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US Army Corps of Engineers
Topographic Engineering Center

Hyperspectral Image Exploitation SBIR Phase II Final Report

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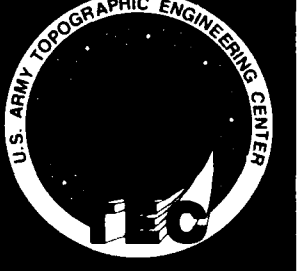

Prepared for:
U.S. Army Corps of Engineers
Topographic Engineering Center
Fort Belvoir, Virginia 22060-5546

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1991	Final Report Oct. 1, 1989 - Oct. 31, 1991

4. TITLE AND SUBTITLE
Hyperspectral Image Exploitation
SBIR Phase II Final Report

5. FUNDING NUMBERS
DACA72-89-C-0018

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

SETS Technology, Inc.
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Topographic Engineering Center
Fort Belvoir, VA 22060-5546

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TEC-0015

11. SUPPLEMENTARY NOTES
Effective 1 October 1991, the U.S. Army Engineer Topographic Laboratories (ETL) became the U.S. Army Topographic Engineering Center (TEC).

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The primary goal of the Hyperspectral Image Exploitation project is the development of a prototype software system for the processing and analyzing of hyperspectral data sets. This software system will be used by the Topographic Engineering Center, (TEC) to help evaluate the field of Hyperspectral Remote Sensing in general, and computer-based, hyperspectral analysis techniques in particular. The primary software system being developed under this project is called the Hyperspectral Image Cube Processing System, or HIPS. HIPS is being developed on Sun Microsystems workstations, and utilizes a state of the art, window-based graphical user interface for user input and the display of images, graphs, tabular data, and other system output.

14. SUBJECT TERMS
Hyperspectral, Spectroscopy, Computer Image Processing, Remote Sensing

15. NUMBER OF PAGES
42

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

CONTENTS

TITLE	PAGE

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NTIS CRA&I ☑
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By
Distribution /
Availability Codes
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PREFACE

This report, the Final Technical Report, combines two technical reports previously entitled Interim Technical Report, September 30, 1990 and Final Technical Report, October 31, 1991. The Interim Technical Report, summarized technical activity for the period October 1, 1989 through September 30, 1990. The Final Technical Report, October 31, 1991, summarized technical activity for the period October 1, 1990 through October 31, 1991.

In order to span the HIPS development period, from September 30, 1990 through October 31, 1991, the two partial reports have been incorporated under one cover. Part 1 of this Final Technical Report, incorporates the Interim Technical Report and Part 2 incorporates the Final Technical Report. The only appendix to the previous reports included in this report is Appendix A, HIPS Development Plan, April 1991, to the Final Technical Report, October 31, 1991. All appendices to the Interim Technical Report are considered to have been superseded by Appendix A to the Final Technical Report, October 31, 1991; the HIPS™ Software Description.

This report was prepared under Contract DACA72-89-C-0018 for the U.S. Army Topographic Engineering Center, Fort Belvoir, Virginia 22060-5546 by SETS Technology, Inc., Mililani, HI 96789. The Contracting Officer's Representative was Sam Barr.

PART 1

Interim Technical Report

HYPERSPECTRAL IMAGE EXPLOITATION

September 30, 1990

CONTENTS

*Appendices A through D from the Interim Technical Report are superseded by Appendix A, "HIPS Development Plan," Final Technical Report, page 26.

Section 1: Executive Summary

This report summarizes the activities of SETS, Inc. under the Hyperspectral Image Exploitation project (Contract DACA72-89-C-0018) over the first year of the contract's two year term. This project began on October 1, 1989, and will terminate on September 30, 1991. This *Interim Technical Report* covers the period October 1, 1989 through September 30, 1990.

The primary goal of the Hyperspectral Image Exploitation project is the development of a prototype software system for the processing and analyzing of hyperspectral data sets. This software system will be used by ETL to help evaluate the field of Hyperspectral Remote Sensing in general, and computer-based, hyperspectral analysis techniques in particular.

The primary software system being developed under this project is called the Hyperspectral Image Cube Processing System, or HIPS. HIPS is being developed on Sun Microsystems workstations, and utilizes a state of the art, window-based graphical user interface for user input and the display of images, graphs, tabular data, and other system output.

In addition to the development of HIPS, the first year of this project has involved the development of several other software packages that were not deliverables under this contract, and the delivery and installation of these software packages on the customer's computers. The purpose of these additional software packages has been to provide the customer with an interim hyperspectral analysis capability while HIPS is being developed, and to provide SETS with feedback from the customer on the behavior and capabilities of hyperspectral analysis systems, so that the design and implementation of HIPS could be improved.

HIPS is being developed in four partially overlapping phases. Phase 1 involves the design and specification of HIPS. Phase 2 involves the building of the "infrastructure" of HIPS. Phase 3 involves the development of the "functional toolkit" of HIPS. And Phase 4 involves the implementation of advanced hyperspectral processing techniques. These phases are described in detail in the *HIPS Development Plan* (Appendix A).

During the first year of this project, most effort was expended on the first two phases of HIPS development. The design process is now about ninety percent complete. Most of the remaining design work is associated with Phase 4. The infrastructure is now about seventy percent complete and will be finished in the early part of the second year. The development of the functional toolkit and advanced processing techniques will be carried out in the second year of the project.

The overall development of HIPS is proceeding according to the *HIPS Development Plan* and is essentially on-track. The completion of the infrastucture of HIPS has lagged somewhat over the last two months due to problems with the SETS' workstation used for this software development project. This workstation is now fully back on line, and development is expected to proceed rapidly during the first quarter of the second year.

The level of effort expended on this project was slow at the start but is not back on track. Spending at slightly over the originally projected rate is anticipated for the remainder of the project.

Section 2: Activities and Progress

This section gives an overview of the various activities that have been conducted in the task areas of this project. The first sections detail the general administrative activities involved in initiating the project, the variety of meetings that have been held between the customer and SETS personnel, software deliveries that have already been made to the customer, and sofrware design activities. The last fifteen sections describe progress in the fifteen individual task areas that were delineated in the *HIPS Development Plan* in May 1990 (See Appendix A).

Administrative Activities

This task area involves the establishment of project management and accounting mechanisms for performing the statement of work and monitoring work progress. Most of the activities in this area were performed in the first two months of the contract period.

In October 1989 when the contract began, the contract was reviewed by SETS personnel to establish approximate time lines as well as deliverable schedules. A significant amount of communications took place with the customer to assure that contractor and customer expectations matched.

Also in October 1989 a reporting and accounting system was set up. The accounting system provides the Principle Investigator and Project Manager with timely reports on expenditures, so that costs can be controlled and project tracking can be conducted. The initial format of the monthly reports was also established, with four sections containing a summary, description of work performed, schedule of progress, and a budget analysis.

In October 1989 the initial configuration of the technical staff was established for this project. Tom Lundeen was assigned as Principle Investigator and Project Manager, Bernie Simmons was assigned as Project Administrator, Pamela Blake was assigned Technical Advisor and Science Manager, and John Lindelow was assigned as Software Manager

Finally, in October and November of 1989, the original proposal submitted by SETS, Inc. to the customer was reviewed to determine if any recent technical advances had impacted the proposed system. In particular, changes in computer hardware and software technology were examined for possible impact. It was decided from this review that the Sun Sparc Station was still the best available development platform, and that the X-Windows system was the best available windowing environment. Uncertainty regarding an appropriate X-Windows programming toolkit prevailed, however. (For more information, see the Task 6 description below.

Project Reviews and Other Meetings

During the first year of this project, SETS hosted several formal and informal project reviews at SETS' facilities, which were attended by the customer's COTR. SETS personnel also met with the COTR and other ETL personnel at the cutomer's site on several occassions. In addition, SETS' senior programmer, Juliana Lo, attended Xhibition '90 to learn more about the

programming techniques and tools being used to develop HIPS. These meetings are detailed as follows.

