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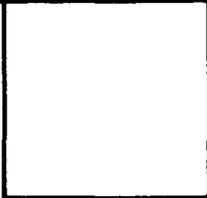
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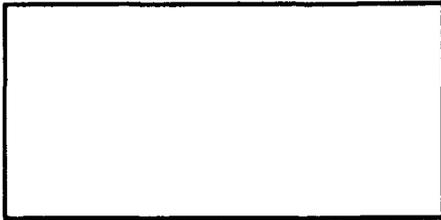
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HIGH SCHOOL APPRENTICESHIP PROGRAM (HSAP) REPORTS

VOLUME 13

PHILLIPS LABORATORY

RESEARCH & DEVELOPMENT LABORATORIES

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Bolling Air Force Base

Washington, D.C.

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## PREFACE

This volume is part of a 16-volume set that summarizes the research accomplishments of faculty, graduate student, and high school participants in the 1992 Air Force Office of Scientific Research (AFOSR) Summer Research Program. The current volume, Volume 13 of 16, presents the final research reports of high school (HSAP) participants at Phillips Laboratory.

Reports presented herein are arranged alphabetically by author and are numbered consecutively -- e.g., 1-1, 1-2, 1-3; 2-1, 2-2, 2-3.

Research reports in the 16-volume set are organized as follows:

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3	Summer Faculty Research Program Reports: Phillips Laboratory
4	Summer Faculty Research Program Reports: Rome Laboratory
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6	Summer Faculty Research Program Reports: Arnold Engineering Development Center; Civil Engineering Laboratory; Frank J. Seiler Research Laboratory; Wilford Hall Medical Center
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# 1992 HIGH SCHOOL APPRENTICESHIP REPORTS

## Phillips Laboratory

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5	Exploring Electromagnetic Effects	Anthony W. Davis
6	A Research Library on Your Computer Terminal	Catherine E. Downey
7	Force Applications Control Variable Study	Brandon J. Ellena
8	Fuzzy-C Optical Tracker	Blake Ethridge
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11	Iterated Function Systems: Fractal Modeling of Real-World Natural Systems	DeLesley S. Hutchins
12	Scientific Visualization of a Carbon-60 Molecule	Mindee A. Jeffery
13	Research into the Causes of Pre-Fires	Brad L. Karmioli
14	Synthesis and Purification of Fullerenes	Alexandra Kitty
15	Using Fuzzy Logic in the Design of Systems to Destroy Missiles Based on Infrared Emissions	Erik J. Krause
16	Investigation of Neural Network Based Lightning Warning System for the Kennedy Space Center	Frank A. Lasley IV
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THE DEVELOPMENT OF A MULTI-DIMENSIONAL  
FOURIER TRANSFORM TO BE USED TO  
PREDICT THE LIGHT SCATTERING OFF AN OPTIC

Christopher A. Browning

Final Report for:  
Summer Research Program  
Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
Kirtland Air Force Base, Albuquerque, N.M

July 1992

THE DEVELOPMENT OF A MULTI-DIMENSIONAL  
FOURIER TRANSFORM TO BE USED TO  
PREDICT THE LIGHT SCATTERING OFF AN OPTIC

Christopher A. Browning

Abstract

Fourier Transform algorithms are used to calculate the power spectral density of an optical surface in order to predict light scattering from those surfaces. An algorithm was written to produce data files for surface plots of the optic and data files for plots of the Fourier Transform. The program can read data from a file, put the information into a file in coordinate format, compute the Fourier Transform, and put it into a file in coordinate form so that they can be plotted and examined.

## INTRODUCTION

A Fourier Transform takes a function  $h(t)$ , where  $h$  is the height and  $t$  is the time, and produces another function  $H(f)$ , where  $H$  is the amplitude and  $f$  is the frequency. The relationship between  $h(t)$  and  $H(f)$  is:

$$H(f) = \int_{-\infty}^{\infty} h(t) e^{2\pi i f t} dt \quad (1)$$

$$h(t) = \int_{-\infty}^{\infty} H(f) e^{-2\pi i f t} df \quad (2)$$

If  $\omega$  is equal to  $2\pi f$  and  $H(\omega) = [H(f)]_{f=\omega/2}$  then equations 1 and 2 can be written as:

$$H(\omega) = \int_{-\infty}^{\infty} h(t) e^{i\omega t} dt \quad (3)$$

$$h(t) = \int_{-\infty}^{\infty} H(\omega) e^{-i\omega t} d\omega \quad (4)$$

The total power in a signal is the same if the frequency domain or the time domain is found, which is known as Parseval's Theorem:

$$\text{Total Power} = \int_{-\infty}^{\infty} |h(t)|^2 dt = \int_{-\infty}^{\infty} |H(f)|^2 df \quad (5)$$

Many times one only wants to find the amount of power in the frequency from  $f$  to  $f+df$ . Vary  $f$  from 0 to  $\infty$ . This is defined as the one sided power spectral density (PSD) of the function  $h$ :

$$P_h \equiv |H(f)|^2 + |H(-f)|^2 \quad 0 \leq f < \infty \quad (6)$$

When  $h(t)$  is real  $|H(f)|^2 = |H(-f)|^2$  so  $P_h = 2|H(f)|^2$ .

When  $h(t)$  goes endlessly from  $-\infty$  to  $\infty$ , its total power is infinite so one looks for the power spectral density per unit time. This is found by calculating the PSD of a long but finite section of  $h(t)$  and divide the Psd by the length of the  $h(t)$  used.

In most situations, the function  $h(t)$ 's value is recorded at evenly spaced intervals of time, called sampling. The interval that the function is sampled at is  $\Delta$ . Given any sampling interval  $\Delta$ , there is a special frequency  $f_c$  called Nyquist critical frequency:

$$f_c \equiv \frac{1}{2\Delta} \quad (7)$$

The Nyquist frequency is the highest frequency component that can be measured with the sampling interval  $\Delta$ . If a sine wave of the Nyquist critical frequency is sampled at its positive peak then the next sample will be at its negative trough, in other words, the sampling would take place at the maximum and minimum values of the function. If one samples a continuous function  $h(t)$  at an

interval of  $\Delta$  and it is band-width limited to frequencies with smaller amplitudes,  $H(f)=0$  for all  $|f|>f_c$ , then  $h(t)$  is completely determined by the sampling. The formula:

$$h(t) = \Delta \sum_{n=-\infty}^{\infty} h_n \frac{\sin[2\pi f_c(t-n\Delta)]}{\pi(t-n\Delta)} \quad (8)$$

gives  $h(t)$  exactly. If the continuous function  $h(t)$  is not band-width limited, then all of the PSD outside of the frequency range  $-f_c < f < f_c$  is moved into the range. When this occurs it is called aliasing. Any frequency in the range is aliased (falsely transmitted) into the range by discrete sampling. After a signal is discretely sampled there is little that can be done to remove the aliased power. Aliasing can be overcome by knowing the natural band-width limit of the signal or enforce a known limit, e.g., with an analog filter, and sample at a high rate to give at least two points per cycle of the highest frequency present.

Once the function  $h(t)$  has been completely sampled, the assumption that the transform outside the range  $(-f_c, f_c)$  is equal to 0 can be made. If this is true then it is possible to tell if aliasing has taken place by examining the transform. If the transform over the interval  $(-f_c, f_c)$  is approaching zero as it approaches  $f_c$  or  $-f_c$  then, more than likely, there was little or no aliasing. But, if the transform is approaching some finite value other than zero then aliasing has occurred.

Discrete Fourier Transform maps  $N$  complex numbers  $(h_k)$  into

N complex numbers ( $H_n$ ), where  $h_k \equiv h(t_k)$  and  $t_k = k\Delta$ .  $H_n$  is the discrete transform of N points  $h_k$ .

$$H_n = \sum_{k=0}^{N-1} h_k e^{2\pi i k n / N} \quad (9)$$

The transform dose not depend on any dimensional parameters.

$$H(f_n) \approx \Delta H_n \quad (10)$$

The formula for discrete inverse Fourier Transform is:

$$h_k = \frac{1}{N} \sum_{n=0}^{N-1} H_n e^{-2\pi i k n / N} \quad (11)$$

Parseval's Theorem in discrete form is:

$$\sum_{k=0}^{N-1} |h_k|^2 = \frac{1}{N} \sum_{n=0}^{N-1} |H_n|^2 \quad (12)$$

#### PROBLEM

The people I was working with were trying to predict the scatter off an optic by calculating the PSD of the surface of the optic and applying vector scattering theory. My job was to adapt the Multi-Dimensional Fourier Transform subroutine from the book Numerical Recipes (Fortran) so that it would read the data gathered from the Atomic Force Microscope at the University of New Mexico, transform it, and write it to a file in a format that

could be read by a graphics program so that it could be plotted and analyzed.

#### METHODOLOGY

First I needed to test the algorithm so I wrote a couple of simple three dimensional functions with known results in array form to put into the subroutine. These functions were written in two dimensional arrays with the x value as the column, the y value as the row, and the z value as the number stored in the array location (x,y). This is the easiest form to get a mental picture of the function. The Fourier subroutine only reads a one dimensional array where the first number is the real component of a complex number and the second is the imaginary component. I had to develop a subroutine that rewrote the two dimensional arrays into one dimensional complex arrays where the imaginary term is zero. To use the plotting program Surfer version 4 the array had to be put into coordinate form (x,y,z). I had to write a subroutine that wrote the original array into this form and another subroutine to write the transform into this form.

I put two simple functions, a rectangle and a comb, into the program to verify that it worked. When the first function, a rectangle, was run through the transform a sinc function should have come out but the transform came out with the peak, which should have been in the center of the plot, split into four pieces and put in the corners of the plot. A subroutine was need to put the transform into the right order. After that the

transforms were still not looking quite right. After some work it was discovered that there were imaginary components in the transform and the real components were the only ones being plotted. Using the distance formula:

$$D=\sqrt{x^2+y^2}$$

where  $x$  is the real component and  $y$  is the imaginary component, another file was written. This file, with both components included, turned out to be the correct plot for the Fourier Transform. The three dimensional rectangle is shown in figure 1. The Transform of the rectangle is shown in figure 2. This is a graph of a Sinc function which, according to Linear Systems, Fourier Transforms, and Optics by Jack D. Gaskill, is the correct result. Notice the large peak in the center and the four medium peaks along the axis. With the small peaks in the corners, there can be no doubt that this is a Sinc function. The second function that was run through the program was a comb function, figure 3. There are nine spikes on the plot of the comb, on the transform of the comb, as well, there are nine spikes. Checking Gaskill's book, this transform was also verified. The last function that was put into the Fourier Transform was the Sinc function that was the transform of the rectangle. The program was not totally correct until the inverse transform was checked. There was one minor step that was left out of the Fourier subroutine. The results of the inverse transform need to be divided by the total amount of data points in the array that was

put into the routine. With this small adjustment made, the program reproduced the original rectangle that I started with, figure 5. Also, the subroutine that reordered the original transform is not needed for the inverse transform.

After the subroutine was verified and was operating like it should, a driver program was written that would read the array information and run all of the subroutines and write two data files. One file was the original array in coordinate form and the other was the Fourier Transform, also in coordinate form. Information gathered by the Atomic Force Microscope was then put into the program. The initial data plot is figure 6, and the Transform is figure 7. These were given to another part of the group to analyze.

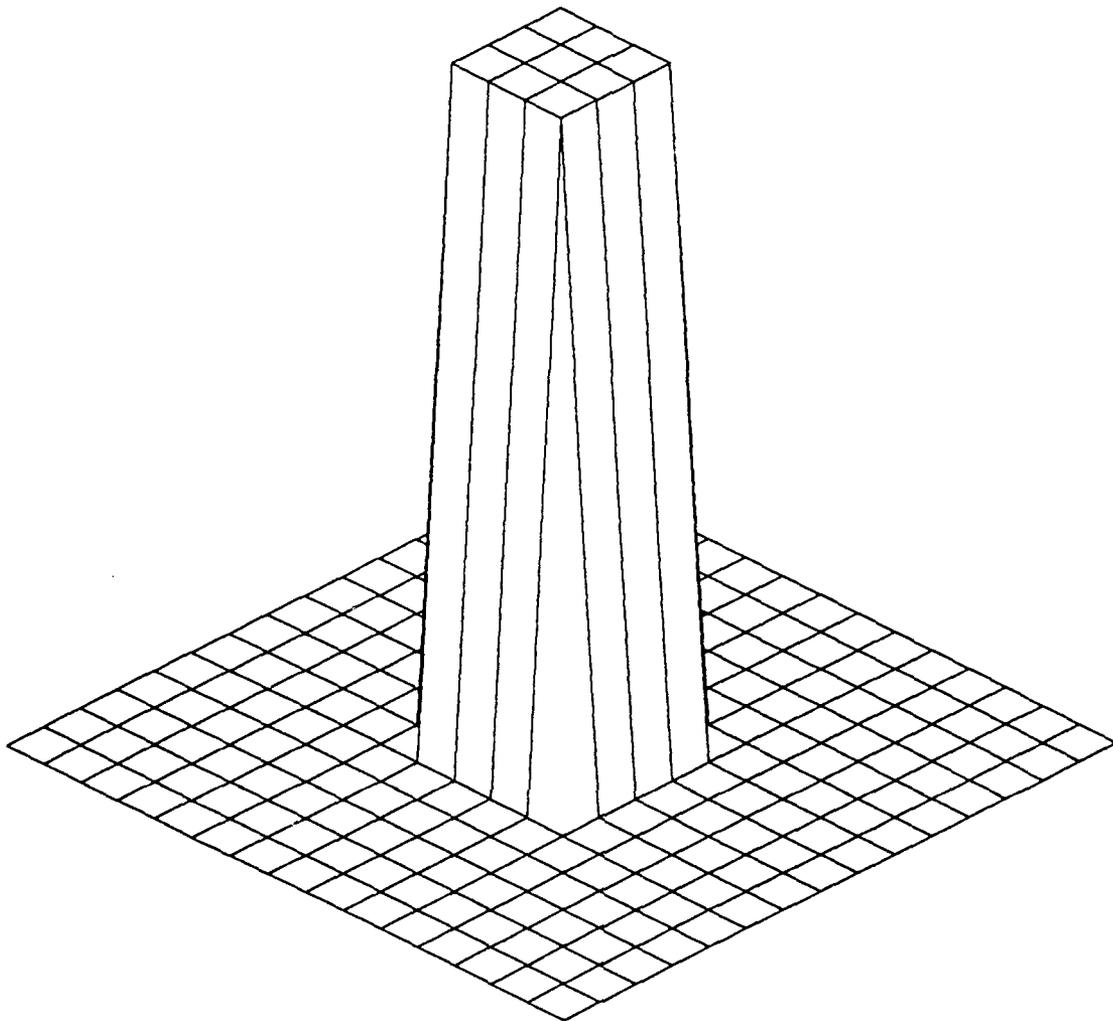


Fig.1 Surfer plot of a Rectangle

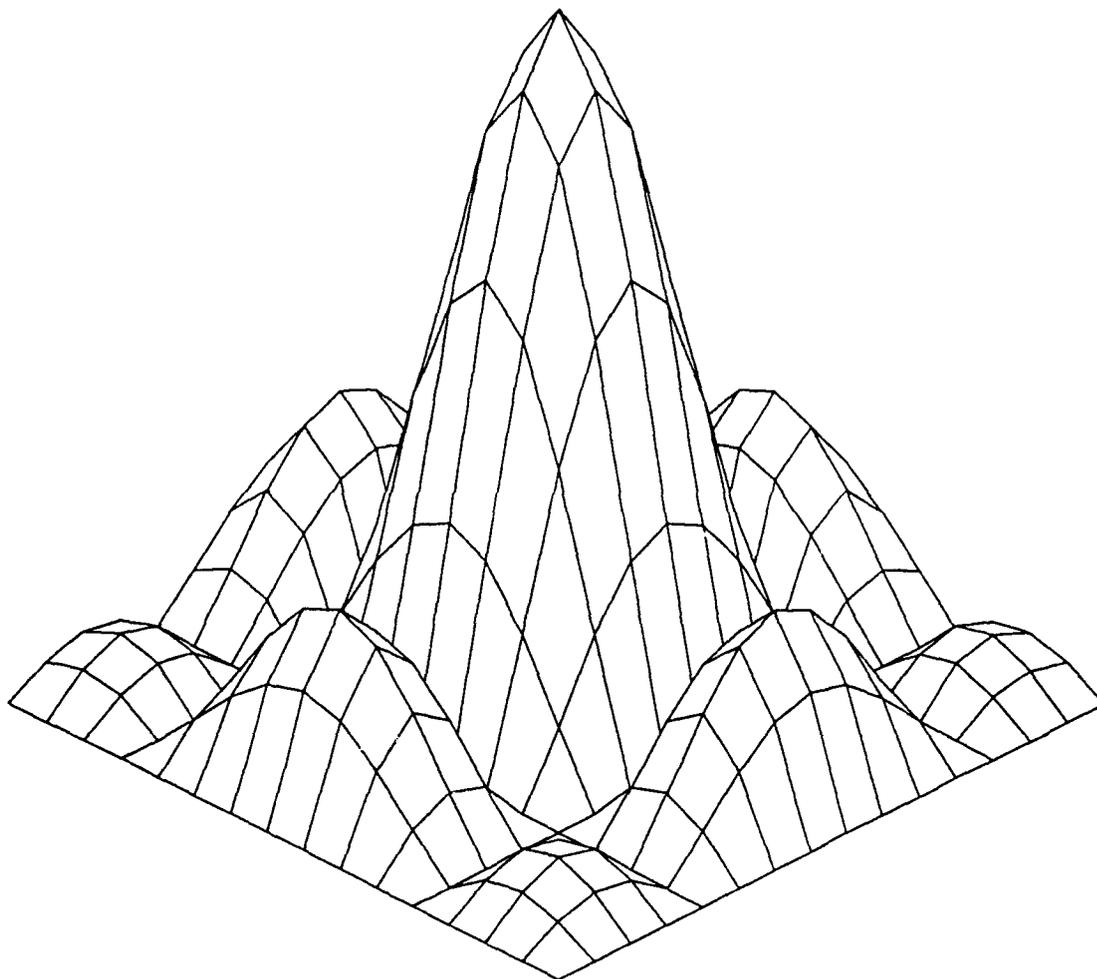


Fig.2 Fourier Transform of a Rectangle

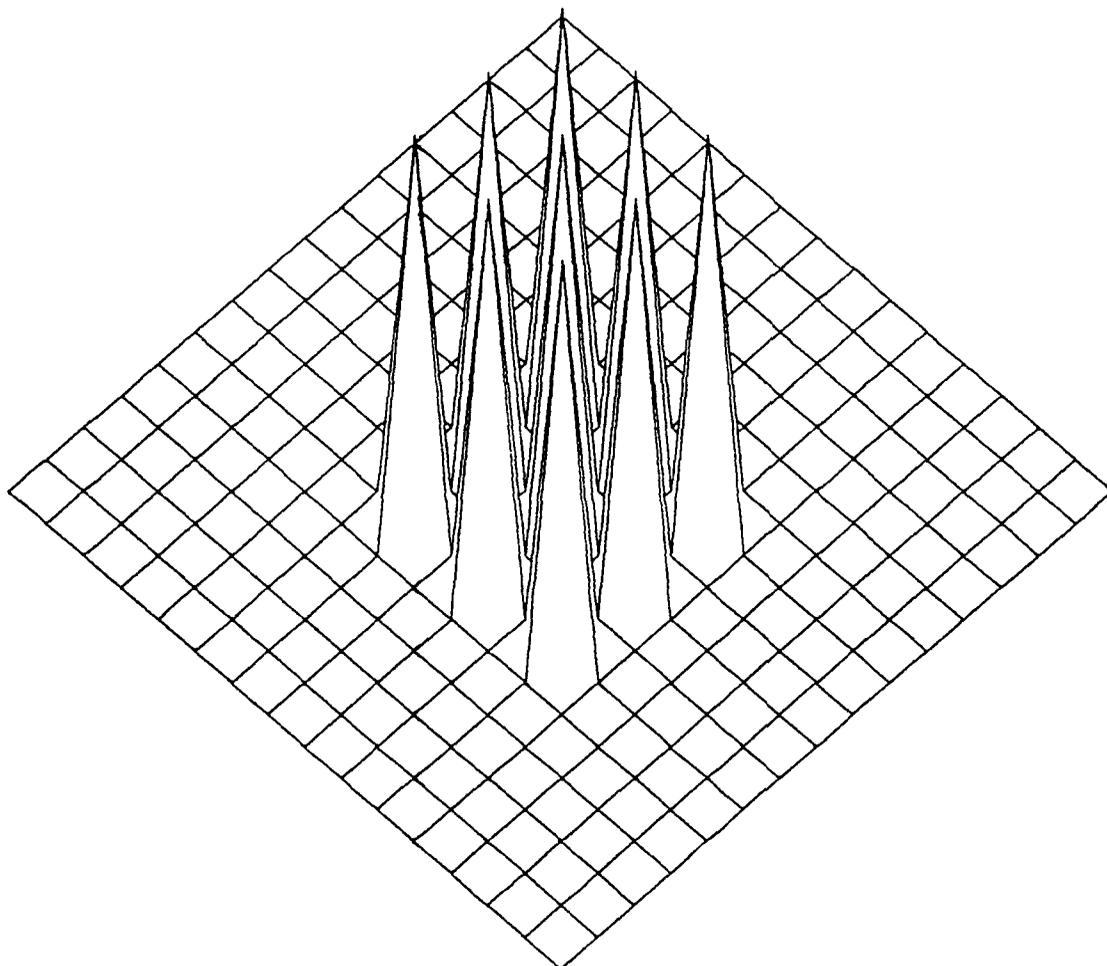


FIG. 3 SURFER PLOT OF A COMB

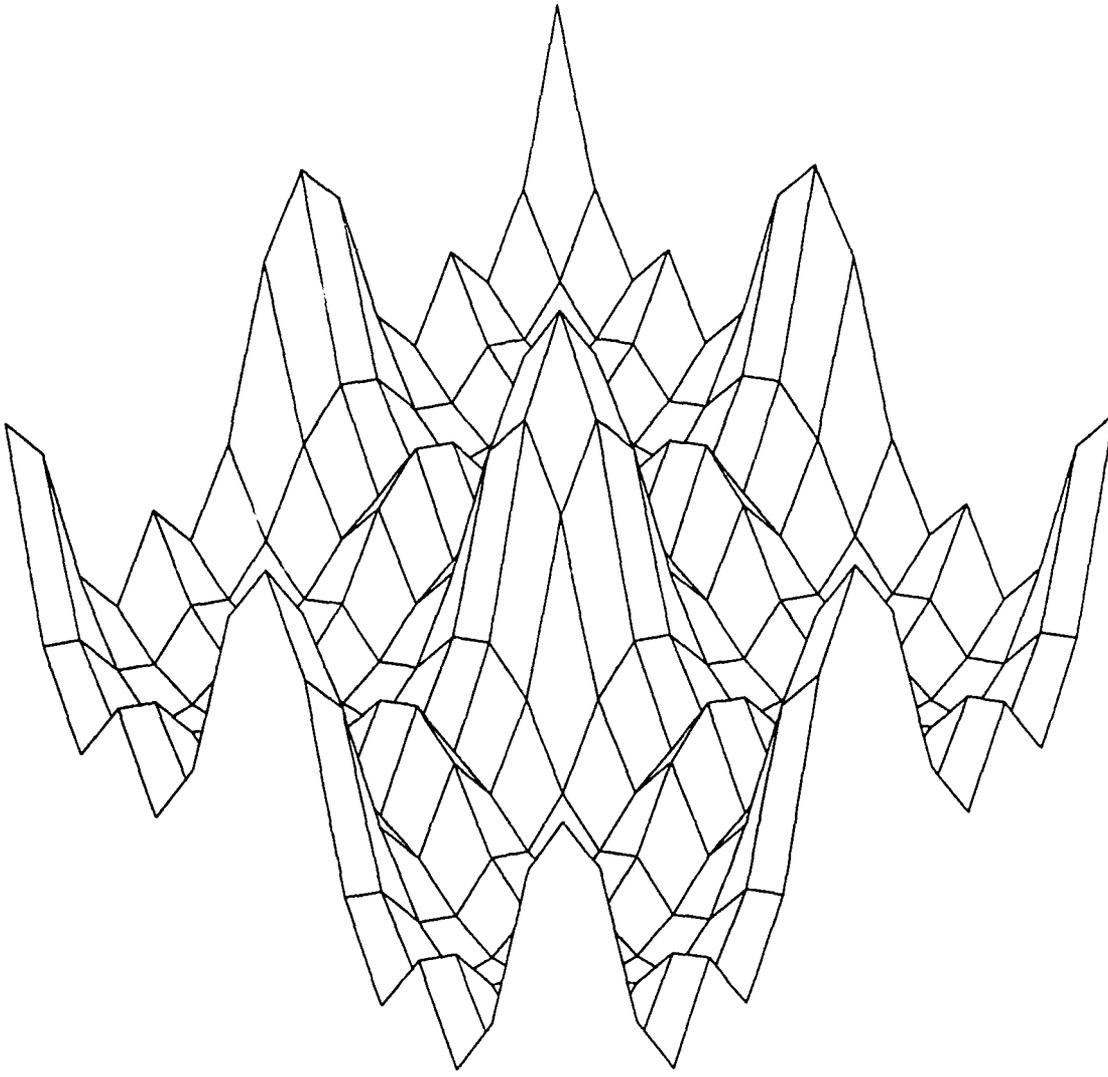


Fig.4 Fourier Transform of a Comb

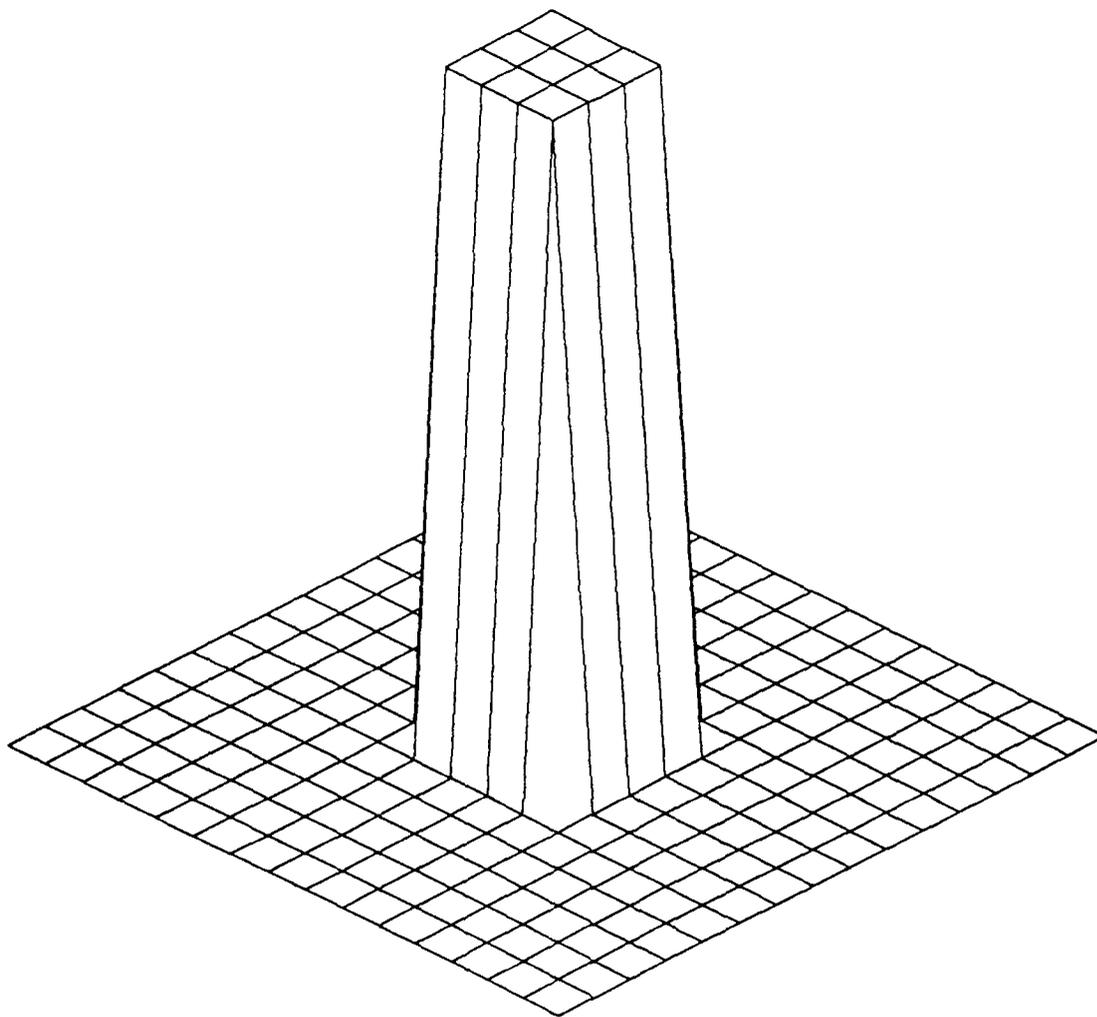


Fig.5 Inverse Transform of a Sinc Function

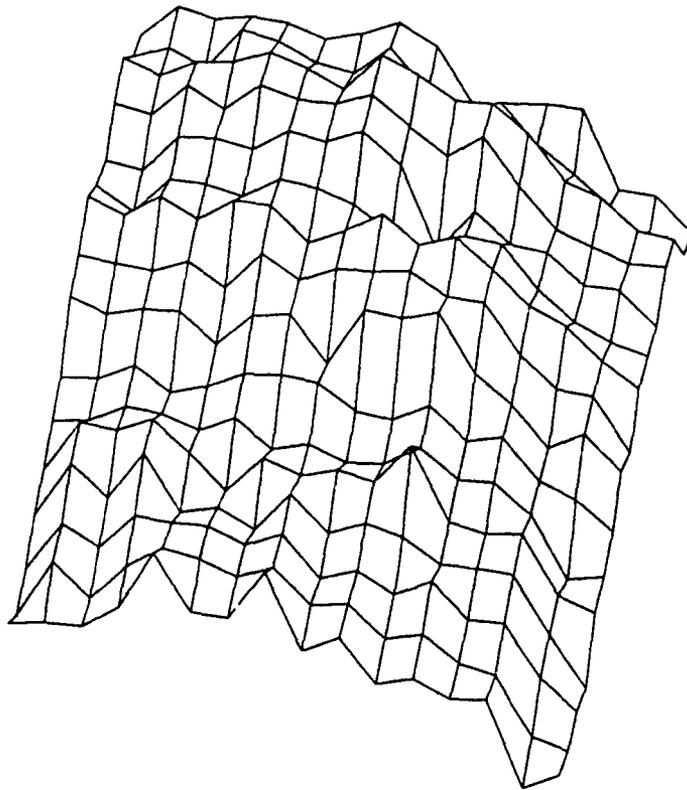


FIG.6 SURFER PLOT OF AFM DATA

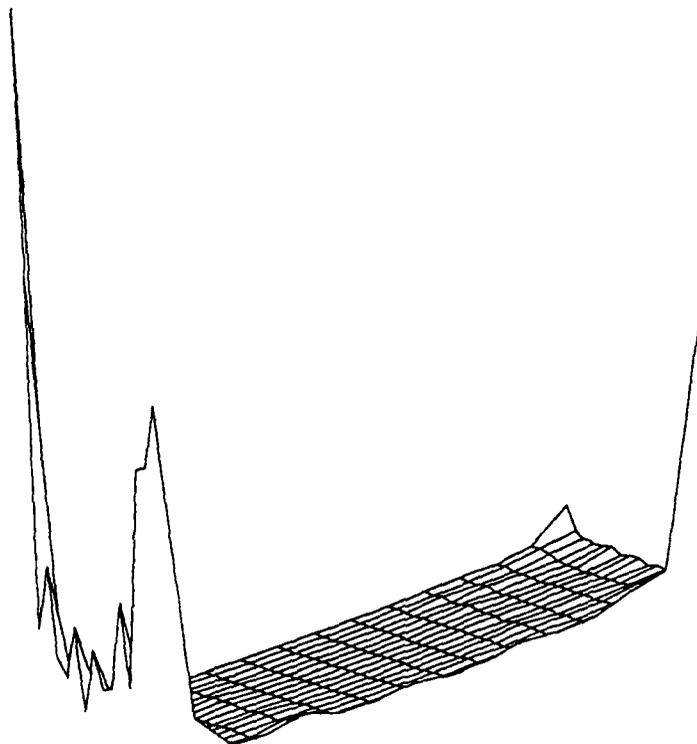


FIG. 7 FOURIER TRANSFORM OF AFM DATA

**THE DOCUMENTATION AND STUDY  
OF GROUND LEVEL ENHANCEMENTS**

**Melanie Carr  
Summer Apprentice  
Arlington High School**

**Final Report for:  
Summer Research Program  
Geophysics Directorate  
Phillips Laboratory**

**Sponsored by:  
Air Force Office of Scientific Research  
Hanscom Air Force Base, Bedford, MA**

**August 1992**

**THE DOCUMENTATION AND STUDY  
OF GROUND LEVEL ENHANCEMENTS**

Melanie Carr

Abstract

Ground level enhancement (GLE) data were studied. Data from neutron monitors all over the world have been collected. In order to make further study possible, these data need to be standardized and processed. Researchers at Phillips Laboratory have been put to the task using the Cyber and GL9000 computers. Variations in data pose many questions which, when answered, will make the data more effective for scientists to use. The causes, intensity, and prediction of GLEs need to be studied in order to understand how the sun works and to insure safe space journeys for astronauts and orbital equipment.

THE DOCUMENTATION AND STUDY  
OF GROUND LEVEL ENHANCEMENTS

Melanie Carr

INTRODUCTION

The sun is a variable star. Though great progress has been made in the study of the Earth's light source, much still remains unknown. For example, the sun emits a variable amount of particles each day (Foukal, 1990). At random times, once or twice a year, the sun shoots out an unusually high number of these solar relativistic protons (Gentile, 1991). These events are recorded by satellite sensors and neutron monitors and precipitated by solar flares (Jaroff, 1989). They are called Ground Level Enhancements (GLEs).

GLEs present a hazard to human beings. The radiation in the particles causes chromosome damage and ultimately cancer to living cells. Large amounts can be immediately fatal. The protons can penetrate spacesuits and shielding materials on satellites. On Earth, electronic, computer, and radio signals could be disturbed as a result of a GLE. Severe power outages in Canada have been traced to a similar particle flux (though not a GLE). Since these forces are not yet predictable, they pose a serious threat to astronauts and valuable satellite instruments (Joselyn, 1992).

Many factors are involved in the study of GLEs. For these to be researched adequately, efficient data must be

preserved and made available. The GLE Project at the Phillips Laboratory seeks to achieve these goals by computerizing all the data for 53 different ground level events in a standard format (Gentile, 1991).

#### THE GLE PROJECT

The standardization of all GLE data is not an easy task. The most advantageous data to researchers are the direct readings from the neutron monitors (uncorrected data), pressure information, corrected data, and percentage increase. These data are collected and recorded over a period of time which ranges from 7200 seconds (2 hours) to 60 seconds (1 minute) according to the capabilities of the station. Ms. M.A. Shea, a leader in the field of geophysics, has selected a 2-4 day time period for each event in which hourly and small-time data are to be entered and processed (Gentile, 1991). The hourly is for the entire interval while the small-time is only for a specific period of hours in which the event is believed to have taken place. Many stations have contributed data favorable to these restrictions. However, variations are numerous.

Jack Campbell, a scientist on a Boston College contract with the AFOSR, has catalogued all the data that is available for the documented events. A catalog has been compiled for each station as well as each event. Folders of raw data that have been collected for each event must be checked routinely so that the catalog will always be up to date.

## METHODOLOGY

Each set of data from each station for each event needs to be checked, entered, processed, plotted, and printed. If there are no problems with the data, this process is basically routine. Unfortunately, this case is not often found. Problems can be the result of many factors. Most data cannot be relied upon with confidence until it has been checked several times.

Besides the readings from the monitors, background information is required of every station. Longitude, latitude, altitude, type of monitor, standard pressure, unit of pressure used, and barometric pressure coefficient must all be taken into account. The geographic coordinates as well as the altitude are important to determining factors such as distance from geomagnetic poles, distance from the top of the atmosphere, and distance from other stations. There are variations in the neutron monitors so the type of monitor must be specified. The standard pressure, unit of pressure used, and barometric pressure coefficient are used to determine the corrected cosmic ray intensity from a standard equation.

Uncorrected intensity ( $I_{UC}$ ) is corrected using the background information and the pressure readings. The difference between the mean station pressure ( $P_0$ ) and the barometric pressure ( $P$ ) at the time  $I_{UC}$  was recorded is multiplied by a barometric pressure coefficient ( $B$ ). When  $e$  is raised to the power of the resulting value, then

multiplied by  $I_{UC}$ , corrected intensity ( $I_C$ ) is the product. The equation is as follows:

$$I_C = I_{UC} e^{B(P_0 - P)} \quad (1)$$

(Shea, private communication)

The percent increase relies on a baseline time interval. This also has been selected by Ms. Shea for each event. The data are measured in percentage increase or decrease from the corrected intensity baseline value. Thus the percent increase is calculated and plotted in a graph. These data are used to compare with other stations the increase in the cosmic ray intensity during the event.

Since there are different time intervals in the data sets, counts (the readings, corrected or uncorrected) must be measured in counts per second. All data are given in counts per interval so it must be converted.

Data must be preserved in its given form as well as its counts-per-second, percentages, and corrected format. Thus all enterable raw data must be entered in an "e-file." A "c-file" is then made that contains the e-file data that have been processed to the fullest degree.

Louise Gentile, a computer expert (also on the Boston College contract), has programmed the computers to perform the processes that need to be done. A barometric pressure

correction program (bpcp) uses uncorrected and pressure readings to correct the data using a method mentioned earlier. The counts-per-second program (csp) changes counts per interval to counts-per-second and records percent increases. The command, "plg," plots the percentages in a graph (Gentile, 1991). This plot serves as a valuable record which makes it easy to pinpoint the onset and maximum of each event in each station.

The GLE Project is progressing steadily. The cataloguing and assembly of data was begun a little over ten years ago, but the collection of data started more than twenty years prior. Since events keep happening, data keeps piling up. In fact, Event #53 was recorded June 25, 1992 (Campbell, private communication). Almost all data up to this point has been entered by workers at Phillips Laboratory or sent here in the standard computerized format.

#### APPARATUS

The Cyber and GL9000 computers are used for the database. The project was begun on the Cyber. Now that the Cyber is outdated and the GL9000 better fits the needs of the project, all files must be moved from the Cyber over to the Vax (GL9000). Computer problems occasionally hamper the project's progress. This summer, especially, was frequented with reconfigurations and reprogramming of the machines on which the researchers need to rely.

The Cyber system of the Phillips Laboratory is to be

shut down August 31, 1992. Numerous magnetic reclaim tapes are full of data and can only be read by the Cyber system. These data must all be transferred to other programs using the Cyber. Not only is it outdated but the Cyber is also very expensive to maintain (Jacavanco, private communication). For this particular project, the Cyber is useful in that it is easier to enter data than on the Vax. However, processing is more efficiently done on the Vax.

There are two programs that move Cyber material to the Vax. They are called hyperchannel and file transfer protocol (Gentile, 1991). Commands within these programs can transfer data not only from system to system, but within the certain directories and sub-directories that make up the database.

In addition to the computer files, GLE data are stored in solid form--in paper. All the "raw data," master copies of data sent directly from the station, are kept filed in folders by event. All data that have been entered and processed are printed out and filed in event books. There are also the station catalog book, event catalog book, and other forms of reference used to solve problems that arise (Gentile, 1991).

## RESULTS

Even though most of the data has been entered and processed, a great deal still remains to be done. All the

events must be updated. Problems in data must be solved. Most of the data must be verified and checked.

Updating the events is a difficult task. The researcher must go through every piece of information from one event. He or she must check all the data and make sure it has been entered correctly. Through the years, better methods of processing have been found, so many files need to be re-processed or even re-entered. The entire process requires hard work and much time. Phillips Laboratory found the need to hire summer workers to help with updating and other necessary tasks. This summer, Sue Jacavano, a senior at Fairfield University, came back for her fifth summer. Other summer employees through the years include Nick Vickers and Galen McKinley.

Throughout the time that GLEs have been documented, researchers from all over the world have been studying their characteristics. M.A. Shea, D.F. Smart, Steve Kahler, and Dave Webb, co-workers involved in the GLE project, are often invited to conferences where geophysicists from all over the world gather to share their information and learn from others' study. Each participant in the conference usually submits a written paper to be submitted and some are invited to make oral presentations. These conferences provide researchers with the opportunity of exchanging ideas for the continuation of their work.

## CONCLUSIONS

In a way, the GLE project will never reach completion. Stations will continue to see unusual rises in the levels of solar relativistic particles in their data. Since there is now a standard format for the data, data from new GLEs will be sent to the database via computer. Technology in neutron monitors will make data more precise and easier to work with. When all existing data is assembled and processed, further study of all ground level enhancements will be possible.

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PROGRAMMING BAR CODE READERS FOR  
INVENTORY PURPOSES USING  
THE INTERACTIVE READER LANGUAGE

Kyle R. Conway

Final Report for:  
Summer Research Program  
Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
Kirtland Air Force Base, New Mexico

August 1992

PROGRAMMING BAR CODE READERS FOR  
INVENTORY PURPOSES USING  
THE INTERACTIVE READER LANGUAGE

Kyle R. Conway

Abstract

Programs were written for bar code readers for the purpose of taking inventories. The readers used were INTERMEC 9440 TRAKKER readers, and were programmed in the high-level computer language Interactive Reader Language (IRL). The programs written were: an updated version of the Automated Material Control System (AMCS), and the original version of BenchStock, a bench stock program that allowed a user to scan a label and then enter the quantity of that item. Comprehensive user guides were written for each.

PROGRAMMING BAR CODE READERS FOR  
INVENTORY PURPOSES USING  
THE INTERACTIVE READER LANGUAGE

Kyle R. Conway

Introduction

Taking large inventories and keeping track of large inventories is a formidable job due to the sheer size inventories can be. Bar codes, which are series of symbols encoded in patterns of vertical lines, and bar code readers, the hand-held devices with wands utilizing lasers to read the bar codes, are used to make the job faster and easier by simplifying and speeding up the inventory collection process.

Programs for the readers can be written for specific applications. These programs are written in the high-level computer language called Interactive Reader Language (IRL). When new programs are written they need simple, explanatory user manuals. Step-by-step manuals that list every step are preferred because users reading the manuals are told exactly what to do.

Problem

The problem was to create two user-friendly programs with non-ambiguous user manuals for use by Logistics Material Control Activities (LMCA) control managers and equipment custodians. One program, AMCS EAID version 2.0, was already in use, but contained two major bugs that could interfere with getting a complete inventory: one was that users could enter the location of their inventory collection and scan one label onto the end of the location, resulting in the reader treating

the location and label as a single incorrect input; the other bug was that users could enter account numbers in lower case letters where upper case letters were needed.

The second program was the original version of a bench stock program where users could scan a label and then enter the quantity of that item. After each program was written or corrected, a comprehensive user manual that was easy to use and understand was needed for the each program.

### Methodology

The PC-IRL computer package, made by INTERMEC Corporation, is one that: will compile, run, and debug IRL programs on an IBM or compatible personal computer; will download to a hand held reader; and will download to an erasable, programmable read-only memory chip (EPROM). Using PC-IRL and the WordStar word processor, by MicroPro, programs were edited, tested, and changed on the PC. Programs were also tested in application on hand-held scanners.

Corrections to the bugs of AMCS EAID v2.0 were relatively straight forward. To fix the first, the one of scanning a label onto a location, a carriage return was needed to separate the location and the scanned labels. Therefore, the processes of entering locations and scanning labels needed to be made separate so that the user was forced to perform them separately. To accomplish this, the program was changed so that users would choose to scan or key in locations. They could also use <F5> to toggle between the two. If they chose to key in

locations, no scanned labels would be accepted until <ENTER> was pressed; if they chose to scan locations, only scanned data or <F5> would be accepted. (When locations were scanned, the necessary carriage return was automatically added.) Thus, this problem was solved by making it impossible for the carriage return not to be entered. The second problem, where users would enter account number in lower case letters, was solved with a subroutine that would, unseen by the user, take the account numbers, character by character, and capitalize all lower case letters.

After correcting these bugs, a comprehensive, non-ambiguous user manual was written. It was written in a step-by-step manner so that each step had its own bullet statement. This entailed thinking through all parts of the program, without taking any steps for granted. The TRAKKER 9440 screen was represented in a block so that the user reading the manual knew exactly what s/he should see. Figure A is an excerpt of the manual.

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AMCS EAID Inventory Version 2.1 06/23/92 Enter ACCOUNT then press ENTER.>_ <
---------------------------------------------------------------------------------------

FIGURE 1

1. This is the opening screen.

1.1. Enter your account number.

The first three chars.  
must be numeric. The  
last two must be alpha.

1.2. Press <ENTER>.

---

FIGURE A

This manual was meant to leave everything explained with no questions unanswered.

BenchStock v1.0 was written using AMCS EAID v2.1 as a skeleton. It was changed so that, after a label was scanned, the user would be prompted to key in the quantity of the scanned item. BenchStock's user manual, too, was written using the AMCS EAID v2.1 manual as a skeleton.

### Results

Two functioning programs with user manuals were written.

### Conclusions

The two programs were user-friendly, and manuals were easy to understand.

### Summary

In summary, two user-friendly bar code reader computer programs were written using IRL. For their users, manuals were written. The programs were written to be as easy to use and understand as possible, and the user manuals were written to explain, step-by-step, how to run each program.

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High Resolution Statistical Models for Prediction of Cloud Cover.

Jeffrey P. Cutler

Interpretation of an Icing event during WISP-90

Jeffrey P. Cutler

Fill Program to Prepare Satellite Overlays

Jeffrey P. Cutler

Final report for:

AFOSR Summer Research Program

Phillips Laboratory

Sponsored by:

Geophysics Directorate Atmospheric Prediction Branch

Hanscom Air Force Base, Bedford, Massachusetts

August, 1992

High Resolution Statistical Models for Prediction of Cloud Cover.

Interpretation of an Icing event during WISP-90

Fill Program to Prepare Satellite Overlays

Jeffrey P. Cutler

Abstract

The creation of high resolution statistical weather forecasting models was studied. A statistical weather model is developed through taking large amounts of data and creating a composite equation. Data was collected from January to December of 1989 and processed by a cra2 computer in Alberque, New Mexico. From this data a statistical model will be developed by a contractor that will predict the formation of clouds.

The development of icing conditions caused by the presence of supercooled liquid water (slw) was studied. Using a numerical model modified to accept the presence of slw, a new consideration in the prediction of icing conditions was theorized.

A Fortran program was created to fill in computer maps so that they could use be used for satellite overlays. The program fills in large areas of an array by creating a massive chain of points that determine values of pixels at each point of the compass.

## High Resolution Statistical Models for Prediction of Cloud Cover.

Jeffrey P. Cutler

### Introduction

As computers have become more powerful, meteorologists have begun to use more sophisticated mathematical and statistical models for forecasting weather patterns. These models have to take into account a myriad of factors over a large time frame and large area in order to develop an accurate forecast. Current models tend to be accurate only when predicting large weather patterns, but often lack the high resolutions needed to predict conditions in a specific area. This lack of resolution is a major concern of both the Air Force and civilian organizations. A higher resolution model would be able to more accurately predict conditions that would affect flight, satellite visual and infrared photography, as well as military exercises. The MOS-Based High Resolution Cloud Prediction model is being created in order to provide the high resolution necessary to predict whether or not a cloud will exist at a given point when starting conditions are known. The model's resolution is expected to be very high. Figure 1 shows a relatively low resolution cloud forecast by an older model. Figure 2 shows the actual cloud analysis for the same period as figure 1.

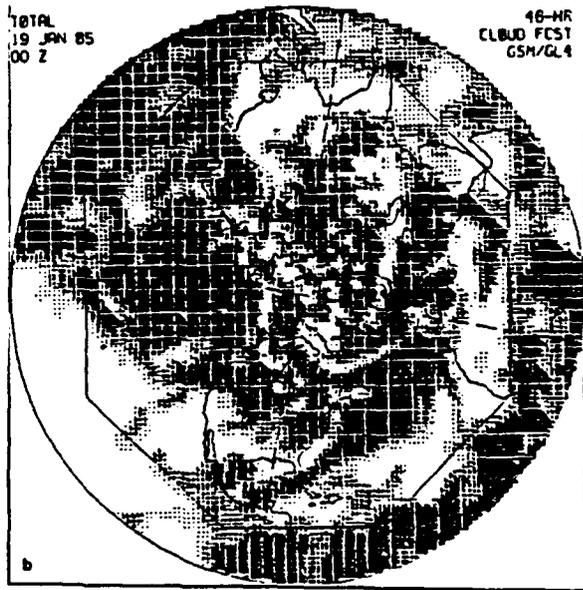


Fig. 1.

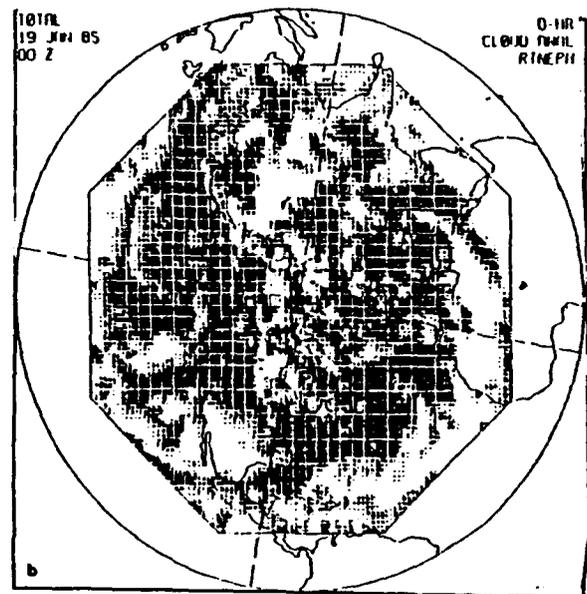


Fig. 2.

#### Description of the Model, its Applications, and Initial Data

The Model Output Statistics (MOS) based High Resolution Cloud Prediction (HRCP) model uses a statistical approach to attain higher levels of resolution. This higher resolution is needed because earlier models could not detect turbulence scale motion over a large computer grid; this motion is a major factor in cloud creation. A statistical model uses data gathered over a long period of time to make an equation that gives the probability of certain weather conditions occurring given starting conditions. A statistical model was used instead of a mathematical model because it tends to be more accurate over a shorter time period, and includes a large amount of data relevant to the goals of the researchers using the model. The MOS-HRCP model is being created in order to predict the existence of cloud over any place in the northern hemisphere, using MOS forecasts, at any time given time.

The model was commissioned by the Air Force for many uses. The main use will be to predict the existence of clouds over an area where satellite photographs have been requested. It is very costly to maneuver a satellite, and the Air Force would like to increase the life of their satellites, by not wasting fuel on a change of orbit that will bring a satellite over a cloud covered target. The MOS-HRCP model could save the government millions of dollars. The same is true for civilian organizations. Another application is the prediction of cloud conditions at airfields. Many smaller planes are not equipped with navigation gear to fly in foul weather. A high resolution cloud prediction model will allow aircraft controllers to determine the safety of small aircraft flights into an airport by providing detailed flight conditions. Air traffic controllers will be able to take into consideration the chance of fog, or icing conditions, and be better advised on the ability of aircraft to land at their airport.

The model uses data from January, 1989 to December, 1989 containing surface and high altitude observations from around the world provided by the National Climatic Data Center(NCDC). As the tapes sent to us by NCDC contained data collected every three hours it had to be filtered so that we would process every twelve hours worth of data in order to keep the volume of number crunching low enough to make model runs feasible. In all, seventy-two tapes were processed.

#### Procedure

The data received from NCDC was processed into twelve hour time periods on a Digital VAX at the Air Force Interactive Meteorological System (AIMS) in Bedford,

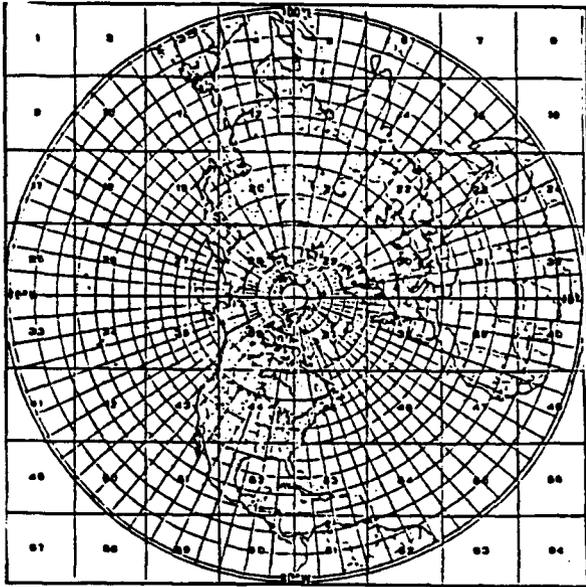


Fig. 3.

Massachusetts. It was then transferred to the Air Force cray2 supercomputer in Albuquerque, New Mexico. At the cray2 the data was processed by the Global Spectral Model(GSM) in order to create predictions of factors relevant to the formation of cloud. The model output was in spectral coordinate form, and needed to be converted to a polar grid similar to figure 3.

The spectral coordinate system uses crossing sine and cosine waves to position a point on a

map of the earth. As the data was transferred back to AIMS it was converted to a half-mesh grid, and backed up onto 8mm magnetic tape. These tapes will be sent to a contractor who will create an equation based on the GSM data that will predict cloud formation. This equation will assign coefficients representing each prediction's influence on the formation of cloud, and then take a summation of all of the factors and give the probability of a cloud forming based on MOS forecasts.

## Interpretation of an Icing event during WISP-90

### Introduction

As the nature of the Air Force's strategy has shifted from high altitude operations to low-level, the prediction of low altitude icing phenomenon has become increasingly important. Also, icing affects civilian operations as well. As one of the main causes of aircraft accidents, icing has long been a major concern of both military and civilian organizations. The methods currently used for predicting the development of icing conditions are outdated, and aircraft safety could be greatly improved by the use of new theories and computer models.

#### Description of Model and Initial Data

The model used for this experiment was created by the National Center for Atmospheric Research (NCAR) and Pennsylvania State University. The original model did not allow for the existence of water whose temperature was below freezing without have become ice (supercool liquid water), and was modified by adding an adjustment for ice/water saturation. The model determined whether supersaturated air would be represented as liquid or ice cloud using an equation based on temperature. The model assumes that all supersaturated liquid is removed from the atmosphere.

The data used as initial starting conditions was collected in Colorado on February 13, 1990 as part of the normal National Weather Service surface and high altitude observations. Data was also included from the Winter Icing and Storms Project 90 (WISP 90), which

Mountains. The model made predictions at grid points that were situated 33 kilometers apart. These predictions were then interpolated to a 10 kilometer pressure surface grid which made the data easier to interpret and gave the model a higher resolution.

#### Results of Model run

Plots were made showing horizontal windfield, vertical windspeed, cloud forecast, relative humidity, pressure variations, and a cross section showing angular momentum and equivalent potential temperature. The model shows a cloud forming along the front range of the Rocky mountains, figure 4, which is also the location of a few interesting predictions. Figure 5 shows a strong wind impacting the front range, which creates tries to lift air over the mountains. The cloud in figure 4 seems to be following the lines of ascent shown in figure 6 the angular momentum and equivalent potential temperature of the air along the front range. The above results suggest that this slantwise ascent might be an important part of the creation of icing conditions, and should be considered when making predictions about the existence of supercooled liquid water.

