Reports sent Ostler 11/5

GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT INITIATION

Date: November 3, 1971

Project Title: Communication and Electronic Systems Compatibility

Project No: E-21-612

Principal Investigator: Dr. D. T. Paris

Sponsor: Rome Air Development Center (AFSC); Griffiss AFB, N. Y.

Agreement Period: From October 1, 1971 Until October 1, 1972

Type Agreement: Contract No. F30602-72-C-0118

Amount: $24,994.00

Reports Required: Monthly Status Reports; Final Technical Report

Defense Priority Rating: DO-A7 under IMS Reg. 1

Sponsor Contact Person (s):

Technical Matters
Dr. W. W. Everett, Jr.
Project Engineer
Interference Analysis & Control Section
RADC(RCCI)
Griffiss AFB, N. Y. 13440
Phone: (315)330-2841

Administrative Matters
(thru G.R.A.)
Admin. Contr. Off.
ATTN: Procurement Div.(PMA)
Rome Air Development Center(AFSC)
Griffiss AFB, N. Y. 13440

Assigned to: Electrical Engineering

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- Photographic Laboratory
- Project File
- Other

RA-3 (6-71)

GEORGIA INSTITUTE OF TECHNOLOGY

OFFICE OF RESEARCH ADMINISTRATION

RESEARCH PROJECT TERMINATION

Date: October 5, 1972

Project Title: Communication & Electronic Systems Compatibility

Project No: E-21-612

Principal Investigator: Dr. D. T. Paris

Sponsor: Rome Air Development Center (AFSC); Griffiss AFB, N.Y.

Effective Termination Date: 10/2/72

Clearance of Accounting Charges: by 10/31/72

Grant/Contract Closeout Actions Remaining:
Final Invoice & Closing Documents
Final Report of Inventions
Gov't. Property Inventory/Certificate
Classified Material Certificate on Negative Reply

Assigned to: School of Electrical Engineering

COPIES TO:

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- Project File
- Other _____

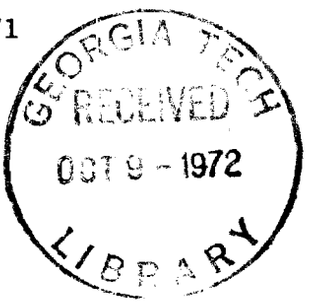
RA-4 (6-71)

E-21-612

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

November 9, 1971



Dr. Woodrow Everett, Jr.
RADC-RCC
Griffiss AFB, New York 13440

Ref: USAF Contract No.
F30602-72-C-0118

Dear Dr. Everett:

Enclosed you will please find copies of reports on three trips taken by Georgia Tech participants in the Post Doctoral Program:

October 6-7, 1971; Rome, N.Y.; D. T. Paris
October 27-28, 1971; Washington, D. C.; A. M. Bush and D. T. Paris
November 4, 1971; Wright Field; D. T. Paris

It is hoped that these reports can serve as adequate descriptions of the first month's activities. If additional information is required, please let me know.

Sincerely yours,

Demetrius T. Paris
Professor and Director

DTP:jms

cc: Mr. Alfred A. Camp
Office of Research Administration

MEMORANDUM

For limited distribution.

TO: File

FROM: D. T. Paris

SUBJECT: Trip Report

A meeting of Post-Doctoral Program participants was held at RADC, Rome, N.Y. on October 6-7, 1971.

The first day of the meeting was limited to "senior partners" representing six educational institutions. Thus, in addition to Dr. Woodrow W. Everett, Jr., Program Director, present on the first day were:

Bob Cotellessa, Clarkson
Scott Gilmour, Buffalo
Ben Leon and Warren Peele, Purdue
Will LePage, Syracuse
Ron Thomas, Air Force Academy

and myself. Discussion focused mainly on funding, on general operational problems, and specific plans for the coming year. A decision was reached to hold additional meetings of the group as follows:

December 28-29, 1971	Georgia Tech
February, 1972	Keesler AFB
May 8-9, 1972	Purdue
July, 1972	Air Force Academy (Workshop)

(Informal contact with Mr. Vince Palmiero, cognizant Contracts Officer at RADC, revealed that our contract for just under $25k will be in the mail to us next week, but goes into effect as of October 1, 1971. Woodie Everett will put in a request to RADC for an additional two man-year effort at Georgia Tech during this year.)

The second day of the meeting was devoted to discussions with Major Benson of DCA. Present were Cotellessa, Gilmour, Wlater Ku (Cornell), Peele, Thomas, Woodie Everett and myself. Major Benson reported interest in the areas of

1. Technical Control
2. Wideband communication systems for graphic equipment
3. Bandwidth reduction
4. Switching at high digital rates

arranged in that order of priority. However, for political reasons and to set a precedent, Major Benson suggests that initially only a single one-man-year project be submitted for funding by DCA. To this end, a two-day presentation in Washington by Post-Doc Program participants will be organized by Major Benson either for Oct. 27-29 or Nov. 10-12 time periods. (Dave Shultz and any other graduates of Georgia Tech who work at DCA could be of help.)

According to Major Benson, the hottest DCA project at present relates to planning (for implementation in 1975) of a new Automatic Secure Voice Communication System. A total of $1,000,000 of R&D money has been tabbed for this purpose. The project will begin with a complete study of factors that bear upon narrowband and wideband communication systems and will include such areas as Lipreaders, Adaptive Prediction Coders, Digital Vocoders, Kalman coders, Voice Excited Vocoders, Narrowband and Wideband KDC signaling and Transmission Technology, Group Modems, Group Multiplexing, and Wideband A/D Techniques Evaluation.

Consideration is being given to include the Naval Post Graduate School and the AFIT in the Post-Doctoral Program.

GEORGIA INSTITUTE OF TECHNOLOGY
School of Electrical Engineering

MEMORANDUM November 1, 1971

TO: File

FROM: Bush and Paris

TRIP REPORT - VISIT TO DEFENSE COMMUNICATION AGENCY, WASHINGTON, D. C. AND RESTON, VA.

1. Evening of October 27 spent in conversation with Ron Thomas (AFA), Walt Ku (Cornell), Ben Leon (Purdue), Woody Everett, A. M. Bush and D. T. Paris.

2. The morning of October 28 was devoted to coordination with Major Lonnie Benson of DCA Washington. Talked with Mr. Scott, Mr. Smith, Mr. Dix and Mr. Jones. Discussion centered on organization and mission of DCA, possible utility of the Post Doctoral Program. Uncovered area of long-range technical forecasts to be one area, "gunfighters" as another.

3. The afternoon of October 28 was devoted to a presentation at DCA - Reston, Va. concerning the Post Doctoral Program and its capabilities. There were 18 DCA personnel present (including Dave Shults). Bush, Dees, and Paris represented Georgia Tech. Paris made a 6-minute talk describing the total Georgia Tech capabilities in the communications/electronics area.

4. October 29; Thomas, Everett and Paris spent the morning with Major Benson and Mr. Smith at DCA in Washington, and discussed Post Doctoral participation in communications technology forecasting for the 1973-1983 time period. A total of four man-year effort (with slightly over one man-year by Georgia Tech) is seen as an immediate possibility. A workshop, scheduled for late November or early December will include representation from Post Doctoral Program including Georgia Tech.

5. Bush, Perini (Syracuse), Ku, Cotellesa, Eveleigh (Syracuse) discussed with Dr. Jon Baylis of DCA - Reston mutual areas of interest in speech digitization and in general digital communications interests. Dr. Baylis and Dr. Aaron Goldberg (who was not present) will give to Major Benson short work statements on (1) analog/digital compatible switching centers and (2) evaluation of linear predictive coding as a technique for voice digitization. Georgia Tech appeared to be the only site well enough equipped to handle the voice work.

6. On the morning of October 28, Leon met with I. P. Plotkin on Tech Control and Systems Control. In the afternoon, Leon, Perini, Eveleigh, Cotellesa, Bush and Paris met with Lowell, Fife, Plotkin and Benson of DCA, and discussed this subject at some length. They will attempt to write work statements. It would be helpful to give Benson some work statements from our own point of view. Basic issues are:

   A. Establish the minimum number of parameters that should be measured in order to determine the state of a communications channel when it is

      (i) non-operative
      (ii) nearly non-operative

   B. Arrive at the most cost effective way in which the state of each node in a global communications system can be described so as to optimize routing according to some selected criteria.

   C. Establish techniques and models for systems availability. This is a complex combinatorial problem aimed at estimating lower bounds of availability.

   These are three areas in which Hammond, Kamen and Fielder, respectively, can make significant contributions.

7. Reception at DCA was unexpectedly enthusiastic. DCA FY 72 funds are not being committed as fast as originally projected.

DTP:jms

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

MEMORANDUM

TO: File

FROM: D. T. Paris and W. T. Rhodes

SUBJECT: Trip Report - Wright Field, November 3-4, 1971

1. Al Sheppard, Bill Free (Electronics Division), and Paris visited the Aerospace Research Laboratories in the morning of November 3. Lt. Col. W. M. Hart, Jr., who directs the Plasma Physics Research, described ARL as being the Air Force's major in-house laboratory for basic research. Some outside research presently is being funded but only to complement in-house projects. Col. Hart, (has earned PhD and seemed technically competent) would welcome visits by other, more knowledgeable Georgia Tech personnel (e.g. Hooper and Gallagher, of the Electronics Division) with interests in the plasma - atomic collisions - laser fields. In view of the breadth of basic research being conducted at ARL, members of the EE faculty would most likely profit considerably by establishing one or more contacts with personnel in this laboratory, approximately 70 of whom hold the PhD degree. Organizationally, ARL is subdivided into the following major units: Thermomechanics, Chemistry, Energy Conversion, Fluid Dynamics, Plasma Physics, Applied Mathematics, General Physics, Hypersonic, Solid State Physics, and Metallurgy and Ceramics.

2. Later in the morning of November 3, Sheppard, Free and Paris visited with a Mr. Maynard, who heads up the Microwave Sources Group of the Electronics Technology Division, Air Force Avionics Laboratories. Discussion focused mainly on the recent re-organization of their Division, but Mr. Maynard expressed interest in Gordy's PhD thesis (advisor, G. P. Rodrigue). A Mr. Larry Yarrington, who works for Mr. Maynard, would welcome an opportunity to visit Georgia Tech so that he can see a demonstration of Mr. Gordy's technique. Generally, the Microwave Sources Group is interested in device development (Dale Ray would find areas of common interest.)

3. In the afternoon of November 3, Sheppard, Free and Paris visited with Mr. J. H. Ross, who directs the Fibrous Materials Branch of the Air Force Materials Maboratory. Another branch, i.e. the Electromagnetic Materials Branch, according to Mr. Ross, is interested in ferrite work.

4. Morning of November 4, Sheppard, Paris and Dr. Gilmour (Buffalo U.) met with Dr. Carl Miller, Chief Scientist at ASD. Dr. Miller has provided partial funding for our Post-Doctoral participation, and the purpose of this meeting was to outline areas of mutual interest.

Addendum to AF Avionics Labs trip report: W. T. Rhodes

Wednesday, November 3, 1971

1:30 - 2:30: Talked with Mr. Ken McCoin of the Radar and Microwave Techniques Laboratory about their current and future interests in optical processing research. McCoin was quite cordial. General conclusion drawn from the conversation is that their present and future interests in this area are limited strictly to processing of synthetic aperture side-looking radar data. His laboratory is considering making the investment in a full capability processing facility of their own (approx. $1,000,000). Their outside contracting is almost exclusinvely with the University of Michigan and with Goodyear Corporation, and the chances of breaking into that club appear quite small. Developmental work in other areas involving optical processing of radar signals is being left in the hands of the Laser and Electro-Optics Technology Branch (see below).

Thursday, November 4, 1971

8:45 - 11:30: Had an extended and very pleasant conversation with Dr. Dave Flannery who is in charge of the coherent optical processing activities of the newly established Laser and Electro-Optics Technology Branch of the Avionics Lab. The organizational structure has just been settled and the group still lacks direction to a large degree. Their present emphasis appears to be on real-time processing capabilities, and in-house they are beginning to investigate various IFLM (Image Forming Light Modulator) devices. Some emphasis seems to be placed on optical processing of radar signal information, though they have no clear idea as yet of the problems to be solved. Though the budget for Flannery's group is presently small (through fiscal year '72-'73) there are indications that it will grow. He appeared quite willing to cooperate to the extent he was able should a solid proposal-worthy idea be generated here.

There are a number of people in that laboratory branch interested in space qualified communication laser systems, and a substantial amount of money is being spent in this area. A special report will be prepared for Professor Callen on this subject.

1HD

E-21-612
Paris

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

December 6, 1971

Dr. Woodrow Everett, Jr.
RADC/RCC
Griffiss AFB, New York 13440

Ref: USAF Contract No.
F30602-72-C-0118

Dear Dr. Everett:

Following is a summary of Post-Doctoral Program activities by Georgia Tech participants during the time period November 1, 1971 to December 1, 1971. — Monthly #2

1. On November 10, 1971, Major E. G. Royer, USAF Academy, visited the Georgia Tech campus and held technical discussions with me and several other members of the Electrical Engineering faculty. Possible Post-Doctoral customers were identified during the visit. These include Kirtland AFB (see item 2 below) and Eglin AFB. Current plans call for visits to both facilities sometime in the immediate future.

2. As a result of a telephone contact by Major Royer, LtC Marvin Barth and Maj. H. T. Hinrichs, Kirtland AFB, visited my office on November 18, 1971. Technical discussions on EMP with several faculty members, graduate students and with me were followed up with a quick tour of the facilities. It was decided that a return visit to Kirtland AFB might well be in order sometime in January, 1972.

3. Consulting agreements have been initiated with R. F. Cotellessa, A. S. Gilmour, Jr., and G. M. Salati.

Sincerely yours,

Demetrius T. Paris
Professor and Director

DTP:jms

bc: Mr. Alfred A. Camp
Office of Research Administration

12/7

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

File

E-21-612

Paris

POST-DOCTORAL PROGRAM QUARTERLY REPORT - ?

Not scheduled ?

December 7, 1971

1. Synopsis of Work

(Dr. Everett)

2. Progress to Date

Primary emphasis was placed on the definition of the problem. On November 4, 1971, Scott Gilmour and Demetrius Paris conferred with Dr. Carl Miller at ASD. It was established that Georgia Tech's contribution to this effort will focus on the countermeasure capabilities and limitations of microwave sources.

Dr. G. P. Rodrigue, Professor of Electrical Engineering at Georgia Tech, has been designated program manager on this project. In addition to Dr. Rodrigue, and one (or more) engineers from the Electronics Division of the Engineering Experiment Station will begin participating in the program in January 1972.

Dr. Rodrigue has contacted both Dr. Miller and Dr. Gilmour by telephone. It was agreed that close coordination will be essential for the success of this program.

3. Participants and Travel

RADC Post-Doctoral contract with Georgia Tech was finalized after the beginning of the Fall Quarter, 1972. Because of internal procedures, formal budgetary charges for personal services will not commence until January 1, 1972. In the meantime, work on this project has begun.

Travel, during the period covered by this report, included a trip by D. T. Paris to Wright Field on November 3-4, 1971.

4. Papers, Publications, Presentations

NA

Al Becker
File

E-21-612
Paris

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

March 3, 1972

POST-DOCTORAL PROGRAM QUARTERLY REPORT #2

1. Synopsis of Work

Dr. Everett

2. Progress to Date

Efforts during this quarter have concentrated on coordinating our task with that at SUNYAB. A meeting was held at WPAFB with Drs. Carl Miller (ASD), Scott Gilmour (SUNYAB), H. A. Ecker (GIT), and G. P. Rodrigue (GIT). Dr. Miller outlined his broad areas of responsibility and interest in the ECM field. A statement of work for this task is being prepared based on these discussions.

Initial efforts have begun to survey the systems end of the ECM field especially as regards Air Force interests. To this end, a good degree of coordination with an ongoing ECM contract at Georgia Tech with the Avionics Lab is desirable. To gain access to this information a "need to know" must be established and steps are being taken to have Dr. Carl Miller generate this justification.

3. Participants and Travel

Dr. G. P. Rodrigue, Professor of Electrical Engineering, is the principal Post-Doctoral Participant and, essentially, the technical leader on this project.

Travel, during the last quarter, included a trip by Dr. Rodrigue and Dr. Ecker (Electronics Division, Engineering Experiment Station) to WPAFB on February 4, 1972. A copy of the pertinent trip report is attached.

Coordination with Dr. Scott Gilmour has been continued on a regular basis.

4. Papers, Publications, Presentations

NA

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

ELECTRICAL ENGINEERING

February 8, 1972

MEMORANDUM

TO : D. T. Paris

FROM : G. P. Rodrigue

SUBJECT: Trip Report (WPAFB)

On Friday, February 4, I visited several individuals at WPAFB with (from time to time) Drs. Ecker and Harrison of Electronics Division.

We met for about one hour with Jim Kastle and Chuck Hoey (EW). Their interest is in the ECM area. In particular they are interested (obsessed?) with the problem of microwave sources. The Air Force will initiate a tube exploratory development program in FY73, and they wanted Georgia Tech to become familiar with it and respond if possible. They will send us a background, survey report that we should read before pursuing program. (This is a rather involved program in personnel and background and I'd be happy to amplify conversationally. It is potentially a big program, $1M.)

Later in the a.m., Scott Gilmour, Carl Miller (ASD), Alan Ecker, and I discussed the Post Doc. ECM area. Miller outlined his interests and problems, and Gilmour and I will get together a letter outlining a proposed effort for this Post Doc. task.

In the p.m., we met with Don Rees and Bill Edwards (Avionics Lab). An existing program at EES was discussed briefly. We also mentioned this ECM-tube program. Edwards group (in particular Sonny Maynard) will be involved as the contacting agency for this effort.

All three groups -- Miller, Hoey, and Edwards -- will be involved in the tube research program. Georgia Tech is in pretty good shape on this in spite of lack of experience because (1) our students have behaved (as opposed to Stanford, Michigan, Johns-Hopkins) and (2) several of us have known these people at WPAFB for some time.

RADC/RCC (Dr. Everett)
Griffiss AFB NY 13440

February 28, 1972

MEMORANDUM TO: Scott Gilmour
Demetrius Paris

The second quarterly report is due to Dr. Carl Miller at ASD on that effort on March 22, 1972. Please submit your inputs for this report as soon as possible but no later than March 15. I will compile the report and forward to Dr. Miller.

Best regards,

Woodrow W. Everett, Jr.
RADC Post-Doctoral Program

an

E-21-612

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

June 21, 1972

POST-DOCTORAL PROGRAM QUARTERLY REPORT

1. Synopsis of Work

Dr. Everett

2. Progress to Date

Efforts during this quarter have concentrated on a study of potential enemy threat radars. This has included early warning, acquisition, track, and AA units. The needs for ECM microwave tubes must be determined within the framework of potential threats. A tabulation of system parameters such as operating frequency, power levels, PRF, etc., is being made. During the next quarter a similar study of U.S. ECM systems will be initiated.

