A THIRD SPACE: TECHNOLOGICAL ART AS ARTISTIC PRODUCTION AND TECHNOLOGY RESEARCH AND DEVELOPMENT

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A THIRD SPACE: TECHNOLOGICAL ART AS ARTISTIC PRODUCTION AND TECHNOLOGY RESEARCH AND DEVELOPMENT

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For Zachary, Sofia and Geronimo.

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SUMMARY

While the visual arts and technology development map oppositionally in our culture, there are similarities in work. Visual artists and technology developers imagine, conceptualize, design, and build artifacts and then release them into the world. As part of this work, many artists and technologists develop high levels of conceptualization, technical, and fabrication skill. While artists have always worked with industrial technologies such as paint and pigment chemistry, metalworking equipment, heavy machinery, and kilns, for example, many postindustrial artists are using high technology both as medium and highly-charged cultural material. These artists work with similar materials as technology developers: electronics, computation, robotics, bioengineering materials, and smart materials, for example. Their work often bleeds into technological development as they create new technologies and new interactions with technologies in the course of their projects.

This dissertation traces the evolution of the ideas of art and technology from foundations in ancient Greece through the present. There are tensions between technological art, or art that uses high technologies as a medium, and the contemporary art world, as well as between technological art and engineering practice. This dissertation locates technological art along a spectrum between traditional fine art and engineering practice, in a third space of both artistic production and technological R&D. Through examples from my work and the work of others, I surface the dynamics of practice in this third space and how these practices can lead to emergent art and technology.

CHAPTER I

INTRODUCTION

While the visual arts and technology development map oppositionally in our culture, there are similarities in work. Visual artists and technology developers imagine, conceptualize, design, and build artifacts and then release them into the world. As part of this work, many artists and technologists develop high levels of conceptualization, technical, and fabrication skill. While artists have always worked with industrial technologies such as paint and pigment chemistry, metalworking equipment, heavy machinery, and kilns, for example, many postindustrial artists are using high technology both as medium and highly-charged cultural material. These artists work with similar materials as technology developers: electronics, computation, robotics, bioengineering materials, and smart materials, for example. Their work often bleeds into technological development as they create new technologies and new interactions with technologies in the course of their projects.

LED video artist Jim Campbell (Figure 1), for example, holds several patents in video image processing [33, 32, 113]. Artists Laurent Mignonneau and Christa Sommerer hold patents and application filings, including one for a solar-powered informational building façade along with architect Michael Shamiyeh [178] (Figure 2). Artist Hubert Duprat works with caddisfly larvae as a material (Figure 3) and holds patent related to this work [57]. The abstract for Duprat's patent reads as follows:

> Process for the production of precious sheaths characterised in that precious materials which, by virtue of their size, can enter into the composition of the sheaths, are made available to aquatic larvae of Trichoptera. The invention consists in making available to the aquatic larvae of Trichoptera precious materials which, by virtue of their size, can enter into the composition of the sheath. Fourteen of the twenty families of Trichoptera are capable of working with these materials to produce a movable

Figure 1: Jim Campbell's *Scattered Light*, 2010.

> sheath (the sheath represented belongs to the family Sericostomatidae). The natural living conditions of these larvae should be reconstituted as far as possible: quality of the water, nutrients, temperature, current. This invention makes it possible to obtain the production by these larvae of finely worked casings using precious materials....

The patents are evidence of novel algorithms, platforms, and materials that Campbell, Mignonneau and Sommerer, and Duprat, respectively, are using to actualize their work. The normative assumption is that these artists are protecting their intellectual property through utility patents. Yet setting aside this assumption for further considerations, we can see that not only are they innovating technologically, but they are expanding the notion of utility. Jim Campbell is an electrical engineer as well as an internationally recognized artist with work in the Museum of Modern Art's permanent collection. While one could imagine Hubert Duprat's patent being used to filter and concentrate various substances from an aquatic environment in, for example, the mineral industry, he filed his patent as a means of protecting caddisflies from

Figure 2: Laurent Mignonneau, Michael Shamiyeh, and Christa Sommerer's solar powered media façade. 2008.

Figure 3: Hubert Duprat's caddisfly larvae.

exploitation by the jewelry industry [189, footnote 14]. The media façade project of Shamiyeh, Mignonneau, and Sommerer appears to be a straightforward attempt to institutionalize a novel technology, though their approach toward the façade as a "membrane for the display of interactive digital content" and concern for the preservation and visibility of the underlying historical building façade suggests an ecosystem of concerns developed as artists within the interactive arts community [128].

While utility patents provide an institutional verification of invention, patenting is not the only mechanism through which we can understand artist innovation. Artists' work may translate into industrial contexts. Large-scale machine performance art group Survival Research Labs (SRL) created the *Pitching Machine*, 1999, which members describe as follows:

> Arguably the most dangerous machine ever fabricated at SRL. Going by the innocuous title of the *Pitching Machine*, this device launches 6 foot 2" x 4"s at a velocity of 120 m.p.h. This provides a calculated range of 800 ft. It is equipped with an automatic loading system holding 20 boards and is powered by a 500 cubic inch El Dorado engine. [184]

The machine is controllable by a web interface. Testing conducted by SRL found that firing six foot 2 x 4 lumber boards at speeds of 110 miles per hour could penetrate a 0.125-inch thick steel plate, with "excellent" accuracy and repeatability [184]. The pitching machine debuted in SRL's 1999 performance *The Arbitrary Calculation of Pathological Amusements* at the ICC cultural center in downtown Tokyo coincident with the emperor's birthday celebrations. According to SRL, "a user at the ICC a few miles away was able to demolish targets in Yoyogi Park" [185].

SRL continued to develop the pitching machine to fire at speeds up to 200 miles per hour. In 2005, they received a request from Shell Oil to rent the pitching machine for tests. Shell engineers were in need of

> . . . a method to deploy a 1.2" steel rod which have 2" O.D. silicon nitride spacers attached to it down a well. Traditional deployment methods cannot be used because of the brittle silicon nitride spacers that are

Figure 4: SRL's *Pitching Machine* at their *Ghostly Scenes of Infernal Desecration: An SRL End of Days Production* show at the 2006 ZeroOne San Jose arts festival, co-located with the International Symposium for Electronic Art (ISEA) 2006.

> attached to the rod. Also the varying diameters are a problem for injector heads. [186]

After testing, Shell engineers determined that the *Pitching Machine*, optimized for their application, would work well to push long sections of bimetallic heating rods with silicon nitride insulators into a well pipe several thousand feet into the ground in order to heat oil shale. The engineers were planning to freeze the ground above and below the well, leaving it to pressure-cook for three years at roughly 400 degrees Fahrenheit before pumping out the oil. This method was an alternative to strip mining the shale in order to cook it in large vats above ground [186].

The story of All Power Labs, manufacturers of biomass gasifiers for small-scale power generation, further illustrates dynamics of artist invention. In 2001, a group of San Francisco Bay artists founded an experimental facility in Berkeley, California. The facility, called the Shipyard, was created by and for the artists, who brought in roughly fifty shipping containers and built out their own workspaces inside them to form a collective artists' workspace. This ran afoul of the city of Berkeley's code-enforcement department, and after three months the city turned off power to the Shipyard. The Shipyard responded by creating an off-grid, three-phase system with

Figure 5: The Shipyard with solar panel installations in 2007.

enough power to run its lathes, mills, and welders and continue business as usual. This power system consisted of a seventeen-thousand-pound, forty-eight-volt battery array from a telecom station, whereby each cell held five thousand ampere hours. The ongoing challenge was generating the electricity. Solar panels augmented standard fuel generators but did not provide the energy density needed to run the facility (Figure 5). Jim Mason, a principle figure in the founding of the Shipyard, began experimenting with gasification of solid plant waste matter to create fuel for a combustion engine [14]. The art facility had in part become a power engineering and generation facility.

One of the first public gasification prototypes created by Mason and Shipyard-related artists was *Mechabolic: Cyborg speculations in Machine Metabolism*, or, as they described it, “a trash-to-fuel land speed racer slug” [90]. It was a 130-foot vehicle divided into three sections: heart, lungs, and abdomen. *Mechabolic* traversed

Figure 6: *Mechabolic: Cyborg speculations in Machine Metabolism* 2007.]

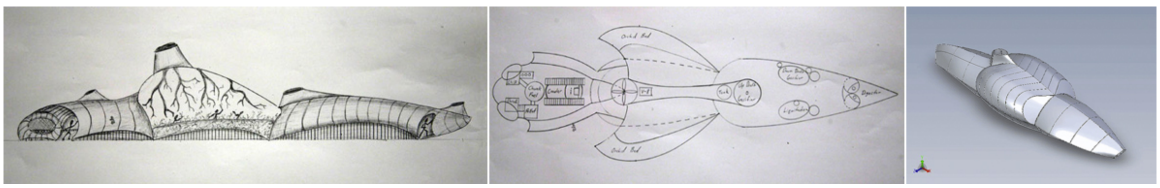


Figure 7: Process drawings of *Mechabolic*.

the desert Black Rock City during the 2007 Burning Man experimental art festival, consuming compost waste from the city and turning it into the fuel that it ran on (Figure 6). *Mechabolic* included an on-board garden to generate the plant matter necessary for the process.

Jim Mason and others continued experimenting with and developing gasification equipment. He describes their artist-invention process in the following way:

> We're using typical strategies of scrappy junkyard artists which is let's take good ideas, figure out preexisting stuff that exists in the world, reconfigure it expertly, and make it do the stuff that you need it to do without having to buy it off the shelf as a passive consumer item [14].

In 2008 Mason led an open-source Gasifier Experimenter's Kit (GEK) initiative as a way to encourage a "cultural conversation" and "playful, creative engagement" with the technology instead of building a "done product in a black box that you couldn't see" [14]. By 2011, the GEK platform served as the basis for Mason's All Power Labs, a supplier of pallet-sized biomass gasifiers. GEK systems have been ordered by over forty-five universities, research institutions including the U.S. Department of

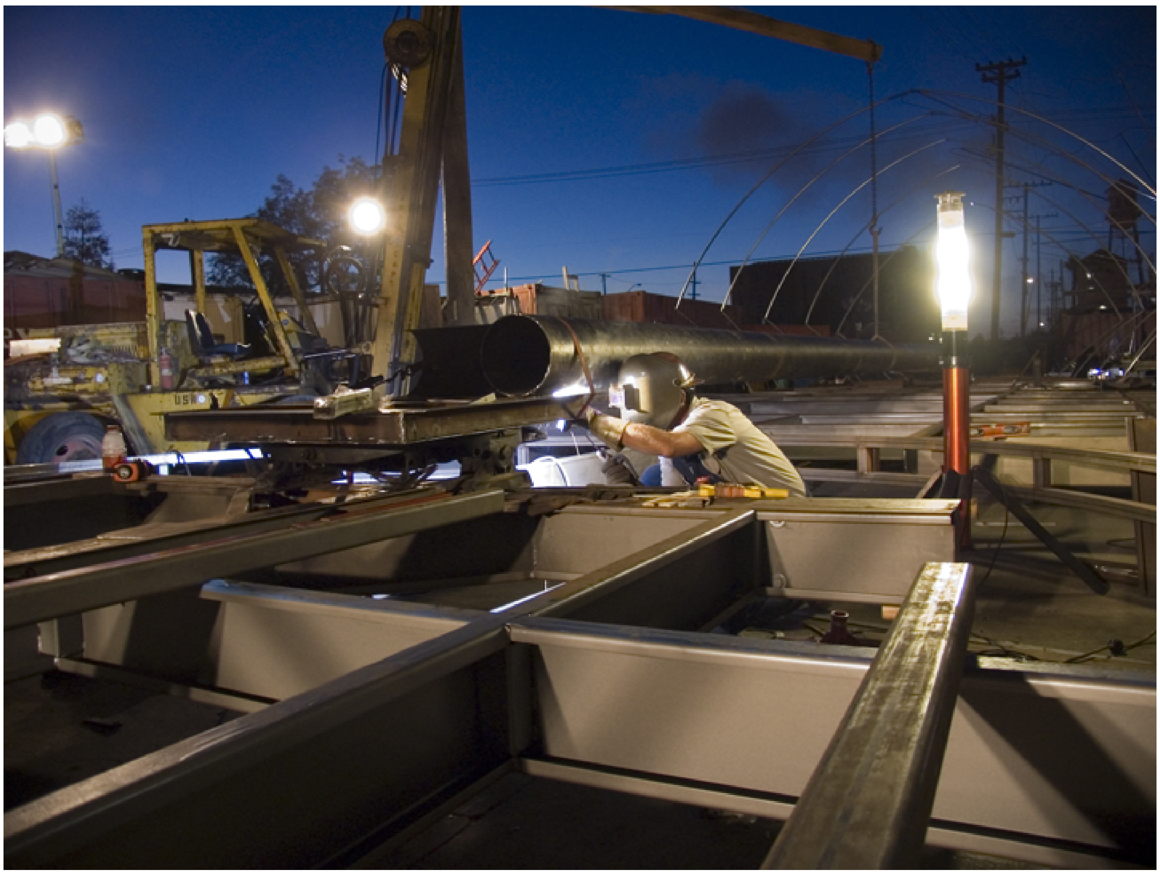


Figure 8: Fabricating *Mechabolic.*

Figure 9: Gasification equipment on board *Mechabolic*.

Figure 10: The All Power Labs's *Power Pallet*.

Agriculture and U.S. Department of Energy, and off-grid communities in the developing world. When asked about the change in focus from making art to making green power generators, Mason replied:

> It seems possible to me that the next "art/tech like" cross-fertilization is going to happen between art and energy. I think energy is going to become, or at least has the potential to become, a creative idiom of pleasurable hacking, creativity and self-expression. I think it is going to follow a similar transformation from raw technical/commodity problem to an idiom for social and creative expression- the same progress we have witnessed in computing, cars, organic farming, food/cuisine, and many other technical idioms ultimately rerolled into more anthropological idioms.
>
> We don't yet know what the desktop pc and internet is for current mainframe energy economy, but it seems very plausible, and quite likely, that there are similar dynamics ahead for energy. Energy, like so much else, seems destined to move away from a centralized, top down, commodity economy, towards a more distributed, bottom up, participatory and expressive economy. Intentionally adding art to this process, understood in the broadest sense as "creative self-expression", is likely to accelerate and better identify the opportunities and good ahead.
>
> Thus for the Shipyard V2.0, we are going to add to the current creative endeavors and formalize the creative power hacking by recasting the yard as a "Center for Art and Energy". A facility, information resource and gathering of people engaged broadly in the endeavor of creative power hacking. A place to experiment with power generation and conversion as an idiom and medium of art- in all its social, sensual, conceptual and existential dimensions.
>
> What would power look like if it was art? [124]

The pun in the last sentence aside, the confluence of multiple categories: "geek," "fabricators," "mechanical," "electronic," "art" in the first sentence and "the mash up of art and tech" in the second, as well as the "cross-fertilization" and "recombinatory mojo" of art and energy points to an evolving contemporary phenomenon. Knowledge and know-how are easily shared over the World Wide Web, which tends to provide information with relatively little regard for categories and taxonomies. Computing equipment, including microcontrollers, have become ubiquitously accessible, as have Internet-supported distribution logistics, novel fabrication equipment, and

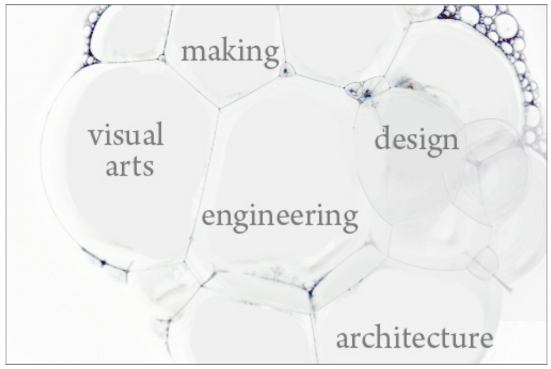


Figure 11: The boundaries between the building disciplines have blurred.

sophisticated materials. Technology has become a cultural currency. It is a medium of exchange and expression. We in the developed world swim in it.

As a result, the boundaries between the building disciplines have blurred, particularly with respect to technological development. These disciplines include the visual arts, engineering, design, and architecture, and they further blur with "making,"—practices of hands-on, craft-based artifact creation for creation's sake, that often use contemporary electronics, microcontroller technologies, and rapid prototyping equipment. Knowledge and material resources, techniques, manufacturing processes, and cultural frameworks such as open source development, intellectual property protection, collective action, and microfunding traverse the boundaries of these disciplines and communities. These phenomena are contemporary with the emergence of a creative innovation economy whereby technology development no longer tends to be centralized in larger institutions such as corporations, universities, and government research centers, but is also prevalent in smaller entrepreneurial clusters.

The concept of contemporary innovation not only applies to technology and the current bubble of new technology companies and venture capital investment. It also applies to social innovation—projects in microcredit, open courseware, and open source technology and architecture. Furthermore, the steady success of the creative industries writ large during a time of economic downturn has led to governmental funding and support of the creative innovation economy, which is characterized by a more independent, less institutionalized approach to the production of value.

This dissertation focuses on a slice of this larger picture. It is concerned with how the visual arts can contribute to technology research and development through art production. While it is true that technological invention has contributed to the arts, particularly with respect to interactive art processes, fabrication techniques, and as a material itself, this dissertation considers the dynamics involved in how dynamics of practice can lead to emergent art and technology. The effect technology has had on artwork is investigated in Steven Wilson's *Art + Science Now* [197], Edward Shanken's *Art and Electronic Media* [179], Christiane Paul's *Digital Art* [146], and Andrea Grover's book sprint[1] project *New Art/Science Affinities* [81], among others.

The general thesis of this dissertation is that technological art can be thought to inhabit a third space of artistic production and technological research and development lying on a spectrum of practice between the traditional arts (art that uses traditional mediums) and engineering, with computer science and human-computer interaction taken as engineering disciplines. This configuration establishes technological art as participating in a space of artistic production, research, and innovation, as opposed to a being a movement within the contemporary art system. That said, the perhaps more interesting aspect of this work is in articulating the tensions and dynamics within this way of situating technological art. This dissertation combines

[1] *New Art/Science Affinities* was written and designed in one week by four authors and two designers using a collaborative authoring process known as a 'book sprint.' The idea of book sprinting is derived from 'code sprinting,' a method in which software developers gather together in a room to work intensely on an open source project for a limited period of time. Lead author of *New Art/Science Affinities* Andrea Grover places this book about contemporary art within the context of the the larger cultural landscape described above:

> The book sprint method was adopted in order to understand this very moment in art, science and technology hybrid practices, and to mirror the ways Internet culture and networked communication have accelerated creative collaborations, expanded methodologies, and given artists greater agency to work fluidly across disciplines [130].

history, practice, and evidence in order to surface mechanisms, rationales, and vocabularies that articulate the potentials of technological art with respect to both artistic production and technological research and development. Throughout the chapters, I investigate the literature in relevant areas of disciplinary history, art history, design studies, and creativity studies. The value of this construction of technological art as both artistic production and technology R&D is that it allows us to consider possibilities for both emergent art and emergent technologies along a spectrum between artmaking and technology development practices.

Technology development is primarily the domain of engineering, taken broadly to include computer science, human factors, and related disciplines such as human-computer interaction. The arts and engineering are oppositionally mapped along the spectrum of disciplines primarily because of engineering's scientific foundations, which are absent in our conventional concept of the arts. Yet from the cases described in this introduction we can see evidence of art and engineering coming together as building disciplines. In chapter 2, I establish the common roots of art and technology development through the original meanings of the words techné and ars as skill, particularly as applies to practice-based skill. This chapter describes the dynamics and tensions in the relationship between art and technology today by establishing three historical splits in the trajectories of what we now understand art and technology development to be. In particular, I chronicle the hesitancy of the contemporary art system to accept technological art as a genre or movement, in the way that it has assimilated other activities such as performance art and video art. In chapter 3, I review the development of practice at the intersections of art and technology which support this combined space of artistic production and technological research and development.

After this groundwork is laid, Ch. 4 describes my piece, *Robotany*, and the contributions it makes toward understanding interactions with technology. Specifically, I use a reflective methodology based on phenomena occurring during the exhibition of the piece to derive a framework of interpretation of interactive art. I then describe how this framework translates to support the interpretation of interactive technologies. Chapter 5 continues with a description of my in-progress art installation, *Jade*, showing how the work of creating it led directly to a series of novel technologies that have been incorporated into a patent application filing through Georgia Institute of Technology. I take a closer look at the process of creating *Jade* in Chapter 6, and I compare it to a parallel process whereby an engineering team created similar technologies. This work is part of a larger comparative case study of the work practices of arts and engineers as they invent technologies that I undertook through a grant from the NSF CreativeIT program. [2] This work has led to an evidence-based vocabulary describing work processes and practices along the spectrum between the arts and engineering. In the next and final chapter, I explicitly describe the dynamics at play in this third space of artistic production and technological research and development and how they lead to emergent work.

The intended audience of this work includes the technological art community, as well as artists and engineers wishing to engage with this community. Scholars of technological art interested in the underdeveloped histories of the field as conventionally told will be interested in Chapter 2, which gives a detailed historical description of the origination of the fields we now come to understand as art and technology from the terms "techné" and "ars," the disciplinary combinatorics that followed, and the history and dynamics of the rejection of technological art from the contemporary art system. Interested engineers and others outside of the technological art field can find a description of the relationships between art and technology that coalesced into

[2] See this page on the NSF web site for more information about the CreativeIT program: `http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=501096` [139].

technological art in Chapters 2 and 3. Researchers interested in the potential contributions of technological art to technology research and development can find examples from my work in Chapters 4 and 5. Researchers, practitioners, project managers, and educators interested in patterns of creative process along the spectrum between art and engineering will find this contribution in Chapter 6. Readers interested in the dynamics of emergence through technological art practice can find an evidence-based description in Chapter 7, the conclusion.

CHAPTER II

DISCIPLINARY ORIGINS, OR THE THREE SPLITS

2.1 Introduction: Scanlan, Richards, and Klein

In 2003, artist Joseph Scanlan used a gallery space to process consumer byproducts into high-grade potting soil, which he then sold through the gallery (Figure 12). The process took five years of research and development, resulted in a patent [173], and was developed into a commercial product. Scanlan's *Paydirt* holds a multiplicity of meanings and implications. In addition to being an art piece and a technological innovation, *Paydirt* can be seen as a metacommentary on the relationship of the artist to the contemporary gallery system, a do-it-yourself ecological project, and a satire on the status that the patent and innovation system can bring.

Catherine Richards's art piece, *Method and apparatus for finding love* (2002, Figure 13) is a patent application to the U.S. Patent Office [164]. Her application both challenges and utilizes the patent system to assist in the pursuit of love. The application cites Marcel Duchamp's prior art, *The Bride Stripped Bare by Her Bachelors, Even* as a proposed apparatus for the transmission of desire. As of this writing, Richard's application is cited in five issued patents, including one from Microsoft Corporation.

Modernist painter Yves Klein holds a patent. It is commonly thought that he laid an intellectual property claim to the color International Klein Blue. His *brevet d'invention* does not describe the chemical composition of the pigment, but the procedure of smearing it on the bodies of models and transferring the imprint to a surface. The patent also covers "A titre de produits industriels nouveaux, les décorations ou

Figure 12: Joseph Scanlan's *Paydirt*, 2003.

Figure 13: Image from Catherine Richards's U.S. Patent Application *Method and apparatus for finding love*, 2002.

Figure 14: New interactions with technologies circa 1960. Yves Klein's *Anthropométrie de lépoque bleue.*

intégrations architecturales obtenues par application du procédé spécifié" (new industrial products, decorations, or architectural elements obtained by applying the method specified) [95] (Figure 14).

As the previous chapter illustrates, visual artists as a group are skilled in technical work. Artists as a whole have traditionally worked with industrial technologies such as paint and pigment chemistry, metalworking equipment, and kilns, as well as materials such as metals, resins, and coatings. Many post-industrial visual artists use high technology as both medium and highly-charged cultural material. The work of these artists often bleeds into technological development as they create new technologies and new interactions with technologies in the course of their projects. On the other hand, we can see tensions erupting into humor as artists Richards, Scanlan, and Klein

Figure 15: Paleolithic spearthrower.

approach the role of technology developers. Why? What are the intersections and the tensions between the worlds of art and technology development?

2.2 Etymology

Humans have been making art and technology since prehistory, though whether an object is categorized as art or as technology follows a culturally determined spectrum. Is this Paleolithic utensil (Figure 15) a combination of art and technology? Is the horse leaping off the handle simply for decorative purposes? Or is the gesture a symbolic instruction set for using the utensil? Hermeneutically, our interpretations of this utensil say as much about our culture now, arguably more, than Paleolithic culture.

The timeline in Figure 16 plots the various definitions of "art" and "technology" historically according to when they appeared in the English language per the Oxford English Dictionary (OED) [3, 8]. Note that "art" in the sense of the fine arts or visual arts did not appear until the nineteenth century. The primary definition of art throughout history is "skill." Definition I. of "art" in the OED reads, "Skill; its display, application, or expression," with definition I.1 reading, "Skill in doing something, esp. as the result of knowledge or practice." The OED lists an obsolete

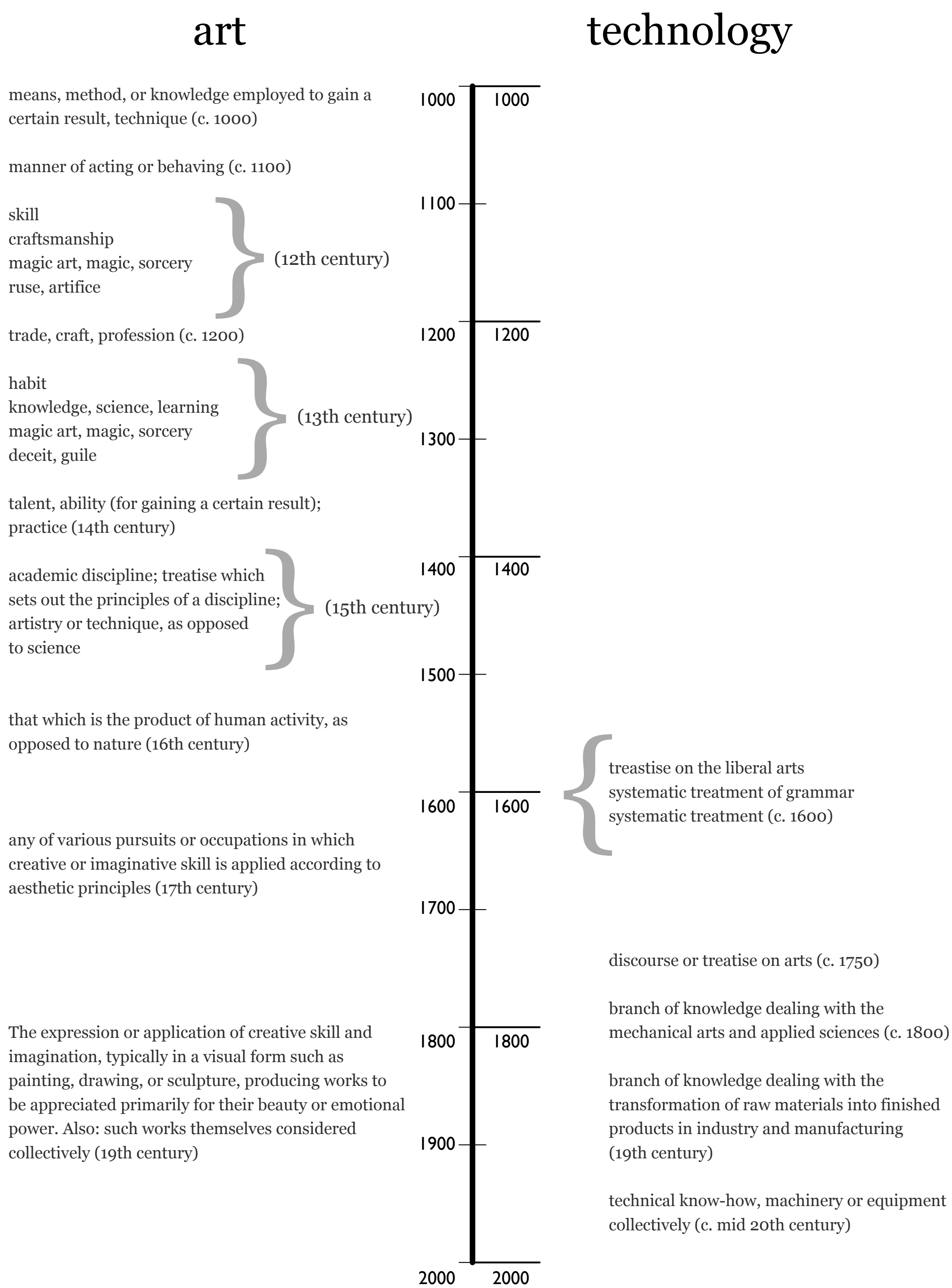


Figure 16: Timeline of the definitions of the terms "art" and "technology." All text is directly quoted from the OED entries for "art" [3] and "technology" [8].

definition as definition 2: "Skill in the practical application of the principles of a particular field of knowledge or learning; technical skill. Obs." This cluster of definitions of art as skill concludes with definition 3a., "A practical application of knowledge; (hence) something which can be achieved or understood by the employment of skill and knowledge; (in early use also) a body or system of rules serving to facilitate the carrying out of certain principles," and definition 3b., "A practical pursuit or trade of a skilled nature, a craft; an activity that can be achieved or mastered by the application of specialist skills; (also) any one of the useful arts."

These definitions center on the concept of the skilled practical and technical application of "knowledge or practice" or "the principles of a particular field of knowledge or learning." If this "field of knowledge or learning" were to be science, then we would have the contemporary definition of engineering. ABET (formerly the Accreditation Board for Engineering and Technology) defines engineering as "the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind" [143]. The word "technology" does not appear in the ABET definition, or for that matter in the OED definition of "engineer" [4], although, in contemporary usage and practice, we situate the development of technology within the domain of engineering.

The cluster of terms that are precursors to "engineer," i.e. "enginour," "engyneor," "engyneour," "engynour," "yngynore," appeared in the Middle Ages from the Latin *ingeniator*, meaning one with *ingenium*, the ingenious one. These terms originally referred to one who designs and constructs mechanical military machines ("engines," for example, catapults), and were integrated into the domain of the mechanical arts. The word evolved to include craftspeople, carpenters, and architects [4].

The bridge toward the modern definition of "art" as referring to fine art appears in definition 7 of "art" in the OED: "Any of various pursuits or occupations in which creative or imaginative skill is applied according to aesthetic principles." This definition evolved into definition 8, "The expression or application of creative skill and imagination, typically in a visual form such as painting, drawing, or sculpture, producing works to be appreciated primarily for their beauty or emotional power." A note by definition 8 reads, "Although this is the most usual modern sense of art when used without any qualification, it has not been found in English dictionaries until the 19th cent. Before then, it seems to have been used chiefly by painters and writers on painting."

The word "technology" appears in English usage by the seventeenth century [8]. Its emergence corresponds to the rise of the use of the suffix "-logy" in English and the association of "art" with skill of a particular creative or imaginative nature (though not yet in the sense of fine art) [3]. Throughout the seventeenth and eighteenth centuries, "technology" was used to designate a "systematic treatment" or "treatise'," i.e. a systematic exposition of the principles of a subject, particularly grammar, rhetoric, the liberal arts, or practical arts. The word was associated with "terminology," especially "the terminology of a particular art or subject; technical language or nomenclature" [8, def. 2]. An association with the mechanical arts occurred circa 1800, in roughly the same time period that the concept of the fine arts emerged.

The root of "technology" is the ancient Greek $\tau\varepsilon\chi\nu\eta$ (written in English as "techné"). $\tau\varepsilon\chi\nu\eta$ is the ancient Greek term for "art, craft" [6]. It is listed in the OED as derived from "the Indo-European base of Sanskrit *taks-* to fashion, *taksan* carpenter, ancient Greek $\tau\varepsilon\kappa\tau\omega\nu$ carpenter (see TECTONIC *adj.*), classical Latin *texere* to weave (see TEXT *n*)" [7]. $\tau\varepsilon\chi\nu\eta$ became *ars* in Latin which in turn became "art" in English. $\tau\varepsilon\chi\nu\eta$ also evolved directly into the English term "techné," defined by the OED as "an art, skill, or craft; a technique, principle, or method by

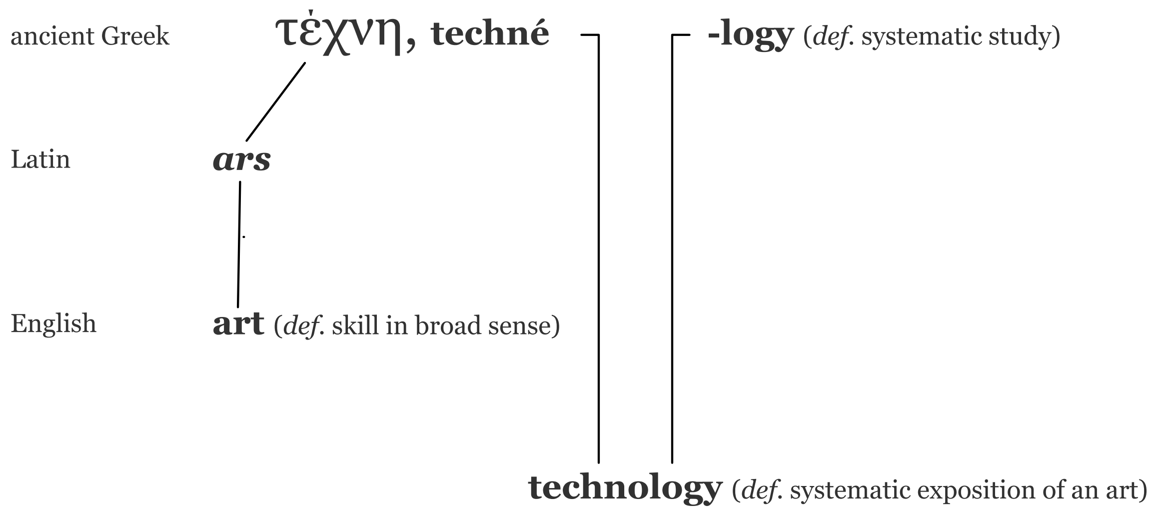


Figure 17: Diagram of the premodern development of the terms "art" and "technology."

which something is achieved or created. Also: a product of this, a work of art [6]." Note that the "work of art" in this definition refers to an artifact or discipline created through craft and practical skill, not to a work of fine art. The suffix of "technology," -$\lambda o \gamma \iota \alpha$ ("-logy") denotes a systematic exposition [2]. The suffix comes from $\lambda o \gamma o \varsigma$ ("logos"), or "word, discourse" [5]. So technology was originally a systematic exposition of an art. A conceptual diagram of this evolution appears in Figure 17.

The application of the words "art" and "technology" to refer to a broad category of skill-based practices and their resulting work endured until the nineteenth century, when our contemporary understandings of art and technology were differentiated from this broad understanding. The definitions of both art and technology continued to carry with them senses of technical skill and technique, as well as the practical application of principles. By the twentieth century, however, the terms had been carried to their extremes on polar ends of the spectrum of disciplinary experience, with technology referring to a skill-based, practical application of scientific principles and art as a distinctly nonscientific, skill-based application of creativity, expression, and imagination.

2.3 Premodern "art"

In the early 1950's, Renaissance scholar Paul Oskar Kristeller published an influential essay titled "The Modern System of the Arts" [99, 100]. In this essay, Kristeller traces the premodern concept of the arts and discusses the emergence of the modern concept of the fine arts during the eighteenth century. Near the beginning of the essay, Kristeller writes:

> The Greek term for Art ($\tau\varepsilon\chi\nu\eta$) and its Latin equivalent (*ars*) do not specifically denote the "fine arts" in the modern sense, but were applied to all kinds of human activities which we would call crafts or sciences. [99, p. 498]

Larry Shiner, Professor of Philosophy, History, and the Visual Arts, expands on Kristeller's thesis in his own book, *The Invention of Art*. He further describes the concept of *techné* and *ars* in the first chapter "The Greeks Had No Word for It":

> *Techne/arts* embraced things as diverse as carpentry and poetry, shoemaking and medicine, sculpture and horse breaking. In fact, *techne* and *ars* referred less to a class of objects than to the human ability to make and perform. [180, p. 19]

Kristeller and Shiner argue that the premodern sense of art underwent a radical transformation in the eighteenth century to form the modern system of fine art. Kristeller's and Shiner's scholarship demonstrates that there was no cohesive concept of fine art before the eighteenth century, though foundations upon which this new concept stood were emerging during the Renaissance. Kristeller and Shiner's thesis stands in opposition to philosopher and critic Arthur Danto's thesis [48] that a cohesive narrative of fine art has continued throughout the centuries to an end in postmodernism.

Kristeller and Shiner both cast the discussion of visual art as mimesis in Plato's *Republic* [150] and Aristotle's *Poetics* [16] in terms of art's broader definition of skilled fabrication. In Book X of the *Republic*, Plato condemns the mimetic arts, specifically painting and poetry, as mere imitation and thus not promoting truth and knowledge. Aristotle, in discourse with Plato, also characterizes painting and poetry as mimetic, and therefore a productive science. Mimesis, or imitation, for Aristotle is a natural part of learning and can be a first step toward more sophisticated understanding. The point for Kristeller and Shiner is that there is no characterization of painting, poetry, or performance in these works that would indicate that they held the status of fine arts as we understand it today. Plato's and Aristotle's arguments hold under the primary definition of the arts — as skilled fabrication.

This sense of "art" comes more into focus through Shiner's argument that the Aristotelian tradition gives an unnecessarily narrow portrayal of art (*techne*):

> In the *Nicomachean Ethics*, for example, Aristotle defined productive *techne* as the "trained ability of making something under the guidance of rational thought" (1140.9-10). Yet the general meaning of *techne* for Greek culture was not so narrowly rationalist or "technical" as Aristotle's formula suggests; instead, it included a dimension of spontaneous tact. This wider sense of *techne* as involving supple understanding had a parallel in the Greek notion of *metis*, the "cunning intelligence" of the hunter or of Homer's Odysseus. The ancient practitioners of various arts from medicine and military strategy to pottery making and poetry were neither "artisans" nor "artists" in the modern sense but artisan/artists: skilled and tactful practitioners. [180, p. 23]

Kristeller uncovers the fact that there is no evidence of any philosopher writing a systematic, dedicated treatise on the arts understood in the sense of the fine art. Nor does it seem that the arts understood in this sense were assigned a dedicated place in a disciplinary or knowledge schema — at least not until eighteenth century divisions of knowledge (most notably the *Preliminary Discourse* to the *Encyclopédia* of Diderot, i.e. Jean Le Rond d'Alembert's *Discours Préliminaire des Éditeurs*, 1751). Kristeller writes:

> Thus classical antiquity left no systems or elaborate concepts of an aesthetic nature, but merely a number of scattered notions and suggestions that exercised a lasting influence down to modern times but had to be carefully selected, taken out of their context, rearranged, reemphasized

> and reinterpreted or misinterpreted before they could be utilized as building materials for aesthetic systems. [99, p. 506]

Shiner describes the emergence of fine art in the eighteenth century in this way:

> To insist that there was a break between the premodern system of art and the modern system of fine art is not to deny the existence of continuities, especially since the elements of both fine art and craft were united under the old system. One can indeed find singular aspects of the modern ideals of fine art, the artist, and the aesthetic scattered among ancient Greek writers, Renaissance painters, and seventeenth-century philosophers, but those ideas only coalesced into a regulative discourse and institutional system at the end of the eighteenth century.

According to Kristeller and Shiner, concrete notions of the arts as fine arts before the Renaissance are modern or postmodern backreadings. The etymology of the term "art" described in the previous section supports Kristeller's and Shiner's thesis, as the notion of art involving a particular creative or imaginative skill or aesthetic principles does not appear until the seventeenth century. At this time, according to Shiner, art was recast from an act of construction or building to an act of special creation, which also called for the experience of art to be one of isolated contemplation and separation from context.

2.4 How the premodern work acts

Shiner describes the way artifacts and events that we would consider to be art in a contemporary sense were integrated into the lives of premodern society:

> Unfortunately, popular histories, museum displays, symphony programs, and literary anthologies encourage our natural bent to focus on whatever in the past seems most like the present and to pass over differences. For example, Renaissance paintings are almost always presented framed on museum walls or isolated on lecture hall screens or art book pages with little to remind us that almost all were originally made for a specific purpose and place —parts of altars or wedding chests, built into bedroom walls or council hall ceilings. . . .Viewing Renaissance paintings in isolation, like reading Shakespeare's plays out of literature anthologies or listening to Bach passions in a symphony hall, reinforces the false impression that the people of the past shared our notion of art as a realm of autonomous works meant for aesthetic contemplation. [180, p. 14]

Figure 18: Michelangelo's *The Last Judgment*, Sistine Chapel, painted 1537-41.

See Figure 18 for a famous example. As viewers, we are often presented with isolated images from Michelangelo's frescos. We need to remind ourselves that though we are used to viewing Renaissance paintings on museum walls or as isolated images, these were originally integrated into specific locations and contexts. Shiner describes the difference between viewing a contemporary performance and a premodern performance:

> For most of us, going to a performance of *Antigone* is an "art" experience like going to the symphony or ballet on a Saturday night. But when the ancient Athenians first witnessed *Antigone*, they did so as part of a religious-political festival, the annual "City Dionysia." Citizens received the price of a ticket from their township council and sat with their respective political "tribes" as they did at civic assemblies held in the same amphitheater. The priests of Dionysus, who performed sacrifices at an altar on the floor of the great amphitheater, sat in specially carved seats in the front row. . . The five-day festival opened with a great religious procession and ceremonies honoring the war dead, introducing war orphans raised at state expense, and recognizing Athens's allies and their tribute money. Only then did the contests begin, featuring nine tragedies, three satyr plays, five comedies and twenty choral hymns to Dionysus. [180, p. 19]

Shiner's depictions are rooted in a broader spectrum of cultural construction and situated in the lived experience of a public. Both art-making and art-experiencing were integrated into that continuum of experience.

2.5 Knowledge schemas and disciplinary histories

The ancient Greeks organized the human arts and sciences into a system of elementary disciplines called the "liberal arts": grammar, rhetoric, dialectic, arithmetic, geometry, astronomy, and music [99]. In medieval Europe, the liberal arts were divided into the trivium, which was composed of logic, grammar, and rhetoric, and the quadrivium, encompassing arithmetic, geometry, astronomy and music theory. At times, the trivium was combined with the threefold division of philosophy (logic, ethics, and physics) [99]. Hugh of St. Victor added the seven mechanical arts—weaving, armament, commerce, agriculture, hunting, medicine, and theatrics. Kristeller and Shiner describe the seven mechanical arts as having several subcategories. For example, the armament category included forging and architecture [99, 180]. Practitioners of the liberal arts were called *artista*, while practitioners of the mechanical arts were called *artifex* [180]. Both Kristeller and Shiner point out that the arts as we understand them are not grouped together or singled out in any of these schemes but scattered among various sciences, crafts, and other human activities that to our contemporary sensibilities seem to be of disparate nature. To illustrate how these medieval categories and roles are alien to contemporary disciplinary categories, Kristeller remarks that painters often belonged to the druggist guilds because they ground pigments, sculptors belonged to the goldsmith guilds, and architects belonged to the stone masons guilds [169, 99, 180]. These artists/artisans/*artifex* held various ranks and statuses, and many worked for patrons who often gave exacting specifications for the work, including content, design, size, and materials [180, pp. 28-30].

During the Renaissance, a small group of artists under court patronage did achieve a higher level of prestige. To adorn their palaces, Renaissance royalty needed artificers, the most sought-after being Leonardo, Michelangelo, Titian, and Dürer. During this time, Vasari produced a collection of biographies, mistranslated as *Lives of the Artists*. The correct title of this book, first published in 1550, is *Lives of the Most Excellent Painters, Sculptors, and Architects*. Shiner points out that this is a crucial difference. During the Renaissance there was no universal concept of the "artist" that separated "painters, sculptors, and architects collectively from glassblowers, ceramicists, and embroiderers" [180, p. 40]. Vasari used the term *artifice*, i.e. "artificer," to describe these roles [180, p. 40].

During the fifteenth and sixteenth centuries, painting and sculpture were sometimes considered to be under the mechanical disciplines and were at other times understood as liberal arts [99]. The work of Leonardo can thus be understood less as polymathic undertakings in separate disciplines than as a continuum of work. The integrated work of Renaissance painters in developing optics and anatomy can be seen in the same light. Shiner reports that

> Alberti and Leonardo projected an image of the artist as a "craftsman-scientist." Such knowledge was crucial to "invention," a term derived from classical rhetoric, which did not mean "creation" in the modern sense but the discovery, selection, and arrangement of content. [180, p. 46]

In contemporary terms, Fillipo Brunelleschi, the builder of the dome of the Basilica of Santa Maria di Fiore in Florence from 1420 to 1436 (Figure 19), was an engineer, architect, sculptor, goldsmith, watchmaker, and fortress builder. He was experienced in hydraulic constructions and mechanics, and expert in mathematics, i.e. the theory of proportions and perspective. In his *Commentarii*, circa 1447, Lorenzo Ghiberti, creator of the "Gates of Paradise" bronze doors of the Baptistry of San Giovanni (Florence Cathedral) (Figure 20), wrote that artists should be learned in construction, anatomy, optics, and theoretical and practical mathematics [169, pp. 18-19].

Figure 19: Basilica of Santa Maria di Fiore, showing the dome that Brunelleschi built from 1420 to 1436.

It is reported that Ghiberti's studio during the construction of the Baptistry doors was akin to an industrial laboratory. Painters, sculptors, engineers, and technicians apprenticed. Alongside stone-cutting, bronze-pouring, painting, and sculpture, apprentices were taught anatomy, optics, calculus, perspective, and geometry, as well as vault construction and canal digging [169, pp. 22-23]. Leon Battista Alberti established the idea that a "scientific conception of art" (i.e. perspective and proportion) established mathematics as the common ground of the painter and the scientist [13] in [169, pp. 18-19]. Painters during this time were collaborators on the production of scientific knowledge. Perhaps the most well-known example is Vesalius's *De humani corporis fabrica*, published in 1543 and illustrated by painters from Titian's studio [169, p. 29] (see Figure 22). German painter, printmaker, engraver, and mathematician Albrecht Dürer published instructions on how to use the compass and the square (1525), a study of fortifications (1527), and work on the proportions of the human body (1528) [169, p. 27]. His 1514 engraving *Melencolia I* features depictions of a magic square, a rhombohedron, and tools for geometry and architecture (on the ground below the figure) including a compass and a square (Figure 21).

Science and philosophy historian Paolo Rossi describes the milieu of the "mechanitians" of the sixteenth century. These artisans were the "goldsmiths, the carvers of

Figure 20: Ghiberti's *Gates of Paradise*, east doors of the Baptistry of San Giovanni, Florence, 1425-52.

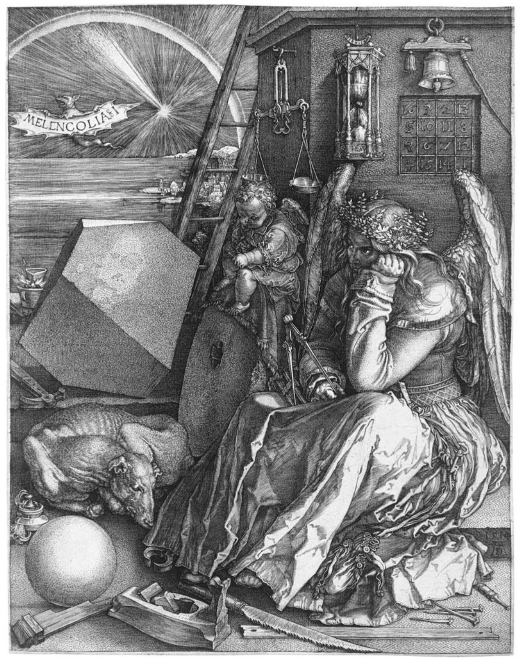


Figure 21: Dürer's *Melencolia I*, 1514.

precious stones, the alchemists, the watch makers, the printers, the organ-makers, the dyers [158, bk. I, chap. 24]." Much of their knowledge was formed autonomously and was considered common by the learned [169, p. 5]. However, there was a move by some prominent scholars and educators to recognize that the work of artisans, engineers, and technicians had knowledge value, and that acculturated people (acculturated men) should give up their disdain for "operations" or "practice" and study the techniques and the arts. Within this movement, there was a sense that building utilitarian objects and machines was a means of modifying or altering nature in a way that could contribute to the understanding of nature in a way that rhetorical or contemplative intellectual study could not [169, p. 11]. So while there was a prejudice in learned society against people who worked with their hands, there was a reversal among some sixteenth-century intellectuals and practitioners who thought that this work was more valuable than idle reasoning. Though writing in the seventeenth century, Diderot expressed this sentiment in his entry for "art" in the *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers* (Encyclopaedia

Figure 22: Page 190 from Vesalius's *De humani corporis fabrica*, 1543.

or a Systematic Dictionary of the Sciences, Arts and Crafts) that he authored with d'Alembert. Here Diderot points out the prejudice whereby "to turn one's attention to sensible and material objects" constitutes "a derogation of the dignity of the human spirit." This prejudice, according to Diderot, has led to a glut of "proud reasoners or useless contemplatives" . . . "and ignorant, lazy and disdainful, petty tyrants" [169, p. 12].

The medieval and Renaissance disdain toward the mechanical arts can be traced to Aristotle, as Rossi does, in *Politics*:

> Aristotle had excluded "mechanical workers" from the category of citizens . . . Thus the opposition . . . tended to break down on the basis of technique and science; that is between a knowledge oriented toward practice and use, immersed in material and useful objects, and rational knowledge oriented toward the search for truth. [169, pp. 13-14]

Even Leonardo had to confront this attitude. He is quoted in Rossi as writing:

> You [writers] have placed painting among the mechanical arts; to be sure, if painters were as capable of praising their work in writing as you are, I doubt that it would be under so base a designation. If you call it mechanical, because it is first manual in that the hands draw what they had in the imagination, you writers manually design with the pen what is found in your mind. [169, p. 29]

This is not to say that the "techno-artisans," to use Rossi's phrase [169, p. 15], of the fifteenth century were uneducated. The literature of artists, engineers, and master craftsmen included the writings of Brunelleschi, Ghiberti, and Leonardo, as well as Alberti's and Palladio's works on architecture, Dürer's two treatises on descriptive geometry and fortifications (1525 and 1527), and Tartaglia's work on ballistics (1537) [169, p. 16]. The approach of fifteenth-century techno-artisans differed from their medieval counterparts in that an articulation of science was not typically a part of the approach of the artisans of the Middle Ages. Artisans of the Middle Ages produced Roman basilicas and Gothic cathedrals as well as the water mill, windmill, plane, winder, compass, gun powder, spectacles, mechanical clock, and scale. Medieval technical writing focused on technique and was devoid of attempts at theoretical understandings, general principles, or verifiable and reproducible facts [169, pp. 31-33]. Art historian Erwin Panofsky, author of *The Life and Art of Albrecht Dürer*, cited in Rossi [169, p. 33], compares medieval technical writing with that of Alberti:

> A medieval treatise on architecture, for instance, whether covering the whole field or concentrating on a special problem, shows only what things can be done and how they should be done; it makes no attempt to explain to the reader why they have to be done in this peculiar way, let alone to supply him with a system of general concepts on the basis of which he may cope with problems not yet foreseen by the writer . . .
>
> This was precisely what a writer like Leon Battista Alberti proposed to do. Basing himself on Vitruvius, but varying, expanding and even correcting him in all directions, he derives his prescriptions from general principles such as practical purpose, convenience, order, symmetry and optical appearance. He divides the tasks of the architecture in different classes which, taken together, form a coherent and comprehensive system from city planning to the construction of fireplaces, and he tries to corroborate his statements both by deductive, though naturally not always critical, reasoning and by historical evidence. [153, pp. 242-43]

Rossi compares the practices of medieval artisans with developments during the Renaissance:

> the creators of those admirable masterpieces moved on a plane of artisan empiricism which always remained at the level of practice . . . the collaboration between technical and scientific knowledge that was ushered in at the beginning of modern times is to be considered as one of the central and fundamental aspects of the new culture. [169, p. 35]

2.6 The Querelle (the first split)

Over the next two centuries, two splits cleaved the liberal arts and mechanical arts disciplinary schema. The first of these splits emerged during the seventeenth century, when the sciences were recognized as a distinct domain of knowledge based on mathematics and systematic physical experimentation. At least three dynamics were at play in this split: (1) The prejudice for thinking over making or working with one's hands had deprecated the mechanical arts in the disciplinary schema [180]; (2)

The techno-artisans of the Renaissance, because of the theoretical bases that they applied to their investigations, escaped this deprecation [169]; (3) The primacy of the scientific mode of inquiry and the scientific disciplines were championed in the 1690s by scholarly advocates interested in shaking off the authority of classical antiquity that had weighed on academic life during the Middle Ages and Renaissance [99]. This debate, known as the *Querelle des Anciens et des Modernes* set rationalist epistemologies at odds with hermeneutic and experiential knowledge-making, ultimately placing the arts and humanities on a separate developmental trajectory than the sciences. Kristeller summarizes the dynamics of the Querelle:

> a point by point examination of the claims of the ancients and moderns in the various fields led to the insight that in certain fields, where everything depends on mathematical calculation and the accumulation of knowledge, the progress of the moderns over the ancients can be clearly demonstrated, whereas in certain other fields, which depend on individual talent and on the taste of the critic, the relative merits of the ancients and moderns cannot be so clearly established but may be subject to controversy. [99, p. 525]

Science was thus an effective tool in demonstrating the superiority of modern knowledge over ancient knowledge. This pulled scientific pursuits out of their contextualized milieu and foregrounded science as an independent and prioritized discipline. Kristeller also cites Charles Perrault's *Parallele des Anciens et des Modernes* of 1688-96. These four volumes divide knowledge into the following system: the three visual arts (painting, sculpture, and architecture), eloquence, poetry, and the sciences (including music). In his preface, Perrault asserts that progress in eloquence and poetry cannot be understood with the same confidence as attends the sciences [99, pp. 526-527].

