DEVELOPMENT OF LAND ANALYSIS SYSTEM DISPLAY MODULES

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I. Introduction

The LAS display modules were developed to allow a user to interactively display, manipulate, and store image and image related data. To help accomplish this task, these modules utilize the Transportable Applications Executive and the Display Management System software to interact with the user and the display device. Figure 1 shows how these components relate to one another and the shaded box is where the major focus of this discussion will be. First, the basic characteristics of a display will be outlined; some of the major modifications and additions made to the display management software will be discussed next; finally, all available LAS display modules along with a short description of each will be listed.

II. Basic Display Characteristics

The LAS display modules do not interact with one specific type of device, but they do assume the display has several basic characteristics. They are: (1) a set of memory planes for storing image data, (2) a set of graphics planes for storing graphics data such as text, linework, histograms and tick marks, (3) a look-up table for mapping image data, and (4) a pointing device for user interaction with the display.

A display can be thought of as a stack of memory and graphics planes (figure 2). Memory planes can be described as two-dimensional planes with each pixel in the memory plane having an intensity value that ranges from 0 through 255. Graphics planes are similiar in organization to memory planes except that each pixel of a graphics plane does not hold a value between 0 and 255 but rather a value of either 1 or 0 representing either an "on" or "off" state. Graphics planes are usually used as an overlay to an already displayed image and may be displayed in a number of colors depending on the display.

A look-up(LUT) table allows a user to alter or map the relationship between the values in the memory planes and the displayed intensities (figure 3). A look-up table can be thought of as a list of "from" and "to" translations such that each possible input data value (0 through 255) is an index into a table of output intensity values. For example, if the first entry in the LUT is 100, every pixel in the memory that has a value of 0 will be displayed as though it had an intensity of 100. The original image data remains unchanged but is displayed with different intensities. Each LUT has three components--one for the red band or component of the image, one for the green component, and one for the blue component.

The fourth characteristic, a pointing device, is usually available with a display and includes such devices as a trackball, joystick, or mouse. These devices provide capabilities such as cursor movement. Many of the LAS display modules also make use of the function buttons found on these devices.

III. Modifications and Additions to the Display Management System

In designing and developing the LAS display modules, it was discovered that several modifications to the prototype DMS that we were working with were necessary to meet all the user-defined requirements. These changes were adopted by the Goddard Space Flight Center and have been incorporated in the DMS presently being distributed. One such modification involved changes to several of the DMS tables which store device and image tracking information. Most of these modifications consisted of moving fields from one table to another or adding fields to a table. The first table that needed modification was the display device table which holds device specific information (figure 4). Fields were added to store cursor information which includes the active cursor number, the cursor shape, size, color and blink rate. A graphics plane mask was also added to store the graphics planes which are currently on. The display memory table which holds information about each memory plane in a device was modified next (figure 5). Several fields were moved from this table to the image configuration table. This was to allow each defined image to have its own shift, zoom, memory window, and source file name rather than linking these attributes to a specific memory plane. The last table to be modified was the image configuration table which holds information about each defined image (figure 6). The image configuration table was renamed to the display parameter table to clear up some user confusion and the image group information was removed. A field was also added to keep track of LUT table information, to store a graphics active record list name, and to store the LAS file window and band numbers.

The second modification involved coordinate conversions. These routines caused one of the largest problems encountered in LAS display module development. The LAS display modules use three different coordinate systems to reference the spatial locations of the image (figure 7): (1) file coordinates which represent the line and sample location from the upper-left corner of the original LAS image as it resides on disk, (2) image coordinates which represent the line and sample location from the upper-left corner of the image as it resides in the memory plane, and (3) screen coordinates which represent the line and sample location from the upper-left corner of the display screen. Because of the different coordinate systems, it was necessary to write coordinate conversion routines. Differences in display origins, differences in the manner that displays handle zooming and shifting of memory planes, and differences in how pointing devices return cursor coordinates made it difficult to integrate the conversion routines.

The method of shift calculation was also modified and was made a device dependent calculation. Originally, the same shift calculation was used on all types of devices. This caused problems with devices that handled shifting differently. For example, the Raster Technologies Model One/25 display only allows shift values in multiples of 4 in the X direction and multiples of 2 in the Y direction but the Deanza IP8500 display does not impose this restriction. Therefore, a different shift calculation routine was needed for each.

