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OVERVIEW OF THE LAND ANALYSIS SYSTEM (LAS)

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ABSTRACT

The Land Analysis System (LAS) is a fully integrated digital analysis system designed to support remote sensing, image processing, and geographic information systems research. LAS is being developed through a cooperative effort between the National Aeronautics and Space Administration Goddard Space Flight Center and the U.S. Geological Survey Earth Resources Observation Systems (EROS) Data Center.

LAS has over 275 analysis modules capable of performing input and output, radiometric correction, geometric registration, signal processing, logical operations, data transformation, classification, spatial analysis, nominal filtering, conversion between raster and vector data types, and display manipulation of image and ancillary data.

LAS is currently implemented using the Transportable Applications Executive (TAE). While TAE was designed primarily to be transportable, it still provides the necessary components for a standard user interface, terminal handling, input and output services, display management, and intersystem communications. With TAE the analyst uses the same interface to the processing modules regardless of the host computer or operating system.

LAS was originally implemented at EROS on a Digital Equipment Corporation computer system under the Virtual Memory System operating system with DeAnza displays and is

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presently being converted to run on a Gould Power Node and Sun workstation under the Berkeley System Distribution UNIX operating system.

INTRODUCTION

The Land Analysis System (LAS) comprises a wide spectrum of functions and statistical tools designed to ingest, manipulate, and analyze digital data, and to generate special output products. It provides to the user the tools necessary to perform image processing and analysis efficiently. LAS, running under the Transportable Applications Executive (TAE), also provides a flexible framework for algorithm development and for application projects and production image processing.

This paper provides an overview of both LAS and TAE, and describes how LAS was implemented at the U.S. Geological Survey EROS Data Center (EDC). While the supporting EDC components or subsystems, such as display, statistical, data base management, and interfaces are described, other sites may have a different LAS environment due to hardware configuration, system processing requirements, and operational procedures.

History

LAS and TAE originated at the NASA Goddard Space Flight Center (GSFC). Since TAE has such an important role in the development of LAS and since TAE was developed before LAS, this discussion will start with TAE.

The need for a generic user interface and executive system became apparent after development in 1975 of the Atmospheric and Oceanographic Information Processing System, and in 1977 of the VISSR Atmospheric Sounder (VAS) Processing System (Dalton and others, written commun. 1981). This was followed in 1978 by another system for the interactive display and correlation of United States census data (Dalton and others, 1979). Although these systems were developed on similar computer systems there was very little sharing of software or data.

By 1980, NASA faced development of several more systems, including the VAS/Severe Storms Data Assimilation project. These projects were to be supported by the Space Data and Computing Division (SDCD) at the GSFC. In response to these projects and others they were already supporting, a group within the SDCD proposed to develop the Standard Applications Executive, now known as TAE (Howell and others, written commun. 1980). TAE would provide system service libraries, a user interface, and other utilities that could be used as a framework upon which to develop application programs. This new executive system could bind sets of applications programs into an easily operated system transportable between computers, would support user operation of programs through a consistent, friendly, and flexible interactive user interface, and would provide a familiar environment for application programmers and system designers, freeing them from some redundant design tasks. The TAE was written by Century Computing, Inc.,

Overview of the Land Analysis System (LAS)

By B. K. Quirk and L. R. Oleson

INTRODUCTION

The Land Analysis System (LAS) is a comprehensive, general purpose, interactive image processing system. This document is intended to serve as an introductory handout for people interested in LAS. It includes a brief overview, several papers written on LAS, a list of the LAS applications modules that have been released to users at the EROS Data Center (EDC), and a list of some of the documentation that is available for both LAS and the Transportable Applications Executive (TAE). Additional information is available from the appropriate support office, either LAS or TAE.

LAS originated at the NASA Goddard Space Flight Center (GSFC) in the early 1980's in support of the Landsat program and has since been expanded by both the EDC and GSFC in a cooperative effort to its present capabilities.

LAS includes over 275 applications modules that can be used for image geo-referencing, spatial and spectral image enhancements, signal processing, color transformations, multispctral classification, spatial analysis, surface generation, and output product generation. LAS has transparent user interfaces for moving image data to a relational data base management system, a statistical package for tabular and statistical analysis, and geographic information systems, such as ARC/INFO. LAS also has a color display system with significant display and manipulation capabilities. LAS uses the TAE developed by NASA. TAE provides a common user interface to all LAS modules and different computer systems, and hence facilitates system transportability. LAS is currently implemented on VAX computers. The EROS implementation of LAS is on a VAX 11/780, see Figure 1.

Color displays which are currently supported include DeAnza, Raster Technologies, IIS and IVAS. Although LAS is a public domain system, it does require an interface to several proprietary software packages. These packages

include IMSL, RIM, SPSS-X, and ARC/INFO. IMSL is required by approximately 20 modules, while the other three packages provide added capabilities and are not required to run the basic system.

The EDC and GSFC are continuing to enhance the functionality and utility of LAS, through the development of new modules and the enhancement of existing modules. In addition, both organizations are pursuing the implementation of a more transportable version of LAS, which would be available on both VAX/VMS and UNIX based systems, and a version which would be available for micro-based workstations.

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which still maintains and enhances it under contract to GSFC.

The development of LAS under TAE started in the late 1970's when GSFC identified the need for image processing software to investigate the radiometric and geometric characteristics of the new Thematic Mapper scanner, which was to be launched on Landsat D, designated Landsat 4 following placement into orbit. This software package was known as the Landsat-D Assessment System, the forerunner of the Land Analysis System (Bracken and others, 1979a). In 1981, the Landsat-D Assessment System was modified to provide the basic software for the initial processing of Landsat-4 Thematic Mapper (TM) data until the production system was available. This Landsat support was referred to as TM Scrounge processing.

In 1982, GSFC decided to expand the system capabilities and use it as a replacement for its proprietary image processing system. This meant a major development effort to provide the equivalent capabilities. In 1983, to reflect this change, the Landsat-D Assessment System was renamed the Land Analysis System or LAS.

At about the same time, EDC also decided to phase out its proprietary analysis system and develop or acquire a more generally available system. Since both EDC and GSFC were embarking on the same path, a Memorandum of Understanding was signed to formalize a project for the coordinated joint development and support of LAS and TAE.

From 1983 to 1985 both sites worked toward the completion of a baseline LAS. This baseline LAS is now available from the Computer Software Management and Information Center (COSMIC).

Even though the baseline system is complete, developments continued both at EDC and GSFC. The staff at the EDC constitutes a diverse user community with research, applications, and production responsibilities. These interests range from remote sensing research and development, through image processing, to involvement in geographic information system (GIS) cooperative projects. Consequently, the LAS development at EDC continues to provide additional capabilities. Table 1 provides a comparison of the current applications software at GSFC and EDC. In comparing the sites, such capabilities as digitizing, statistical analysis, and data base management system were identified. This table provides an overview of how two sites have set up their systems to provide the capabilities needed by their respective organizations. These sites use a combination of proprietary and non-proprietary software and in all likelihood will continue to do so. For example, GSFC uses the proprietary International Imaging Systems (IIS) display software while EDC uses a non-proprietary package developed at the EDC.

<u>Functional Overview</u>

LAS application modules are accessed by the user through the TAE interface. TAE allows the selection of LAS

Table 1.--Applications software component comparisons at GSFC and EDC.

	GSFC	EDC
User Interface	TAE	TAE
Image Processing	LAS	LAS
Display	IIS*	LAS display modules
Statistical	SAS*	SPSS-X*, S*
DBMS	-	RIM*
Digitizing	AMS	ARC/INFO*
Geographic information	LAS	ARC/INFO*, LAS
Catalog Manager	TAE	TAE, EDC
General Support	IMSL*	IMSL*

* Proprietary Software

modules and parameters through both menu and command language modes, accommodating both the first-time and the experienced user.

LAS, using TAE, was designed to provide a complete spatial analysis system for research, applications, or production work. TAE provides the user interface, miscellaneous utilities, and on-line documentation, while LAS provides the following three components:

- raster image processing capabilities.
- statistical analysis capabilities.
- vector processing capabilities.

LAS is primarily a raster image processing system with interfaces to a data base management system (DBMS), statistical package, and vector processing system, and the capability to easily interchange data between systems. Image processing modules comprise roughly two-thirds of LAS and can be categorized into the areas of input, output, radiometric correction, geometric registration, signal processing, logical, data transformation, classification, spatial analysis, nominal filtering, display manipulation, and miscellaneous utilities. These raster image processing capabilities provide a user with the necessary modules to do traditional image processing.

The need to ingest, analyze, edit, and output statistical data stored in a tabular format is essential to the EDC user community. These capabilities include the use of a statistical analysis package and a DBMS to provide sampling, inventory, summarization, and reporting capabilities on both raster and vector data sets. The interface from LAS to the statistical package or DBMS is through a file or files in tabular format. This makes the change to another statistical package or DBMS easier. Byte, integer or real data, and array, or character strings can be stored in these tables. Once in this format, data can be transported to a statistical package, DBMS, or to users outside the EDC community. Raster data can be used in its entirety or sampled, and combined or intersected with vector data stored as points, lines, or polygons.

The vector processing capabilities provide for the capture and transformation of map-based vectors and coordinates. These capabilities consist of five related components. These components are:

- entry, display, and editing of vector data.
- copying and merging of vector files.
- data conversion routines between commonly used vector formats.
- coordinate or projection conversions of the data.
- generation of geographic grids such as UTM or latitude and longitude.

These components provide the capabilities to digitize map information for image registration, select training site polygons for image classification, or perform other spatial analysis tasks needed by the EDC user community.

In order to provide a complete capability in a timely fashion, it was decided to combine both proprietary and non-proprietary software into a system that would provide vector and statistical data analysis capabilities.

LAS ENVIRONMENT

The EDC processing environment consists of the following components:

- Hardware and system-level software components.
- TAE.
- LAS application modules and files.
- LAS display modules.
- Data base management system.
- Statistical package.
- Raster and vector interfaces.
- Output product generators.

Each of these components will be discussed in detail in the following sections. Figure 1 provides an overview of the LAS environment at EDC.

Hardware and System-Level Software Components

LAS runs on several types of computer systems, including Digital Equipment Corporation (DEC) VAX 11/780 computers, while selected components of LAS run on the Gould Power Node 9050 computer and Sun Microsystem workstations. LAS has been transported to a variety of other configurations, such as a MicroVAX II, with varying memory, tape drives, and display devices.

Each EDC computer system typically has 8 to 16 megabytes of main memory, several gigabytes of disk storage, multidensity 1,600/6,250 bpi tape drives, and a number of alpha-numeric video display terminals. Display subsystems consist of a DeAnza cluster with 512-by-512-by-112-bit image memory, two color monitors, and trackballs for the manipulation and display of image data, or a Raster Technologies color display subsystem (Rastertek) with a 512-by-512-by-24 bit image memory.

