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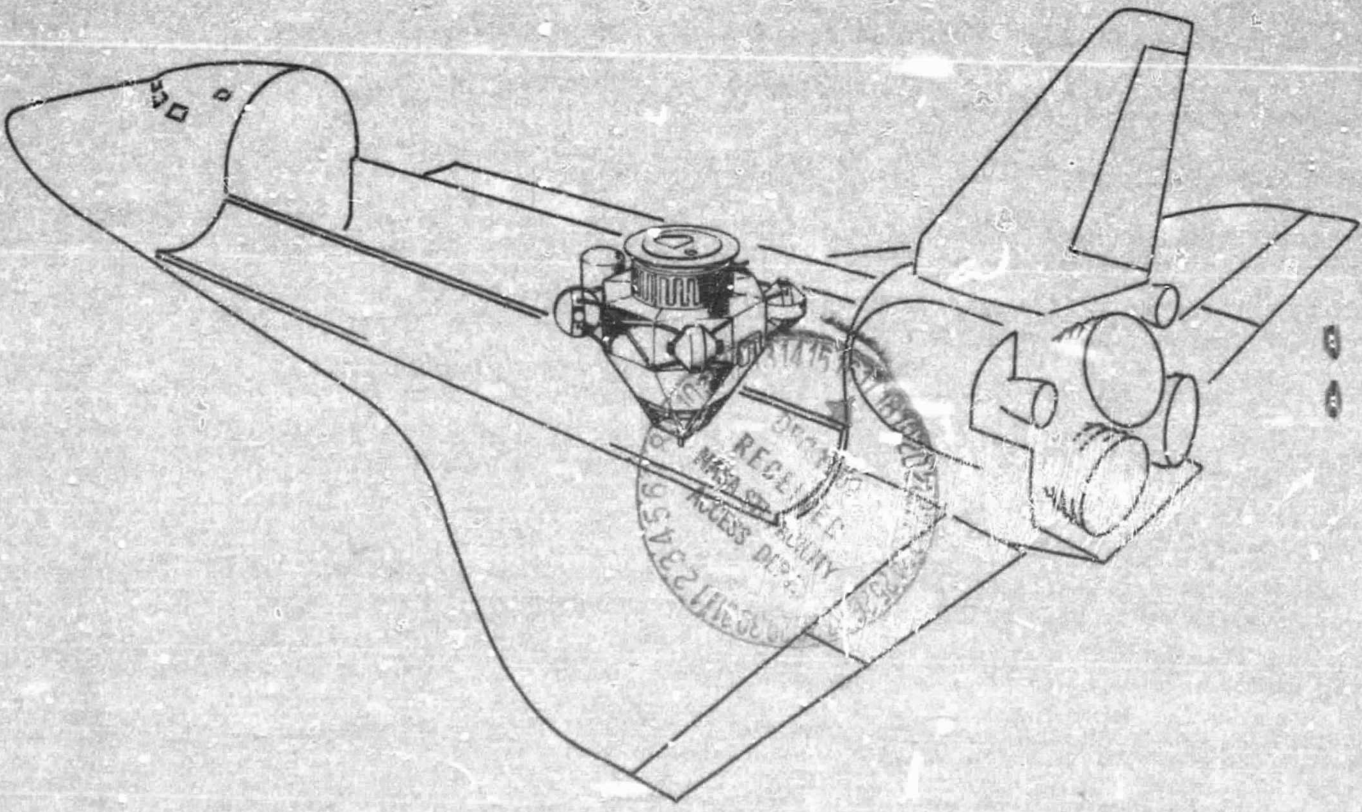
Final Report March 1981

Feasibility Study of the Solar Scientific Instruments for Spacelab/Orbiter



MARTIN MARIETTA

Contract: NAS5-26362

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FEASIBILITY STUDY OF THE SOLAR SCIENTIFIC INSTRUMENTS FOR SPACELAB/ORBITER

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FOREWORD

This study was performed under Contract NAS5-26362 for the Goddard Space Flight Center of the National Aeronautics and Space Administration under the direction of Richard Donnelly, the Contracting Officer's Representative. The final report consists of one volume with four (4) attached appendices.

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1.0 INTRODUCTION

This study was conducted to evaluate the feasibility and economics of mounting and operating a new set of solar scientific instruments in the backup Skylab Apollo Telescope Mount (ATM) hardware.

The new instruments used as the study test payload and integrated into the ATM were; the Solar EUV Telescope/Spectrometer; the Solar Active Region Observing Telescope; and the Lyman Alpha White Light Coronagraph. Detailed experiment requirements data was obtained from furnished "Experiment Requirements Documents"(ERDs).

The backup ATM hardware consists of a central cruciform structure, called the "SPAR", a "Sun End Canister" and a "Multiple Docking Adapter End Canister", as shown in Figures 1-1 and 1-2. Basically, the ATM hardware and software provides a structural interface for the instruments; a closely controlled thermal environment; and a very accurate attitude and pointing control capability. The hardware is an identical set to the hardware that flew on Skylab. The latest status indicates that the hardware is in bonded storage and relatively intact at the Marshall Space Flight Center. The ten remaining ATM rate gyros have been reworked to fix a problem that occurred during the Skylab mission.

Three concepts were baselined from the study: The "ATM Integrated" and the "IPS" and "AGS" concepts. The ATM concept utilized to the maximum extent possible the remaining backup hardware and software. A separate structure was required for this concept to mount it into the Orbiter payload bay. The IPS and AGS concepts utilized only the canister and associated canister equipment. In both of these concepts, the canister was mounted to the attachment rings of the pointing systems. All three concepts are shown in Figure 1-3.

Study results concluded that the test instrument payload was physically too large to fit within the ATM canister envelope and that extensive modification would be required to accommodate them. However, it was also concluded that the ATM backup hardware and software had a high potential for reuse, for payloads that fit within the canister

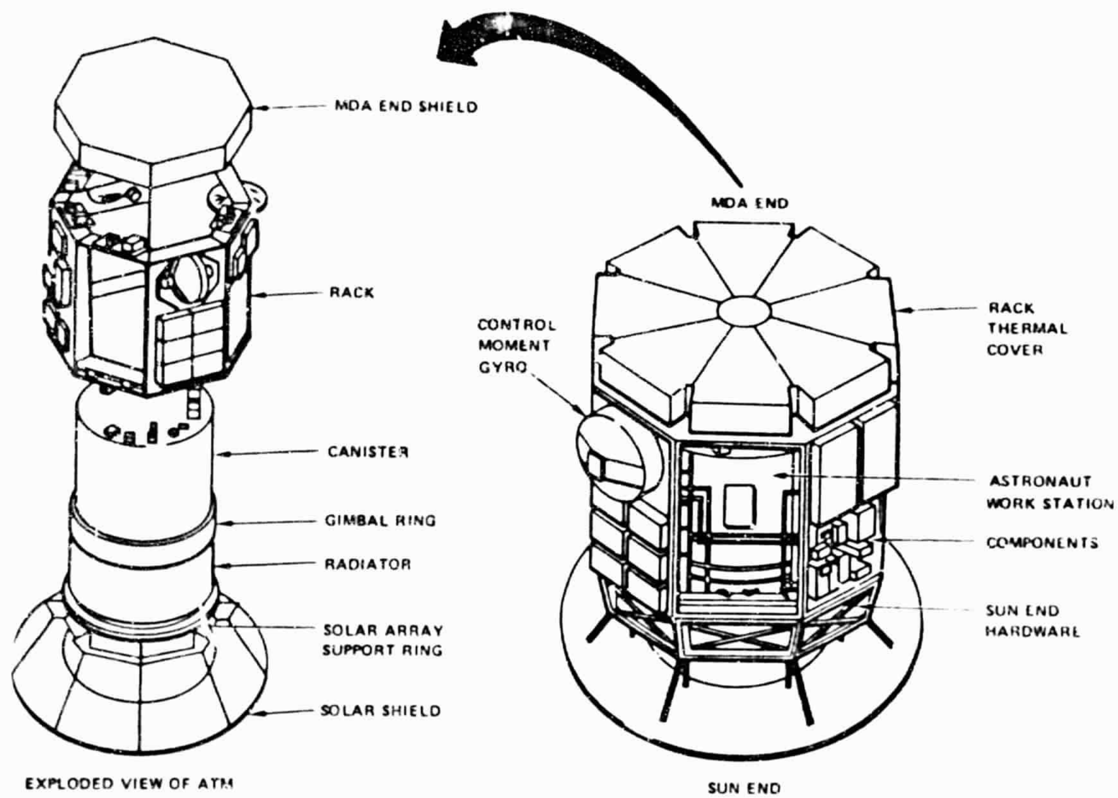

Figure 1-1 Apollo Telescope Mount (ATM)

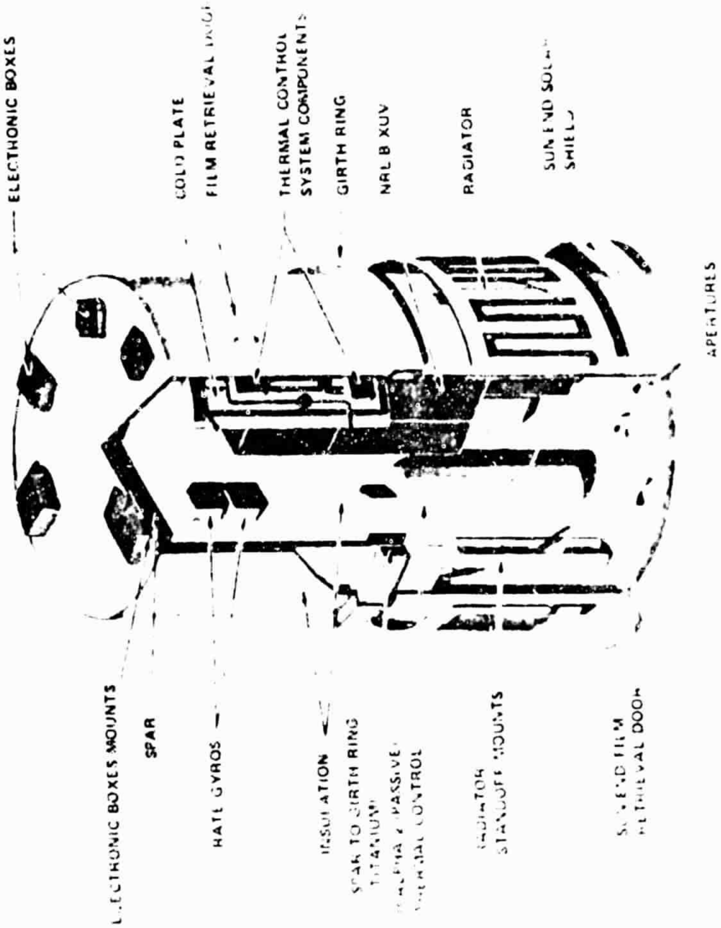

Figure 1-2 ATM Canister Cutaway View

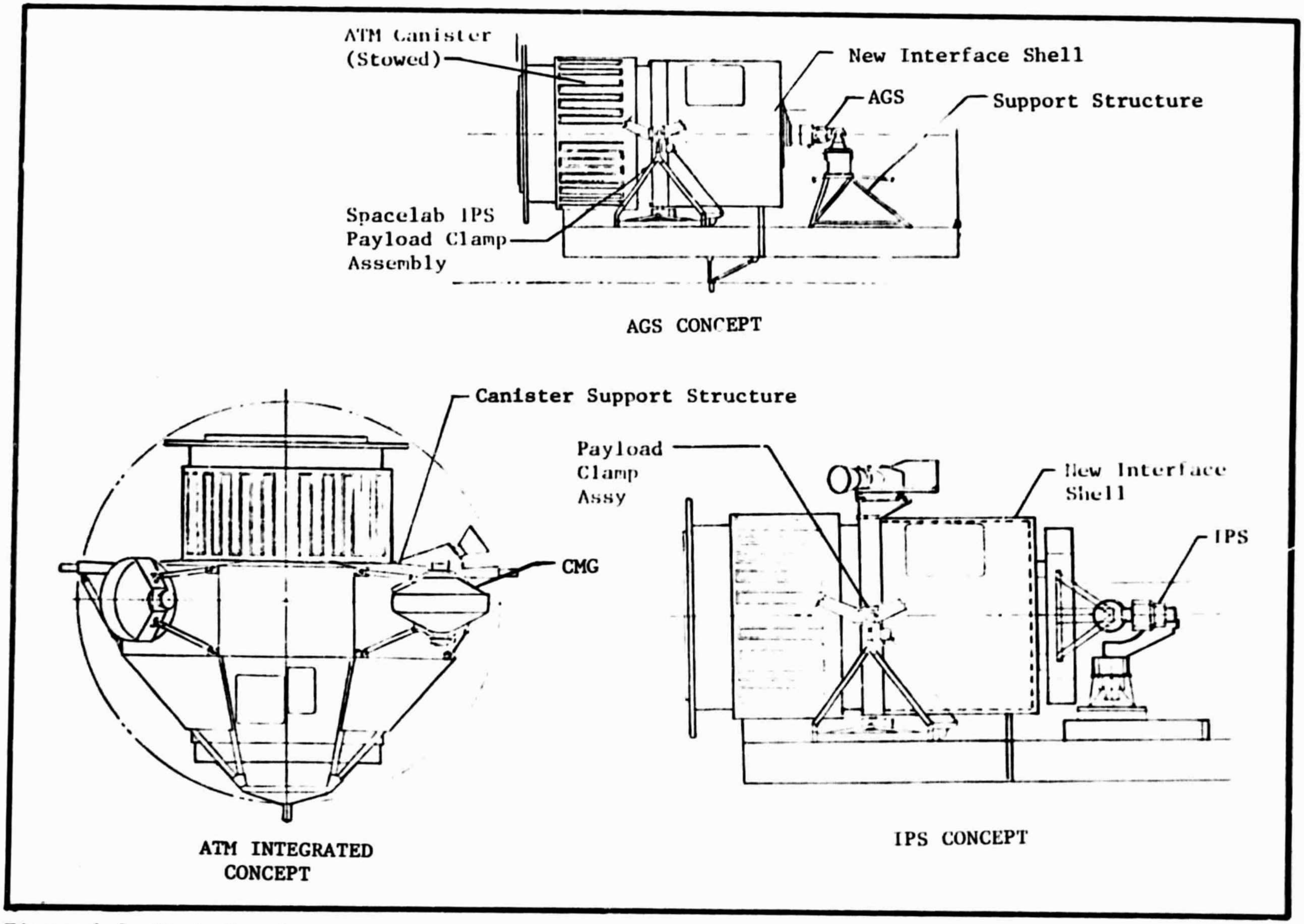

Figure 1-3 Study Baseline Design Concepts

envelo! . By selecting payloads, very little modification of the ATM is required; making the ATM reuse approach economically attractive, as well as providing the close thermal control, poin'ing and stability required by many of the instruments being developed for the Spacelab/ Orbiter era.

1.1 Purpose

The purpose of this report is to summarize and document the results of the ATM hardware and software reuse study effort. It further defines and details (Section 7.0 "Recommendations") those additional tasks that should be considered for further study.

1.2 Scope

The study effort was limited to conceptual design. Analyses were con...cted only where necessary to validate design concepts and establish subsystems approaches. Additional studies will be required to refine the baselined concepts discussed in this report.

2.0 INSTRUMENT INTERFACE AND OPERATIONAL DATA ANALYSIS

The instrument interface and operational data was compiled to provide a standard data base for the study team on the three (3) specified instruments; 1) Solar Extreme Ultraviolet (EUV) Telescope and Spectrograph (SUETS), 2) Solar Active Region Observing Telescope (SAROS), and 3) Spacelab Lyman Alpha (SLA) - White Light Coronagraph (WLC) (i.e., combination of these two instruments is defined as the Acceleration Region Coronographs - ARC).

2.1 Solar Extreme Ultraviolet Telescope and Spectrograph (SEUTS)

2.1.1 Instrument Description - This instrument is a grazing incidence telescope with high EUV reflectivity feeding a diffraction grating at near-normal incidence. This grating spectrally disperses the radiation and images in each point of the spectrometer's entrance aperture onto a small spot in the focal plane so that spatial information is preserved. Adequately stigmatic images are produced over an 8 arc min long slit and over a spectral range of 21.0 to 47.0 nanometers. Schumann-type photograph film is used to gain the full performance of the optical system. Spatial resolution of at least 2 arc sec and spectral resolution of 0.005 nanometers is achievable throughout the central 4 arc min field of view (FOV) at all wavelengths with even better performance in the Rowland Plane.