In addition to the modifications made to DMS, several new utilities were also written to save, recall, and access information from three types of image related files.

The first type, the display parameter file, is a disk file that stores the parameters necessary to recreate a view of an image. This information includes the zoom and shift factors applied to the image, the LAS image name, the LAS image window, the LAS image bands, and the look-up table information.

The second type of image related files are the graphics overlay files which are disk files that contain information necessary to display graphics data along with descriptive attributes for the data. There are four types of graphics overlay files: files that store point data, files that store line data, files that store polygon data, and files that store annotation data. In conjunction with these modules, routines were also written to clip the graphics data and to automate label placement.

The last image related file is the active record list. This session temporary disk file contains the name of the graphics overlay file it references, pointers to the currently active records of the graphics overlay file, and graphics plane masks to indicate which graphics planes the data is currently displayed in. These active record lists allow a user to display or manipulate a defined subset of graphics overlay data which helps speed processing time.

Routines are also currently in development to convert the graphics overlay data to formats useable by other software packages.

IV. LAS Display Applications

The LAS display modules themselves have been grouped into five categories. Color display modules provide status information, allow allocation and deallocation of the display, allow loading and manipulation of images in the display memory planes, and saving images from the memory planes back to disk. Mapping modules apply, save, and restore intensity and pseudo color mappings. Graphics overlay modules create, save, modify, and restore text and linework and generate histograms and tic marks. Arithmetic modules generate output images by performing arithmetic, logic, rotation, and convolution operations on images, and cursor modules define and turn a cursor on and off and determine cursor locations and intensity values.

The following is a list of all the LAS display modules available at the EROS Data Center along with a short description of each. These modules are operational on a Deanza IP8500 display running on a VAX 11/780 with a VMS operating system and on a Raster Technologies Model One/25 display running on a SUN Microsystems workstation with a UNIX operating system at the EROS Data Center. A subset of these modules are also operational on a I2S Model 75 at the Goddard Space Flight Center. As for the future of the LAS display module development, there are approximately eight modules left to develop and/or enhance. Some of these enhancements involve taking advantage of display hardware characteristics to improve performance. There are also plans to implement these modules on an I2S IVAS display at the Western Mapping Center in Menlo Park, California, and on a Deanza IP8500 display at the EROS field office in Anchorage, Alaska.

Module	Description
ADJUST	Allows the user to interactively adjust the brightness and/or the contrast of a displayed image with a linear mapping through movement of the pointing device. Horizontal movement adjusts brightness, and vertical movement adjusts contrast.
ALLOC	Allocates a display for a user and optionally initializes that display following allocation. A display must be allocated before executing any other display functions with the exception of DSTAT and some of the graphics overlay functions.
ARITH	Allows the user to perform several arithmetic operations on images. ARITH-ADD allows the user to add two images; ARITH-SUB allows subtraction of one image from another; ARITH-MULT allows multiplication of two images; and ARITH-DIV allows division of one image by another. Note that there must be a memory plane available for storing the resulting image data. All arithmetic operations involve only two images.
CPYGOF	Subcommand -ARL copies records from an active record list into a specified graphics overlay file. Subcommand -GOF copies records from a specified graphics overlay file into another graphics overlay file. Deleted records will not be copied. Subcommand -CLEAN removes deleted records from the specified graphics overlay file.
CURPOS	Displays the line and sample values in file, image, screen, or memory coordinates; also displays the image intensity value(s) at the cursor position for each image band currently being displayed. The intensity values for the image being viewed are displayed in RGB order. The default is to display the file line and sample coordinates along with the image intensity values.
CURSOR	Turns the cursor on or off.
DALLOC	Deallocates the display allocated by a user.
DEFATT	Defines an attribute name or list of names for a graphics overlay file (GOF). A maximum of 35 attribute names may be defined for a single GOF type.
DEFCUR	Defines a cursor. DEFCUR allows the user to define the shape, size, color, and blink rate of a cursor. The defined cursor will be turned on at the center of the screen.

