also among those attending), could potentially contribute to a favourable hearing from the [British] Government of India. It would be almost two more years before the outbreak of WWII would change this scenario almost completely.

The BAAS was meeting in India for the first time, but this was not its first meeting abroad.[151] They had though, thus far, restricted their visits to the dominions but not visited any colonies of the British Empire. The first such meeting was held in Canada, where the Dominion Government saw this meeting as endorsing "the political and economic as well as the scientific importance of Canada to the Empire". The men of science in turn hoped to "gain wider audience for their activities and greater attention from their own government".[152] To convince their governments, scientists in the

[150] Even Gandhians like the chemist Prafulla Chandra Ray did not entirely agree with Gandhi's denial of the need for heavy industry in India. Ray himself established and led the Bengal Pharmaceutical and Chemical Works in Calcutta. See Pratik Chakrabarti, (2004) and Lourdusamy, (2004).

[151] For a history of other BAAS meetings abroad, see Michael Worboys, "The British Association and Empire: Science and Social Imperialism, 1880-1940," in Roy Macleod and Peter Collins, eds., *The Parliament of Science: the British Association for the Advancement of Science 1831-1981* (Northwood: Science Reviews, 1981), 170-187. Rebekah Higgitt has more recently revisited the topic focusing upon the motivations of their hosts, see Rebekah Higgitt, *Picnicking Overseas: British Association Meetings in Canada, South Africa and Australia, 1884-1929*, paper presented to the British Society for the History of Science Annual Meeting, 2007. I would like to thank Rebekah for sharing her paper with me.

[152] Worboys, (1981): 173, quoted in Higgitt, (2007): 4. Quoted with author's permission.

dominions "were involved with selling the idea that science –sometimes very much in the abstract – creates colonial development. Given their evident success in extracting funds, it is interesting how vague they usually were about the nature of the benefits".[153] Most were confident of the tremendous benefits of the meeting, the Prime Minister's Office in Australia, for example, argued that a BAAS meeting should have "the benefit of contact with a number of the foremost scientists of the world"; provide a medium for wide advertisement of Australia and moreover, give "tangible expression" to Australia's interest in scientific matters. They were also clear that the benefits of such a meeting were "likely to be reaped over a period of two decades", thus justifying the hospitality costs involved (often huge) "for a wider and broader scientific outlook".[154] India was not a dominion of the British Empire – but neither was it exactly akin to other British colonies.[155] The [British] Government of India was not expected to find shared interests with the nationalists, or the Indian Science Congress. But the meeting did take place, and the government was represented at the meeting.[156] The presence of important scientific men from Britain helping promote visibility of local scientific establishments could well be true in the case of the Indian meeting. The Indian Science Congress was after all the

[153] Higgitt, (2007): 5.

[154] Higgitt, (2007): 12.

[155] I would like to thank Roy MacLeod for suggesting that I take seriously nomenclature of the British Empire, "Dominions, India and the Colonies". I am not suggesting that India was not a colony, or for that matter enjoyed a status anywhere close to that of the dominions. I will agree with MacLeod that the usage needs its own history, but that does not fall within the scope of this thesis.

[156] I have not found any commentary on the meeting or its history, apart from a report of its proceedings. It will be interesting to know how the idea was introduced and where, and the arguments for holding such a meeting in India at considerable expense. Higgitt has suggested that the BAAS delegation to the Indian meeting was smaller compared with other meetings, and this in turn introduced the idea even in the Dominions, of inviting smaller delegations of "the really important scientists" as opposed to the large congregations of 300 or more members meeting as if for a regular annual meeting.

only (relatively) uncontroversial representative platform for scientists in India. It is no less interesting though, that the vague coupling of “science with colonial development” was being made contemporaneously in the dominions. The Viceroy, and Indian nationalists, (some of them scientists) presented various shades of this argument at the Indian meeting. The broadly dual purpose of the meeting, of presenting advances of scientific research in both the “mother country” and in India, but also of collectively arriving at a lesson on the place of this research in Indian society appears to have considered by all present, including the Viceroy. Rutherford’s address began with an acknowledgement of Indian scientific achievements and then made an explicit distinction between the two questions; the first section was entitled ‘Industrial Research in Britain’, drawing a connection between scientific research and industry in Britain, to show the “importance of Science as a factor in national development”.[157] The second section was based on his own researches in “Pure Science” on the ‘Transmutation of Matter’ where he drew his audience through a lucid description into his own journey from the tabletop, wax and string radioactivity experiments towards scaled up ‘big-science’ equipment resembling, as he would put it, icons in the film of H. G. Wells’ *Things to Come*.

Rutherford’s address spoke to the Indian scientific community as the chosen ones to lead the nation towards progress. He began with a theme that many among his audience were quite seriously thinking about: the organisation of science as a national activity. “I have tried to outline the contribution to scientific knowledge made in India, and the need of the immediate future in science is to play its part in national welfare- science *not only as a*

[157] Rutherford, (1938, 2003): 431.

form of intellectual activity, but *also as a means of furthering the progress of her peoples*."[158] Having acknowledged that the Indian scientific community had demonstrated their ability to contribute to scientific knowledge, it was time Rutherford suggested, they started thinking of using this knowledge for generating opportunities that would contribute to the betterment of life for the Indian masses.

The scientific community of India, Rutherford further argued, should organise itself towards the goals of progress through planning through a centralised coordination of *applied scientific and industrial researches led by the government*.

> "The utilisation of science implies, … a planned scheme of research. The experience of some of the Overseas Dominions may prove of service to India. In Canada and in Australia there are State and Provincial Governments as well as Federal Governments and in both cases it has been found expedient that the research organisations of the country should be truly national and responsible to the Federal Government alone. Even in an empire the size of India,[159] whose resources and needs of various provinces are widely different, it would seem that centralised organisation of research is the only way of avoiding waste of money and effort. The detailed planning of research must be in the hands of those with the necessary specialised knowledge and they must be able to act without suspicion of political or racial influence."[160]

Scientists should govern the administration of science, not administrative bureaucrats. Even with government funding, Rutherford asked of his Indian colleagues and addressed the representatives of the [British] Government of India, to note that scientific activity

---

[158] Rutherford, (1938), quoted in Norah Richards, *Life and Work of Sir Shanti Swarup Bhatnagar* (New Delhi: New Book Society of India, 1948), 112-113.

[159] It is worthwhile to note here that Rutherford addresses India as "empire", thus reasserting MacLeod's suggestion calling for a nuanced understanding of India's position with the larger British Empire.

[160] Richards (1948), 111.

should be left free of bureaucratic and political interference. It is not always clear if Rutherford wanted to suggest Indian scientists should now en masse dedicate their research to the betterment of the Indian population, when he suggested centralisation and planning of industrial research in India. Rutherford immediately continued to argue that that limited as research may be given the increasing specialisation in physics research, "the universities should be left free as far as possible to develop their own lines of research and encouraged to train young investigators, for it cannot be doubted vigorous schools of research in Pure Science are vital to any nation if it wishes to develop effectively the application of Science, whether to agriculture, industry or medicine".[161] Rutherford seems certain of the need to support advanced teaching as well as fundamental research in the university. Only well-trained scientists were capable of developing sound technological, industrial, agricultural and medical applications. Rutherford could well be said to share the assumptions of scientific industrialism.

Rutherford charted this process of progress for India within the boundaries of the British Commonwealth. His address worked with the idea that India would soon acquire dominion status unlike her present status of empire, and his suggestions were drawn form experiences in the dominions but not so much from Britain. It was clear to him as to those his address was read to, that the size and diversity of requirements in India were far more variegated and thereby activities of an organisation like the DSIR in India would be scaled up significantly. Nonetheless, centralised coordination of the utilisation of scientific research for industrial development was offered as the most efficient way to

[161] Rutherford, (1938, 2003): 437.

direct the progress of India. Rutherford, a New Zealander, had established nuclear physics first at the McGill University in Montreal, Canada, before he moved to England carrying with himself the experience of research and educational conditions in the British Dominions. He was alluding to the government of science by a governmental agency like the Department of Scientific and Industrial Research (DSIR) in Britain, which was the model for those established in the Dominions in early twentieth century. Rutherford was accommodating of the uncertainty surrounding British departure from India. The Dominions were not separated at birth from Britain, but they were significantly independent to be able to organise national life. If imperial politics stayed out of the way of "expert men" in particular, science could be utilised for the progress of Indian masses even under continuing British presence. Definitions of progress have never been separate from politics, and Indian nationalists along with many members of the scientific community in India did not agree with continuing British rule. But there were two agreements that could allow both sides to cloak the discomfort of imperial politics: the professed universality of science and their collective commitment to the upliftment of the Indian masses. Five years later, his colleague Archibald Vivian Hill would echo Rutherford's proposal yet again reinforcing the idea of centralisation of government led scientific research for war purposes, and in free India. Centralised coordination and concentration resonated equally well with concerns of state formation among members of the scientific community linked with nationalist political leadership. Together, they would lay the foundations for organising scientific and industrial research after Indian independence.

Linlithgow did not entirely agree with Rutherford. To begin with, he made it quite clear that the scientists in his audience were a rather small elite and not the "real" Indians he was in charge of governing. The "real Indian" had begun to occupy the mind of British administrators in India, especially beginning the 1930s, to offset the increasing disfavour they now showed the nationalist elite.[162] He followed it up with doubts about the scientists' value to administration.

> "It may be argued, that scientists, of all people, are those who can help least in this respect [administration of progress], since scientists speak a universal language and science is science the world over. But I – and I speak with diffidence as a layman ... it is difficult to dissociate a scientist from the background against which he works and from the effect of his work on the development of his times. The Scientist has his place not only in the world of science but also in society as a whole. The backgrounds against which scientists in India and the West pursue their activities are vastly different and the possible effects on society from the impact of their discoveries on everyday life must inevitably vary."[163]

The community of science may have claimed to possess a universal language, but Linlithgow was doubtful of the extent to which they could overcome their location. While he does not develop his comment on what this might mean for the universal language of science, he does express doubts on the shared presumption of his Indian and British audience that the universality of science has conceivably universal impact - that the

[162] Sir James Grigg, the Finance Member to the government wrote to Chancellor of the Exchequer, Neville Chamberlain in 1934: "[…] India is the most desperately poor and inefficient and backward country you can imagine. The representative Indian is not to be found among the few tens of thousands of noisy politicians, journalists, stock exchange gamblers and clerks; he is an almost naked creature clad in a loin cloth and an umbrella who squats about among his crops by day and breeds like a rabbit by night. And in my view we have for years neglected the second class for the first". Grigg to Chamberlain, May 13 1935, Grigg Papers, PJGG 2/19/2 (d); quoted in Benjamin Zachariah, "British and Indian Ideas of 'Development': Decoding Political Conventions in the Late Colonial State" *Itinerario*, 3, no. 4, (1999): 163-209.

[163] *Proceedings of the Indian National Congress 1938*; MSS EUR F 97/84, Oriental and India Office Collections, British Library (henceforth OIOC).

material advancement and progress of the Indian population, could be similarly stimulated as in Britain or Europe. Linlithgow also anticipated another doubt that dominant sections of the scientific community and the Indian nationalist bourgeoisie would never come to admit in the next decade. The Indian nationalist bourgeoisie and the scientific community were convinced that they knew the specificity of Indian problems better than the British government ever did, and increasingly, better than the Indian masses ever would. This despite of the universality of their knowledge, or perhaps as they would argue, because of the universality of their knowledge. Linlithgow, for the moment, was more concerned with the impact of scientific practice in India. "But that difference [of doing science in India] in no way diminishes, the value to us in India of the informed interest, of the advice, and of the wide and varied experience… Your knowledge, your experience, *your very aloofness from the Indian background* will impart a special value to any analysis of the problems which confront us here; … in some measure the efforts of India to solve her own problems in her own way."[164] The scientific community could hardly disagree on their preciousness in his administrative vision – but they may not have missed Linlithgow's rendering India, Indian problems but also India's scientists very local. Wasn't the joint meeting about their having overcome locality?

Linlithgow certainly agreed with Rutherford that progress itself was necessary, and that science was going to contribute to material advancement of the empire; "I can imagine no more fascinating challenge to young scientists in this country than the employment of their brains and the application of the latest scientific knowledge to the attempt to solve

[164] Ibid, emphasis added.

the manifold problems of material advancement that confront us on every side". India was in transition, he said, following recent political reforms, and this will "inevitably lead to an increased determination among Indians that India should continue in increasing degree to make her own individual contribution to world history and world concepts". Both Rutherford and Linlithgow had proposed "progress" that addressed material advancement in the same template as "individual contributions to world history and world concepts". Both were happy for different reasons for the Indian scientific community to lead this progress. If their aloofness from the "Indian background" allowed them to belong to the commonwealth of science for Rutherford, this aloofness qualified them to participate in the administration of Indian progress for Linlithgow. Given the imperial context, the joint meeting became in Linlithgow's patronising words, "a recognition of India's scientific coming of age". The Indian scientific community was now judged capable of administering the civilising mission for their own kind.

The Indian scientists among the BAAS's hosts in India had an agenda of their own: they wanted a confirmation of their status in the imperial and international scientific community, but they also wanted to establish an advisory role for themselves in the government of Indian progress. Shanti Swarup Bhatnagar, physical chemist at the University Laboratories of Industrial Chemistry, Lahore, was convinced the "presence [of the members of the BAAS] here today proves that in the world of science there are no barriers between the East and West, that science can transcend racial, political and economic boundaries, and that scientists the world over are a fellowship dedicated to the pursuit of truth, to the service of humanity and to the cause of good friendship". Syama

Prasad Mukherjee,[165] (son of Asutosh Mukherjee, the founder of the Indian Association for the Cultivation of Science, Calcutta), asserted that the "conscious collaboration between pure and applied science is being fostered everywhere" and asked for "this joint session historic in its composition give a clear and definite lead to the future activities in India in this direction…. The practical application of scientific knowledge […] all contributing to the steady increase of the prosperity, joy and happiness of the people, is a question of paramount importance in a country where millions are sunk in poverty, disease and ignorance." Prosperity, joy and happiness were components of Mukherjee's idea of progress. Material prosperity alone did not qualify as progress. Progress was about freedom, from alien political rule, and more so about being counted among equals internationally. "When the clouds of distrust and oppression that hang over the world will tilt.... Humanity will then proceed in a spirit of common brotherhood to higher … reaches of knowledge and happiness. Let India and her scholars play their part in this noble re-making of man's destiny. Rich with traditions and thoughts and endowed with strength and vitality, India claims the right of being treated as a companion with equal rights in the world's march towards a higher and nobler civilization…." Rutherford, Linlithgow, Bhatnagar, Mukherjee – all had arrived at matching conclusions: Scientific industrialism would lead to progress, and progress was certainly about contributing to "world concepts" and "nobler civilisation" – progress was about making history.

---

[165] Syama Prasad Mukherjee was the son of Austosh Mukherjee, the founder of USC. He was also the Vice Chancellor of the Calcutta University between 1934 and 1938. He was elected to the Bengal Legislative Council as a candidate of the Indian National Congress, and he resigned his position with the rest of the Council with the outbreak of WWII. Subsequently he was elected as an independent candidate. He joined and became the president of the Hindu Mahasabha in 1944 and also founded the Bharatiya Jana Sangha in 1951, both Hindu nationalist organisations. He left the organisation following the assassination of Gandhi in 1948. In independent India, Jawaharlal Nehru inducted him into the cabinet as Minister for Industry and Supply in 1950. He remains a key figure in the institutionalisation of Hindu nationalist politics in independent India.

The [British] Government of India, on the other hand, was working within an established logic. Not consistently and purposefully engaged with the scientific community at large, certainly not those with nationalist aspirations in India or for that matter science advisory bodies in England,[166] the bureaucracy continued to frame the debate on progress of India in terms of economics and a rather skewed understanding of market. Economics as a language to frame questions of material advancement had a peculiar role to play in the debates on progress for both, articulate nationalists and the [British] Government of India. If economic nationalism was a detour to describe the moral economy of Britain's "un-British" rule over India, it was also the language that the [British] Government of India came to use to justify the necessity of continued imperial rule for the betterment of Indian masses.[167] The 1930s were unstable years for the world economy in general and very few remained unimpressed by the Soviet experiment in rapid industrialisation through intensive five year plans. The Indian nationalist bourgeoisie was no exception. Many came to insist upon privileging the processes of planning for industrialisation, and often marginalised its roots in the political system of the Soviet Union, or for that matter when alluded to, in planned reconstruction of Nazi Germany. There was no reason to perceive this as anachronistic - state intervention in regulating markets was acceptably re-written even in New Deal America. If demands for support for industrialisation in India had been gaining momentum decisively since WWI, it found a suitable anchor in the weak moment of depression economy coupled with Soviet success in rapid

---

[166] See Roy MacLeod, "Scientific Advice for British India: Imperial Perceptions and Administrative Goals, 1898-1923," *Modern Asian Studies* 9, n. 3 (1975): 343-384.

[167] I mean here the late 19th century economic nationalism of Dadabhai Naoroji, Gopal Krishna Gokhale, Mahadev Govind Ranade and the moderates of the Indian National Congress. See Goswami (2004) and Zachariah (2005).

industrialisation of a primarily agricultural economy. The [British] Government of India now had to find arguments to deny that any such demand was justified at all.

An office of Economic Adviser to the Government of India was created in May 1938, and Theodore Gregory was appointed to the position. Gregory had studied and lectured at the London School of Economics, and was Cassel Professor of Economics at the University of London between 1927 and 1937. His job became one to help show that India did not need state-aid, specifically British aid, and tariffs for the development of industrial infrastructure that Indian nationalists and industrialists had begun to steadily argue for. Reiterating arguments raised by others before him, he argued in his report that India did not actually need industries that were "not directly stimulated by and serving agriculture". His intention was to "dispose of a particular intellectual complex – the fear that without state-aid there would be no ancillary employment at all, or only ancillary employment of a negligible amount in a predominantly agricultural country".[168] What Gregory offered was a legitimate academic expression to government policy; those demanding state-aid had gotten the question wrong. The needs of the Indian economy were agriculture related, and as such demands for supporting large-scale industrialisation not related to agriculture were irrelevant. This argument became unsustainable finally with the outbreak of WWII but even more so with the Japanese occupation of Burma when appeasement of the nationalist bourgeoisie (and therefore meeting their demands for industrialisation of India) as well as well as the need for industrial production closer

---

[168] For a comprehensive discussion on development debates in colonial India see Zachariah, (2005). Theodore Gregory, *Memorandum on 'Protection and Secondary Industries'*, dated 6/5/1938, Gregory Papers, IOR, MSS.EUR.D 1163/1, f. 12; quoted in Zachariah, (2005), 97-98.

to the war front, made industrial research and development in India an immediate necessity. It would take yet another British scientist, A. V. Hill, to declare the necessity of urgent industrialisation in India. But Gregory's argument would continue to enjoy support for two more years, and it was four more years before the urgency of scientific and industrial research, to sustain Empire, finally arrived home.

2.2 National Planning Committee

> "[O]ne of the major powers of the state is to produce and impose […] categories of thought that we spontaneously apply to all things of the social world, including the state itself".[169]
>
> Pierre Bourdieu, (1994): 2.

Gregory's appointment indicated that expert advice and evaluation had become necessary of the imperial state, following the peculiar arrangement created with The Government of India Act of 1935.[170] The Act had introduced provincial autonomy, and proposed a federal organisation of Indian provinces and princely states through elections. The Indian National Congress contested elections thereafter and in 1937, formed provincial governments. The governments thus established were responsible for local government while the [British] Government of India kept control over foreign, defence and fiscal policies. A legitimate space was thus created for debating the obligations and demands of government. If Gregory and others in the India Office were still doing their best to assert

---

[169] See Pierre Bourdieu, (1994): 2.

[170] Among others see, Percival Spear, *A History of India, Volume II* (New Delhi: Penguin Books, 1965), Chapter 17, 206-220.

that progress for India should translate to strengthening of an agricultural economy, Indian nationalists and the scientific community now found the rightful opportunity for continuing eloquence on Soviet industrialisation as a remarkable accomplishment. The Indian National Congress and a section of the scientific community, now as legitimate representatives of the population in British India, joined hands to form a National Planning Committee for the development and progress of India in October 1938.

Meghnad Saha, Palit Professor of Physics, University Science College, Calcutta, wrote to Jawaharlal Nehru, the president of the Indian National Congress, "On behalf of the Indian Scientists, I would appeal to you to accept the chairmanship and guide the deliberations of the [National Planning] Committee".[171] Nehru was travelling in Europe and Saha's letter informed him that ministries of the Congress Provinces had met, and the ministries for industry (and not agriculture or home affairs) had resolved for the appointment of a National Planning Committee (NPC) in October 1938. "I assure you on behalf of myself and other scientist colleagues who have been asked to serve on the Committee, of our willing cooperation and service"; these scientist colleagues, Saha revealed to Nehru had already given much thought to the "problem of reconstruction of the economic and industrial life of the country" that now needed to be coordinated for fruitful outcomes. The Congress Ministries had agreed that to "tackle successfully the problems of poverty, unemployment and national defence, the country must push on with the schemes of large scale industrialisation". But they needed very clear guidance and that, Saha suggested, only Nehru could offer. The National Planning Committee first appointed leader was

[171] Meghnad Saha (MNS) to Jawaharlal Nehru, October 7 1938, MNS Papers, Nehru Memorial Museum and Library (NMML).

Mokhshagundam Visvesvaraya, an engineer and technocrat, then the Dewan (Prime Minister) in the princely state of Mysore in South India. Visvesvaraya had begun writing on the issue of reconstruction of India in the 1920s, borrowing freely from the Soviet experiment, and fascist nationalist reconstruction in Italy and Germany.[172] However, Visvesvaraya was not a politically popular leader in the same manner as Jawaharlal Nehru in the Indian National Congress. If the history of Indian nationalist struggle has often been equated with the history of the Indian National Congress – it poses a historiographical problem. But as a pragmatic channel for the Indian anti-colonial struggle, leadership of the Indian National Congress was comfortably compliant with nationalist aspirations of varied colours. Gandhi's priority for rural development made him an improbable political ally for British plans of reconstruction in India, and a significant section of the Indian nationalist bourgeoisie were looking for a strong antidote to this trajectory, which they saw as no less than a catastrophe for the future of free India. If Nehru accepted leadership of the NPC, as an influential political leader, his leadership would signify wider acceptance of planning for industrialisation; and ensure its implementation in government, further consolidating scientific industrialism as a secular ideology against the (perceived) Gandhian regression and the conservatism of religious nationalism. Nehru accepted leadership of the NPC and Visvesvaraya stepped down. Saha advised Nehru that large-scale industrialisation was "imposed upon us by world conditions" as much as by the necessity "of maintaining a proper standard of life of

---

[172] See (all by) M. Visvesvaraya, - *Reconstructing India* (London: P. S. King & Son Ltd, 1920); -*Planned Economy for India* (Bangalore City: Bangalore Press, 1934); -*Nation Building: A Five Year Plan for the Provinces* (Bangalore City: Bangalore Press, 1937); -*Reconstruction in Post-war India: A Plan of Development all Round* (Bombay, 1944). His appreciation for fascist nationalist reconstruction was not exceptional, many among the nationalist bourgeoisie held the Italian and German governments in favourable view.

India's millions". Nobody, to his mind, could effectively control these imperatives. The scientific community, in Saha's person, had made their claim upon representing the masses of India.

Just how a large-scale industrialisation was carried out was not cause for much alarm. By accepting the plan for industrialisation, the Congress Ministries, in Saha's opinion anyway, had not committed to any ideology. "It is a scheme of social advancement and of social uplift necessitated by the laws of evolution and the particular "ism" by which the objective is to be realised may be regarded for the present as a secondary affair." Nonetheless, Saha hoped that the NPC should provide for India something like Sun Yat Sen's *San Min Chin* (Three Principles of the People) in China.[173] There was no agreement on the ideal and Saha was deeply concerned. "This haze must be removed by a clear cut new philosophy of life and action." It is telling that Saha located the spring of "life and action" and the "ideal" in Nehru's political leadership of what he otherwise saw as a technocratic exercise to be discussed by experts. Saha, and others like him had great hope in Nehru's leadership. Nehru's understanding of socialism was based on the awe many felt about Soviet industrialisation. However, his uncompromised commitment to industrialisation as the way for India's development drew Saha, among others to his support.[174] Seen this way, Saha argued, even the limited scope of self-government offered by the "Constitution of 1935" was enough to begin spade work on mapping the country's

[173] Saha went to the extent of arguing that Sun Yat Sen had actually replaced Confucius in the minds of the Chinese masses, and this strengthened their resistance to Japan, even if it was only partially successful.

[174] For a detailed analysis of the Gandhian vision of development in the context of arguments for science based industrialisation see Zachariah, (2005), Chapter 4, "The Debate on Gandhian Ideas," 156-210; Prakash (1999), Chapter 7, "A Different Modernity," 201-226, and Chatterjee (1986, 1999), Chapter 4, "The Moment of Manoeuvre: Gandhi and the Critique of Civil Society", 85-130.

resources and to send scholars abroad just like Russia and China had done, to study specialised aspects of reconstruction work. Saha was well aware that this was not going to be enough given that treasury, banking and fiscal policy were all under the control of the [British] Government of India. It would be difficult, but it was necessary not only in the march towards a free India, but because these activities held the potential to raise "battle-cries" which could "divert the popular mind from the whirl pools of communalism, provincialism and other new cankers".[175] A well-coordinated program for development could help control unreason and social strife. It could help build state, nation and establish self-rule over the Indian population.

Most scientists both in India and Britain put their weight in the modernisation vision and soon committees were established to take stock of Indian natural resources, scientific and technical manpower including one scientific instruments committee.[176] The NPC discontinued work at the outbreak of war, when political leadership of the Congress resigned from provincial governments and many of them, including Nehru, were imprisoned. The Committees of the NPC redefined the Indian terrain with categories they had come to see as characteristics of a modern society that independent India was to be. Indian scientists and engineers wrote extensively on what they imagined a decolonised India would look like – in these committees and elsewhere. 'Modern India' was at once a scientific and political project. Most agreed on an economy based on scientific

---

[175] MNS to Nehru, October 7 1938, MNS Papers, NMML.

[176] K. T Shah, (for Indian National Congress, National Planning Committee) *Engineering Industries and Scientific Instruments Industries, Reports of the Sub-committee[s]: Scientific Instruments* (Bombay: Vora Publishers, 1948).

industrialism and 'science' - whatever it may have meant to each of them – set the parameters of both - decolonisation and the social order in independent India.

2.3 On the Necessity of a Disjunction - Scientific and Industrial Research is not Industrial Planning and Development

> "After the Board has been in existence say for two years, they will clamour if no industries are brought into existence. They will say we have been squandering the money given to us. We must therefore guard very much against giving such a false impression about our possibilities to the public…. In the representation from the National Institute of Sciences we have therefore insisted on the necessity of the separation of the two functions of the industrial and scientific research, and of industrial planning and development. *I, as a scientific man, do not wish to take upon myself the responsibilities for which I am not fitted. Let it be thrown on the political and industrial leaders."*
>
> Meghnad Saha to Shanti Swarup Bhatnagar, March 29, 1940.[177]

Barely had the surveys of the National Planning Commission begun when with the outbreak of WWII, the cataloguing of India's natural resources (at least) became an express concern for the imperial government in relation to material requirements for the war effort. In protest of being dragged into war without the consent of elected representatives of people of India, the Congress provincial governments resigned their offices. The [British] Government of India responded by arresting them. The provincial governments had abdicated from participation and control over the collaborative planning of resources in India for war purposes. One step removed from the larger concerns of progress and confronted by the immediacy of wartime needs, ideas of progress began to be replaced by 'development' in reconstruction parlance. This was also the first

[177] MNS to SSB, March 29 1940, MNS Papers, NMML.

coordinated exercise of scientific industrialism – research and production would have to be coordinated to deliver necessary services and equipment or the war. Far too many fronts of the war were open and afire – decisions would be expediential, taken locally, and could potentially involve Indian expertise. The field of shaping Indian development was now open temporarily more for contest between the (British) Government of India, the nationalists in prison, industrialists, Gandhi and Gandhians, communists and radical democrats, and finally the British scientific community.

War took priority. In December 1939, Dewan Bahadur Arcot Ramaswami Mudaliar (henceforth Mudaliar), commerce minister on the Viceroy's executive committee visited Bhatnagar in Lahore. Impressed by work being carried out in applied and industrial chemistry, he recommended that Bhatnagar be given charge of the wartime science effort in India. As a result, the Board of Scientific and Industrial Research (BSIR) was established in April 1940.[178] The Board would now provide advises to the [British] Government of India by evaluating proposals for research from universities, industries and trades and research institutes for approval of funding. In August 1940, Bhatnagar took over the position of Director, Scientific and Industrial Research and moved to Calcutta to work in the Test Laboratory of the Government of India. Wartime work could not be coordinated from within the university laboratory. The mandate for the BSIR was almost the same as that of the Department of Scientific and Industrial Research (DSIR) in Britain, except that the BSIR was constituted entirely for war related scientific and

[178] The BSIR continued and extended the Industrial Intelligence and Research Bureau (IIRB) that was established in 1934. The IIRB served as a testing laboratory and reported on the feasibility of industrial establishments for the [British] Government of India. Mudaliar remained the ex-officio chairman of the Board.

industrial research.[179] The BSIR had but a small testing laboratory of the Industrial Intelligence and Research Bureau for its works and therefore, Bhatnagar and his colleagues decided to collaborate with existing university laboratories and research institutions by awarding grants for small projects.[180] Stable funding for research came only a year later in November 1941, with the establishment of an Industrial Research Fund. The bureaucratic logic was as strong as ever in the [British] Government of India and the need for "a legal entity to disburse the funds" was felt. Accordingly, a Council for Scientific and Industrial Research (CSIR) was established two years later on March 12 1942, again with Mudaliar as the president. Following the Japanese occupation of Burma in 1942, the testing laboratory and BSIR's activities were moved from Calcutta to Delhi. Funding was dedicated to the coupled "scientific and industrial research", and no apparent distinctions or divisions of labour were made between the university laboratories or research institutions, like the Indian Institute of Science in Bangalore. The BSIR and the CSIR were the first experiments of scientific industrialism in India. However, this was far from a nationalist exercise towards the development or progress of India. The [British] Government of India had established these institutions for war effort, within the logic of imperial preference. Political leadership of the nationalist bourgeoisie

[179] The Department of Scientific and Industrial Research (DSIR) in Britain was established in 1914, and provided the model for similar organisations in the Dominions, a DSIR in New Zealand (1926), CSIRO in Australia (1926) and the CSIR in South Africa (1945). For a history of the events and organisations leading up to the establishment of the CSIR in India see V. V. Krishna, "Organisation of Industrial Research: The Early History of CSIR, 1934-47," in Roy MacLeod and Deepak Kumar, eds., *Technology and the Raj: Western Technology and Technical Transfers to India 1700-1947* (New Delhi: Sage Publications, 1995), 289-323.

[180] The Committees under the BSIR were: Glass and Refectories; Industrial Fermentation; Dyestuffs; Fuel Research; Vegetable Oils; Cellulose Research; Heavy Chemicals; Drugs; Plastics, Sulphur Research; Essential Oils; Metals, Applied Physics; Scientific Instruments; Internal Combustion engines; Distillation and other chemical plants; Radio research; Statistical standards and quality control; Building material; Electro-chemical industries.

was largely in prison, but this in no way meant that practising scientists with nationalist aspirations did not participate in the researches for the war effort. Even if leadership of the BSIR and the CSIR was entrusted to SS Bhatnagar, given his distance from Congress nationalist politics– the network of scientists finally involved with war related research in India was a completely mixed community. Meghnad Saha, the most vociferous nationalist of them all, accepted a grant to build vacuum pumps at the Palit Laboratory in Calcutta. However it was perhaps the mixed nature of this community that prevented their participation in the larger British scientific war effort, even for the South East Asia Command. A community infiltrated by nationalists and sympathisers (however mild and pragmatic) of the fascist governments in Europe, and increasingly also of Soviet politics could not be easily trusted to loyally support imperial efforts at winning a global war.

Scientific industrialism's first operative lessons were thus taken in collaboration with the imperial government, led by scientists not necessarily with nationalist aspirations and with goals not defined on the path towards the progress or material advancement of India. The most palpable goal was one of the defences of an amorphous territory called British India. This sensibility nestled within a tense intermingling of nationalist aspirations, the struggle of the Indian scientific community with the necessity of goal-oriented scientific research, their need for participation in world history and the immediate excitement of transitions *practised* within an immediate context of defending the territory of British India were consolidated into the corpus of scientific industrialism. Scientific industrialism as practised in the *research laboratory* had made small contribution to the development of industry, but it was now also conjoined with the defence of India.

Decoupling any of its components, learnt in practice, would have to be explained and argued for. Any claim otherwise, would count as politics.

2.4 The Anxious Imperium - Archibald Vivian Hill Visits India

An extraordinary meeting of the Royal Society was held in the St. Stephens' College Delhi on January 3 1944. "A specially prepared sheet of parchment bearing the historic *Obligation* was taken to India by Professor Hill, and for the first time in the Society's history a Meeting of the Society was held outside the United Kingdom."[181] The [British] Government of India had invited Archibald Vivian Hill, the biological secretary of the Royal Society for advises on the organisation of scientific efforts. Hill visited India for a little more than five months surveying institutions of science education and research in India "during which he was able to assist and encourage Indian scientists in their desire to apply scientific and technological methods to the development of their country".[182] The Viceroy General of India, [Lord] Archibald Wavell argued, "India, one of the oldest civilisations, has perhaps felt the impact of modern science later and less than any other great people…. But if India is to play the part in the world to which her size, her population, her history and her position entitle her, she too must make every possible use of scientific advancement…. Science is the most international of all human interests."[183]

---

[181] Visit to India by the Biological Secretary *Notes and Records of the Royal Society of London* Vol. 4, No.1 (April 1946) pp. 63-64.

[182] Ibid.

[183] H.E. Lord, "Wavell on Indian Science," *Current Science* 1, (January 1944): 3.

Hill's visit to India was proof that the British Government of India was at last ready to pay attention to the nationalist elite it had so wanted to bypass through rural development in the desire to be of service to the real Indian in the villages. It was testimony to the pressing demands of war, but also to the rise in importance of scientific activity for the Empire. The resignation of the Congress governments in the provinces had given them just that opportunity. But the impact of the Quit India movement - called and led by Gandhi beginning August 1942 at the peak of nationalist anti-colonial struggle, was clearly showing up in the wartime policy of the [British] Government of India. Some in the India Office and in London were convinced that an evaluation of the scientific capability of the country by an eminent scientist would provide for a suitable appeasement.

The final push came from a symposium on "Postwar organisation of Scientific Research in India" organised in Calcutta by the National Institute of Sciences of India.[184] "Official" scientists like Shanti Swarup Bhatnagar and non-official scientists, like Homi Bhabha and Saha met to consider three questions attended the symposium: "how should the war time infrastructure in science and technology be assimilated for peace time civil organisation; what should be the organisational model for science and technology adopted for post-war and independent India; and how should India benefit from the commonwealth structure".[185] The Government of India "requested the services" of A. V. Hill to "advise

---

[184] *Proceedings of the National Institute of Sciences of India* X (1944). The volume contains papers from the symposium of September 27-28, 1943.

[185] S. P. Agharkar, H. J. Bhabha, S. S. Bhatnagar, D. M. Bose, J. A. Dunn, J. C. Ghosh, J. de Groof Hunter, B. C. Guha, S. L. Hora, P. C. Mahalanobis, S. K. Mitra, J. N. Mukherjee, K. G. Naik C. W. B. Normand, M. N. Saha, H. K. Sen, S. S. Sokhey, V. Subrahmanyam and M. Visvesvaraya, among others, attended the

the organisation of scientific and industrial research as a part of the Indian post-war reconstruction plan, and its coordination with the corresponding activities".[186] An important recommendation of the symposium was the establishment of a National Research Council, "outside the control of official government machinery but accountable to the Government of India".[187] Non-official scientific institutions like universities were expected to dominate the Council, "to plan the main lines of scientific work in accordance with national needs; to ensure balanced development of all branches of science and prevent duplication; to advise relevant authorities regarding the training and supply of scientific personnel for pure and applied research".[188] Recommendations of the National Institute for Sciences did not eventually converge with Hill's suggestions, which in fact were diametrically opposite of the agreements at the symposium. But some of those present found good reasons to ally with imperial ambition.

The choice of Hill for this task was not random. Hill had earlier tried in 1941, without success, to get the [British] Government of India interested in getting Indian scientists enrolled in the war effort.[189] With the Japanese occupation of Burma, the [British] Government of India now felt the heat of the war. The nationalist elite could no longer be

---

symposium. See V. V. Krishna, *S. S. Bhatnagar on Science, Technology and Development, 1938-54* (New Delhi: Wiley Eastern Ltd, 1993), 13-15. The following details on the symposium are from Krishna.

[186] A. V. Hill *Scientific Research in India* London: William Chowers and Sons, 1944. [Introduction]

[187] Some members, especially M. Visvesvaraya, preferred the establishment of a "National Council of Industrial Research" instead of a general council coordinating scientific research.

[188] Activities of the Council were to be organised under four boards: the Board of Scientific Research, Board of Agricultural Research, Board of Medical and Public Health Research and Board of Engineering Research. The Boards would organise Research Committees that would then organise National Laboratories.

[189] A. V. Hill to Max Born, October 13, 1941, Hill Papers.

ignored.[190] Hill was also a Nobel Laureate in physiology but this was not the only qualifying credential he brought with for this trip. Hill made his first contributions to war efforts that were not entirely related to physiology during WWI. He held the military ranks of captain and brevet-major during the war and served as Director, Anti-Aircraft Experimental Section, for the Munitions Inventions Department, leading a group that came to be called "Hill's brigands". When he visited India in November 1943, he held several positions in Britain, but his deputation was from being the Biological Secretary of the Royal Society, a position he held between 1935 and 1945. Hill was also a member of the War Cabinet Scientific Advisory Committee (1940-46), chairman of the Defence Research Society (1940-51) and chairman of the Executive Committee of the National Physical Laboratory (1940-45). He was at the same time a Member of the British Parliament (1940-1945), as a representative of the University of Cambridge to the House of Commons as an independent conservative, and a member on the University Grants Committee (1937-1944).[191] Moreover, his immediate superior at the Royal Society who approved of his deputation as President for the special meeting was Henry Dale. Dale was the Chairman of the Scientific Advisory Committee to the War Cabinet 81942-1945). Hill was someone who clearly possessed a significantly comprehensive overview on British war effort and organisation of science in Britain at the time. He could inform (or placate) his audience as much as he could glean information from the Indian situation in a useful manner for the [British] Government of India. And Hill's diplomatic abilities

---

[190] Sanjoy Bhattacharya and Benjamin Zachariah, "A Great Destiny: The British Colonial State and the Advertisement of Post-War Reconstruction in India, 1942-1945," *South Asia Research* 19, no. 1, (1999): 71-100.

[191] Archibald Vivian Hill, *Lectures, Physiology or Medicine 1922-1941* (Amsterdam: Elsevier Publishing Company, 1968).

had already been recognised at the beginning of the war with a more formidable ally regarding the question of war effort.

Hill went to the United States for what has been called "Hill's Mission" on March 9 1940. His visit was partially motivated by Henry Tizard's desire to "bring American scientists into the war before their government".[192] The trip to India was perhaps then an effort to bring in Indian scientists to recognise the continuing relevance of Empire, and the need to support allied war effort before the nationalist government, especially the imprisoned political leadership of Indian National Congress could be negotiated with. The Congress had already demonstrated its unwillingness to be dragged into the war effort by tendering resignations from the provincial governments. Hill could perhaps convince the Indian scientific community of imperial goodwill, the community was a part of the Indian bourgeoisie if not always and explicitly nationalist. He was to, of course, also advise Louis Mountbatten of the South East Asia Command. Hill was informed about the "possible fields of extra mural work in connection with the armed forces in India such as signals and electrical equipment, wireless communication and air borne forces" which he should pay attention to during his visit.[193] In choosing a man of science, the [British] Government of India had done well, and the response from the scientific community in India was immediate but varied.[194]

---

[192] See David Zimmerman, *Top Secret Exchange: The Tizard Mission and the Scientific War* Montreal and Kinston: McGill-Queens University Press, 1996), especially Chapter 3, "Hill's Mission", 49-70.

[193] A.O.R.G to A. V. Hill, September 22 1943, Hill Papers.

[194] Wartime diplomacy and intelligence gathering involving renowned scientists was not uncommon. For a possible comparison see Mark Walker, "Physics and Propaganda: Werner Heisenberg's Foreign Lectures under National Socialism," *Historical Studies in the Physical Sciences* 22, no. 2 (1992): 339-389.

Hill's credentials were magnificent enough but for the crowning glory, he brought with him the Royal Society. Unprecedented in the history of the organization established in 1640, an extraordinary meeting of the Royal Society was held in India. The meeting was held to ceremonially admit four recently appointed Indian fellows of the society: the botanist Birbal Sahni, the physicists Kariamanikkam S. Krishnan and Homi Jehangir Bhabha, and the physical chemist, Bhatnagar. Neither of the four had been able to attend a meeting of the Society to confirm their admission to fellowship.[195] The best occasion for this award, Henry Dale, the president of the Society had suggested, would be the Indian Science Congress session in January 1944.[196] Dale wrote to the President of the National Academy of Sciences at Allahabad, that the Royal Society was sending an emissary in Hill to "strengthen the bonds of understanding and true comradeship between our Indian colleagues and the men of science in this country".[197] Who were these Indians

---

[195] A. V. Hill to Birbal Sahni, November 18 1943, Hill Papers.

[196] Henry Dale to Birbal Sahni, October 29 1943, Hill Papers.

[197] Henry Dale to the President, National Academy of Science, Allahabad, October 29 1943, Hill Papers. The Indian Science Congress discussed the establishment of a science academy (1930). Meghnad Saha led the establishment of a provisional United Provinces Academy of Sciences (1933), and the Council of the academy wanted to change its name to an "Indian Academy of Sciences", or establish a new body that was more representative (1933-35). An academy committee of the Indian Science Congress Association chose Calcutta as the centre for the academy, and several meetings with various science societies were held to consolidate a constitution and nature of the organisation. Raman and his colleagues of the Association of South Indian Scientists were not happy with the decision. They registered displeasure with the "little group at Calcutta" for its "unconstitutional procedure", its "non-representative character", "cliquishness" and "indecent haste". Raman refused to be nominated to this academy; the Indian Science Congress Association considered his opinions. Within ten days of meeting each other (April 1934), Raman with the support of the Dewan of Mysore, declared the establishment of an Indian Academy of Sciences in Bangalore and announced it in the newspapers. The Indian scientific community was divided over the formation of two academies; the Allahabad academy was renamed "National Academy of Sciences" and eventually a third organisation, the National Institute of Science was established to paper over the divisions (1935). The two academies continued to be regionally preferred and active, but a rift between Meghnad Saha and CV Raman was established. See Singh (1992), 93-96. That only two members signed the parchment was a result of a controversy over which of the two existing Academies of Science, in Allahabad and Bangalore was representative of the Indian scientific community in correspondence with the Royal Society. One of

then? Hill was confronted with a problem he hardly could begin to think about. What he had in mind was the mandate for this visit - a stubborn political ambition to appease the scientific community at large. When Hill arrived in India on November 9, 1943, he found the Indian scientific community divided between the National Academy of Sciences, Allahabad (established by Meghnad Saha, and led by the Indian Science Congress Association) and the Indian Academy of Sciences, Bangalore (established by Raman and led by the Association of South Indian Scientists). The Bangalore academy had not figured in the Royal Society's correspondences. Raman was upset and as a mentor who had nominated three of the four designated to sign the parchment, he asked Bhabha, Krishnan and Sahni to register their protest.

> "We … feel that if a function of the kind proposed, which clearly affects only the Fellows of the Royal Society, is held for the purpose of obtaining our signatures in India, then it should be entirely unconnected with the meeting of any other society or organisation in India".[198]

Hill was not in the least pleased with the bother. The Indian Science Congress was his preferred platform to impress, cajole and motivate Indian scientists towards participating in the war effort and the continuation of post-war imperial preference. Even Churchill had written a piece for the occasion! In the report of the extraordinary meeting only two of the named, Bhabha and Bhatnagar, signed the parchment and were admitted to the

---

Hill's tasks during this visit was to help strengthen one such institution – and contribute to a single national framing for the scientific community in India.

[198] B. Sahni, K. S. Krishnan, H. J. Bhabha and C. V. Raman, to A. V. Hill, December 2 1943, Birbal Sahni Papers, NMML.

Society.[199] Bhabha apparently had realised that despite Raman's displeasure, Sahni, Krishnan and he should attend the meeting, because "[Raman's] not attending will not be such an unfriendly gesture as our not attending".[200] Hill struggled to have prominent Indian scientists accept the privilege of an extra-ordinary meeting of the Royal Society in India.

Hill's report on the trip began with his incredulity that Indian scientists and scientific establishments were not enrolled into war effort: at once calling attention to the need for drawing on all 'available' resources in the gruelling war effort, to the indifference and arrogance of the imperial regime in London, and a tribute to the strength of Indian science.[201] He never expressed any doubts about the Indian scientific community's loyalty to the British Empire or for that matter any dilemmas that could arise in organising scientific research in India around imperial preference. He put his weight behind the arguments on the urgency of industrialisation pressed upon him by scientists, media and nationalists alike. Scientific industrialism was the answer to India's poverty. In conclusion Hill declared, "I have assumed throughout that the scientific method rightly and confidently used, will provide the framework within which national development will be planned by Indians for India. In their task they can be sure of the cooperation and

---

[199] Visit to India by the Biological Secretary *Notes and Records of the Royal Society of London* Vol. 4, No. 1 (April 1946) page 64.

[200] Homi Bhabha to Birbal Sahni, December 21 1944, Sahni Papers, NMML. Bhabha did not mention Bhatnagar in the letter, and it is not clear if they had discussed this among themselves already. Bhatnagar was connected with the Dorab Tata Trusts and with Ardeshir Dalal, a representative of the Tata's on the department of planning. But Bhabha had rebelled against his mentor, and just how much displeasure he incurred on this count is difficult to gauge for lack of documents.

[201] Archibald Vivian Hill, *Scientific Research in India* (Simla: Government of India Press, 1944); and - *India: Scientific Development or Disaster* (London: India-Burma Association, 1944).

goodwill of their scientific colleagues elsewhere. *No other method can possibly succeed*."[202]

Hill's trip was considerably controversial; he was even accused of "industrial espionage" in the press, of wanting to sabotage industrial production in India. But he hoped that the community he best wanted to assuage, the Indian scientists would "rise above their differences and contribute substantially to the new World".[203] Bhatnagar, and Bhabha had already seen sense in making a courteous gesture towards the anxious imperium, but Sahni and Krishnan had refused to participate in the ceremonies. And these were but the chosen few of the scientific community at large, not all of whom agreed with Hill's suggestions for the organisation of Indian scientific research. In stark contrast with the recommendations of the National Institute of Sciences (NIS) symposium, Hill favoured the establishment of a centralised governmental department coordinating all scientific and industrial research, with *concentrated executive power*. Even though suggestions for the organisation of research committees, boards and national laboratories were alluded to in Hill's report, the main distinction between his model and that proposed by the NIS was that he preferred the organisation of research entirely under government control. What Hill suggested was also in violation of the "Haldane Principle" followed in the organisation of the Department of Scientific and Industrial Research back in London.[204]

---

[202] Archibald Vivian Hill, *Scientific Research in India* (Simla: Government of India Press, 1944).

[203] Singh (2004), 174-178.

[204] The "Haldane Principle" argued by proponents of "freedom of science" was employed to safeguard the DSIR from direct political influence. The DSIR, though directly accountable to the British Parliament, maintained autonomy of organising research and related executive authority. If the CSIR of India, established in 1942, was to be organised on similar lines as the DSIR, Hill's suggestions were clearly not in line with practice in London.

Bhatnagar as Director of the CSIR supported Hill's suggestions. Surprisingly, even Saha, agreed.[205] Bhatnagar may have accepted Hill's suggestions but realised that he has thus also compromised his own ability to take decisions. The Department of Scientific and Industrial Research was to be organised under a bureaucrat of the [British] Government of India, under whom he would have to carry out his work. He resolved this predicament by demanding a bureaucratic assignment to his position as Director of Scientific and Industrial Research. Failing this, he was prepared to resign his position. The position of a Secretary to the Government of India was eventually created for Bhatnagar.[206]

Hill's deputation was representative of several agendas in Britain as well as that of the [British] Government of India during the war. It reflected the desire to build a post-imperial network where Britain would continue to have significance in the post-war world order – an effort cautious of Indian nationalist articulations of their own visions of a decolonised India, where nonetheless increasingly many more came to acknowledge if not share their belief that scientific research and industrialisation was imperative. Hill's suggestion for *government* control of scientific and industrial research was not acceptable in England, but this was empire. Continuing British presence on the sub-continent was under question but continuing British interest in the region was obvious. A favourably inclined political leadership, in control of scientific research on the sub-continent would

[205] Saha was connected into the "freedom of science" debates in England during the interwar period. He had also attended the historic 1931 meeting in London, but he actively supported Hill's model. M. N. Saha, "Department of Scientific Research," *Science and Culture* 14, 1948. Unsigned Editorial. Reprinted in Santimay Chatterjee, Ed. *Collected Works of Meghnad Saha* IV, (Calcutta: Orient Longman India Ltd., 1993), 138-165.

[206] Bhatnagar's strategy became the precedent during the creation of a similar position for Homi J. Bhabha, once nuclear exeptionalism was firmly established in the minds of the political leadership of India.

provide an overview of scientific activity should the need arise to safeguard British interests. Hill's trip resulted in the organisation of "goodwill missions" in the last years of the war for two groups, one of Indian scientists and another of industrialists to visit scientific and industrial research facilities in the United Kingdom, the United States of America and Canada. Hill's mission to India was politically motivated and its implications for the organisation of science in India –during and after the war proved significant.[207] His continuing correspondence especially with Bhatnagar is revealing of the extent to which his support or disfavour would impact scientific research in free India. Raman was not a member of the mission.

2.5 A Hamlet without the Prince of Denmark, The Indian Scientific Mission

Among the several tangible outcomes of Archibald Vivian Hill's visit to India were two goodwill missions, of Indian scientists and industrialists respectively, that visited the UK, USA, and Canada to see for themselves applied scientific and industrial research laboratories of the Allies. British commitment to appeasing Indian elite and enrolling their support for the war effort was quite evident. The missions were funded and given

[207] Following Hill's visit, some rapid activity began that enrolled Indian scientists in the British war effort. Notable among these was radio physics. "In view of urgent need for all possible collaboration on radio research and especially in view of need for this sort of work to be done for the Japanese War in India Minster of Aircraft production has expressed regret as Chairman of Radio Board at postponement of Mitra's visit and has asked whether matter can be reconsidered. If Mitra were willing to come in advance of others, he would be most welcome." See "Secretary of State to Government of India", Confidential Code Telegram of 16 May 1944, IOR/L/I/1 73-78 [File 16/ 26/H], OIOC. The [British] Government of India requested a postponement of Mitra's visit "for reasons of violent war and deteriorating transport conditions". The War Office also wanted Bhatnagar to visit ahead of the good will mission, but he "did not want to be singled out" from the accompanying members of the goodwill mission and his department in Delhi was reluctant to let him go. It can be safely said that some projects involving Indian scientists and the impetus to some research fields were a result of Hill's visit. However, Hill's mission was intended much more to lock the Indian scientific community into the post-war allied scientific scene.

time and attention despite the war. The Indian Scientific Mission included seven scientists and administrators from important scientific institutions.[208] Raman's exclusion from the mission was not taken well, and not just in southern India but even in Bombay press. Hill's political mission was not lost on his Indian audience.

> "An Indian Scientists Mission without Sir CV? A Hamlet without the Prince of Denmark? No, the clue perhaps lay elsewhere; Sir C. V. Raman is not merely a scientist, dead to life all around. He is also a patriot. Under Prof. Hill's auspices, in a mission sponsored by the Government of India, will they be touring at their own will? Will they be touring at their free discretion? Is there a free Government behind them? Sir C. V. Raman is a great scientist, but not a good salesman for British wares".[209]

Patriotism was thrust upon Raman at a good time. Ironically, this would amount to a criticism of nationalists like Meghnad Saha, who had associated with the Indian National Congress. The mission was controversial, but the political positions of its members were complicated, as were their motivations for attending the mission.

The mission's first stop was the United Kingdom. The Royal Society and the British Council managed their visits to various laboratories, including some involved in the war effort. Henry Dale, the President of the Royal Society also managed to get them an audience with the Royal couple – an event that he thought left them quite impressed. Back home, the press was not so impressed. The mission was feasting, they said, while

[208] The members on the Indian Scientific Mission (1944) were Nasir Ahmed, Director, Indian Central Cotton Committee, Bombay; Colonel S. L. Bhatia, Deputy Director, Central Indian Medical Service, Calcutta; Sir Shanti Swarup Bhatnagar, Director, Board of Scientific and Industrial Research, Government of India, Delhi; Sir Jnan Chandra Ghosh, Director, Indian Institute of Science, Bangalore; Professor Sisir Kumar Mitra, Professor of Physics, Professor Meghnad Saha, Professor of Physics, Calcutta University, Prof. J. R. Mukherjee, Professor of Chemistry, all three from University College of Science, Calcutta.

[209] News clipping, *The Blitz* October 28, 1944, Sahni Papers, NMML, quoted in Singh, (2004), 176.

parts of India were slipping into famine conditions. The mission spent a good eight weeks visiting various British facilities of relevance to their expertise. Generating goodwill among these men was not a trivial issue anymore as the India Office became increasingly aware of the loss of British hegemony over India.

The next stop was the United States. Ernest O. Lawrence of Radiation Laboratory, University of California Berkeley was informed: "These gentlemen, who are in the United States under the auspices of the Indian Agency General and the British Government, are the most distinguished men of science in India. All of them are cultured gentlemen, mostly if not all Oxford and Cambridge graduates, and their visit here is for the purpose of acquainting themselves with the organisation of science and technology in the United States to the end that they may better plan the future of India in the interests of its people."[210] The mission visited several laboratories but this time under strict vigilance when it came to "atomic cities".

Meghnad Saha wrote a report of this visit in the journal *Science and Culture*. "We vaguely heard of the atomic cities, and passed close some of them. We met Dr. Vannevar Bush, the erstwhile MIT electrical engineer, who handled the fine war-time organization of scientists and technicians known as OSRD, having a budget larger than that of the peace-time Government of India."[211] The scale of research expenditure was impressive in

---

[210] Frank B. Jewett, National Academy of Sciences, to Ernest Orlando Lawrence, December 15 1944, EOL Papers.

[211] M. N. Saha, "Experience as member of the Indian Scientific Mission -1946," in Santimay Chatterjee, ed., *Collected Works of Meghnad Saha* IV (Calcutta: Orient Longman Ltd and Saha Institute of Nuclear Physics, 1993).

the United States. Here though, the war effort was kept more secret from the visiting delegation. Their curiosity nonetheless invited suspicion and Saha was finally questioned by the Federal Bureau of Investigation (FBI) on just how much he was aware of nuclear fission research in relation to the war-effort.

Saha's report came to his audience after Hiroshima and Nagasaki, and in hindsight, he sought to explain why it was the Americans who were able to produce atomic weapons. "Countries like England had the requisite scientific and technical knowledge but being in the midst of the War it was impossible for them to spare the amount of power, manufacturing plant and personnel which was necessary for bringing the effort to a successful termination. The USA could find all this, not merely because she was outside the main arena of War, but for the fact that President Roosevelt long before the War broke out had, by his personal initiative, taken steps to harness three rivers of America for power, namely, the Tennessee, the Colorado and the Colombia. It was the surplus power obtained from the Grand Coulee and the Tennessee lines which could supply the

---

Saha closely followed Vannevar Bush's activities as "the chief architect of wartime science policy and a strong advocate of university research". [Leslie (1993), 6]. In his arguments about the organisation of a Department of Scientific Research in independent India, Saha referred in comprehensive detail to Bush's "report [where] the idea of a National Research Foundation was first broached, consisting of non-official scientists with an elected chairman, which was to be entrusted with "the development and promotion of a national policy for scientific research and scientific education, the support of basic research in non-profit organisations, development of scientific talent in American youth by means of scholarships and fellowships, with the support of long range research on military matter by means of contract or otherwise". See Saha, "Department of Scientific Research" (1948). The *Journal of Scientific Industrial Research* published by the CSIR also referred to Bush "The defence Department keenly interested in the promotion of basic research, has to take steps to encourage such research activities in universities and civilian research centres where the climate for free inquiry and creative endeavour is favourable…. In the USA, basic research in the Army is carried on largely outside the Department by contract…. Dr. Vannevar Bush in his oft-quoted report, points out how vital such partnership is for the promotion of national security, and stresses the need for a 'permanent, independent, civilian controlled scientific organization having close liaison with the Army and the Navy, but with funds drawn from the Congress." Editorial, *Journal of Scientific and Industrial Research*, VI, no. 12, December 1947.

atomic cities with the huge amount of energy required for the experiments which led to the successful evolution of the 'Atom Bomb'."[212] Written in retrospection of the atomic bombs gives a certain slant to Saha's observations. But it was most certainly industrial development and planned state intervention in energy policy that held explanatory power to the spectacular American prowess the world came to witness matters he had stressed beginning 1934 in *Science and Culture*, and would stress again and again in the future. American political leadership had prudently led industrialisation in important sectors in the interwar years, and that was why Americans could build atomic bombs, something even England could not accomplish.

After visiting Britain, Canada and the United States, many from the group then continued to visit the Soviet Union in June 1945 to attend the 220th anniversary of the Russian Academy of Sciences, thus completing the circle of references that would determine the shape of international science and politics for at least the next four decades to come. The meeting was rather heavily politically charged. France had been liberated and Hans von Halban, Frederic Joliot-Curie's collaborator on the pile design before the war was back from work on the Manhattan project. The British were unsuccessful in stopping him from proceeding to France and discussing matters with Joliot-Curie, who in turn attended the meeting in Moscow and discussed the Manhattan project with Soviet scientists. Given Joliot-Curie's political sympathies, and the suspicious Indians fresh from being questioned about and denied visits to the "atomic cities", there is good chance that some from the Indian delegation heard, confirmed and discussed matters nuclear just a month

---

[212] Ibid.

before August 1945. The significance would hardly be lost on them.[213] Their visit also generated much hope in the country for post-war reconstruction work, "it is reasonable to hope that its' [scientific mission] members may come to be regarded as apostles of a new era; for their unique experience will authorise them to select and urge the adoption of such among Prof. Hill's proposals as they deem best applicable to Indian conditions".[214]

Scientific Goodwill Mission to U.K. & U.S.A., 1944-45.
At I.C.I. (Imperial Chemical Industries), Billingham-on-Tees, U.K., during November, 1944.
Front Row (L to R) : Dr. Nazir Ahmed, Sir J. C. Ghosh, Prof. M. N. Saha, Dr. S. S. Bhatnagar, Dr. J. N. Mukherjee

Figure 2.1: Indian Scientific Mission, Reproduced with permission from the Meghnad Saha Archives, Saha Institute of Nuclear Physics, Calcutta.

---

[213] John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Cambridge: MIT Press, 2006c), 119 and 298. Krige has argued, "Joliot-Curie … made it very clear that he was not going to accept the official anti-Soviet posture of Britain and the United States. He attended the meeting in Moscow to celebrate the two-hundred-twentieth anniversary of the Soviet Academy of Sciences in June 1945, along with other left-wing French and British scientists. Groves did not allow any members of the Manhattan Project to attend and senior British physicists like Chadwick were also stopped from going. At this gathering, Joliot-Curie reputedly discussed details of the American bomb project quite openly with his hosts." He "came away impressed by how the Soviet Academy of Sciences was able to coordinate the work of a number of specialised institutes…"

[214] Editorial, "Scientific Awakening," *Current Science* 14, no. 3 (March, 1945).

Hills' visit enabled the emergence of organising science on a national scale in India in a decisive manner. This in no way implies that the scientific community in India was oblivious of each other; the case was quite the contrary. There was however, no organising principle linking their practical efforts with each other. Their work was intellectually linked into the international scientific community, and that was their main referent. The laboratory as a location to further scientific industrialism was a very recent phenomenon for the nationalists among them. The scientific community in India had understood and even employed the nationalistic idiom in their arguments about doing science, but the emergence of a national-state framework was quite another idiom. If they had identified their commitment to things national so far, now came the time to define priorities of the emergent nation-state that would enframe a national order of things. The mission became a part of the informal importation program being put in place at the threshold of Indian independence, which included study tours, invitation or arrival of scientists to reflect upon specific problems, temporary visits by scientists from abroad, conferences, and surveys of special topics by individual scientists or by commissions.

This re-structuring recast actors, institutions and priorities in contest, collaboration and conciliation making it imperative that they reach an understanding of their positions vis-à-vis one another to create a system of access to resources and power. The references from this mission were to prove vital in allowing Indian scientists to imagine, or re-imagine some of their endeavours - and pursue those in power and responsible for funding with a sense that they were attainable and necessary. Imperial ambition held its own plan but in the meanwhile, the war was almost over. Japanese occupation of Burma gave a robust push to coordinated pursuit of scientific and industrial research in India. Wars end and the nature of Japanese defeat with the use of atomic bombs would now work the early years of scientific and industrial research in India into yet another phase of organising scientific research on the national scale.

2.6 The Nuclear Question

Physicists had been aware of the potential for nuclear energy beginning 1939. Additionally, some members of the Indian scientific community were aware of 'atomic cities' in the Unites States following the Indian Scientific Mission (1944-45), or then some of them had heard Joliot-Curie in Moscow (early 1945). Indian students were studying at the Radiation Laboratory, Berkeley as well as the Cavendish Laboratory, Cambridge. All of their suspicions or piecemeal information, and for some more direct experiences, must have all fallen into place after August 1945. The significance of atomic weapons for scientific research, and the implications thereof for the organisation of research now confronted the Indian scientific community, even as questions of organising scientific research for national development were already well under discussion in the Indian Science Congress, as well as in the Indian National Congress.

As the apex organisation for scientific and industrial research in wartime, the CSIR awarded grants, established research laboratories and determined policy on science research. It was the only coordinating institution for scientific and industrial research in India. Only five years old, its director, Shanti Swarup Bhatnagar had planned for an ambitious expansion of the CSIR and had secured support, but even more so, funding for the establishment of at least three more "national laboratories" – a National Physical Laboratory, National Chemical Laboratory and a National Metallurgical Laboratory. Part of the funding came from the Tata Industrial House, which had also most recently matched government funding for the physicist Homi Jehangir Bhabha's initiative in establishing the Tata Institute for Fundamental Research, Bombay, (TIFR) dedicated to fundamental research in nuclear physics.

An Atomic [Energy] Research Committee (AERC), established under the CSIR of India met for the first time on May 15 1946. Although little can be discerned from available documents about why Homi Jehangir Bhabha was appointed the chairman, one most likely reason for his choice as a leader can be the establishment of the TIFR one month prior to Hiroshima and Nagasaki. He must have appeared a "visionary". No less consequential for his choice was his connection to the Tata industrial family, given also that JRD Tata was also a member of the Board for Research on Atomic Energy. The meeting was held at Bombay House, headquarters of the Tata industrial establishments. The national context was being established for those involved in nuclear research but India was under imperial rule. National priorities were only in the making and atomic energy research was still an ambiguous commitment even in the international context. What were very clearly known were the wartime uses of nuclear energy, but there had been no time in the preceding six years of war to work out its potential for peacetime use as thoroughly. It was not even self evident that either would have been worked out that speedily at all if not for the war. In no way was it obvious as to how nuclear research could be organised as a state-funded activity, least of all those did not even have a sovereign state or habits of sovereign government.

In its very first meeting, the AERC declared the TIFR an institute of priority in the national context. The committee appeared to agree upon that there simply were not enough funds available in India in the near future for investment in atomic research compared to the US and Britain and therefore, "it is necessary that all large scale research in atomic physics in the near future should be concentrated at one centre in the country". And this one centre would be the recently established Tata Institute of Fundamental Research, Bombay. In the press release for the meeting, the AERC noted a second set of decisions upon grants for nuclear research for immediate implementation. Meghnad Saha at the department of physics, University Science College, Calcutta, would receive both capital and recurring grants "towards the expenses for the operation of a cyclotron"; Debendra Mohan Bose at the Bose Institute, Calcutta, received similar grants for research on transuranic elements and finally, the Tata Institute of Fundamental Research would establish a 200 million volt betatron with a ten-member team for its operation.[215] Even to those not directly involved in the decision making process, it was "quite obvious that your [Bhabha's] Institute will in future provide the best facilities for work in nuclear physics".[216]

The meeting deliberated upon "the general policy that would have to be followed in order

---

[215] *Notes Issued to the Press on the proceedings of the first meeting of the Atomic Energy Research Committee held on 15 May 1946, Bombay House* MNS Papers, (Bhabha Folder) NMML.

[216] Piara Singh Gill to Homi Jehangir Bhabha, May 24 1946, D-2004-00314, TIFR Archives.

to develop atomic research in India in the shortest possible time with the limited resources in money and scientifically trained men at the country's disposal. … [R]apid progress …demands the concentration of resources and of men." Faced with a lack of sufficient resources and of a shortage of trained personnel, the Atomic Energy Research Committee arrived at a decision on concentration of resources. What wartime had also conclusively brought home was the impending independence of India. Establishment of national institutions was a part of building the nation. The shortage of personnel in India can be well imagined to be acute as there were not many industrial, state-led or university laboratories engaged in fundamental research. For that matter, there were not that many university departments imparting graduate training in science in 1947.[217] Furthermore, even if there were at least two Indian students who had obtained their PhD's in nuclear physics during the war, the Indian scientific community and laboratories were not enrolled into allied war effort - the experience of which had altered post-war physics practice in England, Canada and the USA. The shortage of trained personnel was felt in numbers as well as in their relevance for nuclear research at the national scale.