The experiment objective is to execute a scientific investigation addressing several fundamental problems of solar physics, these are:

1) The energy and mass balances in closed magnetic field regions in the corona and the processes by which these regions are heated.
2) Mass and energy transport into the solar wind.
3) The characteristics of the emergence and evolution of coronal active regions and their relation to flare activity and coronal holes.

2.1.2 Ins̈ ̈ment Characteristics

2.1.2.1 Structural and Mechanical - The telescope is mounted on a rigid stable optical bench to achieve stability in longitudinal displacement. The SEUTS is attached to an offset adjusting system and will be mounted to the Pointing System with a three point kinematic mount (See Figure 4.1.3.1-1 and 4.1.3.1-5). The instrument will be constructed in two packages, connected by electrical and electronic control and data cables. The larger part (Figure 2-1) is an optical bench with all optics and mechanisms. The smaller part is the electronics (Figure 4.1.3.1-1).

The telescope and spectrograph are shown in Figure 2-1 and is 135 inches long, 22 inches wide, and 36 inches high. This package is attached to the offset adjusting system and mounted to the ATM, as shown in Figure 4.1.3.1-5/7, by the three point kinematic mount. The offset adjusting system will provide a ±0.5 degree movement to the optical axis. The three point kinematic mount consists of three individual mounts and consists of two fixed mounts and one flexible mount and weigh approximately 100 lbs.

The SEUTS electronics assembly (Figure 4.1.3.1-7/5) is 23 inches long, 9 inches high and 17 inches wide, having a weight of approximately 60 pounds. This assembly contains the electronics to accomplish the following functions: Command and data handling; data collection, power, sun sensor control, offset pointing control, camera mechanism control, and general mechanism control.

The SEUTS weight is shown in Table 2-1.

Table 1-1 SEUTS Equipment Weight

1)	Telescope & Spectrograph Unit	-	360 lbs
2)	Offset Adjustment System & Kinematic Mount	-	100 lbs
3)	Electronics Package	-	60 lbs
	Total Weight	-	520 lbs

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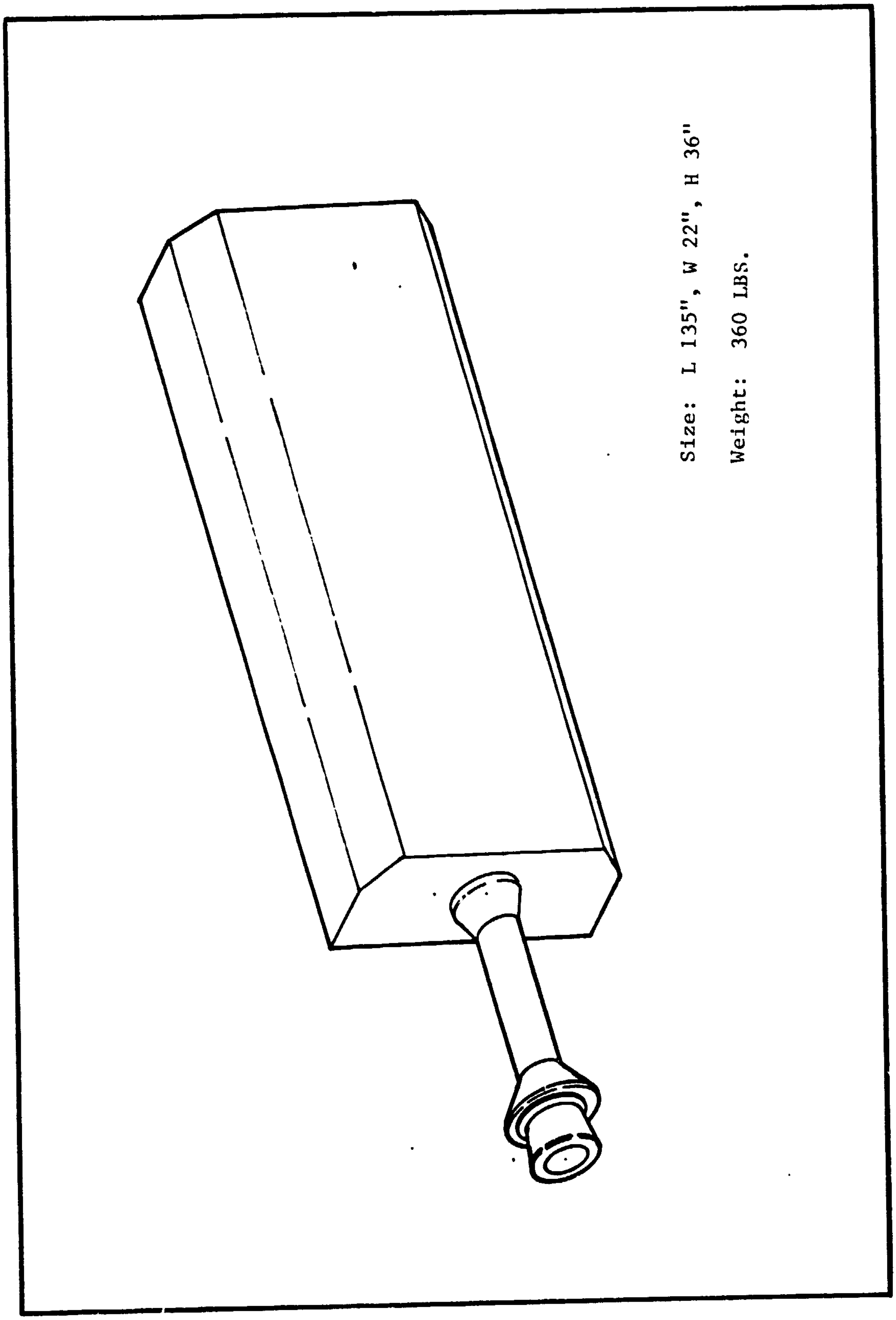

Figure 2-1 Solar EUV Telescope and Spectrograph (SEUTS)

2.1.2.2 Electrical Power - The SEUTS has five (5) operating modes and requires an average power of 160 watts. The power usage for these operating modes are as shown in the following table.

Table 2-2 Operations Power Requirements

Mode	Description	DC Power	Operating Time	No. Operations
1	Camera line profile	114 W	60 min.	10
2	Camera Flare	114 W	60 min.	5
3	Combined Modes 1 & 2	114 W	60 min.	15
4	Amplifying Image Detector	129 W	60 min.	10
5	Mode 2 Flare Standby	62 W	10-20 hrs.	
	Heater Power: 50 W Continuous for all Modes			

2.1.2.3 Thermal Control - The SEUTS will be aligned and operated at room temperature (22 degrees centigrade). The design is relatively insensitive to bending and side-to-side distortions. However, since its focus is sensitive to longitudinal displacements, the structure must be held at very close to the alignment temperature and thermal control is needed to minimize temperature differentials from front to rear of the instrument. Passive thermal control will be used and is provided by the ATM, with heaters used, as necessary, to maintain the minimum operating temperature.

The ATM will provide no active interface with the SEUTS but will provide a controlled benign environment as described in Section 4.3. The film carried in the Telescope and Spectrograph film reel assembly require temperatures below 110° F. The maximum temperature the film can withstand is 110° F for no more than 1.0 hour. After landing, the film must be removed before this temperature limit is reached.

2.1.2.4 Controls and Displays - A television display of the slit-jaw camera data is required (i.e., $H\alpha$ TV image). Controls on the Aft Flight Deck (AFD) to initiate command sequences necessary to carry out observing programs stored on-board. The AFD and Payload Operation Control Center Controls (POCC) are listed below in Tables 2-3, 2-4, and 2-5.

Table 2-3 Operation Control Requirements

1) Point and Roll Direction/Redirection
2) ATM Pointing and Roll Control
3) Offset Adjuster Position Control
4) Exposure Control
5) Instrument Control/Command Reissuance
6) Instrument Safing

Table 2-4 POCC/AFD Instrument Status Display (By Request from AFD)

Parameter Status	Parameter Status
Instrument Controller Power (on/off)	Entrance Slit Position (1 thru 4)
H-alpha Camera Power (on/off)	Offset Adjuster Position
H-alpha Cooler Power (on/off)	Film Frame Number
TV Camera Power (on/off)	Zero-Order Monitor Reading
Film Camera Power (on/off)	UTC of Shutter Operation
AID Camera Power (on/off)	Sun Sensor Reading
Aid Cooler Power (on/off)	Offset Adjuster Position
AID High Voltage (on/off)	Pointing System Pitch
Offset Adjuster Power (on/off)	Pointing System Yaw
Zero-Order Monitor Power (on/off)	Pointing System Roll
Film Camera Advance (on/off)	Temperature Sensor #1 - #7
Film Clamp (open/closed)	
Film Camera Door (open/closed)	
Telescope Door (open/closed)	
H-alpha Shutter (open/closed)	
EUV Shutter (open/closed)	
AID Mirror (in/out)	
Launch Lock (lock/unlocked)	

Table 2-5 POCC/AFD COMMAND AND CONTROL CAPABILITY

Instrument Controller Power on/off	Telescope Door open/close
H-alpha Camera Power on/off	H-alpha Shutter open/close
H-alpha Cooler Power on/off	EUV Shutter open/ close
TV Camera Power on/off	AID Mirror in/out
Film Camera Power on/off	Launch Pin lock/unlock
AID Camera Power on/off	Entrance Slit Step forward/ reverse
AID Cooler Power on/off	
AID High Voltage on/off	Offset Adjuster Step right/left
Offset Adjuster Power on/off	Converter Power on/off
Zero-Order Monitor Power on/off	Instrument Controller Reset
Film Camera Advance	Sun Sensor Power on/off
Film Clamp open/close	
Film Camera Door open/close	
Total Commands - 44	

2.1.2.5 Contamination Control - During the SUETS Operation, it will be necessary to constrain thruster firings, waste dumps, and water dumps.

2.1.2.6 Command and Data Handling - A data transmission rate of 1250 bits per second on the data bus, and high rate data transmission of 2.05 Mega bits per second is required. Details of these requirements are described in Section 4.2.

2.1.2.7 Operating Time and Modes - The operating modes and times are described in Section 2.1.2.2, Table 2-2. The total experiment operating time is to be approximately 90 hours. The total sunlit operational time for a Shuttle mission of 7 days is approximately 102 hours when post insertion and pre re-entry thermal conditioning is considered. Due to the these experiment operating time requirements, joint operational programs with other experiments must be worked out.

2.1.2.8 Orbital Requirements - The Orbit altitude desired is to be as high-as-possible, consistent with other pointing platform instruments. The desired inclination is to be 28.5 degrees or higher. The launch time and inclination is to be chosen so that the Orbiter Beta angle constraint of 60 degrees is not exceeded, but so that sun time is maximized. The Orbit parameters are to be chosen to minimize time in the South Atlantic Anomaly (SAA).

2.2 Solar Active Region Observations from Spacelab (SAROS)

2.2.1 Instrument Description - The SAROS instrument consists of two (2) distinct components; 1) an x-ray Telescope and 2) a pointed collimated Bragg Spectrometer. These components are packaged in a single integrated package, Figure 2-2.

The prime objective for SAROS is to make detailed measurements of the temperature, density, and pressure within coronal loops in order to precisely determine the absolute values of the radiative and conductive heat loss terms for a given solar magnetic field loop. Secondary objectives are 1) Evaluate the magnetohydrodynamics of coronal loops, and the problem of the reconnection of magnetic field lines; 2) Evaluate x-ray bright points to establish a physical description, 3) Evaluate eruptive prominences, coronal transients, and depletions; and 4) Evaluate element abundances to assist in understanding both plasma and solar behavior.

The imaging system will provide high spatial resolution full disk x-ray Heliograms which can be recorded either as images on photographic film or as a video image. In addition, pointing information from the spectrometers in the form of a fiducial mark can be superimposed on the video image. This allows control of the spectrometer pointing in real time and records their location for later analysis. The video image will be available to the payload specialist on the Shuttle aft flight deck. It is also available to the experimenters on the ground by transmission in digital form, via the high rate multiplexer (HRM).

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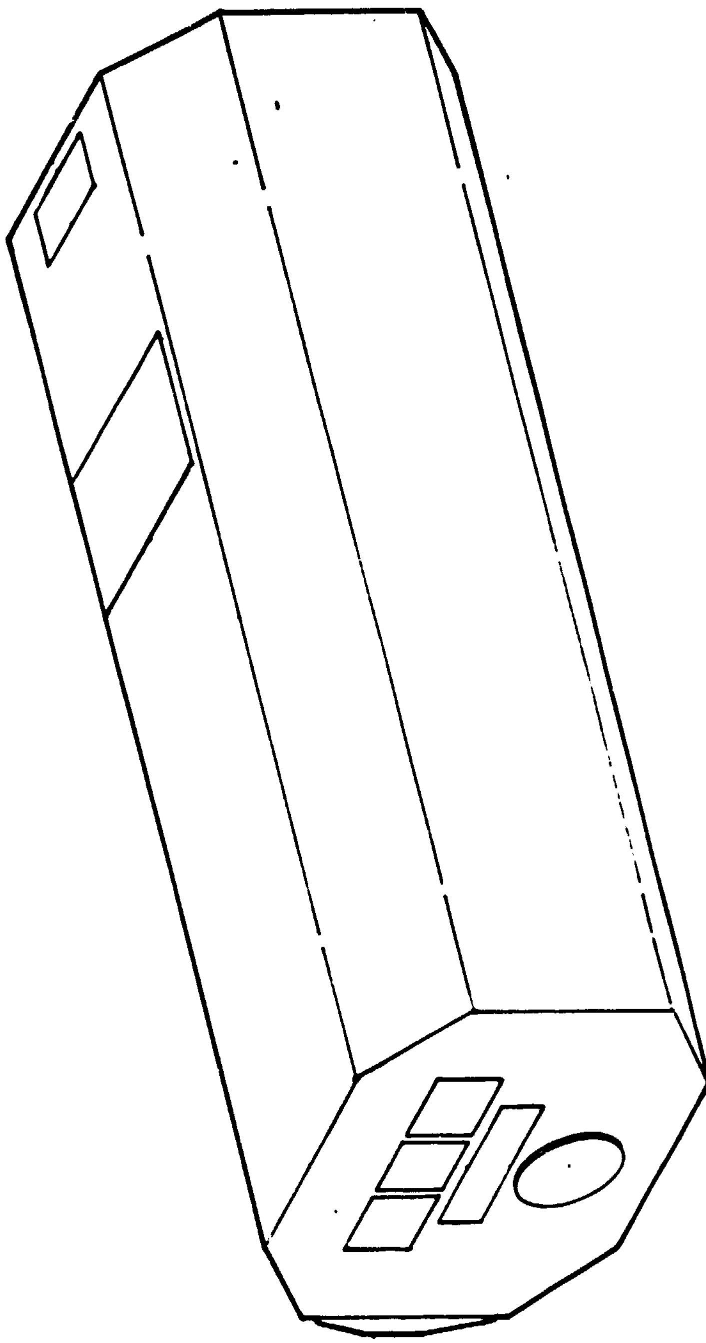

Size: L 109.5", W 39.4", H 37"

Weight: 1224 LBS.

Figure 2-2 Solar Active Region Observations From Spacelab (SAROS)

The imaging system consists of:

1. A grazing incidence x-ray mirror fabricated of fused silica and having a spatial resolution in visible light of 0.5 arc seconds.

2. An invar mirror mount and optical bench are provided to hold the mirror without distortion and maintain the location of the focal plane to within $\pm 5 \times 10^{-3}$ cm over a temperature range of $\pm 3^{\circ}$ C.

3. A focal plane assembly consisting of two photographic cameras and one video camera mounted on a three position rotary turret.

4. The two (2) photographic magazines are sized to hold 19.00 cm diameter film magazines. Each of the two magazines will contain one of two complementary types of film, one film being chosen for high sensitivity and one for high spatial resolution.

5. The video camera consists of a microchannel plate with a proximity focussed phosphor coupled by relay optics to a slow scan vidicon. The resulting pictures will have a spatial resolution of 5 arc seconds.

6. An Hα telescope consisting of a narrow band filter and optical train is mounted within the x-ray mirror. The telescope will allow Hα images to be recorded on film silultaneously with the x-ray images. The images will be used to provide independent roll information and to align the x-ray images with ground based observations.