The success of these arguments led to an intellectual shift felt throughout humanity that would ultimately prioritize the type of consciousness that anthropologist Catherine Lutz describes as entailing "notions of rationality, objectivity, control of attentional processes in the interest of solving technical problems, nonemotionality, and linear thought" [112, p. 73]. Kristeller continues his discussion of the Querelle:

> Thus the ground is prepared for the first time for a clear distinction between the arts and the sciences, a distinction absent from ancient, medieval or Renaissance discussions of such subjects even though the same words were used. In other words, the separation between the arts and the sciences in the modern sense presupposes not only the actual progress of the sciences in the seventeenth century but also the reflection upon the reasons why some other human intellectual activities which we now call the Fine Arts did not or could not participate in the same kind of progress. [99, p. 526]

Kristeller describes another writing of Perrault, *Le Cabinet des Beaux Arts* (1690). Here Perrault rejects the organization of the liberal arts in favor of the "beaux arts" categories Eloquence, Poesie, Musique, Architecture, Peinture, Sculpture, Optique, and Mechanique. Kristeller concludes:

> Thus on the threshold of the eighteenth century we are very close to the modern system of the fine arts, but we have not yet quite reached it, as the inclusion of Optics and Mechanics clearly shows. The fluctuations of the scheme show how slowly emerged the notion which to us seems so thoroughly obvious. [99, p. 527]

Collaboration between techno-artisans, master craftsmen, and scientists had continued to develop throughout the Renaissance. The theoretical tradition of the Renaissance techno-artisans joined well with the mathematical and principle-based foundations of science. Furthermore, the rising importance of solving practical problems through instrumentation (epitomized in the work of Galileo using telescopes and other devices for empirical observation and time measurement) and the increasing economic importance of some sectors of the traditional mechanical arts, such as metallurgy, mining, cartography, and navigation, led to a re-evaluation of technical knowledge. There was an increasing demand for the services of some artisans and engineers, who experienced a rise in social prestige similar to that of some Renaissance court painters and sculptors [169, pp. 35-38]. So while earlier in the fifteenth century the category of the artisan included a spectrum of roles in the mechanical arts, which we would recognize as ranging from art to craft to engineering, by the late Renaissance, science's need for principle-based technical know-how and instrumentation pulled the techno-artisans out of the artisan's milieu and joined them with scientific practice in engineering roles that evolved in ever-increasing specialization. This coincides with the addition of the suffix "ology" to "techné" to form the term "technology", or a systemization of techné.

2.7 The category of fine art (the second split)

The shuffling of disciplinary categories continued through the eighteenth century. The table of knowledge from Ephraim Chambers's *Cyclopedia* of 1728 (Figure 23) still included painting under the category of optics and sculpture under mechanics (trades and manufacture). But as described in the previous section, seventeenth-century developments in the sciences and the resulting academic Querelle established deep divisions between the sciences, humanities, and arts. In 1746, Charles Batteux published an influential book, *Les beaux arts réduit à un même principe* (The fine arts reduced to a single principle) that established the term "beaux arts" as encompassing music, poetry, painting, sculpture, and dance. Batteux supported this grouping with an explicit principle —that the beaux arts were involved with the imitation of nature's beauty. Batteux differentiated between three categories of arts: the mechanical arts, which provide utility; the beaux arts, which provide pleasure; and eloquence and architecture, which provide both utility and pleasure. Batteux also established two other criteria to differentiate the beaux arts from the other arts: genius, which is the imitation of nature's beauty, and taste, which is a judgment of how well nature's beauty is imitated [180, p. 83].

By 1751, the modern beaux art category had arrived. Diderot and d'Alembert's *Encyclopédia* begins with a comprehensive table of knowledge based on Francis Bacon's division of the human faculties into memory (history), reason (science), and imagination (poetry) [100, p. 22], functionally a division into the liberal arts, the sciences, and the arts. This table exclusively groups the fine arts of poetry, painting,

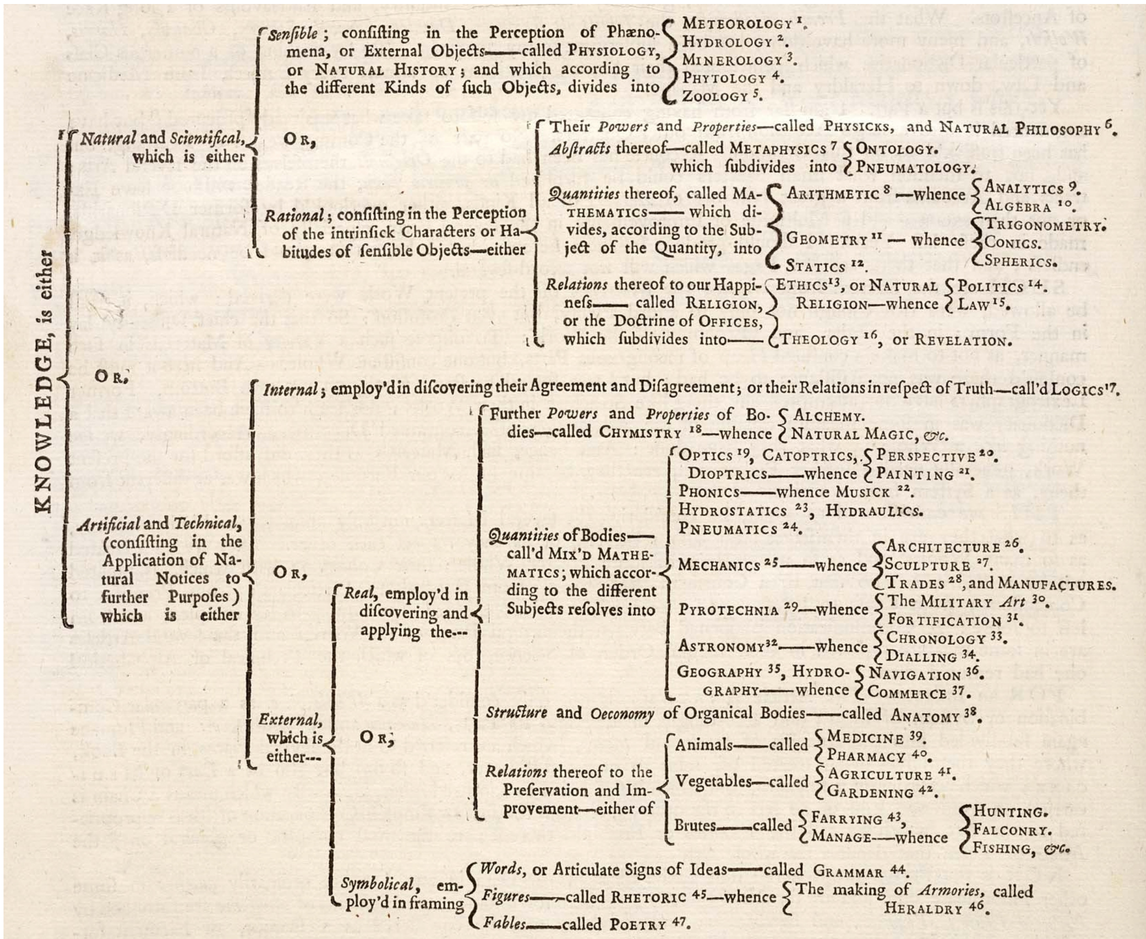


Figure 23: Table of knowledge from Ephraim Chambers' *Cyclopedia*, 1728. As appears in Shiner [180, p. 81]. Note that Painting is under the category of Optics and Sculpture is under Mechanics.

sculpture, engraving, and music under the defining faculty of imagination (Figure 24). Between 1750 and 1770, the category of the beaux arts spread throughout Europe, becoming *belli-arti* in Italian, *schöenen Künste* in German, and "fine arts" in English [180, pp. 83-84].

This disciplinary reorganization and association of genius and imagination with the fine arts had implications. It separated fine art from craft and artist from artisan, deprecating the later within society. Genius was conceptually separated from rule-following, and inspiration from technical skill and utility. Institutions such as art museums and the art market coevolved with the emergence of fine art practice and

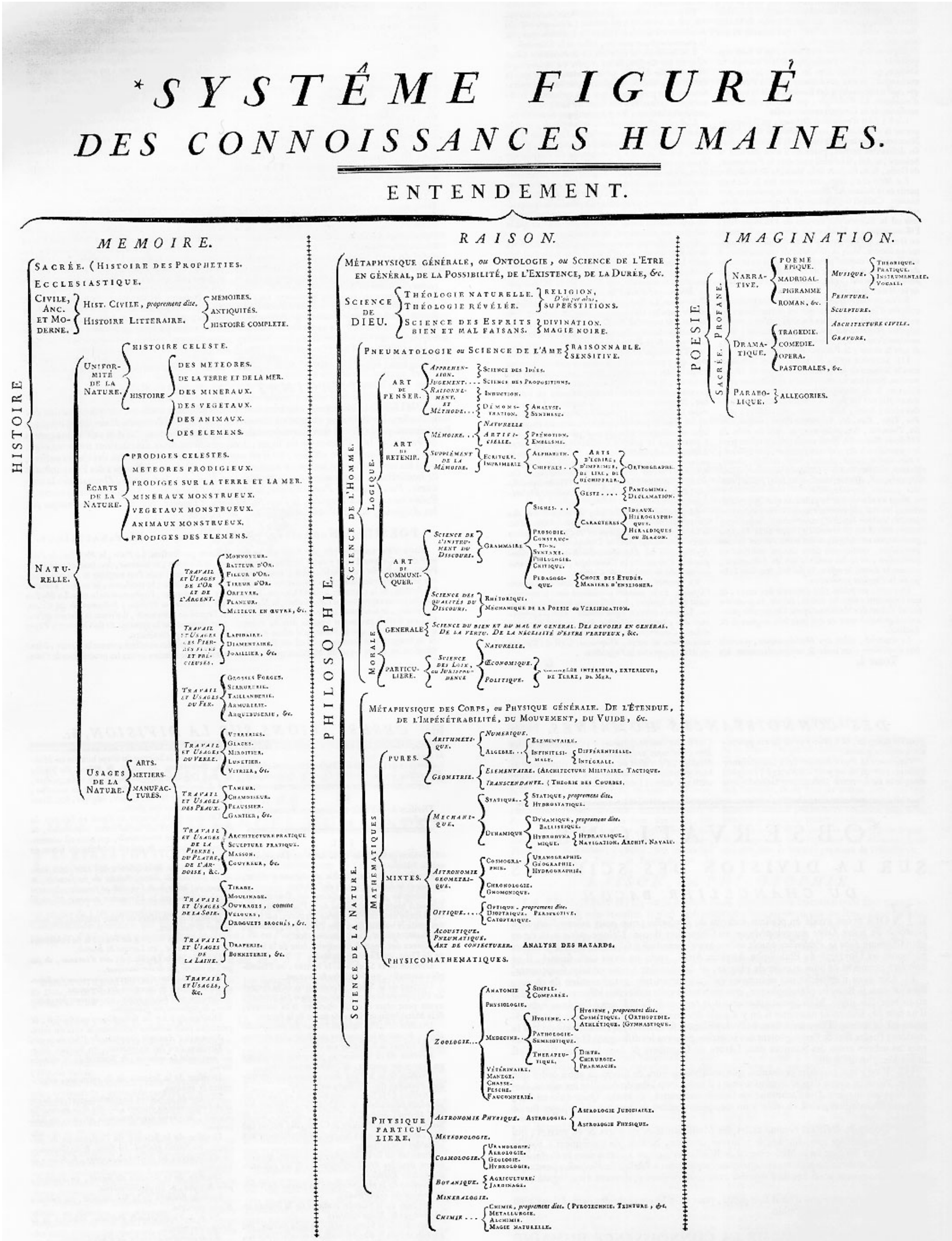


Figure 24: Diderot and d'Alembert's table of knowledge from the *Encyclopédia*, 1751 showing the fine arts in their own exclusive category. As appears in Shiner [180, p. 85].

Figure 25: Johan Zoffany's *The Academicians of the Royal Academy*, 1771-72. Painted for George III. As appears in Shiner [180, p. 101].

formed what Kristeller and Shiner call the modern art system [99, 180]. Art that had become fine art was no longer functionally integrated into society. Instead, works are isolated in protected cultural venues such as museums, galleries, and academies. Shiner writes:

> . . . prior to the eighteenth century neither the modern ideas of fine art, artist, and aesthetic nor the set of practices and institutions we associate with them were integrated into a normative system, whereas after the eighteenth century, the major conceptual polarities and institutions of the modern system of art were largely taken for granted and have been regulative ever since. Only after the modern system of art was established as an autonomous realm could one ask, "Is it really art?" or, "What is the relationship of 'art' to 'society'? [180, p. 14]

While the sciences split from the liberal and mechanical arts in the seventeenth century, art split from the liberal arts, craft, and notions of utility in the eighteenth century into an exclusive category labeled "fine art." These reorganizations led to the contemporary disciplinary categories of science, humanities, and fine art. From the eighteenth through early nineteenth century, civil and mechanical engineering evolved out of the ranks of the artisans.

2.8 The twentieth-century art system (and the third split)

The story of art described above might seem to imply that once the fine arts were extracted from the background of artist/artisan creation, they remained a pure pursuit of art objects in the contemporary sense. The actuality is of course not so absolute. Once the fine arts were established, artwork became subject to a dynamic of assimilation and resistance [180] as some forms were accepted into the modern art system and some were rejected. Photography stands as an example of an art form assimilated into the fine arts category, whereas illustration and typography, for example, were not.

While many individuals contributed to the invention of photography, the painter and printmaker Louis Daguerre refined the process to the level of a breakthrough invention in 1838. Though Daguerre was not trained in science or engineering, he became one of the first artist-inventors of the modern age. The French government bought the daguerreotype patent and immediately placed it in the public domain.

The invention of photography is credited with setting modern art, particularly painting, on a trajectory free from realistic depiction. The intersection of photography, mechanics, painting, and sculpture that emerged after photography's invention is less frequently articulated. This work resonates with Renaissance intersections of perspective, optics, anatomy, and painting as well as prefigures contemporary work at the intersections of art and technology.

2.8.1 The strange case of Marey and Muybridge

Daguerre's nineteenth century discovery of a reliable photographic process directly preceded later century developments in kinematics and scientific records of motion.

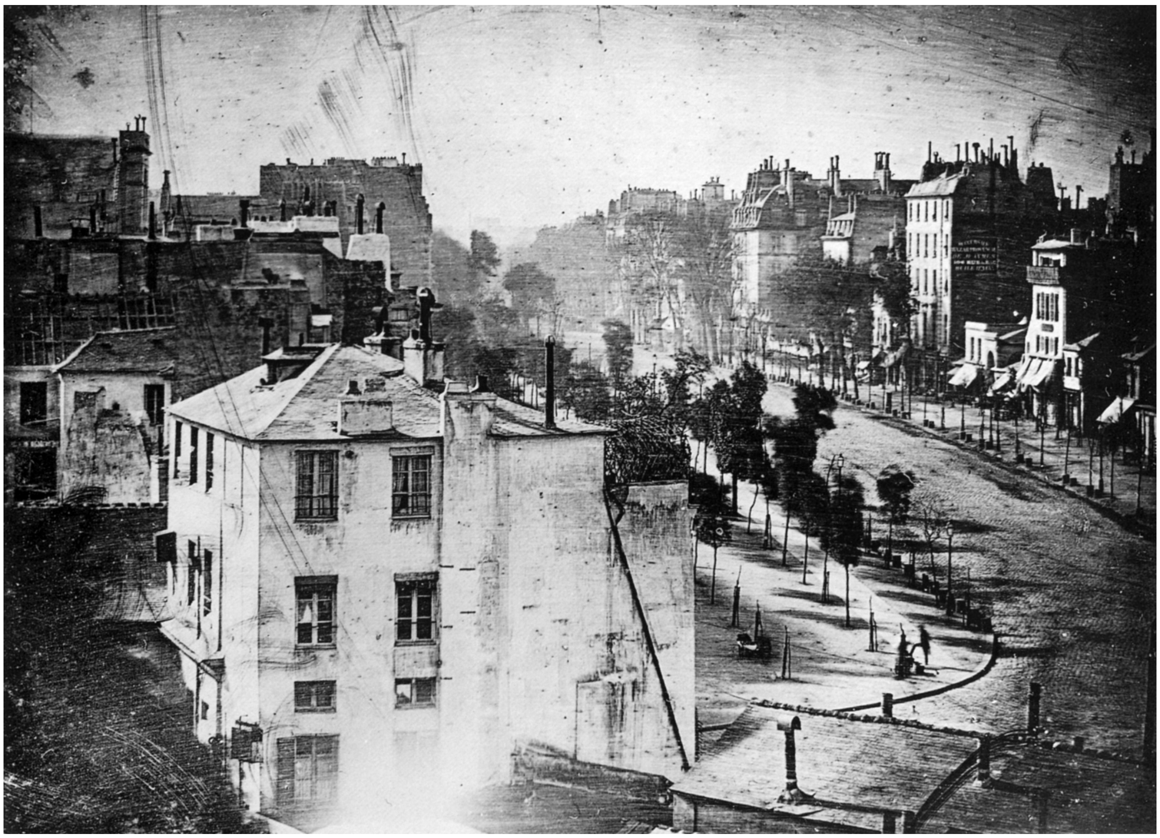


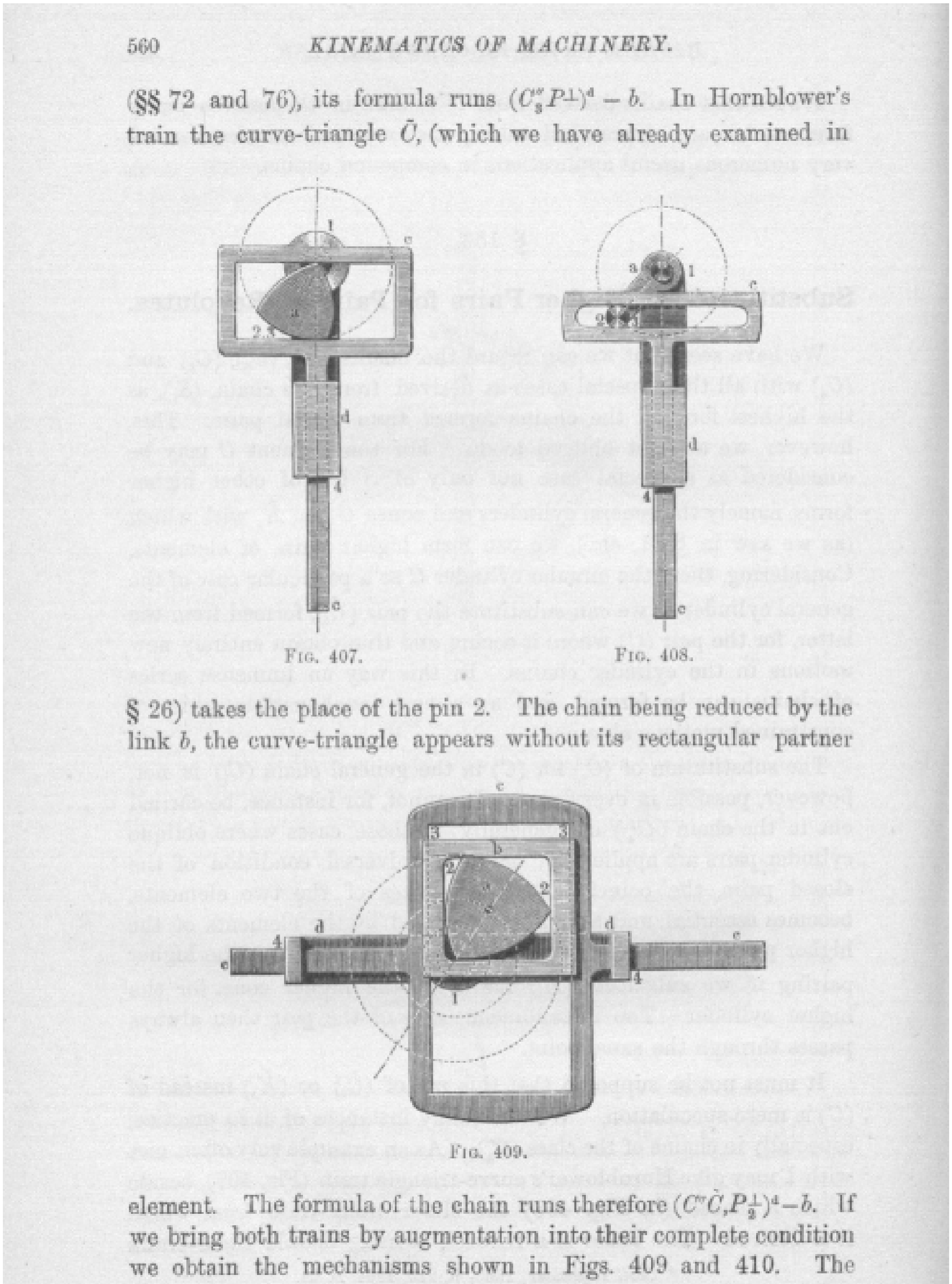
Figure 26: *Boulevard du Temple* by Daguerre, 1751.

In the 1870's, German professor of kinematics, Franz Reuleaux, developed the first comprehensive analysis of mechanical devices and theorized the primary relationships between mechanical elements to ensure the most economical and frictionless work advantage [1] (Figure 27) [162]. Whereas mainstream approaches to machine design at that time depended on experience and trial and error, Reuleaux's work abstracted and systematized the elements of machine design [30, pp. 220-221].

In the 1880s, shortly after Reuleaux's book *Kinematics of Machinery* was published, scientist, physiologist, and inventor Étienne-Jules Marey developed chronophotography to systematically study the mechanics of animal and human movement. Through chronophotography, Marey extensively documented, analyzed, and catalogued the movement kinematics of living creatures in similar spirit as Reuleaux's study of machine mechanisms. Marey's work also hearkens back to Vesalius' human anatomy studies during the Renaissance (see Figure 22 and Figure 28).

Marey had initially used electromechanical devices of his own making to better understand insect motion, the flight of birds, and the paces of horses (Figure 29). Marey concluded that there was a moment when all four hooves of a galloping horse were off the ground at the same time. He published these results in a book in 1873 [122]. That year, the former governor of California Leland Stanford, a businessman and race-horse owner, read Marey's book and hired landscape photographer Eadweard Muybridge to settle the question of whether all four hooves left the ground during the gallop. Muybridge was able to capture all four hooves off the ground using a photographic image of a horse trotting. In 1878, to capture the motion of a galloping horse, Muybridge lined a track with numerous glass-plate cameras. The shutters were

[1] Cornell University houses the most complete set of a series of simple mechanical models beautifully built by Reuleaux. Images of the Reuleaux Collection of Mechanisms and Machines can be found through Cornell's *Kinematic Models for Design Digital Library* at `http:\\kmoddl.library.cornell.edu`.



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(§§ 72 and 76), its formula runs $(C_3^{\prime\prime}P^{\perp})^d - b$. In Hornblower's train the curve-triangle $\tilde{C}$, (which we have already examined in

§ 26) takes the place of the pin 2. The chain being reduced by the link b, the curve-triangle appears without its rectangular partner

element. The formula of the chain runs therefore $(C''\dot{C},P\frac{\perp}{2})^d - b$. If we bring both trains by augmentation into their complete condition we obtain the mechanisms shown in Figs. 409 and 410. The

Figure 27: Page from Franz Reuleaux's *Kinematics of Machinery*, 1876 [162].

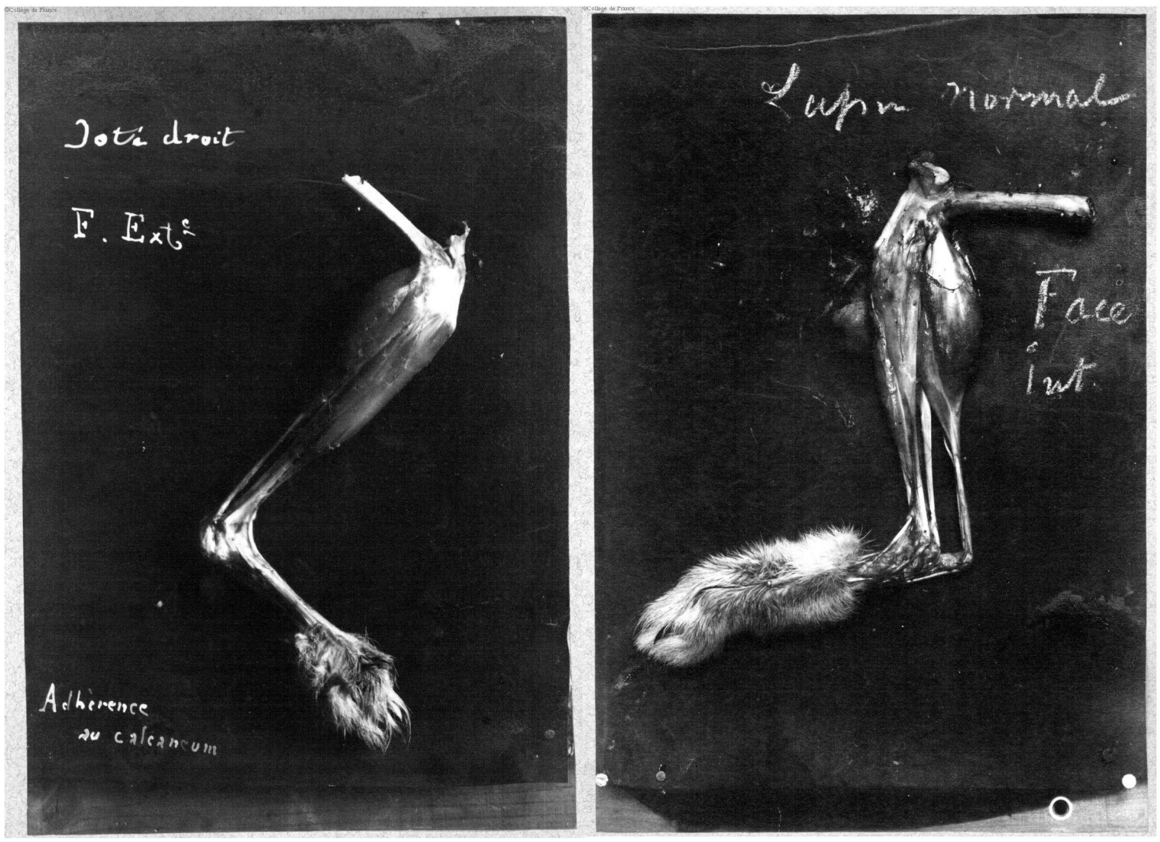


Figure 28: Research photographs by Marey made between 1887 - 1889.

triggered with wires as the horse passed. He concluded that all four hooves did indeed leave the ground during the gallop. See Figure 30 [135].

In 1882, Marey invented a single chronophotography device to verify and refine his earlier results. Marey recorded the first series of live action photos (see Figure 31 and Figure 32) with a single camera by employing an altered rifle and a circular configuration of photographic plates (Figure 33), not unlike a contemporary View-Master toy.

Marey and Muybridge were exact contemporaries. They were both born in 1830 and passed in 1904. They visited each other's studios on several occasions, and their work ran nearly in parallel. Their common project of studying motion in humans and animals placed their work not only in discourse with each other, but created parallel roles for both men. Marey began this work from the position of a scientific researcher and engineer. He had invented various devices to conduct his motion studies, including the chronograph rifle. He studied the photographic output of his research and interpreted the data in them, however the work stands alone as artwork with the visual qualities of pattern and rhythm, tensions between repetition and divergence, and transparency and overlap (see Figures 31 and 32). Muybridge was a professional photographer who had gained an artistic reputation for his photographs of the Yosemite Valley and Alaskan inhabitants in the late 1860's. Yet when he answered Leland Stanford's request, he embraced systematic photographic studies and research of human and animal motion.

Both Marey and Muybridge published volumes on their research. Both men were inventors. Marey filed an application for a "Système de bateau auto-générateur de force motrice, par l'utilisation du mouvement des vagues" [121], a machine he invented to support his later research on the motion of steam. Muybridge held patents for methods and apparatuses for photographing objects in motion [137, 136] (Figure 34) as well as for a magic lantern [136]. Classifying one man as an artist and the

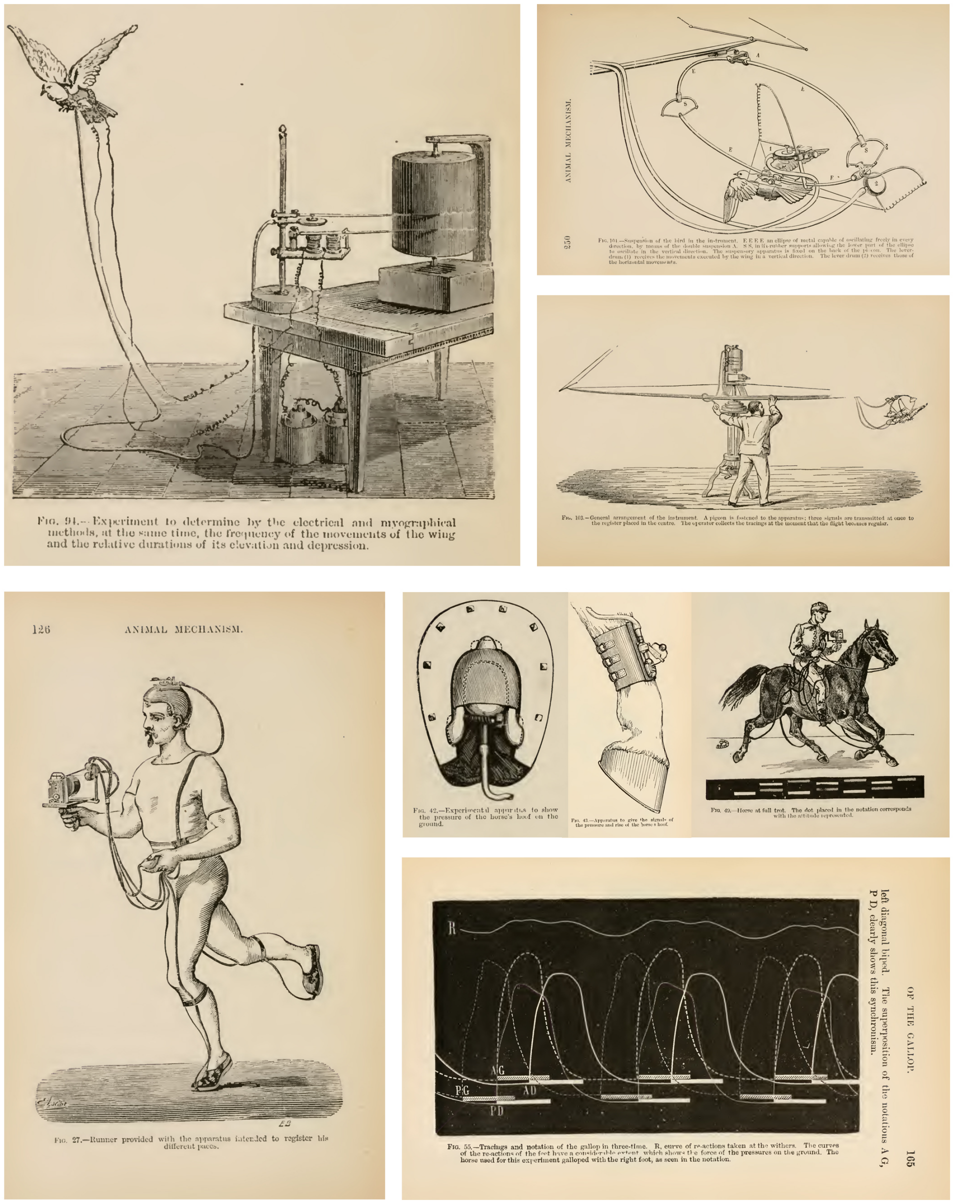


Figure 29: Collage of figures from Marey's *Animal mechanism: a treatise on terrestrial and aerial locomotion*, 1873 [122].

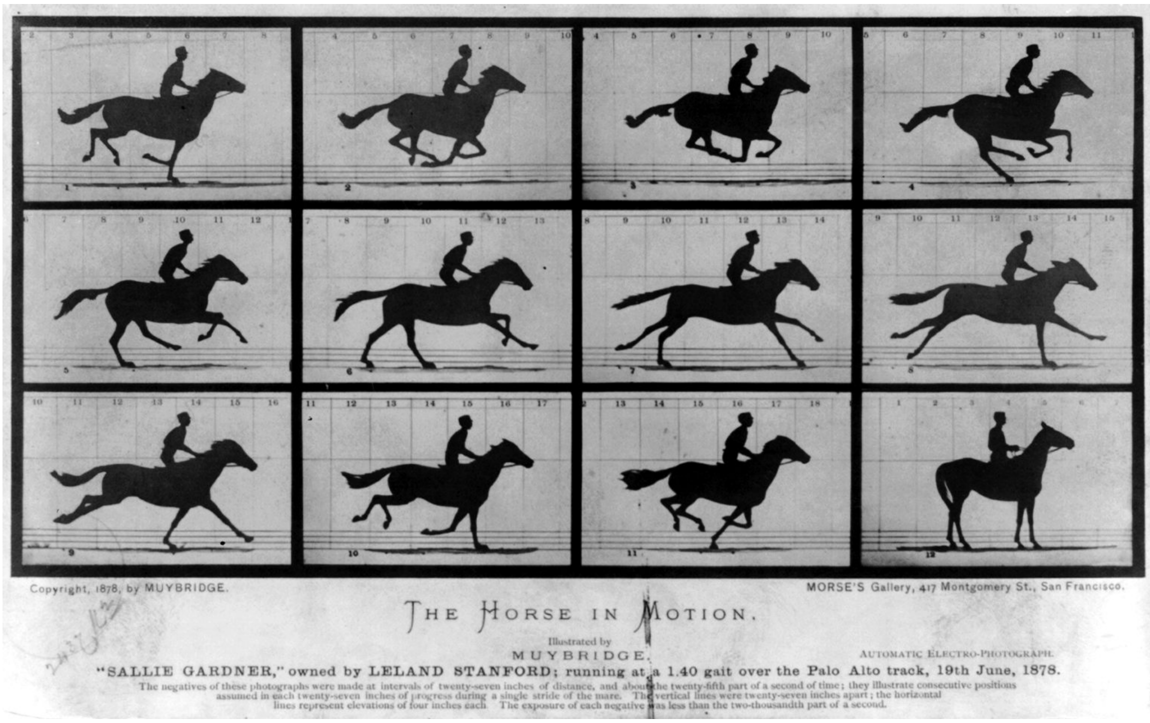


Figure 30: *The Horse in Motion* by Eadweard Muybridge. "Sallie Gardner," owned by Leland Stanford, running at a 1:40 gait over the Palo Alto track, 19th June 1878.

other as a scientist is a matter of identity. Both Marey and Muybridge were acting in the roles of scientific researchers, artists, and inventors who published their scholarly work. They both made significant contributions to the domains of science, art, and invention. Yet history classifies Muybridge within the artistic canon as one of the leading figures in nineteenth-century photography and Marey within the scientific canon.

2.8.2 Marey, Duchamp, and the modern art system

The ends of Marey's and Muybridge's careers coincided with the beginning of Marcel Duchamp's. Duchamp is a leading artist of the twentieth century; a conceptual and technical pioneer whose interventions into the establishment of the twentieth-century art system continue to be investigated by artists in his wake. During an interview with Pierre Cabanne, Duchamp points to Marey as an influence:

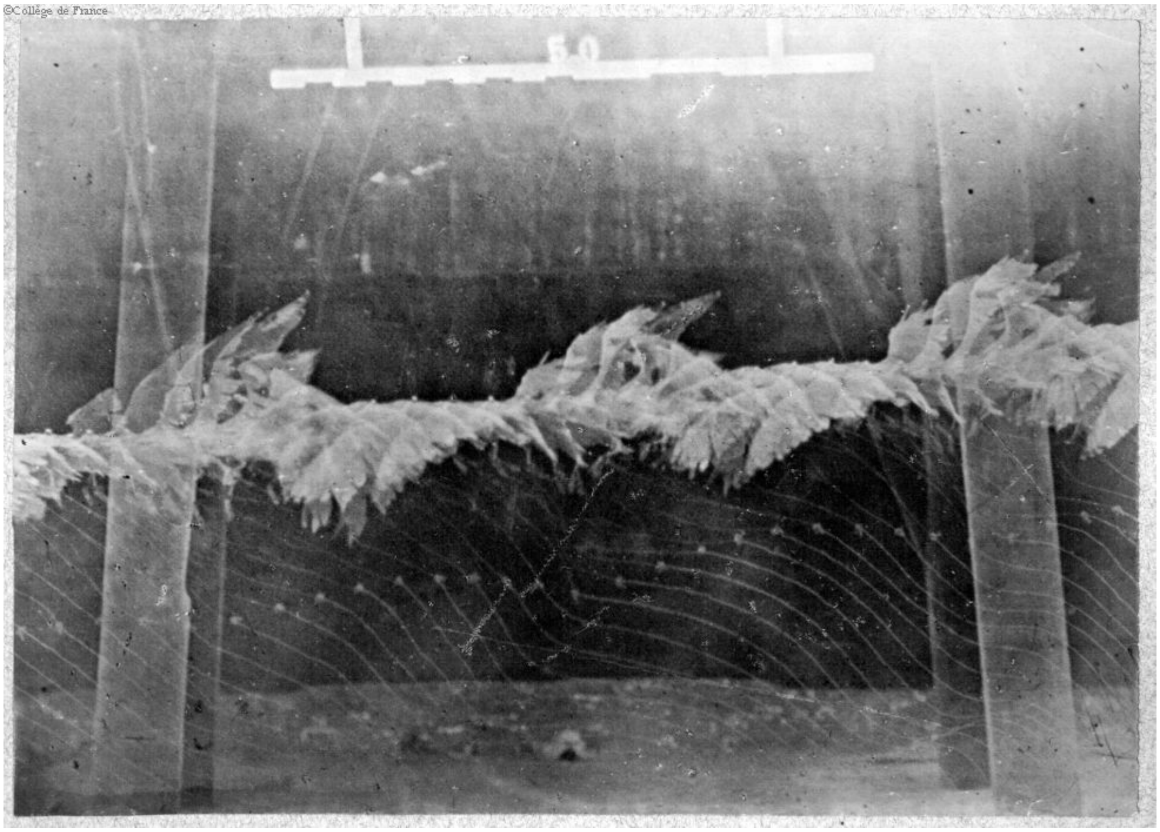


Figure 31: Bird in flight photographed by Marey between 1887-89.

Figure 32: Étienne-Jules Marey, *Cheval blanc monté*, 1886, locomotion du cheval, expérience 4, Chronophotographie sur plaque fixe, négatif.

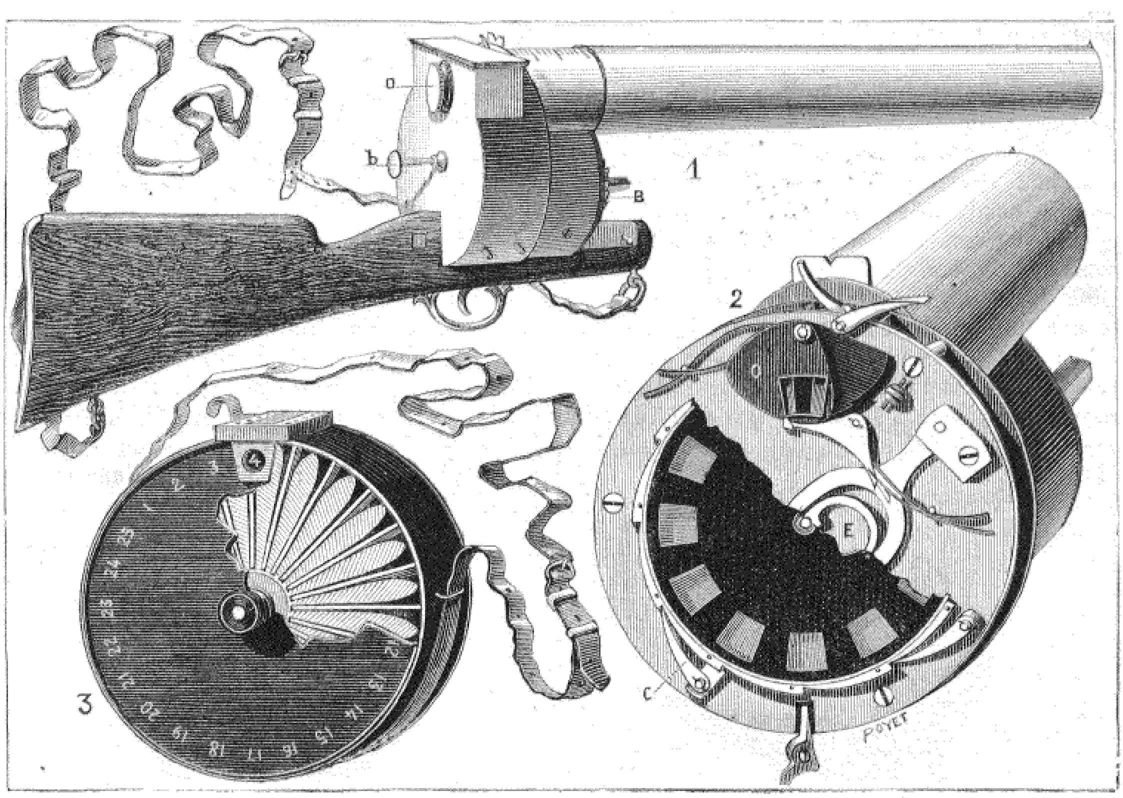


Fig. 2. Mécanisme du fusil photographique.
1 Vue d'ensemble de l'appareil. — 2. Vue de l'obturateur et du disque à fenêtre. — 3. Boîte contenant vingt-cinq plaques sensibles.

Figure 33: Figures of Marey's chronophotography rifle [155]

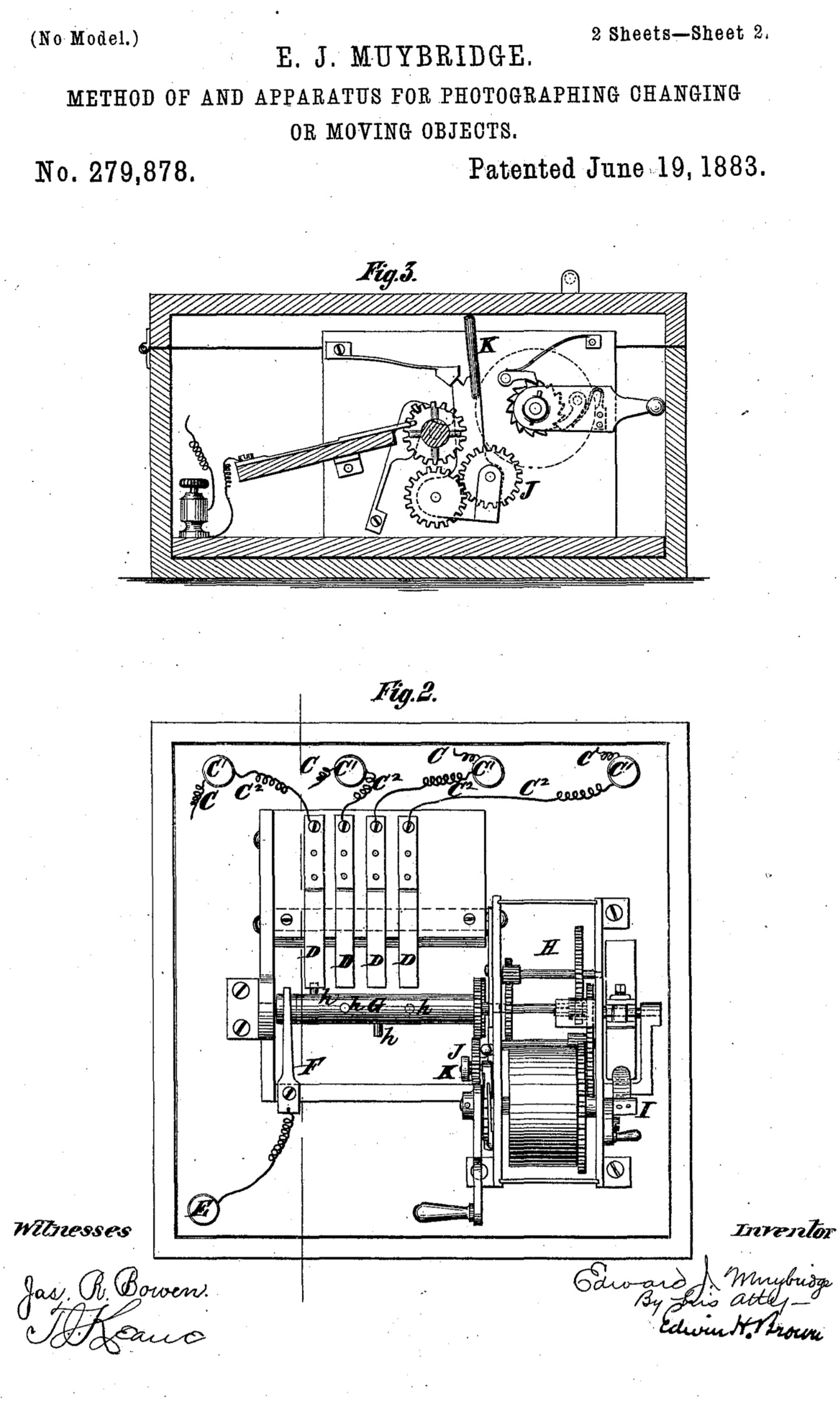


Figure 34: Drawings from Muybridge's patent *Method of and Apparatus for Photographing Changing or Moving Objects.*

> . . . In one of Marey's books, I saw an illustration of how he indicated people who fence, or horses galloping, with a system of dots delineating certain movements . . . That's when I got the idea for the execution of the *Nude Descending a Staircase*. I used this method a little in the sketch, but especially in the final form of the picture. [31]

Because of this interview, the influence of chronophotography on Duchamp's early work is well-reported [10, 30, 87, 101, 170]. Duchamp also stated:

> Chronophotography was at the time in vogue. Studies of horses in movement and of fencers in different positions as in Muybridge's albums were well known to me. [187] in [39, p. 393]

Looking at Duchamp's early paintings (Figures 35 and 36), we see softly-structured, relatively static compositions influenced by Cezanne and heading toward a Cubist sensibility. While Duchamp would have been familiar with Muybridge's *Woman Walking Downstairs* (1887) (Figure 37), it is Marey's chronophotographic studies (see Figures 38, 39, 41, and 42) that effectively lend structure to Duchamp's seminal *Nude Descending a Staircase, No. 2* (French: *Nu descendant un escalier no. 2*) (Figure 40), completed in 1912. Marey's influence is apparent particularly in light of Duchamp's previous work (Figures 35 and 36). While Muybridge presented his motion studies frame-by-frame sequentially, Marey created superimposed images within one frame. The high contrast dots and lines that Marey placed on the clothing of his figure models served to produce a clear record of movement, which Marey analyzed extensively (Figures 39 and 41). Similarly dotted circles (Figure 42) are apparent in Duchamp's painting (Figure 40).

The connections between chronophotography and Duchamp's work are all the more apparent when viewing other Cubist work (see Figure 43). Cubist painting typically rendered static still lives from multiple perspectives. Duchamp's painting challenged the status quo by depicted a Cubist abstraction in motion. When looking at the painting against work of Marey, we can see the visual relationship. Seen in this way, we can trace a direct line from Marey's work to Duchamp's innovation with *Nude*

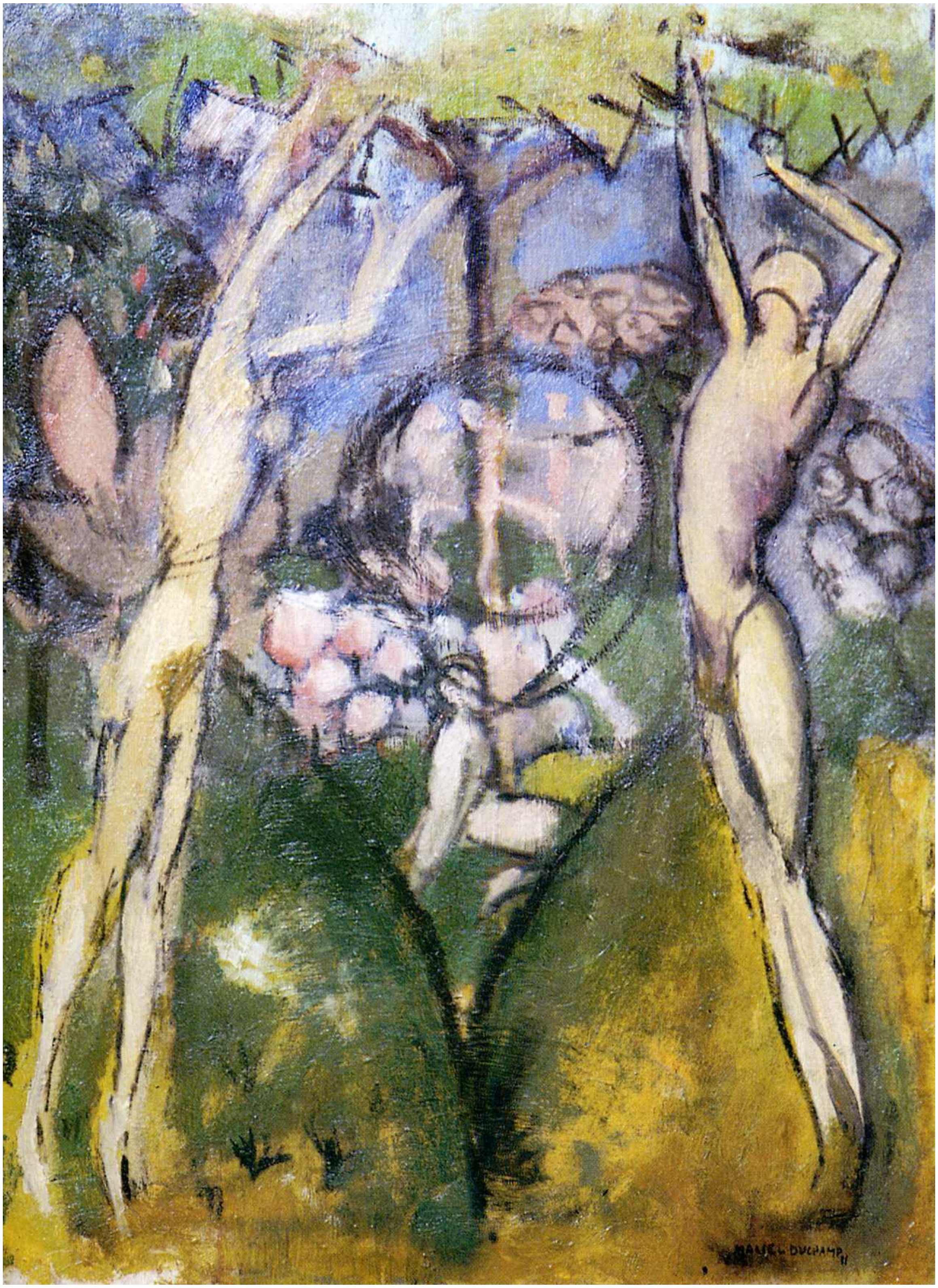


Figure 35: Marcel Duchamp, *Young Man and Girl in Spring*, 1911.

Figure 36: Marcel Duchamp, *Portrait (Dulcinea)*, 1911.

