MICROWAVE IMAGE PROCESSING LAB

Leland Pierce
Radiation Laboratory

March, 1991

The University of Michigan
Microwave Image Processing Lab

1 Introduction to the facility

The Microwave Image Processing Lab (MIPL) is a facility for advanced, general purpose image processing as well as remote sensing data processing. The equipment is used for image aquisition, manipulation, analysis, and display. At present, the lab is exclusively concerned with remotely-sensed images and all of the associated ground-truth data. This data can be assembled with tools available here at MIPL into a Geographic Information System (GIS).

The facility consists of three processing stations:

1. SUN-4 workstation with specialized graphics display hardware, 40 Megabytes of memory, and nearly 2 Gigabytes of hard disk storage space.
2. A standard video display terminal attached directly to the SUN, allowing it most of the capabilities of the SUN server.
3. A Compaq (PC clone), likewise with specialized graphics display hardware, its own hard drive, but also with network access to the hard disk on the SUN.

Images can be input from a number of sources:

video camera attached to the Compaq,

as a file transferred over the Internet computer network,

2 standard sizes of cartridge tapes,

standard 9-track tapes,

data encoded on a CD-ROM disk,

a large (map-sized) digitizing table, with

5.25 inch floppy disks,

3.5 inch micro floppy disks, and

40 Megabyte cartridge tapes on the Compaq.

Images can be output to any of the six standard magnetic media formats mentioned above, as well as printed in color with an ink-jet printer or in black-and-white with a LaserWriter. Color images can also be output to 35 mm film and from there can be made into slides, prints, and transparencies.

A number of different third-party software packages are installed in the lab which provide most of the funtionality necessary for the work carried out here.

This software enables almost any user to perform complex image processing tasks without extensive training. A collection of programs developed in-house provide extensions to the packages in the area of polarimetric remote-sensing data, specifically from the JPL AirSAR. This sort of customization is ongoing; MIPL continues to write custom software in a timely manner for any user with a specific need that is not addressed by the current software.

2 General Capabilities

All of the typical image processing functions are supported by the various packages, including:

raster-to-vector conversion, and vice-versa,
image filtering of many kinds,
image arithmetic,
image pseudo-coloring,
look-up table transforms,
coordinate system conversions,
image classification (supervised and unsupervised),
image histograms,
3D perspective image generation,
watershed and drainage,
image warping of many kinds,
and many other utilities.

Depending on your application and expertise one package will probably be the best choice. When more than one package is necessary for a task, conversion routines are necessary to translate the formats of the files between the different packages, but many of these are already written and more can easily be added as necessary. This allows one to make full use of all the packages. As more packages are added, more translation programs will be written for them. This is planned as an ongoing project in order to provide the best functionality that can be offered anywhere.

Input and output of images has already been mentioned in the introduction, but now some important details will be presented.

INPUT AND OUTPUT:

- The 9-track tape drive is self-loading with a maximum density of 6250 bits per inch.

- The cartridge tape drive accepts either DC300 or DC600 cartridge tapes.

- The Internet network connection can access many sites throughout the country and even the world. File transfer can be accomplished with FTP or telnet. BITNET access is also available through various gateway computers.
- The 2 floppy drives on the Compaq are standard size and format.
- The tape drive on the Compaq uses 40 Megabyte DC2000 cartridge tapes which must be formatted in the tape backup format of the PC.

INPUT ONLY:

- The CD-ROM drive accepts 5 inch optical disks written in High Sierra or ISO-9660 formats.
- Hardcopy can be entered through the Eikonix full-color image scanner. This provides 8 bits for each color and 4096×4096 pixel resolution mounted on a light table with focal length variable from several inches to several feet.
- Maps may also be entered as collections of line segments or polygons through the 44 inch×60 inch Calcomp digitizing table. The table provides a resolution of 0.01 inch.

OUTPUT ONLY:

- Apple LaserWriter for any text as well as black-and-white image data. The images are dithered to provide a grey-scale image. Resolution is 100 dots per inch.
- Tektronix 4696 inkjet color printer. Uses dithering to create different shades of the colors. Uses black, cyan, magenta, and yellow ink to create the image. Resolution is 120 dots per inch. Paper is 10 inches wide on a spool.
- Matrix PCR film recorder allows high-quality output of image data to 35 mm film. The film can then be processed to yield color prints of any size, color slides, and color transparencies. An extensive labelling program exists to allow for presentation-ready slides of images.