The spectrometer consists of:

1. A three channel multi-grid collimator mounted in a single assembly which defines the field of view of the spectrometer.

2. Three Bragg crystal analyzers each of area 12.5 x 25.0 cm^2. The crystals used will be ADP, Beryl and RBAP.

3. Individual detectors for the three crystals. The detectors are thin windowed, flow proportional counters using a 90:10 mixture of argon and methane as the detector gas. They are mounted to a common drive assembly which is not counterbalanced.

4. The pointing drive which employs two motors for operating recirculating ball screw-jacks which provide the two-axis motions. These motions are sensed by transducers installed across the gimbal elements and additionally by shaft encoders fitted to each motor shaft. The single step size of the pointing system is 5 arc second with a total scan capability of $\pm\frac{1}{2}$ degree. The pointing drive is protected during launch and re-entry by latching the spectrometer in a position where it is held clear of the screw-jacks and thus unloaded.

   The latching mechanism is motorized and will be fully redundant to ensure relatch prior to re-entry.

5. A fiducial system which is mounted to the collimator backbone. It consists of a back-illuminated mask which projects an image of the collimator field with cross hairs to locate the center of the collimator filed on the sun.

6. The proportional counter gas flow system with its associated gas storage reservoirs, regulators, valves and gas delivery and density control electronics.

Access is required to provide pre and post flight access to the film canisters of the two (2) cameras. The nitrogen purge system must also be accessible for filling prior to flight during the offline Ground Operations activities.

2.2.2 Instrument Characteristics

2.2.2.1 Structural Mechanical - The experiment is contained within a cylindrical structure of octagonal cross section. The overall dimensions are length 109.5 in., width 39.4 in., and depth 37 inches. The main load bearing structure is an aluminum honeycomb center plate running the length of the instrument and dividing the package into two halves. Radial stiffness is provided by bulkheads positioned at various locations along the center plate. A cylindrical thin walled aluminum shell provides torsional rigidity and environmental protection for the instrument system. The two instruments are located on either side of the center plate. In both cases, the electronic packages are mounted at the rear of the instruments, within the basic envelope. The total mass of the instrument is 555 kg (1224 lbs.).

Three mounting adapters as described in Figure 4.1.3.1-5 are used for mounting to the ATM. One of the mounting points is at the forward or sun-pointed end and the remaining two are at the central bulkhead. In order to allow sufficient access to the instrument after it is attached to the ATM, the adapters can be attached to either side of the experiment structure. Since the load bearing structure is symmetrical, this does not affect the structural integrity.

2.2.2.2 Electrical Power - The SAROS requires an average DC power of 212 watts per orbit (including 60 watts of heater power) and 340 watts of peak power. Continuous power is required after Ground Operations integration (Level IV) to maintain a vacuum in the video camera's Microchannel Plate of (TBD) watts. There are five (5) operating modes for the SAROS and these are described in Table 2-7 in Section 2.2.2.7. The average power for each of these modes are shown below in Table 2-6.

Table 2-6 SAROS Power Summary

Modes	Operating Power	Heater Power
1	104 watts	135 watts
2	222 watts	20 watts
3	148 watts	20 watts
4	264 watts	20 watts
5	150 watts	20 watts

2.2.2.3 Thermal Control - The SAROS requires a non-operating environment of 0-30 deg C (32-86 deg. F) and an operating envii onment of 20 ± 30 deg. C (68 deg. F). The integrated package environment is to be 10 ± 5 deg. C (50 deg F). Hot spots such as the electronics package must either be supplied with cold straps or allowed to radiate directly to the ATM cold plates mounted on the canistered walls.

2.2.2.4 Controls and Displays - The controls and displays (Table 2-7) that are required consist of a TV display at the AFD for display of video images so that pointing programs and Spectrometer/Camera sequences can be commanded to experiment.

The SAROS will be controlled by an instrument controller which will provide sequences of commands to operate the instrument. Command sequences needed to carry out observing programs will be stored on-board. When a sequence is initiated, from the POCC o: ?D, the controller will sequence the operation of shutter, film advance, etc. to provide the desired set of photographic exposures.

Table 2-7 POCC/AFD Controls and Display Requirements

Display	Commands	
+28V Source	Power A	On/Off
A +5V	Power B	On/Off
B +5V	Dep 1 Restart	On/Off
Dep 2 Voltage	Dep 2 Restart	On/Off
Dep 3 Voltage	Dep 3 Restart	On/Off
Dep 1 Run	Dep 1 Backup	On/Off
Dep 2 Run	Survival Heater	On/Off
Dep 3 Run	Move Cursor	Up/Down
Dep 1 Backup Run	Move Cursor	Right/Left
Dep 1 Backup On	Change Step Size	3
Survival Heater On	Go to Special Sequence	

2.2.2.5 Contamination Control - During the SAROS Operation, it will be necessary to constrain thrusted firings, waste dumps, and water dumps.

2.2.2.6 Command and Data Handling - The command and data handling requirements include providing for a data rate of 7300 bits per second on the data bus and 524.3 kilo bits per second of high rate data, as near continuous communication with the ground as possible is required during the experiment operating time.

2.2.2.7 Operating Modes - The SAROS has five (5) operating modes per Orbit as shown in Table 2-8.

Table 2-8 Modes of Operation

Mode 1	-	On-Orbit Standby, 30 min.
2	-	Video Imaging and Display, 15 min.
3	-	Normal Data Taking, 15 min.
4	-	Data Taking with Interactive Spectrometer Control, 20 min.
5	-	Data Taking with Two Cameras, 10 min.

2.2.2.8 Orbital Requirements - The Orbit altitude desired is to be between 200 to 400 km at a near equatorial circular Orbit. An experiment desire is to minimize the time exposed to high radiation sources, such as the South Atlantic anomaly.

2.3 Spacelab Lyman Alpha - White Light Coronagraph

2.3.1 Instrument Description - The Spacelab Lyman Alpha - White Coronagraph is a joint program of the Smithsonian Astrophysical Observatory (SAO) and the High Altitude Observatory (HAO). The Spacelab Alpha Coronagraph (SLAC) and the White Light Coronagraph (WLC) will be operated in a joint fashion as co-observing instruments which together comprise the Acceleration Region Coronagraphs (ARC) experiment. The ARC is considered to be a single instrument in the mechanical/optical sense, but the SLAC and WLC will function as separate instruments in the electrical/thermal sense. The instruments will interface separately with the Command and Data Management Systems and with the electrical systems. Each instrument has its own thermal control system and the thermal interaction is to be minimized. A mechanical interface exists and the WLC is mounted to the SLAC with a three (3) point kinematic mount but otherwise each coronagraph is structurally self-sufficient.

The ARC co-observing instruments will measure coronal temperatures, densities, and flow velocities for solar structures throughout the solar wind acceleration region of the inner corona. Data from both ARC instruments are required to achieve the following principal scientific objectives:

1) Determine the coronal atomic hydrogen and proton temperatures from 1.2 to 8 solar radii from sun center.
2) Determine coronal atomic hydrogen and electron densities.
3) Determine coronal mass flow velocities.
4) Specify at least an upper limit to non-thermal velocities in the Corona.
5) Determine the coronal electron temperature.
6) Study coronal momentum and energy transfer in conjunction with models of the coronal expansion.
7) Estimate the mass flux of the solar wind, particularly that arising from regions other than coronal holes.

The SLAC is an ultraviolet coronagraph using a slowly-scanning telescope mirror to observe a 30 arc minute x 100 arc minute sector of the corona from 1.2 to 7.4 solar radii. The sector is selected by rolling the pointing system ATM) around the sun center. Offset pointing also permits occasional solar disk observations as well as coronal observations out to 8.0 solar radii. A Spectrograph analyzes the telescope image light spectrally and observes a coronal strip. Discrete-anode microchannel array detectors provide spatial and spectral information. The SLAC is comprised of the following major subsystem: Mechanical (i.e., front aperture and door, sunlight trap, telescope/internal occulter mirror, baffles, entrance slit, spectrograph case, grating drive, detector mount and main instrument case), Optics (i.e., telescope mirror, diffraction grating, sunlight trap mirrors and alignment mirror), detector assemblies, thermal control and electronics.

The WLC is comprised of the following major subsystems: Mechanical (i.e., aperture door, light tube/optical bench combination, optics housing and structural mounts), Optical (i.e., external occulting disks, heat dump mirror, focussing lenses, folding mirrors, internal occulting disk and polaroid filters), thermal control (i.e., heated panels, multilayer insulation and surface coatings), data recording (i.e., 35 mm film camera), and electrical (i.e., 8080A processor, motor drivers, thermal control system controller and power supplies. The door mechanism, flip mirror and calibration path devices are designed with a manual override system so that in the event of a primary drive system failure the component can manually be removed from the optical path.

2.3.2 Instrument Characteristics

2.3.2.1 Structural and Mechanical - The Spacelab Lyman Alpha-White Light Coronagraph is shown in Figure 2-3, and is 130.5 inches long, 40 inches high, and 37 inches wide. The combined instrument weight is 749 lbs. The SLAC and the WLC are mounted together on the three (3) point kinematic mount and the SLAC will be mounted to the ATM through a co-alignment system. This interface and system are shown in Section 4.1, Figures 4.1.3.1-7/8.

In addition to the main structure, an electronics assembly, separate from the telescope will operate the WLC. The electronics rack will be detached from the telescope primarily to eliminate the thermal heat source from the precisely aligned telescope. This electronics package will not be coupled to the SLAC. The WLC will be kinematically hard-mounted onto the SLAC and the joint instrument will be a co-aligned, co-observing instrument package. Access is required to the WLC film assembly.

2.3.2.2 Electrical Power - The ARC requires an average DC power of 197 watts, with the SLAC using 150 watts average power during its 9 operating modes, and the WLC using 47 watts average power during its 6 operating modes. These operating modes are shown in the following Tables 2-9 and 2-10.

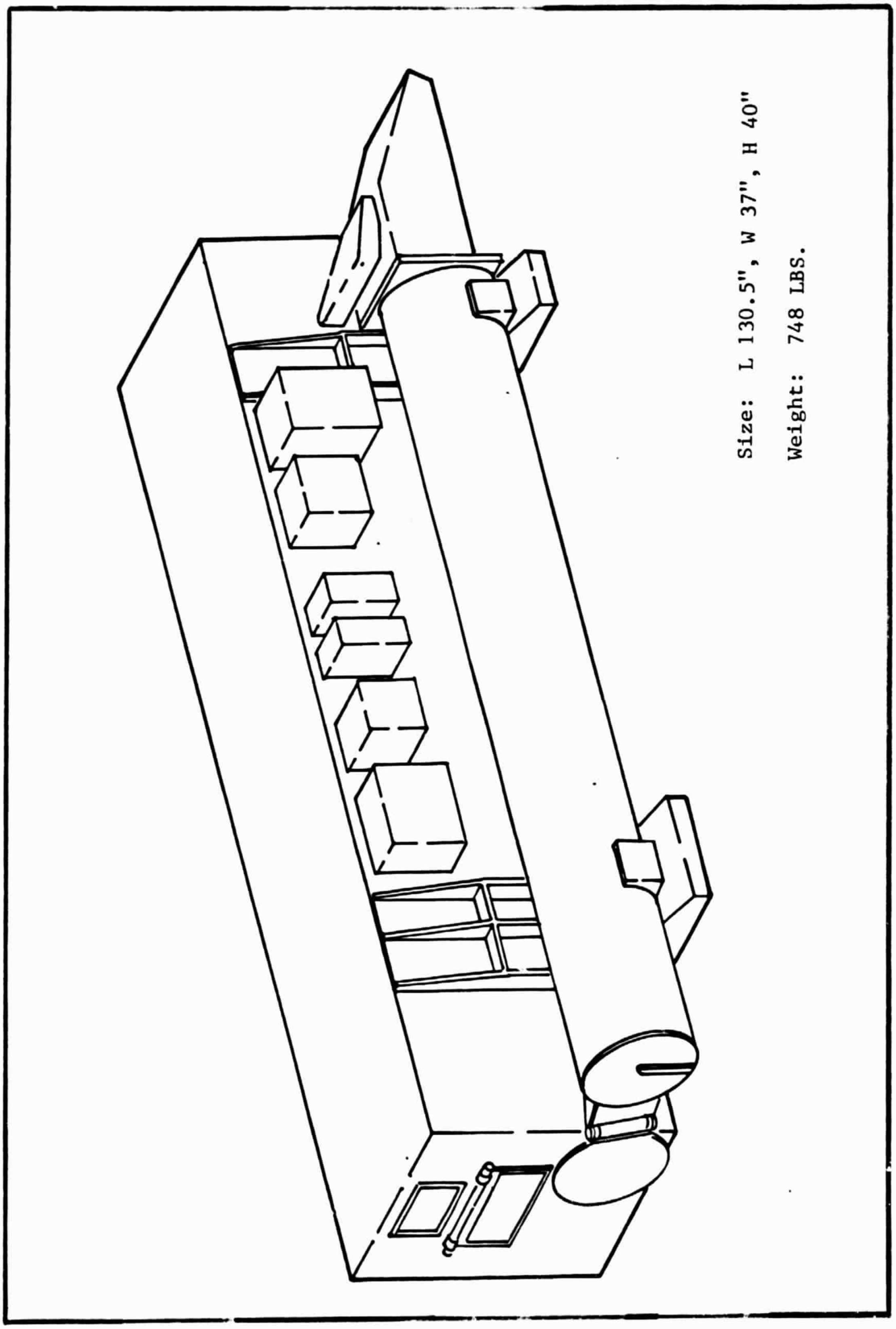

Figure 2-3 Spacelab Lyman Alpha-White Light Coronograph

Table 2-9 SLAC Power Operating Modes

Mode 1	-	Launch and Reentry	-	0 Watts
2	-	Power Down	-	60 Watts
3	-	On-Orbit Standby	-	84 Watts
4	-	Survey	-	147 Watts
5	-	Intensity	-	153 Watts
6	-	Profile	-	153 Watts
7	-	Hi Spect. Res.	-	153 Watts
8	-	Elect. Temp.	-	147 Watts
9	-	Disk	-	153 Watts

Table 2-10 WLC Power and Operating Modes

Mode 1	-	Launch and Reentry	-	0 Watts
2	-	Turn-On	-	55 Watts
3	-	Standby	-	40 Watts
4	-	Operate	-	70 Watts
5	-	Turn-Off	-	0 Watts
6	-	Troubleshoot	-	70 Watts

2.3.2.3 Thermal Control - The ARC is designed to operate in the near 0 degree centigrade operating conditions of the spacelab thermal shroud. The WLC has an active TCS in conjunction with multi-layered insulation blankets and surface finishes will heat the structure to hold the temperature to within a 21 $\pm$ 3^{o} C range from proper operation. The SLAC could operate at higher temperatures than 0^{o} C but a thermal re-design would be required. The externally mounted SLAC electronics box must be cooled separately. The WLC Film Canister contains film which is subject to damage when the film is subjected to high temperatures for prolonged periods of time.

2.3.2.4 Controls and Displays - The ARC requires AFD controls and displays but no television display is required. Normally, the ARC is controlled or operated via canned observing modes or data collection modes stored in the Dedicated Equipment Processor (DEP), but these modes can be specified by sending mode sequence commands from the AFD. Table 2-11 identifies the SLAC Controls and Displays, and Tables 2-12 and 2-13 identifies the WLC Controls and Displays.

