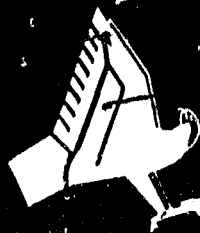


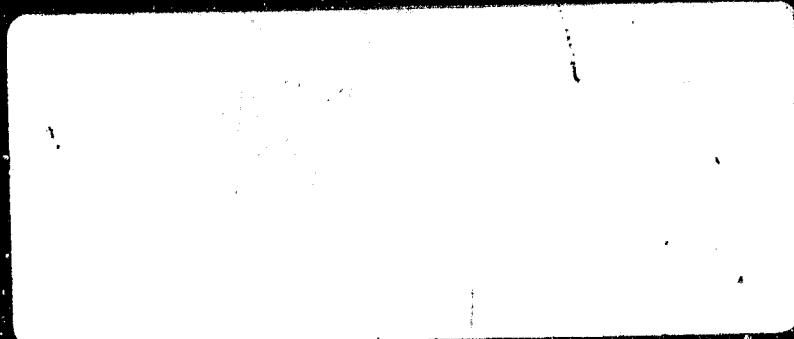
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IDIMS/GEOPAK:
Final Report and Users Manual
for a Geophysical Data Display and
Analysis System



Prepared Under Contract No. NAS5-26325

for the

National Aeronautics and Space Administration
Geophysics Branch (Code 922)
Goddard Space Flight Center
Greenbelt, Maryland 20771

by

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April 4, 1982

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COLOR ILLUSTRATIONS

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INTRODUCTION

OBJECTIVES

The primary objective of the present contract effort is to describe the application of an existing image analysis system to the display and analysis of geophysical data and to investigate the potential for expanding the capabilities of such a system toward more advanced computer analytic and modeling functions. The specific objectives of the study are outlined as follows:

- o To compile and describe the major features of the Goddard Space Flight Center IDIMS (Interactive Display and Image Manipulation System) and its applicability for image-type analysis of geophysical data;
- o To begin development of a basic geophysical data processing system to permit the image representation, coloring, interdisplay and comparison of geophysical data sets using existing IDIMS functions and to provide for the production of hard copies of processed images. The appropriate subset of IDIMS functions with ancillary instruction for their application to geophysical data processing would comprise the GEOPAK system;
- o To produce an instruction manual and documentation for the GEOPAK sub-system including descriptions of its abilities and limitations;
- o To conduct a training course for Goddard Space Flight Center Code 922 personnel in the use of the IDIMS/GEOPAK that will provide users with an understanding of both capabilities and limitations of the system;
- o To evaluate the effectiveness of the current IDIMS/GEOPAK system for geophysical data analysis and to make recommendations for future system enhancements of the existing system.

The interpretation of magnetic and gravity data is of considerable importance to both exploration and theoretical geophysics. Accordingly, tremendous advances have been made over the years in the processing and analysis of such data. For example, many complex analytical techniques, such as filtering, continuation, and spectral analysis, once considered highly theoretical, are now routinely employed in the analysis of geophysical data.

Contrary to the increased sophistication of the analytical tools provided by automated processing technology, the interpretive strategy remains far from automatic. The meaningful interpretation of geophysical data requires the continuous application of educated and experienced judgement on the part of the scientist in order to select the analytic methods most appropriate to the particular research problem and the most relevant to the study area. The pictorial representation of the available data is an indispensable aid to this evaluative process.

Typically, geophysical data are represented by contour maps in which a set of cut-off points are set by the selection of a convenient contour interval. For each of the cut-off values lines are drawn on the map to connect sample locations having data values of equal magnitude. This process of contouring, however, introduces bias due to the artificial reduction of continuous measurements to a limited number of discrete class intervals, and due to the subjective construction of continuous lines between discrete, if not widely separated, sample points. Either case results in a loss in accuracy or loss of data resolution or both. In addition, regardless of the care taken in its construction and the ability of the interpreter to compensate for the inherent bias in the contour map, even the computer-aided drawing of such maps does not provide the interpreter with the flexibility for real-time tailoring of the map for optimum interpretation.

Modern image processing systems, which have been developed for the interactive analysis and manipulation of digital pictures such as LANDSAT data, offer opportunities to manipulate large data sets with surprising speed and flexibility. Such systems provide the capability to create immediate pictorial representations of data. The results of various data manipulations may be displayed as gray-tone or color images on a video monitor, complete with graphic overlays such as map outlines and captions. Furthermore, most systems are capable of the production of permanent "hard" copies of images in a fraction of the time generally required for map production.

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Although a geophysical data set such as earth magnetic anomaly values would not fit the conventional notion of an image, the extension of image processing into this new domain is quite natural when one overcomes the typical equation of the terms "image" and "photograph". Sabins (1978, p.6) advises, "the term 'image' is merely a general term for any pictorial representation, irrespective of the wavelength or imaging device". The essential quality of an image relative to the application of automated systems is that it be composed of spatially ordered, point-sampled finite measurements of some physical attribute of the object being imaged and that the measurements may be assigned to locations on a regularly-spaced rectangular grid called a "raster". Whereas a LANDSAT image is composed of regularly-spaced samples of light intensity as reflected from the earth's surface, the individual picture elements ("pixels") of a geophysical data image might represent the magnitude of magnetic or gravitational field anomalies averaged over a sample area of the earth's surface. When such pixel values are used to modulate a display device such as a video monitor, a "picture" of the earth is produced which is as legitimate as that produced by the light wavelengths used for the LANDSAT picture. This ability to display and intercompare geophysical "pictures" of the earth defines the real strength of image processing as a tool for geophysical data analysis.

BRIEF HISTORY OF THE PROJECT

When originally proposed, in July of 1979, this GEOPAK geophysical data analysis system was to be developed as a sub-system of Goddard's IDIMS II image analysis system. The contract agreement written in April of 1981, however, provided for system development on Goddard's AOIPS facility using the METPAK software of Code 930. A demonstration of the AOIPS facility was held by Code 930 personnel in July of 1981 at which time agreement was made to develop the GEOPAK system out of processing routines then being written as revisions of the METPAK software. This revision of METPAK was called GENPAK by the Code 930 program developers. In December 1981 GEOPAK development was shifted back to the IDIMS II system on which its development has proceeded up to the present.

READER'S GUIDE

While the IDIMS system is extremely well documented in the IDIMS User's Manual, much of the content of its two large volumes is either not strictly relevant to the processing of geophysical data or may be useful only to very advanced applications which only the experienced system user may fully appreciate. The present volume describes those aspects of the IDIMS system which the Phoenix Corporation team determined to be directly applicable to the needs of the geophysical data analyst. The report

sections that follow should enable the novice user of the IDIMS/GEOPAK to produce both true- and pseudo-color maps of geophysical data sets, compare images of data sets, produce difference maps, perform a variety of filtering and transformation functions upon data sets, and obtain descriptive statistical information regarding the data.

The first two sections, "MAJOR FEATURES OF IDIMS/GEOPAK" and "IDIMS II", provide a general description of the GEOPAK subsystem and a specific description of the Hewlett-Packard and IDIMS system and user interaction therewith. The included information details the command language of IDIMS and its capabilities.

The third section of the volume is a a tutorial for the novice user. Given that the user has gained some small familiarity with the use of the terminal, this section provides a step-by-step guide to the production of three geophysical data-analytic products. Use of this tutorial does not require full assimilation of material included in the system description, but could serve as an introduction to the system.

The remaining sections, provide respectively an evaluation of the current IDIMS/GEOPAK system which enumerates its present strengths and limitations, and recommendations for future enhancements to the existing system.

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DATA FLEXIBILITY

IDIMS/GEOPAK is equipped to handle either gridded or irregularly-spaced (e.g., flight-line) data as long as the data are input to the system in raster (line by sample) format. In the case of ungridded data, the raster should contain some constant value in image locations having no data. Some limitations may be imposed in attempting to manipulate ungridded data, but displays of such data may be useful, for example, in assessing sampling density in a study region. Counts of sampled vs. unsampled pixels could yield a measure of such density.

While all images are displayed by IDIMS/GEOPAK in byte format, i.e., 8-bit digital values between 0 and 255, the actual data input to IDIMS may be of any form, including floating-point and complex. Moreover, all major data manipulations may be performed upon the data in its original form (except complex) at the original resolution and precision, leaving the rescaling of the data until the display step. Importantly, the user need not actually modify the original data in order to create a display. Either a new image may be created in the appropriate data type or an intermediate image for display will be created by IDIMS at the time an image is called into display.

IMAGE SIZE

The system will permit a display of up to 512 lines by 512 samples, but the actual size of the image may be up to 32,767 lines by 16,383 samples (for 32-bit real data). Most functions may be applied to any image or user-specified portion of the image regardless of size (within the limits stated above).

IMAGE DISPLAY

The IDIMS system will display a single-band 512 x 512 image in either gray-tone, monochrome (red, blue, or green), or false-color representation. The initial display mode for all pictures, the gray-tone image, is formed as each of the digital values, 0-255, modulates the picture intensity between black (0) and white (255). The display disk will store up to 3 images or bands of one image in this gray-scale format.

When operated in true-color mode, each of the 3 images in the display memory is assigned a color of red, green, or blue depending upon its location. Upon display, the gray-scale is replaced by intensities of these colors. Simultaneous display of the three colored image planes will produce a "true color" image on the display screen.

Probably the most useful display feature for geophysical work, the IDIMS/GEOPAK pseudo-coloring capability permits the user to remap the image pixel distributions into the desired number of class intervals and to assign colors to the class intervals or "bins" of each mapping. Colors may be assigned either from a chart of standard colors or may be selected from a screen-displayed array of 4096 different colors using the moveable cursor. Up to 8 mapping tables and pseudo-color tables may be permanently stored and recalled during subsequent sessions and may be applied to any image.

IMAGE ENHANCEMENT

Image contrast may be controlled by data rescaling (data values changed) or by remapping (values changed only for display). Mapping may be performed by command statement if the desired cutoff values are known or limits may be specified by interactive manipulation of the image histogram.

MAGNIFICATION

The entire image may be magnified via several common interpolation methods or expanded by repetition of lines and samples. A "zoom" feature of the display is provided which permits expansion (by line and sample repetition) of an area designated by the cursor.

GRAPHICS

The IDIMS provides a display graphics plane for overlay of text and/or map outlines or other graphic information onto displayed images. Options are provided to change the color of graphic overlays and to enhance their contrast with respect to underlying images. The user may even "draw" an overlay using the trackball-controlled cursor.

Any image may be overlain with a rectangular grid or tic marks at a user-specified spacing and starting position.

Annotation text, captions, or labels may be placed over any image or over unused portions of the 512 X 512 display screen and recorded along with other graphics and the underlying image to form a new image.