It would be nine more months before the AERC would meet again; and one more year before Bhabha would give up wanting the betatron for the TIFR altogether. Bhatnagar, Bhabha and Saha soon went to England for the Empire Scientific Conference, the British Commonwealth Official Science Conference and the Newton Tercentenary for well over five weeks. What followed was a renewal of their collegial alliances with the international scientific community. They actively sought information on progress in

[217] See David Arnold, *Science, Technology and Medicine in Colonial India* [Cambridge History of India] (Cambridge: Cambridge University Press, 2000), 191.

research they felt deprived of during the war.[218] This was the occasion to discuss the organisation of post-war research, even nuclear research, with physicists from Britain and the USA actively engaged in the field. The question of nuclear research in India was far from settled.

2.7 The Commonwealth of Science, The Empire Scientific Conference

> "[T]he implementation of many of the recommendations made at the Royal Society's Conference would require Government action, either in the expenditure of public money, or in the provision of facilities which can only be provided by Government and sometimes through the collaboration of more than one Government. I feel strongly, therefore, that *we, as Official Scientists, should not hesitate to do all we can to convince our Governments, where this is necessary, of the importance of the proposals for the extension of facilities for independent fundamental research at Universities throughout the Commonwealth*… It is, therefore, our duty to satisfy ourselves that the recommendations we finally put forward can, in fact, be carried through and *that they take into account the national interest both of the individual countries of the Commonwealth and of the British Commonwealth as a whole*".[219]

[218] MNS to Niels Bohr, June 14 1946, Niels Bohr Archive. Saha asked for reprints of research published by those in Copenhagen during the war years. Saha's student Dhiren Kundu, who went to Pittsburgh to work on the cyclotron presented at the annual meeting of the American Physical Society (June 1946) where he found "This meeting of the American Physical Society was one of the biggest and many papers on nuclear physics containing academic materials which were so long under censorship, were read by prominent scientists like Fermi… Wigner… Dempster. The various isotopes of the four well established trans-uranic elements were reported by Seaborg and different aspects of the pile and chain reactions were discussed, within limit of censorship by others". D. N. Kundu to MNS, June 23 1946, MNS Papers, SINP.

[219] Sir Edward Appleton, "Opening Statement by the Chairman," *Report of the Proceedings of the British Commonwealth Scientific Official Conference* (London: His Majesty's Stationary Office, 1946): 14-20.

The need for holding an "Empire Scientific Conference" was already discussed among secretaries of the Royal Society in the early years of WWII.[220] The war effort had brought together scientists of the British Empire, especially those from the Dominions. By the time the Conference took place, the desire may have to been to continue this fruitful collaboration for interests of the Empire as much as it may have been prompted by the desire to continue associations within a world order getting increasingly nationalised. Initial meetings were attended by representatives from Canada, Australia, New Zealand, South Africa and India, secretaries of Research Councils and the Royal Society. Bureaucrats from the [British] Government of India represented the sub-continent. The British Government pledged its support in July 1944 and by August the preparations for an Empire Scientific Conference, to be held as soon as the war was over, began in the imperial capital of London.

This was not to be an assembly of scientists alone. The wartime coordination of scientific activities had brought the administrative state and scientific establishments close enough that the British Government in turn made plans to organise its own meeting prompted by a related purpose: coordination of scientific activities with imperial preference. The British Commonwealth Scientific Office announced another official conference, which in turn would include officials and science administrators from colonial governments. This conference would be held in close association with the conference of the Royal Society.

---

[220] A proposal to organise an Empire Scientific Conference has been attributed to the efforts of Alexander King (Ministry of Supply and later head of the United Kingdom Scientific Mission of the British Commonwealth Scientific Office in Washington DC.), and Neville Wright (New Zealand Office in London). The Secretaries of the Royal Society involved were A. V. Hill and Sir Alfred Egerton. See *The Royal Society Empire Scientific Conference June-July 1946: Report* I & II (London: The Royal Society, 1948).

The entire meeting lasted for five whole weeks, first three weeks led by the Royal Society and the other two by the British Commonwealth Official Scientific Conference.[221] There were limited printing facilities and restrictions on food, lodging, and the limited laundry facilities were a spot of bother. London had barely begun to walk towards recovery from the war, but the Crown would not lose face. On Monday, June 17 1946, the King and the Queen of England declared open the Conference at 11 am in the Beveridge Hall of the Senate House, University of London; leaders of attending delegations presented the delegates to the royal couple. Some of the Indian delegation had hardly had the time to forget their first meeting with the King and Queen.

The Royal Society Conference took place for a week each in London, Oxford and Cambridge, and laboratory visits followed in the afternoons. The idea was that the delegates would feel free to discuss and share opinions in the Royal Society meetings free from the fetters of bureaucracy and nationality. Decisions and plans for collaborations thus arrived at among free minds could be then formalised in the official meeting in the following two weeks. After all, those assembled knew very well, said Sir Robert Robinson, the president of the Royal Society, “Science acknowledges only the limitations of man’s mind and of human powers of observation, experiment and reasoning; it knows no frontiers of nationality or sect.”[222] “The discovery of the energy stored in matter”, Robinson continued, “was a great triumph of research and the work of no one man

[221] The attending delegations came from: Australia, Burma, Canada, Ceylon, East Africa, Eire, Gold Coast, Hong Kong, India, New Zealand, Nigeria, Palestine, Sierra Leone, South Africa, Southern Rhodesia, Trinidad, United Kingdom and West Indies.

[222] Sir Robert Robinson, “Presidential Address,” *The Royal Society Empire Scientific Conference June-July 1946: Report* I (London: The Royal Society, 1948): 16.

contributed as much to it as that of Lord Rutherford, a great son of the Empire". Rutherford was a New Zealander, and this was the time to acknowledge contributions from the Dominions, if not colonies to assert bonds and reinstate the moral economy of the Empire. The Indian empire stood in its usual perplexity – neither dominion nor colony, represented for the first time by rather confident scientists most of whom were re-visiting British institutions, not as strangers or as visitors in awe – but as alumni in collegiality.

Bhatnagar as Director, Scientific and Industrial Research, Government of India, led the Indian delegation. Raman withdrew his attendance from the meeting and refused to recognise the National Institute of Sciences as a representative body of Indian Science. Bhatnagar presented his take on 'Organisation of Science in India and some of the Problems in Applied Science.[223] He also contributed to discussions on exchange of scientists within the Empire, and Meghnad Saha, to discussions on the dissemination of scientific information within the Empire, owing perhaps to his engagement with the Indian Science News Association. Homi Bhabha was asked to lead discussions on comic ray research. Saha was disappointed there was hardly any discussion on nuclear physics even during an adjunct international conference on fundamental particles and low

[223] The others members of the Indian delegation were Homi Jehangir Bhabha, Director, Tata Institute of Fundamental Research, Bombay; Sir Jnan Chandra Ghosh, Director, Indian Institute of Science, Bangalore; Rai Bahadur S. L. Hora; Khan Bahadur Mian Mohammed Afzal Hussain; Sir Kariamanikkam Krishnan, Professor of Physics, University of Allahabad; M. S. Krishnan, Indian Institute of Science, Bangalore; Prasanta Chandra Mahalanobis, Professor of Statistics, Indian Institute of Statistics, Calcutta; J. N. Mukherjee; Meghnad Saha, Palit Professor, University College of Science, Calcutta; Birbal Sahni, Professor, Institute of Paleobotany, Allahabad; M. R. Siddiqui; Colonel Sir Sahib Singh Sokhey, Haffkine Institute, Bombay; and Darashaw N. Wadia, Geologist. In the very first minutes of Bhatnagar's presentation, he recorded his appreciation for the House of Tata philanthropy towards scientific and industrial research in India, a theme that will recur in the following Chapters.

temperature physics. The Newton Tercentenary was a "flat affair".[224] The Americans had not sent their top men; in any case none that were "even distantly connected with any atomic project". There was yet a "hush-hush" about nuclear research. What he learnt in the meeting was not different from what he claimed he had already learnt in 1944 from Eugene Wigner in the USA: "no definite advance ha[d] been made either in the theory of fundamental particles or theory of quantum electrodynamics since [P. A. M] Dirac's work on the electron. [Alexandru] Proca giving an outline of his work said apologetically that we have to keep our brains ready for the reception of new discoveries which may be made with the aid of the atomic pile, the cosmic ray, and the betatron and the cyclotron".[225] Saha perceived, "that the next big lead lies with experimental physicists and will come from the use of high energy particles which would come from the projected 400-inch cyclotron, giant betatrons and synchrotrons". After the meeting, Saha was unsure if he should advise his students back home to work with theoretical physics. "I am of the opinion" he wrote to Kothari; "that we should keep a watch on the theoretical speculations, watch very carefully the onrush of experimental facts, but should

---

[224] MNS to D. S. Kothari, August 2 1946, MNS Papers, SINP. The following presented at the meeting; Niels Bohr, Christian Møller, Leon Rosenfeld, Wolfgang Pauli, William Wentzel, Erwin Schrödinger, Max Born, Kemmer, Walther Heitler and Homi Bhabha. Saha thought, "The result was very disappointing, everybody seemed to have a different theory which explained one phenomena, and left everything else unexplained. They did not appear to even understand each other… The atmosphere was trifling…The Indian workers on Meson theories and fundamental particles shining by the reflected light of their Western prototypes have been as a rule arrogant, but I am glad that I did not waste my time on such barren enterprises". Saha also informed Kothari that Bhabha was planning to go to Zurich to work in a team with Pauli, Wentzel and Fierr. Saha must be referring to Bhabha as the "arrogant" worker. The souring of their relationship had begun with the disagreements on the Board for Research on Atomic Energy (BRAE) decision on a Central Nuclear Research Station.

[225] MNS to Satyendranath Bose, July 27 1946, MNS Papers, SINP; Alexandru Proca (1897-1955), a Romanian theoretical physicist is known for Einstein-Proca systems [relativistic quantum mechanics] and Proca Equation, a relativistic equation for massive spin one particle.

otherwise stick to our own lines".[226] The Commonwealth of science was presented as an advantageous alliance, but nuclear research apparently was not on the agenda. That would have to be negotiated only bilaterally.

Raman registered his disappointment with the Royal Society.

> "The Royal Society, in spite of its distinguished past, was unfortunately tending to become more a political than a purely scientific body. Some of the officials of the Royal Society seemed to be more interested in maintaining British contacts with India than to any purely scientific research. The mixture of politics and science … was not likely to prove a success and it was not well that India had taken a step, which would enable her to take an independent line in the international scientific field."[227]

Raman's allegation was true; Hill's visit, the Indian Scientific Mission and the Empire Scientific Conference were all parts of reconfiguring imperial preference in a post-war world. But he must have been clearly aware that this was far from an aberration – scientific internationalism was never divorced from political internationalism. It was only being configured differently now, and to his disfavour. His refusal to attend the meeting may have invited patriotic interpretations, as would his sharp critique of the Royal Society, but he would have to, just like Saha would have to, confront the inadequacy of evoking "universal science' or "nation" alone to secure priority and patronage for scientific practice in free India. Bhabha, Saha and Bhatnagar realised that they were negotiating as much for their own position in the imperial network as they were for India's place in the near uncertain futures waiting to unfold. India is where they belonged

---

[226] MNS to D. S. Kothari, August 2 1946, MNS Papers, SINP.

[227] News Cutting, *The Hindu* (date not known) Document No. RP. 9.52, Raman Research Institute Archives, quoted in Singh, (2004), 177.

now, even though how India belonged in the Commonwealth would eventually configure in their practice, within Cold War politics.

2.8 New India

The Indian Science Congress meeting of January 1947 was shaped in the spirit of independence even though the formal end of imperial rule took place in August that year. Jawaharlal Nehru, Vice President of the new Interim Government in New Delhi, leader of the Indian National Congress, was also chosen as chairperson of the Indian Science Congress. He wrote a letter to the Royal Society on behalf of the Science Congress; "I am writing this letter on behalf of the Executive Committee of the Indian Science Congress Association. The Association is anxious to promote the cause of international cooperation in scientific work and research, and in particular, to develop contacts between Indian scientists and eminent men and women of science in other countries… The Committee… would be glad if the Royal Society could accept this invitation and arrange to send a small team of scientists to India. Our Association will meet all the expenses and where necessary, meet the cost of air passages to and from India."[228] It was not the first time the Congress would host foreign delegates, nor was Nehru elected its president the first time, but the moment of independence determined the novelty of this meeting. That Nehru was presiding signalled to both - those visiting and those at home, that scientific activity had priority and would play an important role in the life of the new country. There was an

[228] Jawaharlal Nehru to the President, Royal Society of London, October 12 1946, quoted in "The Indian Science Congress –Delhi Meeting, 1-8 January 1947," *Notes and Records of the Royal Society of London* 5, no.1 (October 1947): 27.

explicit acknowledgement that science required international collaboration, and the new government was willing to patronise this cause.

But the Congress of 1947 was only proposed as the beginning of this exchange, Nehru further wrote. "With a view to furthering this cause, the Association wishes to invite some distinguished scientists from other countries on short visits to India, beginning with the next session of the Indian Science Congress Association…. It is hoped that each scientist will find it possible to visit important centres of work in India in his own field of study, and according to his convenience, to give a few lectures, take part in discussions and advise on scientific matters."[229] Expert advise from scientists abroad would become a feature of the new government, sometimes also to the chagrin of local scientists. Nonetheless, this was the time to plan and build for new enterprises, those that the national government wanted to be proud of.

Nehru had invited members of the Royal Society and the BAAS, but the significance was equally convincing for the Information Department of the British Government. On November 14 1946, R. W. Brock in the Information Department of the India Office asked the Films Division if they could produce two films.[230] The first he wanted was a two-reel film covering the inaugural session of the Constituent Assembly of India, of "great historic and topical significance. Moreover, "the meeting of the assembly will, of course, represent not only a definite triumph for H[er] M[ajesty's] G[overnment]'s policy as

[229] Ibid.

[230] R. W. Brock to A. S. Graham, November 14, 1947, IOR/L/I/1/709, F. 462/14Q, OIOC.

embodied in the agreements reached in India by the Cabinet Mission but also the culmination and final justification of two centuries of British rule". The second was a smaller one-reel film, to cover the visit ten leading British scientists to India. The "overriding aim is to indicate, as widely as possible in regard to India-British relations that while some links are being severed, new ones are emerging and others are being strengthened."

The Royal Society and the BAAS sent delegations to Delhi.[231] It was of course not only the British that were invited. Delegations came from Canada, the United States, France, the USSR and China, and the hosts paid for all the local expenses.[232] Nehru managed to impress the visiting delegations: "it is significant to see what a large place the furtherance of scientific development plays in the plans of political leaders".[233] The delegations were also invited to the foundation stone laying ceremonies of the National Physical Laboratory of India, an industrial research laboratory (unnamed) and a ceremony for confirming honorary degrees of the University of Delhi. If the Congress was an invitation to collaboration and goodwill by the new country, it also served the purpose of the Empire to showcase what it was leaving behind to aid the progress of India. The Viceroy General of British India, Lord Wavell was present as chancellor of the university and

---

[231] The Royal Society delegation comprised: Professors Patrick Maynard Stuart Blackett, W. Brown, Charles Darwin, Munro Fox, L. J. Mordell, Sir Harold Spencer Jones, and Sir D'Arcy Thompson, Professor P. B. White, D. Stamp See Sir Charles Darwin, in *Nature* (15 March 1947).

[232] The members of the delegations were: Canada: W. F. Hanna, T. L. Tanton, R. B. Thomson; China: Professor S. S. Chen; France: Professor Hadamard; USA: A. F. Blakeslee, W. E. Deming, E. Newton Harvey, O. Riddle and Professor Harlow Shapley; USSR; Professors Bolshaikov, E. N. Pavlovsky, S. Umarov, V. P. Volgin.

[233] See "The Indian Science Congress –Delhi Meeting, 1-8 January 1947," *Notes and Records of the Royal Society of London* 5, no.1 (October 1947): 28.

impressed the audience by speaking Russian when he conferred degrees on the Soviet delegates.[234] The delegates could not afford to diligently attend the sessions of Congress as a result of the numerous ceremonies. But this was the time to get and give impressions. The visiting delegates gave lectures each evening, as was customary in such assemblies, but to an audience of about two thousand people. This was a surprisingly large crowd for most visiting but the audience managed to convince them of their interest and enthusiasm.[235]

Brock's films about the Constituent Assembly of India or the Indian Science Congress never got made. "Prophetic treatments", he was told, were dangerous.[236] About the film for "Indian Scientists" (sic) the Films Division argued, "it is extremely difficult for people sitting in England at this time to produce a story which can give the feeling that it is what the Indians themselves would collaborate in saying […] We recommend holding until… we can arrange for cooperating in film making through the new machinery…. This may be more complicated than the old but we think it is better to wait." Many were equally convinced that new was more complicated than the old, especially those leading the establishment of the new. But the justification of Empire, severance of imperial rule and continuation of scientific collaboration were all ceremoniously enacted in the Indian Science Congress of 1947.

---

[234] Lord Wavell, born Archibald P. Wavell (1883-1950) was Viceroy and Governor General of India from 1943 to February 1947.

[235] See "The Indian Science Congress –Delhi Meeting, 1-8 January 1947," *Notes and Records of the Royal Society of London* 5, no.1 (October 1947): 30.

[236] Helen Mouilpied to R. W. Brock, August 11 1947, IOR/L/I/1/709, F. 462/14Q, OIOC.

Conclusion

The subcontinent was partitioned and free of imperial rule in August 1947. A significant section of the scientific community had taken time to weld their practice to the national context and cause. They would hardly find anytime for research in the next few years – this was the time to dream and make plans. Even those that had thus far avoided active engagement with politics of the Indian National Congress now saw merit in supporting its governmental activities – the Congress was after all becoming the proprietor of the state in the making. Nationalists, industrialists, scientists, political leaders in India, the [British] Government of India, British scientists involved with matters relating to India – and many of the categories overlapped - all agreed on that India was backward and needed a very good post-war plan for development. Every group offered ways of accomplishing what was clearly a gargantuan task. Their motivations shaped their suggestions and various groups laying claims on representation began to settle the contest for “upliftment of the masses”.

The [British] Government of India was trying to convince the industrialists and nationalist political leadership that India did not need industry, tariff protection or state aid because the task of development was about strengthening agriculture and its ancillary sectors. Agriculture needed to be developed, because it was in the villages that a majority of the Indian population lived and worked in. The [British] Government of India was also convinced that this was their way to show the *masses* of India that the nationalist bourgeoisie was not committed to their cause. This was not only about material progress, but material progress of the correct sections of populace was very important.

If war effort following the Japanese occupation of Burma changed the perspective on development for the [British] Government of India, it was for two reasons. First was the realisation that the war against Japan could not be fought without industrial effort and research directed towards technological development close to the war front. The other reason was their inability to ignore the nationalist elite even if they were safe behind bars. If they wanted political support for “their” war in India, or for that matter forego political unrest within British India even as all resources were now required to fight the advancing Japanese the nationalist elite had to be appeased to ensure a minimally stable political regime. Demands for industrialisation and scientific research in the plans for post-war development of India had to be made. I would like to further argue that British efforts for development were not mere responses to nationalist struggles or for that matter driven by war effort alone. These efforts were also informed by long-term British national interests and therefore ridden with conflict and cooperation within various sections of [British] Government of India bureaucracy and British society at different times.

The bind was a terribly irresolvable one. In the early years of the war, the [British] Government of India actually found in Gandhi an ally in their quest for development of agriculture in India. Gandhi proffered a rewritten “Constructive Program” in 1941 and 1943 for the “regeneration of Indian society”. He argued for building up the village economy of India, which to his mind appeared self-sufficient, familiar and morally acceptable. Agriculture and rural development played a dominating role in Gandhi’s plan for a free India. Even if he was not entirely hostile to science research and technological development, he did not see the merit in it being offered as the primary solution to the problems of material and moral improvement in free India, and most certainly not on a scale similar to Soviet industrialisation. With his leading the Quit India Movement beginning August 1942, he became an unlikely ally for the [British] Government of India but by then his plans rose steadily in favour of the industrialists in India who were growing sceptical of the uncertain socialisms of the nationalist political leadership, especially Nehru. In Gandhi they found an ally that did not want to disturb the existing patterns of property holding, who nonetheless did acknowledge a limited role for science and technology. Gandhi was popular also because in him both the industrialists and the British found an ally against the nationalist elite.

The Indian nationalist political leadership first and foremost demanded a political framework of sovereignty and self-rule. As a free country, they would pursue industrialization of India and the group of scientists associated with them, for example Meghnad Saha and those active within the National Planning Committee, wanted to invest in fundamental research. No nation, country or state to their mind could appear naked on world stage, and the correct attire was one that was culturally, economically and politically participating in the world as an equal. This was imperative and imposed upon this country being born "by world conditions". Scientists threw in their lot with nationalist leadership also because that was the only group that offered them hope for both the practice of science and in their pursuit of a modern society " away from the traditions and superstitions of India". Even if their British colleagues supported them and they had benefited from patronage for training in science in England, their place in Indian society was not supported by the [British] Government of India or Gandhian ideologues.

Industrialists were not always obvious allies because some of the scientists had belief in certain socialisms. But this was not the case always. The industrialists did cautiously support the nationalist cause because in free India, they would after all, be regulated by many of these who had already been in power in provincial governments.

What this mire of changing alliances makes amply clear is that not much about what constituted the national in these years can be taken for granted. Development was not divorced from politics and therefore the goals and path to development were determined by the aspirations and ambitions of those mobilizing the argument. Development meant much more than economic growth, and held moral implications. It was thus inseparable from progress even for the scientific community, although such an idiomatic separation began to seep in once the actual plans began to be drawn up by aspirations of the elite that became articulate in the name of the masses. Development would take on quite another meaning under watchful eyes of the Cold War.

A significant and powerful section of leaders in India and in Britain though it imperative that history of India must be made to unfold in acceptance of the broader ontology of western science and modernity in order to overcome the malady that bothered the protagonist Salim Sinai's grandfather, Aadam Aziz in Salman Rushdie's *Midnight's Children*. India and Indians were – like radium – a discovery, and therefore a subject of European power. It must be in making radium a subject of their inquiry that their own subject status and subjectivity would be established as legitimate agents of science, and of history. Aadam Aziz could well belong to the same generation of Indian elite classes as the physicist Jagdish Bose, educated in Europe but more so, in “European” science. The generations following the likes of Aziz and Bose would have to find ways to participate collegially in the discovery of any more radium subjects to come and become masters at least of their own worlds, and thus contribute to “world history and world concepts”.

CHAPTER 3: A QUESTION OF NATIONAL IMPORTANCE, OR WHY NUCLEAR PHYSICS COULD NOT BE ESTABLISHED IN BANGALORE, 1938-1947

> "It is clearly the intention of the Atomic [Energy] Research Committee to create a monopoly in this subject for certain favoured laboratories and individuals to the exclusion of others. This is not a surprising attitude on their part in view of the large sums of money which they seek to obtain from Government – an attempt, which, if successful, would have the result of starving out everyone else from the field. Such a claim does not, however, seem to be either in the general interests of the country or of the progress of science in the great sub-continent."[237]
>
> Chandrasekhara Venkata Raman (August 1947)

In the year 1938, Chandrasekhara Venkata Raman sent a student from the Indian Institute of Science, Bangalore, to the Cavendish Laboratory, Cambridge to train in nuclear physics, and come back to establish the field in Bangalore. Rappal Sangameswara Krishnan sailed for England on an Overseas Scholarship of the Royal Commission for the Exhibition of 1851, the same scholarship that had in fact enabled Ernest Rutherford himself to come to England from New Zealand. In the 1930s, the Cavendish Laboratory was leading experimental nuclear physics research in Europe and was centred on Rutherford and his students. Krishnan, however, left for England almost a year after Rutherford died. Significant changes occurred in the laboratory's research priorities following Rutherford's death but Krishnan's arrival was opportune. The cyclotron in "Cambridge got a faint evidence of a beam in August 1938"[238] and on October 1 1938, Krishnan was admitted as a research student at the Trinity College, Cambridge. R. S.

---

[237] C. V. Raman, *Memorandum on Atomic Research in India*, "Submitted to the Ministries of the Government of India" August 1947, RSK Papers, 3.

[238] John L. Heilbron and Robert W. Seidel, *Lawrence and his Laboratory: A History of the Lawrence Berkeley Laboratory* (Berkeley: University of California Press, 1989), 342.

Krishnan was awarded a PhD in nuclear physics by the Cambridge University in 1941. He returned to Bangalore and was appointed as lecturer at the Indian Institute of Science, Bangalore. Since his return, he struggled for five years to establish nuclear physics and more specifically, a particle accelerator laboratory to study artificial radioactivity and fission. He was among the very few contenders for nuclear physics research in India in the early 1940s. In 1947, he was completely denied access to resources for setting up such a laboratory in Bangalore.

Irrespective of Krishnan's skills, the Institute and its patrons, and eventually the Atomic Energy Research Committee of the Government of India, did not identify with Raman and Krishnan's ambitions at an Institute arguably dedicated to industrial research. Wartime priorities played their part in undermining possibilities of pursuing basic research, and Raman's declining fortunes with the patrons of the Institute affected his ambitions in no mean way. After the use of atomic bombs on Hiroshima and Nagasaki, even if the relevance of research in nuclear physics became less of a question, a national-statist framework began to emerge which allowed the question to be discussed outside the walls of the Institute. I would propose that Raman's inability to generate support outside the IISc, and arguments of state led priority of nuclear research resulted in a complete rejection of proposals to establish nuclear physics in Bangalore.

Figure 3.1: Passport Issued to Rappal Sangameswara Krishnan for his travel to England, July 1938. Reproduced with permission from R. K. Ramanathan, son of R. S. Krishnan.

3.1 C. V. Raman and Nuclear Physics

Chandrasekhara Venkata Raman began his career in the Indian Financial Services, which took him to Calcutta in Bengal away from his native southern India in 1907. He also began to work his evenings at the Indian Association for the Cultivation of Science

(IACS) laboratories.[239] Raman's presence invigorated the laboratories and a small group of students gathered around him conducting research mainly after working hours, on Sundays and holidays. Asutosh Mukherjee, Vice Chancellor of the Calcutta University, noticed his activities and in 1917, Raman was invited to take up the Palit Chair in Physics at the newly established University Science College.[240] Raman resigned from his position in the bureaucracy and continued work at both the IACS and the University Science College. Experiments leading to the award of a Nobel Prize for Raman in 1930 were carried out in these laboratories with the assistance of Kariamanikkam S. Krishnan.[241] The award of the Nobel Prize brought with it eminence and in 1933, Raman was appointed the very first Indian director of the Indian Institute of Science, Bangalore (IISc). Raman also established the Institute's department of physics. Raman's departure from Calcutta was marked by controversy over the leadership and organisation of the IACS, and this would eventually crop up in his attempts to mobilise funding for a well-equipped nuclear physics laboratory in the years to come.

---

[239] Mahendralal Sircar established the Indian Association for the Cultivation of Science, Calcutta with local philanthropy in 1876. The organization aimed at combining "the character, scope and object of the Royal Institution in London and the British Association for the Advancement of Science"; the context of its establishment can be found in the following works: Kumar, (1995), 198-200; Baber, (1998), 228-230; Prakash, (2000), 59-60; Lourdusamy, (2004), 56-99; Chakrabarti, (2004), 158-163.

[240] Establishment of the University Science College, Calcutta will be dealt with in more detail in Chapter 4.

[241] Sir C V Raman was awarded the Nobel Prize in physics in 1930 for his work on light scattering, which came to be called the Raman Effect. The effect deals with change in frequency of monochromatic light after scattering. The spectrum of this scattered light allows for an observation and insight into molecular structures of materials, and hence proved important in the study of properties of materials.

For details on Raman's career and biography among others see S. Bhagavantam, "Professor Chandrasekhara Venkata Raman," *Biographical Memoirs of Fellows of the Royal Society London* 17, (1972): 565-579; Rajinder Singh, *Nobel Laureate C. V. Raman's work of Light Scattering: Historical Contributions to a Scientific Biography* (Berlin: Logos Verlag, 2004); G. Venkataraman, *Journey into Light: Life and Science of C. V. Raman* (Delhi: Penguin Books, 1994); G. Venkataraman, *Raman and his Effect* (Hyderabad: Universities Press, 1995); Abha Sur, "Aesthetics, authority and control in an Indian Laboratory: The Raman-Born Controversy on Lattice Dynamics," *Isis* 90, (1999): 25-49.

The Institute itself was founded in 1909 with the initiative of Jamshed Nusserwan Tata of the Tata Industrial House.[242] While his plans were to emulate The Johns Hopkins University in the United States, he succeeded in generating support from the [British] Government of India, the local Maharaja (king) of Mysore and nationalist elite to establish a much trimmed version of what could have been a university dedicated to fundamental research and advanced teaching.[243]

The newly established department of physics around Raman energetically pursued research on Raman effect, crystallography and spectroscopy. Rappal Sangameswara Krishnan (henceforth Krishnan) was one of Raman's first students in Bangalore. In 1938, Krishnan was awarded the Overseas Scholarship of the Royal Commission for the Exhibition of 1851. Raman suggested that Krishnan should proceed to England and study nuclear physics at the Cavendish. In his letter recommending Krishnan, Raman wrote of Krishnan's five-year experience in experimental physics in Bangalore. Krishnan had been awarded a Doctor of Science degree by the Madras University (1936). Raman especially mentioned Krishnan's work on a phenomenon termed "Krishnan effect" in colloid optics

---

[242] See: F. R. Harris, *Jamsetjee Nusserwanjee Tata: The Chronicle of his Life* (Bombay: Blackie and Sons (India Ltd), 1925/1958); R. M. Lala, *The Creation of Wealth: The Tata Story* (Bombay: India Book House, 1981); D. E. Wacha, *The Life and Life Work of J N Tata* (Madras: Ganesh Publications, 1915); B. S. Saklatvala and K. Khosla, *Jamsetji Tata* (New Delhi: Publications Division, Ministry of Information and Broadcasting, Government if India, 1970); Lovart Fraser, *Iron and Steel in India: A Chapter from the Life of Jamshedji N. Tata* (Bombay: The Times Press, 1919); D. Hawthorne, "Tata, Indian Industrial Genius," *Asia* 25, (1925): 494-9, 541-3; J. L. Keenan, *A Steel Man in India* (New York: Duell, Sloan and Pearce, 1943); F. James, "The House of Tata: Sixty Years of Industrial Development in India," *Asiatic Review* (July, 1940): 251-260 and Verrier Elwin, *The Story of Tata Steel* (Bombay: TISCO, 1958).

[243] For histories of the Indian Institute of Science see B. V. Subbarayappa, *In Search of Excellence: A History of the Indian Institute of Science* (Bombay: Tata McGraw Hill Publishing Company Ltd., 1992); Kim Patrick Sebaly, "The Tatas and University Reform in India, 1898-1914," *History of Education* 14, no. 2 (1985): 117-136 and R. M. Lala, *The Creation of Wealth: The Tata Story* (Bombay: India Book House, 1981).

and light scattering, not forgetting to mention that this was discussed and cited by Hans Muller at the Cavendish Laboratory.[244] Raman recommended Krishnan as a "highly gifted experimental physicist", in particular, with high voltage and high vacuum techniques. Krishnan was recommended for the scholarship to specialize in nuclear physics at the Cavendish Laboratory "so that on his return to Bangalore this field of research in physics could be developed at this Institute. He has familiarized himself as far as possible with the present state of the subject by theoretical study, and I feel confident that he will prove himself competent to utilize with benefit to himself the facilities available at Cambridge for study and research in nuclear physics".[245] As he would claim later, nuclear physics was the scientific "problem of the times". The department of physics at an institute dedicated to research and advanced teaching would keep its prominence in entering this exciting field. By 1938, Raman had supervised 80 students who now held important positions in Indian universities, colleges and industry.[246] There was no way to imagine just how difficult the mentoring of nuclear physics at Bangalore would eventually become, for someone who had invigorated physics research, established a journal of physics, an academy for Indian science, and won the Nobel Prize.

---

[244] Hans Muller, in the "*Proceedings of the Royal Society*," (June 1938): 235.

[245] Raman to Board of Research Studies, Cambridge University, July 10 1938; UA BOGS I, R. S. Krishnan 1940-1, Manuscripts Section, Cambridge University Library.

[246] P. Krishnamurthi, *Sir C. V. Raman, A Short Biographical Sketch* (Bangalore: The Bangalore Press, 1938), 13-16.

3.2 “Mecca of Physics for the Empire”

Arthur Eddington called the Cavendish a “Mecca of physics for the Empire”.[247] J. G. Crowther in his history of the Cavendish noted, “[t]he Cavendish reached the supreme heights of its achievement when it was an imperial institution, directed by a Dominion citizen from the other end of the world. Under Rutherford, research workers had come in numbers from all quarters of the globe. Massey and Oliphant came from Australia, Ahmad and Bhabha from India, Schonland from South Africa; Shenstone and Terroux from Canada, Kara Michailova from Bulgaria; Chao from China; Bjerge and Jacobsen from Denmark; Goldhaber, Kuhn and Riezler from Germany; Occhialini from Italy; Shimizu from Japan; Niewodniczanski, Sosnowski and Wertenstein from Poland; Bretscher from Switzerland; Bainbridge and Oppenheimer from the United States; Chariton, Gamow, Kapitza and Leipunski from the USSR, among many others.[248]

Rutherford was taken well as an undisputed mentor of physics in the Empire. A year after Rutherford’s death, perhaps before Krishnan’s departure to Cambridge - Raman inaugurated a portrait of Rutherford sponsored by the College Science Association of Loyola College, Madras. In his speech, Raman recalled one meeting with Rutherford in Cambridge, when on a walk together they spotted some students playing tennis at about

---

[247] Jeff Hughes, “1932: the *annus mirabilis* of nuclear physics?” *Physics World* (July 2000): 46. Eddington wrote in a “lyrical booklet” written for the purpose of raising funds for expansion of the laboratory and purchase of expensive apparatus in 1934.

[248] J. G. Crowther, *The Cavendish Laboratory: 1874-1974* (London: Macmillan Publishers, 1974): 201. Also see: Egon Larson, *The Cavendish Laboratory: Nursery of Genius* (New York: Franklin Watts, 1962); Richard T. Glazebrook, “The Cavendish Laboratory, 1876-1900,” *Nature* 110, (1926): Supplement 52-58; H. F. Newall, Ernest Rutherford, J. J. Thompson, C. T. R. Wilson et. al., *A History of the Cavendish Laboratory* (London: Longmans Green, 1910).

one o'clock in the afternoon. Raman drew "the professor's" attention to this upon which Rutherford responded, "See Raman, we do not want to produce book-worms. We want men who will govern an Empire". Raman's narration drew laughter from the assembled crowd.[249]It was well accepted that those that governed the Empire and those that helped govern it, were trained in institutions like Cambridge and Oxford. Imperial authority and Indian claim upon the authority of science were both supported by the very same institution. Raman was acutely aware of this predicament; like other practicing scientists from colonial settings, he overcame this through a belief in the professed universality of scientific knowledge. "… Science transcended all nationalism. [They] should learn to base their ideas on the supreme things in life and try to outlive narrow-minded nationalism".[250]

3.3 Nuclear Physics at the Cavendish

Three important scientific discoveries in the year 1932 in hindsight proved to be immensely significant for the history of nuclear physics and cosmic ray physics. Carl David Anderson at Caltech identified the positron particle (a positively charged counterpart of the electron); John D. Cockcroft an engineer to begin with, and Ernest Walton both at the Cavendish carried out the first artificial disintegration of the atomic

[249] News clipping "*Tributes to Lord Rutherford: Portrait Unveiled, Sir C. V. Raman's Speech*", RSK Papers, most likely from the daily "The Hindu" and most likely from 1938. R. S. Krishnan's private papers are held by his family. All documents mentioned here onwards as RSK papers have been obtained through kind courtesy and permission of Krishnan's son, R. K. Ramanathan.

[250] News clipping "*Tributes to Lord Rutherford: Portrait Unveiled, Sir C. V. Raman's Speech*", RSK Papers - most possibly from the daily "The Hindu" and most possibly from 1938. 'They' refers to the assembled crowd of students.

nucleus using a particle accelerator (called the Cockcroft-Walton generator after its builders); and James Chadwick again at the Cavendish discovered the neutron - the first uncharged subatomic particle to be identified. Writing about the significance of these discoveries, Jeff Hughes notes; “These three discoveries are usually seen as having transformed nuclear physics by providing the solid basis on which later research was built. The neutron, for example, simplified nuclear theory and was the key ingredient in both the discovery of artificial radioactivity by Irene and Frederic Joliot-Curie in 1934 and, ultimately, in the discovery of nuclear fission by Otto Hahn, Fritz Strassmann and Lise Meitner in 1938. The positron, meanwhile, opened up new ways of thinking about cosmic rays and enabled new kinds of particles to be discovered. And the artificial disintegration of the atom ushered in the machine age of nuclear physics, establishing the regime of “atom-smashing” physics. So significant have the discoveries of 1932 become, in fact, that the year has come to be invoked as the *annus mirabilis* of nuclear physics by scientists and historians alike.”[251]

Two of the three significant discoveries were made at the Cavendish. This changed when the regime of atom smashing machines was taken over by the Americans, especially Ernest Lawrence at the Radiation Laboratory, University of California Berkeley. Following the successful implementation of the cyclotron principle by Ernest Lawrence and Stanley Livingston in 1933, other American as well as European laboratories began to consider the cyclotron for their laboratories. It was nonetheless not a self-evident decision to make. The cyclotron was far from reliable and extremely difficult to build.

---

[251] Jeff Hughes, (July 2000): 43-48.

The Berkeley teams took pride in "tinkering", an activity perfected to a concept in American scientific practice just prior to and during WWII. This implied a non-negotiable need for technical craft among the team members involved – and if working outside Berkeley, it was absolutely essential to have someone actually trained in Berkeley to help move the process. Even as late as July 1938, a worried Livingston after his trip to the East coast wrote to Lawrence, "Don't let this get out, but I did not find a single cyclotron operating".[252]

There were other reliable options for smashing atoms. The Van de Graaff generator, made operational by Merle Tuve and his team at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington was one such apparatus. It produced better beams for exact work, but of utmost importance was that it did so by scaling up devices physicists were already familiar with. In 1934, just about the time when Eddington was touring the Cavendish to write a booklet for circulation to "potential benefactors", Bernard Kinsey passed by and reported to Lawrence, "They are all scared stiff at the thought of setting up an oscillator".[253] The Cavendish was only getting ready for further expansion of the laboratory and the construction of larger particle accelerators. Younger members of the laboratory felt that the Cavendish would have to acquire a cyclotron and an electrostatic generator if they wanted to stay competitive in the emerging field of nuclear physics.

---

[252] Stanley Livingston to Ernest Lawrence, July 28 1938, EOL Papers, quoted in Heilbron and Seidel, (1989), 322. For details on difficulties of replicating the cyclotron in locations other than Berkeley see John L. Heilbron and Robert W. Seidel, "Chapter VII: Technology Transfer," in *Lawrence and his Laboratory: A History of the Lawrence Berkeley Laboratory* (Berkeley: University of California Press, 1989), 317-352.

[253] Kinsey to Lawrence, October 4 1934, EOL Papers, quoted in Heilbron and Seidel, (1989), 324.

Mark Oliphant, assistant director of research, was planning for machines of even higher energies than those in Berkeley – and he informed Rutherford about his intentions quite assertively. After all, as he put it across, "It is a thing we need urgently, and not in some distant future when all the cream has been scooped off by folks whose results we dare not trust too deeply".[254] James Chadwick left the Cavendish (1935) for a professorship at Liverpool and thought the cyclotron would strengthen his position in the department apart from being "a beautiful piece of apparatus". Oliphant too left the Cavendish (1936) for a professorship in Birmingham. Doubts on the technical and financial aspects of building such a mammoth finally plagued Rutherford and Cockcroft. With Chadwick and Oliphant gone, the pursuit of particle accelerators at the Cavendish proceeded with Cockcroft's pronouncement after his visit to Berkeley in 1937: "Although the Cavendish Laboratory pioneered with high voltage methods the distinguished scientists they have come to the conclusion that the cyclotron is superior and are adopting it".[255] Cambridge did not have to additionally sponsor a candidate to Berkeley. Relying upon imperial preference, they benefited from the Berkeley experiences of Donald Hurst, an 1851 Exhibition fellow.

[254] Oliphant to Rutherford, August 25 1935, Ernest Rutherford Papers, Archive for the History of Quantum Physics.

[255] John Heilbron and Robert Seidel talk of another source of funding before the decisive grant from the automobile manufacturer Lord Austin came in May 1936. Peter Kapitsa, the Soviet physicist was prevented return to the Cavendish by the Soviet Union in 1934. The Soviet government offered to purchase all of his apparatus from the Mond Laboratory to recreate his working conditions and even as efforts to secure his return were attempted, Cambridge finally agreed to parting with the laboratory equipment. The sale brought in 30 000 GBP to the laboratory and increased budget for purchasing large magnets. See Heilbron and Seidel, (1989), 327; citing Cockcroft from reports by Rockefeller Foundation officials from May 1937, and Stewart Cockburn and David Ellyard, *Oliphant: the life and times of Sir Mark Oliphant* (Adelaide: Axiom Books, 1981), 63. See also See Lawrence Badash, *Kapitsa, Rutherford and the Kremlin* (New Haven: Yale University Press, 1985).

With his help, "Cambridge got a faint evidence of a beam in August 1938", almost a year after Rutherford died.[256]

3.4 Krishnan and Wartime Transformation of the Cavendish

Figure 3.2: R. S. Krishnan (second from right) with unidentified colleagues in Cambridge. Reproduced with permission from R. K. Ramanathan, son of R. S. Krishnan.

The Rutherford era of the Cavendish Laboratory was over with his death in October 1937, and in many ways the era of nuclear physics at the laboratory as well. Krishnan's years at the Cavendish were marked by two pressing concerns: the first was the search for a suitable successor to lead the laboratory; not least important in the search process was a concern with continuing to focus upon nuclear physics research. Some were convinced that the Cavendish was no longer the right place for experimental nuclear physics,

[256] Heilbron and Seidel, (1989), 342.

especially using particle accelerators, the very purpose for which Krishnan had come to the laboratory. This pressure came from the rapid development of particle accelerators of higher and higher energies being built in the United States. Only five years after the Cockcroft-Walton particle accelerator, the laboratory was already questioning its place in the field. The second pressure came with the outbreak of WWII in September 1939 when the laboratory's workers were dispersed (first) into British and (soon after) other Anglo-American laboratories tethered to Allied scientific war effort.

In the records of the last pre-war annual dinner on 19 December 1938, the change was well pronounced. Present were the new leader of the Cavendish, William Lawrence Bragg, J. J. Thomson, the American physicist Irving Langmuir, and the patron of the new Austin Wing, Lord Austin. Austin felt his duty to remind the physicists that they may find it necessary to pay attention to the social and economic aspects of their work. Langmuir lamented the present concentration on nuclear physics, especially in America, and hoped that Bragg would direct some attention to such topics as solid-state physics and the structure of living matter. [John] Findlay and [Hugh] Barkla produced a commentary on the lighter side of laboratory life in the form of a Western Brothers dialogue and finally, "the Mayor of Free School Lane (Dr. Carmichael) presented a portrait (painted in a grand manner by Dr. Bhabha) of Professor Bragg to Lord Austin, and a new all metal Austin Wing to Dr. Bragg. The company finally dispersed in the region of midnight…. Dr. Bhabha painted with much power; although the portrait presented at the dinner was a rapid cartoon only".[257]

Krishnan perhaps attended this dinner. If he did, he may have met Homi Jehangir Bhabha for the first time. Bhabha was awarded the senior 1851 studentship in theoretical physics, the first Indian student to be awarded one in "open competition".[258] Within less than a year, Bhabha returned to India and joined the Indian Institute of Science, Bangalore, in fact Krishnan's alma mater. Many of those present at the dinner got actively involved in scientific war effort. The demographics of the laboratory changed drastically and this affected what Krishnan could accomplish during his stay at the Cavendish.

Krishnan was awarded a doctoral degree in May 1941 for work on *Investigations in Artificial Radioactivity*. "It should be emphasized", Krishnan wrote, "that investigations with the cyclotron cannot be carried out by one man alone." His collaborators on the day-to-day working of the cyclotron were Dennis Hugh Thomas Gant and Effraim Alfred Nahum, and Dr. T. E. Banks.[259] He also acknowledged Cockcroft, [Dr.] Lewis, Donald Hurst, Robert Latham, and [Dr.] Solomon for help with continuing construction of the

---

[257] This account of the dinner is paraphrased from Ronald G. Stansfield, "The Cavendish Society and its post-prandial proceedings," (Manuscript at the Cambridge University Library, Cavendish Laboratory papers, 1982); also printed in the *British Society for the History of Science Newsletter* 19/8/1982.

[258] Homi Bhabha was awarded a PhD by the Cambridge University in 1935. Bhabha worked on theoretical physics of cosmic rays. Bhabha had won the senior fellowship, as Rutherford wanted to state to his audience in India, in "open competition" at Cambridge. Ernest Rutherford (1937/1938) Researches in India and in Great Britain, Presidential Address to the Indian Science Congress, Reprinted in *The Shaping of Indian Science: Indian Science Congress Association Presidential Addresses* Volume I Hyderabad: Universities Press.

[259] R. S. Krishnan, *Investigations in Artificial Radioactivity* (PhD Dissertation 1183, Cambridge University Library, 1941), vii. Gant and Nahum were awarded their BA in 1938 and 1939 respectively from the Cambridge University. Gant was awarded his degree posthumously as he was killed in an air raid: *Cambridge University Gratuiti*, Manuscripts section, Cambridge University Library and Archives. I have been unable to trace details on Dr. T E Banks.

cyclotron. Krishnan also thanked Norman Feather for “suggestions” and for making “a radium E source” for experimental work.

The first part of Krishnan’s dissertation was a detailed description of operation and output of the cyclotron, aspects of completing the construction and difficulties of keeping the cyclotron in running condition. He also wrote about working Geiger counters. Krishnan had spent his two years at the Cavendish coordinating experiments and continuing construction on the cyclotron. He claimed discovery of nine isotopes and published twelve papers, all dealing with deuteron bombardment of heavy elements including uranium and thorium, during his stay at the Cavendish. The thirteenth was published after the war. Of these, he published three on his own, one with Norman Feather, two with Gant, three with Banks and four with Nahum. They published four of these in *Nature*, six in the *Proceedings of the Cambridge Philosophical Society*, and three in the *Proceedings of the Royal Society*.[260]

[260] See in chronological order: R. S. Krishnan and D. H. T. Gant, “Deuteron bombardment of Silver,” *Nature*, 144, (1939): 547; R. S. Krishnan and T. E. Banks, “A new type of disintegration produced by Deuterons,” *Nature*, 145, (1940): 777; R. S. Krishnan and T. E. Banks, “Fission of Uranium and Thorium under Deuteron bombardment,” *Nature*, 145, (1940): 860; R. S. Krishnan and E. A. Nahum, “Deuteron bombardment of the heavy elements, Part I - Mercury, Thallium and Lead,” *Proceedings of the Cambridge Philosophical Society*, 36, (1940): 490; R. S. Krishnan, “Deuteron bombardment of Silver,” *Proceedings of the Cambridge Philosophical Society*, 36, (1940): 500; R. S. Krishnan, “Deuteron bombardment of Gold,” *Proceedings of the Cambridge Philosophical Society*, 37, (1941): 186; R. S. Krishnan and T. E. Banks, “A new type of disintegration produced by Deuterons,” *Proceedings of the Cambridge Philosophical Society*, 37, (1941): 317; R. S. Krishnan and E. A. Nahum, “Deuteron bombardment of the heavy elements, Part II – Platinum,” *Proceedings of the Cambridge Philosophical Society*, 37, (1941): 422; R. S. Krishnan, “Deuteron -Tritium reaction in Fluorine,” *Nature* 148, (1941): 407; R. S. Krishnan and D. H. T. Gant, “Deuteron induced fission in Uranium and Thorium,” *Proceedings of the Royal Society*, 178, (1941): 474; R. S. Krishnan and E. A. Nahum, “Cross-section measurements for disintegrations produced by deuterons in the heavy elements,” *Proceedings of the Royal Society*, 180, (1942): 321; R. S. Krishnan and E. A. Nahum, “Excitation function measurements for disintegrations produced by deuterons in the heavy elements,” *Proceedings of the Royal Society*, 180, (1942): 333; Norman Feather and R. S. Krishnan, “The radiations emitted by U239/92, and its formation in the deuteron bombardment of Uranium,” *Proceedings of the Cambridge Philosophical Society*, 43, (1947): 267 (received April 14 1941, publication voluntarily withheld during the war).

Krishnan's examiners were the Swiss-German physicist Egon Bretscher and John D. Cockcroft. In his report on Krishnan's thesis,[261] Bretscher felt nothing new was added to the methods in use in nuclear physics, but the description was "clear and well written". It would have been useful to look into the theory of the cyclotron to "increase its efficiency" but he did not think Krishnan had accomplished that. Bretscher was convinced Krishnan had mastered the technique "of making and using [Geiger counters] and avoided the pitfalls which they present to the unaware" (sic). Krishnan had claimed discovery of nine isotopes, and Bretscher found that as far as "new radioactive species are concerned", after checking Krishnan's observations with results in recent publications he found as a rule "agreement of fact if not interpretation". Approving Krishnan for the doctoral degree, Bretscher summarised his judgement as follows; "It is evident that Mr. Krishnan has made full and reasonable use of the facilities at his disposal. He had the advantage that practically all the tools for such work were at his disposal and that nobody else was requiring the service of the cyclotron as all other members of the team are engaged in war work. His attitude towards research is one of collecting as much and as quickly as possible a large amount of empirical facts without much regard for deeper mechanism of the processes involved. His method has led him to some valuable results which justify his way of procedure. I am of the opinion that his work does not reveal much original thought, but this may be due to the fact that he was a novice when he came to the laboratory."

[261] Egon Bretscher, *R. S. Krishnan, PhD Examination Report*, February 20 1941, UA BOGS I, R. S. Krishnan 1940-1, Manuscripts Section, Cambridge University Library.

Cockcroft was more effusive in his judgement of Krishnan's work. "On the outbreak of war, Mr. Krishnan was left with the junior laboratory assistant to run the cyclotron. His success in keeping the complex apparatus operating satisfactorily since that time is in itself a substantial achievement." Cockcroft was impressed with Krishnan's "experimental ability in keeping the cyclotron running almost single-handed for a long period" for comprehensive study of radioactivity produced by deuteron bombardment of the heavy elements and discovery of nine new radioactive isotopes. "Throughout this period Mr. Krishnan has received very little direction owing to the absence of so many senior workers in Nuclear Physics. He has selected his own problems and done so with good judgment." Both Bretscher and Cockcroft were convinced that Krishnan's work on interpretation of his experiments would have benefited from some more experimental work, but neither had doubts about his skills in running a cyclotron and working Geiger counters, or about his judgement to pick experiments and perform them.[262] Even if Krishnan was not involved in any direct manner to the nascent British scientific war effort, he did contribute to research considered important for wartime problems in nuclear physics. One of his papers, co-written with Norman Feather in April 1941, detailing experiments bombarding uranium nuclei with deuterons, was not published until after the end of the war. Cockcroft would reiterate an appreciation of Krishnan's experimental technique in letters recommending him to the IISc. Eventually, this was not sufficient to secure him funding for the establishment of a nuclear physics research facility in Bangalore.

[262] John D. Cockcroft, *Report on the dissertation of Mr. RS Krishnan*, February 18 1941, UA BOGS I, R. S. Krishnan 1940-1, Manuscripts Section, Cambridge University Library.

3.5 Raman and the Establishment of Nuclear Physics in Bangalore

Cockcroft's advocacy of the Cavendish cyclotron was vindicated in 1939, when the Nobel Prize in physics went to Ernest O. Lawrence for the successful implementation of the cyclotron principle. In India, Raman gave a lecture at the Senate House of the Madras University "paying tribute to Prof. Lawrence" for the "discovery of the cyclotron", but not in the least reassuring his audience that one of his own students was working with "what is called the Cavendish Cyclotron".[263] Raman explained the cyclotron principle and the difficulties of building and running one to an assembly of scientists and intellectuals. The cyclotron was not made in a day, he said. "The building of the cyclotron involved many difficulties and called for vast resources but Prof. Lawrence succeeded in building them…. The work of Prof. Lawrence has so tremendously impressed the Scientific world that cyclotrons were "increasing like mushrooms" in America. *Almost every civilised country, barring India, had one*." Raman's statement reveals his complete belief in scientific activity as a sign of civilisation. He had sound reasons for his continuing belief - his conviction had been acknowledged when he was awarded the Nobel Prize in 1930, and admitted into the courts of the Empire.

When Raman deputed Krishnan to the Cavendish, nuclear physics done with particle accelerators had become an important field of inquiry; and with the Nobel Prize, Raman now thought it fair to place the crown of civilisation alongside Oppenheimer's theoretical hat on the cyclotron. His announcement that "The very first actual investigation made

[263] News Clipping, "Key to the Universe: The Discovery of Cyclotron, Sir C. V. Raman's Tribute to Prof. Lawrence," most likely from the daily *The Hindu*, (January 7, 1940), RSK Papers.

with what was known as the "Cavendish Cyclotron" was made by Mr. R. S. Krishnan, who took his D.Sc. degree from Madras University" was received with cheers. The announcement marked Raman's pride in his personal association with the cyclotron and therefore in some way his own continuing connection with the frontiers of science. The association would contribute to his credibility in the eyes of scientific and intellectual community around him, a capital that would still fall short when time came to mobilise funds for nuclear research in Bangalore.

3.6 Homi J. Bhabha and Cosmic Ray Work in Bangalore

Hormasji Jehangir Bhabha was educated at the Elphinstone College and Royal Institute of Science, Bombay, before he proceeded to take a mechanical sciences tripos at Cambridge [264]. He came from a remarkably elite family, being related from his maternal side to the Tata family of Tata Industrial House, owning among others, the largest steel plants in India. The Tata's were also engaged in philanthropic work and actively promoted higher education and research in colonial India. The Indian Institute of Science was one of their creations. Bhabha's uncle, Dorab Tata was a patron of the Gonville and Caius College, Cambridge, where he was admitted as a student. Having taken the mechanical sciences tripos in 1930, he then chose to pursue studies in mathematics and theoretical physics. When he registered as a research student in mathematics, he also

[264] A tripos is a final honors examination for the B.A. degree at the Cambridge University in England

decided to change his first name. He would prefer to be called Homi Jehangir Bhabha, the name he would keep for the rest of his life.[265]

Cavendish, as we have seen, made Cambridge the centre for experimental nuclear physics. But in Paul Adrien Maurice Dirac and Ralph Fowler, Cambridge certainly had important theoretical physicists on board.[266] Dirac's work had significant influence upon Bhabha but he also visited important centres for theoretical physics in continental Europe. He spent time at Niels Bohr's Institute for Theoretical Physics in Copenhagen, with Wolfgang Pauli in Zurich and Enrico Fermi in Italy. He was awarded a doctoral degree in mathematics for his thesis *On cosmic radiation and the creation and annihilation of positrons and electrons*. Beginning 1935, he held the senior 1851 studentship and continued to work in Cambridge. [267]

[265] University authorities did not accept his decision in 1930; "His first name is to be regarded as Hormasji despite his having written "Homi" on his P.R. form at graduation BA 1930"; but they did in 1959 when he was awarded the Doctor of Science Honoris Causa; "We learned just before the congregation at which he was presented for an Hon. Sc. D that he preferred to be known and was commonly referred to by the first name Homi. See also Who's Who 1959." *Cambridge University Gratuiti*, Manuscripts Section, Cambridge University Library, Cambridge. Bhabha was not the only Indian to simplify and shorten his name; Chandrasekhara Venkataraman rescripted his name to Chandrasekhara Venkata Raman thus making it easier to simply write C. V. Raman. Incidentally, Raman won the Nobel Prize the same year that young Homi Bhabha wanted to first change his name.

[266] Among others, see Andrew Warwick, *Masters of Theory: Cambridge and the Rise of Mathematical Physics* (Chicago: University of Chicago Press, 2003).

[267] Bhabha's work in cosmic ray physics has been partly dealt with by David Cassidy, *Uncertainty: the Life and Science of Werner Heisenberg* (New York Freeman, 1991) and David Cassidy, "Cosmic Ray Showers, High Energy Physics, and Quantum Field Theories: Programmatic Interactions in the 1930s," *Historical Studies in the Physical Sciences* 12, no.1 (1981): 1-40. For Bhabha's work in Cambridge (1935-38) see: Bhabha H.J. and Heitler. W, "Passage of Fast Electrons Through Matter," *Nature* 138, (1936): 401. Bhabha H.J. and Heitler. W, "The Passage of Fast Electrons and the Theory of Cosmic Showers," *Proceedings of the Royal Society* A/ 159, (1937): 432-458.

Bhabha went on a vacation to India in late 1939, and the outbreak of war prevented his immediate return to England. He initially stayed on with family in Bangalore, where his father worked in the public instruction office of the Maharaja of Mysore, and was a member on the council of the IISc. In November 1939, he was appointed special reader at Raman's department of physics and by January 1940, he began teaching.[268] Five months later, the Dorab Tata Trusts gave a grant to support Bhabha's experimental cosmic ray physics research.[269] A theoretician enticed by experimental work demands explanation. Robert Millikan, Victor Neher and William Henry Pickering from Caltech, were in and around Bangalore, from around December 1939 to March 1940, carrying out cosmic ray experiments using the balloon technique.[270] As a theoretician, Bhabha understood well that wholly new phenomena could be discovered by Millikan's methods. In addition, the significance of India's geographical location close to the geomagnetic equator, a factor that made physicists like Millikan travel from the USA to India only for experiment purposes, was a wonderful opportunity for Bhabha and other physicists in India, first, to familiarise themselves with the balloon technique and conduct experiments of their own.

---

[268] In the British and therefore the Indian university system, if not a temporary instructor, one began teaching career as a lecturer, and then progressed to being a reader and finally a professor. The positions involve a gradual decrease in teaching load, and in the science faculty allowed for more time in research. Also, as a reader and professor, one can employ graduate assistants and have PhD students, which are rarely allowed for a lecturer.

[269] The grant amount was Rupees 5 000.

[270] Robert Millikan and the physics group at the Norman Bridge Laboratory of Physics, California Institute of Technology were credited for pioneering work on measuring cosmic ray intensity with specially built instrument carrying balloons. See Robert H. Kargon, *The Rise of Robert Millikan* (Ithaca: Cornell University Press, 1982) and Goodstein. Judith R., *Millikan's School* (New York: W. W. Norton, 1991).

Millikan's presence must have inspired Bhabha to consider experimental work to further his theoretical interests in pursuing the meson particle. [271]

Within a year, Bhabha had risen high in favour of the Institute but also in Raman's estimation. Raman nominated Bhabha for the Fellowship of the Royal Society on July 20 1940, and upon his election, the [British] Government of India conferred upon him the status of professor as "a personal distinction". In March 1941, Bhabha held charge of the department when Raman travelled for five months to the United States. The Dorab Tata Trusts increased his grant award for further research.[272] On January 20 1942, Bhabha officially accepted the professorship and leadership of the cosmic ray laboratory at the IISc. He was allowed to employ an experimental physicist and 4 post-graduate students. In a remarkably short period of time, Bhabha had derived tremendous benefit for his scientific talent from his family connection and his location in India. Bhabha had been awarded distinctions prior to his arrival in India, but an FRS would not have necessarily brought a professorship and his own research group if he had continued to work in England. These were not insignificant accomplishments. Bhabha had begun to settle well

[271] *Meson*: an extremely unstable and heavy electron within cosmic rays. It is also found in particles with the same electric charge as an electron.

[272] In November that year, the Institute committed rupees 40 000 and the Dorab Tata Trusts committed rupees 60 000 over a period of five years for the maintenance of a cosmic ray laboratory at the Institute. Bhabha's Cosmic Ray Research Unit, funded by both the IISc and the Dorab Tata Trusts, thus carried out researches in wartime Bangalore. In March 1945, council minutes of the IISc placed on record "its appreciation of the valuable and generous co-operation given by the successive commanding officers of the 84th Air Depot of the US Air Force in Bangalore and in particular by Col. M. C. Robinson and his staff to Prof. H. J. Bhabha, FRS of the Cosmic Ray Research Unit of the Institute in carrying out important high altitude cosmic ray experiments". Neither the minutes nor the report of the Unit describe in any detail the number of flights or experiments carried out, or for that matter when the cooperation began but leave it at "cooperation given by successive commanding officers". Bhabha's researches and stay in Bangalore ended by June 1945 when he moved to Bombay, to establish his own laboratory for fundamental research in nuclear physics. See *Minutes of an extraordinary meeting of the council of the Indian Institute of Science, Bangalore, Friday March 2 1945*, Archives of the Indian Institute of Science, Bangalore, p. 6.

in Bangalore but his father died in July 1942, and his mother's desire to move back to Bombay closer to her family, which included the Tata household, may have contributed to a certain extent to his plans for the next years.[273]

Bhabha's stay in Bangalore involved intellectual support from Raman as well as benefits arising from working in an institution patronised by family. It was in this interim period during the war, faced with opportunities and constraints both, Bhabha wrote a proposal to the Tata family, this time for funding and support to establish a research institute dedicated to fundamental research in the physical sciences - more specifically mentioning the need for research in nuclear physics towards the cause of nuclear energy such that when the option becomes feasible, "India would not have to look elsewhere for experts but will find them at home". If anything, the proposal signalled that Bhabha was willing to stay back in India, in a period apparently closer to the threshold of independence. Krishnan was on his way back home. His was not to be such an elegant journey towards realising his ambitions to establish nuclear physics in Bangalore.

3.7 "A Scheme for Power Production from Uranium Fission"

Krishnan sailed for India in the middle of the war and from his urgent messages to the Board of Research Studies, he was quite eager to get home. Back in India, Krishnan made

[273] Jamshed Bhabha, *The JRD Tata I knew* (no date) accessible on http://tatamail.com (October 9, 2006) under History/ Lasting Legacies. Jamshed Bhabha, younger of the two brothers seems to suggest this possibility. Given Jamshed Bhabha's inability to move from his work place with Tata Steel in Jamshedpur, Bihar and the mother's dissatisfaction with "English administration" in the region, may have affected Bhabha to imagine moving to Bombay.

at least two applications for university positions, Allahabad and Bangalore. He asked for letters of support from Bragg for the Allahabad position, and from Cockcroft for the Bangalore position. Bragg vouched for that Krishnan was “a first rate experimenter and an assiduous worker”. “He was effectively in charge of the cyclotron at this Laboratory after the war started, and executed this responsible task well…. I can think to say without hesitation that he is one of the best Indian students that has been through the Cavendish for many years. He is young for such a responsible post as a Professorship (Krishnan was 31 years of age), but if I may so put it, I think it is a fairly safe gamble that he will develop into a good head of a department”. Cockcroft wrote, “…during two years [of the three that Krishnan was at the Cavendish] he was in complete charge of the running of, and work carried out on, the Cambridge cyclotron. The fact that he could do so this when most of the more senior staff were withdrawn at the outbreak of the war, is a strong recommendation for Dr. Krishnan’s abilities as an experimental physicist… and in my opinion, [Krishnan] is the best experimental physicist from India who has worked in the Cavendish Laboratory during my residence here, that is over a period of fifteen years”.[274]

In March 1942, Krishnan began his first efforts for the establishment of a nuclear physics laboratory. He submitted a proposal entitled “A scheme for power production from uranium fission”. [275] On his copy of the proposal, Krishnan noted, “Submitted in March

[274] Typewritten copies of letters (unsigned) from Sir William Lawrence Bragg, Cavendish Laboratory, Cambridge (dated February 5, 1942) and Prof. J. D. Cockcroft, Jacksonian Professor of Natural Philosophy, Cavendish Laboratory, Cambridge (dated February 6, 1942); RSK Papers. I have been unable to ascertain if the position in Allahabad was eventually offered to Krishnan, but it was offered at some point during the war years to Homi J. Bhabha, who was with the department of physics in Bangalore when Krishnan came back from Cambridge.

[275] Copy of proposal, “*A Scheme for power production from uranium fission, submitted by R. S. Krishnan to the Council of the Indian Institute of Science*” March 1942; RSK Papers.

1942 and withdrawn after consultation with Sir C. V. Raman and the Director". The proposal is not noted in the Council minutes, so it is highly probable that it was withdrawn even before being tabled to the council for discussion. From available sources, it is not clear if he discussed the proposal with the newly appointed professor, Homi Bhabha. "The most important discovery made in nuclear physics in 1939 is the fission of uranium nucleus when it is bombarded with neutrons obtained from either a natural or artificial source. …A great deal of interest is attached to this discovery as it provides a method for the utilisation of the vast store of energy in uranium nucleus. It may be mentioned here that a considerable amount of work is being carried out in England and America with a view to harness the energy thus released from uranium fission for practical needs." The IISc was an institute dedicated to industrial and applied research, and as such, Krishnan proposed his scheme within the framework of possible applications of nuclear research. He was ready to follow upon his research at the Cavendish. Krishnan was back in India in late 1941, so he was not in England in the heydays of accelerated nuclear research, or at least the talk of it. But his paper with Norman Feather on deuteron bombardment of uranium was not to be published until after the war, that could not have failed to impress on him the significance of the particular research problem. Nor was there any way to miss the withdrawal of scientists from the laboratory leaving him to manage the cyclotron.

