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ADDENDUM REPORT

TO

ATMOSPHERIC SCIENCE FACILITY

PALLET-ONLY MODE

SPACE TRANSPORTATION SYSTEM PAYLOAD

FEASIBILITY STUDY

VOLUME 3

(NASA-TM-X-73008) ADDENDUM REPORT TO ATMOSPHERIC SCIENCE FACILITY PALLET-ONLY MODE SPACE TRANSPORTATION SYSTEM PAYLOAD FEASIBILITY STUDY, VOLUME 3, REVISION A (NASA) 50 P HC $4.00 CSCL 22B G3/16

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1.0 INTRODUCTION

This volume is an addendum to the interim report entitled "Atmospheric Science Facility Pallet-Only Mode Space Transportation System Payload", Volumes 1 and 2, JSC 10683, Revision A. Volumes 1 and 2 document a study that was conducted on the feasibility of accomplishing selected atmospheric science missions using a pallet-only mode.

During the study, certain unresolved issues were identified and reported in Section 9.0 of Volume I. Two of these are addressed in this Volume (3). The first issue was that of assuring that the on-board computer facility was adequate to process scientific data, control subsystems such as instrument pointing, provide mission operational program capability, and accomplish display and control. The second issue evolved from an investigation of the availability of existing substitute instruments that could be used instead of the prime instrumentation where the development tests and schedules are incompatible with the realistic budgets and Shuttle vehicle schedules. Some effort was expended on identifying candidate substitute instruments in Section 7.0 of the interim report, and the performance, cost, and development schedule trade-offs found during that effort were significant enough to warrant a follow-on investigation. This addendum documents the results of that follow-on effort, as it applies to the Atmospheric Sciences Facility.

2.0 SOFTWARE REQUIREMENTS FOR ATMOSPHERIC SCIENCE FACILITY PAYLOAD FUNCTIONS

2.1 INTRODUCTION

This section contains the results of a study that establishes from available information the software functional requirements that will satisfy all payload elements in the management and control of the ASF (Atmospheric Science Facility) mission. These software functional requirements were used to estimate the size of the computer memory required to support the ASF mission.

The intent of this study was to size the computer memory and not to impose requirements on the hardware components of the ASF payload with the possible exception of the payload computer.

Software, as defined in this section, is the sequences of instructional information resident in a digital computer memory. The complete sets of software relative to the computers in which they reside are referred to as computer programs. In this section, the words software and computer programs were used interchangeably, since they essentially have the same meaning. Software includes the logic, mathematics, data handling, and computer control instructions required to perform computational functions. Examples of the computational functions are control for electronic equipment interfacing with the computer, computations for analysis, and data management solely within the computer.

2.2 STUDY OBJECTIVE

The study objective was to determine if the currently defined payload computer could adequately provide on-board data processing, data transfer, data entry, and display associated with the operations for an ASF mission. The study methodology consisted of initially determining the software functional requirements, and then developing from these requirements a software-sizing estimate. The resultant sizing estimate formed the criterion for the determination of the adequacy of the payload computer memory size. Many of the ASF instruments are still in the conceptual design stages; thus the detailed instrument characteristics needed for development of algorithms or for the determination of a method of calculation of data to be processed or displayed are not available. An additional step in the study consisted of comparing the payload software functional requirements that were developed as part of this task to an existing software package for a check of the sizing estimates.

The ASF flight software will be prepared as modular programs to maintain flexibility in the software development, operation, and maintenance. The flight software will consist of individual instrument application program modules and an executive operating system. The executive operating system will be a set of software service functions that will provide structural order as well as a standard interface between the instrument programs and the avionics hardware. The ASF software modules are structurally similar to the orbiter computer software architecture so that a valid sizing comparison could be made. The comparison was made at the smallest possible software system functional element, and these comparisons served as the basis of a building block for software sizing. The experiment computer and subsystem computer software sizing were estimated separately.

2.3 ASSUMPTIONS

A number of assumptions were made at the start of the study to provide guidelines for software sizing. These assumptions were as follows:

a. The ASF/AMPS (Atmospheric, Magnetospheric and Plasmas in Space) payload will be automated to the maximum extent possible. This, however, does not preclude manual operation, when required.

b. The payload computers (experiment computer and subsystem computer) will accept state vectors, mission elapsed time, Greenwich mean time, and attitude and attitude-rate data from the Orbiter computer or from the uplink. The transfer rate will be a maximum of 25 samples per second.

c. The mass memory will be available for all flight phases.

d. The mass memory will accommodate the display formats software, and all data processing software required for the command and data management subsystem.

e. No capability will exist for communications between the experiment and/or subsystem computers and the Orbiter computer with the exception of navigational updates and uplink commands.

f. Data processing, to the maximum extent possible, will be performed on-board the vehicle.

g. The caution and the warning data processing will be performed by the Orbiter computer.

h. The rates at which instrument data are sampled will be limited by the RAU (remote acquisition unit) to 1, 10, or 100 samples per second.

i. The 1 Mbps data bus word transfer structure will be 16 bits plus parity, plus synchronization.

j. The subsystem computer will have adequate speed and computational capacity to control the four APS (AMPS pointing systems) required for the ASF. No manual override capability will be provided except for initialization.

k. Tape recorders will be provided for the storage of scientific data from the instruments. These tape recorders will be accessible in flight for tape changes.

l. All software generation will be accomplished in a high order language (HOL). An inefficiency in the language will be allowed for in the sizing estimates.

m. Uplink data transfer is not for real-time use with the exception of initialization of certain experiments. Uplink data will be stored in the mass memory for further usage.

2.4 COMMAND AND DATA MANAGEMENT SUBSYSTEM DESCRIPTION

The CDMS (Command and Data Management Subsystem) will consist of the experiment computer, subsystem computer, and all other associated devices required for the acquisition, processing, displaying, storing, and transmitting of all scientific and engineering data generated by the ASF payload.

2.4.1 Experiment Portion of CDMS

The experiment portion of the CDMS will consist of the following components:

a. Experiment computer

b. Backup (B/U) computer (capability to operate in place of either the experiment or subsystem computer)

c. EXP I/O (Experiment input/output) unit

d. MMU (Mass memory unit)

e. Fourteen RAU's (remote acquisition unit)

f. Keyboard/CRT (cathode ray tube) display

g. Dedicated experiment display unit

h. Dedicated experiment control unit

i. Control/display unit

j. Wideband analog recorders

k. A/A (Alarm/advisory) electronics/panel

l. Computer display/control panel

The CDMS will acquire data from various instruments and data sources and will format these data through the input/output units, thus allowing the experiment computer to perform on-board processing. The extent of processing will be dependent upon the instruments being used, the mission timeline, and the complexity of the processing algorithms. The processed data will be stored on magnetic tape recorders or downlinked in either real-time or delayed time, depending on the experiment requirements.

A functional block diagram of the experiment computer and its interface with the CDMS is shown in figure 2-1. The experiment portion of the CDMS will provide to the ASF payload all services associated with the command and control of each instrument, as well as data acquisition, data preprocessing, data compression, and finally, transmittal of all data generated during each mission.

Commands will be transmitted to the pallet-mounted or boom-mounted instruments, and the igloo-mounted subsystem via the 1 Mbps PCM (pulse code modulation) data bus. These commands will be initiated in real-time by the programmed sequences (software), the flight crew, or the ground controllers.

Commands will also be sent to the subsatellite through the S-band phase-modulated RF link.