December 1989: On December 4 and 5, 1989, a general project review was held at SETS' facilities, with the customer's COTR attending. Discussion focused on the current status of the project, the look and feel of the hyperspectral data processing system being developed, the customer's views on the expectations and anticipated use of the system, and the goals of the project for the next several months. It was reiterated that the major goal of the customer is the development of a hyperspectral data processing system for the purpose of evaluating the field of hyperspectral remote sensing for the identification and discrimination of various targets within a scene. During this month, the customer's COTR was trained in the use and capabilities of the CHAPS system, and SETS personnel received valuable feedback on the operation and ease of use of this system.

March 1990: On March 22, a general project review was held at SETS' facilities, with the customer's COTR attending. The current status of the project was presented, along with plans for the development of the software system. A special presentation on the X Windows system was given to the COTR by John Lindelow and Tom Lundeen. The set of viewgraphs presented at this meeting can be found in the March 1990 monthly report. The COTR was also at SETS on March 23 and March 26-8, in conjunction with the project review of another project. During this time, extensive discusions between the COTR and SETS personnel on the project were held.

May 1990: Juliana Lo attended the Xhibition '90 conference in San Jose, California. She studied the state of the art in X-windows based GUI's, and identified several possible GUI programming utilities that may be useful in developeing HIPS.

June 1990: On June 20 and 21, the customer's COTR visited SETS and held wide-ranging discussions with a variety of SETS personnel. Topics included project status, project management, progress on HIPS I/O, the HIPS Graphical User Interface, Xhibition '90, the HIPS spectral library interface, HIPS functions and algorithms, and other topics. The customer's COTR also received demonstrations and training in the use of *Hyperview*, a prototype of HIPS, and *Imagetool* (see below).

July 1990: On July 25 and 26, Tom Lundeen and Juliana Lo traveled to the customer's site. They installed a demonstration version of HIPS on the customer's Sun 3/160, reviewed the customer's facilities, and discussed with the COTR the design and implementation of HIPS.

August 1990: In late August, Pamela Blake traveled to the customer's site, installed the LOWTRAN atmospheric modeling program, and held extensive discussions with the COTR on the use of LOWTRAN.

September 1990: On September 24-26, the customer's COTR visited SETS and again held wide-ranging discussions with SETS personnel on a variety of topics related to the development of HIPS.

Software Deliveries

During the first year of this contract, SETS delivered, installed, and maintained several software packages on the customer's Sun workstations, and provided training to the customer in the use of these packages. All of these software systems, except LOWTRAN and the Xview Library, were developed by SETS. None of these systems were formal deliverables under this contract. They were delivered to the customer so that: 1) The customer could have an interim hyperspectral analysis capability while HIPS was being developed; and 2) The customer could provide SETS with feedback on the behavior and capabilities of hyperspectral analysis systems, so that the design and implementation of HIPS could be improved.

CHAPS. In Phase I of this SBIR contract, the CHAPS software system was utilized as a prototype of hyperspectral processing systems. Development of CHAPS continued during the first year of the current contract (Phase II of SBIR), in order to provide the customer with an evaluation system while the first version of HIPS was being prepared. The CHAPS system was maintained on the customer's Sun 3/160 computer system during the first year of the contract. In addition, the *CHAPS User's Manual* was updated in order to better reflect new developments.

Imagetool. SETS developed and delivered to the customer the *Imagetool* software system. *Imagetool* is a highly interactive, multi-purpose image viewing tool, based on SunView. *Imagetool* was delivered to the customer on a magnetic cartridge tape in May of 1990.

Hyperview. In addition to CHAPS and Imagetool, SETS developed and delivered to the customer the *Hyperview* software system. *Hyperview* is a prototype 3D analysis tool, based on SunView, that allows for the interactive viewing and analysis of hyperspectral cubes. *Hyperview* allows the user to scan through a cube like a movie (i.e. frame by frame), extract spectrum for display, and expand a section of the cube for better viewing of the scene. *Hyperview* was delivered to the customer on a magnetic cartridge tape in May of 1990.

Xview Toolkit Library. In July 1990, SETS personnel traveled to the customer's site and installed the *Xview Toolkit Library* on the Sun 3/160 at the customer's site. The installation of this toolkit was a prerequisite for the installation of the *Demonstration Version of HIPS.*

Demonstration Version of HIPS. In July 1990, SETS personnel installed a *Demonstration Version of HIPS.* This demonstration version utilized the HIPS graphical user interface (GUI), performed input/output using the CHAPS I/O system, and contained a minimal set of functions.

LOWTRAN. In August 1990, Pamela Blake traveled to the customer's site and installed the LOWTRAN atmospheric modeling program (developed by AFGL) on two computers at the customer's site, along with an additional SETS-developed program for formatting data prior to entry into the LOWTRAN program.

Design Activities

This task area involves the design and specification of the software system. This activity began in the first month of the project (October 1989). Design activities continued through December,

and in early January 1990, a *Preliminary System Specification* was released (see Appendix B). Design meetings involving all of the key programmers and scientists were held in the early months of 1990. In March a *Draft HIPS Software Specification* was produced. In June it was decided to split this Software Specification into two parts--an Infrastructure Specification detailing the architecture of the software system, and a Functional Specification describing each of the functional elements of HIPS. The *HIPS Infrastructure Specification* can be found in Appendix C and the *HIPS Functional Specification* can be found in Appendix D.

The design process of HIPS will continue at a low-level in the second year of the project. Both the Infrastructure Specification and the Functional Specification will be revised as new approaches and useful functional elements are identified and incorporated into the design. See the *HIPS Development Plan* in Appendix A for a further description and a time line of the design phase.

Task 1: Project Management

This task involves the day-to-day management of the HIPS software development project. Activites are on-going and include supervision of personnel, assignment and monitoring of tasks, task and resource scheduling, customer communications, report writing, communication with executive management, scheduling and holding meetings, conducting project reviews, problem solving, budget management, and project tracking.

Tom Lundeen served as the project manager for the first six months of the project. In April 1990 project management responsibilities were shifted to John Lindelow, due to Tom Lundeen's involvement in other projects. In September 1990, project management responsibilities were again shifted, this time to Linda Chock, due to John Lindelow's departure from SETS. The COTR was kept advised of these changes and concurred.

In May 1990 the *HIPS Development Plan* was released (See Appendix A). This document outlines a set of milestones and deliverables, describes the four main phases of development for this project (design, infrastructure development, functional toolkit development, and advanced capability development), and broke the development activities into fifteen discrete tasks (which are described in this section).

The *HIPS Development Plan* is currently the blueprint for the development of HIPS. In October 1990 the *HIPS Development Plan* will be revised to detail development activities in the final year of the contract period.

Task 2: Development of Basic Software Architecture

This task involves development of the "framework" for HIPS software development. Included here are such basic elements as the directory structure, makefile system, and source code control system (SCCS). Also included under this task is the development of the "HIPS Executive"--a set of routines that controls the basic operations of HIPS. Sub-tasks include the development of routines to control command line and batch mode processing (including the parseargs() routine), the development of processes for inter-process communications among HIPS programs, the development of routines for the recording and execution of history files, the development of routines for interprocess communications, and the development of

programming guidelines.

Subtask 2.1: Development of HIPS Directory Structure
Subtask 2.2: Development of HIPS Makefile System
Subtask 2.3: Development of HIPS SCCS Structure
Subtask 2.4: Development of Routines for Command Line and Batch Mode Execution (including the parseargs() routine)
Subtask 2.5: Development of Routines for Recording and Execution of History Files
Subtask 2.6: Development of Routines for Interprocess Communication
Subtask 2.7: Development of HIPS Programming Guidelines

During the first year of this project, great progress was made in constructing the basic software foundation of HIPS. The directory structure and Makefile system were implemented. The SCCS system was studied and its use was widely discussed. Implementation of the SCCS will not occur until early in the second year of the project, however, because of the unnecessary burden that SCCS puts on programmers during the early stages of a system's development. The use of SCCS will become critical when the coding of the functional toolkit of HIPS is started in the fall of 1990.

Significant progress was made in the development of the main controlling modules of HIPS. In particular, the parseargs() program was completed in early 1990. This program will act as one of the main "interpretors" of user input in the complete HIPS system, with most user requests being funneled through, interpreted, and dispatched by this routine. The parseargs() routine is a key part of the command line interface of HIPS, batch mode processing, and history processing, and is a key element of the modularization of HIPS.