Example outputs from the system are included at the end of this document.

The three image processing packages that we now have are: ERDAS, GRASS, and PCI. They each have their own strengths and weaknesses and so using all of them may become necessary in the future. Right now ERDAS is used for Geographic Information System (GIS) developement while PCI is used for the custom image processing described in the next section. A conversion program allows the porting of the ERDAS data into PCI format.

3 Processing of JPL AirSAR data

The data from the JPL AirSAR can be in 1 of 3 formats at the moment. None of these formats are easily integrated into a standard image processing package, and so specialized software has been developed in conjunction with one of these packages to specifically process this data. Among these programs are those that read the data tapes, calibrate the images, synthesize an image at an arbitrary polarization, calculate and display a polarization signature, calculate and display phase-difference histograms, and convert between the formats.

The compressed images are approximately 7.7 Mbytes each with 10 bytes of data for each pixel in the 1024×750 image. A calibration routine written at JPL and ported to the equipment here is used to calibrate these images. A polarization signature of a region of interest in the image can be displayed as well as printed. An image based on a particular polarization can then be generated which will maximize the contrast between any two types of target in the image. Classification based on this image will then be channeled toward the targets of interest. Phase difference histograms can also be generated for regions of the image and classification based on these statistics can also be carried out.

The high-resolution format images are approximately 101 Mbytes each, and have 32 bytes of data for each pixel in the 4096×750 image. As above, routines for calibration, polarization signatures, synthesis, and phase-difference histograms are available for similar processing tasks. One area that we are particularly interested in is the calibration based on this format *vs.* the calibration based on the compressed format. Devising algorithms to calibrate an image based on the images of in-scene calibration targets is a major research topic and has yet to be resolved satisfactorily. A preliminary calibration procedure is used here.

The compressed/high-resolution data format combines the high-resolution aspect and the compressed aspect giving an image that is 24.6 Mbytes with 8 bytes of data per pixel in the 4096×750 image. Since this format is new, no data products have yet to be recieved in this format, hence no programs have yet been written to process this data. A simple expedient in the near future would be to write a conversion program from the compressed/high-resolution to high-resolution format and then use the programs developed for that format.

A major issue in the processing of remote-sensed data is to decide which pixels in the image correspond to what features on the ground. The general procedure for dealing with this issue is through image warping and the development of a detailed Geographic Information System (GIS) that covers the area of interest. This GIS is normally developed by the investigator through a variety of means which include:

digital elevation data tapes from USGS,
land use data from the state Dept. of Natural Resources,
forest cover maps, perhaps from a local forest ranger,

soil maps from the local library or state government,
road maps, etc.

All of this data, of varying quality, must be integrated into a final set of data covering the area of interest and with all the parameters of interest specified. This is a tremendous task. A preliminary GIS has been developed here for certain areas in northern Michigan, and for the Duke forest in North Carolina. In our case, the GIS is finally warped to cover each SAR image as closely as possible, then the regions so specified are used by various programs to extract backscatter or phase-difference averages from each region. This has already been done and works well.

4 Conclusion

The Microwave Image Processing Lab here at the University of Michigan, EECS Dept., in the Radiation Lab is committed to the most flexible image processing configuration possible with proven user support for any custom programming needs. It is the goal of the lab to become the premier microwave remote-sensing image processing center in the country.

