UNITED STATES AIR FORCE

HIGH SCHOOL APPRENTICESHIP PROGRAM

1989

PROGRAM MANAGEMENT REPORT

VOLUME I OF III

UNIVERSAL ENERGY SYSTEMS, INC.

Program Director, UES
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Program Administrator, UES
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Submitted to

Air Force Office of Scientific Research

Bolling Air Force Base

Washington, DC

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INTRODUCTION

In the near future the United States may face shortages of scientists and engineers in fields such as physics, electronic engineering, computer science and aeronautical engineering. High School students are currently not selecting to prepare for careers in these areas in numbers large enough to match the projected needs in the United States.

The Air Force faces "a formidable challenge - the acquisition and retention of the technological competence needed to ensure a strong national security, both in-house and in the industrial and academic base which supports defense preparedness." The Director of the Office and Science of Technology Policy in the Executive Office of the President in 1979 responded to this need by requesting the federal agencies to incorporate in their contract research programs the mechanisms to stimulate career interests in science and technology in high school students showing promise in these areas. The Air Force High School Apprenticeship Program is an example of the response to this.

Under the Special Studies section of the Summer Faculty Research Program an Air Force High School Apprenticeship was initiated. This program's purpose is to place outstanding high school students whose interests are in the areas of engineering and science to work in a laboratory environment. The students who were selected to participate worked in one of the Air Force Laboratories for a duration of 8 weeks during their summer vacation.

The Air Force High School Apprenticeship Program was modeled after the Army's High School Program, which is very successful.

The following time schedule was used in order to accomplish this effort.

TABLE 1
AIR FORCE HIGH SCHOOL
APPRENTICESHIP PROGRAM

Calendar of Activities

December	o	Identify schools and laboratories for participation
	o	Prepare informational material for schools and installations application forms for students and mentors, and covering letters.
	o	Disseminate information
	o	Recruit apprentices, mentors
January	o	Send student applications to teachers
February	o	Applications with teacher recommendations
	o	Receive mentors' project descriptions and student requirements
	o	Make preliminary selection of students for referral to mentor
March	o	Make preliminary matching of students with mentors; send letters with several student applications to each mentor
	o	Mentors interview students, inform UES of choice
April	o	Send letters of placement to students, with acceptance forms to be signed by them and parents and returned to UES
	o	Place 2nd year apprentices
	o	Make final matches
	o	See that security clearances are started, where applicable
	o	(Mentors provide background reference material to chosen apprentices)
	o	Encourage enrichment activities: arrange for films, speakers, tours, ect.
May	o	Send letters to students and mentors re-opening session
	o	Send students Apprentice Handbook
June	o	Arrange general orientation for students and mentors
July, August	o	Administer and monitor apprenticeships
	o	Check on enrichment activities
	o	Distribute evaluation forms to students and mentors
September	o	Analyze evaluations
	o	Prepare final report to Air Force

RECRUITING AND SELECTION

Application packages and the flyer were distributed to the laboratories and to the various high schools within convenient driving distance of the laboratories (typically less than 20 miles).

There was a total of 270 applications received by UES on the program. When the applications were received, a copy was sent to the appropriate laboratory for review. The laboratory mentor screened the applications and conducted personnel interviews with the high school students then sent UES a prioritized list of their applicants. There were a total of 103 participants on the program, selected from the 270 applications.

The laboratories participating in the program along with the number of students assigned to the laboratory is listed below:

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Geophysics Laboratory	8
Occupational and Environment Health Laboratory	3
Astronautics Laboratory	10
Rome Air Development Center	15
School of Aerospace Medicine	7

Participant Laboratory Assignment
1989 High School Apprenticeship Program

Aero Propulsion Laboratory
Wright-Patterson Air Force Base, Ohio

1. Matthew Bold
2. Robert Bradford
3. Roxanne Fischer
4. Terence Hill
5. Alisha Hix
6. Christopher Miller
7. Bradley Reigelsperger

Armament Laboratory
Eglin Air Force Base, Florida

1. Jules Bergmann
2. Steven Bryan
3. Tonya Cook
4. Kathryn Deibler
5. Chris Ellis
6. Dana Farver
7. Kenneth Gage
8. Reid Harrison
9. Derek Holland
10. Jeffrey Leong
11. Byran McGraw
12. Neil Overholtz
13. Shan-ni Perry
14. Lisa Schmidt
15. Patricia Tu
16. Danielle Walker

Armstrong Aerospace Medical Research Laboratory
Wright-Patterson Air Force Base, Ohio

1. Michael Chabinyc
2. Ann Hartung
3. Keisha Hayes
4. Angela Karter
5. Douglas Marshak
6. Carolyn Mellott
7. Britt Peschke
8. Jennifer Walker

Astronautics Laboratory
Edwards Air Force Base, California

1. Ross Benedict
2. Peter George
3. Sharron Groom
4. Lloyd Neurauter
5. Sandra Novak
6. Sonya Park
7. Alexander Sagers
8. Richard Sims
9. Benjamin Sommers
10. Shirley Williams

Avionics Laboratory
Wright-Patterson Air Force Base, Ohio

1. Matthew Brewer
2. Sook Hee Choung
3. Sheri Cody
4. Christine Garcia
5. Lori Harris
6. Amy Listerman
7. Joan McManamon
8. Allison Potter
9. Julie Roesner
10. Jerard Wilson

Engineering and Services Center
Tyndall Air Force Base, Florida

1. Gregory Dixon
2. Dorothy Iffrig
3. Byron Kuhn
4. Scott Lamb
5. Keith Levesque
6. Cyrus Riley
7. Robin Woodworth

Flight Dynamics Laboratory
Wright-Patterson Air Force Base, Ohio

1. Tremayne Anderson
2. Eric Bailey
3. Mark Boeke
4. Wendy Choate
5. William Davenport
6. Andrea Dean
7. Cedric McGhee
8. David Merritt
9. Valerie Petry
10. Kimberly Shock
11. Mark Screven
12. James Wilkinson

Geophysics Laboratory
Hanscom Air Force Base, Massachusetts

1. Stephen Britten
2. Brian Burke
3. Eric Eisenberg
4. Christopher Guild
5. Maki Inada
6. Susan Jacavanco
7. David Kelleher
8. John Walker

Occupational and Environment Health Laboratory
Brooks Air Force Base, Texas

1. Jonathan Jarrell
2. Andrea Perez
3. Alan Thomason

Rome Air Development Center
Griffiss Air Force Base, New York

1. Daniel Abbis
2. Matthew Anderson
3. Carolynn Bruce
4. Katherine De Bruin
5. Benjamin Dreidel
6. Stephanie Hurlburt
7. Michael Marko
8. Karen Panek
9. Thomas Potter
10. Richamond Real
11. Eric Shaw
12. Shane Stanek
13. Juliet Vescio
14. Katie Ward
15. Barbara Westfall

School of Aerospace Medicine
Brooks Air Force Base, Texas

1. Jeanne Barton
2. Whitney Brandt
3. Christina Cheney
4. Brian McBurnett
5. Lori Olenick
6. Joanna Saucedo
7. John Taboada

INFORMATION PACKAGE

7 March 1989

Dear :

Enclosed are the mentor applications forms for the 1989 USAF High School Apprenticeship Program. The mentors and project descriptions have been approved by UES.

Enclosed are the applications for the High School Apprenticeship program for the summer of 1989. The following mentor and previous high school participant have been matched and selected to work with each other for the coming summer.

Student	Mentor
1.	

The following is a previous high school participant in the program and is selected to participant in the program for this summer. She needs to be matched with one of the approved mentors for this summer.

Student

1.

The remainder of the students need to be evaluated by the approved mentors for possible selection in the program for this summer. Please provide to UES a listing of the mentor recommendations for students by 1 April 1989. Please return the application forms with the bottom portion filled in for the students recommended for participation in the program. Please return the mentor participation forms along with the students' applications.

We have a total of 100 positions available on the program for this summer. We will select as many as possible to fill this available positions. We anticipate that about ___ high school students will be selected to participate with the mentors at the ________.

If you have any questions concerning this information, please do not hesitate to contact us.

Sincerely,

UNIVERSAL ENERGY SYSTEMS, INC.

Rodney C. Darrah
Program Director

Enclosure

xc:

2149s

MODEL PLACEMENT LETTER TO STUDENT

13 April 1989

Dear :

Congratulations! You have been selected to participate in the Air Force Office of Scientific Research High School Apprenticeship Program as an apprentice to _________ at the _________ to work on Project: "_________" from June 19 to August 11, 1989. Enclosed is an acceptance form for you and your parent or guardian to sign. Also enclosed is your W-4 form which needs to be filled out and returned along with your acceptance form to me by April 27, 1989.

The Apprenticeship Program provides an exciting opportunity for you, and we hope you will take advantage of the work experience to learn more about scientific research, career opportunities in science and engineering, and the education necessary to prepare yourself for such careers. On June 19, 1989, the first day of the program, you are expected to attend an orientation session with other apprentices and mentors and to ask questions about any concerns you might have. Many of those concerns are discussed in the Apprentice Handbook which is enclosed. The Handbook also contains suggestions for getting the most out of the summer experience, and references to other work experience programs and financial assistance available for college education. Please read the Handbook before the orientation session, so that time will not be used for questions answered in the book.

You will be expected to begin work promptly at 8:00 a.m. on June 19. If for any reason you cannot begin work on that day, or cannot report to work on any future work day, you must inform your mentor at _______________.

We hope you will enjoy your apprenticeship. I will be available throughout the summer should problems arise that cannot be solved by your mentor.

Sincerely,

UNIVERSAL ENERGY SYSTEMS, INC.

Rodney C. Darrah
Program Director

RCD/nt
2230s

STUDENT ACCEPTANCE FORM

for participation in

Air Force Office of Scientific Research

High School Apprenticeship Program, 1989

I, ________, accept the position of apprentice in the Air Force Office of Scientific Research High School Apprenticeship Program from June 19, 1989 to August 11, 1989 to work with __________ at the __________ on Project: "____________". I understand that I will receive a stipend of $______ for the summer apprenticeship for which I must participate during the entire session.

Date ______ Signature of student ______________________

High School ______________________

PARENT CONSENT

As the parent/guardian, I certify that my son/daughter/ward has my permission to participate in this project for secondary school students. It is my understanding that he/she will be subject to the regulations of the host institution and the project. I understand that should a health emergency arise I will be notified, but that if I cannot be reached by telephone, such medical treatment as deemed necessary by competent medical personnel is authorized.

Date_________ Signature of parent__________________

Daytime phone__________________

2232s

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

1. How did you hear about program?

   - o Previous mentor
   - o Notice on bulletin board
   - o Memo from personnel office
   - o Verbal request from personnel office
   - o Other, specify__________ __________________

2. Did you volunteer to be a mentor?

   Yes__ No__

3. Did the student application provide sufficient information?

   Yes__ No__

4. If no, what additional information would you want to see included on the student application form?____________________

   ____

   ____

5. Did you interview the student who was placed in your laboratory before the program started?

   Yes__ No__

6. If no, would an interview have been useful?

   Yes__ No__

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   A lot__ Some__ Not at all__

8. How much did the student contribute to the research of your laboratory?

   A lot__ Some__ Not at all__

9. How would you rate the student's performance?

   Excellent__ Fair__ Poor__

10. Would like to participant as a mentor for the program next summer?

Yes___ No___ If No, Why?____________

11. Would you want the same student in your laboratory next summer?

Yes___ No___ If No, Why?____________

12. Did the work of the student influence his/her choice of

a. courses in coming school year? __Yes __No __Don't know

Explain ______________________________

b. career choice? __Yes __No __Don't know

Explain ______________________________

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

AERO PROPULSION LABORATORY

1. How did you hear about program?

   3 Previous mentor
   0 Notice on bulletin board
   2 Memo from personnel office
   0 Verbal request from personnel office
   1 Other, specify:__________

   Division Office

2. Did you volunteer to be a mentor?

   4 Yes
   2 No

3. Did the student application provide sufficient information?

   5 Yes
   0 No
   1 Don't Know

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   1 Yes
   5 No

6. If no, would an interview have been useful?

   2 Yes
   4 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   5 A lot
   1 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   4 A lot
   2 Some
   0 Not at all

9. How would you rate the student's performance?

   5 Excellent
   1 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   5 Yes
   1 No
   If No, Why?

   No relevant program

11. Would you want the same student in your laboratory next summer?

   6 Yes
   0 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 1 - Yes 1 - No 4 - Don't Know

   Explain:

   One mentor expressed that the student did change her area of study to engineering, while two of the mentors commented that as freshman there courses are already set.

   b. career choice? 1 - Yes 2 - No 3 - Don't know

   Explain:

   One mentor believed student's interest in engineering was aroused but wasn't interested in any one area.

If you have suggestions or comments on the program, please use the space below.

Comments were that it is an excellent program ~~were~~ where both the student and the lab benefited while another mentor was looking forward to having the student returning.

PLEASE RETURN BY 15 September 1989

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ARMAMENT LABORATORY

1. How did you hear about program?

    10 Previous mentor
    0 Notice on bulletin board
    0 Memo from personnel office
    0 Verbal request from personnel office
    5 Other, specify:__________

    Mentors heard about the program in various ways, from interoffice memos, Branch Chiefs.

2. Did you volunteer to be a mentor?

    15 Yes
    0 No

3. Did the student application provide sufficient information?

    13 Yes
    1 No
    1 N/A

    One comment was that student was selected by lab coordinator as science fair winner.

4. If no, what additional information would you want to see included on the student application form?

    One mentor would like to see questions on technical interest and projects students are interested in.

5. Did you interview the student who was placed in your laboratory before the program started?

    8 Yes
    7 No

6. If no, would an interview have been useful?

    9 Yes
    0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

    13 A lot
    2 Some
    0 Not at all

8. How much did the student contribute to the research of your laboratory?

    9 A lot
    6 Some
    0 Not at all

9. How would you rate the student's performance?

    14 Excellent
    1 Fair
    0 Poor

10. Would like to participant as a mentor for the program next summer?

    14 Yes
    1 No
    If No, Why?

    Will be PCS.

11. Would you want the same student in your laboratory next summer?

    12 Yes
    3 No
    If No, Why?

    Not eligible.

    Graduated.

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 2 - Yes 5 - No 8 - Don't know

    Explain:

    Six mentors commented that the students courses were already pre-determined.

b. career choice? 3 - Yes 2 - No 9 - Don't know

Explain:

Three mentors expressed that the students career goals were already determined before the apprenticeship, while one comment was that the student will be joining the Air Force, and a student that has not decided on a different career.

If you have suggestions or comments on the program, please use the space below.

An excellent program - with outstanding students.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

1. How did you hear about program?

   5 Previous mentor
   1 Notice on bulletin board
   1 Memo from personnel office
   0 Verbal request from personnel office
   1 Other, specify:__________

   Mentor last year.

2. Did you volunteer to be a mentor?

   8 Yes
   0 No

3. Did the student application provide sufficient information?

   8 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

   Specific mathematics and computer skills would help.

5. Did you interview the student who was placed in your laboratory before the program started?

   2 Yes
   6 No

6. If no, would an interview have been useful?

   2 Yes
   4 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   6 A lot
   2 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   4 A lot
   4 Some
   0 Not at all

9. How would you rate the student's performance?

   7 Excellent
   1 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   6 Yes
   2 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   7 Yes
   1 No
   If No, Why?

   Too busy.

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 2 - Yes 2 - No 4 - Don't know

      Explain:

      Courses chosen range from Biomedical to Chemical Engineering.

   b. career choice? 1 - Yes 2 - No 5 - Don't know

      Explain:

      Student knew before apprenticeship but working on the program reaffirmed his interest.

If you have suggestions or comments on the program, please use the space below.

Comments that the program is excellent.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ASTRONAUTICS LABORATORY

1. How did you hear about program?

   7 Previous mentor
   0 Notice on bulletin board
   0 Memo from personnel office
   0 Verbal request from personnel office
   2 Other, specify:__________

   Previous year program.

   Was a mentor last year.

2. Did you volunteer to be a mentor?

   9 Yes
   0 No

3. Did the student application provide sufficient information?

   8 Yes
   1 No

4. If no, what additional information would you want to see included on the student application form?

   Desires, goals, plans, why he/she wants to work here.

5. Did you interview the student who was placed in your laboratory before the program started?

   3 Yes
   6 No

6. If no, would an interview have been useful?

   6 Yes
   0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   4 A lot
   5 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   4 A lot
   4 Some
   1 Not at all

9. How would you rate the student's performance?

   6 Excellent
   2 Fair
   1 Poor

10. Would like to participant as a mentor for the program next summer?

   7 Yes
   2 No
   If No, Why?

   No high school/college junior or senior.

   Will be leaving Edwards.

11. Would you want the same student in your laboratory next summer?

   4 Yes
   3 No
   If No, Why?

   He has graduated from high school.

   Poor attendance, work attitude.

12. Did the work of the student influence his/her choice of

a. courses in coming school year? 2 - Yes 3 - No 4 - Don't know

Explain:

Student interest is in chemistry or pharmacy - not engineering.

The student is pursuing math & science to gain entrance into engineering schools.

EE major in a chem lab!!

b. career choice? 2 - Yes 4 - No 2 - Don't know

Explain:

Strengthen career choice of Electrical Engineering.

The summer program motivated student to pursue aerospace research.

Discussed colleges and career aspirations.
College major already selected.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

AVIONICS LABORATORY

1. How did you hear about program?

   5 Previous mentor
   0 Notice on bulletin board
   3 Memo from personnel office
   0 Verbal request from personnel office
   2 Other, specify:__________

   Mentors received information from supervisors, another mentor commented that he was given a stack of applications to choose the top 3.

2. Did you volunteer to be a mentor?

   10 Yes
   0 No

3. Did the student application provide sufficient information?

   10 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   0 Yes
   10 No

6. If no, would an interview have been useful?

   6 Yes
   2 No
   1 Maybe

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

    8 A lot
    2 Some
    0 Not at all

8. How much did the student contribute to the research of your laboratory?

    2 A lot
    8 Some
    0 Not at all

9. How would you rate the student's performance?

    9 Excellent
    1 Fair
    0 Poor

10. Would like to participant as a mentor for the program next summer?

    7 Yes
    1 Maybe
    2 No
    If No, Why?

    Two mentors didn't want to participate next year due to the time the students required.

11. Would you want the same student in your laboratory next summer?

    5 Yes
    5 No
    If No, Why?

    Four of the no responses were due to the students will be attending college, while one mentor thought the student would benefit by seeing other labs.

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 1 - Yes 6 - No 3 - Don't know

    Explain:

    The six no responses were because as college freshman, students classes are already planned.

b. career choice? 6 - Yes 3 - No 1 - Don't know

Explain:

Most of the students have already made their career choice were as one mentor indicated the student changed from Navy ROTC to Air Force ROTC.

If you have suggestions or comments on the program, please use the space below.

It is difficult to find work a high school student can fully understand or perform. With the exception of some computer work, they simply do not have the physical science background to understand solid state research.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ENGINEERING AND SERVICES CENTER

1. How did you hear about program?

   4 Previous mentor
   0 Notice on bulletin board
   1 Memo from personnel office
   0 Verbal request from personnel office
   2 Other, specify:__________

   Memo AFESC internal.

   Suggested by RDXI.

2. Did you volunteer to be a mentor?

   7 Yes
   0 No

3. Did the student application provide sufficient information?

   6 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   1 Yes
   6 No

6. If no, would an interview have been useful?

   4 Yes
   2 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   6 A lot
   1 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   4 A lot
   3 Some
   0 Not at all

9. How would you rate the student's performance?

   6 Excellent
   1 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   5 Yes
   2 No
   If No, Why?

   Probably will not be here.

   Will not be here.

11. Would you want the same student in your laboratory next summer?

   4 Yes
   3 No
   If No, Why?

   On the no responses the mentors indicates the student have graduated or they are attending college.

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 1 - Yes 1 - No 5 - Don't know

   Explain:

   As the majority of mentors states - course are usually determined, one mentor relaid that the subject never came up.

b. career choice? 0 - Yes 1 - No 6 - Don't know

Explain:

The no response indicated that the student's career choice was already made.

If you have suggestions or comments on the program, please use the space below.

One mentor suggested that more area high schools should be given a chance to participate. Another mentor commented that all apprentices should be seniors.

PLEASE RETURN BY 15 September 1989

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

FLIGHT DYNAMICS LABORATORY

1. How did you hear about program?

   5 Previous mentor
   0 Notice on bulletin board
   1 Memo from personnel office
   0 Verbal request from personnel office
   4 Other, specify:__________

   From my branch chief.

   Memo from WRDC/FIOP programs branch.

   Notice from FIV.

   Been these before.

2. Did you volunteer to be a mentor?

   9 Yes
   1 No

3. Did the student application provide sufficient information?

   10 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   2 Yes
   8 No

6. If no, would an interview have been useful?

   7 Yes
   0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   6 A lot
   4 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   6 A lot
   4 Some
   0 Not at all

9. How would you rate the student's performance?

   10 Excellent
   0 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   9 Yes
   1 No
   If No, Why?

   Let someone else in the group participate.

   Depends on work available for student.

11. Would you want the same student in your laboratory next summer?

   9 Yes
   1 No
   If No, Why?

   Not available.

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 3 - Yes 1 - No 6 - Don't know

   Explain:

   The three yes responses were expressed by the laboratory equipment that the students used helped in making their decisions for courses for the coming year.

b. career choice? 3 - Yes 2 - No 5 - Don't know

Explain:

The two responses indicated that one student changed their career to Mechanical Engineering while another student changed to Automotive Engineering.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

GEOPHYSICS LABORATORY

1. How did you hear about program?

   5 Previous mentor
   0 Notice on bulletin board
   2 Memo from personnel office
   0 Verbal request from personnel office
   1 Other, specify:__________

   Verbal - Branch Chief.

2. Did you volunteer to be a mentor?

   8 Yes
   0 No

3. Did the student application provide sufficient information?

   8 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

   Computer experience.

5. Did you interview the student who was placed in your laboratory before the program started?

   7 Yes
   0 No

6. If no, would an interview have been useful?

   1 Yes
   0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   8 A lot
   0 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   7 A lot
   1 Some
   0 Not at all

9. How would you rate the student's performance?

   8 Excellent
   0 Fair
   0 Poor

10. Would like to participate as a mentor for the program next summer?

   7 Yes
   1 No
   If No, Why?

   Two summers is enough.

11. Would you want the same student in your laboratory next summer?

   7 Yes
   0 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 2 - Yes 2 - No 4 - Don't know

   Explain:

   The responses indicated that students already had courses chosen for next school year.

   b. career choice? 3 - Yes 1 - No 4 - Don't know

   Explain:

   Most of the responses indicated that the students career choices were made prior to the summer effort.

If you have suggestions or comments on the program, please use the space below.

One mentor suggested that students should be able to interact with each other such as tours, lunches, etc.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/labor ıtory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

OCCUPATIONAL AND ENVIRONMENT HEALTH LABORATORY

1. How did you hear about program?

   0 Previous mentor
   0 Notice on bulletin board
   0 Memo from personnel office
   0 Verbal request from personnel office
   3 Other, specify:__________

   Staff briefing.

   Request from unit.

   Told from front office.

2. Did you volunteer to be a mentor?

   2 Yes
   1 No

3. Did the student application provide sufficient information?

   2 Yes
   1 No

4. If no, what additional information would you want to see included on the student application form?

   Could've provided more information, like classes taken etc.

   Never seen.

5. Did you interview the student who was placed in your laboratory before the program started?

   2 Yes
   1 No

6. If no, would an interview have been useful?

   1 Yes
   0 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   2 A lot
   1 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   1 A lot
   2 Some
   0 Not at all

9. How would you rate the student's performance?

   2 Excellent
   1 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   2 Yes
   0 No
   If No, Why?

11. Would you want the same student in your laboratory next summer?

   1 Yes
   1 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 2 - Yes 1 - No 0 - Don't know

   Explain:

   One mentor expressed that the student had decided to take more computer classes.

   b. career choice? 1 - Yes 1 - No 1 - Don't know

   Explain:

If you have suggestions or comments on the program, please use the space below.

A mentor suggested that they have a project competition with the winners receiving tuition assistance scholarships.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

Name of student apprentice

Name of mentor/laboratory

Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ROME AIR DEVELOPMENT CENTER

1. How did you hear about program?

   5 Previous mentor
   0 Notice on bulletin board
   3 Memo from personnel office
   1 Verbal request from personnel office
   0 Other, specify:__________

2. Did you volunteer to be a mentor?

   9 Yes
   0 No

3. Did the student application provide sufficient information?

   8 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

5. Did you interview the student who was placed in your laboratory before the program started?

   0 Yes
   9 No

6. If no, would an interview have been useful?

   5 Yes
   4 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

   6 A lot
   3 Some
   0 Not at all

8. How much did the student contribute to the research of your laboratory?

   4 A lot
   4 Some
   1 Not at all

9. How would you rate the student's performance?

   7 Excellent
   2 Fair
   0 Poor

10. Would like to participant as a mentor for the program next summer?

   8 Yes
   1 No
   If No, Why?

   No time.

11. Would you want the same student in your laboratory next summer?

   9 Yes
   0 No
   If No, Why?

12. Did the work of the student influence his/her choice of

   a. courses in coming school year? 1 - Yes 6 - No 2 - Don't know

      Explain:

      Comments ranged from students already having courses set before the summer effort to a student choosing a liberal arts program.

   b. career choice? 3 - Yes 3 - No 3 - Don't know

      Explain:

      The responses indicated that the majority of the students have already chosen careers where as another comment was that students have not made and decisions.

If you have suggestions or comments on the program, please use the space below.

One mentor suggested that due to Air Force personnel traveling that a dual mentorship is necessary. Another mentor would like to have the start date set back due to students that can't except due to exams.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

SCHOOL OF AEROSPACE MEDICINE

1. How did you hear about program?

   5 Previous mentor
   1 Notice on bulletin board
   0 Memo from personnel office
   0 Verbal request from personnel office
   1 Other, specify:__________

   From Chief Scientist.

2. Did you volunteer to be a mentor?

   7 Yes
   0 No

3. Did the student application provide sufficient information?

   7 Yes
   0 No

4. If no, what additional information would you want to see included on the student application form?

   Be allowed to telephone top candidate(s).

5. Did you interview the student who was placed in your laboratory before the program started?

   1 Yes
   6 No

6. If no, would an interview have been useful?

   4 Yes
   2 No

7. In your opinion, how much has the student's work in your laboratory contributed to his/her understanding of the nature of scientific research?

    7 A lot
    0 Some
    0 Not at all

8. How much did the student contribute to the research of your laboratory?

    5 A lot
    2 Some
    0 Not at all

9. How would you rate the student's performance?

    7 Excellent
    0 Fair
    0 Poor

10. Would like to participant as a mentor for the program next summer?

    7 Yes
    0 No
    If No, Why?

11. Would you want the same student in your laboratory next summer?

    6 Yes
    1 No
    If No, Why?

    Student has entered college.

12. Did the work of the student influence his/her choice of

    a. courses in coming school year? 1 - Yes 2 - No 4 - Don't know

    Explain:

    First hand experience in a laboratory setting was very encouraging

    Student was already interested in chemistry.

    Freshman year course work fairly set. We did discuss it.

    Curricular set H.S., few electives.

b. career choice? 2 - Yes 1 - No 4 - Don't know

Explain:

It affirmed indication toward physical science applied to medicine.

Student had clear career goals prior to tenure in our laboratory.

Already had strong biological interests and career ideas.

Discussed often. Already has strong career ideas in related area.

If you have suggestions or comments on the program, please use the space below.

PLEASE RETURN BY 15 September 1989

to: Susan Espy
Coordinator

Universal Energy Systems
4401 Dayton-Xenia Road
Dayton, OH 45432
Address

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
APPRENTICE EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A HIGH SCHOOL STUDENT)

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL)

I. <u>How much were you exposed to each of the following during your summer apprenticeship? (Circle one letter per line.)</u>

A	B	C	D	1.	Philosophy of research
A	B	C	D	2.	Use of scientific method to solve problems
A	B	C	D	3.	Use of experimental checks and controls
A	B	C	D	4.	Measurement techniques
A	B	C	D	5.	Design of equipment
A	B	C	D	6.	Calibration of reagents, standards, and instruments
A	B	C	D	7.	Process of design of an experiment
A	B	C	D	8.	Data analysis (with or without computer assistance)
A	B	C	D	9.	Computer programming
A	B	C	D	10.	Acquisition and use of scientific literature (books, audio visual)
A	B	C	D	11.	Identification of new questions as a consequence of scientific exploration
A	B	C	D	12.	Teamwork in scientific research
A	B	C	D	13.	Use of advanced scientific equipment
A	B	C	D	14.	Other students with similar interests and goals
A	B	C	D	15.	Scientists working in different areas of research
A	B	C	D	16.	Information on scientific careers

II. How much has your experience as an apprentice contributed to your development in each of the following? (Circle one letter per line)

A B C D 1. Working with adults

A B C D 2. Responsibility on a job

A B C D 3. Understanding of scientific principles

A B C D 4. Scientific vocabulary

A B C D 5. Ability to write a technical report

A B C D 6. Understanding of your interests and abilities

A B C D 7. Educational goal setting

A B C D 8. Insights into career opportunities in science

A B C D 9. Career goal setting

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL
E = NOT AVAILABLE/
NOT RELEVANT)

III. To what extent did you benefit from the following?

A B C D E 1. Planned lectures or seminars

A B C D E 2. Explanations of work by mentor

A B C D E 3. Tours of other laboratories or installations

A B C D E 4. Informal talks with mentor

A B C D E 5. Discussions with other scientists

A B C D E 6. Interactions with other apprentices

A B C D E 7. Advice from the program coordinator

(A = STRONGLY AGREE
B = AGREE
C = DISAGREE
D = STRONGLY DISAGREE)

IV. How do you feel about your research apprentice experience?

A B C D 1. I enjoyed the experience

A B C D 2. I liked the scientific research

A B C D 3. I was satisfied with the way I spent my time

A B C D 4. I learned a lot

A B C D 5. I feel I contributed to the research results

V. Would you want to return to the same mentor next year?

o Yes o No: If No, why?

- o personality conflicts
- o lack of interest
- o want a different experience
- o want a different location

VI. What did you like most about the program?

VII. What did you like least about the program?

DO NOT SIGN

RETURN FORM TO YOUR COORDINATOR BY 15 September 1989
date

Susan Espy
Name of Coordinator

Universal Energy Systems
4401 Dayton-Xenia Rd.
Dayton, OH 45432
Address
2361s

1989 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
APPRENTICE EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A HIGH SCHOOL STUDENT)

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL)

I. How much were you exposed to each of the following during your summer apprenticeship? (Circle one letter per line.)

A	B	C	D		
39	30	15	5	1.	Philosophy of research
28	32	19	10	2.	Use of scientific method to solve problems
35	21	25	8	3.	Use of experimental checks and controls
34	17	21	17	4.	Measurement techniques
29	27	22	11	5.	Design of equipment
24	19	18	28	6.	Calibration of reagents, standards, and instruments
27	33	18	11	7.	Process of design of an experiment
60	18	7	4	8.	Data analysis (with or without computer assistance)
48	16	18	7	9.	Computer programming
42	27	16	4	10.	Acquisition and use of scientific literature (books, audio visual)
26	33	18	12	11.	Identification of new questions as a consequence of scientific exploration
52	22	11	4	12.	Teamwork in scientific research
54	17	13	6	13.	Use of advanced scientific equipment
25	26	25	14	14.	Other students with similar interests and goals
43	29	16	1	15.	Scientists working in different areas of research
40	29	16	4	16.	Information on scientific careers

II. How much has your experience as an apprentice contributed to your development in each of the following? (Circle one letter per line)

A	B	C	D	
66	19	4	0	1. Working with adults
52	28	8	1	2. Responsibility on a job
40	33	14	2	3. Understanding of scientific principles
35	39	14	1	4. Scientific vocabulary
30	32	22	5	5. Ability to write a technical report
42	37	9	1	6. Understanding of your interests and abilities
38	32	16	3	7. Educational goal setting
52	21	12	4	8. Insights into career opportunities in science
42	28	16	4	9. Career goal setting

(A = A LOT
B = SOME
C = A LITTLE
D = NOT AT ALL
E = NOT AVAILABLE/
NOT RELEVANT)

III. To what extent did you benefit from the following?

A	B	C	D	E	
8	28	22	6	25	1. Planned lectures or seminars
65	17	5	1	1	2. Explanations of work by mentor
24	23	26	7	9	3. Tours of other laboratories or installations
65	14	7	2	1	4. Informal talks with mentor
37	37	12	2	1	5. Discussions with other scientists
23	22	24	12	9	6. Interactions with other apprentices
6	16	29	19	18	7. Advice from the program coordinator

(A = STRONGLY AGREE
B = AGREE
C = DISAGREE
D = STRONGLY DISAGREE)

A	B	C	D	IV.	How do you feel about your research apprentice experience?
59	27	2	0	1.	I enjoyed the experience
50	31	7	0	2.	I liked the scientific research
30	43	11	4	3.	I was satisfied with the way I spent my time
60	27	1	0	4.	I learned a lot
38	39	8	3	5.	I feel I contributed to the research results

V. Would you want to return to the same mentor next year?

59 Yes 24 No: If No, why?

2	personality conflicts
3	lack of interest
18	want a different experience
1	want a different location
1	was to busy

VI. What did you like most about the program?

The majority of the responses were that the most enjoyable part of the summer effort was working with various types of scientist and the relationship between the students and their mentors. The students also commented on the scientific experiences they had during their appointment. The students were also impressed on how they were treated as part of the research teams and the equipment that they were exposed to in the laboratories. Some of the students responded that they have chosen different careers due to the experience they had during the summer. The responsibility the students were given was also mentioned. A few of the students also enjoyed giving presentations, and the writing of a technical report. One student commented that working with the Air Force was the most enjoyable for him.

VII. What did you like least about the program?

The students responses varied. The major complaint was that the students were not kept busy during their summer appointment or they did the same thing everyday which got boring. Another area of concern was the pay schedule, they felt that they should not fill out timecards that the pay should be sent at the first of the summer, also students thought the pay was to low for doing research type work. Students also commented that the mentors seemed to be too busy to spend any time with the apprentices. Other comments were that the program is too short, that 10 to 12 weeks would be more beneficial. A few of the students mentioned that they did not like the hours that they had to work, that a full time position was to much for their first job. Four of the students commented that they did not like writing any type of reports or give any presentations. While another student mentioned that students were not given permission to go TDY during his summer at the laboratory. Another student was concerned that there was no programs for undergraduates beside ROTC.

DO NOT SIGN

RETURN FORM TO YOUR COORDINATOR BY 15 September 1989
date

Susan Espy
Name of Coordinator

Universal Energy Systems
4401 Dayton-Xenia Rd.
Dayton, OH 45432
Address
2361s

LIST OF PARTICIPANTS FINAL REPORTS

RESEARCH REPORTS

1989 HIGH SCHOOL APPRENTICESHIP PROGRAM

Technical Report Number	Title	Participant
VOLUME I		
Aero Propulsion Laboratory		
1	Flat Plate Heat Pipe	Matthew Bold
2	High Power Sources	Robert Bradford
3	Oils Change with Friction	Roxanne Fischer
4	Liquid Chromatography	Terence Hill
5	Laser Doppler Velocimeter Testing	Alisha Hix
6	LIPS-III Satellite Program	Christopher Miller
7	Aircraft Engine Axial-Flow Compressors and Mathematical Modeling of Compressor Performance	Bradley Reigelsperger
Armament Laboratory		
8	Operation & Protocol Manual	Jules Bergmann
9	Fuzes and Guns	Steven Bryan
10	Adaptions of Existing Star Catalogs for Space-Based Interceptor Applications	Tonya Cook
11	Differences in the Activation Energy of Nitroguanidines	Kathryn Deibler
12	Comparison of Average vs. Spectral LOWTRAN in Calculating Exitance	Chris Ellis
13	The Creation and Installation of Z-248 Help Menus	Dana Farver
14	File Size Analysis and Transfer Program	Kenneth Gage
15	Design of In-House Radar Control System	Reid Harrison
16	HSAP Event Summary	Derek Holland

35	Computer Support for the Minuteman III Demonstration Motor Test and the Advanced Solid Axial Stage	Lloyd Neurauter
36	Thermoplastic Binders	Sandi Novak
37	Pyrolytic Carbon on Carbon Fibers	Sonya Park
38	Engineering Design Evaluation	Alexander Sagers
39	Carbon-Carbon	Richard Sims
40	Create a Database on the VAX network	Benjamin Sommers
41	Space Structure	Shirley Williams

Avionics Laboratory

42	Model of a Lambertian Surface	Matthew Brewer
43	F-15 Radar Simulation	Sook Hee Choung
44	Analyzing Electro-Optic Sensors	Sheri Cody
45	Computer Circuitry	Christine Garcia
46	Rotate Image	Lori Harris
47	Ada Programming	Amy Listerman
48	An Investigation of the GaAs Mesfet	Joan McManamon
49	The Optical Spectroscopy of Ti3+ doped YA10	Allison Potter
50	The Research and Development Division	Julie Roesner
51	Evaluating Ada Compliers	Jerard Wilson

Engineering and Service Center

52	Theorized Effects of Simulated Aircraft Loading on the Density of Asphalt Concrete Pavements	Gregory Dixon
53	Environmental Simulation Chamber Studies of the Atmospheric Chemistry of Hydrazine	Dorothy Iffrig
54	HQAFESC Technical Information Center	Byron Kuhn

91	Error Injector Unit Project Testing Programs	Richmond Real
92	Test Plan for the Evaluation of Advanced Sector Operations Control Center (SOCC) Workstations (PRDA 89-4)	Eric Shaw
93	Analog Optical Processing Experiments	Shane Stanek
94	Cartographic Applications for Tactical and Strategic Systems	Juliet Vescio
95	Infrared Camera User's Manual	Katie Ward
96	A Study of Optic Turbulence	Barbara Westfall

School of Aerospace Medicine

97	The Influence of Broad Spectrum Light on Neuroendocrine Responses and Performance	Jeanne Barton
98	CorTemp Disposable Temperature Sensor	Whitney Brandt
99	Electrically and Chemically Induced Release of L-Glutamate from Hippocampal Mossy Fiber Synaptosomes	Christina Cheney
100	Determination of Restriction Enzyme Patterns of Raw DNA with Biotinylated Probes to Heat Shock Protein and Tumor Necrosis Factor	Brian McBurnett
101	The Influence of Broad Spectrum Illumination on Circadian Neuroendocrine Responses and Performance	Lori Olenick
102	Neurochemistry of Photic Entrainment of the Circadian Activity Rhythm in the Syrian Hamster	Joanna Saucedo
103	Developing a Fast Circuit to Integrate the Signal in a Video Frame	John Taboada

FINAL REPORTS

AERO PROPULSION LABORATORY

Summer Apprentice Program Final Report

Flat Plate Heat Pipe

Matthew Bold

Wright Patterson Air Force Base

Wright Research Center

Thermal Lab

Mentor: Won Chang

August 28, 1989

Section 1- Introduction

This summer I had the opportunity to work at the Thermal Energy Laboratory at the Wright Patterson Air Force Base. The lab serves many purposes at the research center, including thermal laboratory fabrication, testing and diagnostics as related to thermal management technologies for future spacecraft applications, high temperature thermal transport, heat rejection, and thermal energy storage. Among the many projects being either built or tested include: the Double Wall Artery Heat Pipe, life tests on the 25 low temperature and five high temperature heat pipes, the Unidirectional Nickel Diode Heat Pipe, the Osmotic Heat Pump, the Flat Plate Heat Pipe, and the Eutectic Fluoride Thermal Energy Storage Capsules. The lab has produced, and has plans for many future publications ranging from technical reports on present and past projects to publications on new theories, equations, and new applications.

The Thermal group is involved with SDI (Strategic Defense Initiative) but its work extends into many aspects of life. Heat pipes are being used in medicine, aircraft, cars, and even home electronics.

My work in the lab included: designing test stands, instrumentation and testing of both the Flat Plate Heat PIpe and the Osmotic Heat Pump, and contributing to the manufacturing of the Nickel Unidirectional Diode Heat Pipe. The work was always exciting and I was made to feel a necessary part of the lab.

Section 2- Appreciation

I would like to show my appreciation to the following people for there help in showing me how the lab operates, and how a heat pipe works. They were all very busy people but could always find the time to help, and guide me.

Brian Hager

Don Reinmuller

Won Chang

Mike Ryan

Mike Morgan

John Tennant

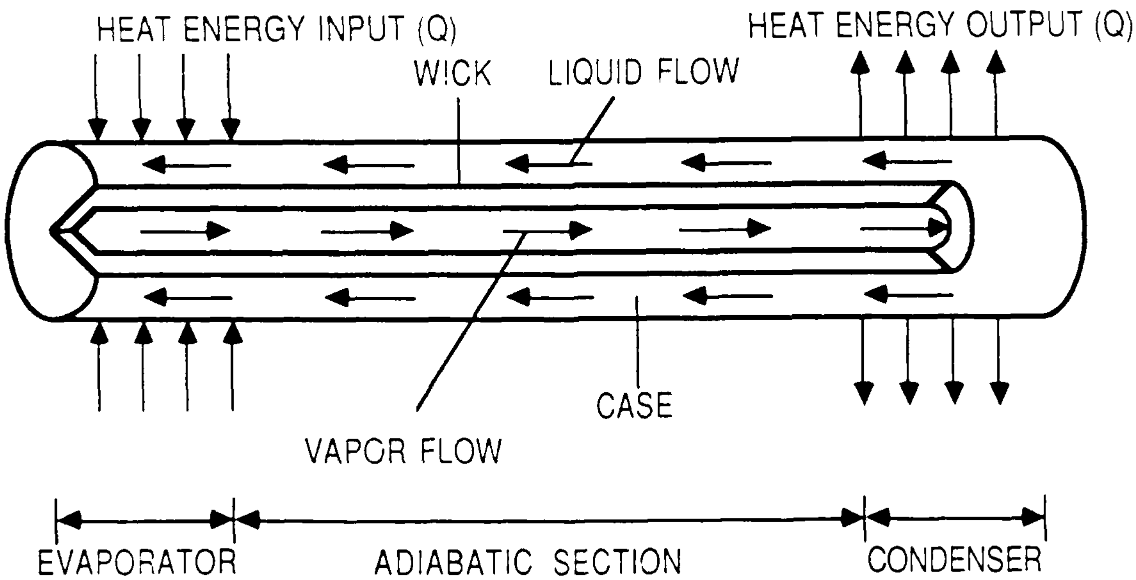
Brian Donovan

Thank You

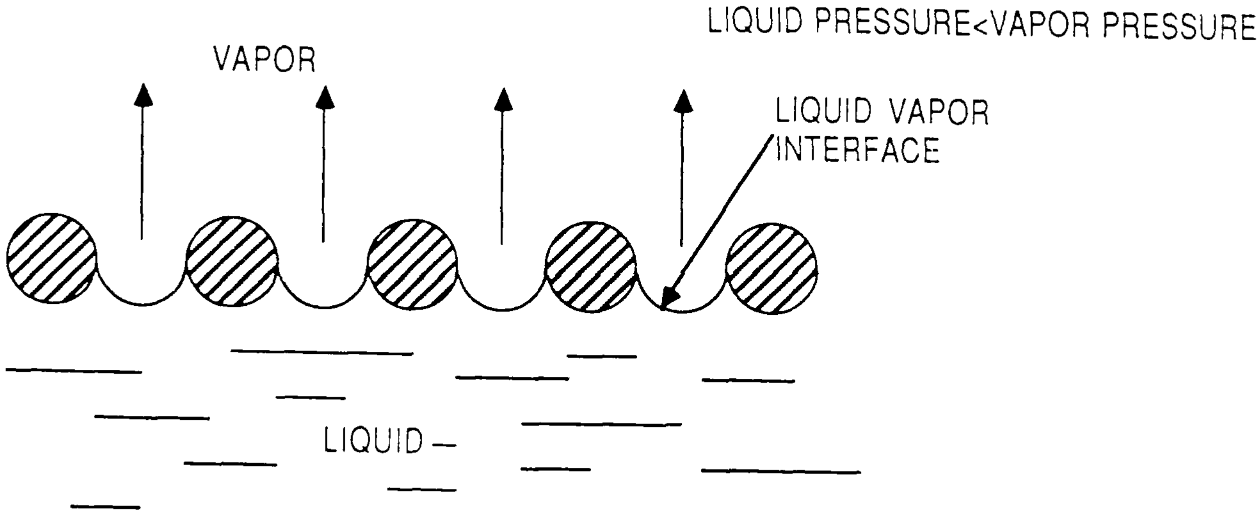
Section 3- Cylinder Heat Pipe Theory and Design

A heat pipe is a device used in the transfer of thermal energy (Q) over a specified distance with a very low temperature gradient. A heat pipe acts much like the radiator in a car. As the engine heats up, the heat must be removed or the engine may overheat. One way to cool the engine is to pump a fluid, usually water or antifreeze, around the engine through tubes. As the fluid passes around the hot engine parts it collects thermal energy or heat. The heater fluid then may be taken to a radiator where through the use of fins the heat is passed off to the air flowing around it. The heat pipes being worked on in the thermal lab eliminate one principal of the car cooling system, the pump needed to flow the fluid through the engine. Because many of the heat pipes are used on satellites, and spacecraft spend long periods of time in space, they need to conserve energy for more critical electronics and other components, the system should be passive. A passive system does not require a pump. A pump may be composed of moving parts which may fail easily and may require an outside source of energy to run. Most heat pipes use the thermal energy being removed as the energy to run the pipe.

A heat pipe consists of three primary parts; the container, the wick, and the working fluid and the pipe as a whole consists of three primary sections: 1) the evaporator, 2) the adiabatic section, and 3) the condenser section. Thermal energy enters the pipe in the evaporator section (Q in) and the working fluid begins to evaporate as the thermal energy is changed into mechanical energy. The type of working fluid used depends in the temperature ranges required. The working fluid in a moderate temperature heat pipe is water, ammonia, methanol, or acetone. The high temperature heat pipes may use a liquid metal and the cryogenic heat pipes may use a liquid gas such as liquid hydrogen or liquid oxygen. As the fluid changes from its liquid state to its vapor state the pressure builds because a vapor usually takes up more room then a liquid. Because of the pressure the vapor is forced to the condenser end where the heat is released and the vapor is condensed. The condensed fluid is returned to the evaporator section through the wick by capillary action.



The pressures that affect the capillary action are created in the particles of the wick, if the wick happens to be a cindered or metal felt wick or in the mesh of the screen, if the wick is a screen wick. As the vapor pressure increases in the evaporator the meniscus found at the point of vapor and liquid contact deepens because the vapor pressure is greater then the liquid pressure. In the condenser section the meniscus levels out because the pressure of the condensing vapor is not that much greater then the liquid pressure. This creates a pressure difference in the wick and the fluid in the wick tries to compensate for this pressure difference by pumping more fluid to the evaporator section.



This pumping is possible because liquids and gases diffuse from an area of greatest concentration or of greatest pressure to an area of least concentration or least pressure. The fluid also is pulled to the evaporator section because it is an area of last concentration because some of the fluid was evaporated.

The heat pipe is subject to a number of problems that may make the pipe not function as a heat pipe. One, if not enough energy is put into the evaporator section the pipe may not prime or the cycle will not start. The only method of heat transfer will be through conduction through the heat pipe case or the wick. Two, if too much energy tries to enter the evaporator the fluid may begin to boil and so much vapor pressure may be created that the vapor in the condenser may not have a chance to condense before it is returned to the evaporator. If this occurs vapor will be returned instead of a liquid and the vapor cannot evaporate because it is already a vapor, dry out occurs. A small amount of energy may still be transferred throughout the pipe but a majority will be transferred by conduction through the case and the wick or by some other means. A third type of problem may occur if a non-condensable gas enters the pipe. The gas may be left there from when it was constructed, created by the interaction between the materials, off gassing, or allowed to enter through a leak in the pipe case.

To prevent these problems careful designing is needed. Among the many considerations to be taken note of during the designing of a heat pipe are:

1)the total length of the pipe;

2)will the pipe remain linear or will it be bent;

3)the temperature ranges expected for the pipe;

4)the type of pressures the pipe be subjected to;

5)the type of mission the pipe will be used on;

6)the expected life of the pipe;

7)Is burst power to be expected and if so how much and how often;

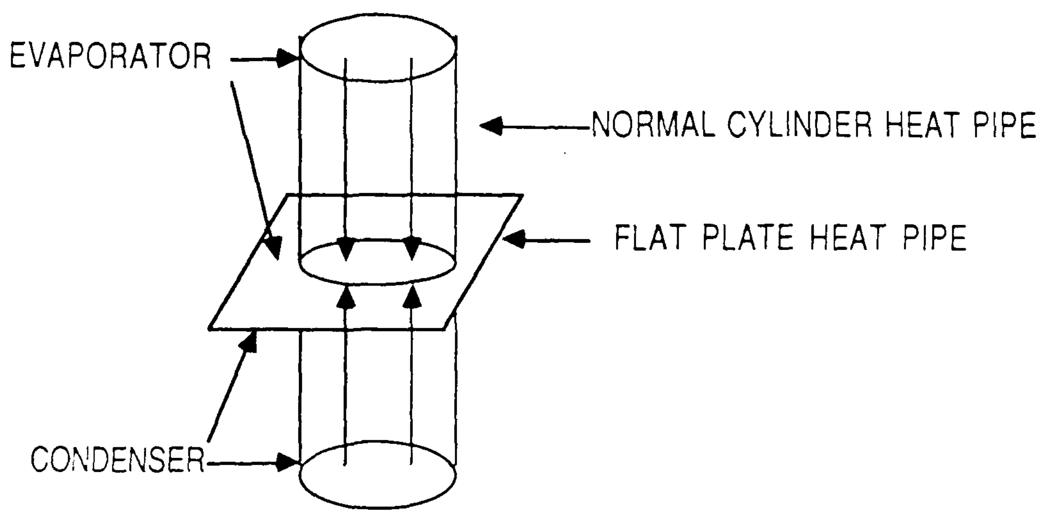
8) the required shape of the pipe; cylindrical, cubic, flat, etc; and

9) Are the materials chosen compatible for the conditions previously described?

Among the many design considerations available are: case material and shape, wick material and formation, and the working fluid. The choices must be compatible though, or off gases may be created, the working fluid may break down, the wick may be damaged, or the case may be damaged.

Section 4- Flat Plate Heat Pipe Theory and Operation

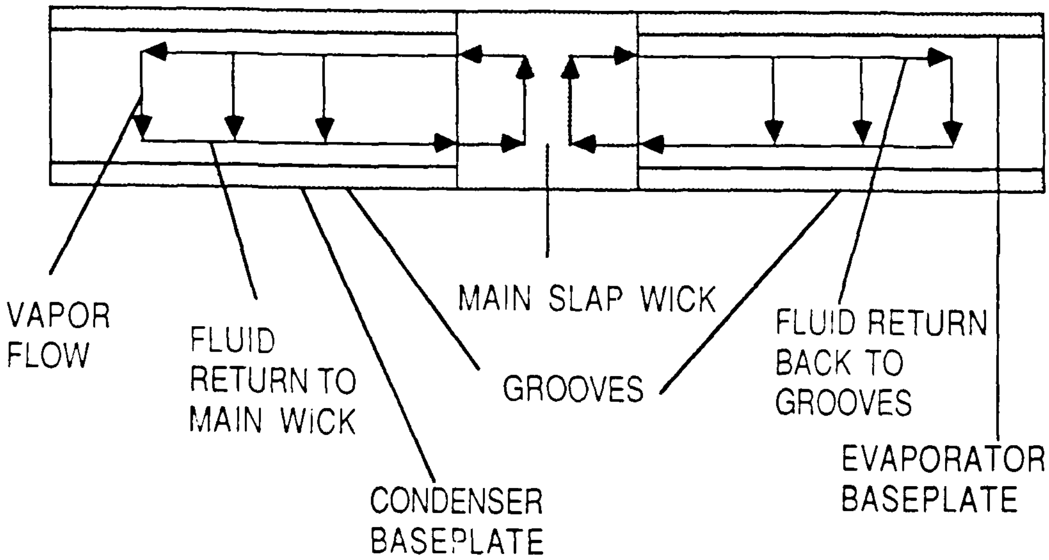
The flat plate heat pipe works in approximately the same way and has approximately the same configuration as the heat pipe previously described except it is in a flattened form.



The top baseplate acts as the evaporator and the bottom as the condenser. Running down the center of the pipe, between both the base plates, acting almost as a divider, is the main wick, made of powdered nickel cinder. Running perpendicular to the main wick are grooves, a full set to each plate, made of the same material as the main wick, and spaced at 60 grooves per square inch. The plate is mounted on the side flow heat pipe and acts as a transfer device between electronics, mounted on the evaporator side to the side flow on the condenser side. The plate has dimples which are solid aluminum all the way through the pipe, which may be drilled out to allow the electronics to be mounted. The plate is also crimped around the edge, approximately 2/3 of an inch to seal off the plate.

The dynamics are not quite known, but its intended dynamics will be described. The working fluid is held in the grooves until heat is added to the evaporator. As the heat enters it is changed from thermal energy to mechanical energy as the working fluid, in this case acetone, is evaporated and the vapor pressure pushes the vapor to the condenser, directly across from the evaporator. On the condenser baseplate the vapor is condensed, heat is released, and the fluid is wicked through the condenser grooves to the main wick. The main wick wicks the fluid up to and then out through the evaporator baseplate grooves.

INTERNAL DYNAMICS OF FLAT PLATE HEAT PIPE



That seems simple enough, but that cycle may only occur in that fashion if the plate is perfectly level, perfectly formed, and if there are no obstructions, such as the dimples. The plate also must have even heat flux, which is not always possible in the case of electronics, which may take the form of many small components scattered across the plate in an uneven fashion. During the first tests a number of small heaters were used to simulate the electronic components and then a large heater with an even heat flux was used to model the plate.

The problem of modeling the plate is complicated even more when the plate is tilted. When the plate is tilted with 90 degree rotation such as in illustration "A" the plate tends to dry out quickly with low power flux. When the plate is tilted with 0 degree rotation such as in illustration "B" the plate operates fairly evenly with no dryout observed at moderate and even moderately high fluxes. The effect of the tilt on the plate is due to gravity and the ability of the grooves and the main wick to wick the fluid back to the evaporator. Gravity pulls the fluid to the bottom of the plate. When the plate is situated as in illustration "B" the main wick is able to wick the fluid to the top of the plate, but in figure "A" the grooves are not capable of wicking the fluid up high enough so the plate begins to dry out.

ILLUSTRATION "A"

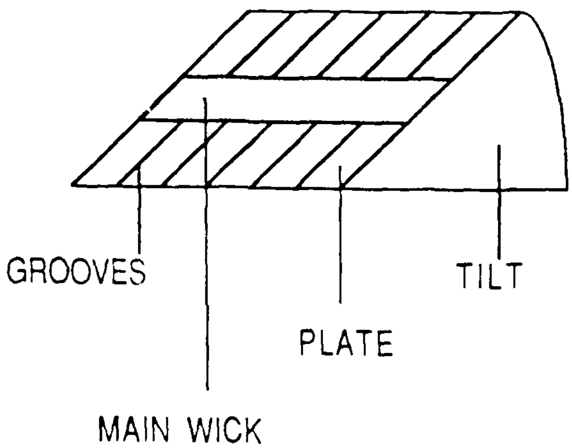
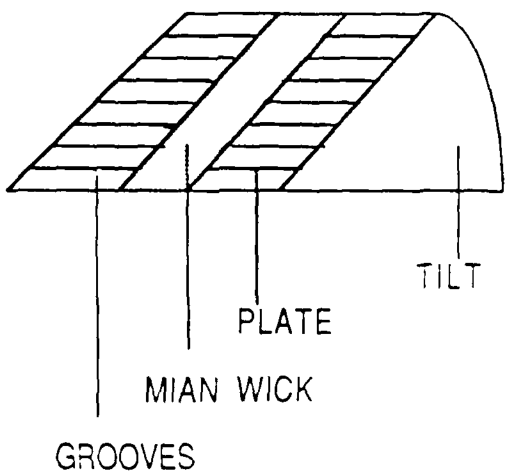


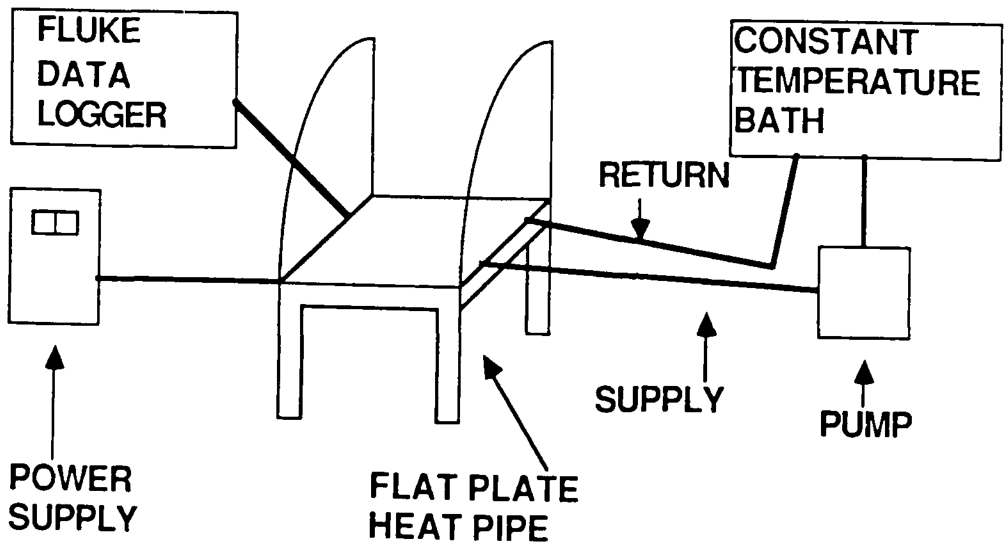
ILLUSTRATION "B"



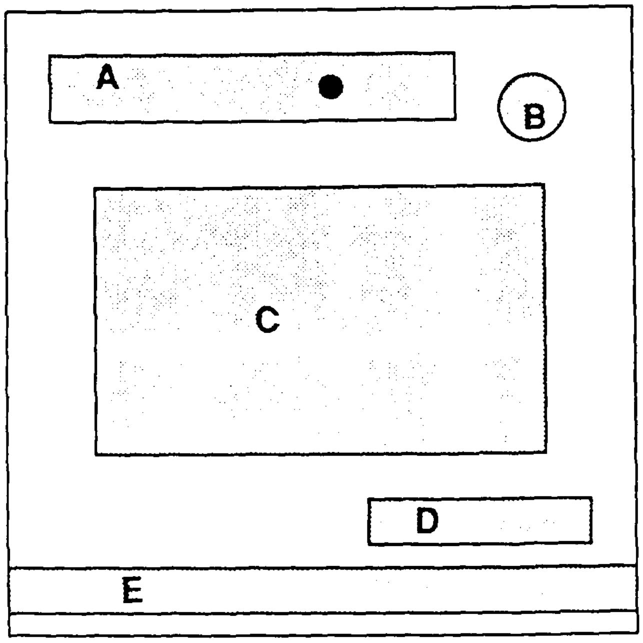
During future testing a full heater will be added to allow modeling with a full heat flux. Since the plate will be operating in space as well as in the atmosphere the plate must be able to be cooled convectively as well as conductively through the sideflow heat pipe. In space there is very little, if any gasses or liquids, so the only way for heat to escape is through the sideflow. To simulate this the plate will be thoroughly insulated, and a cool block with water at different temperatures flowing through it will be used to simulate the sideflow.

Section 5- Flat Plate Testing Procedure and Testing Data

The plate was originally instrumented with five heaters of varying sizes on the evaporator side with 30 type "T" thermocouples placed on both sides. The heaters were connected to a power rack containing three transformers with 10 amp meters, but they were later connected to four Vairac auto transformers with 2 amp 10 amp meters. The thermocouple readings were fed into a Fluke 2280A data logger where the temperatures were recorded to paper readout and a cartridge computer tape. The data was then transferred to the Zenith 238 computer by the Prologger Fluke Communication Software and was then loaded into Lotus 1-2-3. In 1-2-3 the data was put into graph form then printed out through the Lotus Printgraph program on a plotter for analysis.



FLAT PLATE HEAT PIPE

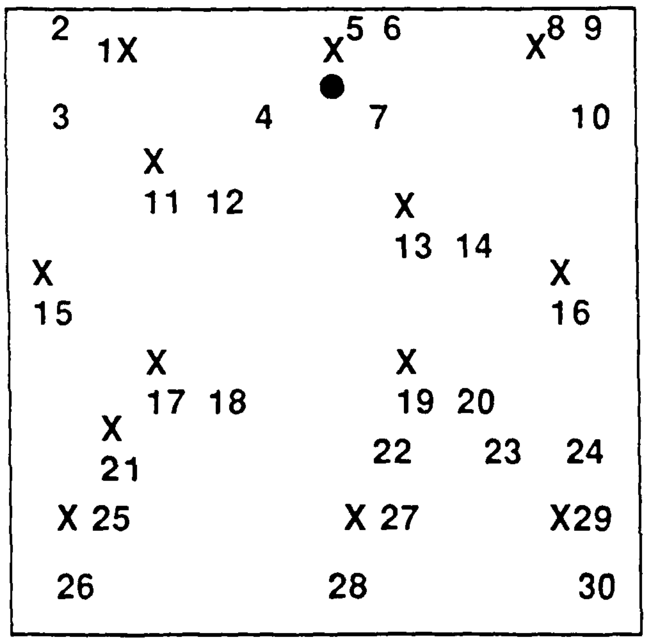


A RESISTANT HEATER
1.5X7.0" 64.7 VOLT/2.57AMP
B RESISTANT HEATER
1.37" DIAMETER 39.3 VOLT/0.53 AMP
C RESISTANT HEATER
3.0X6.0" 84.53 VOLT/3.72 AMP
D RESISTANT HEATER
6.0X.05" 51.64 VOLT/0.98 AMP
E RESISTANT HEATER
1.0X12" 67.09 VOLT/2.69 AMP

● LIQUID FILL TUBE CONDENSER SIDE

EVAPORATOR SIDE

FLAT PLATE HEAT PIPE



X THERMOCOUPLE ON EVAPORATOR SIDE

THERMOCOUPLE ON CONDENSER SIDE

● LIQUID FILL TUBE CONDENSER SIDE

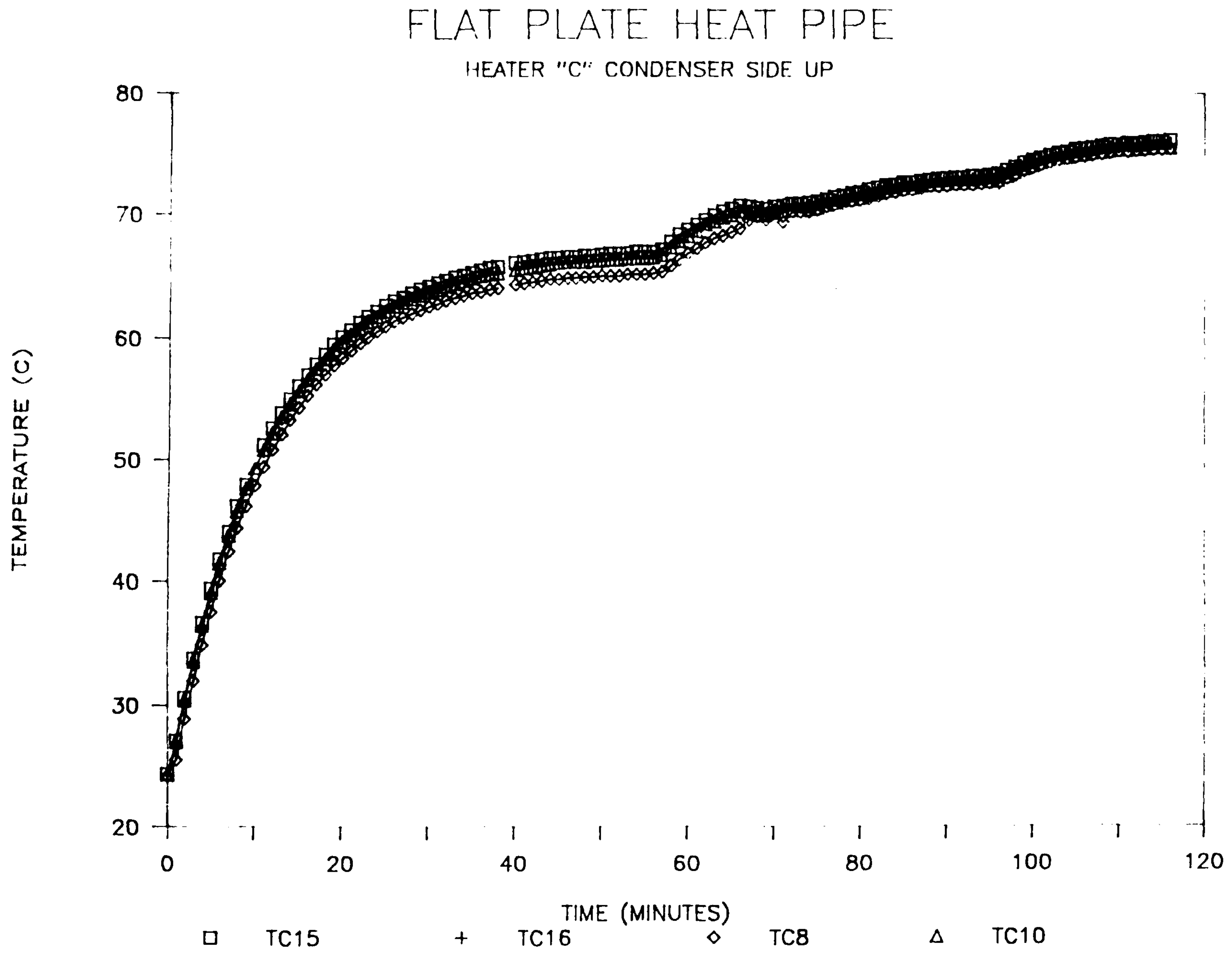
THERMOCOUPLE PLACEMENT

Section 5.1.1- Cold Startup Test

The first test performed was at 180 degrees tilt and 0 degrees rotation. This was a cold startup, meaning that it was taken from room temperature (24.4 degrees C) to optimum operating temperature (65 degrees C) with one burst of power using heater "C", then a slow progression to 75 degrees C. The initial power input was 41.1 watts, then after steady state was achieved in 1 hour 30 minutes, the power input was increased to 50.32 watts then, after steady state was achieved in 40 minutes, the power was increased for the final time to 55.9 watts and steady state was achieved after 20 minutes.

Section 5.1.2- Cold Startup Test Data

A large temperature difference, 9.2 degrees C, was noticed between thermocouple 17 and 18 which disappeared in later tests. No reason was established, but it is possible that there was a gas slug present and if there was it might tend to move around the plate and this problem might appear between other thermocouples. Most of the other temperatures seemed close together showing that even distribution of heat was occurring and the plate seemed to operate smoothly.

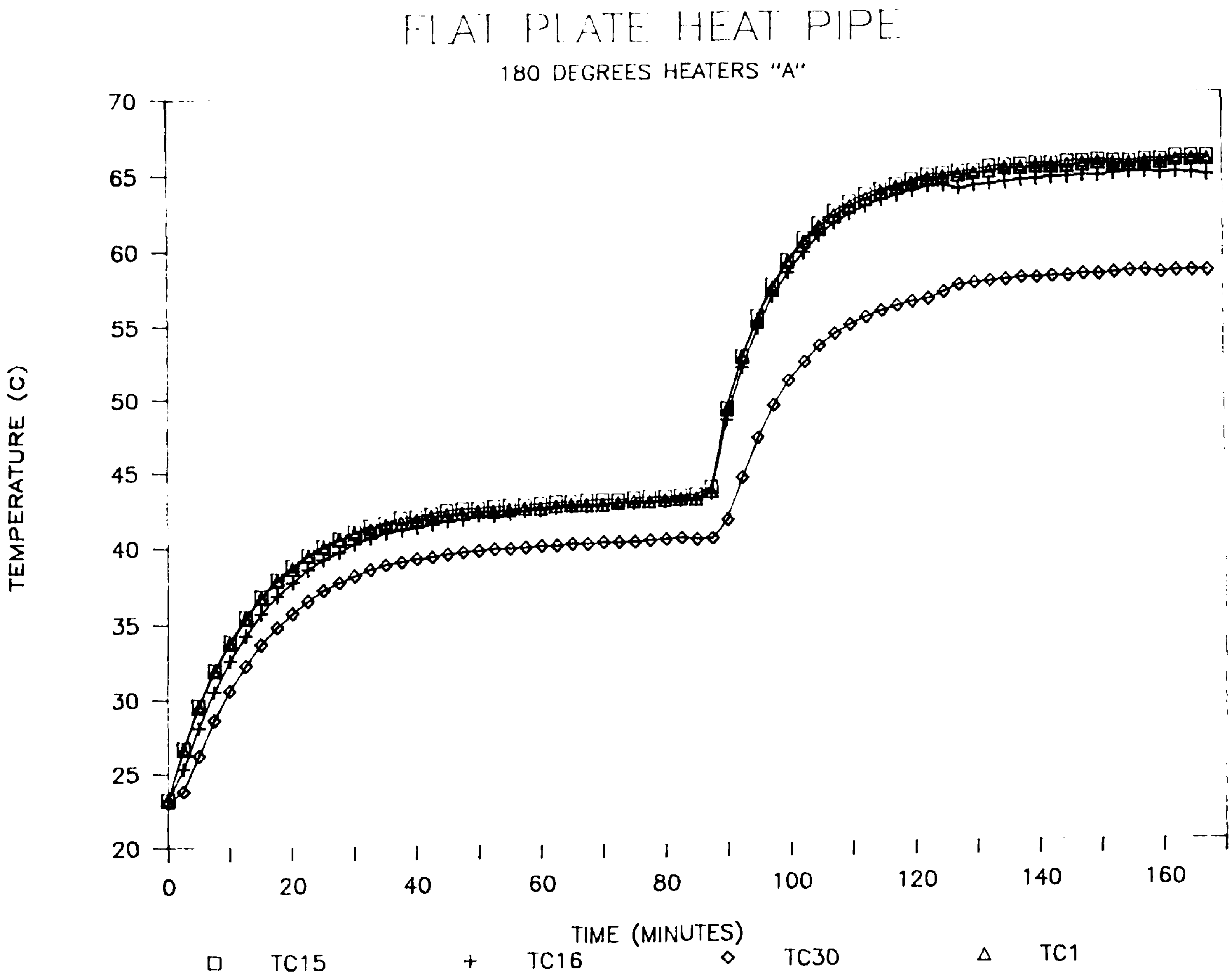

FLAT PLATE HEAT PIPE
HEATER "C" CONDENSER SIDE UP
TEMPERATURE (C)
80
70
60
50
40
30
20
0
20
40
60
80
100
120
TIME (MINUTES)
□ TC15
+ TC16
◇ TC8
Δ TC10

Section 5.2.1- Isolated Heater Test

The second step was to test the effect of the performance of one isolated heater on the performance of other isolated heaters. We wanted to find the distance required between heaters before the performances would effect each other. The plate was operated at 0 degrees tilt and 0 degrees rotation with each of the heaters "ACDE" being operated separately first then the combinations "AE", "DE", and "CE" .

Section 5.2.2- Isolated Heater Test Data

The specific effects are not known yet. Little if any difference was observed between the combinations. It is possible that with higher energy inputs the difference may become substantial and may effect the performance but it does not appear it will make much difference at lower energy inputs.



FLAT PLATE HEAT PIPE
180 DEGREES HEATERS "A"
TEMPERATURE (C)
70
65
60
55
50
45
40
35
30
25
20
0
20
40
60
80
100
120
140
160
TIME (MINUTES)
TC15
TC16
TC30
TC1

Section 5.3.1- 90 Degree Rotation Tilt Test

A small test of only three runs was done, all done at a rotation of 90 degrees. The first was done while the plate was flat, 0 degrees tilt and the second was done with the plate at 15 degrees tilt. With the plate at 90 degrees rotation the main slab wick will be horizontal as the plate is tilted.

Section 5.3.2- 90 Degree Rotation Tilt Test Data

As soon as the plate was tilted 15 degrees the temperatures on the upper and lower part of the plate began to separate, the upper getting hotter and the lower cooler. This may show that there is a pooling of fluid at the bottom of the plate and that it might dry out if more energy were put into the plate or if the same energy level were left for a longer period of time.

Section 5.4.1- 0 Degree Rotation Tilt Test

The plate was then tested to see if it would dry out if it was tilted at 0 degrees rotation. The plate was tilted at the angles 0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, and 180 degrees. Each test used heaters "ACDE" together with each run at a power level of 15 volts for a total of 36.6 watts

Section 5.4.2- 0 Degree Rotation Tilt Test Data

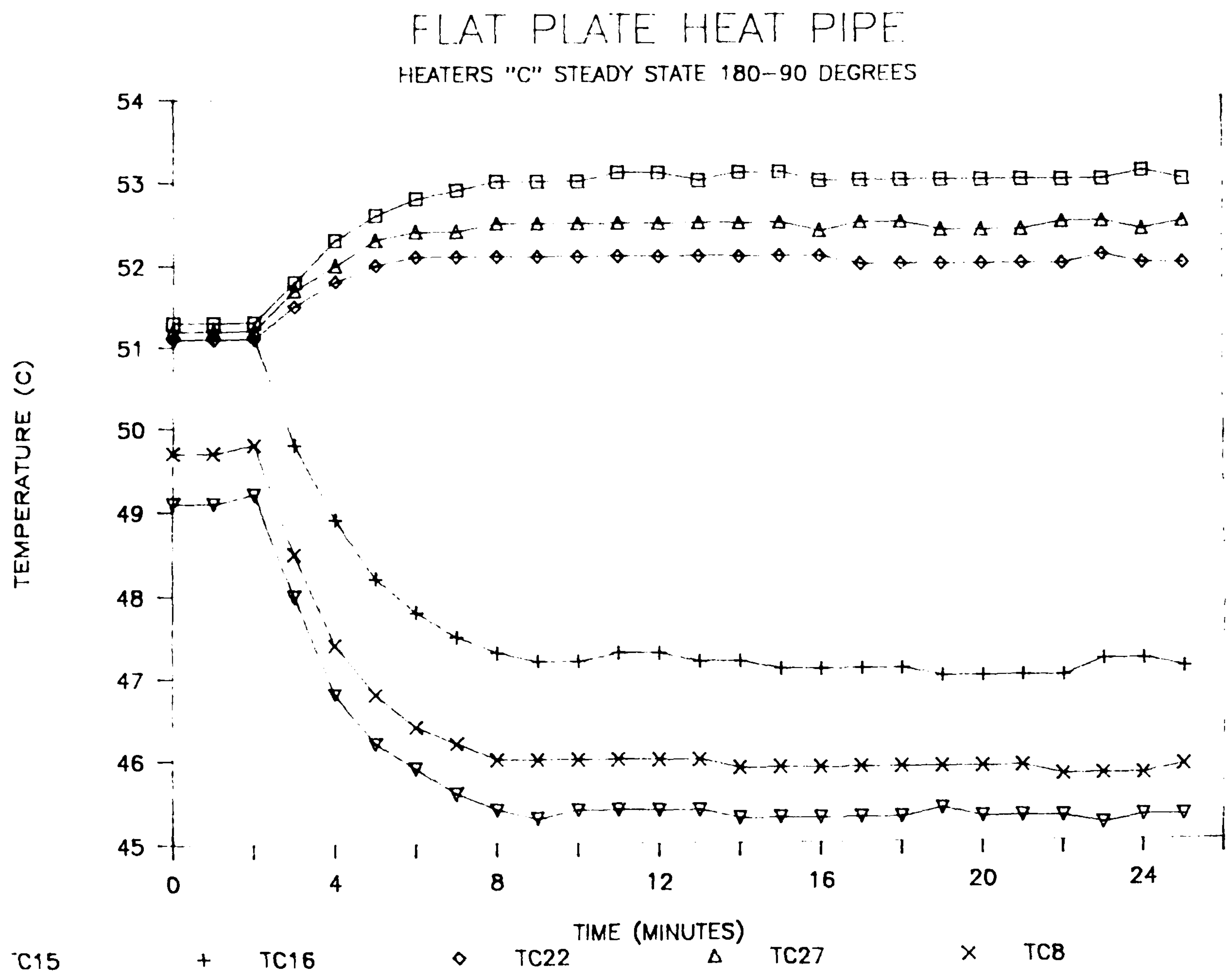
It was thought possible that the plate might dry out as it approached 90 degrees tilt, but a very small temperature difference was noticed and the plate performed very well at 90 degrees tilt. It is possible that the main slab wick wicked the working fluid to the upper portion to supply fluid to the upper part of the plate.

Section 5.5.1- Direct Tilt Test

In test 5, the plate was brought up to steady state at 0 degrees rotation and 0 degrees tilt, then was taken to 90 degrees tilt in one quick motion. This made the temperature differences that occurred during the previous test easier to observe.

Section 5.5.2- Direct Tilt Test Data

It was found that the plate operated very smoothly during a 90 degree tilt and did not seem to demonstrate any signs of instability. The temperature difference between the upper part of the plate and the lower was about 7.5 degrees.



FLAT PLATE HEAT PIPE
HEATERS "C" STEADY STATE 180-90 DEGREES
TEMPERATURE (C)
54
53
52
51
50
49
48
47
46
45
0
4
8
12
16
20
24
TIME (MINUTES)
'C15
TC16
TC22
TC27
TC8

Section 5.6.1- Forced Convection Test

This test was to find the performance of the plate during forced convection. To simulate the conditions the plate would be under while operating in a vacuum and while attached to the side flow heat pipe, modifications were made to the test setup. The whole plate was insulated with 1" of FiberFax fiberglass insulation, aluminum foil, and duct tape. In a vacuum, convection would not occur because there are no free flowing gases, so heat loss through convection was kept minimal by the use of the insulation. Since the side flow heat pipe is quite large it would be difficult to test the flat plate on the side flow so a cool block was used. Water at different temperatures was pumped through the block to simulate the vapor flows in the side flow. The cool block was placed on the condenser side, in the center of the plate running parallel with the slab wick, and a silicon conductive grease was used to make sure there was full contact between the plate and the block. The supply and return temperatures were read by two type "T" thermocouple probes and the flow was read by a digital flowmeter. All measurements were fed into the Fluke. The amount of energy being conducted through the cool block could be found by using the formula (M Cp (delta T)) which can be reduced to (M (delta T)) because the specific temperature of water is 1. The mass is the flow, measured in mL per second, and the delta T is the difference in temperature between the supply and the return in the block.

Section 5.6.2- Forced Convection Test Data

Because of the difficulty of the operation and because it was thought unnecessary, the full tilt test was not performed. The plate was tested with the cool block both up and down using heater "C" only. The water being pumped through the block was set at the following temperatures; 5 degrees, 25 degrees, 35 degrees, 40 degrees and 50 degrees, with a energy input of 100 watts.

There were no irregularities found in the data. The temperatures on the outside of the plate were higher because they were further from the cool block. The temperatures were cooler around the supply end of the block than at the return possibly because the water in the cool block has more energy by the time it reaches the return end.

Section 6- Conclusion

The full analysis of the data is not available yet because the tests are not complete and the plate has not been modeled. It will probably be one to one and a half more years before testing will be complete although an abstract is being submitted in October and a paper is being prepared for early next year.

Section 5- Reference

Beiser, Arthur Applied Physics Schaum's Outline Series McGraw-Hill Book Company 1976

Chi, S. W. Heat Pipe Theory and Practice Washington: Henishpere Publishing Corp. 1976

Heat Pipe Design Handbook Prepared for N.A.S.A by B&K Engineering June 1979

Dunn P. D.; Reay, D. A. Heat Pipes Third Edition Pergamon Press 1982

SUMMER APPRENTICESHIP

FINAL REPORT

Apprentice: Rob Bradford

Mentor: Dr. Peter Bletzinger

Lab: POOC-3 High Power Sources

Summer 1989

ACKNOWLEDGEMENTS

I would like to thank the following people for their help and advice throughout my apprenticeship.

David Dolson, John McCord, Michelle Dunnigan, Dennis Grosjean and Bob Knight

Special thanks to my mentor, Dr. Peter Bletzinger, for his knowledge and patience.

INITIAL OBSERVATIONS
AND GENERAL DESCRIPTION

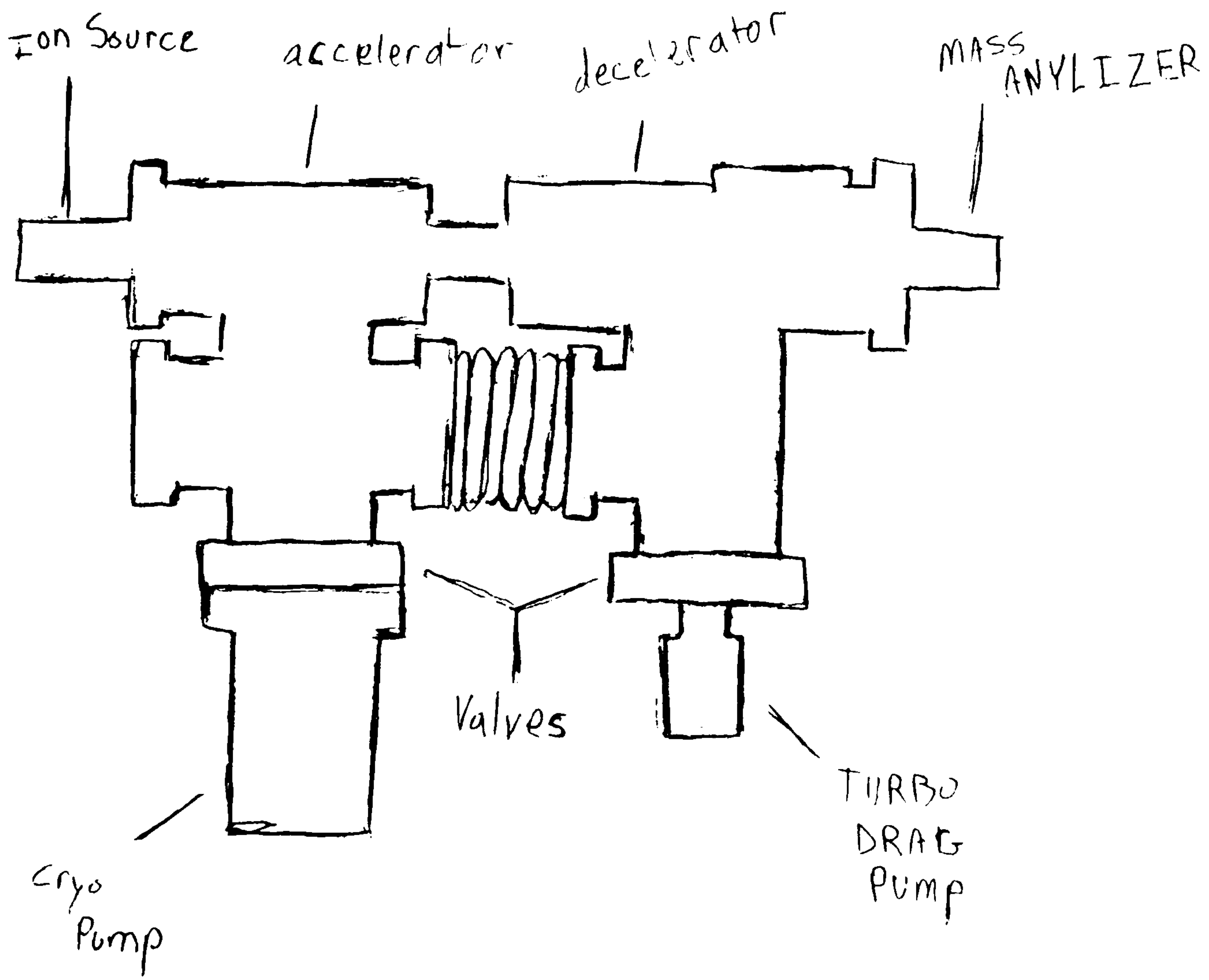
Unfortunately, my lab was plagued with set-backs previous to my arrival. As it was explained to me, they had suffered from vaccume leaks, ion source failure, and inaccurate readings from their data collecting machines. Because of these set-backs, my eight weeks were spent rehabilitating the lab. This, however, was hardly a dis-appointment; rather, I believe I benefitted even more. I say this because, I got to see first hand how a real lab is brought to life. From contact with other apprentices, I realized that many of their jobs, though interesting and educational, were monotonous routines of poking at calculators and looking over endless piles of data. Not so in my case, I can truly say that I'm one of the lucky ones. I got not only plenty of hands on technical experience, but a close up look at the way each machine in the lab works internally as well. Now, because the work I did was basically on rehabilitation, I'm far from knowledgeable on the ultimate purpose of the lab. However, I'll tell what I know.

From what I overheard and surmised on my own, the purpose of the lab was to isolate things called radicals. Radicals, appearently, are molecules that exist only for split seconds under natural conditions. They are believed to contain extremely high energy potentials and have practical applications as the new generation of rocket fuels. Ultimately, researchers hope to find a way to isolate and control these radicals so they can begin to apply them to every day use.

DETAILED DESCRIPTION

The radical my lab was investigating was the CH+ radical. In order to study this CH radical, the researchers in my lab had two seperate exeriments. The experiment I was involved with consisted of a vaccume chamber and an ion gun. The idea was to introduce methane (CH_4) into the vaccume. Then, the methane was to be bombarded with ions which would break it down into CH_3+, CH_2+, CH+, C+, and H+. Using a mass spectometer, the team can isolate and record valuable information about the CH+ radical.

As I stated before, my purpose was to help revive the lab. So, I have no experience on which to base a more detailed report. The best I can do is to supply diagrams of the equipment I worked with.


Ion Source
accelerator
decelerator
MASS ANYLIZER
Valves
Cryo Pump
TURBO DRAG Pump

FINAL OBSERVATIONS

Although I wasn't part of any organized research this summer, I learned much more about lab techniques and procedures than I ever have before. I learned how to solder and put together circuits in a safe and proper manner. I learned about how electrical components work and how they can be used. I also learned how to work properly with high vaccume systems. Most important to me, I learned a new computer language. The computers in the lab I worked in used BASIC 5.0. This language is actually not BASIC at all, but a mixture of BASIC, PASCAL, and FORTRAN. By the end of my apprenticeship, I was very familiar with this language. I believe I benefitted most from the computer programming because that is the field I intend to major in, in colledge.

All and all, it was a fun and educational summer, and I am very gracious that I was able to participate in this program.

High School Apprenticeship Program

Final Report

Student:

Roxanne Fischer

Mentor:

Robert L. Wright

Lubrication Branch

Fuels and Lubrication Division

Aero Propulsion and Power Laboratory

August 24, 1989

A special thank you is extended to those at Wright Patterson Airforce Base with whom I had the pleasure to work under.

As an upcoming senior at Tippecanoe High School my application provided background such as the completion of two years of chemistry and math courses up to the Calculus stage. The knowledge of mine being an active member in the science club and math league was also given. With this exceptance into the apprenticeship program was granted.

The assigned mentor, Lt. Kelley, was relocated thus changing my mentor to Mr. Robert Wright. Under Mr. Wright in the Fuels and Lubrications Laboratory is were the duration of my contract was spent. Though all under the same division, time was divided among several different lab environments so as to provide a large base of knowledge.

Throughout the duration of the summer I was instructed in a wide range of testing methods. These methods were used to determine how oils change with friction, wear and heat factors. The task of daily testing on such equipment as:

Differential Temperature Analyzer (DTA)

Differential Scanning Calorimeter (DSC)

Ferrogragh Analysis Machine

Foam Test

Viscosity Test

Micro Carbon Residue Tester (MCRT)

Wear Particle Analyzer

FT-IR Spectrometer

Atomic Absorption Spectrometer (AA)

were routine. In addition on the WPA I was given an individual task. The standard method of operation requires that the filter be flushed thru with a cleansing solution between readings. Through trials and experimentation my goal was to determine of this was efficient and accurate. The result was the changing of procedure to not only rinsing but to remove the filter to back flush it.

This experience has proved to be one full of learning not only on an academic level but as well as personal. To work with professionals in a science related field gives a true sense of the practicality of the theorems. I now strongly consider such an area of study and look to further research the opportunities.

Summer Apprenticeship

Terence Hill

Dr. Ronald Butler

Aero Propulsion Laboratory

28 August 1989

Acknowledgments

I would like to thank the following for helping me in my work at the laboratory, Ronald Butler, my mentor for allowing me to work in the propulsion fuel and lubrication laboratory, a unique opportunity, I hope to look back on fondly. Steve Anderson for showing me around, and helping me get started in the laboratory. Erik Gustafson for teaching me the liquid chromatography procedure. Ellen Stewerd and Ed Pitzer for helping me find things and letting me work with them. Thank you for letting me enjoy this fascinating experience.

Introduction

Liquid chromatography characterizes group composition of oils and fuels by measuing content of paraffins,olefins,and aeromatics by chemically holding them in a polerized column. Freon, or low solvent liquid, is running through the column to carry it to the dielectric meter which compares the content whith that of pure freon. The diffrence is converted to an electric signal and is recorded. Each hydrocarbon group,paraffins,olefins,and aeromatics, is released by the column at a diffrent time, which is also known as the retention time.

Paraffins are are never held back , because they are saturated and have no bonds for the column to hold on to. Because they are not detained they are the first to go through, and be recorded. The aeromatics are next,they have only single bonds ,and are quickly released. The last ones that come out are the olefins which have at least one double bond.In order for olefins to come out the freon must change directions through the column.

The two main types of samples I did were JP-4 and JP-8. The reason I tested them was to find the aeromatic content .This was done because some aircraft using JP-4 were switching to JP-8 ,and the O-rings that swelled up with JP-4 didn'twith JP-8,so the fuel leeked out . The Air Force wants to find out the diffrence in Aeromatic content,and what compounds were different. The laboratory will use my information and other information to decide what will be done.