In order to "undertake a scheme for the power production from uranium fission", Krishnan would require an intense neutron source, and the only one which he knew was completely satisfactory for this purpose he said, was "a modern cyclotron". Krishnan sought to reassure his benefactors by telling them that during his three years in Cambridge, he had in fact made detailed drawings for the construction of a similar one in the Institute in Bangalore. Aware that the cost of a cyclotron would be intimidating nonetheless, he immediately proffered, “For the present, however, a good start can be made with a radium-beryllium source…”. Drawing up a budget one fifth that of a cyclotron for the radium beryllium source, Krishnan concluded, “Besides the problem of power production, many other important lines of investigations in pure and applied nuclear physics could also be started. The provision for a cyclotron laboratory in the Institute at a later stage would, however, be necessary to complete the equipment”. The Tatas could have found interest in the “power production” potential of nuclear research, and Krishnan had Raman’s support for research at the frontiers of physics. At this stage, Krishnan was ready to begin with the establishment of nuclear physics, and willing to wait a short while for the cyclotron as his preferred machine but this was to change in the next couple of years.

Along with Raman, and Krishnan, Bhabha must have understood the significance of the proposal. The director of the IISc, J. C. Ghosh, a chemist, could have hardly missed the discovery of fission and the award of the Nobel Prize for Lawrence two years ago. In the absence of documentation, one can only speculate as to why this proposal may have been withdrawn after discussions with the director and Raman. Three broad arguments can be made. The Tata’s had only just funded a separate cosmic ray unit for Bhabha in the department of physics, yet another separate unit for the same department could well have potentially upset other departments. It is quite likely that budget constraints, and priority for war related research would have seriously weakened chances of competing for funding with departments presumably doing "useful wartime applied research".[276] Such an accusation was made exactly in February 1942. The British resident at the Mysore Court wrote to the Educational Commissioner with the Government of India. "There seems to be no improvement in the atmosphere of the Indian Institute of Science…" he said, citing various complaints from professors including that the director was simply not allowing enough work and appeared "jealous" of the electrical technology department. At least two professors wanted to resign. Notably, he also cited that the "feeling among the staff generally was no one but Bengalees need apply for vacancies" and others were not appointed.[277] Ghosh was the second Indian director of the IISc, (Raman had been the first) but his appointment was contested. The Dewan (Prime Minister) of Mysore was concerned that the professors and students, "except the eight from Bengal are dead against [Ghosh's appointment]".[278] An Englishman was more acceptable to the students and professors at the IISc as against a "Bengalee". The question was as much of regionalism in British India, as much as it was difficult for the British staff of the Institute to imagine working under an Indian director, something that had showed up also during Raman's directorship.[279]

---

[276] For an overview on wartime research at the IISc, see Subbarayappa (1992).

[277] D. Fraser to John Sargent, 18 February 1942. NAI Folder, IISc Archives. Ghosh was a professor of chemistry at the University of Dacca, when Meghnad Saha asked him if he would like to be considered for the directorship of the IISc in January 1939.

[278] Mirza Ismail, the Dewan of Mysore was convinced that Syamaprasad Mukherjee, a member of the IISc council and a prominent nationalist had made efforts for Ghosh's appointment in order to make the institute a "Bengalee show". His disappointment went to the extent that he wanted to abolish the position of director and have the office of the Dewan of Mysore preside over the institute with the help of the registrar. Mirza Ismail to Sir Girija Shankar Bajpai, 24th April 1939, NAI Folder, IISc Archives.

[279] Raman had been accused of ignoring Bengali students when he was a professor in Calcutta as well. See Singh (2004), 17-19.

There were additional burdens of history that came with having Raman as a mentor. It was close to four years since Raman had been made to resign as the director of the Institute amidst controversy.[280] Given then, both Raman's and Ghosh's disfavour with the Institute staff and at least part of the Council, it must have looked considerably difficult at the moment to secure a substantially large budget for another separate unit within the department of physics. Coming in from any of these perspectives, none of those involved in the decision-making seem to converge with Raman and Krishnan's interests at this stage. To Ghosh's credit, despite regionalism being dragged in to explain and accuse appointments, ambitions and politics, he did not step back when the opportunity to support Krishnan's project came up again three years later.

Krishnan considered leaving the Institute, and requested a letter of support from Bhabha for a position in physics in the Central Provinces and Berar Education Service, a position in public instruction and not a university position with research facilities. [281] Bhabha agreed support Krishnan, who was incidentally only three years his junior in age. On

---

[280] The story leading up to Raman's resignation from the directorship of the Indian Institute of Science is well covered in Rajinder Singh, (2004), 96-113; Sur, (1999): 25-49, Venkataraman, (1994), 261-283; and Subbarayappa, (1992), 112-151. Amidst budget cuts from the Government of Mysore, the Tata's and the [British] Government of India during the early years of the great depression, Raman's department of physics was established with capital funding equaling almost the entire years contribution from the three sources! Raman also consolidated research in physics and chemistry in the new department and suggested staff cuts for the electrical technology department. He then suggested that staff from the electrical technology department build apparatus for the physics laboratory, the professor – a close associate of the Tatas, resigned in protest. Raman then began encouraging applications from émigré scientists in Europe: the Indian members at the IISc were unhappy because they were engaged in actively "indianising' the IISc and the British staff were not happy about having Germans, often prominent scientists working with or over them. Max Born, George de Hevesy, and Rudolf Peierls were made offers; only Max Born came and this angered Syamaprasad Mukherjee (member on the IISc council) who was campaigning for a Bengali applicant. Raman did not share the same kind of nationalist commitment as Mukherjee or Saha and this only contributed to the increasing conflict between Raman and the scientific community in Bengal.

[281] Bhabha to Krishnan, July 27 1942; RSK papers.

August 1 1942, Krishnan accepted a lectureship with the department of physics at the IISc, stayed on at the Institute, and continued teaching. There is no further mention of the fission scheme until June 1945.

In the intervening years, the configuration of the department of physics at the IISc changed, and so did the framework of science organisation in British India. A. V. Hill visited India a year after Krishnan began teaching at the IISc, and Raman's displeasures with the scientific community in India and with the Royal Society in England only increased. They also became public knowledge.[282] Bhabha's dissenting stance proved consequential for the establishment of nuclear physics in Bangalore. Bhabha had attended the Indian Science Congress of 1944 against Raman's wishes, but he had also discussed the establishment of an institute for nuclear research with Hill. Bhabha's own institute, the Tata Institute of Fundamental Research was established even as he was in Bangalore and then moved to Bombay in June 1945.

3.8 June 1945: Proposal for the Expansion of the Physics Department

On June 1 1945, a letter from the Registrar of the Institute was forwarded to Krishnan through Raman. A joint committee of the Court and the Council of the Institute had requested the views of various heads of departments and their respective staff members on the "introduction of higher technical training"; "That the time has now come to prepare a carefully considered scheme for the expansion of the existing departments in

[282] See Chapter 2 of this thesis.

order to bring them into line with similar departments *in the foremost institutions of USA….*" The period of energetic tidying up in India had begun. It seemed like the war was ending, in Europe at least the war was over, and independence from British rule was immanent. Organising a nation-state required that all institutions, especially those connected to government funding, take stock and plan for what was to resemble a fundamental reconstruction of everyday life and science towards a venerable goal - an independent India. In the Indian Institute of Science, this goal was imagined in working towards departments that resembled "those in the foremost institutions of the USA". There appears no attempt to refer to British or European institutions. It would be trite to attribute this decision as attempts to distance from the departing coloniser. To begin with, the plans of the Institute were drawn with the idea of replicating The Johns Hopkins University, and therefore the new directive could be seen in continuation of the first plans. Not of any lesser importance the shift internationally, of centres of science and engineering education to the USA, which had begun even before the war.

Krishnan responded with a proposal. He had received his own copy of the memorandum for the expansion of the department, though they were otherwise addressed to the heads of departments. Moreover, Krishnan wrote his response addressed to the Registrar, even if through Raman. He was emerging as the successor to Raman, who was to retire in 1948, and as such, seems to have been allowed by Raman and accepted by the Institute as the one who would reorganise the department. If only to remain within the conversation generated by the Institute's administration, Krishnan reiterated that his proposal was to "bring [the department of physics] into line with similar departments in the foremost institutions of the USA".[283] After a brief overview on the existing conditions of the department and its laboratories, Krishnan asked for the provision of a suitable building, a good workshop, adequate research staff and sufficient funds - regular things departments are made of. What is more interesting is how he proposed he would organise these regular things. In the proposed reorganisation, Krishnan stated, "The one important branch of physics which has been actively pursued in every physical laboratory in the world except in India is nuclear physics…. It is only proper that a premier institution like the Indian Institute of Science should have a nuclear physics laboratory similar to the one at Berkeley in California, USA. Any expansion of the activities of the physics department should, therefore, be directed towards the creation of a nuclear physics laboratory".[284]

Krishnan again reminded his benefactors of the experience he gained at the Cavendish where he took part in the construction and running of the cyclotron, and that he was sent there for the explicit purpose of starting nuclear physics at the Institute. He recounted the sketches he made for "the construction of a fairly big-size cyclotron at Bangalore". A fully equipped radiation laboratory should necessarily possess a cyclotron, an electrostatic generator and an isotope separator - along with materials to work with and detection devices, proposed Krishnan. [285] Krishnan had come away from the hesitations he had in 1942, when he first proposed to make do with a radium-beryllium neutron source to begin with. Having drawn the necessary picture of a comprehensive research

[283] Registrar, IISc to The Head of the Department of Physics, June 1 1945; RSK Papers.

[284] Krishnan to Registrar, Indian Institute of Science, Bangalore, June 20 1945; RSK Papers.

[285] The list of materials included naturally radioactive substances, artificially radioactive substances, stable isotopes, and neutron beams; and the detection devices include counters (presumably Geiger), electroscopes, electrometers, photographic films, mass spectrometers and standards.

facility for nuclear physics, he again proposed that a good start could indeed be made with a "fairly big size cyclotron", an intense natural radium source and detecting instruments, if supported by its own precision workshop and an efficient new liquid air plant.[286] Reasserting the usefulness of such laboratory equipment, Krishnan argued for the radiation laboratory not only for training physicists and for fundamental research in nuclear physics, but also to undertake problems in applied nuclear physics, "chemistry, metallurgy, radiology, geology, physiology and medicine". With this plugged the idea of his laboratory into the institute's agenda of scientific industrialism and into the larger agenda of contributing to Indian independence, even if not very explicitly.

3.9 August 1945: Krishnan and the Atomic Bomb

Krishnan submitted his proposal only 15 days before the first atomic bomb was dropped on Hiroshima. Whatever deliberation may have taken place on the expansion of the department towards nuclear physics research within the fortnight became extraneous once the world knew of Hiroshima and Nagasaki. The war was over, and irrespective of who carried out nuclear research and where, the spectre of the atomic bomb would linger on the horizon demanding an allusion de rigueur.

[286] Krishnan proposed a capital expenditure Rupees 10, 00,000 and a recurrent expenditure of Rupees 1, 00,000 per annum, and warned that the figures "may appear astronomical" but assured his benefactors that they were much smaller compared with those in similar departments in the "foremost institutions of the USA".

Krishnan's first response was to write an article on 'Atomic Energy' where he traced a linear history of the concept from Becquerel to the war-effort. [287] A sense of excitement rushes through the text,

> "It is estimated that one cubic metre of uranium oxide is capable of developing 10 (raised to 12) kilowatt- hours of power in less than 0. 01 sec. The sudden release of such a tremendous energy gives rise to a blinding flash many times brighter than the midday sun, which is followed by a tremendous and sustained roar and a heavy pressure wave. This causes destruction to men and material on a scale hitherto unknown. Because of this fact, the discovery of the atomic bomb has made warfare *terrific beyond imagination*".[288]

Catching his breath in the last paragraph, Krishnan wondered, "If the tremendous energy released from the atomic explosions is made available to drive machinery, it will bring about an industrial revolution of a far reaching character. … But there are obvious difficulties connected with the control of the evolution of atomic energy…it is necessary to emphasise that the prospects of producing cheap atomic power are *none too bright*…." As he dreamt the dream of many who anticipated the purposeful use of atomic energy in August 1945, the sense of caution was not abandoned collectively. But at the same time, Krishnan, like others in his position, was given the rationalization for his new laboratory in this event. He spent the next year working upon this opportunity.

---

[287] Krishnan R. S, "Atomic Energy," *Current Science* 14, (August 1945): 185-187.

[288] Emphasis added.

3.10 1946: Call to Propose a High Voltage Generator

Krishnan began communicating with particle accelerator laboratories and suppliers of related equipment with a newfound vigour. He first wrote to Paul Scherrer at the *Physikalisches Institut der Eidgenössische Technischen Hochschule* [ETH], Zurich.[289] Scherrer's laboratory may have already inspired Krishnan's proposal of June 1945, because in Zurich they possessed the three particle accelerators Krishnan mentioned were necessary for a well-equipped radiation laboratory - a high voltage generator, an off-the-shelf cyclotron, and a Van de Graaff generator.[290] In the scribbles on the margins of Scherrer's response, Krishnan calculated the rupee cost estimates only for the high voltage generator from Swiss Francs. Furthermore, Scherrer had clarified that a pulse generator could also be used for generating hard x-rays, and for nuclear photo effect, obviously in reference to a question that may have been asked of him. [291] This is probably the first reference one can find to Krishnan's eventual change in preference, willingly or may be not, from the cyclotron to the high voltage generator as the particle accelerator for nuclear physics research in Bangalore.

---

[289] For details on Scherrer's work and his laboratory see: H. Frauenfelder, O. Huber and P. Stähelin *Beiträge zur Entwicklung der Physik: Festschrift zum 70 Geburtstag von Professor Paul Scherrer* (Basel: Birkhäuser Verlag, 1960) and Kurt Alder, *Paul Scherrer 1890-1969: Vorträge und Reden gehalten anlässlich der Gedenkveranstaltung* (Basel: Paul Scherrer Institute, 1990).

[290] Scherrer to Krishnan, January 3, 1946; RSK Papers.

[291] The pulse-generator is not a particle accelerator but a high voltage generator.

The Atomic Energy Research Committee (AERC) and its adjunct Board for Research on Atomic Energy (BRAE) of the CSIR met for the first time in May 1946. [292] The first set of grants from the CSIR were made for continuing construction of the Calcutta cyclotron, radioactivity research at the Bose Institute and for a betatron at the newly established Tata Institute of Fundamental Research, Bombay. It is difficult to imagine that none on the AERC or BRAE were aware of Raman and Krishnan's plans. No mention was made.

In September that year, the Director of the Institute, J. C. Ghosh, informed Raman that the Institute was to establish a High Voltage Engineering Laboratory equipped with a 3 million volt generator.[293] Having visited Scherrer's laboratory himself, the director observed, in Zurich, they were using a 2 million volt generator for experimental nuclear physics. Considering a potential two-way utilisation of a high voltage generator, the director requested a note within the next five days if the department of physics would consider sharing the generator with the High Voltage Engineering Department. It is difficult to determine just how Ghosh arrived at the possibility of sharing the high voltage generator between the department of physics and the engineering department that was to make the purchase: first, as a sharing arrangement logistically, but more than that as a potential way of arranging equipment such it would be feasible physically, and function as required efficiently enough for both parties. However, as far as convincing Krishnan

[292] The Government of India established an Atomic Research Committee in 1946, which first met on May 15, 1946 to consider "the general policy that would have to be followed in order to develop atomic research in India in the shortest possible time with the limited resources in money and scientifically trained men at the country's disposal". There is no comprehensive history of the (Indian) Atomic Energy Committee but it has been dealt with to some extent in Abraham (1998) and Perkovich (1999). I will deal with the history of the organization as it intersects with the history of nuclear physics education and research more specifically in Chapter 5.

[293] J. C. Ghosh to C. V. Raman, September 25, 1946; RSK Papers.

went, given that nothing seems to have transpired for more than a year, Krishnan was persuaded just enough to submit yet another note on the very same day as the request was made.

3.11 September 1946: Sharing the High Voltage Engineering Department Generator

Krishnan's proposal of 25th September 1946, ended with a short note clarifying that this was a "tentative scheme" submitted at the director's request, and "at short notice".[294] Even so, the proposal ran into four typewritten pages and was quite detailed on the physical settings of the laboratory to be established. There appeared no statement of doubt about the arrangement, and Krishnan was willing to share the equipment. A physical plan of the building was laid out, including the placement of various research and workshop rooms, and obligatory shielding. Krishnan had proposed a reconstruction of the existing laboratory hall of the department. In the year between his last proposal and the present offer to share the equipment of the HV engineering department, there was ebb in Krishnan's enthusiasm, even as, for the first time, something concrete was on the offer to initiating nuclear physics at the Institute. This ebb could have been a result of sheer fatigue from writing proposal after proposal, as it could have been from the realisation that he did not have enough support to realise his ambitions.

Krishnan already made a connection with industry in his second proposal. The IISc was

[294] *Note submitted to the director, Indian Institute of Science, with reference to his letter to Sir C. V. Raman dated 25th September 1946*, September 25 1946, RSK Papers.

established as an institute for applied research, but given the history of predominantly fundamental research at the department under Raman, this connection would have to be actively evoked. The Tata's had already funded both Saha's and Bhabha's endeavours in nuclear physics, but they were also a patron of the IISc. Krishnan was motivated primarily by the research and teaching potential of particle accelerators, this was what a credible physics laboratory had to engage with. Making a good case should not have been incredibly difficult prior to or after 1945, but apparently, it became only more so.

Krishnan made a list of equipment that would be necessary to make use of the high voltage generator as a particle accelerator, including detecting devices. [295] He noted the requirements of additional staff - one senior lecturer, two research assistants, a laboratory assistant, an operator or a skilled mechanic, an assistant mechanic and a peon [help]. This time round, the section on expenditure was the smallest. As capital expenditure, Krishnan only described it as "money required to purchase the list of equipment", the recurring expenses for staff, and maintenance, boiling it down to a mere fourth of what was claimed in the last proposal.[296] An entirely new request was made for Krishnan's deputation to laboratories abroad, especially the ETH Zürich and the Cavendish Laboratory, Cambridge, to familiarise himself with high voltage accelerator assembly and observe improvisations effected in the two laboratories. He did not propose taking any technical staff with him. "It should be emphasised" Krishnan argued, "that the accelerator

[295] Krishnan listed the following parts: An accelerating tube, high-vacuum pumping system - three diffusion pumps, a discharge tube, heavy water, power stack comprising a motor, an AC generator, transformer, rectifiers, smoothing circuits, a tall Bakelite paper cylinder, a leather belt to drive the alternator, a magnetic box assembly comprising electromagnets, and detecting devices comprising a cloud chamber, Geiger counters and counting sets, Ionization chamber and linear amplifier.

[296] The sum Krishnan came to was Rupees 25 000 per annum.

assembly has to be fabricated in situ after getting the necessary parts from abroad. It is necessary to point out that in practice no description of the sets in other laboratories can take the place of experience of running the same under different conditions". The war was over, and it was safer to travel. Even as sections of some laboratories remained occupied with continuing military work in the USA and England, visiting the laboratory in Zurich was a safe and important option, as was the Cavendish.[297]

The request foregrounded an important aspect of constructing particle accelerator assemblies; Krishnan's emphasis that any given description of such a set-up was entirely inadequate to replicate has been evoked time and again by cyclotroneers and particle accelerator builders. Krishnan's experience with the Cavendish cyclotron had taught him that he would require hands on experience with high voltage generators before he set out to assemble one himself. The Council granted his deputation within five days of the request, and agreed to fund this trip from the recurring expenses of the high-voltage engineering department.[298]

Three and a half months later Krishnan arrived at the conclusion that the proposed sharing arrangement with the high-voltage engineering department was not workable for experimental nuclear physics. In this period, he corresponded with colleagues at the

[297] Scherrer's laboratory was probably one of the best equipped on the continent with three particle accelerators; it was not involved in the war effort, nor did it suffer from war damages. Scherrer responded to Krishnan's request for information, and since the director of the Indian Institute of Science also visited the laboratory, a framework of cordiality was established. See Alder, (1990) and Frauenfelder. (1960).

[298] Minutes of the Council meeting of 30 September 1946, Indian Institute of Science, Bangalore; IISc Archives. The Council approved deputations aboard of three other members if funds were available for deputation in the same meeting. They came from the departments of pharmacology (USA), Communication Engineering (USA) and High Pressure Reactions (UK or USA) and were for 8, 6 and 12 months respectively.

Cavendish, and with Scherrer, but also with General Electric (GE) - the firm supplying the high-voltage generators. In his letter to the General Manager of GE-India, Krishnan inquired if the firm was aware of an arrangement as proposed in the Institute, and requested that his letter be forwarded to "principals in the USA by airmail" requesting information on laboratories in the USA or elsewhere that may have opted for this arrangement.[299]

Krishnan also contacted Robert Latham at the Cavendish. Latham had just recently returned from wartime activity. Krishnan asked two questions of his old colleague - "whether the high voltage laboratory is still under secret research" and "who is in charge of the laboratory now".[300] There were no secrecy restrictions any more on the HT lab, responded Latham. He had not yet consulted Bragg, but he had talked to Edward S. Shire, who was in charge of nuclear physics at the Cavendish and William E. Burcham, who was in-charge of the 1 MeV set, and both saw no difficulty in accommodating Krishnan.[301] Krishnan wrote to Shire and requested consent to work in the high-tension

---

[299] Krishnan to M. Ganguly, International General Electric Co. (India) Ltd. December 22 1946; RSK Papers; Krishnan inquired if GE had designed and supplied 2 or 3 MV DC Generators to laboratories in the USA or elsewhere, if they could design and supply one to the department and what would be the costs involved. (The HV Engineering department was buying a 3 MV impulse Generator and a 1 MV AC Generator). The firm's Bangalore office responded the very next day saying; "We have no information available in this office whether the equipment we are supplying for the HV Testing Laboratory can be used for nuclear physics work", but they were forwarding the letter to the US office. The RSK papers do not contain any further response from GE, USA.

[300] Krishnan to Robert Latham, November 25 1946; RSK Papers.

[301] Robert Latham to Krishnan December 18 1946; RSK Papers. Latham also described the reorganisation of the cyclotron since Krishnan had left the Cavendish and mentions trouble with the 2MeV HT machine under S. Devons. Latham had been back from the war effort for a year but felt that he had "lack of research to show for it" – "much time is still being spent on cyclotroneering" he thought.

laboratory. He also asked for the building plans and blueprints for the assembly.[302] Shire was willing to accommodate Krishnan's requests, but explained the constraints under which he would have to adjust himself in the laboratory.[303] The number of research students had gone up at the Cavendish and Shire warned that "it would be wrong of me to let you come with the impression that we can devote a great deal of attention and time to special help for you, much as we would like to do so". Shire nonetheless offered two interesting opportunities – he was willing to let Krishnan help in the erection of the new 5 MeV set, which coincided with his intended period of visit. He also sent Krishnan the details of their equipment and the contact at English Electric Co. Ltd., who were building their electrostatic generator.[304] Old contacts at the Cavendish revived, Krishnan looked forward to the visit. It was four years since he was last in Cambridge, and almost the same time since he first put forward the proposal to establish a particle accelerator facility in Bangalore. Krishnan also wrote to Scherrer, almost a year since their last communication - this time asking for the details of the high-tension set in the Zurich laboratory.[305] For the first time since the sharing arrangement was suggested, Krishnan

---

[302] Krishnan to E. S. Shire, Cavendish Laboratory, January 17 1947; RSK Papers. Krishnan had heard about Shire leading nuclear physics at the Cavendish from both Robert Latham and Vikram Sarabhai, who were in Cambridge in late 1946. Sarabhai was a student at the Institute during the war and he returned to Cambridge soon after. Sarabhai worked with Robert Millikan and then with Bhabha on cosmic ray. Like Bhabha, he came from a privileged family of wealth. He first established the Physical Research Laboratory, Ahmedabad, then led India's space program and later led the Atomic Energy Commission after Bhabha's death (1966-1971).

[303] Shire to Krishnan, 27 January 1947, RSK Papers.

[304] Krishnan wrote to the English Electric Company (Krishnan to Mr. Brown February 1947; RSK Papers) inquiring if they would duplicate the Cavendish machine for Bangalore, and what would be the costs involved. The company responded with willingness to show Krishnan the equipment when he visited the company but said it would be impossible for them to give any particulars or if they could duplicate them because "we have no experience with the machine we are making for Cambridge. The machine is making satisfactory progress, but it is still too early to know whether it will be satisfactory or not". (J. K. Brown to Krishnan, July 15 1947; RSK Papers).

[305] Krishnan to Scherrer, December 10 and 19 1946; RSK Papers.

voiced doubts of its practicability. He asked for Scherrer's opinion on this matter.[306]

Among Krishnan's other correspondents was Vikram Sarabhai in Cambridge. Sarabhai was confident that the proposed arrangement of sharing high voltage generators was technically impossible to work with. He was perhaps the only one to say so unless Scherrer responded with a similar answer. Instead, he proposed the Philips High Tension Generator as a dependable machine, given the recent experiments in Eindhoven.[307]The alternative, he suggested was the Van de Graaff machine, especially the MIT design, which fit into a small room. The MIT proposal did not interest Krishnan, but he followed up on the Philips recommendation to find out that the promised DC Generator for atomic research would be available only in 1948, but the High Tension Generators on the other hand were available immediately.[308]

Krishnan had developed a good overview on the equipment being built and purchased by important laboratories in Europe and to some extent the USA. A perspective on the research agendas and budgets of these laboratories, prepared him to better argue for the laboratory he wanted to establish in Bangalore. Krishnan was finally able to imagine his laboratory now that for the first time plans appeared to be moving ahead. In the meanwhile, the Vice Chancellor of Dacca University asked Krishnan if he would be

[306] Scherrer's response is not among the RSK Papers and Scherrer's correspondence is not archived.

[307] Vikram Sarabhai to Krishnan, February 8 1947, RSK Papers Sarabhai was talking about the introduction of the Phillips HT Generator in pressurised tanks, a machine that would eventually be bought in 1951 by Homi J. Bhabha for the Atomic Energy Commission.

[308] Krishnan to A. C. van Dorsten, Philips Laboratories Eindhoven, February 14 1947; Dorsten to Krishnan, March 10 1947; and J. Christiansen, Philips Electrical Co. India Ltd. to Krishnan March 26 1947; RSK Papers.

willing to consider a professorial position. Krishnan confidently replied that he had earlier considered leaving the Institute because there were no facilities for nuclear physics in Bangalore; but now there were attempts being made. "In view of this, I feel that I should await further developments before taking a final decision and that it would not be correct for me just now to be a candidate for a position elsewhere". [309] He was hopeful of the circumstances and thought it "correct' to await further development, completely unable to imagine, as no one else could - the obstacles that would eventually put to an abrupt end any possibility of realising his proposal.

3.12 January 1947: Third Proposal

On January 15 1947, Krishnan finally informed the director J. C. Ghosh, that the proposed sharing arrangement was not practicable. He detailed the unsuitability for nuclear physics of each of the three high voltage units being purchased for the high-voltage engineering department.[310] His deputation abroad, he argued, would be not worthwhile if eventually there was no proper equipment for nuclear physics research at the department of physics. The two high voltage generators that were indeed useful for atomic research were the DC voltage multiplier set similar to those used in the Cockcroft-Walton generator, and the Van de Graaff electrostatic generator. Since neither of these was useful for high tension testing, the Institute may as well consider buying separate

[309] M. Hasan Khan Bahadur, Vice Chancellor, Dacca University to Krishnan, January 24 1947 and Krishnan to M. Hasan, February 14 1947; RSK Papers.

[310] Krishnan to the Director, Indian Institute of Science, January 15 1947; RSK Papers.

units, which were easily obtainable. Krishnan wanted the council to discuss his letter seriously.

Like every single of his letters to the council or the director before this, this one too went through Raman. This time round, Raman wrote a three-page letter to preface Krishnan's reservations on the director's sharing arrangement. For the first time since the relay of proposals began in 1942, Raman placed the Bangalore project in comparison with other attempts within India to establish "atomic research".[311] It had only recently become necessary to make a case given the establishment of the AERC and the appearance of a national policy on nuclear research in India. A public announcement of grants to Saha, Bhabha and Bose only made it mandatory that Bangalore lay claim upon a share in the scramble for funding, and a mandate for nuclear research in free India. It was also quite recently that such a comparison was made possible with similar projects coming up in Calcutta and Bombay.[312] The three laboratories had come into play against each other in a dynamic caught in the inundation of Indian independence and state formation, the imperative of nuclear research and struggle for a share of scarce resources - resources of skilled manpower, funding and natural materials. But Raman and Krishnan were yet one more proposal away from being superseded.

In January 1947, Raman was a year away from retirement and it is in that context that his

---

[311] Raman to the Director, Indian Institute of Science, January 16 1947; RSK Papers.

[312] The two projects form the next two chapters of this dissertation. It would suffice here to say that Saha's attempts to build a cyclotron in Calcutta began definitively in 1941-1942, and Bhabha's new laboratory for fundamental research in nuclear sciences was established in 1944 – 45.

preface to Krishnan's note must be read. Raman made explicit reference to the bomb as a rationalisation for "atomic research" and then placed the research laboratory within this concern as the one place capable of handling this problem of the times. "It is now common knowledge that the accomplishment of atomic fission on a mass scale and the consequent release of nuclear energy have been the most outstanding by products of atomic research, having found their application in the so called Atom Bomb"… the tremendous possibilities of nuclear research cannot be overemphasised and it truly is the "Problem of the Times". Recounting his concern with the need to establish nuclear physics back in 1938, he specifically mentioned Krishnan's experimental work with uranium bombardment at the Cavendish, not forgetting to add that all attempts to establish nuclear physics research at the Institute since then had not materialised. It was crucial to Raman's argument this time that context had changed - of immediate concern was that Raman would retire within a year and he was concerned that his efforts to establish nuclear physics with Krishnan had not succeeded in five years. Yet another change from his habits of doing science was the scaffolding of nation and state that was coming up, not in India alone, but in the international context as well. "Since then the situation has changed" he said, "and all countries have felt the paramount necessity of developing sources of atomic energy by every conceivable method. India does not wish to lag behind in this respect, judging from the recent pronouncements of the spokesmen of the Government of India…." Bangalore could contribute, Raman argued, to keep India up with the times. But it was precisely this argument that would turn against their efforts, and bring Raman and Krishnan in direct conflict with the emerging national program.

Raman anticipated the keen competition for resources and spelled out the Institute's plan to make clear exactly why there would be no conflict of interest. In doing so he already anticipated the next and the last proposal Krishnan would write. "The Calcutta University is setting up a cyclotron, while the Tata Institute of Fundamental Research in Bombay is going to have a Synchrotron (sic).[313] It is time that a start is made in this Institute also in order to keep its status as the foremost Research Institution in India…. In order to avoid duplication of the type of work carried out elsewhere in India, the new laboratory could be equipped with a High Tension set capable of generating voltage up to 5 MV. This is comparatively cheaper to set up than a cyclotron or a synchrotron". The proposal would be read by at least three groups on the council - the Tata's, the government of Mysore and the representatives of the Government of India. Raman had to try to convince all three. The Tata's could probably be convinced that there was no conflict or duplication with the laboratory in Bombay, the regional government could be convinced of the need to maintain the prestige of the Institute and prevent from being taken over by maybe Bombay or Calcutta; and the government of India had already asserted its desire to not "lag behind" in atomic research. In the five years since Krishnan first proposed to establish a nuclear physics laboratory, much had changed as Raman pointed out. The local and the international references had shifted, and it was no longer sufficient to argue from within the laboratory. But science and politics had fused in a particular manner in the Indian context. The logic of concentration, politics of regionalism, and Raman's disfavours with the Tata's and with Hill, and therefore Bhatnagar; all of these combined together proved so strong that Krishnan was unable to break out alone.

---

[313] All documentation shows that Bhabha wanted a betatron. Plans for a Harwell like synchrotron came much later (1950).

3.13 January 1947: The Last Proposal

The last proposal only detailed the note that Krishnan had already handed in on January 16 1947. As such, it was not an altogether different proposal. It was a plea for reorganisation of the department in view of Raman's upcoming retirement, and it called for an establishment of a separate nuclear physics department. Unlike the previous note though, the longest section in this proposal was the budget - drawn separately for the departments of "general physics" and "nuclear physics". The budget was drawn with reference to funding recently received from the Government of India for reorganisation under the "five year expansion programme of the Institute"; and the expenditure for nuclear physics was adjusted to new moneys. The new capital grant coming for reorganisation would be able to provide for a new building; and also pay for detector equipment and equipment for the general physics department. In balance, the department would need a capital grant of Rupees 300,000 for purchase of a 5 MeV high-tension apparatus. The total recurring expenditure for the bifurcated department was drawn such that when the increase in funds was taken into account, the net additional expenditure per annum would only be Rupees 2500, which Krishnan felt was modest and could be secured. [314] The reorganisation grant came at a critical juncture and with a major part of the expenses – both capital and recurring - taken care of by the increased funding, Krishnan and Raman may have found good reason to feel realistic about their budget. With this confidence, Krishnan also made a request to the Council on the same day to add

[314] *Reorganisation of the Physics Department,* January 20 1947, RSK Papers.

laboratories in the USA - the MIT, Westinghouse Laboratories and the Carnegie Institution of Washington to his itinerary of Zurich and Cavendish.[315] Nothing moved between March and June, and Krishnan did not leave for his trip to Zurich, Cambridge and New York according to plans. He would never make that trip.

Krishnan submitted a special note on June 10 1947 at the director's request; "In view that … a 100 MV Betatron is going to be set up at the Tata Institute of Fundamental Research in Bombay and that a Cyclotron Laboratory is already in existence at Calcutta it may be well to point out the circumstances which led to the proposal of the setting up of the electrostatic generator here". Judging from the contents of the note, it seems to address the same questions as anticipated or maybe even precipitated by Raman's note in January 1947. [316] "…without in any way competing and duplicating the type of work that would be carried out at Bombay and Calcutta, a Nuclear Physics Laboratory can be set up in this Institute using electrostatic generators for accelerating particles". But the three laboratories were competing and each was aware of the precarious situation they were in. From comparing their efforts to laboratories in Europe and America, the time had come that Krishnan had to refer to proposed work in Bombay and Calcutta to justify his share of government funding. Bhabha was the chairperson of the Atomic Energy Research Committee and Meghnad Saha of Calcutta was a member of the Committee as well. In addition, Bhabha was a member of the Tata family, a patron of the Indian Institute of

[315] Krishnan to the Director, Indian Institute of Science, January 20 1947; RSK Papers. Krishnan received an approval of his travel to the USA on February 21 1947, but the Council resolution deputed him to visit only the International General Electric Co, New York.

[316] *Special note on the setting up of a nuclear (atomic) research laboratory in this Institute* June 10 1947, RSK Papers. Underlined emphasis is from the original.

Science. Krishnan did not have political power to match the other two projects - what he had was his experience of working with the cyclotron in Cavendish, but so had B. D. Nagchoudhuri in Saha's laboratory who trained with E. O. Lawrence in Berkeley. Raman's own tribulation with the Institute and his general approach to national politics did not place him in position to mobilise political support for Krishnan. Krishnan decided to defend his electrostatic generator against the cyclotron and the betatron or synchrotron using three arguments that were doing the round - budget constraints, urgency and contribution to development of atomic energy in India. Krishnan argued that an electrostatic generator could be installed at a reasonable cost when compared with a cyclotron and a synchrotron or a betatron, and it would contribute towards the training of new students and researchers required for the country.

A month before Indian independence, time was an additionally crucial concern. The new country was taking birth in a moment when the paradigm for credibility, security and national sovereignty was new and imperious. Those who wanted to participate in fortifying a national state, would have to actively participate its making. Krishnan made a cogent argument. "Whereas the equipments to be set up in Bombay and Calcutta entail heavy engineering jobs and would easily take <u>about five years</u> to complete and be ready for work on nuclear physics, the work of training physicists could be started in this Institute <u>within a year</u> as ready made Generators … are available". Krishnan proffered his proposal as a pragmatic one, for the first time making a link to medicine and biology. Reiterating his original motivation of "giving students <u>intensive training in fundamental nuclear physics</u>", Krishnan now plugged into the goal of "producing trained scientists for investigations connected with atomic energy…" - an argument closely resembling Bhabha's justification for the need of a separate laboratory for fundamental research in nuclear sciences.

Krishnan's claims for patronage were not unusual, but what may have raised eyebrows were his comments on the usefulness of a betatron and the cyclotron as particle accelerators - given especially that the proposal and the note eventually reached both Bhabha and Saha. The most important application of a betatron at the time, Krishnan claimed, would be for investigating the possibility of creating artificial mesons. However for this purpose a betatron with energy in the neighbourhood of 200 MV would be more appropriate, clearly indicating the one with 100 MV proposed by Bhabha was not adequate given also Bhabha's interest in the meson problem. The cyclotron, on the other hand, Krishnan claimed, depending on the design, accelerated particles to fixed energies but remained rather cumbersome, complicated and elaborate to handle - a reason why it had not taken precedence over electrostatic generators of even lower energies – by then his own preferred machine.

3.14 July 1947: Nip It in the Bud!

Krishnan had not disaggregated particle accelerator building, particle accelerator based research, and accelerator based nuclear physics research; neither did Raman. They both harboured doubts about the utility of Bhabha's betatron even for the production of mesons, but Meghnad Saha dismissed Bhabha's ambitions as simply a distraction from what the AERC ought to be doing; research on the generation of atomic energy and building a pile. In May 1947, Saha wrote to Bhatnagar; "I feel that the programme submitted by Dr. Bhabha is amateurish and fragmentary. What is proposed is not atomic physics but cosmic rays. The Committee would not be discharging its duties towards the country unless it can prepare a more comprehensive scheme".[317] The Committee, Saha felt, had not outlined a clear programme of work unlike those on the UK, USA or even the United Nations Atomic Energy Commission. None of these expressed any interest in "general problems of nuclear physics and cosmic radiation". Even if creation of artificial mesons was an interesting problem, 'there seems to be no close link of either cosmic rays or very high-energy particles with fission phenomena". The UK, Sweden, and Switzerland were prioritising construction of atomic piles over particle accelerators. If high-energy accelerators cost as much as an atomic pile, and Saha claimed to have taken the estimates from Eugene Wigner, then the "best course for development of atomic energy in the country" was an issue worth serious discussion.[318]

Bhatnagar did not agree. He assured Saha that his advice was taken seriously and even more he had been appointed on various important committees. Bhatnagar was also

---

[317] MNS to SSB, May 12 1947, MNS Papers, NMML.

[318] He also proposed geophysical explorations of fissile ores, and processes of isotope separation for industrial research on a large scale. MNS to SSB, May 23 1947, MNS Papers, NMML.

The two-page note deals entirely with Saha's re definition of AERC agenda written in response to a newspaper announcement by the Government of India that "they were willing to finance a big scheme". In a letter written the previous day on May 22 1947, Saha had already written to Bhabha with the same questions raised in the note but more over asking that in the next meeting they define "in precise language the ground … to cover, regions of interest, the effort needed, and should proposal the lines of action, and steps to be taken in order of priority…and should define its attitude with respect to the requirements of the defence department as well as to the peaceful utilisation of Atomic Energy. MNS to HJB, May 22 1947, MNS Papers, NMML.

convinced that Bhabha was "singularly free of ego". He wrote, "In the early stages of our country's development at least one laboratory should get fully developed".[319] He added, "I am not against any other laboratory either but we should discuss these things amongst ourselves and arrive at a satisfactory solution". The Council of the IISc met on June 30 1947, and decided to appoint a Committee, "to consider an application that [Krishnan] be deputed to some of the premier High Voltage Laboratories in the United States of America and also to consider the scheme for setting up of a Nuclear Physics Laboratory at the Institute".[320] Krishnan was asked to attend a meeting, which to be held in Bombay. The members on the Committee were Bhabha, Saha and K. S. Krishnan,[321] all members of the Atomic Energy Research Committee; H. J. Taylor, a physics teacher (earlier at the Cavendish) at the Wilson College, Bombay, who had recently begun collaborating with Bhabha in experimental cosmic ray physics research; and the director J. C. Ghosh and Registrar, A. G. Pai, of the Indian Institute of Science, Bangalore.

Before the Committee could meet, in July 1947, Bhatnagar wrote a letter to Bhabha about "J. C. Ghosh's" plans to begin nuclear physics education and research in Bangalore, arguing that it had to be stopped.[322] But clearly, Bhabha knew about this before. Bhatnagar had an eagle eye view over the organisation of science education and research

---

[319] SSB to MNS, May 19 1947, MNS Papers, NMML.

[320] Registrar, Indian Institute of Science to Krishnan, July 23 1947, RSK Papers.

[321] K. S Krishnan (not related to R. S. Krishnan) was Raman's assistant in Calcutta when the discovery of the Raman Effect was made (1928). He had since moved to Dacca. In 1947, when this Committee was formed, he was Director of the National Physical Laboratory, New Delhi.

[322] Bhatnagar to Bhabha, July 19 1947, Sir. Shanti Swarup Bhatnagar Papers henceforth referred to as SSB Papers.

in India - and for him, this was not Krishnan's proposal or for that matter Raman's idea - but a project of the director of the Institute, J. C. Ghosh. The Institute, he felt, should not be allowed to establish a chair in nuclear physics for Krishnan because was in conflict with the development of Bhabha's laboratory - as *the* centre of nuclear research in India. Bhabha lost no time and sent a telegram of his agreement - further requesting Bhatnagar to write to Meghnad Saha with this idea.[323] At least at this moment, Bhabha appears convinced that Bhatnagar could convince Saha to vote negatively on the Bangalore proposal, but Bhatnagar was not thinking on the same lines. His letter to Bhabha the very next day suggested that *both Ghosh's and Saha's* move to establish nuclear physics laboratories should be suppressed through the representatives of the council.[324] Whether Bhatnagar, or for that matter Bhabha, wrote to other council members of the IISc is not clear. Bhatnagar did write to R. Choksi, the Dorabji Tata Trusts representative on the council.[325] Bhatnagar mentioned the primacy of the Tata Institute of Fundamental Research for nuclear physics research in India, and as such, the creation of another chair for Krishnan in nuclear physics would be an "unnecessary duplication" of Tata efforts and therefore unwise use of philanthropy. Bhatnagar enjoyed no mean support and influence with the Tata Trusts. He had secured funding for the establishment of three national laboratories of the CSIR from the Tatas in the recent years. His word was not to be taken lightly.

---

[323] Bhabha to Bhatnagar, Telegram of July 25 1947, SSB Papers.

[324] Bhatnagar to Bhabha, July 26 1947, SSB Papers.

[325] Bhatnagar to R. Choksi, July 26 1947, SSB Papers.

3.15 July 1947: Committee on the Question of a Nuclear Physics Laboratory

The Committee to deliberate upon the question of a nuclear physics laboratory in Bangalore met within a month of its appointment. The first meeting took place on the 31st of July 1947, in Bombay at the Royal Institute of Science, and not in Bangalore. The choice of location itself in a way demonstrated that the decision on the laboratory would now be taken outside the premises of the Institute, literally and figuratively. The Institute had failed to arrive at a decision for long and when there was an impetus, it no longer had the power to deliberate on the issue in isolation. This was precisely because the impetus now came from the imperative for nuclear research following the end of the war, an imperative that would be as binding on others motivated towards nuclear research. Among those present for the meeting were, the director of the Institute, J. C. Ghosh, H. J. Bhabha, H. John Taylor, and C. V. Raman. R. S. Krishnan attended the meeting "on invitation".

Remarkably absent were Meghnad Saha - a former classmate of the director J. C. Ghosh, as well as K. S. Krishnan, Raman's research assistant from Calcutta; both were members of the AERC. Saha could have argued for a mandate for nuclear physics research and education within the university system and in research institutions, given that his laboratory was rooted in the University of Calcutta. His membership on the AERC would have given him the legitimacy to make a strong case. K. S. Krishnan was leading the National Physical Laboratory, had no direct interest in nuclear physics research, and as such may not have had an interest in this meeting. However, the relationship between both these men and Raman was not exactly amiable. Raman's departure from Calcutta had not been exactly cordial and K. S. Krishnan may have harboured misgivings about the Nobel Prize going to Raman alone.[326] There may have been simpler reasons for the absence of these men in the meeting, but the inability of any member on the Committee to seriously argue the case for nuclear research in universities would consequentially also affect the future of Saha's own laboratory.

The Chairman of the meeting and Director of the IISc, J. C. Ghosh, began the meeting with an introduction to the Committee "to report on the proposal for the inclusion of Nuclear Physics as an essential part of the equipment of trained research workers in Physics". Ghosh then placed the proposal in background of the recent establishment of the Department of Power and Engineering with a section of High Voltage Engineering at the Institute and argued, "…the study of Nuclear Physics could also be profitably started if the equipment being ordered for the Power Engineering Department and the High Voltage Engineering Laboratory were suitably modified". RS Krishnan was asked to make his proposal to the Committee, and "He laid special emphasis on the need for producing trained personnel in nuclear physics research in India". The two main objectives of the new laboratory, Krishnan argued, were those of providing 'advanced

[326] Saha was involved in the controversy that contributed to Raman's departure from Calcutta in 1933, as well as in the one that led to Raman's resignation from the position of Directorship of the Indian Institute of Science, Bangalore in 1937. See S. N. Sen, ed., *Professor Meghnad Saha: His Life, Work and Philosophy* (Calcutta: Meghnad Saha Sixtieth Birthday Committee, 1954); Santimay Chatterjee, "Meghnad Saha and C. V. Raman: Fact and Fiction," *Indian Physical Society Diamond Jubilee Number* (1995): 43-47; and Rajinder Singh, (2004). K. S. Krishnan was Raman's principal research assistant when he made the discovery of the Raman Effect, and there may have been misgivings that the Nobel Prize eventually went only to Raman. As late as 1999, A. R. Verma, Director of the National Physical Laboratory wrote: "Krishnan strongly felt that he had been treated unjustly and that he was denied the credit by not sharing the Nobel Prize. It was clear that he carried a hurt feeling all his life on this matter". See Rajinder Singh, (2004).

training' to graduate students working towards their masters and doctoral degrees, and second, that of providing a facility for "carrying out fundamental investigation in pure nuclear physics… and also in applied nuclear physics". Krishnan anticipated the high voltage generator as a useful machine for the type of work proposed in the new laboratory. Krishnan was expected to withdraw from the meeting when the Committee would discuss on the matter.

His mentor, CV Raman stayed on in the meeting, took up the case, and he first argued for the proposed laboratory within the existing department of physics. Raman began by stating that the department of physics at the IISc was a "flourishing school of physics" given the number of research problems they tackled and the "highly specialised" team of researchers they employed. He further argued that nuclear physics "would be the most active branch of physics" in the times to come and since IISc was at the time a premier research institute of India, it was imperative that researchers in the laboratory learn to handle problems in nuclear physics. Given that Krishnan had actually trained at the Cavendish in exactly this line of research, Raman judged that it made him the obvious choice at the department to run the Bangalore facility. Raman then put on the table the recent grant from the Government of India to the Institute specifically aimed at the expansion of the department of physics. The available funding for departmental expansion, Raman argued was enough to build a research facility for nuclear physics dedicated as much to training graduate students as for fundamental research on the "properties of the nuclei".[327]

[327] Raman was talking of a capital grant of Rupees 300 000 and a recurrent grant of Rupees 10000.

Taking the cue from Raman's confidence in the sufficient budget, H. J. Taylor argued that the estimated budget was "entirely inadequate". Agreeing with Taylor, Bhabha further outlined an argument that was to become national policy on nuclear research for the next two decades. Bhabha argued that since a large part of the Institute budget came from the Government of India, the Institute's own plans could not be drawn in isolation from the "wider policy of the government in scientific matters". This wider policy of the Government in "scientific matters" was read out to the meeting from the minutes of the AERC. The government wanted to centralise and concentrate. Quite obviously, Bhabha and Taylor did not manage to convince Raman. The meeting did not reach any conclusion, at which point Ghosh, requested Bhabha and Taylor to submit a written report elaborating upon their position. Bhabha and Bhatnagar had already discussed inviting Krishnan to join the TIFR. At end of the meeting, Bhabha invited Krishnan to move to Bombay.

3.16 September 1947: Bhabha-Taylor Report

If Raman hotly contested the arguments raised by Bhabha and Taylor at the meeting in June 1947, the decision to reject the Bangalore proposal all together was still not arrived at in the meeting. Ghosh continued to favour the establishment of nuclear physics at the IISc, not least for the prominence it would bring the Institute within the national framework. The Bhabha-Taylor report was written against this background of uncertainty. The report reached Krishnan and Raman on the September 3 1947, and

Krishnan immediately wrote a response, which was again prefaced by Raman and submitted the next day to the director.

The IISc council minutes of September 8 1947 were prefaced with two important notices. The council welcomed the nomination of H. J. Bhabha as a Tata *family* nominee on the council of the IISc as of August 22, 1947.[328] The minutes also welcomed Prof. Meghnad Saha's appointment of on the council as a nominee of the Ministry of Education, Government of India. The appointment of Bhabha and Saha, both members of the AERC on the Council, made it clear that there was little chance any further appeal from Krishnan on nuclear physics research in the department would get a fair hearing. The Bhabha-Taylor report and a written response from Krishnan were published in the minutes. The emphasis was on the impracticality of establishing a laboratory for nuclear physics in Bangalore under given circumstances. This was not a foregone conclusion from the meeting in June 1947, as the matter seemed to be under serious debate. Bhabha's decision embodied his position with the state (as chair of the AERC), his relation to the patrons, the Tata family, and his position as a physicist. He had Bhatnagar's support and neither Saha not K. S. Krishnan attempted to support Raman and Krishnan's proposal. Politically, Krishnan was never before in a weaker position, and the disappointment must have been tremendous. This battle was impossible to fight.

The "Report on the Proposal to start a Department of Nuclear Physics at the Indian Institute of Science, Bangalore" by Bhabha and Taylor is an interesting document not so

[328] *Minutes of an Ordinary Meeting of the Council of the Indian Institute of Science, Bangalore*, Monday September 8 1947, IISc Archives, 1.

much because it was the final written word on the end of efforts to establish nuclear physics in Bangalore. It was also the first articulation and execution of a national policy on the organisation of nuclear research in free India. "…[W]e do not feel that it is desirable or even possible to give a considered opinion without reference to wider questions. There is at present very little nuclear research of any kind going on in India, and its development is an urgent matter. The development and use of atomic energy is a question of national importance."[329]

The report[330] argued that Krishnan's proposal needs to be examined on three counts; "in relation to the proposed budget; in relation to other possibilities for the development of the present Physics Department" and finally "in relation to the wider development of nuclear physics in India". Bhabha and Taylor first argued that nuclear physics "cannot simply regarded as another branch of physics, comparable to say acoustics or optics. The immense progress in this field in recent years, and its fundamental character, places it in a category by itself… for the same reason we do not believe that the subject could be adequately taken up on a small scale". The authors of the report, one of who was the author of the AERC policy on scientific research, at the outset declared the exceptional nature of nuclear physics research. Science and warfare were now coupled in the political imagination in an unprecedented manner. If Krishnan was rearticulating his ambition to

---

[329] *Minutes of an Ordinary Meeting of the Council of the Indian Institute of Science, Bangalore*, Monday September 8 1947, Appendix- D, "Proceeding of the Meeting of the Committee to go into the question of setting up a Nuclear Physics Laboratory at the Institute, held at the Royal Institute of Science" Thursday July 31 1947, 26-27, and [Appendix] *Report on the Proposal to Start a department of Nuclear Physics at the Indian Institute of Science, Bangalore by Dr. H. J. Bhabha and Dr. H. John Taylor*, 27-30, IISc Archives.

[330] I have at times resorted to using "the report" as shorthand for writing "the Bhabha-Taylor report" every single time, for easier reading.

establish nuclear physics research in a facility funded by the state, he was counting on the imperative of nuclear research in the new India. But then, he was also bound by the very same imperative to contend with other claims upon the state's agenda for nuclear research. The AERC held the monopoly over that mandate and confronted Krishnan's proposal with a scale that was far removed from and overwhelmed the plans of a department of physics in a research institute.

Moreover the discussion over the proposed budget took quite another turn altogether when Bhabha and Taylor reveal their own version of nuclear physics research as physics research of the future; "…interest now centres increasingly on particles of higher energies. We do not question that a 3 MeV accelerator would be a valuable tool, but we do not believe that a modern department of nuclear physics could for long be content with a single instrument of this type. Indeed Dr. Krishnan himself, at the end of his note, suggests that the setting up of a 3 MeV accelerator is a preliminary step to the establishment of a 5 MeV pressurised generator. *This equipment too would soon prove insufficient and it would become necessary to obtain even larger and costlier instruments*. Such a development would be inevitable if the department were desirous of keeping abreast of modern work. It appears to us that if the Council of the Institute pursues the plan of instituting a department of nuclear physics, it will be necessary to face, in the very near future, very much larger capital expenditure than is at present contemplated". A department of physics in a university setting would not be able to cope for too long, with the scaling up of expenses required, if not to establish, then to maintain and expand nuclear physics based upon accelerators. Bhabha and Taylor, in India, were not the only ones to arrive at this conclusion.

While Bhabha and Taylor were convinced of the usefulness of high voltage generators, they were not convinced of their continuing relevance in a research field, which they envisioned would require machines of higher and higher energies. This would require "very much larger capital expenditure" which Bhabha and Taylor were convinced, was not planned for in the proposal. However, this revealed yet another facet of their judgement on the budget, if Krishnan and Raman had miscalculated budget requirements, they could have been asked to rewrite the proposal with realistic budget advice. However, that is not what Bhabha and Taylor suggested, instead they worked from the assumption that the budget of the university department from the government of India would not increase in required amounts to support a well equipped laboratory for nuclear research. Nuclear research, in the national plan, would no longer be possible in university laboratories. Saha had arrived at the same conclusion as well, and begun efforts to separate the Palit Laboratory from the Calcutta University to establish an Institute of Nuclear Physics.

One Lecturer and one research assistant, and Krishnan himself were not an adequate team to run a particle accelerator facility, the report argued. Furthermore, Bhabha and Taylor thought that the salaries marked for both positions were inadequate to attract "men of the necessary calibre". Three people, of whom only one was a professor, could not give advanced training in nuclear physics at the graduate level, when the field was increasingly specialising into several branches, experimental and theoretical. Bhabha and

Taylor further argued that a laboratory for graduate training in nuclear physics ought to have more than one professor and a dedicated team of more than three people.

The report wanted to establish that Krishnan and Raman had underestimated the scale of nuclear research. Thereafter came the discussion on nuclear research in post-war and independent India. By locating nuclear research as a "question of national importance", Bhabha and Taylor pre-empted any scaling down of arguments back into the context of the laboratory or the university for the establishment of nuclear research and education. They also reminded their audience: the three members on the Committee evaluating the Bangalore proposal (Saha, Bhatnagar and Bhabha) were also members on the Council of the Indian Institute of Science, and the AERC. They could not be expected to vote favourably in what was now being established as conflict of interest between the proposed facility of the department of physics at the Institute and national interests.

The Tata's had generously *matched* funding for Bhabha's laboratory, but they were motivated by more than the promise of a possible energy source for industrialisation - Bhabha was a member of the family. The local government had also contributed to the institute. Nuclear research at the national scale demanded state funding, and if the state were in the making – the AERC would now participate in its formation to ensure its own future. In June 1947, Bhabha's own laboratory was barely two years old and he was now also leading the national program on atomic energy. Bhatnagar as the director of CSIR and Bhabha as the chairperson of the AERC wanted to embed the TIFR in the national program. But if this were to be done, it would be fair to say that they would have to jealously guard state funding to establish priority of the TIFR laboratory as the national laboratory for nuclear research.

> "Our view is that the Indian Institute of Science could not profitably pursue nuclear physics without the provision of much greater resources in money and personnel. If we are right in this, the establishment of a Department of Nuclear Physics at Bangalore would inevitably cause a division of resources which would seriously impede the rapid development of nuclear physics in India. This division moreover runs counter to the considered policy of Government…. We are of the opinion therefore, that the setting up of a separate department … is inadvisable. We would like it to be clear that this recommendation is made in the light of the present situation and applies only to the immediate future. We believe that by adopting the right policy now a sufficient number of trained men may become available in India to enable many establishments for research in nuclear physics to be set up in a few years time."[331]

Having earlier removed the possibility of discussion from the laboratory to the national program, Bhabha and Taylor finally judge that the realisation of Krishnan's proposal was a possible impediment to the national program. This argument would be the most difficult to counter in mid-1947. "[T]his division [of men and resources] moreover runs counter to the considered policy of Government" - with this, Bhabha and Taylor established the authority of the AERC's mandate as binding and legitimated by state monopoly. Having delivered their judgement, Bhabha and Taylor further clarified that their recommendation was applicable only in the immediate future; nonetheless, they also suggested possible avenues of development and expansion for the department of physics at the Indian Institute of Science. "Not much importance has been attached in India to bringing together in one department a number of researchers of professional standing in closely related branches of physics, so that a real centre comparable with those in scientifically

[331] Ibid, 30.

advanced countries may be built up. We would recommend that if further money is to be expended… it should be spent on strengthening the existing lines of work and those closely related thereto by the appointment of more than one professor within one department.” Motivated by the desire to brace his laboratory and prevent the duplication of research agenda of the AERC, Bhabha and Taylor’s suggestions for further development of the department could not be entirely dismissed. They indicated that further development along the lines of research already being pursued in the department would enable the establishment of a centre comparable to “those in scientifically advanced countries”.

One aspect of the unfavourable decision on Bangalore can be explained in the context of contest and conflict. There is enough room to interpret this decision against the background of strong personalities and ambitions. But that would not do sufficient justice to the problems of organising nuclear research after WWII. There were no obvious answers. A similar debate was underway in Britain. Margaret Gowing argues, “Debates about the proper functions of Harwell, and its frontiers with the universities on the one side and with Risley and the weapons people on the other were to continue throughout the next twenty five years”.[332] An Advisory Committee on Atomic Energy was appointed under John Anderson, the Minister in charge of atomic energy in the wartime coalition government. The Committee in turn appointed a Nuclear Physics Sub-Committee led by James Chadwick who confronted similar questions, of defining in the first instance the functions of Harwell as the atomic energy *research* establishment in Britain, and how this

---

[332] Margaret Gowing, Independence *and Deterrence: Britain and Atomic Energy, 1945 –1952 Policy Execution II* (London: Macmillan, 1974), 204.

in turn was to impact funding and research agenda for universities. As Gowing explains, the Cavendish Laboratory led research in nuclear physics internationally in the early and mid thirties. Subsequently, pupils of Rutherford established nuclear physics research at other universities, but even before the war there was a feeling that Britain had "fallen behind the United States in the number of her cyclotrons".[333] The three cyclotron facilities at the outbreak of war were Birmingham, Cambridge and Liverpool. In 1946, these three facilities did not have state of art equipment, and "there was in Britain almost no apparatus comparable with that available for research in the United States". John D. Cockcroft, leading Harwell, and the co-inventor of the Cockcroft-Walton apparatus, was a member of the sub-committee. He had submitted his plans for research with particle accelerators at Harwell to the sub-committee while he was in Canada in the final days of war effort.

Chadwick was not convinced of Cockcroft's plan. He did not envision Harwell engaged in basic research so extensively. That, he thought, was better done in the universities. Chadwick's argument may well have been Raman and Krishnan's argument. "In my opinion Harwell should not in general take up work which can more readily or more appropriately be done in university laboratories, for this would diminish the close collaboration with the universities we wish to encourage; it would in the long run injure the universities and it does not make best use of our limited manpower. I think most of us

[333] See Table 1.2, "The World of Cyclotrons in 1938", and compare the 2 completed assemblies in Britain with the "9 completed and 27 under construction" in the USA. See also Gowing, (1974): especially Chapter 2, "Labour's Machinery of Government," and Chapter 18, "Research: Harwell's Role". See also Jean Bocock, Lewis Baston, Peter Scott and David Smith, "American Influence on British Higher Education: Science, Technology, and the Problem of University Expansion, 1945-1963," *Minerva* 41, (2003): 327-346.

have recognised from the beginning that over-development of Harwell might have quite serious effects…. Harwell would end up absorbing more men "than we can afford or the men will be spread too thinly… I would fell happier if it were recognised that some of these developments are being undertaken as part of the general programme of the country and not especially for Harwell". [334] Injury to universities notwithstanding, Chadwick was equally concerned that Cockcroft's agenda would deviate from what should be seen as primary responsibility for Harwell, work on nuclear energy related questions alone.

AERC policy outlined by Bhabha, Bhatnagar and Krishnan, and supported by Taylor in the Bangalore case on establishing but one centralised facility would have in turn found agreement with Cockcroft. Harwell was after all going to be a university type organisation. Like Bhabha and Bhatnagar, Cockcroft was anxious to develop that one good facility for state of art nuclear research in Britain. Cockcroft and Bhabha, but even Saha, had come to accept the logic and standards of atomic laboratories in the United States, one of "comprehensive provision". A centralised service organisation like Harwell would be able to provide a team of specialists on various machines, including particle accelerators along with the necessary administrative and ancillary services. Harwell should be able to procure expensive equipment that universities would not be able to obtain individually; and offer the opportunity for interdisciplinary research "beyond the university". Cockcroft did not understand why his arguments could be seen as not beneficial for the country. Universities in the United States, Cockcroft was perhaps thinking primarily of Berkeley, had expensive equipment and inter-disciplinary research

---

334

teams even before the outbreak of war. British universities were comparatively small, especially when it came to support services like engineers, technicians, contract officers, in fact hopelessly under-equipped to carry out "large scale developments. Bhabha and Taylor's doubts about the feasibility of a nuclear research facility, especially when they thought Krishnan's skills would be much better utilised if he instead chose to work at a centralised laboratory, could have been well informed by similar concerns.

3.17 Raman and Krishnan Respond

Building upon the arguments on budget, drawing on the authority of nationalism, participating in the mantle of the new state, and recommending the furtherance of Raman's research, Bhabha and Taylor reasserted the constraints of urgency upon nuclear research in the country thus presenting a fortified claim, but this was challenged by Krishnan. He submitted a note in response, endorsed by Raman.[335] The note served the purpose of registering Krishnan's disappointment with the decision but it was not to have any effect on the decision itself. Krishnan did not pursue the matter any further or mobilise support for his proposal after the decision.

Krishnan's note dealt individually with each of the four arguments against the establishment of a nuclear research facility in Bangalore. Krishnan presented, "The proposals put forward as well as the present note are accentuated only by one motive, namely, "the creation of an active school of nuclear physics research and thereby

[335] *Minutes of an Ordinary Meeting of the Council of the Indian Institute of Science, Bangalore*, Monday September 8 1947, "Note by Dr R. S. Krishnan, endorsed by Sir C. V. Raman", 30-32, IISc Archives.

maintaining the prestige of the Indian Institute of Science as one of the foremost centres of research in Physics in India". In his first argument on the insufficiency of budget, he proposed; "It is not the intention to embark on large-scale projects in several specialised branches (both theoretical and experimental) of nuclear physics *on the American model* but to concentrate only on specific fruitful branches as is being done in Universities and Research Institutions *in England*…." Krishnan had pitched his main argument finally from within the laboratory, and all previous references to the American model were rejected very explicitly in favour of continuing with the British or European model. The necessary scale of research for an Indian national program was a central theme in the Bhabha-Taylor report, and Krishnan's response was to emphasise the modesty of his scheme, justified again with examples of laboratories in Europe. He had to establish that he was not in competition with other laboratories in India, but this time round he wanted to say that his scheme was supplementing the efforts on the national scale, thereby important in the larger picture but nowhere as illustrious as the Bombay scheme.

Krishnan went on to argue that the research technology proposed was on an appropriate scale for these ends; "With this modest aim in view, the installation of a 3 MeV High Voltage Generator has been suggested…. That this generator cannot become out of date and useless in the near future will be evident from the fact that the Universities of Oxford and Glasgow are just now going in for 1 MV Generators. Suffice it is to say that at the Cavendish Laboratory, *the foremost Atomic Research Centre in England*, the bulk of nuclear physics research is still being carried out with a 1 MV set which was installed in 1936, in spite of the fact that the set is not suited for certain types of investigations."

Without going into a discussion of the scientific merit of Krishnan's claim, the assessment of his argument would depend on how aware the Committee members were of budget constraints for bigger machines to accelerate particles in Europe's reconstruction economy following the war. If the members of the Committee, especially Bhabha and Taylor, were convinced that European laboratories themselves were struggling to keep up with the increasing resources of American laboratories, and its results on experimental practice - Krishnan's insistence on positing the British model may not have been as convincing.

The number of staff for the facility, Krishnan argued was not underestimated; "It is common knowledge that in order to run a high voltage generator of the type proposed, what is needed is an experienced nuclear physicist devoting his full time and assisted by enthusiastic young research workers who are eager to learn and profit by their training and not a team of senior research staff members *as may be needed for running a cyclotron or a betatron*." Finally, he came to the sensitive argument of the "question of national importance", Krishnan foreground the shortage of trained scientific manpower and then offered his facility as one in need of encouragement in order to train "enough technical personnel for national projects if any to be started in India like the Harwell project in England. …I am encouraged to bring forward these facts because it is my earnest desire to be of service to the Institute and to the Nation in the wider context in initiating nuclear physics research here and to train as many students as possible in this field. As far as I can see there is no division of resources or effort of the country, as funds have *already been made available* to the Institute for the expansion of the Physics department of which this scheme forms a part of."

On the suggestion of developing the department of physics into a centre for research on solid state physics, Krishnan acknowledged that the Bangalore school had built a reputation but "the present line of investigation on the nature of the solid state will be handicapped in no small measure when the present Head of the Department retires …it is needless to point out that the lines of investigation pursued in any department <u>invariably depend on the head of the department</u>. After five years of persistent efforts, Krishnan did not succeed in realising the plan to begin nuclear physics research and education in Bangalore. He continued with research in solid-state physics. He did not make any further efforts to move to a location where he could pursue nuclear physics. Bhabha invited Krishnan to move to Bombay, but Krishnan did not accept. Referring to a conversation the two had on September 9 1947, Krishnan carefully considered the "problem".[336] He cited his involvement with the [Raman]- Born controversy which necessitated his continuing research in solid-state physics towards a successful conclusion.[337] Krishnan further cited his poor health as the other reason why he could not leave Bangalore and the Institute. Thus, "It may not be possible for me to accept your kind offer. I am fully aware that acceptance of your offer will give me exceptional facilities for work in nuclear physics and the pleasure of working in your institute… I am sure you will understand my position and agree with the stand I have taken". The response from Krishnan does not seem curt, but for that matter is not entirely convincing

---

[336] Krishnan to Bhabha, September 24 1947, RSK Papers.