DESCRIPTIVE STATISTICS

Functions are provided to obtain descriptive statistics of any image including maximum, minimum, mean, and variance as well as pixel counts for any classification specified by the user. Histograms may be produced for either original image data or for display images. A profile function permits a graphics display of image intensity values along a line defined by the user by selection of points with the cursor.

More complex descriptive capabilities such as Fourier transforms are also available to the IDIMS/GEOPAK user.

DATA INTERCOMPARISON (visual)

Images may be compared visually by either simultaneous or sequential display of images on different monochrome planes or by "flickering" (rapid alternating display) of several images at a time interval controllable by the user. The flicker feature may be applied to images or to mappings or to pseudo-colorings. Alternatively, images may be viewed on split screen.

Simultaneous display of up to three data sets, each loaded into a different primary color plane, can yield interesting representations of the multivariate data in which color variation may be interpreted in terms of the interaction of the variables.

Several options are available for control-point registration of images at different scales and/or projections.

DATA INTERCOMPARISON (numerical)

At present, only pixel-by-pixel (or pixel group) comparisons are possible with the IDIMS system. Two images of equal size may be compared on this basis to yield a measure of similarity in terms of the number of points equal to each other within a user-specified tolerance.

Arithmetic operations performed between equal-size images may yield useful interpretive results such as difference maps in which a new image is created from the difference between two images at each pixel location.

"HARD COPY" RECORDING

Several options are available for the recording of permanent color copies of images. A Dunn camera on-line to the COMTAL

display system enables one to photograph any image appearing on the display screen. This camera device is equipped for either 8 X 10 inch polaroid sheet film or 35mm roll film. Images are photographed from a high-quality monitor which displays an image identical to that on the larger user monitor.

Off-line color photographs may be made either from tape or disk records of images via the Optronix Film Recorder.

Gray-tone reproductions of images may be produced on large sheets using the Versatek Electrostatic Plotter.

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IDIMS II

System Description

The Interactive Digital Image Manipulation System (IDIMS) is designed for the manipulation, analysis, interpretation and processing of a wide variety of image data. It is intended to be an analysis and technique development tool for the non-programming user. Many of the time-consuming chores of bookkeeping, cataloging, efficient I/O handling, etc., are performed by the system leaving the user free to concentrate on the interpretation.

Figure 1 shows the basic configuration of the IDIMS hardware. The heart of the system is the Hewlett-Packard 3000-II mini-computer. An array processor (ASAP I) is interfaced with the central processor unit to enable the system to rapidly handle bulk data. Images can be input directly to the system using either of the three 9-track, 1600 BPI tape drives. A table digitizer is available for digitization of maps. The data are usually temporarily stored in a disk drive unit. The monitoring of the data is achieved by means of a color television screen, and the data are colored by the machine by assigning various colors (obtained by intermingling the three electron beam guns of the video monitor) to the various gray levels of the data set. The number of color levels and range of data set values to which they are applied are controlled by the input console. Three data sets, each assigned to a different color gun may be displayed simultaneously to generate a color display on the cathode ray tube which resembles a photographic color composite. The central processor enables a variety of digital analysis functions, and data output is by photographs of the video monitor, line printer, or magnetic tape.

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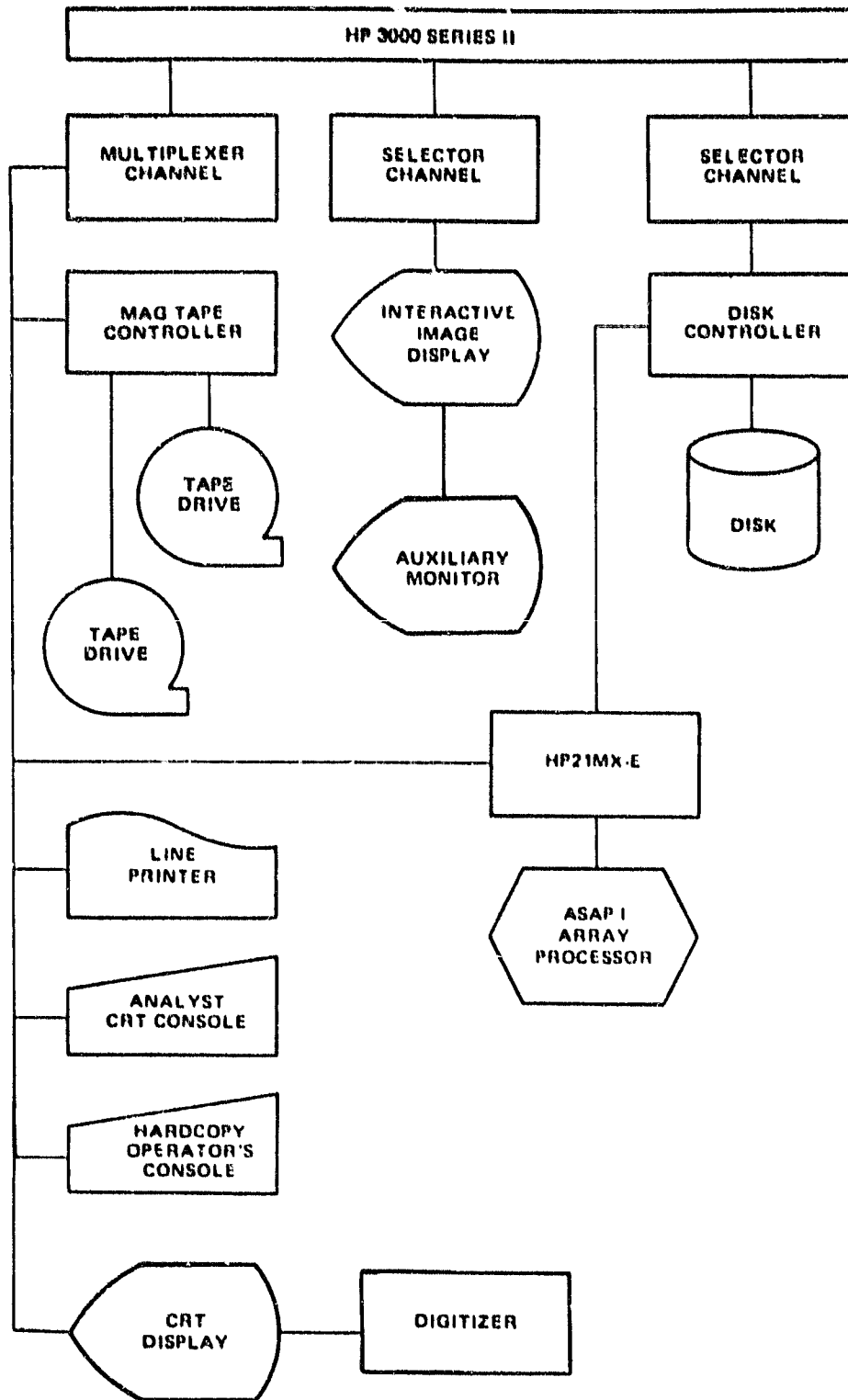


Figure 1 Configuration of the IDIMS II hardware (After ESL, INC, 1981)

System Operation

OBTAINING AN ACCOUNT ON IDIMS-

Arrangement for an account on the IDIMS system should be arranged through the system manager. Currently this is:

Robert Grigsby
Bldg. 16W
344-5084

TERMINAL OPERATION-

While specific characteristics of computer terminals tend to vary with manufacturers and models, the IDIMS terminals presently available in the HP-3000 suite may be described as follows:

The image display terminals are preset and will, in general, require no adjustment by users of the GEOPAK system. If difficulties are encountered in their operation, however, the computer operations personnel or other IDIMS users may provide assistance.

The DECWRITER terminals, located in the IDIMS terminal room, are hard-wired to the HP-3000 and will, generally, be set to the appropriate settings. These terminals need only be turned on and a carriage return should elicit the prompt (a colon, ':') to initiate the session. Due to their direct connection to the HP-3000, they can also operate at a high baud rate, and print at a rapid rate relative to remote connections. If difficulties are encountered, however, settings should be as follows:

ON-LINE/OFF-LINE --	ON-LINE
UPPER CASE/LOWER CASE --	UPPER CASE
HALF/FULL --	FULL DUPLEX

The Bell TTY-42 terminals are the most numerous and require the most adjustment by the user. Before using, check to see that the terminal is hooked to a telephone and that the settings are as follows:

FULL-HALF DUPLEX button is "UP" (Half-duplex)
PARITY button is "UP"
CPS button is "UP" (30cps)

The ON/OFF switch is located in the left rear of the machine. When ready, set the LOCAL/TALK switch to LOCAL and dial the one of the computer telephone numbers, currently 344-4980 (and 4981, 2, 3, or 4). When the tone is heard, press the DATA button. A carriage return will

elicit the colon prompt.

During a session the following terminal commands may be useful for changing lines, deleting lines, or aborting an operation:

ctrl H (backspaces deleting characters)
ctrl X (deletes the current line)
ctrl Y (halts processing and returns control to terminal)
ctrl S (halts the normal terminal I/O)
ctrl Q (resumes the normal terminal I/O)

Each of these commands is entered by striking the key indicated while holding down the control (ctrl) key.

BREAK (requests a system break during which time the user may:)
ABORT (terminates program run, not recommended for termination of IDIMS as files may be lost, or the user may perform file utility operations in MPE-mode aft., which the user may
RESUME to continue operation of the program at the point of the BREAK.)

When running the IDIMS program, any processing function may be terminated with the ">CANCEL" command and the program itself should be terminated with the ">END" command (described below).

GENERAL SESSION INFORMATION-

In the following discussion, ('_') underscore indicates a system response, (CR indicates a carriage return, and parentheses will indicate optional parameters.

Session Initiation-

Press (CR) to generate a colon ':'. Then type:

_ HELLO (Session Name), User Name, Acct. Name (CR)

The system will respond with a few lines of accounting information:

Session number = nnnnn
Date, Time
HP 32000 v. uu. ff

You are now in the general computer environment. Using the several systems available, you can build and transfer files, write programs in FORTRAN, BASIC, or APL, etc. The use of these subsystems is beyond the scope of this manual, but the appropriate manuals are available in the computer library.

The IDIMS subsystem is entered by typing:

```
_ RUN IDIMS.PUB;LIB=P
```

The system responds with a greeting and accounting text followed by a line number (all IDIMS lines are prompted by a line number).

Interaction with IDIMS-

When being used in session mode, the IDIMS Command Interpreter is always in one of four states:

1. Idle State. A line number prompt will appear on the user's terminal; any IDIMS statement may be entered.
2. Interpreting a previous user statement. The user cannot enter any statement during this generally brief period.
3. Executing a System Function. No statements may be entered during this time. Most functions may be terminated, however, by typing CTRL Y (i.e., typing 'Y' while simultaneously holding down the CTRL or CONTROL key), or by using the ">CANCEL" command.
4. Executing a Processing Function. During this state the user may enter any non-command statement, e.g. Display control statement or String definition statement. Also some System Functions may be entered.