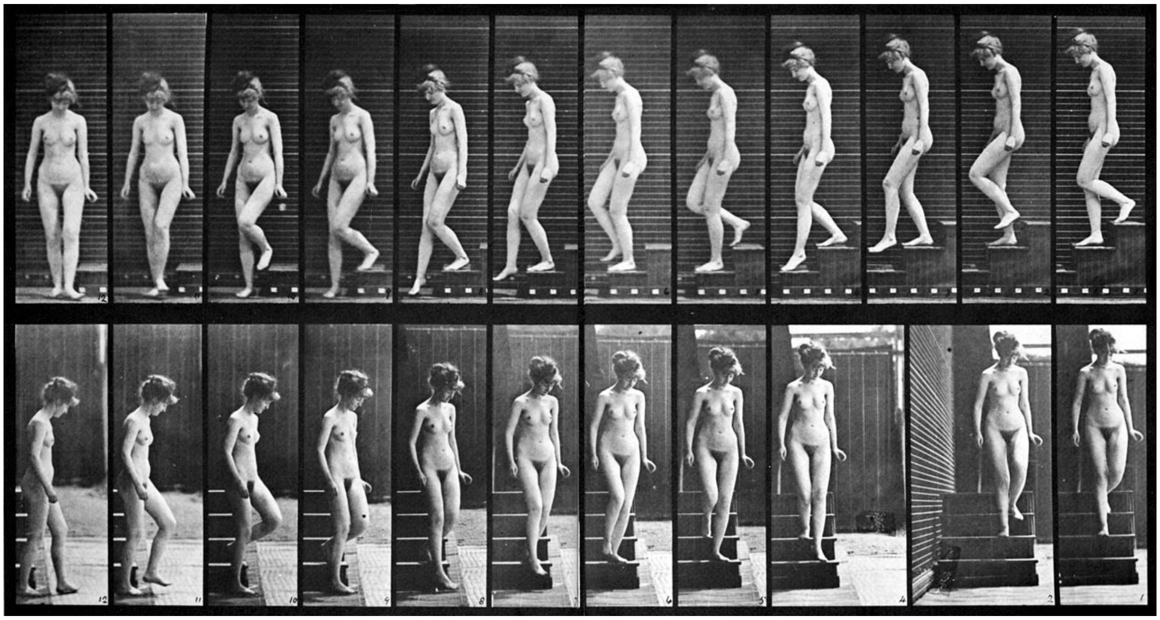


Figure 37: Muybridge's *Woman Walking Downstairs*, 1887.

Descending a Staircase. Duchamp wrote about the five versions of *Nude Descending a Staircase* that he created between 1911 and 1918. He declared that they were not paintings, but:

> ... an organization of kinetic elements — an expression of time and space through the abstract presentation of movement ... we must bear in mind that, when we consider the movement of form in space over a certain time, we are entering the realm of geometry and mathematics in the same way as when we construct a machine. [154, p. 3]

Nude Descending a Staircase so thwarted the conventions of Cubism that jurists at the 1912 Cubist Salon des Indépendants asked Duchamp to voluntarily withdraw the piece [10].

Historically, Duchamp is understood as a provocateur whose challenges to the avant-garde trajectory defined new areas of artistic production over the following century, including Dadaism, conceptual art, and kinetic art. Marey's work lent the formal structure apparent in *Nude Descending a Staircase*, enabling Duchamp to challenge Cubism's multi-perspectival explorations of static imagery. I argue that the work of Marey is an oft-missed key to understanding the nature of Duchamp's

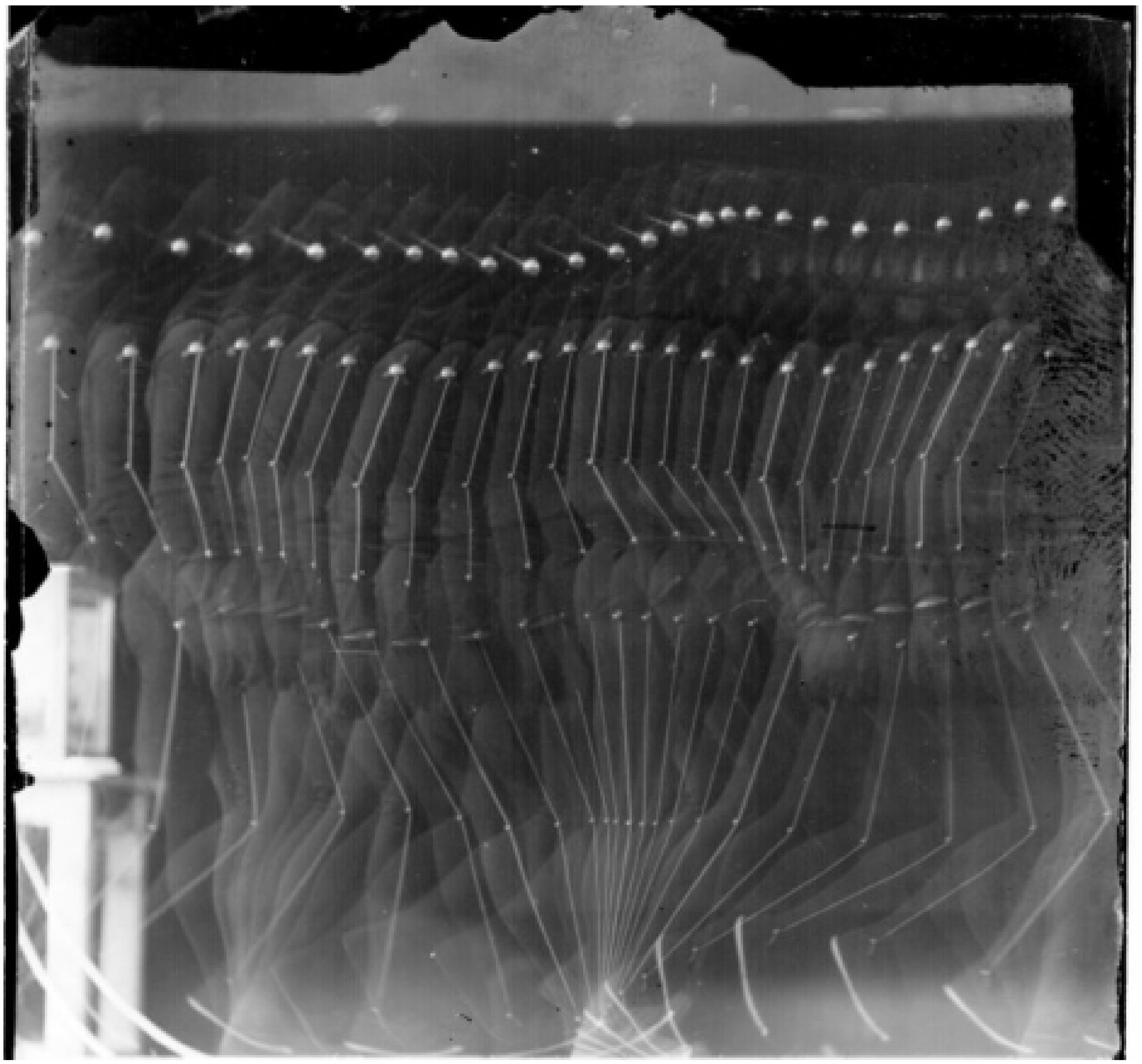
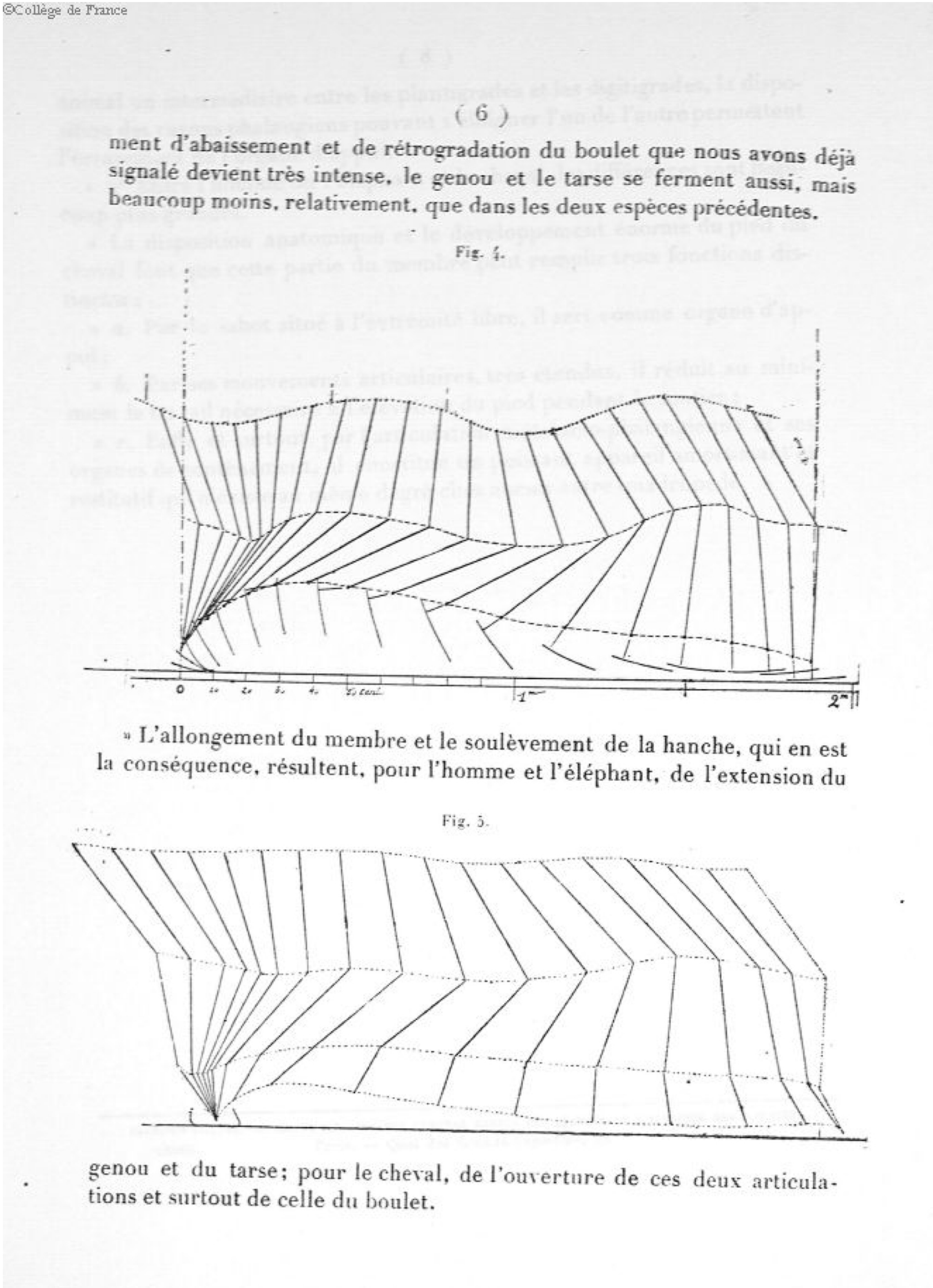


Figure 38: Marey's chronophotographie géométrique - locomotion de l'homme, dynamomètre, 1884.



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ment d'abaissement et de rétrogradation du boulet que nous avons déjà signalé devient très intense, le genou et le tarse se ferment aussi, mais beaucoup moins, relativement, que dans les deux espèces précédentes.

Fig. 4.

» L'allongement du membre et le soulèvement de la hanche, qui en est la conséquence, résultent, pour l'homme et l'éléphant, de l'extension du

Fig. 5.

genou et du tarse; pour le cheval, de l'ouverture de ces deux articulations et surtout de celle du boulet.

Figure 39: Marey's chronophotographie géométrique - locomotion de l'homme, dynamomètre, 1884

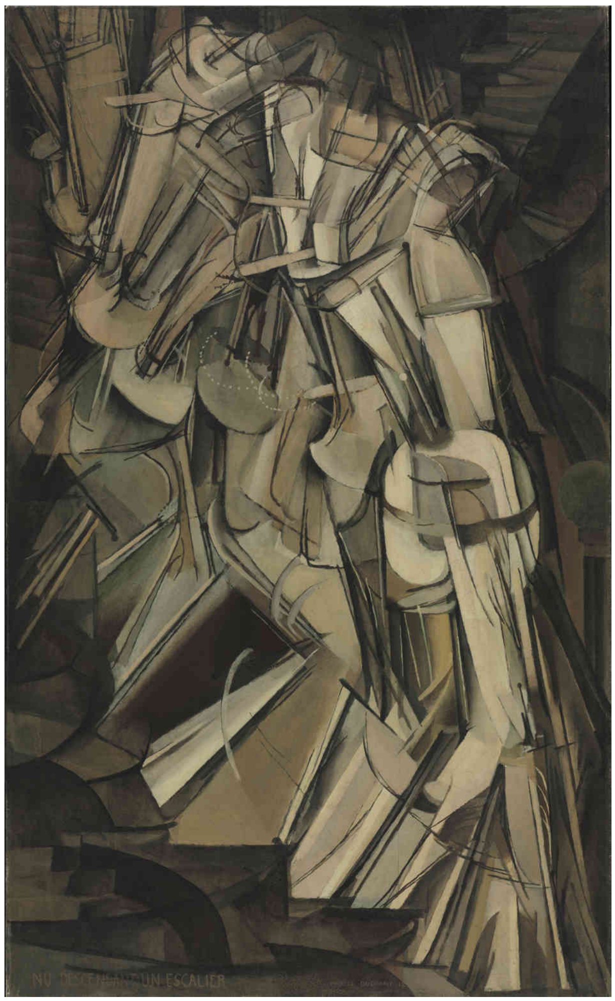


Figure 40: Marcel Duchamp's *Nude Descending a Staircase, No. 2* (French: *Nu descendant un escalier no. 2*), 1912.

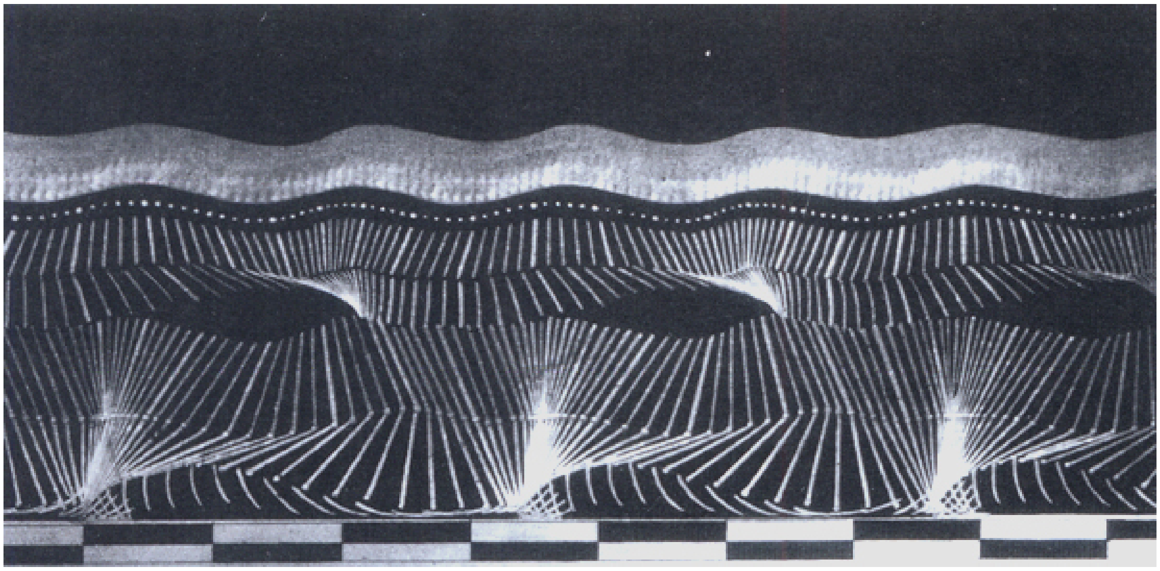


Figure 41: Chronophotographie sur plaque fixe by Marey, 1886.

Figure 42: Motion study by Marey.

Figure 43: Pablo Picasso's *Still Life With a Bottle of Rum*, 1911.

engagement with science, research, and technology, and that the lack of recognition of the nature of this engagement indicates a fundamental characteristic of the fine art system.

In 1913, Duchamp conducted an experiment. The experiment consisted of holding a linen thread horizontally at arms length at a height of one meter and allowing it to drop onto a canvas on the floor. The thread would land in a curved shape on the canvas, which Duchamp recorded by gluing the fallen thread down in place. He then transferred the curve to a thin wooden template. He repeated this experiment three times, producing a canvas and a thin wooden template / ruler from each of the three fallen strings (Figure 44). From Duchamp's notes:

> ... This is not a painting. The three narrow strips are called *Three Standard Stoppages* from the French *3 Stoppages-Etalon*.
>
> ... This experiment was made in 1913 to imprison and preserve forms obtained through chance, through my chance. At the same time, the unit of length: one meter was changed from a straight line to a curved line without actually losing its identity [as] the meter, and yet casting a pataphysical doubt on the concept of a straight line as being the shortest route from one point to another. [51, pp. 273-274]

The *Three Standard Stoppages* is conventionally interpreted as indicating Duchamp's disdain for science [10]. He was, after all, an artist with irreverent tendencies. But this is too easy a target. Duchamp could also be interpreted as running experiments on motion and measurement — the tracing of a curve through space — as Marey had done. Duchamp's experiments and the resulting artifacts were research resulting in, to use Duchamp's words from a quote above, "an expression of time and space through the abstract presentation of movement" [154, p. 3]. As such, Duchamp would not have been simply critiquing science, but engaging with science through his working method much in the same way that he challenged the discipline of art throughout his career as an artist. This is a deeper engagement with science than the depiction and interpretation of scientific content that we see in the work of the Futurists and the Surrealists.

Figure 44: Marcel Duchamp,*3 Standard Stoppages*, 1914.

I was led to this interpretation based on my discovery of a similarity in the forms Marey used in his research (Figures 46 and 47) and Duchamp's stoppages (Figures 44 and 45). Duchamp's research data has a nearly identical graphical quality as those of Marey. The white on black presentation originated from two sources: 1) Marey's photographic setting, which he devised to provide high contrast between data points and background; and 2) the nature of the engraving technology of Marey's time.

Duchamp has stated that *3 Standard Stoppages* is his most important piece [101]. He reused the forms from this piece to create *Network of Stoppages* (Figure 48) in 1914. Again, note the visual similarity between *Network of Stoppages* and Marey's

Figure 45: Closeup of Marcel Duchamp's *3 Standard Stoppages*, 1914.

work (Figure 49). This visual similarity is a clue to deeper investigations and processes undertaken by the two men, revealing similar concerns with movement, measurement, systemization, and abstraction. Duchamp incorporated *Network of Stoppages* diagrammatically into *The Bride Stripped Bare by Her Bachelors, Even (La mariée mise à nu par ses célibataires, même)*, commonly called *The Large Glass (Le Grand Verre)*, which he created between 1915 and 1923. *Network of Stoppages* was used to situate the images constituting the *Nine Malic Molds (9 Moules Målic)* within the larger piece (see Figures 50 and 51).

The lack of critical attention to the spectrum of Duchamp's engagement with Marey's work is indicative of a disciplinary position staked by the fine art system. For an oeuvre to be considered within this system, it must lie within accepted concepts, practices, and institutions, even within the avant-garde. So while Marey's work could arguably be considered more engaged with the discourse of modern art,

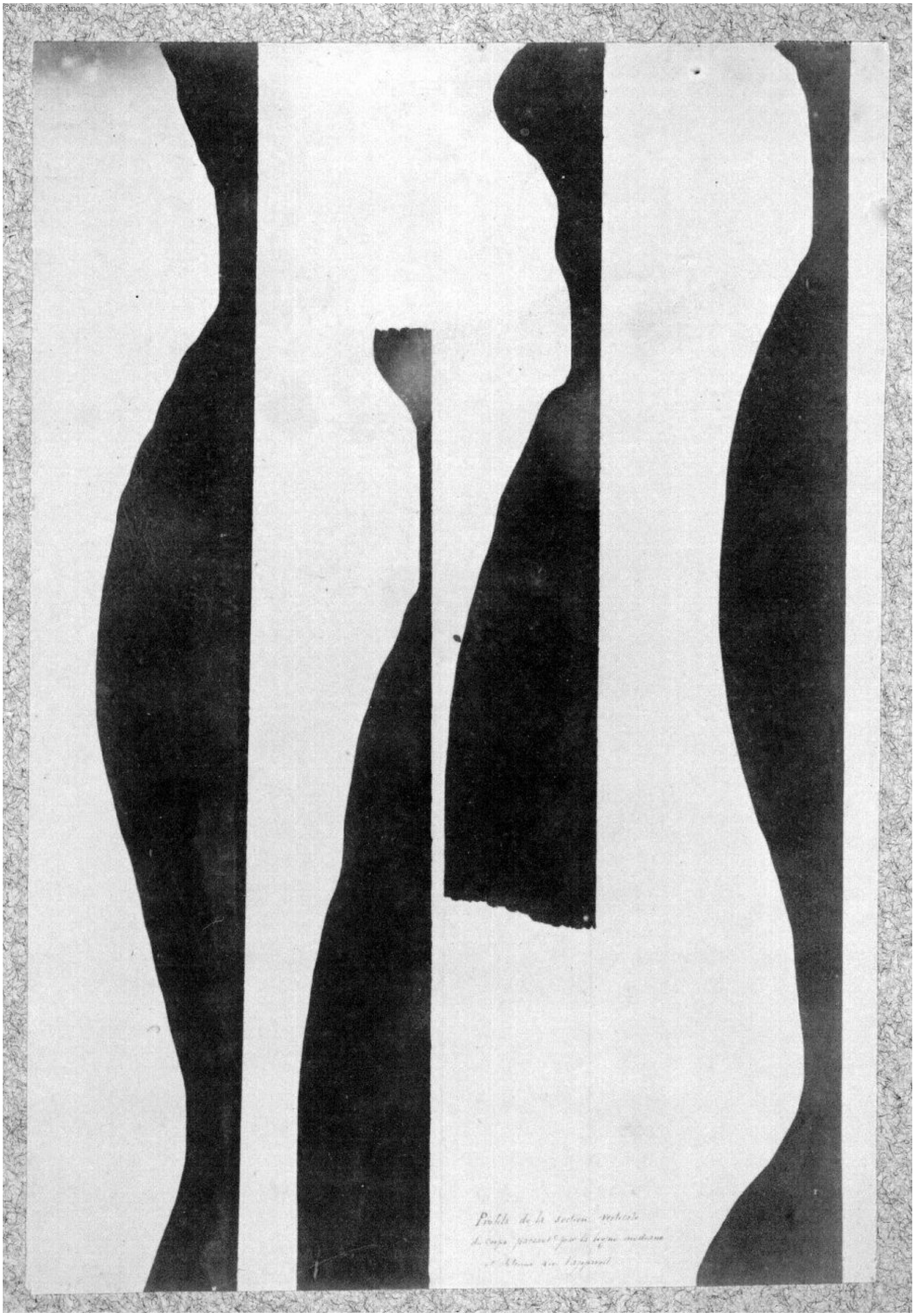
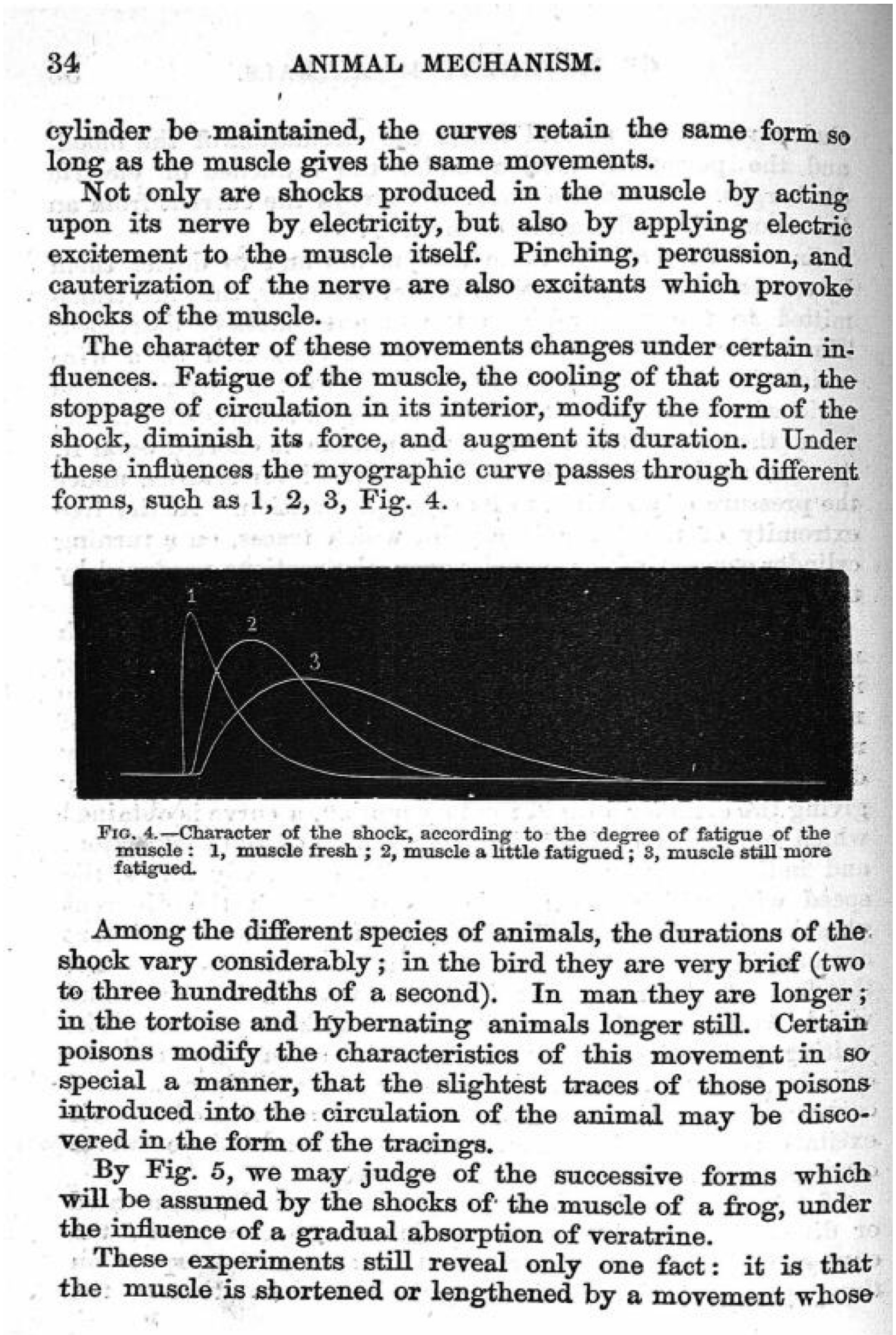


Figure 46: Data graphic by Marey. 1887-1889.



34 ANIMAL MECHANISM.

cylinder be maintained, the curves retain the same form so long as the muscle gives the same movements.

Not only are shocks produced in the muscle by acting upon its nerve by electricity, but also by applying electric excitement to the muscle itself. Pinching, percussion, and cauterization of the nerve are also excitants which provoke shocks of the muscle.

The character of these movements changes under certain influences. Fatigue of the muscle, the cooling of that organ, the stoppage of circulation in its interior, modify the form of the shock, diminish its force, and augment its duration. Under these influences the myographic curve passes through different forms, such as 1, 2, 3, Fig. 4.

Fig. 4.—Character of the shock, according to the degree of fatigue of the muscle: 1, muscle fresh; 2, muscle a little fatigued; 3, muscle still more fatigued.

Among the different species of animals, the durations of the shock vary considerably; in the bird they are very brief (two to three hundredths of a second). In man they are longer; in the tortoise and hybernating animals longer still. Certain poisons modify the characteristics of this movement in so special a manner, that the slightest traces of those poisons introduced into the circulation of the animal may be discovered in the form of the tracings.

By Fig. 5, we may judge of the successive forms which will be assumed by the shocks of the muscle of a frog, under the influence of a gradual absorption of veratrine.

These experiments still reveal only one fact: it is that the muscle is shortened or lengthened by a movement whose

Figure 47: Data chart by Marey, 1879.

Figure 48: Marcel Duchamp, *Network of Stoppages*, 1914

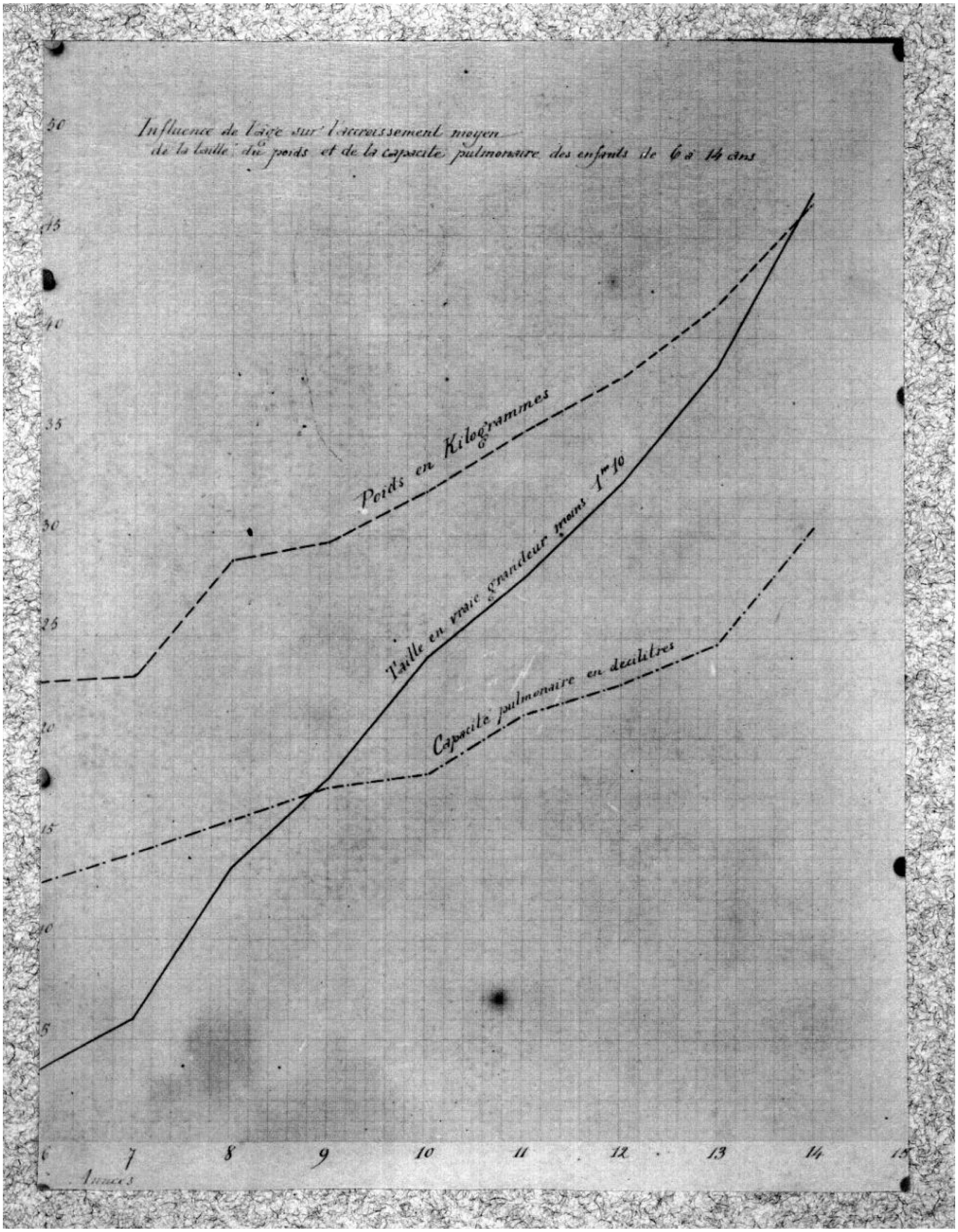


Figure 49: Chart by Marey, 1887 - 1889.

Muybridge is considered within the canon but Marey is not. The institutionalized relationships between the legacies of Marey, Muybridge, and Duchamp indicate the cultural constructions of the relationships between art, science, and technology. Marey is designated as a scientist, and Muybridge and Duchamp are considered artists without a recognition of the entangled relationships between artistic invention, scientific research, and technological invention.

Duchamp pushed against the boundaries of the modern art system throughout his career. Around the time of *3 Standard Stoppages* (1913) and *Network of Stoppages* (1914), Duchamp prepared, submitted to juries, and exhibited a series of *Readymades* such as *Bicycle Wheel* (1913), *Bottlerack* (1914), and *Fountain* (1917) (Figures 52, 53, 54, respectively). Beginning in 1920, Duchamp continued his work with a series of kinetic, optical machines, including *Rotary Glass Plates, Precision Optics (Rotative plaques verre, optique de précision)*, in 1920 (Figure 55), and *Rotary Demisphere, Precision Optics (Rotative Demisphère, optique de précision)* in 1923. Duchamp insisted that these pieces were not art and that he was not acting as an artist in creating them [190]. While Marey was not eligible to be considered an artist, Duchamp found himself unable to be considered anything but an artist. Ultimately, Duchamp resigned as an artist and became a chess player.

In terms of art history as viewed by the contemporary art system, Duchamp's work is predominantly understood as a watershed of art reflexively pushing its boundaries and defining itself by defying itself. Duchamp is remembered as an artist who challenged existing notions of what art could be, particularly with *Nude Descending a Staircase* and *Fountain*. Duchamp is less remembered as an artist who reached the boundaries of the modern art world and defined what art could not be and what the artist could not be. His mechanical explorations, which to his mind prefigured the future directions of his work [30], were not assimilated into concepts of what art was.

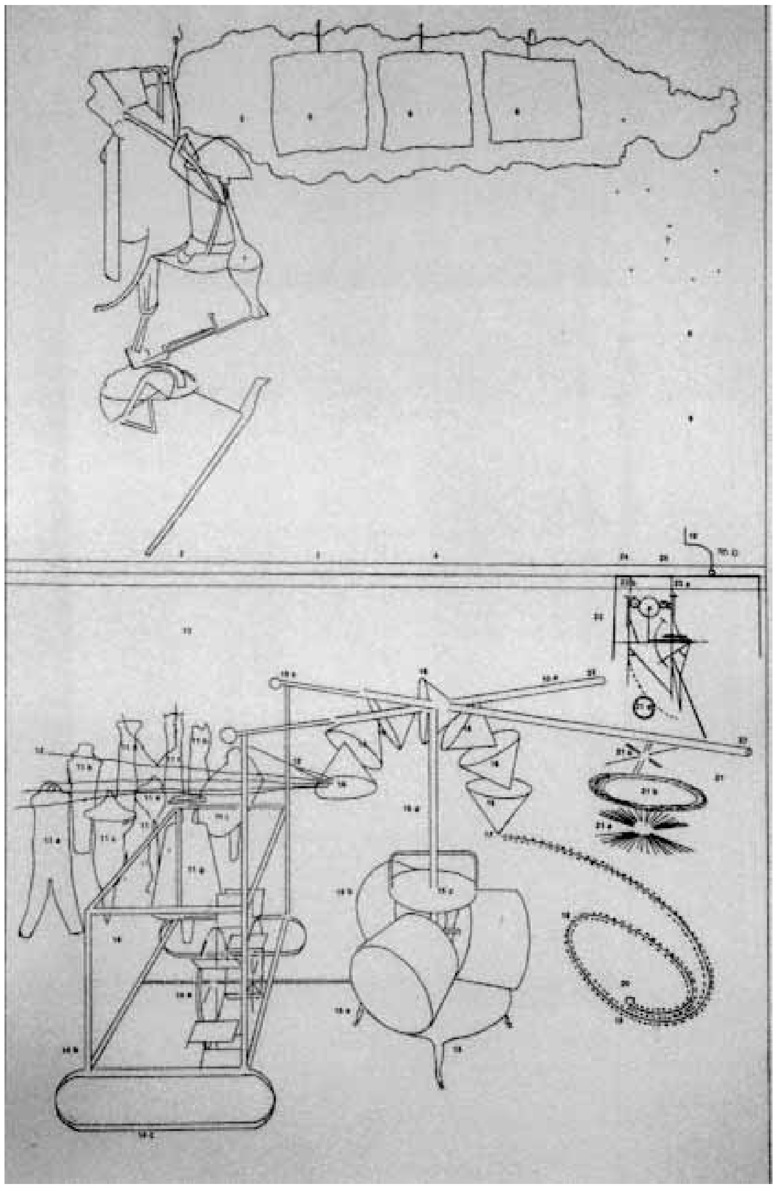


Figure 50: Diagram based on Marcel Duchamp's etching, *The Large Glass Completed*, 1965. Note the inclusion of the *Network of Stoppages* in the lower left quadrant of the piece.

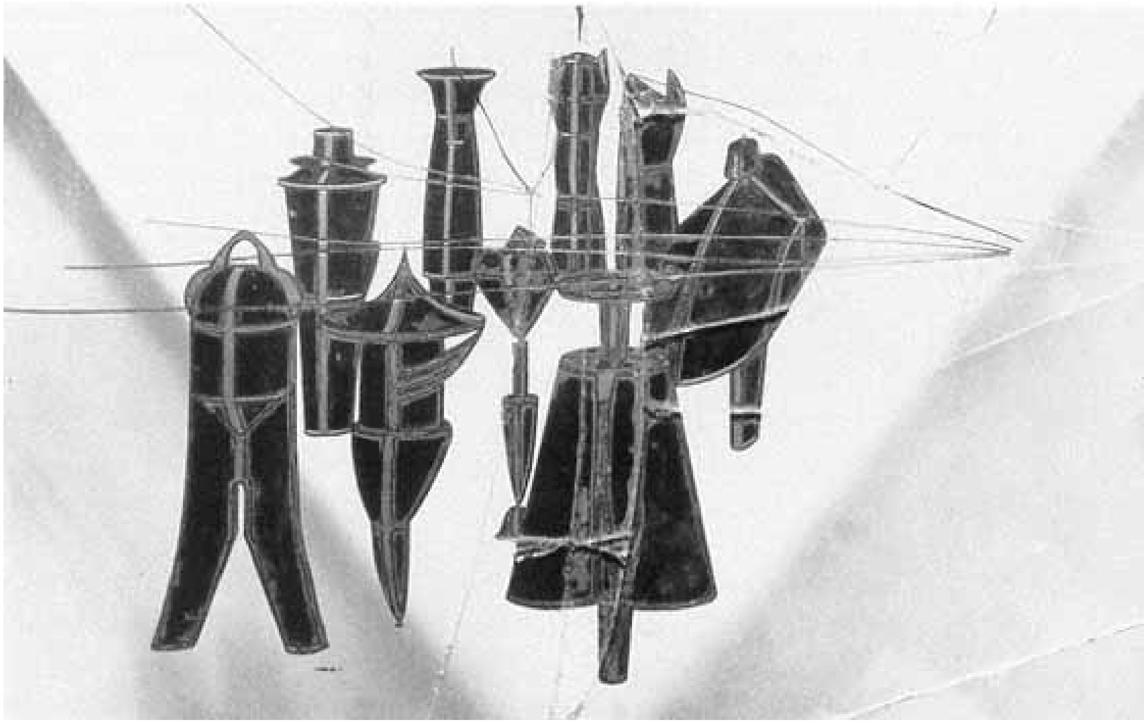


Figure 51: Marcel Duchamp, *Nine Malic Molds (9 Moules Målic)*, 1914-15.

Figure 52: Marcel Duchamp's *Bicycle Wheel*, 1964 (replica of 1913 original).

Figure 53: Marcel Duchamp's *Bottlerack*, 1961 (replica of 1914 original).

Figure 54: Marcel Duchamp's *Fountain*, 1950 (replica of 1917 original).

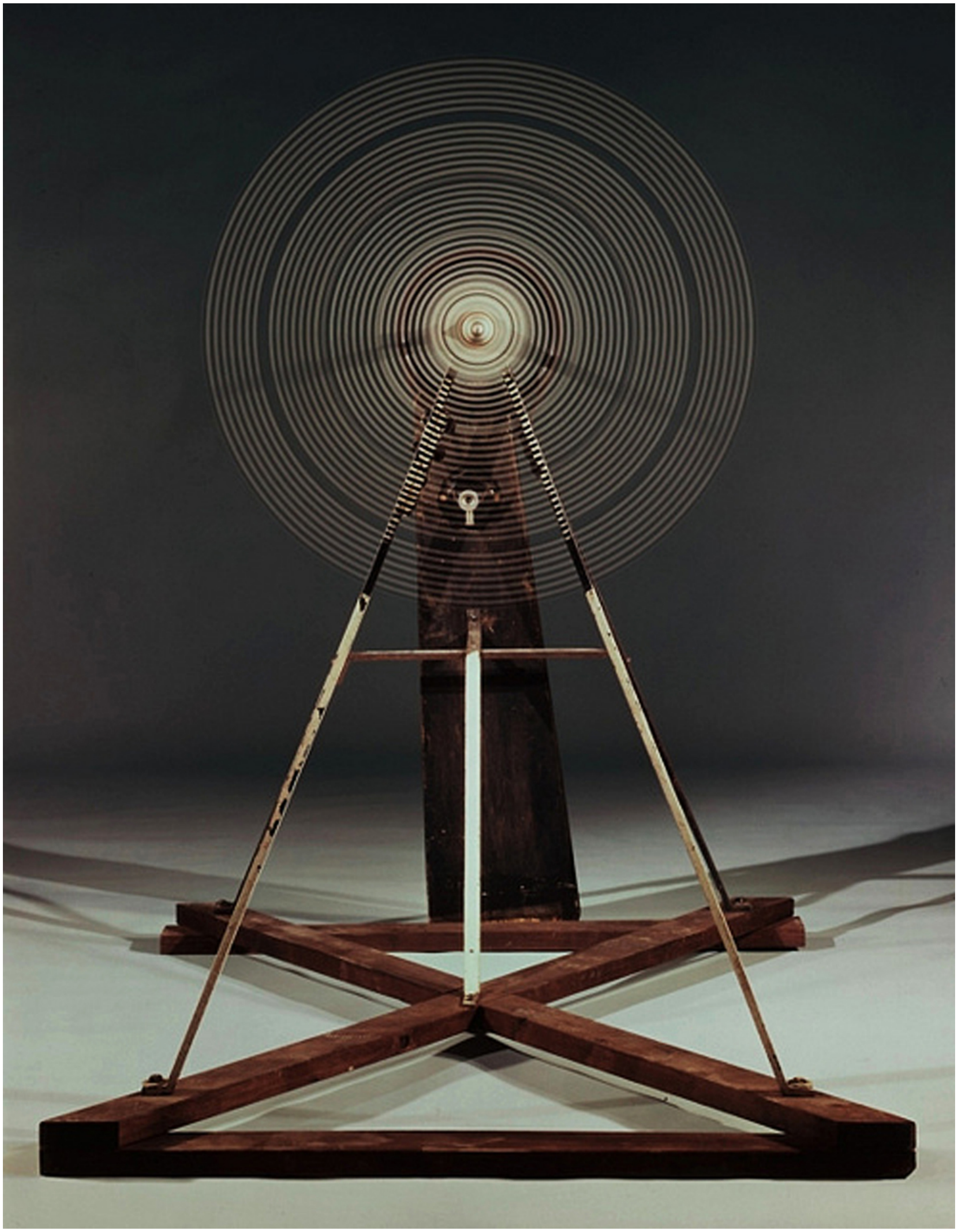


Figure 55: Duchamp's *Rotary Glass Plates (Precision Optics)*, 1920.

Though Cubism and Futurism are often cited as emerging from themes of relativity, speed, and machine culture, these investigations remain on the conceptual level. They float above the nitty-gritty of invention work, favoring notions of formalism and the avant-garde over the more bourgeois and mercantile utility of technology. Duchamp's explorations were in part born of the art, science, and technology entanglements of Marey's and Muybridge's work. Science and technology were not just the content of his work, they were colleagues. Yet the dynamics of this rich history are elided in the stories of Western art. Duchamp and Marey's work can be seen as a test of the cultural construction of the relationship between art and technology. At this time, art asserted its autonomy as an independent, bounded discipline. It was made clear that artwork engaging science and technology as a medium would be in another category from the beaux arts. This is the third split.

2.8.3 The third split in the twenty-first century

Contemporary technological art, or art using high technology as a medium[2], exists in a separate art world, to use sociologist Howard S. Becker's term[3], than the contemporary art world. Technological art is exhibited at dedicated venues such as Ars Electronica, Transmediale, Zero1 San Jose, Center for Art and Media Karlsruhe, and science museums with little crossover and recognition by the mainstream museum and gallery systems. This is true of the work of high profile practitioners including MacArthur ("Genius Grant") Fellows Ned Kahn (see Figure 56) and Camille Utterback (see Figure 57). Technological artwork is also exhibited at the academic

[2]Related terms include"digital art" and "new media art". These terms emphasize art created with digital mediums such as software, hardware, or network protocols. The term "technological art" encompasses these.

[3]Becker describes an art world as "the network of people whose cooperative activity, organized via their joint knowledge of conventional means of doing things, produce(s) the kind of art works that art world is noted for" [20].

Figure 56: Ned Kahn's facade for Technorama, the Swiss Science Center, 2002.

technical conferences SIGGRAPH[4] and CHI[5]. The technological art community has their own texts and their own discourse in journals such as *Leonardo* [118], net sites such as Rhizome.org [163], and blogs like we-make-money-not-art.com [49].

From our investigation of the evolution of the term "art", we can see that the concept of art is relative to its time. The modern art system has established a discourse that, while avoiding a concrete definition of art, provides boundaries for the classification of fine art. Art made with high technology, with a few exceptions, is not part of twentieth and twenty-first century art discourse. This seems an omission, if not a blind spot. To have to refer back to Cubism, Futurism, and Surrealism to

[4]the Association for Computing Machinery's Special Interest Group on Computer Graphics and Interactive Techniques

[5]the Association for Computing Machinery's Special Interest Group on Human-Computer Interaction

Figure 57: Camille Utterback's *Text Rain* at the Phaeno Science Center in Wolfsburg, Germany, 2005.

have significant discourse about the relationship between art and technology within the boundaries of the modern or contemporary art systems signals a dynamic at play.

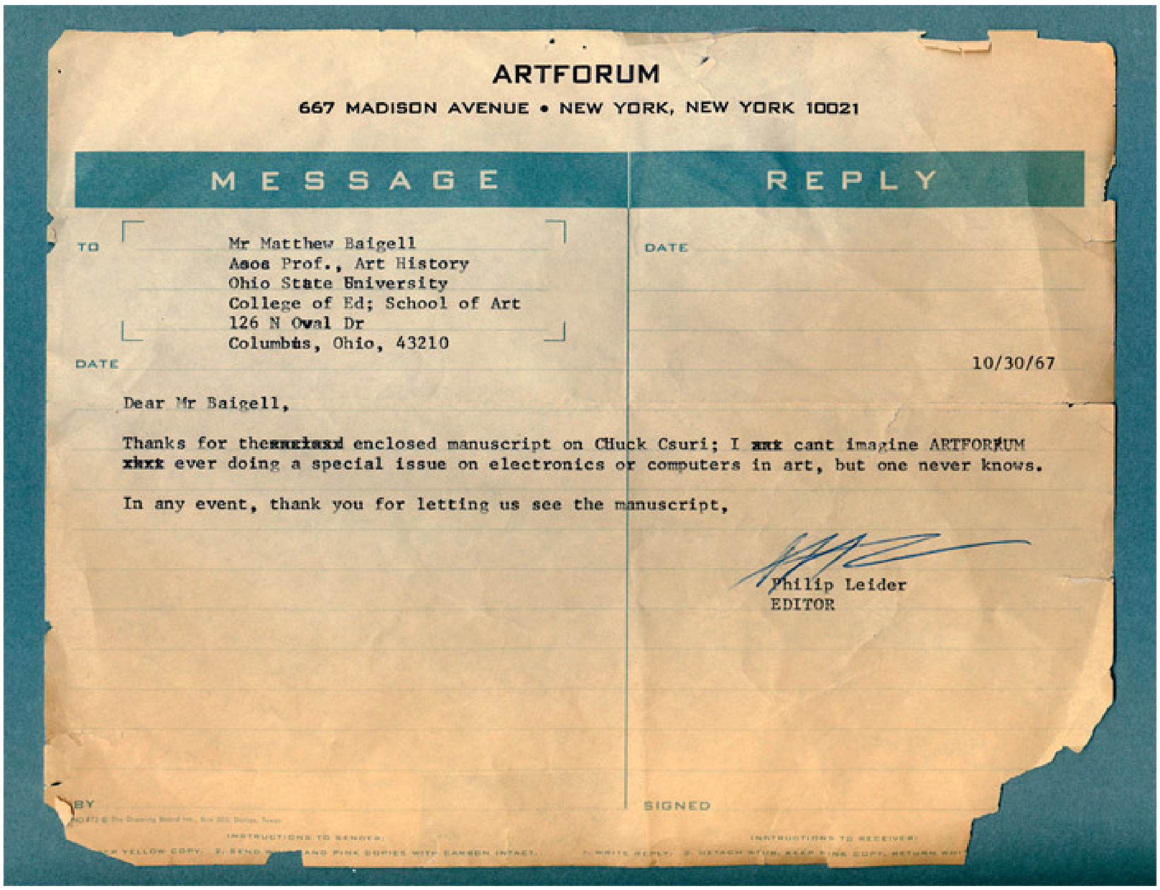
Claire Bishop, Professor of Contemporary Art, Theory and Exhibition History at The City University of New York (CUNY), writes in the journal *ARTFORUM* of "contemporary art's repressed relationship to the digital":

> There is, of course, an entire sphere of "new media" art, but this is a specialized field of its own: It rarely overlaps with the mainstream art world (commercial galleries, the Turner Prize, national pavilions at Venice). [22]

The Introduction to the same issue of *ARTFORUM* featured an image of a 1967 memo sent by the magazine's editor, Philip Leider (Figure 58), responding to a writer's pitch with, "I can't imagine ARTFORUM ever doing a special issue on electronics or computers in art, but one never knows" [102].

In the English language abstract for his book, *Media, New Media, Post Media* (written in Italian), writer and curator Domenico Quaranta summarizes the situation:

> Along the last sixty years, a complex body of works has been developed along the edge between art, science and technology. An increasing number of artists came up putting their hands on the new tools that technology placed at their disposal, trying to get in touch with engineers and scientists, collaborating with them, entering university labs as well as research



ARTFORUM
667 MADISON AVENUE • NEW YORK, NEW YORK 10021

MESSAGE | REPLY

TO
Mr Matthew Baigell
Asoc Prof., Art History
Ohio State University
College of Ed; School of Art
126 N Oval Dr
Columbus, Ohio, 43210

DATE

DATE 10/30/67

Dear Mr Baigell,

Thanks for the enclosed manuscript on CHuck Csuri; I cant imagine ARTFORUM ever doing a special issue on electronics or computers in art, but one never knows.

In any event, thank you for letting us see the manuscript,

Philip Leider
EDITOR

BY

SIGNED

Figure 58: 1967 memo sent by *ARTFORUM's* editor, Philip Leider.

> and development centers. After a long preparation, this research literally boomed along the Nineties, when the increasing accessibility of new technologies and the development of a "digital culture" made it possible for it to acquire a critical mass of artists. Festivals and specialized art centers sprang up like mushrooms, and many books and magazines, investigating the present and documenting the past, have been published.
>
> Yet, notwithstanding this flourishing, neither the label "New Media Art" nor the artistic practices it refers to were able to conquer the official art criticism or, more generally, the contemporary art world. Just a few works of New Media Art were able to enter the permanent collection of a museum, and even less were able to escape the limbo of the museum's warehouses. New Media Art is more or less absent in the contemporary art market, as well as in mainstream art magazines; and recent accounts on contemporary art history completely forgot it.
>
> How can we explain this segregation? Why "official" art criticism and history have still so many difficulties in integrating the artistic research on new media technologies into their interpretation of the art history of the Twentieth century, even now that this research can be considered in all its historic relevance? Why the art market, that was able to greet video, installation and performance, is still unable to accept and distribute artworks based in software, hardware or computer networks? [156]

Theories have surfaced as to why this could be so. The art object is prioritized in the commercial gallery system as a singular object for sale and investment. Much digital art, new media art, and net art exists in a more ephemeral and instantly reproducible format. On the other hand, performance art typically leaves no object behind and was readily admitted into the contemporary art world. Another point that has been raised is that technological art presents issues for archivists, because the technology could fail over time or become obsolete. On the other hand, works recorded on videotape have been translated onto more contemporary media without a loss.

Jack Burnham, in his oft-cited book, *Beyond Modern Sculpture*, writes of early experiments with kinetic sculpture by Duchamp, Alexander Calder, and Naum Gabo. Burnham quotes Gabo:

> Mechanics have not yet reached that stage of absolute perfection where it can produce motion in sculptural work without killing, through the

> mechanical parts, the pure sculptural content; because the motion is of importance, and not the mechanism which produces it. [72, p. 169] cited in [30, p. 232]

Burnham cites the financial and technical difficulties of building kinetic sculpture as creating a moment in history when kinetic sculpture "challenged but did not destroy the aesthetic partition between Kinetic constructions and static sculpture" [30, p. 226]. This issue was put to rest ten years later by the work of kinetic sculptor George Rickey, which was successful mechanically and commercially within the contemporary art world. Perhaps it is the case that technological art still has too many seams showing, and these seams are jarring, disrupting aesthetic participation or contemplation.