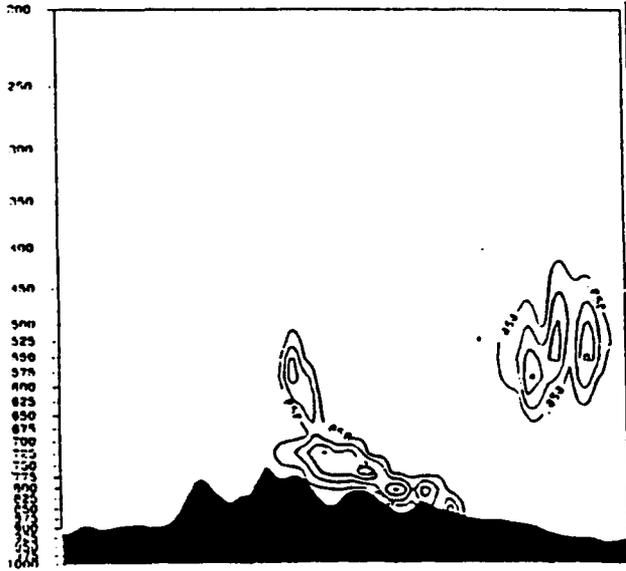


Fig. 4.

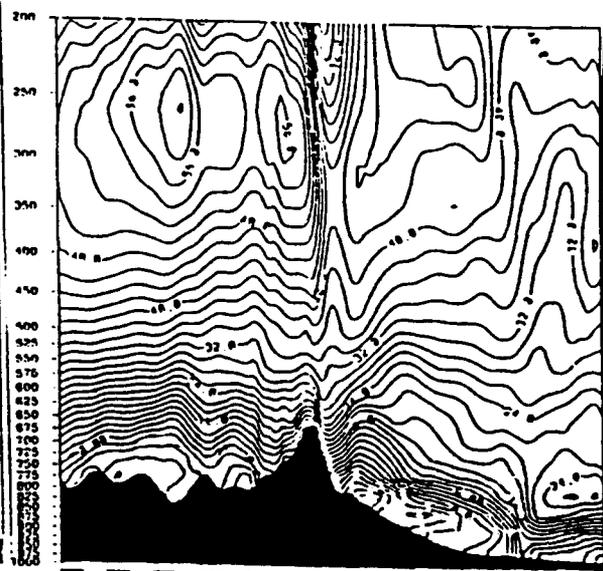


Fig. 5.

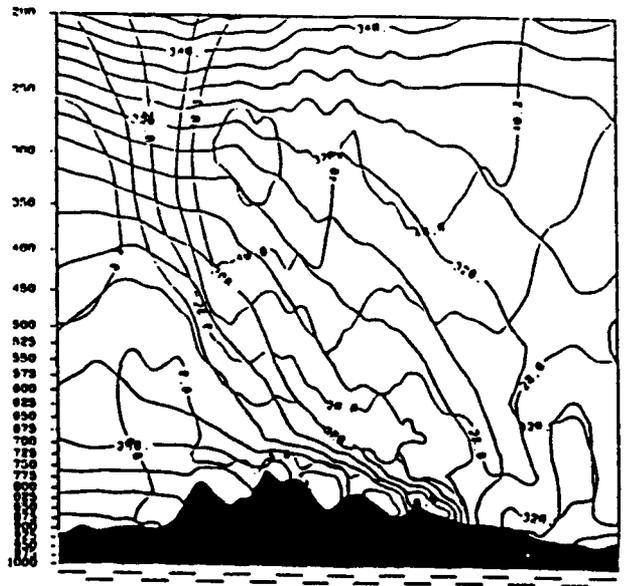


Fig. 6.

## Fill Program to Prepare Satellite Overlays

### Introduction

When looking at satellite imagery, it is important to be able to determine the boundary between land and water. Also, a human observer might need to be able to determine where land ends so that they can determine the different intensities of clouds resulting from backscatter differences between the land and water. One of the researchers at the Geophysics Lab in Bedford, Massachusetts needed a map of Florida as an overlay for some satellite imagery. In the past a computer operator would have had to outline the map using a bit pad. A more efficient means of doing this was requested.

A program that would fill in large areas of an array was needed to fill in the ocean and a few lakes with a low pixel brightness so that a computer program could discern the difference between land and water. Since the map provided was one color, except for the border marking coastline, a large memory array was needed in order to fill the proper area. There were some holes present in the border that needed to be filled with the same pixel brightness as the border.

### Procedure

A Fortran program was written to fill in both the holes in the border and the large areas taken up by water. The program was set up to be able to fill any 512x512 array with a value input by the user. The program reads in the initial array, placing the values of each pixel at a point in another array. For example, the value of a pixel might be  $x=139$   $y=248$   $color=128$ . Then the program asks you to identify the color of the border. With this information the program can fill in the array with any value that the user wants. Users are warned that a hole in the border will set the whole array to the color of the fill. A user could use another program to find the location of holes and then enter those values with a point setting loop. The fill program works by starting at one point; it then checks the color value of each point north, south, west, and east. If the color value is not equal to the color of the border or the color value of the fill, that pixel is set to the color value of the fill. Each of these points then checks a point at the four points of the compass, creating a massive repeating chain. If the color value of a pixel is equal to the border or fill color, the program does not change the value of that pixel, rather, it stops that part of the chain.

## Conclusion

The file that needed to be processed was successfully completed and the overlay was written to the proper to the proper channel. The program completes a job that would have taken an experienced operator three days to complete in approximately three minutes, with better resolution than is possible by the old method.

**EXPLORING ELECTROMAGNETIC EFFECTS**

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Final Report for:  
Summer Research Program  
Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
Kirtland Air Force Base, Albuquerque, NM

August, 1992

## EXPLORING ELECTROMAGNETIC EFFECTS

Anthony W. Davis  
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### Abstract

As the the military assets of this nation become more advanced, they make increasing use of microelectronics for guidance and control. These microelectronics are very sensitive to microwave energy, and in an effort to combat this fault, most assets are shielded, or "hardened" against this threat. In an effort to assess the effectiveness of this shielding, Phillips Labs has several groups devoted to testing military equipment at various energy levels and across a large bandsread. During the summer, the testing was centered on an aircraft and its various components and accessories, including its navigation and targeting pods. A variety of test procedures were used to assess this hardening, most of which involved radiating the asset and measuring the power absorbed by the various systems. Due to the sensitive nature of the data gained, the writer of this paper has no knowledge of the specific abilities of the assets to resist damage from electromagnetic energy.

## EXPLORING ELECTROMAGNETIC EFFECTS

Anthony W. Davis

### INTRODUCTION

As the recent war in the Gulf illustrated, advanced technology provides an impressive advantage over less prepared nations. This country's weapons arsenal continues to become increasingly sophisticated. While the new generation of weapons provides this country with a strategic edge, the electronics employed in these systems is now seen as one of the holes in the sophisticated armor. In the past the fear has been concentrated on the enormous electromagnetic pulse generated in a nuclear blast. Electronic systems have been shielded or "hardened" against this type of high level pulse. Very little attention had been paid to the possibility of a weapon specifically designed to emit a constant supply of destructive electromagnetic energy in the form of microwaves. As artificial pacemaker wearers may know, microwave energy can induce unwanted electrical currents into an electrical circuit, disrupting normal current flow and potentially damaging the sensitive components. Now research is underway to protect defense equipment from harmful microwaves which could render them useless. This series of tests focused on an aircraft and its accessories, including its navigation and targeting pods. By using low power testing, we assessed the abilities of each component to withstand microwave energy.

### APPARATUS

The testing apparatus in each test remained essentially the same. A signal generated by a network analyzer was amplified by a

microwave amplifier and radiated into free space by a horn type antenna suitable for the frequency. During field maps the transmitted energy is measured by a b dot probe and returned to the network analyzer for comparison with the signal leaving. For actual testing, a variety of probes measured current and voltage in the electronic systems, while b and d dot probes measured the microwave energy which entered the housing. The testing was conducted in an anechoic chamber to eliminate reflections and assure a controlled beam direction. Testing was also conducted in remote locations outdoors for the same reason, but this time letting the energy dissipate into free space instead of absorbing it with graphite impregnated cones. Also, testing was conducted in a reverberation chamber, a large aluminum box, intended to reflect the microwave energy and radiate the asset evenly from all sides. Specific frequencies and power settings are restricted information.

#### PROCEDURE

The first step in any test, aside from making coffee, was to make a field map. This would be used to make sure the equipment was working properly, but more importantly to provide information about the radiated area to be used later to correct the final data. It is important to know how much energy is passing through an area before the asset is placed there to compare this with the energy which enters the asset. Also, if the same cables are used for the field map as the data acquisition, cable losses can be eliminated. To make a field map, a b dot probe was placed in the

center of the area to be occupied by the asset and the frequency was swept through the frequencies to be used in the testing. The probe was then moved to locations marking the outside edges of the asset to ensure the beam width of the horn antenna would not collapse at the higher frequencies and fail to cover the entire asset. The horn antenna and probes are polarized, meaning the E (electric) field is oriented in a certain direction while the B (magnetic) field is 90 degrees rotated from the E field. The orientations are referenced to the E fields, so a vertical polarization means the E field is vertical, while the B field is horizontal. If the probe is not oriented correspondingly, the measurements will be background noise. The shielding of the assets will vary depending on the polarization of the energy, so both vertical and horizontal orientations were tested, and thus the field mapping was done in both the horizontal and vertical positions. The field map, as well as all testing, was conducted by a computer, and the resulting data was saved to disk to be used later.

Another group decides where the probes should be placed in the assets, taking into account openings in the outer case, sensitive circuits, and large cavities. The asset is then placed into the chamber or onto the concrete pad where it will be tested. A similar procedure to the field map is used for testing the asset, except there are now more probes to test in each orientation. Also, the asset is rotated to determine hardness in every direction. The network analyzer sweeps through the specified frequencies and compares the power leaving through the amplifier to the power returning from the probe. The data is also saved to

disk for later correction.

Since the conditions of the area were mapped earlier in the field map, it is a simple matter to subtract the differences between the field map and the data, thus producing a shielding effectiveness ratio, expressed in Db. At this point the data becomes Classified and I have no knowledge of the results.

This data is all well and good, but what does it mean? How much microwave energy is actually dangerous? For this measurement, high levels of energies are used to see at what point the system actually becomes disrupted. This "upset testing" is conducted in the same manner, except the power is increased instead of the frequency. The functioning of the asset is monitored by the equipment until it fails. This testing used in conjunction with the earlier coupling test can predict the ability of an asset to withstand microwave energy without the need for high power testing, which is potentially harmful to the asset and requires more money and time to perform.

## CONCLUSIONS

As the data became corrected, it also became classified, so the results cannot be included in this report. As the field of low power testing improves, the need for costly high power testing equipment will diminish. There will always be a need for high power equipment to test the results of low power measuring, however. The combination of the various measuring techniques will ensure the next generation of military equipment will be safe from the latest threat.

## ACKNOWLEDGMENTS

I would like to thank all the people at the WSM division of Phillips Labs for the wonderful learning experience, and especially Capt. Thomas Loughry for taking the time to impart his knowledge in the area of electromagnetics to me and remaining patient when I looked at him as though he had recited the Odyssey in its original Greek.

A RESEARCH LIBRARY ON YOUR  
COMPUTER TERMINAL

Catherine E. Downey

Final Report for:  
AFOSR Summer Research Program  
Phillips Laboratory  
Geophysics Directorate

Sponsored by:  
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August 1992

A RESEARCH LIBRARY ON YOUR  
COMPUTER TERMINAL

Catherine E. Downey

Abstract

Through use of a CD-ROM machine, the resources of an entire research library, and more can be at your fingertips. CD-ROM machines have brought a new age of technological advancement to scientific research. On an individual database, you are able to look up papers written on a particular subject, or by a particular author over a time frame of anywhere from one year to four or five years. With a CD-ROM connected to your network all of this research can be found without leaving your own PC. Initially it is a complicated process to connect the CD-ROMs to the network, and small problems may arise, and need to be found and corrected, so the databases will run properly. Finding these problems can be done by having certain people use the databases, and report what causes problems. Once all of these problems are solved, the CD-ROM can help people to find information in a simpler, and more convenient way than ever before available.

A RESEARCH LIBRARY ON YOUR  
COMPUTER TERMINAL

Catherine E. Downey

INTRODUCTION

A recent development in information services and databases, is the Compact Disk Read Only Memory (CD-ROM). CD-ROM drives use a laser to read information stored on a Compact Disk (CD). The Compact Disks are basically like floppy disks in that information is stored on them, and they are used in conjunction with a drive which can take that stored information, and display it in a way we can read it. One of the big differences between CDs and floppy disks, is the amount of information they can hold. It only takes one CD to hold all of the information from an entire encyclopedia, which is a lot of information. This summer I used the CD-ROMs at the Geophysics Directorate of the Phillips Laboratory to research the topics of triggered lightning, and recent advances in lightning simulation, especially having to do with Laser Induced Plasmas (LIPs). I also did a search on dust and sand, emphasizing the particle make up of blowing dust in the desert. When the CD-ROMs were installed on the network, I was one of the people who used the system and documented the problems and discrepancies in the network version. I also wrote a short paper of tips for people who will be using the CD-ROMs when the system is made available to all the scientists on the network.

PROBLEM

The main problem that was faced in introducing the CD-ROM

onto the network, involved finding the problems, and mistakes in the way that the program ran. To do this it was necessary to have people who had some idea of how the CD-ROMs were supposed to work.

### METHODOLOGY

Since not that many people had experience with the CD-ROM, those that did were asked if they would help evaluate the program. The advantage to the people who were evaluating the program was that they would be able to access the CD-ROMs on the network, thus saving them from a trip to the library, where the CD-ROM drives are located. In exchange, the people who were evaluating the system would report any discrepancies which they found. During the test period, I tried this program on four different PC's, and each one had different problems with the system.

### RESULTS

I have included as an appendix the report I wrote describing the problems I found with the system.

### CONCLUSIONS

I feel that the CD-ROM is an incredible new piece of technology, which will become more and more popular in the future. It allows you to search resources in a way never before possible. Simply by typing a term into the computer, it will come up with a list of all of the documents it has that contain that term in them.

This allows for a search with a much broader overall base, because you can see what other areas involve your search term. Lists containing cited references allow you to search for any related documents that include similar base ideas and theories.

Another big advantage of the CD-ROM, is that one CD can hold the same amount of information as five to twenty floppy disks. This amount of information is continually increasing as lower mass lasers and lightweight plastic lenses are developed. Recent developments with blue-green lasers have brought promise for faster CD's that will be able to hold more data due to the shorter wavelength of this new type of laser.

CDs are also safer for the environment than floppy disks, and other data sources. One CD can hold anywhere from 500 Mbytes of information to over 1 Gbyte. This is what enables 1 CD to hold the same amount of information as 5 to 20 floppy disks. Another advantage of CDs is that since they hold so much information, many software companies include their manuals on the CDs, which saves the paper that these manuals would otherwise have been printed on, which in effect saves trees. Many of the boxes that CDs come in are recyclable, to help save on waste products as well, and many of the CDs have original packaging which is made of recycled products.

CDs are also more portable than floppy disks, due to the fact that you need considerably less of them to store the same amount of information, and they are not effected by electro-magnetic radiation or dust as floppy disks are. So you would have no problem bringing them through an x-ray machine at an airport,

except that they might set it off due to their metal core. At least your data would not be ruined if you were flying to an important meeting though.

Although prices of CD-ROMs are high now they should go down a significant amount as the quantity bought increases. Another factor that will lead to the deduction in price is the new CD recording machines. As these become readily available, more CDs will be produced, which will allow for a greater selection of databases, in turn enticing more people to buy CD-ROM drives, and eventually CDs.

Another advantage is to the software developer, because at least now CDs are read only memory, which means that the average person can't copy CDs, so they will have to buy their own copies which in a way is also good for the consumer, because since demand will stay high, prices will be able to remain low. Until the market increases the prices will stay at their current high levels. The possible down fall to this comes in the new production of CD recording machines. For people don't realize that by copying disks they would in effect be driving up the disk's original prices. Another reason that prices should go down is that as the price of the recording devices and blank CDs go down, it should cost the computer companies less to produce one CD than 5 to 20 floppies.

Another possibility for the future would be coded CDs. If you could put information on a CD in a way that you would need a special CD-ROM drive to read it, you could store classified information this way, and even transfer it, due to the portability

of the CDs. Some companies are already experimenting with this.

I feel there is a great future for the CD-ROM, and the usefulness of this technology is immeasurable. I have no doubt that this is a great invention, that can save time as well as money.

#### Acknowledgements

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## APPENDIX

### Some of the problems with the network version of the PL/GP Library CD-ROM databases

A few problems have been found with the CD-ROM databases, as used on the network. The main problems stem from the differences between individual PCs attached to the network. Results of the CD-ROMs on the network are being reported from four different PCs, which produced four different sets of results. This is mainly due to the fact that everyone has different things loaded on their PCs, which mostly effects the RAM available, but may also effects other properties of the databases.

To run a fielded version of Computer Select, you need 512K RAM. Out of the four computers used, not one had that amount of memory. To get 512K you would have to wipe out almost everything except for DOS. Two of the computers didn't even have enough memory to run the non-fielded version of Computer Select, or the other two databases. This can be changed by modifying the configuration of your computer, but who wants to modify the entire configuration on their computer? If people are going to have to do that it would be just as easy for them to go to the library to use the CD-ROMs. Isn't there a way for more memory to be used straight from the GL9000, and less from the individual PC's? Or in some way lessen the amount of memory required in the PC's? Could some of the required memory be found some where else in the network?

Another big problem with these databases, is output. Some

PCs won't print, and some save the files to strange places. The problem with printing also has to do with individual PCs some of which are configured with more than one printer, and don't have their primary printer as LPT1. This may be because a personal printer is connected to the PC, or for some other reason. Two of the databases, Computer Select, and National Technical Information Service (NTIS) both assume that you are out-putting on LPT1. It would be really nice if somehow an initial question screen like the one in Science Citation Index (SCI) could be incorporated for these two databases, or the SCI one could be used as the responses for all three of the databases.

Some of the default answers in the question screen would be better if they were changed. Question #2 asks if you want form-feed after printing each record or page, and the default is "no". The problem with this is that it tells you that if you are using a laser printer to answer "yes". Everyone in PL/GPAA is connected to a laser printer through the network, and other than when the network is down, or there is some other problem, people generally use the laser printers, so wouldn't yes be a better default? For question #6, the default for "what drives may be used for saving search strategies and records?" is c:\dechnet\sci\, and on some of the computers there were problems using this path to save things. Files tended to get lost, and were hard to find since they weren't where they were supposed to be. Personally I prefer saving to floppy disks due to the fact that the information is not that

permanent, and why have it take up space on the hard drive when it isn't necessary. Even if the default was for the hard drive, it might be better if a different path was specified.

When it comes to printing, another annoying problem is that the print commands from the data bases don't clear the queues of the laser printers on the network, so to get the document to actually print, after you have already specified it to do so from within the database, you must either exit to DOS(which is not an option in SCI) and use a print command or disconnect from the network. It would be a lot more convenient if there was a command within the print program which would clear the printer queue.

When you save files and bring them up in a word processing program such as WordStar, some additional problems are faced when printing. If the document is from Computer Select, the margin may be wrapped around, with the text starting at the margin, and going to the right edge of the page and then continuing at the left of the page on the next line down, and then skipping to the next line, and beginning at the margin again. It looked as if the margin mark was not on the edge of the page where it should be, but to the right of that. In SCI and NTIS the right side of the document just gets truncated, generally by one or two words, which makes it almost impossible to read. If you want to be able to read these documents after printing them, you have to reformat the whole document which is very tedious.

In addition to the problems with printing, saving can also be a chore. You have to be sure when you save to specify the drive you want, and a path if necessary, or else your file could get lost in a black hole somewhere. Things have been found under decnet\temp, or in the system configuration file. This would also benefit from a carry over screen like the one used in the SCI database, as it would allow for the user to choose those options that best fit him and his PC. The one thing that is needed though, is a lot better directions about how to get back to change your original choices if you don't like them, along with more information as to what the different choices mean, can do, and how they affect your use of the CD-ROMs. To change any of the choices for the questions in the initial set-up screen after you originally answer them you must go to DOS, and get into the sub-directory c:\decnet\sci, and delete the file isicde.ini. Then when you re-open SCI, the initial set-up questions appear again.

Could a screen be implemented between the main menu, and the CD-ROM applications menu, which would be similar to the questions asked in SCI? That would instead carry over for all three of the databases. It would be nice if it were permanent instead of disappearing, if you could make the choices you wanted to be the defaults, so if it were necessary to change something it wouldn't create a big hassle. Since you could set your own defaults, if it were fine the way it was, you could just hit F10, and go straight to the CD-ROM applications menu to get started on your search.

Another way to do this would be to have a general screen that would work for all of the databases, but add an extra choice into the CD-ROM applications menu which would allow you to access your choices if you ever wanted to, but this way you wouldn't have to see them unless you wanted to. This would probably be the most user-friendly option.

Some individual PCs have brought up some interesting problems that weren't encountered by other PCs. Two of the PCs printed "bad command or file name" whenever you selected a choice from a menu that had to do with the CD-ROM, and when you chose a data base from the CD-ROM applications menu, it printed "invalid directory" on the screen. Despite what it said on the screen, there was no further problems, but it was confusing. Another strange message that was encountered, said "remote computer not listening." This happened when the server was disconnected and being used for something else. It seems as though messages that are more helpful, or at least relevant, could be printed, which might give a better idea of what is actually wrong. It would be helpful if there was some type of short reference sheet that would give some messages and ideas of what they could possibly mean, or at least a general idea of whether it mattered that the computer "didn't have enough memory, and the search may at some point be disconnected."

Some of the databases have their own little quirks too. In the title list search of NTIS, the up arrow brings you up the

screen what seems to be some random amount, and it would be nicer if it just brought you up a line, in case you missed something. If you wanted to go up multiple lines, you would have used the **page up** key. In SCI, if you go to database, and ask to change the database, it tells you to put the new CD in the drive, and hit return, which is quite impossible while sitting at your PC. It would be nice if from that point you could select to change the CD you are using, since now the only way to change the CD to a different year, is to go all the way back to the CD-ROM applications menu and re-select SCI with a different year. It would also be nice if there was a place in SCI that would allow you to run a DOS command.

Sometimes when you are using SCI the menu freezes and the clock stops, which makes it impossible to select anything, or even to exit to the main menu or DOS. This is a real nuisance, as you have to restart the entire computer, and wait for it to boot, and then restart the network, and wait for that, and then go all the way back to where you were. This tends to happen if you leave the keyboard idle for a little while.

Every once in a while, when you get into SCI, it says it can't find any compact disks, to check the CD-ROM drive and press **return** to continue, **esc** to return to DOS. If you try the other databases, they don't work either. Computer select will print "bad command or file name" on the screen, and then return to the CD-ROM

applications menu. NTIS will let you choose what type of search you want to use, and then it will give you the message "no databases found on disk(s) :c press any key to continue." Then if you exit the network, and start it up again, it stops on #5 starting the re-director, and prints "Incorrect DOS version \*\*ERROR\*\* unable to start the re-director. There were start up errors." If you then tell it to start the net again it doesn't do anything, and freezes up. You then have to terminate, and restart the computer, and tell it to start the network again. It will work this time, and the SCI searches will actually function, but it takes a long time to go through that entire process, again it would probably be easier to just walk to the library.

In the dialogue command search of NTIS, the first letter of whatever term you enter is cut off and ignored. If the word "laser" was entered, the computer would search for the term "aser". This can be corrected by entering "llaser" instead of "laser", but it would be easier if this wasn't necessary.

Another problem with the network, is when it gets bogged down the CD-ROM gets impossibly slow, so much that if you really need to find something, it would be faster to walk to the library, and use the CD-ROMs there. When it gets bogged down really bad the CD-ROM won't even work, and loading a database is almost impossible, if not impossible.

I think that the CD-ROM on the network is a great resource that will become available, the only downfall I see in it's possible future is if it becomes to complicated, confusing, or tedious to run. The key to getting full use out of the system is making it easy and time conserving, so that it will be an asset. I hope some of my suggestions will be helpful.

FORCE APPLICATIONS CONTROL VARIABLE STUDY

Brandon J. Ellena  
HSAP Student  
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Phillips Laboratory

Final Report for:  
AFOSR Summer Research Program  
Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
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September 1992

## FORCE APPLICATIONS CONTROL VARIABLE STUDY

Brandon J. Ellena  
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### Abstract

Air Force Space Command has recently shown a desire to deliver reentry vehicles to precise positions on Earth. Correcting for in-flight errors and atmospheric conditions in these RVs was studied. By giving the RV the ability to alter its flight path, it is able to compensate for these errors. Just by changing the angle of attack of the RV, it was possible for the RV to cover an area of about 24 square miles.

## FORCE APPLICATIONS CONTROL VARIABLE STUDY

Brandon J. Ellena

### INTRODUCTION

Research in the dynamics of reentry has been going on since the early days of space exploration. Studies have ranged from getting astronauts home to attacking enemy targets from space. Recently, Air Force Space Command has shown a desire to deliver reentry vehicles (RVs) from an Earth orbit to precise locations on the ground. This concept is termed "Force Applications." Three missions have been derived for this concept: 1) a hypersonic kinetic kill vehicle, 2) a delivery vehicle for conventional munitions, and 3) an orbit-to-Earth delivery system (e.g., a peace-time delivery vehicle to deliver space-based information to a point on earth). The mission studied here is the hypersonic kinetic kill weapon (Penetrators) seen in Fig. (7-1).

The purpose of this study was to add a control variable to the Penetrator. This would suggest it is possible to correct for errors in the vehicle's reentry flight, or to divert the Penetrator to another nearby target.

### APPROACH

A program was written by Capt. Kerry Hicks, PhD that takes given initial conditions for the reentry and solves for the trajectory to the ground. The equations Capt. Hicks' program solves are briefly described in the next section.

Basic Equations of Relative Motion. Vinh et al. present equations for motion relative to the rotating Earth. These were

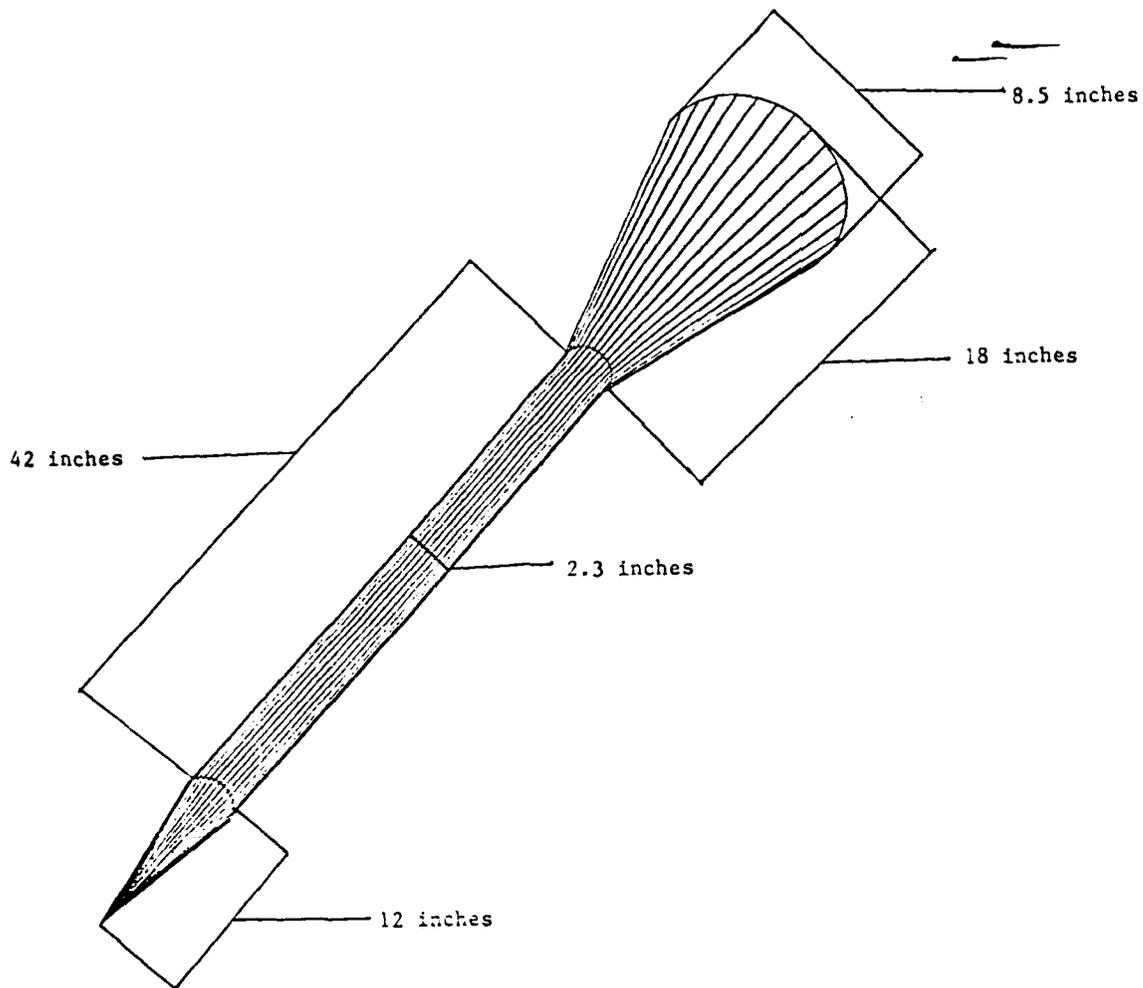


Figure (7-1): Penetrator Model

explained in a reentry dynamics lesson from Capt. Hicks. The equations of motion are:

$$\dot{r} = \frac{dr}{dt} = V \sin \gamma \quad (7-1)$$

$$\dot{\theta} = \frac{d\theta}{dt} = \frac{V \cos \gamma \cos \psi}{r \cos \phi} \quad (7-2)$$

$$\dot{\phi} = \frac{d\phi}{dt} = \frac{V \cos \gamma \sin \psi}{r} \quad (7-3)$$

$$\dot{V} = \frac{dV}{dt} = -\frac{D}{m} - g \sin \gamma + \omega_{\oplus}^2 r \cos \phi \left( \sin \gamma \cos \phi - \cos \gamma \sin \phi \sin \psi \right) \quad (7-4)$$

$$V\dot{\gamma} = V\frac{d\gamma}{dt} = \frac{\ell}{m}\cos\sigma - g\cos\gamma + \frac{V^2}{r}\cos\gamma + 2\omega_{\oplus}V\cos\phi\cos\psi \quad (7-5)$$

$$+ \omega_{\oplus}^2 r \cos\phi \left( \cos\gamma\cos\phi + \sin\gamma\sin\phi\sin\psi \right)$$

$$V\dot{\psi} = V\frac{d\psi}{dt} = \frac{\ell\sin\sigma}{m\cos\gamma} - \frac{V^2}{r}\cos\gamma\cos\psi\tan\phi \quad (7-6)$$

$$+ 2\omega_{\oplus}V \left( \tan\gamma\cos\phi\sin\psi - \sin\phi \right) - \frac{\omega_{\oplus}^2 r}{\cos\gamma}\sin\phi\cos\phi\cos\psi$$

r is the radius from the vehicle to the center of the Earth.  $\theta$  and  $\phi$  are the longitude and latitude of the vehicle respectively. V is the vehicle's velocity relative to the Earth.  $\gamma$  is the flight-path angle.  $\psi$  is the heading angle and  $\sigma$  is the bank angle. These are graphically shown in Fig. (7-2).

#### PROCEDURE

Coding a new routine was the first step in proving that it would be possible to make these changes in the flight path of the Penetrators. Capt. Hicks' program NEIGHBOR was used for the modification. The program was modified so that it would loop through a range of flight conditions. This new part of the program would change the magnitude ( $C_L$ ) and orientation ( $\sigma$ ) of the lift. Once this was compiled, run, and proven to work, the program could generate the data to show an "impact footprint." This new section of code works as a driver for the program. It steps through various lift magnitudes ( $C_L$ ) and orientations ( $\sigma$ ) and stores the needed data in a file. Then, using a function, it

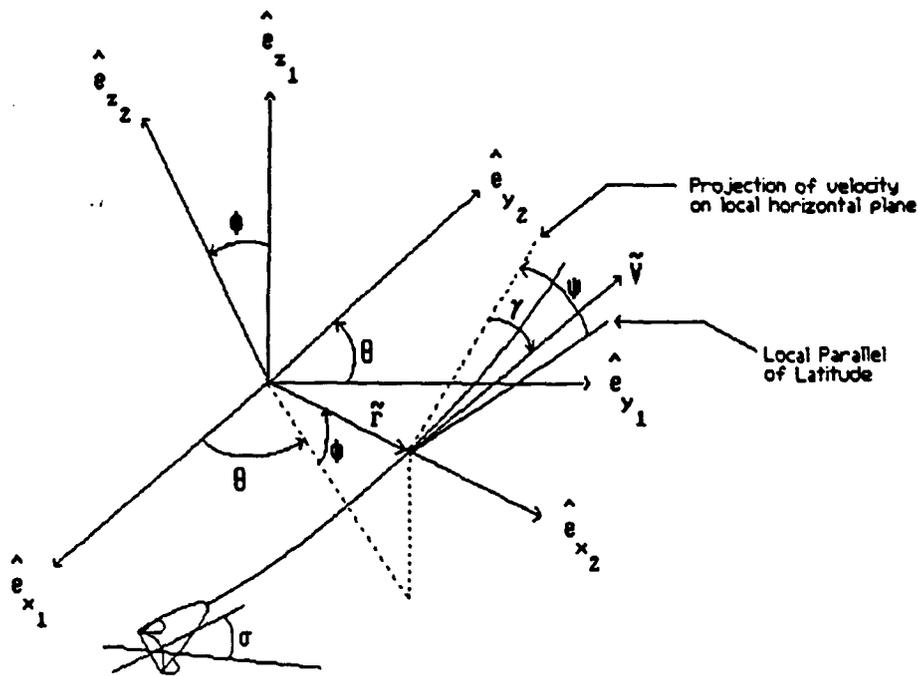


Figure (7-2): Variables Used in Reentry Equations

calculates the drag coefficient. A function is used because it is not possible to change the lift without affecting the drag. After this is done the program prints the data to the screen and solves for the trajectory.

The function used to calculate the drag coefficient was obtained using data derived from an analytical wind tunnel program called APAS. After entering the cross sections of the RV being used and getting a diagram of the vehicle, an altitude vs. mach number table for the craft was entered. This was taken from a graph of the altitude vs. mach number for of a similar RV during a simulated reentry. The graph was made using a commercial GRAPHER program. After running the data through APAS, a file of lift vs. drag at various angles of attack was created.

GRAPHER was used to fit a single curve through data from the APAS runs. This is shown in Fig. (7-3). Eq (7-7) gives the  $C_L/C_D$  relationship found.

$$C_D = .523765C_L^2 + .000489029C_L + .0814705 \quad (7-7)$$

Note, the data was not available for an exact altitude vs. mach number graph, because this would require knowing  $C_L$  and  $C_D$  in advance! As mentioned above, a similar RV was used to generate the initial altitude vs. mach number graph. [See Fig. (7-4).] Ideally, the function would have been used to refine the graph and repeat the process with APAS until there was no change in the results. In this case the curve was close

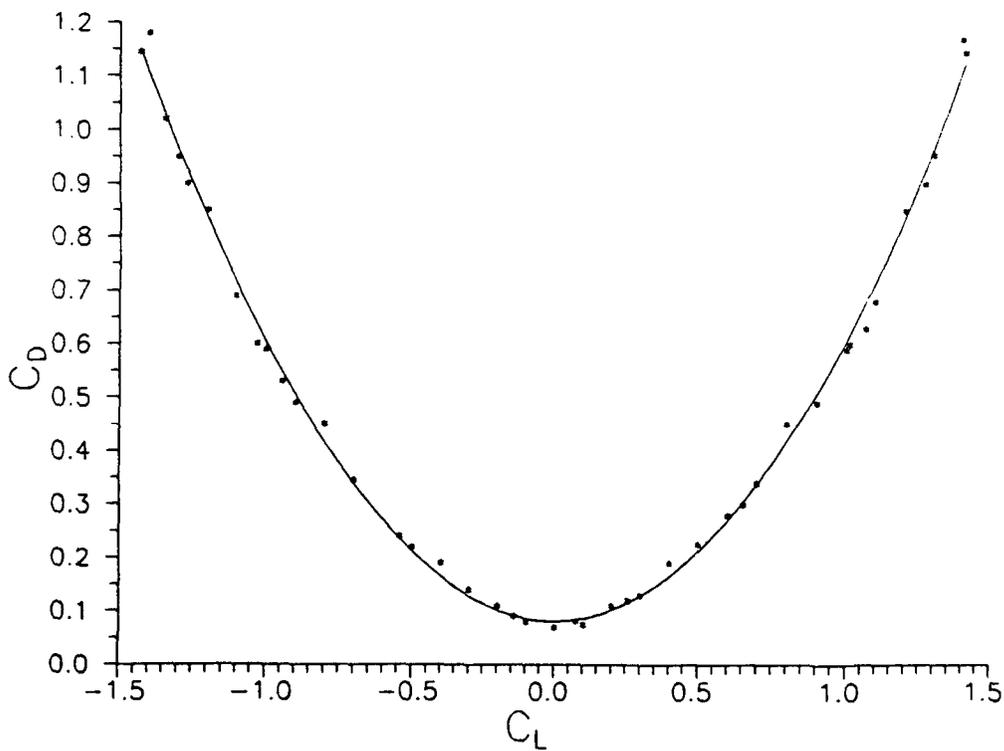


Figure (7-3):  $C_L$  and  $C_D$  Relationship

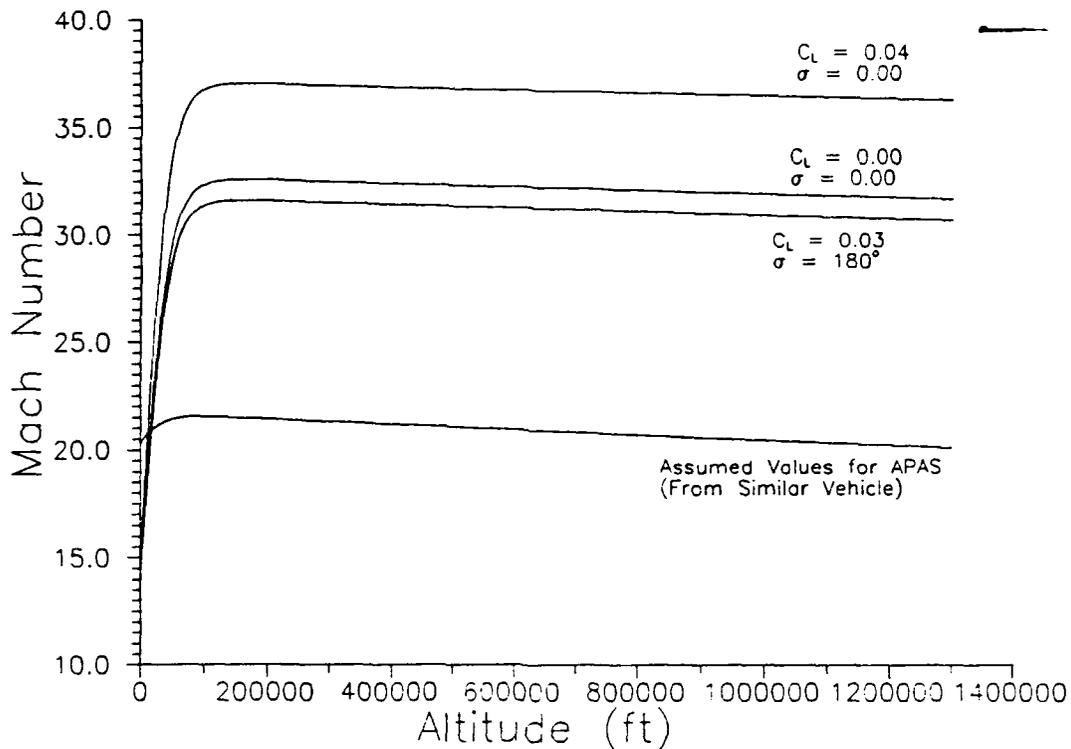


Figure (7-4): Altitude vs. Mach Number

enough for the purposes of this study. For reference, an altitude vs. mach number graph is shown for an RV with the characteristics given by Eq. (7-7).

The programming was completed and the next step was to produce an impact footprint. The lift vectors were calculated to give the largest and most complete footprint possible.

Table (7-1) lists the  $C_L$  and  $\sigma$  ranges that were investigated.

### RESULTS

The data was collected by running the modified NEIGHBOR program. The next step was to compile the data and plot it. Using a commercial contour mapper (SURFER), the computed longitude, latitude, and impact velocity were plotted, shown in Fig. (7-5). Then, the  $C_L$  and  $\sigma$  effects on the RVs trajectory

TABLE (7-1): Range of Parameters Studied

RUN #	$C_L$	Step	Sigma	Step
1	0.0 - .023	.0005	0 - 300 degrees	10 deg
2	.023 - .02725	.000425	0 - 260 degrees	20 deg
3	.0269 - .0278	.0003275	0 - 310 degrees	10 deg
4	0.0 - 0.04	.0005	-85 - 85 degrees	10 deg
5	.001 - .04	.001	95 - 265 degrees	10 deg
6	0.0 - .03	.001	-180 - 180 deg	10 deg
7	.001 - .03	.000096	-174 - 174 deg	10 deg
8	.03 - .04	.00033	0 - 180 degrees	2.5 deg

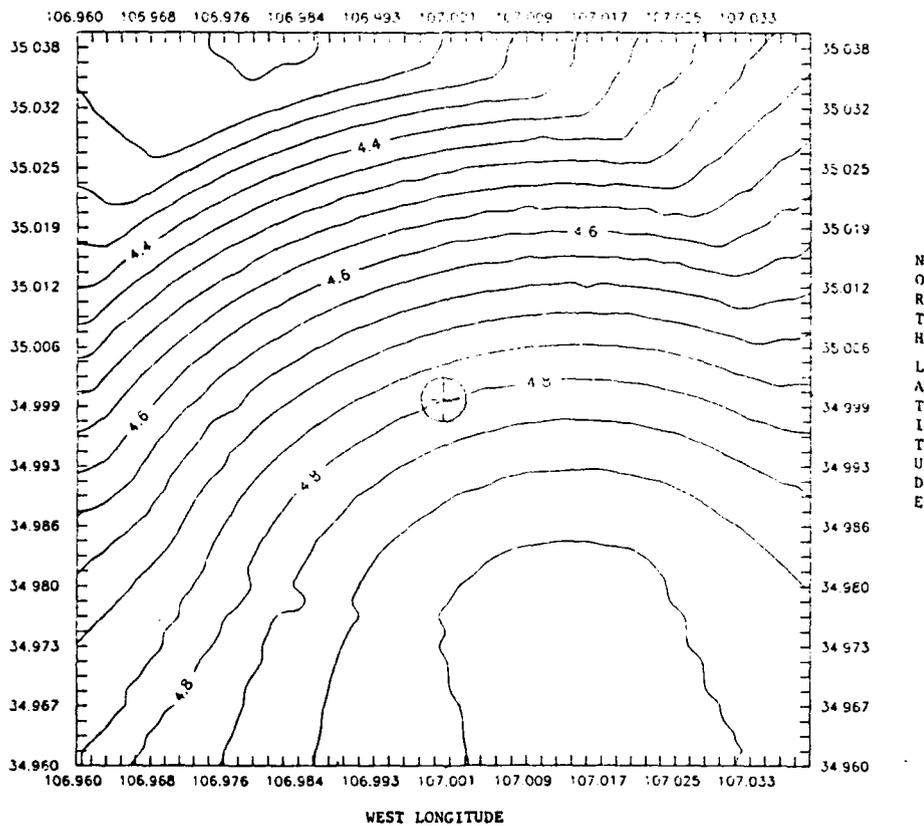


Figure (7-5): Impact Velocity (km/sec) for Impact Area

were plotted separately. The effect of  $C_L$  for  $\sigma = 0^\circ$  on the trajectory of the RV is shown in Fig. (7-6). The effect of varying  $\sigma$  with a  $C_L = 0.02$  is shown in Fig (7-7). The resulting footprint is shown in Fig. (7-8).

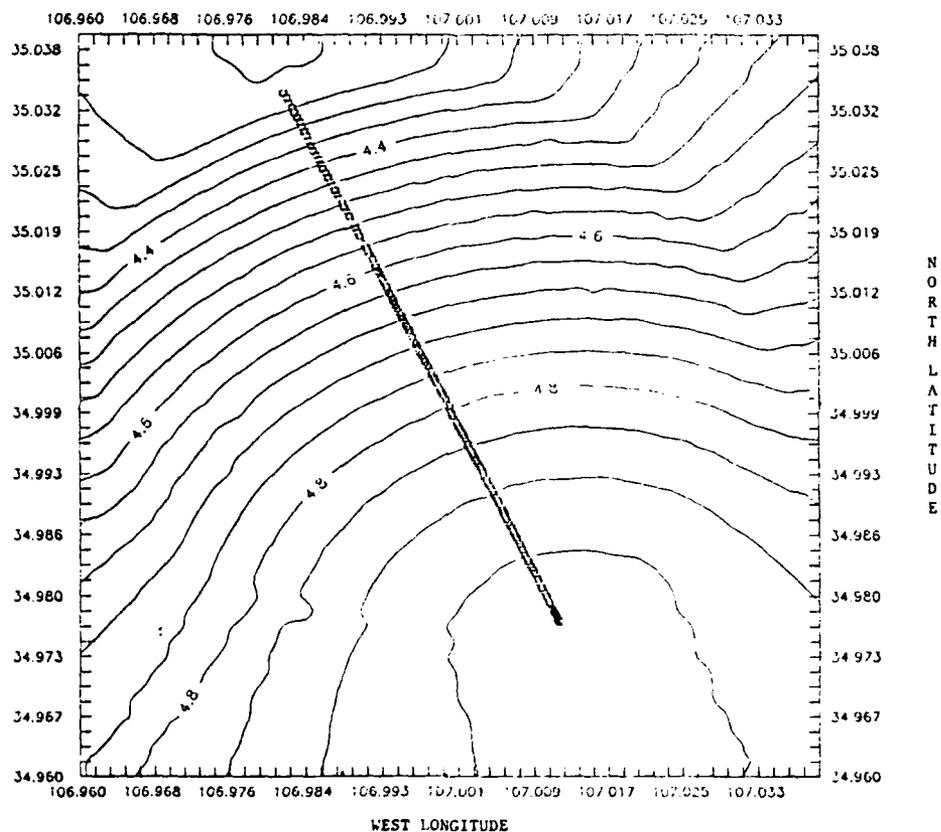


Figure (7-6): Effect of Varying  $C_L$  ( $\sigma = 0^\circ$ )

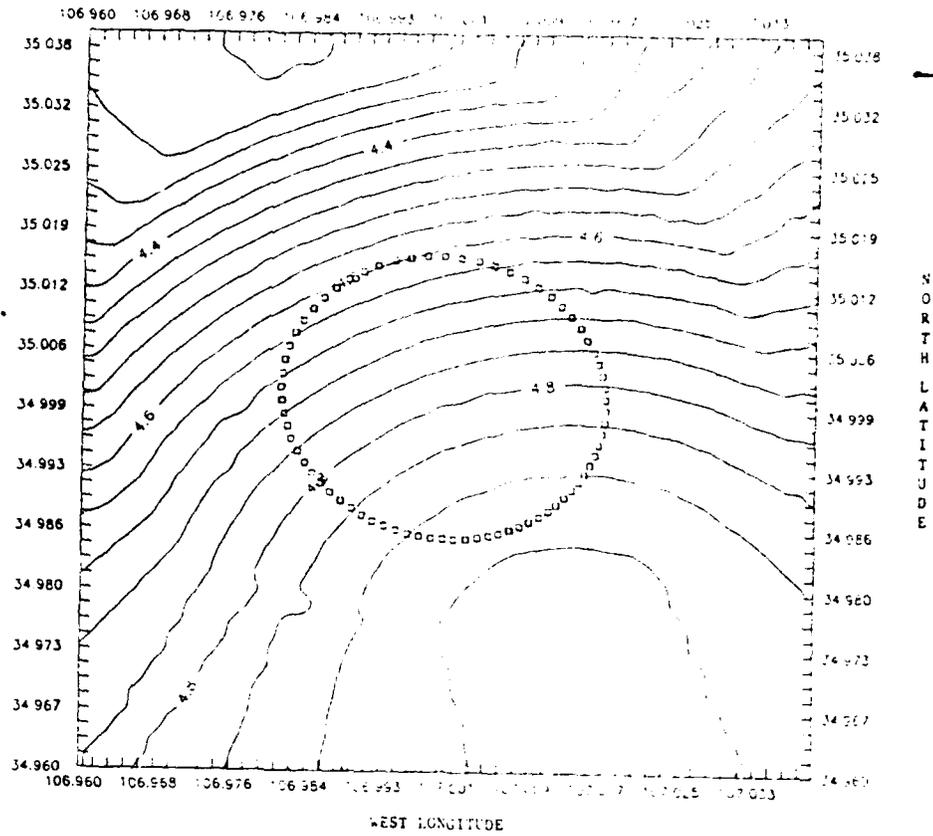


Figure (7-7): Effect of Varying  $\sigma$  ( $C_L = 0.02$ )

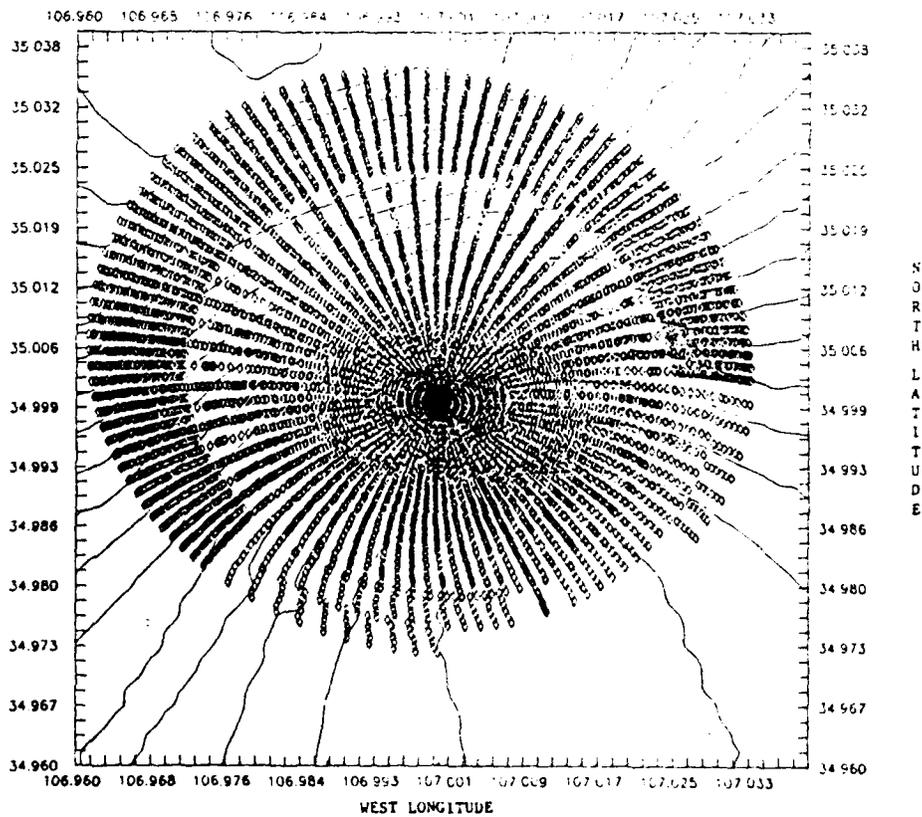


Figure (7-8): Impact Footprint

## CONCLUSION

This study consisted of determining the possibilities of using a control variable to correct or alter the flight of a RV. After completing this study, it was found to be possible to greatly alter the impact point of the RV by controlling the lift during the flight. The size of the impact area was found to be about 24 square miles.

## RESEARCH RECOMMENDATION

A recommendation is made for further work into this study. A strong topic for review is the possibility of having two or more  $C_L$  and  $\sigma$  values added during the RV's flight. This might expand the footprint area.

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# **FUZZY-C OPTICAL TRACKER**

Blake Ethridge

Final Report for:  
AFOSR Summer Research Program  
Phillips Laboratory

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Research and Development Laboratories  
Culver City, Ca.

August 1992

# Fuzzy-C Optical Tracker

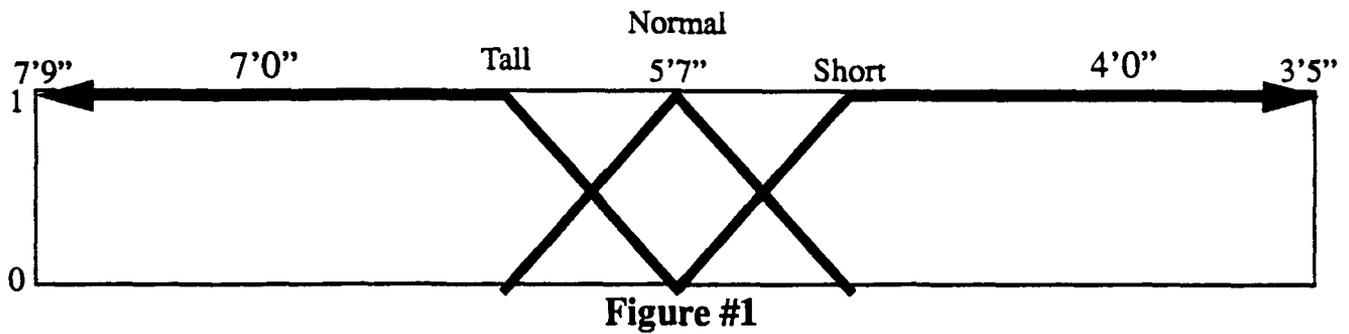
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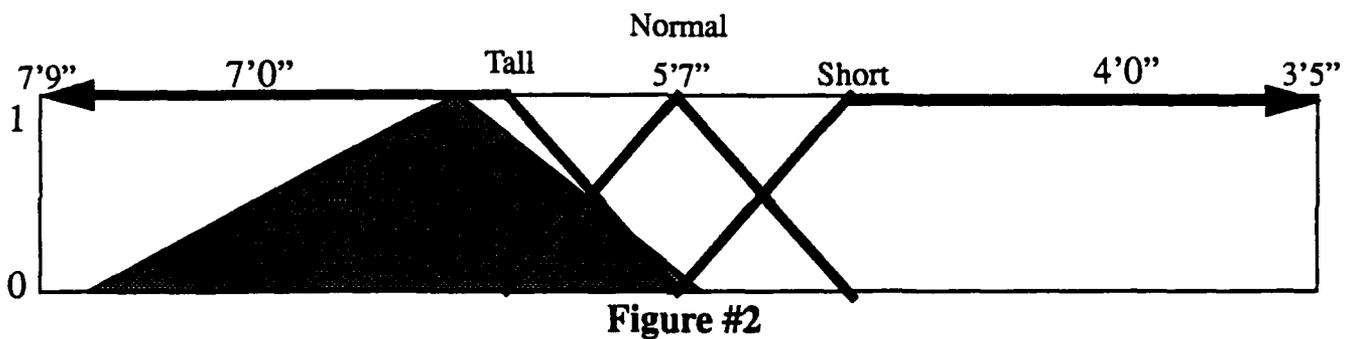
## **Fuzzy Logic**

Fuzzy Logic is based on human concepts such as: mostly, primarily, partially, few, etc. It deals with the idea of uncertainty by allowing an object to be a partial member of a given group. This is unlike conventional Boolean logic which defines an object as either a member or not a member of a given group.