3. Participants and Travel

Dr. G. P. Rodrique, Professor of Electrical Engineering, is the principal Post-Doctoral Participant and, essentially, the technical leader on this project.

Travel, during the quarter, included a trip by Dr. Rodrigue to WPAFB on May 1, 1972. Copy of the trip report is attached.

Coordination with Dr. Scott Gilmour has been continued on a regular basis.

4. Papers, Publications, Presentations

On May 4, 1972, Dr. R. H. Pettit presented a seminar at RADC on the subject of jamming of communications systems. Copy of his presentation is attached.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

May 1, 1972

TO: D. T. Paris
H. A. Ecker

FROM: G. P. Rodrigue

SUBJECT: Trip Report (ASD-WPAFB) 4/27/72

Very briefly, the day was a loser, and we again did not emerge with a statement of work. I did get a picture of the ASD organization in that area and it is attached. If interested in gory details, keep reading.

Scott Gilmour, Dave Lockett (both of SUNYAB) and I met with Don Laycock (ASD) for most of the AM and some of the PM. Lockett was with Gilmour on another mission for Carl Miller on Microwave acoustic delay lines, has no clearance, and sort of oscillated in and out of our meeting. A long and rambling discussion ensued from which I formed the following opinions.

Gilmour and Carl Miller used to work together at CAL. Miller wanted to have Gilmour work with him (consult) but had no way to do so. The Post Doc program was a solution. Miller must, however, show a "product" received for the money that is good for the ECM people. (He has no consulting $.)

Somehow Miller asked Laycock to "manage" the effort (i.e. generate the product). Not that Laycock doesn't work for Miller (see chart). Laycock seems to feel that the sort of thing Gilmour and I propose should be done with in the Air Force, and fairly obviously sees no real need or justification for it outside. The difficulty in generating a work statement for Carl Miller is perhaps obvious!

I suggested we compile a set of generator requirements based on 1) Present Air Force inventory 2) Planned Development programs 3) Long range threat predictions. I also mentioned the possibility of tying in effectiveness in a possible extension or enlargement of the effort. Laycock said threats were well known far in advance as were prime powers but made further comments.

It was all left rather up in the air. Laycock is to try again on the work statement and be in touch with us. It is not probable that we could get his sponsorship at ASD to open up the doors necessary to collect the information needed for (1) and (2) above.

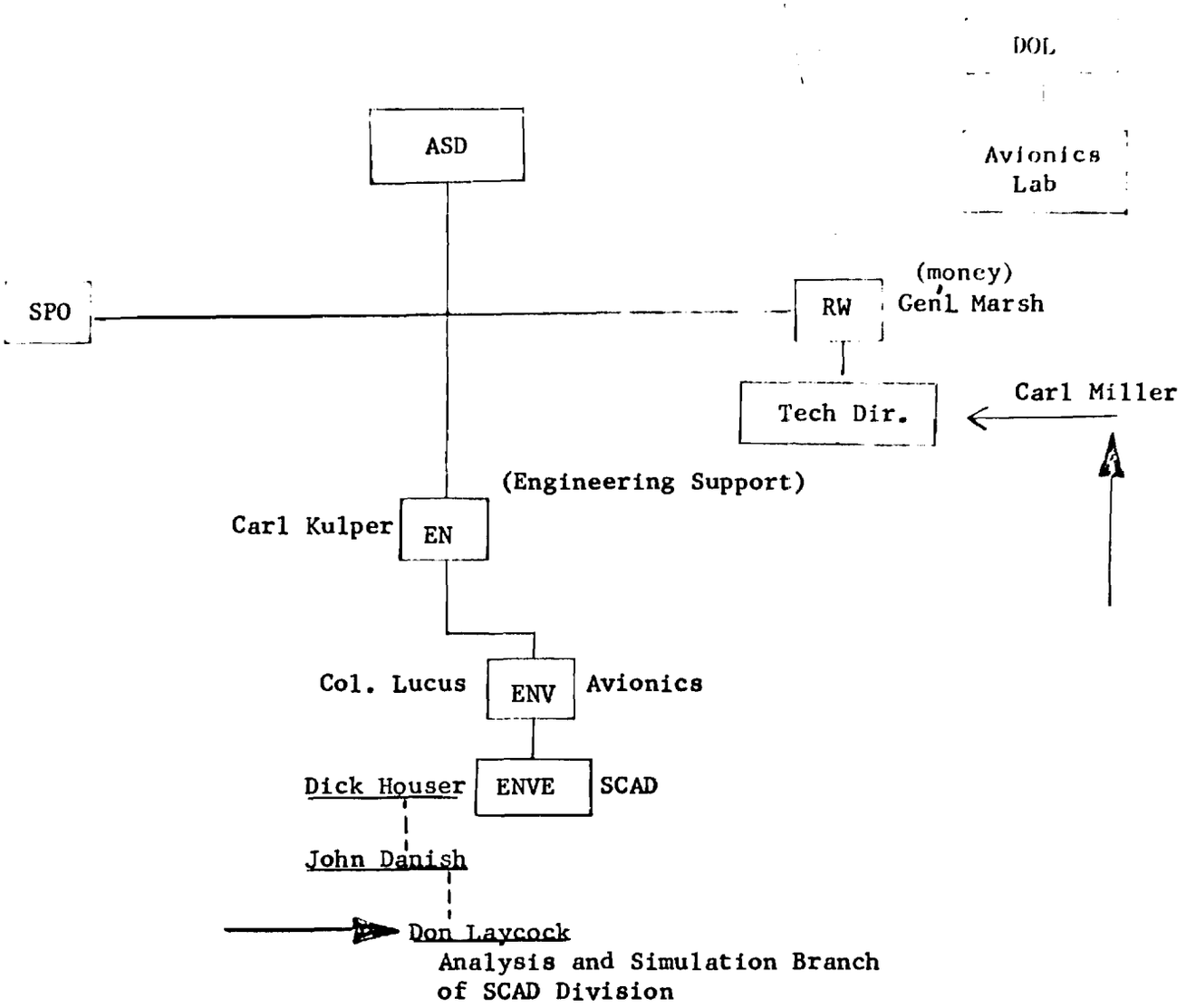
Laycock is a non-believer in expendables. He has been with ASD about 3 years (no prior tube experience). He is in a supporting role with SCAD where he spends about 1/2 time. He is technical monitor for tube development work sponsored through CAL. Laycock feels surveys of the microwave tube industry are quickly obsolete and should be avoided.

Tube work gets sponsored by:

SPO
SCAD
F-15
B-1
RW
Labs-Helberg-Edwards, etc.

A Dr. Yarington (young Ph.D.) has been hired to work with Sonny Maynard in tube work.

Gilmour sits in on meetings of the Working Group on Microwave Devices. Bill Edwards and Lou Kiosa are members of that group.


DOL
ASD
Avionics Lab
SPO
RW
(money)
Genl Marsh
Tech Dir.
Carl Miller
(Engineering Support)
Carl Kulper
EN
Col. Lucus
ENV
Avionics
Dick Houser
ENVE
SCAD
John Danish
Don Laycock
Analysis and Simulation Branch
of SCAD Division

ATTACHMENT I

FINAL REPORT

POST DOCTORAL PROGRAM, GEORGIA INSTITUTE OF TECHNOLOGY

U. S. Air Force Contract No. F30602-72-C-0118

October 1972

Prepared for

Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York 13440

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

September 22, 1972

FINAL REPORT

AF Contract No. F30602-72-C-0118

1. Synopsis of Work

Dr. Everett

2. Progress to Date

During the period 1 October 1971 to 1 October 1972, efforts under the Post Doctoral Program at Georgia Institute of Technology may be grouped into the following categories:

(1) PDP Administrative Meetings and General Program Development
(2) Electronics Counter Measures (ECM)
(3) Electromagnetic Interference/Pulse (EMI/EMP)
(4) Modeling Digital Communications Systems
(5) Adaptive DPCM Speech Transmission
(6) Consulting Activities

A summary of the efforts in each category are described in what follows.

Efforts in Category (1) include administrative meetings of PDP participants ("senior partners") and subsequent meetings between Georgia Tech PDP participants and Air Force personnel at various laboratories for the purpose of developing programs of research using the PDP mechanism. These efforts include meetings at Rome Air Development Center, Aerospace Research Laboratory, Air Force Avionics Laboratory, Air Force Materials Laboratory, Defense Communications Agency, Air Force Armament Laboratory, Keesler Air Force Base, Data Transmission Company (DATRAN), Purdue University, and the Air Force Academy (Third Annual Workshop of the RADC Post Doctoral Program). Trip reports covering these activities are included as Appendix I. These activities served the purposes of advertising the Post Doctoral Program and identifying possible areas of interaction between educational institutions having considerable technical capabilities and the Air Force laboratories having persistent operational problems. In general, the PDP participants were well-received at the Air Force installations. At least two exploratory development programs (both with Defense Communications Agency) were initiated as a direct consequeuce of these activities. Investigators have, in a relatively short time, become aware of many specific operational problems and are in a very good position to offer constructive proposals for the solutions of some of these problems. It is anticipated that a number of research programs will ensue.

Efforts in Category (2), Electronics Counter Measures, are described

in some detail in Appendix II. Briefly, a number of telephone conversations and meetings at Wright-Patterson Air Force Base were held to address the problem of the limitations of microwave sources in ECM applications. No definite program of research in this area has resulted to date; it is anticipated that none will ensue in the near future. A technical report of the the work accomplished will be prepared jointly by Gilmour (ASD-WPAFB) and Rodrigue (Georgia Tech) and published under separate cover.

Development activities in Category (3), EMI/EMP, include a visit to the Air Force Weapons Laboratory to discuss EMI/EMP effects on cables in aircraft and attendance at the first meeting on the FAA-NAFEC Computer Noise Study in Washington, D.C., and Atlantic City, N. J. R. W. Larson and J. L. Hammond of Georgia Tech were the principal participants. An FAA task has been initiated at NAFEC in Atlantic City which involves Larson at Georgia Tech, Revay (Florida Institute of Technology), Peele (Purdue), and Eveleigh (Syracuse).

Efforts in the area of digital communications have been rewarding. As a consequence of the activities documented in Appendix I, a joint research program involving Georgia Tech, Purdue University, and the Defense Communications Agency in Reston, Virginia, has been initiated. The program is in the area of modeling digital communications systems. The technical progress on this program is being reported under separate cover. Appendix IV contains documentation of the activities in this area conducted under the direct auspices of the PDP at Georgia Tech. Continued research efforts are anticipated in this area with DCA. Principal participants include Hammond at Georgia Tech and Huang and Leon at Purdue.

Efforts in Category (5) have also resulted in a research program involving Georgia Tech, North Carolina State, and the Defense Communications Agency in the area of adaptive differential pulse code modulation (ADPCM) for digital transmission of speech. Bush and Barnwell at Georgia Tech and O'Neil at North Carolina State are the principal participants. Technical progress is being reported under separate cover. Appendix V contains relevant documentation of the PDP activities in this category. It is anticipated that research programs in this area will be continued.

The last category of PDP activities at Georgia Tech include the consulting activities of O. M. Salati at ENT Air Force Base in Colorado, and K. L. Su at Rome Air Development Center, Rome, New York. Salati's activities have been in the EMI/EMP areas and included visits to Peterson Field, ENT Air Force Base, NORAD Cheyenne Mountain, the Air Force Academy, and Kirtland Air Force Base. Letter reports from Salati are contained in Appendix VI. Su spent the summer in residence at RADC to acquaint himself with technical problems and organizational procedures there. His activities included presentations at RADC and the Air Force Academy, and visits to several universities which are participating in the Post Doctoral Program.

3. Participants and Travel

PARTICIPANTS: (All Georgia Tech personnel unless otherwise specified.)

CATEGORY I. Administrative and General Program Development

Dr. D. T. Paris, Director, School of Electrical Engineering
Dr. A. P. Sheppard, Associate Dean of Engineering
Dr. W. T. Rhodes, Assistant Professor of Electrical Engineering
Dr. T. P. Barnwell, III, Assistant Professor of Electrical Engineering
Dr. J. E. Brown, III, Assistant Professor of Electrical Engineering
Dr. R. H. Pettit, Associate Professor of Electrical Engineering
Mr. W. R. Free, Principal Research Engineer
Mr. D. W. Robertson, Principal Research Engineer
Dr. R. P. Webb, Associate Professor of Electrical Engineering
Dr. J. M. Akridge, Senior Research Engineer
Dr. A. M. Bush, Associate Professor of Electrical Engineering
Dr. K. L. Su, Regents' Professor of Electrical Engineering
Mr. H. W. Denny, Senior Research Engineer

CATEGORY II. Electronics Counter Measures

Dr. G. P. Rodrigue, Professor of Electrical Engineering
Dr. H. A. Ecker, Principal Research Engineer
Dr. G. R. Harrison, Principal Research Engineer

CATEGORY III. Electromagnetic Interference/Pulse

Dr. D. T. Paris
Dr. R. W. Larson, Associate Professor of Electrical Engineering
Dr. E. B. Joy, Assistant Professor of Electrical Engineering
Dr. J. D. Norgard, Assistant Professor of Electrical Engineering
Dr. J. L. Hammond, Professor of Electrical Engineering

CATEGORY IV. Modeling Digital Communications Systems

Dr. J. L. Hammond
Dr. T. C. Huang, Purdue University
Dr. B. Leon, Purdue University
Dr. R. Kitahara, Purdue University

CATEGORY V. ADPCM Speech Transmission

Dr. D. T. Paris
Dr. A. M. Bush
Dr. J. B. O'Neil, North Carolina State
Dr. T. P. Barnwell
Dr. R. H. Pettit

CATEGORY VI. Consulting

Dr. K. L. Su
Dr. O. M. Salati, University of Pennsylvania
Dr. P. R. Hirschler, Assistant Professor of Electrical Engineering

POST DOCTORAL PROGRAM

FINAL TRAVEL REPORT 1971-1972

NAME	TRAVEL TO AND FROM	DATE(S)
Barnwell, T. P.	Washington, D. C.	Dec. 2-3, '71
"	Washington, D. C.	April 12-14, '72
Brown, J. E.	Washington, D. C.	Dec. 2-3, '71
Bush, A. M.	Washington, D. C.	Oct. 27-29, '71
"	Biloxi, Mississippi	Feb. 22-24, '72
"	Washington, D. C.	April 12, '72
"	Newton, Mass.	April 23-27, '72
"	Kiamesha Lake & Rome, N. Y.	April 30-May 4, '72
"	DCA - Reston, Virginia	June 26-27, '72
Ecker, H. A.	Dayton, Ohio	Feb. 4, '72
Hammond, J. L.	Washington, D. C.	Mar. 15-17, '72
"	Washington, D. C.	April 25, '72
"	Washington, D. C.	June 1-2, '72
"	Washington, D. C.	June 13-14, '72
"	Washington, D. C.	Sept. 6-7, '72
Joy, E. B.	Denver, Colorado	Jan. 17-19, '72
Larson, R. W.	Washington, D. C.	June 13-14, '72
Norgard, J. D.	Denver, Colorado	Jan 17-19, '72
Paris, D. T.	Rome, N. Y.	Oct. 5-7, '71
"	Washington, D. C.	Oct. 27-29, '71
"	Dayton, Ohio	Nov. 3-4, '71
"	Washington, D. C.	Dec. 1-3, '71
"	Ft. Walton Beach, Fla.	Jan. 12-13, '72
"	Colorado Springs, Colorado	Jan 17-19, '72
"	Biloxi, Mississippi	Feb. 22-24, '72
"	Indianapolis, Ind. (Purdue)	May 7-9, '72
Pettit, R. H.	Washington, D. C.	Dec. 2-3, '71
"	Washington, D. C.	Mar. 8-9, '72
"	Biloxi, Mississippi	Feb. 22-24, '72
"	New York	Mar. 19-24, '72
"	Kiamesha Lake & Rome, N. Y.	April 30-May 4, '72
Rhodes, W. T.	Huntsville, Alabama	June 20, '72
Rodrigue, G. P.	Dayton, Ohio	Feb. 4, '72
"	Dayton, Ohio	April 27, '72
Su, K. L.	Griffiss AFB	June 16,-Aug. 21, '72
"	Colorado Springs, Colorado	July 10-14, '72
Webb, R. P.	Ft. Walton Beach, Fla.	Jan. 12-13, '72

4. Papers, Publications, Presentations

PAPERS: (Copies are included in Appendix VII.)
R. H. Pettit, "Jamming of the Computer Communications Systems," RADC Seminar, 4 May 1972

P. R. Hirschler, "Finite Memory Algorithms for Testing Bernoulli Random Variables."

PRESENTATIONS:

K. L. Su, "Network Synthesis and Applications," Seminar at RADC, 6 July 1972.

K. L. Su, "Symbolic Representation of the Chinese Written Language," Communications - Electronics Workshop, U. S. Air Force Academy, 12 July 1972.

APPENDIX I

Post Doctoral Program Administrative and General Program Development Activities

MEMORANDUM

For limited distribution.

TO: File

FROM: D. T. Paris

SUBJECT: Trip Report

A meeting of Post-Doctoral Program participants was held at RADC, Rome, N.Y. on October 6-7, 1971.

The first day of the meeting was limited to "senior partners" representing six educational institutions. Thus, in addition to Dr. Woodrow W. Everett, Jr., Program Director, present on the first day were:

Bob Cotellessa, Clarkson
Scott Gilmour, Buffalo
Ben Leon and Warren Peele, Purdue
Will LePage, Syracuse
Ron Thomas, Air Force Academy

and myself. Discussion focused mainly on funding,on general operational problems, and specific plans for the coming year. A decision was reached to hold additional meetings of the group as follows:

December 28-29, 1971	Georgia Tech
February, 1972	Keesler AFB
May 8-9, 1972	Purdue
July, 1972	Air Force Academy (Workshop)

(Informal contact with Mr. Vince Palmiero, cognizant Contracts Officer at RADC, revealed that our contract for just under $25k will be in the mail to us next week, but goes into effect as of October 1, 1971. Woodie Everett will put in a request to RADC for an additional two man-year effort at Georgia Tech during this year.)

The second day of the meeting was devoted to discussions with Major Benson of DCA. Present were Cotellessa, Gilmour, Walter Ku (Cornell), Peele, Thomas, Woodie Everett and myself. Major Benson reported interest in the areas of

1. Technical Control
2. Wideband communication systems for graphic equipment
3. Bandwidth reduction
4. Switching at high digital rates

arranged in that order of priority. However, for political reasons and to set a precedent, Major Benson suggests that initially only a single one-man-year project be submitted for funding by DCA. To this end, a two-day presentation in Washington by Post-Doc Program participants will be organized by Major Benson either for Oct. 27-29 or Nov. 10-12 time periods. (Dave Shultz and any other graduates of Georgia Tech who work at DCA could be of help.)