DELATT	Deletes an attribute name or list of names from a graphics overlay file (GOF). A maximum of 35 attribute names may be deleted from a single GOF.
DELDPF	Deletes the specified display parameter file (DPF) entry from the DPF associated with the specified image file. If no image file is specified, the image file that generated the image currently being viewed is used.
DELGOF	Deletes a record from a graphics overlay file. -REC allows deletion by record number or attribute, and -CURSOR allows deletion by cursor location.
DSTAT	Lists display status. Lists detailed information and status of a specific display, or lists summary information and status of all displays.
ENGRAVE	Allows the user to engrave the displayed graphics data into the displayed image. (Not currently implemented.)
FILL	Replaces the values inside or outside a predefined polygon with the value specified (-VAL) or with values based on the mapping created from the specified break points (-MAP).
FITLIN	Fits a line to a set of points and saves it in the graphics overlay file along with a label and attributes. A minimum of 2 and a maximum of 32 points may be chosen to do the line fit.
FLICKR	Allows the user to flicker several images on the display or to flicker the displayed image through several mappings. FLICKR has two subcommands, FLICKR-IMAGE and FLICKR-MAP. FLICKR-IMAGE will display from two to ten images, one at a time. FLICKR-MAP will display one image through different mappings. From two to ten mappings can be applied to the currently displayed image, one at a time.
FRMDSP	Copies the displayed image from the display's memory plane(s) to a LAS disk file (subcommand -DISK) or into other memory plane(s) (subcommand -MEMORY). Copying the image to disk allows the user to apply the mappings to the image data and/or save the parameters of the image to the associated display parameter file (DPF) and/or save the displayed graphics to the associated graphics overlay file.

HISTO	Displays a histogram for any one or all components of either the currently displayed image (subcommand -IMAGE) or the pixels that comprise a line within the currently displayed image (subcommand -LINE). HISTO generates a histogram of the image currently being displayed either from the "original" data (as it is stored in the display memory planes) or from the data after it has been "mapped."
INIT	Performs a partial or complete initialization of the allocated display using the subcommands -DISPLAY, -IMAGE, -PLANE, -MAP, or -ARL. -DISPLAY does a complete initialization of the display. This includes the image planes, graphics planes, mappings, all DMS tables and all of a user's active record lists. -IMAGE deletes a specified image from the display parameter table. -PLANE initializes the specified image and/or graphics planes. -MAP initializes a mapping to a linear mapping. -ARL deletes any or all of a user's active record lists.
LODDPF	Reads the look-up table (LUT) data from the specified entry in the image's associated display parameter file (DPF) and applies the mappings to the components of the displayed image specified by the parameter MAPCOMP. The user may also choose to apply the zoom and pan factors from the entry to the displayed image.
LODGOF	Generates an active record list of the requested records from a graphics overlay file (GOF). Only records from this list may be drawn and/or manipulated on the display.
LOGIC	Allows the user to perform several logical operations on images. The user may perform a logical AND, OR, or exclusive OR on images stored in the display's memory planes. Note that there must be a memory plane available for storing the resulting image data. All logical operations involve two and only two images.
LSTDPF	Either prints out all of the fields of one specific display parameter file (DPF) entry, or prints out the names of all the entries in the DPF associated with a LAS image. If no LAS image name is entered, the LAS image that generated the image currently being viewed is used. If a DPF entry is specified, then all of the fields of that one specific DPF entry will be printed out. However, if no DPF name is entered, all of the entries in the DPF associated with the image will be printed out. The output for this program can be routed to the terminal, to the printer, or to a text file by the PRINT parameter.