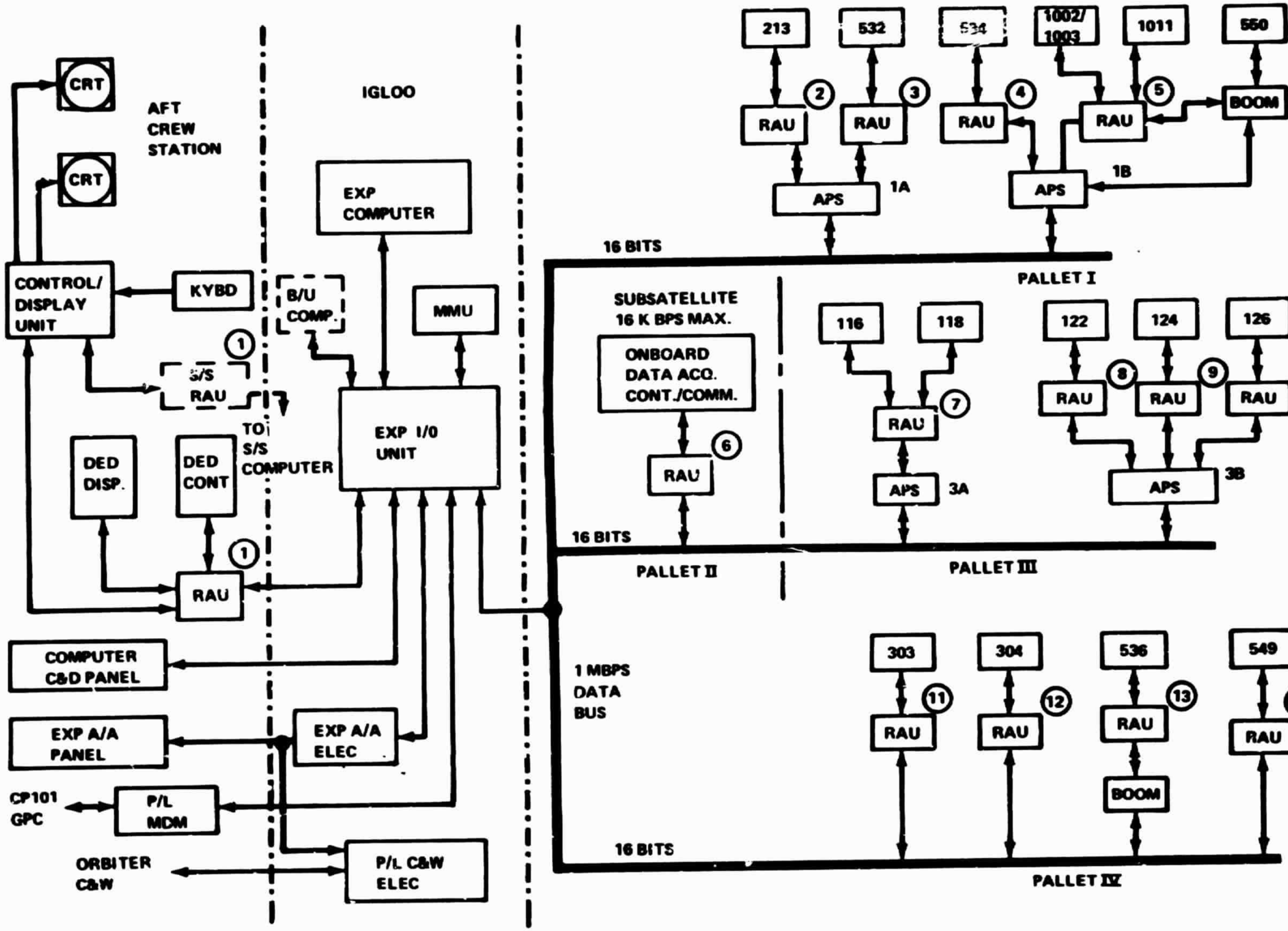

Figure 2-1.- Command and data management subsystem for the experiment computer.

The experiment computer also controls the sequences of turn-on, warmup, operation, standby, and turn-off for individual instruments or groups of instruments. All commands are managed through the 1 Mbps PCM data bus utilizing remote acquisition units.

2.4.2 Subsystem Portion of CDMS

The subsystem portion of the CDMS consists of the following:

a. Subsystem (S/S) computer

b. Backup computer (see paragraph 2.4.1)

c. SS I/O (Subsystem input/output) unit

d. Fifteen remote acquisition units

e. Dedicated subsystem display unit

f. Dedicated subsystem control unit

A functional block diagram of the subsystem portion of the CDMS is shown in figure 2-2. The subsystem portion of the CDMS controls the operation of the full ASF subsystem payload, which includes the pallets, the pointing system, the subsatellite latch/release mechanism, the thermal and electrical subsystems, and the boom deploy/retract mechanism.

2.5 FUNCTIONAL REQUIREMENTS

This section defines the functional requirements of the computer software to support the ASF mission. The sequence of experiments performed will be under computer software control except for a manned override capability that can be exercised either on-board or via uplink commands. The computer performs initialization, inflight calibrations, start/stop of the scientific instrument operation, data acquisition, data processing, data storage, AMPS pointing system control, and all other miscellaneous operations required. An experiment will usually consist of one or more scientific instruments operating at one time under computer software control as shown in figure 4.1.5-1, (Volume I) ASF mission timelines.

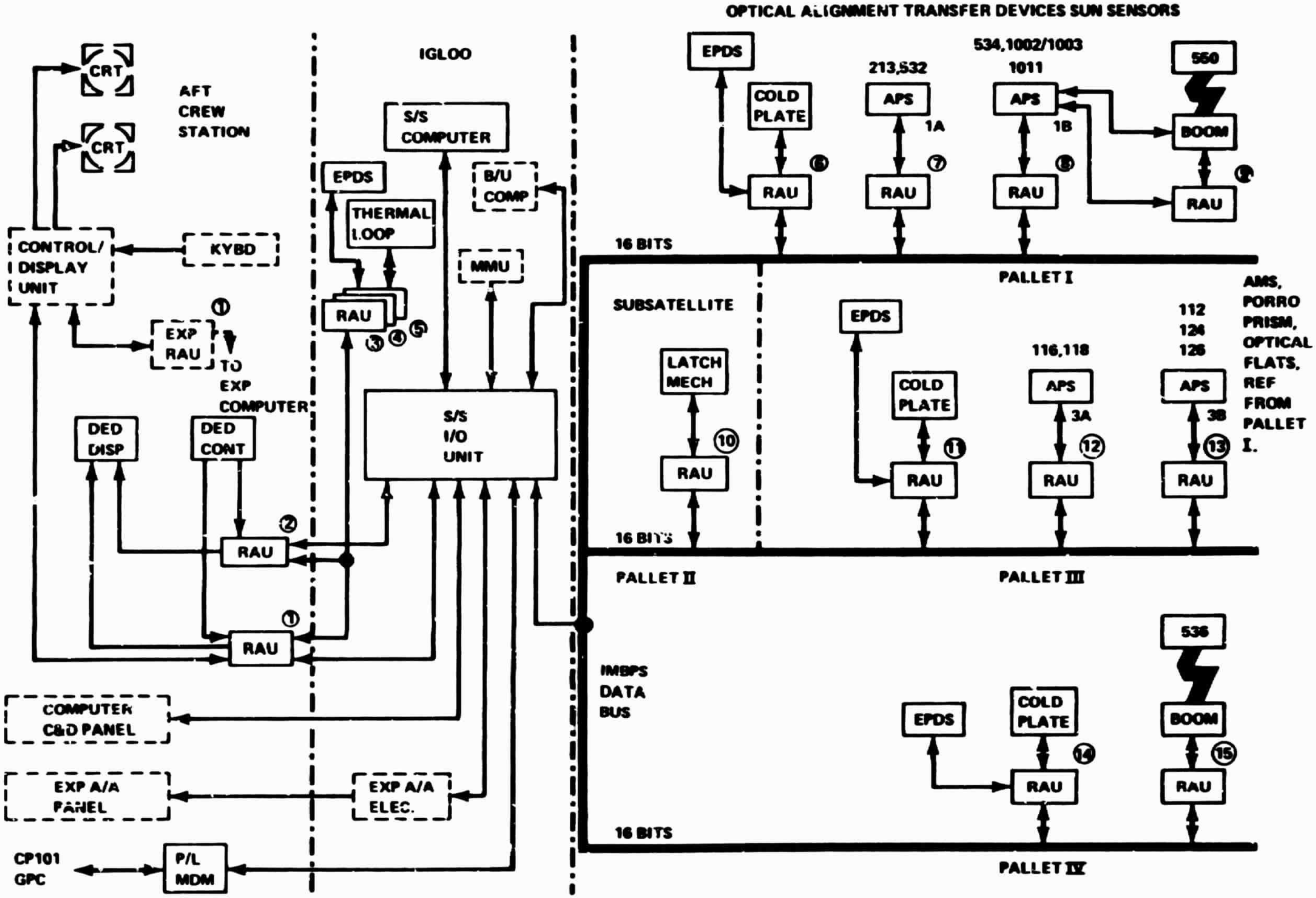

Figure 2-2.- Command and data management for the subsystem computer.

