# REQUIREMENTS FOR AN EOS-ORIENTED WORKSTATION

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ABSTRACT

We discuss the initial efforts for the determination of functional and performance requirements of a workstation specifically directed toward scientific users of the proposed NASA Earth Observing System (EOS) Information System.

## 1. INTRODUCTION

A major thrust of the Earth sciences in the 1990's and beyond will be the systematic, unified investigation of dynamic global-scale processes and of changing regional phenomena. The NASA Earth Observing System (EOS) is intended to provide the capability to scientifically monitor these global scale, dynamic processes over long periods of time. The systematic study of these global processes will require the collection and organization of very large quantities of raw and processed sensor data, collateral data, and address a great range of physical parameters [Ref.4].

In the past, programs dealing with Earth observation were more specifically sensor based. Large quantities of data were created and archived, but the majority was not used or even effectively cataloged. Because of these previous experiences, NASA's planning for the EOS concept empasizes its role as an information system, of which the multiple sensor platforms are only one centralized data centers, which are to be readily accessible by scientific users.

This vision of an EOS information system which coordinates the distribution of EOS data suggests a requirement for a workstation which allows the individual scientific user convenient access and interaction with such a system (see Figs. 1 and 2). For example, users of EOS information will have requirements and access patterns that are typical of their fields. Some users will require wider coverage with low resolution data and others will need smaller coverage with higher resolutions.

A composite of the many types of anticipated user data requirements includes: catalog searches by regions, wavelength, resolution, or times; browsing of low resolution data; scanning data of given regions along different "dimensions" of imaging parameters; time series analyses of low and high resolution data.

Present image processing systems often have the capacity to store large amounts of data, but do not have capabilities for conveniently accessing data in the modes described above.

Moreover, it is important that such a workstation should efficiently and conveniently execute certain data processing functions which are expected to be common to EOS-oriented scientific users.

Automated processing requirements include capabilities for geometric and radiometric manipulation of large data sets. Among these functions are dead-reckoning of image data, coregistration of dissimilar imagery, analysis of image content, and a range of tools for visualization of multiple imagery sets.

Commercial image processing systems have applications functions that are oriented toward general image processing, rather than on the functions mentioned above for the specific sensors that are planned for EOS such as MODIS, HIRIS, and SAR (Table 1).

Such a set of functions should contain tools which allow the user to conveniently browse and select data online, and to organize and examine the received data. It is expected that the full dataset will generally be transfered offline using media such as optical disk.

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These data issues lead naturally to a vital role for a Geographic Information System (GIS), ie. a spatial database. Its role is discussed in more detail in section 3.4.

The following section briefly outlines the methodology for specifying the requirements for such a system. The driving user requirements are identified both for functions and performance characteristics.

## 2. METHODOLOGY FOR DEVELOPMENT OF A SPECIFICATION

At this time, a detailed specification of all the EOS-type image processing functions has not yet been defined. The methodology for determining the requirements for an EOS-oriented workstation and formulating preliminary design recommendations involves first understanding the typical operational scenarios for users in relevant scientific disciplines. These scenarios are used to derive the workload and functional requirements for the workstation. This process is illustrated in Fig. 3.

The types of scientific disciplines and backgrounds which are expected to use such a workstation include [Ref.3]:

- o global hydrologic cycle
- o global biogeochemical cycles
- o biological oceanography
- o inland aquatic resources and biogeochemical cycles
- o forest environments
- o land biology
- o tropospheric chemistry
- o geology
- o interior of the earth
- o oceanic transport
- o polar glaciology
- o sea ice
- o tropospheric science
- o middle atmosphere science
- o aeronomy

Although numerous sensor types are under consideration for EOS platforms, the most important of these are expected to be MODIS, HIRIS, and SAR (see Table 1).

The typical analysis workloads involve various data types consisting of sensor, calibration, and ground truth data, as well as non-EOS collateral data. The volumes and access patterns of the various user types for browsing and down-loading data will drive the workload specifications.

The functional requirements will be the specifications for image processing and display, data analysis, and database management. Functional performance, such as accuracy, will be included. Accurate models and data rates of the relevant EOS sensors will be required for creating these specifications.

EOS-type data analysis is expected to be region driven, data driven, or problem driven. Therefore, the workstation must have the capability to support user access to data using multiple keys for searching the database (see section 3.4).

The workstation's execution of these functions on the workloads will be constrained by the specification of approximate response time or throughput requirements for functions, and capacity requirements for data storage.