Table 2-11 SLAC Controls and Displays

Controls	Source
1. Science Mode Load	POCC/AFD
2. Mode Sequence	POCC/AFD
3. Message to DEP	POCC/AFD
4. Discrete Commands (8)	POCC/AFD
- SLAC Power	
- Heater Power 1	
- Heater Power 2	
- Vacuum Override	
- TBD	
- TBD	
- TBD	
- TBD	

Display
1) Detector Data
2) Instrument Status Data #1/#2
3) Survey Data
4) Wavelength Scan Data
5) DEP Message to DDS
6) DEP Memory Load

Table 2-12 WLC Controls

Controls	Source
Standby Power on/off	POCC/AFD
TCS on/off	
$H\alpha$ TCS on/off	
Instrument pwr on/off	
initialize instrument	
door - open/close	
single/double Sequence	
halt	
std mode	
calibrate	
transient	
clear exp	
motorpower off/on	
insert$H\alpha$	
insertcal	
insert/remove mirror	
pathcornal	
pathHa	
pathcal	
nextfilter	
filterN(n)	
close/open Shutter	
matrix	
advance	
advanceN(n)	
time exp(n)	
coronal time(n)	
Hatime(n)	
filter seq	
inhibit/enable Film	
setframes	
inhibit/enable Sync	
wait(n)	
syncpulse	
door open override	
D4 auto/manual	
center D4	
step D4 X, Y	
read CMD register(n)	

Table 2-13 WLC Displays (AFD on Command)

Descretes	Analogs
SLAC Sync	Temp Hα
Shutter Open/Closed	Temp 1
Shutter Closed	Temp 2
Door Closed CMD	Temp 3
Door Closed	+28V SLPwr
Door Open CMD	+28V Stby Pwr
Door Open	+5V PWR
F.W.P. 1A-4A	+15V PWR
Geneva Lock A/B	-15V PWR
Calib Mirror In	
Hα In	**Serial Data**
Program Run	+28V Motor PWR
Up Running	X Pointing Error
Flip Mirror In/Out	Y Pointing Error
Film Advance	X D4 Error
DEP Busy	Y DR Error
Motor Power	Film Remaining
	Temperatures (10)

2.3.2.5 Contamination Control - During the operation of the ARC, it will be necessary to constrain thruster firings, waste and water dumps.

2.3.2.6 Command and Data Handling - The command and data handling requirements of the ARC are divided into those required by the SLAC and those required by the WLC. The data requirements of the SLAC are 900 bits per second through the data bus and from 25 to 50 kilobits per second of high rate data.

The data requirements of the WLC are 300 bits per second through the data bus and the 35 mm film which is to be removed after landing.

2.3.2.7 Operating Times and Modes - The ARC requires six (6) dedicated Orbits per day having two (2) hours of daylight observing on eight (8) hour centers. The operating modes for the SLAC and the WLC are described in Tables 2-9 and 2-10 respectively.

2.3.2.8 Orbital Requirements - The Orbit altitude required is above 200 km, but a higher altitude of 400 km or better is preferred. No inclination is specified.

2.4 Pointing Requirements

The pointing requirements of all the instruments are discussed in Section 4.5.

2.5 Mission Requirements

Mission requirements have been reviewed of all instruments selected for this study as well as the instrument/experiment operating requirements and scientific objectives in order to establish an integrated set of mission requirements and still satisfy the thermal, communications, and power requirements. The integrated requirements are as follows: Altitude 400 km (216 n.mi.); Inclination 28.5 degrees; Beta angle of approximately 52 degrees (Launch date Dec. 18); Attitude will be solar inertial with the x axis in the Orbit plane; mission duration, 7 days. These requirements also place specific requirements on the Orbiter such as, no OMS kits are required and 1 energy kit is required for supplemental electrical power.

3.0 ATM REUSE REVIEW AND ASSESSMENT

The ATM reuse review was accomplished in three (3) phases: 1) The post Skylab Spacelab/Multiple Telescope Mount (MTM) ATM feasibility study documentation review; 2) ATM drawing review; and 3) Review meetings with the Lead Engineers of the Spacelab/MTM ATM feasibility study.

3.1 Documentation Review - The documents shown in Table 3-1 were reviewed. These documents covered both the initial Spacelab feasibility study and the follow-on Multiple-Telescope mount study as well as the Skylab Operations Handbook. All Working Group Minutes and Action Items were also reviewed.

3.2 ATM Drawing Review - In addition to the documentation review, ATM drawings were obtained from storage and reviewed. These drawings and a parts list and hardware status is presented in the attached Appendix A.

This status contains the drawing number and hardware list, the location of the part on the ATM, the No. required, spares in storage, modification requirement, and the Original vendor.

3.3 ATM Review Meetings - The review meetings held with the Original STS/Spacelab/MTM Study conducted in 1974 and 1975 are as follows:

Engineering Technical Lead	-	G. Stone
Structures	-	J. Swickard
Thermal	-	C. Class
G & C	-	L. Cloud
C & DM	-	T. Rasser
Power	-	O.B. Smith
Contamination	-	E. Ress

All original study leads are still employed by Martin-Marietta, Denver.

Table 3-1 ATM Review Documents

Document/Title			Date Prepared
1) Spacelab ATM Payload Interface Definition Document			Feb. 1974
2) Spacelab ATM Feasibility Study:			
	Vol. I	Technical Report	Sept. 1974
	Vol. II	Executive Summary	March 1975
	Vol. III	Structures	Nov. 1974
	Vol. IV	Thermal	Nov. 1974
	Vol. V	Attitude and Pointing Control System	Nov. 1974
	Vol. VI	Instrumentation and Communication	Nov. 1974
	Vol. VII	Controls and Displays	Nov. 1974
	Vol. VIII	Contamination	Nov. 1974
	Vol. IX	Electrical Power	Nov. 1974
3) Final Report ATM Shuttle Payload Feasibility Study (F74-07)			Oct. 1974
4) Progress Report, Multiple Telescope Mount (MTM) (ED-2002-1764)			Feb. 1974
5) Integrated Mission Planning, First Two Years of Shuttle Missions, Mission ATM-B, Spacelab Mission Pallet Only, Apollo Telescope Mount			Oct. 1974
6) APCS Analysis of the ATM as a General Payload Carrier			Dec. 1974
7) Spacelab MTM Feasibility Study Working Group Meeting Presentations and Minutes			
8) Skylab Operations Handbook, Apollo Telescope Mount Systems and Experiments Description			July 1971

4.0 ATM, IPS & AGS DESIGN CONCEPTS

4.1 Structural/Mechanical

4.1.1 Introduction - This section provides the results of the structural/mechanical portion of the study on the feasibility of mounting new solar instruments in the existing ATM hardware. The study work has been of a conceptual design nature consisting primarily of layouts and providing analysis only where required to validate the design approach. The previous ATM study work has been utilized as a starting point, and new approaches have been investigated only where benefits could be gained without the sacrifice of the existing, workable system.

The ATM hardware was evaluated for use in three different pointing systems; the existing ATM fine pointing control system, the Instrument Pointing System, and the Annular Gimbal System.

A set of self-imposed requirements/guidelines used during the study are listed below:

- Utilize to a maximum the existing ATM hardware.
- Maintain the canister center of gravity to within 1.5 inches of the spar/canister centerline (to achieve similar pointing accuracies as on Skylab).
- Baseline film removal in the OPF after ATM removal from the Orbiter (previous studies have shown film able to withstand re-entry soak temperatures).
- Assume shared STS flights (payload of opportunity).

4.1.2 ATM Hardware Review - This section is presented to review the characteristics and capabilities of the existing ATM hardware and to provide the background such that the design concepts presented in following sections can be more easily followed. The existing ATM hardware can be divided into three major structural levels; the SPAR Assembly, the Canister Assembly, and the Canister Support Structure.

Figure 4.1.2-1 depicts the ATM SPAR as configured for the Skylab mission.

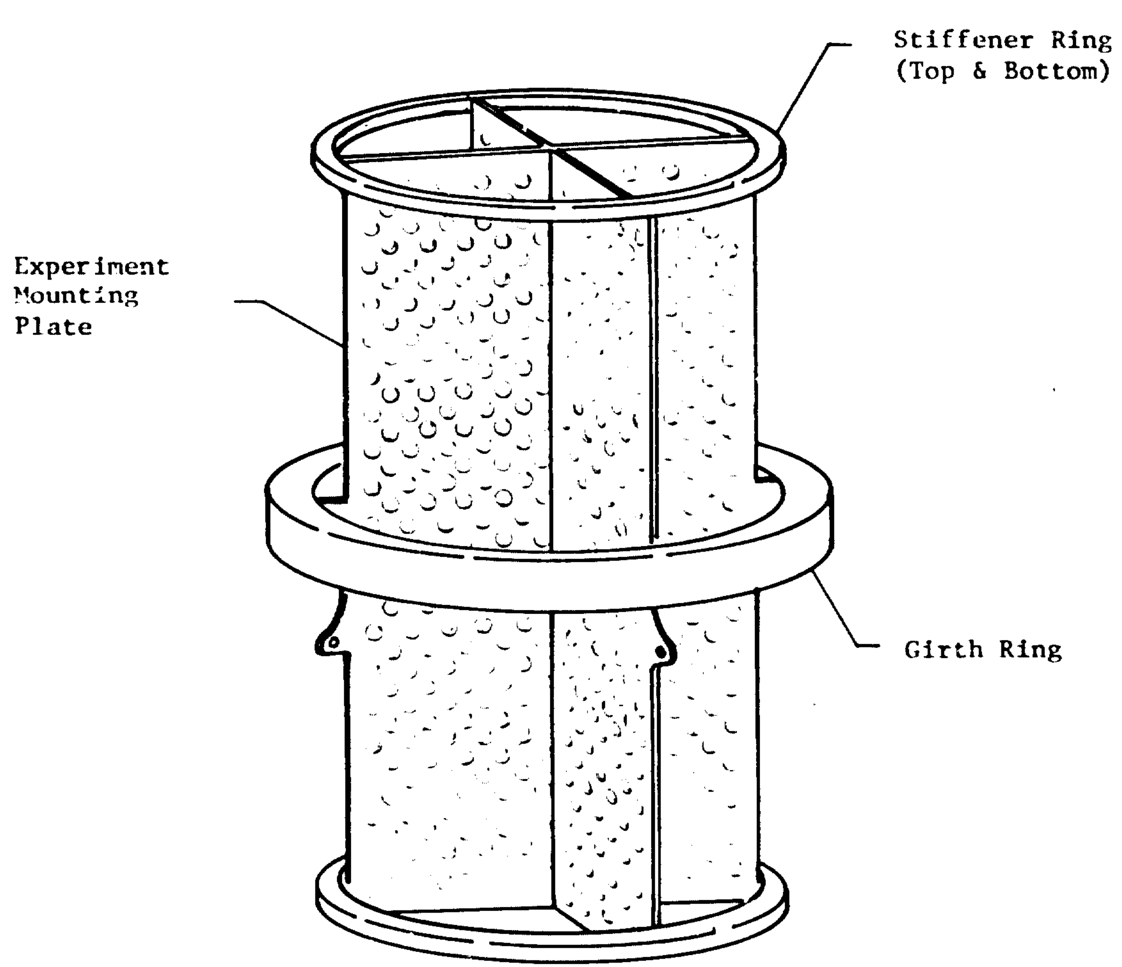

Figure 4.1.2-1 ATM SPAR

This cruciform SPAR provides the structural interface for the instruments and serves as the system optical bench. The SPAR consists of the experiment mounting plate, stiffener rings, and the girth ring. The experiment mounting plate provides eight mounting surfaces for instrument attachment. These plates are made from 1-1/8 inch aluminum plate and are approximately 60" x 120" each. Two-inch diameter lightening holes are located over the surface of the plates and cause a 40% weight reduction. In use, multilayer insulation blankets completely enclose the mounting plate to prevent thermal gradients on the plates. Stiffener rings located top and bottom increase the overall stiffness of the assembly. The girth ring adapts the SPAR assembly to the next structural assembly (Canister Assembly) and also interfaces with the fine pointing system,gimbal rings and the launch lock system. The girth ring is 88 inches in diameter and is 8 inches deep in cross section. The overall SPAR assembly is 88 inches in diameter and has a length of approximately 120 inches. The total assembly weighed approximately 1400 lbs. on Skylab.

As shown in Figure 4.1.2-2, the ATM Canister is made up of the SPAR assembly, the Sun End Canister and the MDA End Canister. This assembly contains the instruments, has a complete self-contained active thermal control system, and is the element that is pointed by the fine pointing system. The girth ring from the SPAR assembly can be seen in the figure at the interface of the two canister assemblies.

The Sun End Canister is a cylinder, open at one end, made up from two concentric shells and the sun shield assembly. Eight cold plates form the inner shell and permit heat transfer via radiation from the SPAR mounted instruments. The outer shell is made up of four radiator panels which exchange heat from the cold plates via the fluid medium and radiate it to space. Forward on the canister is the sun shield assembly which shades the radiator panels from solar impingement and houses the aperture doors for experiment viewing.

The MDA End Canister is similar in construction to the Sun End Canister except that there is only a single shell consisting of 8 cold plates.

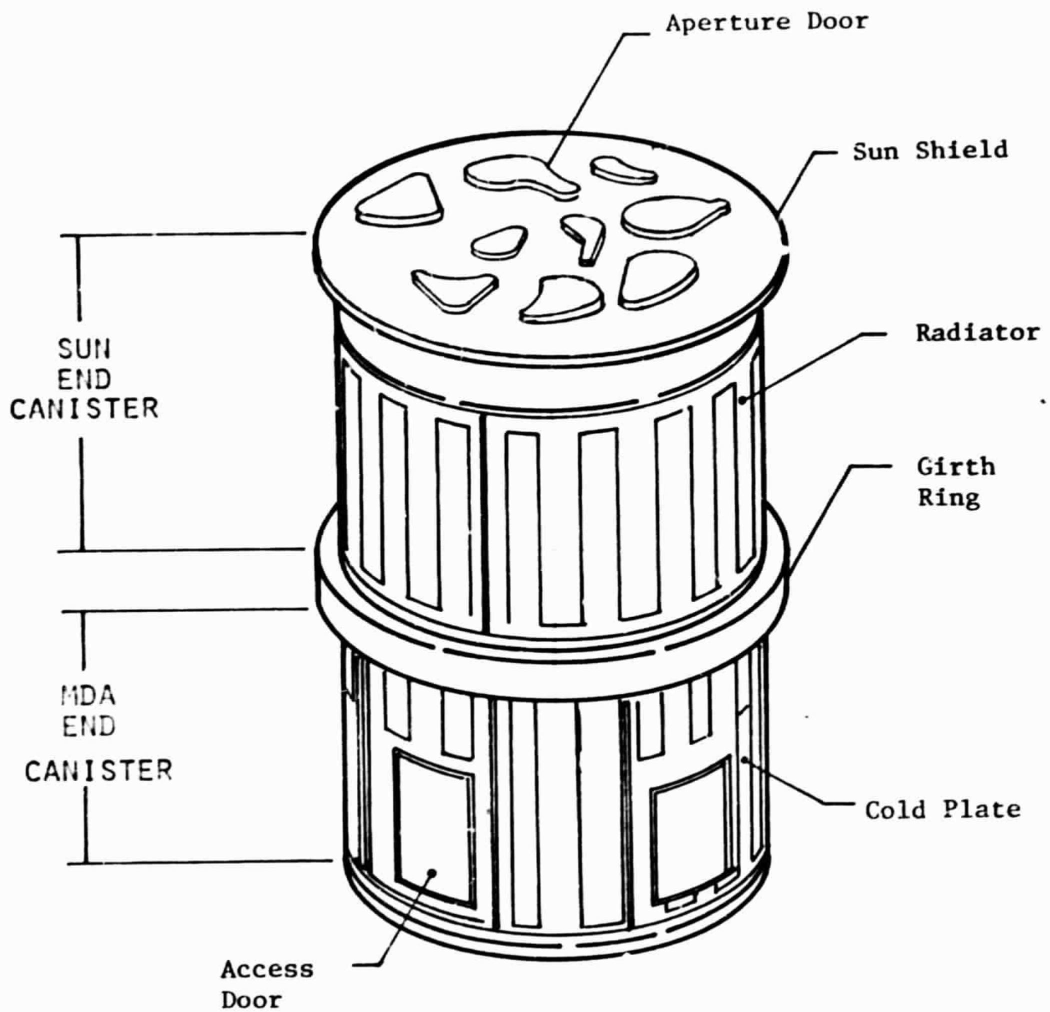

Figure 4.1.2-2 ATM Canister

Additionally, five of the cold plates have access doors in the panels for film and experiment access. The aft end of this canister has a simple bulkhead design for the external mounting of subsystem equipment. Overall ATM Canister dimensions are: 107 inch diameter at the sun shield and a length of 128 inches. Without instruments, the assembly weighs approximately 4100 pounds.

In actual usage, the instruments are built up on the SPAR assembly which is supported by a GSE support fixture. After instrument integration and checkout, the canisters are installed over the top and bottom of the SPAR and are structurally connected to the girth ring. Cabling hookup and fluid connections between the cold plates and radiators complete the assembly.