Following mid-century media theorist Marshall McLuhan, perhaps the medium is the message [125]. Technological and digital mediums may be charged with connotations of industrialization, commercialization, and exclusive epistemological status which otherwise overwhelms the autonomy of the work of art built with these mediums. Along these lines, it may be that to the collective mind of the contemporary art system, technological art falls into art critic Clement Greenberg's category of "kitsch." In his influential essay, "Avant-Garde and Kitsch" (1939), Greenberg constructs kitsch as "mechanical and operates by formulas. Kitsch is vicarious experience and faked sensations. Kitsch changes according to style, but remains always the same. Kitsch is the epitome of all that is spurious in the life of our times" [80].

Both too-apparent seams and industrial, commercial, or kitsch charges could distract from the larger, more meaningful implications of a technological work of art. Although claiming technology as an artistic medium is itself a cultural act, the conceptual development of technological art seems lost on the contemporary art world. Writing in 1996, media theorist Lev Manovich distinguishes between "Duchamp-land" and "Turing-land." According to Manovich, Duchamp-land (the contemporary art world) requires art objects that are "oriented towards the 'content' ", "complicated," and that share an “ironic, self-referential, and often literally destructive attitude towards its material, i.e., its technology, be it canvas, glass, motors, electronics, etc.” On the other hand, Turing-land (the new media art world) is oriented “towards new, state-of-the-art computer technology, rather than ‘content,’ ” produces artworks that are “ ‘simple’ and usually lacking irony,” and that “take technology which they use always seriously” [119]. This analysis configures the split between the contemporary art world and the technological art world as a matter of substance and discourse. Writing on new media in 1997, the artistic director of Documenta X in Kassel, Catherine David, expresses a perspective aligned with that of Manovich:

> New technologies are nothing other than new means to an end. Alone they are of significance; it always depends upon how they are applied. I am against naive faith in progress, glorification of the possibilities of technological developments. Much of what today's artists produce with New Media is very boring. But I am just as opposed to the denunciation of technology. For me technology in itself is not a category according to which I judge works. This type of categorization is just as outmoded as division into classical art genres (painting, sculpture...). I am interested in the idea of a project; ideally the means of realizing the project should arise from the idea itself.

Quaranta cites both the research orientation of technological art and the conceptual orientation of contemporary art when he writes in 2011: “In the contemporary art world, art is not appreciated as creative research on a given medium, but as a powerful statement on the world we are living in.” Manovich's recommendation, made in his 2003 Ars Electronica review, reads:

> At the end of the day, if new media artists want their efforts to have a significant impact on cultural evolution, they indeed to generate not only brilliant images or sounds but more importantly, solid discourse. That is, they need to situate their works in relation to ideas that are not only about the techniques of making these works. The reason that we continue discussing Duchamp's urinal or Paik's early TV sculptures as though these works were created today has nothing to do with the artistic and technological skills of these artists — it has to do with their concepts, i.e. the discursive statements these artists were making through their objects. In short, if modern and contemporary art is a particular discourse (or a

> game) where the statements (or moves) are made via particular kind of material objects identified as "artworks," digital artists need to treat their works as such statements if they are to enter the larger cultural conversation. This means referring to the historical and presently circulating statements in the fields of contemporary art and/or contemporary culture at large. [120]

These arguments imply that in order for new work or new genres to be accepted into an art system, they need to engage with ideals, forms, and discourse existing in that system. The primary art historians and critics of the twentieth century have established the disciplinary autonomy of the fine arts without a recognition of the historical connections between art and technology as established in this chapter. Technological art, rejected at nearly every turn by the contemporary art system, has written its own trajectory and history. This dynamic characterizes the third split between the evolution of art and the evolution of technology. The artists whose work is described at the beginning of this chapter — Sandlin, Richards, and Klein — are surfing the tension of this split. By officially registering their art as technological invention through the patenting system, these artists are colliding the tensions between the contemporary fine art system and art as technology, producing humor. The meaning of their double entendre-ed projects shifts depending whether they are viewed from the rarified air of the contemporary art system or the administrative prestige of the technology patenting system.

2.9 Summarizing the three splits

In the premodern era, the primary disciplinary division was between contemplative knowledge and hands-on practice. The boundaries between the building disciplines that we accept today were not distinct. The categories of art and engineering that we recognize today were part of the spectrum of mechanical arts in the Middle Ages and the Renaissance. The domain which we, in contemporary time, understand as art was integrated with the practices of society.

To summarize, the three historical splits that separated art from technology are:

First split The formulation of a mathematical basis for scientific knowledge during the late Renaissance brought about a prioritization of measurement, quantification, and principle-based knowledge which cleaved science away from the non-scientific disciplines. At the same time, the need for principle-based technical know-how and instrumentation pulled the techno-artisans and the engineers out of the artisan's milieu and joined them with scientific practice. The foregrounding of systematic and scientific modes of thought by the "Moderns" in opposition to the "Ancients" in the *Querelle des Anciens et des Modernes* in the late seventeenth century further set rationalist epistemologies at odds with hermeneutic and experiential knowledge-making, ultimately placing the arts and humanities on a separate trajectory than the sciences. These developments coincided with the addition of the suffix "ology" to "techné" to form the term "technology", or a systemization of techné.

Second split The mechanical arts are further differentiated from the beaux arts in the mid-eighteenth century. Fine art became a category distinct from the other arts and crafts. The fine arts were institutionalized in Diderot and d'Alembert's *Encyclopédia* of 1751. Art academies, art galleries and museums, and the art market co-evolved with the emergence of fine art as a category.

Third split The modern and contemporary fine arts rejected technological art as a fine art. Instead of engaging technology in a critical, reflective, or contemplative mode as content within the conventions of the fine art system, technological art engaged technology as a material, intrinsically engaging technological issues. Technological art retains its own disciplinary domain and trajectory at the intersections of arts, technology, research, and science.

While some technological art critics, artists, and thinkers attempt a more or less one-sided discourse with the contemporary art system, Quaranta points to another option:

> Historically the New Media Art world filled the gaps between one creative arena and another, between arts and science, arts and technology. This was its mission, its destiny. [157]

This is the direction explored in this dissertation. In this spirit, I will memorialize an excerpt from a spirited web article by Ellen Pearlman on Hyperallergic.com in response to a recent panel at the New Museum in New York titled "What's Wrong With Technological Art?":

> Try talking about military technology, technological art informed by feminism, bad technological art, politically incorrect collaborations, or condescending Artforum editors to the hoards who streamed non-stop for two days through the gates at the World Maker Faire at the New York Hall of Science, despite the inconvenience of the Number 7 train being unexpectedly on the fritz.
>
> The fair was chockablock bursting with babies, kids, teenagers, geeks, college students, and parents, in that order. Every science nerd in a 250-mile radius was out in full force. Engines, motors, computer chips, electricity, radios, TV, printers all became art objects, as did NYU ITP graduate Laewoo Kang's adorable robots that moved according to Twitter feeds, with kids practically tearing down the house jumping all over themselves yelling, "Look Mom, robots!"
>
> . . . But, in terms of a smackdown between the the New Museum and Maker Faire, the winner is neither. It's the dark horse coming from behind, the Dumbo Arts Festival, where under a blazing full moon scores of Brooklynites massed on the filthy cobblestone streets directly beneath the Brooklyn Bridge to watch the Stan Vanderbeek-like immersive projection mapping light show until the clock struck midnight. They voted a resounding yeah to technological art for the masses . . . [147]

See Figures 59, 60, and 61. I will let this be an answer to the question, "who will determine the technological art/new media art discourse?" It could be a combination of artists, audiences, and less preciously-established outlets for discourse.

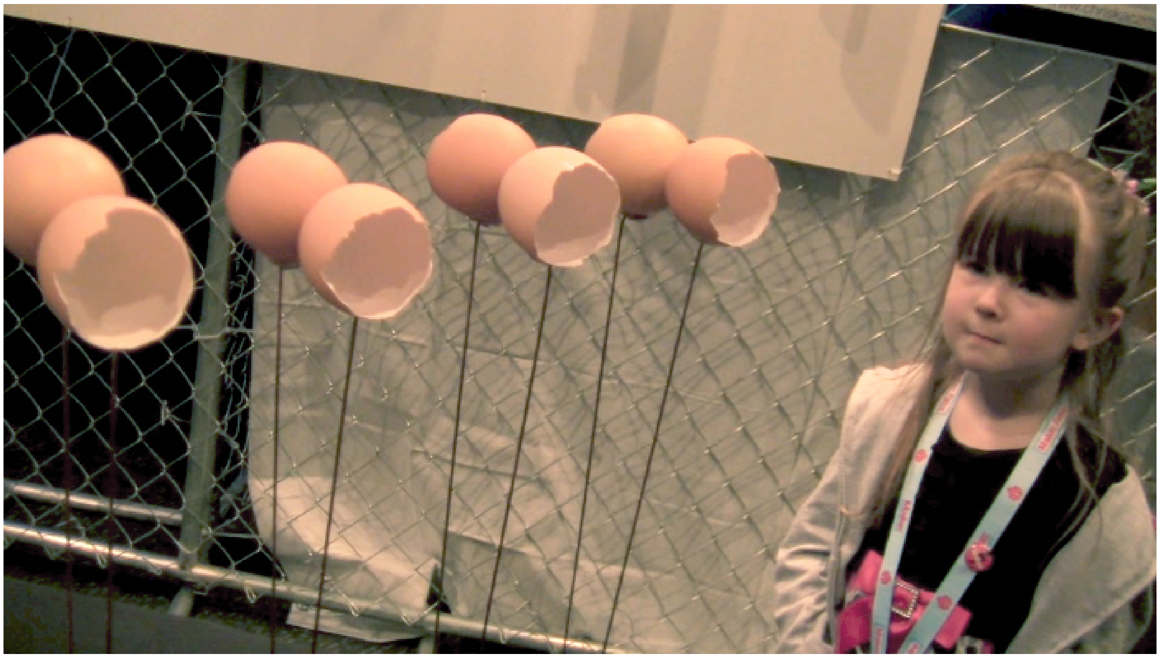


Figure 59: *Solar Symphony* by Chris Kaczmarek with rapt viewer. Photo by Ellen Pearlman for Hyperallergic.com.

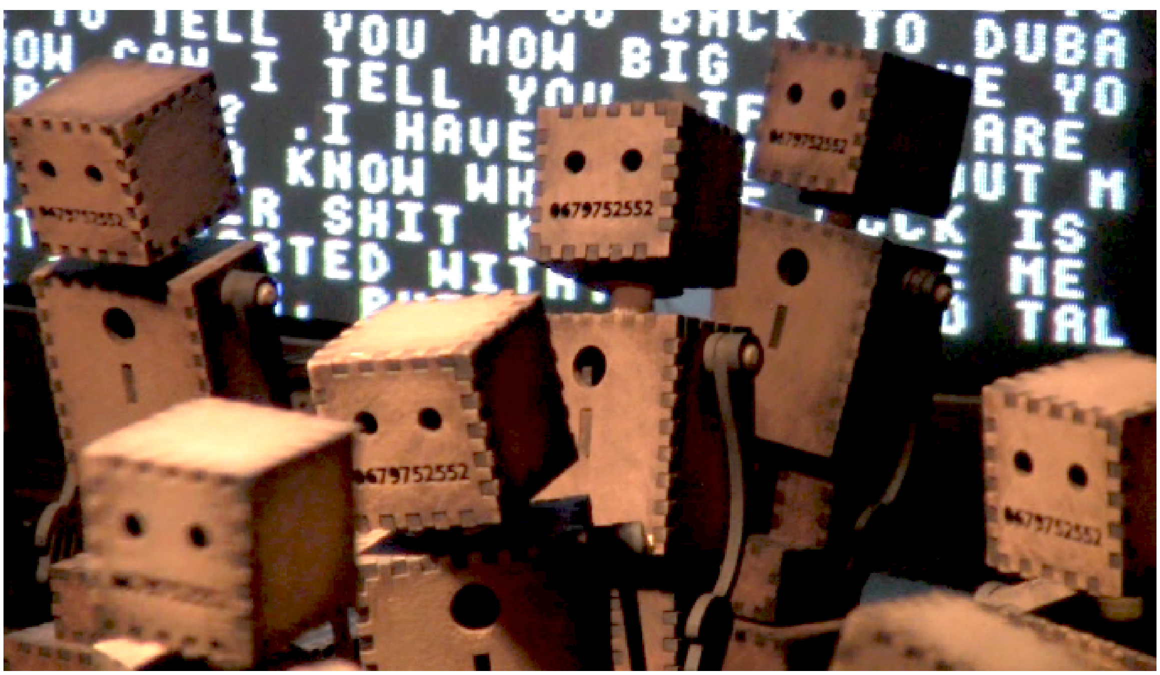


Figure 60: *I Want To* by Laewoo Kang. Photo by Ellen Pearlman for Hyperallergic.com.

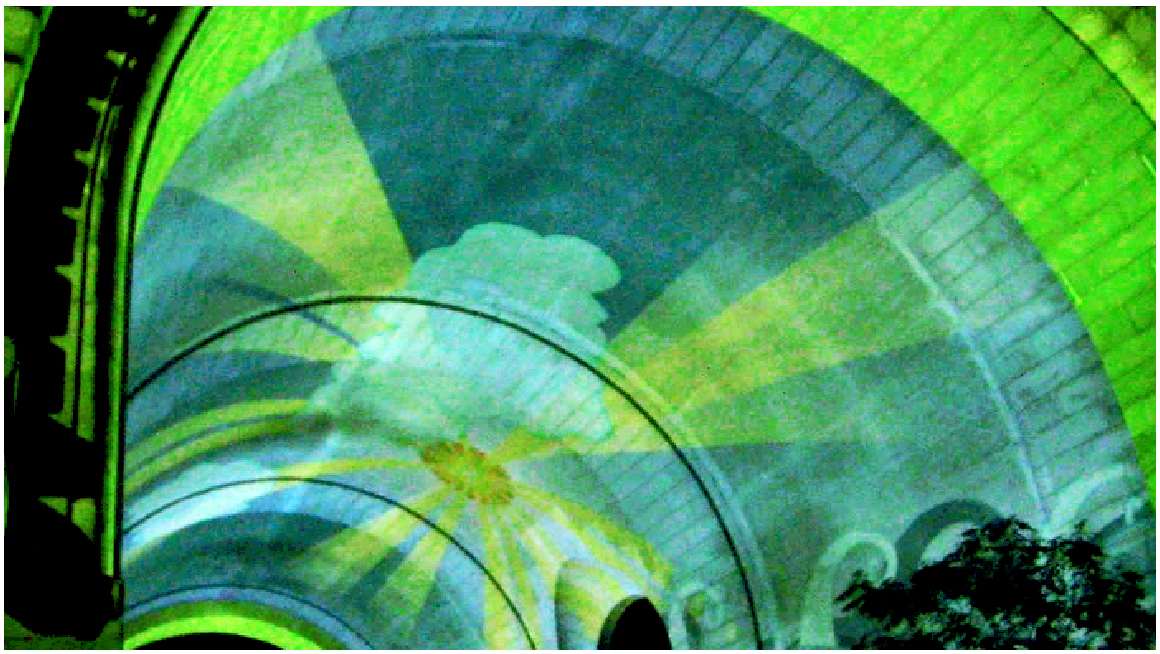


Figure 61: Archway of the Brooklyn Bridge as seen from below during the Dumbo Arts Festival, 2012. Photo by Ellen Pearlman for Hyperallergic.com.

CHAPTER III

BEYOND THE PARADIGM OF CONTEMPORARY ART

3.1 Introduction: Jean Tinguely's Homage to New York

In 1960, kinetic sculptor Jean Tinguely collaborated with Bell Labs research engineer Billy Klüver to create an elaborate machine that destroyed itself during a machine performance in the sculpture garden of the Museum of Modern Art in New York. Tinguely called the piece *Homage to New York* (Figure 62) and explained it in this way:

> This machine... It's a sculpture. It's a picture... It's a companist [composer or pianist]. It's a poet. It's a decoration. It's a situation. This machine is... a tentative of synthesis of plastic arts.
>
> The factor of autodestruction is a natural factor... Autodestruction is necessary because this machine is grandiose, spectac... This machine's life, very intensive... This intensive life of this machine is the cause of the autodestruction. [148]

Tinguely spent three weeks building *Homage* under the Buckminister Fuller Geodesic Dome in the museum's garden. Klüver brought him material from a dump in New Jersey and recruited his assistant Harold Hodges from Bell Labs to construct the timing and triggering devices that would, along with Tinguely's motors, release smoke, ignite fire, smash bottles containing odors, and play a piano with mechanical arms. At performance time, the machine sputtered and the best laid plans for the piano-playing, bottle-smashing, silver dollar-throwing machine sputtered as well. Yet the machine smoked, caught on fire, and twisted and turned. After it had stopped moving and the fire had been put out by the fire department, the audience moved in and collected the remains of the machine as souvenirs [149]. There must have been quite a contrast

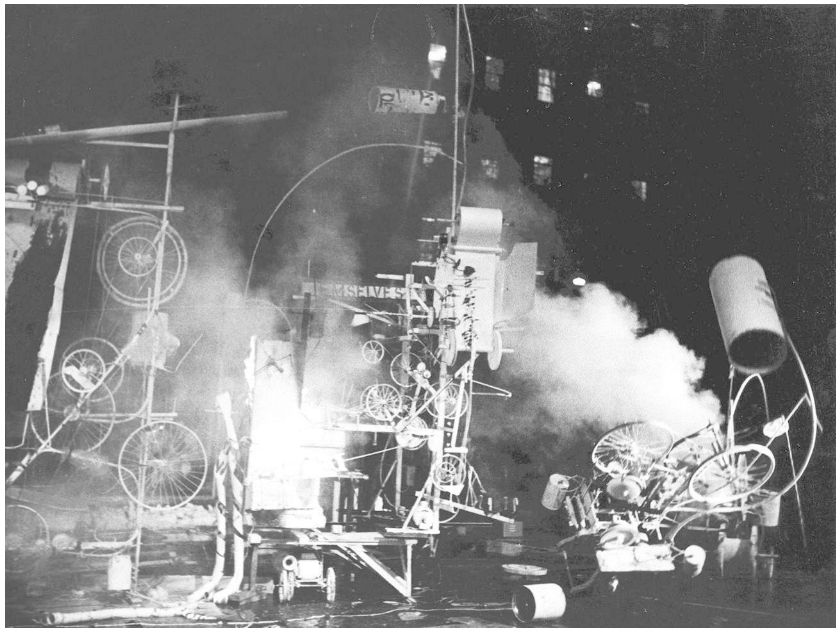


Figure 62: Jean Tinguely's *Homage to New York*, 1960, at the Museum of Modern Art's sculpture garden.

between the self-immolating, scrap-iron machine constructed of refuse odds and ends and the optimistic and clean technophilia of the Fuller Domes.

3.2 Experiments in Art and Technology

Through collaborating with Tinguely, Klüver experienced, to use his word, a "shift":

> A shift happened because, from my own experience, I had worked in 1960 with Tinguely to do the machine that destroyed itself in the Garden of MoMA. At that time I employed—or coerced—a lot of my co-workers at Bell Labs to work on the project.

Figure 63: Robert Rauschenberg and Billy Klüver's *Soundings*, 1966.

Figure 64: Robert Rauschenberg, *Open Score*, 1966. Performance presented as part of *9 Evenings: Theatre and Engineering*.

> When I saw that, I realized that the engineers could help the artists; the engineers themselves could be the materials for the artists. After the event, I got besieged by a lot of artists in New York like Andy Warhol, Robert Rauschenberg, Jasper Johns—all of them. Robert Whitman and Rauschenberg put the notion together that it should be a collaboration between artists and engineers, where they were equally represented. The idea was that a one to one collaboration could produce something that neither of the two could individually foresee. And that was the basis for the whole thing, and the system developed from there. [88, p. 8]

Klüver and artist Robert Rauchenberg collaborated on further art and technology pieces throughout the late 1960s and early 1970s, including *Soundings* (Figure 63). *Soundings* reads like a contemporary interactive art piece in terms of the configuration of visitor input and response. *Soundings* consisted of panels of silkscreened and silvered Plexiglass which both reflected the visitor's image and supported a collage

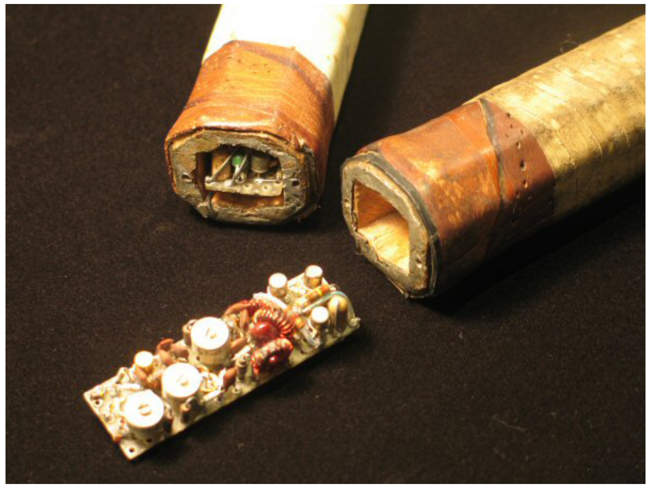
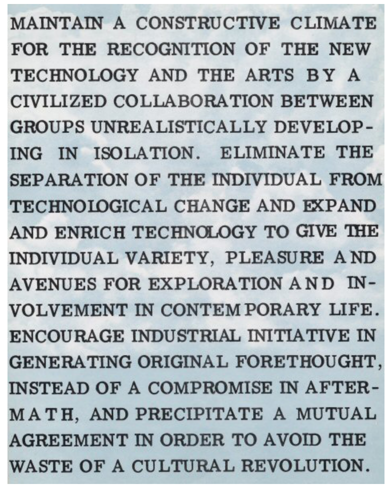


Figure 65: Tennis racquets equipped with electronic components, designed by Bill Kaminsky and Jim McGee for Robert Rauschenberg's *Open Score*, 1966.

of everyday wooden chairs. The system picked up the sounds of visitors' voices and divided these sounds into four frequency bands. Each frequency band would trigger a different constellations of lights illuminating the plexiglass from behind. For example, a child's high-pitched voice would illuminate a different pattern of imagery than that of an adult. Rauschenberg expressed his intention with the piece as "to use to the vocabulary of commonplace objects and to dissolve. . . the needless separateness between man and technology" [142].

In 1966, Klüver and Rauschenberg joined ten artists with forty engineers from Bell Labs to produce *9 Evenings: Theatre and Engineering*. *9 Evenings* was a series of performances incorporating high technology in New York City's 69th Regiment Armory, the site of the historical 1913 Armory Show. The high technology of the time that was used in the performances included video projection, wireless sound transmission, and Doppler sonar [96]. Rauschenberg's contribution was a tennis game between Frank Stella and Mimi Kanarek called *Open Score* (Figure 64). A small FM transmitter was placed inside the handles of the tennis racquets (Figure 65). Contact microphones were attached to the rims to pick up the reverberations produced by the impact of the balls. These data were relayed by short wave to



MAINTAIN A CONSTRUCTIVE CLIMATE FOR THE RECOGNITION OF THE NEW TECHNOLOGY AND THE ARTS BY A CIVILIZED COLLABORATION BETWEEN GROUPS UNREALISTICALLY DEVELOPING IN ISOLATION. ELIMINATE THE SEPARATION OF THE INDIVIDUAL FROM TECHNOLOGICAL CHANGE AND EXPAND AND ENRICH TECHNOLOGY TO GIVE THE INDIVIDUAL VARIETY, PLEASURE AND AVENUES FOR EXPLORATION AND INVOLVEMENT IN CONTEMPORARY LIFE. ENCOURAGE INDUSTRIAL INITIATIVE IN GENERATING ORIGINAL FORETHOUGHT, INSTEAD OF A COMPROMISE IN AFTERMATH, AND PRECIPITATE A MUTUAL AGREEMENT IN ORDER TO AVOID THE WASTE OF A CULTURAL REVOLUTION.

Figure 66: Experiments in Art and Technology Manifesto.

transmitters and from there to the Armory speakers. Each time a ball was hit a loud “bong” rang throughout the Armory. At the same time, the impact of the balls hitting the racquet strings triggered an automatic mechanism that shut off one of the thirty-six lights on the Armory ceiling. The game continued until the Armory became dark [26]. Infrared video cameras captured a silent crowd of about three hundred people moving in darkness and projected this image on a giant screen [103]. Other art pieces/technologies included the Ground Effect Machine. The Ground Effect Machine, by artist Lucinda Childs and engineer Per Biorn, was a metal and plexiglass cubicle that moved about the performance area on an air cushion. A goal of Lucinda Child’s work is to create objects that give rise to movement [25].

Klüver and Rauschenberg’s greatest collaboration was the formation of Experiments in Art and Technology (E.A.T.), an organization with the goal to develop collaborations between artists and engineers in order to join artistic and technological creation and exploration. They formed E.A.T. in 1966 along with with engineer Fred Waldhauer and artist Robert Whitman. Klüver believed that the engineer required the participation of the artist who, as a “visionary about life” and an active agent of social change, involved the engineer in meaningful cultural dialog. For Klüver, the artist had an obligation to incorporate technology as an element into the artwork, since technology had become inseparable from our contemporary lives. Quoting Klüver:

> the artist is a visionary about life. Only he can create disorder and still get away with it. Only he can use technology to its fullest capacity... the artists have to use technology because technology is becoming inseparable from our lives. [97, p. 38]

The E.A.T. Manifesto (Figure 66) expands these ideas:

> Maintain a constructive climate for the recognition of the new technology and the arts by a civilized collaboration between groups unrealistically developing in isolation. Eliminate the separation of the individual from technological change and expand and enrich technology to give the individual variety, pleasure and avenues for exploration and involvement in contemporary life. Encourage industrial initiative in generating original forethought, instead of a compromise in aftermath, and precipitate a mutual agreement in order to avoid the waste of a cultural revolution. [58]

A common theme in the statements of Kluver and Rauschenberg is the bridging of the gap between the individual and high technology, with high technology being a condition of contemporary life that could otherwise lead to alienation between the individual and technology. Kluver additionally emphasized that the artist could help the engineer think critically about their work and the consequences of their work "instead of a compromise in aftermath." On another occasion, during an interview with Garnet Hertz in 2002, Klüver stated, "what happens, of course, is that the artist widens the vision of the engineer... I think there is a huge consciousness inside technology that hasn't been tapped" [88, p. 9].

EAT established a Technical Services Program to provide artists with technical information and assistance by matching them with engineers and scientists as collaborators. Engineers were recruited initially from Bell Laboratories in Murray Hill, New Jersey and IBM Labs in Armonk, New York. E.A.T.'s Technical Services Program also supported members with newsletters and project updates, rental equipment, forums on emerging technologies such as holography, lasers, and computer-generated

Figure 67: First meeting of EAT in November 1966.

imagery, documentation resources in science and engineering, and a telephone assistance line run by engineers from E.A.T. offices. In conjunction with the Technical Service Program, E.A.T. organized thirty conferences, inviting artists and scientists from specialized research labs and private companies including the Massachusetts Institute of Technology, Eastman-Kodak, and Columbia University. These conferences provided information about and access to newly-developed technologies for artists for use in their work [1]. Klüver reports:

> Artists and the art community responded enthusiastically to E.A.T. By 1969, given early efforts to attract engineers, the group had over 2,000 artist members as well as 2,000 engineer members willing to work with artists. Expressions of interest and requests for technical assistance came from all over the United States and Canada and from Europe, Japan, South America and elsewhere. People were encouraged to start local E.A.T. groups and about 15 to 20 were formed. [96]

The response of art critics to E.A.T.'s work ranged from critical to lukewarm to non-existent. As Sylvie Lacerte writes in her research on E.A.T.:

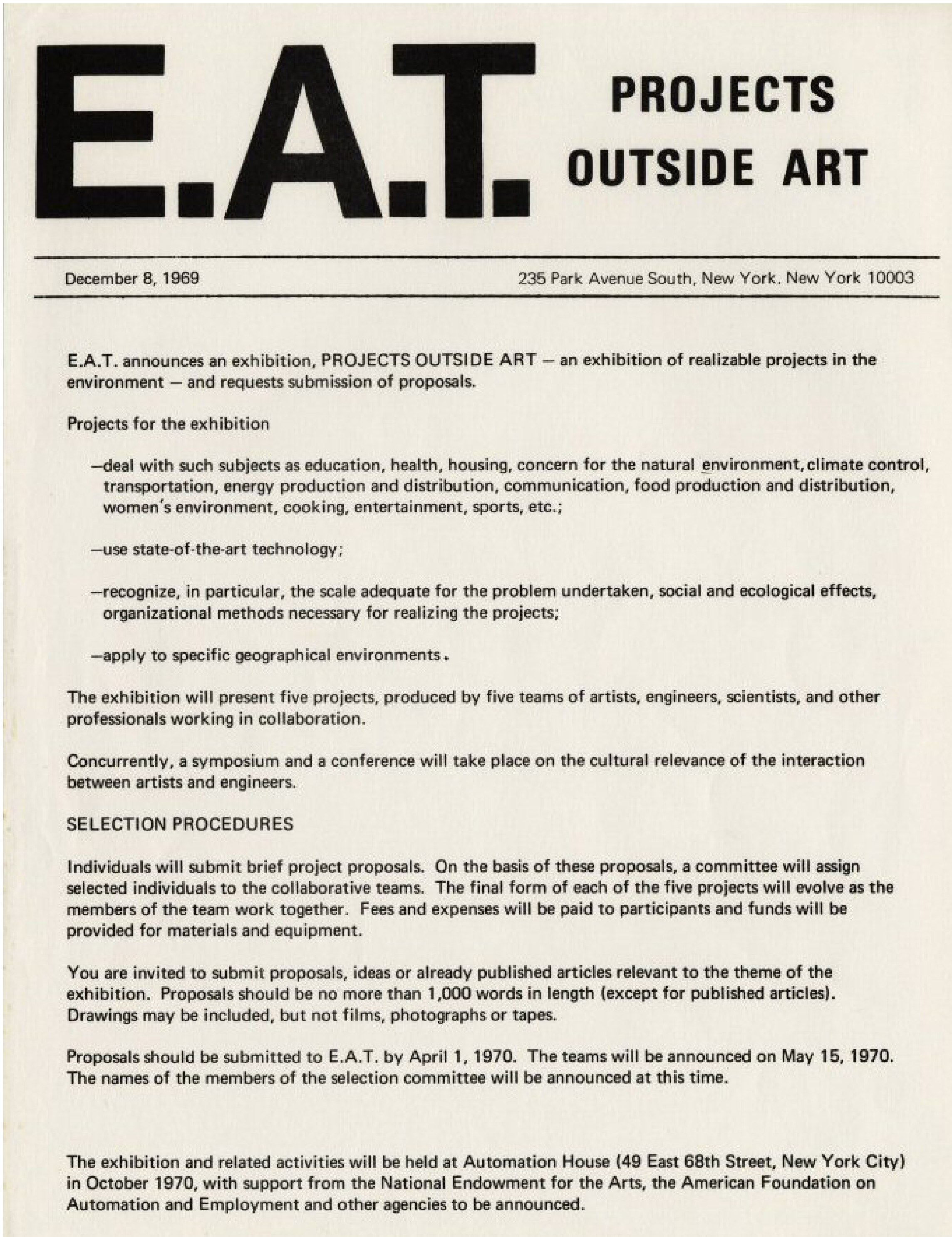
> To understand the lukewarm and sometimes dreadful reviews *9 Evenings* gleaned, we must bear in mind that art criticism continued, with few exceptions, to be founded on the modernist literary and artistic paradigm. At the time, Clement Greenberg was still disseminating Kant's theories on the autonomy of art through the separation of aesthetic, social, and scientific spheres. So imagine a series of hybrid performances, cross-fertilizing various artistic disciplines, industry and technology, and based on collaborative work. . . when *9 evenings* rolled into the Armory, critics were, on the whole, bemused at having few points of reference with which to analyze what was going on. . . [103, p. 163]

Lacerte casts *9 Evenings* within the contexts of 1960s art discourse. She points out that many of the pieces in *9 Evenings*, including Rauschenberg's *Open Score*, referenced the military use of technology in the Vietnam War [103]. For example, Rauschenberg's piece incorporated infra-red technologies used by the American military in Vietnam. In this way, the appropriation of a technology creates a charge beyond the immediate discourse of the piece. Lacerte also mentions the minimalist aesthetic of a choreography piece, called *Solo*, by Deborah Hay at *9 Evenings* [103]. Still, the event was dismissed by prominent art critic Lucy Lippard because, according to her, the artists' approach "was not radical enough" [107] in [103, p. 173, note 370].

Lacerte points out another issue that potentially influenced the reception of E.A.T.'s work by the contemporary art system. The artifacts were too rough around the seams to become commodities. Lacerte writes:

> the performances nonetheless represented a fugitive moment that could never become *commodified* enough to cross the art market's threshold, as had been the case with Conceptual Art. Indeed, the ideas of the Conceptual artists enjoyed such outstanding success that the international art market found a non-equivocal way to capitalize on the zeitgeist of that movement, although the artists had strived, in the beginning, to escape the traditional bourgeois, capitalistic art circuits. [103, p. 173]

Many of the artists who participated in *9 Evenings* and other E.A.T. events were contemporary art system insiders. Recognizable names include Rauschenberg, John Cage, Frank Stella, and Yvonne Rainer. Yet in this analysis of E.A.T.'s work, we come back around to the issues expressed in the previous chapter. Technological art was difficult to connect with the predominant art discourse of the times, the moments of performance and interaction were ephemeral and at times disfunctional, the products of technological art were materially rough around the seams, and this roughness contributed to difficulty in commodifying the work.



E.A.T. PROJECTS OUTSIDE ART

December 8, 1969 — 235 Park Avenue South, New York, New York 10003

E.A.T. announces an exhibition, PROJECTS OUTSIDE ART – an exhibition of realizable projects in the environment – and requests submission of proposals.

Projects for the exhibition

–deal with such subjects as education, health, housing, concern for the natural environment, climate control, transportation, energy production and distribution, communication, food production and distribution, women's environment, cooking, entertainment, sports, etc.;

–use state-of-the-art technology;

–recognize, in particular, the scale adequate for the problem undertaken, social and ecological effects, organizational methods necessary for realizing the projects;

–apply to specific geographical environments.

The exhibition will present five projects, produced by five teams of artists, engineers, scientists, and other professionals working in collaboration.

Concurrently, a symposium and a conference will take place on the cultural relevance of the interaction between artists and engineers.

SELECTION PROCEDURES

Individuals will submit brief project proposals. On the basis of these proposals, a committee will assign selected individuals to the collaborative teams. The final form of each of the five projects will evolve as the members of the team work together. Fees and expenses will be paid to participants and funds will be provided for materials and equipment.

You are invited to submit proposals, ideas or already published articles relevant to the theme of the exhibition. Proposals should be no more than 1,000 words in length (except for published articles). Drawings may be included, but not films, photographs or tapes.

Proposals should be submitted to E.A.T. by April 1, 1970. The teams will be announced on May 15, 1970. The names of the members of the selection committee will be announced at this time.

The exhibition and related activities will be held at Automation House (49 East 68th Street, New York City) in October 1970, with support from the National Endowment for the Arts, the American Foundation on Automation and Employment and other agencies to be announced.

Figure 68: The press release for E.A.T.'s *Projects Outside Art*, 1969.

In 1969, E.A.T. put out a call for *Projects Outside Art*. The press release for *Projects Outside Art* (Figure 68) reveals the societal engagement and discourse embedded within:

> Projects for the exhibition deal with such subjects as education, health, housing, concern for the natural environment, climate control, transportation, energy production and distribution, communication, food production and distribution, women's environment, cooking, entertainment, sports, etc.

This list of social concerns points to contributions from the collaboration with engineers more so than from the discourse of the contemporary art world at the time.

Klüver, reflecting in the year 2000 on the work of E.A.T., writes:

> In the seventies, emerging hardware technologies used in communications, data processing, and control and command instrumentation led to a new generation of software systems that were of great interest to artists. Realizing that artists could contribute significantly to the evolution of this software, E.A.T. generated a series of projects in which artists participated in these areas of technological development. E.A.T. undertook interdisciplinary projects that extended the artists' activities into new areas of society.
>
> Projects realized at this time included: *The Anand Project* (1969), which developed methods to produce instructional programming for India's educational television through a pilot project at Anand Dairy Cooperative in Baroda (India); *Telex: Q&A* (1971), which linked public spaces in New York (U.S.), Ahmadabad (India), Tokyo (Japan) and Stockholm (Sweden) by telex, allowing people from different countries to question one another about the future; *Children and Communication* (1972), a pilot project enabling children in different parts of New York City to converse using telephone, telex and fax equipment; a pilot program (1973) to devise methods for recording indigenous culture in El Salvador; and finally a large-screen outdoor television display system (1976-1977) for the Centre Georges Pompidou in Paris. [96]

From these examples we find art and technology projects speaking to social practices with technology that likely influenced the sensibilities of both the collaborating artists and engineers. Twenty-eight regional E.A.T. chapters were established throughout the U.S. in the late 1960s to promote collaborations between artists and engineers

Figure 69: Thomas Wilfred with his light art, *Lumia*, 1960. Wilfred had been creating light art since the early twentieth century.

and expand the artist's role in social projects related to new technologies. E.A.T. continued throughout the 1970s, 80s, 90s and 2000s until Klüver's death in 2004. Over the course of these years, Klüver took dozens of artists, including Marcel Duchamp, on tours through Bell Laboratories [85].

3.3 Watershed years

3.3.1 The Los Angeles County Museum of Art's Art & Technology program

Although technological art has a history in the work of light artists throughout the twentieth century (see Figures 69, 70, 71, 72), the late 1960s were watershed years in the development of technological art. The Los Angeles County Museum of Art (LACMA) ran an Art and Technology (A&T) program from 1967 - 1971. The program was directed by curator of modern art Maurice Tuchman and included prominent artists such as Robert Irving, James Turrell, Richard Serra, Claus Oldenburg, Roy Lichtenstein, Jean Dubuffet, and Andy Warhol. Theoretical physicist Richard Feynman served as an active advisor. The A&T program placed artists within high-technology corporations to create projects. Two exhibitions resulted, one at the Osaka World's Fair in 1970 and one at LACMA in 1971.

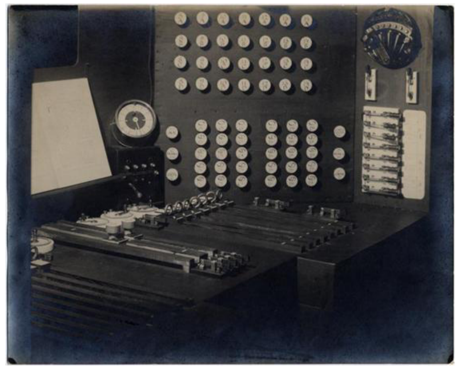


Figure 70: The interface of Wilfred's light organ, *Clavilux*, circa 1920.

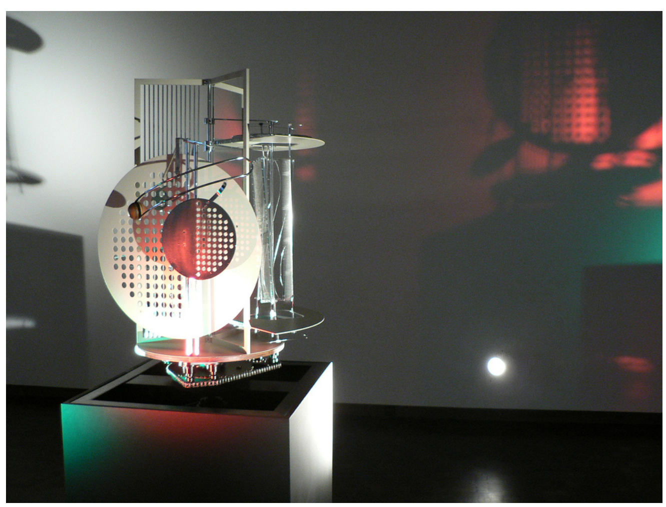


Figure 71: Replica of Laszlo Moholy-Nagy's *Light-Space Modulator*, 1922-30. Van Abbe Museum.

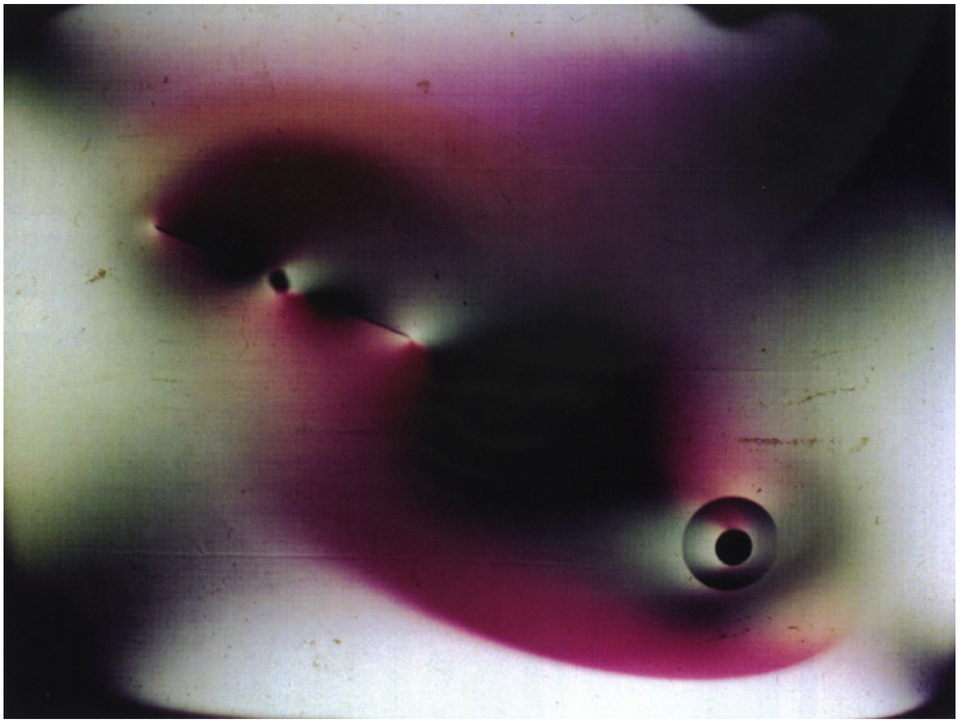


Figure 72: Still of Oskar Fischinger's Lumigraph film, circa 1969.

The work that was created through the LACMA A&T program spoke to both the creation of art objects and arts research. Many of the pieces articulated qualities found in recently-created digital technological art. For example, Andy Warhol's collaboration with Cowles Communications incorporated Cowles' 3-D printing process. Curator Maurice Tuchman describes this piece, *Rain Machine* (Figure 73), as engaging with

> man's transformation of nature into artifice: it was a giant field of three-dimensional printed flowers, seen through sparkling transparent curtains of water, falling like rain. [191, p. 29]

Tuchman wrote that Warhol's piece exemplified a quality shared by the other pieces in the program: "an emphasis on transient images and evanescent phenomena. At Expo there was no object which sat in a traditional relationship to a ground" [191, p. 29].

The co-project of artist James Turrell, artist Robert Irving, and Garrett Corporation's Life Sciences Department investigated the nature of perception. This work did

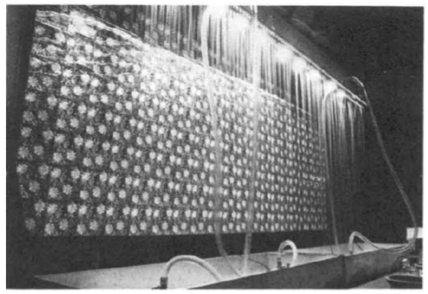


Figure 73: Andy Warhol's *Rain Machine*, 1970.

not produce an artifact. Instead, the artists devised and conducted a research project with Dr. Ed Wortz, Head of the Life Sciences Department. Experiments included investigating the perception experiences of thirty to forty subjects in a dark anechoic chamber (Figure 74). Turrell, Irving, and Wortz also duplicated a then-recent experiment by Kristian Holt-Hansen of Coopenhagen University that characterized the sense of taste through its correlation with tonal pitch. They also conducted experiments with a small number of subjects on alpha wave conditioning using an EEG machine. After the duration of the A&T program, Irving continued to work with Wortz on Garrett projects, specifically a symposium initiated by NASA on habitability research, which led to further collaborations between Irvin and Wortz on spacecraft environments.

One marked dynamic in both the E.A.T. and LACMA A&T projects is the level of corporate/industrial collaboration. The contemporary art world has relied on corporate investment to a large extent, but managed to keep this investment on the level of direct contribution without contact between the artist and the corporation. This theoretically served to separate the vision of the artists from the hegemonic influence of industry. Of course this is an ironic position because the contemporary art market responds to and elevates art that fits into its market demands, which can only have an effect on art production. Technological art, on the other hand, relies in part on commercial and industrial technological advances and access to technologies produced in this realm.

Figure 74: Robert Irving and James Turrell in the anechoic chamber.

The Bauhaus may be considered a previous exemplar of a relationship between art and industry, but the dynamics are significantly different. The Bauhaus attempted to reconnect the artist with the milieu of artisan-driven production by emphasizing the common foundations of art and craft as applied art. The Bauhaus did not look nostalgically toward the previous era of hand-crafted work. Instead, it sought to integrate the artist into the production methods of industrial society. From the Bauhaus Manifesto as formulated by director and founder Walter Gropius and summarized by Alfred H. Barr, Jr., Director of the Museum of Modern Art in the 1930s:

> - most students should face the fact that their future should be involved primarily with industry and mass production rather than with individual craftsmanship
>
> ...
>
> - because we live in the 20th century, the student architect or designer should be offered no refuge in the past but should be equipped for the

> modern world in its various aspects, artistic, technical, social, economic, spiritual, so that he may function in society not as a decorator but as a vital participant. [18]

Gropius' statement on the intentions of the Bauhaus reads:

> The Bauhaus does not pretend to be a crafts school; contact with industry is consciously sought...the old craft workshops will develop into industrial laboratories: from their experimentation will evolve standards for industrial production...The teaching of a craft is meant to prepare for designing for mass production. Starting with the simplest tools and least complicated jobs, he gradually acquires ability to master more intricate problem and to work with machinery, while at the same time he keeps in touch with the entire process of production from start to finish. [140, p. 93]

In contrast, technological art's relationship with industry is through an independent but common use of technology. This relationship has to do with a commonality of technological materials, not something akin to the larger social and design program of the Bauhaus. Klüver's vision could be considered to have some parallels with that of the Bauhaus, in the sense that bringing artists and industry together would ameliorate alienation from the processes of industrial technological creation and usage. Yet the work of E.A.T. originated in a different cauldron than that of the Bauhaus. It was a postmodern version. The emphasis for the artists of E.A.T. and the LACMA A&T program can be characterized in terms of the pursuit of artistic vision with the aid and resources of industry. Industry, in turn, contributed these resources based on the possibility that there would be a mutually beneficial exchange of creative thought. Still there was a tension between what was seen by some as a cultural advance and by others with ambivalence. In the words of the co-curator of the LACMA program, Jane Livingston:

> Art and Technology has had as one of its first premises the assumption that it is possible, and perhaps valuable, to effect a practical interchange between artists and members of the corporate-industrial society. The various cultural attitudes surrounding such a premise are deeply ambivalent. On virtually every level, including the popularly shared ideas and fears about the influence of "advanced technology" on the life of the masses,

Figure 75: John Whitney conducting research on computer animation during an artist residency at IBM Labs, 1966-69.

> as well as the many subtle analyses of writers and critics evaluating the relationships between art, or the humanities and technology, qualities of emotionalism and partisanship prevail. [110, p. 43]

The industrial/artistic collaborations that ensued through E.A.T. were carried forward in the structure of LACMA A&T and created a paradigm for relationships between technological artists and industry. This paradigm structured artist-in-residence programs for technological artists in industry throughout the 1970s, 1980s, and 1990s. Such programs include IBM's artist-in-residence program (see Figure 75), Interval Research's artists-in-residence program, and Xerox PARC's artists-in-residence programs.

3.3.2 Computer art

Computer art in the 1960s developed independently of E.A.T. and LACMA's A&T program. Digital technologies and art had been coupled since the early days of digital computing in the 1960s, particularly in Britain. By 1965, computer-related art reached enough critical mass that the London Institute of Contemporary Art began planning an exhibition titled *Cybernetic Serendipity* [160]. The show opened in 1968 and drew a crowd of 40,000 visitors [67]. Pieces on exhibition ranged from algorithmically-generated graphical patterns, computer-generated musical scores by the likes of John Cage, painting machines by Jean Tinguely, and a robot by Nam June Paik. Honeywell commissioned kinetic sculptor Rowland Emett to create a mechanical computer (Figure 76). The catalog described cybernetics, digital computing, and robotics to the general public [160]. Other watershed events in computer arts include the Computer Arts Society's *Event One* in London in 1969. Here contemporary machines were shown alongside artworks. No differentiation was made between object, process, materials, or method, nor between the disciplinary backgrounds of the makers [123]. Computer Arts Society's manifesto included the idea that its members understood the profound impact that computing would have on humanity, thus one of the missions of the Computer Arts Society was to provide "a forum in which artists and scientists [could] jointly work out these implications" [123, from a promotion leaflet drafted by Alan Mayne circa 1969].

The Computer Arts Society collection is now housed in the Victoria and Albert Museum in London. Other exhibitions of computer, digital, and interactive arts of the time include *The Machine as Seen at the End of the Mechanical Age* (MOMA, curated by K.G. Pontus Hulten, 1968); *Software: Information Technology: Its New Meaning for Art* (Jewish Museum, New York, curated by Jack Burnham, 1970); and *Information* (MOMA, curated by Kynaston McShine, 1970). Paul Brown and Catherine Mason, in a special history issue of *Leonardo Electronic Almanac* (2005), discuss the reception of this work, which by now will strike a familiar chord:

> The computer-based work was problematic—it challenged the understanding of the humanities-trained theorists (who would not at that point in time have had any exposure whatsoever to computer systems). In consequence, the computational work was identified with technological absolutism and the modernistic emphasis on intrinsic media qualities. If it had occurred later, it might have been more correctly identified with more postmodern concerns like non-linearity and emergence. However, these concepts were, at that time, almost unknown outside a small scientific community [29].

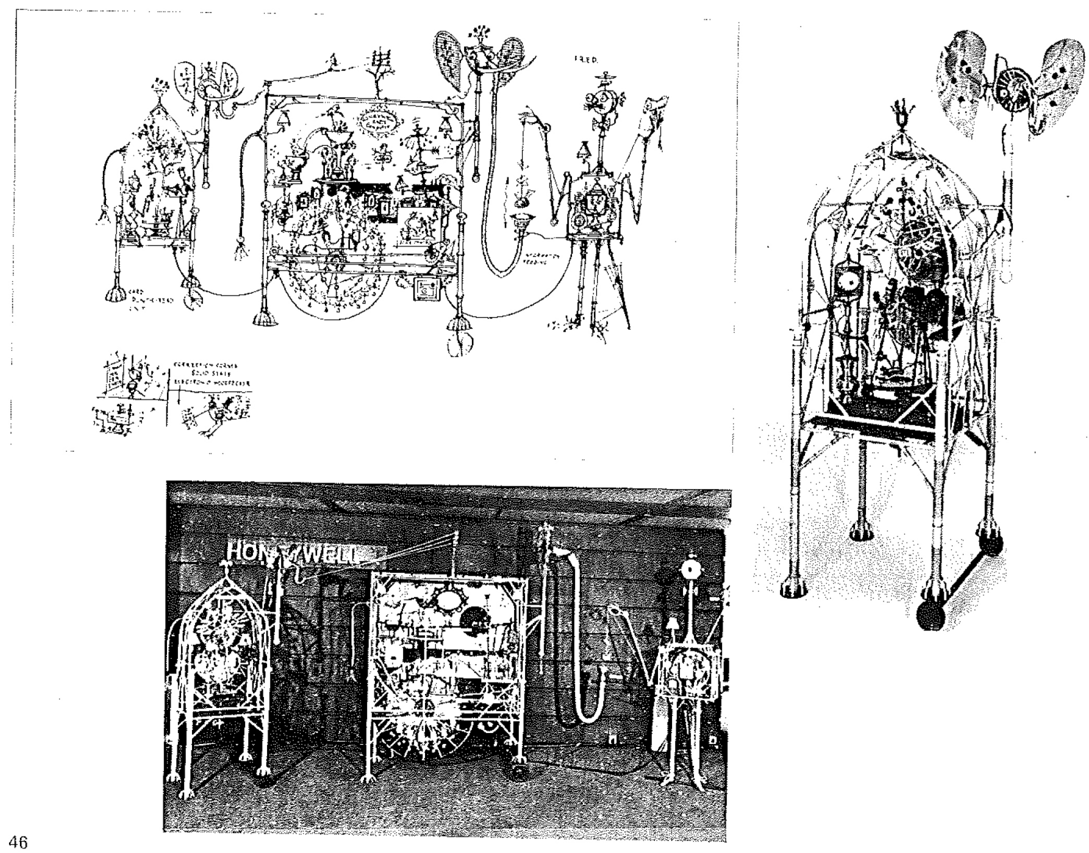


Figure 76: The Honeywell Emett 'Forget-me-not' (peripheral pachyderm computer), 1966. Image from the *Cybernetic Serendipity* catalog.