These specifications for workloads, functions and performance will be used to derive recommendations for software, hardware, and system configuration.

The three image processing functions that are considered of utmost importance and whose performance requirements drive the system design are geocoding, coregistration, and visualization of multiple bands of imagery. These functions are discussed in section 3.5.

For an EOS-specific workstation to be useful, it must satisfy the throughput requirements of prospective users. For enhanced capabilities, both functional and performance, it is intended that the basic workstation configuration will be compatible with optional "add-on" hardware modules.

A top-level design for the basic workstation configuration is under development as a result of the ongoing specification of requirements. Some discussion of preliminary conclusions of the present study follows in the next sections.

## 3. LOGICAL ORGANIZATION OF THE WORKSTATION

### 3.1 General

One unique aspect of an EOS-relevant workstation is its reliance on a GIS Management System (GISMS) for coordinating all relational aspects of processing. For example, although raster images are not physically stored in the GIS, the boundaries of the image coverage areas are stored there. Pointers to the appropriate images in the image database are also stored there.

The overall organization of the EOS workstation software from the standpoints of flow of control and flow of data is shown in Fig. 4. The four main functional blocks of modules are the user interface, the applications executive, the block of applications software, and the GISMS.

### 3.2 User Interface

The user interface coordinates the user's physical access to the workstation. The devices that it manages for input and output will include the displays, the keyboard, joystick and mouse devices, the printer and image hardcopy device.

The user interface also provides syntactical checking of all lexical input commands, and contains a window manager for parsing iconic and graphical inputs.

### 3.3 Applications Executive

The applications executive accepts syntactically correct inputs from the user interface and initiates the necessary commands for the activation and execution of applications software. Its logical structure is a collection of command files and a selection module for choosing the appropriate command file.

Each command file contains logic for insuring that the applications software for which it is responsible has access to the required inputs. These may be user-provided inputs, as well as internally stored data types such as image, calibration, geographic, and others.

Obtaining the necessary inputs will generally require formulating queries to one of the databases. These may be generated directly by the user or indirectly by some software module. Because of the central role of the GISMS, any query that does not explicity reference a particular data item will be referenced using the GISMS even though that data item may likely not reside in the GIS. The command files in the applications executive will coordinate the transfer of data products to and from the user interface and the databases.

These command files also contain logic for semantic checking of commands. For example, if a request for data has been formulated and these data are not available, then this information is passed on to the user and the appropriate applications module is not activated.

### 3.4 GIS Management System (GISMS)

The GISMS controls access to the three main databases of the workstation system: the GIS or spatial database, the image database, and the text database. This coordination will allow the formulation of complex relational queries which combine information from all the databases.

As discussed above, the spatial database contains geographically oriented pointers to other databases, as well as geographically indexed collateral data. The image database contains all sensor images.

The text database contains all textual annotations of data, such as calibration information and processing history. It can also be used to organize documentation of research such as reports and papers.

### 3.5 Applications Software

The Applications Software block will contain all of the image processing and data reduction functions. Three applications in particular are expected to drive the computational capabilities of the workstation. These are geocoding, coregistration, and visualization of multi-dimensional data sets. These three functions are discussed in subsections 3.5.1-3.5.3.

Some capability for atmospheric calibration will also be included. However, this particular application will not be considered as important for driving the specifications as the three functions mentioned above.

The Applications Software block will have the capability of containing multiple copies of certain selected applications modules according to data type. For example, certain numerically intensive routines will be realized in software as separate copies for efficiently dealing with inputs in various integer or real data formats.

#### 3.5.1 Geocoding

Geocoding is the process of assigning geographical coordinates to pixels in an image. Geocoding allows the presentation of an image to be viewed as a map, rather than as the particular geometric transformation of the sensor that is involved. This is particularly useful in the case of SAR imagery, where the near range portion of the image tends to be rather compressed.

However, image registration with a map allows not only a more natural presentation, but also makes it possible to readily cross-reference and access ground truth and other ancillary data stored in a spatial database. In fact, such geographically based organization of imagery allows efficient ways of selecting and examining archived imagery.

Mathematically, geocoding is the determination of a geographical pre-image of the sensor transformation for each image pixel. Geocoding first requires relating the sensor coordinate system to an Earth coordinate system. Dead reckoning, tracking, and ground control can be used to obtain ephemeris estimates. Platform attitude sensors or ground control are generally used for attitude information, although SAR phase history may also be used [Ref.1].