According to Major Benson, the hottest DCA project at present relates to planning (for implementation in 1975) of a new Automatic Secure Voice Communication System. A total of $1,000,000 of R&D maney has been tabbed for this purpose. The project will begin with a complete study of factors that bear upon narrowband and wideband communication systems and will include such areas as Lipreaders, Adaptive Prediction Coders, Digital Vocoders, Kalman coders, Voice Excited Vocoders, Narrowband and Wideband KDC signaling and Transmission Technology, Group Modems, Group Multiplexing, and Wideband A/D Techniques Evaluation.

Consideration is being given to include the Naval Post Graduate School and the AFIT in the Post-Doctoral Program.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

MEMORANDUM

TO: File

FROM: D. T. Paris and W. T. Rhodes

SUBJECT: Trip Report - Wright Field, November 3-4, 1971

1. Al Sheppard, Bill Free (Electronics Division), and Paris visited the Aerospace Research Laboratories in the morning of November 3. Lt. Col. W. M. Hart, Jr., who directs the Plasma Physics Research, described ARL as being the Air Force's major in-house laboratory for basic research. Some outside research presently is being funded but only to complement in-house projects. Col. Hart, (has earned PhD and seemed technically competent) would welcome visits by other, more knowledgeable Georgia Tech personnel (e.g. Hooper and Gallagher, of the Electronics Division) with interests in the plasma - atomic collisions - laser fields. In view of the breadth of basic research being conducted at ARL, members of the EE faculty would most likely profit considerably by establishing one or more contacts with personnel in this laboratory, approximately 70 of whom hold the PhD degree. Organizationally, ARL is subdivided into the following major units: Thermomechanics, Chemistry, Energy Conversion, Fluid Dynamics, Plasma Physics, Applied Mathematics, General Physics, Hypersonic, Solid State Physics, and Metallurgy and Ceramics.

2. Later in the morning of November 3, Sheppard, Free and Paris visited with a Mr. Maynard, who heads up the Microwave Sources Group of the Electronics Technology Division, Air Force Avionics Laboratories. Discussion focused mainly on the recent re-organization of their Division, but Mr. Maynard expressed interest in Gordy's PhD thesis (advisor, G. P. Rodrigue). A Mr. Larry Yarrington, who works for Mr. Maynard, would welcome an opportunity to visit Georgia Tech so that he can see a demonstration of Mr. Gordy's technique. Generally, the Microwave Sources Group is interested in device development (Dale Ray would find areas of common interest.)

3. In the afternoon of November 3, Sheppard, Free and Paris visited with Mr. J. H. Ross, who directs the Fibrous Materials Branch of the Air Force Materials Maboratory. Another branch, i.e. the Electromagnetic Materials Branch, according to Mr. Ross, is interested in ferrite work.

4. Morning of November 4, Sheppard, Paris and Dr. Gilmour (Buffalo U.) met with Dr. Carl Miller, Chief Scientist at ASD. Dr. Miller has provided partial funding for our Post-Doctoral participation, and the purpose of this meeting was to outline areas of mutual interest.

Addendum to AF Avionics Labs trip report: W. T. Rhodes

Wednesday, November 3, 1971

1:30 - 2:30: Talked with Mr. Ken McCoin of the Radar and Microwave Techniques Laboratory about their current and future interests in optical processing research. McCoin was quite cordial. General conclusion drawn from the conversation is that their present and future interests in this area are limited strictly to processing of synthetic aperture side-looking radar data. His laboratory is considering making the investment in a full capability processing facility of their own (approx. $1,000,000). Their outside contracting is almost exclusinvely with the University of Michigan and with Goodyear Corporation, and the chances of breaking into that club appear quite small. Developmental work in other areas involving optical processing of radar signals is being left in the hands of the Laser and Electro-Optics Technology Branch (see below).

Thursday, November 4, 1971

8:45 - 11:30: Had an extended and very pleasant conversation with Dr. Dave Flannery who is in charge of the coherent optical processing activities of the newly established Laser and Electro-Optics Technology Branch of the Avionics Lab. The organizational structure has just been settled and the group still lacks direction to a large degree. Their present emphasis appears to be on real-time processing capabilities, and in-house they are beginning to investigate various IFLM (Image Forming Light Modulator) devices. Some emphasis seems to be placed on optical processing of radar signal information, though they have no clear idea as yet of the problems to be solved. Though the budget for Flannery's group is presently small (through fiscal year '72-'73) there are indications that it will grow. He appeared quite willing to cooperate to the extent he was able should a solid proposal-worthy idea be generated here.

There are a number of people in that laboratory branch interested in space qualified communication laser systems, and a substantial amount of money is being spent in this area. A special report will be prepared for Professor Callen on this subject.

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SCHOOL OF
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December 7, 1971

MEMORANDUM

TO: File

FROM: D. T. Paris

SUBJECT: Trip report; Washington, D. C., December 1-3, 1971

Evening of December 1, 1971. - Woody Everett and I discussed Post-Doctoral Program (PDP) matters concerning the forthcoming Atlanta meeting, monthly and quarterly reports, consultants, and PDP customer work. The present contract is being augmented by $10K, for which an additional DD 633 form and brief statement of work must be submitted to RADC. The DCA work, presently anticipated at a level of 6 to 8 man-years for one year beginning January, 1972, (of which 2 1/2 to 3 1/2 man years is slated for Georgia Tech), will have to be handled through new contracts with participating universities.

Morning of December 2, 1971. - Woody Everett and I discussed various Automatic Data Processing (ADP) technology forecast issues and problems with Mr. Harry Smith and Major Benson of DCA. Initial phase (first six months in 1972) will concentrate on a program for determining AUTODIN (i.e. Automatic Digital Network) modifications to accommodate ADP. The first crucial deadline is January 31, 1972, when the requirements data base must be established. Formal approval for funding this effort was anticipated during the day.

Meanwhile approval for a two-manyear effort on Tech Control had been obtained. Ben Leon (Purdue) will be the project manager, and subject to his approval, Joe Hammond (who earlier had prepared a detailed proposal) may be supported under this program from one-half man year to a full man year level during the first year.

In addition, a two manyear effort on Adaptive DPCM Speech Transmission Study seems certain from a funding point of view. Aubrey Bush will be the project manager, with Ben O'Neil (and up to three other post-docs at N.C. State) acting as consultants on the project at a level not to exceed 0.8 manyear for all four consultants combined.

Major Benson would invite a write-up from Aubrey Bush on the problem of direct conversion from voice to digits. Such things as current work, feasibility, and method of attack should be discussed in the presentation. (Any other topics directly related to future communication systems, lasers, etc. could also serve as suitable subject for presentation). This information should be sent directly to Major Benson.

(A side trip at noon to NSF revealed that the instruction books on the preparation of undergraduate instructional equipment will not be ready for another two weeks or more.)

Afternoon of December 2, 1971. - Woody Everett, Jose Perini, and I held technical discussions with Mr. Besin concerning FAA supported work at Syracuse (Perini) and Cornell (Ku).

Later the same afternoon, Woody Everett and I spent considerable time discussing possible EMP effects on FAA facilities with Mr. F. S. Sakate. FAA goal in this regard is a status report by May 1972 on what is feasible; PDP may well get involved in this work. Mr. Sakate will be invited to the Atlanta meeting of the PDP. (He received his MSEE from Georgia Tech in the late forties; his daughter has been admitted to Georgia Tech and plans to enroll as EE freshman next fall.)

A FAA announcement is pending within the next two weeks on the award of the Grounding, Bonding, and Shielding study effort.

Evening of December 2, 1971. - Barnwell, Brown, and Pettit joined me and Everett, Peele (Purdue), Lancaster (AFA), Gilmour (Buffalo), Leon (Purdue), Cotellessa (Clarkson) and Pervini (Syracuse) for general discussions concerning PDP matters.

December 3, 1971. - DCA Workshop: program attached. Most persons in attendance were civil service personnel. Doug Robertson of the Electronics Division, joined the PDP group. At the end of the day, Mr. Harry Smith announced that the PDP has been "retained" to work on the total ADP problem. Woody Everett then gave a brief description of the program.

ADDENDUM BY PROFESSOR JAMES E. BROWN, III

Summary of Workshop

The theme of the Electronic Data Processing-Telecommunications Planning Workshop, held at the Headquarters of the Defense Communications Agency (DCA) on 3 December 1971, was "Telecommunications Switching Concepts and Requirements." The purpose of this workshop was to exchange ideas and present the key issues that are confronting DCA in the computer-communications area. The workshop considered current telecommunications switching schemes available for data communications, reviewed enhancement programs related to these schemes, and correlated the schemes with future requirements to support on-line computer based systems.

Presentations from selected industrial firms and government agencies were scheduled to highlight the key issues related to the workshop theme. The industrial firms represented were DATRAN and TYMESHARE. DATRAN discussed their plans for installing a nation-wide communications network for providing realiable, high-speed digital communication to the major U.S. cities. TYMESHARE discussed their communication network which connects computer centers across the country. DATRAN's system is to be a competive network to the Bell System while TYMESHARE uses the existing Bell System communication network to link computer centers to potential users.

The government agencies represented were the Communications Operations Division Headquarters (USAF), Joint Technical Support Activity (JTSA) of DCA, and Research and Development Division of DCA. The various existing computer-controlled communications systems managed by the DCA were discussed with respect to current capability, use, and data transmission requirements such as volume of the traffic, data-rate requirements, priority considerations, and security problems.

The objective which we have been presented is to identify and confirm the parameters for telecommunications switching requirements for consideration in future planning for the Defense Communications System.

Impressions

It was apparent from the conference that the existing military communications networks are inadequate for the volume of traffic they desire. There appears to exist three alternatives to the military's dilemma:

a) Scrap the existing systems and start anew;
b) Make the existing systems more efficient by
    i) improving the encoding-decoding of information
    ii) reduce the amount of information that needs to be transmitted;
c) Develop an additional communication system network to add to the existing systems.

The primary consideration to which alternative is adopted, I suspect, will be the monetary one (which suggests alternative (b)).

It also appears that the military favors digital communication as opposed to analog communication. The reason for this is probably obvious: digital communication can be made more reliable, easily allows the use of digital computers, and enables coding of the message for security purposes. The emphasis on digital communication lends additional importance to the speech encoding (vocoders and linear predictive coding) work being done at Georgia Tech.

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January 17, 1972

MEMORANDUM

TO: File

FROM: D. T. Paris

SUBJECT: Trip report USAF Armament Laboratory, Eglin AFB, Florida, 1-13-72

Participants (in addition to writer) :

James M. Akridge, Senior Research Engineer, Chemical Sciences and Materials Division, Engineering Experiment Station
Albert P. Sheppard, Associate Dean for Research, College of Engineering
Roger P. Webb, Associate Professor of Electrical Engineering

1. Major Harold Pfeifer and Leo Wilson, Terminal Ballistics Branch

Keen interest was expressed in new ideas and devices to measure temperature (2000° F max) and pressure under transient conditions (milliseconds) for assessment of behind-the-target environment. Approximately 60-75% of the branch effort is contractual.

2. Mr. Clinton Varnado, Weapons Compatibility Branch

Major problems relate to rf interference with fuse circuitry. He plans to contact Warren Peele (whom he knows personally) to exchange views on RFI and EMP.

3. Lt. Col. Jack A. Graff and 1st. Lt. Karner, Guidance and Control Modules Branch.

Have recently been assigned the responsibility to develop in-house capability in guidance and (digital) control. Electro-optics is a major element of this effort. Lt. Karner plans to send Professor Webb a copy of an RFP next month on a new controls project.

4. Mr. Vito W. Marinelli, Fuses Branch

Most of the technical discussions focused on electro-optical fuses.

5. Dr. Bernard Kulp, Chief Scientist

Laboratory has capability in systems analysis, starting an effort in controls, and terminal guidance offers the most pressing problems.

6. Major Bill Miller, Product Assurance Division

The work of this division did not seem to be pertinent to electrical engineering

Brief presentations concerning the Post Doctoral Program were made to all persons visited, with the exception of Major Miller. They all expressed varying degrees of interest in the possibilities offered by this program.

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February 28, 1972

MEMORANDUM

TO: D. T. Paris

FROM: R. H. Pettit

SUBJECT: Trip Report; Keesler AFB PDP meetings; Biloxi, Mississippi
February 23-24, 1972

The following is a summary of the events, discussions, meetings, etc. of the Keesler AFB PDP meetings, with Professors Paris, Bush, and Pettit attending from Georgia Tech. Joining the group of Principal Investigators were Dr. Bruce Mathews and Dr. Ed McCarter of Florida Technological University, Orlando, Florida, and Dr. Harry Weber and Andy Revay of Florida Institute of Technology.

Morning of February 23 - This session was devoted to PDP business discussions and was attended only by the PDP principal investigators and some PDP post-doctoral participants. All senior partners were given an opportunity to report on new developments in contact/contracts. Major Lancaster and Dr. Paris reported on efforts to interest the Military Academy in the PDP program and its usefulness in attacking persistent operational problems of the U.S. Army. Dr. Paris also reported on his visit to Eglin AFB and Kirtland AFB for the purpose of developing contacts there.

Dr. Everett then reviewed for the principal investigators the continuing business for each school for the next year. He reported that the proposed DCA project funding had not been approved by the contract review board at the time of presentation by Harry Smith. However, it is believed that the projects must still be undertaken, although probably on the basis of several smaller projects instead of one large project. Georgia Tech will continue its efforts along these lines. Final decisions may be known by the end of May.

The remainder of this session was devoted to the preparation of a detailed agenda for the technical session of the following day, a report by Dr. Leon on the Purdue Symposium (May 8), and a report by Major Lancaster on the preliminary plans for the AFA Workshop (July).

Afternoon of February 23 - A continuation of the business meeting of the morning. Dr. Everett stated that a trial project involving Kentucky, Clarkson, FTU, and FIT would be initiated in the Fall, 1972, in which PDP trainees would take their graduate courses at more than one school, while participating in PDP research. Some senior partners expressed the view that many problems would be involved in this project, so that the participants should make careful studies and plans before actual invitiation. The rest of the afternoon involved various miscellaneous discussions among the attendees, with several agreeing to discuss with appropriate Keesler AFB representatives their desire to obtain accreditation for their technological training programs.

Morning of February 24 - This was the first part of a technical program presented by PDP participants to PDP customers and, primarily, to officer students in the Keesler Communications/Electronics schools. Many of the students hold BSEE degrees and some hold MSEE degrees. Part of the introductory remarks were made by Colonel Reginald D. Fifer, Jr., who is the Deputy Chief, Plans and Programs, Directorate of Command Control and Communications, HQ. USAF. Col. Fifer is a strong advocate of the PDP approach. In July, he will be assigned to DCA.

After some introductory remarks, Dr. Everett made a brief presentation concerning the nature and objectives of the Post Doctoral Program.

The technical sessions consisted of nine informal presentations. Dr. Leon discussed the network/systems control area. Mr. Peele presented some results on inter-systems effects (Cheyenne Mountain). Dr. Perini's topic was Antenna Pattern Distortion/Antenna Farms. Dr. Ku then discussed some of his work in the design of solid state devices and in the modelling of noise sources. The last speaker before the lunch break was Major Lancaster who described the role of the AFA in the PDP.

Afternoon of February 24 - Continuing the morning's technical program, Dr. Bush discussed voice digitization and Speech Compression work at Georgia Tech. His presentation was very well received by customers and C-E students alike. Dr. Cotellessa described some fundamentals of digital spectral analysis techniques, followed by Dr. Gilmour with the topic of High Power Effects/ Switching. The last technical presentation concerned intra-system analysis by Dr. Paul.

Invited guests, attending the presentations on the second day, included the following:

Mr. Fred S. Sakate - FAA
Mr. Charles J. Andrasco - FAA
Mr. Y. S. Fu - AFCS
Dr. Phil Stover - Wright-Patterson AFB

Dr. Stover was contacted by Dr. Paris concerning Georgia Tech's plans to submit an unsolicited proposal involving high power switching studies.

GEORGIA INSTITUTE OF TECHNOLOGY
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March 15, 1972

MEMORANDUM

TO : D. T. Paris

FROM : R. H. Pettit RHP

SUBJECT: Trip Report. Data Transmission Company (DATRAN); Vienna, Va., March 9, 1972.

I have decided to take this opportunity to summarize some general information in the area of data communications, which I believe will be of interest to the faculty, as well as to present some details of my visit to DATRAN on March 9th. Accordingly, I have chosen to divide this report into the following sections:

A. General Information Concerning Data Communications
B. Brief History of DATRAN
C. Discussion of Visit of March 9th
D. Results from the Visit

A. General Information Concerning Data Communications

There can be little doubt now that a revolution is coming in the field of data communications. In 1961 the president of AT & T predicted that by about 1975, the volume of information communicated between machines will be greater than the amount of information communicated between people. Recent studies still support this prediction. Dramatic growth of data transmission averaging 30% to 39% per year is indicated for these seven key industries: securities, insurance, manufacturing, banking and finance, retailing, health care, and information services. Another indication of the growth is the expectation that the number of data transactions will increase from the 14 billion of 1970 to 250 billion by 1980, a growth of 1650%. Dollar projections indicate that by 1980 data transmission will exceed $2 billion, exclusive of voice, video and picture transmission; by 1985, between $5 and $10 billion. The existing telephone company network, designed for voice communications, cannot accommodate these requirements -- hence DATRAN (and others!).

B. Brief History of DATRAN

The beginning of DATRAN traces back to 1966, when University Computing Company, a $23 million computer services company (now doing $125 million) felt constrained by available communications. First, it attempted to buy a large block of Western Union stock so as to influence the direction of that company. This failed. This was followed by a company feasibility study on the development of a new data network, which was quite positive, leading to a market study in early 1968, also highly favorable. Thus, Data Transmission Company (DATRAN) was formed as a subsidiary of UCC. The next two years were devoted to additional studies of market needs and growth, computer models of the data markets, various possible communications networks, and the financial structure of the company. In November, 1969, DATRAN applied to

the FCC for permission to proceed with the network as a specialized common carrier. The idea of competition in this regulated industry has been quite unsettling to some, as can be easily imagined. Bell has announced intentions to build a separate data netowrk for service in 1980. Western Union is proposing a new network of its own. DATRAN's plan calls for their initial network, serving 35 metropolitan areas across the country, to be in operation by the end of 1974. I was told at the meeting that final FCC approval to proceed is now expected this month.

To date, DATRAN has gambled about $12 million. This has been held to a minimum by the company's assuming a primary role as system integrator and working with firms like Stromberg-Carlson, Martin-Marietta, Collins, Raytheon, etc. as suppliers. They expect an investment of $400 million for their initial network. Their proposed nationwide all-digital switched network consists of a microwave trunking system, computer-controlled switching centers and local distribution systems expecially configured for each of the 35 metropolitan areas. This local distribution may involve short-hop microwave links, cable, and/or optical transmission. The network will be able to accommodate several different data rates, with error rates less than 1 in 10^7. A total of 259 microwave relay and terminal stations will be constructed initially.

