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AFOSR-TR- 91 0953

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IAW AFR 190-12
Program Manager

Energy Systems, Inc.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
18 April 1991

3. REPORT TYPE AND DATES COVERED
Final 1 Feb 88-29 Sep 90

4. TITLE AND SUBTITLE
United States Air Force
High School Apprenticeship Program
1990 Program Management Report (w/atch ~~1, 2, &~~ 3)
Volume II of IV

5. FUNDING NUMBERS
F49620-88-C-0053

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Universal Energy Systems, Inc. (UES)
4401 Dayton-Xenia Road
Dayton OH 45432-1894

8. PERFORMING ORGANIZATION REPORT NUMBER
AFOSR-TR- [illegible]

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NI
Bldg 410
Bolling AFB DC 20332-6448

Lt Col V. Claude Cavender

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Air Force High School Apprenticeship Program's purpose is to place outstanding high school students whose interests are in the areas of mathematics, engineering, and science to work in a laboratory environment. The students selected to participate work in an Air Force Laboratory for a duration of 8 weeks during their summer vacation.

91-18956

14. SUBJECT TERMS

91 1223 190

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLAAIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT
UNCLASSIFIED

20. LIMITATION OF ABSTRACT
UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std 239-18

UNITED STATES AIR FORCE

HIGH SCHOOL APPRENTICESHIP PROGRAM

1990

PROGRAM MANAGEMENT REPORT

VOLUME II OF IV

UNIVERSAL ENERGY SYSTEMS, INC.

Program Director, UES
Rodney C. Darrah

Program Manager, AFOSR
Lt. Col. Claude Cavender

Program Administrator, UES
Susan K. Espy

Submitted to

Air Force Office of Scientific Research

Bolling Air Force Base

Washington, DC

December 1990

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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.

There has been a few incidents concerning misuse of the computers in the laboratories. On two separate occasions the laboratory has had to revoke computer privileges on four high school students. Both of these incidents happened at the same laboratory.

Two years ago two students wrote a program to shut down the computer system at the laboratory and to steal users access codes. These students were removed from the laboratory and one of the students was dismissed from the program, while the other student finished his apprenticeship at the UES facility.

This year a similar incident happened. Two other students were involved with basically the same incident. One student wrote a program that would send repeating messages to the various computer terminals. Included in this program was a password interception program were the users would type in their password and the program would retrieve that password. The other student involved also wrote and executed a password stealing program, and was involved in the unauthorized use of a government computer in writing a fraudulent letter. The student also obtained unauthorized access to a computer modem.

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, etc.
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 516 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 132 participants on the program, selected from the 516 applications.

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

Aero Propulsion Laboratory	7
Armament Laboratory	16
Armstrong Aerospace Medical Research Laboratory	7
Arnold Engineering and Development Center	6
Avionics Laboratory	6
Astronautics Laboratory	12
Engineering and Services Center	15
Electronic Technology Laboratory	5
Flight Dynamics Laboratory	9
Geophysics Laboratory	7
Materials Laboratory	1
Occupational and Environmental Health Laboratory	3
Rome Air Development Center	15
School of Aerospace Medicine	13
Weapons Laboratory	10

Participant Laboratory Assignment
1990 High School Apprenticeship Program

Aero Propulsion Laboratory
Wright-Patterson Air Force Base, Ohio

1. Matthew Bold
2. Hee Sun Choung
3. Katharine Day
4. Chris Hatch
5. Chet Nieter
6. Jennifer Pollock
7. Carol Rogers

Armament Laboratory
Eglin Air Force Base, Florida

1. Steven Bryan
2. Toyna Cook
3. Heather Cox
4. Kathryn Deibler
5. Chris Ellis
6. Dana Farver
7. Kenneth Gage
8. Reid Harrison
9. Derek Holland
10. Christine Riendeau
11. Lisa Schmidt
12. Patricia Tu
13. Troy Urquhart
14. Gregory VanWiggeren
15. Danielle Walker
16. Eric White

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

1. Rex Ballinger
2. Douglas Brungart
3. Caroline Chuang
4. Keisha Hayes
5. Douglas Marshak
6. Jeremiah Rogers
7. James Shamiyeh

Arnold Engineering and Development Center
Arnold Air Force Base, Tennessee

1. Timothy Craddock
2. Myra Medley
3. Julie Reece
4. Jonathan Sanders
5. Jason Scott
6. Gerald Turner

Astronautics Laboratory
Edwards Air Force Base. California

1. Alisha Conroy
2. Debra Meyer
3. John Moro
4. Lloyd Neurauter
5. Joseph Padilla
6. Melanie Pyle
7. Thomas Quinn
8. Tracy Reed
9. Benjamin Sommers
10. Stephanie VanMeter
11. Rebecca Weston
12. David Youmans

Avionics Laboratory
Wright-Patterson Air Force Base, Ohio

1. Brian Barclay
2. Mark Boeke
3. Michael Chabinyc
4. David Collins
5. Austin Flack
6. Jerard Wilson

Engineering and Services Center
Tyndall Air Force Base, Florida

1. Jennifer Brewer
2. Philip Dorsch
3. David Eshleman
4. Richard Hartzer
5. Thor Johnson
6. Tracy Lamb
7. Brent Miller
8. Debra Piechowiak
9. Jonathan Protz
10. Julie Scruggs
11. Michael Stone
12. Amy Thomas
13. Michael Thompson
14. Jeffrey Ward
15. Robin Woodworth

Electronic Technology Laboratory
Wright-Patterson Air Force Base, Ohio

1. Matthew Brewer
2. Matt Elwood
3. Shelly Knupp
4. Christopher O'Dell
5. Suzette Yu

Flight Dynamics Laboratory
Wright-Patterson Air Force Base, Ohio

1. Jean Ay
2. Matthew Becker
3. Wendy Choate
4. Andrea Dean
5. Rachael Lyon
6. Cathie Moore
7. Roderick Morgan
8. Stanley Wall
9. Douglas Wickert

Geophysics Laboratory
Hanscom Air Force Base, Massachusetts

1. Stephen Britten
2. Weihaw Chuang
3. Christopher Guild
4. Jason Klingensmith
5. Galen McKinley
6. Jeffrey Sayasane
7. Paul Swietek

Materials Laboratory
Wright-Patterson Air Force Base, Ohio

1. Jennifer Walker

Occupational and Environment Health Laboratory
Brooks Air Force Base, Texas

1. Gary New
2. Andrea Perez
3. Michael Smid

Rome Air Development Center
Griffiss Air Force Base, New York

1. Daniel Abbis
2. Mark Anania
3. Bridget Bordiuk
4. Todd Gleason
5. Christopher Hailes
6. Edward Holmes
7. Kimberly King
8. Kathryn Lee
9. Jason Lenio
10. Kevin Olson
11. David Petrillo
12. Thomas Potter
13. Daniel Russell
14. Philip Schremmer
15. Eric Shaw

School of Aerospace Medicine
Brooks Air Force Base, Texas

1. Anthony Barnes
2. Whitney Brandt
3. Deann Cooper
4. Matthew Felder
5. Christopher Hudson
6. Sonya Longbotham
7. Brian McBurnett
8. Heather Neville
9. Lori Olenick
10. Joanna Saucedo
11. Wendy Shields
12. Brent Strawn
13. John Taboada

Weapons Laboratory
Kirtland Air Force Base, New Mexico

1. David Cochrell
2. Gregory Hays
3. David Knapp
4. Aaron Leing
5. Kerim Martinez
6. Ryan McAlhaney
7. Margaret Morecock
8. Philip Ortiz
9. Brian Rizzoli
10. Chris Stoltenberg

INFORMATION PACKAGE

23 March 1990

Dear :

Enclosed are the mentor applications forms for the 1990 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 1990. The following mentors and previous high school participants have been matched and selected to work with each other for the coming summer.

Student	Mentor
1.	
2.	
3.	

The following is a previous high school participant in the program and is selected to participate in the program for this summer. He 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 15 April 1990.

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 15 high school students will be selected to participate with the mentors at the Rome Air Development Center.

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: Lt. Col. Claude Cavender

MODEL PLACEMENT LETTER TO STUDENT

13 March 1991

1~
2~
3~

Dear 4~:

Congratulations! You have been selected to participate in the Air Force Office of Scientific Research High School Apprenticeship Program as an apprentice to 5~ at the 6~ to work on Project: "7~" from June 18 to August 10, 1990. 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 May 11, 1990.

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 18, 1990, 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 18. 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 8~.

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/mt

STUDENT ACCEPTANCE FORM

for participation in

Air Force Office of Scientific Research

High School Apprenticeship Program, 1990

I, 1~, accept the position of apprentice in the Air Force Office of Scientific Research High School Apprenticeship Program from June 18, 1990 to August 10, 1990 to work with 2~ at the 3~ on Project: "4~". I understand that I will receive a stipend of $5~ 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

1990 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 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

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

____
Date

1990 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?

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

   Assistant Chief Scientists.

2. Did you volunteer to be a mentor?

   7 Yes
   0 No

3. Did the student application provide sufficient information?

   7 Yes
   0 No
   0 Don't Know

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

   Specific information regarding computer experience.

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

   4 Yes
   3 No

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

   6 Yes
   1 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

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?

   2 A lot
   5 Some
   0 Not at all

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

   4 Excellent
   3 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?

   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? 0 - Yes 1 - No 6 - Don't Know

   Explain:

   She was already planning on an Engineering degree at U. of K.

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

   Explain:

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

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ARMAMENT LABORATORY

1. How did you hear about program?

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

Section Chief.

I have been a mentor for 3 years.

2. Did you volunteer to be a mentor?

16	Yes
0	No

3. Did the student application provide sufficient information?

12	Yes
1	No
3	N/A

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

I did not see the application, or pay much attention to it. I just accepted the student assigned to me.

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

10	Yes
6	No

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

5	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?

15	A lot
1	Some
0	Not at all

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

10	A lot
6	Some
0	Not at all

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

15	Excellent
1	Fair
0	Poor

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

14	Yes
2	No

If No, Why?

I will be away.

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

10	Yes
6	No

If No, Why?

All the no responses indicate the students will be attending college and not eligible for the program.

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

a. courses in coming school year? 5 - Yes 2 - No 9 - Don't know

Explain:

Most of the comments indicate that the courses are already set. But toward the math and science courses.

b. career choice? 7 - Yes 1 - No 8 - Don't know

Explain:

The comments consist that students are still deciding, two of the students definitely want in the science careers.

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

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

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

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ARMSTRONG AEROSPACE MEDICAL RESEARCH 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
   0 Other, specify:__________

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?

   I didn't see the application form.

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

   2 Yes
   5 No

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

   2 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?

   3 A lot
   4 Some
   0 Not at all

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

   2 A lot
   5 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?

    4 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?

    She graduated.

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

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

       Explain:

       Gained additional knowledge & training in lab that allowed testing out of some pre-requisite courses.

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

       Explain:

       Comments include that the student has new insight to engineering, and another student wants to go into medicine

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

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ARNOLD ENGINEERING AND DEVELOPMENT CENTER

1. How did you hear about program?

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

    Supervisor.

2. Did you volunteer to be a mentor?

    5 Yes
    1 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?

    4 Yes
    2 No

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

    1 Yes
    1 No
    0 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?

    4 A lot
    2 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?

6 Excellent
0 Fair
0 Poor

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

6 Yes
0 Maybe
0 No
If No, Why?

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 3 - No 2 - Don't know

Explain:

The no responses indicate that courses are pre-determined and not many options.

b. career choice? 4 - Yes 0 - No 2 - Don't know

Explain:

Heightened interest in chemistry/chemical engineering.

Solidified his intent to pursue an engineering career.

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

I would suggest that students requiring a security clearance he given advanced notice so that the necessary processing could be completed prior to their coming to work. A ten week program (instead of 8) should be offered as an option for the students.

This program was a very positive experience for me as well as her. I would enjoy participating in the program again.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ASTRONAUTICS LABORATORY

1. How did you hear about program?

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

   Request from XRX.

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?

   At a high school level there isn't a lot of detailed scientific technical questions you can ask for.

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

   4 Yes
   5 No

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

   4 Yes
   1 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
   2 Some
   0 Not at all

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

    6 A lot
    3 Some
    0 Not at all

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

    9 Excellent
    0 Fair
    0 Poor

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

    9 Yes
    0 No
    If No, Why?

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? 2 - Yes 4 - No 3 - Don't know

    Explain:

    Most of the responses indicate that student's courses are already set for the upcoming year.

    b. career choice? 1 - Yes 3 - No 5 - Don't know

    Explain:

    Two of the comments were that the student's have their career's planned, even as far as job opportunities. One student wants to go in the medical profession.

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

Let the students accrue leave (annual & sick) and let them work more than 40 days!

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

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

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

AVIONICS LABORATORY

1. How did you hear about program?

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

2. Did you volunteer to be a mentor?

6 Yes
0 No

3. Did the student application provide sufficient information?

4 Yes
2 No

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

Previous police record and descriptions of any court imposed fines or punishment.

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

0 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?

2 A lot
4 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
0	Fair
1	Poor

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

5	Yes
1	No
	If No, Why?

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

5	Yes
1	No
	If No, Why?

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

a. courses in coming school year? 1 - Yes 3 - No 2 - Don't know

Explain:

I think his courses were pretty well planned out before he came to the lab. What he learned here probably reinforced his choices rather than changing them.

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

Explain:

All of the responses indicate the students' have chosen a career; from chemical engineer to computer science.

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

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

Name of student apprentice

Name of mentor/laboratory

Date

1990 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?

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

The comments for the Other category were notifications from AFESC staff.

2. Did you volunteer to be a mentor?

14	Yes
1	No

3. Did the student application provide sufficient information?

14	Yes
1	No

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

Never saw a student application from.

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

4	Yes
11	No

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

8	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?

9	A lot
5	Some
1	Not at all

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

9	A lot
5	Some
1	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?

13	Yes
2	No
	If No, Why?

The "no" comments were because of the time that it takes, and the other mentor will be traveling.

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

15	Yes
0	No
	If No, Why?

If I were to do it again.

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

a. courses in coming school year? 5 - Yes 4 - No 6 - Don't know

Explain:

The majority of the comments as before where that the courses are already determined.

b. career choice? 4 - Yes 3 - No 8 - Don't know

Explain:

The comments range from students that have not decided, to a student choosing to be an engineer and Air Force pilot.

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

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

ELECTRONIC TECHNOLOGY LABORATORY

1. How did you hear about program?

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

Through Lab Operation Division (ELA).

Verbal request from boss.

Co-worker.

2. Did you volunteer to be a mentor?

4	Yes
1	No

3. Did the student application provide sufficient information?

5	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?

3	Yes
2	No

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

1	Yes
1	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
0	Some
0	Not at all

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

    3 A lot
    2 Some
    0 Not at all

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

    4 Excellent
    1 Fair
    0 Poor

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

    5 Yes
    0 No
    If No, Why?

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

    4 Yes
    1 No
    If No, Why?

    Student has limited interest in research.

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

    a. courses in coming school year? 0 - Yes 1 - No 4 - Don't know

    Explain:

    Responses indicate that courses are pre-determined.

    b. career choice? 0 - Yes 0 - No 5 - Don't know

    Explain:

    I think she has gained an appreciation for the challenging nature of research.

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

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

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

____
Date

1990 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?

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

   Branch office.

   WRDC/FIOP

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?

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

   3 Yes
   5 No

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

   4 Yes
   1 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
   3 Some
   0 Not at all

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

5 A lot
3 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?

7 Yes
1 No
If No, Why?

Only if a project is available for use by student!

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

6 Yes
2 No
If No, Why?

Comments indicate student's are not eligible.

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

a. courses in coming school year? 1 - Yes 2 - No 5 - Don't know

Explain:

Student had already chosen Engineering Curriculum for College.

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

Explain:

Student already targets Aerospace future.

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

Work must be available that a student can get involved in for the duration of there stay. If it is not, I will not take any more students.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

GEOPHYSICS LABORATORY

1. How did you hear about program?

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

2. Did you volunteer to be a mentor?

5	Yes
0	No

3. Did the student application provide sufficient information?

5	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
4	No

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

3	Yes
1	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?

3	A lot
2	Some
0	Not at all

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

3	A lot
2	Some
0	Not at all

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

5	Excellent
0	Fair
0	Poor

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

5	Yes
0	No
	If No, Why?

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

5	Yes
0	No
	If No, Why?

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

a. courses in coming school year? 0 - Yes 0 - No 5 - Don't know

Explain:

Courses probably selected prior to the summer job.

b. career choice? 0 - Yes 1 - No 4 - Don't know

Explain:

Was already planning to enter MIT in an engineering field.

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

The main comment is that they would like to see the program expanded to 10 to 12 weeks, also that the stipend should be raised to compete with jobs outside of research.

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

MATERIALS LABORATORY

1. How did you hear about program?

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

2. Did you volunteer to be a mentor?

   1 Yes
   0 No

3. Did the student application provide sufficient information?

   1 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
   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?

   1 A lot
   0 Some
   0 Not at all

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

1	A lot
0	Some
0	Not at all

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

1	Excellent
0	Fair
0	Poor

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

1	Yes
0	No
	If No, Why?

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

1	Yes
0	No
	If No, Why?

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

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

Explain:

Student is pursuing a career in Civil Engineering.

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

Explain:

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

She was really a pleasure to work with. She was self motivated and a diligent worker who was genuinely interested in everything going on within the lab. She did a outstanding job. Would like to see her back next year!

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

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

____
Date

1990 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
   1 Memo from personnel office
   0 Verbal request from personnel office
   1 Other, specify:__________

   My supervisor.

2. Did you volunteer to be a mentor?

   1 Yes
   1 No

3. Did the student application provide sufficient information?

   2 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
   2 No

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

   2 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?

   0 A lot
   2 Some
   0 Not at all

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

2	A lot
0	Some
0	Not at all

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

2	Excellent
0	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?

2	Yes
0	No
	If No, Why?

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

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

Explain:

Student was already interested in science courses.

b. career choice? 0 - Yes 0 - No 2 - Don't know

Explain:

Student is already set to take engineering in college.

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

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

____
Name of student apprentice

____
Name of mentor/laboratory

____
Date

1990 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?

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

Director of Photonics Labs.

Branch Chief sent me a memo.

2. Did you volunteer to be a mentor?

10	Yes
1	No

3. Did the student application provide sufficient information?

10	Yes
1	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
11	No

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

6	Yes
5	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
7	Some
0	Not at all

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

3 A lot
8 Some
0 Not at all

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

10 Excellent
1 Fair
0 Poor

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

8 Yes
3 No
If No, Why?

The "no" responses indicated that they did not have the time to devote to the students.

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

8 Yes
3 No
If No, Why?

Give someone else the opportunity to work here.

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

a. courses in coming school year? 2 - Yes 2 - No 7 - Don't know

Explain:

Courses pre-determined but students were influenced for courses at the advanced levels.

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

Explain:

The majority of the comments were that the career choices were reinforced.

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

Great Program! Thanks!

PLEASE RETURN BY 14 September 1990

to: Susan Espy
Coordinator

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

Name of student apprentice

Name of mentor/laboratory

Date

1990 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?

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

   Laboratory Chief Scientist

   Letter from SAM/CA.

2. Did you volunteer to be a mentor?

   13 Yes
   0 No

3. Did the student application provide sufficient information?

   13 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?

   4 Yes
   8 No

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

   4 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?

   12 A lot
   1 Some
   0 Not at all

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

9 A lot
4 Some
0 Not at all

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

11 Excellent
2 Fair
0 Poor

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

12 Yes
0 No
If No, Why?

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

11 Yes
2 No
If No, Why?

The student stated she did not have the patience for research work. Therefore, I would prefer giving another student an opportunity to participate in next year's program.

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

a. courses in coming school year? 1 - Yes 3 - No 9 - Don't know

Explain:

The responses indicated that courses are pre-determined, although one comment indicated that it influenced the student's college courses.

b. career choice? 5 - Yes 0 - No 8 - Don't know

Explain:

Indicated a change from nursing to biological research.

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

This is an excellent program. It helps students realize what "research" means, and gives them some independence in the laboratory setting.

PLEASE RETURN BY 14 September 1990

Name of student apprentice

to: Susan Espy
Coordinator

Name of mentor/laboratory

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

Date

1990 USAF/UES HIGH SCHOOL APPRENTICESHIP PROGRAM
MENTOR EVALUATION QUESTIONNAIRE
(TO BE COMPLETED BY A MENTOR)

WEAPONS LABORATORY

1. How did you hear about program?

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

Supervisor.

Program Coordinator on site.

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?

One mentor commented that questions should be asked concerning technical capabilities.

I chose a student I was familiar with, I never saw the applications.

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

1	Yes
7	No

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

3	Yes
3	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?

   6 A lot
   2 Some
   0 Not at all

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

   8 Excellent
   0 Fair
   0 Poor

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

    7 Yes
    1 No
    If No, Why?

    Just every few years.

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

    7 Yes
    1 No
    If No, Why?

    Student starting college.

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

    a. courses in coming school year? 3 - Yes 1 - No 4 - Don't know
    Explain:

    Most comments were that the courses have already been set. One commented that the student changed from nuclear engineering to electrical engineering.

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

    Comments were that the work was parallel to career choices.

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

PLEASE RETURN BY 14 September 1990

____
Name of student apprentice

to: Susan Espy
Coordinator

____
Name of mentor/laboratory

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

____
Date

1990 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 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?

○ Yes ○ No: If No, why?

- ○ personality conflicts
- ○ lack of interest
- ○ want a different experience
- ○ 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 14 September 1990
date

Susan Espy
Name of Coordinator

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

1990 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		
46	27	26	6	1.	Philosophy of research
36	35	26	8	2.	Use of scientific method to solve problems
45	23	26	11	3.	Use of experimental checks and controls
42	26	18	19	4.	Measurement techniques
38	30	24	13	5.	Design of equipment
30	20	20	35	6.	Calibration of reagents, standards, and instruments
39	31	19	44	7.	Process of design of an experiment
80	17	6	2	8.	Data analysis (with or without computer assistance)
65	17	11	13	9.	Computer programming
47	28	22	8	10.	Acquisition and use of scientific literature (books, audio visual)
34	44	18	9	11.	Identification of new questions as a consequence of scientific exploration
62	30	9	4	12.	Teamwork in scientific research
61	26	11	7	13.	Use of advanced scientific equipment
34	29	26	16	14.	Other students with similar interests and goals
51	29	17	7	15.	Scientists working in different areas of research
48	33	20	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		
77	21	7	0	1.	Working with adults
68	27	10	0	2.	Responsibility on a job
46	34	22	3	3.	Understanding of scientific principles
57	27	16	5	4.	Scientific vocabulary
33	46	19	7	5.	Ability to write a technical report
65	30	10	0	6.	Understanding of your interests and abilities
55	33	14	3	7.	Educational goal setting
60	29	13	3	8.	Insights into career opportunities in science
51	33	19	2	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		
15	19	21	2	48	1.	Planned lectures or seminars
73	22	5	4	1	2.	Explanations of work by mentor
27	28	22	5	23	3.	Tours of other laboratories or installations
73	19	7	5	1	4.	Informal talks with mentor
59	27	14	2	3	5.	Discussions with other scientists
36	19	22	10	18	6.	Interactions with other apprentices
16	22	25	18	24	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?
79	22	4	0	1.	I enjoyed the experience
59	37	3	6	2.	I liked the scientific research
51	41	10	3	3.	I was satisfied with the way I spent my time
73	25	6	1	4.	I learned a lot
55	37	5	7	5.	I feel I contributed to the research results

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

72 Yes 31 No: If No, why?

1	personality conflicts
5	lack of interest
23	want a different experience
10	want a different location

VI. What did you like most about the program?

35 of the students thought that the mentor and the various people in the laboratory was what they liked the most about the program. They commented that they were treated as adults and not as high school students, that what they thought or accomplished was important. 29 of the students liked the exposure to a work atmosphere. The students were very thankful to have the opportunity to work beside scientist and engineers doing real research. Another comment was that the equipment, laboratories, and computers are what 19 of the students liked the most. Eleven of the students liked the project that they were assigned to, and the learning experience that they had. A few students expressed that before they received the position that they had not decided on a career, but 8 students have now due to the program. Five of the students liked the different employment opportunities that are available, while 2 of the students liked learning more about the Air Force and the opportunities that they have available.

VII. What did you like least about the program?

The majority of what the students liked least was that the program was not long enough. The 12 responses indicated that the program should be lengthened to 10 to 12 weeks. Eleven of the students commented at they were not keep busy. The mentors did not either have the time to spend with them, or the students finished the projects that the mentors had assigned. Six of the students disliked writing a final report at the end of the summer. While another six students thought the pay should be higher considering the type of work they were doing. Five of the students commented that they did not do the project that was originally discussed once they got there. Another five students least liked the timecards and there schedule, also the delay in getting their paychecks. Four students responded that their mentors were TDY and was not available for most of the summer. Four other students commented that they did not get along with the people in labs, that they were treated like "gofers" and doing errands, and office work. Another 4 students disliked the project they were doing, some of the comments were that they did not think it was real research but "busy work". Other comments consisted of no sick or holiday pay, lack of information about UES, no positions available for college students, getting up early, lack of air conditioning, and even that the water tasted funny.

DO NOT SIGN

RETURN FORM TO YOUR COORDINATOR BY 14 September 1990
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

1990 HIGH SCHOOL APPRENTICESHIP PROGRAM

Technical Report Number	Title	Participant
VOLUME I		
Aero Propulsion Laboratory		
1	Flash Plate Evaporator	Matthew Bold
2	Frozen Start Up	Hee Sun Choung
3	Nonaqueous Battery Research	Katharine Day
4	Setup Tecplot	Chris Hatch
5	Flash Plate Evaporator	Chet Nieter
6	Final Report to UES	Jennifer Pollock
7	Frozen Start Up	Carol Rogers
Armament Laboratory		
8	Wind Velocimeters for Calculating Ballistic Trajectories	Steven Bryan
9	Star Availability for Sensor - Specific Evaluation (S.A.S.S.E.)	Tonya Cook
10	Development of a Customized Database System for the Distribution of EPIC Hydrocode Software	Heather Cox
11	Synthesis and Characterization of 3-Picrylamino-1,2,4-Triazole	Kathryn Deibler
12	Neural Target Identification	Chris Ellis
13	Space Debris Analysis	Dana Farver
14	Enhancement and Integration of Post Process Utilities for the EPIC Hydrocodes	Kenneth Gage
15	Design of In-House Radar Control and Data Acquisition Systems	Reid Harrison
16	1990 HSAP Final Event Summary	Derek Holland

17	MSIS: Multi-Sensor Integration System	Christine Riendeau
18	Enhancement of RTD 710A Interface	Lisa Schmidt
19	Current Simulations in Electromagnetic Launcher Power Supplies	Patricia Tu
20	Advanced Signal Processing Operations for Guided Interceptors	Troy Urquhart
21	Ballistics Applications in Aerospace Research	Greg VanWiggeren
22	Optical Processing: Digital Imagery Acquisition and Analysis	Danielle Walker
23	Fractal Landscape	Eric White

VOLUME II
Armstrong Aerospace Medical Research Laboratory

24	Summer Apprenticeship Final Report	Rex Ballinger
25	3-D Audio Displays	Douglas Brungart
26	Integrated Protection by Pressurized Containment in Flight Environments	Caroline Chuang
27	Cockpit Accommodation	Keisha Hayes
28	Electron Microscopy Techniques	Douglas Marshak
29	AAMRL/AFOSR Summer Research Apprenticeship Report	Jeremiah Rogers
30	Camouflage, Concealment, and Deception	James Shamiyeh

Arnold Engineering and Development Center

31	Converting Saturn Data Base into Paradox 3.0	Timothy Craddock
32	X-ray Computer Tomography and IR Analysis Models for Propulsion Systems	Myra Medley
33	Demulsification of Oil and Water Using Salts and Commercial Surfactants for the Purpose Purpose of Reclaiming Waste Oil	Julie Reece
34	Propulsion Wind Tunnel Standard Tunnel Conditions Equations Documentation	Jonathan Sanders

35	Program Final Report	Jason Scott
36	Real-Time Radiography Ray Tracing	Gerald Turner

Astronautics Laboratory

37	The Summer in Review	Alisha Conrow
38	Synthesis of Two Cage Compounds	Debra Meyer
39	Fundamental Rocket Exhaust Measurements	John Moro
40	Analytic Predictions of Hydroxy-terminated Polybutadiene (HTPB) Modulus using Random Iterative Discrete Node Algorithm (RIDNA)	Lloyd Neurauter
41	Liquid Engine Computer Codes	Joseph Padilla
42	Determination of Active Surface Area and Density of Carbons	Melanie Pyle
43	No Report Submitted	Thomas Quinn
44	High School Apprenticeship Program Final Report	Tracy Reed
45	1990 Final Report	Benjamin Sommers
46	No Report Submitted	Stephanie VanMeter
47	A Comparison of Electric Propulsion Orbit Transfer Methods	Rebecca Weston
48	No Report Submitted	David Youmans

Avionics Laboratory

49	Ada Compiler Evaluation Capability Testing Utility (ACEC)	Brian Barclay
50	Pattern Based Machine Learning	Mark Boeke
51	Pattern Based Machine Learning: A Comparison of ADA Function Decomposer Versions	Michael Chabinyc
52	Computer Simulation of SDI	David Collins
53	Final Report Summer 1990	Austin Flack
54	No Report Submitted	Jerard Wilson

Engineering and Services Center

VOLUME III
Electronic Technology Laboratory

Rome Air Development Center

95	Pre-Commissioning and Capabilities of the Workhorse Scatterometer: A Final Report	Daniel Abbis
96	No Report Submitted	Mark Anania
97	Radar Range Equation and Radar Design and Simulation	Bridget Bordiuk
98	No Report Submitted	Todd Gleason
99	Cartographic Applications	Christopher Hailes
100	Application Software Development for use on Directory Specific Network	Edward Holmes
101	Various Projects in Data Analysis of Surveillance Systems	Kimberly King
102	Network Processing Element Test and Evaluation	Kathryn Lee
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104	Activities at RADC Photonics Lab	Kevin Olson
105	Overview of Neural Networks	David Petrillo
106	Surface Analysis	Thomas Potter
107	Software Inventory Control System Database	Daniel Russell
108	Artificial Neural Networks	Philip Schremmer
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School of Aerospace Medicine

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111	Final Report	Whitney Brandt
112	Preliminary Testing of an Inert Gas Concentrator Using Carbon Molecular Sieve	Deann Cooper
113	Affects of Anti-G Straining Maneuvers on Blood Pressures in Man; Affects of +Gz on the Cardiovascular System of Baboons	Matthew Felder

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122	UES Report	John Taboada

Weapons Laboratory

123	Phase Conjugation and Beam Coupling	David Cochrell
124	Final Report	Paul Hillman
125	A Study in C	David Knapp
126	Final Report of Summer Mentor	Aaron Laing
127	Statistical Analysis of Cone Penetrometer Data	Kerim Martinez
128	No Report Submitted	Ryan McAlhaney
129	Microwave Susceptibility Testing of Micro-Circuitry	Margaret Morecock
130	Construction of a Delay Circuit for Data Acquisition Coordination	Philip Ortiz
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FINAL REPORTS

AEROSPACE MEDICAL RESEARCH LABORATORY

SUMMER APPRENTICESHIP FINAL REPORT

REX MICHAEL BALLINGER

AAMRL/HED

8/6/90

ACKNOWLEDGMENTS

I WISH TO EXPRESS MY THANKS TO THE FOLLOWING PEOPLE FOR THEIR PART IN THE AIR FORCE MENTORSHIP PROGRAM:

LT. COL. WILLIAM MARSHAK
MAJ. MICHAEL MCFARREN
LONNY SHIMP
JIM NEWELL
BRIAN ZAFF
DAN SNYDER
UES
USAF

MAJ. MCFARREN WAS SCHEDULED TO LEAVE AAMRL/HED JUST TEN DAYS AFTER MY DEPARTURE; THEREFORE, MY JOB WAS TO COMPLETE SOME OF HIS UNFINISHED PROJECTS. ALSO, MAJ. MCFARREN WAS ABSENT ON LEAVE FOR MUCH OF MY STAY AT AAMRL/HED, SO I HELPED OTHER MEMBERS OF THE OFFICE WITH CLERICAL DUTIES.

MY TASK FOR MAJ. MCFARREN WAS TO SET UP A SYSTEM OF ORGANIZATION IN THE HED LIBRARY, ORGANIZE IT, AND PLACE IT IN A RIM DATABASE FOR ACCESS BY THE ENTIRE STAFF. THE HED LIBRARY HAD BEEN NEGLECTED FOR SEVERAL YEARS, SO IT TOOK A GOOD NUMBER OF TIME TO ORGANIZE THE ROOM. PRIOR TO THIS JOB, I HAD NO EXPERIENCE IN FORMING DATABASES, ESPECIALLY IN RIM; THEREFORE, I OFTEN HAD TO CALL UPON DAN SNYDER, LONNY SHIMP, AND OTHER MEMBERS OF THE STAFF FOR HELP WHEN MAJ. MCFARREN WAS NOT AVAILABLE.

THE HED LIBRARY ON RIM WAS DIVIDED INTO FOUR MAJOR RELATIONS WITH ATTRIBUTES:

MAGAZINE ARTICLES (MA)
YEAR AUTHOR MAGAZINE KEYWORDS AAMRL#
ACADEMIC PAPERS (AP)
YEAR AUTHOR UNIVERSITY KEYWORDS AAMRL#
COMMERCIAL PAPERS (CP)
YEAR AUTHOR COMPANY KEYWORDS AAMRL#
MILITARY PAPERS (MP)
YEAR AUTHOR ORGANIZATION KEYWORDS AAMRL#
PROJECTS
YEAR ORGANIZATION PROJECT-NUMBER KEYWORDS AAMRL#

THE AAMRL# WAS THE NUMBER THAT THE PAPER WAS FILED UNDER IN

THE ACTUAL LIBRARY. THE KEYWORDS WERE SUBJECT TERMS OF THE PAPER. THE INFORMATION ABOUT THE PAPER IS ACCESSED BY USING THE SELECT ALL COMMANDS. FOR EXAMPLE,

INPUT:

```
SELECT ALL FROM AP[ACADEMIC PAPERS] WHERE AUTHOR EQ HOLMES_J
```

OUTPUT:

```
YEAR       AUTH.        UNIVERSITY        KEYWORDS         AAMRL#
----       -----        -----------       --------         ------
69       HOLMES J       USC              CRT DISPLAYS      2021
71       HOLMES_J       USC              DECISION-MAKING   2345
```

THE DIFFERENT RELATIONS IN THE DATABASE WERE GIVEN CERTAIN NUMBER RANGES TO BE FILED UNDER IN THE LIBRARY:

PROJECT: 0000-0999

MA: 1000-1999

AP: 2000-2999

CP: 3000-3999

MP: 4000-4999

MF DENOTES MICROFICHE

LOWERCASE LETTERS (a,b,c,...) DENOTE VOLUME NUMBER

ALSO, I HELPED LONNY SHIMP CONVERT FORTRAN PROGRAMS FROM A VAX SYSTEM OVER TO A PC, AND I HELPED BRIAN ZAFF PREPARE FOR BRIEFINGS BY CUT AND PASTING PETRI-NETS.

EQUIPMENT:

IBM PC AT
NEC MULTISYNC JC-1401P3A
MOUSE SYSTEMS PC MOUSE
PACKARD BELL P8286
NEC MULTISYNC II
IBM PRO 420100
PRINTRONIX
DIGITAL LNO1
VAX 8650 MAINFRAME
ZENITH DATA SYSTEMS: ZWX-248-6Z, ZVM-1380, LAPTOP

3-D Audio Displays

Student: Douglas Brungart

Mentor: Richard McKinley

Harry G. Armstrong Aerospace Medical Research Laboratory

August 20, 1990

Acknowledgements

I would thank the following people for their assistance this summer:

Nancy Allen
Tim Anderson
Kristi Kline
Jim Gillespie
Dwight Henderson
Tom Moore
C. W. Nixon
Dave Ovenshire
Edward Riegelsberger
Janet Slifka
Denise West
William Yee

And to all of the other employees of AAMRL and SRL who have made me feel at home during my apprenticeship.

I would also like to offer special thanks to the following for their extra efforts to help me throughout the summer:

Mike Branicky
Ron Dallman
Mark Ericson
Angie Obert
Britt Peschke

Finally, I want to thank Richard McKinley for his guidance, dedication, and personal interest and because he never assigned a project that was too easy.

1. Introduction

The three dimensional sound localization research at AAMRL represents most recent development in the ongoing sound localization studies at BBA. Localization technology simulates sound sources at different locations relative to the listener using only a stereo headset. AAMRL/BBA has already completed the development of a two dimensional localization system. This system uses firmware with a software driver to project a standard sound source to any azimuth relative to the listener.

To complete the 3-D research the laboratory has built a geodesic dome, fourteen feet in diameter, that mounts 272 evenly distributed loudspeakers. This dome integrates a magnetic head-tracker to plot the head movements of subjects in response to sound stimuli. The dome is capable of generating fifteen different sounds at any one time, and can move any or all of those sounds around the dome at a rate of 720 degrees per second. In addition, the dome can use three speakers to produce a phantom sound anywhere between those speakers. Thus the dome can produce fifteen sounds at discreet locations, five sounds at any location, or any combination thereof.

The complexity of the system being researched, and of the equipment used to conduct this research, make localization an extremely exciting field of study. My participation in this research has consisted of writing a computer model to track sound rays and aiding in the calibration of the loudspeakers in the localization dome.

2. Sound Ray Tracing

My first project at AAMRL consisted of designing and coding a program to trace the paths of sound rays as they bounce off the walls, ceiling, and floor of a rectangular room. The program accounts for first, second, and third order rays (i.e. one, two, or three total bounces) and reports the angle of azimuth, angle of elevation, and total distance travelled at the termination of each ray. The program also graphically displays the room and the sound rays in three dimensions.

Later in the summer some further requirements were added to the program specifications. It now processes the angle of azimuth and elevation of both the source and the receiver. In addition, it finds the data for all possible sound rays in a room in any of the three orders and prints the data in a concise tabular report.

The first task the actual program must perform is the calculation of the angle of azimuth and elevation at the origination of each ray and the total distance travelled by that ray. This is accomplished by generating a virtual mirror image of the target across a wall in the room. This resulting mirror image can be mirrored across another wall to generate a second bounce, and across a third wall to generate a third bounce. This procedure must be carefully monitored to ensure that the virtual image is not created by mirroring off the same wall two consecutive times, as these two consecutive mirror images would cancel each other out. The x, y, and z coordinates of the source and the virtual image of the target can be used to find the angle of azimuth and elevation of the original ray and the total distance travelled before the ray contacts the receiver.

Once this information has been calculated the program can find the bounce points of the ray. The ray is checked against each of the three walls in its path until a bounce point that is inside the room is found. The ray is then advanced to that point, that point is recorded, and the current path of the ray is mirrored across the line perpendicular to the wall at the bounce point. This process is repeated until the ray reaches the receiver.

The processes outlined above are repeated for every possible first, second, or third order ray in the room. In any room where the source and receiver lie along an axis, however, there will be a number of repeated rays. To correct this problem the program places all of the rays of each order into a binary tree and eliminates any duplicate rays.

The final aspect of the program, the graphics display, is handled two different ways by the program. On the IBM PS/2 the program uses a VGA graphics adapter to display three different views of the room, one down each of the X, Y, and Z axes. On the Silicon Graphics Iris, the program displays the rays with a three dimensional perspective.

The program is intended to produce data for use in the three dimensional sound dome. It is hoped that the distances travelled by the sound rays can be converted into time of arrival at the receiver and that, along with the angles of azimuth and elevation, this data can be used to simulate the acoustic properties of a sound source within a room.

3. Calibration of the 3-D Localization Dome

Before the localization dome can be used for actual testing, the 272 loudspeakers that are attached at each of the vertices of the geodesic dome must be individually calibrated. This task involves attaching a microphone to the speaker being calibrated, generating pink noise through that speaker, and using a spectral analyzer to tweak the potentiometers attached to each speaker.

The hardware driver in the dome separates the control of the speakers into seventeen boards, each controlling sixteen speakers. The board are calibrated individually. A relay switch allows the sixteen speakers on the board to be selected sequentially by a pushbutton switch. Thus, in order to reach the sixteenth speaker on a board speakers one through fifteen must first be selected.

A microphone tripod is be attached to each speaker in the queue. This can be accomplished by using c-clamps or "bungy" cords. The size of the dome, however, can make the attachment of the tripod a considerable challenge. Extension poles are necessary to reach some of the speakers, and a great deal of climbing is also required.

One the tripod is attached, the speaker being calibrated is activated and used to produce pink noise from a noise generator. The microphone is attached to a Bruel & Kjaer 2131 spectral analyzer, which gives a very precise reading of the total sound, in dB, produced by the speaker. The potentiometer on the speaker controller board for the speaker being calibrated is "tweaked" with a small screwdriver until the spectral analyzer reports a total sound output of 98 dB.

To ensure proper calibration, all equipment must be calibrated before any speaker calibration can begin. The B&K and microphone are adjusted with a microphone calibration devise at 94 dB. The tripod is then attached to a previously calibrated speaker and the pink noise generator is adjusted until a reading of 98 dB is achieved.

When the dome is complete it will be used for testing the reactions of subjects to sound sources at different azimuths and elevations. Eventually the laboratory will build a device that can take input from a PC and generate sound in a stereo headset to simulate a sound from any direction relative to the listener. This technology will be used to create early warning systems for the pilots of combat aircraft.

4. Other Projects

In the course of the summer I was given a number of miscellaneous assignments which significantly contributed to my summer apprenticeship. In order to write the ray tracing program, I first had to learn the programming language 'C'. Although I already knew Pascal and BASIC, I found 'C' to be more challenging and more powerful than anything I had worked with before. In addition, I was asked to research spherical geometry and the equal distribution of points on a spherical surface. This problem forced me to use the interlibrary loan system at the tech library. Finally, my mentor suggested that I write a user friendly menu utilizing windows for the software that drives the localization dome. This project taught me a lot about file, screen, and memory manipulation in Turbo C.

5. Conclusion

My summer apprenticeship at AAMRL/BBA has been a valuable and rewarding experience. I have been exposed to the real world of scientific research, and all of its advantages and drawbacks. Furthermore, I have received on the job training in computer programming that will help immensely when I start college this fall. The most important advantage of my apprenticeship, however, has been the opportunity to see the everyday jobs of real engineers, scientists, and technicians. This experience will prove invaluable as I continue my education and plan for my career.

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INTEGRATED PROTECTION BY PRESSURIZED CONTAINMENT IN FLIGHT ENVIRONMENTS

Air Force Office of Scientific Research

1990 High School Apprenticeship Program

Caroline C. Chuang

Harry G. Armstrong Aerospace Medical Research Laboratory

Biomechanical Protection Branch

August 1990

ACKNOWLEDGEMENT

I would like to thank my mentor Mr. John Buhrman for his advice and supervision on the research projects that I completed for him. I also appreciate the opportunity to observe the laboratory experiments.

I thank Mr. Chris Perry for showing me how to use the laboratory's computer system and its scientific software packages, for helping me understand some of the concepts in statistics, and for permitting me to watch some of his tests.

I thank Lt. John Tallarovic for teaching me how to use the computer graphic package and digitizer.

In addition, I thank the entire staff at the Biomechanical Protection Branch for making me feel comfortable in new surroundings and for making me feel free to ask questions or ask for help.

INTRODUCTION

The Air Force Office of Scientific Research High School Apprenticeship Program has offered a great opportunity for high school students to work closely with researchers, to observe laboratory experiments, and to learn from experts in fields which, otherwise, would have remained unexplored under the high school curriculum. During my eight weeks at the Aerospace Medical Research Laboratory, I have had the opportunity to see various research facilities and experiments. I have learned a new programming language FORTRAN and a set of commands for several PC tools such as dBASEII, Ezgraf, laser printing, and digitizing. The Aerospace medical Research Laboratory has a very friendly staff. They are ready to offer help and area very eager to answer any question I may have. Under the guidance of my mentor Mr. John Buhrman, I have completed two modifications of a computer program and have written two new programs. In addition, I have analyzed data from further studies and organized them in a presentable graphic or tablet form. This program has exposed me to experimental research, scientific principles, and good work habits. Through firsthand experience provided by this program, I have narrowed my career goal to the engineering or medical field.

TECHNICAL DESCRIPTION

The following programs describe the programs that I modified or developed for this project.

I. WILCOXON RANK SUM TEST PROGRAM

Initially, a program had been written to perform Wilcoxon Signed Rank Tests for paired samples (using populations of equal size). However, unpaired analysis (using populations of unequal sizes) was needed to ensure that the same probability distributions were used for the two analyzed populations. For this reason, I wrote a program to perform the Wilcoxon Rank Sum Test on two unpaired samples with each population size ranging from 3 to 25. Also, the program calculates the standard deviation and the mean of each population as well as the percentage difference between the two populations. Now, this new program is available for laboratory's researchers to analyze data from their future experiments.

II. RANDOMIZED BLOCK DESIGN PROGRAM

The Randomized Block Design Program was written to create a test matrix consisting of a designated number of sequences. Each sequence would contain a designated number of test cells that would be arranged in their positions within the sequence randomly. This program was designed to generate the described test matrix using a randomized block design. This program allows the user to create up to twenty sequences with three to ten test cells. Additional rules were used in the program. The rules for this randomized block design were summarized as follows:

1. Each test cell may not appear more than once in each sequence.
2. When the number of sequences is less than the number of test cells, each test cell may not appear more than once in the same position of any sequence; however, if the number of sequences is greater than the number of test cells, the test cell must appear at least once in each position of the sequence.
3. The same sequence may not appear more than once in a test matrix. (The exception occurs when the number of test cells equals three as explained in Rule #4.)
4. When the number of test cells is three, there are only six combinations possible. In this case, the combinations must be allowed to repeat when the number of sequences exceeds six.

This program was designed with the laboratory's needs in mind. The experimental design (randomized block design) was ideal to ensure that the test cells would be evenly distributed. This program will be used by the researchers in the laboratory to set up the test matrix for future test plans.

III. Overall, the program has provided valuable opportunity for me to observe and work on computational and experimental projects. Through this experience, I have learned the importance of scientific method in performing experiments. Much of my time spent at the Biomechanical Protection Branch was reading former studies and technical reports in order to get a better understanding of the project. This preparation helped me to comprehend the technical jargon in order to facilitate any communication with the staff and to increase awareness of exactly what was happening in the laboratory. The technical background from the readings also helped me form my own hypothesis about the results of a particular test. I was then able to apply the knowledge I acquired from the laboratory work to other fields. My research oon experimental design and my randomized block design program emphasized the importance of a well designed test matrix to ensure that cummulative affects of retesting do not affect the results from the test program. My Wilcoxon Rank Sum Test Program, analysis of data from former studies, and organizing data from former studies taught me how to collect and to analyze data as well as preparing it in graphic or tablet form. Through discussions with various researchers and through this work experience, I have learned the importance of a disciplined approach and have become more interested in engineering and medical research.

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Dietrich, Frank H, and McClave, James T., Statistics, Dellen Publishing Company, San Francisco, 1985.

PREFACE

My name is Keisha Hayes; I represent Harry G. Armstrong Aerospace Medical Research Laboratory ,Human Engineering Division, Workload and Ergonomics Branch (AAMRL/HEG). I would like to give great appreciation to my Branch Chief Maris Vikmanis, mentors Greg Zehner, Kathleen Robinette and Jenny Whitestone. I also give special thanks to Staff Sergant Michael Greene.

This paper is presented as a culmination of my three eight week apprenticeships. The entire tenure was with the Ergonomics Branch where under watchful eyes I studied Cockpit Accommodation as well as other engineering tactics. The majority of my time was spent measuring dimensions of cockpits and creating manikins to fit into their respective airplane cockpits. The work that I accomplished will be incorporated into numerous data bases and serve as possible models for future use.

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.

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).

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 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 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.

By taking advantage of the fact the smaller pilot will move the seat upward and the larger pilot downward, 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.

Elctron Microscopy Techniques
Doug Marshak
Major John Grabau
Harry G. Armstrong Medical Reasearch Lab
August 22, 1990

Acknowledgments

I wish to thank the following people for the opportunity to spend this summer working for them:

Maj. John Grabau
SSgt. Joe Maslanka
TSgt. Matt Chase
Dr. Dave Mattie

Their friendliness and knowledge would make me recommend this job for any high school student.

This was my second year working in the Harry G. Armstrong Medical Laboratory Toxic Hazards Division as an assistant to the electron microscope technicians. Our job was to take photographs using the two kinds of electron microscopes: the transmission electron microscope and the scanning electron microscope. These photographs would later be studied by researchers. I unfortunately did not receive much of an opportunity to participate in the analysis of these photographs, but I did receive plenty of experience in the techniques of electron microscopy.

The process begins with the taking of samples. In this case livers from rats were used. Studies in the Toxic Hazards Division included the use of mice, pigs, and primates as well. These samples were placed in liver fixative to harden them and later miced into small blocks about the size of a pin head Onced miced, these samples were ready for processing.

Processing usually took about three days. The samples were exposed to a series of chemicals, including fixatives, cleaning agents, and stains. Among these chemicals was osmium, which stained the samples a dark blue, and several percentages of ethyl alcohol and propylene oxide, both of which cleaned the samples of any films or debris left over from surgery or fixing. Once processed, the samples were embedded in a yellowish plastic called epon.

Each epon capsule was about the size of a paper clip and contained one sample. Typically, about ten capsules were made for each tissue taken from an animal, and each capsule would contain a sample from the same tissue. The sample was embedded in the tip of the capsule, so it took on the appearance of the tip of a pencil. The tips of these blocks were then cut with a diamond knife to get very thin slices of the samples. These slices were placed on copper grids, which were the "slides" of the transmission electron microscope. These grids would then be placed under the scope and photographed, developed, and later analyzed for results.

I did not process any samples for the scanning electron microscope, so I cannot describe that process. I can, however, say that samples for this scope were mounted on a small tack rather than embedded in plastic, and the process appeared to be much simpler.

From what I understood, much of my work was for a study of the effect of hydraulic fluid on the liver. However, I also assisted in the micing of rat skin for an investigation into the possibility of computer simulations as a substitute for lab animals. While my work in this area was very superficial, it was exciting to see this possibility explored during a time when animal rights has become an important issue. I can say that I am proud to have helped in the effort, no matter how small my part was.

Basically, the experience I gained from this summer will be very helpful in college this fall. The college I am attending has two electron microscopes also, and I will be ahead of other students in knowledge of their uses and techniques thanks to this summer.

AAMRL/AFOSR Summer Research Apprenticeship Report

Jeremiah T. Rogers

October 11, 1990

Air Force Office of Scientific Research Apprenticeship, Summer 1990

EXCITING EXPERIENCE

When this apprenticeship program first stated, I was very skeptical. I had no idea what I would be doing or who I would be doing it with. Then I received a call from my mentor and he gave me a full description of what I would be doing and what his expectations of me were. I was scheduled an appointment to meet with Mr. Anderson. He gave me another overview of the work I would be doing, a few books to study and a tour of where I would be working. In short, I was made to feel at home.

The first day of work Mr. Anderson was on TDY, so I met Janet. Janet is a civilian contracter and she was also working in conjunction with Mr. Anderson. She showed me the computer to work on and she gave me a few instructions on how the editor system works. Other than that I was basically left alone to become acquainted with the editor.

Two days later I was given my first actual problem to handle. Janet gave me this 20 page program in pascal, told me to type this in and verify that it works in Pascal. Then translate the Pascal into 'C'. Needless to say I was dumbfounded.

After about three days, the entire program was entered in the computer. Then I had to go back and correct all the little typing errors which affected the program compilation. Now for me I would never have noticed these minute errors, so I called for help. I asked Mr. Anderson and he helpedme look for certain things which would direct me to the typographical errors. Finally after another few days all the errors were gone.

Then after a few futile tries at translating Pascal to 'C', I decided I had better learn C first. I obtained a book about C from Mr. Anderson. From there I read a few pages at a time and at the end of each interval I would try to write my own very simple program in 'C'. At first I was very successful, but then as the book became more complicated, so did the programs. Even though I was not as successful, I was constantly learning more. This process carried on until I felt I was ready to tackle the 20 pager!!

I started going through the program line by line changing little commands which are stated differently in 'C'. I was actually very successful. However I would always eventually encounter a problem which I could not solve. Then I was forced to call in assistance from Mr. Anderson. He would consistently analyze the problem and always find the solution. Through this process I (we) slowly worked our way through the program, successfully changing it to 'C'. The last I had heard after I had left, he had solved the last problem we were working on. Needless to say it was thoroughly tiring and relentless. However, it was also rewarding and fun.

I neglected to mention that many times throughout the eight weeks, I was forced to turn to others for help. Occasionally Mr. Anderson was not at work and I could not turn to him for help.

On these occasions I asked Janet for help. Janet was always willing to help me. She would stop whatever she was doing and assist me. This was whether the assistance was a simple error fixing or a complete lesson on a certain command. I always came away with a better understanding of 'C'.

Finally I would like to say that in all honesty I really did learn a lot. The knowledge I gained will be very helpful in the future. I used to be somewhat intimidated by computers, now I know that through patience and sweat that I can control them.

Summer Apprenticeship Report
Camouflage, Concealment, and Deception

by

James Shamiyeh

Mentor: Lt. Col. William Marshak

Harry G. Armstrong Aerospace
Medical Research Laboratory

August 5, 1990

Acknowledgements

I would like to thank a number of people for making my summer apprenticeship not only a valuable learning experience, but an enjoyable experience as well. First and foremost, I thank my mentor, Lt. Col. William Marshak. He did more than simply guide me through my scientific activities. He always took the time to help me place all of my activities and readings in the proper perspective. He always made sure that I knew how my projects fit into the "big picture." He also exposed me to an area of engineering that I had always taken for granted--human factors engineering. Lt. Col. Marshak stressed to me the fact that engineering advancements, as brilliant as they may be, are of very little use to mankind unless they are implemented in a way that allows them to be properly and safely used. Thus, whatever type of engineer I become, I will always remember to consider the human factors aspects of whatever I am doing.

I would also like to thank Dr. Gregg Irvin, chief scientist at SAIC (Science Applications International Corporation), and his SAIC associates --Tracy Donohue, Greg Keep, and Tom Haberlandt. Dr. Irvin and his associates work on the base on different aspects of the "Camouflage, Concealment, and Deception" project. I spent a great deal of my time with them during the first four weeks of my apprenticeship, helping them finish experiments before leaving for the Netherlands. (Many of the decoys that they designed were tested at Soesterberg Air Base in the Netherlands.) Dr. Irvin and his associates made me feel like I truly belonged from day one, and for this I am grateful. They always "utilized" me instead of simply "keeping me busy." Also, Dr. Irvin was never too busy to sit down with me for an hour and discuss the human visual system.

Finally, I would like to thank Dave Sivert, a contractor with LTSI. Without his help, I could never have completed my silhouette project. He taught me how to develop the film.

Introduction

During the eight weeks of my apprenticeship, I spent time on a wide variety of tasks and not on just one project. Thus, I will follow my mentor's suggestion and discuss each of these tasks in detail. I will then give an in-depth account of my "independent" project that consumed much of my final four weeks. Almost everything that I did during this apprenticeship involved some type of camouflage device. The first such camouflage device was the "masking pattern."

1.0 MASKING PATTERNS

I spent some of my time helping Greg Keep formulate and perform an experiment to determine which two "masking patterns" out of a group of four were the most effective. A "masking pattern" is a pattern that is based on airplane shadows. It is etched onto a parking pad by a special acid spray, and its purpose is to "hide" an airplane resting on it. The four patterns to be tested were formulated by orienting model planes in a variety of ways and then shining light on them from a variety of angles. The resulting shadows were then studied to see which would most likely hide a parked airplane. The four patterns that were eventually chosen were not single airplane shadows, but combinations of different shadows. The patterns were made of only straight lines so that they could be etched onto a real parking pad with relative ease. We tested the patterns by utilizing the terrain-board. It is a 1/700 scale model of an Air Force base. We made 1/700 scale parking pads (octagon shaped with rectangular runways attached--see Figure 1) and then painted the four different 1/700 scale masking patterns on them. A "blank" parking pad was also made for the experiment. We used a 1/700 scale F-15 and a 1/700 scale F-16 for the stimuli in the study.

The experiment was divided into eight blocks for each subject, with each block consisting of twelve trials and a separate set of conditions. One of these conditions was the subject's distance from the terrain board (either 1.5 or 2.5 nautical miles after scale translation). Another condition was the order of the five pads (the blank pad included). (Note: Within one block of trials, I placed each of the pads on a predetermined location on the board and did not rearrange them until the next block. This method proved to be very time-efficient, and since the subject did not know this fact, it did not help them "guess" which pad contained the plane.) Another condition was the orientation of the pads. I placed the pads so that either they all were "octagon-up, runway down" or all "octagon-down, runway up." These two orientations effectively simulated what attacking pilots would see when approaching parallel to the runway strips from either direction. Finally, each block utilized only one stimulus, either the F-15 or the F-16. A block of trials was conducted as follows. Mr. Keep covered the subject's eyes, and I placed the five pads (including the blank one) onto predetermined locations on the terrain board. (Note: All pad and plane locations were predetermined by a random number generator in order to prevent human bias.) I then set a plane on one of the pads. Mr. Keep uncovered the subject's eyes for three seconds, and the subject then told us which pad he felt contained the plane. The subject's eyes were again covered, and I placed the plane on another pad. This process was completed twelve times per block. With twelve trials per block, eight blocks per subject, and ten subjects, a total of 960 trials were executed.

Several aspects of this study helped substantiate the data. For example, this study contained some "subject deception." The subject was told that a plane would always be sitting on one of the pads, but during one-sixth of the trials, I did not place a plane on any pad. This told us which pad looked most like it contained a plane when actually no plane was present. Also, the blank pad was an important factor. If, for example, the subject made an error when the plane was on the blank pad fifteen percent of the time, and the subject made an error when the plane was on pad "A" seventeen percent of the time, pattern "A" is not necessarily an effective masking pattern.

After all the data was collected and analyzed by a statistical program, two of the patterns were clear "winners." (See Figure 2 and Figure 3 for the most effective masking patterns.) As we had expected, they were the two patterns that occupied the most space on the pad--the "busiest" patterns. Helping Mr. Keep with every aspect of this project gave me insight into how a statistical study is accomplished. In addition, I provided useful service to him, for this experiment could not be executed by one person.

2.0 KC-135 AND AWACS:TWO-DIMENSIONAL DECOYS

I spent a great deal of time during the first two weeks of my apprenticeship helping the SAIC workers actually construct a two-dimensional "silhouette" decoy of a KC-135 (with a detachable "dome" that convert it to an AWACS silhouette.) The flat, single color decoy was constructed out of a special mesh-like fabric. Its purpose is to provide an inexpensive, effective way to trick an attacking pilot into thinking a plane is where it is not. The construction of the life-size decoy was the final stage of a long process, a process which I was soon to begin for two other airplanes. Thus, helping finish the KC-135 project helped me with my own project in later weeks.

Before I arrived, Dr. Irvin and his associates had already completed the preliminary process (which I will explain later). They had chosen eight reference points and had calculated the distance from each perimeter point to each of the reference points. The first step of construction was to measure and mark the eight reference points onto a vacant runway. (See Figure 4) We then measured and marked each perimeter point, always using three reference points to insure accuracy. We marked fewer points for straight lines and many more for curves. After all the points were plotted (over 500 of them), we traced the outline of the decoy with very bright pastels. Next we placed the pieces of fabric over tracing, and with painstaking care we made sure that the seams were even. (For the person deploying the decoy, the seams are his best clue as to how the pieces fit together.)

Finally, we cut the fabric, following the outline which was visible through the mesh.

After the decoy was finished, we went to the top of a nearby observation tower to observe our work. The decoy was not extremely convincing from such a short distance, but it was much more convincing than I had expected. The theory behind the success of the two-dimensional decoys is that an attacking pilot must identify an object and choose it as a target in a matter of seconds and from a relatively distant location. Thus, pilots often act on instinct. The decoys are meant to trick these instincts.

3.0 PLANNING MY OWN SILHOUETTES

One day Lt. Col. Marshak suggested that I complete the entire "silhouette process" for two Soviet planes. At first I did not understand. Why would decoys of Soviet planes be needed by the United States Air Force? Then he explained further. When pilots train, their targets are often simple, stereotypical "bull's-eyes." The pilots would benefit much more if their training experiences were more realistic. Since using real planes as targets for the training pilots would become quite expensive, a cheaper method is needed. Lt. Col. Marshak felt that the two-dimensional "decoys" were the perfect target. A paper silhouette would be very cheap, simple to mass produce, and easy to deploy. Also, as was proven by successful two-dimensional decoys, the silhouettes are convincing substitutes for real planes. Thus, the Soviet plane silhouettes that I was making would hopefully help the training of better pilots.

The MiG-29 Fulcrum and the Su-25 Frogfoot were the two planes that Lt. Col. Marshak decided would be excellent targets. The first and most tedious part of the "silhouette process" was building scale models of the two planes. (This was done in the midst of several other activities with SAIC and therefore took several days to complete.) After the models were built, the next step was to observe different shadows of the planes to see which ones looked most like the real airplanes. Dr. Irvin had told me that he had found from experience that the most convincing shadows were created when the azimuth of light was twenty degrees. Using simple trigonometry, I measured the height of my lamp and divided it by the tangent of a twenty degree angle to find how far the plane should be from the light. After marking the distance with a white piece of paper, I placed a model on the paper. I then darkened the room, turned on a lamp pointed at the plane, and observed different shadows simply by changing the orientation of the plane. I then completed the process for the other plane.

I found four or five realistic, "lifelike" shadows for each of the two planes. The next step in the process was to photograph these shadows. This was difficult because almost all of the work had to be completed in the dark. (Otherwise I would have exposed the film.) First I turned all the lights off except for the lamp pointed at the white paper. I then placed a plane (the Su-25 first) onto the white paper in order to reproduce one of the realistic shadows that I had found earlier. Once I had found the proper placement of the plane, I placed white paper markers on the floor (off of the white paper) pointing to the nose and the front landing gear. I then turned off the lamp and waited until my eyes became dark adapted before continuing. Once I could see relatively well, I took a piece of "black-and-white" photographic paper out of the box. I picked up the model plane and placed the photographic paper over the white paper. I then returned the plane to its former position (using the markers), but this time it was on the photographic paper. When I was sure of the plane's position, I flashed the lamp's light onto the plane for approximately two seconds. A photograph of the shadow had been taken! I completed this process four more times for the Frogfoot and then five times for the MiG-29.

The next step in the process was developing the film. Developing this film was no more of a challenge then developing any other film, but since I had never developed film, I had to learn. Dave Sivert, a photographer working for LTSI, showed me how to use the chemicals and how to develop the film--three minutes in the developer (Dektol), one minute in the stopper (water+indicator containing acetic acid), and four minutes in the finisher. After developing the photos and rinsing them, I was ready for the next phase of the "silhouette process"--digitizing the shadows.

Before using the digitizing tablet, I made tracings of the shadows in the photos. I then taped a tracing (an Su-25 first) to the digitizing tablet, simply a huge board. At this point I picked six or seven reference points around the plane's perimeter. My choice of points was somewhat random, but I tried to insure that every perimeter point would have at least two points in its general vicinity and that the angle formed by the perimeter point and the two reference points (vertex at perimeter point) was not too small or too large. (Note: Long distances or extremely small or large angles reduce the accuracy of this trigonometric method of measurement and should therefore be avoided whenever possible.) After choosing these points and marking them on the perimeter, I began to digitize. The digitizer is operated by a computer mouse that has a clear surface which contains "cross hairs." In order to "digitize" a point, I simply moved the mouse so that the point where the cross hairs meet was directly above the desired point, and I then "clicked" the mouse. When a point is digitized, it appears on the computer monitor. Another feature of the digitizer program is that it records the exact x and y coordinates (in millimeters) of each point that is digitized. Thus, whenever I digitized a reference point, I was able to record its coordinates for later use. One major consideration when digitizing was how many points to use. Since every point that I digitized would one day be plotted on some airfield, I wanted to use as few points as possible. (I vividly remembered my experience constructing the KC-135.) When digitizing a curved part of the plane I used many points, and when digitizing a straight line I used just a few points. (A curve requires many points if it is to be drawn smoothly. A line requires only two.)

The final phase of the "silhouette process" was to feed the data from the digitizer into a spreadsheet and manipulate it into a useful form. I was able to modify a spreadsheet that Dr. Irvin had used for the KC-135 and the AWACS. First, I erased the KC-135 coordinates from the first two columns of the spreadsheet and imported my new file from the digitizer in its place. (X-coordinate was in column 1, and Y-coordinate was in column 2.) I used the next two columns of the spreadsheet for the scale translation. Every coordinate in the first two columns was multiplied by the reciprocal of the scale of the model that I built, and the new value was inserted in column three(x) or four(y). (For example, the Frogfoot model was 1/72 scale. I therefore multiplied all of the digitizer coordinates by 72.) The next six to eight columns utilized the distance formula to calculate the distance from the point in that row to each reference point. (See Figure 5 for spreadsheet example.) Thus, before recalculating the spreadsheet, I erased the KC-135 reference points and inserted the new reference points. The final stage of this part of the process was to print a basic XY graph of the airplane. The picture aids immensely when the silhouette is actually constructed.

Lt. Col. Marshak will decide if the silhouettes that I designed will ever be constructed and used.

4.0 MEETING THE MEN WHO USE THE MACHINES (Lesson in Human Factors)

One day Lt. Col. Marshak was making a trip to a test wing to examine the pilot instrument panel in a KC-135 parked there, and he brought me along. The instrument panel had been recently modified and many pilots were having problems using it. When the panel had been redesigned, the engineers had obviously not considered human factors. When we entered the cockpit, one of the plane's pilots expressed his opinions about the panel. He showed us the parts of the panel that were well designed and the parts that were difficult to use. I quickly realized that if the engineers had simply talked to him or someone like him before designing the panel, many problems could have been avoided. The next day, I again accompanied Lt. Col. Marshak to the test wing, this time to see a B-52. The navigators' panels of the B-52 were in the process of being redesigned, and Lt. Col. Marshak was not going to allow human factors to be ignored again. He took photos of the panel, always placing rulers at the bottom of the photographs. A developer could then enlarge the photos of the instruments to life-size, using the rulers in the photos as a guide. Thus, when the panel is redesigned, Lt. Col. Marshak can move his photos around to simulate the new design. This will give the designing engineers a good idea as to whether or not the new panel is "user friendly." My experiences these two days taught me that human factors problems with new designs can be prevented with just a little foresight.

5.0 CONCLUSION

My summer apprenticeship provided me with many very valuable experiences. When not busy with the aforementioned activities, I spent my time reading Dr. Irvin's and Lt. Col. Marshak's books about the human visual system and the function of the brain. This material has given me what I feel to be a lifelong fascination with the human body, and I hope to one day pursue this interest in medical school. Thus, I did not only learn about camouflage and human factors engineering during my apprenticeship, but I also developed a clearer idea of what I want to do with my life.

Figure 1

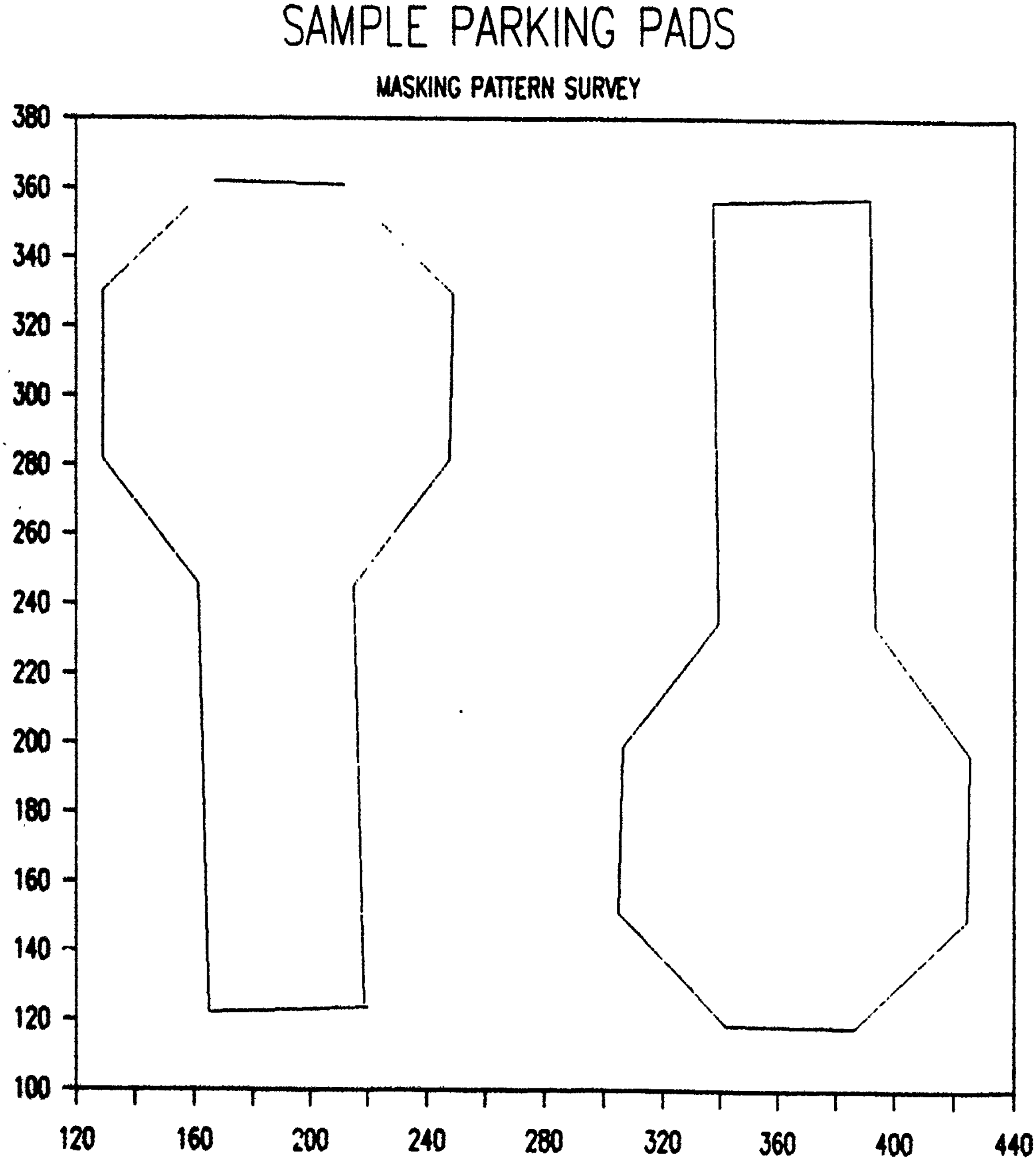
SAMPLE PARKING PADS
MASKING PATTERN SURVEY
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
120
160
200
240
280
320
360
400
440

Figure 2

"DANCER" MASKING PATTERN

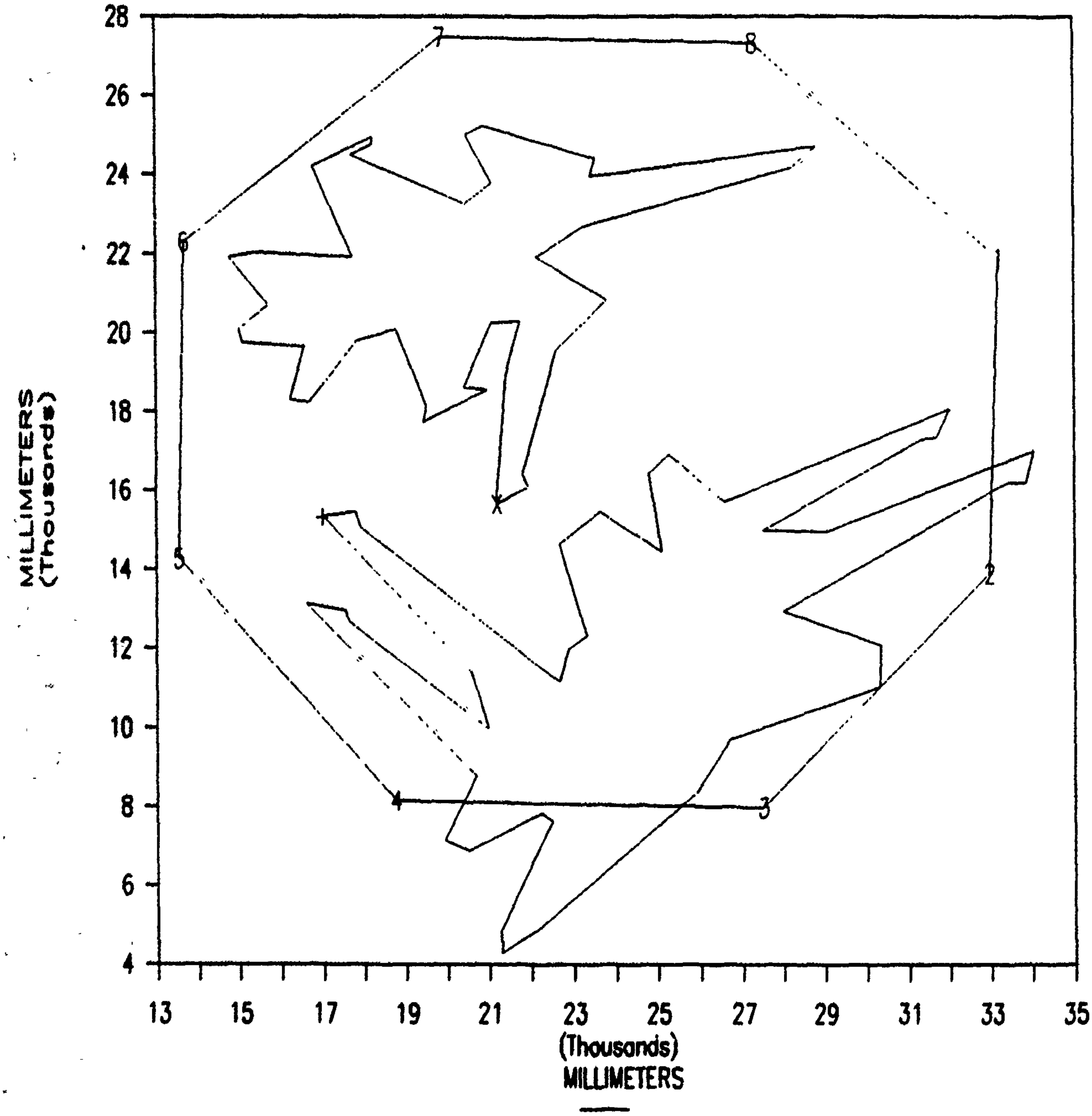

Figure 3

"SIAMESE TWINS" MASKING PATTERN

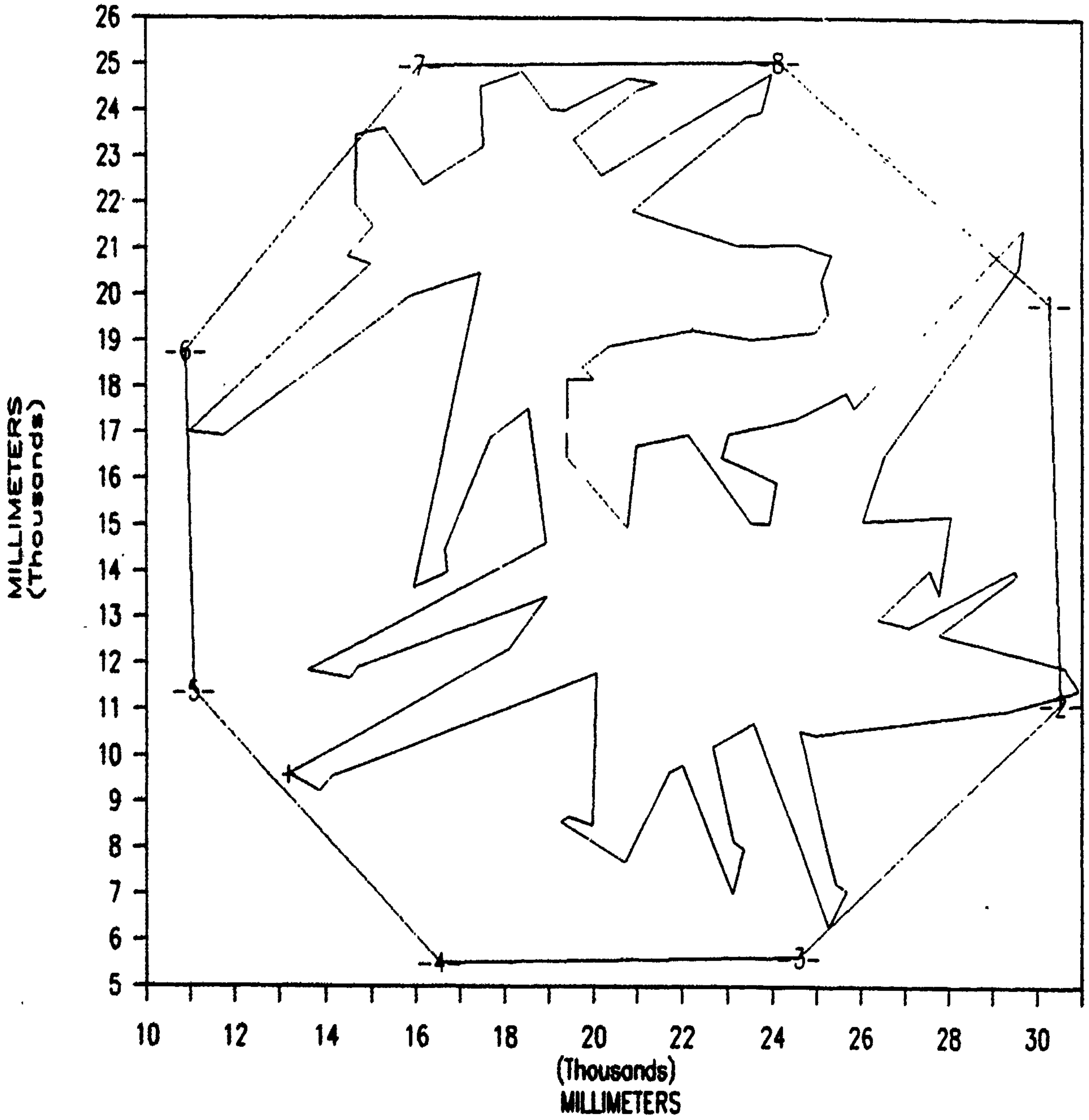

Figure 4

AWACS/KC-135 Silhouette

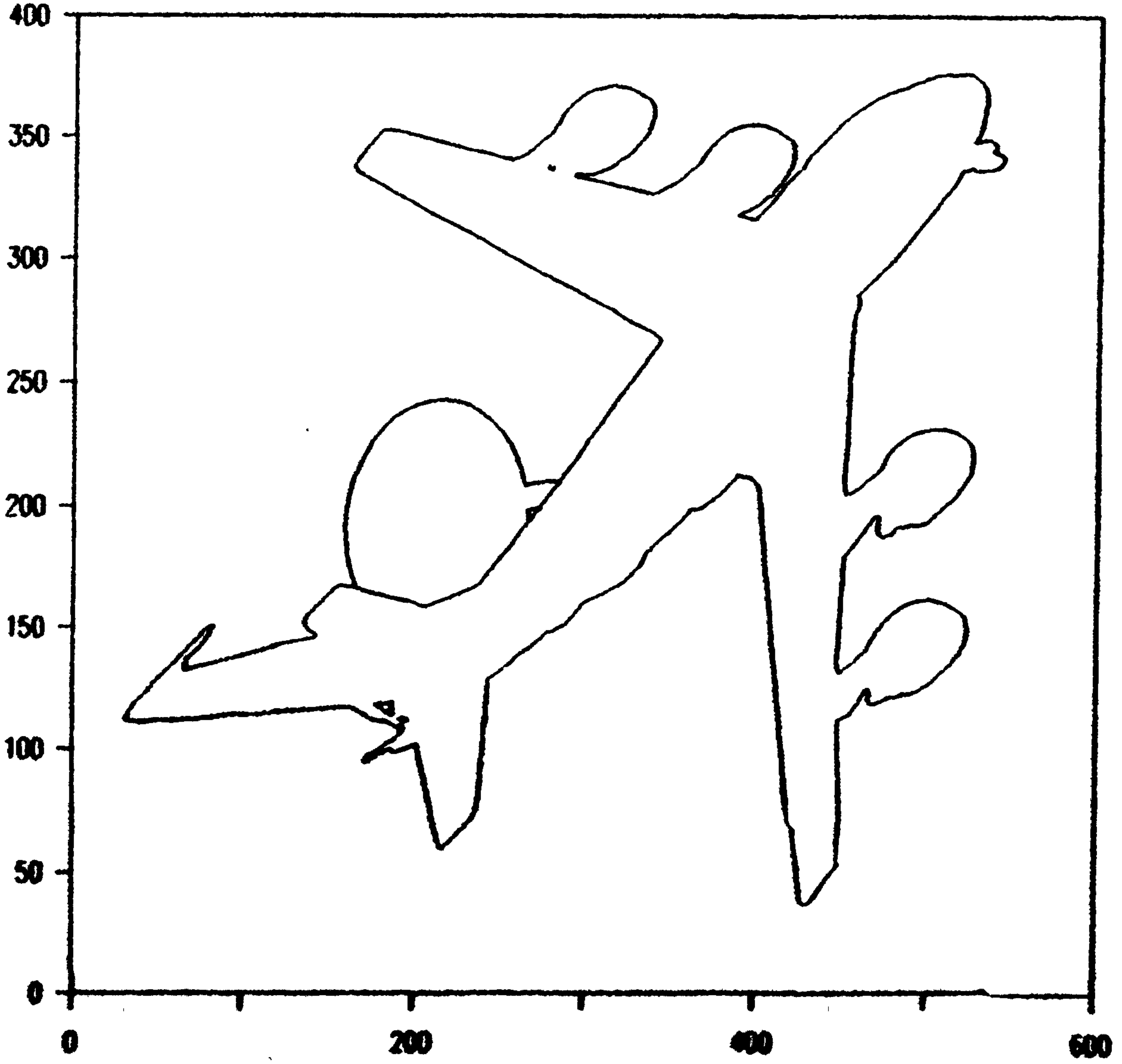

Figure 5

SPREADSHEET CALCULATES THE DISTANCE FROM EACH PERIMITER POINT

OF THE Su-25-ST1 AIRCRAFT TO SIX SPECIFIED REFERENCE POINTS

COORDINATES ARE FROM THE FILE: H:\2-D\DOT_1.WK1

WORSHEET NAME: H:\2-D\SAVE.WK1 DATE UPDATED: 08-08-90

	INPUT COORDINATES				DISTANCE FROM EACH OF SIX R			
	SCALE MM		ACTUAL MM		Dist	Dist	Dist	Dist
	X	Y	X	Y	REF 1	REF 2	REF 3	REF 4
1	+244.16	241.081	17580	17358	2953	5473	5878	7678
2	237.94	236.491	17132	17027	2426	5282	6232	8221
3	231.44	232.408	16664	16733	1939	5186	6640	8769
4	230.12	233.195	16569	16790	1952	5278	6743	8832
5	229.25	232.332	16507	16728	1871	5250	6795	8915
6	228.92	230.532	16483	16598	1742	5146	6801	8991
7	226.94	226.627	16340	16317	1428	4970	6912	9241
8	225.19	223.203	16214	16071	1153	4827	7022	9465
9	222.47	216.991	16018	15623	666	4580	7210	9849
10	221.38	213.719	15940	15388	418	4449	7296	10034
11	219.70	208.166	15819	14988	0	4243	7445	10343
12	218.13	198.809	15706	14314	683	3897	7653	10805
13	216.91	195.36	15618	14066	944	3831	7789	11019
14	215.41	192.926	15510	13891	1140	3836	7933	11209
15	214.52	190.415	15446	13710	1331	3809	8039	11367
16	213.73	191.506	15389	13788	1274	3895	8074	11366
17	213.15	188.868	15347	13598	1467	3852	8163	11512
18	211.14	184.177	15203	13261	1834	3865	8395	11830
19	209.42	180.652	15078	13007	2115	3913	8591	12083
20	207.51	176.417	14941	12702	2449	3984	8821	12380
21	205.15	171.701	14771	12362	2827	4111	9101	12725
22	205.55	171.244	14800	12330	2847	4079	9086	12724
23	204.08	169.799	14694	12226	2983	4179	9224	12872
24	203.04	169.748	14619	12222	3015	4254	9294	12932

ARNOLD ENGINEERING DEVELOPMENT CENTER

Converting Saturn Data Base
Into Paradox 3.0

By:
Timothy Craddock

A.J. Cable and L.L. Campbell
AEDC/CALSPAN

Aug. 20,1990

Acknowledgements

I would like to thank Larry Campell, John Cable, Wayne Jennings, and Gerald Cook for helping me solve some very tough problems. I would also like to thank Jerry Smith, Greg Denny, Janice Denny, Jason Chandler, Cathy Crumm, and Jack Hawkins who from the first day became my friends and co-workers. I also want to thank the US Air Force and UES for giving me a chance to work at AEDC this past summer.