After relating the sensor and Earth coordinate systems, a reference geoid or terrain model is used for determining an intersection with the locus of points constituting the sensor transformation's pre-image.

Although it is anticipated that imagery will be geocoded at centralized EOS facilities, the EOS workstation must have a capability to also accomplish this task to potentially higher accuracies. Because the different sensor types employ differing geometric transformations, a separate geocoding procedure must be used with each sensor type.

#### 3.5.2 Coregistration

Intuitively, coregistration is the process of spatially transforming or "warping" different images of the same scene so that when they are stacked, the overlaying pixels correspond to the same ground resolution element.

The accuracies of geocoding and rectification procedures are limited by the accuracies of their input reference data, such as ephemeris, ground control, and terrain models. These accuracies may not be sufficient to achieve the coregistration of independently geocoded images.

The joint use and application of multiple-sensor image data sets is necessary for achieving the full potential of remote sensing. Therefore, a capability for coregistration distinct from geocoding is required.

Coregistration is generally a difficult problem because of the dissimilarities in images. A recent review in [Ref.2] enumerated 90 references. For example, some of the variables which can potentially contribute to dissimilarities in imagery are differences in:

- sensor type
- wavelength
- incidence angle
- polarization
- illumination changes
- scene content changes
- sensor position changes

The workstation will be used to support both automatic and interactive coregistration of dissimilar source imagery. However, because such automatic methods are not always reliable, the workstation design considerations will be driven by the need to efficiently support the interactive approach. Interactive techniques can also be used for correcting registrations produced by automated algorithms.

An example of the interactive coregistration of aircraft and SIR-B satellite SAR imagery, taken from [Ref.8], is shown in Fig. 5-8. Matching points were obtained interactively to create a deformation grid for the image that is to be warped. Then this image is resampled as defined by the deformation grid.

One of the sources of error for interactive registration is the small residual pixel error in specifying the initial match points. The EOS workstation will have the capability to approximately specify such points for subsequent refinement. A background software process will subsequently refine the locations of these points using the computed intersections of refined edges. An example of this capability is shown in Fig. 9 and 10. These figures show the complexities involved in coregistration arising from image dissimilarities.

### 3.5.3 Data Product Visualization

It has been said that science is generating data with 21st century technology, but is using 19th technology to understand this data [Ref.6].

An important feature of the workstation for scientific usage of EOS data will be the capability to visualize mutiple data products efficiently. The usual presentation aids available from image processing techniques will include IHS-RGB transformations [Ref.7], digital elevation models, and stereoscopic, orthographic, and perspective views. Examples of perspective view presentations can be found in Fig. 11-13.

The large number of spectral bands of overlapping EOS-type imagery increases the "dimensionality" of the data set so that there is a potential problem for effectively viewing this data. Rather than trying to find a simultaneous visual presentation of this higher dimensional data set, the approach taken for the EOS workstation involves an effective set of tools for creating and viewing sequences of lower dimensional processed images. Such an image sequence would "freeze" spatial dimensions and show variations arising from other parameters. Shown at near-video rates, such a sequence can allow the user to "navigate through the parameters" of the data set.

What is required is a convenient interactive facility for specifying such a sequence of lower dimensional images as a function of chosen parameters. The workstation will allow such interactive parameter specification using a joystick. The actual processing and selection of the imagery will be a background processing activity, but the specification process will be real-time. An example of such a presentation is in Fig. 14, where the desired parameter has been encoded as false-height disparity and is visualized using a perspective view.

This "joysticking" capability will also be applicable for specifying viewpoints for generating the perspective views of terrain model data discussed above. In this way, a "fly-by" sequence can also be interactively specified. Again, the actual computations of the perspective views will be generated as background processing. Once completed, the sequence of computed "fly-by" views can be viewed at near-video rates.

### 3.5.4 Text Processing

The capability for creating research documentation should also be hosted on the workstation. Recently, research into "hypertext" has prompted the development of research tools which combine word-processing and database manipulation [Ref.5]. Such tools are used for organizing a writing environment which goes beyond the lexical features of ordinary word-processors.

Such an environment allows a user to outline, structure, link, search, and display text fragments according to some conceptual structure. An analogy can be made with a collection of topical notecards used in the organization of a research paper. A recent commercial example of such a hypertext facilities is Apple Macintosh's Hypercard.

Eventually, this workstation should have the capability to integrate such a hypertext facility into its operation. This will more fully automate the process of merging the data and text that is so characteristic of writing research papers.

