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REQUIREMENTS AND SPECIFICATIONS OF THE SPACE TELESCOPE FOR SCIENTIFIC OPERATIONS

D. K. WEST

MARCH 1976

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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REQUIREMENTS AND SPECIFICATIONS OF THE SPACE TELESCOPE FOR SCIENTIFIC OPERATIONS

D. K. West

March 1976

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland
ABSTRACT

Requirements for the scientific operations of the Space Telescope and the Science Institute are used to develop operational interfaces between user scientists and the NASA ground system. General data systems are defined for observatory scheduling, daily science planning, and science data management. Hardware, software, manpower, and space are specified for several Science Institute locations and support options.

*Part II of the Space Telescope Science Institute Study.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
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<tr>
<td>BPI</td>
<td>Bits Per Inch</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>FFT</td>
<td>Fast Fourier Transform</td>
</tr>
<tr>
<td>H/W</td>
<td>Hardware</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>IPF</td>
<td>Image Processing Facility</td>
</tr>
<tr>
<td>IUE</td>
<td>International Ultraviolet Explorer</td>
</tr>
<tr>
<td>JPL</td>
<td>Jet Propulsion Laboratory</td>
</tr>
<tr>
<td>MOC</td>
<td>Mission Operations Center</td>
</tr>
<tr>
<td>MY</td>
<td>Man-Years</td>
</tr>
<tr>
<td>OAO</td>
<td>Orbiting Astronomical Observatory</td>
</tr>
<tr>
<td>OTA</td>
<td>Optical Telescope Assembly</td>
</tr>
<tr>
<td>RFI</td>
<td>Radio Frequency Interference</td>
</tr>
<tr>
<td>SCPS</td>
<td>Support Computer Processing System</td>
</tr>
<tr>
<td>SECO</td>
<td>Secondary Electron Conduction Orthicon</td>
</tr>
<tr>
<td>SI</td>
<td>Scientific Instrument(s)</td>
</tr>
<tr>
<td>SOC</td>
<td>Scientific Operations Center</td>
</tr>
<tr>
<td>SSM</td>
<td>Support Systems Module</td>
</tr>
<tr>
<td>ST</td>
<td>Space Telescope</td>
</tr>
<tr>
<td>STDN</td>
<td>Spacecraft Tracking and Data Network</td>
</tr>
<tr>
<td>S/W</td>
<td>Software</td>
</tr>
<tr>
<td>TA</td>
<td>Target Acquisition</td>
</tr>
<tr>
<td>TELOPS</td>
<td>Telemetry Operations Processing System</td>
</tr>
<tr>
<td>TM</td>
<td>Telemetry</td>
</tr>
<tr>
<td>VICAR</td>
<td>Video Image Communication and Retrieval</td>
</tr>
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REQUIREMENTS AND SPECIFICATIONS OF THE SPACE TELESCOPE FOR SCIENTIFIC OPERATIONS

SPACE TELESCOPE
SCIENCE INSTITUTE STUDY
PART II

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<td>24</td>
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REQUIREMENTS AND SPECIFICATIONS OF THE SPACE TELESCOPE FOR SCIENTIFIC OPERATIONS

I. ST OPERATIONAL REQUIREMENTS

The operational requirements for the Space Telescope (ST) presented here are those which are relevant to the relationship between the ST Science Institute and the NASA ground system. The requirements given in this section address the technical interfaces between mission operations, scientific operations and the NASA support facilities serving both these functions.

The requirements are presented in four areas: Spacecraft Operations, Spacecraft Data Management, Science Operations, and Science Data Management. In addition to the basic conceptual requirements which should not change significantly over the ST development period, there are quantitative requirements and specifications which are design and operational dependent. Current baseline values for this latter type are listed separately as System Parametric Data.

A. Spacecraft Operations

The primary function of Spacecraft Operations is to control the orbital operation of the spacecraft to insure the health and welfare of the ST for the life of its mission. Other important functions are: mission planning and scheduling of the Support Systems Module (SSM) and the Optical Telescope Assembly (OTA) subsystem tests; monitoring status and engineering data; spacecraft command control; routine and emergency analysis of ST performance; specification and update of all spacecraft operational constraints; and initiation of spacecraft emergency procedures.

The requirements for Spacecraft Operations are separated into three areas: mission planning, command message generation, and spacecraft security.

1. Mission Planning

The operation of the spacecraft requires long-range and daily planning in support of: the technical feasibility evaluation of guest observer’s proposals, ST on-orbit updates and earth returns, routine SSM and OTA subsystem tests, special calibrations and other checkout procedures, and special maneuvers for constrained SI observations.
2. Command and Message Generation

The implementation of the mission plan requires: specification and updates to all spacecraft operational constraints and procedures, daily preparation and input of subsystem command procedures; and command message review, evaluation, and final approval.