Liquid Chromatography

In order to operate the liquid chromotography the equipment must be turned on, then set the first helium tank to 10 psi, turn the direction knob on the freon cylinder to refill.Set the syringe pump switches to operate,refill,pump,run. The cylinder should fill with freon. Set the direction knob to the purge position, open the purge valve. Next set the switches to operate, deliver, purge, run. After the freon starts flowing turn the run switch to stop, close purge valve, set the direction knob to deliver. Set the first helium tank to 60 psi and the second to 20 psi. Then get the system ready for samples by setting the purge switch to pump, stop switch to run ,and hit the "rapid pressurization" button. After it pressurizes let the voltmeter settle between 200 and 400 microvolts (μv). Use the balance knob to help set it. While it settles goto the computer and enter the rawfile, processedfile, and sample name.

After the voltmeter settles fill a vial with freon to the shoulder. Next add 100μl of the sample. Put the lid on the vial. Set the vial in th auto-sampler,then push 'run single' button.When the injector needle goes into the vial push the 'GC/LC' button. If olefins are in the sample back flush, change direction of freon,after the paraffins and aeromatics have come out. If it is unknown that olefins are in the sample than make a test run by not backflusing.Find out when the last aeromatic comes out. Make another sample and run it, backflushing whenthe last aeromatic exits. A run takes eight minutes then the information is sent to the computer for analysis.

Put the computer on the graphics screen. Type in the raw file the sample was run on. Display the baseline and retention times. After the graph has been displayed, check for any peeks which should not be there (i.e. the backflush). Then go modify the file and take any unwanted retention times out, but be sure not to mess up the wanted peeks. When everything is as wanted list the processed file and copy the percentage of the peeks. Change the raw file and processed file and do another run untill percentages of two runs are with-in .1 of a percentage point of each other . Print out the two runs out on the computer, first graph then print the processed file,then print the other run.

Inventory

I took in three large cabnits. I took down the name, purity,quanity, number, chemical company,and cabnit and shelf location. After that I typed it into a data base. This was done so the people in the laboratory could find chemicals easier by knowing cabnit and shelf the chemical is setting on. The data base will also be used to find out what chemicals the laboratory has in stock.

Column

The column made for the liquid chromatography Iwas doing is made exclusively at wright patterson in the propulsion laboratory. The first step is putting the column on the pump, it is put on backward. Next pump 25 ml of acetone through the column. After that pump 25 ml of distilled water. Next pump 25 ml of nitric acid(HNO_3) that has been dilluted to .001 m or to a Ph of 2.05. Then pump 25 ml water, 25ml silver nitrate($AgNO_3$),25 ml water, 65 ml nitric acid , 25ml water ,25 ml acetone, 1400 ml butyl chloride, the butyl chloride takes about 18 hours , so it sits overnight. When thats done put it on the liquid chromatography and let about 150 ml of freon run through it, then its ready to run.

Equipment

The equipment used for the liquid chromatography consist of a Whatman partsil 5 scx column,but first run through a variety of chemicals described above. Also used is an Applied Automation Inc. diekectric detector.This detector has seperate paths for freon to run through,one with the sample and the other the control path. The detector measures the diffrence between the two paths. A Hewett Packard volt meter and Applied Automation electronics unit monitor the electric output and send it to the computers. An Isco LC-5000 syringe pump which pumps through freon and measures the preasure inside the system.

Results

Isaw and learned about many ways how substances can be broken down and analyzed. In refrence to the making columns, how using diffrent chemicals can bring about diffrent results. I learned many chemical names, types of chemicals, and ways they are organized into groups, by boiling point and types of chemical bonds,single or double. I gained an under standing of how to operate computer data base. Another thing gained was the exposure to an office envirenment.

My apprenticeship ended before I could find out what will happen to the O-ring leakege problem.Earlyer in the program it was discovered that there is no octane diffrence in Sohio economy, medium, and premium grades of unleaded gasoline.The only diffrence was assitives like alcohol, and methane. JP-8 type fuel has no olefins while JP-4, unleaded gas, and diesel fuels have small amounts of olefins. All fuels tested had a high amount of parafins, and most had a high amount of aeromatics.

Other Summer Observations

In the laboratory there are many things to be learned and experienced. One thing I learned which intrigued me was the types of fuel aircraft use.The F-4 Phantom uses JP-4,except for the Navy they use JP-5 because its more stable. The F-16 uses JP-8,and the SR-71 Blackbird uses JP-7. Another thing I learned was how gas chromatography works. A small column is placed in an oven and a liquid sample put in it . As the oven temperature increses parts of the sample boil off and are recorded. Gas chromatography breakes the sample into compounds,not just groups as liquid chromatography does.

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
HIGH SCHOOL SUMMER
APPRENTICESHIP PROGRAM

ALISHA L. HIX

AUGUST 31, 1989

1989 SUMMER REPORT
AERO PROPULSION LAB
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
WRIGHT PATTERSON AIR FORCE BASE

ACKNOWLEDGEMENTS

I would like to express my appreciation to the Test Group in the Aero Propulsion Lab for their continued acceptance and support. They have been a tremendous help both in and out of the office. I would like to specifically thank Douglas C. Rabe and Donald A. Hoying for their patience and help as I learn more about the lab and its purpose. I especially thank Don for a million explanations and endless advice.

I. COMPRESSOR RESEARCH FACILITY BACKGROUND

A. CRF HISTORY

The Compressor Research Facility (CRF) at Wright Patterson Air Force Base was established in the late seventies to help reduce the cost required to perfect prototype compressor designs, which generally have to go through two to eight redesigns before they can become operational.(1) Since it was built, the facility has improved the methods of testing as modern technology would permit. The method presently being used is known as laser anemometery.

This particular type of velocity measurement system incorporates a set of laser beams as probes as an alternative to physical probes like the hotwire. This is ideal for the CRF because the light probes are unaffected by the motion of the compressor blades. Two different systems are in use presently. The first is the Laser Transit Anemometer, or LTA. The second is the Laser Doppler Velocimeter, or LDV, shown in figure #1. Both systems are based on timed light reflections, and have the capability of taking several thousand measurements per second.

The light reflections are read by placing a quartz window in the side of the compressor case. Because quartz has a low refractive index relative to other types of glass, or other transparent media that can withstand the pressure ratio pushing against it from inside the compressor, the laser light is inhibited insignificantly by its presence.

B. HARDWARE BACKGROUND

The LTA uses a simple system based on the velocity equation

$$v = (\text{delta})\ d\ /\ (\text{delta})\ t$$

where '(delta) d' is the change in distance, and '(delta) t' is the change in time. Two parallel beams are formed from a single input beam and focussed over a distance of 400 mm to form two focal points, each with a diameter of 0.016 mm and separated by a known distance, SS. (see figure #2) As dust or seed particles pass through the first focal point, light reflections are read by the photomultipliers. A computer will then time how long it takes for the particle to pass from the first focal point to the second. Then using the distance between the two focal points, the velocity of the particle can be calculated. A statistical velocity is then calculated from the particle velocities. If the particle was small enough to accurately follow the flow of the fluid around it, the velocity of the fluid can be assumed.

The LDV system is based on the same equation; however, the system optics are more complex. Although it still consists of two focussing beams, the focussing distance has been changed as well as making the resulting focal point wider. Since the beam origin is narrower than of the LTA, the beams appear as pencil beams. In addition,the beams are no longer parallel, but rather are focussed to cross at their beam focal points. (diagram shown in figure #3) The resulting focal point consists of an interference pattern of approximately twenty light planes. (figure #4) Dust or seed particles passing through these light planes cause reflections which are read by the LDV photomultipliers. (doppler burst shown in figure #5) The particle velocity is then calculated knowing the distance between the planes. A statistical velocity is calculated for each particle from the calculated particle velocity between the planes. A statistical fluid velocity is then calculated from the statistical particle velocities.

C. SEEDING BACKGROUND

Because fluid flows in a compressor can change significantly over a relatively short distance it is important that the seed particles being used are capable of following such an erratic flow accurately, therefore the particles need to be exceptionally small to reduce particle lag due to weight. If the particles are too small; however, the reflection won't be intense enough for the photomultiplier to detect. The seed must also be able to withstand relatively high temperatures and pressure ratios without changing phase.

II. LDV TESTING

A. PROBE VOLUME MEASUREMENT TEST

1. PROBE VOLUME MEASUREMENT INTRODUCTION

Because the calibration of the LDV optics has a direct effect on the size and shape of the focal point of the laser beams, as well as the number of fringes present, it was necessary to calculate and measure the focal point of the LDV to find out the exact dimensions, and number of fringes for this particular configuration. A set of calculations from Reference 2 (figure #2) was used to analytically determine the dimensions of the probe. Using the sheer edge of the jet nozzle, measurements were taken to indicate where the effective boundaries of the focal point were. These measurements were then used to calculate the dimensions of the focal point. The following describes in detail the methods used to measure the focal point and explains the results.

2. PROBE MEASUREMENT TEST EXPERIMENTAL SETUP

The experimental measurement of the focal point was performed using an experimental setup like that in figure #7. The probe volume was traversed approximately one millimeter away from the nozzle edge through the flow field produced by the jet. Because the edge of the nozzle produced a sheer flow, accurate probe boundaries were established by finding at what traverse table coordinates accurate velocity measurements could no longer be taken.

The inside diameter of the nozzle was subtracted from the difference between the boundary coordinates for each side of the probe on a given axis. This difference was the experimental dimension of the probe on a given axis, and was calculated for the x-axis and the z-axis. The y-axis dimension was calculated by knowing the maximum angle at which accurate velocity measurements could be taken, and applying basic trigonometry to that angle and the known dimensions of the probe on the x and z axes.

3. EXPERIMENTATION / RESULTS

Measurements were taken on the X, and Z axes. To determine actual boundaries for each axis both the velocity and frequency measurements were plotted against the respective flow or jet angle for each reading. (Plots shown in appendix B) When the reading began to show a marked decrease from the expected velocity or frequency, this was recorded as the boundary. Once the boundaries were established, the dimensions were calculated for each axis. The conclusions showed the focal point as being approximately one mm wider than it was long, with dimensions being roughly three mm on the x-axis, and four mm on the z-axis.

B. COMPRESSOR WINDOW TEST

1. COMPRESSOR WINDOW TEST INTRODUCTION

The Compressor Window Test was a series of tests conducted to determine what the maximum angles of attack to the perpendicular of the compressor window could be and still obtain accurate velocity measurements. When the converging laser beams passed through the compressor window, the light was refracted both when entering and exiting the window. This refraction caused the beams to refocus differently than without the window. The results of these tests indicated at what angles the beam focal points no longer cross, how severe the effects of the uncrossing of the beams were on the velocity readings taken, and the change in the focal volume position.

When dealing with light passing from one transparent medium to another the most obvious concerns were reflection and refraction. In the tests done with the LDV those concerns were dealt with by coating the quartz window with an anti-reflective coating and repositioning the focal volume, respectively. Of greater concern is the substance through which the beams pass. The compressor window is made of fused silica, or quartz, a uniaxial crystal which causes a double refraction when light is introduced against its axis. Upon refocussing the double refraction caused an interference pattern. (Effect of double refraction on a focussing beam can be seen in photo A, Appendix A). This could introduce the problem of an interference pattern within an interference pattern. One effect of this could be multiple reflections from a single fringe, which would result in an incorrect velocity reading due to an unknown number of fringes and an unknown distance between each reflection, or subfringe. Another less drastic effect could be increased turbulence, and less accuracy. Another problem, that could be introduced with the greater angle of attack, is a change in the shape of focal volume and, effectively, the shape of the fringes. If the fringes were to be deformed drastically, it could have the same effect as a fringe containing an interference pattern; however, it is believed that the focal points of the laser beams will uncross before this can occur.

The analytical phase of the test used a given angle of incidence with the LDV beam specs to predict by calculation what effect a window of a given thickness and index of refraction when introduced at an angle would have on the LDV probe volume. Calculations were derived from scale drawings using a set of beams neglecting the window effect set at the far side of the window as a reference point to calculate the change in focal point position. The experimental phase used the LDV with an angled window like those used in the CRF to determine if the prediction was accurate.

2. ANALYTICAL PHASE

The analytical phase of the test included the application of the Laser Transit Anemometer (LTA) calculations to the optics of the LDV, and the calculation of radial and axial throws of beams introducing angles to multiple axes. The necessary information needed for the software included calculating the angle of incidence for the LDV rays and beams, finding the focal distance of the rays and beams, and calculating the width of the beams at the origin. The software for both was written into a generic program for use with future LDV testing.

Upon completion of the software and the analysis of the program results, it was determined that the LDV could be used at an angle to the compressor window without causing a significant rise in the standard deviation of the velocity readings. The maximum angle anticipated to be applicable was on the order of ten degrees both axially and circumferentially.

3. EXPERIMENTAL PHASE

a. EXPERIMENTAL SETUP

The experimental setup of the compressor window test included a MicroVAX computer system, a fused silica (quartz) window, window bracket, circular window traverse, W-axis rotator with controller, jet bracket, free-flow jet, seeder, water manometer, and an LDV two color laser system. The seed used in the test was induced by the seeder which atomized the isopropyl alcohol/polystyrene suspension, then mixed the resulting aerosol with air from a shop valve operating between ten and twenty psi. The diluted aerosol was then routed through a plastic hose to the jet, which directed the stream across the focal point of the laser. The water manometer read the pressure to help regulate the air speed. The window, held with the specially designed bracket, was bolted to a circular traverse and placed between the LDV and the jet configuration. The circular traverse was then bolted to a magnetic base which secured it to a steel tripod base. (refer to figure 7 for setup diagram)

b. EXPERIMENTATION

Several sets of experiments were taken using TSI_ACQUIRE.COM as the data acquisition software and HPLOT.COM as the data reduction software. Data was first taken without a window to conduct a flow sensitivity test before introducing the window. Upon introducing the window perpendicular another data set was taken which tested the boundaries indicated by the first test. Finally, eight data sets were taken with the window at varying angles from five to forty degrees with five degree intervals between each data set.

Data points were taken with flow angles at five degree intervals from zero to fifty degrees, and at one degree intervals from fifty to sixty for the first data set. The same was done for the second, with a perpendicular window, except to test at flow angles of five degree intervals all the way to sixty. The window angle tests for five, ten, and fifteen degree window angles were taken at flow angle intervals of ten degrees from zero to sixty. The same was done for a twenty degree window excluding ten and thirty. The rest were done at flow angle intervals of twenty degrees. All window tests were conducted in the first quadrant of the plane containing the LDV fringes, and included a symmetry test done in the fourth quadrant at flow angles of -40 and -60 degrees.

4. ANALYSIS

Upon completion of all laser testing data analysis was done with PV-WAVE. Since the drop in velocity following the increasing flow angle should have correlated directly with the law of cosines, both velocity and frequency were plotted against the flow angle on a cosine curve. It was expected that each point would fall directly on or close to the cosine curve. As the plots (appendix C) show, most reading were as expected. The discrepancy between the experimental data and the cosine curve in the flow sensitivity tests both with and without the window were found to be related to turbulence.

5. CONCLUSIONS

The LDV should prove to be an accurate flow velocity measurement instrument to the CRF for future tests. Up to forty degrees, no distortion in the focal point or fringes was observed either through the appearance of the probe when magnified or through the velocity measurements taken. The only notable problem occurred with the window perpendicular to the beams' bisector. Here the reflection from the window was directed back into the laser where the photomultipliers were located. This reflection interfered with the original beams causing several interference patterns to be formed and redirected back at unpredictable angles when reflected off lens and aperture surfaces. These oblique reflections coupled with the original reflection off of the window, which formed another focal point before reaching the laser aperture, caused a marked increase in turbulence and both velocity and frequency readings were more erratic. This can be avoided by putting the laser at a slight angle (about two or three degrees) to direct reflections away from the aperture.

Although the laser beams are focussed and should cross at those beam focal points, no difference is detected when the window is at such an angle as to cause the beam focal points to uncross. There could possibly be a slight change in fringe spacing or diameter; however, it was not evident in any of the measurements taken.

III. THE NAFCOT PROJECT

A. INTRODUCTION TO THE NAFCOT PROBLEM:

A test was conducted by the CRF early in 1989, known as NAFCOT. At the beginning of the test a problem arose when the isopropyl alcohol in the seeding solution began to dissolve the rubber lining inside of the storage tank, and form a black rubbery composite on the inside of the test cell as a result. As the black rubber collected on the inside surface of the compressor window, the reflections became increasingly difficult for the photomultipliers to detect. Measures taken to remedy the problem were replacement of the storage tanks, and cleaning of the test cell; however, the problems reoccurred upon continuation of the test, albeit less acute.

Samples of the rubbery material from several stages of the test cell were sent to the Materials Lab for composition analysis. The results indicated that the material consisted of polystyrene and a plasticizer called triethyleneglycol bis(2-ethyl hexanoate).

B. ANALYSIS

To determine the origin of the rubber three spectrographs from the Materials Lab Report were digitized, scaled, and placed one on top of the other. (Plots shown in appendix A) The first graph was of the rubber, the second was of the PSL, and the third was of the plasticizer, which was believed to originate from either the rubber tank lining, the rubber hose lining, or both. When all three graphs were examined on the same scale, it became noticeable that although many of the peaks in the rubber composite graph did match closely to the peaks of the polystyrene or the plasticizer graphs, other substances were present. Since the rubber only occurred in the presence of the synthetic oil, mobile SHC 640, used for lubrication in the test cell, it was a strong possibility that the oil had acted as a catalyst to the polystyrene and plasticizer and had changed the spectrum by its presence. Isopropyl alcohol might also have been present in small quantities according to the spectrum.

C. CONCLUSIONS

It is believed that the substance originated as a result of the plasticizer acting on the PSL. Although the known origin of the plasticizer was the storage tanks and hoses, the isopropyl alcohol was considered to be the source of the rubber composite. NAFCOT was the first test in the CRF where the test group had chosen the alcohol as a suspension medium for the PSL. When the alcohol dissolved the rubber, it released the plasticizer used in its production.

To avoid the recurrence of such obstacles, one of two actions should be taken: the removal of all rubberized material coming in contact with the alcohol in its liquid state, or a substitution of another more suitable substance in place of the alcohol.

Apprendices can be obtained from

Universal Energy Systems, Inc.

SUMMARY OF SUMMER ENGINEERING APPRENTICESHIP

Christopher C. Miller

Mentor: Lt. Michael Chung

Solar Energy Lab

August 31,1989

Acknowledgements

I thank the Air Force Office Of Scientific Research and Universal Energy Systems for establishing and managing the High School Apprenticeship Program. This program has given me the unique opportunity to see first-hand, before my own college entrance, the work typically done by engineers. My interest in the field of engineering and respect for those in the field has increased as a result of the eight week program.

I also thank those people within the solar energy lab for making my apprenticeship educational and enjoyable. In particular I thank the following people: Lt. Michael Chung for setting up tours in the neighboring labs and for taking the time to explain and demonstrate ideas that were unfamiliar to me, Capt. Robert K. Morris for explaining the LIPS-III experiment and giving me a basic understanding of the data reduction process and of the data itself, and Kevin Thayer for acquainting me with and making me comfortable with the laboratory and the engineers and for being very patient and helpful over the eight weeks.

I. General description of research

My primary task involved helping in the data reduction process for the LIPS-III satellite program. The raw data received from the satellite had to be organized into a presentable and easily read form that would allow the engineers to analyze the data quickly and concisely.

The Living Plume Shield (LIPS-III) satellite was launched in the spring of 1987 into a high radiation orbit. The purpose of the LIPS-III is to evaluate the performance and long term durability of technologically advanced solar cells and solar cell concentrators in a space environment and to compare the performance levels of various cells and arrays using varying methods of solar cell fabrication and solar array assembly. The experiments on the satellite tested the following: the effects of coverglasses varying in type and thickness on the solar cell's long term performance, the effects of soldering versus welding on a solar array's durability, the difference in the long term performance of solar cells varying in material (GaAs, Si,Si doped with Ga,GaAs/Ge), and the effects on GaAs cells when fabricated and assembled by varying methods. The results of this experiment will allow the engineers to test the long term durability and performance of new technologies within the photovoltaic field. This, in turn, will allow the engineers to find the optimum solar cell material and array assembly technique suited for an extended space life.

From time to time I tested the electrical performance of solar cells using a solar simulator to simulate the sun's intensity in the space environment. This was done before and after the cells underwent experimental testing so as to record the effects of the experiment on the solar cell's electrical performance. Both GaAs and Si cells were tested.

The solar energy lab is primarily concerned with developing more survivable, effecient, and powerful solar array systems to provide electrical power for satellite systems. This effort to provide powerful electrical systems to satellites is far from an individual lab effort. Just within the Aero Propulsion Laboratory one finds the Battery Laboratory producing storage units for electrical energy produced by the solar arrays and the Thermal Energy Lab producing heat dissapation devices to reduce the negative effects of high temperatures on solar cell effeciency. This list is far from complete, but it illustrates the necessity of pooling the knowledge and efforts of specialists to produce a single advanced system.

II. Detailed description of research

In order to measure the solar cell's electrical performance on the LIPS-III satellite, the satellite is programmed to apply twenty-four loads of varying resistance. Incorporating Ohm's Law in the program (I=V/R), one can then find the corresponding current and voltage data. This raw data along with other data such as temperature and cosine attitude error are sent to the Naval Research Laboratory where the data is modified and calculated values are supplied. This modified data is then sent to the Air Force on floppy disk where it must be organized into a form that can be easily read and analyzed. A FORTRAN program developed for the LIPS-III experiment is used in conjunction with the data file sent by the NRL. The program reads the data from the data file and derives the I-V data pairs, the short circuit current, the open circuit voltage, and the maximum power point along with the current and voltage points corresponding to that point. This data is saved on the computer's hard disk. At this point a graphics package (GRAFTALK) is loaded into the computer to read the entered datafile and generate the I-V curve. A hard copy of the I-V curve is produced and the data is transferred from hard disk to soft disk. Data acquisition occurs often, but the data is only reduced and analyzed approximately every ten to twenty days. The process uses an IBM Personal Computer AT System and an Epson Spectrum LX-80 dot-matrix printer.

Solar cell testing was done using a Spectrolab Solar Simulator Model X25 Mark II and a VAX computer system. Prior to testing, the lamp has to be calibrated. Once a year solar cells are sent to an altitude of approximately 30,000 feet, representative of 1 AMU or 1 sun, by using a weather balloon. A reading of the cell's electrical performance is made in a fashion similar to the LIPS-III satellite by applying loads of varying resistance.

With this data the lab then tries to recreate the electrical performance of the solar cell with the lamp by varying its intensity. When the electrical outputs are matched, the lamp intensity is known to be similar to that of the sun's. This lamp intensity of 1 AMU is then used as a testing standard to insure continuity of test readings. When the intensity of the lamp is correct, the cell is placed upon the testing block with tweezers and the electrical contacts from the simulator to the cell are made. The lamp's current and voltage are stabilized and the lamp is turned on. The data is read into the computer system and a hard copy of the I-V curve along with the corresponding numerical values and efficiency rating are produced by a Digital LNO3 Plus Script Printer.

III. Results

The LIPS-III satellite has been in orbit for approximately 1-1/2 years now. From the data obtained, graphs have been produced plotting the maximum power output and the short circuit current versus the number of days in orbit. The graphs of most of the cells show a subtle decrease in these two values. This negative effect on a cell's performance in the radiation environment of space decreases mission lifetime. As the experiment continues over time (a predicted ten year life) both the maximum power and the short circuit degradation are expected to greatly increase. This degradation is a result of the entrance of electrons and or protons, primarily low enrgy, into the solar cell through the coverglass and the substrate, the material on which the cell is mounted. The damage resulting from the radiation is in the form of ionization and atomic displacement within the cell. A detailed description of radiation effects on the solar cell will not be given since it is beyond the scope of this report.

The extent of radiation damage suffered by a cell is dependent upon the thickness of the cell's coverglass, its substrate and the material of the cell itself. A typical Si solar cell degrades approximately 19% to 25% over a seven year period when orbiting in a high radiation belt. The new generation of GaAs cells have not yet been fully tested for extended exposure to radiation. One of the aims of the LIPS-III experiment is to test the resistance of the GaAs cell towards radiation exposure and to test the effects of innovative coverglass and solar collector designs on the rate of degradation. It is predicted that the new coverglasses and collectors will decrease the amount of degradation suffered by a cell since they both shield the cell from the space environment, but this has yet to be proven over the extended testing period provided by the LIPS-III satellite.

Experiences and Lessons

During the summer I was fortunate to tour several labs within the Aero Propusion Laboratory. These included the Thermal Energy Lab, the Battery Lab, the Thermionics Lab, and the Turbine Engine Division. These tours provided me with the opportunity to see the work done by engineers representing several of the major branches of engineering. I also attended weekly staff meetings and a few briefings given by private companies holding government contracts. Through independent reading I gained a basic understanding of the theory behind photovoltaics, a basic understanding of electricity, and a basic understanding of the goals and challenges faced by engineers in the photovoltaic field. I became aware of the differences between the project aims of the Department of Defense and NASA while preparing solar cell samples for an underground nuclear test simulating the effects of a weapons' attack on the cells. NASA is concerned with designing cells that can withstand damage resulting from environmental conditions; while, the DOD is concerned with designing cells that can not only withstand environmental damage but also that damage inflicted by a weapons' attack. I learned a lot during my eight week apprenticeship. I also learned that I have much more to learn.

BIBLIOGRAPHY

Agrawal, Brij N. *Design Of Geosynchronous Spacecraft.* Englewood Cliffs: Prentice-Hall, Inc., 1986.

Solar Energy Handbook. Radnor: Ametek, Inc., 1984.

U.S. Air Force, Air Force Wright Aeronautical Laboratories. *Air Force Solar Cell Flight Experiments For The LIPS-III*, Wright Patterson AFB, March 1988.

U.S. Air Force, Air Force Wright Aeronautical Laboratories, *Data Reduction For The Air Force Experiments On LIPS-III*, Wright Patterson AFB, Sept 1988.

AIRCRAFT ENGINE AXIAL-FLOW COMPRESSORS AND MATHEMATICAL MODELING OF COMPRESSOR PERFORMANCE

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HIGH SCHOOL APPRENTICESHOP PROGRAM
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AIRCRAFT ENGINE AXIAL-FLOW COMPRESSORS AND MATHEMATICAL MODELING OF COMPRESSOR PERFORMANCE

ABSTRACT

A literature survey was done to understand the role of the axial-flow compressor in aircraft gas turbine engines, and to show the need for computer modeling of compressor performance at both design and off-design speeds. Important compressor considerations such as stability and stall margin are addressed and examined through the use of a compression system mathematical model. Through both steady-state and time-dependent investigations, the usefulness of the computer model is demonstrated.

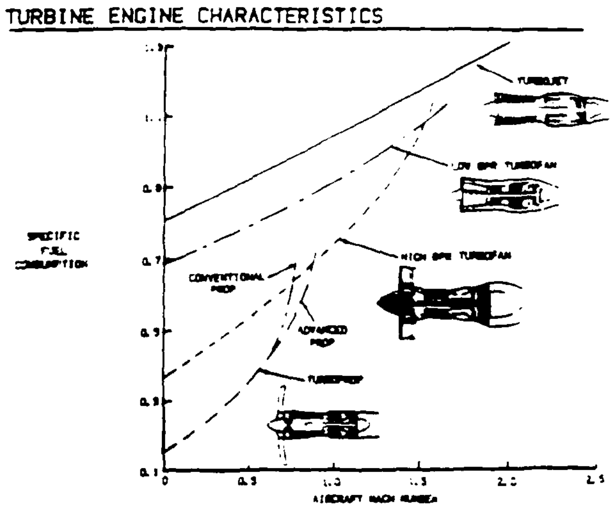


FIG 1 : TYPES OF AIRCRAFT GAS TURBINE ENGINES

INTRODUCTION

Propelling todays most advanced high performance aircraft are axial flow gas turbine engines (Fig. 1). These engines have three basic performance considerations: specific weight, specific fuel consumption, and thrust per unit frontal area [1]. The engine is judged on these three factors. The core of the engine is made up of three parts: the compressor,

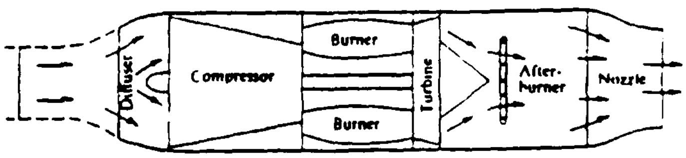


FIG. 2 : AIRCRAFT ENGINE SCHEMATIC [6]

the combustor, and the turbine (Fig. 2). Although all three are of equal importance and dependent upon each other, the compressor will be discussed here.

The performance of the engine is governed by the performance of the compressor (Fig. 3). The compressor must allow the engine to start readily and accelerate rapidly to the speed at which it was designed. It must also provide satisfactory performance over a range of air speeds, pressure ratios and air flows when varying flight conditions require [1]. When operating a compressor one must consider its operating envelope (Fig.4). Within this envelope are the design speed (the speed at which the compressor was designed to operate) and the off-design speeds. The envelope is defined by the operating line and the stall limit line. The stall limit line shows where the flow through the blades of the compressor becomes irregular and separates from the blade, causing compressor performance to deteriorate rapidly, or stall.

Using the computer model two simulations were run in order to demonstrate its ability to accurately predict condition changes. The data is then graphically presented and explained.

BACKGROUND

The basic function of the compressor is to increase the pressure of the air so that proper combustion can

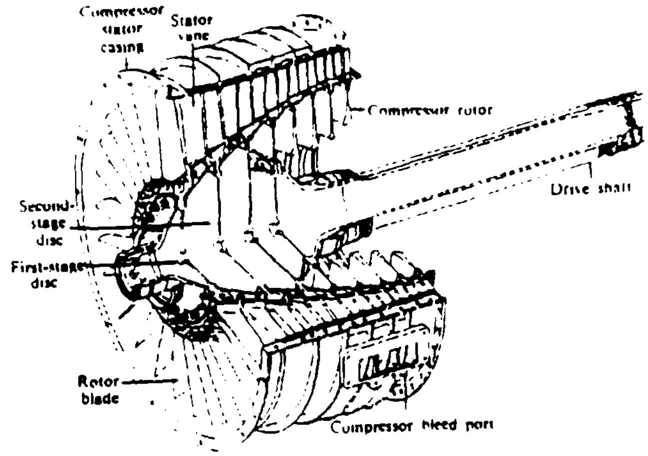


FIG. 3: COMPRESSOR SCHEMATIC [6]

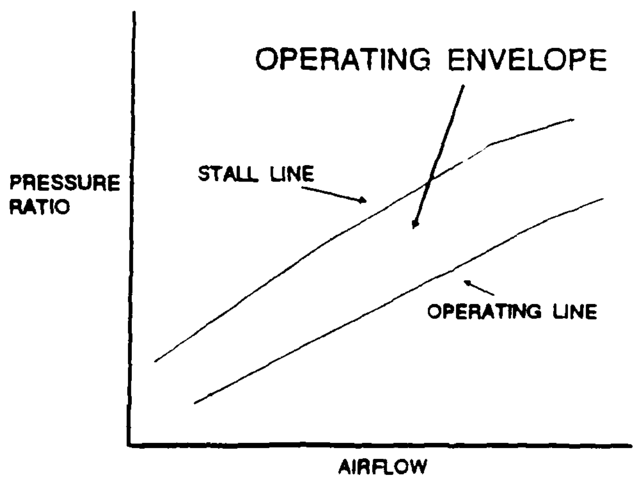


FIG. 4 : COMPRESSOR OPERATING ENVELOPE

be achieved and the required engine thrust delivered. In order for this to be accomplished, the air flow must pass through a number of blade rows. The first row of blades are the inlet guide vanes. These ensure that the air enters the first stage of the compressor at the proper angles to the blades. Each compressor stage consists of a rotating blade row (rotor) and a stationary blade row (stator). The air flow is turned in the first rotor and energy is added due to the rotor speed. This energy manifests itself as an increase in temperature and pressure of the air leaving the rotor. The stator removes all or part of the flow turning and redirects the flow to properly enter the next rotor (Fig. 3). In this manner, the individual stage pressure rises contribute to the overall compressor pressure rise.

Concepts of the compressor have been known for approximately one hundred years. One of the earliest experimental axial-flow compressors was obtained by Parsons, in 1884, by running a turbine in reverse, but it had poor blade design which led to poor efficiency. The performance of axial flow compressors were considerably improved by the use of the "Isolated-Airflow theory" used in fans for ventilation and air conditioning. The "Royal Aircraft Establishment in England" began developing axial flow compressors for jet propulsion in 1936 [1]. Since then, compressor design and performance has been greatly improved.

It is important to be able to predict both design and off design performance of compressors in order to ensure adequate compressor performance over the entire range of engine operating conditions. It is also important to know how the compressor would react to dynamic (time dependent) changes in inlet and/or exit conditions. For example, if a missile were launched from an aircraft and the hot gases from the missile exhaust were ingested into the compressor, what would happen? The engine may not be designed to handle the temperature change and it may cause the compressor to aerodynamically stall. During aerodynamic stall the air flow around the blades becomes separated from the blade due to the high angle-of-attack of the air entering the stage. If the compressor does not return to normal operation from the stall, the plane may crash destroying a multi-million dollar aircraft and possibly causing loss of life.

Because of the expense and time involved with experimentally testing compressors, analytical mathematical methods of predicting off-design performance have been developed. Such a model, when used in conjunction with experimental data, can provide valuable insight into compressor performance under conditions impractical or impossible to test experimentally. One method is the "Blade-element

Method" [1]. It involves a radial stacking of a series of blade sections or blade elements. The theory proposes that if the performance of each blade element is known, the blade-row performance can be determined, and that overall compressor performance can then be obtained. This theory is useful for obtaining only a small part of the compressor map over which all blade elements in the compressor remain unstalled.

Another method is the stage stacking method [1]. This method requires that the performance of each stage of the multistage compressor is obtained and presented so that its performance is a function only of its inlet equivalent weight flow and wheel speed. A stage-by-stage calculation gives individual stage pressure and temperature ratios, so that overall compressor pressure ratio and efficiency can be calculated for the assigned values of compressor weight flow and wheel speed. Stage-stacking performance curves and stage-by-stage calculations are useful when reliable stage performance curves are available. There are three phases of calculation procedures. During the first phase, points of maximum compressor efficiency at each speed are calculated. The second phase involves determining the stall limit line, which identifies the maximum obtainable pressure ratio at each compressor speed. Finally, the points along lines of constant compressor speed are calculated from the stall limit to maximum flow (Fig. 5). The stall limit or surge line is known as the backbone of the compressor map and represents a "boundary" that should not be crossed. Operation of the compressor to the left of the stall line results in rapid deterioration of compressor performance. As a result, compressor operating lines are always established well below the stall line, with the margin of safety known as the "stall margin."

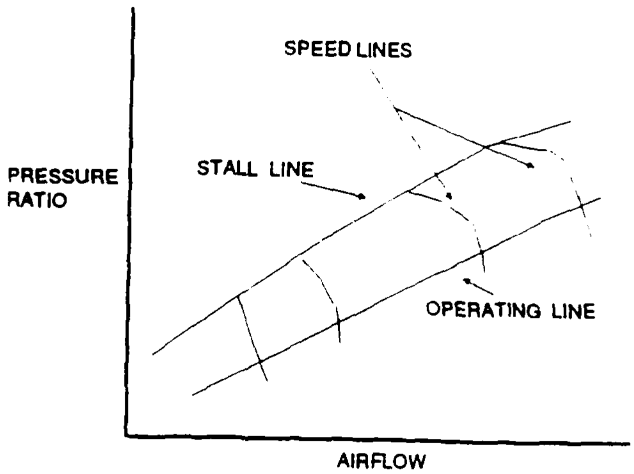


FIG. 5 : COMPRESSOR PERFORMANCE MAP

MODEL APPLICATION AND RESULTS

The stage-by-stage model used in the current effort uses a control volume representation to simulate compressor performance, including performance to the left of the stall line (in-stall performance). The control volume method is an engineering approach that relates the movements of mass, momentum, and energy across volume boundaries to changes that take place in the control volume. The size and number of control volumes are specified by the user and governed by the geometry of the represented compressor. Figure 6 shows the control volume arrangement. There are thirty eight control volumes used to represent the inlet ducting, compressor, and discharge volumes. Each compressor stage is represented by a control volume. This allows for analysis of individual stage behavior, as well as overall compressor performance. The equations governing the mathematical calculations are developed from the

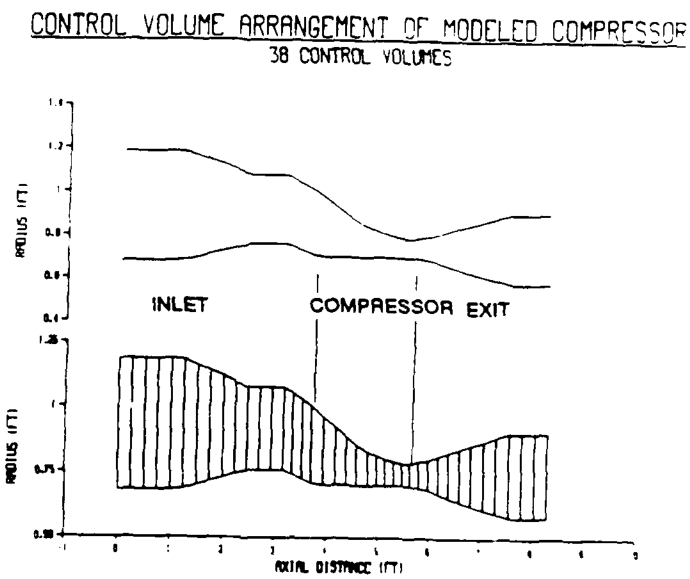


FIG. 6 : MODEL REPRESENTATION OF COMPRESSOR

principles of conservation of mass, momentum, and energy. These state that mass, momentum, and energy cannot be created or destroyed. In addition to the physical geometry, pressure and temperature curves describing each stage's performance must be input into the model.

The model can represent the computed output either printed or graphically. For analysis purposes, the graphical form is used. Model output includes air flows, pressures, temperatures, and velocities, etc. at each of the calculating stations (control volume boundaries).

In order to run the model, temperature, pressure, and flow characteristics were input for each of the ten stages. The data for these characteristics were taken from an experimental test previously preformed. The computer model then uses the stage performance information to predict the performance of the compressor at the desired speeds and operating conditions. This enables the compressor to be "tested" for various conditions at any time quickly and easily. Not only is computer modeling more convenient, but it is also a lot less expensive than running a prototype test. The model takes one person and a computer where as running a test takes a large number of people and numerous hours of work.

In order to validate the predictions made by the computer model, they were compared to data taken from an actual compressor tested in the Compressor Research Facility at Wright Patterson Air Force base [2]. The model predictions were closely related to the experimental data therefor verifying the models accuracy.

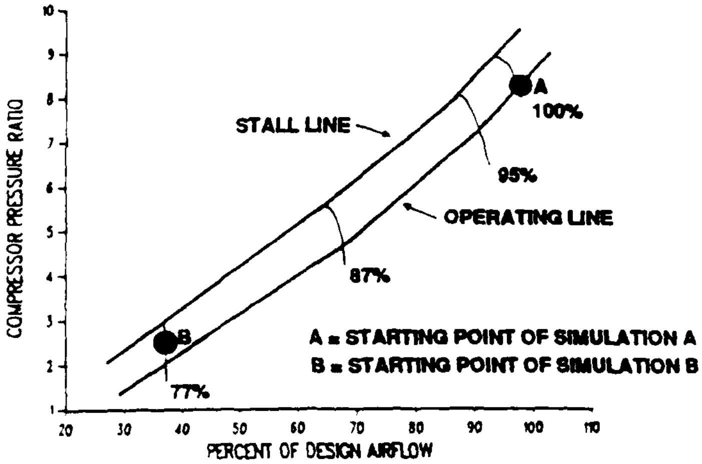


FIG. 7. MODEL PREDICTED COMPRESSOR PERFORMANCE MAP

The way that the model is set up, stage characteristics taken from experimental data are input into a curve-fitting program. This program assembles the data into characteristic curves and represents it as curvfit data. This data is then used in both the steady-state model or the dynamic model. The steady-state model's output provides the initial conditions required by the time-dependent model. Both the steady-state and the dynamic models output plot files which are then graphically represented by a plotting program.

The usefulness of the computer model was demonstrated by simulating two feasible conditions. The first simulation (A) represents the compressor ingesting hot gasses from the exhaust of an aircraftlaunched missile. The second simulation (simulation B) is a prediction of the compressor reaction to a throttle closure (a demand for increased engine thrust).

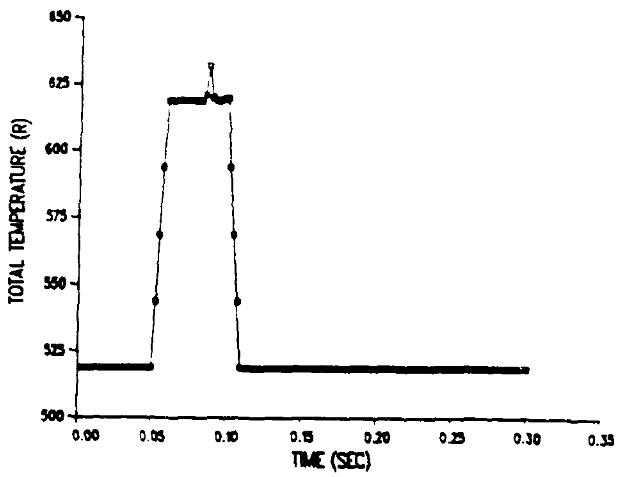


FIG. 8: IMPOSED INLET TEMPERATURE CONDITION FOR SIMULATION A

Figure 7 shows the percent of design speed at which the simulations were run. The starting points for the simulations are shown on the speed lines.

In simulation A, the compressor inlet temperature was momentarily ramped up 100 degrees to represent the hot gas ingestion at a rate of 10,000 degrees R per second (Fig. 8). The increase caused compressor operation to the left of the stall line. The type of compressor behavior shown in Fig. 9 is known as compressor surge, and is characteristic of compressor stalled performance at higher speeds. When surge occurs, the compressor experiences large oscillations of air flow from forward to reverse flow and back [4]. Unless the condition causing the instability is removed, surge continues in a cyclic fashion. In simulation A, note that when the inlet temperature was returned to normal, representing the hot gas leaving, the compressor performance returned to its original conditions (Fig. 10). In this sense, the compressor instability was recoverable.

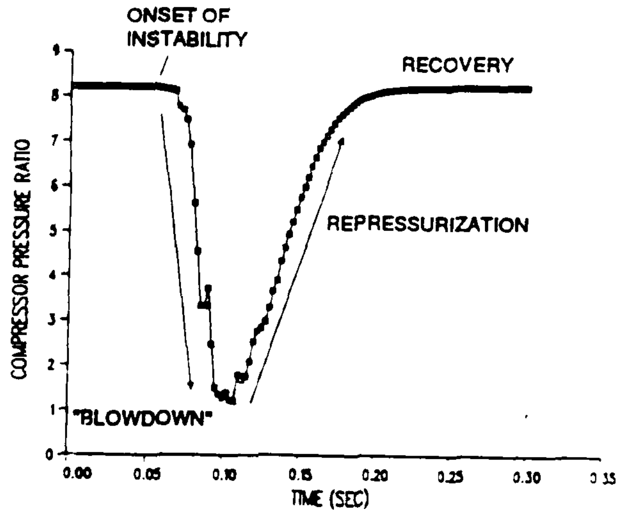


FIG. 9 : MODEL PREDICTED RESPONSE FOR SIMULATION A

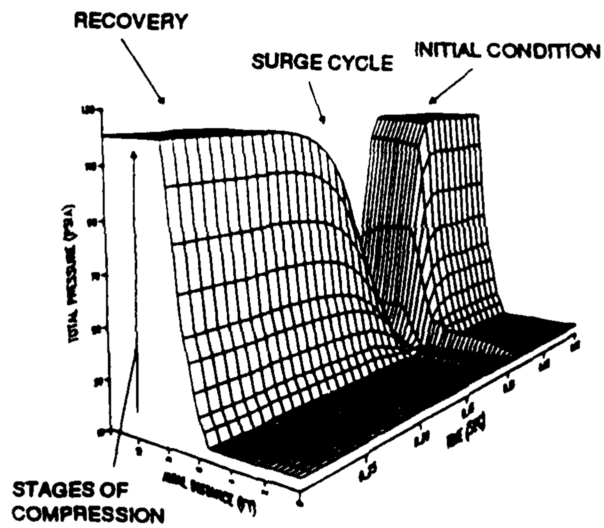


FIG. 10 : MODEL PREDICTED PERFORMANCE OF COMPRESSOR RESPONSE TO INLET TEMPERATURE RAMP

In simulation B, as the closure increased, the compressor pressure ratio increased until the stall point was reached, again resulting in stalled compressor operation (Fig.11). The type of stalled operation now experienced is characteristic of stalled performance at lower speeds. This stall, rotating stall, can be non recoverable. Unlike a surge, rotating stall produces noncyclic, "steady" performance at a much reduced pressure ratio and air flow. As predicted by the model the stall was nonrecoverable (Fig. 12) and therefore the compressor would fail and unless an air-restart is accomplished, would most likely result in a crash.

SUMMARY AND CONCLUSION

A literature survey was done to better understand the compressor in axial-flow turbine engines, and to show the need for computer modeling of compressor performance at both design and off-design speeds. A stage-by-stage axial compression system mathematical model was used to demonstrate prediction ability. The accuracy of the model was previously validated by comparing model predictions with experimental data. A demonstration of the model was done using two possible scenarios. The information is graphically represented and presented. In conclusion, the modeling technique is proven effective by it's ability to predict conditions accurately and inexpensively, therefore justifying the need for continued research and development on the subject. During this study, much was learned about the compressor and its important roll in high performance aircraft engines. The usefullness the computer modeling technique was realized, and the ability of the model to predict compressor performance was also learned.

ACKNOWLEDGEMENTS

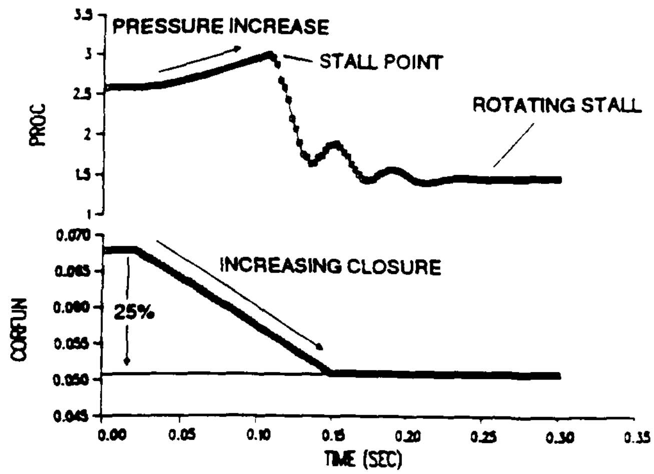


FIG. 11 : IMPOSED THROTTLE CLOSURE AND MODEL PREDICTED RESPONSE FOR SIMULATION B

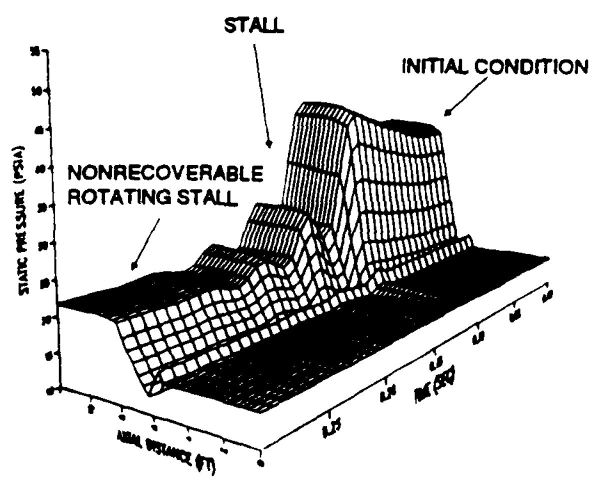


FIG. 12 : MODEL PREDICTED PERFORMANCE OF COMPRESSOR RESPONSE TO THROTTLE CLOSURE

The author would like to acknowledge the following people for their contribution to the success of this project: Lt. Keith Boyer (WRDC/POTX) for his overall guidance and teachings, Dr. Milt Davis, Lt. Connie Dowler, and Steve Gorrell for their technical advice and guidance. The authors would like to acknowledge Universal Energy Systems, Inc. for sponsoring the science apprenticeship program through which this work was done, and also Wright-Patterson Air Force Base for allowing the use of its state-of-the-art equipment and facilities.

REFERENCES

1. Johnsen, I.A., and Bullock, R.O.,"Aerodynamic Design of Axial-flow Compressors," NASA, SP-36, Lewis Research Center, Cleveland, OH, 1965.
2. Boyer, K.M., and O'Brien W.F., "Model Predictions for Improved Recoverability of a Multistage Axial-Flow Compressor" AIAA Paper No. 89-2687, Presented at AIAA/ASME/SAE/ASEE 25th Joint Propulsion Conference, Monterey, California, July 1989.
3. Davis, M.W., Jr., "A Stage-by-Stage Post Stall Compression System Modeling Technique, "AEDC-TR-86-34, Arnold AFS,TN February 1987.

4. Greitzer, E.M., "Review--Axial Compressor Stall Phenomena," Journal of Fluids Engineering, Vol. 102, June 1980, pp. 134-151.

5. Gates, G.C. Editor, " The Aerothermodynamics of Aircraft Gas Turbine Engines," AFAPL-TR-78-52, July 1978.

6. Hill, G.P., Peterson, C.R., "Mechanics and Thermodynamics of Propulsion," Addison-Wesley Publishing Company, Reading Massachusetts, 1965

ARMAMENT LABORATORY

HIGH SCHOOL APPRENTICESHIP PROGRAM

Jules Bergmann

Niceville High School

OPERATION & PROTOCOL MANUAL

SUMMER 1989

NAME

intro - introduction to commands

DESCRIPTION

This section describes the operation and protocol of several general utility commands written for the Sun-3/110 (although most could be converted to other flavors of unix) running SunOS 3.4. All commands (except for graphics(1) and parts of gserv(1)) were written by Jules Bergmann during his brief and sweet apprenticeship at AFATL/SAI. Therefore these pages not only report his endeavors but document them as well.

ACKNOWLEDGEMENTS

Starla Christakos
For turning me loose on all this wonderful stuff.

Charles Coker
For providing the much needed user perspective (i.e. reality.)

Mike Couvillon
For putting up with the reams of paper that jlpd, rdb, and every other printer program seemed to produce on its first run (birth rights, I think.)

Derek Holland
For absolutely nothing. (Seriously, for being someone to talk to.)

Brian Kernighan
For developing the wonderful C language.

Dennis Ritchie
For developing the wonderful C language.

Laura Sterrett
For giving me this opportunity to work.

BUGS

Doesn't follow standard report form.

NAME

add - A Display eDitor

SYNOPSIS

add [options] [filename | -]

DESCRIPTION

add is an interactive graphics editor that runs on sun computers under sunview. add is capable of editing and/or creating both irradiance and color files. It provides commands for simple drawing (point, box, etc..), colormap manipulation, and basic signal processing.

OPTIONS

-x<x size>
Sets the absolute x dimension of the image.

-y<y size>
Sets the absolute y dimension of the image.

-X<X size>
Sets the image window's x dimension

-Y<Y size>
Sets the image window's y dimension

-s<pixel size>
Sets the number of screen pixels per actual data pixel. (Hard to explain, just mess around with it.)

-i<conversion>
Specifies the method of converting images from intensities to colors. 1 specifies a standard (and extremely slow) logarithmic conversion. 2 and 3 work in an identical to method 1, except they use highly optimized algorithms. 4 is a plain linear conversion (usually fast.) 3 is the default. If the -i is specified, the input file is expected to (and must be) intensity values. (Mutually exclusive with -c.)

-c Specifies that the input file is a color file. (Mutually exclusive with -i.)

-M<max val>
Set maximum value for use in intensity to color conversions. Defaults to the actual maximum value in the input file. Valid only with -i.

-m<min val>
Set minimum value for use in intensity to color conversions. Defaults to the actual minimum value in the input file. Valid only with -i.

USAGE

GENERAL DESCRIPTION

Add deals with two basic types of images, Color Images and Intensity Images. A color image is a 2 dimensional array of bytes, with each byte representing a given color (determined by the current ColorMap). An intensity image is a 2 dimensional array of 4 byte floating point irradiance values. To display an intensity image, it must first be converted into a color image format (see colorz(1)). add displays the current image type in the 'mode:' text item (on the control panel, see below.)

add's screen layout consists of 3 windows: the image window, the control window (divided into the ColorMap display and the control panel), and the histogram window (which probably shouldn't be a first class window.) Most of add's features are accessed via the mouse as described below.

The control panel is the most important non-graphic window (and the only one) because it provides information on the image. The 'File:' item displays the file name of the image currently being edited. The 'Display:' item should not be messed with, as its operation is currently in a state of limbo (in the past it has been used to allow editing of multiple images, a desirable feature that raises numerous important user interface questions, to be dealt with later.) The 'x:' and 'y:' items display the x and y position of the mouse within the image (valid only when the mouse is actually positioned it the image window.) The 'c:' item displays the byte value of the pixel that lies at that location. The 'value:' item displays the intensity value at that location (valid only when editing an intensity file.) The 'setColor:' item displays the current color's byte value. The 'setValue:' item displays the interpolated intensity value of the current color (valid only ...) The current type of image is displayed in the 'mode:' item. The image window (i.e. box, circle, or line.) Finally, there are six action buttons:

Act	Access file input & output menus, and screen parameters. (See FILE INPUT & OUTPUT)
Col	Access color manipulation menus. (See COLORMAP MANIPULATION)
Quit	Quits add without saving the image.
Serv	Use image processing services. Discontinued feature.
Do	Access sub-picture manipulation menus. (See

SUBPICTURE MANIPULATION)

Draw — Reconvert the image values from intensity to colors and redisplay. (Needless to say, valid only with an intensity file.)

BASIC IMAGE EDITING

add's two most basic and least used features are the point and box drawing ones. To place a dot on the image, merely position the mouse over the appropriate pixel and press down on the left mouse button. The pixel should change to the currently selected color (which is shown in the solitary box at the bottom of the control window.) To draw a box, place the mouse over one of the four corners and click the right mouse button. The move the mouse over the diagonally opposite corner and click the right button again. A box filled with the current color should appear.

The value placed into the image by the point and box commands vary depending on the type of image being edited. When editing a color image, the byte at that position is merely set to the current color. If the image is an intensity one, the current color is interpolated back into an irradiance value, and this value is placed into the image (unfortunately, there is no feature to specify an exact irradiance value, at least not yet.)

The effect of the right button can be changed by modify the 'Right:' item located on the control panel (merely click the left button over it.) It can be used to draw a line, a circle, or as is default, a box.

More advanced editing features are provided by the subpicture editing commands, which are covered later.

Most of add's commands are accessed thru menu selections. There are four main menus, some consisting of sub-menus. The directory structure is described in detail below.

LOADING & SAVING FILES

The act menu is used to load files, save files, and change display attributes (window and absolute sizes). It is divided into three appropriate sub-menus Load, Save, and Screen.

The Load options are as follows:

Color — Prompts for file name in shelltool window to load as a color file. This file must be the same dimensions as the current file.

Intensity — Prompts for file name in shelltool window to load as an intensity file. This file must be the same dimensions as the current file.

ColorMap — Prompts for file name in shelltool window to load as a ColorMap file. This file should consist of 3 256 byte sections, (red, green, blue) with byte meanings sun standard.

The Save options are as follows:

Color — Prompts for file name to save the current color values to (i.e. the bytemap).

Intensity — Prompts for file name to save the current intensity values to (i.e. the irradiance values).

Pixrect — Prompts for file name to save the current image to as a Sun standard pixrect file. This is useful in conjunction with the Ani program.

ColorMap — Prompts for file name to save the current ColorMap to (in the same form as described above for loading a ColorMap.)

COLORMAP MANIPULATION

Editing the ColorMap is accomplished in several ways. To select the current color, (i.e. the one to draw with) place the mouse pointer over the intended color on the ColorMap window and press the left mouse button. To select a color for editing (i.e. ma manipulating the red, green, and blue components), move the mouse pointer over the intended color and press the middle mouse button. Three slider bars are provided for changing the rgb values, along with several buttons described as follows:

Done — This closes the window and saves the changes to the colormap.

Reset — This restores the rgb values to their original values (i.e. before editing began.)

RGB — This restores the rgb values to their initial values (i.e. when add first started up.)

Cancel — This closes the window and forgets the changes.

A special menu is provided to allow manipulation of a continuous range of colors. Before accessing the col menu, the range must be specified by placing the mouse pointer over the first color in the range , pressing the middle mouse button, and then placing the pointer over the last color in the range and pressing the middle button again. After this has been done the following col menu functions are available:

Blend — This will blend the rgb values between the endpoints of the range to create a smooth shaded transition form one color to the other.

Replicate — This will replicate a color range in a yet to be determined manner. (Not Implemented Yet.)

Range/RGB — This will create an RGB scale in the current range.

Range/Grey — This will create a Grey scale in the current range.

Range/Red — This will create a Red scale in the current range.

Range/Blue — This will create a Blue scale in the current range.

Range/Green — This will create a Green scale in the current range.

SUBPICTURE MANIPULATION

add includes several commands to manipulate sub-pictures. Selecting a sub-pict is similar to selecting a range of colors for ColorMap manipulation. First place the mouse over one corner of the sub-pict being created, click the middle mouse button, then place the mouse over a diagonally opposite corner of the sub-pict and click the middle button again. An outline should appear displaying the outer sub-pict. Several menu options in the 'Do' are available:

Histogram — Performs a histogram of the current sub-pict and displays the output in the previously mentioned histogram window.

Threshold — Allows a threshold to be performed on the intensity values within the sub-pict. add prompts for the min and max values from within the shelltool.

Place	Draws out the current sub-pict on the picture upon a left mouse click. Intensity values that are zero will not be transferred (i.e. transparent.) Weird things occur when the a sub-pict is placed close to itself. (Please experment with this command before attempting to do serious damage.)
Image	
Reset	Reset the sub-pict state. Useful to remove the sub-pict box from the image without reselecting a new sub-pict.
Sobel	Performs a sobel operator on the sub-pict.
Kircsh	Performs a kirsch operator on the sub-pict.
Life	Runs the classic life game. As a pixel ages, it 'red'ens. Causes spurious crashes. For a more compleat implementation see blife(1).

DIAGNOSTICS

None

BUGS

Too numerous to mention

NAME

ani - animate a sequence of pixrect files

SYNOPSIS

ani [-s<pixsize>] [-x<xsize>] [-y<ysize>] filename

DESCRIPTION

ani animates a sequence of pixrect files on the screen while displaying various information such as file name, position, velocity, etc. ani expects its input in either the specified file or the default 'ani.script' as a sequential list (i.e. ls -1 format.)

OPTIONS

-x<xsize>
: Sets the x dimension of the input raster. Default size is 128.

-y<ysize>
: Sets the y dimension of the input raster. Default size is 128.

-s<pixsize>
: Sets the number of screen pixels per image pixel. Default is 2.

USAGE

ani expects an input file made up of pixrect files and/or commands. A command should (and must) be preceded by a #. A file should not be preceded by a #. Upon reading a file, ani will load and display it. ani acts upon its various commands as follows:

i0:filename
: This specifies the filename ani will display in the 'File Number' display area.

i1:time
: This specifies the time ani will display in the 'Time after Launch' display item.

i2:observ alt
: This specifies the altitude ani will display in the 'Observer Alt' display item.

i3:target alt
: This specifies the altitude ani will display in the 'Target Alt' display item.

i4:range
: This specifies the range ani will display in the 'Range' display item.

i5: This tells ani to update the current clipping position.

xf:filename
This specifies an external file for ani to use. An external file contains a list of commands grouped together such that the last command in a group is '##'. Every time ani encounters an #xr in the source file, the next group of commands in the external file are executed. This is useful for separating image data (i.e. range, distance, etc.) from the actual image list.

xr Execute the next group of commands (i.e. until the next '##') from the external file.

SEE ALSO
ani(1),colorz(1)

DIAGNOSTICS
None.

BUGS
None known.

NAME

colorz - convert irradiance realmap to color bytemap

SYNOPSIS

colorz [-x<xsize>] [-y<ysize>] [-c<crange>]

DESCRIPTION

colorz translates an input file of real (i.e. floating point) irradiance values into a bytemap of color values rangeing from 0 to crange-1. colorz performs this conversion either logarithmicly or linearly.

colorz works by computing the ratio of the difference between a given irradiance and the minimum irradiance (for the input file) to the difference between the maximum and minimum irradiances (for the input file). This ratio is then scaled to produce a number between 0 and crange-1. (The logarithmic method is similar, except the log of all values are used instead.)

The logarithmic scale is better suited for input that contains a few very hot spots that would otherwise drown out most of the other picture elements.

colorz translates form stdin to stdout.

OPTIONS

-x<xsize>
Sets the x dimension of the input raster. Default size is 128.

-y<ysize>
Sets the y dimension of the input raster. Default size is 128.

-c<crange>
Sets the number of output colors produced. Default range (and maximum value) is 256.

SEE ALSO

rdb(1),dither(1)

DIAGNOSTICS

None.

BUGS

None known.

NAME
dither - convert color bytemap to B&W bytemap

SYNOPSIS
dither [-x<xsize>] [-y<ysize>]

DESCRIPTION
dither translates an x*y 256 color byte-sized raster into a 8x*8y 2 color byte-size raster, suitable for printing using rdb(1).

dither translates form stdin to stdout.

OPTIONS
-x<xsize>
Sets the x dimension of the input raster. Default size is 128.

-y<ysize>
Sets the y dimension of the input raster. Default size is 128.

SEE ALSO
rdb(1),colorz(1)

DIAGNOSTICS
None

BUGS
The grey scale used by dither could stand some modifications.

NAME

fsd - Full Screen Display

SYNOPSIS

fsd [options] filename

DESCRIPTION

fsd displays images on the screen (note: it does not run under SunView.) Its primary purpose is for displaying large pictures that add (from which it is derived) cannot handle, due to memory limitations.

fsd provides indentical command line options as add. For a description of irradiance vs. color files, etc. see add(1). To manipulate ColorMaps (i.e. after fsd has displayed the image), use setcol(1).

OPTIONS

-x<x size>
Sets the absolute x dimension of the image.

-y<y size>
Sets the absolute y dimension of the image.

-X<X size>
Sets the image window's x dimension

-Y<Y size>
Sets the image window's y dimension

-s<pixel size>
Sets the number of screen pixels per actual data pixel. (Hard to explain, just mess around with it.)

-i<conversion>
Specifies the method of converting images from intensities to colors. 1 specifies a standard (and extremely slow) logarithmic conversion. 2 and 3 work in an identical to method 1, except they use highly optimized algorithms. 4 is a plain linear conversion (usually fast.) 3 is the default. If the -i is specified, the input file is expected to (and must be) intensity values. (Mutually exclusive with -c.)

-c
Specifies that the input file is a color file. (Mutually exclusive with -i.)

-M<max val>
Set maximum value for use in intensity to color conversions. Defaults to the actual maximum value in the input file. Valid only with -i.

-m<min val>
Set minimum value for use in intensity to color conversions. Defaults to the actual minimum value in the input file. Valid only with -i.

DIAGNOSTICS

None

BUGS

Does not clear full screen (or provide an option to.) Others.

NAME

graphics - interactive graphics front end for dsm(1).

SYNOPSIS

graphics + hostname

DESCRIPTION

graphics is an interactive front end for dsm(1) written by SAIC/Huntsville with numerous modifications, extensions, and bug fixes by AFATL/SAI. dsm stands for digital seeker model, and was also written by SAIC and improved upon by AFATL/SAI.

graphics must be run after dsm and must have the specified format. Hostname specifies the host which dsm is running on. graphics also allows earlier versions of dsm (i.e. ones that use pipes) to fork/exec it, passing fd's of input and output pipes as arguments.

USAGE

GENERAL DESCRIPTION

graphics provides an interactive front end for the digital seeker model (formerly the high fidelity seeker model.) A description of how dsm works is beyond the scope of this manual (i.e. read the source.)

graphics consists of two windows, the image window and the control window. The control window is made of 5 vertically stacked panels. The first panel is the title panel (non-modifiable.) The next item is the small image. It is used to specify which portion of the image the large image window should display (should the large image window happen to be magnified.) The next item describes which array is being displayed (Input Scene, Blurred Input, FP Array, Sig Processing.) The next panel displays messages from dsm describing the current processing state. The final panel contains several items described below.

Clicking the right button in the image window creates a panel that displays both color and intensity values for the pixel currently under the mouse. While displaying the signal processing image, it also gives the location of the various centroids. A second click of the right button will remove the window.

FILES BUTTON

The files button opens the files window which displays a list of available rec files, formatted into columns by array. The current rec file in each column is highlighted. To specify a new rec file in a specific column, place the mouse over that item and click the left button. The three buttons at the bottom are described as follows:

Cancel — Exits back to graphics, forgetting the changed rec files.

Edit — Currently has no effect (or no useful effect.) To edit a rec file, it is best to startup another shelltool, and vi it from there.

Done — Exits back to graphics, saving the changed rec files.

SPECIAL BUTTON

The Special button performs miscellaneous commands (most of which are AFATL/SAI extensions) described as follows:

Load/Initial — Loads file save.scene into scene array.

Load/Blurred — Loads file save.blurr into blurred input array.

Load/FPA — Loads file save.fpa into fpa array.

Load/Sig Proc — Loads file save.proc into signal processing array. For show only (i.e. there's not much to do except look at it.)

Save/Intensity — Saves the current array as an intensity image to the file save.test.

Save/Colors — Saves the current array as a color image to the file save.ani.

ScrDump — Performs a screendump that works with an apple laserwriter.

Zoom — Resizes the large image window's pixel size to 12x12, 8x8, or 6x6.

Size — Resizes the arrays to 256x256, 128x128, 96x96, or 64x64.

Auto-Off/Auto-On — When dsm is in Auto-On, it will automatically execute all steps (i.e. it is not necessary to press the 'STEP' button all the time.) Real automatic execution is available with gserv(1).

STEP BUTTON

Performs the next step (or what dsm thinks is the next step.) Not always valid after loading a file or doing a specific step. It is better to use 'Do Step' (see below).

DO STEP BUTTON

Allows a specific step to be executed. The load scene step is similar to pressing 'STEP' after initially running the program (i.e. it loads in the standard scene.rec specified image.)

QUIT BUTTON

Exits dsm.

EXAMPLES

To run graphics with dsm, type

```
dsm9&
graphics + zeus&
```

SEE ALSO

dsm(8),gserv(1)

DIAGNOSTICS

None.

BUGS

The socket interface cannot currently support full networking. The problem deals with sending floating point values from computers with different formats (i.e. an NP1 and a Sun). This is solvable by using XDR (eXternal Data Representation), but the conversion time would probably defeat the purpose of running dsm on a separate machine. Several solutions exist, one, don't use the value query features of the graphics, two, redirect the query to dsm (i.e. the user asks graphics, then graphics asks dsm), finally since the second solution might cause the user wait while dsm is computing something else, create a third program to act as a middleman allowing dsm to chug away on the next step while allowing graphics to query values. It should be noted that most other data (i.e. messages, character values, etc.) should be close enough in format to transfer, or the conversion using XDR would be trivial and fast.

NAME

gserv - batch front end for dsm(1).

SYNOPSIS

gserv + hostname filename

DESCRIPTION

gserv is a front end for dsm(1) (similar to graphics(1)) that allows batching of dsm(1) commands that would otherwise require hours of tedious 'mousing' with graphics(1). It also allows dsm to be run from a terminal (i.e. graphics requires SunView.)

gserv must be run with format as specified. The hostname is the host on which dsm is running. The commands will be read from filename.

gserv derives its name from 'graphics server', because it serves the function of the 'graphics' program.

USAGE

gserv works by reading in a file (specified in the command line), made up of commands each consisting of one character (slightly meaningful) and some arguments. These commands roughly follow those of graphics(1), and are described as follows:

ltype:filename.
: Loads filename into array as specified by type (i.e. scene blurred fpa processed /.)

s<i,c>type:filename
: Saves type as either an intensity or color image (see add(1)) into filename.

dtype
: Does step specified by type.

dx
: Does next step. (note: it is very easy for dsm(1) to become confused as to what the next step is. It is better to specify the step exactly with the above command.)

rtype:recfile suffix
: Loads recfile as specified by type with suffix as specified (i.e. rf:test will load fpa.test into fpa.rec.)

ctype[type...]:save type
: Performs a complex command. First ads loads filename with appropriate suffix into fi... type after 'c'. Then it does each step as specified by the types

following up until the colon. Finally it saves all types after the first colon to filename with appropriate suffix (if a 'C' proceeds a save_type, it will be saved as a color file.) (See EXAMPLES)

q Signifies end of file (i.e. quit.) Very important to include this.

EXAMPLES

The following file loads a scene into the 'scene' array and performs all steps, finally save the signal processing array as an intensity image:

```
ls:test.tst
db
df
dp
sip:test.proc
q
```

The following does the same, except it uses the complex construct:

```
csbfp:p:test
q
```

The following does the same, except it saves the fpa for later reuse and saves the signal processing as a color image for viewing:

```
csbfp:fCp:test
q
```

The following reuses the previously save fpa, this time with a different .rec file:

```
rp:sobel
cfp:Cp:test
q
```

SEE ALSO

dsm(1),graphics(1)

DIAGNOSTICS

None.

BUGS

None known.

NAME

manf - strip page breaks & indent

SYNOPSIS

manf

DESCRIPTION

manf removes the first and last three lines from every page and indents each line 8 spaces. **manf** translates from stdin to stdout. **manf** is useful when printing formatted documents.

EXAMPLES

This example prints the the cc man page to jlp.

```
man cc | manf | jlp
```

SEE ALSO

jlp(1)

DIAGNOSTICS

None.

BUGS

None known.

NAME

plot - a trivial 2d/3d line plotting program

SYNOPSIS

plot

DESCRIPTION

plot is a relatively simple 2d/3d plotting program, developed for (although not limited to) displaying 6-dof output. It allows viewing of multiple images each consisting of multiple dimensions of data. Editing functions available mostly deal with changing screen parameters, adding axes labels, image scaling, etc.

Two versions of plot exist, an interactive one and a network one. The version described here is the interactive one (the network version is still in an expermental stage.)

USAGE

GENERAL DESCRIPTION

plot deals with structures known as 'Plot Data' (pldat). Each pldat consists of n-dimensions of real data points, along with system information such as color, dimensional extrema, etc. Related pldat's are strung together into a list known as a 'Plot Data List' (pdlst). In the normal operation of plot, only one such list exists, named '2d plot list'. Should generation of 3-dimensional images become necessary, plot creates an internal list known as '3d plot list' (although this list is currently accessible using the Data List commands described below, only a knowledgeable user should attempt to make modifications or other serious harm.) These are the data structures of plot.

plot's screen layout is rather simple. Initially there is only one window with a group of primary command buttons on top of the image display. It is in this image display that plot does its magic.

PRIMARY COMMANDS

The xxx buttons at the top of the plot window are known as the 'Primary Command Buttons'. They allow hierarchical access to plot's graphing features. They function as follows:

Plot — Plots the current pdlst in either 2d or 3d (depending on the Dimension switch in the global window.) Screen parameters dealing with axes, viewing position, etc. are all set in the global and display windows.

Load — Opens a filename requester window. Simply

	type a valid filename and click 'OK' (or type return). To cancel without loading, click 'Not Ok'.
Look	Opens a Plot Data window showing information on the first pldat in the current pdlst. Also updates values in the window if it is currently open. (See PLOT DATA WINDOW.)
Global	Opens the global window showing information on global parameters. Also updates values in the window if it is currently opened. (See GLOBAL DATA WINDOW)
Display	Opens the display window showing information on display parameters. Also updates values in the window if it is currently open. (See DISPLAY DATA WINDOW)
Clear	Clears all pldat's from memory and wipes clean the image display. (Use cautiously, there is no UnDo button.)
Rotate	Opens the rotation window showing information on 3d rotation parameters. Also updates values in the window if it is currently open. (See 3D ROTATION WINDOW)
Quit	Exits from plot.

GLOBAL DATA WINDOW

The global data window displays information pertinent to a whole list. It is often used to bring all pldat's into line (i.e. setting a constant min-max throughout a list.) All text items except for the 'List:' item are modifiable. It is important to press return after modifying an item (otherwise plot will not be alerted to the change.) The item functions are as follows:

Name:	Displays the name of the current pdlst. Not modifiable.
XYZ MinMax:	These multiple items display the global extrema values for the pdlst.
Redo	Refigures global extrema based on <u>current</u> extrema in individual pldat's (note: each pldat is not refigured based on its data.)
SetAll	Sets extrema of all pldat's to global values (i.e. the values contained in XYZ MinMax.)

RedoAll	Refigures global extrema based on <u>raw</u> data in individual pldat's (note: each pldat's extrema is also refigured to reflect its data.)
XYZ Axis:	These multiple items display the global axes setup for the pdlst. (See AXIS DESCRIPTION)
SetAll	Not to be confused with the XYZ MinMax/SetAll, this button sets the axes setup for each pldat to the global setup. In smart mode this also does a 'RedoAll' as defined above.
Smart:	This switch should be left on 'Yes' for all but the most advanced users (and abusers) of plot. (See SMART MODE)
Dimension:	Switches display output between 2d and 3d mode. (See 3D PLOTTING)
Square	Refigures global extrema so that all axes are of same length.
Next	Advances global display to next list (usually '3d Plot List'.) Advanced use only.
Done	Closes global data window (none destructive however.)
Clear	Clears out just this pdlst (rather than all pdlst's as with the primary button 'Clear'.) This key has not been fully debugged and its use is not highly recommended.

DISPLAY DATA WINDOW

The display data window contains information pertinent to the graphing of data. All items contain modifiable code. (It is important to press return after modifying any item, in any window.) The individual item functions are as follows:

Label:	Shows the overall graph label, to be displayed at the top of the image canvas. This will be displayed in both 2d and 3d modes.
X-Label:	Shows the x-axis label. Displayed only during 2d plotting.
Y-Label:	Shows the y-axis label. Displayed only during 2d plotting.

Axis steps: Sets the number of steps (i.e. where numbers are displayed) to occur between the ends of the axes. Valid only during 2d plotting.

Points: This switch controls whether or not individual points will be plotted in addition to lines.

Skip?Dots: Defines how dense the plotting of points will be. For example a value of 1 will plot every dot, 2 every other dot, 3 every third dot, etc.

CrossConnected Shows whether or not individual points on different pldat's will be connected. Useful for showing time relationship between two or more pldat's while also displaying x,y, and z axes (i.e. pretty 3d picture.)

XYZ Theta: These items show the x,y, and z rotation performed upon the data before 3d viewing. (See 3D PLOTTING)

View Distance: Shows the distance from the observer to the origin used in the 3d translations. Best set to 1.

3d axis type Sets 3d axis type to either fixed or auto scaling. (3D PLOTTING and 3D ROTATION WINDOW)

3d Expansion Displays the amount extra space allocated around edge of image, useful for 3d rotation. (See 3D PLOTTING and 3D ROTATION WINDOW)

Done Closes the display data window (non-destructive.)

PLOT DATA WINDOW

The plot data window shows information on individual pldat's (the work horse data structure of plot.) Changing items does not insure that global values will be updated (i.e. it is important to use the 'Redo' buttons in the global data window. The items behave as follows:

Name: Displays the filename from which this pldat was loaded. (See PRIMARY COMMANDS, Load)

Dim: Displays the dimensions of data. Not modifiable.

Num: Displays the number of data points. Not modifiable.

XYZ MinMax: Displays the x,y, and z extrema. Modifiable.

Color Displays which color will be used in plotting.

XYZ Axis: Displays the axes setup for this pldat. This is the final word on what values will be used (i.e. overrides global data axes setup values.)

Display Shows whether or not the pldat will be considered in display related options (i.e. global/'RedoAll', primary/'Plot'.) For example, if a pldat is currently not being displayed, its extrema will not be considered during an XYZ MinMax/'RedoAll'. It is better to turn the display to 'off' rather then set the color to 'white'.

Next Advances the plot data window on to the next pldat in the current pdlst. If it is at the end, it will start over on the list. Its operation is undefined when no data exists in the current list.

Done Closes the plot data window (non-destructive.)

Redo Refigures the local extrema to truly reflect actual data values.

Copy Adds a copy of this pldat to the current pdlst.

Kill Removes this pldat from the current pdlst. Not highly reliable.

3D ROTATION WINDOW

The rotation window allows the creation of simple 3d animation type plots. Although it is not a movie scripting language, it can be used to create some interesting effects. For details of 3d plotting see 3D PLOTTING.

The window describes a rotation as a set of starting and finishing angles for each of the x, y, and z axis and as a starting and finishing value for the viewer distance. It also computes the step size for each axis and for the view distance (Non-modifiable.) At the bottom of the window is the 'Steps:' item, which actually displays the number of frames in the rotation. There are two buttons described as follows:

Plot Starts the 3d rotation. It is necessary to have the list in 3d mode.

Closes the 3d rotation window (Non-destructive.)

AXIS DESCRIPTION

Since data files read into plot often contain more than 2 (or 3) dimensions, for example:

```
10.0  55.0  12.0  14.0
11.1  1.01  3.21  15.0
```

and it is often necessary to plot one dimension versus another in an arbitrary (and non-deterministic) way, plot allows flexible axes setup. In the global data window (also in the plot data window) there are three items, 'xaxis:', 'yaxis:', and 'zaxis:'. These items represent which data dimension will be plotted on which axis. For example, if 'xaxis:' contained 1 (one), and 'yaxis:' contained 2 , then in the above example, the 10.0, 11.0, ... data column would be plotted along the x-axis, and the 55.0, 1.01, ... data column would be plotted along the y-axis. If the plot is 3d, then the 'zaxis:' controls which data dimension is plotted on the y-axis of the graph. It is important to emphasis that the XYZ axes values shown in the global data window are not guaranteed to be representative of the XYZ axes values in the individual pldat's (clicking the 'SetAll' feature under the XYZ axes items on the global data window will set all pldat's appropriately.)

3D PLOTTING

When doing 3d graphs or rotations, plot uses several parameters to process and display the data. Important to both graphing and rotation are the observer position parameters, XYZ Theta, and the View Distance (located in the display data window.) It is important to note that the x,y, and z rotations are done in that order, so expect some difficulty in creating displays right the first (or last) time.

Doing a 3d rotation is similar to plotting multiple individual graphs. One problem that does occur deals with the auto scaling plot does to fill the image canvas. This distorts the 'magnification' of a rotation, and sometimes defeats the whole purpose of doing a rotation at all. To sclve this problem, plot allows a choice between auto scaling and fixed scaling (This choice does not affect plain 3d graphing), as well as image canvas 'expansion' (which affects plain 3d plotting.) When a rotation is auto-scaled, plot refigures image canvas parameters at each step to fill the image canvas completely with the image. Using fixed mode during a rotation will leave the image canvas parameters alone after making an initial adjustment for the first frame. Since this often causes an image to rotate out of the image canvas, plot allows the initial window to be expanded by an expansion factor during the initial frame (i.e. an expansion factor of .5 will produce an (.5*2 +1 = 2) canvas area twice the size needed to hold the initial frame, while a 1 would produce an area (1*2 +1 = 3) three times the necessary size. To best use these features, it is necessary to experment. (These items exist in the display data window (See DISPLAY DATA WINDOW).)

Unfortunately, it is non-trivial to provide quality axes labels during 3d plots, therefore, only axes extrema are labeled. (The author apologizes.)

SMART MODE

This should always be on. It basically allows power users (i.e. people reading the source code) to get around. Rather then calling this smart mode and setting it 'on', it should be called stupid mode and be set 'off'.

SEE ALSO

add(1)

DIAGNOSTICS

No such file or directory

An attempt was made to load a file that doesn't exist.

BUGS

3d rotation is slowed down somewhat because of the complex list manipulations occurring internally (i.e. the continuous cycle of list creation, plotting, deletion, over and over and ... .) No sure fire way exists to view exact values of points (i.e. in 2d mode general values can be found with pointer, and no method exists in 3d mode), an interactive list would be nice.

NAME

manf - strip page breaks & indent

SYNOPSIS

manf

DESCRIPTION

manf removes the first and last three lines from every page and indents each line 8 spaces. manf translates from stdin to stdout. manf is useful when printing formatted documents.

EXAMPLES

This example prints the the cc man page to jlp.

```
man cc | manf | jlp
```

SEE ALSO

jlp(1)

DIAGNOSTICS

None.

BUGS

None known.

NAME

rdb - raster dump for ln03

SYNOPSIS

rdb [-x<x size>] [-y<y size>] [-c<conv>] [-t<thresh>] [infile [outfile]]

DESCRIPTION

rdb converts a given bytemap into a file suitable for printing on an ln03, (i.e. sixel graphics). The printer output is black & white, so it is necessary to preprocess color files (see dither(1)).

The infile and outfile arguments default to stdin and stdout if not specified (note: An infile must be specified inorder to specify an outfile).

OPTIONS

-x<x size>
: Sets the x dimension of the input raster. Default size is 128.

-y<y size>
: Sets the y dimension of the input raster. Default size is 128.

-c<conv>
: Specifies the conversion type. Type 1 will print odd byte values (i.e. value & 0x1). Type 2 will print all values greater then or equal to the threshold given with the -t option (i.e. value >= thresh).

-t<thresh>
: Sets threshold level for printing. Valid only with -c2.

EXAMPLES

This example shows how to print a 128x128 color bytemap

```
dither <infile -xy128 | rdb -xy1024 -c1 >rd.out
jlp -P vega::csa0: -b rd.out
```

Note the -xy1024 file size on rdb. This is due to the expansion caused by dither (i.e. 8 x 128 = 1024).

SEE ALSO

dither(1),colorz(1)

DIAGNOSTICS

rdb:infile/open
: The specified input file cou'd not be opened.

rdb:outfile/onen
: The specified output file could not be opened.

None

BUGS

None known.

NAME

setcol - set colormaps (non suntools)

SYNOPSIS

setcol r
setcol l <u>filename</u>
setcol x

DESCRIPTION

setcol allows editing of the display buffer's (/dev/fb) colormap. It is useful along with fsd(1) in displaying large images beyond add(1)'s memory capacity.

The first form sets the ColorMap to the standard 256 color rgb range used by add(1),dsm(1),etc.

The second form allows setcol to load in a ColorMap called filename. File must be in add(1) format.

The third form enters into an interactive mode.

USAGE

The interactive mode of setcol (i.e. setcol x) provides simple features for the setting, reviewing, blending, etc. of color values. The commands are made up of single characters (some what meaningful) followed by necessary arguments in the stated fo-mat.

s<u>col</u>:<u>red</u>,<u>green</u>
: Sets color <u>col</u> red, green, and blue components as specified.

r<u>fromcol</u>,<u>tocol</u>:<u>red</u>
: Sets the red, green, blue components of colors in the range [fromcol, tocol]

o<u>fromcol</u>,<u>tocol</u>:<u>red</u>
: Offsets the red, green, and blue components of colors in the range [fromcol, tocol] by the specified red, green, and blue values

d<u>col</u> Divides the ColorMap into two sections. Colors above col are set to black while colors below are set to white (col is set to black.)

L<u>filename</u>
: Loads ColorMap filename. Identical to setcol l filename.

S<u>filename</u>
: Saves current ColorMap as filename (standard add(1) format.)

R Reverses colors (i.e. color 0 <--> color 255, color 1 <--> color 254, etc.)

b*fromcol*,*tocol*
Blends the colors in the range [fromcol, tocol].

x*col* Examines red, green, and blue components of col.

x*fromcol*,*tocol*
Examines red, green, and blue components of colors in range [fromcol, tocol].

B Displays a color scale along the right of the display (usually well away from where fsd loads images.)

n Attempts to refresh screen image. (Doesn't seem to work. Try quitting then running setcol again.)

q Quits out of setcol.

SEE ALSO
fsd(1),add(1)

DIAGNOSTICS
open error
An error occurred while attempting to open a ColorMap file. Usually means the named file didn't exist.

read error
An error occurred while reading a ColorMap file. Usually means the file wasn't standard add(1) format.

BUGS
Does not provide a simple method of quickly adjusting global rgb values. To be addressed in the future.

NAME

topr - convert color bytemap to pixrect

SYNOPSIS

topr [-s<pixsize>] [-x<xsize>] [-y<ysize>] filename

DESCRIPTION

topr converts color bytemaps into sun standard pixrect files, the format that ani(1) expects.

topr takes a list of files (usually from the file 'ani.script', or filename, if it is specified) internally draws them, then writes them out with a .pr suffix.

OPTIONS

-x<xsize>
: Sets the x dimension of the input raster. Default size is 128.

-y<ysize>
: Sets the y dimension of the input raster. Default size is 128.

-s<pixsize>
: Sets the number of screen pixels per image pixel. Default is 2.

SEE ALSO

ani(1),colorz(1)

DIAGNOSTICS

None.

BUGS

None known.

NAME

jlpd - printer daemon for networked vax printing

SYNOPSIS

jlpd

DESCRIPTION

jlpd runs as a daemon and allows printing of text and graphic files on networked vax printers. Access to the daemon is usually thru the jlp(1) line print command.

jlpd works by logging onto a remote vax system and opening both an ftp and dcl session. It uses ftp to then transfer a file from the sun workstation to the temporary device on the vax, and then merely executes the necessary dcl commands to print the file.

jlpd exits when it receives a quit message (usually issued as jlp quit.)

SEE ALSO

jlp(1)

DIAGNOSTICS

open_iport/bind (48; Address already in use)

jlpd is already running. (i.e. don't worry).

BUGS

jlpd does not print errors. Most errors, such as trying to print a non-existent file are usually caught by jlp(1).

It should be noted that jlpd's idea of a vax/dcl states is very simple and usually quite robust. The probability does exist that jlpd could become 'mixed up', in which case it would be necessary to 'kill -9' it.

NAME

addendum - last minute additions to report.

DESCRIPTION

Due to the time frame in which this report was prepared, please excuse any typographical and grammatical errors (as well as the change in viewpoint in the intro.)

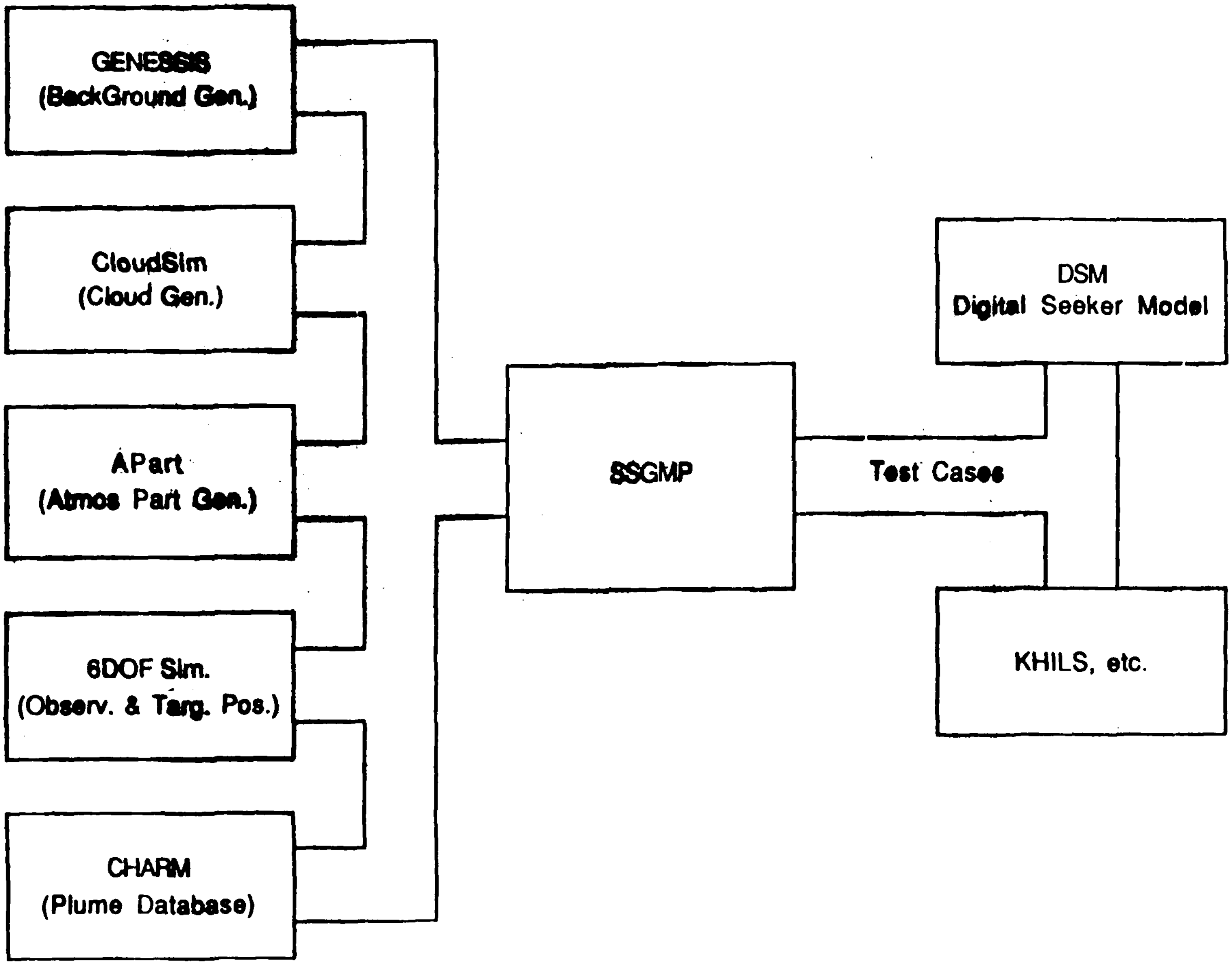
The source to all the programs were originally to appear in this report, but due to size limitations (i.e. 5000+ lines, 150+ pages.) they will not. For a copy, please contact Charles Coker at WILLIAMS2@UV4.EGLIN.AF.MIL, or myself via the forwarding address:

226 Trudell
San Antonio, TX 78213

BUGS

Well, they should have been apparent.