## 4. SUMMARY

The EOS workstation described above will allow EOS-era researchers to more fully realize the potential benefits of working with large sets of multi-spectral data. There is a high expectation for a dramatic increase in user efficiency for choosing, organizing, manipulating, and visualizing this EOS data.

## 5. REFERENCES


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SAR

Sensor Type: Synthetic Aperture Radar
Incidence Angles: 15 deg. - 55 deg.
Frequencies: L, C, X Bands; L, C Quadpole
Polarization: HH, VV
Height: 824 km.
Azimuth Angle: - + 60 deg.
Resolution Modes:
  Local High Res
    Swath: 30 - 50 km.
    Res: 20 - 30 m.
  Regional Mapping
    Swath: 100 - 200 km.
    Res: 50 - 100 m.
  Global Mapping
    Swath: max. 400 km.
    Res: 200 - 500 m.

HIRIS

Sensor Type: High Resolution Imaging Spectrometer
Height: 824 km.
Resolution: 30 m.
Swath: 30 km.
Spectral Range: 0.4 - 2.5 um.
Number of Channels: 200

MODIS-T

Sensor Type: Medium Resolution Imaging Spectrometer
Height: 705 km.
Resolution: 1000 m.
Swath: 1513 km.
Spectral Range: 410 - 1040 nm.
Number of Channels: 64

MODIS-N

Sensor Type: Medium Resolution Imaging Spectrometer
Height: 705 km.
Resolution: 500 m.
Swath: 1513 km.
Spectral Range: 470 - 2130 nm.
Number of Channels: 25