3. Spacecraft Security

The health and safety of the ST requires: monitoring spacecraft engineering data in real-time and post pass, indepth analysis of spacecraft performance in both routine and emergency situations, controlling and transmitting all real-time commands as well as advanced planned stored commands, and the initiation of spacecraft emergency procedures.

B. Spacecraft Data Management

Spacecraft data management includes telemetry (TM) processing and engineering data display.

1. Telemetry Processing

The processing of spacecraft requires: TM staging, storage, and error checking; 1M data processing and conversion to engineering units; limit checking and out of limit flagging; and data storage for on-demand call up.

2. Data Display

Engineering data display requirements are: display to subsystem controllers of all relevant subsystem data pages, instant alarm displays, strip chart recordings of time dependent data, printouts and history tapes of spacecraft performance data.

C. Scientific Operations

Scientific operations is mainly concerned with the planning and implementation of scientific programs on the ST. The requirements for SI operations fall into the logical categories of long-range observatory planning and scheduling, guest investigator support, daily planning, real-time operations, and quick-look data processing and display.
1. Long-Range Observatory Planning and Scheduling

The requirements in this area are: proposal evaluation for operational feasibility and total telescope time requirements; target availability as function of time of year, target list screening for operational constraints and guide star availability, specific time observations timeline generation, long term Observatory scheduling, preparation of computer input planning data, and the preparation of target acquisition aids (finder fields, etc.).

2. Guest Investigator Support

Guest Investigator support includes: the maintenance of user manuals for program planning including sample programs and data; user orientation training and familiarization with operational and data processing interfaces; staff astronomer assistance to the user for long-range planning prior to his observing run on the ST; staff astronomer and operator assistance to the user in the daily implementation of observations, target acquisition and the specification of data processing tasks; the collation and evaluation of quick-look and final processed data for the user's output data package; and staff astronomer response to questions arising during the user's scientific analysis and publication period.

3. Daily Planning

The daily planning of observations requires: target sequencing, background constraint timelining, SI operation sequencing, SI mode specification, observational and operational constraint checks, specific time and specific slew generation, preparation of real-time target acquisition and SI operational procedures, preparation of moving target (solar system) ephemeris, and the specification of offset guide stars.

The daily preparation of delayed mode observing plans requires: SI observation profile input tape generation, operational constraint checks, SI command load generation, and command message validation and approval.

The daily preparation for real-time operation requires: generation of real-time command procedures, preparation of target acquisition data and identification aids, generation of the real-time pass computer input file, and the validation and approval of real-time pass-profiles.

4. Real-Time Operations

Real-time operations requires: the real-time commanding of SI's, the execution of small adjustments to spacecraft pointing to accomplish closed-loop-to-ground
target identification and target positioning in SI apertures, the commanding of ST data readout and TM transmission, and the processing and display of engineering and science data.

5. Quick-Look Data Display

SI and spacecraft operational verification using quick-look data displays requires: real-time and near-real-time display of selected engineering and science data, image condensation and zooming for real-time or near-real-time TV display and evaluation. The primary data display hardware is a computer interactive TV screen with pseudo color. Permanent hard copy, and supporting hard copy is in the form of strip chart recordings, photographic copy, and computer output tapes and printouts.

6. Quick-Look Data Processing

The evaluation of ST performance and science data quality requires: minimal geometric and radiometric corrections, pixel averaging and smoothing; annotation and guiding such as counts vs. wavelength, subframe selection, zooming and condensing for visual TV display, spatial and intensity enhancements, and color scale and gray scale assignment.

D. Science Data Management

Science data management presents very demanding requirements on ST ground data handling systems in terms of processing complexity and large data volumes.

The requirements for this task can be separated into the subtasks of: data preprocessing, data processing (including image processing), data enhancement, data calibrations, interactive processing, data products, support data, and final data archival and retrieval.

1. Data Preprocessing

Preprocessing of ST data requires: short term storage of all engineering and science TM; selection and conversion; quick-look processing; decommutation of science data; and output data formatting for high density tape, remote displays, and data storage and content documentation.

2. Data Processing

Science data processing is defined to be the application of standardized corrections and calibrations to the preprocessed data prior to its delivery to the user for scientific analysis.
Background corrections are required for the removal of backgrounds due to:
particle radiation (such as in the South Atlantic Anomaly), scattered light from
internal and/or external sources, and sky background (such as zodical light).

Noise correction techniques are required to remove noise due to: random
noise sources present in sensor and camera electronics, and periodic noise
induced by spacecraft radio frequency interference (RFI) and/or transmission
links.

Geometric corrections to image data are required to correct pixels for: tele-
scope optical image distortion, SI optical distortions, and electronic image
distortions in sensor/camera systems.

Radiometric corrections are required to take care of: non-uniform response
characteristics of optical photosensitive components, intensity transfer character-
istics of sensors and camera systems.