The third major ATM structural element is that structure which supports the ATM Canister and provides the interface to the vehicle. On Skylab, the ATM Rack Structure performed this function and interfaced with the MDA. Due to size problems (cargo bay envelop violations), the previous ATM study determined that the ATM Rack Structure approach could not be used.

Figure 4.1.2-3 is the Canister Support Structure (CSS) developed in the earlier ATM feasibility studies. This structure interfaces with the ATM Canister Assembly via pitch and yaw gimbal rings connected to the SPAR girth ring. The CSS also provides the launch/landing lock interfaces between the structure and the ATM Canister. Construction is a combination of an eight-sided torque box and truss-type structure. A direct Orbiter interface is used with a standard statically determinate type interface consisting of two primary longeron attachments (at the canister centerline), one stabilizing longeron attachment, and the keel fitting located also at the canister centerline. Truss structure ties the Orbiter interface trunnions back to the torque box structure.

The inner surface of the torque box provides the structural attachments for both the gimbal rings and also houses a new launch/landing lock arrangement also developed during the earlier studies.

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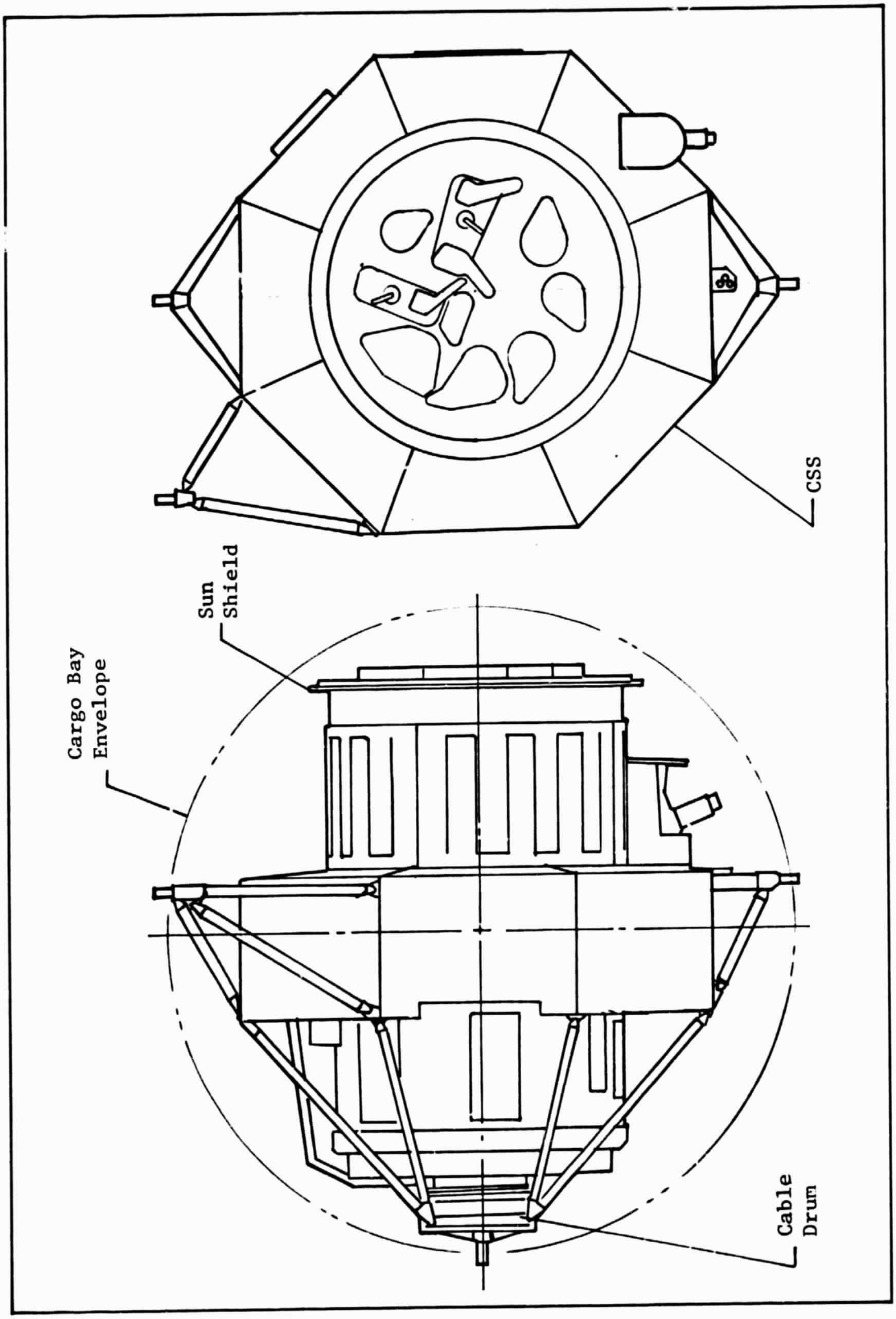

Figure 4.1.2-3 ATM Canister Support Structure

The one shot, ordinance initiated lock on Skylab does not lend itself to a redesign that allows relatch for landing. A ball-screw driven latch concept was proposed as the design fix and this concept will be baselined for this study also.

The figure also depicts the ATM Canister/CSS in the cargo bay envelope and shows the limits imposed on the ATM Canister length. Two areas on the existing canister system require modification to fit the cargo bay envelope. The Sun End Canister Sun Shield requires a reduction in diameter from 107 inches to 104 inches to fit the envelope and provide sufficient clearance. A cable drum which maintains control over the cabling during roll maneuvers is shown near the keel area. As configured on Skylab, the cable drum would extend beyond the bay envelope. The figure shows both the modified cable drum and sun shield.

The top surface of the CSS incorporates a slight slant which serves to prevent solar reflection back onto the radiator surfaces. A startracker and acquisition sun sensor from the ATM Rack Structure have also been relocated to the CSS.

Preliminary design data from the earlier study indicates a total weight of 1900 pounds for the 142 inch x 194 inch x 173 inch structure.

Figure 4.1.2-4 illustrates a new element developed during the previous studies. This Electronics Component Unit (ECU) supports the subsystem equipment (control, power and pointing) that was originally mounted on the ATM Rack Structure. This concept uses a Spacelab pallet to mount a new equipment truss which supports approximately 2500 pounds of subsystem equipment. Thermally sensitive equipment is located on Spacelab cold plates on the truss and a sun shield is provided over the entire pallet to prevent solar entrapment.

4.1.3 ATM Pointing System Concept

4.1.3.1 Instrument Mounting Concept - This section addresses the integration of the Solar Instruments into the existing ATM hardware. In this ATM Pointing System concept, the ATM Canister Support Structure with the ATM Pointing System is baselined and the main

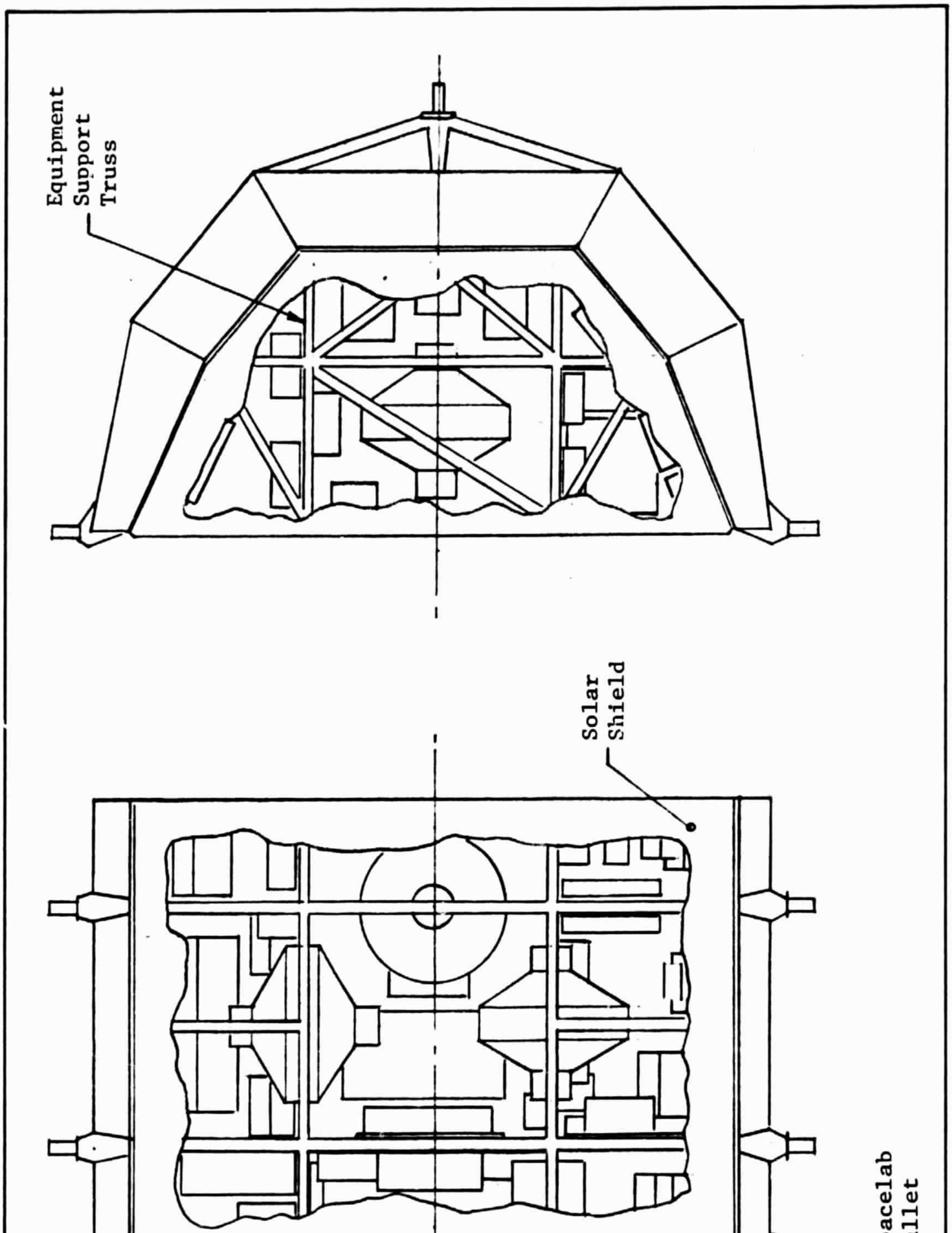

Figure 4.1.2-4 Electronics Component Unit

discussion is centered on the instrument mounting approaches.

The relationship between the volume available for instrument mounting as provided by the ATM Canister and the instrument size is shown in Figure 4.1.3.1-1. Note that SEUTS will fit within a quadrant if mounted at a diagonal. The mounting envelope restrictions (i.e., 36.5 inch radius) are due to the canister cold plates and SPAR stiffener rings. It is apparent from the figure, that a simple approach involving secondary structure to adapt the instrument is not feasible.

Three design concepts for instrument mounting were evaluated: An external shroud concept, a new canister approach, and a two instrument concept.

The external shroud concept (Figure 4.1.3.1-2) was an attempt to mount two instruments within the existing canister and provide an external shroud on the outside surface of the canister to house the third instrument. There are a couple of obvious problems with this approach. Due to the geometry of the gimbal rings and the CSS, the third instrument ends up being located approximately 80 inches off the canister centerline. The CG offset effect on the pointing system is so significant that an almost equal weight (750 pounds) must be provided at a similar offset as ballast. Additionally, at this amount of offset, the canister can only be rotated through less than 90° due to interference with the cargo bay side walls. These problems were deemed to be of sufficient magnitude to drop this approach from further consideration.

The second approach considered, examined the potential of providing a new structural enclosure to mount the three instruments and utilize as much of the existing ATM hardware to outfit the thermal and pointing systems. Potential reuse items identified include: ATM Sun End Canister radiators, Sun End and MDA End Canister cold plates, thermal control system pumps, valves and other components, and the pointing drives (assuming the mass properties for the new canister would be similar to the existing canister). New components required include; the canister