TABLE 1

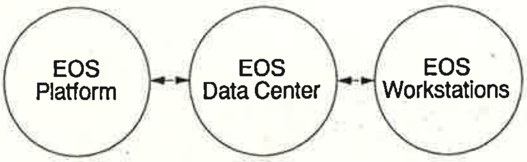


Figure 1. The EOS System

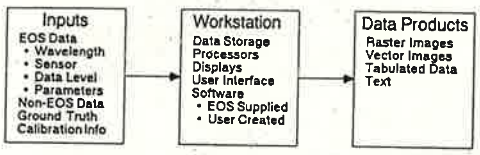


Figure 2. User View of Workstation

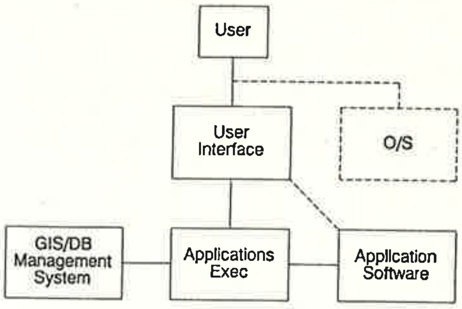


Figure 3. Major Software Sections

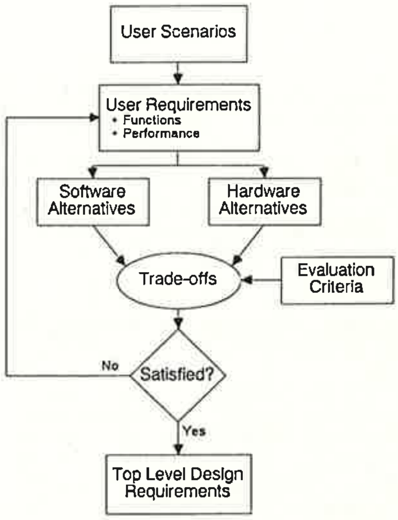


Figure 4. Workstation Design Process

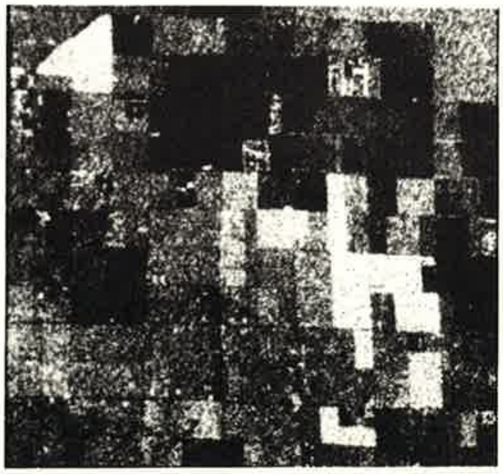

Figure 5. JPL Aircraft-SAR Image #1

Figure 6. Landsat Image

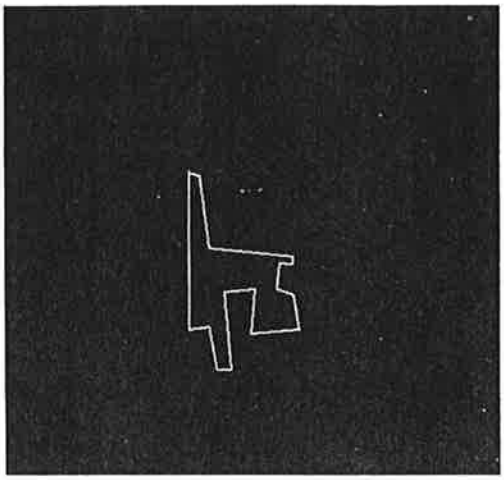

Figure 9. Operator selected edges of a feature in Figure 5.

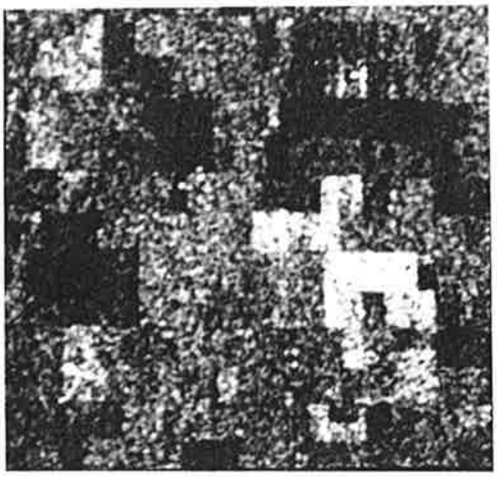

Figure 7. SIR-B SAR Image

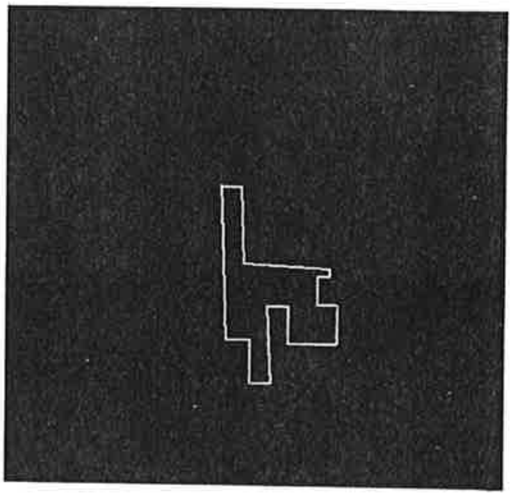

Figure 10. Automatically corrected edges of the same feature as in Figure 9.

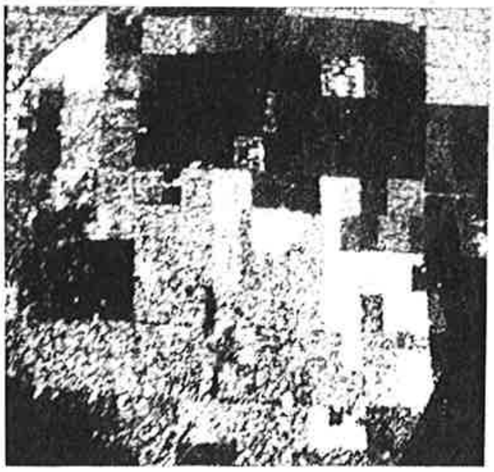

Figure 8. JPL Aircraft-SAR Image #2

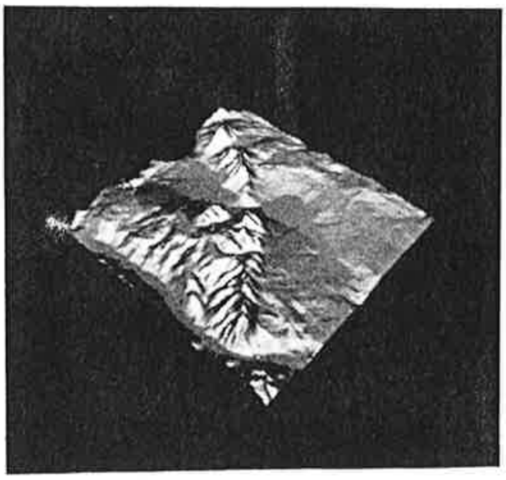

Figure 11. Perspective View

Figure 12. Perspective View

Figure 13. Perspective View

Figure 14. The ratio between Figure 5 and Figure 6 encoded as height and presented as a perspective view.