The experiment computer functional requirements and subsystem computer functional requirements are described separately in this section.

2.5.1 Experiment Computer

2.5.1.1 Data acquisition.- The experiment computer will acquire data from the various scientific instruments under software sequential control. This sequential procedure is dependent on the particular experiment being performed as shown on the ASF mission timeline (Figure 4.1.5-1 of Volume I). The following data characteristics of the 15 scientific instruments are shown in Table 2-I. The subsatellite data rate is constrained by the S-band PM system at 16Kbps.

2.5.1.2 Data processing.- The experiment computer will process incoming scientific data as required for crew evaluation by displaying the instrument performance data and status. The instrument end products are not defined to an extent that will allow detailed processing requirements to be defined at this time. Therefore, the minimum software functions are as follows:

a. Application of trigonometric functions, exponential functions or algebraic functions required for display of some data;

b. Interaction between instruments required for cross/auto correlation. (See Table 2-I);

c. Data processing in near real time. Where data rates exceed the computer real-time processing capability, the data will be stored on magnetic tape and played back into the computer for processing at a later time.

d. Special processing routines required for the subsatellite data (complementary to data generated by the pallet-mounted instruments). The extent of the special processing routines are undefined at this time.

e. Possible requirements for Fourier analysis, image processing, and signature analysis as instrument definition continues.

2.5.1.3 Data storage.- The experiment computer will store the processed data, as required, prior to output for display, downlink transmission, or recording.

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TABLE 2-I.- INSTRUMENTS SCIENTIFIC DATA CHARACTERISTICS

Instrument no. and title	Data form	Scientific		Measurement period	Housekeeping data	Interaction with other instruments	Data processing requirements
		Data	Data rate				
116 Airglow spectrograph	Film	N/A	N/A	Exposure time 1 to 1000 seconds approximately 700 exposures	Analog signals six 8-bit (words) 480 bps	Operate in support of No. 303 and No. 304	Data on film housekeeping data processed for status display.
118 Limb scanning infrared radiometer	Digital	12-bit (word)	12 Kbps	Operates from dark side of the terminator. Data period ranges from 40 seconds to 66 seconds	Analog signals six 8-bit (words) 480 bps	None	Process all data for crew evaluation of instrument performance and status.
122 UV-VIS-NIR Spectrometer	Digital	16-bit (word) at 1 Kbps for 8 spectrometers	8 Kbps	Continuous	Analog signals twenty-four 8-bit (words) 320 bps	None	Process all data for crew evaluation of instrument performance and status.
124 Fabry-Perot interferometer	Digital	200 8-bit (word)	1.6 Kbps	Continuous cycling at 2 minutes intervals for duration up to 100 seconds	Analog signals seven 8-bit (words) 560 bps	Operated in conjunction with No. 213	Process all data for crew evaluation of instrument performance and status.
126 Far IR spectrometer	Digital	10-bit (word)	1 Kbps	3 minutes per data takes: up to 3 data takes during a given revolution	Analog signal eight 6-bit (words) 200 bps	Operated in conjunction with No. 213	Process all data for crew evaluation of instrument performance and status.
213 Lidar	Digital	2 16-bit (word) per data point. 50 data points taken	16 Kbps	Continuous	Analog signals 10-bit (word) 1 Kbps	Operated in conjunction with No. 118, No. 124 and No. 126	Process all data for crew evaluation of instrument performance and status.
303 Electron accelerator	Digital	Bandwidth 10 MHz 1 MHz	5 Kbps	15 minutes each revolution	Analog signals 15 to 20 8-bit (word) 16 bps	Operated in conjunction with No. 116 and No. 534.	Process all data for crew evaluation of instrument performance and status.
304 MPD ARC	Digital	Bandwidth 1 MHz	1 Kbps	15 minutes each revolution	Analog signals 10 to 15 8-bit (word) 16 bps	MPD ARC is a subsystem of particle accelerator system	Process all data for crew evaluation of instrument performance and status.

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TABLE 2-J.- INSTRUMENTS SCIENTIFIC DATA CHARACTERISTICS (CONCLUDED)

Instrument no. and title	Data form	Scientific		Measurement period	Housekeeping data	Interaction with other instruments	Data processing requirements
		Data	Data rate				
532 [illegible] Release module	Digital	6-bit (words) and 8-bit (words)	77.5 Kbps	15 minutes near mid-daylight	Combined with scientific	Concurrent with operation of No. 303 or No. 304	Process all data for crew evaluation of instrument performance and status.
534 OBIPS	TV photometer	N/A	N/A 2 Kbps	30 minutes during each revolution	TBD	None	Process photometer data video TV monitor of images produced by the beams.
536 Triaxial fluxgate (on boom)	Digital	16-bit (word)	600 bps	3 minutes during each revolution	Combined with scientific	Data will provide interlock for accelerator operations	Process all data for crew evaluation of instrument performance and status.
549 Level I diagnostic	TV	N/A	N/A	15 minutes each revolution	Analog signal two 8-bit (words) 16 bps	Operate in conjunction with No. 303	Housekeeping data processed for status display. Video replay on TV monitor from video tape.
550 Level II beam diagnostic group (on boom)	Digital	Bandwidth 10 MHz 1 MHz 0.1 MHz	6.5 Kbps	15 minutes each revolution	Analog signal 10 to 15 8-bit (words) 12 bps	Supplement the operation of No. 303, No. 304, and No. 549	Process all data for crew evaluation of instrument performance and status.
1002 Pyrheliometer and spectrometer	Digital	16-bit (word)	320 bps	2 or 3 scans per revolution. 10 minutes per scan	Combined with scientific	None	Process all data for crew evaluation of instrument performance and status.
1011 Ultraviolet occultation spectrograph	Film	N/A	N/A	20 or more exposures during 20 minutes scans	TBD	Complement the operation of No. 116	Data on film. Housekeeping data processed for status display.

2.5.1.4 Telemetry processing.- The data from the scientific instruments will be organized into an identifiable format for downlinking (downlist). Each format will have a pre-established bit rate and commutation sequence in a pre-established measurement set with identification bits. The downlist function may require time tagging of individual data quantities, nd if required, the time tag will be the G.m.t. and mission elapsed time from the master timing unit.

The total quantity of data generated by the ASF instruments may be greater than the capability of the system. Therefore, data compression techniques within the computer should be considered.

2.5.1.5 Instrument command and control.- The experiment computer provides all services associated with command and control of each instrument. The proper sequence of turn-on, warm-up, operation, standby, and turn-off for individual instruments or groups of instruments, consistent with the mission timeline, is controlled through the computer software. The computer will control the conduct of the experiment or experiments until completion, or until a man-in-the-loop override command is received. Following the completion of the particular experiment, the computer will be reloaded with the next experiment program for the subsequent experiments. The 15 scientific instrument control requirements are shown in Table 2-II. The contents of command data words are shown with the number of bits required for the command data word format; for example, instrument no. 116 - 10-bit command data word consists of 1 bit for power (standby/operate), 1 bit for mirror shift and 8 bits for exposure control.

The commands may consist of either single steps or a sequence of steps. The software will be capable of checking the validity of each command generated. This operation may take on several forms depending on the instruments. The command may be routed back to the computer, its image verified, and a verification bit sent back to the instruments, or housekeeping data may be monitored to indicate execution of commands. Commands that are not verified may be displayed to the crew.

The computer will control the mass memory for transfer of stored programs to the experiment computer memory.

Commands are sent to the subsatellite, following its deployment, through the S-band PM system. These commands may be generated in the same manner as those generated for the other instruments.