Figure 77: Art or machine? Image from *Event One*, 1969. Suspended work by Philip Hodgetts senses activity in the room and displays it.

Figure 78: John Lansdown, a member of CAS, rehearsing computer-generated dance notation for choreography with dancers from the Royal Ballet School, London, 1969.

The artwork in the images from *Event One* (Figure 77) and the Computer Arts Society (Figure 78) prefigure the computer science research areas of ambient displays and embodied interaction, respectively. These were the beginnings of work at the intersection of art and computer science research.

Artist David Rokeby mastered his practice of embodied interaction in 1986 with his development of *Very Nervous System* (Figure 79). *Very Nervous System* invites people to move within their everyday environment. Their movements evoke music from the system, thus exploring the resonant nature of interaction and its ability to create insight into people's movement in their familiar spaces. Like many digital artists, Rokeby has written extensively on interaction with computing devices. While computer science, specifically the subfield of human-computer interaction (HCI), defines interaction as the "joint performance of tasks by humans and machines" [89], to Rokeby, "A technology is interactive to the degree that it reflects the consequences of

Figure 79: David Rokeby and *Very Nervous System* in Potsdam, 1993. Rokeby invented the system in 1986.

our actions or decisions back to us" [166]. In the 1980s, Rokeby came to consider topics HCI researchers in the 2000s have been exploring as part of HCI's contemporary discourse:

> The computer as a medium is strongly biased... Because the computer is purely logical, the language of interaction should strive to be intuitive. Because the computer removes you from your body, the body should be strongly engaged. Because the computer's activity takes place on the tiny playing fields of integrated circuits, the encounter with the computer should take place in human-scaled physical space. Because the computer is objective and disinterested, the experience should be intimate. [165]

Intersections between digital art and interaction with computing devices continues to be explored through a dedicated Digital Arts Community at the major academic conference for human-computer interaction, CHI. Several artists have exhibited art or written papers for this technical conference (see Figures 81, 82, 80 for examples).

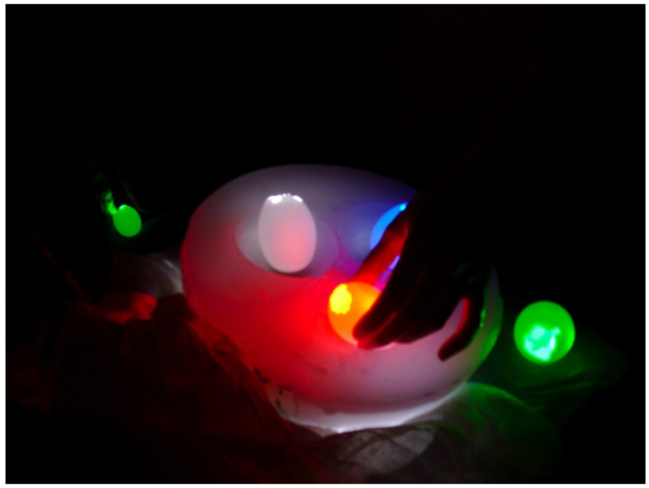


Figure 80: *Fragile* by Carla Diana, from a paper given at alt.chi 2008 as part of the larger *CHI* program.

Work at the intersections of computing and digital art is an active area of art production. Major pieces include Chaos Computer Club's *Blinkenlights:Arcade*, a playable monitor created from the facade of the Bibliothèque Nationale de France, Paris, as part of the Nuit Blanche festival, 2002 (Figure 83) and Rafael Lozano-Hemmer's *Pulse Spiral*, shown here at the Center for Contemporary Culture, Melnikov Garash, Moscow, Russia in 2008 (Figure 84). The hanging lights of *Pulse Spiral* pulse according to the heart rate of visitors as sensed by the input device they are touching. This piece is reminiscent of Philip Hodgetts's piece shown in Figure 77. Incidentally, Lozano-Hemmer is one of the few technological artists who have broken into the contemporary museum and gallery system.

3.4 Institutional and research developments in the 1970s, 80s, and 90s

Throughout the 1970s, 80s, and 90s, support for practices at the intersection of art and technology continued to grow. Ars Electronica, in Linz, Austria, was founded in 1979 to support the festival of the same name. Under the platform of supporting the linkages between "Art, Technology, and Society," Ars Electronica takes "ars" in

Figure 81: *Virtual VJ* by Steve Gibson and Stefan Müller Arisona. *The User in Flux* workshop performance. CHI 2011.

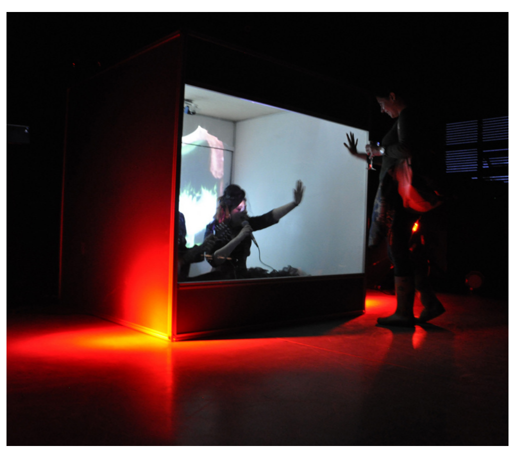


Figure 82: *humanaquarium* at *The User in Flux* workshop performance. CHI 2011.

Figure 83: Chaos Computer Club's *Blinkenlights:Arcade* at the Nuit Blanche festival, Paris, 2002.

Figure 84: Rafael Lozano-Hemmer's *Pulse Spiral* at the Center for Contemporary Culture, Melnikov Garash, Moscow in 2008.

Figure 85: Matthew Gardiner with *Oribotics* (origami robotics) at Ars Electronica Futurelab.

a broad sense. The Prix Ars Electronica has been awarded to Pixar for computer animation (2005, Distinction Award), Linux/Linus Torvalds (1999), and Wikileaks (2009) in addition to artists such as David Rokeby (2002). Ars Electronica has built a museum, a media center, and FutureLab, a research and development facility. FutureLab's various divisions invite visiting artists and researchers to conduct interdisciplinary research in architecture, biology, chemistry, graphics, informatics, art, media design, media technology, music, physics, sociology, and telematics (see Figure 85 of researcher Matthew Gardiner and his *Oribotics*, developed at Ars Electronica Futurelab). Siemens Corporation also contracts with Ars Electronica Futurelab for research and development purposes. This work has resulted in a handful of patents.

V2_ was founded as a punk collective in Rotterdam in 1982. By the mid-1980s it had grown to be an "Institute for Unstable Media." V2_ initially supported new technology and electronic media in the audiovisual arts. It grew to organize interactive video and sound installation exhibitions, as well as experiments with robotics and the use of computation to support electronic music and digital imagery. V2_ also organizes public events and created a publishing program to encourage discourse on art, theory, technology, and society. The technologies that V2_ supports grows as high technologies develop, moving from computing in the audiovisual environment to network and communications media, virtual reality, open source hardware and software, and electronic textiles. In the 1990s, V2_ founded the biannual Dutch Electronic Art Festival (DEAF), which it continues to organize, and created an international media laboratory, hosting artists from around the world for production, research, and knowledge exchange. From the V2_ web site:

> The often long-term research projects focus on the use of new technical possibilities for artistic means, research on the cultural and social implications of these techniques and the development of technically innovative (web) applications. They have resulted in software tools, but also in mixed media applications and interactive installations in public space. Apart from that, V2_ also organizes workshops and expert meetings to exchange knowledge and experiences with other professionals. [193]

Knowledge practices are particularly important in the field of technological art for the following two reasons: (1) the medium of high technology is a moving target, and artists develop shared strategies for using this technology as a medium; and (2) the coupling of technology to society implies a near-responsibility for artists who are adopting these technologies to critically examine their practices.

Zentrum für Kunst und Medientechnologie (ZKM) in Karslruhe, Germany combines exhibition space with research and library facilities to support contemporary new media art. ZKM was founded in 1989, but had been in the planning stages since 1980. The NTT-InterCommunication Centre in Tokyo, another large exhibition, research, and documentation facility, was established in 1997, having been in the planning stages since 1990.

In 1992 and 1993, respectively, the technology research think tanks Interval Research and Xerox PARC, both in Silicon Valley, established artist-in-residence programs. Interval Research was founded in 1992 by Paul Allen, co-founder of Microsoft Corporation, and David Liddle, a computer industry veteran. Interval was a research setting "seeking to define the issues, map out the concepts and create the technology that will be important in the future" [161]. Intervals think tank included filmmakers, designers, musicians, cognitive psychologists, artists, computer scientists, journalists, entrepreneurs, engineers and software developers.

The Xerox PARC artist-in-residence program (PAIR), initiated by researcher Rich Gold at Xerox PARC, paired new media artists with Xerox engineers and researchers. Chief scientist of Xerox Corporation from 1990-2000, John Seely Brown, frames artists in the PAIR program as researchers and innovators. In his introduction to Craig Harris's book, *Art and Innovation*, which chronicles the PAIR program, Brown writes:

> Innovation is a necessary component of any contemporary corporation's success, and yet how to achieve innovation remains for many companies an irksome mystery... The PAIR Program—the PARC Artist-in-Residence program—is one of the ways that PARC seeks to maintain itself as an innovator, to keep its ground fertile, and to stay relevant to the needs to Xerox. The PAIR program invites artists who use new media into PARC and pairs them with researchers who often use the same media, though often in different contexts. The output of these pairings is both interesting art and new scientific innovations. The artists revitalize the atmosphere by bringing in new ideas, new ways of thinking, new modes of seeing and new contexts for doing. All of these innovations mulch the soil and plant new and unexpected seeds. Who knows what wonders will grow when two complex, well-established intellectual traditions meet? The cross-fertilization between both disciplines seems to occur at almost the genetic level.
>
> ...Xerox is, after all, The Document Company, and what artists fundamentally make are documents, particularly new forms and genres of documents. Artists are really document researchers discovering new kinds of documents, new uses for documents, new ways of constructing documents, new ways for documents to look, sound, and behave, new methods for constructing documents and even new definitions of what constitutes a document.

> . . . In trying to make this leap, artists put tremendous pressure on current technologies. “Why can’t we do this with this printer?,” “ Why can’t we use this program in this way?,” “What if we did this with this scanner?” are all questions that flow from artists who confront what the rest of us think are good pieces of technology. But for the artist who is looking into the future and seeing entirely new forms of documents, this current stuff isn’t quite right. We benefit from paying attention to these demands, for what artists pioneer often becomes the norm. Unusual art pieces of today can become core media models not many years from now. [28, pp. xi-xiii]

In a later interview with Linda Naiman, an entrepreneur who specializes in arts-based learning for business, Brown extrapolates on the dynamics of the artist as innovator in a research and development setting:

> There are three ways I look at [the impact of an art experience]. One is the notion that engaging in these types of activities evoke deeper responses, deeper emotions. It brings forth many of the tacitly held beliefs and assumptions that you have. So think of it as evocative of the tacit knowledge.
>
> The second is that focused conversations are built and fused together around evocative objects that concern problems that the researcher has on his or her mind. I have said very often, it was the researcher that had the real problem, but the interaction with the artist actually made a big difference. Now that’s a complex interplay, ’cause it takes over; it’s like a conversation that unfolds over many months.
>
> The third concerns the power of simplicity. Simplicity prior to complexity doesn’t mean much. But simplicity, after you pass through the wall of complexity, after you have marinated in a fully nuanced reading of the situation and then rendering it in very simple ways is extraordinarily powerful.
>
> . . . And so, my favourite saying is that “Picasso can say more with five lines than most of us can say writing an entire book.” Picasso does not traffic in commas, and parentheses. When you’re doing a painting or sketch, you do not have qualifiers. You have to be crystal clear about matters, and that’s one of the beauties of art as a primary language, primary in that you can’t make caveats and qualifiers around everything. Also note that the image you construct is meant to be an evocative object for both you and others. You’re conversing with yourself as well with others. [138]

In these two long quotes, Brown describes artists’ potential contributions to research and development. In the first quote, he emphasizes artists’ alternative but often valid perspectives on media and technology. In the second quote, he emphasizes the more ineffable and tacit aspects of a research and development problem that the artist can potentially access and portray through their work.

Innovations and outcomes that came from PAIR include the following:

- Artists Jon Winet and Margaret Crane worked with PARC computer scientists to create an interactive Web site that allows mental patients to communicate with each other, their doctors, and their friends, a decade before Facebook.

- Documentary filmmakers John Muse and Jeanne Finley worked with PARC cultural anthropologists Lucy Suchman, Jeanette Blomberg, Susan Newman, and computer scientist Randy Trigg to create a nested situation of spectatorship and study. The filmmakers made a film documenting anthropologists studying artists as the anthropologists studied them. In other words, the anthropologists studied the artists making a film about the anthropologists studying artists. This process was iterated until the methodologies of each group began taking on those of the other.

- Vocalist Pamela Z, who uses physical gestures to control banks of electronics that alter her voice, worked with gesture-recognition scientist Michael Black and document philosopher David Levy, "thereby altering their understanding of what is possible in this area" [78, p. 18].

- Interactive novelist Judy Malloy worked with *Lambda MOO*[1] scientists to develop the first interactive detective novel in a multiperson MUD. Malloy also co-wrote a hypertext novel with a female PARC scientist that explored gender across the artist-scientist disciplines.

[1] *Lambda MOO* is an early MOO, a type of on-line community. A MOO is an object-oriented MUD. The MUD acronym stands for multi-user dungeon. *Lambda MOO* was created by Pavel Curtis at Xerox PARC.

In these examples, we can see research relating to the creation of artifacts (Wilnet and Crane), creative and investigative processes (Muse and Finley), human-computer interaction (Pamela Z), and cultural production at the intersections of art and technology (Judy Malloy). Other intangible contributions are implied in Rich Gold's statement, "PAIR is an opening into using some of the methodologies of art in scientific research, which is a creative activity itself and therefore is always on the lookout for new techniques to be borrowed from the other professions" [78, p. 19].

Research in the arts can take many forms: materials and process research, form research, technical research, and investigations into forms of expression. The arts process has also been used formally in arts-based research, particularly in psychology and social science, to leverage the creation process to explore and understand experience. Technological art holds a singular position at the intersections of art and technology. To re-quote writer Quaranta from Chapter 2:

> Historically the New Media Art world filled the gaps between one creative arena and another, between arts and science, arts and technology. This was its mission, its destiny. [157]

Technological art can hold a "third place" at the intersections of art, research, and technology development. The previous examples in this section describe some of the configurations that can exist in this space. There have been episodic programs supporting research at the intersections of art and technology. Theoretical supports for this research, in other words, research supporting this research, is less common. The research team of Linda Candy and Ernest Edmonds are foremost among researchers supporting this area.

Candy is a researcher with a background in computer science, specifically computer-aided learning. Edmonds is a digital artist with a background in mathematics and philosophy. After a series of group meetings in the early 1990s, Candy and Edmonds founded the Creativity and Cognition conference series, now a well-established conference series sponsored by the ACM (Association for Computing Machinery). The early meetings of this conference included artists and researchers involved in computing. These two communities previously had not had much contact with each other. In fact, one of the early motivations for the Creativity and Cognition conferences was to cross-pollinate between the two groups. Candy and Edmonds founded Creativity and Cognition Research Studios in 1998 as a joint venture between the School of Art and Design and the Department of Computer Science at Loughborough University in England. The goals of the studio were to operate within the inter-disciplines of creative cognition, media, and digital arts in order (quote):

- to create a strategy for encouraging innovation and change;
- to foster inter-disciplinary work between artists and technologists;
- to drive digital art practice in ways that are new and challenging. [36, p. 16]

Candy and Edmonds's interest in technological art focuses on ways that digital art adopts and expands the interactivity inherent in digital media, thus creating an interplay between art and media innovation. They point out that since the 1970s, computation has enabled more participatory, interactive artwork. At the same time, the complexity and rigidity of computational systems have presented a challenge to the working methods of artists [34]. Their research focuses on mediating the dynamics of creativity, interactivity, collaboration between the art and technological disciplines, and the complexity of computing. In the Preface to their first book, *Explorations in Art and Technology*, they write:

> Participation in interactive art brings with it the kind of engagement in the creative process that is normally denied the art viewing public. Interaction is central to art practice today but is not part of conventional gallery culture. The new art and technology experiences do not necessarily fit comfortably into familiar cultural contexts. Being in interactive spaces is engaging and interesting. Children and adults too can have fun with this kind of experimental art. It is one example of the new forms and audience relationships that are developing at the intersection of art and technology. [36, p. xi]

At the same time:

> Artists use digital technology to create artworks in ways they cannot achieve in any other way... And if it involves many years of struggle to take them on that unknown road, then that is what must be faced. For innovative people, this does not just mean becoming skilled using a particular software application, rather it means developing strategies by which they can realize the challenges they have set themselves. Such strategies involve pushing the boundaries of what is technically possible, which means always needing to learn new methods, new knowledge and new ways of working. [34, p. 265]

A large part of the Creativity and Cognition research strategy is to understand the creative processes involved in working across disciplines with technology. Thus, this research operates on two levels: that of enabling new digital artwork and increasing the understanding of creative practices at the intersections of art and technology. From 1998-2003, Candy and Edmonds directed an artist-in-residence program focused on collaboration between artists and technologists to create digital art projects. They simultaneously conducted a study on the creative practices within these collaborations. Candy and Edmonds used a practice-led action research methodology to study these creative practices as they unfolded.

One goal of Candy and Edmonds's study was to learn how to develop conditions to support "art and technology innovation" [36, p. xii]. The resulting book and publications report on environments that support the creation and development process, conditions for individual and collaborative creativity, and the accounts of the practitioners with respect to the collaborations [36]. Outcomes included principles relating to creating environments that are responsive to the artist's evolving creative needs [2], including the idea that a process of using practice-led action research to co-evolve tools along with the art practice can create a better creative working environment. Candy and Edmonds's research also led to principles for sustaining successful collaboration between artists and technologists such as devising a shared language,

[2] In Chapter 6, I articulate this pattern of creative practice as *stochastic*.

developing common understandings of the artistic intentions and vision from both the artist and technologist perspectives, and other communication practices related to a partnership model of collaboration. Through this research, Candy and Edmonds established the concept of studio-as-laboratory for the dual purposes of art creation and art research.

3.5 Related research policy in the new millennium

In the 2000s and 2010s, a critical mass of technological art became visible through international exhibitions, public interventions, symposia, and specialized academic programs. At the same time, many nations were redefining the terms of technological innovation in ways that created opportunities for technological art. Recent structural changes in Western industrialized economies, such as the development of the knowledge economy, competition from emerging nations in the manufacturing sector, economic crises, and grand scale challenges such as climate change, have led national leaders to seek and support new commercial sectors within their countries. This has led to innovation economies fueled by increasingly rapid technological change.

Millennial European Union innovation policy exemplifies this shift. In March 2000, the EU Heads of State and Government meeting at the European Council in Lisbon set an overarching goal to make the EU "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" by 2010 [65]. The policy supporting this objective became known as the Lisbon Strategy. One of the main goals of this ten-year plan was for government, university, and corporate research and development (R&D) spending to reach three percent of each member nation's gross domestic product (GDP) within the decade. Throughout the Lisbon Strategy and subsequent strategic guidelines concerning innovation, such as the European Council communication *More Research and Innovation—Investing for Growth and Employment: A*

Common Approach, we can see a strong association between economic objectives and institutional R&D [42]. The shift to a broader rhetoric emphasizing creativity and innovation in addition to institutional R&D is apparent in the 2006 EU communication, *Putting knowledge into practice: A broad-based innovation strategy for the EU* [66]. Here the EU Council promotes a broader understanding of innovation, including a recognition of the contribution of the arts and culture to economic and social innovation, as well as the necessity of nurturing "creative talents." Thus we see a shift in focus from institutional R&D to a more speculative innovation economy valuing creativity as a key resource in the new economic environment.

While traditional manufacturing industries in Western countries have suffered detrimentally from external shocks such as the rise of industry in emerging countries and rolling economic crises, the knowledge-based creative sectors were more resilient. According to a United Nations report, in 2008, despite the twelve percent decline in global trade, world trade of creative goods and services continued to increase, reflecting a fourteen percent growth rate from 2002 to 2008 [192]. A recommendation in the same report suggested that "Policy strategies to foster the development of the creative economy must recognize its multidisciplinary nature—its economic, social, cultural, technological and environmental linkages." Here the "creative economy" refers to a loose intersection of the arts, culture industries, business, and technology, particularly digital technology. In this thinking, economics are explicitly linked with creativity, technology, and human social and cultural development in the sense that the ability to create and circulate creative intellectual capital can produce income, jobs, and export earnings.

The later Lisbon Strategy years saw both the 2008 economic crisis and the 2009 European Year of Creativity and Innovation. The role of this initiative was to highlight innovation and creativity as a response to the global downturn and the rise of competitive Asian economies. Prioritizing creativity and innovation in conjunction with the knowledge economy represents a transition from the mindsets, divisions of labor, and practices that determined success in the industrial economy to an economy where creativity, entrepreneurship, knowledge resources, skills, and expertise function in an interconnected, globalized economy running on a combination of information and know-how.

The shift in policy rhetoric from industry-focused research and development to creativity-fueled innovation brought discussion of the arts to innovation discourse. For example, the Amsterdam Declaration of 5 February 2010 states:

> Beyond their contribution to cultural diversity, creative industries represent indeed a great economic and social potential. In order to take full advantage of this potential, there is a need to combine arts and creativity with entrepreneurship and innovation. These industries are not only a source of inspiration but represent also an enormous asset to be turned into competitive advantages and the creation of new and better jobs in Europe. [64]

The relationship between the arts and innovation in this discourse is supported by the associative relationship between the arts and creativity, and creativity and innovation. Other discussions of the role of art in innovation policy configure "humanistic" contributions of the arts:

> Art and culture can make a vital contribution to the achievement of objectives that reconcile wealth creation with sustainability and respect for common humanist values because one of the features of art and culture is that they help us to transcend purely economic or utilitarian constraints. [94]

INNO-Grips is a research agency that supports European policy. INNO-Grips configures the arts in a more direct relationship to technological innovation. Their report titled *Innovation Unbound: Changing innovation locus, changing policy focus* positions artists in multidisciplinary innovation labs, along with engineers, architects, designers, sociologists, businessmen, and policy-makers [19, p. 27]. INNO-grips sets forth a vision of a network of multidisciplinary and interdisciplinary innovation labs supporting Europe as the "global innovation leader in effectively addressing complex social, environmental and economic challenges through sustainable, human-centered and democratized innovation." In this vision, these innovation labs "create and support the combination of social, scientific and artistic disciplines" [188, p. 9]. One example of an entity in "the new innovation ecosystem of EU Inno labs" is the ArtScience Labs network based in Paris and at Harvard University in the United States.

Three programs existing within the context of the EU policy framework place artists centrally within the innovation team. Disonancias is a Basque organization supported by the corporate Xabide Group and the Basque government. Disonancias places artists in companies, research centers or public institutions to work along with members of these organizations on innovative projects. Disonancias promotes the capability of artists to "propose new and different innovation paths, introducing detours and dissonance into the usual processes of thought and action." Disonancias puts forth the view of artist-mediated innovation "not as an end in itself, but as a tool to change ways of acting, attitudes and values, beyond that of economic benefit" [53]. Disonancias was awarded a Good Practices Award from the 2009 European Year of Creativity and Innovation.

AIRIS is an on-going Swedish artists-in-residence project supported by TILLT, an organization initiated by the region of West Sweden in 1973 to promote and support collaboration between artists and firms. Under AIRIS, artists join a company for a period of 10 months to work together on a project. The AIRIS project has three main goals: "to create an interface for interaction between industry and the culture sector, to enhance the creative capabilities of industry with regard to a specific business development goal, and to create new employment opportunities for professional artists" [183].

Jill Scott, Professor for Research in the Institute of Cultural Studies in Art, Media and Design at the Zürich University of the Arts, runs the Swiss Artists-in-Labs project under the sponsorship of the Swiss Federal Office for Culture (Bundesamt für Kultur, or BAK). Since its founding in 2006, this project has placed more than thirty-two artists into residencies within twenty-eight Swiss scientific research laboratories. In this program, artists are placed within a research laboratory specifically to interpret this context and the research the lab is conducting. Sometimes the artists collaborate with research scientists within the labs and sometimes they retain a residency there, creating work within the environment without collaboration. Collaboration depends upon the individual cases and the relationship developed between the artist and the scientists at the time. Overseeing research from the Artists-in-Labs project evaluates and compares the results and processes of these projects with a view toward documenting the artifacts of collaboration and cross-comparing successes and challenges to collaboration or embeddedness in the individual cases. Outcomes focus on the process of knowledge transfer and mutual influence across the disciplines. This program is currently ongoing and has resulted in two books documenting the residencies, as well as various public exhibitions, workshops, and conferences [175, 176].

While the European Union and the Council of Europe purposefully develop pan-European arts and culture policies, there has never been a great deal of interest in the United States in formulating arts and cultural policies at the federal level. The largest share of government support for the arts and culture is typically provided indirectly through tax concessions, encouraging individual and corporate giving [141]. Yet in 2003, The National Academies Press of the United States published a book titled *Beyond Productivity: Information, Technology, Innovation, and Creativity* in 2003. The book argues for institutionalized support for integrated art and technology practices, which they term "ITCP" for "Information Technology and Creative Practices." It views certain "art and design practices as forms of computer science research and development" [131, p. 96]:

> This new kind of art and design practice looks increasingly like technical research, but it is done from an artistic or design rather than a scientific

> perspective—it asks different kinds of questions and uses different kinds of methods to search for answers. [131, p. 97]

This book was followed up by a program at the U.S. National Science Foundation (NSF) called CreativeIT, which funded work at the intersections of art, music, performance, design, creativity research, and information technologies. The CreativeIT program in turn led to the first joint meeting of program directors and high level representatives of the NSF and the National Endowment for the Arts (NEA) [83]. This joint meeting led to a roadmap for developing and supporting art, technology, and research strategies at the national level [84]. The executive report describes the meeting:

> . . . on September 15th-16th 2010, over fifty-five thought leaders and stakeholders (artists, engineers, computer scientists, and practitioners who straddle disciplinary boundaries) were convened for a two-day interactive discussion about the challenges and opportunities for advances in the creative innovation economy and education institutions. The main goal was to identify synergies and foster collaborations across and between constituencies and develop a set of actionable areas of mutual interest: inquiry, collaboration, funding opportunities, lifelong learning, and innovation that are recognized by both the National Science Foundation and the National Endowment for the Arts. The workshop goal highlights the importance of the national intellectual currency that bridges Arts + Sciences + Technology research. [83]

A priority of the joint NSF/NEA meeting was to support the expansion of the STEM (science, technology, engineering, and mathematics) foundations of research and education to STEAM (STEM plus arts). These developments intersect with current discourse within and beyond the NSF to expand some STEM educational programs to STEAM programs. STEAM discourse had been an undercurrent in education, science, and technology circles before recent momentum from the NSF CreativeIT program and the joint NSF-NEA workshop described above. STEAM was given further impetus through a NSF five-year research award to Brown University, the University of Rhode Island, and Rhode Island School of Design (RISD) to study the effects of climate change on marine organisms and ecosystems. Recently, U.S. Congressman James Langevin from Rhode Island introduced federal STEM to STEAM legislation, which as of this writing is under committee debate. The legislation is House Resolution 319, Expressing the sense of the House of Representatives that adding art and design into Federal programs that target the Science, Technology, Engineering, and Mathematics (STEM) fields encourages innovation and economic growth in the United States [104].

A handful of public universities in the United States have combined arts and technology programs which exemplify STEAM, including the CADRE program at San Jose State University in Silicon Valley, the University of Washington's DXARTS program, and Arizona State University's Arts, Media, and Engineering program. The later is funded largely through an NSF IGERT (Integrative Graduate Education and Research Traineeship Program) grant. The prestigious art academies Art Institute of Chicago and Rhode Island School of Design have arts-based research and technology programs.

Canadian educational and innovation policy has provided funding opportunities for infrastructure and research that bring together practitioners from the arts, science, and engineering to create new working methodologies for innovation. By funding arts research at the same levels as scientific research, Canadian funding institutions such as Canada Council for the Arts (CCA), National Sciences and Engineering Research Council of Canada (NSERC), and the Canadian Foundation for Innovation (CFI) have prioritized artistic inquiry as an integral component of innovation. These initiatives have enabled artist-researchers to establish research labs based on art practices.

3.6 Summary: From ideology to innovation

Beginning with Jean Tinguely's *Homage to New York*, which aimed to set the machine free from its machine nature, we historically trace supports for technological arts and their ideologies throughout the postmodern era. Billy Klüver and E.A.T. ideologized the artist as having an obligation to incorporate technology into artwork, since technology had become inseparable from contemporary life. This concept of the artist as having a responsibility to society expanded the artist's role. The Los Angeles County Museum's Art and Technology program placed artists directly within industrial settings, supporting both artifact creation and non-artifact producing research. This program paved the way for artist-in-residence programs in technology industries over the next forty years. John Seely Brown of Xerox PARC articulated the role of the artist as an innovator within the technology research setting, describing technological artworks as pictures of technological potentials formed in a way that is "evocative of the tacit knowledge." Over the course of the new millennium, federal institutions and funding organizations began following the logic of industrial artist-in-residence programs, linking the arts with the creativity and innovation they were seeking to nurture to support their economies. In the 1990s, researchers Linda Candy and Ernest Edmonds had begun formalizing practice-led artist research at the intersections of art and interactive technologies by dually supporting an artists-in-residence program and studying the phenomena that occurred within that program. These developments at the intersection of artistic production and technological research and development provide the context for the presentation of my research in the following chapters.

CHAPTER IV

ROBOTANY:BREEZE

4.1 Breeze

Breeze is a robotic live Japanese maple that senses and responds to visitors through 360 degrees. *Breeze* was designed around the radial morphology of a tree as opposed to the bilateral symmetry of android robots. *Breeze's* 360 degree 'eye' is a catadiotropic lens positioned above the canopy (Figure 86). Its compound 'ears' are a custom ultrasonic sensor array positioned radially below the canopy. The joint structure of the tree limbs is actuated through gross and fine nitinol-based muscle systems (Figure 90). Because its entire canopy is active, *Breeze* can conduct several physical conversations at once (Figures 87, 88, and 89). Due to the use of the shape memory alloy, nitinol, as an actuator, *Breeze's* many limbs move silently and smoothly, without the mumbling and grumbling of motor-based actuation.

I built *Breeze* for the first time during the spring and summer of 2006 while a visiting researcher at the Swiss Federal Institute of Technology (Eidgenössische Technische Hochschule Zürich, or ETHZ). *Breeze* is the first piece in a series I call *Robotany*. The *Robotany* projects are interactive techno-organic art pieces which have the side effect of revealing things about human interaction with technology. Another side effect of the *Robotany* pieces are that the technologies created to realize them are often novel. In this chapter I focus on discussing *Breeze* in light of the lessons it holds for interaction with technologies. In the following chapter (Chapter 5), I discuss the next piece in this series, *Jade*, with an emphasis on the the technology that emerged from it and, particularly, the process of developing this technology. Following that in Chapter 6, I compare this development process with that of an engineer who has

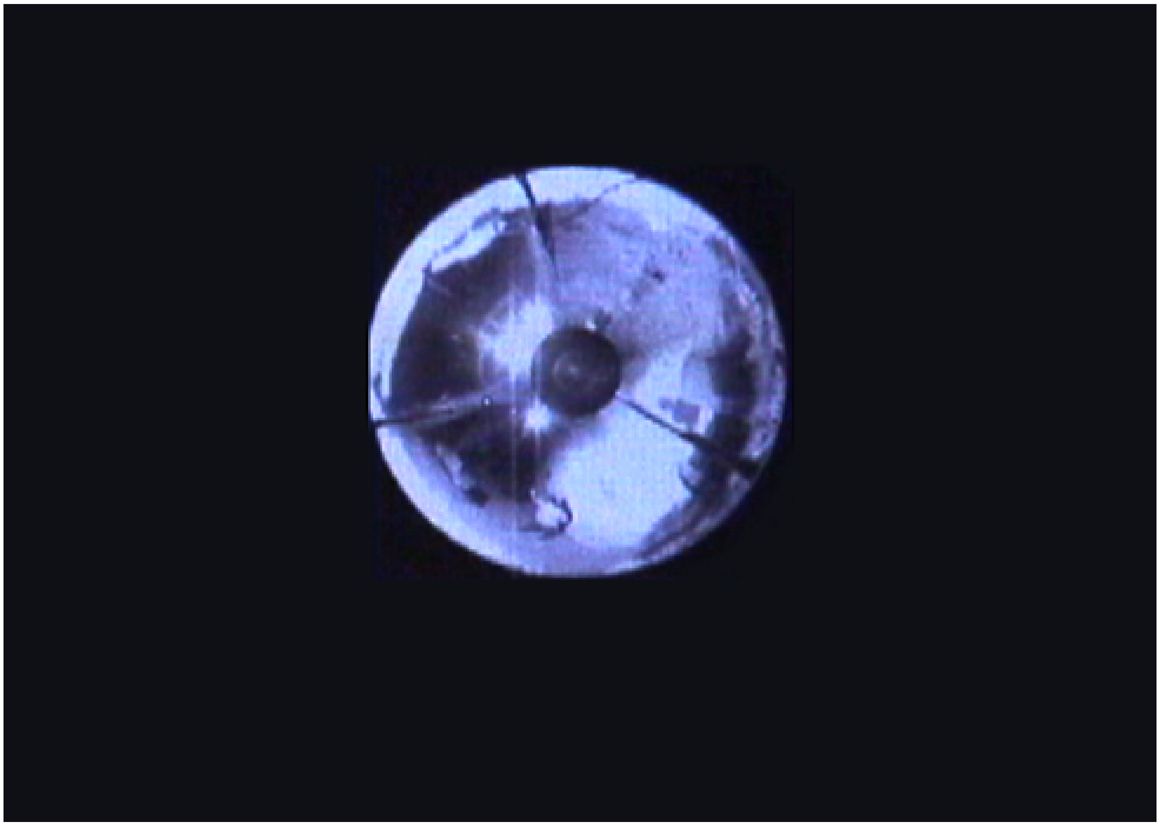


Figure 86: Video still from *Breeze's* 360 degree eye, 2006.

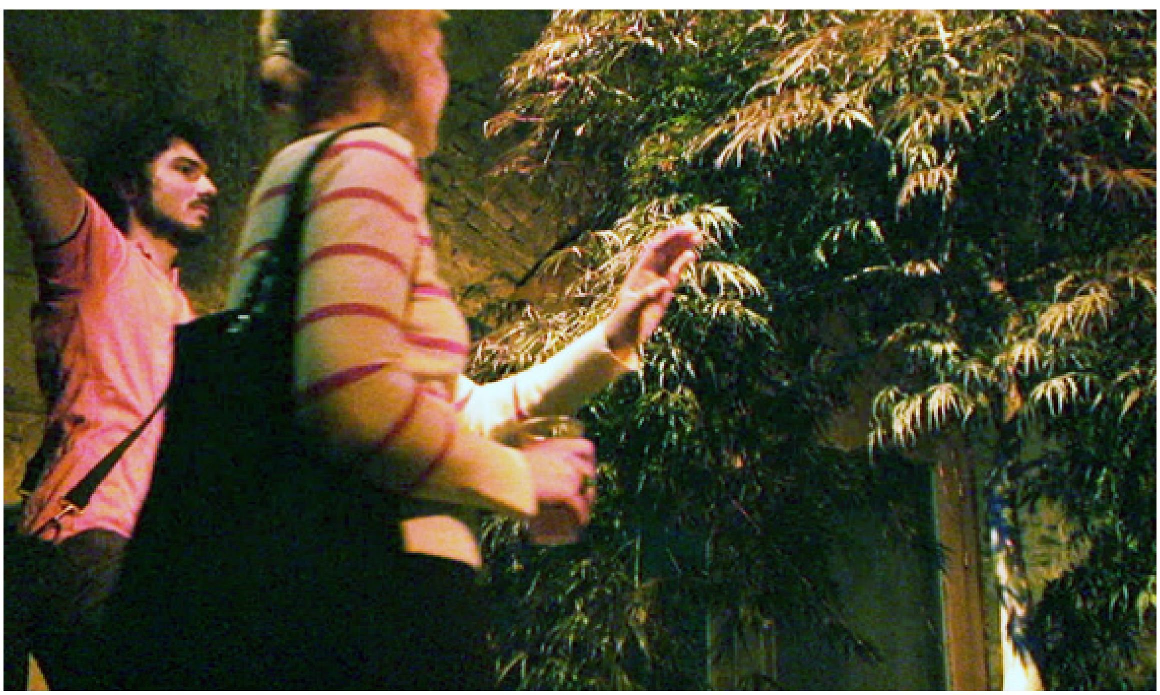


Figure 87: Visitors interacting with *Breeze* at the Belluard Festival in Fribourg, 2006. The tree was bathed in red light in the evening to keep it on its diurnal schedule.

Figure 88: Visitors interacting with *Breeze* at the Belluard Festival in Fribourg, 2006.

Figure 89: Visitors interacting with *Breeze* at the Belluard Festival in Fribourg, 2006.

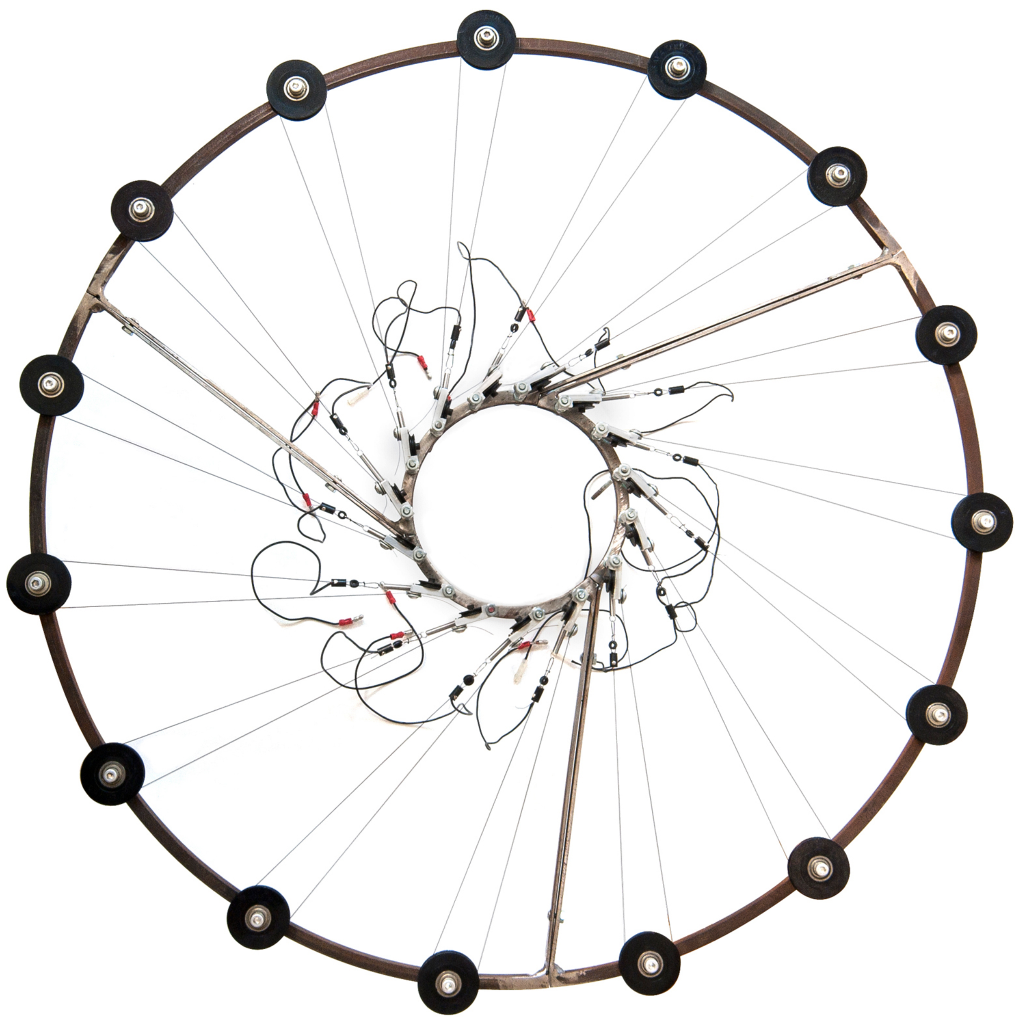


Figure 90: *Breeze's* nitinol-based robotic actuator, 2010.

developed a similar technology. While the methodologies of this chapter and Chapter 5 tend toward reflective, the methodology in Chapter 6 tends toward empirical.

Breeze was commissioned by the Belluard Arts Festival in Fribourg, Switzerland and was exhibited there for two weeks in 2006. It was funded by Fondation Nestlé pour l'Arte and the Canton of Fribourg. Later in 2006, Breeze appeared at the first Zero1 Biennial art festival in San Jose. Breeze was created with the help of John Taylor, who programmed the Max/MSP/Jitter video motion capture system, and Daniel Bauen, who aided in the production of the actuation mechanism. Joe Martin designed and built the ultrasonic sensor components. Breeze also appeared at the academic technical conference for human-computer interaction, CHI, in 2010.

4.2 Methodology

I developed the framework and methodology for understanding visitor interaction with *Breeze* in the years between exhibitions (2006 to 2010). In 2011, Linda Candy and Ernest Edmonds, whose work in the 1990s and early 2000s is profiled in the previous chapter, published methodological guidelines for such practice-based research [38]. My research and outcomes [40, 41] were published previous to the publication of their book describing these guidelines; however, their methodologies align with those that I derived in process. I introduce Candy and Edmonds's methodologies in this section, as a support to contextualize my research decisions and framework.

Candy and Edmonds's work continues in what is arguably the longest and most robust contemporary program on art and technology. In the new millennium, Candy and Edmonds moved Creativity and Cognition Studios from England to the University of Technology, Sydney. For their most recent research project, which led to the publication of the book *Interacting: Art, Research and the Creative Practitioner* in 2011 [38], they focus on establishing methodological guidelines for practice-based research with interactive art. For Candy and Edmonds, research within creative practice is necessarily bound to creating work and investigating their implications through exhibition or contact with visitors. They established Beta_Space, an exhibition space for experimental and in-process technological art in Sydney's Powerhouse Museum. Through Beta_Space, artists can explore the phenomena arising from prototype interactive artwork and visitor participation, thus iterating their work with audience involvement. This creates new formative relationships between artist, audience, work, and curation. It also creates new roles for the museum as not only a site for exhibition, but as a site for the creation of new work and new knowledge [38]. Using Beta_space as a research site, Candy and Edmonds's Ph.D. students pursued practice-based research through creating interactive artworks, exhibiting them to the public, and then analyzing the interactions in various ways under the methodological guidance of Candy and Edmonds.

Candy differentiates between practice-based and practice-led research as two different but related types of practitioner research. If the research stems from the making of an artifact and contributes knowledge about artifact creation, it is called "practice-based." If the research focuses on the creative process of creating artifacts, with the goal of contributing to larger understandings of creative practice, it is said to be "practice-led" [35]. Candy and Edmonds's research in the 1990s and early 2000s on the practices of collaboratively creating digital art pieces was practice-led. Their more recent contributions published in *Interacting:Art, Research and the Creative Practitioner* are from practice-based research. Similarly, my research with respect to *Breeze* extrapolates from its creation and exhibition cycle to derive a framework and principles for interactive technologies. This is practice-based research. In Chapter 6 I compare the creative process of building the art piece *Jade* with an engineer's creative process in developing a similar technology. This is practice-led research.

Candy and Edmonds's students' practice-based research has led to a range of outcomes including creation strategies and audience engagement models. These outcomes are reached through a spectrum of both empirical and reflective methodologies, with common elements of practice, theory, and evaluation combined in ways specific to the project at hand. Practice, or the activity of creating artwork, is the basis for conducting the research. Theory, as understood in the context of practice-based research, consists of different ways of examining, critiquing, and applying areas of knowledge relevant to the project and the individual's practice. Evaluation involves bringing the work to a public. Methods of evaluation can range from direct observation to monitoring and recording to interviewing visitors. Each of the elements of practice, theory, and evaluation has an outcome. Through practice we have the work of art. Theory can bring design criteria as well as theoretical frameworks used to interpret the piece and to extrapolate this interpretation to larger domains of application. From evaluation comes a testing of the theory. All of these elements, practice, theory and evaluation are intertwined and influence each other. It should not be implied that they proceed in a linear fashion, i.e. first practice, then theory, then evaluation. These elements may occur in any order, and are iterated for best practices. For example, an artist may begin with theory, and then develop an artwork to test and refine that theory. Another path would follow the creation of an artwork which is then observed in interaction with visitors to support the development of theoretical frameworks. This is the trajectory I have taken with *Breeze*.

It is important to note, as Candy and Edmonds do, that creating artworks is a distinct sphere of practice. The appropriation of research methods and research values from other disciplines is typically not the best path. Candy and Edmonds's approach acknowledges that research methods should best match artistic goals and values, as well as honor the creation process. Along similar lines, it is important to engage with visitors in ways appropriate to the art experience. Candy acknowledges that these considerations may be at odds with studies where subjects are given tasks and asked to follow a prescribed sequence or route through the experience. For research that involves visitors to an artwork, the autonomy of the visitors agency should be respected [35].

Candy points out that some researchers primarily value empirical studies that lead to results which are expressible in linguistic or numerical terms in order to minimize ambiguity. She argues:

> The question of ambiguity is central here. Explanations expressed in mathematical form use a universal notation that is unambiguous to those that have learnt it. Likewise, musical scores have similar characteristics with, perhaps, more room for interpretation. Without an unambiguous 'language' for all artefacts, whether visual forms or interactive installations, there is room for multiple responses and interpretations. That ambiguity is after all fundamental to the nature of art and its complex relationship to our capacity for appreciation. [35, p. 54]

A research process incorporating both reflection and empiricism combines essential elements of the traditional art critique with research, in many instances enabling the extrapolation of results to larger instances beyond the individual piece. Candy writes:

> For the practitioner researcher, creating a work and then reflecting on the process and outcome is a pathway to understanding some of the underlying questions and assumptions (we might call them 'working hypotheses' or 'theories in use') that have not been articulated beforehand. The process of making something can facilitate a form of 'thinking-in-action' that is needed in order to move towards a clearer understanding. [35, p. 54]

Candy's notion of 'thinking-in-action' relies upon Donald Schön's concept, 'reflection-in-action' [174], which in turn relies on John Dewey's exploration of reflection and thinking through experience [50]. She relates these ideas to the foundations of practice-based research:

> The concept of 'reflective practice' has had a significant influence on the methodological foundations of practice-based research. Reflective practice involves a process of reflecting on one's actions and learning how to act differently as a result. The starting point of reflective practice is the lived

> experience of a practitioner. Donald Schön's ideas on reflective practice have been influential because he located research enquiry within practice itself and asserted the value of practitioner knowledge as having distinct contributions to make to professional capabilities. He recognised that what he referred to as 'technical rationality' was inadequate for improving professional development and thereby challenged the existing orthodoxies in research traditions. His concept of reflection-in-action provides a plausible explanation for how the practitioner makes explicit some of the tacit knowledge (Polanyi, 1966 [152]) embedded in action and, thereby, learns how to act differently. The notion that practitioners themselves are capable of bringing tacit understandings to solving problems in hand, which can then be used to produce well-founded insights, rather than drawing upon the lessons from external sources of knowledge, was a radical idea at the time. [35, p. 43]

Reflective methodologies depend upon two concrete elements: the artwork and visitor interaction with the artwork. The nature of the art experience implies particular values which respect these. The artwork is not instrumentalized, and visitor participation should be thought of as is diverse and complex. Candy writes:

> The interactive scenario provides an opportunity to observe and record events over time with many people. However, it is important to note that for most artists doing research, the artefact is not purely 'instrumental' in the process, i.e. purely a convenient device for gathering information, and thereby secondary to the goal of deriving evidence. Viewing it this way would be to diminish its essential ambiguity. An artwork has multiple meanings and although it is possible to deploy it in the search for understanding through empirical means, this does not suggest that it embodies a particular kind of knowledge (Scrivener, 2002a [177]). The artwork stands for itself and there is no single recipe for interpreting or responding to it. On the other hand, for the practitioner researcher, being able to explore how people respond and behave when interacting with the work can be an invaluable way of moving the development of the work forward. [35, p. 40]

Also, observation should recognize complex phenomena related to engagement with a piece:

> This means that audience engagement is not judged merely by how long people look at a work but, more importantly, by how well they develop a sustained interaction with it and, going even further, a 'relationship' with it that brings them back time and time again. Direct observation of an art

> system in action, interacting with people, is the only way to understand what actually takes place [35, p. 39]

Though practice-based research as Candy proposes relies heavily on the subjectivity, observation, and intuitions of the practitioner, results should contribute to larger knowledge areas. Candy writes:

> The research process and its outcomes are bound to have implications for the individual's practice and indirectly, therefore, the artefacts that arise from that practice in the future. In this way practice-based research becomes an integral part of the creative process and can have life-long durability. However, contributing to personal effectiveness is not on its own enough to justify the label 'research' in its full and formal sense. For that, the making a clear contribution to knowledge must be evident. [35, p. 53]

Candy and Edmonds's practice-based research methodologies described above align with my approach to interpreting visitor interaction with *Breeze* and extrapolating this interaction into a framework applicable to interactive technologies. Specifically, their organization of practice-based research into the components of practice, theory and evaluation give shape to my methods. Candy's discussions of the importance of recognizing ambiguity as an essential quality of artwork and allowing an open framework for multiple interpretations on the part of the visitors to the piece align with the values embedded within my approach. Her recognition of the validity of artist reflection on directly observed phenomena supports the methodological path I followed. This all said, as I wrote earlier in the chapter, I did not have access to Candy and Edmonds's methodologies and methodological considerations until after my work with *Breeze* had been completed. Instead, I initially looked to cultural anthropologist Clifford Geertz's interpretive theories.

Geertz's work focuses on symbolic systems of meaning within the anthropological interpretation of culture. These symbols play a patterned role in the behaviour of individuals within a society [74]. One aspect of Geertz's work that appealed to me with respect to this project is his method of mapping phenomena to points in the cultural ecology. I was inspired by Geertz's focus on symbolic cultural systems and narrative construction to strive to locate the phenomena I was observing within a cultural system of meaning. My approach to interpreting visitor interaction with *Breeze* was to write a series of reflections related to the potential and multiple meanings of the interactions. My goal was to develop "sources of illumination" [74, p. 45] that would contribute to the enlargement of discourse. I was not concerned with striving to find something that could unequivocally be understood as an exact understanding.

Given these goals, I was limited by a constraint that may be surprising to researchers of interaction with technology such as those in the human-computer interaction (HCI) community. I would not interview visitors to understand how they understood the tree. As the artist of the piece, I am reluctant to interrupt a visitor's art experience. This interruption would override my goals as an artist providing the experience. Also, the end of the art experience cannot be specified. Is the experience over when the visitor steps away from the piece? Leaves the premises? Goes to sleep at night? Many people repeatedly visited the tree during the three weeks of the Belluard festival and festival setup. Was some aspect of the art experience continuous between visits? *Breeze* is primarily an artwork. This territory must be respected.

Another constraint is that interaction with *Breeze* took place largely through physical action. Using language to describe the embodied realm can be problematic. For example, a visitor to Breeze in Fribourg asked us, "So the tree moves when I move, so what?" This statement indicates that he understood the interaction proposed by the tree, was not particularly affected, and did not find much more to the experience. As he was saying this, however, he was dancing actively around the tree indicating that there was another experience he was having but not describing. People do not usually dance around trees in everyday public situations.

Given these constraints, I relied upon direct observation and video recordings of the embodied interaction of the visitors. From these, I wrote a series of reflections that together create an expandable framework for understanding interaction with *Breeze*, and then extrapolated each of these reflections to consider interactions with technology. These methods align with Candy and Edmonds's methodological guidelines, particularly with respect to ambiguity, multiple interpretations, and the validity of artist reflection on directly observed phenomena. These methods also triangulate with Geertz's focus on symbolic cultural systems and narrative construction to locate phenomena within a cultural system of meaning. The first reflection I present aligns with not only Geertz's method, but also content. The second two reflections leverage philosophy and and dynamics present in related artworks, respectively. These are attempts to circumvent traditional evaluation techniques in order to access a richer system of meaning while honoring the values native to the presentation of artwork.