Session Termination-

The IDIMS system is normally terminated with the system command '>END'. In general, the END function will initiate a series of prompts which will force the user to properly dispose of on-line images by either storing or deleting them.

IDIMS program termination will be signalled by the message, "END OF PROGRAM"

The session may be terminated by entering the BYE command next to the system prompt:

```
_ BYE
```

MPE/3000 acknowledges termination by printing the following information:

```
CPU (sec)= cputime  
CONNECT(min) = connecttime  
date,time
```

where

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`cputime` = Total central processor time used during the session, in seconds, logged against group and account.

`connecttime` = Total wall clock time between log-on and logoff, in minutes, logged against group and account.

Current date (day, month, year)

Current time (hours:minutes AM/PM)

For accounting purposes, the connect time is rounded upward to the nearest minute, and the central processor time is shown in seconds. Both sums are added to the usage counters for the session's account and group.

Data Types and Data Storage Conventions-

The IDIMS system is designed to handle a variety of data types. The maximum number of samples per line of the image is a function of the data type and is summarized in the table below. The maximum number of lines (or records) per image is given as the number of lines times the number of bands and must not exceed 32,767. The maximum number of bands per image is 255.

Images may be stored on IDIMS in either single- or multi-band format. While most geophysical data will be stored as single-band images, some advanced use of GEOPAK may make use of multi-band storage. For example, a 3-band image may be created for a magnetic anomaly data set with anomaly values in one band and latitude and longitude coordinates of the sample points stored in two other bands. Such a system would permit the user to maintain size correspondence between these data sets during various scale-changing operations. Likewise additional bands of other geophysical data might be added. If this storage convention is utilized, however, the analyst must use additional care in data manipulation and even become more aware of algorithms used in various operations to avoid inappropriately applying an operation to a given band. That is, unless band designators are used in referring to images, operations will be performed on all bands. Other meaningless situations might result from, for example, inadvertently displaying geographic coordinate data.

If data is stored in multi-band format, two arrangements are possible. In band-by-band (BB) format, all records for each band are stored sequentially. In line-by-line (LL) format, the data for all bands are interleaved in alternating lines. Single data sets are stored in band-by-band format. Images stored in multi-band formats must, of course, be of equal dimension. (Any single-band images of equal dimension may be combined into multi-band images via the function ">UNITE"

Some functions require that the user specify the data type by an integer designation. Each processing function has been written to allow all data types for which the function is appropriate. Functions for which data type restrictions exist explicitly explain such restrictions in the documentation for the function, and IDIMS will display an error message to notify the user that a restriction has been violated. When data type is to be specified, the following designations are commonly used:

<u>Data Type</u>	<u>Integer Designator</u>	<u>Max No. Samples</u>
bit data	0	32,767
8-bit data (byte)	1	32,767
16-bit integer data (single precision integer)	2	32,767
32-bit integer data (double precision integer)	3	16,383
32-bit real data (single precision real)	4	16,383
64-bit real data (double precision real)	5	8,191
64-bit complex data (single precision complex)	6	8,191
128-bit complex data (double precision complex)	7	4,095

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Language Features

The IDIMS system language accepts six types of statements:

- (1) Processing Commands
- (2) System Control Commands
- (3) Display Control Commands
- (4) Arithmetic Assignment Statements
- (5) Textual String Declarations
- (6) Replies to Queries

Processing Commands mathematically manipulate the input images in the computer CPU to form output images, printouts, or magnetic tape recordings. As in the case of generating a constant or a filter image, it is not always necessary to supply an input image in order to produce an output image.

System Control Commands deal with the data management and image display aspect of the system. They include such functions as STORE which transfers images from disk to tape, END which initiates the end of session sequence, and FRAME which displays several images in succession. These functions do not mathematically manipulate the image pixel values (when they deal with images) except for scaling the pixel values for display or reducing a large image for display as required.

Display Control Commands display images on the video monitor and manipulate the scaled gray levels to vary the appearance of the image on the monitor. Some of these commands control the presentation of graphical information on the graphics overlay planes. All commands that deal with the display are included in the display controller.

Arithmetic Assignment Statements provide the capability for using the IDIMS system as a calculator, either to directly compute the values of algebraic functions of input numbers, or to assign arithmetic values to named variables that are to be used later in processing images.

Textual String Definitions allow the user to assign any string of characters to a name. Subsequent use of that name is equivalent to the use of the entire string of characters defined by the name. This feature may be used to advantage when specification of processing commands or options becomes repetitive and time-consuming.

Replies to Queries must be provided by the user for mandatory parameters or for optional parameters when operating prompt mode. In general, the prompting statement will supply a description of the nature of the expected response as to whether the reply should be alphabetical or numerical in nature.

STATEMENT CLASSIFICATION-

In order to determine the type of statement encountered, the system makes use of three special characters:

> (greater than)
: (colon)
= (equal sign)

Processing and System Commands are distinguished by the presence of the "greater than" character (>).

Display Control Commands are distinguished by the absence of any of the special characters listed above.

Arithmetic Statements are distinguished by the presence of the "equal" sign (=) and the absence of the "greater than" sign (>).

Textual String Declaration Statements are distinguished by the presence of the colon (:).

STATEMENT CONTINUATION AND COMBINATION-

In issuing commands, statements may be continued beyond a single line, if necessary, and continued on successive lines to a maximum of 1008 characters (approximately 14 lines). To continue a statement to the next line, simply type a "plus" sign (+) as the last character of the line, carriage return (CR), and continue the statement normally on the next line. For example:

```
LONG.IMAGENAME1 LONGER.IMAGENAME2+      (CR)  
YETANOTHERIMAGE>ADD>SHORT.NAME (CR)
```

Several statements may be input to IDIMS in the same line if they are separated by semi-colons (;). For example:

```
P1 P2>ADD>P3; P4 P5>ADD>P6; P3 P6>DIVIDE>P7 (CR)
```

is equivalent to to the three command lines:

```
P1 P2>ADD>P3 (CR)  
P4 P5>ADD>P6 (CR)  
P3 P6>DIVIDE>P7 (CR)
```

Additional discussion of statement types is presented in the following sections.

PROCESSING COMMANDS-

The processing of images is directed by the Processing Command. Generally, the user specifies an input image (or images), a function list (with parameters, if desired), and output image(s) name(s) in the following format:

```
input image name>function(parm1= parm2=...parmn=)+  
                >output image name                (CR)
```

This format allows the user to specify multiple inputs, multiple functions, and/or multiple outputs in a single command. An entire processing task can be coded into a single command by specifying multiple functions. Intermediate picture files, if necessary will be created and deleted by the system between functions, so that the user need only specify the name of the final output image, regardless of the number of steps it takes to arrive at the final result. Note also that the specification of parameters need not be included in the command statement. The IDIMS system will prompt for all mandatory parameters not included in the command statement, and, unless the prompting is disabled via the "SET" function, prompts will be issued for optional parameters as well.

The user should know what to expect from a function in the way of prompts, however. This information is explained in detail in the function descriptions provided in the IDIMS User Manual as well as in Appendix A of this report. Information regarding most functions or commands may also be obtained through use of the "HELP" function. For a listing of essential information concerning any function (while in Idle State) the user may type.

```
>HELP (function name) (parentheses required)
```

IDIMS will respond with a brief description of the function and parameters.

For purposes of analyzing geophysical data, a subset of IDIMS processing functions was selected from the IDIMS library. These are listed in Appendix A with one-sentence descriptions and page references to the IDIMS User's Manual where more detailed documentation may be found.

Input Specification-

The input specification of a command statement identifies the images to be input to the processing function(s). Normally it consists of the name(s) of an image(s) with the optional size and spectral band modifiers. Some functions (those which generate an image) do not require an input image, and the field should be omitted in this case.

Image Names. A separate image catalog is maintained by the system for each user. Each of a user's image names may contain

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up to 35 characters. The image name must start with a letter and may consist of any combination of (upper case) letters, numbers, and the period ("."). A user may refer to another user's images (for input only, and on condition that the IDIMS system manager has allowed access to this user's files) by specifying a qualified image name. The qualified image name is formed by prefixing the owner's name (from the account number) and a period to the image name and enclosing the entire string in single quotes, e.g.,

'KEITH.SUB'

(The quotes denote a qualified name specification.)

This refers to the image named SUB belonging to the user KEITH. The user can gain access to other users' images only if they are on-line. User identification is not required when referring to the user's own images.

Image Size and Spectral Band Modifiers Spatial and spectral subsections of images can be specified for input to processing functions. The format for specifying image subsections is:

image name(spatial modifiers) [spectral modifier]

The order of spatial vs. spectral modifiers may be reversed, but must be enclosed by their respective parentheses or brackets as indicated, following the image name. Spatial subsections of images may be specified for any process and are defined by:

sl - starting line
ss - starting sample
nl - number of lines
ns - number of samples

For example,

WMAG (1 1 256 128)

refers to the upper left subsection of an image named WMAG. The size of the subsection is 256 lines by 128 samples.

The spectral band modifier (band number(s)) can be used if the image exists as a multi-band image. One merely follows the image name with the number(s) of the desired band(s) enclosed in brackets. For example,

WMAG [3]

refers to band 3 of an image named WMAG.

Processing Function Parameters-

The majority of IDIMS processing functions require an interaction with the user to control the function execution. When operating in parameter prompt mode (the default condition and best for the beginner), the user will be prompted for the values of parameters. Parameter values may be single values or a list (array) of values. Parameters may be specified by

- (1) Enclosing in parentheses after the function name in the command line, or
- (2) Responding to a parameter prompt generated by the IDIMS executive.

Local Parameters. Local parameters are passed to the function in the command line. The general form of parameter definition is:

function name (parameter name 1= value(s) parameter name 2=
value(s) parameter name n= values(s))

An example of a local parameter specification is:

>ENTER(NL=288 NS=512 DATATYPE=3 FILELIST=4)>OUT IMAGE (CR)

Note that a parameter may be specified more than once in a command line. In this case the last specification is used. This attribute of IDIMS allows for corrections without retyping an entire command line.

The use of local parameter definitions implies that the user is knowledgeable as to both the parameter names and acceptable parameter values for a given function. If an incorrect parameter name is supplied, or if the value given is inappropriate, IDIMS will prompt for the parameter.