TABLE 2-II.- INSTRUMENT CONTROL REQUIREMENTS

No. 116 - Airglow Spectrograph (three 10-bit words)

- Standby and operate power - 1 word (1-bit)
- Collimating mirror movement - 1 word (1-bit)
- Spectrogram exposure control - 1 word (8-bit)

No. 118 - Limb Scanning Infrared Radiometer (Five 10-bit words)

- Standby and operate power - 1 word (1-bit)
- Scan mechanism rate and angle - 1 word (5-bit)
- Scan mechanism mode - 1 word (2-bit)
- Inflight instrument calibration - 1 word (1-bit)
- Cryogenic dewar top-off - 1 word (1-bit)

No. 122 - UV-VIS-NIR Spectrometer (Thirty-six words)

- Standby and operate power - 4 words (8-bit)
- Instrument mode selection - 4 words (8-bit)
- Grating scan rate - 4 words (8-bit)
- Grating position for specific wavelength selection - 4 words (8-bit)
- Microprocessor program modification - 4 words (8-bit)
- Accumulated time and readout time
    - Hours - 4 words (10-bit)
    - Minutes - 4 words (11-bit)
    - Seconds - 4 words (11-bit)
    - Milliseconds - 4 words (16-bit)

TABLE 2-II.- INSTRUMENT CONTROL REQUIREMENTS (Cont'd)

No. 124 - Fabry-Perot Interferometer (Three 5-bit words)

- Standby and operating power - 1 word (5-bit)
- Instrument operating mode (3) - 1 word (5-bit)
- Instrument scan rate - 1 word (5-bit)

No. 126 - Far IR Spectrometer (Five 16-bit words)

- Standby and operating power - 1 word (1-bit)
- Scan rate and length - 1 word (2-bit)
- Integration time during data take - 1 word (6-bit)
- Inflight calibration - 1 word (3-bit)
- Cryogenic dewar top-off - 1 word (4-bit)

No. 213 - Laser Sounder (Two 16-bit words)

- Standby and operating power - 1 word (1-bit)
- Wavelength tuning - 1 word (15-bit)

No. 303 - Electron Accelerator (Thirteen words)

- Capacitor bank charge current - 1 word (16-bit)
- High voltage switch (four positions) - 1 word (3-bit)
- Power processing unit I output voltage - 1 word (16-bit)
- Power processing unit I output current I - 1 word (16-bit)
- Control grid voltage - 1 word (16-bit)
- Control grid frequency - 2 word (16-bit)
- Cathode heater - 1 word (16-bit)

TABLE 2-II.- INSTRUMENT CONTROL REQUIREMENTS (Cont'd)

- Diverging lens voltage - 1 word (16 bit)
- Converging lens voltage - 1 word (16-bit)
- X-Z sweep coil voltage - 1 word (16-bit)
- Y-Z sweep coil voltage - 1 word (16-bit)
- Control console power on/off - 1 word (1-bit)

No. 304 - MPD Arc (Four words)

- Capacitor bank charge current - 1 word (16-bit)
- MPD Arc plenum pressure - 1 word (16-bit)
- Solid state switch - 1 word (16-bit)
- Control power on/off - 1 word (3-bit)

No. 532 - Gas Release Module (Six words)

- Gas bottle select - 1 word (4-bit)
- Gas pressure regulate - 1 word (16-bit)
- Gas mode - 1 word (2-bit)
- Grating control - 1 word (16-bit)
- Gas filter control - 1 word (16-bit)
- Low voltage on/off - discrete command - 1 word (1-bit)

No. 534 - Optical Band Imager and Photometer System (Eight words)

- Door open/close - 1 word (1-bit)
- Sunshield in position - 1 word (1-bit)
- Aperture control - 1 word (4-bit)

TABLE 2-II.- INSTRUMENT CONTROL REQUIREMENTS (Cont'd)

- Filter selection - 1 word (4-bit)
- Gain - 1 word (4-bit)
- Mode of TV operation - 1 word (3-bit)
- Calibrator position - 1 word (1-bit)
- Calibrator light on/off - 1 word (1-bit)
- Pointing - TBD

No. 536 - Triaxial Fluxgate (Four words)

- Power on/off command - 1 word (10-bit)
- Various sampling rates - 1 word (10-bit)
- Data format changes (commands to subsatellite microprocessor) - 1 word (10-bit)
- Display controls - 1 word (10-bit)

No. 549 - Level I Diagnostic (Two 16-bit words)

- Gas supply open and close - 1 word (16-bit)
- Nozzle valves (4) open and close - 1 word (16-bit)

No. 520 - Level II Beam Diagnostic Group (Seven words)

a. Faraday Cup Probe

- Outer Grid Potential - 1 word (16-bit)
- Inner Grid Potential - 1 word (16-bit)

TABLE 2-II.- INSTRUMENTS CONTROL REQUIREMENTS (Concluded)

b. Retarding Potential Analyzer

- Outer Grid Potential - 1 word (16-bit)
- Retarding Potential - 2 word (16-bit)
- Suppressor Grid Potential - 1 word (16-bit)

c. All instruments - power on/off - 1 word (2-bit)

No. 1002 - Pyrheliometer Spectrometer (Four 4-bit words)

- Door open/close - 1 word (4-bit)
- Power on/off - 1 word (4-bit)
- Initiate data sequence - 1 word (4-bit)
- Initiate calibration - 1 word (4-bit)

No. 1011 - Ultraviolet Occultation Spectrograph (Eight 10-bit words)

- Instrument pointing - 1 word (1-bit)
- Tracker on/off - 1 word (1-bit)
- High voltage on/off - 1 word (2-bit)
- Exposure control - 1 word (1-bit)
- Start of data - 1 word (1-bit)
- Calibration source in place - 1 word (1-bit)
- Calibration source on/off - 1 word (1-bit)
- Door open/close - 1 word (1-bit)
- Film advance and exposure sequence - 1 word (2-bit)

The computer will control and transfer downlist data to the analog magnetic tape recorders. This operation may be automatically controlled by the computer software and, if required overridden by the crew.

Crew-generated commands are primarily entered through the keyboard unit. These commands are limited to initiating certain sequences of experiments, overriding certain preprogrammed sequences, and altering the resident software to a limited degree.

2.5.1.6 Display.- The experiment computer software will provide the capability to fully utilize the display hardware.

The 15 display requirements for the scientific instruments are shown in Table 2-III. A unique display format will be stored in the computer memory. Additional software for displays will be stored in the mass memory unit and will be available for inputting to the computer upon crew request.

The software will contain the necessary general conversion capability for displaying data in engineering units.

2.5.1.7 Support services.- The support services encompass all other functions required to support the ASF mission, including the overall executive program that provides the near-real-time data processing capability. The scientific instruments data will be organized into an identifiable format for recording on the analog magnetic tape recorders. The alarm/advisory electronics unit will be monitored for potential out-of-tolerance conditions and crew hazards which will be displayed on the alarm/advisory panel. The keyboard functions will provide for the man-in-the-loop interface (aft crew station). All uplink commands and navigation updates will be processed and acted upon, as required.

The execution of caution and warning system commands from the Orbiter computer will be processed and displayed to the crew. Interface requirements between the experiment and subsystem computers will be implemented. All miscellaneous operations not specifically listed will also be included in the support services function.

TABLE 2-III.- INSTRUMENT ENGINEERING DATA DISPLAY REQUIREMENTS

No. 116 - Airglow Spectrograph

A. Alphanumeric - 5 lines

- Optical configuration
- Relative pointing angle
- Spectrogram exposure completion
- Film supply status
- Operational status monitor

B. Graphic - None

No. 118 - Limb Scanning Infrared Radiometer

A. Alphanumeric - 7 lines

- Scan rate and angle selected
- Scan mode
- Instrument pointing angle
- Detector temperature and bias voltages
- Telescope temperatures
- Cryogen supply status
- Operational status monitor

B. Graphic - One of data from 4 to 12 spectral channels

TABLE 2-III.- INSTRUMENT DISPLAY REQUIREMENTS (Cont'd)

No. 122 - UV-VIS-NIR Spectrometer

A. Alphanumeric - 3 lines

- Scan rate, and mode and wavelength selection
- Instrument pointing angle
- Operational status monitor

B. Graphic - One of detector counts as function of integration time (Histogram or multichannel analyzer presentation)

No. 124 - Fabry-Perot Interferometer

A. Alphanumeric - 8 lines

- Operating mode and scan rate
- Photomultiplier tube dark current calibration status
- Calibration data
- Detector temperature
- Instrument pointing angle
- Photomultiplier power supply voltage
- Integration time
- Operational status monitor

B. Graphic - One of output data plotting intensity versus wavelength.

No. 126 - Far IR Spectrometer

A. Alphanumeric - 7 lines

- Spectral range
- Scan rate and angle

TABLE 2-III.- INSTRUMENT DISPLAY REQUIREMENTS (Cont'd)

- Instrument pointing angle
- Detector temperature and bias voltage
- Internal Instrument temperature
- White light interferograms (calibration data)
- Operational status monitor

B. Graphic - One of interferograms; plot detector amplitude versus displacement.

No. 213 - Lidar

A. Alphanumeric - 6 lines

- Instrument pointing angle
- Laser output wavelength and wavelength variance alarm
- Pulse duration and caution and warning alarm for variance from required value.
- Laser head temperature and caution and warning over temperature alarm
- Operational status monitor

B. Graphic - None

No. 303 - Electron Accelerator

A. Alphanumeric - 35 lines

- Accelerator operation parameters
- Housing parameters
- Operational status monitors.