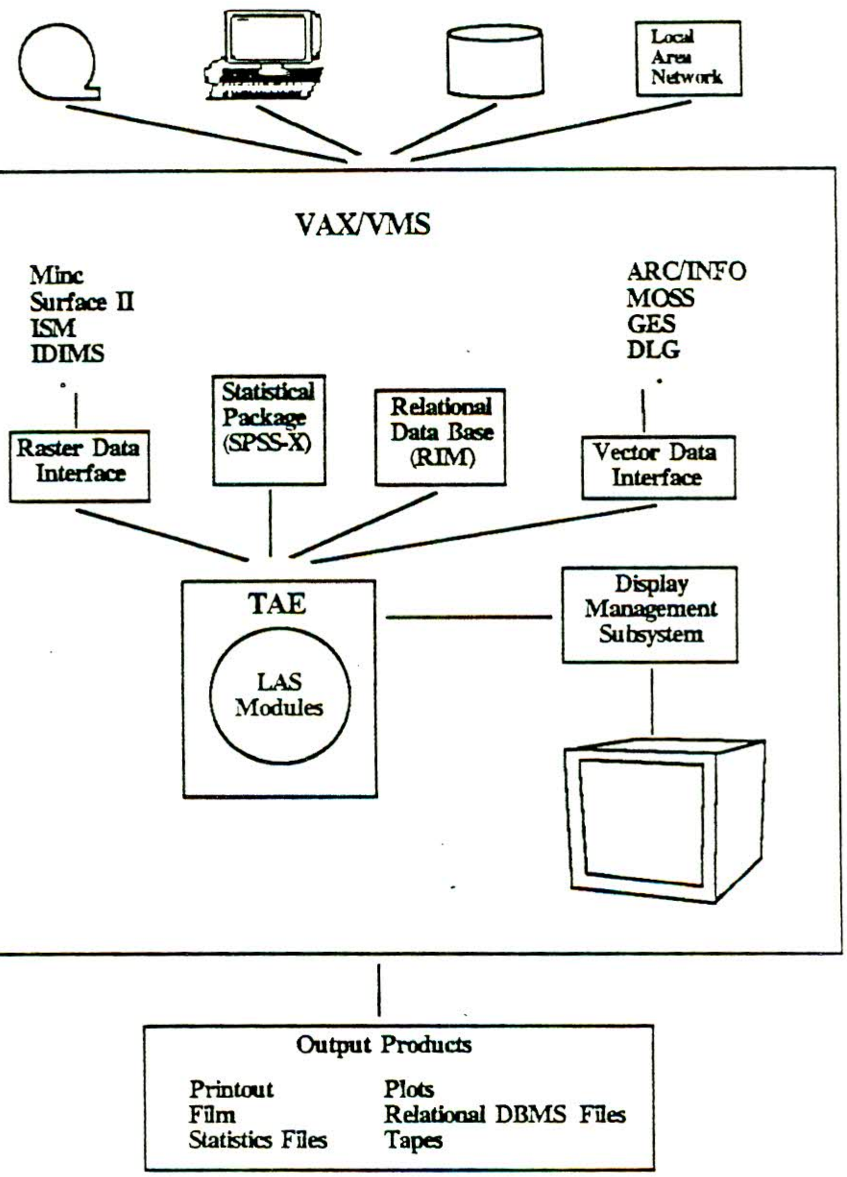

Figure 1.--Overview of the EROS Data Center LAS processing environment.

The hardware for final product generation consists of a MacDonald Dettwiler Color FIRE 240 film recorder, a Versatec 8224 electrostatic printer and plotter, and an Applicon AP5500 color plotter.

The VAX's, Power Node, and Sun workstations are all on a local area network. This allows users to transfer text, images, and other data between computers to shift processing loads, or to take advantage of unique hardware or software capabilities.

TAE

TAE meets several user requirements:

- Consistent, interactive, easily learned interface.

either execute the module or save the parameter values to a parameter file. Tutor screens are probably the most common method of using TAE, especially for novice users.

The use of tutor screens and TAE command mode are described in detail in the TAE User's Reference Manual (Century, 1985).

Non-Interactive Processing: Batch and Script Files. There are two methods under TAE of running LAS in a non-interactive mode: in batch mode or by using script files. A detailed description of these can be found in the TAE Users Reference Manual (Century, 1985) and TAE Utilities Reference Manual (Century, 1983), respectively.

To execute a single module in batch mode, a user will interactively invoke the module, set the parameter values, save these values, and exit the module, and then submit the module in batch mode.

An alternative method used when executing a series of modules is to set up a file of command lines via the host editor and then execute the file in batch mode. This is called a procedure file in TAE. The procedure file cannot have the same name as an existing module under LAS.

Script files are command files that allow the user to run one or more LAS modules in an interactive mode, but without user intervention. Script files can be set up in two ways. The first method involves using the host editor to create a file of LAS commands as they would appear if a user were running the modules in command mode, while the second method requires the user to run the modules interactively, saving these commands in a file for re-execution later.

LAS

The LAS application modules provide the user with the tools necessary to perform various analyses of image data.

Several basic procedures or scenarios are used in image processing. Among these are classification, clustering, Fourier transformation and filtering, geometric correction and registration, image repair, radiometric correction, statistics manipulation, and nominal filtering. The following figure (fig. 2) provides a flow diagram that shows the commonly used LAS modules required to carry out the supervised classification scenario. It starts with the input image and takes the user step-by-step through the alternative paths available to accomplish a classification. This scenario does not utilize all of the LAS modules available, but the ones listed in the scenario allow the user to accomplish the basics.

For every LAS module the user is provided two types of documentation. The on-line or "soft documentation," provided through TAE, and a hard copy. The on-line documentation is a subset of the information available in the hard copy and is stored as part of each module's proc

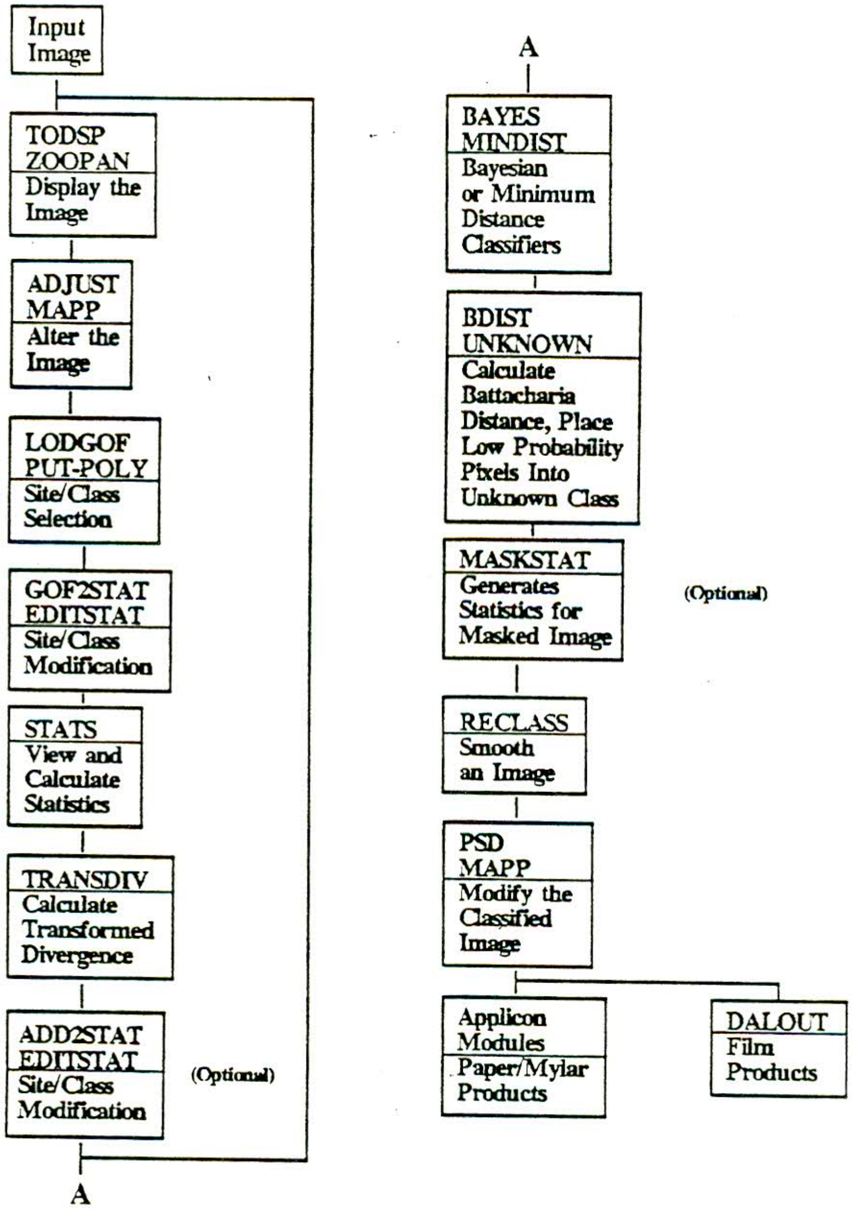

Figure 2.--Typical scenario for supervised classification using LAS at the EROS Data Center.

definition file (PDF). LAS employs many file or data structures. It has image, history, statistics, look-up tables, and geometric registration or transformation. LAS limits input image data to BYTE, INTEGER*2, INTEGER*4, and REAL*4 types. Individual module user's guides have information on limitations, such as image size, that apply specifically to those modules.

LAS Display Modules

The LAS display subsystem is composed of an underlying structure called the Display Management Subsystem (DMS) to which the applications modules have been interfaced. Figure 3 provides an overview of both DMS and the display application modules. The lower half of the figure provides a schematic of DMS. DMS utilizes the

- a set of graphics planes in which to store graphics data.
- look-up tables to store mappings for images.
- a pointing device for user interaction with the display.

LAS image data can be displayed and manipulated using special hardware features such as panning and zooming. Modified images, image mapping tables or graphics, and annotation information created can be saved on disk files for later usage. Images can also be viewed on the displays of computer systems on which they are not stored via the EDC local area network, for example, images on the VAX's can be viewed on any Sun's Rastertek.

The LDM, using DMS, allows a LAS user to display, interactively manipulate, and store images and image-related information. The LAS display modules to display images, modify mappings, generate pseudocolor, flicker images or mappings, manipulate the cursor, and perform arithmetic operations presently exist. Another important feature of the LDM is the mensuration or graphics modules. These modules allow the placement of points, lines, polygons, and annotation on the graphics planes of the display. These graphics can be associated with a specific image, such as training sites for supervised classification.