To illustrate the differences take the statement, "Basketball Players Are Tall People." This statement when applied to Boolean logic would mean either that all basketball players are tall people, or that no basketball players are tall people. All basketball players are not tall, and all basketball players are not short. Thus Boolean logic can not deal with the statement about basketball players height. When this statement is applied to Fuzzy logic several steps would follow, the information used in the following example is approximated and has no scientific value. The first step is to define the membership functions for height, say tall, normal, and short; next, these membership functions would be assigned values. Tall people will be defined as anyone over 6'2" and will include partial membership to people down to 5'7". People with normal height will be defined as being between 6'2" and 5'0" where 5'7" will be the center. Short people will be defined as people 5'0" or shorter with partial membership to people up to 5'7". Figure #1 is a diagram of these membership functions.



The triangle in the center represents the set of people with normal height. The other shapes which continue in both directions represent the tall (left side) and short (right side) people. The next step would be to place another triangle in the figure which would represent basketball players, this is done in Figure #2.

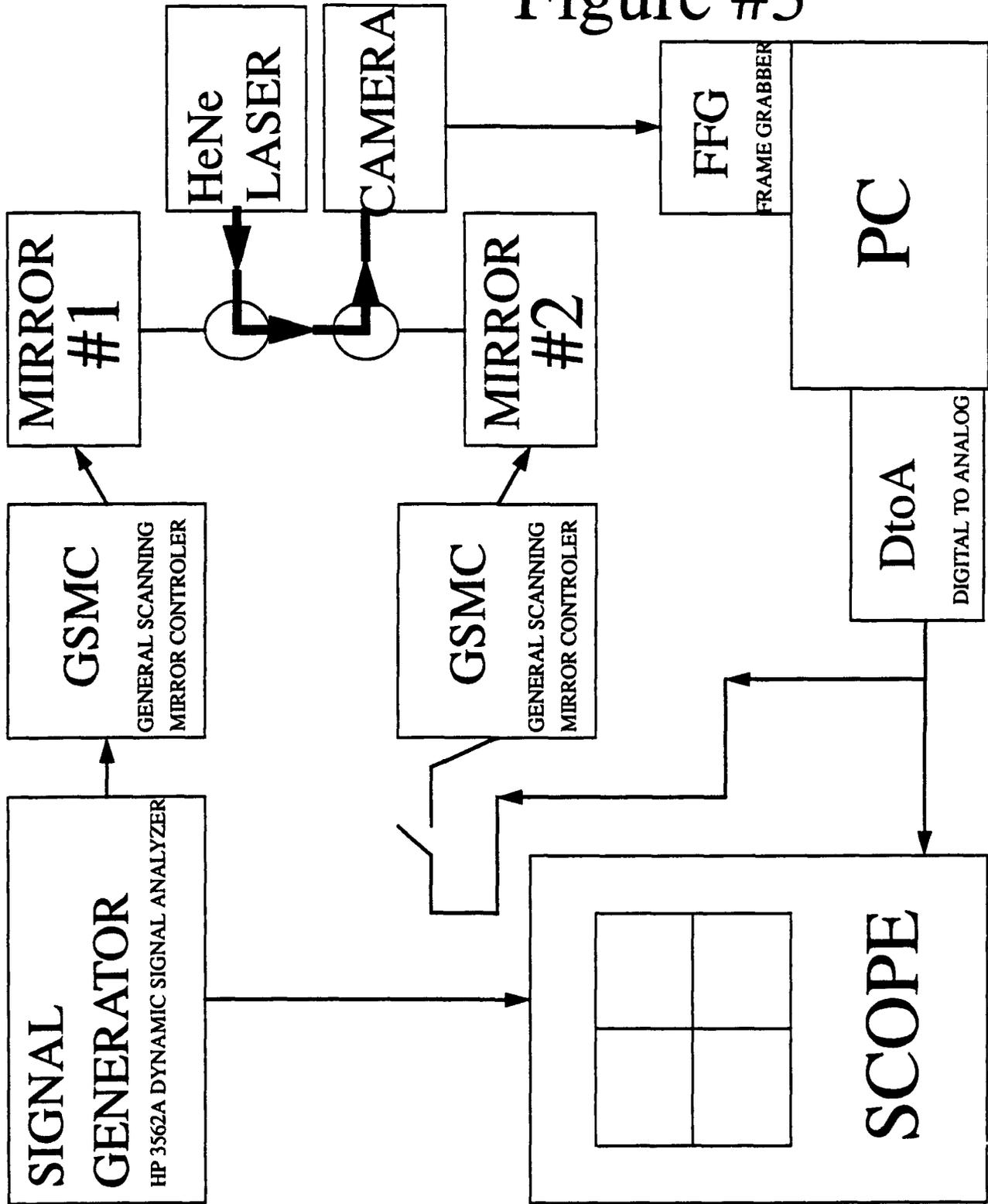


The grey area in Figure #2 represents basketball players. This area peaks at the height of 6'4" which indicates the most common height among basketball players. This grey area, though, is contained in all of the membership functions. This means that all basketball players are not tall. It does show that most basketball players are tall, a few are normal, and even fewer are short. This example shows how fuzzy can deal with information which is neither correct or false, but is partially correct and somewhat false. Conventional Boolean logic, though, could not deal accurately with this type of information.

## Introduction

Although it might have been interesting, my mentor, Patty Wallentine, and I did not spend the summer applying fuzzy logic to the height of basketball players. On the contrary we applied it to a Fuzzy-C Optical Tracker. Before the Fuzzy logic could be used, a system had to be built for it's application. Figure #3 is a schematic block design of this system. An optical tracker does just what the title suggests, it visually follows a object. The object that was tracked in this experiment was a Helium-Neon (HeNe) Laser. The beam from this laser was directed toward a mirror (Mirror #1) which reflected the beam to another mirror (Mirror#2) which in turn directed the beam into a camera. Both mirrors are attached to General Scanning Mirror Controllers(GSMC), and could only spin on their vertical axes allowing the beam to move only horizontally across the cameras detector. Mirror #1 is controlled by a HP 3562A Dynamic Signal Analyzer which acted as a Signal Generator. The signal created by the analyzer caused the vertical variation in the direction of the beam. This variation became the control error signal in the experiment. The control error was defined as the distance from the center of the camera to the edge of the camera so if the beam was to the right of the camera's center, the control would be a positive value and if the beam was to the left of the camera's center the control error would be a negative value. The camera's signal was sent to both a monitor (not in Figure #3) and to a frame grabber on a Personal Computer. The PC contained all the software used in the experiment and was the system controller. It sent out a correction signal through a digital to analog translator to both a scope and Mirror #2 via a switch attached to the GSMC. This switch was closed when the system was run closed loop and was open when the system was run open loop. The goal of the software applied to this system was to keep the HeNe Laser on the center of the camera while Mirror#1 was controlled by a source unknown to the software. This was to be accomplished by moving Mirror #2 in a way to conteract the movement in Mirror #1. The software used in this experiment was developed using a Fuzzy-C Development System release 2.1 which was developed by *Togai InfraLogic, Inc.*

Figure #3



## Discussion

The software that was used in this project was all written or taken from the system development manual before I arrived this summer. Because of this I did not get to participate in the actual designing of the software, but I did get to work with it. Since fuzzy logic is not an exact system it allows for the user to work with it. My involvement started at this point. One of the many programs that were used was titled PDFC.TIL. This contained the membership function parameters and the rules that applied to them. Appendix #1 is a copy of PDFC7 which is one of the programs that was compiled into the software and applied to the system. The first variable in the program is the error. The error, as mentioned before, was calculated by measuring the distance of the beam away from the center of the camera. This camera had a total width of 256 pixels. The center was defined as zero with the left extremity defined at -128 and the right extremity defined at 127. In the set, there were a total of five membership functions: LNE(Large Negative Error), NE(Negative Error), ZE(Zero Error), PE (Positive Error), and LPE(Large Positive Error). The next variable was delta error. Delta error was an average of the last two errors. It only had three membership functions: NdelE(Negative delta Error), ZdelE(Zero delta Error), and PdelE(Positive delta Error). The next variable is the control output. This is the output that drives mirror #2. It has a total of seven membership functions within the range of -10 volts and 10 volts. They are VLNU(very large negative output), LNU(Large Negative Output), NU(Negative Output), ZU(Zero Output), PU(Positive Output), LPU(Large Positive Output) and VLPU(very large positive output). In the software, these outputs are measured between 0 and 4095, 0 corresponding to -10 volts and 4095 corresponding to 10 volts, with 2048 being the center and equivalent to zero or no correction. The next part of the program is the rules which are written in an IF-THEN format. All the numbers in this program were varied, made smaller and larger, to find what worked best. Figure # 4 is a graph of data stored during the application of these membership functions to the system. The two lines that run together are the error and delta error, and the line that is flat on top and bottom is the output correction. From 0 to approximately 55, it is running open loop and from 55 on, it is closed. This particular set did not work that well, but it did decrease the error some

when it was closed. Many of the different PDFC programs we attempted matched the error exactly during open loop but either went unstable during closed loop or were on the edge of being unstable. The error was never brought down to zero using the fuzzy controller, but it did shrink to half its size which means the control loop was working, but not to its optimum capability.

An open loop transfer function was also calculated for the optical system. Figure #5 is this transfer function. The X axis measurement is the frequency of the driving signal which was produced by the dynamic signal analyzer. The Y axis measurement is the magnitude and phase of the system in dB and degrees, respectively.

Due to the massive amount of time it was taking to work with the Fuzzy in the real system, we decided to make a simulation of the system. At first *MatrixX* was the program that was going to be used, but after working with it for a couple days we decided to use *Simulab* in *Windows*. This was easier to work with and we were making progress in developing the simulation, but unfortunately my summer apprenticeship time was up before the simulation was done.

## Conclusions

Although I succeeded in learning a lot about computers, lasers, optics, and different kinds of logic, my mentor and I did not succeed in getting the Fuzzy-C Optical Tracker to work perfectly this summer. We did not fail, though, infact we did decrease the error in practically all of our attempts, and Patty, my mentor, will continue to work on the project until she does get the Fuzzy to work. My personal conclusions about the HSAP are very positive. I learned much more than I ever expected to this summer. I learned to use *FrameMaker*, *Matlab*, *Simulab*, *MatrixX*, and a little about C. I in no way am an expert on these programs and languages, but I can use them. I also enjoyed working with everyone at Phillips Labs. They were all helpful and kind, they never seemed to get frustrated with my lack of knowledge on computers, and they always were available to answer questions.

Figure #4

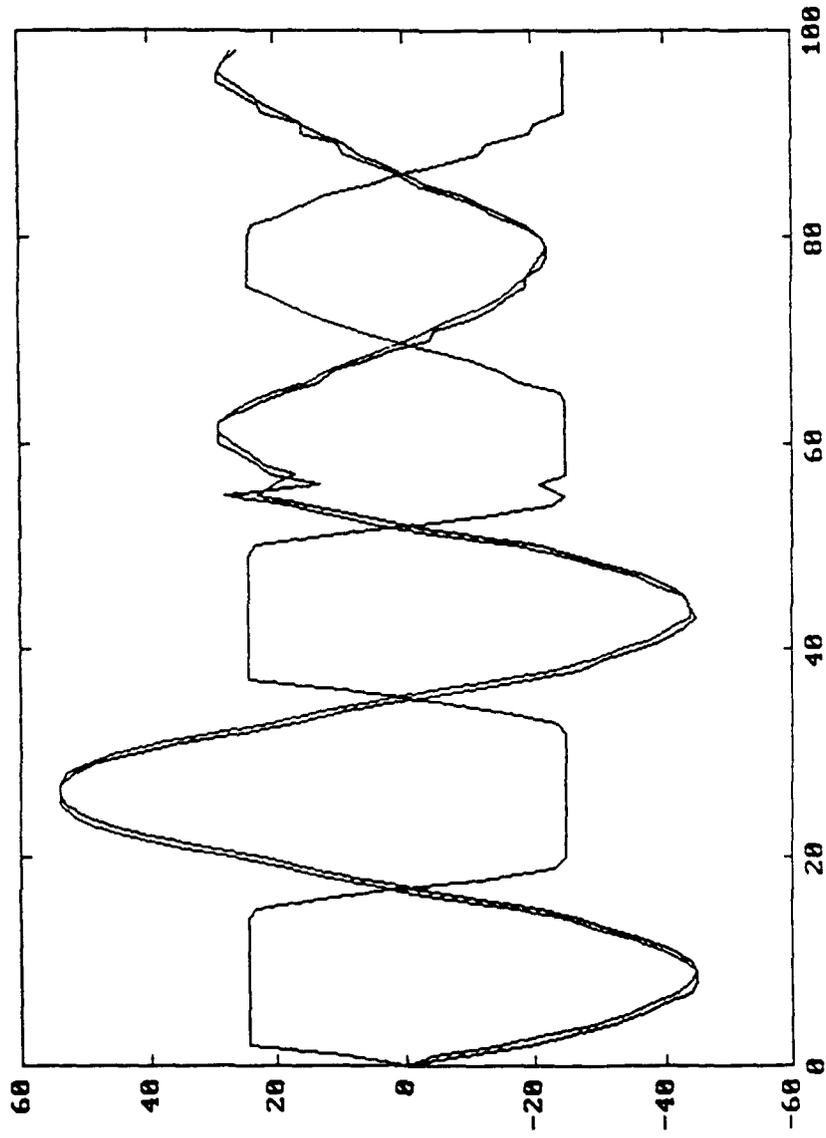
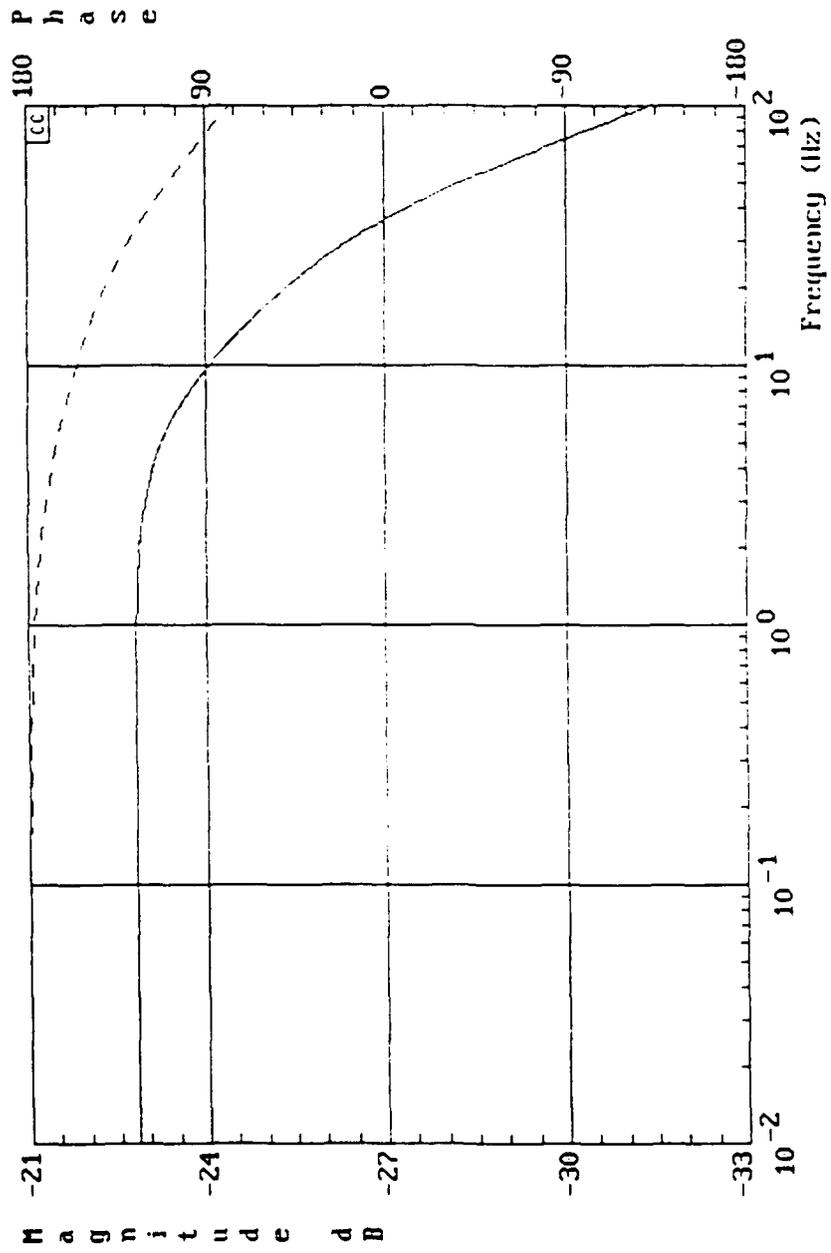


Figure #5



## Thanks

I would like to thank Nancy Miller, my first mentor, whose enthusiasm for everything she does is amazing; and Alice Ling who, was always there when a computer died on me, or even a couple times when they started to scream at me. I would also like to thank Dennis Duneman, who always helped me find disks, keys, manuals, cords, or whatever I needed, bright and cheerful Dave Holmes, who always had the answer when no one else around did; Derrell Kolozsy, a college student, for his help in doing everything; and Dave Tyler whose knowledge of colleges and his great perspective on life. Most of all though, I would like to thank Patty Wallentine, who put up with me all summer, who let me work with her on her project, and who never let me slack off. Thanks!

# Appendix #1

```
/*  
* PDFC7  
* A PDFC (Proportional+Derivative Fuzzy_c Controller) for an optical tracker  
*/
```

PROJECT PDFC

```
VAR error  
  TYPE signed byte  
  MIN -128  
  MAX 127  
    MEMBER LNE  
      POINTS -128 1 -63 1 -19 0  
    END  
  
    MEMBER NE  
      POINTS -63 0 -19 1 0 0  
    END  
  
    MEMBER ZE  
      POINTS -19 0 0 1 19 0  
    END  
  
    MEMBER PE  
      POINTS 0 0 19 1 63 0  
    END  
  
    MEMBER LPE  
      POINTS 19 0 63 1 127 1  
    END  
END /* error definition */
```

```
VAR delta_error  
  TYPE signed byte  
  MIN -128  
  MAX 127  
    MEMBER Ndele  
      POINTS -128 1 -19 1 0 0  
    END  
  
    MEMBER Zdele  
      POINTS -19 0 0 1 19 0  
    END  
  
    MEMBER Pdele  
      POINTS 0 0 19 1 127 1  
    END  
END /* delta_error definition */
```

```
/* The Control variable is uout. Its  
* possible outputs range from -10v to 10v within 12-bits unsigned. */
```

```
VAR uout  
  TYPE unsigned word  
  MIN 0  
  MAX 4095  
    MEMBER VLNU  
      POINTS 0 1 1436 1 1639 0  
    END  
  
    MEMBER LNU
```

# Appendix #1

```
                POINTS 1436 0 1639 1 1877 0
END

MEMBER NU
POINTS 1639 0 1877 1 2048 0
END

MEMBER ZU
POINTS 1877 0 2048 1 2219 0
END

MEMBER PU
POINTS 2048 0 2219 1 2458 0
END

MEMBER LPU
                POINTS 2219 0 2458 1 2628 0
END

MEMBER VLP
                POINTS 2458 0 2628 1 4095 1
END
END /*uout definition */

/* Define the PDFC FUZZY knowledge base to control the plant. */
FUZZY PDFC_Control

OPTIONS
    OUTPUTSCOPE is "public"
END

RULE Rule_1      /* System is below steady state. */
    IF error is LNE and delta_error is Ndele THEN uout is LPU
END

RULE Rule_2      /* System is near, but below, steady state. */
    IF error is LNE and delta_error is Pdele or delta_error is Zdele
    THEN uout is LPU
END

RULE Rule_3      /* System is below steady state. */
    IF error is NE and delta_error is Ndele THEN uout is LPU
END

RULE Rule_4      /* System is below steady state. */
    IF error is NE and delta_error is Pdele THEN uout is PU
END

RULE Rule_5      /* System is at steady state. */
    IF error is ZE and delta_error is Ndele THEN uout is PU
END

RULE Rule_6      /* System is at steady state. */
    IF error is ZE and delta_error is Zdele THEN uout is ZU
END

RULE Rule_7      /* System is at steady state. */
    IF error is ZE and delta_error is Pdele THEN uout is NU
END
```

# Appendix #1

```
RULE Rule_8      /* System is near, but above, steady state. */
  IF error is PE and delta_error is NdeLE THEN uout is NU
END

RULE Rule_9      /* System is near, but above, steady state. */
  IF error is PE and delta_error is PdeLE THEN uout is LNU
END

RULE Rule_10 /* System is above steady state */
  IF error is LPE and delta_error is NdeLE THEN uout is LNU
END

RULE Rule_11 /* System is above steady state */
  IF error is LPE and delta_error is PdeLE or delta_error is ZdeLE
    THEN uout is LNU
  END
END /* Fuzzy rulebase definition */

/* Define connects for rulebase with error and delta_error defined
 * as inputs and uout defined as output. */

CONNECT
  FROM error
  TO PDFC_Control
END

CONNECT
  FROM delta_error
  TO PDFC_Control
END

CONNECT
  FROM PDFC_Control
  TO uout
END

END /* of PROJECT PDFC definition */
```

THERMAL CONTROL USING SCRAPERS IN A  
ROTATING-DISK, WETTED-WALL CHEMICAL REACTOR

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Phillips Laboratory

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August 1992

THE USE OF SCRAPERS FOR THERMAL CONTROL IN A  
ROTATING-DISK, WETTED-WALL CHEMICAL REACTOR

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ABSTRACT

This paper describes the rotating-disk, wetted-wall reactor, how it functions, and the use of scrapers for thermal control in the reactor. It is shown that as the exothermic reaction of gaseous chlorine and basic hydrogen peroxide takes place, much water vapor is produced. Water vapor is shown to have a first-order effect on the performance of a laser driven by a rotating disk system. Water vapor in the effluent is generated largely at the gas-liquid interface. Therefore it is the attempt of this study to try and model a way to scrape heated liquid off the rotating disks and consequently minimize water vapor production.

# The Use of Scrapers for Thermal Control in a Rotating-Disk, Wetted-Wall Chemical Reactor

Erik B. Fleming

## INTRODUCTION

The Chemical Oxygen Iodine Laser (COIL) is the shortest wavelength chemical laser in existence today. While right now the Rotocoil device at Kirtland Air Force Base is capable of generating around twenty-five kilowatts of power, [1] scientists are still working on ways to improve the output.

The laser functions through the use of a wetted-wall, rotating disk generator which produces singlet delta oxygen,  $O_2(^1\Delta)$ . Singlet delta oxygen is oxygen in an excited state that proves to be the fuel for an excited iodine laser. This oxygen is produced by combining liquid basic hydrogen peroxide (BHP) and a gaseous chlorine ( $Cl_2$ ). BHP is a solution of a strong base (KOH) and hydrogen peroxide, usually about one-half water and one-quarter each of the solutes by weight.

The rotogenerator consists of a total of 57 nickel disks, each 37mm in diameter and .89mm thick. The disks are mounted on a common shaft and are each spaced approximately 2.5mm apart. The entire disk pack is inserted in a nickel vessel with the side walls and roof closely fitted to the the disks. [2] (Figure 1) The disks are partially submerged in a pool of BHP. Rotation of the disks forms a film of liquid BHP on the exposed portions of the disks, which allows for a large surface area for the chlorine that flows between the disks. The chlorine and BHP

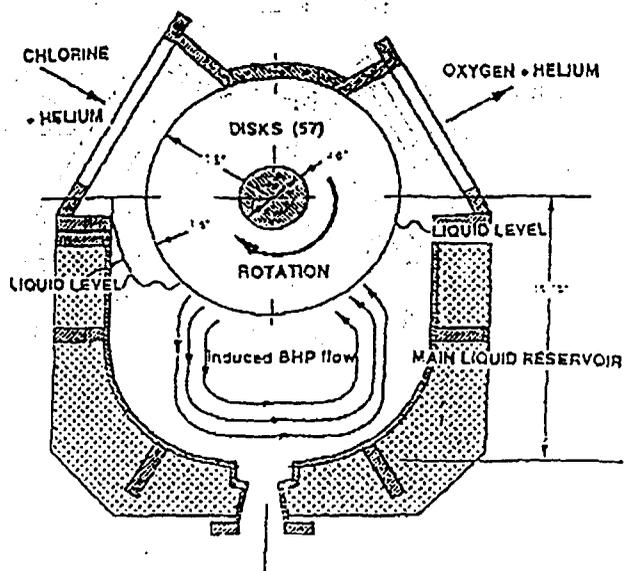
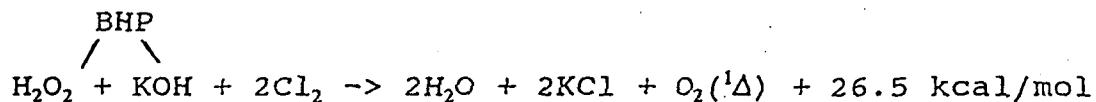


Figure 1. RotoCOIL Rotogenerator

react to form the singlet delta oxygen, with the chemical reaction [3]:



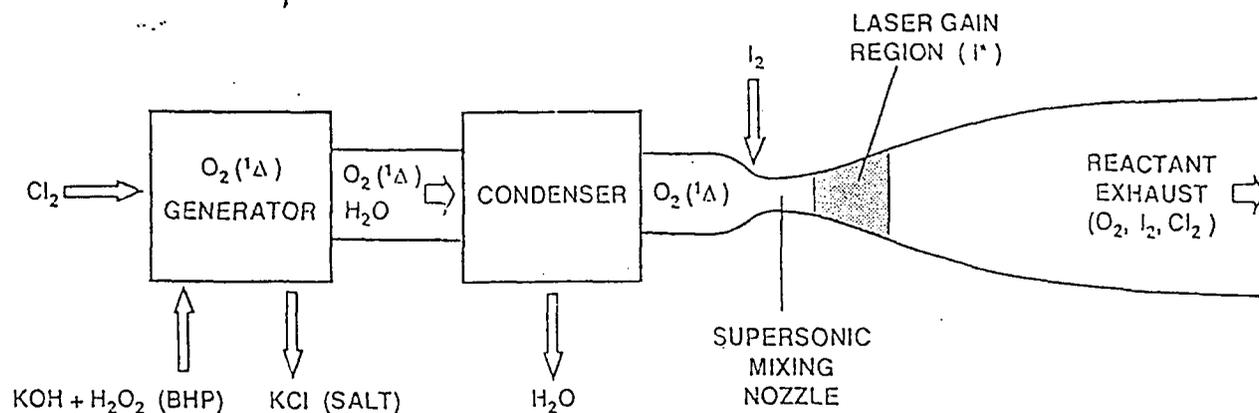
The singlet delta oxygen and water vapor created by the heat of the reaction travel through a cold trap where much of the water is condensed out. The singlet delta oxygen is then mixed with atomic iodine. The oxygen transfers its excited state to the iodine, which then lases at 1.315 microns. (Figure 2)

#### STATEMENT OF PROBLEM

The rotating-disk, wetted-wall chemical reactor is used to create a high surface area to volume ratio to efficiently react gas flows with liquid. The optimal use of such chemical reactors

often depends on the ability to maintain a constant temperature

FIGURE 2



- Chemicals are stored and handled conventionally
- Exhaust is handled with commercially available scrubbers
- "Room temperature" operation, no chemical combustion

in the reactor over a long period of time. This steady state condition is difficult to achieve because of the adhesion of reacted liquid to the surface of the rotating disks and the transfer of heat to or from the disk surface. This transfer of heat causes an increase of water vapor within the system. Water is a source of COIL laser power degradation in rotating-disk generator devices.[3] It is observed that as the temperature within the generator increases over time, thus producing more water vapor, the laser power decreases.(Figure 3) "The presence of water vapor adversely affects the characteristics of COIL, and COIL cannot operate effectively with more than 10% water vapor."[4] The temperature increase is due to the exothermic BHP and Cl<sub>2</sub> reaction. As observed by Dickerson, Hon, and Blauer of Rocketdyne, the reaction gives off a waste heat of 26.5

kcal/mol.[1]

The power decline occurs even when the chlorine utilization,

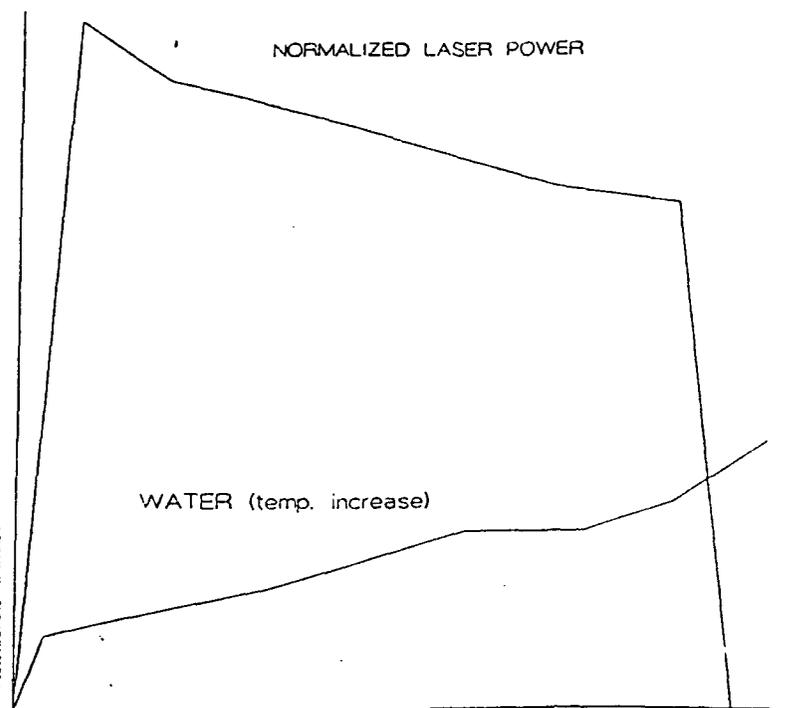


FIGURE 3

nozzle inlet gas temperature, and singlet delta oxygen yield remain the same.[3] This goes to prove that water is what disrupts the laser system. Water has long been known to significantly quench excited iodine atoms.[3] Water entering the laser nozzle decreases laser performance in several ways. First, it interferes with the dissociation process in the mixing nozzle. Second, water quenches the excited iodine. Third, the heat added to the iodine quenching shifts the equilibrium in the pump and reduces gain.[1]

One way to steady state operation is to remove reacted liquid from the disk by scraping it before the thermal conduction of the liquid transfers heat between the liquid and the disk surface. This study was conducted to understand the effects of scraping on the operation of a rotating-disk, wetted-wall

chemical reactor, and to develop a methodology for modeling the process to design a system for optimized reactor performance.

#### METHODOLOGY

The idea to solve the problem of heat buildup on the disks is through using disk scrapers. The idea behind the scrapers is that as the disk rotates in the BHP bath, the scrapers will scrape off the hot liquid created in the reaction. The heat then does not continue through the generator and eventually heat the disk up, instead it is scraped off, and therefore allows the disk to remain at a constant unheated temperature. Thus, the water vapor production would reach a constant level and a normalized laser power would remain constant as well. (Figure 4)

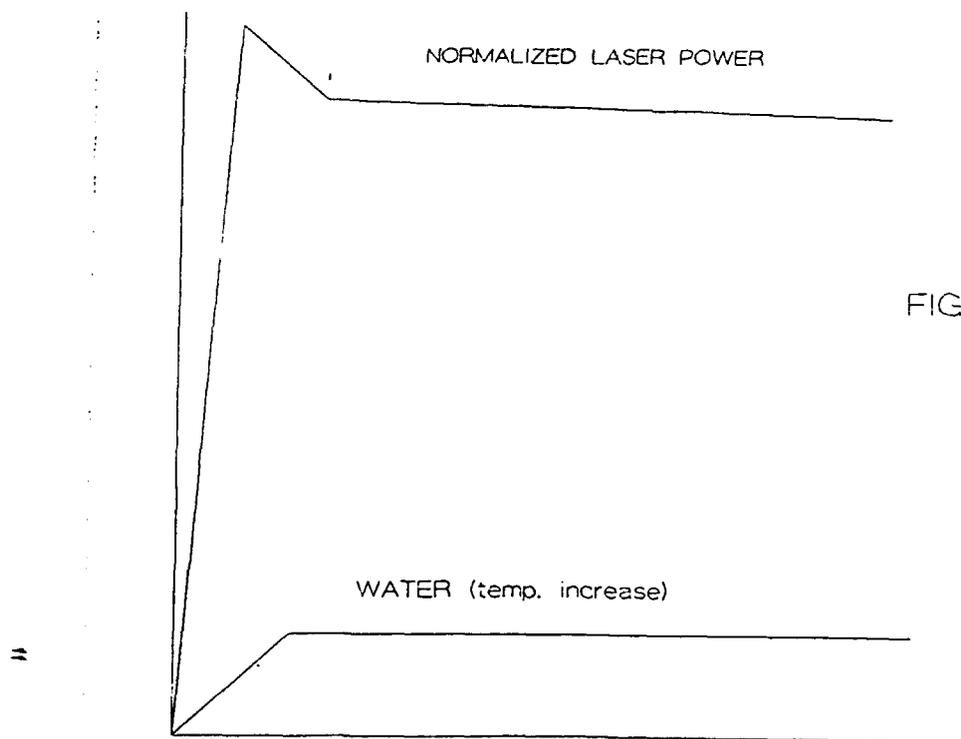


FIGURE 4

The scrapers will be placed in the 2.5mm gap between each disk, and will scrape each disk as it reenters the BHP bath. The first tests were done on a small model generator containing 7 disks

instead of the 57 that the normal generator has.

The first type of scraper tested was made out of teflon. This material was chosen because of its availability, low coefficient of friction (.04), machinability, compatibility with the chemicals used, and low cost. The teflon was cut into triangular shapes approximately 230mm in length, from 5mm to 20mm in width, and 2.5mm in thickness. (Figure 5) The idea was good in that the scraper was able to scrape the side of the disk, but the problem with using this scraper came with the amount of friction involved. The problem is that the disk is scraped with too much surface area as seen in the cross section in figure 5. The whole side of the scraper hits the disk as it rotates, and consequently causes too much friction for the motor to be able to turn the generator disk pack. Another problem was found in the material

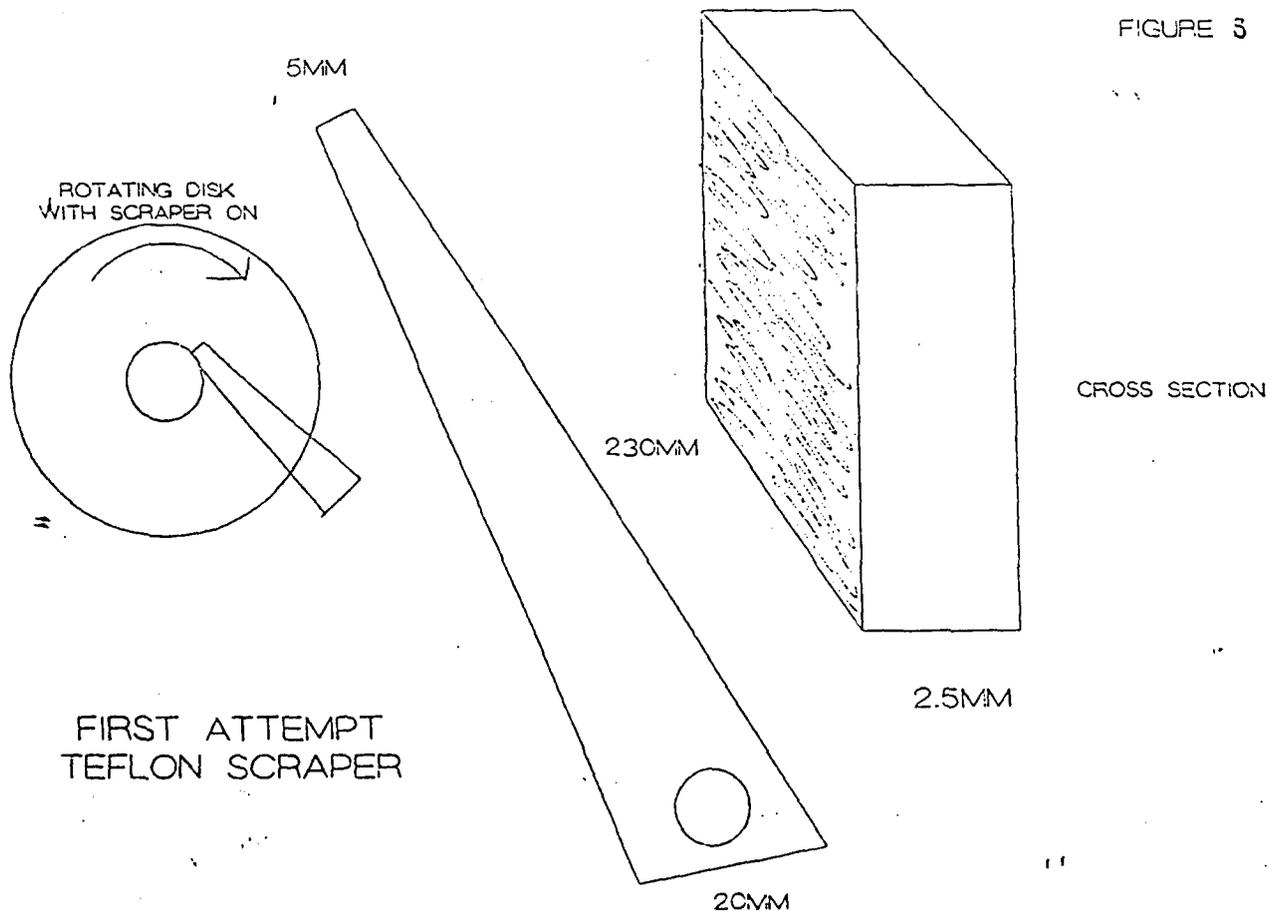
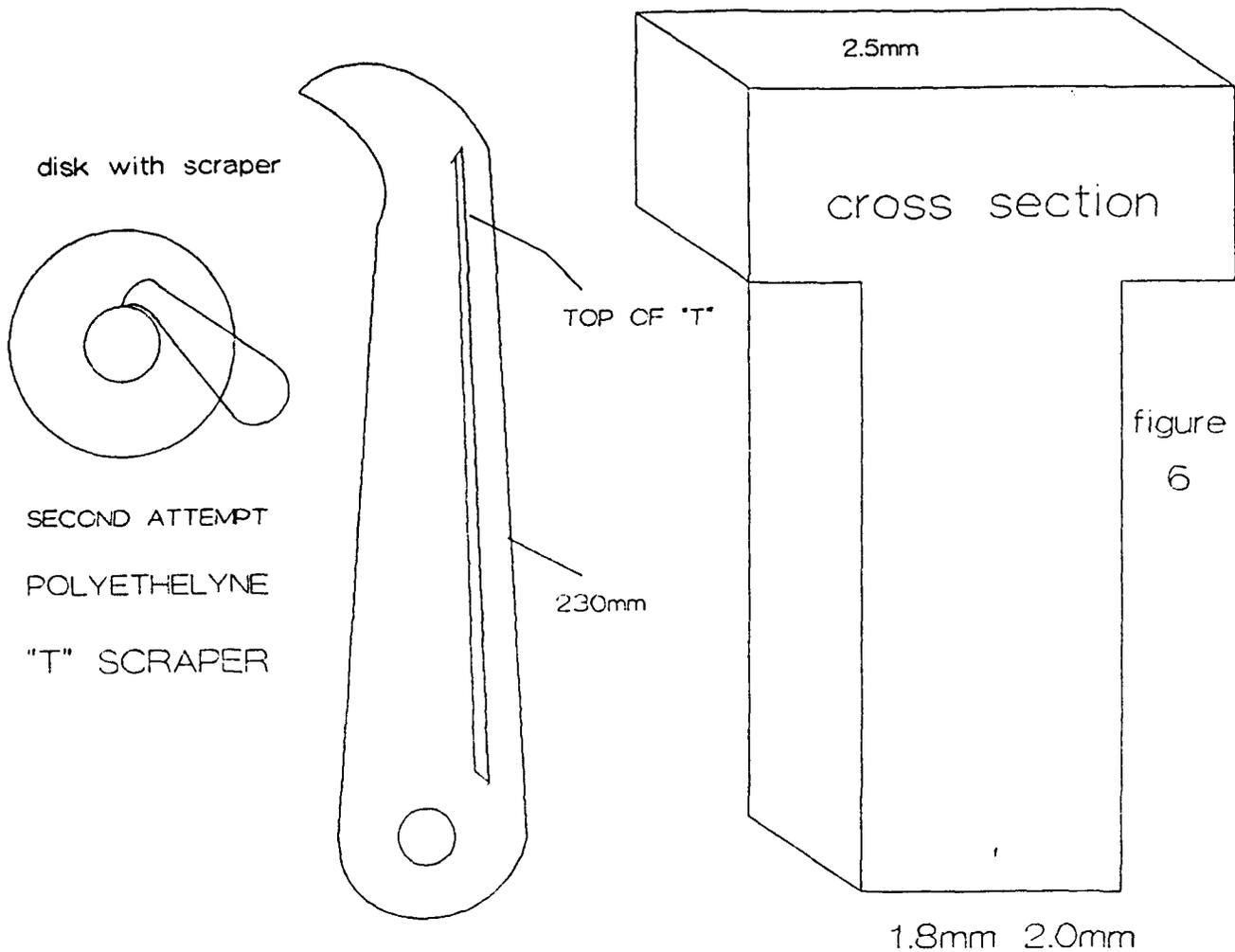


FIGURE 5

chosen. The problem was that the teflon gets too easily bent out of shape and becomes deformed. Its lack of a definite form affected its ability to scrape effectively. Although the first attempt did show that the idea of liquid scraping will work, the problem still remained of a shape, material, and size of an effective disk scraper.

To reduce the amount of friction a new shape of scraper was needed. The "T" shape was chosen. This would allow for complete scraping of the disk, yet it should cut down on the surface area that touches the disk. With this shape, no strength of the scraper is lost because the base of the "T" provides the support needed to withstand the torque of the rotating disk. Theoretically, the "T" shape scraper should cut down on friction by at least half over the straight edge scraper, and it should increase efficiency by at least 10% over the rotogenerator without a scraper at all.[5]

The material chosen to make the scraper out of was polyethelyne. It is much like the teflon, except that it is a stiffer material that would hold its shape better. The plan was to build the scraper with a 2.5mm top, and a base of approximately 1.8mm to 2.0mm.(Figure 6) A problem, however, came in the making of the scraper. Because of such a small area of material, it was too difficult to machine the scraper to the exact measurements by hand. The only way to get the exact shape would have been to have it factory made, and due to lack of funding, the scraper could not be made before this paper was written.



SECOND ATTEMPT  
POLYETHELYNE  
"T" SCRAPER

### RESULTS

Because of complications in machining the scrapers, no test was actually done on the large device. However, the small 7 disk model generator did give some promising results. Polyethelyne was found to be a good material to use in order to withstand the conditions within the rotogenerator. Even though a "T" shape scraper could not be built by hand, the shape still looks promising as a strong and effective way to scrape that does not cause a high amount of friction.

### CONCLUSIONS

Research shows that one of the main causes of laser power

degradation is water vapor. This vapor comes from the exothermic BHP an  $Cl_2$  reaction which causes adhesion of heated liquid to the disk, and eventually begins to heat the disk itself. However, this temperature rise can be minimized if not neutralized through the use of disk scrapers. The idea, as seen in the model generator tests, will work, but it is just a matter of machining the parts to the exact size and installing them in the big device in order to test. Although no conclusive measurements were made as to how much scraping will improve the efficiency of the laser, it is believed that efficiency may be increased anywhere from 10% to 50%. This project took time, and it is a shame that the major tests were not done by the time this report was written. Government cutbacks stalled this project quice a bit, and therefore the project would need more time to begin to show results.

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**SETTING UP A WORKSTATION-BASED COMPUTING AREA  
FOR DEVELOPMENT AND SIMULATION**

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## **SETTING UP A WORK-STATION BASED COMPUTING AREA FOR DEVELOPMENT AND SIMULATION**

**Jeff R. Hay  
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### **Abstract**

The Satellite Design and Simulation Center of the Space and Missiles Technology directorate of Phillips Laboratory is a relatively new area. As such, much equipment must be installed, updated and configured to operate properly. This paper describes the set up trials of four sets of hardware: A Digital Equipment Corporation VAXstation 3, four X-windows display terminals built by Network Computing Devices, An Apple Macintosh IIsi, and laser- and thermal-type printers. It may serve as a guide for installations of similar equipment and hopefully alleviate many of the frustrations necessarily involved in setting up new computing areas of the caliber of the Satellite Design and Simulation Center.

## SETTING UP A WORK-STATION BASED COMPUTING AREA FOR DEVELOPMENT AND SIMULATION

Jeff R. Hay

### BACKGROUND

Computers, with all their power and newly-found networking ability, are still far from problem-free when it comes to installing multiple machines from different vendors, even when the vendor's products are supposedly compatible. Many of these quirks were discovered while setting up the Satellite Design and Simulation Center of the Phillips Laboratory. The Center is, hardware-wise, a ethernet-based network of workstations, personal computers and terminals with access to the rest of the Phillips Labs and the international Internet network. The hub of the Center's network is a Sun 4/260 called Yoda, followed closely by an IBM RS/6000 nicknamed Simi. Yoda and Simi, along with an Intel i386-based personal computer from Unisys and a couple of printers were all that existed of the Satellite Design and Simulation Center before the project detailed by this paper began. As of this writing, Yoda, Simi and the Unisys system still exist, as well as a DEC VAXstation 3, an Apple Macintosh IIsi, four X-windows display terminals from NCD, and an additional laser printer. The installation and set up of the last four systems is covered in this paper.

### DEC VAXstation 3

Due to software restraints and lack of funding, the VAXstation could not be connected to the ethernet. The workstation contained the required hardware, a DEQNA Qbus-ethernet adapter, but VMS, the native operating system of the VAX, only works with the DECnet protocol, not TCP/IP (Internet). Software such as TGV Cooperation's *Multinet* could remedy this situation. However, the DEC machine is installed as a functional stand-alone design station and serves that purpose well without connections to the ethernet.

The machine was donated to the Satellite Simulation Center by another division of the Phillips Lab. It came with VAX/VMS V4.7a, a simple windowing environment for the console called VMS Workstation Software, and McDonnell-Douglas' CAD/CAM/CAE software, Unigraphics II (UGII). Although the ULTRIX operating system was available, it was thought better to update the version of VMS instead of installing ULTRIX. The ULTRIX system would provide compatibility with Yoda and Simi (both of which run various adaptations of UNIX), but the available versions of the CAD software ran only under the VMS operating system. It is understood that newer releases of UGII also support ULTRIX and other UNIX systems. Along with updating VMS, the VMS Workstation Software (VWS) would be switched to DECwindows, Digital's adaptation of MIT's X-Windows protocol, and the CAD software would remain untouched. At least, that was the plan.

Upgrading VMS proved to be a frightful experience. Digital does not allow users to upgrade directly from, for example, VMS 4.7a to VMS 5.1; first, all minor versions and bug-fix releases must be installed. Therefore, to upgrade from VMS 4.7 to 5.1 (the newest release of VAX/VMS available to the Center), involved, to use Digital's terminology, one installation and four updates.<sup>1</sup>

Unfortunately, Digital has decided to only allow installations of major updates to the VMS operating system, ie, those (such as 4.0 and 5.0) that have a minor release number of 0. Therefore, VMS 5.0 was installed on the VAXstation, completely erasing the V4.7a system previously installed. Then, versions 5.0-1 and 5.0-2 were updated and a mandatory bug-fix update for versions 4.7a through 5.0-2 was added. Then, after one complete installation, three updates and almost three days, the operating system could be brought up to VAX/VMS V5.1.

The next task was to install VMS' form of X-windows, DECwindows. The installation procedure was relatively painless; the only problem was running the software. First, DECwindows complained

---

<sup>1</sup> An **Installation** completely destroys any previous system on the disk and creates a new one; an **Update** simply modifies some of the system files, leaving the user database and any other installed software intact.

because DECnet was not installed. (Apparently, Digital assumes that if one wishes to run X-windows, one has a network to run it on) Conveniently, the DECnet setup software allows DECnet to be initiated even if only one machine is running DECnet; this satisfies DECwindows and gives the DEQNA ethernet controller something to do (continuous loopback). Once DECnet was running, DECwindows would create a mouse pointer, reset the screen to just the top five lines, and exit, using the five-line screen as a very dumb terminal. Upon its exit, DECwindows displayed an error message on the screen, but it was cleared by VMS (to make room for a login prompt) too quickly to be readable. After several days, it was discovered that the error message, which reported that two required font files were not found, stopped appearing when DECwindows was completely re-installed, but re-installing just the font files did not work. After the second installation, DECwindows loaded and ran without problems.

A new problem was quick to surface: McDonnell-Douglas' CAD software, Unigraphics II, did not recognize DECwindows as a valid terminal and would not run; however, it did recognize the VMS Workstation Software. The installation of VWS went smoothly, however running the software proved to produce the same problem DECwindows reported, two required font files were apparently missing. The solution, also, was reminiscent of DECwindows -- reinstall VWS and it worked perfectly. It was also discovered that the VAXstation could run both DECwindows and VWS, but not during the same boot. Two command procedure files (DODEC.COM and DOVWS.COM, see figure 1) were written to switch between VWS and DECwindows and reboot the system (as required). These work without problem for any user in VWS, but only the SYSTEM account can reboot the system in DECwindows - all other users just freeze the system. This is apparently a bug in the DECwindows 1.0 environment. (another, unrelated bug occurs when a user stops the DECwindows Session Manager process from within a DECwindows window, which results in being unable to exit DECwindows)

After the successful installation of VMS 5.1, DECwindows, and VWS, the DEC VAXstation ran, and continues to run, without major problems. Hopefully, at some point in the future, a new version of

```

! DODEC.COM - Switch a VAXstation from the VAX Workstation
!           Software (VWS) environment to the DECwindows
!           environment. (REBOOTS THE MACHINE!)
!
$ Config == "SYS$SYSTEM:SYSGEN"
$ Config
USE SYS$SYSTEM:DECW.PAR
WRITE CURRENT
EXIT
! The DECwindows Install Guide explains how to make DECW.PAR
! (The next line reboots the VAXstation)
$ @SYS$SYSTEM:SHUTDOWN 0 SHUTDOWN YES NO LATER YES NONE

```

Figure 1 - DODEC.COM

UGII or another design program will become available to the Center that supports the VAX ULTRIX operating system, which would alleviate many, if not all, of the aforementioned difficulties in the VMS-based system. Until then, at least, the system is usable.

### Apple Macintosh IIsi

True to its design, the Macintosh was fairly easy to install. Using *TCP/Connect II* from InterCon in conjunction with an ethernet adapter made by Asanté Technologies, the Mac was talking on Internet within ten minutes of opening the package. However, all was not well in Apple land. For unexplained reasons, the Macintosh would freeze while the TCP software was running.

The freezing problem was extremely difficult to diagnose, as incompatibilities within Macintoshes usually are. Intuitively, the problem seemed to be caused by mis-matched port addresses or some similar incorrect configuration. However, Macintoshes don't usually like people changing them in such ways, so any counter action would be tricky at best.

The IIsi was previously configured with System 6.0.1 and an ImageWriter printer attached to an Appletalk prot. Since System 6.0.1 was fairly well tested, and the TCP software was developed and

tested under 6.0.1, it was assumed that the Appletalk port was providing the incompatibilities. This assumption apparently proved true; once the Appletalk and all other ports were disabled, *TCP/Connect II* ran without hanging the system. At the present, there is still no known way to use Appletalk in conjunction with the Asanté controller, even though all documentation hints that it should work.

### **NCD X-windows Terminals**

Network Computing Devices made very capable, flexible terminals in their XNCD19 series of X-windows display terminals. Unfortunately, the terminals were almost too capable for the purposes of the Satellite Design and Simulation Center. The NCD terminals are configured to automatically determine their IP address based on their controller's ethernet addresses via the BOOTP/TFTP Internet protocols. If this fails, they will automatically check for the existence of DECnet via the MOP protocol develop by Digital Equipment Corporation. If they do find an IP address, they will search out their default boot server (in this case Yoda, the Sun 4/260), their symbolic name, and other configuration information.

In the Center's case, the IP addresses assigned to the NCD terminals were previously used at Phillips Lab by machines no longer in use. This produced the interesting effect of the terminals thinking they were different machines and finding a different boot server, a Hewlett-Packard machine which happened to be in the same building as the Center. This problem persisted for many days, until the old IP address/symbolic name mapping was changed to reflect the new setup by the division of the Phillips Lab responsible for such things. Once the map had been updated, the first NCD terminal booted up with minimal difficulties, and the other three came up almost flawlessly.

Only one problem remains with the terminals. They will run Tom's Window Manager (TWM), the window manager supplied with X-windows from MIT, and a window manager built into the terminals themselves, as one would expect. However, they will not allow users to log in if they attempt to run

another window manager such as Sun's Openlook (OLWM) or the popular Motif (MWM) managers. It has not been definitely determined if the problem lies within the terminals or XDM, the X-windows display manager; however when a user on a terminal attempts to run Sun's Open Windows environment, the terminal (or XDM) does not allow login, while Open Windows is displayed on the console's screen. This scenario is the same even when the display is supposedly redirected via the \$DISPLAY name. This suggests that the problem lay in XDM, not in the display terminals themselves.

### **Printers**

Overall, the installation of printers went fairly smoothly. A Texas Instruments MicroLASER Turbo printer was installed and seemed to work without error. An optional communication card was added to the printer which allowed it to simultaneously use a RS-232/422 port, an Appletalk port, and a Centronics Parallel connection. All three ports may be individually configured to use HP Laserjet II emulation, Adobe's PostScript Level 2 language, or HP II with automatic detection and switching to PostScript. The installation of the communications board was no more or less difficult than is to be expected, although getting the printer together after the board was installed took several attempts. Due to cable shortage, only the RS-232 port has been tested, but the printer seems to work completely without errors, with the exception of the automatic Postscript detection sometimes failing.

A Tektronix Phaser IIIpsi color thermal printer was already connected to Simi before the project began. However, color output was "inverted," with blue and purple printing as red, red printing as green, and black and white printing as the opposite color. This problem finally resolved itself into the application software (the KHOROS package developed by the University of New Mexico) having the output colors defined incorrectly; the printer seemed to produce reasonable output with other applications.

The only other printer the Center has installed is a Hewlett-Packard Laserjet III attached to both Yoda and the Unisys 386; it has provided no problems worth mentioning.

## Summary

The Satellite Design and Simulation Center of the Air Force Phillips Laboratory has had its share of complications in setting up equipment. Most of the problems encountered seemed to stem from various manufactures of computing equipment deciding how to implement their systems. Even with defined standards, incompatibilities arise from almost any new piece of machinery. This dilemma will most likely exist from now until computers are no longer used -- every vendor has their own ideas of what would work better then the standard depicts, and will implement that idea in their next piece of equipment; however with time the standards should become more standardized.

The majority of the problems encountered at the Center arose from the Digital Equipment VAXstation 3 in general and the software available in particular. The Digital-provided software (VMS, DECwindows, VWS) at first seemed to have no end of problems and bugs, but almost every one encountered was eventually solvable. The available versions of other software were either just to outdated to support, or otherwise unable to perform, their desired roles. Lack of experience with VAX systems may also have contributed somewhat to the problems encountered.

The TCP/IP-related machines (Macintosh, NCD terminals), on the other hand, had little problem communicating with the machines already in place, Yoda (a Sun 4/260), Simi (an IBM RS/6000), and a Unisys Intel-80386 based personal computer. Even when running under different operating systems (SunOs [Sun's UNIX], AIX [IBM's UNIX], MS-DOS, and the Macintosh Operating System [MOS/Finder]), the TCP/IP protocols provided a consistent enough interface to provide reliable communication between computers.