AFATL/SAI Scene Generation



TSG Utility Programs

for Sun/UNIX (SunView)

Visual/Graphics

- o add/fsd — Visual editors/inpectors
- o plot — 2d/3d 6DOF plotter
- o Ani — Test set animation utility

DSM Modifications

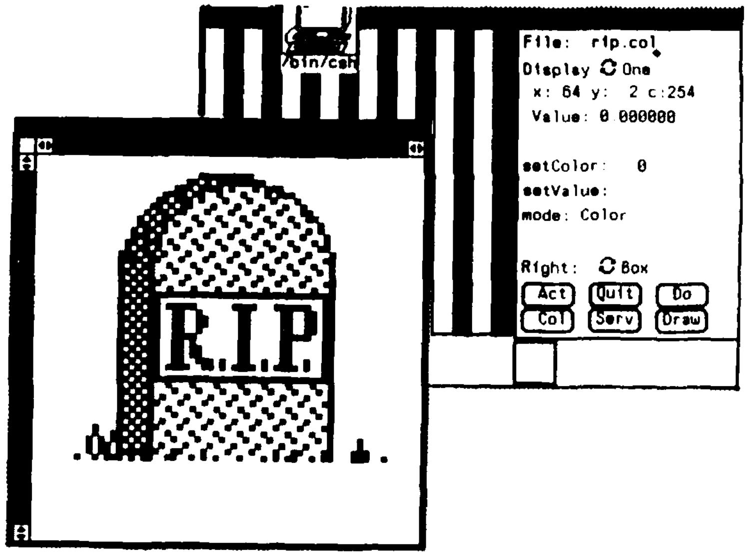
- o GServ — Non-interactive server for DSM
- o VaxDSM — Vax text/graphic version of DSM

Hardcopy/Printer

- o sd — Screendump utility
- o rdb — Raster dump program for ln03
- o jlp(d) — Printer daemon & client

ADD (A Display eDitor)
FSD(Full Screen Display)

Example:



Features:

- o Visual inspection of Color/Intensity Images.
- o Basic Drawing Features...
  - o Point.
  - o Line.
  - o Box.
  - o Circle.
- o Basic Image Processing...
  - o Histogram.
  - o Threshold.
  - o Sobel edge operator.
  - o Kirsch edge operator.
- o Sub-picture manipulation (Cut & Paste).

Conversion from Intensity values to color:

Intensity Array

6.332e-03	8.921e-01	
7.56e-02	3.312e-01	
2.34e+01	2.234e-01	
4.332e+02	5.343e+02	

$$\frac{(8.921e\text{-}01) - \text{MinValue}}{\text{Maxvalue} - \text{Minvalue}} \times (\#\text{ of Colors}) = 052$$

$$\left(\frac{\ln(8.921e\text{-}01) - \ln(\text{Min})}{\ln(\text{Max}) - \ln(\text{Min})} \times (\#\text{ of Colors}\right)$$

Color Array

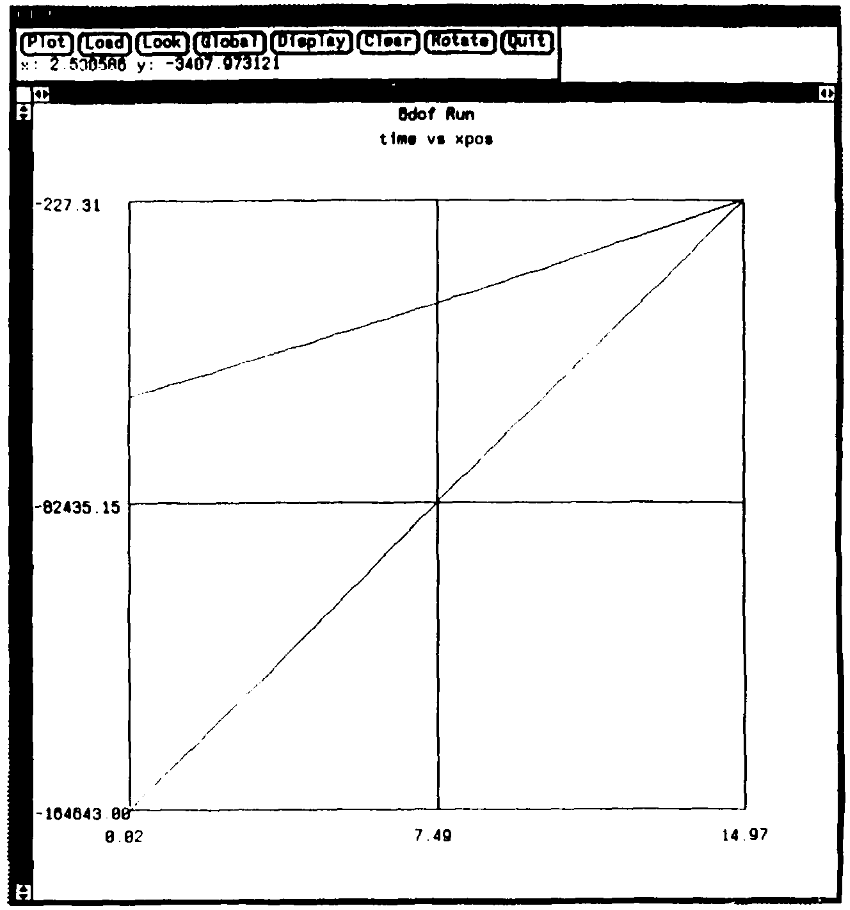
255	052	102	231	
128	213	089	239	
122	091	213	137	
097	011	137	198	

Plot (2d/3d 6dof plotter)

Features:

- o Multiple data sets (i.e. Interceptor and Target).
- o Multiple Dimensions (i.e. VelX,VelY,VelZ,AccZ,...).
- o User adjustable:
  - o Plot extrema.
  - o Axis (i.e. X vs Y, Z vs X, etc.).
  - o Titles, etc.
- o 3d Plotting
  - o User adjustable:
    - o rotation angles.
    - o viewing distance.
    - o *Scaling.*
  - o Rotation of axis *in* all dimensions.
- o Hardcopy capabilies.

Example:

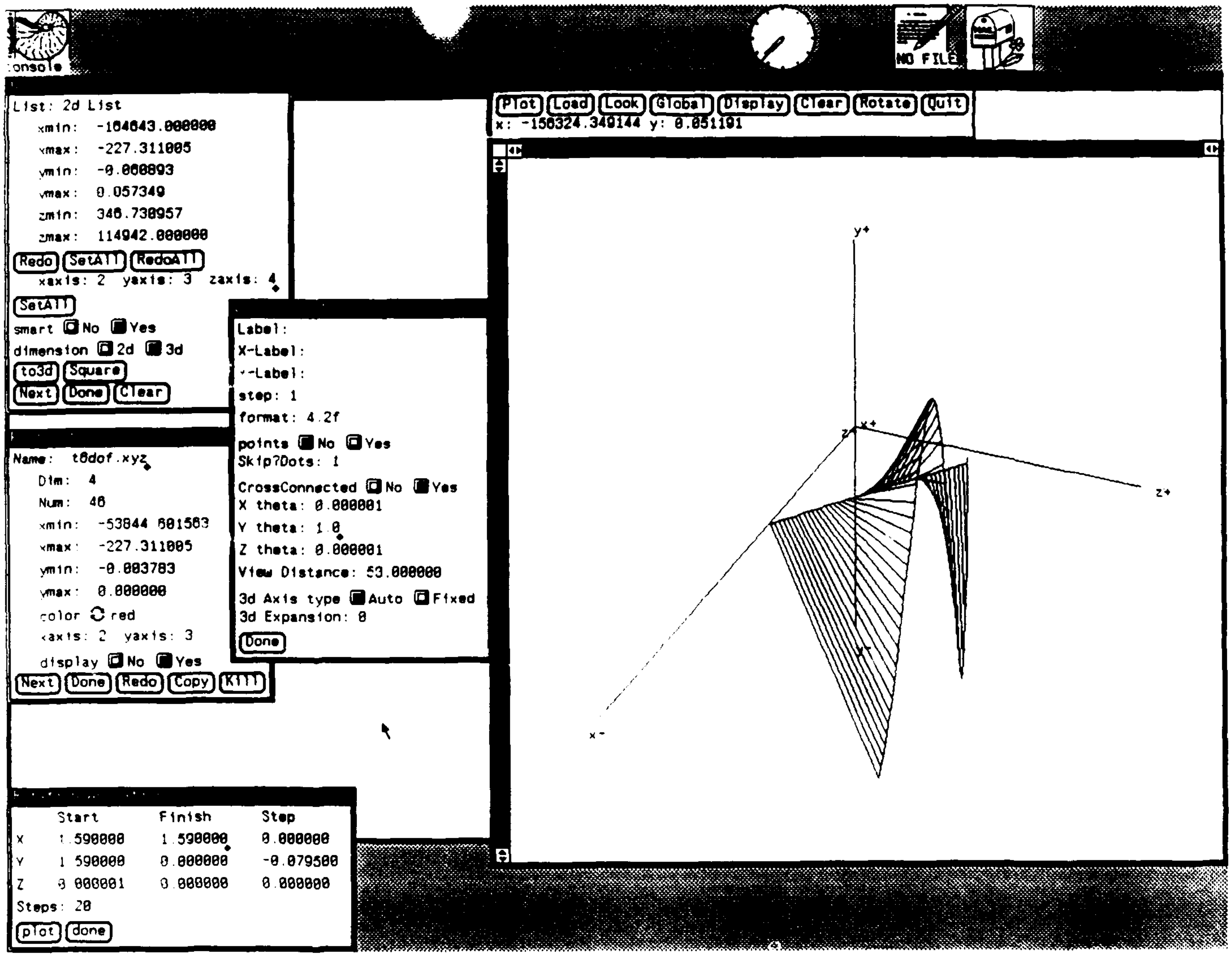


Output from 6dof simulation:

Time	X veloc.	Y veloc	etc.
.500	1.23e+01	2.34e+02	...
1.000	2.10e+01	5.21e+02	...
1.500	3.82e+01	4.99e+02	...

Original Point, X axis rot., Y axis rot., Z axis rot., Scaling, Perspective = Transformed Point

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \begin{bmatrix} \cos\partial & -\sin\partial & 0 & 0 \\ \sin\partial & \cos\partial & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\partial & 0 & \sin\partial & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\partial & 0 & \cos\partial & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\partial & -\sin\partial & 0 \\ 0 & \sin\partial & \cos\partial & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & a \\ 0 & 1 & 0 & b \\ 0 & 0 & 1 & c \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} d & 0 & 0 & 0 \\ 0 & d & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & d \end{bmatrix} = \begin{bmatrix} x \\ y \\ 0 \\ 1 \end{bmatrix}$$


Console
NO FILE
List: 2d List
xmin: -164643.000000
xmax: -227.311005
ymin: -0.060893
ymax: 0.057349
zmin: 346.730957
zmax: 114942.000000
Redo SetAll RedoAll
xaxis: 2 yaxis: 3 zaxis: 4
SetAll
smart No Yes
dimension 2d 3d
to3d Square
Next Done Clear
Name: t6dof.xyz
Dim: 4
Num: 46
xmin: -53044.601563
xmax: -227.311005
ymin: -0.003703
ymax: 0.000000
color red
xaxis: 2 yaxis: 3
display No Yes
Next Done Redo Copy Kill
Label:
X-Label:
Y-Label:
step: 1
format: 4.2f
points No Yes
Skip?Dots: 1
CrossConnected No Yes
X theta: 0.000001
Y theta: 1.0
Z theta: 0.000001
View Distance: 53.000000
3d Axis type Auto Fixed
3d Expansion: 0
Done
Plot Load Look Global Display Clear Rotate Quit
x: -156324.349144 y: 0.051191
y+
x+
z+
x-
Start Finish Step
X 1.590000 1.590000 0.000000
Y 1.590000 0.000000 -0.079500
Z 0.000001 0.000000 0.000000
Steps: 20
plot done

Ani (Scenario Animation)

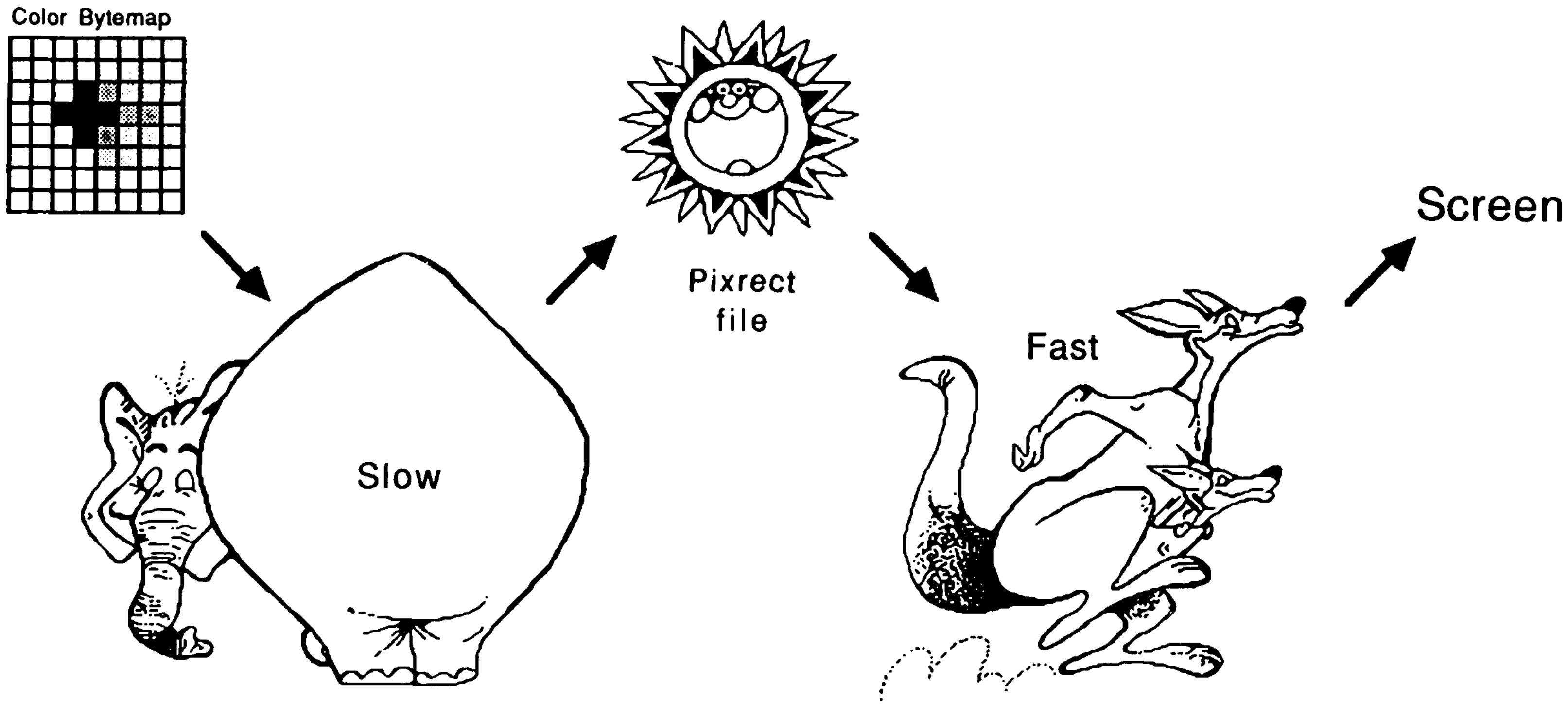
Features:

- o Animates sequence of scenes
- o Uses Sun pixrect as intermediate for smooth constant animation.
- o Allows an external tag file for:
  - o Scene name
  - o Altitude
  - o Range
  - o etc.

Operation:

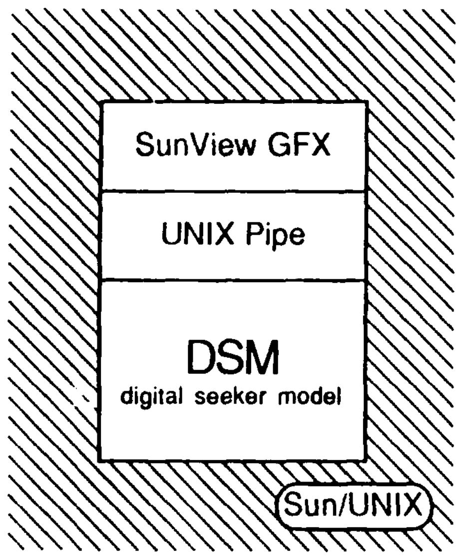
1. Convert from Color bytemap to Sun Pixrect format.

2.. Display Sun pixrect on screen

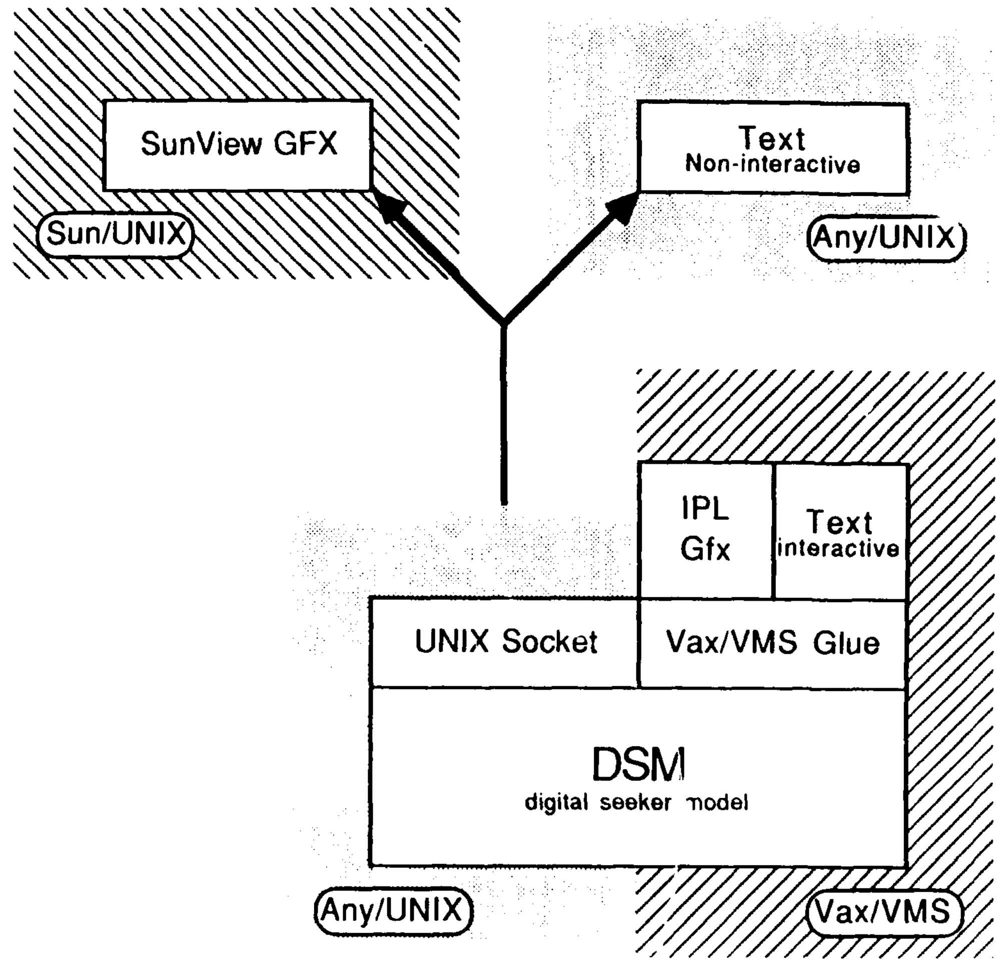


Digital Seeker Model

Before

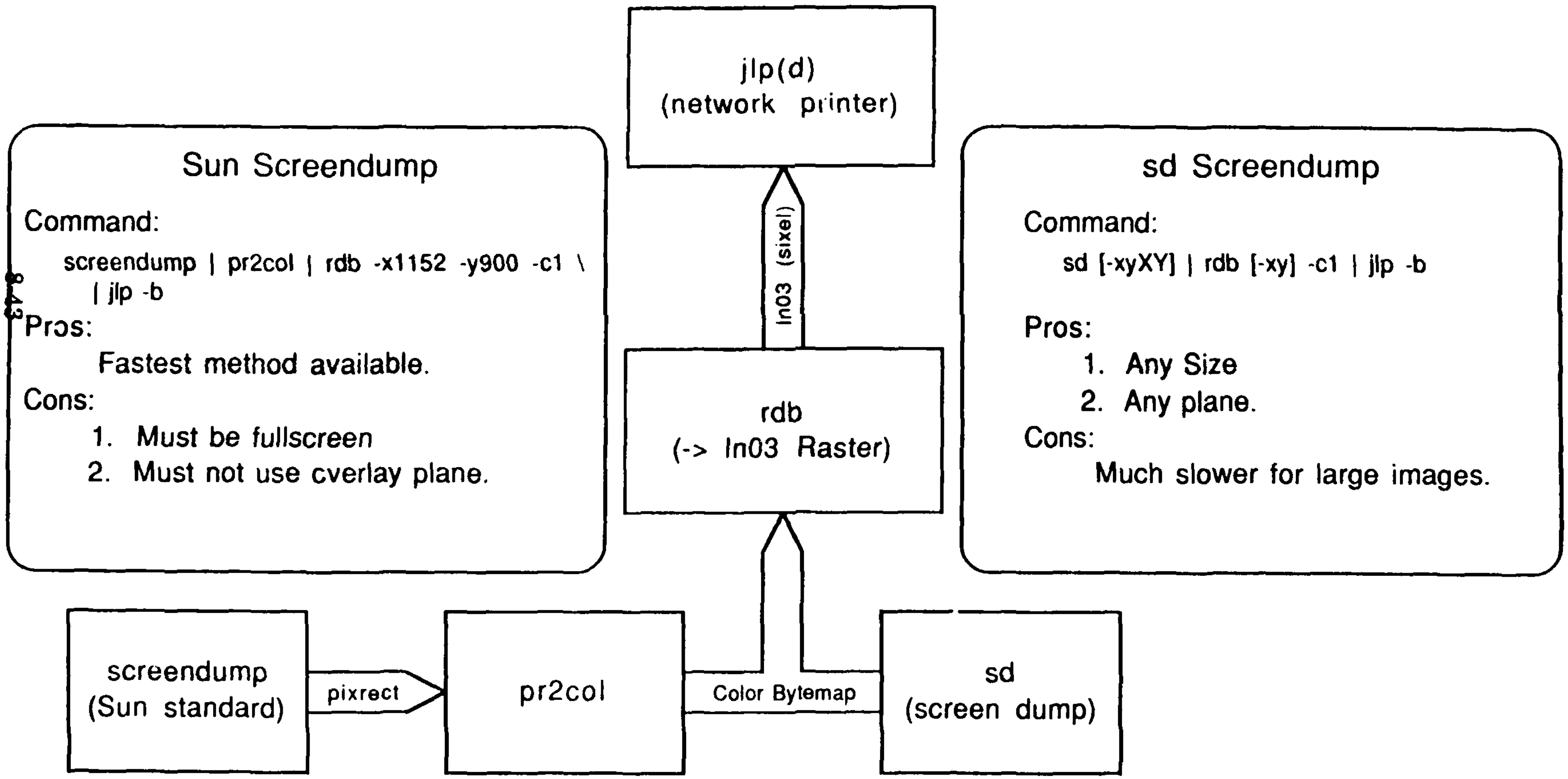


After



Hardcopy Utilities

(For Screendumps)



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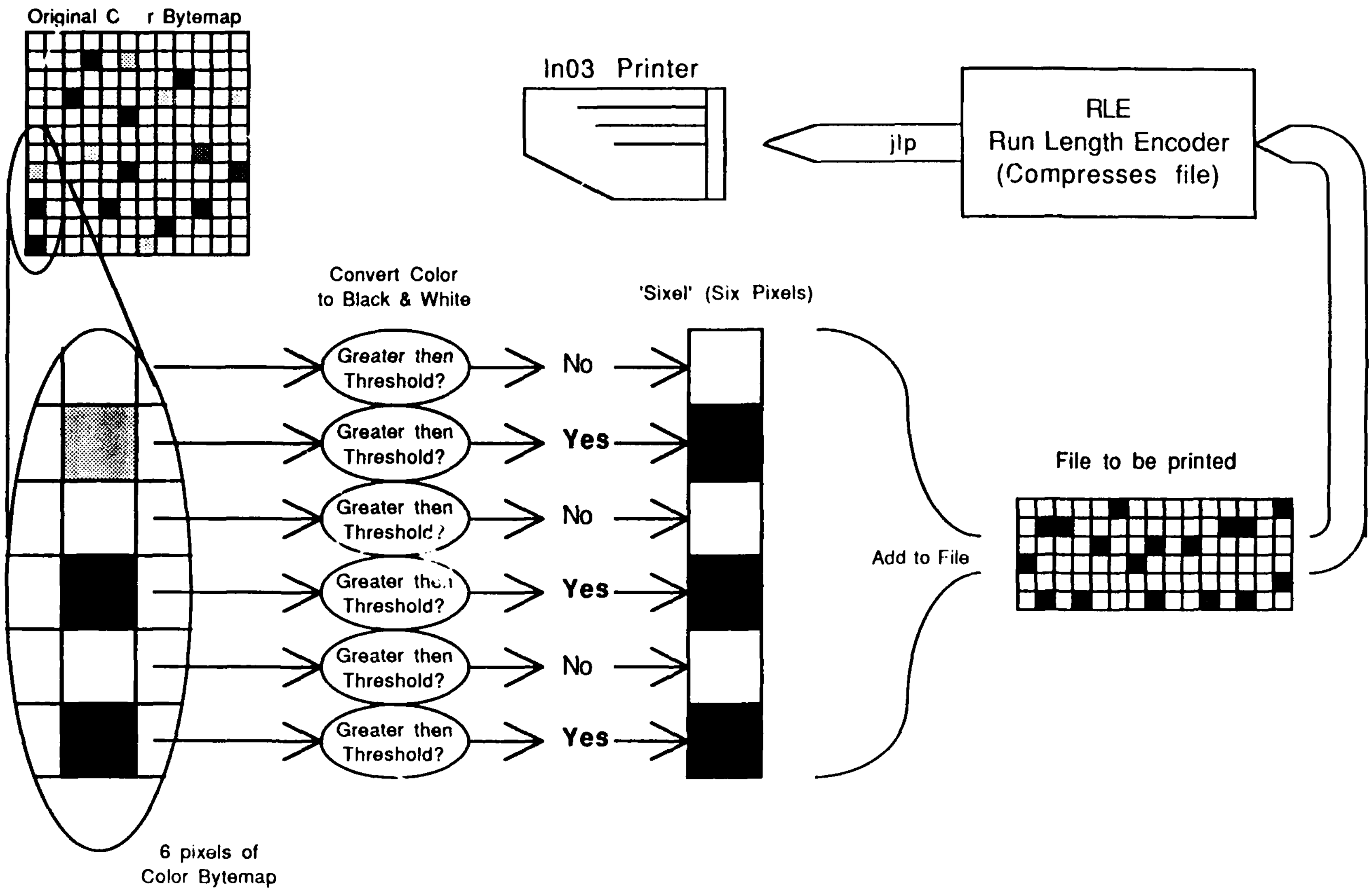

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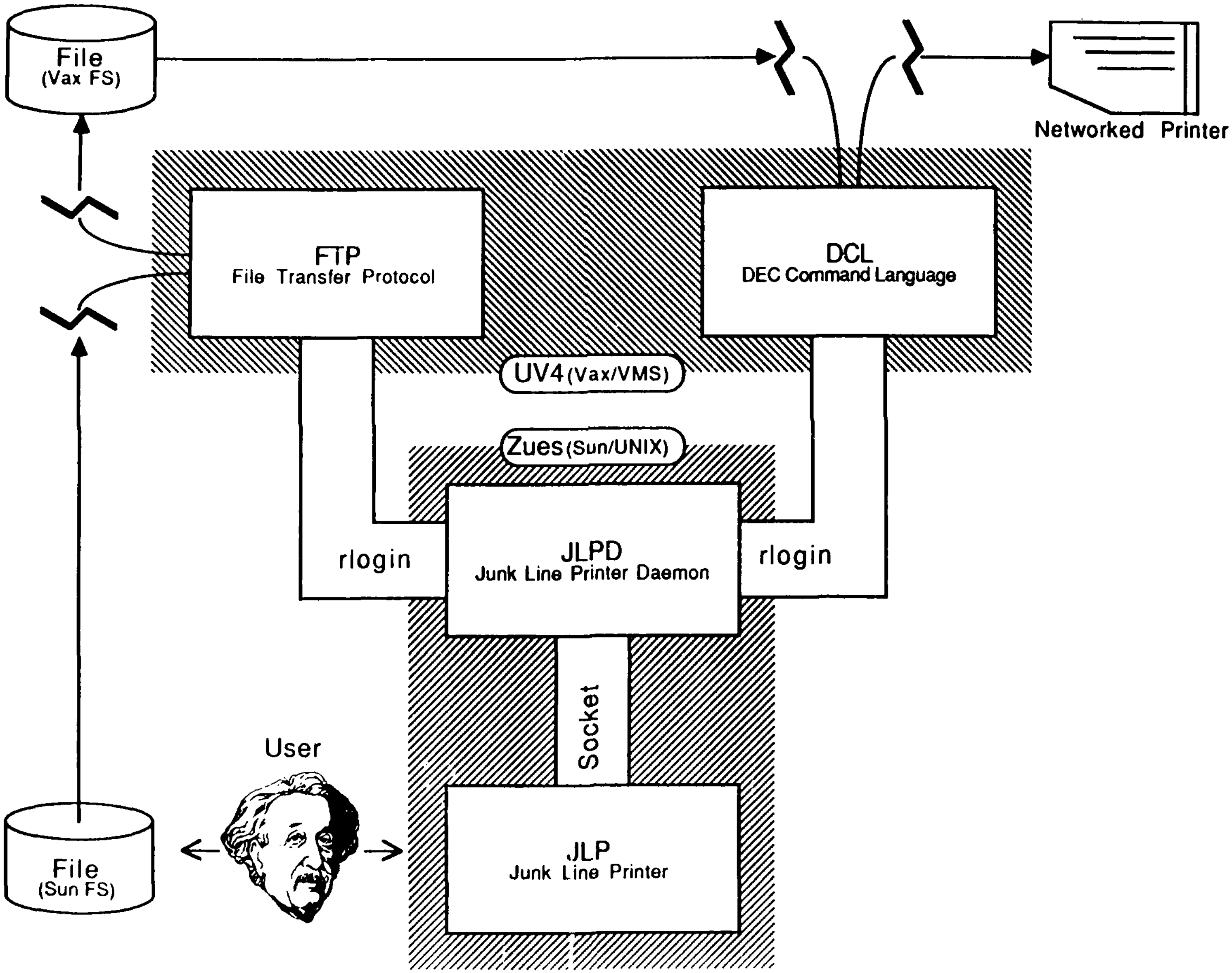

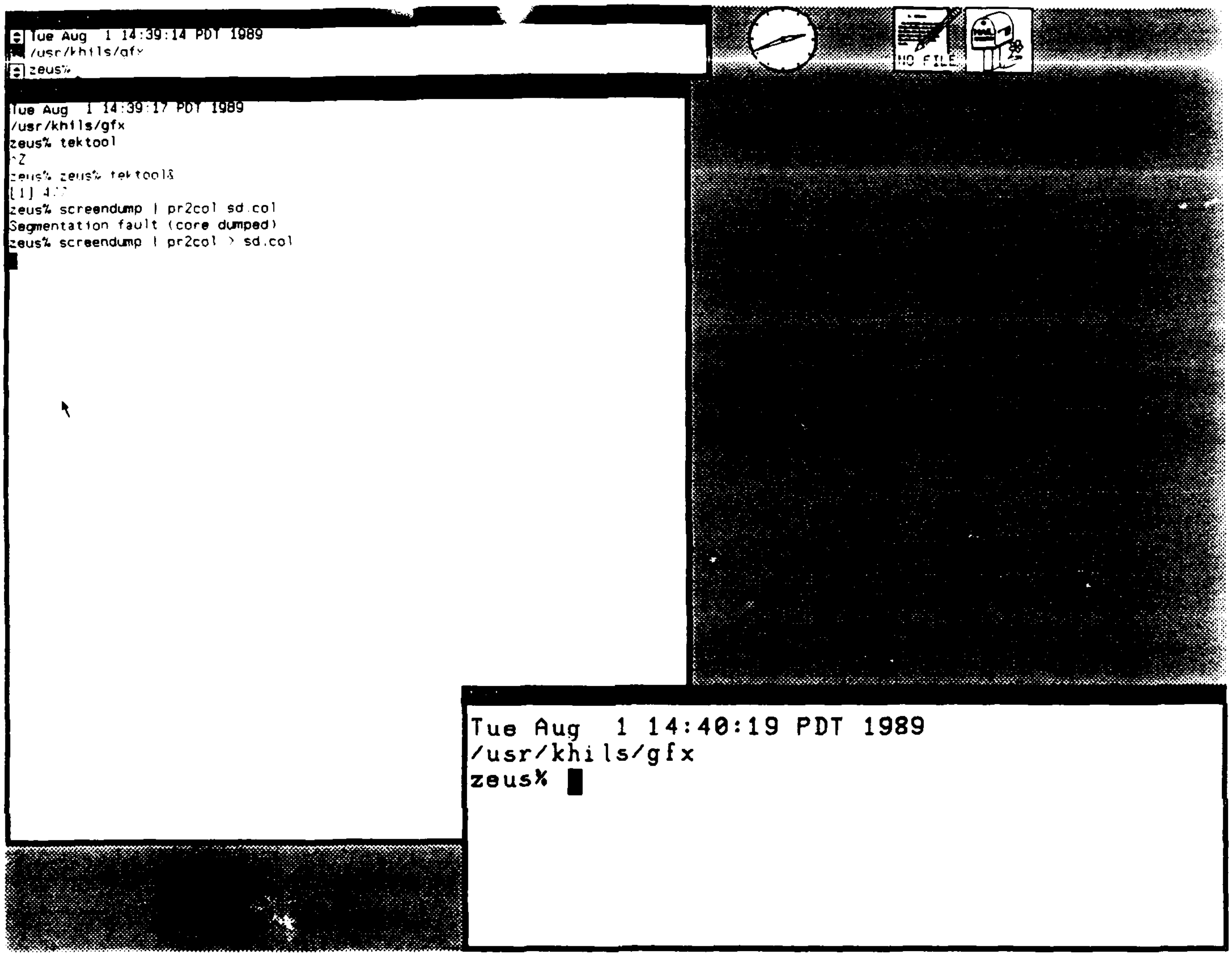
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^Z
zeus% zeus% tektool&
zeus% screendump | pr2col sd.col
Segmentation fault (core dumped)
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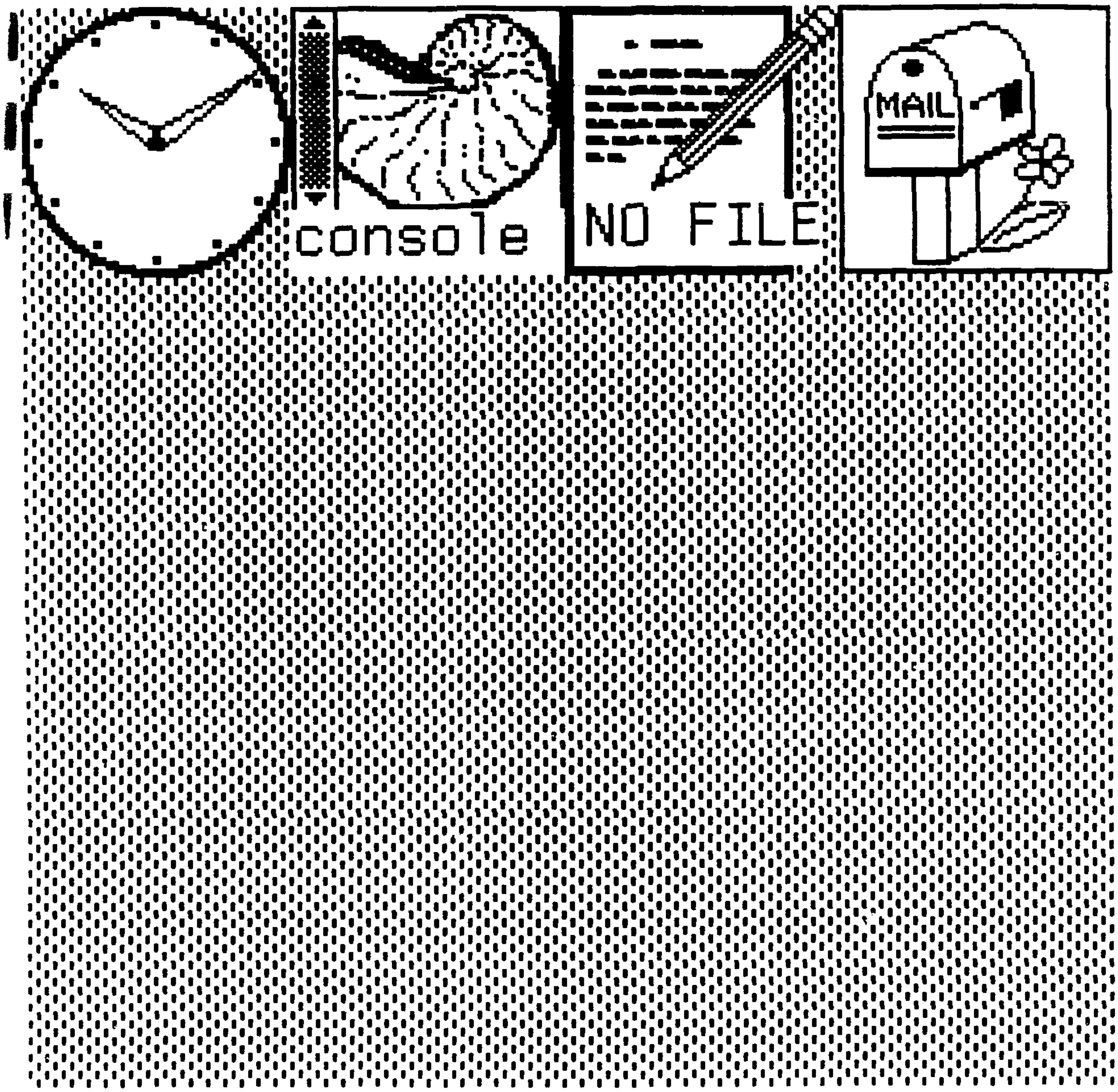
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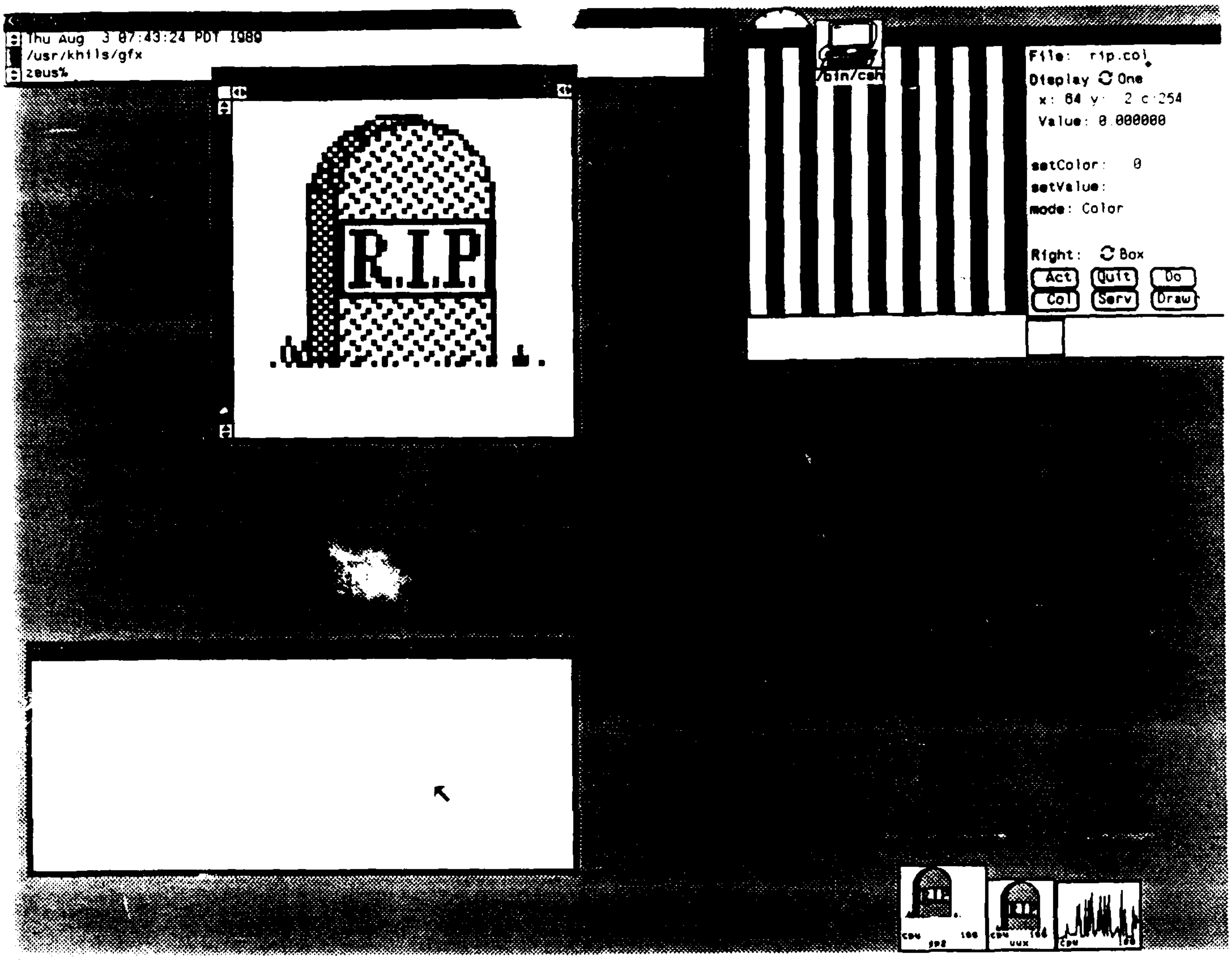
MAIL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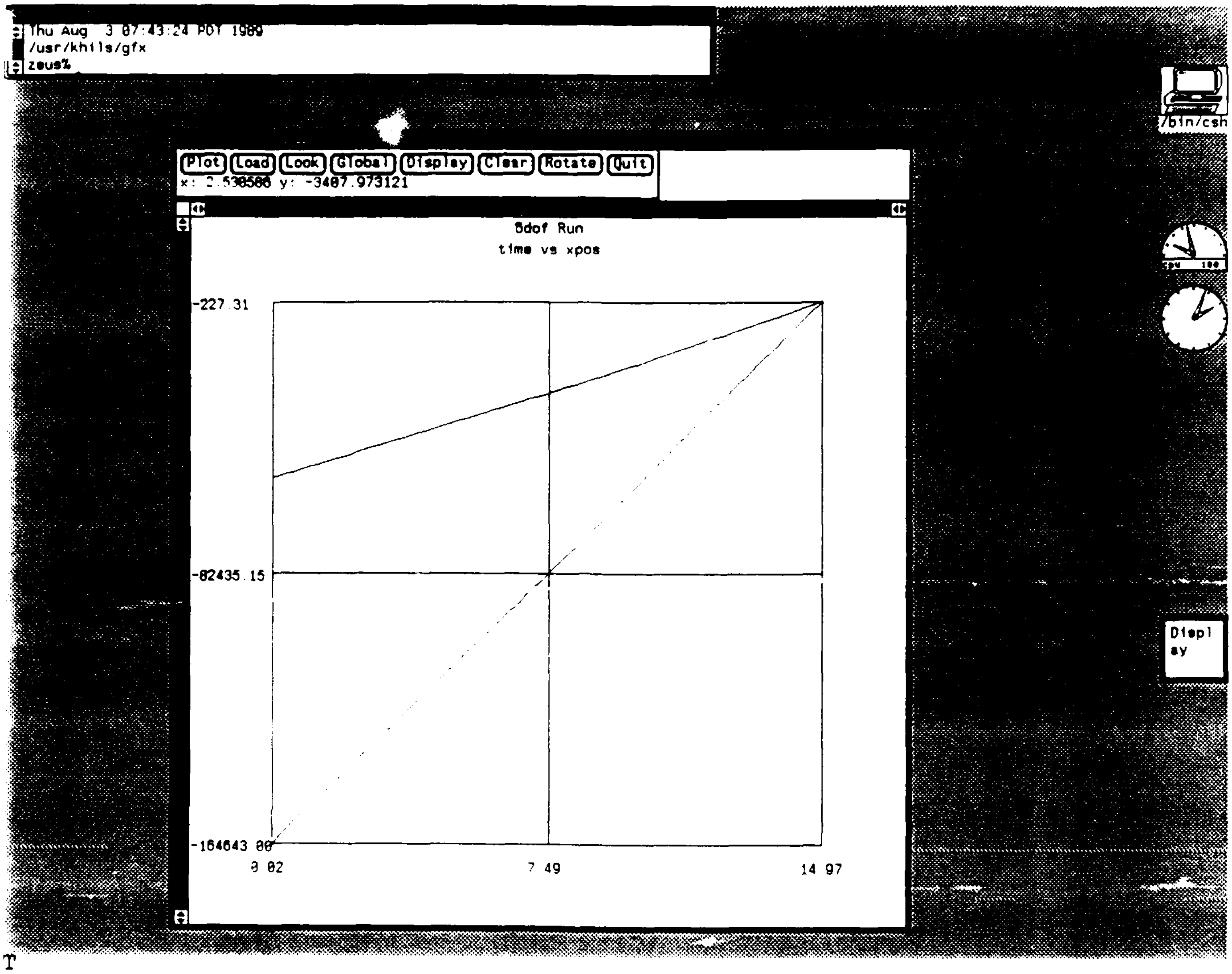
zeus%
R.I.P
/bin/csh
File: rip.col
Display One
x: 64 y: 2 c:254
Value: 0.000000
setColor: 0
setValue:
mode: Color
Right: Box
Act
Quit
Do
Col
Serv
Draw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Plot
Load
Look
Global
Display
Clear
Rotate
Quit
6dof Run
time vs xpos
-227.31
-82435.15
7.49
14.97
Displ
ay

HIGH SCHOOL APPRENTICE PROGRAM

SUMMER 1989

Steven Bryan

Crestview High School

MUNITIONS DIVISION

FUZES AND GUNS BRANCH

ACKNOWLEDGMENTS

I would like to thank my mentor, Robert Orgusaar, for so patiently and completely explaining fuzes and the electronic designs behind them. I would also like to give special thanks to Kathy Drake, Shelley Pollard, and Donna Welle for their extra efforts in helping with the computer programs and with my report. I also would like to extend thanks to Don Cunard, Scott Turner, Paul Palpallatoc, Andy Gillespie, Scott Nass, Scott Teel, and all the other people at MNF for their time and help this summer. I have enjoyed the opportunity to work with test equipment, participating in experiments, and contributing to scientific research. I would like to come back again next summer and continue my research and fellowship with the personnel at the lab.

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BACKGROUND

The component of the missile warhead which initiates detonation is the fuze. The fuze may perform its function while the warhead is traveling toward a target or awaiting the approach of a target. A stimulus is required for the fuze to function (1).

A fuze is intelligent when it controls payload detonation at the correct time and condition. Fuze action is be divided into two phases: (1) safety/arming and (2) initiation.

The safety and arming mechanism has a dual purpose. The safety system must ensure initiation does not occur during storage, handling, launch forces, etc., and still be able to select the proper stimuli for initiation. The arming system overrides the safety mechanism and readies the warhead for initiation. This is accomplished by sensing circuits that evaluate environmental characteristics or target return signal to initiate detonation (2).

An initiator causes the fuze explosive train to function. An explosive train consists of a series of successively larger explosions which ultimately detonate the main warhead. The first element in the train is the primer. The primer converts electrical or mechanical stimuli into explosive energy. The explosive in the primer is extremely sensitive and is set off easily. The primary explosion sets off booster explosions, consisting of less sensitive explosives, until enough energy is reached to detonate the main charge. The explosive train will be in operative condition only when the safety and arming barriers between the sensitive and insensitive elements of the train are removed.

There are two types of initiations: out-of-line initiation and in-line initiation. An out-of-line initiation uses an interrupted explosive train, i.e., an explosive train with the primary explosives physically separated from the booster explosives by a barrier. This interrupts the explosive path and thus prevents premature detonation of the warhead. An in-line initiation uses a non-interrupted explosive train, i.e., an explosive train with no physical interruption of the explosive elements. This system uses electrical detonators, such as short outs and switches, to prevent fuze detonation prior to fuze arming (3).

An example of an in-line initiation is an experimental detonator called a slapper detonator. A slapper detonator is made of a thin strip of copper sandwiched between layers of kapton. The copper strip tapers down to a thin bridge in the middle. The kapton is covered by a plastic shield with a hole directly over the bridge. High voltage is sent through the copper strip causing the copper to explode. The explosion generates high pressure and causes kapton to be fired through the hole in the plastic shield and into a booster explosive. The impact sets off the booster explosive, initiating the explosive train which ultimately detonates the warhead (4).

A fuze needs to know when to initiate the explosive using the previous described methods. One method of determining this is used in a proximity fuze. A proximity fuze initiates warhead detonation at a specific time and place to cause maximum damage to an enemy target. The fuze sensors are activated by some characteristic feature of the target, such as, reflected radio waves, interrupted light waves, induced magnetic fields, and pressure changes, for example. Physical contact is not required to initiate detonation, hence the name "proximity sensor" (5).

One type of proximity fuze is the radio frequency fuze or RF fuze. An RF fuze sensor transmits radio waves which propagate in a large lobe (See figure 1). Reflected energy from the target is received by the sensor and is used to determine target range, velocity and general location. RF sensors have the advantage of not being affected by fog, clouds, or light rain. The problem with RF sensors is the resolution of target location. The RF sensor will identify a target anywhere within its sensing lobe, but not its specific location inside the lobe.

Countermeasures are another problem for RF sensors. The RF sensor can receive energy from other sources that may deceive the fuze and cause premature detonation.

Another type of proximity sensor is an optical sensor. The optical sensor uses pulses of light to locate targets. Current optical sensors use a conical beam with a narrow field of view to determine target range, velocity, and location. But, as in the RF sensor, the location of the target is not specific, plus the optical sensor cannot detect a target through aerosols.

The optical sensor is not as susceptible to countermeasures because of its narrow field of view. To deceive the sensor, false signals must be beamed straight down the detector's "line of sight."

Current infrared optical sensors use analog processing to recognize a target. To be recognized, these devices set a threshold level for the returning signals to exceed. A cloud will partially

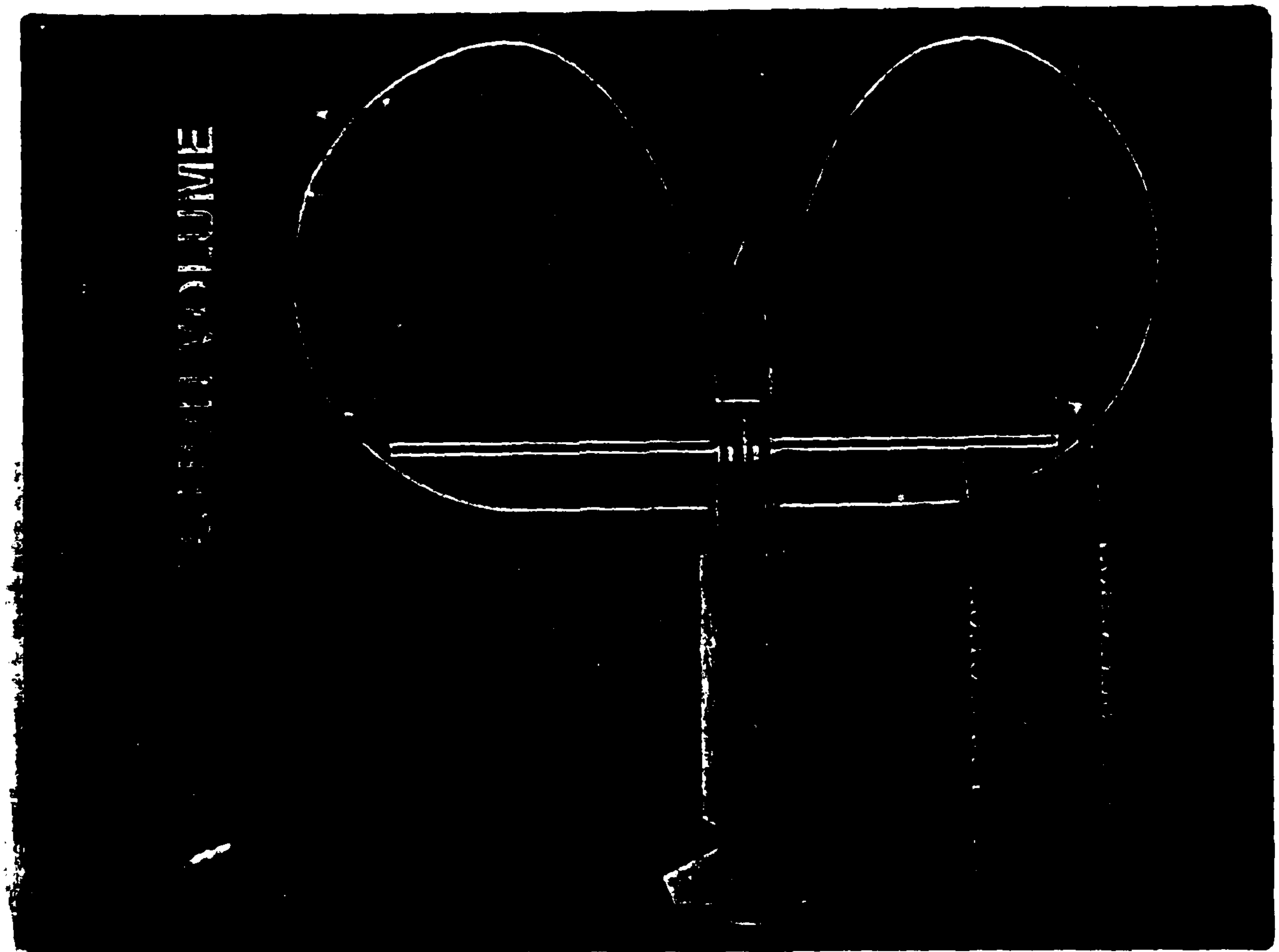


FIGURE 1

reflect transmitted energy back into the receiver, causing the threshold limit to be exceeded. The sensor may prefunction if this is present on one channel or will raise the threshold level if it is present on more than one channel. If it raises the threshold level, the target in the cloud may not be detected (6).

OPTICAL PROXIMITY SENSORS

During this summer, I helped conduct an optical proximity sensor test. The test objective was to measure signal attenuation through an aerosol of variable density using an active optical proximity sensor. The active optical proximity sensor consists of a infrared laser transmitter and receiver. The transmitter emits laser pulses towards the target and reflected energy is captured by the receiver. Aerosol between the sensor and target attenuates the return signal. Data from the test will be used to develop digital signal processing techniques for future optical proximity sensors.

The Infrared Optical Sensor currently being developed uses digital signal processing. Signal returns are digitally processed to separate low frequency aerosol returns from high frequency target returns. The technical challenge is to develop sufficiently high speed algorithms that can process signal returns between each transmitted laser pulse.

T[illegible]ical sensor uses fiber optic bundles to direct received ene[illegible] to the detector. One detector is used per sector of the sensor. Resolution is determined by the number of fibers used per sector. The greater the resolution, the better the estimate of the target's location.

A laser diode pulse or drive circuit and fiber optic receiver array had to be fabricated for the test. The laser diode used in the transmitter was prepackaged, but I breadboarded the drive circuit from the circuit diagram supplied by the contractor. Basically, the drive circuit is just a switch. When the switch is off, a capacitor is allowed to charge, and when on, the capacitor's energy is released, effecting a laser pulse. The breadboarded drive circuit was tested for signal strength and pulse rate.

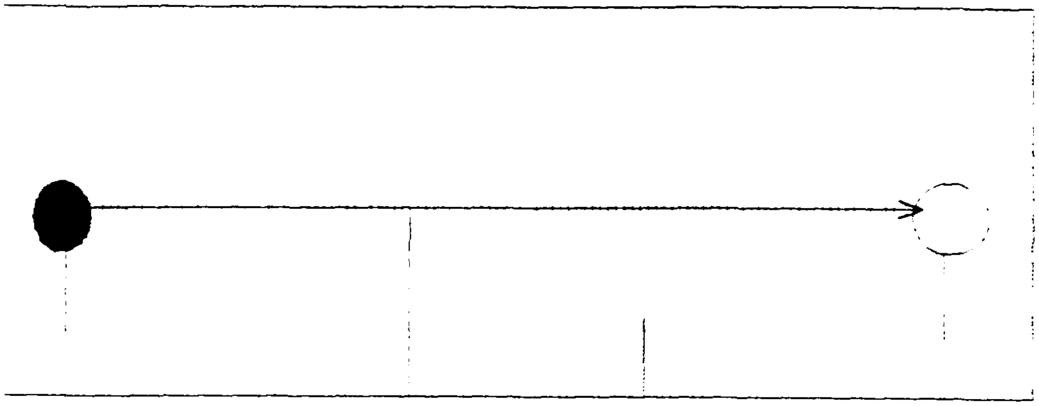
The optical receiver uses a coupled fiber optic array for azmuthal resolution. I fabricated the fiber optic array used in the optical receiver. The optical fibers are cut to a standard length then set into a mold and epoxied to a fan-shaped holder. The array is mounted in front of a gold mirror which collects and focuses the returning light signals into the fiber optics. The return light wave signals are carried through the fiber optics to a silicon photodetector. The photodetector is biased using high voltage. When the light from the fibers hit the detector a current is sent to the detector creating a digital signal. This signal was recorded using a Hewlitt Packard HP-54100 digital oscilloscope (7).

AEROSOL TESTING

The test was conducted in the McKinley Climatic Laboratory. The initial temperature in the test chamber was -30 degrees Fahrenheit. Snow was blown on the floor as a source of moisture. The temperature was raised to 23 degrees Fahrenheit and steam was injected into the chamber to create the aerosol. The temperature was increased and additional steam was added to increase aerosol density as the test progressed. A portable insulated building was used as our control center to protect the cold sensitive equipment. The oscilloscope was used to measure the laser pulse of the reference beam and the target beam. The purpose of the reference leg was to correlate signal attenuation with aerosol density as the basis for a test standard. If someone wished to recreate our experiment, they would have to match the same attenuation level to obtain the desired aerosol density. The reference leg consisted of a IR laser transmitter pulsing through the aerosol onto a receiver (See figure 2.). The test leg consisted of a co-located laser transmitter/receiver, aerosol medium, and target (See figure 3). The test leg was used to record reflected signal returns off a simulated target. The test leg and reference leg were closely aligned to ensure that similar aerosol densities existed (See figure 4). A Zenith Z-100 computer was used to record the data. All participants in the test were required to have laser eye exams before and after the test as a safety precaution. My assignment for the test was to set up the reference leg and test leg, integrate the data acquisition system, and record the test data. A computer program, TG-4, was used to record the signal return data from the receiver.

RESULTS/CONCLUSIONS

I recorded 104 samples of data during the test. We were able to receive the return pulses through the most dense aerosol in the test. The return signals were still strong enough to be seen and we were able to discriminate the target signals from the cloud returns. The signal processing portion of the test will be conducted by another MNF employee. The challenge is to program a processing program on a chip



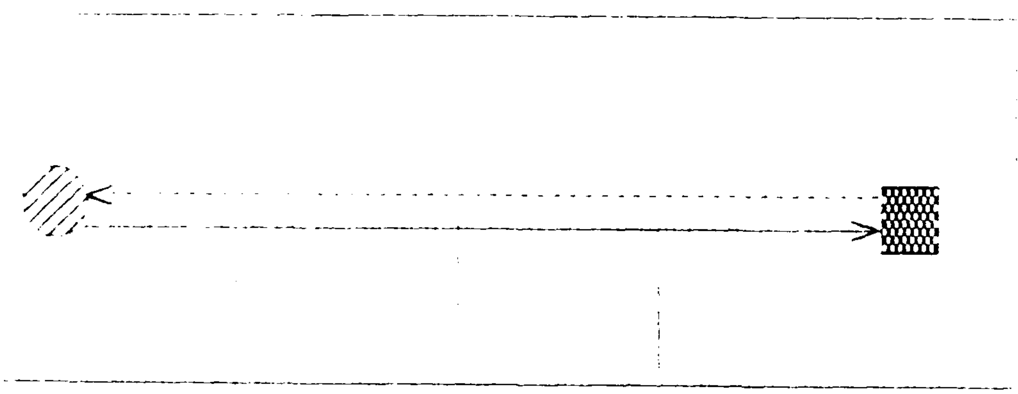
TRANSMITTER

PULSED IR BEAM

AEROSOL MEDIUM

RECEIVER

FIGURE 2



TRANSMITTER RECEIVER

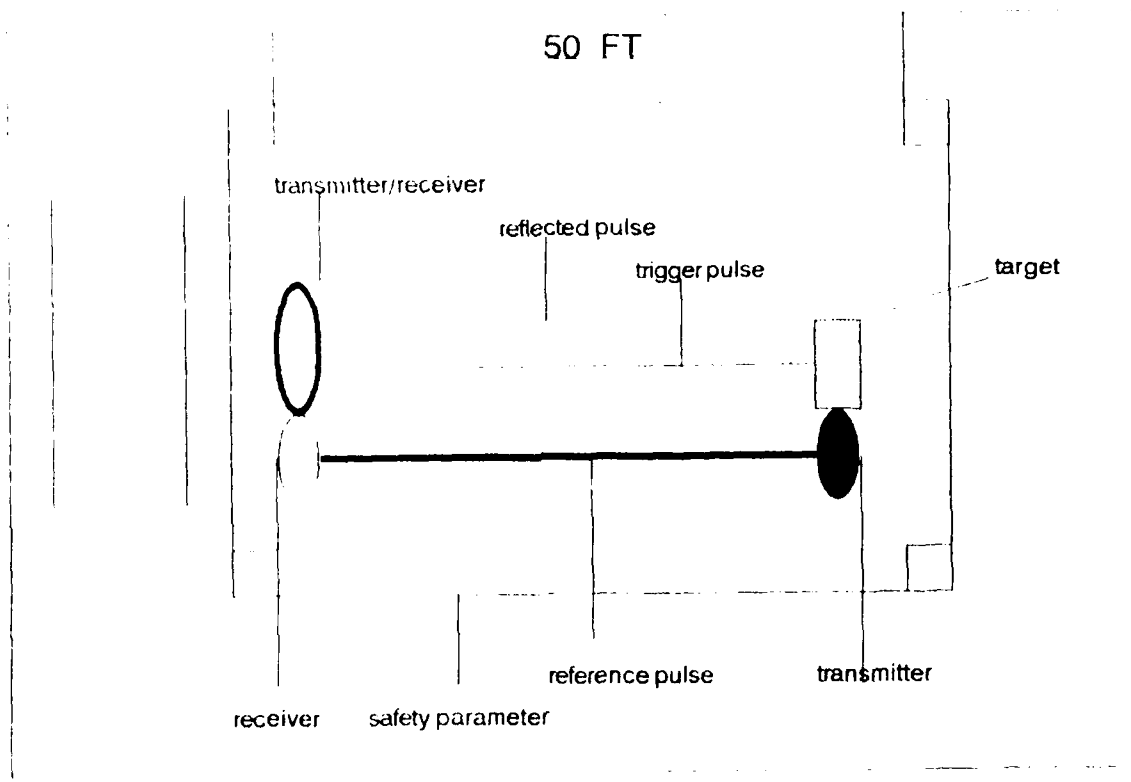
REFLECTED ENERGY

AEROSOL MEDIUM

TARGET

PULSED IR BEAM

FIGURE 3



AEROSOL TEST SETUP

FIGURE 4

and see if the chip can process the data fast enough to meet fuze timing requirements.

MISCELLANEOUS

Anti-Armor Fuze Technology Program. My objective was to test a candidate laser diode and laser pulsing circuit to see if we could duplicate the contractor's test results. The contractor was using laser diode specifications for 5 KHz operation to design his system, but was planning to implement this design running it at 50 KHz. I tested this device at 5 KHz and measured a 120 volt signal. I repeated the test at 50 KHz and found the return signal dropped to only 3 volts. My test findings were reported to the program manager to aid in further design planning (8).

Beam Sight Technology Incorporating Night Vision Goggles (BSTING). The BSTING program is developing a helicopter fire control system for crew-served weapons that will increase the effectiveness of special operations gunners using night vision goggles. One of the system design concerns is helicopter/gun shock and vibration. Shock and vibration levels must be known so system components can be adequately "hardened" to withstand the harsh environment. I used the program TG-4 to analyze previously recorded helicopter/gun shock and vibration data. The raw data was digitally filtered at 500 KHz and a Fast Fourier Transform was performed to determine the power spectrums. I found the worst case to be less than 60 g's at 500 KHz. This information will be given to the BSTING contractor to aid their design (9).

Tours. This summer, I also visited some of Eglin's other research facilities. One of these was the BEF or Ballistic Experiment Facility. They test fire projectiles to determine flight stability and structural integrity. The BEF also tailors propellant loads for the guns to obtain desired velocity (10).

I toured the seeker test tower on top of the Air Force Armament Lab building. This tower was designed to test missile seekers, such as air-to-air and air-to-ground seekers. Both optical and radio frequency seekers can be evaluated from this facility. I saw a millimeter wave (MMW) air-to-ground missile seeker being tested. It was being used to image targets moving through the trees on the ground several thousand feet away.

A tour of all of the branches of the laboratory was given to all summer professors and apprentices. I saw the Optics Laboratory, the Image Processing Lab/Radar Signal Processing Lab, and the Laser Simulation Lab all in the AFATL main building. Then we went to the Aeroballistic Research Facility where projectiles are fired down a tunnel, photographed, and their flight paths are analyzed. We also went to the HERD, the High Explosives Research and Development Facility. The HERD is currently developing insensitive explosives. These explosives are less susceptible to sympathetic detonation and can be stored closer to the flight-line to save loading time. We visited the Dynamics Test Facility and the SDI (Strategic Defense Initiative) facility where I saw the electromagnetic (EM) gun. The EM gun fires a projectile at high velocity using magnetic force.

On August 11, all HSAP students attended a seminar. Each student gave a briefing on the major effort they worked on. Following the seminar, we had a HSAP luncheon at the Sound.

In summary, I helped test a theory that an optical sensor could overcome its weather limitations and locate a target within an aerosol. I built test equipment and recorded data we received for later signal processing. I conducted a test using a laser diode to find the signal output at various levels. I also reduced vibration data using the computer program TG-4.

REFERENCES

1. The Bureau of Naval Weapons, Weapons Systems Fundamentals, Volume 2 (Washington, D.C.: U.S. Government Printing Office, 1963) 6,7.

2. The Bureau of Naval Weapons, Weapons Systems Fundamentals, Volume 2 (Washington, D.C.: U.S. Government Printing Office, 1963) 71-80.

3. Steve Smith, Mechanical Engineer, Fuzes and Guns Branch, Munitions Division, interview. Eglin Air Force Base, 24 July 1989.

4. Vern Newsom, Electronics Technician, Fuzes and Guns Branch, Munitions Division, interview. Eglin Air Force Base, 25 July 1989.

5. The Bureau of Naval Weapons, Weapons Systems Fundamentals, Volume 2 (Washington, D.C.: U.S. Government Printing Office, 1963) 56-65.

6. Robert Orgusaar, Electrical Engineer, Fuzes and Guns Branch, Munitions Division, interview. Eglin Air Force Base, 17 June 1989.

7. Robert Orgusaar, Electrical Engineer, Fuzes and Guns Branch, Munitions Division, interview. Eglin Air Force Base, 25 June 1989.

8. Mike Caraway, Electrical Engineer, Fuzes and Guns Branch, Munitions Division, interview. Eglin Air Force Base, 20 July 1989.

9. Don Cunard, Mechanical Engineer, Fuzes and Guns Branch, Munitions Divisions, Interview. Eglin Air Force Base, 30 July 1989.

10. Scott Nass, Laboratory Technician, Fuzes and Guns Branch, Munitions Division, interview. Eglin Air Force Base, 1 August 1989.

ADAPTIONS OF EXISTING STAR CATALOGS FOR SPACE-BASED INTERCEPTOR APPLICATIONS

by: Tonya Monique Cook

Mentor: Laura Sterrett
August 14, 1989
AFATL/SAI

I would like to give a special thanks to everyone who made this opportunity possible and also to everyone who invested so much time and effort in me along the way, especially...

Laura Sterrett

Randy Wells

Dr. Norm Klausutis

Mr. Don Harrison

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I. INTRODUCTION

In the beginning, many weeks were spent at SAI learning much about computers, star charts, the government and its procedures, space-based interceptors, and star sensors. The specific work for the summer consisted of the construction of a star catalog for use in a star sensor for space-based interceptor applications. For interceptor initialization, star cataloging use in a star sensor was necessary. In theory, a basic space-based interceptor would consist of six parts: the seeker, the focal plane array, the signal processor, the guidance processor, the IMU, and the thrusters. To initialize the IMU, a star sensor could be added to this basic design. The components of a star sensor include: the optics, focal plane, signal processor, and a pre-stored star catalog. This star catalog would be used for navigation by providing references for the scenes fed in from the star sensor optics. In addition, this star catalog could be used to produce background scenes for interceptor seeker testing.

To create the star catalog, certain steps must be taken. First, data reduction must be performed to extract the necessary data. Then, sensor processing should occur to produce data acceptable to the chosen star sensor. Position specific processing would then be used to eliminate data not pertaining to sensor position. An example would be stars on the solar or lunar orbit. Attitude specific processing should then be done. This procedure would be used to sight the appropriate stars for navigational purposes. Finally star selection will occur to generate the pre-star catalog.

Prior to actual star catalog development, several tasks were accomplished. Assisted by the prior knowledge of BASIC, two weeks

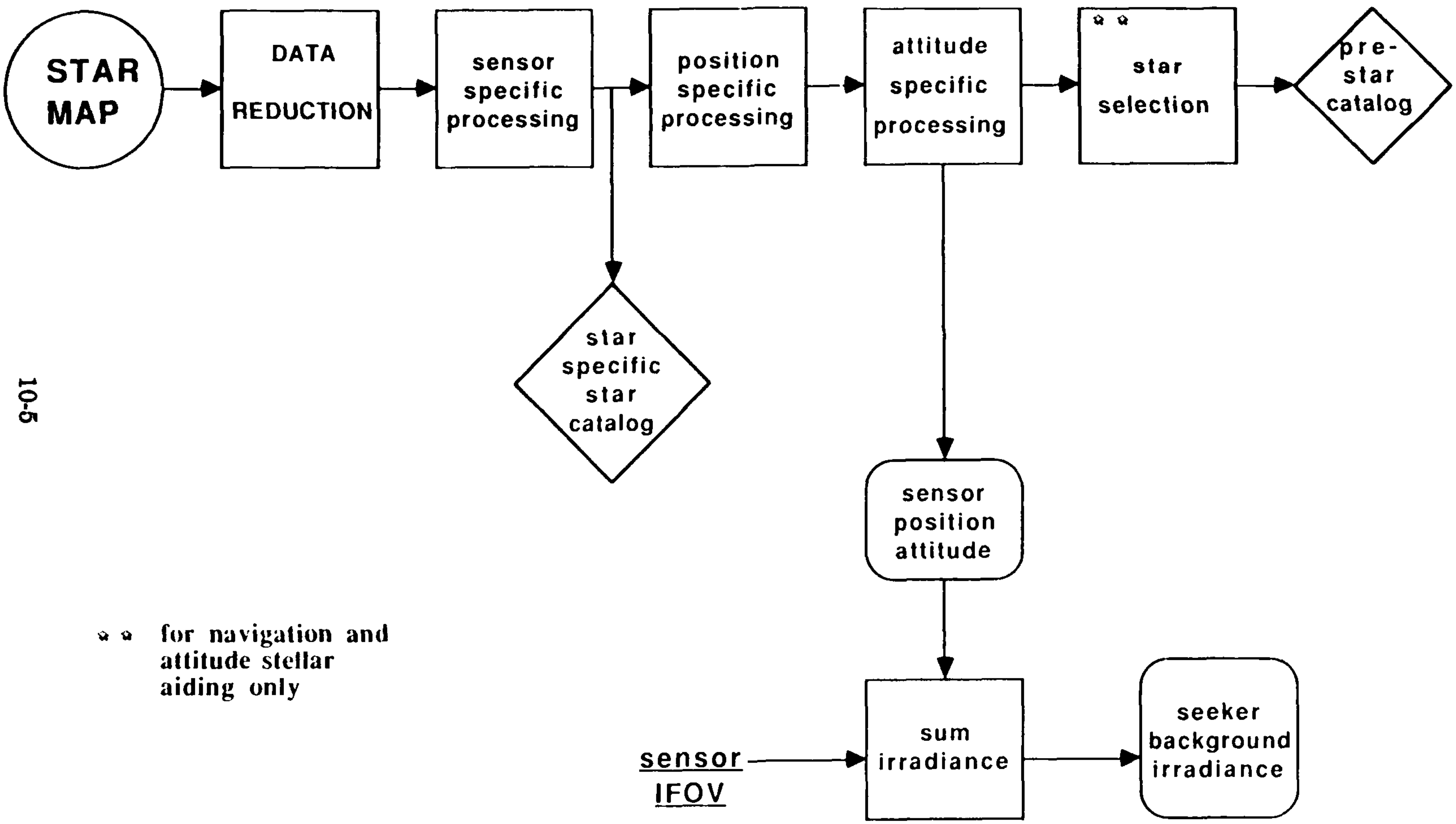


Figure 1 Star Catalog Procedure

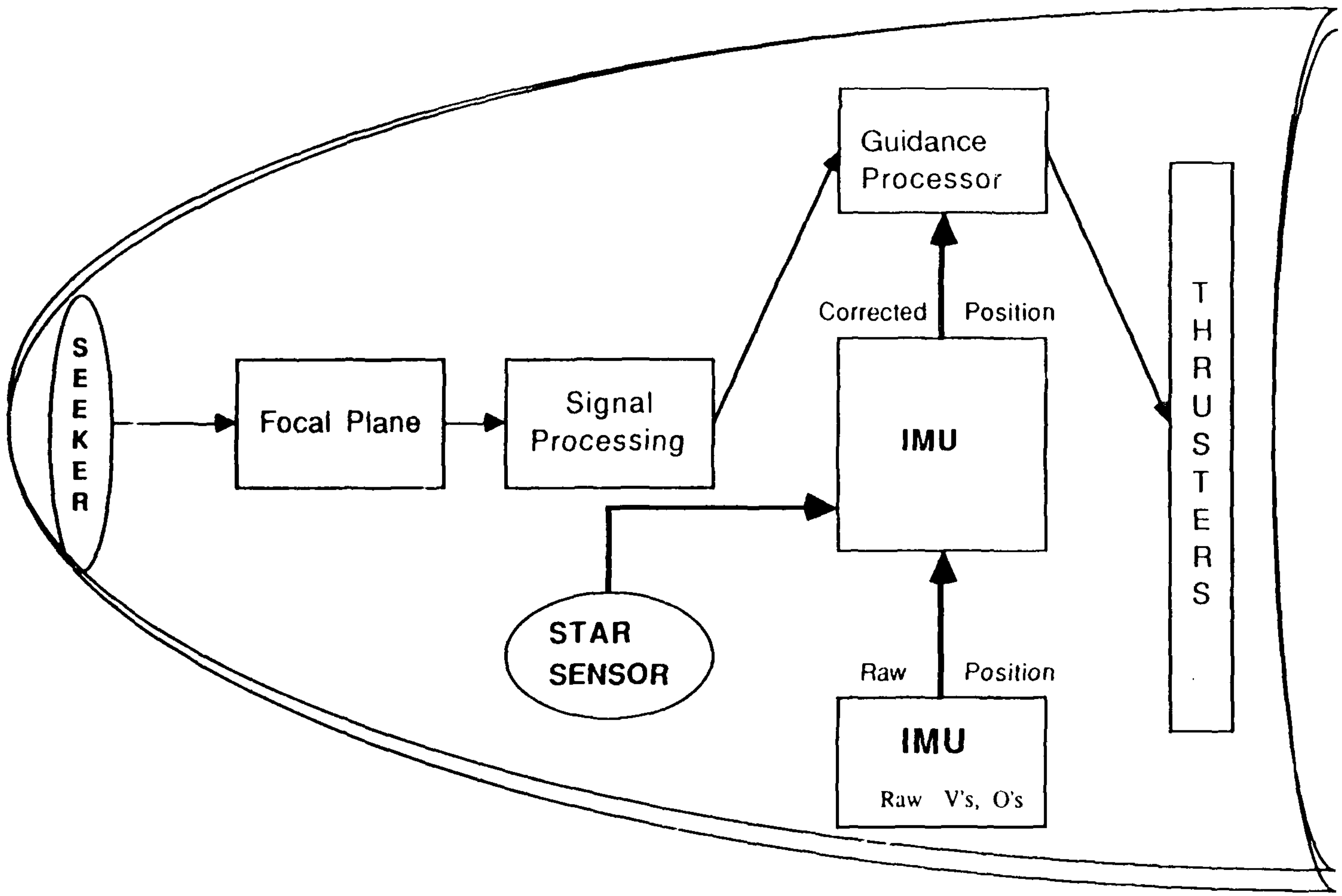


Figure 2. Space-Based Interceptor Components

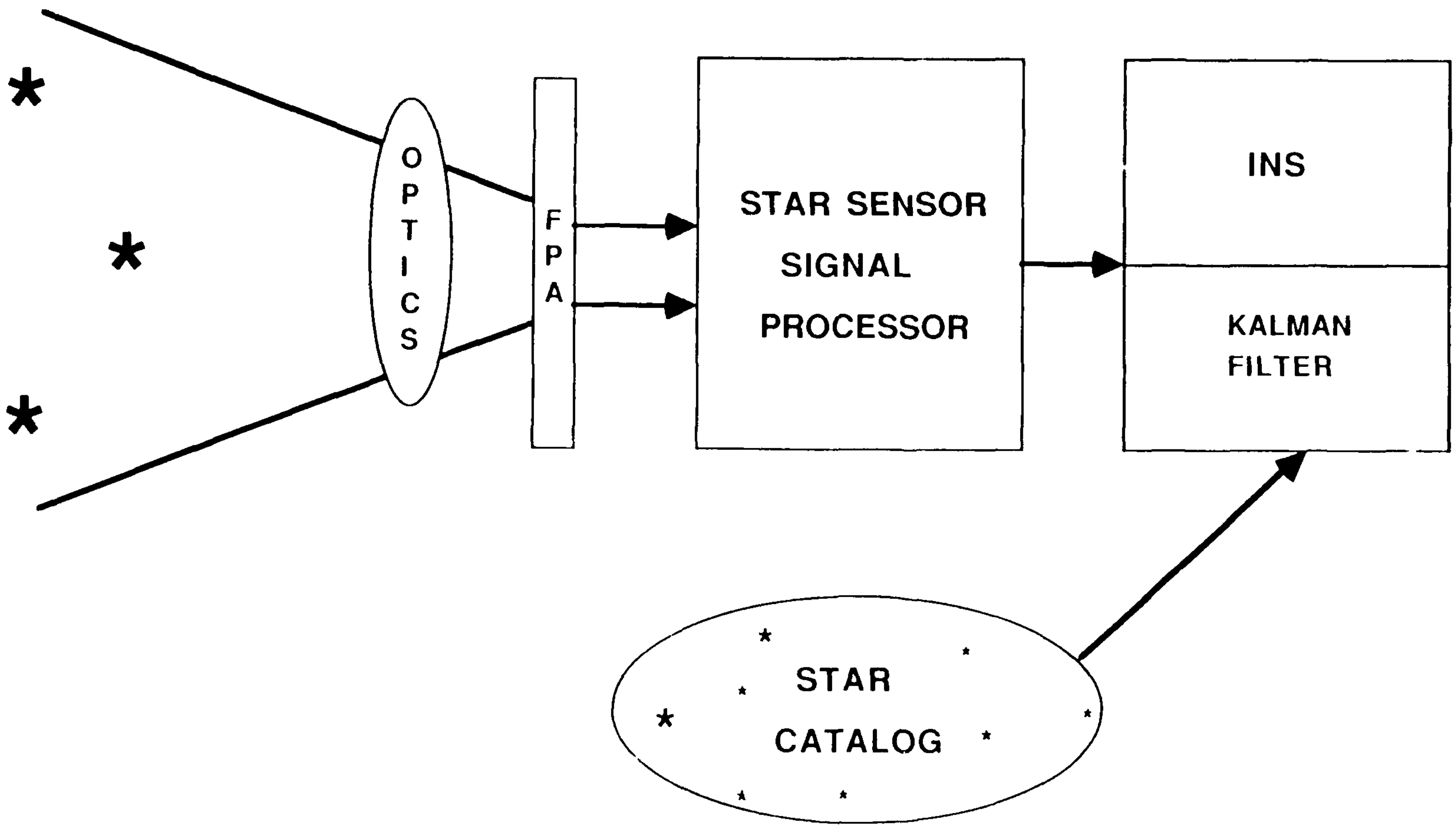


Figure 3. Star Sensor Components

TESTING OUT CELL NEIGBOR SEARCH CODE

MARKED CELLS ARE NEIGHBORS OF CELLS 0,1 AND 528

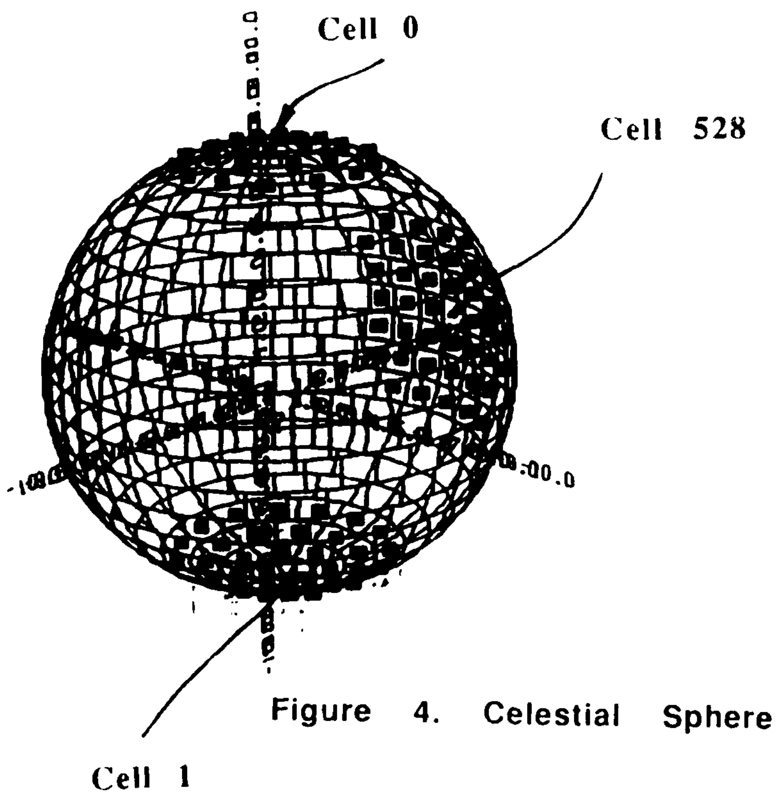


Figure 4. Celestial Sphere Cell Division

were spent becoming familiar with FORTRAN. Proficiency of this language was reached by study of the manuals and hands-on application. Programs for numerical analysis algorithms were written. Another week passed and literacy of FORTRAN reached a level which permitted star catalog programming. Soon after this, the first star charts arrived, and programming became essential. For the weeks to come, an uphill battle was fought to manipulate the star chart data into the finished product for the space-based interceptor IMU initialization.

II. BACKGROUND

Basic research was done in the Technical Library to review the physics required. While there, astronomy information about Jansky units and other star information was collected. Finally, the last basic learning was done to develop proficiency in a graphics software package, DISSPLA. An understanding was reached of many subroutines and the four levels of this package in addition to which commands transfer one to another. The cumulative knowledge of FORTRAN, DISSPLA, and astrophysics proved very beneficial in our work.

III. PROCEDURE

After reception of the IRAS star map, the data reduction began. A program was written to read in the data as character strings and separate the data into certain groups of characters. The purpose of this program was to reduce the data from 30,000 blocks to make manipulations of star data easier. The first data reduction produced a new data file with only the essential information for the catalog. This data then had to be run through a conversion program, Convers., that was written to convert each element of data to a useful form. For instance, right ascension and declination had to be converted from hours, minutes, and seconds to a radian measure. From here the information such as right ascension, declination, flux densities in particular sensor wavebands, irradiance, and intensities were used to try to obtain temperatures of the stars to produce blackbody curves. From the blackbody curve, intensities of stars at shorter wavebands were obtained.

For the next day or so, Planck's Equation was used, and information gathering on a test source became necessary. The test source was to be a well-known, well-studied star to compare its data with that of the same star run through certain computations. This test source comparison would assure accuracy on the blackbody curve manipulations and results. Surprisingly, after running the modified Convers. program, debugging, checking the math, and comparing our test information, the conclusion was reached that for the given wavelengths of over 12nm, the equations and calculations were invalid for the shorter wavebands that were needed. Further, it became evident that something needed to be done to obtain the magnitude of each star. Magnitude was not given in the star data that was being dealt with. Therefore, some rearranging of the schedule and ordering a different star map was in order.

During the wait for the other maps, graphical display methods were developed using the DISSPLA graphics package. The first task was to mathematically and graphically produce the celestial sphere. The celestial sphere was divided into 8 degree cells which produced 529 cells of equal surface area. These cells were formed by drawing encircling longitudinal and latitudinal lines to form a gridded sphere. The program to do this was logically called Celldiv.

The mathematical process wasn't very difficult, but due to emulator problems and an unfamiliarity with DISSPLA, Celldiv modifications proved challenging. Before tackling the real problems, DISSPLA had to be learned. to do this reading and study of the DISSPLA manuals was done, and Celldiv, was flowcharted in its entirety. Further, a stripped version of Celldiv., Try., was created. Here, many attempts were taken to produce axes and to delete appropriate cells. Also, output to a printer was needed, but because of emulator limitations, output on the LN03 printer was impossible. After overcoming many roadblocks, though, axes were created in the correct position and the back half of the celestial sphere was suppressed.

With that step completed, the new star charts arrived. The tapes were mounted and the star data was stored on Orion, the microvax in the Image Processing Laboratory. The original process then began all over again. Data reduction was performed and the calculations involving Planck's Equation were executed to create and apply spectral radiance emittance of a blackbody as a function of wavelength at various temperatures. Then, deletions of cells containing the sun or moon, planets, and the earth limb were conducted.

The next step that needs to be taken is to create a subcatalog with stars designated to particular cells and the neighboring cells surrounding the sighted cells. Following those steps, stars that have an intensity less than the sensor's threshhold must be deleted, and then the first star catalog will be generated.

Following that, a subcatalog for navigational and attitude stellar aiding will be created. All star cells near the ecliptic must then be deleted, and special considerations must be taken to avoid and/or delete doublet stars.

VI. SUMMARY

In theory, once the star catalog and subcatalog are generated, the sensor of the vehicle will be able to be tested with authentic surroundings for star navigation. Input readings on FOV and vehicle attitude will be read in. Next, using the subcatalog, it will be determined which star cell(s) the sensor is pointed at for a given time period in that trajectory. The sensor will then select a star cell in or near the sensor boresight at a given in the trajectory. From here the single brightest star in the cell shall be sighted and computations to select a star cell near a 90 degree boresight shall commence. Then, the brightest star from that cell will be selected. Because the neighboring cells and brightest stars are predesignated, navigational agility will be increased. Further, another use for the star catalog is to produce background scenes for testing the interceptor seeker.

V. CONCLUSION

In conclusion, this summer has been very productive. The team, individually and cumulatively, won many battles and took many steps toward the star map's completion. Star charts were obtained containing the information that we needed. Then, the data was reduced and blackbody curves were produced with the temperatures of the stars at particular wavebands. The cell division process was then perfected and the graphics manipulations were mastered. Of course, there were many time-consuming problems along the way such as emulator incompatibilities, but nothing that couldn't be overcome or by-passed.

IV. RESULTS AND ACCOMPLISHMENTS

After the star maps were received, uploading a file from a tape to the vax cluster was accomplished. Additionally, transferring a file from EBCDIC to ASCII was achieved. DISSPLA was learned, and a modified program to hide lines and delete axes in spherical coordinates was completed. Finally, the graphical set-up for the adapted version of the star catalog was produced.