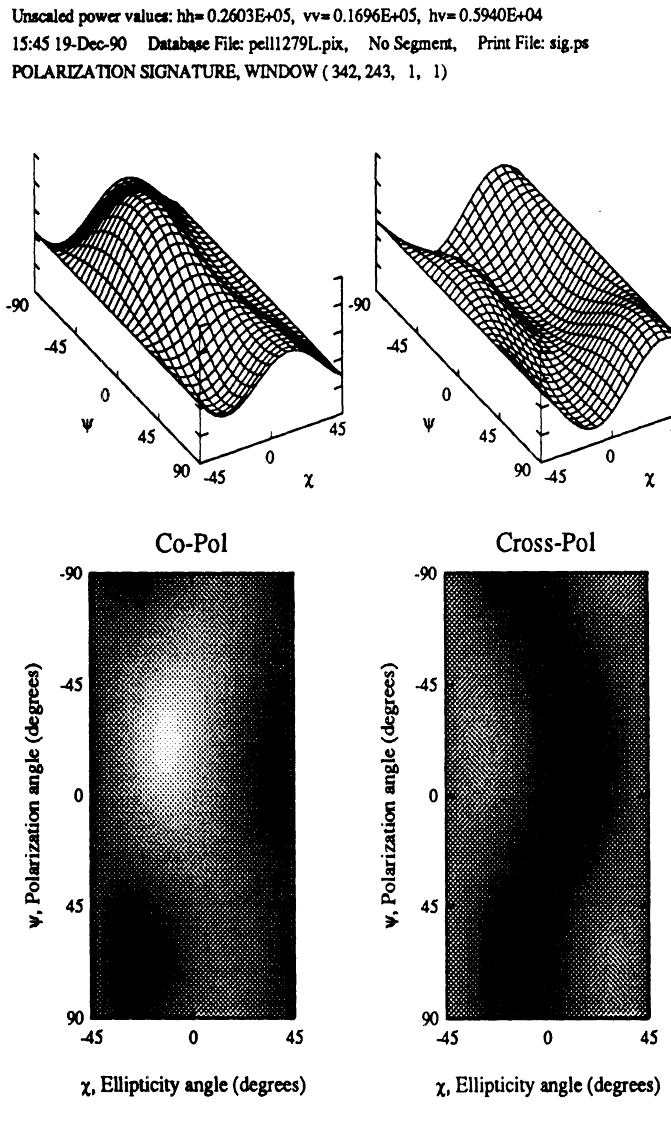


Figure 1: An invaluable tool in Polarimetric SAR work is the *polarization signature*, shown here. The variation of the backscattered power for different polarizations is highlighted in 2 ways: (1) a "co-pol" signature, representing the backscatter when the transmitted and received signals are the same polarization, and (2) a "cross-pol" signature, representing the backscatter when the transmitted and received signals are exactly perpendicular. The variation of these signatures with different targets can be used for target interpretation.