C. Discussion of Visit of March 9th

I was received by DATRAN officials in a most courteous and warm manner, obviously due in part to the desire of DATRAN to participate in the designing and planning of any new networks set up by DCA to handle military data transmission requirements. DATRAN is aware of possible participation by Georgia Tech, thru the PDP program, in studies of DCA possibilities along these lines, and recognizes that we may have some influence there as a "disinterested third party." However, I also believe, perhaps naively, that I was being received well, just as a representative of Georgia Tech who is interested in their technical activities.

Mr. David E. Gourley, Vice President for Marketing, and Dr. Loren A. Benson, Chief Scientist, spent considerable time with me. They gave me a review of the company's history, its current status with FCC, its market projections, and described how they will use computer models to schedule the network implementation and to evaluate and monitor the network's construction. It was interesting to see computer generated maps of customers which show things like the distribution of banks in the country, or the distribution of computer users in San Francisco, etc. They use the computer to evaluate proposed microwave sites from the point of view of interference with existing microwave and/or satellite systems, etc. They have what appears to be an extremely efficient operation.

I next visited with Mr. Charles R. Fisher, Director of Switching Systems Engineering, who gave me a run-down of some of the technical details of the system and gave me a tour of their somewhat limited laboratory facilities. One of the interesting experiments being performed involves the optical transmission of test data to the roof of the nearby Holiday Inn and back, on a continuous basis. From this they hope to gather sufficient meaningful data as to the effects of rain, fog, sleet, etc. on optical transmission to permit consideration of optical links as part of the proposed local distribution systems.

D. Results from the Visit

Ultimately, perhaps the most useful result of the visit will be in the reports and publications that I was given for later study, as time permits. I have a copy of each of the following:

(1) "DATRAN System Description and Operation," approximately 40 pages.

(2) "Comments of DATRAN Before the FCC," October, 1970, 118 pages.

(3) "Before the FCC - Final Commission Order Docket No. 18920," approximately 175 pages of report on the DATRAN application, etc.

(4) Several miscellaneous papers concerning various aspects of DATRAN.

It is hoped that ideas for research proposals will ultimately be generated from these, through DCA or others as appropriate. I plan to investigate the possibility of offering as a Senior Elective a course describing these very exciting new developments in telecommunications. These developments, when incorporated in our present courses, should be of great significance in motivating and exciting our students. A side result of the visit was the tentative arranging of Mr. Fisher's visit to Atlanta in October, 1972, to present a talk to the local IEEE COMTECH Group.

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SCHOOL OF
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April 3, 1972

MEMORANDUM

TO : D. T. Paris

FROM : R. H. Pettit

SUBJECT: Trip Report - IEEE Convention (March 20-23, 1972) and Bell Labs (March 24, 1972)

There was a full slate of high quality technical sessions at IEEE dealing with communications, with particular emphasis this year on computer-communications interaction.

One of the most interesting sessions was "Communications - Tomorrows Substitute for Transportation", consisting of four papers and a panel discussion. One dealt with the proposition that industrial and office robots and remote communications networks can enable many workers to perform their jobs from remote control stations at or near their homes. The suggested benefits include:

1. Additional income opportunities to depressed areas in both rural and urban ghettos
2. Decreased conjestion, frustration, expense, and pollution caused by commuting
3. Reduced problems of regional unemployment
4. Relief of pressures for rural to urban migration
5. Creation of unlimited potential for education, job training, and entertainment.

Such a national remote employment program would require great efforts in communications, control systems, electronics, and computers, with great benefits to the national economy, the engineering profession, and the average citizen. One of the panelists, having just studied such possibilities for the Seattle area, expressed a firm conviction that new rapid transit systems will be white elephants to the public long before they are completed. Perhaps we can do some work along these lines through the office of Transportation, or even conceivably with MARTA, although this approach seems completely at cross-purposes to MARTA.

Another particularly good session was "New Areas in Communications". One paper reported on Purdue's current work with their state agriculture department in which earth resources sensors in airplanes (and later, in satellites) provide information for crop prediction and classification, measurement and mapping of thermal pollution in rivers, tree species identification, etc. An entire session will be devoted to this subject at the International Communications Conference in June. It appears reasonable that we could work on similar problems with the University of Georgia and our Georgia Department of Agriculture in providing the communications, data processing, etc. technical know-how for the benefit of our own state.

I have a copy of the 1972 IEEE Digest which contains abstracts of all of the papers presented at the conference. Members of the faculty are of course welcome to use it as they see fit.

On March 24, I visited Dr. Jack Salz in the Advanced Data Communications Department of Bell Labs, Holmdel, New Jersey, for the purpose of discussing their current research efforts in communications, with particular interest in the coming computer communication networks. I had short discussions with Drs. R. D. Gitlin, R. W. Chang, and J. F. Hayes and obtained detailed information about their current research efforts. (These gentlemen are working with Dr. Salz.) From the discussion with Jerry Hayes, I have better ideas of the types of theoretical problems that DCA is likely to be interested in, and which we can propose studying at the appropriate times. In particular, the areas of switching configurations seems ripe for attack, with many technical questions to be answered.

Another result of my trip is the conviction that the ideas associated with these new areas of communications should be introduced into our curriculum as soon as possible. I plan to develop a proposal for our curriculum committee for a senior elective course dealing with these coming developments in telecommunications. The course would be expected to provide maximum excitement and motivation for the student. In addition, I would like to make plans for a graduate course which concerns nationwide/global communication networks of the type being developed and discussed for DATRAN and DCA.

RHP/nm

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

May 11, 1972

MEMORANDUM

TO: File

FROM: D. T. Paris

SUBJECT: Trip Report - May 7-9, 1972

A meeting of Post Doctoral participants was held at Purdue University at 8:00 A.M. on May 8, 1972. Items discussed included new and potential customer contracts, contract renewals, and Air Force Academy Workshop. Of specific interest was the fact that the new contract with Georgia Tech went out from RADC for signatures on May 1, 1972. The initial funding level is $129,600.

The Air Force Academy Workshop will take place on July 10-13, 1972, with limited presentations by Post Doctoral people; most of the talks will be made by potential customers. I was asked to make the presentation on behalf of Georgia Tech on July 12. (Inputs from various Georgia Tech faculty will be needed for this purpose.) Attendance will also be limited because of space limitations. It was projected that either two or three faculty will represent Georgia Tech.

I had a long conversation with Woody Everett on the morning of May 8 concerning Georgia Tech's contributions to the Post Doctoral Program, and allocations of funds for same. One new item of business concerns the recent allocation of $50,000 from FAA to conduct noise investigations on computer equipment at Atlantic City, N. J. It is thought that Professor Larson will be the most likely candidate for this assignment.

A total of five papers were presented by EES personnel at the Purdue 1972 Symposium on Electromagnetic Hazards, Pollution and Environmental Quality.

DTP:jms

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

23 June 1972

MEMORANDUM

TO: File

FROM: W. T. Rhodes

SUBJECT: Report on Trip to Marshall Space Flight Center, Huntsville, Alabama, on June 20, 1972.

Purpose of trip was to discuss with Joe Kerr of the Astronics Laboratory the proposal I am presently preparing: "Systems and Techniques Development for Optical Processing of Satellite and Aerial Earth Resources Photographic Data."

Both he and John York of his group had suggestions relating to the emphasis of the proposal and projections of Kerr's activities during the coming year.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

July 25, 1972

MEMORANDUM

TO : File

FROM : A. M. Bush and D. T. Paris

SUBJECT: Trip report; Air Force Academy Workshop, July 10-13, 1972

I. PDP Business meetings; July 10, 4:00 P.M. and July 13, 3:00 P.M.

1. Total of '72 business $1,168,000
2. Funds must be depleted by the end of the contract period; i.e. by Oct. 1, in the case of our first contract. Also, $24,000 from RADC must be spent by Dec. 31.
3. Possibly, only three contracts will be negotiated starting next year. Georgia Tech will be the nucleus for the Southeast and will let out subcontracts.
4. Next PDP meeting will be in February at Keesler. Ray Pettit most likely will be asked to talk on ADP.
5. Dr. Everett's desire is to keep a ceiling on all sponsors to 25% of the total PDP business.
6. Each lead man is responsible for quarterly reports to customers
7. List sponsors as co-authors on papers published

II. Business meetings with sponsors

1. Information on these is contained in attached schedule
2. Major Benson would like to know when visits are made to SEF ahead of scheduled time.

III. Workshop - Attached:

1. Agenda
2. List of attendees
3. A. M. Bush's report

DTP/nm

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

July 25, 1972

MEMORANDUM

TO : D. T. Paris

FROM : A. M. Bush

SUBJECT: Trip Report

The Third Annual Workshop of the RADC Post Doctoral Program was held at the Air Force Academy in Colorado Springs July 11, 12, 13, 1972. A list of attendees is attached. Georgia Tech was represented by

D. T. Paris
A. M. Bush
K. L. Su
H. W. Denny

The program format attached was followed with minor changes.

In addition to informal discussions between attendees, resulting in better understandings of objectives in projects we are already involved in, formal discussion sessions with prime sponsors were held at lunch, dinner, and in the evenings.

The following observations were noted:

- The next Workshop will be held at Keesler AFB in February, to be contiguous with Mardi Gras.

- The summary talks did not seem to me to be as well received as the technical talks. Woody and "managers" should in the future give this information. Other talks should be more technical. If a new customer is attending, of course, strategy will be changed.

- Benson has 12 mo. more at DCA.

- DCA Task 12423 Auto Intelligibility Test for Auto Sevocom, unless classified, would be in line with our interests.

- Realignment of PDP for better management.

- Consortium.

AMB/ded

Attachments (2)

APPENDIX II

Post Doctoral Program Development Activities
in
Electronic Counter Measures (ECM)

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

ELECTRICAL ENGINEERING

February 8, 1972

MEMORANDUM

TO : D. T. Paris

FROM : G. P. Rodrigue

SUBJECT: Trip Report (WPAFB)

On Friday, February 4, I visited several individuals at WPAFB with (from time to time) Drs. Ecker and Harrison of Electronics Division.

We met for about one hour with Jim Kastle and Chuck Hoey (EW). Their interest is in the ECM area. In particular they are interested (obsessed?) with the problem of microwave sources. The Air Force will initiate a tube exploratory development program in FY73, and they wanted Georgia Tech to become familiar with it and respond if possible. They will send us a background, survey report that we should read before pursuing program. (This is a rather involved program in personnel and background and I'd be happy to amplify conversationally. It is potentially a big program, $1M.)

Later in the a.m., Scott Gilmour, Carl Miller (ASD), Alan Ecker, and I discussed the Post Doc. ECM area. Miller outlined his interests and problems, and Gilmour and I will get together a letter outlining a proposed effort for this Post Doc. task.

In the p.m., we met with Don Rees and Bill Edwards (Avionics Lab). An existing program at EES was discussed briefly. We also mentioned this ECM-tube program. Edwards group (in particular Sonny Maynard) will be involved as the contacting agency for this effort.

All three groups -- Miller, Hoey, and Edwards -- will be involved in the tube research program. Georgia Tech is in pretty good shape on this in spite of lack of experience because (1) our students have behaved (as opposed to Stanford, Michigan, Johns-Hopkins) and (2) several of us have known these people at WPAFB for some time.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

May 1, 1972

TO: D. T. Paris
H. A. Ecker

FROM: G. P. Rodrigue

SUBJECT: Trip Report (ASD-WPAFB) 4/27/72

Very briefly, the day was a loser, and we again did not emerge with a statement of work. I did get a picture of the ASD organization in that area and it is attached. If interested in gory details, keep reading.

Scott Gilmour, Dave Lockett (both of SUNYAB) and I met with Don Laycock (ASD) for most of the AM and some of the PM. Lockett was with Gilmour on another mission for Carl Miller on Microwave acoustic delay lines, has no clearance, and sort of oscillated in and out of our meeting. A long and rambling discussion ensued from which I formed the following opinions.

Gilmour and Carl Miller used to work together at CAL. Miller wanted to have Gilmour work with him (consult) but had no way to do so. The Post Doc program was a solution. Miller must, however, show a "product" received for the money that is good for the ECM people. (He has no consulting $.)

Somehow Miller asked Laycock to "manage" the effort (i.e. generate the product). Not that Laycock doesn't work for Miller (see chart). Laycock seems to feel that the sort of thing Gilmour and I propose should be done with in the Air Force, and fairly obviously sees no real need or justification for it outside. The difficulty in generating a work statement for Carl Miller is perhaps obvious!

I suggested we compile a set of generator requirements based on 1) Present Air Force inventory 2) Planned Development programs 3) Long range threat predictions. I also mentioned the possibility of tying in effectiveness in a possible extension or enlargement of the effort. Laycock said threats were well known far in advance as were prime powers but made further comments.

It was all left rather up in the air. Laycock is to try again on the work statement and be in touch with us. It is not probable that we could get his sponsorship at ASD to open up the doors necessary to collect the information needed for (1) and (2) above.

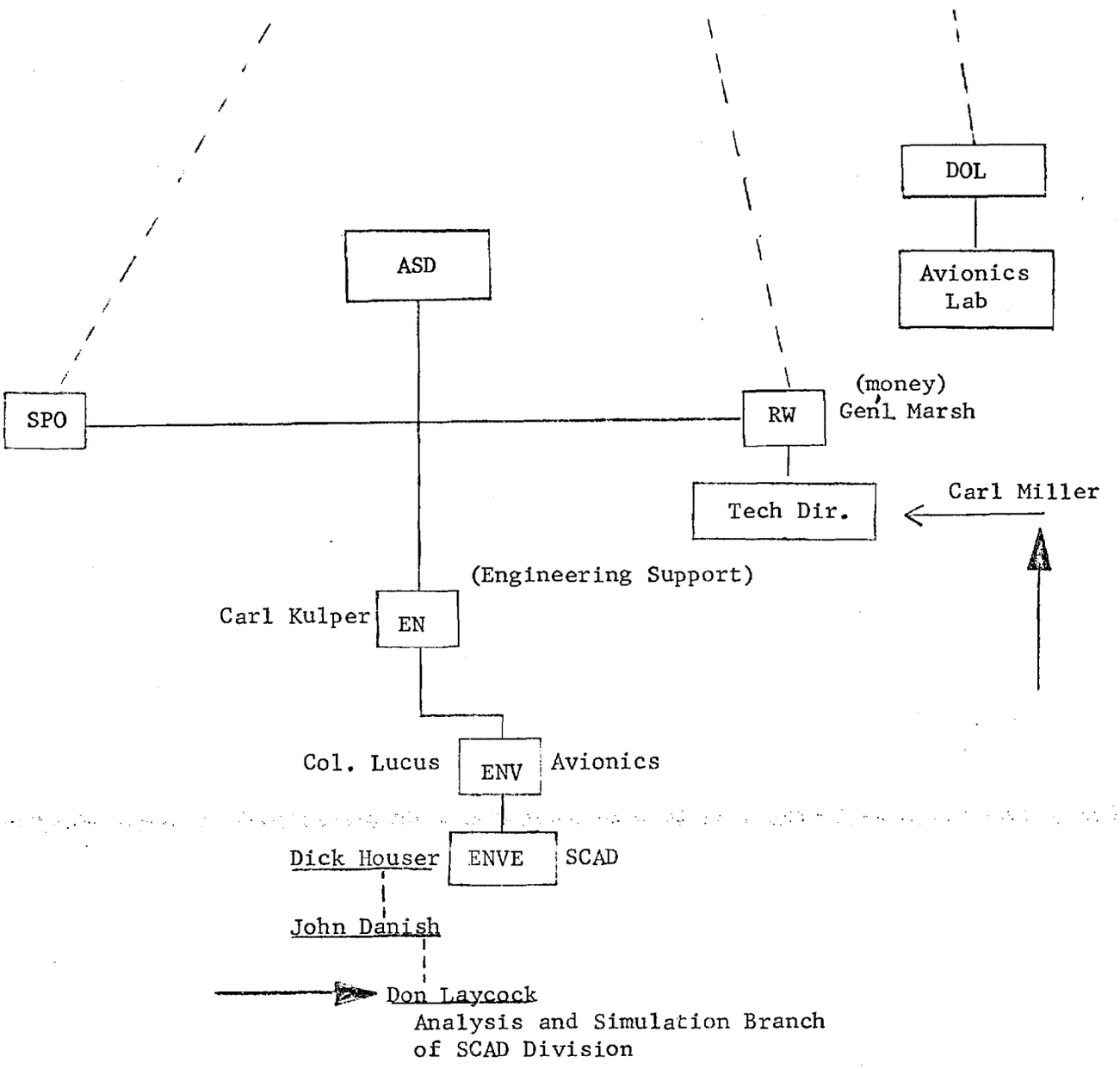
Laycock is a non-believer in expendables. He has been with ASD about 3 years (no prior tube experience). He is in a supporting role with SCAD where he spends about 1/2 time. He is technical monitor for tube development work sponsored through CAL. Laycock feels surveys of the microwave tube industry are quickly obsolete and should be avoided.

Tube work gets sponsored by:

SPO
SCAD
F-15
B-1
RW
Labs-Helberg-Edwards, etc.

A Dr. Yarington (young Ph.D.) has been hired to work with Sonny Maynard in tube work.

Gilmour sits in on meetings of the Working Group on Microwave Devices. Bill Edwards and Lou Kiosa are members of that group.


DOL
Avionics Lab
ASD
SPO
RW
(money)
Genl Marsh
Tech Dir.
Carl Miller
(Engineering Support)
Carl Kulper
EN
Col. Lucus
ENV
Avionics
Dick Houser
ENVE
SCAD
John Danish
Don Laycock
Analysis and Simulation Branch
of SCAD Division

APPENDIX III

Post Doctoral Program Development Activities
in
Electromagnetic Interference/Electromagnetic Pulse Areas

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA. GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

January 20, 1972

MEMORANDUM

TO: File

FROM: E. B. Joy, R. W. Larson, J. D. Norgard, D. T. Paris

SUBJECT: Report of trip to Air Force Weapons Laboratory (Kirtland AFB) and NORAD (Colorado Springs) on Tuesday, January 18 and Wednesday, January 19, 1972.

I. Tuesday, January 18 (AFWL)

A. 8:00 - 10:00 A.M., discussion mainly with Captain Larry West. Also attending: Lt. Col. Marvin Barth, Major Tom Hinrichs, Major E. G. (Lindy) Royer, Capt. Mike Baran and Lt. Dan Higgins.

Principal topics of discussion:

1. Interaction of EMP, especially with cables.

2. Transfer functions in the circuit sense. (Models should give R,L,C equivalent circuits.)

3. Assess hardness of systems (pre-manufacture modeling and post-manufacture testing).

4. Principal interest: aircraft, cables.

5. Pulse characteristics - double exponential $\Delta f \sim 100$ MHz, $E \simeq 10^4$ v/m, (must integrate over all frequencies).