VII. References

Burden, Richard L., Numerical Analysis,
Prindle, Weber, and Schmidt,
Boston, MA, 1981

Etter, D.M., Structured FORTRAN 77,
The Benjamin/Cummings Publishing Company,Inc.,
CA, 1983

Siegel, Robert and Howell, John R., Thermal Radiation Heat Transfer, McGraw-Hill Book Company,
NY, 1981

Williams, John E., Modern Physics,
Holt, Rinehart, and Winsten Publishers,
NY, 1980

CA-DISSPLA, User Manual,
Computers Associates International, Inc.,
USA, 1988

The Cambridge Encyclopedia of Astronomy,
Crown Publishers Inc.
NY,1977

McGraw-Hill Dictionary of Scientific Terms,
McGraw-Hill Book Company,
NY, 1974

Webster's II New Riverside University Dictionary,
Houghton Mifflin Company,
USA, 1984

attitude- The position or orientation of an aircraft, either in motion or at rest, as determined by the relationship between the axes and some reference line or plane or some fixed system of reference axes

BASIC- A procedure level computer language well suited for conversational mode of a terminal computer. Derived from Beginning All-purpose Symbolic Instruction Code

binary star system- a pair of stars located sufficiently near each other in space to be connected by the bond of mutual gravitational attraction, compelling them to describe an orbit around their common center of gravity.

blackbody- an ideal body which would absorb all incident radiation and reflect none

boresight- (1) a telescopic device utilizing a a boresighting reticle to align the axis of a weapon with a target; it is attached to the exterior of a barrel or tube by a mount. (2) Initial alignment of a directional microwave or radar antenna system by using an optical procedure or a fixed target at a known location

celestial sphere- an imaginary sphere of indefinately large radius which is described about an assumed center, and upon which positions of celestial bodies are projected along radii passing through the bodies

cells- non-overlapping regions of equal surface area

cellwidth- width of cells whose centers are at the same latitude; width of declination zones.

character string- a string or group of characters that contain numerical digits, alphabetical letters, or special characters

data reduction- process of reduction to elliminate nonessential data and extract useful data for calculations

declination- the angular distance of a celestial object north or south of the celestial equator

DISSPLA- a graphics software package

doublet star- a star which appears as a single point of light to the eye but which can be resolved into two points by a telescope

flux density- (1) the integral over a given surface of the component of a vector perpendicular to the surface; by definition, it is proportional to the number of lines of force crossing the surface. (2) the amount of some quantity flowing across a given area per unit time

FORTRAN- A family of procedure-oriented languages used mostly for scientific or algebraic applications; derived from formula translation

FOV- field of view

IFOV- instantaneous field of view

irradiance- the amount of radiant power per unit area that flows across or onto a surface

jansky- a unit of measurement of flux density

magnitude- the relative luminance of a celestial body

pitch- angular displacement about an axis parallel to the lateral axis of the vehicle pixel- smallest unit of a sensor that composes the focal plane array

Planck's Law- a formula for the intensity of radiation emmitted by a blackbody, as a function of frequency, and of the body's temperature

right ascension- a celestial coordinate; the angular distance taken along the celestial equator from the vernal equinox eastward to the hour circle of a given celestial body

roll- rotational or oscillatory movement of an aircraft or similar body about a longitudinal axis through the body

SAI- Guidance Interceptor Technology Branch

yaw- the rotational or oscillatory movement of a ship, aircraft, rocket, or the like about a verticle axis

Appendix B1. Tored

```
C       *********THESE DIMENSION GOOD DATA***********

        REAL FM
        CHARACTER SNA*1,SND*1,AMS*1,ST*3,CI1*2,SS*1,CI2*1,L*1
        INTEGER RAH,RAM,DEC,DEM,DV,VMA,PMA

C       *********THESE DIMENSION NON-ESSENTIAL DATA********

        INTEGER A,B,D,E,G
        CHARACTER S*3,U*6,V*5,H*7,R*7,T*7

C       *************************************************

        CHARACTER*20 IN,OUT
        WRITE(*,'(A)') ' INPUT FILE NAME ?'
        READ(*,10)IN
        WRITE(*,'(A)') ' OUTPUT FILE NAME ?'
        READ(*,10) OUT
 10     FORMAT(A20)
         OPEN(15,FILE=IN,STATUS='OLD')
         OPEN(16,FILE=OUT,STATUS='NEW')
        DO 85 I=1,12460
          READ(15,25)NUM,L,RAH,RAM,RAS,APM1,A,SNA,EPS,B,C,SND,DEC,
     1        DEM,DES,APM2,D,AMS,SOE,E,F,G,PM,VM,ST,H,DV,VMA,PMA,R,S,T,
     1        CI1,SS,U,CI2,V,RA,DC

CC          READ(15,21)NUM,L,RAH,RAM,RAS,APM1,A,SNA,EPS,B,C,SND,DEC,DEM,
CC     +        DES,APM2,D,AMS,SOE,E,F,G,PM
CC  21      FORMAT(I6,A1,I2,I2,F6.3,F7.4,I2,A1,F6.3,I2,F6.1,A1,I2,I2,F5.2,
CC     +        F6.3,I2,A1,F5.2,I2,F6.1,I3,F4.1)
CC          READ(15,22)VM,ST,H,DV,VMA,PMA,R,S,T,CI1,SS,U,CI2,V,RA,DC
CC  22      FORMAT(F4.1,A3,A7,3(I1),A7,A3,A7,A2,A1,A6,A1,A5,F10.8,F11.8)

  25     FORMAT(I6,A1,I2,I2,F6.3,F7.4,I2,A1,F6.3,I2,F6.1,A1,I2,I2,F5.2,
     1        F6.3,I2,A1,F5.2,I2,F6.1,I3,F4.1,F4.1,A3,A7,3(I1),A7,A3,A7,
     1        A2,A1,A6,A1,A5,F10.8,F11.8)
         WRITE(*,35)NUM,L,RAH,RAM,RAS,APM1,SNA,EPS,SND,DEC,DEM,
     1        DES,APM2,AMS,SOE,PM,VM,ST,DV,VMA,PMA,CI1,SS,CI2,RA,DC
  35     FORMAT(I6,A1,I2,I2,F6.3,F7.4,A1,F6.3,A1,I2,I2,F5.2,F6.3,A1,
     1        F5.2,F4.1,F4.1,A3,I1,I1,I1,A2,A1,A1,F10.8,F11.8)
         WRITE(16,45)NUM,RAH,RAM,RAS,SNA,EPS,SND,DEC,DEM,DES,AMS,SOE,
     1        PM,VM,VMA,PMA,RA,DC
  45     FORMAT(I6,I2,I2,F6.3,A1,F6.3,A1,I2,I2,F5.2,A1,F5.2,F4.1,F4.1,
     1        I1,I1,F10.8,F11.8)

  85    CONTINUE
  99      STOP
        END
```

Appendix B2. Convert

```
      REAL*4 LAMBDA(4),FLUX(4),A(4),T(4)
      CHARACTER*1 DSIGN
      CHARACTER*20 IN,OUT
      INTEGER RAH,RAM,RADC,DD,DM,DS
      DOUBLE PRECISION DRAH,DRAM,DRADC,DG,MN,SC,RTASC,DECLIN
      WRITE(*,'(A)') ' TYPE INPUT FILE NAME, INCLUDING EXTENSION'
      READ(*,12)IN
12    FORMAT(A20)
      WRITE(*,'(A)') ' TYPE OUTPUT FILE NAME, INCLUDING EXTENSION'
      READ(*,12) OUT
10    FORMAT(11X,I2,I2,I3,A1,I2,I2,I2,11X,4(E9.3))
       OPEN(10,FILE=IN,STATUS='OLD')
       OPEN(20,FILE=OUT,STATUS='NEW')

C     !!!!!!!!THIS NUMBERS THE ENTRIES!!!!!!!!!!!!!!!!!!!!!

         ICOUNT=1
        CJSKY=3.0E-14
        PI=3.14159265+
        DLAMBDA=1.0
C    *** 1.0E-06m 4/cm 2******
        C1=3.7415E+04
        C2=1.43879E+04
        C=2.9979E+10
        H=6.6256E-34
               LAMBDA(1)=12.0
               LAMBDA(2)=25.0
               LAMBDA(3)=60.0
               LAMBDA(4)=100.0
            DO 100 J=1,100000
     READ(10,10,END=99)RAH,RAM,RADC,DSIGN,DD,DM,DS,(FLUX(I),I=1,4)
     WRITE(20,10)RAH,RAM,RADC,DSIGN,DD,DM,DS,FLUX(1),FLUX(2),FLUX(3),
    1FLUX(4)

C           CALCULATING ANGLE OF ASCENSION!!!!!!!!!!!!

        RTASC=FLOAT(RAH)*15.0+FLOAT(RAM)*.25+FLOAT(RADC)*.0417
        WRITE(20,14)ICOUNT,RTASC
14      FORMAT(1X,I6,1X,'ASC= ',D20.6)

C     !!!! CALCULATING ANGLE OF DECLINATION!!!!!!!!!!

         DECLIN=FLOAT(DD)+(FLOAT(DM)/60.)+(FLOAT(DS)/3600.)
        IF(DSIGN.EQ.'-')DEC=-DEC
C        WRITE(*,20)DG,MN,SC
        WRITE(20,30)DSIGN,DECLIN
30      FORMAT(8X,'DEC=',5X,A1,D15.8)
20      FORMAT(1X,'DG=',D15.7,1X,'MN=',D15.7,1X,'SC=',D15.7)

C           CALCULATING JANSKY CONVERSION OF FLUX!!!!!!

         DO 44 IJ=1,4
44      FLUX(IJ)=FLUX(IJ)*(3.0E-14/(LAMBDA(IJ)**2))
             DO 45 II=1,4
45           A(II)=(C1*DLAMBDA)/((LAMBDA(II)**5)*FLUX(II))
```

```
               RATIO1= -LAMBDA(2)/LAMBDA(1)
               CX=(A(1)*(A(2)**RATIO1))**(1/(1+RATIO1))
                 DO 48 JJ=1,4
48                T(JJ)=C2/(LAMBDA(JJ)*ALOG((A(JJ)/CX)+1))
                  TAVG1=(T(1)+T(2))/2.0
                WRITE(*,220) T(1),T(2),T(3),T(4)
220            FORMAT(1X,4(F18.5,2X))
         ICOUNT=ICOUNT+1

100     CONTINUE
99          STOP
        END
```

Differences in the Activation Energy of Nitroguanidines

By: Kathryn D. Deibler
Mentor: Lt. Steven D. Whitney
AFATL/MNE

Acknowledgments

I would like to thank Dr Norm Klausutis and Mr Don Harrison for coordinating the activities for the apprenticeship program and making it run smoothly. I appreciate the advice and encouragement provided by Mr Gary Parsons and his staff at the HERD. I would like to thank Mrs Lois Walsh and Mrs Mitzy Rowe for helping with the presentation materials. A special thanks to Mr Stephen R. Struck for clearing up problems I had with the Differential Scanning Calorimeter and the calibration of it. I would especially like to thank Lt Steven D. Whitney, my mentor, for explaining the chemistry behind my experiments. I appreciate the patience, time, and help Lt Whitney provided throughout the summer.

List of Figures

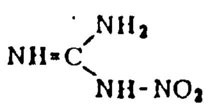
This summer I worked as an apprentice at the High Explosives Research and Development Laboratory (HERD). An objective of the HERD is to develop an insensitive high explosive. An insensitive high explosive is one that will not react when thermal, impact, friction, shock, or electrostatic stimulants are applied accidentally; however, the explosive will go off with great power when desired. The benefits of insensitive high explosives in munitions are they can be stored closer to a given airfield and more munitions may be kept in eacn munitions storage igloo.

The purpose of my project was to determine if differences in activation energy and pre-exponential factor, which are kinetic parameters, exist between two types of nitroguanidine (NQ) explosive: IH NQ and ICT NQ; two particle size ranges: 106-210microns and >297microns; and three particle shapes: cubical, spherical, and ground and sieved. Activation energy is the amount of energy required to raise a molecule to a state in which it can react. The pre-exponential factor, also called the frequency factor, is the number of molecules colliding per unit volume per second. Explosives with a high activation energy also have higher thermal stability and a high pre-exponential factor. This experiment contributed to two programs, one was the characterization of TNT and NQ mixtures as an insensitive high explosive and the other was a foreign weapons evaluation of NQ produced in Germany. To find the activation energy and pre-exponential factor of NQ I used DSC method of Ozawa, which is based on variable heating rates. Calculations of the activation energy and pre-exponential factor are based on a plot of the logarithm of the heating rate versus the reciprocal of the peak temperature. This method is the basis of an

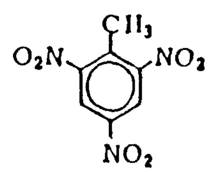
ASTM technique developed by Committee E27 on Hazard Potential of Chemicals (Ozawa 1970).

Nitroguanidine (NQ), $CH_4N_4O_2$, is not very sensitive to shock or impact, but is powerful. It has an excellent chemical stability. NQ based propellants are practically flashless and less erosive than propellants based on explosives of comparable force. NQ is also an important component in solid rocket propellants (Meyer 1981, Fedoroff 1974). The two types of nitroguanidine I used were IH NQ made at Indian Head, Maryland, recrystallized in an aqueous solvent forming cubical crystals, and ICT NQ produced in Germany, recrystallized in dimethylformamide, an organic solvent forming spherical crystals.

Nitroguanidine alone cannot be used for melt-casting because NQ has a high melting point, but mixtures of TNT and NQ with a 50:50 weight ratio can be effectively used. I used the standard 2,4,6 trinitrotoluene (TNT), $C_7H_5N_3O_6$, "symmetrical" isomer for my tests. TNT has a low sensitivity to impact and friction, a high explosive power, and chemical and thermal stability. It is compatible with many other explosives and has a low melting point making it favorable for melt-casting. As seen in my tests involving TNT mixtures, the addition of small amounts of diverse materials accelerates the thermal decomposition of TNT (Kaye 1980).



Nitroguanidine



TNT

Procedure

The main instrument I used was a Perkin-Elmer System-4 Differential Scanning Calorimeter (DSC). It produces a trace of the endothermic and exothermic events which take place as the temperature of the sample rises. The System-4 DSC consists of a Perkin-Elmer Model 3600 Data Station, a System 4 Microprocessor Controller, and a DSC-4. The data station is composed of three modules: the visual display unit displays the output; the keyboard is used to enter input by the user; and the data processing module houses the system electronics and two floppy disk drives. The System 4 Microprocessor Controller is used to program the DSC-4 from an initial temperature to a final temperature. The DSC-4 head holds the reference and sample pans and heats them at the specified heating rate from the initial temperature to the maximum temperature.

When I ran my first tests, I weighed the explosives into vented aluminum sample pans. The result from these tests were invalid because the TNT evaporated through the ventilation hole. Next I used unvented aluminum sample pans, but the pressure of the TNT caused the seal to pop allowing the TNT to evaporate. Finally I used Large Volume Capsules, O-ring stainless steel sample pans, sealed using the Perkin-Elmer Quick Press. This seal was strong enough to withstand the internal pressure and suppress the vaporization of the TNT. Since there was moisture in the stainless steel sample pans' original container, I dried them by heating them to over 100^{o}C (the boiling point of water) in a vacuum. To weigh .50mg of each explosive into the sample pans, I used a Mettler AE 163 digital scale with an accuracy of +/- 0.01mg.

I heated the samples in the DSC at five heating rates: 2°C/min, 5°C/mi 10°C/min, 20°C/min, and 40°C/min. I compared five nitroguanidines varying by the type of recrystallization, shape, and particle size: IH (cubical) NQ 106-210microns and >300microns; ICT (spherical) NQ 106-210microns, >300microns, and ground and sieved to 106-210microns; 50:50 weight ratio mixtures of .50mg of TNT with .50mg of each type of NQ; and TNT. For each heating rate and explosive, I ran three replicate tests. To conduct a run, I prepared the sample in a stainless steel sample pan, and crimped the pan closed. This sample was placed in the DSC head next to an empty sample pan used as a reference. I set the starting temperature at 50°C, the increase temperature rate accordingly, and the final temperature to 350°C After each test, I used the Thermal Analysis Data Station to determine the temperature at which the NQ decomposed. Results in each case were similar to those in Figure 1. Peaks going down show an endothermic reaction and peaks going up show an exothermic reaction. At about 80°C an endotherm appears where the TNT melts. I used the peak temperature of the exotherm which is the decomposition of NQ in calculating the activation energy and pre-exponential factor. On some scans there was more than one exothermic peak. In such cases I used the temperature of the first peak because it was consistent throughout all the runs.

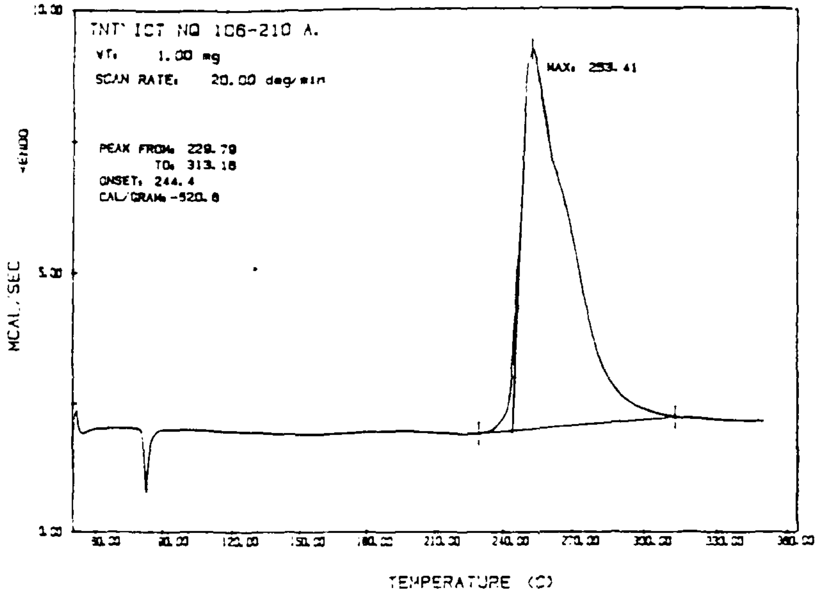


Figure 1.
DSC Sample Scan

	$2^{O}C/min$	$5^{O}C/min$	$10^{O}C/min$	$20^{O}C/min$	$40^{O}C/min$
1. IH NQ 106-210M	3	3	3	3	3
2. IH NQ >297M	3	3	3	3	3
3. ICT NQ 106-210M	3	3	3	3	3
4. ICT NQ >297M	3	3	3	3	3
5. ICT NQ crushed 106-210M	3	3	3	3	3
6. TNT	3	3	3	3	3
7. TNT/IH NQ 106-210M	3	3	3	3	3
8. TNT/IH NQ >297M	3	3	3	3	3
9. TNT/ICT NQ 106-210M	3	3	3	3	3
10. TNT/ICT NQ >300M	3	3	3	3	3
11. TNT/ICT NQ crushed, 106-210MS	3	3	3	3	3
TOTALS:	33	33	33	33	33 =165

Table 1. **NUMBER OF DSC TESTS**

To find the activation energy and pre-exponential factor of each type of NQ, I set up a spread sheet using SuperCalc3. The spread sheet included the average peak temperature (Kelvin) for each rate and explosive, least squares slope, and equations for the activation energy of each explosive, pre-exponential factor at each heating rate for each explosive, and the average pre-exponential factor for each explosive. Log heating rate (log(B)) versus reciprocal peak temperature is plotted and the least squares slope found (appendix C), then the activation energy (E) and pre-exponential factor (Z) are calculated as described in the equations given below (appendix B):

$$E = 2.19R \frac{d\log B}{d(1/T)}$$

$$Z = \frac{BEe^{E/RT}}{RT^2}$$

where E = activation energy, J/mol (cal/mol)
R = gas constant, 8.314 J/mol K (1.987 cal/mol K)
B = program rate, K/min (deg/min)
T = peak temperature, K (near the middle of the range)

where Z = pre-exponential factor (Arrhenius Frequency factor), min^{-1}

(Ozawa 1970)

Once a week and when I changed the heating rate, I made a temperature correction on the DSC-4 using a 6.54mg sample of Indium in a dried stainless steel sample pan. With the standard accuracy of +/- $0.1^{o}C$, I made the correction using the known melting point of Indium, $156.61^{o}C$.

Results

The decomposition temperatures obtained from the DSC test were as follows:

1\. IH NQ 106-210u (degrees C)
2°C/min - 207.41, 207.28, 206.09
5°C/min - 219.45, 218.94, 220.7
10°C/min - 227.98, 227.58, 228.92
20°C/min - 241.98, 241.9, 241.96
40°C/min - 253.68, 255.28, 256.21

2\. IH NQ >297u (degrees C)
2°C/min - 205.57, 207.39, 204.86
5°C/min - 218.68, 219.06, 217.09
10°C/min - 227.97, 226.43, 226.12
20°C/min - 241.79, 240.75, 240.45
40°C/min - 253.18, 252.08, 252.04

3.ICT NQ 106-210u (degrees C)
2°C/min - 225.32, 224.25, 224.31
5°C/min - 238.56, 237.8, 238.3
10°C/min - 247.05, 247.21, 247.16
20°C/min - 258.11, 258.35, 258.23
40°C/min - 265.4, 266.16, 265.91

4\. ICT NQ >297u (degrees C)
2°C/min - 224.79, 225.27, 224.88
5°C/min - 237.64, 237.84, 236.86
10°C/min - 244.58, 245.9, 245.96
20°C/min - 255.41,256.94, 256.5
40°C/min - 264.5, 264.84, 265.94

5\. ICT NQ crushed 106-210u (degrees C)
2°C/min - 223.52, 223.72, 223.69
5°C/min - 236.71, 236.94, 237.06
10°C/min - 245.64, 247.11, 245.78
20°C/min - 257.27, 255.38, 256.04
40°C/min - 265.12, 265.73, 265.57

6\. TNT (degrees C)
2°C/min - 246.47, 252.41, 252.07
5°C/min - 265.53, 268.54, 263.12
10°C/min - 282.16, 277.46, 283.11
20°C/min - 304.9, 308.49, 302.78
40°C/min - 321.55, 321.41, 321.52

7\. TNT/IH NQ 106-210u (degrees C)
2°C/min - 195.77, 207.87, 194.54
5°C/min - 204.31, 204.76, 208.07
10°C/min - 214.3, 218.71, 212.88
20°C/min - 237.66, 223.97, 230.65
40°C/min - 249.06, 252.99, 246.48

8. TNT/IH NQ >297u (degrees C)
2°C/min - 201.49, 199.44, 198.52
5°C/min - 207.07, 207.32, 211.05
10°C/min - 214.2, 214.97, 213.96
20°C/min - 228.29, 226.82, 229.27
40°C/min - 247.26, 248.34, 250.77

9. TNT/ICT NQ 106-210u (degrees C)
2°C/min - 215.2, 214.6, 214
5°C/min - 229.22, 229.89, 229.84
10°C/min - 239.03, 239.11, 237.91
20°C/min - 253.41, 250.43, 251.42
40°C/min - 262.14, 258.26, 262.53

10. TNT/ICT NQ >297u (degrees C)
2°C/min - 215.03, 214.44, 217.02
5°C/min - 232.53, 231.52, 232.68
10°C/min - 238.95, 236.63, 236.7
20°C/min - 250.3, 252.97, 249.98
40°C/min - 260.18, 262.17, 263.11

11. TNT/ICT NQ crushed 106-210u (degrees C)
2°C/min - 214.93, 217.59, 214.7
5°C/min - 227.17, 227.39, 231.46
10°C/min - 237.79, 236.68, 235.5
20°C/min - 249.39, 249.41, 249.83
40°C/min - 261.03, 260.8, 259.24

I converted these results to degrees Kelvin and averaged them to obtain a mean value for each test condition. I used the SuperCalc3 Least Squares Program to plot the line of the logarithm of the heating rate versus the reciprocal peak temperature (appendix C). I compared the activation energy of the type of recrystallization method, the particle size, and particle shape. Finally I compared the pre-exponential factor of each explosive.

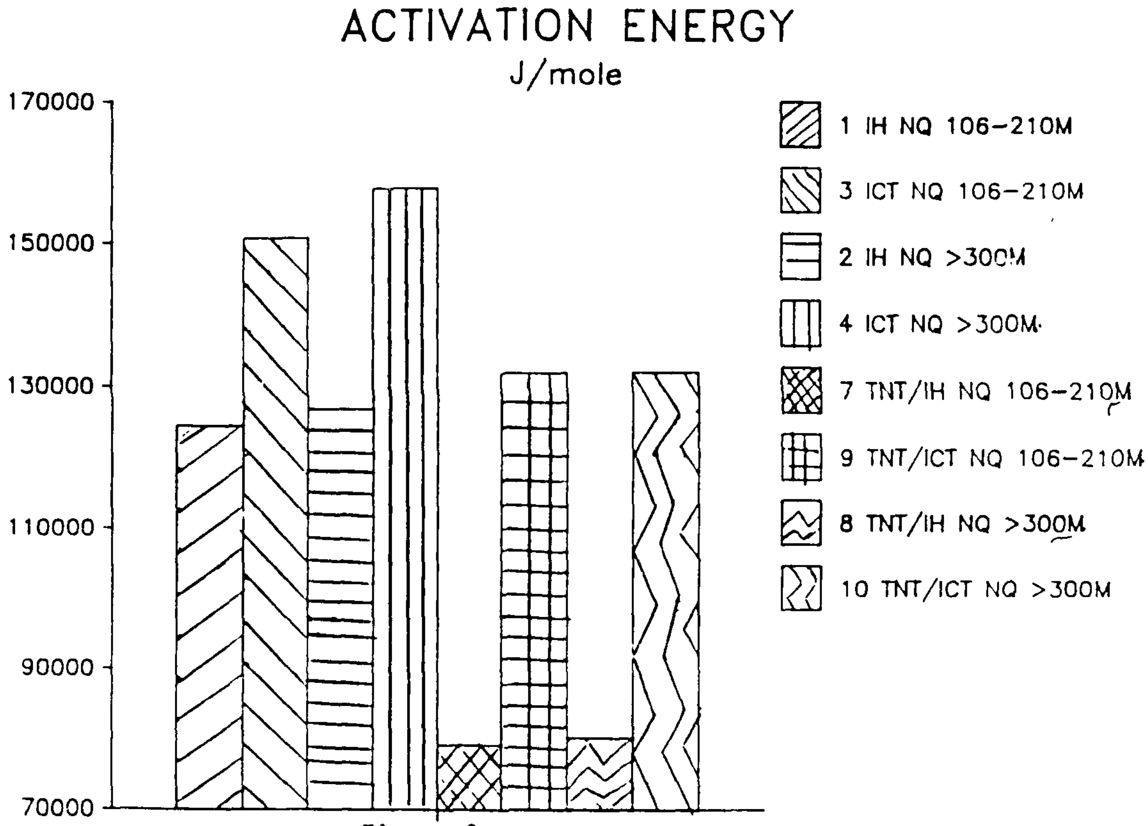


Figure 2

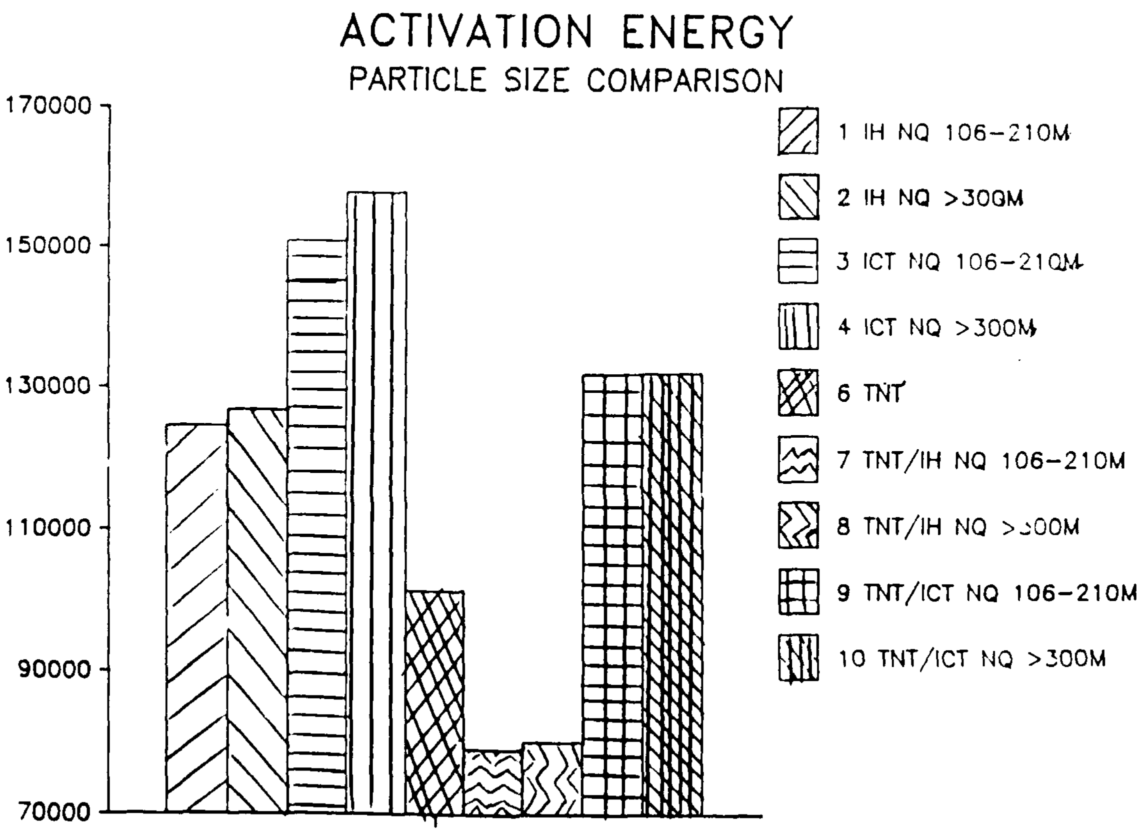


Figure 3

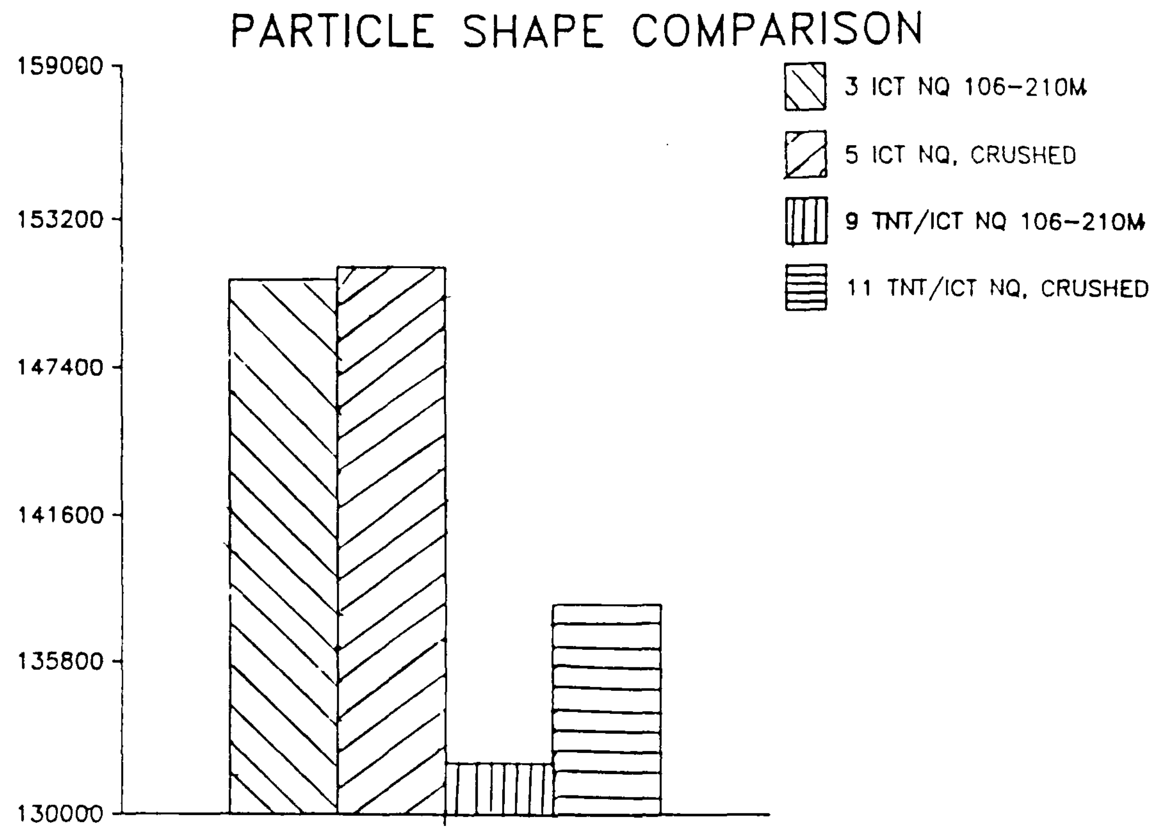


Figure 4

PRE-EXPONENTIAL FACTOR

		Average
1.	IH NQ 106-210 u	4826.70 e9
2.	IH NQ >300 u	9412.47 e9
3.	ICT NQ 106-210 u	948568.71 e9
4.	ICT NQ >300 u	5296857.93 e9
5.	ICT NQ, crushed	1150118.77 e9
6.	TNT	1.20 e9
7.	TNT/IH NQ 106-210 u	.09 e9
8.	TNT/IH NQ >300 u	.13 e9
9.	TNT/ICT NQ 106-210 u	17043.13 e9
10.	TNT/ICT NQ >300 u	17865.75 e9
11.	TNT/ICT NQ, crushed	79638.06 e9

Table 2

Conclusions

A difference in activation energy and pre-exponential factor between IH NQ and ICT NQ does exist. Since the ICT NQ has a higher activation energy and pre-exponential factor, it is more thermally stable. There seems to be a small difference in the activation energy and pre-exponential factor due to particle size and particle shape, but it is not significant compared to the margin of error. The addition of TNT to either NQ lowered the activation energy, i.e., TNT causes the NQ to be more sensitive and less thermally stable. From the viewpoint of thermal stability the ICT NQ is possibly the better NQ to use in insensitive high explosives. The particle shape and size do not effect the sensitivity significantly.

Summary

I compared the activation energy and pre-exponential factor, kinetic parameters, of two types of nitroguanidine; IH NQ and ICT NQ, two particle size ranges; 106-201microns and >297microns, and three particle shapes; cubical, spherical, and crushed. I used a variable heating rate method of Ozawa using a differential scanning calorimeter to find the activation energy and pre-exponential factor. I found the ICT NQ has a higher thermal stability thus the ICT NQ may be the better nitroguanidine to be used for insensitive high explosives.

References

Fedoroff, Basil T., and Sheffield, Oliver E. Encyclopedia of Explosives and Relate Items, Volume 6. Springfield, Virginia: National Technical Information Service, 1974, pp. G154-G159.

Kaye, Seymour M. Encyclopedia of Explosives and Related Items, Volume 9. Springfield, Virginia: National Technical Information Service, 1980, pp. T235-T298.

Ozawa, T. "Kinetic Analysis of Derivative Curves in Thermal Analysis." J Thermal Anal. Volume 2, 1970 pp. 301-324. (As described in: Baker, K. F. "Thermal Stability of Potentially Hazardous Materials by Differential Scanning Calorimetry (DSC)." DuPont Company, Application Brief.)

Perkin-Elmer. Instructions to Perkin-Elmer Model 3600 Data Station PETOS OS/12. Norwalk, Connecticut: Perkin-Elmer, 1983.

Meyer, Rudolf. Explosives. Deefield Beach, Florida: Verlag Chemie, 1981, pp. 240-242.

APPENDIX A

	Explosive	2/min	5/min	10/min	20/min	40/min
1	IH NQ 106-21ou	480.08	492.85	501.31	515.1	528.21
2	IH NQ >300u	479.09	491.43	500.32	514.15	525.58
3	ICT NQ 106-210u	497.78	511.37	520.29	531.38	538.97
4	ICT NQ >300u	498.13	510.6	518.83	529.43	538.24
5	ICT NQ, CRUSHED	496.79	510.05	519.33	529.38	538.62
6	TNT	523.47	538.88	554.06	578.54	594.64
7	TNT/IH NQ 106-210u	472.54	478.86	488.45	503.91	522.66
8	TNT/IH NQ >300u	472.97	481.63	487.53	501.28	521.94
9	TNT/ICT NQ 106-210	487.75	502.8	511.83	524.9	534.13
10	TNT/ICT NQ >300u	488.65	501.4	510.57	524.23	534.97
11	TNT/ICT NQ, CRUSH	488.89	501.82	509.81	522.69	533.51

Table 3. Average Peak Temperatures (K)

ACTIVATION ENERGY

Compound	Activation Energy (J/mol)
1. IH NQ 106-210u	124492 +/- 17442
2. IH NQ >297u	126841 +/- 15074
3. ICT NQ 106-210u	150865 +/- 9163
4. ICT NQ >297u	157810 +/- 10623
5. ICT NQ crushed	150865 +/- 9163
6. TNT	101259 +/- 12614
7. TNT/IH NQ 106-210u	79040 +/- 20091
8. TNT/IH NQ >297u	80061 +/- 29877
9. TNT/ICT NQ 106-210u	131947 +/- 14053
10. TNT/ICT NQ >297u	132057 +/- 12903
11. TNT/ICT NQ, crushed	138058 +/- 14130

Table 4. Calculated Activation Energies

	2^o/min	5^o/min	10^o/min	20^o/min	40^o/min
1	4565.11	4826.27	5587.11	4757.35	4397.66
2	8983.54	9594.59	10663.95	8892.93	8927.37
3	993886.20	893605.03	939608.25	870049.06	1045695.01
4	5412924.87	5078527.08	5536631.04	5036563.68	541964.97
5	1208384.07	1105498.42	1127095.13	1115186.41	1194429.83
6	1.13	1.37	1.39	1.01	1.08
7	.05	.09	.11	.12	.11
8	.06	.10	.15	.17	.15
9	18044.01	16028.74	17726.44	15575.42	17841.03
10	17411.77	18089.87	19752.75	16659.82	17414.53
11	78332.76	77469.41	89373.71	76206.38	76808.03

Table 5. Pre-exponential Factor (min^{-1} $x10^9$) at each heating rate

APPENDIX B

CALCULATION OF THE ACTIVATION ENERGY AND PRE-EXPONENTIAL FACTOR
ICT NO 106-210u

ACTIVATION ENERGY (E) J/mol

$$E = 2.19R \frac{d\log B}{d(1/T)}$$

The peak temperatures were converted to Kelvin ($K = {}^{o}C + 273.15$) and the logarithm of the heating rate is plotted against the reciprocal of the peak temperature (dlogB)/(d(1/T)). This line is plotted using SuperCalc3 least squares (Appendix C). slope = -8285.79 K

Heat rate B (°C/min)	Log B	Temperature (K)	1/T
2	.30103	497.28	.00200818[illegible]
5	.69897	511.37	.0019555[illegible]
10	1	520.29	.00192200[illegible]
20	1.30103	531.30	.0018818[illegible]
40	1.60206	538.97	.0018553[illegible]

E = 2.19 * 8.314 J/mol K * -8285.79 K
 = ABS-150864.85 J/mol

PRE-EXPONENTIAL FACTOR (Z) min^{-1}

$$Z = \frac{Ee^{E/RT}}{RT^2}$$

Expressed in logarithmic form,

$$LnZ = LnB + LnE + E/(RT) - LnR - 2LnT$$
$$LnZ = Ln[(BE)/(RT^2)] + E/(RT)$$

$$Z = e^{Ln[(be)/(RTT)] + E/(RT)}$$

B C/min	E/RT
2	151.55[illegible]
5	54.0041185[illegible]
10	[illegible]
20	14.1385570[illegible]
40	[illegible]

$$Z = \frac{10\ K/min * 150864.85\ J/mole}{10\ K/min * 520.29^2} * e^{150864.85\ J/mole/\ (10K/min\ *\ 520.29\ K)}$$

$LnZ = Ln(10*150864.85)/(8.314*520.29^2) + 150864.85/(8.314*520.29)$

$Z = 9.3961e14\ min^{-1}$

APPENDIX C

LOG RATE = Y 1/T = X

Explosive	SLOPE	Y INTERCEPT
1. IH NQ 106-210u	-6837.34+/- 957.93	14.58+/-31.26
2. IH NQ >297u	-6966.34+/- 827.79	14.87+/-26.46
3. ICT NQ 106-210u	-8285.79+/- 503.19	16.93+/-14.03
4. ICT NQ >297u	-8667.22+/- 583.34	17.69+/-15.52
5. ICT NQ crushed 106-210u	-8312.02+/- 544.02	17.01+/-15.09
6. TNT	-5561.36+/- 692.68	10.97+/-30.78
7. TNT/IH NQ 106-210	-4341.06+/- 1103.28	9.88+/-54.58
8. TNT/IH NQ >297u	-4397.08+/- 1640.69	10.00+/-79.24
9. TNT/ICT NQ 106-210u	-7246.78+/- 771.71	15.14+/-24.21
10. TNT/ICT NQ >297u	-7252.83+/- 708.59	15.16+/-22.20
11. TNT/ICT NQ crushed	-7582.4 +/- 775.97	15.82+/-23.23

Table 6. Least Squares Equations

Figure 5.

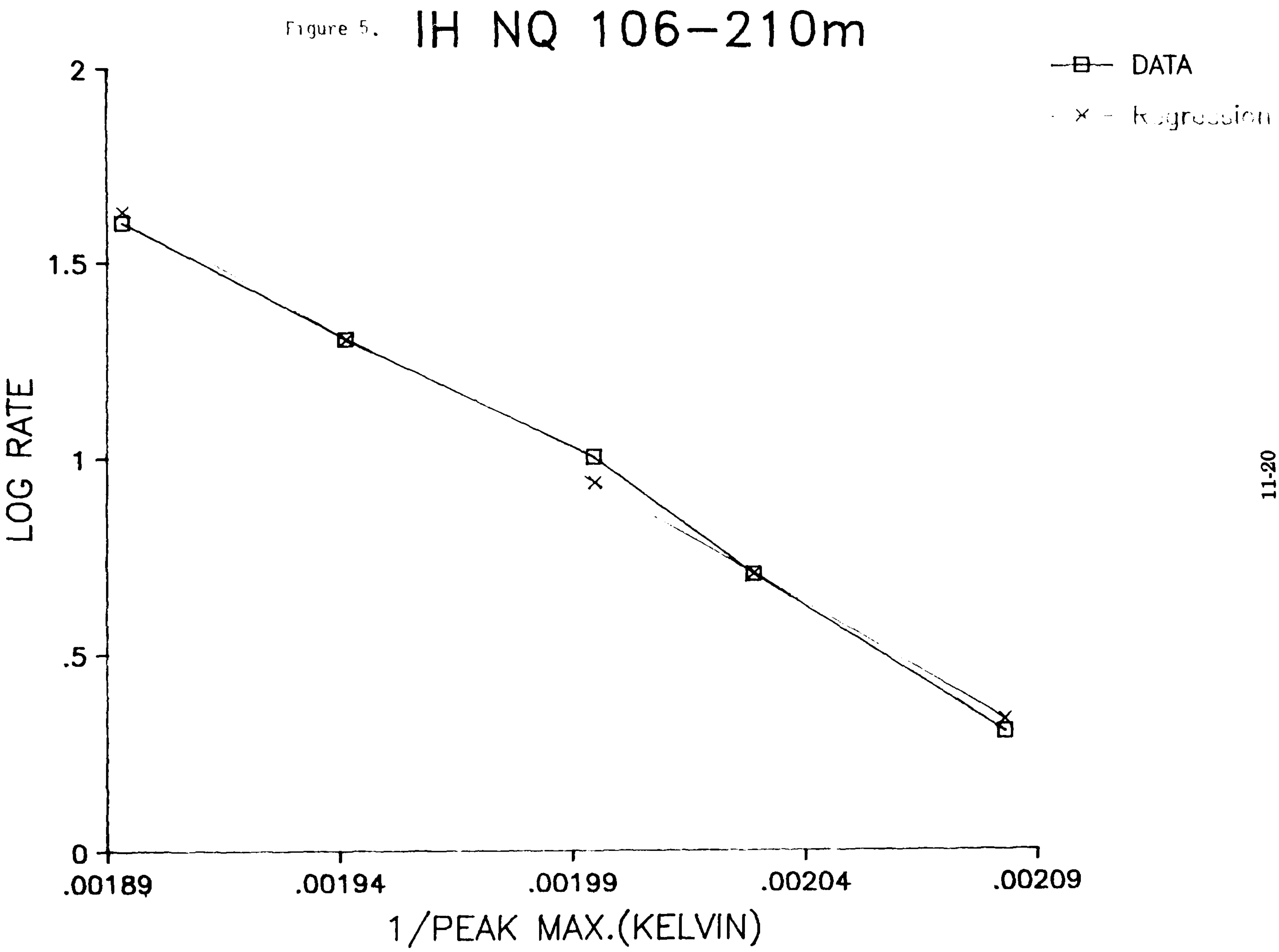

IH NQ 106–210m
DATA
Regression
2
1.5
1
.5
0
LOG RATE
.00189
.00194
.00199
.00204
.00209
1/PEAK MAX.(KELVIN)

Figure 6.

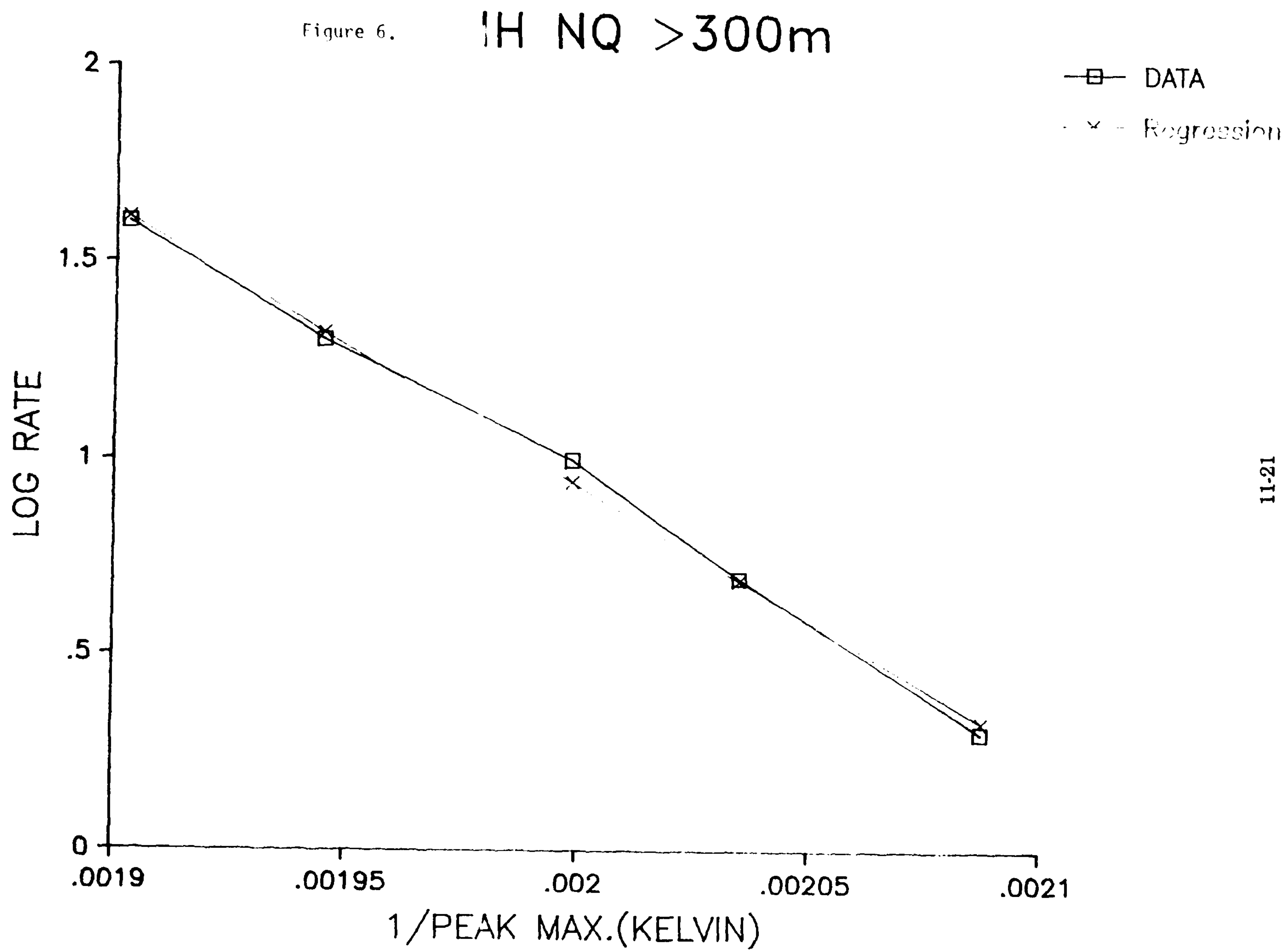

IH NQ >300m
DATA
Regression
LOG RATE
2
1.5
1
.5
0
.0019
.00195
.002
.00205
.0021
1/PEAK MAX.(KELVIN)

Figure 7. ICT NQ 106–210M

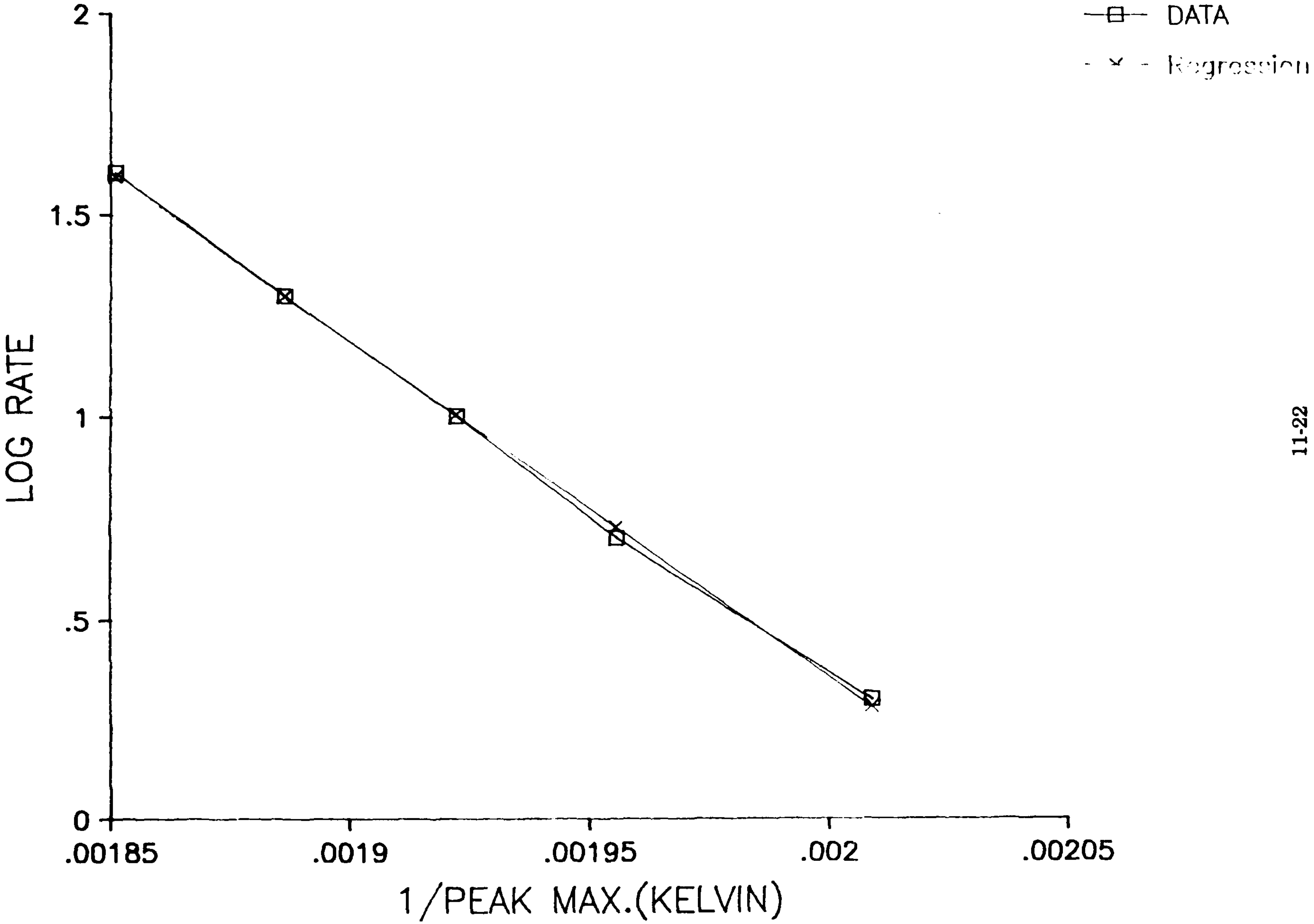


Figure 8.

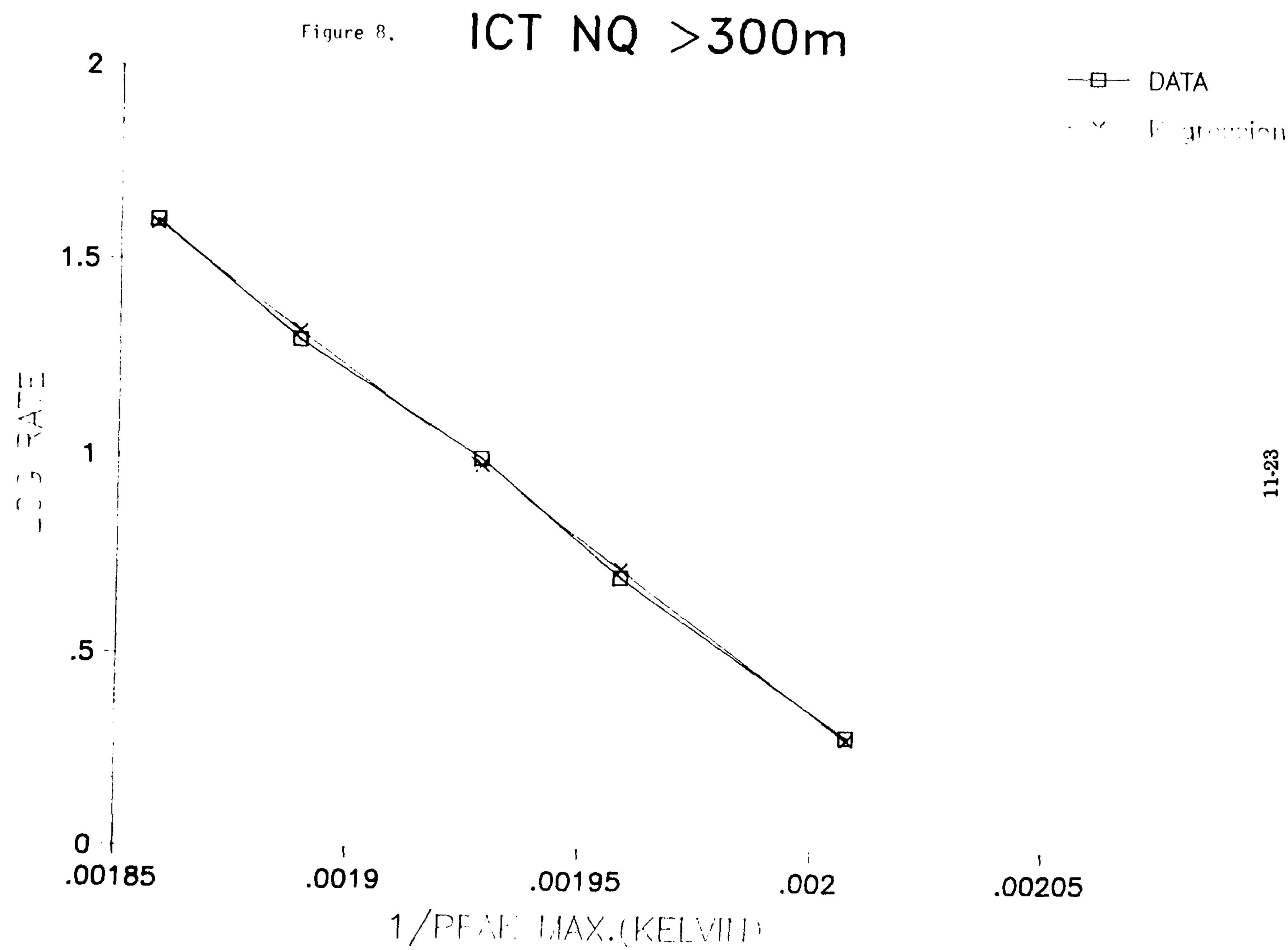


Figure 9.

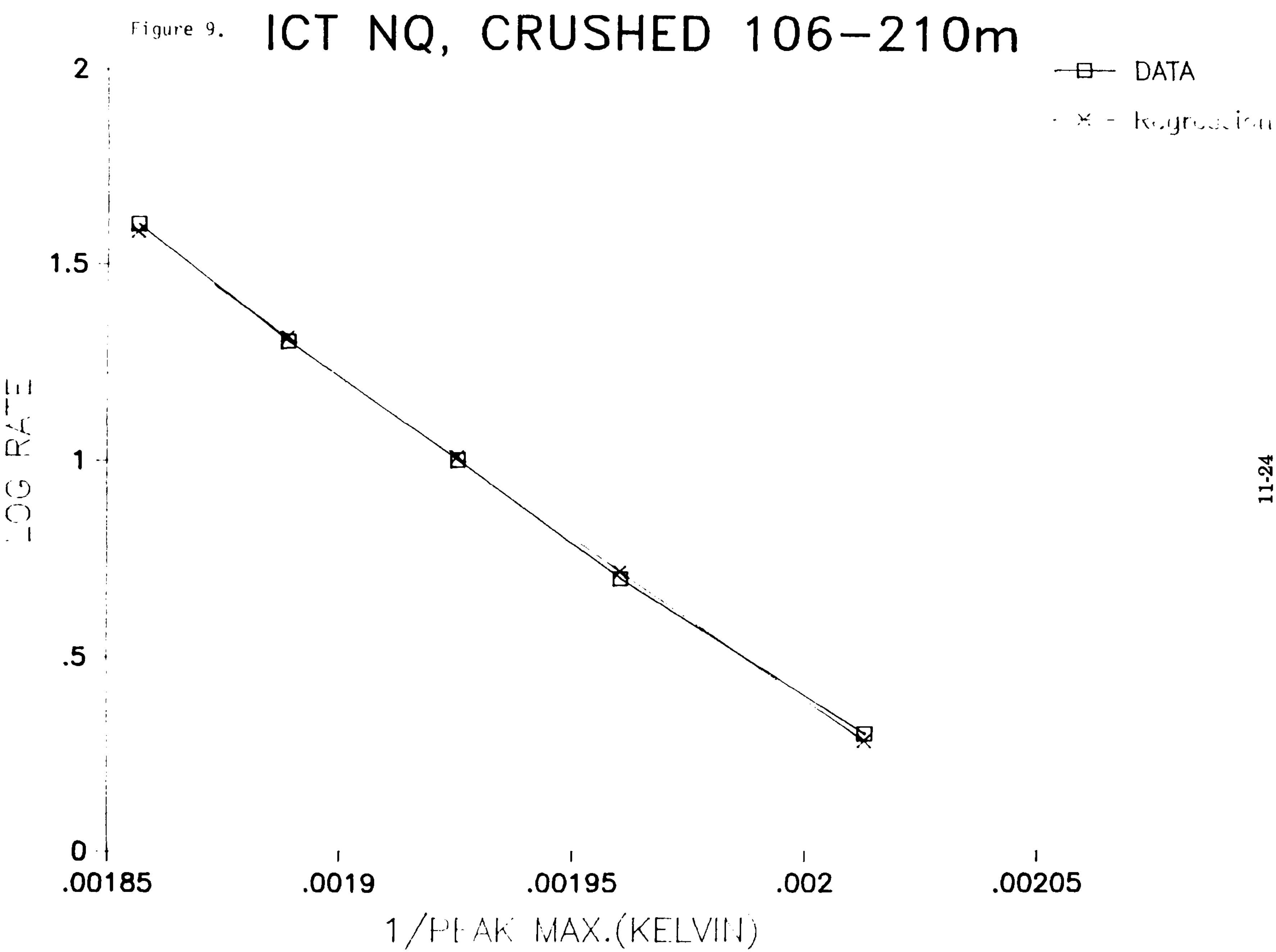

ICT NQ, CRUSHED 106–210m
DATA
Regression
2
1.5
1
.5
0
LOG RATE
.00185
.0019
.00195
.002
.00205
1/PEAK MAX.(KELVIN)

Figure 10. TNT

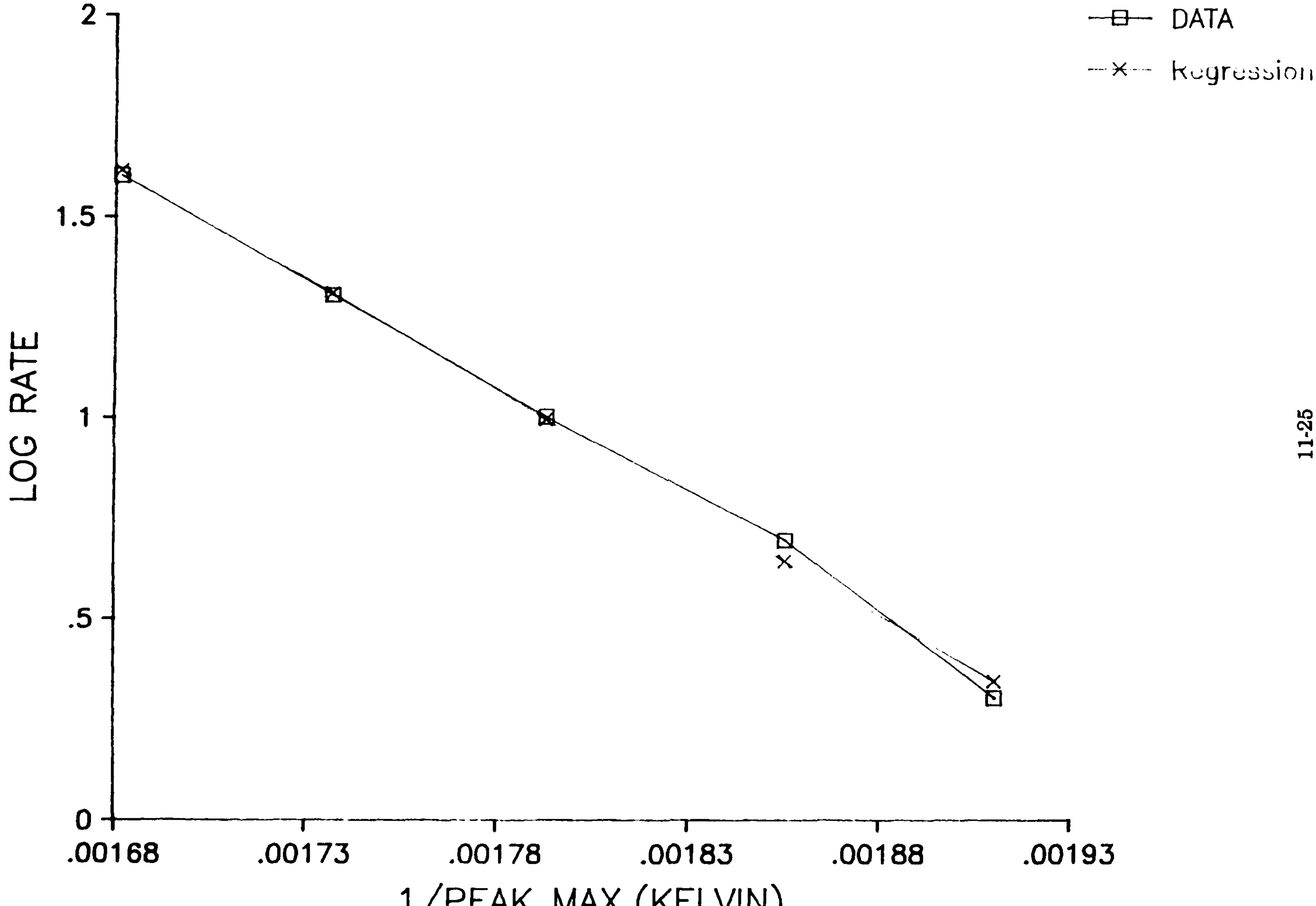


Figure 11. TNT/ IH NQ 106—210M

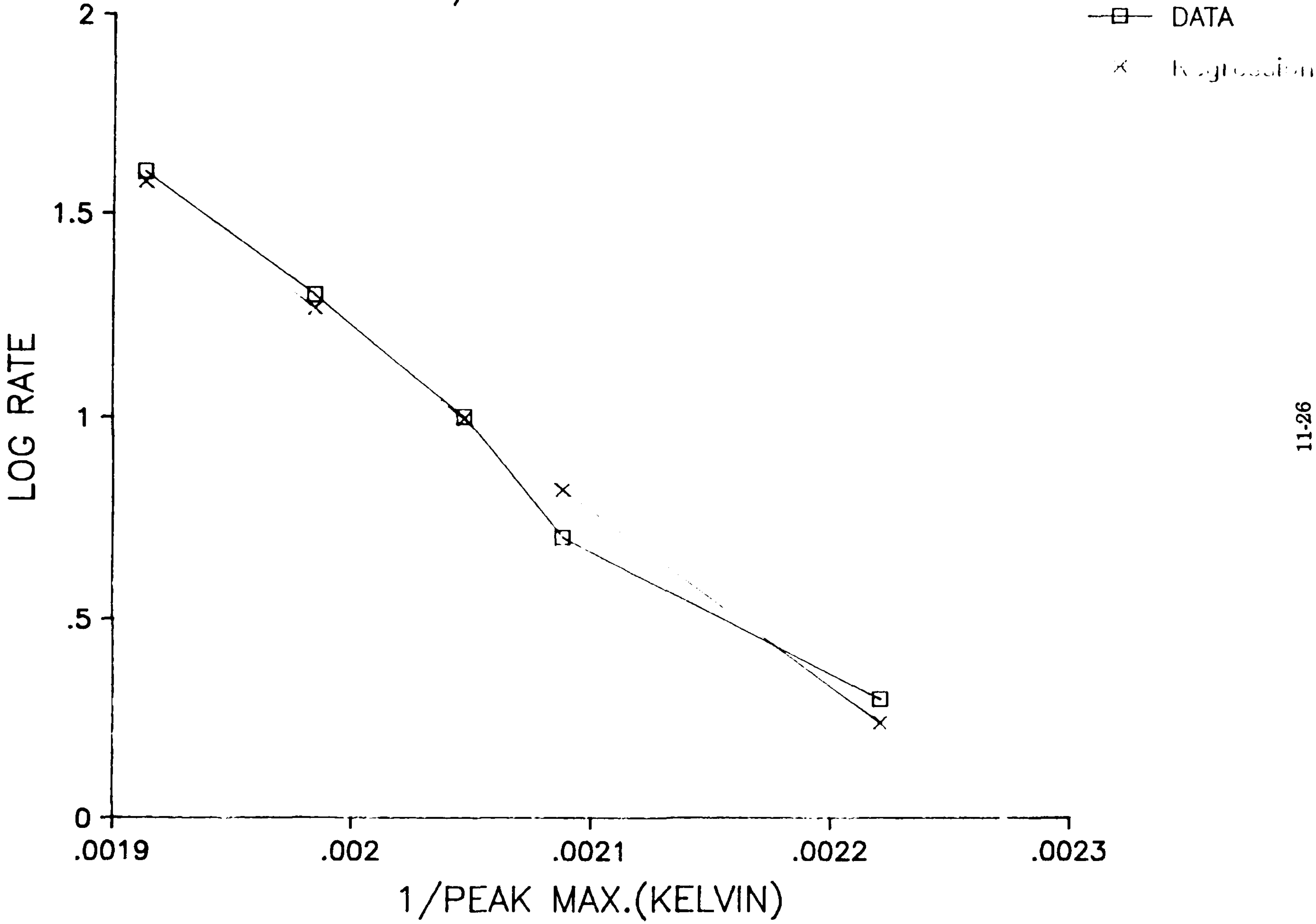


Figure 12. TNT/ IH NQ >300M

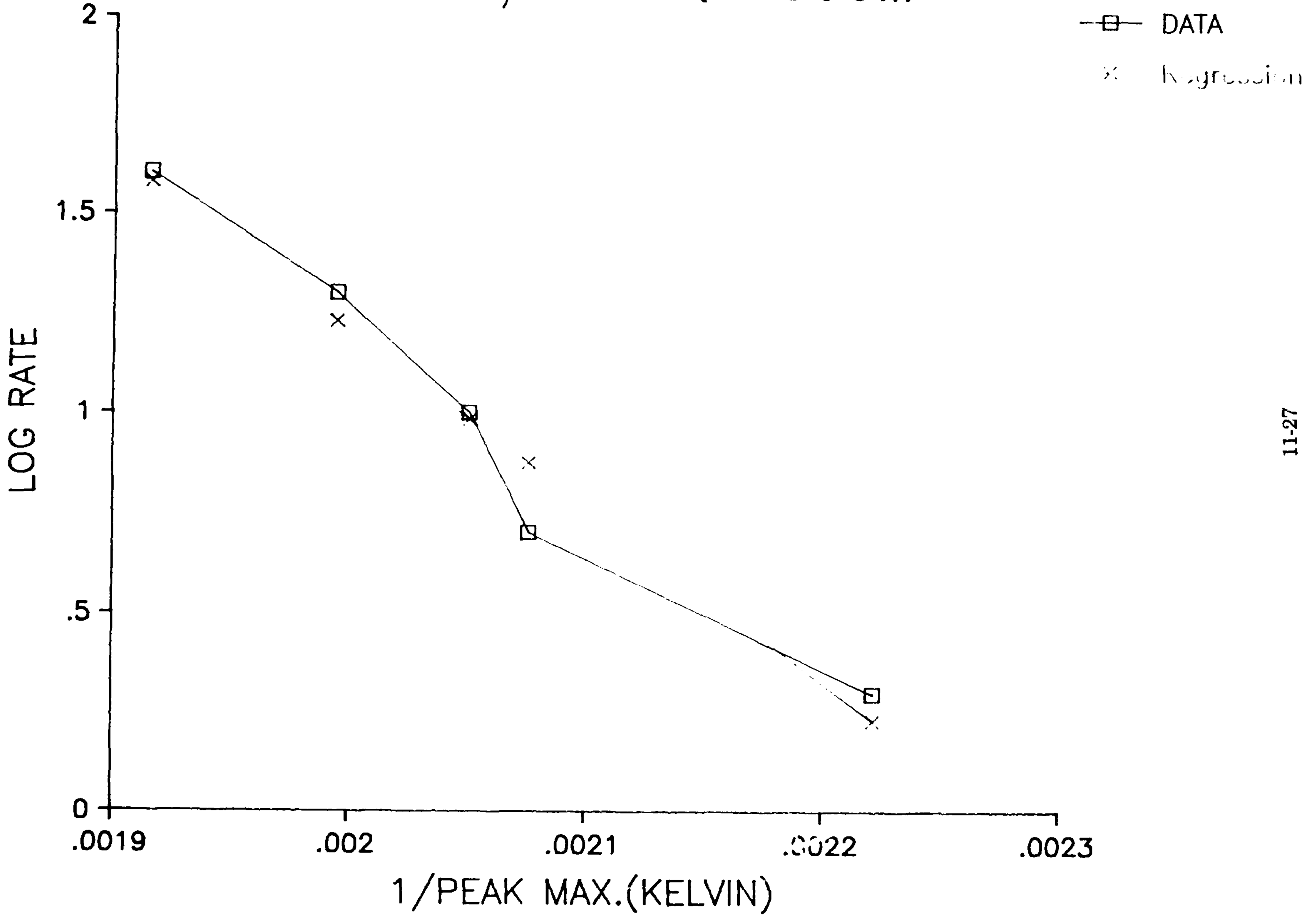


Figure 13. TNT/ICT NQ 106–210m

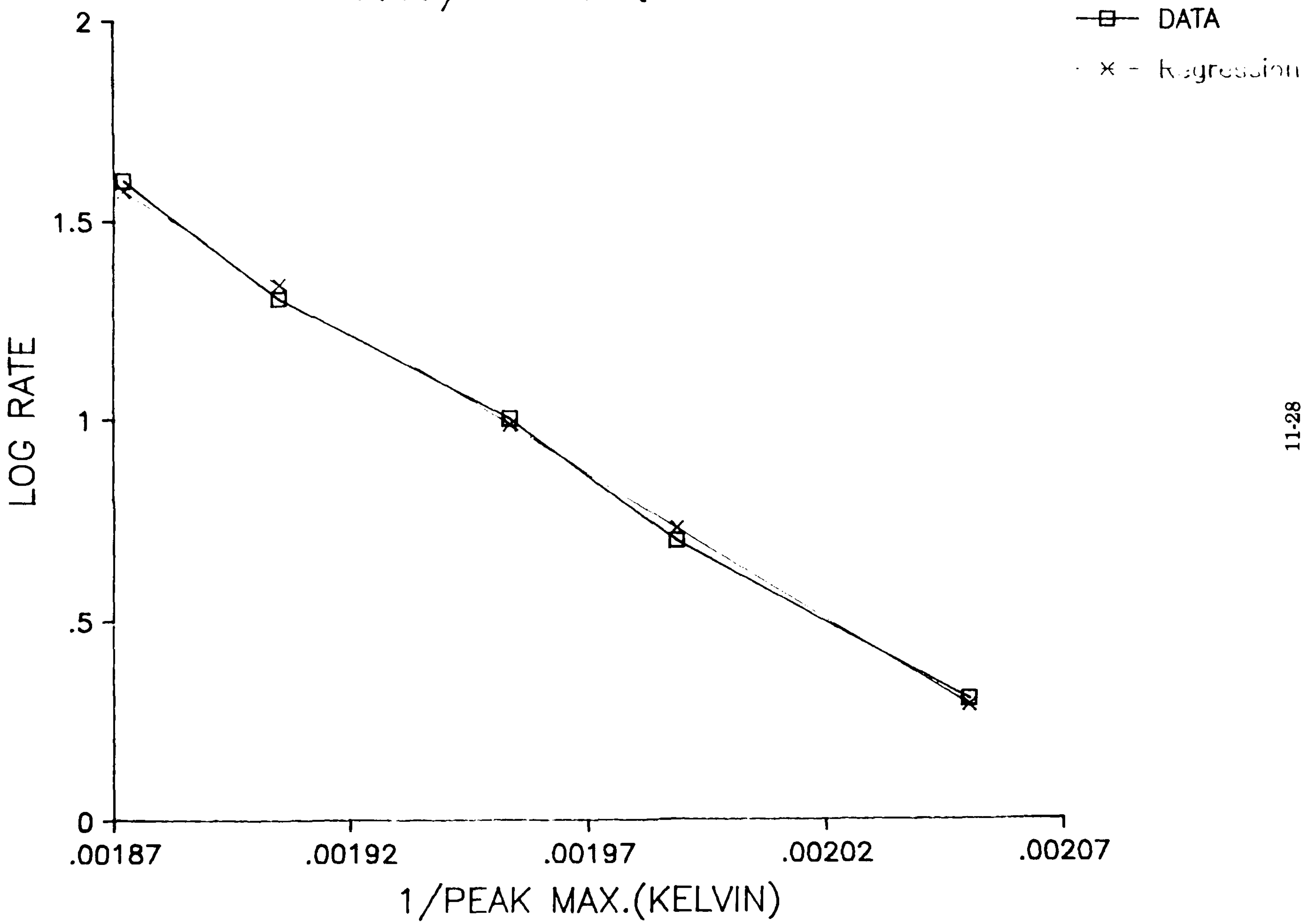


Figure 14. TNT/ ICT NQ >300M

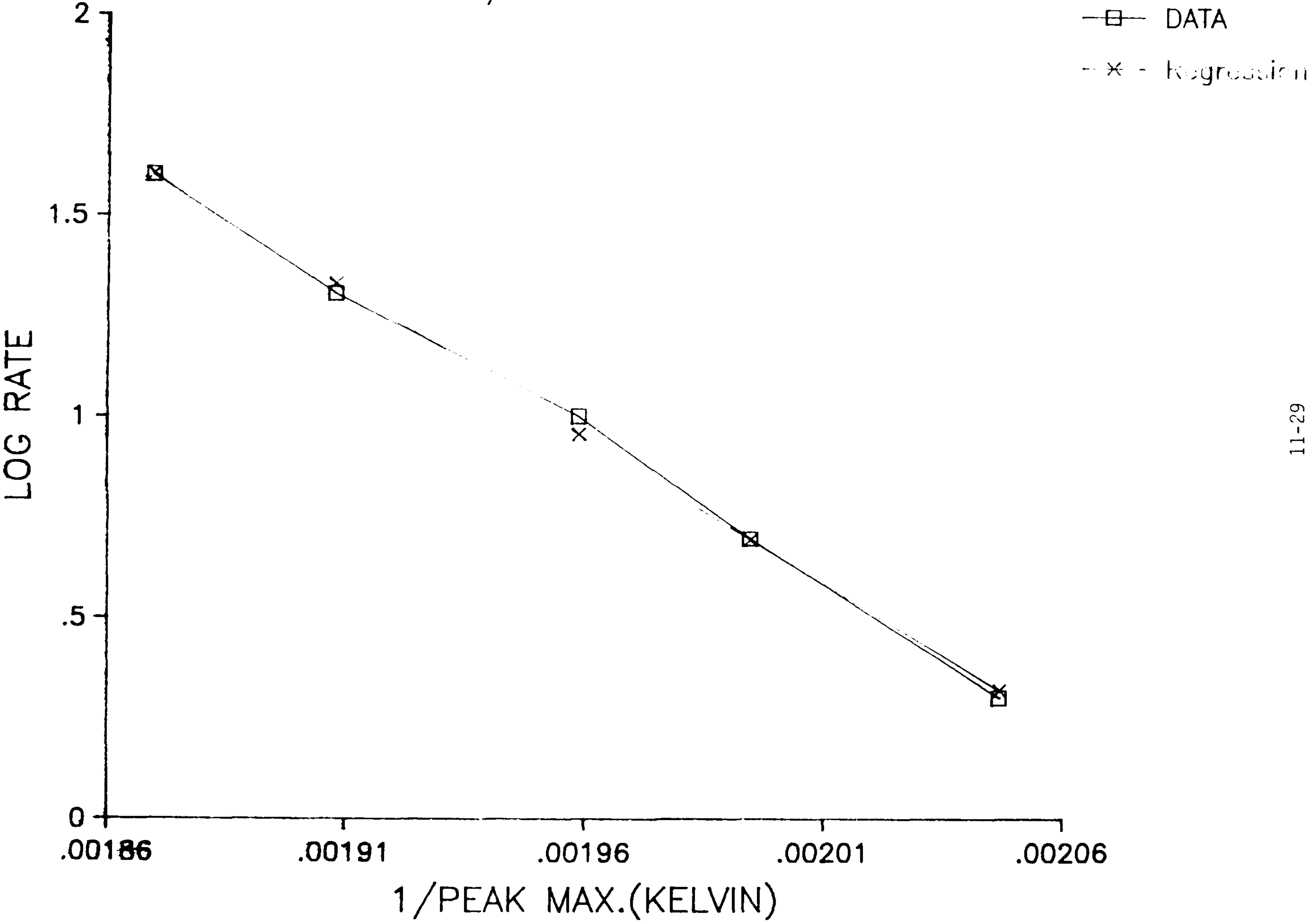
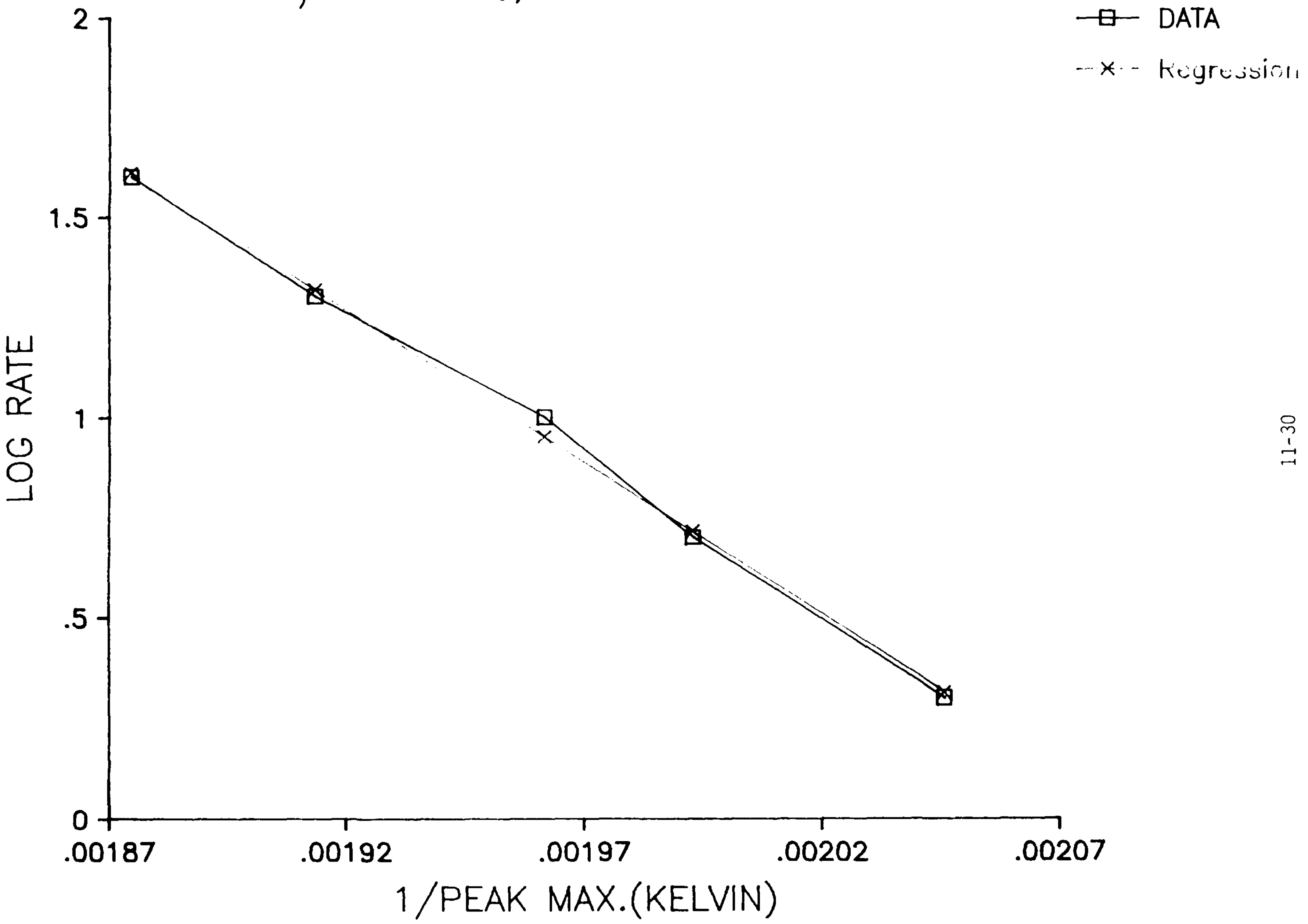


Figure 15. TNT/ICT NQ, CRUSHED 106–210m



Comparison of Average vs. Spectral LOWTRAN in Calculating Exitance

by

Christopher Ellis

mentors:
Michael Deiler
Mike Wallace

Research Paper for 1989 HSAP Program

]

TABLE OF CONTENTS

SECTION 1. INTRODUCTION

1.1 Introduction to summer research

The following is my final report on my research during the 1989 summer High School Apprenticeship Program (HSAP), Eglin AFB, Air Force Armament Lab, Advanced Guidance Instrumentation Division , Radar & Image Simulation Section (AFATL/AGI/RIS).

1.2 Introduction to hardware and software used

My summer research involved an enormous amount of computer work, giving me experience that will last well into my future. My primary machine was a GPX Graphics Workstation coupled to a Digital MicroVax. I also used the RSPL (Radar Signal Processing Lab) facilities extensively for plotting work. The PrintServer 40 served as an invaluable tool for printing out graphs.

Another challenge presented to me this summer was learning a new language, FORTRAN. My extensive experience with BASIC and PASCAL, though, eased the transition quite well.

1.3 Introduction to passive armaments

Missile technology, although it has developed infinitesimally since its conception, is still in the midst of amazing technological developments. With these improvements are also several ambitious goals, guideposts for the future. One need, in particular, is the development of passive seekers. Passive armaments, much like our eye, gather wave energy for analysis while giving no sign of their presence. In contrast, active seekers, such as Radar, transmit a signal that can be detected and/or jammed by the enemy. Passive armaments are ideal in that they give no clue of their existence until they are detected or their mission is completed.

SECTION 2. THE INFRARED

2.1 Introduction

The infrared spectrum is an ideal choice for missile seekers. Aside from IR lasers, which are active, there are passive IR seekers which merely 'listen' to IR wavelengths emitted by an object, such as a tank or an airplane. Also, for nighttime uses, where visual light is virtually nonexistent, seekers sensitive to IR can pick up targets out of darkness.

An important term to know is the micron(u), or micrometer. It is a unit of length and measures wavelength.

The term infrared refers to the range of the electromagnetic spectrum from .8u to 1000u. Visible light, in contrast, occupies the range from .4u to .8u.

2.2 Wavenumbers

Another important concept to understand is the wavenumber. The values with unit u are wavelengths, measured in microns. When dealing with intervals of one or two microns, it is inconvenient to subdivide into many parts. To compensate for this, there is a concept called the wavenumber. It, too, is a measure of wavelength, and is given by:

$$Wn = \frac{10,000}{u}$$

Thus, the 4-5u range could be restated as the wavenumbers 2500-2000. The wavenumber has units cm^{-2}. This number is also the number of waves per centimeter.

Two ranges in the infrared spectrum are of particular interest and were used in the summer's research. These are the 4-5u range (2500-2000) and the 8-12u range (1250-830).

When talking about the IR, the term blackbody comes up. A blackbody is one which is a perfect absorber; and since energy is conserved, a perfect emitter. A blackbody is the perfect object for IR study, and theoretically can never actually exist.

SECTION 3. EXITANCES AND TRANSMITTANCES

3.1 Definition

Exitance, with units W cm^{-2}, is a value which tells how much energy is emitted by an object per unit surface area. The total exitance is the integration of the exitance curve over the interval of the wavenumbers. The total exitance is an important descriptor of how 'bright' an object will be.

Transmittance is a value, usually a percentage, which tells what percentage of each wavelength will survive a particular scenario, in our case, going through the atmosphere

The three factors I used to calculate exitance are Plank's curve, the plume curve, and the output of the LOWTRAN program.

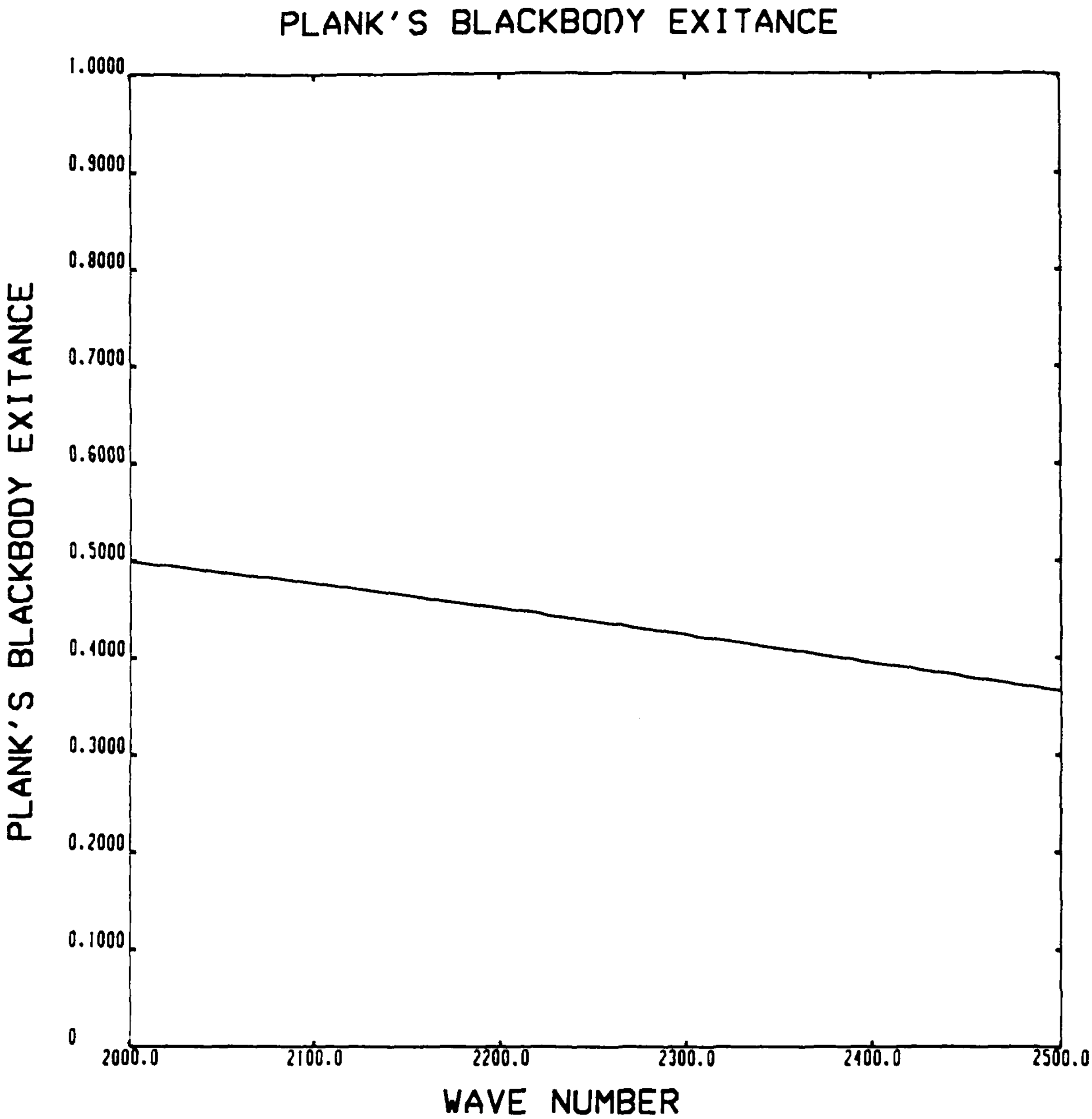
3.2 The three factors: Plank, plume, and LOWTRAN

The Plank curve is a theoretical one. It was first described by Plank in the late nineteenth century as an outgrowth of quantum mechanics. For a given temperature and frequency (wavenumber), it will give the exitance of a blackbody. Since a blackbody represents an ideal, other values can be calculated from it. Various parts of the plume are different temperatures, and the range from 300K to 800K was considered.