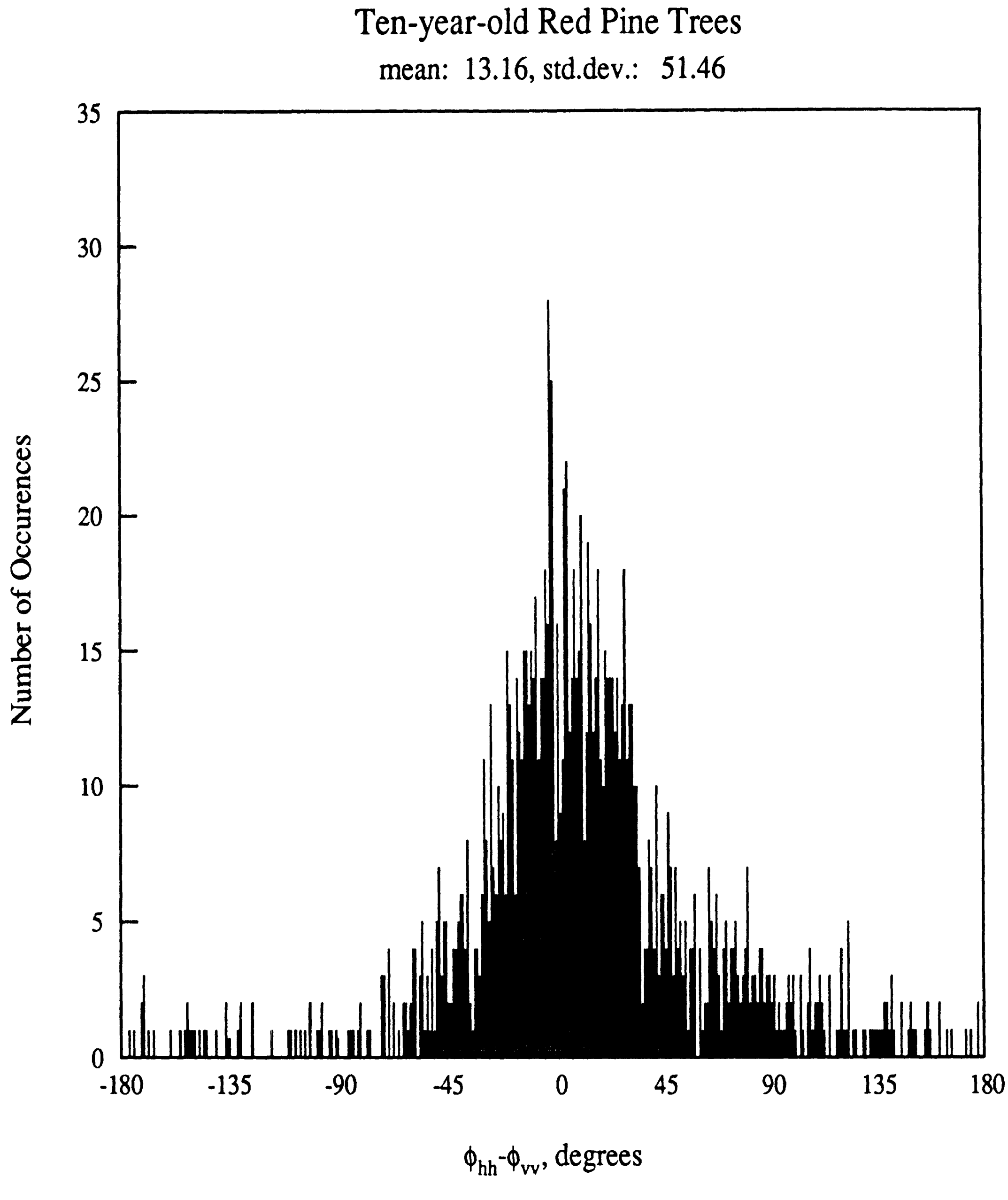


Figure 2: Polarimetric SAR's can also supply phase information between the different polarizations. Shown here is a histogram of the phase difference between the hh-polarized return and the vv-polarized return over a certain area in an image known to be mostly Red Pine trees. The mean and standard deviation tend to vary with different tree species.