Data Base Management System

One capability in LAS, which was specifically requested by the user community, was a data base management system (DBMS). DBMS's allow users to organize and manipulate tabular data within a computer. They allow users to ingest, store, organize, retrieve, and manipulate tabular data and in some instances use relational algebra or calculus on the data. Currently, at EDC, LAS is interfaced to the RIM relational data base management system (RDBMS).

Relational Information Management System (RIM). RIM is a proprietary relational data base management system developed by Boeing. Data in RIM can be created, modified, deleted, and combined using RIM commands. RIM has a query language and allows the user to perform relational operations on the data base. Another series of commands allow the user to create new relations from existing ones. The user can intersect, union, join, project, or subtract one relation with or from another into a new relation. RIM also has a programming interface, a HELP and report-writer capability, as well as the capability to unload the data base for transfer between computers.

Data within LAS are moved to and from the RDBMS through an intermediate table structure. Consequently, LAS is not directly linked to any RDBMS but uses an intermediate structure that with a minimum of effort can be interfaced to any RDBMS. An example of using a RDBMS within LAS would be one in which each record of the data base represents a polygon on a map. The columns could

SUMMARY

This document provides an overview of LAS and TAE, including information on the history, an explanation of the components within LAS as it is presently configured at EDC, and, in some instances, details on how individual components work. Enhancements continue to be made in the areas of the catalog manager, statistical analysis and display modules, and the raster data interface.

LAS is a digital analysis system with over 275 modules designed to support remote sensing, image processing, and GIS research. LAS provides these capabilities with a combination of proprietary and non-proprietary software. LAS as a system is continuing to be developed both at the EDC, GSFC, and other government and university sites. Questions on LAS or TAE can be directed to COSMIC or EDC.

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Implementation of the Land Analysis System on a Workstation

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IMPLEMENTATION OF THE LAND ANALYSIS SYSTEM ON A WORKSTATION*

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ABSTRACT

The Land Analysis System (LAS) provides a broad range of functional capabilities in the general areas of image processing and analysis, tabular data processing and analysis, geographic data input and manipulation, and custom product generation. To enhance the functionality and utility of LAS to its users, implementations of LAS are being extended to microprocessor-based workstations. The LAS host-computer and workstation implementation approach centers on the development of highly transportable and functionally modular software and the utilization of hardware-independent interfaces and integration techniques. This includes the conversion of LAS to the UNIX operating system environment to further reduce hardware dependencies and to expand the utility of LAS to users on a broad range of processors.

INTRODUCTION

In June 1984 a Memorandum of Understanding was signed between the U.S. Geological Survey, National Mapping Division and the National Aeronautics and Space Administration (NASA), Goddard Space Flight Center to serve as a vehicle for extensive cooperation between the Survey's EROS Data Center (EDC) and the Goddard Space Flight Center's Information Extraction Division for the development, implementation, and maintenance of the Land Analysis System (LAS). The principal objectives of the development of this state-of-the-art image processing and analysis system include (1) the development of transportable software that can be freely and openly shared among government agencies and universities and installed on a variety of computer systems hardware; (2) the incorporation of a comprehensive user-friendly interface and array of executive services supporting raster, vector, and tabular data input, management, communication and display; and (3) a reliable and easily supported library of applications software modules that can be configured into production job streams to support routine operational tasks, while maintaining a flexible environment in support of research activities directed toward the development of improved processing techniques and algorithms for earth science data applications.

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Originally developed and implemented on minicomputer hardware, efforts are continuing to enhance the functionality and utility of LAS to its users, not only through the development of new and enhanced applications modules and system utilities, but also through the implementation of LAS on microprocessor-based workstations. Extending LAS to the workstation domain (1) allows greater flexibility in the configuration of hardware and software to meet the needs of a particular application or processing scenario; (2) lessens the potential impact of processing resource conflicts on users by placing a significant amount of dedicated processing resource directly in the hands of the user; and (3) allows more efficient utilization of the host-computer's resources by distributing highly interactive data capture, display, and analysis tasks to the workstation. Also, through the implemention of LAS on microprocessor-based systems, the availability of LAS is expanded to a larger number of potential users on a broad range of processors. This paper provides a brief overview of the functional characteristics of LAS, discusses the LAS software development and hardware integration approach being followed by EDC, and reviews the current status and plans for the implementation of LAS on microprocessor-based workstations.

LAND ANALYSIS SYSTEM OVERVIEW

LAS is an integrated system of hardware and software components providing for the input, storage, manipulation and analysis of a variety of digital image, tabular, and geographic data. Initially released to users in the fall of 1985, LAS provides a flexible user interface; extensive data-file management, reformatting, and conversion utilities; and interfaces to specialized peripheral devices and software packages that support a host of data processing, display, and analysis functions.

LAS application modules are accessed by the user through the Transportable Applications Executive (TAE). Developed by the NASA Goddard Space Flight Center's Image and Information Analysis Center to provide a standard and portable interface for users of scientific research and analysis systems, TAE presents a flexible, user-friendly interface to LAS users. As an applications executive, TAE unifies the many subprograms of LAS and facilitates user interaction with the computer by standardizing the user interface to application programs, shielding the user from the host operating system, and providing a congenial environment for both experienced and novice users. TAE provides menus for program selection, tutored displays for setting program parameters, a command mode for program selection by experienced users, and extensive help features.

Enhanced data-file management capabilities are provided by the LAS Catalog Manager. As an extension to the host operating system's file management utilities, the Catalog Manager provides greater flexibility in the naming of data files through the use of filename aliases, the ability to archive and retrieve data files to and from tape, and

allows the user to browse the catalog or search for specific data files by user-specified attributes. The Catalog Manager also provides a mechanism for the user to logically link or associate the various data files relating to a particular project or application, allowing enhanced data file tracking and manipulation.

At the core of LAS is a suite of over 200 data processing, analysis, and display modules, which can be categorized into the general functional areas of data input and output, preprocessing, signal processing, image classification, spatial manipulation, color display, custom product generation, tabular data processing and statistical analysis, geographic data input and manipulation, and general utilities. LAS accommodates the input and output of a variety of raster, tabular, and vector data in a number of data types and formats. Preprocessing capabilities include radiometric correction and image enhancement, as well as geometric correction, registration, and transformation functions. Signal processing functions are provided in such areas as intensity transformations, filters, and convolutions. Image hue, intensity, and saturation transformations and principal components analysis capabilities are also available. Some of the supervised and unsupervised image classification functions available in LAS include density and multispectral level slicing, minimum distance, maximum likelihood, and spectral or spatial classifiers. Spatial manipulations include reclassification, proximity and neighborhood analysis, and overlay processing.

LAS display application modules can be grouped into five general categories. The core set of color display modules provides display status information and allows the allocation and deallocation of a display, the loading and manipulation of images in the display memory planes, and the saving of images from display memory to disk. Mapping modules apply, save, and restore intensity and pseudocolor mappings. Graphics overlay modules create, save, modify, and restore text and linework and generate histograms and tick marks. Arithmetic modules generate output images by performing arithmetic, logic, rotation, and convolution operations on images. Cursor modules define, enable, and disable the cursor, determine cursor locations, and return intensity values.

Capabilities to produce high-quality hardcopy presentation materials are available with LAS through the combination of data preprocessing and manipulation modules and interfaces to specialized hardcopy devices. Modules are provided to register, merge, annotate, resize, or format data for custom product generation. Device-dependent interfaces and application modules are available for black-and-white electrostatic or color ink-jet plotters providing capabilities to plot graphic, raster image, or merged graphic and image data to size or scale. Also, LAS supports custom color film product generation on a McDonald-Dettwiler & Associates Color FIRE-240 film recorder.

The tabular data analysis subsystem of LAS provides storage, manipulation, query, and analysis capabilities for tabular information derived from a variety of sources including raster images, digitized map data, aerial photo interpretation and ground samples. In addition to providing a basic set of statistical analysis routines in support of image classification and analysis activities, LAS also provides a generic tabular data interface to statistical packages such as the Statistical Package for the Social Sciences (SPSS) or relational data base management systems such as the Boeing Commercial Services Relational Information Management System (RIM).

Although LAS is primarily a raster-based processing system, capabilities for the input, storage, manipulation, and conversion of vector data also exist in LAS. EDC has developed and demonstrated a prototype vector data interface system that utilizes the RIM relational data base management system for the reformatting, topological editing, and structuring of vector data for interfacing to a number of vector data capture and analysis systems. Portions of this RIM-dependent prototype system have been incorporated into the LAS domain, including modules for the conversion of raster data to the RIM vector data structure and vice versa. Also, EDC has developed capabilities in LAS to move point, line, polygon, and associated attribute data generated during a LAS display session to and from either the internal LAS tabular data structure or a relational data base management system such as RIM.

EDC is continuing to enhance the functionality and utility of LAS through the incorporation of new processing algorithms and analysis routines and the implementation of enhanced system-level interfaces and utilities. Application-level enhancements are continuing in the areas of display applications, additional tabular data processing and analysis functions, geographic data ingest and manipulation, and individual application modules as required by ongoing research and development activities. LAS system-level development activities to enhance the performance and utility of the LAS Catalog Manager, label services and associated file-handling utilities, as well as tabular and raster data interfaces, are also underway. In addition to these enhancements, EDC is pursuing the implementation of LAS on microprocessor-based workstations to further enhance its utility.

WORKSTATION IMPLEMENTATION APPROACH

EDC's model of a LAS workstation involves a 16- or 32-bit, microprocessor-based system configured with a minimum of 4 Mbytes of main memory; at least 150 Mbytes of disk storage; a serial communications interface capable of data transfer rates of at least 10-15 Kbytes per second; and a high-resolution color raster display with trackball or mouse, at least three image display memory planes, and a 2-bit graphics plane. These workstations can optionally be configured with additional main memory and disk storage, additional display memory planes and higher resolution graphics, a reel-to-reel or cartridge tape interface, a

digitizer, a graphics plotter, or other specialized peripheral devices depending on the application. The LAS applications executive, TAE, requires that these systems run under a multi-user, multi-tasking operating system. However, functionally, these workstations are intended to be primarily single-user systems.

The potential functional uses of a LAS workstation and the implied relationship or dependency on a host-computer are endless. For example, a LAS workstation might be used for interactive display and analysis or for technique development on a representative subset of data, with the host system providing data ingest, preprocessing, final processing, and output support. The workstation could be used for data capture, edit, and display in support of a routine production or research-specific task. Or, the workstation could be configured with a full complement of LAS data processing, analysis, and display software where the host-computer is used primarily for data staging or for access to specialized peripheral devices.