The SATURN DATA BASE program contained over 2500 shot records which were stored on three RLO2 disks on a PDP-11 computer terminal. The size and complexity of the program made it difficult to search through, which was the whole purpose for keeping the data base. I started my work by reading through the Paradox 3.0 introduction book. After I became familiar with the program, I created two new data base tables on the Paradox 3.0 data base system. We kept only the most important fields, 47 in all, which made the tables much smaller. The old data base, Saturn Base, was not as efficient as was previously thought. Because of its size and run-time, very little data had been put on the computer for approximately four years. So I had to update the records to the current shot. The process of converting the already stored records in Saturn Base to Paradox was lengthy and hampered by numerous problems and limitations. A more detailed account of the problems I encountered will be described later in my report. I shall now relate to you the entire process I followed in my work this summer.

I started my work in front of a computer and remained there the entire summer. My first objective was to become familiar with the Paradox data base program. After I went through the introduction book, I created two Paradox data base tables: <u>MDL-DATA</u> (Model data) and <u>G-DATA</u> (General Information). I then proceeded to manually input approximately 700 shot records, up to where the data base ended.

From there I proceeded to convert the old data base records to ASCII files by way of an .RGL program. This process took about seven to eight hours to convert one disk. This was caused by the way the old data base searched through its records to retrieve information.

After this process concluded, I used Z-STEM$_{PC}$'s Kermit transfer program to transfer the ASCII files from the PDP-11 to my PC. One problem arose when the two versions of Kermit that I was using were incompatable. When that problem was solved, I encountered another problem because the Kermit program would only transfer 94 characters per line. I needed to have it transfer 255 characters per line in order for the Paradox tables to read the information properly. I then rewrote the .RGL program to take in these limitations. Attatched is a copy of the .RGL program I wrote to correctly transfer the necessary information (page 6). After I fine tuned the program to function properly, I then was able to transfer the files to my PC correctly. More frustration arose when I discovered I had to manually take out all carraige returns from my ASCII file. This task took approximately one hour to finish.

Although many problems arose, several meaningful results did come out of this maddness. Besides gaining meaningful experience in computer programming and problem solving, I got all but one of the disks transfered. I also saved CALSPAN and Arnold AFB two months of hair pulling, teeth clinching heartache. As a part of my experience, I learned how better to communicate with my co-workers and the proper way to incorporate patience in all problem solving techniques. Furthermore I learned that many times the most simple applications can turn into giant monsters.

REFERENCES

Larry Campbell - Test Engineer

Wayne Jennings - Test Engineer

Gerald Cook - Computer Programmer

Greg Denny - Test Engineer

Jack Dewitt - Test Engineer

Jerry Smith - Technical Assistant

```
Debug
Open DL1:Preshot.DBF as 1 using Shot_No.1,Date,Title,
   Test_Type,Mod_Type,Mod_Matl,Diap_Rel_P,Pow_Type,Bt_Gas,
   Sr_Gas,Lr_Gas,Hps_Ser_No,Hpsa_Ser_No,Lt_Ser_No
Open DL1:Postshot2.DBF as 2 using Shot_No.2,Piston_Wgt,
   Powder_Wt,Pc_Crg_Pr,Pt_Crg_Pre
Open DL1:Postshot3.DBF as 3 using Shot_No.3,Bt_Pres,Ur_Press,
   Dr_Press
Sort 1 D by Shot_No.1
Temp Shot pic 99999
Mon pic 99
Da pic 99
Yr pic 9999
Output DL1:Preshot1.ASC
Set width 94
Set length 20
Conditionals
Selectif (Shot_No.1 < 6200)
Endconditionals
Main
Move Shot_No.1 to Shot_No.2
Find Shot_No.2 in 2
Move Shot_No.2 to Shot_No.3
Find Shot_No.3 in 3
Gregorian Date to Mon Da Yr
Print [Next,1] Shot_No.1
Print [Current,6]1 (",")
Print [Current,7] Mon
Print [Current,9]1 ("/")
Print [Current,10] Da
Print [Current,12]1 ("/")
Print [Current,13] Yr
Print [Current,17]1 ("/")
Print [Current,18] Title
Print [Current,58]1 (",")
Print [Current,59]Test_Type
```

```
33 Print [Current,91]1 (",")
34 Print [Next,1]Mod_Type
35 Print [Current,23]1 (",")
36 Print [Current,24]Mod_Matl
37 Print [Current,51]1 (",")
38 Print [Current,52]Diap_Rel_P
39 Print [Current,60]1 (",")
40 Print [Current,61]Piston_Wgt
41 Print [Current,69]1 (",")
42 Print [Current,70]Powder_Wt
43 Print [Current,78]1 (",")
44 Print [Current,79]Pow_Type
45 Print [Current,87]1 (",")
46 Print [Next,1]Pc_Crg_Pr
47 Print [Current,8]1 (",")
48 Print [Current,9]Pt_Crg_Pre
49 Print [Current,17]1 (",")
50 Print [Current,18]Bt_Pres
51 Print [Current,25]1 (",")
52 Print [Current,26]Bt_Gas
53 Print [Current,29]1 (",")
54 Print [Current,30]Ur_Press
55 Print [Current,38]1 (",")
56 Print [Current,39]Sr_Gas
57 Print [Current,42]1 (",")
58 Print [Current,43]Dr_Press
59 Print [Current,51]1 (",")
60 Print [Current,52]Lr_Gas
61 Print [Current,55]4 (",")
62 Print [Current,59]Hps_Ser_No
63 Print [Current,62]1 (",")
64 Print [Current,63]Hpsa_Ser_No
65 Print [Current,66]1 (",")
66 Print [Current,67]Lt_Ser_No
67 Endmain
```

X-RAY COMPUTED TOMOGRAPHY AND IR ANALYSIS MODELS FOR PROPULSION SYSTEMS

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AUGUST 10,1990

1.0 ACKNOWLEDGMENTS

I would like to thank my mentors, Martha Simmons and Rita Walker, for helping to increase my understanding of the science and engineering field, and giving me an idea of what it is like to be a woman in a science field. I would like to express my appreciation to everyone who works in the Sverdrup Technology Department. They have all been very helpful and understanding. Finally, I would like to thank Carlos Tirres who was in charge of this program at AEDC, the Air Force, and Universal Energy Systems for allowing me to have this opportunity.

2.0 INTRODUCTION

I worked on two projects this summer. The projects were initiated by Sverdrup's Technology Department and involved different aspects of solid rocket motor (SRM analysis. I also worked with several other people on special projects in the Technology Department. This was very helpful for me as I learned to operate a personal computer (PC) and to apply several different computer programs. For example, I learned to use LOTUS to calculate formulas, prepare spread sheets, and produce graphs. I used MS-DOS in order to upload and download data files from the mainframe computer to the PC and to execute programs. This report will explain the work that I accomplished on the two technology projects directed by my mentors.

3.0 OBJECTIVE A

The first project involved applying an infrared (IR) radiation model for analysis of the IR emission characteristics of propulsion generated plumes. The objective for this project was to complete the post-test analysis of the Strategic Defense Initiative Organization (SDIO) SRM test series. This work involved validation of the Standard Infrared Radiation Model (SIRRM),(Ref. 1). The word validate means to compare actual collected test data to calculated results from the computer program. Improved accuracy and validation of computer programs, such as SIRRM, increases the confidence level in the application of calculated results and identifies the viable range for application of the model.

4.0 APPROACH A

In 1989, SDIO sponsored four test series in the J-4 Propulsion Test Cell at AEDC. Four superBATES motors were test fired at simulated altitudes of approximately 100 Kft in the orientation as shown in Fig. 1. These motors were exactly alike except for the amount of aluminum (Al) in the propellant. Aluminum is added to SRM propellants in order to stabilize the burning process. As Al burns it combines with oxygen in the combustion chamber and produces aluminum oxide (Al_2O_3). Plume emission data and Al_2O_3 particulates were collected during the tests. Fig. 1 shows the probe used to collect particle data inserted into the plume from the left side. Other nonintrusive radiation measuring instruments, sixty in all, were also installed in the test cell.

The radiation from a solid rocket exhaust plume results from basically two sources: the gaseous exhaust products and condensed Al_2O_3 particulates. Al_2O_3 will exhibit a continuum thermal-type radiation; the gases in the exhaust will exhibit characteristic band-type radiation. This signature can be thought of as the fingerprint which can be used to identify a target.

Al_2O_3 particle samples were collected by a probe inserted into the plume exhaust. These samples were sent to the Grumman lab for analysis to determine the optical properties of the actual particles produced by the SRM combustion process. Al_2O_3 is very white in the pure form. When collected in the plume, the particles are contaminated and look dark, sometimes even completely black. Optical data measured from the pure form of Al_2O_3 was used by SIRRM in the original analysis. The results were not valid because the Al_2O_3 in the exhaust plume is not represented by the pure properties. The Al_2O_3 becomes contaminated in the combustion process and therefore the emission properties change.

New particle optical properties (POP) were measured using the samples collected from these tests. The new data takes the form of the emissive properties of Al_2O_3 as a function of wavelength, temperature, and particle size. This new measured data were entered into the SIRRM computer program and the accuracy of SIRRM was re-evaluated.

5.0 RESULTS A

Calculated spectral results showing the effect of particle optical properties and representative data are shown in Fig. 2. The most recent calculations are represented by curve no.3. These results indicate an improvement in the model. However, an underprediction of the data is observed. Other factors involving searchlight radiation is felt to account for some of the differences shown here. The general features of the data are contained in the calculation. The particle continuum can be observed across the entire wavelength range. The water radiation band is seen centered at 2.7 microns and 6.3 microns, CO_2 near 4.3 microns, CO near 5.0 microns and HCl clearly visible around 3.5 microns. The radiation beyond 7 microns is attributed to H_2O and Al_2O_3 continuum.

6.0 CONCLUSIONS A

The SIRRM computer program was evaluated using improved particle optical property data files for input. It was shown that the agreement with representative data improved.

7.0 OBJECTIVE B

The other project I worked on was x-ray computed tomography for analysis of SRM anomalies. The objective for this project was to develop limited angle computed tomography (CT) for nonintrusive diagnostics of SRM testing. Nonintrusive means not affecting the firing of the rocket when collecting the data. Conventional radiography has been used at AEDC to measure burn rates and to observe formation of anomalies in the motor during testing. Conventional radiography is a two-dimensional representation of a three dimensional object; therefore, the internal layers are sometimes hidden by outer layers. Computed tomography is a technique that provides a three-dimensional view of the object which allows one to observe the internal surfaces. Data supporting this work were taken in January of 1989. This report describes the work that was involved in the analysis of the data.

8.0 APPROACH B

Computed tomography has been used in hospitals with one source and one detector which rotate around the patient to obtain several views. Using one source and one detector is suitable for this application because the patient can remain still during the data acquisition. However, it is not advantageous for rocket motor testing since the data must be acquired quickly due to the fact that the motor burns quickly. Eleven sources and eleven detectors, equally spaced around the motor, acquired data simultaneously during the firing. This gives eleven views of the motor which was determined to be the minimum number for an acceptable reconstruction of the motor. X-ray photons are the source of radiation and the detectors are the film which record the data. The film was positioned on a light box in front of a high resolution video camera focused at the best spot to observe the crack. The Quantex image processor was used to digitize and store the data on a floppy disk for reduction on a PC. Digitized means that the Quantex takes the image and converts it to numbers corresponding to different shades of gray between zero and 250. The lightest white is 250 and the darkest black is zero.

The next step was to reduce the data using the PC and programs written expressly for this purpose. One program was written to analyze a cross section of the motor in the area where the crack was located . This first slice, Fig. 3, is obviously not centered. If the images are not all centered the reconstruction will contain artifacts and will not be clear (Ref. 2). Another computer program was used to center the data and calipers were used to verify the center, Fig. 4. After all eleven slices were centered they were saved to a file.

Before reconstructing the image the nonlinearity of the film had to be corrected. This was accomplished by using an x-ray image of a step wedge with known intensities to compare with the radiance intensities the Quantex digitized. Since the wedge had five steps this intensity ratio (I/Io) gave five points. Linear equations were then developed to interpolate to the twelve values shown in Fig. 5. After the corrections were completed, the data were uploaded to the Amdahl mainframe computer which reconstructed the images. Finally, the images were downloaded to a PC for display.

9.0 RESULTS B

Fig. 6 is a schematic of the motor used in these tests showing two orientations. From this angle a crack is visible as shown. When looking at the motor from another angle, Fig. 7, the first crack is no longer seen, but two new ones appear. Consequently, it is necessary to use more than one angle to effectively investigate anomalies such as cracks. Figs. 8 are the CT reconstructions obtained for this study. Image A (Fig. 8a) is an idealized illustration of the motor. The outer black ring is the case which appears black because the case is almost transparent to the X-rays. The black hole and the line in the middle of the reconstruction are the bore and the slot which were cut into the propellant to make it burn radially. The green portion in the middle is the propellant. Image B (Fig. 8a) is an actual 11-angle reconstruction of a slice taken across the motor below the crack; thus, it looks like the idealized representation. Image C (Fig. 8a) is the reconstruction of a slice where the crack first starts to appear. The crack is positioned directly across from the slot. A conventional X-ray radiograph taken at an angle straight across the slot probably would not show the crack, because it would be obscured by the slot. This illustrates why CT is superior for this application. Image D (Fig. 8a) is a slice farther upstream on the motor in the area where the crack is apparent. Several additional slices (0.03 in. apart,axially) as shown in Figs. 8b and 8c were taken to determine how far the cracks extended. As seen in Fig. 9, when these slices were "stacked up" using a three-dimensional display program. It was determined that the area with cracks only extended about 0.3 in. along the axis of the motor.

10.0 CONCLUSIONS B

X-ray radiography has been used at AEDC for measuring propellant burn rate and for anomaly observations during testing. Computed tomography has been used for measuring propellant burn rate during testing and for examining / measuring propellant voids before testing. This is the first time the limited angle technique has been employed at AEDC to examine a crack before testing.

This is important because cracks tend to expand and propagate during testing and change the performance of the motor. If the limited angle CT technique can locate a crack before testing, it will be able to locate it during the test and monitor its growth. Computed tomography is, therefore, a promising technique for investigating the effects of motor anomalies on the performance of the motor.

11.0 LESSONS LEARNED

Before I came to work at AEDC, I had absolutely no experience on computers. During the eight weeks I have been here, I have had the chance to learn how to operate a PC. I learned how to use MS-DOS to upload and download files and to execute programs. I gained experience in using the mainframe computers. The program I used the most and learned the best was LOTUS. I used this program to setup spreadsheets in order to calculate formulas and to produce graphs.

The opportunity to be able to work in an office environment with engineers and associates has been an excellent learning experience for me. I was able to see real life applications instead of textbook suggestions to problems. Most importantly, I learned that engineering is a team effort and not necessarily an individual job. Hopefully, the experience I gained using computers and the lessons I learned will not only give me a headstart in college but also an incentive to complete my college degree. I enjoyed working with Carlos Tirres who was very supportive and with my mentors who taught me more than I ever thought I would learn this summer. My mentors played a major role in the confirmation of my decision to become an engineer. In my opinion, this is an excellent program and should be continued and possibly expanded in future years.

12.0 REFERENCES

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2. Schneberk, D. J., Azevedo, S.G., Martz, H.E., and Skeate, M.F., "Sources of Error in Industrial Tomographic Reconstructions", Materials Evaluation, Vol. 48, No. 5, pp. 609-617

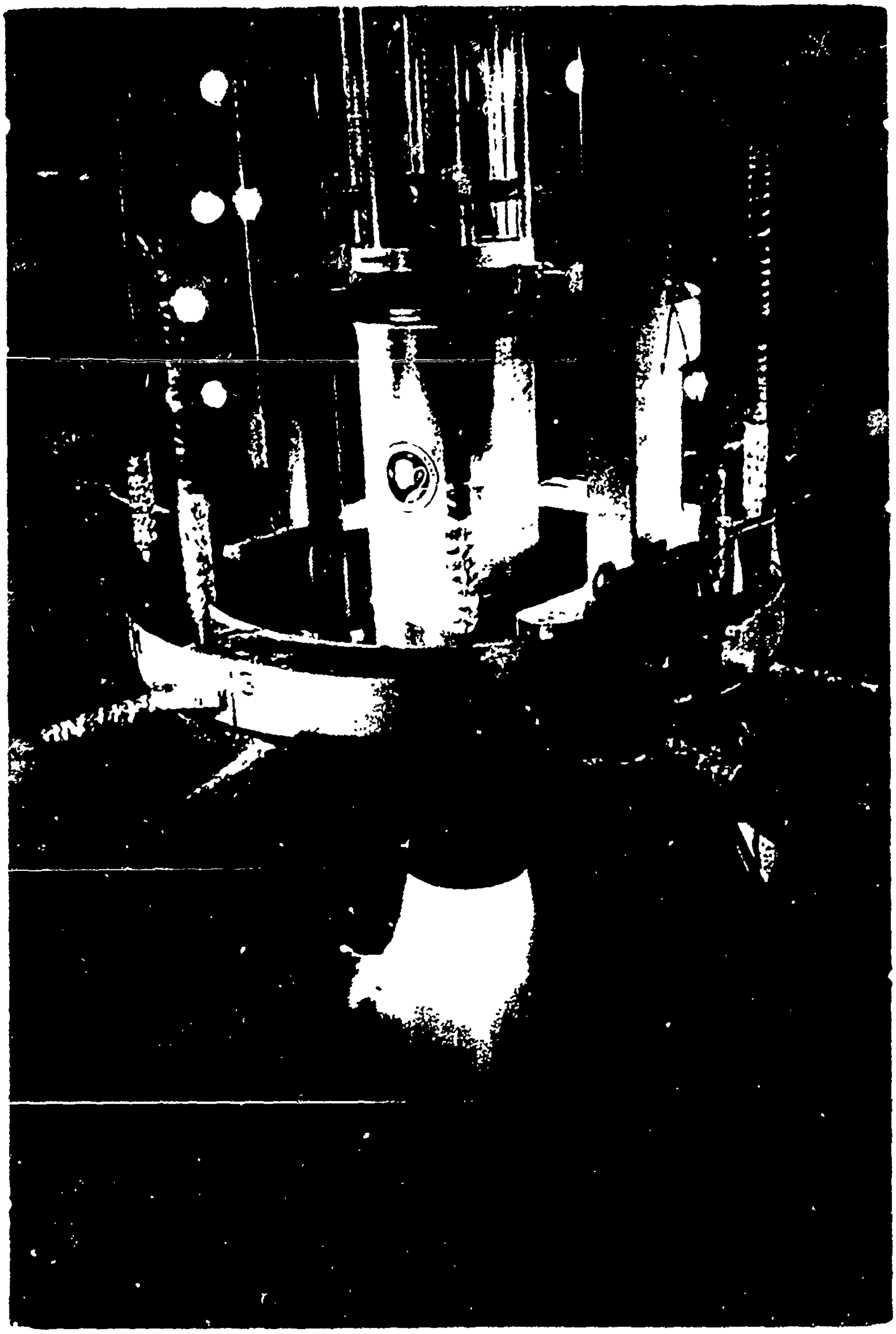


Figure 1. SuperBATES Firing In J-4 Propulsion Test Cell.

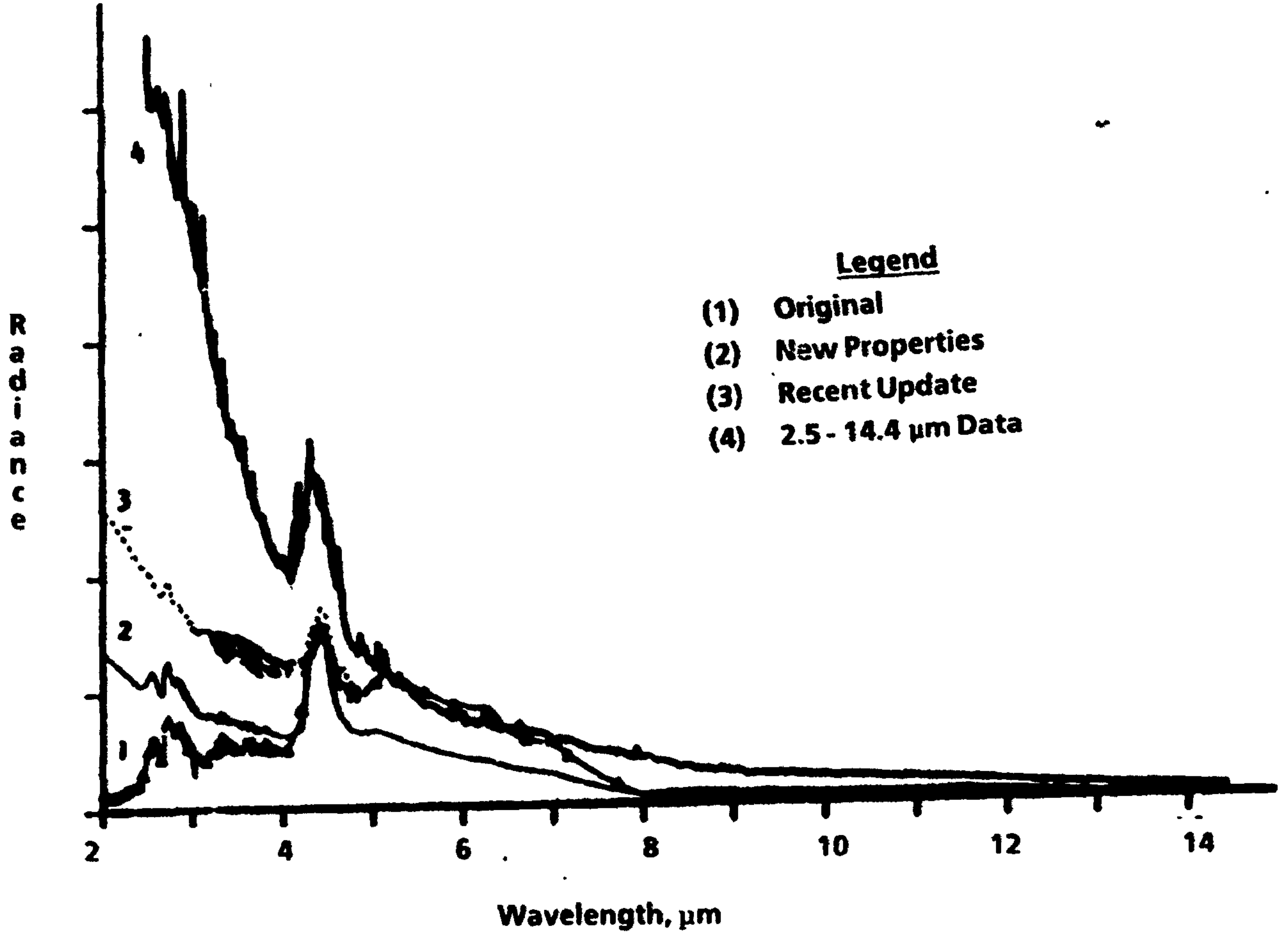


Figure 2. $Al_2 O_3$ Optical Properties Effects on Spectral Radiance Predictions.

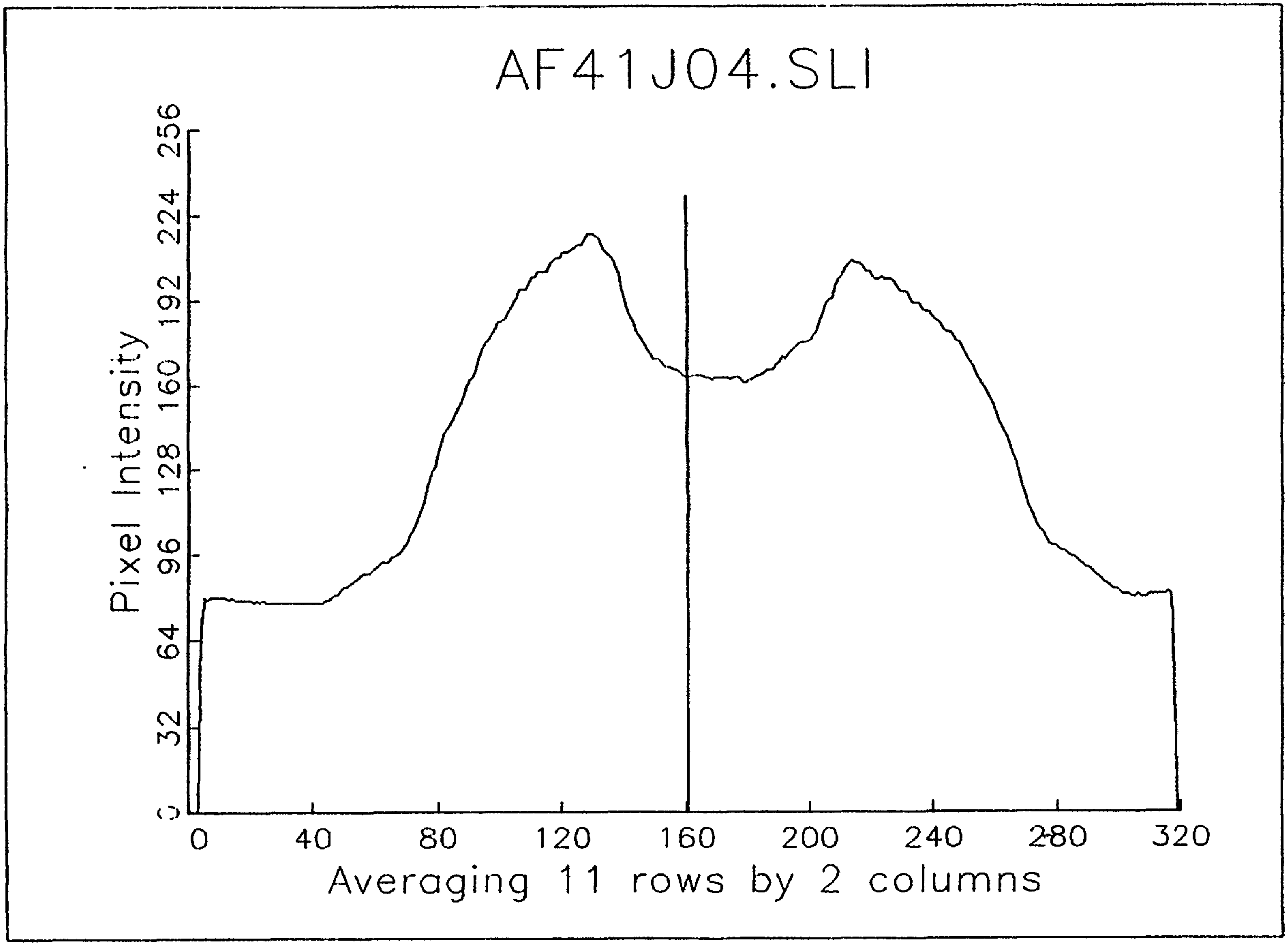


Figure 3. Cross Section of Motor, Not Centered.

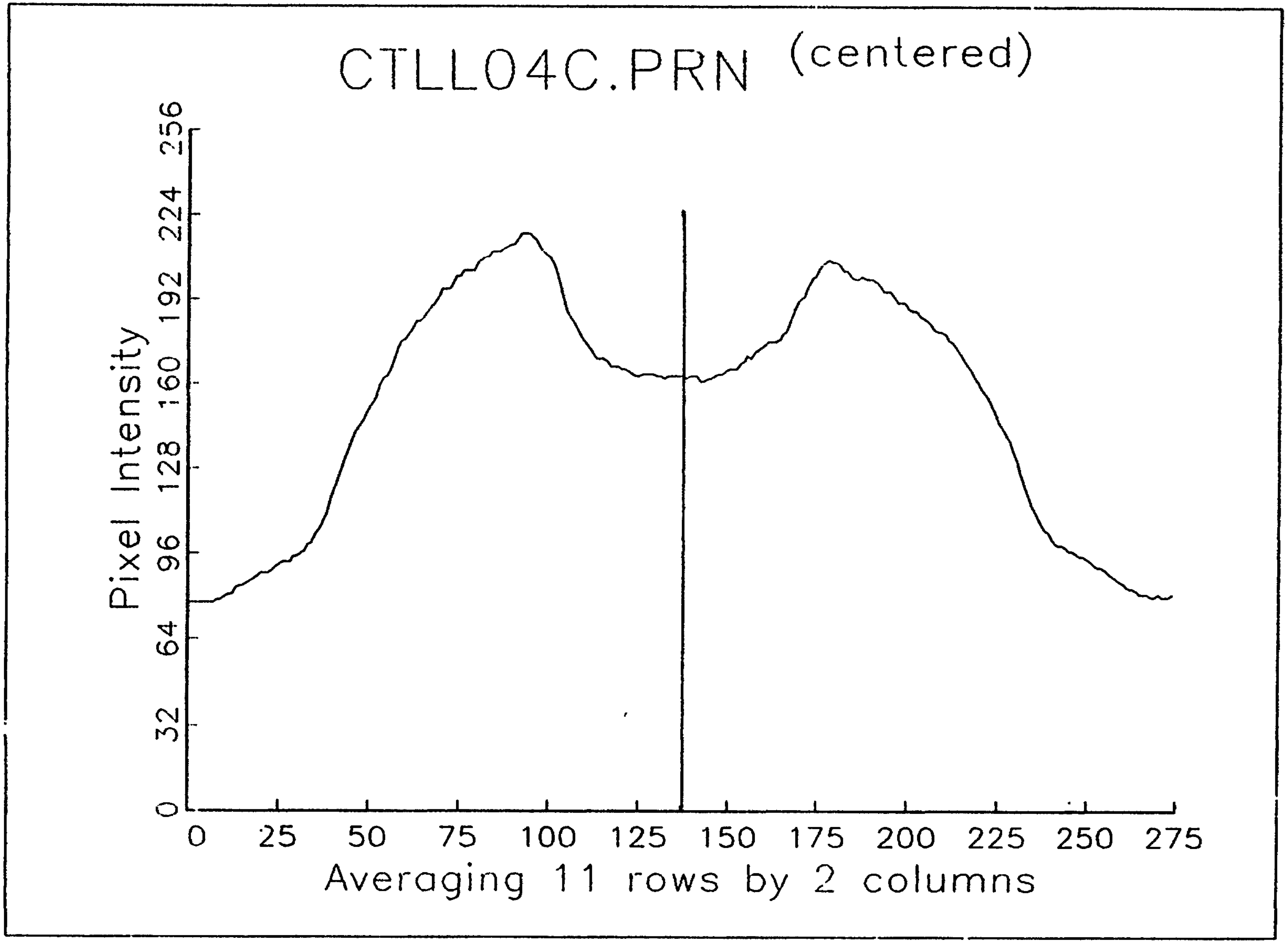


Figure 4. Cross Section of Motor, Centered.

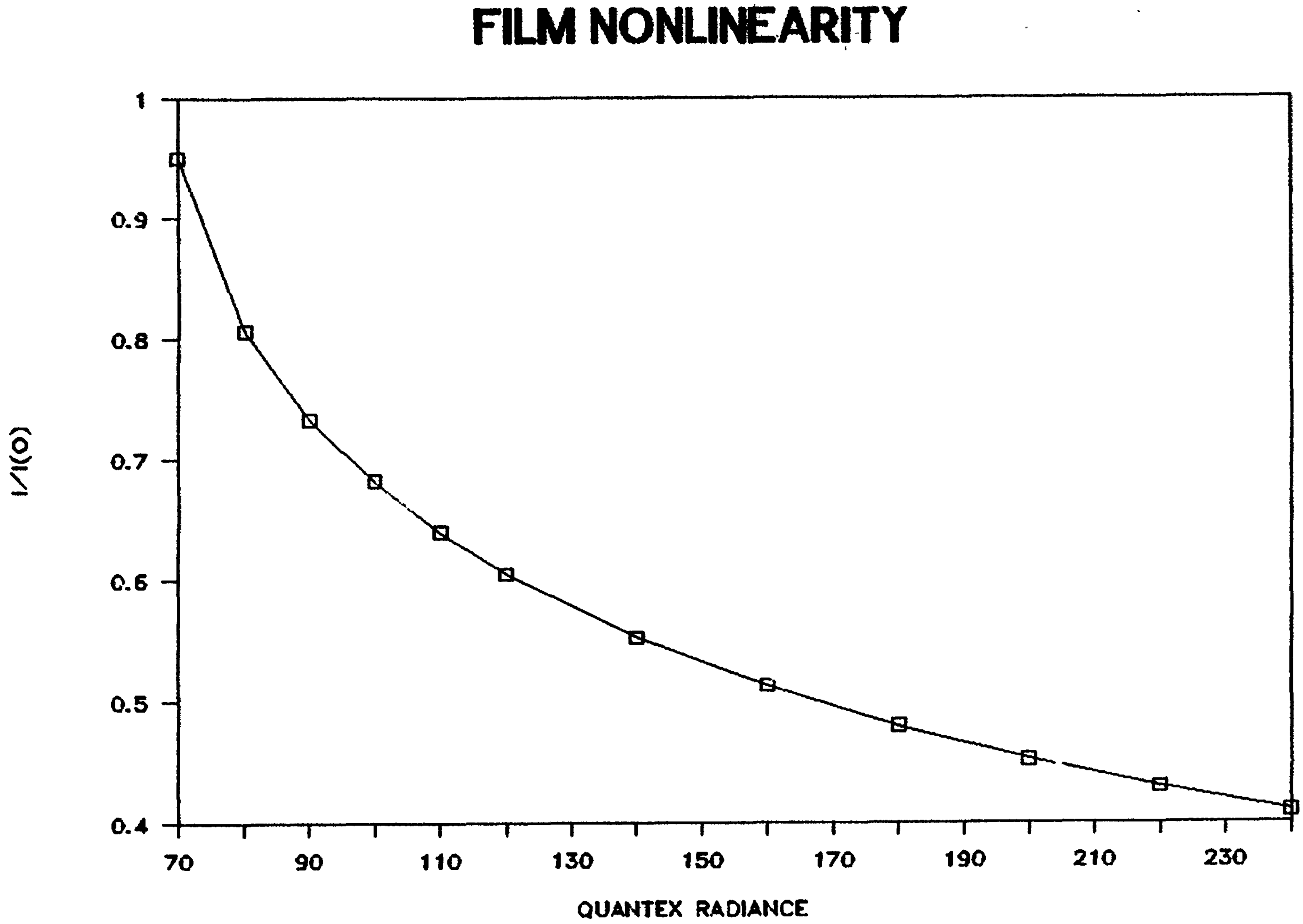


Figure 5. Corrections for Film Nonlinearity.

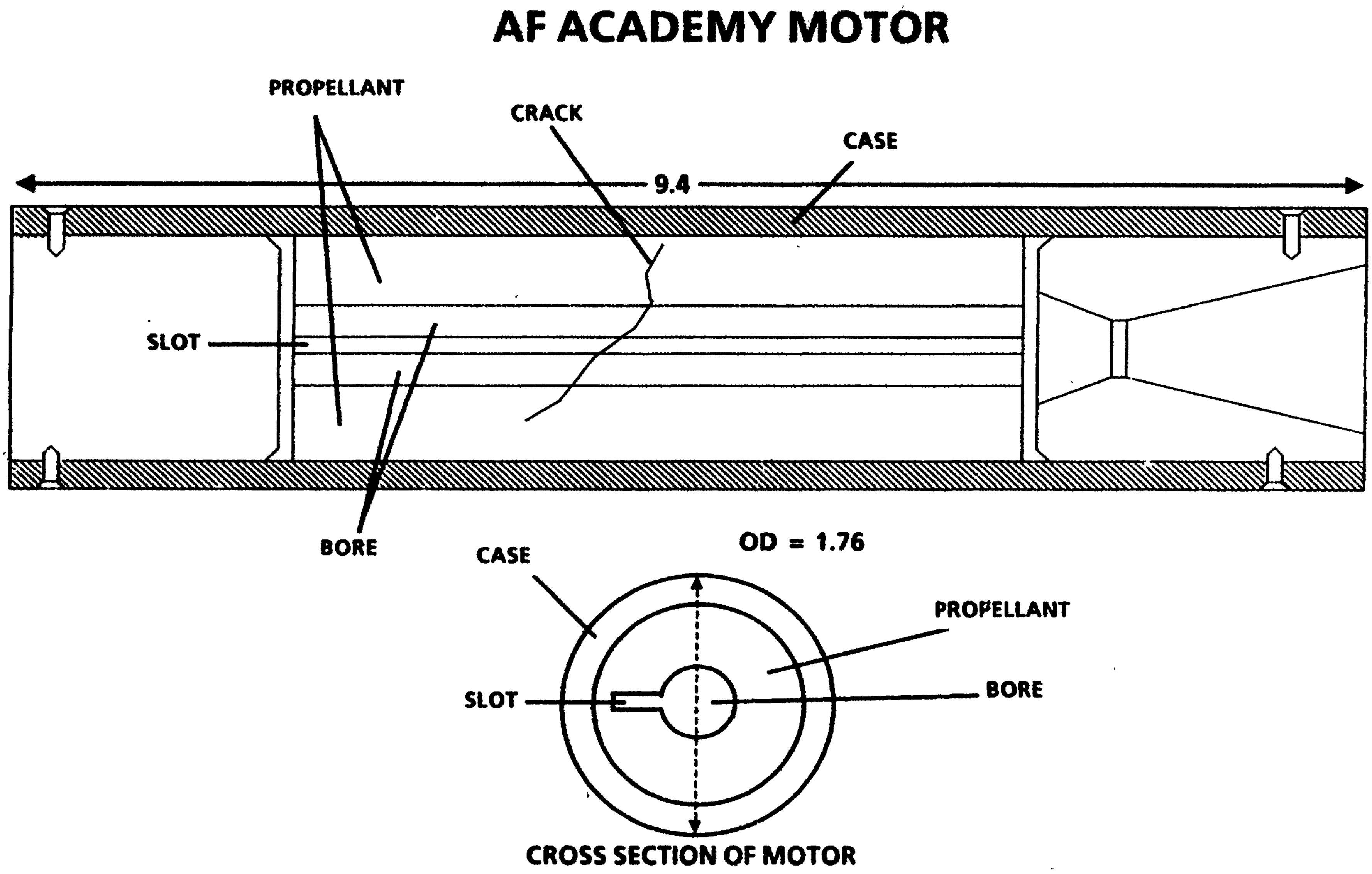


Figure 6. Schematic of AF Academy Motor .

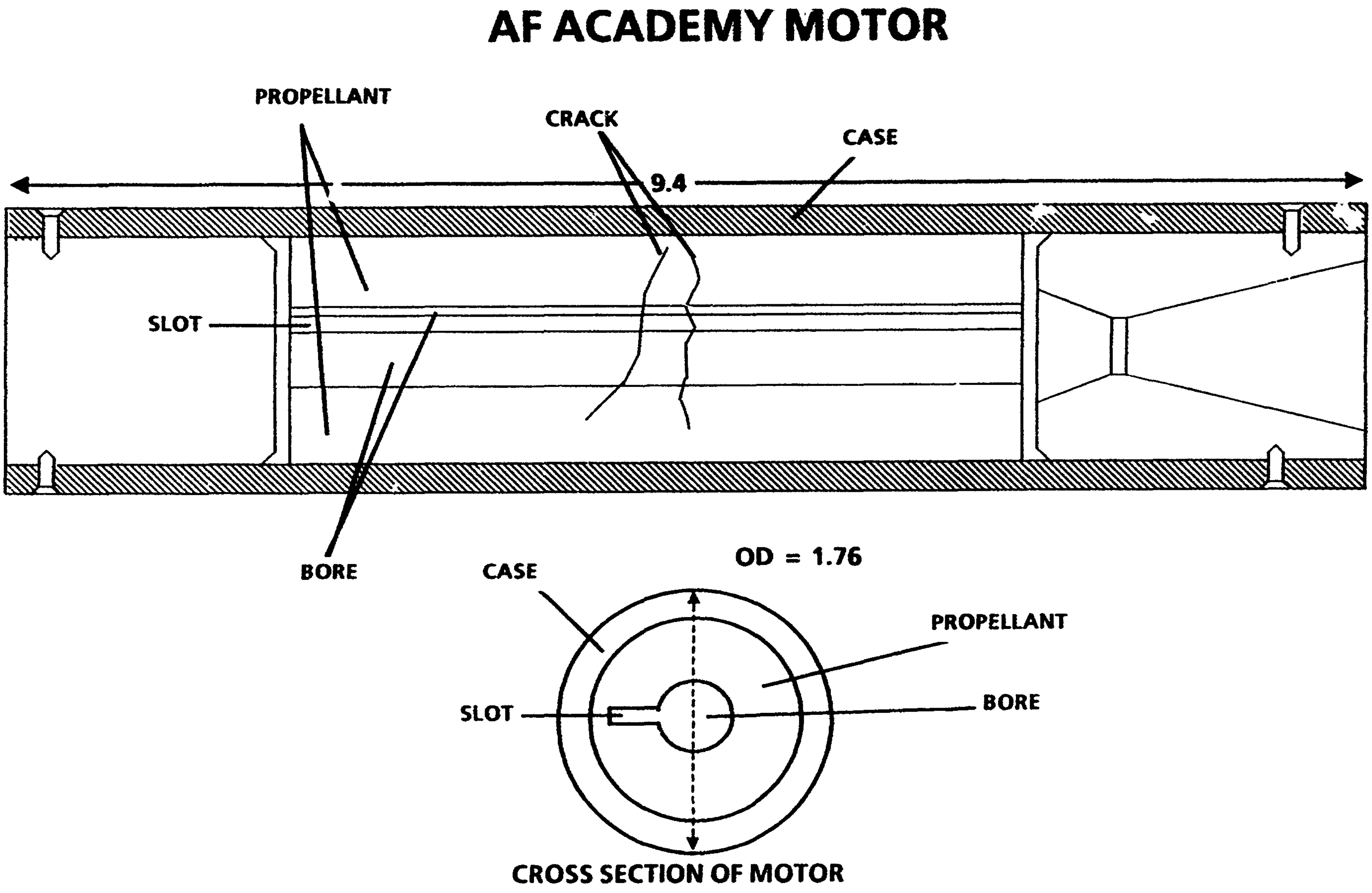


Figure 7. Schematic of AF Academy Motor, Different Angle.

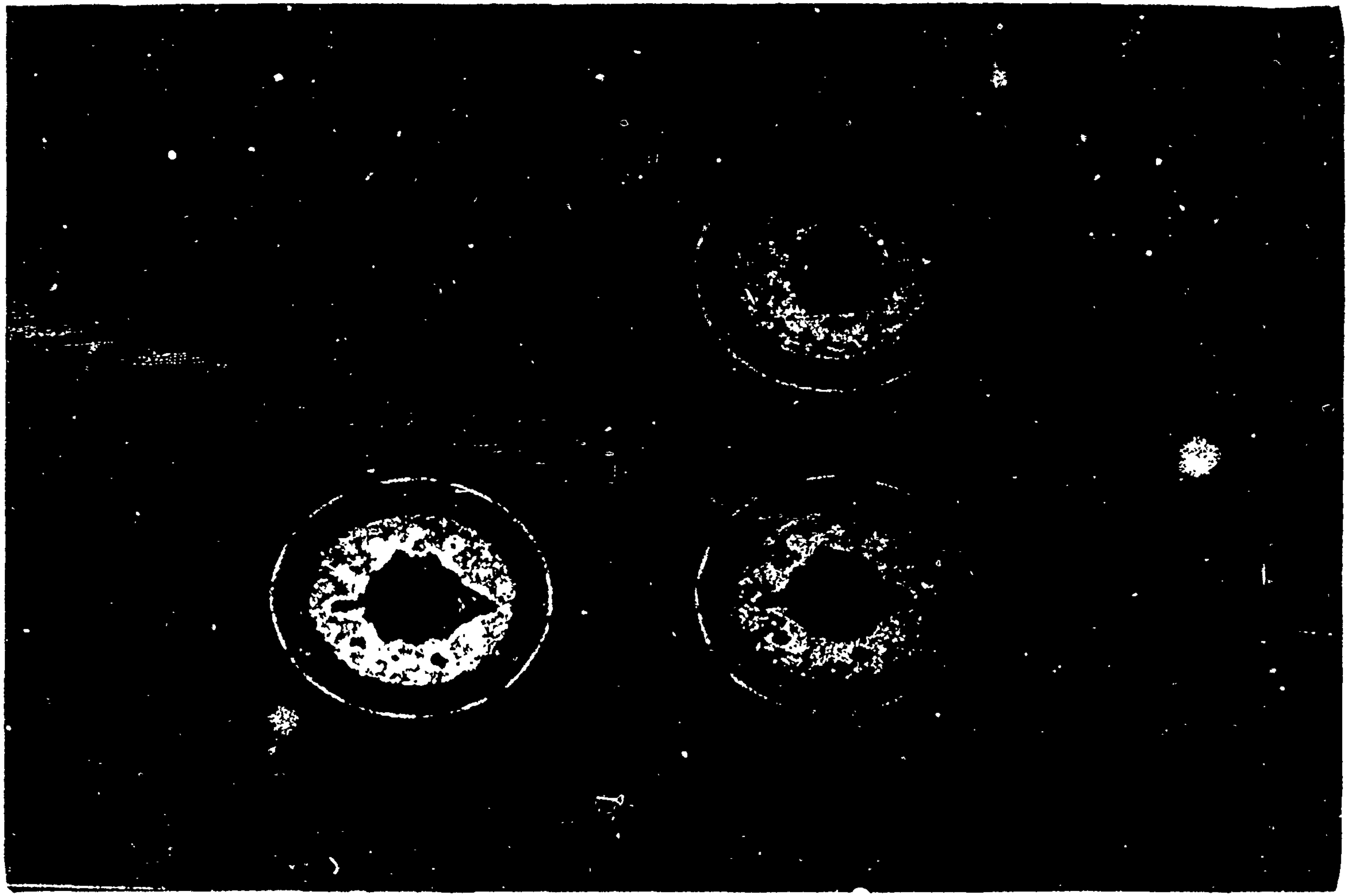
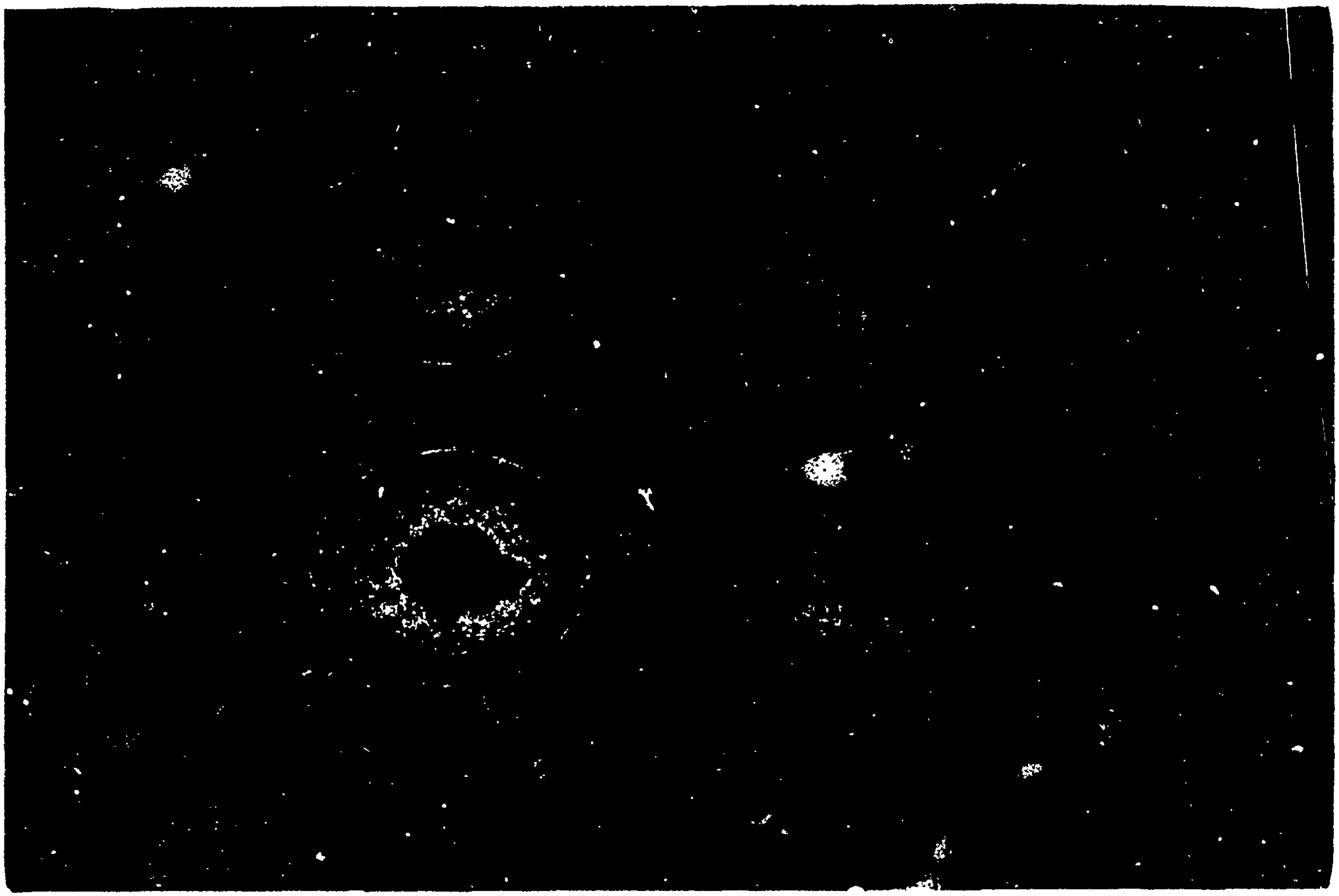
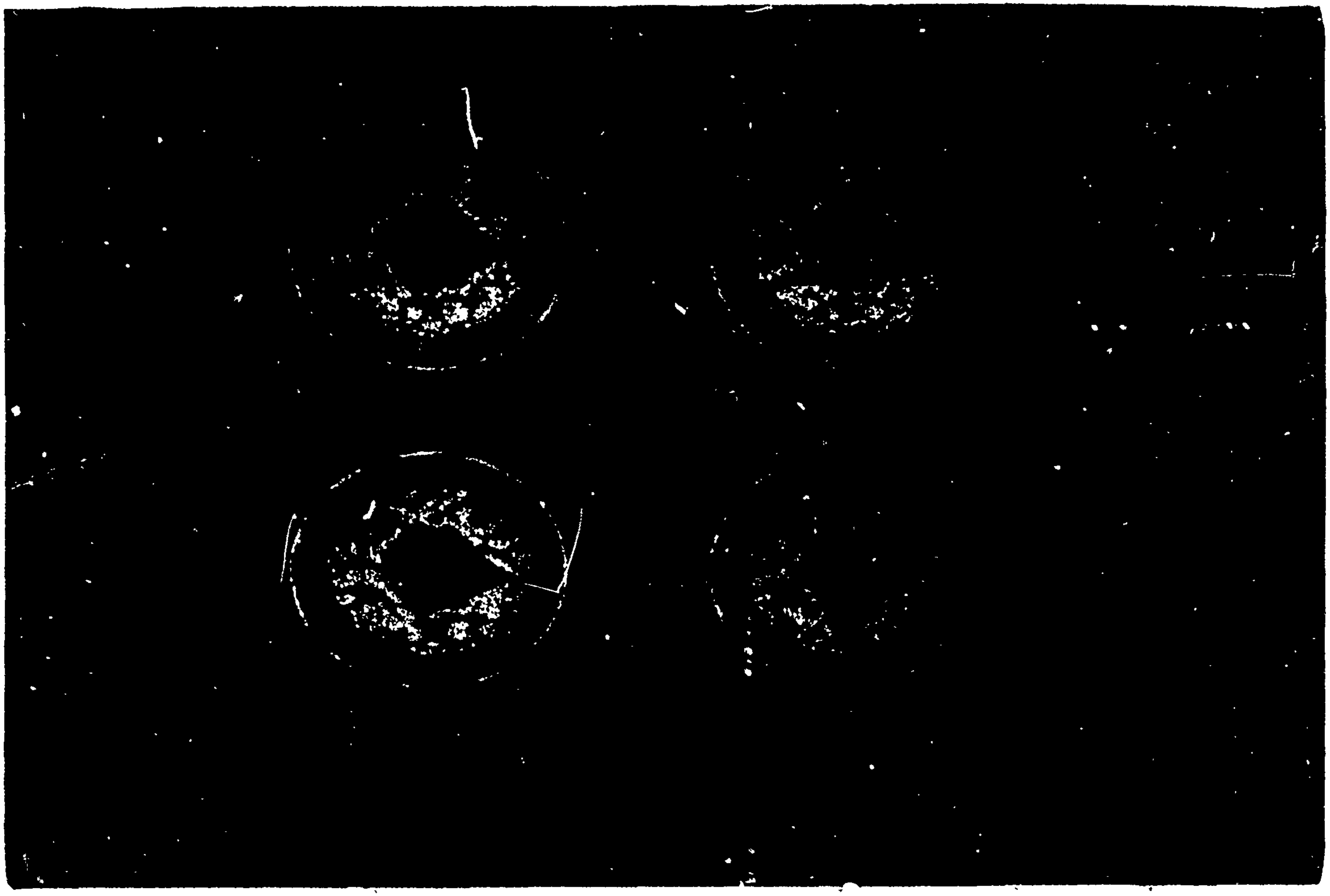


Figure 8. CT Reconstructions.

a. Forward Positions.



b. Continued
Mid Positions.



c. Concluded
Aft Positions.

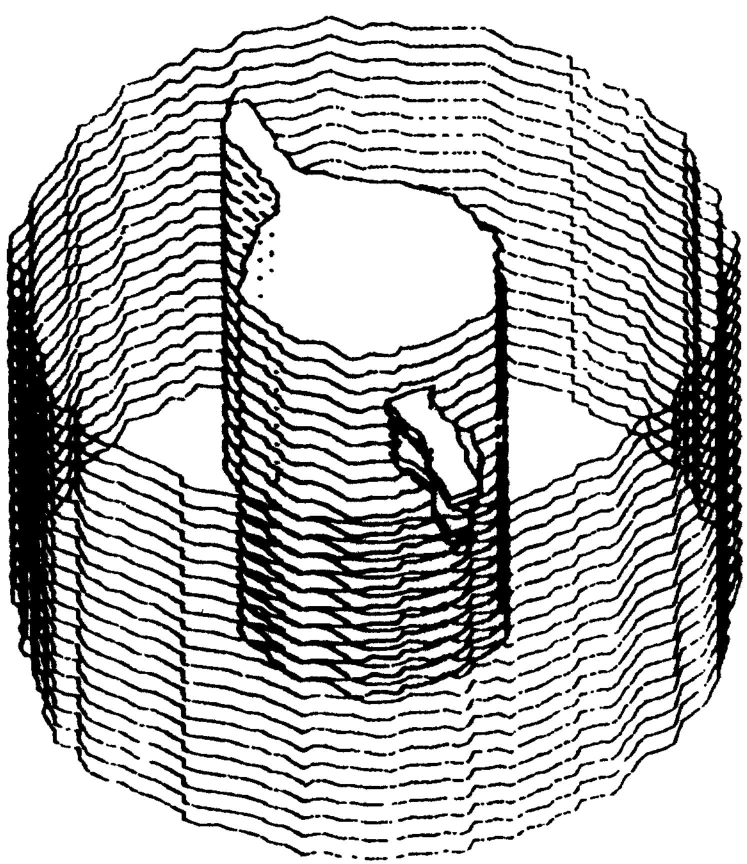


Figure 9. 3-D Reconstructed Image

DEMULSIFICATION OF OIL AND WATER USING SALTS AND COMMERCIAL SURFACTANTS FOR THE PURPOSE OF RECLAIMING WASTE OIL

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Mentor: Steve Ary

Alternate Mentor: Curtis Baker

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August 1, 1990

ACKNOWLEDGMENTS

I acknowledge with appreciation the tremendous help and instruction I received from Gayle Shelton and Penny Miller. I would also like to thank Jack Lamons and Jim Thomas for teaching and allowing me to use their equipment. Appreciation extends to everyone who made the high school apprenticeship program possible. The experience has made me more confident in choosing an engineering career.

GENERAL DESCRIPTION OF RESEARCH

Emulsified oil and water cause a problem in the process of reclaiming waste oil. A simple description of an emulsion is a suspension of particles of one liquid in a second, immiscible liquid. The emulsion usually has a milky and thick appearance. The water in the emulsified oil can interfere with the machines in the steam plant that reuse the oil. The emulsified oil and water cannot be treated in the centrifuge that has been built to treat waste oil here at AEDC. A solution needs to be found or all of the emulsified oil will need to be drummed up and sent off, which is very expensive. Generally, to break emulsions, a change in the pH, salt content, or heat is induced. This research will explore the possibilities of using commercial surfactants and salts to break oil and water emulsions. The problem of emulsified oil will become more severe in the future. If the subject of pollution and recycling is taken as seriously as it should be, reclaiming waste emulsified oil is a must. This research is only testing commercial surfactants and salts for their demulsification effectiveness. A more extensive research to determine the effects of corrosion, temperature, and time is suggested for further development to solve the problem of treating emulsified oil.

DETAILED DESCRIPTION OF RESEARCH

The research began by obtaining commercial surfactants. The following seven were suggested and chosen: Nalco V7F107C, Nalco R-S, Nalco B8C038, Pluronic L-101, Mobil B#E9768, Mobil B#F9743, and Pluronic F68. The following salts were also suggested and chosen: sodium carbonate, potassium chloride, silica gel, calcium chloride, and magnesium sulfate. The objective of the research was to evaluate these elements, the surfactants and salts, for their ability to remove the water from a sample of emulsified oil. A Photovolt instrument (aqua titrator) was used to measure the amount of water left in the sample after being treated with these elements. The lower the value measured with the Photovolt instrument, the lower the amount of water left in the sample after treatment. Therefore, the most effective element will produce the lowest measured value.

The commercial surfactants were tested first. Five ml of emulsified oil were placed into each of seven test tubes. Then, 0.05ml (1% of 5ml) of the commercial surfactant was added to the emulsified oil (Table I). The test tubes were then left to centrifuge for approximately 30 minutes. The same process as above was repeated with the exception of adding 0.5ml (10% of 5ml) of the commercial surfactants to the emulsified oil (Table I).

The salts were then tested. Five ml of emulsified oil was placed into each of five test tubes. Each of the test tubes was weighted and a 10% measurement of each of the salts was added to the emulsified oil (Table II). The test tubes were then left to centrifuge for 30 minutes. A 20% measurement of each of the salts was then prepared and left to centrifuge for 30 minutes (Table II). After that, a 10% saturated solution of each of the salts was prepared and added to five more test tubes of emulsified oil (Table III). These samples were then centrifuged for 30 minutes.

Because of the promising separation of the oil and water by calcium chloride, saturated solutions of 15% and 20% (Table III), and solids of 1%, 5%, and 15% (Table IV) were prepared and added to five new test tubes of emulsified oil and centrifuged for 30 minutes. Fifteen percent solids of sodium carbonate and magnesium sulfate were also performed because of their notable separation (Table IV). Observations of all the above experiments were made and recorded.

The Photovolt instrument was then used to determine the amount of water present in each of the samples. Five tests were performed on each, and the highest and the lowest answers were deleted and the average of the three remaining was recorded in parts per million (ppm) (Tables I - IV). This was done because the water amounts were so minute that consistent readings were difficult to obtain.

A lot of equipment was used to conduct this research. Pipettes were used to extract all of the emulsified oil and the liquid demulsifiers. A balance was used to determine the amount of solid demulsifiers to add. Test tubes were used to hold the samples, and a centrifuge was also used. The Photovolt instrument also aided in the research.

Observations of the samples played a major role in analyzing the results. The Photovolt instrument was used to determine the amount of water present, which are the results used in comparing the effectiveness of the demulsifiers.

CONCLUSIONS

In conclusion, from observations and from the Photovolt instrument results, the demulsifier that was found to be the most effective was calcium chloride in the 15% and 10% solid form. Close behind was magnesium sulfate in the 15% solid form. Overall, the salts obviously were more effective than the commercial surfactants. Out of the commercial surfactants, Pluronic F68 in the 10% form was the best demulsifier for the emulsified oil and water tested.

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Textbook of Chemistry, copyright, 1949, by Ginn and Company, The Colloidal State of Matter, page 453.

Principles of Physical Chemistry, copyright, 1951, by Macmillan Company, Surface Phenomena and Colloids, page 260.

TABLE I. Photovolt Results for Commercial Surfactants

Commercial Surfactant (Added to 5ml emulsified oil)	Amount of Water, ppm	
	For .05ml Surfactant	For 0.5ml Surfactant
#1 Nalco V7F107C	2153	1875
#2 Nalco R-S	1944	1563
#3 Nalco B8C0138	2349	2527
#4 Pluronic L-101	1921	2083
#5 Mobil B#E9768	1801	2491
#6 Mobil B#F9743	2219	2709
#7 Pluronic F68	2670	1338

Note: ppm, parts per million of water in sample

TABLE II. Photovolt Results for Salts

Solid Salt (Added to 5ml emulsified oil)	Amount of Water, ppm	
	For *10% Salt	For *20% Salt
#1 Sodium Carbonate	1797	2184
#2 Potassium Chloride	1312	1592
#3 Silica Gel	1948	1955
#4 Calcium Chloride	1055	1307
#5 Magnesium Sulfate	1639	1341

Notes: ppm, parts per million of water in sample
*Percent by weight of emulsified oil

TABLE III. Photovolt Results for Saturated Salt Solution

Saturated Salt (Added to 5ml emulsified oil)	Amount of Water, ppm		
	*10% Solution	*15% Solution	*20% Solution
#1 Sodium Carbonate	2146	-	-
#2 Potassium Chloride	1767	-	-
#3 Silica Gel	2528	-	-
#4 Calcium Chloride	1307	2059	2692
#5 Magnesium Sulfate	4052	-	-

Notes: ppm, parts per million of water in sample
*Percent by volume added to 5ml of emulsified oil

TABLE IV. Photovolt Results for Salts

Solid Salt (Added to 5ml emulsified oil)	Amount of Water, ppm		
	*1% Salt	*5% Salt	*15% Salt
#1 Sodium Carbonate	-	-	1878
#2 Potassium Chloride	-	-	-
#3 Silica Gel	-	-	-
#4 Calcium Chloride	2947	1867	1044
#5 Magnesium Sulfate	-	-	1086

Notes: ppm, parts per million of water
*Percent by weight of emulsified oil

PROPULSION WIND TUNNEL

STANDARD TUNNEL CONDITIONS EQUATIONS DOCUMENTATION

J. R. Sanders

Mentor: M. L. Mills
Calspan Corp, AEDC Division

ARNOLD ENGINEERING DEVELOPMENT CENTER

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August 25, 1990

Acknowledgements.

Mike Mills, my mentor, taught me a lot. He took me around most of the facilities at AEDC and gave me a very good understanding of what engineering is like, on the field and in the office.

Dan Cunningham, my assistant mentor, taught me the necessary skills to operate the computer in our office building.

Carlos Tirres, the person who oversaw the program at AEDC this summer, helped make my stay more comfortable and introduced me to all the other apprentices.

All of these people at AEDC helped make my summer a most enjoyable and unforgettable experience, but Mr. Mills was the most influential to me this summer.

Description of the area that I worked on.

This summer I had a very exciting time at AEDC learning new skills in computers and learning various aspects of engineering. I worked this summer in the propulsion wind tunnel (PWT) area. These tunnels are large ducts ranging in size from a few feet in diameter to over 50 feet in diameter in some places. Wind is blown through these ducts into a test chamber. These tunnels are named from the size of their test chamber and the speed in which wind is carried through them. One tunnel, 4T, has a 4 foot by 4 foot test chamber this is where the 4 comes from. The T means that the winds inside this tunnel travel around the speed of sound. This T stands for Transonic. Another tunnel, 16T, has a 16 foot by 16 foot test chamber. The T means the same thing that it does in 4T. The most complex propulsion wind tunnel at AEDC is the 16S. The 16 again stands for the size of the test chamber which in this case is the same as that for 16T. The S stands for supersonic and indicates that the winds inside this tunnel can travel 3-4 times faster than the speed of sound. When a test is running, there is a model of such things as aircrafts in the test chambers. The wind blows through these test chambers onto the model. There, through the use of computers, engineers and technicians simulate actual conditions that these aircrafts could undertake while in operation. The engineers make any changes which will make the aircraft fly smoother, and again test these models until they meet up to certain standards. This is basically what happens in the area that I worked.

What I did this summer.

I revised the Propulsion Wind Tunnel (PWT) Standard Tunnel Conditions Equations Documentation into an electronic spreadsheet format. To do this, I copied the old documentation into the spreadsheet. Since an electronic spreadsheet has a great deal of flexibility, I could then incorporate any changes that needed to be made. I found out what needed to be changed by looking through a book of changes. This book had all the changes over the past several years.

Why I was asked to do what I did.

The reason I was asked to revise the equations was to save engineers a lot of time and keep them from making mistakes. The engineers run tests in the various tunnels and all of the equations are used each time the tunnels run and are very important so they needed to be neat. The equations were previously handwritten and often sloppy. By revising these equations, it made it much easier for the test engineers to keep the tunnels running smoothly. To make sure that these test engineers do not make any mistakes and that they keep the tunnels running smoothly, I was to document these equations. The test engineers could then have a copy of all the equations at their fingertips if they needed them.

Approach to problem.

I first copied all of the handwritten documentations into my electronic spreadsheet. I next looked through several books of changes. I then incorporated any necessary changes to my electronic spreadsheet. I then gave these completed drafts to my mentor who corrected anything that I might have gotten wrong. After he's finished, he will send these drafts to various AEDC personnel who need copies of the equations to perform their jobs sufficiently.

Equipment I used.

I used the computer in our section, the Cowbarn. I used a VT220 keypad to insert and revise my data. I also used several different booklets where the equations were documented.

Results.

I revised the standard tunnel conditions equations for all three wind tunnels. This took all eight weeks that I was working at AEDC. The equations will be ready to distribute to various AEDC personnel as soon as my mentor has made any other changes that he feels necessary.

Lessons learned.

I learned a lot this summer. I learned that teamwork is very important, especially in the field of engineering. I also learned that no matter how much people criticize the government, its organizations are very worthwhile and run by very competent people. In one experience I had this summer, my mentor took me inside the 16T propulsion wind tunnel near the stilling chamber, a place where the wind is slowed down almost to a degree of stopping. The problem was that there was a rip in a screen in the stilling chamber. This screen is used to keep any unwanted debris from doing major damage to something, such as a compressor, in a wind tunnel. The rip was about 6 feet long, but it did not quite extend to where the actual flow of air was. My mentor, along with some engineers, concluded that it was not necessary to replace the screen. If the screen were replaced, it would cost tax payers money. This the engineers knew and took into consideration when they made their decision about whether or not to replace the screen. This proves how competent most government officials are and gave me faith in the government.

1990 USAF-UES SUMMER HIGH SCHOOL APPRENTICESHIP PROGRAM FINAL REPORT

Jason Scott

Mentor: Lt. Greg Nordstrom

Research Location: AEDC/DOTR

August 10, 1990

Acknowledgements

I wish to thank the Air Force Systems Command and the Air Force Office of Scientific Research for sponsorship of this research. Universal Energy Systems must also be commended for their concern and help to us in all administrative and directional aspects of this program. My experience was rewarding and enriching because of many different influences. Lt. Greg Nordstrom provided me with support, encouragement, and a truly enjoyable working atmosphere. I would also like to thank Ben Abbott and Ted Bapty for teaching me many new things and for making this summer very enjoyable. Finally, I would like to thank Carlos Tirres for all his help in insuring that my experience at AEDC would be memorable.

Turbine Engine testing generates massive volumes of data at very high rates. A single engine may have several thousand sensors and test periods lasting for several hours. Because of the huge amount of data this produces it is not feasible to digitally store this information. The Computer Assisted Dynamic Data Montioring and Analysis System (CADDMAS) project will process the data on-line at the speed of acquisition by the use high-computation algorithms. These algorithms effectively compress the data into useful information that is easier to store.

The CADDMAS project is made up of several main parts:

1. *The Numeric Processing Element* uses a *T800* transputer and a *Zoran Signal Processor* [4] to supply the most of the computational power of the system.

2. *The Graphics Processing Element* incorporates a *Texas Instruments TMS34010* [3] with a dual frame buffer. This processing element performs quick. smooth display of dynamic signals.

3. *The Storage Processing Element* uses a *SCSI* interface to store large quantities of information.

4. *The I/O Processing Element* provides a variety of configurable digital parallel I/O lines.

I have been mostly involved with the development of the hardware and software for the Graphics Processing Element. The GPE provides a high performance. high resolution. color display interface. This processor receives processed information from a mamy of sensors and integrates the data into a display screen. System users need high resolution graphics to display data from the large number of sensors. The engineers need high-speed rendering to display dynamically changing information so that it will appear as continuous time to the operator. This device also integrates information from several clusters of Numeric Processing Elements.

The GPE is a dual-CPU computer. with high-speed general purpose computation. and high-speed. high resolution color graphics. The graphics resolution is

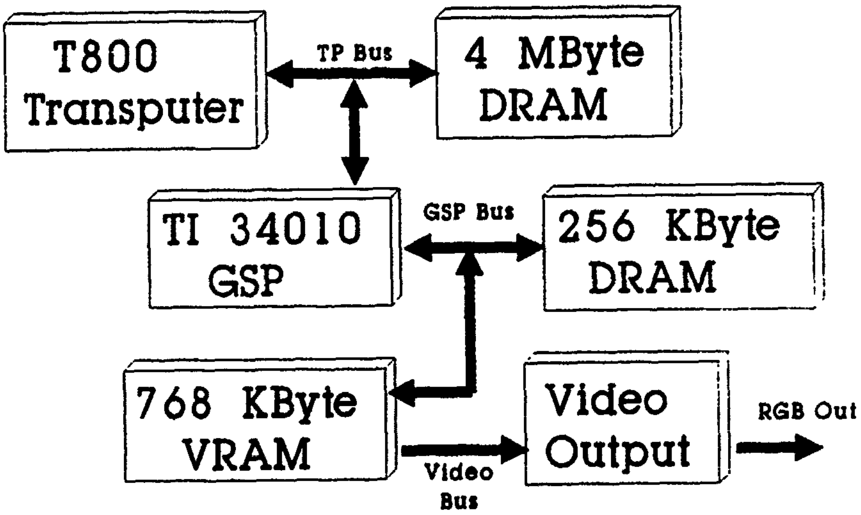


Figure 1: Graphics Processing Element Block Diagram

1024x768 with 16 simultaneous colors. The GSP has 256K Bytes of DRAM for program and data storage functions. There is enough video memory (768K bytes) for dual frame buffers. With the double buffering technique. all drawing can occur in the invisible screen. Only completely drawn images are visible on the display. This reduces the flicker caused by repeated clearing and redrawing of the graphics screen. The GSP also supplies the video timing. The video logic converts the digital pixel value information into an analog Red-Green-Blue(RGB) signal for display on a CRT monitor. (See figure 1).

One of the first things that I did when I began work was to solder the components on the Graphic Processor printed circuit board. I was also involved in the troubleshooting and programming the PALs on the board. The next step I worked on was software development. I learned how the very basic routines for drawing text.

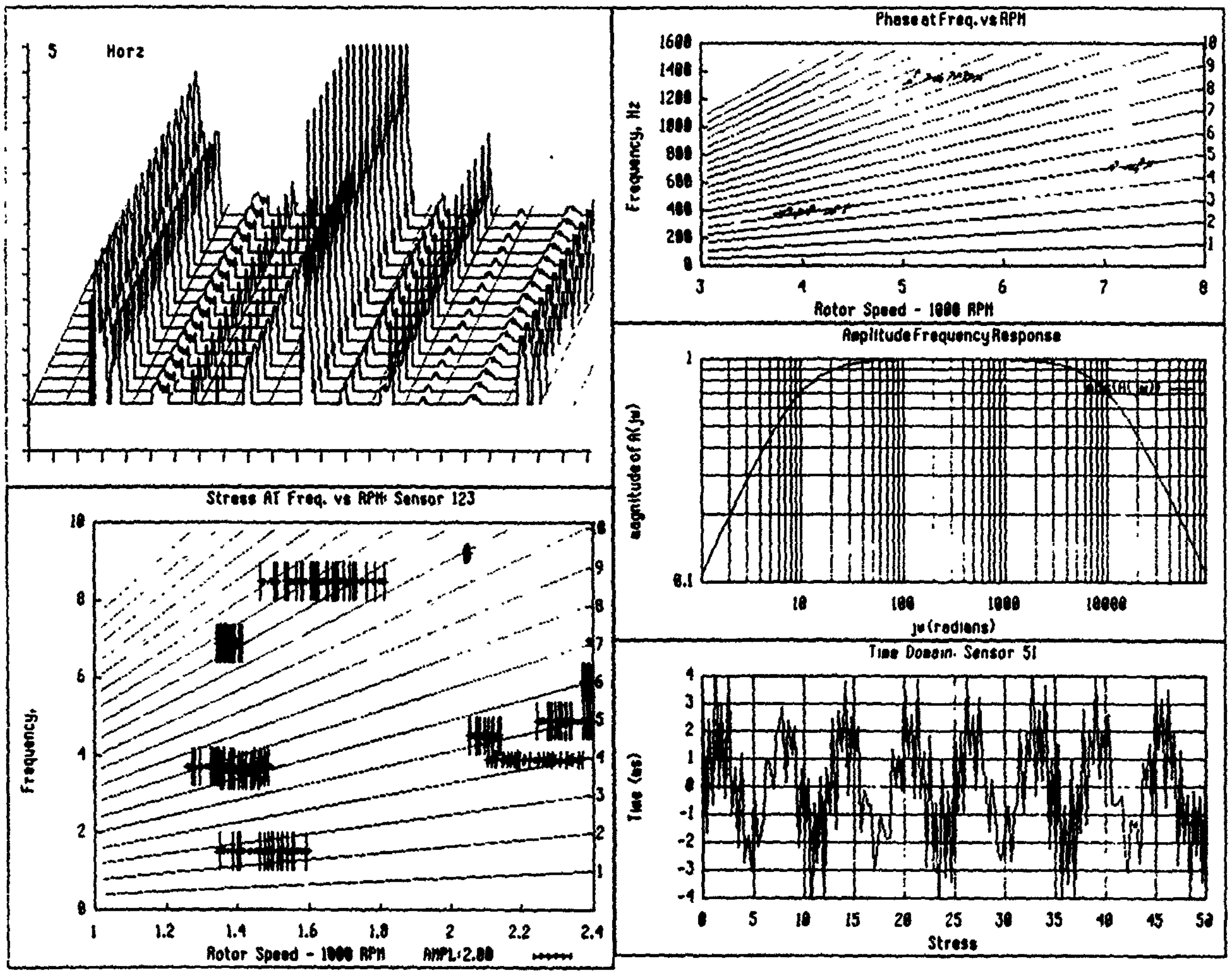
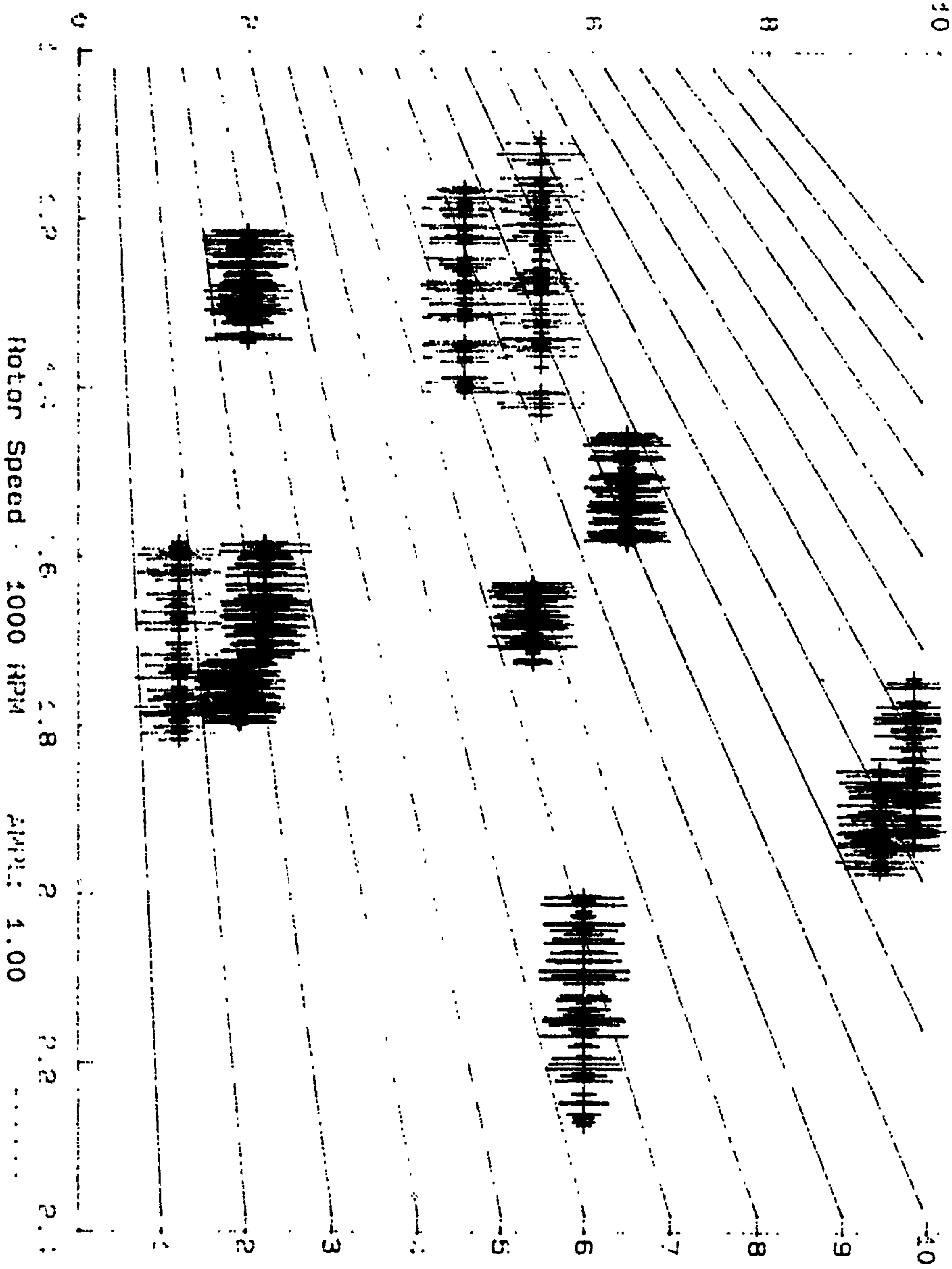


Figure 2: Typical Graphics Display

lines, etc. on the TI GSP worked. Then I began work on modifying GNUPLOT, a plotting package from the Free Software Foundation which has been ported to the GPE. The GNU software runs on the T800, with a special TI34010 graphics chip device interface to translate into display list commands. The GNUPLOT program is fully portable to almost any computer by simply adding that computers drawings routines. We can use GNUPLOT to display multiple plots on their workstation during a test. After a test the engineer can take a copy of a certain section of the test data he is interested in back to his personal computer and view it using GNUPLOT.

I modified the GNUPLOT program to do several specific functions that our test engineers need to have available to them. I wrote subroutines to plot campbell and phase campbell diagrams. These are plots with frequency on the y-axis. rotor speed on the x-axis. and stress on the z-axis. The z-axis is represented as vertical line with varing amplitudes on the graph. In a phase campbell there is phase data instead of stress data. In a phase campbell the phase data is represented with a arrow tip pointed in the relative direction of the phase. I also added a function to display a campbell label which includes a scale for engineers to measure the data. a label for the scale. and the scale value that the graph is drawn to. To make it easier to operate GNUPLOT I developed a mouse driven menu to execute the commands used most often. Figure 2 shows a typical screen dump from the GPE with several of these special plots. Figure 3 shows a high quality plot of a particular campbell window.

Figure 3: Campbell Diagram Plot



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[1] Abbott, B., Biegl, C., Sztipanovits, J.: "Multigraph for the Transputer", Proceedings of the Third Conference of The North American Transputer Users Group, April 1990.

[2] INMOS Limited: "Transputer Reference Manual", 1989.

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[4] Zoran Corporation: "ZR34345 32-Bit IEEE Floating-Point Vector Signal Processor User's Manual"

REAL-TIME RADIOGRAPHY
RAY TRACING

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AUGUST 14, 1990

ACKNOWLEDGEMENTS

During the summer I came in contact and worked with many people. I would like to take this opportunity to thank them.

Mr. Paul Girata - I met Paul on my first day. He showed me how to operate the video laser disk and how to run Quattro, which was very essential in the completion of my project. Thanks, Paul.

Mr. Mike Anderson - I also met Mike on my first day. I do not know how, but Mike made me feel as though I belonged here. Thanks, Mike.

Mr. Jeff Bain - I met Jeff during my first week here. I guess I worked more with Jeff than with anyone else. We used the same computer in the video lab and whenever I needed it, Jeff was willing to go somewhere else. Thanks, Jeff.

Mr. Ben Williams - Even though it was late in the summer before I met Ben, he helped me a great deal. He gave me insight into my project through the work he was doing. Thanks, Ben.

Ms. Linda Whittemore - It too was late in the summer when I met Linda, but she did more for me than anyone can know. When I needed a video for my oral presentation, she took time from her busy schedule to help me put it together. Thanks, Linda.

Ms. Jennifer Moffitt - Jennifer also helped me a great deal towards the end of the summer. She made the viewgraphs for my presentation and if I needed a change she was more than willing to make it. Thanks, Jennifer.

Ms. Rita Walker - I met Rita before I ever began working here. She was the one who interviewed me. I did not work much with Rita until the end of the summer. She seemed very appreciative of anything I did for her, and that made me feel good. Thanks, Rita.

Dr. Bob Frederick - I am very glad that Bob was my mentor. Even though he claims that having a doctorate makes him forget things, he never forgot to help me. Everytime I had a questions, no matter what he was doing, he would take time out to help me. He made me begin to think like an engineer and not just a high school student. He always seemed to know how to keep me fresh. Thanks for everything, Bob.

LIST OF SYMBOLS

SYMBOL	DESCRIPTION
a	Displacement of Ray Along Screen, Meters
b	Y-Intercept, Meters
d	Distance Source is Offset From Centerline of Motor, Meters
HVT	Thickness of Material Needed to Drop Intensity to Half its Original Value, cm
I_o	Intensity Output, rad/min.
I_s	Intensity at Screen, rad/min.
L	Distance Ray Travels Through Motor, Meters
m	Slope
M	Materials to Model Case, Propellant, and Bore
n	Identification Subscript
OTSD	Object to Screen Distance, Meters
r	Radius of Circle, Meters
R_D	Distance Ray Travels From Source to Screen, Meters
STOD	Source to Object Distance, Meters
STSD	Source to Screen Distance, Meters
x	X-Coordinate of Point
x_n	X-Solution to Ray/Circle Intersection
y	Y-Coordinate of Point
y_n	Y-Solution to Ray/Circle Intersection

GREEK SYMBOL	DESCRIPTION
μ	Linear Attenuation Coefficient, cm^{-1}

1.0 INTRODUCTION

Real-Time Radiography (RTR) is basically taking x-rays of a rocket motor as it is firing. Figure 1 shows that basic set-up. In RTR, x-rays are transmitted through a rocket motor by a source. These x-rays are projected onto a screen which converts the x-ray light to visible light which is then recorded by a video camera. Inside of the rocket motor is the burning solid propellant, which is denoted by the shaded areas in Figure 1. As the propellant burns, the inner surface of the propellant moves outward. The inner surface of the propellant is hard to determine in actual data.

Real-Time Radiography Ray Tracing uses a computer to predict images that are produced by x-rays transmitted through a rocket motor for analysis. The analysis of these images is used to determine the inner surface position of the burning solid rocket propellant. This is compared to the actual data from real x-rays to determine accuracy. The objective is to design a tool to predict the outcome of real-time radiographs of solid rocket motors. The scope included deriving formulas for a two-dimensional ray tracing program, then programming them into a spreadsheet. The calculated intensity values from the spreadsheet generated video images for analysis.