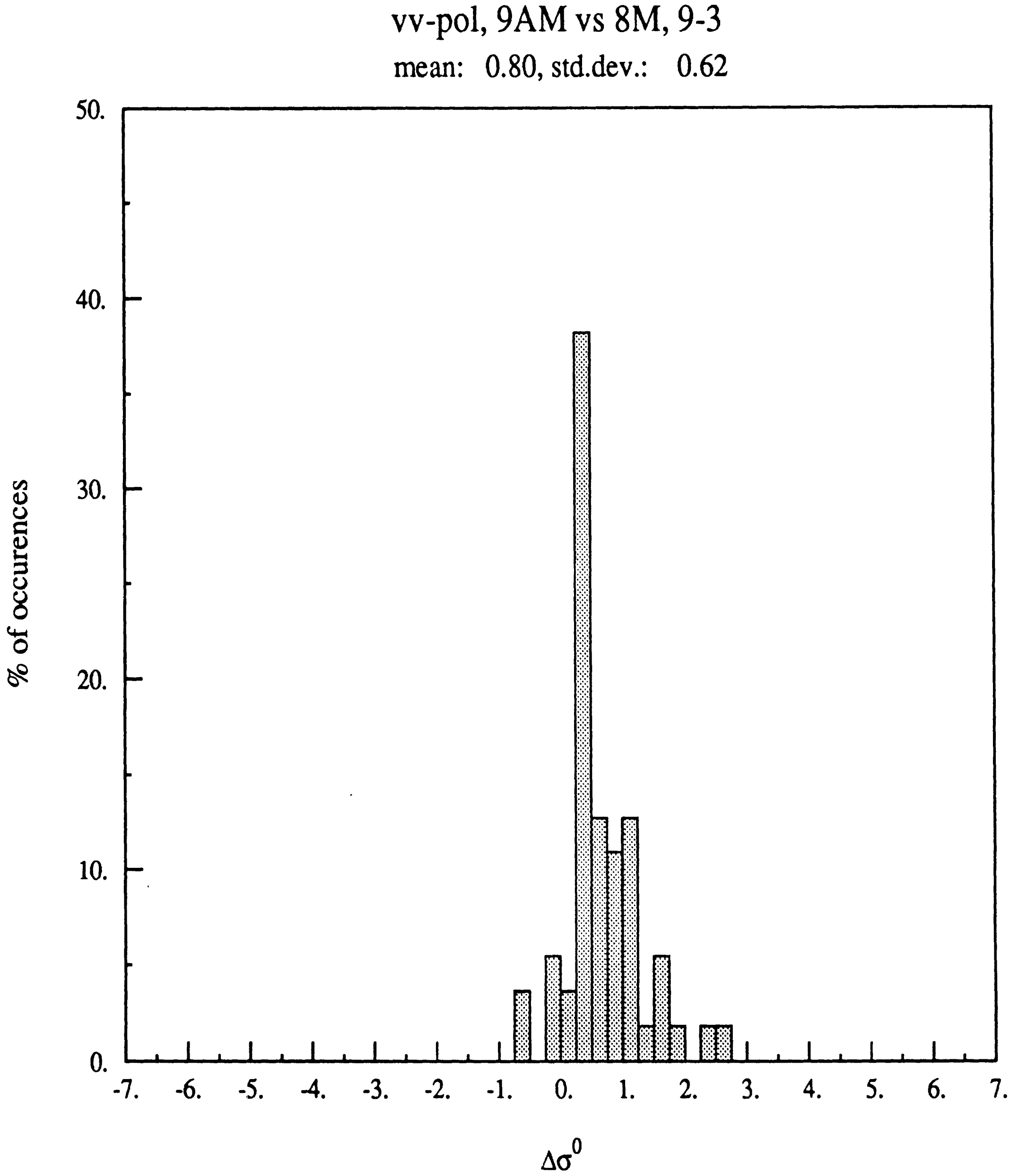
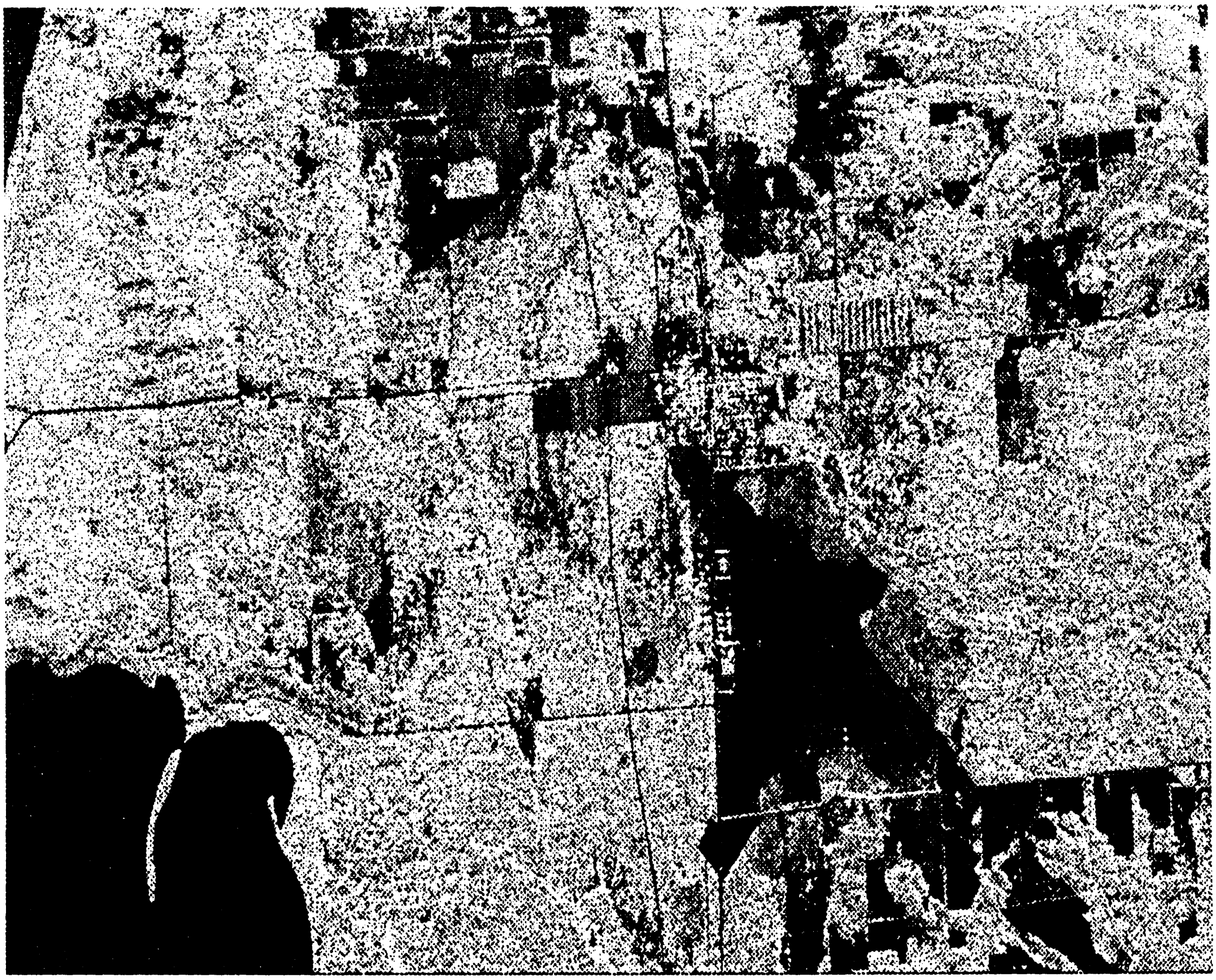