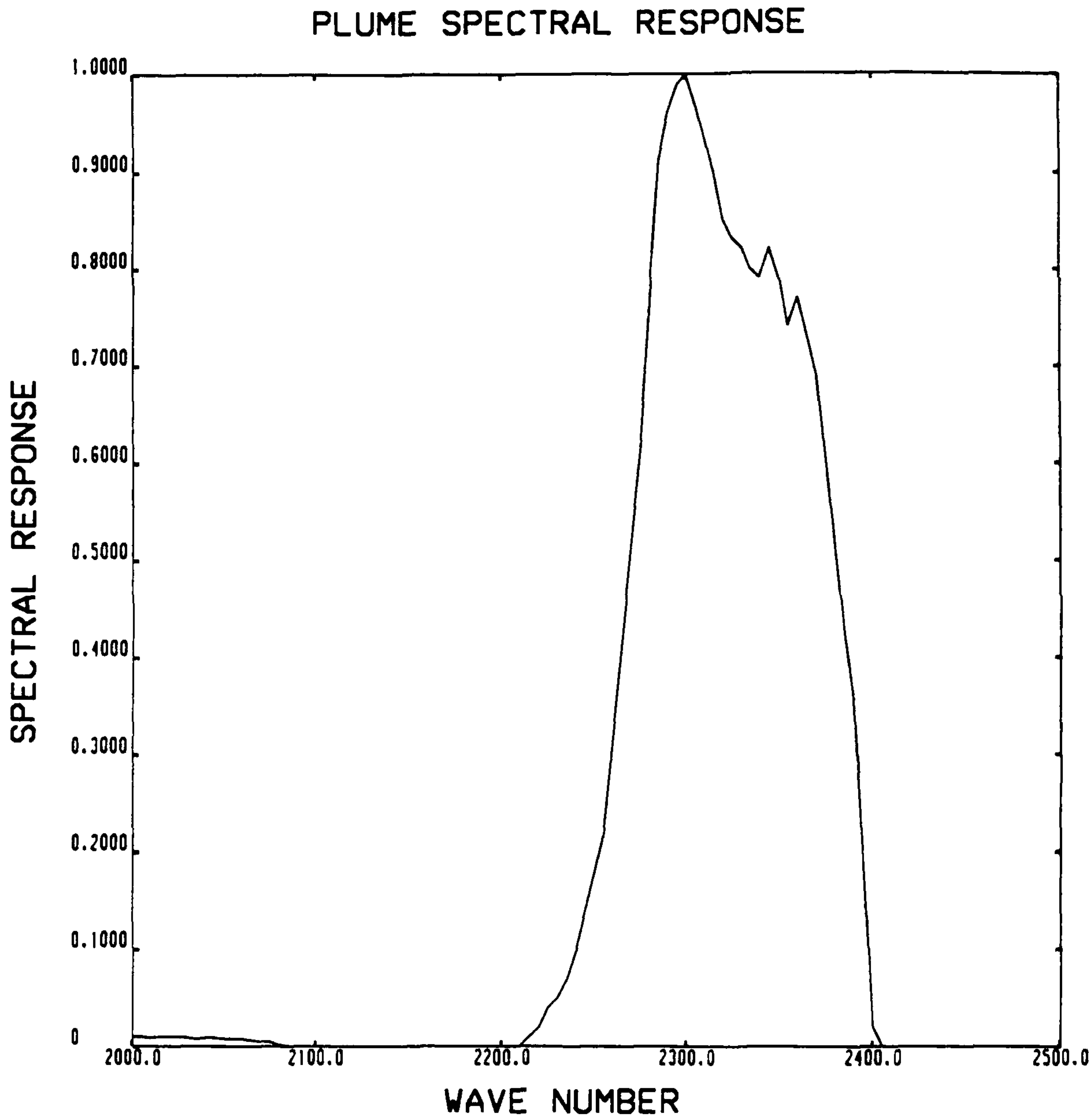
The plume curve is what is known as a spectral response curve. In the plume, there are two abundant chemicals which emit radiation in the IR spectrum - CO_2 and H_2O. The spikes in the graph are due to particularly high emissions by these substances. The plume file contains coefficients, normalized to one, which 'correct' Planks curve. By multiplying the plume value of a given wavelength by Plank's blackbody exitance for that wavelength, the exitance at that wavelength for that plume can be found.

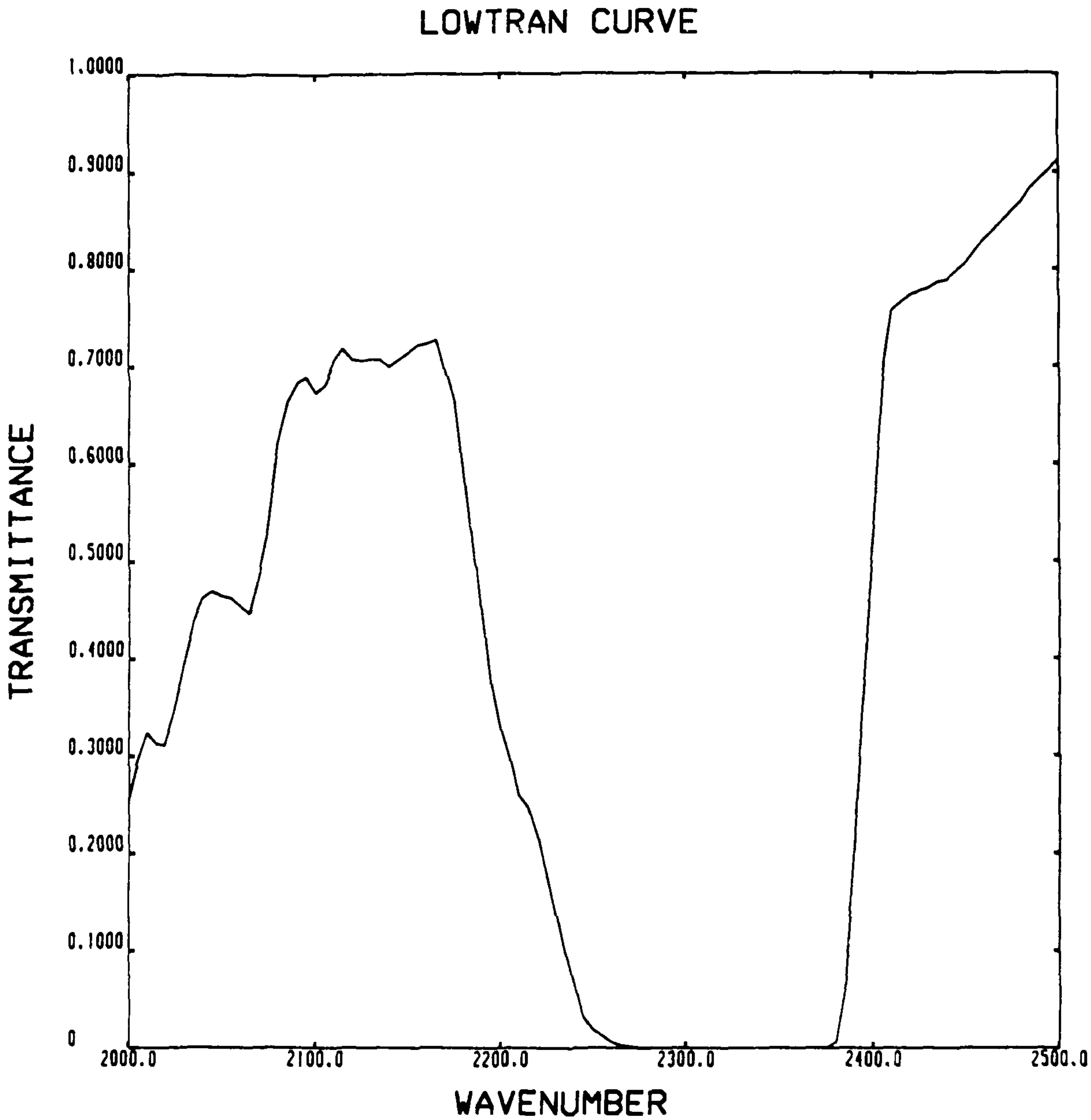
Now, the energy must travel through the atmosphere, where some of it may be absorbed. The LOWTRAN program aids here.

LOWTRAN is a program which tells what percent of the energy at each wavelength will make it through a certain path through the atmosphere. It uses three parameters; H1, the attackers height, H2, the target's height, and R, the range (distance between the two planes. The LOWTRAN value for a particular wavelength is multiplied by Plank's value (an ideal curve) and the plume value (corrects Plank because the plume isn't a perfect blackbody). The result is the exitance for the part of the plume with the temperature specified in Plank's curve, and the distances specified by the LOWTRAN parameters.



PLANK'S BLACKBODY EXITANCE
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0
2000.0
2100.0
2200.0
2300.0
2400.0
2500.0
WAVE NUMBER
PLANK'S BLACKBODY EXITANCE


PLUME SPECTRAL RESPONSE
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0
SPECTRAL RESPONSE
2000.0
2100.0
2200.0
2300.0
2400.0
2500.0
WAVE NUMBER


LOWTRAN CURVE
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0
TRANSMITTANCE
2000.0
2100.0
2200.0
2300.0
2400.0
2500.0
WAVENUMBER

SECTION 4. PROCEDURE

4.1 Introduction

Looking at the resultant exitance graph for the interval 4-5u (2500-2000), it can be seen that the area encapsuled by the curves is quite small. This common area, 'legal' as determined by the three factors (plank, plume, LOWTRAN) is the exitance for the entire interval of 4-5u. To find the total exitance (area), the integral of the product of the three curves was found. To facilitate the examination of smaller intervals (In particular, 20Wn intervals) the integration was broken up into 20 Wn parts. The total exitance is simply the sum of all the integrations.

4.2 Programming

To accomplish this, I extensively modified a FORTRAN program, EXITANCE, which integrated only Planks curve. Modifications were made to read data from a LOWTRAN and plume file, and to break up the integration into 20 Wn parts, so that smaller ranges could be examined. Later, it was further modified to read multiple sets of LOWTRAN data, necessary since at times I was dealing with 60 different LOWTRAN cases.

4.3 LOWTRAN specifics

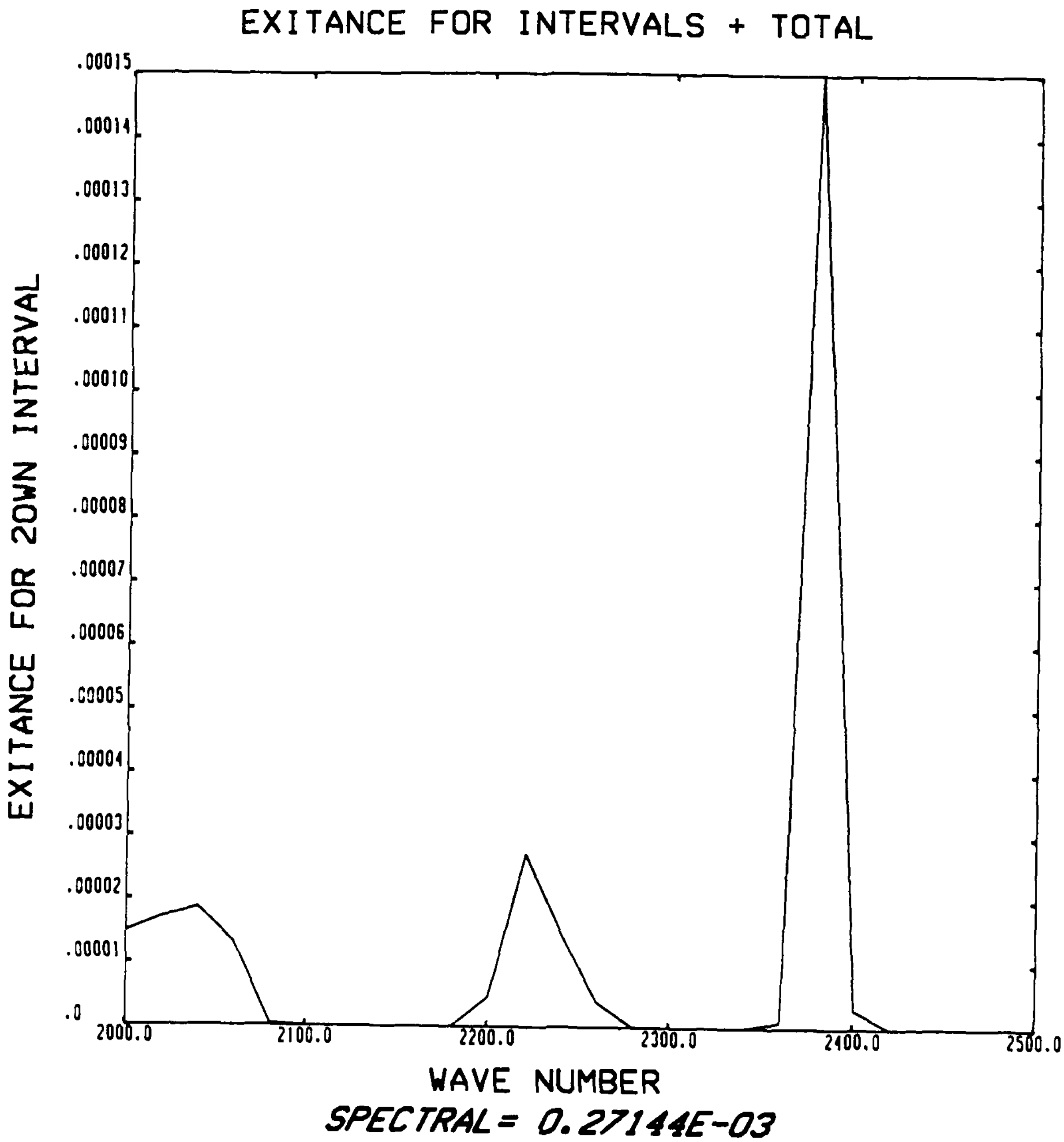
I used a wide variety of LOWTRAN parameters in order to get an accurate picture of what was going on. H1 (our height) spanned from 5K ft to 25K ft. H2 (target height) spanned from 5K ft to H1 plus 10k ft. The range spanned from 1k ft to 10k km. It is important to note that the LOWTRAN program is not perfect; several cases were 'spit out'. Specifically, when ABS(H2-H1) > R (the angle of attack was > 45^{o}), and when H1 and H2 were equal I did not concern myself with why these were rejected by the program, rather I worked around them. Any gaps noted are due to these 'illegal cases'.

4.4 Implementation

The actual integration was performed via Simpsons rule, a procedure which approximates area using parabolic arcs. The formula was at times tricky to use in a FORTRAN program, but its extreme accuracy rapidly outweighed any inconvenience it caused.

The exitance values next had to be plotted. A superb plotting program, XYPLOTF, was used. It read file data and produced Tektronics plot commands. It, too, had to be 'automated', since it was producing about 60 plots at a time. The TEKLASE procedure then produced the printable file. The digital PrintServer 40 was used to print out the plots.

Although the actual time required to type in code and supervise the printing of plots was extensive, a great deal of



EXITANCE FOR INTERVALS + TOTAL
.00015
.00014
.00013
.00012
.00011
.00010
.00009
.00008
.00007
.00006
.00005
.00004
.00003
.00002
.00001
.0
EXITANCE FOR 20WN INTERVAL
2000.0
2100.0
2200.0
2300.0
2400.0
2500.0
WAVE NUMBER
SPECTRAL= 0.27144E-03

'behind the scenes' work was done. Endless hours were spent in abstraction; coming up with schemes for modifying programs. The interpretation of data, too, took a great deal of effort. With several hundred graphs to consider, attempting to crunch the data to a more manageable form was a primary goal.

So it can be seen that by using Plank's equation, a plume graph, and a LOWTRAN graph that the total exitance of an object over a range of frequencies can be calculated. Simple, right? Wrong!

SECTION 5. AVERAGE LOWTRAN vs. SPECTRAL LOWTRAN

5.1 Introduction

In the procedure outlined, a spectral value of LOWTRAN was used, i.e. a LOWTRAN value calculated for each frequency. In the past few years, however, it has become permissible to use an average value, simply the average of all the spectral values. Supposedly, this is just as accurate as using the spectral values. In my research, I have discredited that theory for the interval of 4-5u (2500-2000).

5.2 Comparison of Graphs

The accompanying graph shows the resultant exitance with average LOWTRAN. The common area, what we call the total exitance, is outlandishly large. The next graph is an total exitance graph comparing the AVERAGE vs. SPECTRAL method. It shows the exitance as integrated over 20 Wn intervals. This way, we're not just looking at 2000-2500, but rather 2000-2020, 2020-2040, etc.
The flabbergastingly larger curve is the AVERAGE one. At the bottom is the total exitance in the entire range for both methods. As can be seen, the total exitance using the average LOWTRAN is nowhere near where is should be, by using the spectral values.

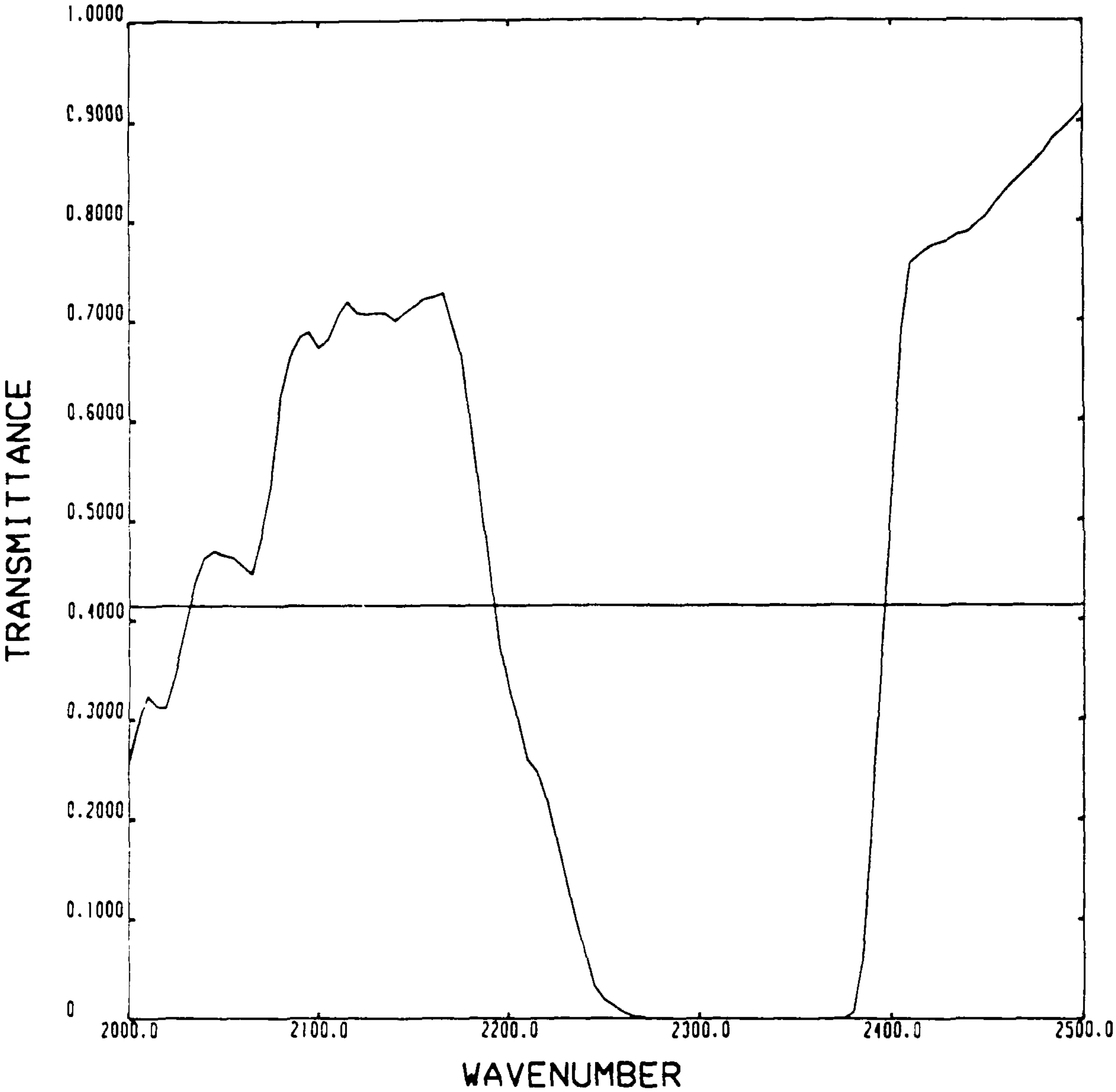
The next graph is the result of my efforts to compress the data. Each graph is for a particular LOWTRAN H1 and a particular Plank temperature. The x-axis is the range, in kilometers, and the y-axis is the ratio of the average total exitance to the spectral total exitance. The graphed lines are for each H2 used. The results are nothing less than shocking. The y-axis tells how many MAGNITUDES greater the 'average ' is!

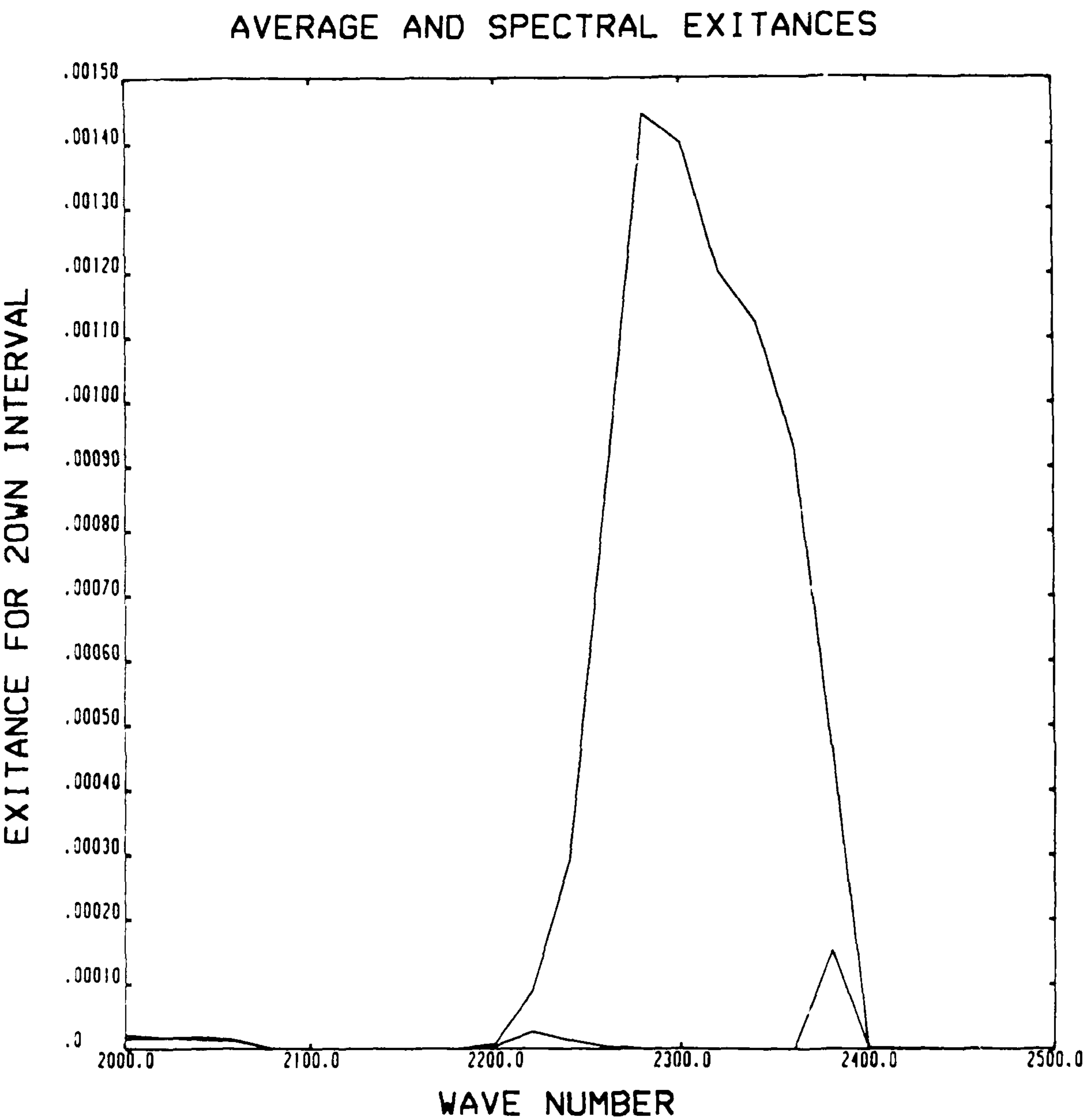
5.3 Conclusions

The average values are up to 50 MAGNITUDES greater than the spectral values. For all temperatures and cases to be noted, the average value is many magnitudes greater than the spectral value.

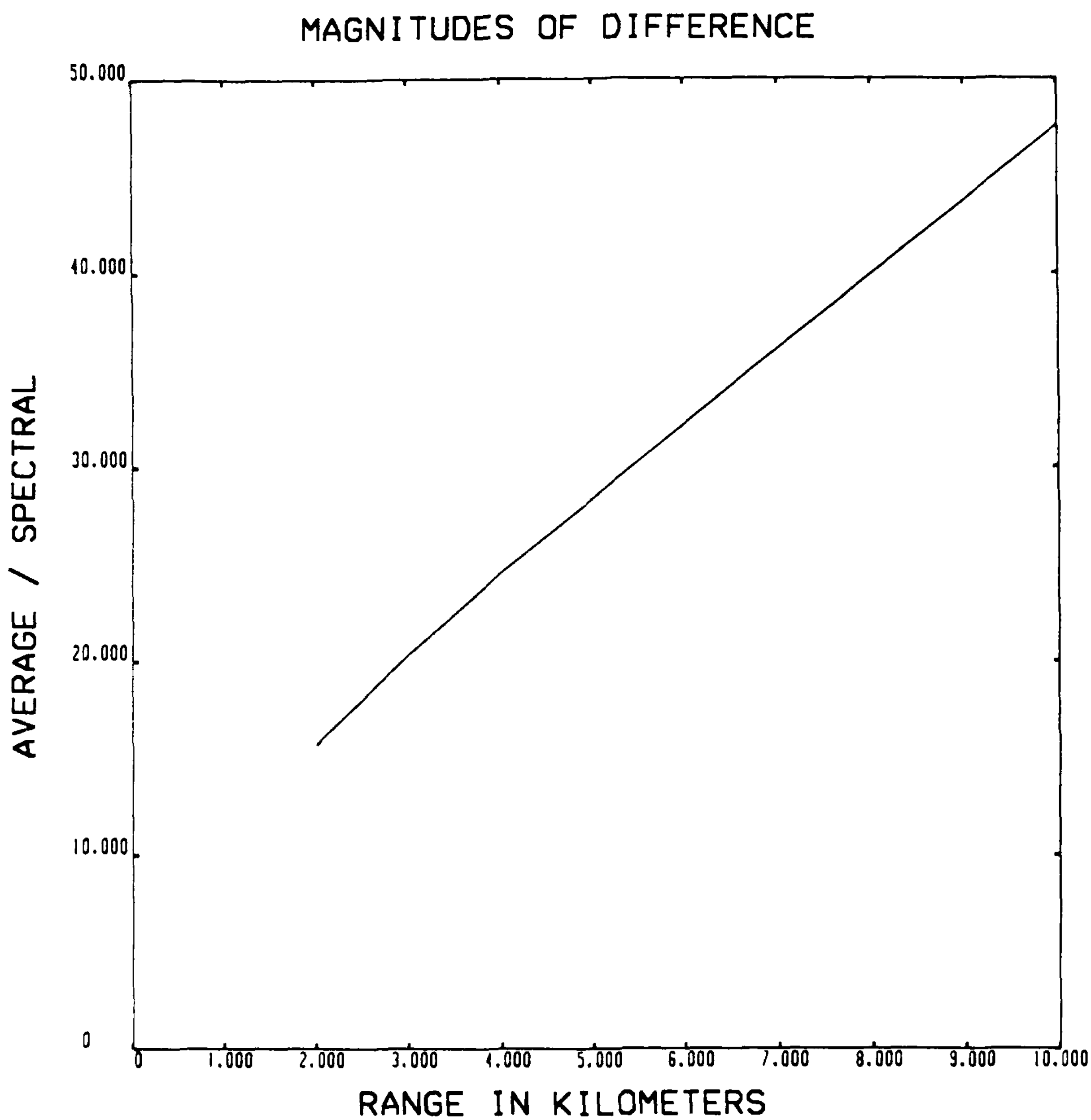
After concluding my research in the 4-5u range, I proceeded to the 8-12u range. Would the same result hold? Would the average value work?

AVERAGE AND SPECTRAL LOWTRAN

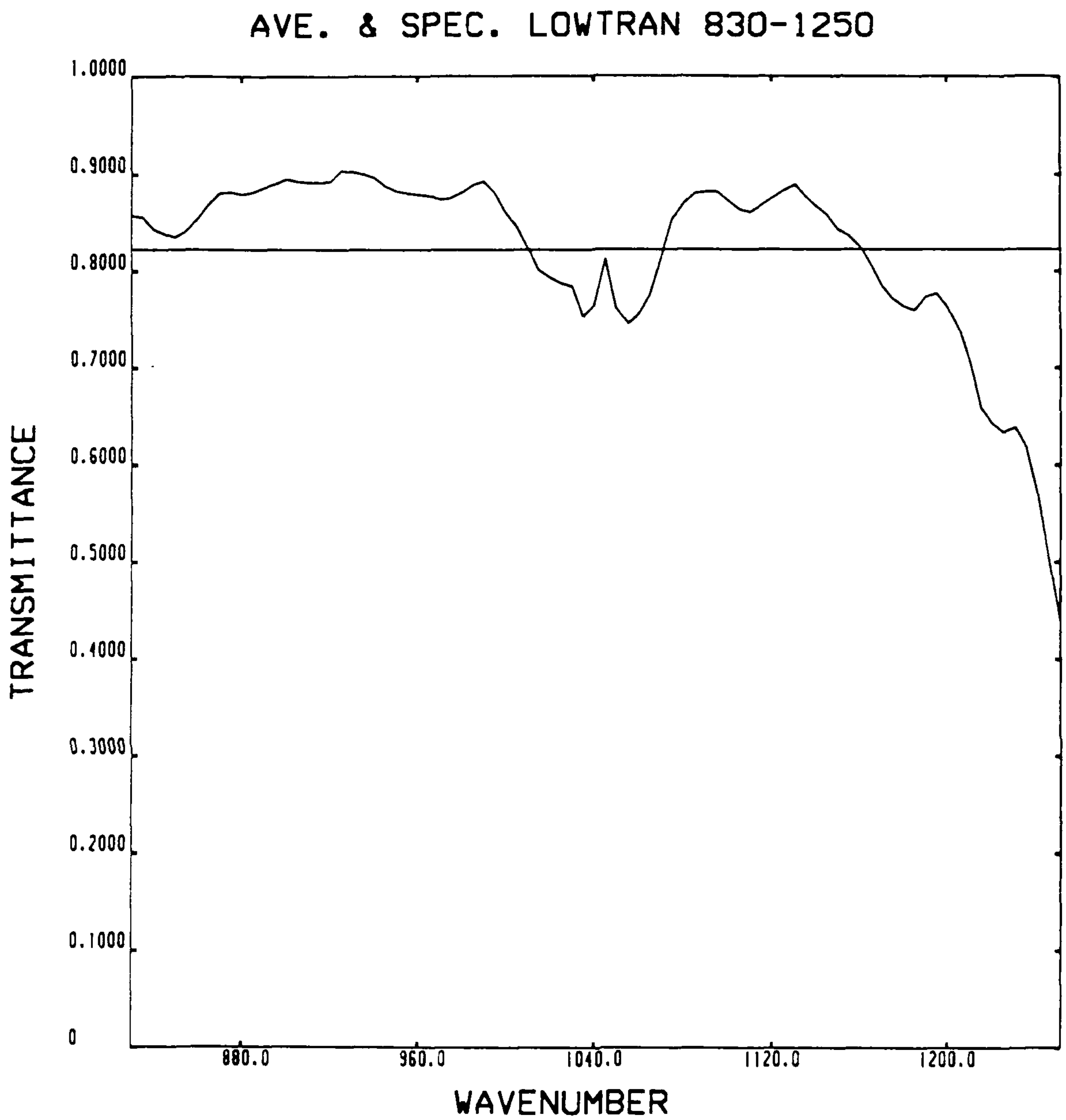


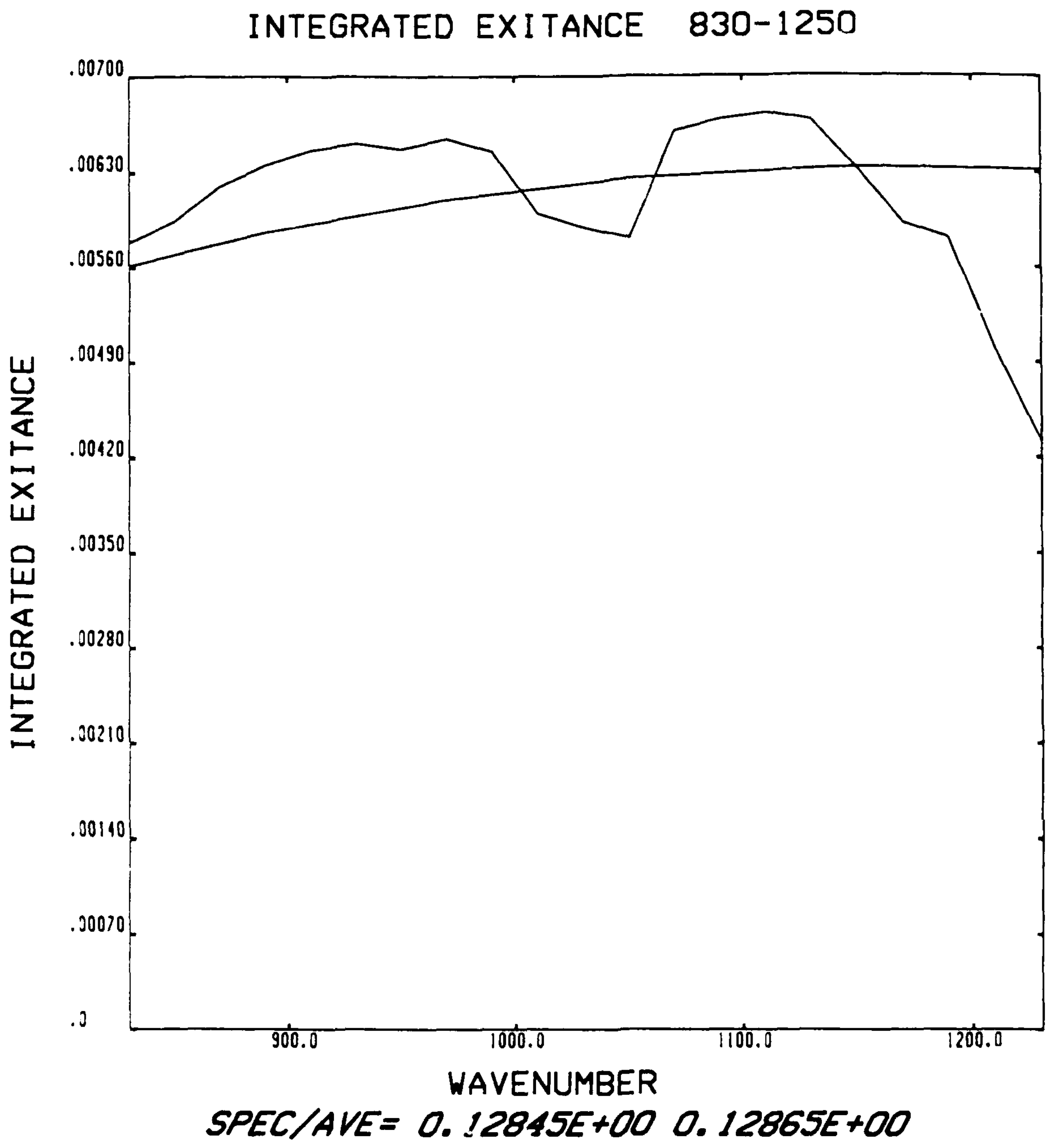


SPEC/AVE= 0.27144E-03 C.77758E-02


MAGNITUDES OF DIFFERENCE
AVERAGE / SPECTRAL
RANGE IN KILOMETERS
50.000
40.000
30.000
20.000
10.000
0
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000

The results of the same procedure in the 8-12u range is shown in the accompanying graphs. The average value does work, and quite well. The deviation of the average value from the spectral is minimal, and in fact, less than one percent. For the 8-12u range, it is valid to use the average LOWTRAN value for atmospheric transmittance.


AVE. & SPEC. LOWTRAN 830-1250
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0
TRANSMITTANCE
880.0
960.0
1040.0
1120.0
1200.0
WAVENUMBER



INTEGRATED EXITANCE 830-1250
.00700
.00630
.00560
.00490
.00420
.00350
.00280
.00210
.00140
.00070
.0
900.0
1000.0
1100.0
1200.0
INTEGRATED EXITANCE
WAVENUMBER
SPEC/AVE= 0.12845E+00 0.12865E+00

SECTION 6. CONCLUSIONS

6.1 Summary

For the interval of 4-5u (2500-2000) when calculating resultant and total exitance, the average value of LOWTRAN should be shunned. The results can be up to 50 magnitudes greater than the spectral method, far from an accurate result.

For the interval of 8-12u (1250-850), the average value of LOWTRAN does produce an accurate result. The Deviations are far smaller than any error introduced when integrating.

6.2 Epilogue

Although the average LOWTRAN has passed the test for the 8-12u range, the general use of averages should be avoided; as shown here, it may work in one instance while falling apart for a similar one. Perhaps some unwary scientist saw that the average was accurate for the 8-12u range, and when he worked on the 4-5u range he assumed the same. To avoid future misconceptions, and as a rule of thumb, averages should be avoided whenever possible, and especially in this case, where it takes little additional work to use spectral values.

6.3 Acknowledgments

I would like to extend my most sincere thanks to the people who made this summer research possible and to those who made my albeit short term the most challenging, and rewarding, ten weeks of my life (Michael Deiler, for being such an excellent teacher, Mike Wallace, for taking me on at AGI, Capt. Larry Jones, whose insight was invaluable to me, Don Harrison and Norm Klausutis, for keeping up and managing the HSAP program, Russel Dukes, Thomas Marler, Lee Prestwood, and 2Lt. Doug Evans, for letting me know when it was time to leave the computer and eat lunch).

APPENDICES

Bibliography

1. Didday, Rich. Fortran for Humans. West Publishing Co. (New York: 1977).

2. Dierker, Campbell. Calculus with Analytic Geometry. Prindle, Weber & Schmidt, Inc. (Boston: 1978). 399-405.

3. Hudson, Richard. Infrared System Engineering. John Wiley & Sons. (New York: 1969). 20-95.

4. Jones, Capt. Larry. Personal Correspondence. August, 1989.

...In addition to the innumerable user manuals for the VAX/VMS system.

```
      PROGRAM EXTANCE
C      THIS PROGRAM FINDS THE EXITANCE OF A BLACKBODY
C      USING PLANK'S EQUATION.  THE NUMERICAL INTEGRATION IS
C      PERFORMED VIA SIMPSON'S RULE.
C
C           This program was modified by Chris Ellis to input LOWTRAN
C      and PLUME files, then integrate them and spit out the resulting
C      file.
C
      REAL TEMP,WANS,INC,RUNEV,RUNOD,WNUMEV,RWNM0,RWNM2M
      REAL WNUMOD,WEVEN,WODD,W0,W2M,p(2500),l(2500,2)
      real temp1, temp2, inctemp,WANSSPEC,WANSAVE
      INTEGER M,WNUM0,WNUM2M,LOWWAVE,HIGHWAVE,INCWAVE,cases(100,3),flag
      CHARACTER*20 FILENAME, plfile, lofile, TITLE
      CHARACTER*4 TEMPC, H1C, H2C, RANC
      print*,'Enter plume file, lowt file'
      plfile='PLUME.dat'
      lofile='LOWTRAN.dat'

       PRINT*,'ENTER TEMPERATURE1,2,inc (IN DEGREES KELVIN) = '
       READ*,TEMP1, temp2, inctemp
       PRINT*,'ENTER START WAVENUMBER= '
       READ*,LOWWAVE
       PRINT*,'ENTER STOP WAVENUMBER= '
       READ*,HIGHWAVE
       PRINT*,'ENTER LENGTH OF WAVENUMBER INCRIMENTS= '
       READ*,INCWAVE

      open(unit=1, file=plfile          , status='old')
      open(unit=2, file=lofile          , status='old')
      open(unit=3, file='thisisit.dat' , status='new')
C     open(unit=4, file='caselist2.dat' , status='old')
C
C     do c=1,60
C        read(4,*,end=31 )cases(c,1),cases(c,2),cases(c,3)
C     end do
C
31    do c=2000,2500,5
         read(1,*)junk,p(c)
      end do
C
C
     do 70 case = 1, 60

5     do 20 c=2000, 2500, 5
         read(2,*)junk,l(c,1)
20    CONTINUE
      count  = count + 1
      read(2,*)junk, avelo
      IF (JUNK .NE. 9999) THEN
         PRINT*,'AVERAGE NOT AT 9999'
         STOP
      END IF

      DO 25 C=2000, 2500, 5
         L(C,2) = AVELO
25    CONTINUE
C
      do 66 temp = temp1, temp2, inctemp
27    FORMAT (' ',A20)

       do 63 flag = 1,2
        DO 60 WNUM0=LOWWAVE,HIGHWAVE-INCWAVE,INCWAVE
           WNUM2M = WNUM0 - INCWAVE
           RWNM0 = FLOAT (WNUM0)
           RWNM2M = FLOAT (WNUM2M)
```

```
      INC = 5.
      RUNEV = 0.
      RUNOD = 0.
      M = (WNUM2M - WNUM0)/10
C
      DO 500 I = 1,M
        WNUMEV = RWNM0 - (2. * INC * I)
        WNUMOD = RWNM0 - ((2. * INC * I) - INC)
        IF (I .EQ.M) GOTO 450
        WEVEN=(WNUMEV**3.)/(EXP(1.44*WNUMEV/TEMP)-1.)*
     +  p(wnumev)*l(wnumev,FLAG)
        RUNEV = RUNEV + WEVEN
450     WODD=(WNUMOD**3.)/(EXP(1.44*WNUMOD/TEMP)-1.)*
     +  p(wnumod)*l(wnumod,FLAG)
        RUNOD = RUNOD + WODD
500   CONTINUE
C
      RUNEV = 2. * RUNEV
      RUNOD = 4. * RUNOD
C
      W0=(RWNM0**3.)/(EXP(1.44*RWNM0/TEMP)-1.)*p(rwnm0)*l(rwnm0,FLAG)
      W2M=(RWNM2M**3.)/(EXP(1.44*RWNM2M/TEMP)-1.)*
     +p(rwnm2m)*l(rwnm2m,FLAG)
C
C     WANS IS THE EXITANCE VALUE. IT IS IN WATTS/CM**2.
C
      WANS = 3.75E-12*(INC/3.)*(W0+RUNEV+RUNOD+W2M)
      PRINT*,'WAVE:',WNUM0,'-',WNUM2M,'TEMP:',TEMP,'EXITANCE:',WANS
      WRITE(3,*) WNUM0, WANS
      IF (FLAG .EQ. 1) WANSSPEC = WANSSPEC + WANS
      IF (FLAG .EQ. 2) WANSAVE = WANSAVE + WANS
60    CONTINUE
63    continue

      WRITE (3,*) WANSSPEC, WANSAVE
      WANSSPEC = 0.0
      WANSAVE  = 0.0
66    continue
70    continue
      CLOSE (UNIT=1)
      close (unit=2)
      close (unit=3)

      STOP
      END
```

```
C =====================================================================
C =                                                                   =
                          PROGRAM XYPLOT
C =                                                                   =
C =====================================================================
C =                                                                   =
C =  AUTHOR:     MARK CORBIN                                          =
C =                                                                   =
C =  HISTORY:    5-22-85   PROGRAM QUICKP CREATED                     =
C =              5-24-85   MODIFIED TO COUNT THE # OF INPUT POINTS    =
C =              6-12-85   QUICK CREATED FROM QUICKP TO BE MADE OF    =
C =                        REAL FORTRAN, INSTEAD OF FLEX STATEMENTS   =
C =                                                                   =
C =  REVISIONS: COLLEEN STEWART                                       =
C =              10-8-85   OPTION ADDED TO PLOT CHARACTER SELECTED BY =
C =                        USER (DO NOT CONNECT WITH LINES)           =
C =              3-13-86   OPTION ADDED TO PLOT ADDITIONAL DATA ON    =
C =                        SAME FRAME AS PREVIOUS DATA                =
C =              10-6-86   NAME CHANGED TO XYPLOT                     =
C =              11-17-86  ELIMINATED CHOICE OF EMPHASIZE AND LABEL   =
C =                        INCREMENTS (DEFAULT SET TO 1 FOR BOTH)     =
C =              1-14-87   OPTION ADDED TO PLOT SYMBOL ON LINE        =
C =                                                                   =
C =              Unspeakably brilliant modifications made             =
C =                     by Christopher Scott Ellis                    =
C =           under the exquisite leadership an direction of          =
C =                           Michael Deiler                          =
C =                                                                   =
C =              6-27-89   Option to plot multiple data on one graph  =
C =                        Improved so that there are no ominous lines =
C =                        connecting seprate sets.                   =
C =                                                                   =
C =  PURPOSE:    A QUICK PLOTTING ROUTINE TO READ IN X,Y PAIRS AND PLOT =
C =              THEM WITH SC4020 COMMANDS.  THE DATA CAN BE ENTERED IN =
C =              MANUALLY, OR READ IN FROM A FORMATTED DATA FILE.     =
C =                                                                   =
C =====================================================================
C
      PARAMETER (MXNUM=50)
C
      COMMON /COMDAT/ NUM, X(MXNUM), Y(MXNUM), TEXIT, TEXITA, TITLE
C
      CHARACTER ANSWER,CHINPUT,CHOICE,FILENAME*50,SELECT,SYMB
      CHARACTER*5 temp2, h12, h22, ran2
      CHARACTER*30 TITLE, XTITLE, YTITLE, TESTZ,ZTITLE
      CHARACTER EVAL*12, EVAL1*12, TESTY*40, QUERY
      CHARACTER*5 temp, h1, h2, ran
C
      LOGICAL LLABELS
C
      DATA IEMPX, IEMPY, LABX, LABY
     *     /  1,      1,    -1,   -1 /
      DATA LLABELS /.FALSE./
      DATA NUMPLOT /0/
        QUERY = 'G'
C
      DO 50 I = 1,30
         PRINT*, ' '
   50 CONTINUE
      PRINT*, '                    PROGRAM XYPLOT FOR QUICK PLOTTING'
      PRINT*, ' '
C
C =====================================================================
C =                                                                   =
C =                      INITIALIZE THE PLOTTER                       =
C =                                                                   =
```

```
C ======================================================================
C
      CALL PLTIDY
C
C ======================================================================
C =                                                                    =
C =                          INPUT DATA TO PLOT                        =
C =                                                                    =
C ======================================================================
C
      CALL GETDAT
C
C ======================================================================
C =                                                                    =
C =                            FIND-MIN-MAX                            =
C =                                                                    =
C ======================================================================
C
   10 XMAX = -1.E20
      YMAX = -1.E20
      XMIN = 1.E20
      YMIN = 1.E20
      DO 100 I = 1,NUM
            XMAX = MAX( XMAX, X(I) )
            YMAX = MAX( YMAX, Y(I) )
            XMIN = MIN( XMIN, X(I) )
            YMIN = MIN( YMIN, Y(I) )
  100 CONTINUE
C
      PRINT*, ' MIN, MAX VALUES FROM DATA:'
      WRITE(*,1000) XMIN, XMAX, YMIN, YMAX
C
C ======================================================================
C =                                                                    =
C =                      MENU FOR LABEL OPTIONS                        =
C =                                                                    =
C ======================================================================
C
      PRINT*,' TIME TO ENTER TITLES FOR PLOT'
      IF (LLABELS) THEN
         PRINT*,' (RETURN) -- TO RE-ENTER LABELS AND MIN,MAX,INC VALUES'
         PRINT*,'    K -- KEEP CURRENT LABELS AND MIN,MAX,INC VALUES'
         PRINT*,'    T -- RE-ENTER TITLE ONLY.'
         PRINT*,'    P -- PLOT NEW DATA ON SAME FRAME AS LAST PLOT'
         PRINT*,'    S -- SKIP PLOT'
         PRINT*,' ENTER CHOICE: '
         ANSWER = ' '
      ELSE
         ANSWER = ' '               ! FORCE THE 1ST TIME THRU TO ENTER
         LLABELS = .TRUE.
      END IF
      IF (.NOT.ANSWER.EQ.'S') THEN
         IF (.NOT.ANSWER.EQ.'P') THEN
          IF (.NOT.ANSWER.EQ.'K') THEN
            IF (.NOT.ANSWER.EQ.'T') THEN
C
C ======================================================================
C =                                                                    =
C =                    INPUT TITLE AND AXES LABELS                     =
C =                                                                    =
C ======================================================================
C
                PRINT*,' ENTER X AXIS LABEL (30 CHAR MAX): '
                PRINT*,'123456789012345678901234567890'
                XTITLE = 'wavenumber -> wavenumber + 20'
                PRINT*,' ENTER Y AXIS LABEL (30 CHAR MAX): '
```

```
          PRINT*,'123456789012345678901234567890'
          YTITLE = 'EXITANCE IN WT/CM**2'

=====================================================================
                                                                    =
          ENTER MIN, MAX, AND LABEL INCREMENT                       =
                                                                    =
=====================================================================

          PRINT*,' ENTER X GRID MIN,MAX,INCREMENT:'
          PLXMIN = XMIN
          PLXMAX = XMAX
          PLXINC = 100
          PRINT*,' ENTER Y GRID MIN,MAX,INCREMENT:'
          PLYMIN = YMIN
          PLYMAX = YMAX
          PLYINC = (YMAX-YMIN)/10
       END IF     !END OF GETTING NEW LABELS
          PRINT*,' ENTER TITLE OF PLOT (30 CHAR MAX): '
          PRINT*,'123456789012345678901234567890'

       END IF     !END TO GET TITLE ONLY.

=====================================================================
                                                                    =
                          SET MARGINS                               =
                                                                    =
=====================================================================

       CALL SETMIV( 80,80,80,100 )

=====================================================================
                                                                    =
      NCHX,NCHY ARE THE # OF CHARACTERS IN THE GRID LABELS          =
                                                                    =
=====================================================================

       NCHX = 6
       NCHY = 6

=====================================================================
                                                                    =
          CHECK FOR NUMBERS WITH LARGE MAGNITUDES                   =
                                                                    =
=====================================================================

       IF (LOG10(MAX(1.E-5, ABS(PLXMAX))).GE.5.0) NCHX = -5
       IF (LOG10(MAX(1.E-5, ABS(PLYMAX))).GE.5.0) NCHY = -5

=====================================================================
                                                                    =
    MOD TO CALL GRIDMC, WHICH IS THE SAME AS GRIDIV EXCEPT          =
  FOR THE ADDITION OF THE LAST PARAMETER (1), WHICH SIGNIFIES       =
        TO DRAW TICS INSTEAD OF THE FULL GRID                       =
  GRIDMC ADVANCES THE FRAME AND SETS UP THE X,Y SCALE FACTORS       =
                                                                    =
=====================================================================

       CALL GRIDMC(1,PLXMIN,PLXMAX,PLYMIN,PLYMAX,PLXINC,PLYINC,
     *             IEMPX, IEMPY, LABX, LABY, NCHX, NCHY, 1)

=====================================================================
                                                                    =
                          LABEL PLOT                                =
                                                                    =
=====================================================================
```

```
         CALL CHSIZV (3,3)
         CALL TCHV (500,50,XTITLE)
         CALL TCRV (50,500,YTITLE)
         CALL TCHV (500,950,TITLE)
         CALL CHSIZV (3,3)
         WRITE(EVAL,621)TEXIT
         WRITE(EVAL1,621)TEXITA
         FORMAT(E12.5)
         TESTY = 'SPEC/AVG=' EVAL' EVAL1
         TESTZ = 'AVG  EXITANCE =' EVAL1
         CALL ICHV (500,15,TESTY)
         CALL ICHV (501,16,TESTY)
         CALL CHSIZV (3,3)

         NUMPLOT = NUMPLOT - 1
      END IF  !END OF ADVANCING FRAME,SETTING MARGINS,LABELING PLOT

=======================================================================
                                                                      =
                        CHOOSE TYPE OF PLOT                           =
                                                                      =
=======================================================================

      PRINT*,' ENTER CHOICE FOR TYPE OF PLOT: '
      PRINT*,'  L -- CONNECT POINTS WITH SOLID LINE '
      PRINT*,'  S -- CONNECT POINTS WITH SYMBOL AT 10 INTERVALS '
      PRINT*,'  P -- DO NOT CONNECT POINTS '
      SELECT = 'L'
      IF (SELECT.NE.'L') THEN
         PRINT*,' ENTER SYMBOL TO BE PLOTTED '
         READ(*,1010) SYMB
         JN = -ICHAR(SYMB)
      END IF

=======================================================================
                                                                      =
                              NOW PLOT                                =
                                                                      =
=======================================================================

      X1 = MIN (PLXMAX, MAX (PLXMIN,X(1)))
      Y1 = MIN (PLYMAX, MAX (PLYMIN,Y(1)))
      DO 200 M = 2,NUM
         X2 = MIN (PLXMAX, MAX (PLXMIN,X(M)))
         Y2 = MIN (PLYMAX, MAX (PLYMIN,Y(M)))
         IF (SELECT.EQ.'P') THEN
            CALL POINTV(X1,Y1,JN)
         ELSE
            if (x2 .gt. x1) CALL LINEIV (X1,Y1,X2,Y2)
         END IF
         X1 = X2
         Y1 = Y2
      CONTINUE
      IF (SELECT.EQ.'P') THEN
         CALL POINTV(X1,Y1,JN)
      ELSE IF (SELECT.EQ.'S') THEN
         ISTEP = MAX (1,(NUM/10))
         IMIN  = MAX (2,(ISTEP/2))
         IMAX  = NUM - 1
         DO 300 I = IMIN,IMAX,ISTEP
            X1 = MIN (PLXMAX,MAX(PLXMIN,X(I)))
            Y1 = MIN (PLYMAX,MAX(PLYMIN,Y(I)))
            CALL POINTV (X1,Y1,JN)
         CONTINUE
      END IF
```

```
      PRINT*, '--- PLOT #',NUMPLOT,' FINISHED <---'
  END IF   !END OF PLOTTING DATA

!====================================================================
!                                                                   =
!                    MENU FOR DATA OPTIONS                          =
!                                                                   =
!====================================================================

  PRINT*, ' WHAT OPTION DO YOU DESIRE NOW?'
  PRINT*, ' G -- GET NEW DATA      P -- PLOT CURRENT DATA'
  PRINT*, ' T -- TYPE OUT DATA     S -- STOP'
  PRINT*, ' ENTER CHOICE:'
  CHOICE = QUERY
    IF (QUERY .EQ. 'G') THEN
       QUERY = 'P'
       GO TO 25
    END IF
    QUERY = 'G'
  CONTINUE

  IF (CHOICE.EQ.'S') THEN
     STOP
  ELSE IF (CHOICE.EQ.'T') THEN

!====================================================================
!                                                                   =
!                      TYPE OUT DATA                                =
!                                                                   =
!====================================================================

     PRINT 1030,NUM,((I,X(I),Y(I)),I=1,NUM)
  ELSE IF (CHOICE.EQ.'G') THEN
     CALL GETDAT
  ELSE IF (CHOICE.EQ.'P') THEN
     GO TO 10
  END IF

  GO TO 20

  FORMAT (' XMIN,XMAX: ',2G12.4,/,' YMIN,YMAX: ',2G12.4,/)
  FORMAT (A1)
  FORMAT (A30)
  FORMAT (/,' # OF X,Y PAIRS: ',I5,/,' I,X(I),Y(I):',/,
 *        (1X,I5,1X,2G14.5))

  END

!====================================================================
!                                                                   =
!                    SUBROUTINE GETDAT                              =
!                                                                   =
!====================================================================
!                                                                   =
!THOR:       MARK CORBIN                                            =
!                                                                   =
!ISTORY:     6-12-85   CREATED                                      =
!                                                                   =
!VISIONS:    COLLEEN STEWART 10-3-85                                =
!                                                                   =
!RPOSE:      TO GET THE DATA TO BE USED IN PLOTTING ROUTINE QUICK   =
!                                                                   =
!====================================================================

  PARAMETER (MXNUM = 50)
```

```
COMMON /COMDAT/ NUM,X(MXNUM),Y(MXNUM),TEXIT,TEXITA,TITLE
  character*30 title

DIMENSION ARAYN(20)

CHARACTER CHINPUT, FILE*80, ANSW*1
LOGICAL OK
  INTEGER FLAG1

PRINT*, ' OPTIONS: '
PRINT*, '         M -- ENTER DATA FROM TERMINAL  '
PRINT*, '         F -- ENTER DATA FROM A FILE '
PRINT*, ' (OTHER) -- KEEP CURRENT DATA '
PRINT*, ' ENTER SELECTION: '
CHINPUT = 'F'

IF (CHINPUT .EQ. 'F') THEN

=================================================================
                                                                =
                 GET DATA FROM A FILE                           =
                                                                =
=================================================================

   CONTINUE
   PRINT*, ' THIS PROGRAM WILL COUNT THE # OF X,Y PAIRS. '
   PRINT*, ' THE DATA SHOULD CONTAIN ONE X,Y PAIR ON EACH RECORD'
   PRINT*, ' ENTER FILENAME (RETURN TO SKIP): '
   FILE = 'THISISIT.DAT'
   IF (.NOT. FILE.EQ.' ') THEN
      IF (FLAG .EQ. 0) OPEN (UNIT=1,NAME=FILE,STATUS='OLD',
*     READONLY,ERR=90)
      FLAG = 1
      OK = .TRUE.
      NUM = 0
      PRINT*, ' ENTER TWO WORD NUMBERS TO BE PLOTTED '
      PRINT*, '    - (1,2) -  FOR 1ST TWO WORDS '
      NW1 = 1
      NW2 = 2
      IF (NW1.EQ.1.AND.NW2.EQ.2) THEN
      PRINT*, ' HEADER INFO (Y/N)'
      ANSW = 'Y'
      FORMAT(A)
      IF(ANSW .EQ. 'Y')THEN
            READ(1,FMT='(A30)') TITLE
            PRINT*
         PRINT*
         PRINT*
         PRINT*
         PRINT*,TITLE

            FORMAT(2X,E10.9)
       PRINT*,' VAL = ',TEXIT,TEXITA
      END IF
      READ(1,*) TITLE
      DO 100 I = 1,MXNUM
            READ(1,*,END=70,ERR=80) X(I),Y(I)
            NUM = NUM + 1
        CONTINUE
      ELSE
         MAXWD = MAX(NW1,NW2)
         DO 200 J=1,MXNUM
            READ(1,*,END=70,ERR=80) (ARAYN(K),K=1,MAXWD)
            X(J) = ARAYN(NW1)
            Y(J) = ARAYN(NW2)
            NUM = NUM + 1
```

```
            CONTINUE
         END IF
            READ (1,*) TEXIT, TEXITA
          PRINT*, NUM,' POINTS READ IN'

      END IF
   END IF        ! OF GETTING DATA FROM A FILE

   IF (CHINPUT.EQ.'M') THEN

==================================================================
                                                                 =
                   GET-DATA-MANUALLY                             =
                                                                 =
==================================================================

      PRINT*, ' MAXIMUM # OF POINTS: ',MXNUM
      PRINT*, ' ENTER # OF POINTS (0 TO SKIP):'
      READ(*,*) NUM
      IF (NUM.GE.1) THEN

                  CHECK VALUE OF NUM

         IF (NUM.GT.MXNUM) THEN
            PRINT*, ' *** # POINTS ',NUM,' TOO LARGE ***'
            PRINT*, '      RESET TO ',MXNUM
            NUM = MXNUM
         END IF

                  NOW INPUT DATA

         DO 300 I = 1,NUM
            PRINT*, ' ENTER X,Y PAIR FOR POINT # ',I
            READ(*,*) X(I),Y(I)
         CONTINUE
      END IF
   END IF        ! OF GETTING DATA MANUALLY
   RETURN

   PRINT*, ' *** ERROR OPENING FILE, TRY AGAIN *** '
   OK = .FALSE.
   GO TO 10

   PRINT*, ' *** ERROR READING IN DATA, TRY AGAIN *** '
   GO TO 10

   FORMAT (A1)
   FORMAT (A50)

   END
```

The Creation and Installation of Z-248 Help Menus

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Introduction

The Z-248 help menus were created to aid the computer user. Two different levels were made. One is for the expert, a user already acquainted with the basic commands. This menu executes commands to make it easier for the user to operate the computer. Dangerous commands were excluded from the menu to help prevent accidents. The other menu is for the novice. It tells the user how to use commands vital to the use of a Z-248. The novice menu does not execute commands like the expert menu. Someone who does not know the dangers of a command may end up doing more harm than good. Therefore the novice menu was made to avoid such incidents. It cautions the user of any dangerous commands and leaves out those not essential to the basic use of a computer. It strongly urges the user to read the MS-DOS manual if he is unclear about a command. The novice menu only provides a basic explanation of the necessary commands. To truly learn how to use the Z-248 the user must read the manual.

Begin Statements

The first line in the menu must be a BEGIN statement. The BEGIN statement assigns labels to the mouse functions. The label refers to a statement which is executed when the mouse function occurs. The BEGIN statement may also declare movement functions of the cursor with the mouse. If a button or movement is to be ignored then only type the coma. For example:

```
BEGIN     lfbtn,midbtn,,lfmot,rtmot,upmot,dnmot

lfbtn:    TYPE 'LEFT BUTTON'
midbtn:   TYPE 'MIDDLE BUTTON'

lfmot:    TYPE 0,75
rtmot:    TYPE 0,77
upmot:    TYPE 0,72
dnmot:    TYPE 0,80
```

If the left button is pressed then 'LEFT BUTTON' appears on the screen. If the middle button is pressed then 'MIDDLE BUTTON' appears on the screen. If the right button is pressed then nothing happens because it has been omitted from the BEGIN statement. The labels lfmot, rtmot, upmot, dnmot enable the mouse to move the cursor left, right, up, and down.

The TYPE Statement sends characters to the console as if they had been typed by the keyboard. Special characters such as ENTER and ESC can be entered by using their ASCII values. Other characters are enclosed in double quotes. The cursor statements in the above example (TYPE 0,75) use the extended codes in the TYPE statement. A list of the extended codes may be found in the LOGITECH Mouse User's Manual. The TYPE statement is limited to an 80 character string.

The EXECUTE statement may be used to chain together a long sequence of statements. The statements are divided among several different labels. When the EXECUTE statement is activated the labels will refer to different statements thereby executing several strings in one action. For example:

```
lfbtn:      EXECUTE label1,label2,label3

label1:     TYPE "TO BOLDLY GO
label2:     TYPE "WHERE NO MAN HAS"
label3:     TYPE "GONE BEFORE..."
```

If the left button is pressed then label1, label2, and label3 will be executed.

Popup Statements

The POPUP statement allows the user to design a popup menu. This is the most flexible menu, but one program is limited to only five popup menus. The popup menu allows items to be positioned anywhere on the screen. The menu must first have a label then the POPUP statement. Following the POPUP instruction are the parameters. The first indicates the line number at which the menu will start; the second parameter is the column number; the third determines the color or properties of the characters. When the third parameter is a number it determines the colors of the menu. This number is derived in much the same way the numbers used in colorset are. The BASIC manual contains a list of the numbers that represent the colors. Using these numbers in the following equation the color number for the menu can be determined.

Background * 16 + Foreground = Color Number

If the parameter is a string such as NORMAL, INVERSE, or BOLD then it indicates the character properties.

The menu that appears on the screen is made by the TEXT command. TEXT allows the user to compose a string of any characters, but the string must be enclosed in double quotes. The TEXT statement permits information to appear on the menu. The SELECT statement pairs an item from the menu to a label. The label will be executed when the item is selected. Menu items that do not have a SELECT statement cannot execute labels or be selected by the mouse. The SELECT instruction must be followed by the row, column, and width of the item. The row and column are relative to the original position of the popup menu. Many times the SELECT statement is followed by ,13. This is the ASCII value for ENTER and serves as such. The last line of the menu is a PEND statement. This ends the popup command. An example of a popup menu:

```
ltbtn:     POPUP [illegible],5
           TEXT "-------------------------------------"
           TEXT " LIST DIRECTORY        CLEAR SCREEN "
           TEXT " CHKDSK                ABORT        "
           TEXT "-------------------------------------"
           SELECT 1,2,15,dir
           SELECT 2,2,15,chkdsk
           SELECT 1,24,12,cls
           SELECT 2,24,12,NUL
           PEND
dir:       TYPE "DIR"
chkdsk:    TYPE "CHKDSK"
cls:       TYPE "CLS"
NUL:       NOTHING
```

Menu Statements

The MENU statement is similar to the POPUP statement except that it is not as flexible. The menu consists of options which, if selected, will execute statements. The menu cannot contain text that does not execute a statement or label. The MENU statement contains a variety of parameters. The first is the title, which must be in double quotes; the second and third parameters position the menu on the screen by row and column; and the fourth sets the color or character properties. The second, third, and fourth parameters all operate like those of the popup menu. Following the MENU statement are the options. The OPTION statement limits the items to appearing one under the other. The OPTION statement contains a label which refers to a statement to be executed when the item is selected. Finally, the MEND statement ends the menu definition. An example of the MENU statement is the following:

```
Ltest:    MENU "Title" 1,20,NORMAL
          OPTION "Item 1",Label1
          OPTION "Item 2",Label2
          OPTION "Item 3",Label3
          MEND

Label1:   TYPE "NUMBER 1"
Label2:   TYPE "NUMBER 2"
Label3:   TYPE "NUMBER 3"
```

Batch Files

The novice menu uses batch files and help files to display the information for the commands. In the menu program, the TYPE statement changes to the C drive and BAT directory then it executes the batch file needed. The batch file clears the screen and types the corresponding help file. When an item is selected from the menu the help file is the only thing the user sees. The help file gives a brief explanation of the command selected from the menu. The help file strongly urges the user to read the DOS manual and cautions the user about any dangers. The novice menu is broken up into levels of difficulty. The first menu contains commands that are necessary and quite common. The second menu includes commands that can be dangerous to a novice. This menu cautions the user and omits complex instructions. The third menu has commands that are not necessary, but make operation easier. The expert menu also uses batch files. These files execute certain graphics programs. A common batch file clears the screen, changes to the C drive, changes to the desired directory, and types the desired filename. The files were edited in WordStar using the non-document mode and KX to save them. Then the files were copied to the BAT directory. The batch files can be executed by typing the filename without the extension.

Extra Binary Files

The expert menu supplies the user with several extra binary files to make operation faster and easier. One of the commands included is SDIR, Sorted DIRectory Listing. SDIR displays more information and has more options than the DIR command. Not only does the command sort the directory but it displays four files across which allows for more information per screen. It also lists the version, time, and date of the listing. The options permit the user to clear the screen, pause, list hidden files, change the number of columns, or determine how the files are sorted.

The ALSEARCH command allows the user to find a specific file in any drive and directory. It will search from one drive to another as specified. A user may search from drives C to E. By using wildcards the user may find more than one file. If a user wanted to find all color files he could enter color*.* as the file he wanted to find. ALSEARCH would find all files beginning with color. When a file is found the drive, directory, sub-directories, and filename are all listed. Then the user is asked if he wishes to continue searching. The command will skip to the next directory after it has found one file by the name specified.

The BROWSE command allows you to view a file by scrolling. The user may scroll left, right, up, and down. The PgDn, PgUp, Home, and End keys also function with this command. The F1 key will display options such as finding specific text. The BROWSE command will not permit the user to edit. The BROWSE command will technically display binary files, but they are not readable.

CGCLOCK turns the clock on or off. When the clock is on, a running digital clock is displayed in the upper right hand corner of the screen. The clock shows hours, minutes, seconds, and p.m. or a.m.

LPTPORT switches the parallel ports. It does not indicate which port is in use. The port automatically switches to port 1 when the computer is rebooted.

The VTREE command displays all directories and sub-directories in a fashion that is easy to read and understand. A single line breaks into the directories that branch to sub-directories. This makes it possible for more information to fit onto one screen.

Color

The expert menu contains a popup menu that changes the color of the screen. The colors were made in BASIC then compiled using BCOM20G and LINK. An example of a color program in BASIC:

```
10 CLS
20 SCREEN 0:COLOR 6,8,0
30 CLS
```

The COLOR command changes the colors. The first number is the foreground and the second is the background. The number representing each color may be found in the BASIC manual. Sometimes the foreground color does not appear until after several returns. The following example is a listing of a BASIC program that displays all colors.

```
10 CLS:SCREEN 0:COLOR 15,8,0:LOCATE 4,22
20 PRINT "THESE ARE POSSIBLE BACKGROUND COLORS":PRINT :PRINT
30 BL$=STRING$(77,32)
40 FOR I=1 TO 8:IF I=7 THEN 60
50 COLOR 15,I,0:PRINT I;BL$;
60 NEXT I:PRINT :PRINT :PRINT TAB(22)"THESE ARE POSSIBLE
   FOREGROUND COLORS"
70 PRINT :PRINT :PRINT TAB(15):FOR F=1 TO 15
80 COLOR F,8,0:PRINT F;:NEXT F
90 PRINT :PRINT :PRINT :PRINT TAB(26)"NOW--PICK YOUR COLORS!"
   :PRINT
100 PRINT "SCREEN 0:"::PRINT "COLOR FG,BG,0":END
```

Apprendices can be obtained from

Universal Energy Systems, Inc.

FILE SIZE ANALYSIS

AND

TRANSFER PROGRAM

KENNETH GAGE
HIGH SCHOOL APPRENTICESHIP PROGRAM
AFATL/MNW
MENTOR : LT. MARK HAND
SUMMER 1989

SECTION 1 - INTRODUCTION

This summer I participated in the High School Apprenticeship Program for the first time. Through others I had heard of how excellent the program was, and I was not disappointed. The experience was valuable, rewarding, and enjoyable. With the help of my mentor, Lt. Mark Hand, and in his abscence, Mike Nixon, I learned how to function and perform in a scientific and technical environment. My tasks for the summer included bringing the computer facility to an operational level, becoming familiar with FORTRAN, learning to program in UNIX, and developing a program to transfer dangerously large files from the Multiflow minisupercomputer to the VAX 8650, thus preventing a catastrophic system failure.

SECTION 2 - COMPUTER FACILITY CONSTRUCTION

My first assignment, which I undertook with fellow apprentice Neil Overholtz, was to bring MNW's computer facility back up to an operational state. Earlier this year, the computer room was reconfigured for added security in the anticipation of the changeover of MNW's computer facility from unclassified data processing to classified, or TEMPEST, processing. This reconfiguration consisted of the removal of an entire wall and setting it back to close the computers off from the outside. New locks were installed on the front door, which was now the only means of access, and a five ton air conditioning unit was also put in. Now came the time for cleanup.

SECTION 2.1 - COMPUTER FACILITY CLEANUP

Bringing the computer facility up to operational capacity required that the room be thoroughly sanitized. All equipment that was not literally tied down had been moved out into the hall to facilitate reconstruction and had to be reinstalled. The ceiling had been removed and the resulting dust covered everything thickly. The main computers cannot function in a dusty room because the computers use air to cool themselves, and if a large amount of dust is ingested, it will gather on the microchips, causing them to heat up and become damaged. Because of this, the room had to be spotless and free of dust beflore the computers could come back on line. First Neil and I replaced the ceiling tiles because that creates a lot of dust in itself. We then vacuumed the floor foot by foot, removing all traces of the construction work. We had to vacuum the area ourselves with an industrial Shop-Vac because the custodian's vacuum cleaners couldn't handle the debris. Now we moved all the equipment back to its proper location in the room and this ended the cleanup portion of my first task.

SECTION 2.2 - ETHERNET NETWORK

Now that the initial cleaning had been finished, all that remained was to reconnect the computers to the ETHERNET network. The ETHERNET network was designed by the Digital Electronics Corporation and it allows for high speed data transfer between numerous computers. It can theoretically transfer data at about ten megabytes per second, but we rarely attain that rate. Ten megabytes per second is actually a somewhat mediocre speed, since the best networks can transfer data at over one hundred megabytes per second. The main network in MNW's computer facility consists of ETHERNET cable, which is strung throughout the ceiling, and H4000 transceiver units, which provide linkup to either a computer or a DELNI. A DELNI is a multiplexer which allows multiple computers to interface with a single transceiver. A DECNET may also be connected to a DELNI. A DECNET allows non-processing or dumb terminals to connect to the ETHERNET, because the DELNI by itself is not equipped to handle them.

SECTION 2.3 - INSTALLATION OF ETHERNET

Reinstallation of the ETHERNET required the stringing of tens of yards of cable throughout the ceiling and the connection of a half dozen H4000 transceivers. Little other work needed to be done simply because all the DELNI and DECNET linkups were intact and needed only to be reattached.

Now that the computers were on line and operational, MNW could begin the hydrocode simulations so vital to their work.

SECTION 3 - INTRODUCTION TO FORTRAN

My next assignment was to become familiar with the FORTRAN programming language. My mentor, Lt. Hand, was not present at the summer's opening and I therefore came under the expert tutelage of Mike Nixon for this part of my studies. I accomplished this assignment by reading FORTRAN programming manuals and questioning Mike Nixon, Neil Overholtz, and Bryan McGraw. While learning FORTRAN I developed a simple program to calculate sales tax. This program read input data from the terminal screen, determined the required sales tax from the read data, and printed the total back on the screen. My knowledge and experience of FORTRAN is limited to the rudimentary basics, but my need for this knowledge is limited as well. I was not required to program in FORTRAN. I only had to understand and follow the logic and processing of it, which I am fully capable of doing.

SECTION 4 - UNIX OPERATING SYSTEM

My final task before undertaking my main project was to learn how to program and function on the UNIX operating system. The UNIX operating system today is the commercial standard in the computer world. It is fast, effective, efficient, capable, compatible, and best of all, user-friendly. It is very easy to learn and manipulate. It was developed by the Bell Laboratories of AT and T in New Jersey to provide a computing environment conducive to programming research. To this end, the UNIX system has many tools, including text manipulation and documentation processing utilities, an electronic mail network, and a modern, efficient file storage system.

SECTION 4.1 - LEARNING UNIX

I learned how to work with the UNIX operating system by reading introductory books to UNIX and by reading a UNIX utilities manual. I read the UNIX documentation that came with the system only when necessary, since it was difficult to understand and the examples were useless to my work. I concentrated on three areas in my studies: file transferring, file listing, and filtering. My mentor had already given me a general idea of what my main project was about, and I knew that studying these functions would be most beneficial to my upcoming work. As for practice by developing simple programs not directly related to my project, there was no time, and I therefore had to concentrate solely on my project and learn from my mistakes as I went along.

SECTION 5 - FILE SIZE ANALYSIS AND TRANSFER PROGRAM

My final and most important task was to develop an autonomous file transfer program which would locate files larger than one megabyte on the Multiflow minisupercomputer, copy them to the VAX 8650, and then delete the original. The program would then send a message to the owner of that file, notifying him of the transfer and instructing him to put the file onto a storage tape. The reason behind my program is found in the EPIC3 hydrocode. When running on the Multiflow, the EPIC3 hydrocode simulation creates numerous large data files. If the amount of data storage exceeds the available disk space, a system failure results. This destroys a great deal of memory, the simulation is ruined, and money is lost as the machine lays idle. These failures had occured periodically in the past and it was my job to prevent them from happening again.

SECTION 5.1 - FILE LISTING

To make the task of developing the program easier, I decided to divide it based on the function of each section. The first section was tasked with locating the large files. Many different methods came to mind, the first being an 'ls' command coupled to an 'awk'. The 'ls' lists the statistics of each file in a directory. The 'awk' scans this data as input and separates the large files from the small. This method was successful but it was also clumsy and required prior setup in the proper directory. The next method I tried was a 'du' coupled with an 'awk'. This was more effective because it required no previous setup in the proper directory, but it neglected to show the owner of the file, which is a necessary piece of information later on. The final and most effective method of analysis was the 'find' command. The 'find' searched through all directories for files which met its specifications, which in this case was a memory usage of more than one megabyte. 'Find', unlike the other methods, didn't need an 'awk' to separate the files and it was the fastest, most effective method of searching the directories. This is the method I incorporated into my program.

SECTION 5.2 - FILE TRANSFERRING

The second task of the program was to copy the files over to the VAX 8650, where its expansive disk packs could store all the data. I had already realized that only the root directory, or super-user, had the privileges necessary to transfer files owned by someone else and only root could provide the autonomous operation necessary to the functioning of this program. It also became apparent that an 'awk' statement was necessary to allow for variations in filenames and owners. The 'awk' would receive its input data from the previous command by means of a 'pipe'. A 'pipe' is simply a connector that makes the output of the previous command the input of the following one. The 'awk would be coupled to the previous 'find' command and would get the filename and its owner from the output. The 'awk' creates a command shell and places a copy command in it for each file specified. With this set-up, it was easy to test proposed methods by simply changing the copy comand the 'awk' created. I tried four different commands: 'copy', 'file transfer program', 'move', and 'remote file copy'. 'Copy' was the simplest, but it was unable to transfer data between machines. File transfer program or 'ftp' was a very effective and powerful copy command, but it required direct user interface and couldn't pass the autonomous function requirements. One of best means of tranferring the files was 'move' because it removed the need to delete the original files, but, it too couldn't transfer data between machines. Remote file copy or 'rcp' operated the same way as 'copy', but it allowed for data tranfer between machines over the ETHERNET, making it the obvious choice for my program.

SECTON 5.3 - FILE OWNER NOTIFICATION

After the files had been copied and subsequently deleted, all that remained was to notify the owner of the tranferred file and instruct them to remove the files from the VAX8650 disk. None of the electronic mail functions on the UNIX system were suitable for my program because all required direct user interface. The only thing possible to do was to copy a message file into the directory of the owner. Whenever that user logs on, a command in his login file types this message to the screen.

SECTION 6 - CONCLUSION

My transfer program was placed onto the Multiflow Super Computer's system and set to execute every thirty minutes. This program prevents the Multiflow's disk from filling up with large output files. Often when the disk would fill up during a calculation, system failure would occur and many hours of processing would be lost. Now my program prevents this from occurring and saves the engineers in the computational mechanics team much headache and time in the future. My summer as a high school apprentice has been a great experience. I have learned a tremendous amount about computers and their operation and interaction. I have gained much experience which I'm sure will be very beneficial to my future.

SECTION 7 - ACKNOWLEDGEMENTS

Many people have helped me this summer and I greatly appreciate their help and advice. I thank all those who sponsor and support this excellent program. I have thoroughly enjoyed working with and talking to the engineers in my branch, especially Mr Bill Cook. I have especially enjoyed working with fellow apprentices Bryan McGraw and Neil Overholtz. I would never had got through the summer without the many hours of help given to me by Neil. He is a tremendous apprentice and has been a model for me to pattern myself after. I would also like to thank Mr Mike Nixon for filling in for my mentor when he was gone on TDY. He helped me a tremendous amount and I truly appreciate him. Most of all I would like to thank Lt. Mark Hand for giving me the opportunity to work in the Lab and learn all I did. I appreciate the tasks he gave me which were really challenging. I have truly enjoyed his friendship and tutelage.

BIBLIOGRAPHY

ECONET FORTRAN USERS GUIDE, MAY 1985

ULTRIX-32 QUICK REFERENCE, COPYRIGHT 1987, DIGITAL EQUIPMENT CORPORATION, MERRIMACK, NEW HAMPSHIRE.

ULTRIX-32 SUPPLEMENTARY DOCUMENTS, VOLUME 1, GENERAL USER, COPYRIGHT 1984, DIGITAL EQUIPMENT CORPORATION, MERRIMACK, NEW HAMPSHIRE.

VAX-11 FORTRAN LANGUAGE REFERENCE MANUAL, COPYRIGHT 1982, DIGITAL EQUIPMENT CORPORATION, MAYNARD, MASSACHUSETTS.

VAX-11 FORTRAN USER'S GUIDE, COPYRIGHT 1982, DIGITAL EQUIPMENT CORPORATION, MAYNARD, MASSACHUSETTS.

VAX FORTRAN FOR ULTRIX SYSTEMS USER MANUAL, COPYRIGHT 1986, DIGITAL EQUIPMENT CORPORATION, MAYNARD, MASSACHUSETTS.

UNDERSTANDING FORTRAN: SECOND EDITION, MICHEL BOILLOT, MAY 1985.

INTRODUCTION TO FORTRAN, COPYRIGHT 1986, GOULD ELECTRONICS INC., FORT LAUDERDALE, FLORIDA.

INTRODUCING THE UNIX SYSTEM, COPYRIGHT 1983, HENRY MCGILTON AND RACHEL MORGAN, MCGRAW-HILL PUBLISHING, NEW YORK, NEW YORK.

UNIX UTILITIES: A PROGRAMMER'S REFERENCE, COPYRIGHT 1987, R. S. TARE, MCGRAW-HILL PUBLISHING, NEW YORK, NEW YORK.

Design of In-House Radar Control System

AFATL/AGA/RF

Reid R. Harrison

School: Walton Sr. High

Mentor: Frank Arredondo

Summer 1989

Eglin A. F. B. Armament Laboratory

Air-to-Air Guidance Branch

A C K N O W L E D G E M E N T S

I would like to thank the following people for helping me during my summer term at AFATL. They have all significantly contributed to my experience.

Mr. Frank Arredondo

Mr. Darryl Huddleston

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Maj. Robert Johnson

Mr. Johnny Walker

Mr. David Rogers

Mr. Tom Speed

Mr. Bruce Quarles

Dr. Norm Klausutis

In addition to these people, I would also like to thank the other apprentices at Eglin for enhancing my social experience here.

TABLE OF CONTENTS

1. INTRODUCTION

This summer I worked with Frank Arredondo and Darryl Huddleston in the RF/Millimeter Wave Laboratory. This lab is room 484 in the Eglin Armament Laboratory. This was my second year in the HSAP program, and I continued work on the In-House Radar program that I started last summer. I will return next summer to complete my three-year term.

2. PROJECT BACKGROUND

The long-term goal of the In-House Radar program is the creation of a working pulse doppler X-band radar system for use in testing new low-cost components. The radar system we are using is currently installed in the RF laboratory. The two antennas being used are attached to the roof above the lab, and are connected to the electronics via waveguides. The search antenna is a horizontal bar containing three transmitters, each covering a certain general elevation. This antenna rotates 360 degrees to cover the entire surrounding area. The track antenna is a parabolic dish antenna that can adjust its elevation and azimuth to track targets that the search antenna locates.

The antennas are controlled by the radar control system, which is located on a test bench in the RF lab. This system consists of a transmitter, receiver, radar electronics, and a system controller. The system controller is a computer that reads and sends data over a 1553 serial bus. This bus is the main artery of communication for the radar system. The system also includes additional components such as a plasma display system and control panels.

Our short-term goal is to allow the radar to be controlled by other computers in the lab, such as a PDP 11/44 minicomputer or a Z-248 microcomputer. This will eliminate many older radar components that would be difficult to repair, and will add flexibility to the system.

This summer, I worked with the aspect o. .sing a Z-248 to display radar data.

3. PROCEDURE

3.1 SOFTWARE ROUTINES

My first major task this summer was to write several software routines. These routines were written in C and FORTRAN, which I learned. Eventually, the routines will be incorporated into the radar system.

The first set of routines written was a coordinate conversion utility. I wrote the software on the Radar Signal Processing Laboratory VAX computer, using FORTRAN 77. These programs convert points in space from the rectangular coordinate system (X, Y, Z) to the spherical coordinate system (Range, Elevation, Azimuth). This conversion is needed because the radar sends target position in rectangular coordinates. However, when specifying a target to track, the user must tell the radar its position in spherical coordinates.

I also wrote a routine in Turbo C on a Z-248. The routine consists of functions that manipulate 16-bit data words. As previously mentioned, the radar sends data and receives control signals over a 1553 serial bus. All data on the 1553 bus is in the form of 16-bit data words. In a typical data word, the last 10 bits might hold the speed of a certain target. My functions allow the user to extract those bits and convert them from binary to decimal, allowing for fractions and negatives.

3.2 PLASMA DISPLAY FEASIBILITY STUDY

Another task I was assigned involved the evaluation of a plasma display system. This consisted of a plasma display and a display processor unit, or DPU. The plasma display is a monochrome graphics screen with a resolution of 512 X 512 pixels. The display and the DPU were parts of the original radar system. A suggestion was made that this be interfaced with a Z-248 in order to have a user-controlled hardware display. The Z-248 would send data to the DPU over a parallel bus. I investigated the feasibility of this proposed setup.

An study of a DPU revealed that the unit contained four circuit boards: a CPU/PROM board, a RAM board, a host interface module, and a display interface module. I focused my attention on the host interface module. This is where the DPU would receive data and control signals from the Z-248. After researching schematics and testing the board with lab equipment, I concluded that the data signals could be interfaced, but that the control signals would require a great deal of time and experimentation to interface. I then concluded that the alternate approach to a user-controlled display would be the best choice.

3.3 DISPLAY EMULATION SOFTWARE

The alternate display method required a software-emulated display on a Z-248. Last summer I wrote a radar graphic display program in BASIC. This year I converted the program to C language and enhanced its capabilities. The program receives target location and target type data over a serial communications port at a data rate of 2400 baud. The program stores the data in a buffer in RAM. It then interprets the data and uses it to update its target type/location/status database. The program displays this data on the screen in an easily readable color high-resolution graphic format. The program is capable of displaying up to fifteen moving targets simultaneously.

Since the radar is not yet capable of sending data in this form, a radar data simulator program was written. I aided in designing and debugging this small software routine. It sends 'canned' target data over a standard RS-232 serial bus to a Z-248 running the radar display software. During tests, the display software successfully received and displayed the data.

4. RESULTS & CONCLUSIONS

This summer I further familiarized myself with the In-House Radar System. I dealt with the radar from a systems standpoint, focusing on hardware-software integration. My minor software routines will later be integrated into controller software.

I determined through investigation that the plasma display route was not feasible. Therefore, I continued work on my display emulation software. After converting the program to C and upgrading it, I documented my software thoroughly. Next year, I plan to continue work on the radar system. I will enhance existing software and write new software to meet the needs of the growing system.

5. REFERENCES

FORTRAN Manuals

GW-BASIC Manuals (Interpreter & Compiler)

Radar Technical Manuals & Schematics

Turbo C Reference Guide

Turbo C Users Guide

Appendices can be obtained from

Universal Energy Systems, Inc.

1989 HSAP Event Summary
SAI/AFATL

Derek Holland
MENTOR: Starla Christakos

Acknowledgements:

I would like to thank the following people for their patience, understanding, and wisdom without which I could never have done anything and for which I am very grateful:

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Laura Sterrett,

Dorothy Williams,

Everybody else at SAI,

and my mentor,

Starla Christakos.

Order of Summary:

Background and Definitions

Projects :

I. Analysis of Edge Operators

II. Modifications to DSM

III. Implementation of Boeing LEAP

IV. Miscellaneous

Background and Definitions

During the summer I worked for the Eglin Armament Laboratory, a participant in the Summer Apprenticeship Program, sponsored by Universal Energy Systems. During that time, I read, researched, and programmed under the direction of Starla Christakos, section chief of the Signal Processing Section of SAI.

I worked on several projects throughout the summer. The first, implementation of edge detection and then analysis on a Digital Seeker Model; the second, the implementation of an primitive form of hardbody detection on the same model; the third, translation of LEAP algorithms to work with DSM; finally, several other unimportant tasks. This report is a summary of those ventures.

Since the projects were separate, I have tried to keep each separate in the report. This first section serves mostly as a tool for definitions, to be used for the separate 'project' sections of the report.

I have enjoyed this summer immensely. I have not only gained insight into how computers work, but also a working knowledge of two computer languages. I have learned how to structure my programming and produced readable results. I have gained valuable insight into areas never covered in high school and look forward to participating in the apprentice program next year.

DSM

The Digital Seeker Model is a simulation that runs on a Sun workstation under UNIX. It consists of two parts, one in C and the other in FORTRAN. The C part handles the grahics, and the FORTRAN accomplishes the 'grunt work.' I primarily concerned myself with the FORTRAN section of the simulation.

DSM simulates a generic space-based guided missile (interceptor), specifically a kinetic energy weapon. It is designed so that one can step through the image processing phase of engagement, leading to the theoretical destruction of the target.

In ordinary program flow, the user specifies a given set of seeker parameters, which are then loaded into the program from record files. The program loads the input scene into memory, simulates the operation of optics, simulates the focal plane array, and then performs the signal processing algorithms specified by the user. It is possible to save an image at any stage, and then execute from that image if one is performing many operations on one image. This cuts down on time considerably. Because of the length of DSM, I will not discuss each addition that I made to it, or ramble about each line's meaning. The current version of the program is included to satisfy immediate curiosity.

THRESHOLDS

Once DSM has provided a simulated output image from the FPA, it is the duty of the signal processing section to extract some intelligible information from it. The simplest form of this extraction is the threshold. It is, by definition, the screening out of noise from a picture to leave only relevant data. There are several ways to set the criteria by which pixels are judged relevant or extraneous, among them the fixed value threshold, the percentage threshold, the adjustable threshold, and the heuristic threshold.

The fixed value threshold works by reading the irradiance values of each pixel or box in the array. If the current pixel does not have a value greater than some set constant, then that pixel is set to zero; otherwise, it is left as is. Although simple, this is a very effective hunt-and-peck technique.

The percentage threshold is a bit more complex. In it, two values are specified. These are the percentage from the top and the percentage from the bottom. This time, before the pixel-by-pixel comparison, the maximum pixel value is determined. Using this data, the comparison figures relevancy by determining what percentage the current pixel is of the maximum value pixel. If the current pixel conforms to set percentage guidelines, it is kept in the picture. The set percentage guidelines may require that all pixels aboe or below a certain threshold be zeroed, or that all pixels between certain percentages be zeroed.