3. Data Enhancement

Data enhancement techniques are useful tools for certain special applications
of data and image processing and analysis.

Image enhancement techniques include: spatial frequency manipulations, con-
trast enhancement and intensity thresholding.

Deconvolution of spectral features which are empirical slit profiles and other
instrumental functions to enhance spectral resolution will be a useful tool for
several special analysis applications.

4. Data Calibrations

Wavelength calibration is required for spectral data. Calibration data is ob-
tained from: analytical functions, and spectral line reference points in com-
parison spectra.

Flux calibration, both relative and absolute, is required. Flux will be calculated
as a function of wavelength or filter bandpass. Calibration data will be obtained
from standard star observations and SI sensitivity functions and internal sources.

Other calibrations required to be applied to the science data are: time corre-
lation of spacecraft and/or SI engineering data with the science data, application
of pre-determined calibration tables and functions, and conversion to user
oriented measurement units.
5. Interactive Processing and Display

Manual intervention to on-line data processing through the use of computer interactive terminals will be applicable in cases where: interaction is necessary for non-standard data processing tasks, and when it is used as a software development tool. Black and white and color TV display of SI engineering and science data is required for real-time operations and for off-line retrieval and review of final data products.

6. Data Output Hard Copy Products

Final data output products requirements call for: high density tapes for long term storage; computer compatible tapes in several standard formats for user analysis; high resolution photographic output in standard sized prints, transparency and microfilm; plots, strip charts, and computer printouts.

7. Support Data

In addition to the calibration data requirements mentioned above, there is a requirement for observation related orbital, SI, and spacecraft information which includes: GMT correlations; SI status data; relevant temperature and voltage histories; spacecraft pointing, guidance errors and offsets; off-axis location of bright sources; background monitor data; orbital velocities relative to line of sight and orbit and attitude data.

8. Final Data Archival and Retrieval

Final processed data will be temporarily archived in the Science Institute for immediate, short term use and permanently archived in the National Space Science Data Center (NSSDC) where it will be made available to the public through an efficient and convenient retrieval system. The ST archival and retrieval system requirements include: long term storage of all final processed science data on tape and photographic media, maintenance and timely publication of ST "plate files" and observation lists, observation index, SI performance histories, computer interactive data displays for user preview of data, and rapid data retrieval and distribution.
E. GROUND SYSTEM PARAMETRIC DATA

1. Long Range Planning
   Observing Proposal Cycle 1 yr  
   Astronomical Programs 25/yr  
   Principal Investigators 4/yr  
   Guest Investigators 50/yr  
   Spacecraft Pointings (including TA) 4000/yr  
   Guest Investigators Present 6/day  
   Plan Lead Time 3 mo

2. Daily Planning
   Observations 50/day  
   Stored Commands (average) 10K/day  
   Spacecraft Slews (maximum) 10/day  
   Minimum Lead Time 12 hrs  
   Command Message Time Span 24 hrs  
   Maximum Lead Time 72 hrs

3. Real-Time and Quick-Look
   Real-time Contacts (average) 2/orbit  
   Maximum Length 30 min  
   Minimum Length 5 min  
   Command Load Uplink (maximum) 1K/orbit  
   Display Data Points 500 × 500  
   Image Data Base Size 2000 × 2000  
   Image Update Delay Time 1 min

4. Data Preprocessing
   Maximum Data Frames 50/day  
   Maximum Bit Rate 3 × 10^9 bits/day  
   Input Transmission Rate 1 MBS  
   Batch Output Delivery Time 24 hrs  
   Quick-Look Delivery Time 1 min  
   Temporary Storage of Raw Telemetry 1 week
5. Image Processing

- **Data Frames (average)**: 15 (2000 × 2000)/day
  - 21 (512 × 512)/day
- **Bit Rate (average)**: $6 \times 10^8$/day
- **Output Delivery Time**: 1 week
- **Applications Software Update Time**: 1 day
- **Display size**: 500 × 500 elements

6. Data Archival and Retrieval

- **Data Frames (average)**: 5.5K (2000 × 2000)/yr
  - 7.5K (500 × 500)/yr
- **Bit Volume (average)**: $2 \times 10^{11}$/yr
- **Storage Time**: 50 yrs
- **Retrieval Time**: 1 week
- **Bit Error Rate**: $10^{-6}$/yr

II. DATA SYSTEMS DEFINITION

In this section, the operational requirements presented in Section I are followed in the development of the ground system design and the interfaces between the Mission Operations Center (MOC) and the Science Institute. Specifications for hardware, software, manpower, and space are derived for the Science Institute functions and responsibilities defined in the "Space Telescope (ST) Science Institute Study".

In order to better understand the total scope of the ST data systems, we will first develop the specifications for a completely independent dedicated capability for science planning and data management.