The end result is the VAX being a standalone machine, dedicated to development with McDonnell-Douglas' Unigraphics II software. All other machines are connected to each other, to Phillips Lab, and to the world via ethernet and the Internet protocols (TCP/IP family).

ITERATED FUNCTION SYSTEMS  
FRACTAL MODELING OF REAL-WORLD NATURAL SYSTEMS

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Bolling Air Force Base, Washington, D.C.

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Abstract

Iterated Function Systems are sets of points created by the random application of equations chosen from a given array of transformations. Depending on the set of transformations, the end set of points from this entirely unpredictable and seemingly-random system can describe many natural objects. Experiments were conducted to determine the exact relationship between the set of transformations and the resulting pattern. A set of trigonometric equations was written to allow precise construction of I.F.S. that could describe any fractal-based object. A program was written to implement this, and leaves, trees, clouds, mountains, and other objects were created. However, by nature all I.F.S. are mathematically perfect, and sometimes do not model nature well. More experiments were conducted to determine how several different I.F.S. could be combined to allow more varied and complex structures. It was found that by mapping different transformations of the I.F.S. to the points of other generating I.F.S. it was possible to construct extremely varied objects. It was possible, for example, to construct a tree with differing branch angles, leaves and bark, none of which was in mathematically perfect tree. A computer program was written to implement this and various objects were created to model nature extremely precisely, as well as decrease computation time for various other fractal objects.

# ITERATED FUNCTION SYSTEMS

## Experimental Report

Iterated function systems are self-similar fractal objects that can be used to describe a variety of natural functions. An iterated function system is described by 6 arrays of floating point values which are called A, B, C, D, E, and F. Each iterated function system has a different number of elements, which correspond to the elements in each array. For instance: the information describing element 3 of an I.F.S. would be stored in A<sub>3</sub>, B<sub>3</sub>, C<sub>3</sub>, D<sub>3</sub>, E<sub>3</sub>, and F<sub>3</sub>.

An I.F.S. is generated as follows:

- 1) The starting values of X and Y, (ie. X<sub>0</sub> and Y<sub>0</sub>) are set to random values
- 2) A random integer R is chosen with a value between 1 and the number of elements in the I.F.S.
- 3) The following equation is applied to the X and Y coordinates:

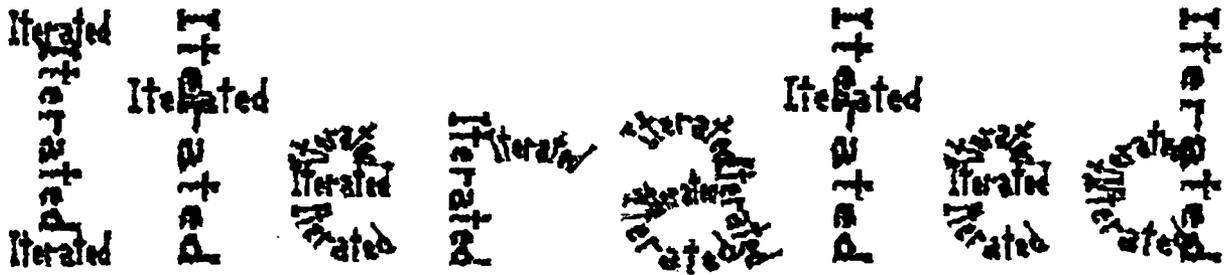
equation #1

$$X_{n+1} = A_R X_n + B_R Y_n + E_R; \quad Y_{n+1} = C_R X_n + D_R Y_n + F_R;$$

- 4) Steps 2-4 are repeated infinitely (in a theoretical I.F.S, in real life 2500 - 100,000 is usually sufficient)

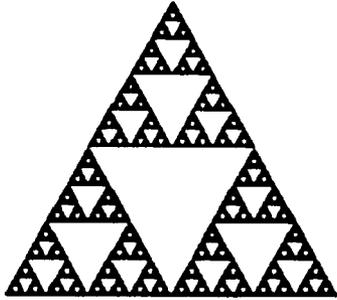
One would think that the resulting set of points from such a random process would be a huge chaotic mess, but that's not what happens. Aside from the first 50 or so points where the system has not "settled down" the result is an extremely complex structure, which depending on the array values, can be made to describe anything from trees to leaves, mountains, clouds, waterfalls, and landscapes, as well as abstract figures like spiraling vortexes or lacy geometric patterns.

Here is an example:

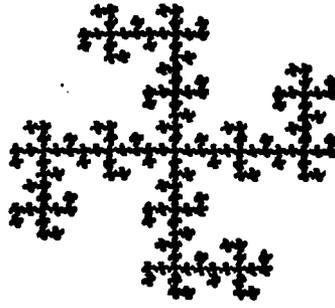


"Iterated," a complex I.F.S.

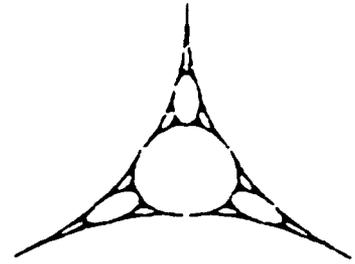
The following page shows twelve of the more striking I.F.S. that were created along with the above figure by Chaos, one of the two main programs written for this project. (see following report for more information on Chaos)



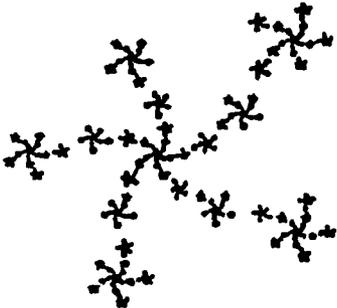
The Sierpinski Gasket



A nazzi I.F.S.



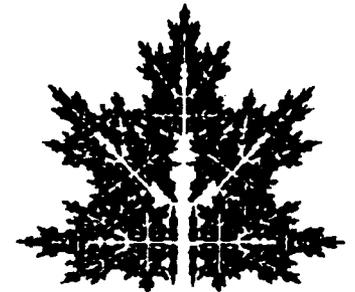
Appolonian oval packing, as an IFS.



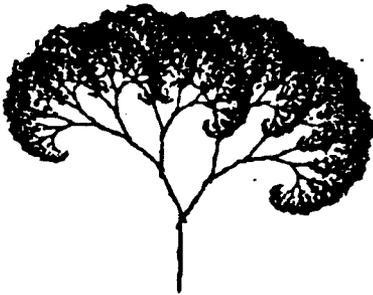
An I.F.S. vortex



An I.F.S. spiral



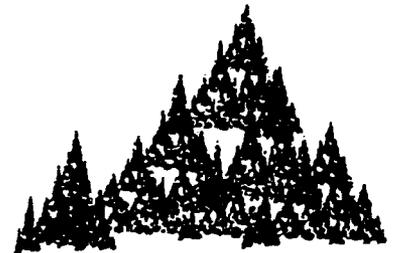
An I.F.S. Maple Leaf



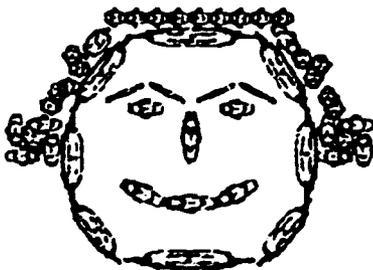
An I.F.S. tree



A rendition of Barnsley's famous fern.



An I.F.S. mountain



George Washington (sort of)



An I.F.S cloud



A Rendition of a Landscape designed by Barnsley

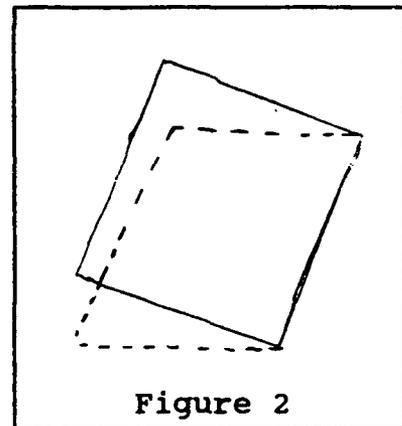
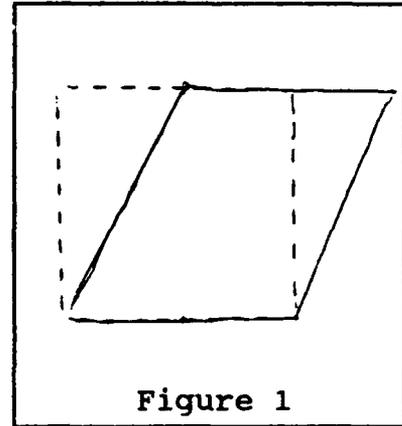
Although it was easy to understand what Iterated function systems were, A clear understanding of how the equation worked, and thus how it would be possible to design original I.F.S, was not immediately forthcoming. However, after much thought and careful examination of the few I.F.S. images that were available, an explanation surfaced.

Imagine that there is a box. When equation #2 is applied to each point on the box it is stretched, rotated, scaled down, and moved to another location. Here is a brief summary of why. A simple scaling occurs when B and C are 0, and A and D are less than 1.

$$(ie \ X_{n+1} = 0.5*X_n; \ Y_{n+1} = 0.5*Y_n)$$

However, when the new X value depends on the old Y value as well as the old X value, then the new X value is greater (or smaller) depending on the Y value. The

result is a parallelogram, see figure #1 for clarification. Then, if the new Y value is also dependent on the old X value as well as the old Y value, the result is a rotation, see figure #2. If A,B,C and D are smaller than one, the box is squashed along one axis, the other, or both. E and F move the new figure to another position.



## Hard-Coding Original I.F.S.:

Having figured this out, the next task was to figure out how to design original I.F.S. With knowledge of equation #2's mechanics creating crude figures was possible by altering A,B,C,D,E and F. Uncertainty remained however, as to what effect certain types of transformations would do to figures. For instance, what would the output be if the top of the Sierpinski gasket was flipped? (ie.  $C = 0$  and  $D = -0.5$ ) Several programs were written to show all possible flipping combinations in several different Sierpinski configurations. These experiments showed that a great deal of variety can be achieved by simply flipping certain parts of certain figures, even though the figures themselves retain the same shapes. In programming the sierpinski programs a peculiar problem showed up. During the program debugging some of the E and F values must have been changed. When the program was rerun some of the patterns didn't match the previous ones! The problem lay in the position of zero. The first time, the triangle was centered on the X axis, while the bottom of it rested on the Y axis. The second time it was centered on both the X and Y axis. The seemingly insignificant change in the position of 0,0 in relation to the figure produced completely different patterns!

This lead to the conclusion that while the shape of a figure may stay the same, the position of 0,0 weighs heavily on the final outcome. This fact generates some problems. An examination of a fractal shape might reveal how to make it using I.F.S. code, but in practice an entirely different shape might form. A way to tell precisely where zero would have to be placed for any given figure has not yet been found.

#### An Easier Way to Create Original I.F.S.:

While it is possible to work with the I.F.S code directly, it is not easy. It would be nice to be able to take a small box, already stretched and rotated, and be able to find the A,B,C,D,E and F values for it. By thought and experimentation the equations to do this were discovered. If  $X_s$  is the total size of the figure on the X-axis,  $Y_s$  is the total size of the figure on the Y-axis,  $A_n$  is the angle that the box is turned,  $X_l$  is the X-length of the box,  $Y_l$  is the Y-length of the box,  $X_p$  is the X-position of the box, and  $Y_p$  is the Y-position of the box, then

#### Equation set #2

$$A = \cos(A_n) * X_l / X_s;$$

$$B = \sin(A_n) * Y_l / Y_s;$$

$$C = \sin(360 - A_n) * X_l / X_s;$$

$$D = \cos(360 - A_n) * Y_l / Y_s;$$

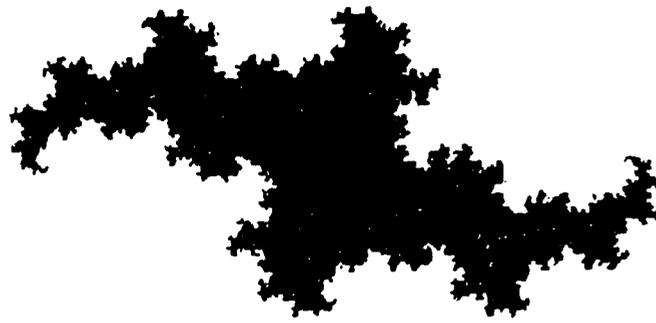
$$E = X_p;$$

$$F = Y_p;$$

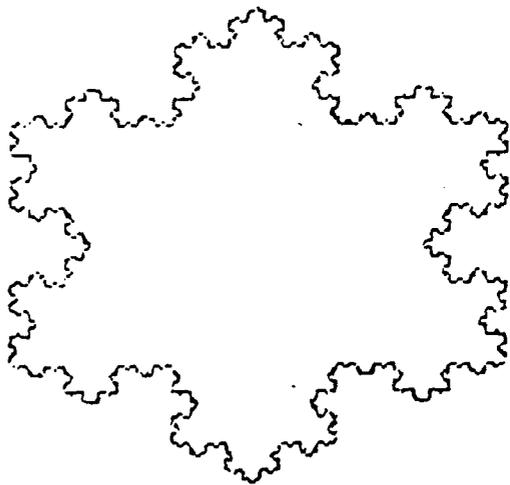
This knowledge enabled the programming of Chaos, which allows the user to create I.F.S. figures from a multitude of different boxes. Using Chaos, I.F.S. were applied to various famous fractals, such as Apollonian circle packing, as well as objects in nature, such as trees. (see page 11-2) For simulating Von Koch curves however, a different strategy was necessary.

Von Koch curves are created by taking a starting figure, called the initiator, and replacing each of its lines with another figure, which is called the generator. Then continue applying the generator to each of the lines of the resulting figure. Now if the initiator were simply a line, an I.F.S. could easily be modeled after it because each part of the generator would just be a copy of itself, and a box could describe it. If the initiator is something like a triangle however, it would be necessary to put a copy of the figure described above in several different places. This can easily be done by printing out the X and Y coordinates only after they have been rotated and placed at a different location by equation #2. Vkoch is the name of a program that was written to do this. The advantages of applying the chaos algorithm to Von Koch curves are speed and precision. An I.F.S. generates a Von Koch curve quickly at equivalent of infinite applications of the generator in 10-20 seconds. Other programs have to apply the generator a limited number of times, and then draw thousands of tiny lines, which can take anywhere from 5 to 30 minutes.

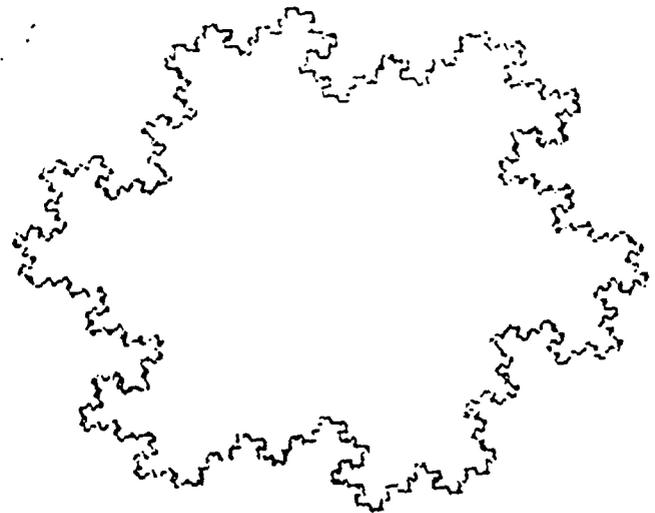
The following pages show a few outputs from the vkoch program



The Von Koch-McEuen dragon,  
created by the chaos algorithm



the Von Koch snowflake



Variation on the Gosper curve,  
created by the chaos algorithm

## Other Equations for I.F.S.:

While many objects can be created by I.F.S. using equations #1 and #2, more variety could probably be obtained by using different equations. While designing original I.F.S it would have been useful many times if it were possible to use bent boxes. The equation that was written to map the X-axis on to a given circle of radius R is as follows.

### Equation #3

$$X = (\cos(Ax + B))(Cy + R) + E;$$

$$Y = (\sin(Ax + B))(Cy + R) + F;$$

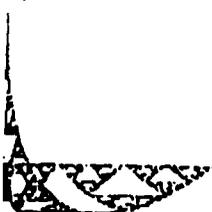
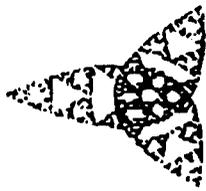
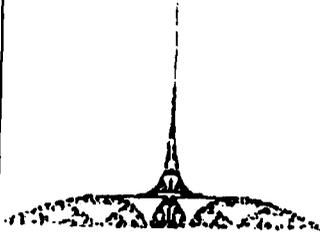
An example of these in action is shown on page 11-1, in the "Iterated" I.F.S. Following this lead all sorts of different equations were written. Most of these have not been investigated in much detail, but it is hoped they will prove useful sometime. The program Equation was written to apply these equations to the Sierpinski triangle.

The following page shows printouts from Equation

These are the images produced when different equations are applied to the Sierpenki triangle.

The boxes above each figure show what equation produced it.

In all of these equations  $b = 90$ ,  $c = 0.7$ ,  $d = 200/\pi$ , and  $Z = x + iy$ .

$a = 200/180;$ $nx = \cos(a^*x+b)^*(c^*x+d);$ $ny = \sin(a^*y+b)^*(c^*x+d);$	$a = 200/180;$ $nx = \cos(a^*x+90)^*(c^*y+d);$ $ny = \sin(a^*x+90)^*(c^*y+d);$	$a = 200/180;$ $nx = \cos(a^*x+b)^*(c^*y+d);$ $ny = \sin(a^*y+b)^*(c^*x+d);$	$a = 200/180;$ $nx = \cos(a^*y+b)^*(c^*x+d);$ $ny = \sin(a^*x+b)^*(c^*y+d);$
			
$a = 400/180;$ $nx = \cos(a^*x+b)^*(c^*x+d);$ $ny = \sin(a^*y+b)^*(c^*x+d);$	$a = 400/180;$ $nx = \cos(a^*x+b)^*(c^*y+d);$ $ny = \sin(a^*x+b)^*(c^*y+d);$	$a = 400/180;$ $nx = \cos(a^*x+b)^*(c^*y+d);$ $ny = \sin(a^*y+b)^*(c^*x+d);$	$a = 400/180;$ $nx = \cos(a^*y+b)^*(c^*x+d);$ $ny = \sin(a^*x+b)^*(c^*y+d);$
			
$a = 200/180;$ $nx = \cos(a^*x+b)^*(c^*x+d);$ $ny = \sin(a^*y+b)^*(c^*y+d);$	$a = 200/180;$ $nx = \cos(a^*y+b)^*(c^*x+d);$ $ny = \sin(a^*x+b)^*(c^*x+d);$	$nx = (x^*x)/50;$ $ny = (x^*y)/75;$	$Z = Z^2;$ $nx = (x^*x - y^*y)/125;$ $ny = (2^*x^*y)/125;$
			
$a = 100/180;$ $nx = \cos(a^*x+b)^*(c^*x+d);$ $ny = \sin(a^*y+b)^*(c^*y+d);$	$a = 100/180;$ $nx = \cos(a^*y+b)^*(c^*y+d);$ $ny = \sin(a^*x+b)^*(c^*x+d);$	$nx = (x^*x^*x)/6000;$ $ny = (x^*y^*y)/7500;$	$Z = Z^3;$ $nx = (x^*x^*x - 3^*x^*y^*y)/10500;$ $ny = (3^*x^*x^*y - y^*y^*y)/10500;$
			

## Applications:

Iterated function systems are invaluable to researchers who want to store or transmit images. Normally, the color of each pixel on a screen would have to be sent. On a screen 640 \* 480 pixels the amount of time and space required would be enormous. but if an I.F.S. is applied to the image, the information can be sent simply by sending the A,B,C,D,E and F values. Also, the resulting image can be magnified, while a simple picture could not be. Research with Iterated function systems can extend the range of pictures to which an I.F.S can be applied, making image storage and transmission far easier. Also, Iterated Function Systems may provide insights into genetics. DNA can contain a substantial amount of information, but its capacity isn't near that required to detail the position of every single cell in the human body, or for that matter, in a plant. Yet I.F.S. can create successful images of leaves, trees, ferns, and variety of other items. The bronchial structure is fractal, as is the circulatory system. DNA may simply define the basic fractal pattern, in a way similar to an I.F.S. and define such things much more easily. I.F.S. can be applied to image-compression and genetics, as well as modeling of real-world images.

## Phase II

During the first stages of research, when the I.F.S. were being hard-coded to try and figure out what made them tick, a program was written to generate a very simple I.F.S. with four transformations. Due to a bug in the program however, the coordinates for the dot were applied to one of the four transformations, but then, unless the fourth transformation had been selected, *the coordinates were applied to the fourth transformation before being printed out.* The result was an interesting pattern of crosses, instead of the blank, featureless box the corrected program made. Due to lack of time, the topic was not pursued, and was soon forgotten. After the completion of Chaos, Vkoch, and the numerous other small programs however, it seemed the end of research had come at last. But suddenly that one early experiment came to mind and a new set of questions surfaced. The program could really be separated into two I.F.S., a blank wall, and a dot. That being so, why did this double-system create this particular pattern? If two iterated function systems were paired together, would they create an entirely different pattern from either of them? Would the fact that the dot was printed only after both transformations mean that only part of a greater image was being shown? Or like I.F.S., would the greater image be shown in the smaller image? Thus the second stage of this project, on multiple I.F.S. began.

In the first set of experiments the relationship between the entire figure, and the part that was displayed when the dot was only plotted in one position was determined. A program was written that displayed pairs of I.F.S. in two colors. The first color represented the set of coordinates after the first combination, the second color the set of coordinates after the second combination. The answer was depressingly unexciting. There was no relationship, because there was no entire picture. The two colors formed not one, multi-colored image, but two entirely different images, each a subset of the other.

In the second set of experiments, the relationship between the two patterns and their I.F.S. components was discovered. In these experiments the dot was printed only after both transformations, to avoid confusion. It had been previously found that the image created when the dot was printed between the two transformations could be reproduced by reversing the order of the I.F.S.

The relationship between the pattern produced by the combination and the two component I.F.S. was surprisingly simple. The transformations of the second I.F.S. were "laid down", but instead of those same transformations being "inside" each transformation like a normal I.F.S., the transformations of the first I.F.S. were inside them. The transformations of the second were inside the transformations of the first, etc. Thus the underlying structure of the resulting pattern was precisely the same as it's component I.F.S., except on alternate levels. This also produced another effect. There were two separate patterns,

this discovery correlated these two as well. The first pattern could be found inside the boxes of the second I.F.S., and the second pattern could be found inside the boxes of the first I.F.S.

The third set of experiments determined whether this pattern continued in "chains" of more than two I.F.S. The pattern was basically the same, except a few things were clarified. It turned out that no matter which I.F.S. was applied first, the I.F.S. that was applied just before the dot was plotted was always the one whose transformations were "laid down" first, with the transformation of all the other I.F.S. counting back "inside" those.

I.F.S. combinations are most useful when the two component I.F.S. are fairly similar, like several different I.F.S. trees. In this case, the pair models nature more closely by providing several separate sets of branching angles. First one set is applied, then the next, making a more varied tree. The same can be said of rock patterns, horizons, and a variety of other objects in nature. I.F.S. chains are not terribly useful however, because they can be generated by single I.F.S. since eventually the figure appears in an unaltered, if smaller than usual, form. All that has to be done is apply the sets of boxes to the transformations to create a complex I.F.S. of several hundred transformations.

Despite the fact that I.F.S. chains failed to provide a new and revolutionary way of using I.F.S., the prospect of using multiple I.F.S. to describe an object was intriguing. For instance, a standard I.F.S. tree is mathematically perfect, and has no leaves, just branches splitting finer and finer unto infinity. Now while these micro-twigs can simulate foliage at a distance, they don't truly emulate nature. I.F.S. leaves have been created, as well as several different I.F.S. trees. What would happen if instead of the new point for an I.F.S. being that I.F.S.'s old point applied to the chosen transformation, the new point for an I.F.S. would be another I.F.S.'s old point applied to the chosen transformation. In other words, if  $X_1, Y_1, A_1, B_1, C_1, D_1, E_1, F_1$  are the chosen transformation and point coordinates for I.F.S. number 1, and  $X_2, Y_2, A_2, B_2, C_2, D_2, E_2, F_2$  are the chosen transformation and point coordinates for I.F.S. number 2 then

Equation set number 4

$$X1_{n+1} = A1*X2_n + B1*Y2_n + E1; \quad Y1_{n+1} = C1*X2_n + D1*Y2_n + F1;$$

but

$$X2_{n+1} = A2*X2_n + B2*Y2_n + E2; \quad Y2_{n+1} = C2*X2_n + D2*Y2_n + F2;$$

Thus, instead of having a picture of itself in that box like it normally would, I.F.S. number 1 has a picture of I.F.S. number two in that box. This makes it possible to define a twig structure with several boxes, and map a leaf into every one of them.

One might argue that this destroys the true fractal nature of the I.F.S. Quite to the contrary, it remains as much of a fractal as ever. The leaf existing in that particular box alters the way the I.F.S. looks, and so the leaf is copied into every other box, preserving the integrity of the I.F.S. What's more, it allows greater diversity, because the leaf in itself is an entirely different, completely self-similar I.F.S., contained in another one.

The program MIFSD (Multiple Iterated Function System Design) was programmed to implement this. In it's present version, It allows I.F.S. to be loaded into a linked list, and allows the different transformations of each I.F.S. to be mapped to other I.F.S. in the list. In addition, it also allows I.F.S. "chains" to be defined and treated like single I.F.S.

Although it is sometimes difficult to define a complex, realistic, natural object, almost any object, with the possible exception of escape-time fractals, can be described by a M.I.F.S. (Multiple Iterated Function System, as the objects created by many interlinked I.F.S. have been dubbed). Using MIFSD, M.I.F.S. have been successfully applied to trees, and M.I.F.S have been designed to simulate shrubs, rocks, L-systems, and D.L.A. (Diffusion Limited Aggregation, a type of fractal).

Below is listed a "fairly simple" M.I.F.S for a tree:

- 1) tree -- 2) tree2  
    \ - 3) curvtree
- 2) tree2 -- 5) tree2  
    \ - 6) treelim
- 3) curvetree -- 4) tree  
    \ - 5) tree2
- 4) tree -- 7) treelim  
    \ - 9) curvtree
- 5) tree2 -- 7) treelim  
    \ - 8) treelim2
- 6) treelim -- 8) treelim2  
    \ - 9) curvtree
- 7) treelim -- 10) treelim2  
    \ - 10) treelim2
- 8) treelim2 -- 10) treelim2  
    \ - 11) llimb
- 9) curvtree -- 10) treelim2  
    \ - 10) treelim2
- 10) treelim2 -- 11) llimb  
    \ - 12) limb
- 11) llimb -- 13) leaf
- 12) limb -- 13) leaf
- 13) leaf
- 14) bark (the trunks to all the larger trees are mapped to this)
- 15) smbark (smooth-bark, for the twigs)

Tree, Tree2, and Curvtree are basic I.F.S. trees with varying branch angles.

Treelim is a basic tree with one branch much lower than the other.

Treelim2 has two small branches at the bottom, and one big one at the top.

Llimb and Limb are long and short branches with leaves.

Unfortunately, due to the way MIFSD manages memory, all attempts to save the images produced have failed. this page is the only demonstration of MIFSD results there is at this time.

## Applications

The advantages of M.I.F.S. are many. First of all, by allowing several different I.F.S. structures to be combined, it allows (as mentioned above) a detailed, magnifiable image of almost any natural object, in a minimum of space. Another advantage is speed. DLA is one of the most time-consuming fractals in existence. It is generated by simulating a sea of anywhere from one to a million points that move randomly around, with one solid point in the middle. Whenever a floating point touches the solid one, it too becomes "solid" and other points can stick to it. The result is a very interesting random dendrite, but the computational time is incredible. M.I.F.S. can simulate a DLA fractal, and while it won't be perfect, it will be much faster. L-systems are a fractal similar to Von Koch curves, but much more complex. They are defined by several strings of symbols, that list the fractal structure in turtle graphics format. Unfortunately, like Von Koch curves, they have a limited precision and are even more time-consuming. M.I.F.S. can easily be applied to an L-system, since the methods they use for defining the fractal structure are similar, and can generate it with infinite precision and easy magnification in a fraction of the time. As L-systems are widely used as the "standard" for defining plants, this could be very useful. The third advantage is that they can define a standard for the fractal rendering of real-world objects, being even more flexible than L-systems, and able to do just as much.

Scientific Visualization  
of a Carbon-60 Molecule

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Final Report  
Summer Research Program  
Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington, D.C.

Mentor: Terry F. Galati  
Animation Advisor: Tom Elkins

August 1992

Scientific Visualization  
of a Carbon-60 Molecule

Mindee A. Jeffery  
Student  
Quartz Hill High School

ABSTRACT

The following is a description of the process involved in creating and animating a computer generated visualization of a Carbon-60 molecule. The process involved calculating the geometry of the fullerene and solving the problem of how to model its geometry. The Ray Tracing method of creating a 3-D picture on a 2-D screen will be discussed, as will the process of creating the animation, and converting that animation to video tape.

# Scientific Visualization of a Carbon-60 Molecule

Mindee A. Jeffery

## INTRODUCTION

Carbon-60, also referred to as a Buckyball or Buckminster Fullerene, is a recently discovered form of carbon. The molecule is a hollow sphere with one carbon at each vertex of the twelve pentagons and twenty hexagons that make up the ball's 32 faces. Essentially, the buckyball is the shape of an American soccerball. Due to their hollow closed structure, the buckyballs can be used to "cage" other molecules. This potential has created a great deal of excitement within the scientific community.

Due to the microscopic size (.701nm in diameter) and the limits of current microscopy, the best pictures of Buckyballs are two dimensional. These pictures leave much to be desired, as the geometry of the ball is very complicated and must be viewed at many different angles so that the scientific implications of its structure can be easily grasped.

Using computer graphics and animation tools such as Wavefront, scientists and engineers can more easily visualize the complex structure of this molecule.

## METHODOLOGY

The modeling of the buckyball began with calculating the buckyball's geometry. Final calculations indicated that each polygon must be rotated inward 30 degrees, if they are to come together forming a symmetrical sphere.

Physically modeling the fullerene on the computer began with the formation of a single pentagon. This pentagon was created with the aid of a 2-dimensional primitive. A sphere was placed at each vertex of this primitive. The spheres were then connected by cylinders, the spheres acted as "carbons" and the cylinders as "bonds." With the completion of this three-dimensional model the primitive was deleted.

After finishing the pentagon a third cylinder was added to each sphere. This third cylinders were rotated 72 degrees from each of the other cylinders and then rotated inward 30 degrees. This pentagon with the hanging bonds was then copied five times. Each of the five copies was then rotated and translated until each copy was connected to one vertex of the original pentagon.

These six pentagons formed exactly half of the fullerene. The first half was then copied as a group and the copy was then rotated and translated until it fitted with the first half forming a symmetrical, spherical form of Carbon.

After completion of the model, materials must be chosen and applied. The material selection allows for a choice in different kinds of illumination models (light), color, and texture. A higher illumination creates better definition for the objects. An illumination of zero makes the object on the screen appear two-dimensional. A higher illumination will give the illusion of shadows and depth, which will give the appearance of a third dimension. The third dimension of the spheres is also better defined because of added specular highlights and diffuse shading. The cylinders, or bonds, appear translucent because a transmission coefficient was added for that effect.

The next step in the process of creating a scientific visualization is to choose a motion path for the object. A motion path is created by choosing a position for each frame in the animation. Instead of positioning the model in each frame, and moving the model miniscule amounts over 150 frames, key frames can

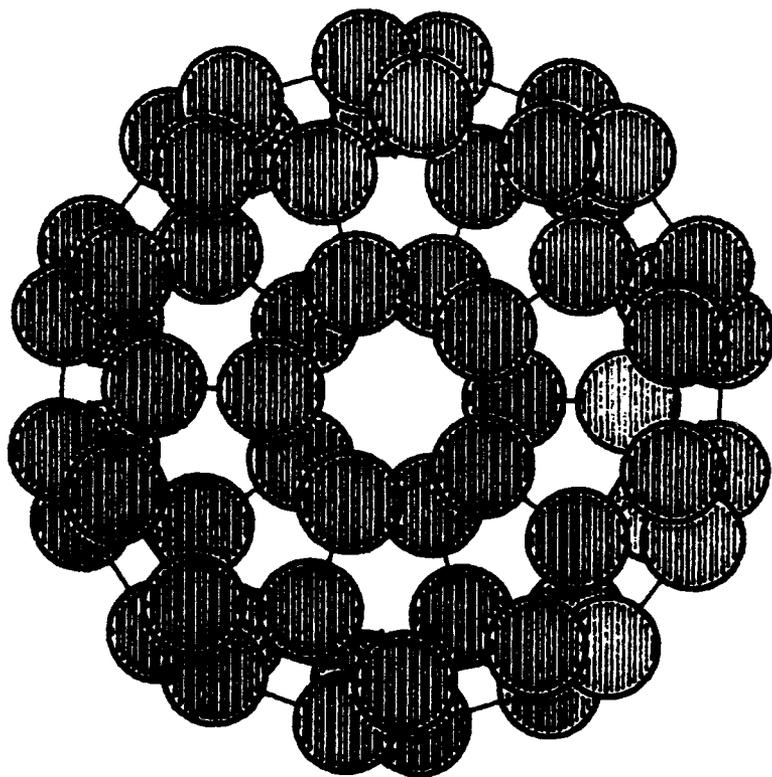
be used to make the task less tedious. The object is placed in key positions in certain frames, and a spline is created through the points you have specified on the motion graph. This creates a fluid motion, with minimal effort.

The next step in the process of creating the animation is to render all the frames of the motion path. By stating that the computer is "rendering the frames" it simply means the computer is drawing pictures of the frames. The computer does this using the position and direction of the lights and camera, the position and orientation of the objects, and the properties of the materials assigned to the objects. This procedure is called the Ray Tracing method.

This Ray Tracing method is the computer's method of calculating how a ray of light hits the objects on screen and bounces back to the camera. The computer traces the rays of light from the light source to an object. It then calculates the angle at which the ray hits the object, the angles at which the ray bounces off the object, and follows the ray until it hits other objects, the camera, or passes by the camera. The computer will then cease to trace the ray. Based on the length of the rays, the angle the rays hit the camera, and the materials applied to the object, the computer uses this ray tracing method to determine the color of every pixel that appears on the screen.

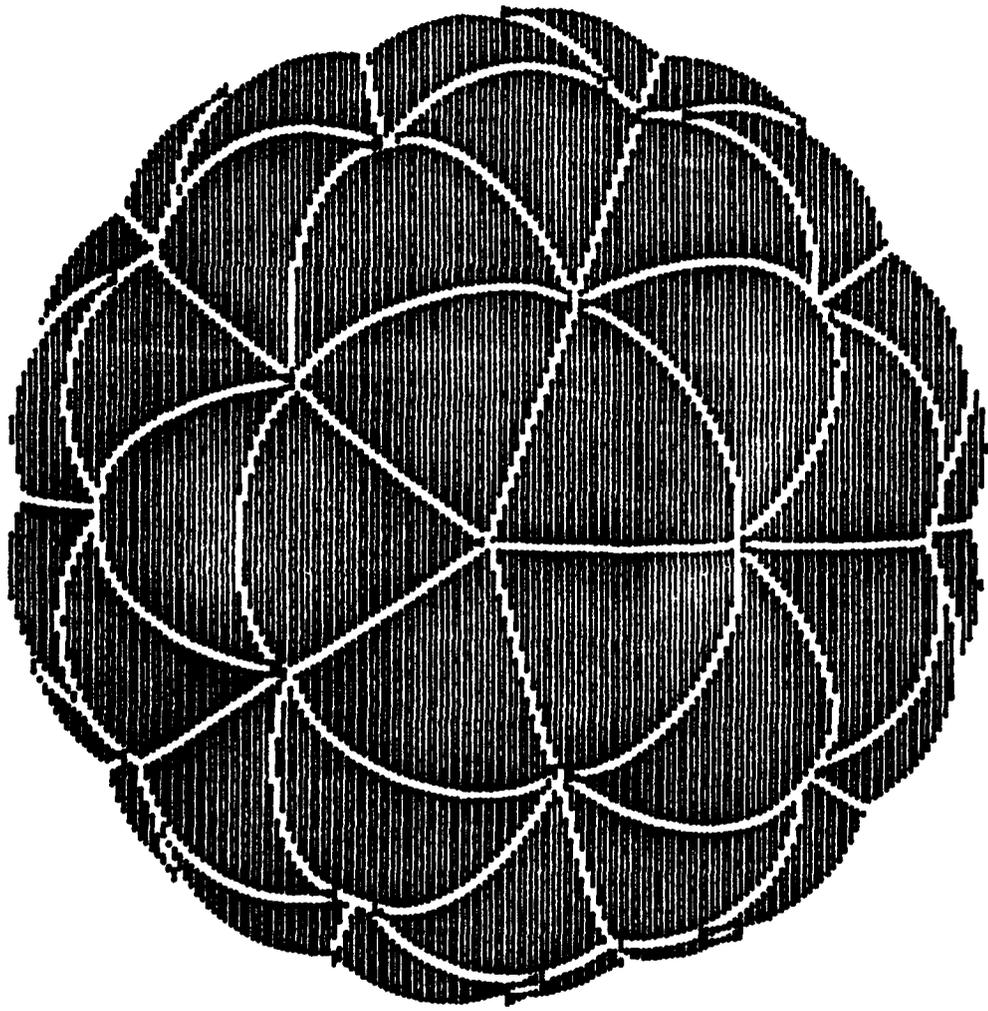
The frames are rendered on a 24-bit image file which contains the capabilities for over 16.7 million colors per picture, and a screen size of 736 by 482 pixels. These factors make each file over one million bytes. Because these factors are so large, a small computer does not have the capabilities to manage them. They are therefore transferred to an encoded video image by a process that compresses the files to a 4-bit image that is less than 100k bytes. The object is then easily transferred into an animation by a delta compression method. This method stores the entire first frame and from then on only stores the changes between frames. This process compacts the animation and allows it to be

transferred to an Amiga computer. Special hardware once again decompresses the animation into a standard television image in real time, and can be recorded by a standard VCR. This entire process was automated by programs developed by Tom Elkins and Russ Leighton of Phillips Laboratory.



Bucky 60

*Book by M. S. Dresselhaus, A. L. Endrey*



Bucky 60

*D. J. O. D. v. l. a. l. h. k. a. M. I. e.*

RESEARCH INTO THE CAUSES  
OF PRE-FIRES

Brad L. Karmioli  
High School Student  
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Final Report for:  
High School Apprenticeship Program  
Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
Solling Air Force Base, Washington D.C.

August 1992

RESEARCH INTO THE CAUSES  
OF PRE-FIRES

Brad L. Karmiol  
High School Student  
Albuquerque Academy

Abstract

The Shiva Star/Marauder project, which is attempting to produce high energy compact toroids, has recently suffered many problems with pre-fires. It was hypothesized that the brass electrodes which channel the current to the gas, forming a plasma, might be the problem. However, after much research and testing, it does not appear that the electrodes are the problem, but rather an engineering flaw in the set up of the hardware.

## RESEARCH INTO THE CAUSES OF PRE-FIRES

Brad L. Karmiol

### INTRODUCTION

The Shiva Star/Marauder project which I worked on this summer is an experiment which is attempting to produce high energy compact plasma toroids which would have multiple applications. The project is still struggling to form the plasma toroids, however, and one of the biggest difficulties has been a string of pre-fires. These pre-fires occur when the capacitor banks are charging. What should happen is the energy from the capacitor banks should build to a certain level, and then be delivered to the gas in the center load, forming a plasma. During a pre-fire the energy is channeled too early and to the wrong place during the charging phase. This has many bad repercussions, including destruction of hardware, depositing carbon and other unwanted substances in the load where they make the proceeding few shots of plasma toroid formations, nearly useless, and the obvious waste of time and money.

### DISCUSSION OF PROBLEM

There were two different theories on why the pre-fires kept occurring. One idea was that there is a flaw in the engineering of the entire system itself. The other idea was that something was wrong with the brass electrodes, which are supposed to channel the current at the correct voltage. The decision was made to investigate the latter, because it seemed more likely, and it would be easier to research and

less expensive to fix. There were many potential problems with the electrodes, however. Everything from incorrect gapping to residues from the current electrode cleaning method to a problem with the box which holds each pair of electrodes had to be researched as a possible culprit.

#### METHODOLOGY

Our first test was to gap each pair of electrodes to be sure they were properly positioned. This involved setting them with a precision of 15 ten thousandths of an inch. It was a slow process, and it did not fix the pre-fire problems. Next we set up a small experiment with just one pair of electrodes and the devices necessary to channel voltage across the gap between the electrodes. We hoped to produce a pre-fire and thereby isolate the problem. We tried cleaning the electrodes with four different types of alcohol, leaving bits of paper towel used to clean the electrodes in different places on the electrodes, gapping the electrodes incorrectly, and spraying various substances, including carbon, onto the electrodes. Then we experimented with the boxes containing the electrodes, sanding them to remove any residues and cleaning them with assorted liquids.

#### RESULTS

We were unable to produce a single pre-fire regardless of what we did to the electrodes. This frustrated one scientist to the point that he suggested cleaning the electrodes with peanut butter so as to guarantee a pre-fire. However, when I had finished my summer

apprenticeship the results of sanding the boxes housing the electrodes were not complete.

#### CONCLUSION

The electrodes are more resistant to pre-fires than anyone imagined, and are not directly responsible for the rash of pre-fires that Sniva Star/Marauder has suffered. It is not likely that the boxes housing the electrodes are responsible either. This suggests that there could be a major engineering flaw that has surfaced under the higher voltage conditions that Sniva Star/Marauder has recently begun operating under. Now research must be put into that hypothesis.

**SYNTHESIS AND PURIFICATION  
OF FULLERENES**

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**Final Report for:  
Summer Research Program  
Phillips Laboratory**

**Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington, DC.**

**August 1992**

**SYNTHESIS AND PURIFICATION  
OF FULLERENES**

**Alexandra N. Kitty  
Student  
Good Counsel High School**

**ABSTRACT**

A carbon arc reactor for vaporization of graphite or carbon rods was designed and used to manufacture fullerene containing soot. The soot was collected from the reactor after vaporizing 212.4g of carbon rods and Soxhlet™ extracted with carbon disulfide. This yielded 11.76g of fullerenes. A toluene solution of these fullerenes was extracted on a Shodex HPLC column.

Synthesis and Purification  
of Fullerenes

Alexandra N. Kitty

INTRODUCTION

Fullerenes are a family of polymorphs of carbon in which the carbon atoms define pentagonal and/or hexagonal faces of closed polyhedra. These structures allow each carbon atom to satisfy all its bonding requirements and therefore result in stable molecules. "Fullerene" is applied to these molecules in honor of R. Buckminster Fuller who pioneered the use of similar polyhedra in architectural design. The best known example of the fullerene family is C<sub>60</sub> which is shaped like a soccer ball (fig.1).

The existence of C<sub>60</sub> was first predicted by Osawa in 1970.<sup>1</sup> In 1985, a team of chemists from Rice University in Houston - Smalley, Curl, Heath and O'Brien - and Kroto from the University of Sussex, UK., reported production of microscopic amounts of C<sub>60</sub>.<sup>2</sup> In 1990, however, a method for producing gram quantities of C<sub>60</sub> and C<sub>70</sub> was discovered.<sup>3</sup> Krätschmer, Lamb, Fostiropoulos, and Huffman used a carbon arc to produce milligram quantities of a C<sub>60</sub>/C<sub>70</sub> mixture. Since then, another method has been described. Taylor, Hare, Abdul-Sada, and Kroto used laser vaporization to generate C<sub>60</sub>-containing carbon soot.<sup>4</sup> The method used this summer to produce C<sub>60</sub> is similar to that of Krätschmer *et al.* because it fit in with our main goal: to produce gram quantities of fullerenes for further investigation as to their use in carbon-matrix materials.

## METHODOLOGY

The carbon rods used to make C<sub>60</sub> were 12 inches long, grade POCO3. Various sizes of carbon rods were vaporized (after being cut to six inches to accommodate the reactor): 3/16"x 12" (9.8g ea.), 1/8"x 12" (4.6g ea.), and 1/4"x 12" (18g ea.). In all, 212.4g of carbon was vaporized. The apparatus consisted of an eighteen inch Pyrex bell jar sealed with a Buna gasket onto a metal feedthrough collar set on a metal baseplate. A two-stage mechanical pump (3.2 cfm) was used to evacuate the system. Helium (99.99%) was used as an inert buffer gas. A Miller Thunderbolt 225 CC AC arc welder powered the arc. The vaporization chamber and its components are shown in Figure 2. Two water-cooled electrodes, one manually fed (fig. 2b) and the other stationary (fig. 2a) inside the bell jar, were used to vaporize the carbon rods. A copper cooling coil, shown as fig. 2e, and a metal shield (fig. 2g) insulated the metal feedthrough collar from the heat produced at the stationary electrode. The helium inlet tube (fig. 2h) was directed at the stationary electrode where the arc was formed.

After attaching a six-inch carbon rod to the manually fed electrode, the reactor was evacuated to less than 5 torr and back-filled with 100 torr of helium. During the reaction, the automatic pressure controller maintained and regulated the pressure. Carbon vaporization was accomplished at 150-175 amps by slowly feeding the manually-fed electrode into the reactor, touching the carbon rod to the stationary electrode, and thereafter feeding the electrode to maintain an arc. Once the rod was vaporized, the arc welder was turned off and the pressure brought back up to atmosphere with helium. The stump of the vaporized rod was replaced with another graphite rod and the process repeated.

After vaporizing all the carbon, the reactor was opened and dismantled while soot and "slag" (deposits formed around the contact point of the electrodes) was collected in extraction thimbles. The thimbles were loaded into a Soxhlet extractor and thoroughly extracted with carbon disulfide. Using a rotary evaporator, the carbon disulfide was removed yielding 11.76g of crude fullerenes.

High Performance Liquid Chromatography (HPLC) was used to separate the crude fullerenes into nine fractions, fraction 1 having the most C<sub>60</sub> and fraction 9 having the least. Fractional purity will be

tested at a later date. The column used was a SHODEX™ GPC-HF 2003 (20x500mm). A saturated solution of crude fullerenes in toluene (approx. 5mg/mL) was injected onto the column and eluted with pure toluene. The elution was monitored with a UV detector (590 nm) as per Meier and Selegue.<sup>5</sup> The solvent was removed from the fractions using a rotary evaporator.

## RESULTS

A variety of systems for the production of fullerene-containing soot have been discovered. These include laser ablation<sup>4</sup>, carbon arc vaporization<sup>3,5,6,7,8,9,10</sup> and sooting flames.<sup>11</sup> Carbon arc systems appeared to be the simplest and most practical for the production of large quantities of fullerenes.

Our vaporization apparatus (fig.2) was the result of ideas gathered from the literature.<sup>3,5,6,7,8,9,10,12</sup> For simplicity sake, the apparatus was similar to a system used by Haufler *et al.* utilizing a stationary electrode with a graphite base and water-cooled feedthroughs.<sup>6</sup> Initially, an electrode fed vertically onto a stationary electrode by means of gravity (gravity-fed electrode) was attempted. This would eliminate the need for a linear motion feedthrough and therefore reduced the possibility of vacuum leaks. The gravity-fed electrode was an inconvenient design because every time a carbon rod was changed, the bell jar covering the system had to be removed. Later, a linear motion feedthrough was tested and found to work much better than the gravity-fed electrode. Given more time, a design in which two graphite rods attached to electrodes and fed toward each other manually or by computer control would have been implemented.

As with other experiments using stationary electrodes<sup>7,13,14</sup>, volcano-shaped deposits (slag) formed at the contact point of the electrodes. These volcano-like formations are where "nanotubes" are hypothesized to exist.<sup>10, 11, 12</sup> Nanotubes are suggested to be microscopic carbon structures that are hollow and tubular made up of thousand of carbon atoms. A molecular model of a C<sub>100+</sub> fractional nanotube is shown as figure 6. Researchers hypothesize that nanotubes retain the grid-like atomic structure common to the spherical fullerenes (e.g. C<sub>60</sub>, C<sub>70</sub>), but are much longer. Scientists look forward to discovering practical uses for these new molecules. Given the times constraints of this project, we were unable to investigate our material for the presence of nanotubes.

As suggested<sup>8,13</sup>, carbon disulfide, as opposed to toluene or hexane, was used to extract crude fullerenes from the soot collected in the reactor. Both CS<sub>2</sub> and toluene solutions of the crude fullerene extract are red-brown.

High Performance Liquid Chromatography (HPLC)<sup>3,15</sup> on a SHODEX™ column, was used to separate a toluene solution of crude fullerenes into nine fractions. Both HPLC and column chromatography were tested, but HPLC better suited our purpose because the HPLC system was easily automated. It also gave a better loading capacity than column chromatography and HPLC separated the fullerenes well, as evidenced by the definite differences of color in the purified solutions.

UV detection and differential refractometry were used to monitor the elution of material coming out of the HPLC (figs. 3 and 4). Even though the purity of the fractions collected has not been measured, it can be hypothesized from information in the chromatograms and the literature<sup>12,15</sup> that approximately 84% of the material collected is C<sub>60</sub> (fig. 1), 14% is C<sub>70</sub> (fig. 5), and 2% is fullerenes of higher atomic weight. The C<sub>60</sub> molecules manufactured will be further investigated for use in production of carbon-matrix materials.

## CONCLUSIONS

Many different ways of producing carbon 60 and other fullerenes have been previously reported. The carbon arc system, being the simplest and most practical, was used to manufacture fullerene containing soot. It is possible that the slag, collected from the reactor along with the soot, contains nanotubes. HPLC was used to separate a toluene solution of mixed fullerenes into separate fractions and worked better than did column chromatography. The exact amounts of fullerenes collected will be known at a later date.

## ACKNOWLEDGMENTS

I want to thank all of the people who made this a memorable summer, especially my mentor, E. J. Wucherer, who guided me through many new concepts and showed me that chemistry is fun. A special thanks to Mike Carr for assistance in our research and to Steve Osborn, Kevin Chaffee, Dave Elliott, Robert Behdadnia, Brad Lormand, and Tracy Reed for their influence and friendship. I would also like to show my appreciation to my aunt and uncle, Mary Lou and John Rusek, for a place to stay and parental guidance while I was away from home. Last, but not least, thank you mom for your encouragement and support.

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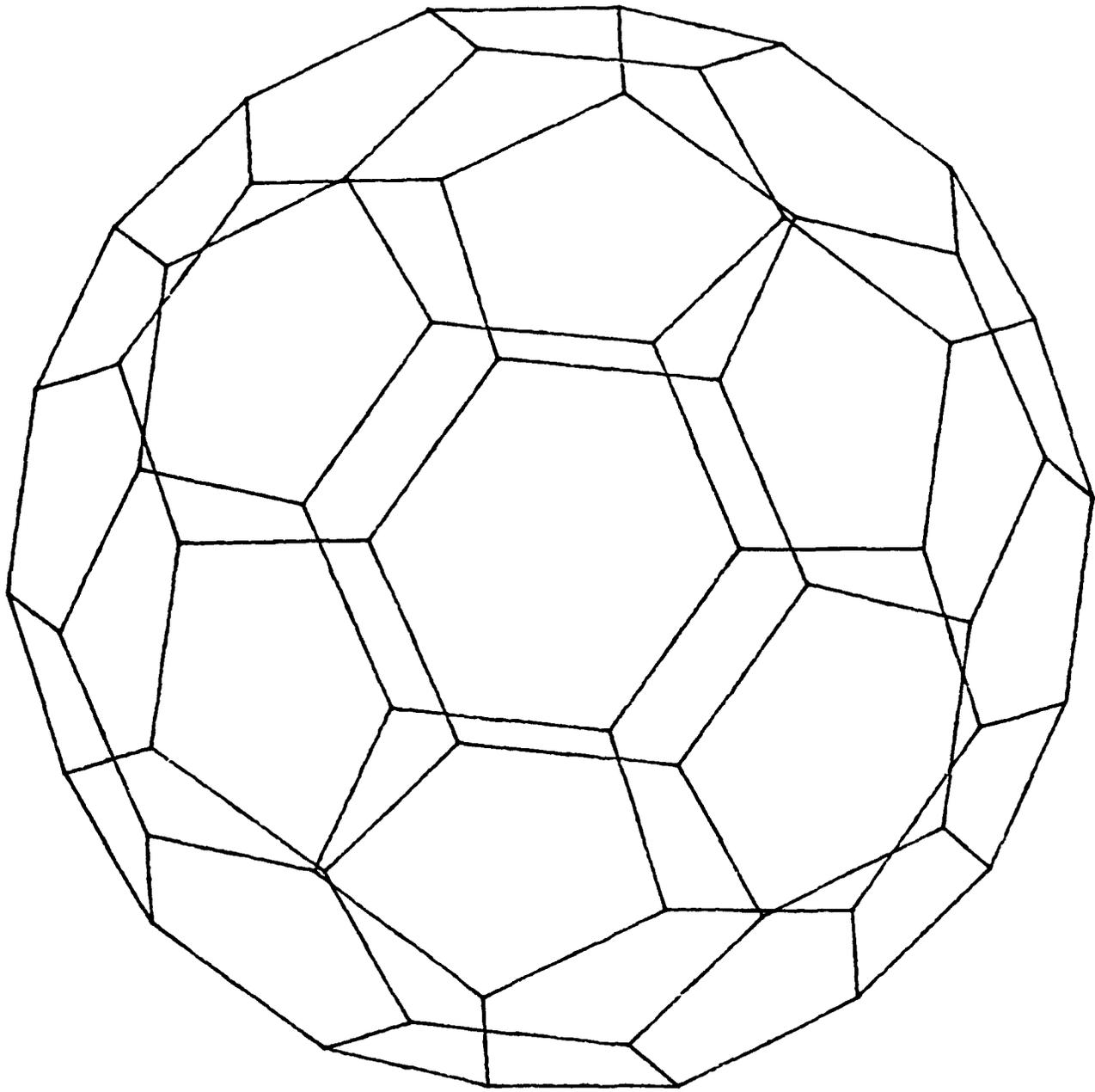
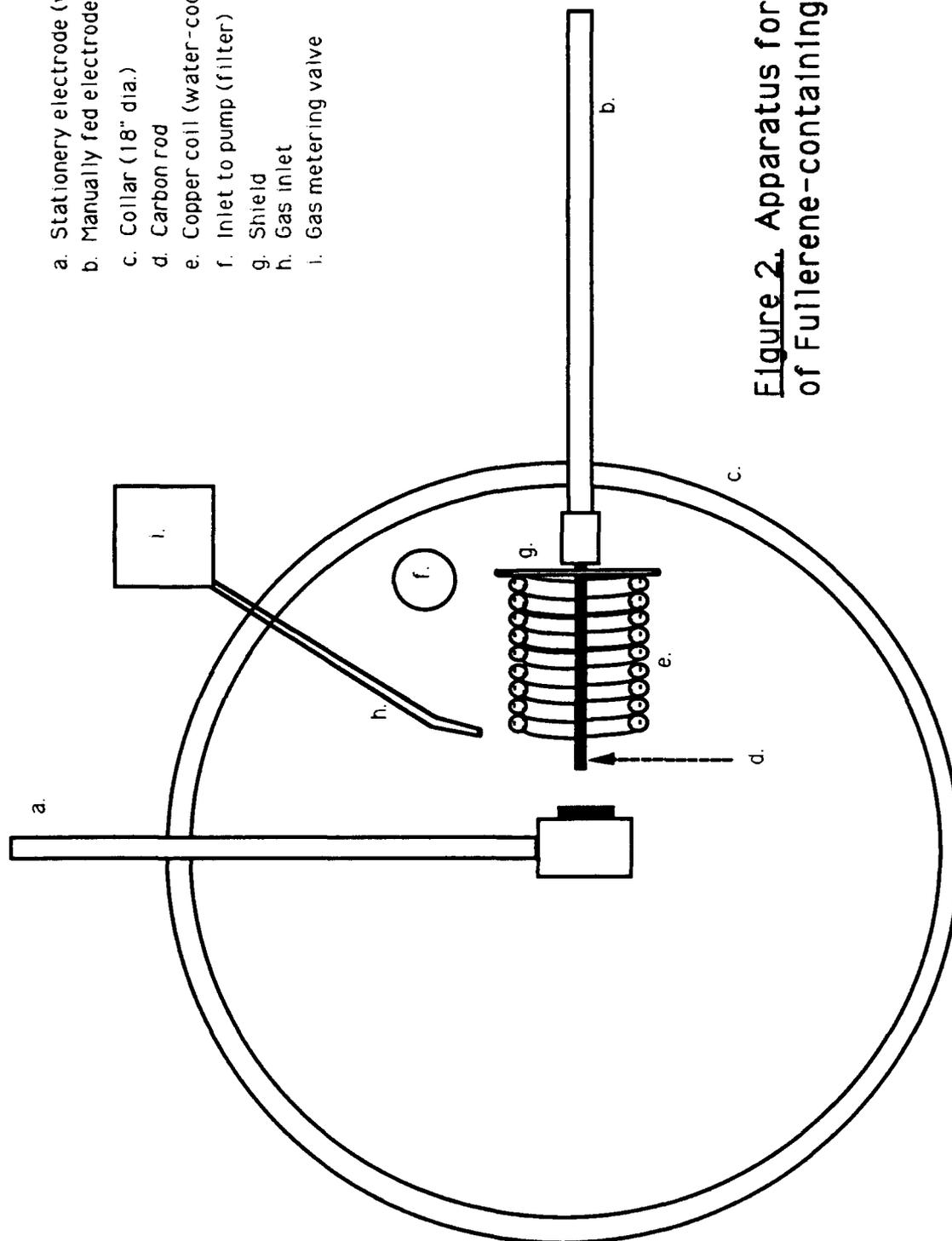


Figure 1: Carbon 60



- a. Stationary electrode (water-cooled)
- b. Manually fed electrode (water-cooled)
- c. Collar (18" dia.)
- d. Carbon rod
- e. Copper coil (water-cooled)
- f. Inlet to pump (filter)
- g. Shield
- h. Gas inlet
- i. Gas metering valve

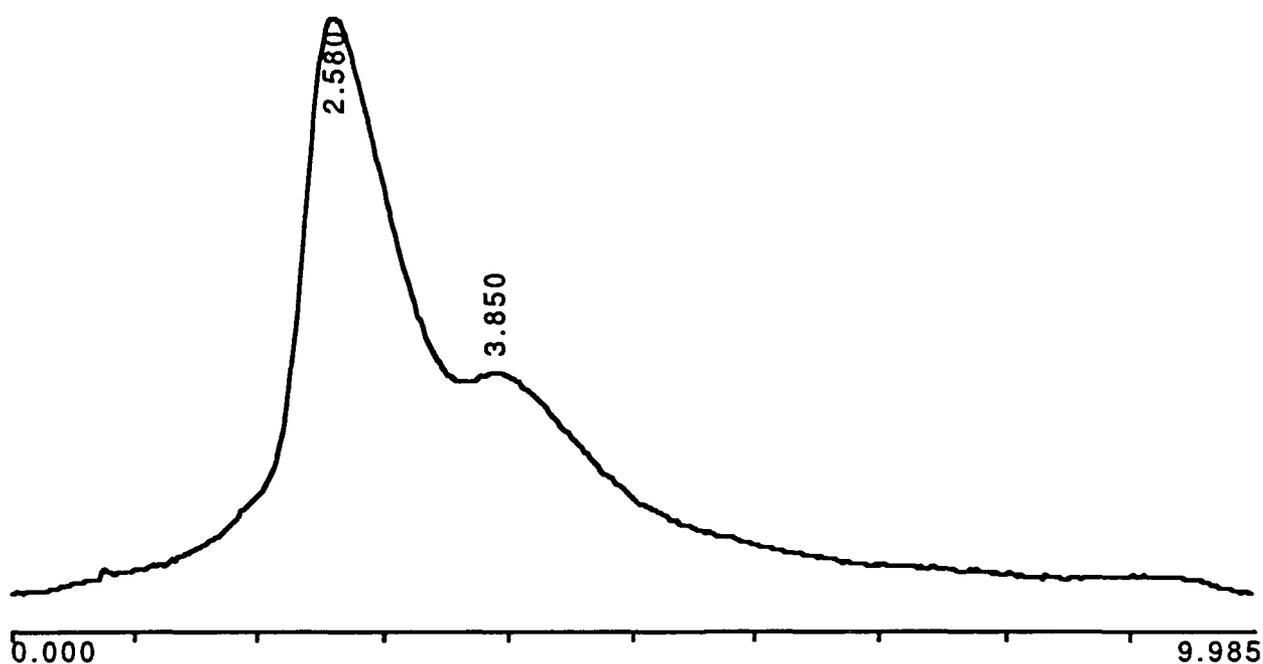
**Figure 2.** Apparatus for Production of Fullerene-containing Soot.