In order to accommodate the various functional configurations of LAS workstations and host computers, flexibility in the configuration of applications software is required. Also, to be in a position to take advantage of advances in computer processor and peripheral device technology, favorable hardware cost-for-performance ratios, and to extend the life of costly software, dependencies on specific computer hardware, operating system, and peripheral devices must be minimized. These requirements greatly influenced EDC's approach to LAS implementation by dictating development of highly transportable and functionally modular software as well as the utilization of hardware-independent interfaces and integration techniques wherever possible.

To guide LAS development EDC has developed a set of LAS software development and coding standards for both the C and FORTRAN programming languages. These standards are an extension to the core set of coding standards used in a variety of EDC application software development activities. The need for LAS development standards for transportable software was made evident with the first attempt to port LAS to a new operating system. Originally developed on Digital Equipment Corporation (DEC) VAX 11/780 hardware under the Virtual Memory System (VMS) operating system, a large number of LAS application modules were coded using VMS-specific FORTRAN compiler extensions, significantly reducing portability. Even though LAS application modules were largely written in FORTRAN, EDC is now coding many new applications and system-level modules in C to further enhance software portability. For example, the LAS display application modules developed by EDC were written entirely in C and implemented under both the VMS and UNIX operating systems. Also, the LAS library of system support routines for such services as disk and tape access as well as data manipulations, originally written in the VMS Macro-Assembler language, have largely been rewritten in C to reduce VMS dependencies and enhance portability to other operating systems.

The utilization of TAE inherently enhances the portability of LAS, isolating the user from the underlying operating system and assisting the applications programmer by providing such services as a common interface for terminal access and communication, parameter definition and ingest, message handling, script file creation, and session logging. In addition, TAE provides considerable flexibility in packaging application software to meet the needs of a particular application by providing convenient mechanisms for user menu definition and allowing commonly used modules to be combined into single procedures or "procs." To further enhance TAE, the NASA Goddard Space Flight Center has funded the development of a prototype version of TAE that utilizes the window management features available on a number of systems for enhanced presentation and manipulation of TAE menu, tutor, and help screens. A beta test version of this TAE window application is currently available for UNIX-based SUN microprocessor systems marketed by SUN Microsystems, Inc.

LAS also utilizes device-independent software interface techniques to further minimize dependencies and increase portability. For example, the LAS display application modules developed by EDC use the TAE Display Management Subsystem (DMS), jointly developed by the NASA Goddard Space Flight Center Image and Information Analysis Center and EDC, to provide a device-independent interface to color display devices. DMS minimizes application software dependencies on a particular display device by providing a generic set of image manipulation functions for device allocation, deallocation, and initialization; image transfer and setup; image viewing alteration; cursor manipulation; and image enhancement. In cases where device independence is not possible or practical, alternative approaches must be used. For example, several LAS application modules were originally developed to use a floating-point array processor. Since workstation configurations seldom include array processors, identical modules were developed that do not require an array processor to execute, in order to maintain full functionality to the user. These techniques have also been used for interfaces to external software packages where generic data tables and structures are utilized for interface to various statistical packages or data base management systems.

Another major thrust toward hardware independence involves the implementation of LAS under the UNIX operating system. When LAS software is fully implemented under UNIX, not only will LAS be available to a larger number of hardware systems as more vendors offer UNIX-based systems, but also the portability of LAS software to other non-UNIX operating systems is improved as system dependencies are further minimized. The implementation of application software under UNIX is enhanced by the use of the C programming language. Both TAE and DMS were written in C under the VMS operating system, and relatively minimal effort was required to convert these systems to UNIX. The presence of TAE and DMS under both VMS and UNIX allowed EDC to concurrently develop the LAS display applications modules

in C under both operating systems. A user can now utilize the same LAS display software on different display hardware operating under a common applications executive on both UNIX and non-UNIX systems, thus demonstrating the complete integration of transportable software with peripheral-device and operating-system independence.

Implementation of LAS on a variety of computer systems requires effective data communications among heterogeneous systems. To meet this requirement, EDC has implemented a local area network utilizing device-independent hardware interface techniques. EDC minicomputers and microprocessor workstations supporting LAS applications have been configured as a local area network using Ethernet and Network Systems Corporation's HYPERchannel and HYPERbus data communications hardware. This network uses an implementation of the proposed Federal Information Processing Standards for local area networks issued by the National Bureau of Standards, which conforms to the International Standards Organization (ISO) model for Open Systems Interconnection. The network software developed by EDC uses the transport layer of the proposed ISO standard protocols. These standard protocols were chosen because they provide greater flexibility of interface to new computer systems and other networking software.

LAS application-level utilities have been developed that allow the user to easily transfer LAS images and associated data sets among the several nodes of the network. Where appropriate, data transfer capabilities also have been incorporated directly into LAS applications modules. For example, a network interface has been incorporated into the LAS display application module that loads an image from disk to color display memory, allowing a user on a workstation to select, for local display, an image that resides on any LAS system on the local network with sub-imaging, reformatting, and data transfer being accomplished automatically.

Even though EDC has successfully demonstrated the benefits of software portability and hardware independence, the concept of complete hardware independence must be looked upon as a goal rather than a guaranteed result. System and device dependencies can only be minimized and isolated, not entirely eliminated. Also, the realities of performance trade-offs, conflicting application requirements, and development overhead must be factored into software system development and implementation plans. EDC will continue to strive to achieve the highest level of software portability and hardware independence practical, to expand the availability and prolong the life of LAS software.

CURRENT ACTIVITIES and PLANS

Functional subsets of LAS have been implemented on DEC MicroVAX II hardware, which uses the VMS operating system. Since LAS was originally developed under VMS on DEC VAX 11/780 hardware, the effort required to accomplish this task was minimal. To date, two MicroVAX installations of LAS have been accomplished by EDC, one at EDC's Alaska

Field Office in Anchorage, Alaska, and a second at the U.S. Geological Survey Western Mapping Center in Menlo Park, California. Although these particular systems are currently intended to be used in a standalone mode, to provide processing capabilities where none previously existed, they can be looked upon as seeds for future upgrades to host-computer and workstation configurations. EDC also plans to acquire the recently announced VMS-based VAXstar, a 32-bit desktop microprocessor, to evaluate its potential use as an LAS workstation.

Efforts are also under way to implement LAS under the UNIX operating system both on minicomputer hardware and microprocessor workstations. EDC has several UNIX-based SUN microprocessor systems configured with color raster displays to support LAS applications. These SUN workstations are currently being used primarily for interactive display applications. Although the full complement of LAS display applications modules have been implemented on these workstations, to date only a few nondisplay modules have been converted to UNIX. Unfortunately, as indicated earlier, a large number of the application modules developed in the early stages of LAS were written using VMS-specific FORTRAN compiler extensions, requiring significant modification or rewrite of the modules to achieve the desired level of transportability. As a result, the nondisplay application modules currently available under UNIX represent the functional areas of tape input and output, data format and type conversion, and preprocessing, with the majority of the analysis and processing modules yet to be converted.

A firm schedule for the full implementation of LAS under UNIX has not been established. However, EDC will continue to convert LAS application modules to UNIX with development priorities based on individual application project requirements. In addition, other organizations have expressed interest and support for the implementation of LAS under UNIX. The NASA Goddard Space Flight Center is also committing development resources to convert LAS to UNIX in a common effort to enhance its portability to other systems and thereby expand its availability to a larger number of potential users.

SUMMARY

Initially released to users in the fall of 1985, LAS provides a broad range of functional capabilities in such areas as image processing and analysis, tabular data processing and analysis, geographic data input and manipulation, and custom product generation. Efforts are continuing to enhance the functionality and utility of LAS to its users, not only through the development of new application routines and system utilities, but also through the implementation of LAS on microprocessor-based workstations. The LAS host-computer and workstation implementation approach centers on the development of transportable and functionally modular software as well as the utilization of hardware-independent interfaces and integration techniques. This approach provides flexibility

for the packaging of applications software to meet the needs of a particular application or research project, maintains a uniform user interface and applications software set between the host-computer and workstation, and minimizes the need to modify software to fit specific hardware and operating systems. Subsets of LAS have been ported to DEC MicroVAX hardware under the VMS operating system. Also, efforts are underway to convert LAS to the UNIX operating system environment for implementation on both minicomputer and microprocessor hardware. The implementation of LAS under UNIX, coupled with the development of transportable software and the incorporation of device-independent interfaces, will significantly reduce hardware dependencies and expand the availability of LAS to a larger number of potential users on a broad range of processors.

The Land Analysis System (LAS): A General Purpose System for Multispectral Image Processing

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THE LAND ANALYSIS SYSTEM (LAS): A GENERAL PURPOSE SYSTEM FOR MULTISPECTRAL IMAGE PROCESSING

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ABSTRACT

The Land Analysis System (LAS) is a general purpose image processing system that is available in the public domain. The LAS provides a comprehensive and well documented set of functions for manipulation of multispectral remotely sensed data. The initial release (Version 3.1) has over 240 functions and utilities that provide the user with a complete image analysis environment ranging from basic pixel manipulation to complex classification algorithms. A User's Guide provides a detailed description of each function in terms of purpose, input parameters, examples, algorithm, error messages, and user notes. Additional documentation is available to describe the implementation of new functions including the applications programmers guide, the image and statistics input/output packages, and the pixel manipulation routines. The source code is distributed to simplify system maintenance. The LAS uses the Transportable Application Executive (TAE) as the user interface. This interface is designed to accommodate both novice and experienced users by allowing menus and tutored prompting for parameters or terse command line inputs. The LAS currently runs on mini- and micro- computer systems under the DEC VMS* operating system. Conversion to the UNIX operating system is in the planning phase.

INTRODUCTION

The purpose of this paper is to provide an overall description of the initial release (version 3.1) of the Land Analysis System (LAS), a general purpose image processing system for manipulation of multispectral image data. The LAS was developed by the Space Data and Computing Division (SDCD) at the NASA Goddard Space Flight Center (GSFC) to satisfy the image processing requirements of the Laboratory for Terrestrial Physics (LTP), also at GSFC. The SDCD was responsible for system design, coding, integration, and documentation. The LTP was responsible for supplying functional requirements and for performing acceptance testing. The EROS Data Center (EDC) also participated in design reviews and provided programming support.

*Trade names are given for descriptive purposes only, and do not imply endorsement by NASA.

The LAS was originally developed as an engineering and scientific assessment tool for evaluation of data from the Landsat-4 Thematic Mapper (TM) sensor (Fischel 1982). It was also used for oneyear after launch of Landsat-4 to perform the operational processing of TM data. As such, the system was initially designed to support the production requirement of one radiometrically and geometrically corrected TM image per day. A Digital Equipment Corporation VAX 11/780 with a Floating Point Systems AP180V array processor was used to provide the necessary computational throughput. It was proposed that, following the completion of TM ground processing in July 1983, the LAS could be expanded to an interactive general purpose image processing system to satisfy the requirements of the LTP earth resources scientists.