TABLE 2-III.- INSTRUMENT DISPLAY REQUIREMENTS (Cont'd)

B. Graphic - Five

- PPU II output voltage amplitude and waveshape
- PPU II output current amplitude and waveshape
- Accelerated current amplitude and waveshape
- Acceleration voltage amplitude and waveshape
- Grid current amplitude and waveshape.

No. 304 - MPD Arc

A. Alphanumeric - 5 lines

- Instrument pointing angle
- Discharge current
- Discharge voltage
- Storage gas pressure
- Operational status monitor

B. Graphics - Fifteen displays of discharge current and voltage pluse amplitude and waveforms

No. 532 - Gas Release Module

A. Alphanumeric - 22 to 24 lines

- Bottle number (4)
- Gas mode (2)
- Gas system pressure
- Chamber pressure
- Chamber photodiode signal

TABLE 2-III.- INSTRUMENT DISPLAY REQUIREMENTS (Cont'd)

- Chamber temperature
- Mass filter rf voltage
- Electronics box housekeeping data (maximum 10 to 12 lines)
- Operational status monitors

B. Graphics - Two

- Monochrometer intensity versus wavelength
- Mass filter ion intensity versus mass count

No. 534 - Optical Band Imager and Photometer System

A. Alphanumeric - 1 line of operational status monitor

B. Graphic - 1 television monitor per camera (total of 2)

C. Annunciator lights - one for each 4 systems

- Door position
- Sunshade position
- Filter seection (photometer)
- Television camera direction
- Calibrator position
- Video tape status
- Video gain

No. 536 - Triaxial Fluxgate

A. Alphanumeric - 4 lines

- Power control
- Boom extension and retraction

TABLE 2-III.- INSTRUMENT DISPLAY REQUIREMENTS (Cont'd)

- Boom jettison

- Operational status monitors

B. Graphic - Two

- Power spectra of each subsatellite component of the magnetic field vector

- Wave propagation vector and polarization display over broad range of narrow frequency bands.

No. 549 - Level I Diagnostic

A. Alphanumeric - 6 lines

- Storage pressure (2)

- Release burst (2)

- Television camera angle relative to Orbiter reference axes.

- Operational status monitors

B. Graphic - one Orbiter television camera or instrument CCC TV camera

No. 550 - Level II Beam Diagnostic Group

A. Alphanumeric - Estimated 25 lines

- Peak and RMS valves of all parameters

- Housekeeping parameters

- Operational status monitors

B. Graphic - Five

- Faraday cup probe collector current

- Retarding potential analyzer voltage

TABLE 2-III.- INSTRUMENT DISPLAY REQUIREMENTS (Concluded)

- Retarding potential analyzer collector current
- Cold plasma probe current
- Cold plasma probe floating potential

No. 1002 - Pyrheliometer/Spectrometer

A. Alphanumeric - 5 lines

- Door position
- Power on/off
- Initiate data sequence
- Initiate calibration
- Operational status monitors

B. Graphics - None

No. 1011 - Ultraviolet Occultation Spectrograph

A. Alphanumeric - 8 lines

- Tracker acquisition
- High voltage on
- Door open
- Calibration source position
- Calibration source on
- High voltage meter reading
- Frame counter
- Operational status monitors

B. Graphics - None

2.5.2 Subsystem Computer

2.5.2.1 AMPS pointing system.- The subsystem computer will provide all command and control functions for the positioning and tracking capability of the APS. The operational functions required of the APS are as follows:

a. Initial alignment and updates,

b. Attitude determination,

c. Stabilization, and

d. Tracking.

The subsystem computer software will possess characteristics similar to a digital autopilot.

The initial alignment will require sightings by the star tracker. The angular data will be compared with the star catalog stored in the Orbiter computer memory and the calculated angular data will be transferred to the GRA (gyro reference assembly) for platform alignments. The subsystem computer will transfer the outputs from the GRA to the Orbiter computer for Orbiter positioning. The stabilization of the APS by the subsystem computer is maintained through the monitoring of gyro reference assembly error signals.

Each APS must continue to be a stable platform, even while the Orbiter changes attitudes. The Orbiter position and the target position are both sent to the subsystem computer. The subsystem computer will convert the information into inertial coordinates and vector commands which will be transformed to target line-of-sight coordinates before being sent to the gimbal torque motors for aligning the APS.

The subsystem computer and the Orbiter computer will interchange information for proper APS operation. The transfer of data and the calculations will be accomplished in real time.

2.5.2.2 Control/monitor.-

2.5.2.2.1 Thermal, structural, and mechanical subsystem: The subsystem computer will control and monitor the thermal, structural, and mechanical subsystem (TSMS).

The function of the thermal subsystem will be instrument cooling or heating, as required. The following units will be monitored as required; primary and back-up freon pumps, interloop heat exchanger inlet and outlet temperatures, pump status, igloo heat exchanger inlet and outlet temperatures, cold plates inlet and outlet temperature, temperature and pressure of the internal environment of the igloo, status of the gaseous nitrogen fans, and the thermal conditions in the payload bay. The freon loop will be controlled with the primary and backup freon pumps being turned on and off, as required.

2.5.2.2.2 Electrical power and distribution subsystem: The subsystem computer will control and monitor the electrical power and distribution system (EPDS) located in the aft crew station, igloo, and payload bay. Voltages and loads will be monitored at the power converters and at power distribution points in the payload bay. Remote circuit breakers and switches may be commanded by the computer or crew.

The instruments that require capacitor banks operation will be monitored by the computer for adequate capacitor charge to insure a proper discharge sequence.

2.5.2.2.3 Boom and platform: The subsystem computer will control and monitor the extension and retraction of the boom to maintain the desired instrument position. The subsystem computer will control and monitor the platform latching/unlatching mechanism for the subsatellite deployment, retrieval, and retention operations.

2.5.2.3 Support services.- The support services will include any other functions that are required to support the ASF mission that have not been discussed previously. These functions will include the overall executive program that provides the real-time control and monitoring of the ASF instrument operations. A second function will be the alarm/advisory electronics unit that will monitor subsystems for potential out-of-tolerance conditions which will be displayed on the alarm and advisory panel. Another function will be the man-in-the-loop interface provided by the keyboard capabilities in the aft crew station.

2.6 SIZING RESULTS

2.6.1 Experiment Computer

The ASF software functional requirements, as defined in the paragraph 2.5 were compared to the latest Orbiter software estimates. The experiment computer software requirements of the individual instruments for data acquisition, processing and storage, command and control, and display are shown in Table 2-IV. All memory sizing is presented as 16-bit words. The data acquisition has a computer memory requirement of an estimated 3600 words. The command has a memory requirement of an estimated 1650 words. The telemetry processing requires an estimated 730 words, regardless of the instruments being downlisted. The support services requirement was estimated to be 22900 words. An extremely conservative approach was used in estimating the software sizing. The ASF mission timeline, figure 4.1.5-1 of Volume I was analyzed for the worst case of instrument loading on the computer. Orbital revolutions 36 through 41 have eleven instruments operating simultaneously. These are identified as nos. 116, 118, 122, 124, 126, 213, 303, 532, 534, 536, and 550.