Figure 3: Another kind of histogram is shown here, where the change in the backscatter over time is measured in several different tree stands, but all are the same kind of tree.



1024 Pixels by 750 Lines.

FILE: pell1279L.pix Date: 19-Dec-90
Channel: 12
Window: (0,0) to (1024,750)
Pellston, MI. April, 1990 hh-image

Figure 4: For a quick preview of image data a black-and-white dithered image can be printed on the local LaserWriter quite easily. Shown is the L-band, hh-polarized, backscattered power (linear scale) taken on April 1, 1990 over Pellston, MI (one of our major test sites).

Figure 5: For a color preview of image data an ink-jet printer can produce a dithered hardcopy as well. Shown here is the Pellston site again on April 1, 1990 with the red channel being the hh-polarized image, green: vv, and blue: hv (multiplied by 2). Some colorful features on plots like this may serve to highlight vegetation of particular interest.

Figure 6: For high-quality color output of image data the film recorder is used. Shown here is a print made from 35 mm print film. Any 35 mm film may be used and the output formats are as diverse as your local photoshop allows: 8×10 prints, slides, and transparencies are typically available.

Appendix

The University of Michigan
Microwave Image Processing Lab

Detailed Specifications

Compaq Deskpro 386/20

HARDWARE

1 MByte RAM,
80387 math co-processor chip,
60 MByte Hard Drive,
5-inch floppy drive,
3.5-inch floppy drive,
40 MByte tape cartridge drive,
Ethernet,
IEEE-488 card,
VGA Adapter,
Serial/Parallel port,
Extra color monitor (512×512×24 Sony) for images,
Eikonix Image Digitizing Color Camera, and electronics (8 bit),

SOFTWARE

Appropriate drivers and interfaces for the above hardware products, PLUS:

ERDAS Remote-Sensing image processing software pkg. (Especially useful for driving the Eikonix image digitizer.)

NFS with FTP/Telnet for network file transfer, etc. allows use of hard drives on the SUN-4 as PC file systems.

SUN 4/260

HARDWARE

40 MBytes of RAM,
2 - 900 MByte Hard Drives,
TAAC graphics display (32 bit depth) accelerator board set, with associated $1024 \times 1024 \times 24$ color display,
SummaSketch tablet (Mouse for TAAC Display),
network connections (Internet, UMnet, etc.),
SCSI interface card,
IEEE-488 interface card,
CD-ROM drive using High Sierra or ISO-9660 format for 5-inch disc platters.
Cartridge tape drive,
9-track reel tape drive (self-loading),
Tektronix 4696 color printer (paper and transparencies),
Apple LaserWriterII,
Calcomp 9100 digitizing table with 44"×60" surface,
Matrix PCR film recorder (35mm color film output),
Extra terminal (AT&T).

SOFTWARE

Appropriate drivers and interfaces for the above hardware products, PLUS:

PCI Remote-Sensing image processing software pkg,

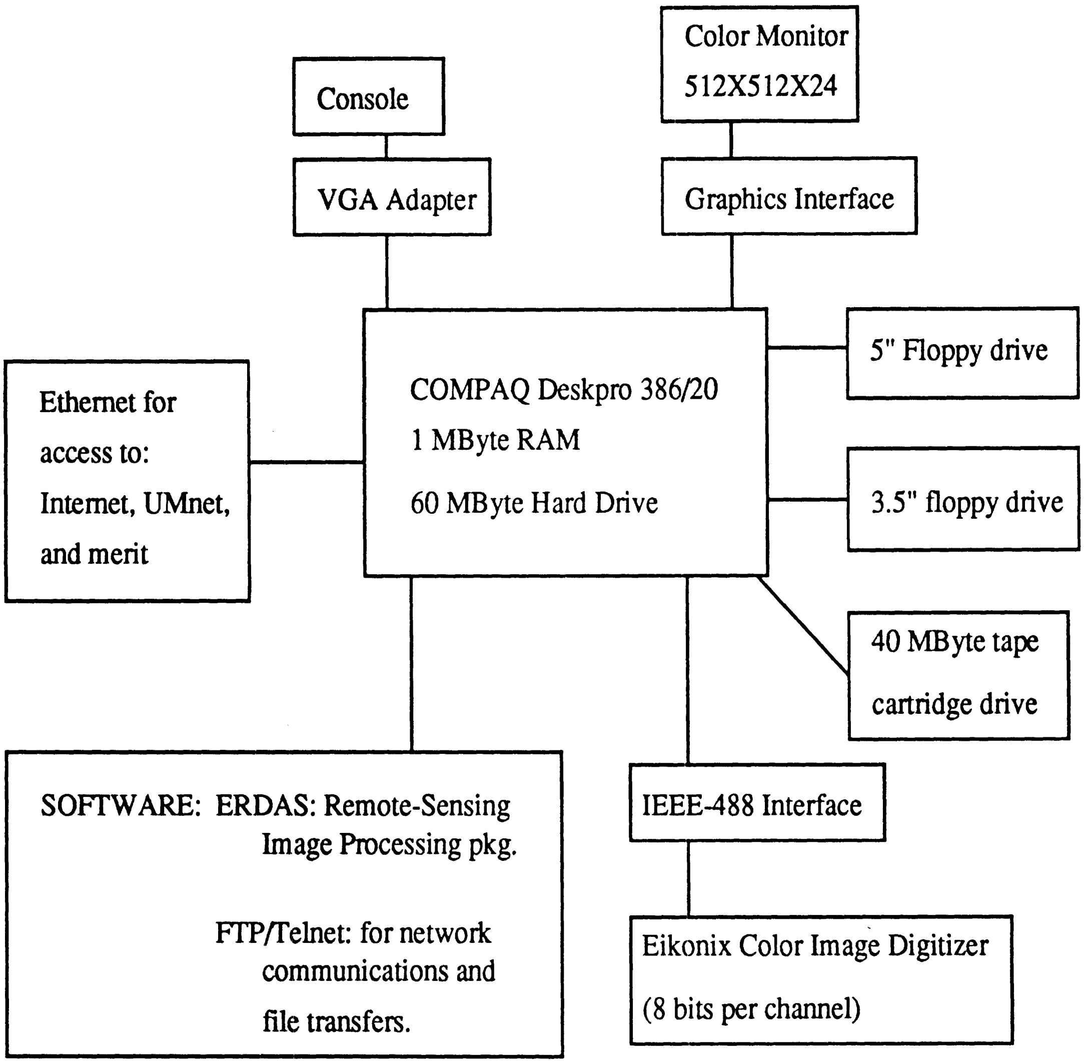
ERDAS Also for Remote-Sensing, but with different capabilities and a different philosophy of implementation and usage,