2.0 RAY TRACING APPROACH

2.1 Nature of X-Rays

The basic equation of x-ray attenuation is Beer's Law [1]. It states that:

$$I_s = I_0 exp(-\mu L) \qquad (1)$$

where:

I_s = Intensity at the Screen
I_o = Intensity Output
μ = Linear Attenuation Coefficient
L = Distance Through Material

This is the equation used to determine the intensity loss of an x-ray as it travels through a material. The linear attenuation coefficient is the constant of loss for different materials. This equation must be modified to account for an object with many materials and a R_D-squared intensity loss. The modified equation is:

$$I_s = \frac{I_o}{R_D^2} exp\left(-\mu_1 L_1 - \mu_2 L_2 - \mu_3 L_3 - \ldots - \mu_n L_n \right) \tag{2}$$

where:

R_D = Distance X-Ray Travels from Source to Screen
n = Subscript Denoting Material Identification

2.2 Absorption Coefficients

The linear attenuation coefficient (μ) is a constant that is determined using the half-value thickness (HVT). The HVT is the thickness of material needed to drop the intensity of half of its original value. The HVT is a function of the type of material being used a long with the energy level of the source. As the intensity output of the source increases, the HVT increases, which in turn causes μ to decrease. The values of μ that were used [2] can be found in Figure 2 and Table 1. Since the HVT is a known value, μ can be found accordingly:

$$\mu = \frac{0.693}{HVT} \tag{3}$$

2.3 Ray Tracing Model

Values of the path length, L, must be calculated for each material a ray passes through. The model shown (Figure 3) allowed simulation of the case, propellant, and bore of a rocket motor. In order to be able to solve Equation 2, first one must solve for R_D and each L. These distances will be explained as they are used. The source is located to the far left and the screens are located to the far right.

Begin by calculating the R_D distance using the Pythagorean theorem:

$$R_D = \sqrt{STSD^2 + (a-d)^2} \tag{4}$$

where:

STSD = Source to Screen Distance

a = Displacement of the Ray Along the Screen

d = Source Offset Distance

This equation allow the ability to offset the source from the centerline. The next step in the analysis was to calculate L. Begin by describing the ray path using a simple line

$$y = mx+b \tag{5}$$

where the slope is

$$m = \frac{(a-d)}{STSD} \tag{6}$$

and the Y-intercept is

$$b = (STOD)(m) + d \tag{7}$$

where:

STOD = Source to Object Distance

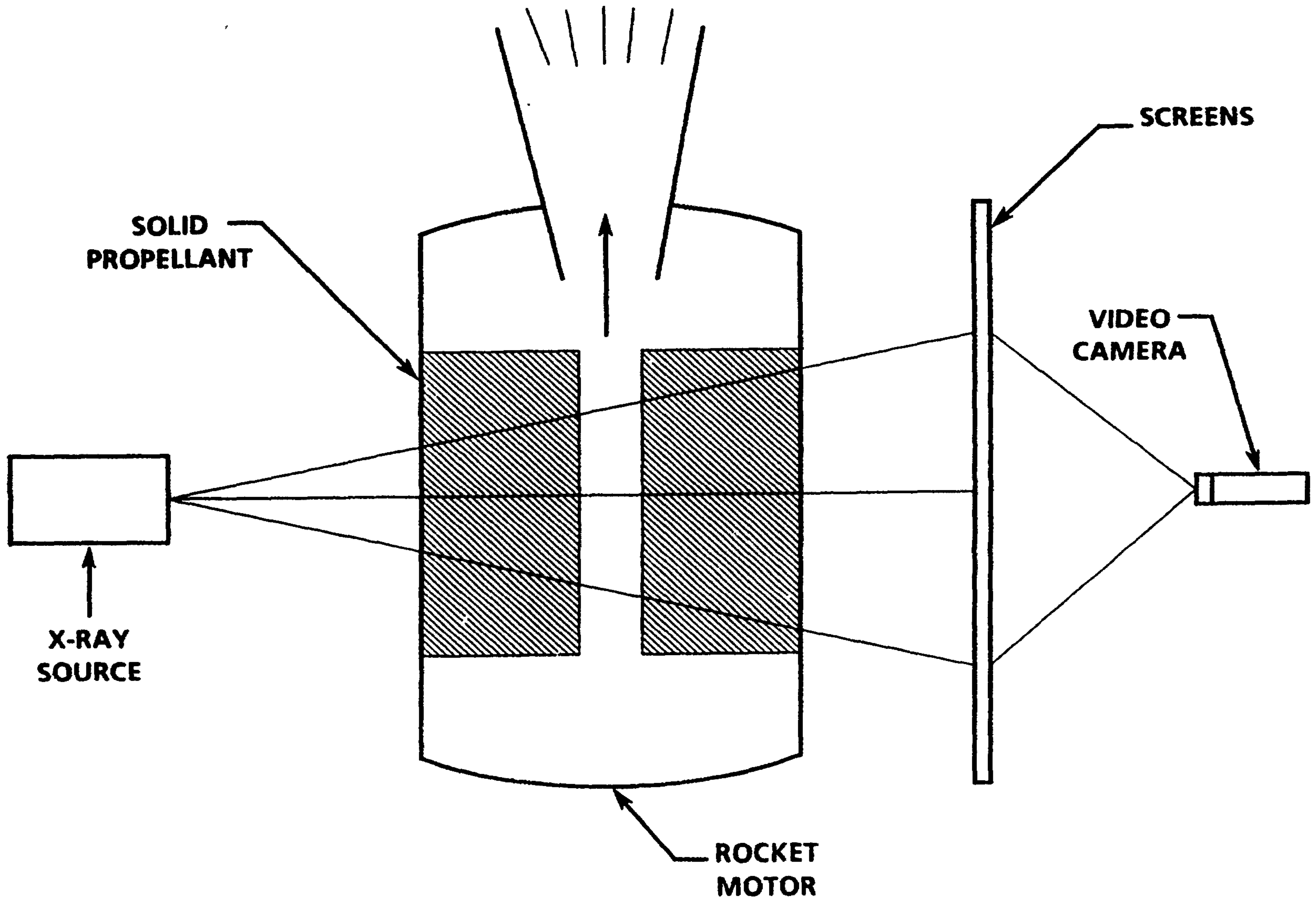

Figure 1. Real-Time Radiography.

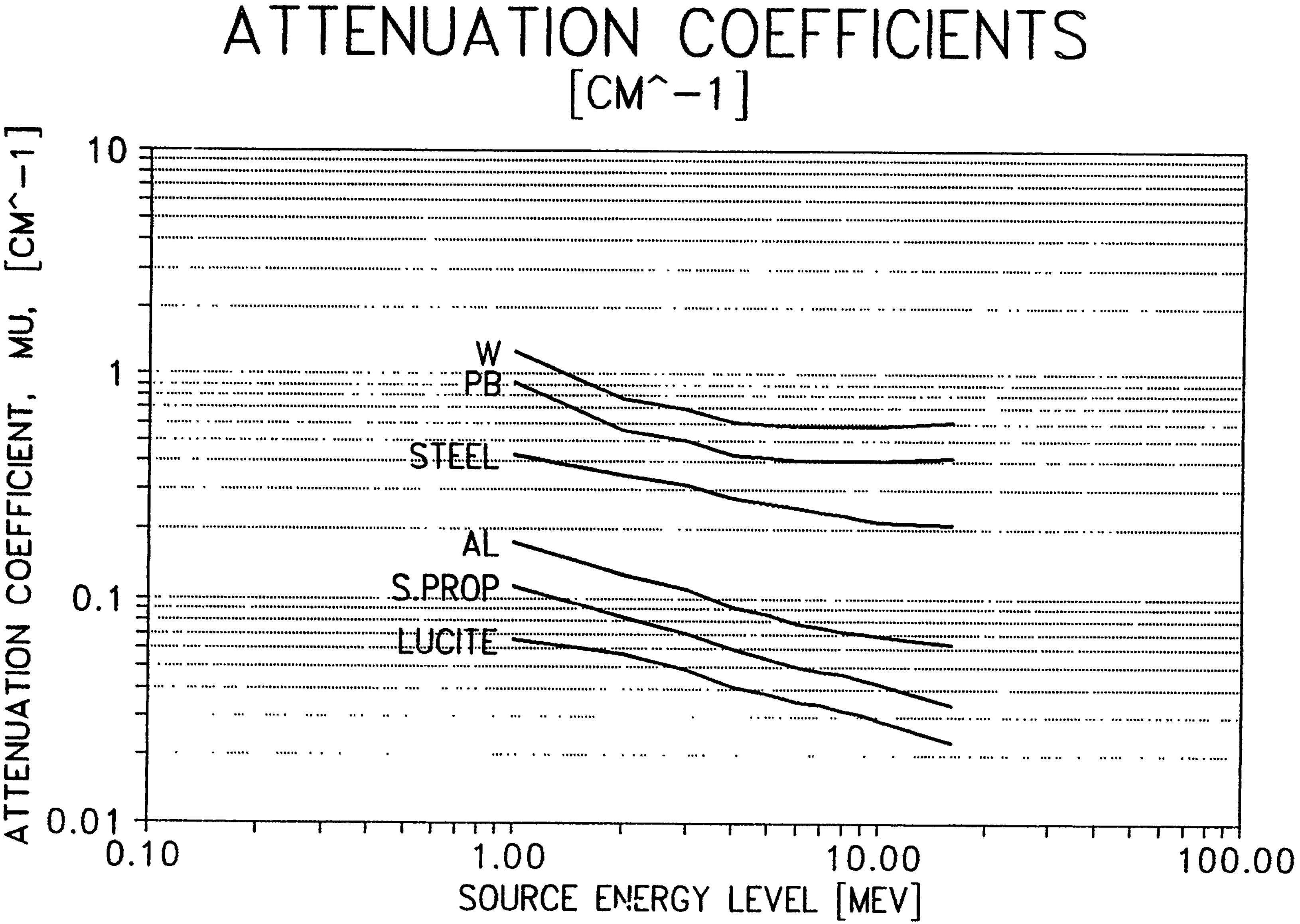

Figure 2. Attenuation Coefficients (cm^{-1}).

	1 MeV	2 MeV	3 MeV*	4 MeV	5 MeV*	6 MeV	7 MeV*	8 MeV	9 MeV*	10 MeV	16 MeV
Tungsten	1.260	0.770	0.686	0.603	0.590	0.578	0.578	0.578	0.578	0.578	0.603
Lead	0.924	0.554	0.494	0.433	0.420	0.408	0.408	0.408	0.408	0.408	0.420
Steel	0.433	0.347	0.312	0.277	0.262	0.248	0.239	0.231	0.224	0.217	0.210
Aluminum	0.178	0.128	0.110	0.092	0.085	0.078	0.075	0.072	0.071	0.069	0.063
Concrete	0.154	0.112	0.096	0.081	0.074	0.068	0.065	0.063	0.062	0.060	0.055
Solid Propellant	0.114	0.083	0.071	0.060	0.055	0.050	0.048	0.047	0.044	0.042	0.034
Lucite	0.066	0.057	0.049	0.041	0.038	0.035	0.034	0.032	0.031	0.029	0.023
Air	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

* INTERPOLATED

Table 1. Attenuation Coefficients (cm^{-1}).

(REFERENCE 2)

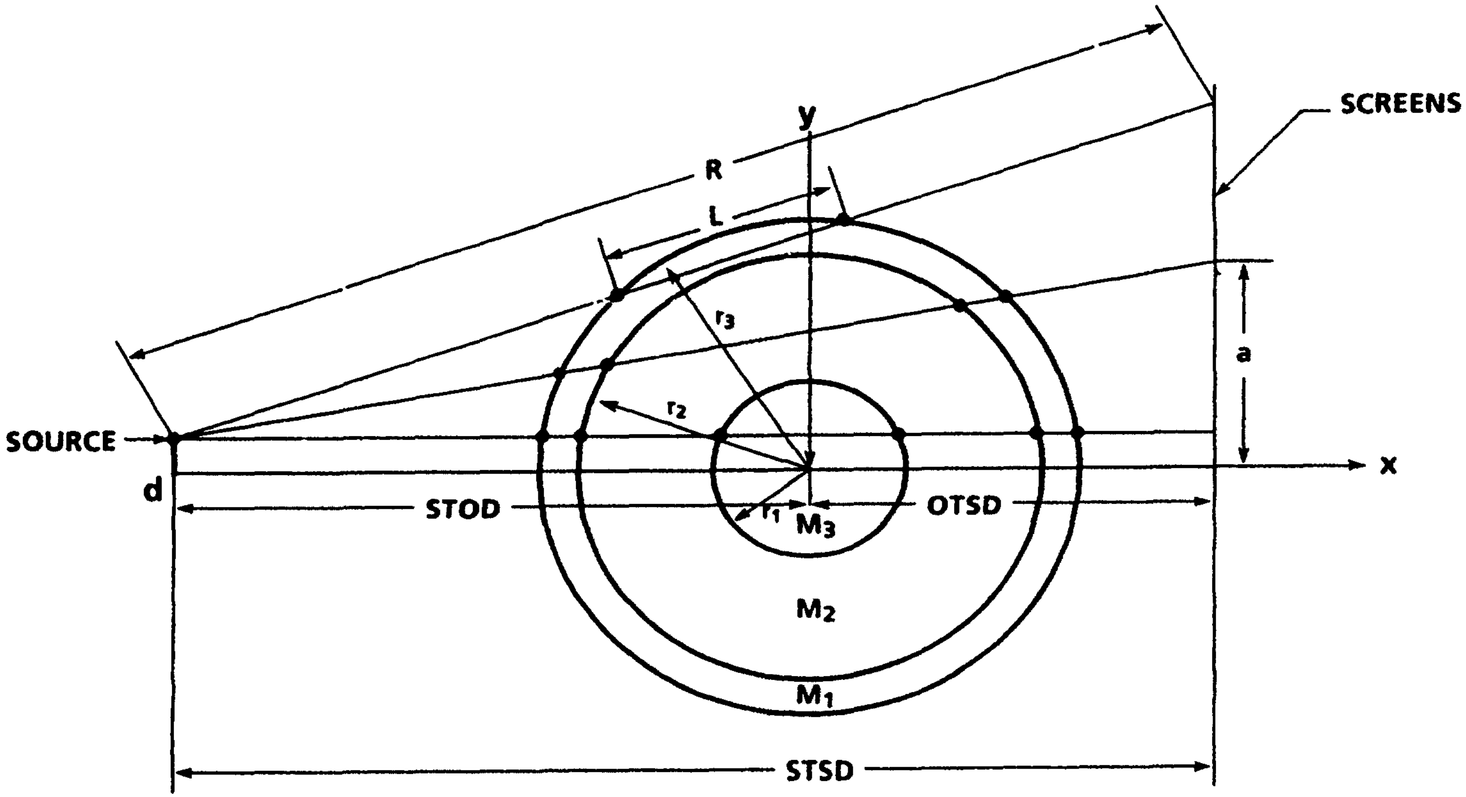

Figure 3. Model Used.

Mathematically, in rectangular coordinates, a circle is described using the standard equation:

$$r^2 = x^2 + y^2 \tag{8}$$

where:

r = Radius of Circle

Combine equations 5 and 8 to obtain the three quadratic equations with changes only in the radius:

$$x^2(1 + m^2) + x(2mb) + (b^2 - r_1^2) = 0 \tag{9}$$

$$x^2(1 + m^2) + x(2mb) + (b^2 - r_2^2) = 0 \tag{10}$$

$$x^2(1 + m^2) + x(2mb) + (b^2 - r_3^2) = 0 \tag{11}$$

and solve for x using the quadratic formula. Substitute these x-values into Equation 5 to obtain the corresponding y-values. Use these values in the distance formula to obtain the L distances:

$$L_1 = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{12}$$

$$L_2 = \left(\sqrt{(x_3 - x_4)^2 + (y_3 - y_4)^2} \right) - L_1 \tag{13}$$

$$L_3 = \left(\sqrt{(x_5 - x_6)^2 + (y_5 - y_6)^2} \right) - L_2 \tag{14}$$

where:

x_1 and x_2 = the roots obtained using r_1

x_3 and x_4 = the roots obtained using r_2

x_5 and x_6 = the roots obtained using r_3

$y_1 \ldots y_6$ = values obtained using corresponding values for x

Anytime the quadratic formula is used there are three possibilities of results. When solving Equations 9, 10, and 11, there are three conditions. If there are two real roots, there are two different values for x. This represents a ray passing through the circle. If there is one real root, the values for x are the same which indicates the ray is tangent to the circle. If there are two complex roots, there are two imaginary values for x which must be set equal to zero for all practical purposes. This is the condition which the ray does not intersect the circle. The reason for subtracting L_2 from L_3 and L_1 from L_2 is to give the true distance through each different material. Now that the R_D distance and the L distance are known, they can be substituted into equation 2 to solve for the intensity at the screen.

2.4 Spreadsheet

Once all of the equations were derived, they were programmed into a spreadsheet. The spreadsheet will allow for versatility and utility, easy access, and quick graphs. Table 2 shows a sample of the input sheet of the spreadsheet. Once the spreadsheet is programmed, it generates intensity values which were converted from digital signal to analog signal using a Matrox Image Processor. These analog signals were then recorded on to a video laser disk. When the video is played back, determining the inner surface of the propellant was easy. This simulation of a burning propellant appeared very similar to actual x-ray data taken from a firing.

```
Please enter these values in column C.
------------------------------------------------------------
Intensity output                                Io= 240.00
Source to object distance (meters)            STOD= 2.92
Object to screen distance (meters)            OTSD= 1.02
Radius (meters)                                  r= 0.19
Second radius (if any)                           r= 0.18
Third radius (if any)                            r= 0.05
How much does inner radius move per series?    irm= 0.04
What is the maximum value of a? (meters)      Amax= 0.43
What is the minimum value of a? (meters)      Amin= -0.43
How much is the source offset ? (meters)         d= 0.15
Which of the following materials will you be    M1= 7
 using? (max. 3) Please enter the numbers of    M2= 6
 the materials in cells C20,C21,& C22.          M3= 8

1. Tungsten
2. Lead
3. Steel
4. Aluminum
5. Concrete
6. Solid Propellant
7. Lucite
8. Air

What energy level wil you be using (MeV)?
 Please enter in cell C25.                     MeV= 4
------------------------------------------------------------
```

Table 2. Spreadsheet Input.

3.0 EXAMPLE RESULTS

3.1 Transmitted Intensity Profiles

Figures 4 through 7 show intensity profiles of four different models. Figure 4 shows the profile of a solid cylinder. This is denoted by $\mu_1 = \mu_2 = \mu_3$. Figure 5 shows the profile of a cylinder made of one material, but with a hole in it. This is denoted by $\mu_1 = \mu_2; \mu_3 = 0$. Figures 6 and 7 show the profiles of models similar to rocket engines. There are three different values for μ in each figure to model the case, propellant, and bore. The difference between these two is in the case. In Figure 6, the value for $\mu_1 > \mu_2$ and in Figure 7, the value for $\mu_1 < \mu_2$.

3.2 Burn Simulation

Figure 8 shows a profile of a simulated burn. The burn is simulated by moving the inner radius outward at specified intervals. Each time the inner radius moves the intensity profile is recalculated. This step is one of the major functions of ray tracing. It allows the user to determine the surface of the simulated propellant which can be compared to actual data. The spreadsheet input is listed in the Appendix.

3.3 Image Generation

In order to generate images, the intensity values must be run through one of the two programs called PLOTPROF or PLOTVERT. These programs work interactively between the personal computer and the Matrox image processor to convert the intensity values to analog signal which is recorded on to the video laser disk.

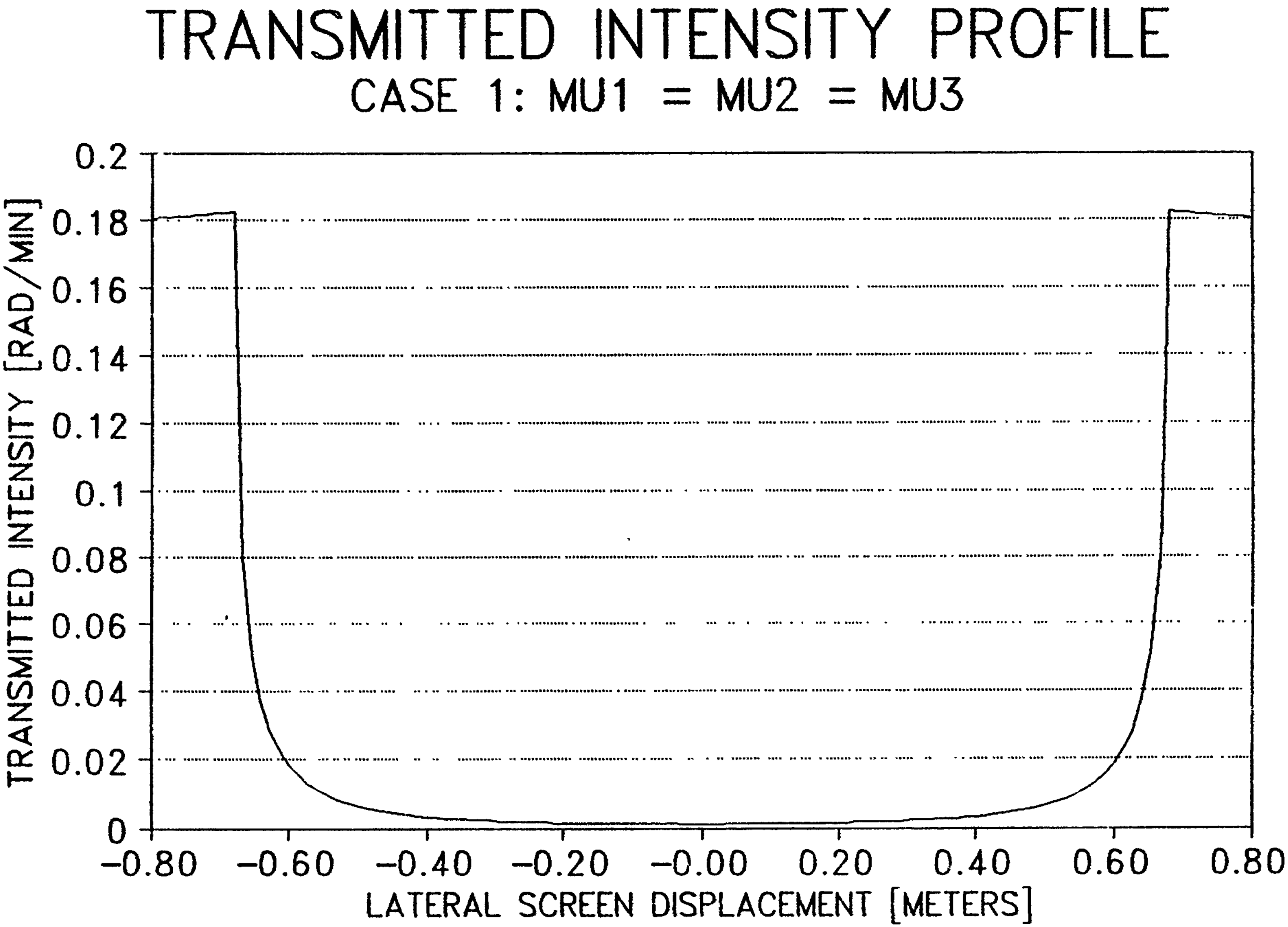

Figure 4. Profile 1.

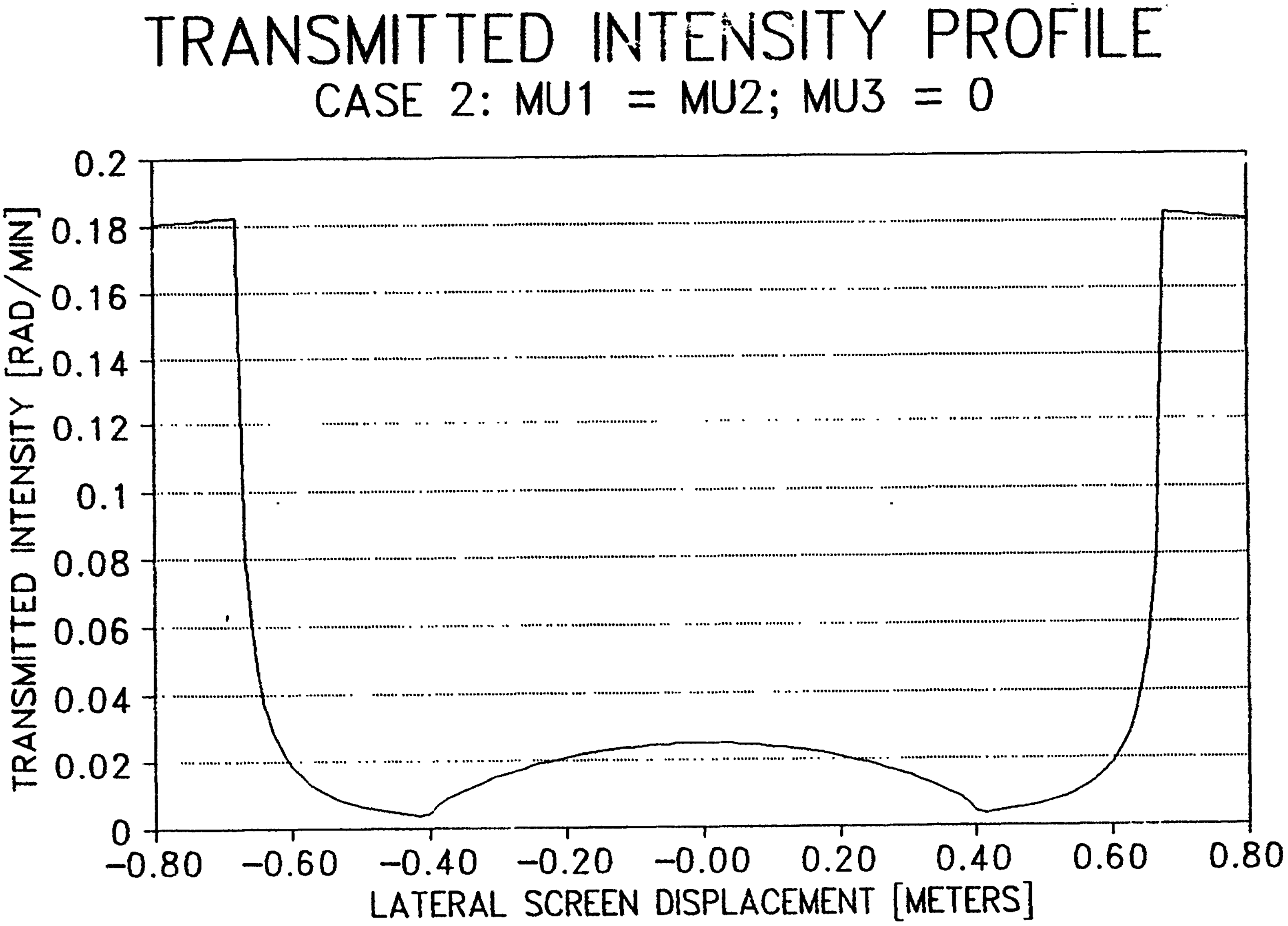

Figure 5. Profile 2.

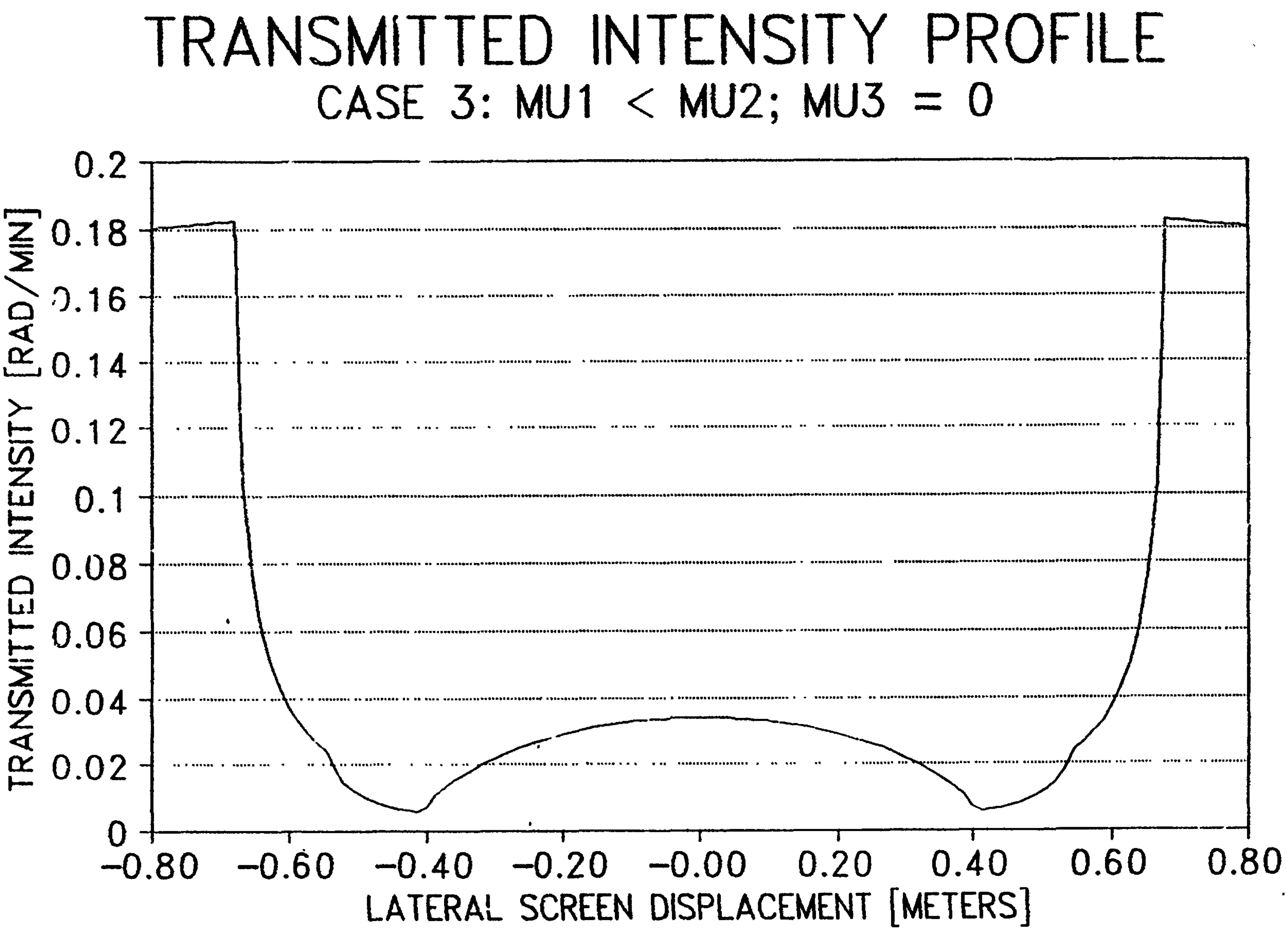

Figure 6. Profile 3.

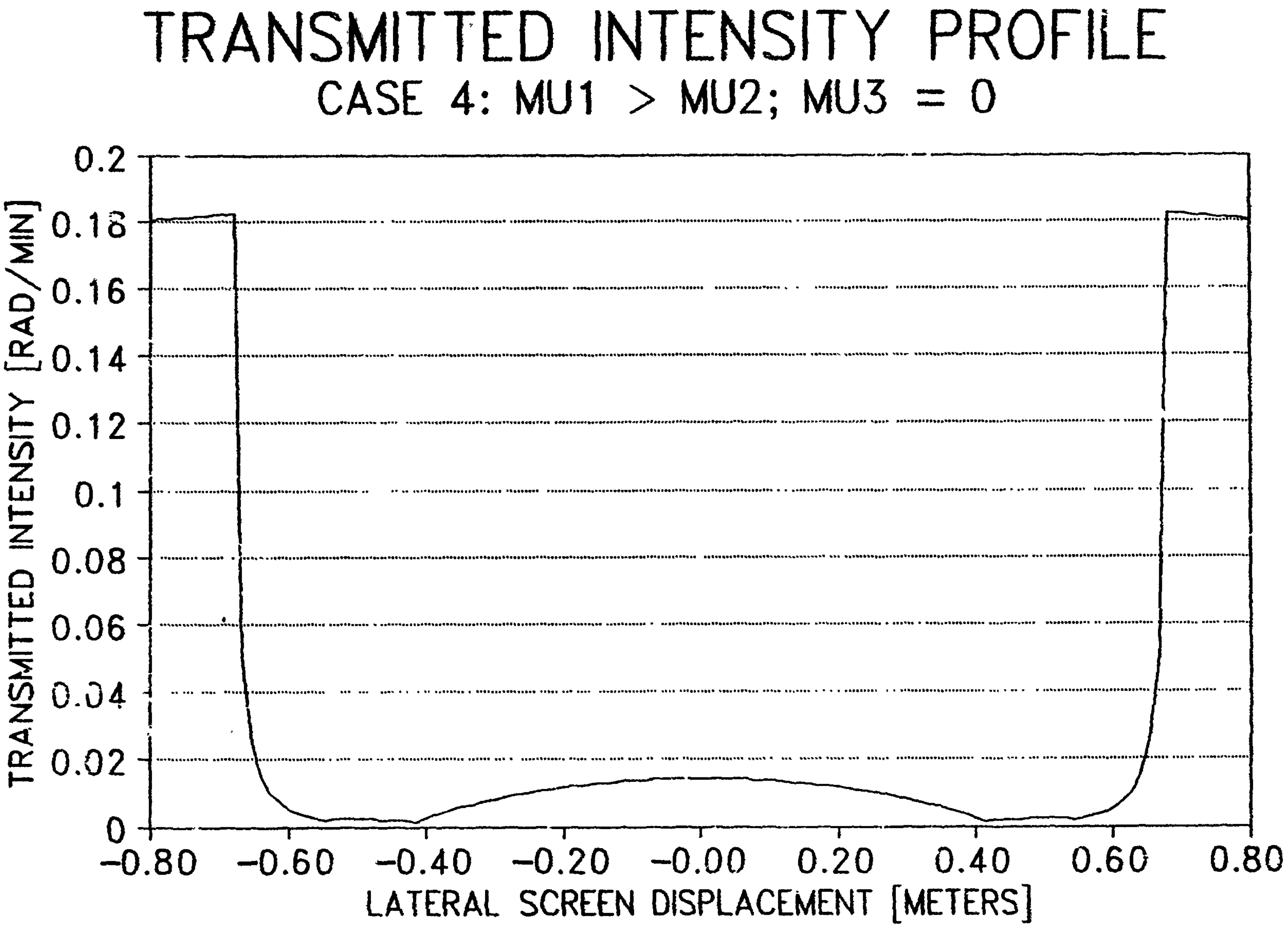

Figure 7. Profile 4.

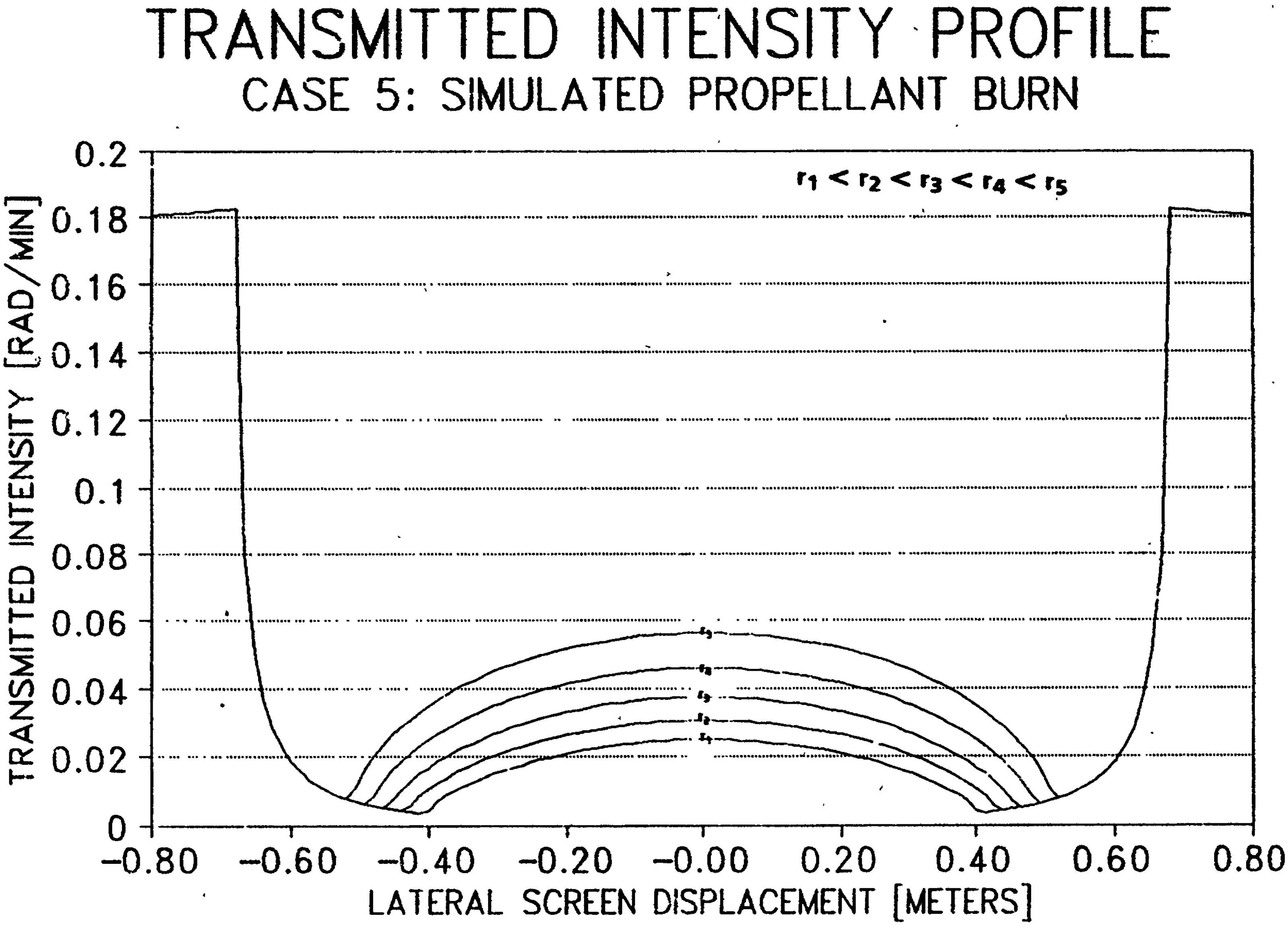

Figure 8. Profile 5.

4.0 CONCLUSIONS AND RECOMMENDATIONS

With other factors taken into consideration, such as penumbra and intensity scatter, these x-ray predictions can become more and more accurate. Research and development of this program will continue to improve it.

The ray tracing program can evaluate new test requirements by predicting the quality of the x-rays based on user specifications. It can also be used to evaluate how new x-ray sources could improve these images.

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2. Brunty, B. J., High-Energy Radiography, Section Six: The Nondestructive Testing Handbook on Radiography and Radiation Testing, The American Society for Nondestructive Testing, Columbus, Ohio, 1984.

APPENDIX

INPUT FOR CASE 1

```
Please enter these values in column C.
-----------------------------------------------------------------
Intensity output                                        Io= 300.00
Source to object distance (meters)                    STOD= 3.00
Object to screen distance (meters)                    OTSD= 1.00
Radius (meters)                                          r= 0.50
Second radius (if any)                                   r= 0.40
Third radius (if any)                                    r= 0.30
How much does inner radius move per series?            irm= 0.02
What is the maximum value of a? (meters)              Amax= 0.80
What is the minimum value of a? (meters)              Amin= -0.80
How much is the source offset ? (meters)                 d= 0.00
Which of the following materials will you be            M1= 6
 using? (max. 3) Please enter the numbers of            M2= 6
 the materials in cells C20,C21,& C22.                  M3= 6

1. Tungsten
2. Lead
3. Steel
4. Aluminum
5. Concrete
6. Solid Propellant
7. Lucite
8. Air

What energy level wil you be using (MeV)?
 Please enter in cell C25.                             MeV= 6
-----------------------------------------------------------------
```

INPUT FOR CASE 2

```
Please enter these values in column C.
-----------------------------------------------------------------
Intensity output                                        Io= 300.00
Source to object distance (meters)                    STOD= 3.00
Object to screen distance (meters)                    OTSD= 1.00
Radius (meters)                                          r= 0.50
Second radius (if any)                                   r= 0.40
Third radius (if any)                                    r= 0.30
How much does inner radius move per series?            irm= 0.00
What is the maximum value of a? (meters)              Amax= 0.80
What is the minimum value of a? (meters)              Amin= -0.80
How much is the source offset ? (meters)                 d= 0.00
Which of the following materials will you be            M1= 6
 using? (max. 3) Please enter the numbers of            M2= 6
 the materials in cells C20,C21,& C22.                  M3= 8

1. Tungsten
2. Lead
3. Steel
4. Aluminum
5. Concrete
6. Solid Propellant
7. Lucite
8. Air

What energy level wil you be using (MeV)?
 Please enter in cell C25.                             MeV= 6
-----------------------------------------------------------------
```

INPUT FOR CASE 3

```
Please enter these values in column C.
-------------------------------------------------------------------
Intensity output                                      Io= 300.00
Source to object distance (meters)                  STOD= 3.00
Object to screen distance (meters)                  OTSD= 1.00
Radius (meters)                                        r= 0.50
Second radius (if any)                                 r= 0.40
Third radius (if any)                                  r= 0.30
How much does inner radius move per series?          irm= 0.00
What is the maximum value of a? (meters)            Amax= 0.80
What is the minimum value of a? (meters)            Amin= -0.80
How much is the source offset ? (meters)               d= 0.00
Which of the following materials will you be          M1= 4
 using? (max. 3) Please enter the numbers of          M2= 6
 the materials in cells C20,C21,& C22.                M3= 8

1. Tungsten
2. Lead
3. Steel
4. Aluminum
5. Concrete
6. Solid Propellant
7. Lucite
8. Air

What energy level wil you be using (MeV)?
 Please enter in cell C25.                           MeV= 6
-------------------------------------------------------------------
```

INPUT FOR CASE 4

```
Please enter these values in column C.
-------------------------------------------------------------------
Intensity output                                      Io= 300.00
Source to object distance (meters)                  STOD= 3.00
Object to screen distance (meters)                  OTSD= 1.00
Radius (meters)                                        r= 0.50
Second radius (if any)                                 r= 0.40
Third radius (if any)                                  r= 0.30
How much does inner radius move per series?          irm= 0.00
What is the maximum value of a? (meters)            Amax= 0.80
What is the minimum value of a? (meters)            Amin= -0.80
How much is the source offset ? (meters)               d= 0.00
Which of the following materials will you be          M1= 7
 using? (max. 3) Please enter the numbers of          M2= 6
 the materials in cells C20,C21,& C22.                M3= 8

1. Tungsten
2. Lead
3. Steel
4. Aluminum
5. Concrete
6. Solid Propellant
7. Lucite
8. Air

What energy level wil you be using (MeV)?
 Please enter in cell C25.                           MeV= 6
-------------------------------------------------------------------
```

INPUT FOR CASE 5

```
Please enter these values in column C.
------------------------------------------------------------
Intensity output                                  Io= 300.00
Source to object distance (meters)              STOD= 3.00
Object to screen distance (meters)              OTSD= 1.00
Radius (meters)                                    r= 0.50
Second radius (if any)                             r= 0.40
Third radius (if any)                              r= 0.30
How much does inner radius move per series?      irm= 0.02
What is the maximum value of a? (meters)        Amax= 0.80
What is the minimum value of a? (meters)        Amin= -0.80
How much is the source offset ? (meters)           d= 0.00
Which of the following materials will you be      M1= 6
 using? (max. 3) Please enter the numbers of      M2= 6
 the materials in cells C20,C21,& C22.            M3= 8

1. Tungsten
2. Lead
3. Steel
4. Aluminum
5. Concrete
6. Solid Propellant
7. Lucite
8. Air

What energy level wil you be using (MeV)?
 Please enter in cell C25.                       MeV= 6
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ASTRONAUTICS LABORATORY

THE SUMMER IN REVIEW

Alisha A. Conrow

Astronautics Laboratory

Edwards Air Force Base

ACKNOWLEDGMENTS

I would like to thank Roy Surovec, my mentor, and Laurie Woodworth, my friend. I also give my thanks to the rest of the area 1-30 employees especially Dave Barry, Sgt. Dave Foxx, Chris Gazze, Ross Goebel, Minh Lee, Hieu Nguyen, and Dan Schwartz.

I have spent the last seven weeks working at the Astronautics Laboratory on Edwards Air Force Base. I work in the Solid Rocket Propellant Development Division (RKPL), Area 1-30. My mentor is Roy Surovec, an engineer working in the Rheometrics Lab.

Rheometry is the study of the flow of solid particles in a liquid. Rheometry studies the mechanical properties of non-Newtonian fluids. In my area, tests were generally run on the mechanical properties of propellants and liquid crystal polymers. With the help of the Rheometrics Stress Rheometer (RSR) and the Rheometrics Mechanical Spectrometer (RMS), these and other substances can be tested under very controlled circumstances. Temperature and stress can be controlled and monitored by the operator as well as being saved and processed by the computer.

I personally tested a number of bead suspensions under various conditions on the RSR. After gaining my results as printed out on the computer, I also plotted them out in a graph, viscosity vs. time.

My research enhanced my previous knowledge about the use of scientific method in the laboratory. It also bettered my computer skills , taught me to calibrate and operate a Rheometer and plotter, and my data will be a source of information for Rheometric work in the future.

Although I primarily worked in the Rheometrics Laboratory, I was exposed to most of the other functions of the Propellant Development Laboratory. I learned the steps necessary to the production of a propellant as well as taking part in actual testing and mixing.

Before the actual ingredients of a propellant are decided on, the desired properties of that propellant must be identified. A specific propellant may require a fast burn rate or a minimum smoke trail, but still must have the optimum thrust.

A propellant consists of solid fuel particles and oxidizer to burn, and a plasticizer to bind all the solid particles together. A number of other substances such as curatives or catalysts may be included. Because there are an unlimited number of substances that fall into each of these categories, the combinations, too, are unlimited. When the engineer finds an agreeable combination, he/she can use the Specific Impulse (Isp) program to theoretically combust the proposed propellant. The computer calculates the maximum thrust based on the ingredients, pressures, etc. I had the opportunity to become very familiar with the Isp program by actually running a number of tests.

If the results gained by the Isp program are satisfactory, a mix sheet is created. The mix sheet is basically a list of instructions for the person who will be doing the mix. It includes a list of ingredients and amounts, specific instructions on how to add each of these ingredients,mixer time and speed, vacuum time, etc. This sheet is given to the mixer operator who will produce a small-scale sample of propellant. This propellant is cast into various molds and is cured in an oven. Once this sample is cured, it is tested on a small scale for it's mechanical properties, burn rate, etc.

If again the propellants properties are satisfactory, a larger scale-up mix is done. This propellant is cast into motors to be fired, tensiles to be observed, samples to be tested, etc. When the motors are fired, they are monitored very closely by a computer that takes readings on burn rate, pressures, thrust, and so on.

As an apprentice, I had the opportunity to sit in the control room during a firing and I also viewed a number of mixes. After viewing a number of mixes I began to participate in them, weighing out samples, starting the mixer, operating the vacuum, and scraping the blades. I did all of this under supervision and although I never actually cast a propellant, I learned by watching how this was done.

As I mentioned before I gained quite a bit of experience with computers. I used the computer to test rheometric samples, run the Isp program, create mix sheets and input data using dBASE, and to use a word processor. I also became familiar with CADKEY, a computer design program.

I have learned, too, about the engineering field. Engineering, although diverse, is an unstable profession on a whole. Job security is almost null. Engineering often depends upon the government to contract out work to private companies. Because of this, lay-offs, much like McDonnell-Douglas, are far from unusual. It seems that much of an engineers time is spent not on creating, but on paper work and struggling with the budget.

All in all, this is a very beneficial program. It gave me new insight into various types of engineering as a profession and taught me to see the pros , as well as the cons of engineering.

SYNTHESIS OF TWO CAGE COMPOUNDS

1990 Apprenticeship Program

DEBBIE MEYER

Edwards Air Force Base

The past eight weeks have been spent learning lab techniques by working with organic materials. As A result, I gained an understanding of Diels - Alder reactions and became familiar with testing apparatus such as; Gas chromatography, Liquid chromatography, Thin Layer chromatography, Nuclear Magnetic Resonance, and Ultra Violet spectrums. My work consisted of two reactions with the objective of obtaining cage compounds. The cage compounds will later be tested as additives for solid and liquid propellants.

The first reaction scheme consisted of three steps. The first step was cracking the dicyclopentadiene which was a Retro Diels - ALder reaction. 50 mL. of dicyclopentadiene was heated to 175°C in methanol. The vapors distilled at 45°C to make cyclopentadiene which was collected in a flask immersed in a cold bath at -10°C to prevent a reverse reaction.

The second step was a Diels - Alder reaction. 20 g. of freshly cracked cyclopentadiene and 32.7 g. of benzoquinone were combined in a methanolic solution at -70°c. The reaction mixture was allowed to warm to room temperature and the product, dione diene, was obtained by suction filtration. 24.68 g. of the dione diene was collected by recrystallization from methanol. This was a forty-seven percent yield.

Photolysis was the last step, this step was necessary to form a cage compound. 10 g. of the dione diene was taken in ethyl acetate and irradiated for thirteen hours with a medium pressure mercury lamp. A Pyrex filter was used to block out ultra violet light that had a wavelength less than 310 nm. 7.28 g. was collected by recrystallizing from ethyl acetate. This was a seventy-two percent yield.

Throughout the first reaction, tests were made to determine how pure the products were. Nuclear Magnetic Resonance Showed peeks that represented the location of protons. By knowing the location of the protons, it was possible to determine what was present in the products. An Ultraviolet Spectrum of the dione diene was taken to insure that it would absorb in the region of interest. Liquid chromatography , Gas chromatography, and melting point were also tests used to determine properties and structure.

Thin Layer Chromatography was used to determine when a reaction was complete. A few drops of starting material was placed on the left side of a silicagel slide. About four drops of the product was placed on the right side of the slide. In most cases, the slides were developed in a hundred percent ethyl acetate. The Thin Layer Chromatography slide was visualized by ultra violet light and by P.M.A. char. The slide shows two things, Retention factor and color. Analyzing the color and retention factor of the dots on the T.L.C. slide, the completion of a reaction can be determined.

Upon the completion of reaction scheme one, reaction scheme was started. The first step was the reduction of the enedione. 18 g. of the enedione was taken in methanolic solution and 41.17 g.of cerium chloride heptahydrate. The cerium chloride heptahydrate was added to get the two alcohol groups in a cis position so they would later help to form a cage compound. To this mixture was added 4.118 g. of sodium borohydride in small portions with the help of Solid Addition Funnel. The reaction mixture was monitored for completion by T.L.C. which indicated it was pure. The reaction mixture was poured into water and extracted with ether. The organic layer was washed with water and dried over anhydrous magnesium sulfate. Removal of the solvent under vacuum furnished 18 g. of enediol. This was a 96.9 percent yield.

The last step of the second reaction was rearrangement. 10 g. of the diol was taken in 42.9 mL. of potassium t-BuOH. At room temperature, 38.6 mL. of t-butoxide was added and stirred for sixteen hours. When the T.L.C.

showed absence of starting material, the reaction mixture was poured on crushed ice, acidified and extracted with methylene chloride. The organic layer was washed by water and dried over anhydride magnesium sulfate. Removal of the solvent furnished a solid. This last step of reaction scheme two sythesized a cage compound.

The objective of obtaining cage compounds is to increase potential energy. The greater the ring strain, the more energy a molecule will contain. The products from reaction schemes one and two contain this ring strain energy. They will be tested as additives for solid and liquid rocket propellants.

ACKNOWLEDGEMENTS

I would like to thank everyone in the A.R.I.E.S office at Edwards Air Force Base. They were always eager to to help and encouraged me to pursue a career in chemistry. As a result of working with such wonderful people, I have decided to major in chemistry.

I especially need to thank Dr. Jeffrey Gilman, Dr. Suresh Suri, and Rob Mantz who worked with me in the lab. Not only did they teach lab techniques, but also explained the objectives of each step. I was able to do a reaction with a complete understanding of why it was done and how it could later be used.

I would also like to thank UES for giving me this wonderful opportunity.

I. Final Report on Summer High School Apprenticeship

"Fundamental Rocket Exhaust Measurements"

Student: John Moro

Mentor: Dr. Michael Holmes

Astronautics Laboratory

Astronautical Sciences Division

Phenomenology Branch

Experimental Data Collection Section

August 31, 1990

II. Acknowledgments

Through this program, I worked with many people. Each person helped make this program a memorable and successful experience. I would like to thank each individually for his/her part in helping to make this program fun and interesting.

First, I want to thank Dr. Phil Kessel, Branch Chief, for giving me the opportunity to be included in the branch meetings where upcoming issues were discussed. I enjoyed being a part of the meetings and being able to see firsthand how the engineers interacted together in order to prepare for and solve particular problems.

Secondly, I would like to thank our Section Chiefs, Captain Joe Cor and Tom Smith, for following my progress and helping with any problems that I encountered. I want to thank Tom Smith for having me make copies of slide presentations, too. By doing so, I was able to see more of what was taking place within our branch. I also want to thank Captain Cor for answering any questions that I had about the Air Force in which I'm highly interested in pursuing a career.

I would like to give special thanks to my mentor, Dr. Michael Holmes, for taking time from his schedule to help me become more familiar with using the computers. I thank him also for explaining the purpose of our work and how it related to the lab's goals. His patience and understanding helped make the apprenticeship most enjoyable.

I would like to thank Dr. Dave Stanford and Cliff Paiva for

demonstrating the importance of mathematics in their particular areas of research. Frequently, they demonstrated how formulas enabled them to obtain desired information and results.

I want to thank Roy Hilton and his co-op student from Cal Poly, San Luis Obispo, Paul Carrannanto, for giving me assistance on the computer when my mentor was busy or unavailable. I also want to thank Marty Venner for his assistance and support.

I would like to thank Lieutenant Thierry Woods for allowing me to create diagrams on the computer for him. I would also like to thank him for talking with me about the Air Force Academy and Air Force ROTC as well as answering numerous questions concerning college programs in general.

Last, but not least, I want to give thanks to Debbie Lisenbery, Branch secretary, and Debbie Horton, Technical Services secretary, for handling my time cards and the Branch mail.

III. General Description of Research

My specific research and efforts consisted of reduction and analysis of rocket particles taken from rocket plumes. The data received from the particles was reduced in such a way that enabled an analysis to be made of the data collected. I helped reduce the data from histograms which were developed from particles of $Al_2 O_3$ (Aluminum oxide) which were observed through a scanning electron microscope. With the reduced data I made particle imitations from which an analysis could be made. The results supplied particle sizes from rocket motors. Each particle emits a certain amount of radiation which can be detected. The larger the particles, the more radiation emitted and therefore, the easier it is to detect and track a rocket.

In general, the information gained from this research will be used by the Air Force and the SDI program as a defensive measure which will enable the U.S. to detect, track, and eventually destroy hostile launched missles.

IV. Detailed Description of Research

The histograms I used for this research were known as number density histograms. They provided the basic number of particles and their different sizes. My job was to reduce this information in such a way so as we could analyze the data represented on the histogram. I set up a data file with the information from the histograms, and with the use of a FORTRAN compiler and program, the data I typed into the computer was plotted on a graph. This was done, because the histogram records a very narrow amount of the particles, and the validity of its numbers is uncertain. By creating the graph, a larger area of particles was observed and a margin of error was indicated, which made the graph more accurate than the histogram.

As an aide to this research, I used the MicroVax computer, the Sun computer, a laser printer, and the FORTRAN language. On the MicroVax computer system I wrote a program which created imitations of particles of different sizes and distribution. These particle imitations were then taken to the Chem Lab where the results were to be compared to the histograms so we could see what the differences were, if any. The results have not been returned in time to be included in this report.

V. Results

Through my research, I learned that the Al_2O_3 particles were very small and hard to formulate a pattern from which a comparison or study could be made. I discovered that solid rockets are easier to detect because their plumes contain larger particles which emit a higher radiation level. Liquid rockets, on the other hand, are much harder to study because their plumes contain no particles at all. Liquid rocket plumes only contain soot, which is very hard to detect. I also discovered that besides rocket particles giving off heat, the rocket body additionally gives off heat. Dr. Dave Stanford explained how he could calculate the radiation emitted without detecting the heat from the rocket body itself. He used Planck's Law of Emission and Lambert's Law of Optics to do this. Once he figured out the radiated intensity, he calculated the power falling on a pixel from the radiating source. The power came from a beacon positioned on the rocket and the detector was a surface plate with many pixels, each of which would detect a certain amount of radiation.

VI. Other Interesting Observations and Lessons Learned

Throughout my apprenticeship, I observed that each engineer or group of engineers, have their own assigned task which would contribute to the total goal or effort. For example, I concluded that Dr. Stanford's calculations were conducive to my study of particles. While I was studying particles of different sizes and the radiation emitted, he was calculating how to detect the radiation without detecting heat from other sources on the rocket. The results of identifying the type of rocket were the same.

In conclusion, I was able through the summer program to gain a better understanding of an engineer's work. I realized that engineers are constantly doing research by reading books, going to different labs, and conferring with other engineers. Many times, engineers research a problem by seeing if some other engineer had met the same difficulty and found a solution.

This summer apprenticeship was very interesting and beneficial to me. I feel that through this program I have developed a better understanding of the engineering field, the education involved, and the typical work ethic required. I was very impressed with the professionalism I observed at the Astronautical Laboratory and the dedication of all the employees. The apprenticeship program was very worth while to me and because of it I feel more confident in my desires to pursue an engineering career.

Analytic Predictions of Hydroxyterminated Polybutadiene (HTPB) Modulus using Random Iterative Discrete Node Algorithm (RIDNA)

Final Report from
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Period of Employment
20 June 90 - 24 August 90

Acknowledgements

Having worked on a project where I was given a great deal of freedom and the bulk of the responsibility I had cause to seek assistance or knowledge from all of the members of RKBA on one occasion or another, all of whom deserve my thanks. First I would like to thank Mr. Terrence Galati, my mentor, for inviting me back for a second summer here at the Laboratory and for giving me virtual control over one of his many research projects. Next I would like to thank Mr. Jerry Gallardo and Mr. Alex Sagers for their invaluable computer support. Both provided me with large amounts of their time and resources. I also must thank Mr. Lester Tepe, the section chief of RKBA, for his assistance as well as all of the other members of RKBA for their time and friendship.

Abstract

The Random Iterative Discrete Node Algorithm (RIDNA) represents a significant advance in microstructural constitutive theory as applied to polymeric binder materials used in the manufacture of solid rocket propellant. A recent supercomputer version of RIDNA allows one to assess the viscoelastic behavior of a variety of polymeric binders. This work concentrates on optimizing the convergence criteria used in RIDNA to minimize computer cost and preserve accuracy of modulus behavior using hydroxyterminated polybutadiene (HTPB) as a baseline material. Taguchi experimental design techniques were used to establish the sequence of 20 RIDNA runs. Predictor equations and statistical validation were then used to find the optimum convergence criteria which both minimized computer run time and preserved the overall secant modulus of HTPB. After optimization, RIDNA predicts the average secant modulus of HTPB to be 105.39 psi with an average run time of 439 min with variance of 36.5 and 183 respectively when stretched to 600% strain.

Introduction

The Random Iterative Discrete Node Algorithm, known as Random IDNA or RIDNA for this study, is the culmination of the Microstructural Propellant Constitutive Theory program conducted by I. L. Davis and R. G. Carter of Thiokol Corporation, (Contract: F04611-87-C-0041). This computer code has been billed as the largest and most comprehensive amorphous polymer network simulator currently available.[1] The code was part of a larger effort to characterize solid rocket propellant using constitutive theory–actual molecular modelling of the polymeric binder and packed particulate. The polymeric binder described by RIDNA is coupled with a solids dispersion algorithm and then linked with an algorithm to compute solid particle–binder stresses. All three of these microstructural characterizations are significant technical challenges. This work examines the first challenge–the polymeric binder description using RIDNA. RIDNA's primary function is to compute the viscoelastic response of a polymer network. It does this through two other codes: CLENGTH and CONNECT. CLENGTH uses Monte Carlo calculations to create polymer chains based on characteristic molecular structure and then provides force cubics which describe chain elasticity. CONNECT uses the CLENGTH chains and randomly creates a 3-D network which is used as the input to RIDNA. The user can then modify the input deck to impose a strain history on the network. The output of RIDNA consists of graphical plots of deformed model geometry throughout the strain history and force/displacements of the boundaries of the network. Figure 1 shows a representative network of 3000 polymer chains. The strains are imposed on the boundary nodes–those nodes that are within a distance of 15% of the model length. The boundary nodes remain fixed relative to other nodes in the boundary. All other nodes are free to move subject to polymeric chain forces, interaction forces and viscous forces. One expects the nodes to reach equilibrium (sum of the forces around each node to be near zero) after the nodes are moved in the direction of the resultant load for each node in a stepwise fashion. This work examines the RIDNA code using random networks of hydroxyterminated polybutadiene (HTPB) to investigate the sensitivity of secant modulus and computer run time to convergence criteria.

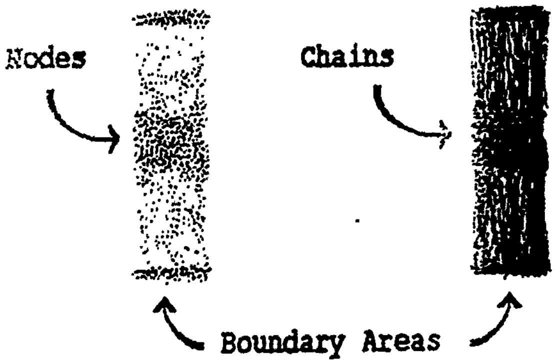

Figure 1. Randomized HTPB Network of 3000 Chains

The power of supercomputers makes the contributions of RIDNA evident. A serious drawback to microstructural constitutive theory is the enormous amount of CPU time required to describe the molecular behavior of polymers. RIDNA was originally developed on a MicroVAX computer. A 5000 chain network of HTPB required *four weeks* of CPU time to compute the stress-strain behavior to 500% strain. At the Astronautics Laboratory, the RIDNA code running on a VAX 8650 machine required 70 hours of CPU time.

We recently modified RIDNA to run efficiently on the Cray 2 supercomputer at the Air Force Supercomputer Center, Kirtland AFB. The above problem require 5 hours of CPU time. The high computer cost had prevented many runs of RIDNA, in fact, the 5000 chain HTPB problem had been the only run at the conclusion of the development effort. We present 29 runs of networks with 2500 to 5000 chains to demonstrate the code's capability and to optimize the convergence criteria to minimize computer time. As computer power increases and costs decrease, microstructural constitutive theory becomes a viable tool for assessing the elusive behavior of polymeric binders and eventually characterizing solid rocket propellant.

Series I Computational Runs

This series represented the first set of Cray 2 supercomputer runs that were run in order to discover the first-order relationship between the convergence criteria and CPU time. Modulus was examined, but the primary emphasis of the first series was determining sensitivity to computer time. A Taguchi two-level, five factor design of eight runs ($L_8\ ^{2-5}$)[2] was chosen to investigate the first-order behavior of five input variables, with CPU time and modulus as results. The input factors were orthogonally coded to preserve the magnitude of each effect. The HTPB chemistry data was kept constant throughout these runs. Table I shows the entire matrix of input variables on the left, and the output in the two rightmost columns.

Table I. Series I Experimental Design with Results

Run Number	A	B	C	D	E	F	CPU Time minutes	Average Modulus
Run 1	3000	35	0.008	20	1E-7	0.001	249	131.2
Run 2	3000	35	0.002	30	1E-8	0.001	518	120.6
Run 2a–Recover	3000	35	0.016	30	2E-6	0.001	80	144.4
Run 3	3000	75	0.008	30	2E-6	0.001	77	124.3
Run 4	3000	75	0.016	20	1E-7	0.001	250	149.3
Run 5	4000	35	0.008	20	2E-6	0.001	246	127.1
Run 6	4000	35	0.016	30	1E-7	0.001	330	141.8
Run 7	4000	75	0.008	30	1E-7	0.001	498	128.2
Run 8	4000	75	0.016	20	2E-6	0.001	157	145.7
Run 9–midpoint	3500	55	0.012	25	1.05E-6	0.001	224	134.6
Run 10–maximum	5000	100	0.0001	50	1E-8	0.001	893	89.6
Run 11–minimum	500	100	0.001	50	1E-8	0.0001	51	108.8
Run 12–varied	5000	100	0.001	100	1E-8	0.0001	2852	111.2

A) Number of Polymer Chains

B) Number of Nodal Sweeps
C) Global Stopping Move Size (Fraction of the shortest maximum chain length)
D) Number of Global Sweeps Allowed
E) Absolute Nodal Stopping Force Magnitude
F) Nodal Stopping Force Fraction

Note: Runs 1–8 represent a Taguchi $L_8\ ^{2-5}$ Design

Factor A was the number of polymer chains. This was thought to have the greatest effect on computer time. More polymer chains implied more calculations of chain forces, viscous forces and interaction forces. The low setting was 3000 chains, the high setting was 4000 chains. Factor B was chosen to be the maximum number of nodal sweeps, with 35 the low setting and 75 the high setting. This factor controlled the maximum number of iterations that were allowed for any given node if none of the equilibria conditions were met. We thought this factor was second in importance on affecting CPU time; higher nodal sweeps implied more calculations for each node to reach equilibrium. Factor C was chosen to be the global stopping move size. This represented the fraction of the shortest maximum chain length which was used as a measure of global convergence. In other words, if all of the chains have moved less than this fraction (0.4% low and 0.1% high) of the shortest chain, then the network was considered to have reached equilibrium for the current step. Factor D was chosen to be the maximum number of global sweeps allowed during the convergence check above. This limited the number of global iterations to 20 for the low setting and 30 for the high setting. Factor E was the nodal absolute stopping force. This was the residual force that was acceptable for a node to be considered at equilibrium. The nodal force units are expressed in "harbos" an atomic force unit based on atomic energy ("hartree") and atomic distance ("Bohr radius"). Values for factor E ranged from 1e-7 for the low setting and 2-e6 for the high setting. The majority of this data was processed using a spreadsheet on an Epson PC compatible where it was quite simple to enter the conversion factors into the equations during the processing phase. Some conversion factors are shown in Table II [3].

In Run 2, factor E was originally chosen to be 1e-8 harbos; this run consumed 518 CPU minutes and was deemed too expensive since in a properly designed Taguchi matrix, one starts with the least expensive run (all low settings) and progresses with more expensive runs. Run 2a represented a recovery; factor E was increased to 2e-6 harbos, resulting in 80 min of CPU time. Since E was originally thought to be a minor factor, it was aliased with the ABC interaction. Factor F was nodal stopping force fraction. This represents the fraction of the original force present at the node to be considered to have reached equilibrium. Factor F was kept constant for the Taguchi series, but was varied to see its effect in runs 11 and 12.

Table II. Experimental Data Atomic Unit Conversion Constants

Unit	Conversion	Unit
Atomic Stress	4,259,047,696	psi
Bore Radii	0.529118	Angstroms
Electron Masses	9.109e-28	grams
Time Periods	2.4205E-17	seconds
Hartree	27.211396	electron volts
Atomic Force 'Harbos'	0.0000000823	Newtons

The Taguchi $L_8\ ^{2-5}$ design is a fractional factorial design. A total of 32 runs would be needed to completely characterize all variations of five input factors on a first-order basis. By aliasing factor D, global sweeps, with the AB interaction and aliasing factor E, absolute nodal force, with the ABC interaction, the 32 required runs can be folded into 8 runs–provided that one's aliasing assumptions are valid. A taguchi analysis software package on the Epson PC compatible, when given the input and output data for a matrix will yield equations that are capable of predicting the output of any run within the bounds of the matrix's highs and lows. Below are the predictor equations that were derived for secant modulus and CPU time from the factor coefficients:

Average Secant Modulus

$$\hat{Y}_{\overline{E}} = 136.5 + 8.8C - 1.825D - 1.125E + 0.875AB - 0.8A - 0.75AC + 0.375B \qquad (1)$$

To maximize secant modulus set : $A_-B_-C_+D_-E_-$

Yields : $\overline{E}_{max} = 150.3$ psi (predicted)

To minimize secant modulus set : $A_+B_+C_-D_+E_+$

Yields : $\overline{E}_{min} = 125.9$ psi (predicted)

$\overline{E}_{CPU_{max}} = 128.2$ psi (validated in L_8 matrix–Run 7)

$\overline{E}_{CPU_{min}} = 148.0$ psi (predicted)

$\overline{E}_{midpoint} = 136.5$ psi (predicted)

$\Delta\% = -1.4\%$

$\overline{E}_{Run9} = 134.6$ psi (actual computer run)

CPU Time

$$\hat{Y}_{CPU} = 235.9 - 95.875E + 71.875A - 32.625AC - 31.675C + 10.375D + 10.125AB + 9.625B \qquad (2)$$

To maximize CPU set : $A_{+}B_{+}C_{-}D_{+}E_{-}$

Yields : CPU $_{max}$ = 498 minutes (validated in L_8 matrix–Run 7)

To minimize CPU set : $4_{-}B_{-}C_{+}D_{-}E_{+}$

Yields : CPU $_{min}$ = 59.25 minutes (predicted)

CPU $_{\overline{E}_{max}}$ = 251 minutes (predicted)

CPU $_{\overline{E}_{min}}$ = 306 minutes (predicted)

CPU $_{midpoint}$ = 235.9 minutes (predicted)

$\Delta\% = -5\%$

CPU $_{Run9}$ = 224 minutes (actual computer run)

Equation 1 predicts the average secant modulus. Factor C, the global stopping move size had the most significant effect, varying secant modulus by -8.8 psi (0.8%) to +8.8 psi for 1.6% stopping move size. Factor D had an effect of ±1.8% psi, the other factors and interactions accounted for ±1% or less. From the equation (2), one can see that factor E as the most effect on computer time, not factor A as originally thought. Aliasing factor E with ABC was a poor choice, since one has no way of knowing if the effect of the fifth factor was indeed factor E or the interaction of ABC. The recovery run from 2 to 2a indicated that factor E had a significant effect on CPU time. As factor E was changed from 1e-8 harbos to 2e-6 harbos, CPU time decreased from 518 min to 80 min. Factor A had a significant effect also, adding 144 min when going from 3000 chains to 4000 chains. The AC interaction and Factor C alone accounted for ±32 min each. Factor D, factor B, and the AB interaction had minor effects at ±10 min each.

Using the capabilities of the section's wide variety of computers and software applications for animation Mr. Galati and myself generated graphic representations of the taguchi networks created by the Cray2. The individual pictures were generated and strung together into an animation on the VAX computer system here at the Astronautics Laboratory. The files were then transferred over to an Amiga 2000 where the animation was edited and enhanced to produce a finished animation. All of this was done using in-house software developed chiefly by Russ Leighton of RKBA.

Figure 2 shows the eight runs in the first Taguchi design. Notice the clump of polymer chains in the center of the specimens. This represents a non-equilibrium condition, since true equilibrium would be indicated by an even distribution of nodes. The Young's moduli of the runs ranged from a high of 150 psi to a low of 125.9 psi. From these runs, it became clear that the networks converged to reach equilibrium based on the selected criteria, however, the the criteria may have been too "loose" to reach a meaningful relaxed state. We feel that lower secant modulus values would lead to a more accurate state of equilibrium. This rationale led to the creation of the second Taguchi design described in the next section. Run 10 represented the "midpoint" run. From the predictor equation, if all of the factors are set to 0, the secant modulus and CPU time would be 136.5 psi and 235.9 minutes respectively. Even though the factors were prioritized improperly in this first Taguchi design, the model was still valid to five percent. This was encouraging, since we had no idea, a priori, what the effect of these five factors would be. Run 11 was run with only 500 chains to create a computer graphics model for animation purposes. The RIDNA code has the ability to put out a PATRAN neutral file containing the XYZ coordinates of the nodes and chains. This file was then displayed on a Tektronix XD88/30 3D graphics workstation to assess the physical geometry of the network. Runs 10 and 12 tested the maximum chain limit of the code. The VAX version of the code could handle 20K chains, but due to the expense of CPU time, only 5K networks have been run. On the Cray 2 version, we hard-coded a 5K chain limit to minimize in-core memory requirements. Since the Cray 2 is a linearly-addressed machine, all of the code, including the large network arrays are in-core throughout the run. Run 12 also tested the limits of cost, since this run consumed 2852 min-at a cost of $9506.67. It was this run that convinced us that the key to true equilibrium could be found in lower secant moduli. Run 10 had a secant modulus of 89.6 psi and Run 12 exhibited 111.2 psi. The graphical representation of the networks showed them to be fully-relaxed, without severe clumping of chains in the middle. From the first series, the physics of the RIDNA code appeared to be valid; our next investigation was to determine the secant modulus-to-cost relationship.

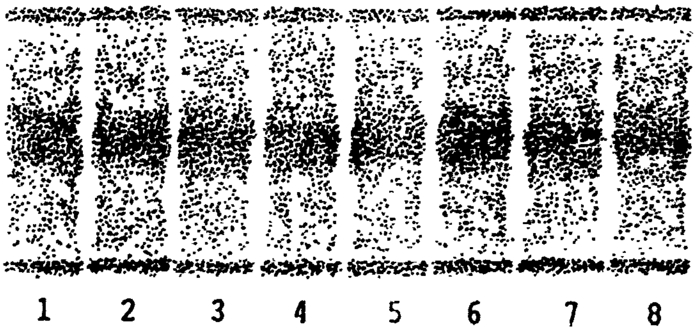

Figure 2. Series 1 Networks at 250% Strain

The RIDNA runs on the Cray2 yield an output deck that is typically in excess of 3000 lines. Upon my arrival at the Laboratory my first task was to sort through the output files of the first eight runs to find boundary area, original and current position, and boundary forces for each time phase. My solution was to write a series of macros for the data editor on the Laboratory VAX cluster. These macros first remove all extraneous data from the files, and then create new files consisting only of the data necessary to the analysis in a special format that can be transferred directly into a spreadsheet program on the Epson computer. Figure 3 shows the nodal step histograms for Runs 1 through 8. These plots show the number of steps a selected node required to reach equilibrium. This gives an indication of how quickly the nodes reach equilibrium depending on the convergence criteria selected. The curves fall into two families: those with a hump in the 0 to 8 range and those with a hump centered around 17 steps. The differences in these two families can be explained by the absolute nodal stopping force. The large force (2e-6 harbos) resulted in a high number of nodes reaching equilibrium in 8 iterations or less. The small force (1e-7 & 1e-8 harbos) resulted in most nodes reaching equilibrium in 17 steps–requiring more CPU time. The "tail" on the far right portion of the graph represents those nodes which did not reach equilibrium within the 35 nodal sweep limit. This indicates that a limit larger than 35 was needed to allow some of the "stiff" nodes to reach equilibrium.

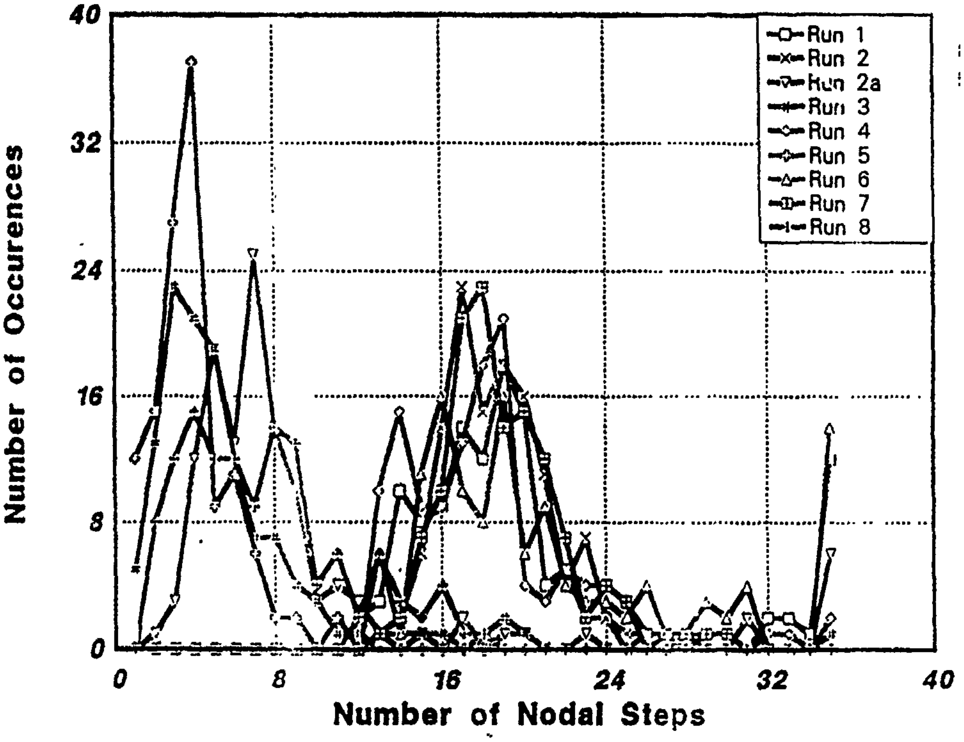

Figure 3. Series 1 Nodal Step Histogram

Figure 4 is a plot of the secant moduli for the first series of runs. Initial data was not output for these runs, so the data starts at 50% strain. From the curve, the overall average (from 50% to 250% strain) is

183.5 psi with a varience of 237.3. Even though the variation was large, one can be encouraged that after all of the supercomputer time has been spent, the curves are mostly linear.

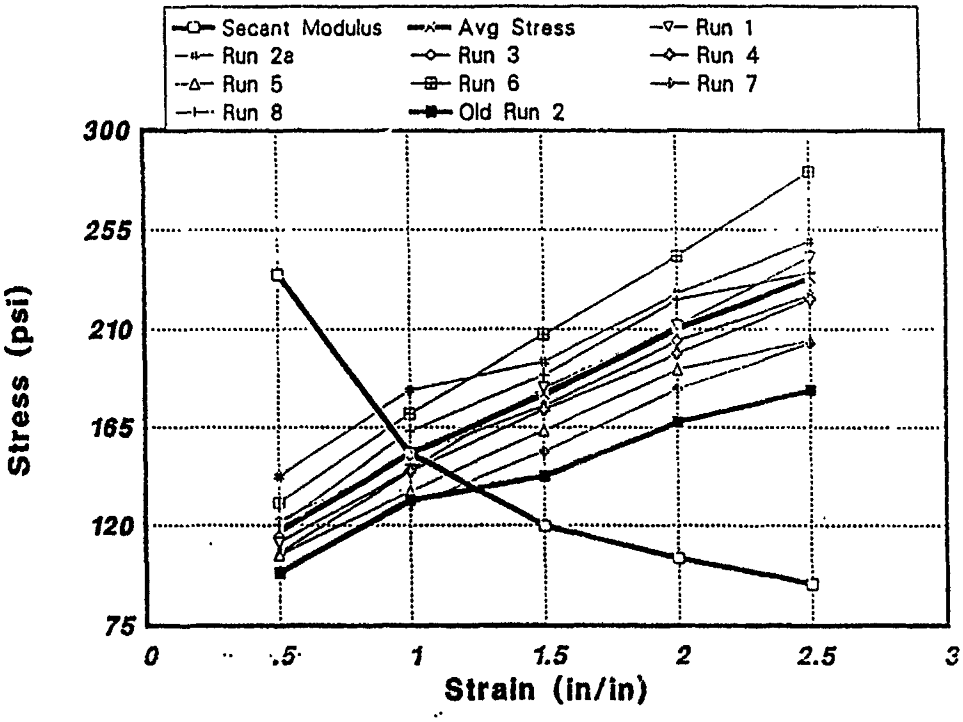

Figure 4. Series 1 Analytic HTPB Secant Moduli

Figure 5 shows a scatter plot of the first 12 runs plotting CPU time versus Average Secant Modulus. In addition to the runs actually performed on the Cray 2, the Taguchi predictor equations allowed us to analytically predict the remaining 24 runs (8 + 24 = 32 full factorial of runs). The triangles on the left were predictions indicating the direction to lower secant modulus while minimizing CPU time. We thought that a minimum existed between secant modulus and CPU time for the HTPB network that we were investigating. Learning from our mistakes in posing our first experimental design, we created the second series in hopes of finding valid minima for secant modulus and CPU time. The cray2 supercomputer runs from series I used 107 hours, 5 min.

Series II Computational Runs

Table III shows the input factors and the results of the second Taguchi design matrix. Again. orthogonal coding of the input factors was used. From the first series, we felt that the number of chains in the network and the maximum number of nodal sweeps were small players in achieving equilibrium so we kept these

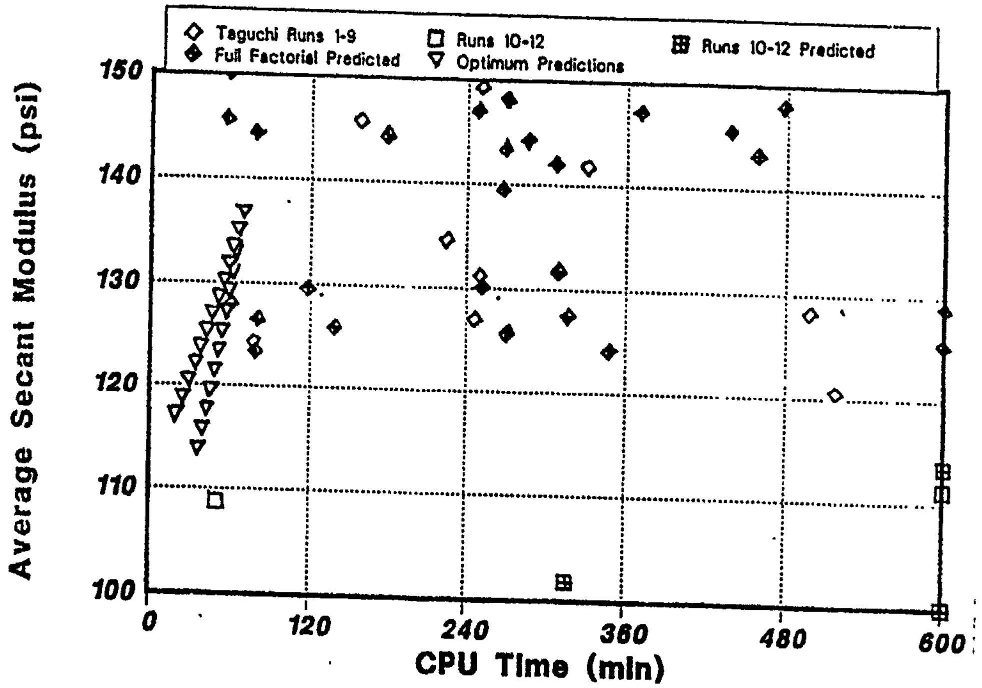

Figure 5. Series I CPU Time vs Average Secant Modulus

values constant at 2500 and 35 respectively. We chose a Taguchi L_8^{2-1} experimental design. This allowed only one factor, D, to be aliased, in this case with the ABC interaction; the two-way interactions (AC, AB, BC) were preserved. Since the nodal absolute stopping force was a strong factor in the first design, we assigned it to factor A. We set the low value (in terms of computer cost) to 5e-8 harbos and the high value to 1e-8 harbos. Factor B was chosen to be the global stopping move size. This is the global equilibrium condition which checks the relative changes in chain length. When the chain motion from one iteration to the next varied less than 0.4% for the low setting and 0.1% for the high setting, the network was considered to have reached equilibrium. Nodal stopping force fraction was chosen to be factor C. This is the fraction of the original imposed force which was treated as having reached equilibrium. The low setting for factor C was 0.1% the high setting was 0.05%. The Number of global sweeps was chosen as factor D and aliased with the ABC iteration. We chose this alias pattern because A & C were nodal criteria and the presumed weak ABC interaction would not mask the effect of the number of global sweeps allowed. Ideally, one should not reach the maximum number of global sweeps, because the network would have reached equilibrium before then. The output can be seen in the right two columns. We were encouraged by the lower and more consistent secant moduli, as well as the reasonable CPU times to reach this accuracy. CPU time was much higher overall because we were using ten strain steps instead of the original five steps in the first series.

Table III. Series II Experimental Design with Results

Run Number	A	B	C	D	CPU Time (min)	Average Modulus
Run 1	5E-8	0.004	0.001	35	404	100.6
Run 2	5E-8	0.004	0.0005	50	852	89.2
Run 3	5E-8	0.001	0.001	50	745	97.0
Run 4	5E-8	0.001	0.0005	35	866	100.0
Run 5	1E-8	0.004	0.001	50	456	103.4
Run 6	1E-8	0.004	0.0005	35	437	112.7
Run 7	1E-8	0.001	0.001	35	702	92.3
Run 8	1E-8	0.001	0.0005	50	811	92.9

A) Absolute Nodal Stopping Force Magnitude
B) Global Stopping Move Size (Fraction of the shortest maximum chain length)
C) Nodal Stopping Force Fraction
D) Number of Global Sweeps Allowed

Note: Runs 1–8 represent a Taguchi $L_8\ ^{2-4}$ Design

Figure 6 shows the HTPB specimens at 275% strain. The polymer chains appear evenly distributed with smooth necking of the specimens in the center. Figure 7 shows the stress-strain plots of the second series. The code was instructed to output the initial stress state and to get values at 25% and 75% strain. An error in the input deck caused steps of 50% strain after the initial 75% so the maximum strain was 475%, not 500% as desired. The secant modulus curves form a tighter family with an average of 98.5 psi and a variance of 48.99 from 25% to 475% strain.

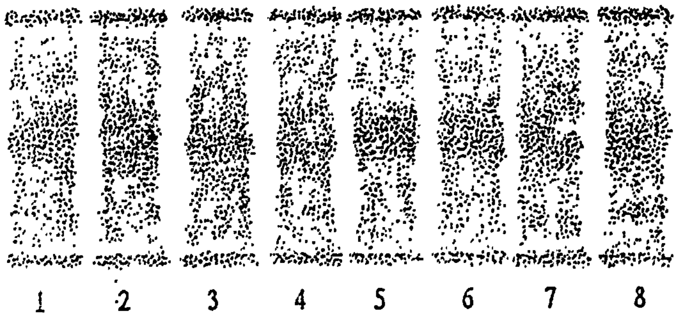

Figure 6. Series 2 Networks at 275% Strain

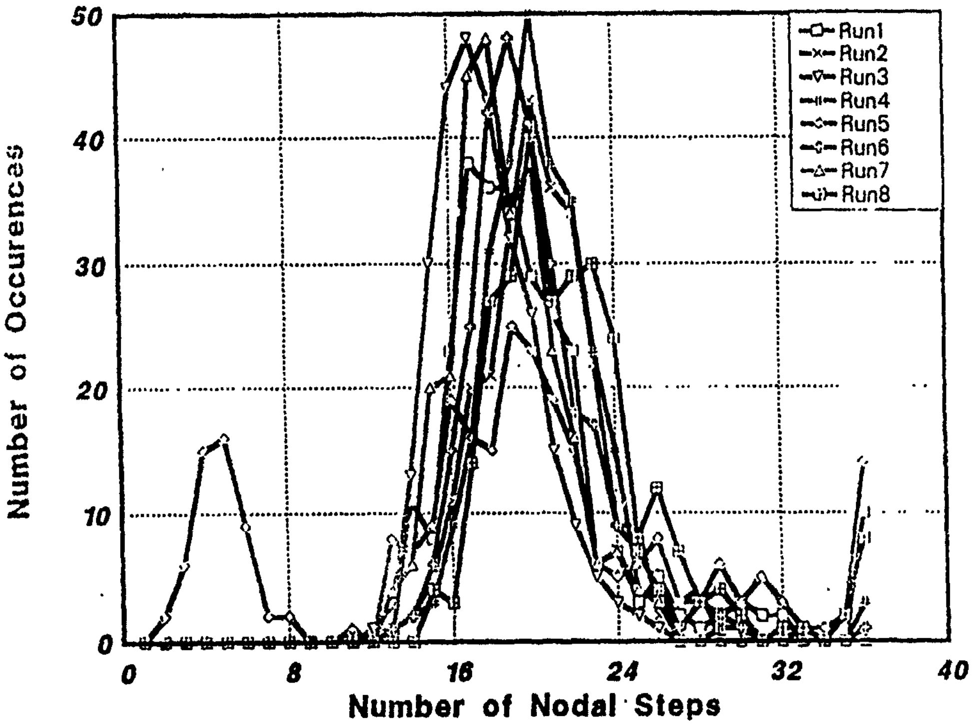

Figure 7. Series 2 Nodal Step Histogram

Average Secant Modulus

$\hat{Y}_{\overline{E}} = 98.51 - 4.7625AB - 2.9625B - 2.8875D + 2.2875AC + 1.8125A + 0.7125BC + 0.1875C(3)$

To maximize secant modulus set : $A_+B_-C_+D_-$

Yields : $\overline{E}_{max} = 112.7$ psi (validated in L_8 matrix–Run 6)

To minimize secant modulus set : $A_+B_+C_-D_+$

Yields : $\overline{E}_{min} = 84.02$ psi (predicted)

$\overline{E}_{CPU_{max}} - 91.7$ psi (predicted)

$\overline{E}_{CPU_{min}} = 111.7$ psi (predicted)

CPU Time

$\hat{Y}_{CPU} = 659.3 + 121.937B + 82.4125C - 59.8625AC - 57.462A + 56.8125D + 33.162AB - 24.9625BC(4)$

To maximize CPU set : $A_-B_+C_+D_+$

Yields : CPU $_{max} = 979.6$ minutes (predicted)

To minimize CPU set : $A_+B_-C_-D_-$

Yields : CPU $_{min} = 342.4$ minutes (predicted)

CPU $\overline{E}_{max}$ = 437.4 minutes (validated in L_8 matrix–Run 6)

CPU $\overline{E}_{min}$ = 816.1 minutes (predicted)

Figure 8 shows a scatter plot of CPU time average secant modulus. The remaining 8 runs (8 + 8 run= 16 full factorial for L_8^{2-1}) are plotted completing the family of runs for the second series. On the left are trend lines showing loci of minima for this experiment. Using the equations, the lowest secant modulus occurs when factor A is high, factor B is high, factor C is low and factor D is high with a predicted CPU time of 816 minutes. The lowest CPU time of 324 minutes yields a secant modulus of 111.7 psi. The highest CPU time of 980 minutes yields a secant modulus of 91.7 psi. According to the Taguchi predictor equations the minimum secant modulus attainable in this series was 84.02 psi and the maximum was 112.7 psi. This demonstrates that spending more computer time does not necessarily improve the accuracy. These two series of runs demonstrate the importance of careful selection of convergence criteria to get the desired results at a minimum cost. The relationship of CPU Time and Average Secant Modulus is obscured by the variability imparted by the random network. The cray2 supercomputer runs from series II used a total of 87 hours, 53 min.

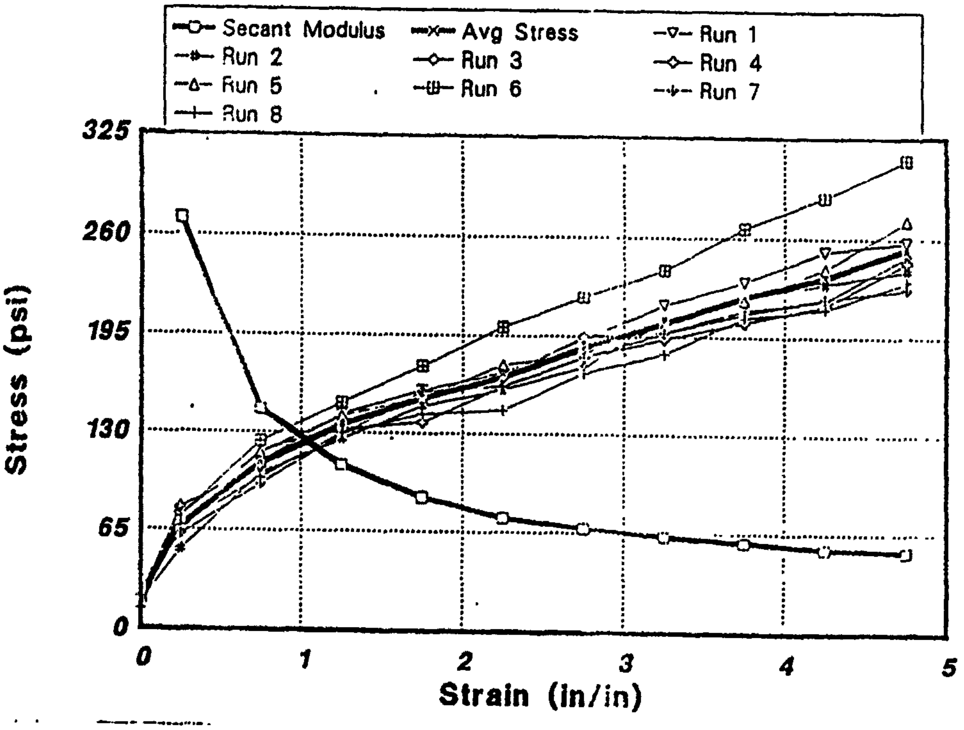

Figure 8. Series 2 Analytic HTPB Secant Moduli

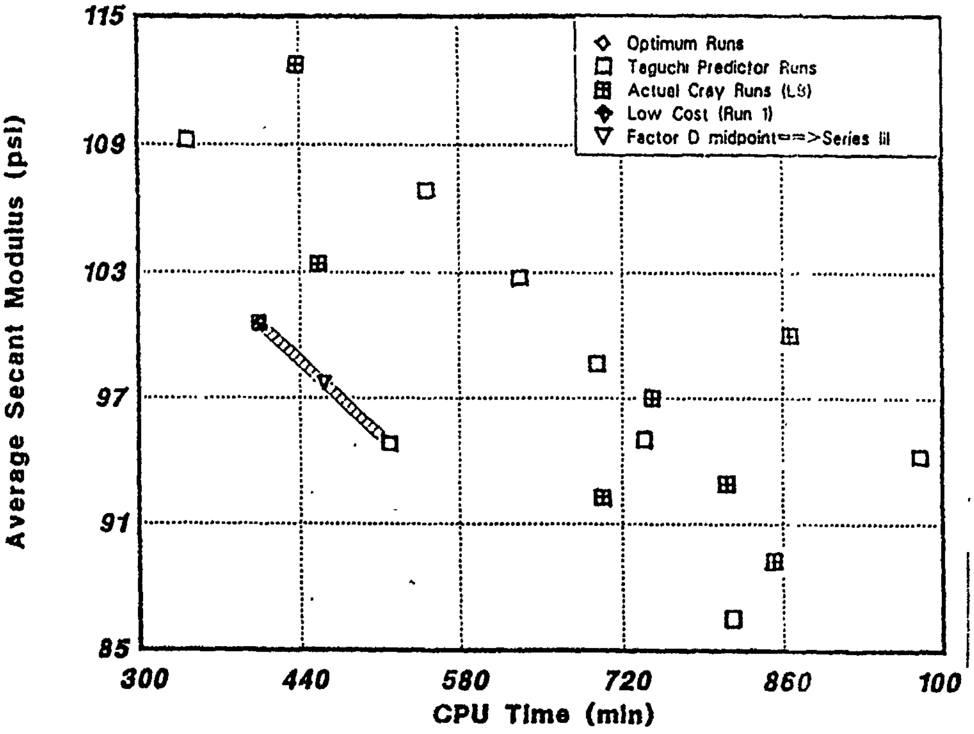

Figure 9. Series 2 CPU Time vs Average Secant Modulus

Series III Computational Runs

The third series of runs was based on the optimum convergence criteria derived from the second series. We kept the convergence criteria for the next eight runs constant and simply recreated the network for each run. This gave us an indication of the variability in secant modulus and computer time based solely on the randomization of the network. Each of the networks contained 2500 polymer chains that were created using the Cray 2 version of CONNECT intrinsic random number function. The seed for this function was the Cray real-time clock value. Figure 10 shows all eight runs plotted together. The average stress and secant modulus are also displayed. The average secant modulus from 25% to 600% strain was 105.39 psi with a variance of 36.5 psi. The average CPU time was 439 min with a variance of 184 min. The large variability in computer time suggests a strong dependence on the physical arrangement of the network. The correlation between CPU time and secant modulus is not clear from Figure 11. The spread in secant modulus was 18% of the average secant modulus, while spread of CPU time was 9% of the average CPU time. Using the current set of convergence criteria, the randomness of the network and the limited number of runs prevented us from finding a definitive minima for secant modulus and CPU time. The cray 2 supercomputer runs from series III used a total of 58 hours, 32 min.

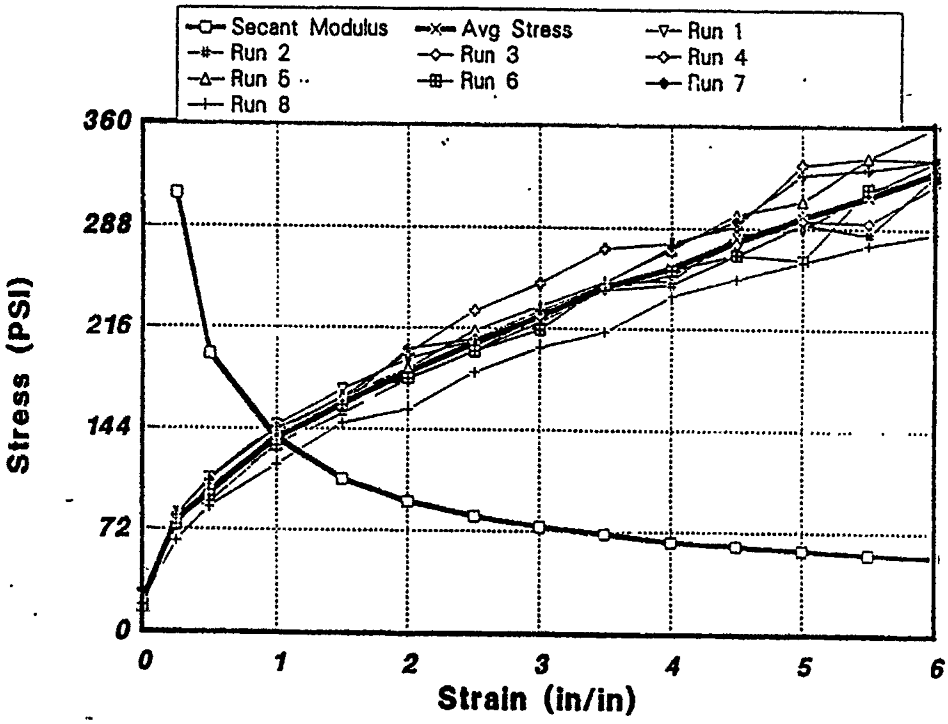

Figure 10. Series 3 Analytic HTPB Secant Modulus

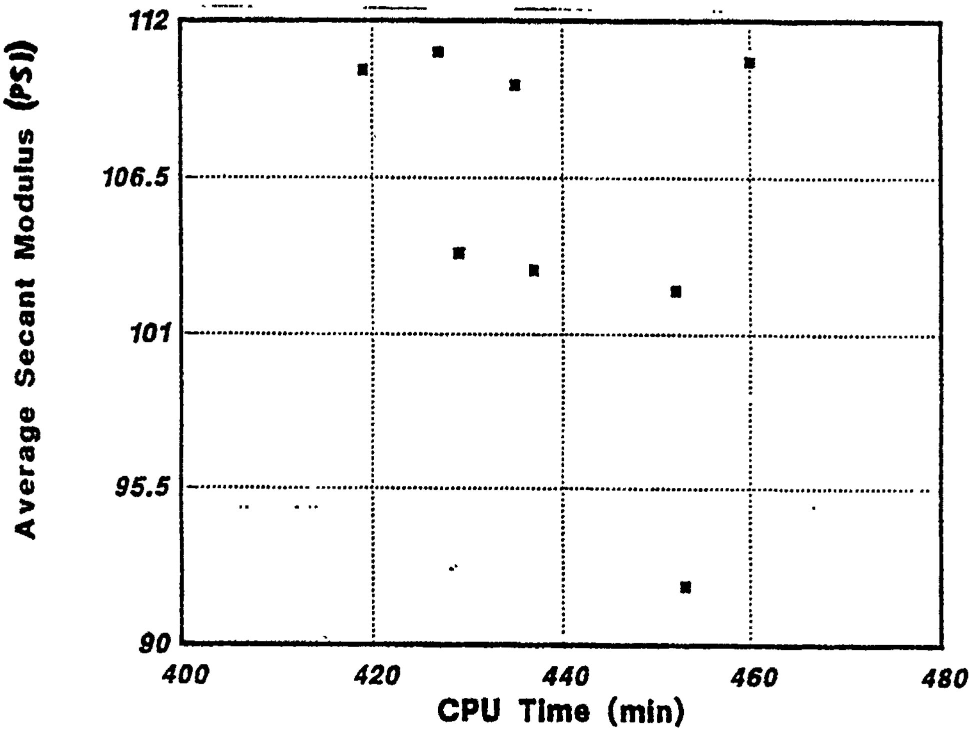

Figure 11. Series 3 CPU Time vs Average Secant Modulus

We compared the results of this series with the second series to determine statistical significance. Below is a summary of an F-test between the second and third series, comparing both average secant modulus and average CPU time.

F Test for Moduli Series 2 & 3

(1) Hypotheses: H_0: $\mu_I = \mu_{II}$ (both series exist in the same population)

H_1: $\mu_I <> \mu_{II}$

(2) $\alpha = 0.05$ (95% confidence interval)

(3) $\overline{\overline{Y}} = 101.9619$

i) MSB = 188.3482

ii) MSE = 42.74284

iii) $F_0 = \frac{MSB}{MSE} = 4.40654$

(4) F_c = F(0.05, 1, 14) = 4.60 critical value of F distribution

(5) Since F_0 is less than F_c, reject H_1 and conclude H_0 with 95% confidence.

The F-test validated the hypothesis that the second and third series data fall within the same population with 95% confidence.

Conclusion

After 29 computer runs and 253 hrs 30 min of Cray 2 time, we are reasonably confident that RIDNA can predict the viscoelastic behavior of HTPB. We were able to find a minima for CPU time and secant modulus within the inherent variability of the randomized networks investigated. The predictor equations can be used to simulate other RIDNA runs without actually using the supercomputer. Once the convergence criteria has been selected, one can perform the supercomputer run to get analytic behavior. We consider RIDNA to be a viable tool in microstructural constitutive theory for predicting viscoelastic behavior of polymeric binders.

Future work must include validation of analytical predictions with experimental results. RIDNA's nodal force algorithm needs extensive rewriting to take full advantage of the Cray 2's vector-processing capability. We estimate that CPU requirements could be cut in half over current optimized runs. We would like to explore using nodal energy derivatives instead of forces to accelerate convergence of the network. Finally, there may be merit in using fractal geometry for creating the polymer network instead of using random number generation to compare the difference in viscoelastic response.

Having participated in such a key role in a scientific research project has given me a great deal of insight into the process of scientific research. I feel that this experience will give me an advantage over my peers and serve as an excellent foundation for my academic career as well as my future in engineering.

References

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2. R. G. Launsby, S. R. Schmidt, "*Understanding Industrial Designed Experiments*"; CQG Limited Printing, Longmount, Colorado (1989).

3. Conversation with R. G. Carter, July 1990.

Liquid Engine Computer Codes

Joseph Padilla

Ann Krach

Edwards Air Force Base,

Astronautics Laboratory

23 August 1990

1. Introduction.

During my eight week apprenticeship at the Edwards Air Force Base, Astronautics Laboratory. I performed various tasks under the auspices of Mrs. Ann Krach. Most of these assignments involved the use of the Digital Vax computer to develop batch files and help files for liquid engine analysis computer codes.

2. General Description of Research.

As an apprentice, I developed executable batch files and help files to the specifications of my mentor. In order to develop the files, it was necessary to read through the programming manuals and literature concerning the VAX operating system. I also consulted with other programmers within my section to determine how a certain code would work. The codes which I developed were then mailed or copied from my account to RKCODES via computer. RKCODES is a set of computer utilities and programs for use by RKBA Engineering Design Evaluation. These utilities aid in the Design and Evaluation of mechanical systems. Once the files were placed on RKCODES, they were available for anyone on the system.

3. Detailed Description of Research.

I worked on a number of codes on the VAX computer system including, the Two Dimensional Kinetic Pre and Post Processors, the Expanded Liquid Engine Simulation, Integrated Design Engineering Analysis Software, and RAO, A Method Optimum Nozzle Contour Program. My first project was to write help files and executable batch files for the Two Dimensional Kinetic (TDK) Post Processor. The Two Dimensional Kinetics Post-Processor (TDK-POST) is a data post-processor for the JANNAF standard TDK code. The main functions of the TDK-POST are to read the TDK postprocessing output file and to communicate with the user in alphanumeric or graphic modes to display desired results. Upon completing the batch file, I tested program and debugged any errors that might have occurred during execution. The files were then installed on RKCODES by Mr. Russ Leighton.

The next project which I worked on was the Expanded Liquid Engine Simulation (ELES). For this project I had to create an executable batch file and an on-screen help file. The ELES computer code is a preliminary systems analysis code to develop liquid rocket vehicles. It is capable of revealing subsystem interactions and design choice impacts on total vehicle performance. I also tested the batch file with sample data and debugged any errors that might have occurred during execution. This was also installed on RKCODES.

The next project which I completed was RAO, a method optimum nozzle contour program. With this project, I created an executable batch file and help file. This calculates a supersonic exhaust nozzle contour which gives maximum thrust for its length.

The final help files which I completed were for the TDK Pre-Processor and the I-DEAS, Integrated Design Engineering Analysis Software. Both of these programs did not have to be placed in RKCODES but the help files were installed describing how to access the programs. The TDK pre-processor is a program that will preprocess data suitable for input to the TDK program. I-DEAS is a package that provides capabilities for solid modeling and engineering analysis. Also included with my report is a sample copy of the I-DEAS and Pre-TDK help file included in RKCODES.

Finally, another project that I worked on but did not complete was the GFTM, Generic Fluid Transfer Model. This program was an interactive program that could not be placed on RKCODES because it could not be run on a user disk outside of RKCODES. It also had problems in dealing with cryogenic and storable propellants.

As a result of my work, most of the tasks assigned by my mentor were completed within the eight week period of my apprenticeship. The computer codes which I have previously discussed are now available for use through RKCODES. I feel that I learned an extensive amount of information concerning the VAX computer system and computer codes which I could not have learned in school.

I-DEAS - INTEGRATED DESIGN ENGINEERING ANALYSIS SOFTWARE.

I-DEAS is a package that provides capabilities for solid modeling and engineering analysis. The four families of modules currently available on the I-DEAS Level 5 are the Solid Modeling Family (Geomod), the Finite Modeling and Analysis Family (Supertab), System Dynamics Analysis Family (Systan), and the Test Family (Tdas).

In order to run I-DEAS and its modules it is necessary to set the I-DEAS environment to Level 5. This can be done by placing the following line in your login.com file:

```
$ IDEAS5 :== @USER$DISK33:[IDEAS.V.INS]IDEASSIGN.COM
```

After logging in, type IDEAS5 at the prompt and the computer should reply by indicating that it is set for the I-DEAS Level 5 environment. Type IDEAS at the prompt to begin running I-DEAS.

I-DEAS Level 4 is also available for running the TDK Preprocessor. In order to use I-DEAS Level 4 write the following line in your login.com file:

```
$ IDEAS4 :== @USER$DISK17:[IDEAS.L41.INS]IDEASSIGN.COM
```

Type IDEAS4 to activate the Level 4 environment and then type IDEAS to activate the I-DEAS program.

Further documentation for I-DEAS and its modules can be obtained from Ann Krach (5332) in the RKBA.

Additional Information:

/Geomod /Supertab /Systan /Tdas

I-DEAS Geomod

The Solid Modeling family consist of modular software tools to develop designs for mechanical systems. The solid modeling family is used to build and analyze a mechanical system model that consists of 3-D geometric solid objects.

Some features of the Solid modeling family include constructing a wireframe profile of an object using construction geometry and using the system assembly module to determine the relationship between components and subsystems. Geomod also creates and manages features and develops libraries of form features.

I-DEAS Supertab

I-DEAS Finite Element Modeling & Analysis analyzes the statics, dynamics, heat transfer, and potential flow behavior of mechanical components and structures. Finite Element Modeling and Analysis builds a complete finite element model, including physical and material properties, loads and boundary conditions.

Some features of the Finite Element Modeling and Analysis Family include adaptive meshing to redefine mesh density based on information resulting from a finite element analysis or model checking values. Model Solution performs linear statistics, heat transfer, normal model dynamics, potential flow and forced response analysis on models created in FEM.

I-DEAS Systan

The I-DEAS System Dynamics Analysis Family is an interactive, graphics oriented system for modeling and analysis program used to design complex mechanical systems. Computer graphics and database management can be used to rapidly assemble and verify a system model.

Ideas Systan also evaluates the modal performance in terms of modal, frequency, or transient response of an interconnected linear system. Pre/post-processing and interfacing are transparent, allowing convenient data transfer from modal test results, finite element modal test results, and databanks.

I-DEAS Tdas

I-DEAS Test Data Analysis Family uses test data analysis software, graphics and modeling capabilities and data processing in the testing environment. Tdas accepts an analytical model of a system and test data. It can then manipulate the test data and make comparisons between test results and the analytical model.

Tdas has general analysis tools as time history and mathematical function processing, histogramming, and statistical analysis. Tdas also does data analysis in spectrum generation, modal analysis and fatigue life estimation.

TDK PRE-PROCESSOR - TWO DIMENSIONAL KINETIC PRE-PROCESSOR.

The TDK pre-processor is a program that will preprocess data suitable for input to the TDK, Two Dimensional Kinetic Program. Some features of the TDK pre-processor are menu driven commands, it is modularized, will do the formatting, will write the reaction data given the propellants and enthalpy.

The TDK preprocessor will only run on I-DEAS level 4.0 and it cannot be used on I-DEAS level 5.0. In order to run I-DEAS level 4.0 you need to enter the following statement in your login file:

```
$ IDEAS4 :== @user$disk17:[ideas.141.ins]ideassign.com
```

In order to run IDEAS and the the TDK pre-processor, log into SCIVX1 and type IDEAS4 at the prompt in order to set the I-DEAS environment to level 4. The computer should give you a message stating that you are currently in the level 4 environment. Then type IDEAS at the command prompt and soon IDEAS will prompt for a terminal type, a model filename, new model file, model description and system of units. Enter the appropriate terminal type and simply press return for the other questions until you reach the question "Enter operation mode." At this question enter P for program. The next question will ask for "Select Menu" where you enter R to run program. IDEAS will then prompt for a program file name where you would enter:

```
"user$disk17:[ideas.tdkpp]tdk" (include quotes).
```

The program will now begin to execute and in a few moments it will display the main menu of the TDK Pre-processor. The Menu consists of 4 selections: 1) Create New Input Deck - takes you to another menu which you can change the preset values for your own TDK input deck. 2) Write Input Deck - will create the actual input deck for TDK based on the values you entered previously. This input deck can be sent directly to TDK after leaving I-DEAS. 3) Display Nozzle Only - will ask you about the geometry of the nozzle, and then draw it on the screen for you. You can use this option if you want to make hard copies of the proposed nozzle before ever running analysis. 4) Exit I-deas - will halt the processor and I-DEAS.

Use of the TDK preprocessor is limited to one user at a time. If one user is currently using the preprocessor, it cannot be accessed by anyone else.

Further documentation on the TDK Preprocessor can be obtained by contacting Tom Elkins or Ann Krach in the RKBA at 5303 or 5332.

4. Other observations learned from summer experience.

During the summer experience, I toured the other laboratories such as the chemistry lab and the composites lab. I attended an OD session discussing the function of our section as an engineering analysis group. I worked on other computer programs such as X-Plot and Patran by assisting the other apprentices in their research. I also became acquainted with other apprentices and co-ops from other high schools and colleges. Finally, near the end of my apprenticeship I saw the testing of a solid rocket motor and after the quench cycle I was able to see the nozzle. I really enjoyed my apprenticeship and the excellent experience in research.

5. Acknowledgements

First of all I would like to thank all of the people at the lab who helped me with my work. Special thanks to Ann Krach for selecting me for the project and helping me become acquainted with the computer system. I would also like to thank the other scientists, apprentices, and coops for their cooperation and time, especially Lloyd Neurauter, Terry Galati, and Jerry Gallardo.

Determination of Active Surface Area and Density of Carbons

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Mentor: Mr. Les Tepe
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Air Force Astronautics Laboratory / RKPB
Edwards Air Force Base, CA 93523
June 20, 1990 - August 22, 1990

ACKNOWLEDGEMENTS

I would like to let Universal Energy Systems know that their efforts in the mentor program are greatly appreciated. Because of these efforts, many college and high school students are offered great opportunities in their various fields of study. I would like to thank my mentors and supervisors Dr. Ismail M. K. Ismail, Mr. Les Tepe, and Dr. Wesley P. Hoffman for all their time and support. I would also like to thank Mr. Matt Mahowald and Ms. Hong Phan for their help and patience in the lab and with the computers.

OBJECTIVES

I had three main objectives in the area of Carbon research at the chemistry laboratory this summer. My first objective was to work with Systems 1, 2, and 3 which determine the active surface area (ASA) of carbon fibers. ASA being defined as the sum of the areas of active sites which are located on the basal plane of the fiber. Second was to analyze the data obtained from these systems by creating graphs and tables in order to compare different sample results. Finally, to determine the density of a variety of carbon black and fiber samples using bromoform, carbon tetrachloride, and benzene.

APPLICATIONS

The chemistry lab's main focus is rocket nozzle technology. More specifically, the fabrication of the rocket nozzle. An ideal material for this would have high strength, high stiffness, and low weight. For this reason, carbon and graphite fibers are being used more and more in aerospace applications.

In order to be useful components, graphite fibers must be embedded in a ceramic, plastic, or metal matrix. The properties of these materials must be evaluated so that the right fraction of the composite that is fiber and that which is matrix can be determined. Therefore, the density is determined to aid in these calculations.

APPARATUS

The ASA apparatus (Figure 1) and a computer are used for this research. A quartz reactor connected to a diffusion pump, roughing pump, and vacion pump enable the system to be vacuumed, or cleaned. The cold trap, which is periodically immersed in liquid nitrogen, allows the trapping of CO_2 which is critical in the ASA determination. The reactor, which holds the carbon fiber sample in a quartz boat, is mounted to an oven and temperature controller. Two baratron heads enable pressure readings to be fed into the computer and two thermocouples permit temperature control and the collection of data.

PROCEDURE

1. ASA

The first step in activating the System is to place a fiber sample into the reactor and evacuate at 950°C. This breaks the carbon - oxygen complexes which are located on the basal plane (Figure 2) and allows the sites to become active. After outgassing, the sample is cooled and introduced to oxygen at a pressure of 5.0 Torr. Exposure time and temperature range from 16 to 88 hours and 250°C to 350°C in order to ensure complete coverage of the sample.

After exposure, the system is evacuated for 30 minutes to remove all physically adsorbed oxygen from the sample and system. The liquid nitrogen bath is then raised, the temperature increased to 950°C, and the desorption cycle started for two hours. After the desorption cycle, the liquid nitrogen bath is lowered, the cold trap heated, and the amount of trapped CO_2 is measured. The value of ASA can then be computed.

2. Density

In order to determine density, a small amount of sample is placed in a clear bottle. Different amounts of bromoform, carbon tetrachloride, and benzene are then added to achieve a state of equilibration in which a majority of the sample particles are suspended in the liquid. Bromoform, which has a density of 2.890 g/cc, was the heaviest chemical used followed by carbon tetrachloride with a density of 1.594 g/cc and benzene which has a density of 0.8765 g/cc.

After equilibration is reached, the density can be calculated by weighing 2.00 cc of the mixture on a balance and dividing by 2.

Example: Columbia carbon N330 (as received)

$$D = 3.646g / 2cc = 1.823 \text{ g/cc}$$

A majority of the results obtained from this experiment have proven to be accurate to the third decimal place.

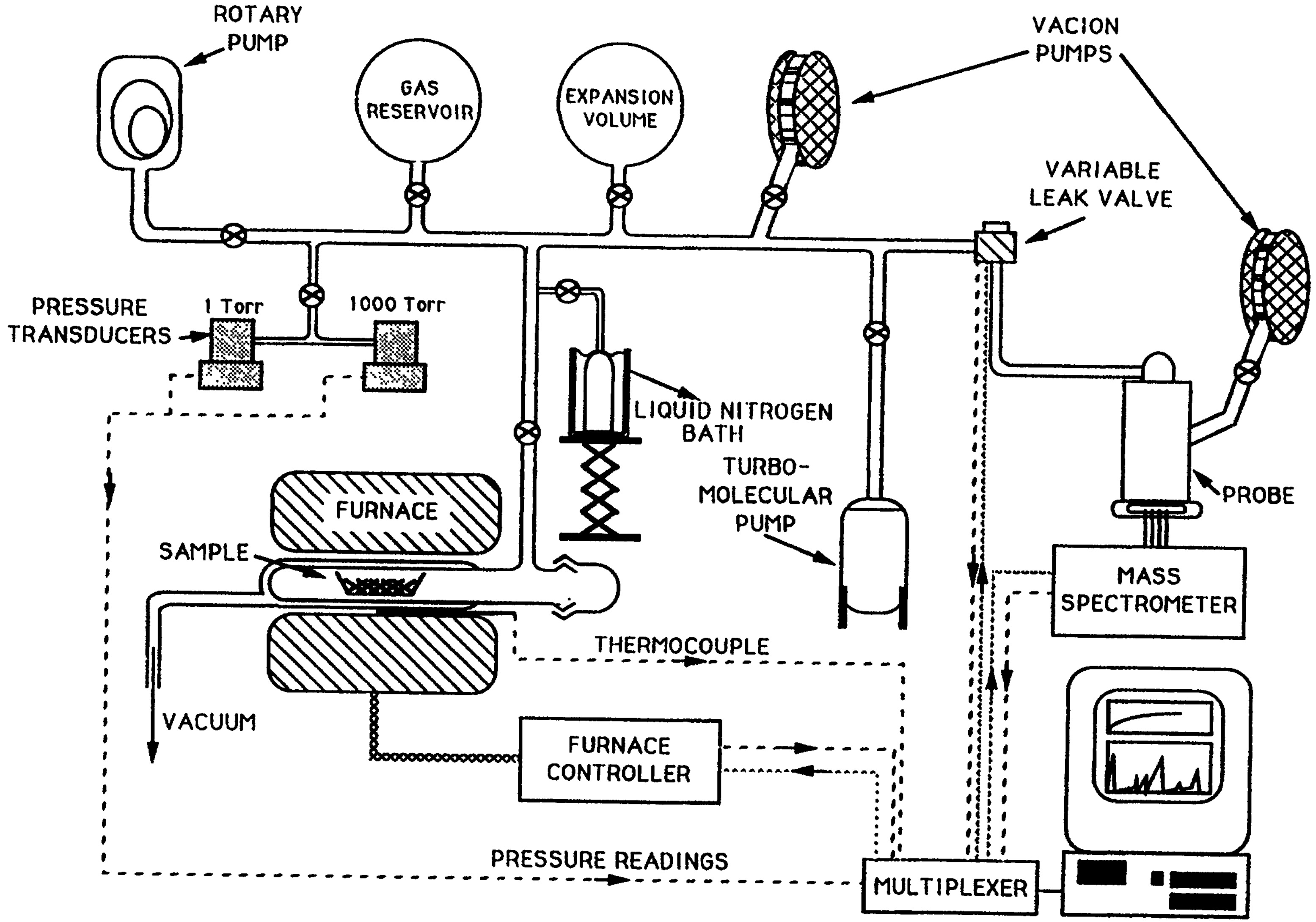
ANALYSIS AND RESULTS

I was able to create graphs and tables with the Macintosh computer in order to analyze and compare data. The first four tables (Tables 1-4) contain the data collected from Systems 1, 2, and 3. The samples used for these runs were Columbia Carbon N330, N550, N762, and N990. It is apparent from the results that ASA depends on the sample history. For example, the first run with CC N550 resulted in an ASA value of 1.618 m^2/g. If we look further down the table, however, the third run shows that an ASA value of 2.249 m^2/g was obtained even though the temperature and time were identical. From this data we can conclude that ASA depends on experimental parameters such as temperature and time.

The next table (Table 5) shows the density of carbon samples at different levels of burn-off (B.O.). This table suggests that the density of the sample increases as the percentage of burn-off increases. This is also shown by the graph of graphitized columbia carbon (Figure 3). The extra samples in Table 5 are the results obtained by using the density technique previously explained.

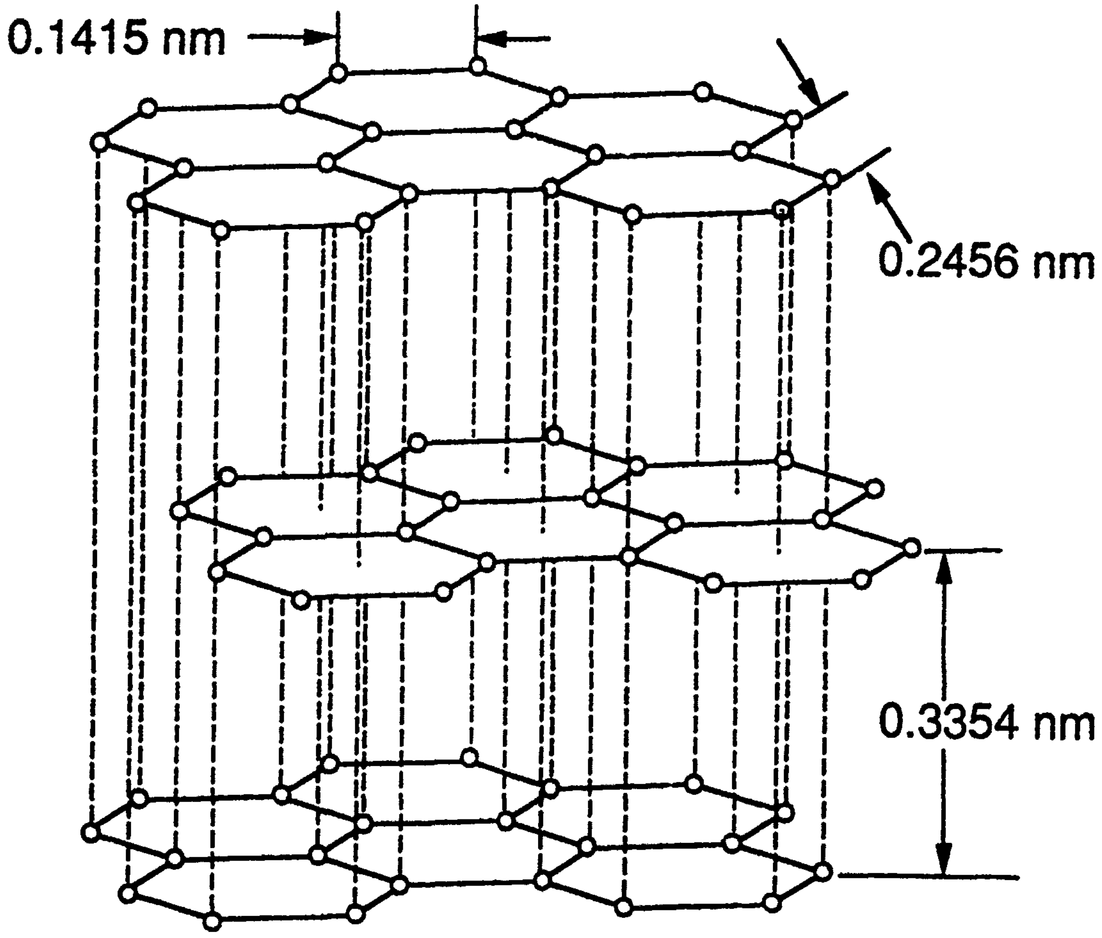
CONCLUSIONS

I have no doubts that my experiences this summer will greatly help in the next few years of college and in my future career. I learned alot in the area of Carbon research and in laboratory techniques. I also gained new knowledge and skills on the computer since I have had only limited experience with them previous to my employment here. Scientific research is very interesting and I've really enjoyed the opportunity that I've had to participate in this program. Thanks again to all of the people that have made the program possible. The experiences I've gained have made this summer exciting and enjoyable.



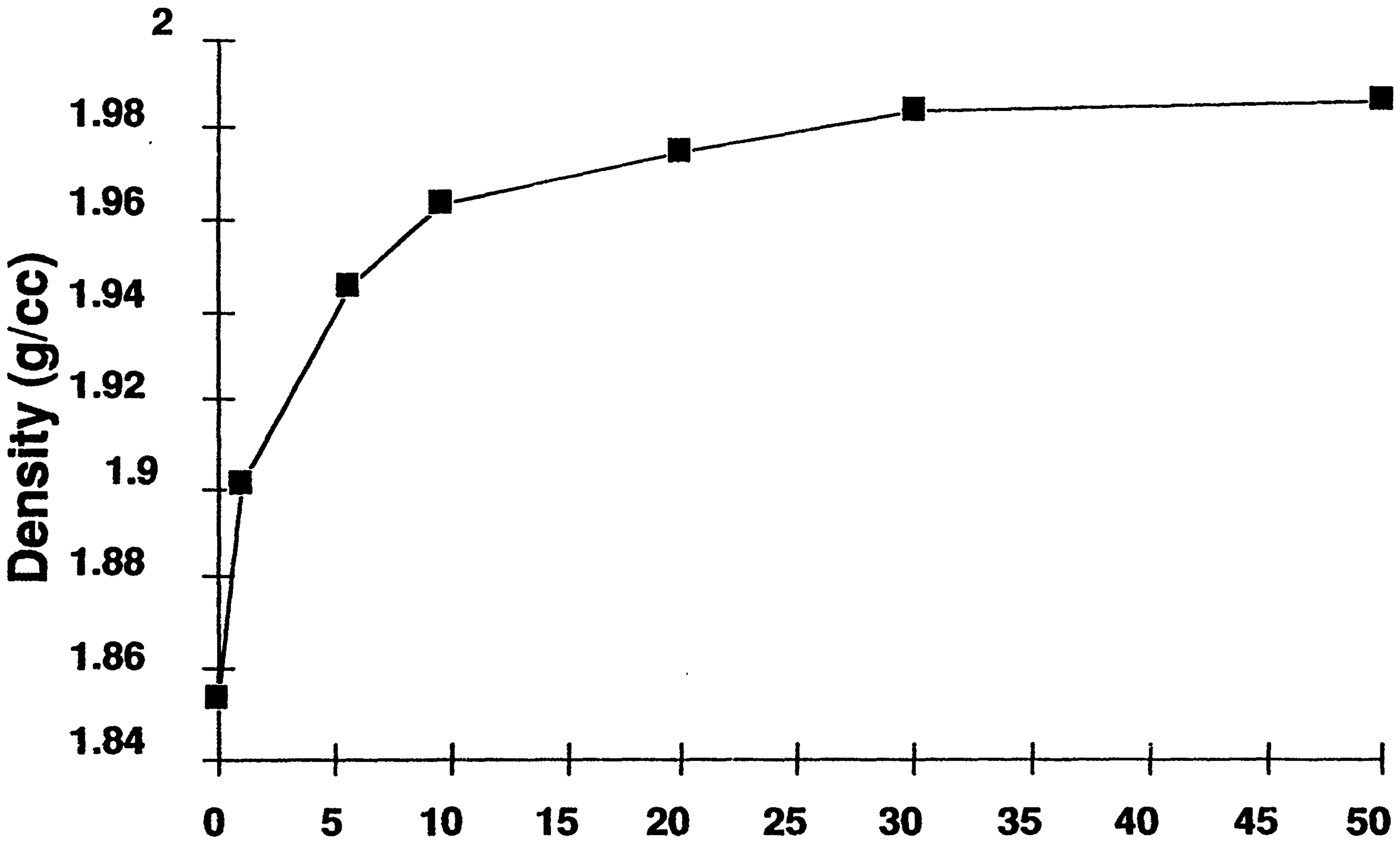
Schematic Diagram of the Apparatus Used for Determining the Active Surface Area of Carbons

Figure 1



Structure of Graphite

Figure 2



Density (g/cc)
2
1.98
1.96
1.94
1.92
1.9
1.88
1.86
1.84
0
5
10
15
20
25
30
35
40
45
50
% of B.O.

Figure 3

Columbia Carbon N550 P = 5.0T

Run #	Temp.	Time	ASA (m^2/g)
1	300°C	16 hrs	1.618
2	300°C	64 hrs	2.497
3	300°C	16 hrs	2.249
4	300°C	16 hrs	1.981
5	275°C	16 hrs	1.960
6	275°C	16 hrs	2.027
7	275°C	64 hrs	3.003
8	250°C	16 hrs	2.023
9	350°C	16 hrs	3.653
10	250°C	16 hrs	2.440
11	250°C	16 hrs	2.400
12	250°C	64 hrs	3.262

Columbia Carbon N330 P = 5.0T

Run #	Temp.	Time	ASA (m^2/g)
1	300°C	16 hrs	5.160
2	300°C	64 hrs	8.755
3	300°C	16 hrs	6.643
4	300°C	16 hrs	7.238
5	275°C	16 hrs	6.187
6	275°C	16 hrs	6.189
7	275°C	64 hrs	8.821
8	250°C	16 hrs	6.448
9	350°C	16 hrs	11.343
10	250°C	16 hrs	7.583
11	250°C	16 hrs	7.529
12	250°C	16 hrs	9.524

Tables 1 and 2

Columbia Carbon N990 P = 5.0T

Run #	Temp.	Time	ASA (m^2/g)
1	300°C	64 hrs	0.352
2	300°C	16 hrs	0.298
3	350°C	16 hrs	0.389
4	250°C	16 hrs	0.268
5	300°C	88 hrs	0.593
6	300°C	88 hrs	0.636
7	300°C	16 hrs	0.503

Columbia Carbon N762 P = 5.0T

Run #	Temp.	Time	ASA (m^2/g)
1	300°C	64 hrs	1.020
2	300°C	16 hrs	0.791
3	350°C	16 hrs	1.074
4	250°C	16 hrs	0.677
5	300°C	88 hrs	1.205
6	300°C	88 hrs	1.355
7	300°C	16 hrs	1.163

Tables 3 and 4

Effects of Heat on Density

Saran	Density (g/cc)
Saran (as received)	1.542
Saran (heat treatment)	2.202
V3G 0% B.O.	1.883
V3G 10% B.O.	1.891
V3G 50% B.O.	1.908
Pyro C	2.019
WCA	1.463
Unknown	2.228

Table 5

Thomas Quinn

Final Report Number 43

No Report Submitted

High School Apprenticeship Program Final Report

by: Tracy Reed

8-26-90

I would like to thank Dr. John Rusek and Dr. Shannon Lieb for all their help during my time at the Astonautics Lab.

During my eight weeks working at the Astronautics Laboratory I worked on two projects, Methods for Analysis of Reactive Surfaces (MARS) and Advanced Polymer Components (APC). For the MARS program my project was to grow ammonium perchlorate (AP) crystals, and for APC I was to do tensile testing on several advanced polymers. I also used the ISP program to compute the theoretical ISP's of rocket propellants we came up with.

I began my summer by checking out several books from the Technical Library at the Astronautics Laboratory. I learned all I could about crystal structure, growth, and methods of growing AP crystals from these books. I then choose the method I thought to be the most suitable.

The last time AP crystals of any considerable size had been grown was at China Lake Naval Weapons Center in the early seventies. The scientists there choose the temperature control method to grow the crystals. They lowered the temperature by one tenth of a degree per day causing the water that the AP was dissolved in to hold less AP. The extra AP that the water could not hold grew on the seed crystals suspended in the solution. Lowering the temperature at this rate was not suitable for our purposes. I choose the evaporation method the be most the most appropriate. I built a device to grow the crystals in which consisted of a large glass container with a seed crystal mounted in it. The seed crystal was glued to a length of bent glass that held the crystal securely in the center of the solution. The container had a lid on it with several holes in it to let the water evaporate. The evaporation of the water slowly raises the concentration of the AP until the water can no longer hold it all and the excess begins forming on the seed crystal thereby increasing its size.

The container holds two liters of water to which I added about four hundred grams of AP. As it dissolved in the water a foam began to collect on the top. I eventually concluded that this was an additive in the AP, an anti-caking agent. I spent several days filtering out the additive.

I then set up the experiment one morning but by that afternoon the seed crystal had dissolved. The next morning hundreds of tiny crystals had grown in the bottom of the container. This proved to us that the temperature in the laboratory was not stable enough to grow crystals in. I decided the whole experiment needed to be put in a temperature bath. The temperature controller for this bath has been ordered and as soon as it gets in the crystal growth experiment will continue.

I also worked on the APC project. The goal was to put the specimens through tensile testing under various conditions and compare it to the published data to see which method gave us the most accurate data. The specimens are to be tested on the 50,000 pound MTS machine at the Composites Lab. The specimens to be tested are Ryton, Vectra C130, and Vectra A625. A test matrix was created that included all the conditions we wanted to test the specimens under, such as dogboned or rectangular. I cut the proper number of dogbones from each material as specified by the test matrix. Then I sanded the ones that required sanding. The specimens were cleaned, load tabs glued on, and strain gauges put in place. Then the leads were soldered to the strain gauges. The actual testing of the materials began shortly after I left.

I also worked on many different types of computers and became familiar with many operating systems while I was at the Astronautics Lab. On the PC I used the ISP computer program to do theoretical calculations on many new rocket fuels being thought up by my colleagues. I learned how to input the data, analyze the output, and compare these against the standard Hydrogen and Oxygen fuel mixture.

I also used the Vax facility at the AL and the Cray 2 at Kirtland AFB to assist in using MOPAC and CADPAC. We used these programs to come up with an accurate model of AP for MARS.

1990 FINAL REPORT

by

Benjamin Charles Sommers

ACKNOWLEDGEMENTS

I would like to thank Dr. Steve Rodgers for his help and support as my mentor. I also appreciate the help, support, and friendship of Captain Steve Thompson and Lieutenant Roeland van Opijnen. Cris Sandstrom, Dr. Pat Carrick, and Captain Tim Wiley were always willing to lend a helping hand. Finally, I would like to thank Debbie Meyer, John Hagen, Ken Dinndorf, Alan Risse, and Lieutenant Rob Mantz for their help and friendship.

My third summer here at ARIES through the UES High School Apprenticeship program was a very enjoyable one. I met many new people and made some new friends. During the summer, I had basically three projects. The first and main project was the Q&A database project for organizing scientific reference data. The second project was organizing and re-structuring the Chem Lab Technical Field Library. The third project was finding wavelength values on the spectra from Dr. Pat Carrick's experiment.

My mentor, Dr. Steve Rodgers, was on vacation during my first week, but I was informed by Dr. Pat Carrick that I would be working with the Q&A database program. I familiarized myself with the program and I was ready to start when Dr. Rodgers returned to officially assign the task to me. I proceeded to design the computerized "form" into which scientific articles would be entered. This form has fields for TITLE, AUTHOR, REFERENCE (the publication from which the article was taken), COMPOUNDS the article deals with, and KEYWORDS. I then organized and entered over 325 articles from Dr. Carrick's files. He has hundreds more remaining, and the ultimate goal is to get everyone in the ARIES office to enter their articles into this network database so they will be accessible to everyone else.

After about four weeks on the Q&A database, Dr. Rodgers assigned a different task to the summer hires in the ARIES office. Debbie Meyer, John Hagen, and I became acquainted with the Chem Lab Technical Field Library. We were involved in the identification, classification, and organization of Technical

Library reference materials. We also introduced many new journals and other publications to the Technical Library. Among these new publications were Physical Reviews (A, B, C, and D), The Astrophysical Journal, Bulletin of the Atomic Scientists, and The American Journal of Physics. We added more recent Chemical Abstracts to the Technical Library as well. During this time, I became familiar with many technical reference publications, and I learned how to conduct searches for scientific literature.

My last two weeks were spent working with Dr. Pat Carrick and Ken Dinndorf on Dr. Carrick's Oxygen discharge experiment. First, I used a ZEOS computer to determine wavelength values for the peaks on the spectra they took while the experiment was running. The ZEOS computer gives graphs of the emission spectra of the substance that is run through it. An example is given as page three. I then compared these values with those in the M.I.T. wavelength tables and the Pearse/Gaydon molecular spectra book. Through this process, we determined that the substances present in the discharge were diatomic oxygen, atomic oxygen, and ionized oxygen atoms.

Working on three different projects over the summer provided some good variety and gave me a chance to work with many different people. I feel I made a small but important contribution to the work at ARIES. More importantly, I learned about several different types of work. I appreciate the opportunity that UES has given me to work in a scientific environment. The experience working with adults was also important. I benefited considerably from my three summers at the Astronautics Laboratory.

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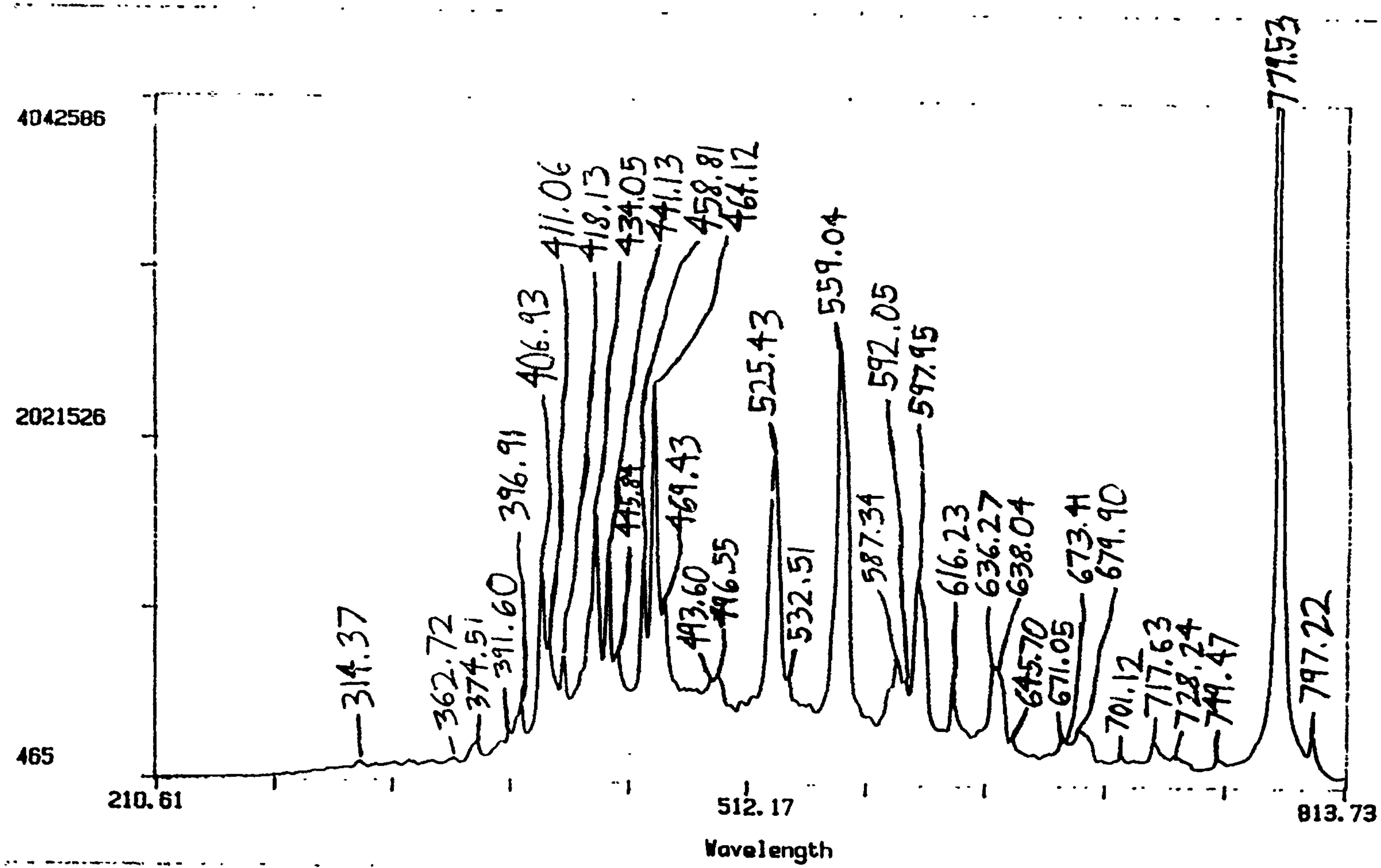

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Stephanie VanMeter

Final Report Number 46

No Report Submitted

A COMPARISON OF ELECTRIC PROPULSION ORBIT TRANSFER METHODS

Rebecca F. Weston and Captain Kerry D. Hicks, PhD

Applications Analysis Office

Astronautics Laboratory (AL/XRF)

August 17, 1990

A COMPARISON OF ELECTRIC PROPULSION ORBIT TRANSFER METHODS

Notation

a = semi-major axis of orbit

e = eccentricity of orbit

F_r = acceleration in the R direction

F_s = acceleration in the S direction

F_w = acceleration in the W direction

i = inclination of orbit

$n = \sqrt{\frac{\mu}{a^3}}$, mean motion

r = radius of orbit

x, y, z = cartesian coordinate axes

Δt = a numerical time step

μ = the gravitational constant of the earth

ν = the true anomaly

ω = argument of periapsis

1. Introduction

This is an analysis of two types of electric propulsion thrusters and of two different types of launches. The first objective was to determine which type of thruster, ammonia arcjet or zenon ion, is more efficient in a particular orbit transfer application. Then, the more efficient thruster was applied to two types of simulated orbit transfers to determine the satellites better type of transfer.

The analysis was done because of increased interest in the field of electric propulsion (EP) recently. There are many advantages to EP, such as the relatively low cost, increased launch capacity, potential for improved operability, and advancements in technology which accompany EP (e.g., longer lasting batteries and much lighter, radiation-resistant solar arrays). Presently, low-thrust ion and arcjet systems exist, have been tested, and are ready for flight; thus, they were chosen as the subject of this study (2; 6).

The application of these technologies is unlimited and can be applied to many types of space vehicles. Current thrusters can be used to maneuver satellites or future space stations. The field of EP is constantly growing and getting closer to reaching a goal of higher-thrust capability.

The analysis of thrusters and launches was done on a 386-class computer with the program ASAP (Artificial Satellite Analysis Program), which simulates the orbits of satellites for analysis purposes (5). Captain Kerry Hicks modified ASAP to incorporate some of the aspects of the different cases. In order to do these modifications a number of derivations had to be done.

To understand the derivations one must first understand the coordinate system used. In this study the R-S-W coordinate system in Fig. 1 was employed. The R-axis is along the satellite's radius; the S-axis is 90° to the R-axis, pointing in the direction of increasing true anomaly; and the W-axis is perpendicular to both the R and S axes such that $\bar{W} = \bar{R} \times \bar{S}$ (1:397-398). It is assumed the reader is familiar with the classical orbital elements.

While increasing the semimajor axis, many small perturbations occur. Of particular interest is the effect of low-thrust on the satellite's orbit. This is well documented as (1:399; 7:89):

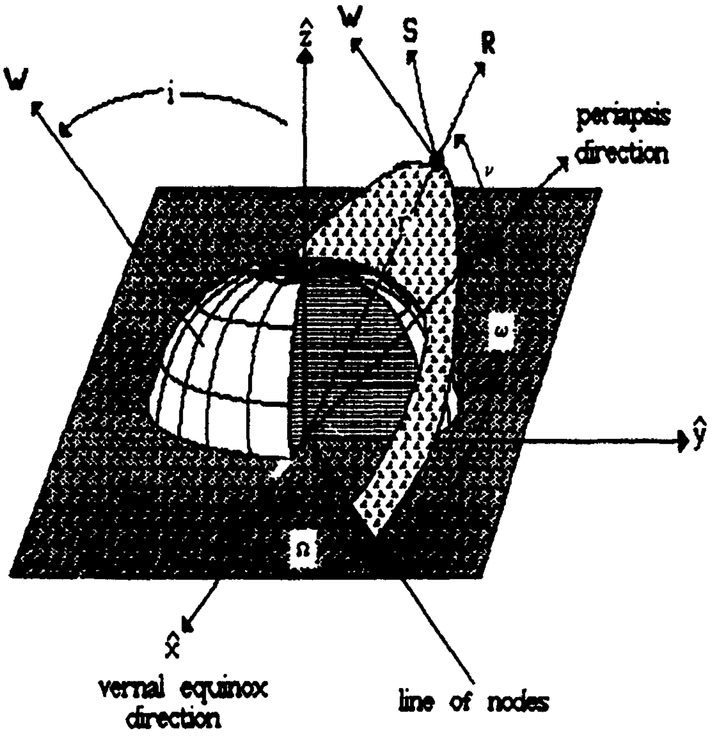

Figure 1. Coordinate System Employed

$$\dot{a} = \frac{2e \sin\upsilon}{n\sqrt{1 - e^2}} F_r + \frac{2a\sqrt{1 - e^2}}{nr} F_s \qquad (1)$$

$$\text{let } C = \frac{2e \sin\upsilon}{n\sqrt{1 - e^2}} F_r \qquad (2)$$

$$\text{let } D = \frac{2a\sqrt{1 - e^2}}{nr} F_s \qquad (3)$$

F_s and F_r are the accelerations in the S and R directions, respectively.

Due to the shadow effect the orbit becomes slightly elliptical ($e > 0$). The orbit must be corrected for e to remain small (i.e.,

$e \leq 0.01$) and to be approximately circular. The drift from circular orbit can be ignored, or it can be corrected using the equation (1:401):

$$\dot{e} = \frac{\sqrt{1 - e^2}\sin\upsilon}{na} F_r + \frac{\sqrt{1 - e^2}}{na^2 e}\left[\frac{a^2(1 - e^2)}{r} - r\right] F_s \qquad (4)$$

$$\text{let } A = \frac{\sqrt{1 - e^2}\sin\upsilon}{na} F_r \qquad (5)$$

$$\text{let } B = \frac{\sqrt{1 - e^2}}{na^2 e}\left[\frac{a^2(1 - e^2)}{r} - r\right] F_s \qquad (6)$$

Since a circular orbit is desired, in this study, the eccentricity must equal zero. $\dot{e}$ is approximated by

$$\dot{e} \approx \frac{0 - e}{\Delta t} \qquad (7)$$

where Δt is a numerical time step (4). Thus, $\dot{e}$ is a known value.

The total acceleration squared is defined as the sum of the forces squared:

$$A_c^2 = F_r^2 + F_s^2 \qquad (8)$$

Rearranging:

$$F_r = \pm\sqrt{A_c^2 - F_s^2} \qquad (9)$$

Substituting this into Eq. 4 produces:

$$\dot{e} = \pm A \sqrt{A_c^{2} - F_r^{2}} + BF_s \tag{10}$$

Solving for the acceleration in the S-direction yields

$$F_s = \frac{B\dot{e} \pm A \sqrt{A^2 A_c^{2} - \dot{e}^2 A_c^{2} B^2}}{A^2 + B^2} \tag{11}$$

when the discriminant $\left(A^2 A_c^{2} - \dot{e}^2 A_c^{2} B^2\right)$ is positive. A negative discriminant implies unrealistic thrust requirements. (Unrealistic here describes a thrust which can not be produced in one time step.)

If the discriminant is negative, no physically realistic solution exists; thus, $\dot{e}$ must be too large to correct in one time step. The best that can be done is to maximize the reduction in e. This is done by using eqs. (12) and (13) below:

$$F_s = A_c \cos\beta \tag{12}$$

$$F_r = A_c \sin\beta \tag{13}$$

The angle β is given by

$$\tan\beta = \frac{-A}{-B} \qquad (14)$$

where care must be taken to select the correct quadrant (4).

As previously mentioned, the eccentricity can be left uncorrected, but it grows much larger than 0.01. Figure 2 illustrates this growth. The acceleration in the $\hat{W}$-direction has previously been zero; as a result, there has been no inclination change up to this point. The optimal way to perform a plane change is a thrust pattern given by Wiesel (7:92-93). This is:

$$\tilde{F}_w = \begin{cases} -F_w\hat{W} & -90^\circ < \nu + \omega < 90^\circ \\ F_w\hat{W} & 90^\circ < \nu + \omega < 270^\circ \end{cases} \qquad (15)$$

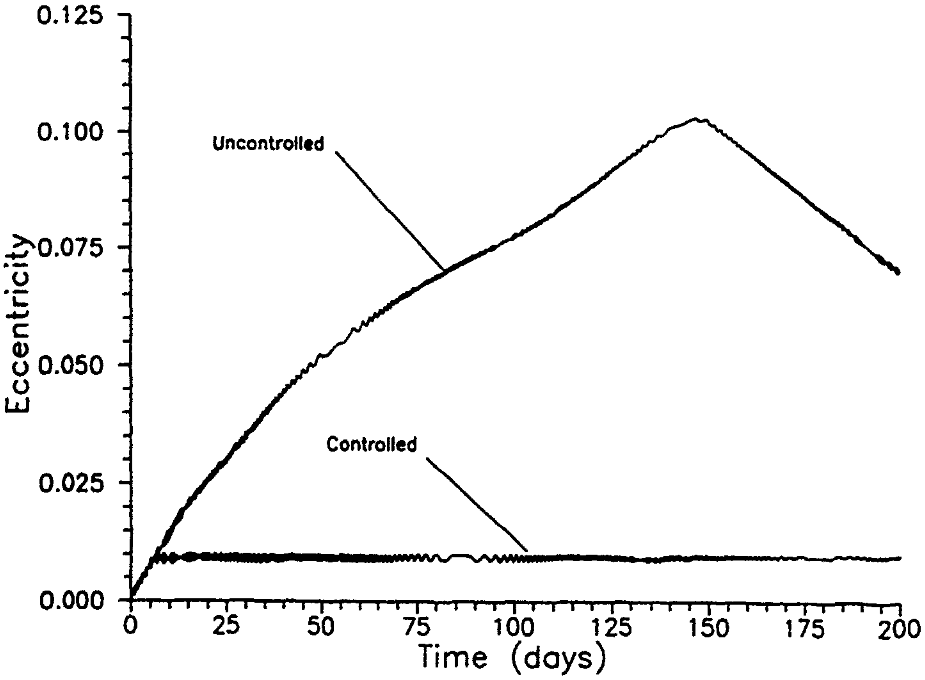

Figure 2. Effect of Controlling a Satellite's Eccentricity

The change in the inclination per orbit is

$$\Delta i = \frac{4a^2 F_w}{\mu} \qquad (16)$$

where μ is the gravitational constant of the earth.

The equations of orbital motion in rectangular coordinates can be expressed by (5:3-1)

$$\dot{x} = V_x \qquad (17)$$

$$\dot{y} = V_y \qquad (18)$$

$$\dot{z} = V_z \qquad (19)$$

$$\bar{x} = V_x = -\mu \frac{x}{r^3} + \text{perturbations} \qquad (20)$$

$$\bar{y} = V_y = -\mu \frac{y}{r^3} + \text{perturbations} \qquad (21)$$

$$\bar{z} = V_z = -\mu \frac{z}{r^3} + \text{perturbations} \qquad (22)$$

with V_x, V_y, and V_z being the velocity in the x, y, and z directions, respectfully. At this time the only perturbation which can really be controlled is that of small thrust; however, other perturbations were included. Some of the other perturbations which affect the satellites are atmospheric drag, solar pressure, and the third-body effect of the moon. The shadow effect also plays a role in the orbit of the satellites.

2. Results

The comparison between the ammonia arcjet and the zenon ion thruster was done by simulating the orbit transfer of two satellites, one by arcjets and the other by ion. Both satellites were launched from 28.6° N (Cape Canaveral) and deployed in a low-altitude earth orbit (LEO) (a = 6785.58 km). The satellites then spiraled out towards geosynchronous radius (42,164 km). After geosynchronous radius was achieved, the satellites began their plane change (inclination change) to achieve geostationary orbit (GEO) at i = 0°. The starting mass of each satellite was 6214 kg, and they both carried solar cells capable of supplying thirty kilowatts of power. Table 1 summarizes the two satellites.

Table 1. Initial Thruster Data

TYPE OF THRUSTER	XENON ION	AMMONIA ARCJET
life span	7,500 hours	1,250 hours
initial mass	6,214 kg	6,214 kg
initial i	28.6 °N	28.6° N
initial a	6678.14 km	6678.14 km
power supply	30 kW	30 kW
# of thrusters	2	3
total thrust	1.0 N	1.3 N
mass flow rate	2×10^{-5}	1.3252×10^{-4}
efficiency	95%	95%
array mass	230.77 kg	230.77 kg
array area	230.77 m^2	230.77 m^2

(Data adapted from Refs. 3; 6; 8)

While the satellite which used the ion thruster takes longer to achieve final orbit (Figs. 3 and 4), it delivers more mass to orbit than an ion thruster (Fig. 5). Therefore, when the need to deliver more mass to orbit outweighs the amount of time taken, an ion thruster is more efficient than an arcjet; therefore, ion propulsion was employed for the remainder of the research. The results of this study are summarized in Table 2.

This first analysis was done to compare two different types of thrusters, and does not take into account solar degradation due to the Van Allen radiation belts. Studies show approximately a seventy percent degradation in solar cells occurs when spiraling out through the radiation belts (8). Taking this factor into account another question arises: "Is there a more efficient way to launch to GEO yet avoid the Van Allen radiation belts?"

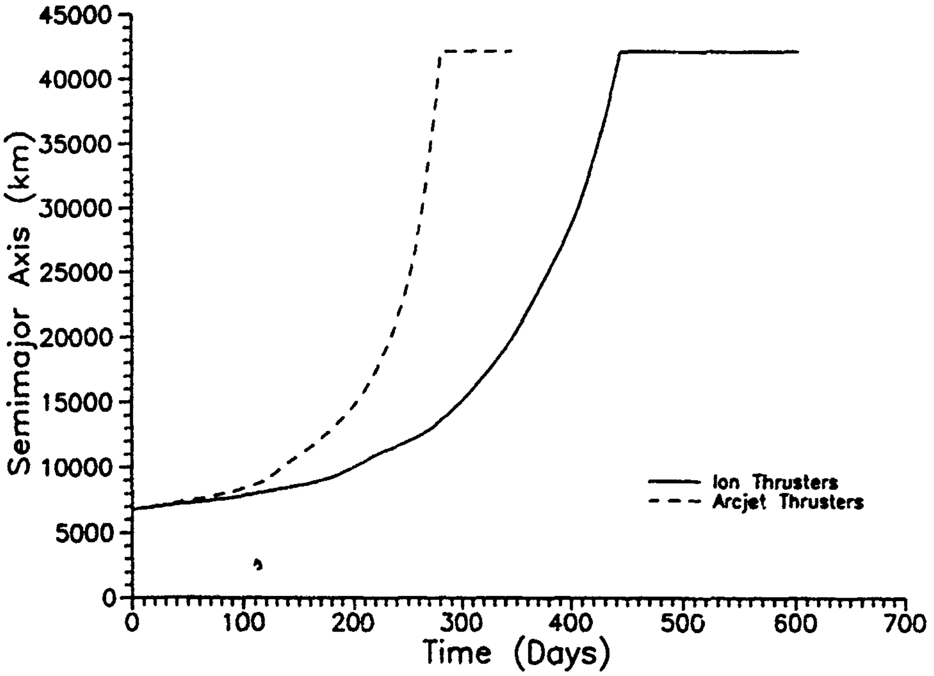

Figure 3. Comparison of the Semimajor Axis Histories for Both Thrusters

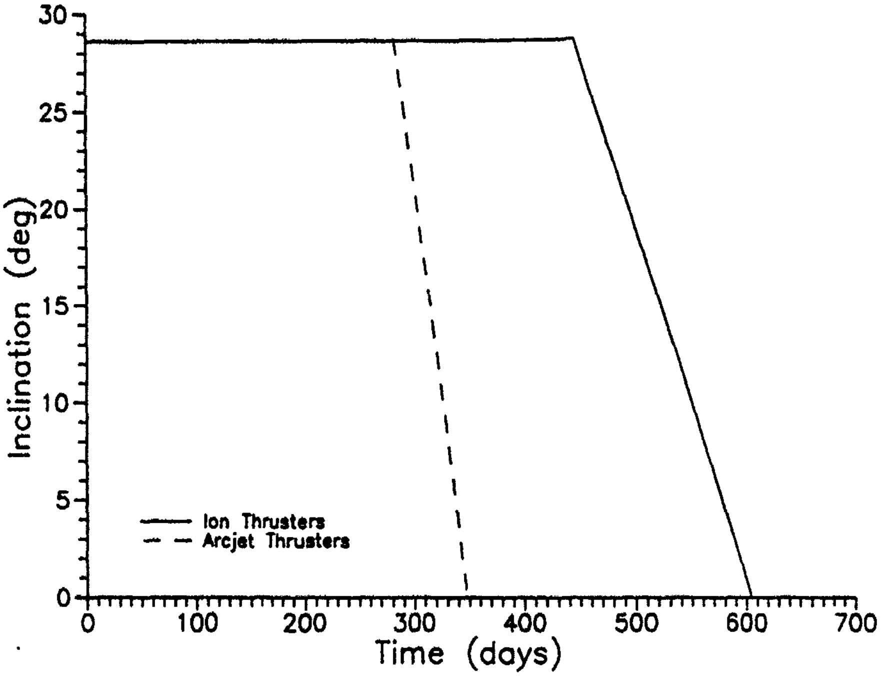

Figure 4. Comparison of the Inclination Histories for Both Thrusters

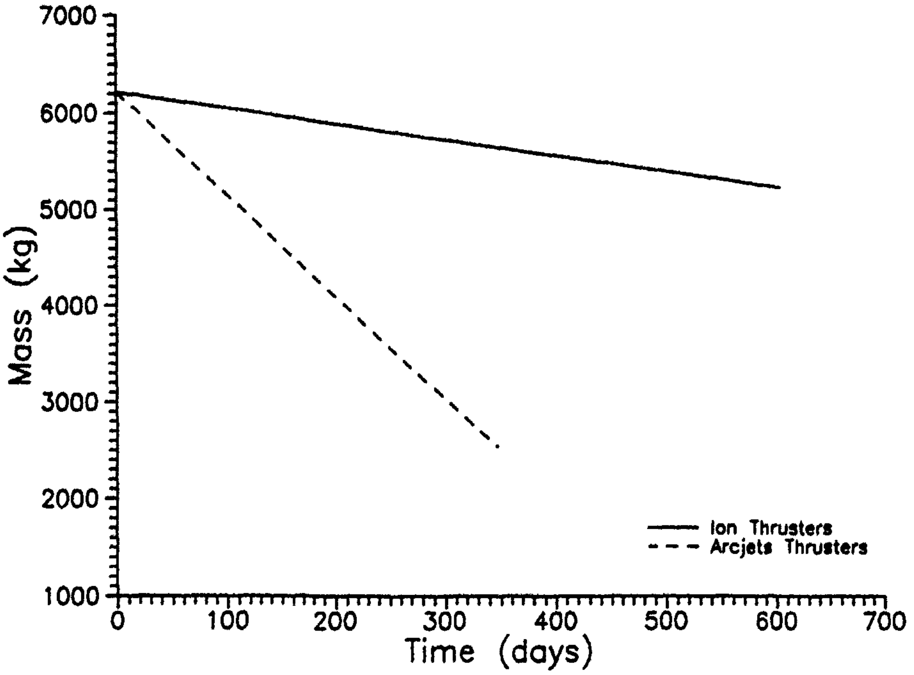

Figure 5. Comparison of the Mass Histories for Both Thrusters

Table 2. Final Thruster Data

TYPE OF THRUSTER	XENON ION	AMMONIA ARCJET
final mass	5222 kg	2537 kg
final i	$< .1^\circ$	$< .1^\circ$
final a	42,127 km	42,159 km
final time	604 days	347 days

This question was answered by the study of two different orbit transfer schemes. Each of the satellites carried four ion thrusters, two of which were needed to replace the first pair (the ion thrusters used in this study have a 5000 - 10,000 hour life span). The initial masses of the satellites were the same; however, in order to simulate degradation of solar cells, one of the satellites had a larger array mass. This fulfills the need for extra solar cells due to degradation. Table 3 summarizes the initial data on the two orbit transfer vehicles.

The first satellite was delivered to orbit at 28.6° N, as done in the previous tests. It began to spiral out from LEO, and do the plane change to GEO, just as before. In this study, however, degradation was taken into account along with all the other perturbations. Since this satellite must pass through the radiation, many of the solar cells become inoperable on the journey out to GEO. To provide the satellite with the needed power to deliver it's payload to GEO the satellite must carry more solar cells, thus decreasing the amount of payload carried.

The second satellite was placed into a low-altitude polar orbit, and thus avoided the radiation belts altogether by spiraling clear of the belts (Fig. 6) before the plane change. No degradation occurred in this transfer so the arrays could be sized to provide only the necessary 30 kW. The large plane change caused the satellite to use much of its

Table 3. Initial Orbit Transfer Data

ORBIT TRANSFER	POLAR	FLORIDA
life span	7,500 hours	7,500 hours
initial mass	5,541 kg	5,541 kg
initial i	90.0 °N	28.6° N
initial a	6785.58 km	6785.58 km
power supply	30 kW	30 kW
# of thrusters	2	2
total thrust	1.0 N	1.0 N
mass flow rate	2×10^{-5}	2×10^{-5}
efficiency	100%	100%
array mass	230.77 kg	824.18 kg
array area	230.77 m^2	824.18 m^2

(Data adapted from Refs. 3; 6; 8)

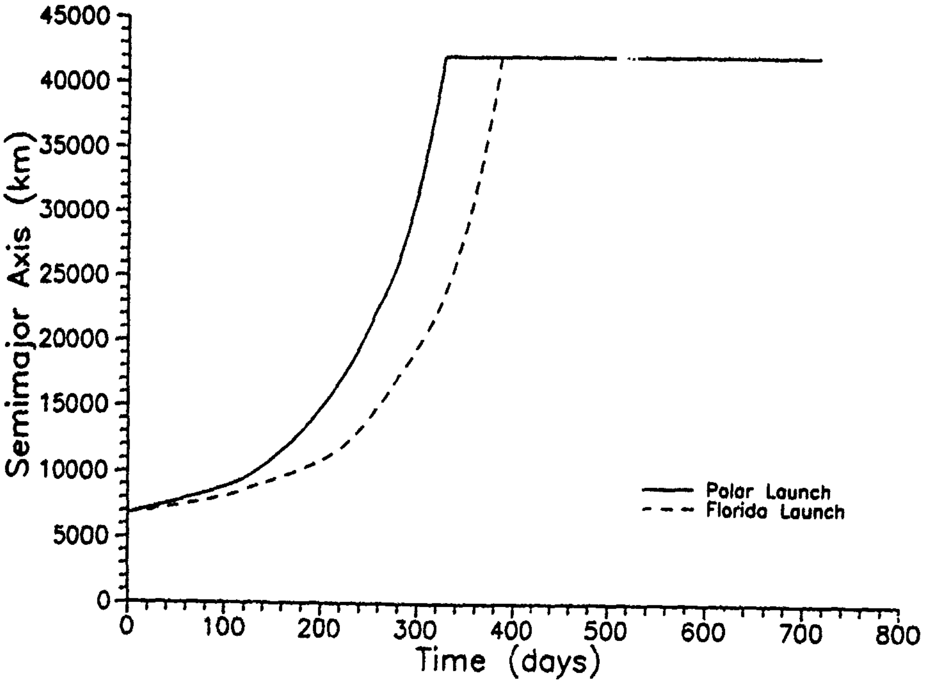

Figure 6. Comparison of Semimajor Axis Histories for Both Launches

mass and also increased the time involved to complete the plane change (Fig. 7). Table 4 summarizes the final data on the satellites.

While the Florida launch case appears to arrive with more mass (Fig. 8), 593 kg of this is "dead" solar cells. Taking this into account, the final mass of the Florida launch case would be ≈ 4049 kg. In addition to the weight of the "dead" solar cells, the Florida launch requires radiation shielding for the electronics onboard, further reducing the mass.

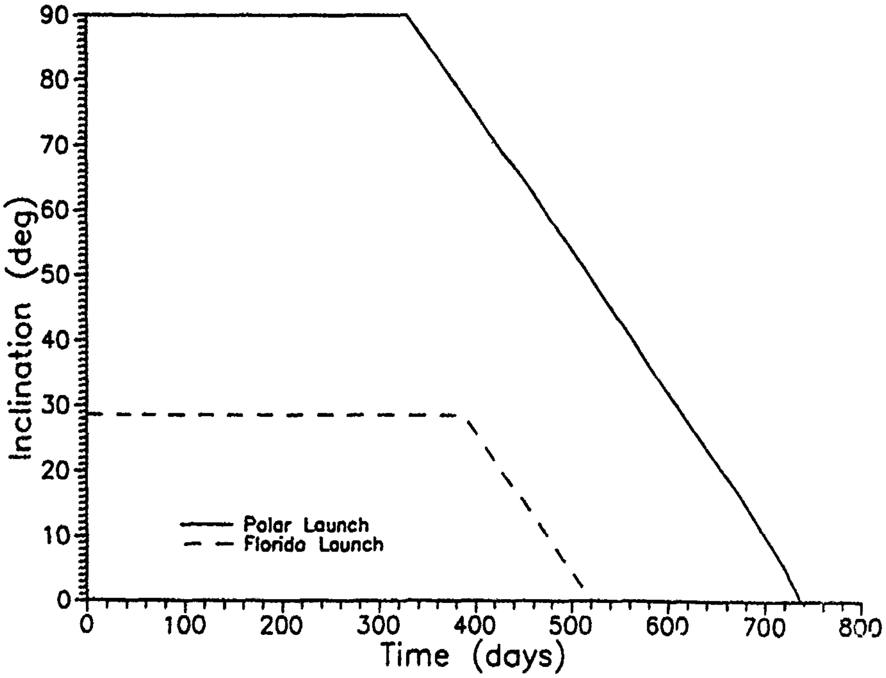

Figure 7. Comparison of Inclination Histories for Both Launches

Table 4. Final Orbit Transfer Data

ORBIT TRANSFER	POLAR	FLORIDA
final mass	4,298 kg	4,642 kg
final i	< 0.1°	< 0.1°
final a	42,163 km	42,126 km
final time	736 days	520 days

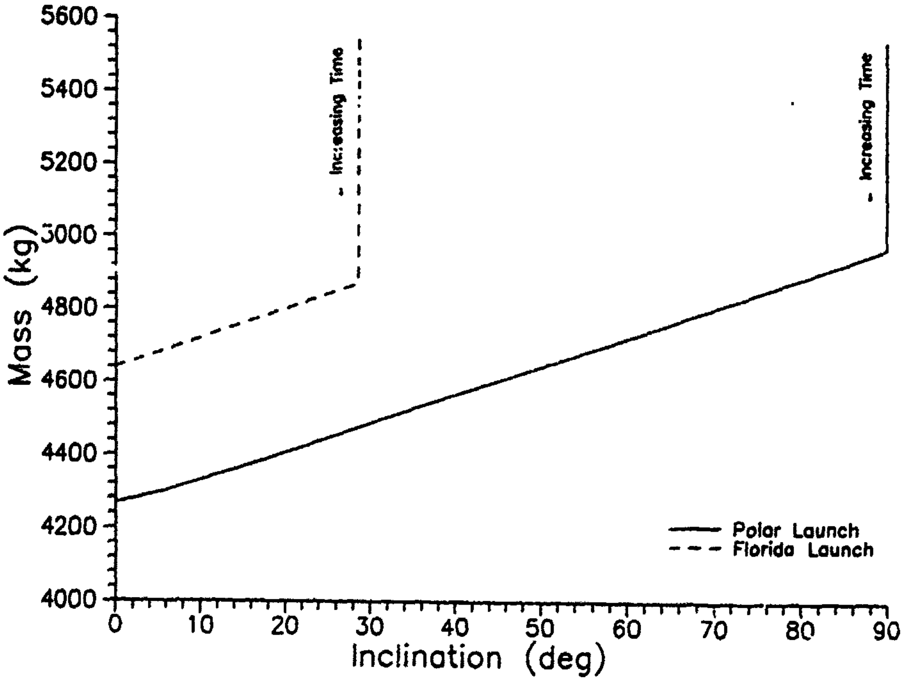

Figure 8. Comparision of Mass/Inclination Histories for Both Launches

3. Conclusions

The results of the analysis of the two different thrusters shows that though a satellite with arcjets arrives at GEO in a shorter time than a satellite with ion thrusters, the ion thrusters consume much less fuel. In the study of the two orbit transfers the best type of transfer also depends on whether time or mass is more important in that application. For time-critical masses, arcjets appear best and for mass-critical missions, ion thrusters are superior.

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Acknowledgments

There are a number of people that I want to thank for making this summer work for me. First is my mentor Kerry Hicks. He encouraged me, and did a good deal of the work on this project, not to mention teaching me orbital mechanics in two weeks. Next is Paul Castro, Pete Moutsatson, and everyone else in XR; they supported me throughout the summer and always made me feel welcome. There are so many people who have helped me in the past three months in so many ways: Kelly Calabio, Sal Castillo, Alan Sutton, Wayne Roe, Rich Hertle, Georgia Woodland, and most of all my family and friends. Thanks to everybody, I'll never forget you.

David Youmans

Final Report Number 48

No Report Submitted

AVIONICS LABORATORY

AIR FORCE OFFICE
OF SCIENTIFIC RESEARCH
(AFOSR)
HIGH SCHOOL
SUMMER APPRENTICESHIP
PROGRAM

BRIAN BARCLAY

BEAVERCREEK HIGH SCHOOL

1. Acknowledgements

I would first like to thank the men and women of WRDC/AAAF for putting up with me, working around me, and generally not letting me get in the way of their work. I would especially like to thank my mentor, Marc Pitarys, and his co-worker, Kenneth Littlejohn, for helping me through my major projects and always having something new for me to do. I wouldn't have been able to learn or accomplish as much without them, and for that I am truly grateful. I would also like to thank my co-workers in the AFOSR apprenticeship program, Austin Flack and Jerard Wilson, for making my job a little more interesting.

2. General Description of Research

As an apprentice in the AFOSR program I was exposed to many new concepts. After familiarizing myself with the facilities available to me, the bulk of my research focused on the creation of software tools to assist in using the Ada Compiler Evaluation Capability (ACEC) and research on applying hypertext to avionics software documentation.

Ada is the Department of Defense's standard high-order computer programming language. The application used to evaluate Ada compiler performance is called the Ada Compiler Evaluation Capability. Currently the running of these tests is both cumbersome and time-consuming. My mission was to create a tool to assist in using the ACEC. This resulted in a menu-driven application to automatically compile and run any selected ACEC tests. This utility was originally written on a Digital Equipment Corporation (DEC) VAX computer but could be transportable to other systems. After three weeks of work, the basic utility was completed. I then went on to enhance the look of the utility using DEC's Screen Management Graphics (SMG) program.

Perhaps a more creative and amusing research topic was the study of applying hypertext tools on the Macintosh IIcx computer to enhancing the use of software documentation. The first demonstration was an Operational Flight Program (OFP) Components documentation application. The demonstration was created with Apple Computer's HyperCard using a flowchart-like format with which the user could select specific topics using a mouse. HyperCard, however, does not make full use of the Macintosh II's capabilities. Because of this, I transferred the OFP presentation to Silicon Beach's SuperCard which allows enlarged screens. This makes the presentation easier to use. After this experience I began working solely in SuperCard. I studied the feasibility of creating government documents using hypertext for greater ease of use. I transferred the tables of contents from several F-16 software specifications manuals to SuperCard to demonstrate this application. Finally I began working with a fellow student in creating interactive hypertext documents describing the F-16 control and display panels. These computer-based documents would allow the user to go through every capability of the panel and receive a brief description of the function of each switch, knob, or display. Three such models were made, and they should prove to be valuable tools in the future.

3. Detailed Description of Research

During my time in the AFOSR program I developed a software tool known as the Ada Compiler Evaluation Capability Testing Utility (ACECTU). This program was written on a Digital Equipment Corporation VAX computer using Ada. Its purpose is to create command files that, when executed, will compile and/or execute selected Ada Compiler Evaluation Capability (ACEC) benchmark tests which test the efficiency and accuracy of the Ada compiler.

In order to complete both the basic version of the ACECTU program and the SMG graphics version of the ACECTU program, many different skills must be mastered. Besides basic Ada programming, I had to learn how to call VAX/VMS commands from Ada. In addition I had to master the use of SMG graphics commands and VT100 screen manipulation commands.

One key to the ACECTU program is that after the command files are created, they are copied to the directory where the user wishes to compile and/or execute the ACEC compiler tests. To accomplish this, one must do what is known as spawning a subprocess. Contained in the Ada package 'LIB', the SPAWN command creates a new user and links that user to the caller's process. It has the effect of logging in to the system again without logging off. Because of this, the user can execute system commands separate from his current process from inside a program. The Ada SPAWN command is used in the following format:

```
LIB.SPAWN (STATUS=> status variable,
           COMMAND_STRING=> command the user
            wishes to call);
```

The status variable is of type 'COND_VALUE_TYPE' from the Ada package 'CONDITION_HANDLING' and returns a code indicating whether or not an error occurred during the calling of the command.

The keys to the graphics version of the ACECTU program are the SMG graphics package commands. SMG is a package that allows the user to create a subset of the screen in order to allow a 'windows' effect in a program. I will describe in detail the commands used in the SMG version of ACECTU.

There are three main commands used to create an SMG window in a program: create_virtual_display, create_pasteboard, and paste_virtual_display. The format for calling these procedures is as follows:

```
SMG.CREATE_VIRTUAL_DISPLAY ( status variable,
                             ROWS=> # of rows in window,
                             COLUMNS=> # of columns,
                              DISPLAY_ID=> integer variable,
                             DISPLAY_ATTRIBUTES=> what
                              kind of border the window will
                             have);
```

```
SMG.CREATE_PASTEBOARD ( status variable,
                                        PASTEBOARD_ID=> integer variable);

SMG.PASTÉ_VIRTUAL_DISPLAY (status variable,
                                        DISPLAY_ID=> same variable as
                                         in create_virtual_dispiay,
                                        PASTEBOARD_ID=> same variable
                                         as in create_pasteboard,
                                         ROW=> row in window to start on,
                                         COLUMN=> column in
                                          window to start on);
```

Again, all status variables are of type 'COND_VALUE_TYPE'. The '_ID' variables are used for reference when one has to refer to a certain virtual display or pasteboard from another command.

In order to put something into a window, one must use one of the following procedures:

```
SMG.PUT_LINE ( status variable,
                         DISPLAY_ID=>  integer display id variable,
                        TEXT=> "What you want to print");

SMG.PUT_CHARS ( same parameters);
```

SMG.PUT_LINE adds a carriage return after printing while SMG.PUT_CHARS does not.

If the user wishes to read a single keystroke from the keyboard into a window, he must execute a create_virtual_keyboard procedure and the read_keystroke procedure after creating a window. These procedures are written as:

```
SMG.CREATE_VIRTUAL_KEYBOARD ( status variable,
                               KEYBOARD_ID=> integer
                               keyboard id #);

SMG.READ_KEYSTROKE ( status variable,
                     KEYBOARD_ID=> integer keyboard id #,
                      DISPLAY_ID=> display id #,
                     TERMINATOR CODE=> variable
                      to receive ASCII representation of key
                     pressed,
                     PROMPT=> "User prompt"'
```

The terminator code is an unsigned longword variable from the Ada package 'SYSTEM' that will return the ASCII representation of the key pressed.

If one wishes to label a window, he simply calls the following procedure:

```
SMG.LABEL_BORDER ( status variable,
                   DISPLAY_ID=> display id #,
                   TEXT=> "Label",
                  POS_CODE=> position of label,
                   RENDITION_SET=> type of
                  letters to be used);
```

The POS_CODE is a special code from package STARLET. Available codes are STARLET.SMG_K_TOP, STARLET.SMG_K_BOTTOM, STARLET.SMG_K_LEFT, and STARLET.SMG_K_RIGHT. The rendition set is also a special starlet code. Some examples are SMG_M_BOLD and SMG_M_INVERSE.

Perhaps the most powerful PROCEDURES are CREATE_MENU and SELECT_FROM_ MENU. They allow the user to create a menu, move through a menu using the arrow keys, and select which item they want. They are called as follows:

```
SMG.CREATE_MENU ( status variable,
                  DISPLAY_ID=> display id #,
                  CHOICES=> array containing menu choices,
                   MENU_TYPE=> starlet code);

SMG.SELECT_FROM_MENU ( status variable,
                       KEYBOARD_ID=> keyboard id #,
                       DISPLAY_ID=> display id #,
                       SELECT_NUM=> unsigned longword
                         variable representing the position in
                        the array of the selection,
                       SELECT_STR=> string representing
                        the word selected);
```

Some possible starlet codes for MENU_TYPE are SMG_K_HORIZONTAL (choices displayed horizontally), SMG_K_VERTICAL (choices displayed vertically), and SMG_K_BLOCK (choices displayed horizontally and vertically). The most difficult and puzzling aspect of the SMG package appeared at this point. The version of SMG I received had been entered incorrectly. After spending a considerable amount of time reading manual after manual I found that when the SMG package accessed the system using an 'IMPORT_VALUED_ PROCEDURE' pragma, more parameters were needed to allow the package to execute correctly. Several of the menu parameters were created as descriptor parameters and not reference parameters, a quality unique to the menu procedures.

Finally, if a user wishes to delete a window, he executes:

```
SMG.DELETE_VIRTUAL_DISPLAY ( status variable,
                             DISPLAY_ID=> id of display to be
                             deleted);
```

If a window is not deleted, it will remain on the screen even if a clear screen is performed. This can cause many problems if multiple windows are used.

The final facet of the ACECTU program is screen manipulation. The VT100 package contains many necessary procedures to keep a program that does not utilize SMG graphics running smoothly and cleanly. The VT100 procedure used most often is the simple CLRSCR (clear screen) command. It is often necessary to clear the screen to keep data from running together and confusing the user. The other necessary procedure in the non-SMG version of the ACECTU program is GOTOXY. This procedure sends the cursor to a position on the screen given in the parameters. This is necessary in ACECTU because of the "Select specific files for compilation/execution" option. In order to facilitate scrolling through 334 different ACEC tests, a multi-column menu is needed. I used GOTOXY to create a four-column menu which greatly increased the speed and functionality of this part of the program.

The purpose of my research of hypertext was to determine and demonstrate the ease with which Air Force avionics software documentation can be implemented using computer-based hypertext documents. Currently, it is very difficult to read the delivered software documentation. The hierarchical structure of the documents can go as high as eight sections deep. I found documents created with hypertext to be much easier to use, and found the scripting of hypertext documents to be quite easy to master. After only hours of working out of a book, one can produce outstanding results that can be understood by almost anyone. Hypertext is definitely an alternative that should be considered as we venture into the age of high technology.

4. Other Interesting Observations

With this being my first technical job, in addition to working for the military, I've certainly learned that one should finish his current work before trying to do anything else. With sensitive work being performed, an inquisitive mind can often be a dangerous thing in the defense work environment. One should always ask questions and make detailed analyses of potential effects and results before any action is taken.

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Pattern Based Machine Learning

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16 August 1990

Introduction

The question posed whenever one talks of Artificial Intelligence (AI) is: how can a machine be made to learn? This has been one of the problems of AI that researchers have tried to solve for years. It is now widely held that Machine Learning (ML) is an essential part of AI. A computer or a machine must learn to adapt and change its programming as the input is varied in order to be truly described as a learning machine. Richard Forsyth put it well when he said, ". . . machine learning is the key to machine intelligence." (3)

Hence, the question arises. How can one program a machine to learn? If I attempted to give a complete answer in this paper it would read like a Los Angeles phone book. I will try to present a picture of how the research that I have helped on this summer fits into ML.

Yet, as ML is an essential part of AI, Pattern Based Machine Learning (PBML) is essential to ML. The project being conducted to determine how a machine recognizes pattern in functions has been going on in WRDC-AART for nearly two years. In this project, we are attempting to show that Dr. Tim Ross's algorithm for function decomposition is effective in being able to take a finite function and reduce it to a simpler form. This actually accomplishes two things:

it teaches a computer to recognize pattern within a function and it simplifies the process of function decomposition, which is itself an old mathematical problem.

In this report I will try to explain what was involved in my summer research, and also what has been done in the PBML study so far. I will describe the processes of our analysis at all of the levels that it partakes. Some of the topics included are theories of and beliefs about AI and ML, function decomposition, and data reduction. The function decomposition algorithm is the foundation of this research, and my comprehension of how it works is incomplete. Due to this I will, with my existing knowledge, try to explain its processes and those processes that evolve from it as well as I can.

There are many people who I would like to thank that have taught me much about the procedures and processes behind PBML over the past eight weeks and have made my work a valuable learning tool. I would like to thank my mentor, 2 Lt. Tim Taylor, and Dr. Tim Ross for their patient assistance and teaching. I would also like to thank summer hires Dr. Tom Gearhardt, Dr. Mike Breen, Dr. Tom Abraham, Shannon Spittler, and Michael Chabinyc for being such a help to me. I thank my neighbor across the street, Mr. J.B. Schroeder, for informing me of the AFOSR High School Apprenticeship Program in the first place and for all of his favors. I thank everyone at Universal Energy Systems: Mr. Rodney Darrah, Mrs.Sue Espy, and Mr. Danishek for sponsoring this program and for their assistance in keeping the program running smoothly for the eight weeks. I also thank everyone else in AART who helped me at work. Finally, if your name is not on this list and it should be, thank you also.

1. PBML as a Sub-field of AI

1.1 Background on AI

AI is a field of computer science that has been around since the 1950's that is concerned with making software and, to not such an extent, hardware that can duplicate the processes of the human brain. The chief long term goal of AI is to build a computer that can perform as an equal to the human mind.

Over the past three decades AI has come from the pages of science fiction magazines to a field that has produced working commercial products for almost a decade. Several expert systems, software that is designed to fool the user into thinking he is communicating with an expert in a field such as medicine when the expert is actually is a computer, have come into the market. These programs have had several problems. Among these are high cost and large memory and system requirements. Heavy demands have been made by the business and engineering communities for the AI industry to produce products that are intelligent enough to be practical.

Researchers have not been able to solve the problem of programming a computer to perform inductive reasoning. They have been able to program deductive reasoning abilities into AI software. Problems such as this old favorite have kept countless great philosophers awake at night.

> Yesterday the sun rose in the East and set in the West.
>
> Every day of my life it has risen in the East and set in the West.
>
> Never in living memory has anyone seen it do anything else.
>
> Therefore it will rise in the East tomorrow too. (Forsyth 4)

The last line has no proof for it. This is what differentiates between deductive and inductive reasoning.

Although AI software has not come along very far yet, all of the research involved in it has not gone to waste. Cognitive Science has progressed immensely since the advent of AI research. Cognitive Science helps us to discover how we learn. The research done in AI has shown that the way we learn from day one is very similar to how a computer is programmed. If discoveries are made in how a human or a machine learns, then the new knowledge can be applied to the other type of learning.

1.2 Background on ML-a field of AI

ML is best described as a field of AI which is attempting to develop software and hardware that can adapt itself to a change in its initial state without having to be re-programmed. With traditional programs, every bug would have to be fixed by the programmer, software company, or possibly the user. This causes wasted time for the programmer, frustration for the user, and makes the software company a lot of money in selling upgrades, unless they want a good reputation and give the upgrades away for free. ML research is trying to cause computers to fix their own errors and change with the situation.

PBML is trying to teach a machine to recognize pattern. In my summer research, this pattern recognition deals with patternness in functions, but it can also deal with other topics such as retina and fingerprint scanning. Function decomposition is the foundation that the rest of PBML is built around. This process can be done by hand to a certain extent, but quickly becomes nearly impossibly complex. This is where the function decomposition program, written in the DOD's Ada language, comes in. It can decompose functions eight times as complex as a human, and it can minimize the computational cost without the human error factor. It also runs on our VAX at a speed of about three orders of magnitude faster than a human.

Herbert Simon states that if we are to teach a computer to learn, we have to understand how we learn by, in turn, simulating our learning processes in a program. (Machine Learning I 35) Along with this, a computer must have an immensely large and powerful processor that has the processing ability of the mind. (Forsyth 239-240) I myself believe that for a machine to learn at the same rate a person learns, the machine must have several more input devices than it does currently, and these devices must be user-independent so the machine can monitor its environment for input. Many ML researchers believe that if a computer is to learn, then it must go through a "childhood" stage where it is very limited in its ability. This is analogous to a computer with input devices that are user-independent, as the aforementioned one.

2. The Process of Function Decomposition

2.1 Introduction

Function decomposition, the underlying process of the PBML study, has only been recently explained in some detail to me. It is a mathematical process that involves finite functions, binary, one to three dimensional arrays, and partitioning of variables just to name a few. This process cannot be explained in words alone, so in the appendix there are diagrams that accompany the following descriptions of the steps from deciding what function one wants to check for a decomposition to determining the final recomposed, reduced function.

2.2 Choosing a Function, Conversion to Binary, and Basic Table Syntax

Refer to diagram 2.4 for sections 2.2-2.4.2. First, before a function can be decomposed one must be chosen to be decomposed and it must be converted to a binary string. Some of the functions used in the study include xor gates, parity, prime numbers, randomly generated functions, and even atypical functions such as an ASCII character. For my examples I use as an input function a chaotic sequence that is called Fibinachi's ideal propagation of rabbits (Fipr). For a more complete description of this interesting sequence, see section 4. This is a good example because it does not need to be converted to binary. The sequence generated by Fipr is already a binary string. I believe that the decimal to binary conversion is not inherent to comprehending the function decomposition process; therefore, I do not include it for sake of space.

Second, one decides how many variables the function is to be run on, and puts the function in a one-dimensional table. The range of the number of variables normally associated with hand done function decomposition is from four to six. Once you get above six variables the process becomes incredibly complex, and cannot really be done by hand. Also, functions run on three or less variables are too simple to be useful and are also boring because of their simplicity. To decide how long the binary input function string must be one takes two and raises it to the power of the # of variables. If there were four variables, the input function would be 16 digits long. Obviously, with each increase of one in the number of variables, the process becomes more complex. As the number of variables goes up, the time to complete a decompostion increases in a semi-geometric way.

Once the input function is found, it is placed in a column-type one-dimensional table with binary values from 0 to one less than (the number of values in the input function) on the left, and the input function itself on the right. Each of these values on the right has its own distinct binary value in the left hand column. As you can see, the number of digits in the binary value is equal to the number of variables. Let these variables be called $x_1, x_2, \ldots, x_{\#\text{ of variables.}}$ (Ross 13) This is what goes over the binary values on the left. The input function on the right has a column heading that is a function of the variables mentioned just before. This function is $f(x_1, x_2, \ldots, x_{\#\text{ of variables.}})$ (Ross 13) In the example we can see that f(0, 0, 0, 0,)=1 and f(0, 0, 0, 1)=0 and so on until the 32nd input function value.

2.4 Vacuous Variables and Shared Variables

Third, checks are made for vacuous variables(vv) and shared variables. The process of function decompostion is done so that a function may be reduced and therefore, be made simpler and easier to manipulate. The main way this is accomplished is through vvs. These are variables whose value has no effect on the input function. If a variable is vacuous, it is taken out of the equation. This makes a function simpler by a factor of two. The process of checking for vvs is described in detail in the next section.

2.4.1 The Check for Vvs

In 2.2, the function is placed into a one-dimensional matrix. In this step, the function is placed into a two-dimensional matrix and checks are made for vacuous variables and later on in 2.4.2, checks will be made for shared variables. To place a function in a two-dimensional matrix, the variables must be partitioned into two parts. The union of these partitions is the null set and their intersection is the full set of variables.(Ross 13) For instance, if $v_1=(x_1,x_2)$ and $v_2=(x_3,x_4,x_5)$ then the partitioned, two-dimensional table looks like the one in the diagram. Two other examples of possible partitionment of variables are $v_1=(x_1)$ and $v_2=(x_2,x_3,x_4,x_5)$, and also $v_1=(x_1,x_3,x_5)$ and $v_2=(x_2,x_4)$. All of the partitionment permutations where v_1 has only one variable and v_2 has the rest of the variables are then examined in order to see if 0, 1, more than 1, or all of the variables are vacuous.

Before doing the actual check for vacuous variables, a word needs to be said about how the partitionment works in the diagram itself. Along the top are displayed the variables in v_1 and those in v_2 are shown along the left side. The binary numbers displayed across the top of each column in the table and along the left side of each row are all of the possible values that the v_1 or v_2 variables can take on. The binary values just described are taken in order from x_1 to $x_{\#\text{ of variables}}$. The corresponding value of the input function is placed in that cell. I use the word cell as it is used in a spreadsheet, where each cell has its own unique address. In this case, the address is a binary number. In the diagram I use a text phrase for one example since it is easier to follow, and I have a second example using binary digits.

The actual check for a vv is in itself is a rather simple comparison of the two columns of a partitionment permutation where v_1 has only one variable and v_2 has the rest. If these two columns are the same then the variable is vacuous. After determining the number of vvs there are, if any, they are removed from the equation. From this reduced and simplified equation a new one-dimensional table is generated that has half as much complexity for each vv that was removed and also has half the cost. Cost is the computational complexity of a function. The full cost of a function is the same as the length of the input function and is determined in the same manner.

2.4.2 The Check for Shared Variables

Now checks are made for shared variables(sv). The remaining four variables in the example are partitioned into a series of new two-dimensional tables. Notice that these tables are one half the size of the original two dimensional table because of the vacuous variable. If one of the tables has two pairs of columns that are the same, as in the diagram, then there is a column multiplicity of two. This means that the columns are different, but there are only two distinct column types. The v_1 variables only differentiate between the two different column types. This concept links vvs with svs. As you may have noticed, with a vv, the column multiplicity is one so the variable is vacuous and unneeded, and with a sv the column multiplicity is two and the variables only distinguish between columns.

2.5 A Sample of a Decomposition on Five Variables

Refer to diagram 2.5 for this section. Now that I have described how the decomposition process works, I am now going to do an example of a hand-done decomposition. The function that I am going to decompose is Fipr. This example is the same as the one I did in 2.2 and the following sections in some aspects, except now I am going to add more to the diagrams and describe the process in more detail. Before I start, the diagram that looks somewhat like a checkerboard on the bottom of the diagram is a two-dimensional table that has a black square instead of a one and a white square instead of a zero. This allows one to visualize the function more easily.

I choose that the function will be run on five variables. So, by eqn. 1, the length of the input function is 32. This binary string is the same as the one on the top of the previous diagram that I used to explain the process of function decomposition. It is copied onto a one-dimensional table with the format I described before.

Next, I check the function for vvs. I do not show all five checks, one for each variable, for the sake of space. The only variable that ends up being vacuous is x_2, so it is removed from the equation. After this variable is removed a new one-dimensional matrix of half the first one's length is generated such as the one shown.

This new function has no vacuous variables. I have done the checks, but to keep this concise I left them out. After doing these for a while, I learned to do these checks in my head, and I did so to save space.

The final step is to check the function without vvs for svs. The three possible partitions are shown on the right, and none of these three two-dimensional matrices have column multiplicity of two. The second one down comes close, but the column multiplicity is three, and this does not meet the criteria. The function ended up with a final cost of 16, which is half of the cost of the original function. This is due to the fact that there was a vacuous variable in the original function.

2.6 A Sample of a Decomposition with Don't Cares

Refer to diagram 2.6 for this section. As I have demonstrated, the process of function decomposition will find out if a function can be simplified by discovering if there are vvs. Along with reducing a function it can act as an interpolator of sorts. This process adds a few steps to the process but does not change the basic algorithm. Instead of knowing every value of the input function, some of the values are "masked out". This means that they are given a wild card value. When decomposing the function, this don't care is assigned a one or a zero, depending on which value would make the function have a vacuous or shared variable. This is analogous to showing a person a picture, covering part of it, and asking the person to identify what the whole picture is.

In the example, the left side is what a typical four variable Fipr function would look like. To the immediate right of this is what the function is with four don't cares. I decided to make a diagonal line into don't cares from the upper left to the lower right in the diagram of the function. The don't cares are designated by crosshatching. The same two-dimensional table is shown immediately to the right of the typical one, with the don't cares designated by an X. The one-dimensional table of the input function and the corresponding binary values is below that. If a two-dimensional table is made with $v_1=(x_1)$ and $v_2=(x_2,x_3,x_4)$ then the table looks like the one in the upper right. I substitute in values for the don't cares in order to make x_1 vacuous. This is shown in the two-dimensional table in the middle of the right side.

Therefore, the function has a vv and it also is a Fipr function. It so happens that if a function is run on a large number of variables and the majority of the values of the input function are don't cares, the decomposition does not usually interpolate the function correctly. The results of this example are the same as they would be if I would have done the decomposition with the three tables on the left.

3 The Data Obtained from the Ada Function Decomposer (AFD)

3.1 Background on the AFD

The history of the PBML program goes back to 1989, when the algorithm for function decomposition written by Dr. Tim Ross and Mike Noviskey was translated into the Ada language by Chris Vogt. The program was very rough in its early stages, and when it was running well, ten versions were made which were slight variations of one another. Here is a list of the ten AFD software versions and how they differ.

V1-----Non-shared, exhaustive

V2-----Non-shared, negative decompositions

V2A---Non-shared, negative decompositions, greedy search

V2B---Non-shared, negative decompositions, number of cares cost

V2AB-Non-shared, negative decompositions, number of cares cost, greedy search

V3-----Shared, exhaustive

V4-----Shared, negative decompositions

V4A---Shared, negative decompositions, greedy search

V4B---Shared, negative decompositions, number of cares cost

V4AB-Shared, negative decompositions, number of cares cost, greedy search

3.2 Processing Functions through the AFD

After the AFD was up and running, as many different functions as the PBML group could think of were run through the various software versions. The program ran on a VAX because of the size and complexity of the program and also because some of the nine and ten variable runs would never finish on anything else.

The output from the AFD was in a format that had all of the information needed to do analysis on it, but its format and excessive length needed to be simplified. To do this, the data was reduced into a database that had all of the necessary information for each run and nothing more. Dr. Ross wrote a program that accomplished this in Pascal. For nearly four weeks, I worked on reducing this data by means of this program, and I also worked on debugging this and other programs.

3.2.1 AFD Output-The letter "R"

Some of the more interesting functions included ASCII characters such as char. 82, the letter "R". In diagram 3.2 is the graphic depiction of what the AFD did with char. 82. It is a function on eight variables, with a cost of 256. The AFD interpolated it correctly after only receiving 120 samples out of 256, with the other 136 being don't cares. After 80 samples, it is shown that the AFD was nearly correct, for its only flaw was that it filled in the upper right corner of char. 82. Another interesting find about it is that it did better that a neural network on char. 82. A neural network took 200 samples before it got char. 82 correct. See diagram 3.2.1 for char. 82 on a neural network.

3.2.2 AFD Output-Parity

Another example of AFD output is the parity function in diagram 3.2.2. This function is so highly patterned that it took the AFD only 30 samples out of a total cost of 128 to get the interpolation correct. This parity function proves that it does not recognize letters, or that it just "filling in spaces" as some would believe. This is seen if one investigates the don't cares closely enough, and how the AFD interpolated them.

3.3 Reduction and Analysis of the AFD output.

The program used to reduce the AFD output, which we call afdtodb, takes the output and pulls out all of the important information such as the function name, the date the function was run, the number of variables, the actual input function, the recomposed function, and the time the function took to run. The program then writes this into a condensed database format, with one group of the above parameters for each run. The total number of runs we have at the time that I write this is approx. 2800. The database is about 500K in size. This program reduces the output data by a factor of 25, give or take 5. A nearly complete picture of the data processed by the ten versions of the AFD is shown in this database.

After obtaining a satisfactory database format, the parameters of the runs are currently under analysis in order to find such things as which version is the best overall. By which is best I mean the one that reduces the function to optimal low cost and also runs at a relatively fast computational speed.

Besides investigating the efficiency of the ten versions, the time the functions took to run are under analysis for each version and for different numbers of variables. The runs are being checked to see if they decomposed as well. Also, the runs are being checked for vvs. If a function has a vv, then it makes an eight variable function into a seven variable function. An eight variable function without vvs runs much more slowly than a seven variable function. Because of this, functions with vvs must be analyzed separately that those without vvs.

4. Concluding Remarks

I feel that I benefitted from my summer apprenticeship because I gained a greater understanding of how low-level research is conducted. This was very new and exciting to me because it contrasted well with what I did last summer. Low-level research does not produce usable results, but it projects them. One possible use of PBML is algorithm design. High level research has immediate applications, such as producing or improving upon a product or process. I learned that low level research is frustrating 99% of the time, but the other 1% of the time makes up for it.

I gained a much greater understanding of how computers work at all levels. I learned to use the VAX, program in Pascal, how to make DOS work to my benefit, and how to use a Macintosh.

Also, I discovered a few things during my research. Discovery is for me the most exciting form of learning because I am not just repeating someone else's process. One of the things I discovered is a fractal that is a simple derivative of Fipr. See diagram 4 and the explanation below.

Before I explain the fractal, I will describe what Fipr is. There is, in the first "year", one young rabbit that is represented by a 0. Each year the rabbits propagate following two explicit rules. They are: 1) Each year every young rabbit grows into an adult rabbit, or a 0 becomes a 1. 2) Each year every adult rabbit has one young rabbit that is written immediately after the adult, or a 1 becomes a 10. This sequence is chaotic. If the number of rabbits there are in an individual year is counted, the total, written to the right on the diagram, is the nth term of the Fibinachi sequence. Another way to generate rabbits is to take the previous year, write it after the current year, and this is the next year. What this is saying is that 10110 is the same as the year two years before written after the year before, or 101 + 10 = 10110.

The fractal itself is generated as follows. Take a year that has at least 30 or so rabbits. After each adult that has a young rabbit after it, put some space between them to separate them. Do the same with each young rabbit. Below this line, write the number of adults in each separated group under the group. Take this line of ones and twos and separate it as the rabbits were separated in the line above. Now, write the number of twos in each group below this line. Repeat this process for as long as there are groups of twos and the fractal emerges. It is the same line repeated, but with a shorter length each iteration. The process works in reverse to generate a longer sequence if one ponders this enough.

In conclusion, I feel that this summer's apprenticeship benefitted be because it gave me experience in a variety of fields that I knew little or none about previously. This new knowledge will help me with career choices.

5. References

Carbonell, Jaime G., Michalski, Ryszard S., and Mitchel, Tom M., eds. Machine Learning: An Artificial Intelligence Approach. vol I. Morgan Kauffman Publishers, Inc. 1983.

Forsyth, Richard, ed. Machine Learning: Principles and Techniques. New York: Chapman and Hall Ltd. 1989.

Ross, Tim. The Basic Condition for the Decomposability of Finite Functions. (rough draft of final PBML report). 1989.

For further reading on where Dr. Ross came up with PBML, read Curtis, Allen H. Design of Switching Circuits. New York: D. Van Nostrand Company, Inc. 1962.

Appendix

1011010110110101
1010110110101101

x_1,x_2,x_3,x_4,x_5	$f(x_1,x_2,x_3,x_4,x_5)$
0 0 0 0 0	1
0 0 0 0 1	0
0 0 0 1 0	1
0 0 0 1 1	1
0 0 1 0 0	0
0 0 1 0 1	1
0 0 1 1 0	0
0 0 1 1 1	1
0 1 0 0 0	1
0 1 0 0 1	0
0 1 0 1 0	1
0 1 0 1 1	1
0 1 1 0 0	0
0 1 1 0 1	1
0 1 1 1 0	0
0 1 1 1 1	1
1 0 0 0 0	1
1 0 0 0 1	0
1 0 0 1 0	1
1 0 0 1 1	0
1 0 1 0 0	1
1 0 1 0 1	1
1 0 1 1 0	0
1 0 1 1 1	1
1 1 0 0 0	1
1 1 0 0 1	0
1 1 0 1 0	1
1 1 0 1 1	0
1 1 1 0 0	1
1 1 1 0 1	1
1 1 1 1 0	0
1 1 1 1 1	1

x_1,x_2,x_3	$f(x_1,x_2,x_3)$
0 0 0	s
0 0 1	a
0 1 0	s
0 1 1	a
1 0 0	m
1 0 1	e
1 1 0	m
1 1 1	e

Diagram 2.4
The Basic
Function
Decompositon
Process

		x_1	
		0	1
	00	s	m
x_2,	01	a	e
x_3	10	s	m
	11	a	e

		x_2	
		0	1
	00	s	s
x_1,	01	a	a
x_3	10	m	m
	11	e	e

		x_1	
	0000	1	1
		0	0
		1	1
x_2,		1	0
		0	1
		1	1
x_3,		0	0
		1	1
		1	1
x_4,		0	0
		1	1
		1	0
x_5		0	1
		1	1
		0	0
	1111	1	1

1	0	1	0	1	1	1	1
0	1	0	1	0	1	0	1
1	0	1	0	1	0	1	0
1	1	1	1	0	1	0	1

Diagram 2.5
Fipr
5 variables

x_1,x_2,x_3,x_4,x_5	$f(x_1,x_2,x_3,x_4,x_5)$
0 0 0 0 0	1
0 0 0 0 1	0
0 0 0 1 0	1
0 0 0 1 1	1
0 0 1 0 0	0
0 0 1 0 1	1
0 0 1 1 0	0
0 0 1 1 1	1
0 1 0 0 0	1
0 1 0 0 1	0
0 1 0 1 0	1
0 1 0 1 1	1
0 1 1 0 0	0
0 1 1 0 1	1
0 1 1 1 0	0
0 1 1 1 1	1
1 0 0 0 0	1
1 0 0 0 1	0
1 0 0 1 0	1
1 0 0 1 1	0
1 0 1 0 0	1
1 0 1 0 1	1
1 0 1 1 0	0
1 0 1 1 1	1
1 1 0 0 0	1
1 1 0 0 1	0
1 1 0 1 0	1
1 1 0 1 1	0
1 1 1 0 0	1
1 1 1 0 1	1
1 1 1 1 0	0
1 1 1 1 1	1

		x_2	
		0	1
	0000	1	1
	0001	0	0
	0010	1	1
x_1,	0011	1	1
	0100	0	0
	0101	1	1
x_3,	0110	0	0
	0111	1	1
	1000	1	1
x_4,	1001	0	0
	1010	1	1
	1011	0	0
x_5	1100	1	1
	1101	1	1
	1110	0	0
	1111	1	1

x_1,x_2,x_3,x_4	$f(x_1,x_2,x_3,x_4)$
0 0 0 0	1
0 0 0 1	0
0 0 1 0	1
0 0 1 1	1
0 1 0 0	0
0 1 0 1	1
0 1 1 0	0
0 1 1 1	1
1 0 0 0	1
1 0 0 1	0
1 0 1 0	1
1 0 1 1	0
1 1 0 0	1
1 1 0 1	1
1 1 1 0	0
1 1 1 1	1

x_1,x_3

		00	01	10	11
	00	1	0	1	1
x_4,	01	0	1	0	1
x_5	10	1	0	1	0
	11	1	1	0	1

x_1,x_4

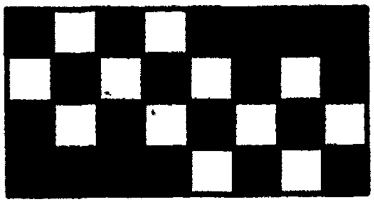
		00	01	10	11
	00	1	1	1	1
x_3,	01	0	1	0	0
x_5	10	0	0	1	0
	11	1	1	1	1

x_1,x_5

		00	01	10	11
	00	1	0	1	0
x_3,	01	1	1	1	0
x_4	10	0	1	1	1
	11	0	1	0	1

x_1,x_2,x_3

		000	001	010	011	100	101	110	111
	00	1	0	1	0	1	1	1	1
x_4,	01	0	1	0	1	0	1	0	1
x_5	10	1	0	1	0	1	0	1	0
	11	1	1	1	1	0	1	0	1



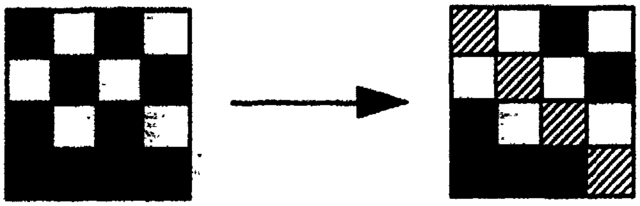


Diagram 2.6
Fipr
don't cares

x_1,x_2

		00	01	10	11
	00	1	0	1	0
$x_3,$	01	0	1	0	1
x_4	10	1	0	1	0
	11	1	1	1	1

x_1,x_2

		00	01	10	11
	00	X	0	1	0
$x_3,$	01	0	X	0	1
x_4	10	1	0	X	0
	11	1	1	1	X

x_1

		0	1
	000	X	1
	001	0	0
$x_2,$	010	1	X
	011	1	1
$x_3,$	100	0	0
x_4	101	X	1
	110	0	0
	111	1	X

x_1,x_2,x_3,x_4	$f(x_1,x_2,x_3,x_4)$
0 0 0 0	1
0 0 0 1	0
0 0 1 0	1
0 0 1 1	1
0 1 0 0	0
0 1 0 1	1
0 1 1 0	0
0 1 1 1	1
1 0 0 0	1
1 0 0 1	0
1 0 1 0	1
1 0 1 1	1
1 1 0 0	0
1 1 0 1	1
1 1 1 0	0
1 1 1 1	1

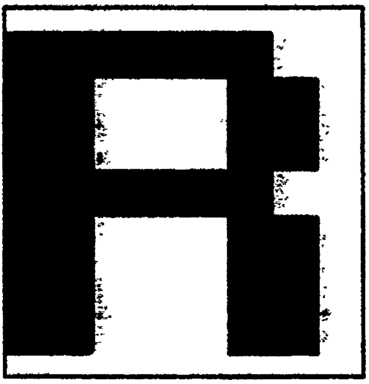
x_1,x_2,x_3,x_4	$f(x_1,x_2,x_3,x_4)$
0 0 0 0	X
0 0 0 1	0
0 0 1 0	1
0 0 1 1	1
0 1 0 0	0
0 1 0 1	X
0 1 1 0	0
0 1 1 1	1
1 0 0 0	1
1 0 0 1	0
1 0 1 0	X
1 0 1 1	1
1 1 0 0	0
1 1 0 1	1
1 1 1 0	0
1 1 1 1	X

x_1

		0	1
	000	1	1
	001	0	0
$x_2,$	010	1	1
	011	1	1
$x_3,$	100	0	0
x_4	101	1	1
	110	0	0
	111	1	1

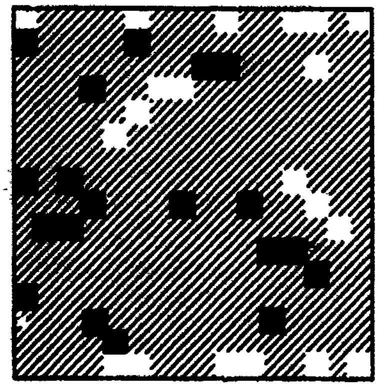
x_2,x_3,x_4	$f(x_2,x_3,x_4)$
0 0 0	1
0 0 1	0
0 1 0	1
0 1 1	1
1 0 0	0
1 0 1	1
1 1 0	0
1 1 1	1

Diagram 3.2
char. 82

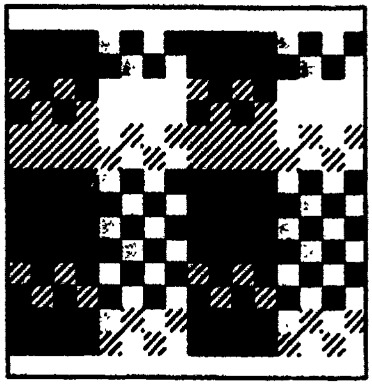


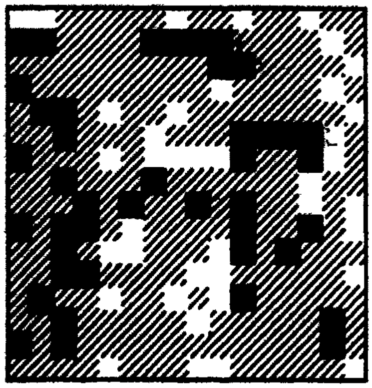
The input function
with don't cares

The recomposed
function

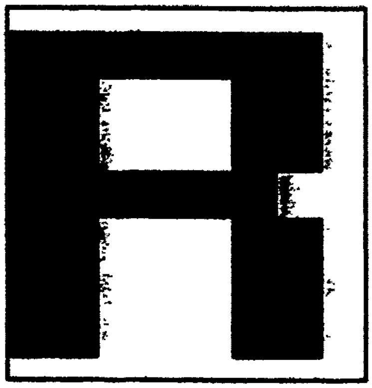


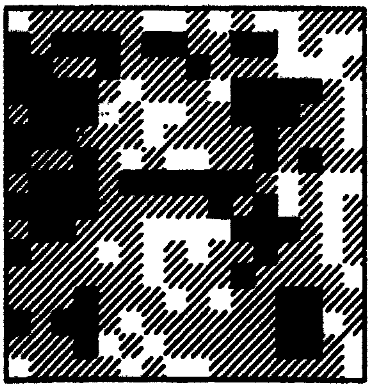
40 samples,
216 don't cares





80 samples,
176 don't cares





120 samples,
136 don't cares

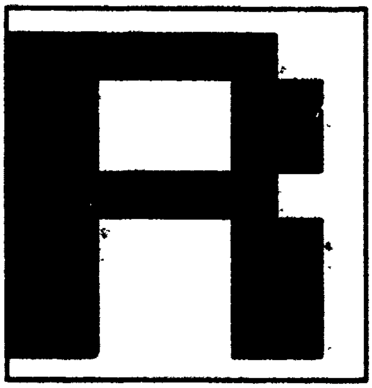
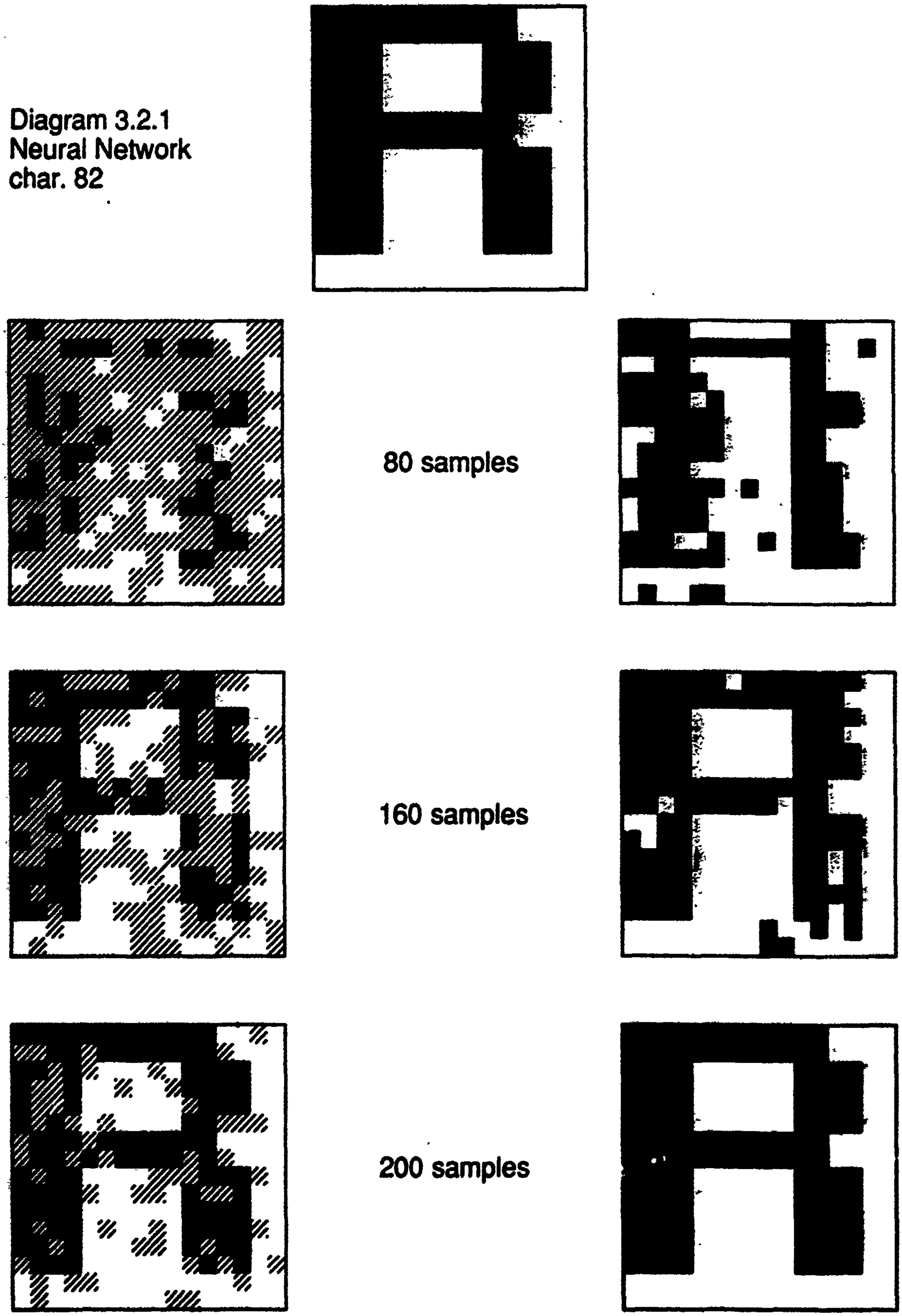


Diagram 3.2.1
Neural Network
char. 82

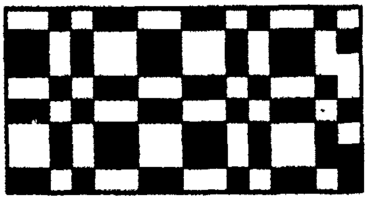


80 samples

160 samples

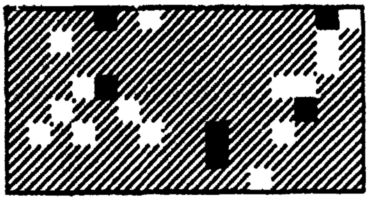
200 samples

Diagram 3.2.2
Parity

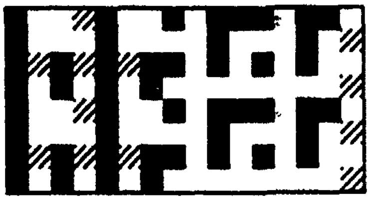


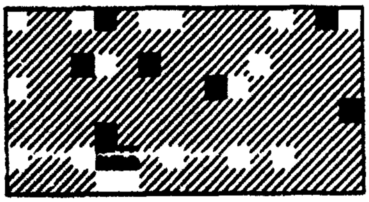
The input function with don't cares

The recomposed function

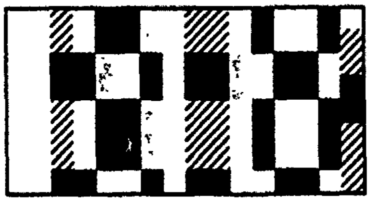


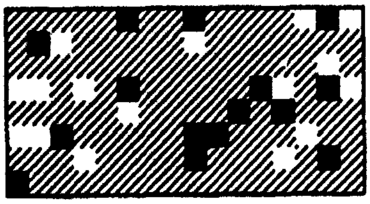
20 samples,
108 don't cares





25 samples,
103 don't cares





30 samples,
98 don't cares

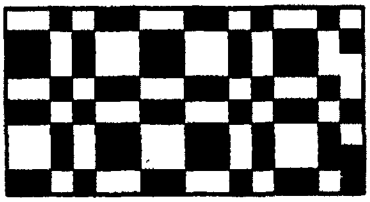
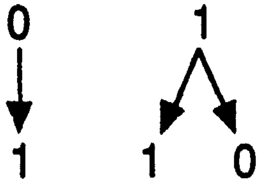


Diagram 4 Fipr, the Related Fractal, and "Theorems".

0=young rabbit 1=adult rabbit



	The number of rabbits each year
	0
0	1
1	1
10	2
101	3
10110	5
10110101	8
1011010110110	13
101101011011010110101	21
1011010110110101101011011010110110	34...

"Theorems"

1. There are never two zeros beside each other.
2. There are never more than two ones beside each other.

The fractal

1 0 11 0 1 0 11 0 11 0 1 0 11 0 1 0 11 0 11 0 1 0 11 0 11 0 1 0 11 0

1 2 1 2 2 1 2 1 2 2 1 2 2 1 2

1 2 1 22 1 2 1 22 1 22 1 2

1 2 1 2 2 1

1 2 1 22 1

1 2

Pattern Based Machine Learning: A Comparison of ADA Function Decomposer Versions

Michael Chabinyc
8/17/90

Introduction

The purpose of the Pattern Based Machine Learning (PBML) project is to develop a theory for automating algorithm design in support of fire-control. The project's key is the concept of function decomposition. The hope is that function decomposition is an important factor in unlocking the full potential of learning/artificial intelligence systems. Whereas most artificial intelligence algorithms need a large data base of knowledge before commencing on any type of "intelligent" activity, the function decomposer needs no pre-entered data. This makes it flexible and gives it many advantages over other types of learning systems. But before the significance of function decomposition can be understood a background in Artificial Intelligence and learning systems must be given. (Learned readers may want to skip down to the portion solely about function decomposition.)

More research in computer science seems to have been done under the banner of Artificial Intelligence (AI) than under that of learning systems. AI came about early on in the computer age. The hope that a machine could be made to think as a person does seems quite natural in some respects. The human mind does seem to follow a logical progression of action and a computer does work by a logical algorithm. The whole idea of having a machine that can think for itself creates a multitude of possible uses. With an intelligent computer one could create a robot intelligent enough to do mundane or dangerous tasks in order to allow humans to work on more beneficial projects. A computer may actually be able to think better than a human in some situations and solve problems that humans could never fully grasp. The ideas for the applications of AI are there, but the implementation is quite a bit more difficult to realize.

AI has been around since the early 1950's, but much of the earliest research is purely theoretical for the fact that the hardware did not exist to carry out the AI theorists' grand schemes. But that is not to say that actual AI devices were not created during that time period. In the beginning of the 1950's, W. Walther created a mechanical device, a "tortoise", that ran under its own power and when its energy supply was low it tried to find an electrical outlet to recharge.(Penrose 1990) But is this actually intelligence?

The great mathematician, computer scientist Alan Turing proposed a hypothetical test to determine if a machine is intelligent, hence the name Turing test. During the test, a computer and a human are hidden from the interrogator. The interrogator must try to identify whether a human or a computer is on the other end. If the interrogator fails then the computer has passed the test.

Probably the most famous AI algorithm is that of K.M. Colby which was designed in the mid 1960's. It simulated a psychologist trying to counsel a patient. The program would ask questions of the patient via a teletype terminal without the patient's knowledge of it being a computer. The objective was to fool the person into thinking an actual psychologist was analyzing him. This algorithm was a direct challenge to the famous Turing test. Eventually most people can begin to see a pattern in the computer's questioning or ask it a nonsensical question to fool it, but with the capacity and complexity of computers today an algorithm can just about fool a person. A problem, though, is that no one can seem to agree on what whether or not passing the Turing test actually qualifies a system as being intelligent.

The largest problem is that one agrees on the definition of intelligence. The greatest disagreements come between the beliefs of strong AI advocates and the ideas of John Searle. Strong AI theorists adopt the most extreme stance on the issue of actual intelligence. According to strong AI, not only are devices that emulate the human mind intelligent, but anything that functions according to a logical system. Even a thermostat qualifies as intelligent under this ideology. The basis for the belief is that mental activity is simply the carrying out of some logical algorithm. The difference between a brain and a thermostat is that the brain is of high-order in complexity. John Searle, an American philosopher, has disputed this claim of strong AI with the idea of a Chinese room. He imagines a person in a room with a set of instructions for manipulating Chinese symbols. Someone formulates a question written in Chinese. The information is fed through a slot to the room, the person in the room manipulates the input and sends it out through another slot. Searle claims that though he may give a correct answer, he still has no understanding of Chinese. Thus he claims that a computer can never really embody genuine intelligence because it has no conscious understanding of what the process that it is performing is doing. (Penrose, 1990)

But these arguments are more on the philosophical question of "What constitutes intelligence" than actual problem solving. Many people are more interested in the commercial side of what AI can do. So-called "expert systems" are created to hold all the information of a profession such as medicine. The hope is that diseases could be better diagnosed through the aid of a computer. These systems are fascinating yet they lack one quality that seems to be very important to human intelligence, the ability to learn. The information that these systems hold must be fed into some type of knowledge base. The beauty of the human mind is its ability to correct mistakes and to improve. A machine may be able to calculate mathematics faster than a person, but it can never expand that ability to other forms of higher math. Learning is as much a part of intelligence as the ability to manipulate data. This is the fact why learning systems are so important.

The definition of a learning algorithm is that it must attempt to: provide more accurate solutions to a problem, cover a wide range of problems, obtain information more economically, and simplify codified knowledge. (Forsyth, Rada 1986) While the AI researcher persist in building "adult" systems, the machine learning researcher tries to create an "infant" that has the ability to mature into an "adult".

Learning system have three major aspects for classification, the underlying learning strategy, the representation of knowle , and the application domain. Underlying learning strategy is basically the amount of inference the algorithm performs in its process of learning. The less inference the more the algorithm depends on the programmer for explicit instruction. Representation of knowledge is the way in which the information is stored. Some examples of storage methods include parameters in algebraic expressions and graphic/symbolic information. The application domain is of course just the area for which the program was designed to work in such as chemistry or image recognition. (Michalski, Carbonell, Mitchell 1983)

Three types of learning systems have been researched the most in the history of machine learning. A neural network is a type of system that simulates the human brain in the sense that it is composed of many different nodes that are interconnected. This type of system is self-organizing and must have training information before it will produce any positive results. A symbolic concept-orientation system uses a graphic representation of information rather than a linear one. The knowledge-intensive system is one that must have a large knowledge base of information before it can begin to work on learning new material. (Michalski, et. al. 1983)

These types of systems have a certain amount of success, but they all must have some sort of information before they can begin to produce results. Function decomposition, on the other hand, needs no training sets. It is a method of pattern recognition that will produce results with no prior information on what it is to be looking for in the information it is given.

The PBML project was conceived by Dr. Tim Ross for a possible means of automated fire-control. He found the idea for function decomposition in a book dealing with logic circuit and switching design. (Curtis 1962) The ADA Function Decomposer (AFD) is the realization of the concept. The function decomposition algorithm was written by Mike Noviskey and then translated into ADA by Chris Vogt.

The most basic statement of the idea behind the function decomposition is that in the process of learning a piece of information only a certain amount of information is needed for recognition. People, for instance, do not remember a face by every feature, but only by certain characteristics. This idea is a good concept for pattern recognition because it could cut the storage space of the information needed to recognize a pattern. This brings up the idea of cost in function decomposition. The lower the amount of information needed to recognize a function, the lower the cost of the function. A decomposable function can be reduced to one or more sub-functions that together have a lower cost than the original function. This is equivalent to the old saying, "The sum of the parts is less than the whole." This ability to compress data gives function decompostion an important role in machine learning.

A summary of the process by which the AFD performs function decomposition is as follows. The AFD takes an input format and then converts it into a binary string. The AFD then tries to decompose the function into a simpler form. The program can be given only a partial sampling of the function to be decomposed and it will then try to create what it thinks is the actual function by finding the simplest decomposition. The algorithm then outputs all the decompostions that it found. The greater the number of samples, the closer the output will come to the original function. (For a much more detailed explanation of function decomposition see Appendix 1)

Function decomposition is not a learning device as most people would conceive of one, but it fits the definition of a learning system as stated before. The algorithm receives a function as input, which can be considered abstractly as its "universe." The AFD then tries to see if a pattern exists in this universe so that it can be decomposed to be stored or learned at a lower cost. This type of learning is not skill refinement such as a person learning to ride a bike, but knowledge acquisition such as a person learning Newton's laws of motion. A teacher may tell a student the basic laws, but he may not understand them without more explanation, just as the AFD needs more samples to create a better picture. The more information it is given the clearer the picture of its universe.

The process is more complex than what has been outlined above, but basically that is how function decompostion works. For a more precise and indepth account of how function decompostion is implemented see Dr. Ross's forthcoming final report on the PBML project.

Function decomposition in itself may not be an entire system of learning, but it could be implemented with other techniques in order to perform more complex tasks. The input into a system could be compressed using a form of function decomposition and then another type of device could be used to make inferences about the information. The full potential of this has yet to be realized as to the fact that research on function decomposition is still in its first stages.

Method

Over 2700 runs were completed using 10 versions of the AFD. Each version has attributes about how it decomposes a function. Version 1 does an exhaustive search for decompositions without looking for shared variables. Version 2 searches exhaustively for decompositions with negative decompositions only without checking for shared variables. Version 2A does the same as 2 without checking all possible decompositions. Version 2B checks for everything 2A does except that it is exhaustive and also subtracts don't cares from cost. Version 2AB is a non-exhaustive version of 2B. Version 3 looks for decompostition that include shared variables exhaustively. Version 4 checks for shared variables and negative decompositions exhaustively. Version 4A, 4B, and 4AB are similar to 2A, 2B, and 2AB respectively except the 4's all look for shared variables.

The functions that were input into the AFD versions were all of different types. Some functions that were input include a bit-mapped letter "r", a sine function, a Fibonacci sequence and many other patterned functions. Random functions were also included to see if the AFD would work correctly only on patterned functions.

The information in the output of the AFD was then compressed into a data base for easier management. Numerous programs in PASCAL were written in order to modify the format and analyze the data in the data base.

A set of 64 functions, Set A, that was run on all versions was then selected. The objective of this was to determine which version of the AFD would always get the lowest cost decomposition in the shortest amount of time. A PASCAL program was written to obtain this information that calculated the average runtime and average p-cost for each version on Set A. The two averages were added together in order to obtain a ranking number for the version. The lower the ranking number the better the version worked.

Another set, Set B, was created which was composed of 119 functions that were run on all versions except V3. The same procedure was done to Set B as Set A.

Results

Fig. 1 Avg. Cost and Avg. Runtime by Version for Set A

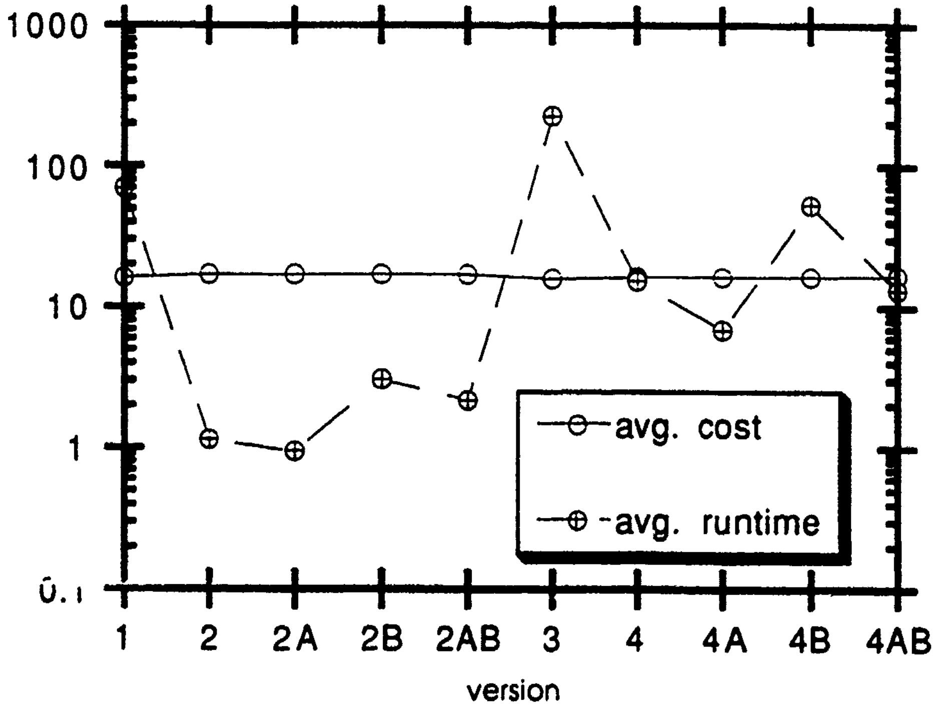


Fig. 2 Rating Number by Version for Set A

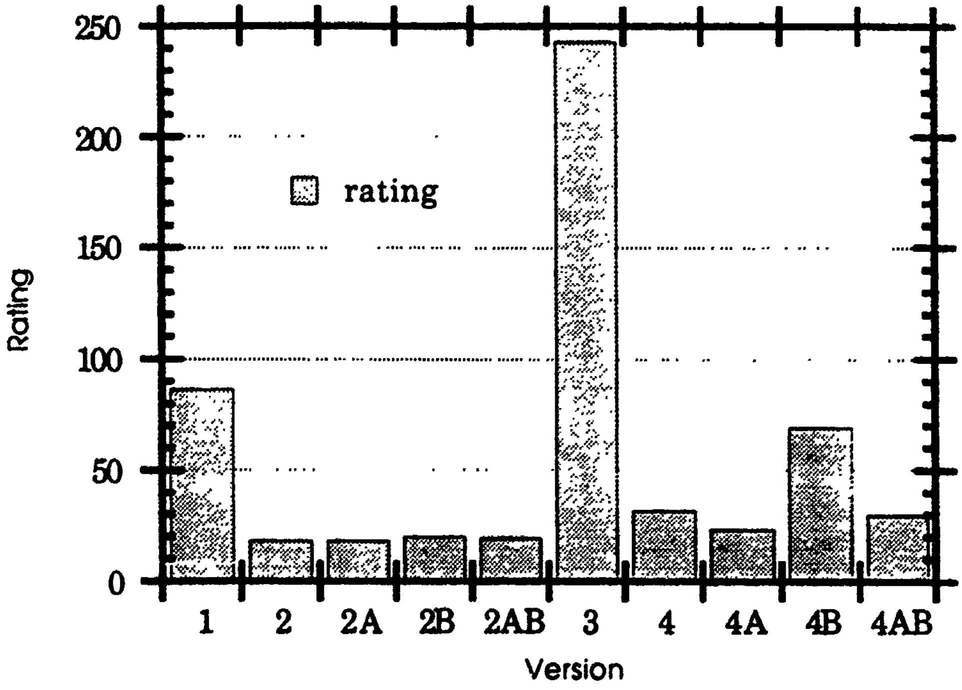


Fig. 3 P-Cost and Runtime by Version for Set B

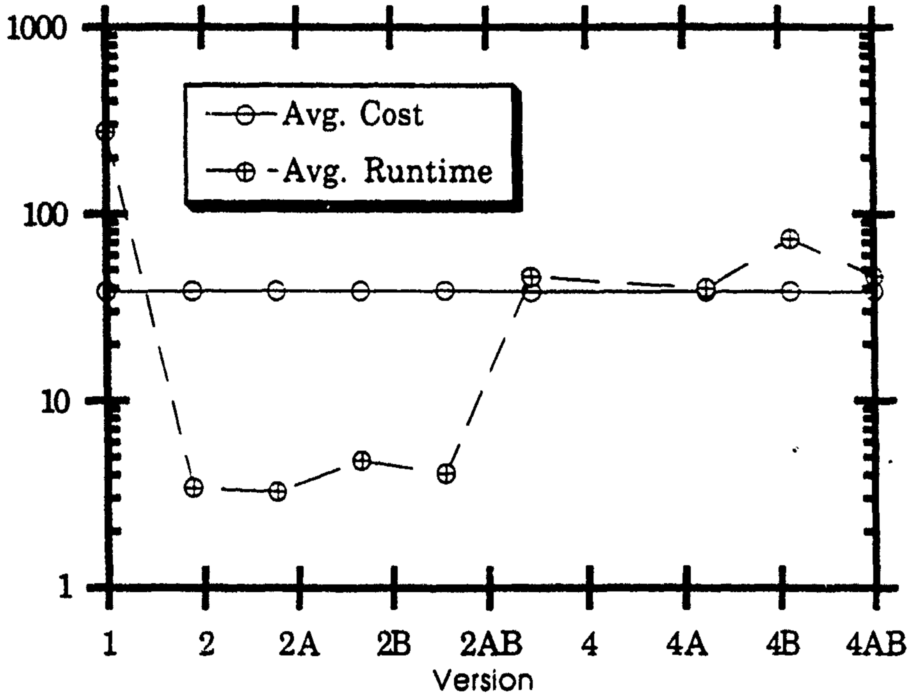


Fig. 4 Rating by Version for Set B

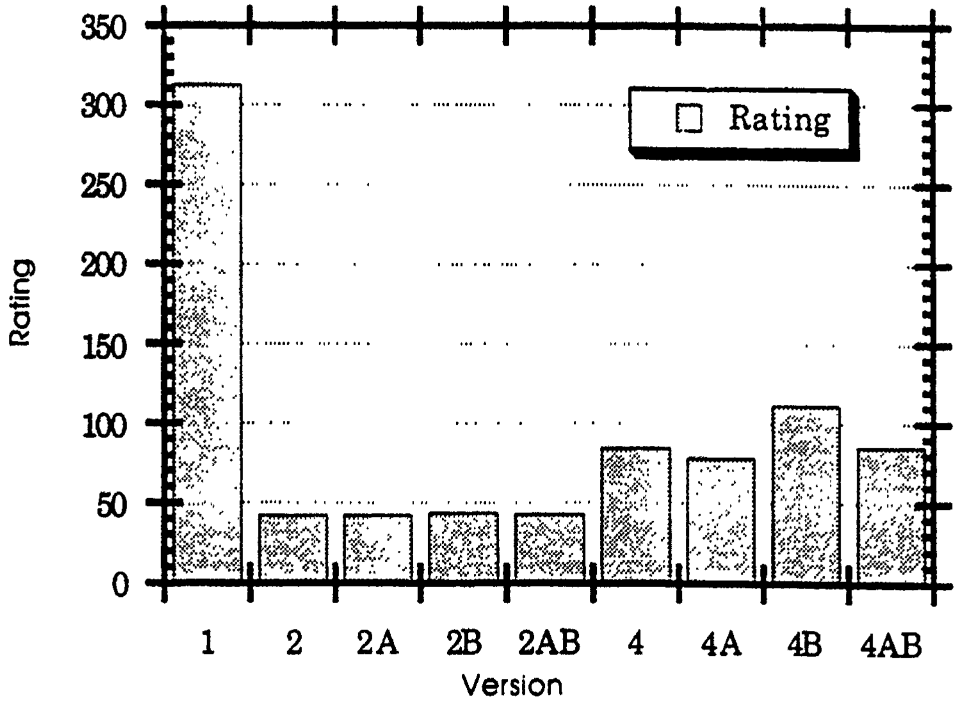


Table1 Ranking by Lowest P-Cost for Set A

Rank	Version
1	3
2	1
3	4
	4A
	4B
4	4AB
5	2B
6	2
	2A
7	2AB

Table 2 Ranking by Lowest Runtime for Set A

Rank	Version
1	2A
2	2
3	2AB
4	2B
5	4A
6	4AB
7	4
8	4B
9	1
10	3

Table 3 Best Overall Version Ranking for Set A

Rank	Version
1	2A
2	2
3	2AB
4	2B
5	4A
6	4AB
7	4
8	4B
9	1
10	3

Table 4 Ranking by Lowest P-Cost for Set B

Rank	Version
1	1
2	4
	4A
3	4B
4	4AB
5	2B
6	2
	2A
7	2AB

Table 5 Ranking by Lowest Runtime for Set B

Rank	Version
1	2A
2	2
3	2AB
4	2B
5	4A
6	4
7	4AB
8	4B
9	1

Table 6 Best Overall Version Ranking for Set B

Rank	Version
1	2A
2	2
3	2AB
4	2B
5	4A
6	4
7	4AB
8	4B
9	1

Discussion

Fig. 1 is a graph of the average p-cost and average runtime by version for Set A. By average cost, V3 did the best overall because it does an exhaustive search. V1 comes in second, but does not do quite as well as V3 because it will not check for shared variables. V4, V4A, and V4B are all tied for third place. V4AB does not do quite as well as these versions because it does a "greedy" search which does not check all possible decompositions. V2B comes next followed by a tie between V2A and V2, and then doing the worst, V2AB. A greater difference was expected between V2A and V2 since V2A performs a greedy search and should have had a higher cost than V2. (See Table 1).

In regard to runtime, V2A did the best, but not by a large margin over V2. This could have been caused by the fact that only three of the functions in Set A had 7 variables or more. V2AB came next above V2B because it only does a non-exhaustive search. V4A did the next best since of the V4's it does the least exhaustive search. V3 did the worst because of its design to do an exhaustive search checking for shared variables. V1 is second worst also due to its exhaustive search. (See Table 2)

In overall ranking, V2A did the best followed by V2. V2 was very close to V2A which is attributed to Set A's deficiancy in higher number of variable functions. V4A did the best of the V4's followed by V4AB. V3 did the worst due to its high runtime even though it did do the best in p-cost. (See Table 3 or Fig. 2)

For Set B, V1 did the best on average cost because, of the versions in Set B, it does the most exhaustive search. The rest of the ranking was the same as on Set A which is not surprising because Set B only includes more runs. (See Table 4 and Fig. 3)

For lowest runtime on Set B the rankings were almost the same as on Set A. V4 did better than V4AB and was the only change in ranking. The gap between V2A and V2 widened, but only slightly. Which is again due to the fact that Set B includes few runs on higher numbers of variables. (See Table 5 and Fig. 3)

The overall ranking for Set B was the same as for Set A except that V4 and V4AB switched places as they did in the runtime ranking. This switch is due to the fact that V4AB checks for more parameters during decomposition and takes longer than V4. (See Table 6 and Fig. 4)

Conclusion

Version 2A did the best on both Set A and Set B which was expected. Since the ranking is weighted towards runtime rather than optimum cost V2A should be the best purely by design. A different ranking system incorporating other parameters could be found to see if V2A is really the most efficient version. V2A's rating could also have been affected by the low number of variables in both sets of functions so a better sample set should be made to try to compensate for V2A's pure speed.

Appendix 1: An Example of Function Decompostion

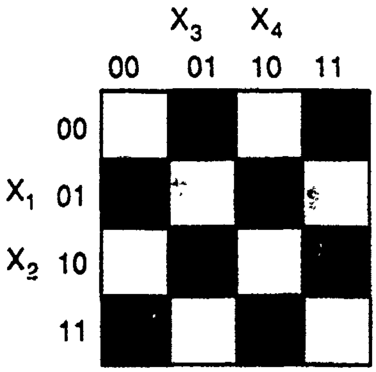
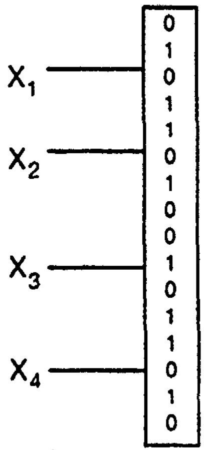


Fig. 1 Checkerboard function

Fig.2 Checkerboard "function machine"



Cost: $2^4 = 16$

Table 1 original function values

X_1	X_2	X_3	X_4	$f(X_1\ X_2\ X_3\ X_4)$
0	0	0	0	0
0	0	0	1	1
0	0	1	0	0
0	0	1	1	1
0	1	0	0	1
0	1	0	1	0
0	1	1	0	1
0	1	1	1	0
1	0	0	0	0
1	0	0	1	1
1	0	1	0	0
1	0	1	1	1
1	1	0	0	1
1	1	0	1	0
1	1	1	0	1
1	1	1	1	0

Fig. 1 is a four variable function with function values shown in Table 1. This four variable function is associated with a cost of 16. The cost of the function is computed by the number of values needed to store, or recognize, the function, in this case 2^4 or 16. Fig. 2 is just a graphic representation of how variables can be seen going into the "function machine".

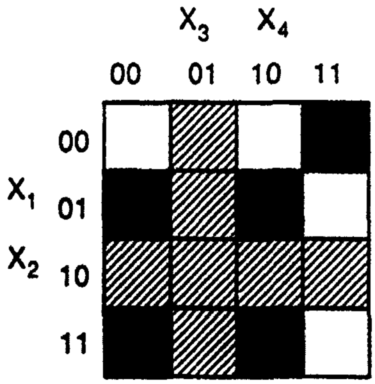


Fig.3 Input fuction

Table 2 input function values

X_1	X_2	X_3	X_4	$f(X_1\ X_2\ X_3\ X_4)$
0	0	0	0	0
0	0	0	1	X
0	0	1	0	0
0	0	1	1	1
0	1	0	0	1
0	1	0	1	X
0	1	1	0	1
0	1	1	1	0
1	0	0	0	X
1	0	0	1	X
1	0	1	0	X
1	0	1	1	X
1	1	0	0	1
1	1	0	1	X
1	1	1	0	1
1	1	1	1	0

Fig. 2 is the checkerboard fuction only with values missing. The cross-hatched blocks are those where information is missing. Table 2 is a function table for this new input function The X's are of course the missing values. The function decomposition process will now be applied to see if the original function can be obtained by using only a sampling of the original information.

Step 1: Check for vacuous variables

Table3 partiton matrix 1

$$\begin{array}{c|cc} & \multicolumn{2}{c}{X_1} \\ & 0 & 1 \\ \hline X_2 & 0 & X \\ & X & X \\ X_3 & 0 & X \\ & 1 & X \\ X_4 & 1 & 1 \\ & X & X \\ & 1 & 1 \\ & 0 & 0 \end{array}$$

The rearrangement of function values in Table 3 is called a partition matrix. The columns in Table 3 are considered to be the same because the X's can be set equal to the values needed to make the columns equal. This property is called column multiplicity and the value for this table is 1. A column multiplicity of one indicates that a vacuous variable exists, that is a variable whose value has no bearing on the function output. This variable is X_1.

Table 4 partition matrix 2

$$\begin{array}{c|cc} & \multicolumn{2}{c}{X_2} \\ & 0 & 1 \\ \hline X_1 & 0 & 1 \\ & X & X \\ X_3 & 0 & 1 \\ & 1 & 0 \\ X_4 & X & 1 \\ & X & X \\ & X & 1 \\ & X & 0 \end{array}$$

$X_2$is not vacuous because the column multiplicity is now 2 instead of 1.

Table 5 partition matrix 3

$$\begin{array}{c|cc} & \multicolumn{2}{c}{X_3} \\ & 0 & 1 \\ \hline X_1 & 0 & 0 \\ & X & 1 \\ X_2 & 1 & 1 \\ & X & 0 \\ X_4 & X & X \\ & X & X \\ & 1 & 1 \\ & X & 0 \end{array}$$

X_3 is vacuous because it has a column multiplictiy of 1.

Table 6 partition matrix 4

$$
\begin{array}{c|cc}
 & \multicolumn{2}{c}{X_4} \\
 & 0 & 1 \\
\hline
 & X & 0 \\
X_1 & 1 & 0 \\
 & X & 1 \\
X_2 & 0 & 1 \\
X_3 & X & X \\
 & X & X \\
 & X & 1 \\
 & 0 & 1
\end{array}
$$

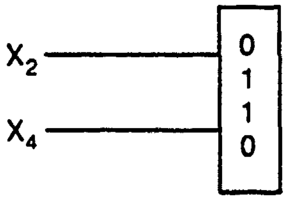
X_4 is not vacuous because it has a column multiplicity of 2.

Step 2: Check what is left over

Table 7 partition matrix 5

$$
\begin{array}{cc|cc}
 & & \multicolumn{2}{c}{X_2} \\
 & & 0 & 1 \\
\hline
X_4 & 0 & 0 & 1 \\
 & 1 & 1 & 0
\end{array}
$$

Fig. 3 Graphic of partition matrix 5



Cost: $2^2=4$

Partition matrix 5 has a column multiplicity of 2. No other decompostition can be performed. X_2 and X_4 are the only variables that have any bearing on the function output. Because of this the cost of the function is now 4 because now only four possible values are needed to recognize the function.

Step 3: Create a New Function Table

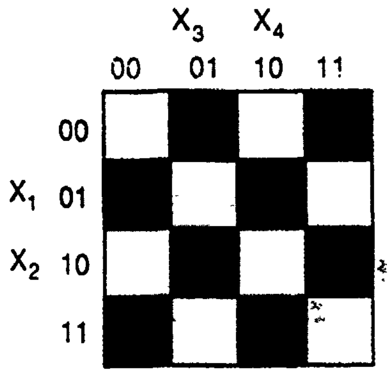


Fig. 4 Recomposed function

Table 8 New function table

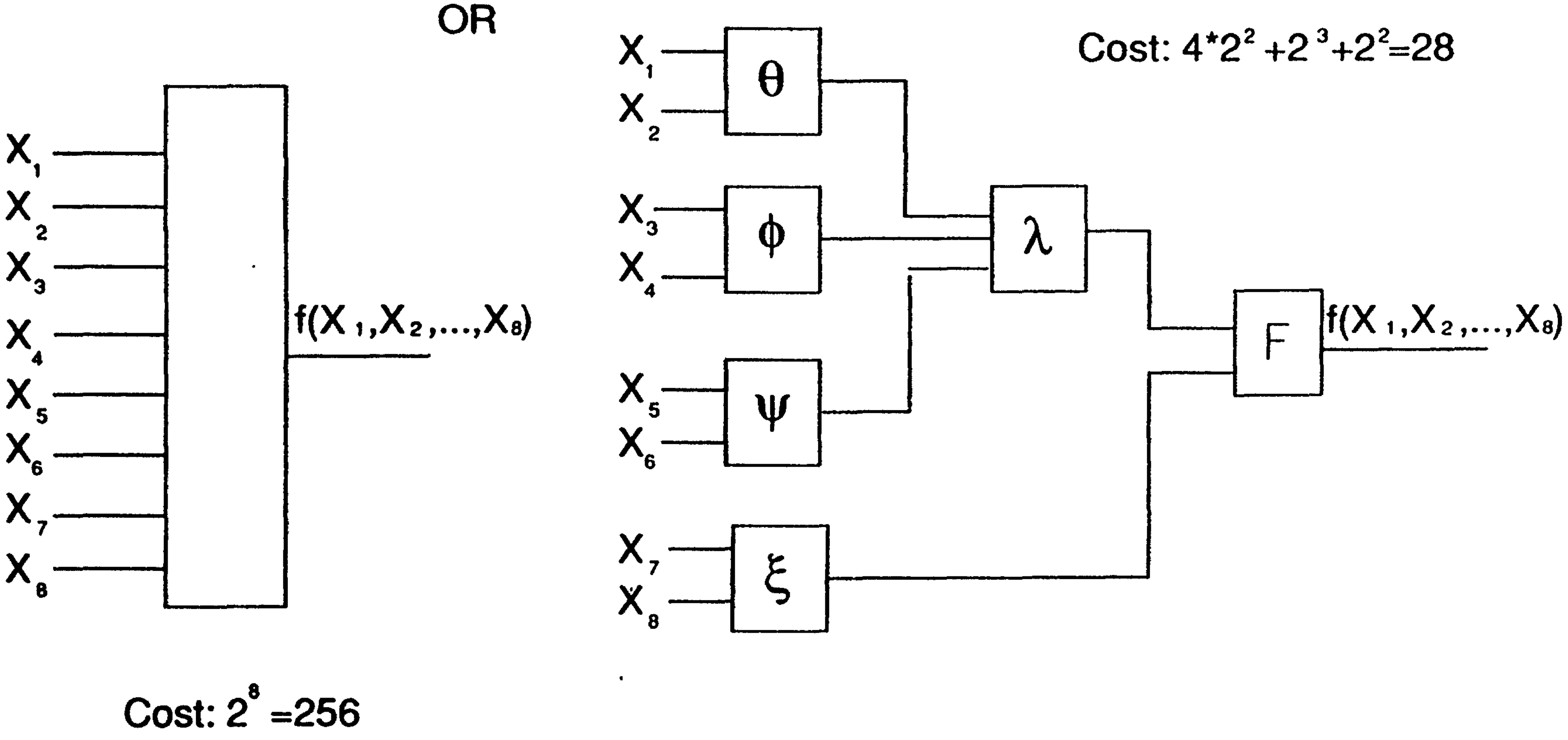
X_1	X_2	X_3	X_4	$f(X_1\ X_2\ X_3\ X_4)$
0	0	0	0	0
0	0	0	1	1
0	0	1	0	0
0	0	1	1	1
0	1	0	0	1
0	1	0	1	0
0	1	1	0	1
0	1	1	1	0
1	0	0	0	0
1	0	0	1	1
1	0	1	0	0
1	0	1	1	1
1	1	0	0	1
1	1	0	1	0
1	1	1	0	1
1	1	1	1	0

A new function table (Table 8) can be created using the Table 7. The values of this function table can be seen to be the same as those in the original function. Through function decomposition the original function has now been recomposed. This fact is especially interesting for no knowledge of the original function is necessary to recreate the pattern. This method of course is not as effective with lower numbers of samples, but it will still come close to the original function.

On numbers of variables greater than 5, the decomposition is almost impossible to do by hand. The decomposiiton may have multiple sub-functions leading into the output. Also with larger numbers of variables, the variables may be shared, that is a variable can have an impact on more than one sub-function. (see Fig. 5)

Fig. 5 General example of function decompostion

$$f(X_1,X_2,X_3,\ldots,X_8) = F[\lambda[\theta(X_1,X_2), \phi(X_3, X_4), \psi(X_5,X_6)], \xi(X_7,X_8)]$$



Acknowledgements

I would like to thank 2nd. Lt. Tim Taylor for explaining the whole idea of function decomposition and helping teach me Turbo PASCAL. I would also like to thank Tim Ross for filling in any information that Tim did not know and allowing me to work on this project.

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Computer Simulation of SDI:

A Summer Apprenticeship

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August 30, 1990

I. Acknowledgements

I would like to express my thanks to all the members of WRDC/AART that were involved with my apprenticeship and made my work there meaningful. I especially thank 2Lt Fred Gruman, 2Lt Greg Bierman, and Alan Wood for keeping me busy and Julie Terry and Jackie Toussaint for keeping them from working me too hard.

II. General description of research

As an apprentice in the Avionics Lab working on SDI research, my job was primarily collection and analysis of SDI simulation data. The two studies our group worked on were the LOCUST scenario study and a study of the "Brilliant Pebbles" concept.

The purpose of the Strategic Defense Initiative (SDI) is to develop a defense system capable of protecting the United States from ballistic missile attack. The conceptual first generation SDI system consists of two parts: tracker satellites, which acquire and track the targets (ballistic missiles) using various active and passive sensor packages, and weapon platforms, which carry kinetic energy weapons (as many as 10 small missiles) which are launched to intercept and destroy the targets.

The LOCUST scenario was developed by Dr. Paul McManamon of the Avionics Lab as an alternative to the large, complex tracker satellites now being researched. LOCUST stands for LOw Cost Ultra-light Sensor/Tracker. A LOCUST system would consist of a large number of these small, relatively inexpensive tracker satellites deployed at a relatively low altitude. Our study of the LOCUST scenario focused on developing an effective satellite arrangement, or constellation, able to acquire a target quickly and track it throughout its trajectory. In this study, we did not concern ourselves with intercepting the missiles, simply tracking them.

The Brilliant Pebble concept is another alternative to the large, complex, and expensive SDI systems being studied now. Unlike the LOCUST concept, the Pebbles idea concerns the weapon platforms. Instead of deploying a handful of large satellites, each carrying multiple missile-killing projectiles, the Brilliant Pebble concept suggests using the weapon platform itself as the kill vehicle. Each weapon platform, or "Pebble", would also be equipped with an infrared tracker to acquire the boost vehicle, and a laser-radar seeker to track it. For this type of system to be effective, an enormous number of Pebbles must be deployed. Ideally, each Pebble would be small, lightweight, inexpensive, and able to be mass-produced. The name "Brilliant Pebbles" reflects an improvement from an earlier concept, "Smart Rocks". Our lab's role in Brilliant Pebble research was more an evaluation of the ability of the lab itself to contribute to work in the field than an actual research study on the concept itself.

III. Detailed description of research

For both SDI studies, I performed simulation runs on the SDI-dedicated VAX/VMS microVAX system, using the SDISEM (Strategic Defense Initiative System Effectiveness Model) program developed by the Coleman Research Company for Avionics Lab SDI research. Output data from SDISEM was processed using PLOTPLUS and VIEW, two programs written by Coleman Research for use with SDISEM, and hard copies produced on a Hewlett-Packard laser printer or HP pen plotter. Some charts were modified for use in briefings with a Macintosh SE using MacDraw.

To do a simulation run of a hypothetical SDI system using SDISEM, alterations are made to an SDISEM data file, which contains the over 500 parameters necessary for a simulation. When a new setup was run, the new settings were documented to provide reproducible results. In the simulations which I programmed, we were primarily concerned with sensor parameters and satellite constellation, so most other parameters remained the same for all simulation runs.

Output from SDISEM is placed in six output files after the completion of each simulation run: the output file, message file, plot file, tracker plot file, history file, and summary file. For the purposes of our group, only the plot, history, and tracker plot file were used. The history file contains the time histories of all simulation bodies. In this file, the state information (position, velocity, and acceleration) of targets, satellites, and projectiles are stored as a function of time. The plot file contains exact values of simulation variables specified in the data file for output. The tracker plot file contains azimuth and elevation of targets as seen from each tracker.

The data as found in these output files is not very useful until processed into a meaningful form. Several programs were available for me to use in this conversion: PLOTPLUS and CONVERT, written by Coleman Research, TRKRANGE and TRKTEST, written by Fred Gruman, and TRKRANGE2 and GNDCOVER, which I wrote with some assistance and FORTRAN instruction by Lt. Gruman. Using the PLOTPLUS program, data from the plot file and tracker plot file was converted into charts and graphs, usually comparing certain variables with time. The CONVERT program uses the data from the history file to create a view file, which is then processed using VIEW to create a three-dimensional view of the battle as seen from a point in space. The programs written by personnel in the Avionics Lab (TRKRANGE, TRKRANGE2, TRKTEST, and GNDCOVER) are used to obtain more specific information from the tracker plot file. Both versions of TRKRANGE count the number of trackers close enough to the targets to detect them using certain sensor parameters. TRKTEST converts the binary tracker plot file to a ASCII file. Finally, GNDCOVER calculates the amount of coverage of the earth's surface that a certain satellite constellation provides.

My task within the Avionics Lab's SDI research was to enter in the data for hypothetical (unclassified) SDI systems. I then processed the output from these simulations (using the above programs) and did some preliminary analysis of this output. Most output, however, went to Lt. Greg Bierman for further analysis. Based on the data I collected, he would suggest an area needing further study. This cycle was repeated until satisfactory results were obtained. My work freed up the professional engineers, allowing them more time to interpret the data and relieving them from performing the simulations, which would often take hours or days, depending on the complexity.

IV. Results

For the LOCUST study, it was shown that such a system, composed of many lightweight trackers, could operate effectively. Our simulations using SDISEM led to the conclusion that the best constellation for the envisioned satellites would be a 300-satellite array (15 rings of 20 satellites each) in a near-polar orbit at about 1500 km altitude. Since a missile becomes harder to track as it travels through its trajectory shedding booster stages, a satellite near the upper range of the missile's altitude curve is more effective: the missile is far away, but still detectable, when launched, and the decreasing range offsets the effects of decreasing detectability (see fig. 1). Satellites in high altitude, however, are more expensive to launch because a higher velocity is required. The large number of satellites (300) necessary for effective tracking is also a problem that increases the cost of the system. However, the initial goal of the study, to show the feasibility of such a system, was met with flying colors.

The Brilliant Pebbles (BP) study was a more complex problem both for the experimenters and SDISEM. This study involved all aspects of the SDI system: trackers, projectiles, seekers, and even different types of threats. However, our study was not exactly a research project, but more a study into the capabilities of SDISEM itself. The research results of this project were used to demonstrate to the Strategic Defense Initiative Office (SDIO) and other groups the potential of SDISEM-based BP work in the Avionics Lab.

A 4225-satellite constellation (65 rings of 65 satellites each) served as the basis of our study. Analysis was done with varying altitudes (500, 900, and 1500 km) and target types (slow- and fast-burn). At low altitudes (500 km), the Pebbles were able to intercept most slow boosters in the boost phase or after releasing only a few reentry vehicles (RVs), the part that actually contains the warhead. Fast boosters, however, managed to release large numbers of RVs before they were intercepted. This greatly increased number of targets effectively "punched a hole" in the BP constellation; in other words, the number of targets exceeded the number of interceptors in range. After breaking through this hole, the RVs and boosters, which continually deployed more RVs (up to 10), continued above and out of reach of the BPs. In the descending part of their trajectory, the constellation was again able to intercept a number of RVs, but again the enlarged swarm of targets swamped the system and were now free to impact the ground. At an altitude of 1500 km, an entirely different battle took place. Even slow targets were able to deploy some RVs before coming in range of the weapon platforms. The constellation had longer to intercept the targets, however. Coverage cannot be depleted at this altitude because the boosters move faster than the BPs, and new Pebbles are constantly coming in range. Despite the delay that exists between booster launch and interception (up to 400 seconds), slow targets and RVs can be intercepted fast enough to prevent any from reaching the ground. With fast boosters, the number of RVs still increases too quickly, and several inevitably get through. At 900 km, a compromise altitude expected to yield more favorable results, effects were much like those at 500 km, but even worse. Fewer were intercepted in early phases, allowing more RV deployment, and available intercept time did not increase enough to make this altitude a viable option. The most promising shield appears to be a two-tiered constellation, with approximately 60-75% of the BPs at 500 km and the remainder at 1500 km. This would allow a large number of intercepts in early boost phase, before excessive RV deployment; those that "punched through" would be intercepted by the upper tier.

The BP study also provided an opportunity to test the limits of the SDISEM program. (This was not an intentional goal, but one that proved to be a necessity all the same.) Due to the large number of satellites and trackers involved, each new simulation took many hours to run. A number of errors, both "fatal" (those causing the simulation to stop) and computational, were found to exist in the SDISEM program. Both Lt. Gruman and I investigated these errors, correcting what we could and trying to avoid those uncorrectable. The majority of errors were found to exist in the Kalman Filter routine; this routine uses matrix algebra to integrate the tracker's current estimation of a target's state with new sensor data. Although outside my realm of understanding, I still was able to help in trouble-shooting, testing possible solutions that Lt. Gruman devised.

V. Other interesting observations and lessons learned

I found the opportunity to work in a professional setting very satisfying. I was treated as an adult capable of doing useful tasks for the group. I believe that this was both a combination of my maturity and the maturity of those I worked with (most of whom were only a few years older than I). The experience was educational; I was able to see the scientific method and problem-solving techniques learned in school at work in real-world situations.

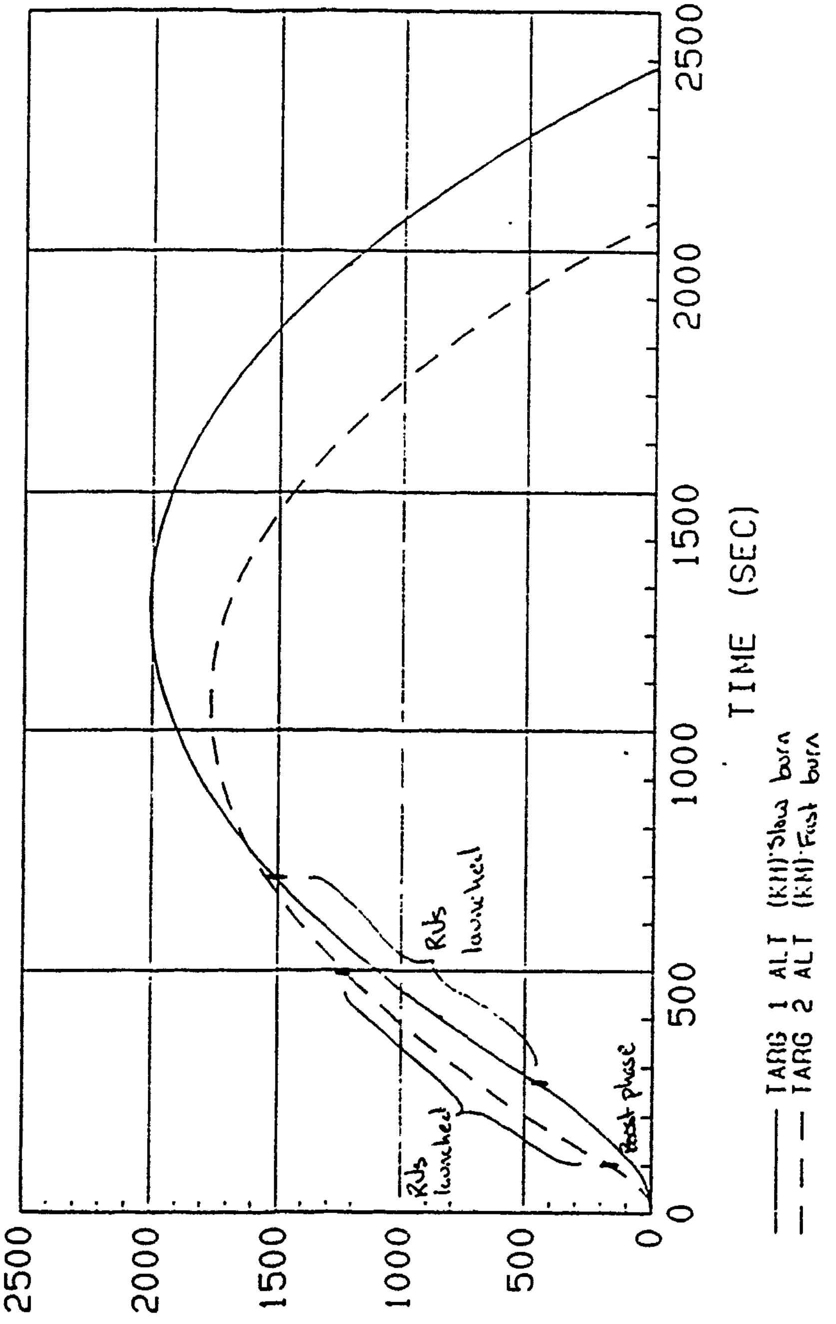

Figure 1. Missile Altitude

VI. Bibliography

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Wood, R. A. and G. Bierman. "SDI System Effectiveness Model Simulation Capabilities." Briefing presented to SDIO/PTS Brilliant Pebbles Task Force, Washington, D.C., 10 August 1990.

AFOSR
High School Apprenticeship Program
WRDC/AAAF-3

DEPARTMENT OF THE AIR FORCE
UNITED STATES OF AMERICA
MCMXLVII

Final Report
Summer 1990

Apprentice : Austin Flack
Mentor : Marc J. Pitarys
WPAFB, OH

1. Acknowledgements

I would first like to thank Marc Pitarys for putting up with me and not letting me get in the way of his work. I would also like to thank him for being SERIOUS. I would especially like to thank Kenneth Littlejohn, for helping me with my struggling birth into the world of ADA programming. I would also like to thank both of them for being so calm, relaxed, and straightforward for without the two of them working in unison; I wouldn't have been able to learn or accomplish as much, and for that I am truly thankful. I would also like to thank my fellow students in the AFOSR apprenticeship program, Brian Barclay and Jerard Wilson, for making my job interesting and seeing to it that I did not get into too much trouble.

Lastly, unknown to all is the part my computer teacher played in my education and eventually the possession of this great job. My teacher, Mr. Roger Wilson, took me in the 8th grade from a sloppy hacker to a well groomed, programmer.

2. General Description of Research

I basically did two categories of of work. Software design, programming and hypermedia implementation. Software design and programming consisted of both the experimentation and implementation. Hypermedia implementation consisted of work with both text and graphics. From the experimentation came the experience for writing source code.

The program that I made for the system manager was a VAX Menu System. I designed it so that a person using the VAX with little or no prior experience could accomplish the necessary commands and programs from within the safe environment of a menu.

The hypermedia applications I did for the Apple Macintosh computer were F-16 controls and display documentation. With the application computer based there was no need to flip pages, and it provided a quick and easy retrieval of information.

3. Detailed Description of Research

Part of my research focused on implementing Ada software from one language into another that when in the final stage is executable by all. The latter half of my stay was spent researching the application of hypertext for avionics software documentation.

Among the projects I accomplished was the conversion of a Pascal program to Ada. In the conversion it grew considerably. Three weeks into this attempt I learned by watching my fellow student, Brian Barclay, how to implement a window structure in Ada. Upon learning this I converted my program to windows. To my surprise a six page Pascal program became a slightly advanced Ada program.

Over several weeks I discovered many new ways to use Ada. I learned how to create a subprocess that would run VAX commands outside of my original program. Oh! What Joy ! This was the routine I was looking for. With this I was able to make my program twice as extensive and more usable that it's ancestor had been. Shortly after this my program had all the text it needed to accomplish its task; so all that was left of it was to debug it and package it for outside use.

With the completion of this project I took it upon myself to learn more of Ada through a supermenu for system users with little or no experience. The result was a simple program which could accomplish most any utility from within the shelter of a menu architecture where almost any error could be rectified. In spite of its error catching ability it was fairly simple to exit from. When you exited from an outside source it would deposit you into the directory from where you came. This program was used often by me and my cohorts to simplify work. From within this program one did all of their work. The only option that was not available was to log directly off the system.

I was reacquainted with networks and subsystems. I pulled out one of my old login.coms and revised it for current use. With all of its TURBO - keys it was of immense assistance in slashing typing time. Others took advantage of my programming and were able to implement it into their logs or copy it entirely. I also wrote a program that was a daily log program for summer apprentices. It was this program that I converted from Pascal to Ada.

I also spent my time implementing a hypermedia application on the Apple Macintosh Computer. I assisted in creating a hyperdocument for F-16 controls and displays. Upon completion the screens would click on at the touch of a button like a menu; then afterwards unlike a menu, at the flip of a switch or click of a button the documentation for the specified object would be put into a working field to be read by the operator. When you selected each object, a switch per say, it would toggle on or off as it does on the display and output the documentation. The text for such an undertaking was quite tedious despite its ease of use.

The learning of the hypertext tool, Silicon Beach's Supercard, was slow and tedious at first but once you had a few working copies to toy with and experiment on you gradually learned how to expect what was needed for the rest of the displays. It was most exciting to graph the displays out on the map. Detail achieved was to be amazed. Down to each individual screw the display is graphically correct, with the only difference coming from the recquired change in size for each computer.

4. Other Interesting Observations

This was my second technical job, in addition to working for the military, I've learned some little tricks about SuperCard that can apply to almost any computer. When working with multiple programs always be sure to save the main one first. When working with a erroneous system be sure to make frequent backups and to keep current hardcopies. Do not trust backups; instead save the file under a totally different location with another name where it is out of harms way. Floppies may be slower but they extract your information and keep it separate from your system. When using a mouse oriented application be sure to run everything from the mouse instead of the keyboard. Be as specific as possible when describing variables. Take full advantage of any preset keys and keypads. Use the Turbo - keys until they become second nature. Description must be complete but do not let it become redundant. Always be sure to maintain the protection level of all information and to make sure private information stays that way. Program loosely so as to not trap yourself in the proverbial box. Always ask specific questions and make detailed analyses on all possible resolutions before action is rashly taken. The old adage still holds true in todays highly advanced world "Haste Makes Waste".

I guess this job has helped me in ways I never dreamed of. This was an excellent experience. I learned programming in new languages; I was paid for my efforts; and I got help for college. What more could I ask? Nothing, except the opportunity to be a part of the college co-op program.

5. Bibliography

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VAX Ada Language Reference Manual. Maynard, MA: Digital Equipment Corporation,1985.

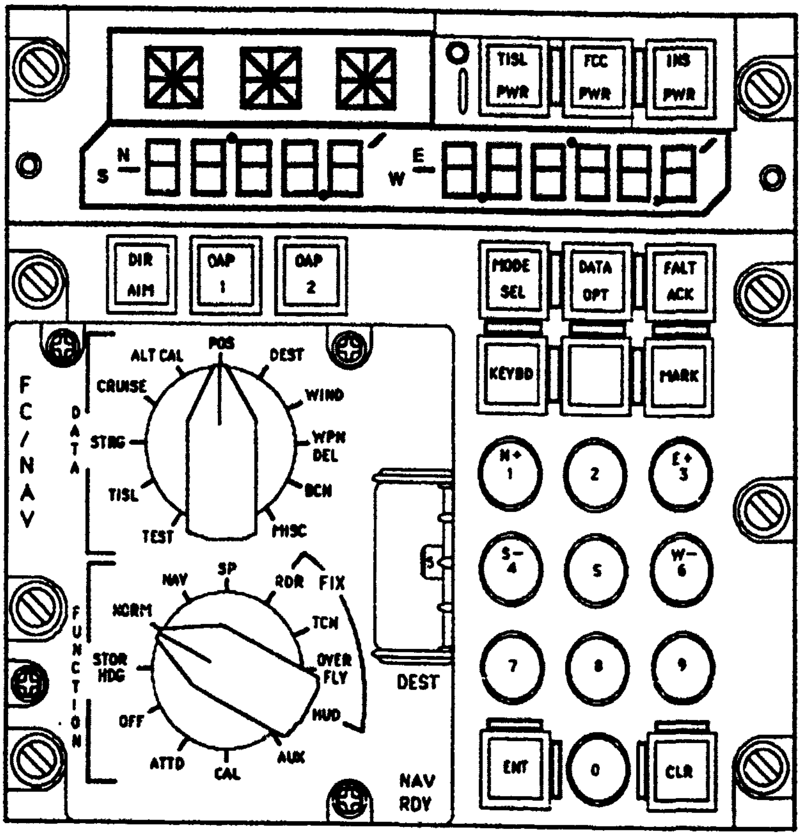
VAX Ada Run-Time Reference Manual. Maynard, MA: Digital Equipment Corporation,1989.

VMS RTL Screen Management (SMG$) Manual. Maynard, MA: Digital Equipment Corporation, 1988.

F-16
CONTROLS & DISPLAY DEMONSTRATION

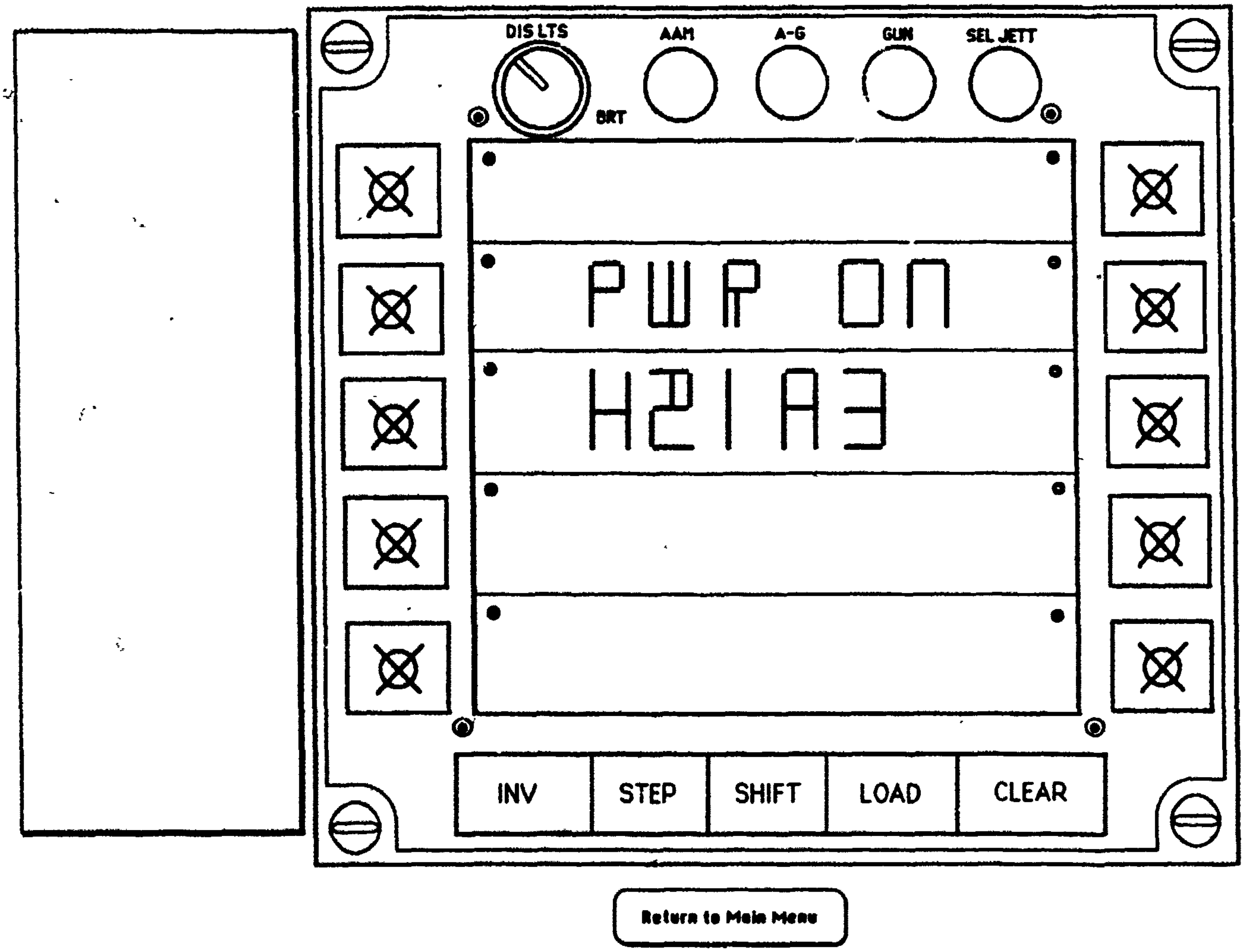
1. FIRE CONTROL / NAVIGATION PANEL
2. STORES CONTROL PANEL
3. HUD DISPLAY PANEL
4. RADAR ELECTRO-OPTICAL DISPLAY
5. HEAD-UP DISPLAY WINDOWS

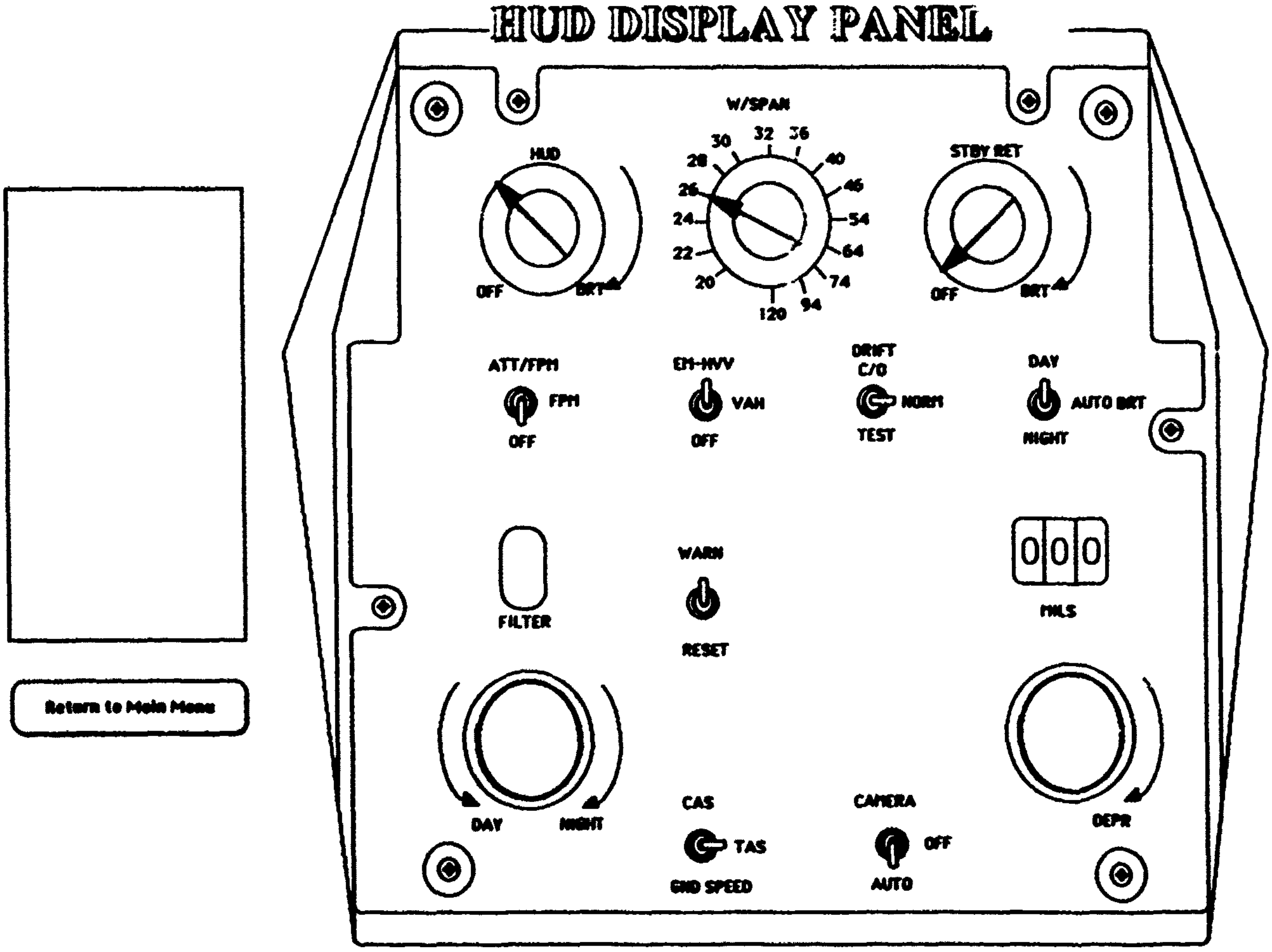
FIRE CONTROL / NAVIGATION PANEL



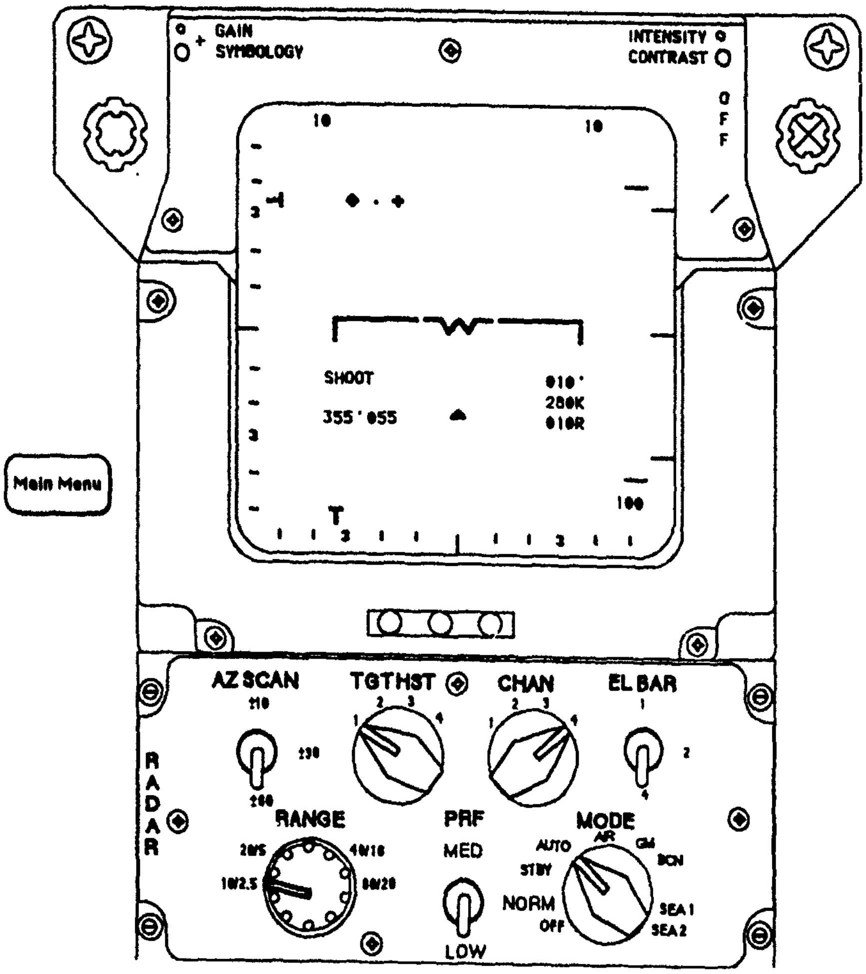
Return to Main Menu

STORES CONTROL PANEL

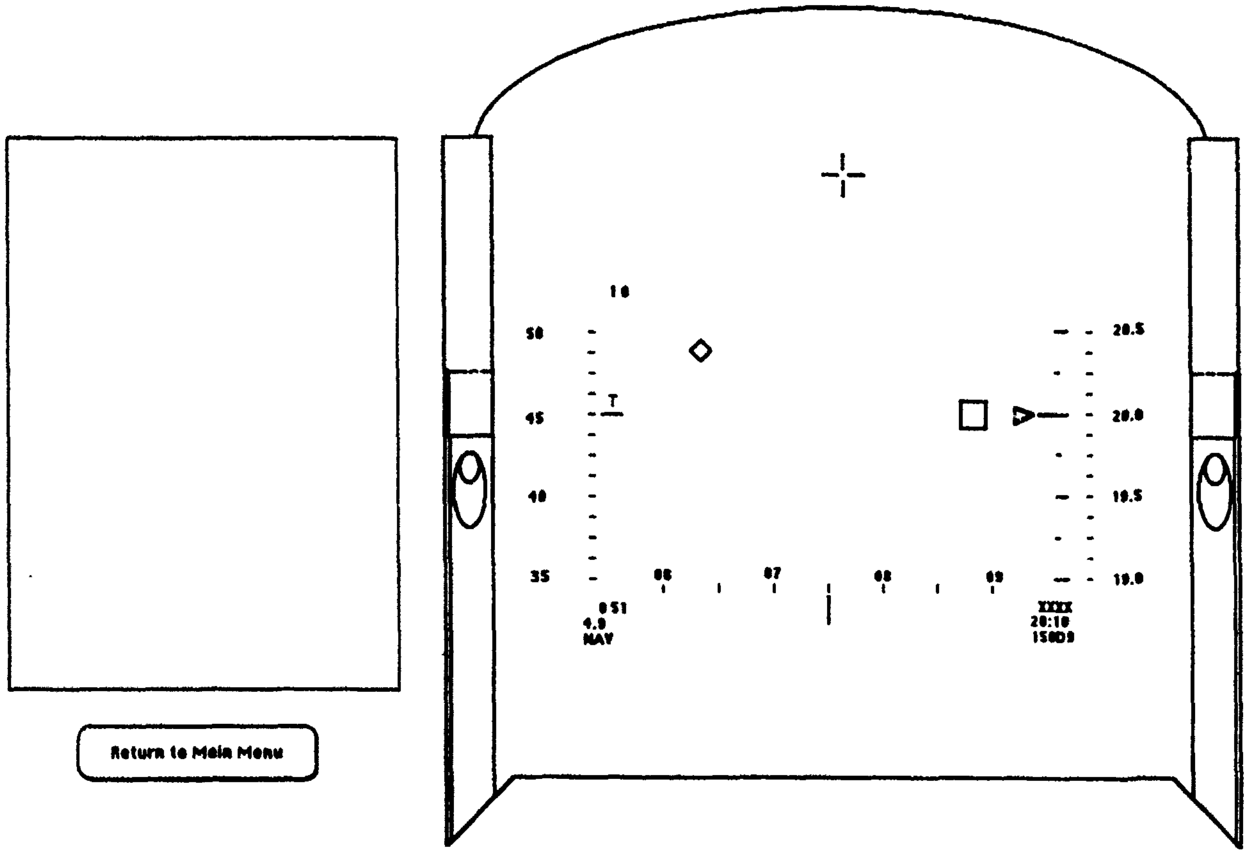



HUD DISPLAY PANEL
Return to Main Menu
HUD
OFF
BRT
W/SPAN
20
22
24
26
28
30
32
36
40
46
54
64
74
94
120
STBY RET
OFF
BRT
ATT/FPM
FPM
OFF
EM-HVV
VAH
OFF
DRIFT
C/O
NORM
TEST
DAY
AUTO BRT
NIGHT
FILTER
WARN
RESET
000
MILS
DAY
NIGHT
CAS
TAS
GND SPEED
CAMERA
OFF
AUTO
DEPR

RADAR ELECTRO-OPTICAL DISPLAY



HEAD-UP DISPLAY WINDOWS



Jerard Wilson

Final Report Number 54

No Report Submitted

ENGINEERING AND SERVICES CENTER

1990 USAF - UES HIGH SCHOOL APPRENTICESHIP PROGRAM

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AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

Conducted by

UNIVERSAL ENERGY SYSTEMS, INC.

FINAL REPORT

SURFACE CATALYZED REACTIONS OF VAPOR PHASE HYDRAZINE

Prepared by:	Jennifer L. Brewer
High School:	Port St. Joe Jr.-Sr. High School Port St. Joe, FL 32456
Research Location:	Environics Laboratory USAF Engineering and Services Center
Mentor:	Dr. Daniel A. Stone, PhD.
Date:	18 June - 10 August 1990

Acknowledgements

I would like to thank Dr. Daniel A. Stone for his invaluable guidance and undaunted patience and enthusiasm. Also, Mr. James Long for getting me started with this project, and Dr. Lawrence Orji for helping me along the way. Thank you to all of the people at the Air Force Engineering and Services Center for being welcoming, helpful, and friendly. You've all made my first job a wonderful experience.

I. Introduction

The Environics Laboratory Hydrazine Research Program has the main purpose of determining the effects and the eventual fate of this substance in the atmosphere. The results, compounded in this laboratory by the use of a spherical environmental simulation chamber, infrared specrometers, and many things still to come and be developed, are used to handle. clean up, and dispose of this chemical, used by several USAF weapons systems, better. In the process of learning as much as possible about this program, my job was to help Dr. Stone in his research.

II. General Description of Research

My apprenticeship entailed certain activities and responsibilities. Basically, these were to research and learn about spectroscopy and the Fourier Transform - Infrared spectometer, and learn and practice how to use the controlled temperature reaction cell, Nicolet Computer System, and the Fourier Transform - Infrared program.

Also to keep a scientific journal, program Macros to do various operations, do runs in the controlled temperature reaction cell, collect the data, manipulate the data collected, acquire the results, plot them and measure the absorbance values of various peaks in these plots.

III. Detailed Description of Research

A. Research

A main part of my beginning research was to learn about Fourier Transform - Infrared spectroscopy, but before that could be accomplished, infrared spectroscopy, in general, had to be understood. These concepts were explained to me through Experiments in Techniques of Infrared Spectroscopy (Reference 1) and a Nicolet manual entitled FT-IR Theory (Reference 2).

After learning the basics of the theory of FT-IR, I had to learn how to use it. A Nicolet FT-IR system was used for all of my research. I had to learn the details, purposes, and functions of this computer system before any data collection was possible. This was accomplished by working throught the Nicolet tutorial Easy Operation 740 (Reference 3) and reading Nicolet User's Manual (Reference 4).

B. Practice

Practice was the next step to be accomplished before I could accurately collect data. I used methanol and acetone in the controlled temperature reaction cell (shown in Figure 1), and monitored their evaporation rates. (Results of this can be seen in Figure 2.)

First, I had to take a blank sample to be compared with the samples of the substances. Then I took many samples of 10 microliters of methanol, with various temperature changes, samples of 10 microliters of acetone, with the same temperature changes,

CONTROLLED TEMPERATURE REACTION CELL

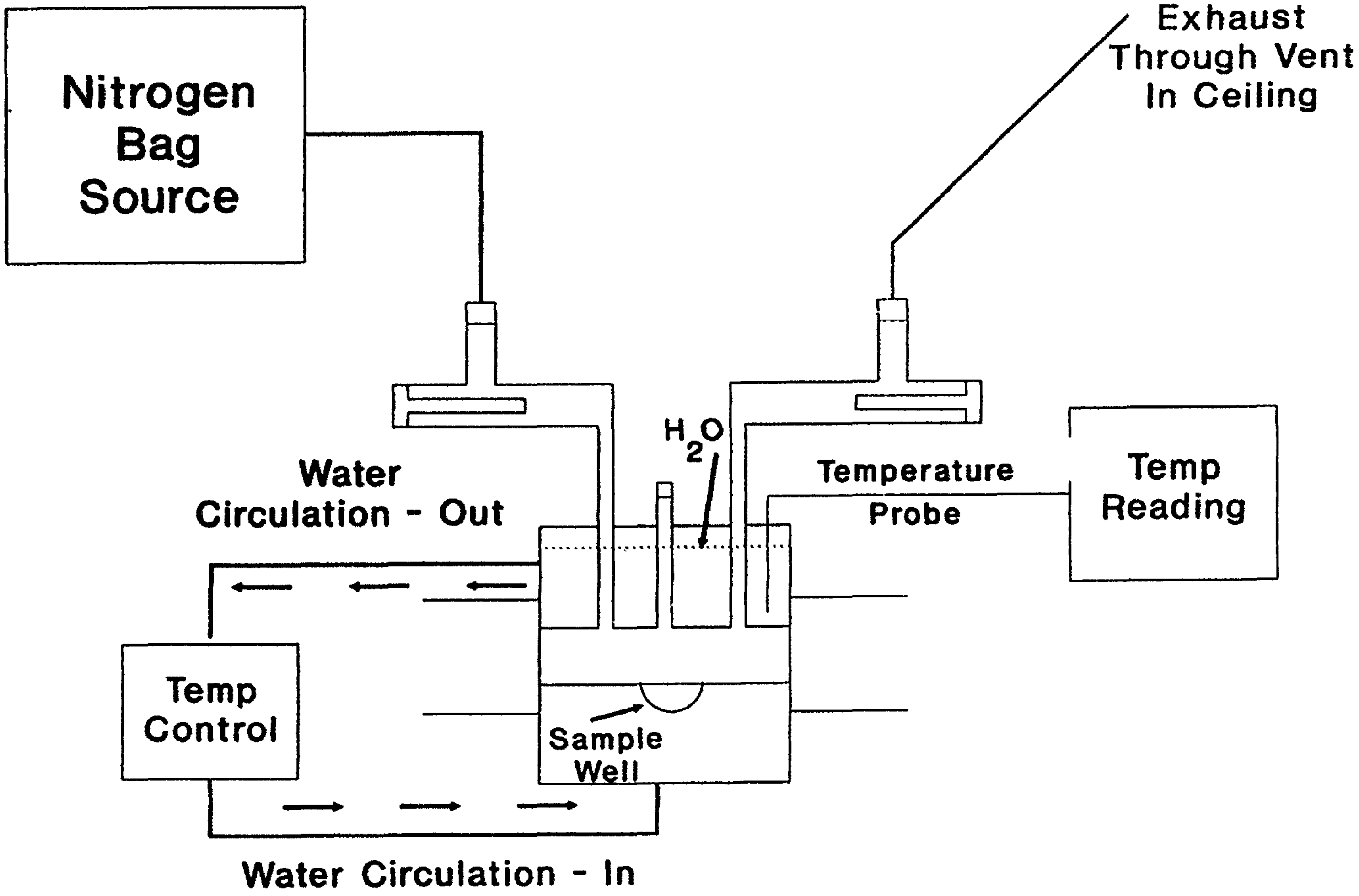


Figure 1

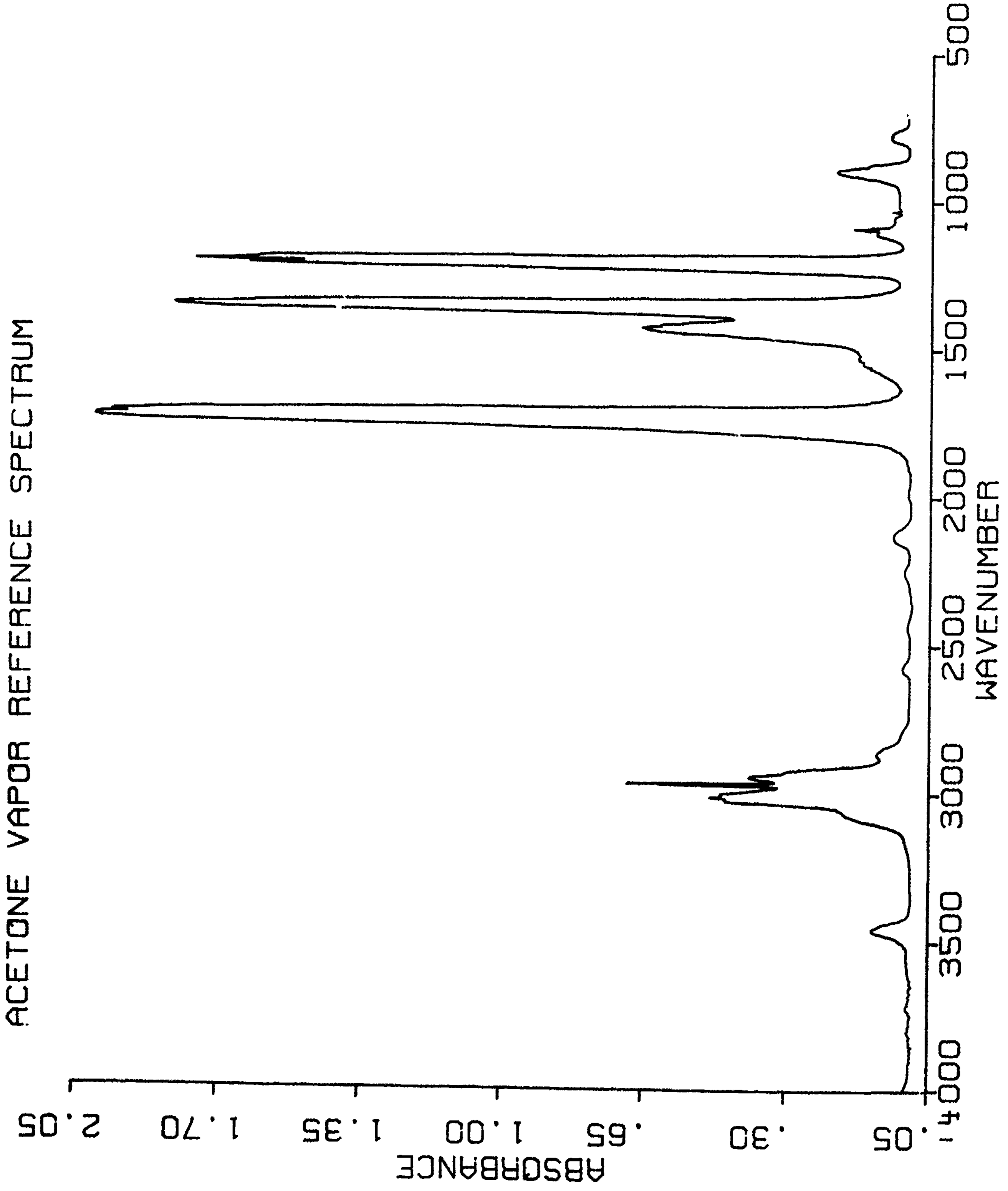
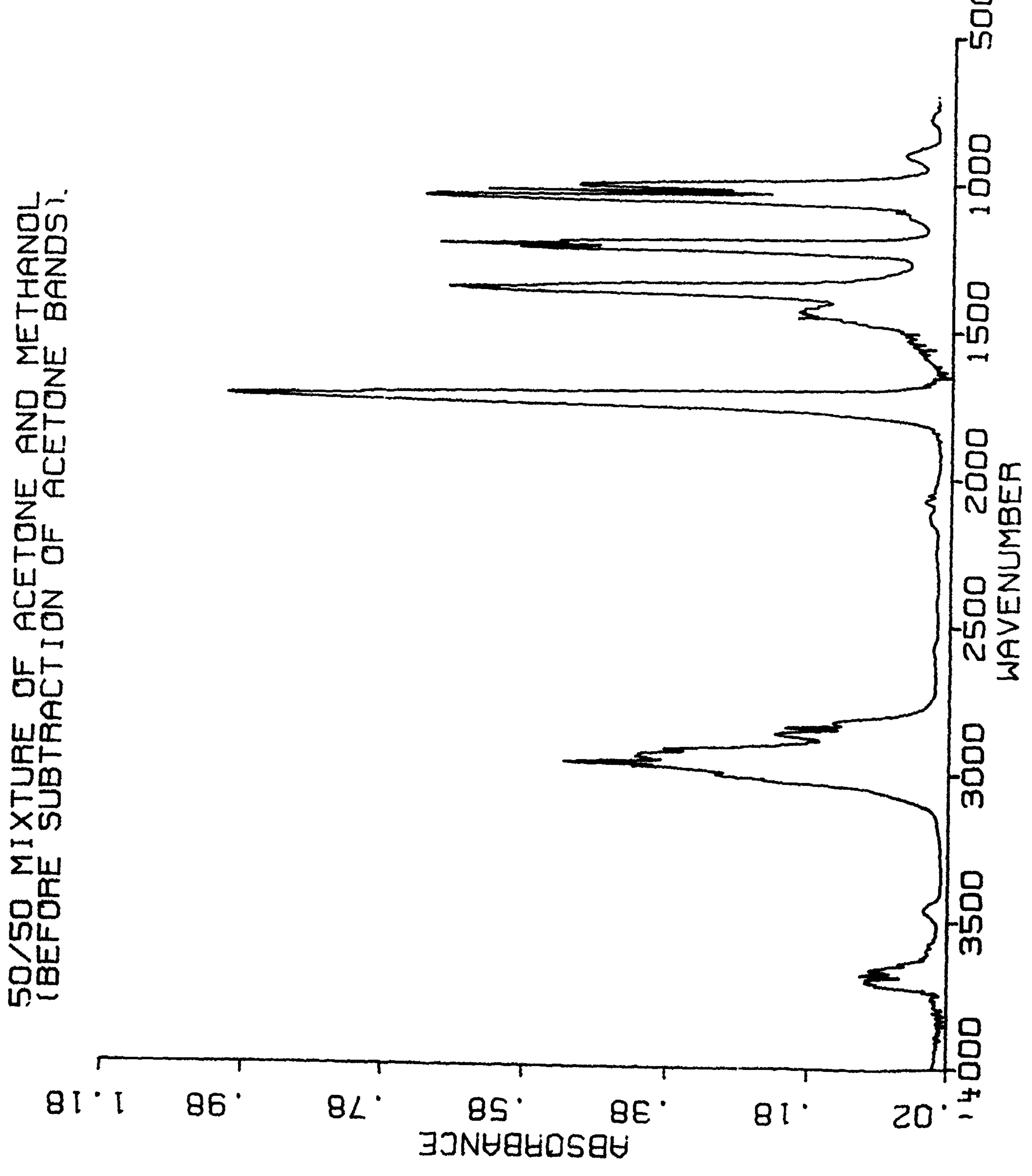

ACETONE VAPOR REFERENCE SPECTRUM
WAVENUMBER
4000
3500
3000
2500
2000
1500
1000
500
ABSORBANCE
-.05
.30
.65
1.00
1.35
1.70
2.05

Figure 2



50/50 MIXTURE OF ACETONE AND METHANOL (BEFORE SUBTRACTION OF ACETONE BANDS).

and samples of 20 microliters of a mixture of each of the substances. with the same temperature changes. These samples contained many scans of the rates of evaporation of these substances. The contents of the blank sample were subtracted from the other samples, and then I used spectral subtraction to remove one of the substances from the mixture (examples of this can be seen in Figure 3). Then I plotted the subtraction results and measured specific peaks to see the differences in their evaporation rates under the different conditions. This was what I was going be doing to the substances hydrazine (Hz), unsymmetrical dimethyl hydrazine (UDMH), and A-50 (a mixture of Hz and UDMH).

C. Data Collection

Once I had a grasp for the techniques to be used in data collection, I started collecting data from hydrazine, unsymmetrical dimethyl hydrazine, and A-50. I, first, had to collect a blank sample, just like before, to subtract from the samples. Then I began to collect hydrazine samples. The reaction cell was set up with a temperature of 20 degrees Celcius and with nitrogen flowing through it at a very slow rate. The samples were taken and then the temperature and flow rate were changed both up and down. The same methods were used in sampling the UDMH and the A-50. (Examples of this are shown in Figures 4, 5, and 6.)

D. Data Manipulation

Once I had all of the samples that were needed I could begin the sample manipulations. Spectral Subtraction is a complicated process in which one component from a mixture is taken out of it.

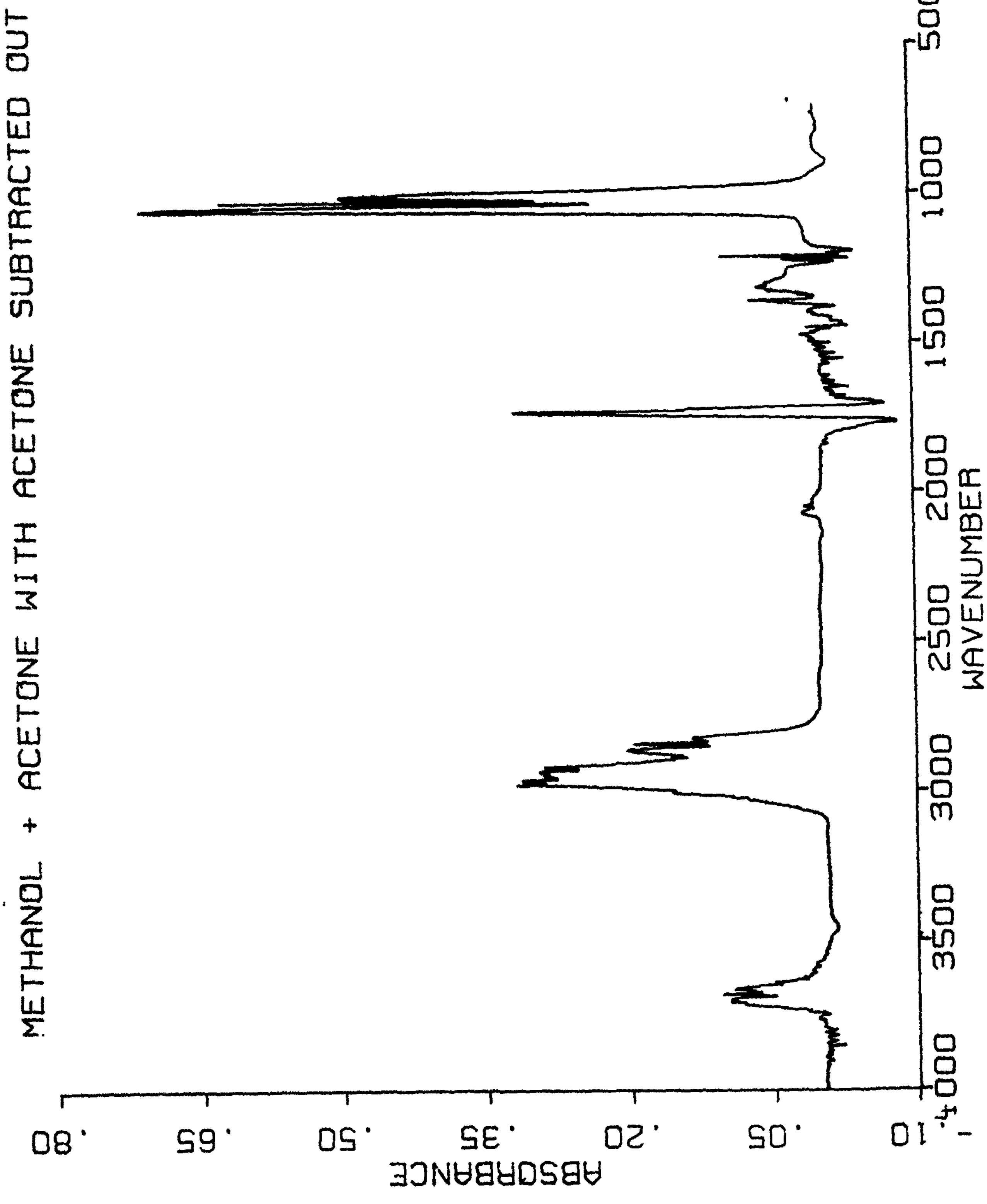

METHANOL + ACETONE WITH ACETONE SUBTRACTED OUT
ABSORBANCE
-.10
.05
.20
.35
.50
.65
.80
WAVENUMBER
4000
3500
3000
2500
2000
1500
1000
500

Figure 3

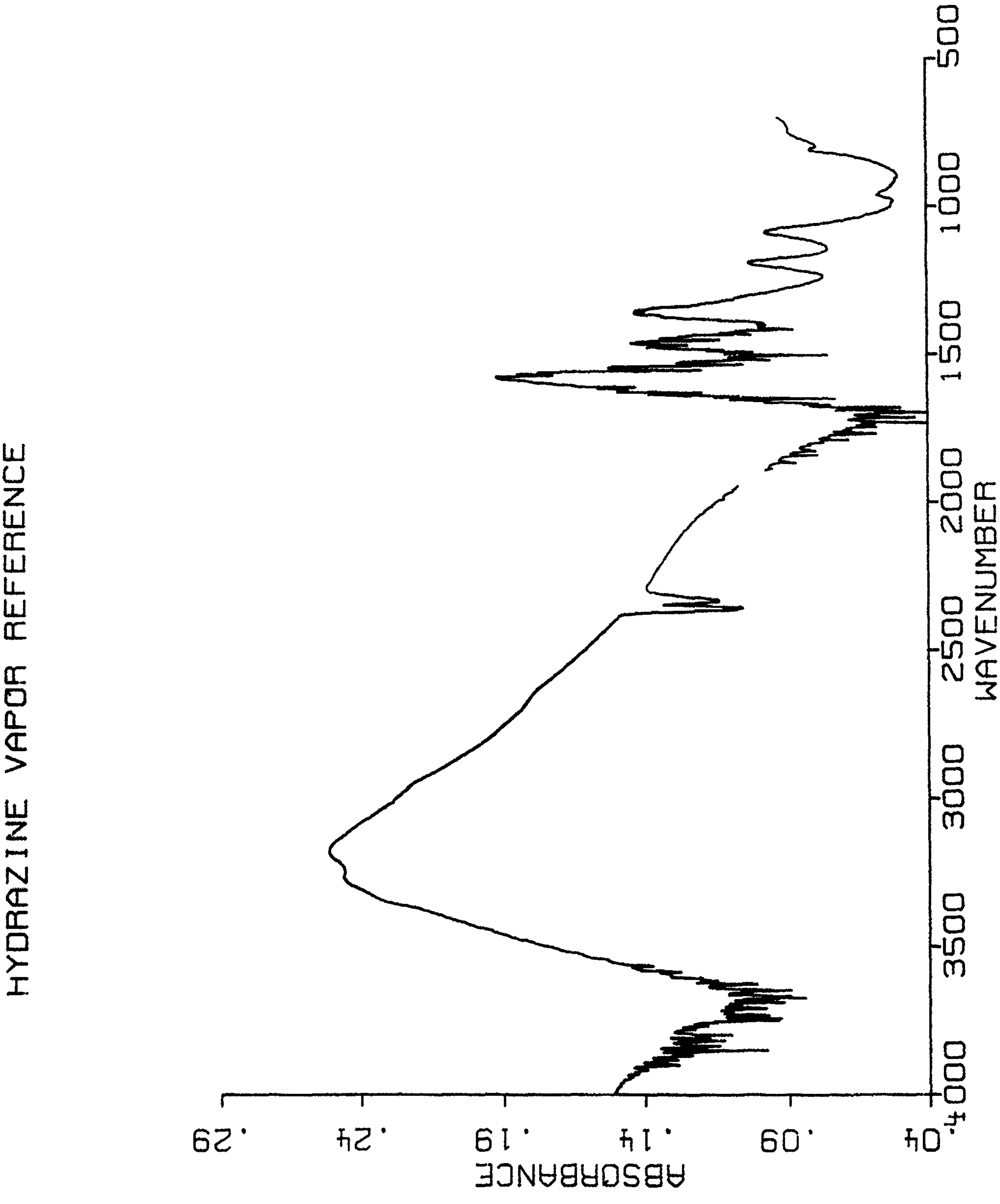

HYDRAZINE VAPOR REFERENCE
ABSORBANCE
.04
.09
.14
.19
.24
.29
WAVENUMBER
4000
3500
3000
2500
2000
1500
1000
500

Figure 4

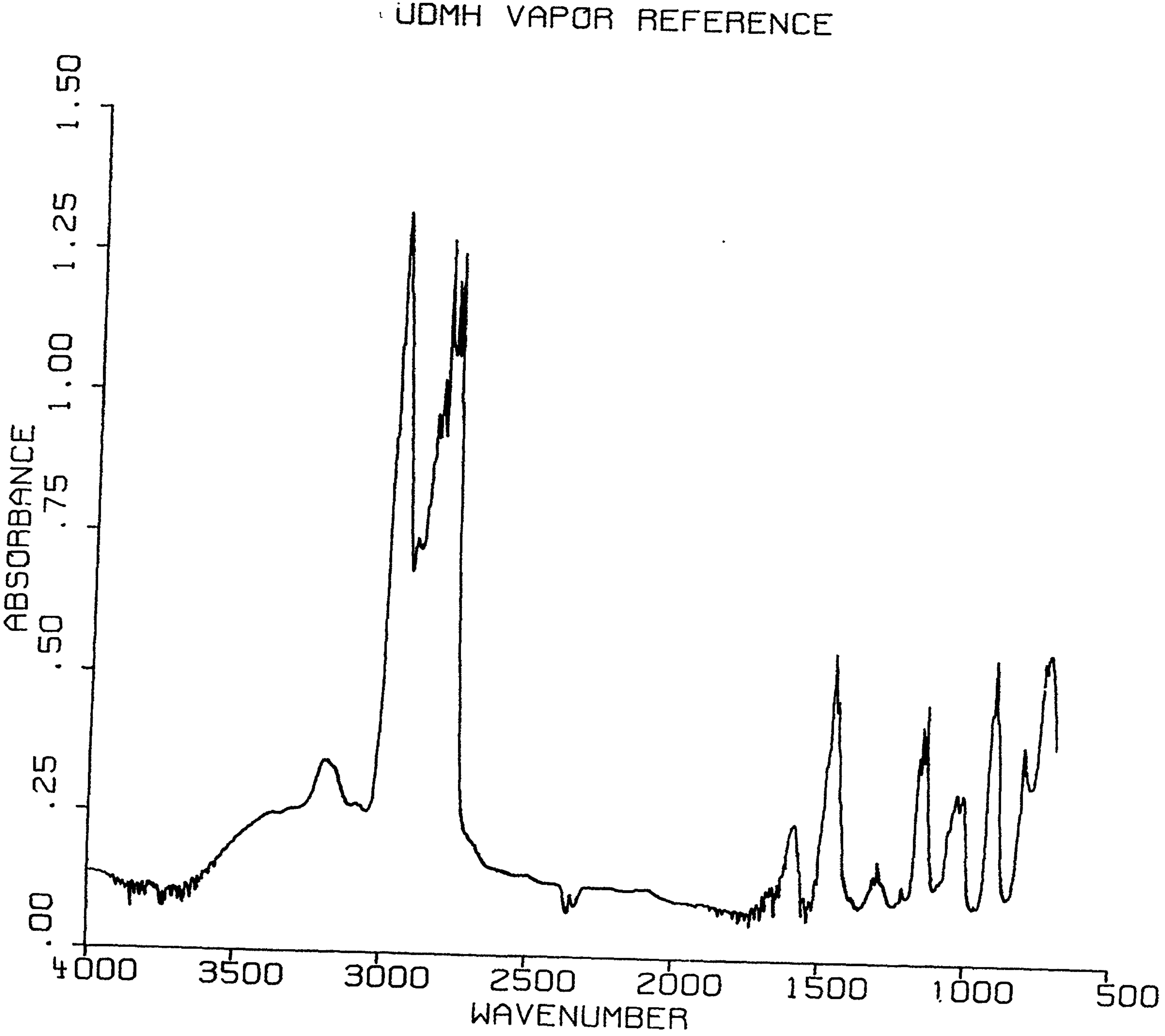

UDMH VAPOR REFERENCE
ABSORBANCE
.00
.25
.50
.75
1.00
1.25
1.50
WAVENUMBER
4000
3500
3000
2500
2000
1500
1000
500

Figure 5

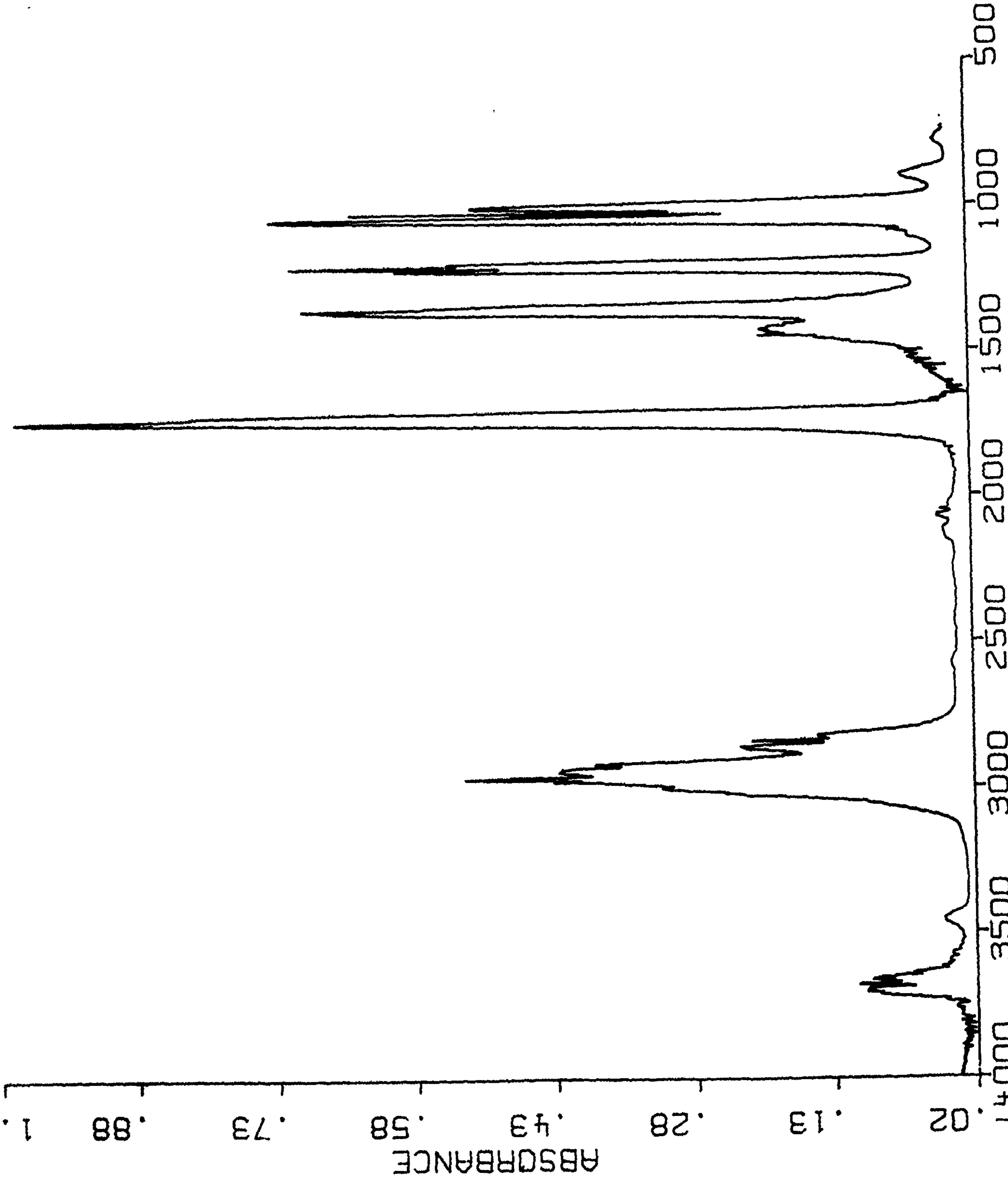

ABSORBANCE
1.03
.88
.73
.58
.43
.28
.13
-.02
WAVENUMBER
4000
3500
3000
2500
2000
1500
1000
500

Figure 6

I subtracted the Hz from the A-50 and then the UDMH from the A-50. This was done by putting one of the scans over the other and then finding an average degree of subtraction where the substance would be taken out of the mixture. Once this was done, the individual evaporation rates of the components were evident.

IV. Results

After a few scans, we started to notice some strange spectra as the results. Dr. Stone soon realized that these were probably the effect of the substances reacting with the type of glue used in the chamber. We decided that we would have to use these results anyway, and they didn't cause much of a problem.

Another problem that was encountered was with a very slow process of getting the contents of the chambers to evacuate. This took a lot of time. There was also an amount of water vapor found in the cell that had to evaporate.

The major problem that we encountered was with the FT-IR. There was a problem with the hard drive which cause major delays and errors in sampling. These problems were never quite overcome, so we had the challenge of trying to work around them.

Because of the great delays in being able to scan and acquire data, the project continues. The results that were acquired are not guaranteed to be accurate. The results from the spectral subtraction were gotten and appear in Figures 7 and 8.

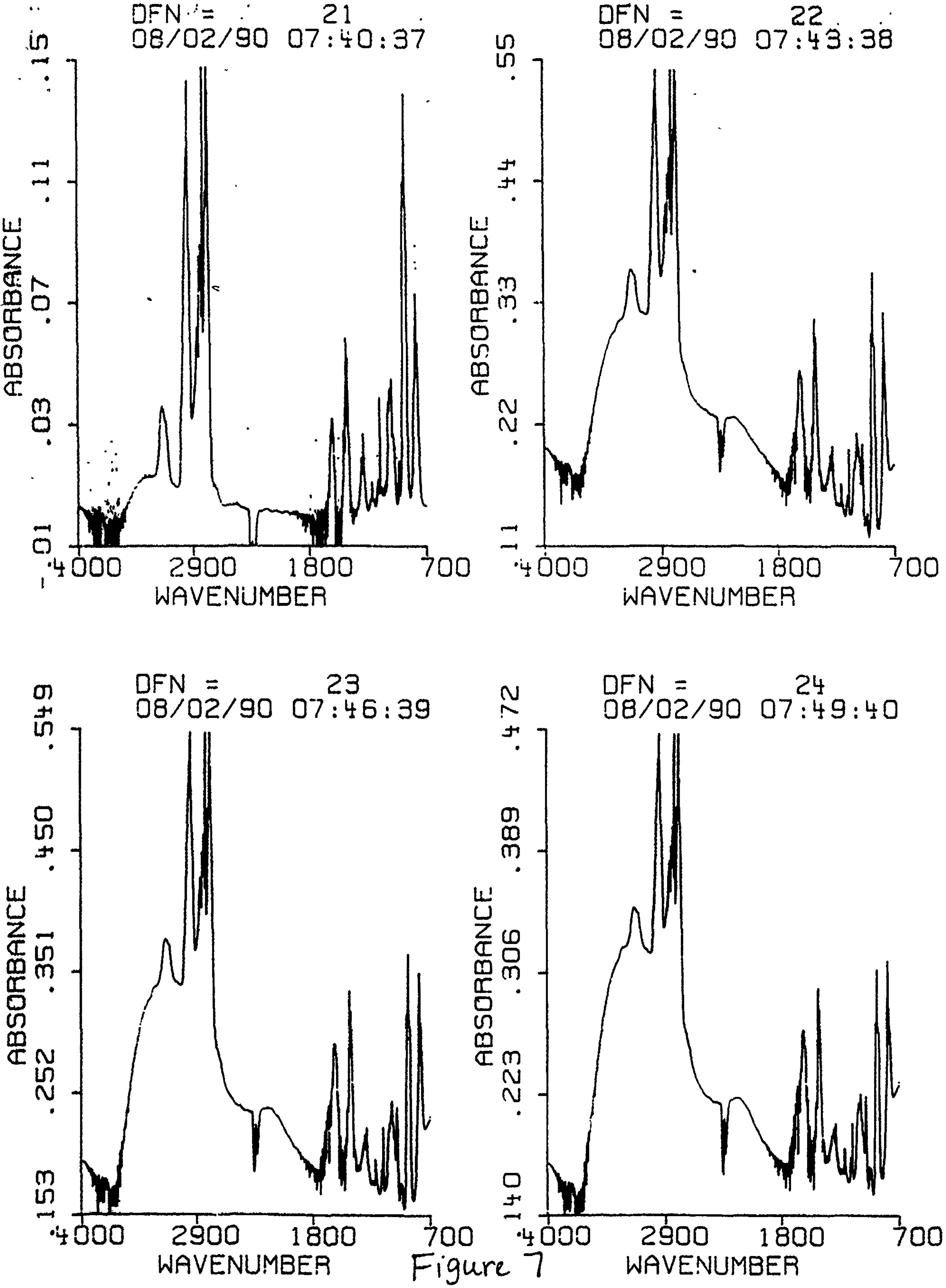

DFN = 21
08/02/90 07:40:37
ABSORBANCE
-.01
.03
.07
.11
.15
4000
2900
1800
700
WAVENUMBER
DFN = 22
08/02/90 07:43:38
ABSORBANCE
.11
.22
.33
.44
.55
4000
2900
1800
700
WAVENUMBER
DFN = 23
08/02/90 07:46:39
ABSORBANCE
.153
.252
.351
.450
.549
4000
2900
1800
700
WAVENUMBER
DFN = 24
08/02/90 07:49:40
ABSORBANCE
.140
.223
.306
.389
.472
4000
2900
1800
700
WAVENUMBER

Figure 7

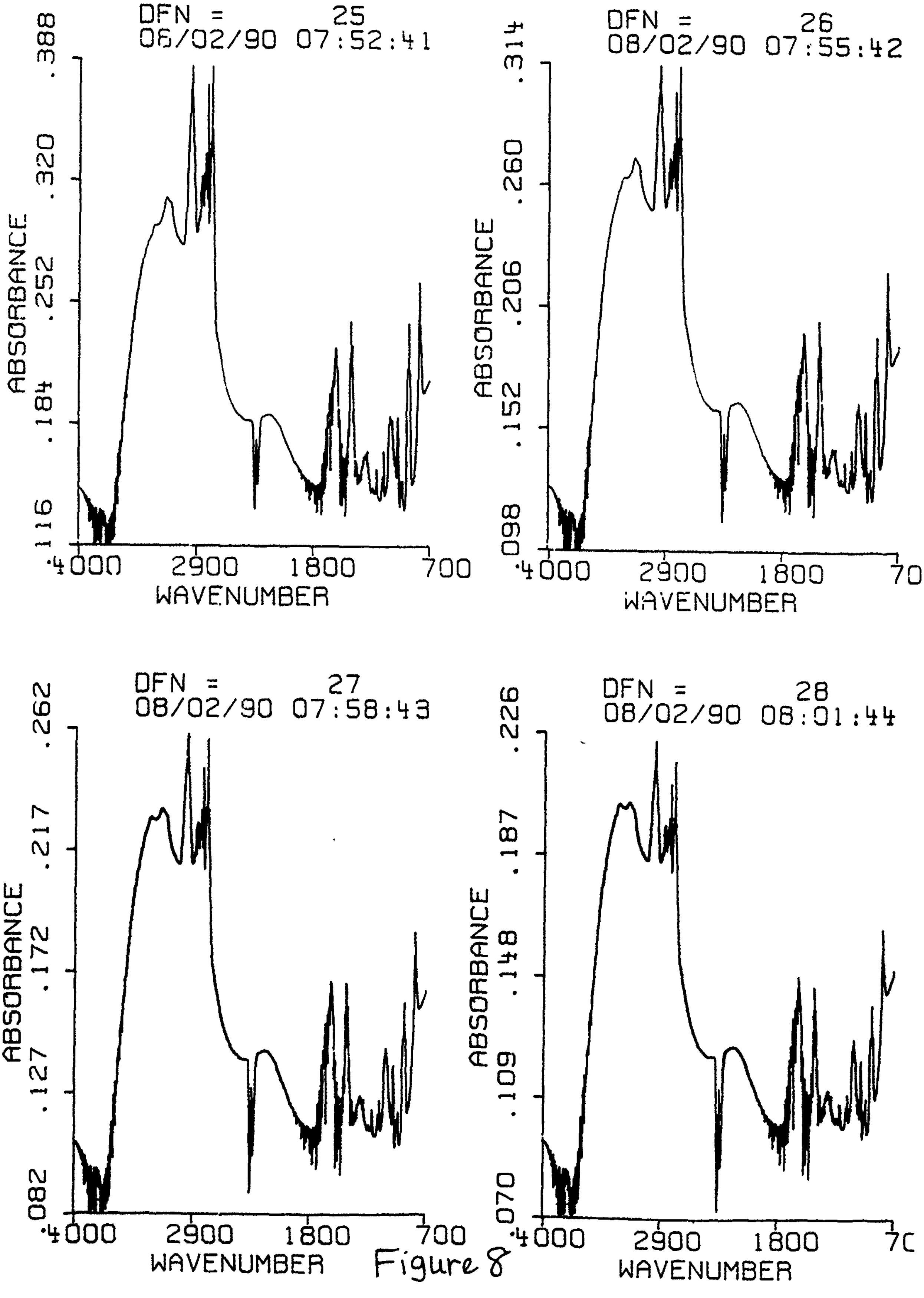
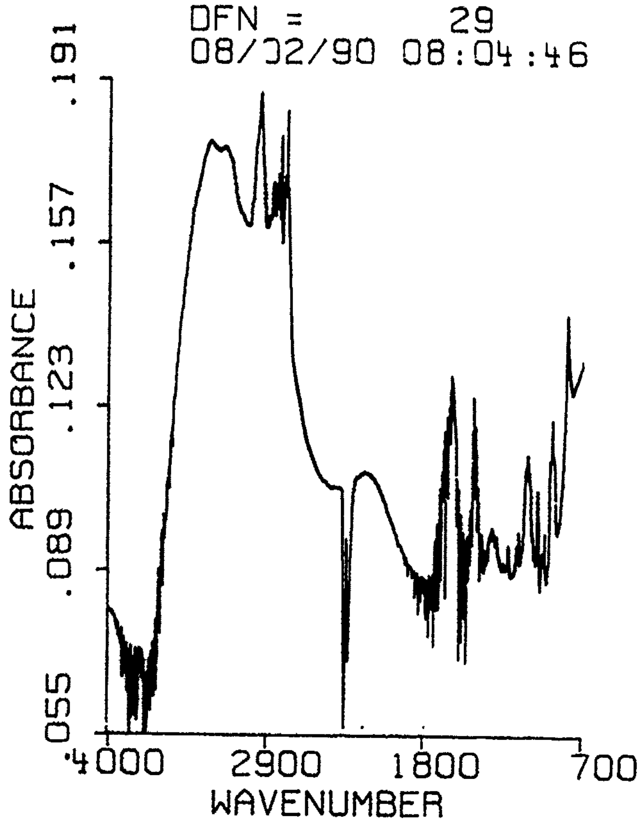
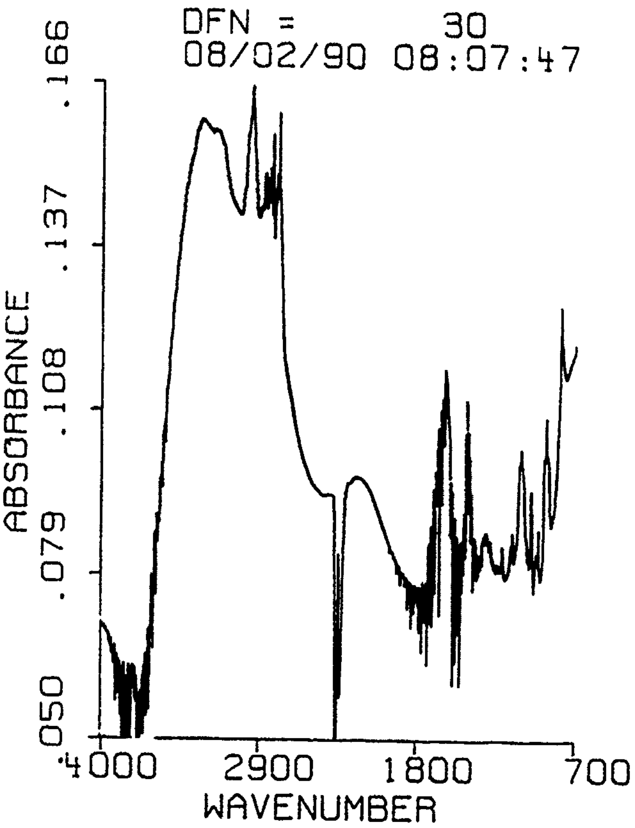

DFN = 25
06/02/90 07:52:41
ABSORBANCE
.388
.320
.252
.184
.116
4000
2900
1800
700
WAVENUMBER
DFN = 26
08/02/90 07:55:42
ABSORBANCE
.314
.260
.206
.152
.098
4000
2900
1800
70
WAVENUMBER
DFN = 27
08/02/90 07:58:43
ABSORBANCE
.262
.217
.172
.127
.082
4000
2900
1800
700
WAVENUMBER
DFN = 28
08/02/90 08:01:44
ABSORBANCE
.226
.187
.148
.109
.070
4000
2900
1800
7C
WAVENUMBER

Figure 8


DFN = 29
08/02/90 08:04:46
ABSORBANCE
.055
.089
.123
.157
.191
4000
2900
1800
700
WAVENUMBER


DFN = 30
08/02/90 08:07:47
ABSORBANCE
.050
.079
.108
.137
.166
4000
2900
1800
700
WAVENUMBER

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1. Experiments in Techniques of Infrared Spectroscopy. R. W. Hannah, J. S. Swinehart, Perkin-Elmer Corporation, Infrared Applications Laboratory, Norwalk, Conn., Sept. 1974 (p. i-viii)

2. FT-IR Theory, Nicolet Instrument Corporation, Madison, WI, 1986

3. Easy Operation 740, User Manual Tutorial for the Nicolet FT-IR Spectrometer.

4. Nicolet User's Manual, User Manual for the Nicolet FT-IR Spectrometer.

HIGH SCHOOL APPRENTICESHIP PROGRAM FINAL REPORT

SIMS. BILLETING

PHILIP DORSCH

Submitted to:

UNIVERSIAL ENERGY SYSTEMS
4401 Dayton-Xenia Rd.
Dayton, OH 45432

8/10/90

Dear Sir/Madam:

This summer I was involved with the High School Apprenticeship Program. My mentor was Major Keith Howell under Col. Maloney in DEH. The project to which I was assigned was a challenging one. I worked in computer applications with Billeting software. The purpose of my stay was to document the Services Information Management System (SIMS) Billeting program. The theory behind this project was to put a person who had no past experience on SIMS or the WANG computer and have him/her go through the program and see what problems and ideas he/she had or couldn't understand. I had no past experience on the WANG computer, so the first hurdle I had to overcome was to learn how the WANG computer operated. I ended up taking a training course that took just over two weeks to complete,(about 84 hrs.). After that, I began my project. I went in to each file and reported my findings, writing down my questions, problems, and recommendations for future modifications. I also summarized each file. When I ran into a problem, Maj. Howell or an assistant helped me.

Although, I had no problems with this project, I still enjoyed doing it. The questions I did have answered themselves as I proceeded farther along in my research. The one recommendation I have; make sure all files print to screen and that there is a help file behind each one, so the user knows exactly what it does and how to do it. I learned a lot from this experience.

This job was a great opportunity to see how a part of the Air Force worked, besides flying. One of my goals for the future is to attend the United States Air Force Academy. I would like to major in electrical engineering and later become a fighter pilot and/or astronaut.

ACKNOWLEDGEMENTS

I would like to thank everyone for the assistance they gave me. All the extracurricular activities that were planned, are also appreciated. I found that everyone I was associated with was very professional, helpful, patient, and over all outstanding! You have my deepest gratitude.

Special thanks to:

COL.	Maloney
LT. COL.	Eagan
MAJ.	Howell
CAPT.	Shock
Mr.	Allen
Mr.	Marshall
Mrs.	Reynolds
Ms.	Marks
Ms.	Elmore

Alternate Pavement Materials

David E. Eshleman

Ms. Pat Suggs HQ AFESC/RDCP

10 August 1990

I. Acknowledgements

I would like to thank Bonnie Castillo and Dean Hitzelberger for all of the help they gave us in the lab when we needed it. My thanks also goes to Capt. Mike Coats, Mr. Jesse Flood, Capt. Charles Manzione, and Ms. Pat Suggs for their assistance while we were working out in the 9700 Area.

II. Purpose

The purpose of our research was to find new materials for the filling of craters during Rapid Runway Repair (RRR). The tests were run on three cements, one manufactured in the United States and two manufactured in Great Britain (all of them are commercially available). The materials were tested for their compressive, bonding, and flexural strength at 5 degrees Farenheit and at -15 degrees Farenheit. We experimented to find the cement with the highest strength in the shortest amount of time.

These results would enable the Air Force to repair bomb-damaged runways in a shorter amount of time. The low temperatures were selected because the problem is that cement works fine at higher temperatures and the Air Force needs a cement that can perform just as well at lower temperatures.

III. Research

The testing itself was done in accordance with ASTM C 109-84, ASTM C 266-77, ASTM C 807-85, ASTM C 39-86, and ASTM C 78-84.

The first task was to calculate the amount of materials needed to complete the experimentation. Since we were dealing with three different cements, the amounts used were considerably different. Not only were we using cement, but we were also using accelerator (which speeds up the reaction in the cement) and water.

Once the materials were measured out, they were placed in the Blue M Environmental Chamber. The chamber was set at a temperature of 5 degrees Farenheit and the contents were allowed to cool for 24 hours. The water was not placed inside because we needed it in its liquid state. Before mixing, we measured the correct amount of ice water, to reach the lowest possible temperature.

The compressive tests were performed in 2" cubes. Each cement was tested in three molds; each mold contained three cubes. At the one, two, and three hour points, one cube from each mold was removed and placed into the Materials Testing System (MTS). The MTS applied constant increasing pressure on the cube. The results were recorded on a graph and also on a digital display which showed the total amount of pressure exerted on the cube. The total pressure was divided by the surface area of the cube (in this case it was four inches since it was a 2" by 2" side). The ideal pressure, measured in pounds per square inch (psi), was 1000 psi at the one hour mark. The cements were then tested at the two and three hour points and the results were recorded. If the sample reached a strength of 1000 psi at the one hour point, another sample was made and tested at 30, 60, and 90 minutes. The Air Force requires the use of a cement that can reach a strength of 400 psi in only 30 minutes. This would allow any aircraft to land on it just 30 minutes after the crater was repaired. One of the British cements was tested a little differently. A 4" by 8" cylinder mold was used because an aggregate had to be used for maximum strength. The results were calculated by dividing the total pressure by the area of the 4" circle.

A bond test was performed on the American cement; however, the results were not good since it was more or less a trial run on that type of test.

The only major problem we ran into was that it took an extra four weeks for our British cement to arrive. This meant we could only do so much testing with the materials on hand. After the cement arrived, we determined from our calculations that we wouldn't have enough materials to complete all of the tests even at only one temperature. More materials were ordered and we tested until we exhausted our initial supply. Ms. Suggs plans to have all of the testing completed by 1 December and the results in a technical report published by February.

IV. Results

At the end of the testing, we found that the British cement that required aggregate was the weakest out of the three. I believe it is because there is much more cement that must set in the cylinder than in the cubes. The other two cements behaved relatively the same and it will be interesting to find out what the results are from the other tests.

V. Observations

In addition to our testing, we worked extensively on the Wang VS Word Processor, Freelance Plus software, and Harvard Graphics software. I enjoyed having the opportunity to work with all of these systems.

The program was a great learning experience because of the people and systems we worked with during our eight week stay. I never realized before how much of an asset the Research and Development Branch is to the Engineering and

APPRENTICESHIP FINAL REPORT

by
Richard C. Hartzer

Mentor: J. Rick Baker

AFESC/DEQ

August 3, 1990

ACKNOWLEDGEMENTS

First, I would like to express my appreciation to J. Rick Baker for helping me to gain a clear knowledge of Privatization and a knowledge of how the the WANG computer system is used for everything from word processing to spreadsheet calculations. I would also like to express appreciation to Ms. Fran Parrish who explained the somewhat complex way government documents are processed and stored. Also, I would like to take this opportunity to thank Allen Nixon who worked with me to help me to gain a further knowledge of the processes involved with organizing privatization projects. And, finally, a word of thanks to my co-worker Michael Stone for helping to make this summer an experience I will never forget.

Over the course of this summer, I had the opportunity to enhance my organizational skills as I helped to put together Private Sector Developement and project management files. These files are used by the DEQ organization to determine the appropriation of funds for several projects on Air Force installations. These projects provide for the financing, design, construction, organization, and maintenance of Visitor's Quarters, Cogeneration Plants, Family Housing Facilities, Supply/Warehouse Facilities, Wastewater Pretreatment Facilities, etc. Also these projects look at finding more effective ways to utilize natural resources such as coal. Since these projects are going to be of such great significance to the Air Force, much time was spent making sure the project activation was completed correctly and on time. During the time I worked on the organizing of these files I learned much about work involved in the career fields of contracting and privatization. For example, to get just one PSD project approved, it is necessary to do an economic analysis of cost and benefits to the government, an environmental documentation report to estimate potential environmental affects of each project, a socioeconomic impact to assess impacts on local economies and people, an operations impact study to ensure the PSD project does not negatively impact base operations, a contract for the project, and a summary paper to consolidate all the information so someone can understand what it all says!

This apprenticeship gave me the chance to work on the WANG computer system and learn different programming skills. I learned how to work on the Word Processing program to create summaries of the various projects being developed. These skills were used to revise statements of work that are used to determine funding for taskings of these projects. After learning to use the word prossesing program on the WANG, I learned to use the 20/20 spread sheet which is also on the WANG system. The WANG 20/20 spreadsheet was used to create the budget for taskings and TDY's for various projects to be carried out by the Air Force in the near future. Learning to use the spreadsheet was difficult because of the many different commands and computer jargon that had to be interpreted in order to create and compute the budget analyses. By trial and error though I was able to gain the knowledge to use the program. My work was reviewed by the staff and was used for costing specific projects.

I feel that these various skills I have sharpened this summer will help me in the future when I have another opportunity to work on similar computer systems. I will also be able to better organize the work that I do as well. Overall I feel that this summer job has been most beneficial to me as a learning and growing experience.

I now understand what it is like to work in the real world away from Burger King or McDonalds. This summer experience has been great and I will always remember the skills that I have learned here.

A Neural Network Edge Enhancer

By:

Thor M. Johnson

Scientific Aid AFESC/RDCF

Tyndall Air Force Base, Florida

1990

Special Thanks To:

Doug Schwartz

(Who helped me with this project)

Mary Reynolds

(Who had the patience to deal with my time cards)

The Guys At The Office

(Who kept life interesting!)

Introduction

A neural network (neural net) is a system composed of many simple analog processing units (Fig. 11) that basically compute the weighted sum of their inputs. The output is then modified via one of the transfer functions (Fig 2.), and sent to the connecting neurodes (elemental processing units). The Hopfield Net, in which the Edge Enhancement System is implemented, is composed of many laterally connected neurodes.

During this summer, I have been involved in research and development of the use of neural networks to enhance edges as a part of a more complex image processing system. This system is being designed for locating the source of a fire, and ascertaining the necessary agent to extinguish it, as well as the precautions necessary in the case of a HAZMAT (hazardous material) fire.

The use of neural nets is advantageous because they can be configured to detect fine edges that other EES's (Edge Enhancement System) fail to locate. They (neural nets) can do real-time image processing (when implemented into a hardware based system, as opposed to a software simulation) which other systems cannot achieve.

Two 2-dimensional grey-scale edge enhancement systems were developed. Lotus 1-2-3^{R}[1] Version 3 was used to implement a software simulation of an edge enhancement system, such as the one suggested by the author (Klimasauskas, 77), and another simulation was constructed in C using Borland's Turbo C V. 2.0. The

---

[1] Lotus and 1-2-3 are copyright Ashton Tate. Other trademarks are copyright their respective companies.

Project Description

Lotus EES is fully operational, and the C version is awaiting revisions.

The EES is dependent on two parameters: the bias applied and the interconnection weights (input filter). The bias allows the user to change the sensitivity of the filter rapidly, thus he can reduce the background level to zero in one pass, and allow the net to gradually bring out the edges, thus sensitizing it to respond to small changes in the input level. The input filter is known as the on-center off-surround (Mexican Hat) filter (Fig. 1)

The Mexican Hat filter tends to intensify changes, but ignores a high bias-- it responds to edges, but ignores or subdues a constant high level input (such as the center of a sheet of blank paper). The Lotus version of the EES uses a nine by nine Mexican Hat filter, while the C system can utilize any filter that is smaller than half the size of the input data matrix (for any useful work to be done). See Appendix I for the input structure for the C file.

A hard limiter function (Fig. 2b) was chosen for the output modifier, due to its simplicity and effectiveness.

Project Description

It is second to the sigmoidal transfer function (Fig. 2a), but does not take much computation (a decision factor for a software simulation) when compared to the sigmoid function. A digital transfer function (Fig. 2c) has been shown to work poorly in any neural network because the neural network is an inherently analog processing unit system (Caudill, 61).

Results/Conclusions

The input data matrix for both EES system is shown in figure 3. The Lotus system's output is shown in figures 4-6. It can be seen that the EES "recognizes" the corners of the square input and dramatically intensified the low-level spikes that were present in the input.

The C EES results (Figs. 7-10) are non-conclusive; the system does not work properly,, thus necessitating the revision of the C code. The C source code is listed in Appendix II for those who wish to try to change it into a useful EES. My comments are included in the listing.

The importance of the design and use of an Image Enhancement System, consisting of an edge enhancer, a spectrum analyzer, and various other components, for fire applications is shown by its being studied by two commercial companies[2]. The final goal is to create a fire detection system capable of determining the size, type, and heat of the fire; thus allowing the optimal

---

[2] Donmar Inc. and American Research Company of Virginia.

Results/Conclusions

extinguishment method to be determined, if indeed the fire does need extinguishing[3].

---

[3] Some fires do not need to be extinguished, such as the jet engine backfire that sometimes occurs when starting the engine.

Results/Conclusions

Figures.

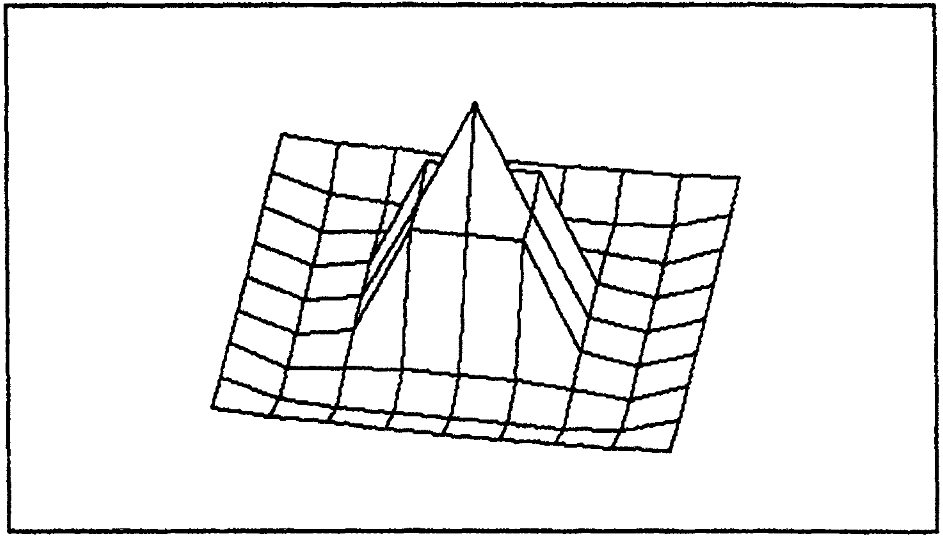


Figure 1. The Mexican Hat Filter

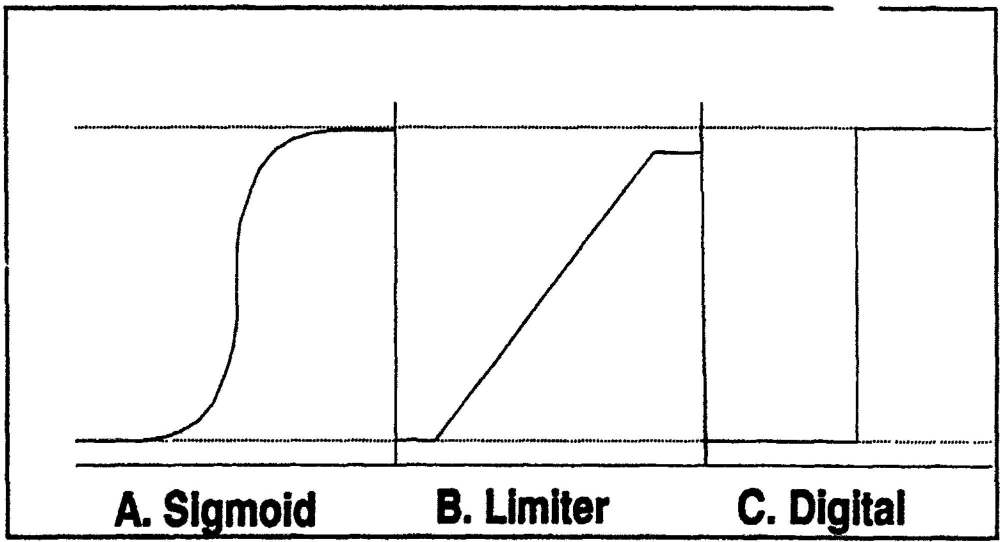


Figure 2. Output Transfer Functions.

Results/Conclusions

Figures (Cont.)

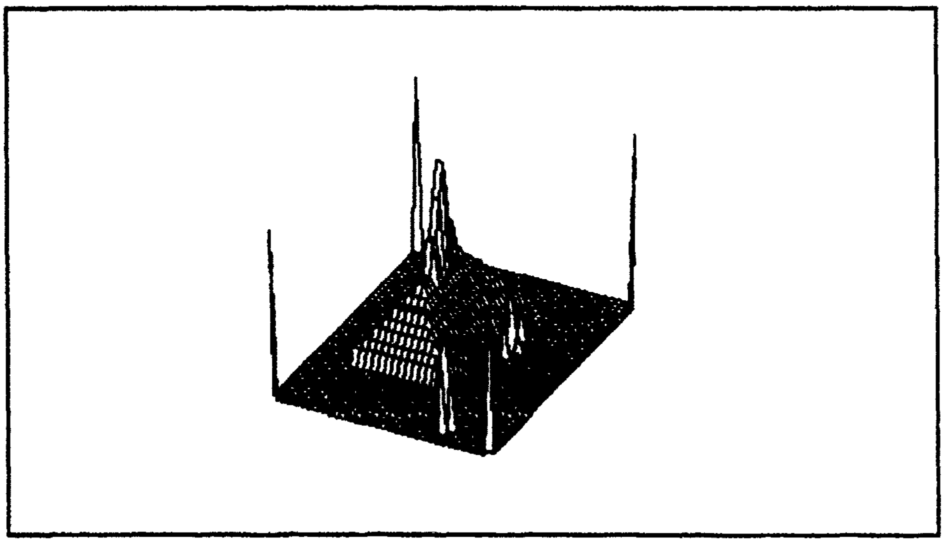


Figure 3. Input Data Matrix.

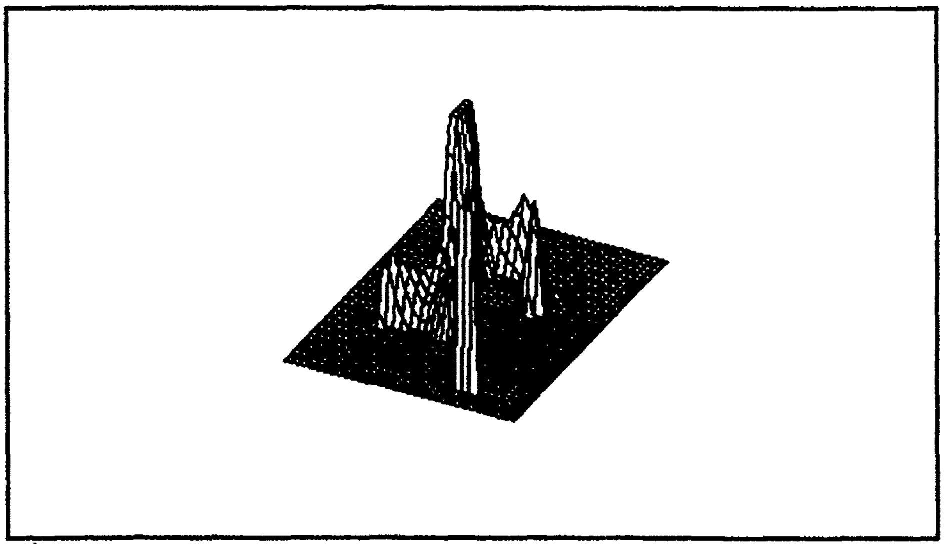


Figure 4. Pass 1 Lotus Output.

Results/Conclusions

Figures (Cont.)

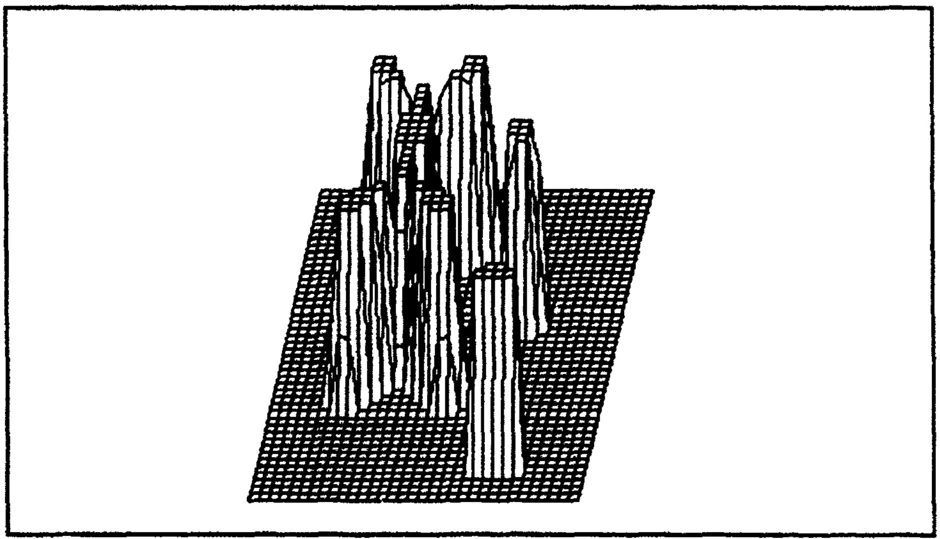


Figure 5. Lotus Pass 2 Output.

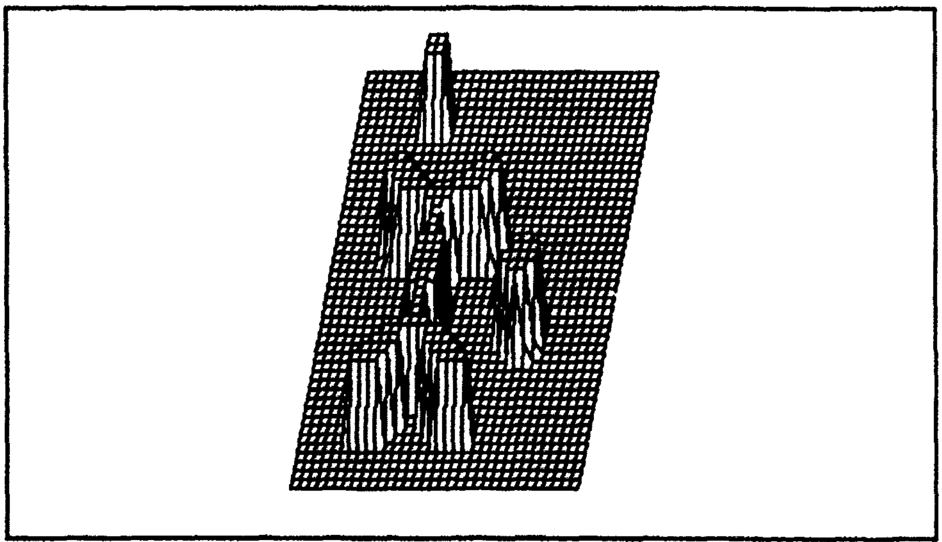


Figure 6. Lotus Pass 3 Output.

Results/Conclusions

Figures (Cont.)

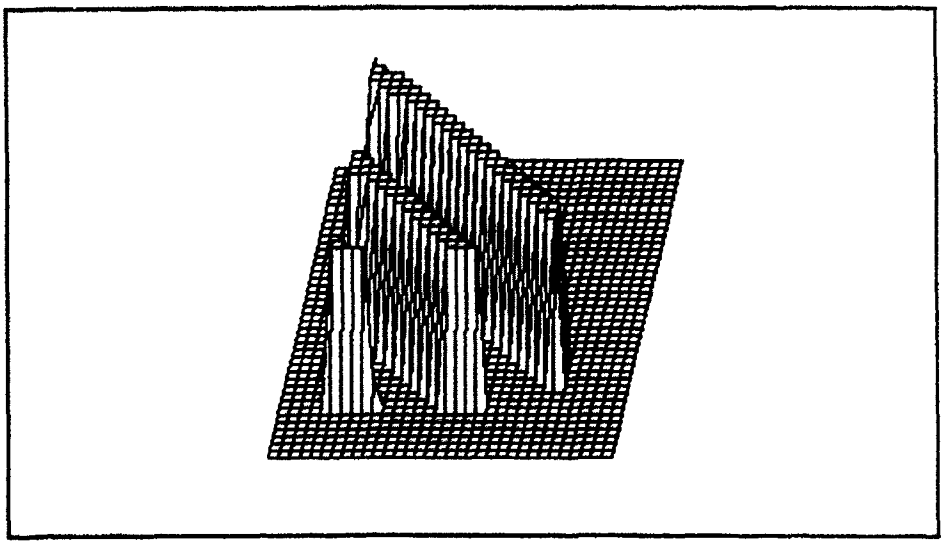


Figure 7. C Pass 1 Output.

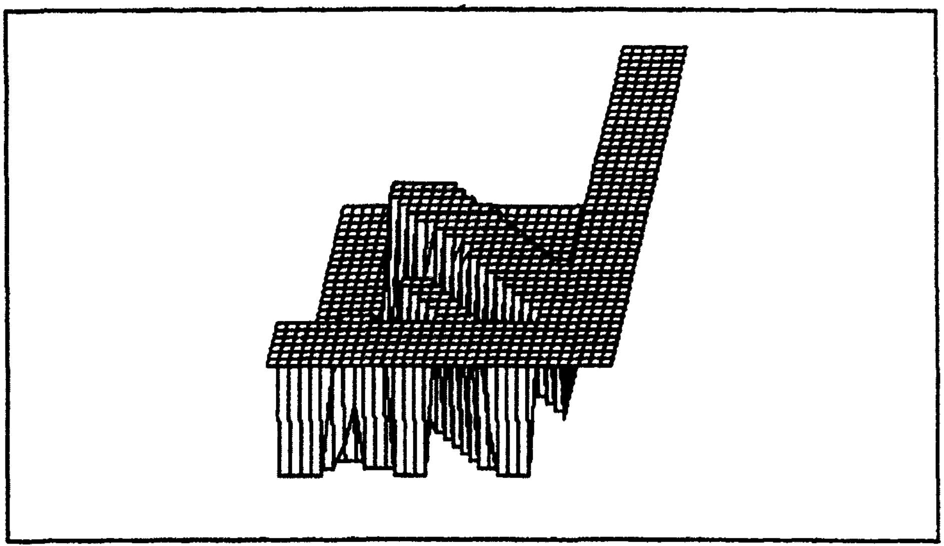


Figure 8. C Pass 2 Output.

Results/Conclusions

Figures (Cont.)

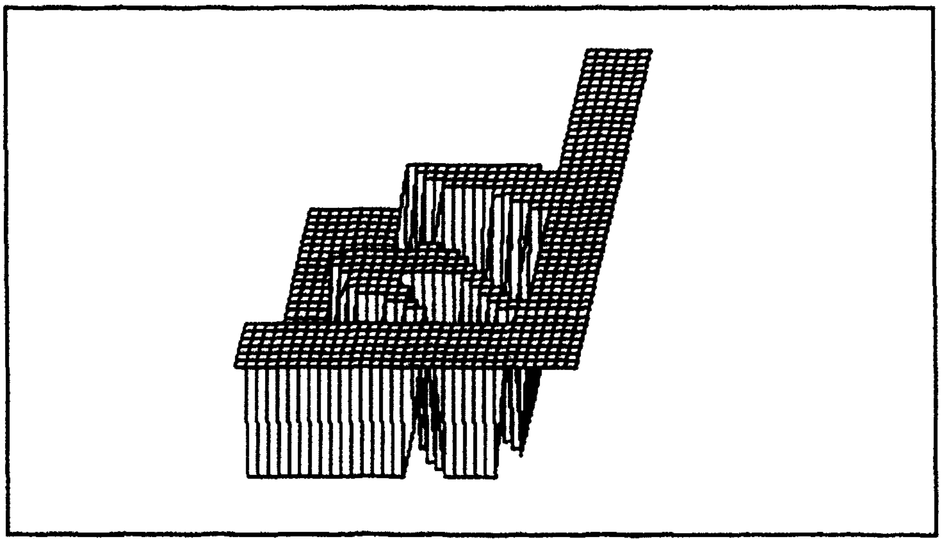


Figure 9. C Pass 3 Output.

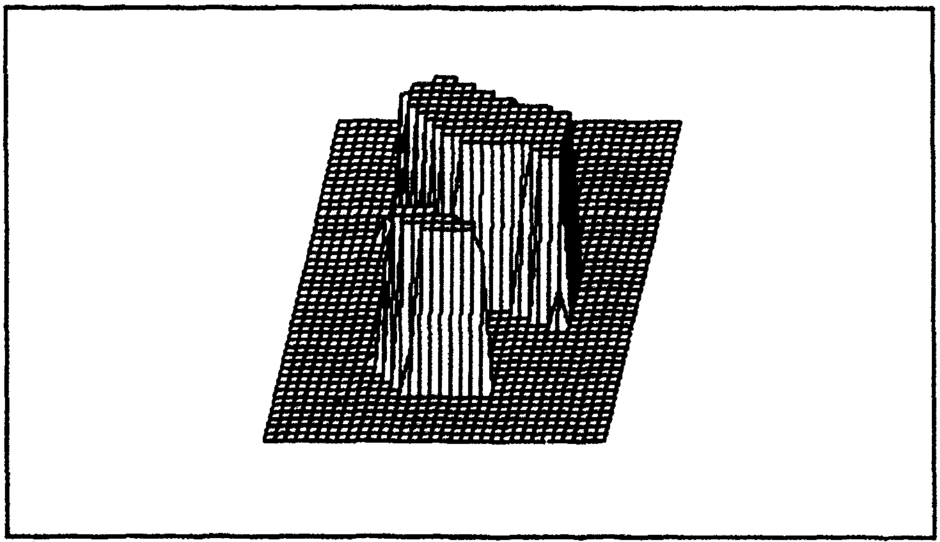


Figure 10. C Pass 4 Output.

Figures (Concl.)

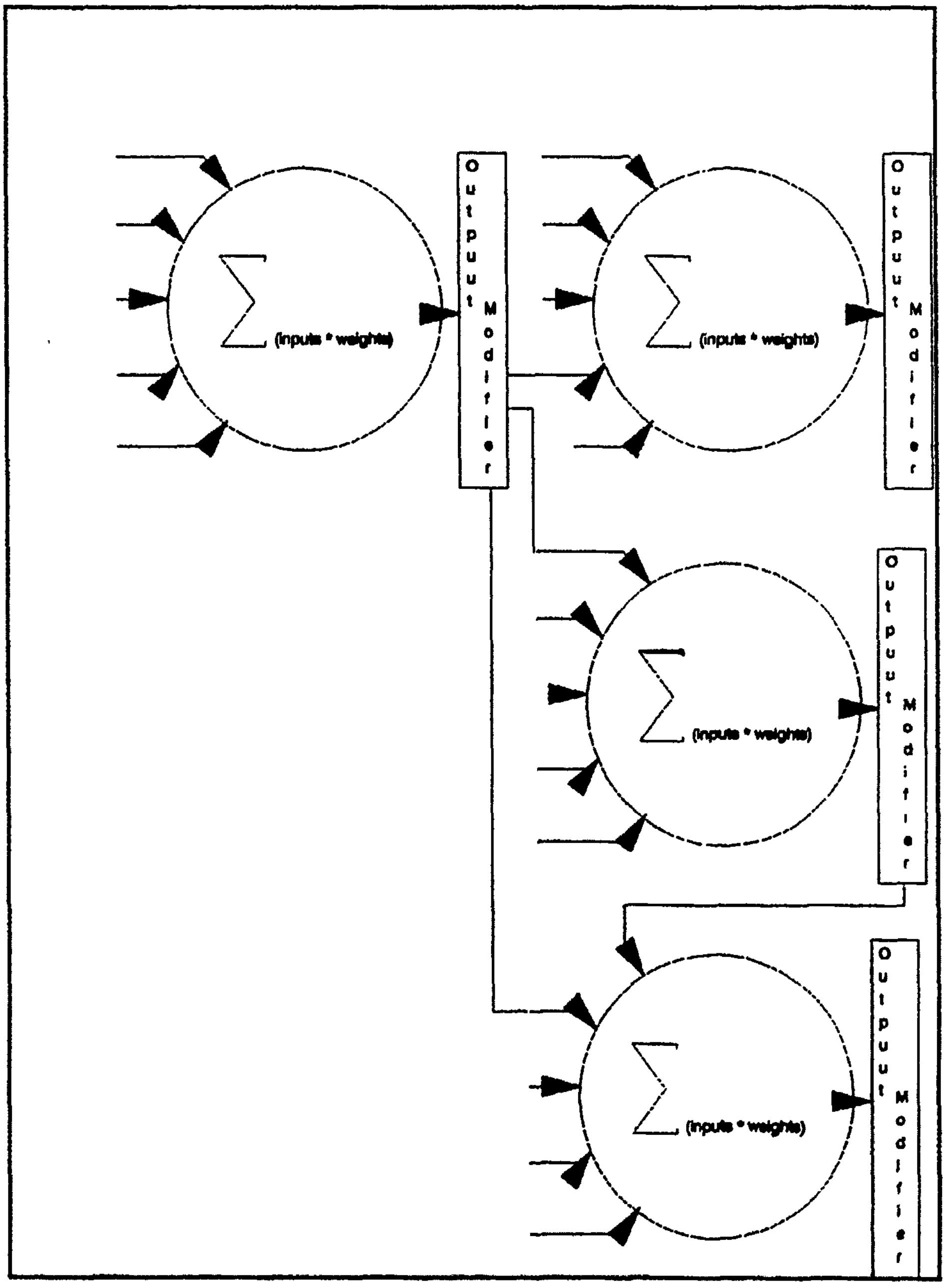


Figure 11. An illustration of a Neural Net.

Literature Cited

Caudill, Maureen. "Neural Networks Primer," AI Expert. August 1989. Pp 61-67.

Klimasauskas, Casimir C. "Neural Networks and Image Processing," Dr. Dobb's Journal. April 1990. Pp 77-116

Appendix I. Input Structure for the C Implementation.

For the Data Matrix:

```
Size_X    Size_Y
Data
```

Notes: Size_X refers to the number of columns in the input matrix. Size_Y refers to the number of rows (not including the header) in the input.

If the **autosize** variable is 1, then the header is ignored, but each input row must be terminated with a carriage return, and the column width must be properly **#defined** in the code.

For The Weight Matrix:

```
Size
Data
```

Notes: The weight matrix is square, so there is only one size parameter. There is no autosize for the weight matrix.

If the bincl variable is set, a floating point number that is placed after the matrix will be loaded as the bias. If it is not set, the extraneous data will be ignored.

Appendix II.   The C EES Implementation

```
#include "adapt.h"
#define TCC
#include <stdio.h>
#include <stdlib.h>
#include <alloc.h>
#include "Ary.TCC"

#define MX      1
#define DTA     2
#define OTHER   3

#define XY      1
#define SQ      2
#define NONE    0

#define COLW    6         /*Column Width*/

float sumproduct();             /* Calculates The Sums*/
                                /*Of the Products of */
                                /*Matrices*/

int bincl;                    /* Include Bias in MX?*/
int stat;
float autosize=1.0;           /* Automatically Size */
char asz[500];

float bias;


/*Core Algoxithims for a 2-Layer-2D Neural Net*/
```

```
NN(omsk,cyclimit)
char *omsk;                    /*Output File Mask*/
int cyclimit;                  /*Cycle Limit*/
{
     int xln,xstrt,cycle;
     int imgx,imgy;
     int x,y,mpt;
     char fnme[80],strg[10];
/*Buffers for Filename*/

     cls();

     xln=loadsq(MX,"NETcon.EES");  /* Load a Sq Matrix
          (Hat)*/
     xstrt=((int)(xln/2))+1;
     mpt=xstrt+2;
     readmat(DTA,"NETdta.EES",&imgx,&imgy);  /*get data*/
     gotoxy(1,1);
     printf("
      ");
     gotoxy(5,5);
     printf("
      \n");

     gotoxy(1,1);
     if(stat)    printf("Bias:
%5.3f\tMXsize:%d\tMdpt:%d",bias,xln,xstrt);
     /***************************Status Check:
     ** ary[1] has Neural Filter   imgx=Max Image X
     ** ary[2] has Test Data       imgy=Max Image Y
     **         No files Open (exc. Stdin,Stdout,etc.)
     ** In {} Lvl 1 (inside func(), outside loops)
```

```
    ***************************************************/
    for(cycle=1;cycle<=cyclimit;cycle++){
        register float sum;
        locate(20,15);
        printf("Pass %d is running...",cycle);
        for(y=xstrt;y<=(imgy-xstrt);y++){
            for(x=xstrt;x<=(imgx-xstrt);x++){

sum=sumproduct((x-xstrt),(y-xstrt),DTA,MX,xln);

                sum-=bias;      /*Subtract Bias*/
                if(sum>1) sum=1.0;
                if (sum<0) sum=0.0;

                if(stat) {
                gotoxy(10,10);
        printf("NNet: Ix:%d\t Iy:%d :=%lf",x,y,sum);}

                aset(DTA,x,y,(float) sum);
                }
            }
    /*now set edges*/

        {
        register int x,y;
        register float num;
        num=aread(DTA,mpt,mpt);  /*get init value*/
        for(y=1;y<mpt-1;y++)        /*top*/
            for(x=1;x<=imgx;x++)
                aset(DTA,x,y,num);
        for(y=1;y<=imgy;y++)        /*left*/
            for(x=1;x<mpt-1;x++)
```

```
                    aset(DTA,x,y,num);

            num=aread(DTA,imgx-mpt,imgy-mpt);
            for(y=1;y<=imgy;y++)          /*right*/
                for(x=imgx-mpt+1;x<=imgx;x++)
                    aset(DTA,x,y,num);

            for(y=imgy-mpt+1;y<=imgy;y++)      /*bottom*/
                for(x=1;x<=imgx;x++)
                    aset(DTA,x,y,num);
            }



        /*** Done With 1 pass NNet, Now write data ***/

        gotoxy(20,1);
        printf("Pass %d completed.  Writing ",cycle);

        strcpy(fnme,omsk);              /*Copy Mask*/
        strcat(fnme,itoa(cycle,strg,10));  /*Add Serial #*/
        strcat(fnme,".EES");            /*and Ext*/
        printf("%s...",fnme);

        writemat(DTA,fnme,imgx,imgy,NONE); /*Write Data*/

        gotoxy(38,1);
        printf("
         ");
        }
    }
    /*out of it!!*/
```

```
main()
     {
     float bias;
     int num;
     char ofle[20];
     cls();
     printf("======================================2D
Driver=============================\n\n\n");
     printf("Output File mask (OUTput ->Output1...):");
     gets(ofle);
     printf("Bias: ");scanf("%f",&bias);
     printf("Passes: ");scanf("%d",&num);
     stat=1;bincl=0;      /* Bias Not Included */
                          /* Status Displayed*/
     NN(ofle,num,bias);
     putchar('\x7');
     cls();
     printf("Complete.  %d passes done.\n",num);

     }



float sumproduct(x1,y1,ar1,ar2,len)
int x1,y1;                /*Start X&Y of ar1[]*/
int ar1,ar2;                   /*arrays of data*/
int len;                       /*symm. len of op*/
{
     int wx1,wx2,wy1,wy2;
     float result=0.0,a,b;
```

```
        wx1=wx2=wy1=wy2=0;

        for(wx1=x1,wx2=1;wx1<x1+len;wx1++,wx2++){
                for(wy1=y1,wy2=1;wy1<y1+len;wy1++,wy2++){

result+=(a=aread(ar1,wx1,wy1))*(b=aread(ar2,wx2,wy2));
                        }
                }
        return(result);
        }

loadsq(ary,fil)                         /*Read a Square Matrix*/
int ary;
char *fil;
{
        FILE *fle;
        float flt;
        int rt,x,y;

        fle=fopen(fil,"r");
        if(!fle) exit(1);

        fscanf(fle," %d",&rt);
        ainit(ary,rt,rt);
        for(y=1;y<=rt;y++){
                for(x=1;x<=rt;x++){
                        fscanf(fle," %f",&flt);
                        aset(ary,x,y,flt);
                        if(stat) {
                                gotoxy(5,5);
                                printf("Mx
%d,%d=%f",x,y,aread(ary,x,y));
```

```
                    }
               }
          }
     if(bincl){  /* is Bias Included?*/
          if((fscanf(fle," %d",&flt)<=5)) bias=flt;
          }
     if(fclose(fle)){
          printf("Cannot close file!\07\n");
          exit(1);
          }
     return(rt);
     }

readmat(ary,fil,x,y)
int ary;
char *fil;
int *x, *y;
{
     FILE *fle;
     float flt;
     register int cx,cy;
     int zx,zy;

     fle=fopen(fil,"r");
     if(!fle){puts("FNF"); exit(1);}

     fscanf(fle," %d %d",x,y);
     if(!autosize) ainit(ary,*x,*y);  /* if Not asize,
                                         init values*/
          else{
          do{
          fgets(asz,999,fle);
```

```
               *x=((int)(strlen(asz)/COLW));*y=0;
               }while(*x<=3);
          while(!feof(fle)){
          fgets(asz,999,fle);
               (*y)++;
               }
          rewind(fle);
          ainit(ary,*x,*y);
     fscanf(fle," %d %d",&zx,&zy);
          }



     for(cy=1;cy<=*y;cy++){
          for(cx=1;cx<=*x;cx++){
               fscanf(fle," %f",&flt);
               aset(ary,cx,cy,flt);
               if(stat) {
                    gotoxy(1,1);
                    printf("Data %d,%d=%f",cx,cy,flt);
                    }
               }
          }
     if(fclose(fle)){
          printf("Cannot close file!\07\n");
          exit(1);
          }
     }

writemat(ary,fil,x,y,mo)
int ary,x,y;
char *fil;
```

```
int mo;                                /*mode*/
{
     FILE *optr;
     register int cx,cy;

     if((optr=fopen(fil,"w"))==NULL ) {
          printf("Can't open %s",fil);
          exit(1);
          }

     switch(mo){
          case XY:fprintf(optr,"%d\t%d\n",x,y);
                    break;