Parameter Prompting. Parameter prompting is designed to permit user interaction with minimal typing. It is the default condition and must be disabled via the SET function. Even if disabled, prompts will be issued for mandatory parameters omitted from the command statement. The general form of the parameter prompt is:

parameter name type of parameter (optional default value)

An example of a parameter prompt is:

PLEASE SUPPLY PARAMETER VALUES FOR FUNCTION HISTOG
NUMBIN SIMPLE INTEGER (DEFAULT=256)
DEVICE CHAR STRING (DEFAULT=LP)
CUMHIST CHAR STRING (DEFAULT=NO)

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In the event that a user has supplied an invalid type of parameter, the user will be reprompted with the message:

parameter name (*ERROR*MUST BE CHAR STRING) or
parameter name (*ERROR*MUST BE NUMBER)

In addition, if the user has supplied the correct type of parameter, but a value which is incorrect for this function, the parameter prompter will reprompt with the message:

*VALUE ERROR*parameter name

Output Specification-

Image Name. Image names are assigned to output images by listing the name(s) after the second '>' in the command statement. Each image in a user's catalog must have a unique name. If the specified name(s) is(are) not unique the user will be prompted for a new name(s) by the message:

OUTPUT PICTURE ALREADY EXISTS

The user must then reenter the processing command using a unique name(s) for the output(s). As previously mentioned, if no output name is specified, a temporary picture is generated.

Reserved Word List-

There are five words which should not be used to name input or output images or textual string declarations. These are:

DO
ELSE
IF
NEXT
THEN.

SYSTEM CONTROL COMMANDS-

The System Commands deal with the data management and image-displaying aspects of the system. These can be divided into general categories as described briefly in Appendix B. The general command format is:

input specification > function specification (CR)

Some of the functions, including HISTORY, LISTCAT, LISTSTR, SESSION, and SET require the use of optional parameters, which assume default values if not specified by the user. If supplied, parameters for system functions must nearly always be specified directly for each function, i.e., as local parameters. The format for specifying such local parameters to a function is:

function (parameter name=value ...etc)

For example:

>LISTCAT(DEVICE=TERM TYPE=ALL) (CR)

would cause a listing at the terminal of both on- and off-line catalogued files. Textual string definitions, may be utilized when supplying local parameters to the system functions.

In contrast to the execution of processing functions, the user will normally not be prompted for parameters for system functions, whether omitted or erroneously specified. If a invalid parameter is specified, an error message will be displayed and the function will terminate abnormally. The user must then reenter the command with the correct parameters specified.

DISPLAY CONTROL COMMANDS-

The display controller is designed to provide an interactive environment for viewing and processing digital images. Manipulations of the images on the display is accomplished with a library of commands. A listing of selected display commands is presented in Appendix C.

In the following discussion, the capitalized portion of commands indicates the minimum portion of the command word that must be entered by the user. Thus, manu of the display commands have a short form. The user is also reminded that display commands do not include) symbol such as the ">".

Allocation of the Display-

The IDIMS display controller will permit only one user at a time to issue display commands. This prevents users from unintentionally overwriting each other's images. As each user enters the IDIMS system, an instruction is issued to acquire control of the display with the GRAB command. This message should, of course, be ignored by any user not stationed at a display terminal.

The Goddard IDIMS is currently configured to two display systems (DeAnza and COMTAL), each located in a separate room of the IDIMS suite. Each of the display systems will permit two users access to the display (although only one may sign-up for use during any time period). Assuming that two users have agreed to share the display monitor, the GRAB command will secure control of the screen by one of the users. Once a user has secured control of the display, that user retains control until either the IDIMS session is ended by the >END command, or through the command "FREE", which simply deallocates the display.

Later in the session the user may wish to reacquire the display with the "GRAB" command. The parameters specified with the "GRAB" command, "SAME" or "RESET", indicate whether the user wishes to reset the state of the display, or wishes to reacquire it in the state in which it was previously released. (Note that other users will probably have overwritten the image data on the display during the period of its release). By acquiring the display in the same state, all user-defined function memory and pseudo-color maps will still exist, as will any graphics data-base information. Resetting the display removes all such information generated previous to FREEing the display.

Organization of Images on the Display Disk-

The CRT display can store three images (or bands) at a time. The organization of images on the display is logically related to the order in which they are displayed by the analyst. In general, image 0 is the most recently displayed, image 1 is that displayed next most recently, and image 2 is that displayed earliest. Each image may be viewed by issuing the command "SElect" and specifying the logical image number, 0-2

As additional images are displayed, a logical rotation takes place in the display memory. Image 0 becomes image 1, image 1 becomes image 2, and image 2 "drops off the end" (is overwritten by the new data) and is no longer viewable on the display, and the image displayed becomes image 0. Exceptions to this rotation rule occur when a user SAVes or RELeases an image or images. The command to SAVE an image removes the image from the normal rotation sequence thereby preventing its being overwritten by new data. The command to RELease an image removes it from this protection.

Image Selection-

As an image is viewed, related information comes to be associated with the image including its function memory mapping, its pseudo-color mapping, the state of the function memory or pseudo-color features (on or off), and the state of the graphics overlay. Any time the analyst SElects that image to be viewed, it will be seen in exactly the state in which it was last seen, unless the option "RETAIN" is specified with the "SElect" command. In this latter case, the image will be viewed with the attributes as they existed for the image displayed immediately preceding the new "SElect" command.

Function Memory and Pseudo-color Memory Control-

During each session, up to 32 (0-31) function memory and pseudo-color mappings may be defined and referred to. The commands "SAVEM" and "RECALLM" control function memory mappings, and the commands "SAVEP" and "RECALLP" exert similar controls over pseudo-color mappings. Of the 32 mappings available for each of these functions, 0 through 7 may be retained permanently

from session to session. The remainder are session-temporary and will be lost upon issuance of the DEND command.

By issuing the command "SAVEM (or SAVEP) n" (where 0 ≤ n ≤ 31), the current function memory mapping (or pseudocoloring) will be saved and named mapping (or pseudocoloring) "n". It can later be recalled to the display by issuing the command "RECALLM (or RECALLP) n". Normally, at the start of a session, the map 0 holds an identity map. Unless this mapping is used for storage by the user, all images will be displayed with this identity mapping when first displayed. If the user wishes to apply the same mapping to all images upon their initial display, map 0 may be used to store another mapping. If map 0 is used for storage, all images called to display during subsequent sessions will first be displayed using this mapping. For example, if the user knows that all images to be manipulated for a time will be in negative form, an inverse mapping may be saved into map 0 so that the images will all come up positive:

```
MAP 0 255 TO 255 0 (CR)
SAVEM 0 (CR)
```

Hours, days, or weeks later, if the analyst is again working with positive images, an identity mapping may be saved into map 0:

```
MAP 0 255 TO 0 255 (CR)
SAVEM 0 (CR)
```

This will override the inverse map.

Similarly, whichever pseudo-color mapping is saved in map 0 will be associated with new images upon their display. However, the normal state of the display at session initiation is "Pseudo-color OFF". When the pseudo-color mode is activated, pseudo-color 0 will be applied first to new images. Note that the normal state of pseudo-color map 0 is a spectrum-like map.

At the initiation of all subsequent sessions, the user permanent maps will be as they were at the end of the previous session. The user temporary function maps will be identity maps, and the user temporary pseudocolor maps will be the spectrum-like maps.

Image Display-

A request for normal display of an image is of the following format:

```
IMAGE.NAME> (CR) or
IMAGE.NAME> DISPLAY (CR)
```

Only a single image at a given time may be displayed in this mode. If the image is less than or equal to 512 X 512 pixels in size, it will be displayed in its actual size on the screen. If

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either the number of lines or the number of samples exceed 512, the image will be reduced automatically in order to accommodate the larger of its two dimensions. Any reduction performed will preserve the aspect ratio of the image. The user is always informed of the reduction factor used by a message of the form:

IMAGE IS BEING REDUCED TO FIT DISPLAY SCREEN BY A FACTOR OF n

Note that the reduction is accomplished by the deletion of lines and/or samples.

If the user does not wish to view images in their reduced form, a spatial subsection of the image may be specified. For example, "BIG.PICTURE (1 1 512 512)" would display the upper lefthand portion of a large image in full resolution.

Image data which has more than one band is treated in two ways. If the image has 3 bands, band 1 is displayed as the red band, band 2 is displayed as the green band, and band 3 is displayed as the blue band of a color image. This loading of display memory will occur automatically in this case, and if the "COLOR ON" mode of the display is active, the image will appear as a full color image. At any rate, all three image planes will be filled. If images have been SAVED, the message "TOO FEW IMAGES RELEASED" will appear and the user must RELEASE images and reissue the display command.

If the image has 2, 4, or more bands, only the first band is displayed as a monochrome image (the case with one band). If the user wishes to view a multibanded image in color, the spectral band modifier must be specified in the command statement. For example:

SPECTRAL IMAGE (2) >

will result in band 2 of SPECTRAL IMAGE being displayed.

FOURBAND IMAGE (4 2 1) >

will result in a "false color" assignment of band 4 to red, band 2 to green, and band 1 to blue in a color display of the image. Again, if not enough images have been RELEASED, a message to this effect will be issued requiring appropriate action by the analyst. For any color (3 band) display, all 3 image planes (0,1,2) must be RELEASED.

Image data which is stored in byte format (8 bits of gray level intensity per pixel) is displayed exactly as it is stored, i.e., an intensity of 10 will be displayed as 10, an intensity of 200 will be displayed as 200, and so forth. All data other than byte data will be scaled as it is displayed according to the minimum and maximum intensity values in the section of the image being displayed. The minimum value will be displayed as intensity 0 (black), the maximum value will be displayed as

intensity 255 (white) and all intermediate values will be scaled linearly between 0 and 255. Note that a non-byte constant image will always appear black. When display of a non-byte image is requested, it is frequently necessary to search the image for the minimum and maximum values in order to scale the image data. (If they have already been determined as a result of some other processing function such as "SCALE", they will already be known to the system). This search accounts for the delay between the time a display request is issued and the time the image actually starts to be displayed. The process of data transformation to byte format for display is time consuming and may cause unnecessary delay in the display of images (particularly during peak operating hours). Virtually all transformation and conversion of data to image format may be performed by IDIMS functions from non-imaging terminals prior to the actual display terminal session. Doing so may save considerable time during display sessions. However, for ease of operation, any data type (except complex) may be called to display directly without explicit scaling and conversion by the user.

Displaying an Image on the Graphics Overlay-

Any non-complex valued image may be superimposed as a mask on the graphics overlay. Any information already on the overlay will be left intact. In this way, several masks may be superimposed as a composite. The format for displaying an image in this manner is:

```
image name > GRAPHICS
```

This system function is particularly useful for the display of map outlines as overlays to geophysical data.