The experiment computer software size requirements for revolutions 36 through 41 are shown on table 2-V. A summary of the estimates for the experiment computer memory requirement is presented in table 2-VI. A conservative figure of 15 percent was used for uncertainty and growth.

2.6.2 Subsystem Computer

The AMPS pointing system software functional requirements was compared with the Orbiter digital autopilot software. The subsystem computer software requirement was estimated to be 9000 words. The control/monitor software requirements were estimated to be as follows: thermal, structural, and mechanical subsystem — 500 words, electrical power and distribution system — 300 words, boom extension and retraction — 600 words, and platform latching and unlatching — 300 words for a total of 1700 words. The support services requirement was estimated as 22,900 words. All software sizing of memory is presented in 16-bit words. A summary of the estimates for the subsystem computer memory software sizing is presented in table 2-VII. A conservative figure of 15 percent was used for uncertainty and growth.

TABLE 2-IV.- EXPERIMENT COMPUTER - INDIVIDUAL INSTRUMENT SOFTWARE REQUIREMENTS (16-BIT WORDS)

Instrument number	Data-acquisition, processing and storage, words	Command and control, words	Display, words
116	60	20	150
118	100	30	560
122	180	200	440
124	1080	10	590
126	580	30	560
213	5000	10	180
303	3400	70	2800
304	700	20	5300
532	240	30	1400
534	600	50	30
536	210	20	850
549	40	10	180
550	4280	30	2500
1002	130	20	150
1011	50	50	240

TABLE 2-V.- REVOLUTION 36 THROUGH 41 EXPERIMENT COMPUTER SOFTWARE SIZE REQUIREMENT

Instrument number	Number of 16-bit words required				
	Data acquisition processing storage	Telemetry processing	Commands	Display	Support services
116	60		20	150	
118	100		30	560	
122	180		200	440	
124	1 080		10	590	
126	580		30	560	
213	5 000		10	180	
303	3 400		70	2 800	
532	240		30	1 400	
534	600		50	30	
536	210		20	850	
550	4 280		30	2 500	
Experiment computer common	3 600	730	1 650		22 900
Total	19 330	730	2 150	10 060	22 900

TABLE 2-VI.- SUMMARY ESTIMATE OF EXPERIMENT

COMPUTER MEMORY SOFTWARE SIZING

Functions	Full words (16 bit)
Data acquisition, processing/storage	19 330
Telemetry processing	730
Commands	2 150
Display	10 060
Support services	22 900
Uncertainty/growth (15 percent)	8 230
Total	63 400

TABLE 2-VII.- SUMMARY ESTIMATE OF SUBSYSTEM COMPUTER MEMORY SOFTWARE SIZING

Functions	Full words (16-bit)
AMPS pointing system	9 000
Control/monitor	1 700
Support services	22 900
Uncertainty/growth (15 percent)	5 040
Total	38 640

2.7 SUMMARY

The APS does not require extensive computational capability from the subsystem computer. The Ball Brothers Research Corp. (SIPS) (small instrument pointing system) study stated that based on a similar system mechanized with a digital computer, the computer speed required for updates of the fine pointing loops of one APS would use 25 percent of the total speed of a computer. If four APS were operating simultaneously, 100 percent of the computer time would be devoted to the pointing system operations.

The software requirements estimate for the ASF mission is 63.4K (16-bit words) of memory for the experiment computer and 38.6K (16-bit words) of memory for the subsystem computer. An extremely conservative approach was implemented in estimating the software sizing. This analysis does not address the recent developments of instrument no. 126 which may have a data rate as high as 1.2 Mbps as discussed in Section 4.0. This will have a definite impact on memory size. The present maximum data rate during revolutions 36 through 41 (worst case) is 128.2 Kbps, but may increase to 1.44 Mbps.

The presently defined payload computer has 64K 16-bit words of memory capacity and will be marginal in meeting the requirements of the ASF mission. The following options should be considered for future studies.

Option 1

A computer with a 64K 32-bit word memory capacity should be considered. This is approximately twice the capacity of the present payload computer.

Option 2

The present payload computers should be investigated for memory additions without the possible penalties of imposing software complexities or reducing computer access time.

Option 3

The scientific instruments should be investigated for the possibility of performing more on-board processing at the instrument level, thus reducing the rates and amounts of raw data. The present state of the art in microprocessors has made this feasible and cost-effective.

Option 4

The number of scientific instruments operating during an experiment should be analyzed for possible reduction.

Option 5

The APS should be further analyzed for the posibility of using a microprocessor at the pallet. If the microprocessor is placed on the pallet and the payload computer memory is expanded as discussed in Options 1 and 2, the requirement for a subsystem computer can be eliminated.

Option 6

The possibility of using one or more of the five Orbiter general purpose computers to supplement the payload computers should be investigated. Much of the Orbiter computer capability is not used during on-orbit operations, but is required during the ascent and descent phases of the flight.

All of these options should be investigated. Implementation of one or more of these options could result in reducing the number of computers from three to two.

3.0 TAPE RECORDER ASSESSMENT

At the writing of the interim report (Volume I and II), many unknowns concerning the ASF (Atmospheric Science Facility) wideband analog recorder existed. The precise type of recorder to be used, the capabilities of the recorder, and the location within the Orbiter crew area were some of the unknowns.

An assumption was made that two recorders could be located in the Orbiter aft crew station. Two were required to allow sequential operation for uninterrupted recording of all unprocessed digital serial data generated by the ASF payload. Further assumptions were made that the recorders would be of the standard Shuttle variety with a 2.4×10^9 bit capacity. Based on using these recorders, seven reels of tape would be required to store the 15.9×10^9 bits of data anticipated during the 7-day mission, a tape change would be necessary approximately once each day.

Subsequent to publication of the interim report, many of the previously unknown details concerning the tape recorder were finalized. The most significant of these unknown details is that the Orbiter tape recorder does not have a reel change capability, therefore, the standard Shuttle recorder is unsuited for the ASF mission. Consequently the tape recorder configuration recommended for the ASF mission is a single tape recorder of the Skylab variety. The recorder should be located in a crew accessible area with the mid-deck area being acceptable. The tape recorder should be a wideband analog machine with reel change capability, and have a bi-directional record and dump capability. Tape length should be no less than 7000 feet, yielding a capacity of 12×10^9 bits per reel. Thereby, two reels would easily accommodate the 15.9×10^9 bits expected during the 7-day mission.

A weight savings of 20 percent (12 pounds) could be realized with this configuration, however, some power and volume penalties would be necessary.

4.0 INFRARED INTERFEROMETER/SPECTROMETER

DATA RATE ASSESSMENT

The data rate for the infrared interferometer/spectrometer instrument no. 126 was initially determined to be 1.2 Kbps for the ASF (Atmospheric Science Facility) interim report (Volume I and II). Subsequent to publication of the report, the infrared interferometer/spectrometer was reassessed in its entirety and the resultant data rate now approaches 400 Mbps during the 40 seconds of instrument operation. If the data are buffered and output at a constant rate throughout the 90-minute revolution in which the instrument is operated, the data rate would approach 3 Mbps. This rate is still far in excess of the maximum allowable for recording on the ASF wideband recorder. It is also too high to be accommodated on the data bus being used by all other ASF instruments.

Two possible alternatives have been considered for accommodation of the data. Quite possibly both will be required.

a. The simplest approach, while still complex, is to make real-time use of the 50 Mbps Ku band downlink. A high-speed, high-volume buffer would, in effect, convert the 40 seconds of 400 Mbps data to just over 5 minutes of less than 50 Mbps data. These data could be input directly to the Ku-band downlink which will not be utilized for other ASF functions. The assumption here, of course, is that the occultation, when the interferograms are generated, occurs during TDRSS (tracking and data relay satellite system) coverage.

b. A second, but more costlier approach, requires the development of a recorder capable of storing ≈ 9 minutes of data at a rate approaching 30 Mbps. This device would enable storage of all data gathered during one occultation, after which the data could be dumped into the Ku-band downlink whenever TDRSS coverage is available.

Numerous methods of on-board processing could also be investigated, but downlinking the data as quickly as possible appears to be the most logical approach. Both of the approaches suggested would be additions to the currently defined ASF data management concept, and would not cause a major impact to this concept.