The specification of requirements proved difficult at first because relatively few references are available in the literature on the subject of remote sensing software systems (Bracken 1983). As a result, it was necessary to develop ad hoc criteria for the design and verification of LAS on the basis of experience with the strengths and weaknesses of the image processing systems then in use by LTP researchers. The first step was to generate a prioritized list of functional requirements from an analysis of the most frequently used image processing functions. The second step was to define further requirements regarding user interface, documentation, image display interface, programmer interface, ease of maintenance, processing speed, and data management. Failure to satisfy these additional requirements can seriously compromise the utility of an image processing system even though it may otherwise provide all of the necessary functions.

In-house development was considered to provide the following advantages as compared to the option of acquiring a commercial system: 1) LTP users were able to exercise considerable influence in the end product by directly participating in requirements specification, design reviews, and system evaluation; 2) the system source code could be made available to other government agencies at minimal cost; and 3) the system could be easily maintained and/or modified internally to evolve with new or changing requirements.

However, it was not necessary to develop all of the system from scratch. An early version of the user interface, the Transportable Applications Executive was already available and numerous applications functions and support services could be adapted from the TM ground processing system already in place. A further reduction in development effort was achieved by using commercial software for image display manipulation, geographic entry system, geographic information system, and mathematical and statistical processing.

The LAS development was expedited by a close working relationship between the system developers in the SDCD and the LTP users and by the efforts of an LTP "Audit Team" who formulated detailed requirements, assisted programmers in interpreting requirements, reviewed design specifications and documentation prior to coding, and performed testing and evaluation as part of the acceptance test. The baseline release of LAS with 240 functions and over 200,000 lines of code was delivered by SDCD in July 1985. The LAS was first implemented on the SDCD's VAX system and then installed on the LTP VAX following the successful completion of the acceptance test in August 1985.

SYSTEM DESCRIPTION

The baseline version of LAS was implemented on a VAX 11/780 under the VMS operating system. The array processor on the SDCD VAX is a Floating Point Systems AP180V (a FPS 5210 array processor is used on the LTP VAX). The image display is the International Imaging Systems (I^2S) model 75 and the display software is the I^2S System 575. The system was written in FORTRAN 77 (~75 percent), C (~20 percent), and Macro 11 (~5 percent). The LAS consists of five major components as illustrated in Figure 1: the user interface, the applications programs, the display interface, the system support libraries, and the external software libraries and systems. The code written specifically for the LAS includes the Applications Programs, the System Support Libraries, the Catalog Manager, and the interface between the LAS and the I^2S display system. The Transportable Applications Executive (TAE) (Szczur et al. 1985), provides the basic environment for applications software development and for the user interface in LAS. The TAE was developed by the SDCD as a general purpose executive. Improvements in user friendliness were included in TAE in response to requirements specified by the LAS development team. The LAS documentation consists of over 1200 pages with system overview, detailed descriptions of the applications functions, system services, applications programmers guide, user manual, the Catalog Manager, and the Transportable Applications Executive.

In addition to the GSFC developed code, commercial software packages were also used in the LAS to expedite delivery of the initial version. Software interfaces (i.e., subroutine calls) are used to access the three ancillary systems, the I^2S System 575 display software, the Floating Point Systems function library, and the International Mathematics and Statistical Library (IMSL). These systems are used respectively to: manipulate the I^2S Model 75 displays from GSFC developed display functions; access the array processor; and support mathematical and statistical computations. Data interfaces (i.e., communications via data files) are used to provide access to four external packages, the I^2S Model System 575 image processing system, the Statistical Analysis System (SAS), the Analytical Mapping System (AMS), and the Map Overlay and Statistical System (MOSS). These systems are used to provide access to the I^2S command interpreter and image processing functions, a general purpose statistical analysis system, a geographic entry system, and a geographic information system, respectively.

The documentation for the ancillary and external systems was provided from the respective software vendors. Additional user notes were written if the vendor documentation was considered to be insufficient or incomplete. The remainder of this section provides a functional description of the GSFC developed elements of LAS. The intent is to summarize the capabilities of the user interface, the applications programs, the data management, and other system commands from a user's point of view. A brief description is also given of the system support libraries.

User Interface

The Transportable Applications Executive (TAE) was used to provide a unified, user-friendly, and flexible user interface. Functions can be executed in a batch or interactive mode and selected from menus or by command entry. In the menu mode a user can search through a hierarchical structured menu tree to locate a specific function. The options available are presented at the bottom of the menu. These include: select a procedure or another menu, request help information, return to the previous menu or to the top of the menu tree, move to a named menu, switch to command mode, or log out of the system. In the command mode, the user can activate a function by entering its name and the required parameters.

In either menu or command mode, the user can activate a tutor screen which prompts for mandatory and optional parameters. Parameters are validated prior to program execution and the user is re-prompted for invalid entries. The amount of typing can be minimized by: abbreviating parameter names, saving, recalling, and/or editing parameter values, and using string definitions and wildcards. Spectral and spatial subsets can be given as part of the image name. Meaningful default values are provided for optional parameters. A sub-command facility is available that limits the prompts in tutor mode to only those parameters required under the selected processing option. Other TAE command options are listed in Table 1. On-line help information is available to describe TAE menus, TAE commands, LAS applications programs, and program parameters. Off-line documentation available for the TAE includes the Primer, User Reference, and Programmer's Guide.

Applications Programs

The LAS applications functions were implemented in response to a prioritized list of functional capabilities that were identified from an internal survey of LTP image processing users. These requirements were drawn from experience with four different image processing systems including: IDIMS (ESL 1983), LARSYS (Spencer and Philips 1973), ORSER (McMurtry et al. 1977), and SMIPS/VICAR (Moik 1973) that represent over 500 or

more applications functions, with considerable overlap in functionality. The result was a selection of over 240 generic functions that provide the user with an end-to-end multispectral image analysis environment with capabilities for basic pixel manipulation, radiometric and geometric transformation, supervised and unsupervised classification, and color enhanced film product generation among others. A summary of the functional capabilities is given in Table 2.

A considerable amount of development effort was devoted to ensure that the functions were "user friendly" and that the documentation was accurate, complete, and consistent. Prior to program execution, the existence of input files is verified and the disk space for output images is allocated. Output images are created only if a functions completes successfully. The documentation was written and reviewed for each function prior to coding and reviewed again for consistency after coding. It was also evaluated by the Audit Team as a part of the acceptance test.

The documentation for each function includes the following: revision date, processing time estimate (where appropriate), purpose, parameters, algorithm, error messages, examples, prerequisites, processing limits (e.g., maximum image size, number of categories, and data types allowed), and references (where appropriate). On-line documentation of the purpose and parameters of each function is provided by the TAE help facilities. A naming convention was used throughout to insure that the parameter names and the valid user responses are consistent.

Catalog Manager

The Catalog Manager (CM) is a logical file management system that allows users to access files using naming conventions which are not dependent on the host operating system. This capability allows the user to specify longer and more meaningful names for images and data files. The CM also allows file attributes to be associated with a catalogued file and supports file searching or listing on the basis of these attributes. The LAS functions were developed using CM routines to facilitate the accessing, addition, deletion, renaming, and listing of images or image-related files for both on-line and off-line data. Archival and retrieval functions are available to transfer data to and from magnetic tape. The CM maintains a directory of the archive tapes and keeps active information about the files in the catalog. This allows users to make effective use of disk space without having to manage a tape directory or keep track of the physical location of files. Table 1 includes a summary of the CM file management utilities.

History Files

The capability for maintaining image history and session logs is provided. Processing history information is maintained for all LAS images and includes image names, applications functions used, and parameter values. The user can elect to add comments to, list, or delete records in the image history. A session log is kept for interactive sessions. The session log is a concise record of the pertinent user entries, program messages, and results appearing at the user's terminal. The user has the option to print or delete the current session log before logging off the system.

Applications Libraries

A set of applications libraries were developed to provide a consistent interface to commonly used system-related functions for use by applications programmers. The libraries include: geometric coordinate translation, image I/O, label services, pixel manipulation, and statistics I/O. The geometric coordinate translation routines are used to translate coordinate pairs between different map projections. The image I/O functions provide efficient read, write, and update access to image data independent of image labels, structure, or data type. The label services functions are used to read, write, or update the LAS image labels. Pixel manipulation functions perform unary (e.g. logarithm), binary (e.g., arithmetic or logical), and miscellaneous (e.g., data type conversion) operations on image lines or line segments. The statistics I/O functions can be used to update, search, and delete information within the hierarchy of the LAS statistics files.

SYSTEM EVALUATION

The LAS software was subjected to an exhaustive acceptance test to evaluate the documentation, functionality, user friendliness, and performance to insure that the requirements were satisfied. Also, a set of designated processing scenarios were used for an additional test to verify that tasks which require the use of multiple functions could be completed effectively. These "macro-modules" are representative of typical science applications research tasks that require the use of two or more functions. Various elements of the overall system were also evaluated, including data archive to tape, retrieval of data from tape to disk, data cataloguing, and session history logging. The macro-modules contain sequences of modules that test aspects of: data transfer, preprocessing, geographic registration, data transformation, creation of raster images from digitized maps, supervised classification, unsupervised classification, spatial and frequency domain feature extraction, and interfacing to the I^2S Model 75 display. The interfaces to the AMS, MOSS, and SAS systems were also evaluated. Considerable effort was spent in the evaluation of the applications functions to verify that the programs performed as documented, the off-line and on-line documentation are consistent, and that any program limits (e.g., maximum image size or number of spectral bands) are correctly noted, and that the default parameters values match the documentation.

CONCLUSIONS

Evaluation of over 240 individual modules, nine macro-modules, and four sub-systems has demonstrated the utility of LAS in that the image processing requirements of the Laboratory for Terrestrial Physics have been met or exceeded by the majority of functions. The LAS has been successfully used on the LTP VAX system since May 1985. The following functional advantages useful features were noted from the acceptance test and from over 18 months experience in using the system:

- o The LAS provides the comprehensive set of image processing capabilities required to support the land analysis research requirements of the LTP and EDC.

- Extensive on-line and hardcopy documentation is available.
- A user only has to master a single interface (TAE), independent of the host system, in order to use any non-display LAS function or utility.
- Novice users can select functions from menus and be prompted for parameters.
- Experienced users can select functions and define parameters via terse commands.
- The standard support libraries facilitate development of new applications programs.
- Only the appropriate data interfaces have to be changed to modify or replace the statistical analysis, geographic entry, and geographic information systems.
- The catalogue manager provides host system independent file management including tape archive and restore.
- Most LAS functions allow processing of images with spatial limits of 8192 pixels per line and 8192 lines, a capacity sufficient to process full TM scenes.