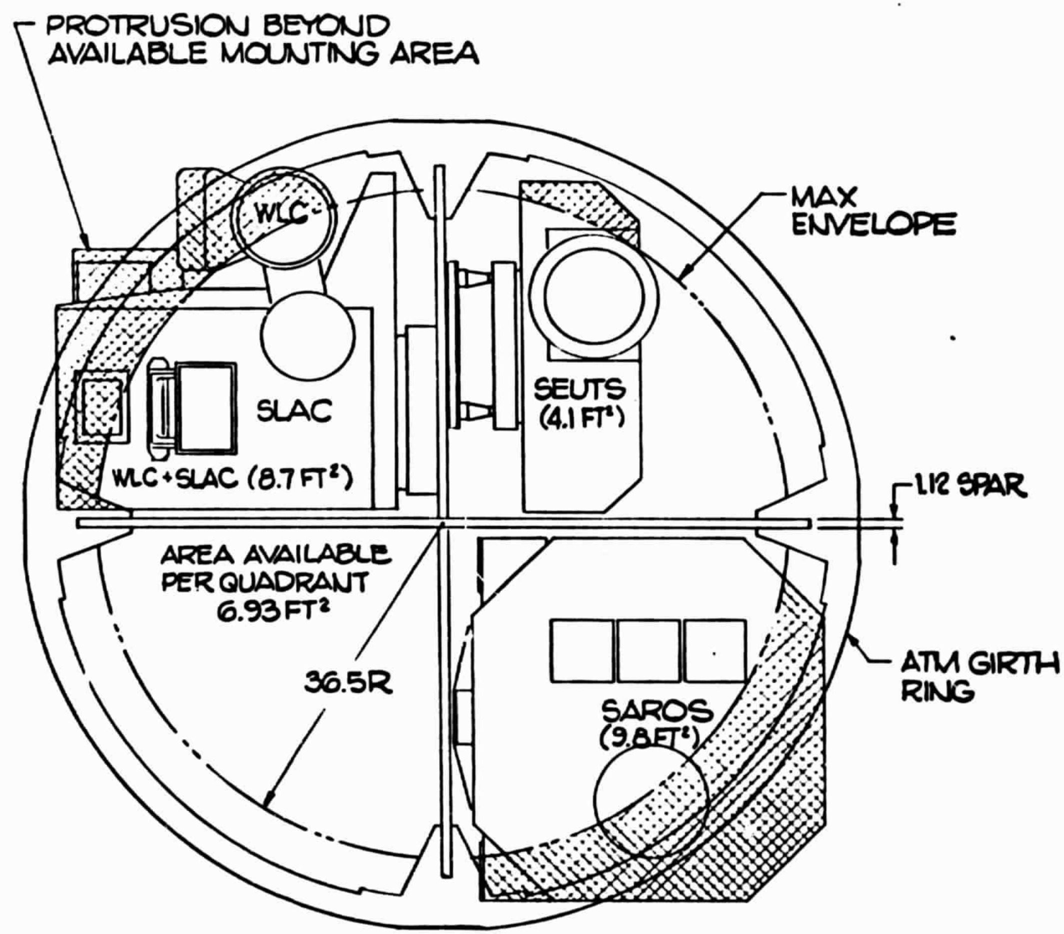

Figure 4.1.3.1-1 ATM Mounting Volume Versus Instrument Cross Section

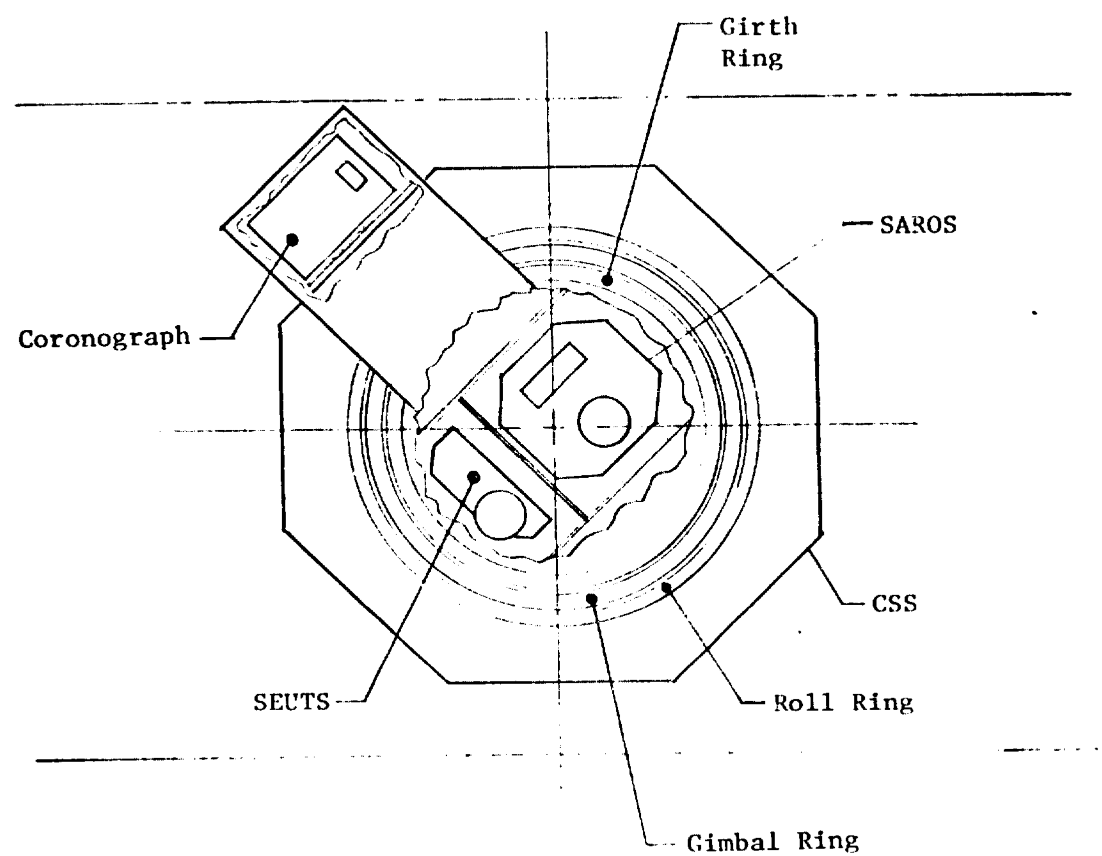

Figure 4.1.3.1-2 External Shroud Concept

structure (approximately 90 inches x 90 inches x 140 inches) and new gimbal rings (pitch and yaw). Figure 4.1.3.1-3 shows a preliminary version of the new canister concept. During the evaluation, it was concluded that the new canister approach was not feasible based on the following points. Additional qualification testing would be required for the new canister approach which could involve thermal vacuum testing as well as vibration testing. The most significant drawback to this new canister scheme is that the pointing system accuracy may not be maintained at the precise levels achieved using the Skylab ATM system. Finally, the cost involved in the design and fabrication of the new elements along with the cost incurred in testing make this option unattractive.

In keeping with one of the groundrules to minimize ATM hardware modifications, a minimum mod approach was developed where only two instruments would be utilized on a single mission. This approach for SEUTS and SAROS is shown in Figure 4.1.3.1-4. The modification required to accomplish this arrangement involves primarily a change out of the experiment mounting plate. This deletion of the cruciform spar and replacement with a "H" section is a fairly simple modification.

The previous ATM study had noted that, due to the complexity of the Sun End and MDA End Canisters, structural mods should be limited to the SPAR and the experiment mounting plate area. The new "H" section mounting arrangement uses the existing girth rings and stiffener rings from the SPAR assembly and would require new 1-1/8 inch aluminum plates along with some bracket changes. As noted in the figure, the two instrument arrangement also includes the mounting of existing ATM SPAR equipment (rate gyro, fine sun sensor, pre-amplifier) and the RAU's for instrument data interfacing. The SEUTS electronic package is shown located near the telescope on the instrument mounting plate. Center of gravity constraints in all three axes have been maintained by the positioning of the instruments and subsystem equipment. Heat rejection from the instruments is primarily towards the open quadrants, however, openings could be provided through the side plates to provide additional local radiation paths.

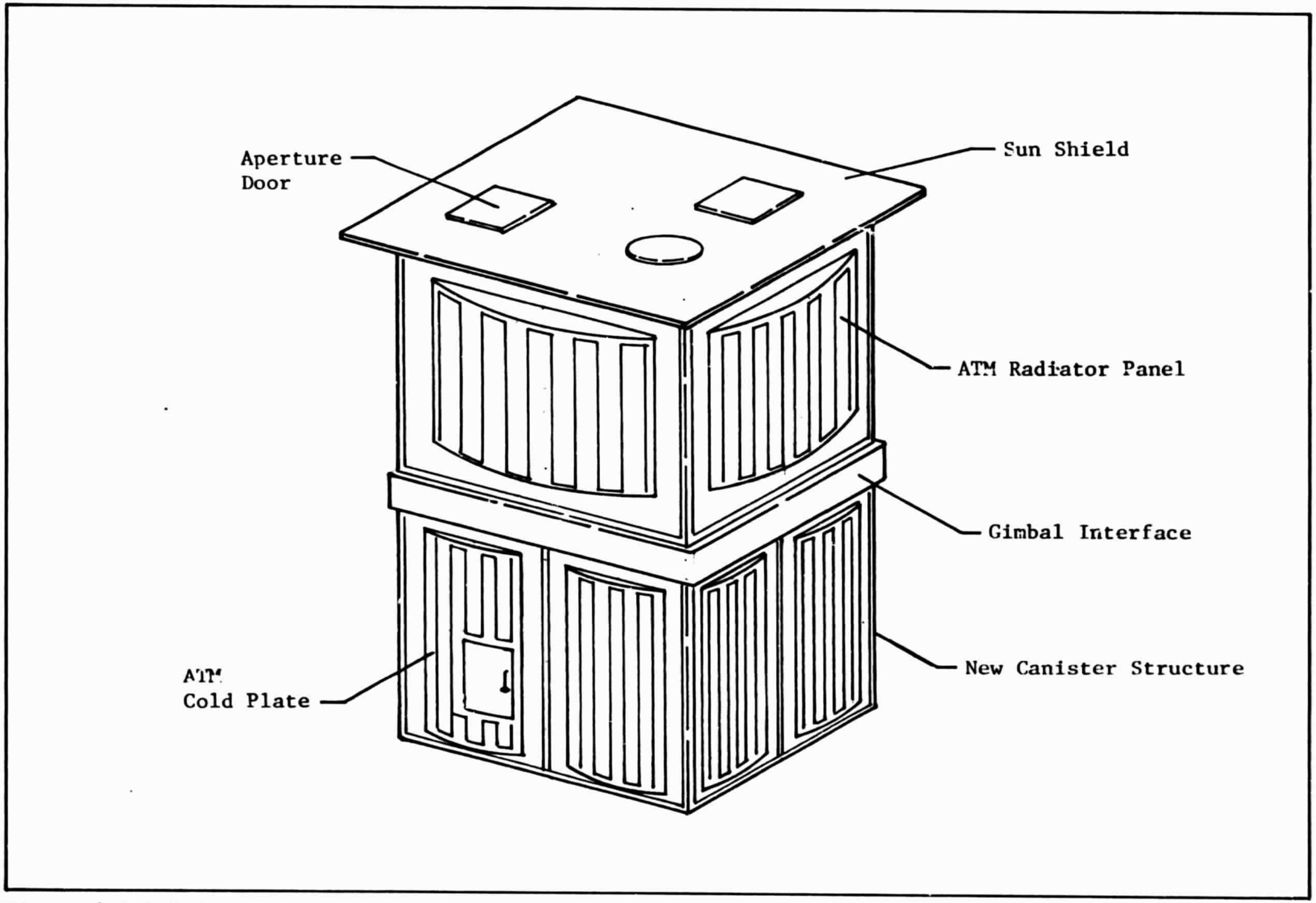

Figure 4.1.3.1-3 New Canister Approach

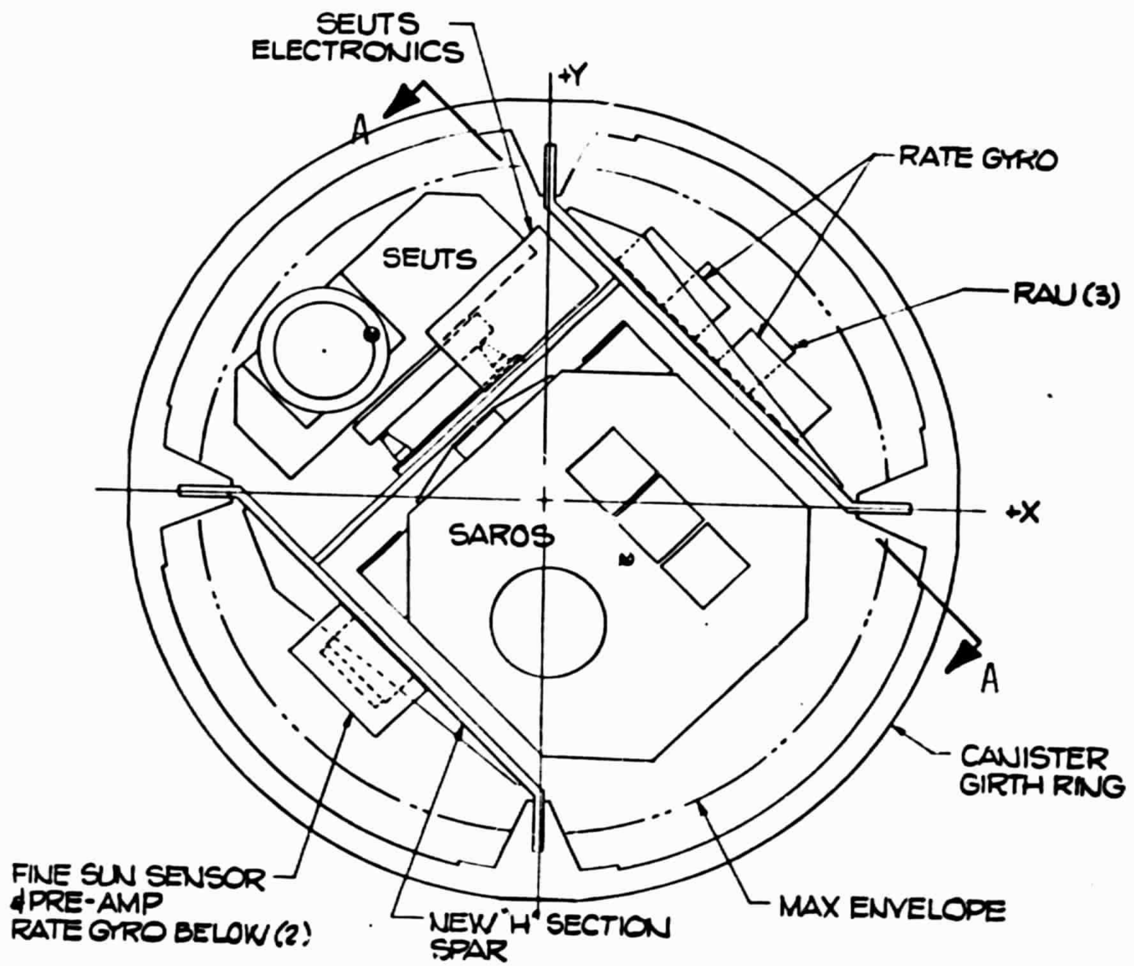

Figure 4.1.3.1-4 SEUTS and SAROS Option, End View

Figure 4.1.3.1-5 is a side view of the ATM Canister cut along the section lines indicated in the previous figure. An envelope restriction of 124 inches is shown at the bottom of the sketch. This restriction is due to the internal length of the ATM Canister. SAROS, at 109.5 inches in length, fits within the length envelope with enough margin to allow positioning to match its CG with the required SPAR CG.

SEUTS has an overall length envelope of 135 inches which includes an eight inch clearance at the aft end for thermal reasons. To accommodate SEUTS, a number of options were considered. Lengthening the entire ATM Canister by providing spacers at the attachment of the Sun and MDA End Canisters to the girth ring is not workable due to the protrusion into the cargo bay envelope. Allowing the SEUTS to protrude through the forward sun shield has some potential in that new aperture doors must be provided in any case to handle the new instrument locations. This local protrusion could accommodate an eleven inch extension and remain within the cargo bay envelope, but only 2-3 inches would be available for the aperture door and insulation forward of the telescope. An offset door arrangement could possibly be devised to handle this space limitation. Another consideration with this approach is the effect of thermal gradients on the instrument. Approximately 15 inches of the telescope would be forward of the cold plate region. Further study is required in order to reach a conclusion on the feasibility of extension through the Sun End Canister.

Access to the instruments is achieved through the five MDA End Canister access doors and two access doors on the Sun End closure. Figure 4.1.3.1-6 indicates a preliminary orientation of the new "H" section spar within the canister that allows fairly good access through the MDA End Canister cold plate access doors. However, due to the location of the access doors near the lower end of the MDA End Canister, they will not provide complete access over the length of the instruments. The forward two access doors are useable only for access just aft of the sun shield. SAROS does have the majority of its access doors on the lower half of the instrument. SEUTS, however, has the film camera