Display Mapping and Pseudo-coloring-

Once the user has entered an image into the machine and manipulated it through processing functions, the result is ready for display. Since it is preferable to retain as much information as possible in the main image, a piecewise linear mapping function is available in display mode which does not permanently affect the main image. This function permits the mapping of the 256 bins (0 - 255) of the main image into a more easily handled number, such as 16 bins. The smaller number of bins can then be colored in various ways to produce, for example, a contour-type map of the data with a custom coloring scheme. The notable distinction between a typical contour map and a contour map produced in this manner is that the actual value of the displayed image at any point may be read from the video monitor even though remapping has been applied to the image. That is, even as a contour map of 16 bins is displayed on the screen, the actual value (from 0 - 255) of any point in the display may be determined using appropriate display commands with the cursor. (In order to determine the original data value corresponding to a point on the screen, the analyst need only

AMINI (minimum value)
(caret; equivalent to EXP, exponentiation)
ALOG (natural logarithm)
ALOG10 (base 10 logarithm)
SIN
COS (trigonometric functions)
TAN
SQRT (square root)
ATAN (arc tangent)
SINH
COSH (hyperbolic functions)
TANH
+, -, *, / (standard arithmetic operations,
add, subtract, multiply, divide)

Arithmetic variables may be used in any FORTRAN expression provided they have been defined prior to use.

TEXTUAL STRING DECLARATIONS-

A user may permanently define a textual (character) string that will be used often, by a name of no more than 8 alpha-numeric characters, the first of which must be a letter. The user can enter the string name instead of the equivalent textual string in a command line. Each user may have a total of 128 different string definitions available at any given time, and such string definitions are available only to the originating user.

The user can define a character string by inputting a string label name (8 characters or fewer) followed by a colon (:) and the corresponding character string. The form of a string definition is:

string name: any textual string

Additional features of the string definition include the ability to concatenate strings and to use previously-defined string labels in subsequent definitions.

Any string declaration can be deleted or redefined by typing the string label name followed by a colon (:) and either the new string definition to redefine, or a carriage return (CR) to delete the definition.

At any time during a session, a user can obtain a listing of his current string definitions by the system command, ">LISTSTR".

REPLIES TO QUERIES-

Whenever the user is prompted for information, the next input is interpreted as the answer to that prompt, unless the command line contains an equal sign ("="), in which case it is processed as an arithmetic command, or a colon (":"), in which case it is processed as a string declaration. This allows the user to perform calculations, if necessary, before answering a request for numerical parameter values, or to define a string which will serve as a shorthand when answering the current and subsequent queries. When a reply is received (i.e., a command line without an equal sign or a colon), it is supplied to the task requesting the reply.

Replies to queries are most frequently requested by the parameter prompter. In these cases, the type of the parameter for which the prompt is issued is briefly described by the prompt (i.e., whether numerical or alphabetic). The user should respond with an appropriate reply, or with a textual string previously defined which contains the desired information. If the parameter is optional, typing of carriage return (CR) as a response will cause use of the default value for the requested optional parameter.

IDIMS/GEOPAK TUTORIAL

As the novice IDIMS analyst is certain to discover, even the existing array of processing options is so voluminous as to allow almost unlimited opportunity for creative data display and analysis. After gaining an initial introduction to the GEOPAK system, many of these options will undoubtedly present themselves to the analyst.

In order to introduce the analyst to the GEOPAK system, a tutorial is presented in the form of selected geophysical processing scenarios with the series of command statements that would be required for completion of the described processing task. Annotation is provided to explain the various steps. As an introductory exercise, the new user should reproduce the sequence at the terminal for a first-hand exposure to IDIMS/GEOPAK. In the interest of brevity, system responses and prompts are omitted from the session examples. The user need only remember that the colon (:) acts as the system prompt and all IDIMS lines must be prompted with a line number. Prior to the use of each function, the user may either consult the function description in the IDIMS User's Manual or use the ">HELP" function to display a full description of function parameters.

The user may, of course, experiment with any of the functions listed in the Appendices and may display and manipulate any of the images produced. Departure from the command sequence may, of course, alter the content of the display disk. At any time, however, the "DSTATE" command will list the contents of the display disk and the ">LISTCAT" command will list on-line images.

Due to the likelihood that multiple users will work through the following examples, it is possible that some of the image names will already exist in the catalog. If the use of one of these names causes the message "OUTPUT PICTURE ALREADY EXISTS", use a different name for your output image. At the end of the session be certain to store any image that you loaded (i.e., via ">LOAD") from an IDIMS storage tape.

SCENARIO 1- Gray-tone Digital Terrain Map

The analyst wishes to display digital terrain data as a gray-tone image. The data set consists of a raster of 101 lines by 360 samples representing the average elevation values of 1-degree blocks of the earth's surface between latitudes 50N and 50S and longitudes 0 to 360. A world map outline is also available as a raster of 288 lines by 512 samples in which segments of the outline are represented by 1's and background values by 0's.

Figure 2 is an example of the digital terrain map produced by the command sequence to follow.

Command Sequence-

```
1. HELLO LITGPK,LITHO.IDIMS
2. RUN IDIMS.PUB;LIB=P
[HP log-on and initiation of IDIMS subsystem]

2a. >LISTCAT(DEVICE=TERM TYPE=ALL)
[If the files TERRAIN1 and MAP512.SOURCE are catalogued,
substitute >LOAD for >ENTER of the next step, and type "YES" for
the appropriate load prompts.]

[Give your image tape to the operator and inform that an "ENTER"
is forthcoming.]
3. >ENTER>TERRAIN1 MAP512.SOURCE
[Parameter values prompted for may be supplied as follows:]
NL=101 288
NS=360 512
DATATYPE=3 3
BANDS=1 1
SPECTYPE=BB BB
FILELIST=1 4
SL=1 1
SS=1 1
LINEINC=1 1
SAMPINC=1 1
TOTLINE=101 288
TOTSAMP=360 512
REALFORM=HP HP
LABELRECS=0 0

>LISTCAT
[Produces a listing of on-line images specifying the size and
data type of each.]

4. GRAB [allocates the display]
5. TERRAIN1>
[Displays the data as a gray-tone image.]
```

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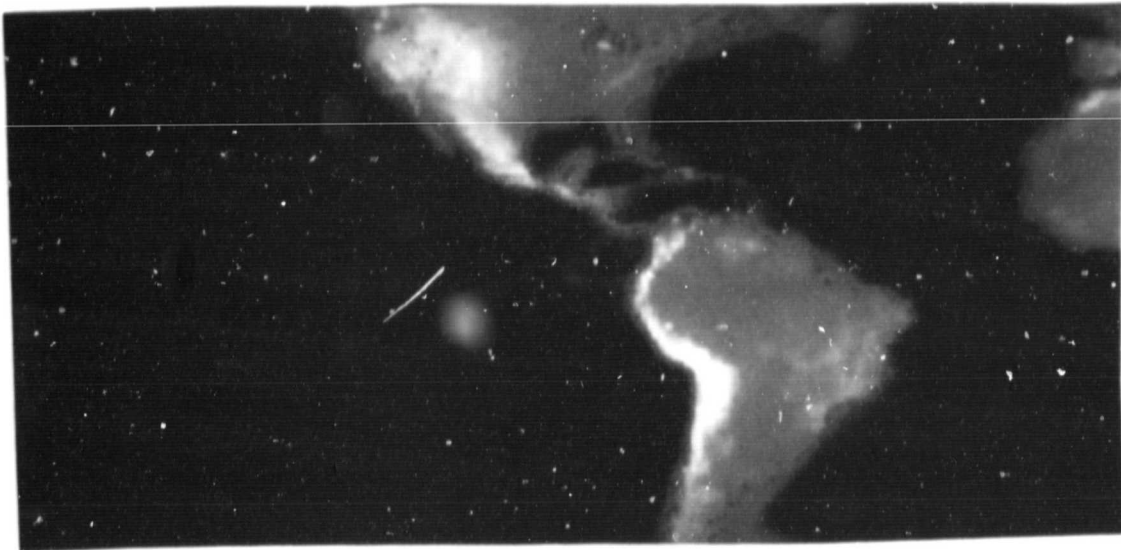


Figure 2. A gray-tone digital terrain map as produced in
SCENARIO 1.

[In order to fill more of the screen and still preserve the aspect ratio, enlarge the data set to 1024 by 288.]

6. TERRAIN1>MAGNIFY>TERRAIN1.BIG

[Parameters for this function are as follows:]

DISPLAY=NONE
INPUT=ALL
OUTPUT=SIZE
NLOUT=288
NSOUT=1024
INTERPOL=NN

[Enlargement is accomplished by nearest-neighbor interpolation.]

7. TERRAIN.BIG>

[Displays the entire image but reduces it by a factor of 2.]

8. TERRAIN.BIG(1 1 288 512)>

[Displays half of the image in full resolution.]

9. TERRAIN1.BIG(1 512 288 512)>

[Displays the other half in full resolution.]

[In order to check the location of images in the display memory:]

10. DSTATE

[Lists the contents of memory and the logical image numbers. Note that the displayed image is marked "Current".]

[Enlarge the map overlay to match TERRAIN1.BIG.]

11. MAP512.SOURCE>MAGNIFY>MAP1024

[Parameters:]

DISPLAY=NONE
INPUT=ALL
OUTPUT=SIZE
NLOUT=288
NSOUT=1024
INTERPOL=NN

[Overlay the displayed portion of the terrain data with the map.]

12. MAP1024(1 512 288 512)>GRAPHICS

[Since the map image contains only 1's and 0's, the bounds must indicate the restricted range, or no image will appear.]

Intensity lower bound (default=128)= 1
Intensity upper bound (default=255)= 1

[Display the first half of the terrain data and overlay with the appropriate portion of the map.]

13. SE L1

14. MAP1024(1 1 288 512)>GRAPHICS

[Enlarge the United States.]

15. SE L0

[Displays the western hemisphere as last viewed.]

16. SB EXPAND 4

[Cursor should appear on the screen. Use the trackball to mark

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the upper left and lower right corner of the portion of the display you wish to enlarge. A carriage return enters each point.]

17. DSTATE

[To check contents of the display memory. Select for display any of the images with the SE command.]

[End the session or go on to SCENARIO 2.]

18. >END

[Store images you loaded to disk via the LOAD command.]

[IDIMS queries whether a listing of the session history is desired. A reply of "YES" (the default) or simply a carriage return will cause a complete listing of all commands, etc., for your session to be printed at the line printer.]

19. BYE

[Terminates the session. Accounting information is listed at the terminal.]

SCENARIO 2- Magnetic Anomaly Map

The analyst's task is to produce a color contour map of MAGSAT scalar magnetic anomaly data in 2-degree block averages over the earth's surface. The magnetic data is formatted on tape in image form, i. e., a raster of 51 lines (colatitudes from 40 to 140 degrees) and 180 samples per line (corresponding to longitude positions from 0 to 358 degrees). The world map overlay consists of a second file with 288 lines by 512 samples.

Figure 3 is an example of a magnetic anomaly map produced by the following command sequence.