The three ancillary systems (I^2S System 575, IMSL subroutines, FPS array processor functions) were all required for the initial delivery of the system. Since that time, additional programs have been written so that the functions that previously only ran on the array processor can now be run with the host cpu. Release 3.2 of LAS incorporates these modifications and miscallaneous problem report fixes. The Display Management System (DMS), a high level device independent display interface (Perkins et al. 1984), is being integrated into LAS so that the image display functions can be accessed directly from TAE without having to invoke the I^2S command interpreter. The DMS integration will be included in the next LAS release (version 3.3) with an anticipated delivery by the end of June, 1987.

Other areas of LAS that warrant further development are: 1) removal of the file group implementation of multispectral images in which each band is stored in a separate file; 2) improved performance in the catalogue manager support of file archival and restore; and 3) developing a portable implementation of the system. These upgrades are expected to be incorporated as part of the LAS conversion to run on workstations under the UNIX operating system. Versions of the TAE and the DMS are already running under the UNIX operating system. The LAS and the TAE are available in the public domain through the Computer Software Management and Information Center (COSMIC) at the University of Georgia, Athens, Georgia.

ACKNOWLEDGMENTS

The successful outcome of LAS development has been a team effort with too many individual participants to be listed in this limited space. Therefore, the authors wish to collectively acknowledge the contributions to this project by the following organizations: NASA/GSFC Space Data and Computing Division, NASA/GSFC Laboratory for Terrestrial Physics, U. S. Geological Survey EROS Data Center, Science Applications Research Corp., Systems and Applied Sciences Corp., Century Computing Corp., and Computer Sciences Corp.

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Table 1: Summary of file management functions and TAE commands.

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file management: place user text in history file, archive disk image to magnetic tape, cleanup temporary files after session, delete image history, display image history, display group definitions and attributes, display data descriptor record, copy files, generate file group, delete file, list files and attributes, rename file, retrieve archive files from/to tape, determines physical characteristics of files on magnetic tape.

TAE commands: abort current process, manipulate batch queue, continue process (after abort), execute VMS command, define command, delete command definition, delete global variables, run function, save (restore) function parameters, show values of function parameters, display values of local and global variables, disable (enable) session logging, end the TAE session, obtain help information, assign a value to a variable, exit

from TAE and logoff VAX, enter TAE menu mode, set library search order (for local versions of functions), display library search order, enter TAE tutor mode.

Table 2: Summary of the LAS application functions.

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arithmetic: absolute value, addition, division, exponentiation, multiplication, arctangent, logical comparisons between pixels and constants, per-pixel maximum and minimum, unary operation (e.g., negation, cosine, sine), bitwise logical operators (and, complement, exclusive or, not, or).

complex: form complex image from real and imaginary images and from magnitude and phase images (and the converse), compute complex conjugate, raise frequency domain image to a power while retaining phase image.

data transfer: read MSS and TM data in various formats, read (write) blocked or unblocked data from (to) magnetic tape, read digital elevation model data, read data in universal tape format.

Fourier analysis: compute Fourier cross correlation between images, generate Fourier correction filter for linear motion, compute 1 and 2-D Fourier (and 2-D inverse) transforms and filters, create amplitude and phase images from 2-D complex Fourier image, generate filter weights by performing inverse Fourier transform on specified modulation transfer function.

geometric transformations: manipulate (create, display, edit) tie point coordinates and transformation coefficients, generate tie point and mapping grid files to correct Landsat (1,2,3) MSS images, refine tie point locations, compute tie points from edge or grey level correlation function, perform geometric transformation, generate mapping grid file from transformation grid file, use tie points to register two images, generate grid file for converting from one standard map projection to another, rotate image by specified angle, compute mapping grid for rotation, scaling, and translation, extract tie points from graphics overlay file, generate mapping grid from arbitrary tie point pairs, convert point coordinates between coordinate systems.

hardcopy and terminal listing: insert vertical or horizontal annotation, create color classification map, list contingency table, produce Versatec image plot of image, reformat disk image for film product generation, transfer images to tape in DICOMED or OPTRONIX format, produce histogram plot from statistics file, produce table of contents of LAS functions, produce graphic display of image intensities, list pixel values, display mapping-grid file, display radiometric look-up table, generate character map of single band image, create 2-D scatter plot from specified band pair, create graphical representation of statistical data, produce 3-D plot of training site statistics.

image display: set bit combinations, define cursor, display image, apply intensity mapping (exponential, logarithmic), flicker series of B/W and pseudocolor look-up tables, manipulate graphics overlay (annotation, points, lines, polygons), display coordinates and intensities at cursor location, list pseudocolor table, locate ground coordinate on geometrically corrected image, assign colors to intensity values, define and edit mensuration data, apply hardware zoom.

image manipulation: compare one or more pairs of images for equivalency, concatenate images, convert image from one data type (e.g., byte, integer, real) to another, copy an image or subset of an image, flip image about vertical and or horizontal axis, superimpose grid on image, insert polygons from one image into another image, perform independent fractional zooming on X and Y axis, interchange rows and columns of an image, change image scale by deleting or replicating pixels.

intensity transformation: apply gaussian transfer function, correct for detector miscalibration in Landsat images, compute histogram equalization to correct regular striping, correct for cyclic offsets in an image, replace cyclic missing lines of data by averaging, perform piecewise linear transformation, apply radiometric look up tables to an image, perform intensity mapping to generate uniform histogram, reassign specified intensity values, linearly rescale image, repair offset or fill broken lines, repair lines or rectangular segments of pixels, generate look-up table from specified stretch function, delete look-up table, perform mappings on selected classes and sites in an image.

multispectral processing: compute per-pixel ratio of one band to linear combination of bands, maximum likelihood supervised classification, canonical analysis, train test and apply linear discriminant classifier, apply linear transformation, multidimensional histogram cluster analysis, isodata cluster analysis, principal components transformation, simplified isodata cluster analysis, minimum distance classifier, classify training sites, assign pixel to unknown class based on threshold of maximum likelihood or chi-square image.

sampling: spatially random selection of pixel within specified class and stratum, obtain graylevels at specified image coordinates, compute unique graylevel combinations from two or more stratified images, use polygonal sites from statistics file to mask image, randomly select specified percentage of pixel blocks, generate separate multispectral image for each class, compute euclidian distance from each pixel to nearest specified target class, systematic pixel sampling.

spatial processing: moving window average, spatial domain convolution, create weight function for convolution, spatial gradient filter based edge enhancement, sliding window local operations, search neighborhood around each pixel for certain characteristics (e.g., min, max), moving window mode filter, select angles and distances to be used for computing co-occurrence matrices, compute mean difference texture values within specified neighborhood, evaluate spatial variability using one of eight texture measures, compute multispectral gradient and histogram, classify gradient image based on user-defined uniformity class limits.

statistics: compute statistics for selected image regions and store in statistics file, combine classes in one statistics files with those in another, compute Bhattacharya distance for class pairs in statistics file, compute mean vector and covariance matrix of an

INDEX OF LAS USER'S GUIDES

Alphabetical Listing of LAS Modules

Module	Comment
ABS	Calculates the absolute value of an image's pixels.
ADDPIC	Adds two images together.
ADD2STAT	Combines some or all classes in a statistics file with those of another.
ADJUST-LDM	Interactive adjustment of brightness values.
ALBEDO	Computes the albedo of Landsat images.
ALLOC-LDM	Allocates a display.
ALTPATH	Equates a RIM data base name with a directory.
ANDPIC	Performs a bit-wise logical AND.
ANNOTATE	Inserts annotation into an image at a specified location.
ANNOTE	Places a text string into a image's history record.
ARCHIVE	Archives LAS images from disk to tape.
ARCTAN	Computes the arctangent (in radians) of an image's pixels.
ARITH-LDM	Performs arithmetic operations.
ASONCP	Copies image associated files between computer systems on the network.
AVERAGE	Averages an input image using a moving window.
AVHRR0	Generates AVHRR band 0 data from two existing AVHRR images.
BANDRATIO	Computes the pixel-by-pixel ratio of an image.
BANGLE	Calculates the beta angle for an image.
BAYES	Performs Bayesian classification on a multiband image.
BCS	Initiates a BCS RIM session.
BDIST	Calculate Bhattacharyya distances between pairs of classes.
BLDPW	Creates/modifies pairwise weighting tables for nominal filtering.
BLDTHR	Creates/modifies threshold table for nominal filtering.
BUTTER	Combines images.
CANAL	Performs canonical analysis/transformation on a multiband image.
CCTEDCS	Reads Landsat MSS data in EDIPS LGSOWG tape format.
CCTL4	Reads MSS data tapes from Landsat 4 and 5.
CCTTIPSA	Reads Landsat 4 and 5 TM data contained on TIPS-A format tapes.
CCTTIPSP	Reads Landsat 4 and 5 TM data contained on TIPS-P format tapes.
CLASSMAP	Creates a color classification map of a classified image.
CLEANUP	Assists users in cleaning up their accounts.
COEFFEDT	Geometric registration, edits coefficients in a transformation grid file.
COMPARE	Performs a pixel-by-pixel comparison of two images.
COMPLEX	Combines two images (real and imaginary) to form a image.
COMPOL	Combines two images (magnitude and phase) to form a complex image.