6. Bundle characterization validity question.

7. Method of attack:

   a) Factorization (especially of leakage problem)
   b) Test design and data analysis (worst case)
   c) Failure threshold
   d) System modeling (parametric analysis)
   e) Assessment of system

8. Aperture coupling and skin currents (radomes, doors, windows, wheel wells, cockpit, etc.)

B. 10:00 A.M. - 12:00 Noon. Mainly discussion with Dr. Carl Baum with many of above group present (except West).

1. Blast characteristics:

   a) Three types
      1) 5-30 Km
      2) low altitudes
      3) high altitude $\sim$ 60 Km and above

   b) Biggest interest in high altitude (cover county)

   c) Use $e^{-at} - e^{-bt}$ (Rise in 4 - 8 nanoseconds)

2. Problem Areas (covered since 1962):

   a) Sensors, ($\frac{dD}{dt}$, $\frac{dB}{dt}$, $\frac{dI}{dt}$, E, B, etc.)

   b) Simulators (Parallel plate, vertical dipole, etc.)

   c) Interaction (theory, parametric studies)

3. Interaction Details:

   a) Macroscopic (skin currents on aircrafts, missiles)

   b) Aperture problem

   c) Cable problems

4. Investigator requirements:

   a) Capability

   b) Simple results

   c) Speed (high value of words/$)

5. References:

   Simulation notes 30, 65, 100

6. July meeting of IEEE on EMP in Albuquerque (see announcement)

C. 1:00 - 3:00 P.M. Visits to Simulators

   1. Vertical Dipole (Pseudo - conical, resistively loaded)
   2. Ground wave launcher for silo testing
   3. ALECS - parallel plane
   4. ARES - parallel plane, double wedge

D. 3:00 - 4:00 P.M., Sensors

   1. Tour by Mr. O'Neill
   2. Viewed many types of sensors

E. 4:00 - 5:30 P.M. - Return to Carl Baum's office

1. Sensors, especially model suppression
2. Singularity Expansion

   Partial fraction expansion of structure and transient function, numerical inversion, principal terms, coefficient of coupling.

F. Action:

1. Send biographies, theses, reports, papers, etc.
2. Possible proposal letter
3. Georgia Tech visit by Baum (March?)
4. Faculty summer position

II. Wednesday, January 19, 1972 - Mainly with Warren Peele and Lt. Larry Corey

A. 7:30 - 8:30 A.M. - Dr. John Sterrett, Scientific Advisor, ACS/C & E

1. Discussion of ground penetration urgency at NORAD
2. SAC vs NORAD priorities

B. 9:00 - 11:00 A.M. - Tour of Cheyenne Mountain

1. Waveguide entries
2. Granite attenuation (1100 ft → 10db@ 2KHz)
3. Bonding, grounding, shielding examples
4. Telephone cable input from "soft" radar (also, power & communication cables)

C. 11:30 - 12:30 - Tour of Air Force Academy with Major Royer.

MEMO TO: Dr. D. T. Paris

FROM: Dr. R. W. Larson & Dr. J. L. Hammond

SUBJECT: Report on trip to Washington, D. C. and Atlantic City, N. J., June 13 and 14, 1972.

This trip was to attend the first meeting on the FAA-NAFEC Computer Noise Study. The attendees and their affiliations at the June 13 and 14 meetings were (showing by "1 & 2" the attendance on the 1st and 2nd day):

CDC Noise Investigation NAFEC

Attendees

Name	Organization
Larry Snyder (1 & 2)	MITRE
William Grinnell (1 & 2)	MITRE
Scott Gilmour (1 & 2)	SUNY @ Buffalo
Roger T. Stevens (1 & 2)	MITRE
W. R. Sousa (1 only)	MITRE
Sid Koslow (1 only)	MITRE
Robert E. Thompson (1 & 2)	MITRE
Ray Barkalow (1 & 2)	FAA
Fred S. Sakate (1 only)	FAA
Joe L. Hammond (1 & 2)	Georgia Tech
Ron Larson (1 & 2)	Georgia Tech
Andy Revay (1 & 2)	Florida Institute of Technology
Virgil Eveleigh (1 & 2)	Syracuse University
Warren Peale (1 & 2)	Purdue University
Woody W. Everett (1 & 2)	RADC Post Doctoral Program
Edward Quish (2 only)	NAFEC NA 140
Ken Nicholls (2 only)	NAFEC NA 140
Paul O'Brien (2 only)	NAFEC NA 140

The main purpose of the first meeting was to acquaint the post doctoral participants with the general nature of the noise problem experienced with the CDC (Computer Display Channel). After the presentation, it still seemed to be an inexplainable phenomenon.

On the second day, the actual facility was visited in Atlantic City. This was a very impressive installation, but no specific solutions were made apparent. The next step is to obtain further data concerning specific errors.

APPENDIX IV

Post Doctoral Program Activities
in
Digital Communications: Modeling Digital Communications Systems

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

March 21, 1972

MEMORANDUM

TO: Dr. D. T. Paris

FROM: J. L. Hammond

SUBJECT: Trip Report; Visit to Sponsor at DCA Reston, Virginia, March 15-17, 1972.

Drs. Leon (Purdue), Huong (Purdue) and Hammond (Ga. Tech) participated in discussions with DCA personnel on March 16 and 17. We arrived in the Washington area late in the evening of March 15 and left in the early afternoon of March 17, 1972.

The visit, the second for Drs. Leonard Huong and the first for Hammond, was for the purpose of outlining the scope and nature of the PDP - DCA project in the technical control area.

We were briefed by Mr. Plotkin of the Defense Communications Engineering Office (DCEO) and D. Fife, B. Butz, B. Bergnan and P. Vena of Systems Engineering Facility (SEF).

In addition, the complete group (including the visitors) had several open sessions in which we attempted to define the problems. It is clear that some further work on problem definition is necessary.

On Friday morning the complete group had a briefing, followed by discussions, with representatives of DATRAN whose technical control problems seem to parallel those of DCA.

The DCA facility in Reston carries out a great deal of classified work so that it may be expedient for the PDP participants to have security clearance. Apparently work of direct interest is not classified.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA. GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

May 1, 1972

MEMORANDUM

TO: Dr. D. T. Paris

FROM: J. L. Hammond

SUBJECT: Trip Report (Reston, Virginia) April 25-26, 1972

The trip was for the purpose of visiting our sponsor at DCA and making a presentation on work completed.

The sponsor was represented by Mr. P. Plotkin and Dr. Bryan Butz. Dr. T. C. Huang (Purdue) and myself gave a presentation on completed portions of our program - principally, an extensive literature survey and preliminary plans for modeling digital communication systems.

The presentation and discussion lasted approximately three hours and were apparently well received.

JLH:jms

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA. GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

June 7, 1972

MEMORANDUM

TO : D. T. Paris

FROM : J. L. Hammond

SUBJECT: Report on June 1-2 trip to Washington D.C.

The purpose of the trip was to visit our Post Doctoral Program sponsor at the Defense Communications Agency, Reston, Virginia. The meeting was attended by DCA personnel, Bergman, Butz, Plotkin and Vena; and PDP personnel, Huang, Kitahara (Purdue) and Hammond (Ga. Tech).

The PDP participants presented plans for simulation studies of monitoring schemes for digital communication systems.

While in Washington, I also paid a courtesy visit to Dr. Schutzman of the Engineering Division of NSF.

JLH/ded

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA. GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

September 11, 1972

MEMO TO: Dr. D.T. Paris

FROM: J. L. Hammond

SUBJECT: Trip report - Washington DC and Reston, Va 9/6, 9/7/1972

The primary purpose of this trip has to discuss progress with our Post Doctoral Program sponsors at the Defense Communications Agency. In addition to myself, Drs. B. Leon, R. Kitahara and T. Huang of Purdue attended the meeting.

In addition to current progress, funding for next year was discussed. No conclusion was reached on new funding.

The sponsors were pleased with the progress at Ga. Tech and seemed anxious to have work in progress completed as soon as possible. Pete Plotkin feels that tangible results from present work are essential for a favorable decision on renewal of the project. (In response to this I plan to add a graduate assistant for the Fall quarter if possible).

In addition to discussions at DCA-Reston, we paid a courtesy visit to Dr. Harry Van Trees, Chief Scientist DCA, who received us cordially. Dr. Van Trees indicated that there are many openings in DCA at levels of GS 12 and higher and that he is making an effort to have these filled with capable people. He solicited our help in recruiting.

APPENDIX V

Post Doctoral Program Activities in Digital Communications: Adaptive Differential Pulse Code Modulation for Digital Transmission of Speech

GEORGIA INSTITUTE OF TECHNOLOGY
School of Electrical Engineering

MEMORANDUM November 1, 1971

TO: File

FROM: Bush and Paris

TRIP REPORT - VISIT TO DEFENSE COMMUNICATION AGENCY, WASHINGTON, D. C. AND RESTON, VA.

1. Evening of October 27 spent in conversation with Ron Thomas (AFA), Walt Fu (Cornell), Ben Leon (Purdue), Woody Everett, A. M. Bush and D. T. Paris.

2. The morning of October 28 was devoted to coordination with Major Lonnie Benson of DCA Washington. Talked with Mr. Scott, Mr. Smith, Mr. Dix and Mr. Jones. Discussion centered on organization and mission of DCA, possible utility of the Post Doctoral Program. Uncovered area of long-range technical forecasts to be one area, "gunfighters" as another.

3. The afternoon of October 28 was devoted to a presentation at DCA - Reston, Va. concerning the Post Doctoral Program and its capabilities. There were 18 DCA personnel present (including Dave Shults). Bush, Dees, and Paris represented Georgia Tech. Paris made a 6-minute talk describing the total Georgia Tech capabilities in the communications/electronics area.

4. October 29; Thomas, Everett and Paris spent the morning with Major Benson and Mr. Smith at DCA in Washington, and discussed Post Doctoral participation in communications technology forecasting for the 1973-1983 time period. A total of four man-year effort (with slightly over one man-year by Georgia Tech) is seen as an immediate possibility. A workshop, scheduled for late November or early December will include representation from Post Doctoral Program including Georgia Tech.

5. Bush, Perini (Syracuse), Ku, Cotellesa, Eveleigh (Syracuse) discussed with Dr. Jon Baylis of DCA - Reston mutual areas of interest in speech digitization and in general digital communications interests. Dr. Baylis and Dr. Aaron Goldberg (who was not present) will give to Major Benson short work statements on (1) analog/digital compatible switching centers and (2) evaluation of linear predictive coding as a technique for voice digitization. Georgia Tech appeared to be the only site well enough equipped to handle the voice work.

6. On the morning of October 28, Leon met with I. P. Plotkin on Tech Control and Systems Control. In the afternoon, Leon, Perini, Eveleigh, Cotellesa, Bush and Paris met with Lowell, Fife, Plotkin and Benson of DCA, and discussed this subject at some length. They will attempt to write work statements. It would be helpful to give Benson some work statements from our own point of view. Basic issues are:

   A. Establish the minimum number of parameters that should be measured in order to determine the state of a communications channel when it is

      (i) non-operative
      (ii) nearly non-operative

   B. Arrive at the most cost effective way in which the state of each node in a global communications system can be described so as to optimize routing according to some selected criteria.

   C. Establish techniques and models for systems availability. This is a complex combinatorial problem aimed at estimating lower bounds of availability.

   These are three areas in which Hammond, Kamen and Fielder, respectively, can make significant contributions.

7. Reception at DCA was unexpectedly enthusiastic. DCA FY 72 funds are not being committed as fast as originally projected.

DTP:jms

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

April 13, 1972

MEMORANDUM

TO: D. T. Paris

FROM: A. M. Bush and T. P. Barnwell

SUBJECT: TRIP REPORT -- April 12, 1972 visit to DCA - SEF

1. List of attendees is attached.

2. The adaptive differential PLM (ADPLM) study is funded at 1 manyear for Georgia Tech and 1 manyear for N.C. State. Jim Bayless wanted to have J. B. O'Neal, N.C. State, as lead on the project. O'Neal will write up a 3 - 4 page work statement per our discussions with Bayless and give us a chance to comment on it before getting it to Bayless. All travel, etc. for this project comes from the 1 manyear we will receive. N. C. State will divide 50/50 between J. B. O'Neal and Ray Stroh. Georgia Tech will divide A. M. Bush 30% and T. P. Barnwell 70%, at least nominally.

3. Woody says the Syracuse contract is being negotiated first as a pilot. It should be complete 1 May. Others will follow immediately from this pattern.

4. T. P. Barnwell and A. M. Bush need to fill security clearances with

Mr. Joe Beaty
Security Officer
DCA - SEF
1860 Wiehle Avenue
Reston, Virginia 22070

5. The Computer Communication Study is still in the mill at 4 manyears over 18 months, to be picked up on expected fallout moneys in FY 72 wind up. Still a long way to go, but still in process.

6. Statements of the ADPLM project and several others which will go out of DCA, probably to industry, or as indicated, are attached.

7. Jim Bayless is now one of 3 Dept. Heads at DCA - SEF. He is coordinator between SEF and Benson's Hdqts. people. All projects will initiate with Bayless.

8. Bayless has requested J. C. Hammett be assigned to DCA - SEF to supervise their speech work.

A. M. Bush/jms

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

April 28, 1972

MEMORANDUM

TO: D. T. Paris

FROM: A. M. Bush and T. P. Barnwell

SUBJECT: Trip Report - 1972 Conference on Speech Communication and Processing

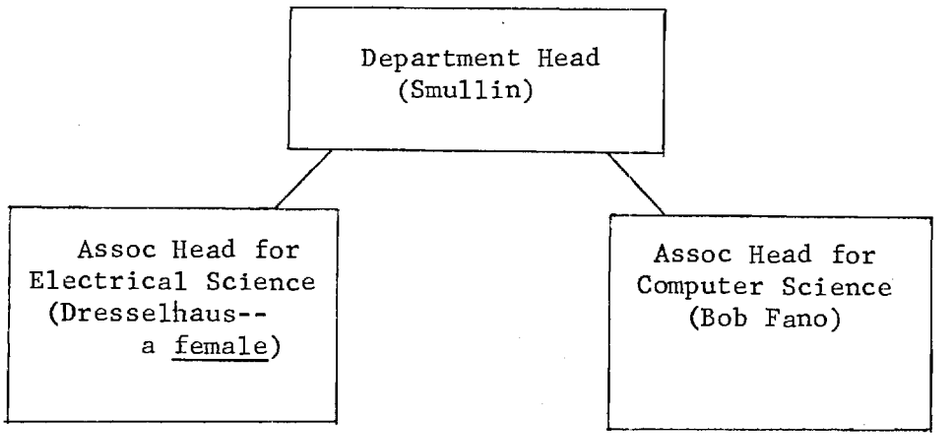
---

1. April 23, 1972 through April 26, 1972 A. M. Bush and T. P. Barnwell attended the 1972 Conference on Speech Communication and Processing, Newton, Mass. On April 27, 1972 A. M. Bush visited at Lincoln Laboratories, Lexington, Mass. While in Newton for the Conference, both Bush and Barnwell visited MIT and Barnwell visited with Donald Alusic, sales V.P. of Digital Equipment Corp.

The Conference itself was very worthwhile, with a good exchange of ideas and data.

While at MIT, we visited with F. F. Lee, Jim Bruce, and the MIT placement office to discuss (1) Computer Engineering programs (2) Speech Synthesis Equipment.

2. Computer Engineering at MIT has developed as follows: (1) The EE Dept now has been restructured as shown:



Approximately 1/3-1/2 of the EE student body is in Computer Science. Neither J. Bruce or J. Wozeneraft is completely satisfied with the program. They definitely do not plan to offer a designated degree for computer science. It has been impossible to achieve a cohesive faculty team in the computer area so far--this is a disappointment to them, but an experience which seems to be common to other schools.

3. H. L. Van Tree will leave MIT to become Chief Scientist of DCA for a two year term beginning sometime this summer.

4. Estil Hoversten may be available as a communications faculty candidate. Likely a similar situation to Schweppe's.

5. AFCRL is dropping speech research efforts. Members of their team will be seeking jobs elsewhere in some cases.

6. Lincoln Labs has several Ga Tech people. Has had good experience with our graduates and would like to get some more. They had developed a training machine video/audio presentation device for Keesler AFB which looked quite interesting.

7. Data on details of the Conference, DEC, or Lincoln Labs programs is available from either TPB or AMB.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

May 8, 1972

MEMORANDUM

TO: D. T. Paris

FROM: A. M. Bush, R. H. Pettit

SUBJECT: Travel Report--1972 IEEE Communications Workshop--Rome Seminar

---

April 30, 1972 through May 3, 1972, we attended the 1972 IEEE Communications Workshop at the Concord Hotel, Kiamesha Lake, N.Y. There were approximately 100 attendees. We had the entire hotel, capacity 4000, to ourselves. Thus the conference was quite informal, with free interchange. No written records of proceedings were kept in order that candor might be promoted in the discussions.

On each of the three days a focal topic was picked. The format was (1) tutorial lecture (2) panel discussion (3) informal discussion sessions. The table below indicates participants in the formal exercises.

	Monday	Tuesday	Wednesday
Topics	Digital Processing	Computer Communications	Source Encoding
Speaker	J. F. Kaiser	D. R. Doll	D. Sakrison
Panelests	S. L. Freeney	R. Sanders	T. Berger
	B. Gold	P. E. Green	L. Dauisson
	J. F. Kaiser	D. R. Doll	J. Flanagan
	H. S. McDonald	R. Binder	J. Limb
	M. G. Taylor	R. Kahn	D. Sakrison

Informal discussions indicated the following:

(1) Ed Arthurs from Computer Center, Bell Labs:

Computer Communication involves different constraints from those typically employed in current analyses; e.g. computers can accept no errors in data which are not correctable; 10^{-5} or 10^{-7} error rates are not meaningful constraints. He suggests some restructuring of curriculum to emphasize computer communications, using books by J. Martin of IBM and by Frank. This was corroborated by Dixon Doll and Mike Ferguson. This possibility was presented by Pettit during an informal session on Tuesday, with the attending group also believing this to be a desirable curriculum change. We will pursue these suggestions.

(2) We seem to be well abreast of Digital Signal Processing techniques.

(3) Our work on speech can be viewed as source encoding work. Where as we are working with actual data, most participants are taking a mathematical approach. A special type course emphasizing the formalism is in order and will be pursued. Our experimental efforts in speech will of course be continued; hopefully both directions can be mutually beneficial.

On Wednesday we drove to Rome N.Y. Thursday morning we visited with Woody Everrett and delivered back-to-back seminars to about 10 people, including

Hollis Hewitt -- Interference Analysis and Control Section
Gerry Capraro -- " " " " "
J. Scheer -- " " " " "
R. Rabe -- " " " " "
J. Corbitt -- Capt USAF, former student at Georgia Tech

The best procedure for defining work statements for the two manyears RADC funded Post-Doctoral work at Georgia Tech seems to be to

(1) select people to be involved

(2) have them write 4 or 5 page descriptions of what they want to do, in consultation with AMB and RHP

(3) send these statements to Woody to hand to appropriate people at RADC

(4) follow up with trip and seminar if desired.