4.3 Phenomena

I documented the first exhibition of *Breeze* in Fribourg in 2006. Collaborators, festival administrators, and I consistently witnessed visitors engaged in ongoing physical interaction with the tree. Through direct observation, we noted a range of spontaneous, unscripted behaviors and movements such as dancing, waving, and even kissing, petting, and toasting Breeze with wine. Visitors would return to the tree multiple times during the festival and repeat these interactions. It was common to witness passersby greeting and saying goodbye to *Breeze*. These behaviors were exhibited across genders and at age groups from one year through roughly seventy years old.

At Zero1 later in 2006, we accepted a donated mountain laurel to replace the Japanese maple that was the original *Breeze* 1.0. Unfortunately this large tree did not have physical characteristics amenable to the piece. The high, stiff canopy rose above people's heads and foregrounded the technological mechanism. Also, the shape memory alloy muscles strained against the high, stiff branches and did not produce the same quality of response as they had in Fribourg. Most visitors spent their time looking at the piece and discussing the robotic mechanisms instead of interacting with the tree. They commented on the design and engineering craft. Even so, at one point a group of visitors joined hands around the tree and sang to it.

We can characterize visitors' interaction with *Breeze* in Fribourg in the following ways: (1) The interaction was engaged. Visitors did not passively visit or look at the tree for a period of time. They were engaged in an ongoing physical dialog with the tree. While they did engage in social interaction with each other, their participation was primarily concentrated on the tree for the duration of their visit. Several visitors returned to the tree multiple times during the festival. It was common to witness passersby greeting the tree as they walked by. (2)The interaction was affectionate. Visitors were very friendly toward Breeze, dancing, waving, kissing, petting, toasting, and greeting the animated tree. (3) Visitors seemed familiar with the tree. We did not observe any hesitation in interacting with Breeze. There were no signs that a visitor felt the tree was uncanny. (4) The interaction was embodied. The activity between visitors and Breeze was physical and anthropomorphized. The sustained attention and gestures of the visitors suggest that meaning was emerging through their embodied participation. (5) There was a sense of communication on the part of the visitors with the tree. Visitors talked to it, greeted it, toasted it with wine, sang to it. They faced the tree, looking at the canopy as if they were face-to-face with a being.

4.4 Interpretation

The exploratory interpretations of visitor interaction with *Breeze* written below are designed to create constellations of meaning that are valid, yet allow space for ambiguity and multiple meaning-making on the part of the visitors.

Figure 91: Still image from the film *The Lord of the Rings*, 2002.

Figure 92: Still images from the film *My Neighbor Totoro*, 1988.

4.4.1 The cultural imaginary

Sapient trees are embedded in our cultural imagination. Trees that communicate with or are physically responsive to humans include the apple trees in *The Wizard of Oz* [70], the Ents in *The Lord of the Rings* [92], and the camphor trees in *My Neighbor Totoro* [132]. With the exception of the apple trees which fought with Dorothy because she picked their apples, the relationship of humans and trees is portrayed in a way consistent with characteristics of visitors' interaction with Breeze: engaged, affectionate, familiar, embodied, and communicative.

Trees are anthropomorphized in our culture. Children talking to trees and tree-huggers are familiar tropes. When a tree comes into such a relationship with a human, it becomes a hybrid being that can be characterized as totem-like. A totem is a non-human being recognizable within a culture's mythology. Totems have a lived relationship to the individuals within a culture, and it is possible for members of that culture to communicate with them.

Animated totemic trees are embedded within our Western cultural mythology. Plant and animal totems form, in the words of cultural anthropologist Bradd Shore, "necessarily abstract and metaphorical relations to humans" [181, p.172]. They are "familiar and congenial to man, yet outside the circle of specifically human things and activities, thus not being subject to the disturbing agencies that abound within that realm" [79, p. 293] in [181, p. 172]. According to this logic, totems would be less apt to fall into uncanniness than androids. We consistently observed and documented a familiar and affectionate stance toward the tree.

In anthropology the meaning of the totem concept has been debated. It is often used to denote to a clan's identification with a non-human species. I am using the concept of the totem in the larger sense, to signify a plant or animal that symbolically is linked to humans through an anthropomorphism of its qualities. The wise, old owl familiar in Western cultures would be another example of such a totem. This understanding of totemism extends beyond that of anthropomorphism. Anthropomorphism is simply the attribution of human-like qualities to another thing. It does not imply an ongoing and consistent symbolic relationship between that species and humans as totemism does. Shore discusses techno-totemism as cross-species participation in the age of technology [181, p. 181]. This includes robots, human-machine hybrids, and *Breeze*, all of which participate in the ambiguities of what is human and what is not. Human communication uses categories to reduce ambiguity, though categorization will never exhaust meaning or experience. Totems permit categorical cross-over and reorganize everyday classification in a way that does not startle us [181].

Here I am linking interaction with *Breeze* to the world of cultural symbols that can be considered to form an everpresent symbolic ecology in Western cultural life.

Breeze, embodied as a sapient totem by visitors to the piece is a magical object already situated within their cultural imagination. This expands our paradigm for robots to a larger spectrum. We can consider robots as android or mechanical forms that complete tasks for us; additionally, we can consider them as magical totems that bridge between the human world and something else.

Totemism as considered here points to a system of anthropological metaphors that may be of research interest. For example, we could consider robots as totems and smart phones as a talismans. Talismans are small, magical tools, often on the scale of the hand, which hold promise and/or protection. Some talismans transmit their powers to the bearer and help them find their way. These examples suggest that engaging with the concept of significant symbols within the cultural imagination could lead to an increased understanding of interactions with technologies. That said, evaluation by traditional scientific means would be difficult. In the words of philosopher Richard Rorty, metaphors such as totems and talismans represent "a voice from outside logical space, rather than an empirical filling-up of a portion of that space, or a logical-philosophical clarification of the structure of that space" [168, p. 13].

4.4.2 The phenomenological field of possibilities

There is a field of possibilities around any tree. A tree could show up to a child as climbable. It could show up as bearing fruit to eat. It could show up as timber. Phenomenological philosopher Martin Heidegger likens this field of possibilities to a clearing, as in a forest [86]. The light and space of a clearing allows the phenomena within it to be intelligible, while the clearing, as the condition of the possibilities of the phenomena, disperses into the background. Meaning is determined by the actors, entities, contexts, and contingencies within that space as seen in the light of the clearing. Under these conditions, some possibilities for interaction and meaning-making emerge and some retire. *Breeze's* manifestation as a totem and the interaction possibilities for visitors occur in such a clearing.

This clearing is an illustration of Heidegger's structure, "Lichtung" [86], literally the German word for "clearing." The Lichtung is a field of possibilities for interaction. It is a central structure of Heidegger's ontology. The nature of the beings, objects and the context (Heidegger's "world") of the interaction determine the possibilities presented in the clearing around the tree. So attributes of *Breeze* contribute to the nature of the interaction, as do the beings present, the social and cultural milieu, and the overall environment. In the case of interactive technologies, the attributes of the computational system contribute to the world which structures the Lichtung. For example, *Breeze* is computationally built upon a stimulus-response model instead of a procedural model. The action behind Breeze's interaction is simple: sense presence and movement and move toward it. Responsivity is less concerned with representing a world, as with object-oriented and procedural computational models, than with supporting action within that world. This computational model creates possibilities for interaction that incorporate open-ended response instead of scripted dialog. A different computational model would contribute to a different field of possibilities. The Lichtung prioritizes possibilities over actuality. Thus, an interactive artifact which incorporates open-ended response (vs. scripted procedure) can create possibilities for ongoing, engaged, unscripted, emergent interaction as we saw with *Breeze*.

As described above, Breeze was presented in two venues: as a fully-funded project in Switzerland and overseas as an unfunded project in the United States. We accepted a donated mountain laurel to replace the Japanese maple which was the original *Breeze* 1.0. Unfortunately this tree did not have physical and material characteristics amenable to the piece. The high, stiff canopy rose above people's heads and fore-grounded the technological mechanism over the totemic nature of the tree. Also, the nitinol muscles strained against the stiff branches and did not produce a mappable response. Within a framework of action and possibility, meaning is as meaning does. Visitors became an audience which approached the piece as an interesting technological object to look at. They commented on the design and engineering craft. The Lichtung revealed meaning that could be named, pointed to and articulated. To use Heidegger's terminology, it became present-at-hand. Heidegger considers this to be a derivative form of experience. In [7, sec. 32], Heidegger presents the example of a door and explains that we make use of a door before we consider its physical or metaphysical properties. In fact, it takes a certain stance toward an object to consider its existence independent of other objects and categorize its properties. This stance is valid for various purposes such as scientific inquiry, but does not exhaust meaning. Another perspective on this breakdown is what I will call a 'hybrid shift.' The emphasis shifted from a balanced hybrid organism to its mechanism.

From a Heideggerian point of view, within any circumstance or Lichtung, there are elements that emerge out of the field of potentials and foreground themselves to us. Along the same lines, there are elements that recede. This dynamic of emergence and receding is what creates the situation. *Breeze* and its visitors exist in a Lichtung, literally, a clearing in a forest, a space where possibilities are illuminated and show up in a certain way. This in turn creates possibilities for interaction giving us an indefinitely complex space, a rich space, a totality of possibilities of action and interaction. Everything that shows up in the Lichtung, this place of encountering, this field of possibilities, does so through Worldhood. This World is neither the objective world of collective experience nor the subjective world of personal experience, but everything that is brought to bear in the manifestation of entities and possibilities in the Lichtung. Simply put, the World can never be intelligible. To get at that kind of presence (present-at-handedness), one has to leave out all the meaningful situatedness which makes things intelligible. Our understanding, our creation of meaning, is grounded in our performative engagement (Verhalten) with the World. A related notion is that of the background. The background is the familiar but concealed. For example, background practices include those that make it possible to open a door or drive a car while daydreaming. The background includes, among other things, the skills that we use to make anything show up as anything (background practices), contexts, and the existential conditions of our coping in the World in time (hence the title of Heidegger's opus, *Being and Time*). These background conditions both generate and are regenerated in our everyday interactions. Like space, and time, and the lighting in the room, the World, the Lichtung, and the background are necessarily withdrawn so that we can perceive and act.

To summarize, our World makes things and actions intelligible to us. Encountering and interacting with an entity creates a Lichtung, a field of possibilities where these entities show up and become intelligible. Interaction possibilities with these entities also become intelligible. Thus these Heideggerian structures, World, Lichtung, and Verhalten (our performative action), support interaction. They form a framework for understanding interaction with artifacts, including interactive technologies, whereby the artifacts are understood as entities enmeshed in a nexus of alternately appearing and withdrawing possibilities. So researchers and developers of interactive technologies (as well as artists) can ask, when a technology (or artwork) is introduced, how does it affect what shows up in the environment to the user (visitor) and what recedes? What possibilities for interaction are presented and which are obscured? These are matters of phenomenological observation that can figure into the design of artifacts. When designers, engineers, and artists create, they are not simply creating artifacts, but technological or artistic clearings.

4.4.3 Physis and poiésis

Breeze is one of many techno-organic hybrids. Other examples include cyborgs and products of bioengineering, as well as art projects ranging from those that mimic organic systems such as Rokeby's *Very Nervous System*, presented in Chapter 3, to those that involve human interventions into natural processes (see Figures 93, 94, and 95), to interactive works that combine nature and hardware like *Breeze* and the piece profiled in the next chapter, *Jade*. The ancient Greeks constructed epistemological understandings upon a fundamental distinction between physis and poiésis. Physis is that which emerges from or creates itself, i.e. nature. Poiésis is the human activity of creating artifacts. What can we learn from using techné to merge physis and poiésis?

From thinking about this constellation of work, we can draw parallels between the processes of nature and those of interactive technologies. On one hand, there are sensorial parallels. Both interactive systems and natural systems operate through a basic pattern of input–response–output. In this sense, natural systems are a paradigmatic model for interactive systems. These parallels may be, consciously or unconsciously, what draws interactive artwork to mesh with natural systems. There is also an evolutionary perspective. The hope for *MEART* is that the cells are growing to learn to become more responsive to the sensory and response cycle that is their life. They change much in the same way that an intelligent, adaptive, interactive system would change. Finally, there is a parallel between these evolutionary systems and the iterative interactive design process. When an interactive prototype, whether an artwork or technology, is brought to the public as part of an artist's or designer's process, the practitioner can evolve the artifact based on the outcomes of visitors' interaction with it. All of these point to cultural parallels between interactive artifacts and nature.

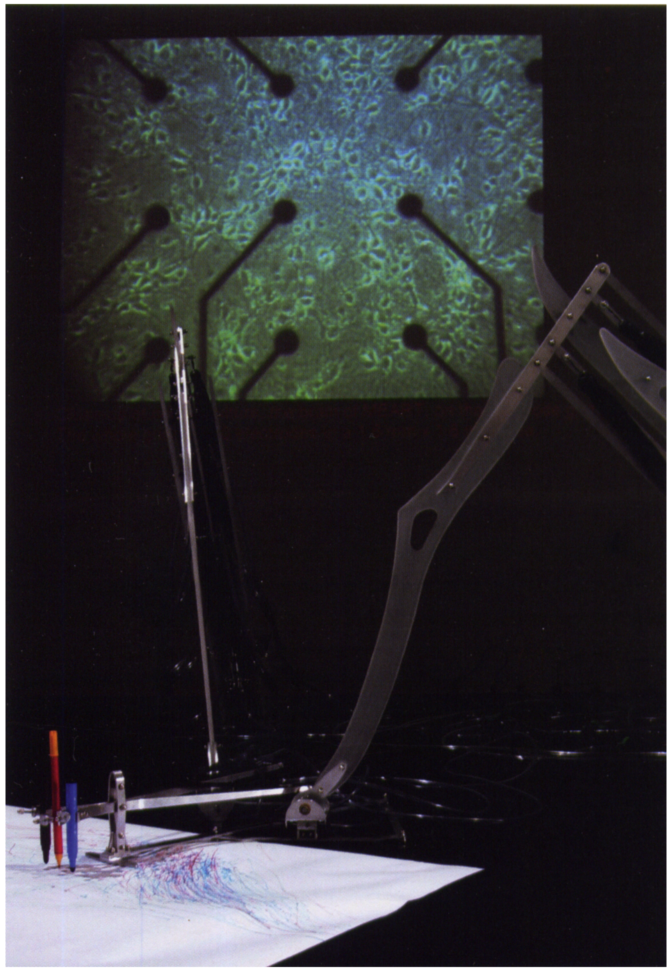


Figure 93: *MEART*, by SymbioticA Research Group, University of Western Australia (Guy Benary, Phil Gamblen, Dr. Stuart Bunt, Ian Sweetman, Oron Catts) in collaboration with Steve M. Potter, Tom DeMarse and Alexander Shkolnik, Laboratory for Neuroengineering, Georgia Institute of Technology, 2004. MEART is a bio-robotic drawing system consisting of a video camera and robotic drawing arm. Its remote 'brain' is comprised from thousands of mouse brain cells grown in a Multi-Electrode Array at Georgia Tech. Its 'nervous system' enables the brain and the body to communicate via the Internet. *MEART* draws by comparing an image to the state of its drawing and iterates to reduce the difference. The hope is that *MEART's* 'brain' evolves and learns as it goes.

Figure 94: *Biopresence* by Shiho Fukuhara and Georg Tremmel, 2004. The artists conceptualized a system that would insert fragments of a deceased person's DNA into tree DNA to create a tree as living memorial.

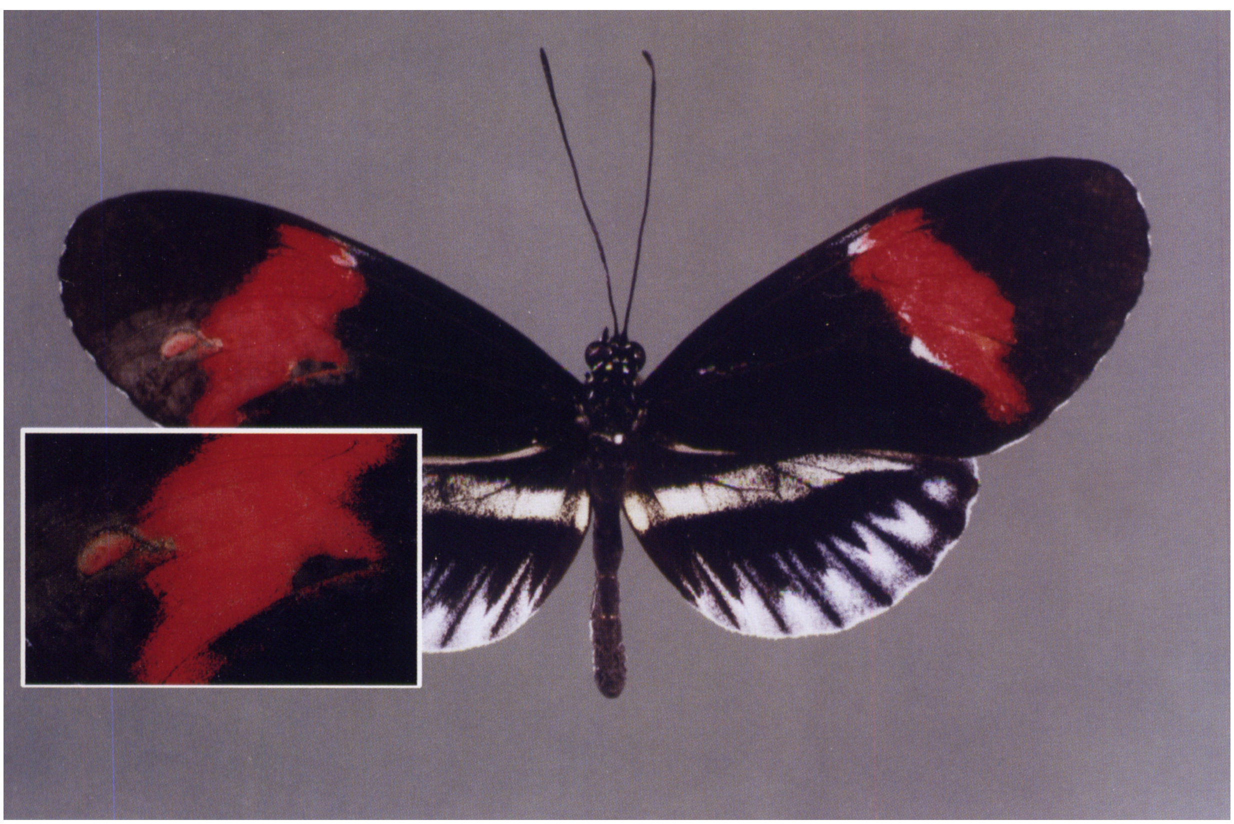


Figure 95: *Nature?* by Marta de Menezes, 2000. Menezes manipulated butterfly embryos in order to design wing patterns.

4.5 Summary

Artists are skilled practitioners who develop skill through repeated creation and presentation of artifacts. Exhibition of these artifacts with visitors, particularly interactive, technological artworks, completes a cycle of understanding for the artist who can then carry this experience forward into future projects. If linked to a technological community, artists can extrapolate these experiences and understandings to alternative ways of framing and considering interactive technologies in general. Candy and Edmonds support this translation of knowledge through their articulation and advancement of methodological guidelines for artists creating interactive artworks and engaging in research. This knowledge can often take a more tacit and reflective form than would otherwise pass through a rational filter and its companion validation practices.

These reflections on *Breeze* are extrapolated to comment on interactive technologies. The overall project of analyzing by writing these reflective episodes forms an indefinitely expandable framework from which to understand a project and its contributions. The collection of reflections then form a constellation of points which when drawn together give an overall picture of the relationship of the artwork to culture and technological development.

The interpretation of *Breeze* as a totem leads to a consideration of our interaction with technologies as reminiscent of culturally symbolic magical objects. The phenomenological interpretation of interaction with *Breeze* reveals philosophical structures also helpful in interpreting interaction with technologies. If the response of the interactive system maps well to our meaning-making sensibilities, our actions can be effortless, unscripted, emergent, and engaged. When *Breeze* was brought to exhibition with the public, it created a congenial space for visitors to act out points from within the cultural imaginary in a way that comments on not only these points, i.e.

human interaction with tree totems, but also on the dynamics of interactive technologies. These dynamics include the value of the cultural imaginary to the interpretation and design of interactive technologies as well as the importance of recognizing not only the technology, but the clearing that is created around the technology. Abstracting *Breeze* as an entity bringing together physis and poiésis allows us to see it in a tradition of artworks doing the same, and leads us to multiple parallels between the process of interactive technologies and nature. As mentioned above, the reflective framework is expandable, so adding more reflections gives more points of reference. As with Geertz's method, this process can continue until a higher and higher resolution picture emerges. At the same time, this method allows for ambiguity and multiple meaning-making. Reflecting on the reflections, we can see categories. The first reflection on the cultural imagination engages cultural and symbolic points of connection. The second reflection bringing in phenomenological philosophy engages with lived experience. The third reflection engages with a constellation of similar artifacts.

Art practice often looks at an issue laterally, incorporating interior knowledge that we didn't know that we knew, but was brought out by engagement with another domain or context. Art has the capability to engage those aspects of experience beyond rationalistic description, beyond vocabulary, beyond language; as such, interpretations that cannot be validated often emerge. To paraphrase philosopher Richard Rorty, to think otherwise amounts to a power play. To assume that in all things there is an implicit that needs to be made explicit is the replacement of creativity with power [167]. Responsibility for the work lies in the artist's engagement with a horizon of understanding, not on external methodologies that frame truth as correctness. It is this engagement that creates openings for practice-based discovery. The challenge for discourse at the intersections of artmaking and technology development is that for technologists to participate, they will need to develop a lens to accept and understand an experience of discovery beyond verification, thus embracing risk, unpredictability, and other consequences that technoscientific research and development methodologies strive to diminish.

CHAPTER V

THINKING THROUGH THINGS: ANATOMY OF AN ARTIST'S PROCESS TOWARD INVENTION

5.1 Jade

Jade is my current in-process art and technology project. Jade alters an everyday jade plant (the type of plant with the round, green, spongy leaves) into a vessel for human heartbeat. Some of the leaves are pruned, altered with electronics, and then reattached magnetically to the plant. A visitor can pluck a leaf and hold it to her or his chest. The leaf then pulses with the sensation of that person's heartbeat. The visitor can then return the leaf to the plant, where it continues to pulse. After a time, the plant will be pulsing with the many different heartbeats of the various people that visited it. Visitors can feel the heartbeats of previous visitors by touching the leaves of the plant.

In the course of creating *Jade*, I developed a novel haptics platform and applications. These technologies are in the patenting process through Georgia Tech's Office of Technology Licensing, which has filed an international PCT patent application for them. One of the applications emerged directly from the art installation. It is an infant blanket that a caregiver can hold to his or her chest and record his or her heartbeat into, causing the soft blanket to gently pulse with the felt sensation of their heartbeat. They can then swaddle their infant with the blanket. Medical research has shown that gentle, rhythmic, tactile stimulation is not only soothing to infants, but may also help guard against sudden infant death syndrome (SIDS). The research path for this invention includes investigating this possibility as well as applications

Figure 96: Concept drawing for *Jade*.

for post-traumatic stress disorder in veterans. Other applications for these high resolution, user-configurable, soft and flexible, localizable haptics include cell phones, videogame controllers, computer interfaces, and industrial controls.

This chapter traces *Jade's* design conceptualization process which is driven primarily by everyday personal experience. As with the results of the reflective framework described in Chapter 4, this trace gives an example of valid knowledge from processes that defy validation in normative rationalist design paradigms.

5.2 Theoretical background

Two primary paradigms used to describe design activity (as opposed to design methodology) are the rational problem-solving paradigm and the alternative presented by Donald Schön, reflection-in-action [1] [174]. The rational paradigm developed from

[1]Schön's reflection-in-action is also mentioned in Chapter 4.

technical systems theory and was expanded by Herbert Simon, one of the founding fathers of artificial intelligence research. Emphasis is placed on the designer using well-defined design procedures and principles to find an optimized solution to a posed design problem. Rational design research consists of discovering objectifiable knowledge, the practical generalization of findings, and portability of process.

The reflection-in-action paradigm of Donald Schön arose in response to aspects of design concealed by the rational paradigm, particularly design knowledge from "the spontaneous, intuitive performance of the actions of everyday life" [174, p. 49]. Schön saw rationalist methods as having no means to account for the tacit understandings and skill that are part of the professional practice of designers, as well as the uniqueness of each design process [2]. Instead of problem/solution frameworks, Schön uses the metaphor of "reflective conversation with the situation" [174, p. 76] to describe how design is practiced.

In his well-received book *Where the Action Is: The Foundations of Embodied Interaction*, computer scientist and human-computer interaction researcher Paul Dourish argues that tangible computing technologies participate in the rich world of embodied activity. He proposes phenomenological philosophy as a foundation for this embodied interaction. In this context, meaning arises from concerned activity in the referential totality of the everyday world, not from symbolic models of the "outside" world held inside the mind [55]. This discussion of embodied interaction focuses on users' interaction with the technologies and does not speak to embodied aspects of designing such technologies.

In a separate thread, design theorists Richard Coyne and Adrian Snodgrass use phenomenology to support embodied design practice, describing the design activity

[2] See also Hubert Dreyfus's essay, "Alchemy and AI" [56] for a similar and earlier discussion within the phenomenological tradition.

as a hermeneutic circle [43, 44]. Hermeneutics traditionally refers to the interpretation of texts. The phenomenological philosophers Martin Heidegger and Hans-Georg Gadamer developed hermeneutics beyond textual interpretation to include the everyday interpretive meaning-making of our experience. The hermeneutic circle, as developed by Heidegger and Gadamer, describes how our interpretation of the world depends upon co-emergent, interdependent partial understandings of parts and whole. We cannot understand the meaning of part of an event until we understand the whole, and we cannot understand the whole until we grasp the meaning of the parts. Another way to understand this circular relationship is to consider that we cannot understand the meaning of a concept until we understand its context, but the context is made up of the concepts that give it meaning. One simple analogy is a sentence. One cannot understand the meaning of a sentence without understanding its words, but one cannot understand the meaning of the words without understanding the sentence as a whole. Any act of understanding consists of this circular interplay between inseparable parts and wholes. The hermeneutic circle underlies all interpretation and understanding. It is not a method, but is prior to logic and methods. The hermeneutic circle is integral to all thoughts, perceptions, and actions. Coyne and Snodgrass quote Gadamer:

> A person who is trying to understand a text is always performing an act of projecting. He projects before himself a meaning for the text as a whole as soon as some initial meaning emerges in the text. Again, the latter emerges only because he is reading the text with particular expectations in regard to a certain meaning. The working of this fore-project, which is constantly revised in terms of what emerges as he penetrates into the meaning, is understanding what is there. [73, p. 36] in [44].

Coyne and Snodgrass read the above quotation with “design” in mind as “text.” They consider a design project as a project(ion) of past and present experiences into the whole of the design. This gives us a portrait of the designer and the design process as embedded in the world of experience instead of preceding, detached, or over and

Figure 97: Silhouette charm bracelet.

above it as in rational design paradigms. Coyne and Snodgrass thus extend Schön's metaphor of design as a reflective conversation to participation in a hermeneutic circle. Design as a hermeneutic circle frames the following description of the design of *Jade*.

5.3 The Project(ion)

The artist remembers the charm bracelets her grandmother and other neighborhood women wore when she was a child (Figure 97). The charms were silhouettes of heads of little girls and boys. The name of each grandchild was stamped on a head. As a child, the artist was fascinated with the charms and the idea that her grandmother carried her grandchildren with her everywhere she went. On the other hand, on closer look the charms were disappointingly generic cutouts.

When the artist was away from her own children, she wondered about having them closer through such a charm bracelet. What if instead of charms of impersonal silhouettes, this bracelet had charms that held their heartbeats, silently, so that when she touched each charm she could feel their heartbeats just as she did when she put her hand to their chests?

When the artist's children were newborns, she would soothe them at night by placing them to sleep prone on her chest or her husband's chest.

Sudden infant death syndrome (SIDS, cot death, or crib death) is a concern of many parents of newborns. Public health initiatives and pediatricians strongly advise parents to keep their newborns sleeping on their backs for the first months of life in an effort to prevent SIDS.

When the artist expressed concern about her newborn child sleeping prone on a parent's chest, her pediatrician replied that there was nothing to fear because the gentle stimulation of the parent's rising chest and heartbeat would keep the infant from falling into sleep apnea.

The artist was given a hand-me-down infant seat that vibrates using electromotors. The crude vibration soothed her colicky infant and he stopped crying, though the motion seemed a little severe.

While tending houseplants, the artist imagined a large jade plant with small devices embedded in some of its leaves. Visitors could pluck one of these leaves, hold it to their chest, record their heartbeat into it, and then put the leaf back on the plant. The leaf would throb with the heartbeat of the visitor. Other visitors could touch the heartbeats of the visitors before them. After a time, the jade plant would be throbbing with the heartbeats of many different visitors.

To actualize the heartbeat charms, the artist thinks about sound pods similar to the jade plant leaves, possibly using a material like that of the jade leaf as a diaphragm. She makes the association:

rubber (plant) → elastomer → polymer → fiber → textile.

Based on the association of heartbeat and textile, the artist decides to design an infant soothing and SIDS/ premature apnea therapy blanket. The blanket is meant

Figure 98: This is not a coffee cup.

to be an infant swaddler or other contact textile. The blanket will transmit a low frequency sound wave of a heartbeat recorded from a parent or other caregiver. This sound wave will manifest in the blanket as inaudible felt pressure.

The artist works to develop an engineering model of sound in a textile in order to find the mechanism that will make a blanket pulse with heartbeat. Following a traditional engineering process, she uses calculations from the literature and devises laboratory experiments.

While walking with a friend and carrying a nearly empty cardboard coffee cup, the artist feels her friend's voice vibrating the walls of the cup as she is speaking (Figure 98).

Having discovered the mechanism that will create the heartbeat in the blanket, the artist abandons the engineering model and experiments. Using a small, low-frequency speaker against a bubble from bubble-wrap, she discovers a mechanism that concentrates the mechanical sound energy, allowing low-frequency mechanical energy to concentrate felt pressure in a localizable spot. Furthermore, the capsule formed by the bubble-wrap and mechanical actuator (in this case a small speaker but could also include other types of mechanical actuators) creates a soft and flexible pod that can be incorporated into textiles and other soft surfaces.

More refined prototypes from this project are brought to the attention of Georgia Tech Research Corporation's Office of Technology Licensing, who issues a international PTO patent application on the technology as well as the suite of applications flowing from it. [3]

5.4 Discussion

5.4.1 The hermeneutic circle

Care should be taken to understand that these events did not occur as a step-by-step, progressive, linear narrative. Each event was not resolved on its own, but in light of the other events. Episodes in the process informed much later episodes, and often looped back around in time to make sense in hindsight. There was a commitment by the artist to pursue the project(ion), but there was no intellectual clarity until the end of the events described above. This example illustrates the hermeneutic circle in design. Background familiarities, experiences, thoughts, associations, and daydreams are projected forward into the design. Once they are part of the design, they form the background considerations that bring further things to light. Michael Polanyi,

[3] International PCT patent application, *Haptic Systems, Devices, and Methods using Transmission of Pressure through a Flexible Medium*, application number: WO2011US59661 20111107 filed on November 7, 2011.

a scientist and philosopher of the phenomenology of tacit knowledge, describes our ability to bring background familiarities to the topic at hand:

> This power resides in the area which tends to function as a background because it extends indeterminately around the central object of our attention. Seen thus from the corner of our eyes, or remembered at the back of our mind, this area compellingly affects the way we see the object on which we are focusing. We may indeed go so far as to say that we are aware of this subsidiarily noticed area mainly in the appearance of the object to which we are attending. [151, p. 214]

Much of this background will be culturally shared and much will be idiosyncratic. A constellation of concepts emerged from the experiences of the designer: the metaphor of the charms, the information about SIDS, and the association between the jade plant leaves, polymers, and textiles. Some of these are culturally shared, some represent domain knowledge, and some are individual. Perceptual experiences also led the designer. The voice resonating in the coffee cup, the sensation of a child's heart beating through their chest, and the crudeness of the electromotor vibration of the infant chair all are projected forward as part of the project of designing. The artist's experiences expanded the design domain by drawing upon familiarities from life outside the conventional problem-solving domain of designing infant soothing and therapy devices. Charms and coffee cups become as relevant as blankets, soothing chairs, sleeping practices, and public health advice.

The design concept could not be manifested without an understanding of how the heartbeat behaviour would be enacted through a mechanism within a soft, flexible, infant blanket form. Behaviour, mechanism, and form are interdependent. They were not considered modularly as in many engineering design projects. The experience with the coffee cup revealed that it would be effective to transmit the low frequency heartbeat sound waves from a transducer such as a speaker or piezoelectric film through sealed air pockets within the textile. It is interesting to note that in this example, the everyday experience with the coffee cup trumped work done through the engineering model. Engineering at the conceptualization stage was abandoned, but now that a satisfactory solution has been found, engineering can play a role in prototype iterations.

5.4.2 Epistemological dualisms

This invention process challenges validity claims of rationalist design methodologies. Design theorists Coyne and Snodgrass, quoted above, address this issue in their chapter "Creativity as commonplace" in their book, *Interpretation in Architecture: Design As a Way of Thinking*. They quote a series of well-known architects on their concept of creativity:

> According to Abercrombie, how the architect resolves the conflicting demands on a project 'remains a mystery of the creative mind'. In the art of architecture there is 'something that evades analysis, something that touches us in the most secret parts of our minds, something not only beyond utility but also beyond all that is rational and everyday' [9]... For Le Corbusier, 'Art is this pure creation of the spirit which shows us, at certain heights, the summit of the *creation* to which man [sic] is capable of attaining' [195]... For Louis Kahn... [t]he key is inspiration: 'Can anyone define inspiration?... It comes out of the essence soul which only has one surge, one force, one energy' [198]. [45, p. 71]

Such portrayals of the artist, designer, or architect as one whose creative abilities are too mysterious and ineffable to understand can be traced to Romantic and Modernist conceptions, yet they persist today. This rhetoric is a manifestation of the fundamental epistemological division between the arts and sciences which we reviewed in Chapter 2. Coyne and Snodgrass refer to this as the "dual knowledge thesis." The dual knowledge thesis portrays these divergent epistemologies as "logical, analytical and rational on the one hand, and subjective, idiosyncratic and irrational on the other." This division "becomes a means of exercising control over people and their behaviour" and are "employed to support the view that different areas of expertise deal with different kinds of reasoning" [45, pp. 72-73]. Technological creativity thus conventionally falls within the domain of the sciences and engineering.

The creative process of artists has remained uncodified. On the other hand, artistic creative processes can be articulated—enough to be beneficial anyway. Articulating creative practice is beneficial both to the individual practitioner and within cross-disciplinary collaborative work. For the individual practitioner, an awareness of process can help them weather the uncertainties of the creative process by giving them a foundational support for their process even if it seems to be ungraspable and diffuse. When working collaboratively, particularly across disciplines, a group understanding of the possible forms of process can help the group mesh and tolerate practices that may be disciplinarily unfamiliar to them. In discussing and researching creative practice, there is likely a sweet spot where discussions and articulation of process are helpful to practitioners, but over-analysis becomes distracting and interferes in the process. This sweet spot will vary among practitioners, with some finding creative benefit in more articulation and some finding benefit in less.

5.4.3 Conceptual thinking and perceptual experiences

Thinking hermeneutically, as described by Coyne and Snodgrass, allows room for a practitioner to alternate between multiple modes of thinking and experiencing. For example, the design activity described in this chapter blends perceptual experiences and conceptual thinking. The metaphor of the charms, the information about SIDS, and the association between jade plant leaves, polymers, and textiles are examples of conceptual thinking on the part of the artist. Feeling the voice resonating in the coffee cup, the sensation of a child's beating heart, and the crudeness of the electromotor vibration of the infant chair are examples of the perceptual experiences that were incorporated into the design. In his book *Graphic Thinking for Architects and Designers*, Professor of Architecture Paul Laseau describes conceptual and perceptual thinking:

> Conceptual thinking seeks out the underlying structure, order, or meaning of experience; it attempts taking possession of the experience, comparing

> it with other experiences, and interpreting it in the light of our knowledge of reality. Perceptual thinking tries to take in the direct experience of an environment, noting the elements from which it is composed and the personal reactions the environment evokes. Often these two modes of thinking are thought of as separate or even in opposition. Creative, dynamic thinking depends upon full integration of conception and perception because they inform and give meaning to each other. [105, p. 192]

Integrating perceptual experience and conceptual thinking can potentially form the parts to wholes aspect of the hermeneutic circle described by Gadamer and Coyne and Snodgrass. Laseau writes:

> Knowing that there are about four hundred varieties of goat's-milk cheeses produced in France adds something to the experience of eating one of them; nevertheless, knowledge of these varieties does not have much meaning until you have tasted one of them. The history of Gothic church construction, including principles and variations, when combined with the overwhelming sensations of moving through the darkness and light of a Gothic church nave, provides a complete, integrated awareness that could not be achieved should either the conceptual or perceptual element be missing. [105, p. 192]

When thinking through lived experience, conceptual thinking links to our world. When thinking technically, conceptual thinking may only link with concepts in the technical or scientific domain. But artifacts participate in the lived world of humans. As such, their meanings and patterns of use are sensitive to context and interpretation as described in the phenomenological reflection on *Breeze* in the previous chapter. Coyne and Snodgrass write:

> Nor are our projections merely arbitrary productions of the subjective imagination. The projection derives from experience brought to bear on the clues scattered in the situation we are in. Anticipations of the completed whole are not the positings of subjectivity but emerge from preunderstandings that inhere within the situation itself.
>
> . . .
>
> Meaning is not fixed and firm, but is historical; it changes with time and as the situation changes. Understanding is in perpetual flux. Meaning is not an immutable object that stands over against us but is an everchanging part of an ever-changing situation. It is not an object, but neither is it

> subjective. It is not something we think first and then throw over onto an external object. It is known from within and can only be so known: we cannot get around in front of meaning, any more than we can get around in front of language. We are embedded in meaning structures, and so cannot view them as objects that can be tested by the criteria of logic. Meaning exists prior to any separation of subject and object. In the interpretive act the Cartesian subject-object dichotomy dissolves. [44, pp.16-17]

5.5 Summary

The artist's development process in this case can be characterized as hermeneutic, allowing conceptual and perceptual episodes to reflect upon one another until the behaviour, mechanism, and form of the invention emerges. The invention process described here challenges validity claims of rationalist design methodologies, yet, at the end of the day, this process resulted in an invention institutionally legitimized through the patenting office at a large engineering university. Part of the thesis of this dissertation is that the visual arts can concretely contribute to technological innovation and this case is tangible proof of that concept. In the following chapter, I articulate patterns of process through which this can occur.

CHAPTER VI

ARTICULATING CREATIVE PROCESS

6.1 Introduction

I began to wonder about the similarities and differences between artists and engineers inventing after the experience of creating the infant blanket resulting from the *Jade* project. At the same time, I realized that there was a unique opportunity at Georgia Tech. Artists were entering the technological academy through the Digital Media graduate programs. Students with fine art backgrounds were becoming educated in engineering and computer science, and developing technologies in the course of their artmaking practice. Some of these artists were developing technologies independently from but in parallel with computer science and engineering labs at Georgia Tech. Perhaps they were responding to local agendas or perhaps Georgia Tech was such a large engineering university that virtually all research on the technological frontier was covered to some extent. Regardless, it was possible to pair these artists with engineers working in the same domain for comparative purposes.

I designed a study to compare the work practices of artists and engineers working separately to develop similar technologies. The goal of the study was to provide evidence-based articulations of different disciplinary practices in order to better understand these paths to innovation and their results. The artists and engineers selected for this study were pursuing their projects independently without any orchestration for study purposes. I organized three artist-engineer pairings for the purposes of the study. One pairing included myself as an artist developing the *Jade* project described in the previous chapter. The other side of that pairing was a professor working with electronic textiles in the Polymer, Textile, and Fiber Engineering.

Another pairing consisted of an engineering team devising a tongue-driven computer interface system, which they were mainly using to help quadriplegics operate their electric wheelchairs, and an artist who was developing tongue-driven ways to make music and interface with digital media. The third pair consisted of an interactive media artist creating a piece that allowed individuals to communicate through their cell phones with a 3D image of the late Dr. Martin Luther King, and computer scientists building a semi-automated 3D animation system that would allow soldiers in Afghanistan to create narratives in the field for communication with the local populace.

The project was funded by the NSF CreativeIT program, under the Division of Information and Intelligent Systems. The CreativeIT program was mentioned in Chapter 3. Its goals were to (1) use technology to understand creativity better; (2) use technology to foster creativity in research, design and education; and (3) understanding how creative thinking creates new products, methods and organizations. Because of the associative relationship between creativity and the arts, the CreativeIT program became one of the first NSF programs to fund research involving the arts. My advisor, media theorist Jay Bolter, is the PI on the grant. We collaborated with Juan Rogers in the Department of Public Policy. Rogers is an expert in case study methodologies and conducts research on the impact and organization of creativity and knowledge in research and development settings. Rogers also has an undergraduate degree in electrical engineering, complementing my experience as an artist with significant coursework in human-computer interaction, electrical engineering, and polymer and textile engineering. Bolter has significant experience with interactive art and computer-mediated forms such as augmented reality narrative.

The goals of our study, titled *Qualitative Analysis of Creative Practices in Parallel IT and Art Projects*, were to: (1) develop a conceptual framework for understanding similarities and differences between creative practices in the arts and engineering disciplines; and (2) to provide knowledge about such similarities and differences. This research project also aligns with the goals of an international, interdisciplinary art and technology community lacking foundational, evidence-based research to articulate their practices.

6.2 Review of academic research on creative practice

6.2.1 Creativity studies

Creativity research is predominantly carried out in the psychology realm, which is fundamentally concerned with mental processes. Creativity studies in Western culture historically tended to focus on the origin of creativity in mental characteristics of the individual, with creative ability following a normal distribution society-wide [171]. Creativity researcher Mark Runco cites educational psychologist Madelle Becker's historical study of creativity research and the evolution of the predominant questions in creative research today:

> (a) What is creativity? (b) Who has creativity? (c) What are the characteristics of creative people? (d) Who should benefit from creativity? And (e) Can creativity be increased through conscious effort? [171, p. 13] from [21]

These questions reveal a formulation of creativity as having a locus in the traits of the individual, particularly mental and personality traits. Seminal points during twentieth century creativity research include Catharine M. Cox's studies in the 1920s combining intelligence estimates and traits developed in childhood including autonomy, persistence, and intrinsic motivation (profiled in [171]). Other preeminent approaches include psychometric pioneer J.P. Guilford's categories of convergent and divergent production (often expressed today as convergent and divergent thinking). Divergent production/thinking moves in multiple directions and thus may be novel. Convergent production/thinking aims for the correct or optimal solution to a problem [82]. Convergent and divergent production was studied by Guilford in the 1950s and 1960s through experimental laboratory studies. One of Guilford's students, William Michael, and his colleague Patricia Bachelor continued Guilford's work, writing:

> In addition to recognition of divergent production as a key component of creative endeavor, it appeared that a higher order convergent production factor involving primarily semantic and symbolic transformations constituted a dimension of potential importance to the creative thinking of mathematicians, engineers, and inventors. It was hypothesized that in creative thinking a variety of psychological operations within a dynamic, interactive system are employed almost simultaneously in a forward and backward manner. [17, p. 157]

Cognitive approaches to creativity focus on the creative problem-solving processes available to every individual. Process-centered approaches in this realm typically focus on cognitive processes and assess creativity in light of problem-solving ability. This work supports the "How can we be more creative" discourse which continues today, particularly in educational and innovation settings. Cognitive science approaches are often linked with research in computing. For example, Boden considers artificial intelligence, particularly generative systems, in parallel with human cognition. This method leads her to a conception of creativity as the generation of ideas that follow a different generative path than conventional ideas. For Boden, creativity arises from the application of everyday mental operations to new mental representations [24].

Social factors for increasing creativity and innovation have been put forth by Amabile [15] and Sawyer [172], whereas environmental factors, including social and cultural factors, that support creative individuals have been researched by Csikszentmihalyi [47] and Simonton [182]. Although these systems models of creativity admit social and cultural factors, their causal emphases are still on traits of creative individuals, alone or in conjunction with moments in history or other privileged circumstances.

Psychologist Paul Locher, in his survey of the research on creative processes of visual artists, writes that "Empirical investigations of the actual working processes engaged by visual artists as they make art are very limited in number" [111, p. 143]. Research on art practice situated within creativity studies includes Miall and Tchalenko's measurements of painters' eye and hand movements. Miall and Tchalenko took a cognitive and perceptual approach to "How does a painter transform a vision of the external world into a picture on the canvas?" [127, p. 35]. They determined that eye movements while drawing a portrait are different than everyday eye movements, as well as the eye movements of novices drawing a portrait. The focus of this study was the high-resolution description of the artists' eye-hand skills from a cognitive perspective. This example also illustrates what is often understood as process studies in creativity research. In general, "there is little research into the details of the creative process based on the observation of creative production by those involved in a particular field of creative endeavour [114, p. 266].

Inherent in the structure of our research study on creative process in the art and engineering disciplines is the notion that creativity can be located in creative practice. Practice is action-based. We are more concerned with the patterns of behaviour and action-in-the world, i.e. the things that we do to realize our creative work. This locates creativity less in the mind and more the the holistic combination of thinking and acting with artifacts with the world. This research configures creativity as something that is enacted—simply put, something that is done, not something that is. Creative practice is a type of Verhalten (see Chapter 4) where action-in-the-world forms a stance that manifests possibilities.

The framework of problem finding and problem solving evolved from creativity researchers using "think aloud" protocols during a process-based research session. These are called "protocol studies" by the community (as opposed to the generally-used term "study protocol.") During a protocol study, subjects are given a task, a limited amount of time to complete the task (typically this amount of time is constructed to be adequate), and are asked to speak their thoughts as they work until their task is completed. Problem finding and problem solving have been discussed at least since Catherine Patrick's studies of artists in the 1930s and has notably been taken up by Jacob Getzels and Mihaly Csikszentmihalyi in their longitudinal study of artists in the 1970s. Patrick developed the methodology that was used with minor modifications by Getzels and Csikszentmihalyi. Patrick created two groups of subjects—a group of fine arts painters and a group from the general population who had never painted or drawn before as a control group. Patrick tasked both groups with responding to a poem by John Milton titled *L'Allegro*. She asked each subject to read the poem and then draw a picture, any picture, that the poem evokes in them. Subjects were asked to talk aloud during the process. Patrick recorded the order in which subjects drew the elements of their pictures and then administered a questionnaire after the session. In analyzing the data, Patrick found distinct periods of what she called "unorganized" thought followed by "organized" thought equally in both groups [145].

Getzels and Csikszentmihalyi recruited thirty-one visual arts students and gave them roughly thirty objects to select from and organize into a still life which they would then draw. The researchers observed and recorded this activity and divided the process into two stages: a "Problem Formulation Stage" consisting of the pre-drawing activity, and a "Problem Solution Stage" consisting of drawing and reflection on the drawings by the subject. The researchers correlated the amount of effort their subjects spent contemplating and handling the objects and organizing the still life with greater levels of creativity exhibited in their drawings. They cross correlated these finding with observed problem formulation while drawing and as exhibited in the responses to exit interviews. Getzels and Csikszentmihalyi construct problem finding as "the way problems are envisaged, posed, formulated, created" and considered the problem-finding tendency in terms of a personality trait [77].

6.2.2 Design studies

The design studies field has collectively produced work focusing on the action of creative process. For example, Donald Schön, whose book *The Reflective Practitioner* was discussed in the previous chapter, conducts in-process studies with design students and professionals. The designers are observed while working and their discussions and artifacts are recorded. These studies record episodes in their practice, as well as in the practices of psychotherapists, scientists, and managers. The goal is not to capture entire work processes or compare processes, but to exemplify and support Schön's thesis that reflection-in-action is central to these professions [174].

Design process studies typically use an experimental procedure employing a design assignment given to subjects asked to follow a think-aloud protocol during a limited design session, i.e. a protocol study as described above. For example, a study by design researchers Kees Dorst and Nigel Cross used the protocol method to locate the "creative leap" in the design process. Their subjects were experienced designers given a design brief and asked to present their solutions after a design session lasting two and a half hours. Their subjects' design concepts were numerically scored along parameters such as technical aspects, aesthetics, creativity, and total judgement by a panel of judges. This data was combined with the qualitative, think-aloud data to produce results addressing the relationship between the way the designers framed the problem and the the judged creative impact of their solution. The authors correlated creative leaps to the formulation of the design problem and built these results in to a model of design as co-evolution of the problem space and the solution space [54]. Similarly designed research studies have been conducted by Cross, Christiaans, and Dorst [46] and Gero and McNeill [75]. Overall, design studies tend to be task-based or session-based instead of based on a holistic, long-term view of process.

Blackwell, Eckert, Bucciarelli, and Earl conducted a comparative, phenomenological study of the experience of design across a broad range of design disciplines and specialist backgrounds including clothing, architecture, graphic design, engineering, drugs, food, and software. The project was called *Across Design* and resulted in multiple research papers. The goal of the project was to "develop a rich understanding of recurring behaviors across different domains, even though these might not apply to every process." The researchers "looked for patterns of professional experience, as understood by the design professionals themselves." The study proceeded through a series of workshops where expert designers presented "case study illustrations" of their practice for discussion with designers from other disciplines. This research established commonalities in design practice across the different fields and triangulated general themes such as the meaning of being a good designer, the relationship of the designer to the customer, the relationship of education to the professions, criteria for good design, representations as communication tools, and uncertainty in collaborative processes [23, 60].

6.2.3 Engineering studies

As with creativity studies and design studies, many studies in engineering design leverage controlled experiments or follow episodic tasks to discover some element or constellation of cognitive functioning. It is worthwhile to note that the boundaries between these domains aren't closed. For example, design studies often includes engineering design and cognitive science in its literature and research.

Empirical research in engineering practice is also conducted within industrial environments, typically through observation sessions and protocol analysis. These studies tend to focus on individual issues within the larger practice, such as design reasoning and design strategies under different conditions. For example, engineering design researchers Ahmed, Wallace and Blessing of Cambridge University researched the experiences of novice and expert engineers within an aerospace context to understand how they applied their experience and knowledge. In their paper, they report an ethnographic methodology, but the actual study process consisted of a mixture of techniques including observational sessions lasting between 90 to 120 minutes conducted using think-aloud techniques and protocol analysis. These were combined with interviews. The engineers were not presented with a special design task, but were observed working on their own design projects. Through analyzing the qualitative data gathered, the researchers reported findings related to patterns of practice, including a tendency toward trial and error on the part of novice engineers and concept evaluation prior to implementation on the part of experienced engineers. This finding framed a cascade of more detailed differentiations between novice and expert practices [11].

In their paper, “The elusive act of synthesis: creativity in the conceptual design of complex engineering products,” Eckert, Wyatt, and Clarkson, as part of the *Across Design* project described above, use case study methodologies to further analyze engineering practices within the context of diesel engine design. The researchers conducted between one and three semi-structured interviews amounting to thirteen interviews in total. While the researchers present multiple, episodic conclusions about process, they do not synthesize these into a pattern of overall creative process. One result of interest to our study is that the engineers’ “emphasis on reliable and repeatable processes caused creativity to be displaced backwards into R&D and forwards into ‘emergency innovation’ during integration” [59]. I will return to this result near the end of this chapter.

6.2.4 Studies within the art and technology community

Research studies of practice or process from within the fine arts community is not conducted. Practitioners are not researchers, and, anecdotally speaking, use of the word “creativity” in a fine arts context would result in immediate discreditation. For a resource that may shed some light on this phenomenon, see Elkin’s book, *Why Art*

Cannot Be Taught [62]. In the fine arts context, "creativity" is considered a wonky, analytical word with no meaning. However, individual artists typically are aware of their process and often will discuss it in the context of an individual project. For a collection of such discussions, see the archive of artist interviews carried out over forty years by William Furlong compiled in the book, *Speaking of Art* [71].

Members of the art and technology community, because of the research familiarity of much of the community (discussed in Chapter 3), do carry out evidence-based research studies on the work begin done in that community. Sometimes this research is carried out from within a research context, as with the work of Candy and Edmonds, sometimes it is carried out to surface and legitimize some aspect of art and technology work, and sometimes it is carried out in the context of a research report for a funding agency.

Case study research by Candy and Edmonds on collaboration between artists and technologists within their residency series is described in their first book, *Explorations in Art and Technology* [34]. Data was collected through observation and the recording of dialog throughout the many collaborations between artists and technologists. This data was analyzed to construct a "co-creativity" model for collaboration focusing on cognitive styles, communication, and the use of knowledge. The purpose of this work was to model the roles played by each party in the creative process in a way that led to recommendations for facilitating collaboration. This model divided the creation process into three phases—concept, construction, and evaluation. These were then detailed according to characteristics that emerged depending whether the phase was artist-led, technologist-led, or an artist-technologist partnership [37].