COMSEP	Separates the real and imaginary components of a complex image.
CONCAT	Concatenates up to ten images.
CONJ	Computes the pixel-by-pixel complex conjugate of a complex-valued image.
CONSEG	Detects boundaries of contiguous pixel groups in an image.
CONTABLE	Generates a contingency table.
CONTROL	Generates four point pairs and grid file to correct MSS image distortion.
CONVOL-LDM	Performs a spatial domain convolution filter as a display function.
CONVERT	Changes images from one data type to another.
CONVOLVE	Performs a spatial domain convolution filter.
COORDEDT	Geometric registration, edits tie point selection files.
COPY	Copies images.
COVAR	Computes the mean vector and covariance matrix of a multiband image.
CPYGOF-LDM	Copy graphics record from an ARL or GOF into a specified GOF.
CROSSCOR	Performs Fourier-domain auto-correlation and cross-correlation.
CURPOS-LDM	Displays the cursor position and image intensity values.
CURSOR-LDM	Turns the cursor on or off.
CWTGEN	Generates weight functions for CONVOLVE.
DALIN	Reads images from tape. Tapes are in DAL transfer format.
DALLOC-LDM	Deallocates a display.
DALOUT	Writes images to tape in DAL transfer format.
DDREDT	Edit DDR files by calling STVEDT.
DEBLUR	Corrects linear motion blur of an image.
DEFATT-LDM	Defines the attributes in a graphics overlay file.
DEFCUR-LDM	Define a cursor.
DELATT-LDM	Deletes attributes from a graphics overlay file.
DELDPF-LDM	Deletes a DPT entry from the associated display parameter file (DPF).
DELLUT	Deletes look-up tables from an image label.
DELGOF-LDM	Deletes graphics from a GOF.
DEMENTER	Reads DEM, DTED, and DTT data from tape to disk.
DEMTORIPS	Transfers DEM data to RIPS.
DISCRIM	Trains, tests, or applies a linear discriminant classifier.
DITTO	Utility used to manipulate magnetic tapes and disk files.
DIVPIC	Divides one image by another.
DMOUNT	Dismounts and unloads a tape.
DPFMAP-LDM	Converts a mapping stored in a DPF to one usable by the MAP module.
DPTLUT-LDM	Apply the look-up table of a DPT entry to the displayed image.
DROPHIST	Deletes history records of an image.
DSPCONTBL	Displays contingency tables.
DSPELE	Displays elevation header information.
DSPGRID	Displays grid and transformation information for a grid file.

DSPGROUP	Displays image group members and attributes.
DSPHISTRY	Displays history records of an image.
DSPLBL	Displays DDR for an image.
DSPLOG	Displays a LAS session history.
DSPRLT	Displays the contents of a radiometric look-up table.
DSPVERSA	Displays an image on the Versatec plotter.
DSTAT-LDM	Displays information on the display.
EDGECORR	Correlation via edges in an image.
EDIPSIN	Transfers EDIPS images from tape into LAS.
EDIPSOUT	Transfers LAS images to tape in a EDIPS format.
EDITSTAT	Performs editing of a statistics file.
ENGRAVE-LDM	Engraves displayed GOF graphics into the displayed image.
FFT1	Computes a one-dimensional Fourier transform.
FFT1FL	Computes a line-by-line, one-dimensional Fourier transform filter.
FFT2	Computes a two-dimensional Fourier transform.
FILECOPY	Copies LAS images.
FILL-LDM	Fill selected polygons with a constant value or user specified mapping.
FILM	Formats images on disk for later generation of film products.
FILMTAPE	Transfers image data to tape for use by Dicomed or Optronics film recorders.
FILTER	Perform a low-pass, high-pass, or median filter.
FITLIN-LDM	Fit a line to interactively user-specified points.
FIXLIN	Generates replacement blocks of image data to be substituted in place of bad image data.
FLAG	Flags homogeneous regions below a threshold, part of the nominal filtering software.
FLICKR-LDM	Flickers images.
FLIP	Flips an image along the x or y axis.
FMOUNT	Used to mount a tape.
FRAME-LDM	Grab frames from the video digitizer.
FRMDSP-LDM	Copies an image from display memory to disk.
FT1PIX	Creates amplitude and phase display for a one-dimensional Fourier transform.
FT2PIX	Creates amplitude and phase display for a two-dimensional Fourier transform.
GAUSTRAN	Applies a Gaussian transfer function to an image.
GEOM	Performs a geometric registration.
GETBLOB	Identifies the regions in an input image which comprise a given class.
GETSAMP	Selects spatially random pixels from a class within a specified stratum.
GOF2RIM-LDM	Converts point, line, polygon, and annotation information from a graphics overlay file to a RIM data base.
GOF2STAT-LDM	Converts polygon information from a graphics overlay file to a LAS statistics file.
GOF2TAB-LDM	Converts polygon information from a graphics overlay file to a labelled table.
GRAD	Computes a local gradient of an image.
GREYCORR	Image correlation using grey-level values.

GRID	Superimposes a grid on an image.
GRIDGEN	Geometric registration, reads transformation coefficients from a grid file and generates a new grid.
GROUP	Creates a file group of the input images.
HINDU	Performs unsupervised classification based on an image's histogram.
HIS2RGB	Translates hue, intensity, and saturation to red, green, and blue.
HISTEQ	Performs a histgram equalization.
HISTO-LDM	Calculates a histogram.
HISTPLT	Produces a histogram of an image.
HRPTCAL	Calibrates AVHRR HRPT data.
HRPTIN	Inputs HRPT formatted images (AVHRR) into a LAS image.
IENTER	Transfers data from tape to disk.
IFFT2	Perform an inverse two-dimensional Fourier transform.
INFARC	Create a compressed raster file from arc data stored in RIM.
INFCPY-Applicon	Copies plot files to tape.
INFCRF-Applicon	Creates compressed raster files from LAS images.
INFCTT-Applicon	Combines the INFMCC and INFTRF modules.
INFLTT-Applicon	Combines the INFCRF, INFMCC, and INFTRF modules.
INFLUT-Applicon	Creates look-up table used by other Applicon modules.
INFMCC-Applicon	Defines LUT, processing type, and number of panels for plots.
INFOPT	Creates Applicon background file or plot file from compressed raster and/or background files.
INFPOLY	Creates a compressed raster file from polygon data in RIM and a look-up table.
INFTRF-Applicon	Creates plottable files from compressed raster files.
INIT-LDM	Initializes all memory and/or graphics planes.
INSERT	Places polygonal areas of image data from one image into another.
INSERT2	Inserts one image into another.
INTERSECT	Compares corresponding pixels from multiple input images and creates a single-band output image representing the permutations of gray levels from the input images.
ISOCLASS	Performs an unsupervised clustering classification.
ITRANSFER	Transfers data from disk to tape.
KARLOV	Performs a Karhunen-Loeve transformation on a multiband image.
KMEANS	Group data into a predetermined number of clusters.
LACIN	Inputs LAC formatted images (AVHRR) into a LAS image.
LASDEL	Deletes an image from the catalog manager.
LASNCP	Transfer images from one computer system to another over the network and enter them in the user's catalog.
LASTORIPS	Transfers LAS images to RIPS.
LINEOFF	Corrects for offsets in image lines in a cyclic manner.
LINEPLOT	Displays pixel values along a row in a bar graph format.
LINEREPR	Replaces cyclically missing lines of data.
LIST	Displays the pixel values of the images.

LISTCAT	Provides catalog information on images.
LODDPF-LDM	Loads a DPT entry from an image's associated display parameter file (DPF).
LODGOF-LDM	Generate an active record list for a graphics overlay file.
LOGIC-LDM	Peforms logical operations.
LOGICAL	Performs logical comparisons between images.
LOWCAL	Performs selected local sliding-window operations on an image.
LPMAP	Generates a character map of an image.
LSTDPF-LDM	Lists DPT entries in an image's associated display parameter file (DPF).
LSTGOF-LDM	Lists graphics record information to the terminal, file, and/or line printer.
LSTIMG-LDM	Lists information on images in DPT.
MAGNIFY	Permits independent fractional zooming of an image.
MAGPHASE	Separates the magnitude and phase components of a Fourier image.
MAGPOWER	Raises the magnitude of each pixel in a frequency domain image to a user-specified power.
MAKEIMG	Create a LAS image from values in a VMS file.
MAP	Performs a piecewise linear transformation.
MAPP-LDM	Apply mappings to an image.
MASK	Masks an image using polygons from a statistics file.
MASKSTAT	Selects pixels from an image based on a classified image.
MAX	Determines maximum value of each pixel in multiple images.
METALOAD	Loads data from the Intergraph into a RIM data base.
MIN	Determines minimum values of each pixel in multiple images.
MINDIST	Performs classifcation based on minimum distance from class means.
MINMAX	Determines the minimum and maximum pixel values of an image.
MKMASK-LDM	Creates an intensity mask in the graphics plane based on intensity values from a memory plane.
MODGOF-LDM	Interactively or manually modifies graphics from a GOF.
MULTIPLY	Multiplies two or more images together.
MULTPIC	Multiplies two images together.
NEIGHBOR	Searches the area within a specified radius of a pixel for certain characteristics.
NOISE	Generates an image of random pixel values with a uniform distribution.
NORMD	Calculates a normalized difference image.
NOT	Creates logical bit-wise complement of an image.
NULLCORR	Geometric registration, reformats tie point search parameter files.
ORPIC	Performs a bit-wise logical OR.
OVERLAY	Creates an output image based on logical relationships between two input images.
PERSPEC	Creates 3-D perspectives from images.

PICSHADE	Create a shaded terrain image or modify an image for sun illumination.
PIVOT-LDM	Rotates, flips or mirrors displayed images.
PIXCNT	Creates a table of frequency information for an image.
PIXCOUNT	Creates frequency information or histogram for an image.
PIXSERT	Inserts rectangular blocks of pixels in an image.
PLANE-LDM	Turns graphics planes on in specified colors or turns graphics planes off.
PLENTER	Reads Landsat 1 and 2 data from tape into a LAS image.
POWER	Raises pixels to a specified power.
PROTEC-LDM	Changes the protection of memory planes.
PSD-LDM	Pseudo color mapping.
PUT-LDM	Place annotation, points, lines or polygons into a graphics plane.
RADIOM2	Applies radiometric look-up tables (RLUTs) to an image.
RADIUS	Creates an image whose pixel values at any point are proportional to the distance to an origin.
RANDSAMP	Randomly selects a given percentage of predetermined pixel blocks.
RASTERIZE	Inserts annotation into a LAS image.
RAS2PTS	Converts a raster image to a point file.
RAS2VEC	Performs a raster to vector conversion.
RCYCLE	Creates region and arc output files in vector interchange format.
RECLASS	Smooths an image using a mode filter.
REDIST	Maps an image to give an output image with a linearly cumulative histogram.
REGISTER	Allows the user to do image registration.
REGLABEL	Performs region labelling.
RELMAP	Maps pixel values of an image according to values defined in a relation stored in a relational DBMS.
REMAP	Geometric registration, generates a grid file.
RENAME	Changes an image's name.
RENUMBER	Reassigns pixel values.
RETRIEVE	Retrieves an archived image from tape to disk.
REWIND	Rewinds a tape.
RIM2GOF-LDM	Converts point, line, polygon, and annotation information in a RIM data base to a GOF.
RIM2STAT	Converts polygon or covariance matrix data from a RIM data base to a statistics file.
RIM2TAB	Transfer data from a RIM data base to a labelled table.
RIPSFT	File transfer between LAS and RIPS.
RIPSTOLAS	Transfers RIPS images to LAS images.
RGB2HIS	Translates red, green, and blue to hue, intensity, and saturation.
ROAM-LDM	Allows a user to view an image on the display.
ROTATE	Rotates an image by a specified angle.
ROTRNSCL	Geometric registration, produces a mapping grid.
SAVDPF-LDM	Saves a DPT entry to the image's associated display parameter file (DPF).
SAVIMG-LDM	Saves the displayed image to the DPT.
SCALE	Linearly rescales an image.