Almost anything in signal processing, filter design, or wideband signal processing techniques will be appropriate.

The trip was rewarding and stimulating.

GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA. GEORGIA 30332

SCHOOL OF
ELECTRICAL ENGINEERING

June 28, 1972

MEMORANDUM

TO : D. T. Paris

FROM : A. M. Bush and T. P. Barnwell

SUBJECT: Trip Report -- Visit to North Carolina State and DCA, June 26-27, 1972

June 26 was spent at North Carolina State with J. B. O'Neal and Ray Stroh reviewing plans for the DCA ADPCM work and touring their facilities and computer laboratories. We developed plans for work for the summer and a presentation strategy for the meeting with Jon Bayless at DCA on June 27. At DCA we met with Bayless and with Ron Sonderegger who will be the new contact man on the speech work at DCA. Pete Vena will be involved with the speech work at DCA as well but was not there on the 27th. Cliff Guffee has done some programming for the DCA in house speech work. We discussed in detail the work planned and a revised work statement will be written up by O'Neal on the basis of this discussion. In August, probably about the last week, a group from DCA will visit Georgia Tech along with O'Neal and Stroh from NCSU to hold a further review and planning meeting. The group from Washington may include not only Bayless, Vena and Sonderegger but a representative from NSA and NRL as well.

The RFP which Barnwell, Brown and Bush responded to was indeed sent to SMU, who won the bid. Georgia Tech was second, technically OK in spite of the earlier letter to the contrary, and only $1K below the winner. In other words, the thing was wired to SMU in two ways: (1) the level asked for was on the order of $350K but the level expected from SMU was much lower, and (2) SMU does not have to include any overhead at all in their bids, ZERO % overhead.

Jack Hammett will be one of two people who will be staff to Harry Van Trees, who is Chief Scientist to General Gould.

AMB/ded

APPENDIX VI

Post Doctoral Program Consulting Activities

ENT Air Force Base
Colorado 80912
30 June 1972

Dr. Demetrius T. Paris
Director, School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Dear Dr. Paris:

Enclosed you will find a statement for consulting and travel expenses on the NORAD activity. The expenses cover two periods from 23 November 1971 through 30 May 1972 and 1 June through 30 June 1972.

The consulting for the first period covered the visits of Lt. Corey and Warren Peele to Phila. and my trip to Syracuse to see Dr. Everett. Two additional days were used to review NORAD documents sent to me by Dr. Everett and to assist Mr. Peele by preparing a list of test equipment.

The consulting for the second period was formy present activities in Colorado Springs. Of the 24 days consulting, 20 cover the 4 weeks in June, 3 cover travel from Phila to Colorado Springs and 1 day covers two half Saturdays spend on the project.

Since I don't know what allowances you make for travel I have reported expenses incurred for the first period. For the June '72 period I used my automobile for travel (I believe this was cheaper than Air Fare plus a rented car or taxi) and reported mileage at 10¢/mile (standard Univ. of Penn. rate). I have included motel recepts but left meals blank since I did not know how you handle per diem expenses. Please figure 5½ days per diem and if per diem includes motel, deduct the motel charge.

My activities here at Colorado Springs are as follows: The first week was taken up by visits to Peterson Field, ENT Air Force Base, NORAD, Cheyenne Mountain and the Airforce Academy. These visits included introductions to most of the persons I would be expected to contact in my work. A good part of the week was also occupied in getting a badge so that I could work in the Mountain.

The second and fourth weeks of June were spent in reviewing a list of documents on the NORAD complex and in preparing a revision of a key document which explains how equipment is to be installed and wired in the Mountain. This mostly concerns shielding and grounding. It is hoped that a working draft of this document will be completed in July.

The third week of June was spent at Kirtland Air Force Base, New Mexico attending a meeting on EMP. Several items of importance emerged from this meeting. In general it appears, however, that the EMP community is not really aware that their work is only a special case of EMC (Electromagnetic Compatibility)

As much of their work is a retread of work carried out by others, the most curious thing that I noticed was a complete lack of experimental data or evidence for much of the work that was discussed.

I trust this report is satisfactory. It is really too early to report too much detail.

Please make out a check for the expenses and consulting and perferably send it to my wife at 570 Rosemary Circle, Media, Pa. 19063. The check should be made out to me and my wife Marie P. Salati and marked for deposit to our account, No. 807-689-5 in The First Pennsylvania Bank.

I hope to see you at the Air Force Academy in July.

Sincerely,

O. M. Salati

ENT Air Force Base
Colorado 80912
1 August 1972

Dr. Demetrius T. Paris
Director, School of Electrical Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Dear Dr. Paris:

Enclosed you will find a statement for the month of July 1972. This includes 20 days of consulting and per diem travel expenses for the June trip to Kirtland AFBase. This last item is in accordance with my understanding with you and Dr. Everett at our meeting in July.

Activities here at NORAD have finally consolidated into something meaningful.

1. I have completed a revision of a section of the NORAD manual on EMP. This has been given to Colonel Sisco.
2. I have been preparing a draft of the reviews I have made of NORAD NCMC documents.
3. Lt. Corey has prepared for me a complete list of all NCMC penetrations and is presently securing drawings so that we can evaluate the importance of these findings.
4. Lt. Corey and I have made a few measurements of ambient signals both in and out of NCMC. We located a few strong noise sounds and have recommended that these be fixed.
5. I have prepared sketches and performance formulas for a dipole antenna and a loop to be used for interim measurements (equipment ordered has not arrived). These have been built and tested.
6. A list of questions concerning the grounding of communications link was prepared. AT&T is in the process of answering these. We have already visited one of the sites involved and will complete this program by 11 August.
7. A measurement program has been outlined so that Lt. Corey can carry these out in my absence. These measurements cover potential penetrations as well as grounds and shields. Some grounding measurements on rock bolts have been completed. It appears that if these are interconnected by wire, they may constitute a good ground.
8. During the next period, we are going to see if within a room, we can reduce the complexity of the grounding system and at the same time maintain system performance. This program will also include a study of the MH Computer system.

It appears that by the end of my stay in August, we will have answered a few of the many nagging problems. I have collected a list of problems which I hope to have studied by some of my students. These are not pressing ones, but problems whose solution would give us assurance that our methods are correct.

Sincerely,

O. M. Salati

APPENDIX VII

Papers Presented

Jamming of Computer Communications Systems

by

Ray H. Pettit
School of Electrical Engineering
Georgia Institute of Technology

I. Introduction

For many military applications of computer communications systems, vulnerability to unfriendly jamming signals must be analyzed. A good criterion for measuring jamming effects is probability of error, regardless of the signaling technique employed (on-off key, frequency shift key, phase shift key). Theoretical analysis has been performed for the case of Gaussian noise interference with the results readily available [1], [2]. However, when the interference consists of Gaussian noise plus a non-Gaussian jamming signal, theoretical treatment becomes much more difficult. The result is that normally, for these cases, computer simulation is utilized in order to gain insight as to optimum jamming and counter-jamming strategies.

The philosophy governing the work here is that, whenever possible, theoretical analysis based on sound mathematical models is desirable. Even if complete theoretical analysis is not feasible in certain cases, any advances along these lines can provide for better performance of computer simulation and stronger confidence in the validity of the results.

The signaling technique chosen for first analysis is NCFSK (Noncoherent Frequency Shift Key), with both sinusoidal jamming and linear frequency modulation jamming investigated. Results already obtained and a summary of continuing efforts are presented below.

The receiver model adapted for analysis is fairly standard for conventional NCFSK receivers [1], [2], and is shown in Figure 1. The input waveform x(t) is considered to be made up of the sum of signal, noise, and jamming during a signaling interval $(0,\tau)$, as below

$$x(t) = s_i(t) + n(t) + j(t) \tag{1}$$

where $s_i(t) = A_s \cos \omega_0 t$ or $A_s \cos \omega_1 t$, depending upon which binary data symbol is being represented. The noise is assumed to be Gaussian.

II. CW Jamming of NCFSK

For the model discussed above, with CW jamming (continuous wave or sinusoidal) we have

$$j(t) = A_j \cos (\omega_j t + \theta_j) \tag{2}$$

with θ_j a uniformly distributed random variable $(0, 2\pi)$.

In order to find an expression for probability of error, we use the total probability formula.

$$P(err) = P(0) \cdot P(err/0) + P(1) \cdot P(err/1) \tag{3}$$

and find expressions for the two conditional error probabilities of (3). For demonstration of technique, we assume equally likely binary symbols.

In calculating P(err/0), we temporarily assume that a 0 is actually present at the receiver input. Thus the filter centered at ω_0 has an output

$$x_0(t) = A_s \cos \omega_0 t + A_j \cos (\omega_0 t + \theta_j) + n_{i0}(t) \tag{4}$$

with the output of the other filter given by

$$x_1(t) = n_{i1}(t) \tag{5}$$

The receiver decision is based on the envelopes of these waveforms. By expressing the noise functions $n_{i0}(t)$ and $n_{i1}(t)$ in terms of their quad-

rature components the envelopes can be written as

$$R_0 = \left\{ [A_s + A_j \cos\theta_j + n_{c0}(t)]^2 + [A_j \sin\theta_j + n_{s0}(t)]^2 \right\}^{\frac{1}{2}} \quad (6)$$

$$R_1 = \left\{ n_{c1}^2(t) + n_{s1}^2(t) \right\}^{\frac{1}{2}} \quad (7)$$

The desired probability P(err/0) is

$$P(\text{err}/0) = P[R_0 < R_1/0] = \int_{r_0=0}^{\infty} \int_{r_1=r_0}^{\infty} f_{R_0R_1}(r_0, r_1/0)\, dr_0 dr_1 \quad (8)$$

The procedure for finding the joint probability density function $f_{R_0R_1}(r_0, r_1/0)$ involves the technique of transformation of random variables. Several steps which will be omitted in this summary, lead eventually to the following intermediate result

$$P(\text{err}/0) = \tfrac{1}{2} \exp\left\{ -\left(\frac{A_s^2 + A_j^2}{4N} \right) \right\} \cdot I_0\left(\frac{A_s A_j}{N} \right) \quad (9)$$

The above steps are now repeated, with the input data symbol assumed to be 1. Therefore, we have now

$$x_0(t) = A_j \cos(\omega_0 t + \theta_j) + n_{i0}(t) \quad (10)$$

$$x_1(t) = A_s \cos\omega_1 t + n_{i1}(t) \quad (11)$$

with the corresponding envelopes given by

$$R_0 = \left\{ [A_j \cos\theta_j + n_{c0}(t)]^2 + [A_j \sin\theta_j + n_{s0}(t)]^2 \right\}^{\frac{1}{2}} \quad (12)$$

$$R_1 = \left\{ [A_s + n_{c1}(t)]^2 + [n_{s1}(t)]^2 \right\}^{\frac{1}{2}} . \quad (13)$$

The desired probability of error now becomes

$$P(\text{err}/1) = P[R_1 < R_0/1] = \int_{r_1=0}^{\infty} \int_{r_0=r_1}^{\infty} f_{R_0R_1}(r_0, r_1)\, dr_0 dr_1 . \quad (14)$$

Using once again the approach of transformation of random variables,

but omitting the cumbersome details, we eventually find

$$P(\text{err}/1) = Q\left(\frac{A_j}{\sqrt{2N}}, \frac{A_s}{\sqrt{2N}}\right) - \tfrac{1}{2} \exp\left\{-\frac{(A_s^2 + A_j^2)}{4N}\right\} \cdot I_0\left(\frac{A_s A_j}{4N}\right) \quad (15)$$

so that the final expression becomes

$$P(\text{err})_{cw} = \tfrac{1}{2}Q\left(\frac{A_j}{\sqrt{2N}}, \frac{A_s}{\sqrt{2N}}\right) = \tfrac{1}{2}Q\left(\sqrt{\frac{J}{N}}, \sqrt{\frac{S}{N}}\right) . \quad (16)$$

III. Linear FM Jamming of NCFSK

For this case, the jamming waveform is represented as

$$j(t) = A_j \cos\left(\omega_j t + \theta_j + k\int_0^t m(t_1)dt_1\right) . \quad (17)$$

It is assumed that the carrier frequency ω_j is midway between the two signaling frequencies ω_0 and ω_1. Hence

$$\omega_j = \frac{\omega_0 + \omega_1}{2} . \quad (18)$$

In addition, we analyze here the case in which the jammer sweep ranges from ω_0 to ω_1, so that the maximum frequency deriation about ω_j is $\pm\left(\frac{\omega_1 - \omega_0}{2}\right)$. The beginning of the jammer sweep may not correspond to the beginning of a signaling interval. This is allowed for by solving in terms of t_0 as indicated in Figure 2, the sketch of a single period of Km(t). Note that the case being analyzed here for illustrative purposes is for sweep period equal to the signaling period.

The choice of filters affects the result. We solve here for an arbitrary choice of filters and leave for future investigation the effects due to specific filters. This, of course, involves straightforward linear system analysis only. We use the narrow band representation to represent the filter outputs due to an input j(t) as

$$j_0(t) = A_{j0}(t) \cos (\omega_0 t + \theta_j + \varphi_{j0}(t))$$
$$j_1(t) = A_{j1}(t) \cos (\omega_1 t + \theta_j + \varphi_{j1}(t)) \tag{19}$$

Changes in filters affect $A_{j0}(t)$, $A_{j1}(t)$, and $\varphi_{j0}(t)$, and $\varphi_{j1}(t)$, but the result, to be derived below, will be a probability of error that is a function of the amplitudes alone independent of $\varphi_{j0}(t)$ and $\varphi_{j1}(t)$.

Following the same procedure as in the first case, we now find P(err/0), to be followed by the determination of P(err/1).

To calculate P(err/0) we assume that a 0 is present at the receiver input so that the filter outputs are given by

$$x_0(t) = A_s \cos \omega_0 t + n_0(t) + j_0(t)$$
$$x_1(t) = n_1(t) + j_1(t) \tag{20}$$

Writing the noise processes in terms of their quadrature components and temporarily simplifying notation by suppressing the time variable leads to the following expressions for the envelopes

$$R_0 = \left\{ [A_s + n_{c0} + A_{j0} \cos (\varphi_{j0} + \theta_j)]^2 + [n_{s0} + A_{j0} \sin (\varphi_{j0} + \theta_j)]^2 \right\}^{\frac{1}{2}} \tag{21}$$
$$R_1 = \left\{ [n_{c1} + A_{j1} \cos (\varphi_{j1} + \theta_j)]^2 + [n_{s1} + A_{j1} \sin (\varphi_{j1} + \theta_j)]^2 \right\}^{\frac{1}{2}}$$

Using Equation (8) and the technique of transformation of random variables, we eventually obtain

$$P(\text{err}/0) = \frac{1}{2\pi} \int_0^{2\pi} \left[Q \left\{ \frac{A_{j1}}{(2N)^{\frac{1}{2}}}, \left(\frac{A_{j0}^2 + A_s^2 + 2A_s A_{j0} \cos X}{2N} \right)^{\frac{1}{2}} \right\} \right.$$
$$\left. - \tfrac{1}{2} \exp \left\{ - \frac{1}{4N} \left[A_s^2 + A_{j0}^2 + A_{j1}^2 + 2A_s A_{j0} \cos X \right]^{\frac{1}{2}} \right\} \right] \tag{22}$$
$$\cdot I_0 \left\{ \frac{A_{j1}}{2N} \left[A_{j0}^2 + A_s^2 + 2A_s A_{j0} \cos X \right]^{\frac{1}{2}} \right\} dx$$

in which $Q(\alpha,\beta)$ is the Q-Function [1], [2] defined as

$$Q(\alpha,\beta) = \int_{\beta}^{\infty} y \exp\left[-\frac{(y^2+\alpha^2)}{2}\right] \cdot I_0(\alpha y)dy \tag{23}$$

We are now lacking P(err/1). Assuming a 1 is present at the receiver input, the envelopes are

$$\begin{aligned} R_0 &= \left\{ \left[n_{c0} + A_{j0}\cos(\varphi_{j0} + \theta_j) \right]^2 \right. \\ &\quad \left. + \left[n_{s0} + A_{j0}\sin(\varphi_{j0} + \theta_j) \right]^2 \right\}^{\frac{1}{2}} \\ R_1 &= \left\{ \left[A_s + n_{c1} + A_{j1}\cos(\varphi_{j1} + \theta_j) \right]^2 \right. \\ &\quad \left. + \left[n_{s1} + A_{j1}\sin(\varphi_{j1} + \theta_j) \right]^2 \right\}^{\frac{1}{2}} \end{aligned} \tag{24}$$

Thus we have exactly the same mathematical problem as for P(err/0). (See Equation (21) for comparison.) The only difference is a swapping of 0 and 1 subscripts in the previous result. Therefore

$$\begin{aligned} P(err/1) = \frac{1}{2\pi} \int_0^{2\pi} & \left[Q\left\{ \frac{A_{j0}}{(2N)^{\frac{1}{2}}}, \left(\frac{A_{j1}^2 + A_s^2 + 2A_s A_{j1}\cos X}{2N} \right)^{\frac{1}{2}} \right\} \right. \\ & - \tfrac{1}{2} \exp\left\{ -\frac{1}{4N}\left[A_s^2 + A_{j1}^2 + A_{j0}^2 + 2A_s A_{j1}\cos X \right] \right\} \cdot \\ & \left. \cdot I_0\left\{ \frac{A_{j0}}{2N}\left[A_s^2 + A_{j1}^2 + 2A_s A_{j1}\cos X \right]^{\frac{1}{2}} \right\} \right] dx \end{aligned} \tag{25}$$

Now using Equation (3) and the following property of the Q-Function [4],

$$Q(\alpha,\beta) + Q(\beta,\alpha) = 1 + \exp\left[-\frac{(\alpha^2+\beta^2)}{2}\right] \cdot I_0(\alpha\beta) \tag{26}$$

we obtain

$$P(\text{err}) = \frac{1}{2} + \frac{1}{8\pi}\int_0^{2\pi}\Bigg[Q\left\{\frac{A_{j0}}{(2N)^{\frac{1}{2}}}, \left(\frac{A_{j1}^2 + A_s^2 + 2A_s A_{j1}\cos X}{2N}\right)^{\frac{1}{2}}\right\}$$
$$+ Q\left\{\frac{A_{j1}}{(2N)^{\frac{1}{2}}}, \left(\frac{A_{j0}^2 + A_s^2 + 2A_s A_{j0}\cos X}{2N}\right)^{\frac{1}{2}}\right\} \qquad (27)$$
$$-Q\left\{\left(\frac{A_{j1}^2 + A_s^2 + 2A_s A_{j1}\cos X}{2N}\right)^{\frac{1}{2}}, \frac{A_{j0}}{(2N)^{\frac{1}{2}}}\right\}$$
$$-Q\left\{\left(\frac{A_{j0}^2 + A_s^2 + 2A_s A_{j0}\cos X}{2N}\right)^{\frac{1}{2}}, \frac{A_{j1}}{(2N)^{\frac{1}{2}}}\right\}\Bigg]\,dx$$

In terms of the average powers, this is

$$P(\text{err}) = \frac{1}{2} + \frac{1}{8\pi}\int_0^{2\pi}\Bigg[Q\left\{\left(\frac{J_0}{N}\right)^{\frac{1}{2}}, \left(\frac{J_1 + S + 2(SJ_1)^{\frac{1}{2}}\cos X}{N}\right)^{\frac{1}{2}}\right\}$$
$$+ Q\left\{\left(\frac{J_1}{N}\right)^{\frac{1}{2}}, \left(\frac{J_0 + S + 2(SJ_0)^{\frac{1}{2}}\cos X}{N}\right)^{\frac{1}{2}}\right\}$$
$$- Q\left\{\left(\frac{J_1 + S + 2(SJ_1)^{\frac{1}{2}}\cos X}{N}\right)^{\frac{1}{2}}, \left(\frac{J_0}{N}\right)^{\frac{1}{2}}\right\} \qquad (28)$$
$$- Q\left\{\left(\frac{J_0 + S + 2(SJ_0)^{\frac{1}{2}}\cos X}{N}\right)^{\frac{1}{2}}, \left(\frac{J_1}{N}\right)^{\frac{1}{2}}\right\}\Bigg]\,dx$$

IV. Conclusions

The familiar model in which Gaussian noise is the total interference is not adequate when more general jamming or interference signals must be considered. In this report a technique has been used to derive an expression for probability of error for NCFSK with two non-Gaussian jamming waveforms plus Gaussian noise. Such theoretical analysis should prove useful in providing the basis for more meaningful computer simulation studies when more complex models are appropriate. Work is continuing along these lines for other signaling techniques as well as other types of jamming waveforms.