Candy and Edmonds's use of the term "cognitive style" refers to "the characteristics of thinking and making in the creative process as revealed in external behaviour and self-evaluation". The features of cognitive style identified were: "the approach used to carry out the project; the role adopted by participants; the ethic adopted that drove the process; the value placed upon level of control over the process; whether the methods used were wholly digital or traditional media combined with digital ones" [34, p. 58]. Notice that these features are more holistic, subjectively-originated, and process-derived than the cognitive features investigated in the studies profiled in the previous subsections on creativity studies, design studies, and engineering studies. These features are practical within the art and technology collaborative context.

This research was continued by Ph.D. students of Candy and Edmonds and is included in their second book, *Interacting:Art, Research and the Creative Practitioner* [38]. Zhang analyzed patterns of communication modes between an artist and two technologists working on a project over a three-month period. She employed non-participant observation followed by semi-structured interviews according to case study methodology. Zhang developed a schema based on different types of communication modes, including common types of conversation within each communication mode, how the modes related to each other, and how they were distributed in terms of frequency and duration across the meetings. Categories of modes were: face-to-face mode, proposal-assisted mode, computer-assisted mode, interactive-artefact-assisted mode and drawing-assisted mode. Zhang found that the mediation tools varied at different stages of a project, and analyzed these at the different stages.

Jill Scott's Swiss artists-in-labs project, mentioned in Chapter 3, places artists in scientific and technology labs to create work, either individually or in collaboration with lab members. Her edited books on the program consist of unstructured reflections on the work by the artists and at times scientists and technologists in the labs that hosted the artists [175, 176]. The reflections stand on their own. It is not a goal of the work to code them or analyze them into central results. Instead, Scott distills the reflections into a series of discourses about education, innovation, ethics, and social engagement. Scott expands on these categories:

> The first group of discourses are education and know-how transfer about situated knowledge, contextual immersion and relational creativity. The

> second group are discourses about ethics including bio-ethics and the artistic interpretation of scientifically robust knowledge. The final category describes discourses about innovation and its social impact on culture such as converging technologies, comparing methodologies and information as progress. [175, p. 7]

One purpose of these reflections and discourses is to encourage self-reflection and engagement with these issues on the part of scientists and the general public.

6.2.5 Summary of research studies across creativity studies, design studies, engineering studies, and art and technology studies

Most of the representative studies profiled in this section were episodic, focused on discrete tasks or multiple tasks over limited sessions. Candy, Edmonds, and Zheng studied collaboration issues throughout complete project cycles. The focus of this work was on features of collaboration at different stages of the art creation process. Scott use a reflective approach to establish discourse in a way akin to essay-writing in the humanities. None of these studies mapped creative process over the course of a project, as our study does. Psychologist Mary-Anne Mace interviewed artists while they were working on their projects. She also came up with a process model of creative practice in the visual arts. This work is covered in our triangulation of our results with the existing literature that appears near the end of this chapter.

Inherent in the structure of our research study on creative process in the art and engineering disciplines is the notion that creativity can be located in creative practice. Practice is action-based. We are more concerned with the patterns of behaviour and action-in-the world, i.e. the things that we do to realize our creative work. This locates creativity less in the mind and more the the holistic combination of thinking and acting with artifacts with the world. This research configures creativity as something that is enacted—simply put, something that is done, not something that is. Creative practice is a type of Verhalten (see Chapter 4) where action-in-the-world forms a stance that manifests possibilities. With this in mind, we constructed our study with a focus on the actions that make up the creative process, instead of conceptual explanations or mental stages of this process.

6.3 Methodology

Noting that artists and engineers were working on similar technological projects at Georgia Tech, we devised a study to pairwise compare their work practices. Specifically, we carried out a comparative, qualitative multiple-case study of three such pairs and studied their work practices in parallel. Although these artists and engineers are conceptually paired for study purposes, they were working separately and on their own accord. The pair described in this chapter includes myself in the role of an artist working on a large Jade plant installation whereby visitors can pluck some of the spongy leaves, hold them to their heart to collect their heartbeat, and (magnetically) reattach them to the plant where they will pulse with the visitors' heartbeats. This piece evolved into an infant blanket that a caregiver could hold to her or his chest, record heartbeat into, and swaddle the infant in the pulse of that heartbeat. This invention held promise in other cases as well, such as lowering the arousal threshold of infants to protect them from sudden infant death syndrome (SIDS) and for post-traumatic stress disorder (PTSD), particularly in the case of soldiers returning from war. This case was compared to that of an engineering team who were developing a soldiers' garment with monitoring and communication capabilities so that soldiers injured in the field could be triaged from a base camp and rescued. This soldiers' garment evolved into an infant garment to monitor infants for SIDS episodes.

This study design has at least two benefits: (1) studying the practices of artists and engineers conceptually bound together through similar projects and technologies throws the creative strategies and design decisions of each group into relief; and (2) such a study is "in the wild" in the sense that phenomena are occurring on their own accord and for their own reasons, without orchestration for study purposes.

Because of the goals of our study, i.e. to compare the work practices of artists and engineers working on similar projects, and our orientation toward creativity as an act manifested in the world, we seek a rich and comparative description of creative practice. Therefore, we use a qualitative case study methodology to document and analyze the creative work processes of study subjects as they are engaged in their professional practice. The case study methodology supports in-depth documentation and analysis of complex relationships and mechanisms within in a few cases as opposed to a study that generalizes to statistical significance with a pre-inscribed set of parameters. Case studies are particularly useful in establishing grounded-in-evidence descriptions of how or why phenomena occur in real-life contexts. As is well-established in the literature of qualitative methodologies [199, 129], case studies generalize to theory as opposed to attributes of a population. We will not be reporting outcomes such as "Engineers use this creative practice while artists use that creative practice." Instead, we use our concentrated lens to give name to and articulate patterns of phenomena in play within these arenas of creativity and innovation.

We studied the work practices of our participants by observing and video-recording work sessions for three hours a week and followed up on these observations with weekly semi-structured interviews that lasted between thirty minutes and two hours. We documented artifacts related to their projects such as notes, tools, technologies, prototypes, and information sources. We verified and triangulated material from interviews, observed work sessions, and artifacts. We constructed detailed diagrams of work processes (see Figures 102 and 107) and used these diagrams as an instrument to elicit clarifications from our subjects. We read texts they had indicated are important to their work and discussed these texts with them. Our subjects also reviewed drafts of our case reports and commented. We studied participants from between four months to one year, depending on the timetables of their projects. Results of data gathering were transcribed, organized, coded, and analyzed for patterns.

I was both a study researcher and a subject. It was through my work on *Jade* that I noticed that I was working in parallel with an engineer at Georgia Tech, leading me to find more artist-engineer pairings around similar projects and ultimately the study design. In my case, Rogers interviewed me and analyzed my materials in order to reconstruct my process. This embedded investigative role in qualitative studies is not uncommon. See Kolodner and Will's study of a mechanical engineering design project [98] and Vattam, Helms, and Goel's study of biologically-inspired design projects [194] for other examples of studies where a study researcher was also a project participant. In this chapter, we present my case and the parallel case. In Chapter 5 I wrote about the process of conceptualizing *Jade* from my point of view. In this chapter, my process is written from Rogers's point of view.

In the following sections I detail the engineering team's process and my process as recorded by Rogers. Rogers and I triangulated this data with the data from the other pairs and derived the models of creative work process reported in this chapter. This work was published in the paper, "Articulating Creative Practice: Teleological and Stochastic Strategies in a Case Study of an Artist and an Engineering Team Developing Similar Technologies" for the Conference on Tangible, Embedded, and Embodied Interaction (TEI 21012) [69]. For an artifact-centered description of this work, see the paper, "Negotiating Uncertainty: Process, Artifact, and Discourse in a Case Study of Technologies to Address SIDS" for the Conference on Creativity and Innovation in Design (DESIRE 2011) [68]. This conference was hosted by the DESIRE Network, a European counterpart of the NSF CreativeIT program.

6.4 The engineering team's process

The engineering project began with a catalytic desire. The lead engineer is a professor in textile engineering with significant experience in computer science and programming. He acknowledged being a systems thinker, a skill and orientation that to him transcended textile engineering and computer science. He reported that he had previously applied his systems orientation across the fields of textile engineering and management, and has contributed to garment manufacturing and distribution systems for the military. For this project, the lead engineer was working with three post-doctoral students.

The engineer answered a DARPA request for a soldiers' garment with special capabilities to monitor a soldier's condition in real-time. These capabilities included vital signs monitoring, identification of if and where the soldier had been injured, and signal transmission of this data to a base station. The lead engineer's motivation to undertake the project was to use his core engineering and systems-thinking competencies to create something that improves the quality of life for U.S. soldiers. To quote him:

> *Whatever I do it has to be useful, helpful, and improve the quality of life. That's the motivator.*

The initial ideation stage of the project consisted of negotiating requirements between DARPA's request and the engineering team. The team brainstormed the requirements they felt would optimize the design and categorized them into seven "ities," as they called them: functionality, connectivity, durability, usability in combat, wearability, manufacturability, and maintainability. They then unpacked each of these "ities" into subsets of related requirements. For example, usability in combat incorporated thermal protection, resistance to petroleum products, and minimization of signature detectability. The team members conceived many of these requirements by imagining a soldier's experience with the garment. For example, they wrote a detailed scenario that described how a soldier would attach the sensors to his or her body, put on the garment, and attach the monitors to the garment. Other requirements came from the team's domain knowledge and experience in textile engineering. For example, the durability requirement included the garment's ability to withstand flexure and

Property (Evaluation Criterion)	Weight (%)	Copper Core with Polyethylene Sheath	Polyacetylene Coated Fibers with Polyethylene Sheath
Electrical Conductivity	30	4	1
Stability (Chemical, Thermal, Water)	20	4	1
Resistance to Electromagnetic Interference	15	2	2
Bending Rigidity/Flexural Endurance	10	3	3
Availability	10	4	1
Elongation and Creep Recovery	5	2	3
Weight	5	1	4
Tensile Strength and Modulus	5	4	3
Cost	2.5	3	1
Total and Weighted Score	**100**	**3.43**	**1.73**

Figure 99: A weighted prioritization matrix from the engineering project.

abrasion. While the project team conceived this requirement, others in the durability category, such as a wear life of 120 combat days, originated from DARPA.

These requirements were reorganized into five components for the design: penetration-sensing, electrical-conducting, comfort, form-fitting, and static-dissipating. Each of these components literally translated into a choice of material to be incorporated into the structure of the textile. The materials were chosen by narrowing down possibilities between candidates using a weighted prioritization matrix. This technique is part of the Quality Function Deployment (QFD) engineering process [12]. Overall, the engineering team's design approach was guided by QFD, and they furthered its development as a design methodology for their engineering community [159][1]. The weighted prioritization matrix for the electrical-conducting component appears in Figure 99. Desired properties are weighted according to their priority. Each potential solution is given a score from 0 (worst) to 4 (best) per property, and the results are calculated to a weighted score. From the team's perspective, the higher the final weighted score, the greater the probability the solution would successfully meet

[1]The engineer in this case has waived anonymity.

the established design requirements and hence the higher the chance of producing an effective garment for the combat scenario. For the team, the matrices surfaced relationships between materials and their properties that might remain invisible if not for this organized approach.

Weighted prioritization matrices were also used to determine fabrication processes. In this case, in-lay knitting and full-fashioned knitting had the highest weighted scores, however the team concluded that the technological complexity of full-fashioned knitting would be too high given the project and the unpredictability of incorporating a single, long, uninterrupted plastic optical fiber into the yarns. For this reason, the team decided to try in-lay knitting and tubular weaving in parallel to see which best suited their goals. Tubular weaving, which rated third on their design prioritization matrix, was the fabrication technology that the team ultimately used based on the specification that the optical fiber could not be cut. Thus the garment was to be fashioned as a seamless three-dimensional textile with head and arm holes all created on the loom. Once these design decisions were made, the team fabricated a series of samples and evaluated them. They found that one of the component fibers they had decided upon through the prioritization matrix was too hydrophobic to be woven properly. The threads attracted and tugged on each other. The solution was to put a coating on these threads.

Project stabilization was of the highest priority for the engineering team. This is expressed by the team leader when describing their design methodology:

> *The detailed analysis adopted in arriving at the... design minimizes the risks associated with the success of the project. All the performance requirements defined by the government can be met by the design and the fabrication technologies are well-proven in the textile industry further improving the chances of success.*

The creative strategy of the engineering team harnessed knowledge, know-how, resources, and systematic decision-making to ensure the success of the project. Bringing together appropriate technological elements in a reliable and safe way is a highly creative process. The engineers leveraged their accumulated knowledge at the initial project stages in order to develop a clear strategic intent and ensure that the final product would pass a public test of satisfaction, safety, and reliability. This clear strategic intent was projected forward to a desired design outcome that guided the project throughout all stages.

The engineers proceeded toward this desired outcome while constantly checking the emergent work against it as a reference, iteratively refining it to match this reference as closely as possible. Thus the requirements and the design concept not only served as a beginning point, but also as a terminal reference leading the project forward from the end state. As the engineers faced intermediate problems and resolved them, they came to deeper and more detailed understandings of this reference. We call this type of creative strategy "teleological." Teleology is a term we borrow from philosophy. A process is teleological when its end acts as a final cause, or "telos," that directs its development. The final cause can be thought of as a predetermined purpose, target, or end state toward which the piece develops.

After the engineers determined their target design and requirements, the teleological process served to stabilize as many parameters as possible and constrain additional potentials and deviations. This allowed the engineers to focus on optimizing solutions for these requirements in order to weave together technical materials to produce a high-functioning product. A series of intermediate problems for the engineering team came during the fabrication stage. These impasses led to a break in the teleological pattern of the engineers' process. While the final design as conceptualized in the beginning of the process was still the guide, the engineers' trajectory toward that goal was interrupted by searches for unknown solutions, brainstorming, trial and error, and multiple, unanticipated decision points.

Many of the samples for testing and proof of concept were produced using a standard table loom and ad hoc hand techniques. The lead engineer had used a locative model from telephony to understand the operation of the optical fibers that would be used to detect penetration through breakage of the fiber. After determining the optimal spacing of the optical fibers in the weave so that the fibers could detect penetration but not attenuate the signal, the team determined that they needed 200 meters of optical fiber to make one garment using the tubular knitting process. The physical integration of the modularly-developed components became a challenge. Because the team found the plastic optical fiber to be brittle, they decided that it had to be protected. The team considered using either an insulated tubing or a sheath of microdenier polyester/cotton blend sliver created using core spinning technology. The core-spun sheath idea was abandoned as impractical given the specifications of standard equipment, so the team set about sheathing the plastic optical fibers with tubing by hand.

The engineering team first attempted to sheath the 200 meter fiber by laying it out along long corridor in a building, but this process did not afford enough space. Next they tried integrating the optical fiber into the garment by spinning it at the same time as they spun a sheath into the garment, but the optical fiber was too rigid. Finally, they threaded the fiber through a sheath by hanging the fiber and sheath out of a third story window at the lead engineer's home. In the lead engineers's words:

> *So one cold morning, my research assistant, she came to our house. We live in a very high house. So we were actually threading from the top and somebody was down at the bottom and getting it. And that's how we made this long length. And that's how we could produce the fabric. And the way the fabric, this had to be wound on something called a shuttle. Again that was a problem. So eventually we had to figure out how to do it. But the thing is the thread has to be put on a spool. So again that was a challenge and eventually we were able to do it. Another dead end, but again we were able to solve it.*

One of the other challenges that presented itself during the fabrication process was how to electrically connect woven insulated conductive threads. The team initially created samples using a blade to scrape the insulation off the threads by hand, but this provisional technique proved impractical for the production of an entire garment, let alone a production run of garments. The group was stuck for a while until one team member found the solutions while shopping in a drug store. He conjectured that they could use nail polish remover to chemically soften the insulation on the thread and a vibrating toothbrush to etch away the insulation and matt the conductive fibers together. This technique was used in the prototype garment fabrication and eventually evolved into a patented process for interconnecting conductive fibers woven into a fabric. The patented process involves a solvent, mechanical abrasion, and ultrasonic spot welding.

On a conceptual level, the engineers were inspired by a computing metaphor when designing the cloth. They initially thought of the cloth as a weave-able, wearable, elastic computer. This metaphor guided the overall project conceptualization through the planning, sample construction, and sample testing stages. While working on the weaving and interconnection issues, the lead engineer had an "aha" moment:

> *Today I might want to monitor my heart rate. Tomorrow I might want to talk to my shirt. So I said to myself, where do I look for a solution that is ubiquitous in terms of providing flexibility and I can still remember that day. I was sitting in my study and I looked out at {anonymized} and I said, "Wow, it's a motherboard. It's a computer motherboard." A computer motherboard gives you the flexibility of plugging in whatever chip you want.*

Realizing the project as a wearable computer motherboard reframed the project. This new metaphor emphasized the flexibility and modularity of the design and enabled the team to see possibilities for attaching various devices to the garment, with the textile acting as a motherboard. This led the team to consider multiple "plug-and-play" applications beyond combat casualty management. The garment could support

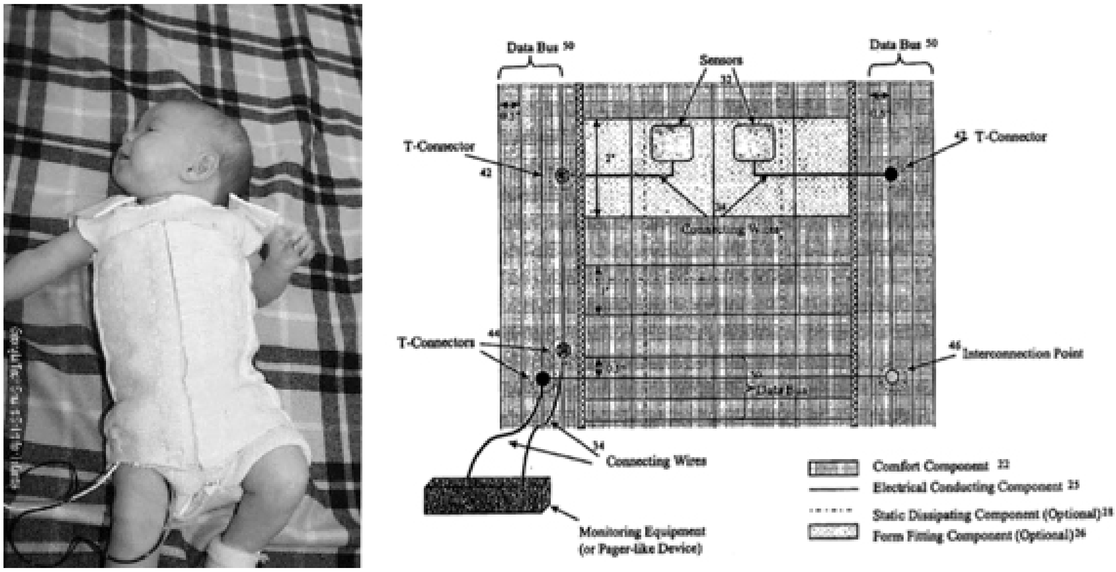


Figure 100: The engineered onesie.

components with functionalities important to athletes, home care patients, or astronauts. A consumer version could allow components to be interchanged according to need or desire. The team did create a robust and innovative garment for monitoring the condition of soldiers, but the "aha" moment reconfigured the telos to a flexible sensate textile that could be used for a spectrum of applications.

The catalyst for the team to apply their technology to SIDS was a newspaper article on local SIDS research. The two pediatricians in the article discussed cardiorespiratory monitoring for infants considered to be at risk. The doctors were using vital sign monitors attached to a vinyl strap that was secured around the infants' chests. These monitors would set off an alert if the infant's breathing or heart rate fell below a certain adjustable threshold. The lead engineer telephoned the pediatricians and suggested they collaborate. The engineering team designed an infant version of their garment with woven interconnects to attach sensors to. This infant onesie went through a series of iterations before being tested on an infant (see Figure 100). The infant wore the onesie for a month so that the engineers could test the wearability, comfort, and ease of use of the electronic garment. According to the

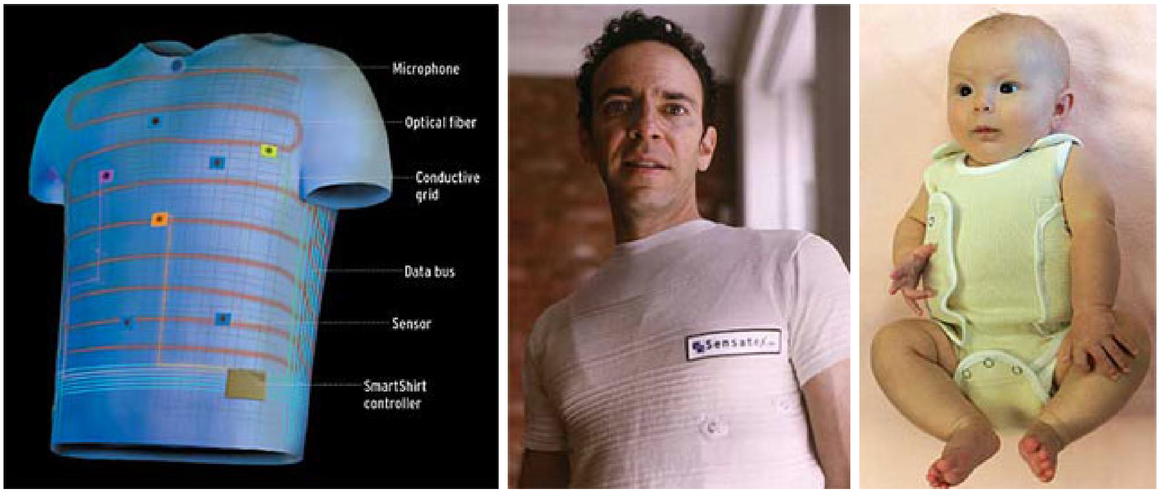


Figure 101: The engineered inventions as products.

mother of the infant and the lead engineer, the technology performed satisfactorily in the wearability, comfort, and ease of use categories. The sensate textile technologies were licensed to a startup company. See Figure 101 for images of their products. A diagram of the engineering team's process appears in Figure 102.

6.5 The artist's process

> *It started out as an art project. My training's in fine art and this project has a lot of different manifestations, but basically what they all have in common is that the idea is to capture a heartbeat inside a sort of charm-shaped device. It originally started out as a way to keep my children's heartbeats with me while I was away from home, so I imagined, I had this experience with feeling speakers. So, for instance, you know the old-fashioned 70's headphones right? They had these really nice membranes that were almost like skin? So, I remember touching them and feeling them move. And I never had a heartbeat in there, but I think at some point later I started, when I thought about heartbeats, I thought right back to that. The sound of a heartbeat, the feeling of a heartbeat, and the texture of heartbeat.*

The technology developed by the artist is a quilted blanket that incorporates novel haptic technologies to physically pulse with the recorded heartbeat of a caregiver. The intended interaction with the blanket is that the mother, father, or other caregiver holds the blanket to their chest to record their heartbeat into it. The recorded

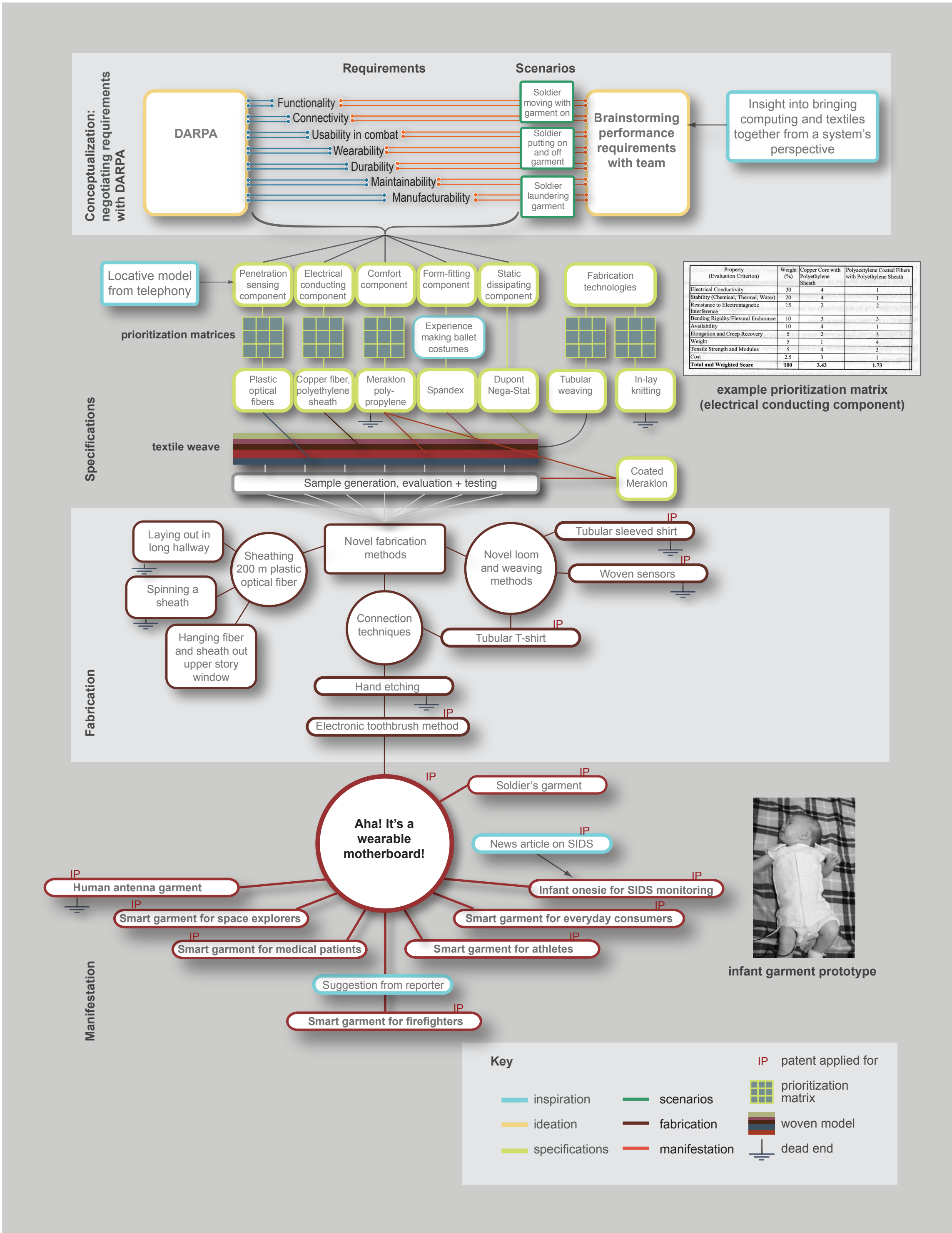


Figure 102: Diagram of the engineering team's work process. The diagram depicts the teleological process in the conceptualization and specifications stages. The teleological process breaks down during the fabrication stage and new possibilities emerge.

acoustic signal is translated into infrasound mechanical energy through electronics in the blanket. The infant can then be swaddled in the blanket and soothed by the silent, low level, rhythmic sensation of the caregiver's heartbeat pulsing through it. Low level, rhythmic, tactile stimulation can be soothing to infants [63]. There are also suggestions in the medical literature that it can support infant arousal response during sleep [126]and thus potentially be of help in protecting against SIDS, though this conjecture has not been tested.

The artist did not begin the creative process with technologies that address SIDS in mind. The goal of her project was to tangibly manifest heartbeat in an intimate object. The question of how to do this guided her process throughout. This goal emerged during her initial separation from her first newborn child:

> *So the idea was that my mother, sorry, my grandmother and all the women in the neighborhood where I grew up wore these charm bracelets, and I don't know if this is something you recognize, but it was a charm bracelet and it had a silhouette of all her grandchildren on it. Have you seen those?...So, when I was a kid, I was fascinated by them. Like, I'm going with my grandmother. Like, is that me? Is that, what part of me is she taking with her everywhere?*
>
> *When I had my child and I was away from her, because I kept going to school and, right off the bat, I wanted to feel her heartbeat, and I thought back to those charms. But the charms are kind of generic. Disappointing, generic silhouettes. And I was like, well, I could really have her with me if I had a pendant. And I could just touch it and feel her heartbeat. I wouldn't hear her heartbeat, I'd just feel it.*

The artist's first step toward tangibly manifesting heartbeat in a charm-like object was to encase a small audio speaker in a small urethane ellipsoid she molded. She attached the speaker to an mp3 player and turned down the gain to get the signal as close to infrasound as she could. Although functionally she could feel but not hear the recorded heartbeat, she concluded that the result was "dumb":

> *It's thoughtless, not compelling. It's just a speaker in a chunk of rubber. It's not well formed; it has no connection to the heart, the form of heart, and heartbeat. The heartbeat and the experience of heartbeat is the first and last thing about the project... I don't have a solution for this.*

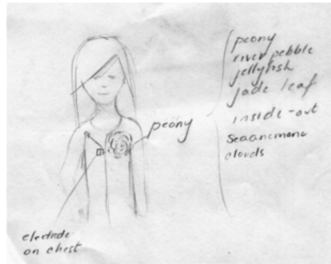


Figure 103: Brainstorming sketch.

The artist's next step was to doodle, draw and write out ideas for tangibly manifesting heartbeat in her sketchbook. Quickly she sketched out various forms heartbeat can take (Figure 103):

peony, river pebble, jellyfish, jade leaf, inside-out, sea anemone, clouds

This brainstorming sketch gives us an interesting point of comparison with the brainstorming activities of the engineering team to list and categorize the project requirements. While at first glance the list of forms in the sketch may seem random, we can also see some of them as metaphors with an exploration of requirements embedded within them. For example, the charm aspect of the project resides in the idea of a peony worn as a pin on the chest and a river pebble that can fit smoothly in the hand. Jellyfish and sea anemones are organ-like creatures, filled with fluid and surrounded by soft tissue like a heart. They often pulse with a rhythm that can be likened to heartbeat. Jade plant leaves are similarly fluid filled, with a tissue-like exterior.

Some of these forms had imagined experiences associated with them. For example, the heartbeat as peony conjured the experience of a corsage with electrodes attached to the chest. The petals of the peony would gently open and close with the beat of the heart. The river pebble and the jade plant leaf had similar experiential actions associated with them. A person could take one of these objects and hold it to their chest to collect their heartbeat. In the case of the river pebble, the person could pass it on to a loved one or toss it back into the river. In the case of the jade plant, one could pluck a leaf from the plant, collect his or her heartbeat into it, and place the

Figure 104: Concept drawing for *Jade*.

leaf back on the plant. After some time the plant would pulse with the heartbeats of the different people who had visited it. One could touch the leaves and feel the different heartbeats. Because this form and interaction could communicate to a larger public, the artist decided to pursue the jade plant as an interactive art installation (Figure 104). Her plan was to use a large, live jade plant and replace some of the leaves with rubber leaves which could collect heartbeat through a small embedded stethoscope bell on the underside of the leaf and produce a throbbing sensation on the top side of the leaf.

Although the artist did not pursue the other forms in this cluster of ideas, they still lent substance to the overall project. For example, the peony idea prompted the artist to build a simple ECG (electrocardiogram) circuit with electrodes (see circuit diagram in Figure 105). Through this project, she developed an understanding of filters and amplifiers for low frequency signals such as heartbeat.

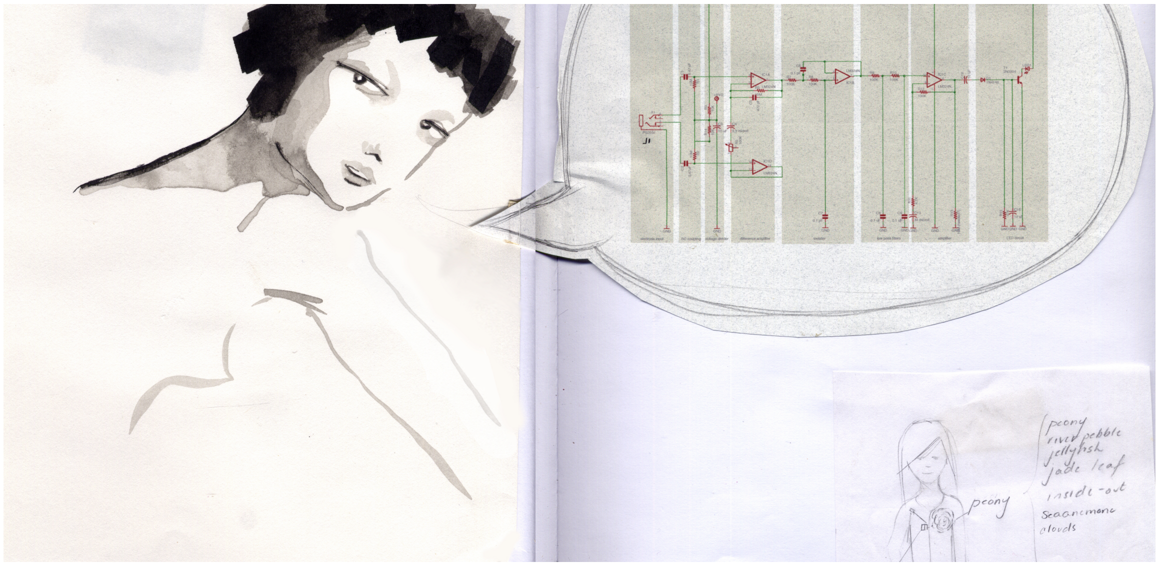


Figure 105: ECG circuit diagram.

In thinking about the development of the interactive jade plant, the artist considered the morphology and material properties of the plant leaves. Jade plant leaves have a skin-like exterior with a spongy interior. It seemed ideal to carve out the inside of the plant leaf to create a vibration chamber for the heartbeat signal. As the artist began working on the jade plant installation, the tactile qualities of the rubbery, elastic leaves led her to a flash of mental associations made possible by her familiarity with textiles and materials:

rubber (plant) → *elastomer* → *polymer* → *fiber* → *textile*

These associations led the artist immediately and directly to a new concept: a blanket that pulses with the heartbeat of a loved one. Such a blanket could be used to soothe an infant or as a telepresence blanket to soothe an adult sleeping without his or her love (Figure 106). This new instantiation of the project carried forward the interaction imagined for the river pebble and the jade plant, that of holding the object to the chest to record one's heartbeat, and then leaving the heartbeat in the object for someone else. The artist's experiments with heartbeat recording and transmission electronics for the *Jade* project became know-how she carried forward into the blanket project.

Figure 106: Telepresence sketch.

Shortly after she decided to create the heartbeat blanket, the artist remembered an experience with her newborn child and her pediatrician. When the artist's children were newborns, the prevailing medical wisdom with respect to preventing SIDS was to keep newborns sleeping on their backs. The artist was concerned because she and her husband often soothed their infant to sleep at night by placing her prone on their chests while they slept. The pediatrician informed the artist that this was not a problem, as the gentle rhythmic sensations of the adult's breathing and heartbeat would keep the infant gently stimulated and would reduce the risk of SIDS. After recalling this experience, the artist read medical articles about the relationship between infant arousal response and SIDS and conjectured that her heartbeat blanket could be used to address SIDS.

At this point the artist began searching for a mechanism to create the heartbeat in the blanket. She considered electroactive polymers, piezoelectrics, and small magnetic coil speakers. After researching the literature, she concluded that the reaction time of the electroactive polymers was too slow. After comparing the properties of piezoelectric sound generation with that of magnetic coil speakers, she settled on the speakers due to their ability to better handle low frequencies and simpler driver electronics. The artist then began to investigate sound propagation in a textile. She was imagining different textile and polymer configurations such as quilting systems and three dimension knits that could accommodate vibration chambers, as well as polymer systems with alternating flexible and rigid sections. She sought out the appropriate equations from physics and devised experiments to measure the displacement of a textile in response to a sound wave. While working with the equations and the experimental setup, she often had the feeling that something was not right and that she was somehow wasting her time:

> *In the whole engineering model, the whole engineering process of doing models, experiments —there was no way of doing a simulation because there were no equations for sound propagation in a textile. I tried. I did*

> *the research, but there wasn't much. It didn't pan out at all. What panned out was walking next to my friend carrying an empty coffee cup.*

While walking with a friend and carrying an empty cardboard coffee cup, the artist felt her friend's voice vibrating the walls of the cup. She abandoned the engineering work. The experience with the coffee cup revealed to her that low frequency sound waves could be transmitted from a transducer, such as a small speaker, through sealed air pockets, like those in larger-sized bubble wrap. The sealed air pockets would concentrate the mechanical energy of the acoustic waves by not allowing them to disperse. This mechanism would create the felt heartbeat pulses. A miniaturized grid of transducers would be cushioned by the air pockets within a quilted blanket. Thus the blanket would remain soft and flexible. Furthermore, these little pods, the combination of a small speaker and air pocket, could be miniaturized to provide localized and infinitely configurable haptics in a variety of objects and devices.

Through her experiments with low frequency electronics during an earlier stage of the process, the artist had developed an understanding of the electronics design. She borrowed a power supply and digital multimeter. She sourced and experimented with different off-the-shelf electronics components: small magnetic coil speakers, amplifiers and passives. She used a small iPod Shuffle to hold the sound file of a recorded heartbeat and transmitted the signal through a low pass filter to get the signal below 20 Hz, and then amplified the signal with an amplifier circuit she built.

The artist experimented with different series-parallel speaker configurations, testing each configuration through the quality of the sensation she felt when touching the speakers. She then soldered the circuit together, reinforced the soldier points with tubing and placed the circuit within a quilt. The artist cut small holes in the quilting to accommodate the small speakers. The next layer of the blanket is a series of sealed air capsules that align with the speakers. She arranged the materials as she proceeded.

The artist checked the prototype as she built it, judging functionality, durability, and comfort through her own sense of touch. When the blanket is turned on, the sensation, but not the sound, of heartbeat can be distinctly felt throughout the blanket. She is happy with the circuit. Although she has not performed any measurements on it because she does not have the equipment to do so, it "feels right" to her. It seemed to her that the air pockets concentrated and localized the mechanical energy from the infrasound waves, as well as provided cushioning so that the electronics could not be felt. The artist has expressed that her next step is to iterate the prototype with a focus on miniaturizing and optimizing the electronics. This includes experimenting with different actuators and flexible mediums.

In comparison with the engineering team's creative strategy, the artist did not attempt to understand the final form of her project early in the process. It was not until she had gone through a series of steps leading to what seemed to be a satisfactory solution that she could conceptualize what the final artifact might be like. In particular, it was not until she had the experience of feeling her friend's voice in her coffee cup that she began forming the whole of the design.

The artist began with the goal of manifesting felt heartbeat in intimate objects. She then proceeded through a series of steps made up of decision points that branched into multiple potentials. She used various approaches to test these potentials before choosing the path forward. These included imagining interaction scenarios, making concept sketches, building circuits, and analyzing various technologies. In this way, she developed deeper understandings of the project as it was forming. Paths not completed, such as further work on the jade plant installation and the peony corsage or building an ECG, still fed forward to inform the final piece. Through experimenting along multiple paths, the artist developed know-how and experience in the domain.

Borrowing a term from probability, we call this type of creative process "stochastic". Stochastic processes are probabilistic processes with non-deterministic outcomes. The process unfolds as a random walk, to use a term from statistical mechanics, with transitions from one step to another. Here the term "random" has a precise definition, meaning not that the process is arbitrary or aimless as in some colloquial senses, but that it is not possible to precisely predict the path or the outcome.

The artist's creative strategy consisted of a walk through a large and open design space where possibilities and constraints emerged upon changes in the design state. The trajectory of the artist's random walk consisted of successive decision points. At each decision point the artist conjured multiple paths and a subset of them were taken to achieve convergence to a design. Since the target design was not defined until a relatively late stage in the process, there was not a stable reference to work toward as there was for the engineering team. Yet by not having a determined project path, the artist stayed open to incoming stimulation and thus was able to access and leverage her stores of personal experience, memories, mental associations, and felt sensations in the service of the project. Through technical experimentation along the way, the artist was able to develop know-how relevant to the project. This know-how contributed to building the first prototype.

If one looks closely, it is possible to see hidden metaphors and constraints that guide the project work toward its resolution. Many of the metaphors that emerged during the initial brainstorming sketch (such as jellyfish and sea anemones) have structural similarities to fluid-filled organs or capsules that can transmit thumping sensations, indicating an undercurrent of thought about form and mechanism that developed throughout the project. This development included imagining interactions with such objects and finally a concrete manifestation of such interaction in a blanket. This manifestation acquired its form through constraints that emerged and stabilized throughout the process. For example, the artist's association with heartbeats, infants, and motherhood constrained the possibilities toward artifacts that emphasized this experiential aspect. While the artist considered other forms that could manifest heartbeat, such as jade plants and telepresence blankets for lovers, the project continued to return to a focus on heartbeat in the context of a mother and infant relationship. A diagram of the artist's process appears in Figure 107.

6.6 Results

6.6.1 Teleological and stochastic creative work processes

As mentioned above, the case study methodology establishes theory from detailed analysis of phenomena. Through our analysis of the work practices in our cases, we have identified two patterns of creative process which we call the teleological and the stochastic. It should be noted that we do not intend that these two models describe all possible processes. Furthermore, we do not strictly identify the teleological strategy with the work of engineers and the stochastic strategy with the work of artists, yet those familiar with these disciplines may recognize that teleological processes are often exemplified in the disciplinary literature of engineering (see [91]) and stochastic processes in the arts literature (see [174, 62]). Overall, the engineers in our study did tend toward teleological processes and the artists tended toward stochastic processes; however, both types of processes were apparent at times in the work of each group.

"Teleological" is a term we borrow from philosophy. A teleological process exists for a specific end or final cause. The near-oxymoron "final cause" is descriptive. Teleological processes specify a clear end goal at the beginning of the project. In the cases in the disciplines that we investigated, this end goal typically took the form of a detailed design. In the initial stages of the teleological process, this design is formulated and then projected forward in time to the end state, from where it drives

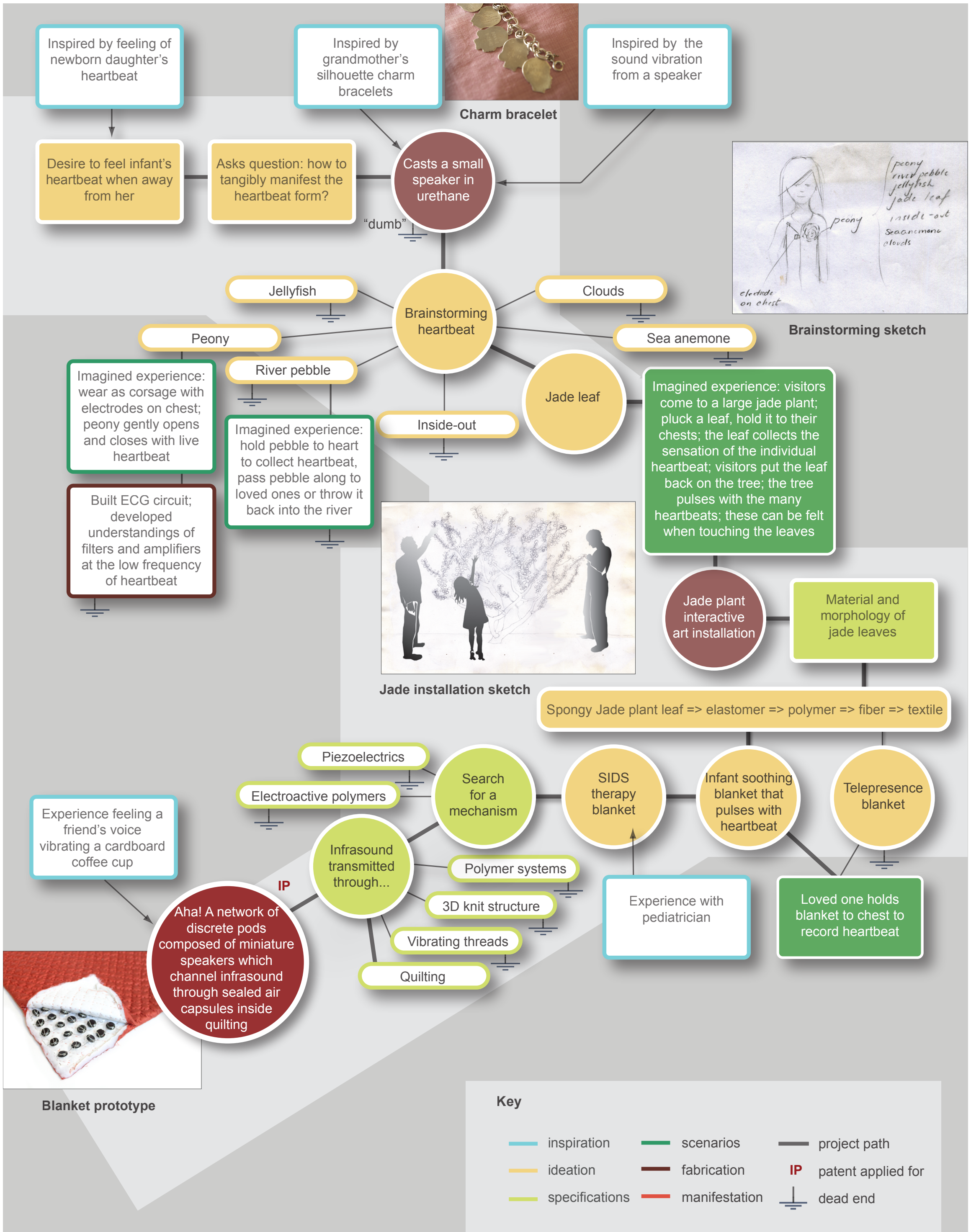


Figure 107: Diagram of the artist's work process. Colored shapes represent the decisions taken to create the final piece. Project stages are not as easily compartmentalized as in the engineering team's process.

and constrains the intermediate process between the initial and end states. It is the final cause of the process.

Teleological creative processes are constrained to solutions that conform to the telos, the final cause. Deviations are discouraged. Emergent work is checked against the telos as a reference, and iteratively refined to match this reference as closely as possible. As practitioners faced intermediate problems and resolved them, they came to deeper and more detailed understandings of the telos that they constructed.

Teleological processes have the benefits of predictable progress toward a predetermined end goal. The probability of successfully meeting project requirements is maximized. Resources can be optimized, as can the safety and reliability of the solution. Teleological processes support stable communication between team members, and the ability to communicate a vision of the final solution to stakeholders at an initial stage in the process. Overall, teleological processes reduce the uncertainty associated with a creative project. Teleological processes require as much complete knowledge related to the project as possible in the beginning stages. In other words, teleological processes frontload the knowledge necessary to complete the project. We see this in the structure of engineering education, where students are required to take years of coursework in science and engineering before their final capstone project. Contrast this to the structure of art education, where students learn their craft through ongoing repetition of creative project work and few lectures.

The other pattern of creative process that we identified and characterized we named "stochastic." "Stochastic" is a term from probability. Stochastic processes are non-deterministic, even when they depend upon initial conditions and are constrained within a subset of resolutions. Stochastic processes have a completely different relationship to the end state than teleological processes. They do not function by fixing the final form of the project early in the process. Instead, the form emerges through a nondeterministic walk through a space of possibilities. The walk consists of multiple steps or decision points, each presenting multiple potentials. These potentials can be experimented with before a way forward is chosen. This allows know-how, knowledge, and experience in the project domain to be developed along the way. Project experiences, even paths not ultimately taken, may feed into the final form.

On a local scale, a stochastic process can appear as a series of random moves, but from a global view, constraints can be found that encourage the process to converge to a design. These constraints are often more covert, less codified, and less articulated. They might not be overtly obvious, even to the practitioner, or they may become obvious in hindsight. This is the nature of intuitive work. Constraints are often hidden in project metaphors or experiential aspects. For example, in the case of the infant heartbeat blanket, the form of the artist's technology was constrained, tethered really, by the relationship between mother and child.

In our study we found that the exploratory nature of stochastic work can lead to emergent, novel, and breakthrough designs. The tradeoff is that stochastic processes carry more uncertainty than teleological processes. Practitioners must weather the vagaries of a nondeterministic creative process. In our study, the practitioners who typically employed stochastic processes relied upon a well-developed, internal compass of authenticity that lent assurance to their decision-making within ambiguous and indeterminate creative conditions. This internal compass was an internal indicator of what the artists knew, subjectively, to be true and authentic per their experience.

6.6.2 Requirements, experience, and values

One of the initial steps in the engineers' creative strategy was to brainstorm and negotiate project requirements. The foundation for this was DARPA's request for proposals (RFP). The engineering team held several meetings to ideate and organize the requirements, the "ities" as they called them (functionality, connectivity, usability in combat, wearability, durability, maintainability, manufacturability) that they deemed to be crucial elements of the design. The lead engineer wrote a white paper in response to the DARPA RFP containing these "ities." The common vision for the soldiers' garment was sealed through DARPA's award for the project. Formalization for the engineers, in the sense of giving form, is a process of determining project requirements and using these to create a program of specifications to materialize in the artifact. In any creative project, a period occurs when potentials are pulled forth from the environment for use in the project, for example in forming the requirements of a project in an engineering process. There is a mapping from the environment of the problem to the requirement space. Choices are made as to what to include and what not to include. This is the first step toward giving material form to a project. In a teleological process, this mapping occurs primarily at the beginning of the project and is sealed into the telos.

The artist filtered her larger environment through personal experience or another domain that was personally configured, such as a world of objects beating with human heartbeat. Instead of explicit requirements engineering, this artist began by trying to give an overall material or metaphorical form to the heartbeat. She first attempted to seal the sensation of heartbeat in a charm-like rubber object. When this did not work to her satisfaction, she turned to brainstorming the form of tangible heartbeat as different objects. As mentioned before, these objects are metaphors and as such hold as many references as the subset of requirements embedded in each of the engineering team's "ities." Both are formalization processes, in the sense described above. However, in a stochastic process, this environmental field of potentials stays close throughout the process and is interacted with often, if not continuously.

Engineers typically adhere to an objective set of values from their disciplinary tradition. These values include the public safety, reliability, efficiency, cost effectiveness, and improving the quality of life. Art can communicate with society through a resonance with the artist's personal goals, expression, or experiences. Thus priorities are often subjectively determined. The points taken out of the environment and the values they reflect are carried throughout the process and manifest in the final form of the technology. The engineered artifact was configured from the requirements of combat casualty care centered around monitoring. Thus, the engineers' SIDS solution strives to ensure safety to the greatest degree possible by configuring a substrate to securely, comfortably, and easily monitor the infant's vital signs and alert caregivers to an interruption in them. The artist's artifact was configured according to the experiences and metaphors of heartbeat. The artist's technology takes a protective approach and emphasizes experiences between caregiver and infant. The technology is configured so that caregivers collect their own heartbeat into the blanket and swaddle their infant in it, with the heartbeat acting as protector.

6.6.3 Constraints

The artist's stochastic creative strategy was informed by personal experiences and an idiosyncratic imagination. Staying true to these elements contributed significantly to the final form of the artifact, as well as helped her negotiate the uncertainty of the creative process. Having an understanding of which sources of knowledge, inspiration, and experience are relevant to a project and being able to develop these into an artifact that has meaning beyond the idiosyncrasies of the creator is a sophisticated art. While the artist's process was stochastic and indeterminate, the internal criteria she stayed true to formed constraints that guided her path toward a solution.

The strongest constraint was the connection between mother and infant expressed by heartbeat. This constraint tethered the multiple emergent potentials toward the solution of the infant blanket either as an object for infant soothing or for addressing SIDS. Thus jade plant installations and telepresence blankets for lovers fell by the wayside as the infant blanket which channels a caregiver's heartbeat emerged. Other constraints to the artist's process include implicit sensual criteria for the heartbeat embedded in an object. Recall that an early experiment with a speaker in urethane was cast away as dumb because it was not able to transform the dumb rubber into a proper physical form to embody heartbeat, prompting the artist to brainstorm alternative forms (peony, river pebble, anemone, etc.) which carried forward further implicit criteria.

The engineering team's use of constraints was more overt. Early in their process, they constrained the multiple potentials that would be present in any project by specifying requirements to be met. Optimized solutions to these requirements enabled the engineers to stabilize as many parameters as possible in order to focus on weaving together multiple technical materials to produce a high-functioning soldier's garment.