The adjustable threshold is a mixed bag technique. By it, no user value is entered. The program figures the threshold value based on a predetermined equation. The equation sometimes relies on functions such as variance of pixel values, average pixel value, etc. Here, the threshold is only as good as the equation one has entered.

A heuristic threshold is an advanced way to produce meaningful data from a noisy image. Because it uses heuristics, the threshold is known for its speed. Although, little work was done in this area of thresholding, it is a challenging subject and probably would suite any simulation well.

THE EDGE OPERATOR

A second way to affect an image is to use an edge operator, or detector. The purpose of this device is to locate places in the image where a distinct change of intensity values occurs. The assumption is made that the objects of interest are at different intensity values from the background. In this setup, a predetermined set of operator values is run over the image and values in the image multiplied by the operator factors The resultant image is usually accentuated in some way, closely related to the function of the operator. To simplify confusion, one can think of an operator almost like a matrix, run over each pixel in an array. The assortment of operators used this summer were the linear compass masks, the Roberts operator, the Sobel operator, the Wallis operator, and the Kirsch operator. (see operator illustration)

COMPASS MASKS

These were 3 x 3 masks designed to bring out edges that ran along a set direction. The edge directions detected by these correspond to the directions on a compass : North, South, etc. For instance, in the SE mask, all edges coinciding with the southeast direction were accentuated. No complex operation was performed on each point, just factor multiplication.

ROBERTS OPERATOR

The Roberts operator is a non-linear 2 x 2 mask, where the value of each point is determined by the equation :

f(x,y) = FPA array
x = row
y = column
f(x,y) = square root(x*x + y*y)
x = f(x,y) - f(x+1,y+1)
y = f(x+1,y) - f(x,y+1)

As one sees, the Roberts sets up one mask weighted for horizontal change, and another mask weighted for vertical change. the squares and roots help to smooth out the inage.

Although effective in accentuating edges, the Roberts operator is ineffective in screening out noise, and therefore is not highly recommended.

SOBEL OPERATOR

The Sobel operator is exactly like the Roberts in overall design, except that the Sobel is a 3 x 3 mask, with x and y being as follows:

x = (a2 + 2*a3 + a4) - (a0 + 2*a7 + a6)
y = (a0 + 2*a1 + a2) - (a6 + 2*a5 + a4)

(In this notation, a0 is the top upper-left box of the operator and boxes are numbered counter-clockwise. Since this notation is easy to express, I will continue to use it.)

The Sobel performed nearly identical to the Roberts in that it did not screen out ANY background noise.

WALLIS OPERATOR

The Wallis operator is a different matter entirely. It supposes that is the log of a pixel's value exceeds the average value of its four nearest neighbors by some value, then it is an edge. The actual equation is defined as:

f(x,y) = log(x,y) - .25*log(a1) - .25*log(a3) -
.25*log(a5) - .25*log(a7)

The Wallis operator does not work well with log scaling.

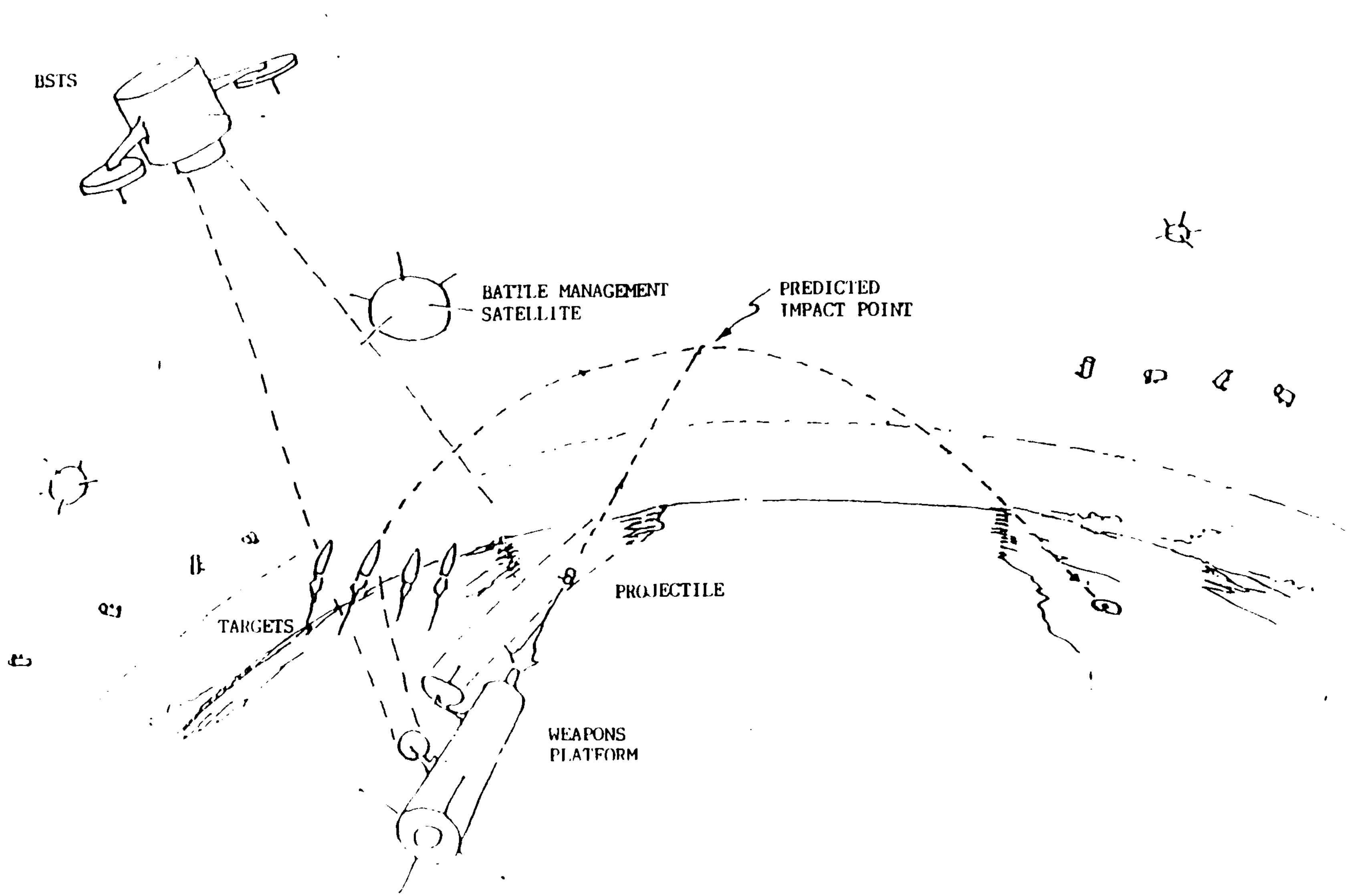
KIRSCH OPERATOR

The Kirsch operator is a non-linear 3 x 3 mask that works differently than most. It is easier to explain the operator after one sees its equation.

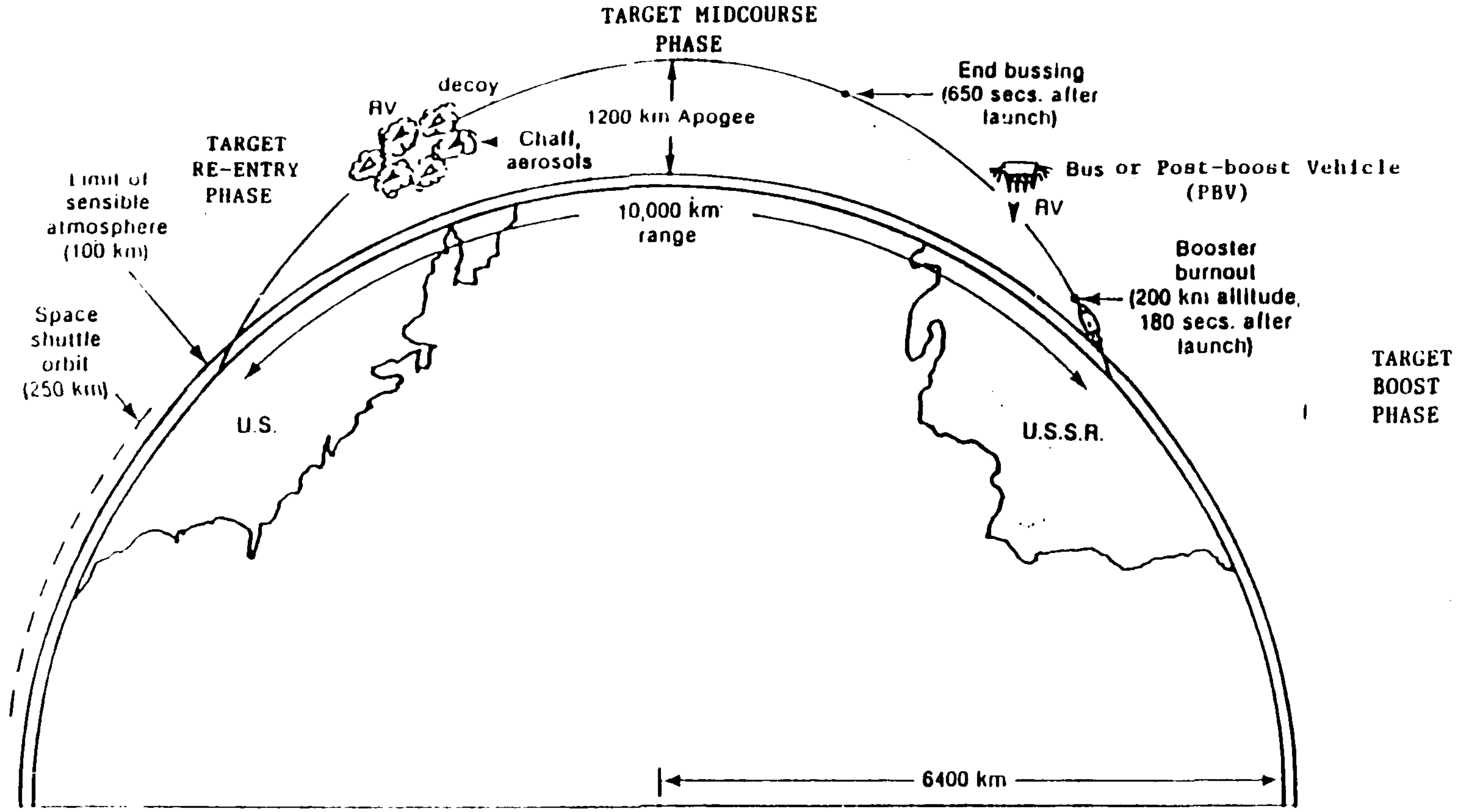
f(x,y) = max(1, max(i = 0 to 7)[5*Si - 3*Ti])
Si = Ai + Ai+1 + Ai+2
Ti = Ai+3 + Ai+4 + Ai+5 + Ai+6 + Ai+7
(THE SUBSCRIPTS OF A ARE EVALUATED MOD 8)

The operator checks for the max change from eight possible directions around the home pixel. The operator multiplies the top three values by a constant, subtracts them from the other five values (multiplied by a lower contstant), and produces a RESULT. This process is repeated for each of the eight directions, and the maximum result is selected.

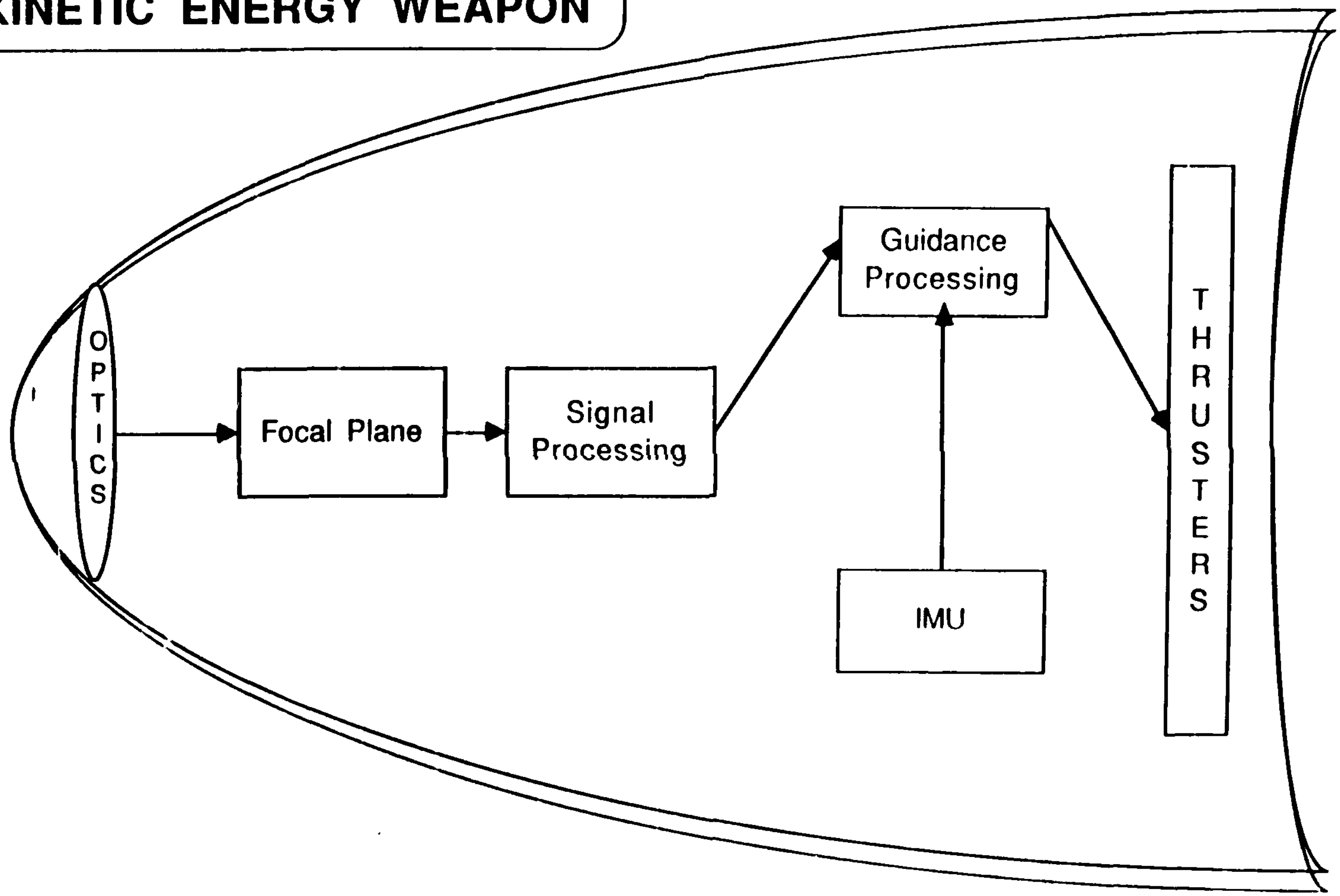
BATTLEFIELD



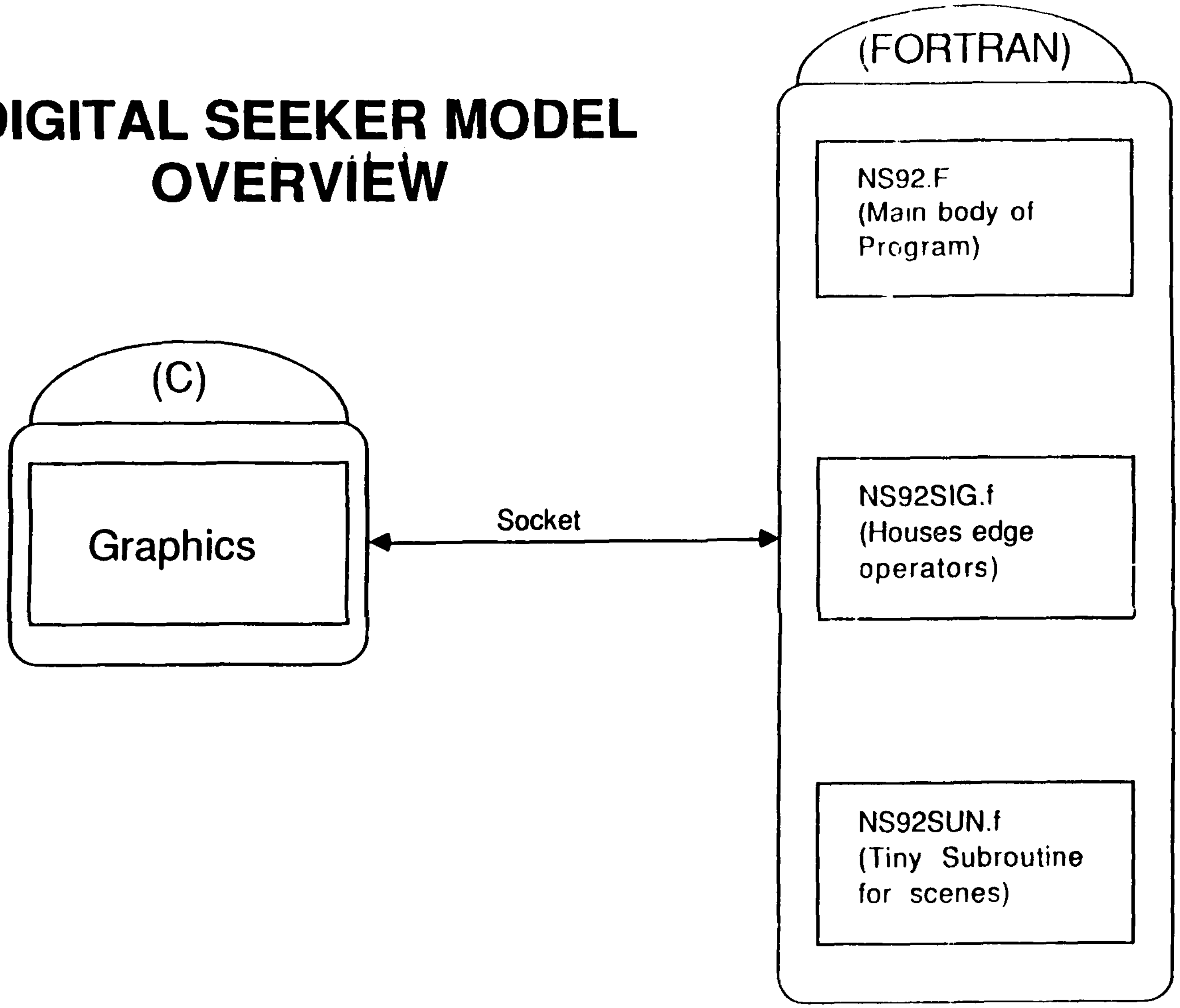
The Flight of a Hypothetical Future Soviet ICBM With the Booster Characteristics of the U.S. MX Peacekeeper, Drawn to Scale



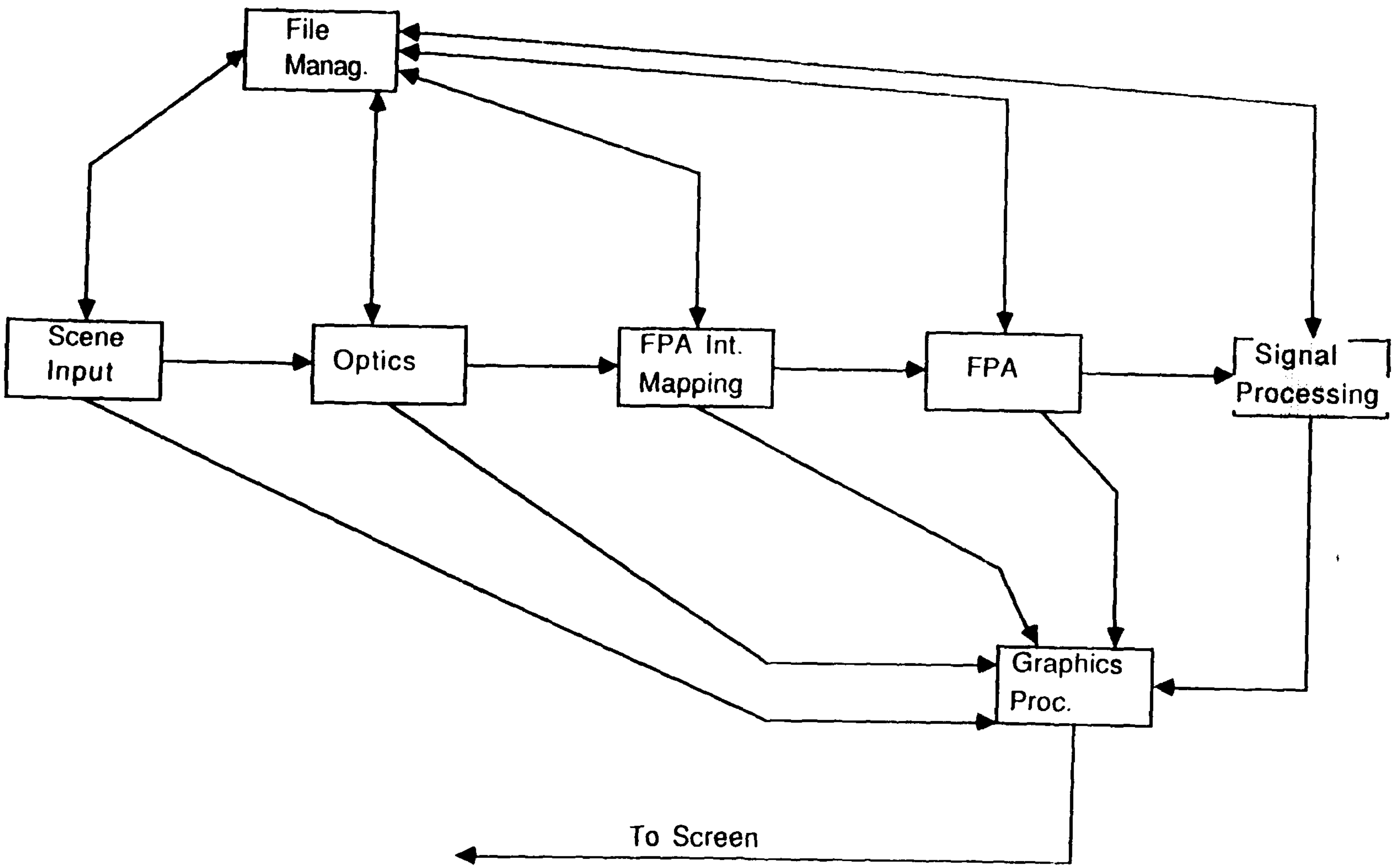
KINETIC ENERGY WEAPON

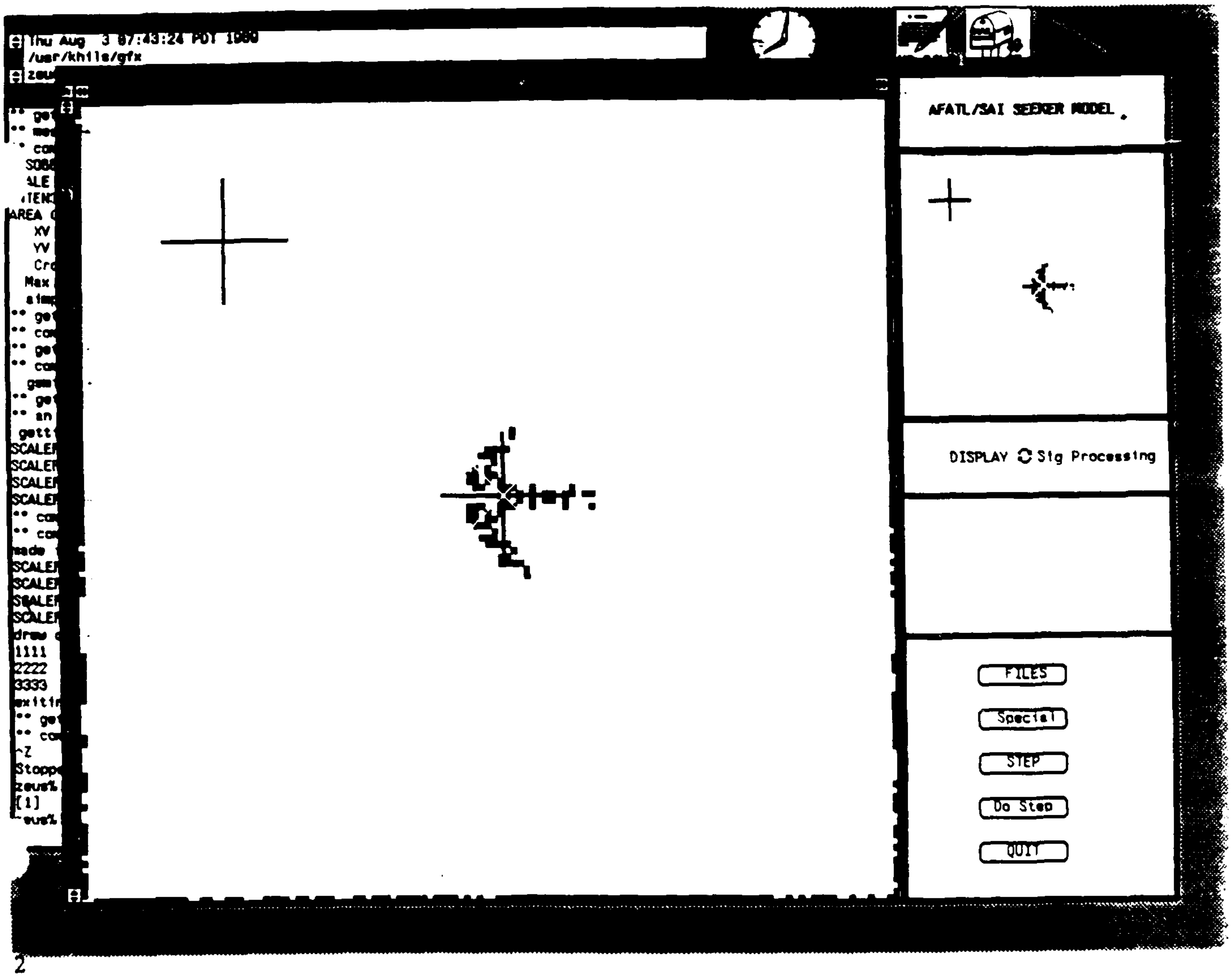


DIGITAL SEEKER MODEL OVERVIEW



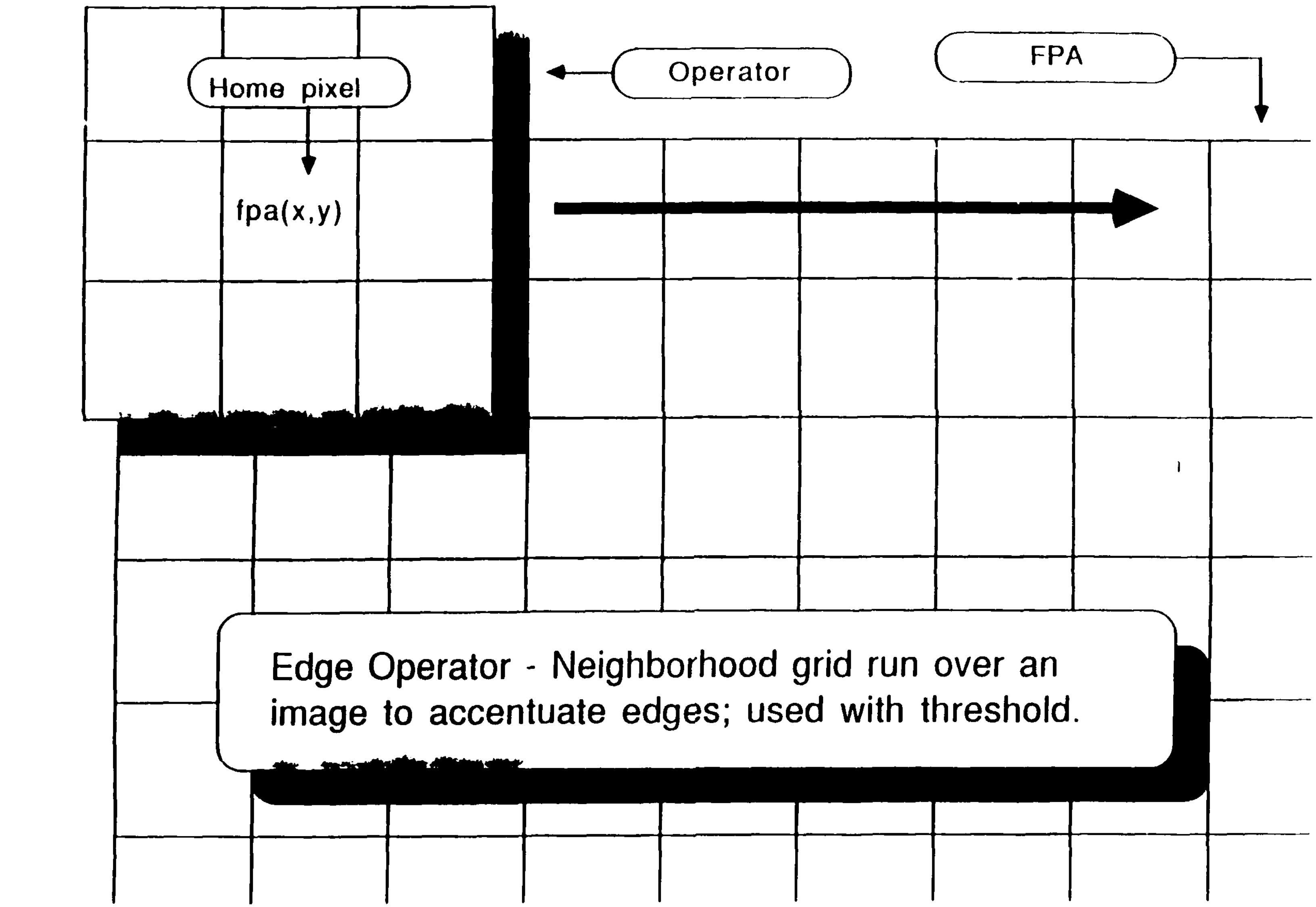
DSM FLOW OUTLINE





DIGITAL SEEKER MODEL
SAMPLE DISPLAY

Operator image scanning



Projects

I

An Analysis of Edge Detection and Thresholding Techniques Using the Digital Seeker Model (DSM)

Report:

A. Purpose

B. Setup

C. Summary of Results

PURPOSE

The purpose of this project was to examine the workings of different thresholding techniques, determine an optimum value of threshold for any different background scene provided, develop and test different forms of linear and nonlinear edge detection algorithms, and generally analyze the performance of these different techniques of shielding out noise from pictures, leaving plumes, from which hardbodies can be determined.

SETUP

The Digital Seeker Model (DSM) runs on a Unix-based machine, a Sun system 3. DSM is made up of three main components; NS9.f, the FORTRAN code that, in effect, handles the calculations for the main body of the program; NS9SIG.f, linked into NS9.f, which is made up of all the edge sharpeners and operators that run during the signal processing phase of the program; and NS92SUN.f, a short program handling part of the scene opening tasks of DSM. Sockets are used to connect this part of DSM with the C graphics routines (this report does not cover them).

DSM is adequate for a sort of point-and-click-eternity style of experimentation when few pictures and even fewer routines are being evaluated. But, when mass quantities are being run through, one needs a sort of script file for the program to follow automatically (to prevent the programmer from spending the rest of his life at the terminal) while one is off conquering the universe or such. Luckily, this is possible. Using a set of commands in GSERV, script files TEST.bsm and TEST2.bsm guided an otherwise stupid program into accomplishing immaculate, wonderous deeds.

Now that all the data files had been generated, there had to be a way to dump them on a printer. Several programs allowed this. The first was COLORZ.c, a program that took data files and converted them into a color format. The second was EXPAND.c, a program that enlarged an image any desired parameters. The third (and most important) was DITHER.c, which set things like grey-scales. The last program was RDB.c, a raster dump which actually did the job of putting the image on the printer. COMFILE allowed me not to lose my place when printing on the LN03 printer.

SUMMARY OF RESULTS

The experiments can be divided into two main phases: phase one, primarily concerned with finding optimum threshold values for ten SENTAR scenes arbitrarily picked from an animation sequence, had three main answers: 1) the optimum fixed threshold value (the value required to successfully screen out all background noise), 2) the optimum percentage threshold value (for noise screening), and 3) the optimum percentage threshold outline value. (This being the value capable of screening out background noise and the peak intensity portion of the plume, leaving an outline to its edges. The following is what I found.

FIXED

DSM_30.bin = 3.0
DSM_70.bin = 2.75
F00001.bin = 2.5
F00010.bin = 2.5
F00030.bin = 2.5
F00050.bin = 2.85
F00070.bin = 2.5
F00080.bin = 2.5
F00110.bin = 3.25
F00120.bin = 4.0

Generalizations : Unfortunately, no one value can be presented as pertaining to every scene chosen. Most of the scenes suffice with a value of about 2.5; however, this does not mean that all can optimize that same value for screening out noise. Fixed thresholding still must be custom-tailored to each image.

PERCENT (AND OUTLINE)

DSM_30.bin =	100%	25%	(30% 25%)
DSM_70.bin =	100%	20%	(27.5% 20%)
F00001.bin =	100%	17.5%	(not poss.)
F00010.bin =	100%	17.5%	(not poss.)
F00030.bin =	100%	17.5%	(not poss.)
F00050.bin =	100%	20%	(30% 20%)
F00070.bin =	100%	17.5%	(30% 27.5%)
F00080.bin =	100%	20%	(29% 20%)
F00110.bin =	100%	25%	(30% 25%)
F00120.bin =	100%	25%	(not poss.)

Generalizations : Again, because of the diversity of values, it is impossible to find ONE value to satisfy all scenes.

The second phase was investigative of the different kinds of edge detectors. These are little subroutines entered in the program that systematically ran over scenes and DETERMINED edges. Five scenes were chosen this time, typical of the mainstream differences between images. Since there is no one optimum value answer, one must describe performances of operators, and to justify my claims, I have included the graphic dumps of all runs in this report.

The operators used were the eight compass-directional masks

(N, NE, E, etc.), one simple horizontal mask and a vertical counterpart, a Kirsch operator, a Roberts operator, a Sobel operator, and a Wallis operator.

OPERATORS

The first scene (DSM_30.bin)produced some interesting results. All the compass masks performed poorly, except the East mask. It was mediocre. The horizontal and vertical masks were fair, not good. These results lead me to the opinion that the compass masks and other linear detection schemes like them should be used in conjunction with another operator. These masks amplify the noise to the extreme that identification of the plume is difficult at best.

The other operators performed well. The Sobel and Roberts did a good job bringing out the plume. The only problem was that they also brought out the clouds. Thresholding is needed for any practical use. The Wallis operator did not turn out well on any images. Because of DSM's logarithmic scaling and black border, the graphics were perverted into some gruesome representation of vomit on the monitor. The Kirsch performed the best by far. It requires minimal thresholding and brings out the plume the best.

The second scene (DSM_70.bin) was similar to the first. Again, the compass operators performed pitifully, as expected. The East mask was again the best of the worst. The other two linear operators were fair.

The nonlinear operators performed as expected, the Roberts and Sobel requiring heavy thresholding, the Wallis looking like gastrointestinal fluid, and the Kirsch performng the best.

On to the third scene (F00010.bin), where results seemed to look mighty familiar. Again ALL the linear operators performed badly (because of the small plume, hardly anything showed up in the noise). Again, the Sobel and Roberts showed the BEAUTIFUL superfluous clouds. Again, the Wallis displayed some inward symbolic gesture of the fires of hell, torture, and subroutine death/failure. Again, the Kirsch was the best of the lot.

The fourth scene (F00080.bin) needs almost no summary. As before, the East mask was the ONLY linear besides the HORIZONTAL that was even fair. As before, Roberts and Sobel mapped out the vast expanse of clouds that give thresholding experts a headache. As in the past, the Wallis looked offensive to my tastes. As before, the Kirsch requires almost no thresholding.

The fifth scene (F00110.bin), unlike the others, shows a rather large plume. In it, all the operators STILL performed as before. The linear masks couldn't distinguish between noise and reality, save the EAST, and this time the VERTICAL. The others were no different. The Kirsch performed the best with predictable results shown from the others.

Generalizations : The linear masks should be used with another operator, not alone. They should be used as speciality masks, chosen by the programmer, wishing to amplify a CERTAIN direction of edges. The East mask performed generally the best. The WEST operator, curiously, always magnified the hottest part of the plume. It found nothing else but that. The horizontal and vertical masks are not even worth discussing. Use thse masks only when nothing else works and you are extremely desparate.

Nonlinear masks worked pretty nicely, save the Wallis. If DSM did not use a logarithmic scale, it would look nice too, BUT... The Roberts and Sobel operators were almost identical in performance, both showing all the clouds. The Kirsch is a wonderful operator, requiring little or no thresholding and really bringing out the plume.

Generally, in both phases, no one value worked for all the scenes. It is impossible to say that a threshold value of 3 will always be best. One must analyze the picture with an operator, perhaps an edge sharpener, and THEN, maybe a minute threshold for a cloud or two. Of all the runs, my choice for a BEST combination would be a Kirsch operator with a low fixed threshold. If needed, run this with a linear compass sharpener.

To allow my results to serve as a guideline for determining the the choices of other signal processing runs, I printed a list of the maximum and minimum values for each of my scenes AT THE FPA PHASE OF DSM. When wondering which operator to choose, see if any of the scenes in question are comparable to mine.

Appendices can be obtained from

Universal Energy Systems, Inc.

PULSE DOPPLER RADAR

AFATL/AGS

Presented By: Jeffrey Leong
Mentor: Mr. John Wolverton
Branch: Air to Surface Guidance
Date: 11 August 1989

TABLE OF CONTENTS

I. Introduction

The high-tech radars that we have today are a culmination of over a century of research and study in the electromagnetic spectrum. Over one hundred years ago in 1886, Heinrich Hertz discovered and successfully demonstrated the basic RADAR (RAdio Detection And Ranging) principle, that radio waves will reflect off objects and can be detected. Shortly after the turn of the century, this principle was first utilized to aid in ship navigation. Shortly thereafter, radar began to improve by leaps and bounds. Within twenty years, the first radar for pulse ranging had been used to measure the ionosphere. Then by the early to mid thirties, with war fast approaching, heavy experimentation was underway worldwide to develop and test various radar concepts for wartime military usage. Probably one of the most famous accomplishments to come from this era is the British "Chain Home" Advanced detection radar used to defend the British Isles against the incessant Luftwaffe night bombing during the Battle of Britain. This radar was used simply to detect the presence of the enemy aircraft in sufficient time to scramble RAF fighters to intercept them. Without this radar system, the United Kingdom would never have been able to stop the Germans from literally bombing them out of existence. Another famous incident in which radar played a key role is the hunting of the Bismarc. After the Bismarc sunk the HMS Hood, the British sent the major portion of their fleet after what they viewed as the most serious threat to their sea "lifeline" with America. Even with the number of vessels chasing the Bismarc, she could have easily taken a more circuitous route to her destination and avoided conventional detection. However, since many of the British ships were equipped with radar systems of some type, They were able to locate the Bismarc and damage her enough that her crew finally scuttled her, thus ending her threat to the allies. Radar experimentation has continued throughout the century, advancing to the high technology pulse doppler radars that we have today in both civilian and military applications. Pulse doppler radar has significant advantages over its predecessor, the continuous wave radar. The variation of the pulse repetition frequency (PRF) of the radar gives pulse-doppler radar an extremely wide range of capabilities. By itself, a pulsed radar is not a good determiner of target speed because the doppler effect on the returning waveform is quite small and therefore extremely ambiguous; however, by pulsing the emissions of radar energy, the pulsed doppler radar is a very good determiner of target range. This is achieved by measuring the time elapsed between when the pulse was sent and when it was received. Since RF energy travels at essentially the speed of light, this is not hard for the pulsed doppler radar to do in fractions of a second; however, the continuous wave radar had very large problems in this area, since there was no specific start time for a specific pulse. Modern pulsed doppler radar solves for both of these problems by varying the PRF. At a very high PRF, the radar is transmitting what approaches in characteristics a continuous wave of energy, thus getting highly precise doppler speed readings; however, at a lower PRF, the radar receives highly precise range data by analyzing the lapsed time. Through use of the high speed processors we have today, pulsed-doppler radar can change PRF at will to keep the user constantly updated on the range, heading and speed of his target in all environments.

TASKS ACCOMPLISHED

I. GENERAL RADAR PROGRAM

The first task that I was given at the lab consisted of compiling a group of nineteen BASIC routines into a workable model capable of running from MS-DOS without the otherwise necessary aid of the GW-BASIC interpreter program. These programs each have special characteristics which enable them to measure different capabilities of various antenna types for use in the computer evaluation of simulated or proposed antenna types. By compiling these programs into an independent MS-DOS software package, I have cut the run time of the programs at least in half, optimizing the user time allotted to this application. In the future, my mentor and others will use this program for the evaluation of various antenna designs involved in their work. The documentation of the MS-DOS version of the software package is included with this report as Appendix A if you desire a more in depth analysis of the capabilities of this package.

II. <u>SUPPORT OF THE IN HOUSE RADAR PROGRAM</u>

A. RADAR TARGET SIMULATION PROGRAMS

My first task in direct support of the In-Hose Radar program was the creation of a program to send simulated radar target data to the radar simulation/control software created by my fellow apprentice Reid Harrison. Since we do not yet have a working hardware interface between the Pulse-Doppler radar and the Z-248 computer, I designed my software to simulate the data feed from a working radar to test and validate the Radar display program. We first determined that the best way to accomplish this was to use the PDP 11/44 as the target simulator. We decided this for two reasons. First, the PDP is available in the RF lab where the radar control equipment is located; and second, the PDP is multi-tasking multi-user system, so by using it, we would not usurp an entire system, but instead use only system time. I began programming a FORTRAN routine to simulate the detection and movement of both helicopters and fixed-wing aircraft. We were successful in transmitting and receiving minor data from the computer and displaying it through the display software, but the more complex calculations to actually simulate target motion became very troublesome to debug and, after several different methods were tried, we decided that the task would be more efficiently completed in a different language. We chose BASIC because it offered the greatest ease of programming coupled with the features we needed for this application. We were finally able to validate the display software to the point where we are convinced that it can decode and display actual radar data when the hardware link is finally established.

B. SCHEMATIC DIAGRAM COMPILATION AND CATALOGING

My next task was the compilation, organization, and cataloging of all the schematic drawings and interface diagrams which display the integration and interaction of the various components of the present radar system. The reason that this task was necessary was to fulfill the final long-term goal of the

In-House-Radar program, that being to substitute other low cost radar components for testing and evaluation. To accomplish this goal, we first must how each of the components fits into the system. We decided that the best way to compile these drawings was to put them into a database off a spreadsheet for easy access. Using the RF lab's Z-248 microcomputer, I documented each of the necessary cards in SuperCalc5, so that whoever needs them later can manipulate them at will. Now that I have cataloged these schematics, they can be readily accessed whenever the chance arises to introduce new components into the system for testing and analysis. A hardcopy of this spreadsheet is included as Appendix B.

C. SCHEMATIC DIAGRAMS

I was also tasked with translating the radar component schematics into a model which could be easily accessed through a Z-248 computer. These schematic diagrams were a pictorial representation of the schematic drawings and interface cards that I had already cataloged, so I had some idea of what was needed in this area. I felt that we would need these diagrams on an easily accessible and easily readable series of computer files. I decided that the best way to do this would be to integrate these diagrams into a series of smaller single sheet schematic diagrams for better user access. For clarity, simplicity, and ease of storage, I proceeded to integrate these drawings into a series of smaller drawings through the use of a computer drawing program. I put all the necessary information in place on the drawings tree, while still leaving room for the addition of other information that future users feel is important. These drawings are all stored on the computer, so they can be readily recalled, recreated, and updated dependent on program needs. These drawings can now be easily fitted to the ever-changing needs of this program. I have included a hardcopy of these drawings as Appendix C.

POSSIBLE FUTURE EXPANSIONS

The In-House Radar program's primary goal is to establish a working pulsed doppler radar system for the future testing of new low cost radar components. In the future, pursuant of this goal, I am sure that the spreadsheet I created will be expanded to contain the use and capabilities of the various components for greater insight into the radar. Later users will most likely expand and update the drawings tree to provide for later upgrades and new test equipment in the system. Future apprentices might look into greater software upgrades or even advanced components of a new test radar.

ACKNOWLEDGEMENTS

I would like to thank the following people for their help and assistance this summer. Without them this program would not be possible:

John Wolverton

Darryl Huddleston

David Rogers

Johnny Walker

Al DiSalvio

Tom Speed

Bruce Quarles

Dr. Klausutis

Mr. Harrison

And all the people in AGS who helped my so much whenever I needed it.

REFERENCES

David Pozar, Ph.D., ANTENNA DESIGN USING PERSONAL COMPUTERS

FORTRAN programming manuals

GW-BASIC manual

Hughes Aircraft's AIRBORNE RADAR

Appendices can be obtained from

Universal Energy Systems, Inc.

ENHANCEMENT OF INPUT AND OUTPUT
FOR THE EPIC-2 HYDROCODE

BRYAN MCGRAW
HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR: MIKE E NIXON
AFATL/MNW

The Summer of 1989 was my second year in the High School Apprenticeship Program under Mr. Mike Nixon. As was the case in the first year, the Summer was a challenging and exciting time. After reviewing my FORTRAN programming skills and re-acquainting myself with the UNIX and VMS computer operating systems, I worked in several different areas of the Computational Mechanics area. I operated the EPIC-2 hydrocode preprocessor, studied, learned, and applied the Graphical Kernel System (GKS) to create a time history plotter to be used in conjunction with EPIC-2 data outputs. I became more attuned to the intricacies and details of working with and applying the knowledge I possess in a direct and effective manner. Most importantly, however, I learned how to think analytically and make a contribution in a way that makes a difference.

In the Computational Mechanics branch of the Munitions Division, complex computer programs of over 20,000 lines in length called hydrocodes are developed and maintained. During the eleven weeks I worked, I was principally involved with the EPIC-2 Hydrocode.

EPIC-2 is a Continuum Mechanics based hydrocode. Hydrocodes are complex computer programs which can simulate the penetration of a projectile into a target. EPIC-2, more specifically, is used to simulate highly dynamic events such as armor penetration and the formation of a shape charged jet.

To run EPIC-2, the user must first work with the preprocessor to set up the problem. To do this, he must create what is called an input deck. This input deck is actually a file which contains several lines of specifically arranged numbers. These numbers tell EPIC the materials to use, the geometry of the projectile and target, specifics and details about the problem, and, finally, what data should be included in the data dumps. This data includes variables such as velocity, stress, strain, and pressure. EPIC-2 uses elements and nodes to help define the material it is using in the problem. Nodes are points in which the mass of the material is represented while the elements represent the volume of the material. In the geometry of the problem, EPIC-2 divides the material into triangles, with the nodes at the vertices and the elements as the area of the triangles.

One of my initial tasks was to create various inputs for my mentor. At this point, he would run the actual calculations and analyze the results. Most of the different calculations we did were designed to gain more information about the capabilities and limits of slidelines. Slidelines are special groups of nodes that function as a unit. EPIC-2, using these slidelines, can more efficiently and accurately predict the outcome of a highly dynamic interaction between a target and projectile. To create the inputs for my mentor, I used a preprocessor written by two other HSAP participants (Mark Fisk and Neil Overholtz) and my mentor. Although I did find some minor problems with the program, I, with Neil's help, fixed them and created the inputs my mentor needed.

After EPIC-2 has completed its calculations, the results must then be analyzed. One of the more important ways of doing this is looking at the results graphically. This can be done in one of two ways. First, the user can look at the geometry of the problem. In this way, the user gets an actual picture of what is happening and a plot of the results contours. Second, the user can plot out the time-history data in an x-y form. My two major tasks were to make these graphic outputs available on MNW's UNIX based computer systems.

Normally, the geometry had been handled one of two ways. The user either had to use Tekpeek or PATRAN. Tekpeek is a graphics option available only on KR's VMS machines and our VMS Micro Vax. It gives the user a line drawing of the geometry. Patran, on the other hand is a much more powerful and sophisticated graphics package which is run only on KR's Digital 8650 Computer. PATRAN allows the user to implement a wide range of options in getting the best possible picture of the problem's geometry. With PATRAN, the user can look at the problem from different angles, rotate the two dimensional plot to give it a three dimensional look and shade it to give an almost photograph-like picture of the projectile and target. Although PATRAN is extremely powerful and sophisticated, it takes a great deal of time to transfer files from our computers to KR's to be used with PATRAN and, occasionally, all the user needs is a quick look at the geometry. To accomplish this goal and to create a plotter which would allow a time history plotter to also be used on our UNIX machines, I wrote and adapted two programs that use the GKS graphics library on MNW's UNIX based machines.

GKS is a system of routines that are called by a FORTRAN program to perform unique high level graphics functions. These functions include, but are not limited to, drawing lines and markers, filling in pre-designated areas with varieties of colors and styles, and placing text strings in any number of different fonts, colors, and sizes. These different graphics attributes can then be inserted into the segmented memory of the Tektronix terminal. With this feature, a user can manipulate whole pictures or just use them as building blocks for more complex efforts. When the programmer wants to use GKS , however, he must perform certain tasks. The program must open GKS, open and activate the workstation, and deal with errors relating to the execution of GKS. Although GKS requires the user to inform the system as to its workstation type identity (i.e. a Tektronix 420700), GKS is device independent in the sense that its commands are the same for each type of workstation. To deal with errors, the programmer sets up a file to be used as an error file. GKS will then write all errors dealing with the execution of GKS to that file. Once these setup procedures have been accomplished, the user then merely tells GKS, through the routines that are defined, what he wants to be done. Once done with the body of the program, the user then closes the workstation and stops GKS. Overall, GKS provides an effective and relatively simple way of drawing graphics and plotting formatted data.

The program to map out the geometry of the problem was actually quite easy since I was able to adapt a program written by Mr. Bill Cook. This program allows the user to monitor the program as it runs, giving the user a first hand impression of the results of the problem. All that was required to make it work like I needed it to was to interface the program with EPIC-2 outputs and make it work on the various devices in our area. The second part, however, was much more difficult because of the fact that I had to use a relatively unfamiliar graphics package and create a plotter up to demanding specifications. But, I ,after many trials, finally created EPLOT, a graphics plotter designed to be used with EPIC-2 data outputs.

EPLOT is an x-y plotter that plots the EPIC-2 output data using GKS graphics. The program reads in the data from the specified file and determines the maximum and minimum values of both the x and y data. After opening up GKS and opening and activating the workstation, EPLOT sets up the window and viewport to normal specifications. GKS uses these specifications to determine where it will draw the graphics that the user specifies. The window specification tells GKS how to map the input graphics into the normalized window of 0.0 to 1.0 in both the x and y direction. The viewport transformation creates a specific area in the terminal in which the window is placed. After setting up the window and viewport, EPLOT draws the x and y axes, centers the title at the top of the graph and the x and y labels next to their respective axis. Next, the plotter divides the each axis into ten equal areas and places a grid in the area where the data is being plotted. Now that the plotter window and graph is set up, the program scales and plots the data. The data must be scaled because, regardless of the size of the data, it has to be plotted in the range of the each axis (0.15 to 0.9). To do this, EPLOT sets up variables called XSCAL and YSCAL which equal .75 divided by the range of x and y values, respectively. The program diminishes each x and y by its own respective minimum and then multiplies each x by XSCAL and y by YSCAL. These values are then increased by .15 to finally place them into the correct area for plotting. Finally, the program labels the tickmarks on the axis with the correct numerical values.

In my second year as a High School Apprenticeship Program, I became even more attuned to the problems and frustrations that accompany solutions to highly technical problems. But I also shared in the thrill of solving a problem and seeing something I created make a contribution to the group as a whole. I became familiar with the EPIC-2 hydrocode by way of both its input and output, creating

inputs and making graphic outputs possible on MNW's UNIX based machines. I would like to thank AFATL and MNW for the opportunity I had to participate in the program and Neil Overholtz and Ken Gage for all of their support. Most of all, however, I would like to thank my mentor, Mr Mike Nixon, for all of his undying patience and expertise.

BIBLIOGRAPHY

AFATL-TR-86-51 USER INSTRUCTIONS FOR THE EPIC-2 CODE, G.R. JOHNSON AND R.A. STRYCK, HONEYWELL INC., DEFENSE SYSTEMS DIVISION, EDINA, MINNESOTA, MAY, 1986.

GKS USERS GUIDE, DIRECTORATE OF COMPUTER SERVICES, EGLIN AFB, FL, COPYRIGHT 1986.

TEKTRONIX REFERENCE GUIDE. COPYRIGHT 1986, TEKTRONIX, INC.

ULTRIX-32 GENERAL USER GUIDE. VOL 1. COPYRIGHT 1984, DIGITAL CORPORATION. MERRIMACK, N.H.

ULTRIX-32 REFERENCE GUIDE. COYRIGHT 1987, DIGITAL CORP.

```
*****************************************************************************
*                                                                           *
*     PROGRAM EPLOT                                                         *
*                                                                           *
*                                                                           *
*     THIS PROGRAM IS AN X-Y PLOTTER THAT IS DESIGNED TO BE                 *
*     USED IN CONJUNCTION WITH THE EPIC-2 HYDROCODE.  IT READS              *
*     IN DATA, SCALES IT, AND PLOTS IT OUT INTO A GRAPH.                    *
*                                                                           *
*     X AND Y ARE THE READ VALUES THAT WILL BE PLOTTED                      *
*     XTICK AND YTICK DRAW AND HELP LABEL THE TICKMARKS                     *
*                                                                           *
*                                                                           *
*                                                                           *
*         BRYAN MCGRAW                                                      *
*         SUMMER 1989                                                       *
*         HIGH SCHOOL APPRENTICESHIP PROGRAM                                *
*         MENTOR: MIKE E. NIXON                                             *
*                                                                           *
*                                                                           *
*****************************************************************************


      INTEGER KERFIL
      INTEGER KCONID,KWKTYP
      CHARACTER*40 TIT
      CHARACTER*10 CHARX(12),CHARY(12)
      CHARACTER*10 XVAR,YVAR
      DIMENSION XAXIS(2),YAXIS(2),XNUM(15),YNUM(15)
      DIMENSION XTICK(11),YTICK(11),X(500),Y(500)
      DIMENSION XBOX(2),YBOX(2),XSCALE(500),YSCALE(500)
      DIMENSION XCT(2),YCT(2)
      DATA YAXIS /0.15,0.15/
      DATA XAXIS /0.15,0.9/
      DATA XBOX /.9,.9/
      DATA YBOX /.15,.9/
      DATA YCT /0.151,0.151/
      DATA XCT /0.151,0.9/

      WRITE(*,*) 'WORKSTATION TYPE?'
      READ(*,*) KWKTYP

      WRITE(*,*) 'COLOR OF PLOT '
      READ(*,*) ICOLI
C
C  THIS READS IN THE DATA AND FINDS THE EXTREME VALUES
C  OF BOTH X AND Y
C
      XMIN=999999.
      YMIN=999999.
      XMAX=-9999999.
      YMAX=-9999999.

      DO 290 I=1,500
      READ(18,*,END=301) X(I),Y(I)
      NCHECK=I
      IF(X(I).GT.XMAX) XMAX=X(I)
      IF(X(I).LT.XMIN) XMIN=X(I)
      IF(Y(I).GT.YMAX) YMAX=Y(I)
      IF(Y(I).LT.YMIN) YMIN=Y(I)
 290  CONTINUE
 301  CONTINUE
      KERFIL = 21
      OPEN(UNIT=KERFIL,FILE='ERRORS',STATUS='UNKNOWN')
```

```
OPENS GKS, THE WORKSTATION, ACTIVATES THE WORKSTATION, AND
MAKES CONSIDERATIONS FOR ERRORS

      CALL GOPKS(KERFIL,5000)
      CALL GKHGCI('TT',JERROR,KCONID)
      IF (JERROR .NE. 0) THEN
         WRITE(*,*) 'CANNOT GET CONN ID'
         STOP
      ENDIF
*****************************************************************************
******* TO BE USED FOR THE 8650 *********************************************
*****************************************************************************
*      CALL GOPKS(KERFIL,5000)                                              *
*      CALL GKHGCI('/tty/dev',JERROR,KCONID)                                *
*      IF (JERROR .NE. 0) THEN                                              *
*         WRITE(*,*) 'CANNOT GET CONN ID'                                   *
*         STOP                                                              *
*      ENDIF                                                                *
*****************************************************************************
*****************************************************************************

      CALL GOPWK(1,KCONID,KWKTYP)
      CALL GACWK(1)

      CALL GSWN(1,0.0,1.0,0.0,1.0)
      CALL GSVP(1,0.0,1.0,0.0,1.0)
      CALL GSELNT(1)

      CALL GSLWSC(3.0)
C
C XAXIS
C
      CALL GPL(2,XAXIS,YAXIS)
      CALL GPL(2,XCT,YCT)
C
C YAXIS
C
      CALL GPL(2,YAXIS,XAXIS)
      CALL GPL(2,YCT,XCT)
C
C CREATES THE TITLE AND CENTERS IT IN THE GRAPH
C
      CALL GSCHXP(1.5)
      CALL GSCHH(.04)
      CALL GSTXAL(2,0)
      CALL GSTXFP(-1,2)
      CALL GTX(.525,0.95,'TAYLOR ANVIL IMPACT')
C
C CREATES THE X AND Y VARIABLE LABELS FOR THE AXIS
C
      CALL GSCHH(.02)
      CALL GSTXAL(2,1)
      CALL GTX(.525,0.12,'TIME (MICROSECS)')
      CALL GSCHUP(-1.0,0.0)
      CALL GTX(0.03,.525,'ROD DIAMETER (mm)')
C
C THIS DRAWS THE TICKMARKS
C
      XTICK(1)=0.15
      YTICK(1)=0.15
      DO 200 I=2,11
      XTICK(I)=XTICK(I-1)+.075
      YTICK(I)=0.15
  200 CONTINUE
      CALL GSMK(2)
```

```
      CALL GPM(11,XTICK,YTICK)
      CALL GPM(11,YTICK,XTICK)
C
C DRAWS THE BORDER
C
      CALL GPL(2,XBOX,YBOX)
      CALL GPL(2,XBOX,YBOX)
      CALL GPL(2,YBOX,XBOX)
      CALL GPL(2,YBOX,XBOX)
C
C DRAWS THE GRIDMARKS
C
      CALL GSLN(3)
      CALL GSLWSC(.3)
      DO 300 I=1,10
      YAXIS(1)=YAXIS(1)+.075
      YAXIS(2)=YAXIS(2)+.075
      CALL GPL(2,XAXIS,YAXIS)
      CALL GPL(2,YAXIS,XAXIS)
 300  CONTINUE

      XVAL=ABS(XMAX-XMIN)
      YVAL=ABS(YMAX-YMIN)
      XCNT=XVAL/10.
      YCNT=YVAL/10.
      YSCAL=.75/YVAL
      XSCAL=.75/XVAL

      CALL GSLWSC(3.0)
      CALL GSLN(1)
C
C SCALES AND PLOTS THE DATA
C

      DO 420 I=1,NCHECK
      XSCALE(I)=(X(I)-XMIN)*XSCAL+.15
      YSCALE(I)=(Y(I)-YMIN)*YSCAL+.15
  420 CONTINUE

      CALL GSPLCI(ICOLI)
      CALL GSPMCI(ICOLI)
      CALL GSMK(3)
      CALL GPL(NCHECK,XSCALE,YSCALE)
      CALL GPM(NCHECK,XSCALE,YSCALE)
C
C THIS LABELS THE TICKMARKS
C
      XNUM(1)=0.
      YNUM(1)=YMIN
      DO 530 I=2,11
      XNUM(I)=XNUM(I-1)+XCNT
      YNUM(I)=YNUM(I-1)+YCNT
  530 CONTINUE

      DO 550 I=1,11
      WRITE(7,590) XNUM(I)
  550 CONTINUE
      DO 551 I=1,11
      WRITE(7,590) YNUM(I)
  551 CONTINUE
  590 FORMAT(E8.3)
      CLOSE(7)
      DO 600 I=1,11
      READ(7,610,END=620) CHARX(I)
```

```
  600 CONTINUE
      DO 601 I=1,11
      READ(7,610,END=620) CHARY(I)
  601 CONTINUE
  620 CONTINUE
  610 FORMAT(A8)

      CALL GSCHH(.013)
      CALL GSCHXP(1.0)
      CALL GSTXFP(1,2)
      CALL GSCHUP(0.0,1.0)
      DO 900 I=1,11
      CALL GSTXAL(2,1)
      PX=XTICK(I)-.003
      PY=YTICK(I)-.003
      CALL GTX(PX,PY,CHARX(I))
      PX=XTICK(I)-.001
      PY=YTICK(I)-.001
      CALL GSTXAL(3,4)
      CALL GTX(PY,PX,CHARY(I))
  900 CONTINUE
C
C CLOSE AND DEACTIVATE WORKSTATION
C
      CALL GDAWK(1)
      CALL GCLWK(1)
      CALL GCLKS
      STOP
      END
```

ENHANCEMENT OF INPUT AND OUTPUT FOR EPIC3 HYDROCODE CALCULATIONS

NEIL OVERHOLTZ
HIGH SCHOOL APPRENTICESHIP PROGRAM
AFATL/MNW
MENTOR. MIKE E. NIXON
SUMMER 1989

SECTION 1 - INTRODUCTION

My third summer as a high school apprentice was very beneficial to me. I gained a very in-depth understanding of the work being done by my mentor, Mike Nixon, and the computational mechanics section of AFATL/MNW. My work this summer directly affected the work being done by our section. My main task was to expand on the work I completed last year and create complete documention of the process I previously developed. I also worked extensively with the EPIC3 hydrocode program. I developed experimental inputs for flyer plate tests being run by Mr Bill Cook in the dynamic materials laboratory. I also enhanced a GKS viewgraph maker I created. However, when the summer began, MNW's computer facility was not at an operational level. This was my first task of the summer.

SECTION 2 - COMPUTER FACILITY SETUP

Before this summer began, our computer room had just been under extensive construction. Two walls were knocked out and a new door was installed. All this was in the process of getting the room ready for Tempest operation. During this time the computers were down and covered with tarps to protect them. When I began work the computer room was a wreck. Cleaning up the room and bringing the computers back up to operational level became the task for myself, fellow apprentice Ken Gage, and the other members of the computational mechanics section.

SECTION 2.1 - COMPUTER FACILITY CLEANUP

The computer room was in shambles. Most of the ceiling tiles were gone and wires of all types were hanging down. There was a two inch layer of dust over the entire room, and manuals were strewn from one end of the room to the next. The computers had tarps covering them but the room was so dirty, it would be a miracle if the computers worked when we were finished cleaning. We began by using a shop-vac which did a great job but was very slow considering it only could vacuum approximately 1 square inch at a time. We also placed all the wires back in the ceiling and replaced all of the ceiling tiles. We then removed the tarps and began getting ready to bring the computers up.

SECTION 2.2 - COMPUTER FACILITY INSTALLATION

To bring the computers back up we first had to connect our facility to the ETHERNET running throughout the armament lab. The computers were connected to a DELNI which connected to an H4000 tranceiver which taps directly into the ETHERNET. Once we had the system installed, we brought the computers up. Luckily everything went fine. This was amazing considering they had been down several weeks. Now that our computer facility was operational I could begin work on my real tasks.

SECTION 3 - EPIC3 HYDROCODE PROGRAM

Most of my work this summer involved the use of EPIC3, a three dimensional hydrocode program used in AFATL/MNW. A hydrocode program is used to simulate penetrations a projectiles into targets and the interaction of high explosives and liners. EPIC3 is a 30,000 line FORTRAN program which performs such calculations in three dimensions. However, a three dimensional calculation is much larger than the two dimensional calculations done using EPIC2. The number of nodes and elements used are enormous and the output files are huge.

SECTION 3.1 - EPIC3 MODEL CONFIGURATION

EPIC3 uses what is called an element to make up the geometry of the projectile or target model. Each of these elements is comprised of four nodes, or mass points. The nodes are arranged into a tetrahedral element. The elements of EPIC3 are formed into bricks. These bricks are made of six elements apiece and are shaped together forming a model. The way the model is generated is by creating an EPIC3 input file. When ran through EPIC3, the model shapes are made by

EPIC3 geometry generators. These shapes are created according to information given in the input file. EPIC3 is capable of generating rods, flat plates, and spheres. Once the calculation has been run, a graphics package called PATRAN is used to produce a plot of the calculation.

SECTION 3.2 - PATRAN

PATRAN uses a neutral model file in drawing the plot. This neutral file is created by running an EPIC3-PATRAN translator. This translator reads the EPIC3 output file searching for the information about the calculation at a certain time or cycle specified by the user. This information includes X, Y, and Z data for each node, the nodes comprising each element, and property ID's. The translator then creates the neutral model file with all of this information. This file is very large however because it is written out in ASCII text to be read by PATRAN. PATRAN is then used to draw the picture. However, the time required to produce such a plot often takes hours and if the calculation is a very large one, PATRAN is unable to process that many nodes and elements. That is why the task given to me last summer was to create an interface to the EPIC3-PATRAN translator which would greatly reduce the neutral file size and the time needed to produce such a plot. The interface I developed was called TRANIX.

SECTION 4 - TRANIX

TRANIX is a series of FORTRAN programs and system routines which reduces the time PATRAN takes to plot an EPIC3 calculation and reduces the neutral model file size. The goal of TRANIX is to remove the interior portion of the model leaving the exterior shell. When a three dimensional plot is finished, the only part which can be seen is the outside anyway. So it would be possible to remove the interior nodes and elements from the model before the plot. The way TRANIX does this is it first executes program 'elemfaces'. This program divides each tetrahedral element into its four individual faces and writes each face out to a file called model.all. A system sort is then executed on this file which places all faces which are alike in adjacent order in the file. A system 'uniq' is then executed which removes all faces which are repeated in the file. These are the faces which are shared by two elements. These are interior faces of the model. Next program 'extnodes' is executed which determines the exterior nodes of the model and places them into a file. Then program 'extneu' is executed. This program uses the exterior face file, exterior node file, and the original neutral file to produce a neutral file of just the exterior shell of the model. This new neutral file is at least seventy-five percent smaller. Also the plot time is reduced from several hours to a few minutes. TRANIX is one of the most used and most beneficial programs used by my mentor.

SECTION 4.1 - TRANIX ENHANCEMENTS

When this summer began my job was to clean TRANIX and make it as efficient as possible. I began by stripping off a couple of routines which were slightly helpful but very troublesome to use. I also reduced the number of files used by TRANIX, making the process much cleaner. I then rewrote several of the FORTRAN routines to prevent any excess looping or file manipulation. This improved the efficiency of the process. TRANIX was now ready to be made distribution ready.

SECTION 4.2 - TRANIX DOCUMENTATION

For this to be done, extensive documentation of the package was required. First of all, I internally documented eacn of the FORTRAN programs, describing each routine. I then internally documented the controlling command shell explaining the process logic and labeling each of the files used. The next part of the documentation involved writing a user's instruction manual. Once this was completed TRANIX was distribution ready. This documentation of TRANIX was very tedious. The documentation had to be very precise and able to be followed by any user.

SECTION 5 - EPIC3 INPUTS

Anopther aspect of my work dealing with the EPIC3 hydrocode was creating the setup of two calculations. These calculations were for experiments being done by Mr Bill Cook in the Dynamic Materals Laboratory. These two experiments were copper flyer plates striking ceramic targets. The first of these was a cylindrical shape with a varying heighth around the circumference. The next was a eight pointed star.

SECTION 5.1 - CYLINDRICAL FLYER PLATE

The hard part about these calculations was the inability of normal EPIC3 drivers to create such shapes. To create the cylindrical flyer plate, my task was to use PATRAN to set up the geometry and use PATRAN drivers to output an input file to run through EPIC3 to perform the calculation. I developed this input which ended up being very large because of the strange shape. This model is now calculation ready.

SECTION 5.2 - STAR SHAPED FLYER PLATE

To create the star shaped flyer plate I first created an input for a regular flat plate. I then placed a wedge of bricks on each side of the plate to produce the star shape. The side of each wedge however was flat and to make tne point I designed a new brick which was made of only three elements. By placing this on the end of each wedge, the point was made. There are few erros still being worked out with the calculation but the model is correct.

SECTION 6 - GKS VIEWGRAPH MAKER

Another project I worked on was a GKS viewgraph maker I developed during my second summer. This viewgraph maker uses the Graphic Kernal System(GKS) to place text on the screen to create viewgraphs. What I did this summer was add a couple of options such as font color and font style. I developed the program to work on our MICROVAX computer, but the MICROVAX was not working much of the summer and I had to reconfigure the program to work on our other machines. GKS for each machine is slightly different, which required reprogramming for each computer. Now that this has been done, making viewgraphs is a relatively easy chore for the people of AFATL/MNW.

SECTION 7 - CONCLUSION

My three years as a high school apprentice have been very rewarding. I have been exposed to many aspects of the engineering profession and have learned a great deal from my experiences. In my work in the Armament Laboratory, I have learned as much as I did in all my years of schooling. I have thoroughly enjoyed working with the people in my branch, other apprentices, and my mentor.

SECTION 8 - ACKNOWLEDGEMENTS

I would like to thank Universal Energy Systems for sponsoring the program. I would also like to thank the Armament Laboratory, Dr Klausutis, Mr Don Harrison, Mrs Ellen Long, and Mrs Mary Newsom for their support of the program. Working with the people in my branch has been very beneficial. I have received much advice and help. I would like to express my appreciation for Thad Wallace, Seargent Bob Thomas, Captain Nick Yakaboski, Dave Wagnon, Captain Don Lorey, Mike Gunger, Dr Robert Buchl, Mr Bill Cook, and Lieutenant Mark Hand. I have also had the pleasure of working with other apprentices which I especially appreciate. These include Mark Fisk, Bryan McGraw, and Ken Gage. The most important person in the apprenticeship program however has been Mr Mike E Nixon. He has been a helpful, understanding, and patient teacher. He has also been a terrific friend and I would like to thank him for all that he has done.

BIBLIOGRAPHY

AFATL-TR-86-51 USER INSTRUCTIONS FOR THE EPIC-2 CODE,G.R. JOHNSON AND R.A. STRYK , HONEYWELL INC., DEFENSE SYSTEMS DIVISION, EDINA, MINNESOTA , MAY 1986.

AFATL-TR-87-10 USER INSTRUCTION FOR THE EPIC-3 CODE, G.R. JOHNSON AND R.A. STYRK, HONEYWELL INC., DEFENSE SYSTEMS DIVISION, BROOKLYN PARK, MINNESOTA, JANUARY 1987

ECONET FORTRAN USERS GUIDE, MAY 1985

PATRAN PLUS USER MANUAL, VOLUME 2, COPYRIGHT 1987 BY PDA ENGINEERING, SANTA ANNA, CALIFORNIA.

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ULTRIX-32 QUICK REFERENCE, COPYRIGHT 1987, DIGITAL EQUIPMENT CORPORATION, MERRIMACK, NEW HAMPSHIRE.

ULTRIX-32 SUPPLEMENTARY DOCUMENTS, VOLUME 1, GENERAL USER, COPYRIGHT 1984, DIGITAL EQUIPMENT CORPORATION, MERRIMACK, NEW HAMPSHIRE.

VAX-11 FORTRAN LANGUAGE REFERENCE MANUAL, COPYRIGHT 1982, DIGITAL EQUIPMENT CORPORATION, MAYNARD, MASSACHUSETTS.

VAX-11 FORTRAN USER'S GUIDE, COPYRIGHT 1982, DIGITAL EQUIPMENT CORPORATION, MAYNARD, MASSACHUSETTS.

VAX FORTRAN FOR ULTRIX SYSTEMS USER MANUAL, COPYRIGHT 1986, DIGITAL EQUIPMENT CORPORATION, MAYNARD, MASSACHUSETTS.

UNDERSTANDING FORTRAN: SECOND EDITION, MICHEL BOILLOT, MAY 1985.

Summer Project

for the

High School Apprenticeship Program

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Aerodynamics Branch
Eglin AFB Armament Laboratory

18 August 1989

An Analysis of the Offset Fin Configuration

using

Computational Fluid Dynamics

(CFD)

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank those that I worked with while participating in the High School Apprenticeship Program for the past two summers. They have taught me about different aspects of my working environment from different standpoints and, among other things, they have taught me about life. I sincerely thank each and every one of them for their tolerance of me and the extreme amount of patience they have expressed in teaching and helping me.

I would like to thank:
Mr. Gregg Abate, "Mentor Abate"
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Mr. Jerry Wincnenbach
Mr. Carroll Butler
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Mr. Bill Newbold
Mr. Rudy Jonnson
The personnel at the Aeroballistic Research Facility, Ballistics Experimental Facility, and Computational Fluid Dynamics
Mr. Don Harrison
Dr. Norman Klausutis

and all those who worked with the High School Apprenticeship Program.

It has been an exciting summer.

Thank you for your support!

In an attempt to find more efficient missile configurations, the Aerodynamics Branch of the Air Force Armament Laboratory (located on Eglin A.F.B., Florida) is investigating the concept of the "offset fin." This missile configuration possesses fins placed at an offset angle less than 90 degrees to a plane tangent to the body. This fin design is quite different from conventional fin designs, in which fins are perpendicular to the body. The Aerodynamics Branch decided to investigate the aerodynamic penalties as a result of the offsets. A series of free flight tests were conducted as part of the offset fin investigation, along with an EAGLE code run of the configuration with a 45 degree fin offset. This paper will discuss the investigation.

The offset fin configuration has an advantage in packaging simplicity over conventional finned missiles. The offset fin configuration provides an innovative alternative to the wraparound fin models. Built upon the Army flex-fin concept, the offset fins will wrap around the body of the model when placed in the tube for launching. Once in flight, the fins will mechanically pop-up flat but at an angle to the missile body.

Subscale models of 0, 30, 45, and 60 degree fin offset (Figure 1) were manufactured to be tested in the Aeroballistics Research Facility. The Aeroballistics Research Facility (ARF) is an 800 ft. instrumented spark range in which engineers can obtain experimental position, attitude, time history profiles of the model in flight. This facility provides engineers with a controlled environment in which to monitor model flights. The models were shot down the range at Mach .5-1.6. The data was collected and processed through the digital VAX system on a program known as ARFDAS. ARFDAS is a ballistic range data reduction system which analyzes both symmetric and assymmetric bodies. Once the data collected from the tests was reduced, it was discovered that, unlike the wraparound fin configuration, there was no roll reversal. Roll reversal is when, at subsonic and transonic speeds, the model tends to roll one way (Figure 2a), while at supersonic speeds,the model rolls in the opposite direction (Figure 2b). There was also a slow decrease in model stability of the 60 and 45 degree fin offset, unlike the 30 and 0 degree fin offset in which model stability rapidly dropped. Fortunately, there was no direct correlation between increase of drag as a function of the degree in offsets.

Another part of the investigation included Computational Fluid Dynamics. The purpose in Computational Fluid Dynamics (CFD) is to computationally solve flow characteristics. By modeling an arbitrary body and defining the flow field around the body, the fluid dynamics equations about the body in the flow field can be solved. Engineers must not only define the body and the flow field (gridding) to a computer system, they must also provide the computer with certain aerodynamic restrictions or laws in which the flow may behave. With this in mind, the Eglin Arbitrary Geometry ImpLicit Euler (EAGLE) Code was developed. The purpose of the EAGLE Code was to numerically solve the flow around a body. Euler's equations were used in the solving of the fluid flow. Euler's equations do not, however, take into account viscosity, thus the boundary layer that develops along the length of the body surface is not taken into account.

The EAGLE code is divided into three segments, the first being surface generation. The surface is created with a series of input statements. For example:

$INPUT ITEM='POINT',POINT=1,R=0,0,0$

specifies a specific point (named as POINT 1) at 0 units in the x,y, and z position. A two dimensional body is created with these input statements. The body surface is copied and rotated around to create a three-dimensional solid body (Figure 3). The next step is the grid generation, in which a grid or flow field is generated around the body in the same manner the surface is generated. The flow in this region is governed by the laws and restrictions given by engineers (such as flow may not pass normal to the body or flow may not go through the body of the model). Figure 4 indicates the vast size of the grid as to the model size. The enormous size of the grid is to ensure that any pertinent flow behavior is charted. Figure 5 displays the model of a 45 degree offset fin configuration [illegible] in the grid. Before the model can be run through EAGLE code, all the points and grid lines from the surface and grid generation must match in both spacing and in amount. The final stage of EAGLE code is the actual flow solver in which Euler's flow dynamics equations are used to determine the flow around the body. The flow solver converts the model and the grid from physical space (Figure 6a) to computational space (Figure 6b). The point A, B, C, and D in physical space (Figure 6a) correspond to the same points in computational space (Figure 6b). It is in computational space that the flow is solved. Computational space simplifies the solution, since the grid lines in physical space may be spaced differently, the same grid lines are spaced equally linear in computational space. Once the flow is solved, the results (of which are in computational space) are then converted back into physical space. The EAGLE code must be run on the Cray2, a supercomputer located in Kirtland AFB, New Mexico, due to the vast amount of computation and memory needed to store specific outputs from the code. The results from the run must then be verified with experimental data collected from actual tests.

A graduate student from the University of Florida, Mr. Bill Newbold, modeled a wraparound fin configuration during his summer research in CFD. Due to the similarity in shape and size between the wraparound fin configuration and the offset fin configuration, the input statements from Newbold's project were modified to construct a offset fin configuration with a 45 degree fin offset (Figure 7). The modified program is shown in Appendix A. The fin geometry was changed and specified as being infinitely thin fins. This configuration was then run through the EAGLE code on the Cray2 at both 0 and 5 degrees angle of attack with a speed of Mach [illegible]. Figure 8 and 9 indicate the results of the code run. In viewing the Mach contours, it was noted that, though valid data could be derived from these plots, the jaggedness of the lines indicate that the gridding used was too coarse. The amount of points in the surface and grid generation was limited because of the high cost in using more points. This was a test run to check if the configuration was modeled correctly and to find any problems in modeling and running the offset fin configurations.

In comparing with actual results, there was not enough confidence in the EAGLE code results to make any correlations. These results were limited due to the coarse gridding and the infinitely thin fins. Turbulence in the afterbody was not taken into account for due to the infinite length of the sting. Another flow behavior not taken into account for was viscosity or the viscous effect (mentioned earlier in the paper while discussing Euler's equation).

The basic offset fin configuration was generated and two cases were run at 0 and 5 degrees angle of attack. Though the results were qualitatively good for its purposes, the gridding was too coarse. In recommendations for future work with the offset fin in CFD, fin thickness should be added and more work should be done in refining the grid while maintaining a reasonable amount in cost. Mr. Gregg Abate will be continuing the project of the EAGLE code runs. He will be investigating the viscous effects and finding out the results of the EAGLE code are affected by the lack of viscosity. Other model configurations will be generated and tested, along with the possibility of using other CFD codes.

In conclusion, the investigation is still advancing forward. The search for an innovative missile configuration provides engineers with the motivation to develop new ideas for missile designs, towards the future of the world.

The High School Apprenticeship Program provides an excellent opportunity for students to learn things that sometimes do not come out of books or classes. I, as a student, have barely seen the "tip of the iceberg" while in the program. In enhancing my knowledge with college education, I will dive into this new realm eagerly, knowing somewhat of what is to come and how it will be of use to me in my career as an Air Force officer. Fortunately, I was able to work in my particular area of interest, Aerodynamics. Since I will be majoring in Aerospace/Aeronautical Engineering at Embry-Riddle Aeronautical University, the experience and knowledge I have acquired these past two summers will be quite invaluable and will provide me an advantage that most students will not have.

The computer technology and advanced equipment still fascinates me with the efficiency of time it provides. Yet, technology is still improving and more is being done to increase computer memory storage, decreased size of equipment, and building more supercomputers. I feel priveleged to have been a part of this program, to have been able to work with the supercomputer, and to have work alongside many excellent professionals in my future jobline. Hopefully, I will one day return, not as a High School Apprentice but as an officer, with a few more years at hand and a ton of knowledge to apply. Once again, I thank you.

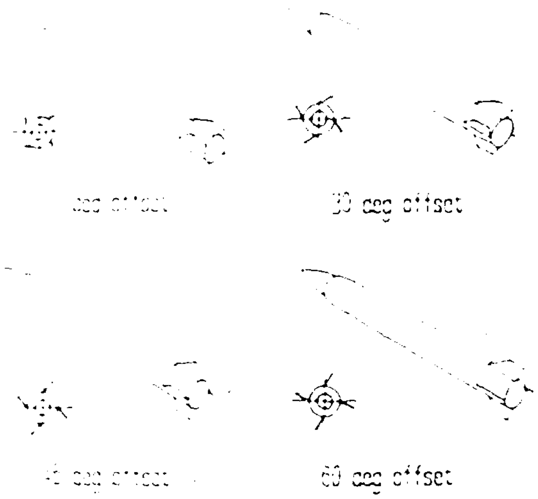


Fig. 1 The four offset fin configurations in an isometric view alongside a view of [illegible]

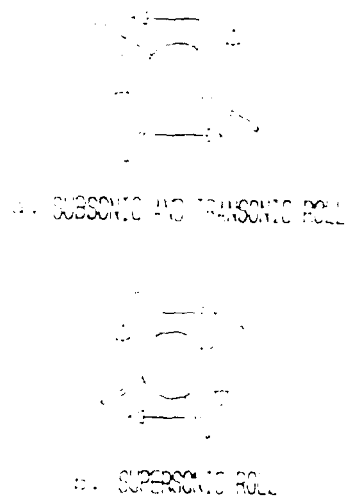


Fig. 2 A head-on view of a projectile with roll reversal.

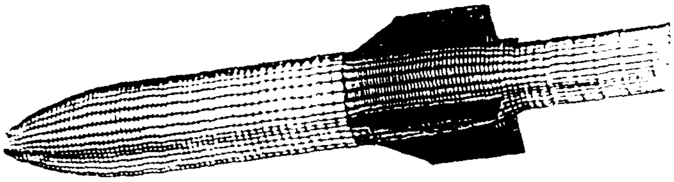


Fig. 3 [illegible] example of a projectile that has [illegible] to produce the three-dimensional picture

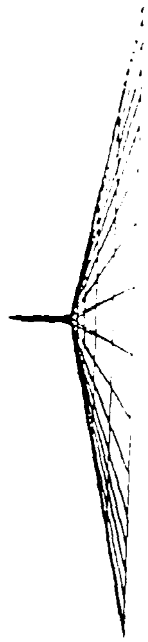


Fig. 5 The grid extends outward in a perfect parabola, circumferencing the model generation.

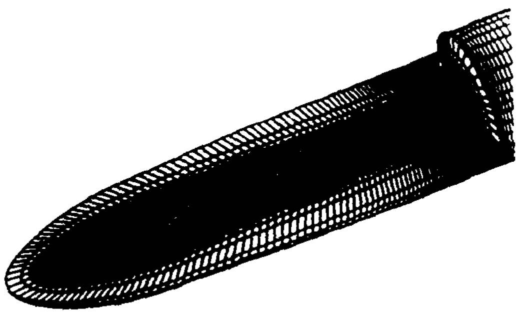
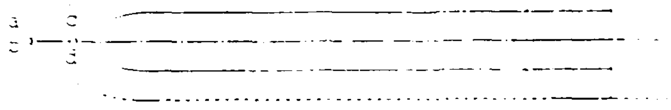
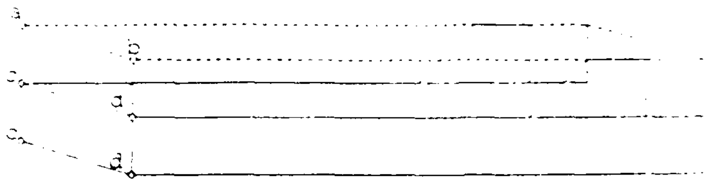


Fig. 4 The offset fin configuration embedded in a flow field.



a. physical space



b. computational space

Fig. 6a The surface is generated into EAGLE code using physical space.
Fig. 6b The flow solver converts physical space into computational space. Once the dynamics equations are solved, the results are converted back into physical space.

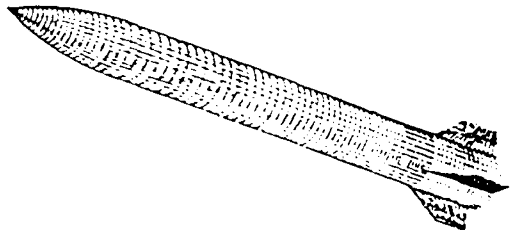


Fig. 7 The offset fin configuration with 45 degree offset

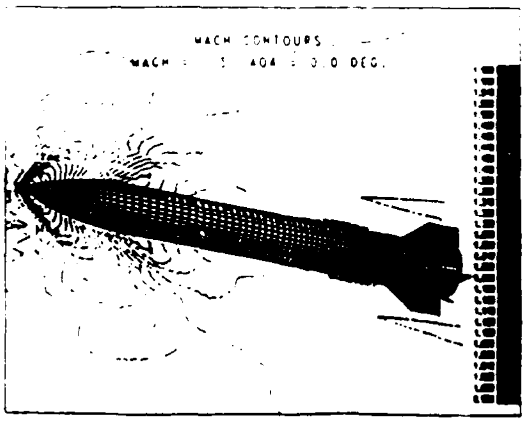


Fig. 8 Mach contours from EAGLE code at 0 deg angle of attack.