5.0 SUBSTITUTE INSTRUMENTS

5.1 INTRODUCTION

In assessing the potential of a 1981 mission, an obvious conclusion became evident in that many of the prime instruments would not be available by that time. The two basic reasons for this were that certain instruments were very complex and the money required for their development would not be sufficient to allow a crash program to ensure delivery, and secondly, some of the specified instruments operating parameters were beyond the current state-of-art and would require more development time then would be available to meet a 1981 launch.

As a result, past programs were searched for similar sensors and instrumentation that could meet part or all of the requirements of the prime instruments. The results of this search were reported in Section 7.0 of Volume 1 of the Interim Report and show that partial or total substitutes were found for seven of the fifteen prime instruments. A recommended follow-on investigation revealed that many instruments existed that, with minor modifications or improvements, would be suitable for use on the Orbiter. Further comparison of the substitute instrument performance with the scientific objectives of the experiments showed two more substitute instruments which are described in this section. Although these instruments only partially fulfill requirements of the prime instruments, they can be available for a 1981 mission, and will yield a substantial amount of the data desired in that time frame. The two candidate substitutes would be used in place of 213 LIDAR and 303 Electron Accelerator.

5.2 INSTRUMENT NO. 213 LASER SOUNDER (LIDAR)

5.2.1 Introduction

The requirements for this laser system are that it should be tunable from 200 nanometers (nm) to 30,000 nm with an output energy of 1 joule per 10 nsec pulse, and these requirements are well beyond the state-of-the-art. There are, however, both fixed and tunable frequency lasers in various stages of development that could be considered for meeting part of the objectives as the state-of-the-art advances to the full capability. Satisfactorily flying and operating a limited capability LIDAR (Laser Sounder) on early AMPS missions will represent the first major milestone toward the end goal. Techniques of space-qualifying a laser will be established, operational procedures will be developed and data will be collected that can be used to substantiate or adjust assumptions used in analytical models of atmospheric transmissivities and constituent densities. Furthermore, world-wide mapping of at least some constituents may possibly reveal the presence of anomalies not before detected in the few widely scattered measurements that have been made. A search was undertaken to locate lasers suitable for meeting at least these limited objectives.

5.2.2 Search Results

Many articles have been published about laser development efforts and concepts, but in trying to find suitable existing lasers that could be ready for a 1980 or 1981 flight, there was a great scarcity of candidates. In fact, no fixed-frequency pulsed lasers were found in the Ultraviolet or Infrared ranges of interest that are sufficiently far developed to be usable in that time frame. A commercially available tunable dye laser was found that can meet a limited number of experiment objectives established by the AMPS Science Definition Working Group. It has been produced and operated in sufficient quantities to verify its performance and establish its reliability. While many potential sources of suitable lasers were not contacted, enough were contacted to be reasonably certain that findings are valid. Organizations queried regarding existing lasers, those being developed, and those considered feasible within the bounds of current knowledge are Honeywell, Minneapolis, MN; International Laser Systems, Orlando, FL; Sylvania, Mountain View, CA; Hudson Korad Department, Santa Monica, CA; McDonald-Douglas, Astronautics Division, St. Louis, MO; Drug Enforcement Agency, Washington, DC; Air Force Avionics Laboratory, Wright Patterson AFB, OH; Lockheed Missiles and Space Company, Sonnyvale, CA; Brooks Aerospace Medical Center, San Antonio, TX; Spectrophysics, Mountain View, CA; Chromatix, Mountain View, CA; Molectron, Sunnyvale, CA; Rice University, Houston, TX; AVCO ERL, Everett, MA; NASA LRC, Hampton, VA; and Coherent Radiation, Palo Alto, CA.

Some of these organizations are developing lasers ultimately intended for space science experiments such as AMPS. It is unlikely that they are far enough along in development to be completed and integrated into an AMPS payload by 1980. It was concluded that the Chromatix CMX-4 unit is a sound choice as a substitute for Instrument 213 and will require minimal modification to prepare it for operation in space.

5.2.3 Characteristics

The CMX-4 system employs flash lamp pumping of circulating dyes, with birefringent filter tuning. The filter, inside the laser cavity, is scanned by a computer, integral to the system, to achieve tuning across the visible and ultraviolet bands. Dye changes are necessary when switching between the visible and UV bands. This is a simple 2-minute operation requiring changing only two quick disconnects.

The four-liter dye reservoirs must be located in a pressurized compartment where the change in connections can be made manually. The dye will be pumped to the pallet-mounted LIDAR unit. The system must be flushed with methanol for 30 seconds when changing dyes, and 20°C water at 2 gal/min is required to cool. Neither of these requirements appear difficult to accomplish on the Orbiter. System characteristics are as follows:

Wavelength range - 435nm to 730nm (basic unit)
265nm to 365nm (by frequency doubling)

Bandwidth at 600nm - 0.3 wave number (broad band)
0.1 wave number (narrow band)

Power Output (peak) - 7Kw at 600nm (wide band)
4.6Kw at 600nm (narrow band)

Power Output (avg) - 250 milliwatts

Energy per Pulse (max) - 7 milijoules at 30pps,
1 microsecond duration

Pulse Width (minimum) - 1 microsecond

Pulse Repetition Rate - adjustable from external triggering
to 30 per second

Power Input - 4.5Kw

Weight - 330 lbs (150.4Kg)

Size - 35.5" (90.2cm) × 40" (101.6cm) × 24" (61cm)

5.2.4 Predicted Results

While the recommended substitute LIDAR will not meet all the LIDAR requirements desired by the AMPS Science Definition Working Group, it can measure density profiles of some constituents such as sodium. Published results of experimental resonant scattering measurements of sodium using ground-based lasers can be used for estimating spaceborne results.

In Vol. I, Paragraph 8.2.1.1 it was pointed out that to obtain results similar to those achieved in reference 1, would require approximately 1 kilo joule per second. This is a requirement only if the time of each sample is reduced from 250 seconds to one second and the range is 300 km instead of 90 km. It is important to realize that neither of the conditions are necessary.

The sodium layer is about 90 km above the Earth. With the Orbiter at 190 km, the range is only 100 km. Since the sodium layer is likely not to vary substantially over relatively short distances, it is more realistic to consider it constant over a fairly long sample period, and conduct the measurements at lower energy levels. This brings laser requirements into the realm of possibility and obviates the eye damage hazard mentioned in Vol. I.

Another experimental system and corresponding results are reported in reference 2. In this system, a flash lamp pumped dye laser and a collecting aperture of 45cm with uncooled detector was employed to measure the naturally occurring sodium layer at about 90 km altitude, with a 2 km resolution in altitude. With a laser output of 200mj per pulse, a train of 600 pulses were required to accumulate an average of about 20 counts. The Chromatix CMX-4, orbiting at 190 km altitude will be 100 km above the same sodium layer, so the range loss will be $(90/100)^2$ or 0.81. Operating at 30pps, energy loss will be a factor of 7/200 or 0.035. Assuming identical collecting optics are used, the total loss factors (less than the experimental system) will be 0.81 x 0.035, or about 0.028. Therefore, to achieve the same number of counts, the chromatix unit will require 600/0.028 or 21,400 pulses to achieve the same number of photoelectron counts. At a pulse repetition rate of 30 pulses/second, this will require 710 seconds or about 12 minutes. In a 90-minute orbit, this represents an along-the-track spatial resolution of 12/90 x 360; or 48 degrees. It is reasonable to assume a five-fold increase in detector sensitivity can be realized by cooling. This assumption would yield an along track angular resolution of about 10 degrees. Furthermore, it is quite possible that current development efforts will yield more efficient dyes by the time Spacelab I flies, which will improve resolution still further.

Past measurements are spot measurements in a few places such as Northeastern United States and France. Circumferential resolution of previous measurements is therefore not even definable. Operating the CMX-4 to get a resolution on the order of 10 degrees will provide a map that does not presently exist, and will represent a major technical and scientific step forward.

5.3 INSTRUMENT NO. 303 ELECTRON ACCELERATOR

5.3.1 Description

An electron accelerator capable of meeting the preliminary specifications of Instrument 303 was developed, designed, and fabricated by Visidyne, Inc. The 30 kW model was successfully flown on a rocket in April 1975 from Alaska.