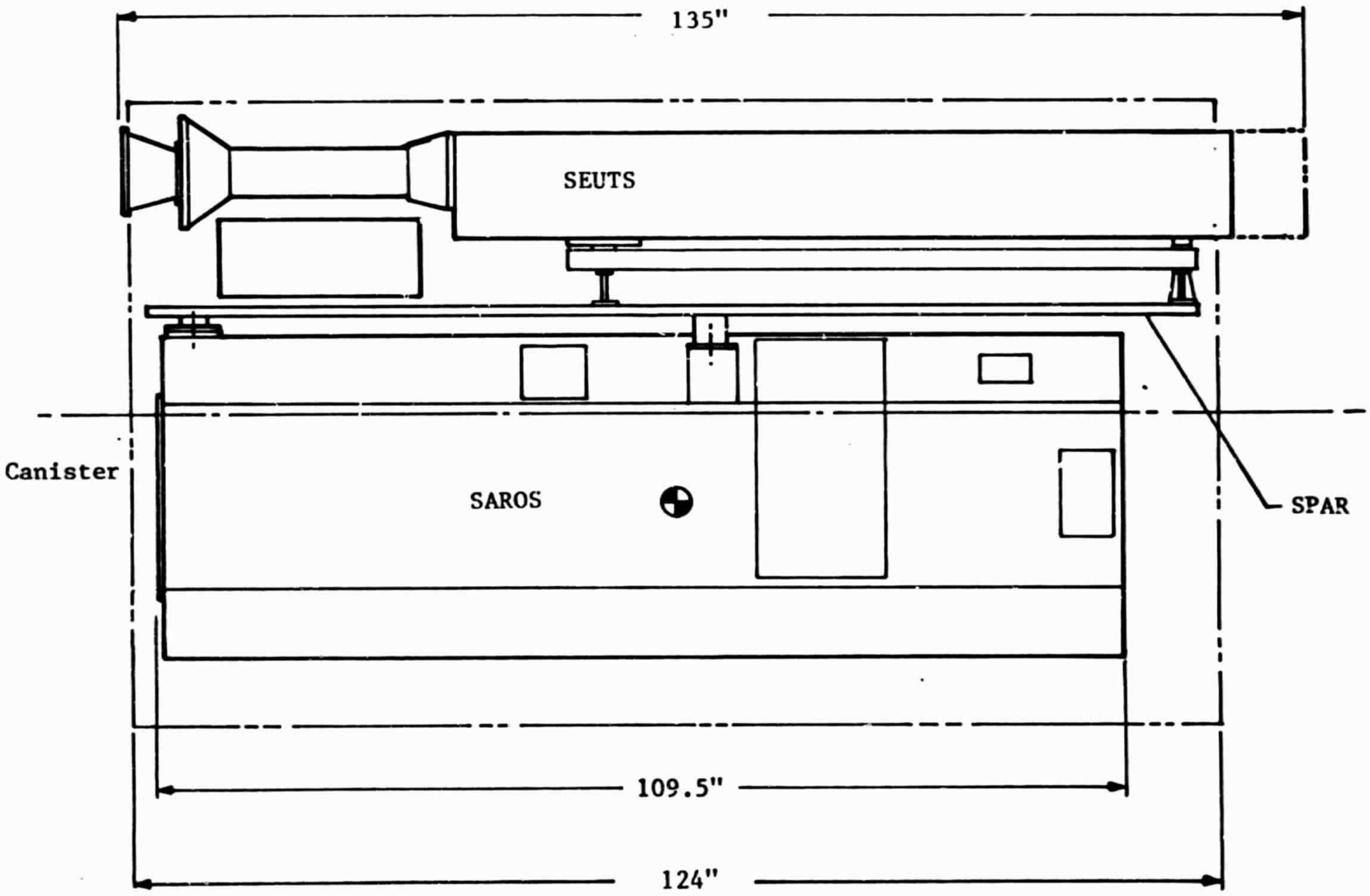

Figure 4.1.3.1-5 SEUTS and SAROS Option, Side View

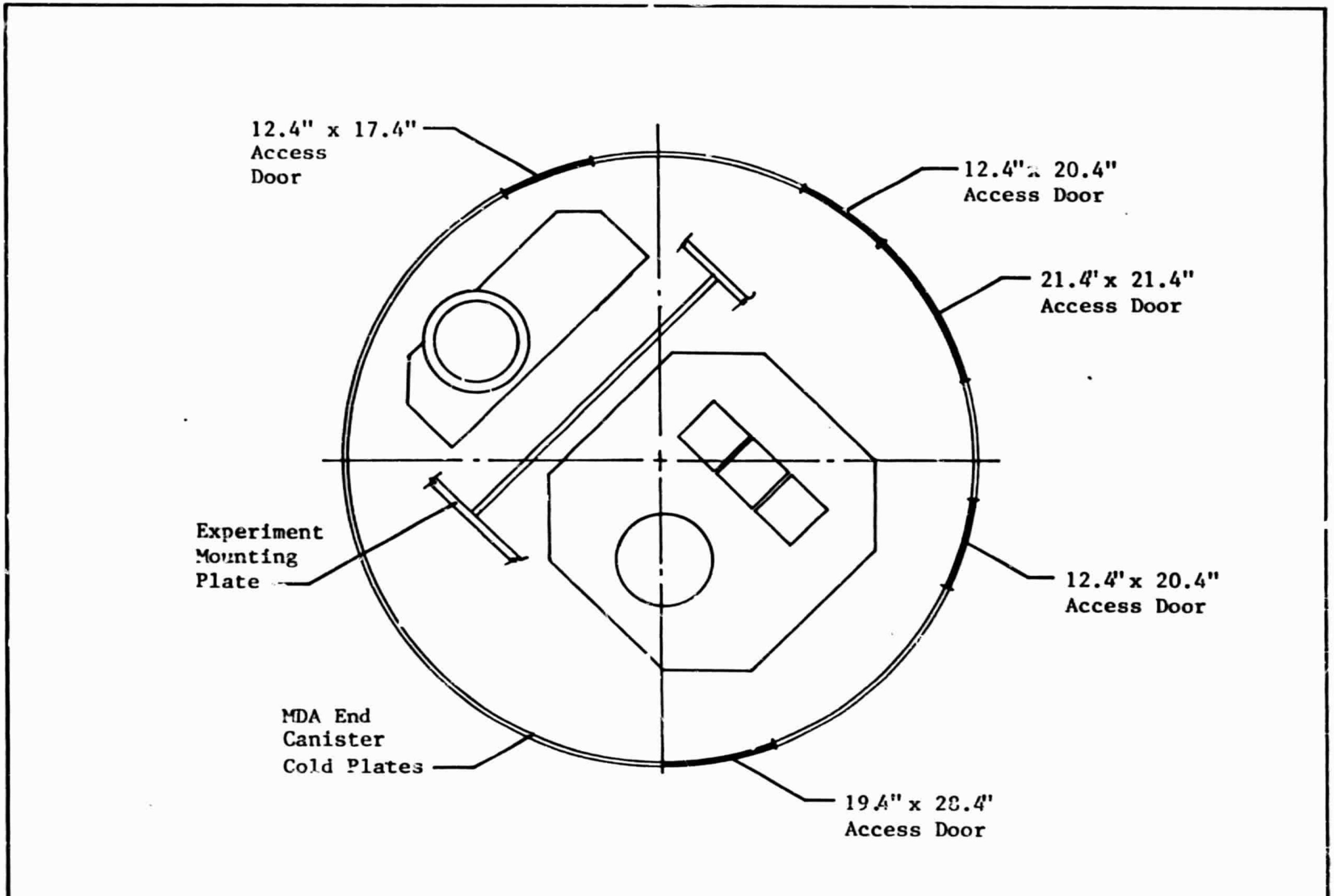

Figure 4.1.3.1-6 Instrument Access

located approximately at the midpoint, and access compatibility requires additional investigation and data.

Figure 4.1.3.1-7 is an end view of the canister showing a two instrument arrangement with SEUTS and ARC. Note that it is not possible to combine SAROS with ARC in the available canister space. The same "H" section spar arrangement as for SEUTS and SAROS is used for these instruments with the same subsystem equipment locations. Here again, the CG can be maintained by relocation of subsystem equipment or by the use of ballast. Figure 4.1.3.1-8 is the side view of the SEUTS and ARC instrument configuration. In this combination, both SEUTS and ARC exceed the 124 inch length envelope. At 130.5 inches, ARC appears to be better suited to the protrusion approach because additional space would be available for door construction. The large forward cross section would, however, require a sizeable door and cutout to handle the protrusion. Access provisions are similar to that shown in Figure 4.1.3.1-6.

In both instrument approaches, the forward sun shield area requires modification to align the aperture doors with the new instruments field of view. The existing ten doors in the Sun End Canister were checked against the new solar instrument requirements, and were found to be incompatible. Because of malfunction during Skylab, the aperture door mechanism will also require some upgrading to insure better reliability. Any door redesign effort should consider a universal door approach that would allow alternate instruments and locations to be flown without a complete door redesign. The two instrument design concept has baselined the replacement of the existing door arrangement with two new doors that will handle either SEUTS and SAROS or SEUTS and ARC. Revision of the entire sun end closure assembly is required to provide the new doors and also provide the cargo bay envelope clearance.

4.1.3.2 ATM System Configuration Options - In order to provide a complete pointing system, the ATM Canister/Canister Support Structure requires a sizeable list of supporting electronics and equipment.

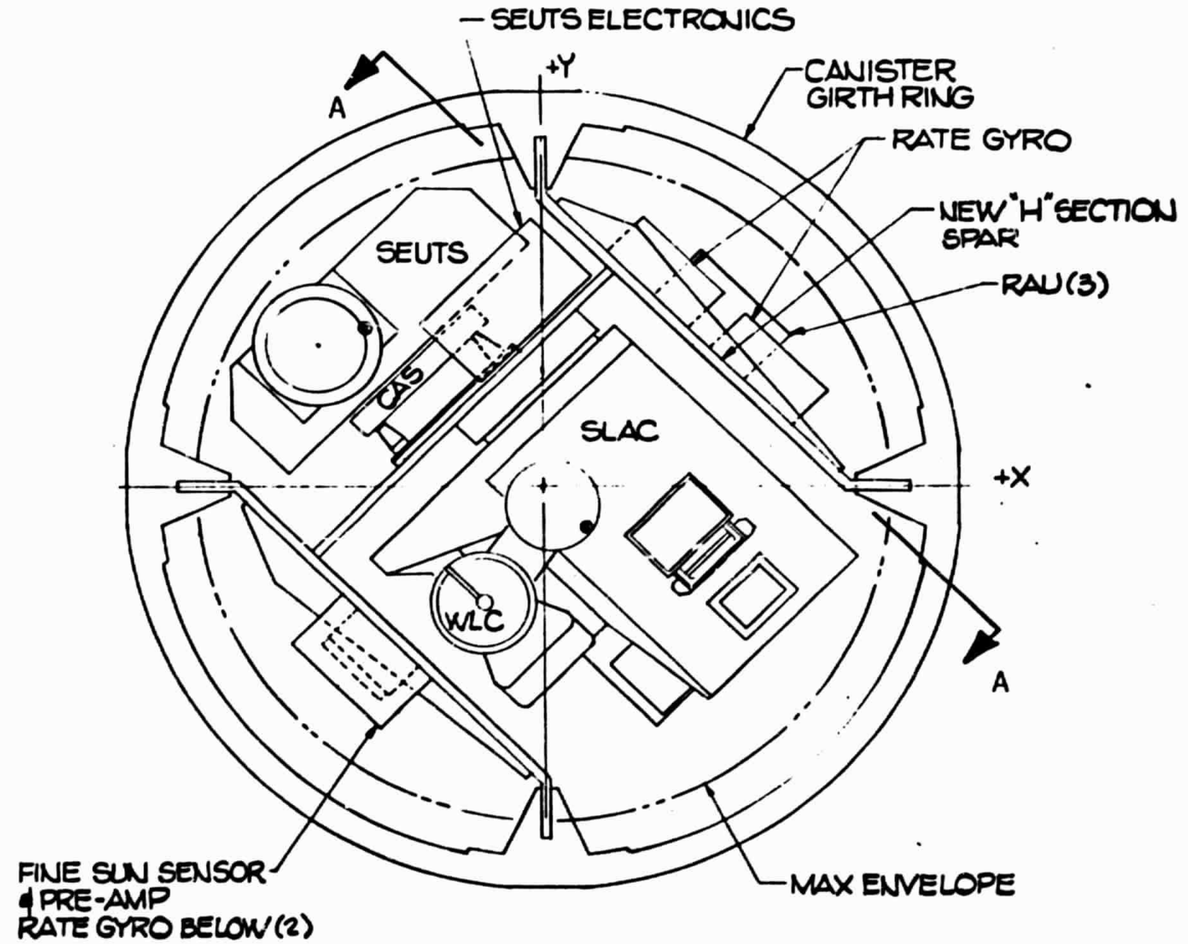

Figure 4.1.3.1-7 SEUTS and ARC Option, End View

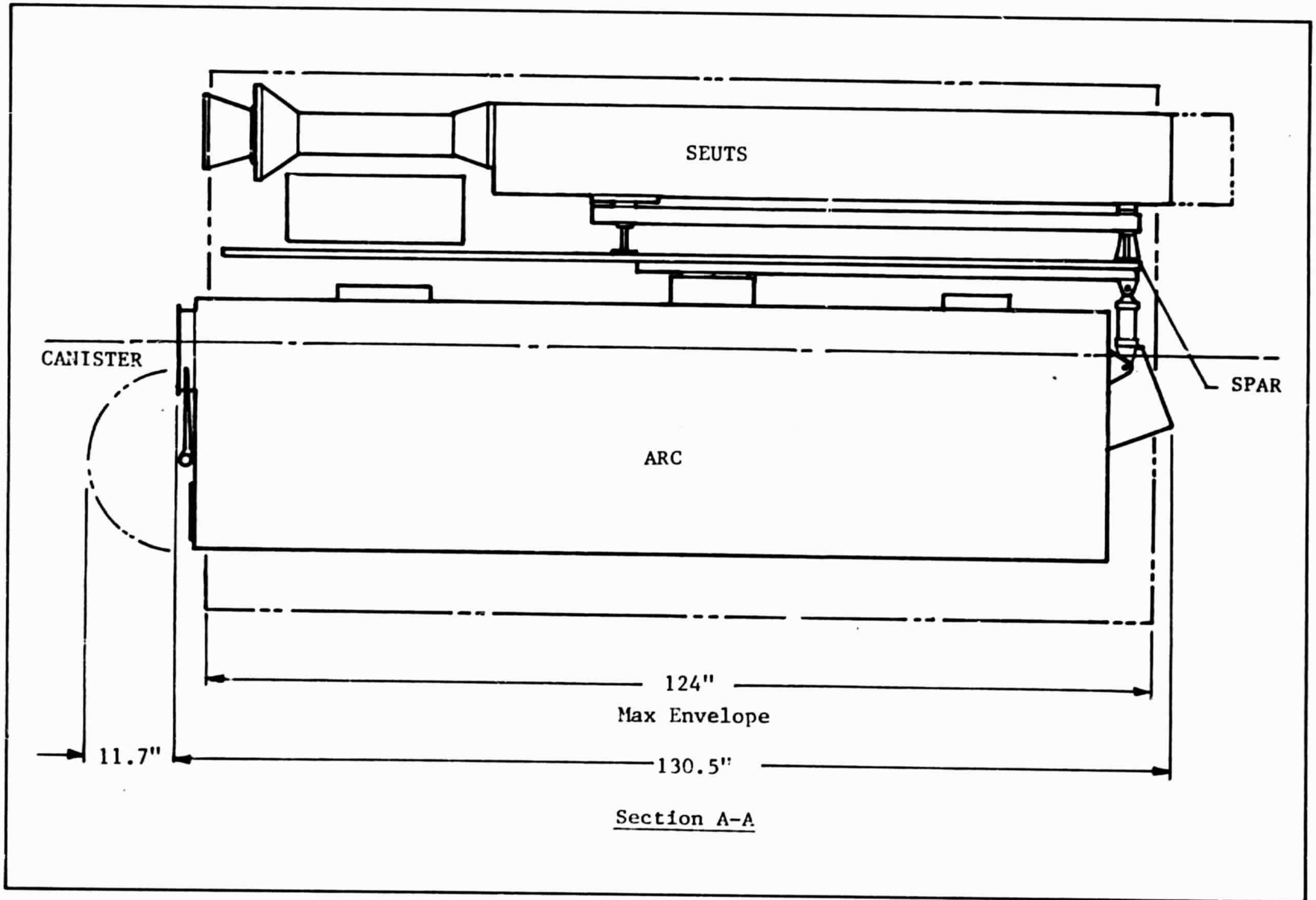

Figure 4.1.3.1-8 SEUTS and ARC Option, Side View

As mentioned in Section 4.1.2, the Skylab supporting hardware was proposed to be relocated off the ATM Rack Structure and integrated into the new Electronics Component Unit (ECU). In addition, to interface properly with the instruments, the use of Spacelab data system components have been baselined (see Section 4.2). The use of these three major system elements allows for two primary system configurations. The first system uses the ATM Canister/Canister Support Structure along with the ECU that includes the Spacelab Igloo (containing C & DH components). The second option involves the ATM/CSS and the ECU, but utilizes the Spacelab module to provide the C & DH interfaces. Both of these approaches were looked at during the former ATM studies.

This study investigated the feasibility of combining the subsystem equipment from the ECU (including the Igloo) onto the Canister Support Structure. Figure 4.1.3.2-1 depicts this Integrated ATM configuration.

The Spacelab Igloo is shown mounted on the Canister Support Structure torque box structure using a similar structural interface as on the pallet. Mounting of the three Control Moment Gyros (CMG) uses the orthogonal arrangement similar to Skylab. A truss structure supports the CMG's and reacts the launch and landing loads (as well as the reaction torques) back into the CSS structure. Control and data handling, power, and pointing control equipment is now located below the CSS octagon structure on equipment trusses located off the keel support truss members. A list of the truss-mounted equipment is provided in Table 4.1.3.2-1.

A thermal enclosure is provided over this equipment and as noted in the table, cold plates are required on some of the electronics. The Orbiter active cooling system would be connected to the cold plates using the Orbiter to payload interface system.

The integrated ATM Figure 4.1.3.2-1 also shows the new, two door, aperture door arrangement discussed previously.