Date: Thu, Aug 20, 1992 14:17  
Data: Fullerene.rev.me-13AUG92-053

Sample: Crude Fullerene in Toluene eluted with Toluene.  
Injections every 10 minutes.  
True retention = peak time + 20 min.  
Channel A is UV Detector 590 nm  
Channel B is Refractive Index Detector

Method: Fullerene.rev.me  
Sampling Int: 0.3 Seconds

Chromatogram:



Analysis: Channel B

Peak No.	Time	Type	Height( $\mu$ V)	Area( $\mu$ V-sec)	Area%
1	2.580	N	40637	1633776	99.834
2	3.850	N	254	2753	0.168
Total Area				1636529	100.002

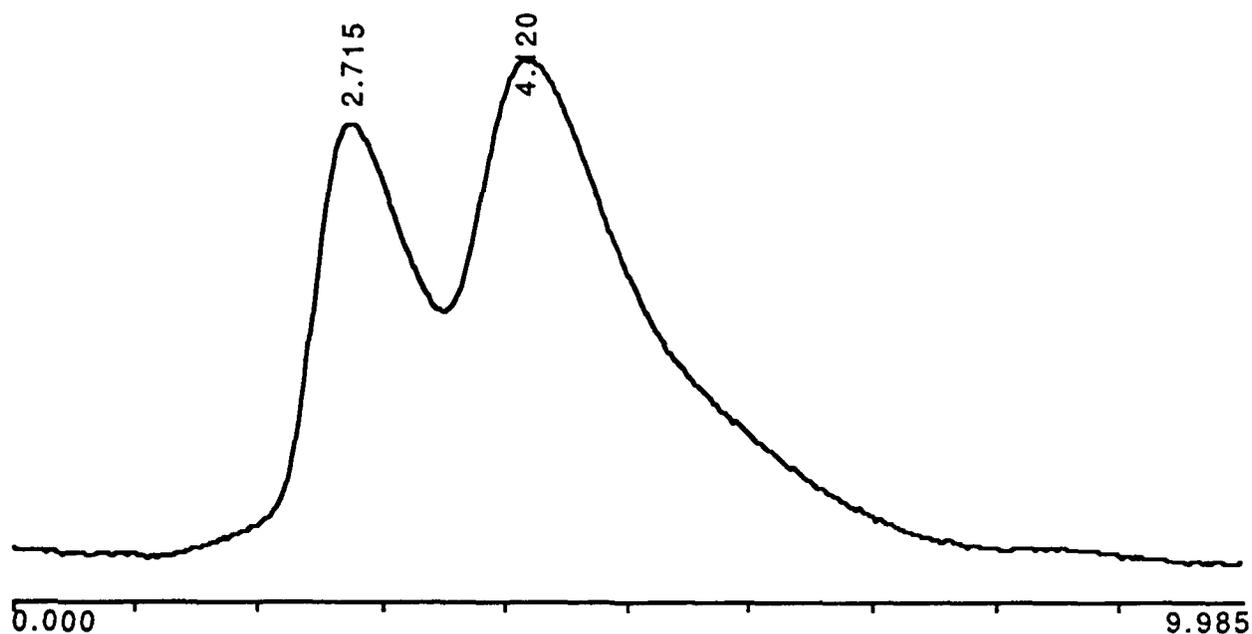
Figure 3: Refractive Index Chromatogram of Fullerene Separation.

Date: Tue, Aug 18, 1992 9:54  
Data: Fullerene.rev.me-13AUG92-053

Sample: Crude Fullerene in Toluene eluted with Toluene.  
Injections every 10 minutes.  
True retention = peak time + 20 min.  
Channel A is UV Detector 590 nm  
Channel B is Refractive Index Detector

Baseline File: Fullerene.rev.me-13AUG92-053-B  
Method: Fullerene.rev.me  
Sampling Int: 0.3 Seconds

Chromatogram:



Analysis: Channel A

Peak No.	Time	Type	Height( $\mu$ V)	Area( $\mu$ V-sec)	Area%
1	2.715	N1	95908	5978043	35.212
2	4.120	N2	112083	10998964	64.787
Total Area				16977007	99.999

Figure 4: UV Chromatogram of Fullerene Separation.

Figure 5: Carbon 70

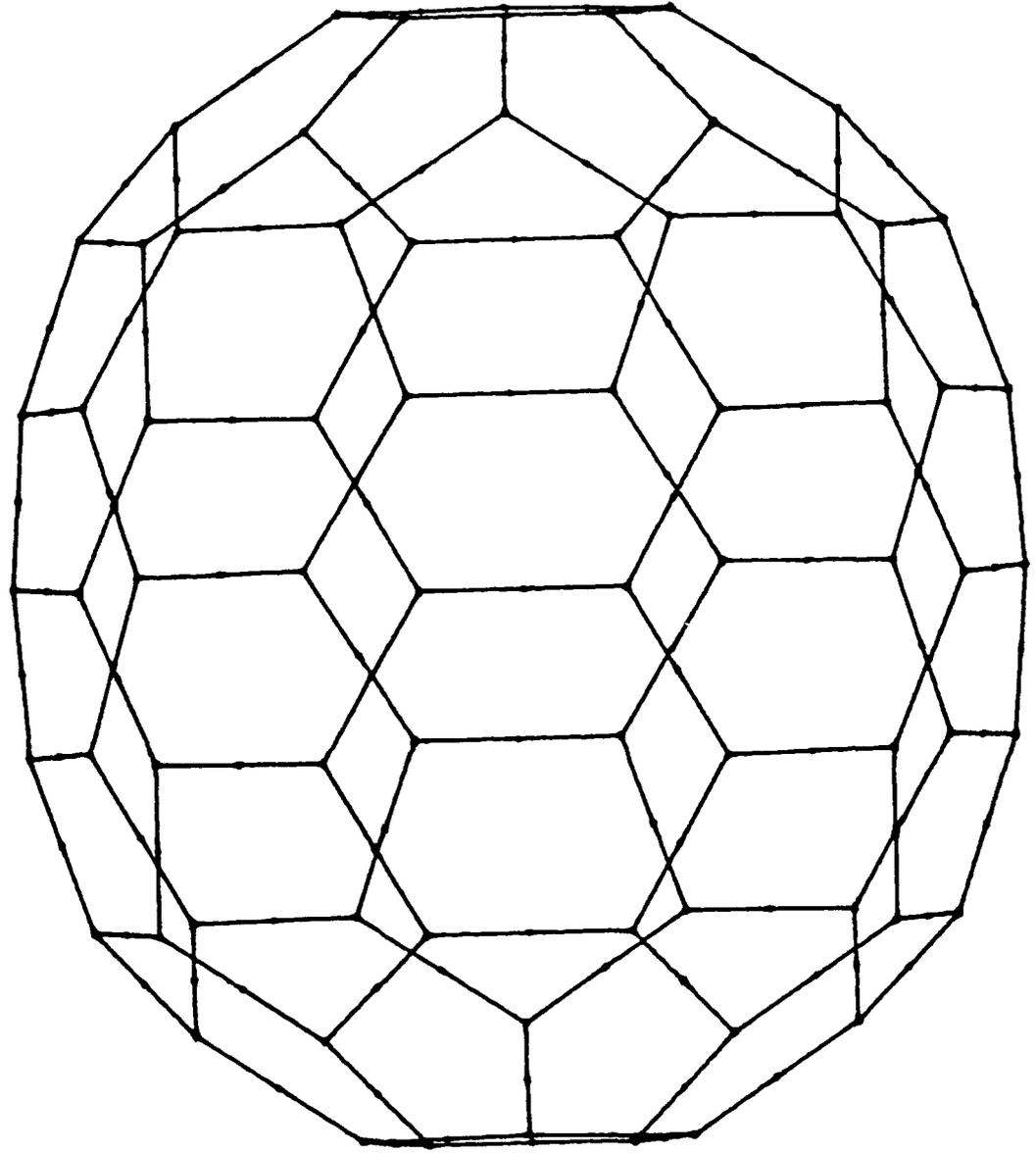
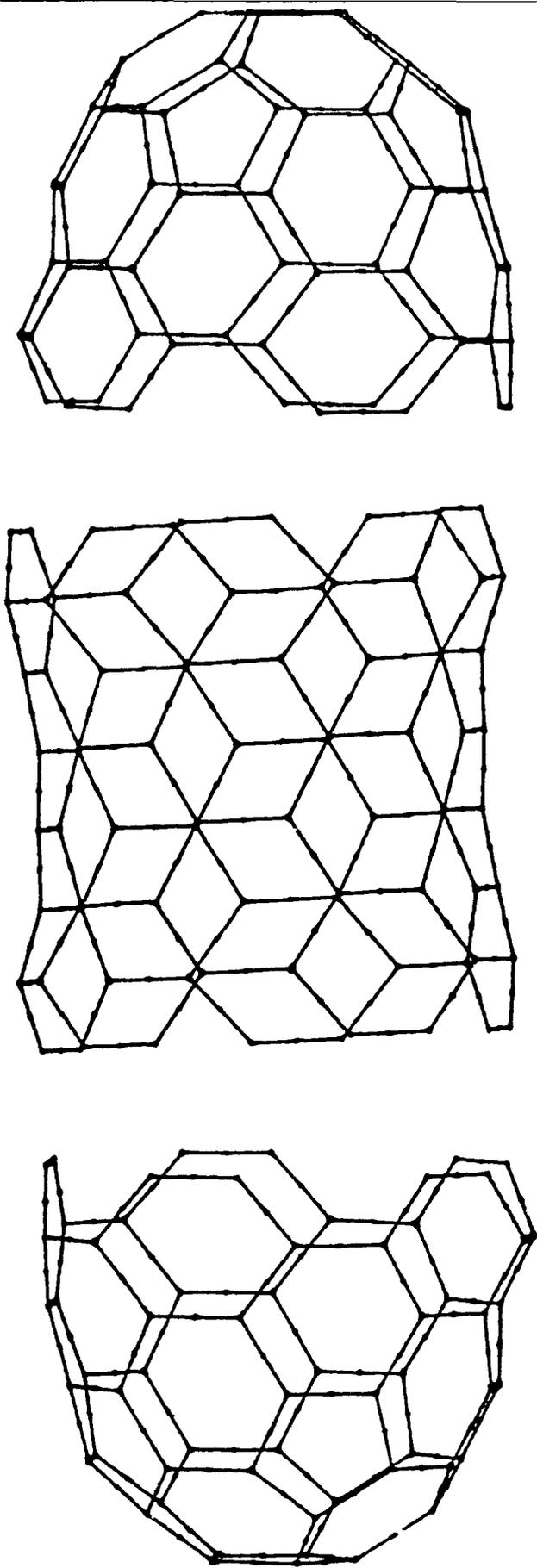


Figure 6: Nanotube



USING FUZZY LOGIC IN THE DESIGN OF SYSTEMS TO  
DESTROY MISSILES BASED ON INFRARED EMISSIONS

Erik J. Krause

Final Report for:  
Summer Research Program  
Phillips Laboratories

Sponsored by:  
Air Force Office of Scientific Research  
Wright Air Force Base, Albuquerque, New Mexico

August 1992

# USING FUZZY LOGIC IN THE DESIGN OF SYSTEMS TO DESTROY MISSILES BASED ON INFRARED EMISSIONS

Erik C. Krause

## Abstract

Fuzzy logic is a type of logic in which values do not need to be precise. This is important when controlling a process because it allows some degree of error in positions or items without causing problems. In the case of an incoming missile, fuzzy logic makes locating the missile close enough with enough control to keep a method of destruction, such as a high power laser, aimed at a certain location for a sufficient amount of time to destroy the propellant or the warhead of the missile. By using infrared emissions data, it is possible to locate the base of the missile. By estimation from the data available, it is then possible to decide where to aim a laser, or other device to destroy the intended target.

## USING FUZZY LOGIC IN THE DESIGN OF SYSTEMS TO DESTROY MISSILES BASED ON INFRARED EMISSIONS

Erik J. Krause

### Introduction

Fuzzy logic is a relatively new mathematical system which has many important applications. In control of processes, an allowable degree of error makes it possible to not need precise positioning of items to be acted upon. In the case of a missile, information about the infrared emissions of the propulsion system may be collected. With this data, it is possible to estimate the location of the missile body, and then use a fuzzy logic control to aim a laser or other device to destroy the missile. The fuzzy logic control allows for changes in position of the rocket body, and also changes in the infrared emissions, much more readily than does standard, or crisp, logic control. By designing a prototype controller for such a device, different scenarios may be simulated with reasonable accuracy.

### Methodology

By designing a simulator which allows random changes in variables, such as location of the missile, a simplified aiming system may be designed. The simulator, when completed, allowed for changes in position of the missile plume. Some other possible additions to the simulator

include: sideways movement of the plume, changes in plume length, a variable angle towards vertical or horizontal, and movement towards or away from the scanning device. The last addition would make it necessary to look at the plume in a three dimensional manner, or to estimate positions of the three dimensional missile from two dimensional data. These factors were not used in the simulator designed, but are possibilities for future additions.

This particular simulator draws a sample image of a missile plume. It then generates values of heat according to amounts of different colors in the image. This simplified model helps to develop a prototype controller for the missile destruction system. The controller bases its estimates on the values arrived at from the calculations done on the image of the plume. This simple simulation and the data generated by it are good samples to design a simple controller for. These programs may be modified and changed to suit a real problem instead of just the theoretical.

#### Results

From this simple model of the missile plume, it was possible to create another program to take the data generated by the first, and then to use the data to locate the most probable location of the missile body. The use of fuzzy logic was helpful in that there was no definite

temperature which was considered the key to where the missile body lay. By using fuzzy logic, several values could be considered the hottest part of the flame, the not as hot part, and the part cooler than that. Fuzzy logic allows this type of reasoning, whereas crisp logic does not.

The controller designed was made simpler by using fuzzy logic because of the ability to depend on relative or approximate values instead of definite values. The controller also would work with larger errors in positions of the plumes and could also handle estimation with less data.

#### Conclusions

Fuzzy logic does have an application in this field, and in other similar areas. Fuzzy logic makes it possible to use less information, and also less definite information to generate fairly accurate approximations of events and necessary actions.

#### References

The principle reference for the fuzzy logic information which led to the controller is a handbook called, "Fuzzy Logic. Refresher Course". This book is a list of handouts and slides for a one day course given at the University of New Mexico on Tuesday, July 14, 1992. The class was sponsored by The University of New Mexico College of Engineering, Professional Engineering Development/Workshop Programs.

**INVESTIGATION OF NEURAL NETWORK BASED  
LIGHTNING WARNING SYSTEM FOR  
THE KENNEDY SPACE CENTER**

Frank A. Lasley IV

Final Report for:  
AFOSR Summer Research Program  
Phillips Laboratory / GPAA

Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base Washington, D.C.

August 1992

**INVESTIGATION OF NEURAL NETWORK BASED  
LIGHTNING WARNING SYSTEM FOR  
THE KENNEDY SPACE CENTER**

Frank A Lasley IV

**Abstract**

Preliminary Macintosh C source code written by a local contractor for a neural network based lightning warning system at (KSC) Kennedy Space Center was investigated and modified in order to operate on data sets larger than three days. It was determined that modification for data sets larger than three days would not be practical without extensive knowledge of Macintosh toolbox calls and the proprietary source code for the backpropagation neural network itself. C code was written to filter lightning, wind, wind divergence, and electrical field data from KSC and generate a file suitable for implementing as input into the IBM PC based Neural Networks Professional II program.

INVESTIGATION OF NEURAL NETWORK BASED  
LIGHTNING WARNING SYSTEM FOR  
THE KENNEDY SPACE CENTER

Frank A Lasley IV

Introduction

NASA is concerned with the threat that lightning poses to launch vehicles and its ground personnel. Cloud to ground lightning is a major threat to both launch vehicles and ground personnel alike. Also of concern is triggered lightning (lightning caused by a man made object - a Shuttle for example) a threat to Shuttles once they are airborne. A reliable method of predicting the probability of lightning strikes hours before a shuttle launch would reduce the danger to ground crew meanwhile allowing protective measures to be taken in order to prevent extensive damage to the launch vehicle and its components.

NASA has set up a large number of sensors on the ground at KSC. Electrical field sensors, wind direction and speed indicators, and thermometers are located on towers surrounding the launch pad and shuttle landing strip. Raw data from these towers has been archived on streaming tape and converted into tab delimited ascii Excel spreadsheet format.

KTAADN, Inc, a government contractor implemented a backpropogation Neural Network for Macintosh platforms that predicts lightning at (KSC) Kennedy Space Center. This system ingests spreadsheet data and predicts lightning 0, 30, 60, and 120 minutes from the current time. If such a system proved to be efficient a similar system could be implement to operated in real time at KSC.

The Macintosh based system is written in Think C version 4.0 and is not portable. After training on training data sets it shows some efficiency. It is, however, limited to training on data sets of three days or less. In real time the

operation of such a limited system would be unrealistic, thus adjustments to work with larger data sets have become necessary. Modifications were made to the source code allowing slightly more than four days to be processed. At this point, further modifications were impossible due to our lack of proprietary backpropagation code, which was available to KTAADN, and only to them.

The project of implementing a Neural Network on the IBM PC was then undertaken. NeuralWorks Professional II software was chosen to be used. The final project became the writing of C code to process the spreadsheet data and format an output file suitable for import into the NeuralWorks program. This task was partially completed during the eight week period and some modifications are required.

#### Methodology - PC based Neural Network

C code conforming to "ANSI C" standards was written to ingest and manipulate the spreadsheet data. The code was compiled using Borland Turbo C++ version 1.0. The spreadsheets are in tab delimited ascii Excel format. In order to transport these files to the IBM PC from the Mac, DecNet's NetCopy was used to transfer the files across the PC network. Because the files were formatted for use on the Mac, the end of line markers are carriage returns. PC text format in general uses carriage returns and linefeeds to mark end of lines. Standard file manipulation routines on the PC detect these carriage return linefeeds and thus it was necessary to write a routine to change the format of the Mac spreadsheet files to PC format. The conversion routine written is called "crg2lnfd".

The bulk of the code that was written is contained in a file called "ltng\_ftr.c" which ingests the converted spreadsheet data and combines the data that are necessary to use as input into the network. The program asks what data

to use and then prompts for filenames before the spreadsheet files are scanned for date correspondence. The files are then read in as text file line by line. Each line of data is then scanned and the necessary data is written to an output file in a special format using an "!" to mark a comment, an "i" to mark desired input, and a "d" to mark desired output. The output "[filename].nni" file is then suitable for use as input into NeuralWorks Professional II. With some modifications to the code one will be able to train the NeuralWorks Professional II, PC based neural network with the output file.

#### Concluding Remarks

The field of artificial intelligence and its applications in weather forecasting is intriguing. A neural network based lightning warning system at KSC could prevent launch time disasters and reduce the likelihood of damage to future launch vehicles. It is likely that artificial intelligence will soon be in use in real time at KSC and other locations to predict lightning and other weather phenomena efficiently.

#### Acknowledgements

I would like to thank Captian Rick O'Donell for his consulting on neural networks, Joseph Doherty for his assistance with C, and Dr Arnold Barnes for his excellent mentorship. I would also like to thank the other people at the Atmospheric Sciences Division, Geophysics Directorate, Phillips Laboratory, Hanscom AFB, Massachusetts. These people were very helpful and made my work environment one of both comfort and learning.

## Appendix

Files and their usage.

"crg2lnfd.c" - conversion routine which converts Mac text files to PC text file format by replacing carriage returns with carriage return linefeeds.

"ltnng\_ftr.c" - program which takes electrical field, wind divergence, wind tower data, and lightning strike data as input and outputs a formatted output file for input into NeuralWorks Professional II.

POLYESTER SYNTHESIS  
AND ANALYSIS

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Final Report for:  
Summer Research Program  
Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington D.C.

August 1992

# POLYESTER SYNTHESIS AND ANALYSIS

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## Abstract

Polymers were created by an acid-base reaction of terephthaloyl chloride and three different hydroquinone monomers. The three used were hydroquinone, tertiary-butyl hydroquinone, and phenyl hydroquinone. Before synthesis, the three base monomers were purified by crystallization and the solvents used were distilled to insure a lack of contaminants. The polymers were formed by slowly adding the terephthaloyl chloride to a solution of one the hydroquinones in pyridine and methylene chloride or diethyl ether. When completed, the newly formed product was washed with distilled water followed by acetone. Then, Thermal Analysis and Fourier Transform Infrared (FTIR) spectroscopy were performed on the three different species.

# POLYESTER SYNTHESIS AND ANALYSIS

Brad M. Lormand

## INTRODUCTION

As the needs for space colonization and exploration increase, so does the need for lightweight materials that can be applied to rocket motor casings and other integral parts of the spacecraft and its propulsion system. Therefore, the need for new polymers is rising at a fever pitch. This summer's research dealt totally with the making of 3 hydroquinone polymers, the purification of the needed ingredients, and the analysis of the finished product by various means. These polymers had never before been made at Phillips Laboratory and success was questionable. However, the polymerization worked successfully and three species were created that proved to have the predicted thermal properties. The created substances were compressed into pellets and demonstrated high melting points or no melting points at all. Presumably, a practical use can be found for these polymers in some level of application.

## PREPARATION

Before starting the actual synthesis, many preparatory steps were taken to insure the formation of the purest polymers possible. Unwanted impurities included non-reactive components that might inhibit proper polymerization. Each base monomer would need to be crystallized from a saturated

solution and the solvents used would have to be distilled to 99.9+% purity. To begin with, each hydroquinone monomer was tested for solubility in various solvents. Hydroquinone (HQ) was readily soluble in distilled water. Tertiary-butyl hydroquinone (TBHQ) and phenyl hydroquinone (PHQ) were both soluble in methylene chloride (MCL). Small samples of 5% solutions of each of these were made for analysis by the gas chromatograph/mass spectrometer. This gave an idea of impurities that were present in the products being used before crystallization. This piece of equipment was used again to analyze the purified products and to show whether or not the impurities were being removed.

The MCL and water needed for crystallization were distilled and collected in 5 liter glass flasks. For each crystallization, a small amount of solvent was poured into a flask and heated on a hot plate. One of the HQ monomers was added until no more could be dissolved. The solution was then gravity filtered into a sealable container and cooled. A seed crystal of the same monomer was added to start the formation of the crystals. When the process was complete, the mixture was then vacuum filtered and the purified monomer crystals were put in a dish and dried in a vacuum oven at 100 degrees Celsius to dry off all solvent used. These monomers would serve as the base half of the acid-base polymerization reaction.

The acid half of the reaction was created by adding a measured amount of terephthaloyl chloride (TCL) to MCL. This

can form terephthalic acid (TA), by reacting with water vapor in the air. Therefore, the chloride needed to be filtered by a syringe pump, thereby keeping it dry and chemically unchanged. The purified monomers and acid solution were then analyzed by the gas chromatograph and showed to be 99.5% pure or better (pgs. 17-13 to 17-20).

Another crucial part of preparation is the calculations concerning monomer/solvent concentration and polymer yield. Every monomer used an equal molar value, with the exception of pyridine, which was twice the molar amount of monomer. The theoretical yield of polymer was based on the equivalent amount of moles of reactants.

Also before the synthesis was performed, the predicted structures of the polymers were created using the computer program, Desktop Molecular Modeller by Crabbe and Appleyard, Oxford University Press. The program found the minimized energy state for each polymer and gave an accurate plot of each. The results of minimization (pg.17-10) showed that each polymer forms straight chains with each of its rings twisting in alternating directions.

### POLYMERIZATION

The process by which all three polymers were synthesized used a 3-necked reaction flask, ice bath, hot plate, beakers, heating module, and vacuum filter. The reaction flask had a thermometer and stirrer. A neck held a container that was occupied by the measured amount of acid solution. This con-

tainer was equipped with a manipulatable regulator to control the addition of the acid inside into the reaction flask. The base solution was made with the proper amount of HQ, solvent and pyridine. MCL was used as the solvent for TBHQ and PHQ, but distilled diether was needed for HQ because of HQ's lack of solubility in MCL. The concocted base solution was then poured directly into the bottom of the reaction flask and brought down to zero degrees Celsius by placing an ice bath around the bottom of the flask. When the proper temperature was achieved, the addition of the acid solution began. This reaction proved to be highly exothermic, so the addition of the acid was kept very slow to avoid boiling away the solvent(s). When all the acid solution was finally added, the now milky mixture was cooled down to zero degrees. At this point, a white solid substance could be seen in the bottom of the flask. After a few minutes at zero degrees, the ice bath was replaced by the heating module. The acid container was then replaced by a condenser that led to another flask collecting vaporized solvent(s). During the heating of the mixture, an amount of water ten times the predicted polymer yield was added. This addition would aid in the removal of pyridinium hydrochloride, a by-product of the reaction. With almost all of the MCL having been removed, the reaction flask was removed and its contents poured through a vacuum filter. What remained appeared to be the desired polymer with a small amount of by-product contaminants. These unwanted substances were removed by multiple water and acetone washes, again each

being ten times the calculated theoretical yield by weight. Following each wash, the water or acetone and polymer mixture was again vacuum filtered. When all washes were done, the finished product was set in a vacuum oven to dry overnight.

Each of the three polymerizations performed with HQ, TBHQ, and PHQ were done in almost exactly the same way, with the exception of the making of the HQ polymer. The actual reaction seemed to be only slightly exothermic, so the ice bath was removed. All other steps described were applicable to all three polymerizations.

#### ANALYSIS

Following the making of the three polymers, some scientific analysis of the finished products was performed. Each polymer specimen was weighed and the actual yield was calculated. The making of the HQ/TA polymerization resulted in only a 59% yield. A substantial amount of low molecular weight polymer was lost in the vacuum filtering of the acetone wash. Some of the smaller particles fell through the filter paper into the collection of liquid impurities. The TBHQ/TA polymerization resulted in a 95% yield; PHQ/TA, a 78% yield.

Another of the analytical procedures performed on each polymer was FTIR spectroscopy. This equipment analyzed the frequency of the emitted radiation produced by molecular vibration. Careful analysis of the data produced gave an idea of the structure of each polymer. The data on page 17-11

shows the presence of the substituent tertiary-butyl and phenyl groups in their respective polymers.

Thermal analysis performed on compressed pellets of each polymer showed that all three exhibit high melting points or no melting points at all (pg 17-12). The TBHQ/TA polymer showed to have a melting point of about 392 degrees Celsius. The PHQ/TA polymer melted at about 320 degrees Celsius, but the HQ/TA polymer appeared to initially degrade at about 289 degrees Celsius without a melt.

### CONCLUSION

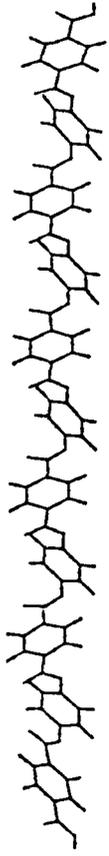
Over the course of eight weeks, much success was had in the synthesis of three relatively new polymers, the purification of the monomers and solvents needed for synthesis and the analysis of the finished products. The polymers made appeared to be suitable for many applications on Earth and in space, but only further testing and analysis can prove their usefulness. The research just done shows that each polymer can be made easily and with desirable efficiency.

### ACKNOWLEDGEMENTS

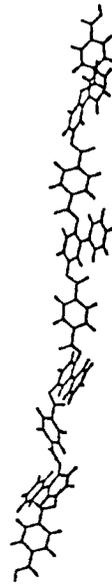
There are many people at Phillips Laboratory that deserve my gratitude for a successful summer of research. I would like to give a sincere thank you to my mentor, John J. Rusek, for guiding me through just about everything this summer. I would have been severely lost the whole time without him. Also, a great thank you to Dr. Kevin Chaffee, Dr. David Elliott of Arkansas Tech University, Steve

Osborn, Robert Behdadnia, Tracy Reed, Alex Kitty and Mindee Jeffery for various reasons including calculus and physics lectures, broadening of my computer literacy, reduction of data, and friendship. I also owe thanks to Mike Carr for all his patience in teaching me what GCMS and FTIR were actually doing and his assistance in collecting the necessary data. Finally, I give my love and thanks to my grandmother, Betty Willey who always gave me love and support and free rides to and from work.

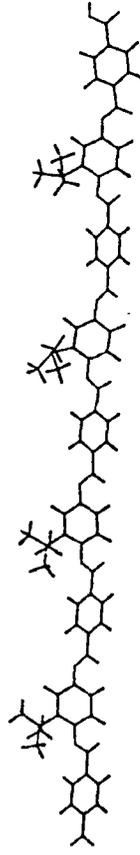
HQ/TA Polymer

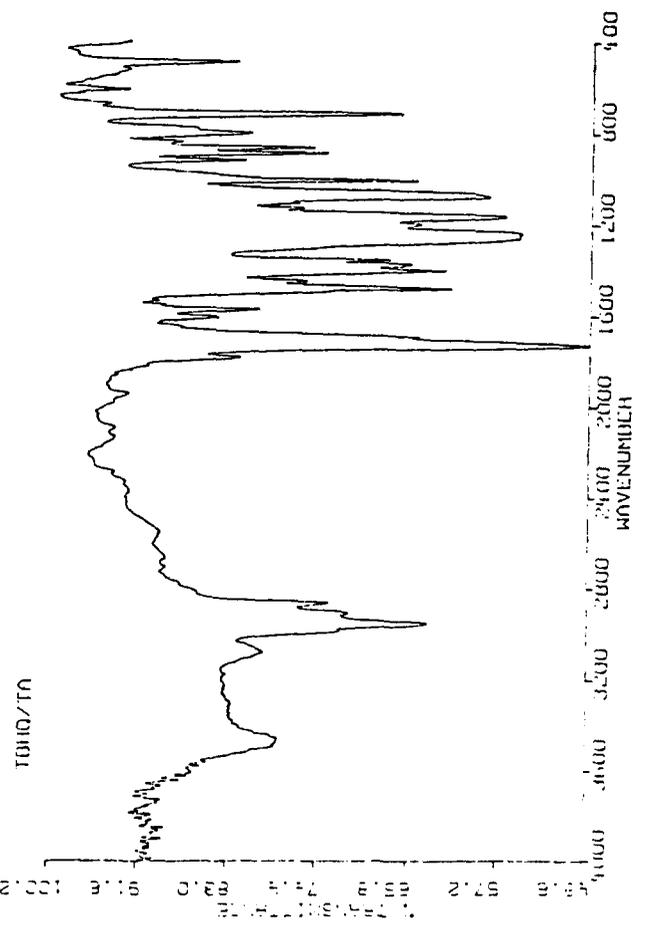
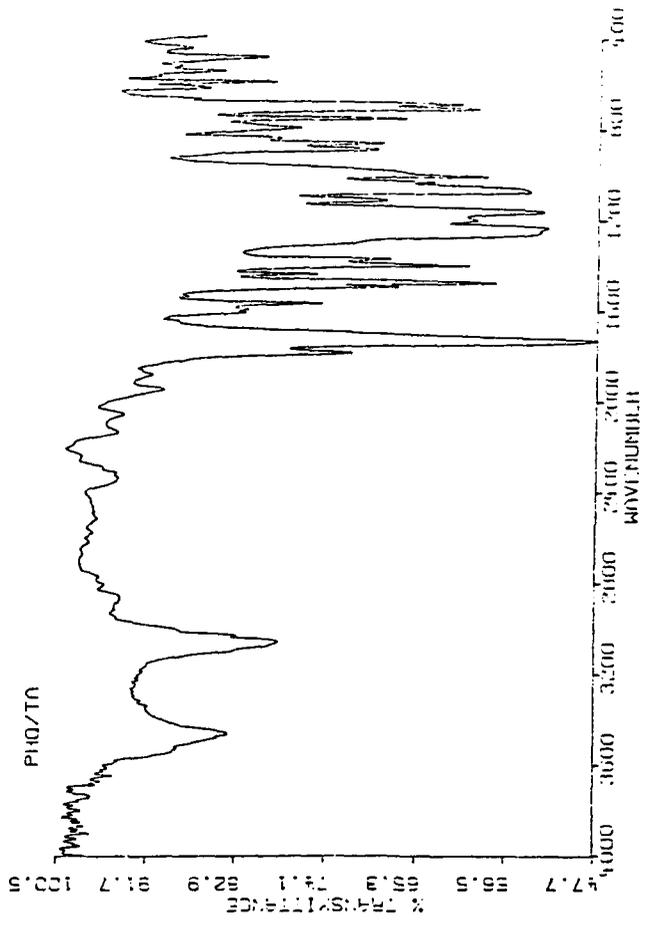
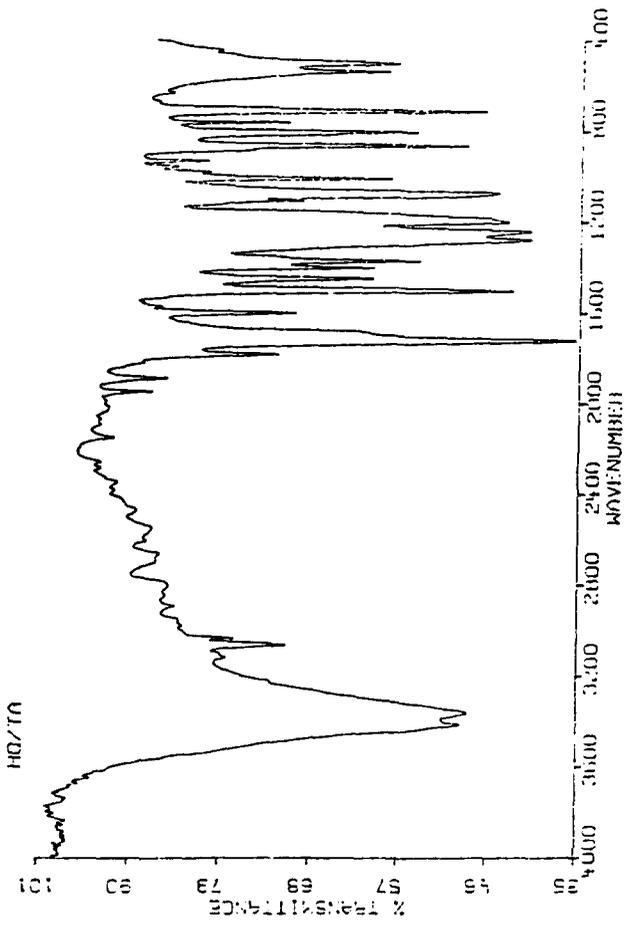


PHQ/TA Polymer



TBHQ/TA Polymer

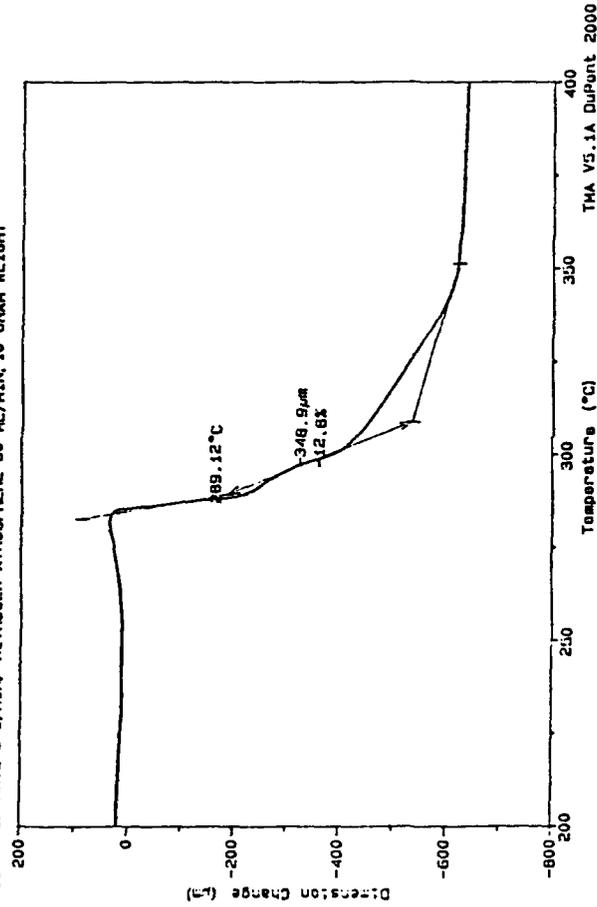




Sample: HQ/TA POLYMER  
Size: 2.7230 mm  
Method: TMA ON LCP  
Comment: RATE 3°C/MIN, NITROGEN ATMOSPHERE 50 ML/MIN, 10 GRAM WEIGHT

# TMA

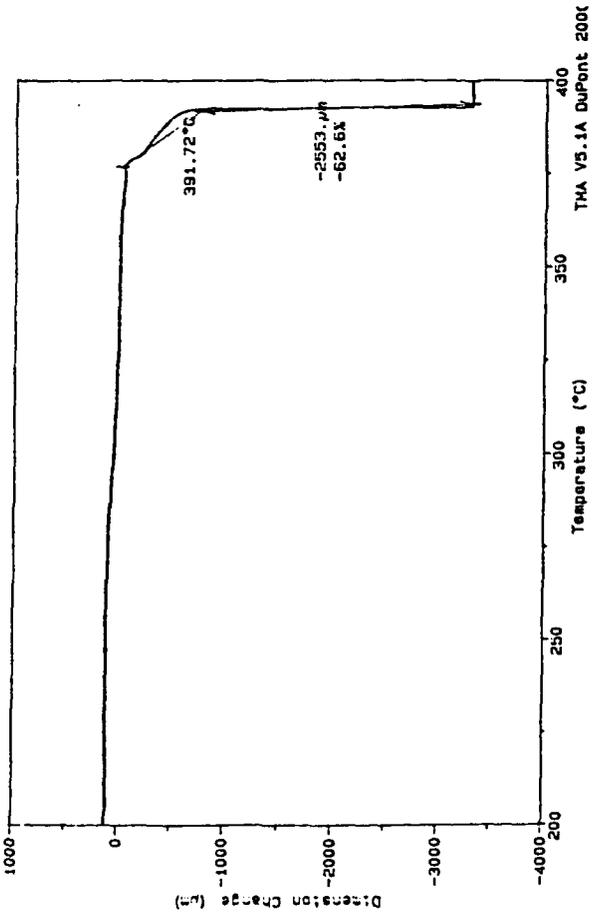
File: C:\TMAJOHN.30  
Operator: PAUL JONES  
Run Date: 6-Aug-92 12:15  
Comment: RATE 3°C/MIN, NITROGEN ATMOSPHERE 50 ML/MIN, 10 GRAM WEIGHT



Sample: TB/TA POLYMER  
Size: 4.0760 mm  
Method: TMA ON LCP  
Comment: RATE 3°C/MIN, NITROGEN ATMOSPHERE 50 ML/MIN, 10 GRAM WEIGHT

# TMA

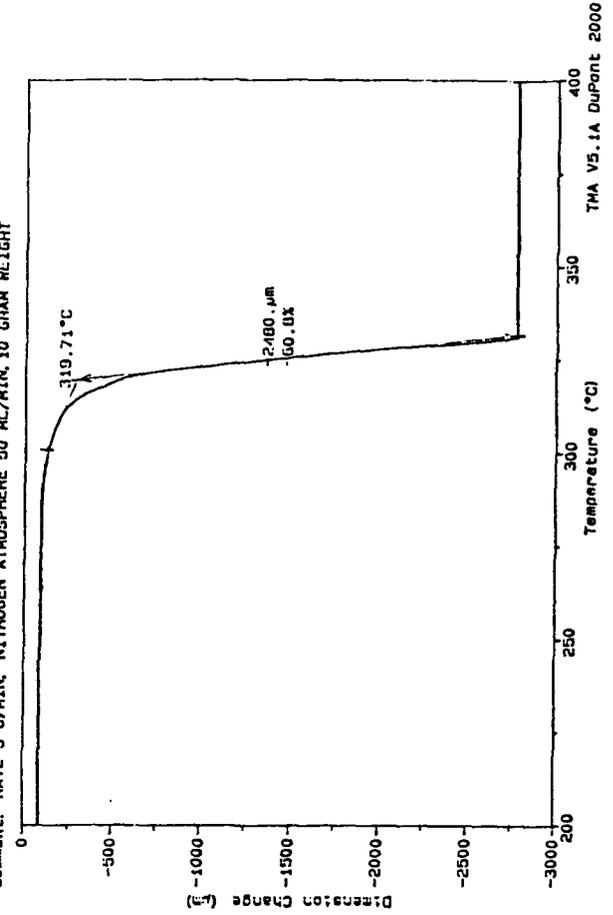
File: C:\TMAJOHN.31  
Operator: PAUL JONES  
Run Date: 6-Aug-92 15:42  
Comment: RATE 3°C/MIN, NITROGEN ATMOSPHERE 50 ML/MIN, 10 GRAM WEIGHT



Sample: PHO/TA POLYMER  
Size: 4.0760 mm  
Method: TMA ON LCP  
Comment: RATE 3°C/MIN, NITROGEN ATMOSPHERE 50 ML/MIN, 10 GRAM WEIGHT

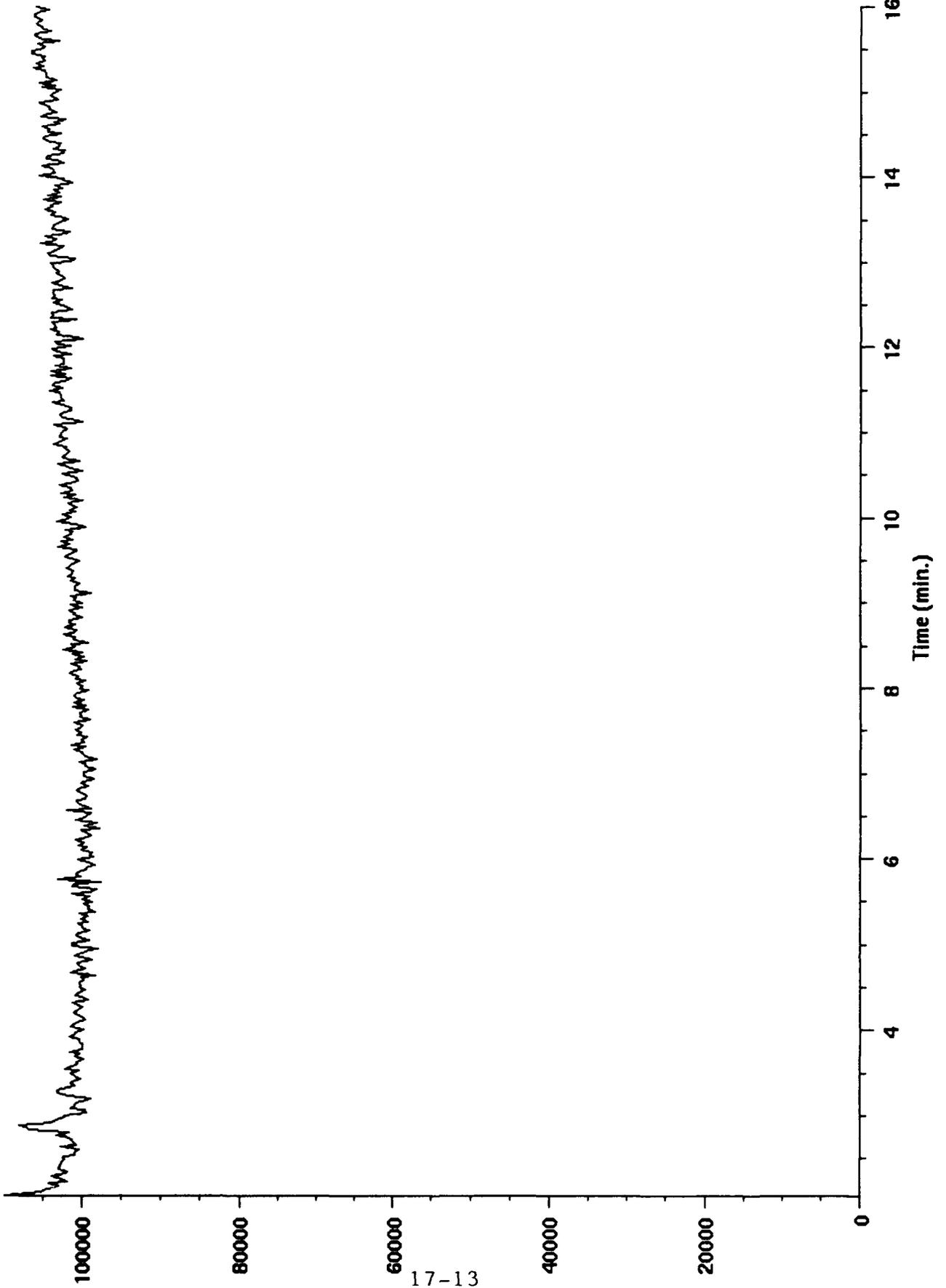
# TMA

File: C:\TMAJOHN.33  
Operator: PAUL JONES  
Run Date: 7-Aug-92 07:30  
Comment: RATE 3°C/MIN, NITROGEN ATMOSPHERE 50 ML/MIN, 10 GRAM WEIGHT



TIC of XHQ0401004.d  
MC/PyR

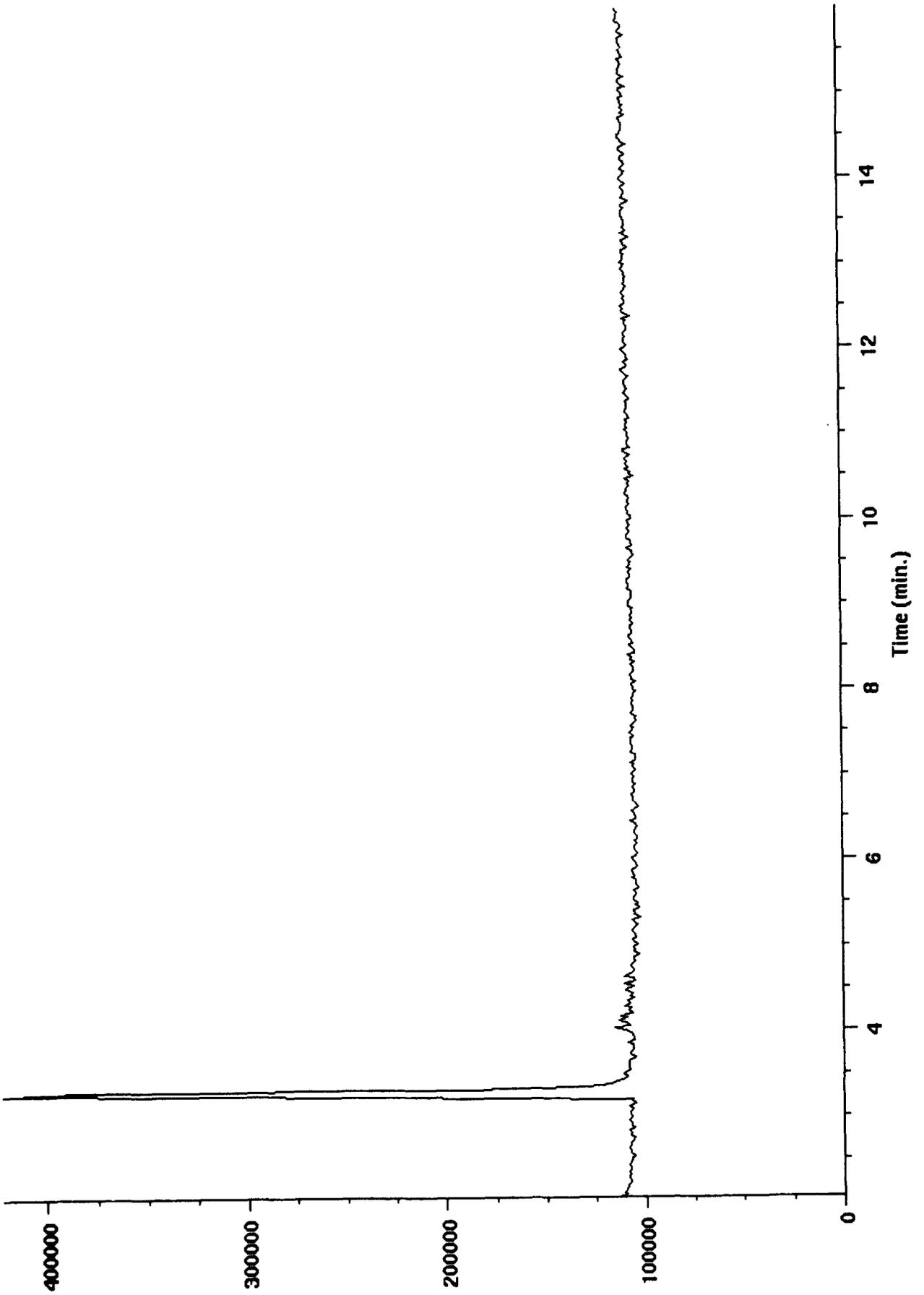
Abundance



TIC of XHQ0501005.d

110000 MC/PYR

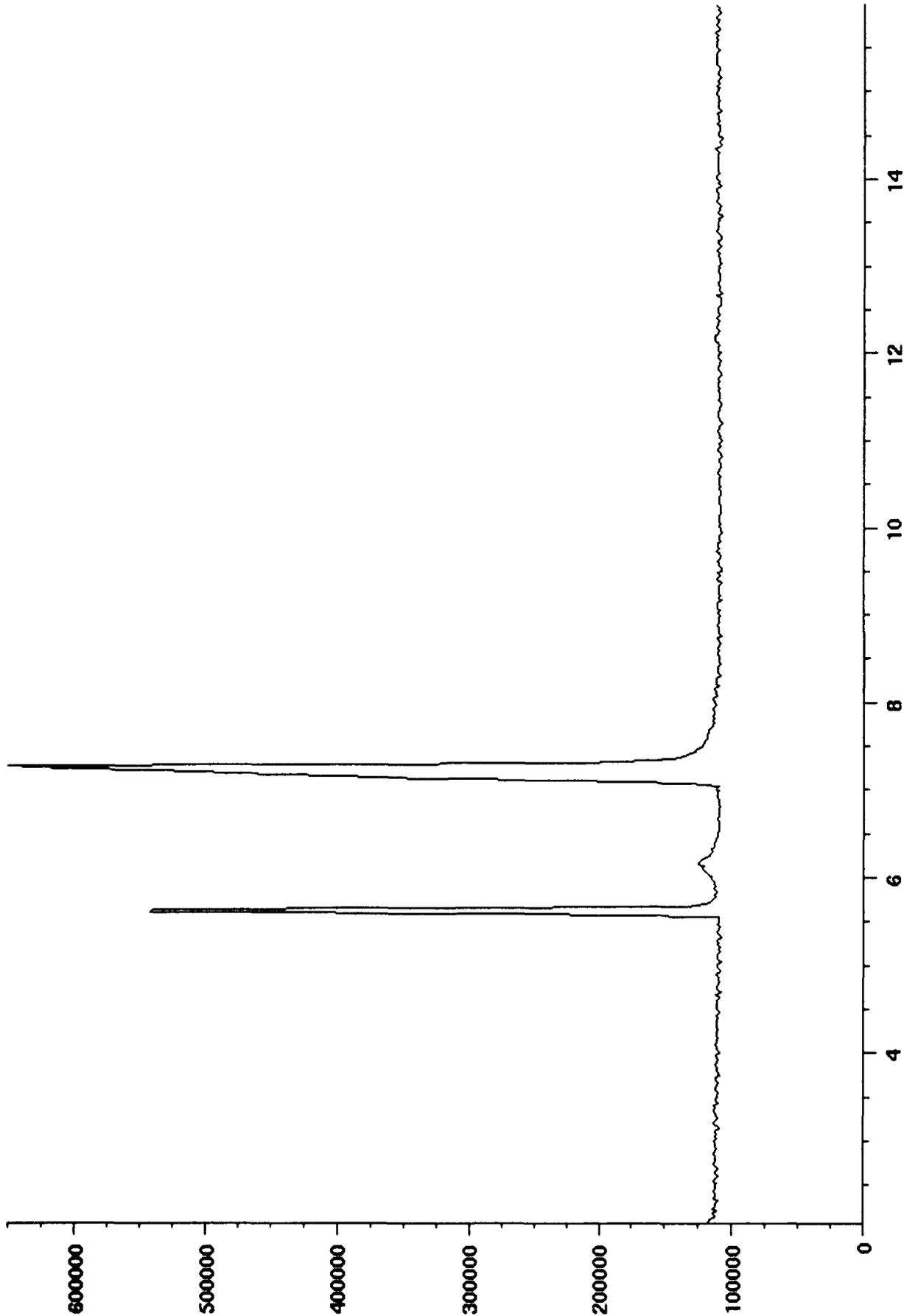
Abundance



TIC of XHQ0601006.d

*φ-H<sub>2</sub> in Me<sub>2</sub>N<sub>2</sub>*

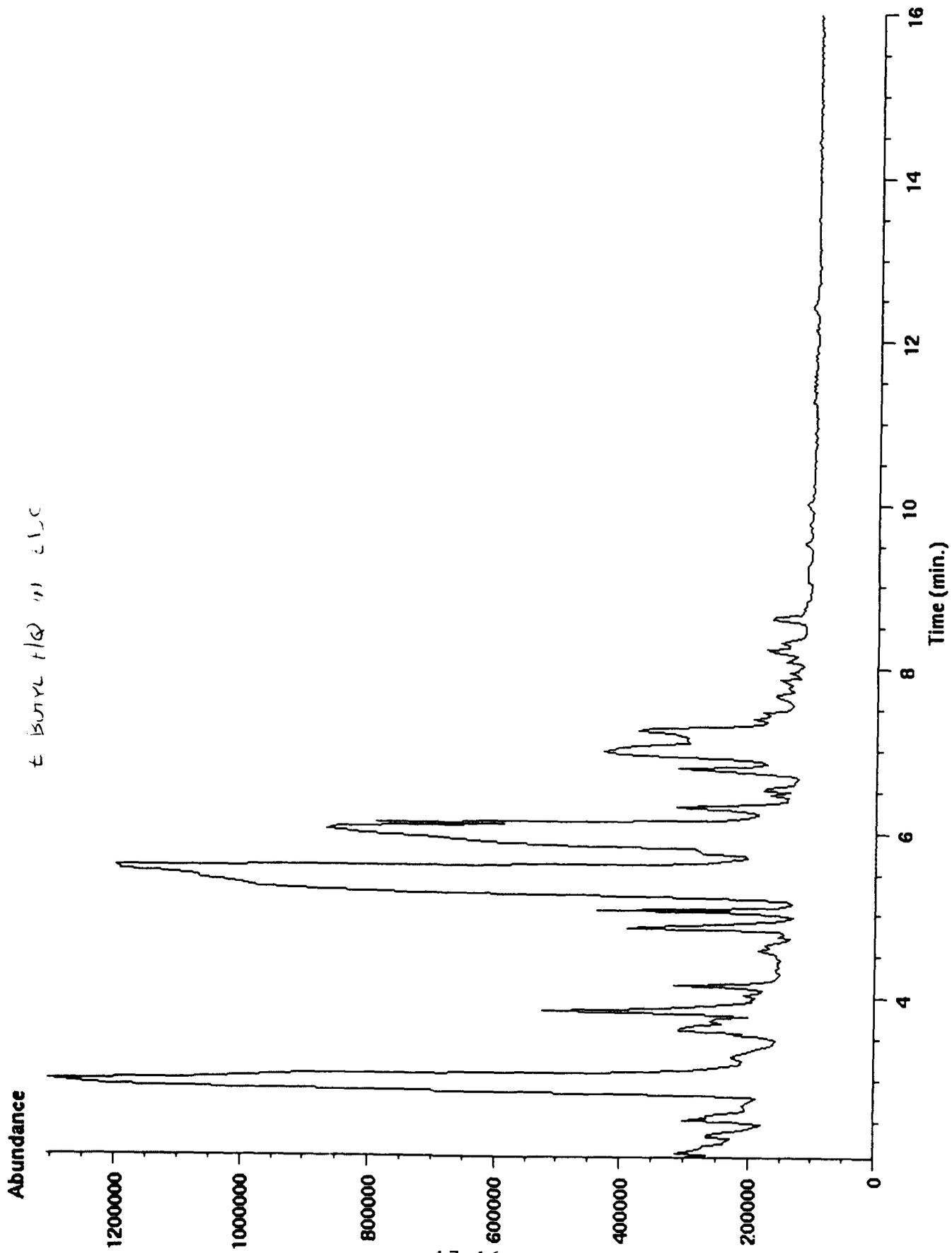
Abundance



Time (min.)