[337] Sur, (1999), and R. Singh, "Max Born's Role in the Lattice Dynamic Controversy," *Centaurus* 43 (2001): 260-277.

either. That Bhabha and Krishnan met and discussed an appointment for Krishnan in Bombay signals cordiality between the two, and of Bhabha's positive judgement of Krishnan as a capable researcher.

Raman submitted a memorandum to the "Ministries of Government of India".[338] "Experimental scientific research in India", he argued, "necessarily suffers under the limitations set by the backwardness of the country in respect of technical and industrial progress". If huge expenditure can be justified at all in a context of limited sources, and insufficient infrastructure, research should be directed to "benefit the common man", a choice made with the necessary consequence "that support is denied to other objects which may be equally deserving and possibly even more urgent and important". In this context, "the chief interest of atomic investigations is the possibility of utilising atomic power for practical purposes". Given that "what remains to be solved is the engineering problem of [generating heat from a pile] in such a manner that the generation of power becomes economical". Raman was quite hopeful of that a "determined attack of this engineering problem may lead to a practical solution". This in itself was "a justification for public funds being expended on investigation conducted in India on the practical aspects of this problem". Raman, like Saha, approved of large-scale applied research, but "the scheme put forward by the Atomic Energy Research Committee bears no relation to … practical problems…."[339]

[338] C. V. Raman, *Memorandum* (1947), RSK Papers.

[339] Raman *Memorandum* (1947): 2.

The AERC was supportive of a betatron at the TIFR and a (synchro) cyclotron in Calcutta. The consequences of this decision, he wrote, were "brought home painfully" to him when recommendations of the AERC "torpedo[ed] the very modest scheme" put forward by R. S. Krishnan. Raman was convinced the AERC wanted to "create a monopoly in this subject for certain favoured laboratories and individuals in the exclusion of others". And he was right. In 1948, atomic energy was declared one of three areas of public monopoly.[340] Raman well understood that competition was necessary because of the large sums involved, but if successful, "it would have the result of starving out everyone else from the field". But this was "not in the general interests of the country' nor for the "progress of science in the great sub-continent". Concentration of atomic researches in the manner planned by the AERC was not going to contribute to the progress of India or the progress of scientific research.

Raman argued that the betatron and synchrocyclotron were intended for the "production of mesons", which was of theoretical interests only and had no practical significance whatsoever (Saha would reiterate this argument in a years time). Nonetheless, to begin large and expensive research projects "involving competition with other countries and in fields in which they are already the acknowledged leaders" would deprive "scientific institutions all over India of funds urgently needed for their development". He did not think this was justified at all, instead he suggested that the staff of the TIFR "construct with the materials available at their disposal a Betatron capable of producing particles of

[340] Francine Frankel, *India's Political Economy, 1947-77* (Princeton, N.J.: Princeton University Press, 1978), 77. The other two sectors under government monopoly were the manufacture of arms and ammunition and railways.

energy 1MeV, and make it work successfully within a set limit". If they were successful, the funds allotted to them were justifiable. If they wanted to buy the apparatus from abroad, "it may be safely predicted" he argued, "by the time it arrives in this country and is put successfully into commission, the original inventors in America would have advanced the designs to such an extent that the instrument purchased would soon become obsolete". Raman could not approve Bhabha's pursuit of the meson at public expenditure, more so if it meant other laboratories like his own were not going to be funded at all. Bhabha did give up on wanting the betatron altogether, but not because of Raman and later Saha's criticism of his ambitions.

Conclusion

One can but speculate on why Krishnan did not move to Bombay. Krishnan knew Raman was to retire in 1948, and he would succeed Raman as the chair of the department of physics. To some extent, this meant freedom to organise research, and the prominence and facilities that came with leading a department earlier led by a Nobel laureate. Moreover, if Krishnan did move to Bombay – it would be owing to his skills with the cyclotron. He was also aware of what it would take to build, maintain and run a cyclotron. It would mean less time for research, and shared resources with a team. There was little chance he could be his own master in an institution established and led by Bhabha. That in itself may not have appeared attractive if he wanted to build his own group and lead his own research. Three Germans and a Frenchman applied for Raman's position. Cockcroft recommended Krishnan and he was appointed. Krishnan continued research in solid-state physics and the Bangalore department became an important centre for solid-state research in India.

Raman was drawn to nuclear physics as an exciting new field in the early 1930s. Krishnan was fortunate to gain experience on the Cavendish cyclotron and had hoped to make good use of them once back in Bangalore. Through the end, he remained assertive and involved in the plans to establish nuclear physics at the IISc. Raman mentoring Bhabha, and as a leader in an institution patronised by the Tata's, both could have brought him industrial and political support for nuclear physics in Bangalore. For reasons both of personality and historical conjuncture, that did not materialise. Bhatnagar's need to consolidate an empire of laboratories without duplication of efforts; Bhabha's and Bhatnagar's (and many others) increasing belief that nuclear physics research could not be extended in university laboratories; Tata interests in Bhabha's fortunes; and the rift between Saha and Raman resulting in their failure to find shared interests, all contributed to that *a strong argument for funding nuclear physics research in university settings was never made*. Raman and Krishnan may have argued their own cause, and Saha later fought his own battles but no organised debate ever took place, at least not in a manner comparable to the way in which the argument for centralisation and concentration was presented through the AERC, and the CSIR.

In the fourteen-year history of the department, the government of Mysore, the [British] Government of India and later the AERC were closely involved in the management of teaching and researches at the Indian Institute of Science. As such, decisions made by the princely state, the colonial government and independent state had come to be seen as an expression and extension of national educational policy. This aspect of the IISc administration explains the context for Bhatnagar, and Bhabha's decisions. Raman and Krishnan may have contested their judgement, but their decision was accepted not as arbitrary state intervention, but legitimate state policy even at a historical moment when state power was not exactly configured. The state was affected in the decision.

Figure 3.3: R. S. Krishnan with Jawaharlal Nehru at the Indian Science Congress held at the Indian Institute of Science, Bangalore, 1951. Reproduced with permission from R. K. Ramanathan, son of R. S. Krishnan

CHAPTER 4: NOT ONLY SMASHING ATOMS - NUCLEAR PHYSICS AT THE UNIVERSITY SCIENCE COLLEGE, CALCUTTA, 1938-1955

> "The fact of the matter is that we have very little equipment but we have some. My own interest in this business [atomic energy] is not a very new interest. I think the first time the question came up before me was before the last war, and I was instrumental in helping one of the universities in India to get the first cyclotron machine into India… But the point is this: are we going to carry on in that petty, local, limited way or are we going to set up what is called a pile; it may be a small pile."[341]
>
> Jawaharlal Nehru, (January 1948).

Meghnad Saha at the University College of Science, Calcutta led the attempts to build the very first cyclotron for nuclear physics research and education on the Indian sub-continent. Saha sent his young student Basanti Dulal Nagchoudhuri (henceforth Nag) to the University of California Berkeley, the "Mecca of cyclotroneering", to read for a doctoral degree in nuclear physics. Nag would learn the intricacies of building and running a cyclotron and come back to India to establish a particle accelerator facility. Combined with his awareness of nuclear physics as the emerging frontier of physics research, and his fascination for the "nucleus-buster", Saha's quest for the cyclotron was deeply embedded in his pledge to the larger project of building a modern India, fully equipped to function culturally as an equal among equals in the moral economy of international science. Whereas Raman and Krishnan failed to establish nuclear physics in Bangalore, Saha and Nag were successful in instituting both a teaching and research program in nuclear physics in Calcutta, even though the cyclotron itself took 14 years to

---

[341] Jawaharlal Nehru, Atomic Energy Bill, Speeches on the Atomic Energy Bill in the Constituent Assembly of India, Legislative, on April 6 1948; *Constituent Assembly of India (Legislative) Debates*, Official Report, Vol. V, No. 1, pp. 3315-17; Reproduced in *Pandit Jawaharlal Nehru on Atomic Energy* Bombay: Bhabha Atomic Research Centre, 1989.

be fully operational. The cyclotron, I will argue, became the organizing principle in the Palit Laboratory, University Science College, Calcutta, and later in the Institute for Nuclear Physics, for the entire endeavour or enterprise of establishing nuclear physics research and education in Calcutta.

Saha's active engagement with nationalist politics of the Indian National Congress enabled him to secure funding for the cyclotron project as a part of a larger commitment to nation building. Even though his pre-war connection was the Radiation Laboratory at Berkeley, the scale of the Calcutta apparatus and its goals were largely those of a small university laboratory. The cyclotron would be used for basic research, but more so for training graduate students in laboratory technology for nuclear physics. By war's end, the significance of the field was significantly recast. With this scaling up in political significance and in no mean way, of the nature and size of research equipment, many considered centralisation of nuclear research inevitable. Saha scaled up the university laboratory into an independent institute for nuclear physics within a year of Indian independence, but centralisation of nuclear research for India was not a matter of creating a comprehensive research facility alone. Nuclear research had to be connected to scientific industrialism that Saha himself had championed since the 1930s. But even more so, national security interests would also have to be addressed, and for that one required not only political and industrial alliances, but also an engagement with the state apparatus for funding and acquire nomination for the mandate. Saha's ambition to establish his laboratory as *the* central laboratory for nuclear research in India was not realised. But that is only one part of the story.

Another part is about the successful transformation of a university laboratory into a research laboratory for fundamental research and advanced education in nuclear physics. The construction of the cyclotron, led by Saha's student Basanti Dulal Nagchoudhuri, played a central role in this transformation. The change was accomplished within the larger context of transition of India, of nuclear physics and international politics. Work on the cyclotron in Calcutta began as a nationalist project under late colonial rule and Saha's main claim outside the laboratory was of contribution to medical problems. Once the nuclear field began to be gradually established after 1945, the Calcutta project was rendered local and petty in competition with the Tata Institute of Fundamental Research, Bombay that was established with clear connections to industry. This meant that even if funding scaled up significantly for the Calcutta laboratory in comparison with their pre-war budget, requirements for nuclear research had risen so high, that it was not money enough to establish and maintain a comprehensive facility. Industrial infrastructure especially for electronics components in India was far from developed or reliable, but even money could not buy everything in the international market. Components and apparatus for nuclear research could not be easily imported in the immediate years after the war. The Americans were not willing to share, and the Europeans, including the British were anxious to establish their own facilities as a part of the larger process of post-war reconstruction. Construction on the Calcutta cyclotron was continually troubled with shortages of components and trained technicians, as much as laboratory personnel were struggling with the instability of Calcutta's political environment during wartime, being close to the Eastern front and later with the violence of partition. Difficult as it was, construction on the cyclotron was completed in 1954 and the laboratory continued to receive steady and increasing state funding. Saha was not actively engaged in nuclear physics research himself (even though he was to some extent engaged in cosmic ray physics research), but he began by wanting to equip his laboratory for cutting edge research. The transformation of a university laboratory into an independent research institute with a working research cyclotron, but moreover, with a broad agenda for advanced education was no mean achievement. Saha and the members of the Palit Laboratory may have felt the loss of priority in the national context, but they began as and remained the only significant laboratory engaged with basic research in nuclear physics outside direct state control up until 1955. This chapter furthers the main arguments of the thesis in narrating how the origins of nuclear physics as a research field in Calcutta was motivated by the modernist imperative of the field; and further more, how the emergence of a national-statist nuclear field recast the laboratory's significance and delimited its research pursuits.

4.1 University Science College (USC), Calcutta

The University College of Science was established in 1914 as a part of the University of Calcutta, the same year as the Great War began. The University of Calcutta itself was established in 1857 but did not have teaching responsibilities or for that matter a faculty of science. The universities primary responsibility was one of conducting examinations and awarding degrees. Teaching continued in affiliated colleges, and hardly any advanced teaching or graduate research was offered. The Indian Universities Act of 1904 had allowed universities to receive endowments, appoint professors and lecturers, and have their own teaching agendas.[342] George Nathaniel Curzon, the Viceroy General of India, introduced this act around the same time that the decision to establish an Indian Institute of Science was being publicly debated. Almost ten years after the act, the University College of Science (USC) was established with philanthropy thus generated.

In the sub-continents history, Lord Curzon is remembered less for the Indian Universities Act of 1904 than for the much controversial partition of Bengal in 1905, an event that had significant consequences in the prelude to the establishment of USC. The *Swadeshi* Movement took momentum in protest of partition, and it was in the insistence of providing self-created opportunities, services and products within India that the National Council for Education was established in Bengal in 1906.[343] A small section of this Council broke away and established the Bengal Technical Institute on July 1, 1906. Sir Asutosh Mukherjee, then Vice Chancellor of the Calcutta University, persuaded philanthropists to donate their funds and the infrastructure of the Institute to the university (1912). He was unable to persuade the [British] Government of India to make matching grants to the endowments, but could nonetheless secure some capital grant and a small recurring grant from the Government and some from the Reserve Fund of the

---

[342] S. C Ghosh, "Calcutta University and Science," *Indian Journal of History of Science* 29, no.1 (1994): 49-61. Presidency College of Calcutta, established in 1817 and then called the Hindu College, where Saha studied for his degree was one such college where advanced degrees and some research in science was carried out. Jagdish Chandra Bose and Prafulla Chandra Ray were professors in physics and physiology, and chemistry respectively at the Presidency College when Saha was a student. Meghnad Saha and Satyendranath Bose were classmates at the Presidency College, Calcutta and J C Bose taught them physics during undergraduate studies. Together they wrote the first English translation of Einstein's theory of relativity in 1916.

[343] See Sumit Sarkar, *The Swadeshi Movement in Bengal, 1903-1908* (Delhi: People's Publishing House, 1973).

Calcutta University.[344] The college opened its doors to students in 1916, in the midst of WWI, in a city ridden with food and clothing shortages. Chandrasekhara Venkata Raman was appointed the first Palit Professor in physics (1917), Debendra Mohan Bose was appointed the first Ghosh Professor in applied physics (1920), and Meghnad Saha was recruited as the first Khaira Professor in Physics (1921).[345] With three chairs in physics alone, the young institution made an ambitious start.

4.2 Meghnad Saha and Nuclear Physics

When Meghnad Saha was offered the Khaira Professorship at the USC in 1920, he wrote his acceptance to the university chancellor Asutosh Mukherjee from the laboratories of Walther Nernst, professor of physics at the Friedrich Wilhelm University, Berlin. Saha was working on experiments in high temperature physics in Nernst's laboratory. He wrote, "On my return to India, I wish to continue this line of research and if you are good enough to procure for me a research grant of about £500, I shall be able to organize a laboratory where, besides work in this line, we can also take up industrial works

[344] Taraknath Palit gifted a sum of Rupees 1.4 million for "the promotion and diffusion of scientific and technical education and the cultivation and advancement of science, pure and applied, amongst his countrymen by and through indigenous agency" in 1912. A year later, Rashbehary Ghosh, donated Rupees 1 million for "the furtherance of the University College of Science", endowing four chairs in (i) applied mathematics, (ii) applied physics, (iii) chemistry, (iv) botany, along with eight studentships for graduate research assistants. The earnings from the fund were to maintain a chair in physics and another in chemistry, with the infrastructure being maintained by the University. The funds also provided for distinguished graduates to pursue higher studies in science in an "advanced country", with funding from the Palit endowment.

[345] The Palit and Ghosh chairs were named after the endowments (cf. 4) and the Raja of Khaira, king of a princely state, endowed the Khaira Professorship.

connected with high temperature (such as ceramics, enamelling and glass, and metallurgy)".[346]

Upon his return from Berlin in 1921, Saha joined the department as Khaira Professor but within two years, he left for University of Allahabad. He had not received sufficient grants to buy equipment and the laboratory lacked proper facilities for graduate research. Saha had maintained an interest and engagement with experimental physics through his constant attempts at experimental verification of his own theoretical work in thermal ionization in relation to stellar spectra.[347] This was one of his main motivations for his trip to European laboratories in 1920-21. Not satisfied with the condition of the laboratory, he urged the chancellor to approach philanthropists, "While European and American scientists are eagerly extending their activity into the region opened up by me, here owing to lack of funds, I have been doomed to a state of torpor and inactivity."[348] Saha had developed two useful connections to fund his ambitions for an up-to-date laboratory: he wanted to seek philanthropic donations and he could provide services for

---

[346] MNS to Asutosh Mukherjee, 20 August 1921, Meghnad Saha Papers, Nehru Memorial Museum and Library, New Delhi (Henceforth MNS Papers, NMML).

[347] John Eggert, a student of Walther Nernst in Berlin showed that ordinary thermodynamic expression for the effect of temperature on the equilibrium of chemical reactions can be applied to the calculation of the extent to which under different conditions neutral atoms of the gaseous elements are converted into positive ions and free electrons. Saha developed this theory further and introduced the ionization potential of the element. He tabulated the values of this percentage ionization at various temperatures and pressures and noted the significance this held for the interpretation of the spectra of elements under solar and stellar conditions. See Arthur A. Noyes and H. A. Wilson, "The Thermal Ionization of Gaseous Elements at High Temperatures: A Confirmation of the Saha Theory," *Proceedings of the National Academy of Sciences of the United States of America* 8, no.10 (1922): 303-307. His research interest required very good telescopes and equipment that could withstand high temperatures. These were not easily available to him and they were difficult to obtain even in England as he found out during his stay in Alfred Fowler's laboratory at the Imperial College, London. He later travelled to Howard Shapley's laboratory at Harvard where it appeared possible to pursue this work.

[348] MNS to Asutosh Mukherjee, December 6 1922, MNS Papers, NMML.

industry. Saha's entrepreneurial skills would continue to be important in the coming years for his activities both as a scientist and in his commitment to nation building.

Saha began to make applications for positions at other universities in India. He was offered professorships at the Benaras Hindu University and the University of Allahabad. Saha moved to Allahabad where he stayed for the next fifteen years (1923-1938). In his attempts to furbish a laboratory, among others he wanted to make an application to the Rockefeller Foundation.[349] Saha did not eventually have the perfectly equipped laboratory or library in Allahabad either, but he managed to build a group of young and enthusiastic researchers. The teaching load, as he confessed, was rather heavy leaving only the hot summer months for research work, which Saha and his students nonetheless carried through. It was during these years that Saha was elected a Fellow of the Royal Society of London.[350]

---

[349] Saha wrote to Robert Millikan at Caltech and Henry Norris Russell at the Princeton University to support an application to the Rockefeller Foundation or the Carnegie Trusts for buying scientific apparatus. Robert Millikan in turn asked CV Raman, who incidentally was in Caltech at the moment, if Saha's request for funding was justified. Raman is quoted to have said, "[while] Saha has done some excellent theoretical work, he is in no sense an experimentalist or an organizer, and funds spent in the way Saha requested would not be likely, he feared, to represent the wisest expenditure which could be found… if Saha had inspired confidence in India in his ability to get results through the organization and direction of research he was confident that it would not have been necessary for him to apply in this country". Russell agreed with Millikan and added that Fowler had made similar remarks about "Saha's attitude" in the laboratory. They both agreed on writing cautious letters to Saha regarding his request. Letters: MNS to HNR and RRM (September 18 1924); RRM to HNR (October 21 1924) and HNR to RRM (October 27 1924); in the Henry Norris Russell Papers, Princeton University. Copies obtained through kind courtesy of David DeVorkin.

Raman was aware that Saha had resigned from the Khaira Professorship because of lack of experimental facilities. I am not sure if Saha heard of Raman's opinion of his scientific practice, but the two men seem to have always shared a tense relationship.

[350] Saha's election as a Fellow of Royal Society in 1927 was not uneventful. He was proposed by Alfred Fowler and seconded by G. T. Walker. There was a serious discussion about his politics because he was in Berlin during the War, which the [British] Government of India claimed was a centre for "Indian revolutionaries". He was "in receipt of literature" from the "well known Bolshevik, M. N. Roy" and he was alleged to have sheltered Nalini Gupta, "who was convicted in the Cawnpore Bolshevik Case".

Saha was awarded a grant by the Carnegie Corporation (1936) and he set out on what would later prove to be a momentous trip.[351] Among the several invitations he received and the appointments he made, one went to Niels Bohr at the Institute for Theoretical Physics, Copenhagen. It would be a pleasure, Bohr replied, "that you may be able to join our informal conference on atomic physics".[352] The Institute in Copenhagen at this juncture was in the beginning stages of building a cyclotron with money from the Rockefeller Foundation.[353] This would be but the first atom-smasher Saha encountered on his trip. At the meeting, he must have also met the young Indian physicist, Homi Jehangir Bhabha.

Saha continued his journey to the observatories in Harvard, Princeton and Mount Wilson. On August 25 1936, Saha wrote to Ernest O. Lawrence at the Radiation Laboratory of the University of California, Berkeley. He was eager to see the famous "cyclostat" laboratory in Berkeley.[354] Lawrence and Saha had earlier met in Berlin along with Lawrence's

---

[351] Saha travelled to the United States and Europe. The Universities Bureau of the British Empire proposed Meghnad Saha for the grant. Ernest Rutherford and Arthur Eddington at the Cavendish supported his application. His grant was awarded for "work on astrophysics hampered by lack of a good library and lack of facilities to carry on observational work". "Universities Bureau of the British Empire, 1930-38," Series III. A, Box 356, Folder 8, Carnegie Corporation of New York Records.

[352] Niels Bohr to MNS, May 19 1936, Niels Bohr Papers, NBA, Copenhagen.

[353] For details on the conference see Finn Aaserud, *Redirecting Science: Niels Bohr, Philanthropy and the Rise of Nuclear Physics* (Cambridge: Cambridge University Press, 1990), 235-237.

[354] MNS to EOL, August 25 1936, EOL Papers. It is incredible that Saha should have made the mistake of calling the cyclotron 'a cyclostat'.

colleague, Jesse Beams in 1927.[355] Saha took that trip to Berkeley. He left much impressed.

Back in Harvard only a few days later, he wrote to Lawrence again. “Since my arrival at Harvard, I have been thinking of writing to you about the cyclotron. The more I have been reading about it, the more I am impressed with its wonderful promise as a weapon of attack on the nucleus”.[356] “I have been hoping” he further wrote, “to get some grant for opening a section in my laboratory on nuclear physics, but I have not yet succeeded. Hence, I am compelled to defer my decision about the construction of a cyclotron. But I hope that if I succeed in getting the grant, you will kindly help me with advice and the help which you were kind enough to promise”. Saha wrote this letter on the last day of the Harvard Tercentenary Conference of Arts and Science.[357] One lecture on the use of isotopes as indicators in biological research from the conference would stay well in his mind. The lecture was delivered by August Krogh, a biologist from the Copenhagen University who was also closely associated with experimental biology program at Bohr’s Institute for Theoretical Physics. For Saha, the lecture made a crucial link between cyclotrons and medical research, a practice and an argument that would be made again and again in the immediately following years. Four years later, he would evoke the

---

[355] Ernest Lawrence and Jesse Beams worked together on very fast electric switches incorporating Kerr cells at this time. Lawrence had then recently worked on photo-ionization, which may have provided them common interest. See Heilbron and Seidel, (1989), 22.

[356] MNS to EOL September 12 1936, EOL Papers.

[357] The Harvard Tercentenary Conference was held from August 31 to September 12, 1936. Krogh’s lecture seems to have stayed with Saha as he well recalled it four years later. There were many other physicists, and chemists of renown at the meeting discussing also cosmic radiation and nuclear physics, like Otto Struve, Arthur Eddington, Robert A. Millikan, Arthur Holly Compton, W. F. G. Swann, Merle A. Tuve, Gregory Breit, Eugene Wigner, Peter Debye, to name a few.

argument decisively to solicit funds for his cyclotron as a medically useful tool. Cyclotrons and nuclear physics research figured prominently in almost every single scientific assembly during Saha's journey thus far. After his trip to Berkeley, Saha began to visit cyclotron laboratories purposefully with the intention of planning to build one back home.

Barely a fortnight later, Saha wrote yet another letter to Lawrence. His next stop was the Princeton cyclotron. Milton White, the Berkeley trained cyclotroneer in Princeton found in Saha a knowing audience. He had read reprints from the Rad. Lab and had been able to follow the details on the Princeton assembly, he said. A discussion on the costs involved left him disheartened. "It made me sad" he said, " since such an apparatus will be beyond my purchasing power."[358] It was clear that trying to build one without substantial funds would be futile activity. Not entirely dispirited, he laid out the first ideas for an installation they would begin building in Calcutta more than five years later. He could begin with a "very small cyclotron, say something like your [Lawrence's] first one" to gain experience. The materials, he could buy in England.[359]

The journey proved immensely important in more ways than one for Saha. He had begun the journey with the Copenhagen meeting. Back in London on his way back to India, Saha wrote a confidential letter to Niels Bohr. Arthur Holly Compton at the University of

---

[358] MNS to EOL, September 22 1936, EOL Papers. White informed Saha that the costs for the materials of the cyclotron would be nearly 12 000 dollars, perhaps an underestimated cost anyway.

[359] It is not clear whether Saha refers to the 11 inch experimental cyclotron built by Stanley Livingston in 1932 (Heilbron and Seidel (1989) pp. 100-101, 135) or the 27 inch cyclotron based on the Poulson magnet (Heilbron and Seidel (1989) pp. 127-135).

Chicago supported by Paul J. Langevin at the Collège de France, were proposing Saha for the Nobel Prize. He wanted Bohr to support this nomination.[360] The nomination did not result in an award, but Saha returned well established within the physics community as an important scientist.

Back in Allahabad after this rather eventful trip, things slowed down a bit. Saha wrote to Shapley about how spoilt he felt after working at the Harvard Observatory and in the "Shapley atmosphere". This would turn out be his last year in Allahabad. He was proud of his graduate students– a team he would be proud to present to Bohr on his trip to India for the Indian Science Congress of 1938.[361] Saha had not lost sight of the plan he laid out to Lawrence in his last letter of September 1936. As the first step, he recommended one of his graduate students for graduate studies at Berkeley. In August 1938, Basanti Dulal Nagchoudhuri sailed for Berkeley.

---

[360] MNS to Niels Bohr September 30 1936, MNS Papers, SINP.

[361] MNS to Niels Bohr September 14 1937 MNS Papers, SINP; The team was Daulat Singh Kothari, (Astrophysics) who would become scientific advisor to the defence ministry in 1947 and write the official Government of India publication on the effects of nuclear explosions; R. N. Ghosh (Acoustics); G. R. Toshniwal (Wireless Telegraphy), who would establish a radio and electronics manufacturing business in free India; P. K. Kichlu (Spectroscopy) and Romesh Chandra Majumdar (Astrophysics). The last of these, R. C. Majumdar also attended the Copenhagen meeting in 1936.

4.3 An Indian in Berkeley, California

Experimental physics research in the 1930s was moving from the study of the atomic shell to the core – i.e. the nucleus and nuclear physics.[362] Even if Europe still maintained a lead in discoveries in nuclear physics, the United States took lead in the development of nuclear research technologies, especially in building particle accelerators.[363] Ernest Lawrence, Stanley Livingston and the team at the Radiation Laboratory of the University of California Berkeley were responsible for working the cyclotron principle of accelerating particles to higher energies. Success in Berkeley was followed by several attempts to build the cyclotron at various other laboratories in the US and in Europe.[364] It was normal to take several years to complete a cyclotron, and it was always a big step for accelerator builders to make the transition to becoming experimenters and actual accelerator users themselves, if at all.

In January 1940 Edward Condon of the Westinghouse Research Laboratories wrote to Ernest Lawrence that he was coming to Berkeley; "At Berkeley of course, I hope to learn all about cyclotrons and about nuclear physics in general and medical tracer work." Berkeley was the place to go if one wanted to learn *all about cyclotrons*, and ancillary research agendas. "I will bring along", he continued, "a hatful of slides about our atom

---

[362] For an overview on the transformations in nuclear physics in the 1930s see: Roger H. Stuewer, *Nuclear Physics in Retrospect: Proceedings of a Symposium on the 1930s* (Minneapolis: University of Minnesota Press, 1979).

[363] For a general history of particle accelerator techniques in the 1930s, see Heilbron and Seidel, *Lawrence and his Laboratory: A History of the Lawrence Berkeley Laboratory I* (Berkeley: University of California Press, 1989), especially 45-102.

[364] See John Heilbron, "The First European Cyclotrons," *Rivista di Storia della Scienza* 3, no.1 (1986): 1-44.

smasher …”.[365] The Berkeley team was a good group to discuss one’s equipment with, after all they were constantly engaged in improvising and scaling up the machines making them only bigger and bigger, and building them in even more places. Almost all early cyclotrons were built either with help from a physicist/technician from the Lawrence laboratory in Berkeley, or by sending a scientist/technician to the laboratory.[366]

Saha recommended Nag as a good candidate, and trained him for work in Berkeley. Nag pursued extra lessons nuclear physics and cosmic rays. More so, he was given lessons in research techniques, especially in “manipulation of wireless apparatus” for which there were good arrangements in the Allahabad laboratory.[367] Saha was aware that Nag would be entirely new to the experimental world in Berkeley and expressed faith in his abilities to help himself.[368] Lawrence accepted Nag as a PhD candidate and reiterated his willingness to help with the construction of a cyclotron in India should funds became available. Lawrence sent diagrams and blue prints of the cyclotron. The fresh graduate, a self-funded student on his way to Berkeley, set asail on S.S. Cilicia on August 5 1938.

A letter from Nag’s father, U. C. Nag, arrived in Berkeley before Nag reached California. Nag’s father, a professor of English at the Benaras Hindu University informed Lawrence that his son would like to work with the Radiation Laboratory. He inquired about the

---

365 Edward U. Condon to EOL, January 4 1940, EOL Papers.

366 See Robert Seidel, “The Origins of the Lawrence Berkeley Laboratory,” in Peter Galison and Bruce Hevly, eds., *Big Science: The Growth of Large Scale Research* (Stanford: Stanford University Press, 1992).

367 MNS to EOL March 26 1938, EOL Papers, G. R. Toshniwal, a student at the laboratory was involved in research on wireless technology.

368 MNS to EOL July 30 1938, EOL Papers.

expenses in Berkeley for a man "of very average means" and expressed his pleasure and deep desire for his son to study in Berkeley. Not in the least, because his own older brother had studied at the same university almost 30 years before. That his uncle had been a student at Berkeley was a lucky coincidence but it was of no mean importance that Nag came from a family of means to support his studies abroad.

Like he had promised Nag's father, Lawrence took good care of the young recruit. He helped find a place to stay and invited him over for dinner, making effort to make his arrival easy. Nag had arrived in a Radiation Laboratory with a routinely operational 37-inch cyclotron, an enlarged version of the old 27-inch cyclotron.[369] The twenty-one year old young boy still used to signing his letters "yours obediently", had arrived from a department largely integrated around one professor and his research agenda. A laboratory converging upon a research installation now confronted Nag. His first taste of laboratory life in Berkeley was a page long memo enlisting suggested electrical and mechanical maintenance operations on the 37-inch cyclotron, William Brobeck noted: "Mimeographed check charts could be made similar to those used in automobile service stations".[370]

---

[369] Heilbron and Seidel, (1989), 269-281.

[370] William M. Brobeck to Donald Cooksey, July 29 1938, EOL Papers, Cooksey Folder; for Brobeck's role in Berkeley see Heilbron and Seidel, (1989), 228. Brobeck was a mechanical engineer and he took over general planning of new cyclotrons at Berkeley in 1936.

Nag found the "dedication of the lab men to Lawrence" and "the responsibility he felt for them" quite impressive.[371] Lawrence was also convinced of his new student and recommended him for a teaching assistantship in February next year. Nag had done "surprisingly well" in his preliminary examinations in electricity and magnetism and had demonstrated with his work in the Rad. Lab that he was also "very good with his hands".[372] Settled into the routine of the laboratory, the next two years in Berkeley were eventful. The very next year Lawrence was awarded the Nobel Prize for his successful implementation of the cyclotron principle. Lawrence also found time to write back to Nag's father and Saha, two people who wrote to him relentlessly about Nag's performance in Berkeley. He informed them that the young student was well trained in physics, doing rather well and was proving himself capable of independently handling experimental work.[373] "In his first year he did particularly fine work, but this summer, [he is] rather attracted to the California scenery and climate. However, I gave him a talking to, and now he is hard at work again and is getting some interesting work accomplished."[374] Nag completed sufficient work to be awarded a doctoral degree for his thesis "*An investigation of the three artificially radioactive isomers Zn 69, Br 80 and Pt 197"* in a year's time. His accomplishments at Berkeley would be put to harsh test once

---

[371] Herbert Childs, *An American Genius: The Life of Ernest Orlando Lawrence* (New York: E. P. Dutton and Co, Inc., 1968), 267.

[372] EOL to Raymond T. Birge, February 21 1939, EOL Papers.

[373] EOL to U. C. Nag November 27 1939, EOL Papers. In the two years that Nag was in Berkeley, his father wrote regularly to Lawrence inquiring after his son and for advice in matters of the journey back home during the war; Lawrence wrote in this letter, "Being a father myself, I think I can sympathize completely with your concern for your son so far from home, and I am glad to send you assurance of his excellent progress".

[374] EOL to MNS, January 11 1940, EOL Papers.

he began to replicate the cyclotron back in Calcutta. A year into WWII, he was ready to leave for India.

4.4 Beginnings of the Calcutta cyclotron 1940-44

On November 14 1940, Saha sent a telegram. Nag had to be stopped from leaving the USA, and instead begin the purchase of equipment for a cyclotron at the Palit Laboratory, University Science College, Calcutta. Just to make sure, he sent a letter to Nag's father as well.[375] While Nag worked on his PhD, Saha had moved to Calcutta as Palit Professor of physics and raised funds to build his own nucleus busting installation. Saha was no stranger to the University Science College Calcutta, having left the College in 1923. Returning to the same department and the city of his alma mater fifteen years later, a much accomplished man in science with a good measure of political influence, he came convinced that if he had to build a credible department of physics and laboratory, he had to encourage nuclear physics research.

Immediately before Saha, Debendra Mohan Bose held the Palit Chair in Physics (1934-38) and was interested in radioactivity research and cosmic ray physics. He was leaving the position to move next door as director of the Bose Institute established by his uncle, the physicist and physiologist, Jagdish Chandra Bose. Of the other two chairs, Sisir Kumar Mitra working on radio physics occupied the Ghosh Chair in applied physics and B. B. Ray working with cosmic ray physics occupied the Khaira Professorship. Saha

[375] MNS to U. C. Nag November 11 1940, EOL Papers.

began a serious reorientation of the laboratory and teaching perhaps with more faith this time round to be able to raise funds for constructing a cyclotron and he was proved not entirely wrong. That however, does not seem to be the only plan he had in mind.

THE BINA SCIENTIFIC INSTRUMENT COMPANY, CALCUTTA
From L to R : Prof. M. N. Saha, Mr. Akshay Kumar Saha, Mr. K. L. Saha (Proprietor)
Photograph probably taken in 1945

Figure 4.1: Meghnad Saha at a local Scientific Instruments Manufacturing Unit. Reproduced with permission from the Meghnad Saha Archive, Saha Institute of Nuclear Physics, Calcutta.

The Palit professorship and its incumbent laboratory was the first chair in physics at the USC, established and first held by C. V. Raman (1917). D. M. Bose took most of his equipment with him and that was Saha's opportunity to refurbish the laboratory around his own research agenda. Beginning anew, Saha could reorient teaching and research ambitiously. Saha's initial attempts were aimed at transforming the laboratory and associated teaching from primarily undergraduate teaching towards (post)-graduate research. Carrying over his experience from Allahabad, he appointed young assistants. Saha introduced nuclear physics as a compulsory subject in MSc physics curricula of the Calcutta University in 1939.[376] In the next ten years, Saha established the concerns of the Palit laboratory as engaged with broad-based nuclear physics education and research, especially strong in biophysics, and nuclear chemistry.

Barely a year after Saha moved to Calcutta, the unexpected discovery of nuclear fission by Otto Hahn and Lise Meitner in Berlin in 1938/9 further boosted the interest for nuclear physics worldwide. Saha found added inspiration in the event and published a short note on uranium fission in *Science and Culture*.[377] A war began in Europe, and the year ended with the announcement of the Nobel Prize for Ernest Orlando Lawrence. Many a cyclotroneer rejoiced in this newfound weight of justification to continue with their expensive and difficult projects. Raman expressed his proud association with the cyclotron by informing his audience of Krishnan's work at the Cavendish. But here was Saha's student studying with the master himself! Saha expressed his appreciation that Nag had been accepted as a student and congratulated Lawrence with the same sense of agency as he had invited Nehru to lead the National Planning Committee the previous

---

[376] An optional paper in advanced nuclear physics was introduced for the same course in 1941.

[377] "Uranium Fission" (1940) in *Science and Culture,* which was the journal of the Indian Science News Association started by Saha in 1934.

year; “On behalf of Indian physicists and myself, I wish to congratulate you on your well deserved honours”, he wrote.[378]

Saha’s understanding of the changing frontiers of modern physics was shaped in no mean measure by his experiences on the journeys he took in 1936. August Krogh’s lecture at the Harvard Tercentenary, the Copenhagen particle accelerators within the Institute for Theoretical Physics and Ernest Lawrence’s laboratory in Berkeley established for him the centrality of a particle accelerator in nuclear research. In a public lecture Saha told his audience (in third person, a style peculiar to his time); “The lecturer visited some four years ago the International Congress of Physical Medicine which was held in London in 1936 [...] There he realized for the first time the great part which physics was destined to play in the near future in the art and profession of healing. Later he attended the Harvard Tercentenary where Prof. Krogh of the university of Copenhagen gave a lecture on the use of isotopes as indicators in biological research.[379] Last year the Rockefeller Foundation of New York devoted a large part of its report to the description of the cyclotron, the latest physical apparatus used for "Nucleus-busting" and the development of the science of molecular biology, which makes use of recent advances in the physics of the nucleus of the atom. All these indicate the growing importance attached by medical

---

[378] MNS to EOL, November 14 1939, EOL Papers.

[379] For more on August Krogh and the Copenhagen experimental biology proposal see Finn Aaserud, (1990), 191-198.

men to the recent discoveries in physics and their eagerness to utilize them for medical research."[380]

By the time he left for Calcutta, Saha was deeply involved in nationalist politics through this active participation in the National Planning Committee. Saha, like others participating in the NPC, supported Nehru's leadership because he found it ideologically acceptable and politically necessary at a critical juncture of Indian nationalist politics when the organization of development in free India was deeply contested. His relationship with Nehru proved crucial for the beginnings of the cyclotron project, as Saha approached Nehru for support to raise funds.

Before Saha approached Nehru to seek funds from the Dorab Tata Trusts, that very connection with the Tata Family had already been made, of all places, in Berkeley. John H. Lawrence, Ernest Lawrence's brother and a medical doctor working with leukaemia, was also working at the University of California Berkeley. The brothers agreed on the possible benefits of cyclotrons in medical research, and for treatment of cancers, and they discussed this with other physicists.[381] Ernest Lawrence had also evoked this argument to raise funds for cyclotroneering from the Rockefeller Foundation and as an argument, it

[380] M. N. Saha (1940) Physics in aid of Medicine, Public Lecture at the Royal Asiatic Society of Bengal in *Science and Culture*, 6, 49 and 110 (with P. K. Sen); reprinted in Santimay Chatterjee, ed., *Collected Works of Meghnad Saha* IV (Calcutta: Orient Longman Ltd and Saha Institute of Nuclear Physics, 1993).

[381] EOL to Arthur Holly Compton, September 19 1938, Lawrence wrote; "In response to your request, I am glad to put in writing the substance of the views of my brother and myself which were brought out in our conversation of yesterday. Doctors Ewing and Mood and other leaders in the field have emphasized the fact that the direction offering the most immediate promise of practical advances in cancer therapy is that of radiation. … May I urge again the view that the great cancer centres should have the new radiation implement at their disposal, and may I assure you that in the event of an undertaking to install cyclotron equipment in other medical centres, we will do everything in our power to be of assistance."

was coming to be well rehearsed in physics circles familiar with the Berkeley system. Donald Cooksey wrote to Ernest Lawrence with information on a "source of money to fight leukaemia". He noted the Tata family in India, and scribbled Saha's name next to it. The Tata family, Cooksey mentioned had set up a large foundation for funding leukaemia research, and owned "big iron and steel works in Jamshedpoor". It is not at all clear if their source of information was Saha, or if he was the one they would contact for further information. But given Berkeley practice with its coupling of medical research and physics, they had identified a source of funding in India, and possibly discussed this with Nag.[382]

Saha argued for funding stressing upon the medical uses of the cyclotron. Nehru in turn evoked the argument in his letter to the Dorab Tata Trusts. "From the point of view of medical research and relief, the most remarkable property of the Cyclotron is to make ordinary atoms like those of sodium and phosphorous radio-active like radium. …I have gone into this matter to some extent and I feel sure that the Cyclotron is going to play an important part in medical research in the future."[383] Saha's quest for the cyclotron was also supported by the directors of two local medical research institutions of "high repute". Colonel R. N. Chopra of the School of Tropical Medicine and Hygiene and Dr. J. B. Grant of the All India Institute of Hygiene and Public Health, both, Nehru claimed had

[382] Donald Cooksey to EOL April 29 1938, EOL Papers, Cooksey Folder.

[383] Quoted in N. N. Dasgupta, (1954) *Plan for an Institute of Medical Physics* Calcutta, Institute of Nuclear Physics publication to raise funds for a separate institute. There is no specific date given for the letter, but mentioned to be written in 1940.

encouraged Saha's ambitions because they had identified in the cyclotron possible benefits for medical research and treatment.

Arguments for producing isotopes and radium were important to the Dorab Tata Trusts who were working on the establishment of a cancer hospital and research centre in Bombay.[384] The hospital opened in February 1941, a year after the trust made their grant for the Calcutta cyclotron. The Dorab Tata Trust could have been convinced for several other reasons as well. This was not the first time they would be making a grant for purposes of higher education and research. Additionally, Saha's application came within a year of Ernest Lawrence's Nobel Prize. If this meant visibility for the cyclotron and its activities, Saha could claim a share of that prominence in his student at Berkeley. The grant was for Nag to come back and build one in Calcutta. The Rockefeller Foundation report had also devoted pages to explaining the cyclotron installation just the previous year. It was well within the mandate of a large philanthropic foundation to patronise what appeared to be a promising research facility with (medical) institutional, political and academic support.

An insufficient but nonetheless significant amount of money - Rupees 60 000 was granted by the Dorab Tata Trusts in 1940. This became the "nucleus for further

---

[384] M. K. Subramaniam, "Tata Memorial Hospital for the Treatment of Cancer and Allied Diseases," *Current Science*, (July 1945): 140. As early as 1932, the Governor of Bombay Frederick Sykes had suggested that the Tata's fund a radium institute for cancer therapy. According to the original plans drawn up that year, the institute was to begin work with 400 milligrams of radium. Dorab Tata died the same year and plans were held-up. In the following years, the trustees chose instead to work on a more ambitious plan for a cancer hospital equipped for surgery, x-rays as well as radium. It was to be a befitting memorial for Jamsetjee Nusserwan Tata and his two sons, Dorab and Ratan. A reference to Jamsetjee Nusserwan Tata can be found in Chapter 3 of this dissertation, for his efforts to establish the Indian Institute of Science, Bangalore.

grants".[385] Saha had explicitly included Nag in his application to the Dorab Tata as the one responsible for the construction of the cyclotron. "It is on this understanding that the grant was made.[386] Saha asked Nag to begin negotiations for the purchase of parts essential for the assembly; but he warned Nag should place the final orders only when he received the wired money.[387]

In his letters to Lawrence, Saha had once earlier discussed the construction of small cyclotron, primarily aimed gaining experience and training students in the laboratory. By 1940, Saha had raised funds for a 37-inch cyclotron.[388] Nag had worked on the 37 inch in Berkeley and that perhaps allowed Saha to imagine replicating a similar one safely. The scene in Berkeley was very different. One year before funds for the Calcutta installation became available, the cyclotroneers at Berkeley were making drawings for a 184-inch cyclotron "weighing in the neighbourhood of 5000 tons…[which] will produce 200

[385] I have not been able to locate the actual application for this grant and therefore cannot determine how much money Saha asked for from the Dorab Tata Trusts. It is consequently difficult to tell why a larger sum was not granted. Saha was certainly aware that this sum was not adequate for the establishment of a well equipped cyclotron facility.

[386] MNS to U. C. Nag November 11 1940, EOL Papers. The acceptance of this was apparently not an easy process. The donations were made with "conditions put forth by the Tata Trusts". I have been unable to trace further the details on the conditions.

[387] MNS to EOL Telegram of November 14 1940. Saha asked that Nag begin negotiating specifically for the iron yoke, pole pieces, copper ribbons, oscillators, ion sources, and other parts Lawrence would consider essential. In 1940, Saha had raised funds to purchase of the magnet, pumps and oscillators from the USA.

[388] Saha did not clearly state the size of the cyclotron he had in mind in his letter to Lawrence in, even though he did mention it would be the size of the first one Lawrence built. If we think of the very first cyclotron that Stanley Livingston built to confirm the principle of a cyclic accelerator, the magnet poles were no more than 9 inches in diameter. However, if one thinks of the first experimental cyclotron, it was 11 inches. If we take Stanley Livingston's classificatory scheme for cyclotrons in 1940, a 37-inch cyclotron would count as a small cyclotron, with the medium cyclotrons beginning at 42-inches. The Bombay groups beginning construction in 1952, did actually go for a 12 inch "baby cyclotron", as a prototype and for training purposes as well.

million volt alpha particles".[389] If Berkeley was leading the way, the installations were only getting bigger and bigger, with higher and higher energies. The installation being planned for Calcutta was in the same range of size and energy as the machines Saha saw in 1936; the Copenhagen cyclotron begun in 1935-36 had a 36-inch magnet,[390] and the Princeton cyclotron had a magnet of 35-inches.[391] It must have been amply clear to Saha even at the moment he embarked on this extraordinarily expensive purchase of research equipment, that they were not going for the state of the art installation. It would be misleading though, to suggest that the Calcutta cyclotron was going to be outdated apparatus for research in nuclear physics. Many believed that it was still possible to do physics research, and most certainly train students and researchers with such an installation. Walther Bothe and Wolfgang Gentner in Heidelberg and Frederic Joliot-Curie in Paris were working with similar sized installations contemporaneously.[392]

Nag took the oral exams for his PhD and was all "primed for the occasion". He then postponed his trip home and began scouting materials for the cyclotron. Donald Cooksey had promised to take care of him for the next two months, in case Saha could not raise

---

[389] EOL to Alfred Loomis, December 27 1939, EOL Papers. In this letter, EOL mentions that the machine will certainly yield 200 million electron volts but possibly 300 as well. Warren Weaver, in a letter to Karl Compton in January 1940 (EOL Papers), expected the voltage "for singly charged particles will conservatively be above 100 million". He had written to Compton to seek his opinion on the advisability for the Rockefeller Foundation to fund this project with a capital grant of 1, 500 000 dollars, aside of the 86 000 dollars committed by the University of California Berkeley as yearly maintenance costs for this project the next ten years.

[390] Heilbron and Seidel, (1989), 321.

[391] Heilbron and Seidel, (1989), 310. Among other contemporary projects in the making, the government of Poland sent a scientist to Berkeley with a commitment of 100 000 dollars for a cyclotron to be constructed in Warsaw, a sum that surprised Lawrence as well. EOL to Alfred Loomis, December 27 1939, EOL Papers. The Polish project, of course was aborted with the beginning of WWII.

[392] Heilbron and Seidel, (1989), 321.

funds for this continued stay. The Tata grant was to be used entirely for purchase of materials.[393]. Both Cooksey and Lawrence were away from the laboratory in early December, Lawrence at the MIT and Cooksey in New York but they were kept very well informed and involved in Nag's negotiations. "It is a wonderful thing that such a project can even be contemplated at this time, …" thought Cooksey.[394] Armco – the American Rolling Mills Company gave the " blueprints necessary" for the Calcutta installation, but the materials were going to take some time.[395] It was a year since WWII began and even though war effort in the USA had not yet taken momentum, the pressure of war orders and rising prices of raw materials for industrial use was affecting the plans for the 184-inch cyclotron.[396] Nag had established an association with Lawrence's laboratory, but more so with Donald Cooksey and Alfred Loomis. Their help proved essential in procuring various cyclotron components.[397] Donald Cooksey helped procure steel and copper for the magnet in times when Loomis and Lawrence were touring Wall Street for material for the 184-inch cyclotron.

---

[393] Donald Cooksey to EOL, November 20 1940, EOL Papers and Basanti Dulal Nag to Donald Cooksey, December 12 1940, EOL Papers, Cooksey Folder. Attached was a copy of Saha's letter confirming that Nag as responsible for constructing the Calcutta cyclotron. Saha calculated that "60 000 rupees would be about 25 000 dollars", and supposed that the Calcutta University would "supply the rest". Nag finally received 1500 dollars on January 23rd 1941, to begin making the purchases. (Registrar, Calcutta University to EOL letter and money-wire message from the Imperial Bank of India of January 23 1941, EOL Papers)

[394] Donald Cooksey to Henry Newson and Art Snell May 5 1941, EOL Papers, Cooksey Folder.

[395] Helen Briggs to EOL December 17 1940, EOL Papers. For Armco, see Heilbron and Seidel, (1989), 283, 308-309.

[396] Childs, (1968), 291. For wartime shortages affecting the Berkeley 184 inch cyclotron see Heilbron and Seidel, (1989), 483.

[397] Alfred Loomis a retired investment banker and a "first rate amateur physicist" was with the Rad. Lab as head of microwave work under Karl Compton in October 1940. Heilbron and Seidel, (1989), 205 and 494.

Nag had some more time before he left the United States. Almost five months later, in early May, Armco had the magnet ready and the other things were "coming nicely". Before leaving, he wanted to take an extensive trip to various cyclotron "outfits", as Cooksey called them, within the USA to observe and learn about their practices and experience, on his way to "take charge of the construction of a cyclotron for Saha".[398] Cooksey thought Nag was capable, and "most useful as an expert in the manipulation and management of the 37-inch cyclotron".[399] He wrote to Henry Newson and Arthur H. Snell at the University of Chicago, Milton White at the Princeton University, Jack Livingood and Roger Hickman at the Harvard University, Franz N. D. Kurie at the Indiana University Bloomington, James M. Cork at the University of Michigan Ann Arbor, and John Dunning at the Columbia University.[400] Amidst Nag's frenzied trips back and forth to laboratories and industrial firms, the purchases were on their way to completion, but his time with the immigration office had definitely run out. On April 4, the Immigration and Naturalisation Services demanded a clarification on why he had not left the United States after he had obtained his PhD.[401] By June, they asked the same of Lawrence, and further asked him to get Nag to respond to their letters.[402] Lawrence explained Nag's business with the cyclotron, and further ensured them, Nag would be sailing back home, perhaps in July.

---

[398] Donald Cooksey to Milton White, May 5 1941, EOL Papers, Cooksey Folder.

[399] Donald Cooksey to Milton White, May 5 1941, EOL Papers, Cooksey Folder.

[400] Donald Cooksey to all enlisted, May 5 1941, EOL Papers, Cooksey Folder.

[401] US Department of Justice, Immigration and Naturalization Services (INS), Special Assistant to the Attorney General, to Nag, April 4 1941, EOL Papers.

[402] US Department of Justice, INS, Special Assistant to the Attorney General, to Lawrence, June 10 1941, EOL Papers.

Saha began preparations in Calcutta to house the installation. The old tabletop laboratory space was insufficient. Apart from securing larger space, it also had to be constructed as a coordinated research space requiring continuous electricity supply and wiring installations. After negotiations with the university, the cyclotron laboratory was given its own space within the premises of the college – in an old garage. Construction began in earnest.[403] Yet another important development were the small grants from the newly established Board of Scientific and Industrial Research for war effort. Saha began training other younger members of the laboratory for the cyclotron project. On October 1st 1940, Kamalesh Ray and Tripurendra Kumar Kundu began working on the manufacture of vacuum pumps. Their prototypes worked just fine – but the pumps were never scaled up for manufacture.[404] Large brass tubes were simply not available in India.

4.5 Nag Comes to Calcutta

Nag left for Calcutta in late June 1941 but it was not the safest time to sail to India. The Pacific Ocean was no longer safe onboard an American liner.[405] Nag arrived safely and by September 1941, he was ready to begin work in the Palit Laboratory. Adapted by now

403 The cyclotron garage ended up as built space of 4000 square feet over two floors, and was completed in a years time with a cost of 30 000 rupees.

404 Government of India, Department of Commerce, *Report on the Technical Work of the Board of Scientific and Industrial Research for the year 1940-41*, IOR V/24/1966, OIOC.

405 U. C. Nag to EOL, June 8 1941, EOL Papers. Nag's worried father asked for Lawrence to help his son fly home safely. Lawrence replied (July 9 1941) that after a discussion they did not think it necessary and Nag had sailed for home and should arrive safely.

to the Berkeley pace, he found the Calcutta laboratory work progressing slower than he expected in the very first week.[406] The materials he had shipped from the US had not yet arrived, and those that had, were stuck with customs. He began some experimentation, and other laboratory members were enthused enough to his satisfaction. He longed though, for the Berkeley 184-inch cyclotron that he hoped to work with sometime in the future.

Even as Nag settled in and the components of the cyclotron began trickling in, Saha received a letter from the imprisoned Jawaharlal Nehru.[407] He wanted an update on the cyclotron he had helped get funded. Saha was pleased to have Nehru's interest in the new project, but reiterated Nag's feelings and replied that the work was actually progressing rather slowly. He hoped the "East would not flare up" as they would hopefully receive their materials at least by November, and gave Nehru the details on the purchases. The construction, of course, would take at least two years.[408] Nehru immediately responded with surprise. Why would it take that long to build the cyclotron? Saha replied with equal haste; he ought to have told Nehru he felt now, "even in the USA it generally takes three years to complete a cyclotron. So we have not asked for any unusual length of time".[409] Time would become a crucial argument against the Calcutta team's efforts to build a

[406] Nag to EOL, September 9 1941, EOL Papers.

[407] The Indian National Congress leadership had resigned in protest from provincial governments in 1939 after WWII began. In anticipation of political unrest, almost all of Congress leadership including Jawaharlal Nehru was arrested and put behind bars.

[408] MNS to Jawaharlal Nehru, October 27 1941, MNS Papers, NMML. Even though Nag had made 16 000 dollars worth of purchases in the US, they had received only 6000 dollars worth of materials so far.

[409] MNS to Jawaharlal Nehru November 14 1941, MNS Papers NMML.

cyclotron in the later years, but their situation would not be entirely misunderstood or their efforts completely misread. Saha argued that the war had made things difficult for buying materials in several ways. Many electronic components that were purchased off the shelf in Berkeley were difficult to procure in Calcutta, especially more so because of war. Almost everything was at least "50 times dearer" even when available, and shipping was not reliable over the Pacific Ocean. Electronic components that were also of use for war related purposes could not be procured. Such imports were handled by the Munitions Board of the Government of India whose priority was the Eastern war front and not university research in sciences.[410] The 50-ton magnet had arrived and construction had begun. The magnet was the first component to be installed by a local civil engineering firm, Jessop and Co, hoisted towards the completion of the buildings. Nehru was released from prison on December 4, and Saha was delighted. He would have liked to have Nehru come and see the laboratory.[411] That was not about to happen very soon.

4.6 Organisation of the Cyclotron Group

Nag had been provisionally appointed "cyclotron officer" when he was in Berkeley to authorise his purchases on behalf of the USC. Once back in Calcutta, the question of his position within the department was raised. Saha was quite clear that Nag should lead the

---

[410] Nag to Donald Cooksey November 12 1941, EOL Papers, Cooksey Folder. Nag was sharing notes with Cooksey, and had heard of similar difficulties in obtaining materials in Berkeley as well because of the Naval Department works.

[411] MNS to Jawaharlal Nehru, December 5 1941, MNS Papers NMML. He was also happy for Congress solidarity with the USSR following Hitler's invasion, and asked to meet with Nehru as soon as he would have him come to Allahabad for resuming NPC work.

construction of the cyclotron. His remarkable entrepreneurial skills came of use again - Saha mobilised an endowment to fund a reader's position for Nag.[412] Nag's responsibilities were negotiated with the Council for Post-Graduate Teaching in Science of the Calcutta University, such that he taught only post-graduate students, only nuclear physics and devoted a significant part of his time for research, which in his case translated to building the cyclotron.[413]

The second most important person to join the cyclotron group was Bindu Madhab Banerjee. As of early 1941, he was working with Sisir Mitra, holding the chair in applied physics at the same department. Banerjee was designing electro- acoustical and high frequency apparatus as a part of Mitra's BSIR grant, when he shifted over to Saha's cyclotron project. He had taken the British Radio-Engineering Diploma examination before he joined university. Banerjee had practical experience with radio technology from his work with Mitra. John Heilbron and Robert Seidel have identified reliance on radio-technology as a distinctive feature of the Berkeley radiation laboratory's approach to particle accelerators. Lawrence himself, but also many of the laboratory's earlier workers had been radio hams. "The laboratory was so filled with radio-waves, that its members could light a standard electric bulb merely by touching it to any metallic surface in the

[412] Saha procured the funds from a local philanthropist, Tarinicharan Sur. Nag was beginning work one step higher than most fresh PhD graduates normally did at the time.

[413] Satyendranath Bose to the Registrar, USC, September 21 1950 where Bose recounts the terms of the endowment in order to routinise the conditions of Nag's position as opposed to being subject to review every year.

building. Many cyclotron laboratories were to eek out their resources by cannibalizing old radio parts".[414]

Nag and his colleagues began to assemble and build various parts for the cyclotron. Vacuum pumps continued to be a problem. Nag had bought some in the US but the consignment never reached Calcutta. As the legend goes, the Japanese perhaps torpedoed the pump carrying ship on Pacific waters. [415] The team had working prototypes, scaling up was impossible. Saha recounted this problem to the BSIR. "The chief difficulty lies in the obtaining of raw materials for the manufacture of various instruments. Metal is the most important raw material and unless various devices are introduced for getting the metals in various shapes, as for example in the form of plate, tube and rod which serve again as the basis for the manufacture of scientific instruments, development in the production of instruments cannot be much hoped for. The Metals Committee subsequently instituted, will, it is hoped, solve many other difficulties encountered by the Scientific Instruments Committee. In fact, it would appear that the labours of the latter Committee begin at a stage when those of the Metals Committee are over."[416] It was one thing to award grants for building scientific instruments but this was not going to make

---

[414] Heilbron and Seidel, (1989), 127.

[415] The story of the "lost or sunk valves and pumps" has been in currency since the 1940s. In my discussions with those associated with the laboratory, I heard again and again that the consignment was sunk when the ship sank after being torpedoed by the Japanese. Robert S. Anderson retells this in his work (Anderson: 1975). From the archival documents available, it is difficult to ascertain why the consignment did not reach and Saha only mentions that the "consignment was lost in transit" or "one consignment carrying the valves and pumps did not arrive owing to the outbreak of war with Japan". Perhaps the reasons were obvious to his audience. What is certain though is that the valves and pumps did not reach Calcutta and that "hampered progress on the cyclotron".

[416] Government of India, Department of Commerce, *Report on the Technical Work of the Board of Scientific and Industrial Research for the year 1940-41*, IOR V/24/1966, OIOC.

any sense without coordination with materials supply. The BSIR was after all, as mentioned before, the very first experiment in scientific industrialism. The serious difficulty of assembling infrastructure of materials to assemble infrastructure of laboratories, to further claim an assembly of scientific and industrial research capable of delivering products and services for the material advancement of India was indeed going to be a long journey.

In March 1942, Lawrence wrote inquiring after his student and the progress of the Calcutta cyclotron.[417] Work on the 184 inch cyclotron in Berkeley was proceeding well, he said, as “fortunately the government [was] inclined to permit us to go ahead with the completion of the giant cyclotron despite war conditions, as it is felt that it might ultimately be useful one way or another in the war effort”. Personally though, Lawrence felt he could see “only the remote possibility of the giant cyclotron being of any value in this war”. The boys in the Berkeley laboratory had read Nag’s letters, and Lawrence thought perhaps after the war, a Berkeley delegation could go over the Calcutta and join Nag’s crew. This could have done wonders for the Calcutta project; unfortunately, it was never to happen.

4.7 Organisation of Other Groups in the Palit Laboratory

The focus of this chapter is cyclotron-building activity at the Palit Laboratory, University College of Science, Calcutta. It is therefore important to know just where the cyclotron

[417] EOL to Nag, March 2 1942, EOL Papers.

belonged within the larger concerns of the laboratory. The Palit Laboratory was one of three at the department of physics, the other two being led by S. K. Mitra (radio-physics) and B. B. Ray (cosmic ray physics). Within the Palit Laboratory, the cyclotron was not the only research technology and nuclear physics was not the only teaching and research concern. The laboratory continued experimental research in cosmic ray physics, spectroscopy, thermal ionization, biophysics and nuclear physics. There were at least two other smaller laboratories dedicated to the study of x-rays and wireless technology within this larger agenda.[418]

Of these groups, the biophysics section took the strongest lead in research. Philanthropic funding, especially for medicine related research was much more forthcoming. The group was organised under N. N. Dasgupta, and he was engaged with building an electron microscope (for which he later went to Stanford). Cosmic Ray research at the department had already begun under the leadership of Debendra Mohan Bose between 1934 and 1938. Even though Bose took his own researches and apparatus with him, Saha took interest in continuation of his researches. Since a sufficient core group with training in carrying out cosmic ray research seems to have been left behind with the department, it was not difficult to continue this line of work. Saha began to occupy his summer

[418] In the first years of his joining the USC, Saha requested for funding to better equip the wireless and x ray laboratories, and for research apparatus for cosmic ray work, spectroscopy in the extreme ultraviolet, and thermal ionization of gases. Correspondence between the department of physics, the post-graduate council in science, the Palit Trust that funded the laboratory and the Registrar, Calcutta University, of March 25, April 29, and May 8 1939, and MNS to Registrar, Calcutta University, March 19, 1940, MNS Papers, NMML.

vacations and his summerhouse in Darjeeling, a hill station not far from Calcutta, for research in cosmic rays.[419]

4.8 Saha as a Member of the Indian Scientific Mission 1944-45

Archibald Vivian Hill's visit to India in 1943-44, as we saw in Chapter 2, resulted in two "goodwill missions". Saha travelled out as a member of the Indian Scientific Mission to the United Kingdom, Canada and the United States of America in 1944.[420] This was Nag's chance to obtain the missing components for the cyclotron, ask for information on troublesome problems with the cyclotron and get updates on the conditions of nuclear physics research, especially in Berkeley. In October 1944, he wrote to Donald Cooksey to expect Saha in Berkeley in December that year. He also reported progress, "we have got resonance with protons with our cyclotron" he wrote and then followed it up by three pages worth of details on the two technical problems that were giving them a great deal of trouble. [421] He asked for ideas to work around the problems, but he also wanted Cooksey to send him current reprints, newer blue prints, typescripts, diagrams to get an

[419] Registrar, Calcutta University to MNS, April 26 1940, MNS Papers, NMML.

[420] Hill's diplomatic visit of 1943-44 had resulted in this mission, and a group of Indian scientists would now visit allied research facilities for a demonstration effect of what coordinated scientific and industrial research would look like. The visit is discussed in detail in Chapter 2 of this dissertation.

[421] BDN to Donald Cooksey October 29 1944, EOL Papers, Cooksey Folders. The two main problems Nag enlists are those with tungsten filaments that seem to thin out within a few hours and then fuse, and ion gauges. The Calcutta group was using RCA 45 filaments which were available locally but there was something "terribly wrong with the way we open these valves" as they require 50% larger than normal filament voltage for any workable emission". Nag suspected they were destroying the oxide coating on opening and thus "reduces their lives [the gauges] and us to despair".

idea of what was going on in Berkeley. Nag repeated twice, “I do feel so out of touch with things, now that we can think of working with problems”.

Just a couple of days later, he wrote to Saha updating him and repeating the problems he had already written about to Cooksey and reminded the professor of his need for reprints, blueprints, and diagrams in use for measurements in radioactivity in Berkeley. “We feel very out of touch here”, he could not help repeating to his mentor as well.[422] Cooksey forwarded Nag’s letter to Joseph Hamilton, and asked Tom Putnam to gather materials to be sent with Saha. Joseph Hamilton was in charge of the medical cyclotron as director of the Crocker Radiation Laboratory. He worked with John Lawrence in medicine related biophysics when Nag was at Berkeley. Cooksey asserted “Anything that we can do for Nag, short of sending a cyclotron to Japan is okay.”[423]

Once in the US, Saha got in touch with both Lawrence and Cooksey and told them he would visit Berkeley in the second week of January and would like to discuss Nag’s concerns.[424] In his letter to Lawrence, he also noted a special request. He wanted Lawrence to recommend Nag to another member of the Indian delegation, Bhatnagar, the man “who runs the gov[ernmen]t’s department of scientific research”. A good recommendation from Lawrence would be very helpful for Nag to seek government funding and strengthen his position back in India. Bhatnagar was the strongest science

[422] BDN to MNS, October 31 1944, EOL Papers, Cooksey Folder.

[423] Donald Cooksey to Joe Hamilton, note of December 18 1944, EOL Papers, Cooksey Folder.

[424] MNS to EOL and Donald Cooksey, December 11 1944, EOL Papers.

administrator in wartime India, and controlled state funding for scientific and industrial research. Saha had benefited from BSIR and CSIR grants, one of which was also for Nag's research. Even before going to Berkeley, he wrote to Nag about new techniques in cyclotrons. "It is said that the cyclotron is now almost foolproof. By simply pressing a number of buttons, one can keep it going for hours together". He would try to get a priority release for some important equipment that could bring the Calcutta cyclotron up-to-date. Construction on the cyclotron had begun four years ago, and most of it took place in isolation during the war – which was not yet over. Cyclotron designs were changing, and at least in the USA, their sizes and energies were only getting bigger. If Nag remained in good favour with Bhatnagar, the cyclotron group at the Palit Laboratory could get ambitious with its projects and perhaps do something big.