A. Observatory Scheduling and Daily Observation Planning

Hardware and software are required to support long-range observatory scheduling and daily observation planning. Computational tasks include: exposure time estimation, constraint violation checks, determination of accurate coordinates, guidestar selection, and target availability.

1. Software

GSFC has been working a low cost approach to generalize space astronomy science planning through the use of existing Orbiting Astronomical Observatory (OAO) and the International Ultraviolet Explorer (IUE) software. Existing
software can be modified to meet ST requirements and incorporated into a
long-range observatory scheduling software system for the ST. The general
system is at present about 60% complete. The daily observational planning and
scheduling system required for the ST can also be derived from existing IUE
and OAO software.

Tables II-1 and II-2 show the program sizes for the long-range and daily science
planning software systems. The total requirement is for 108K machine instruc-
tions and for about two hours of 360/75 equivalent computer time per day. These
estimates are based on the sizes of identical and/or equivalent programs de-
veloped for OAO and IUE, as well as on the current work being done at GSFC
to build the science planning systems through the use of existing software. The
programs listed are written in Fortran and run on the IBM 360/75 and 360/91
computers.

2. Hardware

Hardware specifications are obtained from the requirements for program run
time, core size, disk space, tape drivers, and interactive terminals.

As seen in Table II-3 and II-4, existing programs will fit in 100K words on a
360/75 computer or an equivalent of 3.2 million bits of core storage. Science
long-range planning can be accomplished at any time and does not require a
dedicated computer. Daily planning, however, must be done on an on-demand
around-the-clock basis which does require a dedicated computer. Daily planning
will take 108 minutes of 360/75 time per day. Long-range planning will run an
average of 10 minutes per day.

Computers smaller than the 360/75 would be adequate for daily planning pro-
vided they can dedicate the required core and are not slower than 1/5 the speed
of a 360/75. A medium sized computer like a Sigma 9 which is about 1/3 to
1/5 the speed of a 360/75 can be configured with 128K of core, at least four
tape drives, interactive terminals, and large disk space. Detailed specification
of this hardware is given in Table II-5.

3. Staff

The Science Institute will support mission operations by providing an operational
crew co-located with the Mission Operations Center. The function of this staff
will be to conduct all phases of on-line scientific operations required to effec-
tively conduct mission operations. These functions include: daily planning, ob-
servation implementation, real-time operation, quick-look data verification, and
the coordination of mission and science planning.
### Table II-1
Observatory Planning and Scheduling Software Sizing

<table>
<thead>
<tr>
<th>Program</th>
<th>Instructions (K)</th>
<th>Runs/Mo.</th>
<th>Mins</th>
<th>Mins/Mo.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Availability and Telescope Time Req.</td>
<td>15.5</td>
<td>4</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>Sky Constraints</td>
<td>8.3</td>
<td>4</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Guide Stars, Finder Fields and Accurate Coords.</td>
<td>11.2</td>
<td>4</td>
<td>18</td>
<td>72</td>
</tr>
<tr>
<td>Scheduler</td>
<td>12.4</td>
<td>4</td>
<td>19</td>
<td>76</td>
</tr>
<tr>
<td>Output Compilations</td>
<td>8.0</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Target File Maint.</td>
<td>2.6</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>User Planning Aids</td>
<td>2.0</td>
<td>2</td>
<td>3</td>
<td>6</td>
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</table>

**Totals**

<table>
<thead>
<tr>
<th>Instructions (K)</th>
<th>Runs/Mo.</th>
<th>Mins</th>
<th>Mins/Mo.</th>
</tr>
</thead>
<tbody>
<tr>
<td>60K</td>
<td></td>
<td></td>
<td>288 Mins/ Month</td>
</tr>
</tbody>
</table>

### Table II-2
Daily Planning and Scheduling Software Sizing

<table>
<thead>
<tr>
<th>Program</th>
<th>Instructions (K)</th>
<th>Runs/Day</th>
<th>Mins</th>
<th>Mins/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>1.6K</td>
<td>2</td>
<td>1.0 M</td>
<td>2</td>
</tr>
<tr>
<td>Subcycle Initialize</td>
<td>4.0</td>
<td>2</td>
<td>1.0</td>
<td>2</td>
</tr>
<tr>
<td>Segment Schedule</td>
<td>16.0</td>
<td>2</td>
<td>2.0</td>
<td>4</td>
</tr>
<tr>
<td>Command Generator</td>
<td>12.0</td>
<td>2</td>
<td>2.0</td>
<td>4</td>
</tr>
<tr>
<td>Output</td>
<td>4.0</td>
<td>3</td>
<td>2.0</td>
<td>6</td>
</tr>
<tr>
<td>Display Graphics</td>
<td>10.4</td>
<td>3</td>
<td>30.0</td>
<td>90</td>
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**Totals**