LSTGOF	List out graphics record information to the terminal, line printer, or text file. The graphics records or attribute definitions of the GOF for the displayed image or that of a user-specified image may be listed. In the case of graphics records, the user may specify to list out only the active records.
LSTIMG	Reads the display parameter table (DPT) and prints to the terminal a listing of information for either one or all of the images currently in the memory planes of the allocated display. The information can be displayed in short or long form. The short form includes information about the image name, the protection state of the memories used by the image, the image age, and the memory planes used by each image. The number of free memory planes and a list of the active graphics planes are also displayed to the terminal. The long form includes all of the information in the short form as well as information about the file window from which the image was taken, the bands of the LAS image that were used, the memory window in which the image was placed, the LAS image name from which the image was taken, and the active record list name associated with the image.
MAPP	Allows the user to create and apply mappings to a displayed image. Using the following subcommands, MAPP applies each of the following mappings to the displayed image. -PWL creates a piecewise linear mapping from a set of mapping pairs. -CURSOR creates an arbitrary piecewise linear mapping using the cursor to select breakpoints. -EXP creates an an exponential mapping and scaling. -LOG creates a logarithmic mapping and scaling.
MEASUR	Allows the user to find the ground coordinates of a point location (-POINT), the length of a line (-LINE), or the area of a polygon (-POLY). (Not currently implemented.)
MKMASK	Creates a mask in the graphics plane of specified intensity values from the single-band displayed image.
MODGOF	Allows the user to modify a record in the graphics overlay file. The record may be modified manually or interactively with the cursor.
PIVOT	Allows the user to pivot images. The user may perform a 90, 180, or 270 degree clockwise rotation, a flip (about the horizontal axis), or a mirror (about the vertical axis). Note that for every memory plane used by the input image there must be a memory plane available for storing the resulting image data.

PLANE	Turns graphics plane(s) on in a specified color or turns graphics plane(s) off. The -ON subcommand allows the user to turn graphics plane(s) on in specified color(s). The -OFF subcommand allows the user to turn graphics plane(s) off.
PROTEC	Changes the protection state of the memory planes that an image uses.
PSD	Allows the user to create pseudocolor mappings to be applied to black and white images. PSD-MAN assigns a specified color to a gray level range and/or to specific gray level value(s). PSD-DEF assigns a defined color to a range of image value(s) and/or to specific image value(s). PSD-PIECE defines a pseudocolor mapping through the specification of break points. PSD-PALET allows the user to assign a defined color to a gray level range and/or specific gray level value(s) from a palette using the cursor for color selection (this subcommand has not been implemented).
PUT	Allows the user to interactively place points, lines, polygons and/or annotation into a graphics plane and also create a record in the point, line, polygon or annotation graphics overlay file. The -POINT subcommand allows the user to place points in a graphics plane. The -LINE subcommand allows the user to place a set of points which defines a line in a graphics plane. The -POLY subcommand allows the user to place a set of points which describes the vertices of polygons in a graphics plane. The -ANNOT subcommand allows the user to place annotation in a graphics plane. The graphics plane number can be changed by changing the global variable DMSGPLN or by incrementing the graphics plane number when in pointing device or manual mode.
ROAM	Allows a user to view (in higher resolution) portions of the last image displayed with TODSP. ROAM-WIND will view a user-specified or default window of the last image displayed with TODSP. ROAM-MOVE will view a user-specified neighboring high-resolution window of the last "roamed" image. Neither ROAM-WIND or ROAM-MOVE can view a window that lies outside of the image initially displayed by TODSP.
SAVDPF	Saves an entry from the display parameter table (DPT) in an associated display parameter file (DPF). All parameters necessary to define the specified image are saved in the image's associated DPF.
SAVIMG	Makes a new entry in the display parameter table (DPT) containing the information necessary to redisplay the viewed image in its current state.

SHOGOF	SHOGOF displays and/or erases graphics data from the specified active record list. The user may select (by attribute) data to be displayed and/or erased in the graphics plane indicated by the global parameter DMSGPLN. Graphics displayed with the image use the -IMG subcommand. Graphics may displayed without an image if the user runs the -NOIMG subcommand and specified the window of the graphics to be displayed.
SHOIMG	Displays either an image whose attributes have been saved in the display parameter table (DPT) or an image whose red, green, and blue components are from different entries of the display parameter table. The image data is assumed to be present in the display's memory planes. The bands of the image will be displayed with the mappings and other attributes found in the display parameter table. The user may also choose to associate an active record list name with the displayed image.
SHOMAP	Allows the user to display the values of the mapping applied to the displayed image. The mapping may be written to the terminal, line printer, or to a text file as an input gray level value followed by its red, green, and blue output values or on the display's graphics plane as a graphic representation. Function button 1 may then be used to toggle between displaying a graph of the mapping, a gray level wedge, or both.
SLICE	Sets a range of pixels in the displayed image to a user-specified color. The image must be a single-band black and white image. The user may choose a band slice, a high-level slice, or a low-level slice through the use of the function button.
TIC	Allows the user to place major and minor tic marks in or around an image. The user specifies the number of pixels between each major and minor tic mark.
TODSP	This utility copies single or multiple images or image windows from a LAS image file to a display's refresh memories. TODSP-LOCAL will load the image data from the host system and TODSP-NET will allow the user to load image data from a remote system using the network software to retrieve the data.
ZOOPAN	Allows a user to expand any portion of the image currently being displayed by using the function buttons on the pointing device and to pan over the image using trackball/joystick on the pointing device. The image is zoomed about the center point of the display. The graphics are also zoomed and panned along with the image.