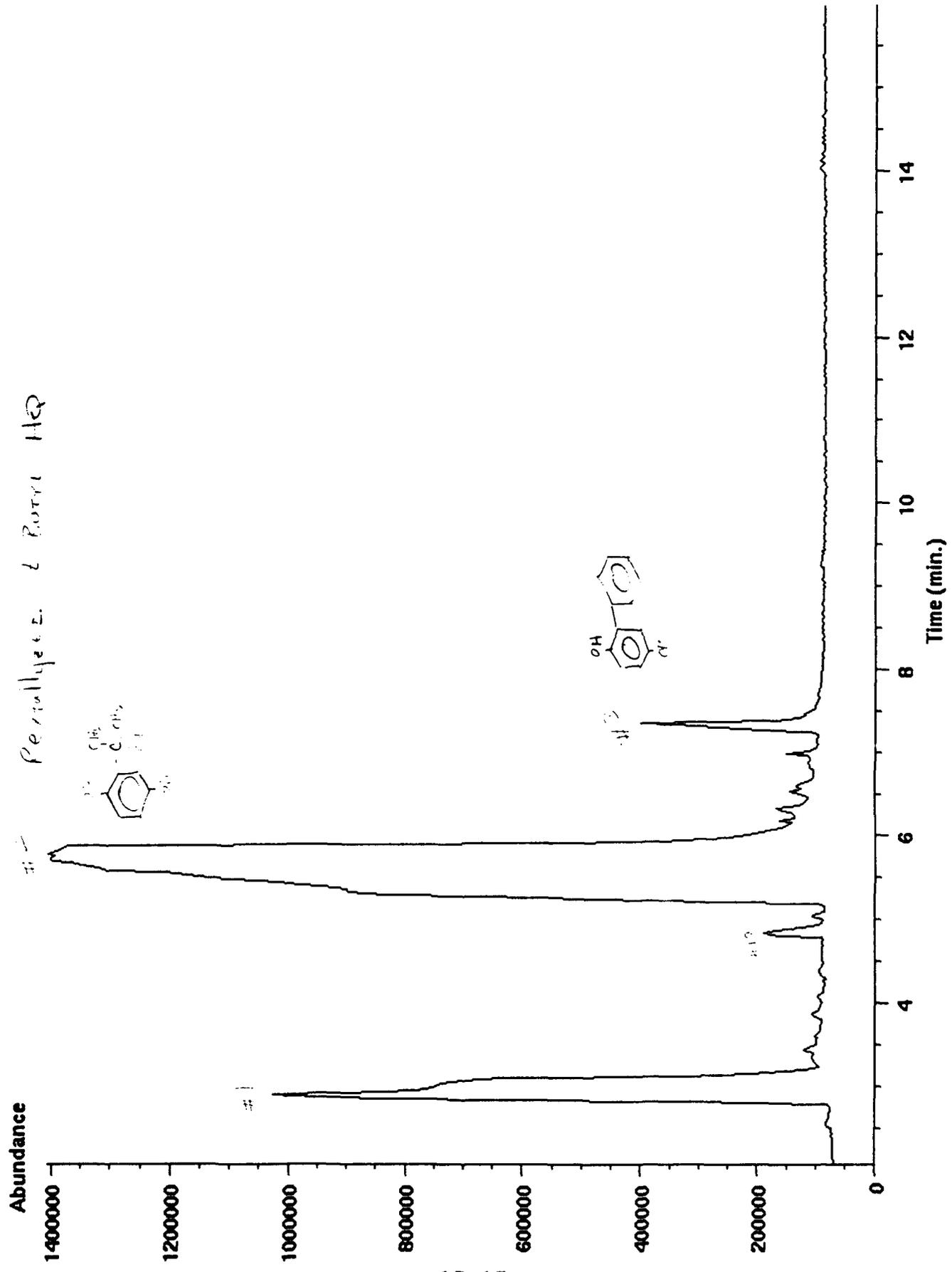
TIC of XHQ0301003.d

t-butyl f10 in 2LC

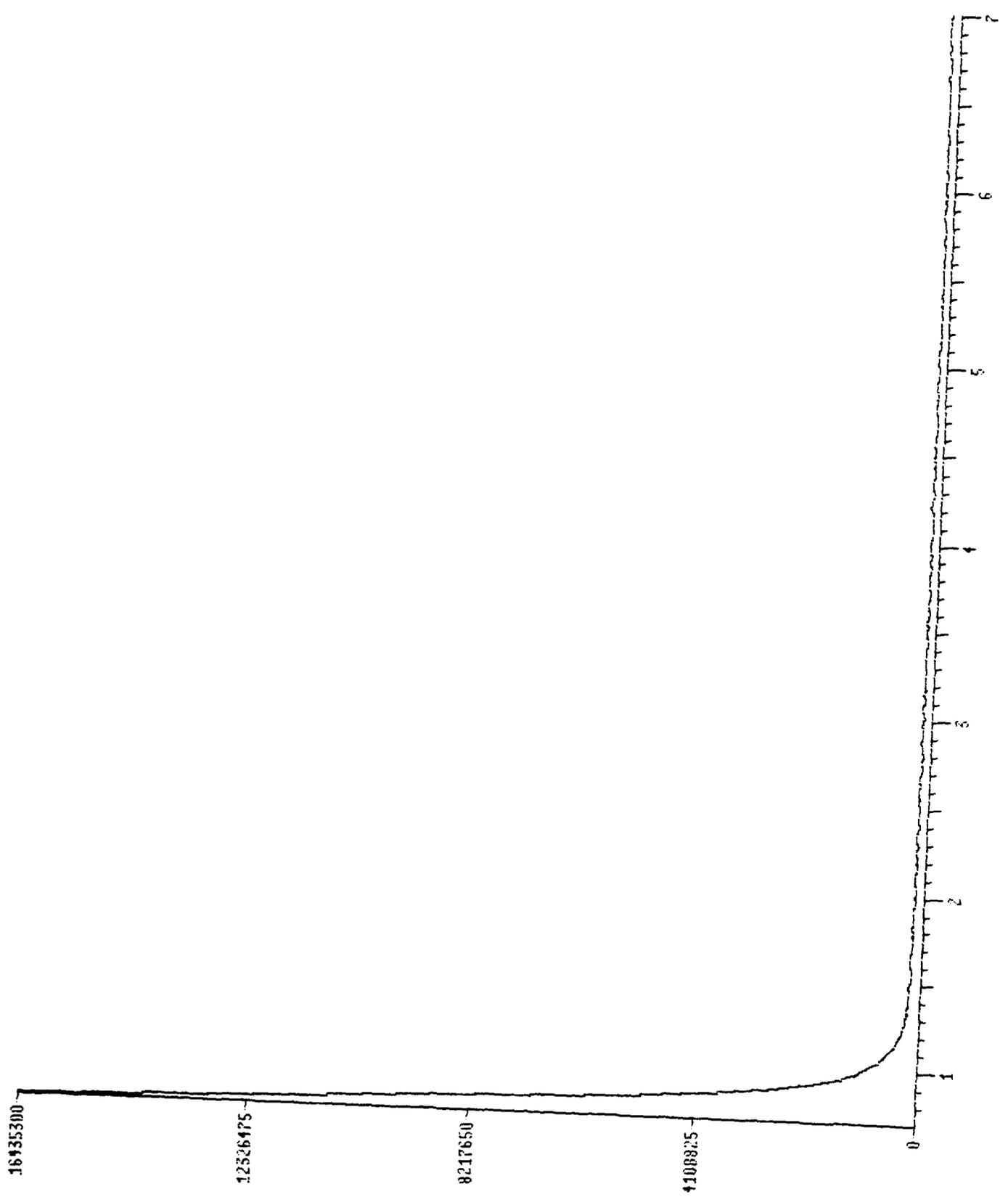


TIC of XHQ0101001.d

Perallyle. & Butyl HQ



End of plot. Time = 0.70 to 7.01 minutes  
Chart speed = 3.15 cm/min



17-18

1: TIC of DATA:ETHER.D

A LOOK AT THEORETICAL SPECIFIC IMPULSE  
IN POTENTIAL SOLUTION PROPELLANTS

Matthew W. Losey

Abstract

The theoretical specific impulses along with the chamber temperatures of various potential, environmentally compatible, solution rocket propellants were calculated and analyzed. The solution propellants consisted of oxidizer-salt combinations in conjunction with energetic polar polymer binders to give an energetic propellant with no HCL in the exhaust. Both the specific impulse and the chamber temperature calculations were obtained through the Theoretical ISP Program and then charted as a contour graph. The results are evidence that there is potential for rocket propellants that are safer to the environment and just as energetic.

## A LOOK AT THEORETICAL SPECIFIC IMPULSE IN POTENTIAL SOLUTION PROPELLANTS

Matthew W. Losey

In the development of solid rocket propellants, mechanical and ballistic properties are carefully considered in the initial stages of development. Sometimes these properties can be theoretically predicted beforehand since they may be directly related to the characteristics of the ingredients and their weight proportions. The most important ballistic property of any rocket propellant is its specific impulse, or  $I_{sp}$ . The performance of a rocket motor is evaluated on its  $I_{sp}$  and therefore optimum mixtures of the ingredients are used to give the best possible performance. Although ingredients yielding the most energetic propellant are desired, new concerns for environmental safety have placed demands for propellants that are energetic and at the same time cause little or no damage to the environment. In the search for a clean and energetic propellant, a great deal of theoretical calculations are used to point research towards propellants that keep a high performance.

The performance of a solid propellant depends greatly upon the thermodynamic properties of the ingredients. The most important ingredients of a solid propellant are the fuel and the oxidizer. The fuel in a propellant usually consists of a powdered metal, with powdered aluminum along with a binder being the most widely used. The binder is usually a type of polymer used to hold the ingredients together and affects some of the

mechanical properties. The oxidizer supplies oxygen to the system to help with combustion. The most widely used is ammonium perchlorate due to its high oxygen availability per mole, bulk accessibility, and low cost. However, ammonium perchlorate produces hydrogen chloride (HCL) in the exhaust. This gas is highly toxic and viewed to be hazardous to the environment when present in large quantities. Therefore, alternative oxidizers have been researched to reduce the toxicity of propellant exhaust and still have as good of, or better, performance.

When considering an alternative oxidizer, or simply the amounts of metallic fuel, oxidizer, and binder in a propellant, the  $I_{sp}$  is a critical factor. The specific impulse,  $I_{sp}$ , is defined as "the thrust that can be obtained from an equivalent rocket which has a propellant weight flow of unity."<sup>1</sup> It can be calculated from thermodynamic data of propellant ingredients as demonstrated by the following equation,

$$I_{sp} = (1/g) \sqrt{2\Delta H/m}$$

where  $g$  is the gravitational constant, and  $\Delta H$  is the change in heat content of the propellant mass  $m$  from its initial state in the rocket motor to its burned state as it leaves the rocket nozzle. This equation holds true provided that the exit pressure of the gas equals the external pressure.<sup>2</sup> If  $p_1$  is the pressure

1. George P. Sutton and Donald M. Ross, Rocket Propulsion Elements (New York: John Wiley and Sons, 1976), 29.

2. Thor Smith, "Elastomeric-Binder and Mechanical-Property Requirements", Industrial and Chemical Engineering, 52, no. 9 (September 1960): 776-780.

of a heated gas undergoing isentropic expansion through a converging-diverging nozzle to the environmental pressure,  $p_2$ , then,

$$I_{sp} = (1/g) \sqrt{2gJ C_p/M T_c [1 - (p_2/p_1)^{R/C_p}]}$$

where  $J$  is the mechanical equivalent of heat;  $C_p$ , the average molecular specific heat;  $M$ , the average molecular weight of exhaust gas;  $T_c$  the chamber temperature; and  $R$ , the gas constant.<sup>1</sup> Many factors, such as the heat of formation, the density of the oxidizer, and the chamber pressure, end up affecting the specific impulse. For example, the more positive the heat of formation of the oxidizer, the better the  $I_{sp}$ , since less energy is required to decompose the oxidizer. Because chamber pressure and gas expansion affects the specific impulse, it is standard to have the chamber pressure at 1000 p.s.i and have the gases expanded to 14.7 p.s.i. when calculating the  $I_{sp}$ .

The calculation of specific impulse for rocket propellants at Phillips Laboratory was first performed with the Theoretical ISP Program produced first for the mainframe computer in the 1960's by Curtis Selph and Robert Hall. It was subsequently adapted for the microcomputer environment by Robert Acree in May, 1987. The Theoretical ISP Program is a one-dimensional isentropic equilibrium program with the capability of finding an optimum specific impulse for a given set of ingredients, considering ionized exhaust products and solving Chapman-Jouget wave detonations. It is this microcomputer version with a grid-  
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3. Eli Mishuck and L.T. Carleton, "Chemical Principles of Solid Propellants." Industrial and Chemical Engineering 52, no. 9 (September 1960): 754-760.

search modification by Tim Magee that has been used to calculate the  $I_{sp}$  data in this report.

Calculating, theoretically, the specific impulse of a propellant can help determine whether or not producing that propellant is worthwhile. The research in this report deals primarily with the  $I_{sp}$  of possible, environmentally safe oxidizers in conjunction with a variety of polymers. The purpose was to find the best possible combinations of oxidizer-salts with polymers to demonstrate the potential for a propellant that is energetic and emits no highly hazardous toxins in the exhaust.

Some of the oxidizer-salt combinations looked at include: hydrazinium nitrate / hydrazine (HN/HY), hydrazinium nitrate / sodium nitrate (HN/SN), ammoniumdinitramide / ammonium nitrate (ADN/AN), ammonium nitrate / hydrazinium nitrate (AN/HN), ammonium nitrate / lithium nitrate (AN/LN), and ammonium nitrate / ethylenediammonium dinitrate (AN/EDDN). Some of the polar polymer binders used with these oxidizers were polyvinyl alcohol (PVA); the polyallyl amines: polyallyl amine (PAAM), polyallyl amine nitrate (PAAMN), polyallyl amine nitroformate (PAAMNF); the polyvinyl amines: polyvinyl amine (PVAM), polyvinyl amine nitrate (PVAMN), and polyvinyl amine nitroformate (PVAMNF), and polyacrylamide (PA). Aluminum was used as the metal fuel, varying between 15 and 20% of the total weight composition, the amount of polymer varied between 8 and 18%, and the oxidizer filled in the rest of the composition. The levels of polymer and aluminum were limited to a specific range because amounts outside of this range would rarely result in an effective propellant.

The  $I_{sp}$  data is generated using the Theoretical ISP Program and then transferred to a graphing program to be analyzed as a contour plot.\* More points than simply the optimum Isp are produced to show the effects of reducing or raising the amounts of any one variable. The amounts of polymer are varied along with the amounts of aluminum to produce the x and y axis respectively. The  $I_{sp}$  data is plotted as an elevation level. In this way, the exact amounts of each ingredient to produce the optimum specific impulse are known. Comparisons between the data will show which of the oxidizers and which of the polymers give the best propellants.

A3L, a developmental solution propellant, was used as a base-line to compare with the other oxidizers. A3L has S-HAN5 (primarily hydroxylammonium nitrate) as its liquid oxidizer and PVA as its polymer with a small amount of an additive, GNX. When calculated, the weight proportions that gave an optimum Isp of 261.05 were PVA at 11%, S-HAN5 at 65%, Al at 20%, and GNX at 4%. By substituting the other liquid oxidizers for S-HAN5 and leaving out the small amount of GNX, it was determined that four of the candidate oxidizers had potential to be more energetic than the PVA/S-HAN5 combination. Table 1 shows a comparison between the optimum  $I_{sp}$  of the different oxidizers with the PVA polymer.

Table 1.  $I_{sp}$  of Oxidizer with PVA

Oxidizer	$I_{sp}$
-----	

\*For more information on producing specific impulse data and producing contour graphs see Appendix A.

HN/HY	274.80
HN/SN	267.63
ADN/AN	266.41
AN/HN	263.04
S-HAN5	262.92
AN/HN/SN	257.27
AN/EDDN	257.13
AN/HN/LN	254.77
AN/LN	246.63
HN/LN	229.48
LN/U	216.07

Hydrazinium nitrate (HN) proved to be a common component for the more energetic oxidizers. The heat of formation for HN is -59.01 Kcal/mol, while all but two were well below that; the heat of formations for AN, LN, EDDN, and U (urea) were -87.37, -115.47, -156.19, and -79.63, respectively. The only exceptions were HY and ADN. The heat of formation of ADN was slightly higher than HN at -35.8 and HY had the only positive heat of formation with +12.05. Although HY gave very high  $I_{sp}$  values compared to the rest of the field, it produced low chamber temperatures which can be a problem for the combustion of aluminum. The problem with low chamber temperatures will be discussed later on. The combinations containing LN were relatively less energetic than the others, even with the HN/LN combination.

Once the oxidizers were evaluated, the four determined to be the best were calculated with the various polymers. For most of the systems, optimum  $I_{sp}$  was found at low polymer levels with high levels of aluminum. For most propellants, a minimum level of polymer is required in order for it to be effective, therefore, not only were the optimum  $I_{sp}$  values looked at, but

also polymer levels at a weight of 14%. Since some systems have problems combusting aluminum at levels over 20%, Al ranged only from 15% to 20% of the total weight composition. Tables 2, 3, 4, and 5 show the results of the four oxidizers with the various polymers.

*Table 2. HN/HY Oxidizer with Polymers*

Polymer w/ HN/HY	$I_{sp}$ Optimum	$I_{sp}$ w/ 14% Polymer
PVAMNF	279.97	279.51
PAAMNF	279.71	279.07
PVAMN	278.67	277.03
PAAMN	278.13	275.90
PVAM	275.03	267.24
PVA	274.80	268.56
PAAM	273.91	264.75
PA	273.19	265.67

*Table 3. HN/SN Oxidizer with Polymers*

Polymer w / HN/SN	$I_{sp}$ Optimum	$I_{sp}$ w/ 14% Polymer
PAAMNF	269.52	269.20
PVAMNF	269.39	269.08
PVAM	268.87	264.42
PAAMN	268.55	268.46
PVAMN	268.34	268.32
PAAM	268.31	262.66
PVA	267.63	264.46
PA	265.92	261.50

*Table 4. ADN/AN Oxidizer with Polymers*

Polymer w/ADN/AN	$I_{sp}$ Optimum	$I_{sp}$ w/ 14% Polymer
PVAM	269.83	269.12
PAAM	269.40	267.85
PAAMN	267.72	267.56
PAAMNF	267.70	266.63
PVAMN	267.19	266.59
PVA	266.41	265.98
PVAMNF	266.14	265.18
PA	264.73	263.02

*Table 5. AN/HN Oxidizer with Polymers*

Polymer w/ AN/HN	$I_{sp}$ Optimum	$I_{sp}$ w/ 14% Polymer
PAAMNF	268.17	267.76
PVAMNF	267.99	267.57
PVAM	267.55	263.39
PAAMN	267.17	267.14
PVAMN	267.05	266.94
PAAM	266.78	261.13
PVA	265.96	263.04
PA	264.23	260.05

An analysis of the various polymers and their oxidizers reveals that the order of energetic value established with the PVA polymer is consistent throughout all the polymer data. For example, the HN/HY composition remains the most energetic regardless of the polymer used. Of the polymers, the nitroformates (PVAMNF, and PAAMNF) tend to be more energetic. This is due partly to the fact that they contain energetic nitroformate groups. Within the polymers themselves there is a drop of  $I_{sp}$  from optimum to 14% weight composition, some more dramatic than others. The non-ionic polymers experienced the largest drop in  $I_{sp}$ . From this data, it was determined that the combinations of oxidizer and polymer that hold the best potential for a possible, energetic propellant were any of the nitrate, nitroformate polymers in combination with HN/HY, HN/SN, or AN/HN, or the ADN/AN oxidizer with some of the non-ionic polymers (PAAM, PVAM).

Another aspect, aside from the specific impulse, to look at when formulating possible propellants is the chamber temperature. With metalized systems it is important to have a chamber temperature high enough to combust the metal fuel. If the chamber temperature is not hot enough, the metal will not combust as effectively and the result will be a loss in  $I_{sp}$ . To reveal

the actual chamber temperature, a substitute for the aluminum is used in the Theoretical ISP Program. The substitute has all the characteristics of normal aluminum except effects on temperature caused by combustion. In order for the system to combust effectively, the chamber temperature given must be greater than or equal to the melting point of aluminum oxide. Table 6 lists a few of the polymer and oxidizer combinations at their highest possible chamber temperature in the range of 8-18% polymer level when Al is 15% of the weight composition.

*Table 6. Maximum Chamber Temperatures of Systems*

System	Temperature
HN/HY / PAAMNF	2293°K
HN/HY / PAAMN	2128°K
HN/HY / PAAM	1730°K
HN/SN / PAAMNF	2594°K
HN/SN / PAAMN	2451°K
HN/SN / PAAM	2064°K
AN/HN / PAAMNF	2526°K
AN/HN / PAAMN	2379°K
AN/HN / PAAM	2036°K
ADN/AN / PAAMNF	2450°K
ADN/AN / PAAMN	2627°K
ADN/AN / PAAM	2580°K

Melting point of  $Al_2O_3 \approx 2300^\circ K$

Taking in to account the chamber temperature when evaluating Isp eliminates a few of the possible systems. Although the HN/HY oxidizer proved to be extremely energetic, the resulting chamber temperatures were not sufficient enough for proper combustion for most of the polymers. Generally, any system which had a nitrate or nitroformate polymer tended to burn at a higher temperature than the other polymers. The HN/SN eutectic burned higher than the other proposed oxidizers. Going back to the previous formula

for  $I_{sp}$ , it can be derived that  $I_{sp}$  is nearly proportional to  $T_c/M$ , where  $T_c$  was the chamber temperature, and  $M$  was the average molecular weight of exhaust gas. As the system burns hotter, the resulting  $I_{sp}$  is increased. The HN/SN eutectic has good potential as an oxidizer since it produces an energetic system that can burn all of the available aluminum.

With concerns for a clean environment, research in the area of rocket propellants has shifted its focus from simply energetic propellants to energetic and clean propellants. Moving away from the perchlorate oxidizers which contain hazardous exhausts, the propellant field is looking to other types of oxidizers that can be as effective. The ADN/AN oxidizer-salt proved to be a strong possibility with its high specific impulses and high chamber pressures. Other possibilities exist with HN/SN and AN/HN eutectics. While the toxicology of such salts must be considered for future systems, they can be combined with some of the more energetic polymers to produce systems that theoretically have as good of an  $I_{sp}$  as some of the contemporary propellants. If the A3L propellant is used as a base-line, then the calculations of some of the systems demonstrated become attractive. For future propulsion systems, the criteria for a good rocket propellant involves not only good performance, but good on the environmental compatibility as well.

## APPENDIX A

### Sample Isp Data and Graph Generation

The following pages contain a step-by-step example of creating a detailed graph which plots the variable components of a propellant and resulting ISP. The program to calculate the ISP data is the AFAL Theoretical ISP Program Micro Version by Beckman and Acree with a grid search modification by Tim Magee. The data is transferred to the graphing program Axum using the import feature within Axum. A variety of graphs to display the components and ISP are available, ranging from simple line charts to three dimensional surface grids. In this example, a contour grid was chosen for its easy readability and access to three dimensions. The sample propellant is the A3L propellant and its ingredients: PVA, S-HAN5, Aluminum, and GNX. The amounts of PVA and AL were varied, Al between 15 and 21% of the composition, and PVA between 8 and 16%. GNX remained constant at 4% and S-HAN5 filled the remaining portion of the composition.

#### Generating Isp Data

The Micro version of the Isp program requires an input file with a .dat extension in which the propellant's data is stored along with specifics for generating the data. When the input file is used by the program an output file is created with the same name as the input file only with an .out extension. This output file contains the  $I_{sp}$  data from which Axum will import. Included below is the sample input file.

```

NSP
SAY
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
LIB
  S-HAN5  -93.98  1.680      C0.0640  H4.2957  N2.0622  O4.1090
    PO.0087
  PVA     -49.69  1.269      C2.0000  H4.0000  O1.0000
  AL      0.00  2.70      AL1.0000
  GNX     -79.30  1.3540     C1.0000  H6.0000  N3.0000CL1.0000
CHP
  1000.
EXP
  14.7

ITR
  1000
NOU
TAB
  ISP          3          3
SEL
      1
      2
      3
      4

STP
  1
OPT
  1.00      1.00      1.00      1.0
  100.00
      1.0
  4.0
      1.00
  15.0000  0.5      15.0000  21.0000
      1.00
  8.00      0.10     8.00      16.0
XEQ
END

```

Each of the three lettered control cards has a specific purpose, some of which are vital to tailoring the output to a file that is easily imported by a graphing program. For example, the LIB card contains specific information concerning the ingredients such as the heat of formation (first column), and the density (second column). Important to the output file, however, are the NOU, TAB, STP, and OPT cards.

The NOU control card simply cancels the normal output format

and leaves the programmer with the choice of output features.

The TAB control card arranges the data into a tabulated format of side by side columns. It is followed by the name and coordinates of the information the programmer wishes to receive, in this case Isp , which has the coordinates of 3,3 in the standard output file.

The STP control card is part of the grid search modification and controls the number of grid shifts or grid refinements. Although setting STP at 1 kept the program from shifting, it did however ensure the output file to be in perfect numerical order within the bounds set by optimization, an important feature for importing.

The OPT control card is used to create a range of Isp calculations with the program stopping once the optimum is reached. With the STP card set at 1, however, the program will calculate for the entire range specified. The AL is set to range from 15% to 21% of the weight with intervals of 0.5. The PVA is set to range from 8% to 16% of the weight with intervals of 0.1. The first two lines under the OPT control card specify the total weight amounts to equal 100% and the second two lines specify GNX to equal 4%. Consequently, S-HAN5 fills in for the amount left over after PVA, AL, and GNX.

With these control cards, the output file should be tailored in such a way as to be easy to organize into a data sheet once imported into the graphing program. Following, is the first few lines of the output file resulting from the above input file.

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

PROPELLANT LIBRARY

S-HAN5	-93.9800	1.6800	C .0640	H 4.2957	N 2.0622	O 4.1
PVA	-49.6900	1.2690	C 2.0000	H 4.0000	O 1.0000	
AL	.0000	2.7000	AL 1.0000			
GNX	-79.3000	1.3540	C 1.0000	H 6.0000	N 3.0000	CL 1.0

THE COUNTER TO LIMIT THE NUMBER OF  
 ITERATIONS IS NOW SET AT 1000. ANY DATA  
 POINT WHICH EXCEEDS THIS COUNTER SHOULD  
 BE VIEWED CRITICALLY BEFORE ACCEPTANCE.  
 STP

1

OPTIMIZATION INPUT

1.000	1.000	1.000	1.000
100.000	.000	.000	.000
.000	.000	.000	1.000
4.000	.000	.000	.000
.000	.000	1.000	.000
15.000	.000	.000	.000
.000	1.000	.000	.000
8.000	.100	8.000	10.000
CHAMBER PRESSURE = 1000.000			

S-HAN5	PVA	AL	GNX	DENSTY	ISP
73.000	8.000	15.000	4.000	1.716	259.595
72.900	8.100	15.000	4.000	1.716	259.599
72.800	8.200	15.000	4.000	1.715	259.603
72.700	8.300	15.000	4.000	1.715	259.611
72.600	8.400	15.000	4.000	1.714	259.612
72.500	8.500	15.000	4.000	1.713	259.612
72.400	8.600	15.000	4.000	1.713	259.612
72.300	8.700	15.000	4.000	1.712	259.609
72.200	8.800	15.000	4.000	1.712	259.603
72.100	8.900	15.000	4.000	1.711	259.601
72.000	9.000	15.000	4.000	1.711	259.587
71.900	9.100	15.000	4.000	1.710	259.579
71.800	9.200	15.000	4.000	1.709	259.566
71.700	9.300	15.000	4.000	1.709	259.552
71.600	9.400	15.000	4.000	1.708	259.537
71.500	9.500	15.000	4.000	1.708	259.525
71.400	9.600	15.000	4.000	1.707	259.505
71.300	9.700	15.000	4.000	1.707	259.486
71.200	9.800	15.000	4.000	1.706	259.464
71.100	9.900	15.000	4.000	1.706	259.440

To simplify the importing procedures it is suggested that all material prior to the data columns be deleted. This can be done with any text editor.

### **Producing the Isp Data Sheet**

Within Axum, there are two files necessary for the production of a graph, one is the data sheet file with the extension .dsf and the other is the graph file with the .grf extension. It is possible to have two graphs for the same data sheet or to simply view a graph off of the graph's file. The data sheet by itself, however, will not produce a graph.

To create the data sheet, select FILE from the Data Sheet Menu. Select IMPORT and enter the name of the output file with the extension and filespecs if it is not located within the Axum\data directory. Limit the columns imported by changing the end column from END to about 6. The rows should stay the same unless the data does not begin at the start of the document. When all specifications are set, press <F10>. The output file should appear in the data sheet.

Before creating the graph, it is important to modify the data sheet. Column and data specification must be exact in order for the program to graph properly. Columns which contain irrelevant data should be deleted by selecting DELETE from the COLUMN menu.

The columns should be named according to their corresponding axis. The Isp column should be the Z axis, name it by selecting MODIFY SPECS from the COLUMN menu. In this example the Column

containing the PVA amounts will be assigned the X axis and the AL amounts the Y axis. Their respective column names will be "x" and "y".

Rows with irrelevant data such as blanks or chamber pressures can be deleted. Select DELETE from the ROW menu and enter "IF (x<1)." This will delete all rows whose "x" column data is less than 1.

Included below is the example data sheet.

	x	y	z
1	8.00	15.00	259.60
2	8.10	15.00	259.60
3	8.20	15.00	259.60
4	8.30	15.00	259.61
5	8.40	15.00	259.61
6	8.50	15.00	259.61
7	8.60	15.00	259.61
8	8.70	15.00	259.61
9	8.80	15.00	259.60
10	8.90	15.00	259.60
11	9.00	15.00	259.59
12	9.10	15.00	259.58
13	9.20	15.00	259.57
14	9.30	15.00	259.55
15	9.40	15.00	259.54
16	9.50	15.00	259.52
17	9.60	15.00	259.51
18	9.70	15.00	259.49
19	9.80	15.00	259.46
20	9.90	15.00	259.44

### Producing the Isp Graph

Once the data sheet is saved, the graph can be created by moving to the GRAPH menu. After selecting CREATE, there is an option for the axes type. For this example it will be XY, if the graph were to be a surface grid, it would be 3D.

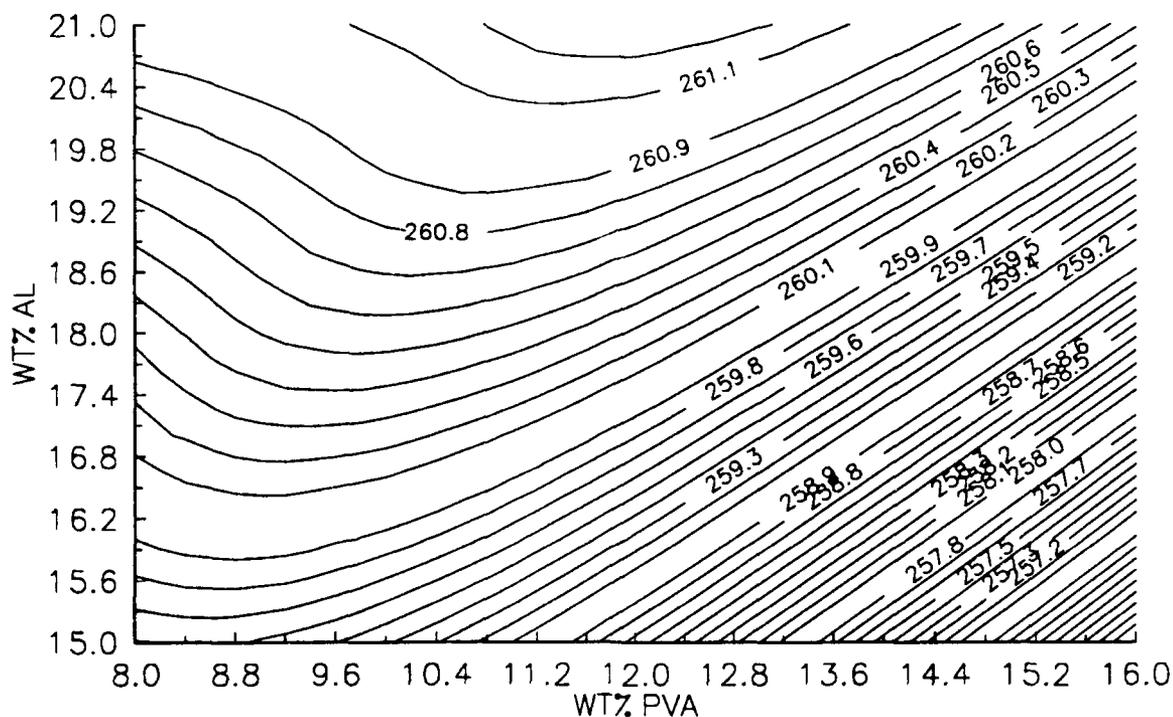
Proceed to the first entry under plot type, press <enter>, and select the plot type (contour-grid for this graph). Now the location of the different axes' data must be specified. This is done by inserting the names of the columns with the appropriate

data under each axis column. Since the column with the PVA data is to be the X axis, the column name, x, is placed under the X axis column.

Pressing <F10> will accept the sheet and takes you back to the former menu. The graph can now be viewed, saved or modified. Modifications include titles, number of contours, sizes, colors, axes types (XY, 3D, and more), plot types (contour-grid, surface grid, and more). Included is the contour plot of the A3L propellant.

### Isp data as a contour graph

Baseline system: A3L, a developmental solution propellant  
A3L contains: PVA / S-HAN5 / AL / GNX



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**MASTER OSCILLATOR POWER AMPLIFIER BASICS**

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**Final Report for:  
Summer Research Program  
Phillips Laboratory**

**Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington, D.C.**

**August 1992**

# MASTER OSCILLATOR POWER AMPLIFIER BASICS

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## ABSTRACT

The objective of this project is to obtain the largest amount of power into an amplifier from a laser possible. Without knowledge of optics, this task is almost impossible. The first thing that needed to be accomplished was to learn basic optic theory. Then progress to ray tracing. We are trying to manipulate the beam from a diode laser into an amplifier creating a Master Oscillator Power Amplifier (MOPA).

## INTRODUCTION

One of the projects at the Phillips lab this summer involved a novel Master Oscillator Power Amplifier for use in laser satellite communications. Previous researchers first hurdle was to couple the maximum amount of light from the laser diode into the optical amplifier. This is the portion of this experiment that I call my own.

I was required to do a vast amount of studying to learn about what was being done and why problems were arising. I needed to learn the nature of light and how imaging works. Ray tracing turned out to be a difficult task to master. I was required to calculate distances, angles, and other pertinent information. All of this is usually done using a computer program, but in order to fully understand the concepts, I had to do calculations by hand.

## THEORY

Basic optic theory was fairly simple to learn. The concept which is used most is refraction. Refraction occurs when light waves in one medium enter another medium, the light waves bend. The law of refraction, or Snell's Law, states that when a ray of light is refracted at an interface dividing two uniform media, the transmitted ray remains within the plane of incidence and the sine of the angle of refraction is directly proportional to the angle of incidence.

$$*n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Ray tracing seemed to be simple until I had to do the actual calculations. Ray tracing involves three basic things; an object, lenses, and an image. Basically, there is a ray of light emitted from the object. We needed to trace its path from the object through a lens and see where the image should appear. In order to do this, I was required to calculate the distance from the lens to where the image should appear, the radius of the lens, and the angles of refraction, given the distance from the object to the lens, focal length of the lens, the indexes of refraction of the media, and the object height.

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

Formula used to determine image distance.

$$\frac{1}{f} = (n - 1) \left( \frac{1}{r'} - \frac{1}{r''} \right)$$

Formula used to determine radius for a biconvex lens.

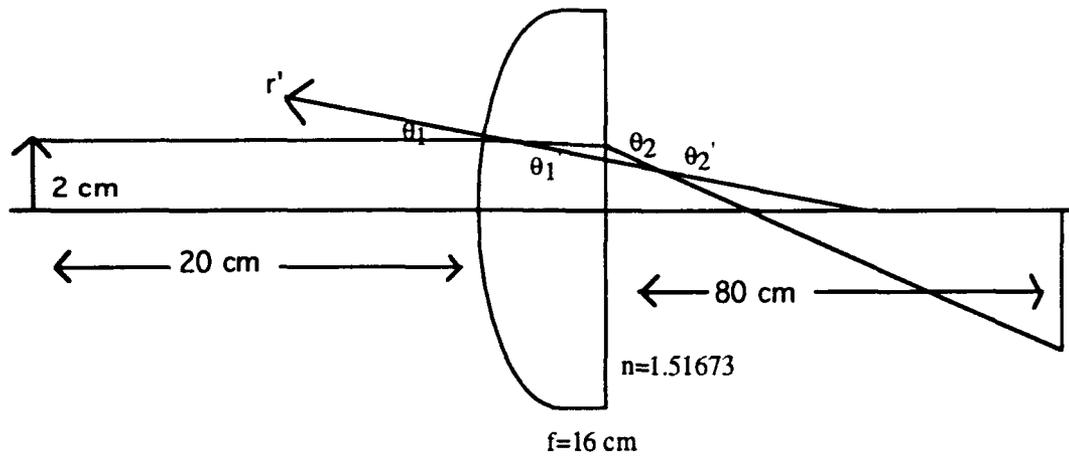
o = distance from lens to object

i = distance from lens to image

f = focal length of lens

n = index of refraction

r = radius of curvature



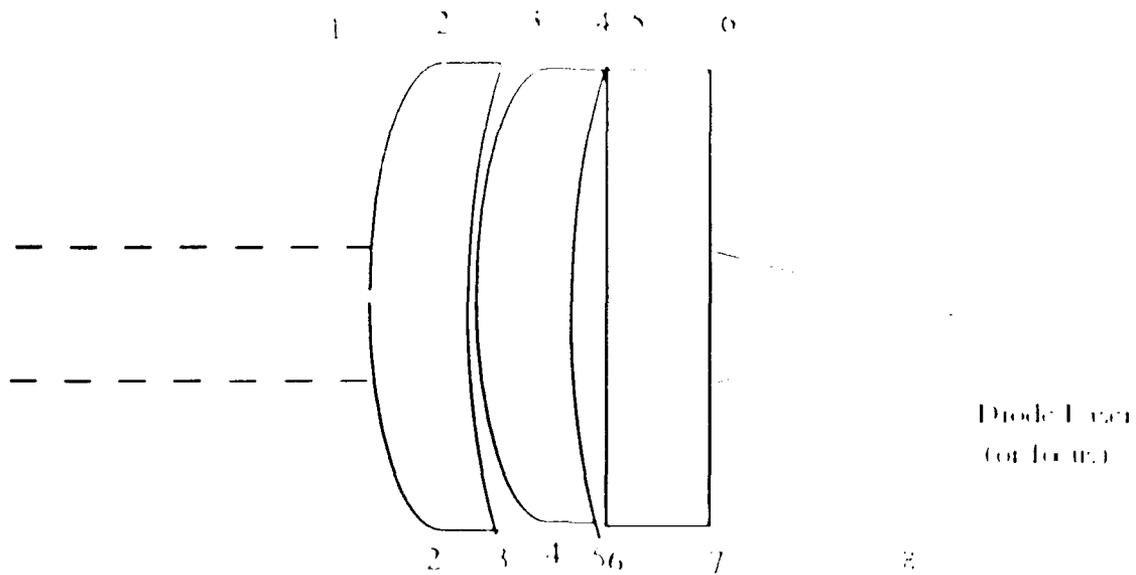
Sample problem exercising ray tracing skills.

**EXPERIMENT**

After investigating alternatives, we used an off-the-shelf lens assembly. I used my ray tracing skills to analyze parameters for this experiment.

Melles Griot Part Number GLC002					
Surface	Radius	Thk.	Dia.	Glass	Index
1	9.789	2.50	10.00	SF11	1.76312
2	79.436	0.20	10.00	air	1
3	5.491	2.50	8.50	SF11	1.76312
4	6.949	1.00	7.40	air	1
5	0.000	4.00	8.50	SF11	1.76312
6	0.000		8.50	air	1

Pertinent Information for the diode collimating lens used in our experiment.



Functional diagram of our lens assembly

Once the basic theory was completed, we set this up in the laboratory. Our goal was to couple fifty percent of the output power into the amplifier. The amplifier was one  $\mu\text{m}$  high by four hundred  $\mu\text{m}$  wide by one mm long. The diffraction limited spot from our laser and lens is around two  $\mu\text{m}$ . The small working distances led to long alignment sessions. We feel the amount of time taken to align this is the most critical element for the cost of this project. Our end-of-summer result was nearly twenty percent coupling efficiency. Part of this result was a mismatch of operating wavelength, between the available laser diode and optical amplifier. We ordered a new laser diode that matches the amplifier, but have not yet received it.

## APPLICATIONS

There are many applications for a Master Oscillator Power Amplifier (MOPA). A MOPA is a device which takes a steady frequency and amplifies it to a higher power density at the same frequency. This is a demand that can be met by a superconducting quantum laser. We are using an optical amplifier that is very noisy after being used for a long time. A very divergent wave front from the laser diode is the cause of the noise. The light beam size was 100  $\mu\text{m}$  and the power was 100 mW.

**COMING IN FOR A LANDING**

**Diane M. Monaghan  
High School Apprentice  
Phillips Laboratory**

**Final Report for:  
ASFOR Summer Research Program  
Phillips Laboratory**

**Sponsored by: Air Force of Scientific Research  
Edwards Air Force Base, Edwards, CA**

**August 1992**

## COMING IN FOR A LANDING

Diane M. Monaghan  
High School Apprentice  
Phillips Laboratory

### Abstract

The LEAP program (Lightweight Exo-Atmospheric Projectile) has made much progress in the past few years. Now the program is being tested for capabilities for use in space exploration as well as its original purpose. Testing for this type of application is being formulated. Landing a vehicle is the first step to this testing. The steps to find the perfect landing platform are covered.

## COMING IN FOR A LANDING

Diane M. Monaghan

### INTRODUCTION

For the past few years a great deal of research has been done relating to the idea of a Kinetic Kill Vehicle, one that could be projected into space to destroy unfriendly projectiles before entering the atmosphere. The LEAP program (Lightweight Exo-Atmospheric Projectile) is devoted to developing and testing these projectiles. Starting out as a massive 200 pounds the vehicle is now down to about thirteen or fourteen pounds due to extensive research on smaller thrusters, nozzles, tanks, and seekers. Progress continues as the vehicles become smaller and more able by way of new ideas and technology. Some day this type of vehicle will be a major help to defending our great country and the world.

### DISCUSSION

The LEAP vehicle was originally intended to destroy unfriendly targets, but new effort has recently been put into applying this type of technology to other things, such as space exploration. If such a vehicle could maneuver itself in space, which it has the capabilities to do, it could be very useful in space experiments. Right now a test is being formulated to prove that this type of vehicle can be safely landed, as if on another heavenly body.

This is the project to which I was assigned for the summer. A unique part of this experiment is that we are using existing hardware for most of the test, with the

exception of a few necessary parts. The basic vehicle has already been assembled, the simulation has already been set up, at least to a point from which we could work from, and the vehicle, or rather one exactly like it, has already been hover tested here in the facility. Granted the experiment still requires much hard work and thought, but as far as budget goes, this project is costing very little and its results could be priceless.

My impact on the project was really only a minor one, yet not one that could be done without. In order to land a vehicle, a landing surface is needed. This is not as simple as slapping a structure together and transporting it into the test facility. There were many difficulties we discovered on the path to constructing a suitable landing surface. Our original objective was to create a picturesque surface, one that resembled the moon, at least from the cameras point of view. Ideas came up for possibly having dust on the surface to create the "ground effect" as the vehicle landed, and to make the surface crater-like, to resemble a more realistic scene. These ideas, although interesting were quickly thrown out or altered, for they were simply unneeded to demonstrate the vehicle's capabilities and proved to be a major safety concern. After a few major decisions were made, we discovered that a certain area was needed to land the vehicle. Trying to keep the picturesque view in mind we came up with the idea of landing the vehicle in a man-made crater, making the inside of the crater safe for the test, and the outside to resemble a more moon-like surface. A background was also thought of to extend the scene.

Attempting to use existing materials, we decided to try to use a satellite dish type of structure for the crater, surrounding it with platforms and supporting it from underneath. This was our best plan until we met up with a major problem. The test is to be conducted in a building, specially constructed to accommodate these types of tests. In

order to receive data on the vehicle in flight, radio frequencies are used to track the motion of the vehicle. Unfortunately our plan was based on using metal structures which would reflect radio signals and interfere with the data collecting process. We had to come up with something else. After a period of thought we came up with the idea of using concrete to make the surface, since it is the right color, it is fireproof, and could be textured to suit our needs. It would be supported by a steel structure, covered with anechoic foam to protect the radio frequencies from reflecting. For the background we decided to use a wooden structure, coated with ablative material for fire safety reasons, that would extend the lunar scene. A model of our plan for the landing surface was constructed and approved, and the plans were drawn up for actual construction.

#### CONCLUSION

Although the test will not take place until later in the year, I am proud to say that I had a part in it. I was exposed to the other aspects of the test in small quantities, everything from the landing gear to the simulation, and I am sure that the Advanced Hover Team will do their hardest to make this experimental application for LEAP a success.

**REDUCTION AND ANALYSIS OF SYNCHROTRON SPECTROSCOPIC DATA**

**Tracy R. Reed  
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Tehachapi High School**

**Final Report for:  
Summer Research Program  
Phillips Laboratory**

**Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington, D.C.**

July 1992

**REDUCTION AND ANALYSIS OF SYNCHROTRON SPECTROSCOPIC DATA**

**Tracy R. Reed**

**Abstract**

During Aug. 1991 and Oct. 1991, Air Force scientists used the National Synchrotron Light Source at Brookhaven National Laboratory to collect EXAFS spectra of various Liquid Crystal Polymers (LCP's) which had been synthesized at Phillips Laboratory, as well as spectra of Ammonium Perchlorate pellets treated with bonding agents. The goal of this experiment was to determine local chlorine chemical coordination by viewing the radial structure function derived from the EXAFS data after computer processing.

## REDUCTION AND ANALYSIS OF SYNCHROTRON SPECTROSCOPIC DATA

### Introduction

In order to truly understand the nature of a material and how it interfaces with itself and others on an atomic level, it is necessary that one know the positions of atoms in the molecule and their distances. This information can be obtained by using Extended X-Ray Absorption Fine Structure Spectroscopy (EXAFS). Liquid crystal polymers (LCP's) and ammonium perchlorate (AP) treated with binders are perfect candidates for EXAFS study. By using this method, a greater understanding of how the polymer chains are positioned and how they might be annealed as well as how bonding agents actually bond the AP in a solid rocket motor can be obtained. This experiment was performed at Brookhaven National Laboratory using the National Synchrotron Light Source (NSLS). Once the data was obtained, it had to be converted into usable form and analyzed using a computer. The computer used was a VAX computer located at Phillips Lab. The program used to analyze the data is called EXAFS. EXAFS was written by Dick Koningsberger and obtained from Case Western Reserve University.

Synchrotron radiation is the electromagnetic radiation emitted from electrons at near light velocities when they are diverted from moving in a straight line(1). This change in velocity causes the electrons to give up some of their energy in the form of synchrotron radiation. Electrons are first accelerated to velocities near that of light by a linear accelerator. They are then injected into a relatively small booster ring where they are accelerated further and collected into bunches. The electrons are then injected into a storage ring where their path is curved periodic points by the dipole bending magnets that hold them in the center of the ring, thereby emitting the synchrotron radiation. As the electrons lose energy, the energy must be replaced. This is accomplished by placing an RF cavity after each curved section. There are also various

focusing devices to keep the beam centered and collimated in the pipe. The NSLS is a high energy synchrotron ring. It has an electron kinetic energy of 2.5GeV.

The synchrotron radiation is allowed to proceed down an evacuated beam transport tube towards the experiment contained within a small hutch. The experimental hutch protects the operators from accidental exposure to the synchrotron radiation. A two crystal monochromator of the boomerang design was used to step through the energy range. The crystals are large pieces of high purity, defect free silicon. As their angle is changed by a stepper motor with respect to the incident radiation, the energy of the radiation being reflected by the crystals changes. The monochromatic radiation then passes through the  $I_0$  chamber. This chamber basically gives a current proportional to the number of photons in beam. After it leaves the  $I_0$  chamber, the radiation goes into the sample chamber and hits the sample pellet. A fraction of the incident X-rays will be absorbed by the electrons of the atoms in the sample. As these atoms de-excite, they emit fluorescent X-rays. This fluorescence is measured in the  $I_f$  chamber, which is placed on the side of the sample chamber at a right angle to the beamline.  $I_f$  is divided by  $I_0$  and plotted over the energy range to get a visual representation of the energies at which the sample was emitting radiation. Each element has specific energies at which it will absorb synchrotron radiation in the X-ray region. This will produce what is called an edge in the spectrum. These experiments were done in the energy range of approximately 2600-3600 eV. The K edge is located at 2823 eV. Shortly after the edge is what is known as the EXAFS region. This is where the most informative data is located.

### Procedure

There are five main steps that one must go through in order to get meaningful information from the EXAFS data. The first step is initialization. In this step, the program is told what kind of EXAFS data it is. In this case, it was fluorescence. The program then reads the file and converts it into an unformatted FORTRAN file for its

own use. This file ends in an .INI extension. It is in this file that the program makes any changes to the data. The original data file is never changed. The program then makes another file, ending in an .JOU extension. This is where a record of all changes to the data is kept.

The second step in the data reduction is the pre-edge subtraction. In this step, the data before the edge is removed so that it doesn't show up when the chi of k is graphed after the subtraction of a cubic spline from the rest of the data.

The next step in the data reduction is inner potential determination. In this step, the location of the edge is determined. The program automatically finds the location of the edge, but it is not always to the users liking. It is customary to set the location of the edge as the middle of the edge, or on a feature that might appear near the middle of the edge. The number that describes the location of the edge is called  $E_0$ . This  $E_0$  tells the program where to start subtracting background from. The middle of the edge is marked with a small triangle. See figure 1.