<table>
<thead>
<tr>
<th>Instructions (K)</th>
<th>Runs/Day</th>
<th>Mins</th>
<th>Mins/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>48K</td>
<td></td>
<td></td>
<td>108 Mins/ Day</td>
</tr>
</tbody>
</table>
Table II-3
Observatory Planning and Scheduling Hardware Sizing

<p>| | | |</p>
<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Size</td>
<td>400K</td>
<td>3200K Bits</td>
</tr>
<tr>
<td>Disk Space</td>
<td>350K</td>
<td>2800K Bits</td>
</tr>
<tr>
<td>Tape Drives</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Terminals</td>
<td>1</td>
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Table II-4
Daily Planning and Scheduling Hardware Sizing

<p>| | | |</p>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Size</td>
<td>400K</td>
<td>3200K Bits</td>
</tr>
<tr>
<td>Disk Space</td>
<td>300K</td>
<td>2400K Bits</td>
</tr>
<tr>
<td>Tape Drives</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Terminals</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table II-5
Daily Science Planning Computer Hardware

A typical medium sized computer system ($\Sigma 9$) which could be used for science planning would consist of:

<table>
<thead>
<tr>
<th>Component</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Processing Unit</td>
<td>$\Sigma 9$</td>
</tr>
<tr>
<td>Core</td>
<td>128K Words</td>
</tr>
<tr>
<td>Disk</td>
<td>98M Bytes</td>
</tr>
<tr>
<td>Card Reader</td>
<td>1</td>
</tr>
<tr>
<td>Tape Drives</td>
<td>4</td>
</tr>
<tr>
<td>Printer</td>
<td>1</td>
</tr>
<tr>
<td>Display</td>
<td>1</td>
</tr>
</tbody>
</table>
B. Data Management

The most demanding of all ST operational requirements are those of science data management. The ST will transmit several image frames per orbit. Each frame requires preprocessing of raw telemetry data to strip out science data and output it in a format suitable for further data reduction tasks. Image processing of 20 to 50 frames per day requires fast computer hardware and highly sophisticated software systems. These requirements identify the need for significant resources.

In order to underline the scope of the ST data management and processing problem, we will now develop the specification of the hardware and software required for a complete SI dedicated data processing capability in the areas of data preprocessing, image processing, general data reduction and data output products.

1. Data Preprocessing

Data preprocessing consists of routine stripping, error checking, decoding, data conversion, and output formatting. A system which would meet the ST preprocessing requirements is specified in Table II-6.

2. Image Processing

The software requirements for a completely dedicated image processing system are shown in Tables II-7 and II-8. The tabulated program sizes are derived from existing image processing software developed for the IUE. The IUE image processing system will accomplish all the types of image processing required.
<table>
<thead>
<tr>
<th>Hardware</th>
<th>IPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software</td>
<td>5K Instructions</td>
</tr>
<tr>
<td>Space</td>
<td>1000 sq. ft.</td>
</tr>
</tbody>
</table>
### Table II-7
Image Processing System Software Sizing

<table>
<thead>
<tr>
<th>Program</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Executive</td>
<td>9 K</td>
</tr>
<tr>
<td>Communications Control</td>
<td>7 K</td>
</tr>
<tr>
<td>Dialog Handler</td>
<td>7 K</td>
</tr>
<tr>
<td>File Management</td>
<td>8 K</td>
</tr>
<tr>
<td>Accounting</td>
<td>2 K</td>
</tr>
<tr>
<td>Output</td>
<td>1 K</td>
</tr>
<tr>
<td>Utilities</td>
<td>7 K</td>
</tr>
<tr>
<td>Total</td>
<td>41 K</td>
</tr>
</tbody>
</table>

### Table II-8
Image Processing Science Applications Software

<table>
<thead>
<tr>
<th>Programs</th>
<th>Old Inst.</th>
<th>New Inst.</th>
<th>Total Inst.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Random Noise and Background Removal</td>
<td>4K</td>
<td>-</td>
<td>4K</td>
</tr>
<tr>
<td>2) Periodic Noise Removal</td>
<td>70K*</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>3) Geometric Correction</td>
<td>25</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>4) Enhancement and Deconvolution</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>5) Wavelength Calibration</td>
<td>20</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>6) Photometric Calibration</td>
<td>17</td>
<td>17</td>
<td>34</td>
</tr>
<tr>
<td>7) Output Products Preparation</td>
<td>2K</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>8) Display</td>
<td>5K</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>115K</td>
</tr>
</tbody>
</table>

*Includes 60K of IPF facility software.
by the ST. The IUE will produce about 20 SEC camera images (up to $1000 \times 1000$ data points, 8 bits deep) per day. The system is designed to provide 24 hour processed data delivery and will be operated 8 hours per day.

The ST will produce about 15 SEC camera images ($2000 \times 2000$ data points, 10 bits deep) per day and about 21 other images ($500 \times 500$) per day. Since the type of processing for ST is the same as IUE, the size of IUE systems programs (shown in Table II-7) can be used directly. Table II-8 gives the sizes for the image processing science applications programs required for the ST including new ST software additions.