Early in the second year of this project (Fall 1990), the basic architectural elements of HIPS described above will be combined with the Cube I/O routines (see Task 3) and the HIPS graphical user interface (see Task 6) to produce the first interim version of HIPS.

Task 3: Development of Cube I/O Routines

This task involves the development of input and output routines for HIPS cubes. These routines are used to read data from disk files and write data to disk files. This task includes the refinement of data file formats and internal data structures, and the development of mechanisms for the specification and utilization of subcube information.

During the first year of this project, a great deal of design and programming effort went into the development of the I/O routines, which are now complete, except for "beta" testing which will occur once the I/O routines are linked into the HIPS system as a whole. The *HIPS I/O Specification* was released in June 1990, as part of the June Monthly Report, and is now incorporated into the *HIPS Infrastructure Specification* (Appendix C).

Task 4: Development of Error Handling Routines

This task involves the development of standardized routines for reporting and logging errors.

Included are routines that programmers may call to report errors and warnings to the user, and routines to log errors in system administration files. The development of an array of standard error messages is also part of this task.

This task was not started in the first year of the project. It will be started and completed in the Fall of 1990, and the error-handling routines will be incorporated into the first interim version of HIPS.

Task 5: Development of Miscellaneous Utility Routines

This task involves the development of miscellaneous routines that are not included under other tasks. In Phase 2 of this software development project, utility routines are usually those needed to complete the infrastructure of HIPS. In Phase 3, utility routines are usually those needed to implement a special user function.

During the first year of this project, a few utility routines were written in conjunction with the development of the I/O routines. Most utility routines will be completed in the second year of the project.

Task 6: Development of Graphical User Interface

This task involves the development of the graphical user interface (GUI) for HIPS. This GUI is being built utilizing the X-windows system and the Xview toolkit. The EXOcode GUIDE (graphical user interface design environment) is being utilized to generate much of the HIPS GUI.

In the first year of this project, many meetings and extensive discussions were held on the HIPS GUI, and two demonstration versions of the HIPS GUI were developed utilizing the software tools described above.

The first of these demonstration version, called *Hyperview*, was delivered to the customer in May 1990, and works within a Suntools windowing environment. The second version--the Demo Version of HIPS--was delivered to the customer in July 1990, and works within an Xwindows/Xtools environment. The development and delivery of these programs and software systems--as well as another program called *Imagetool*--is detailed above in the section titled *Software Deliveries*.

This task also included the study of recent advances in GUI's, acquisition of promising GUI's and GUI development products, and experimentation with such products. In support of this task, Juliana Lo attended Xhibition, which is detailed above in the section titled *Project Reviews and Other Meetings*.

Task 7: Documentation (Hardcopy)

This task involves the production of the interim and final versions of the *HIPS User's Manual*. The interim *HIPS User's Manual* was developed by SETS and released in late September of

1990, and the final *HIPS User's Manual* will be released in September of 1991.

Task 8: On-line Help System

This task involves the development of an on-line help system that will provide the user with multi-level, context-sensitive help. This task was not started in the first year of the project, but will be completed early in the second year of the project.

Task 9: Development of Spectral Library Interface

This task involves the development of an interface between HIPS and a spectral search library. Included are routines for retrieving spectra from the library, and routines for conducting efficient spectral comparisons.

During the first year of this project, effort was expended on the specification of this interface, which is now complete and part of the *HIPS Infrastructure Specification*. Coding of the interface has been started but not completed.

Task 10: Development of Single Spectra Analysis Capability

This task involves the development of routines for the processing and analysis of single spectra. During the first year of this project, the general design of this set of processing functions was researched. In mid 1990, the idea developed to utilize a third-party software package called "PV-Wave" as the foundation for implementing this set of functions. A decision on the utilization of PV-Wave will be made early in the second year of the project. All of the coding of this set of functions will take place in the second year of the project.

Task 11: Development of Function Specifications

This task is part of the design phase of HIPS development. The product of this effort is the *HIPS Functional Specification* (See Appendix D), which contains detailed descriptions of each function that will be implemented as part of HIPS. The combined functions are referred to as the "functional toolkit" of HIPS, because users will utilize these functions as "tools" to manipulate and analyze hyperspectral data sets. The "tools" in the toolkit are individual functional elements from a user's point of view (such as programs for performing display, math, or other operations on HIPS data files). Included in each function specification are descriptions of what the function does, descriptions of the user input, and background information on the function.

During the first year of this project, progress was made toward completing the functional specification. Completion is expected in October of 1990. Appendix D contains a draft version of the *HIPS Functional Specification*.

Task 12: Development of Functional Toolkit

This task involves the coding of the individual functions that will make up the HIPS functional toolkit, which were specified in the previous task. During the first year of this project, individual functions were written as part of the several software packages that were delivered to the customer (see section above titled *Software Deliveries*). The coding of functions that will be delivered as part of HIPS proper, however, is just starting. Coding of these functions will continue throughout the second year of the project.

Task 13: Debugging and Testing

This task involves the debugging and testing of release and final versions of HIPS and other software deliveries. In the first year of this project, activity in this area was clustered in the months that software deliveries were made to the customer (see section above titled *Software Deliveries*). In the second year of this project, a great deal of debugging and testing will occur as the infrastructure of the HIPS software system comes together and functional elements are added.

Task 14: Development of Procedure-Based Analysis Environment

This task involves the development of a procedure-based analysis environment, which will allow users to follow pre-defined flowcharts of common processing sequences with "point and click" ease. During the first year of this project, this environment was conceived and conceptually designed. All development of this environment will occur in the second year of the project. This task corresponds to Phase IV of HIPS development (see Appendix A).

Task 15: Development of Specialized Hardware Interfaces

This task involves the development of one or more specialized hardware interfaces for HIPS. In particular, an interface to the Connection Machine 2 is contemplated. This is a secondary task, and will be undertaken only if time and funding permits. No activity on this task was conducted in the first year of this project.

Section 3: Budget, Schedule, and Personnel Utilization

Spending on this project got off to a slow start in the project's first two months (October and November of 1989). Since that time, design and coding efforts and concomitant spending have been increased. Spending is now nearly in line with originally projected rates.

Cumulative spending through September 30, 1990 totaled approximately $184,434. Of the $304,552 allocated for this project through January 15, 1991, about $120,118 remain. Average anticipated expenditures, per month, through September 30, 1991 is approximately $25,800.

The overall development of HIPS is proceeding according to the *HIPS Development Plan* and is essentially on-track. The completion of the infrastucture of HIPS has lagged somewhat over the last two months due to problems with the SETS' workstation used for this software development project. This workstation is now fully back on line, and development is expected to proceed rapidly during the first quarter of the second year.

PART 2

Final Technical Report

HYPERSPECTRAL IMAGE EXPLOITATION

October 31, 1991

CONTENTS

Section 1: Executive Summary

This report summarizes the activities of SETS Technology, Inc. under the Hyperspectral Image Exploitation project (Contract DACA-72-89-C-0018) over the second year of the contract's two year term. This project began on September 29, 1989 with a completion date of September 28, 1991, which was extended to October 31, 1991. This *Draft Technical Report* covers the period October 1, 1990 through October 31, 1991.

The primary goal of the Hyperspectral Image Exploitation project is the development of a prototype software system for the processing and analyzing of hyperspectral data sets. This software system will be used by the U.S. Army Topographic Engineering Center (TEC) to help evaluate the field of Hyperspectral Remote Sensing in general, and computer-based hyperspectral analysis techniques in particular.

The primary software system being developed under this project is called the Hyperspectral Image Processing System, or HIPS. HIPS is being developed on Sun Microsystems SPARC workstations. HIPS utilizes a state of the art, X-window environment with the Open Look style graphical user interface for user input, including menu selections, parameter choices and data entry; for system output, including the display of images, spectra and vectors, graphs, tabular data, and new data sets; and for requesting printed copies.

During February and March an assessment was made of the development status of HIPS functions, schedule and deliverables, resulting in a revised HIPS development plan, which was published in April 1991. An copy of the *HIPS Development Plan, Revised April 1991* (Appendix A) was provided for information only (not a deliverable item) to the Contracting Office Technical Representative (COTR). During a technical review meeting in May 1991 at SETS' office, the COTR gave informal approval of the plan.