          case SQ:fprintf(optr,"%d\n",x);
                    break;
          }

     for(cy=1;cy<=y;cy++){
          for(cx=1;cx<=x;cx++)
               fprintf(optr,"%5.3f\t",aread(ary,cx,cy));
          fprintf(optr,"\n");
          }
     if(fclose(optr)){
          printf("Cannot close file!\07\n");
          exit(1);
          }
     }
```

SUMMER RESEARCH

Tracy Lamb

Ms. Pat Suggs
HQ AFESC/RDCP
Tyndall AFB, Florida

18 June-10 August 1990

I. I would like to especially thank Pat Suggs for putting up with David and I and for all of her help in the lab and on the research we did. She was a great influence on both of us and very fun to work with. I would also like to thank all of the people in the 9700 area who helped us, especially Capt. Manzione, Capt. Coats, Jesse Flood, Michelle Cutting, and Cathy Bishop. There are also some people in the lab I would like to thank including Dean Hitzlerberger and Bonnie Castillo. All of these people were very nice and helpful to us and I would like to personally thank them all.

II. David and I were working on alternate pavement materials. The object of the research that we did was to find new and better cements to carry out Rapid Runway Repair (RRR) at below freezing temperatures. Three different cements were researched with different percentages of water and accelerator to test their compressive, flexural, and bond strength. We were trying to find better materials for (RRR) at military installations located in below freezing temperature conditions. The British have done research on two cements made by FEB Inc. in Great Britain, Set-45 and ASR-1. We ran the same tests on these two cements and on the Master Builders Set-45 to see if the same results would be obtained. We wanted the cement to set fast; however, we didn't want it to set faster than it could be poured into the spall. We also wanted the repair to be able to survive several passes by F-15s. The maximum time allowed to complete all spall repair activities is four hours. The results of these tests had to fall into this time range with strengths that could withstand passes by F-15s in below freezing conditions. We had to determine how much accelerator we needed and how much water we needed to obtain the best results. From these results airmen out on the airfield would know how much accelerator and water to use per bag of cement. They would also know how fast they had to work in order to get the cement mixed and in the spall before it started to set.

III. The very first thing we did was set the Blue M Environmental Chamber to 5 degrees F and placed our materials in it so they could cool down. Then we read the directions on the cement bags to determine the amount of water per amount of grout suggested and to determine the amount we would use. After making these calculations we determined how much accelerator we were going to use. We then measured out each amount and mixed the ingredients in a bowl for three to five minutes. When we first started to mix the Master Builders Set-45 it looked like it would never liquify. Eventually it became like a thin milkshake. As soon as it had reached that consistency it was poured into the two inch by two inch cube molds so it would set. Occasionally we didn't have our ratios just right and the cement set up before we could get all of it in the mold. We did however have several good tests. After we poured the cement into the molds we set them in the Blue M Environmental Chamber to cool down to the original temperature of 5 degrees F. After about an hour we broke the molds and tested one of the cubes on the MTS Machine for compressive strength. We repeated this again at the second and third hour and recorded the data. This test was completed on all three cements. The next test that was supposed to be done was the bond strength test. Unfortunately we didn't have enough cement to complete all of the tests at both 5 degrees F and -15 degrees F. We had a lot of problems getting lab time because of all of the projects going on. We retested the ASR-1 compressive tests with 4 inch by 8 inch cylinders. We had a hard time getting our water content just right, too; however we were successful and obtained some pretty good results. Because of the delay on the cements from England, the lab time being decreased, and all of the briefings and staff meetings that Ms. Suggs had to attend we weren't able to finish all of the testing we had originally planned to do.

IV. With the data that we obtained we determined which cement appeared to be the strongest and most able to withstand the force of an F-15 landing over an extended period of time. We used the results that were obtained by the British on the FEB Set-45 and ASR-1 to judge what kind of results we were to obtain. At the one hour mark we wanted to get a compressive strength of at least 400 psi. When we did the tests on the Master Builders Set-45 we obtained this result; however, on the FEB Set-45 and the ASR-1 we didn't. The Master Builders appears to be the best of the three even though we haven't been able to complete all of the tests.

V. Not only did we learn about cement and its reactions but we also learned a lot about computers. The first week we were there we learned Harvard Graphics, Freelance, and Lotus 1-2-3. We also learned how to use the Wang Word Processor. All of these different programs helped us with our research and writing our report. Plus we both have a better understanding of computers. Personally, I had never touched a computer before I worked here. Now I can format and copy disks. I can't program yet but at least now I have a little bit of background that I didn't have before. I think this program has been very good for us and I hope everyone who has been involved in it had as much fun as David and I did. We enjoyed working with different people both in the 9700 area and at the lab. They gave us an opportunity to be ourselves and trusted us when we worked by ourselves. All in all this program has proven to me that I do want to go into engineering and that I would really enjoy working out here again next summer.

FINAL REPORT

Brent Miller - Student

Mary Marks - Mentor

HQ AF Engineering and Services Center

Directorate of Engineering & Housing-Food Quality

June 18 - August 10, 1990

ACKNOWLEDGEMENTS

Special thanks and appreciations are extended toward the following individuals.

Ms. Monette Burdeshaw
Ms. Eva Cutchen
Lt Col Pat Eagan
Mrs. Wanda Glasgow
Mr. Ed Hoffman
Maj Keith Howell
Mr. Carl Jacobi
Mrs. Barbara Leslie
Col Maloney (Head of DEH)
Ms. Mary Marks
Mr. Alan Marshall
Ms. Mary Reynolds
Mrs. Judy Tillery

Thanks are also offered to all other members of the HWAFESC staff, for being so kind and helpful toward the summer students, including myself.

I: GENERAL DESCRIPTION

As far as scientific research was concerned, my involvement was limited. My field was that of computer applications. My project was to use a WANG computer to create a computer spreadsheet that was capable of storing data and was easy to maintain and update. This program was to correct a problem that the Air Force was facing.

The problem was that a majority of the Air Force's canned dehydrated rations (B rations) were coming up on their expiration date. These rations were so great in number, that it would have been a huge waste to dispose of them after they had expired. The key to the situation was to use the rations before they expired. The only sensible way to use the rations was to rotate them through the dining facilities at each base. Since the dining hall managers, along with the customers, preferred the fresh foods (A rations), this program was set up to assign a certain number of cans to each base.

After completion, the entire spreadsheet was to be copied and distributed to Headquarters Air Force Commisary System (AFCOMS), each supply depot, and each Major Command (MAJCOM). The information on the spreadsheet was then used to base and coordinate the transition of the B rations from depot to base.

One may think that with all of this information (and more, to be discussed later), there would be an extreme amount of research involved. Actually, most of the information was already laid out for my use. Therefore, very little of my time was spent in the library, while a majority of it was spent in Mrs. Mark's office in front of the computer. My job was to CREATE the spreadsheet and to lay it out, so that it functioned properly, so that all of the information that the computer calculated would be correct. Therefore, most of my time was spent refining the formulas and general setup of the program.

II: DETAILED DESCRIPTION

First, in the procedure, I was required to obtain the "feeding strengths" for each base. A feeding strength is simply the number of rations served at that base for a particular month. Then, next to each base, the feeding strengths for each month were entered into columns. At the end, a "total" column was added for further reference. Next, the feeding strengths were converted into percentages, both of the total Air Force, of European bases, and of bases supplied by depots in the United States. Monthly averages were also included in the spreadsheet.

Later, based upon the feeding percent, and the supply of the particular war reserve material (there were over 80), a certain number of cans were assigned to each base for consumption. The amount assigned to each base was relatively small, therefore, the rations should not be extremely difficult to use.

The only equipment that I used was a WANG terminal, in Ms. Marks' office. The WANG 20/20 Spreadsheet program was the computer tool that enabled me to create the spreadsheet. The 20/20 does many advanced operations, and without many of them, the spreadsheet I created would not have been nearly as impressive, or maybe not even possible. In fact all of the data calculation was done by the computer, with only a few simple computer formulas that I had to enter.

III: RESULTS

Contrary to the belief of many of the personnel in DEHF, this project could be completed on a computer, and by a 15 year old high school student, I might add. This project may need occasional refinement, but there are qualified people there who are quite capable of that. The project has the ability to save the government millions of dollars on the rations that otherwise would have been wasted.

Also, the rations that were used in this project, were merely the on hand rations. There are nearly three times the amount of rations on order. These rations would almost surely be wasted in the long run. Therefore, I suggested that these orders be cancelled, and the contracts be bought out. This would save cost less then the purchase of these rations, and would also save time and money in the distribution of the rations. Lt. Col. Eagan is supposedly reviewing my suggestion for implementation.

Also, another interesting fact is that the single depot in Europe (Germersheim), contains almost as much or more rations as all four of the U.S. depots combined. Now, another depot is being built in Europe. I also suggested that the need for this depot be reviewed.

IV: MISC.

At the young age of 15, I expected to be treated somewhat inferior to the regular staff. Actually, I was not brushed off by anyone, but instead, respected, not in spite, but because of my age.

I also had an interesting experience helping one of my associates. She was assisting with a conference concerning the use of halon in the military. This conference was attended by American and Soviet environmentalists. I had an opportunity to speak with some of the Soviets, which was very enjoyable.

V: BIBLIOGRAPHY

All materials used were non-classified documents supplied by Air Force personnel. No published documents were utilized.

Effects of Compaction on Unsaturated Sand

Submitted to

Captain Steve Kuennen, Mentor
AFOSR High School Apprenticeship Program
Air Base Structural Materials Branch

by

Debra Piechowiak
High School Apprentice
Mosley High School
Panama City, FL

August 10, 1990

Acknowledgements

Thanks to the following people for making this summer a learning experience for me: Captain Steve Kuennen, mentor; Dr. C. Allen Ross, visiting research professor at RDCM from University of Florida; Dr. George Veyera, professor from University of Rhode Island; Blaise Fitzpatrick, graduate student from University of Rhode Island; and Mr. L. Michael Womack, Branch Chief, RDCM, and all the staff at RDCM.

I. General Description of Research

During this summer, several things were done with Ottawa 20-30 sand. During the first week, a video tape was made as the sand was compacted into a clear, plastic tube. The purpose of this was to observe the particles as they changed position during compaction. The sand was compacted into the tube at saturation levels of 20, 40, 60, 80, and 100 percent with and without dye. Better observations were made when there was no dye because the particles could be seen more clearly.

Ottawa 20-30 sand was also compacted into three different size tubes. The tubes had a wall thickness of one inch, one half inch, and one sixteenth inch. After the sand was compacted, the specimen was then placed in the split-Hopkinson pressure bar so that the speed of a wave and the amount of wave energy transmitted through it could be calculated. These tests were dynamic because the energy went through the samples at a very fast rate.

Also, the Ottawa sand was compacted moist and dried out in the oven at 110 degrees Celsius. After the specimens dried, a series of tests for each tube was run in the split-Hopkinson pressure bar to see if there was any significant change in the results. These specimens were then epoxied so that they could be used in the image analysis system.

Tyndall Beach sand was compacted into the same tubes used for the Ottawa sand and tested in the split-Hopkinson pressure bar as well. Three tests per saturation were performed so the results could be compared to those of the Ottawa sand. None of these samples were dried in the oven and tested, and none of these were epoxied because the particles were to small to be seen under the image analysis system.

Static compression tests were also performed on the Ottawa 20-30 sand using the Materials Test System loading device. This machine is a loading and unloading machine that plots the load a particular substance can hold. The soil was compacted in one and four layers and the results were compared. By taking the slopes of the first and second loading curves, a secant modulus, as defined in section three, was calculated.

II. Purpose of the Research

The purpose of this research is to study the effects of moisture on wave speed and transmission ratio of compacted soils. In the past it has been found that soil transmits more energy at levels of 20, 40, and 60 percent saturation than at 0 percent saturation, which is just the opposite of what engineers were thinking. By using the split-Hopkinson pressure bar, field conditions are imitated. The bar passed the same kind of wave through the soil as a bomb would, and it allows for calculation of wave speed and energy transmission ratio. The results can be applied to making buildings stronger than they might be and can also be applied to determining the type of soil and the best saturation to pack the soil at in order to make a bomb shelter stronger in a time of war.

This research was performed at the structural materials branch of RDCM which is set up to test engineering materials. The research fits into the other laboratory research at RDCM because a specific engineering material is being tested.

III. Detailed Description of Research

A. Compaction of Specimens

Two types of soil were compacted, Tyndall Beach sand which has fine, semi-angular particles, and Ottawa 20-30 sand which has larger, rounded particles. Both sands were compacted using the same method and the same equipment. First, the weight of the soil was calculated by finding the volume using the equation

$$V = \pi r^2 h \qquad \text{(eq.1)}$$

Then by multiplying the desired density by the volume, the total amount of soil needed for each layer was calculated. The formula for this calculation is

$$W_s = d \text{ x } v \qquad \text{(eq.2)}$$

where d is the density and v is the volume. The amount of water needed for each layer was then calculated using the equation

$$w\% = S_e \div G_s \qquad \text{(eq.3)}$$

where G_s is a constant of 2.65 and S_e is the saturation times the void ratio of the particular sand being used.

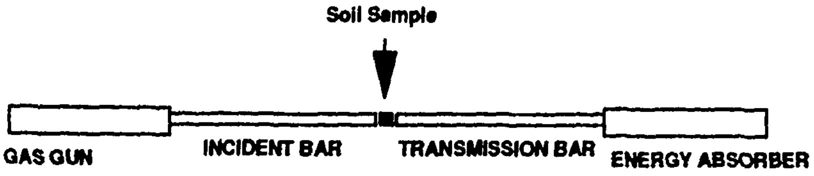
After calculating the amount of soil and water needed for each layer, the sand was measured and placed into paper cups. The water was added, and the sand was stirred with a glass stirring rod. Four individual layers were compacted using the next few steps. The appropriate tube was sprayed with RemGrit TFL 50 Dry Lubricant along with the wafer seal. The wafer seal and o-ring were then placed inside the tube, and the tube was placed on the pedestal. The sand was then placed in the tube and the flange on top of the tube. The correct piston for that layer was placed in the tube on top of the sand and hit several times with the Standard Proctor hammer until the top of it lay flatly on the flange.

B. Testing in the Split-Hopkinson Pressure Bar

The compacted specimens were tested in the split-Hopkinson pressure bar. The bar is actually two bars with a specimen placed in between them. There is a striker bar which hits the incident bar and sends a wave through the bar and the specimen. The tests performed on the sands this summer were done using an eight inch striker bar. On both the incident and transmission bars, there are strain gages that measure the wave being sent through the bar. There is a digital Nicolet oscilloscope which shows a picture of the wave and allows it to be stored on a computer disk to be looked at later. By using the oscilloscope, the starting points of the waves can be found and the wave speed can be calculated. Also, the peaks of the incident signal and the transmission signal can be found and the transmission ratio can be calculated.

When the specimens from this summer were tested, First the ends of the bar were greased with Moly Lubricant to provide for better contact with the sample. The specimen was then placed securely on the bar. The striker bar was pushed back into the gas gun, and the relief valve was closed. The chamber was then pressurized and the gun was fired at 25 psi.

Most of the split-Hopkinson pressure bar tests were performed on specimens that were compacted moist and tested moist, but there was also a series for specimens compacted moist and tested dry. There were three tests for each saturation and the data points were plotted out on the computer so that the charts could be compared to data charts from last summer. In addition, the data from the compacted moist, tested moist and the compacted moist, tested dry series were compared to see if the oven drying at 110 degrees Celcius had a significant effect on the results.



SPLIT-HOPKINSON PRESSURE BAR

C. Materials Testing System

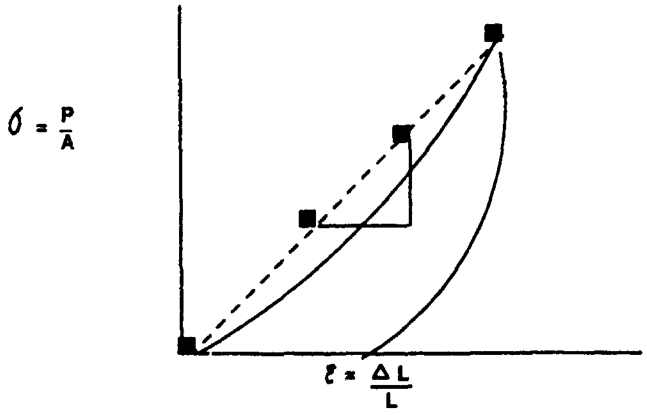
The Materials Testing System (MTS) is a loading machine used for the testing at low strain rates. The maximum load on the MTS was set at 5500 pounds and the mimimum load was set at 0 pounds. Each test took approximately 26 minutes, 20 minutes for two loading cylces and six minutes for two unloading cycles.

The specimens were compacted into each of the tubes; one inch wall, one half inch wall, and one sixteenth inch wall. Both one layer and four layer specimens were tested so that the results could be compared. After the specimens were compacted, the piston for first layer compaction was placed inside the tube. The pedestal was also left in place so that the wafer seal would not be pushed out. The load was put on the specimen and the load-unload cycle was repeated twice. The maximum and minimum loads were recorded on a data sheet, and the MTS recorder made graphs of the cycles.

Using the results, the secant modulus was calculated. The secant modulus is defined as

$$\Delta\sigma \div \Delta\varepsilon = P/A \div \Delta L/L_0 \qquad \text{(eq.4)}$$

where $\Delta\sigma$ is the change in compressive strength, $\Delta\varepsilon$ is the change in axial strain, P is the load, A is the specimen cross-sectional area, L_0 is the initial compacted specimen length, and ΔL is the change in specimen length.



D. Epoxying the Specimens

Two specimens of Ottawa 20-30 sand at each saturation of 0, 20, 40, 60, and 80 percent that were not tested in the split-Hopkinson pressure bar were epoxied. Also, two specimens of each saturation that were tested in the split-Hopkinson pressure bar were epoxied. The epoxy that was used is made by Epotek, and it comes in two parts. Part A is the Resins and Part B is the hardener. The epoxy was measured by pouring about seventy grams of the Resins into a cup and then dividing the amount of Part A used by four. Since the epoxy is a four to one mixture, one fourth of the amount of Part A added is the amount of Part B that was added. Also, about .25 grams of Sudan IV dye was added to darken the mixture.

To epoxy the specimens, the tubes were leaned against tongue depressors. Slowly the epoxy was poured into the tube. The average time it took to epoxy a specimen was about thirty to forty minutes. The epoxy itself is not thin enough to use after about forty minutes. The reason for tilting the tubes that were being epoxied was to allow a space in the specimen where the air could escaped. If an air bubble was left inside the specimen, then the epoxy would not harden correctly or the specimen would not be solid. The average hardening time for the specimens was six to eight hours in the air, one hour in the oven at 65 degrees Celsius for the sixteenth inch tube, an hour and a half in the oven for the half inch tube, and about two hours in the oven for the one inch tube. The total number of specimens needed was sixty. In many cases, the epoxy didn't harden or cure properly so the specimen had to be repacked, retested, and re-epoxied.

IV. Results of Research

All of the data from the split-Hopkinson pressure bar tests has not been recorded and so therefore the results cannot be seen. The specimens are being taken back to University of Rhode Island for microstructural analysis.

V. Other Experiences From the Program

During the summer, I was introduced to many aspects of research and engineering. I realized that I have an interest in engineering, and what I learned has made me think that I may want to pursue my interest in college. I learned that research takes time and patience, and that the results aren't always what you hoped they would be. I was also introduced into a working environment where the people were serious about their jobs and the things that they had to do. I think that I have a greater sense of responsibility because of that. I also went to seminars where other summer faculty members talked about their projects and what they were hoping to achieve, and I learned a little about each of the projects.

Design and Testing of an In-house Electronic Publishing System for National Laboratories

Jonathan M. Protz

Mentor: Larry Testerman

Lab: Engineering and Services Center,
Tyndall AFB, Panama City, FL

August 10, 1990

Acknowledgments

Special thanks go to the following people whom I worked with during my summer apprenticeship:

H. Perry Sullivan, Jr.
Larry L. Testerman
Mary E. Reynolds

Section I

General Description of Research

A. Background

Quick, high-quality publication of technical documents is often not readily available to the technical editors of our nation's laboratories. Publications which are contracted out sometimes get bogged down by bureaucratic red tape. Contracting also requires a large amount of pre-planning, and the final product is not always what was originally envisioned by the editor. Once the document is published, it is very difficult to have changes made. Production in government graphic departments and typesetting shops is also slow for many technical documents because these documents often have low priorities. This project attempted to diminish these barriers. Documents which are electronically typeset and published in-house by the technical editing staff avoid the pitfalls listed above. Electronic publishing allows a document to be quickly and easily changed. Since there is no "red tape" or higher priority documents to slow publication, documents can be produced much more quickly. Another advantage is that all production is done under the supervision of the editor. This results in a final product that is much closer to what the editor originally envisioned.

B. Description

This project, performed at the Air Force Engineering and Services Center (AFESC), Tyndall AFB, Florida, used advanced computer equipment and electronic publishing tools for the production of medium and high quality typeset technical documents. The system was based on two electronic publishing systems: Aldus Pagemaker for the Wang 381 IBM PC/AT compatible, and the Compugraphic Integrator electronic typesetting machine. Both systems imported text from a WANG/IWP wordprocessing network.

Aldus Pagemaker was used for the publication of medium quality documents with little or no integrated graphics. When needed, graphical elements were pasted onto the sheets of type to produce a camera-ready copy. Aldus Pagemaker publications were printed on a 300 dots-per-inch (dpi) laser printer.

For publications which required integrated graphics or a higher publishing resolution, the Compugraphic Integrator was used. Publications which were published using the Compugraphic Integrator system were first set on a typesetting computer. The typeset files were then transferred to the graphics division of AFESC where they underwent final adjustments and were printed as photographic negatives used to produce printing plates.

During the course of the project, two major documents were published. First was the *FY91 Civil Engineering and Environmental Quality Technology Area Plan*. The text was typeset using Aldus Pagemaker on the Wang 381 computer. It was then printed at 300 dpi on a laser printer. Graphic elements produced by Harvard Graphics computer presentation software and by other means were pasted in.

The second publication produced was the *Air Force Special Edition of The Military Engineer*. Because this publication, being a professional magazine, had to be of extremely high quality, it was produced using the Compugraphic Integrator system. The document was set as described above and the negatives were delivered for printing. The publication will be available in late August of 1990.

C. Application

In-house publication of technical documentation can be of great value to almost any research laboratory. The ability to speedily produce medium and high quality documents which combine text and graphics allows researchers to share their knowledge more quickly than ever before.

The Aldus Pagemaker desktop electronic publishing system can be used by any laboratory that has a personal computer system. The relatively low cost of such a system makes it easy for almost any laboratory to obtain one. The medium-quality product of this system would be best suited to laboratories which currently produce typewritten technical documentation.

For laboratories that have access to a graphic design shop or a typesetting shop, an electronic publishing system similar to the Compugraphic system used in this test would allow the laboratory to produce professional documentation which would have otherwise required a contractor. Such a system is slightly more expensive than a desktop system but offers a higher quality final product.

Section II

Detailed Description of Research

A. Hardware and Software Used

2 Wang 381, IBM PC/AT compatible computers

1 Compugraphic Integrator computer running PowerPro typesetting software.

1 36-pin to 9-pin serial null-modem.

1 Hewlet Packard Laserjet compatible laser printer

Wang Local Communications Network

ProComm communcation software for IBM PC/AT compatible computers

Aldus Pagemaker Version 3.0 for the IBM PC/AT
1.2 Megabyte 5 1/4-inch floppy diskettes
Wang to Compugraphic filter for the Compugraphic
Integrator

B. Methodology

The two Wang 381 computers were set up to run Aldus Pagemaker as instructed in the Aldus Pagemaker documentation. One computer (Wang 381 #1) was connected to and configured for the Laserjet printer. The second Wang 381 (Wang 381 #2) was not connected to a printer. However, it was configured for printing on a Postscript compatible printer in case such a printer was required. Both Wang 381´s were connected to the Wang Local Communications Network. Wang 381 #1 was connected to the Compugraphic Integrator through the null modem cable. ProComm was installed on the Wang to allow it to communicate with the Compugraphic Integrator. The Compugraphic Integrator had its own pre-installed communications software which was configured to run in Asynchronus communications mode. The communication link was set up to run at 4800 bits-per-second.

The first document to be produced was the Technology Area Plan. The individual files of the article were downloaded from the Wang Local Communications Network as

Wang documents by Wang 381 #1 using pre-installed software. The individual files were copied onto 5 1/4-inch floppy diskettes. A page template was set-up on Aldus Pagemaker (Figure 1). The text from each of the documents was placed in the template as instructed by the Aldus Pagemaker documentation. When typesetting of the documents was completed, they were printed on the Laserjet laser printer. Graphic elements were then pasted onto the printed pages, producing a camera-ready copy. Revisions were made to the text and it was reprinted. This process continued until final production.

As mentioned earlier, The Military Engineer required an extremely high printing quality that Aldus Pagemaker could not produce. As a result, it was typeset on the Compugraphic Integrator. The articles for the magazine were downloaded from the Wang Local Communications Network as Compugraphic Integrator text-files by Wang 381 #1. These files were also stored on disk. The files were then uploaded as Compugraphic Integrator text to the Compugraphic Integrator using ProComm. The Compugraphic Integrator text was converted into Compugraphic format using the "WangAtext" filter, available from Compugraphic. The document was then typeset as instructed in the Compugraphic Integrator documentation. Figure 2 provides the typesetting details of the Military Engineer.

The completed typeset file was transferred to the graphics division of AFESC. Here, the supplied pictures were scanned as computer images and integrated into the text at locations specified in the typeset file. Proof copies were made and the typeset text was revised. The revised text was then printed as a photographic negative for the printer.

Section III

Results and Conclusions

While the final product of this project was not printed by the time this report was written, pre-production copies show the system has promise. The Technology Area Plan had undergone several changes by August 10, 1990. The Aldus Pagemaker system enabled the editors to make the changes much more quickly and easily than they could have been made using previous methods. The Technology Area Plan will undergo final publishing in late 1990.

The Compugraphic Integrator system also proved to be very useful. The Military Engineer magazine was restructured several times during typesetting. Such restructurings would have proved difficult and time consuming if the magazine was being produced through a contractor or graphics shop. There were some difficulties with this system, however. The Compugraphic Integrator in the AFESC graphic department was not arranging text on a page in the same way the Compugraphic Integrator in the technical editing division. Consequently, final adjustments of the pages had to be done by the graphic department. Issues of the Air Force Special Edition of The Military Engineer should be available in late August.

Figure 1. Page layout for the Technology Area Plan

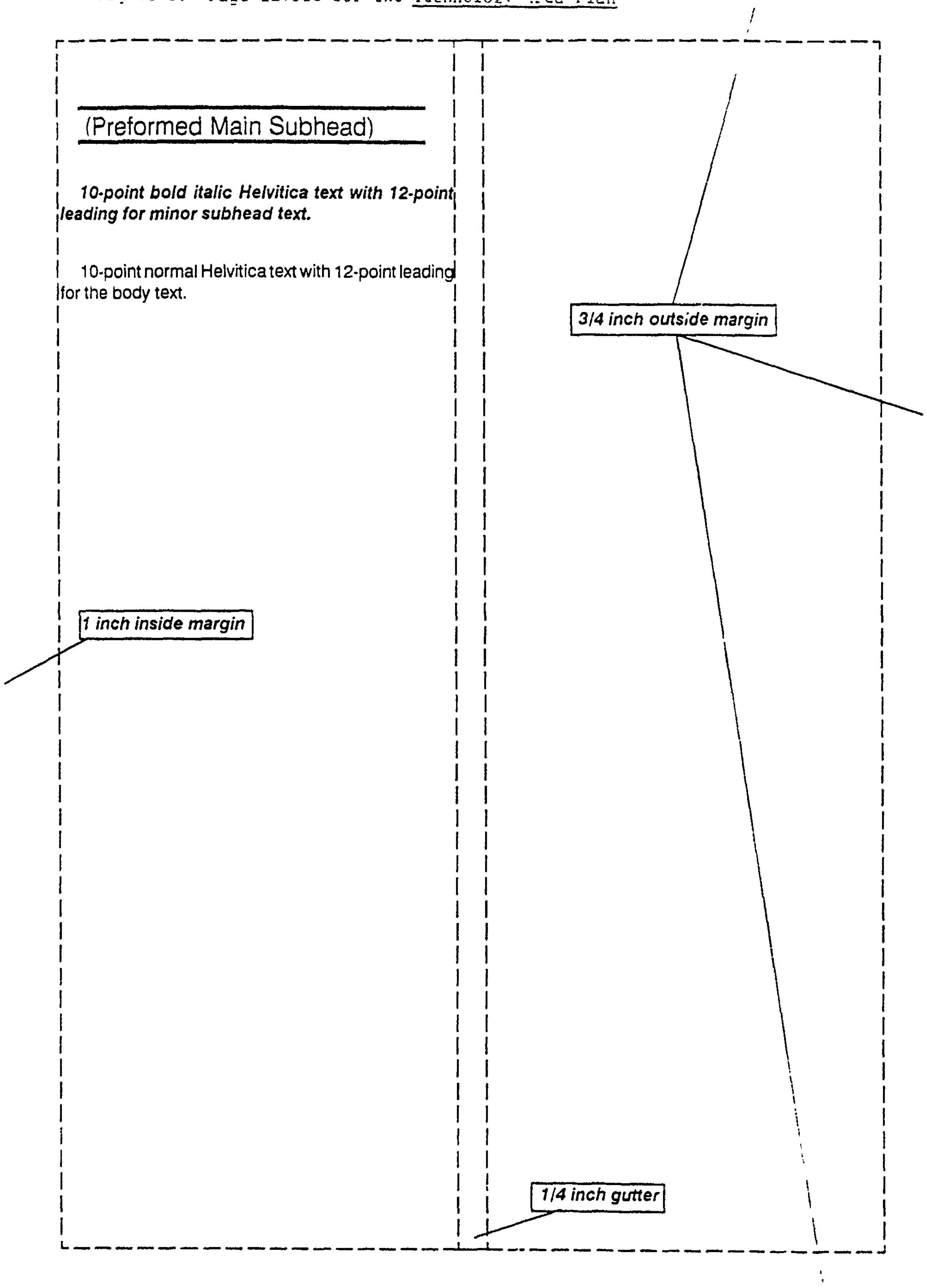
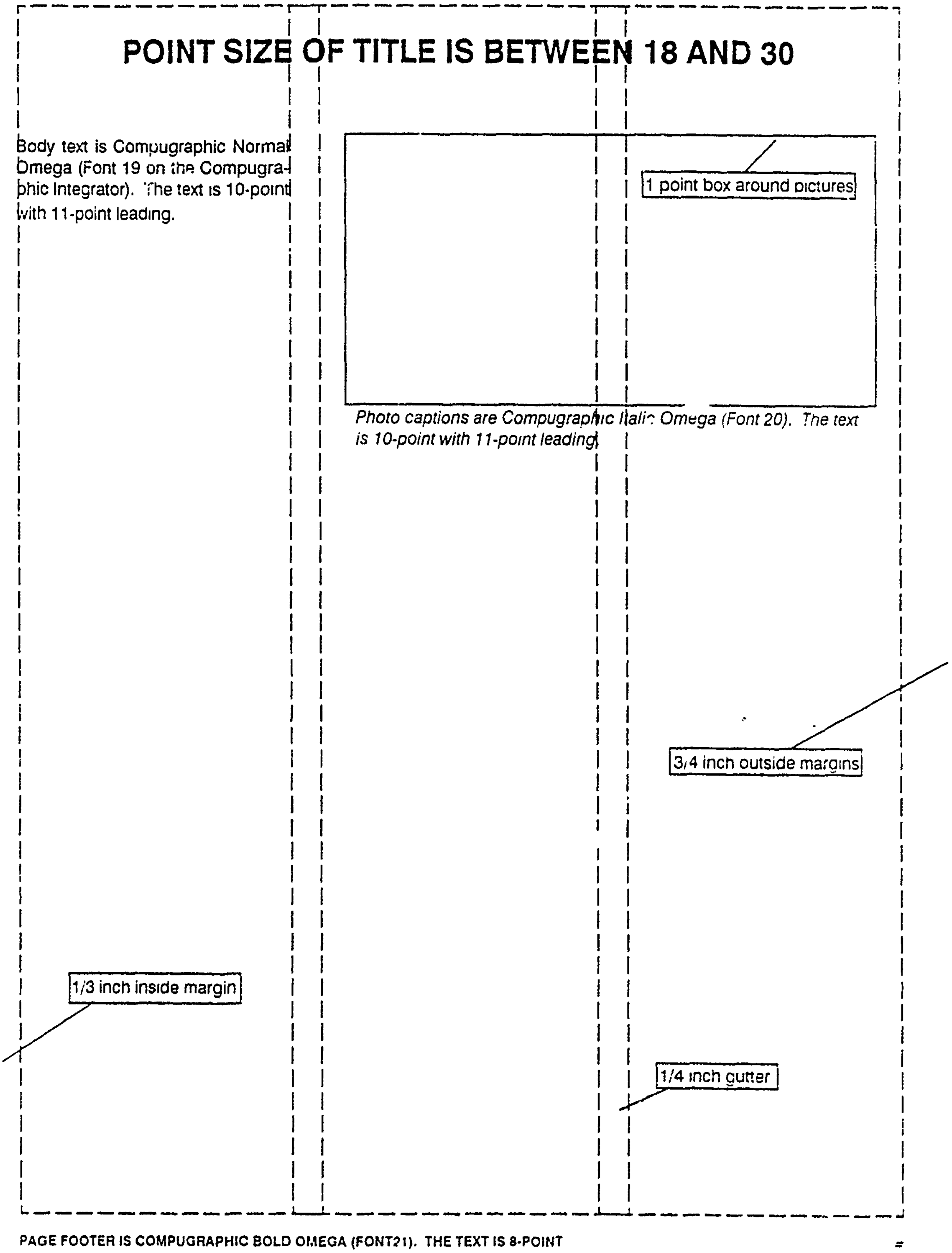


Figure 2. Page layout for The Military Engineer



Summer Apprenticeship at HQ AFESC/DEC

Julie Scruggs

Mentor: Rita Gregory

HQ AFESC/DEC

August 10, 1990

I would like to thank everyone in the Tyndall Engineering and Services Center for helping me and especially the Construction Cost Management Directorate for making my summer apprenticeship worthwhile.

During the time period from June 18 through August 10 I worked for the Construction Cost Management Directorate at Headquarters Air Force Engineering and Services Center, Tyndall Air Force Base, Florida. While working in DEC I learned a great deal about what makes their office so unique. They have an approach to cost analysis that is different from the other services. Instead of using Quantity Take Off (QTO) they use a top down method called Construction Cost Management Analysis System (CCMAS). The CCMAS system allows them to do cost analysis with greater accuracy and speed than is possible with the QTO method. They are currently attempting to make CCMAS the Tri-Service method of cost analysis.

I did a great deal of work with CCMAS by calculating and entering data into the CCMAS tables. The tables are used by the CCMAS program to calculate costs. The tables use such things as area cost factors, equipment factors and freezing degree days to adjust costs for particular structures and locations.

One table that took a great deal of time to update was the T101. I used three different reports, two tables and one ZPBLDG file, to calculate new family categories. First I calculated percentages using the family categories that already existed.

FAM-CAT	QUES-CODE	ANS-CODE	UNI-CODE	CSI-CODE	TOT-FACT
ADMIN	001	01	02	03	0.1354
ADMIN	001	02	02	03	0.0332
ADMIN	001	02	02	05	0.1022

The percentages were calculated for each answer code. For example, answer 01 is 100% of the total facility, 0.1354. Answer 02 has two percentages, one for each CSI Code. For CSI Code 03, 0.0332 is 24.5% of the total 0.1354. CSI Code 05 has a percentage of 75.5. The percentages were then multiplied by the corresponding system factor from the ZPBLDG file for fourteen different Unit Codes. The new Total Facility factors were entered for the new Family Category such as "Hangar" or "Lab".

By attending meetings that included people from other services I could see the CCMAS system explained and demonstrated to them. I also was then able to understand how my tasks related to the entire system and their importance.

The Historical Air Force Facility Costs Book that is published by DEC is also closely related to the CCMAS system. It publishes parametric estimates for Air Force facilities. The data in it comes from the Program, Design and Construction (PDC) system. I assisted Mr. Wesley Hammond in updating it. If the standard deviation was high the facilities were looked at using the PDC. From that it could be determined why there was a large price spread between facilities. Often it was due to the fact that a facility had been classified as new when it was an alteration or it had the wrong category code.

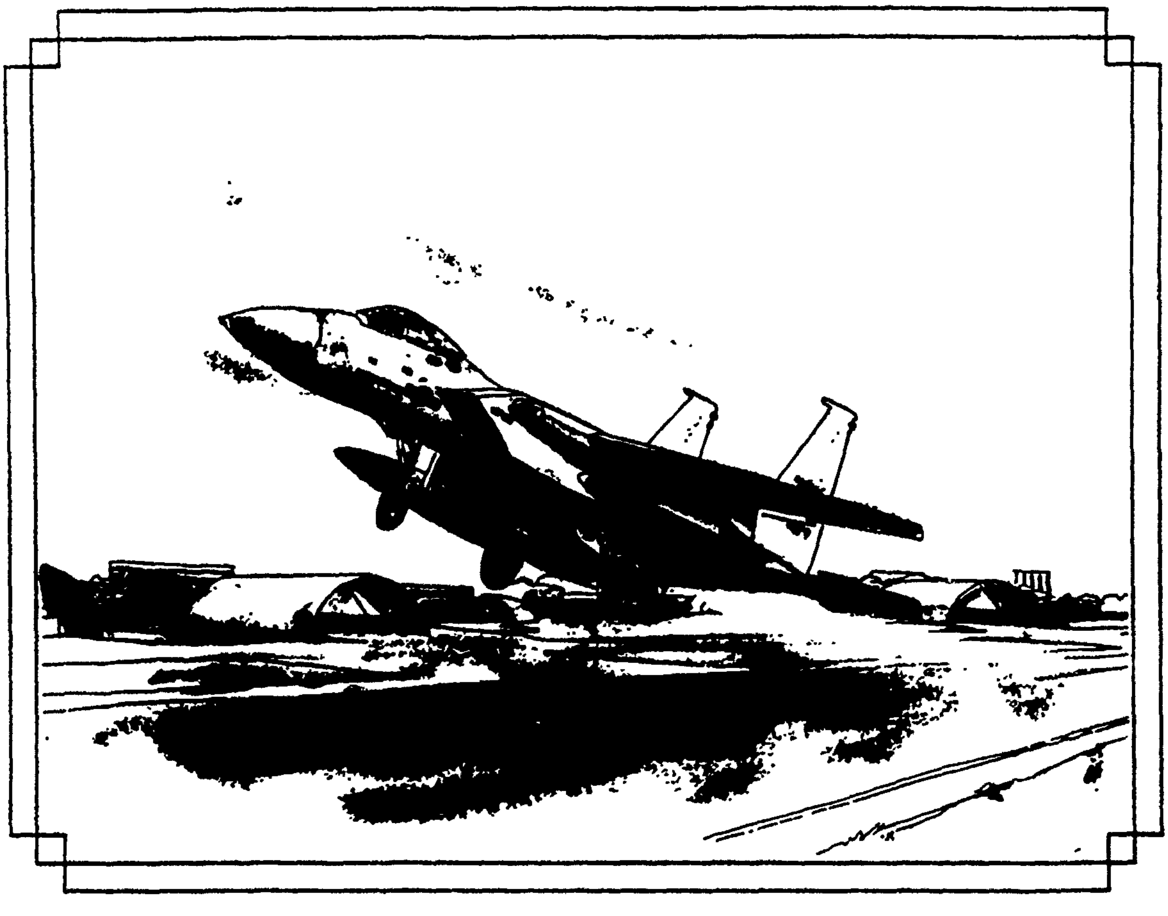
I was also given tours of other areas on Tyndall that related to engineering. I was able to see where and what types of field work were done. I was able to talk to scientists and compare their jobs to those of engineers that I talked to. This was one of my main objectives since one of my main concerns is the distinction between environmental engineering and environmental science.

Michael Stone

Final Report Number 65

No Report Submitted

THE EFFECTS OF HIGH PRESSURE TIRES



Amy L. Thomas
Mentor: Jim Murfee
August 10, 1990
Tyndall Air Force Base

Acknowledgements

I would like to express my sincere gratitude to all of the people who influenced my experience this summer. First, I would like to thank my mentor, Mr. Jim Murfee, who was beneficial in exposing me to the field of engineering. He introduced me to many of the key people at the Air Force Base Engineering and Services Center, all of whom gave me encouragement and support in my future endeavors. To Mrs. Susan Dass, of Applied Research Associates, her guidance and knowledge of the rutting study gave me an understanding of the research process and her duties as my supervisor taught me job responsibility. Also, my appreciation goes to Mr. Bill Dass, Mr. David Timian, and Mr. Tim Patrick of the Pavements Group at ARA who were always willing to help with any problems that arose.

A special thanks goes to Mr. Steve Butler and Mrs. Michelle Newsome of the ARA graphics department in designing my cover page and aiding in the production of the figures accompanying this paper. Thank you to all of the ARA employees who made this summer a memorable experience through all their patience and support. They made my summer a very special one.

Introduction

Beginning in the summer of 1988, construction began on the pavement test sections to be used for the "High Pressure Tire Effects" field test program. Simulated F-15 trafficking was conducted during 1989 followed by calculations continuing through 1990.

During the summer of 1990 damage parameter calculations were done and processing of the optisensor, loadcell, and profilograph data was continued. The optisensor and loadcell data was completed for the heavyweight lane prior to June 1990, and lightweight lane processing was begun and approximately 2500 passes were completed.

Prior to 1988 plans began formulating to test a gyratory pavement. This pavement appeared to achieve better compaction upon use and receive less damage over the same period of time as the Marshall mix. To test and obtain information from this hypothesis an experiment was planned to begin the summer of 1988.

The basic plan of the experiment was to construct two test sections of pavement consisting of gyratory and Marshall sectors. Two loadcarts were prepared, one with five tons of weight and the other with one ton. These were placed over the axles of a high pressure aircraft tire from a F-15 (Figure 1.). Thus simulation of aircraft trafficking was achieved. During the experiment profilographs of the sections were taken with other tests to determine damage incurred.

Construction of the test sections began the summer of 1988 with the laying of the asphalt (Figure 2.). The finished sections had "M" shapes along the length of them (Figure 3). That would later be crucial to the optisensor data.

The section layout of the lanes themselves consisted of twelve sectors (Figure 4 and Table 1). The sectors were of various thickness and composition, and of the twelve, each would be found to last through a number of passes before becoming hazardous. Also, each was damaged differently according to the maximum rut depth (Table 1.).

The "M" shapes would now be the reference to calculate

Figure 1. An F-15 was simulated for the rutting study.

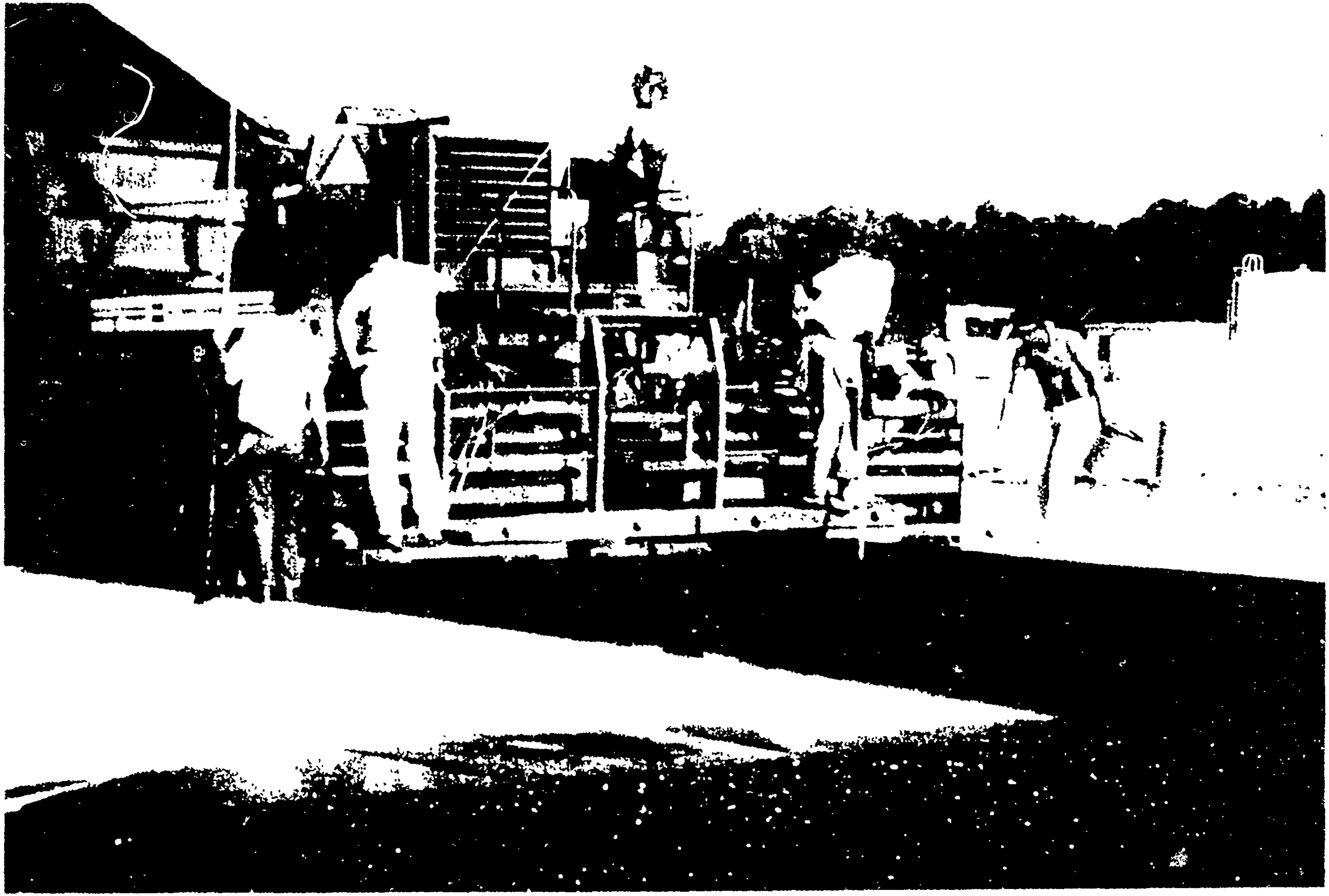


Figure 2. Paver used for laying asphaltic concrete on test section.

Figure 3. Completed test section.

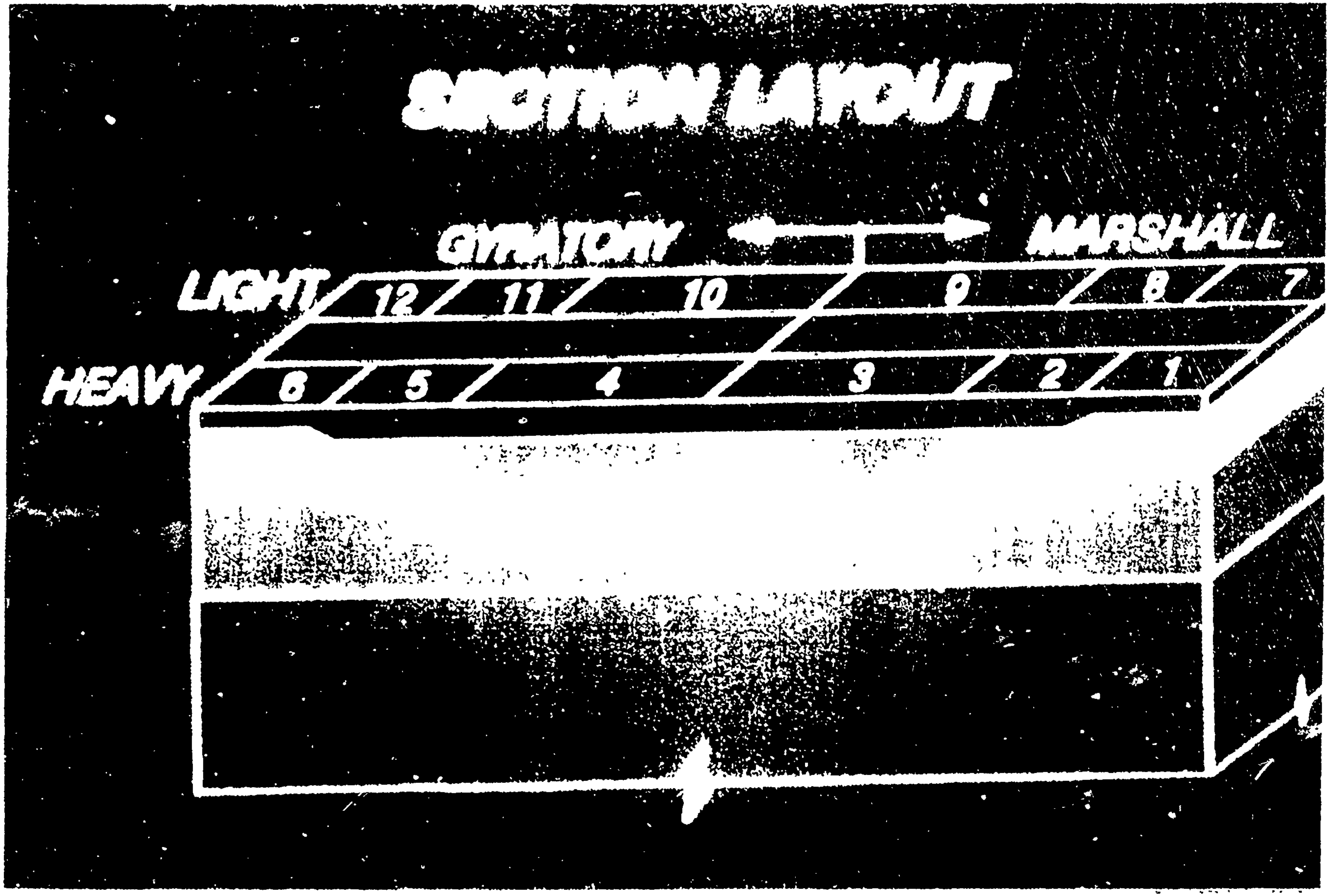


Figure 4. Diagram of the test section layout.

Table 1. Maximum rut depths from representative rut profiles

MIX DESIGN	TEST SECTION TYPE	SURFACE LAYER THICKNESS	STATIONS	PASS NUMBER	MAXIMUM TRUE RUT DEPTH (INCH)
MARSHALL	FLEXIBLE	4 INCH	38-64	3049	1.56
	FLEXIBLE	6 INCH	86-140	5137	2.20
	COMPOSITE	6 INCH	192-304	5817	0.91
GYRATORY	COMPOSITE	6 INCH	326-334	5817	0.32
	COMPOSITE	6 INCH	350-454	10350	0.39
	FLEXIBLE	6 INCH	470-526	10350	0.88
	FLEXIBLE	4 INCH	548-610	9715	1.25

position and velocity of the loadcarts, as shown in Figure 5. Both loadcarts were assembled and loaded to begin trafficking (Figure 6.). A load cell gauge was applied to the tire axle, as shown in Figure 7. The loadcells shown in Figure 7b, judged the amount of applied load incurred during one pass of the loadcart. Each pass contained different points of greater pressure to the tire due to the unevenness of the test sections.

In order to calculate the position and velocity of the loadcart, an outrigger was attached to the bed of the loadcart. A bicycle tire equipped with an optisensor was attached to the end of the outrigger (Figure 8.). The purpose of the optisensor, shown in Figure 9., was to detect each white line of the "M" shape as it was being passed over. These recordings were stored on floppy disks to be processed for further information.

A total of 10,350 passes was made, although some sections were closed off earlier because the damage incurred was hazardous to trafficking. Testing was completed in November of 1989.

During the summer of 1990, damage parameters were calculated from the existing profilographs taken the previous summer. Rut depth and width, area of upheaval, etc. were calculated by a program created by Mrs. Susan Dass (Figure 10.). Profilographs were taken periodically during trafficking. A sample profilograph and demonstration are shown in Figure 11. To begin calculations, a number of

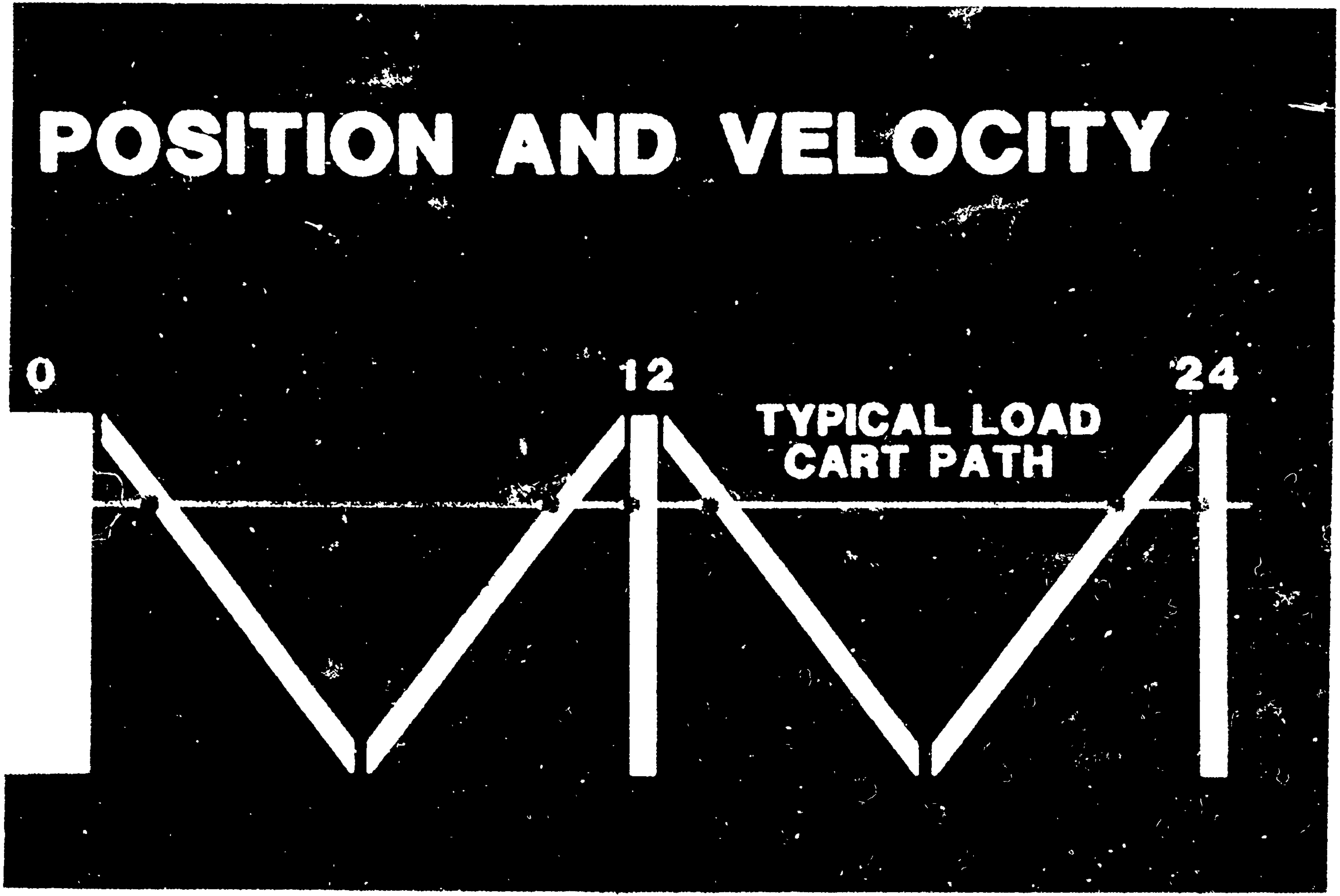


Figure 5. M-shaped patterns used for calculating loadcart position and velocity.

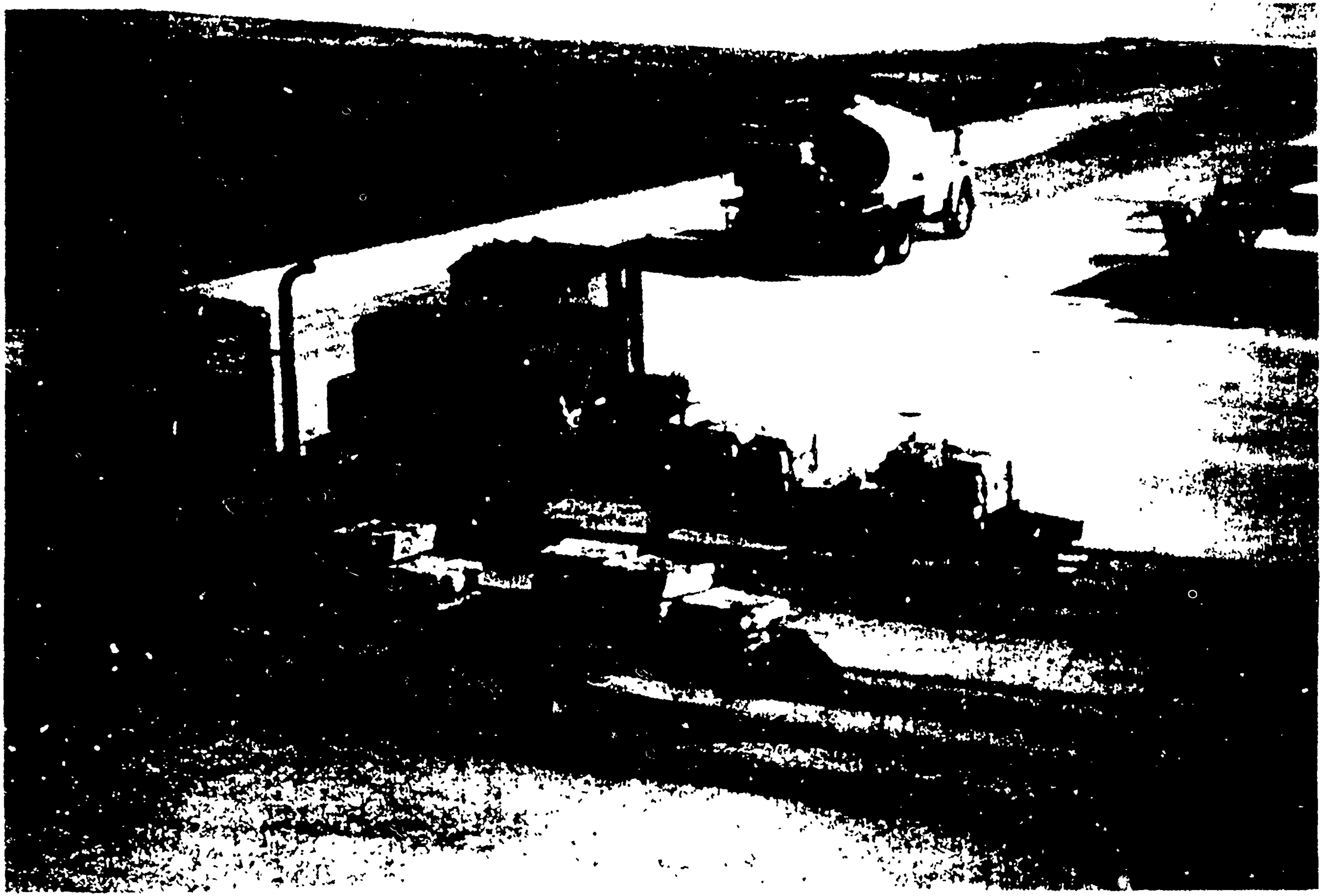


Figure 6. Loadcarts used in trafficking.

Figure 7. Load cell gage attached to tire axle for monitoring applied load during trafficking.

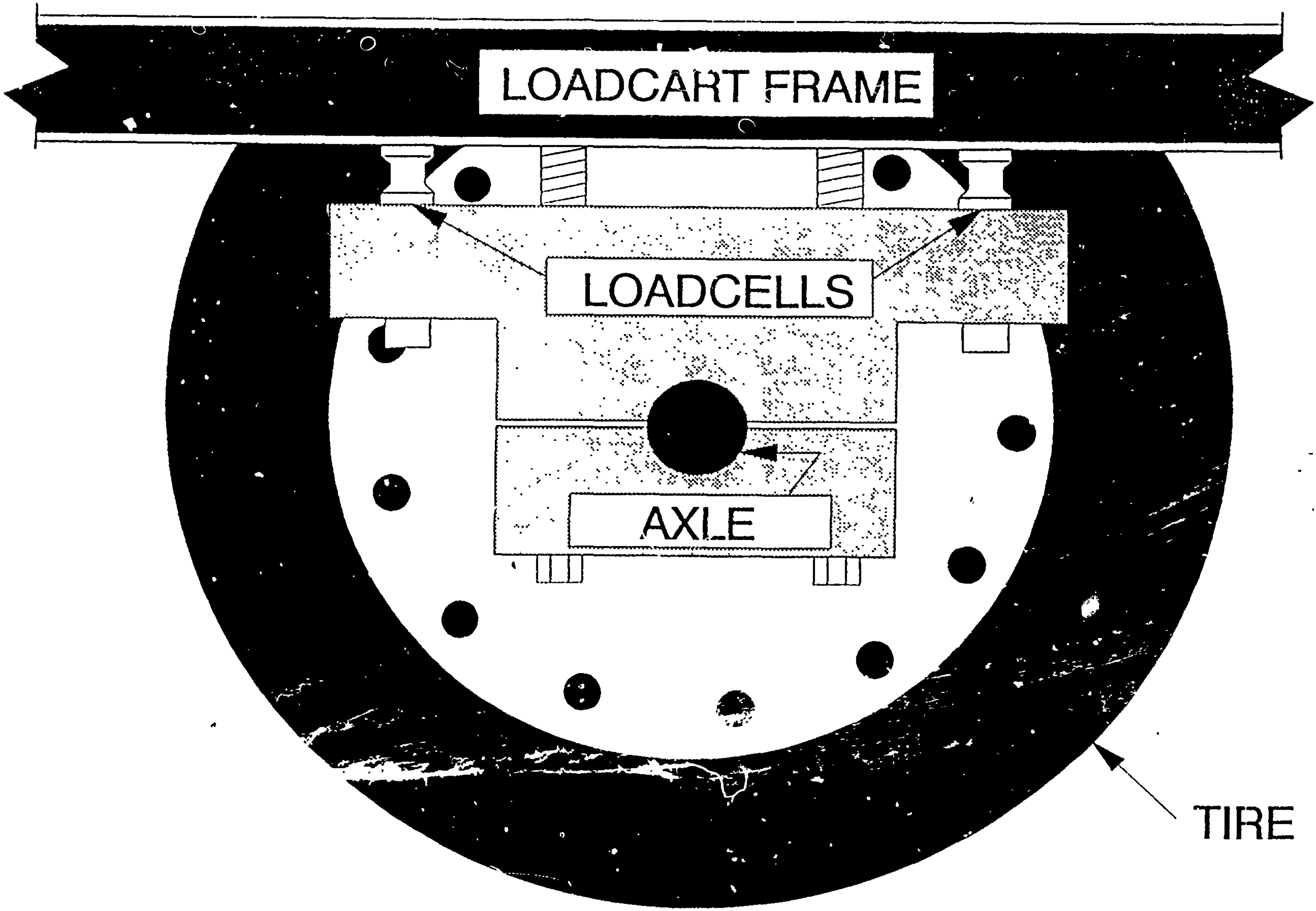


Figure 7b. Position of Loadcells in the Load Wheel Support Assembly.

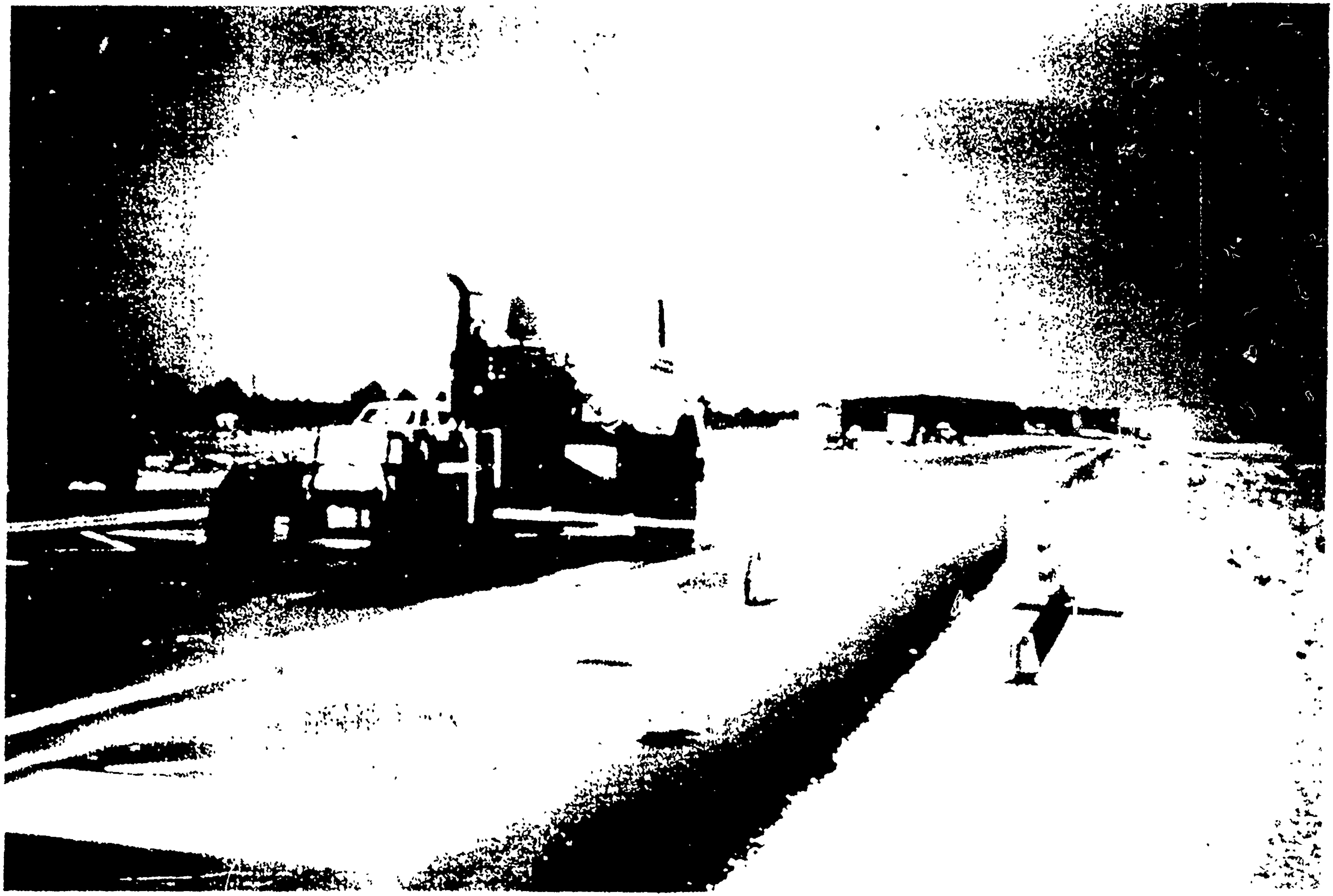


Figure 8. Testing configuration for applying and monitoring the load.

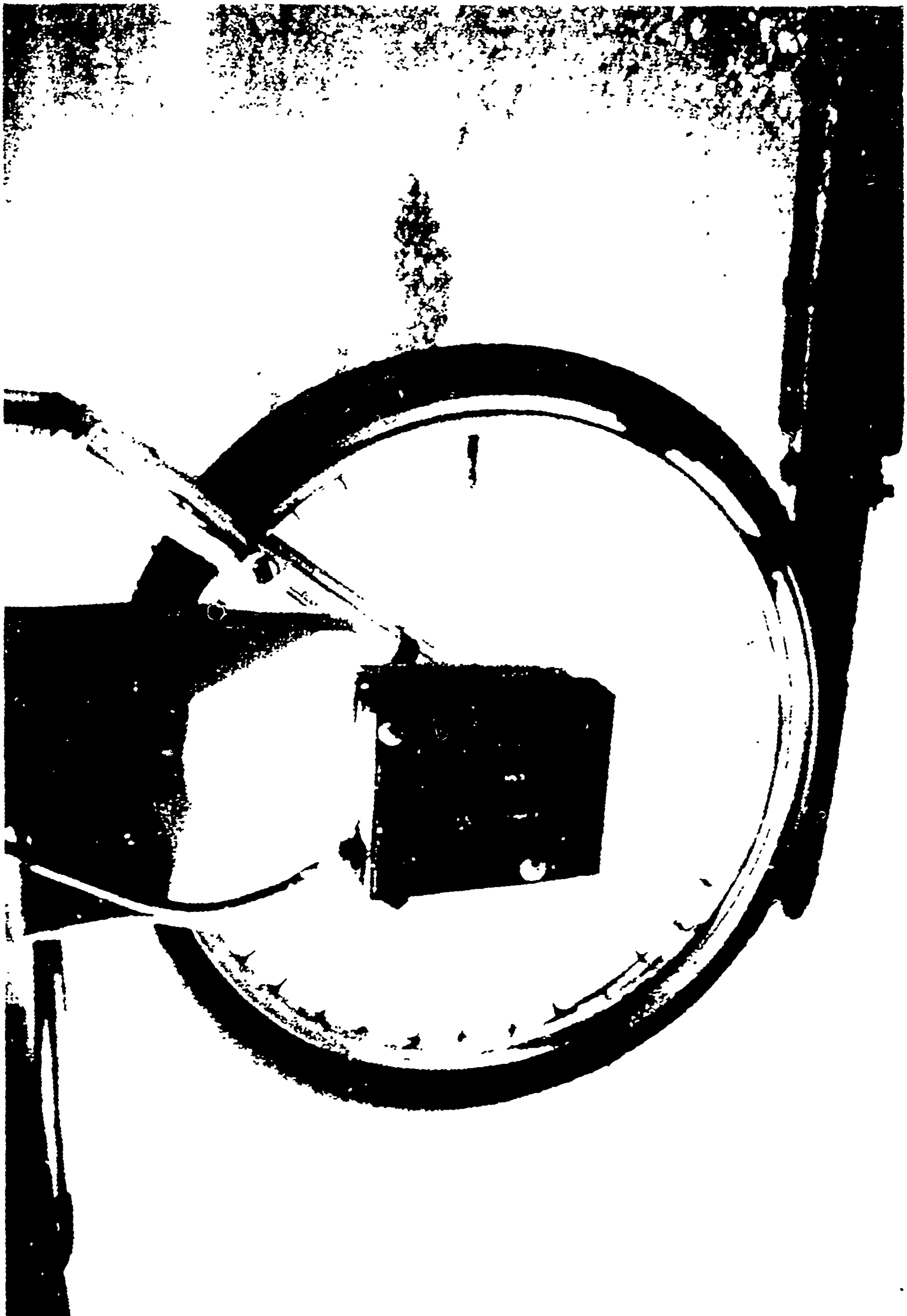
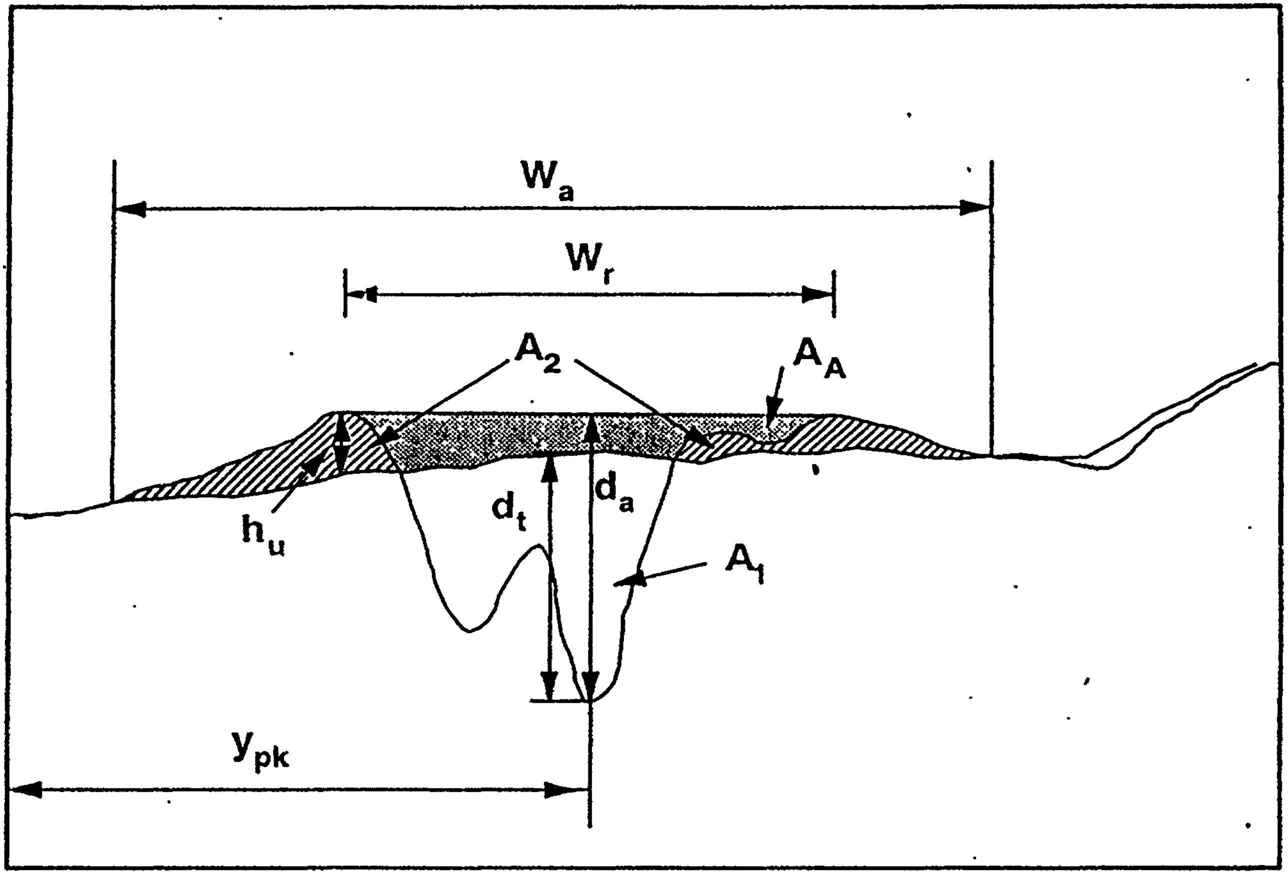


Figure 9. Optisensor gage used to detect white line "M" shapes.



y_{pk} = lateral position of d_a

d_t = true rut depth

d_a = apparent rut depth

h_u = upheaval height

W_r = apparent width of rut

W_a = actual width of rut

A_1 = area of rut below original profile

A_2 = area of upheaval

A_A = additional apparent rut area

Figure 10. Damage parameter definitions

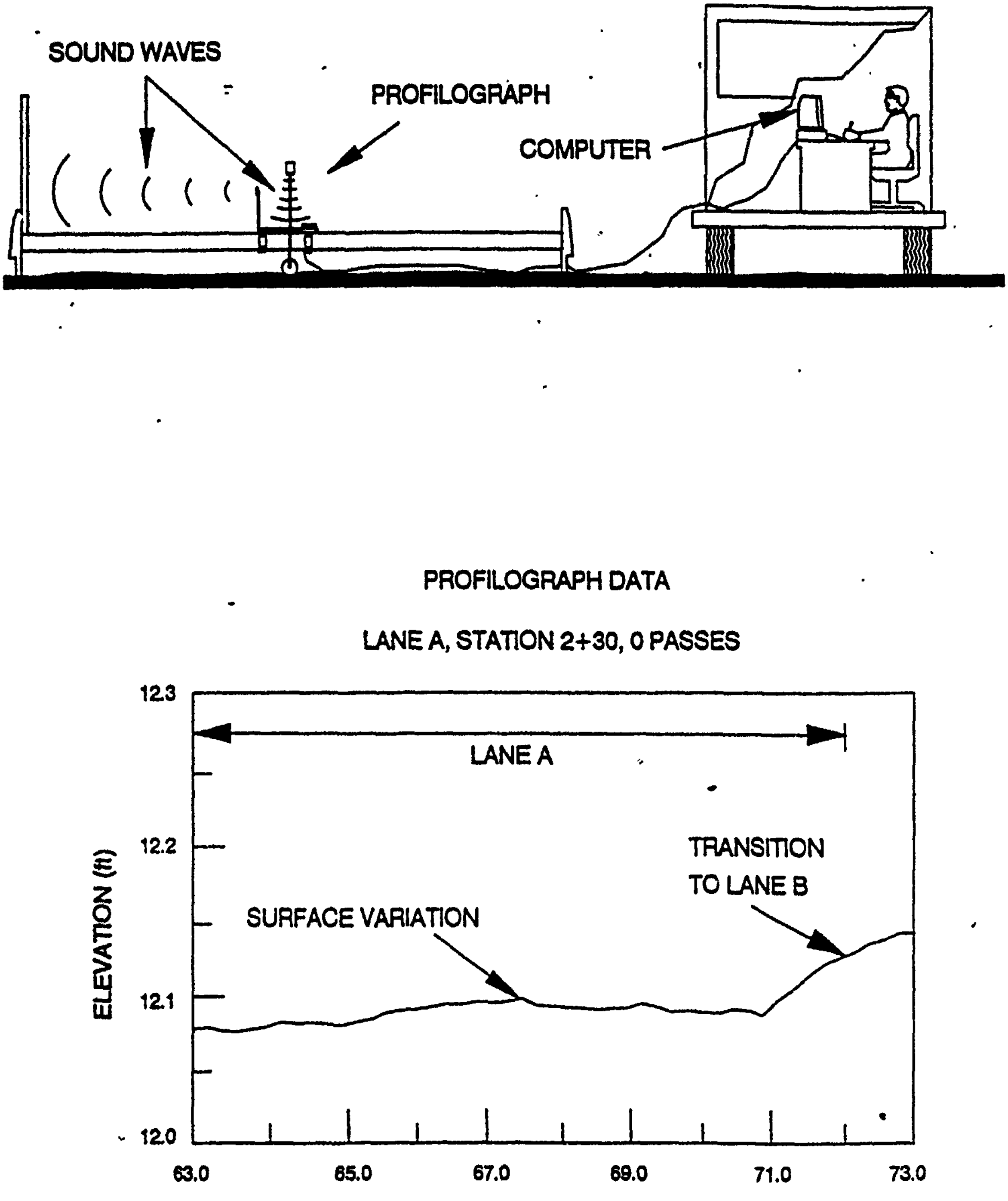


Figure 11. Schematic of Computerized Profilograph with Data Output.

profilographs was done by hand in order to judge the correct method of calculation.

Also, beginning in the summer of 1990 processing began on the lightweight lane optisensor and loadcell data. Information contained on the floppy disks was transferred to hard disks where they were processed and checked for possible mistakes. They were then recalculated by hand and reprocessed until there was a low percentage of error. The new calculations would later be processed for further data. At the conclusion of the summer about one-fifth of the processing had been completed.

The gyratory pavement has proven to be substantially more efficient than Marshall. This is due mostly in fact to its higher percentage of compaction. Continuing experimentation will decide the best thickness desired and relative longevity of the pavement itself.

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The Effects of High Strain Rates on Sand

Submitted to

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AFOSR High School Apprenticeship Program
The Engineering and Services Center,
Tyndall Air Force Base,
Florida

by

Michael Keith Thompson
High School Apprentice
Bay High School
Panama City, Florida

August 10, 1990

Acknowledgements

The author would like to thank the following people for their support and advice: Captain Steve Kuennen, mentor, Dr. C. Allen Ross, visiting professor from the University of Florida, Dr. George Veyera, visiting professor from the University of Rhode Island, and all the engineers of the 9742 building.

Description of Research and Procedures

Through the Air Force Office of Scientific Research High School Apprenticeship Program, the author was given a position as assistant to Dr. C. Allen Ross of the University of Florida. Dr. Ross introduced the author to the research being conducted by the Materials Testing Branch of the Engineering and Services Center, Tyndall Air Force Base, Florida, whose purpose is to test, research, and design assorted materials used by the Air Force for construction of a variety of military structures (examples include materials used in air strips and defense shelters). Current research involves the study of the effects of stress on concrete, foam, and sand (the latter being the subject of this report). Dr. Ross along with Dr. George Veyera of the University of Rhode Island, conducted high strain-rate tests on small samples of sand (primarily Ottawa 20-30 sand) in order to simulate the loads of conventional military explosives. Results from these tests can be used to estimate the stress loads encountered by the walls of underground bunkers. Using the estimations, engineers can design the proper design for which the typical underground shelter can then survive close blasts.

Specimens of sand consisted of cylindrical samples 4 in.

in length (10.16 cm) and 2 in. in diameter (5.08 cm) contained in one of three types of steel sleeves, 1 in. (2.54 cm), 1/2 in. (1.27 cm) or 1/16 in. (0.159 cm) thick. The sand was then kept in place by 1/4 in. (0.635 cm) thick steel wafers containing o-rings along their border (typical specimen is shown in diagram 1). All Specimens were packed to a dry density of 107 pcf (1.715 g/cc). Specimens were tested with two varying conditions. The first of these conditions was the degree of the specimens confinement, or in other words, which sleeve was used: 1 in. thick, 1/2 in. thick, or 1/16 in. thick which provided, relatively, high, medium, or low confinement. The second of these conditions which varied was the saturation level of each specimen. Saturation refers to the amount of void spaces filled with moisture, where void spaces are the spaces between particles of sand. The amount of void space in a specimen can be found using the following equation:

$$\text{Void Content} = (\text{Volume of Specimen}) \times \left(1 - \frac{\text{Dry Density of Sand}}{\text{Solid Density of Sand}}\right)$$

After finding the void content of the specimens, one multiplies by one of the selected saturation levels, 0%, 20%, 40%, 60%, 80%, or 100%, and the density of water (1 g/cc) to calculate the mass of water to add to each specimen (the calculations used to create each specimen are located in appendix A).

Specimens were packed in four equal layers each of 1 in. (2.54 cm) length using a Proctor Hammer to keep an exact count of the work put into packing each specimen (the Proctor Hammer used was calibrated for one foot-pound of work for each blow and a chart of the average blow counts for each saturation and container is located at the end of this report. Steel pistons were also used to correctly pack each sample to the proper depth (or density). Each piston (of which there were four, one for each layer) was 5.5 in. (13.97 cm) long and 1.975 in. (5.017 cm) in diameter with croppings around their circumference which would stop against a flange when its layer had been packed to the proper depth (diagrams 2 and 3 contain schematics of their design and the set up for packing each layer). Before packing a specimen its steel sleeve was sprayed with a Teflon coat (RemGrit TFL 50 Dry Lubricant manufactured by DuPont) to reduce friction between the sand and the sleeve.

After being prepared, specimens are then tested in the Split Hopkinson Pressure Bar or SHPB (diagram 5). The SHPB is composed of three main parts: a gas gun, an incident bar, and a transmission bar. The gas gun itself is made out of steel and contains within itself an inner chamber, an outer chamber, a supply of compressed gas (nitrogen gas was used for the Tyndall gas gun), a nylon seal, a barrel, and a striker bar (there are a variety of striker bars accessible for the gas gun, but the one used for the Ottawa 20-30 tests was 8 in. (20.32 cm) long, all of the striker bars are 2 in. in diameter). The inner chamber of the gas gun is filled until the nylon ring seal is pushed up against the opening of the outer chamber, thus sealing the outer chamber air tight. The outer chamber is then filled to a given pressure (25 PSI for the Ottawa 20-30 tests). When a firing switch is thrown, a firing release valve releases the gas from the inner chamber. The nylon seal opens and the gas from the inner chamber propels the striker bar through the barrel. A timer on the end of the barrel is used to find the velocity of the striker bar just before it impacts into one end of the incident bar, which is placed at the end of the gas gun barrel. A stress wave travels through the incident bar and into the specimen, which is placed between the incident and transmission bars (note- a little bit of Moly Lubricant grease was placed between the wafers and the ends of the bars to provide better contact). The specimen reflects part of the pulse and transmits the rest. Strain gauges (Measurements Group, Inc. model EK-06-250TB-10C) located 40 in. (1.016 m) from either end of the specimen pick up signals from the stress wave as it passes through the apparatus. These signals, registered in volts, go to Signal Conditioning Amplifiers (Measurements Group, Inc. 2311) that amplify the strain gauge signals so that they can be read by an oscilloscope (the Nicolet 4094B Digital Oscilloscope with the Nicolet XF-44 was used at Tyndall). The oscilloscope reads three main pulses: an incident pulse, a reflected pulse, and a transmitted pulse. The data is then stored on floppy disk (using the XF-44, an accessory to the oscilloscope) for further reference. The specimen is disposed of, and a new one is packed for testing.

Two figures are calculated from test data, transmission ratio and wavespeed. The transmission ratio is the ratio of the peak transmitted stress to the peak incident stress. It provides a measure of how much the stress the specimen passes. To calculate it one merely finds the maximum (or minimum because compressive pulses register as negative) voltages of the incident and transmitted pulse and then divides the transmitted by the incident (note-for the Ottawa 20-30 tests the Signal Conditioning Amplifiers were set to scale the incident signal by a gain of 100 while the transmitted pulse was scaled by 1000. This difference was accounted for by multiplying the peak incident stress by 10 before making the ratio calculation.). Wavespeed refers to the speed in which the stress wave travels through the specimen. The first step to calculate wavespeed is to find approximately where each pulse begins. When these times have been satisfactually determined, the difference is taken between them and then a time of 400 us (microseconds) is subtracted to account for the 40 in. of steel between each strain gauge and the specimen. This is now the time (in microseconds) required for the stress wave to pass through the specimen. Converting the time to regular seconds and dividing it into the length of the specimen, 4 in. (0.1016 m), gives the speed of the stress wave in inches per second (or meters per second). (An example of a typical data sheet with calculations is located at the end of this report.)

Corresponding tests were done with an MTS (Materials Testing System) static load hydraulic press. Specimens were loaded slowly (over a period of ten minutes) up to a stress of 1687 lbs./in^2. Throughout the loading procedure, the displacement of the sand (a negative change in length) was recorded and a graph, stress by strain, was produced. Using these graphs, approximate Young's Modula (stress/strain constants) for the Ottawa 20-30 sand at various saturations could be calculated. These were calculated by taking the slope of the secant line from the zero point (stress=0, strain=0) to the point when the load and the displacement are peaked (5300 lbs. of pressure and .0650 in. displacement or 1687 lbs./in^2 of stress and a strain of .01625).

Beyond the tests with the Ottawa 20-30 sand, tests were also performed with local Tyndall beach sand which is much finer and has angular particles as opposed to the rounded grains of the Ottawa 20-30. There was, however, less emphasis on the study of this sand due to the lack of time. Results from SHPB tests have been recorded and are comparable to the Ottawa data.

Observations and Results

Hypothetically it was expected that all of the curves for the graphs of wavespeed, transmission ratio, and blow count (with the x-axis measuring saturation level) would all be bell shaped with the points at 20%, 40%, and 60% representing the peaks of the curves. Moreover it was expected that the 1/16 in. sleeve tests would fall below the 1/2 in. sleeve tests and that the 1/2 in. sleeve tests would fall below the 1 in. sleeve tests without crossing over each other, however this was not the case. It was presumed that because the thinner sleeves provided less confinement, the energy from an incident pulse would be more likely to dissipate out the sides of a specimen rather than through its axis. Therefore transmission ratios and blow counts would be smaller. Nevertheless plots of the data show an erratic behavior in the 1/2 in. and 1/16 in. sleeve tests, and the validity of these tests is more questionable than those with the 1 in. sleeve. With the 1 in. sleeve tests, though, the expected results are seen with peaks in the 40% saturation range with both the Ottawa and Tyndall sand.

Observations of the Program Aside From the Main Research

Although the SHPB tests of the Ottawa and Tyndall sand were the main focus of this apprentices work, many other experiences were gained out of the High School Apprenticeship Program. The author was introduced to the type of work involved in research engineering and was able to learn basic concepts of soils and their behavior. Most important to the author, though, was the chance to see the proceedures of advanced scientific research put to work. Because the author plans to someday pursue his own research projects as a researching collage professor, he found the oppertunity very enriching. The author wishes to see the program continued and hopes that someday he may be able to offer the same help to somebody like himself when he is older.

Appendix

Calculations of Water Weights for Specimen Preparation

Chosen dry density of specimen: 1.715 g/cm^3

Solid density of Ottawa 20-30: 2.65 g/cm^3

Volume of specimen: height*(diameter)^2*pi/4

= 10.16 cm * (5.0927 cm)^2 * 3.1415/4

= 206.96 cm^3

Void content: volume*(1-(dry density/solid density))

= 206.96 cm^3 * (1-(1.715 g/cm^3)/(2.65 g/cm^3))

= 72.67 cm^3

Saturation*Void content*Density H_2O=Water mass specimen

0.0 * 72.67 cm^3 * 1 g/cm^3 = 0 g

0.2 * 72.67 cm^3 * 1 g/cm^3 = 14.534 g

0.4 * 72.67 cm^3 * 1 g/cm^3 = 29.068 g

0.6 * 72.67 cm^3 * 1 g/cm^3 = 43.602 g

0.8 * 72.67 cm^3 * 1 g/cm^3 = 58.136 g

1.0 * 72.67 cm^3 * 1 g/cm^3 = 72.67 g

1990 USAF-UES HIGH SCHOOL APPRENTICESHIP PROGRAM

Sponsored by the
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Conducted by the
Universal Energy Systems, Inc.

FINAL REPORT

Centrifuge Modeling of Explosive Induced Stress Waves in Unsaturated Sand

Prepared by:	Jeff Ward
Mentor:	Mike Womack
Research Location:	HQ AFESC/RDCM Tyndall AFB FL
Date:	August 8, 1990

I. Acknowledgments

I would like to extend my thanks to everyone I came in contact with at work. Everyone was friendly and seemed to always have that extra ten or fifteen minutes to help me with any problem. More specifically, I want to thank Dr. Wayne Charlie and his graduate student, Andy Walsh, for allowing me to work with them. They made me feel like I was an important part of their research project. I would also like to thank Mike Womack for his warm smile and support throughout the entire eight weeks. I would also like to thank Bill Naylor, who operated the centrifuge, and Mike Purcell, who took the time to set and detonate the explosive charges.

II. INTRODUCTION

This report presents the results from a series of explosive tests conducted on unsaturated compacted sands. Tests were conducted at either 0, 20, 30, 40, 60, or 80 percent saturation and were run on a centrifuge at 1 or 30 g's. Conducting a test at 30 g's would allow us to test at prototype stress levels. One explosive (0.8 gram) was placed in each of the three cylinders. When detonated at 30 g's, the 0.8 gram explosives simulated the blast of a 21.6 kilogram explosive. Wave speed and peak stress was recorded from each test in order to find the effects of moisture content on stress transmission, stress wave velocity, and peak stress. These results are important to the Air Force because many crucial structures use compacted soil as backfill. Of particular importance are bombs that penetrate into the ground and then detonate in the compacted soil surrounding underground shelters.

III. GENERAL DESCRIPTION OF RESEARCH

A: What was done

A series of explosive tests were conducted on compacted sands in order to find wave speed and peak stress in different saturation levels of soil. Each test was conducted on the centrifuge at 1 or 30 g's. The tests consisted of three cylinders with Tyndall beach sand compacted in four 2.54 cm layers to density of 1600 kg/m^3. The majority of the tests were conducted at 30 g's because it allowed us to test at prototype stress levels.

A 0.8 gram explosive was placed in each of the three cylinders. When detonated at 30 g's, the 0.8 gram explosive simulated the blast of a 21.6 kilogram explosive. Wave speed, peak stress, length of sample, and weight of sample were recorded from each test.

B: Theory of Centrifuge Modeling

The tests were conducted on the centrifuge because the centrifuge provides an inexpensive alternative to full scale prototype models. Results from tests conducted at one g are stress dependent and therefore non-linear. A scaled model above 1 g is able to be tested at prototype stress levels. The theory of centrifuge modeling says that stresses at the same geometric points in the prototype at one g and the model at n g's should be the same.

The size of an explosive required on the centrifuge to model a full scale prototype scales N^3 if identical explosives are used. For example, 1000 kg of PETN can be simulated in the centrifuge with one gram of PETN at an acceleration of 100 g's. Table 1 presents some centrifugal scaling laws. These scaling laws will only hold true if the material properties are the same in both the scaled model and the prototype.

SCALING RELATIONS

QUANTITY	PROTOTYPE	MODEL
LENGTH	N	1
AREA	N^2	1
VOLUME	N^3	1
VELOCITY	1	1
ACCELERATION	1	N
MASS	N^3	1
FORCE	N^2	1
ENERGY	N^3	1
STRESS (Force/Area)	1	1
STRAIN (Displacement/Unit Length)	1	1
DENSITY	1	1
ENERGY DENSITY	1	1
TIME (Dynamic)	N	1
TIME (Diffusion)	N^2	1
TIME (Creep)	1	1
FREQUENCY	1	N

(TABLE 1)

C: Purpose

The purpose of this study is to see if different saturation levels of sand will affect blast-induced stress wave velocity, stress transmission, and peak stress.

D: Application of Results

These results are important to the Air Force because many crucial structures utilize compacted soil as backfill. Of particular importance are bombs that penetrate into the ground and then detonate in the compacted soil surrounding underground shelters.

IV. DETAILED DESCRIPTION OF RESEARCH

A: Methodology, Equipment, Data Analysis

We compacted Tyndall beach sand into four 2.54 cm layers. Each layer was compacted to density of 1600 kg/m^3 at every moisture content in order to give the required saturation. Samples were tested at saturation levels 0, 20, 30, 40, 60, and 80 percent. The sand was compacted in a thick walled stainless steel cylinder. Each cylinder was 15.88 cm tall and 5.08 cm in diameter. Each test was run with three packed cylinders.

We used two piezo-resistive carbon resistors to measure our stress waves in the soil. The resistors are 4 mm long and 1.5 mm in diameter. The 1/8 watt resistors were placed between the first layer and second layer (resistor A) and another between the third and fourth layer (resistor B). The resistors wers 5.08 cm apart. These resistors are used as a quarter bridge and measure pressure, which is recorded as volts. These resistors were calibrated in order to give us stress measurements at each voltage. These carbon resistors were utilized because of their low cost and ready availability, ability to give a fast response time, and the ability for static calibration.

A Reynolds Model Mk-83 (0.8 gram) detonator was placed in each of the three cylinders. Each explosive

was instantaneous. The explosive charges were placed in styrofoam, which was then placed in the cylinder. The bottom of each detonator was placed on top of the soil. Scaled, the explosive was equal to 21.6 kg.
The voltage and time output from the resistors was amplified (gain: 50) and recorded on an onboard transient data recorder (TDR). The TDR had 16 channels and 256 Kbites of memory per channel. The TDR recorded at a rate of one million points per second. The channels were triggered by a signal from the blasting machine. A video camera was mounted on the centrifuge and a VCR recorded each test.

Before each test we measured the length of the sample, volume, dry mass, water mass, water content, and percent of saturation. After each test we measured the length of the sample in order to find the volume after the blast. We also took a moist mass and then a dry mass of the sample. By these results we found a level of saturation and water content. A sample of the data sheet is given in figure 1.

Wave speeds were found by taking the time difference between the trigger (0 micro sec.) and the arrival time at resistor A (velocity 1), between the trigger and arrival time at resistor B (vel. 2), and between the arrival times of resistors A and B (vel. 3). Then this number is divided into the respective distance the wave travels to reach that resistor.

CENTRIFUGE TEST

DATE 7/23/90
TIME 12:00 P STORED 136 G's 30
TEST 30-20-3
TARGET SATURATION 20 %
SAND TB
TARGET DENSITY 1601.2 kg/m³
OPP. ANDY WALSH
SPECIMEN DIAMETER 5.446 cm Area 23.29 cm²
SPECIFIC GRAVITY 2.65
1lb.= 0.4534 kg 1in.= 2.54 cm

SPECIMEN	CYL. 1	CYL. 2	CYL. 3
PRETEST			
LENGTH(cm)	10.16	10.08	10.08
VOLUME(cm³)	236.63	234.78	234 78
DRY MASS (g)	378.8	378.8	378,8
MOIST MASS (g)	18.78	18,78	18,78
WATER CONTENT (%)	4.95%	4.95%	4.95%
SATURATION (%)	20%	20%	20%
POST TEST			
DEPTH FROM TOP(cm)	5,97	5.56	5.72
LENGTH (cm)	10,00	10.32	10.16
VOLUME (cm³)	232.9	240.35	236.63
MOIST MASS (g)	298.1] 679.8	293.0] 676.6	294.3] 674.8
DRY MASS (g)	662.3-298.1=364.2	658.8-293.0=365.8	657.3-294.3=363.0
WATER CONTENT (%)	17.5/364.2 = 4.81%	17.8/365.8 = 4.87%	17.5/363.0 = 4.82%
SATURATION (%)	18.35%	17.41%	17.56%
	e = 0.695	e = 0.741	e = 0.728

GAGES	1A	1B	2A	2B	3A	3B
Ohms	1019	1054	1048	1047	1058	1010
Depth (cm)	2.54	7.62	2.54	7.62	2.54	7.62
Gain	50		50		50	
Pretriger (volts)	0.0195	0.0440	0.0537	0.2441	0.0293	0.0293
1st Arrival (micro sec.)	35	112	36	112	37	112
(volt)	-0.0293	-0.0293	-0.0098	0.1465	-0.0147	-0.0342
1st Peak (micro sec.)	43	123	44	123	43	122
(volt)	1.9336	1.1670	1.9678	1.3916	2.1973	1.2793
2nd Arrival (micro sec.)	61	142	60	142	62	142
(volt)	0.6738	0.3320	0.8106	0.8252	0.9326	0.2051
2nd Peak (micro sec.)	70	150	70	150	70	149
(volt)	2.8711	1.2451	3.0566	1.5332	4.0088	1.1084
Max. Peak (volts)	3.4815	1.2451	3.2471	1.5332	4.0088	1.2793
Calibration ($\frac{PSI}{VOLT}$)						
Wave Velocity ($\frac{m}{s}$)	657.7		668.4		677.3	

NOTES:

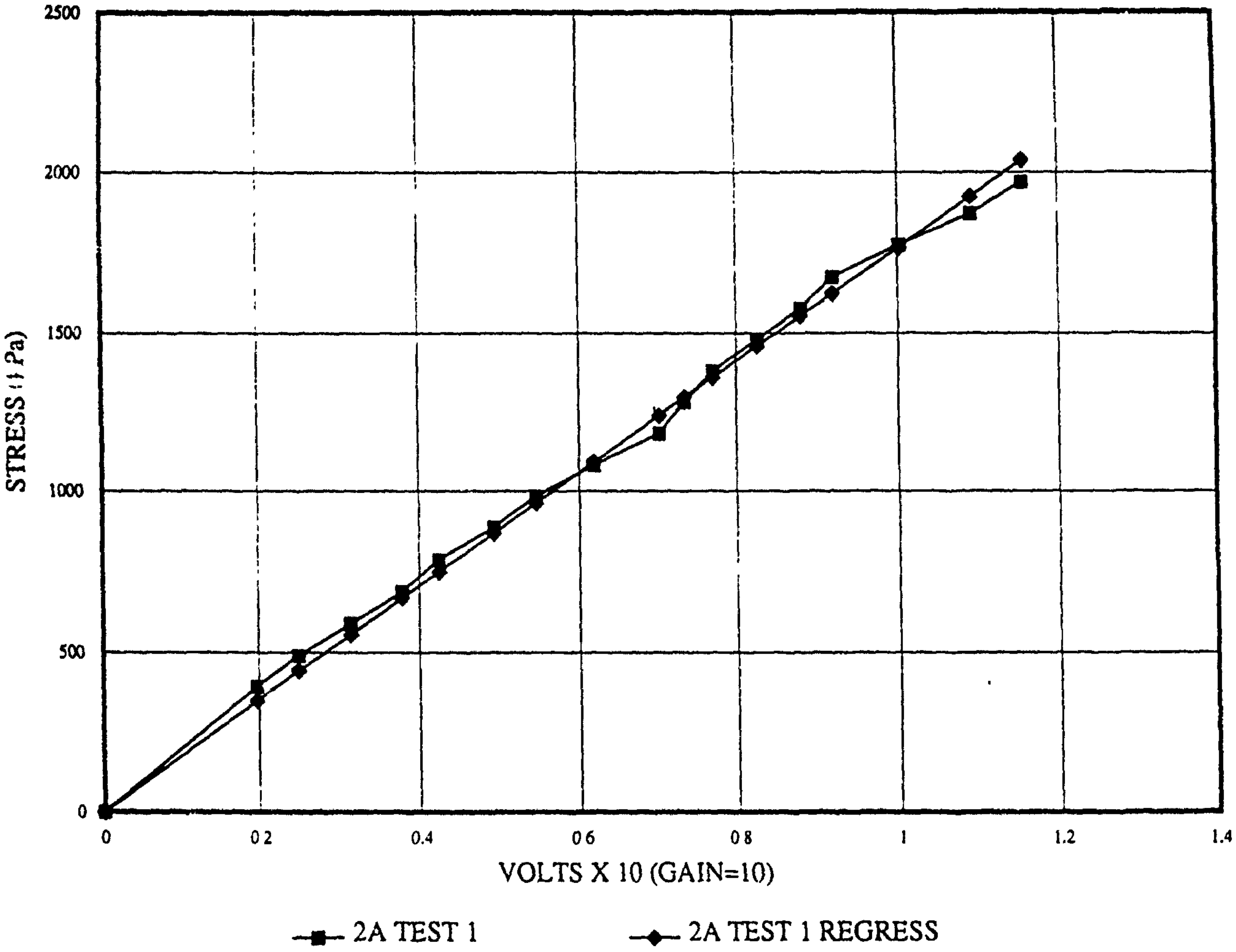
Accel: 200 G's PRETRIG: 0.2930 V
MAX PEAK. 375 μs
~10 V

(FIGURE 1)

For Example: (from fig. 1, resistors 1A and 1B)

velocity = d/t = $0.0508m/112x10^{-6}s-35x10^{-6}s$ =
$0.0508m/77x10^{-6}s$ = 659.74m/s

Peak stress was found by taking the maximum peak (volts) of the wave from the TDR and converting that to stress using our stress vs. voltage relationship (see fig. 2). This relationship was determined by statically calibrating the resistors, then establishing a linear regression of the calibration data.


2500
2000
1500
1000
500
0
STRESS (1 Pa)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
VOLTS X 10 (GAIN=10)
2A TEST 1
2A TEST 1 REGRESS

(FIGURE 2)

B: AFESC Centrifuge Facility

The HQ AFESC centrifuge facility is located at Tyndall AFB, Florida. The centrifuge is housed in a 2.1 m high by 4.9 m diameter, 0.23 m thick reinforced concrete structure. The hydraulic centrifuge (Genisco Ins. of California, model E-185, SN 11) can apply controlled centrifugal accelerations of up to 100 g's with the maximum effective radius to the swinging platform being 183 cm.

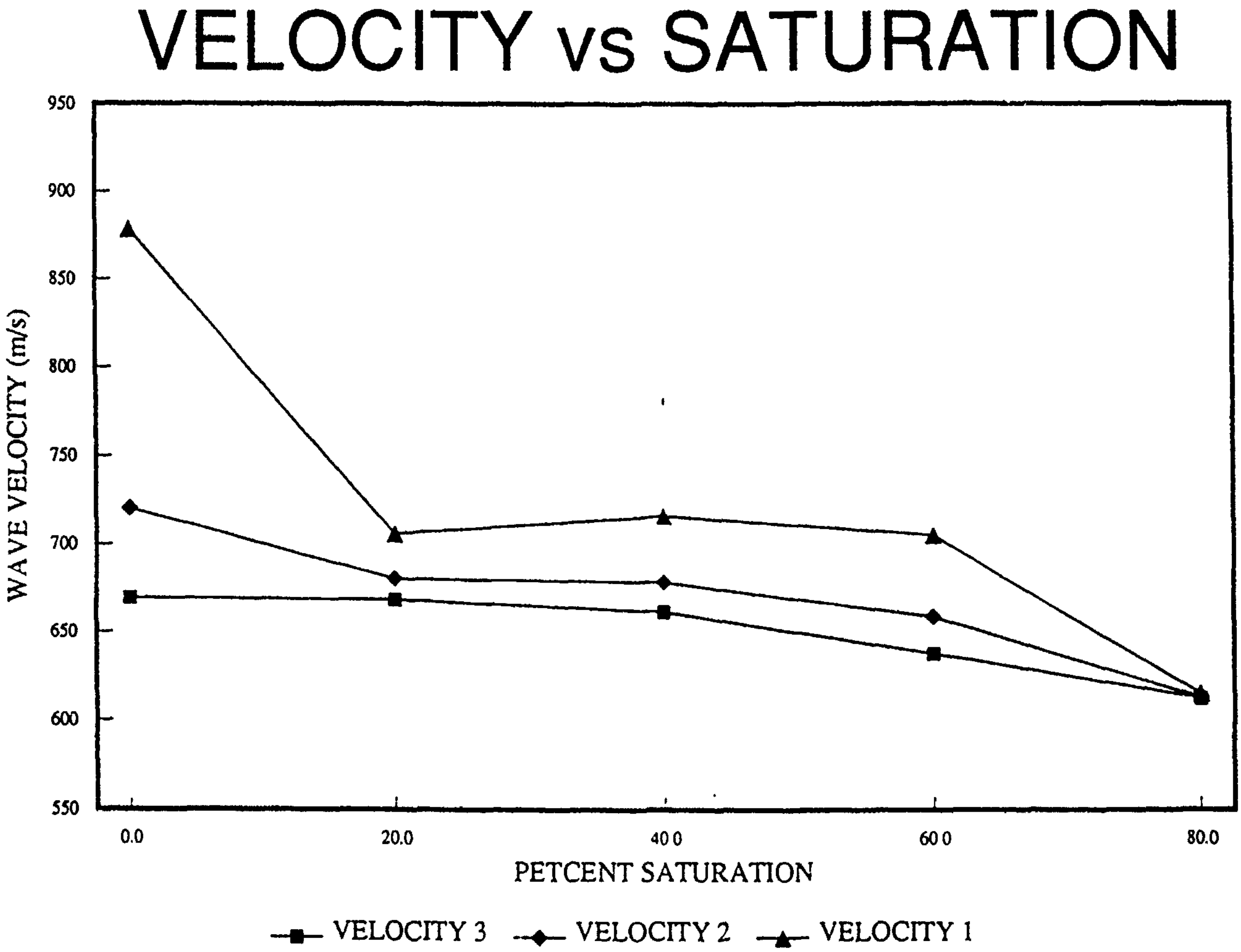
V. RESULTS

Tests were conducted at saturation levels of 0, 20, 30, 40, 60, and 80 percent. All tests were compacted to a density of 1600 kg/m^3 and were conducted at 0 or 30 g's. Table 2 gives stress wave velocities and peak stress as recorded by the carbon resistors. Figure 3 shows a velocity vs. saturation graph comparing velocities 1, 2, and 3. Figure 4 shows a velocity vs. saturation graph displaying velocity 3.

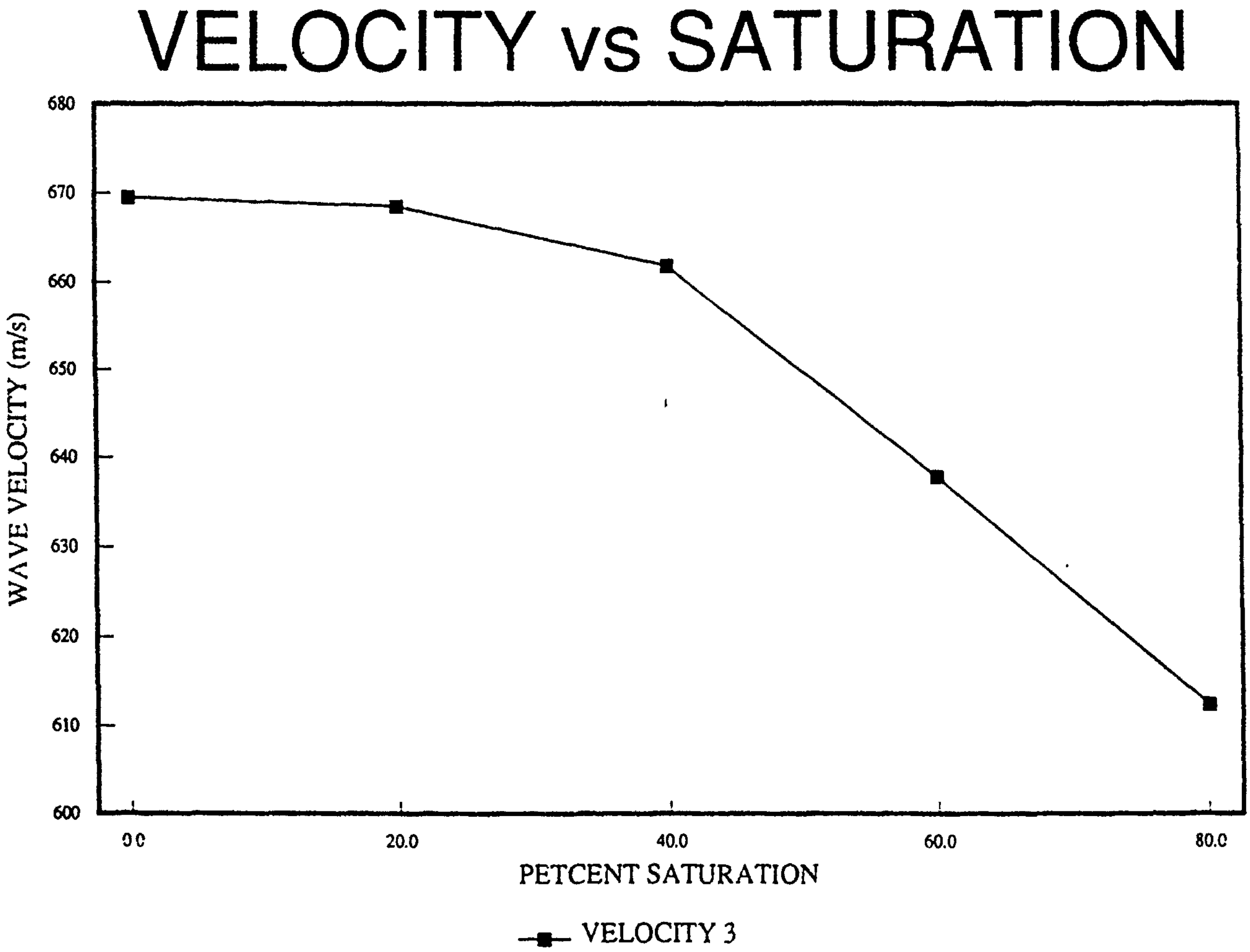
30'g CENTRIFUGE TEST RESULTS 8/8/90
CARBON PRESSURE GAGE (PEAK VOLTS-50GAINNOTE: PRETRIG IS SUBTRAC
FROM PEAK

TEST	CYL	1st ARR. (mic sec) (TRIGER @ TIME=0)	2nd ARR. (mic sec)	VEL 1 (m/s)	VEL 2 (m/s)	VEL 3 (m/s)	1st PEAK VOLT A	VOLT B	VB/VA
30-0-1	c1	33	110	769.7	692.7	659.7	1.25	1	0.80
	c2	41	118	619.5	645.8	659.7	1.22	0.98	0.80
	c3	43	124	590.7	614.5	627.2	1.17	0.93	0.79
30-0-2	c1	31	109	819.4	699.1	651.3	1.41	1.25	0.89
	c2	34	106	747.1	718.9	705.6	1.43	1.37	0.96
	c3	30	100	846.7	762.0	725.7	1.76	1.24	0.70
30-0-3	NO DATA								
30-0-4	c1	19	102	1336.8	747.1	612.0	3.1	1.27	0.41
	c2	32	108	793.8	705.6	668.4	1.7	1.17	0.69
	c3	30	109	846.7	699.1	643.0	1.85	1.18	0.64
30-0-5	c1	26	107	976.9	712.1	627.2	1.9	1.32	0.69
	c2	32	104	793.8	782.7	705.6	1.47	0.99	0.67
	c3	34	108	747.1	705.6	686.5	1.8	0.91	0.51
30-20-1	POOR DATA								
30-40-1	c1	34	108	747.1	705.6	686.5	2.13	1.22	0.57
	c2	37	112	686.5	680.4	677.3	1.81	1.27	0.70
	c3	36	117	705.6	651.3	627.2	2.06	3.91	1.90
30-60-1	c1	36	116	705.6	656.9	635.0	1.98	1.54	0.78
	c2	36	117	705.6	651.3	627.2	2.13	3.28	1.54
	c3	36	114	705.6	668.4	651.3	2.39	2.32	0.97
30-80-1	c1	41	125	619.5	609.6	604.8	1.69	1.31	0.78
	c2	40	125	635.0	609.6	597.6	1.72	1.13	0.66
	c3	43	123	590.7	619.5	635.0	2.71	1.01	0.37
30-20-2	NO DATA								
30-20-3	c1	35	112	725.7	680.4	659.7	1.91	1.12	0.59
	c2	36	112	705.6	680.4	668.4	1.91	1.15	0.60
	c3	37	112	686.5	680.4	677.3	2.17	1.25	0.58
30-30-1	c1	40	119	635.0	640.3	643.0	2	1.24	0.62
	c2	36	112	705.6	680.4	668.4	1.72	1.41	0.82
	c3	39	118	651.3	645.8	643.0	1.94	1.42	0.73
30-40-2	c1	34	111	747.1	686.5	659.7	1.87	2.02	1.08
	c2	35	110	725.7	692.7	677.3	2.03	1.55	0.76
	c3	37	116	686.5	656.9	643.0	2.14	3.51	1.64
			MEAN	741.9	677.7	655.1			
			S DEV	137.6	38.3	29.7			
BELOW EXCLUDE 30-0-4 CYL1 DATA:									
			MEAN	721.4	675.3	656.6			
			S DEV	83.4	36.7	29.0			
									STATS VB/VA
			MEAN 0%	777.4	698.9	669.1		0	0.74
			S DEV 0%	101.5	37.9	31.4			0.12
			MEAN 20%	705.9	680.4	668.5		20	0.59
			S DEV 20%	16.0	0.0	7.2			0.01
			MEAN 40%	716.4	678.9	661.8		40	1.11
			S DEV 40%	25.4	19.2	21.0			0.50
			MEAN 60%	705.6	658.9	637.8		60	1.10
			S DEV 60%	0.0	7.1	10.0			0.32
			MEAN 80%	615.1	612.9	612.5		80	0.60
			S DEV 80%	18.4	4.7	16.2			0.17

(TABLE 2)


VELOCITY vs SATURATION
950
900
850
800
750
700
650
600
550
WAVE VELOCITY (m/s)
0.0
20.0
40 0
60 0
80.0
PETCENT SATURATION
VELOCITY 3
VELOCITY 2
VELOCITY 1

(FIGURE 3)


VELOCITY vs SATURATION
680
670
660
650
640
630
620
610
600
WAVE VELOCITY (m/s)
0.0
20.0
40.0
60.0
80.0
PETCENT SATURATION
VELOCITY 3

(FIGURE 4)

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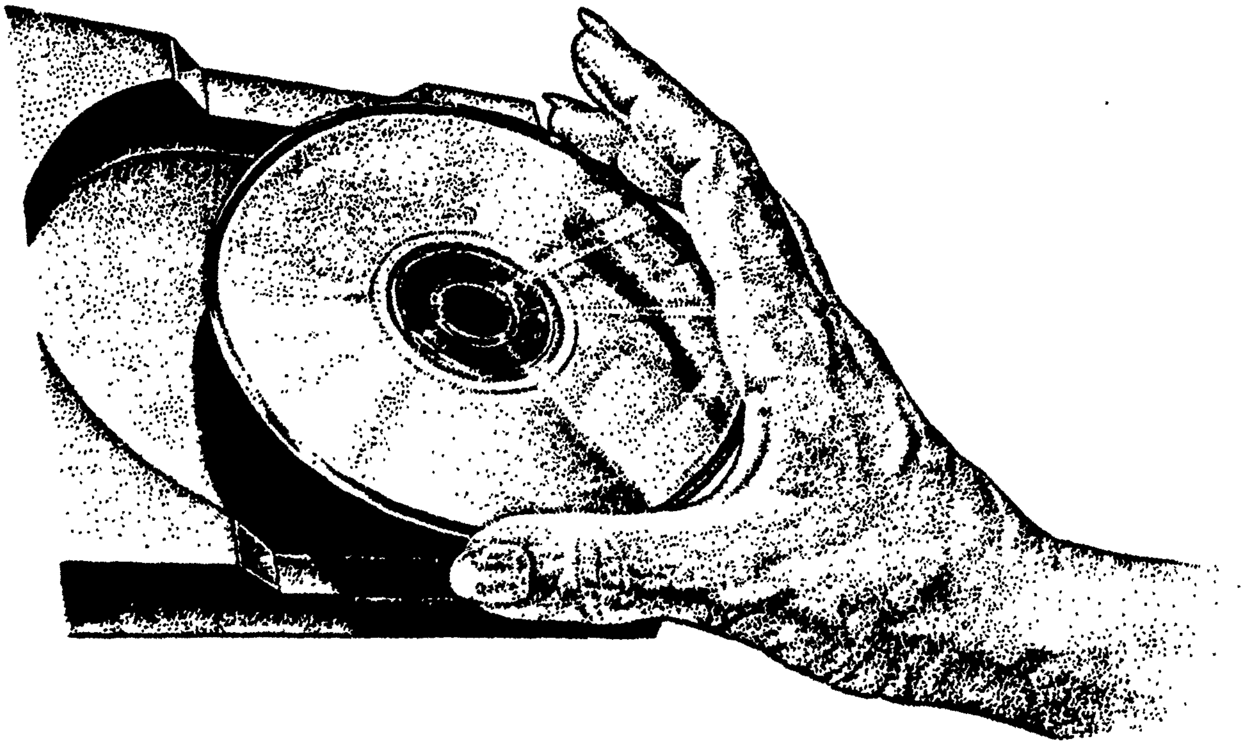
CD-ROM
COMPACT DISC READ
ONLY MEMORY



June - August 1990

By
Robin L Woodworth

ACKNOWLEDGEMENTS

I would like to thank all of those kept me busy during my summer program. I had a great time and learned a great amount of information.

Thanks to: my mentor Andrew Poulis, and Lela Fletcher, Janet Davis, Virginia Davis and a new good friend of mine Linda Baker. I apprieciate you all.

TABLE OF CONTENTS

INTRODUCTION

This User's Guide has been written to assist you in using the Compact Disc-Read Only Memory(CD-ROM) prototype. Throughout this guide it states ways to search for information on specific compact disc, by using the author's name, the title, keywords, publication dates, and ways to expand, narrow, or combine your search with other topics by using Boolean Operators. The CD-ROM was invented to acquire more information in less amount of time, so that the extra time can be used for learning and understanding that information.

The main function keys used throughout your search program are stated in Appendix A for reference, and in Appendix B it states the different compact disc avaliable and a description of each to assist in looking for the right disc to match the information needed.

If extra help is needed or an instruction is not quite understood please ask for assistance. After taking some time and working with the CD-ROM, trying out every way to search, and using these different ways, the CD-ROM will prove in it self that it is an asset to the need of attaining information.

I. BRIEF HISTORY

In 1976 the research on a compact disc format for optical media began, by the inventors Philips N.V. of the Netherlands and Japan's Sony Corporation. They announced their new technology of the compact disc as noise free recorded music. By 1985, joint Philips/Sony described their specification for CD-ROM. This stated that the CD would store information as well as music and that a new form of computer would be made to read and decipher the coded tracks on the CD.

With this new idea, Philips/Sony needed lots of support, music is music, but computer data comes in different forms. Nevertheless, by 1984 there was enough of an industry to support the CD-ROM and the First International Conference was held in Seattle to describe the plans.

By 1985, it was introduced to libraries and was monitored closely to see the reaction of the media. Many agreed and accepted the new CD-ROM due to its built in search and being able to retrieve information in less time that it would take to find the same information in volumes of paper.

By the end of 1989, there had only been 340,000 CD-ROM's installed. This number is good, but compared to how many computer systems are being used, the number is little. Predictions, however, state that by the end of 1990 the number is expected to double.

II. PURPOSE

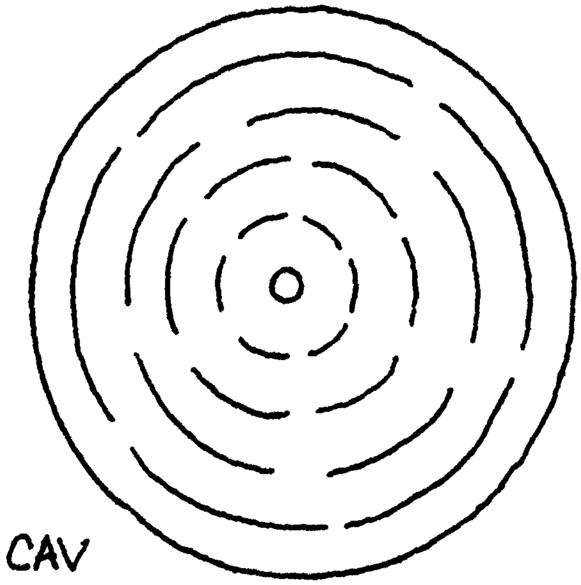
The puropse of the CD-ROM is to search software giving you full, flexible access to large reference databases stored on compact discs. CD-ROM's characteristics are desirable for any information storage and retrieval system. It allows many access points to information. Users can retrieve the information in several different formats and retrieval of information is possible more quickly with CD-ROM than with print. The application of this technology to text and image storage provides several advantages: reliability, ample capacity, organizational, flexibility and permanence reliability. When using the CD-ROM, you can find information through many different ways. For example, you can search by: the publisher, author, several keywords, title, type of document, etc. and combine these to go into a more specific search. This is all possible due to the non-magnetic medium, the CD-ROM disc, so magnetic fields cannot corrupt your data convience.

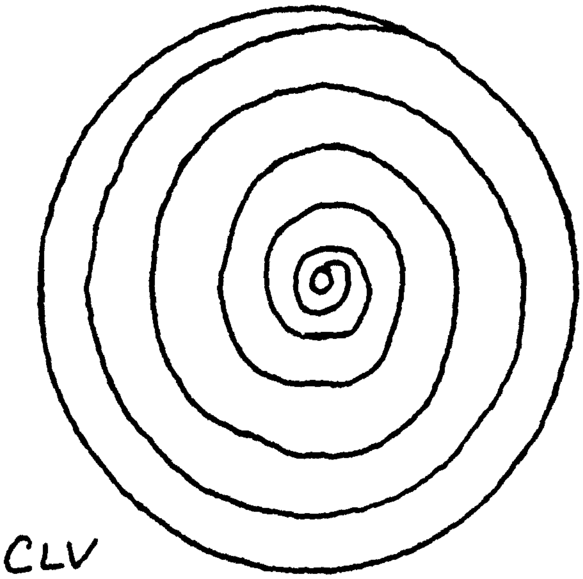
III. WHAT A CD-ROM IS

There are four principle parts of a compact disc system: the Optical Disc Drive, a computer, the Optical disc, and the software that creates the user interface with the data base.

Any computer equipped with a hard disk and at least 512K or 640K of memory will work when hooked up to the CD-ROM disc drive. The one main annoyance of the CD-ROM is that it is essentially for one person to use the system at a time. Access by multiple users is in the development stage.

The compact disc is a very important disc, with many capabilities. First of all a magnetic disk usually spins at a constant rate or a costant angular velocity(CAV). This means that the inside sectors are short and data is densely packed. On the outside radius the data is stored in longer sectors at a much lower linear density. Whereas, a CD-ROM disc spins at a varying rate, faster reading inner sectors, slower reading outer sectors, constant linear velocity(CLV). This type has sectors with the same length sectors and stores more data.





Some problems which make the (CLV), CD-ROM way difficult: it is not ideal for retrieving data, the long track mades it difficult to find individual sectors, and speeding up and slowing down of the disc accounts for a rather slow data access time.

Another way the disc is important is that there are two separate formats which arrange information differently, one way is the common structure called the physical format which means they are all the same size and their data is arranged in exactly the same pattern. The other format is called the logical format in which the information is specified in the file how they are organized, and their location.

Being a non-magnetic disc, it can be washed with soap and water, then can be dried by a lint free cloth. This makes it very convienent for places where information can be wiped out by magnetic fields

One bad point about the read only memory is that it can only be read. It can not be erased, updated or changed without remastering the disc, but solutions have been thought up and different discs have been made. For instance: CD-Prom(Programmable Read-Only Memory), CD-EPROM(Erasable PROM), and CD-WORM(Write Once Read Many).

The disc is 5 inches in diameter and lasts a minimum of 9 years. A CD-ROM disc can hold up to 600 megabytes of data, this number is great. To describe how great this amount is, 600 megabytes is equivalent of about 1600 floppy discs, 275,000 pages of text, 40,000 pages of images, and a secratary typing 90wpm 8 hours a day for more than 8 years to input. Those explain why the compact disc is such an asset in replacing many volumes of paper. if not writting them on disc, then searching certain subjects in the text.

IV. GETTING STARTED

- SCREEN AND MENUS -

When the system is ready for use, highlight the section 'Read CD-ROM' by pressing the <↑↓> arrow keys. These are built in with the number section(see figure 1). Press <↵> Return. Once the starting screen appears choose <F8> to display the database section menu. Insert the compact disc which contains the database you desire. Use the arrow keys to select your choice. After the correct database has been chosen, Return to activate the database.

An introductory screen appears. Type a term that describes the topic you are searching and press the Return key. For more detailed information on the different aspects of the system press <F1> to open the Database Help Window. To help you understand the meaning of the screen you are looking at see figure 2.

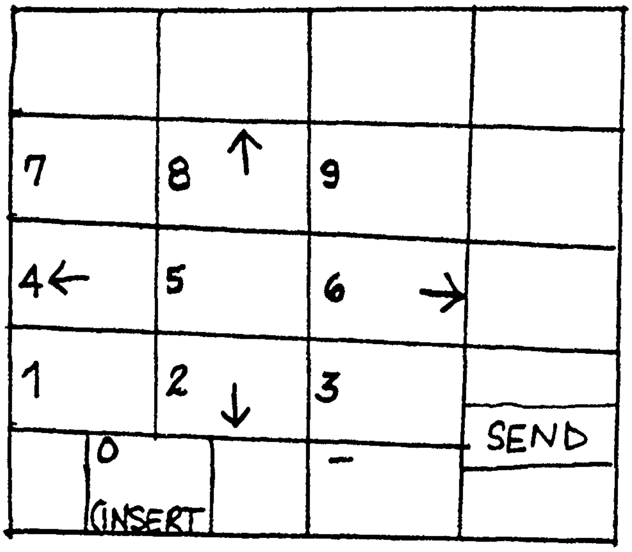


Figure 1

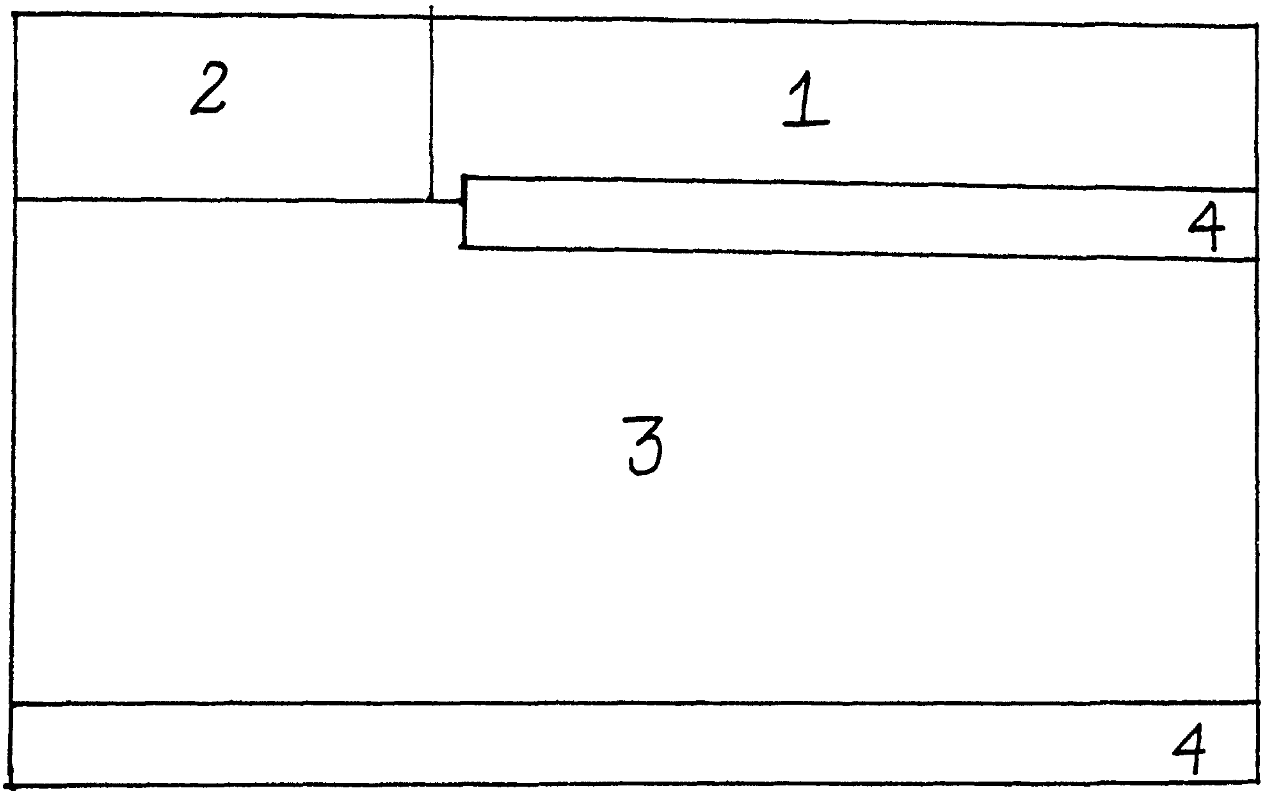


Figure 2

1. Query Window- Build and Enter Queries.
2. Results Window-Number of records found Which record is being viewed. Which record is being marked.
3. Record Display-View list of records retrieved.
4. Prompt Lines-Summarizes the use of which function keys can be used.

V. SEARCH OPERATIONS

- BRIEF SEARCH -

To familiarize yourself with a search, begin with a basic search by following these eight instructions.

1. Type a term in the Query Window that describes your topic.

   EXAMPLE: 1> installation

2. Press Return to start searching.

3. View the results which appear in the results Window and Record Display.

   -Zero records found, go to step 6
   -Some records found, go to step 4

4. If more than one record has been retrieved press return to view the first record, then <F6> to view the next record.

5. To print records press <F7>. Press <CTRL><F7> to save on diskettes or ESC to return to the brief record list.

6. Enter another query to

   -Start a new term.
   -Expand your search to find more records.
   -Narrow your search to find fewer records.

7. Return to Step 1 to enter a different query.

8. When finished, press <F10> to erase your work leaving it ready for the next user.

- EXPAND -

To expand your search, use the OR operator between related terms. Press the return key to start serching.

EXAMPLE: 1> kindergarten or preschool

To find more words related to your subject or words, at the end of each record there are major and minor descriptors.

- NARROW -

To narrow your search, use the AND operator to combine terms and find records containing both terms. Press the return key

to begin the search.

EXAMPLE: 1> kindergarten and reading

Also you can use adj(adjacency) to search a phrase, with the keywords next to each other occuring anywhere in a record.

EXAMPLE: 1> strategic adj defense

VI. SPECIFIC SEARCH

- INDEX -

To get more specific on your search, two more keys will assist you in doing this. They are <F2> and <F4>. The Index key <F2> opens the Index Window. This window will let you look for related terms, see the number of times a term appears in the database and copy indes terms into a new query.

Once the Index Window is viewed, choose the index by pressing the arrow keys.

Then type the keyword wishing to be looked up. Press the return key. The Index Window will show this word and the words surrounding it.

The numbers beside the words indicate the number of times that term occurs in the database. Use arrow keys to highlight a word; press the Tab key(Send) to copy it into your new query. Press Return to search the terms. For a description of each item press <F1> for help.

- HISTORY -

To view past queries, press <F4> to open the History Window. In the History Window it will display all of your queries starting with the first one of that search. Using the arrow keys, highlight the query to refine or view again. After you have chosen the wanted query, press the Tab(Send) key. This will copy it into a new query as n!(where n is the query #). To view again, once it has been transfered press Return. To add to this new query type AND, OR or NOT and [search terms]. The past query and the search term(s) can be in any order and you can combine more than one past query.

```
EXAMPLES: 1> textbooks
          2> 1! and censorship

          1> alcohol
          2> drug abuse not 1!

          1> teenagers
          2> adolescents
          3> youth
          4> 1! or 2! or 3!
```

- AUTHOR -

To find a specific author, type au: author's last name.

EXAMPLE: au: brown

If there are too many authors with the same last name, add the first name and/or initials

EX: au:"brown mike"
au:"brown m p"

If you need a more specific or faster search, add full first name and middle initial. Put quotations around the whole thing so it is searched as a phrase.

EX: au:"brown mike p"

If you're not sure of the correct form, full name, or the middle initial, type as much as you know then a tuncation symbol (*).

EX: au:"brown mik*"

- TITLE -

To find a specific title, you may use as many keywords needed.

EX: ti:wildlife
ti:wildlife society
ti:wildlife society bulletin
ti:wildlife and ti: society

So, there are many ways to search for information, you just need to know exactly what you are looking for, and how to word it correctly to get the right, detailed form.

VII. BOOLEAN OPERATORS

- COMBINE TERMS -

Boolean Operators are used to seperate keywords or bound phrases. These words can be used between many types of words and can change your search tremendously depending on that particular operator. The following words are Boolean Operators and their job performed by each.

OPERATOR	FUNCTION
ADJ	Finds records with the phrase entered in the query. Finds records with terms appearing within a specified number of words of each other. Keywords combined by ADJ may appear in records in any order.
AND	Narrows a search and finds all records containing each of the specified terms.
OR	Expands a search and finds the records that contain any of the terms in the query.
NOT	Narrows a search by finding the records that contain one keyword but not a specified term.
WITH	Narrows a search finding records that contain the specified terms in the same field.
NOTES:	Type a space before and after an operator. Use parentheses if more than one operator is used and queries cannot begin or end with an operator.
<*>	Use a truncation to search for words beginning with the same letters unlimited number of varying characters at the end of a word or phrase.

EX: 1> librar* will retrieve: library, librarian, librarians, and librarianship.

OPERATOR	FUNCTION cont'
	2>"holistic*" with quotations retrieves bound phrases such as holistic approach and holistic evaluation.
</>	Indicates a range of terms. It finds the specified terms, plus any terms falling between them in the index. EX: 1> catalog/ catalogues retrieves catalog, cataloging, catalogue, ..., and catalogues. 2> 1984/1989 retrieves years between 1984 and 1989.
<?>	Indicates a varying character in place of the question mark. EX: 1> g??se will retrieve: geese, goose gese, and gse. 2> wom?n will retrieve: woman and women.

- PARENTHESES -

Terms in parentheses are processed together and may be used as many times as needed, but always in pairs.

EX: su:(drug and alcohol) abuse
su:((drug and alcohol) abuse)
(su:(drug and alcohol) abuse)

NOTE: Terms combined with ADJ or WITH do not require parentheses.

- RESTRICT -

A restrictor defines a group of records. It cannot be used alone in a query and must always follow a search term.

EX: suicide and teenagers and rs:update
titanium and rs:english

- PULL MODE -

The Pull Mode is used to save time and typing by using search terms from a record you are viewing. Press <CTRL><F3> to enter the Pull Mode. Use arrow keys to highlight the term desired and press the Tab(Send) key to copy term into the new query line.

- MARK RECORDS -

To mark records for printing you must be viewing the brief title screen of the retrieved records. After finding the records you would like to print mark it by pressing the number 0 (in the number key section see figure 1). To delete an unwanted mark, press the Delete key. To be certain if the record was marked looking in the Result Window here it shows how many records have been marked.

VIII. FINISHING UP

- SAVE/PRINT -

To save records on a diskette or on the hard disk the keys to press are <CTRL><F7>. Highlight the savefile you want and press Return to save.

To Print Records make sure the printer is ready. For the regular printer the T-switch should be on A. and for the Laser the T-switch should be on B. When the printer is ready, and you know which records you want, press <F7>. The records will print out on the printer.

- EXIT -

To exit press <F10>. A message will appear on the screen asking if you want to end your work session as a precaution. Press the Return key. The queries you entered will be erased, and the system will restart, allowing you to begin a new work session in the database you choose.

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APPENDIX A

KEY	NAME	FUNCTION
<F1>	HELP	View Help Menu
<F2>	INDEX	View index entries surrounding the term you enter
<F3>	FIELD LABLES	View list of searchable fields and abbreviations
<F4>	HISTORY	Review past queries, copy past queries into a new query
<F5>	PREVIOUS	View previous record in a retrieval set
<F6>	NEXT	View the next record in a retrieval set
<F7>	PRINT	Print records in a retrieval set
<CTRL><F7>	SAVE RECORDS	Save records in a retrieval set on a diskette
<F8>	DATABASES	Request information on the database you are using
<F9>	FORMAT	Select format for record display and for printing and saving records
<CTRL><F9>	FULL RECORD	Toggle display from current format to Full Record and back
<F10>	QUIT	Erase current session; begin a new work session
<ESC>	ESCAPE	Leave a function; return to Query Window
<↵ >	RETURN	Choose a database; begin searching, printing, or saving records
<↑↓><←→>	ARROWS	Highlight a selection; scroll through a record

APPENDIX B

DATABASE	DESCRIPTION
NTIS	Comprises bibliographic citations to technical documents from three major US agencies,(DOE)Department of Energy, (DOD)Department of Defense, and (NASA)National Aeronautics and Space Administration. The documents include reports, jounal articles, data files, and computer programs.
SELECTED WATER RESOURCES ABSTRACTS	Includes abstracts of current and earlier pertinent journal articles, monographs, reports and other pub. formats. These documents cover water resources as treated in the life, physical, and social sciences and the related engineering and legal aspects.
USGPO MONTHLY	Comprises bibliographic records representing the entries in the US Government printing Office's Monthly Catalog of UA Government Pub. from July 1976 to the present.
EARTH SCIENCES	Consists of bibliographic records for USGS material in the USGS Library. Also contains geologic maps of the US and its territories that meet criteria by the USGS. Provides information about earth science and natural-resource databases, automated and nonautomated.
ENERGY LIBRARY	Compiled from the OCLC Online Catalog and consists of the bibliographic records for library materials pertaining to energy and related subjects. Such as books, serials, theses, audiovisual media, computer programs, and data files.

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