The Central Processing Unit (CPU) and Input/Output (I/O) times shown in Table II-9 are in minutes of IBM 360/75 computer derived from test runs at GSFC. A standard computer like the IBM 360/91 comes close to meeting the ST requirements for speed and size.

Other solutions can be found in the form of specialized computer hardware systems. Parallel processors using several mini-computers with high speed I/O feeds similar to the Image Processing Facility (IPF) master data processor at GSFC is one example. Also, special purpose hardware (such as hardwired processors for fast Fourier transformation tasks) to accomplish high speed computations can be added to slower computers like IBM 300/75 or a CDC 6400.

A system similar to IPF, which would accomplish the ST image processing task, is shown in Table II-10.

3. General Data Reduction and Hard Copy Facility

Final data reduction and output products generation at the Institute requires a mini-computer and hard copy equipment.

A typical mini-computer system and hard copy facility are specified in Table II-11.

The software required to accomplish general data reduction (non-image processing) is estimated to be about 50K machine instructions.

The space required for these facilities will be about 500 square feet.
Table II-9
Image Processing Science Applications Software Timing

<table>
<thead>
<tr>
<th>Program</th>
<th>Frame Size</th>
<th>Frames Per Day</th>
<th>Mins/Frame CPU</th>
<th>Mins/Frame I/O</th>
<th>Mins/Day CPU</th>
<th>Mins/Day I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Random Noise and Background</td>
<td>2000 x 2000</td>
<td>16</td>
<td>1.9</td>
<td>1.6</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>500 x 500</td>
<td>21</td>
<td>0.1</td>
<td>0.1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2. Periodic Noise Removal</td>
<td>16</td>
<td>60</td>
<td>1.6</td>
<td>960</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>3</td>
<td>0.1</td>
<td>63</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3. Geometric Correction</td>
<td>16</td>
<td>27</td>
<td>1.6</td>
<td>432</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>1.7</td>
<td>0.1</td>
<td>36</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4. Enhancement</td>
<td>16</td>
<td>7.7</td>
<td>1.6</td>
<td>123</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>0.03</td>
<td>0.1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5. Wavelength Calibration</td>
<td>0</td>
<td>6.7</td>
<td>3.2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.42</td>
<td>0.2</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6. Flux (Photometric) Calibration</td>
<td>21</td>
<td>8</td>
<td>3.2</td>
<td>168</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.5</td>
<td>0.2</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>7. Output Products Preparation</td>
<td>21</td>
<td>0.2</td>
<td>1.6</td>
<td>4</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.13</td>
<td>0.1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>8. Display</td>
<td>16</td>
<td>1</td>
<td>3.2</td>
<td>16</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>1.1</td>
<td>0.2</td>
<td>23</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>1871</td>
<td>274</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table II-10
Image Processing Hardware Specifications

The hardware specification for a special purpose computer system similar to IPF is:

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Computer</td>
<td>Σ 5 type ASP</td>
</tr>
<tr>
<td>Terminals</td>
<td>1</td>
</tr>
<tr>
<td>High Density Tape Recorders and Controllers</td>
<td>3-HDT</td>
</tr>
<tr>
<td>Computer Compatible Tape Drives</td>
<td>4-6250 BPI</td>
</tr>
</tbody>
</table>
Table II-11
General Data Reduction Facility Hardware Specification

The hardware for a typical mini-computer system and hard copy facility are specified as:

Mini-Computer System

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>PDP 11/70</td>
</tr>
<tr>
<td>Core</td>
<td>100K Words</td>
</tr>
<tr>
<td>Disk</td>
<td>32M Bytes</td>
</tr>
<tr>
<td>Tape Drives</td>
<td>4</td>
</tr>
<tr>
<td>Card Reader</td>
<td>1</td>
</tr>
<tr>
<td>Printer</td>
<td>1</td>
</tr>
<tr>
<td>Display</td>
<td>1</td>
</tr>
</tbody>
</table>

Hard Copy Facility

<table>
<thead>
<tr>
<th>Component</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Room</td>
<td>1</td>
</tr>
<tr>
<td>Film Processors</td>
<td>2</td>
</tr>
<tr>
<td>Photowrite</td>
<td>2</td>
</tr>
<tr>
<td>Plotter</td>
<td>2</td>
</tr>
</tbody>
</table>

III. SYSTEM CONFIGURATION FOR SCIENCE INSTITUTE LOCATION OPTIONS

Plans for the management of science data are highly dependent on the location of the ST Science Institute. Several configurations are considered: Institute at or near GSFC, Institute Remote-Independent, Institute Remote-Modified, and Institute Remote-Dependent.

A. Institute Located at or Near GSFC

Data management plans for this case assume the use of institutional facilities at GSFC.
Studies have identified several major resources at GSFC which are ideally matched to the ST hardware and software requirements in the areas of science planning and scheduling, data preprocessing, and image processing.