Frank B. Jewett, president of the National Academy of Sciences, USA, wrote the official letter for the delegations trip to Lawrence and conveyed Saha's feelings about the visit, "some of the members of the party, he wrote, are particularly anxious to see and talk with you".[425] Lawrence was going to be away, but Saha would get to meet Cooksey and discuss Nag's problems. He would also get materials to take back for Nag. The 184-inch cyclotron was closed to visitors by government orders, but the delegation could see the 60-inch cyclotron and associated equipment. Lawrence was certainly willing to put in a good word for Nag with Bhatnagar, and trusted that Cooksey would do that job in his

[425] Frank B. Jewett to EOL, December 15 1944, EOL Papers.

absence.[426] A couple of days later, perhaps after having read Lawrence's letter, Saha wrote to Nag from Pittsburgh; "The California people are doing far bigger things, they will be hardly interested in anything small".[427] But the small project had to continue and there were more boys to train. Saha had now arranged for another student Dhiren Kundu to work with Alexander Allen who was building a new cyclotron at the University of Pittsburgh. Saha had understood the implications of the changing nature of wartime Berkeley practice for the Calcutta cyclotron. The Indian delegation arriving in Berkeley could have hardly missed the significance of being denied a peek at the 184-inch cyclotron.

4.9 1945-50: Atomic Energy Research Committee and Board

The Atomic Energy Research Committee of the Council of Scientific and Industrial Research (CSIR), met for the first time on May 15 1946, nine months after Hiroshima and Nagasaki. The press release for the meeting announced two important sets of decisions: there simply were not enough funds available in India in the near future for investment in atomic research compared to the US and Britain and therefore, "it is necessary that all large scale research in atomic physics in the near future should be concentrated at one centre in the country". And this one centre would be the recently established Tata Institute of Fundamental Research, Bombay. The Committee was nonetheless willing to fund at least two laboratories for continuing nuclear research,

---

[426] EOL to MNS, December 19 1944, EOL Papers. Cooksey wrote to Nag that Saha had been in San Francisco "with his very charming companions" and after discussions with Saha had arrived at the conclusion that the supply problem was Nag's worst one.

[427] MNS to BDN, December 21 1944, MNS Papers, NMML.

presumably on a reduced scale as compared to what they anticipated pursuing in Bombay. The Tata Institute of Fundamental Research was given funds to for a 200 million volt betatron, and a ten-member team for its operation. On the other hand, the Palit Laboratory was awarded both capital and recurring grants "towards the expenses for the operation of a cyclotron"; more so, Debendra Mohan Bose at the Bose Institute, Calcutta, got similar grants for research on transuranic elements.[428]

Having begun efforts to establish nuclear physics research and education, and construction on the cyclotron almost five years ago, Saha contested the premises of these decisions. The AERC was encouraging of efforts to establish nuclear physics in Calcutta, and the grant was indicative of state support to further existing research. But the nomination of TIFR as the centralised laboratory for "large scale research" would marginalise the Calcutta laboratory in the national context. Saha was uncertain about just what the Committee meant by "large-scale".[429] Unable to accept a marginal role for his laboratory, Saha was not sure a unanimous agreement on Bombay as the central station for nuclear research had been found during the meeting. He immediately wrote to Bhabha and Bhatnagar arguing that not only was Bombay a rather exposed site and therefore unsuitable for research for an institution under state control. The discussion, he thought, was incomplete since the Committee had postponed discussion on Nag's report because

[428] *Notes Issued to the Press on the proceedings of the first meeting of the Atomic Energy Research Committee held on 15 May 1946, Bombay House* MNS Papers, (Bhabha Folder) NMML.

[429] HJB to SSB, and copy to MNS, January 15 1947, MNS Papers, SINP.

"of the prematurity of considering the founding of a Central Nuclear Physics Laboratory at this stage".[430] No one else seemed to think so.

Saha's quest for the cyclotron, I have argued was embedded in his project of nation building and was realised within his commitment to the National Planning Committee. His engagement with nationalist politics had helped secure funds for the laboratory, and he may have perceived the project as *already* committed within the national-state framework. If provincial governments were an exercise in self-rule, and the NPC were established as a part of this exercise, there was good reason to believe that activities supported and realised within such a program was an expression of priorities of nationalist government. The AERC decision appeared to take away Saha's prerogative to position his project in this manner, and as a result marginalise the project's significance in relation to another that was but a recent establishment. The decision would also place constraints upon the laboratory's participation in scientific life – this would affect their funding, as well as decisions on their research agenda. Bombay was going to get a bigger machine, but also a bigger voice when it came to representing Indian science abroad.

Bhabha may not have been a part of the goodwill mission in 1944, but he was a part of the Indian delegation leaving for London in a month's time. Members of the AERC were all on their way to attend the Empire Scientific Conference, the British Commonwealth

[430] MNS to HJB and copy to SSB, June 1 1946, MNS Papers, SINP. I have been unable to trace this report. Given the correspondence around the report and Saha's anxious struggle thereafter to secure priority for his laboratory, I would like to suggest that the report might have offered further development and restructuring of the Palit Laboratory as the central laboratory for nuclear research in India. This seems plausible also because the Palit Laboratory was separated from the USC in less than two years time from the AERC meeting into an independent Institute of Nuclear Physics.

Official Science Conference and the Newton Tercentenary for well over five weeks for an intense renewal of their collegial alliances with the international community of science.[431] It would be nine more months before the AERC would meet again; and one more year before Bhabha would give up wanting the betatron for the TIFR altogether. This was the occasion to discuss the organisation of post-war nuclear research with physicists from Britain and the USA actively engaged in the field.

Instrumental and experimental techniques had undergone a "complete revolution" during wartime, but advance on theoretical physics, Saha felt, had been relatively small. Mark Oliphant spoke at the Newton Tercentenary about Ernest Lawrence's new project. The USA was going to have a "National Science Laboratory" with a cyclotron whose pole piece had a diameter of 400 inches. The cyclotron required 250000 k.w. of power daily, "nearly the whole power used by the city of Calcutta", Saha added. [432] Oliphant had a grant of "1.5×10^5 pounds for the construction of a synchrotron which will accelerate protons to 500 million volts". These were the new instruments of physics after the war: the atomic pile, cosmic rays, betatron and the cyclotron. The significance of the Calcutta cyclotron was reinforced in the minds of the Indians attending, but the urgency of experimentation was perhaps not as much obvious. The equipment in Calcutta was far

[431] MNS to Niels Bohr, June 14 1946, Niels Bohr Archive; asking for reprints of research published by those in Copenhagen during the war years. Saha's student Dhiren Kundu, who went to Pittsburgh to work on the cyclotron presented at the annual meeting of the American Physical Society (June 1946) where he found "This meeting of the American Physical Society was one of the biggest and many papers on nuclear physics containing academic materials which were so long under censorship, were read by prominent scientists like Fermi… Wigner… Dempster. The various isotopes of the four well established trans-uranic elements were reported by Seaborg and different aspects of the pile and chain reactions were discussed, within limit of censorship by others". D. N. Kundu to MNS, June 23 1946, MNS Papers SINP.

[432] MNS to D. S. Kothari, August 2 1946, MNS Papers, SINP.

from the most exciting ones available, and Saha was not personally driven to look for newer discoveries in the field of nuclear physics, much as he appreciated members of the Palit Laboratory working at the frontiers of physics.

Saha was last in England two years ago, and he could not ignore scouting for parts for the cyclotron yet again. Nag kept him updated of the arrival of parts still being delivered from previous orders. Vacuum pumps continued to bother the Calcutta team - could Saha pursue the order of a [Cenco Hypervac 100 type] vacuum pump placed two years ago?[433] The mechanical pump they had been constructing in Calcutta for the cyclotron chamber was not functioning successfully and "since the pump people are taking such a long time, it is best to have one of our own". Saha had already obtained detailed notes on allied and American war-surplus stores in Calcutta. He had details on what parts could be obtained at what surplus stores and who should be contracted for reduction on prices.[434] Dhiren Kundu wrote from the USA and warned Saha of investing in junk, but top quality radio tubes and other electronics were simply not freely available even in American or British market.

Shortage of components, difficulties of import, and novelty of the construction for most members of the cyclotron team decelerated work on the cyclotron. The period of political turmoil leading to Indian independence in 1947 only added to the difficulties. The Bengal province was partitioned into East Pakistan and West Bengal. Saha's native district fell in

---

[433] BDN to MNS, July 10 1946, MNS Papers, SINP.

[434] Meghnad Saha, Diary (1946) MNS Papers, NMML, p. 58.

East Pakistan. The city, barely recovered from the famine conditions of 1943-44, now saw a huge influx of refugees and partition related violence. A significant number of colleges affiliated to the Calcutta University were located in East Pakistan and the university faced an abrupt decline in number of fee-paying students, and a more general dive in funding. This certainly impacted the funding available for expansion of research activities for the Palit Laboratory. Family matters figured in the laboratory in yet another way. Saha wanted to arrange for his son to come to Europe. Ajit Kumar Saha had just submitted for his Doctor of Science degree in physics at the Calcutta University and Saha was eager for him to spend time "with great minds".[435]

4.10 1947-1948: Towards an Atomic Energy Commission of India

Bhabha and Saha finally got around to discussing the disagreements on the minutes of the first AERC meeting in January 1947.[436] Saha maintained his doubts on what "large-scale" research implied, but Bhabha concluded on his part, "I think I am right in saying that Prof. Saha after this discussion, does not dispute the verbal correctness of the record". Saha, it appeared, had conceded to let the TIFR become the centre of nuclear research in India. The argument of concentration was now acceptable to Bhatnagar, Bhabha and Saha. Later that year, the agreement would be mobilised to truncate the establishment of nuclear physics in Bangalore (discussed in Chapter 3). The Palit

---

[435] MNS to Niels Bohr, note of July 18 1946, MNS Papers, SINP.

[436] HJB to SSB, January 15 1947, MNS Papers, SINP.

Laboratory was accepted into the orbit of state funded research, but Saha was far from prepared to accept this trajectory for the Palit Laboratory.

The AERC was meeting again in February 1947, and Saha wrote to Bhabha regarding his son's application for a travel scholarship. [437] Bhabha thought the best was to recommend the proposal to the Board [of Atomic Research] at the next meeting of the AERC since the sum requested was not especially big. [438] But Bhabha wanted to make, what he called, a general point which arose from this matter of supporting Saha's son but independent from it which he wanted to make confidentially. "We have yet in India, no real top-notch experimenters in nuclear physics or cosmic rays. You and I are essentially theorists who may plan the right experiments perhaps even better than experimenters could themselves but *who are not in a position to give detailed advice on matters of experimental technique or to judge its soundness*".[439] Citing Blackett he wrote, "It is well known that for every nine people who can do good work in the right environment there is only one who can do work on his own in isolation. We have in India many able young men who with proper guidance and if concentrated in a few centres would do admirable work, but who are apt to go astray or languish entirely when left on their own".

---

[437] MNS to HJB, 17 January 1947, MNS Papers, SINP. Ajit Kumar Saha had completed his doctoral degree in physics with work on β ray spectroscopy from the USC and had applied for funds from the ARC to spend a *Wanderjahr* in Europe visiting laboratories in Switzerland (Paul Scherrer), Sweden (Manne Siegbahn), Paris (Frederic Joliot-Curie) and England. His trip was planned such that through his visits and contacts with relevant laboratories, Ajit Saha would be able to get made a sufficiently precise β ray spectrometer.

[438] HJB to MNS, 25 January 1947, D-2004-00559, TIFR Archives.

[439] HJB to MNS, 25 January 1947, D-2004-00559, TIFR Archives, emphasis added.

It was fine that Saha was advising the researches of his son, but Bhabha was convinced that a better way to do it was to get a real experimentalist for the laboratory. Bhabha was acutely aware of the importance of tacit knowledge in laboratory practice. Even though he thought he could plan "better experiments", he had well accepted that he could not advise on experimental technique and probably even more crucial for the success of an experiment, he was unable to "judge the soundness" of a given technique. Bhabha's experiences with planning cosmic ray work for four years in Bangalore had given an overview on the lack of training for experimental work in India, (an argument, especially given R. S. Krishnan's skills with the cyclotron, was surprisingly ignored in the discussions on the establishment of nuclear physics in Bangalore). His claim that he was only a theoretical physicist underplayed that he had taken an engineering tripos in Cambridge. If he was unable to advise or judge experimental practice, he had realized and accepted, he was not capable of training new students and assistants in experimental physics. But if experimental cosmic ray and nuclear physics were on the agenda for his institute, and also at the Palit Laboratory, they would have to accomplish a suitable solution.

The Palit Laboratory had begun construction on their cyclotron about four years ago. Bhabha had only just begun looking for the ten-member team that would work his betatron, and in his mind, he was getting clearer on what had to be done. "I am of the opinion that it would pay the country handsomely to import one or two really first class men from aboard for a limited period, say two years". Bhabha wanted to invite an experimental physicist from America for two years, and he suggested that it would probably be the best way to organize experimental work in Calcutta as well.

Saha only partly agreed with Bhabha.[440] He presented instead three instances that he proposed were *the real* bottlenecks for experimental research in India "the dearth of good mechanics and laboratory men" which he was convinced Bhabha would agree with; and the absence of large engineering or manufacturing concerns producing machinery, electrical goods, scientific instruments or chemicals; and finally the more recent difficulties of importing machinery, chemicals or scientific instruments from abroad. Taking the case closest home, Saha argued that components for cyclotrons were available from the workshops of large industrial firms abroad; Metropolitan-Vickers and Mullards in England, Philips of the Netherlands, Brown-Boveri and Oerlikon in Switzerland, and so on. This could not be taken for granted in India – there simply were no large workshops producing precision-machined components to specification in the country. Given the Calcutta experience with high vacuum pumps and oscillators, even when they could produce these successfully in the laboratory, they could not scale them up to the size required for the cyclotron for lack of very basic materials like large machined brass tubes.

Even after personally visiting the firms in England and USA, Saha had been unable to accomplish much. First, the wartime demand for electronic components and now post-war control of nuclear research related equipment had made it extremely difficult to

[440] MNS to HJB, February 4 1947, MNS Papers, NMML.

obtain much from firms abroad. Adding in a line for irony, Saha wondered if [Ernest O] Lawrence or [Donald] Kerst could have achieved anything if they were born in India! Training men for laboratory work was important, Saha agreed. They had made plans for such activities and proposed them to the Government – but nothing moves with the government of India he complained. This observation was not lost on Bhabha either. The "steel frame" of bureaucracy that gave the British Raj its stability was a feared organization and many were suspicious of its position in free India. Bhabha would eventually find a way around this for himself by becoming a part of the bureaucracy. But for now, he enjoyed Bhatnagar' support and additionally, he had help from the Tata industrial concerns.

Saha's final retort was a clincher. "I am not so much of a theorist as you seem to think. I have planned and performed with my own hands a lot of experiments on spectroscopy and thermal ionization." Saha was convinced he was somewhat of an experimental physicist as well. He had seen the Berkeley cyclotron laboratory almost ten years ago and once since, had not missed the changes in scale and complexity of the equipment. He certainly had accomplished experimental work on thermal ionization and perhaps to a lesser extent in spectroscopy; but it would be fair to say that he was not an experimental nuclear physicist. He was effectively also making a claim that he could advise his students and assistants on experimental technique as well as judge the soundness of a given technique for a given task in nuclear physics as well.

Saha's were equally acute observations on the demoralizing difficulty of working experimental investigations in India at the time. He had gained considerable experience from trying to organize the construction of the Calcutta cyclotron, and spoke about the impoverished industrial infrastructure that was increasingly necessary to support nuclear research, and in the absence of which experimental work suffered. Saha was more worried that Bhabha and he would have to lobby for atomic energy finances, and very soon.[441] The CSIR was being reconstituted and newer members coming in. Saha was not sure if the interests of the AERC would necessarily find place in the priorities of the CSIR; the chance to block funding would be lost if proposals were not budgeted before the end of the financial year. Despite all these concerns, Saha was not able attend the AERC meeting. He registered his disappointment and sent N. N. Dasgupta to represent the Palit Laboratory. He also wrote a short report on the proposed activities with the grant awarded by the CSIR the previous year. This is very likely the first detailed report on the cyclotron, and it provides ample support for Saha's argument on "bottlenecks".[442] Construction on the cyclotron suffered right at the start because a consignment carrying

---

[441] Saha was also actively working on other sources of funding. On February 15 1947 he wrote to the Vice Chancellor of the Calcutta University regarding funding from industrialists. The Finance Minister in the Viceroy's council of 1944, Archibald Rowlands had declared, "All monies contributed towards fundamental or industrial scientific researches will not be liable to income tax". Oil mill owners in Ahmedabad, Gujarat, had diverted significant sums from going to the government into research, and Saha pursued the matter with industrialists in Bengal. Uncertain of government policies in a period of transition, they sought written assurance from the Government that this was indeed the case. Saha was convinced of the need for philanthropic support for scientific research, which was amply articulated in the brochure brought out by the Department of Physics, USC in 1945 explicitly aimed at raising funds for research - not unlike the one that Arthur Eddington wrote for the Cavendish Laboratory in 1936.

[442] MNS to HJB, February 17 1947, MNS Papers, NMML.

valves and pumps did not reach India.[443] But available components had been installed and assembled, something they had also informed the headquarters in Berkeley.[444]

4.11 1946 –1950:An Institute of Nuclear Physics

In a note on experimental physics activities at the Palit Laboratory in 1946, Saha enlisted 10 research workers (technicians), of whom only one, Bindu Madhab Banerjee, was working on the cyclotron. There were four researchers listed under the cyclotron group as a whole: Nag, A. K. Mousoff, Amal Chandra Ghosh and Santimaya Chatterjee, of whom the last three were new graduate students. There were three other groups working on instrument building related work: Electron Microscope Group, Ultra-Centrifuge Group, and the Pump Refrigeration Group and X-Ray Optics Group.[445] The Palit Laboratory was clearly engaged with various researches in physics including those related to, but not necessarily centred on the cyclotron alone. Despite being engaged in time consuming entrepreneurial activities, Saha was still engaged in continuing experimental researches

---

[443] MNS to HJB, February 17 1947, MNS Papers, NMML. Descriptions of measurement for the Calcutta cyclotron are not consistent but not very far in range. In places it is described as 37_ -inch and sometimes as 39-inches.

[444] "List of Cyclotrons" of January 11 1946, EOL Papers, Cooksey Folder; A list of cyclotrons was drawn up in Berkeley in January 1946, Saha's "37-inch cyclotron in Calcutta" was said to be operational. The smooth functioning was severely "handicapped for absence of proper valves and pumps". On his trip to the USA in 1944-45, Saha had managed to place orders for oscillating valves in spite of "prohibitions due to Atomic Secrecy rules" with the help of his American friends, who he wished better remain unknown. He could not place an order for a mechanical pump in the USA and tried to do so when he was in the UK in 1946, with the British firm Messer's' Edwards. The representatives "were unable to make the pumps to his specifications" because they were preoccupied with experiments "for their production for the Atomic energy station at Harwell". Moreover, the pumps for cyclotrons in England were actually bought in the USA. Saha kept trying to get an order processed with American firms.

[445] Meghnad Saha, Diary for the year 1946, MNS Papers, NMML pp. 51-52.

of his own.[446] He was seeking opportunities to send students and research workers from the Palit Laboratory for advanced training in Europe and the USA after the end of the war. Not all of them were engaged in cyclotroneering. Of those that left between 1945 and 1947, Dhiren Kundu was the only student working with a cyclotron in Pittsburgh. The other students who went abroad were: Ambuj Mukherjee at Paul Scherrer's laboratory at the ETH Zurich (β-ray spectroscopy, and some experimental work with the cyclotron), Samarendra Ghoshal at Emilio Segre's laboratory in Berkeley (biophysics), S. K. Ghosh at Manchester (to cosmic rays), and N. N. Dasgupta went to Stanford to work with electron microscopy.[447]

In October 1947, Nag left for Berkeley for the second time. He wanted to perform some experiments, get updated information on nuclear research with particle accelerators, and buy the coveted mechanical pump for the cyclotron. This was not the best timing. By November 1947, the McMahon Act had put in place an even more effective control over the export of "specific classes of declassified equipment such as radiation-detection equipment, mass spectrometers, high vacuum equipment and particle accelerators". Saha was deeply anxious and asked Bhatnagar to raise the issue with the Prime Minister and Syamaprasad Mukherjee. This was "a very serious affair for prosecution of scientific

---

[446] Saha published a note in *Nature* on Origins of Radio-waves from the Sun and the Stars that was "exciting so much interest in scientific circles" (1946) 158, 717. He wanted to follow up the matter experimentally and requested Bhatnagar for a "centimetre and a meter radar equipment" from the disposals department. He sent the article "for perusal of such military authorities who may be interested in the subject". MNS to SSB, February 25 1947, MNS Papers, NMML.

[447] MNS to HJB, January 17 1947, MNS Papers, NMML; MNS to Blackett, September 10 1948, MNS Papers, SINP. S. K. Ghosh built a camera to be used for work with a cloud chamber at the workshop in Manchester for the use of S. Das in Calcutta. The expenses were borne by the Calcutta University.

work in India".[448] Saha reminded Nag that he should get the mechanical pump, no matter how much it cost and even if he had to overstay to procure the same.[449]

Prof. M.N. Saha in front of the Cyclotron
University College of Science & Technology
92 Upper Circular Road, Calcutta.
January, 1947
Print from a photograph, printed in the book
"My Experiences in Soviet Russia"
Meghnad Saha, F.R.S., 1947

Figure 4.2: Meghnad Saha and the Cyclotron in January 1947. Reproduced with permission from the Meghnad Saha Archives, Saha Institute of Nuclear Physics, Calcutta.

---

448 MNS to SSB, 10 January 1948, MNS Papers, NMML; Saha read the announcement in the *Review of Scientific Instruments* 18, (November 1947).

449 MNS to BDN, February 23 1948, MNS Papers, SINP.

Saha had by now spent a considerable amount of energy learning about the organisation of nuclear research in Europe and the USA. He wanted to circulate a report of his findings among the members of the Board of Research on Atomic Energy. Saha was anxious that Bhatnagar had not responded to his request. He was also perturbed on two other counts. Bhabha had set no agenda for a new meeting. And there was no reason that the meeting should always be held in Bombay. He wrote to Debendra Mohan Bose about his worries and if he agreed, Saha would then propose that the next meeting should be postponed by a fortnight and held in Calcutta.[450] "The Delhi men have no idea on the amount of mischief which is being committed to Atomic Energy by adopting stupid attitude of inactivity"; according to Saha, Bhabha was simply not doing enough to push the agenda for nuclear research for the country.

Saha wrote Bhatnagar again.[451] He was certain he wanted his report discussed by the members even if it meant postponing the meeting. Given bureaucratic procedure, the next meeting would take yet another six months, and that he thought was far too late. Saha had also heard about Bhabha's note on the proposal for a nuclear spectrograph in Calcutta. Bhabha was sceptical of its use, as the USA would not supply radioactive isotopes required for the research. Saha included with the letter his correspondence with John Cockcroft who had promised him the isotopes he required from England; and asked of Bhatnagar if he would "kindly ask Dr. Bhabha not to put any further difficulties, but to

---

[450] MNS to DMB, March 17 1947, MNS Papers, NMML.

[451] MNS to SSB, March 19 1947, MNS Papers SINP.

make the grants immediately available to me". Saha reasserted that they were badly in need of funds and anxious of delays given the uncertainty and difficulties of obtaining apparatus from Europe or the USA. Saha was only beginning to feel the effects of centralisation of state funded research, but he had agreed with concentration in principle. He wanted to make one more attempt at getting the Palit Laboratory as the central laboratory for nuclear research in India. Saha began to mobilise local philanthropists towards the establishment of an expanded nuclear physics laboratory that he would call "Institute of Nuclear Physics after [the] American model". In his mind, even now, the competition was open.

Bhatnagar circulated Saha's report on "Atomic Energy Research in USA, UK and other countries" to members of the Atomic Research Board.[452] On April 3 1948, Saha wrote yet another letter to Bhabha addressed "Dear Sir" unlike the usual "My dear Bhabha". He began with that he had not yet received the agenda for the April 9 and 10 meeting. Given the lack of an agenda, Saha proposed that parts of his report be now circulated be discussed with further "amplifications" which he detailed out. He first asked for the meeting to be shifted to Delhi with the Prime Minister and the Vice President attending for "at least an hour", and not on April 9 and 10, but April 16, 17 and 18, 1948. He asked for exploratory sub-committees[453] and finally demanded that pending the formation of

---

[452] SSB to all mentioned, March 27 1948, MNS Papers, SINP. Members who received copies were: K. S. Krishnan, Director, National Physical Laboratory; Darashaw Nusserwan Wadia, Mineral Advisor to the Ministry of Works, Mines and Power, Government of India; Debendra Mohan Bose, Director, Bose Research Institute; Maharajapuram Seetharaman Krishnan, geologist, Geological Survey of India; and Jivaraj Mehta, Director General of Health Services, Government of India.

[453] Saha suggested exploratory sub-committees for investigation of (i) chemical methods of extraction of uranium oxide from low-grade uranium containing minerals, (ii) to purify uranium oxide and convert it to "UF_" which could be then used to obtain pure uranium metal by electrolysis of fused salts, (iii) for

different institutes, "encouragement should be given to Universities and Research Institutes for fundamental and developmental work pertaining to atomic research".

Saha's criticism of the activities of the Atomic Energy Research Committee and its incumbent, the Board of Atomic Energy Research (BRAE) of the CSIR, was that not enough was being done for the organisation of atomic energy research in India. He was not opposed to a central research organisation dedicated to this purpose but he was concerned that no clear-cut plan for nuclear research was emerging under Bhabha's leadership more than a year after Hiroshima and Nagasaki, and six months after Indian independence. Bhabha appeared preoccupied with cosmic ray research, and that according to Saha was not exactly research related to generation of atomic energy. He read extensively the available literature on atomic energy related organisations in the West, and drew up pointed exercises to be pursued if anything meaningful had to be achieved in atomic research. His agitation was only compounded by that the Palit Laboratory was not at the centre of this activity that held much promise of patronage and opportunity for significant work in the national framework.

Yet again, Saha could not attend the meeting of the BRAE, held in Bombay despite his suggestions to hold it later in Delhi.[454] He could not secure air or railway passage. Minutes of this meeting are not available, but it cannot be well imagined that the main

---

pursuing a pilot plant for production of fluorine and hydrofluoric acid from minerals obtained in the country, (iv) to undertake similar investigations with thorium containing ores, (v) to purify locally obtainable graphite and aluminium boron and beryllium metals to the required degree of purity for atomic research purposes, (vi) to organise a supply department for procurement of materials required for purposes of atomic research from both local and from abroad.

[454] MNS to Jnan Chandra Ghosh, April 9 1948, MNS Papers, NMML.

matter of discussion must have been the Atomic Energy Bill introduced that week in the Constituent Assembly of India. The Atomic Energy Bill was introduced in the Constituent Assembly of India in April 1948. A debate followed especially around the issue of secrecy and the nuclear weapons option.[455] In a response to a question on why there were stricter provisions for secrecy in the Indian act than those in the United Kingdom that restricted them only for defence related matters, Nehru's famous retort in frustration was "I don't know how you are to distinguish between the two". He would soon find out that from his defence advisor to be, the British physicist Patrick Maynard Stuart Blackett.[456] The coveted apparatus and technology for nuclear research was capable of both – weapons and energy related work. The Act came with a declaration of expediency to establish prerogative of the state over "industry and materials connected with the production or use of atomic energy" making the enterprise, in Nehru's words, "urgent and highly important". Bhabha submitted a *Note on the Organisation of Atomic Research in India* to Nehru. He asked for the establishment of nuclear research separately from the CSIR. That would take another six years to accomplish.[457]

Saha wrote to Jnan Ghosh, the director of the Indian Institute of Science, Bangalore "some of the clauses [of the Atomic Energy Bill] appear to be dangerous. If the

---

[455] The debate has been discussed in Itty Abraham, *The Making of the Indian Atomic Bomb: Science Secrecy and the Post-colonial State* (London: Zed Books, 1998), especially Chapter 2 and George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (Berkeley: University of California Press, 1999), especially Chapter 1.

[456] P. M. S. Blackett was a British cosmic ray physicist who Homi Bhabha knew from the Cavendish Laboratory. Blackett is credited for having established operations research for war effort. He received the Nobel Prize for his research on cosmic rays in 1948.

[457] See "Note on the Organisation of Atomic Research in India" by Homi J. Bhabha, Chairman, Board of Research on Atomic Energy, *Nuclear India* 26, no. 10 (1989): 3-6.

Government has only got the present closed body in the Atomic Energy [Research] Committee as it is selected (e.g. it has no chemists), they may not give right advice to the Government…. I would also suggest that before the bill is passed into act, opinion of the National Institute of Science should be obtained". Saha also asked Ghosh to send a copy of his report on "Atomic Energy in Europe" to Nehru. None of the contents of this letter are startling; what is remarkable is his request that Ghosh send the report to Nehru, which Saha could as easily have done himself.

The Atomic Energy Bill eventually led to the establishment of the Atomic Energy Commission of India in August 1948, under the Department of Scientific Research (created in June 1948) led by Bhatnagar. Bhabha continued to chair the Commission, and Bhatnagar and K. S. Krishnan were members. The Atomic Energy Commission of India was a mirror image of the Scientific Advisory Committee. Saha was not invited to join the Commission. He was already running out of political favour. Bhatnagar met Saha in company of Satyendranath Bose, Nil Ratan Dhar, and L. K. Maitra at a mutual friend's house. Bhatnagar later wrote to Saha about his disappointment at the conversation going "anti-Nehru". Saha wrote back a troubled response. "… my recollection is that my complaints were particularly against the AEC[I], and if I dragged in Panditji [Nehru], it was only to say that but for Panditji's continued help and patronage I could make no progress in the work which I had taken upon myself".[458] Bhatnagar had found it

[458] MNS to SSB, undated, MNS Papers NMML; the handwritten letter should have been written in early 1948. The sentence "...but for Panditji's patronage…" ends with "nothing could be done" which was crossed out in favour of "I could not make any progress…" Nehru was addressed as Panditji commonly in public life akin to Mohandas Gandhi being addressed as Mahatma. Panditji literally translates to the 'knowing one', or literally a Brahmin.

necessary to bring to Saha's notice that his political views were out of order, and Saha had found it necessary to defend his favourable views on Nehru and considered it important that he make known he was not "anti-Nehru".

Saha's defence was motivated as much by reasons of continuing patronage for his laboratory, but perhaps also because Saha could ill afford to lose Nehru as an ally in the tentative landscape of science organisation in free India. This alliance was one not easily begotten. He reminded Bhatnagar rather poignantly, "You are probably aware that I had contact with Panditji long before either you or Bhabha or any other prominent scientific men had cared to do so, and at a time, when such contacts were considered not quite profitable, nay even dangerous. Witness that I was never be- [k]nighted by the late British Government." Saha was certainly not in good favour of the [British] Government of India and had to contend with this on several occasions.[459]

Transfer of power or the anticipation of independence had not dramatically opened up opportunities for patronage of science with the governing Indian nationalist elite. The Indian National Congress had abdicated from participation in planning of post-war reconstruction of India with their resignation from provincial governments in 1939. This was followed by immediate arrests of the top cadre of leadership who remained

[459] For example, it is often cited that Saha lost his scholarship in high school for allegedly participating in a school protest against a visiting British official. He was not allowed to take the Indian Financial Services examination because of sympathy with "extremist nationalists". I have not investigated these two incidents. What is certain is the protest against and thorough inquiry into his political activities in India, London and Berlin in the 1920s upon his nomination for Fellowship of the Royal Society (FRS), London. He was eventually elected FRS. The British Government never knighted Saha, perhaps not entirely unimaginable for him given the recognition he did receive in England for his achievement in astrophysics. Bhatnagar was knighted before he was elected FRS.

imprisoned for a significant part of the war. There was little interaction between the imprisoned nationalist leadership, and the machinery put together for war effort engaging almost all sections of scientific and industrial research in India for the first time. Bhatnagar perhaps met Nehru for the first time in August 1946,and perhaps Saha enabled this meeting. He reminded Bhatnagar, "…he [Nehru] asked me to tell you to see him with the papers. When I conveyed the information to you, you welcomed it, because as you told me, an officer could not see a Minister unless asked for, and you had not been asked so far by Panditji to do so. My impression is that you told me that you had never met him before personally."

The provincial governments were embedded into the very same structures as the [British] Government of India. The "steel frame of bureaucracy" was deeply entrenched into everyday life of decision making for those participating in government. To be asked to see a Minister was a privilege, and Nehru and Bhatnagar had not met within the framework of science administration or self-rule before WWII. Saha had taken the risk of engaging with nationalist politics, and decisively to his favour in 1938. He perhaps found it unfair that his hard earned political favours should now suddenly slip through his fingers in free India, when it was time to expect an appreciation of active participation in nation building. In any case, Bhatnagar had warned Saha that he had a reputation to take care of and was better off being careful voicing his political opinions.

Centralisation of planning and resources for science research in free India meant that Bhatnagar's political fortunes were only on the rise. Saha was perturbed, not least because of what it would mean for the Institute of Nuclear Physics he wanted to establish. "[The] future of scientific research in India is very dark. Power hunters have gathered round Panditji and trying to mislead him. Recently a proposal was brought before the cabinet of concentrating all research under the prime minister with Bhatnagar as Secretary. This was partly defeated owing to the vigilance of some members but a decision has been taken that all fundamental research would be the care of the prime minister, with Bh[atnagar] as Secretary. So there would be partition of research under ministries just like partition of India?"[460] Partition of research happened indeed. Scientific and industrial research, fundamental research in university settings and soon after atomic energy researches all fell under different ministries with little or no coordination among them at the ministerial level. Any attempt to do so, would count as extra mural activity.

By 1948, Saha had realized that his aim to build a physics department with internationally accepted standards and research agendas could no longer be contained within the existing scale and apparatus of the Palit Laboratory. Saha's ambition was to now reframe the Palit Laboratory into an independent institute dedicated to nuclear physics research. He would have to do so under constraints. Two important sources of funding, the new state and the Tata's, had already committed to one such laboratory on the scale of comprehensive provision in Bombay. The spearhead of science policy in free India, Bhatnagar, was committed to prioritize Bombay as well. Saha's local fortunes had not run out yet. The Calcutta University and the state government of Bengal could be made to see why increased funding for a new institute would prove beneficial locally.

---

[460] MNS to Atma Ram, May 31 1948, MNS Papers, NMML.

The university granted permissions and funds for an extension of the laboratory buildings.[461] This was the beginning of Saha's "Institute of Nuclear Physics after [the] American model".[462] Bhatnagar was not so hopeful; "I do hope you will have funds enough to keep it on the American model. The University College which has produced such excellent results in the past is hardly a place which is even clean enough to be called a laboratory on the American model and so is the case with many others in India including my own".[463]

[461] In 1947, the Vice Chancellor of the university Dr. P. N. Banerjee arranged for a loan of rupees 2 million from the Sur Endowment to be paid back in ten years for new construction in the same campus.

[462] MNS to SSB, March 19 1948, MNS Papers, NMML.

[463] SSB to MNS, March 27 1948, MNS Papers, NMML.

In front of the Magnet of the Cyclotron, Institute of Nuclear Physics,
92, Upper Circular Road, Calcutta.
1948-49 (?)
Front Row (L to R) : Dr. A. P. Patro, Dr. B. D. Nagchowdhury,
Mr. B.M. Banerjee (only part of his face visible), Prof. M. N. Saha

Figure 4.3: Meghnad Saha, B. D. Nagchoudhuri and the Cyclotron Group.
Reproduced with permission from the Meghnad Saha Archive, Saha Institute of Nuclear Physics, Calcutta.

In May that year, Nag wrote back from Berkeley.[464] He had visited the Institute for Nuclear Studies at the University of Chicago and the Argonne National Laboratory. They were building a 120-inch proton synchrocyclotron. Argonne also had two atomic piles. But as far as securing components for enhancing or completing the cyclotron back home

[464] BDN to MNS, May 9 1948, MNS Papers, SINP. He had also talked to Cooksey about Ajit, Saha's son and would discuss that when he was back.

went, “rules have become much stricter in these few months and things are difficult now. They will probably be even more difficult in the next 2-3 years”. It was Nag’s turn to receive updates and further instructions to buy several more parts for the cyclotron.[465] He would have to buy magnet coils as one of coils had short circuited, fibreglass insulator as the insulating cloth was proving cumbersome, and an extra pair of power oscillator tubes which seemed to be cracking all the time. When he would reach England, he should also visit Metropolitan Vickers Research Laboratory at Trafford Parks, Manchester, after all “they [were] claiming that they [were] making a good deal of things for nuclear physics and they are in a position to help others”. There were not that many firms anymore who could claim to be a position to “help others” with time and products that would potentially divert their attention from services for national laboratories. This option had to be checked. There was also some good news. The University Grants Committee had awarded a grant for constructing two floors of added laboratory space in Calcutta.[466]

A slightly ill Nag sailed from New York on May 23 1948. He had spent 1350 dollars and shipped most of the apparatus required through the Scientific Instruments Company.[467] The Radio Corporation of America (RCA) now had an agency in Bombay who could supply possibly some demands in about four months and that was good news. There were

[465] MNS to BDN, May 18 1948, MNS Papers, SINP; Saha was also perplexed that Nag did not borrow more than 700 dollars to buy equipment when he was offered 5 000 dollars by Mrs Watumall, the American wife of the philanthropist Gobindram J. Watumull who did such favours for visiting Indians regularly. Saha insisted that Nag should take as much as required and even more but make sure he got all the apparatus required.

[466] The University Grants Committee made a capital grant of rupees 3.5 million and a recurring grant of 60 000 rupees for three years. In two years, a building with 3000 square meters area was built, with plans for further expansion. In 1950, the Atomic Energy Commission made a further grant of rupees 1.2 million for furniture, fittings and services required in the new building.

[467] BDN to MNS, May 21 1948, MNS Papers, SINP.

things that he could not accomplish. He could not talk to anyone about [separation] mass spectroscopes: they were still "very secret". There was also no chance one could buy heavy water in the USA. One could buy up to 100 grams from Norway. Saha wrote several letters again and again even as the smallest information became available for matters Nag could pursue while he was abroad. It was getting more and more difficult to get books and journals. Nag simply had to make full use of the opportunity of being abroad to bring back information, books, journals, reports and apparatus he could manage to procure.[468] Nag would have to meet Ajit Saha, and visit Harwell along with Trafford Parks. And one could get Kinney Pumps in England now. He would have to try and get more information on those and the new ones advertised by W. Edwards Company. He had to collect publications of the British Association of Scientific Instrument Makers. Saha especially wanted a book by Samuel Goudsmit on the Alsos Mission dealing with war-related research in Germany during the war, particularly the Germany nuclear program.[469]

Nag's trip, officially speaking, was meant for visiting nuclear physics laboratories primarily in the USA but some in the UK for six-months. Official permissions had been procured from the Atomic Energy Commission of the USA for making these visits. The Indian Embassy in Washington did not coordinate these procedures in a timely manner but Nag headed straight for the Radiation Laboratory, Berkeley where Lawrence arranged

[468] MNS to BDN, May 26 1948, MNS Papers, SINP.

[469] MNS to BDN, June 1 1948, MNS Papers SINP; Samuel Goudsmit (1947) *Alsos* New York: Henry Schuman. The American physicist Samuel Goudsmit led the Alsos Mission (1943-45), a military mission to investigate German weapons status, especially for evidence of an atomic bomb capability.

for permissions within ten days, just as he had got the INS off his back in 1941. These days of waiting would have to be accounted for to the Ministry of Education of the Government of India, because they were paying for the trip. Even if Saha allowed him to stay on longer if necessary to get the required apparatus, his funding was limited by bureaucratic measures.[470] The trip had been busy; Nag visited nineteen nuclear physics laboratories in the UK and the USA, but also in Sweden, Denmark, France and Switzerland.[471]

Apparatus bought or ordered abroad was not easy to arrive again. Philips at Eindhoven had discontinued production of certain types of valves and could not send others because of withdrawal of open general licence presumably in the USA. The valves would now have to be secured after an import licence from the USA by Philips and then sent to Calcutta.[472] The "protracted business" of shipping parts that were to be shipped in April, took up until September before they were sent to Calcutta.[473] Permissions from the US-AEC had to be obtained, and "diligent pestering" eventually yielded results. Nag's

---

[470] BDN to The Secretary, Ministry of Education, Government of India, August 1 1948, MNS Papers, NMML; Nag also had to account for having to fly back from New York as opposed to sailing because the Embassy failed to book his passage in time. He would subtract all these days along with days of travel to arrive at a six month working period which was justified by his grant. Strict bureaucratic procedures proved cumbersome not for Nag alone.

[471] Nag visited the following laboratories: UK: Cavendish Laboratory, Cambridge; Bristol University; Birmingham University; Edinburgh University; France: Institut de Nuclear Chemie; Institut Radium; The nuclear physics laboratory of the College de France; Switzerland: Physikalisches Institut, ETH, Zurich; The high voltage laboratory of Brown Boveri Werke; Sweden: Nobel Institute of Physics; Uppsala University; Denmark: Institute of Theoretical Physics, Copenhagen; USA: Radiation Laboratory, Berkeley; University of California, Los Angeles; Nuclear Physics Laboratories, University of Chicago; Argonne National Laboratory; The Carnegie Institute of Technology; the Federal Bureau of Standards and the Columbia University.

[472] A.A.A. Dikkers, Philips Electrical Co. (India) to BDN, October 14 1949, MNS Papers, NMML.

[473] [Tom] from the Griffith-Durney Company to BDN, September 24 1948, MNS Papers NMML.

contacts saw him through the tedious process. Nonetheless, the US-AEC wrote asking for whereabouts of apparatus he had purchased when in the USA, including those he used for experiments in the Rad. Lab.[474] There were charges on each Bill of Lading, which could be adjusted if Nag would have to pay them himself. But if the University was paying for everything, the charges were in order. Favours could be done for Nag; after all, he was "now rated as one of the exclusive leisure class of Europe so much envied in the US". Colleagues back in Berkeley looked at Nag's trip to Europe on his way back from the US as an "excellent vacation". For their part, the Ministry of Education, Government of India saw it but only slightly different. Irrespective of the delays caused by inefficient handling of permissions by the Embassy of India, they made him pay for every extra day after the "exactly six months" that they had agreed to fund. [475] Back home, Nag wrote back to Robert Thornton and Lawrence. He had enjoyed his stay and wished he could have stayed and worked longer at the Rad. Lab. He had used his short visit to study scattering of the delayed neutron, a problem suggested to him by Lawrence. It had been a difficult experiment to analyse, but he sent short notes to Thornton and wondered if he could publish them in local journals in Calcutta to justify his deputation abroad.[476]

Even as satisfactory completion of the cyclotron was proving difficult, other activities at the Palit Laboratory were moving on. The difficulties had not dwarfed Saha's ambitions

[474] BDN to US-AEC, January 10 1949, MNS Papers, NMML; the inquiry was about a pocket chamber Nag had discarded after damages during use in Berkeley itself and a counting rate meter which had been shipped to the USC in Calcutta. The permissions, Nag argued, had been obtained by Griffith-Durney and Co. of San Francisco.

[475] Deputy Secretary, Ministry of Education, Government of India to The Accountant General, Central Revenues, Government of India, September 16 1948, MNS Papers, NMML.

[476] BDN to Robert Thornton, August 30 1948, MNS Papers, NMML.

either. Apart from researches in the laboratory, Saha was actively pursuing the possibilities of procuring a pile, as reactors were called then, to further expand the gradually consolidating Institute of Nuclear Physics in Calcutta. The French example was inspiring for Saha as for others because the French physicist Frederic Joliot-Curie had organised the construction of " a successful pile inspite of refusal of English and American authorities to supply uranium and data about [the] construction".[477] Saha's student Samarendra Nath Sen was at UNESCO when Saha asked him to get in touch with Joliot-Curie "to give us the data for the Institute of Nuclear Physics, Calcutta, which contemplates building a pile". Following Sen's visit, Saha had himself written to Joliot-Curie but not received any response. Jnan Chandra Ghosh, the director of the Indian Institute of Science, was visiting Paris in September 1949, and Saha asked him to meet Joliot-Curie; "probably these talks can be continued only tête-à-tête, not by correspondence". Saha was convinced Ghosh must visit Fort Chântillon and compare the activities of atomic energy research with those in India. He must not forget to obtain all diagrams and plans necessary for building a pile along with precise quantities and the grades of purity of uranium, graphite and heavy water required. All these activities were necessary elements for the making of a premier nuclear research laboratory, especially if it was to be a facility on the national level.

The fervent pursuit of several agendas in nuclear research to be organised at the Palit Laboratory along with its gradual transformation towards a projected Institute of Nuclear Physics despite conceding national priority to the Tata Institute of Fundamental Research

---

[477] MNS to Jnan Chandra Ghosh, September 5 1949, MNS Papers, NMML.

begs explanation. Saha may have been convinced that there was still chance that his Institute of Nuclear Physics could become the central nuclear research station for the country. There were few contenders; in fact, the TIFR was the only one. The magnitude of funding for nuclear research as well as the emerging national policy understood by Bhatnagar and Bhabha made it impossible for any other university laboratory to emerge strong in nuclear research. Saha was well aware that there was little chance any new institutes for nuclear research would be allowed to emerge. If there was one good reason why the Palit Laboratory escaped being snipped out and was able to pursue nuclear research, it was that they began the construction of the cyclotron under colonial rule before the end of WWII and thus before the establishment of the Atomic Energy Research Committee. Saha found Bhatnagar and Bhabha's efforts dissatisfactory. His complaint was that the TIFR was concentrated on cosmic ray research and theoretical particle physics and no experimental nuclear physics of consequence. The only plan Bhabha had thus far for particle accelerators at the TIFR was to buy a betatron and that he had abandoned in 1947 with the discovery of the meson. There was no sign of efforts to construct a pile. If Saha could manage to build a credible Institute of Nuclear Physics with a comprehensive agenda and abundant equipment, there could not exist a stronger argument against its recognition as *the* laboratory of nuclear research in India. For this he required equipment, funding and expertise from home and abroad. Unsure of unquestionable good favour with Prime Minister Nehru, he wrote to persuade the President of India, Sarvapalli Radhakrishnan.

Radhakrishnan was on a trip to the Soviet Union when Saha wrote to him.[478] Saha wondered if Radhakrishnan had found the time to read his book *My Experiences in Russia*. He suggested it would be worthwhile for the President to visit the laboratories of Peter Kapitza. The President should have to see how men of science were treated in the Soviet Union and Saha's books would enable him to appreciate how the "Bolshevik Government has done much for science… My impression is when Russian Gov[ernmen]t is convinced that a scientific man is doing good work, he is not to suffer from dearth of funds or materials". This was well worth emulation and the President had to realise that what he was about to see in the Soviet Union and in Peter Kapitza's laboratory could well be done for Saha's Institute. The Prime Minister had not replied to the special request made on Saha's behalf by the President for increased grant money. Would the President "kindly put in a word or two?" Well aware of Bhatnagar's predisposition to favour Bombay, by October 1949, Saha did not even want his funding proposals to reach Bhatnagar and sought to seek funds directly from the Ministry of Education.[479]

Nag wrote a one-page progress report of the Institute of Nuclear Physics in August 1949, and this is very likely the first report written for the Institute of Nuclear Physics (INP). The INP, he wrote, was organised "to develop into a centre of research and teaching in Nuclear Physics to post-graduate students".[480] The Institute had developed "usual" techniques for nuclear physics research with a cyclotron, a beta-ray spectroscope,

[478] MNS to Sarvapalli Radhakrishnan, September 7 1949, MNS Papers, SINP.

[479] MNS to Humayun Kabir, October 13 1949, MNS Papers, NMML.

[480] *Report on the progress of the Institute of Nuclear Physics* Report of August 22 1949, MNS Papers, NMML. A 'Post-graduate student' refers to the American equivalent of 'graduate student'.

counters, ion-pulse amplifiers, and fluorescent counters. Important activities being carried out were methods of measurement of extremely short life metastable nuclei, development of ion sources and problems of high vacuum and its detection. The report announced an important decision: the cyclotron was being reconstructed to reach 8 MeV energies from its present obtainable energy level of 2 MeV. And this array of activities was planned around the 7 or 8 M.Sc. students coming in every year and a total of 4 research scholars working with the "various instruments outlined" in the report. Almost everyone involved with the cyclotron was working with other experiments in nuclear physics and related areas including Nag. The cyclotron was proving pivotal for the Institute of Nuclear Physics, but it was certainly not the centrepiece of efforts.

4.12 To Parliament

Saha was elected Member of Parliament as an independent candidate from Calcutta in 1952. After 14 years of entrepreneurial activity to establish a frontline nuclear physics laboratory from within the Calcutta University, Saha decided that entering politics professionally would further his goals of scientific enterprise and save his dwindling political fortunes with the national government of free India. He had doubts about this decision but he did take the plunge because he "was feeling like Hamlet who was abscessed with ideas but without opportunity for work". Saha kept company with those "trying for leftist unity" on the national front even though he recognised "the Congress [was] very strongly entrenched in power". Some on the left had come to see the Congress as "reactionary" but Saha thought there was no alternate party. Some of his colleagues agreed that parliamentary life might not really present Saha with opportunities of furthering scientific enterprise the way he wanted. The geologist Darashaw Nusserwan Wadia hoped that Saha's political career would at least be "a quarter as successful" as his scientific career in India and abroad.[481]

Saha offered to host the Indian Science Congress meeting of 1952 in the new buildings of the INP. Saha wanted to use this opportunity to get the Prime Minister to inaugurate the facility. "For this, our laboratory should be in a tip-top condition and the grounds should be properly dressed". Saha needed a small grant for just that and Bhatnagar must help he thought.[482] There was three acres of marshy land to be filled and the laboratory to be refurbished. But his time was now divided between Calcutta and Delhi. Becoming a Member of Parliament involved moving to Delhi in Northern India and closer to the burrows of power. Saha found that the opposition in the parliament did not know how to organise its forces, which meant that the Congress "rule or mis-rule" would continue. Nonetheless, he was satisfied that his presence in the parliament gave him the chance of "studying the problems of the country with greater efficiency".[483] It was certainly not an easy job, he wrote to Archibald Hill; "…I find it difficult, with my training as a scientist, and accustomed to build my views on hard core of facts to identify myself with any of our political parties, and therefore I cannot do anything very effective. But I find that the Public like my views. I feel that if I were given some ministerial job, I could have done it

[481] D. N. Wadia to MNS, February 2 1952, MNS Papers, NMML.

[482] MNS to SSB, June 28 1951, MNS Papers, NMML.

[483] MNS to Jnan Chandra Ghosh, July 4 1952, MNS Papers, SINP.

far better than the professional politician, but I can see that I can only be an Irish member".[484] His presence in Delhi also meant that Saha could renew contacts with his students who now occupied important positions in science in North India like P. K. Kitchlu at the Department of Physics, Delhi University, and Daulat Singh Kothari, Scientific Advisor, Ministry of Defence.

Saha's move to Delhi also meant an increased distance from the INP. He left the reins of the INP mainly in Nag's hand even though he remained honorary director. He took leave to retain the Palit professorship in physics, about which the Palit Trust Governing Body was not very happy. They raised questions about granting him leave from his professorial duties. It was only a year until Saha would officially retire from the professorship, but until then, he would soon have to decide whether he wanted to remain professor of physics or become a professional politician. Under no circumstances was Saha willing to relinquish his position as honorary director of the INP. He allowed the Palit Governing Body to advertise the professorship making it clear that the professorship did not automatically translate to a directorship of the INP; nor did it even mean a direct relationship to the INP. The position was located in the department of physics of the Calcutta University and that is how he suggested they proceed. The one position he prioritised was with the INP and his continuing participation as an elected representative from Calcutta.[485] Saha held the potential to bring opportunities of political patronage to

[484] MNS to AVH, October 8 1952, MNS Papers, NMML.

[485] MNS to SSB, November 4 1952, MNS Papers NMML.

these institutions only that they were not necessarily the priorities of those administering them.

The December issue of the journal *Nucleoneics* that year carried a section on 'World Progress in Atomic Energy'.[486] K. S. Krishnan was interviewed for the one page section on India. Krishnan described the Institute of Nuclear Physics in Calcutta as "[P]robably the most active and certainly the best equipped of the Calcutta centres… under its director, M. N. Saha adheres closely to pure nuclear research, as distinct from cosmic ray work. It possesses a 37-inch cyclotron – the only one in India". Despite conflict, contest and the inability of the AECI to make place for the INP within their agenda for nuclear research, the AECI was well aware of the importance of work being carried out at the INP. Moreover, the AECI appears quite clearly aware of the INP as an asset promoting the image of Indian nuclear research even though outside the government's own plans thus far. This recognition brought more funds to the Institute from the AECI. The short article, however, left Saha quite upset.

Following the article in *Nucleonics* Saha wrote yet again to Nehru with a scathing critique of the AECI.[487] Saha's first argument was that the AECI had completely failed to identify training of personnel for nuclear physics research as a part of its agenda.[488]

---

[486] See *Nucleonics* 10, no. 12 (December 1952): 7-35.

[487] Draft manuscript of letter to J. Nehru, written most likely in late 1952 or early 1953, MNS Papers, SINP. Sections also published as part of Mineral Sources and Mineral Policy, address delivered as chief guest at the 29th Annual General Meeting of the Geological, Mining and Metallurgical Society of India, Calcutta, August 26 1953, reprinted in *Journal of the Geological Society of India* 25, no. 4 (1953): 135.

[488] Saha was also not convinced about how Krishnan had arrived at the conclusion that "trained scientific personnel for atomic energy work in this country does not probably exceed a hundred". This he particularly

Saha's criticisms, ambitions and political career notwithstanding, the Ministry of Natural Resources and Scientific Research, Government of India gave an equipment grant of a million rupees to the INP in 1953.[489] The position of the INP within the national agenda now was far stronger when compared with any other university laboratory in India.

But Saha was yet again unable to attend the AECI meeting of April 1953 as well as the next one in August 1953. He had wanted Nag to represent the INP, but Nag had chosen otherwise. Saha was not at all happy. Nag had begun to act independently of Saha's suggestions.[490] If Saha was quite keen on making INP the central laboratory, he could not proceed without those working in the laboratory. On the other hand, if Saha wanted to prioritise INP within the state led AECI, it is surprising the number of times he is unable to attend it meetings because of prior commitments.

To just what extent anyone in the laboratory was anymore motivated to carry out serious experimentation with the cyclotron is not easily discernable. That is not to say that they were giving up on the cyclotron either. If anything, the cyclotron had proved to be the

---

contrasted with available numbers for UK (11 000) and USA (150 000 of which 7 000 were employed by the US-AEC). Saha obtained these numbers from *Atomic Science News* (March 1953): 258, Draft manuscript of letter to J. Nehru, cf.150. Saha thought the numbers at the end of five years of the AECI's existence were embarrassing. At the INP, this always had been a priority and they had plans to introduce a "post-MSc" program beginning the next year. This was a part of Saha's reorganization of the departments curricula, where students who had obtained their Master's degree most often in physics, were given a chance to appear for a screening examination, which enabled them to enrol for a one year theoretical and to some extent experimental specialization in nuclear physics. This year involved both coursework and laboratory work with the professors. See Institute of Nuclear Physics Year Book Calcutta: INP (1948-55), also referred to as the "green book".

[489] MNS to Jnan Chandra Ghosh, May 21 1953, MNS Papers, SINP. The grant was subject to a review by a committee of scientists.

[490] MNS to Bhatnagar, April 24 1953, MNS Papers, SINP.

central argument for a separate institute of nuclear physics and organisation of nuclear work in Calcutta. But even dating back to the very first years of construction, the cyclotron was hardly ever the only activity that engaged the laboratory. It was coming close to a decade since they had begun work around the cyclotron and on 8 January 1954, Saha finally wrote to Nehru; "The Cyclotron is working". Nehru was visiting Calcutta for the All India Congress Committee meeting. "I am sure that you will be glad to see all these works." He hoped that Nehru would not disappoint them.[491] Nag for his part wrote to Donald Cooksey in Berkeley. Cooksey made a note of Nag's letter on the back pages of his copy of the recently published biography of Saha. "Letter from Basanti Nag to me says the small cyclotron is working producing beams of protons at 5 MeV."[492] Saha was not entirely disappointed. Nehru could not visit the INP but the Government of India, through the AECI awarded recurring grants requested by the INP without reservations.[493] The new special course in nuclear physics was an overwhelming success – 150 students wrote applications for the 15 seats available. It was time to look ahead, and write a five-year plan for the AECI.

4.13 A Working Cyclotron

[491] MNS to Nehru, January 8 1953, MNS Papers, SINP.

[492] Copy of S. N. Sen, *Prof. Saha: His Life work and philosophy* (Calcutta: SINP, 1954); EOL Papers, Cooksey Folder, Bancroft Library. Cooksey also wrote, as a reminder perhaps for others in the lab who might take a peek in the book: "Nag got his PhD from the Rad lab before the war and returned to India where he was in charge of building the small cyclotron referred in the book in Saha's lab. I suspect the Tata foundation helped him in this or later work".

[493] MNS to Nehru, March 29 1953, MNS Papers, SINP.

With the confidence of now possessing a working cyclotron, the Institute of Nuclear Physics wrote an ambitious plan.[494] The plan proposed the establishment of an Institute of Medical Physics around the already existing biophysics section. The plan also made a very clear reference for future establishment of a "hot chemical laboratory" and a research reactor facility. The buildings were to be expanded and scaling up of activities was projected such that in the next five years, the INP would be able to "train personnel in subjects such as nuclear science and technology. Continuing research on established and new lines was to be directed at "assist[ing] the Atomic Energy Organisation (sic) of India in developing Atomic Energy for peaceful purposes in India. The accelerator division had begun work on a Cockcroft Walton generator with 1 MeV energy. But furthermore, a group was constituted to build a linear accelerator patterned on the Harwell facility, as well as an electron synchrotron.

The Department of Atomic Energy (DAE) discussed the plan immediately. Bhabha had recently been appointed Secretary of the DAE, and thus occupied the highest bureaucratic position for atomic energy related organisations in the country. In his response, he first clarified bureaucratic matters. "… all reactors and all plants required for the generation of atomic energy are the exclusive responsibility of the State".[495] As a university laboratory, the mandate for the INP was restricted to research activity and production of isotopes or production of electronic apparatus could not be pursued. The AECI would arrange for import and production of materials needed for work. On the other hand, the plan for

[494] MNS to HJB, December 16 1954, MNS Papers, NMML.

[495] HJB to MNS, December 18 1954, MNS Papers, NMML.

building an electron synchrotron was in principle possible given the experience of the Calcutta group with the cyclotron, however "techniques of other accelerators was not within the experience and knowledge of the group you have". With these revised directives, Bhabha suggested that the INP now rewrite the proposal upon which a discussion of representatives of the INP, DAE and the Ministry of Finance could take place.

Three days later, Saha and Nehru clashed in Parliament. The misunderstanding was about figures on calculating national income of India in relation to planning. Details on numbers notwithstanding, Saha wrote a remarkably dejected letter to Nehru.[496] "All my statements and writings made in perfect good faith, and with the objective of enabling your government to see the truth, are proving extremely irritating to you…. I am sincerely sorry at the deterioration of good relations between us. I was one of the first of India's prominent scientists to contact you, about 1936, when most of our scientists kept at a safe distance from you for obvious reasons. We had worked together at the National Planning Commission, which many of our top scientists, including Sir C. V. Raman and S. S. Bhatnagar categorically refused to join inspite of our best efforts. Krishnan and Bhabha had not come into the picture then…. But in 1946 as soon as you got power, these very men … began to buzz around you like so many flies around a honey pot". Saha reminded Nehru of how all those named had kept away from the Indian Science Congress of 1943 in Calcutta, when Nehru was nominated as president of the Congress as a mark of respect from those assembled. Nehru was then in prison.

[496] MNS to Nehru, December 22 1954, MNS Papers, NMML.

"I have been put into one humiliation after another. I have been asked to take orders from Bhatnagar, whom I consider a very poor scientist, and from Bhabha, who though a good scientist, but is 18 years my junior and the conferment of enormous power on him has made him extremely bumptious". Saha concluded the letter with a plea that he had never asked for personal favours except for grants for institutions he has built for furthering scientific research in the country. His growing disfavour with Nehru, he felt was now potentially harmful to these institutions and therefore he could consider retiring from positions he held. "If I have to do this I shall do it with a very heavy heart, because science is a part of my life and I shall indeed regret to discontinue that life". Saha's disappointment was complete. This was perhaps the moment when it became quite clear to him that with Bhabha now occupying a rather invincible position in the organisation of nuclear research in India, there was absolutely no way to equip research at the INP towards making it a comprehensive facility for nuclear research. That the INP would not become a national facility was not the only consequence of the establishment of the DAE with Bhabha as its secretary. The INP's research mandate was also now firmly under the directive of the DAE. It was a prerogative only of the state, as Bhabha had made it quite clear. Nehru's response was hardly encouraging. Nehru in turn was disappointed that Saha was unable to appreciate "the overall view and conditions existing in the country… After making a strong attack on everything that Government had done and running it down, you were good enough to compare us to Chiang Kai-shek and his failure… I can hardly judge myself. It maybe that you are a better judge of me than I am myself".[497]

---

[497] Nehru to MNS, January 9 1955, MNS Papers NMML.

Saha's political fortune was depleted, ironically during his tenure in parliament. The revised proposal for funding of the INP in the next five years came up for discussion in this atmosphere. A meeting was held in Delhi. Also invited to the meeting was Mark Oliphant, Bhabha's old colleague from the Cavendish, who was well acquainted with Saha. Saha sent copies of curricula and work at the INP for Oliphant's perusal. The debate began with a discussion not specifically about the INP, but about universities and funding for nuclear research and education in general. The discussion was pertinent and timely. Oliphant was facing similar concerns in his efforts to now establish nuclear research in his home country, Australia. Oliphant suggested the DAE look after specific projects alone and leave basic education in nuclear physics as part of broader physics education to the universities. Bhabha agreed with him. Jnan Ghosh speaking from his experience as director of the Indian Institute of Science did not agree. Universities, he proffered simply did not have the funding to promote advanced scientific education and neither could the state governments afford it, nor the poorly funded University Grants Commission. Funding would have to come from the federal government and its agencies dedicated to the pursuit of advanced scientific research, in this case the DAE. Bhabha, as secretary of the DAE saw this as a call upon his office and, nuclear physics he now proposed was not the only branch of scientific research to be promoted in university settings. It was mandatory that a fair treatment be given to various branches of physics and sciences in general. The secretary for finance for his part suggested that irrespective of who disbursed the grant, it was the federal funding and therefore it was important to take this issue to the state governments through the University Grants Commission.

Hardly any agreement was found. Bhabha now began to see the agenda of the DAE as predominantly atomic energy related research not far from the idea Bhatnagar and he shared at the foundation of the Atomic Energy Committee in 1946, and in fact something Saha had also argued should be the case. As recorded in the minutes of the meeting, it does not appear that Saha though present, made any forceful representation at all. As regards the accelerator division, the proposal to put in an additional focussing magnet for the existing cyclotron was accepted. Oliphant pointed out that if an electron synchrotron of 200 MeV was to be built, the cost would be very high and the construction would take much too long for any useful experiments to be carried out in the next five years. Instead, a synchrotron with a capacity up to 50 MeV and the estimated cost of Rupees 1 million would be adequate. The estimate was inclusive of salaries of staff - scientific and other. Three positions, one reader and one lecturer in physics, and one technical engineer were suggested for this project which Saha thought could be completed in four or at most five years. Expansion of teaching responsibilities and the possibility of increasing the number of professors from one to three was acceptable to Bhabha and he proposed a cushion in the grant for increasing prices and contingencies. Nag would now have to work out the fine details of new positions, projects and instruments suggested and accepted in the meeting. That inaugurated another chapter on dealing with bureaucratic mire but that is quite yet another story. For this chapter, it would suffice to say that the cyclotron had come a long way to its completion and served a strong nucleus towards generating funding and credibility for the Calcutta group to organise nuclear research in independent India.

Conclusion

A cyclotron is not an easy thing to build.[498] To be able to successfully implement the cyclotron principle in a research installation was not a self-evident activity. This observation would stand good even when made apart from the context of the sheer magnitude of material and human resources at the Radiation Laboratory in Berkeley. Once away from Berkeley, the cyclotroneers usually found many difficulties in their way. Lawrence wrote to Harold Walke, "As I have written Bernard [Kinsey], you are unjustifiably depressed with your progress. The difficulties are reasonable and natural ones, and it won't be long before you will have them cleared up. You know in the past *we have had plenty of trouble here, and everybody has them at one time or another* … Henry Newson has been in a similar unhappy state of mind to yours, not having a cyclotron running, and this continued to be the case after Art Snell joined him, and they still have their troubles."[499] Ex-Rad. Lab men, explains Childs in his biography of Lawrence, "derived technical benefit from each other and had great good times together". This is the moment when the metaphor of periphery gains currency. Calcutta in India was located quite far from the important laboratories of nuclear physics. The closest point of reference could have been Japan, but there does not seem to be any evidence of attempts at cooperation between Saha and Yoshio Nishina. By 1942, it was anyway not feasible

[498] For difficulties especially in European laboratories see Heilbron, "The First European Cyclotrons" *Rivista di Storia della Scienza* 3, no. 1 (1986): 1-44.

[499] Childs, (1968), 269, emphasis added.

with India and Japan occupying enemy camps in WWII. Industrial support for this effort in India was minimal. Most industrial support for Saha's ambitious enterprise came from the scientific instruments industry in Britain and in the USA in the form of imports. This was unreliable during the war, and got tougher after.