Command Sequence-

1. HELLO LITGPK, LITHO. IDIMS

2. RUN IDIMS. PUB; LIB=P

[HP log on and initiation of IDIMS program.]

2a. >LISTCAT(DEVICE=TERM TYPE=ALL)

[If the files WMAG. INT and MAP512. SOURCE are cataloged, substitute >LOAD for >ENTER of the next step and type "YES" for the appropriate load prompts.]

3. >ENTER>WMAG. INT MAP512. SOURCE

[Parameter values prompted for may be supplied as follows:]

NL= 51 288

NS= 180 512

DATATYPE= 3 3

BANDS= 1 1

SPECTYPE= BB BB

FILELIST= 3 4

SL = 1 1

SS = 1 1

LINEINC = 1 1

SAMPINC = 1 1

TOTLINE = 51 288

TOTSAMP = 180 512

REALFORM = HP HP

LABELRECS = 0 0

4. >LISTCAT

[Produces a listing of images on-line and should verify size and data type of each image by name]

[Produce a print-out of WMAG. INT in floating-point format. After several sample lines of data are printed the analyst may abort the continuation of the function with the control Y.]

5. WMAG. INT>PICVAL(DEVICE=TERM SPACING=1)

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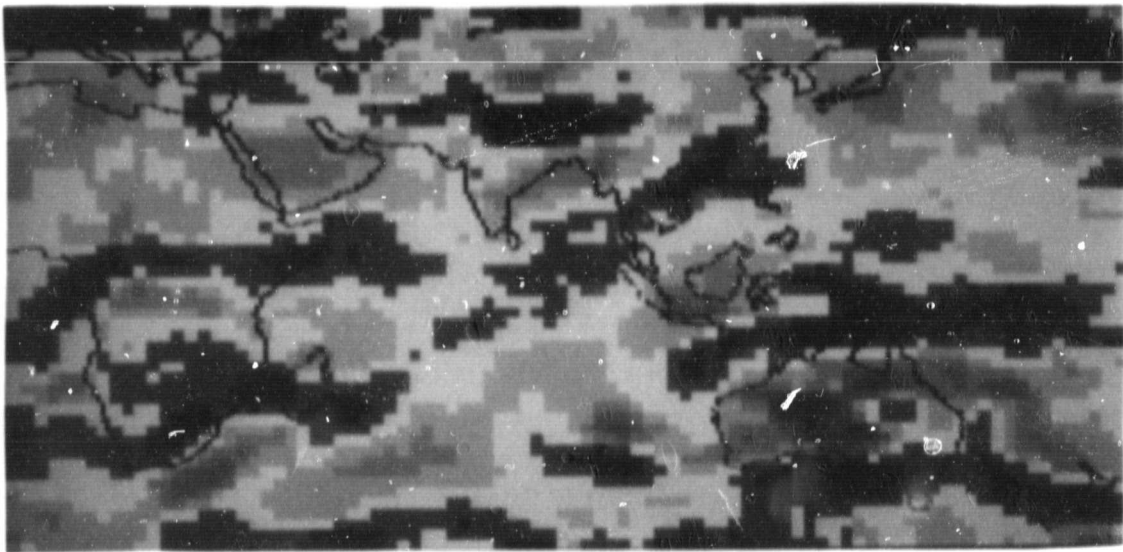


Figure 3. Magnetic anomaly map produced by remapping image display intensities and pseudocoloring with the ACM function as in SCENARIO 2.

[The magnetic data were converted to integer format from real values prior to transport to the HP. The user may wish to return these data to their original form by the following two commands:]

6. >CONSTANT(NL=51 NS=180 DATATYPE=4 +
GREYLEVEL=.01)>CONST.01

[Creates a constant image of size equal to that of WMAG.INT]

7. >WMAG.INT CONST.01>MULTIPLY>WMAG.REAL

[Enlarge WMAG.REAL to 288 lines by 1024 samples.]

8. WMAG.REAL>MAGNIFY>WMAG.BIG

[Function parameters are:]

DISPLAY = NONE
INPUT = ALL
OUTPUT = SIZE
NLOUT = 288
NSOUT = 1024
INTERPOL = NN

[Display each half of the image.]

9. WMAG.BIG(1 1 288 512)>

10. WMAG.BIG(1 512 288 512)>

[The world map data must be enlarged to match the magnetic data. If a 1024 X 288 version of the map overlay already exists and is on-line, this step may, of course, be omitted.]

11. MAP512.SOURCE>MAGNIFY>MAP1024

[Function parameters:]

DISPLAY = NONE
INPUT = ALL
OUTPUT = SIZE
NLOUT = 288
NSOUT = 1024
INTERPOL = NN

[Check the location of images on the display disk]

12. DSTATE

[Should indicate that the western hemisphere of WMAG.REAL is in logical position L0 (displayed), that the first half is in position L1.]

[Overlay each half of the world magnetics with the map outline.]

13. MAP1024(1 512 288 512)>GRAPHICS

[Since the map overlay consists only of values 0 and 1, responses to the parameter prompts will reflect the necessary rescaling for viewing:]

Intensity lower bound (default=128) = 1
Intensity upper bound (default=255) = 1

14. SE L1

15. MAP1024(1 1 288 512)>graphics
Intensity lower bound = 1

Intensity upper bound = 1

[In order to produce a pseudo-color map of the magnetic data, the analyst maps the 0-255 values to a smaller number of bins. A sample magnetic map being used as a model contains 14 divisions.]

16. MAP 0 1 255 to 0 1 14

17. SAVEM 6

[Maps 1 to 255 to 1 to 14 with background set to 0 (black)]

18. ACM

[Call to the ACM function fills the screen with a color display. Colors are selected for each bin from 0 up to 63 by moving the cursor to the desired color for a given bin (indicated by number in the upper left corner of the display screen) and registering the color by entering a carriage return. Use the trackball to move the cursor, and fill the 14 bins from the display colors starting with black for bin 0 and dark blue to light green for bins 1 to 6. Fill bins 7 and 8 with white or gray. Fill bins 9 to 14 with colors varying from yellow to deep red or violet.]

19. END (CR)

[Will terminate the ACM function.]

20. SAVEP 6

[Saves the pseudocolor map]

21. DSTATE

[Will verify that use of the ACM function has removed all previous images from the display memory. They will have to be re-displayed.]

[Restore the magmap and graphics overlays. In order to avoid repetition of lengthy spatial modifiers, define character strings for each designation.]

22. HALF1: (1 1 288 512)

23. HALF2: (1 512 288 512)

24. WMAG.REAL HALF1>

25. MAP1024 HALF1>GRAPHICS

[Graphics bounds as previously designated.]

[Change the color of the graphics overlay.]

26. GR BLACK

[Enhance the contrast of the graphics.]

27. GR CONTRAST

[Color the display using mapping 6 as designed previously.]

28. RECALLM 8

29. RECALLP 6

[Displays a color map of half 1]

30. WMAG.REAL HALF2>

31. MAP1024 HALF2>GRAPHICS

[Graphics bounds = 1 1]

- 32. GR BLACK
- 33. GR CONTRAST
- 34. RECALLM 6
- 35. RECALLP 6

[Half 2 displayed as color map.]

[In order to preserve these maps as finished products for later recall, IDIMS allows for the entire screen, as displayed, to be recorded as a three-banded image.]

- 36. >READBACK>MAGMAP.HALF2
- 37. SE L1
- 38. >READBACK>MAGMAP.HALF1

[Store images and logoff or continue on to SCENARIO 3.]

- 39. >END

[System will respond with request to either store or delete images. In this case all images should be stored with exception of the constant image CONST.01.]

[Before program termination, user is asked if listing of session history is desired. A carriage return (=YES) will yield a line printer listing of all IDIMS commands and responses for the current session.]

- 40. BYE

[Terminates session.]

SCENARIO 3- A Difference Map

The analyst has been supplied two data sets of world elevation data representing average elevations over 1-degree blocks. In order to compare the two data sets, the analyst wishes to produce a third map of the differences between the two data sets within latitudes 50N and 50S from 0 to 359 degrees longitude. As in SCENARIO 1, these data were written to magnetic tape in raster format with 101 lines of 360 samples each. (If the images already exist in the IDIMS catalog, substitute ">LOAD" for the ">ENTER" command of step 3. At the end of the session, be sure to store any images brought on-line from IDIMS storage tape).

Figure 3 exemplifies a difference map of digital terrain data as generated by the command sequence of this exercise

Command Sequence-

1. HELLO LITGPK,LITHO.IDIMS

[System Response]

2. RUN IDIMS.PUB;LIB=P

[IDIMS welcome followed by line number prompt.]

2a. >LISTCAT(DEVICE=TERM TYPE=ALL)

[Produces a listing of all images in catalog.]

[Analyst gives tape to computer operator with instructions to expect an ENTER.]

3. >ENTER>TERRAIN1 TERRAIN2

[Parameter values supplied as prompted:]

NL = 101 101

NS = 360 360

DATATYPE = 3 3

BANDS = 1 1

SPECTYPE = BB BB

FILELIST = 1 2

SL = 1 1

SS = 1 1

LINEINC = 1 1

SAMPINC = 1 1

TOTLINE = 101 101

TOTSAMP = 360 360

REALFORM = HP HP

LABELRECS = 0 0

4. >LISTCAT

[To list images on-line.]

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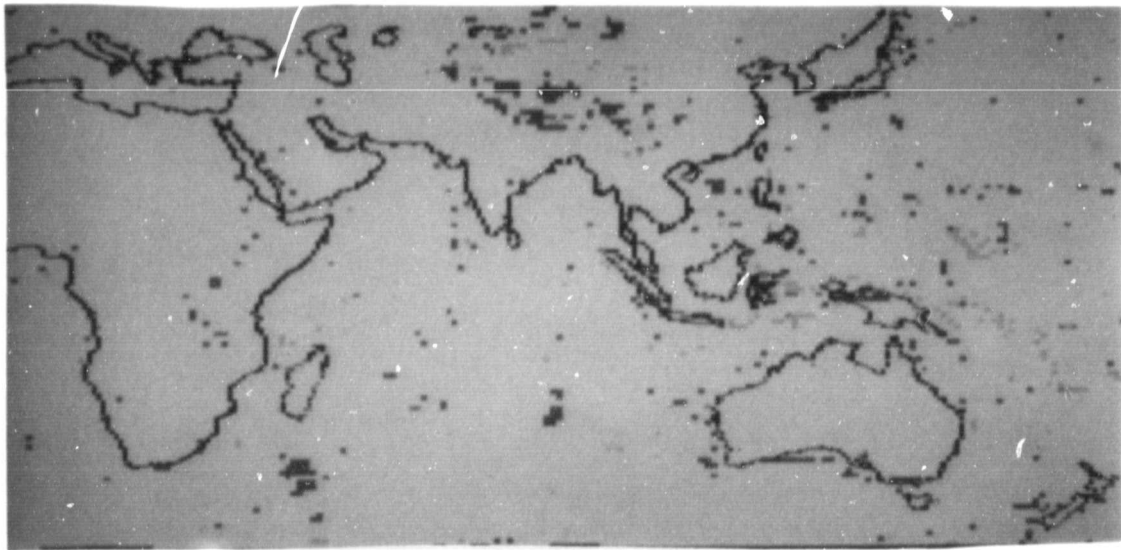


Figure 4 Difference map of two digital terrain data sets.
similar to that produced in SCENARIO 3.