SCATTER	Produces a scatter plot.
SEARCH	Performs unsupervised training site selection.
SEGMOFF	Offsets rows in images. Part of the image repair scenario.
SEGMREPR	Repairs lines or segments in a given image with a constant or by averaging.
SHOGOF-LDM	Displays graphic data.
SHOIMG-LDM	Displays an image.
SHOMAP-LDM	Displays a mapping look-up table.
SLICE-LDM	Sets brightness values to a user-specified color.
SMOOTH	Filters a LAS image, part of the nominal filtering software.
SPECCOMB	Combines Level I and Level II classification images.
SPECSTRT	Categorizes the pixels of an image and produces a separate multispectral image for each class.
SPREAD	Creates an image as a function of distance bewteen
SPSSRIM	Transfers data between SPSS and RIM.
STAT2GOF-LDM	Converts polygon data stored in a statistics file to GOF.
STAT2RIM	Converts polygon or covariance matrix data from a statistics file to a RIM data base.
STAT2TAB	Converts polygon and covariance matrix data from a statistics file to a labelled table file.
STATPLOT	Generates a graphical representation of statistical data.
STATS	Computes statistics for a statistics file.
STATSCUT	Computes statistics, allowing the user to cut some pixel values.
STEREO	Creates the left stereo pair complement.
STRUCT	Computes co-occurrence matrix chi-square values for use in texture analysis.
STVEDT	Allows editing of certian LAS files (geometric registration, DDR, etc.).
SURFACE	Performs various methods of surface image generation and histogramming.
SYSSAMP	Systematically selects blocks of image data and creates an image.
TAB2GOF	Converts point, line, polygon, and annotation information from a labelled table file to a GOF.
TAB2RIM	Transfers data from a labelled table to RIM data base.
TAB2STAT	Converts a labelled table file to a LAS statistics file.
TDPLOT	Creates Versatec plots of training site statistics in in 3-D space.
TESTGEN	Creates test images using one of four methods.
TEXTDIF	Computes the absolute mean difference texture values of an image.
TEXTURE	Calculates spatial variability using any one of eight texture statistics (variance, skewness, etc.).
TIC-LDM	Places tic marks in an image.
TICMARK	Places tic marks in an image.
TIECOPY	Extracts tiepoints from a graphics overlay file.
TIEFIT	Generates a mapping grid file from tiepoint pairs.
TIEMERGE	Geometric registration, merges tiepoint files.
TODSP-LDM	Transfers files from disk to display memory planes.
TOPO	Creates slope, aspect, and contour images.

TPLOT	Prints an image on the line printer.
TRANCOORD	Converts coordinates from one system to another.
TRANSDIV	Calculates transformed divergences bewteen pairs of classes.
TRANSFER	Transfers files between tape, disk, and different formats.
TRANSPOS	Tranposes an image.
TSCLASS	Performs Bayesian or minimum distance classification on selected classes.
UHIST	Produces a gradient image and its histogram from an image.
UMAP	Classifies a gradient image to identify areas of uniformity and non-uniformity.
UNARY	Transforms images via mathematical operators (cosine, logarithmic, etc.)
UNIVENTR	Reads BYTE data in universal tape format.
UNKNOWN	Reassigns low probability pixels to unknown class.
VEC2RAS	Performs a vector to raster conversion.
VMSIN	Converts a VMS file to a LAS image.
VMSOUT	Converts a LAS image to a VMS file.
VMSTODAL	Transfers a VMS file to a tape in transfer format.
WHATISIT	Determines physical characteristics of tapes and files.
WTGEN	Generate a matrix of filter weights for Fourier analysis.
XORPIC	Performs a bit-wise exclusive OR.
ZIP	Performs mappings on selected classes and selected training sites of an image.
ZOOM	Changes the scale of an image by replicating or deleting pixels.
ZOOPAN-LDM	Zooms and pans the displayed image.

Function Listing of LAS Modules

Tapein
- CCTEDCS
- CCTL4
- CCTTIPSA
- CCTTIPSP
- DALIN
- DEMENTER
- DMOUNT
- EDIPSIN
- FMOUNT
- HRPTIN
- IENTER
- LACIN
- PLENTER
- REWIND
- UNIVENTR
- WHATISIT

Diskin
- RIPSFT
- RIPSTOLAS
- VMSIN

Applicon
- INFARC
- INFCPY
- INFCRF
- INFCTT
- INFLTT
- INFLUT
- INFMCC
- INFOPT
- INFPOLY
- INFTRF
- METALOAD

Tapeout
- DALOUT
- DMOUNT
- EDIPSOUT
- FMOUNT
- ITRANSFER
- REWIND
- VMSTODAL

Hardcopy
- DSPVERSA
- FILM
- FILMTAPE
- HISTPLT
- LINEPLOT
- LIST
- LPMAP
- SCATTER
- STATPLOT
- TDPLOT
- TPLOT

Diskout
- DEMTORIPS
- LASTORIPS
- VMSOUT

Radiometric Corrections
- DELLUT
- DSPRLT
- FIXLIN
- GRAD
- HISTEQ
- HRPTCAL
- LINEOFF
- LINEREPR
- RADIOM2
- MAGNIFY
- SEGMOFF
- SEGMREPR

Geometric Corrections
- COEFFEDT
- CONTROL
- COORDEDT
- DDREDT
- DSPGRID
- EDGECORR
- GEOM
- GREYCORR
- GRID
- GRIDGEN
- NULLCORR
- REGISTER
- REMAP
- ROTRNSCL
- STVEDT
- TIECOPY
- TIEFIT
- TIEMERGE
- TRANCOORD

Signal Processing
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- COMPOL
- COMSEP
- CONJ
- CONVOLVE
- CROSSCOR
- CWTGEN
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- FFT1FL
- FFT2
- FILTER
- FT1PIX
- FT2PIX
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- IFFT2
- MAGPHASE
- MAGPOWER
- NOISE
- RADIUS
- WTGEN

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- LOGICAL
- NOT
- ORPIC
- XORPIC

Data Transformations
- ABS
- ADDPIC
- ALBEDO
- ARCTAN
- AVERAGE
- AVHRR0
- BANDRATIO
- BANGLE
- BUTTER
- DIVPIC
- HIS2RGB
- KARLOV
- LOWCAL
- MAP
- MAX
- MIN
- MULTIPLY
- MULTPIC
- NORMD
- PERSPEC
- PICSHADE
- PIXSERT
- POWER
- REDIST
- ROTATE
- RGB2HIS
- SCALE

STEREO
SURFACE
TOPO
TRANSPOS
UHIST
UMAP
UNARY

Classification

ADD2STAT
BAYES
BDIST
CANAL
CLASSMAP
CONTABLE
COVAR
DISCRIM
DSPCONTBL
EDITSTAT
GETSAMP
GOF2STAT
HINDU
ISOCLASS
KMEANS
MASK
MASKSTAT
MINDIST
RANDSAMP
RECLASS
RIM2STAT
SEARCH
SPECCOMB
SPECSTRT
STAT2GOF
STAT2RIM
STATS
STATSCUT
SYSSAMP
TAB2STAT
TDPLOT
TRANSDIV
TSCLASS
UNKNOWN
ZIP

Spatial

AVERAGE
CONVOLVE
CWTGEN
NEIGHBOR
OVERLAY
RENUMBER
SPREAD

STRUCT
TEXTDIF
TEXTURE

Nominal Filtering

BLDPW
BLDTHR
FLAG
REGLABEL
SMOOTH

Display

ADJUST
ALLOC
ARITH
CONVOL
CPYGOF
CURPOS
CURSOR
DALLOC
DEFATT
DEFCUR
DELATT
DELDPF
DELGOF
DPFMAP
DPTLUT
DSTAT
ENGRAVE
FILL
FITLIN
FLICKR
FRAME
FRMDSP
GOF2RIM
GOF2STAT
GOF2TAB
HISTO
INIT
LODDPF
LODGOF
LOGIC
LSTDPF
LSTGOF
LSTIMG
MAPP
MKMASK
MODGOF
PIVOT
PLANE
PROTEC
PSD
PUT
RIM2GOF
ROAM
SAVDPF
SAVIMG
SHOGOF
SHOIMG
SHOMAP
SLICE
STAT2GOF
TIC
TODSP
ZOOPAN

Miscellaneous

ANNOTATE
ANNOTE
ASONCP
CLEANUP
COMPARE
CONCAT
CONVERT
COPY
DITTO
DROPHIST
DSPELE
DSPGROUP
DSPHISTRY
DSPLBL
DSPLOG
FILECOPY
FLIP
GETBLOB
GROUP
INSERT
INSERT2
LASNCP
MAKEIMG
MINMAX
PIXCNT
PIXCOUNT
RASTERIZE
STVEDT
TESTGEN
TICMARK
TRANSFER
WHATISIT
ZOOM

Vector

CONSEG
RAS2PTS
RAS2VEC
RCYCLE

REGLABEL
VEC2RAS

Tabular Data Handling

ALTPATH
BCS
GOF2RIM
GOF2STAT
GOF2TAB
INTERSECT
PIXSERT
RELMAP
RIM2GOF
RIM2STAT
RIM2TAB
SPSSRIM
STAT2GOF
STAT2RIM
STAT2TAB
TAB2GOF
TAB2RIM
TAB2STAT

Catalog Manager

ARCHIVE
LASDEL
LISTCAT
RENAME
RETRIEVE

Partial List of Available Documentation

LAS

- User's Manual for the Land Analysis System (1986)
- Application Programmer's Guide for LAS (7/85)
- File Groups for LAS Applications--LAS
- Pixel Manipulation Subroutines for LAS Applications (Revision 2--2/23/83)

LAS Catalog Manager

- User's Reference Manual--Catalog Manager--UNIX/VMS
- Application Programmer's Reference Manual--Catalog Manager--VMS
- Systems Manager's Guide--Catalog Manager--VMS
- Internals Manual--Catalog Manager--UNIX/VMS

TAE

- User's Reference Manual--TAE--UNIX/VMS
- Application Programmer's Reference Manual--TAE--UNIX/VMS
- Systems Manager's Guide--TAE--UNIX
- Systems Manager's Guide--TAE--VMS
- Utilities Reference Manual--TAE--VMS
- Internals Manual--TAE--VMS
- Primer--TAE
- Tutorial--TAE
- Tutorial--TAE--Programmer's
- Tutorial--TAE--User's
- User-Programmer Dialogue: Guidelines for Designing Menus and Help Files for Interactive Computer Systems (2/83)