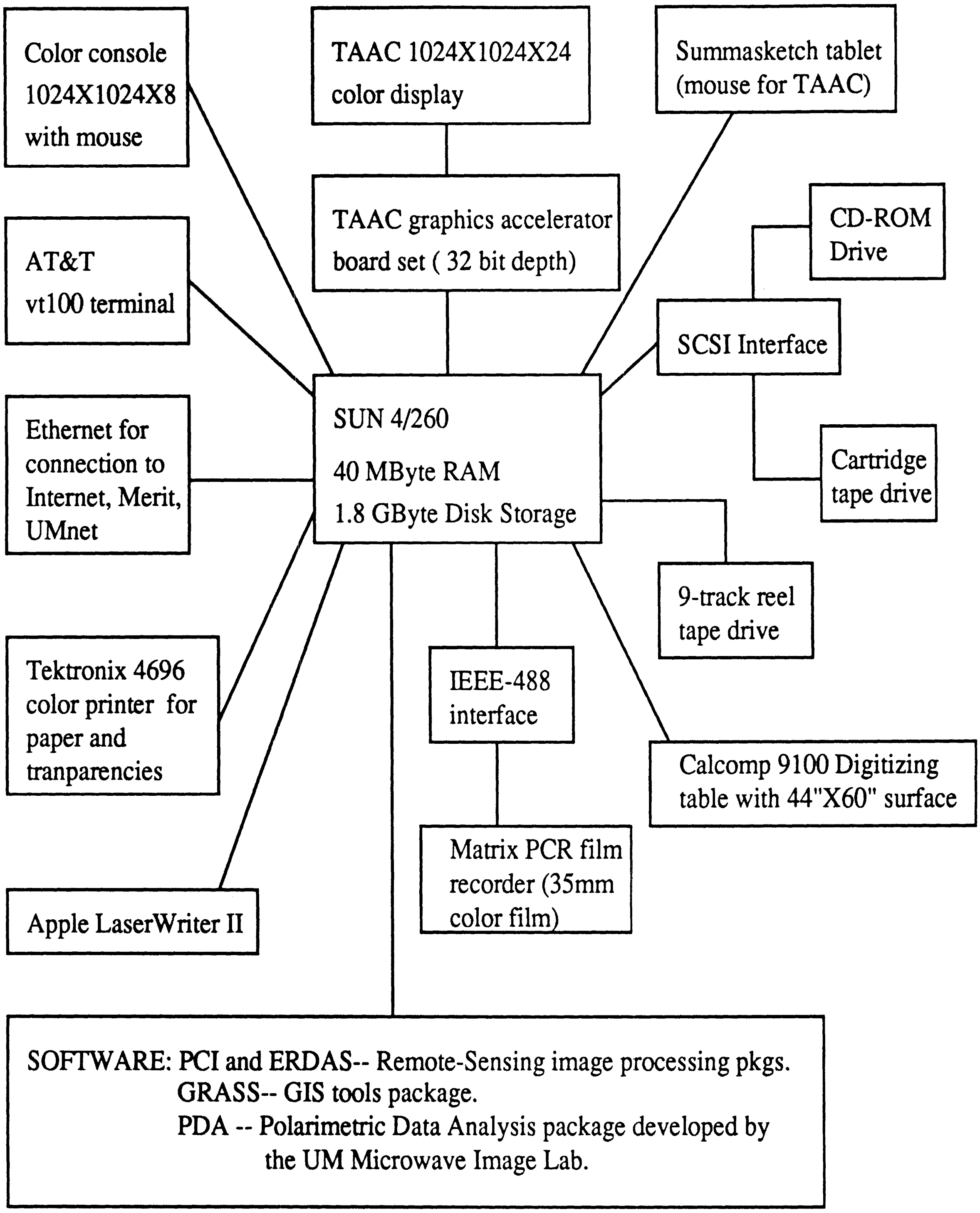
GRASS Primarily a GIS creation/manipulation tool. Allows a greater flexibility in the GIS functions than either of the previous 2 packages. Includes source code.

PDA Polarimetric Data Analysis package developed by the University of Michigan Microwave Image Lab. This is a set of routines for image reading, calibration, synthesis, display, and analysis.

Other UM-developed software includes routines for reading and using ground-truth data, such as USGS elevation tapes, as well as MI-DNR land use tapes, etc.

Various JPL-developed codes have been ported for use in comparisons between differing methods of analysis, including polarimetric calibration.


Color Monitor
512X512X24
Console
VGA Adapter
Graphics Interface
5" Floppy drive
COMPAQ Deskpro 386/20
1 MByte RAM
60 MByte Hard Drive
Ethernet for
access to:
Internet, UMnet,
and merit
3.5" floppy drive
40 MByte tape
cartridge drive
SOFTWARE: ERDAS: Remote-Sensing
Image Processing pkg.
FTP/Telnet: for network
communications and
file transfers.
IEEE-488 Interface
Eikonix Color Image Digitizer
(8 bits per channel)


Color console
1024X1024X8
with mouse
TAAC 1024X1024X24
color display
Summasketch tablet
(mouse for TAAC)
TAAC graphics accelerator
board set (32 bit depth)
CD-ROM
Drive
AT&T
vt100 terminal
SCSI Interface
SUN 4/260
40 MByte RAM
1.8 GByte Disk Storage
Ethernet for
connection to
Internet, Merit,
UMnet
Cartridge
tape drive
9-track reel
tape drive
Tektronix 4696
color printer for
paper and
tranparencies
IEEE-488
interface
Calcomp 9100 Digitizing
table with 44"X60" surface
Matrix PCR film
recorder (35mm
color film)
Apple LaserWriter II
SOFTWARE: PCI and ERDAS-- Remote-Sensing image processing pkgs.
GRASS-- GIS tools package.
PDA -- Polarimetric Data Analysis package developed by
the UM Microwave Image Lab.