References

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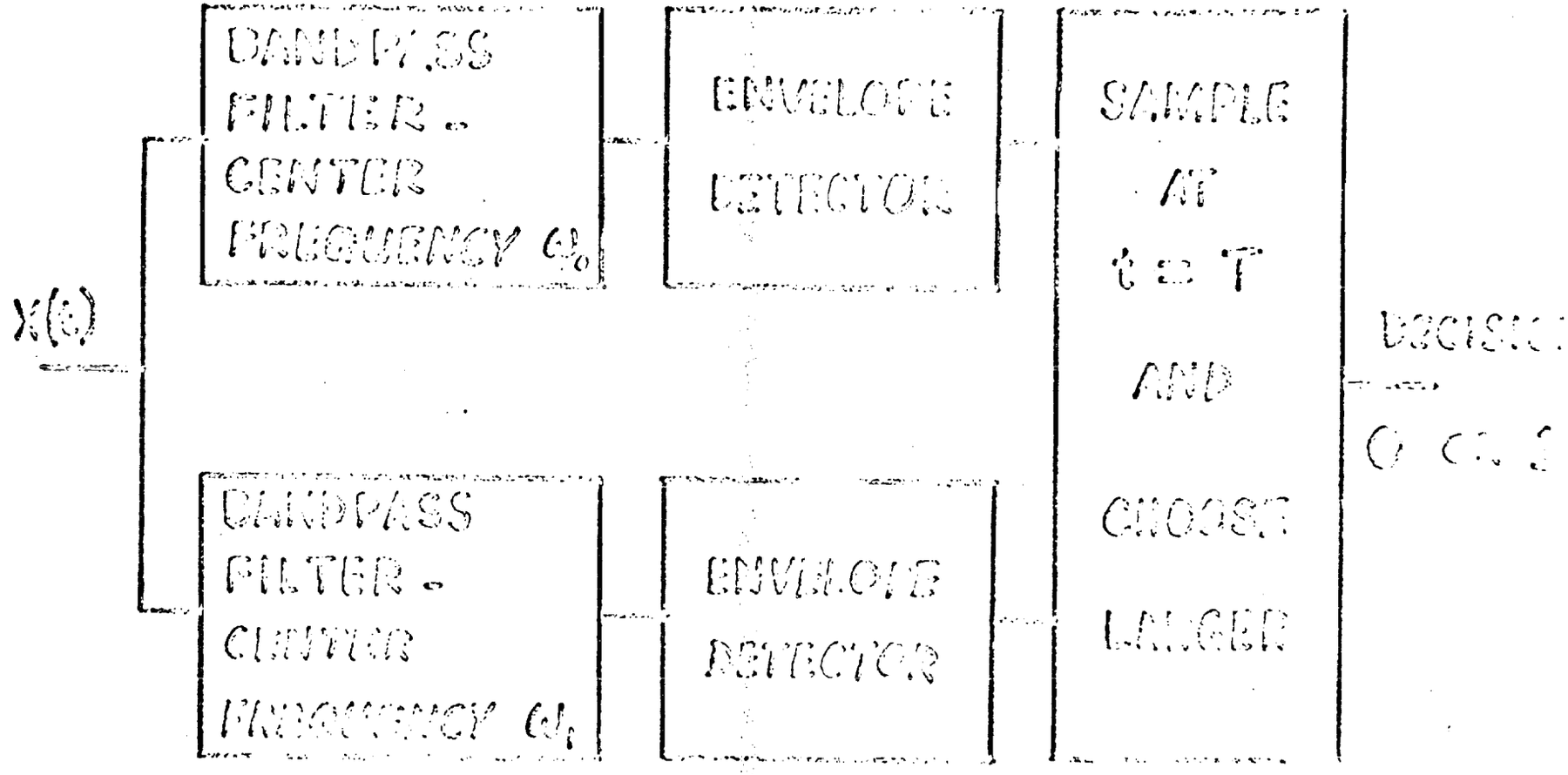

FIG. 1. NCPSK RECEIVER

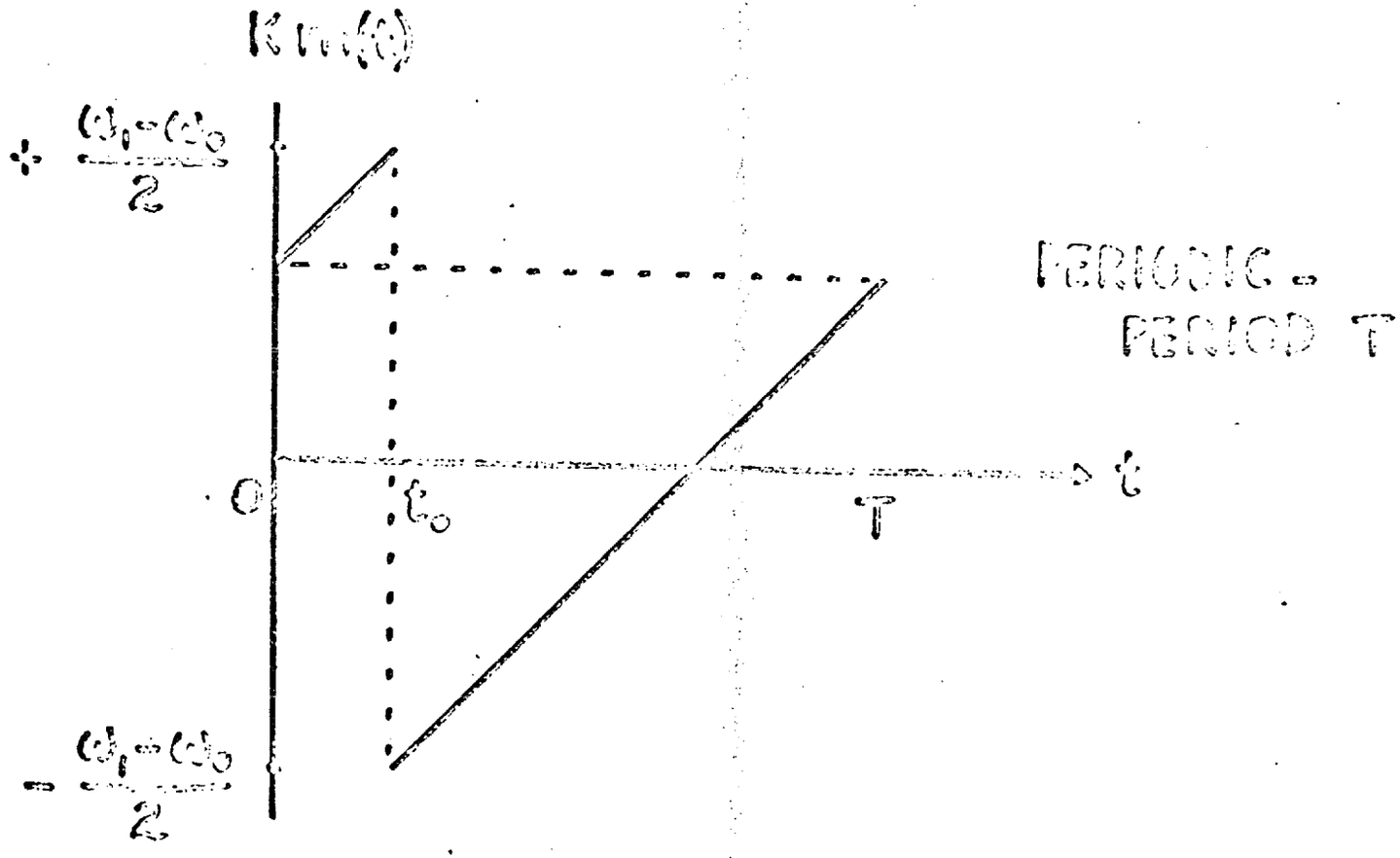

FIG.2. JAMMER FREQUENCY VARIATION

Article Title: Finite Memory Algorithms for Testing Bernoulli Random Variables.

Author's name: Patrick Robert Hirschler

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Georgia Institute of Technology,
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List of symbols:

a	n	A	N	$\mathring{A}$	α	0	.	$<$	$\in$	$\{$
b	o	B	O	$\mathfrak{E}$	γ	1	:	$>$	$\rightarrow$	$*$
c	p	C	P	$\mathfrak{g}$	δ	2	,	$\leq$	∞	
d	q	D	Q	$\mathfrak{m}$	ϵ	3	;	$\geq$	—	
e	r	E	R	$\mathfrak{p}$	φ	4	-	$\sim$	$\lceil$	
f	s	F	S		μ	5	=	(	$\rceil$	
g	t	G	T		ν	6	'	)	$\lfloor$	
h	u	H	U		ρ	7	-	[	$\rfloor$	
i	v	I	V		Δ	8	+	]		
j	w	J	W		$\sum$	9		{		
k	x	K	X					}		
l	y	L	Y				/			
m	z	M	Z				|			

Number of pages: 17

Number of Tables: 0

Number of figures: 2

Proposed running head: Finite-Memory Hypothesis Testing

Abstract

This paper solves the basic multiple hypothesis-testing problem with a time-varying finite-state automaton. Let $X_1, X_2, \ldots$ be a sequence of iid Bernoulli random variables with unknown parameter $p = \Pr(X_i=1)$. The K-hypothesis testing problem is investigated under the following assumptions: the X_i's are observed sequentially, and summarized after each new observation by an m-valued statistic $T_n \in \{1,\ldots,m\}$ which is updated by an algorithm of the form $T_n = f_n(T_{n-1}, X_n)$. Two automata are exhibited that achieve a zero limiting probability of error: $\mathcal{M}_1$, a 2K-state machine resolving perfectly the K simple hypotheses H_k: $p=p_k$ $(k=1,\ldots,K)$; and $\mathcal{M}_2$, a 4-state machine solving the difficult testing-problem H_o: $p=p_o$ versus H_1: $p\neq p_o$. The algorithms do not require artificial randomization. The rate of convergence is related to the Kullback discrimination information between the hypotheses.

Finite Memory Algorithms for Testing Bernoulli Random Variables

by

Patrick R. Hirschler

I. INTRODUCTION

Let $X_1, X_2, \ldots$ be a sequence of iid Bernoulli random variables with unknown parameter $p = \Pr(X_i = 1)$. In this paper we are interested in the follow -ing testing problems:

$$\text{I} \quad \begin{cases} H_k: \ p = p_k & (k = 1, \ldots, K) \\ (\ 0 < p_1 < p_2 < \ldots < p_k < 1\ ) \end{cases}$$

$$\text{II} \quad \begin{cases} H_o: \ p = p_o & \text{versus} \\ H_1: \ p \neq p_o & (\ 0 < p_o < 1\ ) \end{cases}$$

Our intent is to specify for each of these problems an automaton that achieve a zero limiting probability of error, under a finite memory constraint.

Discussion of the finite memory algorithm

Different types have been discussed in detail by Cover, T. (1969). Throughout this paper, we shall adopt the following terminology: a decision rule has a finite-state memory of size m if it can be implemented by an m-state automaton. Thus when X_i takes on a continuum of values a rule based on the last m observations requires an infinite-state memory. Considerations in Cover, T. (1969) have led to the following formulation: Let $T_n \in \{1, 2, \ldots, m\}$ represent the state of the memory at time n, and $d(.): \{1, \ldots, m\} \rightarrow \{H_1, \ldots, H_K\}$ be a decision function that takes decision $d(T_n)$ at that time. An error is made if $d(T_n) \neq H_t$, where H_t denotes the true hypothesis.

Let $P^* = \lim_{n \to \infty} \Pr(d(T_n) \neq H_t)$ be the limiting probability of error. We make the following definition: a K-hypothesis testing problem is m-state achievable iff for every $\epsilon > 0$ there exists an m-state automaton with a limiting probability of error smaller than ϵ. Time-invariant rules (ie, $f_n \equiv f$) with a finite memory constraint do not achieve a zero limiting probability of error (Hellman and Cover, 1970). Threfore the following family of learning algorithms is considered: $T_n = f_n(T_{n-1}, X_n)$ where X_n is the n^{th} observation, and f_n a time-varying function: $f_n : \{1,2,\ldots,m\} \times \{0,1\} \rightarrow \{1,2,\ldots,m\}$ that may involve randomization.

History of the problem

The formulation of the finite-memory constraint as given previously was introduced by Cover (1969). In that paper the two-hypothesis testing problem $H_o: P = P_o$ versus $H_1: P = P_1$ is shown to be 4-state achievable. In addition the problem of testing if the bias of a coin p is less than or greater than a fixed value p_o is solved using a time-varying rule and a 4-state memory. Following the same technique and using randomization, Sengupta,S. (1969) exhibits a rule that gives $\max(p_1,\ldots,p_k)$ as the limiting frequency of heads,with probability one, where the values $p_1,\ldots,p_k$ are known but it is not known which p corresponds to which coin. This latter result is an extension to the case of k coins of Cover's solution to the Two-Armed Bandit problem with finite memory (Cover, 1968).

Results

In this paper two finite-memory algorithms are exhibited which require no artificial randomization, and achieve a zero limiting probability of error under any hypothesis. K simple hypotheses $H_k: p = p_k$ (k=1,...,K) on a Bernoulli random variable are considered first. Section 2 gives one algorithm (Theorem 1) that can resolve perfectly these hypotheses ,and relates the rate of convergence of the procedure to the discrimination information between the hypotheses.

In section 3, theorem 2 proving that the testing problem $p=p_o$ versus $p\neq p_o$ is 4-state achievable constitutes a result of primary importance. The following section is devoted to the elimination of the randomization introduced in the previous algorithms for clarity of exposition. Finally the testing technique is interpreted, and the results are discussed. We now conclude this introduction by describing a comparison procedure used in the sequel.

Comparison procedure

Let $B=(B_1,\ldots,B_n)$ and $P=(P_1,\ldots,P_n)$ be two finite sequences of binary digits B_i, $P_i \in \{0,1\}$. This procedure compares the block B to the pattern P using only 1 bit of memory $Q \in \{0,1\}$ as follows: Q is set automatically to 1 when the procedure is started, so that $Q_o=1$. If $B_1 = P_1$ then $Q_1 = Q_o$, and subsequently if $B_i = P_i$, then $Q_i = Q_{i-1}$ otherwise $Q_i = 0$ $(i=1,\ldots,n)$. Let $Q(B,P)$ be the last value Q_n of Q. It is clear that $Q(B,P) = 1$ iff B and P are identical.

In the following sections, the B_i's correspond to the incoming observations whereas P represents a preselected pattern.

Notation: $\lfloor a \rfloor$ is the largest integer less than or equal to a.

$\lceil a \rceil$ is the smallest integer greater than or equal to a

wp stands for " with probability ".

II.TEST OF K SIMPLE HYPOTHESES

Consider a sequence of coin tosses with unknown bias $p = \Pr(\text{Heads})$, and K distincts numbers $p_1,\ldots,p_K$ satisfying $0 < p_1 < p_2 < \ldots < p_K < 1$.

Theorem 1 Let $X_1, X_2,\ldots$ be a sequence of iid Bernoulli random variables with $\Pr(X_i=1) = p$. The K-hypothesis testing problem H_k: $p = p_k$ $(k=1,2,\ldots,K)$ is 2K-state achievable.

Proof: Let the memory consist of the pair (T,Q) where $T \in \{1,\ldots,K\}$ and $Q \in \{0,1\}$. Consider K sequences $\{t_k^i\}_{i=1}^{\infty}$ $(k=1,\ldots,K)$ of positive integers, and P_k^i a pattern of length t_k^i defined as a sequence of $\lfloor p_k t_k^i \rfloor$ 1's followed by $\lceil q_k t_k^i \rceil$ 0's. Now divide the sequence of observations into successive blocks:

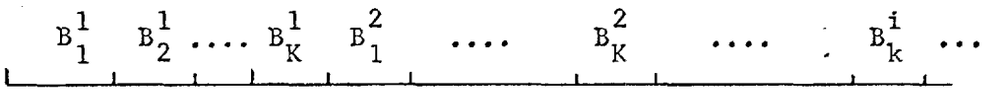

Figure 1

where B_k^i has length t_k^i. Let $\mathbb{m}_1$ be the automaton described by the program:

Start i:= 2;

Cycle i:= i+1;

k:= 0;

Test k:= k+1;

If $Q(B_k^i,P_k^i) = 1$, set $T_n = k$;

If $Q(B_k^i,P_k^i) = 0$, T_n stays unchanged;

If $k < K$, go to Test;

Go to Cycle; End.

Observe that B_k^i checks for the pattern P_k^i. At the end of the block, $Q(B_k^i,P_k^i)=1$ iff the test is successful. If the pattern P_k^i has occurred then the memory T_n is updated to state k, index of the currently favored hypothesis. At each cycle i, this test is performed for all successive values of k after which a new cycle i+1 is started. Thus the updating of the statistics T_n occurrs only at the end of a test block.

Asymptotic behavior of $\mathbb{m}_1$

Let $\alpha_k^i \triangleq \Pr(\text{Transit to state k at cycle i})$, and $A_k \triangleq \sum_{i=1}^{\infty} \alpha_k^i$ $(k=1,\ldots,K)$. Suppose that the following is true for j=1,...,K.