Saha's ambition was to find the best way to fuse the activities in the Institute with his imagination of the national, without dislocating from its primary focus with teaching and research in nuclear physics. He, like many others, was looking for strategies to reconstruct academic life in science in a shifting local and international context – in post-war physics, and in a free India. With wars end a clear nuclear mandate needed addressing and a local, university based research facility established with the purpose of serving teaching and research interests was dwarfed in competition. The scale of experimental physics research, especially nuclear and atomic physics began to dwarf other concerns in terms of funding and personnel requirements. But this was also not a matter of funding alone. If the function of a university department of physics was to train minds and hands in physics research, could those responsible for teaching afford to establish monocultures of research and education in a university setting? There were several reasons for the increasing prevalence of national laboratories as a model for nuclear research following the Second World War, funding, size of equipment and state involvement were a significant part of the argument. Even if state led nuclear research organizations did not want to shunt university laboratories from research efforts, there were good reasons for both to not have any one definite claim that would be necessarily the correct one or for that matter mutually acceptable. In Saha's mind the cyclotron laboratory increasingly became a developmental project. However, there was progressively little space for this level of involvement without being nominated by the state, and that proved elusive. Soviet industrialisation was an object of admiration for the nationalist bourgeoisie, including Nehru. Therefore, Saha's admiration of the Soviet experiment may not have been perceived entirely burdensome in the local context, but he could not be allowed to represent the nuclear question of India in Cold War international politics. Beginning 1945 up until 1949, the Allied powers remained the sole proprietors of nuclear knowledge. If the political and scientific leadership in India was committed to establish large-scale nuclear research in India that was accommodative of the aspiration to sovereignty and autonomy, a carefully plotted critical distance from the Allied powers had to be established within the process of decolonisation. A precarious balance of power and alliances was being accomplished at home and abroad, and confrontational postures were far from necessary on behalf of a newly independent country. If anything, the continuing support for the Calcutta cyclotron and the establishment of the Institute for Nuclear Physics could be taken as signs of acceptance in the national context.

Ernest Lawrence eventually travelled to India in 1953 but he did not visit any laboratory. Saha was perhaps in Delhi and Nag in Calcutta, but Herbert Childs reckons he avoided the city. There may be many reasons why Lawrence did not visit Saha's, or for that matter any laboratory in India. And for one, he was not in good health. Nonetheless, it may have disappointed his former student and a colleague that he would not see their committed efforts at an installation arduously recalcitrant.

CHAPTER 5: THE IMPORTANCE OF BEING NUCLEAR - EXPERIMENTAL NUCLEAR PHYSICS AT THE TIFR, BOMBAY, 1945-1959

> "In New York last week, Dr Bhabha explained how India intends to lift itself by its atomic bootstraps. An important asset, physicist Bhabha believes, is India's tradition of learning. "Those Brahman's who sit on their bottoms all day, he says, are not just sitting. They are thinking and have been doing it for thousands of years. When the young ones turn their thinking to physics, they quickly get rather good at it." [500]
>
> "Atoms for India," *Time Magazine* (February 1955)

"In cosmic rays nature has provided us with the biggest atom smashing instrument in the world, and whole surface of the earth is our laboratory" said Homi J. Bhabha on December 19, 1945 at the formal inauguration of the Tata Institute of Fundamental Research (TIFR).[501] Nine years later, on January 1, 1954 at the foundation stone laying ceremony for a bigger campus of the TIFR, Bhabha returned to the question and said: "Now the accelerators are costly things. For example, one may cost as much as the "Flagship Delhi".[502] This would normally put them outside the scope of what we in India would do with limited finance. However, thanks to nature we have cosmic radiation that provides us with particles that are even more energetic than can be provided with any other accelerator. These can be used to study the same phenomena".[503] Why then did

[500] "Atoms for India," *Time Magazine*, (February 07, 1955).

[501] Homi J. Bhabha, "Lecture delivered at the inauguration of the Tata Institute of Fundamental Research, Bombay December 19 1945," Manuscript from *Collected Papers and Speeches of H J Bhabha* II - *Atomic Energy, Science and Technology*, (Bombay: TIFR Library, n.d.).

[502] Flagship Delhi was a naval warship that was used for diplomatic trips by the Prime Minister Jawaharlal Nehru for his trip to Indonesia in 1950. See Venugopal A, Surendra Ahuja and Surendra Singh, "Indian Navy's Role as an Instrument of India's Foreign Policy, (2001) on www.indiannavy.nic.in/nott_winner_2001.pdf.

[503] H J Bhabha, "Speech delivered at the foundation stone laying ceremony of the new buildings of the TIFR January 1 1954," Manuscript from *Collected Papers and Speeches of H J Bhabha* II - *Atomic Energy, Science and Technology*, Bombay: TIFR Library, n.d.)

Bhabha actively and resolutely pursue a program of accelerator building at the TIFR? This chapter traces the history of particle accelerator building activities at the TIFR, overshadowed by its mentor's shifting interests beginning with cosmic ray physics, through research reactors, and finally fusion research for the period between 1952 and 1959.

5.1 1944-1945: Bhabha Goes to Bombay

Archibald Hill's diplomatic visit to India in 1944 was an important moment in the history of the organization of post-war research in India. After long and detailed discussions with Hill, Homi Bhabha first wrote to Jehangir Rustom Dorab Tata (JRD Tata) of the Tata family with his ideas on founding an institute for research in fundamental physical problems. "The lack of proper conditions and intelligent financial support hampers the development of science in India at the pace at which the talent in the country would warrant".[504] Encouraged by JRD Tata, he then went on to submit a proposal to Sir Sorab Saklatvala of the Dorab Tata Trusts for plans to found a "first class school of research in the most advanced branches of physics in Bombay". Hill's advice was useful because of his "intimate knowledge of the organization of science and scientific institutions" in England. Atomic histories of India repeatedly evoke one paragraph from this letter where Bhabha claimed, "When nuclear energy has been successfully applied for power

[504] HJB to JRD Tata, August 19 1943, Tata Central Archives; JRD Tata to HJB, September 2 1943, Tata Central Archives.

production in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand".[505]

The significance of "nuclear" research in 1943 and 1944 is clearly distinct from one that would come into common parlance after 1945; this was still before the atomic bomb and its terrific demonstration of the atomic energy potential. Bhabha, like other physicists of the time, had anticipated the advent of nuclear energy following the discovery of nuclear fission in 1939. He was certainly as convinced as Saha and Raman of the importance of further scientific inquiry in the field. However, for Bhabha the excitement was not about entry into an exciting frontier of physical sciences in a manner similar to Saha or Raman, because his own field of inquiry stood at the threshold of nuclear physics. Bhabha's research was in theoretical physics of elementary particles and more recently in experimental cosmic ray physics, which shared much in common with the concerns of nuclear physics at the time. In his letter to Saklatvala he added; "the subjects on which research and advanced teaching would be done would be theoretical physics, especially on fundamental problems and with special references to cosmic rays and nuclear research, and experimental research on cosmic rays. It is neither possible nor desirable to separate nuclear physics from cosmic rays since the two are closely connected theoretically".[506]

---

[505] HJB to Sir Sorab Saklatvala, March 12 1944, HJB Papers TIFR Archives.

[506] Ibid.

Bhabha justified his choice of Bombay as a location for the new institute for the advantages it offered the cosmic ray laboratory for under-water measurements, being close to the sea. It was also "one of the first and most progressive" cities of India, which did not have scientific institutions "worthy of its population and … position". Finally, he wrote, the city would provide favourable opportunities to raise funds from other philanthropic organizations in addition to what the Tata's may have to offer. Confident of support from the government of Bombay and the University of Bombay, Bhabha was not asking the Tata's to fund the entire endeavour, although their presence in Bombay had indeed contributed to his decision for locating his institute in the city. Bhabha's judgments on an institute "worthy" of Bombay's progressive population aside, there were indeed a few institutions of note that already existed in the city. The Royal Institute of Science had been established in 1920 for research and advanced teaching in the sciences, as was the Victoria Jubilee Memorial Technical Institute for engineering education. The Wilson College and the Elphinstone College were both undergraduate teaching institutions where Bhabha studied before he went to Cambridge. These institutions would support Bhabha's new institute with personnel and contribute occasionally to infrastructural needs as well. Bhabha perhaps wanted to move to Bombay for family reasons, but this would only fit rather well with the concerns of the Dorab Tata Trusts. Dorab Tata and the family it appears had already been criticised, "especially by other Parsis, for establishing the Indian Institute of Science in Bangalore and not at Bombay" where a significant majority of the community lived.[507]

[507] Interview of February 10 1927, WSC, Rockefeller Foundation, with Sir Dorab Tata, Dr. R. Row and Mr Charles Perrin, RF, RG1.1, Series 464 A, Box 10, F. 78, Rockefeller Foundation Archives, New York. I am grateful to Mary Ann Quinn of the Rockefeller Archive Centre, New York for bringing this document to my notice. The Tata family are Parsi by religious belonging, and Parsis are Zoroastrians who migrated to

Bhabha anticipated a possible comparison and contest with the National Physical Laboratory of the Board for Scientific and Industrial Research (BSIR), plans for which were in the pipeline. Sir Ardeshir Dalal of the Department of Planning and Development, and an associate of the Tata House would be involved in decisions to fund a physical laboratory, by the Tatas or the government. But Bhabha wanted to make it quite clear that not only was his mandate entirely different from the National Physical Laboratory, he thought "it would not be feasible nor advisable to try to do research such as I plan under the same roof as applied physical research and routine testing …".[508] It would be far more efficient if the Board of Scientific and Industrial Research instead subsidized pure research in his proposed institute by providing them 10 per cent of the annual expenditure planned for the National Physical Laboratory. Arguing thus, not only was he clearly staking out his mandate, but also making a test plea for funding from the [British] Government of India, should Dalal be listening.

It was four years since the Dorab Tata Trusts had made their first grants to Bhabha for cosmic ray physics work in Bangalore and an equal number of years since their grant for the Calcutta cyclotron. Bhabha was certainly aware of the project, and quite likely the proposal written by Raman and Krishnan while he was at the Indian Institute of Science,

---

India following the Islamisation of Persia. Most have settled in Western India, and the elite tend to live in and around Bombay. For general histories of the community see, Sooni Taraporevala, *Zoroastrians of India: A Photographic Journey* (Bombay: Good Books, 2000); Piloo Nanavutty, *The Parsis* (New Delhi: National Book Trust, 1970). See also: T. M. Luhrman, 'Evil in the Sands of Time: Theology and Identity Politics among the Zoroastrian Parsis," *The Journal of Asian Studies* 61, no. 3 (2002): 861-889; T. M. Luhrman, "The Good Parsi: The Postcolonial Feminisation of a Colonial Elite," *Man* 29, no. 2 (1994): 333-357; David L. White, "From Crisis to Community Definition: The Dynamics of Eighteenth Century Parsi Philanthropy," *Modern Asian Studies* 25, no. 2 (1991): 303-320.

[508] Ibid.

Bangalore. It is not that remarkable that a cosmic ray physicist did not consider particle accelerators as necessary apparatus for nuclear physics research at this juncture, but it is important for the purposes of this dissertation that Bhabha's plans for the institute did not carry a proposal for any such installation. It would not be very long before he would consider one necessary.

5.2 1945-1946: Foundation of the Tata Institute of Fundamental Research

The Tata Institute for Fundamental Research began work as an independent institute in June 1945 in Bangalore and shifted to Bombay in December the same year. At its core was the continuing Cosmic Ray Unit from the Indian Institute of Science, Bangalore. The institute was located in space rented from one of Bhabha's aunts in Bombay.[509] Bhabha's ambitions to establish the Tata Institute of Fundamental Research as an institute for research in nuclear physics eventually bound his own career and the institute to national commitments in a manner such that separating its research priorities from immediate problems in applied nuclear research became a conscious, necessary and continuing struggle for its employees in the next two decades.

[509] The TIFR began work with two recurring grants of Rupees 45 000 from Dorab Tata Trusts and Rupees 25 000 from the Government of Bombay. Shortly thereafter, the Atomic Energy Research Committee (AERC) Council for Scientific and Industrial Research (CSIR) pooled in another recurring grant of Rupees 10 000 and a capital grant of Rupees 75 000 towards the purchase of a particle accelerator and a team to work it.

"As soon as it was clear that it [the institute] would prove a success",[510] implying perhaps the events of August 1945, the Dorab Tata Trusts and the Government of Bombay increased their grants. The Government of India began to patronise the institute finally making it a "tripartite arrangement". The formal inauguration of the Institute took place in December 1945 in a world where "nuclear" held a different meaning from when Bhabha had made his proposal to the Dorab Tata Trusts. In his speech for the occasion, Bhabha made two important arguments about the institute's mandate for experimental nuclear physics research. The first, he placed in the context of applied research. Working on problems of an 'applied nature' he argued, " has an immediate use in that it helps to train and develop in a manner in which no other mental discipline can, young men of the highest intellectual calibre in a society, into people who can think about and analyse problems with a freshness of outlook and originality which is not generally found. Such men are of the greatest value to society, as experience in the last war showed, for many of the applications of science, which were crucial to the outcome of the war, were developed by men who, before the war, were devoting their time to the pursuit of scientific knowledge for its own sake".[511] Experimental work and problem oriented research was to be encouraged as essential training for the men who would then be equipped to think better solutions.

The other argument Bhabha made, was concerned more with the pursuit of his own research agenda. "The study of cosmic radiation forms the main field of experimental

---

[510] Untitled Note of four pages, Bombay (1950-51), Leon Rosenfeld Papers, Niels Bohr Archive.

[511] Homi J. Bhabha, (1945) op. cit.

research at this institute, though I hope that in the near future experimental work will also extend to nuclear physics. The two branches are very closely knit and indeed the elucidation of an important problem in nuclear physics, namely the origin of nuclear forces, owes its existence to the discovery of the meson in cosmic radiation”. Bhabha found a linking hook where his own interest in particles and cosmic ray research, the agenda of carrying out fundamental research in the new institute and the referent of nuclear physics converged: in the search for the meson.[512]

5.3 1946-1947: A National Laboratory for AECI

A month after Bhabha had moved to Bombay he heard from John D. Cockcroft, still in Montreal involved with allied war-effort. It is unclear if Bhabha had informed his colleagues abroad about his new institute at this stage. Cockcroft still addressed his letters for Bhabha to Bangalore. Bhabha’s other colleagues continued to hope that he would apply for professorships in England.[513] Cockcroft had read reprints of Bhabha’s cosmic ray research during the war. “For the last five and a half years I have read very little physics, being occupied until a year ago with Radar development and its application to

---

[512] Hideki Yukawa, the Japanese physicist, had predicted in 1935 that particles of intermediate mass should exist in nuclear fields that were responsible for strong interaction between protons and neutrons by being constantly exchanged between them. Bhabha suggested this particle be called the “meson” in December 1938 (Published in *Nature*, February 18 1939). Christian Møller and Leon Rosenfeld from the Institute for Theoretical Physics, Copenhagen, supported this usage in January 1939. The use of the term was not without controversy with the American preference for the use of the term “mesotron” led by Robert A. Millikan in support of Carl David Anderson and Seth H. Neddermeyer at Caltech. Cecil Frank Powell in Bristol announced the discovery of the particle in 1947. He was awarded the Nobel Prize in Physics for the discovery in 1950.

[513] M. H. L. Pryce wrote to Bhabha from Montreal hoping Bhabha would write an application for the Wykeham Professorship of Physics at Oxford University (July 7 1945), D-2004-00085, TIFR Archives.

the urgent needs of war… We are now able to think again of nuclear physics and have to catch up with five years of publications. So I was very interested in your ... speculations on mesons of different rest masses, protons of negative charge and so on."[514] Speculating that a good 70 per cent of the Cavendish staff should return to the laboratory in October next year, Cockcroft was hopeful of re-establishing a good group in nuclear physics in a year's time. They would improve the cyclotron and get a pressurised high voltage generator; but they were also considering getting a betatron. The betatron would possibly be useful in meson work he wrote, and it was "certainly interesting for photo-excitation and fission". With the surrender of Germany, the war was over for most involved and this was the time to plan for post-war research.

Back in Birmingham from the war-effort, Mark Oliphant wrote to Bhabha with his plans for post-war research. He was planning to accelerate particles to 100 x 10 million electron volts. Bhabha was taken by surprise, but he was probably not the only one. "Will you please confirm if this number is correct?" he asked. "I was under the impression that Lawrence's big cyclotron costing £200 000 would only produce particles of 100 million volts, ... how do you intend going to ten times this energy?"[515] But Oliphant also wanted to know if it would be better for him to accelerate protons from the beginning or should he begin with accelerating electrons and then move to protons. The idea again was to study mesons and Oliphant wanted Bhabha's opinion on the matter as a theoretical physicist interested in the meson. Both agreed on that Oliphant should accelerate protons

[514] John D. Cockcroft to HJB, July 5 1945, D-2004-00246, TIFR Archives.

[515] HJB to MLEO, September 15 1945, D-2004-00386, TIFR Archives.

and Oliphant sent him the design details for his new idea. He would leave it for Edward McMillan to accelerate electrons and go incrementally for higher energies the Berkeley way.[516] Meanwhile, Peter Dee at the Cavendish, a student of Charles T. Rees Wilson, was also getting interested in light mesons, "the whole question of future research in nuclear physics".[517] Oliphant informed Bhabha that Dee was interested in Bhabha's recent work. He also thought he should share with Dee, Bhabha's response to his questions on accelerating particles. They were all building and talking particle accelerators; there was little way to escape the excitement of men returning to laboratories after 5 years of war effort. Their imagination was not constrained by questions on resources; wartime research had changed their expectations of laboratory equipment and even more so, their newfound mode of practice. The anticipation of the meson combined with the increasing acceptance of particle accelerators as credible equipment to study elementary particles convinced Bhabha to tentatively explore the option for his new institute. A month later Bhabha asked Oliphant; would these machines work well in tropical climate or would he have to air-condition the entire laboratory?

"The experimental research at the moment is mainly in cosmic rays, but I have no doubt that in the near future it will expand into nuclear physics, and in time the Institute may get large equipment such as a betatron, cyclotron and/ or a van der Graaff generator… I would like to know if in your opinion the proximity of the sea is likely to make the site

---

[516] Ed McMillan had worked with Ernest Lawrence in Berkeley. This machine eventually came to be known as the 'White Oliphant"; it never worked.

[517] MLEO to HJB, September 25 1945, D-2004-00386, TIFR Archives.

unsuitable for the operation of instruments like a cyclotron".[518] Bhabha had begun to seriously consider the use of particle accelerators for experimental nuclear physics like other laboratories of the time. If Bombay's humid climate would prove to be a problem, he was willing to consider moving to Poona for dry climate, 120 miles away from Bombay.

Oliphant was confident about electronic equipment working just as fine in tropical conditions. Air-conditioning could prove convenient, but it was not going to be essential. He suggested Bhabha get further advice on this from the Royal Air Force (RAF) and the Navy, "both of which operated radar equipment in Bombay" during the war.[519] Whether Bhabha discussed this with the RAF and the Navy is not clear, but he perhaps did. It was their war surplus material though that would certainly prove useful to the young experimental groups of the institute very soon. The field of meson inquiry was getting exciting already. Oliphant reported that Metropolitan-Vickers had almost completed a 40 million electron volt betatron, and with British Thomson-Houston was now designing similar machines for higher energy ranges; at Schenectady, possibly the General Electric Laboratories, they had observed "copious meson production", "mesons, apparently of all masses", with a 100 million electron volt betatron reported Oliphant. He was willing to send the details and drawings of any of the machines if Bhabha wanted. This was going to be a new field of work at very high energies. Oliphant's accelerator had not yet seen the light of day, but the betatron could be bought. If Bhabha wanted to go anywhere with

[518] HJB to MLEO, December 5 1945, D-2004-00386, TIFR Archives.

[519] MLEO to HJB, January 23 1946, D-2004-00386, TIFR Archives.

the meson of his dreams, getting to work with a betatron was one way to proceed. The moment was opportune; an organization with just the mandate and promise of funds was in the making.

In the first meeting of the Atomic Energy Research Committee (AERC) on May 15 1946, the TIFR was established as an institute of priority in the national context. Bhabha received grants for a 200 MeV betatron and funds to establish a ten-member team. A year later, Bhabha gave up wanting the betatron altogether. But much happened in the meanwhile, to begin with, Bhabha attended the Empire Scientific Conference[520] and from there, he travelled out to the USA. He found the occasion to discuss matters with Oliphant, Cockcroft, Cecil Powell and others in the USA actively engaged in the field. Bhabha may have attempted to purchase a betatron from the General Electric Laboratory, New York on this trip. The General Engineering and Consulting Laboratory (GEL) was in the business of making specialized electrical equipment on an as-ordered basis in this period. [521] GEL was already running a 100 million electron volts betatron in 1945, while Metropolitan-Vickers and British Thomson-Houston in England were mainly working with betatrons of 16 to 40 million electron volt ranges in 1947. It was prudent to get a high-energy betatron from GEL given that they had already gained experience of building one to high- energy specifications, rather than ask Met-Vick to make one to specifications

[520] E. C. Bullard to HJB, May 7 1946, D-2004-00085, TIFR Archives; E. C. Bullard was organizing evening sessions on cosmic rays at the Empire Scientific Conference, and Bhabha was to open the discussions.

[521] Personal correspondence with James Lommel, Manager, Technical Publications, GE Global Research; Research in the GE Collection at the Schenectady Museum for details of this attempt is ongoing.

in England.[522] After discussions on design specifications, it could easily take a couple of years or even more for the machine to be completely installed and operational. The deal with GEL nonetheless did not come through probably because of the restrictions put in place by the McMahon Act on export of dual use technologies.[523] This was but the first blow to Bhabha's plans of organizing a betatron for the TIFR.

If research apparatus was difficult to acquire, manufacture of equipment locally in India was even more difficult. Meghnad Saha reminded Bhabha of the "three real bottlenecks" towards making experimental nuclear physics feasible and credible in India. He particularly highlighted the lack of supporting industrial infrastructure.[524] Saha was not the only person to bring this observation to Bhabha. M. Sreenivasaya, a microbiologist and professor of fermentation technology at the Indian Institute of Science, who Bhabha knew from his Bangalore days, wrote to him with similar observations. He even came up with an action plan. Given that scientific instrument manufacturing in India was insignificant, the moment was "propitious" for building up such an enterprise. "Would the Tata's be interested in starting an industry of this type?" he asked.[525] Germany was

---

[522] British Thomson-Houston was a British heavy industrial and engineering company which merged with Metropolitan-Vickers Company in 1928, even though they kept their separate identities up until 1960. They made the betatron primarily as medical equipment, and were exhibited in the Physical Society's exhibition in London (1954) on their own stand. The Science Museum also exhibited their betatron made in 1947 for the Clarendon Laboratory, Oxford. See E. H. W. Banner, "The Physical Society's Exhibition –London, 1954," *Journal of Scientific Instruments* 34, (July 1954): 229-236.

[523] See Robert Seidel, "Accelerators and National Security: The Evolution of Science Policy for High Energy Physics 1947-1967," *History and Technology* 11, (1994): 361-391. The McMahon Act in the USA was introduced in 1947 following the initiatives of Senator Brien McMahon, with the objective to maintain secrecy around knowledge, instruments and practices related to nuclear research even from partner allies during WWII.

[524] For details on the correspondence between Saha and Bhabha, see Chapter 4.

[525] M. Sreenivasaya to HJB, September 12 1947, D-2004-00085, TIFR Archives.

out of the picture at the time, England could not deliver the goods for want of them in her own laboratories, and American goods were expensive, when they were not diverted for the rehabilitation of European laboratories destroyed during the war.[526] Sreenivasaya had found out that Sweden and Czechoslovakia could provide capital machinery like precision lathes. They were also willing to send technicians for training purposes on a contract basis, and some German technicians could be arranged for. Would Bhabha move this matter with the Tata's, he wondered. Apparently he did not or may be could not. For a lack of top-notch experimentalists, industrial services, laboratory technicians, and import constraints all combined, "we have slowed down most of the expansion we had in mind in atomic research", Bhabha wrote back.[527] He hoped that things would settle down and enable matters to proceed again. Did he mean the betatron or was he thinking more about the state-dispute with the Raja of Travancore regarding trade of thorium rich monazite sands is not very clear from the letter.[528]

This apparent seamlessness between research and related activities for government control of atomic energy on the one hand and experimental physics at the TIFR on the other has become characteristic of history writing and popular narratives about the TIFR.

---

[526] See John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Cambridge: Mass MIT Press, 2006).

[527] HJB to M. Sreenivasaya, October 17 1947, D-2004-00085, TIFR Archives. Sreenivasaya again was not the only one to ask Bhabha to approach the Tata's for taking lead in industrial enterprise. Bhatnagar wrote perhaps to JRD Tata but copied Bhabha on a letter (November 14 1951, D-2004-00192, TIFR Archives), "I hope you will give a thought to these suggestions, for although we all know that Tatas have done much, there is still more to be done and it would only be right if Tatas take this step forward and join hands with American industry or Government in setting up a pig iron industry and in developing the production of Titanium metal in India."

[528] For details on the monazite sands in the Travancore State in South India see: Itty Abraham, (1998), 57-59.

Bhabha himself called TIFR the cradle of India's atomic energy program. In his speech at the inauguration of new buildings in 1962 (the final location of the institute), Bhabha recalled the establishment of the AECI; "The Atomic Energy Commission of the Government of India was first established in 1948, and one of its immediate problems was the shortage of trained personnel in its field. It was therefore, natural that the Commission should turn to the Institute for its work and for carrying out some of its own major projects. The Commission on its part, gave substantial help to the Institute by providing funds for increasing its activities and for specialised equipment for nuclear research." No doubt there were moments when Bhabha was acutely aware of the need to make a distinction between the TIFR and the successive avatars of state institutions for control of atomic energy, but the distinction was precariously sustained between 1946 and 1957 when finally the state's own atomic research agency was established. It is my contention that in recovering the trajectory of experimental physics at the TIFR one can draw away from the disproportionately huge attention scholars have given so far to atomic energy related research alone. In this way one also hopes to repair this imbalance of inevitable involvement in the nuclear energy and weapons program, placed in hindsight, upon almost all of TIFR's scientists and technicians, by histories written after India's "peaceful nuclear explosions" of 1974.[529]

In February 1947, Cecil Frank Powell announced the discovery of two types of mesons. The discoveries were made using photographic plates with a new emulsion from Ilford in

---

[529] A prominent exception has been made for the TIFR mathematician and historian of ancient India, Damodar Dharmanand Kosambi. Kosambi was a strong proponent of solar energy and is often cited in activist literature as a "scientist of humanist leanings". See D. D. Kosambi, *Exasperating Essays* (Bombay: Peoples Publishing House, 1957) and *Atomic Energy for India* (Pune: Popular Book House, 1960).

England, and home made hydrogen balloons. In less than a year, the Rad. Lab in Berkeley produced artificial mesons allowing for a study of meson properties with the laboratory. This may have effectively put an end to the betatron project Bhabha was contemplating quite seriously; it may have even subsequently intensified attention to cosmic ray works at the TIFR. Months were closing in towards the birth of free India and Bhabha's understanding of his own position in the national order of things and his rhetoric were honing to perfection. "A scientific and objective approach to political problems is more than ever necessary at this crucial stage in her history, and would ensure a smooth transfer to her new status as a free and independent nation."[530]

5.4 Research at the TIFR

Most research instrumentation in the early years of the TIFR was cobbled up in the make shift workshop of the institute. The TIFR had inherited, probably their very first instrument, the Wilson Chamber, and some of their staff from the Cosmic Ray Studies Unit in Bangalore. Some new recruits were added to the group by 1948. [531] Bhabha was actively seeking roadmaps for both, the organisation of atomic energy related activities and the organisation of nuclear research in university settings, from the United Kingdom

[530] HJB to P.K. Sanyal, The Indian State Scholars Association, London, March 31 1947, D-2004-00085, TIFR Archives.

[531] A graduate student, A B Sahiar was studying scattering of mesons using the Wilson Chamber and S. K. Chakrabarty who had moved from Bangalore with the group was now Director of the Colaba [Bombay] Observatory and continued collaboration with Bhabha. Ranjan Ray Daniels and Piara Singh Gill were working with photographic plates exposed to cosmic ray radiation at high altitudes. Gill had obtained his doctoral degree in cosmic ray work with Arthur Compton in Chicago and had worked with Edward U. Condon at the Bureau of Standards before returning to India to the Forman Christian College in Lahore when Bhabha recruited him.

in particular.[532] He acquired confidential details from Blackett on the organisation of the Department of Experimental and Theoretical Physics, University of Manchester, including Jordell Bank and for the Department of Physics and Cavendish Laboratory at Cambridge. The Registrar of the TIFR studied these especially with respect to "the strength of the scientific and technical staff" and submitted a memorandum to the AECI.

Plagued by equipment shortage and shortage of trained technical manpower the TIFR, like the laboratory in Calcutta began to chug its way towards ambitions of original research. Bhabha and Saha both drew on their connections into the international community of science in form of expertise, equipment and advice – an otherwise routine practice rendered difficult by politics of the Cold War as well as their distance from the centres of scientific activity. Just as Sreenivasaya had reminded Bhabha, American equipment was expensive if available for purchase, England could no longer send capital goods or equipment to India and Germany was down. One would have to queue up with European firms to procure instruments, and compete often on home ground as well.[533]

Bhabha began to scout for Indian students training at various universities abroad; he often interviewed them in Indian embassies and made them job offers. He had a good idea of what kind of people he was looking for, "What we require in India today are people who are really on top of a certain branch of a subject, however narrow, rather than people who

---

[532] N. D. Godbole, Registrar, TIFR to HJB, note July 26 1949, D-2004-00200, TIFR Archives.

[533] Cecil Powell had offered to release one of his microscopes to Bhabha. The batch was being built at the Cooke-Trouton firm; one such microscope was delivered in India to Vikram Sarabhai in Ahmedabad. "It was just because priorities for delivery before the middle of next year could not be obtained that I accepted your offer to release one…."[533] Bhabha was hoping that it was not his microscope gained in favour from Powell, which had reached Sarabhai instead, because that could mean a wait for almost a year.

have a smattering of a large number of subjects but are incapable of doing any first class work in any of them on their own."[534] Bhabha had asked John Wilson for his frank and confidential opinion of Bibha Chowdhury who had worked in Manchester prior to her arrival as the first female researcher to work at the TIFR.[535] Indian students studying abroad and interested in nuclear physics also found in the TIFR an opportunity for further research. After all, they could realistically only choose between the INP and the TIFR.[536]

The Government of Bombay, and the Tata's would have also liked to see more collaboration with the university and a committee was appointed by the Syndicate of the University of Bombay to "consider the question of fuller and closer co-operation between the University and the TIFR" in 1949. After two years, the committee recommended the formation of yet another committee that would co-ordinate a close collaboration in advanced teaching and research between the two. They also recommended that since the location of the TIFR had not yet been finalised, care should be taken that it is in close proximity to the University, the Indian Institute of Science (the former Royal Institute of Science) and the [Colaba] Observatory.[537]

---

[534] HJB to J. G. Wilson, December 13 1948, D-2004-00085, TIFR Archives.

[535] Bibha Chowdhury later worked with D. M. Bose in Calcutta in cosmic ray work. Cecil Powell cited their work as one of those leading up to the final discovery of the mu meson.

[536] S. N. Ghoshal to HJB, August 20 1950, D-2004-00088, TIFR Archives Ghoshal had worked with Emilio Segrè on providing the "first direct experimental verification of the theory of compound nucleus". People from the TIFR laboratories were also being sent abroad for training especially in experimental work. A. B. Sahiar went to Manchester to work with the Wilson Chamber, especially in conjunction wit a magnet for energy measurement The AECI paid for Sahiar's deputation to Manchester and he also hoped to work towards a PhD in this period, HJB to Blackett, April 13 1950, D-2004-00200, TIFR Archives.

[537] HJB to SSB, March 16 1951, D-2004-00192, TIFR Archives.

Bhabha asked Cockcroft for details on the administrative set up of the atomic energy establishment under the UK government.[538] Hoping that the matter was not confidential, he was interested to know "if the TRE [Telecommunications Research Establishment] at Malvern is an integral part of the atomic energy set-up or whether it simply does work for your atomic energy establishments in developing suitable instruments". In the second half of the letter, he wrote about the need for the designs of a magnet for the Wilson Chamber. He would understand if Cockcroft could not send him the designs for one they had discussed about, but he would be disappointed nonetheless, he said. Bhabha's engagements and correspondence for most of this period were similarly dual: AECI matters in the one half and activities of the TIFR in the other half.

The Scientific Advisory Committee to the Government of India was established around the same time as the Atomic Energy Bill was introduced in the legislative assembly. The Indian members on this committee were Homi Bhabha, Kariamanikkam Srinivasa Krishnan and Sir Shanti Swarup Bhatnagar. In April 1948, Patrick Maynard Stuart Blackett, the British cosmic ray physicist, also accepted membership of Scientific Advisory Committee.[539] In July 1948, Daulat Singh Kothari, a former student of Meghnad Saha, was appointed Scientific Advisor to the Ministry of Defence.

---

[538] HJB to Cockcroft, 5 1948, D-2004-00246, TIFR Archives.

[539] HJB to PMSB, April 1948, D-2004-00200, TIFR Archives; Bhabha had asked Nehru to appoint the Scientific Advisory Committee and also suggested he ask either Blackett or Henry Tizard on advisory positions. Also HJB to PMSB, July 12 1948, D-2004-00200, TIFR Archives.

The establishment of the AECI on August 15 1948 decisively established the moral economy of nuclear research for the next two decades. Saha was not nominated to the Commission despite the recognition of nuclear physics research at the Palit Laboratory, Calcutta, and that was noteworthy. Even more remarkable is the total overlap of AECI membership with that of the Scientific Advisory Committee to the Government of India. There is no reason to presume that Saha may have coveted a bureaucratic position for himself, but given his active engagement with the shaping of policy for nuclear research, it is fair to say that he would have liked to participate in the Commission.

The AECI met for the first time on August 15 1948, exactly a year after Indian independence, with Prime Minister Nehru and Blackett. The contents of the entire meeting's discussion are not available, but the discussion involving Blackett is detailed in a letter Bhabha wrote to Blackett for correct recording of the meeting minutes.[540] It quite likely that Blackett and Bhabha may have discussed matters before the formal meeting, but at the same time Blackett must have been under considerable pressure with the risk of giving politically unsound advice to Nehru. Nehru first questioned Blackett on the "internal policy" of organising atomic research in India. Blackett began; "Nuclear physics is now being done by means of (a) big machines and (b) cosmic rays. Big machines are not worth having unless you have first class engineers and people who have the necessary flair for doing this sort of work… They are difficult things to work… India has not got the engineering capacity to do this job. I would personally avoid big machines at the

[540] HJB to PMSB, August 28 1948, D-2004-00200, TIFR Archives. Bhabha note reads; "I enclose herewith an account of the statements made by you at the first meeting of the AEC[I]. Will you please see that the statements are correctly recorded?"

present." It is not entirely clear if by big machines, Blackett meant particle accelerators or reactors, or both, but with Bhabha's waning interest in the betatron anyway, Blackett's judgment was not going to upset him. Smaller machines, Blackett further argued, were no longer useful for pioneering work. Swiss machines could be bought off the shelf, but there were so many of them around that he felt he could not advise them as good investment for novel research. There was also nothing much that could be done with a cyclotron any longer, he added, unless it was used for making tracer elements for medical research, which could not be made in a pile, and for training people. Making a note of the Calcutta cyclotron, Blackett suggested that it be made to work and used for further training technical manpower which India considerably lacked at the moment. He further recommended that India should not acquire any particle accelerators apart from working the one already existing in Calcutta. What then did he think should be the content of nuclear research in India?

Blackett thought there was a great future for cosmic ray work, not in the least because a number of different fields came together in this research, for example nuclear physics and geo-physics. If the Indians wanted to make "fundamental advances in scientific research", cosmic ray research had to be encouraged. Blackett's bias towards cosmic ray physics apart, the use of particle accelerators for nuclear physics was not self-evident also because cosmic ray energies were much higher compared to those obtained at this time in the machines.[541]

[541] See Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago and London: University of Chicago Press, 1997), 226-230, 316-318; and Hermann, et. al. (1987), Chapter 1.

Nehru then came to the question on India's external policy on atomic research. Blackett replied; "By this I take it that you mean the peaceful application of atomic energy". Matters of atomic energy related research were matters of "external policy" in 1948: for starters, there were issues around thorium and uranium mining. The USA was involved in an intense race for securing materials for building nuclear piles and India was one of the few along with Brazil and Belgian Congo that possessed ores of some significance.[542] But even so, a dichotomy between nuclear weapons research and atomic energy related research simply could not be sustained between 1945 and 1953, because both required construction and operation of nuclear piles, and were not physically separable from each other. This was certainly true for construction of plutonium bombs. What is remarkable though is that this was indeed discursively sustained through out this period.

Surrounded by pressing concerns and rhetoric of peaceful uses of atomic energy, it remained true that skills required for construction of piles were not merely useful but overlapped considerably with skills to build nuclear weapons. There was no successfully functioning atomic energy producing plant in operation up until 1950 and even if the feasibility of atomic energy was known since at least 1940, for those who were not privy to the Manhattan Engineering District and related secret work during the war it was demonstrated for the first time by the atomic bomb. The establishment of Obninsk (1950), the world's first operational nuclear power plant in the USSR followed by Eisenhower's *Atoms for Peace* lecture (1953) made credible both material and discursive

[542] Hindsight has shown that the race for rare earths was soon abandoned once it became clear that the earths, or fissile materials were not so rare after all. See Jonathan E. Helmreich, *Gathering Rare Ores: The Diplomacy of Uranium Acquisition, 1943-54* (Princeton: Princeton University Press, 1986) and for India, see Abraham (2007).

claims on the peaceful applications of atomic energy. Nehru and Bhabha both attended the inaugural ceremony.

Speaking in 1948 then, Blackett's advice for the "external policy" was a lesson in the moral economy of the international atomic politics. India should build a pile. The way to proceed would be to first learn to process thorium and uranium; and then in exchange of these materials internationally, India should try to procure the design for a pile. A small pile (1000 kilowatts) would be useful as a neutron source and was also "thoroughly sensible" because it would not rouse suspicions as to its purpose and serve well to give self-confidence and stimulus to the men. A large pile was not feasible for the same reasons as a "big machine" was not: due to the want of trained manpower.

Nehru then asked a question which had already been discussed amidst tension and frustration for lack of thorough information in the Constituent Assembly of India: he wanted to know "even though the present government is averse to such an idea", if knowledge gained in the process of making piles could be useful for making bombs. Blackett responded unhesitatingly: "I presume that India is not going in for making atomic bombs. India could not be defended against atomic bombs as India could not hit back if she was attacked". India was not in a position to make bombs usefully and therefore a small pile would be good, politically as well as scientifically. Blackett's advice was very clear: cosmic ray work and medical research using tracer elements from the small pile were two areas of fundamental research in nuclear physics India could gainfully make efforts towards; chemistry of radioactive metals and processes of purification of radioactive elements would benefit India in the international scene to obtain materials, equipment and design for continuing research. India could not afford big machines and big piles for lack of technical manpower, and material and political reasons.

In his answer to a last "general question" Blackett replied: "Personally I am against the teaching of nuclear physics in the Universities. It should only be done in the post-graduate classes. The tendency in England to-day is away from such specialized training and more towards giving the students a sound all round basis for their scientific education".[543] There could hardly have been any disagreement on that count. Saha, the only one who had introduced teaching in nuclear physics thus far did so with a general and special course both at the masters' degree level. Bhabha's institute plan had talked of advanced teaching and doctoral degree students from the University of Bombay being able to participate in TIFR activities. Even in Bangalore where nuclear physics could not eventually be introduced, Raman and Krishnan had clearly planned for teaching and research aimed at graduate students. It is nonetheless surprising that Blackett thought one cyclotron facility in Calcutta and possibly a small pile in Bombay were enough to training technical and scientific manpower to establish and extend nuclear physics in India at the time.

The next meeting of the Atomic Energy Research Committee was on September 1 1948; perhaps one of the last few before the AERC was dissolved in favour of the newly

---

[543] "Post-graduate classes" for Blackett and his audience meant graduate studies as understood in the American sense. He was against the teaching of nuclear physics at the first-degree level.

established AECI. Saha could not make it again. He was scheduled to attend another meeting in Delhi, and even though that meeting was eventually cancelled, again he could not procure passage to Bombay.[544] If Saha maintained ambitions of shaping the atomic energy research policy in India in a decisive manner, he was losing important opportunities. He had been unable to attend more than two meetings of the AERC thus far; but more significantly, he had missed attending the meeting to decide on the proposal for the establishment of nuclear physics in Bangalore. The Bangalore attempt was to establish teaching and research in nuclear physics within a department of physics in a teaching institution at graduate level. Supporting this proposal would have strengthened Saha's position and the position of advanced education in nuclear physics in universities in India. He had diligently laboured on writing detailed agenda and plans for the AERC; he had also extensively studied similar organisations in the West. He lobbied with Jnan Ghosh and Bhatnagar to support and pursue this agenda. But he was not present at the meetings to follow up on the agendas and argue for his position. He was perhaps convinced that his proposals carried enough weight that the Atomic Energy Research Board of the CSIR should accept them as self-evident arguments. He could have well been convinced that his presence would perhaps come in the way of his arguments and that it was better left to Ghosh and Bhatnagar to pursue them. Perhaps, even if Saha was well aware of the power and glory that came with being at the helm of affairs as far as nuclear research went, it is not entirely unlikely that his attentions were not singularly focused upon this aspect of organising for science alone.

[544] MNS to HJB, August 29 1948, MNS Papers SINP.

The three years from 1946 to 1948, between the end of the war and the year after Indian independence were like shifting sands under tidal waters. Various local and international interests were actively reconstituting the context of science, politics, the nation and the international. The very nature of scientific practice was being reconstituted. The contest was sharp and every possibility of representation was important. In these two years, Bhabha established himself as the undisputed leader of nuclear research in independent India, Saha saved his laboratory for continuing research in nuclear physics but could not gain any more prestige for it than that of a university laboratory – which of course, he was not happy with. R. S. Krishnan in Bangalore on the other hand, despite his experience and skills was lost to nuclear physics research in India. The scope of what was possible to accomplish in and for nuclear research changed in these two years. Apart from the emergence of the national framework, there were constraints introduced by the international context of nuclear research and the post-war world order. India was in the process of being shunted from the imperial trajectory, the national-state was coming into place. Scientists like Bhatnagar and Bhabha who had not actively aligned themselves with anti-colonial nationalist politics before independence, now became the science administrators of free India. The continuation of Bhatnagar as a key state administrator from the imperial government into free India, and the rise of Bhabha as the leader of the emerging national nuclear establishment, became apparent in 1946 but were cemented in 1948.

The significance of Blackett's advice in this context could have only been enhanced when he was awarded the Nobel prize later that year for his work on cosmic rays. Bhabha only intensified his efforts to get an experimentalist in cosmic ray work for the TIFR. He had already told Saha he was looking for an American experimentalist. He had advice from Blackett and good working relations with Cecil Powell. The two most renowned groups in the US engaged in cosmic ray work at this time, Robert Millikan at Caltech and Arthur Holly Compton at the University of Chicago were facing funding cramps when Vannevar Bush at the Department of Terrestrial Magnetism of the Carnegie Institution informed them that there was no funding for cosmic ray work from the Carnegie Foundation at least. There were two younger groups in Princeton, and Rochester. Two experimental physicists with these groups faced uncertain futures in the US. Frank Oppenheimer at Princeton University was the first of these two in trouble; the other would be Bernard Peters at the University of Rochester a couple of years later. Both were called to testify to the House of Un-American Activities for suspicion of being communists.[545] On October 28 1949, after a serious discussion with the older brother Robert J. Oppenheimer, Bhabha made an offer to Frank Oppenheimer. Would he like to come to India and spend a year to begin with establishing a credible experimental cosmic ray group? He would have a laboratory and two junior assistants for his work, along with a salary for comfortable living in Bombay. He could choose the experiments he wanted to carry out; additionally, Bhabha was meeting with Bernard Peters and Robert Marshak of the University of Rochester to discuss collaboration in experimental work.[546]

---

[545] Silvan S. Schweber, *In the Shadow of the Bomb: Oppenheimer, Bethe, and the Moral Responsibility of the Scientist* (Princeton: Princeton University Press, 2006). Schweber discusses the case of Bernard Peters, as a student of Robert J. Oppenheimer. Oppenheimer testified in the case to HUAC, before he came up for questioning himself.

[546] HJB to Frank Oppenheimer, October 28 1949, Frank Oppenheimer Papers; Bhabha's was not the only invitation Oppenheimer. received. Hans Bethe and Robert Wilson at the Laboratory of Nuclear Studies, Cornell University, and Bruno Rossi at the MIT, among others, also invited him.

Oppenheimer. wanted a regular academic appointment; he was worried the years it took to establish a good experimental laboratory, and then some more to get useful results.[547] Temporary offers coming from kind colleagues were not satisfying enough in terms of work and it did not make any sense to move the family and 'uproot the children" to no further gain. After several postponements, he was to meet with the House of Un-American Activities on December 6 1949, and he was uncertain of the outcome. Barely a week after writing to Rossi with his misgivings about a temporary move, he decided to accept Bhabha's offer and go to India anyway. He would have liked to work with high altitude cosmic ray investigations with cloud chambers and Bhabha agreed with his ideas. Peters was coming to India in January and they would be able to determine success with the recovery of cloud chamber balloon flights before Frank Oppenheimer would begin at the TIFR. Unfortunately, there was not enough helium in India to fly large balloons, but they would use hydrogen. They had normal balloons that they had been using with a 50% recovery rate, which could well serve the purpose Oppenheimer was thinking about. He would be paid a sufficient and tax-free salary, and his travel expenses would be paid for if he were staying at least for a year.

The prospects of experimental cosmic ray work at the TIFR could not have looked better, Peters was collaborating and Frank Oppenheimer might have been on his way to India. Bhabha wanted to wait to take definite steps until Oppenheimer. got his passport – but that was not to happen. In a rough copy of an undated letter to Bhabha that survives among his papers, he wrote, "They have refused to give me one". He was grateful for

[547] Frank Oppenheimer to Bruno Rossi, November 3 1949, Frank Oppenheimer Papers.

Bhabha's offer, and excusing himself for the inconvenience caused, he hoped that if the passport were ever to come through, perhaps the visit could be arranged later.[548]

Frederic Joliot-Curie attended the Indian Science Congress in January 1950. Like Blackett before him, Joliot was invited by Jawaharlal Nehru to attend a special meeting of the Atomic Energy Commission of India on January 16 1950, along with the Bhabha, Krishnan and Bhatnagar.[549] Frederic Joliot-Curie had coordinated the post-war organisation of nuclear research in France without Anglo-American support, or better said, at their considerable displeasure. French autonomy in nuclear energy research and technology was a result of Joliot-Curie's ambitious organisation. His belief that "science and technology were to be forces for the reconstruction and independence of France, instruments that would give back France "its grandeur and its liberty", resonated with Nehru's understanding of scientific industrialism.[550] His experience was thus one of tremendous significance to a country like India, and his left leaning political beliefs, like those of Blackett, made him more accessible to Nehru. Nehru's very first observation was one that would strike cord with Joliot's political commitment to peaceful uses of atomic energy. "Quite apart from the fact that she [India] had not the resources to make atomic bombs and the use of atomic energy for military purposes, she was not interested in its

[548] Frank Oppenheimer to HJB, undated, Frank Oppenheimer Papers.

[549] HJB to FJC, January 12 1950, India File, FJC Papers.

[550] Krige (2006), 98. See also Michel Pinault, *Frederic Joliot-Curie* (Paris: O. Jacob, 2000); Spencer Weart, *Scientists in Power* (Cambridge: Harvard University Press, 1979); Maurice Goldsmith, *Frederic Joliot Curie* (London: Lawrence & Wishart Ltd., 1977).

military uses on principle".[551] He then questioned Joliot-Curie on just when atomic energy could be used for power generation. A discussion followed on the costs and time estimate for power generation. Joliot informed his audience that while the prospects were promising, there was at least a decade before it would become feasible to begin constructing power plants. He also reassured Nehru that his decision to promote nuclear research in India was commendable, "it (is) important that every great nation should take its place in developing and using atomic energy and not leave it to few highly industrialised nations to do it". He also recommended that in India, like in France, and unlike in America – the lack of trained manpower and resources meant, "it was necessary to establish only one centre for atomic energy … a centre that would have characteristics both scientific and industrial".

Joliot had already visited "India's nuclear laboratories in Bombay and Calcutta" and was impressed with Bombay. He was convinced that the TIFR had the "necessary qualities required for successful work in atomic energy". He was not so sure of Calcutta. In a sharp criticism of Calcutta, he commented upon the lack of cleanliness and thoroughness of procedures in the laboratory. More over, even though promising young workers were to be found in the laboratory, he found there was no expert to give them "good and proper direction". Joliot's observations could only have enhanced Bhabha's stature in Bhatnagar and Nehru's eyes.

[551] Minutes of a Special Meeting of the Atomic Energy Commission, January 16 1950, India File, FJC Papers.

Bhabha still needed an experimental nuclear physicist; for now Blackett and Joliot both had advised on building a small pile. Among others, he wrote to Hans von Halban in Oxford if he would like to spend a couple of terms or a year at the TIFR. They were obtaining a radium beryllium source, he said but anything else he would require he would have to bring it with. He concluded the letter saying “We have no high energy accelerators in the place yet”.[552] “Yet”, he had written, implying perhaps that he had not really given up on wanting a particle accelerator after all. It would be about three more years before one would be bought by the AECI for the TIFR off the shelf from Philips Eindhoven. In the meanwhile, the international meeting of December 1950 brought among others, Bernhard Peters, to India. The short collaboration followed by Peter’s own struggles with HUAC eventually brought him to the TIFR in 1951. Bhabha had finally succeeded in getting an experimental cosmic ray physicist to come to India, and stay. Peters left India eight years later for Copenhagen. Particle accelerator builders and experimental nuclear physicists were not that lucky.

[552] HJB to Halban, February 21 1950, D-2004-00085, TIFR Archives; Halban felt he could not go because he had spent four years getting the equipment established and they had finally begun measurement work. Graduate assistants needed his support on a day-to-day basis he said, because their perspective on the experiments was changing almost week to week. It would be unfair to the students, he thought, now that they finally had something working. The Austrian Hans von Halban had been a research assistant with Frederic Joliot-Curie in Paris and worked with Lew Kowarski on the first design of a heavy water moderated nuclear pile in 1939-40, shortly before the German occupation of France. In the beginning of the war, he, along with Lew Kowarski smuggled in heavy water in hiding from the Germans occupying the laboratory and stayed on in England after the war.

5.6 1950: Elementary Particle Physics Meeting

John D. Cockcroft organised an International Nuclear Physics Conference at the British Atomic Energy Research Establishment, Harwell in September 1950. The first two days were dedicated to high-energy physics and the other days to low energy physics. Bhabha was invited to attend.[553] This was an opportunity to see some of the Harwell Laboratories. Harwell was organising their first international meeting. It was an opportunity to show and see the progress of nuclear research in post-war Britain to gain credibility in the eyes in the international community of science.

Credibility was no less important an issue for the Indian community of science. Bhabha had already taken the lead in representing the community outside of India in the field of cosmic ray and nuclear physics. An international conference would require funding but also had to address a community legitimately enough that a meeting in India did not sound an incredible and small affair. In October 1950, the Tata Institute of Fundamental Research "in consultation" with the International Union of Pure and Applied Physics (IUPAP)[554] announced the International Conference on Elementary Particles to be held in Bombay in December 1950. The TIFR was the host and the IUPAP the patron for the conference. The program covered sessions on both experimental and theoretical physics of elementary particles. Invitees could also attend the Indian Science Congress session in

---

[553] John D. Cockcroft to HJB, 12 May 1950, D-2004-00246, TIFR Archives.

[554] Bhabha would become the chairperson of the IUPAP in 1960. For a brief overview on the IUPAP see *70 Years: 1922-1992* Paris: IUPAP Secretariat. For an overview on the IUPAP in relation to the International Council of Scientific Unions and the UNESCO, see Frederick William George Baker, *ICSU-UNESCO: Forty Years of Cooperation* (Paris: ICSU Secretariat, 1986).

Bangalore immediately after the meeting; Bhabha was chairing the Congress that year.[555] In preparation for the meeting, among other things, TIFR acquired photographs of "men who have helped build modern atomic physics" for its library.[556]

The Conference was successful in putting the TIFR on the international map of cosmic ray and nuclear physics research. A finely printed report was produced at the Tata Press in Bombay and sent out to several laboratories the world over. It was the first meeting of its kind in cosmic ray and nuclear research in India. Leading researchers and laboratories were represented, as were Indian scientists. Saha spoke on the origin of cosmic rays. Bhabha's efforts were to build an institution of international standards and his effort to organise this meeting were no different. He could rely on the Tata's for support for hospitality; they owned the legendary Taj Mahal hotel where the conference participants stayed. It was the best five star hotel in the city, next to the sea and the "Gateway of India".[557] The arrangements were rather impressive. The departing physicists wrote a poem to commemorate the occasion: everything had gone rather well.

5.7 1951-1955: A Particle Accelerator Program for the TIFR

After the grand closing of the previous year, the New Year began on a rather curious note. In January 1951, Bhabha and JRD Tata both read newspaper reports about an

---

[555] HJB to EOL, October 9 1950, EOL Papers.

[556] HJB to Mrs. Lettici Ramsey, November 16 1950, D-2004-00085, TIFR Archives.

[557] The Gateway to India was a commemorative large gate built in sand stone 1904 to welcome King George the IV to India.

alleged meeting between Frederic Joliot-Curie and Jawaharlal Nehru, where Nehru offered Joliot-Curie a leading position with atomic energy work in India. There were subsequent denials from Joliot-Curie, and in a conversation with Bhabha Nehru denied such a thing had been discussed at all, even though he had briefly met with Joliot-Curie. Curiously though, Bhabha mentioned "Some two years ago Joliot hinted that he might be prepared to come to work in India if the situation in France became more difficult for him. But the hint was never taken up on our side, and to my knowledge no offer has been made even of a post under the Atomic Energy Commission, much less as the head of it."[558]

If Joliot-Curie had wanted to move to India, Nehru would have found in him someone with the most reliable experience in setting up a nuclear energy establishment without any reliance upon American or British help. Joliot Curie was a communist by conviction and politically active even as a leader of the French nuclear program. After he led the successful construction of the first French nuclear reactor, he was dismissed from his position in spring of 1950 by the French government largely owing to his political activities. If Joliot-Curie had hinted he could move to India a couple of years before, it cannot be guessed why he would have changed his mind two years later. It would be difficult to imagine Joliot-Curie moving to India in a position sub-ordinate to Bhabha's, and perhaps "much less" acceptable to Bhabha if he would have to be now subordinated to Joliot-Curie instead. Whatever Nehru may have said to Joliot-Curie and whatever may have been his response, he did not eventually come to India and Bhabha continued to lead

[558] HJB to JRD Tata, January 31 1951, D-2004-00086, TIFR Archives.

cosmic ray and nuclear physics; as well as nuclear energy related research in India. In June 1951, Bhabha and Bhatnagar started negotiating a special agreement with France on collaboration in nuclear research.[559] In July 1951, Homi Bhabha requested for a personal copy of Isaac Deutscher's book *The Life of Stalin*.[560] The same year Frederic Joliot-Curie received the first ever Stalin International Peace Prize.[561]

The Harwell meeting in 1950 had provided just the occasion to evaluate nuclear research apparatus for India. The very first evidence on a decision to buy a particle accelerator after the demise of the betatron plans is found in a letter, Bhabha wrote to Cockcroft; as chairman, Atomic Energy Commission.[562] "Following my conversation with you and others at Harwell, we are thinking of ordering a linear accelerator on the model that you have at Harwell giving a maximum energy of 15 MeV." Asking for details on the firm and the contact person therein, he requested that Raja Ramanna should be put directly in touch with the person in-charge of the linear accelerator in Harwell. Ramanna led the experimental nuclear physics group at the AECI, which was housed within the TIFR between 1949 and 1950. A plan had been set in motion.[563] An official order for a cascade

---

[559] HJB to SSB, secret telegram of 6 June 1951, D-2004-00192, TIFR Archives. The agreements with France mainly dealt with fissile ore processing technology and the establishment of Indian Rare Earth's Ltd. of the Government of India.

[560] A. E. Ribeiro, PA to Director, TIFR to M/s W. Heffer and Sons Co. London, 19 July 1951, D-2004-00086, TIFR Archives; Isaac Deutscher, *The Life of Stalin* (London: Heffer and Sons, 1950).

[561] The "International Stalin Prize for Strengthening Peace Among Peoples" was instituted in honour of Josef Stalin in December 1949 in the Soviet Union. The prize was renamed the "International Lenin Prize for Strengthening Peace Among Peoples" in 1956 following Nikita Khrushchev's denunciation of Stalin. Previous recipients were asked to return their prizes, and were replaced with the renamed Lenin Prize.

[562] HJB to Cockcroft, July 24 1951, D-2004-00246, TIFR Archives; the typescript is annotated "HJB: aer".

[563] Raja Ramanna was employed as an experimental nuclear physicist with the AECI in 1949. He took his PhD in nuclear physics from Kings College London. Initially, Alan Nunn May supervised him. May was

generator was placed with Philips Electrical (India) Limited on September 4 1951.[564] It would take another two years before the accelerator would be installed and ready for work.

Research and training at the TIFR in these years fell under three broad areas: experimental physics, theoretical physics and mathematics.[565] Students holding Masters' degrees were admitted after an interview and then given training along the lines of that given in "major European and American universities" to cover the lag between university curricula in India and the latest advances in the field. The students could then work towards their doctoral degrees. The Institute also began to hold summer schools for the benefit of teachers and researchers across the country that wanted to make use of the updated library and "proper academic atmosphere" at the TIFR. The Institute had a steady stream of visiting scholars to give special lectures and courses.[566] Bhabha led the group in theoretical physics that was also responsible for training younger experimental

---

soon arrested on charges of espionage and Ramanna finished his work with other professors in the laboratory, although supervised by no one in particular. Ramanna's privileges with the TIFR included the allotment of two rooms in the small housing wing of the Institute at Yatch Club – one for him and one for his piano. See Raja Ramanna, *Years of Pilgrimage* (New Delhi: Viking Publications, 1991).

[564] Philips Electrical (India) Limited to The Director, TIFR, September 4 1951, Philips International B.V. Company Archives; the letter enlists Rupees 308 535 as material costs with installation costs, import duties and costs subject to changes of labour costs in the Netherlands over the next year. In 1950-51, Harwell's linear accelerator produced particles of 15 MeV energy.

[565] Undated note of four pages, Leon Rosenfeld Papers, Niels Bohr Archive, p. 1.

[566] In 1952 and 53 lectures and courses in physics were conducted by Wolfgang Pauli, P.M. S. Blackett, John D. Cockcroft, M. S. Vallarta, Leon Rosenfeld, G. Wentzel, and E. C. Bullard; and in mathematics by S. S. Chern, J. Hadamard, and M. N Stone.

physicists in theory.[567] The school of mathematics, however, was thought of to be the strongest at TIFR.[568]

Cosmic ray physics, nuclear physics and construction of electronic equipment were counted as experimental work. However, cosmic ray research dominated experimental work up until the arrival of the cascade generator in 1953. A survey of intensity of the penetrating component of cosmic radiation was carried out at different latitudes in the atmosphere up to 100 000 feet and the group initially led by Piara Gill found a peak in the intensity of the penetrating component near the top of the atmosphere. Their research, the group submitted "might lead to information of a fundamental nature, *at present unobtainable with the help of the largest accelerator*".[569] The groups were also investigating cosmic radiation below ground level in the Kolar Gold mines in the state of Mysore. In 1950 a student, A. B. Sahiar was sent to study with Blackett and carry out experiments at the Jungfraujoch in Switzerland. When Bernard Peters of the University of Rochester "known for his discovery of heavy nuclei in primary cosmic radiation" joined the TIFR as faculty member, he built a group to work on cosmic ray investigations

---

[567] The theoretical physics group worked on quantum electrodynamics, theory of elementary particles, cosmic rays and theory of phenomena at very low temperatures.

[568] Led by Kosambi, K. Chandrasekharan, Harish Chandra –Bhabha's collaborator from Bangalore, and K. G.Ramanathan, they worked in differential geometry, harmonic analysis, modern algebra and number theory.

[569] Undated Note of four pages, Leon Rosenfeld Papers, Niels Bohr Archive; page 2, emphasis added.

using the photographic emulsion technique developed by Cecil Powell beginning 1950, but more decisively since 1951.[570]

The Institute was now also officially carrying out all research in nuclear physics for the AECI, which as a result had come to be one of the major patrons of TIFR along with the Ministry of Natural Resources and Scientific Research, Government of India. Housed within the TIFR was also a “production unit”, a workshop for the AECI that manufactured Geiger counters, radiation survey meters, amplifiers, scalars required for AECI research, but also for other laboratories carrying our geological and radiochemistry investigations. Even as they waited for the modest cascade generator to arrive, news came of the establishment of a European Nuclear Research Laboratory, later known as CERN.[571] Pierre Auger, the French physicist told Homi that no final decision had been taken yet on the location of the new laboratory, but it was likely to be in Geneva and the plans were proceeding well.

The general elections in 1952 that took Saha into parliament also put Nehru in power again. Bhabha wrote to him in February. “I am writing to remind you of certain general proposals regarding the administration of higher scientific and technical education and research which I believe have met with your general approval in the past, but which have

---

[570] Peters, like Frank Oppenheimer faced investigations by the House of Un-American Activities and chose to leave the USA for India in 1951. His passport was not renewed while in India and he lost his American citizenship.

[571] Pierre Auger to HJB, February 19 1952, D-2004-00086, TIFR Archives. “But the Council of European States which is the new intergovernmental body responsible for the planning, and later for the construction of the laboratory, has been successfully set up. It seems pretty sure that the final location will be Geneva. If you are interested, I shall have a set of papers on the subject sent to you.”

not been put into effect for various reasons. The present juncture after the elections may perhaps be a suitable moment for putting them into effect…. The separation of advanced scientific and technical teaching from research is not desirable".[572] Bhabha referred back to his note of September 1950 to the Planning Commission. His main concern was the "considerable lack of coordination, unnecessary duplication and waste" because the Ministry of Education administered institutes of higher learning while national laboratories came under the Ministry of Natural Resources and Scientific Research. In Bhabha's opinion, "the natural place for the institutes of higher technology and science (including university teaching departments) is under the Ministry, which deals with scientific research" combined with education". This way, universities would be placed in a position to benefit from research facilities available at the national laboratories and teaching from leading researchers in the field.

In March that year, Bhabha wrote an article on "The Development of Atomic Energy in India".[573] He outlined the two main research areas in nuclear physics as those of studying the properties of atomic nuclei, and the other about "the behaviour of the elementary particles out of which atoms are built and of newer particles which have no permanent existence but which are created in the course of extremely energetic atomic collisions". For research in the second field he wrote, "one has to use particles of ever higher energies and to produce these accelerators of larger and larger size have been designed and built. The largest accelerator in operation today produces particles of energy of 450 million

---

[572] HJB to Nehru, February 28 1952, D-2004-00474, TIFR Archives.

[573] Manuscript, Bhabha Papers, TIFR Archives. It is not clear where this article was published.

volts. Two more are under construction in the United States that are expected to yield atomic particles of several thousand million volts. The amount of steel required for these very large accelerators is comparable to that required for a medium sized cruiser, and the electric power required to drive the machine is also comparable to that required to propel a cruiser at a speed of 20 knots. It is at once clear that with her limited technical and financial resources India cannot compete effectively in the field of elementary particle physics through the use of large accelerators." Bhabha was repeating what he said in 1945 and what he would again remind his audience of two years later. This was the reason why the Atomic Energy Commission of India would support research in cosmic ray physics, and this was done in both university and national laboratory settings. Bhabha specifically mentioned grants to the Institute of Nuclear Physics and the Bose Research Institute at Calcutta, the Universities of Delhi and Aligarh, the Indian Institute of Science at Bangalore, and the Physical Research Laboratory at Ahmedabad. The Commission itself, he wrote, "feels that the stage has been reached now when it can embark on the construction of a heavy water reactor, as originally envisaged, while simultaneously going in for an accelerator programme, thus going beyond what was originally thought feasible…. Availability of power is the key to industrialisation, and atomic energy may well provide a short cut to it". The accelerator programme thus began on a note of confidence, within the priority of atomic energy related research and in continuing subordination to cosmic ray research. To begin with, the Institute would have to procure another large lathe for the workshop. There was one in surplus at the National Physical Laboratory in Delhi but that would take six months to arrive.[574]

---

[574] HJB to K. N. Mathur, January 18 1952 and HJB to SSB, January 18 1952, D-2004-00192, TIFR Archives.

5.8 The Three Accelerator Groups

On April 24 1952, John Stuart Foster from the department of physics, McGill University wrote to Homi Bhabha; "Visitors from Brazil have recently raised the question whether we could make a cyclotron similar to ours. It is probable that I could persuade a few of those who took part in our venture to join in such an undertaking and I am writing to learn whether you have reached any decisions on an instrument for your Institute. I assume that the magnet could best be made, or at least the steel portion set up in India. If you are interested now, or at some time not too far in the future, we might discuss details."[575] Foster and Bhabha had perhaps discussed collaboration to build a cyclotron in Bombay. Bhabha was pleased to respond with optimism; "for a long time we had no accelerator programme in the AEC[I], because we thought that the job of setting up plants to treat our raw materials and the preliminary work towards setting up a pile would be more than our trained personnel could cope with. However, our projects have come along so well during the last two years that we did decide this year to embark on an accelerator programme also".[576]

Nonetheless, Bhabha wrote, the TIFR had started modestly. He first wrote about the Philips generator he hoped would be in operation that year. He then mentioned the work of three groups organised under D. Y. Phadke who was "in charge of the electronics and

---

[575] John Stuart Foster to HJB, April 24 1952. For details on the McGill cyclotron see Jerry Thomas, "John Stuart Foster, McGill University, and the renascence of nuclear physics in Montreal, 1935-1950" *Historical Studies In The Physical Sciences* 14, no. 2: (1984: 357-377); "Foster's Lasting Achievements were the creation of the biggest cyclotron in Canada and, more importantly, the production of talented, highly-trained physicists with its help" (p. 357).