The plan was to continue development in four partially overlapping phases. Phase 1 involved the design and specification of HIPS. Phase 2 involved the building of HIPS "infrastructure". Phase 3 involved the development of HIPS "functional toolkit" and test procedures. Phase 4 involved the implementation of advanced hyperspectral processing techniques. These phases are described in detail in the *HIPS Development Plan, Revised April 1991*.

A certain amount of redesign was necessary as development of HIPS progressed. Use of Sun Microsystems' Devguide, which is a more complete screen generator utility than ExoCODE, helped to facilitate the design process. A concerted effort was made to adopt a consistent, easy-to-use "look and feel" for all of the HIPS function control windows, that is, adopting the Open Look style of graphical user interface.

The major efforts during the second year were to complete the infrastructure of HIPS, to implement and test the functional toolkit, and to implement advanced analysis environments and techniques for HIPS. The latter involved the development of spatial and spectral filters, calibration, and classification functions. The procedure-based processing environments and an interface to the Connection Machine that were originally under consideration were not implemented because attention was focused on the X-windows interface and on the intercommunication between functions. Testing guidelines and data sets designed and developed during phase 3 were also applied to the advanced functions implemented during

phase 4.

The original Functional Specifications served as a basis for the draft *HIPS User's Manual*. Many of the details were rewritten to better describe the functions as they were implemented, and screen displays were included with every function. The on-line help feature was also established to provide quick information to the user at the terminal on the various input prompts and options in a HIPS function control windows. The on-line help coincides with descriptions from the *HIPS User's Manual*.

Several new tasks, additional to the original contract specifications, were completed at the request of the COTR. In November and December 1990 a white paper, and subsequent update, recommending a HIPS workstation were prepared and submitted at the request of the COTR. The white papers described both hardware and software requirements necessary for HIPS, and included cost quotations and third-party vendor contact for peripheral equipment. In the months that followed, lengthy telephone conversations ensued with the COTR, to assist in the workstation specification and procurement process. The workstation was finally assembled and configured in August 1991 at the COTR's site. This new hardware acquired by the COTR resulted in a delay in the original delivery schedule of the interim software product; it was agreed that the hardware should be fully configured and functional prior to site installation. A cartridge tape of the interim release was provided to the COTR at an informal technical review meeting held at SETS' office in August 1991.

In May 1991, a review of MODTRAN was completed and, with the agreement of the COTR, determined that it would not be integrated into HIPS.

During August 1991 Synthetic HIPS data sets were developed under a separate contract. These synthetic HIPS data sets were used to test HIPS functions, especially for extracting and comparing spectra. The material spectra for these data sets were from SETS Technology, Inc.'s Spectral Catalog, Version 3.0 and were also used to populate a HIPS Spectrum Library, providing more realistic data for testing HIPS.

The overall development of HIPS proceeded according to the *HIPS Development Plan, Revised April 1991*, and was essentially on-track through August 1991. During September due to the unexpected illness of the Principal Investigator, a one month no cost extension of the contract to move the delivery and installation date into October was requested by SETS and approved by the COTR.

Spending was slightly over the originally projected rate during the last year of the project, through September 28, 1991. A small amount was reserved for site installation of HIPS by the Principal Investigator during 16 - 18 October 1991. The combined result of work accomplished during the two year period is a complete expenditure of the contract funds.

A draft maintenance and support agreement was provided for the COTR's consideration, in the event that subsequent work in HIPS is requested by the customer.

Section 2: Activities and Progress

This section gives an overview of the various activities that have been conducted in the task areas of this project. The first sections detail the general administrative activities involved in revising the project plans for the second year, the variety of meetings that were held between the customer and SETS personnel, software deliveries that were made to the customer, and software design, implementation, debugging, and testing activities. The last section describe progress and completion in the fifteen individual task areas that were delineated in the *HIPS Development Plan, Revised April 1991* (See Appendix A).

Administrative Activities

This task area involved the establishment of project management and accounting mechanisms for performing the statement of work and monitoring work progress. A reassessment of the status of the development of HIPS was undertaken by the Project Manager, Linda Chock, in February and March 1991. This resulted in a revised set of schedules, task assignments, and deliverables. A significant amount of communications took place with the customer to assure that contractor and customer expectations matched. The COTR was kept informed and gave informal approval during the technical review meeting help at SETS' office in May 1991.

The accounting system continued to provide the Principle Investigator and Project Manager with timely reports on expenditures, so that costs were controlled and project tracking could be conducted. The monthly reports were submitted, with four sections containing a summary, description of work performed, schedule of progress, and a budget analysis.

During the second year the technical staff for this project was as follows: Tom Lundeen was the Principle Investigator, Linda Chock was the Project and Software Manager, Carol McCord was the Business Administrator, and Pamela Blake was the Technical Advisor and Science Manager.

It was decided during the first year that the Sun SPARCstation was the best available development platform, and that the X-Windows system was the best available windowing environment. At the request of the COTR, white papers recommending a HIPS workstation were prepared and submitted in November and December 1990, reconfirming the selection of the Sun SPARCstation, and providing detailed configuration for hardware and software. Shortly following was a recommendation to adhere to the Sun Microsystems/AT&T/Xerox Open Look style of graphical user interface for X-Windows, which was approved by the COTR. (For more information, see the Task 6 description below.)

Several items for the Contract Data Requirements List (CDRL) were scheduled and delivered during the last half of the project:

A001	Progress Report	Monthly - 2 copies
A002	Interim Technical Report	October 1990 - 3 copies

A003	Draft Technical Report Final Technical Report	October 1991 - 2 copies 30 days after COTR's approval (COTR has 21 days for review)
A004	Interim HIPS User's Manual	October 1990 - 3 copies
A005	Draft HIPS User's Manual Final HIPS User's Manual	October 1991 - 2 copies 30 days after COTR's approval (COTR has 30 days for review)
A006	HIPS Programs on tape	October 1991 - 2 copies (COTR has 30 days for review)

In addition to the CDRLs above, several informal documents were also delivered to the COTR for information and concurrence:

White Paper recommending a HIPS workstation	November and December 1990
HIPS Development Plan, Revised	April 1991
Sample HIPS User's Manual pages	August 1991
Getting Started with HIPS	August 1991
HIPS Maintenance and Support Agreement - draft	August 1991

Project Reviews and Other Meetings

During the second year of this project, SETS hosted several formal and informal project reviews at SETS' facilities, which were attended by the customer's COTR. SETS personnel met with the COTR to discuss technical issues, review the progress in the development of HIPS and to demonstrate HIPS X-Windows interface. These meetings are detailed as follows.

May 1991: During the week of 6 May 1991 the COTR conducted a site visit and project review at SETS Technology facilities. Discussion focused on the current status of the project, the revised plan for proceeding through the remainder of the contract, as specified in the *HIPS Development Plan, Revised April 1991*, and the look and feel of the hyperspectral data processing system being developed. The COTR was given a demonstration of HIPS interface through its menus, and some of the functions that were developed and being tested. Interim software delivery was scheduled for the week of 24 June. However, the confirmation of this date by the COTR was contingent on having a fully functional workstation at his site.

August 1991: Informal project review meetings were held with the COTR at SETS Technology facilities on 23 August 1991 and throughout the week following. The discussions

included the progress in development of HIPS, the synthetic HIPS data sets which were completed and delivered in mid-August, the HIPS workstation being configured at the COTR's site, the installation schedule, the HIPS Spectrum Library Several demonstrations of HIPS capabilities were presented, and the COTR was allowed time to peruse through HIPS. A draft maintenance and support agreement was prepared for his consideration.

Software Deliveries

The *HIPS Development Plan, Revised April 1991*, had scheduled two software deliveries for HIPS. The Plan detailed a list of functions that would be included during the interim software delivery in June 1991 and for the final delivery in September 1991.

June 1991: The scheduled delivery of HIPS interim software was delayed at the request of the COTR, because the COTR's workstation was not yet installed and configured.

August 1991: Synthetic HIPS data set, HIPS Spectrum Library, atmospheric components spectrum file, documentation, and tape media delivered to the COTR.