The fourth step is the dejumping and deglitching. Occasionally, one gets data with a spike, or glitch, in it. This can be caused by several things. One of which is a jolt to the monochromator during the experiment. This is removed by simply moving the offending point down in line with the other data. Another type of fault in the data is called a jump. A jump is a large apparent increase or decrease in the florescence of the sample. It looks like a small edge. The jump can be a jump up or down, depending on what is causing it. If there is a leak in the  $I_0$  chamber, the jump will go down. If it is a leak in the  $I_f$  chamber, it will go up. The jump will be located at whatever the electron binding energy for the impurity is. When this experiment was conducted, it was found that there had been a leak in the  $I_0$  chamber for most of the time the experiment was taking place. Consequently, nearly all of the data files had jumps in them. See figure 2. In this case it was argon that caused the jump. The electron binding energy of argon is 3205 eV. This jump had to be removed before the data could be

processed any further, adding significantly to the time it took to process the file. The procedure for removing a jump is to give the program the number of the data point immediately preceding the jump. It will then take the difference between that point and the next and move all data points thereafter by that amount. Figure 3 illustrates the data after dejumping.

The last step in the data reduction is the background subtraction. It is unclear how the program subtracts the background, but it is suspected that a cubic spline is taken. The data is then Fast Fourier Transformed and plotted. This is known as the radial structure function. See figure 4. If the data is normalized, the radial structure function contains one peak for each of the groups of nearest neighbors. Its height tells how many nearest neighbors there are, and its position shows the distance. This will be done sometime in the near future using another program on the VAX.

### **Results**

It was found that the EXAFS spectra for the AP and polymer pellets were very different. There were even significant differences between one AP spectra and another due to the bonding agent that was applied. A total of 118 files of EXAFS spectroscopic data were reduced. A much better understanding of the software being used was also gained. Before, it was unclear as to how certain operations, such as the corrections of error in the data were to be done. But now, these kind of problems can be taken care of quite easily. Several bugs in the program were also found. When an unexpected input was given to the program, the program would often crash. The interatomic distances and structure of the specimen can now be determined, leading to a much better understanding of the specimens.

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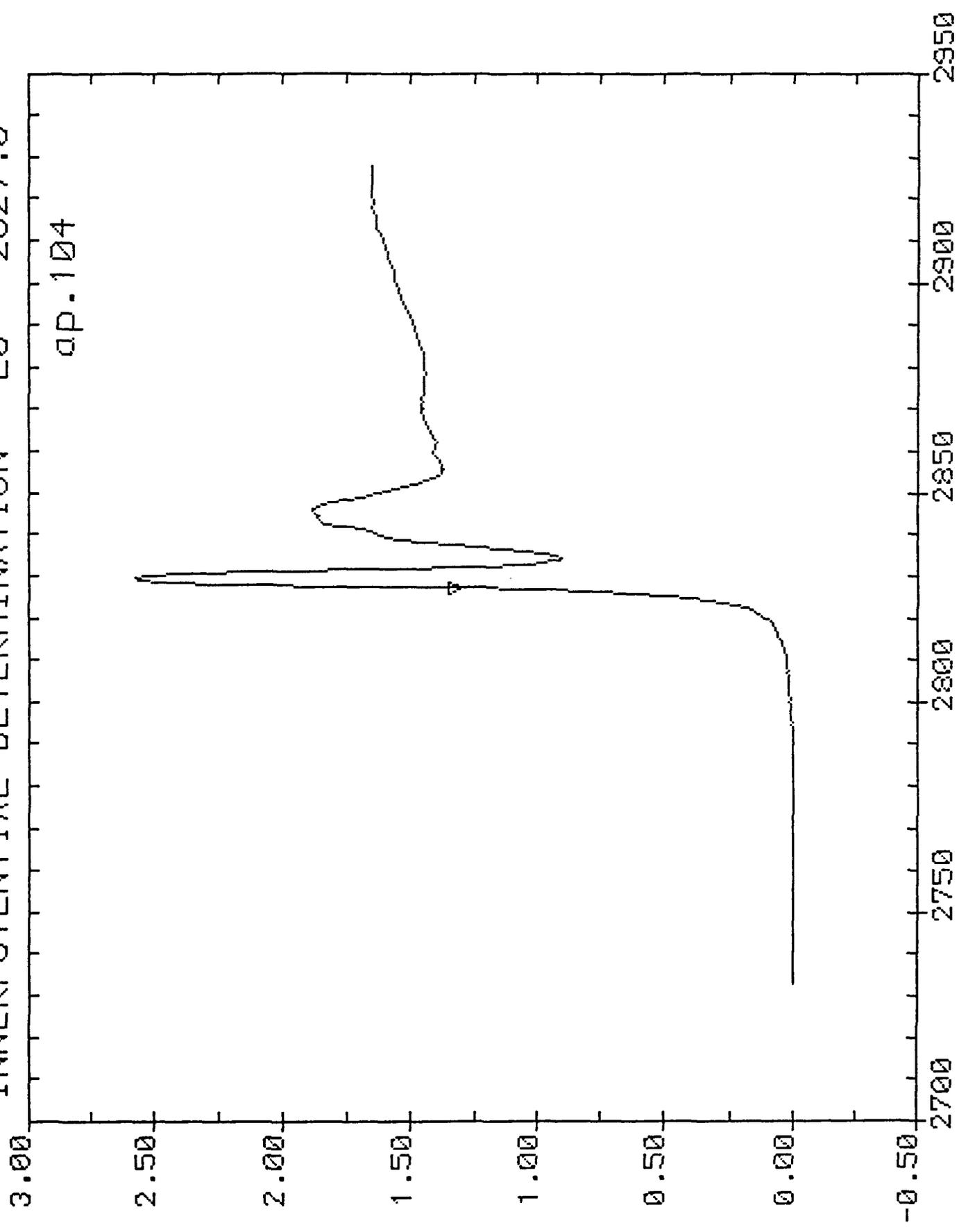
(2) Guy Arthur Derose, "X-Ray Absorption Fine Structure Strain Determination In Thin Films", Case Western Reserve University, Cleveland, 1992

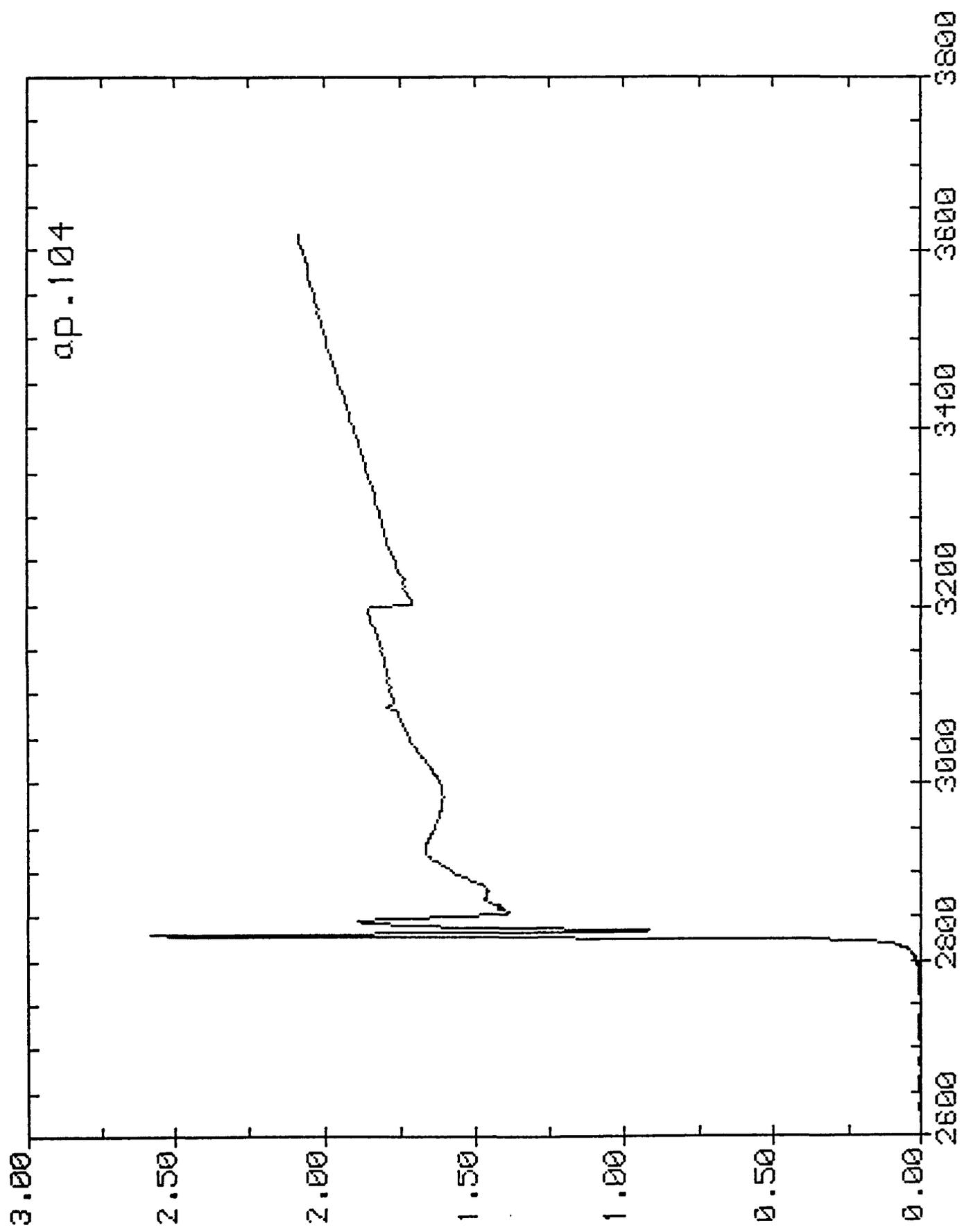
## **Acknowledgments**

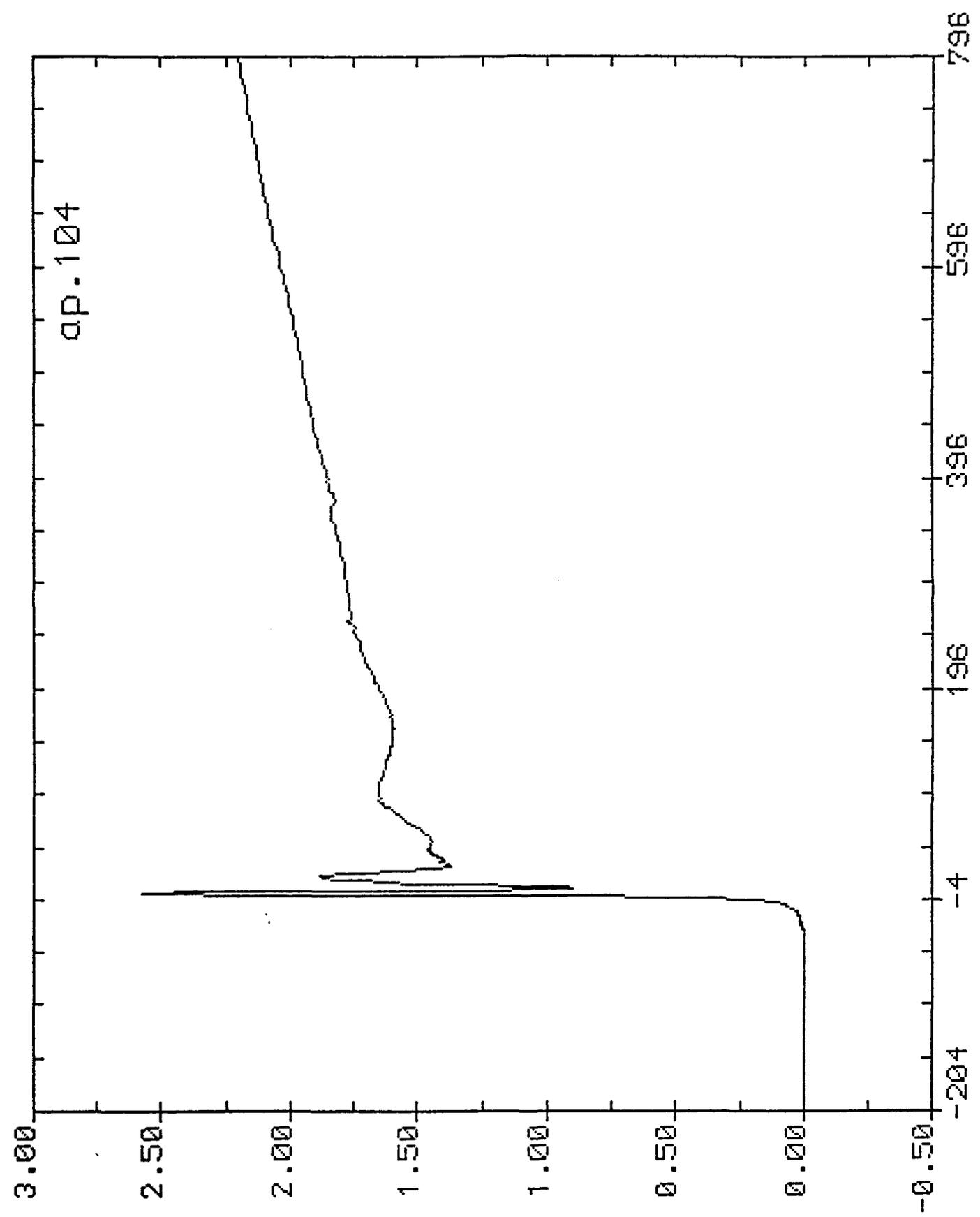
**I wish to thank Dr. Kevin Chaffee for all he has taught me and all of the questions he has answered for me. I also wish to thank Dr. John Rusek and Mr. Steven Osborn for all of their help and support throughout the summer.**

INNERPOTENTIAL DETERMINATION E0= 2827.0

ap.104

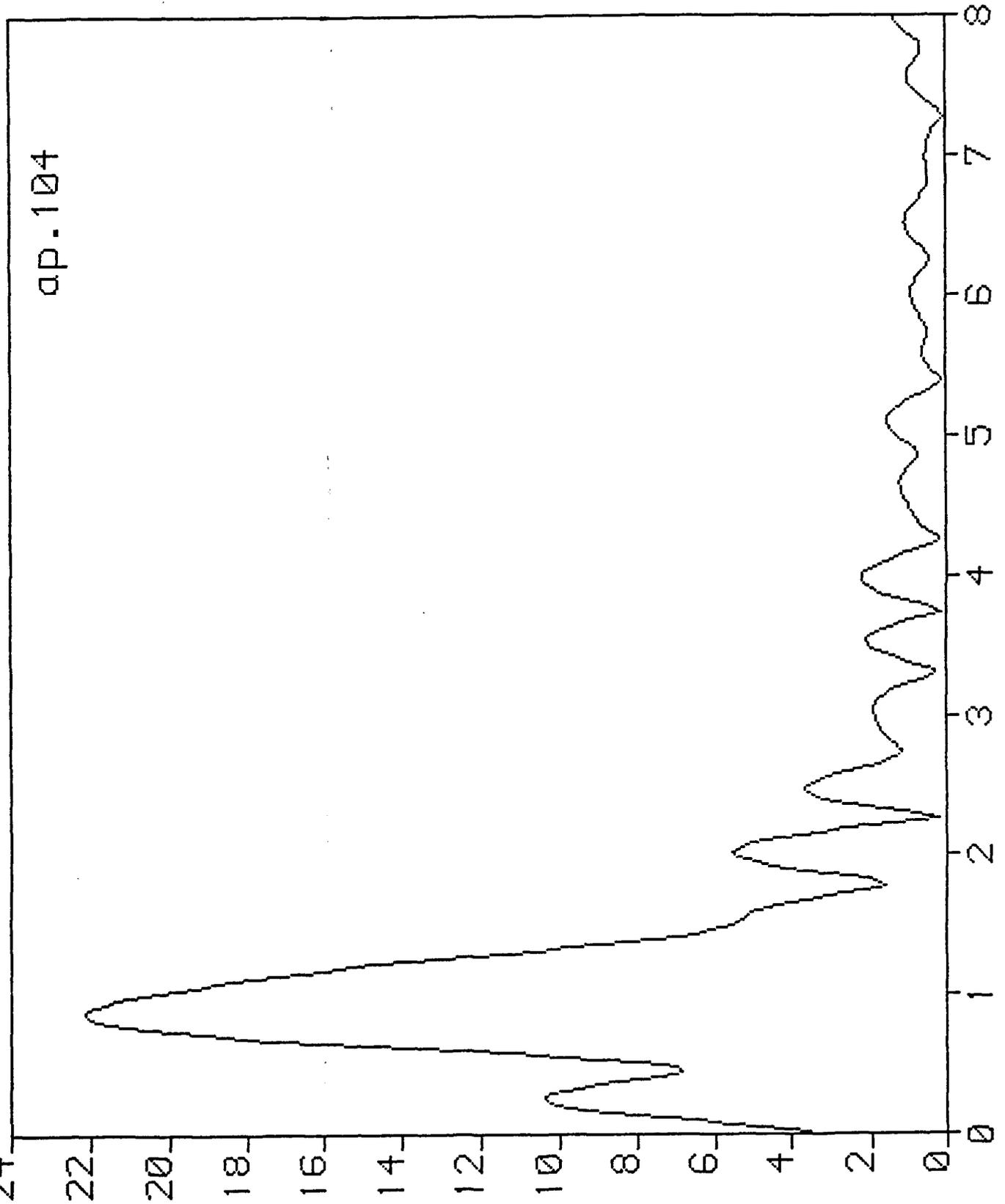






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ap. 104



**INTERPRETING GPS SATELLITE DATA FOR USE  
IN THE STUDY OF IONOSPHERIC EFFECTS ON  
RADIO SIGNALS**

**Jeffrey M. Roth  
1992 AFOSR-HSAP Participant  
*Ionospheric Effects Division***

**U.S. Air Force Phillips Laboratory  
Geophysics Directorate  
Ionospheric Effects Division, Code LIS  
Hanscom Air Force Base  
Lexington, MA 01731-5000**

**Final Report for  
AFOSR 1992 High School Apprenticeship Summer Research Program  
Phillips Laboratory**

**Sponsored by  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington, DC.**

**August, 1992**

INTERPRETING GPS SATELLITE DATA FOR USE  
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RADIO SIGNALS

Jeffrey M. Roth  
1992 AFOSR-HSAP Participant  
Ionospheric Effects Division  
Hanscom AFB, MA

Abstract

The research lab which I received the chance to work in this summer comprises itself of a small group of engineers who study and record the activity of the ionosphere. *Because this research involves using data which comes from not just our site but other sites around the world, we work with such an overwhelmingly large amount of data that computers allow the only feasible way to handle it.* As a result, much of the work that I have done consisted of using computers. This has included modifying and writing data analysis software, loading and processing data tapes on the lab mainframe computers, and generating data plots printouts. I greatly appreciate this opportunity to work for the summer under a technical and challenging objective. I would especially like to thank Charley Andreasen, Greg Bishop, Elizabeth Holland, and Dr. Andy Mazzella, all of whom have let me work alongside them and taught me things the hands-on, exciting way.

# INTERPRETING GPS SATELLITE DATA FOR USE IN THE STUDY OF IONOSPHERIC EFFECTS ON RADIO SIGNALS

Jeffrey M. Roth

## Introduction

In the military and civilian worlds of today, radio signals play a large role in the operation of telecommunications, surveillance, and tracking systems. Because these systems require high degrees of precision, developers must provide adjustments that can take into account any disturbances that may occur. In the upper atmosphere, there is a region called the ionosphere which poses such a problem. Within the ionosphere there are highly ionized gases in the plasmic state due to intense solar radiation. These free-flowing electrons, ions, and neutral particles compose about five percent of the ionosphere making it slightly ionized.

The ionosphere is created mainly by the sun's radiation, and therefore the amount of ionization follows a daily cycle in which it peaks when at periods of the most sunlight and bottoms during times of least. The amount of ionization is measured by a value called TEC (total electron content) which follows this diurnal cycle. (Fig. 1). These TEC values are a measurement made by receiving GPS (Global Positioning System) satellite signals and determining from them the number of electrons that are contained in the

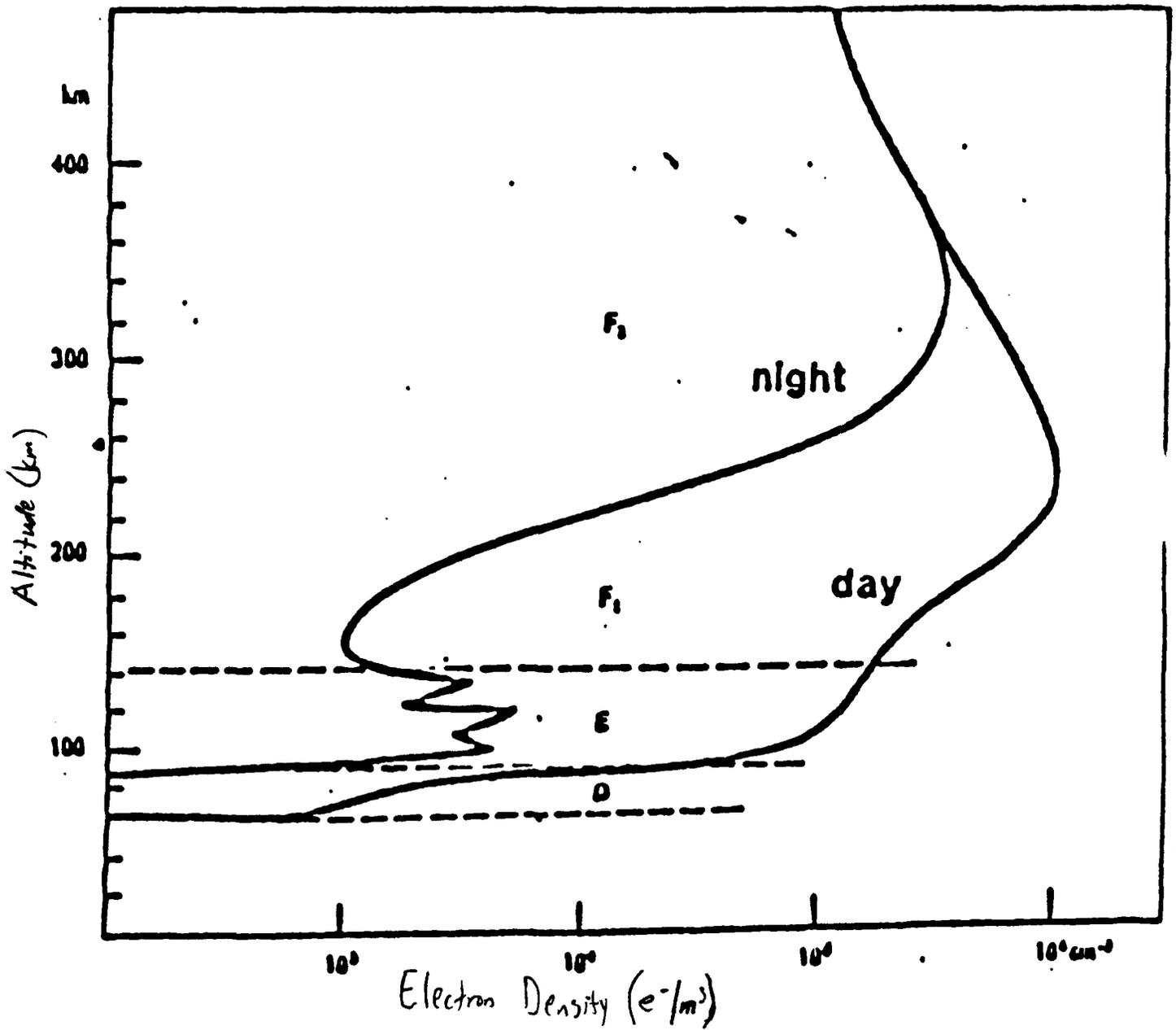


Figure 1: Ionospheric TEC Diurnal Cycle

volume that has a base of one square meter and extends from the surface of the earth to an altitude of about 1000 km. This altitude is generally considered to be the top of the ionosphere; the base begins at roughly 50 km. While the ionosphere technically exists between these two altitudes, the region where the most activity occurs is between 300 and 350 km. Figure 2 shows these general characteristics as a profile.

For the radio systems which must propagate waves through the atmosphere, and hence through the ionosphere also, the region of ionization can seriously impair the system's performance. The problems which the ionosphere can create for surveillance, telecommunications, and tracking systems are deterioration of tracking, imaging, and detection; signal loss; ranging errors; and radio wave refraction and distortion. Since at least one of these effects normally always takes place, radio signal applications require ionospheric models that can accurately predict when activity will occur. Though certain models do exist, a major objective at the Phillips Laboratory is to develop versions that can more precisely anticipate ionospheric activity.

### Discussion

In efforts to create a successful model of the ionosphere we need to analyze ionospheric data. Presently there are five stations that use GPS receivers to collect data. They are Thule, Greenland; the Shetland Islands, UK; Shemya air base in the Aleutian chain; and the geophysics lab at Phillips Laboratory on Hanscom AFB, MA. From these stations we receive raw data in the form of 10 inch magnetic tapes and in chart form. Figure 3 is a chart of about four hours of raw data from Shetland for February 27, 1991. On this chart there are four bands of data. The top line is called the "L1" band and the one directly underneath it is called the "L2" band. These operate at L-band radar frequencies of 1.5 GHz and 1.2 GHz respectively. The bottom two bands are two

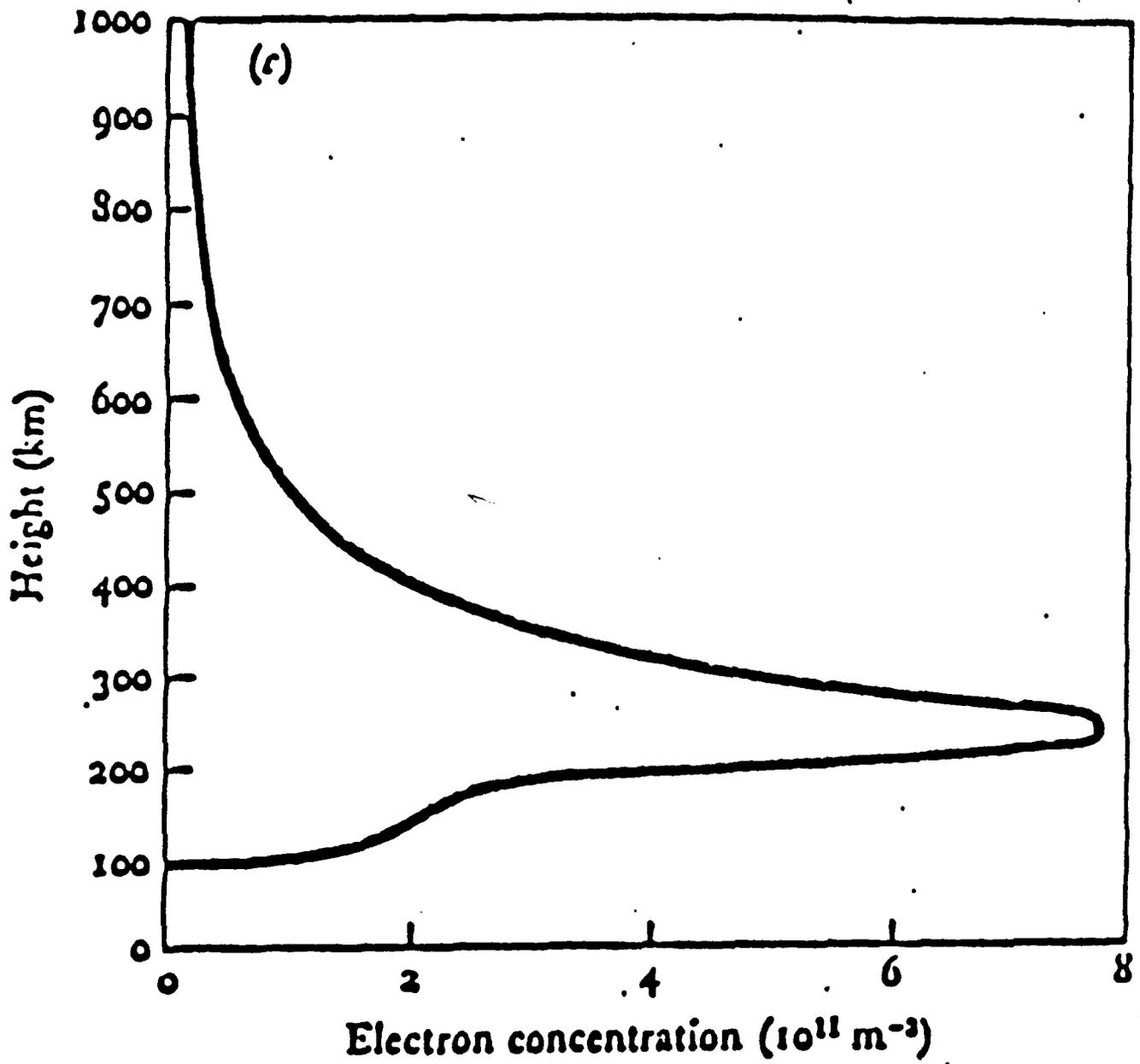
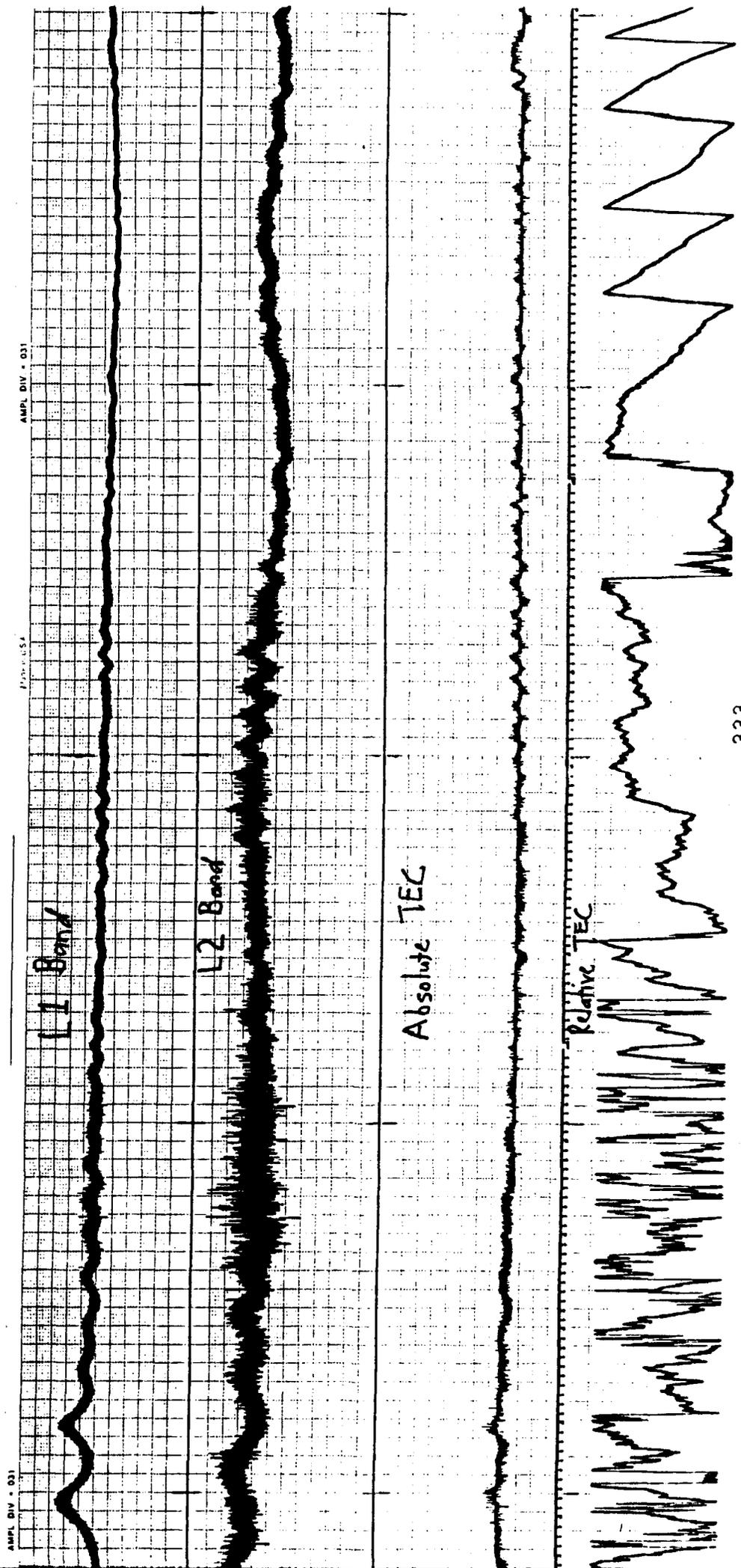


Figure 2: Ionosphere Profile



333

Figure 3: GPS Raw Data From Shetland, UK

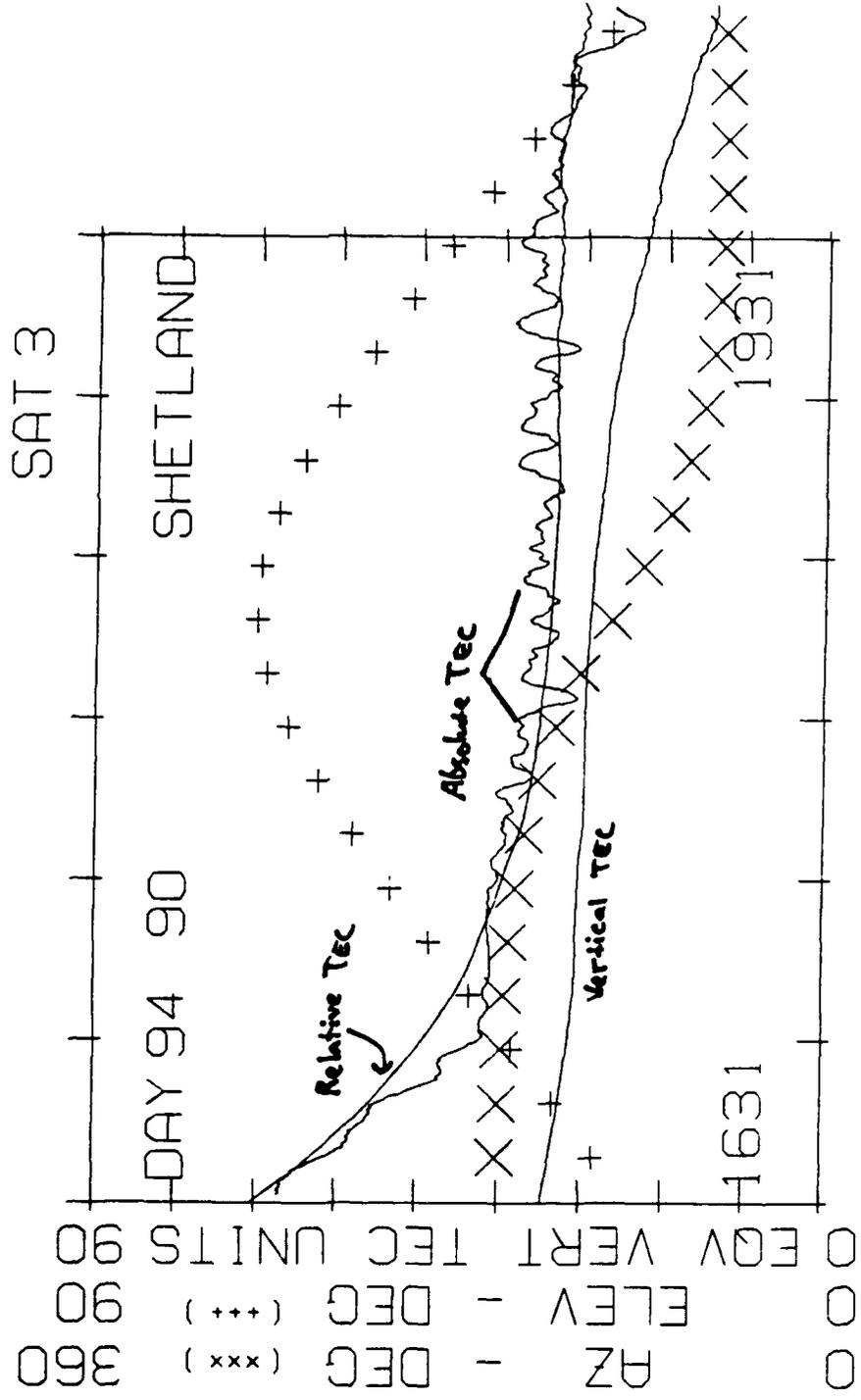
different measures of TEC, Absolute TEC and Relative TEC. Though they measure almost the same thing, they do not appear alike because the scale on the Relative TEC is ten times that of the Absolute TEC scale.

To turn this data into plot form, we use software that processes the raw data and then generates a plot. When I began working the satellite and receiver calibration values that the plotting programs use needed to be adjusted. This is done by generating plots with different calibration values and then comparing the results to see which values should be used. When the best correction values are found, which is a process that is still underway, the rectified plots can then be used to study ionospheric activity.

One type of plot, shown in figure 4, is a pass file. It is simply the graph of a single GPS satellite that passed over Shetland. The three curves on the graph represent Absolute TEC, Relative TEC, and Vertical TEC. The “noisy” curve is Absolute TEC, and the one which tracks it is Relative TEC. The lowest line is Vertical TEC, which is Relative TEC converted to be directly overhead. Because Relative TEC is simply a value of electron content between the satellite and the receiver, as the satellite approaches the horizon and the angle of elevation decreases, this value increases because the line connecting the two bodies is passing through more ionosphere. Vertical TEC takes this into account and computes the electron content at a fixed elevation of 90°. The two other curves on this graph composed of “X’s” and “+’s” map the azimuth and elevation of the satellite respectively.

Another type of plot obtained from the same data is shown in figure 5. This is a 24 hour plot of Vertical TEC of about six satellites. Each satellite pass is also shown with its azimuth and elevation. Note the daily cycle of ionospheric activity show in this plot, as the TEC peaks around early afternoon and is lowest at times with no daylight. A plot which shows the same kind of data as the 24 hour plot but overlays several days of data is called an overplot. An example of an overplot for seven days is provided in figure

PASS FILE: 4



TIME (U.T. - 1/2 HR TICS)

Figure 4: Pass File

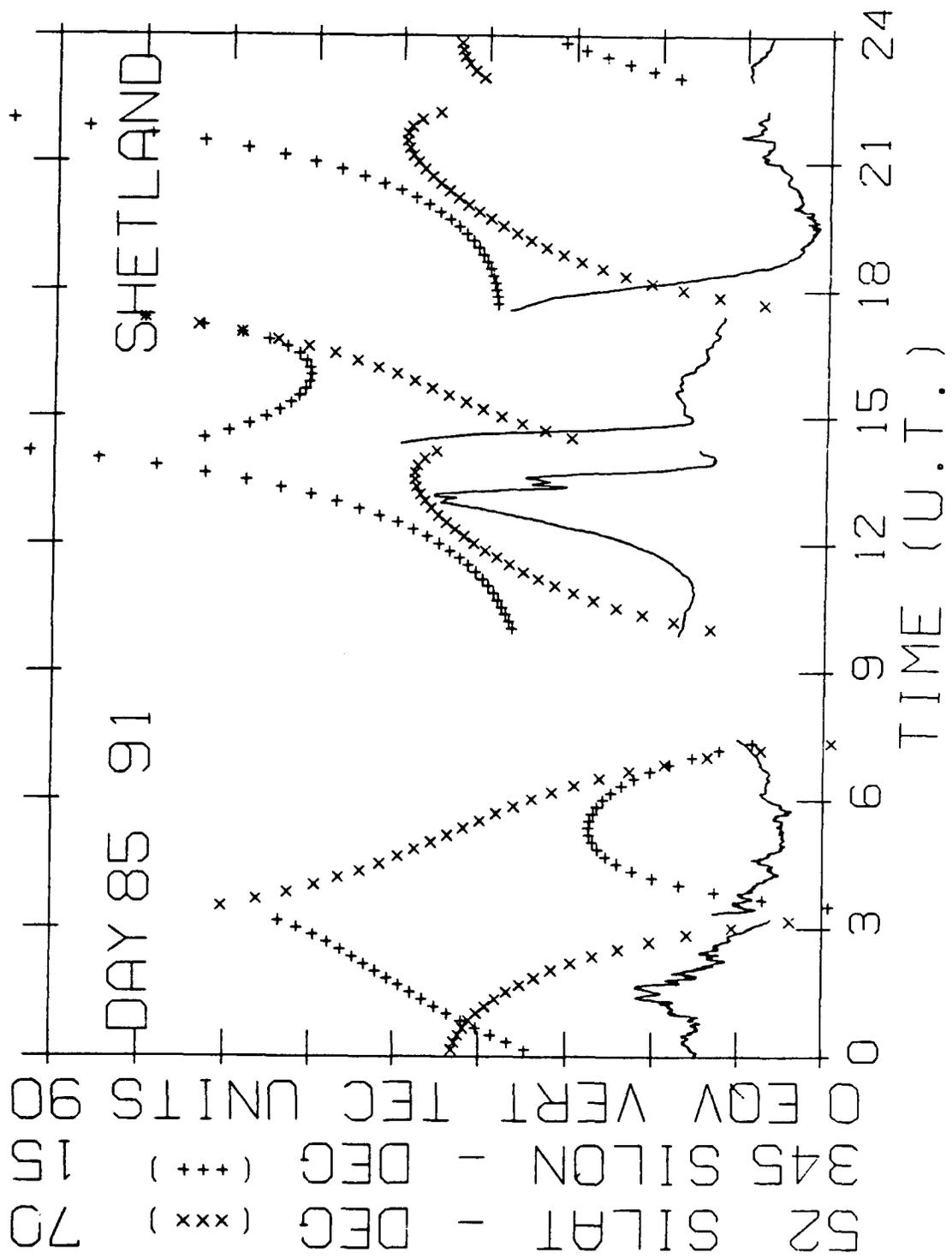


Figure 5: 24-Hour Overplot

6. With an overplot the general variation in TEC can be seen allowing a broader view of data to be seen.

Though calibrating satellite and receiver offset biases by generating plots was one of the major goals of the summer for the people I worked with, most of the work which I performed involved computer programming instead. One project which I worked on with a scientist in the lab was modifying an existing program that allowed data files to be recovered. Occasionally a receiver will zero the data values so that the data will appear to ramp up or down instead of appearing as a smooth curve. Because the program was not working correctly, we had to debug it so that it could join these discontinuities. We also added a feature to the program so that it could interpolate between gaps in the data when there was a succession of zeros for data points. These changes, which are pictured graphically on the computer screen, can then be saved so that the recovered data is ready to be run through the plotting programs.

The project that I spent the most time on, however, was writing a data conversion program. This program converts a RINEX (Receiver Independent Exchange Format) file to regular four-channel data that our plotting programs can handle as input. RINEX is a new data format which is presently being adopted worldwide. The RINEX format is four-channel data, meaning that the receiver which collected it tracks four satellites at a time. Unlike our four channel data files which we process from raw data, the RINEX file contains all four trackers for each type of signal in one file. To make this RINEX data useful to us, our plotting programs must be able to use it as input. However, in its normal form the RINEX files are not compatible with our existing software, so it must be converted to the normal four channel file format. The purpose of the RINEX conversion program is to take the data out of this file and place it in the correct file. Because our four channel data files have only one tracker per file, the program needed to be able to put the correct data into the correct file. This got a little tricky when the RINEX file was not

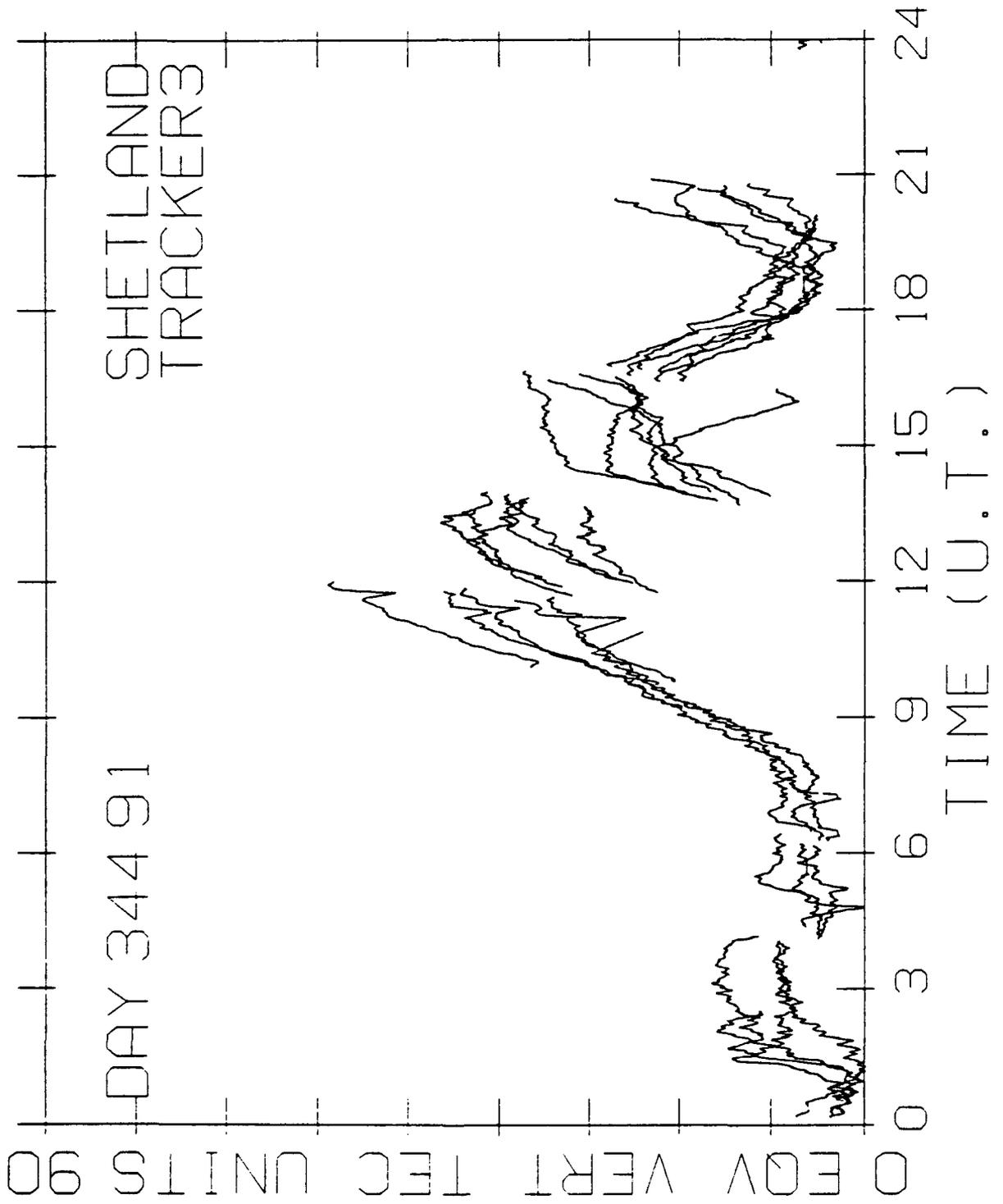


Figure 6: Six Day Overplot

consistent with keeping the data in the same order. The problem was solved, however, and the program was completed.

### Results/Conclusion

From working at the Phillips Laboratory for a second summer, I feel it has been another rewarding experience that has allowed me to become better acquainted with the field of ionospheric research. I have been able to become more familiar with the use of PC's operating under MS-DOS and also received the opportunity to apply my computer programming skills to real world problems. This has allowed me to strengthen my programming and acquire a stronger grasp on the programming language Fortran 77. The benefits of taking part in such a program are extraordinary and will surely aid me as I attend college and choose a course of study. I am grateful to the people at Phillips Laboratory who have treated me as a colleague and allowed me to gain the experience of working in a laboratory.

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**FIBER OPTIC CAMERA PLACEMENT  
IN THE F-16C AIRCRAFT**

**TIMOTHY SANCHEZ-BROWN  
Phillips Laboratory / Electromagnetic Effects**

**684 Mariquita Lane  
Corrales, New Mexico 87048**

**Final Report for:  
Summer Research Program  
Research and Development Laboratories**

**Sponsored by:  
Phillips Laboratory  
Kirtland Air Force Base, Albuquerque, New Mexico**

**July 1992**

**FIBER OPTIC CAMERA PLACEMENT  
IN THE F-16C AIRCRAFT**

**Timothy Sanchez-Brown  
Phillips Laboratory / Electromagnetic Effects**

**Abstract**

**When doing HPM (High Power Microwave) testing and LPM (Low Power Microwave) testing; a problem arises of how to visually monitor equipment inside the cockpit during testing. A camera system is needed to safely accomplish this, but now the problem is to design a system that will not reflect rf and will provide a suitable picture. A fiber optic camera set up will provide the best picture and with it's small dimensions should not cause too much skewing of the microwaves. A support must be used to direct the camera to specific instrumentation within the cockpit. Styrofoam boxes cut in different configurations will prove to be the best all the way around; no rf reflection, lightweight, inexpensive, and durable. Camera and box placement is the only question left. This report goes into detail of set for the instruments; HSI/ADI, THREAT WARNING RECEIVER, and WARNING LIGHT PANEL.**

# FIBER OPTIC CAMERA PLACEMENT IN THE F-16C AIRCRAFT

Timothy Sanchez-Brown

## INTRODUCTION

A major part of electromagnetic effects testing on aircraft is the response of the aircraft at certain points where systems will disrupt or even burn-out. There are instruments in the cockpit that the pilot relies on for safety and navigation. Computers can monitor the data that the instruments are putting out, but at the same time the display might be showing a different story. It would be against safety procedure to have a person in the cockpit as the plane was being radiated. A camera system has been designed to monitor all instruments in the cockpit with minimal interference and rf reflection.

## METHODOLOGY

The fiber optic camera has a low profile and great picture resolution. This combination will allow for numerous possibilities of placement and low rf reflection. The camera system needs a base; a fiberglass set up would be the best. However, the cost would be high and mobility limited. A better option is to use styrofoam blocks as the base. The blocks are inexpensive, durable, lightweight, and don't reflect rf. The blocks are reenforced and velcro placements installed.

## APPARATUS/SET UP

**BEGINS ON FOLLOWING PAGE**

## **A FEW WORDS**

Here are just a few ideas and thoughts that might help your troubleshooting.

If ever the directions I give seem a little unclear; just refer to the diagram. There is a diagram after each set of directions to help with set up.

I have not put down f-stops or focus distances. Those two items will change the most and you must set them by your judgement.

These directions are not carved in stone. If you find a better angle or position, then simply use it! Be sure to check that you are using the correct lens for each position. The lens is labeled on the directions, on the lens box, and on the lens itself.

**GOOD LUCK!!!**

## F-16 COCKPIT CAMERA SYSTEM SET UP

### HSI / A D I SET UP

Camera Type is the EOD FOL CCTV System

Lens Type is the Fujinon TV Lens  
-CF12.5A

1. The only block used in this set up is Block "A". Have the box placed with the letter side up.
2. The box should be placed approximately in the center of the pilot seat directly in front of the HSI/ADI.
3. There should be a small space between the butt of the seat and the lower portion of box. The box should be as parallel to the ground as possible; so a good straight view can be obtained.
4. The fiber optic system should now be set up as it normally would.
5. Conditions may change and needs may change so this information should only be used as a guideline for placement.
6. Special note: Due to some of the positions a crimp in the optic cable may arise. Be sure to remove crimp or cable may be rendered inoperable.

F-16 COCKPIT CAMERA SYSTEM SET UP

NOTE THAT BOX "A"  
SHOULD BE PARALLEL  
TO GROUND. SPACE  
BETWEEN BOX AND SEAT  
MIGHT NEED TO BE STUFFED  
WITH SOMETHING FOR  
STABILITY.

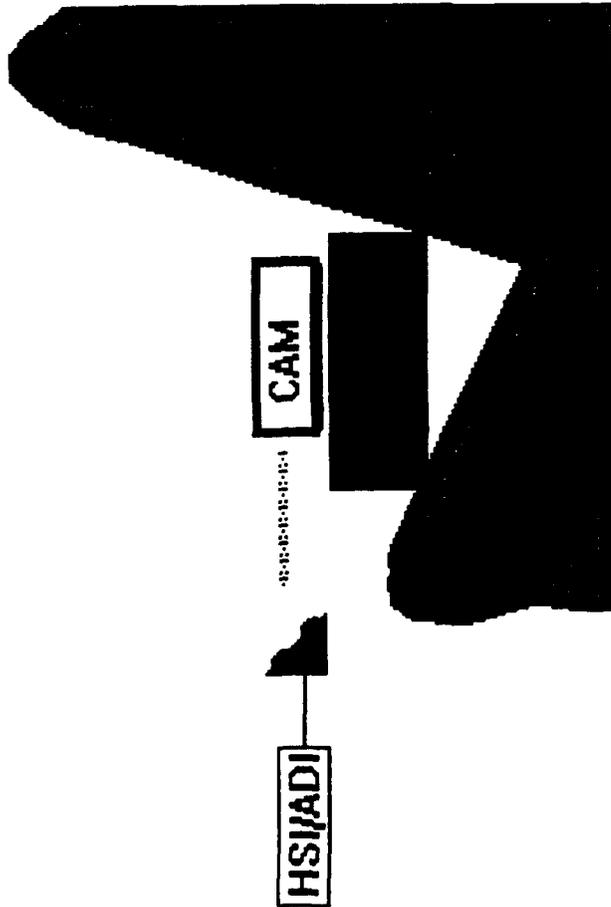


FIGURE A

## F-16 COCKPIT CAMERA SYSTEM SET UP

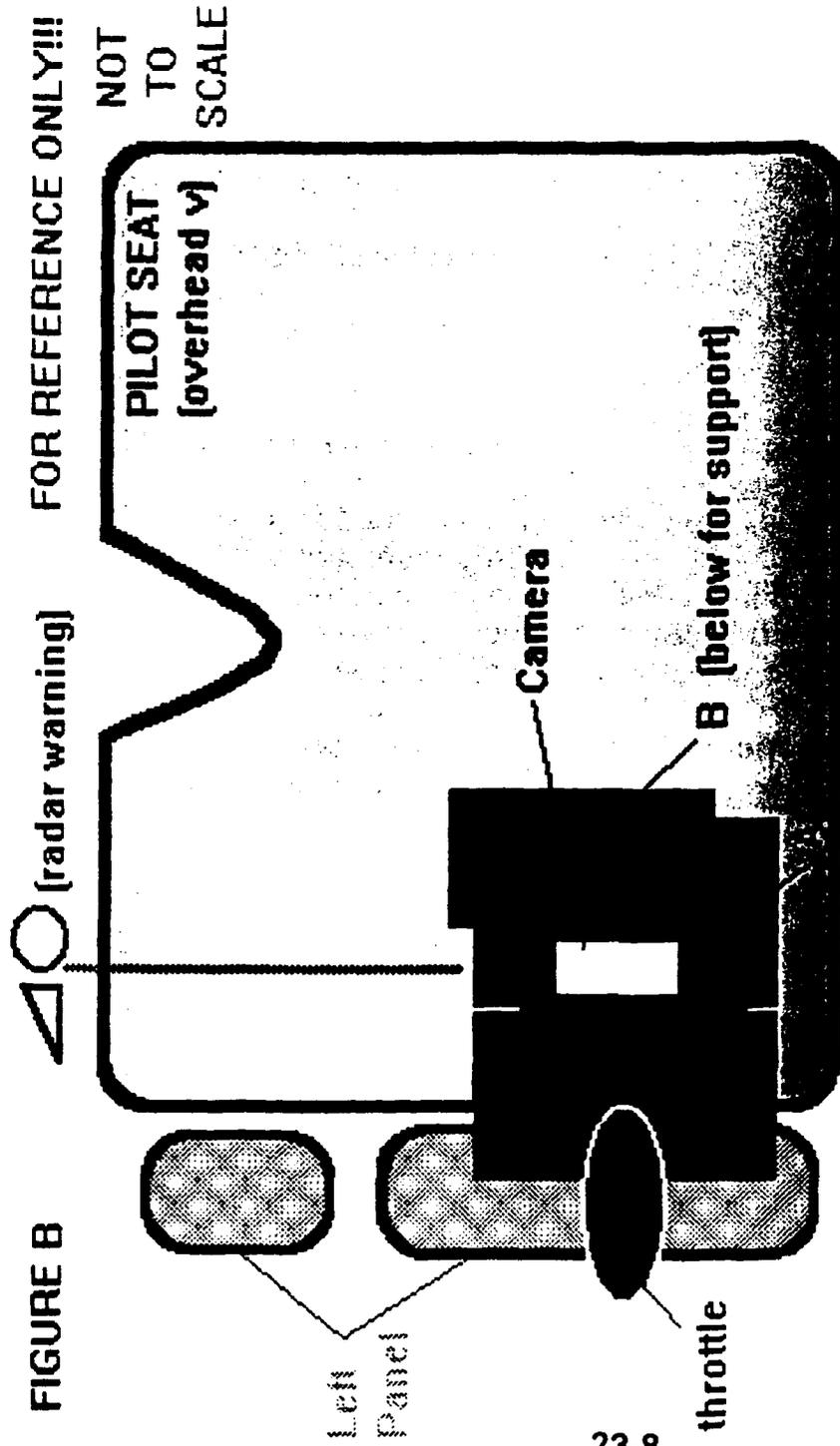
### THREAT WARNING (CONTROLS AND AZIMUTH) SET UP

Camera Type is the EOD FOL CCTV System

Lens Type is the Fujinon TV Lens  
-CF25B

1. The blocks included in this set up are Blocks "A", "B", "C1", and "C2". All blocks are to be placed with the letter sides up.
2. The entire set up will be on the far left of the pilot seat. The general orientation of the set up will be such that it is directed just left of the HUD.
3. Block C1 shall go under the throttle with C2 attached to the right of it. Block A will be in direct visual line of the Threat Warning Receiver; this should place it on top of block C1. Block B will be placed left of A on C2 for support.
4. For clarification refer to diagram on following page.
5. The fiber optic system should now be set up as it normally would.
6. Conditions and needs may change so this information should only be used as a guideline for placement.