6.6.4 Stochastic episodes in the teleological process

Stochastic processes create opportunities for emergent solutions to develop, as we saw in the example of the artist. In the example of the engineering team, we saw a breakdown of the teleological process lead to stochastic episodes through which a new metaphor for the project emerged. This metaphor changed the nature the project telos, resulting in a dramatic and beneficial change in project outcomes. Specifically, when the engineering team faced physical problems during the fabrication of the prototype, i.e. integration of different modules, they switched to a stochastic mode. In their case, they began looking around in their environment for solutions. One solution came in the form of a toothbrush and nail polish remover as a way to solve interconnection problems. Another came in the form of hanging optical fibers out of very high windows. But the value of these episodes was not as much in finding these solutions, although they were certainly beneficial to the project and furthered project intellectual property. These impasses sent the lead engineer into a stochastic mode where he reformulated and reframed the project according to a new metaphor—from a weave-able, wearable, elastic computer to a wearable motherboard allowing for "plug and play" capabilities. It is interesting to note that this episode occurred once the design had to be realized physically. The relationship between making or prototyping and a switch from a teleological to a stochastic process warrants more study.

Not all interruptions in a teleological process result in a stochastic episode that reframes the project. Sometimes an impasse leads to a reformulation of a specific problem, brainstorming to locate a solution, and resolution of the problem. Another engineering team in this study discovered a problem with their signal processing algorithms when they built a prototype. Their tongue drive prototype was malfunctioning in a chiral way, i.e. the algorithms which processed sensor input were not differentiating between right and left input at certain spots. This lead to a team-wide meeting where members brainstormed about why this could be. The team resolved the issue by returning to the physics model for magnetism that they were using. After adjusting their signal processing algorithms to better match this physics model, they solved the problem and continued along their teleological path.

6.6.5 Metaphor

The lead engineeer has a background in computing and textile engineering. He has used this background to build automated logistical systems for the procurement and distribution of soldier's uniforms. He was also one of the first textile engineers to use CAD in the textile design process. When presented with the DARPA RFP, he immediately thought of the textile as a weave-able, wearable computer. This metaphor guided his work and the configuration of the textile through most of the process. When the team's teleological process was disrupted due to fabrication and integration difficulties, they switched to a more stochastic mode. During this time of difficulty, a new project metaphor emerged during the lead engineer's self-described "aha moment". This subtle difference in metaphor, from a computer to a motherboard, was a major project turning point leading to a proliferation of applications for the basic technology the engineering team developed. The lead engineer foregrounds his understanding of the technology as a wearable motherboard in his interviews and publications. He trademarked the project name, "Georgia Tech Wearable Motherboard."

The dynamics of the artist's use of metaphor are more covert. We can find these occurring at two levels. Overall there is a hidden metaphor of a talisman. When discussing another project, the artist mentioned an interest in small, hand-held technologies such as cell phones as talismans or amulets, objects that have a magical and protective power, and considers a river pebble to be an ideal form for such a talisman. This hidden metaphor is carried throughout the project to the configuration of her solution to SIDS, which is a blanket that would function protectively instead of as a monitor and alert. Metaphors are also at work on a form level during her brainstorming stage. Many of these metaphors that emerged, such as jellyfish and sea anemones, have structural similarities to fluid-filled organs or capsules that can transmit thumping sensations, indicating an undercurrent of thought about form and mechanism that developed throughout the project. This development included imagining interactions with such objects and finally a concrete manifestation of such interaction in a blanket. As mentioned above, this manifestation acquired its form through constraints that emerged and stabilized throughout the process. For example, the artist's association with heartbeats, infants, and motherhood constrained the possibilities toward artifacts that emphasized this experiential aspect. While the artist considered other forms that could manifest heartbeat, such as jade plants and telepresence blankets for lovers, the project continued to return to a focus on heartbeat in the context of a mother and infant relationship.

For both types of practitioners in this case, the profitable use of metaphor is part of the fabric of their process. For the engineers, an emergent metaphor led to a deeper understanding of and beneficial expansion of the project. In the case of the artist, project metaphors revealed the covert constraints that tethered the actions of the project to a resolution. In this case a change in metaphor released design constraints for the engineers whereas metaphor established constraints for the artist.

6.6.6 Negotiating the uncertainty inherent in the creative process

The engineers focused resources at the beginning of their process to determine a detailed design that met carefully considered requirements. They then used this detailed design as a reference to check work against throughout the process. This strategy serves many priorities, including: predictable progress toward the predetermined telos; limited deviations from the project plan; an understanding of project costs; project paths which can be stabilized and optimized; stable coordination between members of a team; and a vision of the final technology which can be communicated to stakeholders at an initial stage in the process. The teleological strategy lends stability, predictability, and optimization potentials to the creative process, thus minimizing its uncertainty. The engineer considered the reduction of uncertainty to be a core responsibility of his job. The technology he and his team were developing needed to answer to public tests of satisfaction, safety, and reliability. Minimizing the risk of failure was of the highest priority. This is expressed by the lead engineer when describing his design methodology:

> *The detailed analysis adopted in arriving at the anonymized design minimizes the risks associated with the success of the project. All the performance requirements defined by the government can be met by the design and the fabrication technologies are well-proven in the textile industry further improving the chances of success.*

The engineering team's creative effort is in the service of harnessing the power of technological knowledge and resources. Bringing together appropriate technological elements in a reliable and safe way is a highly creative process requiring a clear strategic intent, particularly so that the final product will pass a public test of satisfaction, safety, and reliability.

The artist's end product is defined at a later stage in the process, and in fact could satisfactorily change and evolve at any point throughout the process, as in the case of the initial directions of the heartbeat as a charm and the jade plant installation. Whereas the engineers in this case consider the reduction of uncertainty as a core responsibility of their job, the artist accepted uncertainty as part of her creative process. Instead of attempting to minimize uncertainty, she cultivated strategies to minimize the potentially negative impact of this uncertainty on her well-being. She achieved this by maintaining internal criteria with respect to the project, as expressed during an interview:

> *When I talk about the project as being well-formed, I fell like I'm able to coherently project into the future what my personal goals for the project are. It's something I can trust. So instead of a project taking me on a wild ride, I feel like I have a better relationship to it.*

For the artist in this study, staying true to an internal compass of authenticity not only helped guide her through the decision points of the stochastic strategy, but also protected her from the vagaries of the process. In this case, her appeal was to what she knew to be true through personal experiences she had cultivated. So while the engineers used a teleological creative strategy to ensure they met external criteria of public accountability and success, it was important for the artist in this case to maintain internal criteria of authenticity in order to endure the uncertainty of the stochastic process in a healthy way. For the artist in our study, personal guidance and experience mitigated risk.

6.7 Triangulation with the literature

6.7.1 Integration with other frameworks

The organization of creative process into teleological and stochastic categories does not conflict with other frameworks. For example, Guilford's concepts of convergent and divergent thinking [82] fit well within both teleological and stochastic processes.

While stochastic processes may seem to correspond with divergent thinking, there are episodes within the stochastic process when a practitioner is narrowing down options and choosing the most beneficial possibility for a project. Teleological processes are highly convergent, but still include the complex ideation that is characteristic of divergent thinking. Also, the parts-to-whole and perception and conception cycles of the hermeneutic circle process can take place in both types of processes as practitioners progress through their work.

Similarly, brainstorming should not be confused with a stochastic process. Brainstorming is a way of generating ideas and can occur within both teleological and stochastic processes. For example, the engineers described in this case study began their teleological process by brainstorming requirements for the design, which were then detailed through specifications and prioritization matrices to create the telos. Brainstorming can occur and reoccur within the context of both teleological and stochastic processes.

The framework of problem solving and problem finding also does not conflict with the teleological and stochastic framework. In the early stages of the engineering project, the engineers negotiated between the DARPA requirements and their competencies and vision for the project to form a series of requirements for the project to meet. Finding these requirements was an episode of problem finding that set them on a problem solving path. Similarly, the artist's desire to manifest a heartbeat in an inanimate object was a problem-finding experience. Discovering the means to do this involved many problem-solving experiences. Both practitioners were able to problem-solve during their creation processes whether they were in a teleological or stochastic mode. Like convergent and divergent thinking, the hermeneutic circle, and brainstorming, problem finding and problem solving can exist at different levels of resolution in the creative work process. For example, in the teleological process, the problem is framed in terms of requirements to meet and solved with the construction of the telos as described above. Yet there are smaller cycles of problem framing and problem solving within each of the modules that were developed to realize that telos. That said, the teleological process tends to have distance between the distinct steps of problem finding and problem solving, whereas this distance is called into question in some depictions of more stochastic or artistic processes.

An understanding of teleological and stochastic processes might help refine design studies research by distinguishing between the types of tasks that study subjects are given and the relationship between that task and the study findings. For example, in their paper, "Creativity in the design process: co-evolution of problem-solution" [54], Kees Dorst and Nigel Cross report on their protocol study with nine experienced industrial designers. They gave their subjects a design brief and two and a half hours to complete the design. They correlated the design processed they witnessed with Maher's framing of design as a co-evolution of problem and solution spaces [116]. The authors write:

> It seems that creative design is not a matter of first fixing the problem and then searching for a satisfactory solution concept. Creative design seems more to be a matter of developing and refining together both the formulation of a problem and ideas for a solution, with constant iteration of analysis, synthesis and evaluation processes between the the two notational design 'spaces'—problem space and solution space. [54, p. 11]

The design problem was, briefly, to create a new design for litter bins on Dutch trains. The authors give the example of Designer 3, whose design concept was rated very highly overall and the highest in terms of creativity. They report:

> the designer has the idea of doing away with the litter bins all together, and just make a hole in the floor of the train. . . He starts designing a special litter container, which sucks in all the litter and compresses it. [54, p. 9]

The researchers give another example to support their co-evolution hypothesis, this time from Designer 4:

> the designer checks whether he is dealing exclusively with the litter bin or with other factors as well. He notes that '..they talk about a litter system... which means we'll also have to deal with the carrying of the litter out of the train... ' So for him the assignment had grown, from 'bin' to 'system', and this became a bit of a problem. The designer asked for more information and translated this 'carrying out of the train' into: 'I'll note down that this is about the litter bin and emptying method... ' Later on, the design assignment was reduced again by ignoring the design of a new emptying method, and adopting the current solution for this part of the system. Some time later the assignment was explicitly reduced again by letting go of a possibly complicated idea of combining the litter bin into the chair: 'I'll drop the chair idea because of time pressure... ' [54, pp. 9-10]

These descriptions of exemplary work that the researchers use to support their co-evolution hypothesis also support a reading of a stochastic process. The description of Designer 4 in particular can be interpreted as a walk through a space of possibilities with rapid formulation and reformulation problem-finding cycles. I submit that it is possible that time pressure could have encouraged the subjects to take a stochastic approach to the design, or the task may have otherwise been a more stochastically-oriented task to begin with. Under different conditions the subjects could have taken a teleological approach, and this could have changed the study results. This possibility suggests that the teleological and stochastic framework is a more low-level framework than that of this protocol study. This also suggests that lower-level frameworks of creative process have a role in designing such studies. That said, Dorst and Cross's description of the dynamics between the problem space and the solution space in the first quote above could be helpful in understanding the step-to-step process within the larger stochastic process. It suggests a higher resolution picture of the dynamics of this process.

6.7.2 Breakdown of the teleological process and emergency innovation, risk, and uncertainty

Another point of triangulation between our study and the literature appears in the work of Claudia Eckert and colleagues as reported in their paper, "The Elusive Act of Synthesis", described earlier in this chapter. Her case study of engineers designing diesel engines in part concludes that:

> Overall it appears that the emphasis on reliable and repeatable processes causes creativity to be displaced backwards into R&D and forwards into "emergency innovation" during integration. [59]

Eckert found that integrating components which were either newly designed or legacy components surfaced physical and/or mechanical incompatibilities. These created points of breakdown in what we would recognize as a highly-constrained teleological process. These breakdowns in turn forced "emergency innovation" that we would describe as stochastic, resulting in emergent solutions. In our engineering case, problems with integration of the optical fiber component and the conductive fiber interconnects forced a stochastic approach which led to emergent solutions and metaphors.

In another paper and as part of the *Across Design* project described at the beginning of this chapter, Eckert analyzes risk and uncertainty across different design disciplines. She discusses the varieties of risk and the perception of risk across these disciplines, including diesel engine design and artistic practice. Eckert writes:

> Design processes involve risk: to life and limb if the product is unsafe, to the financial health of the company if the product is late, unsuccessful or simply the wrong product, as well as to the emotions and careers of the designers. [61]

She also relates design method to risk:

> The risks designers face are a key driver for developing tools and techniques to support the design process and reduce those risks. The risks recognised as crucial correspond to different industries' methodological strengths. Industries and professional communities can learn from each other by examining the strategies used to mitigate lesser risks in fields where they are crucial. [61]

Eckert does not describe or suggest any models that relate process to risk, as does the teleological and stochastic framework. As we discussed earlier in the chapter, these processes negotiate risk and uncertainty structurally. The teleological process constrains deviations, effectively matching the design solution to the requirements determined at the early stages of the process. In more stochastic processes the practitioner needs to weight the possible benefits of an emergent design solution against their and the project's ability to weather the vagaries of the uncertainty of this process.

6.8 Summary and conclusions

Noting that artists and engineers were working on similar technological projects at Georgia Tech, we devised a study to pairwise compare their work practices. Specifically, we carried out a comparative, qualitative multiple-case study of three such pairs and studied their work practices in parallel. This study design has at least two benefits: (1) studying the practices of artists and engineers conceptually bound together through similar projects and technologies throws the creative strategies and design decisions of each group into relief; and (2) such a study is "in the wild" in the sense that phenomena are occurring on their own accord and for their own reasons, without orchestration for study purposes. Furthermore, as a review of the literature shows, most studies on creative practice approach their hypotheses through task-based or episodic studies. This study looks at creative work practice in its entirety, creating a low-level framework for creative practice.

The case study methodology establishes theory from detailed analysis of phenomena. Through our analysis of the work practices in our cases, we have identified two patterns of creative strategy which we call the "teleological" and the "stochastic." The teleological strategy specifies a clear end goal at the beginning of the process. Thorough knowledge in the project domain is valued at this stage. The end goal, otherwise known as the telos, or final cause, directs the development of the project by acting as a terminal reference. Emergent work is iteratively refined to match this reference. Problems and their resolutions lead to a more complete understanding of it. The teleological strategy lends stability, predictability, and optimization potentials to the creative process. Benefits of a teleological creative strategy include predictable progress toward the predetermined telos, the ability to quantify project costs, stable coordination between team members, and the ability to communicate a vision of the final technology to stakeholders at an initial stage in the process.

The stochastic creative strategy has a different relationship to the end state of the project. The stochastic strategy can be characterized as a nondeterministic walk through a space of possibilities. The walk consists of multiple decision points which present multiple potentials. While it may seem as if such wide options would thwart convergence toward a design, this space can actually be constrained through metaphor and experience, though this may not be overtly obvious, even to the practitioner. Paths not taken to completion or paths that dead end can still feed knowledge and know-how into the process. In this way, it is not as important for domain knowledge to be incorporated at the beginning of the process, as in the teleological strategy. Stochastic processes create opportunities for emergent solutions to develop, as we saw in the example of the artist. In the example of the engineering team, we saw a breakdown of the teleological process lead to a stochastic episodes through which a new metaphor for the project emerged. This metaphor changed the nature the project telos. Graphical models of the teleological and stochastic processes are presented in Figures 108 and 109.

We relate the teleological–stochastic framework to the dynamics of constraints and metaphor as well as the negotiation of the uncertainty inherent in creative practice. This framework is compatible with other models of creative activity such as convergent and divergent thinking [82], problem finding and problem solving, and

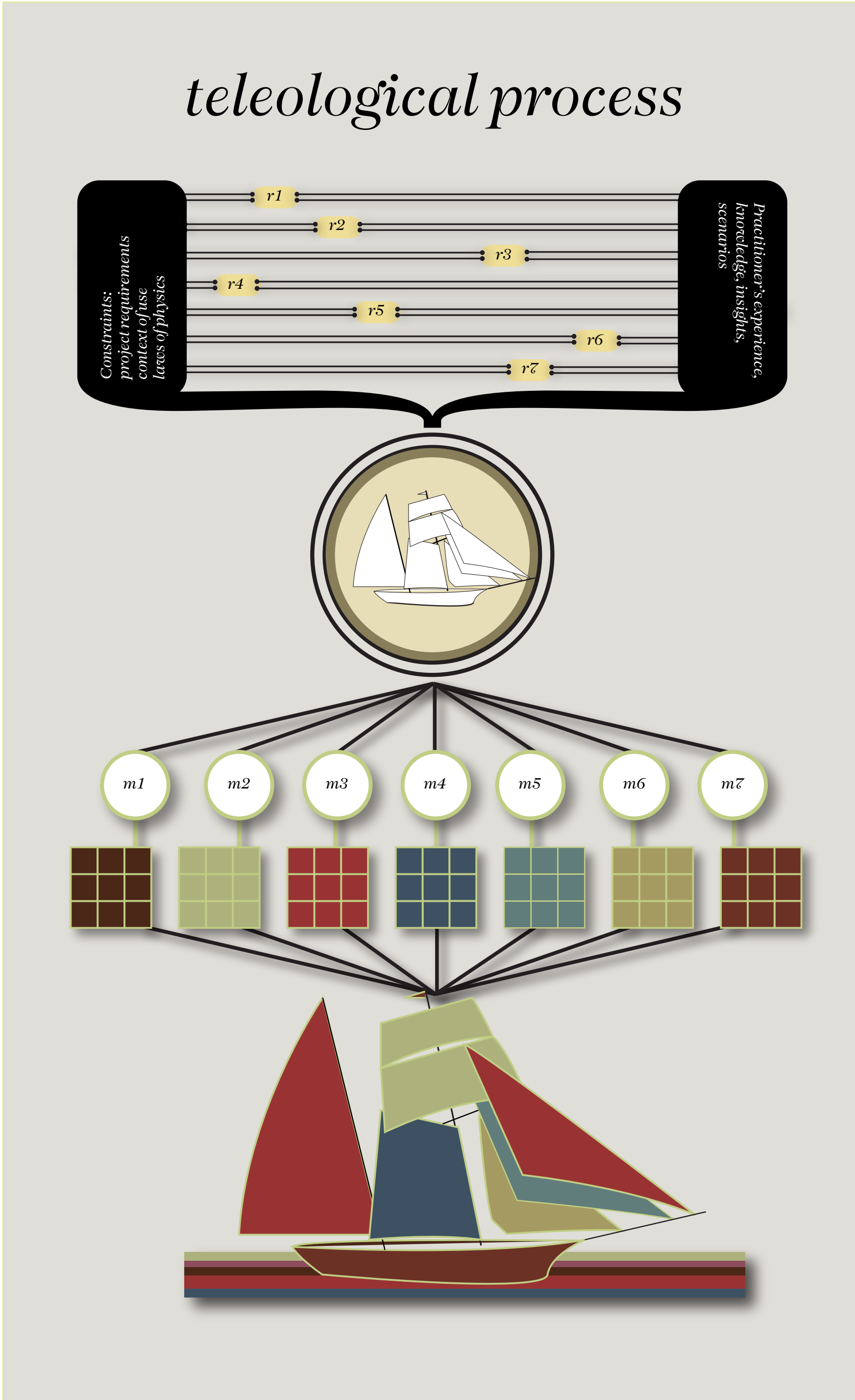


Figure 108: Model of the teleological work process. Requirements are negotiated at the beginning of the process and a detailed design is established. This design is projected to the end state, from where it guides and constrains its development. Typically the development process is divided into modules which will need to be integrated.

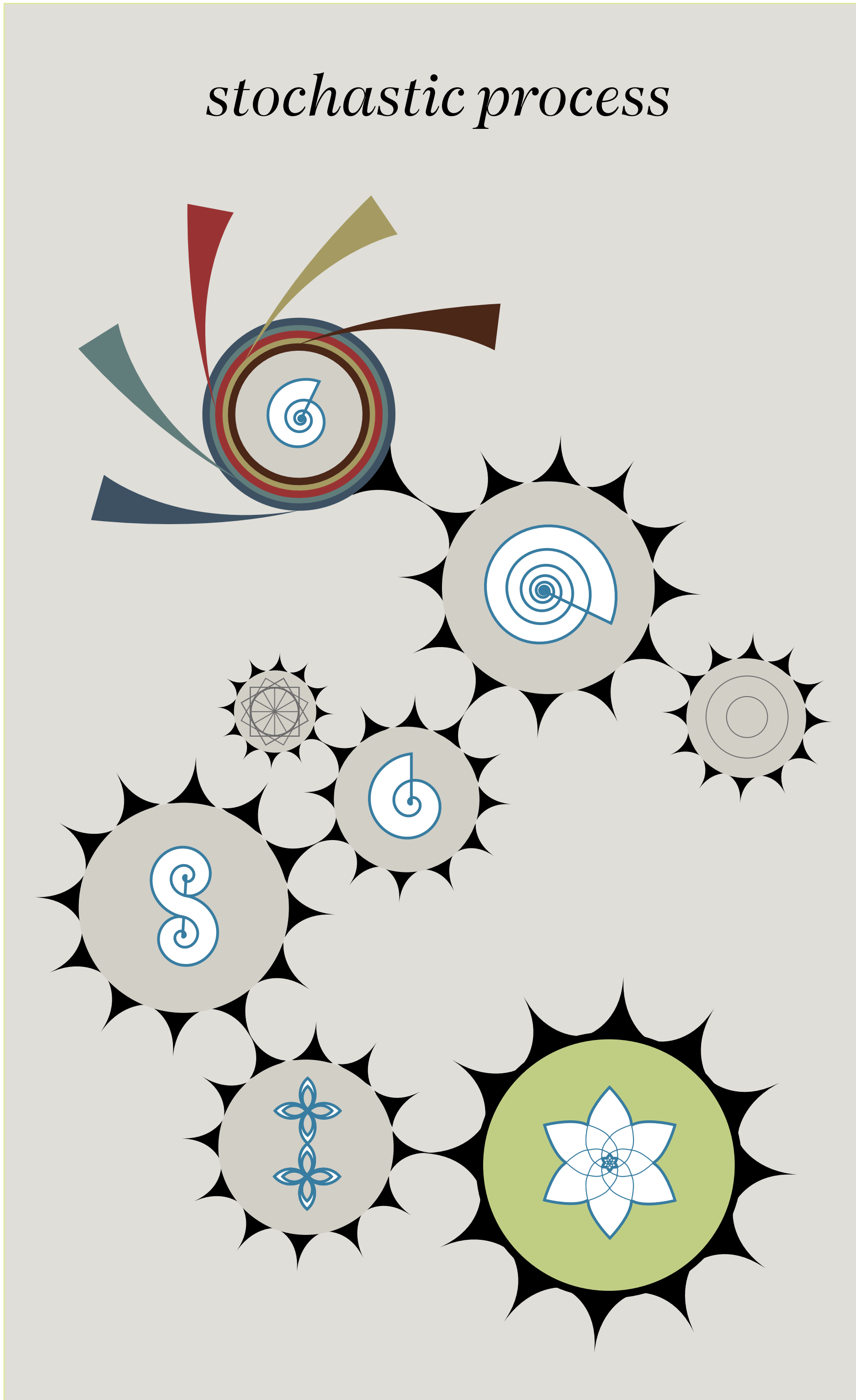


Figure 109: Model of the stochastic work process. Multiple motivations and inputs can initiate a project idea. The project proceeds as a walk through a space of potentials. Each step may present multiple possibilities, some of which are followed. Project dead ends still contribute to the development of project-related knowledge and may feed back at a later stage.

the hermeneutic circle. A triangulation with the literature in design studies shows that there are points of convergence with existing studies. In particular, a recognition of the teleological and stochastic framework can serve as a low-level check on the design of these studies.

I'd like to make it clear that teleological processes and stochastic processes exist independently of discipline. Engineers and artists exhibit both types of process. That said, engineering is more closely identified with teleological processes both within our study and in the literature, and artistic practice is more closely identified with stochastic processes.

A benefit of articulating creative work process in term of teleological and stochastic modes is that this framework can help practitioners be more aware of their process and understand the implications of their process. An awareness of the viability of the stochastic mode in particular can help practitioners feel more at ease when indeterminacy and ambiguity enters their process. This articulation can also support collaboration. If practitioners have a shared vocabulary for communicating their practice, they can balance the challenges and synergies of the teleological and stochastic processes. Candy and Edmonds found that a shared vocabulary around process would help alleviate some of the miscommunication between practitioners across the art and technology-related disciplines [36, 38]. This case study also speaks to contemporary discourse about the relationship between art and engineering as paths to technology development and legitimizes art process through an articulation of its contributions to the creative process. In terms of the overall thesis of this dissertation, teleological and stochastic processes illustrate dynamics at play in technology invention, from both art and engineering orientations.

Further analysis of the data can be done to incorporate iterative cycles within the teleological and stochastic framework. The diagrams and analysis at this stage present a fundamental skeleton of the processes so that future work can concentrate on higher resolution details. It also remains to be seen how these models of practice relate to software development. Our first pass through the data from our software team suggests an intermediate process between stochastic and teleological, one that could be characterized as bricolage, where different modules are collaged together with code interfacing them. We also noted that our software development team was often subject to the effects of intermediate and emerging constraints as project requirements shifted in-process due to changes in objectives, scope, and perceived limits of technology as the project progressed. These conditions may be a result of the perceived flexibility of the computational medium.

CHAPTER VII

CONCLUSION: THE THIRD SPACE

7.1 Summary

The overall thesis of this dissertation is that technological art occupies a third space between the contemporary fine arts and engineering. This third space is a combined space of artistic production and technological R&D. Coming to this conclusion involves recognizing that the intersection of art production and technological R&D exists at all, negotiating disciplinary categories, and understanding the dynamics that make this third space what it is.

In Chapter 1 and the beginning of Chapter 2, I introduced various projects at this intersection of artistic production and technology development. Some of these artist were working from within the contemporary art system, such as Yves Klein, Joseph Scanlan, and Catherine Richards. Others existed outside of this space, such as Survival Research Labs, Sommerer and Mignonneau, and Jim Mason and All Power Labs. The projects of the artists working from within the contemporary art system were tinged with tension and humor. Interesting dynamics at play in all of these examples include expanded notions of utility. Hubert Duprat patented his work with caddisfly larvae as a means of protecting caddisflies from exploitation. Jim Mason's *All Power Labs* evolved out of an art project as a cultural conversation and creative engagement with a central technology, i.e. power generation. Joseph Scanlan's gallery piece, commercial enterprise, patented technology, and research and development project, *Paydirt*, is also a social commentary on the relationships between artists, invention, the contemporary art system, and the status of innovation.

Artists as inventors have a long history taking many different forms. Chapter 2 describes the common history of artists and engineers as skill-based, inventive fabricators, as well as the cleavages in this relationship that took place from the Renaissance through the twentieth century. In particular, during the eighteenth and nineteenth centuries the contemporary art system evolved, bringing with it dynamics of assimilation and resistance. Technological art falls outside its boundaries. While many technological artists bemoan this situation, technological art has retained its own trajectory at the intersection of the arts, technology, research, and invention. Chapters 2 and 3 chronicle the evolution of the contemporary technological art world, with roots in the work of Marey, Muybridge, and Duchamp to Experiments in Art and Technology to corporate artist-in-residence programs. The art and technology community developed as one encompassing art production, collaborations between artists and technologists, research, and technology development. These emerging practices brought with them emerging exhibition, research, invention, and collaboration roles for artists outside of the museum and gallery system.

While the visual arts and technology development map oppositionally in our culture, there are similarities in work. Visual artists and technology developers imagine, conceptualize, design, and build artifacts and then release them into the world. As part of this work, many artists and technologists develop high levels of conceptualization, technical, and fabrication skill. While artists have always worked with industrial technologies such as paint and pigment chemistry, metalworking equipment, heavy machinery, and kilns, for example, many postindustrial artists are using high technology both as medium and highly-charged cultural material. These artists work with similar materials as technology developers: electronics, computation, robotics, bioengineering materials, and smart materials, for example. Their work often bleeds into technological development as they create new technologies and new interactions with technologies in the course of their projects.

This third space is a space of skilled and thoughtful artistic creation and fabrication. Yet artists in these roles are horses of a different color. This dissertation presents a picture of technological artists and technology development engineers as using the same materials but with different techniques, different processes, and different project values. In Chapter 4, I describe my art piece *Breeze* and its exhibition. From this experience, I distill a series of reflections from cultural points of reference. These reflections map to both the space of the art piece and the space of technology development while making room for ambiguity and multiple meanings. Also in this chapter, I profile the research of Candy and Edmonds, who have set foundations for research in this third space. According to Candy and Edmonds, knowledge at the intersections of art and technology often takes a more reflective form than would otherwise pass through a rational filter.

Similarly, personal experiences, perceptions, and cultural points of reference structure the invention of technologies that resulted from the *Jade* project in Chapter 5. The mechanism through which experience is incorporated into the process of art and invention is described as stochastic in Chapter 6. From our study findings, a portrait of the technological artist emerges as developing work from personal experiences, perceptions, and cultural points of reference through an exploratory, stochastic process which is resolved through both technical and tacitly-held knowledge and know-how grounded in the world of the artist's experiences, perceptions, and concepts. To further understand the dynamics of this technological art and R&D space, I expand on the results of Chapter 6 by triangulating them with studies specifically investigating artists' process.

7.2 *Characterizing the third space through practice*

7.2.1 Staying open to ever-emergent possibilities

There have been a series of studies resulting in characterizations of the artist's creative process that triangulate with our description of the stochastic process. Together with our study of technological artists' creative process, these build up a characterization of artists' work and potential contributions to technological research and development. The most relevant work includes the study of problem finding in art by Getzels and Csikszentmihalyi described at the beginning of the previous chapter and Mary-Anne Mace's related evidence-based portrayals of artists' process.

Digging deeper into the particular findings of Getzels and Csikszentmihalyi's 1976 study of visual arts students introduces the terms "presented problem" and "discovered problem." This distinction was originated by Getzels in 1964 as two ends of a problem-solving spectrum [76]. A presented problem has a previously-understood or conventional formulation and a conventional method of solution. A practitioner need only follow established steps to resolve the problem. The practitioner in this case is a problem-solver. A discovered problem lacks these. A practitioner must identify the problem, formulate it, and devise methods to resolve it. Once a solution is found, there is no predetermined standard of correctness to measure against. This practitioner would be a problem-finder. Getzels and Csikszentmihalyi, as noted in the previous chapter, correlated the amount of time their subjects spent contemplating and organizing the objects for the still life with greater levels of creativity exhibited in their drawings as judged by a panel of experts. They found that the artists who spent more time problem finding (i.e. pursuing a discovered-problem approach) and delaying project closure avoided conventional formulations and working methods and thus created work that was more original. Getzels and Csikszentmihalyi's concept of "delay in closure," refers to the artist keeping the problem space open for extended problem formulation. Their analysis concluded that artistic success was most related to delay in closure. They characterize delay in closure as maintaining a level of interaction with the piece in a way that supports problem formulation with attention to the situation at hand, or, to use the language we have been developing, in the world of the piece, rather than in an abstract or conventional problem-solution system. The characteristics of unstructured, unconventional problems and delay in closure triangulate with our model of the stochastic process.

In the 1990s, psychologist Mary-Anne Mace interviewed fourteen artists over the course of their project work in order to "identify significant variables in the art-making process" [114, p. 267]. Following Getzels and Csikszentmihalyi, she initially considered process in terms of the decision-making strategies used to develop the artwork. Mace's descriptive analysis of the artmaking process echos the findings of Getzels and Csikszentmihalyi but in finer detail. Mace found that her study supported Getzels and Csikszentmihalyi's concepts of problem finding and problem solving, but that "rather than existing as distinct stages in a linear process, problem manipulation occurred continually throughout the production of individual works and across related works. . . Problem formulation and solving are not distinct stages, they occur in a cyclic fashion throughout the production of a single work" [114, p. 272].

Mace also verifies the benefit of the delay in closure. She writes that artists may "delay in problem foreclosure and [have a] tendency to formulate problems in a situation made of ambiguous tensions that are not yet fully articulated. . . in order to discover new relations between conflicting elements" and "engage in essentially problem-finding activities of the discovered-problem orientation rather than in a presented-problem orientation" [114, p. 277]. She summarizes her findings related to problem finding and delay in closure:

> The artists' insistence that there is no correct artistic solution to an artwork illustrates the ongoing developmental nature of the entire art-making process. In this way, individual artworks represent particular stages of the ever-changing artistic concept, rather than being isolated islands of creativity. Indeed, the provisional nature of the solution goes hand in hand

> with the tendency to discover the problem in the making process. Only if the problem definition can be delayed can a solution be formulated in the experimental art-making situation itself. This is achieved if the artist responds to physical renditions of current conceptualizations of the artistic problem, ensuring that the problem to be addressed continues to undergo conceptual redefinition. The tendency to delay problem foreclosure ensures that the artist addresses the emerging conceptual, aesthetic, and technical challenges in the developing work by encouraging a reflexive and responsive process. [114, p. 277]

Mace notes that "there may, in fact, be many possible solutions for one particular artistic concept" leading artists to work in series in order to experiment with multiple ways of developing a trajectory [114, p. 275]. Later in the paper she writes, "Indeed, it might be of greater theoretical value to avoid distinguishing between these two apparent stages of the art-making process and, instead, consider art making as a process of responsive and flexible conceptual development" [114, p. 276]. As Mace's paper progresses, her characterization of the artist's process aligns more with our stochastic model than Getzels and Csikszentmihalyi's problem finding–problem solving model. Our stochastic process model emphasizes a walk of multiple decision points through a space of possibilities, where each decision point creates a local set of potentials. Mace gives us a characterization of the artmaking process as one of continuous discovery, experimentation, and redefinition through "a reflexive and responsive process." Combining these gives us a picture of art production and technology development in the third space as staying open to change, particularly changing conceptual, experimental, and technical conditions through a reflexive and responsive process.

After her initial study, Mace conducted another series of interviews with sixteen artists over the course of their project work [115]. When triangulated with description of the stochastic process, a portrait of the artist emerges which reinforces the roles that personal experience, internal stores of knowledge, and material fabrication play in the stochastic process and how these characteristics combine to produce emergent work.

7.2.2 The role of personal experience

Mace found that artists incorporate various aspects of their life, knowledge and experience into the conceptualization of a piece. She writes:

> The sources for ideas are varied within and among artists. They could be life experiences, childhood experiences, inspiration from teaching, children, their domestic situation, artist exhibitions, reading, everyday discourse, and the media. However, rather than involving the deliberate choice of a certain concept and rendering that physically in a given medium, the process of conceptual development is much more reflexive, evolving over time through a series of transformations of that concept. [114, p. 270]

We saw this dynamic explicitly in the description of the invention of *Jade* in Chapter 5. This mining of personal experience does not imply that the work is necessarily autobiographical or solipsistic however. Mace quotes one of her subjects, a writer and illustrator answering a question about where the ideas for work come from:

> It's hard to actually pinpoint... obviously they're things that appeal to me... the images that I use and the language that I use come from me, for example when I did [a book], I set it in Christchurch and in Canterbury, and during the summer that I did it we had this amazing drought and TV news, newspapers, and radio was full of information about the drought... I remember driving up through North Canterbury... and the place was absolutely devastated... and I used all of that, and I didn't even intentionally do it, but when I started to draw the landscape... I actually drew and used all that North Canterbury drought landscape. [114, p. 270]

A painter Mace interviewed answered a question about the conceptualization of work in the following way:

> Well it's funny, you don't actually decide, it sort of happens through experience of things or through other people, or reading things, um... it's a lot of things brought together... I didn't go out there and say, "I'm going to make my work about this," it just sort of came through in my work while I was making it. [114, p. 270]

Another example which specifically links personal experience with cultural production can be found in our study. For one of our subjects, a technological artist, a project was catalyzed when she was cleaning her mother's home after her death and picked up a pincushion in the form of a tomato:

> This was not a piece that I ever intended to make. It really happened because my mom passed away so suddenly. But I had this idea that my mother and other women around the world from her generation who had experienced various forms of oppression found ways to express themselves despite the oppression they were experiencing. And a lot of that expression ended up being the making of things that were beautiful, whether it be the beautiful home, the beautiful clothes, the beautiful clothes, the beautiful food. Because those are worlds that are under your control. So when I was making this piece i was thinking about my mother, she died when she was in her 70s so the kind of things that she would have, big social bubbles that she would have experienced, one would be the Great Depression, which her father experienced and thus the children. One would be the wave of the Women's Movement. One would certainly be the Civil Rights Voting Act…

And thus this subject collapses her personal history into topics of relevance for a larger society. She called this process "putting the pieces together of the things that are very much inside of me" in an act she describes as "recontextualization" and being "at service." She cites the experience she described as an "aha" moment. Immediately upon picking up the pincushion (see Figure 110), the artist made the connection between her and her mother's life and the ways oppressed women made beauty in their world. She said, "as soon as I got the aha moment, a lot of imagery would start happening." The subject also reiterates, "I had not planned to do the current piece I'm working on. I just had not and here I am." The use of personal experience in the artmaking process triangulates between Mace's artist subjects, who were all using traditional mediums, and our technology art subjects. This example details the dynamics of how this process develops into an experience with larger social and cultural relevance. This dynamic can also be found in the invention of *Jade*. Personal experiences are extrapolated to address sudden infant death syndrome and post traumatic stress disorder.

Figure 110: The artist and her muse, a tomato pincushion.

In reading this description of creative process, one may conclude that it is subjective and arbitrary, with all the negative connotations that come with randomness and idiosyncrasy in our culture. However, we can see from the examples that this process has a structure. Combining experience with the stochastic process as a walk through a field of multiple potentials brings an almost Monte Carlo search method[1], typically used in science to locate points of interest in complicated domains. It is up to the skill of the artist to bring out issues of relevance once a fertile point is found.

7.2.3 Internal stores of knowledge

In the report from her second study [115], Mace writes about the store of internal knowledge and experience that the artist builds during their career:

> the genesis of an artwork arises from a complex context of art making, thinking, and ongoing experience. Over time the artist builds an extensive knowledge base about art making that includes explicit and implicit understanding of techniques, skills, art genre, art theory, aesthetics, emotion, values, personal theories, personal interests and experience, previous work, and historical and contemporary art knowledge. This knowledge base is constantly developed and referred to throughout the artist's art-making life and connects current works in progress with past and future artworks. [115, p. 182]

Mace calls this knowledge base "a reservoir of understanding and knowledge" [115, p. 184]. Part of this reservoir is materials-based knowledge. When the artist's medium is high technology, he or she builds up a valid reservoir of technical knowledge. In our study, the artist used her technical store of knowledge in textiles and polymers to fast-associate between the spongy jade plant leaf she was holding in her hands and the possibility of creating a similar mechanism within a textile:

rubber (plant) → *elastomer* → *polymer* → *fiber* → *textile*

[1]Seeing various types of creative thinking as analogous to a Monte Carlo method has also been described by Dr. Pete Ludovice as part of his use of comedy and improv to access innovative thinking.

She had enough technical knowledge to research an engineering model for sound propagation in a textile, and then used her internal compass to judge that the experience with the coffee cup would be more fruitful. Finally, in creating prototypes of the haptic textiles, she used experiences and knowledge learned during creating previous projects with electronic textiles and circuits, including the ECG circuit she had experimented with at a previous stage of this project. Recall that traditionally artists learn their craft through ongoing repetition of creative project work. This dynamic persists in artmaking with technological materials. Through this repeated practice, technological artists build up experience with and knowledge of these technologies, their configurations, and their operations.

7.2.4 The role of material fabrication

The technological artists that participated in our study had varying degrees of formal training in science and engineering. They all used a combination of intuitive, ad hoc, and formal techniques when working with the technological medium. But the relationship between materials and the artist's process goes further than this. Artists tend to think through fabrication. Mace writes:

> As the concept of the work informs the physical structure of the work, the process of physically making the artwork influences the development of the concept of the work. In this way content and form inform each other in an advancing process of development... making an artwork involves a process of negotiation between the artist and the developing work... [115, p. 185]

In a similar way as the piece's conceptual development follows a stochastic trajectory, so too does the materialization of the piece. In this way, the stochastic process allows the artist to remain open to an interactive discourse with their medium. This is a tacit way of working that allows the materials to give information about themselves and guide the process. This occurred for the engineering team in our study as well. Recall that once they reached a point in their process where they were to integrate their modules and create physical prototypes, they faced challenges. These challenges were materials-based. Their inability to resolve their materials led them to take a stochastic approach which in turn led to emergent results. In this way, practitioners learn about the nature of their materials. When the materials are high technology, the practitioners can be guided by them toward emergent manifestations of this nature by staying open to the dialogue with technology as a medium. This keeps the process open for discovery at any moment. At the same time, the characteristics of the technology constrain the process toward resolution, as conceptual tethers do. Just as the relationship between mother and child tethered the artist's process toward the infant blanket design, so too can high technology probabilistically constrain the artist's process toward various potentials over others.

7.2.5 The dynamics of emergence

Mace cites Getzels and Csikszentmihalyi's homeostatic model of motivation, which sets forth that the exploratory behaviour of artists does not resolve issues and achieve a former condition of equilibrium. Instead the process results in a new emergent status of equilibrium. For Getzels and Csikszentmihalyi, through the delay in closure and tendency to formulate problems in a space of ambiguous tensions that are not fully articulated, the artist is able to discover new relations between conflicting elements [77, p. 246] in [114, p. 277]. Mace describes this new project state as emerging from the "background context of information, materials, knowledge, and understanding" that the artist has skillfully built throughout their career. Mace writes that a "consequence of building such an extensive and personally felt knowledge base is that it provides a background for new work and innovation" [115, p. 190].

From our study and the discussion in this chapter, we can trace the dynamics that lead to emergent work in the third space. While these aspects of creative work in the third space are interleaved and not discrete, I break down the dynamic for the sake of clarity and completeness. The dynamics of emergence in technological art can proceed in the following way:

- The technological artist develops work from personal experiences, perceptions, and cultural points of reference
- through an exploratory, stochastic process, which is more than a delay in closure, but still incorporates Getzels and Csikszentmihalyi's concept.
- This process operates in a Monte Carlo seeking mode, whereby indeterminate points are conceptually registered by the artist for relevance and possibilities.
- The artist is supported in her work by a store of experiential, cultural, and technical knowledge.
- All of these elements become involved in a discourse of discovery with the technological materials.

It is part of an artistic method to stay open to the multiple, emergent possibilities throughout the process. With the proper application of skill, where the notion of skill is multiply constructed in line with the characteristics presented here, and coincident conditions, an art piece or invention can emerge.

7.2.6 Tensions with technological communities

Most contemporary engineers have formal training grounded in scientific and engineering knowledge and methods. Through their training, they are instilled with a sense of process which secures their values. These values include proficiency in their knowledge area, clarity in project goals and process, and predictability, reliability, and stability of both process and product. Contrast these characteristics with the indeterminate nature of the stochastic process, relying as it often does on internal knowledge, experience, and reflective methodologies. This process allows for, stays open to, and even encourages and relies on changing project conditions. These aspects are difficult to validate and legitimize within a technological community. That said, some engineers are open to technological research and development by artists. Chief of Xerox PARC, John Seely Brown, appreciated artists' ability to surface that which is "evocative of the tacit knowledge" [138].

Candy and Edmonds have experienced these tensions in the collaborations they arrange between artists and technologists. For example, one of their artist-in-residence participants, a technologist, remarked about his artist partner:

> Sometimes I believe I've resolved the problem with A but the next time we talk it seems he meant something else. It seems difficult to impress upon him the need to look at the problem logically and be very specific. This is not his fault but the problem must be expressed in sequential logical terms. [36, p. 58]

A significant part of Candy and Edmonds's research program focuses on principles to ease these tensions between artists and technologists during collaboration.

7.2.7 Tensions with the contemporary art system

Technological artists and artists using traditional mediums seem to have similar processes and thus similar values embedded within. Still, art made with high technologies, with a few exceptions, is not admitted into the contemporary art system. I presented these tensions in Chapter 2. There is no agreement as to why this is the case. It could be because technological art doesn't participate in the discourses of contemporary art. Perhaps curators don't have a frame of reference or technical experience to exhibit the work. Or perhaps technological artwork does not typically achieve appropriate levels of finish or other aesthetic or vernacular qualities that would make it recognizable to the contemporary museum and gallery system. It may also be that technology foregrounds a collusion with a technical–industrial complex and such artwork is rejected on ideological grounds. Postmodern critical theory, which has significantly influenced art criticism since the 1960s, deconstructs scientific research and technological innovation as manifestations of a modernist metanarrative.

We saw this overall dynamic at work in the early twentieth century through the review of the Marcel Duchamp's work in Chapter 2. Duchamp was creating work addressing the practices of research (*Three Standard Stoppages*) and invention (*Rotary Glass Plates, Precision Optics* and *Rotary Demisphere, Precision Optics*). The contemporary art world accepted this work on its own terms, i.e. in the contexts of Dadaism, Abstraction, and Futurism, with its own interpretation as to its value and meaning, not in terms of what appears from our reading to be Duchamp's intended approach, i.e. that of experimentation with research and innovation.

Another tension between the technological art community and the contemporary art world has to do with research and articulation. Because of the tradition of artist-technologist collaborations, which often took place in corporate or university settings, as well as the long history of *Leonardo*, the research journal dedicated to supporting the A/S/T (art/science/technology) community[2] through multidisciplinary and interdisciplinary research papers, research and articulation is not an alien concept to many in the technological art community. In fact, one could argue, research and articulation of phenomena from within this community helps to explain their relatively entropic work to other communities and institutions, including the technological community and agencies such as the NSF that fund technological work. In this way, research and articulation of practices within this community support the community by smoothing the way toward collaboration, access to technological materials, residencies, and grants. Traditionally, the fine art community has taken a more ambivalent stance toward such articulation of practice. The answer to the topic, "Why art cannot be taught," according to art educator James Elkins, author of the book of the same

[2]A/S/T is an acronym referring to work done at the intersection of art, science, and technology. It does not refer to a formally established group or community. A/S/T could also be thought of as a third space, however I have yet to hear it referred to in this way.

name [62], is, in a paraphrased sentence, because the practice of artmaking is irrational and thus cannot be expressed.[3]

7.2.8 Summary of dynamics in the third space

Our characterization of this third space focuses on dynamics of process and action in the world of the creation of technological art, more so than theoretical or disciplinary characterizations. From our study findings and triangulation with the literature on artistic production, a portrait of the artist emerges that has resonance with the intersection of artistic and technological production as presented in this dissertation. We have demonstrated an exploratory, responsive, stochastic process which is resolved through tacitly-held knowledge, know-how and experience grounded in the world of the artist's experiences, perceptions, and concepts. Central to these experiences, perceptions, and concepts is the conjunction between these and the technological medium the artists are working in and the artifacts they are working with. Concepts and experiences join together with technological fabrication in a dialogue between rich, nuanced, personal experience and the grounded reality of the medium. The artist works in a skill-based dialogue with the technological materials. During this dialogue, the materials reveal elements of their nature that combine with the internal intentions of the project to resolve to an artifact. This process contains the possibility of advancing technology in ways that it would not advance otherwise through market forces or technological agendas. Instead the technology arises in ways that are central to the artist's experience, which can be extrapolated to larger, collective interests if that experience is so constructed.

[3] As an anecdote, I was at an international conference for art and technology in recent years presenting the work on the stochastic and teleological processes. After my talk, an undergraduate art and technology student shook me around the shoulders and said to me, "You are trying to control us!" to which I replied, "No, I'm trying to make sure that the type of work you do is visible so you can get paid." This, in turn, brings up another issue. The topic of getting paid has generally enjoyed classification as taboo in academia. For artists, who often exist on the margins of having a financial life, this issue is very much part of their lived experience.

These evidence-based descriptions of dynamics within the third space from Mace's studies and our study are just a beginning foundation. The construction of work process in this third space as containing rich, experiential nuance from personal experience is in contrast with work that is constructed to be explicit, generalizable, and validatable. The same may also be said of research from the third space, as exemplified by the work in Chapters 4 and 5. This contrast is the result of different experiential sieves. Yet this dissertation has shown that by applying the principles and processes of artmaking we can advance technology in a valid way. While scientific and engineering methods are the norm, there is another way to approach technology research and development that is indirect, stochastic, responsive, and emergent.

7.3 Implications

Prominent configurations of technological art include those of Candy and Edmonds, *Leonardo* Executive Editor Roger Malina, artist Steven Wilson, and art historian Edward Shanken. Through their research, Candy and Edmonds implicitly construct the art-technology space as a space of collaboration between both practitioners and disciplines with common goals. They support this space by making artwork (Edmonds), supporting artists-in-residence programs, and conducting and supporting practice-led and practice-based research at the intersections of interactive art and interactive technologies. Candy and Edmonds focus their work on research methodologies, collaboration, and how research in the interactive arts can inform both the interactive arts and interactive technology research [36, 38].

Roger Malina, executive editor of *Leonardo* publications and *Leonardo* founder Frank Malina's son, constructs work at the intersection of art, science, and technology in terms of a weak case and a strong case. His weak case argues that science and technology are a fundamental element of the human condition, and as such should be reflected in our culture's art. This is especially important when considering students and children and how our culture feeds their imaginations, which ultimately determines the future of our culture. He also argues that artists can contribute to innovation, particularly given the otherwise elaborate strategies for encouraging innovation and the desire expressed by some researchers to draw upon ideas and techniques outside of their immediate domain. This is a similar argument to the one that Xerox chief John Seely Brown makes, as described in Chapter 3. Malina's strong case is that including art in science and engineering environments encourages a fundamental evolution of these fields, beneficially altering the content and direction of future research. Instead of a third space, Malina constructs a network of five nodes. These include: an industrial art, design and entertainment node; science; corporate technology development; a node of worldviews that have appropriated scientific components such as metaphysical systems, religious practices, and electronic arts; and a node he designates as "Situation," which is a node encompassing collaborations, consortia, and collectives [117].

Steven Wilson, author of *Information Arts: Intersections of Art, Science, and Technology*, the encyclopedic compendium of technological art through the early years of the millennium, documented the changing roles of artists who participate in the A/S/T community, particularly as relates to their adoption of research related to technology [196]. Wilson configures an intersection formed by the expansion of the arts on one side and science and technology on the other. The arts and sciences inform each other at this intersection, with research at the center of both cultural and scientific innovation. His book categorizes works, theory (particularly critical theory), and research agendas in this intersection.

Edward Shanken, one of the few art historians focusing on technological art, configures technological artists as artists engaged in our contemporary technoculture, discovering the "poetic significance" of technology [179, p. 16]. Shanken considers technological artists within the continuum of art history while acknowledging their rejection from the contemporary art system. His focus is on how technological art "will create new forms and structures of meaning that expand the languages of art, design, engineering, and science, and that open up new vistas of creativity and invention" [179, p. 51].

A report from the U.S. National Research Council is also worth mentioning again. As described in Chapter 3, this report, which takes the form of the book, *Beyond Productivity: Information Technology, Innovation, and Creativity*, lobbies for support for work at the intersections of computing, the arts, and design. They call the practices at this intersection "ITCP," for information technology and creative practice. The authors write:

> This new kind of art and design practice looks increasingly like technical research, but it is done from an artistic or design rather than a scientific perspective—it asks different kinds of questions and uses different kinds of methods to search for answers. [131, p. 97]

The authors leverage Csikszentmihalyi's systems model of creativity, which locates creativity in the interaction between the individual, a field, and a domain [47]. The authors of *Beyond Productivity* focus on the relationships between creative practices and information technology within this system, with a goal of mutually enriching the fields and domains of both information technology and art and design.

There has not been, to my knowledge, a comprehensive picture or theorizing of this third space of art production and technology research and development, especially one that focuses on the dynamics within that space from the perspective of practice. Future directions of the work of this dissertation could compare and extrapolate these different configurations and theorize their implications. For now, I focus on the implications of my construction of this third space as one of artistic production and technological research and development. I construct this space not primarily in terms of cultural, theoretical, disciplinary, or historical categories, though, as this dissertation shows, all of these are interconnected. Grounding the third space in practice, process, and action-in-the-world leverages and establishes evidence-based foundations for this space. It establishes a field of practice as a foundation for further theoretical and disciplinary discourse.

Thinking of the third space in terms of practice locates this space along a spectrum of practice running between traditional arts practice (using traditional mediums) and engineering. The positioning of this third space along this spectrum allows for open boundaries between technological art and traditional art practice and engineering research and development. This promotes a sharing of information, discourse, and practice between these other arenas, including cultural engagement with issues related to technology, as Chapter 4 on *Breeze* demonstrated. Technical skills, mindsets, and processes can also be shared, or even develop a kind of synesthesia where conceptual metaphors cross the boundaries carved out by tradition. This sharing supports emerging roles for technological artists as polymaths, collaborators, innovators, and interdisciplinary educators.

Technological art as a third space also implicitly carries a message that art need not conform to technological agendas in order to be valued. Making the argument that technological art should be valued simply because it contributes to technological agendas risks involving other forms of art in valuation arguments. Art within the traditional or contemporary art world is embedded within a different social context, and as such will have different evaluative and ideological criteria than technological art. On the other hand, by applying the practices of artmaking to technological development, we can advance technology. In the words of Billy Klüver, founder of E.A.T., "I think there's a huge consciousness inside technology that hasn't been tapped" [88, p. 9]. Care must be taken that this does not become a validity claim for technological art. Validity in the third space is implicitly established through the creation of an authentic work of artistic production. This is primary.

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