August 1991: Interim HIPS software tape and brief introduction to HIPS and sample pages from the *HIPS User's Manual* were delivered to the COTR during his visit at SETS Technology facilities.

October 1991: During 16 through 18 October 1991, the Principal Investigator conducted a site installation of HIPS Version 1.0 on the COTR's SPARCstation. The programs were loaded and recompiled, after some minor modifications mainly to exclude references from the Devguide utility that was used during development. Functionality of the programs were not affected. Two copies of the *Draft HIPS User's Manual* were delivered. A brief tutorial of HIPS was provided as the functions were installed and checked. In addition, the Principal Investigator demonstrated procedures for data exchange between HIPS and the Spectrum Archival Library over the network.

Design and Implementation Activities

This task area involved the design and specification of the software system, as well as the implementation and testing of HIPS, and both hardcopy and on-line documentation. The design process of HIPS continued as modest revisions were made during the second year of the project. Both the infrastructure and individual HIPS functions were revised as new approaches and useful functional elements were identified and incorporated into the design. The Sun Microsystems' Devguide (Developer's graphical user interface design editor) facilitated the screen generation process for all HIPS functions and menus. The following is a summary of activities by task, as described in the *HIPS Development Plan, Revised April 1991* (Appendix A).

Task 1: Project Management

This task involved the day-to-day management of the HIPS software development project. Activities included supervision of personnel, assignment and monitoring of tasks, task and resource scheduling, customer communications, report writing, communication with executive management, scheduling and holding meetings, conducting project reviews, problem solving, budget management, and project tracking.

During the second year the technical and management staff for this project was as follows: Tom Lundeen was the Principle Investigator, Linda Chock was the Project and Software Manager, Carol McCord was the Business Administrator, and Pamela Blake was the Technical Advisor and Science Manager. The COTR was kept advised of these assignments and concurred.

The *HIPS Development Plan, Revised April 1991* (See Appendix A) was published and followed as the blueprint for development activities in the final year of the contract period. An informal copy provided to the COTR, for information purposes only; and he concurred during a meeting at SETS Technology facilities in May 1991. The plan provided an updated schedule of tasks and milestones, and personnel alignments necessary to complete the development of HIPS. Work was planned in four main phases of development (modest redesign, infrastructure development, functional toolkit development, and advanced capability development), and broke the development activities into fifteen discrete tasks (which are described in this section).

Task 2: Development of Basic Software Architecture

This task involved development of the "framework" for HIPS software development. Included here are such basic elements as the directory structure, makefile system, and source code control system (SCCS). Also included under this task is the development of the "HIPS Executive"--a set of routines that controls the basic operations of HIPS. Sub-tasks include the development of routines to control command line and batch mode processing (including an argument parsing routine), the development of processes for inter-process communications among HIPS programs, the development of routines for creating, reading, writing, and manipulating HIPS data sets, the development of routines for interprocess communications, and the development of programming guidelines.

Subtask 2.1: Development of HIPS Directory Structure
Subtask 2.2: Development of HIPS Makefile System
Subtask 2.3: Development of HIPS SCCS Structure
Subtask 2.4: Development of Routines for Command Line and Batch Mode Execution (including the argument parsing routine)
Subtask 2.5: Development of Routines for Interprocess Communication
Subtask 2.6: Development of HIPS Programming Guidelines

During the first year of this project, great progress was made completing the basic software that was begun in the latter part of the first year. The directory structure, the makefile system, and SCCS were implemented early in the second year of the project, and were used throughout

various stages of the system's development. SCCS was used to create and deliver the baseline software, HIPS Version 1.0, to the customer in October 1991.

Significant progress was made in the implementation of the main controlling modules of HIPS. Some minor modifications were made to the argument parsing program which had been completed in early 1990. This program will act as one of the main "interpreters" of user input in the complete HIPS system, with most user requests being funneled through, interpreted, and dispatched by this routine. The argument parsing routine is a key part of the command line interface of HIPS, batch mode processing, and is a key element of the modularization of HIPS.

The basic architectural elements of HIPS described above was combined with the Cube I/O routines (see Task 3) and the HIPS graphical user interface (see Task 6) to generate the HIPS functional toolkit and implement some advanced processing functions for HIPS.

Task 3: Development of Cube I/O Routines

This task involved the development of input and output routines for HIPS cubes. These routines are used to read data from disk files and write data to disk files. This task included the refinement of data file formats and internal data structures, and the development of mechanisms for the specification and utilization of subcube information.

A modest amount of redesign of cube I/O routines took place during the second year. Several redundant functions were consolidated, and new ones added to satisfy the various accesses for a data set. All the basic cube I/O routines are located in a UNIX programming archival library. The I/O routines were coded, unit tested with test programs and test data sets, and linked into the HIPS system as a whole.

Task 4: Development of Error Handling Routines

This task involved the development of standardized routines for reporting and logging errors. Included are routines that programmers may call to report errors and warnings to the user, and routines to log errors in system administration files. The development of an array of standard error messages is also part of this task.

This task was started and completed during the second year. The error-handling routines have been incorporated into a UNIX programming archival library, and are linked to programs in the HIPS functional toolkit.

Task 5: Development of Miscellaneous Utility Routines

This task involved the development of miscellaneous routines that are not included under other tasks. In Phase 2 of this software development project, utility routines are those used to complete the infrastructure of HIPS. In Phase 3, utility routines are those used to implement special user functions.

During the second year of this project, a few utility routines were written in conjunction with doing unit tests for the cube I/O routines. As in tasks 3 and 4 above, these commonly called routines have been included into a UNIX programming archival library.

Task 6: Development of Graphical User Interface

This task involves the development of the graphical user interface (GUI) for HIPS. This GUI was built for the X-windows environment utilizing the XView toolkit, and following the Open Look style of window interface. The Sun Microsystems' Devguide (Developer's graphical user interface design editor) was utilized to generate much of the HIPS GUI.

This task included the study of recent advances in GUI's, acquisition of promising GUI's and GUI development products, and experimentation with such products. After reviewing the "look and feel" of two predominant X-windows graphical user interfaces, Open Look (from Sun Microsystems/AT&T/Xerox) and Motif (from Open Systems Foundation), the COTR selected the Open Look style for the HIPS GUI. In concert with the decision, Sun Microsystems' Devguide was selected to be the interactive design tool which provides the best utilities and features for rapid development of the HIPS functional window interface.

A number of commonly called routines were designed and developed to support the HIPS's interface to the window manager. These window utilities have been included in a UNIX programming archival library, and link into programs in the HIPS functional toolkit.

Task 7: Documentation (Hardcopy)

This task involved the production of the interim and final versions of the *HIPS User's Manual*. The interim *HIPS User's Manual* was developed by SETS and delivered in October 1990; and the final *HIPS User's Manual* was delivered with the HIPS software installation in October 1991 by the Principal Investigator.

The earlier *HIPS Functional Specifications* served as a basis for the current draft *HIPS User's Manual*. Many of the details were rewritten to better describe the functions as they were implemented, and screen displays were included with every function. Many of the screen input fields are filled in with sample information to provide guidance for a new user. A user manual page is divided into five sections as follows:

Function name and description	
Parameters	(prompts and descriptions of the data requested or output)
Applications	(sample uses of the function)
Keywords	(words that are further defined in a Glossary)
Command Options	(function usage in the command mode at a UNIX shell prompt)

Three appendices were added at the end of the manual, a) a Glossary, which defined "keywords" cited for each function, b) Getting Started with HIPS, to guide for a beginning user, and c) References cited in developing HIPS.

Task 8: On-line Help System

This task involved the development of an on-line help system that will provide the user with multi-level, context-sensitive help. It was started and completed in the second year of the project.

The on-line help feature was established to provide quick information to the user at the terminal on the various input prompts and options in a HIPS function control windows. The on-line help coincides with descriptions from the *HIPS User's Manual*

Task 9: Development of Spectrum Library Functions

This task involved the development of basic maintenance functions and an interface between HIPS and a spectral search library. Basic maintenance routines include the ability to create/delete a library, create/delete a sensor, add/delete spectra, list the available libraries, and list spectra in a library. The interface routines are used to retrieve spectra from the library, and for conducting efficient spectral comparisons.