# F-16 COCKPIT CAMERA SYSTEM SET UP



FOR REFERENCE ONLY!!!

NOT TO SCALE

FIGURE B

GENERAL PLACEMENT  
ADJUST IF NECESSARY

## F-16 COCKPIT CAMERA SYSTEM SET UP

### CAUTION LIGHT PANEL SET UP

Camera Type is the EOD FOL CCTV System

Lens Type is the Fujinon TV Lens  
-CF25B

1. The only block used in this set up is Block "A" (note that Block "B" might need to be used between the block and the back of the pilot seat for stability).
2. Box A should be placed with letter side up and box B should be placed on side.
3. This set up should be oriented to look at the area just to the left of the control stick.
4. The fiber optic system should now be set up as it normally would.
5. The Caution Light Panel should now be removed from it's space.
  - Unscrew four corner screws.
  - Panel should be gently pulled out and rested on the seat leaning on the upper left corner of the control stick.  
(see diagram on following page for clarification)
6. Conditions and needs may change so this information should only be used as a reference for placement.

# F-16 COCKPIT CAMERA SYSTEM SET UP

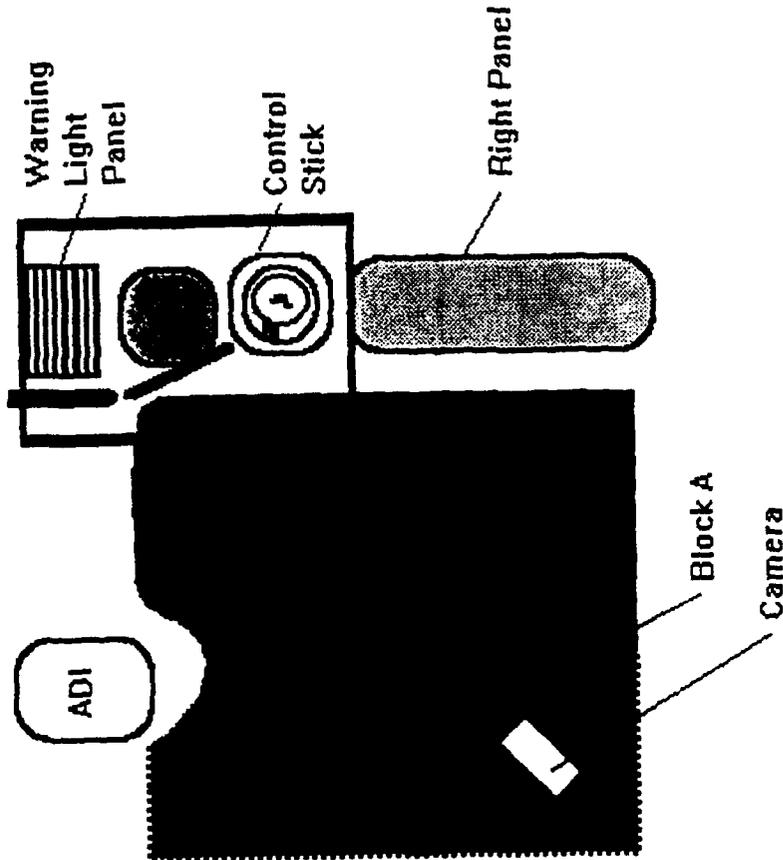


FIGURE C

NOTE THAT SOME OF THE OTHER BLOCKS MIGHT COME IN HANDY FOR STABILITY.

The warning light panel in the insert will be removed and replaced to the upper left hand side of the stick. ( loc. of red bar )

THIS DRAWING IS FOR REFERENCE ONLY!!!! IT IS NOT TO SCALE

A STUDY OF RADIOSONDE DATA  
FOR THE VALIDATION OF ATMOSPHERIC MODELS  
AND FOR USE IN THE CREATION OF AN INVERSION ALGORITHM  
FOR THE FOURIER TRANSFORM SPECTROMETER

Adam Smith  
Summer Research Intern

Final Report for:  
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Phillips Laboratory

Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington, D.C.

September 1992

A STUDY OF RADIOSONDE DATA  
FOR THE VALIDATION OF ATMOSPHERIC MODELS  
AND FOR USE IN THE CREATION OF AN INVERSION ALGORITHM  
FOR THE FOURIER TRANSFORM SPECTROMETER

Adam Smith  
Summer Research Intern  
Phillips Laboratory  
Hanscom Air Force Base

Abstract

During the summer of 1992, several related projects were undertaken by the Electro-Optic Measurements Branch of the Phillips Laboratory. Operating at the Army's Ft. Devens annex in Sudbury, MA, these projects involved such instrumentation as a TPQ-11 weather radar, a .532 and 1.06 micron lidar, various visible and IR cameras, and a Fourier Transform Spectrometer. To help validate and correlate the data gathered by these devices, radiosonde balloons were launched during periods of spectrometer operation, providing temperature and humidity profiles for the immediate area, as well as partial wind speed and direction data. These data have confirmed the MODTRAN atmospheric propagation model, especially in hot, dry conditions. Also, the combination of radiosonde data and measurements from the spectrometer will hopefully lead to an inversion algorithm for producing atmospheric temperature and humidity profiles from spectrometer data.

A STUDY OF RADIOSONDE DATA  
FOR THE VALIDATION OF ATMOSPHERIC MODELS  
AND FOR USE IN THE CREATION OF AN INVERSION ALGORITHM  
FOR THE FOURIER TRANSFORM SPECTROMETER

Adam Smith

INTRODUCTION

The Fourier Transform Spectrometer is a device designed to detect IR radiation from its surroundings, recording these measurements for later analysis by computer. This capability makes it an excellent instrument for studying IR emissions from the earth's atmosphere. The data produced by these measurements are in the form of emission spectra, showing the amount of solar energy absorbed and then re-emitted in the IR range by the atmosphere. This data is usually transformed into a form that may be compared to a standard radiative transfer model such as MODTRAN or FASCODE, which uses radiosonde temperature and humidity profiles to simulate atmospheric emission spectra. However, Dr. J.-M. Theriault, a scientist visiting Phillips Laboratory from the Canadian Defense Research Establishment, Valcartier, hypothesizes that, using a database of measurements from the radiosonde launches, an inversion algorithm could be developed to obtain atmospheric temperature and humidity profiles from spectrometer data. In addition, the correlation of data from the TPQ-11 weather radar and from the lidar with measurements from the spectrometer will support soundings in cloudy or foggy conditions.

## METHODOLOGY

Each day on which measurements were to be taken, several preparatory steps had to be completed. While the spectrometer was being calibrated using two black body IR sources (ambient and controlled warmer temperatures) for reference points, the radiosonde was readied for launch. This involves checking the sonde itself for physical defects and cleaning the contact surfaces of the baroswitch, as well as entering local and initial data into the computer program designed to receive radiosonde data during the flight. At this point, the balloon was filled with helium and attached to the safety parachute and the sonde. The sonde's battery and humidity sensor were connected, and the sonde's transmissions were tuned to the correct frequency for operation. By this time the calibration of the spectrometer would be complete, and measurements could begin. Once the radiosonde and balloon were ready, they were launched. The initial spectrometer readings were begun at this time. This allowed the approximately ninety minutes to two hours of flight time to coincide with the period of measurement by the spectrometer. During this period, the spectrometer alternated between actual data gathering and recalibration to allow for changes in the ambient temperature of the instrument. During the flight, the computer took incoming data from the sonde, displaying plots of pressure, temperature, and humidity, or of wind speed and direction when available (software and hardware difficulties caused the loss or destruction of approximately one half of the wind data).

Later, the radiosonde data were checked for minor errors caused by bad transmissions or occasional glitches in the sonde itself. After these were

corrected, the data could be plotted (FIG. 1) or put into data files for use with MODTRAN. This algorithm simulates spectrometer readings, and one focus of the experiment was the comparison of MODTRAN's output to actual spectrometer readings taken during the radiosonde flight (FIG. 2).

The second goal of the experiment is to create an inversion algorithm to produce radiosonde-like profiles of temperature and humidity from spectrometer data. This method would be widely useful for meteorological purposes as well as for civilian and military aviation, providing accurate temperature and humidity data without the wasteful use of radiosonde balloons or the laser radiation of lidar systems. The spectrometer is relatively compact and inexpensive compared to these systems.

#### RESULTS + CONCLUSION

The simulated spectra generated by MODTRAN from radiosonde data were remarkably similar to the actual spectrometer-produced spectra. In some cases, errors occurred when MODTRAN followed a smoother curve on the radiance versus wavenumber graph (FIG. 2) than was actually indicated by the spectrometer data. However, these errors were small and infrequent, and all in all MODTRAN performed well and accurately, especially in hot, dry conditions.

The inversion algorithm for the conversion of spectrometer measurements to radiosonde-like data was not complete at the time of this report. However, hopes are high for the successful completion of this project, given the high quality of the data already taken. New techniques such as neural networks may

help in the analysis of this problem, which is unsolved to date by anyone. Similar projects in remote sensing of spectra from the atmosphere have already been utilized on meteorological satellites, but these systems have been relatively simple, analyzing at most half a dozen channels, compared to the four thousand of this experiment. These satellites provide temperature and humidity profiles only a few layers deep into the atmosphere, and the thousand-fold increase in the number of channels analysed will provide a correspondingly more complex model of the atmosphere. This increase in the amount of data available to meteorologists and pilots, without the trouble or expense of radiosondes or lidars, could contribute a huge amount to modern meteorological and aeronautical practices.

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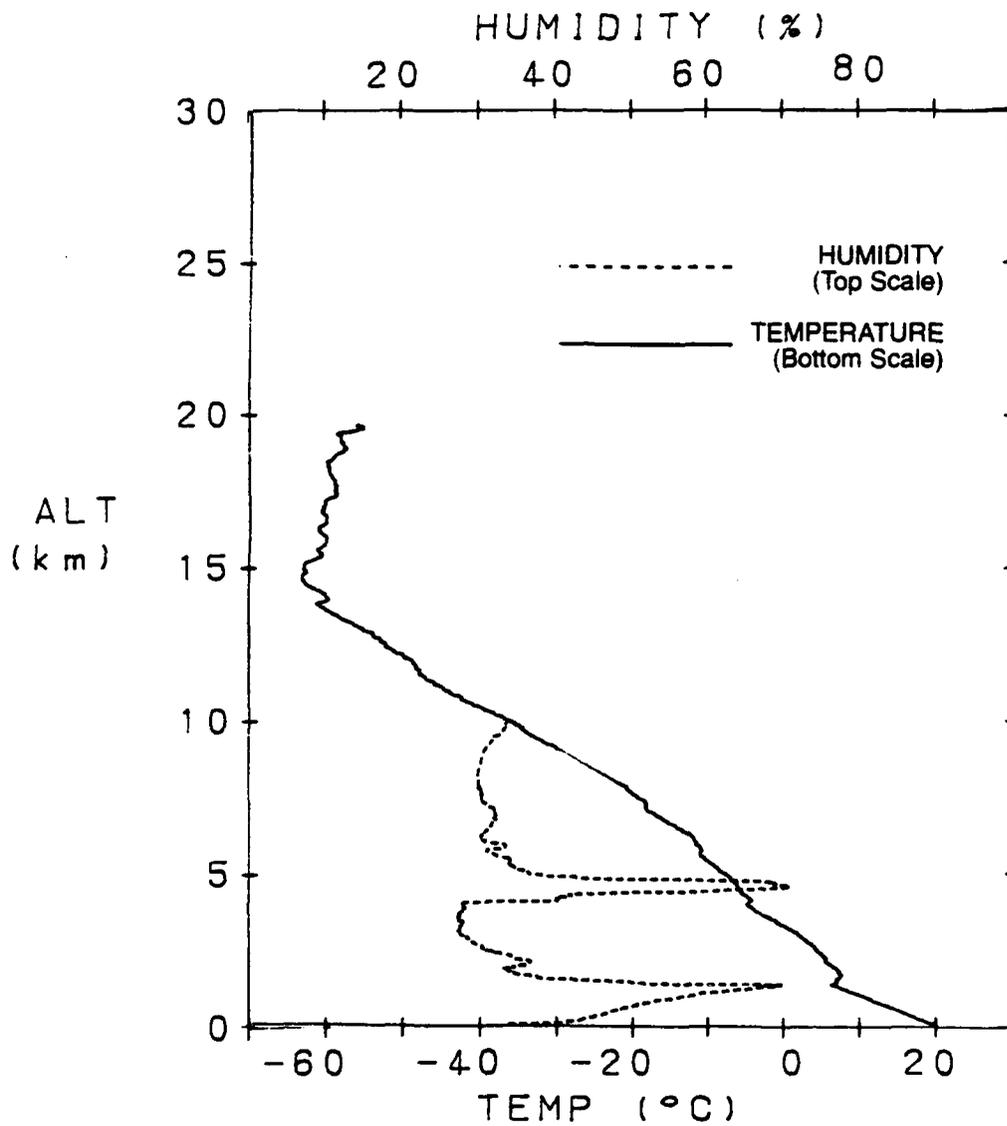


FIGURE 1

# Comparison MODTRAN-MEASURE

Clear Sky

Hot-dry conditions (02 July 92, 1:14)

Sonde Launch 12:55

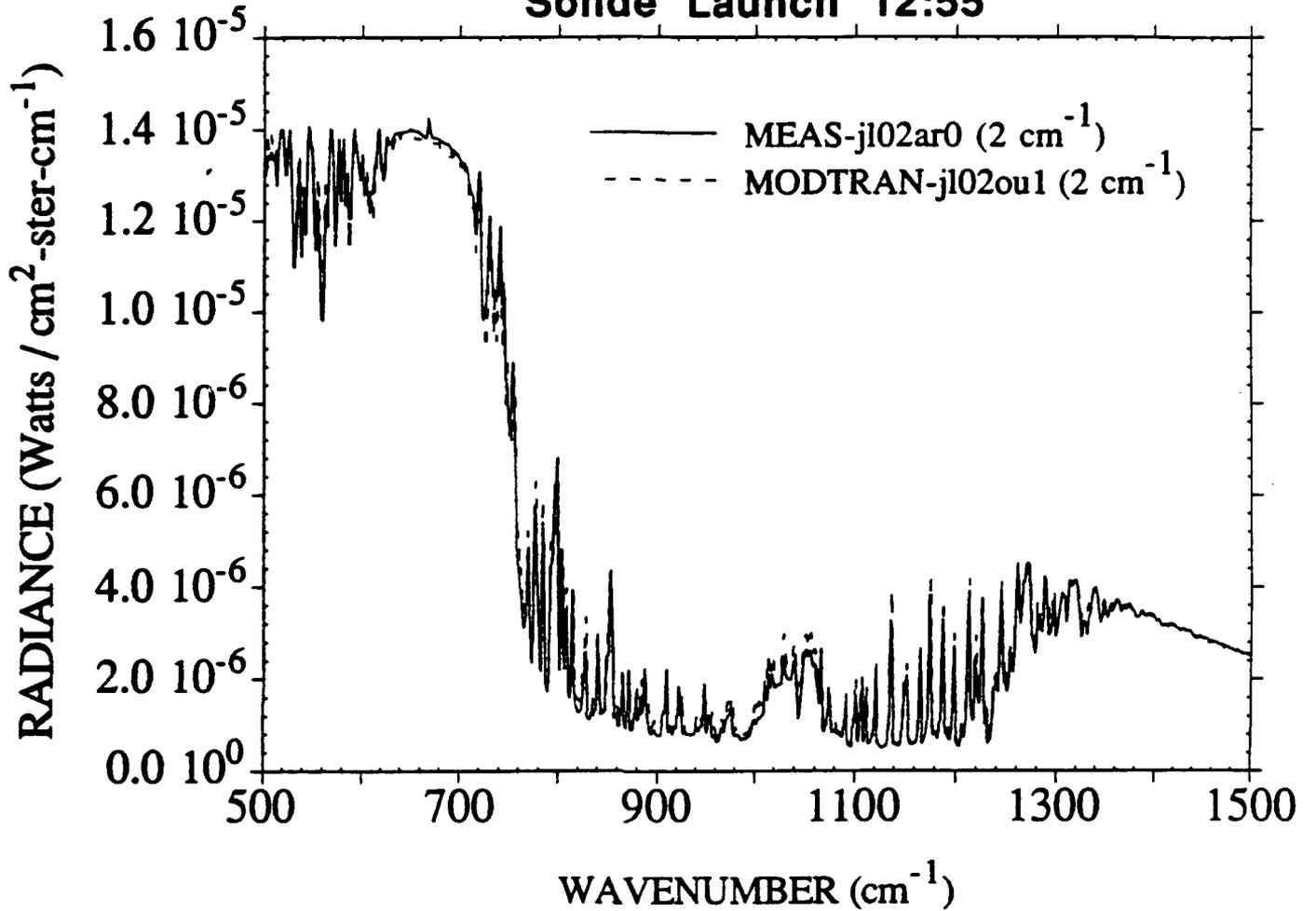


FIGURE 2

**THE DEVELOPMENT OF A NETWORK  
MONITORING PROGRAM**

**Robert N. Tarr  
Student  
La Cueva High School**

**La Cueva High School  
7801 Wilshire  
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**Final Report for:  
Summer Research Program  
Phillips Laboratory  
Kirtland Air Force Base, Albuquerque, NM**

**Sponsored by:  
Air Force Office of Scientific Research  
Bolling Air Force Base, Washington, D.C.**

**August 1992**

## **THE DEVELOPMENT OF A NETWORK MONITORING PROGRAM**

Robert N. Tarr  
Student  
La Cueva High School

### **Abstract**

The previous network monitoring program, PONG, was studied to learn how to contact the other computers on the network; and how to display the results to the screen so that the program would be usable on any machine on the network. A plan was then made for how the new program, Prowler, was to be different from the old program. It was decided, that to keep as much traffic off the network as possible that there would be two programs to Prowler. One program, Prowler\_Main, that would constantly check the network and determine the status of links between different sites; and another program, Prowler, that people would use to display the information found by the program, Prowler\_Main. This was done by having Prowler\_Main write the data that it found to a file. Prowler would then access this data and display it on the users screen.

# THE DEVELOPMENT OF A NETWORK MONITORING PROGRAM

Robert N. Tarr

## INTRODUCTION

The program PONG, written by Paul Zetocha, is used to monitor the status of the network. It was written for the Network Engineering section of the Phillips Laboratory at Kirtland Air Force Base. It displays whether a computer is on-line, if just came on-line, if it is off-line, or if it just went off-line. This program was the basis for my project.

## PROBLEM

The problem with PONG was that everyone who would run the program would slow down the network because they would all be checking the network. This wasn't necessary because everyone would get the same results. This is the reason for the two programs of Prowler that work together. The program Prowler\_Main reads in a list of computers on the network to check. It then checks all of these and writes that data to the file, ErrorList, this file is then read by the program Prowler and the information is then displayed to everyone using that program.

## METHODOLOGY

For this project I used a VT-200 terminal that was connect to a Sun workstation. How the new program was too different from the old program was discussed and written down. Then all of the headings for each function were written out before the actual writing of the code was done. All of the variables that were assumed to be needed were declared and written into

each function. Then the main code was written for the first of the two programs. All of the syntax and basic code errors were debugged and fixed. Then the code for the second program was written. All of the syntax, and basic code errors of this program were then debugged and fixed. Then the two programs started to work together. At this point there was a lot of debugging to be done. First, all problems needed to be pinned down to which program they were in. Then it needed to be determined where in the appropriate program was the problem. After all the debugging was completed and the programs were working together, they were touched up. The documentation was written, and the program was tested.

### RESULTS

The results of rewriting the program were very good. It was a more user-friendly application, including a legend to help identify what each method of display; normal, blinking, underlined, or reverse text; meant about each computer that was being displayed that way. It was also capable of handling more variations in the file NetList, which contains the list of computers to contact, which was a problem in PONG. When PONG checked the LAN links it would check three computers at the other end of the link and compare the results to determine if the link was working correctly or not. If there was only one computer at the other end it would check this computer three times. Prowler handles this case by comparing the building number that is used as the name in NetList. If the numbers are equal then it compares those systems, if not it uses the results it already has and goes on to the next link. This means that it doesn't have to check a single computer multiple times.

### CONCLUSION

In conclusion, I think that this project went very well. I had no complaints about working with the other people. They were happy to take the time to help me if I had a problem with the network, or something that I wasn't used to in the new environment.

If I were to do this project again, without the guidance of my mentor, I don't think that I would change anything that was suggested to me by him.

### RESOURCES

C The complete reference, second edition - Osborne McGraw-Hill

Programmer's Overview Utilities & Libraries - Sun

Mr. Paul Pitz, Network Engineer (PL/SCE)

Mr. Mike Gleicher, Software Engineer (PL/SCS)

Documentation and Software listings of PONG

**DEVELOPING THE VISTA USER'S GUIDE**

**Matthew J. Wick**

**Final Report For:  
AFOSR Summer Research Program, Phillips Laboratory**

**AFOSR Sponsorship**

**August 1992**

## DEVELOPING THE VISTA USER'S GUIDE

Matthew J. Wick

### Abstract

The Phillips Laboratory Management Information System (PLMIS) is being replaced by a renewed system called VISTA. The new system is designed to incorporate personnel's suggestions and further facilitate use of the system. To exploit the potential of the new system, Major John J. Gill and I were asked to write and design a new user's guide to supplement the creation of VISTA.

## DEVELOPING THE VISTA USER'S GUIDE

Matthew J. Wick

### Introduction

Within the past few years, the Phillips Laboratory Management Information System (PLMIS) has proven itself insufficient for practical use. This ineffectiveness, compounded with other recent problems, spawned the development of an updated system capable of regulating all laboratory affairs according to the laboratory's needs. The renewed system, presently named VISTA, will incorporate personnel's suggestions and clarify the duties of each specific user to enable employees to easily fulfill their financial responsibilities. Furthermore, VISTA will prevent problems by utilizing security measures such as passwords, which assure only authorized access, and built-in budgets, which VISTA will not allow the user to exceed. Subsequently, these modifications will increase accuracy, efficiency, and will lessen the aggravation of users at the Phillips Laboratory in the future.

Ameliorating the PLMIS will overcome the principal deficiency of the current system, but after thoroughly exploring the inadequacies of the PLMIS, my mentor, Major John J. Gill, and I concluded that the current user's guide to the PLMIS was another fundamental fault of the current system which required alteration.

The current PLMIS user's guide was intimidating. It consisted of forty-five tedious pages. Explanations were often fragmented and confusing. Further inquiry revealed that, as a result, the current user's guide was rarely read or even consulted. Replacing this insufficient guide became imperative if the laboratory hoped to fully exploit VISTA's potential.

## Methodology

My principal desire in creating a new guide was to produce a manual which would be frequently utilized. Accomplishing this feat required: 1) distinctly defining each specific user's function in a laconic manner, and 2) creating an aesthetically pleasing document enhanced by graphics and text variation.

Engrossed with writing the text, Major Gill and I questioned numerous employees about laboratory procedures. Feedback provided us with a resource of information, from which we extracted general guidelines for each VISTA user to follow. Our next task was expanding these guidelines into clear and concise explanations. Enduring several attempts and revisions, the text eventually evolved into a satisfactory second draft.

Upon completion of the draft, I directed my efforts towards designing the document. After extensively exploring the capabilities of several computer graphics programs, I concluded that Harvard Graphics 3.0 would best serve our purpose. I produced several short sample documents with Harvard Graphics 3.0 to further my preparation for the creation of the VISTA guide. This practice enabled me to familiarize myself with the program and comprehend its vast capabilities. Confident I was prepared, I then concentrated on designing the final draft of the VISTA user's guide.

I divided the guide into five basic sections: the introduction, the system overview for financial management, the system overview for program management, the summary, and the appendices. I then created a background design format for each section. Each page of a division followed this format to maintain uniformity within the five major sections. After several trials and alterations, the formats were acceptable.

The next step was to embody text appropriately. After entering the text for each page, I chose fonts and sizes. I tackled this subtle problem carefully. I recognized the importance of text variation when I initially viewed the current user's guide. The current guide utilized only one type of writing and lacked size or font variation. Hoping to avoid this monotony, I insisted on incorporating text variation in the VISTA user's guide. After producing several variants, I decided upon the best styles for each of the five sections.

The final step was the integration of graphics. The enhancement graphics offered was astounding. By including selected pictorrials, I felt we could easily capture the attention of viewers. Gaining this initial attention was the most important factor in achieving our goal of producing a useful guide. I believe the most piquant graphic in the VISTA user's guide was the stick of dynamite with "PLMIS" written on it. This graphic was uniquely engaging since the personnel of the Phillips Laboratory abhor the current PLMIS. After a probably altering the location of this graphic and others, the guide was nearly complete.

This draft was distributed to numerous individuals. These people offered corrections and alterations, which I implemented into the final VISTA user's guide. With these last changes, the final draft of the VISTA user's guide was completed. Immediately following laboratory approval, preparation for distribution commenced.

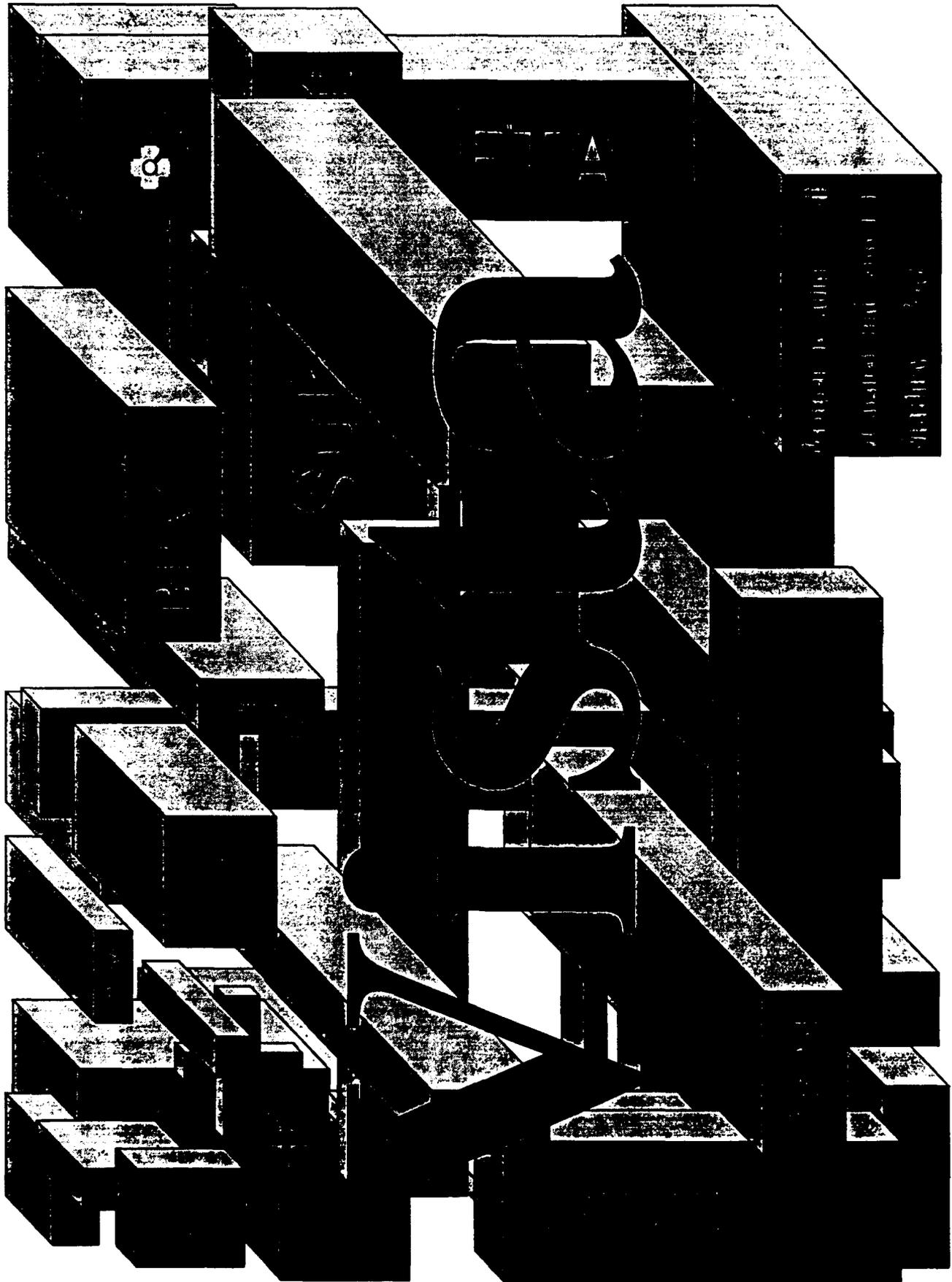
### Conclusion

The VISTA user's guide will augment VISTA's prosperity immensely. Without a completely new guide to facilitate it's use, VISTA's creation would have been futile. The guide, written and designed by John J. Gill and myself, acts as a

supplement which is necessary for the success of VISTA. Without it, VISTA would clearly never achieve it's potential.

1 Atch.

VISTA



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## I. Introduction

## II. System Overview For Financial Management

- a) Program Element Monitor
- b) BPAC Manager
- c) Project Officer

## III. System Overview For Program Management

- a) Thrust Manager
- b) Subthrust Manager
- c) FTA Leader
- d) Project Officer

## IV. Summary

## V. Appendices

- 1) Funds, Designations, and  
Associated Managers
- 2) WS Thrusts, Subthrusts,  
and FTAs



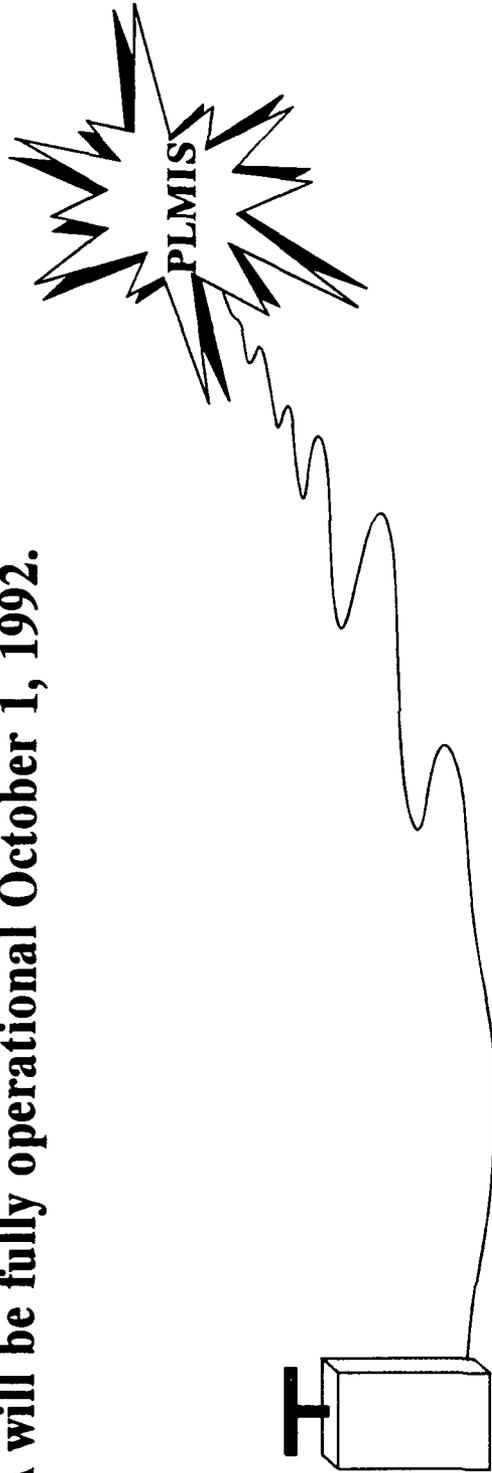
# VISTA

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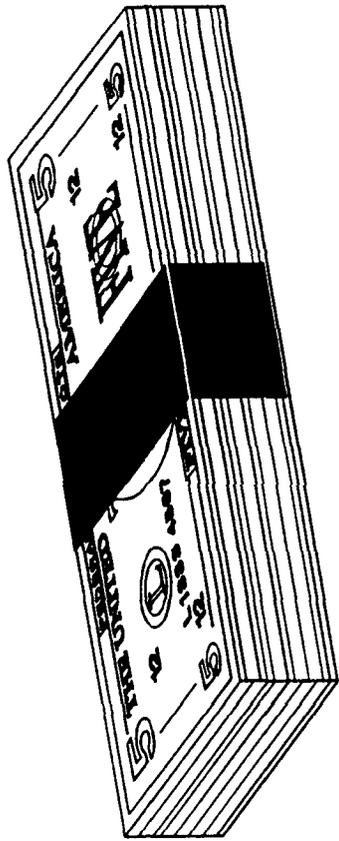
# Introduction

The PLMIS is being updated in order to clarify individual's responsibilities and to incorporate suggestions from Project Officers, Planners, Budget Analysts, and directorate Managers. The updated system, VISTA, is being designed to efficiently and accurately administrate laboratory funding. In contrast to the PLMIS, VISTA will have built-in security to restrict the ability to view and/or alter information to only those individuals who are authorized. Likewise, ceilings will be included on \$ amounts to prevent the allocation of more money than what is authorized. This guide provides an overview of VISTA's structure and individual's responsibilities. Further information will be made available as the system matures. Please phone Computational Services (SC) Customer Support @ 6-4357 (6-HELP) if you have any questions, comments, or suggestions.

**VISTA will be fully operational October 1, 1992.**



# System Overview For Financial Management



Laboratory

Program Element Monitor

Laboratory

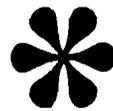
Budget Program Activity

Directorate

Code Manager

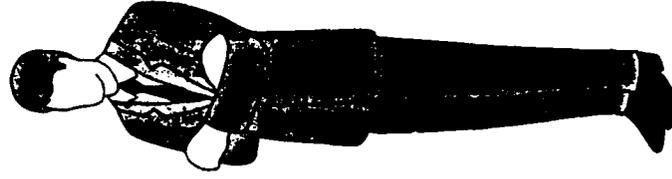
Directorate

Project Officer

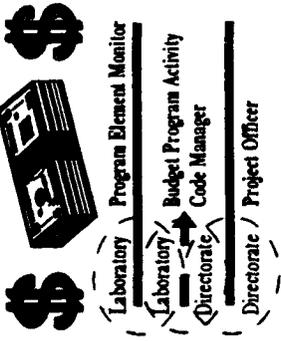


# \* A Note About Budget Program Activity Code (BPAC) Managers

Budget Program Activity Code (BPAC) Managers exist at both the laboratory and directorate levels. A laboratory BPAC Manager is designated when the funds for a given BPAC span two or more directorates (eg., 8809). In this case, the laboratory BPAC Manager allocates a portion of the total BPAC funds to each of the directorate BPAC Managers. The directorate BPAC Managers then allocate \$'s directly to JONs. If the \$'s for a BPAC reside entirely within one directorate, then the laboratory and directorate BPAC Managers are one and the same.

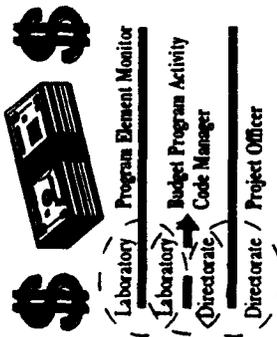


**Synopsis:** The Laboratory BPAC Manager allocates \$'s to the directorate BPAC Manager who, in turn, allocates \$'s to the specific JONs.



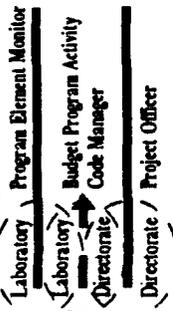
# Program Element Monitor (PEM)

- Program Element Monitors (PEMs) allocate money to BPAC Managers. The designated amount of money apportioned to a BPAC Manager constitutes a BPAC total, which is currently tallied manually. In contrast, VISTA (operational as of October 1, 1992) will automatically tally the BPAC total to insure the BPAC total (and subsequently the Program Element total) cannot be exceeded.
- VISTA will enable the Program Element Monitor (PEM) to enter their assigned Program Element (PE) and view/alter only eligible BPACs. Therefore, the PEM will only be able to allocate money to appropriate BPACs.
- Only the Program Element Monitor (PEM) can modify the BPAC totals. BPAC Managers must contact their PEM to have funds reallocated.
- The Term at HQ AFMC means Program Element Manager which is different than the local definition of a PEM.



# Budget Program Activity Code (BPAC) Manager

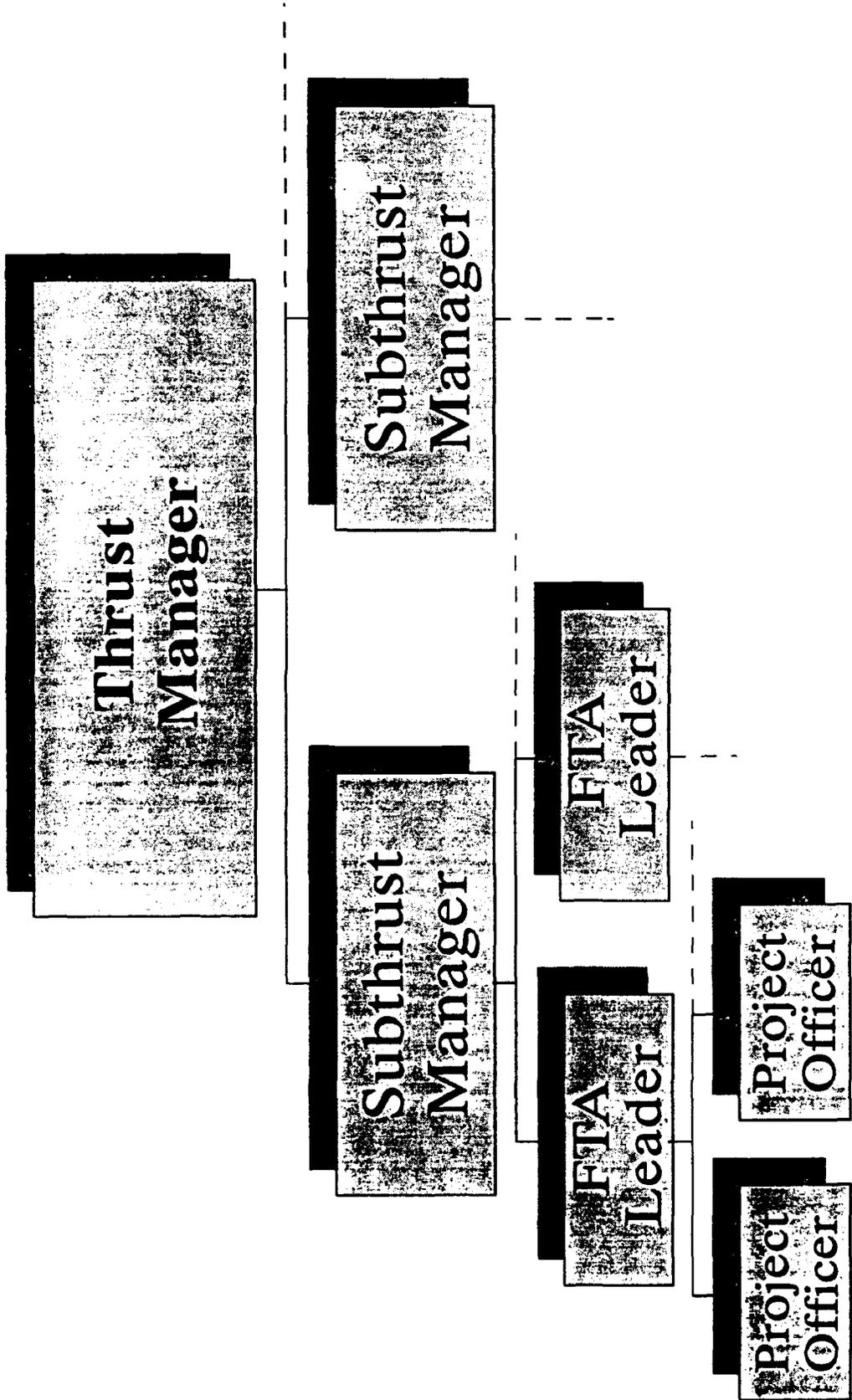
- Directorate Budget Program Activity Code (BPAC) Managers allocate money to specific JONs with the guidance and concurrence of the Focused Technology Area (FTA) Leader. The designated amount of money apportioned to a JON constitutes a JON total. VISTA (operational as of October 1, 1992) will tally the JON total automatically to insure the JON total (and subsequently the BPAC total) is not exceeded.
- VISTA will enable Budget Program Activity Code (BPAC) Managers to enter their assigned BPAC and view/alter/create/delete all directorate JONs within the limitation of the total BPAC funding.
- Only the BPAC Manager can modify the JON totals. Project Officers must contact their BPAC Manager to have funds reallocated.

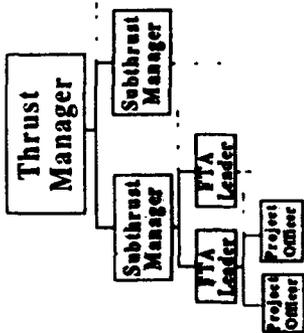


# Project Officer (PO)

- Project Officers (POs) receive funding from the directorate BPAC Manager. The allotted money resides in a "primary" JON. The Project Officer can spend money directly from the primary JON or establish "contract" JONs, or secondary JONs. The sum of money in the primary and contract JONs cannot exceed the amount of money originally allocated to the primary JON.
- The Project Officer is responsible for the creation, management, and execution of the Spend Plan. Requests for additional funding should be referred to the directorate BPAC manager. Likewise, the PO should promptly notify the BPAC Manager if the allocated funds cannot be obligated in a timely manner.

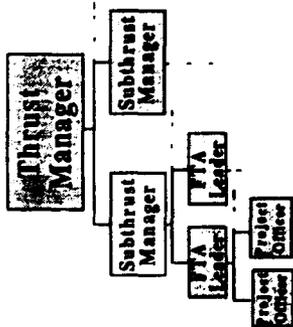
# System Overview For Program Management





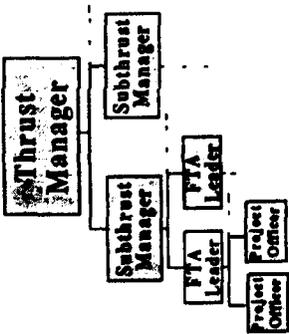
# Thrust Manager

- The Thrust Manager is responsible for giving programmatic direction to the Thrust. The Thrust Manager serves to integrate the accomplishments under the Thrust into the operational Air Force as well well as guide Thrust activities to fulfill future Air Force needs.
- The Thrust manager works closely with one or more Program Element Monitors to insure that an appropriate level of funding is applied to the Thrust for the accomplishment of its objectives.
- The Thrust Manager tracks thrust objectives to meet the Program Management Directive (PMD).



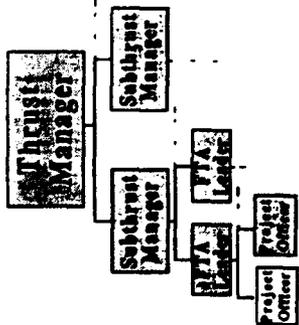
# Subthrust Manager

- The Subthrust Manager provides refined direction to the FTA Leaders based on the programmatic and technical guidance from the Thrust Manager. The Subthrust Manager works directly for the Thrust Manager to accomplish individual Thrust objectives.
- The Subthrust manager works closely with one or more directorate BPAC Managers to insure that sufficient funding is applied to individual projects in an effective manner to permit the accomplishment of the projected goals.



# Focused Technology Area (FTA) Leader

- The Focused Technology Area (FTA) Leader takes direction from the Subthrust Manager and guides the technical activities of the Project Officers towards the accomplishment of the Subthrust objectives.
- The Focused Technology Area (FTA) Leader works closely with the Subthrust Manager and directorate BPAC Manager to insure that the FTA technical objectives are being fulfilled in an appropriate and timely manner.



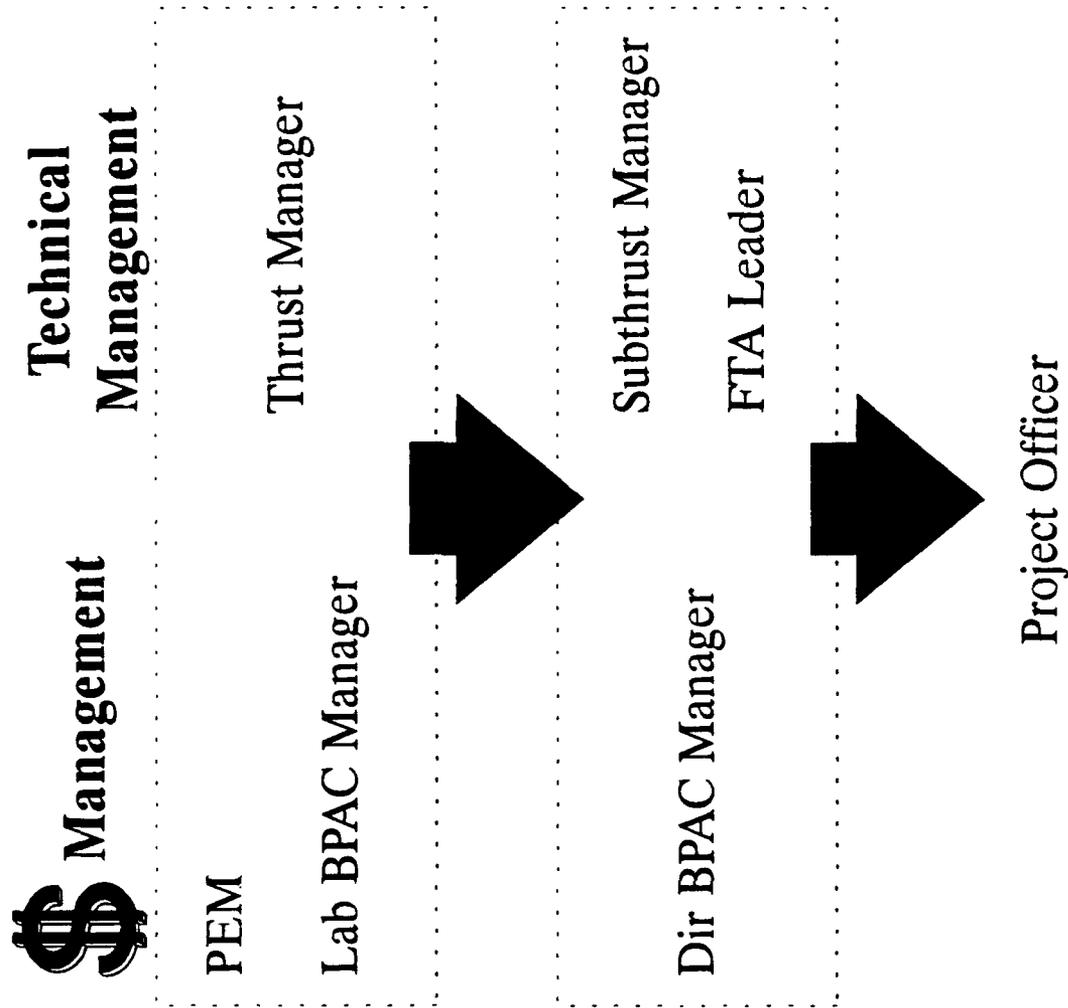
# Project Officer (PO)

- The Project Officer (PO) is responsible for accomplishing individual work units (primary JONs) and managing all contract JONs established using primary JON funds under the guidance of the FTA Leader. The Project Officer will sometimes receive direction from the Subthrust Manager.
- The Project Officer is uniquely responsible for the overall success and daily management of all technical activities and funds control within the scope of the primary JON.

# Summary

This document outlines the technical and financial responsibilities of specific individuals. These roles have been provided under the broad scope of the laboratory's new management system, VISTA. As the system evolves, detailed supplementary documents will be developed which explore and address specific issues regarding how to input and extract management information from VISTA in a manner most beneficial to the specific user.

## VISTA



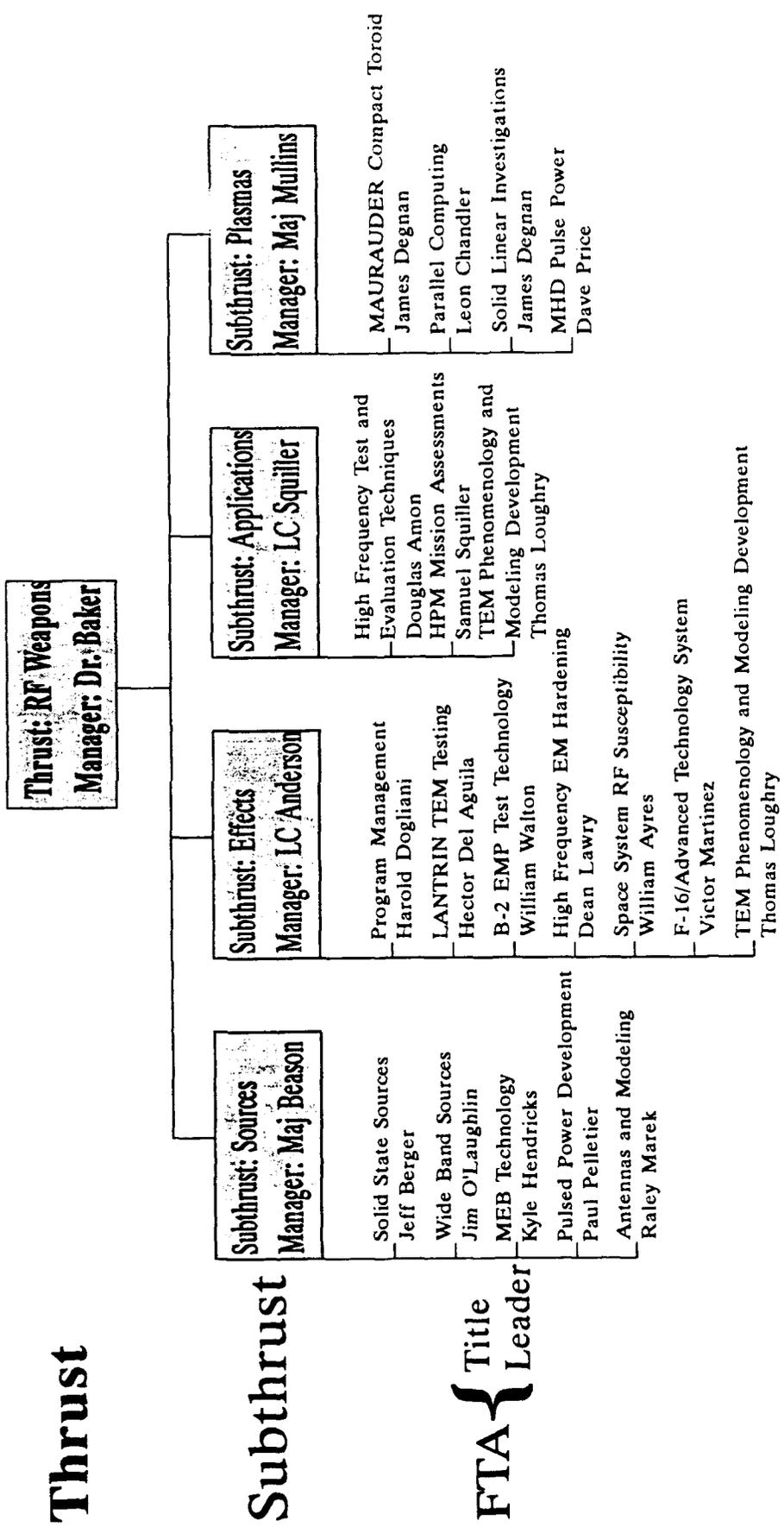
# Appendix 1

Funds, Designations, and associated Managers

PE	PEM	BPAC	Manager
61101F	Dick Keppler	612300	AFOSR Principal Investigators
62101F	Rene Cormier	617601	Charlie Pike
63410F	Gale Nelson	622822	Charlie Pike
63605F	Lance Boucher	623152	Bill Baker
		623277	Bill Baker
64711F	Paula Keintz	632485	Bill Prather
		633763	Bill Prather, Al Sharp, Buddy Walton
		661209	Doug Amon, Mark Stocking
62601F	Craig Hammond	612218	Sam Squiller (with Hank Happ)
		615797	Bill Baker (with Bill Mullins)
		618809	Hank Happ

# Appendix 2

## WS Thrusts, Subthrusters, and FTA's



# Appendix 2

## WS Thrusts, Subthrusts, and FTA's

**Thrust**

**Thrust: Space System Survivability**  
**Manager: Mr. Sharp (acting)**

**Subthrust**

**Subthrust: Satellite Assessment**  
**Manager: Lt Col Johnson**

**Subthrust: Survivability Technologies**  
**Manager: Dr. Sharp**

**FTA** { **Title**  
**Leader**

Satellite Assessment Center Core Lethality	Hank Happ
Signature and Image Simulation	Laddie Marin
Laser Vulnerability Experiments	Jorge Beraun
Space System RF Susceptibility	William Ayres
ATP Performance Simulation	David Mikolajczak
Satellite Materials Properties Database	William DeVault

Space Debris Survivability	Albert Reinhardt
Payload Assessment and Environmental Interaction	Charlie Pike
Space System RF Susceptibility	William Ayres
Spacecraft Survivability Technology	Charles Aeby
Aircraft Shelters (Norway)	Michael Ulshafer
Customer Support In Shock Physics	Michael Ulshafer