LAS Display Module Overview (LDM)

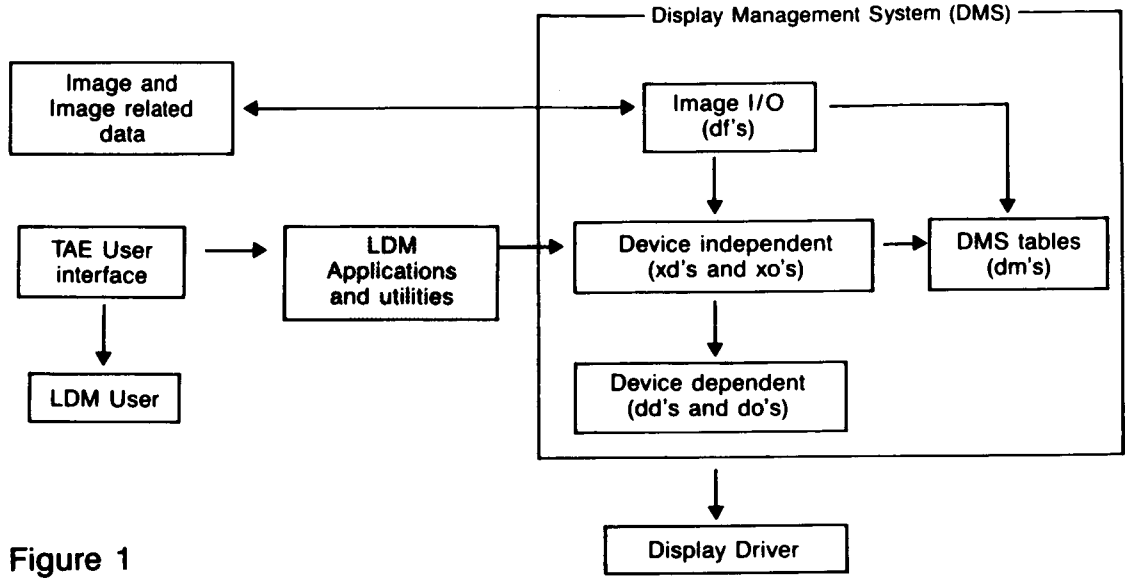

Figure 1

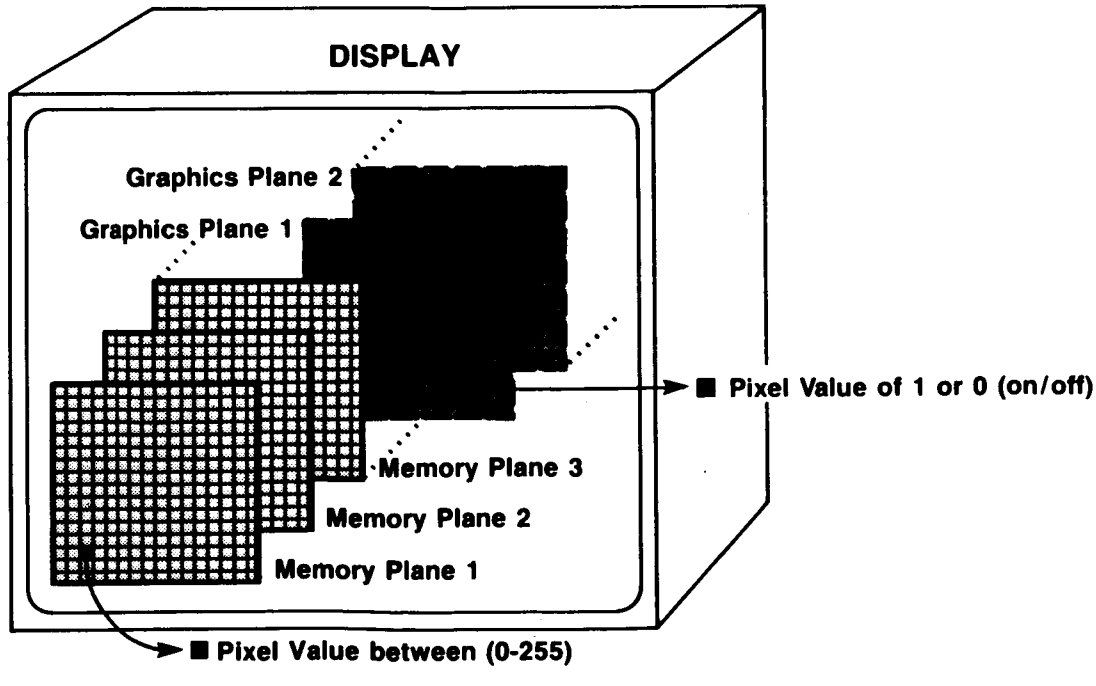

Figure 2

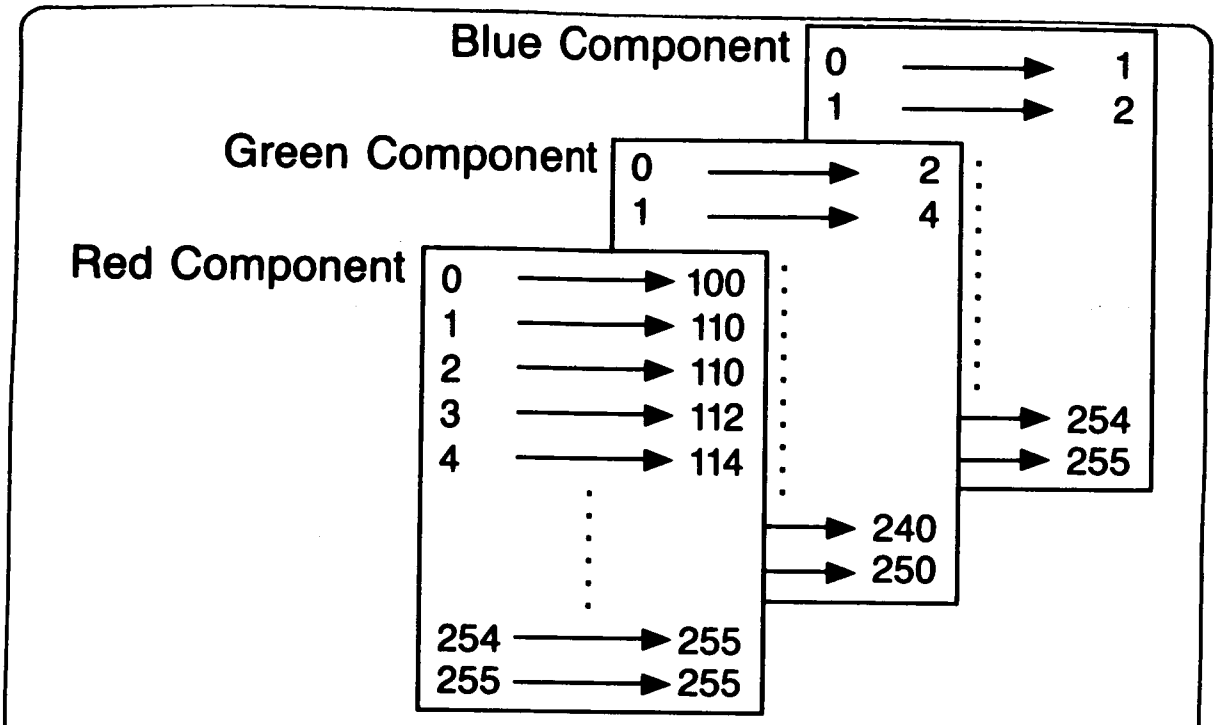

Figure 3

Modifications to DMS tables

Display Device Table (DDT) — Maintains device specific information on each accessible display device.

Active cursor number	Added
Cursor shape	Added
Cursor size (height and width)	Added
Cursor color	Added
Cursor blink rate	Added
Graphics plane mask	Added

Figure 4

Modifications to DMS tables

Display Memory Table (DMT) — Contains information about each refresh memory of the display device.