The International Ultraviolet Explorer (IUE) is an international observatory which will host at least 50 guest observers per year. Astronomers will come to Goddard to carry out their observations in a real-time operating environment similar to ground based observatories. Software and hardware for long-range guest observer scheduling and real-time target acquisition systems are currently being developed for a 1977 launch. These IUE scientific operations systems are ideally matched with the ST requirements for Observatory scheduling, daily science planning, and real-time closed-loop-to-ground target acquisition.

The ST requirements for the temporary storage and preprocessing of spacecraft data and \(1 \times 10^9\) bits per day of science data for merging, stripping, processing, formatting, and quick-look output can be completely satisfied by using the preprocessor in the Image Processing Facility (IPF).

The Image Processing Facility (IPF) under development at Goddard is a large scale fast computer system which will process up to \(1 \times 10^{11}\) bits per day. In addition, IPF is able to accommodate the scientists' need for direct control of calibration data sets, scientific algorithms and applications programs which can be developed and maintained by the user.

The IUE Image Processing System which is under development at GSFC is designed to perform geometric and radiometric corrections; flux and wavelength calibrations; and periodic and random noise removal. This system, which was derived from the JPL (VICAR) image processing system, can be modified and expanded to handle 2000 x 2000 Secondary Electron Conduction (SECO) Camera images produced by the ST. The IUE image processor will be operational early in 1977.

Figure III-1 shows the major elements of the ground system for the case of the Institute located at or nearby GSFC. Those elements which will provide institutional support services to ST are shaded. Unshaded blocks contain ST dedicated facilities. The mission planning computer (Support Computer Processing System (SCPSS)), and Spacecraft Tracking and Data Network (STDN) presently provide institutional support services to OAO. These facilities are well demonstrated and need not be discussed here.
Figure III-1. Science Institute At or Near GSFC
On the following pages, we will list the hardware, software, manpower, and space required to develop and operate the scientific facilities as configured for the At or Near GSFC Option.

1. Preprocessing

Preprocessing of ST data at GSFC would be done in the IPF. The only additional hardware and software which the ST might require would be a display terminal and small amounts of software which might be considered project unique.

2. Image Processing

Most of the SI image processing software will be provided by modifying existing IUE programs. IPF will provide all the systems software required plus some standard correction programs. Special applications programs would be ST unique software.

IPF will provide the major hardware components for image processing. Unique ST hardware will be interactive terminals.

Hardware:

<table>
<thead>
<tr>
<th>Computer System</th>
<th>IPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminals</td>
<td>1</td>
</tr>
<tr>
<td>Integration</td>
<td>IPF</td>
</tr>
</tbody>
</table>
Software Development:

- Program Analysis: 3 MY
- Old Instructions: 50K
- New Instructions: 20K

Operations (16 hrs per day):
- S/W Maintenance: 8 MY
- Technicians: 4 MY

Space: 500 sq ft

3. Observatory Scheduling and Daily Planning

This function will be done on the GSFC Mission Planning Computer (SCPS) which will provide all system software and facility operations.

Hardware:
- Computer System: SCPS
- Terminals: 1

Software Development:
- Program Analysis: 2 MY
- Old Instructions: 10K
- New Instructions: 10K

Operations (24 hrs per day):
- Operators: 4 MY
- S/W Maintenance: 2 MY
- Technicians: 2 MY
- H/W Maintenance: 2 MY

Space: 1500 sq ft

4. General Data Reduction and Hard Copy Lab

The Institute will, in all cases, have a dedicated facility for final data reduction and hard copy output products. The specifications for a typical mini-computer and photo lab are:
Hardware:

- Computer System: PDP 11/70
- Hard Copy Lab: 1

Software Development:

- Program Analysis: 2M
- New Instructions: 50K

Operations (16 hrs per day):

- Operators: 4 MY
- H/W Maintenance: 3 MY
- S/W Maintenance: 2 MY
- Technicians: 4 MY

Space: 800 sq ft

B. Science Institute Remote-Independent

Figure III-2 shows the major elements of the ST ground system for the case of a remotely located independent Institute. NASA support services provided by STDN and the MOC are unchanged. Also, the NASA requirements for an on-site Institute crew co-located with the MOC remains the same. The interface between the Science Institute and GSFC will be standard voice and land data lines. Institute staff will have voice and display terminal communication with the co-located Institute staff at GSFC. The Institute will transmit long-range science plans to GSFC for implementation and will receive SI engineering and science data for processing.

Data management in the case where the Institute is remotely located from GSFC is accomplished with ST dedicated hardware and software at the Institute.

Raw science data and engineering data will be recorded on tape at GSFC. This tape will be transmitted over standard data links or will be mailed to the Institute.