During the second year of this project, minor revisions were made to the design, and programs were implemented and tested. A common set of routines used by most of the spectrum library interface functions have been combined into a UNIX programming archival library as part of the HIPS infrastructure.

Task 10: Development of Single Spectrum Analysis Capability

This task involved the development of routines for the processing and analysis of single spectrum. In late 1990, a third-party software package called "PV~Wave" was evaluated as the possible foundation for implementing this set of functions. It was decided not to use the package. Instead the following functions were developed: Average Spectrum, Band Depth Mapping, Convolve, and Spline. All of the coding of this set of functions were started and completed during the second year.

Task 11: Development of Function Specifications

This task is part of the design phase of HIPS development. The product of this effort is the *HIPS Functional Specification* (Appendix D of the *Interim HIPS Technical Report*), which contains detailed descriptions of each function that will be implemented as part of HIPS The combined functions are referred to as the "functional toolkit" of HIPS, which provide users with the capability to manipulate and analyze hyperspectral data sets. The "tools" in the toolkit are individual functional elements from a user's point of view (such as programs for performing display, math, and other operations on HIPS data files). As explained in Task 7 above, this document has formed the basis for expansion into the *HIPS User's Manual*

Task 12: Development of Functional Toolkit

This task involved the coding of the individual functions that made up the HIPS functional toolkit, which were specified in the document from Task 11. During the second year of this project, the coding of functions that are being delivered as part of HIPS proper took place. The main body of the toolkit consisted of fundamental input and output functions for handling the image data set files, various graphical and image display functions, math and statistical functions, geometric cube manipulation functions, and general utilities.

Task 13: Debugging and Testing

This task involved the debugging and testing of interim and final versions of HIPS. During the second year of this project, a great deal of debugging and testing occurred as the infrastructure of the HIPS software system came together and functional elements were added. Several test data sets were generated to exercise the HIPS functions.

Under a separate contract SETS produced Synthetic HIPS data sets to be used for testing HIPS functions, especially for extracting and comparing spectra. The material spectra for these data sets were from SETS Technology, Inc.'s Spectral Catalog, Version 3.0 and were also used to populate a HIPS Spectrum Library, providing more realistic data for testing HIPS. The first data set contained laboratory reflectance spectra, and the second was based on the first, except that spectra were injected with Lowtran-generated atmospheric components. In addition a HIPS spectrum library was populated with the twenty-five (25) material spectra from the synthetic data set, along with five (5) more spectra. Tapes and documentation for this task were delivered to the COTR in August 1991.

Task 14: Development of Procedure-Based Analysis Environment

This task involved the development of a procedure-based analysis environment, which would allow users to follow pre-defined flowcharts of common processing sequences with "point and click" ease. This was a secondary task, and was not undertaken during this contract. Instead it was decided to focus more attention on the X-windows interface and devote more time to streamlining the user interface and necessary supporting interprocess communications between functions.

Task 15: Development of Specialized Hardware Interfaces

This task involved the development of one or more specialized hardware interfaces for HIPS. In particular, an interface to the Connection Machine 2 was contemplated. This was a secondary task, and was not undertaken during this contract.

Section 3: Budget, Schedule, and Personnel Utilization

Personnel effort and spending on this project increased dramatically during the second year compared to the first year, and is in line with originally projected rates.

Cumulative spending from October 1, 1990 through September 30, 1991 totaled approximately $283,164. Of the $480,975 allocated for this project through September 28, 1991, about $467,598 was expended. The COTR approved a no cost extension through the end of October 1991, due to the unexpected illness of the Principle Investigator, which resulted in a delay of the installation date. Funds were set aside from the original contract to cover expenses for travel and per diem for the site installation during 16 - 18 October 1991. The expenditures from October 1, 1989 through September 30, 1991 averaged $19,485 per month.

The overall development of HIPS proceeded according to the *HIPS Development Plan, Revised April 1991* and was on-track.

APPENDIX A

HIPS DEVELOPMENT PLAN

April 1991

Introduction

This document describes SETS' work plan for the development of the Hyperspectral Image Processing System (HIPS). HIPS is being developed under a two-year Small Business Innovative Research (SBIR) contract with the U.S. Army Corps of Engineers Engineer Topographic Laboratories (ETL). This document details SETS' Work Plan through September 1991. This Development Plan is not a formal deliverable item, and is being provided to the Contract Office Technical Representative (COTR) for information only.

The organization of this document is to discuss the contract milestones, the phases of HIPS development, and the specific task descriptions and personnel assigned. Finally, the *attached HIPS Functions* contains a list of functions, including an extracted brief summary of each, which are anticipated to be delivered in two parts, in June and September 1991, with approval of the COTR. The functions are considered a good working set for HIPS and have been selected from a more complete list presented in Appendix D *HIPS Functional Specifications* of the interim *HIPS Technical Report* delivered to the COTR in October 1990.

Contract Period

The period of this two-year contract is from October 1, 1989 through September 28, 1991.

Milestones

This section describes the major milestones of this software development project through the end of the contract.

Overview

Milestones are defined on the following dates with formal deliverables due only on the October 26, 1990 and September 28,1991. Essentially, at each milestone except the first, SETS will continue to deliver progressively more capable versions of the HIPS software system. Formal deliverable items are indicated by their reference as a Contract Deliverable Line Item (CDRL). The rest are informal deliveries to provide the COTR with information on the progress of the tasks.

May 7, 1990	• HIPS Software Specification • HIPS Development Plan • HIPS software demonstration tape
July 25, 1990	• First interim HIPS Graphical User Interface software demonstration installed
August 1990	• LOWTRAN installed and some training provided
October 26, 1990	• Interim version of the *HIPS Technical Report* (CDRL A002)

	• Interim version of the *HIPS User's Manual* (CDRL A004)
April 25, 1991	• HIPS Development Plan Revised
June 24, 1991	• Second interim version of HIPS software installation
September 16, 1991	• Draft version of the *HIPS Technical Report* (CDRL A003) • Draft version of the *HIPS User's Manual* (CDRL A005) • Final version of HIPS Software (CDRL A006)
November 1991	(Following customer review and approval) • Final version of the *HIPS Technical Report* (CDRL A003) • Final version of the *HIPS User's Manual* (CDRL A005)

Previous Milestones Delivered through October 1990

May 1990: The *HIPS Software Specification* and the *HIPS Development Plan* . These documents, which are not formal deliverables, were delivered as appendices to the May 1990 monthly report. In addition on May 7, 1990, SETS informally delivered a Sun cartridge tape to ETL containing the first HIPS demonstration versions, called, "Hyperview" and "Imagetool."

The *HIPS Software Specification* described the software programs to be developed and included in several different areas of spectral analysis.

The *HIPS Development Plan* detailed plans for HIPS development through September 30, 1990. Development continued following an extension to the plan through March 1991.

The first HIPS software demonstration version, "Hyperview" and "Imagetool," were designed to illustrate the probable "look and feel" of the HIPS graphical user interface (GUI), and did not have significant processing capabilities. Hyperview and Imagetool were built using the SunView windowing environment. Later versions are somewhat different from this demonstration version. HIPS will be based on the X-windows environment and developed with Sun Microsystems' OpenWindows using the Open Look style, and will be increasingly capable of hyperspectral image processing analysis.

July 1990: A demonstration version of the HIPS Graphical User Interface was completed and delivered to the Contract Officer Technical Representative (COTR). This demonstration version was installed at ETL by SETS Technology personnel, Tom Lundeen and Juliana Lo, on July 25-26, 1990.

Note 1: The software was installed on the following computer hardware and software, which is slightly different from the later configuration (see note for June 1991):

- Sun Microsystems 3/160 with a color monitor, 8 M-bytes of RAM, at least 100 M-bytes of free disk space, and with the following software:
- SunOS 4.0.3
- SunView window system

- X-windows and the X-View toolkit and library were also installed in anticipation of the HIPS environment.

Note 2: During SETS' visit to ETL the following tasks were also performed:

- Demonstrated of the HIPS Graphical User Interface with the COTR and other ETL personnel
- Reviewed the ETL facilities

October 1990: The interim *HIPS Technical Report* (CDRL A002) and the interim *HIPS User's Manual* (CDRL A004) were formal deliverables that were completed and delivered on October 26, 1990.