(2.1) Under H_j $\begin{cases} A_j = \infty \\ A_k < \infty \ , \quad \forall\ k \neq j \end{cases}$

By use of the Borel-Cantelli lemma (Loeve,M.,Probability Theory,p 228) we conclude that the automaton transits infinitely often wp1 to statej, and only finitely often wp1 to any other state k. That is $T_n \to j$ wp1, and the procedure makes wp1 only a finite number of mistakes under any hypothesis. Thus the K-simple hypothesis testing problem is solved if we can demonstrate the existence of K sequences $\{t_k^i\}_{i=1}^{\infty}$ (k=1,...,K) satisfying (2.1).

Let t_k^i be the integer such that

(2.2) $\quad \mathrm{Log}_{(H_k)} (\frac{1}{i}) \leqq t_k^i < 1 + \mathrm{Log}_{(H_k)} (\frac{1}{i})$, where $H_k \triangleq p_k^{p_k} q_k^{q_k}$

A transition from state k'to a state k≠k' is performed at cycle i iff $Q(B_k^i, P_k^i)=1$.

Thus, $\alpha_k^i = p^{\lfloor p_k t_k^i \rfloor} q^{\lceil q_k t_k^i \rceil}$. Let $r_k(p) \triangleq \dfrac{p_k \mathrm{Log}\ p + q_k \mathrm{Log}\ q}{p_k \mathrm{Log}\ p_k + q_k \mathrm{Log}\ q_k}$.

The two inequalities

(2.3) $\quad p_k t_k^i - 1 \leqq \lfloor p_k t_k^i \rfloor \leqq p_k t_k^i$

(2.4) $\quad q_k t_k^i \leqq \lceil q_k t_k^i \rceil \leqq q_k t_k^i + 1$

imply

(2.5) $\quad q\,(p^{p_k q_k})^{t_k^i} \leqq \alpha_k^i \leqq \frac{1}{p}\,(p^{p_k q_k})^{t_k^i}$

and by (2.2) we have

(2.6) $\quad q\, p^{p_k q_k} (\frac{1}{i})^{r_k(p)} \leqq \alpha_k^i \leqq \frac{1}{p} (\frac{1}{i})^{r_k(p)}$

Therefore A_k has same convergence characteristics as $\sum_{i=1}^{\infty} (\frac{1}{i})^{r_k(p)}$.

Under H_j: $p=p_j \Rightarrow r_j(p_j)=1 \Rightarrow A_j=\infty$, whereas $r_k(p_j) > 1$ for $k \neq j \Rightarrow A_k < \infty$.

This completes the proof of theorem 1.

Rate of convergence

The probability $\mu_k^j(i)$ of being under H_j in state k at cycle i satisfies the difference equation:

(2.7) $\quad \mu_k^j(i+1) = \mu_k^j(i) \left[1 - \sum_{\substack{h=1 \\ h \neq k}}^{K} \alpha_h^j(i) \right] + \sum_{\substack{h=1 \\ h \neq k}}^{K} \mu_h^j(i)\ \alpha_k^j(i)$

or equivalently,

$$\mu_k^j(i+1) = \mu_k^j(i) \left[1 - \sum_{h=1}^{K} \alpha_h^j(i) \right] + \alpha_k^j(i) \tag{2.8}$$

From equation 2.8, it can be shown that $\mu_k^j(i)$ $(k \neq j)$ converges to 0 like

$$\begin{cases} \dfrac{1}{i^{\rho_j - 1}} & \text{if } \rho_j < 2 \\ \dfrac{\text{Log } i}{i} & \text{if } \rho_j = 2 \qquad (j=1,\ldots,K) \\ \dfrac{1}{i} & \text{if } \rho_j > 2 \end{cases} \tag{2.9}$$

where we define

$$\rho_j \triangleq \min_{h \neq j} \{ r_h(p_j) \} \qquad (j=1,\ldots,K) \tag{2.10}$$

Introducing the self entropy function $\mathcal{E}(p) = -p \text{ Log } p - q \text{ Log } q$, and Kullback discrimination information

$\mathcal{J}(p:p') = p \text{ Log } \frac{p}{p'} + q \text{ Log } \frac{q}{q'}$, we can state the following (let K=2 for simplicity):

Under H_1, $P(e_i|H_1)$ converges to zero like

$$\begin{cases} \dfrac{1}{i^{r_2(p_1) - 1}} & , \text{ if } \mathcal{J}(p_2:p_1) < \mathcal{E}(p_2) \\ \dfrac{\text{Log } i}{i} & , \text{ if } \mathcal{J}(p_2:p_1) = \mathcal{E}(p_2) \\ \dfrac{1}{i} & , \text{ if } \mathcal{J}(p_2:p_1) > \mathcal{E}(p_2) \end{cases} \tag{2.11}$$

In other words, the larger the discrimination information in favor of the alternative hypothesis H_2 against the true hypothesis H_1, the faster will the automaton converge to the right decision. However, the rate of convergence does not exceed $\frac{1}{i}$ in any case.

III. THE POINT TEST

We assume that the parameter p can take any value between 0 and 1. We investigate in this section the following testing problem H_o: $p = p_o$ versus H_1: $p \neq p_o$ assuming $0 < p_o < 1$, and prove the more difficult result:

Theorem 2 Let $X_1, X_2, \ldots$ be a sequence of iid Bernoulli random variables with $\Pr(X_i = 1) = p$. The two-hypothesis testing problem $p = p_o$ versus $p \neq p_o$ is 4-state achievable.

Proof: Let the memory consist of (T,Q) where $T,Q \in \{0,1\}$. Let $\{t_k\}_1^\infty$ and $\{m_k\}_1^\infty$ be two sequences of positive integers, and let P_k be a pattern of length t_k consisting of $\lfloor p_o t_k \rfloor$ 1's followed by $\lceil q_o t_k \rceil$ 0's. Divide the sequence of observations into blocks B_k of length t_k as follows:

m_1 blocks B_1 $\qquad\qquad$ m_k blocks B_k

Figure 2

Let $\mathfrak{M}_2$ be the automaton described by the program P_2:

Start k: = 1;

Cycle k: = k+1: m: = 0;

Iterate m: = m+1:

If $Q(B_k,P_k) = 1$, set T = 0;

Set T = 1 wp $\epsilon_k = \left(\frac{1}{k}\right)^{4k+2}$;

Otherwise T stays unchanged;

If $m < m_k$, go to iterate;

Go to cycle; End.

The block B_k checks for the pattern P_k. A success, i.e., the appearance of the pattern P_k, results in the updating of the memory T which is then set to 0. However, since no test is made that can decide in favor of H_1,

the automaton is allowed to return with probability ϵ_k to state 1. This leak guarantees that the automaton will be in state 0 only if there is strong evidence to support H_o.

The procedure just described is then repeated m_k consecutive times at cycle k. This ensures a small probability of error at the end of the cycle. Suppose that under $H_j (j=0,1)$ the probability of error at the end of cycle k satisfies

$$\Pr(e_k | H_j) \leq \frac{2}{k^2} \tag{3.1}$$

Then $\sum_{k=1}^{\infty} \Pr(e_k | H_j)$ is finite, and by use of the Borel-Cantelli lemma the automaton will make only a finite number of mistakes wpl. We proceed to show that the sequences $\{t_k\}_1^\infty$ and $\{m_k\}_1^\infty$ can be chosen so as to satisfy (3.1).

Let $H_o \triangleq p_o^{p_o} q_o^{q_o}$, $r_o(p) \triangleq \dfrac{p_o \text{Log } p + q_o \text{Log } q}{p_o \text{Log } p_o + q_o \text{Log } q_o}$, and t_k be the integer s.t.

$$\text{Log}_{(H_o)} \left[\left(\tfrac{1}{k}\right)^{4k}\right] \leq t_k < 1 + \text{Log}_{(H_o)} \left[\left(\tfrac{1}{k}\right)^{4k}\right] \tag{3.2}$$

The parameter p of the Bernoulli random variable is fixed and by assumption different from 0,1. It is simple to establish a relation similar to (2.5):

$$c\left(\tfrac{1}{k}\right)^{4kr_o(p)} \leq \Pr(1 \to 0 \text{ at cycle k}) < d\left(\tfrac{1}{k}\right)^{4kr_o(p)} \qquad (c,d < \infty) \tag{3.3}$$

$\mathbb{M}_2$ has same asymptotic behavior as $\mathbb{M}'_2$, the program of which is identical to P_2 except for instruction I replaced by: "Set T = 0 wp $\alpha_k \triangleq \left(\tfrac{1}{k}\right)^{4kr_o(p)}$".

Asymptotic behavior of $\mathbb{M}'_2$

Within each cycle k, we have a time-independent Markov process with transition matrix

$$M_k = \begin{bmatrix} 1-\epsilon_k & \alpha_k \\ \epsilon_k & 1-\alpha_k \end{bmatrix}$$

Let $\underline{\mu}_k(o) = (\mu_k^o(o), \mu_k^1(o))$ be the initial probability vector on the states 0 and 1 at the beginning of cycle k, and $\underline{\mu}_k(m) = (\mu_k^o(m), \mu_k^1(m))$ that same probability

vector after m iterations within cycle k. In addition let $\underline{\nu}_k = (\nu_k^o, \nu_k^1)$ be the steady-state probability vector. Clearly,

$$\underline{\nu}_k = \left(\frac{\alpha_k}{\alpha_k + \epsilon_k}, \frac{\epsilon_k}{\alpha_k + \epsilon_k}\right) \tag{3.4}$$

and by a simple computation,

$$\underline{\mu}_k(m) = \left(\frac{\alpha_k - \delta_k(m)}{\alpha_k + \epsilon_k}, \frac{\epsilon_k + \delta_k(m)}{\alpha_k + \epsilon_k}\right), \text{ where } \delta_k(m) \text{ is given by} \tag{3.5}$$

$$\delta_k(m) = (1 - \alpha_k - \epsilon_k)^m [\alpha_k \mu_k^1(o) - \epsilon_k \mu_k^o(o)] \tag{3.6}$$

Under H_o, $r_o(p) = r_o(p_o) = 1$ implies $\alpha_k = (1/k)^{4k}$. From (3.6) we have

$$\delta_k(m) = (1 - \alpha_k - \epsilon_k)^m \left(\frac{1}{k}\right)^{4k} \left[\left(1 + \frac{1}{k^2}\right) \mu_k^1(o) - \frac{1}{k^2}\right] \tag{3.7}$$

and since $0 \le \mu_k^1(o) \le 1$, we obtain

$$-(1-\alpha_k-\epsilon_k)^m \left(\frac{1}{k}\right)^{4k+2} \le \delta_k(m) \le (1-\alpha_k-\epsilon_k)^m \left(\frac{1}{k}\right)^{4k} \tag{3.8}$$

which implies

$$|\delta_k(m)| \le (1-\epsilon_k)^m \left(\frac{1}{k}\right)^{4k} . \tag{3.9}$$

Under H_1, $r_o(p) > 1 + 1/k$ for large values of k. From (3.6) we have

$$\delta_k(m) = -(1-\alpha_k-\epsilon_k)^m \left[\mu_k^o(o)\left(\left(\frac{1}{k}\right)^{4kr_o(p)} + \left(\frac{1}{k}\right)^{4k+2}\right) - \left(\frac{1}{k}\right)^{4kr_o(p)}\right] \tag{3.10}$$

which implies

$$-(1-\alpha_k-\epsilon_k)^m \left(\frac{1}{k}\right)^{4k+2} \le \delta_k(m) \le (1-\alpha_k-\epsilon_k)^m \left(\frac{1}{k}\right)^{4kr_o(p)} \tag{3.11}$$

Thus we have

$$|\delta_k(m)| \le \left(\frac{1}{k}\right)^{4k+2}, \text{ for large values of k.} \tag{3.12}$$

Choosing now $m = m_k \triangleq -2\text{Log } k/\text{Log}(1-\epsilon_k)$, (3.9) and (3.12) show that

$$|\delta_k(m_k)| \le \begin{cases} \epsilon_k \text{ under } H_o \\ \alpha_k \text{ under } H_1 \end{cases} . \text{ Therefore,} \tag{3.13}$$

$$\Pr(e_k|H_i) \le 2\nu_k^{1-i} \qquad (i=0,1) \tag{3.14}$$

If H_o is true, $r_o(p) = r_o(p_o) = 1 \Rightarrow \nu_k^1 = \frac{1}{1+k^2} < \frac{1}{k^2}$;

If H_1 is true, $r_o(p) > 1 + \frac{1}{k} \Rightarrow \nu_k^o < \frac{1}{k^2}$;

Consequently, $Pr(e_k|H_i) < \frac{2}{k^2}$ $(i=0,1)$, and this completes the proof of theorem 2.

Example: Borel defined a normal number in the base b as a number such that the limiting relative frequency of each digit in the base b expansion is equal to 1/b. Let b = 2. Theorem 2 shows that 2 bits of memory are sufficient to test if a number is normal or not. For example, consider the number 01010000110110010111 ..., i.e., the base 2 expansion of π-3 = .31415926535 ... The problem is that of testing H_o: $p = \frac{1}{2}$ versus H_1: $p \neq \frac{1}{2}$. As it has been shown a zero limiting probability of error can be achieved with a four-state automaton for almost every number.

IV. ELIMINATION OF RANDOMIZATION

Consider a stochastic automaton in which the decision rule uses two types of radomization. One is when an action A_j is performed with probability a_j $(j=1,2,...)$ at any given cycle. The other occurs when a transition is performed with probability ϵ_i at cycle i. We shall give one procedure that shows how this stochastic automaton can be replaced by a deterministic automaton with the same asymptotic behavior.

Let $\mathring{A} = \{ A_i ; i=1,2,...$ ad inf.$\}$ be a set of actions A_i , and let $\alpha = (\alpha_1, \alpha_2, ...)$ be any vector such that $0 < \alpha_j < 1$, $\forall j$. Consider a machine M that performs action A_j with probability α_j at time i. The program P of that machine looks like:

Start i: =0;

Cycle i: i+1;

I Do A_j with probability α_j successively for j=1,...,i;

Go to Cycle; End.

Lemma 1 Let $\{\alpha^i\}_1^\infty$ be an infinite sequence of probability vectors $\alpha^i=(\alpha_1^i,\alpha_2^i,\ldots)$ where $\alpha_j^i > 0$ and $\sum_{j=1}^{\infty} \alpha_j^i = 1$, $\forall j$. Then there exist positive integers n_k^j (j=1,2,...; k=1,2,...) such that $p_j^i \to \alpha_j^i$ $\forall j$, where p_j^i is defined by:

$$p_j^i \triangleq \sum_{k=j}^{i} n_k^j \Big/ \sum_{k=1}^{i} \sum_{j=1}^{k} n_k^j \ .$$

Proof: Let $\{N_i\}_1^\infty$ be a sequence of positive integers. Let $n_i^j \triangleq N_i\alpha_j^i$, $s_i^j \triangleq \sum_{k=j}^{i} n_k^j$. Choose the sequence N_i such that:

(4.1) $n_i^j \geq 1$ $\forall i$, $\forall j = 1,2,\ldots,i$.

(4.2) $s_{i-1}^j / n_i^j \to 0$ as $i \to \infty$.

This is shown later always to be possible. For large values of i, the following is true:

$$s_i^j/n_i^j = (s_{i-1}^j + n_i^j)/ n_i^j \to 1 \quad \text{by (4.2).}$$

Therefore,

$$p_j^i = s_i^j \Big/ \sum_{k=1}^{i} s_i^k \to n_i^j \Big/ \sum_{k=1}^{i} n_i^k \to \alpha_j^i \quad \text{as } i \to \infty.$$

For a possible sequence, choose N_1 such that $N_1 = \lceil 1/\alpha_1^i \rceil$, and subsequently

$$N_i = \max \{ \lceil 1/\alpha_1^i \rceil, \ldots, \lceil 1/\alpha_i^i \rceil, \lceil \sigma_{i-1}^1/\alpha_1^i \rceil, \ldots, \lceil \sigma_{i-1}^{i-1}/\alpha_{i-1}^i \rceil \}$$

where

$$\sigma_i^j \triangleq (s_i^j)^{s_i^j} \quad (j=1,2,\ldots,i).$$

Theorem 3 There exists a deterministic automaton M' which has the same asymptotic behavior as M.

Proof: Let $\{N_i\}_1^\infty$ be a sequence satisfying (4.1) and (4.2) where $\alpha^i=(\alpha_1,\alpha_2,\ldots)$. Consider the machine M' described by the program P with the exception that instruction I is replaced by I':

L_o j: =0;

L_1 j: = j+1; k: =0;

L_2 k: = k+1; If $k \leq n_i^j$ do A_j ; go to L_2;
If $j < i$ go to L_1;

For the first type of randomization, let $\alpha_j^i = a_j \quad \forall i$. Action A_j is performed n_i^j times during cycle i, and thus a proportion of the time equal to p_j^i in the first i cycles. By lemma 1, this tends to $\alpha_j^i = a_j$ as $i \to \infty$.
For the second type of randomization, only two actions are considered: A_i and the complementary action A_i^c with probabilities ϵ_i and $1 - \epsilon_i$ respectively. With $\alpha^i = (\epsilon_i, 1-\epsilon_i)$ this is again a special case of lemma 1.

V.CONCLUSIONS

Now that the two problems have been solved, let us underline the main ideas involved in the testing procedure. If one desires to resolve the hypothe -ses with a zero limiting probability of error, it is necessary to remember an infinite number of observations. This appears impossible under a finite memory constraint. A single observation contains only a finite amount of information. In order to obtain events of arbitrarily high information, the first idea is to compound experiments;i.e., to base the decisions taken on blocks rather than individual observations. The events considered are the appearance of specific patterns of 1's and 0's. Each pattern is matched to a hypothesis in the sense that it possesses the right proportion of 1's. The patterns adopted are sequences of 1's followed by 0's; it is clear that such a choice is arbitrary; any sequence with the right proportion of 1's is satisfactory as long as its structure is preassigned. However, the length of each pattern

is critical; too long patterns would occur too infrequently to ensure convergence, whereas too short patterns would not be meaningful enough to guarantee achievability.

In other words, at time n different models of the series are advanced and confronted with experience. If the prediction of the event is correct, agreement is recorded in the immediate memory Q, while the decision to retain this hypothesis updates the permanent memory T.

The most significant result is theorem 2; it shows the somewhat surprising fact that infinite precision problems and finite memory scheme are totally compatible.

These techniques have been successful in solving a much broader class of testing problems . This will be the object of a forthcoming publication.

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Information and Control

Patrick R. Hirschler

Descriptive Legends

Figure 1: Partitioning of observations into blocks

Figure 2: Partitioning of observations into sequences of blocks

Figure 1

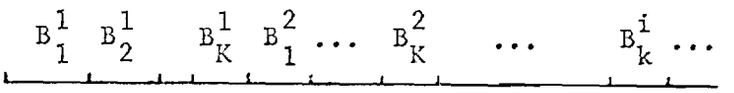

Figure 2