[576] HJB to Foster, April 28 1952, D-2004-00088, TIFR Archives.

instrument division which is being run for the AEC[I] by the Institute". Phadke taught electronics at the local St. Xavier's College in Bombay and was familiar with vacuum technology. He led the work of at least three sub-groups working on particle accelerators. These groups busied themselves with the construction of a 12-inch cyclotron, an open air 1 MeV Van de Graaff machine and a 1 MeV linear proton accelerator. T. G. Varghese led the 12-inch cyclotron group; K. A. George led the Van de Graaff group and R. V. Sitaram was in charge of the linear accelerator. The magnet, as the other parts for the machines were purchased in Bombay's famous *Chor Bazar* selling war supplies left behind by the withdrawing Allied forces after WWII. [577] The intention, Bhabha clarified, "is to proceed next to a linear accelerator of 15 to 30 MeV for electrons on the model of the Harwell and Stanford accelerators. We expect this will take a couple of years, after which we might go in for a fair sized synchro-cyclotron capable of giving say 500 million electron volts. However, the last two steps mentioned above have not been finally decided and we may well change our programme." Phadke went to the USA, England and France that year, and Bhabha promised to add Montreal on his itinerary. Phadke could then have a "preliminary talk with you [Foster] on the question raised in your letter".

Each of the three particle accelerator building groups had a couple of members trained in vacuum technology, physics and engineering. The group also contributed to other activities within the institute like making oil diffusion pumps and a small-scale electrolytic plant for production of heavy water. Between them, the three groups

[577] *Chor Bazar* literally translated means thieves market. Here one could find artifacts ranging from antiques to scrapped machinery, and as the reputation goes, they could be stolen goods as well.

published about the construction of only one of their machines, the Van de Graaff generator.[578] In the meanwhile, the Philips generator was finally installed.

5.9 1953: A Philips Cascade Generator

The nuclear physics group of the Atomic Energy Commission bought a cascade generator from Philips Electrical (India), but the Tata Institute of Fundamental Research housed the machine. A contract agreement was signed between the TIFR and Philips India in June 1952. The apparatus was however not installed until more than a year later. The generator was ready to be shipped from Eindhoven in 1952, but the installation had to be postponed twice. The building was first, not ready and then, too small. The laboratory proposed by the TIFR was considered too small for housing the equipment by Philips technicians and they suggested either sinking of the floor or raising the roof if the installation had to function to its design capacity.[579] The TIFR on the other hand looked at the location as a temporary arrangement until a new laboratory could be built but was keen on optimal performance. The first records from the installation team in Eindhoven are from July 1953. The installation was difficult - there were no hoists in the building. Two

[578] George, Divatia, Mehta, Bhave, Deshpande, Ram and T G Varghese, "The TIFR Van de Graaff Accelerator," *Proceedings of the Indian Academy of Science* L, no. A, (1959): 175. Especially important were experiments for making a good electrostatic belt. It was only in 1955 when they acquired a belt from the United States that the generator began to work properly. The Atoms for Peace meeting of Geneva, following Eisenhower's plea for lifting secrecy around nuclear technology cleared way for import of technologies earlier seen as dual use and not allowed on grounds of national security. The belt mentioned here, but more so designs and then entire nuclear reactor setups, plastic balloons for cosmic ray experiments were now exported and sometimes given as gifts by the United States to countries like India.

[579] Agreement document; and A. J. F. Scheephorst and T. A. Reitsma, Philips Gloeilampenfabrieken to Philips India, Calcutta, March 25 1953, Company Archives, Philips International BV, Eindhoven.

technicians spent 13 and 42 days respectively at the site to help with the installation and training personnel with its use.[580] The TIFR and the laboratories it ran for the AEC[I] now employed 70 nuclear physicists, the largest concentration in India.[581] Activities were only expanding. Bhabha now planned for a separate radio and electronics laboratory dedicated to atomic energy research.[582] On January 1 1954, Nehru led the stone laying ceremony for a spacious new laboratory of the TIFR. The guests were invited also to see the new cascade generator. A professional photographer took a picture of Bhabha sitting in front of the machine – in his fine Italian suit and shimmering socks.

---

580 Philips, Eindhoven, supplied two cascade generators that year and the industrial apparatus division looked at these as major successes. One was installed in Bombay, India, and the other in Lahore, Pakistan, which the two technicians installed on the very same trip after their job in India. *Announcer* VII, no.2 (February 1954). [Monthly Review of the Philips Industries].

581 HJB to H. R. Allen, Imperial College, November 20 1952, D-2004-00085, TIFR Archives.

582 HJB to E. H. Rydbeck, Chalmers University of Technology, Sweden, January 12 1953. Two new appointments were made to the accelerator group in this period, both Indians working in the UK, C. Ambasankaran from Metropolitan Vickers and Evani Kondaiah from Oliphant's laboratory in Birmingham.

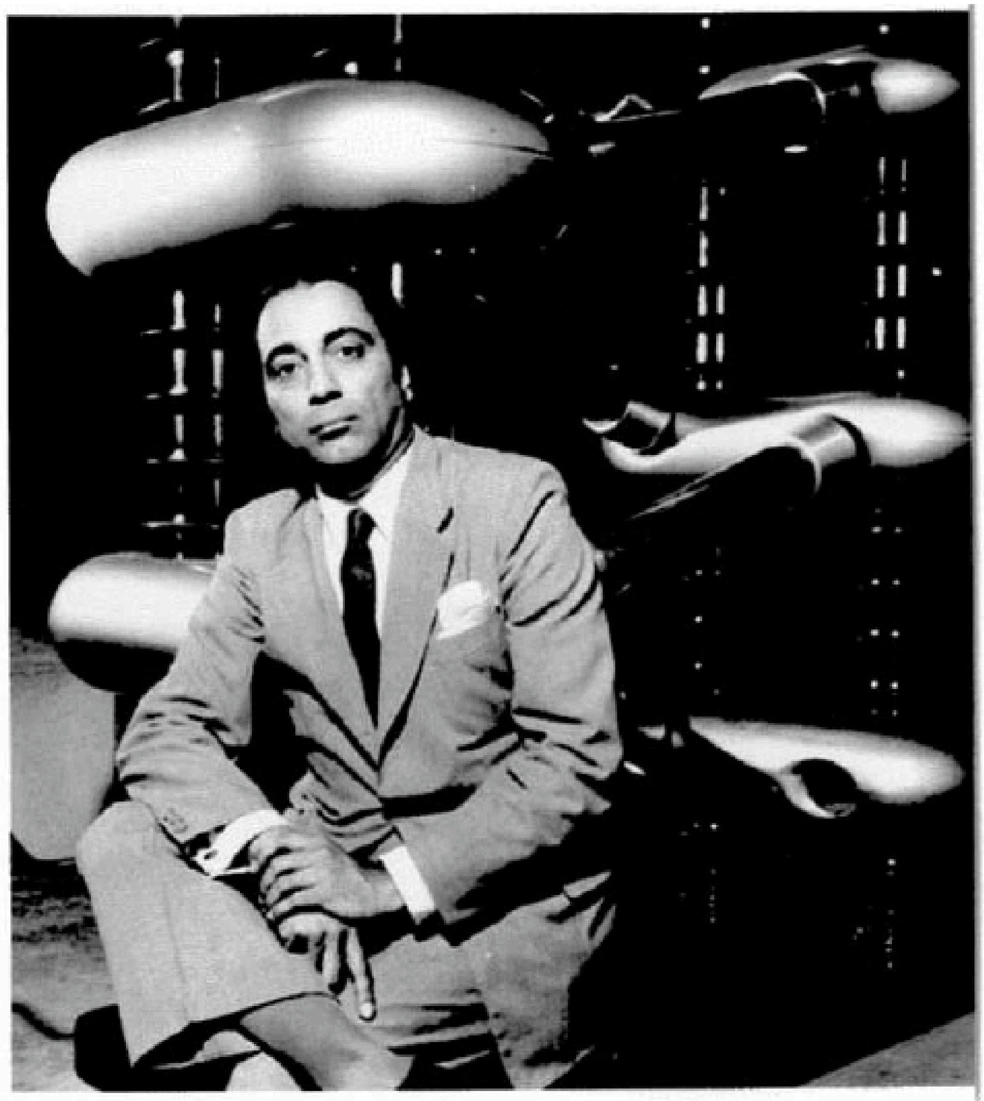

Figure 5.1: Bhabha in front of the Cascade Generator. Reproduced with permission from the Tata Institute of Fundamental Research Archives, Bombay.

5.10 1955: No Large Machine

Bhatnagar's strength as a science administrator came from his endorsement of Hill's model of organising science research under direct governmental control, but not bureaucratic control – in that, Bhatnagar occupied the highest bureaucratic office in a ministry. A year before Bhatnagar's death, a Department of Atomic Energy (DAE) was set up on August 3, 1954 under the direct charge of the Prime Minister through a Presidential Order. Bhabha became a secretary of the Government of India, and directly responsible only to the prime minister. His responsibility for atomic research in India grew only larger, and even more prominent.[583] Particle accelerator builders at the TIFR became the smaller beep on his radar screen.

But even in the larger context, the significance of these small beeps needed to be revaluated. Bhabha decided to consult Mark Oliphant. I would like to reiterate here that Oliphant's advice has to be contextualised, and cannot be taken as self- evident or neutral. Oliphant and Bhabha were colleagues in Cambridge and more so, Oliphant was in a similar position in Australia as Bhabha found himself in India – both were seeking to establish nuclear physics and technology and build national institutions. The one major difference between them was, Oliphant had already built one such laboratory in Birmingham, and he was a part of the British scientific war-effort. His hands on experience with advanced research technology, and his perspective on getting such apparatus established in a context distant from allied war effort made him a good candidate to seek advice from for the Indians. In a note from February 1955, Oliphant gave three reasons why the 60-inch cyclotron was not advisable. Oliphant had visited the

[583] In 1954, as Chairperson AECI, and Secretary, (DAE), Bhabha was responsible for the research agenda of following institutions: The TIFR, Rare Minerals Survey Unit, Indian Rare Earths Limited (processing), AECI research agenda of reactor building. Bhatnagar was also a member of the AECI but he was responsible for the CSIR and its 12 laboratories; National Physical Laboratory, National chemical Laboratory, Fuel Research Institute, Central Glass and Ceramics Research Institute, Central Food Technology Research Institute, National Metallurgical Laboratory, Central Drug Research Institute, Central Road Research Institute, Central Electrochemical Research Institute, Central Leather Research Institute, Central Building Research Institute, and Central Salt Research Institute. K. S. Krishnan was the director of one of the CSIR laboratories, the National Physical Laboratory. His approach to science administration has been discussed in Visvanathan, (1985).

TIFR earlier that year, met with the accelerator group and consulted on construction problems. He began his note stating: "If the Institute is to undertake a program of training, a 60 inch general purpose cyclotron would be a useful piece of equipment. The Philips H. T. unit provides for accurate work in the low energy field… The cyclotron with internal as well as external beam can extend the area of training in nuclear physics to higher energies and is a very useful tool for research with all elements…. However, the question arises, *with limited resources of manpower trained for such work and with limited funds; [if] the luxury of covering all fields can be justified*.[584]

Oliphant was discussing a machine within the Atomic Energy Commission establishment, and not for the TIFR. "A cyclotron within the atomic energy establishment, built specifically for the manufacture of short lived isotopes can be justified only if the demand for those substances is rather large…. The United States of America possesses such machines but the United Kingdom has not felt them to be justified." It was Oliphant's last point though – that may have delivered the blow on this project. "Experience gained in the design, construction and operation of a cyclotron, is not particularly valuable for work upon accelerators for higher energies". But was the group training for work at higher energies? What could they have been training for, if

---

[584] "Note on proposed 60 inch cyclotron" addressed to H J Bhabha and D Y Phadke, February 24 1955, from the Papers of Sir Marcus Laurence Oliphant, Special Collections, University of Adelaide Library, Adelaide, Australia; emphasis added. Mark Oliphant and Homi Bhabha relied on each other's judgment. Oliphant wrote to Bhabha in 1946 seeking his theoretical perspective on the new machine he was planning. However, not everyone was convinced of Oliphant's ambitions, including Bhabha's other confidante and friend Patrick Blackett. In July 1953 Blackett informed Bhabha of Oliphant's work: "…Oliphant has started well in building up a physics school and has actually got some nice but not particularly exciting work going on with a 10 MV Philips HT set. Tietertan is in charge of this. Oliphant is designing and building a big machine of quite original design top give 15 GeV enrolling a new type of mono polar generator. I hope it will work!" PMSB to HJB, July 21 1953, D-2004-00200, TIFR Archives. Bhabha also invited Oliphant to the meeting where funding for Saha's INP was decided later that year (1955). See among others Roderick W. Home, "The Rush to Accelerate: Early Stages of Nuclear Physics Research in Australia," *Historical Studies in the Physical and Biological Sciences* 36, no. 2 (March 2006): 213-241.

they were indeed not the user community – and the nuclear physics group never put any of their machines to use for experiments? I will come back to this question after a detour through another set of reasons leading to abandonment of the 60-inch cyclotron project.

A *community of users* was established for the first time within the TIFR but *for the AECI* with the arrival of the Phillips machine. They were planning experiments with the machine; but the accelerator builders were not involved. Nuclear physicists working with the Philips machine soon found themselves in an uncomfortable situation with respect to research priorities of the TIFR and its surrogate work for the AECI. In April 1955, Evani Kondaiah, who had been hired from Oliphant's Birmingham laboratories, wrote to Bhabha: "I understand that a series of experiments are planned for the 'Reactor work' and the Cascade Generator will not be available for the Fundamental Research'…. So unless action is taken in this direction, now itself, I am afraid, the 'Fundamental Work' will suffer."[585] Raja Ramanna (who led the nuclear physics groups of the AECI) considered Kondaiah's appeal and concluded that a very small generator could not be purchased: those that could be bought were bigger and AECI did not need another machine. Reactor work would get priority on the machine because "this instrument was bought by the department for such work". The AECI would be willing to help construction of a small machine "when necessary".[586] A larger Van de Graaff machine was under construction at Trombay, the Atomic Energy Commissions own research establishment – and that machine would soon be available for fundamental research if required. Until then,

[585] E. Kondaiah to HJB, April 22 1955, D-2004-00386, TIFR Archives.

[586] Raja Ramanna, note of April 24 1954, D-2004-00386, TIFR Archives.

Kondaiah had no choice but to wait or construct a smaller machine. The accelerator groups had completed work on three prototypes and were asked to begin work on design and cost requirements for a 60-inch cyclotron – they were being trained for bigger work, and could not be channelled to build a smaller machine for the TIFR's experimental physicists (who unlike the AECI experimental physicists, did not have their own machine). They spent considerable time on this project and submitted at least two reports in 1954-55. Having worked their way through design and construction principles of the three machines, like Bhabha had wanted them to, the group was now ready to take on bigger projects scaled up from the prototypes. The project was simply dropped.

But Oliphant was also asked to evaluate the organisation of "work in experimental physics" as a whole. A month later, he submitted a scathing critique of scientific practice at TIFR.[587] First, he noted the tension that arose from the TIFR hosting AECI's groups – resonating Kondaiah's complaint. An experimental physics group, very much like a group in theoretical physics, Oliphant argued, had to be organised around individuals. The laboratories of the AECI on the other hand would have to be organised around specific tasks and these two could not be conflated. Oliphant reminded Bhabha of issues not far from those Bhabha had raised with Saha only a few years ago, "The successful pursuit of an experimental program involves far more than definition of the experiments to be performed and the equipment to be employed. Such work must be planned in detail, using the fullest cooperation with theoreticians and with masters of various techniques in all groups. Leadership requires certain ruthlessness in discarding unproductive lines of

[587] MLEO to Bhabha, note of March 31 1955, D-2004-00483, TIFR Archives.

experiment, as well as qualities of discrimination in the choice of experiments as skill in the employment of techniques. I am not at all convinced that these three qualities are present in many of the leaders of your existing divisions". Oliphant asked Bhabha to keep the groups small and try recruiting or training men of "the right calibre" before embarking on plans that are more ambitious.

Oliphant's report pinned down the ambiguity of TIFR's position as a research institution within the larger agenda of the AECI. Bhabha and the TIFR responded in two ways:[588] plans to establish a separate institution dealing with problem focused nuclear technology research were accelerated. The recent agreement for a research reactor with the British had made this move real. Thus far, the AECI had the Phillips Cascade Generator (1953) as their machine, housed within the TIFR. With a research reactor on the way, a separate research facility for the AECI was justified and could settle the ambiguity of mandates. The changes in Anglo-American approach to sharing nuclear technology had finally made it possible for the AECI to gain access to nuclear technology. This in turn refined the status of the TIFR as an institute for "fundamental research", but a rather privileged one. The privilege was maintained in Bhabha's continuing directorship, but it did not easily transfer to its other researchers. Evaluating their status was the other step taken at

[588] I am not suggesting here that Bhabha actions can be entirely interpreted as a response to Oliphant's suggestions. Oliphant's observations may well have legitimated decisions he was already working with. The prospect of a reactor clearly put under question the function of the TIFR within the AECI. In Bhabha's favour, if he had denied reactors to Calcutta, he did not establish the reactor facility as a direct extension of the TIFR's activities and maintained its status as an institute of fundamental research. As such then, this was among the first set of decisions that gradually rendered the TIFR comparable with the Calcutta laboratory, a status that would be confirmed in the very first meeting to decide on a national policy for accelerator based research in India (August 1964). I am saying comparable, but *not equal*, Bhabha's prominence and TIFR's priority was established in 1946, which reflected in the funding pattern and privileges that came with being continually and tightly associated with the AECI.

the TIFR. This changed perspective on the status of TIFR's accelerator builders was soon brought home, as it was to their even less privileged colleagues at the INP in Calcutta.

5.11 1955: An Indian Delegation for Atoms for Peace

If the Empire Scientific Conference (1946) was a plea to maintain imperial preference in post-war international politics, the *Atoms for Peace* in Geneva (August 1955) was an invitation to establish American preference (over the Soviet Union) in Cold War politics.[589] The British, through the Royal Society, presented the Commonwealth as an advantageous alliance, but barely a year after Hiroshima, nuclear research was not for sharing. It was only fair then, American preference should begin where imperial preference hesitated. *Atoms for Peace* was the triumph of nuclear exceptionalism constituted entirely through Cold War politics. If the Americans did not, the Soviet Union would – this was also about super power rivalry for the hearts and minds of men.[590]

[589] I do not mean to evoke here Gier Lundestad's empire by invitation. I am not suggesting that the Americans were *invited* to establish an "American preference" in Cold War politics. I wish to suggest instead that the Americans used the *Atoms for Peace* meeting as another means to establish American preference. The Conference addressed a rather selected audience – "competent scientists, budding engineers and ambitious technocrats", in the heyday of modernisation theory and practice, - with the goal to convince *through them* their political leaders, of the [nuclear] benefits of aligning with the Western world. This thesis has been convincingly developed in John Krige, *Techno-utopian Dreams, Techno-political Realities: The Education of Desire for the Peaceful Atom* Davis Fellowship Paper, 2006. If one were to combine recent scholarship on the American Empire, with scholarship on the Americanisation of Western Europe, while Krige finds "consensual hegemony" more useful over "empire by invitation" as an analytical category, he prefers much more the idea of a "co produced hegemony".

[590] The Indian delegation was invited to visit the Soviet Union *at the Atoms for Peace* meeting in Geneva. Khrushchev and Bulganin visited India in February 1960, and were given a tour of the Tata Institute of Fundamental Research. Bhabha led an Indian delegation to the Soviet Union in the summer of 1960. In February 1961, Bhabha announced that the Soviet Union had agreed to build a reactor for India. In a public statement, Bhabha mentioned inspections required by the IAEA for reactors coming in from the USA as an " infringement upon Indian sovereignty". The Soviet Union was not a member of the IAEA and "hailed the opposition of India and other non-aligned Afro-Asian nations to IAEA controls over their nuclear development programs." An Indo-Soviet agreement was signed on October 7, 1961. *The Hindu* February 3,

Pronounced political influence is hard earned and requires reaffirmation. Saha knew that from his experiences with nationalist politics in colonial India. Bhatnagar had mentored Bhabha in science administration, and their power was accrued in the marginalisation of the Calcutta facility (on the national scene) and dispossession of the Bangalore facility. An invitation to preside over the *Atoms for Peace* meeting in Geneva was the reaffirmation of Bhabha's standing as a science administrator, both at home and abroad. Atomic Energy was now its own department directly under the prime minister, and no longer under the CSIR. Bhabha's position within the government was almost invincible. But invincibility has to be justified, sustained and amplified on a regular basis. The composition of the Indian delegation to Geneva was one such event.

As the only other credible nuclear physics research facility in India, the Institute for Nuclear Physics in Calcutta were asked to nominate delegates. Meghnad Saha recommended a list of scientists and technicians working with the cyclotron group, which included B D Nagchoudhuri, Reader in Nuclear Physics, Bindu Madhab Banerjee, in charge of electronics, and Ajit Kumar Saha. The Calcutta delegation was turned down by the DAE. Saha, angered, demanded an explanation. Bhabha responded that the Geneva meeting was addressed to issues of nuclear technology and nuclear energy, and therefore not of interest to researchers in nuclear physics. Bhabha was making an unsustainable distinction between nuclear technology and nuclear physics research, but what he was effectively doing was denying representation to the Calcutta group. They could not stand in for India.

1961 and *The Statesman,* October 7, 1961. Quoted in Arthur Stein, *India and the Soviet Union: The Nehru Era* (Chicago: University of Chicago Press, 1969), 180-182.

This denial was not unprecedented. In October 1954, Saha was attending a conference in Moscow along with the Scientific Advisor to the Ministry of Defence, his former student Daulat Singh Kothari. Saha and Kothari were delegates of the Government of India. Saha wanted to negotiate a deal for a reactor. "I think I may undertake further task on behalf of the Government of India, if I am permitted", Saha wrote. Following the new Atomic Energy Act in USA, "Pakisthan (sic) may be given a Reactor next year. I was told so by the Committee of Senators and Representatives when I visited Washington… this year… So Pakisthan may have a Reactor earlier than India".[591] The US was less likely to consider a proposal from India, Saha felt because India did not count as a friendly country. Negotiations with the Soviets on the other hand might prove more successful. "We, myself and Kothari, can carry on these talks with appropriate Russian Authorities if the Government of India gives us the authority to do so. We cannot do anything without Government authority, because otherwise the Russians would not talk with us".[592] Saha was now not privy to state decisions, and was unaware of Cockcroft's offer of a research reactor made only a month ago.[593] Clearly, even a suspicion of such a deal would have to

[591] Manuscript letter, (undated) very likely addressed to the Prime Minister, written from the Soviet Union, MNS Papers, SINP. Saha mentions his speech to parliamentarians that year at the Prime Minister's residence, which allows for a fair certainty that it was written in October 1954.

[592] Nehru incidentally, was in Peking and Saha suggested that the Government of India contact him through the Indian Embassy in Moscow before October 29, 1954, the date they were to travel out of the USSR.

[593] Abraham (1998), Chapter 3, "Postcolonial Modernity: Building Atomic Reactors in India," 70-112; and Perkovich (1999), Chapter 1, "Developing the Technological Base for the Nuclear Option, 1948-1963," 13-59.

explained and accounted for to the British. Nothing came out of this effort. But Nehru and Bhabha were cautious that nothing like this could happen in Geneva.[594]

The Indian delegation to Geneva was not a matter of a conference delegation alone. If the logic of concentration was to be followed, state priority implied one delegation, and one voice that would negotiate for the Indian state – scientists became statesmen in nuclear politics, but not without the consent of the state. With Bhabha presiding the meeting, the question of who represented the nuclear in "India" and who could have the power to speak on behalf of the new country was not trivial. Unlike under British colonial rule, Saha and others could no longer represent themselves as scientists alone and participate in international meetings or negotiate for nuclear research apparatus *individually* –a function, first and foremost, of the nature of nuclear technology necessarily established through the use of atomic weapons, the concomitant changes in international order, and not least, of the decolonization of British India. Saha was aware, but was ambitious and refused to give in to the logic of the state and of the technology. AECI prerogative over nuclear research and equipment in India was now complete. Nuclear energy and therefore technology was now more important. If this was to affect the face of the Indian delegation to the meeting, it also affected what the Indians could and did negotiate at the meeting. If the AECI was going to pay for the particle accelerators installed in Bombay, then they were to be firmly embedded in the research priorities of the AECI – and not of the scientists and technicians at the INP in Calcutta, *or for that matter those at the TIFR*.

[594] Instead, Saha participated in the World Assembly for Peace, Helsinki, and the Atomic Energy Conference at Moscow for peaceful uses of nuclear energy in June 1955.

5.12 1955: Atoms for Peace

The *Atoms for Peace* meeting was the direct outcome of the effort begun under President Eisenhower calling for the peaceful use of atomic energy (1953). "A total of 1,428 delegates from 73 nations participated in the first conference, and 1,067 scientific and technical papers were submitted for discussion. The centrepiece of the Untied States' participation was a swimming-pool-type research reactor that had been flown to Geneva and assembled during the conference. Eisenhower took time out from the concurrent Geneva summit conference, at which he made his famous 'open skies' disarmament proposal, to visit the American exhibit and to see the research reactor."[595] Shanti Swarup Bhatnagar had led the Indian delegation to the Empire Scientific Conference; the baton was now passed on to Homi Bhabha. Bhabha led the Indian delegation of 24 persons, members and staff of the Atomic Energy Commission of India. They presented 13 papers at this meeting (the Americans presented over 500), but their presence was magnified several fold.

---

[595] For Eisenhower's speech see:, [http://www.eisenhower.archives.gov/atom7.htm]. Also reproduced in Joseph F. Pilat, Robert E. Pendly, and Charles K. Ebinger, eds., *Atoms for Peace: An Analysis after Thirty Years* (Boulder, Colorado, 1985) Appendix C; For a lucid account of the meeting see Laura Fermi, *Atoms for the World: United States Participation in the Conference on the Peaceful Uses of Atomic Energy* (Chicago: The University of Chicago Press, 1957).

For motivations and outcomes of the meeting see: John Krige, "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence," *Osiris* 21 (2006a): 161-181; Ira Chernus, *Eisenhower's Atoms for Peace* (College Station, Texas, 2002); Martin J. Medhurst, "Atoms for Peace and Nuclear Hegemony: The Rhetorical Structure of a Cold War Campaign," *Armed Forces and Society* 23 (1997): 571-93.

Laura Fermi has hinted at the "many names" suggested for president of the meeting, but how eventually "a French delegate" proposed Bhabha, to which every one agreed.[596] Bhabha's choice could have been a result of several converging interests; for the first, he had been involved with UNESCO before.[597] He was acceptable to UNESCO ideologues because, as Julian Huxley wrote asking Bhabha to consider directorship of the UNESCO just a couple of years before, "[you] are eminently indicated for the post – an eminent scientist, with experience of administration, an artist, with a great knowledge and appreciation of the arts, and at home both in the West and the East."[598] Huxley had asked Bhabha also, because apparently it had become important that the new director was from Asia. If Asia was a concern, Indian, or more precisely Nehru's opinion was being taken quite seriously. The Soviet Union had accepted Indian foreign policy of non-alignment in February that year; Indian foreign policy was supportive of Communist China; the Bandung Conference was planned for later that year. Asia was in the spotlight and appeasing Indian leadership was one way of addressing the situation.[599] Moreover, if

---

[596] Fermi (1957), 17- 21. I have not (archivally) followed upon Bhabha's choice as President for the meeting, a topic deserving attention. Fermi does not mention any names or nationalities proposed or of those that proposed the candidates.

[597] Homi Bhabha was appointed chairperson of the 'Sub-commission on Natural Sciences' at the first General Conference of UNESCO in Paris (1946).

[598] Julian Huxley to HJB, February 1953, (D-2004-0474), TIFR Archives.

[599] Ben Zachariah has argued, "The year 1955, which we might be justified in treating as the highest point of Nehru's career, was in many ways the year of Bandung". On February 8 1955, Foreign Minister Molotov of the USSR accepted Nehru's *Panch Sheel* – the five principles of non-alignment to be followed in Indian foreign policy. See Zachariah, (2004), 214-252, at 216.

Following that, "India's Jawaharlal Nehru was the busiest man in London last week. Britain's Anthony Eden wooed him, Burmese and Indonesian envoys sought him out. Communist China's chief representative conferred with him twice. So did U. S. Ambassador Winthrop Aldrich, who got the full treatment on the "Asian" view of Formosa, featuring Red China's indisputable right to Formosa and the U.S.'s "interference" in Asia's affairs […] There was little enthusiasm for an Indonesian proposal that the Colombo powers mediate (too clumsy) or for another Geneva-type conference (the U.S. disapproved). By default all hopes centred on Jawaharlal Nehru. The question was whether his intervention would do more

Atoms for Peace was about sharing nuclear technology, informed by modernisation theory, with "the world at large", Bhabha was a competent face of that world "an eminent scientist […] at home both in the West and the East" as Huxley already stated. Moreover, he was administering atomic energy research in India: Bhabha's choice was politically desirable and scientifically appropriate.

Bhabha's presidential address to the Conference" contained two unexpected statements that caused surprise.[600] On Nehru's behalf, Bhabha regretted the exclusion of Communist China; "It is a matter of regret that there are several areas of the world which are not directly represented at this Conference". The other statement was "sensational"; "I venture to predict that a method will be found for liberating fusion energy in a controlled manner within the next two decades." Fusion was not on the Conference agenda, and "the very existence of Sherwood was still secret. […] Americans at Geneva were not free to comment upon Bhabha's speech. The British however, did speak out".[601] Raja Ramanna recalls that Bhabha believed fusion research was underway in the "advanced countries", and he wanted to "shake them out of secrecy".[602] Bhabha's statement was unexpected for

---

harm than good. He was insisting that Red China's ultimate right to Formosa must be recognised first […] Vastly relishing his role, Nehru told 3000 Indian students: "Whatever you say must be at the right moment, then it does have some effect," "The Man Between," *Time Magazine* (February 14, 1955).

The Indonesian suggestion for a Geneva-type conference did not happen, but PRC was provided its first international forum and the first endorsement of its legitimate statehood in Indonesia, at the Bandung Conference in April-May 1955.The *Atoms for Peace* Conference took place in Geneva three months later. Bhabha's choice as president of the *Atoms for Peace* meeting could *also* be seen as a reflection of taking Nehru's India seriously.

[600] For an analysis of Bhabha's speech, see Abraham (1998), 98-106.

[601] See Fermi (1957), 73-89, and Joan Lisa Bromberg, *Fusion: Science, Politics and the Intervention of a New Energy Source* (Cambridge, MA: The MIT Press, 1982), 67.

[602] Ramanna, (1991), 64.

most and undesirable for the Americans in particular. What prompted him to go ahead is not obvious. It could well have been an informed suspicion he harboured, and therefore like the nuclear industry, was worried that India should have to invest heavily into nuclear technology only to find it rendered "primitive" in a decade by fusion energy.[603] Indeed, "whatever" he said was "at the right moment" and then it did "have some effect". Bhabha clearly enjoyed being president, and mobilised the opportunity to negotiate both, his own position in American preference, and Nehru's politics of cautious alignment through a strenuous posture of non-alignment. Reporting to Nehru with details on the conference, Bhabha wrote:

> "As far as scientific discussions in this highly sensitive field of atomic energy were concerned, all signs of the cold war appear to have disappeared. This does not of course men that there are no longer secrets being kept back in this field, but these are now either of an industrial nature or in areas which are rather close to weapons development… One should take the opportunity of this excellent atmosphere to push forward with an enlarging of the areas of cooperation in this field, from which, it may be possible in due course to pass gradually to a solution of the tougher problem of atomic armament. The essential thing is that any future action in this field should be taken with tact and consideration, so as not to mar in any way the excellent psychological atmosphere which now exists".[604]

Back at home, "After the conference, he [Bhabha] came to be respected more highly in Indian political circles, and his influence on Pandit Nehru on scientific matters was pronounced".[605]

---

[603] I am also inclined to make an unsubstantiated claim here. Bhabha's statement could have also been a gamble, maybe with British support. If the Americans were conducting fusion research, Bhabha's statement followed by British admission could potentially pave way for an American statement and an opening up of the field. Blackett and Bhabha did enjoy each other's trust, and to some extent Cockcroft as well.

[604] HJB to Nehru, August 24 1955. Reprinted in *Nuclear India* 26, no.10, (1989): 10.

[605] Ramanna, (1991), 65.

The Geneva meeting significantly altered the accelerator builder groups and their activities in Bombay. If the swimming pool reactor displayed at the Geneva meeting was a "centrepiece" in the eyes of the American's themselves, its significance was in no way lost on the visiting delegations. Bhabha was given free reign by Nehru to negotiate for one to be built in India and he negotiated for one with the Canadian Atomic Energy Commission led by William Bennett Lewis, Bhabha's colleague from his Cambridge days. Back home in November 1955, the accelerator group was told, "the Institute has no further interests in the *construction* of accelerators". Like Oliphant had advised, Bhabha concluded that construction of accelerators at the Institute had to be "ruthlessly discarded". An inquiry was instituted into the function and accomplishments of the accelerator builder groups at the TIFR. Following the Geneva meeting, the AECI were completely re-focused upon two reactors, work upon which had to be completed with urgency. The accelerator groups, by early 1956, shifted attention from building prototype particle accelerators, to design and construction of equipment for experiments in plasma physics. They would now focus on fusion energy research.

Exactly one year after the Geneva meeting, Bombay's first research reactor went critical.[606] Bhabha claimed that over 300 scientists were now working with the atomic energy establishment.[607] Four months later, the AECI's own research and development establishment, was created in Trombay - the Atomic Energy Establishment, Trombay

[606] Apsara, built with British help went critical on August 4 1956.

[607] Text of statement by HJB, Chairman Indian Delegation to the Conference on the Statute of the International Atomic Energy Agency on September 27 1956; attachment HJB to Lewis Strauss, October 9 1956, Lewis Strauss Papers.

(AEET), was established at the reactor site, and by August 1957, the AEET's own training school was effective. With one reactor in place, an independent research establishment of the AECI with its own training school in operation, the necessity of a particle accelerator group within the TIFR was in question. If the groups' main purpose was one of training personnel, the AECI now had its own program – if the purpose was research, the AECI always had its own machines. This ambiguity around the groups' function was an expression of the ambiguity of the relationship between the TIFR and the AECI. It was enacted through an evaluation of its member's accomplishments, but the groups had been building prototypes and training in nucleonics. What could they show?

5.13 The Crisis of 1959

Joan Bromberg has argued, "His [Bhabha's] speech in fact forced the first step toward the programs declassification […] In a joint action with Britain thermonuclear research was completely declassified on August 30, on the eve of the Geneva Conference […] The unfettered presentation of research results at the conference allowed crystallisation of the new consensus that the art was, as yet, rudimentary lessened the mood of competition and encouraged the internationalisation of the field through the personal interactions that occurred in Geneva."[608] After the second *Atoms for Peace* meeting in Geneva in September 1958, Bhabha sent K. A. George to Blackett's laboratory at the Imperial College, London for further training and research in fusion.[609] George had earlier led the

[608] Bromberg (1982), Chapter 6, 89-105.

[609] HJB to Blackett, August 19 1958, D-2004-00200, TIFR Archives.

construction of the Van de Graaff machine at the TIFR. To begin with, Phadke, who remained in charge of the three groups, was not entirely convinced of the decision. He wrote to Bhabha about progress in plasma physics experiments and argued; "An extended stay of Mr. George at the Imperial College will retard our work considerably…. In my opinion, Mr. George is mature enough to benefit by a brief stay at various places. I therefore suggest the following programme for Mr George's deputation after the Geneva Conference: 3 months at the Imperial College, 3 days visit each at the following places: Stockholm, Uppsala, Aachen, Saclay and Munich".[610] Bhabha did not agree with Phadke, George would benefit from a year's stay at Imperial. He would have to stay.[611]

In December that year, George wrote to Phadke that he wanted to come back to Bombay.[612] "Getting to know the technique of the work here required only a short time…. I have already discussed with Prof. Blackett and with Dr. Latham, the leader of the High Temperature Group, that the main object of my stay was to learn the technique and to get in touch with the spirit of plasma research, so that it will be of help in starting a formal group there…. I feel that further stay is not going to contribute much towards that objective." George further argued that staying back was going to delay the work he had already started in Bombay and opportunities for original work would be lost. Especially given the shuffling of personnel in the TIFR groups (two from the group were moving on, one to the USA and another to new assignments within the AECI set up), George felt he

[610] DYP to HJB, July 28 1958, D-2004-00308, TIFR Archives.

[611] HJB to DYP, note of July 30 1958, D-2004-00308, TIFR Archives.

[612] KAG to DYP, December 8 1958, D-2004-00308, TIFR Archives.

had to be in Bombay for readjustments. Phadke agreed and forwarded the letter to Bhabha with disastrous results.

Bhabha did not discuss George's return. His questioned instead the prerogatives of the group in proceeding with fusion research. "Any work on fusion must be a substantial project, if it is not to be relatively ineffective. No experimental work on fusion in the Institute should be started until written orders from the Director have been obtained. It should be clear that I am not happy at the considerable number of important projects that you have in your charge, which have not come to a satisfactory and definite conclusion. Till some of the present projects at least are successfully concluded, I cannot agree to any new project being started under you."[613] In a surprise move, Bhabha's note put the focus back on the machines earlier constructed by the accelerator groups, something that was never before discussed seriously in relation to the fundamental research at the TIFR. On December 29 1958, a faculty meeting decided to appoint a committee to consider the "utilisation of accelerators being developed under Dr. D. Y. Phadke".[614]

M. G. K. Menon convened the meeting in early 1959, to decide what could be done with the machines developed by the groups led by Phadke.[615] The first consideration for the meeting was surprisingly not related to continuing training or with fundamental research at low energy levels, but "to make recommendations concerning the usefulness of these

613 HJB to DYP, December 24 1958, D-2004-00308, TIFR Archives.

614 N. R. Puthran, Registrar, TIFR to MGK Menon, February 5 1959, D-2004-00832, TIFR Archives.

615 MGK Menon was a member of the cosmic ray group and had worked with Cecil Powell in Bristol. He would lead the TIFR after Bhabha's death.

units to A. R. Gopal Ayengar in the Biological division of the Atomic Energy Establishment Trombay" (established in 1957).[616] The small groups at the TIFR would now be starved of their equipment to feed the ever-growing research needs of the AECI. Kondaiah's concerns of experimental physics research *within the TIFR* were far from assayed; he was himself in Stockholm for research but the groups themselves now appeared to lose control over their equipment.

The meeting was held on March 2 1959.[617] Phadke first provided those assembled an overview on the machines built by the groups. The cyclotron was built as a training unit and had since been completely dismantled. Its components such as the magnet were cannibalised for other experiments. The Van de Graaff machine on the other hand was accelerating particles up to 400 KeV and that could be converted to an electron machine by changing the ion source, and the room could be air-conditioned. This way, the meeting agreed, the group working with Gopal-Ayengar could straightaway use the Van de Graaff in its present location for irradiation, and Phadke would work out the schedule for adaptations required for such use. The third machine, the electron linear accelerator was potentially of considerable use to the Biology Division. However, this machine still needed three phases of development of the wave guiding tube to bring the beam up to its design value of 7 MeV. Phadke agreed to provide the time schedules for these various

---

[616] MGKM to A. S. Rao, A. R. Gopal Ayengar, Phadke, Raja Ramanna and K. C. Bora, February 11 1959, D-2004-00832, TIFR Archives.

[617] Minutes of the Meeting held on March 2 1959 to discuss the Utilisation of the accelerators being developed at the TIFR by the group working under Dr. Phadke; D-2004-00832, TIFR Archives.

stages of work. By March, the plans were well under way, and George continued to languish at Imperial with Blackett.

In July 1959, Blackett wrote to Bhabha suggesting that George should travel to Princeton to widen his perspective on fusion research. He added though, if George were to gain experience primarily in experimental work, then he was better off at Imperial – and that is where he stayed.[618] But that was clearly not enough. George was denied a promotion when he came back that year. Phadke was disappointed and wrote to Bhabha again. The disagreement between Bhabha and Phadke about George and fusion research at the TIFR in particular, but also about the future of the accelerator builder groups in general, grew stronger. Within a month's time it brought to the fore the deep dissatisfaction of the accelerator group's self perception within the Institute's larger agenda as whole.

The Common Room (faculty) had denied promotion for George on grounds that: "(1) he was not able to bring out any of the instruments to a stage where they could be used as tools of research. (2) He has inadequate number of publications to his credit. (3) His attitude towards his deputation abroad was unsatisfactory." George's was the only case where the promotion had been denied, which also meant no raise in his salary. He petitioned Bhabha.[619] He first recounted his early work with group: "New ideas were presented during that period, … in my Report (1) on the proposed 15 MeV Cyclotron…. It was declared policy in the Section that one's work would not be assessed on

[618] PMSB to HJB, July 16 1959, D-2004-00308, TIFR Archives.

[619] KAG to HJB, September 8 1959, D-2004-00308, TIFR Archives.

publications. Therefore, there was no encouragement for publications as such." The problem of assessing the scientific contributions of cyclotron or particle accelerator builders was not unique to the TIFR. Most laboratories, even more so outside the USA, found it difficult to establish parameters of credibility and originality, especially for granting doctoral degrees, in the case of physicists involved in building particle accelerators. In many cases, apparatus builders only hoped to become users of the apparatus they built. Building complicated apparatus for one, took several years, which meant that builders took time to publish observations of consequence to the community. Given the case of the builder groups at the TIFR, they were but building prototypes for training purposes, familiarising themselves with the technique and technology of particle accelerators. That could hardly have qualified as original and publishable. This judgement, even of George alone, must have appeared rather unfair to the three teams.

Speaking of his later research, George argued that he produced a report on fusion research, "at a time when there was no literature available on the subject". Experimental work began following his assessment and George thought "It is necessary to emphasise in assessing this work that I entered an entirely new and difficult field with no help from any published literature and that even the equipment necessary for neutron detection etc. were developed essentially from scratch and with no previous background."[620] George was convinced the present situation had much to do with a misunderstanding connected

[620] George gave a table comparing the number of publications with those from some other small centres of research where "fusion research has been going on for a similar period": Uppsala where research in fusion had been carried out for 3 years had 2 publications; and Imperial College where research was going on for 2_ years had no publications. TIFR with its 2_ years had 1 publication, which was George's note Neutron Production and Temperature in Zeta published in *Nature* 745, (1958): 182.

with his deputation to Imperial College, which he then tried to explain. Phadke, on his part, wanted to take responsibility for that he had conceived construction of accelerating apparatus "with the object of model study and acquiring the requisite know how for tackling something more ambitious". [621] He further argued, "during the first half of this decade, the foreign goods supply position was inadequate. The local technical help was also woefully lacking. We had to do many jobs ourselves…. All this took time." He reminded Bhabha of the abandoned idea of building a bigger cyclotron following which, Phadke was asked to find some more useful line of work for the group consisting of 4 members. "I asked them to study plasma physics…." George had submitted a report on the possible lines of research, "bearing in mind that we cannot compete with the highly developed foreign nations in the high current pulse discharge work, he chose to study low current plasma". The nine-month deputation to Blackett's laboratory in London further delayed George's research, reasoned Phadke. Refusing to comment on the second reason, as regards the third he wrote; "I think he [George] honestly thought his stay at the Imperial College was of little use to him". The next day, Menon wrote to Phadke regarding progress on the conversion of the Van de Graaff machine for x-ray generation, since he had "promised to deliver in four months".[622]

On November 23 1959, the accelerator group submitted a joint representation to Bhabha. They were responding, "to a faculty evaluation of their group" as having done no tangible work and the likely chance that they may not be able to pursue plasma physics work in

[621] DYP to HJB, September 9 1959, D-2004-00308, TIFR Archives.

[622] MGKM to DYP, September 19 1959, D-2004-00832, TIFR Archives.

the near future.[623] They requested an inquiry into the work of the group and permission to continue research in plasma physics. Quite explicitly, they expressed concern about their future in the Institute. They began with an outline of work on the three machines evaluated late the previous year for utilisation by the atomic energy establishment. The group argued that work on the cyclotron was completed in a span of four years, and made a request that their effort be compared with the Calcutta cyclotron.[624] "We were made to understand by Dr. Phadke that this programme was undertaken so that a group of people may be trained for the construction of bigger accelerators. In those days, we were proud to hear remarks to this effect from the Director when he occasionally visited our group. No publication was intended on this small cyclotron…. Since there was no demand for the 12" cyclotron, it was dismantled in mid-1956 with the permission of Dr. Phadke so that the magnet could be used for plasma work." The plans for a proton-synchrotron, a 60-inch cyclotron, the Van de Graaff, and odd jobs were discussed leading up to the beginnings of plasma physics at TIFR. "When there was no future for the group, after the 60" cyclotron program was dropped. One got interested in fusion research after the First Geneva Conference, and a report was produced in December 1955. This was done at the time when no published work was available".

Reiterating Phadke and George, the note said, "It was the emphatically declared policy in the section that the work of the groups would not be assessed on the number of

[623] Members of the Accelerator Group to Homi J Bhabha, as Director of the Institute, November 21 1959, TIFR Archives, Bombay. The following signed the note: K A George, Research Fellow, Achyut Thatte, Junior Research Officer, Sharad Bhave, Research Fellow, T S Syunry, Research Assistant, and S S. Samant, Technical Assistant.

[624] For details on the Calcutta cyclotron, see Chapter 4.

publications…. Since an institute like ours could have an accelerator programme, we believed until now that we just happened to do that work. Due to reasons beyond our control, the Institute did not undertake any major accelerator work. That is quite understandable". The death of accelerator building within the TIFR was well pronounced. The group had been in existence for seven years and wondered if their work was considered not useful, why they had not been informed for these years. There also appears to have appeared a rift between Phadke and the group. They questioned his knowledge of the faculty's opinions and why he had not bothered to inform them. Finally, they asked for that they be allowed to continue work on plasma physics because: "Most of us joined the Institute because we like academic life and research work. We just happened to be in the Instrumentation section".

5.14 Conclusion

> "It is not an exaggeration to say that this Institute was the cradle of the atomic energy program, and if the Atomic Energy Establishment Trombay has been able to develop so fast, it is due to the assisted take off which was given to it by the Institute in the early stages of its development. It is equally true to say that the Institute could not have developed to its present size and importance, but for the support it has received from the Government of India."[625]

The establishment of an institute dedicated to fundamental research in the sciences, more specially nuclear physics, was Bhabha's contribution to the vision of an independent India. The TIFR makes for an interesting case because the institution was the brainchild of a cosmic ray physicist, who had engaged in both theoretical and to some extent

[625] Homi J. Bhabha, Speech at the Inauguration of the New Buildings, January 15 1962, TIFR Archives.

experimental work in the field before the establishment of this institution. When Bhabha had the opportunity to participate in cosmic ray experiments with Robert Millikan in Bangalore, he had behind him his own work in Cambridge [with Walther Heitler] and his training with PAM Dirac. While the geomagnetic equator provided for a suitable opportunity to carry out experimental work in cosmic ray physics, he was also driven by the possibility of discovering the meson particle.

With the establishment of his own institution, the struggle was to establish a research agenda in nuclear physics that was not dictated by the use of expensive high-energy particle accelerators. Given the scarcity of funding, and of trained personnel in electronics and nuclear physics - *a problem not unique to India,* -[626] and that particle accelerator energies had to yet surpass energies obtained in cosmic rays (at least until 1954), Bhabha concentrated efforts on cosmic ray research. The group at TIFR carried out experiments at heights as well as underground in the Kolar Gold Fields making use of available resources in India. It is in this context that attempts at accelerator building in Bombay have to be understood.

Bhabha's emergence as the leader of India's post-war nuclear research came from a combination of various factors. Bhabha was appointed chairperson of the Atomic Energy Commission of India in 1948, but he was well aware that a 'commission' enjoyed only consulting powers to the government. In order to be able to implement his decisions, he

[626] For difficulties in Europe, see Heilbron, (1986) on Europe's' first cyclotrons. For particle accelerators in Argentina, Australia, Brazil, Japan and Mexico, see R.W. Home, Ana M. Ribeiro de Andrade, Carlos D. Galles, eds., *Historical Studies in the Physical and Biological Sciences* 36, no. 2. Special Volume, (2005).

would have to possess executive powers – like those of Bhatnagar. Bhabha became a Secretary to the Government of India – the highest bureaucratic office in the system.[627] The accelerator group at TIFR was usually overshadowed by Bhabha's energy research agenda and became an experimenting ground reflecting the shifting fortunes of Indian nuclear research nationally and internationally.

Research agenda's of the AECI and TIFR were often conflated well into the early 1950s. Several ad-hoc attempts at separating the two had been insisted upon, the thumb rule being one of priority for AECI research. This conflation had been a result of Bhabha's dual position as a science administrator *of a state program* and leader of a research institution. These were not two institutions with a history of well-defined mandates and structures, which Bhabha had come to lead. The TIFR was established in 1945, and the AECI between 1946 and 1948. Additionally, there were no state organisations to take over administration of nuclear research (but for the CSIR), but the scale of the technology, the budget and the significance of the agenda made AECI research exceptional. It was shaped in the collective deliberations of Bhatnagar, Raman, Saha, Bhabha, and Nehru in the late 1940s. The two entirely new institutions were shaped in Bhabha's engagement, and as such, the conflation lay in his person and not in given institutional mandates. The AECI required research groups focused upon *problems* of nuclear technology and when TIFR was declared as the CSIR laboratory for nuclear research, it could have developed an agenda of applied and industrial research. It did not. Experimental nuclear physics at the TIFR was first caught in the tension between

[627] I do not wish to say, "Bhabha created the position" as an unproblematic suggestion. The process of creating this position requires its own attention, but is beyond the scope of this chapter.

Bhabha’s ambitions and pragmatism in cosmic ray research (1945-1953). Then it was caught between, on the one hand AECI’s priority of reactor building and on the other, fusion research. Precisely because of the scale of nuclear research, a point driven home rather painfully to both Saha and Raman, if the TIFR was to remain an institution of fundamental research in nuclear physics, then the AECI had to have its own research establishment. That was accomplished in the marginalisation of experimental nuclear physics at the TIFR.

CHAPTER 6: CONCLUSION

> "They don't burn their dead in the West. They're not an ignorant people. They're advanced, they're educated, they have science, they have guns and tanks and bombs. […] We have them too! I shouted back. […] So there we were, the imam and I, delegates from two superseded civilisations vying with each other to lay claim on the violence of the West. […] He had had to say to me. "You ought not to do this because otherwise you will not have guns and tanks and bombs."[628]
>
> Amitav Ghosh (2005: p. 296-297)

During the processes of decolonisation, powerful sections of the nationalist leadership of India had come to believe that not having science had serious consequences for the exercise of sovereignty on the Indian sub-continent. The extract above is from Amitav Ghosh's essay, "The Imam and the Indian" about his anthropological fieldwork in an Egyptian village. The Imam was apprehensive of Ghosh's conversations with the local Arab villagers, and questioned his authority to understand and interpret local history and culture. The tensions between them resulted in a heated debate. In the last instance the Imam argued that in the West of science and guns and tanks and bombs, they bury their dead – and when one is like the West, the dead must not be burnt. The pervasive righteousness of the need to "be like the West" is frightening, but Ghosh's response is even more startling. "We have them too". This thought clutters the imagination of independent Indians, particularly of those bothered by "the authority of the West" and by "bombs". It bothers even more those pervious to critical self-reflection like Amitav Ghosh. Ghosh was not exactly proud of his outburst and wrote an essay expressing the

[628] Amitav Ghosh The Imam and the Indian *Granta* No. 20, London: Granta Books, reprinted in *Incendiary Circumstances: A Chronicle of the Turmoil of our Times* (Boston: Houghton Mifflin Company, 2005), 287-298.

tension many others share.[629] A moral critique is not adequate to opine on the nuclear aspirations of India. Understanding the nuclear question in India is not easy. I have not offered a historical justification of India's nuclear aspirations. I have taken seriously the aspirations, actions, and ambitions of my actors. In doing so, I have tried to show that decisions were arrived at by conjecture, informed by interests not of state formation alone. But the state was realised in the collective actions of political leadership, science administrators as well as scientists in the laboratory, and their laboratories as well as nuclear physics education in India were affected by and continually redefined in a shifting local and international context.

This thesis has examined the establishment, transformation, maintenance and extension of nuclear physics as a research field in mid-twentieth century India, prior to and after the use of nuclear weapons at the end of WWII. The establishment of nuclear physics in India in the late 1930s and early 1940s was hardly an exceptional episode in the history of physics; it was a professionally desirable reorientation of the discipline. However, Hiroshima and Nagasaki recast the significance of nuclear research globally, and its coincidence with the formal decolonisation of India proved decisive for the organisation of post-war scientific research in India. Research in nuclear physics was eventually conducted in a decreasing number of research laboratories, fundamental research conducted in even fewer laboratories, all with an increasing scale of research expenditure.

[629] Ghosh wrote another long essay after Indian nuclear tests in 1998 exploring precisely this tension in conversations with "hundreds of people in India, Pakistan and Nepal". See Amitav Ghosh, "Countdown" Ghosh (2005), 77-102.

The institutionalisation of physics research in India was removed from the core of colonial rule, and was patronised by nationalists and philanthropists. Physics practice thus came to be deeply embedded in a nationalist discourse of intellectual accomplishment and progress. Other fields of applied scientific research that perhaps could have been more compatible with advancement of "material progress" of India remained more or less engaged with the colonial state. Undoubtedly many Indians participated in research in medicine, zoology, metrology, geology, and agriculture, but laying *author*itative claim upon those sciences was far more difficult given their inextricability from the colonial state. Mathematics, physics and chemistry provided those opportunities to its Indian practitioners, and the physics community emerged among the strongest in the first half of the twentieth century. Indian physicists were drawn to nuclear physics as a modernist imperative, the exciting frontier of their discipline by the early 1930s. They continued to enjoy support from nationalists, and philanthropists both in India and abroad.

At the same time though, as the chapters in this thesis show, it is unjustifiably reductionist to claim that scientific practice in India continued to be informed predominantly by nationalist politics in the mid-twentieth century. Recent histories of science in India have commented on the political and cultural authority of science, and modernity. I have decentred the discussion on "authority" (without losing sight of it) and instead written about the material culture of science, of the establishment and practice of a research field in India. In doing so, I wanted to historicise physics practice in mid-twentieth century India, which can also contribute an understanding of the changing nature and meanings of the authority of science, but even more so, how it came to be configured specifically for a particular group of *practitioners of science.*

The outbreak of WWII led to significant changes in the structure and immediate interests of the colonial state. For the first, Britain required nationalist political leadership in India to support the war, especially after the Japanese occupation of Burma, when a politically stable climate in British India was most desirable. Not any less important were technical and industrial requirements for an effective South East Asia Command. A doubly appreciative gaze fell upon the physical scientists and industrial researchers in India – they were a part of the nationalist bourgeoisie whose appeasement was considered important, and they comprised the scientific and technical elite that could best serve war efforts. Archibald Vivian Hill's to India was testimony to this changed perception, and those that gained prominence in this period became a part and parcel of the reliable bureaucratic structures of government that were retained in free India. As the director of scientific and industrial researches for war purposes, Shanti Swarup Bhatnagar was the most powerful science administrator in wartime India. He remained so in free India until his death in 1955.

The end of war enhanced the wartime prestige and importance attached to the knowledge possessed by physicists and physical chemists. Peter Galison has argued that the increased scale of physics research after the war "has required scientists to align their activities with broader elements of society".[630] The pursuit of scientific research in India

[630] Peter Galison and Bruce Hevly, eds. *Big Science: The Growth of Large Scale Research* (Stanford: Stanford University Press, 1992), 2.

had always been a part of projects larger than the laboratory, be it in the support of colonial rule or perceived as accomplishment of national culture. Wartime scientific and industrial research, marginal as it may have been in comparison with the Allied scientific war-effort, had allowed for the first coordinated experiment in "scientific industrialism" on a "national-scale" in India. With independence, all of these processes converged as a part of the realisation of an Indian national-state. State-funded scientific research in colonial establishments, research supported by nationalists and philanthropists, as well as scientific and industrial research organisation for war effort became necessary facets of infrastructure in which India became real. The CSIR was the only coordinating institution of scientific and industrial research at war's end, and nuclear research appeared imperative for both development (as an energy source) and security reasons. Given that there were "relatively few powerful state organisations for the pursuit of science" individuals were left with a great deal of autonomy to organise post-war research.[631] The agenda for nuclear research became a collaborative pursuit of political leadership, especially Jawaharlal Nehru, the CSIR, especially Bhatnagar, the Tata Industrial House and the small nuclear research community, and in the process co-produced an almost autonomous nuclear field in free India.

Eventually, the process came to be perceived as inevitable. Speaking in 1957, Nehru argued, "In any event whether we like it or not, it is quite inevitable that we do it, just as it became inevitable when the Industrial Revolution came to the world ... Either you go

[631] Galison and Hevly, (1993), 5. John Krige and Dominique Pestre have argued this in the case of CERN, which also applies equally well in the Indian case, where even the state itself was not quite established. Their other argument, that unlike accelerator laboratories in the US, CERN did not "grow out of a long and continuous national tradition of scientific or scientific military concerns" is also true in the Indian case.

ahead with it, or you succumb and others go ahead … that of course is not good enough… Now we have these mysteries which these high priests of science flourish before us, not only flourish but threaten us with, and at any rate make us either full of wonder of full of fear…"[632] Recent studies have plotted the beginnings of nuclear research in India within this unproblematic assumption even for the beginnings of nuclear research in India. But as my study shows, nuclear research began as modernist imperative in physics research and had to be credibly transformed, justified and tenuously extended after 1945.

The process of concentrating resources for nuclear research in a central facility was necessarily also one of co-option, marginalisation and dispossession of competing facilities. In an attempt to arrive at characteristics of big-science, Bruce Hevly has argued, "Big science has come about through not just an increase in resources devoted to scientific research, but also through the increasing concentration of resources into a decreasing number of research centres, and the dedication of these special facilities to specific goals".[633] University laboratories in India, as elsewhere, were most disadvantaged in this process.[634] The competition between the various laboratories was

[632] Jawaharlal Nehru, "Significance of the Atomic Revolution" Speech at the Opening Ceremony of the Atomic Energy Establishment and naming of the first reactor, Apsara, January 20, 1957. Reprinted in *Nuclear India* 26, no. 10, (1989): 25.

[633] Galison and Hevly, (1993), 356.

[634] The AECI policy on low energy particle accelerators in university laboratory was also gradually relaxed after 1955. The first beneficiary was the Aligarh Muslim University, where Piara Singh Gill, (an experimental cosmic ray physicist who had left the TIFR in 1948), supervised the assembly of a 150 KV Cockcroft Walton machine. The builders were C. S. Khurana and H. S. Hans, of whom Hans was at the Bartol Foundation Research Centre, Philadelphia, where he gained experience with particle accelerators. See C. S. Khurana and H. S. Hans, "150 KV Cockcroft-Walton Type Particle Accelerator" *Indian Journal of Physics* 32, no. 10 (October 1958): 468-472.

locally configured but not in any way unique. As seen in the case of the Palit Laboratory, University of Science College, Calcutta, Meghnad Saha and his students had begun the construction of a cyclotron in a garage and even if the funding prospects only improved, the idea of comprehensive provision for nuclear research could never be fulfilled by the humble and later, but only in comparison, reduced circumstances. Given also the increasingly goal oriented and specialised nature of nuclear research technology in the post-war years, it was far from easy to determine exactly what the mission of a university laboratory might be within the nuclear field. University departments of physics and their laboratories have historically held the responsibility for maintaining heterogeneity of teaching programs, and training students for furthering the discipline, and production of knowledge. If nuclear research were to be continued in a university laboratory, there was a danger of it subsuming this larger goal of advanced education and training in basic research methods. Scaled up budgets would draw the university laboratory into a relationship of accountability to its sponsors – could individual university laboratories then maintain partial autonomy? These concerns were important for Meghnad Saha, and his response was one of transforming the Palit Laboratory into an independent Institute for Nuclear Physics in 1948. His goal was to strengthen the new institute as the central and comprehensive facility for nuclear research in India.

C. V. Raman's efforts at establishing nuclear physics at the Indian Institute of Science, Bangalore, could have potentially begun better. The Indian Institute of Science, Bangalore, was an institution built around applied and industrial research, and was funded by the Tata Industrial House. Raman had established the department of physics with far less teaching responsibilities than Saha's university department and laboratory. IISc catered to advanced training and research, and the department of physics was organised primarily around Raman's researches. As such then, the question was one of establishment of another research unit within the department and that again would not have been without precedent. Homi Jehangir Bhabha was allowed his own Cosmic Ray Unit at the department between 1940-1944. But the same arguments that applied to Saha's university department were mobilised to dispossess Bangalore not only of resources but the mandate to establish nuclear physics, as it were, outside of state policy on nuclear research. Given that R. S. Krishnan was the only experienced nuclear researcher at the IISc, Bhatnagar and soon Bhabha, and the Tata Trusts arrived at the conclusion that it was far better for Krishnan to work at another location, more specifically at the Tata Institute of Fundamental Research, Bombay, the centralised laboratory for nuclear research supported by the CSIR.

The Tata Institute of Fundamental Research, Bombay, (TIFR) was established largely by the efforts of Homi Jehangir Bhabha, as an independent research institute specifically mandated for nuclear research towards the end of the war. Meghnad Saha's efforts in Calcutta were continually supported, even if marginalised on the national scale, because they began work before 1945. Bhabha's new institute did not confront similar problems of transformation, and in 1945, was completely open to being shaped by the changed scale of nuclear research, his scientific ambitions and the interests of the national-state. Even if Bhabha promised close collaboration with the universities, his institution was born free of teaching responsibilities. Bhabha's connection to the Tata family, favour with A. V. Hill, Shanti Swarup Bhatnagar, and later with Jawaharlal Nehru, and finally, his interest in nuclear physics arising from his own scientific research in cosmic ray physics, all contributed to the nomination of the TIFR as the national laboratory for nuclear research. But most decisive among them was the national-statist ambition: By 1948, the Institute of Nuclear Physics' with its roots in the university appeared "local and petty". Nehru was unable and unwilling to make a distinction between the wartime and peacetime uses of nuclear energy. He was not the only one.

I have not written the thesis as a teleological narrative of the realisation of the Indian nation-state in nuclear research, as if it could not have been otherwise. I have tried instead, in each story, to show the stakes involved for doing scientific research within the contingencies and conjectures of the struggle to realise India. Four men stand out as entrepreneurs of nuclear research in India: Chandrasekhara Venkata Raman, Meghnad Saha, Homi Jehangir Bhabha and Shanti Swarup Bhatnagar. Their prominence is reflective of the sources available for research. However, the inclusion of C. V. Raman, S. S. Bhatnagar, but even more so, of the Institute of Nuclear Physics, Calcutta and Meghnad Saha in the same analytic frame, is corrective of the histories of nuclear research in India written thus far. These men were an elite coterie of scientists, scientific statesmen and science-administrators, and their choices proved decisive for how scientific research came to be organised in free India. Hevly has claimed that big science introduces "sponsor relationships" as a part of the "intellectual and social context of big science … influence[ing] plans for further research", but this was hardly a new experience.[635] Their main political support came from princely states, the nationalist bourgeoisie, and later Jawaharlal Nehru and other Nehruvians; they benefited from industrial support otherwise, but their main industrial sponsor, in all cases, was the Tata Industrial House (not unlike the Siemens philanthropy at the turn of the century in Germany). Bhatnagar and Bhabha embodied power and policy – relying upon the bureaucratic state, Saha embraced nationalist politics and Raman struck a posture of aloofness and detachment from all of them. Together they represented a widely shared conception of the place of science in free India.

The stories in this thesis are empirically focused upon particle accelerator building activities in the three facilities. Particle accelerators were not always considered the most necessary equipment for nuclear physics research in all three cases, and their status in the three laboratories was not exactly the same. In Calcutta, members of the Palit Laboratory were hardly ever focused entirely upon research or even construction of the cyclotron, even if it became pivotal for funding and training purposes, and eventually the centrepiece of the Institute of Nuclear Physics. The particle accelerator was planned to become the central apparatus in the case of Bangalore, but it is hard to tell how things would have configured had the plans proceeded. In Bombay, (after a false start in 1946) the preference for cosmic rays allowed Bhabha to resist, or better still, cautiously proceed with building or acquiring particle accelerators up until 1951-52. Even after that, the continuing entanglement with AECI's research agenda (research reactors and therefore nuclear engineering, and later fusion) only overshadowed the work as well as the building

[635] Galison and Hevly, (1993), 359.

activities of the particle accelerator groups. Particle accelerator builders in Bombay were marginal to the institutes' activities even in comparison with those in Calcutta. The Calcutta builders conducted research and obtained degrees using other equipment in the laboratory, and were always hopeful of becoming users of the cyclotron eventually. In Bombay, the goals of the AECI were always overwhelming and provided other opportunities for members to transcend the research laboratory into far bigger projects, of course, of national importance.

Building accelerators and establishing experimental nuclear research facilities in India was not an easy accomplishment, even when patronised by the state or industry. There was always the anticipation of achievement given the way in which science was embedded in Indian society. Masters of their own destiny now, the scientific community was expected to deliver useful applications of their intellectual possessions. In Bhabha's judgement, sound experimental techniques were the forte of experimentalists, and as a theoretician, even though with some engineering and experimental experience, he thought nuclear research in India would be better served by getting the best experimental physicists and technicians to train Indian students. In Saha's perspective, the real bottlenecks were the lack of industrial support, lack of training facilities in India and prolonged bureaucratic procedure to get any thing done. Experience proved them both right.