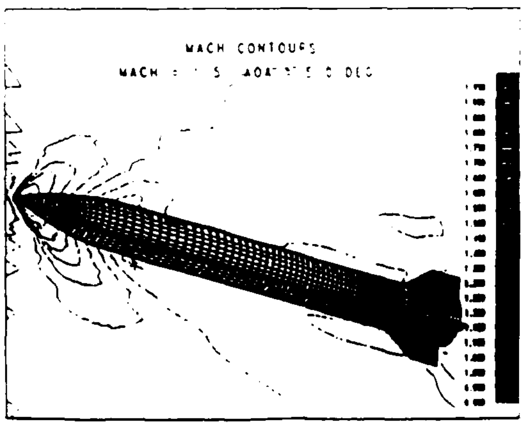


Fig. 9 Mach contours from EAGLE code at 5 deg angle of attack.

```
SINPUT ITEM='POINT', POINT=1, R= 0., 0., 0.S
SINPUT ITEM='POINT', POINT=2, R= -0.8535534, 0., 0.S
*
SINPUT ITEM='POINT', POINT=3, R= 8.666666, 0.5, 0.S
SINPUT ITEM='POINT', POINT=4, R= 9.333333, 0.8535534,-0.3535534S
SINPUT ITEM='POINT', POINT=6, R= 10., 0.5, 0.S
SINPUT ITEM='POINT', POINT=7, R= 10., 0.8535534,-0.3535534S
SINPUT ITEM='POINT', POINT=9, R= 60., 0.5, 0.S
SINPUT ITEM='POINT', POINT=10, R= 60., 0.8535534,0. S
*
SINPUT ITEM='POINT', POINT=51, R= -47.5, 0., 0.S
SINPUT ITEM='POINT', POINT=52, R= 60., 50., 0.S
*
SINPUT ITEM='POINT', POINT=101, R= 2.50, 0.5, 0.S
SINPUT ITEM='POINT', POINT=102, R= 2.50, .8535534, 0.S
SINPUT ITEM='POINT', POINT=103, R= 10.0, 50.0, 0.0S
SINPUT ITEM='POINT', POINT=104, R= 20.0, 50.0, 0.0S
*
SINPUT ITEM='SETNUM', SEGMENT=11, POINTS=24S
SINPUT ITEM='SETNUM', SEGMENT=12, POINTS=52S
SINPUT ITEM='SETNUM', SEGMENT=1, ITERMS=-11,-12S
SINPUT ITEM='SETNUM', SEGMENT=2, POINTS=16S
SINPUT ITEM='SETNUM', SEGMENT=3, POINTS=51S
SINPUT ITEM='SETNUM', SEGMENT=4, ITERMS= -1,-2,-3S
SINPUT ITEM='SETNUM', SEGMENT=5, POINTS=21S
SINPUT ITEM='SETNUM', SEGMENT=8, POINTS=12S
SINPUT ITEM='SETNUM', SEGMENT=9, POINTS=10S
*
SINPUT ITEM='SETVAL', NUMBER=1, VALUE=0.20S
SINPUT ITEM='SETVAL', NUMBER=2, VALUE=0.05S
SINPUT ITEM='SETVAL', NUMBER=3, VALUE=0.05S
SINPUT ITEM='SETVAL', NUMBER=4, VALUE=10.0S
SINPUT ITEM='SETVAL', NUMBER=5, VALUE=0.0325S
SINPUT ITEM='SETVAL', NUMBER=6, VALUE=0.0350S
SINPUT ITEM='SETVAL', NUMBER=7, VALUE=0.04S
SINPUT ITEM='SETVAL', NUMBER=8, VALUE=10.0S
SINPUT ITEM='SETVAL', NUMBER=9, VALUE=0.07S
SINPUT ITEM='SETVAL', NUMBER=10, VALUE=3.0S
*
****************
*
     BLOCK 1
*
****************
*
*       BODY SURFACE
*
SINPUT ITEM='CONICUR', TYPE='CIRCLE', RADIUS=6.5,
      ANGLE=67.38013505,90., POINTS=40S
SINPUT ITEM='SWITCH', REORDER='REVERSE1'S
SINPUT ITEM='CURDIST', POINTS=-11, DISTYP='TANH', RELATIV='NO',
      SPACE=-1S
SINPUT ITEM='SWITCH', REORDER='REVERSE1'S
SINPUT ITEM='TRANS', ORIGIN=2.5,-6.,0.,
      COSINES= -1,0,0, 0,1,0, 0,0,-1, COREOUT=100S
SINPUT ITEM='LINE', POINTS=-12, R1=101, R2=3, DISTYP='BOTH',
      RELATIV=2*'NO', SPACE=-1,-2, COREOUT=110S
SINPUT ITEM='CURRENT', COREIN=100S
SINPUT ITEM='INSERT', COREIN=110, COREOUT=1S
SINPUT ITEM='LINE', POINTS=-2, R1=3, R2=6, COREOUT=2S
SINPUT ITEM='LINE', POINTS=-3, R1=6, R2=9, DISTYP='TANH',
      SPACE=-3, RELATIV='NO', COREOUT=3S
SINPUT ITEM='COPY', COREIN=3, COREOUT=107S
SINPUT ITEM='CURRENT', COREIN=1S
SINPUT ITEM='INSERT', COREIN=2S
SINPUT ITEM='INSERT', COREIN=3, COREOUT=101S
```

```
SINPUT ITEM='BOUNCUR', COREIN=101$
SINPUT ITEM='ROTATE', CURPTS=-4, ANGPTS=-9, ANGLE=0.,90.,
      AXCOS=1,0,0, NORCOS=0,1,0, DISTANG='BOTH', RELATIV=2*'NO',
      SPACANG=-9,-9, COREOUT=11$
*
*      FORWARD OF THE FIN
*
SINPUT ITEM='LINE', POINTS=-5, DISTYP='BOTH', RELATIV=2*'NO',
      SPACE=-5,-6, R1=1, R2=2, COREOUT=102$
SINPUT ITEM='LINE', POINTS=-5, DISTYP='BOTH', RELATIV=2*'NO',
      SPACE=-5,-6, R1=101, R2=102, COREOUT=111$
SINPUT ITEM='CONICUR', TYPE='ELLIPSE', ANGLE=0.,90., POINTS=30,
      SEMIAX=3.3535534,0.8535534$
SINPUT ITEM='SWITCH', REORDER='REVERSE1'$
SINPUT ITEM='CURDIST', DISTYP='TANH', RELATIV='NO', SPACE=-1,
      POINTS=-11$
SINPUT ITEM='SWITCH', REORDER='REVERSE1'$
SINPUT ITEM='TRANS', ORIGIN=2.5,0.,0., COSINES=-1,0,0, 0,1,0, 0,0,-1,
      COREOUT=112$
SINPUT ITEM='EDGECUR', EDGE='LOWER1', COREIN=102$
SINPUT ITEM='EDGECUR', EDGE='UPPER1', COREIN=111$
SINPUT ITEM='EDGECUR', EDGE='LOWER2', COREIN=100$
SINPUT ITEM='EDGECUR', EDGE='UPPER2', COREIN=112$
SINPUT ITEM='TRANSUR', COREOUT=12$
SINPUT ITEM='LINE', POINTS=-5, DISTYP='BOTH', RELATIV=2*'NO',
      SPACE=-5,-6, R1=3, R2=4, COREOUT=103$
SINPUT ITEM='LINE', R1=102, R2=4, POINTS=-12, DISTYP='BOTH',
      RELATIV=2*'NO', SPACE=-1,-2, COREOUT=104$
SINPUT ITEM='EDGECUR', EDGE='LOWER1', COREIN=111$
SINPUT ITEM='EDGECUR', EDGE='UPPER1', COREIN=103$
SINPUT ITEM='EDGECUR', EDGE='LOWER2', COREIN=110$
SINPUT ITEM='EDGECUR', EDGE='UPPER2', COREIN=104$
SINPUT ITEM='TRANSUR', COREOUT=1$
SINPUT ITEM='CURRENT', COREIN=12$
SINPUT ITEM='INSERT', COREIN=1, START=24,1, COREOUT=12$
*
*      FIN AREA
*
SINPUT ITEM='LINE', POINTS=-5, DISTYP='BOTH', RELATIV=2*'NO',
      SPACE=-5,-6, R1=6, R2=7, COREOUT=105$
SINPUT ITEM='BOUNCUR', COREIN=103$
SINPUT ITEM='BOUNCUR', COREIN=105$
SINPUT ITEM='BLEND', DISTCUR='LINEAR', CURVES=-2$
SINPUT ITEM='SWITCH', REORDER='SWITCH', COREOUT=1$
SINPUT ITEM='CURRENT', COREIN=12$
SINPUT ITEM='INSERT', COREIN=1, START=75,1, COREOUT=12$
*
*      AFT OF THE FIN
*
SINPUT ITEM='LINE', R1=9, R2=10, POINTS=-5, DISTYP='BOTH',
      RELATIV=2*'NO', SPACE=-5,-6, COREOUT=106$
SINPUT ITEM='LINE', R1=7, R2=10, POINTS=-3, DISTYP='TANH',
      RELATIV='NO', SPACE=-3, COREOUT=108$
SINPUT ITEM='EDGECUR', EDGE='LOWER1', COREIN=105$
SINPUT ITEM='EDGECUR', EDGE='UPPER1', COREIN=106$
SINPUT ITEM='EDGECUR', EDGE='LOWER2', COREIN=107$
SINPUT ITEM='EDGECUR', EDGE='UPPER2', COREIN=108$
SINPUT ITEM='TRANSUR', COREOUT=1$
SINPUT ITEM='CURRENT', COREIN=12$
SINPUT ITEM='INSERT', COREIN=1, START=90,1, COREOUT=12$
*
SINPUT ITEM='TRANS', COREIN=12, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0,1, 0,-1,0, COREOUT=13$
*
*      TOP BOUNDRY
*
```

```
$INPUT ITEM='LINE', R1=4, R2=7, POINTS=-2, DISTYP='LINEAR',
      COREOUT=2$
$INPUT ITEM='CURRENT', COREIN=112$
$INPUT ITEM='INSERT', COREIN=104$
$INPUT ITEM='INSERT', COREIN=2$
$INPUT ITEM='INSERT', COREIN=108, COREOUT=109$
$INPUT ITEM='BOUNCUR'$
$INPUT ITEM='ROTATE', CURPTS=-4, ANGPTS=-9, ANGLE=0.,90.,
      AXCOS=1,0,0, NORCOS=0,1,0, DISTANG='BOTH', RELATIV=2*'NO',
      SPACANG=-9,-9, COREOUT=14$
*
*       STAGNATION LINE
*
$INPUT ITEM='BOUNCUR', COREIN=102$
$INPUT ITEM='ROTATE', CURPTS=-5, ANGPTS=-9, ANGLE=0.,90.,
      AXCOS=1,0,0, NORCOS=0,1,0, DISTANG='BOTH', RELATIV=2*'NO',
      SPACANG=-9,-9, COREOUT=15$
*
*       OUTFLOW
*
$INPUT ITEM='BOUNCUR', COREIN=106$
$INPUT ITEM='ROTATE', CURPTS=-5, ANGPTS=-9, ANGLE=0.,90.,
      AXCOS=1,0,0, NORCOS=0,1,0, DISTANG='BOTH', RELATIV=2*'NO',
      SPACANG=-9,-9, COREOUT=16$
*
$INPUT ITEM='TRANS', COREIN=11,12,13,14,15,16, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0.70710678,-0.70710678,0.,0.70710678,
      0.70710678, COREOUT=11,12,13,14,15,16$     **BLOCK 1
***************
*
*    BLOCK  2, 3, 4
*
***************
*
$INPUT ITEM='TRANS', COREIN=11,12,13,14,15,16, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0,1, 0,-1,0,
      COREOUT=21,22,23,24,25,26$     **BLOCK 2
*
$INPUT ITEM='TRANS', COREIN=11,12,13,14,15,16, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,-1,0, 0,0,-1,
      COREOUT=31,32,33,34,35,36$     **BLOCK 3
*
$INPUT ITEM='TRANS', COREIN=11,12,13,14,15,16, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0,-1, 0,1,0,
      COREOUT=41,42,43,44,45,46$     **BLOCK 4
*
***************
*
*    BLOCK 5
*
***************
*
$INPUT ITEM='COPY', COREIN=14, COREOUT=51$
$INPUT ITEM='COPY', COREIN=109, COREOUT=150$
*
$INPUT ITEM='LINE', POINTS=10, R1=2.5,50.,0., R2=103, COREOUT=2$
$INPUT ITEM='CONICUR', TYPE='CIRCLE', POINTS=50, RADIUS=50.,
      ANGLE=0.,90.$
$INPUT ITEM='TRANS', ORIGIN=2.5,0.,0., COSINES= -1,0,0, 0,1,0, 0,0,-1$
$INPUT ITEM='INSERT', COREIN=2, COREOUT=1$
$INPUT ITEM='LINE', POINTS=-2, R1=103, R2=104, DISTYP='LINEAR', COREOUT=2$
$INPUT ITEM='CURDIST', COREIN=1, POINTS=-1, DISTYP='BOTH', SPACE=-10,2,
      END='FIRST', RELATIV='NO'$
$INPUT ITEM='INSERT', COREIN=2, COREOUT=3$
$INPUT ITEM='LINE', POINTS=-3, R1=104, R2=52, DISTYP='TANH', SPACE=2,
      END='LAST', COREOUT=4$
```

```
SINPUT ITEM='CURRENT', COREIN=3S
SINPUT ITEM='INSERT', COREIN=4, COREOUT=151S
SINPUT ITEM='LINE', R1=2, R2=51, POINTS=-8, DISTYP='TANH',
      RELATIV='NO', SPACE=-6, COREOUT=152S
SINPUT ITEM='LINE' R1=10, R2=52, POINTS=-8, DISTYP='TANH',
      RELATIV='NO', SPACE=-6, COREOUT=153S
SINPUT ITEM='EDGECUR', EDGE='LOWER1', COREIN=152S
SINPUT ITEM='EDGECUR', EDGE='UPPER1', COREIN=153S
SINPUT ITEM='EDGECUR', EDGE='LOWER2', COREIN=150S
SINPUT ITEM='EDGECUR', EDGE='UPPER2', COREIN=151S
SINPUT ITEM='TRANSUR', COREOUT=52S
*
SINPUT ITEM='TRANS', COREIN=52, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0,1, 0,-1,0, COREOUT=53S
*
SINPUT ITEM='BOUNCUR', COREIN=151S
SINPUT ITEM='ROTATE', CURPTS=-4, ANGPTS=-9, ANGLE=0.,90.,
      AXCOS=1,0,0, NORCOS=0,1,0, DISTANG='BOTH', RELATIV=2*'NO',
      SPACANG=-9,-9, COREOUT=54S
*
SINPUT ITEM='BOUNCUR', COREIN=152S
SINPUT ITEM='ROTATE', CURPTS=-8, ANGPTS=-9, ANGLE=0.,90.
      AXCOS=1,0,0, NORCOS=0,1,0, DISTANG='BOTH', RELATIV=2*'NO',
      SPACANG=-9,-9, COREOUT=55S
*
SINPUT ITEM='BOUNCUR', COREIN=153S
SINPUT ITEM='ROTATE', CURPTS=-8, ANGPTS=-9, ANGLE=0.,90.
      AXCOS=1,0,0, NORCOS=0,1,0, DISTANG='BOTH', RELATIV=2*'NO',
      SPACANG=-9,-9, COREOUT=56S
SINPUT ITEM='TRANS', COREIN=51,52,53,54,55,56, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0.70710678,-0.70710678,
       0.,0.70710678,0.70710678,
      COREOUT=51,52,53,54,55,56S      **BLOCK 5
*
***************
*
*     BLOCK 6, 7, 8
*
****************
*
SINPUT ITEM='TRANS', COREIN=51,52,53,54,55,56, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0,1, 0,-1,0,
      COREOUT=61,62,63,64,65,66S      **BLOCK 6
*
SINPUT ITEM='TRANS', COREIN=51,52,53,54,55,56, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,-1,0, 0,0,-1,
      COREOUT=71,72,73,74,75,76S      **BLOCK 7
*
SINPUT ITEM='TRANS', COREIN=51,52,53,54,55,56, ORIGIN=0.,0.,0.,
      COSINES= 1,0,0, 0,0,-1, 0,1,0,
      COREOUT=81,82,83,84,85,86S      **BLOCK 8
*
*
SINPUT ITEM='COMBINE', COREIN=11,-16, 21,-26, 31,-36, 41,-46,
      51,-56, 61,-66, 71,-76, 81,-86, FILEOUT=4S
SINPUT ITEM='COMBINE', COREIN=11,-16, 21,-26, 31,-36, 41,-46,
      51,-56, 61,-66, 71,-76, 81,-86,CONTENT='YES', FILEOUT=1S
SINPUT ITEM='END'S
```

REFERENCES

1. Abate, Gregg and Wayne Hathaway. "Aerodynamics of Missiles with Offset Fin Configurations." AIAA Paper Presented at the Atmospheric Flight Mechanics Conference. August 1989. pp.2-5.

2. Cipolla, John and Lawrence Lijewski. Program EAGLE User's Manual, Introduction and Grid Applications, Volume I. AFATL-TR-88-117. September 1988. pp. 1,16-19.

3. Gatlin, Boyd and Joe Thompson. Program EAGLE User's Manual, Surface Generation Code, Volume II. AFATL-TR-88-117. September 1988. pp. 48

INTERFACING THE TEKTRONIX WORKSTATION WITH THE RTD 710A DIGITIZER

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AFATL/MNE

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Mr. Dave Applin
TSgt. Bobby Cole
Mr. Stacey Carswell

INTRODUCTION

This summer I worked as a high school apprentice in the Armament Laboratory(AFATL) of Eglin Air Force Base. My mentor, Capt. Schomber, is an officer in the U.S. Air Force and a physical chemist. He works in High Explosives Research and Development Branch. The HERD's purpose is to produce insensitive high explosives. I was involved in the dynamic testing of the explosives. My assignment was to interface their computer workstation with a data collecting instrument.

DESCRIPTION OF THE DYNAMICS LABORATORY

This summer I worked in the Dynamic Laboratory of the HERD facility. Small scale dynamic tests are conducted on explosives there. The purpose of most of the tests is to find the velocity of the shock wave. The equation for velocity is distance divided by time. In order to find the distance, electric pins are setup so they touch the explosive and are placed at a constant distance apart form each other. This distance is measured and, hence, one part of the formula for velocity is fulfilled. To find the time it takes the shock wave to reach each pin, the explosive is first detonated. The electric pins will than receive a signal from the shock wave, and transmit this signal to the Tektronix RTD 710A Digitizers. The digitizer displays a picture of the waveform on a small screen and a digital read out of the data. The tests that use this procedure are:

CRITICAL DIAMETER CONE
CONFINED DENT/RATE
UNCONFINED DENT/RATE

The process of collecting the data is a time consuming one in that they have to go from point to point and write down the information by hand. After doing so, they take the information and plot the points on another computer. Finally, they are able to do the analysis on the explosive. Also found in the Dynamic Lab is a Tektronix Workstation(a computer system used in the lab). The workstation is completely compatible with the digitizers, as the digitizers are also manufactured by Tektronix. By interfacing the two instruments, it would greatly reduce the amount of time to collect and analyze data. Hence, the Dynamic Laboratory would become even more efficient and productive.

DESCRIPTION OF RESEARCH

My objective for the summer was to interface the Tektronix Workstation with the two RTD 710A Digitizers, enabling them to transmit messages to each other. In addition, I was to develop a program that:

Acquires a waveform
Scales it into voltage array
Reads and decodes breakpoint locations and sample rates

When implemented, this program will allow the digitizer to transfer the waveform data to the Tektronix Workstation; enable the workstation to receive this data and plot the points on a monitor; and enable the digitizer to display onto the monitor when an error is found within the digitizer and precisely what the error is.

To accomplish the first part of my assignment the IEEE 488 STD (General Purpose Interface Bus) was used. The IEEE STD Interface allows the instrument to be remotely controlled by a GPIB controller. All front panel controls, except the power-on switch and manual trigger key, can be controlled through the GPIB using a command set. Also, an acquired waveform can be transferred to the controller for further processing, or waveform data can be transferred from the controller for use as a reference waveform. A GPIB connector was used to link together the ports of the digitizers and the Local Area Network (LAN) Interface port found on the back of the 4336 disk drive. After plugging in the connectors, we assigned each instrument an address via the GPIB parameter switch. Scope 1 was set to address 1; scope 2 was set to address 2; and LAN was set to address 0. We also made them talk/listen instruments. To establish the addresses within the computers memory, a command called "gpinit" was used.

Hence, a means of communication between the digitizers and the workstation was established. There were, however, some problems with the development of the program. We learned at a rather late date that the computer did not understand

BASIC(the proposed language of the program) commands. We also learned that we did not have the GPIB drivers. We were, therefore, forced to use a previously written C language program that enables the user to send set and query commands to the digitizers and performs a poll routine upon the instruments. There are two main parts of the program. The first part opens the scopes, making the scopes accessible through write and read statements. It establishes the buffer length to 10000 bytes. It will, however, read more bytes than this and explain to the user how many bytes it is actually reading. It also displays a prompt when the program(gpibtst) is called, informing the user that they are in this particular program. Furthermore, it sets up a way to distinguish which scopes the user is writing to. If the user types in a "s" or "S", it will write to scope 1. If any other letter is typed in, it will write to scope 2. It will than display on the screen the response of the digitizer.

The second part of the program is a simple poll routine for both digitizers. If a Service Request(SRQ) is sent, the digitizers will report this status onto the monitor in an event code. This will inform the user there is a problem within the digitizers.

RESULTS

Both of the RTD 710A Digitizers are sending messages to the Tektronix workstation, and the workstation is receiving these messages. The digitizers did allow the users to change or "set" the digital read out via the keyboard. The digitizers responded to a query(a question about a certain string of data) as read from the monitor. It than displayed this response onto the monitor. The digitizers also sent an event code when a SRQ was sent.

CONCLUSIONS

We found that the C language was the "language of choice" for the Tektronix workstation. Several programs had been written in this language and we could use their subroutines as guides for the program we needed to write. It would, therefore, be quicker and easier to write the programs in C language. Not knowing this before I began my assignment, I learned three other computer languages besides C. They were BASIC, FORTRAN, and UNIX. This is, however, good, for I have not had much computer experience, and I now know the basics of four different computer languages. It has been a productive and worthwhile summer, and I am looking forward to returning next year.

BIBLIOGRAPHY

Clark, Carol R. Programming in Fortran. Addison-Wesley Publishing Co.: Reading, Ma., 1979.

Schildt, Herbet. C, The Complete Reference. McGraw-Hill: Berkley, Ca., 1987.

Tektronix Fortran 77 Reference Manual

Tektronix RTD 710A Instrument Interface Guide

Tektronix Utek Primer

PROGRAM LISTING

```
/*
 * This simple program permits a user to send "set" and "query"
 * commands to one of two instruments connected to /dev/gpiba .
 * The primary benefit of this program is that it shows how to
 * correctly poll one or more instruments when the auto-poll
 * feature is enabled.
 *
 * It is assumed that the following GPIB instruments are attached
 * to /dev/gpiba via gpconf(1) :
 *
 *    /dev/scope   -  a Tek Codes and Formats oscilloscope
 *    /dev/fg      -  a Tek Codes and Formats function generator
 *
 * It is also assumed that gpconf(1) has been used to enable
 * auto-polling of these instruments.
 *
 * ---------------------------------
 *
 * Usage:
 *      This program prompts the user for newline-delimited input
 *      from "stdin".  The first character of each input line is
 *      examined and if it is "s" or "S", the input line (sans
 *      first character) is sent to /dev/scope as a device-dependent
 *      command.  Immediately thereafter, this program reads a
 *      query response (if any) from /dev/scope.
 *
 *      If the first character is not "s" or "S", the same steps
 *      as above are taken, but the input/output device is
 *      /dev/fg instead.
 *
 * Caveats:
 *      This program performs no I/O error checks.
 */
#include <stdio.h>
#include <signal.h>
#include <sys/file.h>
#include <sys/ioctl.h>
#include <box/gpibb.h>
#include <box/gpb_ioctl.h>
#define     BUFLEN     10000
int scope, fg;
main()
{
    int bytes;
    char s[BUFLEN], r[BUFLEN];
    struct gpibconf cfg;
    void poll();
    scope  = open("/dev/scope", O_RDWR, 0);
    fg     = open("/dev/fg", O_RDWR, 0);
```

```
    ioctl(scope, GIOCGCONF,&cfg);  /* get GPIB configure structure*/
    cfg.gc_flags |= GF_ASYNC;      /* enable the signal flag*/
    cfg.gc_mask  |= GI_SRQ;
    cfg.gc_pgrp = getpgrp(0);      /* enable the signal process group */
    ioctl(scope ,GIOCSCONF, &cfg); /* set GPIB configure structure*/
    ioctl(fg, GIOCGCONF,&cfg);
    cfg.gc_flags |= GF_ASYNC;
    cfg.gc_mask  |= GI_SRQ;
    cfg.gc_pgrp = getpgrp(0);
    ioctl(fg ,GIOCSCONF, &cfg);
    signal(SIGURG, poll);           /* Enable "fg" and "scope"
                                     * interrupts.
                                     */
    for (;;) {
        printf("> ");
        gets(s);                   /* Read a GPIB command from stdin */
        if (s[0] == 's' || s[0] == 'S') {
            write(scope, &(s[1]), strlen(s) - 1);
            bytes = read(scope, r, BUFLEN);
            }
        else {
            write(fg, &(s[1]), strlen(s) - 1);
            bytes = read(fg, r, BUFLEN);
            }
        r[bytes] = ' ';
        printf("%s",r);           /* Print response on stdout */
        }
}
void
poll()
{
    unsigned char status;
    /*
     * Poll each instrument on the bus.  If bit 7 of an
     * instrument's status byte is set, that instrument
     * asserted SRQ.
     */
    ioctl(scope, GIOCSPOLL, &status);      /* Serial poll */
    if (status & 0x40)                     /* Test bit 7  */
        printf("* scope status:    %d", status);
    ioctl(fg, GIOCSPOLL, &status);         /* Serial poll */
    if (status & 0x40)                     /* Test bit 7  */
        printf("* fg status:    %d", status);
}
```

THE OPERATION AND RELIABILITY OF A 5MJ PULSE POWER SYSTEM

by

PATRICIA TU

MARK HEYSE, MENTOR

HIGH SCHOOL APPRENTICESHIP PROGRAM 1989

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The people at ESF1 for their friendship and help throughout the summer.

I would also like to thank the people at Building 522 for being there.

The Air Force Armament Laboratory's (AFATL) Hypervelocity Launcher Research Division (SAH) has been developed to research methods of launching guided projectiles using electromagnetic launchers (EML). These launchers are to be used to defend against ballistic missiles and re-entry vehicles targeted at the United States. This research is a part of the Strategic Defense Initiative (SDI) Kinetic Energy Weapon (KEW) technology program. The EML part of the program has three different facilities each consisting of its own power supply to use in meeting SDI research goals. The basic research facility uses capacitors as its power supply. A second facility contains a Homopolar Generator (HPG), which is a rotating machine. The Battery Power Supply (BPS), the newest facility, uses car batteries for its power source. The capacitors in the basic research facility produces up to 5MegaJoules (MJ) of energy in a very short pulse. The short pulse that is produced only allows for single shot research. The HPG produces more energy, but its output is a lower level pulse for a longer period of time. The BPS produces its energy from approximately 14,000 car batteries. It produces high energy levels and also provides an even longer pulse time for multi-shot tests. The HPG and the BPS are more advanced and complicated systems compared to the capacitor system.

An electromagnetic gun consists of two parallel rails

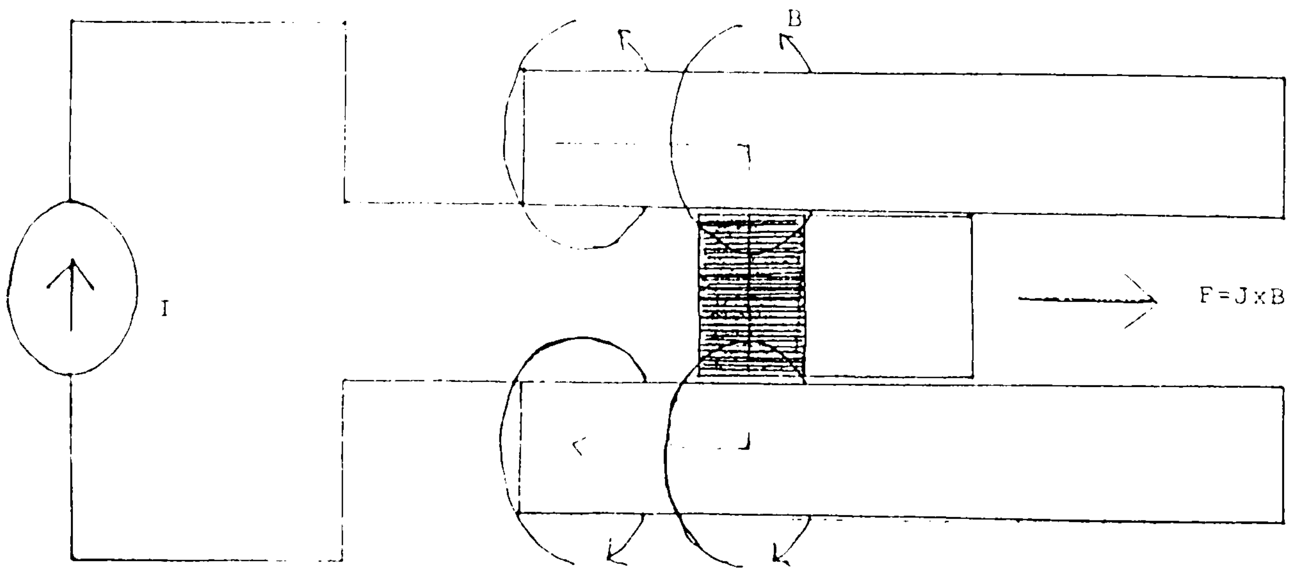


FIGURE 1 BASIC CONFIGURATION OF AN ELECTOMAGNETIC GUN

made of copper. See Figure 1. The power source sends an electric current down the barrel of the gun through the copper rails. The projectile with a current conducting armature makes an electrical connection with the rails and completes the circuit. When the current travels through the armature, a forces is produced that moves the projectile down the barrel of the gun at high velocities. This method of accelerating the projectile allows the gun to fire at higher velocities then can be achieved in a conventional gun with gunpowder.

A 5MJ system is made of 24 banks in parallel all feeding the same gun. Two banks make one module and there are 4 capacitors per bank. The 5 MegaJoule power supply is used for the single shot research on large bore guns. The bore size is 25 to 50 millimeters. The 5MJ system will discharge all the energy stored in the banks into the electromagnetic gun in less then 2 milliseconds. The short duration of the experiment is the reason it is referred to as a pulse power system. For a comparison 5MJ is the same amount of energy needed to run a 60 watt light bulb for just under 24 hours.

The system setup is shown in Figure 2. The ignitron switches are open and will remain open until they are triggered. Prior to a test the charge switches are closed and the capacitor bank is charged. When the desired charge level is reached the charge switches are reopened. The system is now ready to fire. The controller produces a little pulse which then triggers the Marxes. The Marxes produces the bigger pulse which is necessary to close the

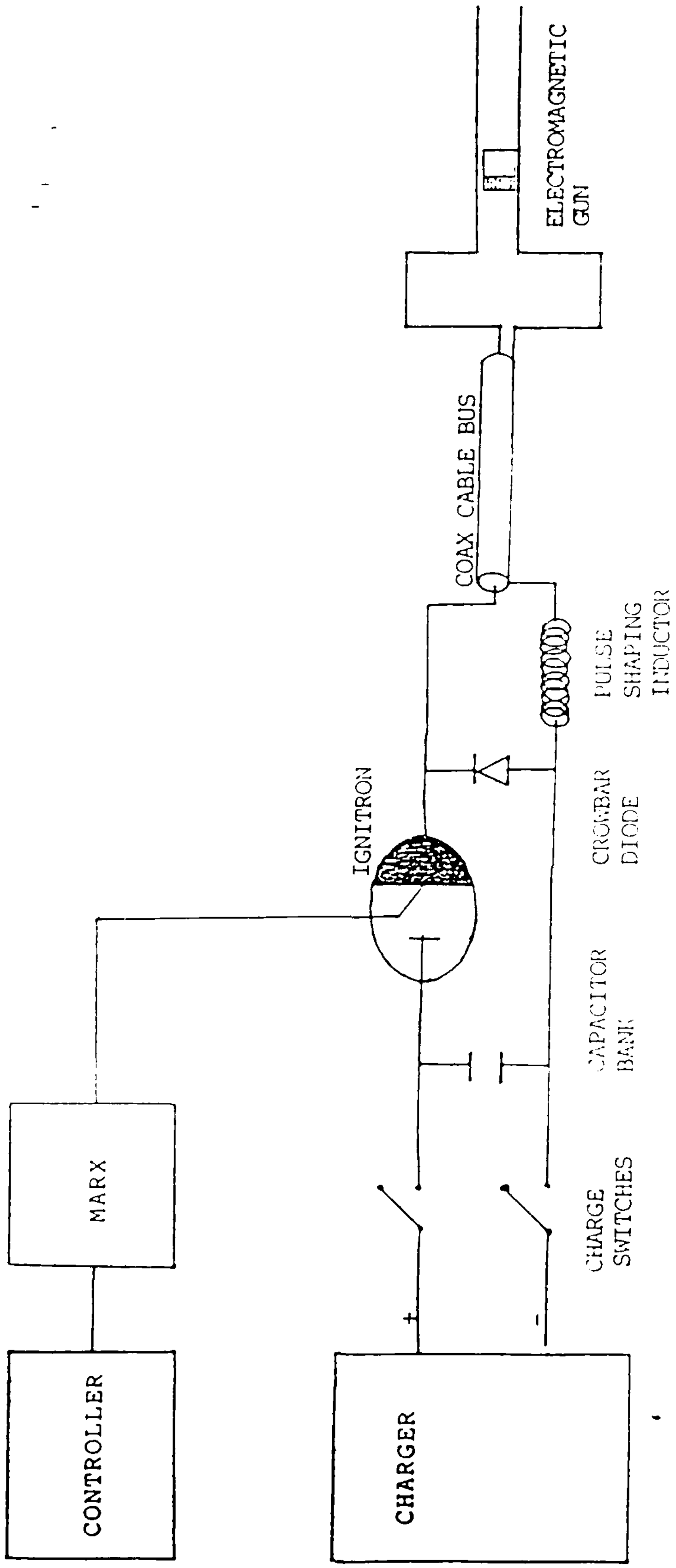


FIGURE 2 5MJ SYSTEM

ignitron switch that allows the energy stored in the banks to be discharged. An ignitron is a vacuum switch that has some mercury in it. See Figure 3. When the Marx triggers the ignitron the mercury becomes a vapor and closes the circuit which allows the stored energy into the gun.

A projectile/armature is loaded into the gun by a pneumatic preinjector. Light gates tell the controller that the projectile is loaded. When the projectiles is loaded the Marx trigger are fired to close the ignitrons. The energy flows from the capacitors to the gun through the coax cable buswork. The energy that returns from the gun goes through the pulse shaping inductor and is directed back to the gun through the crowbar diode. The crowbar diode prevents a voltage reversal on the capacitors and the the pulse shaping inductor keeps the current flowing for about 0.5 milliseconds. The test is completed when the current stops flowing.

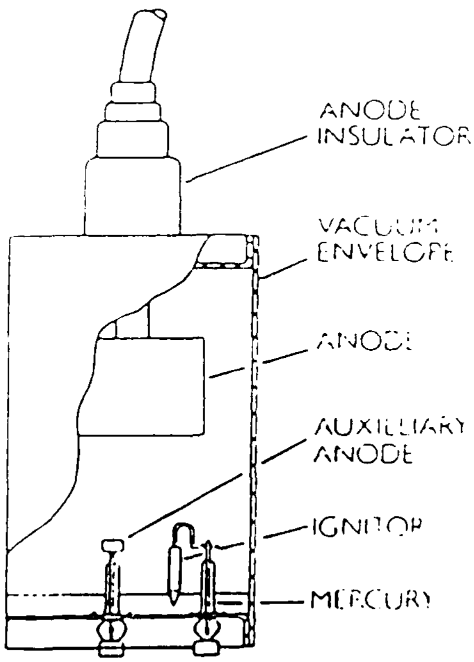


Fig 3
Essential components of a simple ignitron

A ripple fire sequence can be created by setting delay generators to allow the sequential triggering of the Marxes. When the delays are set at the same time the banks are all triggered together. This dumps all the energy stored in the banks in 500 microseconds. This results in a discharge with a sharp rise and fall. If the delays are set at varying times the banks will trigger in sequence and produce a longer pulse time with a lower peak current.

To determine these delay times computer simulations were run to see the expected pulse duration. Delay times and charge levels are varied to acheive a desired current profile. The graph in figure 4 shows the difference between a ripple discharge and one without rippling depending on what is needed different the delay schemes can be used.

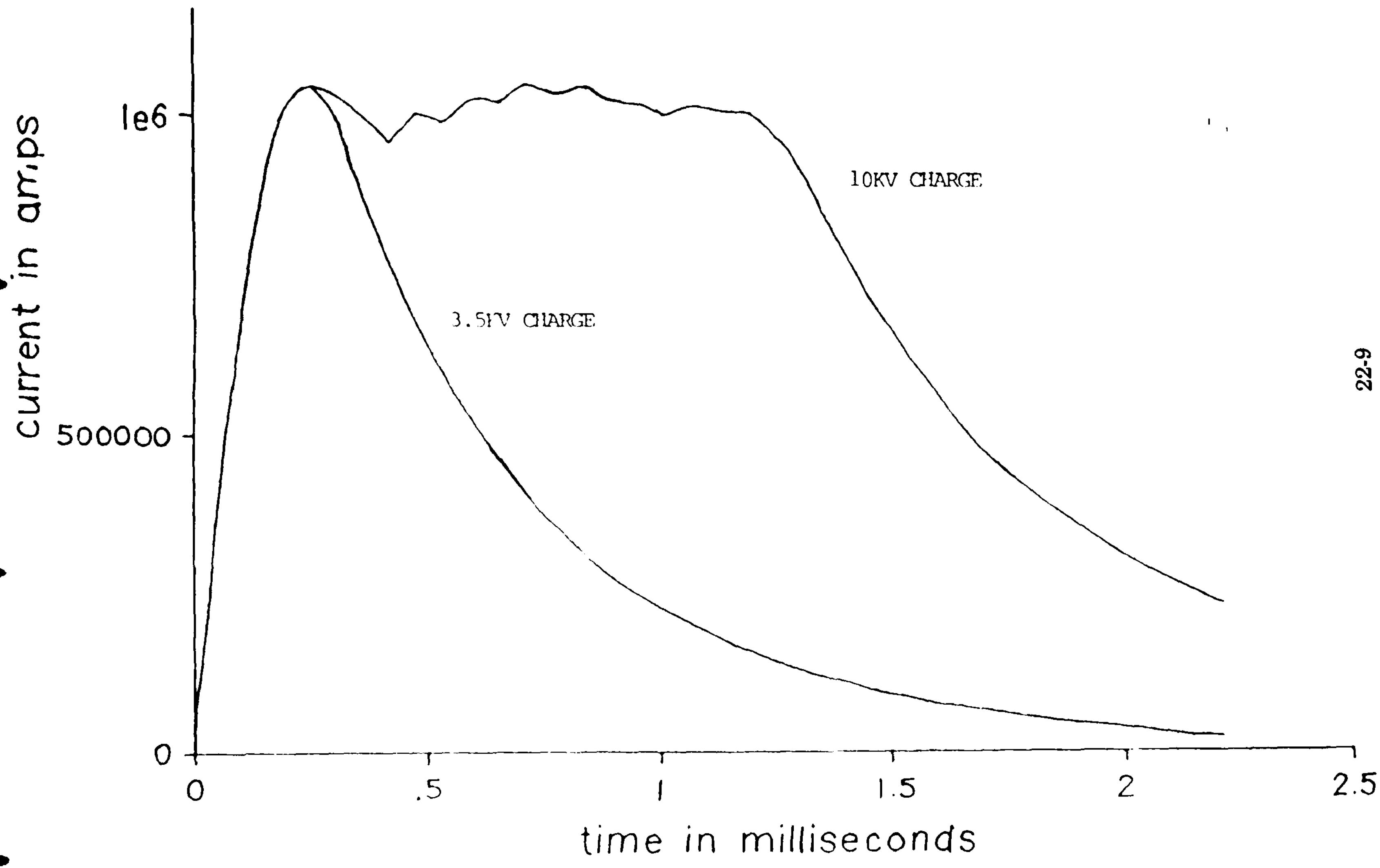


FIGURE 4 CURRENT PROFILES WITH/WITHOUT RIPPLE

To collect the data produced by tests different types of data probes are used. Also used are voltage dividers and passive integrators to convert the parameters monitered on the gun into more usable data.

A rogowski coil is a type of data probe. It is made of sensitive copper coils wrapped around an inner insulator and covered with an outer layer of insulation called heat shrink. See Figure 5. The rogowski encircles a busbar and its coils are sensitive to the magnetic fields produced by current in the busbar. It is connected to an oscilloscope so the data can be recorded. For the data collected by a rogowski to be used, the rogowski must be calibrated. To calibrate a rogowski it is placed together with a calibrated rogowski around a test wire. A current is run through the test wire and is recorded by both rogowskis. A ratio can be set up with the calibrated rogowski and the information recorded by the new rogowski.
The equation that is used

$$\frac{\text{unknown rogowski}}{\text{known rogowski (A/V/S)}} = \frac{\text{volts of known}}{\text{volts of unknown}}$$

A B-dot is another type of data probe that measures the magnetic flux around the rails of a gun. It is made of wire coils like the rogowski. It is placed close to the back sides of the gun rails and is connected by a cable to the scopes.

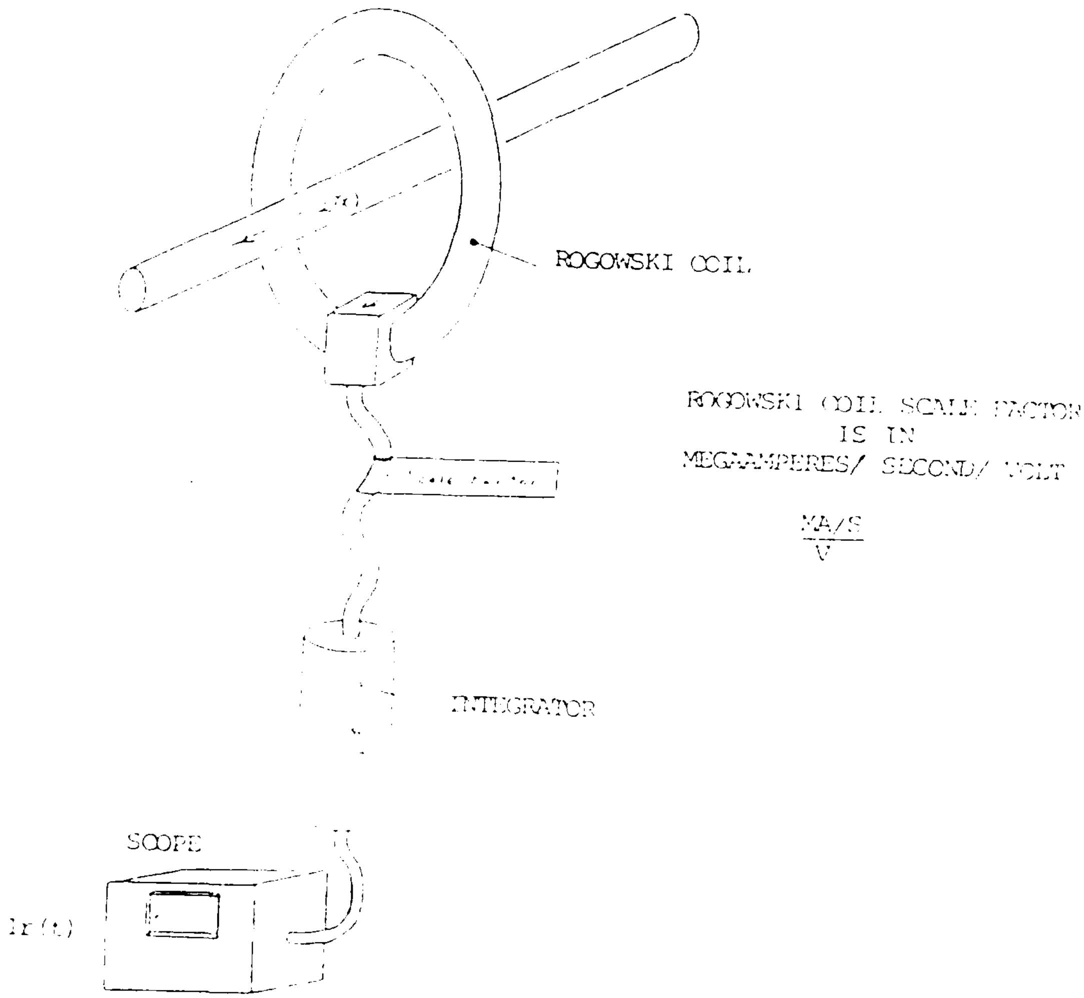
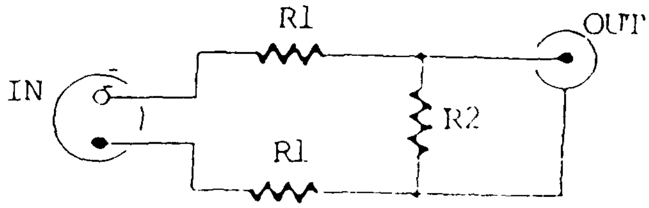


FIGURE 5 ROGOWSKI

Voltage Dividers are needed in the system because the signal produced by the data probes was too high for the scope. A- voltage divider is made with three resistors in series across the input and the output is taken from across the middle resistor. A BNC cable end is added to connect it to the scopes. This way the high voltages will not enter the scopes and produce unreliable data or damage the scopes. See Figure 7.

Passive Integrators are made similar to the voltage dividers. It has two resistors and one capacitor in series across the input and the output is taken from across the capacitor in the center. It is used to integrate the signal produced by a rogowski into a smooth curve proportional to current which is more usable. See Figure 8.

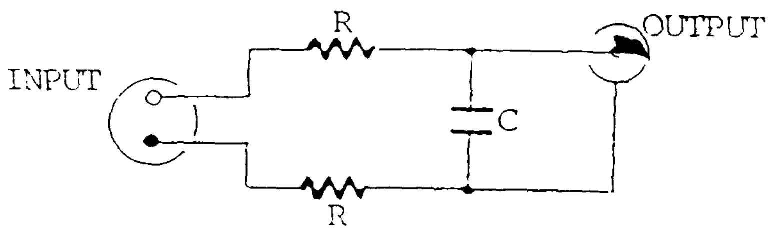
The data probes, voltage dividers, and integrators are needed and used to collect the data produced by each test.



$$\frac{V_{out}}{V_{in}} = \frac{R}{2R_1 + R_2}$$

o FEMALE
• MALE

FIGURE 7 VOLTAGE DIVIDERS



dt=2RC

o FEMALE
• MALE

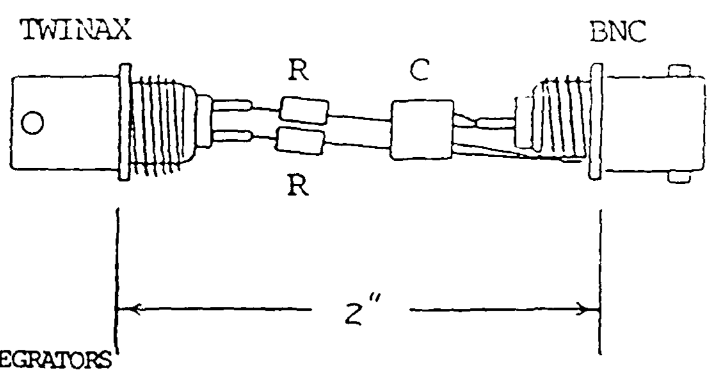


FIGURE 8 PASSIVE INTEGRATORS

Due to changes in the 5mj system over the past year, the original operation checklist had become out dated, so an updated checklist was made. These checklists show what needs to be done in the preshot setup of the system, during a test, and post shot activities to safe the test area. Tatles I-III are the checklists now used for conducting a test.

TABLE I PRESHOT SETUP

1. CONDITION IGNITRONS IF NECESSARY
2. SET IGNITRON DELAYS
3. VERIFY THAT ALL ARE HOOKED UP
4. TURN DELAY GENERATOR POWER ON
5. CHECK DOORS
6. INSPECT BANKS FOR TOOLS AND FOREIGN OBJECTS
7. REMOVE SHORTING CLIPS OF BANKS TO BE USED (YELLOW WIRE)
8. TURN IGNITRON LIGHTS OFF
9. TURN MAIN POWER BREAKER ON
10. CHECK WITH GUN PEOPLE TO SEE IF READY
11. VERIFY ALL PERSONAL HAVE EVACUATED THE TEST AREA
12. TURN DOWNSTAIRS BREAKER ON
13. CLOSE DOOR

TABLE II CONTROLLER OPERATION

1. TURN ON CONTROLLER, 5MJ CHARGER, MARX CHARGER
2. VERIFY THAT RFC BABY BANKS 100KJ BANKS ARE OFF
3. RESET MASTER CONTROLLER TO STATE ZERO
4. VERIFY THAT LIGHT GATES, FIRE SIGNAL, AND SCOPE TRIGGER ARE HOOKED UP
5. SELECT BANKS TO BE CHARGED
6. SET CHARGE VOLTAGE LEVEL
7. TURN MASTER CONTROLLER
8. ANNOUNCE "CHARGING"
9. OPEN DUMP
10. CLOSE CHARGE
11. TURN ON HIGH VOLTAGE (BLACK BUTTON)
12. INCREASE RATE OF RISE VARIAC TILL CURRENT REACHES 1.75 AMPS MONITOR CURRENT SO NOT EXCEED 2 AMPS
13. WHEN DESIRED VOLTAGE IS REACHED TURN RATE OF RISE VARIAC TO ZERO
14. TURN OFF HIGH VOLTAGE (RED BUTTON)
15. OPEN CHARGE RELAY
16. ANNOUNCE "CHARGING MARXES"
17. CHARGE MARXES TO 800 VOLTS
18. TURN MARX OUTPUT VOLTAGE ADJUST (VARIAC) TO ZERO
19. TURN MARX OUTPUT SWITCH OFF
20. START VCR
21. CHECK DAS AND X RAYS ARE READY
22. 5 SECOND COUNTDOWN
23. ANNOUNCE "FIRE"

TABLE III POST SHOT

1. CLOSE DUMPS
2. DISARM CONTROLLER
3. TURN OFF 5MJ CHARGER AND MARX CHARGER
4. TURN DOWNSTAIRS BREAKER OFF IN BAY
5. TURN MAIN BREAKER OFF
6. TURN LIGHTS ON
7. VERIFY EACH BANK HAS DUMPED WITH THUNDERSTICK
8. REPLACE SHORTING CLIPS ON BANKS (YELLOW WIRE)
9. TURN DELAY GENERATOR POWER OFF
10. ANNOUNCE "BANKS ARE SAFE"

Since the 5MJ system was built many tests have been conducted and hardware changes have been made. The tests and changes have been recorded in the 5MJ log book, but the exact reliability of the system with and without changes was not known. Table IV and Table V were made from old log books and the bank reliability could be calculated. Table IV is a charge table of the banks and Table V deals with the system tests.

Table IV was made to show how many times each bank was charged to a certain level. There are 24 banks and the charge levels range from 1KV to 11KV. With this table the total number of times each bank was charged can also be determined. The average number of times each bank was charged is 147. Using this table the banks that have been used more often or that have been underused can be easily seen. In future tests it would be advisable to charge the underused banks to equal them out as much as possible so the wear of each will be similiar to provide a equal testing standard. The banks that were used more have a greater chance of failing. If a few banks failed during an actual shot a possible reason could be excessive overuse. This possibility could be comfirmed with this table.

TABLE IV BANK CHARGE LEVEL

CHARGE LEVEL BANK #	1-3KV	3-5KV	5-7KV	7-9KV	9-11KV	TOTAL
1	27	67	25	12	4	135
2	27	67	25	12	4	135
3	29	62	21	11	3	126
4	29	62	21	11	3	126
5	38	60	21	9	2	130
6	38	60	21	9	2	130
7	38	62	23	9	2	134
8	37	62	23	9	2	133
9	55	64	21	9	2	151
10	56	64	21	10	2	153
11	45	60	22	9	2	138
12	45	60	22	9	2	138
13	42	78	26	16	3	165
14	42	78	26	16	3	165
15	49	73	26	16	2	166
16	49	72	26	16	2	165
17	39	71	28	17	2	157
18	41	71	28	17	2	159
19	34	72	26	19	5	156
20	32	71	26	16	3	148
21	33	69	27	19	2	150
22	35	68	26	17	2	148
23	46	68	28	15	2	159
24	46	68	28	14	2	158

TabLe V was made to show the bank reliability of all system tests since April 12, 1988. When twelve or more banks are charged it is considered a system test. Each shot is labeled either live shot, shorting block shot (static load) or dumped. This table shows the date of the shot, the old name, which exact banks were charged, the charge level (KV), the total number of banks that prefired and did not fire, which exact banks prefired and did not fire, if there were banks that prefired did charging continue, whether the shot was live, shorting block, or dumped, and any comments. The comments try to explain why certain banks did not fire or prefired. It also documents any hardware changes and additions made on the system in the effort to improve it. With this chart the results of hardware changes can be seen in the tests following its changes.

The first half of the table which includes tests #1-#76 begins with a bank reliability of 85.5%. This is at the beginning of the testing of the 5MJ system. There were many problems and ideas for improvement that developed as the system was tested. As the problems and ideas developed some hardware changes and additions were necessary to correct and improve it. An example of a change is the inductor. Inductors were added after test #66 to regulate the current pulse from the capacitors. This regulation prevents the current from exceeding the limits set by the crowbar diodes. For another example, there were many triggering problems in tests #1-#76.

A possible reason was that only one Marx was triggering two ignitrons. To try to solve this problem twelve more Marxes were built. This addition made after test #76 had a significant effect on reliabilities. successful. In the second half of the table which includes tests #77-#136 the bank reliability increases to 93.2% because many problem had been worked out. During these tests, a change was made that unknowingly created a ground loop which caused faulty triggers. The ground loop was on the system during test #116 to #131. The tests between #116 and #131 had many prefires and misfires as the table shows. In a final bank reliability calculation using test #77-#136 omitting tests #116 - #131 the reliability increased to 98.8%.

TABLE V SYSTEM TESTS

	DATE	OLD NAME	BANKS CHARGED	CHARGE LEVEL	# OF BANKS THAT FAILED	BANKS THAT B-DID NOT FIRE P-PREFIRED	CONTINUE CHARGE Y/N	D-DUMPED S-STATIC L-LIVE	
1	4/12/88	ST-1	1-24	2.0					
2	4/13/88	ST-2	1-24	2.0	4			L	
3	4/15/88	ST-3	1-24	2.0	3			S	
4	4/15/88	ST-4	1-24	2.0	3			L	
5	4/15/88	ST-5	1-12	4.0	1			L	
6	4/16/88	ST-6	1-24	4.1	1			L	
7	4/26/88	ST-7	1-24	4.8	15			L	
8	4/29/88	ST-8	1-12	4.8	3			S	
9	4/29/88	ST-9	13-24	4.8				S	
10	4/29/88	ST-10	13-24	4.8	2			S	
11	5/03/88	ST-11	1-12	4.8	3			S	
12	5/05/88	ST-12	13-24	4.8	2			S	
13	5/06/88	ST-13	1-24	4.9	3			S	
14	5/09/88	ST-14	1-24	5.0				D	
15	7/06/88	ST-1	1-24	3.0	1		Y	D	
16	7/06/88	ST-2	3-22	3.0	6	B7-B12		S	
17	7/06/88	ST-3	3-22	3.0	4	B9,13,14,17		S	
18	7/06/88	ST-4	3-22	3.1	4	B9,13,14,17		S	
19	7/06/88	ST-5	3-12 15-22	3.1	2	B17,18		S	
20	7/06/88	ST-6	3-12 15-22	3.1	2	B17,18		S	
21	7/07/88	ST-1	1-22	3.1	2	B17,18		S	2
22	7/07/88	ST-2	1-22	3.0	2	B17,18		S	3
23	7/07/88	ST-3	1-22	3.1	2	B13,14		S	4
24	7/08/88	ST-1	1-24	3.1				S	
25	8/07/88	ST-2	1-24	3.0	1	B12		S	
26	7/08/88	ST-3	1-24	3.0	1	B6		S	
27	7/08/38	ST-4	1-24	5.0				S	
28	7/08/88	ST-5	1-24	5.0 7.0			Y	D D	5
29	7/08/88	ST-6	1-24	6.7				D	6
30	7/11/88	ST-15	1-24	5.4	10	B2,4,6,8,9,11, 15,16,19,23		S	
31	7/13/88	SHOT2	1-24	5.1	1	B11		S	
32	7/13/88	SHOT3	1-22	5.0	22	P1-22		N	
33	7/15/88	ST-19	1-24	4.0	24				7
34	7/18/88	ST-20	1-23	4.0			Y	D	
35	7/22/88		1-22 24	5.0				L	
36	7/22/88	SHOT3	1-22 24	5.2	4	B4,9,11,21		L	8

TABLE II CONTINUED

37	8/04/88		1-24	4.4				L	9
38	8/05/88		1-24	5.0	1	B11		L	
39	8/12/88	SHOT4	1-24	7.0			Y	D	10
40	8/24/88	SHOT5	1-24	7.0	4	B1,2,5,9		L	11
41	9/02/88	ST-25	1-24	9.0	5	B3,4,11,13,14	Y	S	12
42	9/12/88	T1	1-24	4.0	2	B13,14		S	
43	9/12/88	T2	1-24	4.0	2	B7,8		S	
44	9/12/88	T3	1-24	4.0	2	B7,8		S	13
45	9/12/88	T4	1-24	4.0	3	B5,6,19		S	
46	9/12/88	T5	1-24	4.0	2	B6,19		S	
47	9/12/88	T6	1-24	4.0	2	B6,19		S	
48	9/12/88	T7	1-24	4.0				S	
49	9/12/88	T8	1-24	4.0	2	B4 P?	Y	S	
50	9/12/88	R1	1-24	3.8				L	
51	9/12/88	R2	1-24	6.0				L	
52	9/12/88	R3	1-24	4.0	3	B3,4,11		L	
53	9/13/88		1-24	4.0	2	B11,21		L	
54	9/13/88		1-24	4.0	1	B21		L	
55	9/13/88		1-24	6.0				L	
56	9/13/88		1-24	6.0			Y	L	14
57	9/13/88		1-24	6.0			Y	L	15
58	9/13/88		1-24	6.0	5	B11,12,23,24 P?		L	
59	9/14/88		1-24	6.0	1	B2		L	16
60	9/16/88		1-24	4.0				S	
61	9/16/88		1-24	4.0	5	B6,11,13,21,24		S	
62	9/20/88		1-24	4.0	3	B11,21,22		S	17
63	9/20/88		1-24	4.0	2	B11,23		S	
64	9/20/88		1-24	4.0	1	B1		S	
65	9/21/88		1-24	9.0	4	B6,11,13,24		L	
66	9/22/88		1-24	9.0	2	B8,11		L	18
67	11/08/88	ST	1-24	4.0	10	B4,6,8,10,15,19,21,22,23		S	
68	11/08/88	ST	1-24	4.0	7	B4,5,8,10,19,21,22		S	
69	11/08/88	ST	1-24	6.5	6	B1,3,5,15,19,20		S	
70	11/08/88	ST	1-12	6.1	2	B5,6		S	
71	11/08/88	ST	13-24	6.0	4	B14,17,19,24		S	
72	11/08/88	ST	1-24	6.0	8	B4,5,6,10,11,15,19,20		S	
73	11/10/88	ST	1-24	4.0	6	B1,4,6,10,19,20		S	
74	11/10/88		1-24	4.0	9	B4,7,11,15,17,19,20,23,24		S	
75	11/10/88		1-24	4.0	9	B4,11,15,17,19,23,24		S	
76	11/10/88		1-24	4.0	8	B4,7,11,15,19,20,23,24		S	
77	11/22/88	HST1	1-12	4.0				L	19
78	11/22/88	HST2	1-12	4.0				L	
79	11/22/88	HST3	1-12	4.0				L	
80	11/30/88		1-12	4.0				S	
81	11/30/88	HV1	1-12	4.0				L	
82	12/08/88		1-24	9.5	1	B20		D	20
83	12/09/88	HV	1-12	4.0				S	
84	12/09/88	HV2	1-12	4.0				L	21

TABLE II CONTINUED

85	12/21/88	HV	13-24	4.0				S	
86	12/21/88	HV	13-24	4.0				S	
87	12/21/88	HV	13-24	4.0				S	
88	12/21/88	HV	13-24	4.0				S	
89	12/21/88	HV	13-24	4.0				S	
90	12/21/88	HV3	13-24	4.0				L	22
91	12/26/88	HV	13-24	4.0				S	
92	12/27/88	HV	13-24	4.0				S	
93	12/28/88	HV4	13-24	4.0				L	
94	1/17/89	HV5	13-24	5.0				L	
95	2/03/89	HV	13-24	4.0				S	
96	2/03/89	HV	13-24	5.0				S	
97	2/03/89	HV6	13-24	5.5				L	
98	2/10/89	HV7	13-24	7.0				L	
99	2/13/89		13-24	4.0				S	
100	2/13/89	HV9	13-24	7.0			Y	L	
101	2/14/89	HV10	13-24	8.0				L	
102	2/10/89		13-24	4.0				L	
103	2/10/89	HV11	13-24	8.0				L	
104	2/16/89		13-24	9.0			Y	D	
105	2/16/89	HV12	13-24	9.0				L	
106	2/23/89	HV13	13-24	9.0				L	
107	2/27/89	HV14	13-24	9.0				L	
108	2/28/89	HV15	13-24	9.0				L	
109	2/28/89	HV16	13-24	9.5				L	
110	3/14/89		1-12	3.0				S	23
111	3/15/89	HV17	1-14	9.5				L	
112	3/16/89		1-24	4.0				S	24
113	3/16/89		1-24	4.0				S	24
114	3/16/89		1-24	4.0				S	24
115	3/17/89	HV18	1-24	8.5	1	B22		L	
116	3/31/89	HV19	1-24	8.0	24	P1-24	N	L	*25
117	4/25/89		1-24	3.0	5	P9,17,20,21,22	N	D	26
118	4/26/89		1-24	3.0				S	
119	4/26/89		1-24	5.0	4	P14,17,20,21	N	D	
120	4/[illegible]/89		1-24	5.0				S	
121	5/01/89		1-24	3.0				S	
122	5/01/89		1-24	3.0				S	27
123	5/02/89		1-24	3.0				S	
124	5/02/89		1-24	5.0	1	P20	N	S	
125	5/02/89		1-24	3.0				S	
126	5/02/89		1-24	6.0				D	
127	5/03/89		1-24	6.0	2	P17,23	N	D	
128	5/03/89		1-24	6.0	15	P7-14,17,19-24	N	D	
129	5/03/89		1-24	6.0	11	P12-21,23,24	N	D	
130	5/04/89		1-24	6.0				S	28
131	5/04/89		1-24	6.0				S	*29
132	5/04/89		1-24	6.0	1	B10		S	
133	5/15/89		1-24	3.0	4	B5,10,18,20		S	
134	5/17/89	HV20	1-24	8.0	1	B23		L	
135	5/24/89		1-24	3.0				S	
136	5/25/89	HV21	1-24	5.3				L	30

TABLE II CONTINUED

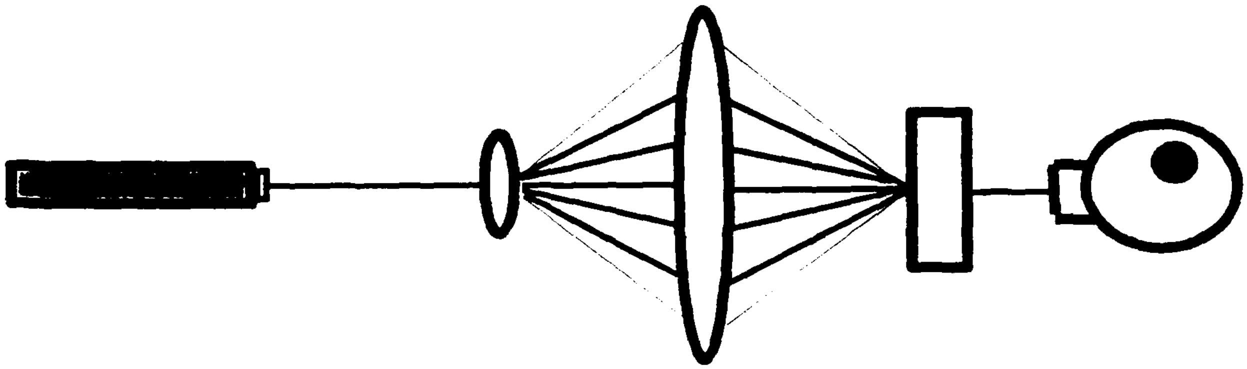
SYSTEM TEST - COMMENTS

1. A bad Marx on Banks 13 & 14
   Changed ignitron on Banks 9 & 17
2. Problem could be caused by Marx or the banks
   Move Marx to find out
3. Bank problem
4. Marx failed
5. Ignitron breaks down twice
   Wall breaker popped
6. Wall breaker popped
7. Marx failed to trigger
8. Low injection velocity
9. Fired into spark gap
10. Charger problem
11. Isolation transformer problem
12. Marx not plugged into charger
13. Bad SCR
14. An ignitron broke down
15. An ignitron broke down
16. Added Ross relay to separate charger and Marx
17. Isolation transformer was not hooked up
18. Add inductors
19. Went to single secondary isolation transformer
20. Bank #20 wiring failed explosively
21. Rewire Banks 13-20
22. Rewire Banks 1-12
23. Test new isolation transformers
24. Test Marx
25. Miss fire - all banks prefired - * BEGINNING OF PROBLEMS
26. Trigger line was not connected
27. Did not get Ripple Fire
28. Did not get Ripple Fire
29. Did not get Ripple Fire - * MADE CHANGES
    1. Insulated power coax cable armor from floor with G-9
    2. Switched delay generator power from wall to batteries
    3. Replaced 2.2 Kiloohms SCR trigger resistors with 12 Kiloohms in the new Marxes
30. All Fired

In conclusion, I have learned a great deal at the Hypervelocity Launcher Technology Division. I have been learning about the operation of the 5MJ pulse power system. I have studied the 5MJ log book to find the bank reliability of previous tests. I helped in the set up of the system of prepare for a test. For example, setting the delay generator, making data probes, and attenuators. I helped update a checklist of the 5MJ system showing the preshot setup, controller operation, and post shot activities. These are some of the things I have been involved with this summer.

Working at the Hypervelocity Launcher Research Division this summer was a very interesting experience that I am grateful I had. This job has allowed me to work with engineers and to have experience in the engineering field. This will have a great influence in decisions about my future.

INFRARED LASER POLARIMETRY



DANIELLE WALKER

HSAP

AGA/IR TECHNOLOGY SECTION

MENTOR: MR. DENNIS GOLDSTEIN

AUGUST 18,1989

ACKNOWLEDGMENTS

I would like to thank the following people.

Mr. Dennis Goldstein for all the patience and consideration he showed me and for all the times he stopped to explain things to me.

Mr. Randall Hodgson for keeping things in perfect balance by teaching me things, yet still treating me as an equal.

Mr.Lynn Deibler for his endless supply of books and help.

The technicians of the Special Projects Laboratory: Michael Vantassel, Howard McCormick, Voncile Houston, and Linda Lau for keeping the laser running and me laughing.

A special thanks to all the people in AGA/IR for their companionship and congeniality.

TABLE OF CONTENTS

I INTRODUCTION

This summer I received the honor of working as a High School Apprentice in the HSAP program at the Air Force Armament Laboratory here at Eglin Air Force Base.

I was placed in the IR Technology Section of the Air to Air Guidance Branch. Under Mr. Dennis Goldstein's patient guidance I was introduced to Infrared Laser Polarimetry.

II RESEARCH

GENERAL

Polarimetry is the optical laws concerned with measuring the polarization state of a beam of light and the polarizing and retarding properties of materials. A polarimeter is a special instrument in optics that finds the polarization state of a light beam. Already knowing how the polarimeter will act on the light, the change, by introducing a sample into the polarimeter, may be determined.

This polarimeter that was worked with over the summer operates in the infrared wavelength region. All of the studies are done with a CO_2 laser source at 10.6um.

To process data and express results the formulas of the Mueller matrix are used. The Mueller matrix is a 4 by 4 real matrix with elements that contain functions of angle and wavelength used to represent optical identity, such as polarization elements. Polarized light is represented by Stokes vectors. The setup, described by Azzam consisted of two fixed polarizers and two rotating retarders. The retarders are rotated differently with one exactly five times as much as the other. The laser is powerful and the signal had to be significantly cut down by numerous beam splitters, so that the detectors were not overwhelmed. Unlike spectopolarimetry only one wavelength is inspected at a time here.

DETAILED

One of my first projects was to generate a data set for error analysis using polarimeter simulation. I did this on the program MathCAD. One example is shown in Fig.1. The Mueller matrix represents the optical identity. The numbers that are found as A and B are Fourier coefficients which represent the expansion of the signal. After making thirty-one different combinations of the errors I combined the data files with a larger program that compensated for the errors. If the second program worked then the final matrix should have elements as close to one as possible. Fig.2 is an example of this. This program had some errors in it but after seeing the results of the tests they were easy to fix. Fig. 3 shows the equations used in the second program to compensate for the errors.

The table was the center of concern in the Optics Lab. All of the equipment, except for the computer was on it. Fig.4 illustrates the final lay

Angle of last polarizer from horizontal.

$$\epsilon 5 \equiv 0.0 \cdot deg$$

Retardances

$$\delta 1 \equiv 91 \cdot deg$$
$$\delta 2 \equiv 91 \cdot deg$$

Angle of first wave plate from expected value.

$$\epsilon 3 \equiv 0.1 \cdot deg$$

Angle of second wave plate from expected value.

$$\epsilon 4 \equiv 0.1 \cdot deg$$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 0.9448442 & 0.9887779 & 0.9750674 & 0.9649503 \\ 1.0302509 & 1.0781559 & 1.0632061 & 1.0521745 \\ 0.9607245 & 1.0053966 & 0.9914557 & 0.9811686 \\ 0.9787102 & 1.0242187 & 1.0100168 & 0.9995371 \end{bmatrix}$$

k	A_k	B_k
0	0.5559744	0
1	0.0013012	0.3727594
2	0.190982	0.1883338
3	-0.0642434	-0.0629118
4	-0.1249497	0.0017447
5	-0.0065056	-0.3727049
6	0.1249345	-0.002617
7	0.0620087	-0.0651155
8	0.0646754	-0.0018065
9	0.0615526	-0.0655468
10	0.1961661	0.1829279
11	-0.0610935	0.065975
12	0.0027094	0.0646438
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	0	0

FIGURE 1

ADJUSTED MUELLER MATRIX

.999936	1.000134	1.000109	.999871
1.000018	.999942	.999992	.999847
.999994	.999992	.999944	.999847
.999831	.999864	.999986	.999695

A 0 = .5566126	
A 1 = .0013027	B 1 = .3731873
A 2 = .1912012	B 2 = .18855
A 3 =-.0629118	B 3 =-.0642434
A 4 =-.1249589	B 4 =-.0008724
A 5 = .0013012	B 5 =-.3727594
A 6 = .1249619	B 6 = 0
A 7 = .0633588	B 7 =-.0638026
A 8 = .064697	B 8 = .0006775
A 9 = .0640234	B 9 =-.0631357
A 10 = .1889993	B 10 = .1903234
A 11 =-.0635811	B 11 = .0635811
A 12 = .0002258	B 12 = .0647002

EPSILON 1 = .0174532925
EPSILON 2 = .0174532925
EPSILON 3 = .00174532925
EPSILON 4 = 0
EPSILON 5 = .00174532925

FIGURE 2

$$m_{11} = 4a_1 - \frac{(1-\epsilon_1)}{2} m_{12} - \frac{1-\epsilon_2}{2} m_{21} - \frac{(1-\epsilon_1)(1-\epsilon_2)}{4} m_{22}$$

$$-(1-\epsilon_2)\epsilon_5 m_{21} - \frac{(1-\epsilon_1)(1-\epsilon_2)\epsilon_5}{2} m_{22}$$

$$m_{12} = \frac{(2m_{22}\epsilon_5 + m_{22})(\epsilon_2 - 1)}{2} - \frac{8(a_2 - 4\epsilon_3 b_2)}{(\epsilon_1 + 1)(16\epsilon_3^2 + 1)}$$

$$m_{13} = \frac{(2m_{23}\epsilon_5 + m_{23})(\epsilon_2 - 1)}{2} - \frac{32\epsilon_3 a_2 + 8b_2}{(\epsilon_1 + 1)(16\epsilon_3^2 + 1)}$$

$$m_{14} = 2\frac{a_1}{\epsilon_3} - \frac{(1-\epsilon_2)}{2} m_{24} - (1-\epsilon_2)\epsilon_5 m_{24}$$

$$= 2b_1 - \frac{(1-\epsilon_2)(b_{11} - b_9)}{2(1+\epsilon_2)} - \frac{(1-\epsilon_2)(10\epsilon_4 - 2\epsilon_5)(b_9 + b_{11})}{\epsilon_3(1+\epsilon_2)}$$

$$m_{21} = \frac{m_{22}(\epsilon_1 - 1)}{2} - \frac{8a_{10} - 16(\epsilon_5 - 10\epsilon_4)b_{10}}{(\epsilon_2 + 1)(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 + 1)}$$

$$m_{22} = -16[-(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(a_9 - a_{12})$$

$$- [illegible]\epsilon_3(\epsilon_5 - 10\epsilon_4)(a_9 - a_{12})$$

$$- 4\epsilon_3(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 + 1)(b_9 - b_{12})$$

$$- [illegible](\epsilon_5 - 10\epsilon_4)(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(b_9 - b_{12})]$$

$$[illegible](\epsilon_2 + 1)(2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 - 1)(2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 + 1)$$

$$\times(2\epsilon_5 - 20\epsilon_4 + 4\epsilon_3 - 1)(2\epsilon_5 - 20\epsilon_4 + 4\epsilon_3 + 1)$$

$$m_{23} = 16[-4\epsilon_3(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(a_9 - a_{12})$$

$$+ 8(\epsilon_5 - 10\epsilon_4)(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(a_9 - a_{12})$$

$$- (4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(b_9 - b_{12})$$

$$[illegible]$$

$$[illegible](2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 [illegible])(2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 [illegible])$$

$$[illegible](2\epsilon_5 - 20\epsilon_4 [illegible])$$

$$m_{24} = \frac{4(a_9 + a_{11})}{(1+\epsilon_2)\epsilon_3} - \frac{8(b_{11} - b_9)}{(1+\epsilon_2)} - \frac{8(10\epsilon_4 - \epsilon_5)(b_9 + b_{11})}{\epsilon_3(1+\epsilon_2)}$$

$$m_{31} = \frac{m_{32}(\epsilon_1 - 1)}{2} - \frac{16(\epsilon_5 - 10\epsilon_4)a_{10} - 8b_{10}}{(\epsilon_2 + 1)(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 + 1)}$$

$$m_{32} = -16[2(\epsilon_5 - 10\epsilon_4)(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(a_9 - a_{12})$$

$$- 4\epsilon_3(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 + 1)(a_9 - a_{12})$$

$$- 16\epsilon_3(\epsilon_5 - 10\epsilon_4)(b_9 + b_{12})$$

$$- (4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 + 16\epsilon_3^2 - 1)(b_9 - b_{12})]$$

$$- (\epsilon_1 + 1)(\epsilon_2 + 1)(2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 - 1)(2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 + 1)$$

$$\times(2\epsilon_5 - 20\epsilon_4 + 4\epsilon_3 - 1)(2\epsilon_5 - 20\epsilon_4 + 4\epsilon_3 + 1)$$

$$m_{33} = 16[16\epsilon_3(\epsilon_5 - 10\epsilon_4)(a_9 + a_{12})$$

$$- (4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 + 16\epsilon_3^2 - 1)(a_9 - a_{12})$$

$$- 2(\epsilon_5 - 10\epsilon_4)(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(b_9 - b_{12})$$

$$- 4\epsilon_3(4\epsilon_5^2 - 80\epsilon_4\epsilon_5 + 400\epsilon_4^2 - 16\epsilon_3^2 - 1)(b_9 - b_{12})]$$

$$\Big/ \Big[(\epsilon_1 + 1)(\epsilon_2 + 1)(2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 - 1)(2\epsilon_5 - 20\epsilon_4 - 4\epsilon_3 + 1)$$

$$\times(2\epsilon_5 - 20\epsilon_4 + 4\epsilon_3 - 1)(2\epsilon_5 - 20\epsilon_4 + 4\epsilon_3 + 1)\Big]$$

$$m_{34} = \frac{8(a_9 - a_{11})}{(1+\epsilon_2)} - \frac{8(\epsilon_5 - 10\epsilon_4)(a_9 - a_{11})}{\epsilon_3(1+\epsilon_2)} - \frac{4(b_9 + b_{11})}{\epsilon_3(1+\epsilon_2)}$$

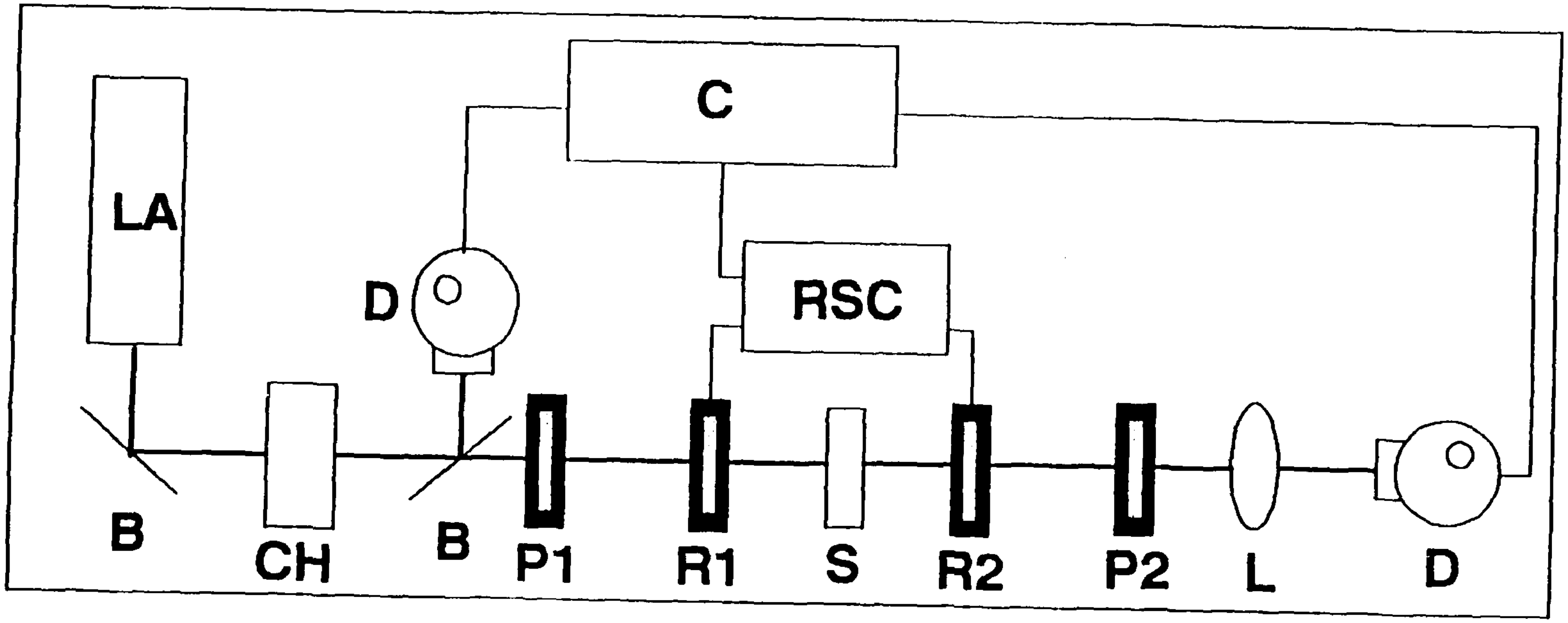
$$m_{41} = \frac{a_5}{(\epsilon_5 - 5\epsilon_4)} - \frac{(1-\epsilon_1)(a_3 + a_7)}{(\epsilon_5 - 5\epsilon_4)(1+\epsilon_1)} - \frac{8(1-\epsilon_1)\epsilon_3(b_3 - b_7)}{(1+\epsilon_1)(5\epsilon_4 - \epsilon_5)} - \frac{4(1-\epsilon_1)(b_3 - b_7)}{(1+\epsilon_1)}$$

$$m_{42} = -\frac{2(a_3 + a_7)}{(1+\epsilon_1)(5\epsilon_4 - \epsilon_5)} - \frac{16\epsilon_3(b_3 - b_7)}{(1+\epsilon_1)(5\epsilon_4 - \epsilon_5)} - \frac{8(b_3 - b_7)}{(1+\epsilon_1)}$$

$$m_{43} = \frac{2(b_3 - b_7)}{(1+\epsilon_1)(5\epsilon_4 - \epsilon_5)} - \frac{4(a_3 - a_7)}{1+\epsilon_1} - \frac{16\epsilon_3(a_3 - a_7)}{(1+\epsilon_1)(5\epsilon_4 - \epsilon_5)}$$

$$m_{44} = \frac{2b_4}{5\epsilon_4 - \epsilon_3 - \epsilon_5} - \frac{2b_4}{(\epsilon_5 - \epsilon_3 - 5\epsilon_4)} = -8a_4 = 8a_4$$

FIGURE 3



LA	LASER
D	DETECTOR
P1,P2	POLARIZERS
R1,R2	RETARDERS
S	SAMPLE
CH	CHOPPER
L	LENS
B	BEAM SPLITTER
C	COMPUTER
RSC	ROTARY BEAM CONTROLER

Diagram of optical table for laser polarimeter

FIGURE 4

out of the table. The laser power was cut down with beam splitters. The chopper chopped the laser signal so that the detectors could distinguish between the laser and background light. The two detector elements were both mercury cadmium telluride (HgCdTe). They had dewars that I kept filled with liquid nitrogen as a coolant. The detector before the polarimeter was photoconductive and the one after was photovoltaic. Having two detectors was very beneficial because when the tests were run the errors in the laser flow would be computed out and would not cause a problem in the results of the data. Fig. 5 shows a stability test run with this setup. The ratio is discovered and able to be used. Fig. 6 shows an early laser stability run that was using the PV detector and a pyroelectric detector in the setup shown in Fig. 7.

III CONCLUSIONS

The Mueller matrices are an essential part of these experiments. They tell how the errors should be acted upon and supply information through mathematical means. The matrices are different for each optical setup. Fig.8 shows the table for the Mueller Matrices. Another thing that is different for each element is the "fingerprint" of the sample in the polarimetry setup. This is the intensity graph. Figures 9 through 13 show the error matrix and intensity graph of a diagonal Mueller matrix, 9 being error free and the others with the errors shown. Figures 14 through 16 display a vertical linear polarizer and the outcome of errors. Figures 17 and 18 show a quarter-wave retarder with its fast axis vertical and the errors and intensity graph.

The results of all the computer work was compared to the actual

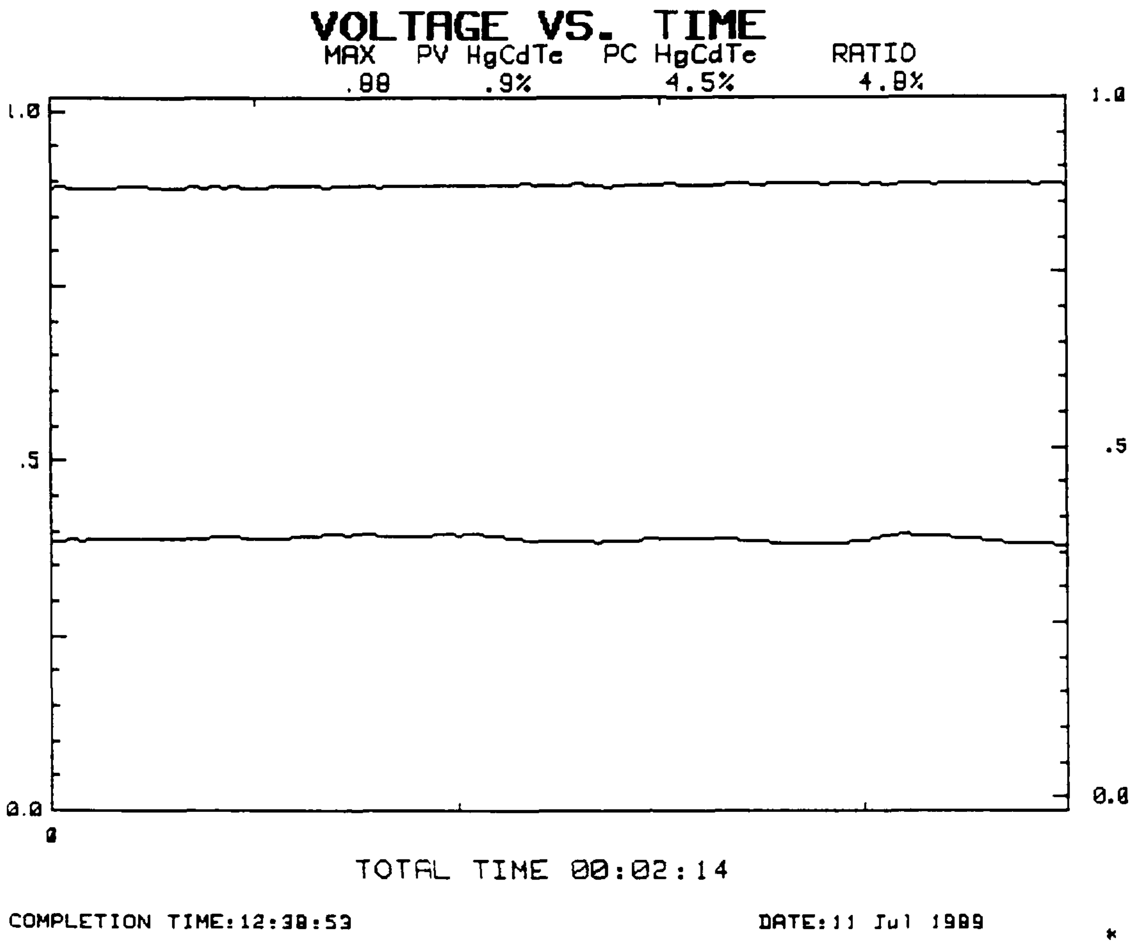

VOLTAGE VS. TIME
MAX PV HgCdTe PC HgCdTe RATIO
.88 .9% 4.5% 4.8%
1.0
.5
0.0
0
TOTAL TIME 00:02:14
COMPLETION TIME:12:38:53
DATE:11 Jul 1989

FIGURE 5

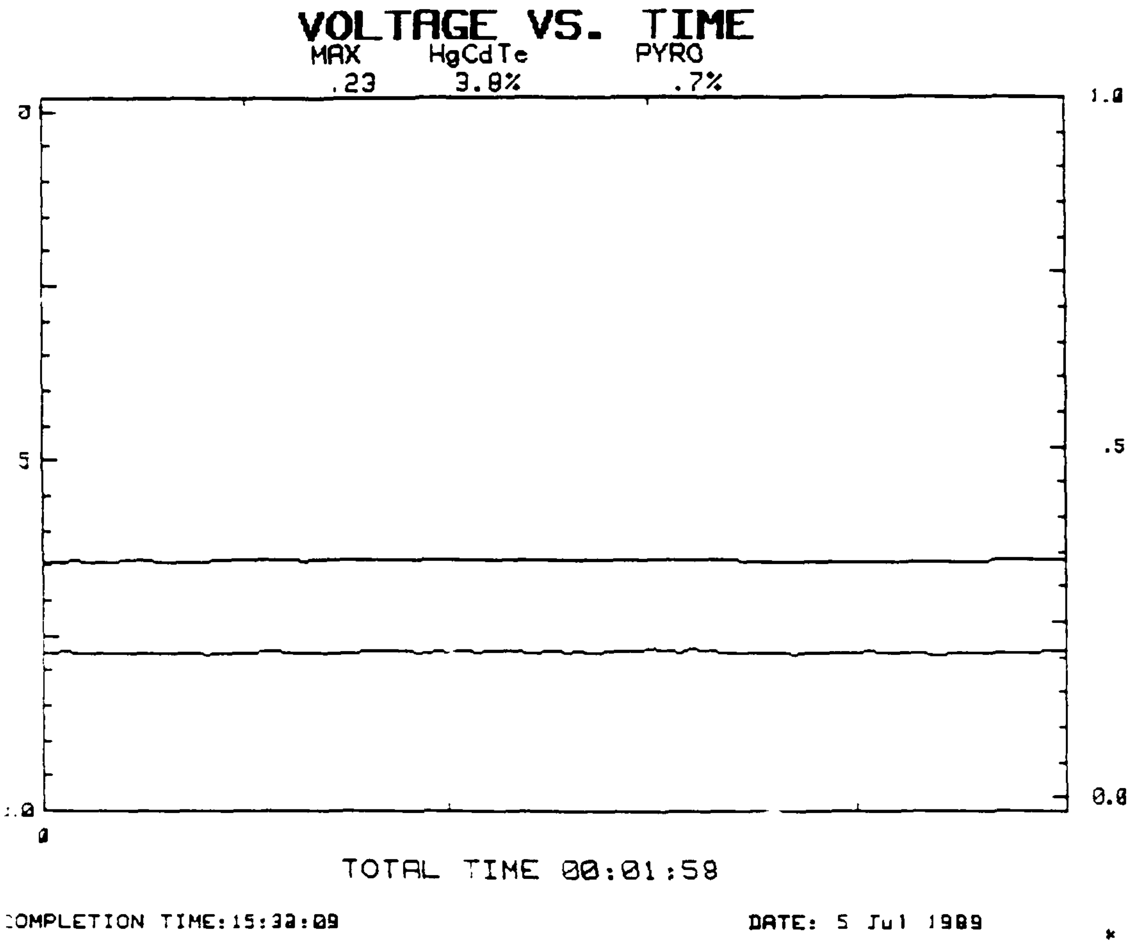

VOLTAGE VS. TIME
MAX HgCdTe PYRO
.23 3.8% .7%
1.0
.5
0.0
TOTAL TIME 00:01:58
COMPLETION TIME:15:32:09
DATE: 5 Jul 1989

FIGURE 6

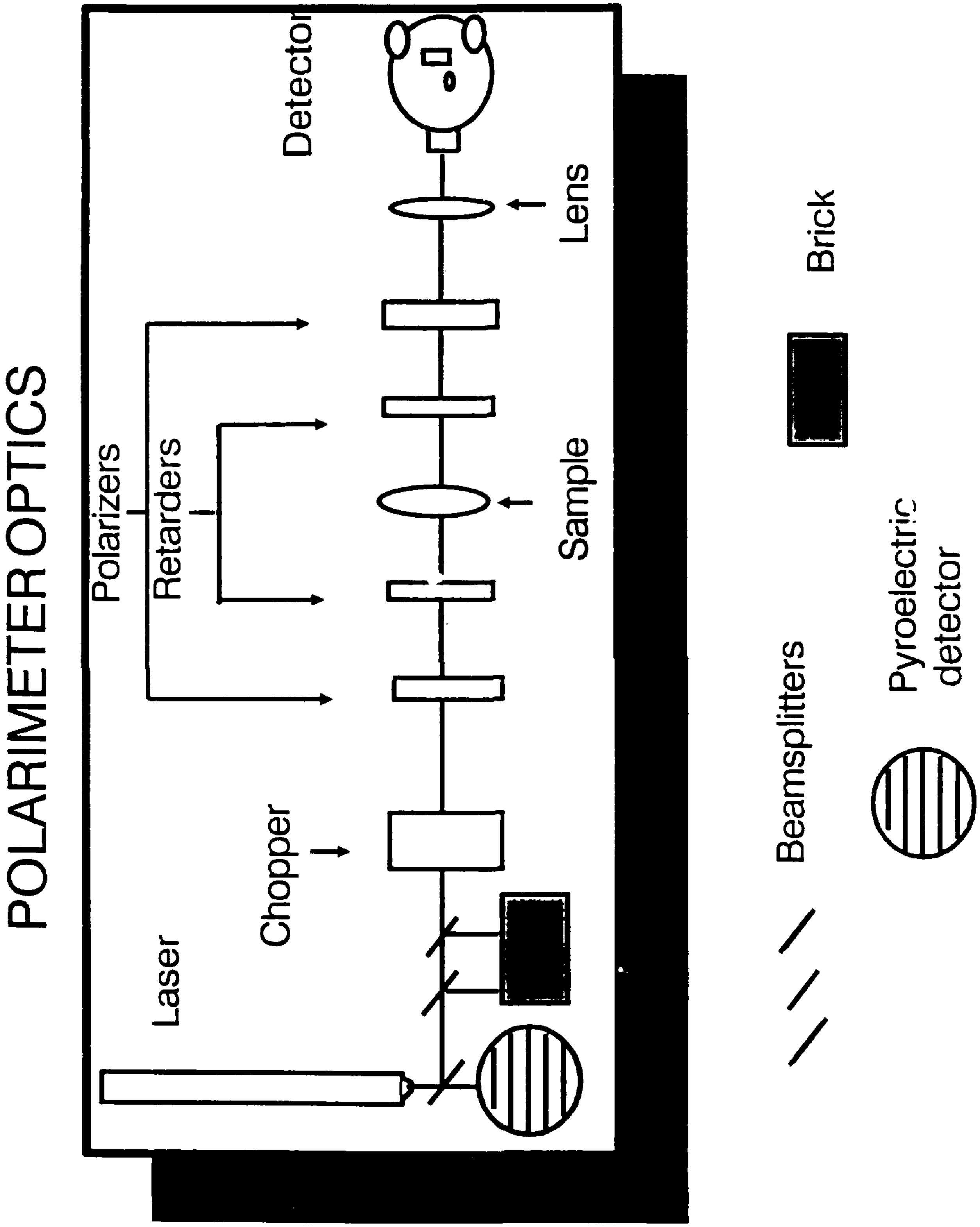

POLARIMETER OPTICS
Polarizers
Retarders
Laser
Chopper
Sample
Lens
Detector
Brick
Beamsplitters
Pyroelectric detector

FIGURE 7

Mueller Matrices

Linear optical element	Mueller matrix
Horizontal linear polarizer	$\frac{1}{2}\begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$
Vertical linear polarizer	$\frac{1}{2}\begin{bmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$
Linear polarizer at + 45 deg	$\frac{1}{2}\begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$
Linear polarizer at - 45 deg	$\frac{1}{2}\begin{bmatrix} 1 & 0 & -1 & [illegible] \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$
Quarter- wave plate fast axis vertical	$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$
Quarter- wave plate fast axis horizontal	$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & 0 \end{bmatrix}$
Homogeneous circular polarizer right	$\frac{1}{2}\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix}$
Homogeneous circular polarizer left	$\frac{1}{2}\begin{bmatrix} 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 1 \end{bmatrix}$

Figure 8

Angle of last polarizer from horizontal.

$$h \equiv 0 \cdot deg$$

Retardances

$$\delta 1 \equiv 90 \cdot deg$$
$$\delta 2 \equiv 90 \cdot deg$$

Angle of first wave plate from expected value.

$$\alpha \equiv 0 \cdot deg$$

Angle of second wave plate from expected value.

$$\beta \equiv 0 \cdot deg$$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

I_n
0.5
0.338
0.159
0.281
0.474
0.482
0.406
0.305
0.117
0
0.117
0.305
0.406
0.482
0.474
0.281
0.159
0.338
0.5
0.338
0.159
0.281
0.474
0.482
0.406
0.305
0.117
0
0.117
0.305
0.406
0.482
0.474
0.281
0.159
0.338

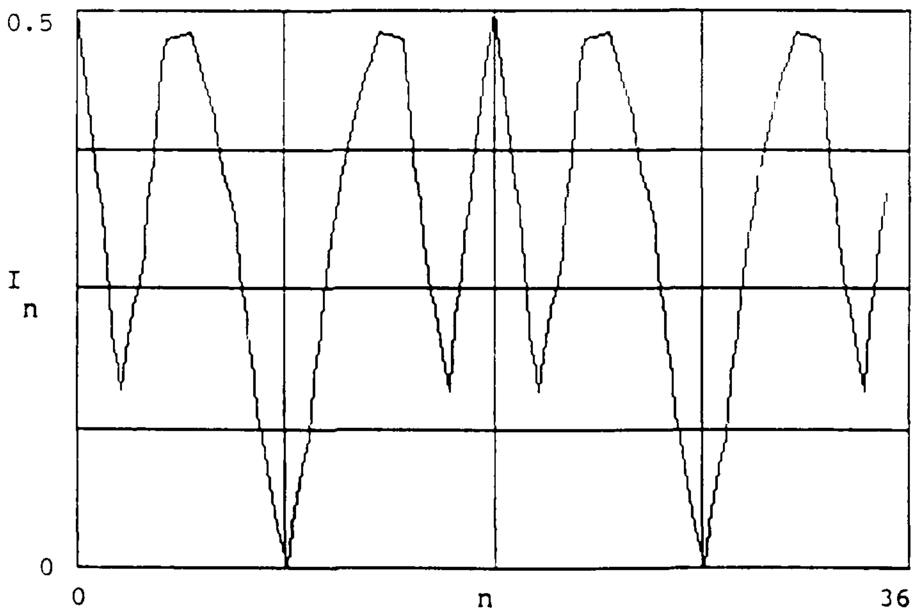


Figure 9

Angle of last polarizer from horizontal.

$$h \equiv 1 \cdot deg$$

Retardances

$$\delta 1 \equiv 91 \cdot deg$$
$$\delta 2 \equiv 90 \cdot deg$$

Angle of first wave plate from expected value.

$$\alpha \equiv 1 \cdot deg$$

Angle of second wave plate from expected value.

$$\beta \equiv 1 \cdot deg$$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 1.005 & 0 & -0.14 & 0 \\ 0 & 0.987 & 0.246 & 0 \\ -0.034 & -0.246 & 0.987 & 0 \\ 0 & 0 & 0 & 0.99 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & -0.14 & 0 \\ 0 & -0.013 & 0.246 & 0 \\ -0.034 & -0.246 & -0.013 & 0 \\ 0 & 0 & 0 & -0.01 \end{bmatrix}$$

I_n
0.494
0.29
0.155
0.32
0.489
0.47
0.395
0.282
0.086
0
0.15
0.324
0.414
0.49
0.452
0.241
0.166
0.381
0.494
0.29
0.155
0.32
0.489
0.47
0.395
0.282
0.086
0
0.15
0.324
0.414
0.49
0.452
0.241
0.166
0.381

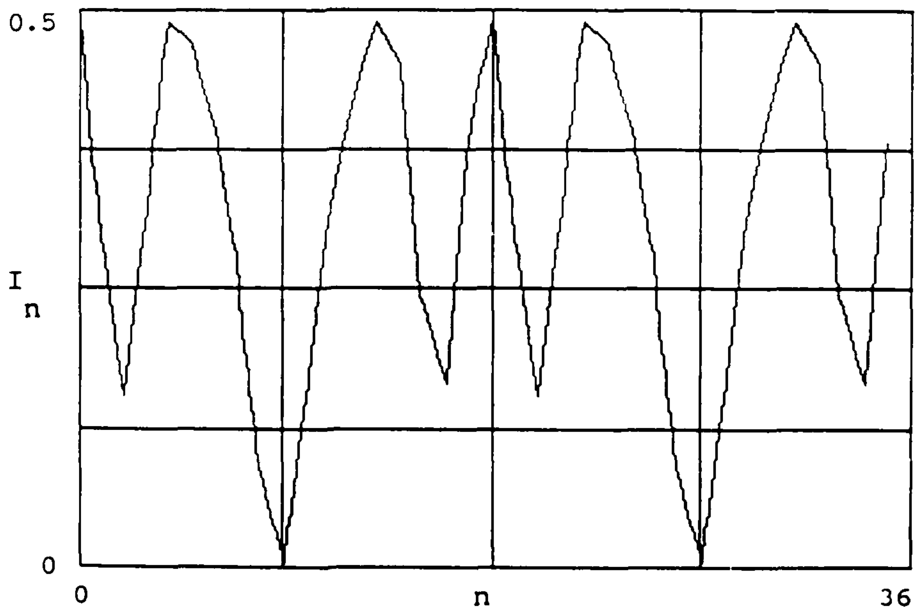


Figure 10

Angle of last polarizer from horizontal.