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[Check small portion of Terrain2]

5. TERRAIN2(1 1 10 10)>PICVAL
DEVICE = TERM
SPACING = 1

[Produce difference map.]

6. TERRAIN1 TERRAIN2>ADD(FACTORS=1 -1)>TERRAIN.DIFF

[Print out descriptive statistics of the difference image.]

7. TERRAIN.DIFF>PICSTAT(DEVICE=TERM)

[If display monitor available, display images.]

8. GRAB [To allocate display.]
9. TERRAIN1>DISPLAY
10. TERRAIN2>
11. TERRAIN.DIFF>

[Enlarge difference map to 512 X 288 and display. In order to prevent loss from display of the two terrain images, SAve them.]

12. SA L1
13. SA L2
14. TERRAIN.DIFF>MAGNIFY>TERRAIN.BIGDIFF

[Parameters:]

DISPLAY = OUTPUT
INPUT = ALL
OUTPUT = SIZE
NLOUT = 288
NSOUT = 512
INTERPOL = NN

[Overlay difference map with world map outline. Must either enter from tape or LOAD from storage tape.]

15. >LOAD

[IDIMS runs through entire list of stored images allowing for loading of each. Select images desired in addition to MAP512.]

16. MAP512>GRAPHICS
Lower bound = 1
Upper bound = 1

[Color map using scheme developed for magnetic data.]

17. RECALLM 6
18. RECALLP 6
19. GR BLACK
20. GR CONTRAST

[Try a new color scheme using TCC.]

21. MAP 0 1 255 TO 0 1 7
22. SAVEM 7
23. TCC NEW BLACK 0 [PURPLE if using DeAnza.]
24. TCC DKBLUE 1
25. TCC MEDBLUE 2
26. TCC LTBLUE 3

- 27. TCC WHITE 4
- 28. TCC PINK 5
- 29. TCC ORANGE 6
- 30. TCC RED 7
- 31. SAVEP 7

[Develop another color scheme using the same mapping. Use the color chart in the terminal room or the color list on page 6-62 of the IDIMS User's Manual (TCC).]

- 32. TCC NEW 0 BLACK
- 33. TCC

etc.

- 39. SAVEP 5

[Compare the colorings with FLICKERP.]

- 40. FLKP 5 7 FOR 500 500

[Terminate the FLICKERP with a carriage return.]

[Save the best version of the difference map. (Must be on screen).]

- 41. >READBACK>TERRAIN.DIFFMAP

[End session.]

- 42. >END

[Store images.]

- 43. BYE

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EVALUATION OF THE IDIMS/GEOPAK SYSTEM

As an overall assessment, we find the IDIMS system very well suited to the needs of the geophysical data analyst. Its mathematical and display capabilities provide the analyst excellent latitude in the manipulation and display of even very large data sets and moderate flexibility in comparison of geophysical data sets. The major limitations of the existing system lie in the area of mathematical or statistical comparison of data and in the manipulation of data at a variety of map projections. This latter deficiency relates mainly to the presently cumbersome manner in which geophysical images, which lack the easily distinguishable landmarks of more traditional images, may be registered with the present control-point methods.

The existing system is well suited to and equipped for the display of geophysical data as an image. The system provides for changes in scale, a variety of data reduction and coloring options, and graphic overlay capabilities which allow the analyst enormous flexibility in developing informative and demonstrative displays and maps in a surprisingly small amount of analysis time. The IDIMS system, moreover, provides for the addition of captions and labels on graphic overlay so that the creative investigator can produce almost any desired representation of data in a form suitable for presentation in a report or lecture. Such a final product may be recorded in its final form as a multi-band image for later recall to the imaging screen or may be recorded in "hard-copy" form on film or as a gray-tone printer plot.

Using an appropriate combination of existing IDIMS functions, almost any mathematical manipulation may be performed on geophysical data sets in either their original form or in image data format. The ability to retain and manipulate the data in original form is a major advantage to the geophysical data analyst. In addition to arithmetic operations, IDIMS provides built-in capabilities for digital filtering, 1- and 2-dimensional Fourier transforms and convolution operations which should enable the analyst to perform on the IDIMS many of the operations routinely applied to geophysical data with the additional advantage of being able to instantaneously view the result of each operation.

With regard to visual comparison of data sets, the IDIMS system provides several options for simultaneous as well as sequential display of data sets. For example, up to three data sets may be appropriately scaled and each assigned to one of the three color planes to yield a true-color picture of the combined data in which each color may be interpreted in terms of the interactions among the data sets at each point. Alternatively, pseudo-color maps of the separate data sets may be examined sequentially or on split screen for comparison. IDIMS provides for direct readout of the intensity value of any image pixel and

allows for a printout or display at the user terminal of data values at image coordinates.

In spite of ample provisions for visual data comparison, the present system provides only limited capacity for mathematical data intercomparison. However, difference maps are easily produced to evaluate pixel-by-pixel variation between data sets. Descriptive statistics and Fourier transforms are also available on the existing system. Even a somewhat inelegant method has been devised to compute Pearson Product Moment correlation coefficients among small neighborhoods of corresponding points of two data sets and to output these as a third image comprised of the correlation values. This method remains untested, however, and should be further explored along with other multivariate statistical comparison procedures as an enhancement to the existing IDIMS/GEOPAK system.

The problem of data registration was not fully explored during this phase of GEOPAK development, but preliminary assessment finds that the use of the presently available functions for this purpose may be difficult to apply to geophysical data. Such application is complicated by the fact that geophysical data displays lack easily distinguishable landmarks characteristic of LANDSAT or similar images. The inability to designate landmarks in the data themselves precludes the selection of control points necessary for the registration or warping routines of IDIMS. Such procedures are not, however, impossible and would require only the maintenance of corollary latitude and longitude images for each data image to facilitate the selection of control points. Alternatively, GEOPAK provides for the overlay of a grid onto any image. (See documentation for the processing function "GRID"). Other possibilities are discussed in the following report section.

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FUTURE ENHANCEMENTS TO IDIMS/GEOPAK

In spite of the deficiencies outlined above, the IDIMS/GEOPAK system remains a useful tool for geophysical data analysis, and it should be noted that the system appears to possess most of the "raw material" for correction of its deficiencies as well as for valuable enhancements. Thus, most of the suggestions to follow may be realized with only small modification to the present system. Some likely extensions of the GEOPAK system are listed below:

- (1) The existing subroutines of IDIMS appear adequate to permit expansion of the statistical capabilities of the GEOPAK sub-system. It is entirely feasible that new functions could be added to IDIMS to allow more sophisticated data comparison. Inasmuch as multispectral image classification is already possible on the present system, it is likely that additional experimentation with appropriate test data sets might also reveal IDIMS capabilities which escaped present scrutiny.
- (2) As map production will undoubtedly remain an important function of GEOPAK, the addition of better-defined procedures and/or new functions for imaging data at a variety of standard map projections would be valuable. Ideally, the user should be able to modify the projection of data simply by calling a function which would convert any standard map projection to any other. Preliminary investigation indicates the definite feasibility of this option.
- (3) Documentation on the use of the table digitizer available for use by IDIMS account holders would provide the analyst with the capability to enter geophysical and geological data from maps not in digital form.
- (4) The installation of a program such as SPHERE for interactive 3-dimensional magnetic modeling would be a valuable addition to GEOPAK. Such a system, appropriately interfaced to IDIMS, would enable the user to input magnetic model parameters and instantaneously view a display of the resultant model field contours. Such a display could be compared with displays of actual data either visually, or even statistically, to assess the appropriateness of a given model.

REFERENCES

ESL Incorporated (1981) IDIMS Functional Guide, Vols 1 and 2, Technical Manual ESL-TM709

Sabins, F. F. (1978) Remote Sensing: Principles and Interpretation, San Francisco W. H. Freeman and Co., 420pp.

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APPENDIX A-
General Processing Functions:
Summary Descriptions

(With Page References To IDIMS User's Manual)

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Utility Functions

ABS	4-23	Takes absolute value of image elements.
ANNOGATE	4-27	Inserts annotation in an image or generates an image that consists of annotation data.
COMPARE	4-63	Compares two images if they are equivalent, and, if they are not gives a measure of how dissimilar they are.
CONSTANT	4-73	Creates a uniform valued image of a specified size.
COPY	4-89	Creates a duplicate of an input image.
CPPICK	4-94a	Allows the analyst to select control points in related images. Corresponding control points are stored in the images mensuration files for use by the REGISTER function.
DICOMED	4-104a	Generates file output on a DICOMED D47 recorder.
GRID	4-157	Overlays a image with two sets of parallel, straight, regularly-spaced grid lines which need not be orthogonal.
GRNDSPOT	4-167	Records the gray level of each image band at user-specified location. Location may be input as line and sample coordinates.
HISTOG	4-189	Calculates the histogram of an image and produces a hardcopy at either the terminal or the line printer.
LPMAP	4-251	Produces a line printer map of an image.
PICPLOTG	4-331	Plots an image using half-tone gray levels on a Versatek Raster Plotter.
PICPRINT	4-335	Prints the image values point-by-point in integer format.

PICSTAT	4-337	Calculates and prints statistics of an image including its maximum and minimum values and the locations of the first occurrences of those values as well as its mean and variance.
PICVAL	4-339	Prints the image values point-by-point in floating point format.
PIXCOUNT	4-341	Counts pixels in an input image within gray level groupings.

Arithmetic Functions

ADD	4-19	Performs weighted additions, pixel by pixel of images of equal size.
DIVIDE	4-109	Divides one image by another on a pixel by pixel basis
LINEAR	4-242a	Performs a point-by-point linear transformation on an input image.
MULTIPLY	4-291	Multiplies input images pixel by pixel to form one or more output images.

Intensity Transformations

MAP	4-267	Performs a specified piecewise linear gray level mapping
NORMAL	4-297	Produces new intensity values by truncating all negative values in the old set to zero, then scaling the old values (from zero to maximum) linearly to new values (from zero to a specified new maximum value)
PEXP	4-315	Exponentiates the intensities of an image
PLOG	4-351	Takes the logarithm of the intensities of an image.
POWER	4-363	Raises the image intensities to a specified power.

SCALE 4-421 Linearly rescales the input image intensities with optional clippings of input data before mapping is applied.