Post-war international politics also came into play with Indian independence for two reasons. The United States and the Soviet Union appeared as world leaders, and the ensuing Cold War presented new choices, new politics and new dilemmas. This newness also compounded with Indian independence, which allowed Indian political and scientific leaders to participate in international politics and science, as a nation-state. This is not to say that Indian science or politics had no ties or connections with the two powers prior to WWII, but the framework of interactions was recast following the crystallisation of the Cold War and Indian independence both. A variety of British interests in the shaping of science research in India were also alive. Patrick Blackett and Mark Oliphant formally advised on nuclear research agenda, while John Desmond Bernal, John D. Cockcroft, John Burton Haldane and A. V. Hill continued to advise more informally on scientific research in free India. Impressed with the French accomplishments in nuclear research and technology, without Anglo-American help or support, Nehru, Bhatnagar and Bhabha also consulted Frederic Joliot Curie.

The scenario began to change considerably in the 1950s. American reluctance to export nuclear research equipment had its impact on both the Calcutta and the Bombay laboratories in the late 1940s. Triggered by the Korean War (1950) and sealed by the Suez Crisis (1956), the US began to perceive an active engagement with the third world as imperative to make the world “safe for democracy”. The gradual stabilising of Western European economies and scientific enterprise, and the Marshall Plan behind them, scientific and technical assistance to the third world became a concern for the US most decisively after 1955. President Eisenhower’s *Atoms for Peace* address in 1953 paved a way out of the “fearful atomic dilemma” dominated by what he called “the military industrial complex”. Scientific and technical assistance became one more weapon in the

Cold War arsenal. After reluctantly supporting the decolonisation of European colonies in Asia and Africa, it became important to make them allies in the struggle against the "godless empire" of the Soviet Union. One outcome was the *Atoms for Peace* meeting in Geneva of August 1955, chaired Homi Jehangir Bhabha. Bhabha's increased political stature, and Bhatnagar's death considerably enhanced his powers as science administrator, and marked the beginnings of a more material and visible American engagement also with particle accelerators for nuclear research in India.

Periodisation of nuclear research in India is remarkably difficult when seen this way. One can place its beginnings roughly around 1938. The first significant change came in 1945 when the research field was entirely recast, irrespective of the scale or nature of the researchers' involvement. The second important change came in July 1947 with the discontinuation of efforts to establish nuclear physics in Bangalore. Even if the AERC was established in 1946 and the AECI in 1948, decision upon the Bangalore facility marks a clearly decisive moment when concentration as a policy decision was arrived at collectively – even if motivated by different reasons or even contested. The third important change came in 1955 with the *Atoms for Peace* meeting in Geneva, when the researchers from Calcutta could no longer claim to represent an Indian delegation and the AECI emerged as the strongest representative of nuclear research in India. The nationalisation and bureaucratisation of nuclear research had been accomplished, with varying effects upon its practitioners in the laboratory.

Figure 6.1: (From Left) Jawaharlal Nehru, Homi Jehangir Bhabha and Jehangir Rustom Dorab Tata at the Tata Institute of Fundamental Research. Ca. 1955. Reproduced with permission from the Tata Institute of Fundamental Research Archives, Bombay.

This thesis has described how certain members of the nationalist bourgeoisie in India - political leaders and scientists - with varying ambitions, capital and skills came to shape the field of nuclear research and in the process realise the Indian national-state. The thesis also brings in the stories of others that were not necessarily motivated by the same sense of purpose, but nonetheless involved in the realisation of these projects and contributed to the eventual accomplishment of nationalisation and bureaucratisation of nuclear research, or one may dare say, scientific and industrial research in India.

CODA

On August 3, 1964, Homi J. Bhabha called for a two-day meeting to discuss the "need for a medium energy accelerator" in the country. Twenty-nine scientists drawn from the Tata Institute of Nuclear Physics, the Saha Institute of Nuclear Physics and the Atomic Energy Establishment Trombay attended the meeting.[636] Bhabha prefaced the meeting with comments on the achievements of the cosmic ray group at the TIFR. In the field of elementary particle physics, he argued, given the costs of a high-energy machine, combined with the accessibility of such machines for Indian researchers at CERN, Dubna and Brookhaven, and the continuing research in cosmic ray physics, the AECI would like to support the establishment of a medium energy particle accelerator facility in India.

A committee had already been appointed to review this question in 1962, and Raja Ramanna read their recommendations: the choice was "only between two types of accelerators, the tandem machine and an AVF (azimuthally varying field) cyclotron". A discussion ensued on the budgets in comparison with the research agenda possible with the two machines proposed. The tandem Van de Graaff machine could be bought from the High Voltage Energy Corporation, Burlington, USA, and the estimates for the AVF cyclotron were taken from one assembled at the University of Maryland, College Park, USA. The purchase of a tandem machine was not complicated, and the expenses could be

[636] The Institute of Nuclear Physics in Calcutta had been renamed Saha Institute of Nuclear Physics after Saha's death in 1956. Attendees were: H. J. Bhabha, R. Ramanna, A. S. Rao, N. Sarma, S. S. Kapoor, C. L. Rao, M. K. Mehta, (all AEET); M. G. K. Menon, B. V. Thosar, D. Y. Phadke, S. S. Dharmatti, D. Lal, E. Kondaiah, S. K. Bhattacharjee, M. C. Joshi, K. K. Gupta, B. Banerjee, R. V. S. Sitaram, C. Badrinathan, H. G. Devare (all TIFR); and B. D. Nagchoudhuri, D. N. Kundu, A. K. Saha, M. K. Banerjee, P. Mukherjee, A. P. Patro, H. K. Basu, A. K. Chatterjee, and M. K. Pal (all SINP). "*Minutes of a meeting held on August 3 1964 on the need for a medium energy accelerator*," D-2004-00832, TIFR Archives

reduced with fabrication of some parts locally. The cyclotron was not an easy proposal. Development work on the AVF cyclotron, designed after a similar one at the Lawrence Research Laboratory, Berkeley, could be contracted to William Brobeck and Associates. "Technical staff in India may not be able to handle the detailed design of the cyclotron and beam handling system, but will determine all important design specifications and retain authority of major decisions."[637] The Committee had estimated that construction on both machines would take approximately four years, with an additional six to eight months for precision beam analysis systems for the cyclotron.

B. V. Thosar of the TIFR argued that the AECI should support both the recommended machines. There was a good deal of work to be accomplished with medium energy particle accelerators and a reliable tandem Van de Graaff machine was desirable for these purposes. "It would supply the immediate needs of workers in nuclear structure and would give meaning to their previous work as well as open opportunities for more important research in the future". On the other hand, given the scope of conceptual work to be achieved in fission physics, spallation studies, production of neutron isotopes and reaction mechanisms, an AVF cyclotron was a worthwhile investment in the long term for producing new results. Construction of a cyclotron "would also promote accessory technological development".[638]

---

[637] *Minutes…* (1964): 18. The first sentence read, "The AEET Staff cannot handle the detailed designs of the cyclotron … which was replaced and typed over with "Technical staff in India".

[638] *Minutes…* (1964): 20.

M. G. K. Menon supported the need to strengthen nuclear physics research in the country but was not supportive of two machines at the same time. He was in favour of buying a tandem machine and willing to consider construction of the cyclotron later. Menon admired the three strong groups in experimental nuclear physics at the TIFR, SINP and AEET, and thought should be provided with medium energy particle accelerators failing which their research would become 'very pedestrian as in ordinary college laboratories and not worthy of large national institutions".[639] Scholarships, fellowships and research funding in India and abroad had generated a significant pool of nuclear scientists in India, he further argued, and unless more and better facilities were offered, they would leave the country for laboratories abroad. Menon also emphasised that the machines available had been well utilised for training and research even when small machines in other laboratories in the USA and Europe were now lying idle. The projected budget for accelerator research in the USA for the next five years, he noted was almost twenty times the budget proposed by the committee.

Bhabha had the last word. "I am fully convinced that we should go in for both these machines in the interest of nuclear research in India".[640] He was convinced the two machines were in fact complimentary. The tandem could be bought, and located where there was already similar work going on, i.e. around the TIFR and the AEET. But the technology of cyclotrons he felt was "neglected in India except for the cyclotron in Calcutta". This field, he proposed, needed to be developed, and therefore favoured the

---

[639] *Minutes…* (1964): 21.

[640] *Minutes…* (1964): 24.

construction of a cyclotron with American expertise and help. A provision for the establishment of an "interuniversity centre" for particle accelerator research was already under consideration, and the cyclotron facility would be established around a university setting, perhaps near Calcutta. "It involves a project too big to put in any one university but fundamental research of an educational nature which involves research should be done in the universities where students from various universities can participate. In that sense, I think I used the word Interuniversity Centre".[641]

This was the first meeting to consider particle accelerator research in "national interest", and a research facility for university staff and students was considered seriously. A national policy was thus outlined. Given varied interests of the Cold War and Nehru and Bhabha's "global activism", Indian researchers had access to CERN, Brookhaven and Dubna. Bhabha died in less than two years after the meeting but the plans with the two proposed facilities proceeded. The AEET and TIFR acquired a tandem Van de Graff machine, and the plans to construct a variable energy cyclotron facility in Calcutta proceeded with help from USAID and the Lawrence Radiation Laboratory, Berkeley. Efforts in Calcutta had finally paid off – they were considered capable of developing cyclotron technology, and while the nuclear physics researchers at the AEET and TIFR were going to continue their research, the accelerator builders would be found other activities, some of them prominent, others not. The facilities were both under Department of Atomic Energy (DAE) control, after which, the program for accelerator-based research

---

[641] *Minutes…* (1964): 24.

in India has only expanded. The permission for an interuniversity centre, outside the control of the DAE was finally given to the University Grants Commission in 1984.

APPENDIX A: LIST OF SOURCES

When I began research on my thesis, I wanted to study of four particle accelerator facilities in India (Saha Institute of Nuclear Physics, Calcutta; Tata Institute of Nuclear Physics, Bombay; Department of Physics, Panjab University, Chandigarh; and Indian Institute of Technology, Kanpur) spanning the period between 1938 and 1970. One important reason for choosing several facilities and a relatively extensive period was my apprehension about finding enough archival documentation. Given that it had proved difficult to find institutional archives for nuclear research in India during my summer trips to India in 2001 and 2002, I had proposed to shape "my own archive" and conduct research in archival material into collections not of obvious relevance to laboratory research in India. Two unforeseen opportunities proved significant: The Tata Institute of Fundamental Research (TIFR), Bombay (Mumbai), officially opened its archives to researchers in October 2005. Around the same time, I met the physicist R. S. Krishnan's son, R. K. Ramanathan in Bangalore. Ramanathan generously gave me time and shared R. S. Krishnan's private papers from the family's collection. These have proved of immense relevance and value to my thesis. As a result, my thesis is based on archival documents, some of which have never been seen or available for review before and others that have not been examined for Indian history.

In the end, this thesis is based upon research at several collections in India, Australia, Europe and the USA. Some of the research, especially into material dating beyond 1959, has not made into the thesis at all. The extent to which different collections have contributed to my research varies significantly, as is the extent to which I have actively employed the documents in my writing. The range is as far wide as one single letter document (Henry D. Smyth Papers) to the entire available collection (R. S. Krishnan Papers). The resulting narratives are by no means even: the Ernest Lawrence Papers and Saha Papers have allowed me to reconstruct to some extent Nag's role in establishing the Calcutta facility and similarly, Raman Papers and more so Krishnan Papers have been useful to understand Krishnan's role in Bangalore. This is not the case for Bombay. If the narrative appears less involved with the story of the accelerator builder groups, than it does with Bhabha's perspective on where the groups belonged, it is largely a function of sources. Personal papers for the builder groups are not archived and an oral history project involving some of them has only been just taken up at the TIFR archives.

My thesis is based upon research at the following archives and collections. I will not claim to have exhausted all possible sources, but that I have searched thoroughly those I became aware of in the last four years.

Institutional Archives

1. Archives and Library, Bose Institute, Calcutta, India
2. Archives of the Indian Institute of Science, Bangalore, India
3. Archives of the Raman Research Institute, Bangalore, India
4. Archives of the Saha Institute of Nuclear Physics, Calcutta, India
5. Archives of the Tata Institute of Fundamental Research, Bombay, India
6. India Office Library and Oriental Collections, British Library, London, UK
7. Cambridge University Archives (Gratuiti, BOGS) Cambridge, UK
8. Royal Society Archives, London, UK

9. Archival Collection and Library, American Institute of Physics, College Park, Maryland, USA
10. South Asia Collections, National Archives and Records Administration, College Park Maryland, USA
11. Carnegie Corporation of New York Records, Rare Book and Manuscript Library, Columbia University, New York, USA
12. Kanpur Indo-American Programme Papers, Caltech Archives, Pasadena, California, USA
13. Kanpur Indo-American Programme Papers, MIT Archives and Special Collections, Cambridge, MA, USA

Collections

1. Bernal [John Desmond] Papers, Cambridge University Library, Cambridge, UK
2. Bhatnagar [Shanti Swarup] Papers, National Archives of India, New Delhi, India
3. Blackett [Patrick Maynard Stuart] Papers, Royal Society Archives, London
4. Bohr [Niels] Papers, Niels Bohr Archives, Copenhagen, Denmark
5. Cavendish Laboratory Papers, Cambridge University Library, UK
6. Chadwick [James] Papers, Churchill College Archives, Cambridge, UK
7. Cockcroft [John D.] Papers, Churchill College Archives, Cambridge, UK
8. Compton [Arthur Holly] Papers, University of Washington, Saint Louis, USA
9. Feather [Norman] Papers, Churchill College Archives, Cambridge, UK
10. Hill [Archibald Vivian] Papers, Churchill College Archives, Cambridge, UK
11. Joliot-Curie [Frederic] Papers, Curie Archives, Paris, France
12. Kothari [Daulat Singh] Papers, Nehru Memorial Museum and Library, New Delhi, India
13. Lawrence [Ernest Orlando] Papers, Bancroft Library and Special Collections, Berkeley, California, USA
14. Millikan [Robert] Papers, Caltech Archives, Pasadena, USA
15. Moyer, [Burton J.] Papers, Bancroft Library and Special Collections, Berkeley, California, USA
16. Neher [Victor] Papers, Caltech Archives, Pasadena, California, USA
17. Oliphant [Marcus L. E.] Papers, University of Adelaide Library and Special Collections, Australia

18. Oppenheimer [Frank] Papers, Bancroft Library and Special Collections, Berkeley, California, USA
19. Peters [Bernard] Papers, Niels Bohr Archives, Copenhagen, Denmark
20. Philips International B.V. Company Archives, Eindhoven, The Netherlands
21. Russell [Henry Norris] Papers, Princeton University, USA
22. Rutherford [Ernest] Papers, Cambridge University Library, UK
23. Saha [Meghnad] Papers, Nehru Memorial Museum and Library, New Delhi, India
24. Saha [Meghnad] Papers, Saha Institute of Nuclear Physics, Calcutta, India
25. Sahni, [Birbal] Papers, Nehru Memorial Museum and Library, New Delhi, India
26. Smyth [Henry] Papers, American Philosophical Society Special Collections, USA
27. Strauss [Lewis] Papers, Hoover Presidential Library and Archives, Iowa City, USA
28. Weaver [Warren] Papers, Rockefeller Foundation Archives, New York, USA

Personal Collections

1. Enakshi Chatterjee and late Santimay Chatterjee, Calcutta, India
2. Lakshman Singh Kothari, (Retired), Department of Physics, University of Delhi, India
3. R. K. Ramanathan, Bangalore, India
4. Ashok Sahni, Professor Emeritus, Panjab University, Chandigarh, India
5. Ravi Shukla, Jawaharlal Nehru University, New Delhi, India
6. Rajinder Singh, Carl von Ozzietsky University, Oldenburg, Germany
7. David DeVorkin, Air and Space Museum of the Smithsonian Institution, Washington DC, USA

Interviews

1. Badrinath, C. (Retired) Tata Institute of Fundamental Research, Bombay
2. Banerjee, Bindu Madhab (Retired) Cyclotron Division, Saha Institute of Nuclear Physics, Calcutta
3. Bhagwat, Pramod Pelletron Division, Tata Institute of Fundamental Research, Bombay

4. Bhattacharya, R. L. (Retired) Department of Physics, University Science College, Calcutta
5. Hans, H. S., (Retired), Department of Physics, Panjab University, Chandigarh
6. Iyengar P.K. (Retired) Chairman, Bhabha Atomic Research Centre, Bombay
7. Kailas, S. Director, Nuclear Physics Division, Bhabha Atomic Research Centre, Bombay
8. Kapoor, S. S. Nuclear Physics Division, Bhabha Atomic Research Centre, Bombay
9. Kothari, Laskhman Singh (Retired) Department of Physics, University of Delhi
10. Mehta, G. K. Professor Emeritus, Nuclear Science Centre (Inter University Accelerator Centre), New Delhi
11. Menon, M. G. K. (Retired) Director, Tata Institute of Fundamental Research, Bombay
12. Mukherjee, P. (Retired) Saha Institute of Nuclear Physics, Calcutta
13. Mukhopadhyaya, Atri. (Retired) Saha Institute of Nuclear Physics, Calcutta
14. Pal, Manoj Kumar. (Retired) Director, Saha Institute of Nuclear Physics, Calcutta
15. Parthasarathi, Ashok. (Retired) Secretary to the Government of India, Department of Electronics, New Delhi and Professor in Science Policy Studies, Jawaharlal Nehru University, New Delhi
16. Peters, Hannah and Susanna. Copenhagen, Denmark
17. Raheja, C. (Retired) Tata Institute of Fundamental Research, Bombay
18. Ramamurthy, V. S. Secretary to the Government of India, Department of Science and Technology, New Delhi
19. Ramanathan, R. K. Bangalore
20. Singh, Virendra. Physics Division, Bhabha Atomic Research Centre, Bombay

Correspondence

1. Baba, C.V. K. (Retired) Tata Institute of Fundamental Research, Bombay
2. Badrinath, C. (Retired) Tata Institute of Fundamental Research, Bombay
3. Bhave, S. S. (Retired) Tata Institute of Fundamental Research, Bombay
4. Lal, Devendra. Scripps Institute for Oceanography, La Jolla, California, USA
5. Mehta, M. K. (Retired) Bhabha Atomic Research Centre, Bombay
6. Thatte, A. P. (Retired) Tata Institute of Fundamental Research, Bombay

REFERENCES

Published Primary Sources

Awbery, J. H. *International Conference on Physics, London 1934: A Joint Conference Organized by The International Union of Pure and Applied Physics and the Physical Society: Papers & Discussions* London: The Physical Society, 1935.

Bhabha, Homi J. "Science and the Problems Of Development" *Science* 51, No. 3710 (1966): 541-548.

Bhabha, Homi J. *Electronics in India* [*Report*], Bombay: Electronics Committee, Government Of India, February 1966.

Bhabha, H.J. and W. Heitler, "Passage of Fast Electrons through Matter" *Nature*, 138, (1936): 401.

Bhabha, H.J. and W. Heitler, "The Passage of Fast Electrons and the Theory of Cosmic Showers" *Proceedings of the Royal Society* A, 159, (1937): 432-458

Chatterjee, Santimay and Meghnad Saha. *Collected Works of Meghnad Saha* Calcutta: Saha Institute of Nuclear Physics/Bombay: Orient Longman (Four Volumes), 1982.

George, Divatia, Mehta, Bhave, Deshpande, Ram and T G Varghese (1959) The TIFR Van de Graaff Accelerator *Proceedings of the Indian Academy of Science* Vol. L (A), p. 175

Hill, Archibald Vivian. *Scientific Research In India* London: Royal Society, 1945.

Hill, Archibald Vivian. *India: Scientific Development or Disaster* London: India-Burma Association, 1944.

James, W. O. "Review of Life Movements in Plants, Sir J. C. Bose and Others" [Transactions of the Bose Research Institute, Vol. VI, London: Longmans Green and Co] *New Phytologist* 30:2 (1931): 142-144.

Krishnan, R. S. "Atomic Energy" *Current Science*, 14, August 1945, 185-187.

Prashad, Baini. *The Progress of Science in India during the Past Twenty-Five Years* Calcutta: The Indian Science Congress Association, 1938.

Rutherford, Ernest. "Researches in India And in Great Britain" reprinted in *The Shaping of Indian Science: Indian Science Congress Association Presidential Addresses, 1914-1947* Hyderabad: Universities Press, 1938: 436-437.

Saha, Meghnad. *My Experiences in Soviet Russia* Calcutta: The Bookman, 1947.

Saha, Meghnad "Progress of Physics in India During The Past Twenty-Five Years" in Baini Prashad, Ed. *The Progress of Science in India During The Past Twenty-Five Years* Calcutta: The Indian Science Congress Association, 1938.

Subramaniam, M. K. "Tata Memorial Hospital for the Treatment of Cancer and Allied Diseases" *Current Science* July1945, p. 140.

"H.E. Lord Wavell on Indian Science" *Current Science* 1, January 1944.

Editorial. "Scientific Awakening" *Current Science* 14, No. 3, March 1945.

"Visit to India by The Biological Secretary" *Notes And Records of The Royal Society of London* 4, No.1, April 1946, 63-64

"The Indian Science Congress –Delhi Meeting, 1-8 January 1947" *Notes And Records of The Royal Society of London,* Vol. 5, No.1, October 1947

Official Publications

Government Of India

Scientific Policy Resolution [Reprint] New Delhi: Department of Science and Technology, Government of India, 1958.

Department of Science And Technology. *Directory of Accelerator Facilities In India* New Delhi: Department of Science And Technology, Government of India, 1986.

United States Government

National Research Council, USA. *Final Report of The Equipment Needs of the Scientific Research Institutions of the Government of India* Washington: National Research Council, Advisory Committee on International Technological Assistance [602 Pages, Map, 28cm], 1955.

Glennon, John P. *Foreign Relations of The United States, 1955-57 Volume VIII- South Asia* Washington DC: Department of State, Government of The United States of America, 1989.

United Kingdom Government

The Royal Society Empire Scientific Conference June-July 1946: Report I & II, London: The Royal Society, 1948.

British Commonwealth Scientific Official Conference 1946: Report of Proceedings London: His Majesty's Stationary Office, 1946.

Journal Archives

Science And Culture (1934-59)

Current Science (1932-1959)

Journal of Scientific and Industrial Research (1942-1959)

Science Reporter (1964, 1966)

Science Observer (1964, 1966)

Secondary Literature

Aaserud, Finn. *Redirecting Science: Niels Bohr, Philanthropy and the Rise of Nuclear Physics.* Cambridge: Cambridge University Press, 1990.

Abraham, Itty. "Rare Earths: Travancore in the Annals of the Cold War, 1945-47", Paper presented at the *Bodies, Networks, Geographies* Workshop*,* Eindhoven, April 2007.

Abraham, Itty. "The Ambivalence of Nuclear Histories" *Osiris* 21 (2006a): 49-65.

Abraham, Itty. "The Contradictory Spaces of Postcolonial Techno-Science" *Economic and Political Weekly* 21, January 2006a, 210-217.

Abraham, Itty. "Postcolonial science, Big-Science and Landscape" in Roddy Reid and Sharon Traweek, eds. *Doing Science + Culture* New York: Routledge, 2000.

Abraham, Itty. *The Making of the Indian Atomic Bomb: Science, Secrecy and the Postcolonial State* London: Zed Books, 1998.

Abraham, Itty. "Science and Secrecy in Making of Postcolonial State *Economic and Political Weekly* 32, August 1997, 2136 -2146.

Abraham, Itty. "Science and Power in the Postcolonial State" *Alternatives* 21, (1996): 321-339.

Ahmad, Aqueil, K. D. Sharma and S. P Gupta. *Foreign Assistance to Scientific Research in India: An Analysis* New Delhi: Research Survey and Planning Organisation, Council of Scientific and Industrial Research, 1966.

Alder, Kurt. *Paul Scherrer 1890-1969: Vorträge und Reden gehalten anlässlich der gedenkveranstaltung* Basel: Paul Scherrer Institut, 1990.

Allibone, T. E. and Guy Hartcup. *Cockcroft and the Atom* Bristol: Adam Hilger, 1984.

Anderson, Robert S. "Patrick Blackett in India: Military consultant and scientific intervenor", 1947-72, Part II" *Notes and Records of the Royal Society of London* 53, no. 3 (1999b): 345-359.

Anderson, Robert S. "Patrick Blackett in India: Military consultant and scientific intervenor, 1947-72, Part I" *Notes and Records of the Royal Society of London* 53, no. 3, (1999a): 253-273.

Anderson, Robert S. "Cultivating Science as Cultural Policy: A Contrast of Agricultural and Nuclear Science in India" in Lloyd I. Rudolph, ed. *Cultural Policy in India* Delhi: Chanakya Publications, 1984.

Anderson, Robert S. "The Government of Scientific Institutions: Case Studies of Two Research Laboratories in the late 1960s" *Contributions to Indian Sociology* 11, no.1, (1977): 137-168.

Anderson, Robert S. *Building scientific institutions in India: Bhabha and Saha* Montreal: Centre for Developing Area Studies, 1975.

Anderson, Warwick. Ed. "Special issue: Postcolonial Technoscience" *Social Studies of Science* 32, nos. 5-6 (2002): 643-658.

de Andrade, Ana M. Ribeiro and R. P. A. Muniz "The quest for the Brazilian synchrocyclotron" *Historical Studies in the Physical And Biological Sciences* 36, Part II (2006): 311-327.

Arnold, David. *Science, Technology and Medicine in Colonial India* The New Cambridge History of India, III, book 5, Cambridge: Cambridge University Press, 2000.

Arnold, David. "Review of Gyan Prakash, Another Reason: Science and the Imagination of Modern India" *The Journal of Imperial and Commonwealth History* 28, no. 2, (2000): 163.

Ashplant, T. G., and Adrian Wilson. "Present-centred History and the Problem of Historical Knowledge", *Historical Journal* 31 (1988): 253-274.

Austin, Granville. *Working a Democratic Constitution: The Indian Experience* New Delhi: Oxford University Press, 1999.

Baber, Zaheer. "Colonising Nature: Scientific Knowledge, Colonial Power and the Incorporation of India into the Modern World System" *British Journal of Sociology* 52, Issue 1(2001): 37-58.

Baber, Zaheer. *The Science of Empire: Scientific Knowledge, Civilisation and Colonial Rule in India* New Delhi: Oxford University Press, 1998.

Badash, Lawrence. *Kapitza, Rutherford and the Kremlin* New Haven: Yale University Press, 1985.

Badie, Bertrand. *The Imported State: The Westernisation of Political Order* [Translated by Claudia Royal] Stanford: Stanford University Press, 2000.

Balagopal, K. "Drought and TADA in Adilabad" *Economic and Political Weekly*, 24, no. 47, November 25 1989, 2587-2591.

Banner, E. H. W. "The Physical Society's Exhibition –London, 1954" *Journal of Scientific Instruments* 34, July 1954, 229-236.

Baviskar, Amita. *In the Belly of the River: Tribal Conflicts over Development in the Narmada Valley* New Delhi: Oxford University Press, 2004.

Basalla, George. "The Spread of Western Science" *Science*, 156, 5 May 1967, 611-622.

Bethe, Hans A. "The Happy Thirties" in Roger H. Stuewer, Ed. *Nuclear Physics in Retrospect* Minneapolis: University of Minnesota Press, 1979.

Bhagavan, Manu. *Sovereign Spheres: Princes, Education and Empire in Colonial India* Oxford: Oxford University Press, 2003.

Bhagavantam, S. "Professor Chandrasekhara Venkata Raman" *Biographical Memoirs of Fellows of the Royal Society London* 17 (1972): 565-579.

Benei, Veronique and Chris Fuller. *The Everyday State and Modern Society in India* London: Hurst and Co, 2001.

Bhambri, C. P. "The Administrative Elite and Political Modernisation in India *Indian Journal of Public Administration* January-March 1971: 47-64.

Bhattacharya, Mohit. "Bureaucracy and Politics in India" in Zoya Hasan, S. N. Jha and Rasheeduddin Khan, eds. *The State, Political Processes, and Identity: Reflections on Modern India* New Delhi: Sage Publications, 1989.

Bidwai, Praful and Achin Vanaik. *South Asia on a Short Fuse: Nuclear Politics and the Future of Global Disarmament* New Delhi: Oxford University Press, 1999.

Bidwai, Praful and Achin Vanaik. "A Very Political Bomb" *Bulletin of Atomic Scientists,* July-August 1998.

Blanpied, William A. "India's Scientific Development" *Pacific Affairs* 50, Issue 1 (1977): 91-99.

Blom Hansen, Thomas and Finn Stepputat, eds. *States of Imagination: Ethnographic Explorations of the Postcolonial State* Durham: Duke University Press, 2001.

Bocock, Jean, Lewis Baston, Peter Scott and David Smith. "American Influence on British Higher Education: Science, Technology, and the Problem of University Expansion, 1945-1963" *Minerva* 41 (2003): 327-346.

Bose, Debendra M., B. V. Subbarayappa and S. N. Sen, *A Concise History of Science in India* Delhi: INSA, 1970.

Bourdieu, Pierre. "Rethinking the State: Genesis and Structure of the Bureaucratic Field" *Sociological Theory*, 12, no. 1, (1994): 1-17.

Bourdieu, Pierre. "The Specificity of the Scientific Field and the Social Conditions of the Progress of Reason" *Social Science Information*, 14, no. 6 (1975): 19-47.

Brass, Paul. *The Politics of India since Independence* Cambridge: Cambridge University Press, 1990.

Bromley, D. Allan. "The Development of Electrostatic Accelerators" *Nuclear Instruments and Methods* 122, (1974): 1-34.

Brown, Andrew. *J. D. Bernal: The Sage of Science* Oxford: Oxford University Press, 2005.

Burcham, W. E. "Nuclear Physics in the United Kingdom 1911-1986" *Reports in the Progress of Physics* 52, no. 7 (1989): 823-879.

Byres, Terence. *The State and Development Planning in India* Delhi: Oxford University Press, 1994.

Cahan, David. *An Institute for an Empire: The Physikalisch-Technische Reichanstalt 1871-1918* Cambridge: Cambridge University Press, 1989.

Cahan, David. "Werner Siemens and the Origins of the Physikalisch-Technische Reichanstalt 1872-1887" *Historical Studies in the Physical and Biological Sciences* 12, II (1982): 253-283.

Capshew, James H. and Karen A. Rader. "Big Science: Price to the Present" in Arnold Thackray, ed. "Science after '40" *Osiris* 7 (1992): 3-25.

Cassidy, David C. *Uncertainty: The Life and Science of Werner Heisenberg* New York: W. H. Freeman and Company, 1992.

Cassidy, David. “Cosmic Ray Showers, High-Energy Physics, and Quantum Field Theories: Programmatic Interactions in the 1930s” *Historical Studies in the Physical Sciences* 12, I (1981): 1-40.

Chakrabarti, Pratik. *Western Science in Modern India: Metropolitan Methods, Colonial Practices* Delhi: Permanent Black, 2004.

Chakrabarty, Dipesh. *Provincialising Europe: Postcolonial Thought and Historical Difference* New Delhi: Oxford University Press, 2000.

Chatterjee, Partha. *State and Politics in India* New Delhi: Oxford University Press, 1998.

Chatterjee, Partha. *Our Modernity* Senegal: CODESRIA-SEPHIS, 1997.

Chatterjee, Partha. *The Nation and its Fragments: Colonial and Postcolonial Histories* Princeton: Princeton University Press, 1994 [1999, Partha Chatterjee Omnibus]..

Chatterjee, Partha. *Nationalist Thought and the Colonial World: A Derivative Discourse?* New Delhi: Oxford University Press, 1986 [1999, Partha Chatterjee Omnibus].

Chatterjee, Santimay “Meghnad Saha and C. V. Raman: Fact and Fiction” *Indian Physical Society Diamond Jubilee Number* (1995): 43-47.

Chatterjee, Santimay and Jyotirmoy Gupta. *Meghnad Saha in Parliament* Calcutta: Asiatic Society, 1993.

Childs, Herbert. *An American Genius: The Life of Ernest Orlando Lawrence* New York: E. P. Dutton and Co, Inc, 1968.

Clark, Norman and Ashok Parthasarathi. “Science Based Industrialisation in a Developing Country: The Case of the Indian Scientific Instruments Industry, 1947-1968” *Modern Asian Studies* 16, no. 4 (1982): 657-682.

Clymer, Kenton J. *Quest for Freedom: The United States and India’s Independence* New York: Columbia University Press, 1995.

Cockburn, Stuart and David Ellyard. *Oliphant: The Life and Times of Sir Mark Oliphant* Adelaide: Axiom Books, 1981.

Cockcroft, Sir John. “Homi Jehangir Bhabha” *Proceedings of the Royal Institution* 41, IV, no. 191, London: The Royal Institution, 1967.

Collins, Harry. *Changing Order: Replication and Induction in Scientific Practice* Chicago: University of Chicago Press, 1992.

Cooper, Frederick. *Colonialism in Question: Theory, Knowledge, History* Berkeley: University of California Press, 2005.

Cooper, Frederick and Ann Stoler, eds. *Tensions of Empire: Colonial Cultures in a Bourgeois World* Berkeley: University of California Press, 1997.

Cooper, Fredrick and Randall Packard, eds. *International Development and the Social Sciences: Essays on the History and Politics of Knowledge* Berkeley: University of California Press, 1997.

Crawford, Elisabeth, Terry Shinn, and Sverker Sörlin. "The Nationalization and Denationalization of the Sciences: An Introductory Essay" in Crawford, Shinn, and Sorlin, eds. *Denationalizing Science: The Contexts of International Scientific Practice* Dordrecht: Kluwer Academic, 1993.

Crowther, J. G. *The Cavendish Laboratory 1874-1974*, London: Macmillan Publishers, 1974.

Darwin, John. "What was the Late Colonial State?" *Itinerario* (1999): 73-82.

Dasgupta, Subrata. *Jagadis Chandra Bose and the Indian Response to Western Science* New York: Oxford University Press, 2000.

Deshmukh, Chintamani. *Homi Jehangir Bhabha* Delhi: National Book Trust of India, 2003.

Duara, Prasenjit. *Rescuing History from the Nation* Chicago: University of Chicago Press, 1995.

Dutt, Krishna, and Andrew Robinson. *Rabindranath Tagore: The Myriad Minded Man* New York: St. Martin's Press, 1996.

Dwivedi, O. P and R. B. Jain. *India's Administrative State* New Delhi: Gitanjali Publishing House, 1985.

Edgerton, David. *Warfare State: Britain, 1920-1970* Cambridge: Cambridge University Press, 2006.

Edgerton, David. "Science in the United Kingdom: A Case Study in the Nationalisation of Science" in John Krige and Dominique Pestre, eds. *Science in the Twentieth Century* Amsterdam: Harwood Academic, 1997.

Edwards, David. "The Victorian Polymath" in Peter Rowlands and J. Patrick Wilson, eds. *Oliver Lodge and the Invention of Radio* Liverpool: PD Publications, 1994.

Elias, Norbert. *State Formation and Civilisation* Oxford: Basil Blackwell, [1939] 1982.

Elias, Norbert. *The Civilising Process* Oxford: Basil Blackwell, [1939] 1978.

Engerman, David, Nils Gilman, Mark H. Haefele, Michael Latham. *Staging Growth: Modernisation, Development and the Global Cold War* Boston: University of Massachusetts Press, 2003.

Escobar, Arturo. *Encountering Development: The Making and Unmaking of the Third World* Princeton: Princeton University Press, 1995.

Ezrahi, Yaron. “Science and the Problem of Authority in Democracy” in Thomas Gieryn. Ed. “Science and Social Structure” *Transactions of the New York Academy of Sciences*, 39 (1980): 43-60

Ezrahi, Yaron. “The Authority of Science in Politics” in Arnold Thackray and Everett Mendelsohn, eds. *Science and Values: Patterns of Tradition and Change* New York: Humanities Press, 1974.

Fermi, Laura. *Atoms for the World: United States Participation in the Conference on the Peaceful Uses of Atomic Energy* Chicago: The University of Chicago Press, 1957.

Foucault, Michel. “Governmentality” in Graham Burchell et. al. , eds. *The Foucault Effect: Studies in Governmentality* Chicago: University of Chicago Press, 1991.

Foucault, Michel. “Truth and Power” in Colin Gordon, Ed. *Power/ Knowledge: Selected Interviews and Other Writings*, *1972-1977*, New York: Pantheon, 1976.

Forman, Paul. “Beyond Quantum Electronics: National Security as Basis for Physical Research in the United States” *Historical Studies in the Physical and Biological Sciences* 18 (1987): 149-229.

Forman, Paul. “Scientific Internationalism and the Weimar Physicists: The Ideology and its Manipulation in Germany after WWI” *Isis* 64 (1973): 151-180.

Frankel, Francine R. *India’s Political Economy, 1947-2004: A Gradual Revolution* New Delhi: Oxford University Press, 2005.

Frankel, Francine. R., Zoya Hasan, Rajeev Bhargava and Balveer Arora. *Transforming India: Social and Political Dynamics of Democracy* New Delhi: Oxford University Press, 2000.

Frauenfelder, H, O. Huber and P. Stähelin. *Beiträge zur Entwicklung der Physik: Festschrift zum 70 Geburstag von Professor Paul Scherrer* Basel: Birkhauser Verlag, (1960).

Friedman, Robert Marc. *The Politics of Excellence: Behind the Nobel Prize in Science* New York: Henry Holt and Company, 2001.

Galison, Peter. *Image and Logic: A Material Culture of Microphysics* Chicago: University of Chicago Press, 1997b.

Galison, Peter. “Three Laboratories: Technology and the Rest of Culture” *Social Research* 64, no. 3 (1997a): 1127-1155.

Galison, Peter and Bruce Hevly, eds. *Big Science: The Growth of Large Scale Research* Stanford: Stanford University Press, 1992.

Geddes, Patrick. *An Indian Pioneer of Science: The Life and Work of Sir Jagadis C. Bose* London: Longmans, Green, and Co, 1920.

Ghosh, Amitav. *Incendiary Circumstances: A Chronicle of the Turmoil of our Times* Boston: Houghton Mifflin Company, 2005.

Ghosh, S. C. “Calcutta University and Science” *Indian Journal of History of Science* 29, no.1 (1994): 49-61.

Golden, William T. *Impacts of the Early Cold War on the Formulation of U.S. Science Policy: Selected Memoranda of William T. Golden, October 1950- April 1951* [Edited with an appreciation by William A. Blanpied] Washington, DC: American Association for the Advancement of Science, 1995.

Goldsmith, Maurice. *Sage: A Life of J. D. Bernal* London: Hutchinson, 1980.

Goldsmith, Maurice. *Frederic Joliot Curie* London: Lawrence & Wishart Ltd., 1977.

Goswami, Manu. *Producing India: From Colonial Economy to National Space* Chicago: University of Chicago Press, 2004.

Goswami, Manu. “Rethinking the Modular Nation Form: Toward a Sociohistorical Conception of Nationalism” *Comparative Studies in Society and History* (2002): 770-799.

Gowing, Margaret. *Britain and Atomic Energy 1939 - 1945,* London: MacMillan, 1964.

Gowing, Margaret. *Independence and Deterrence: Britain and Atomic Energy, 1945 - 1952, 2: Policy Execution* London: Macmillan, 1974.

Guha, Ranajit. *A Subaltern Studies Reader, 1986-1995* Minneapolis: University of Minnesota Press, 1997.

Gupta, Akhil. *Postcolonial Developments: Agriculture in the Making of Modern India* Durham: Duke University Press, 1998.

Harris, F. R. *Jamsetjee Nusserwanjee Tata: The Chronicle of his Life* Bombay: Blackie and Sons, India Ltd., 1958 [1925].

Harrison, Mark. “Science and the British Empire” *Isis* 96, no. 1(2005): 56-63.

Hecht, Gabrielle. *The Radiance of France: Nuclear Power and National Identity after World War II* Cambridge MA: The MIT Press, 1998.

Heilbron, John and Robert W. Seidel. *Lawrence and his Laboratory: A History of the Lawrence Berkeley Laboratory* Berkeley: University of California Press, 1989.

Heilbron, John. “The First European Cyclotrons” *Rivista di Storia della Scienza* 3, no. 1 (1986): 1-44.

Hendry, John. Ed. *Cambridge Physics in the 1930s* Bristol: A. Hilger, 1984.

Hermann, Armin, John Krige, Ulrike Mersits and Dominique Pestre, eds. *History of CERN 1: Launching the European Organization for Nuclear Research* Amsterdam: North-Holland, 1987.

Hewlett, Richard G., and Jack M. Holl. *Atoms for Peace and War, 1953-1961: Eisenhower and the Atomic Energy Commission* Berkeley: University of California Press, 1989.

Hewlett, Richard G., and Oscar E. Anderson, Jr. *Atomic Shield, 1947-1952: A History of the United States Atomic Energy Commission*, Volume 2. University Park: Pennsylvania State University Press, 1962.

Higgitt, Rebekah. *Picnicking Overseas: British Association Meetings in Canada, South Africa and Australia, 1884-1939*, Paper presented to the British Society for the History of Science Annual Meeting, 2007.

Hill, Archibald Vivian. *Lectures, Physiology or Medicine: 1922-1941* Amsterdam: Elsevier Publishing Company, 1968.

Holmes, Robert W and Raj Gopal S. *Research Facilities in Bangalore, Calcutta and Madras* Delhi: Kripal Print Press, 1969.

Home, R. W. “The Rush to Accelerate: Early Stages of Nuclear Physics Research in Australia *Historical Studies in the Physical And Biological Sciences* 36, II (2006): 213-241.

Home, R. W., Ana M. Riberio De Andrade and Carlos D. Galles, eds. “Introduction” Special Issue of *Historical Studies in the Physical and Biological Sciences* 36, II (2006): 209-211.

Hughes, Jeff. “Radioactivity and Nuclear Physics,” in Mary Jo Nye, ed. *The Modern Physical and Mathematical Sciences* The Cambridge History of Science Volume 5, Cambridge: Cambridge University Press, 2003.

Hughes, Jeff. “1932: The *Annus Mirabilis* of Nuclear Physics?” *Physics World* 13, no. 7, July 2000: 43-48.

Hughes, Jeff. “‘Modernists with a Vengeance’: Changing Cultures of Theory in Nuclear Science, 1920-1930” *Studies in History and Philosophy of Modern Physics* 29, (1998a): 339-367.

Hughes, Jeff. "Plasticine and Valves: Industry, Instrumentation and the Emergence of Nuclear Physics" in J.P. Gaudillere and I. Lowy, eds. *The Invisible Industrialist: Manufacturers and the Construction of Scientific Knowledge* Macmillan, 1998b.

Hughes, Jeff. "The French Connection: Nuclear Physics in Paris, 1925-1935" *History and Technology* 13 (1997a): 325-343.

Hughes, Jeff. "Whigs, Prigs and Politics: Problems in the History of Contemporary STM" in T. Söderqvist. Ed. *The Historiography of Contemporary Science and Technology* Amsterdam: Harwood Academic Press, 1997b.

Hurtado, Diego and Ana Maria Vara. "Political Storms, Financial Uncertainties and Dreams of "Big-Science": The Construction of a Heavy Ion Accelerator in Argentina *Historical Studies in the Physical And Biological Sciences* 36, II (2006): 343-364.

Huntington, Samuel J. *Political Order in Changing Societies* New Haven: Yale University Press, 1968.

Indian Science Congress Association. *The Shaping of Indian Science: Indian Science Congress Association Presidential Addresses, 1914-1947* Hyderabad: Universities Press, 2003.

Joerges, Bernward and Terry Shinn, eds. *Instrumentation between Science, State and Industry* Dordrecht: Kluwer Academic Publications, 2002.

Joerges, Bernward. "Do Politics have Artifacts?" *Social Studies of Science* 29, no. 3, (1999): 411-431.

Jungnickel, Christa and Russell McCormach. *Cavendish: The Experimental Life* Canton, MA: Science History Publications, 1999.

Kapur, Ashok. *Pokhran and After: India's Nuclear Weapons Capability* London/ New Delhi: Oxford University Press, 2000.

Kapur, Ashok. "India: The Nuclear Scientists and the State, the Nehru and Post-Nehru years" in Etel Solingen. ed. *Scientists and the State: Domestic Structures and the International Context* Ann Arbor: University of Michigan Press, 1994.

Kaur, Raminder. "Explosive Narratives: The Articulation of 'Nuclear Knowledge' in Mumbai" in Johan Pottier, Alan Bicker and Paul Sillitoc. eds. *Negotiating Local Knowledge* London: Pluto Press, 2003.

Kaviraj, Sudipta. "An Outline of a Revisionist Theory of Modernity" *Arch. European Sociology* 46, no. 3 (2005): 497-526.

Kaviraj, Sudipta "Modernity and Politics in India" *Daedalus* (2000): 137-162.

Kaviraj, Sudipta. *Politics in India* New Delhi: Oxford University Press, 1997.

Kaviraj, Sudipta. "The Modern State in India" in Martin Doornbos and Sudipta Kaviraj, eds. *Dynamics of State Formation: India and Europe Compared* New Delhi: Sage Publications, 1997b.

Kaviraj, Sudipta. *Politics in India* New Delhi: Oxford University Press, 1997a.

Kaviraj, Sudipta. "Crisis of the Nation-State in India" *Political Studies* 42 (1994): 115-129.

Kevles, Dan. "Cold War and Hot Physics: Science, Security and the American State, 1945-56" *Historical Studies in the Physical and Biological Sciences* 20, II (1990): 239-264.

Kevles, Dan. *The Physicists: The History of a Scientific Community in Modern America* Cambridge: Harvard University Press, 1987.

Khilnani, Sunil. *The Idea of India* New Delhi: Penguin Books, 1997.

Kim, Dong-Won. "Yoshio Nishina and Two Cyclotrons" *Historical Studies in the Physical And Biological Sciences* 36, II, (2006): 243-273.

Kochanek, Stanley A. *The Congress Party of India* Princeton: Princeton University Press, 1968.

Kothari, Rajni. *Politics in India* Delhi: Orient Longman, 1970.

Kramish, Arnold. *The Peaceful Atom in Foreign Policy* New York: Harper and Row, 1963.

Krige, John. *Techno-utopian Dreams, Techno-political Realities: The Education of Desire for the Peaceful Atom* Davis Fellowship Paper, 2006d.

Krige, John. *American Hegemony and the Postwar Reconstruction of Science in Europe*, Cambridge: MIT Press, 2006c.

Krige, John. John Krige, "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence," *Osiris* 21 (2006b): 161-181.

Krige, John and Kai Henrik Barth. "Introduction", Global Power Knowledge: Science, Technology and International Affairs" *Osiris* 21 (2006a): 1-21.

Krige, John and Dominique Pestre, eds. *Science in the Twentieth Century* Amsterdam: Harwood Academic Publishers, 1997.

Krishna, V. V. "Organisation of Industrial Research: The Early History of CSIR, 1934-47" in Roy MacLeod and Deepak Kumar, eds. *Technology and the Raj: Western Technology and Technical Transfers to India 1700-1947* New Delhi: Sage Publications, 1995, 289-323.

Krishna, V. V. *Sir Shanti Swarup Bhatnagar on Science, Technology and Development, 1938-54* New Delhi: Wiley Eastern, 1993.

Kulkarni, R. P. and V Sharma. *Homi Bhabha: Father of Nuclear Science in India* Bombay: Popular Prakashan, 1969.

Kumar, Deepak. *Science and the Raj, 1857-1905* New Delhi: Oxford University Press, 1995.

Kumar, Deepak. Ed. *Science and Empire: Essays in Indian context* New Delhi: Anamika Publications, 1991.

Lamont, Peter. *The Rise of the Indian Rope Trick: The Biography of a Legend* London: Little Brown, 2004.

Lala, R. M. *The Creation of Wealth: The Tata Story* Bombay: India Book House, 1981.

Leslie, Stuart W. *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* New York: Columbia University Press, 1993.

Lewis, Michael L. *Inventing Global Ecology: Tracking the Biodiversity Ideal in India, 1947-1997* Hyderabad: Orient Longman, 2003.

Louis, William Roger. *In the Name of God Go! Leo Amery and the British Empire in the Age of Churchill* London: W. B. Norton & Company, 1992.

Lourdusamy, John. *Science and National Consciousness in Bengal, 1870-1930* New Delhi: Orient Longman, 2004.

Low, Morris. “Accelerators and Politics in Postwar Japan” *Historical Studies in the Physical And Biological Sciences* 36, II, (2006): 275-296.

Ludden, David ed. *Reading Subaltern Studies: Critical History, Contested Meaning, and the Globalisation of South Asia* New Delhi: Permanent Black, 2001.

MacLeod, Roy, ed. “Nature and Empire: Science and the Colonial Enterprise” *Osiris* 15, 2000.

MacLeod, Roy. “Review of Gyan Prakash, Another Reason: Science and the Imagination of Modern India *American Historical Review*, (2000): 1720-1721.

MacLeod, Roy. “On visiting the ‘Moving Metropolis: Reflections on the architecture of Imperial Science” in Nathan Reingold and Marc Rothenberg, eds. *Scientific Colonialism: A Cross-Cultural Comparison* Washington DC: Smithsonian Institution Press, 1987.

Macmillan, Edwin M. “Early History of Particle Accelerators” in Roger H. Stuewer Ed. *Nuclear Physics in Retrospect: Proceeding of a Symposium on the 1930s* Minneapolis: University of Minnesota Press, 1979.

Maier, Charles. "Consigning the Twentieth Century to History: Alternative Narratives for the Modern Era *The American Historical Review* 105, no. 3 (2000): 807-833.

Marglin, Frederique Apfel and S. Apfel, eds. *Dominating Knowledge* New York: Oxford University Press, 1990.

McMahon, Robert J. *The Cold War on the Periphery: The United States, India, and Pakistan* New York: Columbia University Press, 1994.

McNiel, Maureen. Ed. "Special Issue: Postcolonial Technoscience" *Science as Culture* 14, no. 2 (2005).

Mehrtens, Herbert. *Moderne Sprache, Mathematik: Eine Geschichte des Streits um die Grundlagen der Disziplin und des Subjekts formaler Systeme* Frankfurt am Main: Suhrkamp, 1990.

Mukerjee, Visvapriya. "Some Historical Aspects of Jagdish Chandra Bose's Microwave Research during 1895-1900" *Indian Journal for History of Science* 14, (1979): 87-104.

Munns, David. "Linear Accelerators, Radio Astronomy, and Australia's Search for International Prestige, 1944-1948" *Historical Studies in the Physical and Biological Sciences* 27, no. 2 (1997): 299-317.

Nagchoudhuri, Basanti Dulal. *Science and Society: Some Reflections* New Delhi: Ankur Publications, 1977.

Nandy, Ashis. *Alternative Sciences: Creativity and Authenticity in Two Indian Scientists* New Delhi: Oxford University Press, 1995.

Nandy, Ashis. Ed. *Science, Hegemony and Violence: A Requiem for Modernity* Delhi: Oxford University Press, 1990.

Nandy, Ashis. "Defiance and Conformity in Science: The Identity of Jagadis Chandra Bose" *Science Studies*, 2, no.1 (1972): 31-85.

Nayar, Baldev Raj. *The Modernization Imperative and Indian Planning* Delhi: Vikas Publications, 1972.

Nayar, Baldev Raj. *India's Quest for Technological Independence* New Delhi: Lancers Publishers, 1983.

Needham, Anuradha Dingwaney. "Interview: Partha Chatterjee" *Interventions* 1, no. 3, (1999): 413-425.

Nehru, Jawaharlal. *The Discovery of India* New Delhi: Oxford University Press, 1946; 2003.

Nehru, Jawaharlal. “The Necessity of Atomic Research”, Extracts from a speech after laying the foundation stone of the National Physical Laboratory at New Delhi on January 4, 1947; Reproduced in *Pandit Jawaharlal Nehru on Atomic Energy* Bombay: Bhabha Atomic Research Centre, 1989.

Nehru, Jawaharlal. *The Unity of India: Collected Writings 1937-40* London: Lindsay Drummond, 1941.

Needell, Allan A. “Nuclear Reactors and the Founding of Brookhaven National Laboratory” *Historical Studies in the Physical Sciences* 14, I (1983): 93-122.

Nobel Lectures, Physiology or Medicine 1901-1921, Amsterdam: Elsevier Publishing Company, 1967.

Nye, Mary Jo. *Blackett: Physics, War and Politics in the Twentieth Century* Cambridge: Harvard University Press, 2004.

Osborne, Michael A. Ed. “Focus Section: The Social History of Science, Technoscience and Imperialism *Science, Technology and Society* 4, no. 2 (1999).

Palladino, Paolo and Michael Worboys. “Science and Imperialism” *Isis* 84 (1993): 91-102.

Penny, [Lord]. “Homi Jehangir Bhabha, 1909-1966” *Biographical Memoirs of the Fellows of the Royal Society* 13, (Nov., 1967): 35-55.

Perkovich, George. *India's Nuclear Bomb: The Impact on Global Proliferation* Berkeley: University of California Press, 1999.

Pilat, Joseph F., Robert E. Pendley, and Charles K. Ebinger. *Atoms for Peace: An Analysis after Thirty Years.* Boulder: Westview Press, 1985.

Potter, David C. “The Prime Minister and the Bureaucracy” in K. Mathur. Ed. *Development Policy and Administration* New Delhi: Sage Publications, 1996.

Potter, David C. “Bureaucratic Change in India” in Ralph Braibanti. Ed. *Asian Bureaucratic Systems Emergent from the British Imperial Tradition* Durham: Duke University Press, 1966.

Prakash, Gyan. “Inevitable Revolutions” *The Nation* April 30, 2007.

Prakash, Gyan. “Review of David Arnold, Science, Technology and Medicine in Colonial India” *Victorian Studies,* Autumn 2002, 149-151.

Prakash, Gyan. *Another Reason: Science and the Imagination of Modern India* Princeton: Princeton University Press, 1999.

Price, Derek J. de Solla. *Little Science, Big Science* New York: Columbia University Press, 1963.

Pyenson, Lewis. “Cultural Imperialism and Exact Sciences Revisited” *Isis* 84 (1993): 103-108

Rahman, Abdur. *A Study of Expenditure in National Laboratories* New Delhi: Council of Scientific and Industrial Research, 1964.

Rahman, Abdur. *State Support to Scientific Research in India: An Analysis of Trends* New Delhi: Research Survey and Planning Organisation, 1966.

Raina, Dhruv. *Images and Contexts: The Historiography of Science and Modernity in India* New Delhi: Oxford University Press, 2003.

Raina, Dhruv. “Four Aspects of the Institutionalisation of Physics Research in India (1900-1950): Substantiating the claims of historical sociology through bibliometrics” *Scientometrics* 42, no. 1 (1998): 17-40.

Raina, Dhruv and S. Irfan Habib. *Domesticating Modern Science: A Social History of Science and Culture in Colonial India* New Delhi: Tulika Books, 2004.

Raina, Dhruv and Ashok Jain. “Big Science and University in India” in John Krige and Dominique Pestre, eds. *Science in the Twentieth Century* Amsterdam: Harwood Academic Publications, 1997.

Ramana, M. V. “*La trahison des clercs*: Scientists and India’s Nuclear Bomb” in M. V. Ramana and C. Rammanohar Reddy, eds. *Prisoners of the Nuclear Dream* New Delhi: Orient Longman, 2003.

Ramana, M. V. and Zia Mian *Prisoners of a Nuclear Dream* New Delhi: Orient Longman, 2003.

Ramanna, Raja. *Years of Pilgrimage* New Delhi: Viking Press, 1991.

Ramos Lara, Maria de La Paz. “Particle Accelerators in Mexico” *Historical Studies in the Physical And Biological Sciences* 36, II (2006): 297-309.

Ramusack, Barbara. *The Indian Princes and their States* New Cambridge History of India III. no. 6 Cambridge: Cambridge University Press, 2004.

Ray, P. C. *Life and Experiences of a Bengali Chemist* Calcutta: Chukerverity, Ghattesjee and Co, 1932.

Richards, Norah. *Life and Work of Sir Shanti Swarup Bhatnagar* New Delhi: New Book Society of India, 1948.

Ross, Ronald. *Memoirs* London: John Murray, 1923.

Roy, Srirupa. *Beyond Belief: India and the Politics of Postcolonial Nationalism* Durham and London: Duke University Press, 2007.

Rudolph, Lloyd I. and Susanne Hoeber Rudolph. *In Pursuit of Lakshmi: The Political Economy of the Indian State* Chicago: University of Chicago Press, 1987.

Sadowsky, Jonathan. *Imperial Bedlam: Institutions of Madness in Colonial Southwest Nigeria* Berkeley: University of California Press, 1999.

Said, Edward. *Orientalism* New York: Penguin, 1978.

Sánchez-Ron, José M. "International Relations in Spanish Physics from 1900 to the Cold War" *Historical Studies in the Physical and Biological Sciences*, 33 (2002): 3-31.

Sarkar, Sumit *The Swadeshi Movement in Bengal, 1903-1908* Delhi: People's Publishing House, 1973.

Schiebinger, Londa. Ed. "Focus: Colonial Science" *Isis* 96, no.1, 2005.

Schweber, Silvan S. *In the Shadow of the Bomb: Oppenheimer, Bethe, and the Moral Responsibility of the Scientist* Princeton: Princeton University Press, 2006.

Scott, David. "Colonial Governmentality" *Social Text* 43, Spring 1995: 191-220.

Scott, James C. *Seeing Like a State: How Certain Schemes to Improve the Human Condition have Failed* New Haven: Yale University Press, 1998.

Sebaly, Kim Patrick. "The Tatas and University Reform in India, 1898-1914" *History of Education* 14, no. 2 (1985): 117-136.

Seidel, Robert W. "The National Laboratories of the Atomic Energy Commission in the Early Cold War" *Historical Studies in the Physical and Biological Sciences*, 32, I (2001): 45-162.

Seidel, Robert W. "Accelerators and National Security: The Evolution of Science Policy for High Energy Physics 1947-1967" *History and Technology* 11 (1994): 361-391.

Seidel, Robert W. "The Origins of the Lawrence Berkeley Laboratory" in Peter Galison and Bruce Hevly, eds. *Big Science: The Growth of Large Scale Research* Stanford: Stanford University Press, 1992.

Seidel, Robert W. "A Home for Big-Science: The Atomic Energy Commission's Laboratory System" *Historical Studies in the Physical and Biological Sciences* 16 (1986): 135-175

Sen, S. N. *Prof. Saha: His life Work and Philosophy* Calcutta: SINP, 1954.

Sen, U. *Scientific Research in Indian Universities* New Delhi: Council for Scientific and Industrial Research, 1965.

Sikka, Pawan. “Science Advice in India” *Technology in Society* 17, no. 4 (1995): 349-363.

Singh, Rajinder. *Nobel Laureate C. V. Ramans’s work on Light Scattering: Historical Contributions to a Scientific Biography* Hamburg: Logos Verlag, 2004.

Singh, Satyajit. *Taming the Waters: The Political Economy of Large Dams in India* New Delhi: Oxford University Press, 1997.

Solovey, Mark. “Science and the State during the Cold War: Blurred Boundaries and Blurred Legacy” [Special Issue: Science in the Cold War] *Social Studies of Science*, 31, no. 2 (2001): 165-170.

Skinner, Quentin. “The State” in Terence Ball, James Farr and Russell L. Hanson, eds. *Political Innovation and Conceptual Change* Cambridge: Cambridge University Press, 1989.

Smith, Bruce L. R. *American Science Policy since World War II* Washington, DC: The Brookings Institution, 1990.

Spear, Percival. *A History of India, Volume II* New Delhi: Penguin Books, 1965.

Stein, Arthur. *India and the Soviet Union: The Nehru Era* Chicago: University of Chicago Press, 1969.

Stuewer, Roger H. *Nuclear Physics in Retrospect: Proceedings of a Symposium on the 1930s* Minneapolis: University of Minnesota Press, 1979.

Subbarayappa, B. V. *In Pursuit of Excellence: A History of the Indian Institute of Science* Bombay: Tata McGraw Hill Publishing Company Ltd, 1992.

Sur, Abha. “Scientism and Social Justice: Meghnad Saha’s Critique of the State of Science in India” *Historical Studies in the Physical and Biological Sciences* 33, no 1 (2002): 87-105.

Sur, Abha. “Aesthetics, Authority, and Control in an Indian Laboratory: The Raman-Born Controversy on Lattice Dynamics” *Isis* 30, no. 1(1999): 25-49.

Suri, Jeremi. “The Cold War, Decolonisation, and Global Social Awakenings: Historical Intersections” *Cold War History* 6, no. 3 (August 2006): 353-363

Söderqvist, T. Ed. *The Historiography of Contemporary Science and Technology* Amsterdam: Harwood Academic Press, 1997.

Thackray, Arnold. “Science after '40” *Osiris* 7, 1992.

Thomas, Jerry. “John Stuart Foster, McGill University, and the Renascence of Nuclear Physics in Montreal, 1935-1950,” *Historical Studies in the Physical and Biological Sciences* 14, no. 2 (1984): 357-377.

Thomas, Lewis. “Scientific Frontiers and National Frontiers: A Look Ahead,” *Foreign Affairs* 62, no. 4, (Spring 1984): 966-994.

Tilly, Charles. *Coercion, Capital and European States, AD 990-1990* Oxford: Basil Blackwell, 1990.

Thosar, B. V. *Growing Up with Science in India* Bombay: Self-Published, ~1981.

Venkataraman, G. *Journey into Light: Life and Science of C. V Raman* New Delhi: Penguin books India Ltd., 1994.

Venkataraman, G. *Raman and his Effect* Hyderabad: Universities Press, 1995.

Venkataraman, G. *Saha and his Formula* Hyderabad: Universities Press, 1995.

Venkataraman, G. *Bhabha and his Magnificent Obsessions* Delhi: DK Publishers, 1999.

Visvanathan, Shiv. *Organizing for Science: The Making of an Industrial Research Laboratory* New Delhi: Oxford University Press, 1985.

Visvanathan, Shiv. “Annals of a Laboratory State” in Ashis Nandy (Ed.) *Science, Hegemony and Violence: A Requiem for Modernity* New Delhi: Oxford University Press, 1990.

Walker, Mark. *German National Socialism and the Quest for Nuclear Power, 1939-1949* Cambridge: Cambridge University Press, 1993.

Walker, Mark. “Physics and Propaganda: Werner Heisenberg’s Foreign Lectures under National Socialism” *Historical Studies in the Physical and Biological Sciences* 22, no. 2 (1992): 339-389.

Warwick, Andrew. *Masters of Theory: Cambridge and the Rise of Mathematical Physics* Chicago: University of Chicago Press, 2003.

Weart, Spencer R. *Nuclear Fear: A History of Images* Cambridge: Harvard University Press, 1988.

Weart, Spencer R. *Scientists in Power* Cambridge: Harvard University Press, 1979.

Weber, Max. *Economy and Society: An Outline of Interpretive Sociology* [edited by Guenther Roth and Claus Wittich; translators, Ephraim Fischoff et al.]. Berkeley: University of California, 1978.

Weinberg, Alvin. *Reflections on Big-Science* Cambridge: Cambridge University Press, 1967.

Weiner, Charles. "Cyclotrons and Internationalism: Japan, Denmark and the United States, 1935-45" *Proceedings No. 2 XIVth International Congress of the History of Science* Tokyo: Science Council of Japan, 1975.

Weiner, Charles, and Elspeth Hart, eds. *Exploring the History of Nuclear Physics* New York: American Institute of Physics, 1972.

Weiner, Myron. *Party Building in a New Nation: The Indian National Congress* Chicago: University of Chicago Press, 1967.

Weiss, Leonard. "Atoms for Peace: Did the 50-year-old Atoms for Peace Programme Accelerate Nuclear Weapons Proliferation?" *Bulletin of the Atomic Scientists* 59, no. 6 (2003): 34-41.

Westad, Odd Arne. *The Global Cold War: Third World Interventions and the Making of Our Times* Cambridge: Cambridge University Press, 2006.

Westwick, Peter J. *The National Laboratories: Science in an American System 1947-1974* Cambridge: Harvard University Press, 2003.

White, Nicholas J. *Decolonisation: The British Experience Since 1945* New York: Longman Press, 1999.

Winner, Langdon. "Do Artifacts Have Politics?" Donald McKenzie and Judy Wajcman, Eds. *The Social Shaping of Technology* London: Open University Press, 1999.

Withers, Charles W. J. *Geography, Science and National Identity: Scotland since 1520* Cambridge: Cambridge University Press, 2001.

Woolgar, Steve and Geoff Cooper. "Do Artefacts Have Ambivalence? Moses' Bridges, Winner' Bridges and Other Urban Legends in S&TS" *Social Studies of Science* 29, no. 3, (1999) 433-449.

Zachariah, Benjamin. *Developing India: An intellectual and social history* New Delhi: Oxford University Press, 2005.

Zachariah, Benjamin. *Nehru* London: Routledge, 2004.

Zimmerman, David. *Top Secret Exchange: The Tizard Mission and the Scientific War* Montreal: McGill-Queens University Press, 1996.

PhD Theses

Abraham, Itty. *Security, Technology and Ideology: "Strategic Enclaves" in Brazil and India, 1945- 1989* Doctoral Thesis, University of Illinois, Urbana-Champaign, 1993.

Anderson, Robert. *The Life of Science in India: A Comparative Ethnography of Two Research Institutes* Doctoral Thesis, Department of Anthropology, University of Chicago, 1971.

Clark, Sabine. *Experts, Empire and Development: Fundamental Research for the British Colonies* Doctoral Thesis, University of London, 2005.

Hughes, Jeff. *The Radioactivists: Community, Controversy and the Rise of Nuclear Physics* Doctoral Thesis, History and Philosophy of Science, University of Cambridge, 1993.

Manzioni, Joseph. *The American Scientific Community, the United States Government and the Issue of International Scientific Relations during the Cold War, 1945-1960* Doctoral Thesis, University of Michigan, 1992.

Raha, Shomikho. *Changing 'Reason of State' in India? The Ganga Water Dispute, Nuclear Policy and Government Business Relations* Doctoral Thesis, Trinity College, Cambridge, 2006.