Memory window	→ To ICT
Source file name	→ To ICT
Shift amount	→ To ICT
Zoom Amount	→ To ICT
Wrap flag	→ To ICT

Figure 5

Modifications to DMS tables

Image Configuration Table (ICT) — Contains information about each image the user has defined
or
Display Parameter Table (DPT)

Memory window	→ From DMT
Source file name	→ From DMT
Shift amount	→ From DMT
Zoom amount	→ From DMT
Wrap flag	→ From DMT
Image group information	→ Removed
File window and bands	→ Added
Look up table data	→ Added
Active record list name	→ Added

Figure 6

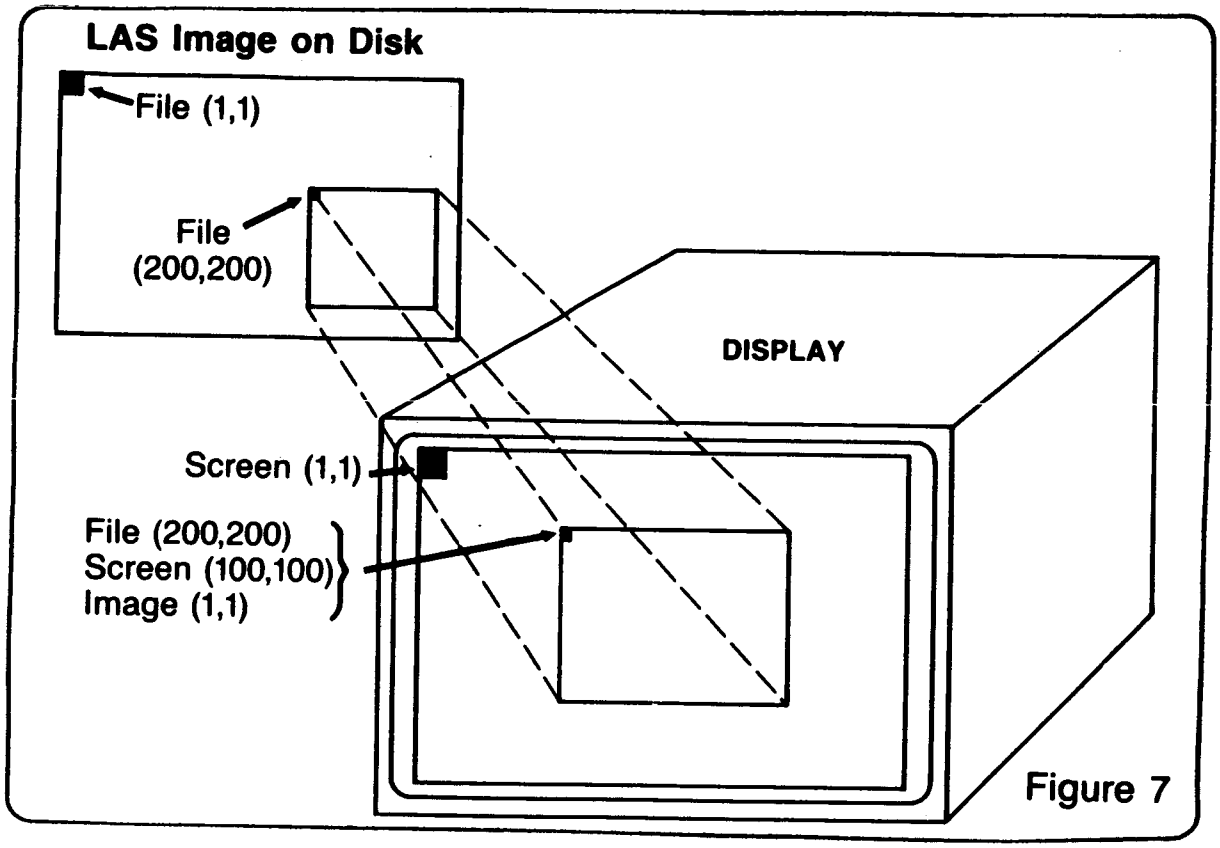
LAS Image on Disk
File (1,1)
File
(200,200)
DISPLAY
Screen (1,1)
File (200,200)
Screen (100,100)
Image (1,1)

Figure 7