The interim *HIPS Technical Report* and the interim *HIPS User's Manual* were spiral bound and mailed to ETL. The interim *HIPS Technical Report* also contained four appendices describing HIPS design and specifications to date:

- Appendix A HIPS Development Plan
- Appendix B Preliminary System Specifications
- Appendix C HIPS Infrastructure Specifications
- Appendix D HIPS Functional Specifications

Milestones through September 1991

Major software milestones are planned for June and September 1991 and are described below. September will include delivery of the draft documentation. In addition, several informal deliveries were made in the recent quarter.

December 1990: An updated White Paper that the recommended a HIPS workstation was prepared and submitted at the request of the COTR. The white paper will be used in procuring a HIPS workstation, including requirements and options for both hardware and software. An interim HIPS Glossary was provided to the customer to accompany the *HIPS Functional Specification* which was first provided in October 1990.

April 1991: The revised *HIPS Development Plan*, this document, detailing SETS Technology's development activities for the remainder of the contract through September 28, 1991, will be delivered.

June 1991: The second interim version of HIPS software will be installed from cartridge tape at the customer's site during the week of June 24, 1991, or shortly thereafter upon coordination with the COTR. The functions which are anticipated to be delivered to the customer in June 1991 are listed below.

File Access and Manipulation Functions

- Open
- Close
- Copy
- Convert

- ASCIItoHIPS
- BinarytoHIPS
- HIPStoASCII
- HIPStoBinary

- Create
- Delete
- List (list data set, picture, palette, or all files in directory)
- Rename

Display Functions

- Diddle
- Display
  - Cursor Position
  - Graphics Overlay
  - Pan (scrollbar capability)
  - Zoom
- Print (Tektronix 4693DX)
  - File image to printer
  - Screen to printer
  - Screen to file

Mathematics and Statistics Functions

- Av (calculate average and statistics)
- Histogram

Geometric Operations

- Rotate

Spectrum Library Functions

- Create Library
- Delete Library
- List Library
- Add Instrument
- Delete Instrument
- Add Spectrum
- Modify Spectrum
- Delete Spectrum
- Search

Spectral Operation

- Mathematical Operations
  - Convolve
  - Spline
  - Spectrum Extraction

Utilities

- Disk Free/Full
- Environment Setting

Several of the functions may appear as part of the overall HIPS executive structure, as a menu, or part of a control button, rather than as an explicit function in a list of commands. For example, the "pan" function under Display is implemented with scroll bars and is not listed as a separate menu item.

This version of HIPS is designed to run on the recommended HIPS workstation, which has a higher capacity than the previous Sun 3 model, and is based on an industry standard X-windows system, using Sun's OpenWindows with the Open Look style. The COTR had a look at both Open Look and Motif and selected Open Look for HIPS.

- Sun Microsystems SPARCstation 2, with recommended options:
  32 M-bytes of main memory
  1.2 G-bytes of SCSI disk storage
  150 M-byte SCSI cartridge tape drive
  Ethernet cable and transceiver

- SunOS 4.1.1 (or later)
- Open Windows 2.0 (X-windows Version 11, Release 4)
- X-View Developer's Toolkit and Library
- Tektronix 4693DX color image printer (Option: network version)

There will be no formal delivery of an updated *HIPS User's Manual* at this time. However, much of the on-line help features are expected to be in place. The COTR will also be given a demonstration during the scheduled May 1991 meeting at SETS Technology. Instructions will again be provided during the installation at the customer's site in June 1991.

September 1991: The following deliverables are planned at the completion of the contract: the draft version of the *HIPS Technical Report* (CDRL A003), the draft version of the *HIPS User's Manual* (CDRL A005), the final version of the *HIPS Technical Report* (CDRL A003), the final version of the *HIPS User's Manual* (CDRL A005), and the final version of HIPS software and documentation (CDRL A006).

Two copies each of the draft *HIPS Technical Report* and the draft *HIPS User's Manual* will be submitted at the completion of the contract. The customer will have 21 days for review and approval of the documents. Within 30 days of approval, SETS Technology will deliver the final *HIPS Technical Report* and the final version of the *HIPS User's Manual*. All documents will be spiral bound and mailed.

Two copies of the final version of HIPS software on magnetic cartridge tape, together with one copy of the documentation will be submitted at the completion of the contract. SETS Technology plans to install the software at the customer's site on the HIPS workstation, and provide instructions for use of HIPS. The customer will have 30 days for review and approval.

The following functions, which are described in detail in the *HIPS Functional Specifications* that was delivered to ETL in October 1990, are planned to complete the final version of HIPS:

Display Functions

- Composite
- Display
  - Contrast Stretch
  - Textwrite
  - Plot
- Traverse

Mathematics and Statistics Functions:

- Data set operations
- 2D Histogram

Spatial and Spectral Filter Functions:

- Band Pass Filter
- Spectral/Spatial Box Filter

Geometric Operations

- Expand
- Shrink

Calibration

- LOWTRAN
- Blackbody Computation
- Flat Field Method
- Gain and Bias Correction

Classification:

- Maximum-Likelihood
- Map 1
- Map 2
- Map 3

Spectral Operations

- Bmap
- Mathematics Operations
  - CalcSpec

The workstation configuration is the same as that described for the June 1991 installation.

Phases of HIPS Development

HIPS development is comprised of four partially overlapping phases. Phase 1 involves the design and specification of HIPS. Phase 2 involves the building of the HIPS software infrastructure. Phase 3 involves the development of the functional toolkit, on-line help messages, and development of testing procedures for the functional toolkit. Phase 4 involves the implementation within HIPS of advanced hyperspectral processing techniques and specialized interfaces. Each phase builds on the ones preceding, although several phases may overlay and can be conducted in parallel.

Most of Phase 1, the design and specification of HIPS, was completed in the first seven months of this project. Design meetings were held, a HIPS Software Specification was produced, and experimentation was conducted with components of various graphical user interface tools. However, with the evaluation of current interactive design tools (IDT's), the design process has been revisited and extended into the recent months. SETS Technology is using the Sun Microsystems Inc.'s Developer's Graphical User Interface Design Editor Tool "Devguide" to create a windowing environment for HIPS functions. Sun's Devguide is a more sophisticated IDT than the previously used ExoCODE, and it offers many advantages for rapid development of a window interface for the HIPS functions. Devguide creates windows based on the Open Look style interface for the X-window system using the X-View toolkit and library. Thus phase 1 will continue through April and part of May, then drop to a low level until the end of the project. As new ideas are identified and accepted, they will be worked into the existing design.

Phase 2, the implementation of the HIPS software infrastructure, has been extended from April 1990 through April of 1991. Most of the basic architecture, including software structure, software build and maintenance facilities, software control mechanisms, user control mechanisms, error handling routines, design of the graphical user interface, input/output routines, will be complete by April of 1991, after which work on the HIPS infrastructure will diminish to a maintenance level.

Phase 3, the implementation of the HIPS functional toolkit will overlap with Phases 2 and 4. In this phase, the "working functions" of HIPS will be coded and debugged. The on-line help messages will be added to HIPS and be integrated with the windows generated by Devguide. In addition this period will encompass the development of test procedures and test data sets, which will be employed to verify and validate the HIPS functions. The basic HIPS functions and procedures will provide the individual tools that will be called and utilized by the advanced hyperspectral processing techniques of Phase 4. It is necessary that some functions be developed during the height of Phase 2 activities, to provide minimal functionality and testing capabilities for the infrastructure build. Similarly, some additional functions may be developed through Phase 4, as needs for additional "tools" are identified.

Phase 4 of HIPS development will involve the implementation of advanced analysis environments and techniques. This primarily involves the implementation of spatial and spectral filters, calibration, and classification functions. This development phase is planned for the final quarter of the contract, from late July through September 1991. Testing guidelines and data sets designed and developed during phase 3 will also be applied to the advanced functions implemented during phase 4. The procedure-based processing environments and an interface to the Connection Machine that were originally under consideration probably will not be implemented because of time constraints.

Task Descriptions

This section describes the major tasks involved in HIPS development. Included for each task are brief descriptions of the task and any sub-tasks, and miscellaneous notes on the utilization of personnel.