The Institute will be responsible for all science data preprocessing. Preprocessed data will be staged for subsequent processing on an image processing computer and final data reduction on the Institute's general data reduction computer.
Figure III-2. Science Institute Remote from GSFC
It is assumed that these computers will be software compatible with existing GSFC software which would be given to the Institute for their conversion and modification tasks.

The following pages list the hardware, software, manpower, and space required to develop and operate the scientific facilities as configured for the Remote-Independent Option.

1. Preprocessing

Preprocessing of ST data can be accomplished at the Institute with a facility similar to IPF.

2. Image Processing

Image processing can be accomplished at the Institute through the use of conventional computers such as an IBM 360/91 or a 370/168 or with special purpose mini-computer systems such as GSFC's IPF. The latter system is recommended as the less expensive of the two and is specified here.
Hardware:

Central Computer: Σ 5 type ASP
Terminals: 1
High Density Tape Recorders and Controllers: 3-HDT
Computer Compatible Tape Drives: 4-6250 BPI
Integration: 5 MY

Software Development:

Program Analysis: 10 MY
Old Instructions: 120K
New Instructions: 22K

Operations (16 hrs per day):

Operators: 15 MY
S/W Maintenance: 10 MY
Technicians: 6 MY

Space: 2000 sq ft

3. Daily Science Planning

This function will be carried out on the Science Planning Computer which will be the responsibility of the Institute. A typical facility is specified as follows:

Hardware:

CPU: Σ 9
Storage: 100M Bytes
Tape Drives: 4
Displays: 1
Integration: 2 MY

Software Development:

Program Analysis: 3 MY
Old Instructions: 50K
New Instructions: 10K
Operations (24 hrs per day):

<table>
<thead>
<tr>
<th>Role</th>
<th>MY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators</td>
<td>4</td>
</tr>
<tr>
<td>H/W Maintenance</td>
<td>3</td>
</tr>
<tr>
<td>S/W Maintenance</td>
<td>4</td>
</tr>
<tr>
<td>Technicians</td>
<td>3</td>
</tr>
</tbody>
</table>

Space: 1500 sq ft

4. Observatory Scheduling

This function can be performed on a dedicated Science Planning Computer or on the image processing system in an off-line mode. A dedicated facility is specified below:

**Hardware:**

<table>
<thead>
<tr>
<th>Component</th>
<th>MY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer System</td>
<td>9</td>
</tr>
<tr>
<td>Terminals</td>
<td>1</td>
</tr>
</tbody>
</table>

**Software Development:**

<table>
<thead>
<tr>
<th>Component</th>
<th>MY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Instructions</td>
<td>60K</td>
</tr>
<tr>
<td>New Instructions</td>
<td>10K</td>
</tr>
</tbody>
</table>

Operations (1 hr per day):

<table>
<thead>
<tr>
<th>Role</th>
<th>MY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators</td>
<td>1</td>
</tr>
<tr>
<td>S/W Maintenance</td>
<td>3</td>
</tr>
<tr>
<td>Technicians</td>
<td>2</td>
</tr>
</tbody>
</table>

Space: 500 sq ft

5. General Data Reduction and Hard Copy Lab

This facility is the same for all location options as specified in Section III-A4.

C. Science Institute Remote-Modified

This option considers the case where the Institute is remote and rents computer time on computers which are not compatible with existing software.
1. Preprocessing is done on the image processing computer.

2. Image Processing

   Hardware:
   
   Terminal 1

   Software Development:
   
   Program Analysis 10 MY
   Convert Old Instructions 120K
   New Instructions 22K
   Computer Hours 5K

   Operations (3 hrs per day):
   
   Computer Time 1K hrs/yr
   S/W Maintenance 8 MY
   Technicians 4 MY

   Space: 800 sq ft

3. Observatory Scheduling

   Observatory scheduling would be accomplished by renting computer time at the existing facility.
Hardware:

Terminals 1

Software Development:

Program Analysis 4 MY
Old Instructions 60K
New Instructions 10K
Computer Time 3K hrs

Operations (1 hr per day):

S/W Maintenance 2 MY
Technicians 2 MY
Computer Time 300 hrs/yr

Space: 500 sq ft

4. Daily Science Planning

This function would be carried out on the Science Planning Computer at GSFC. The specification is the same as described in the Remote-Independent Option.

5. General Data Reduction and Hard Copy Products

This specification is the same for all options.

D. Science Institute Remote-Dependent

In this case the Institute is remote but depends on GSFC to provide preprocessing and image processing support.

1. Preprocessing

This function is accomplished on IPF as specified in the At or Near GSFC configuration.

2. Image Processing

This function is accomplished on IPF as specified in the At or Near GSFC configuration.
3. Observatory Scheduling and Daily Planning

These functions are accomplished as described in the Remote-Independent configuration.

4. General Data Reduction and Hard Copy Products

This specification is the same for all options.