Three separate electron-gun units, each having a self-contained electron gun and high- and low-voltage battery banks, were used. Two of the guns were 3 kV, 5 A units while the third, used in an attempt to neutralize any vehicle charge-up by creating a sheath of low energy particles and increasing the collecting area, was a one kV, 1 A gun. Electron gun specifications are shown in Table 5-I. In addition, the rocket-borne package contained the following:

a. Experiment control unit - used to provide power distribution, payload grounding, timing, data signal and commutation, and all electrical interfaces between the payload and electron guns and instrumentation.

b. Electrostatic analyzer - used to measure the differential electron energy spectra of electrons with energy less than 5 KeV.

c. Magnetometer - was a single-axis instrument manufactured by Schonstedt. The unit was co-aligned with the electron guns and was used to determine the magnetic aspect of the payload during flight.

d. Retarding potential analyzer - provided capability of measuring the integral spectra of returning ions and electrons.

e. Dual-channel IR radiometer - used to measure the induced emission at 2.7 and 4.3 μm.

f. Photometers - two units were included which measured the visible irradiance at 3914Å and 5577Å.

In the experiments this type of instrument would be required for, the electron beam must be modulated so that beam-initiated phenomena can be differentiated from the natural background. The developer used a high-voltage vacuum relay which was used to pulse the electron beam at 0.5Hz repetition frequency.

TABLE 5-I.- ELECTRON GUN SPECIFICATION

Parameter	Value
Beam current:	5 amps at 3 kV
Accelerating voltage:	1 kV to 5 kV
Beam size:	1 cm x 10 cm typical
Maximum beam angular divergence:	5°, 1/2 angle (design parameter)
Maximum filament power required:	Operating, 1 kW. Filament voltage will be 10 volts dc. Beam current will not be reduced if filament voltage drops to 9 volts.
Filament material:	Tungsten
Cathode material:	Lanthanum Hexaboride
Range of operating pressure:	$\leq 1 \times 10^{-4}$ torr
	All performance testing will be done at $< 5 \times 10^{-6}$ torr.
Typical operation duty cycle:	50 percent (1 sec on - 1 sec off)
Operating time at 50 percent duty cycle:	5 minutes
Cooling requirements:	Conductive and radiative. No liquid cooling.
Filament life:	20 hours
Mechanical package size (max):	10 cm diameter x 40 cm long

High voltage was supplied by a unique system of 1,824 lithium cells to obtain the 3 kV. Since the system as used was only to operate 5 minutes, this battery pack had a weight of 73 kg and a volume of $.042m^3$. The system would not be practical for long-term electron-gun usage, but might be useful for short-duration experiments. Other batteries such as nickel-cadmium, lead-acid and silver cells were considered, but lithium batteries have the highest internal resistance. This limited their discharge rate, but at the currents required, this was not a problem. It was an advantage as it limits the instantaneous current that develops if the gun arcs or discharges. The electron gun package as described met a 1200-pound (544-kg) weight budget requirement. The mass properties of the total payload, which includes sensors, electron guns, telemetry, and control, is shown in Table 5-II. A rough layout of the rocket payload is shown in Figure 5-1, and gives an indication of the volume occupied by the various components.

Sustained accelerator operation requires collection of an equal electron return current from the ambient plasma to negate charge buildup on the spacecraft. If potential differences occur, it can cause corona and arcing which can interfere with the operation or damage sensitive instruments and sensors. The charge can be neutralized by firing particles of opposite charge or deploying collectors having large surface areas. Charge buildup will have to be addressed on any Orbiter accelerator. Although the Orbiter has a large surface area, most of it is insulated from the ambient plasma.

5.3.2 General Payload Data

Each 15 kW electron gun module, which included high voltage and filament batteries and controls, weighed about 450 pounds (204 kg). Of this total, approximately 175 kg was batteries which could be replaced by power supplies receiving basic power from the Orbiter. A gun module so configured would weigh in the neighborhood of 45 kg. Approximately 35 kW of input power would be required.

Each of the three gun modules took up 28" of length in a 31" diameter rocket or required a volume of $0.35m^3$. Of this, about $0.15m^3$ was batteries.

The remainder of the payload, consisting of sensors, transmitters, telemetry, control, etc., required about $0.2m^3$ additional volume and weighed about 450 kg.

It is estimated that if power is supplied by the Orbiter, the three electron gun modules (two 15 kW and 1 kW) and controls would weigh about 200 kg and require a volume of approximately $0.6m^3$.

TABLE 5-II.- PAYLOAD MASS PROPERTIES

Item	Weight, lbs.	C.G. station, in.
Instrument deck	120	96
Gun deck 1	547	110
Gun deck 2	428	137
Gun deck 3	622	168
Nose cone	166	74
Telemetry and programmer	128	195
Interstage	110	214
Total	2121 pounds	140
Gun weight gun 1 and 3	450 pounds	
Gun weight gun 2	290 pounds	
Instrument weight	75 pounds	

Instruments

Electron guns with associated batteries
Photometers
Radiometer
Electrostatic analyzer
Beacon experiment (scintillation)
Retarding potential analyzer

Mass properties
Gross weight = 2121 lbs at Sta 140

Housekeeping

S-band telemetry (with ranging receiver-425 MHz)
Gyro or ejectable doors (3 ea)
Nose eject

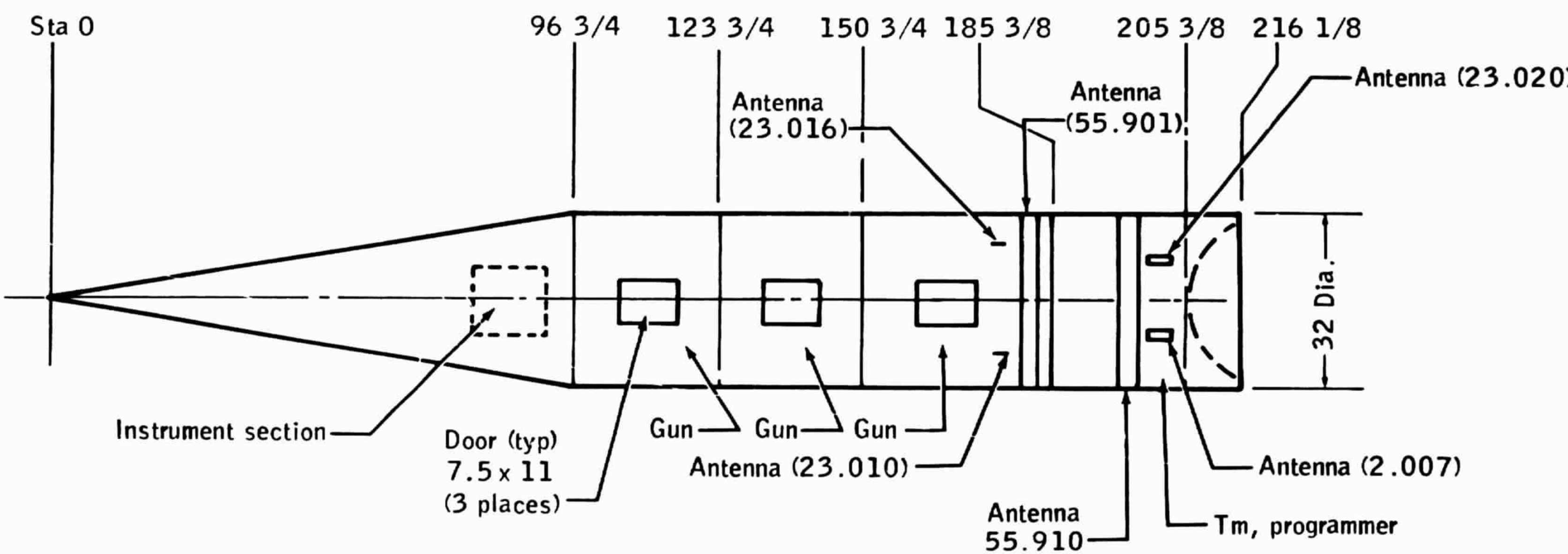

Figure 5-1.- Electron gun test payload (C-1 75-1).

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