Task 1: Project Management. This task involves the day-to-day management of the HIPS software development project. Activities are on-going, and include supervision of personnel, assignment and monitoring of tasks, task and resource scheduling, customer communications, report writing, communication with executive management, problem solving, budget management, and project tracking.

Notes: Linda Chock is primary project technical manager. Tom Lundeen is the principal investigator and consulting project manager. Carol McCord is the project business manager and provides project oversight from an executive management viewpoint.

Task 2: Development of Basic Software Architecture. This task involves development of the "framework" for HIPS software development. Included here are such basic elements as the directory structure, makefile system, and source code control system. Also included under this task is the development of the "HIPS Executive"--a set of routines that controls the basic operations of HIPS. Sub-tasks include the development of routines to control command line and batch mode processing [including the parseargs() routine], the development of processes for inter-process communications among HIPS programs, and the development of routines for the recording and execution of history files.

Subtask 2.1: Development of HIPS Directory Structure
Subtask 2.2: Development of HIPS Makefile System
Subtask 2.3: Development of HIPS SCCS Structure
Subtask 2.4: Development of Routines for Command Line and Batch Mode Execution [including the parseargs() routine]
Subtask 2.5: Development of Routines for Interprocess Communication
Subtask 2.6: Development of HIPS Programming Guidelines

Notes: Juliana Lo is the lead programmer in subtasks 2.1 and 2.2. Linda Chock is the consulting computer scientist, and is working on subtasks 2.3 and 2.6. Tom Lundeen and Ralph Lewis worked on subtasks 2.4 and 2.5.

Task 3: Development of Data Set I/O Routines. This task involves the development of input and output routines for HIPS data sets. These routines are used to read data from and write data to disk files. This task includes the refinement of data file formats and internal data structures, and the development of mechanisms for the specification and utilization of subset information. Generic routines will enable conversion to/from ASCII and binary file formats from/to HIPS data set format. If time permits, the development of a virtual I/O interface will also be undertaken, which will allow HIPS to directly read and write (i.e. without translation to native format) data sets in "foreign" formats.

Notes: Juliana Lo is the lead programmer. Linda Chock is the consulting computer

scientist. Tom Lundeen is the consulting scientist.

Task 4: Development of Error Handling Routines. This task involves the development of standardized routines for reporting and logging errors. Included are routines that programmers may call to report errors and warnings to the user, and routines to log errors in system administration files. The development of an array of standard error messages is also part of this task.

> *Notes*: Tom Lundeen is the lead programmer on this task. Juliana Lo will help integrate the routines into HIPS. Karen Glyn will assure that messages are "user friendly" and are presented in a consistent manner to the user.

Task 5: Development of Miscellaneous Utility Routines. This task involves the development of miscellaneous routines that are not included under other tasks. Exactly what routines will be needed is not easily predictable. In Phase 2 of this software development project, utility routines are usually those needed to complete the infrastructure of HIPS. In Phase 3, utility routines are usually those needed to implement a special user function.

Task 6: Development of Graphical User Interface. This task involves the development of the graphical user interface (GUI) for HIPS. The HIPS GUI follows the Open Look style of window interface. This GUI is being built on the X-windows system and the Sun Microsystems, Inc's Open Windows X-View toolkit. The Sun Microsystems Devguide (graphical user interface design editor) will be utilized to generate much of the HIPS GUI.

This task included the development of two demonstration versions of the HIPS GUI. The first of these demonstration versions, called "Hyperview," was delivered to the customer in May 1990, and works within a SunView windowing environment. The second version was delivered to the customer in July 1990, and works within an X-windows environment of Sun's OpenWindows. The second demonstration version contained only minimal functionality, and read only CHAPS format data sets. The intention of these demonstration versions was to give the customer an idea of the "Look and Feel" of the system that will ultimately be delivered, and to receive customer feedback on the HIPS GUI. After reviewing both Motif and Open Look styles, the COTR selected the Open Look style for the HIPS GUI.

This task also included the study of recent advances in GUI's, acquisition of promising GUI's and GUI development products, and experimentation with such products. Specifically included was the attendance at Xhibition '90 by Juliana Lo. This conference, held in San Jose in May 1990, focused on X-windows-based GUI's. As discussed above, Sun's Devguide has been determined to be the interactive design tool which provides the best utilities and features for rapid development of the HIPS functional window interface.

> *Notes*: Juliana Lo is the lead programmer for the GUI development. Juliana Lo attended Xhibition 90, and was primarily responsible for the two demo versions of the HIPS GUI. Karen Glyn and Georgia Bradley will assure that the HIPS GUI facilitates user interface for processing requirements, and they will assist and provide feedback to the lead programmer. Linda Chock is the consulting computer scientist. Tom Lundeen is the consulting scientist.

Task 7: Documentation. This task involves the production of the *HIPS Technical Report* and the *HIPS User's Manual*. An interim *HIPS Technical Report* (CDRL A002) and interim *HIPS*

User's Manual (CDRL A004) were delivered in October 1990. The *HIPS Technical Report* (CDRL A003) and *HIPS User's Manual* (CDRL A005) are a formal deliverables, due at the completion of the contract, September 28, 1991. It will be delivered in mid-September together with the final HIPS software and program documentation (CDRL A006).

Notes: Karen Glyn and Georgia Bradley are leading this task. Linda Chock is directing the effort, and will do part of the writing of the manual. Juliana Lo will assist in assuring the the manual documents that actual software system. Tom Lundeen and Pam Blake will provide reviews and critiques of the manual while it is being edited.

Task 8: On-line Help System. This task involves the development of an on-line help system that will provide the user with multi-level, context-sensitive help.

Notes: Karen Glyn is leading the task with assistance from Georgia Bradley. Pam Blake is directing the effort and will be responsible for the content and design of the help messages presented to the user. Juliana Lo will code the routines necessary to implement the help system; much of the integration is facilitated by the use of Devguide.

Task 9: Development of Spectral Library Interface. This task involves the development of an interface between HIPS and a spectral search library. Included are routines for retrieving spectra from the library, and routines for conducting efficient spectral comparisons.

Notes: Tom Lundeen is leading this effort. He is providing the design of the interface, and coding the basic routines. Juliana Lo is integrating these routines into the HIPS system.

Task 10: Development of a Single Spectra Analysis Capability. This task involves the development of routines for the processing and analysis of single spectra.

Notes: Tom Lundeen is leading this effort. Linda Chock is the consulting computer scientist. Pam Blake is a consulting scientist.

Task 11: Development of Function Specifications. This task involves the development of detailed specifications for each function in the HIPS functional toolkit. Included in each function specification are descriptions of the input and output for the function, descriptions of the algorithms used by the function, and help information for the function.

Notes: A draft of the *HIPS Functional Specifications* was delivered as Appendix D of the interim *HIPS Technical Report.* Descriptions of the functions, together with screen displays and help information regarding input required from the analyst or scientist, will be be the basis for function descriptions in the *HIPS User's Manual.*

Task 12: Development of Functional Toolkit. This task involves the coding of the individual functions that will up the HIPS functional toolkit, and that were specified in the previous task.

Notes: Juliana Lo is the lead programmer in this effort, with assistance from Georgia Bradley. Linda Chock is the consulting computer scientist.

Task 13: Debugging and Testing. This task involves the debugging and testing of release

versions of HIPS. Most activity is clustered in months in which interim versions of HIPS are due. Test procedures is being developed to validate and verify the HIPS functions, and test data sets with predictable contents must be generated.

> *Notes*: Each programmer will do unit tests on functions he or she has developed and integrated into HIPS. Karen Glyn and Georgia Bradley are developing test procedures and generating test data sets. Pamela Blake and Tom Lundeen are consulting scientists to review and validate test results.

Task 14: Development of Procedure-Based Analysis Environment. This task involves the development of a procedure-based analysis environment, which will allow users to follow pre-defined flowcharts of common processing sequences with "point and click" ease. This task probably will not be done due to time constraints.

Task 15: Development of Specialized Hardware Interfaces. This task involves the development of one or more specialized hardware interfaces for HIPS. In particular, an interface to the Connection Machine 2 is contemplated. This is a secondary task, and probably will not be done due to time constraints.