$h \equiv 1 \cdot deg$

Retardances

$\delta 1 \equiv 91 \cdot deg$
$\delta 2 \equiv 91 \cdot deg$

Angle of first wave plate from expected value.

$\alpha \equiv 0 \cdot deg$

Angle of second wave plate from expected value.

$\beta \equiv 0 \cdot deg$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 1 & -0.018 & 0.036 & 0 \\ -0.018 & 1.035 & -0.036 & 0 \\ 0 & 0.036 & 1.035 & 0 \\ 0 & 0 & 0 & 0.999 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & -0.018 & 0.036 & 0 \\ -0.018 & 0.035 & -0.036 & 0 \\ 0 & 0.036 & 0.035 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

I_n
0.5
0.342
0.155
0.272
0.47
0.484
0.409
0.309
0.123
0
0.108
0.293
0.397
0.478
0.477
0.284
0.154
0.33
0.5
0.342
0.155
0.272
0.47
0.484
0.409
0.309
0.123
0
0.108
0.293
0.397
0.478
0.477
0.284
0.154
0.33

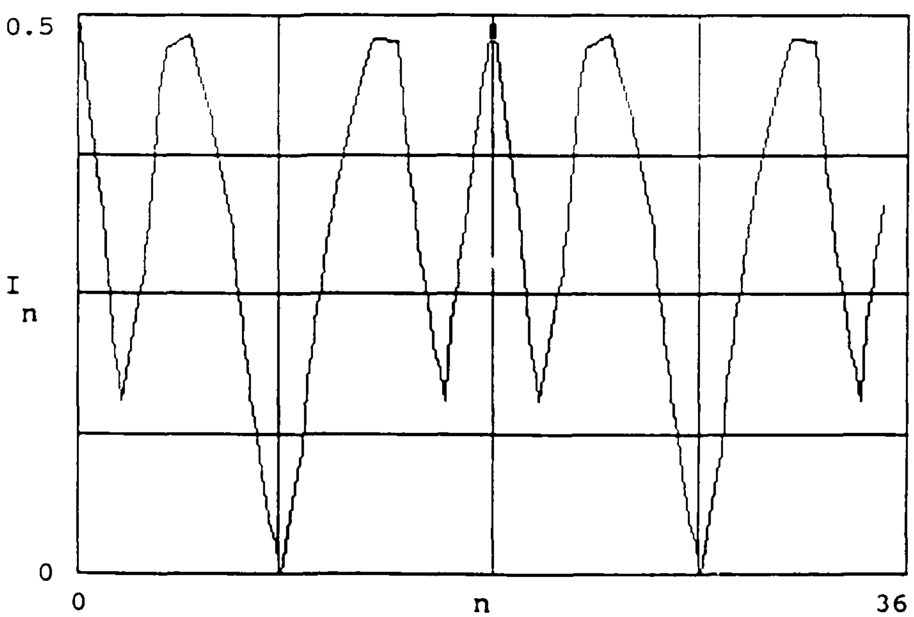


Figure 11

Angle of last polarizer from horizontal.

$$h \equiv 0 \cdot deg$$

Retardances

$$\delta 1 \equiv 91 \cdot deg$$
$$\delta 2 \equiv 90 \cdot deg$$

Angle of first wave plate from expected value.

$$\alpha \equiv 0 \cdot deg$$

Angle of second wave plate from expected value.

$$\beta \equiv 1 \cdot deg$$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 1 & 0.013 & -0.174 & 0 \\ 0 & 0.956 & 0.348 & 0 \\ 0 & -0.348 & 0.956 & 0 \\ 0 & 0 & 0 & 0.985 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0.013 & -0.174 & 0 \\ 0 & -0.044 & 0.348 & 0 \\ 0 & -0.348 & -0.044 & 0 \\ 0 & 0 & 0 & -0.015 \end{bmatrix}$$

I_n
0.492
0.289
0.166
0.337
0.494
0.461
0.387
0.279
0.086
0
0.151
0.33
0.424
0.495
0.442
0.224
0.161
0.384
0.492
0.289
0.166
0.337
0.494
0.461
0.387
0.279
0.086
0
0.151
0.33
0.424
0.495
0.442
0.224
0.161
0.384

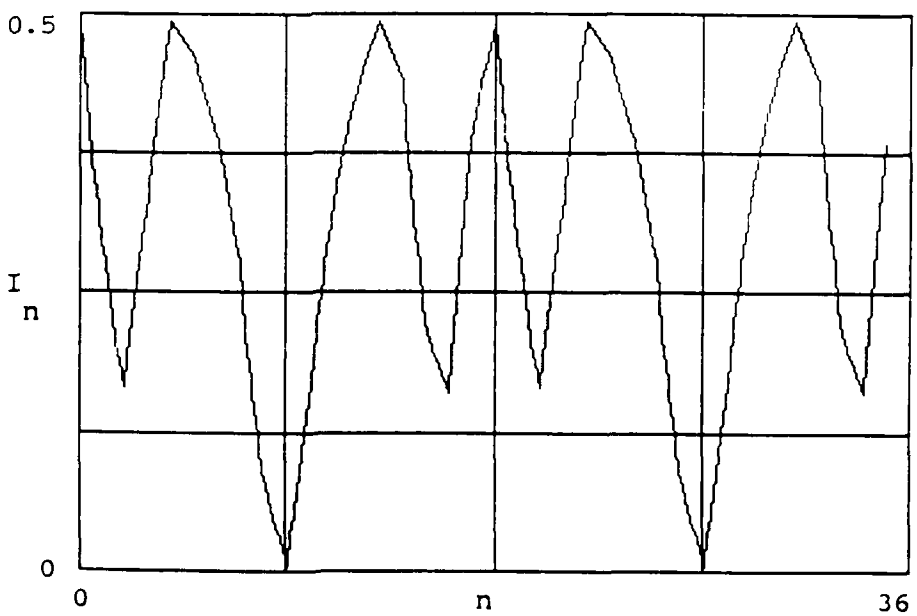


Figure 12

Angle of last polarizer from horizontal.

$$h \equiv 1 \cdot deg$$

Retardances

$$\delta 1 \equiv 91 \cdot deg$$
$$\delta 2 \equiv 90 \cdot deg$$

Angle of first wave plate from expected value.

$$\alpha \equiv 0 \cdot deg$$

Angle of second wave plate from expected value.

$$\beta \equiv 1 \cdot deg$$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 1 & 0 & -0.14 & 0 \\ 0 & 0.968 & 0.314 & 0 \\ 0 & -0.314 & 0.968 & 0 \\ 0 & 0 & 0 & 0.99 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & -0.14 & 0 \\ 0 & -0.032 & 0.314 & 0 \\ 0 & -0.314 & -0.032 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

I_n
0.494
0.294
0.165
0.331
0.492
0.465
0.393
0.287
0.093
0
0.144
0.322
0.419
0.493
0.446
0.229
0.158
0.378
0.494
0.294
0.165
0.331
0.492
0.465
0.393
0.287
0.093
0
0.144
0.322
0.419
0.493
0.446
0.229
0.158
0.378

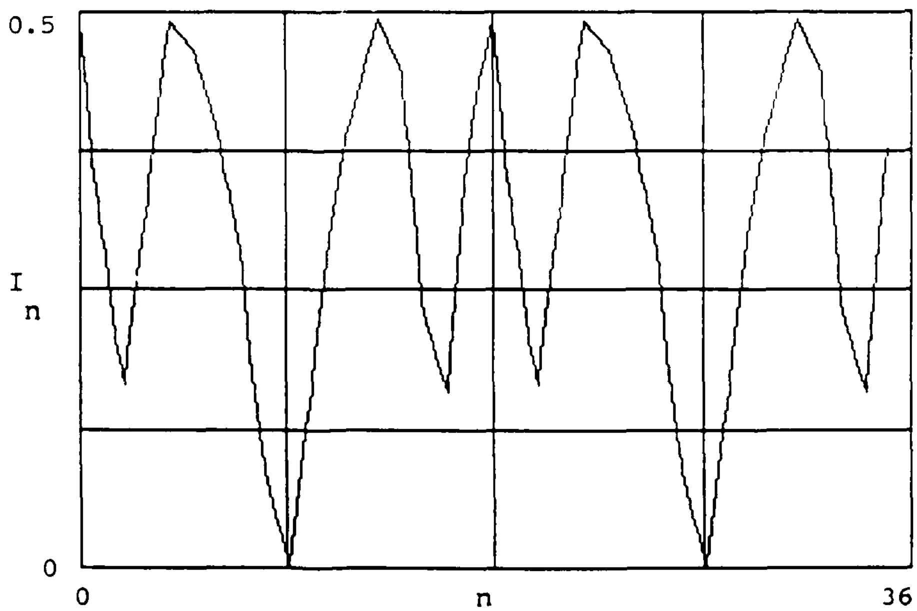


Figure 13

Angle of last polarizer from horizontal.

$h \equiv 0 \cdot deg$

Retardances

$\delta 1 \equiv 90 \cdot deg$
$\delta 2 \equiv 90 \cdot deg$

Angle of first wave plate from expected value.

$\alpha \equiv 0 \cdot deg$

Angle of second wave plate from expected value.

$\beta \equiv 0 \cdot deg$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 0.5 & -0.5 & 0 & 0 \\ -0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

I_n
0
0
0.014
0
0
0.065
0.07
0
0.05
0.125
0.05
0
0.07
0.065
0
0
0.014
0
0
0
0.014
0
0
0.065
0.07
0
0.05
0.125
0.05
0
0.07
0.065
0
0
0.014
0

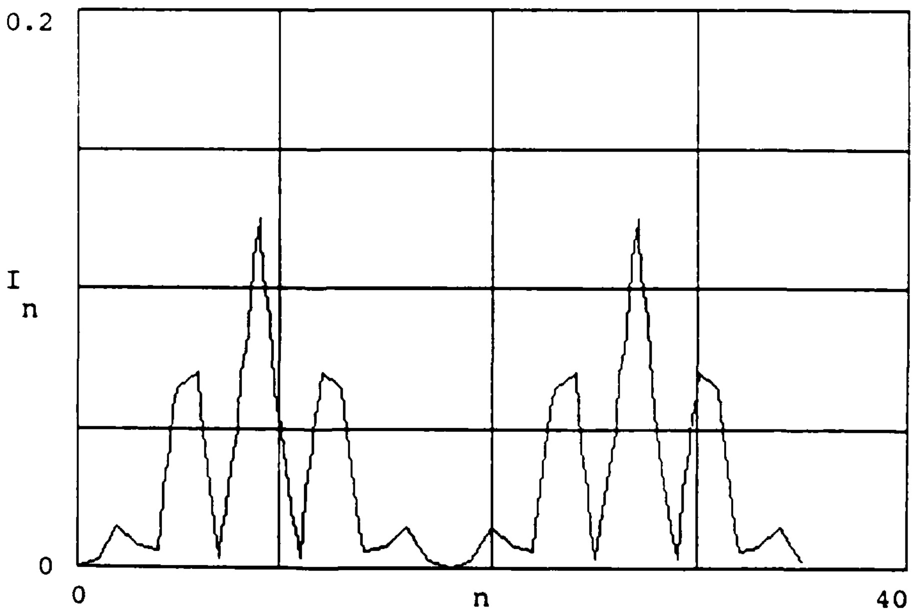


Figure 14

Angle of last polarizer from horizontal.

$h \equiv 1 \cdot deg$

Retardances

$\delta 1 \equiv 91 \cdot deg$
$\delta 2 \equiv 90 \cdot deg$

Angle of first wave plate from expected value.

$\alpha \equiv 1 \cdot deg$

Angle of second wave plate from expected value.

$\beta \equiv 1 \cdot deg$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 0.496 & -0.495 & 0.035 & 0 \\ -0.483 & 0.483 & -0.034 & 0 \\ 0.157 & -0.157 & 0.011 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & 0.035 & 0 \\ 0.017 & -0.017 & -0.034 & 0 \\ 0.157 & -0.157 & 0.011 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

I_n
0
0
0.016
0
0.013
0.076
0.06
0
0.071
0.124
0.032
0.012
0.08
0.054
0
0.011
0.012
0
0
0
0.016
0
0.013
0.076
0.06
0
0.071
0.124
0.032
0.012
0.08
0.054
0
0.011
0.012
0

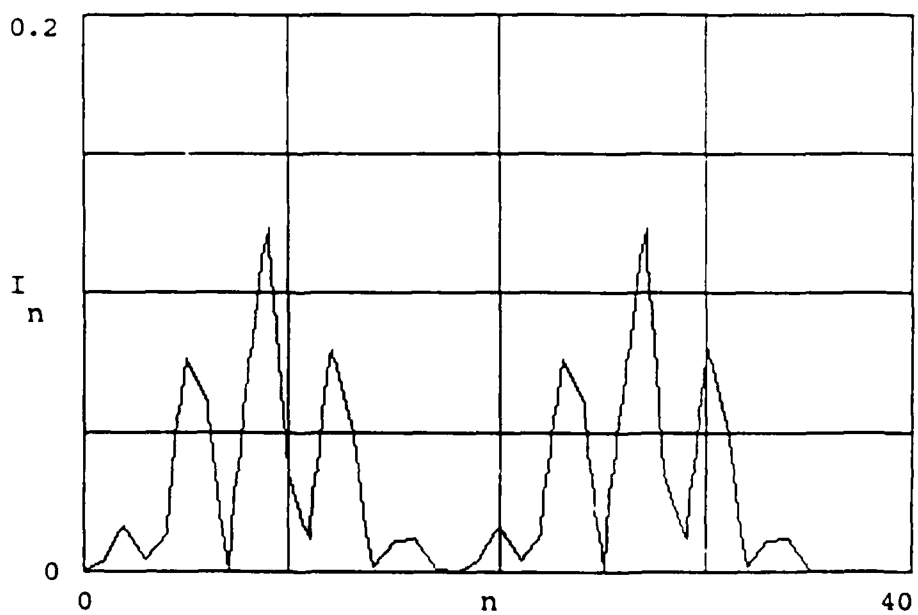


Figure 15

Angle of last polarizer from horizontal.

$h \equiv 0 \cdot deg$

Retardances

$\delta 1 \equiv 91 \cdot deg$
$\delta 2 \equiv 90 \cdot deg$

Angle of first wave plate from expected value.

$\alpha \equiv 0 \cdot deg$

Angle of second wave plate from expected value.

$\beta \equiv 1 \cdot deg$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 0.493 & -0.493 & 0 & 0 \\ -0.478 & 0.478 & 0 & 0 \\ 0.174 & -0.174 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0.022 & -0.022 & 0 & 0 \\ 0.174 & -0.174 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

I_n
0
0
0.013
0
0.013
0.072
0.056
0
0.072
0.123
0.031
0.013
0.084
0.056
0
0.013
0.015
0
0
0
0.013
0
0.013
0.072
0.056
0
0.072
0.123
0.031
0.013
0.084
0.056
0
0.013
0.015
0

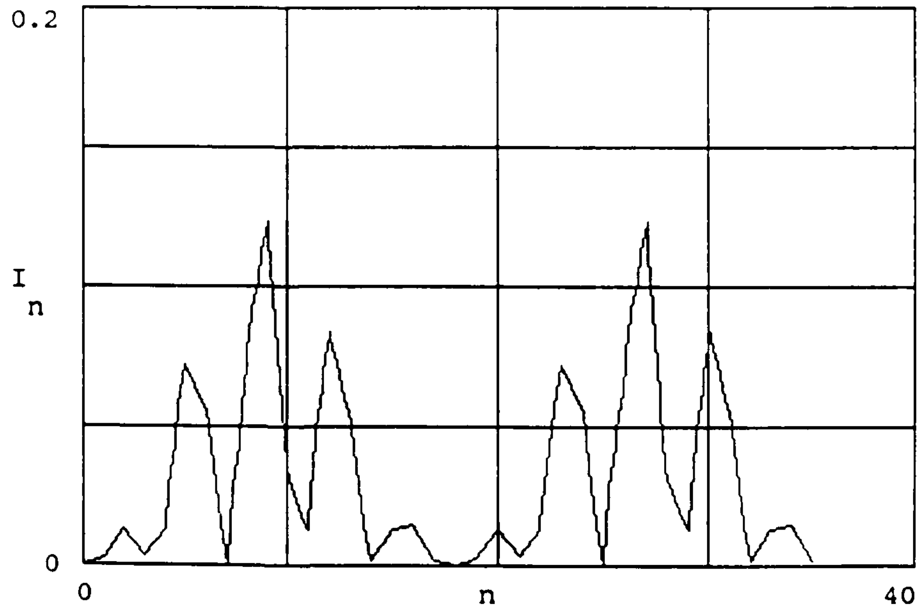


Figure 16

Angle of last polarizer from horizontal.

$$h \equiv 0 \cdot deg$$

Retardances

$$\delta 1 \equiv 90 \cdot deg$$
$$\delta 2 \equiv 90 \cdot deg$$

Angle of first wave plate from expected value.

$$\alpha \equiv 0 \cdot deg$$

Angle of second wave plate from expected value.

$$\beta \equiv 0 \cdot deg$$

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 0.5 & 0 & 0 & 0 \\ 0 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & -0.5 \\ 0 & 0 & 0.5 & 0 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

I_n
0.25
0.148
0.096
0.195
0.185
0.158
0.227
0.166
0.053
0.125
0.202
0.112
0.039
0.104
0.195
0.195
0.161
0.202
0.25
0.202
0.161
0.195
0.195
0.104
0.039
0.112
0.202
0.125
0.053
0.166
0.227
0.158
0.185
0.195
0.096
0.148

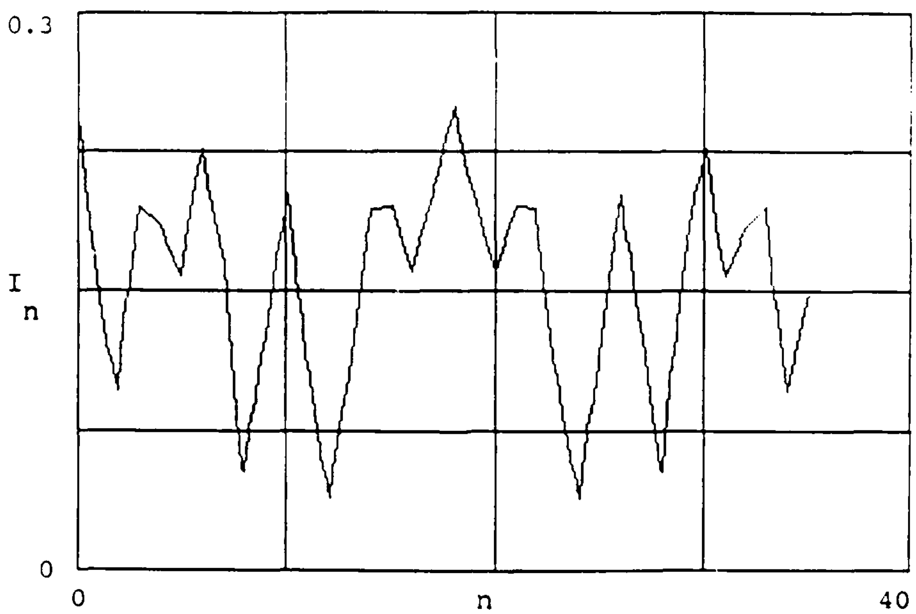


Figure 17

Angle of last polarizer from horizontal.

$$h \equiv 0 \cdot deg$$

Angle of first wave plate from expected value.

$$\alpha \equiv 0 \cdot deg$$

Angle of second wave plate from expected value.

$$\beta \equiv 1 \cdot deg$$

Retardances

$$\delta 1 \equiv 91 \cdot deg$$
$$\delta 2 \equiv 90 \cdot deg$$

I_n
0.246
0.126
0.112
0.21
0.175
0.17
0.233
0.14
0.048
0.147
0.193
0.086
0.042
0.126
0.199
0.183
0.163
0.22
0.246
0.182
0.16
0.206
0.184
0.082
0.042
0.14
0.205
0.103
0.063
0.19
0.214
0.148
0.193
0.176
0.083
0.171

Calculated Mueller Matrix

$$MM = \begin{bmatrix} 0.5 & 0 & 0 & 0.087 \\ 0 & 0.478 & 0 & -0.174 \\ 0 & -0.174 & 0 & -0.478 \\ 0 & 0 & 0.492 & 0 \end{bmatrix}$$

Error Matrix

$$MM - m = \begin{bmatrix} 0 & 0 & 0 & 0.087 \\ 0 & -0.022 & 0 & -0.174 \\ 0 & -0.174 & 0 & 0.022 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

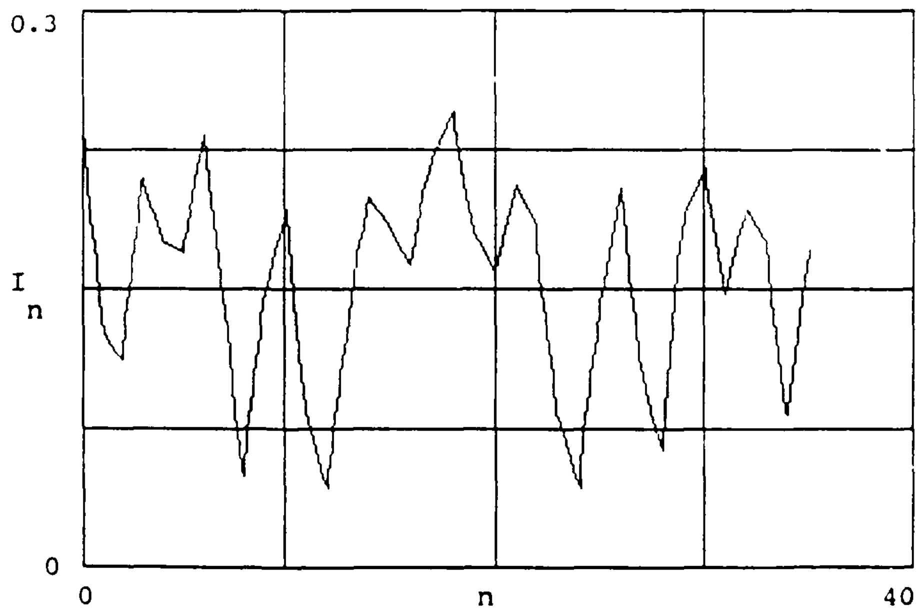


Figure 18

experiments to more accurately fine tune the alignment. The programs that I worked on are able to be used in many aspects of this kind of work.

This work is very valuable, because the experiments that are being carried out are important as the need for more information about infrared electrooptical materials used in seekers and other tactical devices increases. Infrared tactical guidance systems will benefit from this kind of research.

IV MISCELLANEOUS

In both setups the rotary stage controller is present. I learned how to use the handheld controller(855K portable) as well as the Hewlett Packard to rotate the polarizers and retarders.

A large portion of my work was to learn how to operate things so that they could be used . The new multimeters were some of my opportunities. The multimeters had to be set so that we could use them in the data acquisition. I familiarized myself with the commands and put them into the stability programs as well as the analysis programs. The multimeters needed to be programed very precisely. For example, lines of a program such as this do many things.

```
10 OUTPUT 723;"FUNC ACV,.03"     ! AC mode selected;range set(.03)
20 OUTPUT 723;"ARANGE ON"        ! turns on auto range
30 OUTPUT 723;"AZERO ON"         ! turns on auto zero
40 OUTPUT 723;"NDIG 5"           ! sets # of digits shown
50 OUTPUT 723;"TRIG EXT"         ! turns the trigger to an
                                        external source
```

```
60 OUTPUT 723;"DISP ON"          ! turns display on
```

This would be repeated with the number 719 instead of 723 for the other multimeter.

The technical Library as well as the private libraries of Mr. Lynn Deibler, Mr. Dennis Goldstein, and Mr. Randall Hodgson were a great help to me in my research . Most of the articles and books dealt with polarization, spectropolarimetry, lasers, infrared experiments, and other very helpful information that related to my work in the lab.

V BIBLIOGRAPHY

Azzam, R.M.A.,"Photopolarimetric measurements of the Mueller matrix by Fourier analysis of a single detector signal",Optics Letters,2,6 (1978).

Brown, Ronald, Lasers,Tools for Modern Technology. Doubleday and Company, Inc. Garden City, New York (1968).

Goldstein, D.H., Russell A. Chipman, and David Chenault. "Spectropolarimetry of Electo-Optical Materials." Proceedings of SPIE. Vol. 891, Jan.(1988).

Hecht, Eugene. Schaum's Outline Series Theory and Problems of Optics,McGraw-Hill Book Company, New York, (1975).

Hecht, Eugene and Alfred Kajack. Optics, Addison-Wesley Publishing Company, Reading, Massachusetts, (1975).

O'Shea, Donald C. Elements of Modern Optical Design. John Wiley and Sons New York, (1985).

ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

An Alternate Analysis of the Peripheral Vision Horizon Device Flight Data

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& Universal Energy Systems

August 1989

INTRODUCTION

The Peripheral Vision Horizon Device (PVHD) is an instrument to aid pilots in determining aircraft attitude through the use of peripheral vision. Peripheral, or ambient, vision is concerned with the orientation and relative motion of a person in the environment. Central, or focal, vision is used for tasks requiring acuity or resolution. The device's use of ambient vision is meant to free the pilot's foveal vision for tasks that require attention to be diverted from the instrument panel. The interest in these types of devices is the hope of the prevention of aircraft accidents involving spatial disorientation (SDO). The increased awareness of aircraft attitude given by the device should reduce the chance of SDO occurring.

The PVHD consists of a processor unit, that receives attitude information from the aircraft's attitude reference system, a projector, that uses a laser to project a line onto the instrument panel, and a control panel for adjustments. After an initial period of familiarization, the artificial horizon line should be perceived by the pilot's peripheral vision leading to increased awareness of attitude no matter where the pilot's central vision is directed. Situational awareness should also be improved and workload in the cockpit should be reduced.

Tests of the PVHD have given mixed results. In Knotts and Gawron 1984, a test of the PVHD was done in a USAF NT-33A research aircraft operated by Arvin Calspan under contract of the Air Force Flight Dynamics Laboratory. Data on aircraft airspeed, angle of bank and altitude were taken along with the pilot's reaction time to the distraction task. The analysis was done with descriptive statistics because of the small sample size. The test proved inconclusive because of mixed results. (Knotts & Gawron, 1983) Since the PVHD was never designed to have a direct effect on altitude and airspeed, this test may have been measuring the wrong data.

A simulator test with more hopeful results was conducted by Money, Cheung, Landolt, and Pellow in 1984 at Canadian Forces Base Greenwood, Nova Scotia. An Aurora CP140 Flight Deck Simulator was used. A total of 210 simulator tests was performed with 35 pilots. Tasks were conducted that required the maintenance of a steady altitude and heading during the implementation of distraction tasks such as engine failure or induction of the leans. The data was analyzed by the means of the errors in altitude, heading, airspeed, and the other measured values. The procedures did not disorient the pilots sufficiently to degrade simulated aircraft control even when the PVHD was off, therefore no conclusion could be made to show that the PVHD prevents SDO. The study did show that under certain conditions that the PVHD can cause improvement in instrument flying.(Kellog, McNaughton, Horton 1984)

Most tests of the PVHD's effectiveness in reducing SDO (Gillingham, 1984; Hammond 1984; McNaughton, 1984), reducing pilot workload (GIllingham 1984; Hammond 1984; Larys, Portillo, Baughman and Fleming 1987; Nims 1984;McNaughton 1984; and Knotts and Gawron, 1984), and improving situational awareness and flight performance (Gillingham 1984; Larys, et al., 1987; and Hammond 1984) have all shown little evidence that the device has an effect on these parameters. These investigations are regarded as inconclusive because of small sample size, inadequate familiarization, too few evaluation flights, and improper statistical treatment. These tests have never addressed the criticisms of the NASA conference at Ames Research Center in 1984 that the PVHD must be tested directly on its main purpose- to reduce the likelihood of disorientation. The previous tests also have never given the pilots enough familiarization time with the PVHD so that they can learn to use it correctly.

Aeronautical Systems Division (ASD/YPD) contracted General Dynamics to test the PVHD in a F-16B. The PVHD was evaluated on its ability to reduce spatial disorientation, to improve situational awareness, to reduce pilot workload, and to improve pilot performance during precision tasks.

APPARATUS

The Garret PVHD provided the pilot with a roll indication about the aircraft centerline and a pitch change indication was provided with a pilot-adjustable pitch neutral point and gain.(See Figure 1) Turn-rate indication was available during the familiarization period, but not during actual testing. The placement of the device caused the pilot to have to alter his position in the cockpit and hampered the accessibility of certain switches on the right side of the cockpit.

METHOD

Prior to the flight tests the pilots received familiarization training. They had 3.5 hours of PVHD orientation in the Navy Aerospace Medical Research Laboratory vertifuge. In the aircraft itself, the pilots had one 2-hour and three 1.5-hour familiarization sorties which were flown over a water range. Each sortie involved a specific set of flight maneuvers with the PVHD mode changing once per mission to establish subconscious perception of the horizon line.

During the test, three pilots each flew five sorties each. All of the sorties were flown in dusk/night conditions over water to minimalize visual reference points of attitude. A safety pilot was in the second seat of the aircraft to initiate the pitch and roll changes and to record the test data. The flight maneuvers that were chosen were level turns, lazy 8 type maneuvers, contact position on tankers and wing position on tankers. The maneuvers were selected on the basis of contribution to pilot disorientation or high skill and precision demands.

The independent variable in the test was whether the PVHD was on or off. The dependent variable was the pilot estimation of the attitude of the aircraft. The attitude deviation measurement was chosen to be more

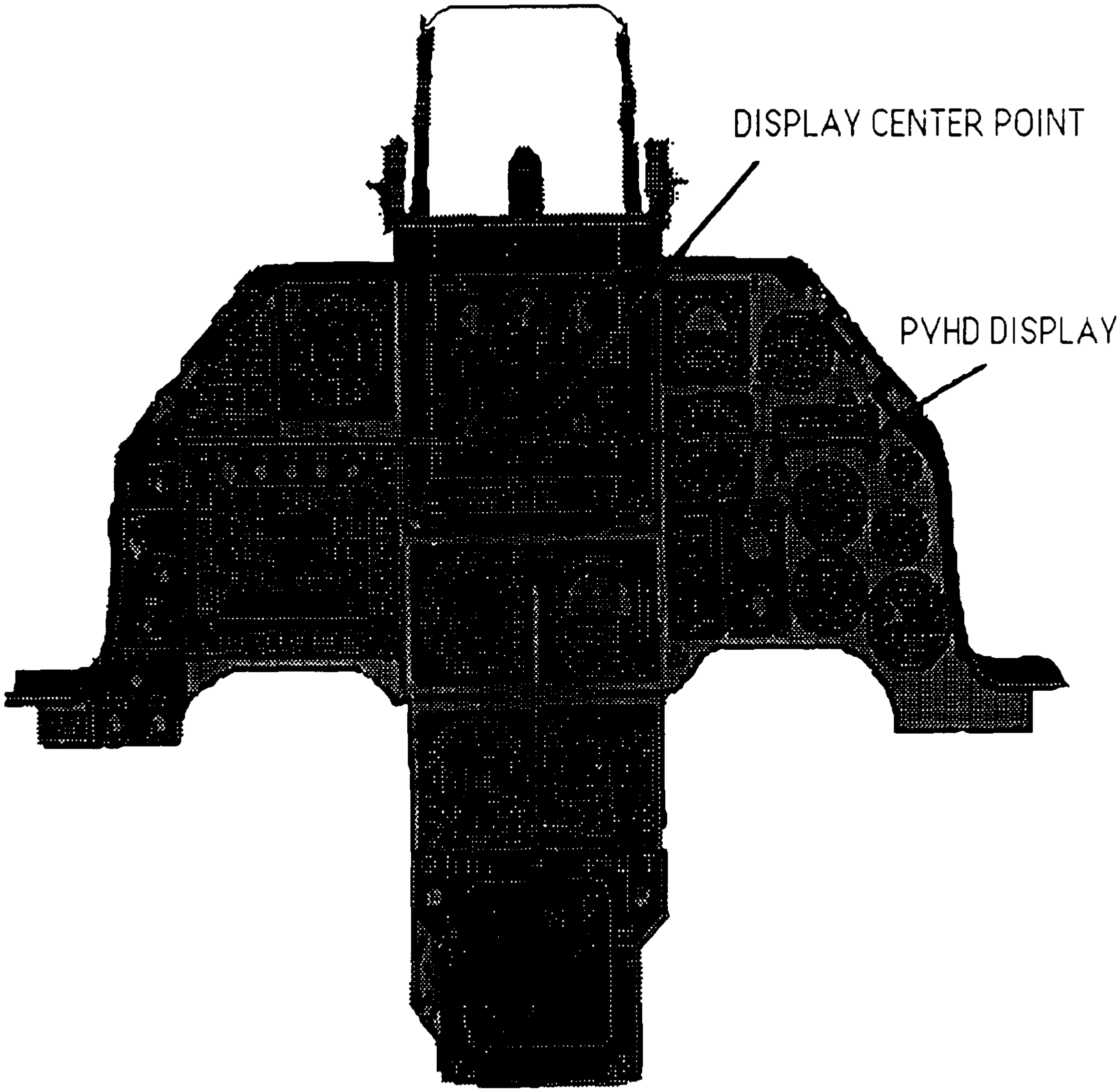

Figure 1 PVHD DISPLAY IN THE F-16 A/B COCKPIT

appropriate to the test than measurement of airspeed or altitude because a pilot's perception of attitude deviation is more directly affected by the PVHD than previously tested variables.

The safety pilot recorded the pilot's estimates of aircraft attitude. The pilot magnitude estimate differences were computed by taking the absolute value of the difference between the pilots' perceived attitude values and the actual attitude values. A 3x2 (Pilot x PVHD) repeated measure analysis of variance was applied to the pilot magnitude estimate difference scores during formation level turns, formation lazy-8, tanker contact position, and tanker wing position maneuvers.

The analysis of these data showed that the PVHD offered no advantage in detecting slow aircraft attitude changes. The analysis failed to show a measurable benefit in preventing or reducing spatial disorientation, increasing situational awareness, reducing workload, or improving pilot performance.(Magnant, Swope 1988)

The purpose of this report is to reanalyze part of the PVHD flight data using an alternative, unconventional analysis to detect subtle influences of the PVHD on pilot performance. The new analysis used at the pilot magnitude estimate differences to derive regression lines for the pilots separately and combined with the PVHD on and off. The regression lines were subjected to a t-test to determine if the difference in slope and intercept of the lines was significant. An F-test was also done to determine if the combined difference in slope and intercept was significant. If Malcom's concept is correct, the PVHD-on line should have a more negative slope compared to the PVHD-off line.

RESULTS

An absolute error value was calculated by finding the difference between the aircraft attitude perceived by the pilot and the actual aircraft attitude. The focus of the analysis was on the attitude error itself rather than trends in positive and negative deviations, therefore the absolute value of the error was taken.

Regression analysis was done on the absolute error in perceived attitude by flight number for all pilots. Regression analyses were also done for the pilots individually to determine any singular effects. Two-tailed hypothesis tests were done on all the regression lines with a significance criterion of $p < 0.05$.

ALL PILOTS

A regression line for the absolute value of delta by PVHD ON/OFF by the flight number for all pilots was done.

A t-test was done for the slopes of the two regression lines, $t(282) = 2.2596$, $p < 0.05$. Another t-test was done for the intercepts of the lines, $t(282) = -1.3638$, not significant (ns). The F-test for combined effect of slope and intercept was $F(282) = 0.2125$, (ns).

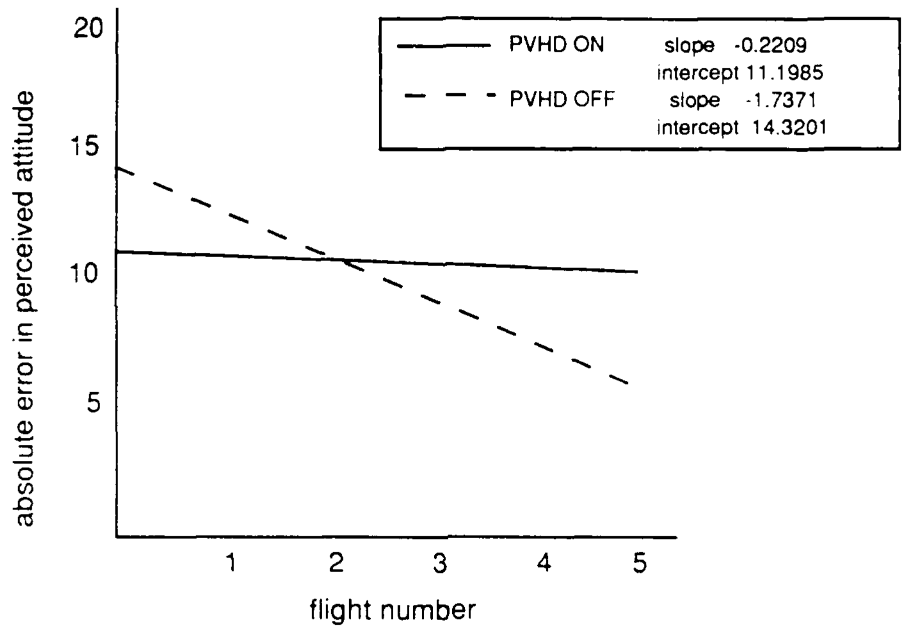

Fig. 2 Regression line of perceived attitude errror on flight for all pilots

PILOTS INDIVIDUALLY

Because the use of data inflates the analysis type I error rate, the significance level for subsequent tests will be 0.01, thus controlling analysis error rate to 0.05.

A regression analysis of absolute error with the PVHD ON/OFF for pilot 1 was done and graphed. A t-test was done on the slopes of the regression lines for pilot 1, t (84)= -0.7253, (ns). Another t-test was calculated for the intercepts of the regression lines, t (84)= 1.3344, (ns). An F-test for combined effect was also done, F (84)= 0.1567, (ns).

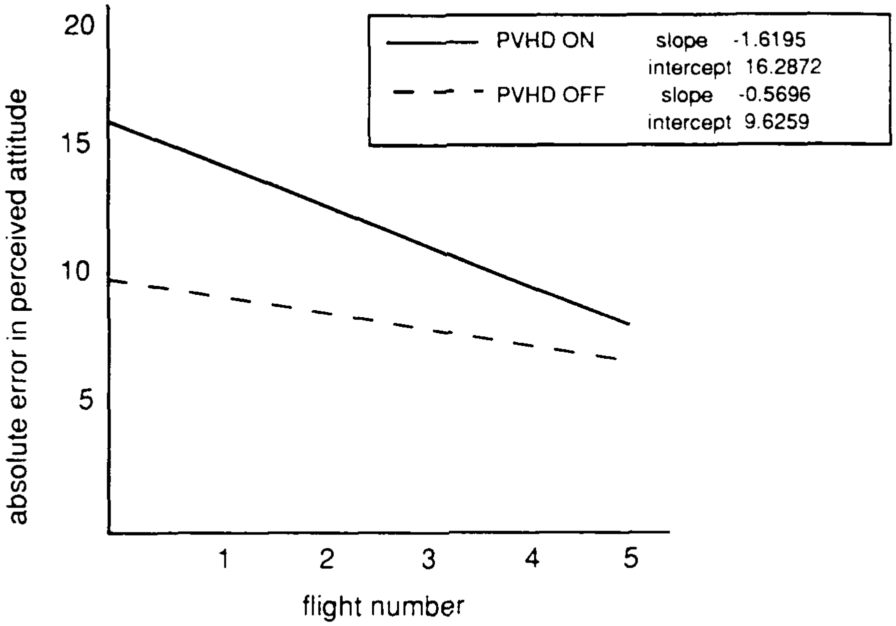

Fig. 3 Regression line of perceived attitude errror on flight for pilot 1

Regression lines for pilot 2 for absolute error by flight by PVHD were done. The t-test for pilot 2 for slope had values of t (97)= 1.8822, (ns). The t-test for the intercepts gave a result of t (97)= -1.0984, (ns). The F-test for pilot 2 gave a value of F (97)= 0.2600, (ns).

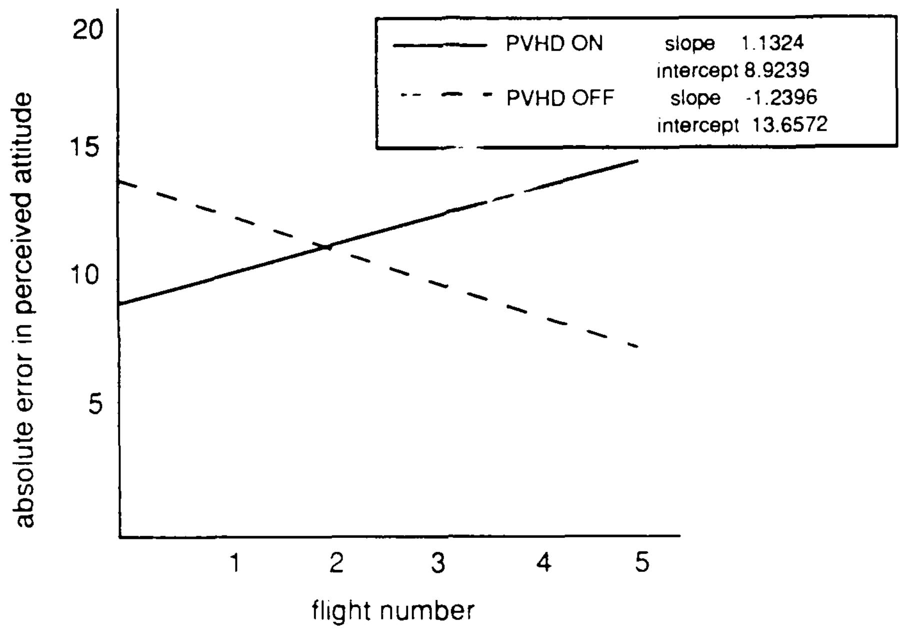

Fig. 4 Regression line of perceived attitude errror on flight for pilot 2

Regression lines for absolute error were also made for pilot 3. A t-test was also done for the regression lines for slope, t (99)= 3.9264, $p < 0.05$. Another t-test of the regression lines for intercept was calculated, t (99)= -3.9700, $p < 0.05$. An F-test was also computed for the combined effect, F (99)= 0.3224, (ns).

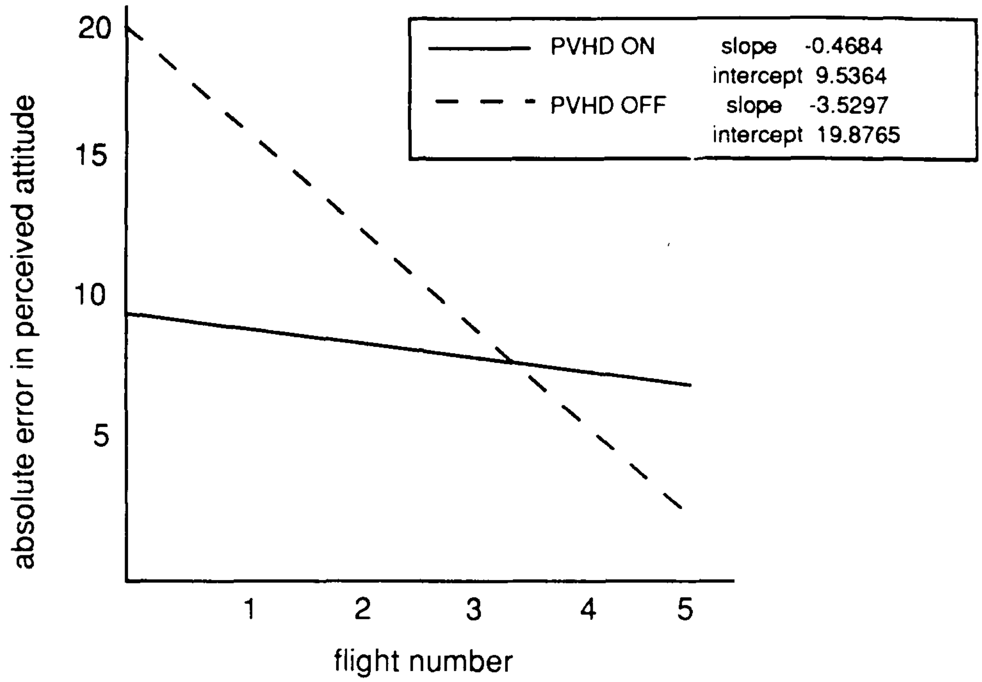

Fig. 5 Regression line of perceived attitude errror on flight for pilot 3

DISCUSSION

The slopes of the regression of attitude error on flight were significantly differrent. The PVHD-OFF regression line had a more negative slope than the PVHD-ON line. Over all, pilots tended to estimate aircraft attitude with more accuracy when the PVHD was off than when it was on which was contrary to the expectations. An expected increase in attitude awareness with PVHD familiarization was not apparent. The regression lines show that the PVHD may in fact have hampered the pilots' ability to estimate aircraft attitude.

Pilot 1 tended to show improvement with the PVHD on and off. The absolute error regression line for PVHD-ON had a greater negative slope than the PVHD-OFF line. The regression line for PVHD-OFF initially had a lower intercept than the line for PVHD-ON. An apparent learning trend was evident in both regression lines. The t-tests for slope and intercept of the regression lines were not significant. The F-test for combined effect was not significant as well.

Pilot 2 showed improvement with the PVHD off. With the PVHD on, pilot attitude estimation worsened as the test progressed. The pilot intially did better with the PVHD on, but as the test continued the mean absolute error grew larger. The PVHD seemed to be a hinderance to the pilot in this test. The t-tests for slope and intercept were not significant. The F-test for combined effect was also not significant.

Pilot 3 showed very high differences in intercept between the regression lines for PVHD ON and OFF. The regression line for PVHD-ON was initially lower than the PVHD-OFFline. The slope of the PVHD-OFF line was more negative than the slope of the PHVD-ON line showing greater improvement over time. The t-test for slope was significant and the t-test for intercept was also significant. The F-test for combined effect was not significant. Pilot 3 was the only pilot to show significant results of the t-tests. This pilot was probably causing the trend toward improvement in the over all results.

CONCLUSION

This analysis and the General Dynamics analysis of the PVHD flight data both show that the PVHD in its current configuration is not helpful in increasing pilot awareness of aircraft attitude in the F-16B. While the PVHD was not useful in this particular aircraft, the device could possibly be put to better use in a cockpit with more area for installation of the device.

The alternate analysis employed in this report is a more rigorous test than has been used in the past studies. This t-test adressed the need for a more compete analysis of the PVHD called for in previous studies. The test can see subtle differences in data in small population size and could potentially be used in other flight tests where flight time is limited.

ACKNOWLEDGEMENTS

I would like to thank Lt. Col. Marshak for accepting me as his apprentice. His guidance proved helpful during the whole summer. I would also like to thank Universal Energy Systems for giving me the opportunity to be an apprentice.

REFERENCES

Kellog, Robert S., McNaughton, Grant B., Horton, Victor W. Peripheral Vison Horizon Device. NASA Conference Publication 2306. Edwards Calif. Scientific and Technical Information Branch, March 1984

Knotts, Louis & Gawron, Valerie. A Preliminary Flight Evaluation of the Peripheral Vision Display Using the NT-33A Aircraft. Calspan Report No. 6645-F-13. NY, NY. Applied Technology Group of Arvin Industries INC. Dec. 1983

Magnant. J. A. Swope J. G. Final Test Report for F-16A/B Installation and Flight Test of a Peripheral Vision Horizon Device. Report 16PR7846. General Dynamics Fort Worth Division, July 1988

Mood, Alexander & Graybill, Franklin. Introduction to the Theory of Statistics. McGraw Hill Book Co. NY, NY. 1963 pp. 329-335

Ross, Diane M. Peripheral Vision Horizon Device (PVHD) Development Test and Evaluation. Technical Report AD-TR-88-48. Eglin Airforce Base, Fl. July 1988

FINAL REPORT

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Workload and Cognitive Assessment Laboratories
Mentor: Dr. Glenn F. Wilson

June 19, 1989 - August 18, 1989

ACKNOWLEDGMENTS

I would like to extend my deepest thanks to Dr. Wilson and everyone else in the lab. These past two summers have been very enjoyable. Working in a scientific research environment has been a wonderful experience for me. I know that much of the information that I have been exposed to will greatly help me at college next year and after. Very seldom do high school students get the opportunity to participate in actual scientific experiments, and I feel that I have gained a greater understanding of the principles of research. I would especially like to thank Iris Davis, a contractor with Systems Research Laboratories, for her guidance and patience throughout the summer. Thank you for allowing me to take an active role in the various projects of the lab.

I. INTRODUCTION

This summer I worked under the guidance of Dr. Glenn F. Wilson in the Workload and Ergonomics Branch at the Armstrong Aerospace Medical Research Laboratory (AAMRL). For the second year in a row, I helped Dr. Wilson and the other members of the laboratory with various projects throughout the summer. As a second year student in the High School Apprenticeship Program, I have been fortunate enough to have been exposed to a wide variety of the experiments conducted in this laboratory.

II. THE F-4 STUDY

For the first few weeks of my summer apprenticeship, I analyzed a large amount of data from a study the lab did last summer on workload and stress in pilots and weapons systems officers of F-4 aircraft. The data I worked with concerned heart rate and eyeblink rate during different intervals of the flight, such as take-off, bombing, landing, etc. I converted the eye blink data of all the subjects into blinks per minute, so comparisons between subjects could be made more easily. I also entered data into a spreadsheet using the Lotus 1-2-3 software, and then I carefully checked page after page of data printouts to make sure all the data had been entered correctly.

III. THE AGARD STRES BATTERY

"There is a growing interest in the effects of environmental stressors on human performance. Particular attention has been given to military and industrial tasks in which stress-induced error may have serious consequences. Unfortunately, differences in testing procedures have hindered the integration of findings for a particular task or a particular stressor" (AGARD-308).

The Advisory Group for Aerospace Research and Development (AGARD) was assembled in June of 1989 to try to come up with a universally accepted performance test battery to measure the effects of environmental stressors. Before this time, many different performance tests were being used, making it virtually impossible for researchers in different laboratories to accurately compare data findings. In addition, even those few particular tests that were widely used had paradigms that could be manipulated by the researcher, making standardization extremely difficult. Consequently, when AGARD recently met, the members developed the Standardized Tests for Research with Environmental Stressors (STRES) Battery.

The AGARD STRES Battery consists of seven different tests, each one chosen because it met the following criteria: (a) preliminary evidence of reliability, validity, and sensitivity; (b) documented history of application to assessment of a range of stressor effects; (c) short duration -- maximum of three minutes per trial block; (d) language-independence; and (e) ability to be implemented on simple and easily-available computer systems.

The seven tests that were chosen by AGARD are: (1) reaction time; (2) mathematical processing; (3) memory search; (4) spatial processing; (5) unstable tracking; (6) grammatical reasoning; and (7) dual-task -- unstable tracking with concurrent memory search.

Reaction Time Task "Digits are presented on a computer monitor, one at a time. The subject reacts to each digit by pressing the appropriate key on the response panel" (AGARD-308). The response is based on (a) the position of the digit, either left or right; and (b) the identity of the digit, either 2, 3, 4, or 5. The task varies by degrading stimulus quality, irregularly presenting the stimuli, increasing complexity of the response, and reversing the original instructions.

Mathematical Processing. "This test requires subjects to perform two arithmetical operations, addition and/or subtraction, on a set of three single-digit numbers, and to determine whether the answer is greater than or less than five" (AGARD-308).

Memory Search. "A set of letters (the 'memory set') is presented on a video monitor, followed by a single letter (the 'probe letter'). The subject has to indicate, by pressing the appropriate key, whether the probe letter is a member of the memory set" (AGARD-308). This task is done using a memory set of two letters, followed by a memory set of four letters.

Spatial Processing. "On each trial, a pair of four-bar histograms is presented sequentially on the monitor screen. The subject must determine whether the second, 'test', histogram is identical to the first, 'standard', histogram, regardless of an orientational difference of 90 degrees or 270 degrees, and respond 'same' or 'different' by pressing the appropriate response key" (AGARD-308).

Unstable Tracking. "A fixed target is presented in the center of the monitor screen. The subject manipulates a joystick in an attempt to maintain the position of a horizontally-moving cursor on the target. The system is inherently unstable: operator input introduces error that is magnified such that it becomes increasingly necessary to respond to the velocity as well as the position of the cursor" (AGARD-308).

Grammatical Reasoning. "A pair of sentences is presented accompanied by three symbols in a particular order. Each sentence either correctly or incorrectly describes the order of an adjacent pair of symbols within the set of three, and the subject is required to compare the truth of the sentences. If both sentences are true, or if both are false, press the key marked 'same'; if one sentence is true but the other is false, press the key marked 'different'" (AGARD-308).

Tracking with Concurrent Memory Search. "During concurrent presentation of these tasks, each proceeds as previously described. Subjects are instructed to allocate equal priority to the two tasks" (AGARD-308).

During most of my summer term the lab, I have been assisting with the running of the lab's first experiment using the AGARD STRES Battery.

First, I ran through all the tasks myself, to get an understanding of the test battery. I proofread all of the instructions on the screen, and I checked for technical errors in the programs. After reporting my findings, many changes had to be made in the original program. Once we were certain that the tasks were running as specified, we set up a schedule to train our first subjects. We decided to conduct this particular experiment using ten female subjects and ten male subjects. The training took approximately eight hours per subject, spread out over two days. The subjects did each task numerous times, in order that their response time and accuracy level would become fairly individually stabilized. After training the subjects, we collected data from them as they did each task while listening to a background of white noise. We ran through each test twice, once during a level of 65 dB white noise, and once during a level of 85 dB white noise.

The experiment has gone very well, with no major problems so far. As I finish my summer internship, the data collection phase of the experiment will end as well. We have already begun to enter the large amount of data we have collected into a statistical analysis program. We have no actual results of the experiment yet, but I have done some research on the possible results. In simple repetitive tasks, noise may actually improve performance initially, but as the exposure time increases, this advantage gradually reverses. Also, performance is likely to decrease when the noise level is reduced. In tasks which involve continuous operation or in tasks that are performed simultaneously, noise may act as a stressor, decreasing the level of performance. Noise may also increase attentional selectivity, but decrease accuracy. Several of the subjects we tested commented that the 85 dB level of white noise was preferable to the 65 dB level, as the higher noise level tended to block out any other distractions that may have been present.

IV. CONCLUSION

I learned a great deal about the procedures of scientific research while conducting the experiment with the AGARD STRES Battery. Explaining the instructions to the subjects and supervising their completion of the tasks was my main job for much of the experiment. This role was necessary in order to ensure that the subjects were following task instructions correctly, so that the data would be usable. All parameters surrounding the experiment must be kept consistent, so as not to distort the results. I enjoyed being an active participant in the testing procedure.

REFERENCE

Advisory Group for Aerospace Research and Development. North Atlantic Treaty Organization. AGARDograph No. 308. AMP Working Group 12 and AGARD Lecture Series 163. "Human Performance Assessment Methods." May 1989.

COCKPIT ACCOMMADATION

BY KEISHA HAYES

HARRY G. ARMSTRONG AREOSPACE RESEARCH
LABORARTORY, WORKLOAD AND ERGONOMICS
BRANCH (AAMRL/HEG)

GREG ZEHNER, MENTOR

PREFACE

My name is Keisha Hayes; I represent Harry G. Armstrong Aerospace Medical Research Laboratory ,Workload and Ergonomics Branch (AAMRL/HEG). I would like to give great appreciation to my Branch Chief Maris Vikmanis, mentors Greg Zehner and Kathleen Robinette.

This paper is presented as a summation of my eight week apprenticeship. During my eight week assignment to the Ergonomics Branch, I studied Cockpit Accommodation. This consisted of measuring the dimensions of cockpits and creating manikins in different sizes to fit in the cockpits.

INTRODUCTORY

All pilots within the anthropometric design range should be able to avoid thrusting their knees forward of the ejection Clearance Line by assuming the correct ejection posture, even though they have adjusted the seat to a considerable different position than recommended, considering their body size.

Vertical seat motion is for the purpose of adjusting the pilot. It is felt that optimum vision both into and out of the cockpit can best be achieved by adjusting to the Down Vision Line.

The 1st to 99th percentile ranges from body sizes to be accommodated are listed below. This is a typical example of the manner in which anthropometric percentile range accommodation is best apply to design. The 1st to 99th percentile accommodation range is applied only to the key dimension (s).

Eye Height, Sitting
Thumb-Tip Reach
Buttock-Knee Length
Buttock-Popliteal Length
Knee Height, Sitting
Popliteal Height, Sitting
Bidetold Breadth
Hip Breadth, Sitting

This study was undertaken to serve three objectives:

To derive new aircraft cockpit geometries in which the techniques as vertical aircraft ejection seat adjustment move the small pilot toward his/her controls and the large pilots away from them, thus avoiding the incompatibilities associated with adjusting the small pilot up and aft, away from hand controls, and the large pilot down and forward, toward hand controls.

To demonstrate the relative ease with which the engineer can accommodate to the 1st to 99th percentile range from male body sizes within the USAF, including reach capability.

To demonstrate appropriate techniques in using the AAMRL Two-Dimensional Drawing Board Manikins an the derivation of basic geometries of two diverse ejection seats and of the selected aspects of cockpits.

All layouts were developed using the AAMRL Two-Dimensional Drawing Board Manikins. Since these designs aids are currently available only in 5th, 50th and 95th percentile sizes, minor adjustments had to be made on the drawing board to represents the 1st to 99th percentile accommodation requirements. In the next that follows, references will frequently be made to 1st and 99th percentile torsos as though actual manikins of these sizes were used. This is a convenience to avoid the otherwise cumbersome necessity to refer frequently to the adjustments made to derive 1st and 99th percentile values.

THE LOW PROFILE COCKPIT GEOMETRY

The impetus for developing the Low Profile Geometry can be traced to conversations with members of the original cadre established at Wright-Patterson Air Force Base, Ohio, to initiate studies leading to what is know as the Advanced Tactical Fighter (ATF).

It was specified by the ATF cadre that the frontal area of the fuselage of a low profile aircraft be significantly less than that typical of aircraft currently in the inventory. Expressed in terms important to the geometry of the ejection seat, the frontal area through the cockpit at Seat Reference Point (SRP).

As body attitude proceeds more and more toward supination, the head is more likely to require frequent if not continuous support. If we also expect the pilot to be able to see comfortably forward both into and out of the cockpit, the head must be supported in an upright attitude, essentially as it assumes in the unsupported situation. The more supine the back angle becomes, the more the head must be rotated forward in order to maintain a natural head orientation.

With the 99th percentile torso still on the drawing board, the minimum uppermost limit for the top of the head rest was marked. These steps in developing the Low Profile Cockpit geometry are illustrated in Figure 1.

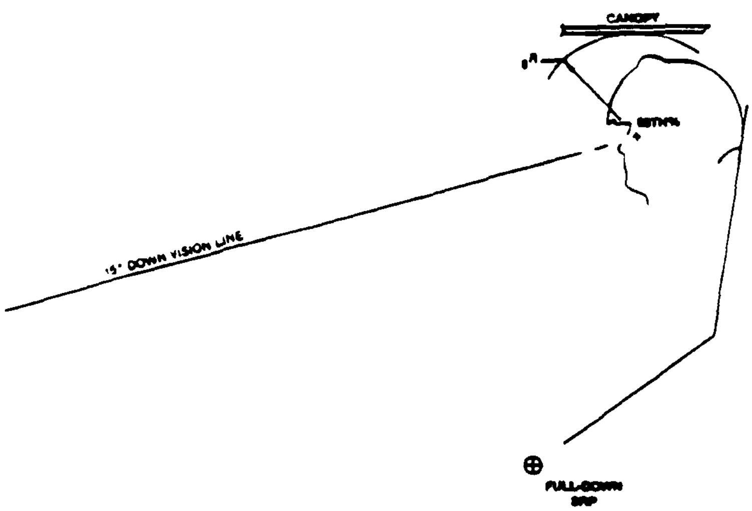


FIGURE 1. The Low Profile Cockpit Geometry - Initial Determinations. A 55 degree lower back angle and 10 degree upper backhead rest and Over-the-Nose Vision Line have been established. Since the 99th percentile eye position will be the highest along the Over-the-Nose Vision Line, the clearance radius to the underside of the canopy can also be indicated.

By taking advantage of the fact the smaller pilot will move the seat upward and the larger pilot downward to reach the Down Vision Line, we need only to accommodate to the minimum practical reach capability compatible with the 99th percentile torso in in the full-down seat adjustment, and to the minimum reach compatible with the 1st percentile torso in the full-up seat adjustment.

Since it was not yet possible to determine the compressed surface of the seat cushion, it was also not possible to indicate the placement of the rudder pedals. For the time being, then, the 99th percentile torso and its limbs were set aside and attention was turned to the uppermost seat adjustment.

The completed Low Profile geometry appears in Figure 2. The upright headrest would be the posture of choice for normal flying. Included is a head rest position which is in the same plane as the lower back and which could be used with the expectation of very high +Gz loadings. A third head rest position, set at 30 degrees from vertical, could be included and would be used on ejection. It would assume an ejection angle set at 30 degrees or less aft. An Ejection Clearance Line was drawn which allows for 2 inches clearance forward of the 99th percentile Buttock-Knee Length.

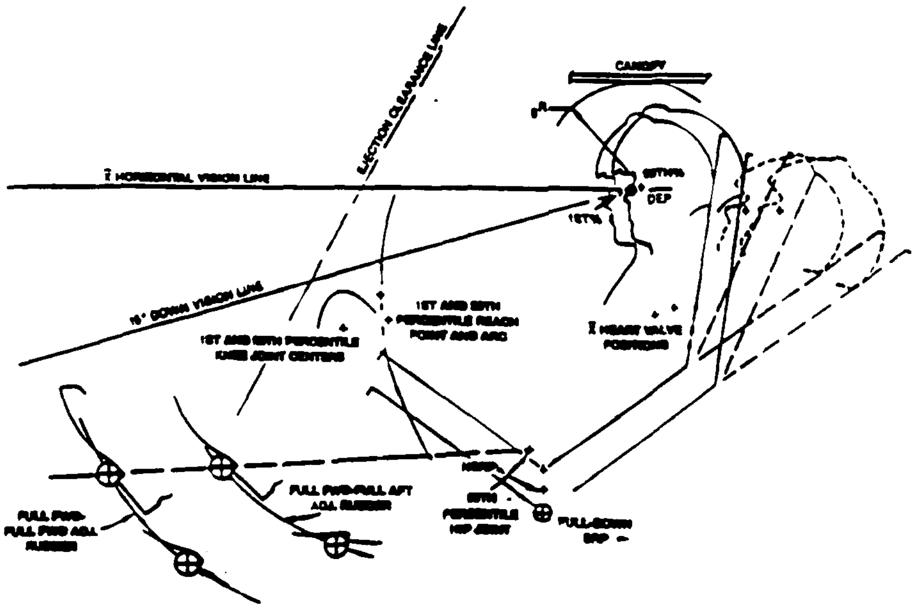


FIGURE 2. The Low Profile Cockpit Geometry - Final Determination.The lowermost seat position is indicated, as is the fulldown Seat Reference Point (SRP) and the traditional Neutral Seat Reference Point (NSRP).

THE VARIABLE COCKPIT GEOMETRY

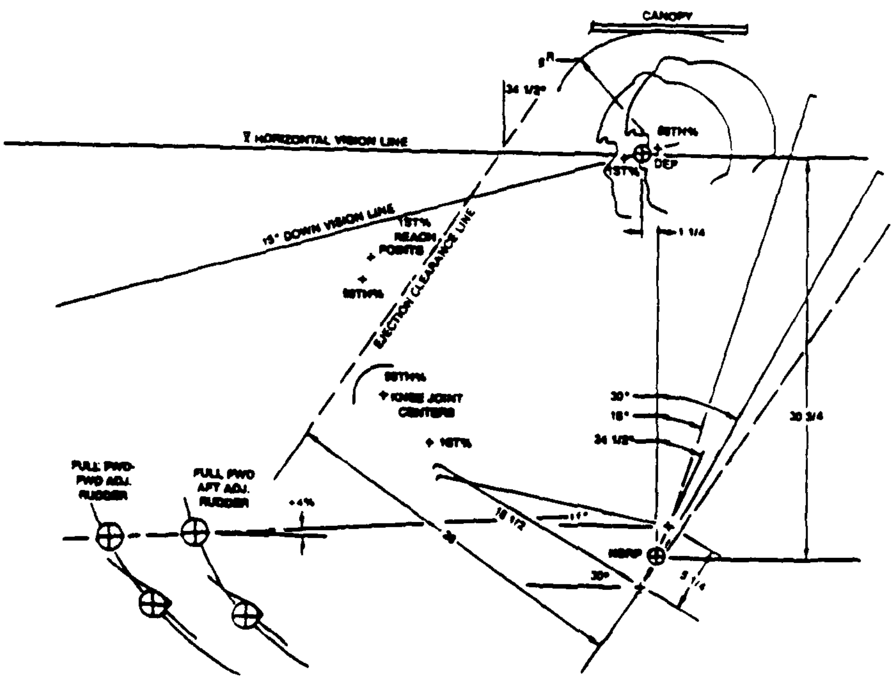
Unfortunately, ejection seat design technology has been such that we have been required to accept what is, in the Human Factors sense, an unacceptable characteristic of ejection seats. At first glance, it might appear that all we need do to solve this incongruity is to adjust pilots along a ramp, the small pilot up and forward and the large pilot down and aft. However, since pilots are known to adjust the seat to positions they choose, and not necessarily to positions the designer choose for them, they can be counted on frequently to adjust themselves higher in the cockpit than recommended by the designer.

On of the purposes of this study is to equate 1st and 99th percentile reach capability. In doing so, it is obvious that the upper torso and shoulders of the smaller pilot will have to be forward of those of the large pilot.

Once the full-down seat geometry was laid out, it was necessary to establish the geometry for the full-up seat. This is most conveniently done using the 1st percentile torso equipped initially with the 1st percentile arm and leg.

To accommodate to the latter requirement without seriously jeopardizing reach equivalence, the manikin was moved upward along the 15 degree Down Vision Line to a point 3 inches from the 99th percentile eye point. By comprising in this fashion, the 1st percentile reach point receded aft approximately 1 inch from that for 99th percentile and head motion while raising the seat would be reduced.

The completed Variable Cockpit Geometry is illustrated in Figure 3.



REFERENCES

Air Standardization Coordinating Committee, "Aircrew Anthropometric Scale Models for Engineering Design," ASCC Advisory Publication 61/36, 11 September 1984.

Kennedy, K.W., "Workspace Evaluation and design: USAF Drawing Board Manikins and development of Geometry Design Guides, "NATO Symposium on Anthropometry and Biomechanics: Theory and Application, 7-11 July 1980, Queens College, Cambridge, England and in Anthropometry and Biomechanics: Theory and Application, NATO Conference Series 111, Vol.16, Edited by R. Easterby, K.H.E. Kroemer and D.B. Chaffin, Plenum Press, New York and London, 1982.

Kennedy, K.W., "Low Profile and Variable Cockpit Geometries to Achieve 1st to 99th Percentile Accommodation," Symposium of the 26th Meeting of the Air Standardization Coordinating Committee, Farnborough, England, November, 1985 and in Volume IV, "Symposium Proceedings," Report of the 26th Meeting of ASCC Working Party 61.

EXPERIENCING A RESEARCH ENVIRONMENT

Kate Karter

Mentors: Chris Perry
John Buhrman

August 23, 1989

Acknowledgements

I'd like to thank everyone at BBP for their advice and insight and especially John Buhrman for showing confidence in my abilities.

This summer I worked in the biomechanical protection branch (BBP) of the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL). AAMRL conducts biomedical research to define limits of human tolerance and to guage performance level under environmental stress in aerospace operations. AAMRL is subdivided into three research divisions. BBP makes up part of the biodynamics and bioengineering division.

BBP primarily conducts research to insure pilot safety. The branch works to develop designs for restraint devices and emergency escape systems. BBP works in building 824, Area B where the acceleration sled, vertical drop tower, and Swiss mode testing facilities are located. These facilities enable BBP to create impact and ejection simulations.

I worked on three major projects throughout the eight week program. I graphed and analyzed data on a series of tests done last fall, wrote an interactive program enabling the user to create four plots per page, and worked with John to set up the pressurized containment suit study.

To test the biofidelity of the ADAM manikin, BBP conducted a series of tests on the acceleration sled last year. A prototype designed by SRL, the ADAM should imitate human response in an ejection or impact situation. The instrumentation inside the manikin is called the RAM. A comparison between the data collected by this device and the data collected by the ADACS, the instrumentation on the sled, served to guage the biofidelity of the manikin's response. Eight forces were measured in both the

-Gx and +Gy directions on both a large and small prototype. Thus, thirty-two graphs made up an appendix of the technical report. To save space, a computer engineer modified the system's graphics program to allow plotting of four graphs per page. I then calculated the means of the data and graphed the results. In most cases the data agreed but in a few cases involving the smaller ADAM the data differed. An inability to restrain the small ADAM properly contributed to the difference.

After graphing and analyzing the ADAM data I wrote an interactive FORTRAN program allowing the user to graph four plots per page. Because the system's graphics program is designed to only graph one plot per page, graphing four plots proved to be both tedious and time consuming. To make this task easier and more efficient I wrote a program that prompted the user for data and titles. I had the program write the input to an output file that when executed would create the plots. Because the program depended on the user, I allowed for several different conditions and for the program to remain flexible.

I spent the remainder of my time working with John on the pressurized containment suit study. A previous study conducted on the suit a year ago using the sled ended inconclusively be-because several unexpected problems developed. The suit fits a baboon and contains two bladders, one over the chest and the other over the abdomen. The bladders should cause the suit to work somewhat like a scuba suit. Instead of undergoing drastic changes of pressure, pilots should be able to adjust gradually to the force of acceleration while wearing the suit.

The suit and bladders underwent tearing in the previous study and have to be repaired. I removed the bladders from the suit so they could be sent to the manufacturer for repairs. The clothing division on base is repairing and modifying the suit. John might use a baboon manikin to test the suit before live animals are used. The manikin must be designed from scratch so I calculated the ninety-fifth percentile of the measurements used in the previous study since the same baboons will be used. The engineers designing the manikin found these measurements too vague and had to take their own. Observing the measuring of the baboons gave me a better perspective of their anatomy and how they fit into the suit. Once the manikin is built and the suit repairs have been made, the testing will begin.

Working on these projects this summer gave me a broad view of scientific research. Working with statistics and the computer gave me experience I hadn't had before. Learning about what components make up a research project helped me decide what type of career I would like to have in the future. I have been exposed to several different stages in research and have learned that it is a group job and that solutions take time to formulate. This has been a great learning experience and I'm glad I had the chance to work in a medical research lab.

The Effect of CTFE on the Liver

Doug Marshak
Dr. David Mattie
Harry G. Armstrong Medical Lab
August 15, 1989

I. Acknowledgements

My thanks and best wishes to Dr. David Mattie, SSgt Joe Maslanka, and SSgt Matt Chase for giving me the opportunity to work with them this summer.

II. General Description of Research

Almost all of my time this summer was devoted to one project: the effect of CTFE on the liver. CTFE is a hydraulic fluid being developed for use in airplanes. However, the fumes from hydraulic fluid are often breathed by those who work on the planes. This study was set up to find the effects of these fumes on the liver. If CTFE damaged the liver, a different hydraulic fluid would have to be found.

III. Detailed Description of Research

The study involved the use of three animal groups: primates, rats, and chickens. Each group was subdivided further. For example, a certain number of rats were injected with 0.5 g/kg of CTFE for 30 days, while other groups were exposed to vapors of either 250 mg/m^3, 50 mg/m^3, or 10 mg/m^3.

The rats and chickens were sacrificed at the end of their exposure period or after a holding period to obtain a small piece of liver. Primates required a simple operation to obtain this tissue. The livers were weighed carefully and liver samples were taken for electron microscopy to find the effect of CTFE on the cells themselves. This is where most of my work was done. By the end of the summer, I was entrusted to collect, fix, and mince liver tissue by myself.

The first step in processing the livers was to mince them into 1 mm by 1 mm blocks. These blocks were then stained and fixed through a process of alcohol dehydration and resin impregnation, which took about one day. Following processing, the samples were embedded in epon, an epoxy resin that was heated and became a hard plastic. These epon capsules were then placed under a microtome for sectioning. This sectioning was done with a diamond knife. The sections obtained were usually about 0.5 millimeters in length and 60 to 90 nanometers in thickness. I learned how to section but did not have an opportunity to cut many blocks. The sections were mounted on a circular, copper grid about 5 mm in diameter. The grids were then placed in the transmission electron microscope (TEM) and pictures were taken. I was shown how the TEM was operated and how to obtain photographs. I developed and printed over 150 photographs of liver cells. The effects of CTFE on the liver cells were observed directly from the pictures.

IV. Results

At the time I left the laboratory the study was incomplete, but it was possible to make some early observations. In the rats CTFE had caused a severe enlargement of the liver. In addition, there was a distinct increase in the number of peroxisomes in liver cells, a potential early sign of cancer in rats. However, in the primates and chickens neither of these conditions were evident.

These results would seem to indicate that primates were not seriously affected by CTFE. However, it is known that rodents are affected by drugs and chemicals much more quickly than primates. Indeed, further studies may see liver enlargement and an increase in liver cell peroxisomes among primates who have been exposed to CTFE for longer periods. However, the results of the present studies indicate that the liver toxicity in rats is not relevant to humans. CTFE can be used as a hydraulic fluid in airplanes provided that simple precautions are observed. I am disappointed that I will not be here to see the conclusion of this study.

The Summer Work Experience at The Harry G. Armstrong Research Laboratory

By, Carolyn Mellott
August 10 1989

I would like to thank all the people at BBM, BBA, CREST and U.E.S. for their time, help, and consideration during the past eight weeks. All the time, effort and kindness of Dr. Kaleps, Rick Rasmussen, Capt. Chris Taylor, Lt. Deborah Determan, Lt. Kristen Kline, Capt. Erasmo Urena, Mary and Gary Merrill, Mary Gross, Annette Rizer, Doris Skinner, and Lt. Eric Spittle have made this summer experience very enjoyable and rewarding.

The Summer Work Experience at The Harry G. Armstrong Research Laboratory

....And this is the centrifuge which allows pilots to experience the forces of acceleration in a controlled environment.... Some people are exposed to harmful surroundings during their work, here at the Toxicology lab mice are used to study these effects which will help us to minimize the risks to humans... This is just an excerpt that one might hear on the AAMRL Tour, which many of the U.E.S. apprenticeship student took Friday August 4th. Although the subjects were diverse, all of the divisions have a common factor in their experiments. All labs must follow a procedure of pre-test, test and post-test.

Before any experiment takes place many pre-test procedures must occur first. After a test plan has been created, it must be approved by superiors. If approval is given the next step is to require an appropriation of funds. Even after the money has been given out in many cases more research of previous similar experiments or data may be collected for preparation of the test. While working on the ADAM model another preparation has to be made, making certain all the Gy and Gz forces equaled zero. This was done by using the Ge-Bod computer program.

The actual experiment is the most exciting phase of testing. This is what makes all of the time and effort before and after the test worth while. Many experiments took place over this summer. Although some were in a different subject areas from work, watching things like the infrared helmet experiments interesting to see. The Head/Neck Pendulum test was quite fascinating since it utilized physics. Seeing the sled test first hand was thrilling because it was the application of the previous work on the Ge-Bod.

When the excitement of the test is over then the final process begins, analysis of the data collected. This experience can be frustrating and tiring until the answer is found. While working on the Perken-Elmer, sometimes the problems seemed to never have an answer but after patience and perseverance an answer was always found. There is a satisfaction of knowing that the data programmed on the Sigmaplot graphs from the ADAM channels might one day be the stepping stone for future breakthroughs in the ADAM model. Then after the data has been analyzed, a report must be written and sometimes be published.

This summer has been a wonderful chance to experience science on a higher level. The things done here builds the confidence and goals of those involved with the U.E.S. program. Having the ability to actually be involved with projects that will make a difference is a foundation to higher achievement long after receiving a college diploma. Getting involved with all the steps before, during and after makes one realize the commitment and ability one must attain for a career in science.

Thank you for this opportunity.

The Summer Work Experience at The Harry G. Armstrong Research Laboratory

<u>THESIS:</u> All labs must follow a procedure of pre-test, test and post-test.

I. Introduction

II. Before any experiment takes place many pre-test procedures must occur first.

III. The actual experiment is the most exciting phase of testing.

IV. When the excitement of test is over then the final process begins, analysis of the data collected.

V. Conclusion

FINAL REPORT

High School Apprenticeship Program

Britt Peschke

Under Mentor, Mr. Richard McKinley

Armstrong Aerospace Medical Research Laboratory

Biodynamics and Bioengineering Division

Bioacoustics Branch

August 18, 1989

Acknowledgements:

I would like to sincerely thank my mentor, Mr. Richard McKinley, and Captain Mark Ericson for their encouragement and guidance. I also appreciate the kindness of all of the Bioacoustics Branch members and Systems Research Laboratories employees.

FINAL REPORT

By Britt Peschke

1. Introduction

I worked this summer in the Harry G. Armstrong Aerospace Medical Research Laboratory, Bioengineering and Biodynamics Division. I was a scientific apprentice to Mr. Richard McKinley in the Bioacoustics Branch. This is the second year in which I have held this position.

My job was to aid in the research projects of the lab. I helped in obtaining literature and equipment, collecting data, running subjects through tests, and analyzing and presenting data. I worked on 3D localization of sound, reverberation of sound in chambers, and infrared communications. I also helped to develop a method to dependably mount a microphone in a subject's ear.

2. Localization

Three-dimensional localization of sound involves subjects trying to determine from which direction a sound is coming from over headphones. A synthesizer, built in-house by Systems Research Laboratories produces sound from all directions. First, I helped in locating and collecting related published articles on localization. Then I aided in setting up and running subjects through azimuth localization in noise. The subject would try to localize in the following conditions:

steady signal

pulsed 2 Hz 70 dBA

pulsed 2 Hz 80 dBA signa.

pulsed 2 Hz 90 dBA signal

Each of these signals was presented in ambient (75 dB), 95 dB, 105 dB, and 115 dB noise conditions with and without Active Noise Reduction (ANR). ANR is a headset system designed by BBA and produced by Bose Corporation which actively cancels noise. This test was run in the VOCRES (Voice Communication Research) sound chamber. The mean magnitude error in degrees and the mean response time in seconds of each subject and across the study was completed. These results were presented in a graph format using the Hewlett-Packard "Charts and Text" program. This study indicated that the localization system would still perform in the high noise environment of the cockpit.

3. Reverberation

I also spent time anal̦zinr r·verberation data of three new sound chambers in the new addition to Building 441. Previously, an audio recording had been made of a cap pistol shot in each chamber. I would then replay this audio recording to a Bruel and Kjaer 2131 Signal Analyzer that would analyze the gunshot at each frequency level. This data was entered into a HP9845 using a program written by Richard Mckinley which would allow its user to determine the reverberation decay time of a 60 dB drop in noise level. The times were figured for 30 frequencies from 20 Hz to 20 KHz. This information is necessary to set up the individual sound systems in each chamber.

4. Infrared Communications

The third project I worked on was infrared communications for use in chemical defense situations. This system consists of headsets which transmit speech using infrared light. We tested the headsets in direct sunlight to measure the effects of the sun's infrared light interference. The headsets were tested on two dummies, one with an artificial mouth and one with an artificial ear; 50, 100, and 150 feet apart; directly facing each other; and also offset +15° and -15°. One test subject would read off words from the modified rhyme test into the microphone of the "talking" dummy which the other subject would hear through headphones of the "listening" dummy. The test measured how well the listener could distinguish what the talker was saying. The results indicated that the sun would not significantly affect the headset use but, as was expected, the further apart the less reliably the headsets performed.

5. Design

Having received many experiences in research this summer, I was also fortunate to help in design. My lab was looking for a reliable method to mount a very small microphone in a person's entrance to the ear canal, comfortably and sturdily. I helped to design and assemble a small foam ear plug with a hollow plastic tube in the center of the plug where we could place a plastic post which was attached to the small microphone. This method is comfortable to the wearer, easy to insert, and dependable to reproduce and to keep immobile.

6. Conclusion

This summer being involved in more than one research project allowed me to obtain a broader knowledge of different topics. I enjoyed the opportunity to be involved in a variety of efforts. Working in the high school apprenticeship program has been an enjoyable experience for me. I believe I have gained valuable knowledge and experience to aid in my future studies and career. I feel fortunate to have been given this opportunity to work in such a productive laboratory with quality people.

TOXICOLOGY

August 21,1989

By: Jennifer L. Walker
Laboratory: Armstrong Aeromedical Research Laboratory
Wright-Patterson AFB, Ohio
Mentor: Capt. Donald Tocco

ACKNOWLEDGEMENTS

I would like to thank the following people for their help with the rats: Mr. Jerry Nicholson, Lt.Col. James Cooper, of building 838; Lt. Virginia Forrest, HM2 Mike Goehring, HM3 Mike Schull, of building 433; and TSgt. Tim Hoeflich, A1C Jeff Kessler, and Capt. Donald Tocco, of building 79. I would also like to thank Capt. Bruce Jarnot for teaching me metal analysis, HM3 Von Rix for help with the computer, and Dr. Robert Carpenter for the information on the physiology of the lungs. I appreciated your help and kindness (and directions) during my stay.

INTRODUCTION

Both the Air Force and the Navy are planning an experiment to provide combustion toxicity information on graphite and/or carbon fiber composites for the assessment of the potential hazards of graphite composite materials involved in aircraft crashes and fires. The experiment involves using Fischer344 rats inside a plethysmograph breathing air from a combustion chamber which will contain the burning composites. My purpose was to train and determine the training time necessary in the plethysmograph so that the experiment will provide accurate and valid results.

First, I had to familiarize myself with the equipment I would be using: an IBM computer; a BUXCO data logger, upper airway monitor, and preamplifier bank; and a plethysmograph. I also had to develop a procedure for training the rats. Since my main purpose was to get the rats used to being in the plethysmograph, the exact time spent inside would not be crucial. Therefore, two rats could be trained on one run since the extra one or two minutes to get the other rat inside would not harm the results. Until the rats for the experiment came, I practiced on a tame spare rat.

Once the actual rats came in and were out of quarantine, rats 1-8 began their training. For three days, they were placed in the plethysmograph for 30 minutes (duration which they will be in the combustion chamber). Unfortunately the results were invalid since the BUXCO was not calibrated between each run. Even though there were no written results, the rats are considered trained. The rats showed a considerable change in behavior. On the first run, they were very active and would struggle to get out. They accepted confinement but still squealed during their second run. By their third run, the rats were basically relaxed.

Rats 13-18 were trained next with a slight change in the procedure. The BUXCO machine was calibrated between each run. These rats had five runs through the plethysmograph. They showed the same basic behavior changes as rats 1-8; by the fifth run, they showed almost no resistance. The data on these rats is accurate. Most of the rats started with a higher respiation rate the first five minutes and were lower for the last five minutes of their duration in the plethysmograph. Overall, the rats [illegible] ower respiration rates on each progressive day. (See da[illegible] ats 13 and 14.) I have concluded that three days o[illegible] g (four or five days for extra insurance) will be neces[illegible] the rats participating in this experiment.

Until the rats came, I helped assist on various different projects. I helped Capt. Bruce Jarnot with metal analyses on a Scanning Electron Microscope. I prepared rat urine samples for TSgt. Tim Hoeflich. Also, I participated in a SimuSolv (computer modeling) class.

By working at the Armsrong Aeromedical Research Laboratory this summer, I was exposed to many different experiences in a science laboratory. I was also able to get a summer job at the new Air Force base to which my dad was assigned. I hope this program continues and is added to even more bases. Thank you for this summer internship.

REFERENCES

1. Virginia Forrest, Lt., Donald Tocco, Capt., "Combustion Toxicity of Graphite Composites", NMRI/TD Protocol #89-3, AF Work Unit 6302158 (DRAFT).

Apprendices can be obtained from

Universal Energy Systems, Inc.