Geometric Transformations

EXPAND 4-127 Expands an image by a specified integer factor (need not be the same for the line and sample directions) using a repeated point expansion algorithm.

FLIP 4-141 Inverts an image top-to-bottom.

MAGNIFY 4-257 Changes the scale of an input image by a specified amount in the line and sample directions allowing more control over the process than with the function EXPAND.

MIRROR 4-281 Reverses an image left-to-right.

REDUCE 4-393 Contracts an image by selecting every Nth point from every Mth line.

REGCOEFF 4-395 Accepts the A and B transformation coefficients and output picture sizes produced by REGISTER, ROTATE, or MAGNIFY and geometrically transforms an image accordingly.

REGISTER 4-399 Performs a spatial mapping of the input image based on either analyst-supplied control points or analyst-supplied transformation equations.

ROT180 4-405 Rotates an image 180 degrees.

ROTATE 4-407 Rotates an image (or coordinate values) through an arbitrary angle and optionally changes the scale.

TRANS 4-477 Shifts an image up or down and left or right with a wrap-around effect in both directions.

TRANSPOS 4-483 Transposes the input image by interchanging the rows (samples) and columns (lines).

ORIGINAL PAGE IS
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AUTOCOR	4-33	Computes the autocorrelation of an image in the Fourier transform domain.
COMPOLAR	4-67	Combines two real-valued images on a pixel by pixel basis to form a single complex-valued image, with the first input image providing the magnitude and the second providing the phase information.
COMRECT	4-69	Combines two real-valued images on a pixel-by-pixel basis to form a single complex-valued image, with the first input image providing the real part and the second input image providing the imaginary part of the output image.
CONJ	4-71	Computes the complex conjugate of a complex-valued input image on a pixel-by-pixel basis.
CROSSCOR	4-95	Computes the cross-correlation of two images in the Fourier transform domain.
IM	4-211	Extracts the imaginary part of a complex-valued image to form a new image.
MAG	4-255	Extracts the magnitude of a complex-valued image to form a real-valued image.
MAGPHASE	4-263	Extracts the magnitude and phase of a complex-valued image to form two real-valued images.
MAGPOWER	4-265	Raises the magnitude of a complex-valued image to a power while retaining its phase to produce a new complex-valued image.
PHASE	4-329	Extracts the phase of a complex-valued image to form a new image.
RE	4-373	Takes the real part of a complex-valued image to produce an output image.
REALIM	4-375	Extracts the real and imaginary parts of a complex-valued image to form two real-valued images.

SPECPOW	4-451	Calculates the average power spectrum of an image as the average of the magnitude squared of the transformed windowed subsections comprising the image.
SPECPOWL	4-455	Calculates the average logarithm power spectrum of an image as the average of the logarithm of the magnitude squared of the transformed windowed subsections comprising the image.

Fourier Transforms and Filtering

CFFT	4-47	Computes the two-dimensional forward Fourier transform of a complex-valued image.
CFFT1	4-49	Performs inverse Fourier transform in one dimension.
CIFT	4-51	Computes the two-dimensional inverse Fourier transform to produce a complex-valued output.
CIFT1	4-53	Performs inverse Fourier transform in one dimension.
FFT	4-133	Performs forward Fourier transform of a real-valued image
IFT	4-209	Computes the two-dimensional inverse Fourier transform of a complex-valued image to produce a real-valued image.
WIENER	4-527	Generates a Wiener-Helstrom least squares filter given the degrading OTF and noise-to-signal power spectral ratio.

Spatial Filtering

AVERAGE	4-35	Produces a new pixel value at a given pixel position as the computed average of the old value at that position and the old values at a specified number of neighboring positions.
CONVOL	4-83	Convolve an image with a mask.

Appendix A. General Processing Functions

Image Formatting and Transfer Functions

CONVERT	4-81	Converts an image from one data type to another, or one spectral organization to the other.
ENTER	4-113	Reads images or image subsections into IDIMS from a 7-track magnetic tape in either standard HP3000 tape or IBM floating-point formats and enters these data sets as named pictures in the user's library.
INSERT	4-213	Overlays a section of an image with data from another image.
MOSAIC	4-285	Combines two or more images to form a single image by abutting the input images.
MOSAICT	4-287	Combines two or more images to form a new image on tape by abutting the input images.
TRANSFER	4-479	Records an image on 7-track digital tape.
UNITE	4-517	Combines single images into a single multi-band image.

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APPENDIX B-
System Control Functions:
Summary Descriptions

(With Page References To IDIMS User's Manual)

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Processing Related

CANCEL	5-5	Terminates an active processing function before its normal completion.
COMMAND	5-7	Provides the user with the capability of specifying a file that is to be used for input commands.

Session Related

DELETE	5-19	Deletes images from the analyst's picture catalog, the disk, and tapes.
END	5-25	Initiates the end-of-session sequence.
LOAD	5-47	Allows the user to load (bring on-line) files that are currently catalogued, but stored off-line.
MPE	5-51	Allows a user to enter a MPE command within a session or job.
PUT	5-56a	Allows the analyst to manipulate the contents of image and graphic memories via the video processor of the display.
RENAME	5-56m	Allows the user to rename a catalog entry.
SET	5-67	Changes user attributes during a session.
STORE	5-73	Transfers entries from disk to labeled magnetic tapes and continues to maintain these entries in the system's library of entries.

Documentation Related

HELP	5-35	Provides the user with documentation related to a designated IDIMS function.
HISTORY	5-37	Lists processing history of an image by presenting the sequence of processing which has been performed on the image by IDIMS.

LISTCAT	5-41	Lists the catalog of the analyst's images.
LISTSTR	5-43	Lists a user's current character string definitions.
SESSION	5-65	Produces a listing of the current processing session, comprising a record of all operations which were initiated by the user during this time period.
SHOWSET	5-71	Allows the user the capability to obtain the current state of parameters for the SET command.

Image Display Related

DISPLAY	5-21	Displays images.
FRAME	5-29	Displays images in sequence.
GRAPHICS	5-33	Displays an image on the graphics overlay.

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APPENDIX C-
Display Control Commands:
Summary Descriptions

(With Page References To IDIMS User's Manual)

Appendix C. Display Control Commands

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General Manipulations

<u>CENTER</u>	6-12	Requests subsequently displayed images to be centered or non-centered.
<u>COLOR</u>	6-13	Views a true-color image on the display.
<u>DSET</u>	6-13a	Changes the state of certain display controller attributes during a session.
<u>DSTATE</u>	6-14	Lists images currently contained in display memories.
<u>FREE</u>	6-16	Allows the analyst to free the display for other users without exiting from an IDIMS session.
<u>GRAB</u>	6-17	Allows the analyst to acquire the display when it has been previously assigned to another user and then released.
<u>INITIALIZE</u>	6-18	Resets the mappings associated with all the images, as well as the mappings in the temporary files, to their initial state.
<u>INTENSITY</u>	6-19	Records the current display controller mapping for use by the computer in applying the same mapping for processing imagery residing on the HP disk.
<u>RELEASE</u>	6-21	Allows the analyst to make an image plane(s) available for writing new images on the display.
<u>SAVE</u>	6-22	Allows the analyst to make an image plane(s) unavailable for writing new images on the display.
<u>SELECT</u>	6-23	Allows the analyst to select for viewing one of the image planes on the display.
<u>SPLIT</u>	6-24	Allows the analyst to display two images together on each half of the display screen, or four images together on each quadrant.

Function Memory

CPLM (CPLMN)	6-29	Allows the analyst to define an arbitrary piecewise linear mapping using the cursor with the image histogram as a reference.
DFM	6-32	Allows the analyst to view a graph of the function memory being applied to the image.
LFM	6-35	Allows the analyst to generate on the line printer a listing of all pairs of values (old vs. new intensity) produced by the current display controller mapping.
MAP	6-38	Allows the analyst to enable or disable the mapping function with a piecewise linear fit of breakpoint pairs entered through the keyboard.
MSB (MSBN)	6-40	Gives the analyst capability to define a single break-point and view the image with this mapping as well as the option to view the function memory mapping created.
RECALLM	6-45	Applies a particular gray level mapping (previously saved by the analyst) to the image currently displayed.
SAVEM	6-47	Saves the current gray level mapping during a session for future use.
TLM	6-48	Applies a real-time linear mapping, under cursor control, to the image being viewed on the display.

Pseudo-Color

ACM	6-52	Assigns pseudo-colors to gray level ranges using cursor selection from a 4096 color display.
CC	6-54	Assigns a given primary color to a range of image values while depicting the other image values as gray levels.

DPT	6-55	Allows the analyst to display the current pseudo-color table as a colored step wedge.
GPT	6-57	Displays a graph (on the graphics overlay) of the intensities of the primary colors versus gray level.
<u>PSEUDO</u>	6-59	Turns the pseudo-color feature of the display on or off.
RECALLP	6-60	Applies a particular pseudo-color mapping (previously saved) to the image currently displayed.
SAVEP	6-61	Saves a pseudo-color mapping during a session for future use.
TCC	6-62	Loads a pseudo-color table with standard colors selected from a table of color names.

Graphics Overlay

DC	6-64	Obtains a graphic readout of the position of the trackball relative to the display screen as well as to the entire image when only a portion is displayed, and the image value at that point.
DRAW	6-65a	Permits drawing on information on the graphics overlay.
GR	6-66	Gains control of the graphics features of the COMTAL display.
<u>HISTOGRAM</u>	6-68	Displays a histogram of the mapped or the original unmapped image using the graphics overlay.
HISTOGV	6-68	As above but displays histogram of actual viewed (mapped) image.
<u>PROFILE</u>	6-69	Displays a graphic representation of the intensity values along a slice between any two points indicated with the use of the cursor.
TIC	6-70	Allows the analyst to surround the image with reference tic marks.

ORIGINAL PAGE IS
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<u>FLKER</u>	6-72	View two or three images alternatively in a timed sequence.
<u>FLKM</u>	6-73	Allows the analyst to apply function memory mappings alternatively in timed sequence to the displayed image.
<u>FLKP</u>	6-74	Allows the analyst to apply pseudo-color mappings alternatively in timed sequence to the displayed image.

Mensuration

<u>AN</u>	6-78	Allows the analyst to overlay a string of text on the displayed image.
<u>SB</u>	6-95	Allows the analyst to select any subsection of a viewed image and to optionally expand that subsection by a specified factor.

Cursor Manipulation

<u>CURSOR (CR)</u>	6-100	Controls the state of the cursor.
<u>DFC</u>	6-103	Allows the analyst to define a shape for the cursor on the display.
<u>MFC</u>	6-105	Allows modification of previously saved cursor shapes.
<u>RECALLC</u>	6-106	Recalls a previously saved cursor shape.
<u>SAVEC</u>	6-107	Saves a user-defined cursor shape for future use.