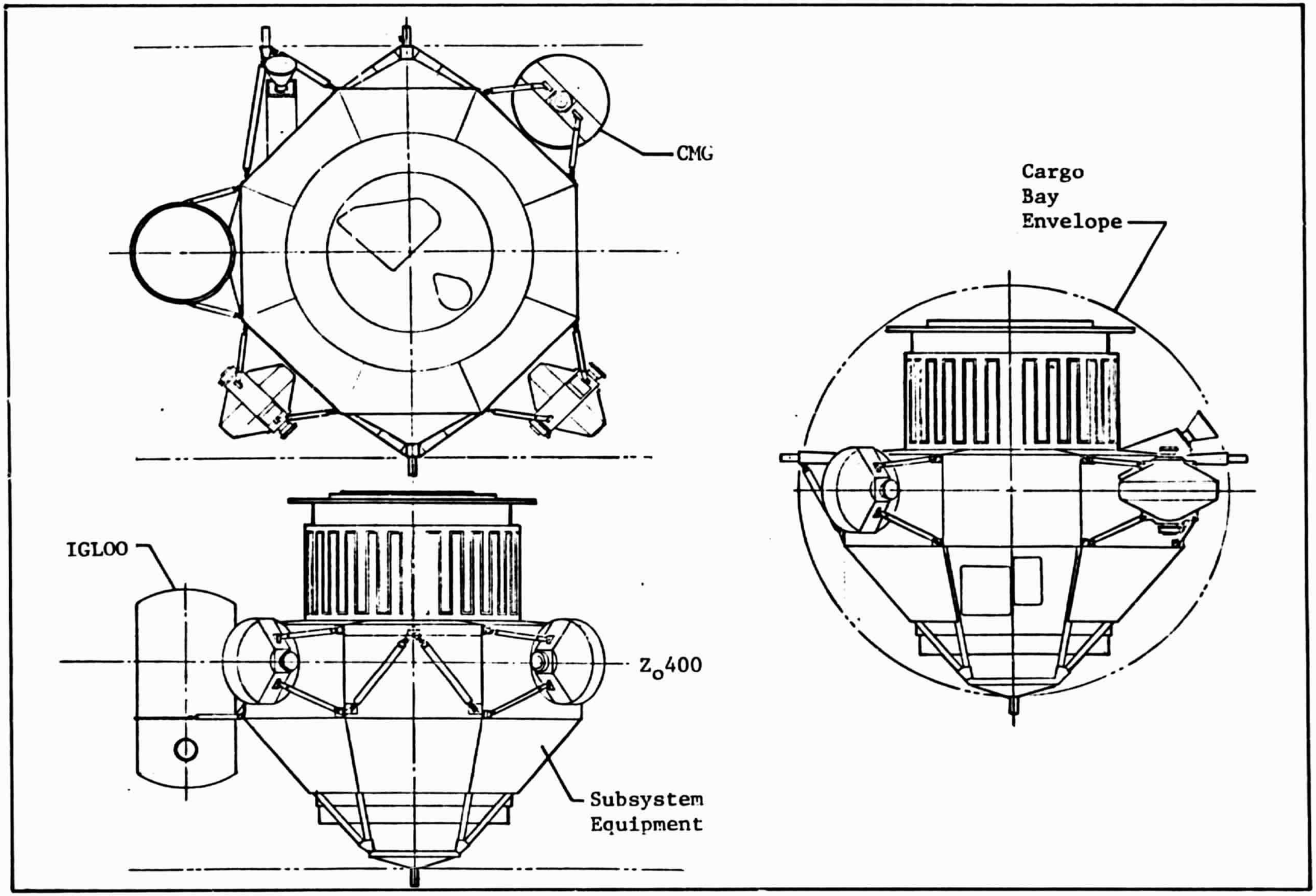

Figure 4.1.3.2-1 Integrated ATM Design Approach

Table 4.1.3.2-1 Integrated ATM Subsystem Equipment List

ITEM	WEIGHT(lbs)	QTY.	REMARKS
CMG Assembly	420	3	
CMG Inverter Assembly	52	3	Cold Plate Mtg.
ATM Digital Computer	100	2	" " "
Experiment Pointing Electronics	185	1	
Workshop Computer Interface	105	1	Cold Plate Mtg.
Acquisition Sun Sensor Elect.	1.5	2	
Voltage Regulator	14	1	
Signal Conditioner Rack	15	4	
Memory Load Unit	20	1	
MLU Tape Recorder	10	1	
Startracker Electronics	32	1	
Remote Acq. Units (RAU)	21	4	New Equipment
Amplifier Package	8	1	" "
Electrical Power Dist. Box	18	1	Spacelab Equipment
Inverters	73	1	" "
High Data Rate Recorder	104	1	" "
Fine Sun Sensor Sign.Cond.	17	1	

Access to the ATM canister is achieved through an opening between the CSS keel trusses (end view in figure). This access arrangement makes use of the capability of the pointing system roll ring to rotate the canister under 1g conditions. This allows the five access doors to be positioned in alignment with the opening.

As shown on the figure, the Integrated ATM measures 204 inches in length (Igloo to CMG's) 194 inches wide (dimension across cargo bay trunnions), and is 170 inches in height. The total system weight with the heaviest combination of instruments is approximately 14,700 lbs. This compares to 16,600 lbs. for the ATM and ECU (Igloo) option which is 307 inches long.

4.1.4 Instrument Pointing System (IPS) Interface - In this concept, the ATM canister is used with very little external modification. The existing thermal control system maintains an acceptable temperature for the experiments. A cylindrical shell provides the structural interface between the ATM canister and the pointing system. The existing ATM pointing system is not utilized because the Instrument Pointing System controls the experiment orientation.

The European Space Agency's Instrument Pointing System (IPS) is a precision pointing mechanism with three rotation gimbals: An azimuth gimbal, a roll gimbal, and an elevation gimbal. (See Figure 4.1.4-1) The payload is connected to the gimbal system at the Payload Attachment Ring (PAR), which is attached in turn to the elevation gimbal.

The PAR, which is provided by Spacelab, connects to the ATM/IPS Structural Interface Shell. This shell as previously mentioned, is a cylindrical support structure which encloses the MDA end of the ATM and attaches to the existing ATM girth ring.

During launch and landing, the payload is separated from the IPS to prevent excessive loading of the gimbal system. The Payload Clamp Assembly (PCA) supports the payload at the girth ring during these periods. The PCA hardware is supplied with the IPS.

An Optical Sensor Package completes the Spacelab-provided IPS equipment. This sensor, which can be used for either solar or stellar experiments, is mounted on the ATM at the girth ring. New hardware is required to mount the optical sensor to the ATM girth ring.

The ATM/IPS system is mounted on a two-pallet train. The Payload Clamp Assembly and the IPS gimbal structure are attached at the pallet hardpoints. The two pallets are fastened together which allows four sill trunnions (two primary, two secondary) and one keel trunnion to support the entire assembly. (See Figure 4.1.4-1)

A Spacelab-provided Igloo also is mounted on the pallet train. This contains electronics associated with the Spacelab data and power interfaces.

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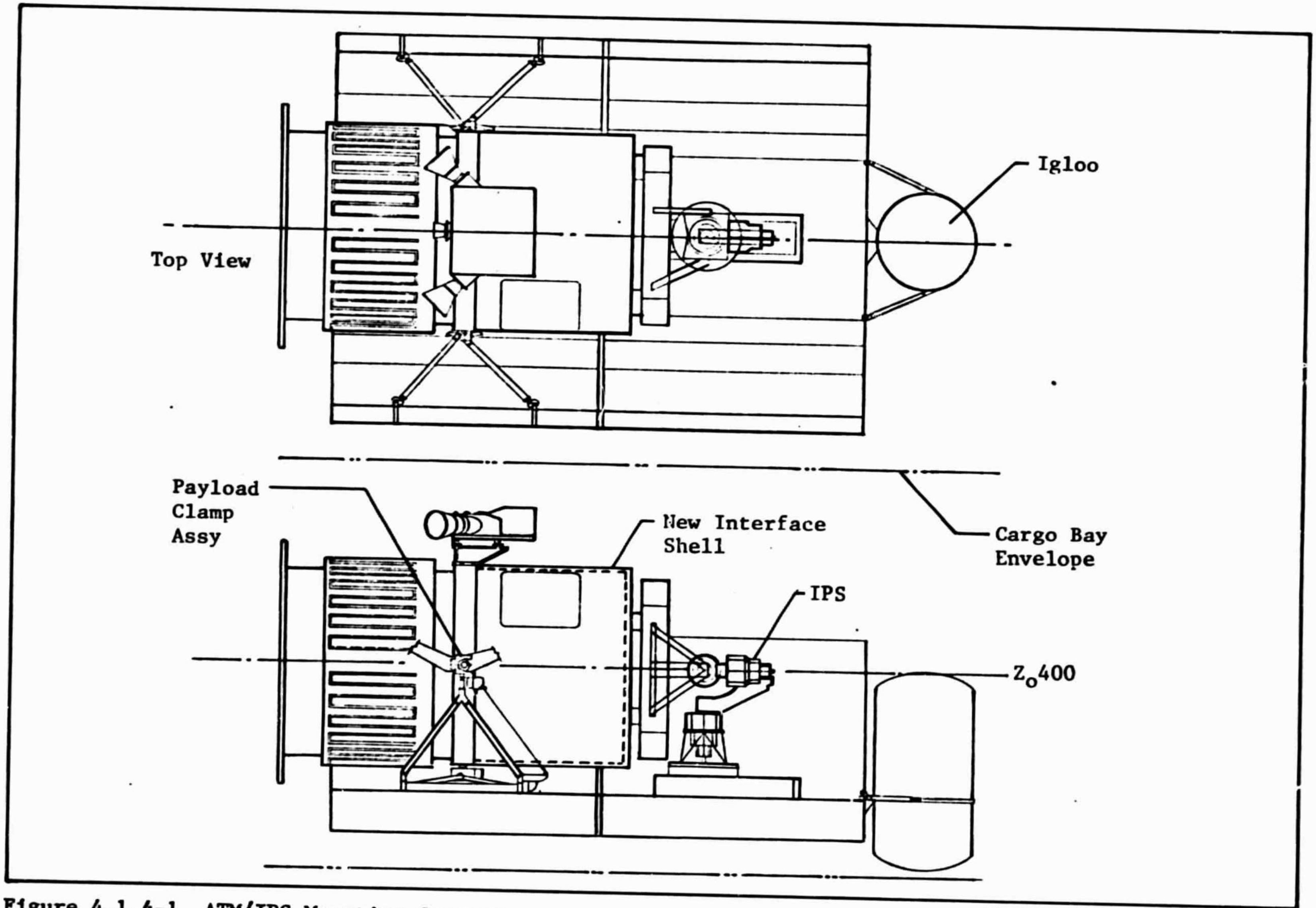

Figure 4.1.4-1 ATM/IPS Mounting Concept

The overall length of the payload from the edge of the Igloo to the outside of the sun end canister of the ATM is 301.3 inches. The center of gravity of the entire assembly, including pallets, is 129.6 inches from the sun end toward the IPS gimbal.

The ATM/IPS concept can accommodate experiment equipment length increases. Canister extenders can lengthen either the sun end canister or the MDA end canister of the ATM.

The total weight of the payload is about 13,000 lbs. The modified ATM canister with experiments and optical sensor weighs approximately 5,762 pounds. This is greater than the 4,405 pounds (2,000 kg) design load for the basic Payload Clamp Assembly hardware. However, if the pallet hardpoints are reinforced and replaceable PCA struts with high enough load carrying capacities are used, the IPS and the PCA can support 6,608 lbs. (3,000 kg), which is well over the ATM weight.

The payload lies within the STS Cargo Bay Envelope when in the stowed condition. The centerline of the stowed ATM is at Z_0400; the outside edge of the sun end of the ATM is at $Z_0582.4$ when the ATM is deployed.

4.1.5 Annular Suspension and Pointing System Gimbal System (AGS)- The ATM/AGS concept incorporates much of the same equipment as the ATM/IPS concept. The modified ATM canister is exactly the same with the same structural shell; the existing thermal control system provides the temperature control. The AGS controls the experiment orientation.

The ASPS Gimbal System (AGS) is a precision three-gimbal pointing system similar to the IPS. (See Figure 4.1.5-1) The payload is attached to the AGS at the Payload Adapter Plate (PAP) which is part of the Payload Mounting Structure (PMS). The PMS connects to the roll gimbal.

The PAP is attached to the ATM/AGS Structural Interface Shell which is identical to the ATM/IPS shell. The launch and landing lock is also the same as in the ATM/IPS concept: the Payload Clamp Assembly.

The same two-pallet train with Igloo is used, and four sill trunnions and one keel trunnion attach the pallets to the Orbiter. The

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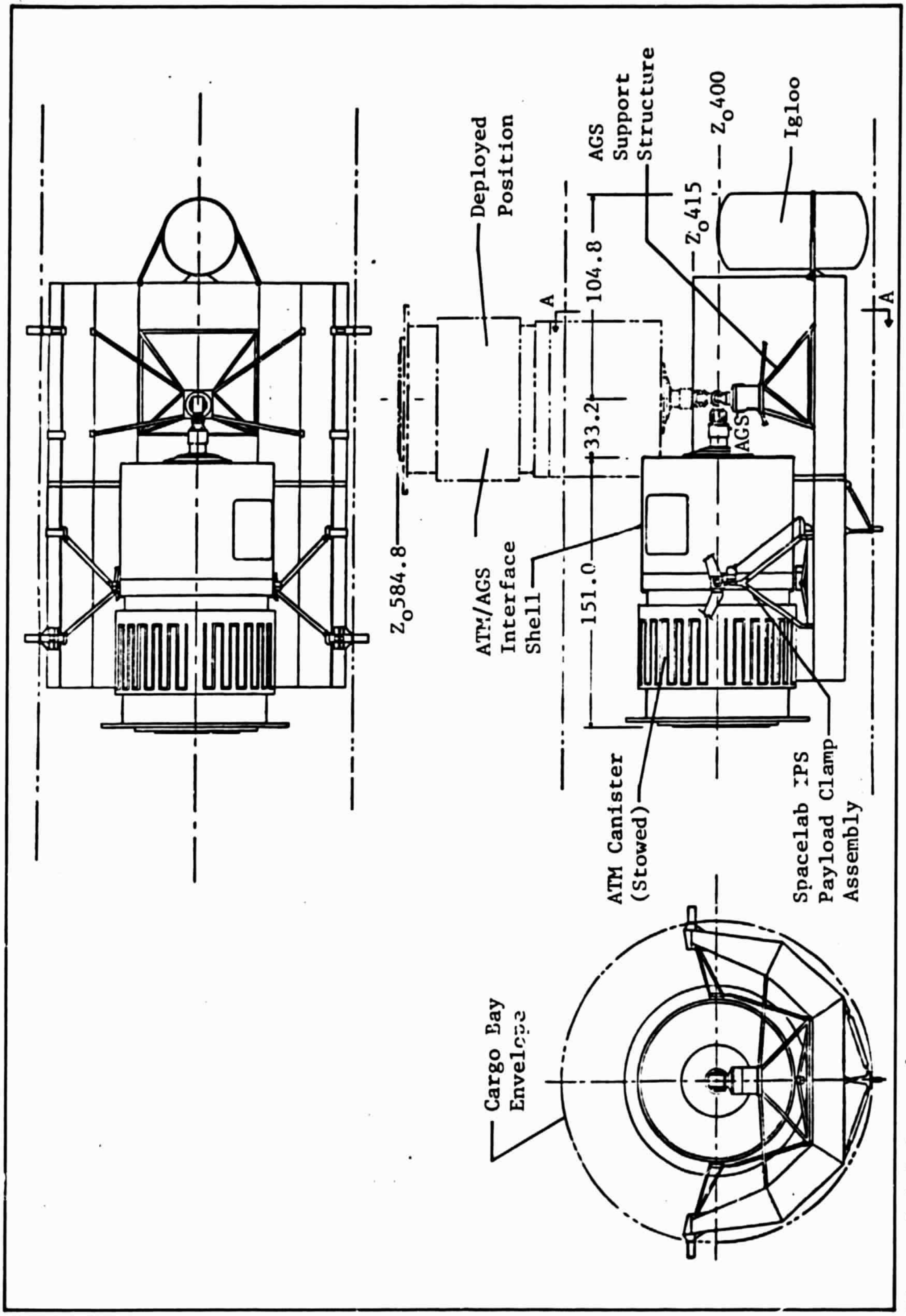

Figure 4.1.5-1 ATM/AGS Mounting Concept

framework supporting the AGS is new.

The overall length is 301.3 inches, with the center of gravity 129.6 inches from the sun end. The ATM/AGS concept can accommodate length increases in the experiments just as the ATM/IPS concept can, using canister extenders.

The total payload weight is about 12,700 lbs.

4.1.6 STS Integration - This section deals with physical interfaces between the Orbiter and the various ATM pointing system options. All of the pointing system options have been evaluated for potential cargo bay locations and have been checked against the following criteria: availability of Orbiter attachment fittings, space for additional cargo, weight of STS cargo chargeable items, location near the Orbiter-combined CG, and the cargo element longitudinal CG location. Of these criteria, cargo chargeable weight and location near the Orbiter CG, bear further explanation.

Included in the STS cargo chargeable weight items are: the bridge and retention fitting weights (keel and longeron), one EPS kit (See Section 4.4, Electrical Power), and the Standard Mixed Cable Harness (SMCH). For purposes of cargo CG, the entire SMCH (786 pounds) was included in the cargo element weight. For a shared flight, the SMCH weight would be shared with other cargo elements, dependent on weight and cargo bay length relationships.

Location of the pointing system near the Orbiter center of rotation (the Orbiter-combined CG is between $X_0$1077 and $X_0$1109) allows the pointing system to deal primarily with rotations (excludes translation effects), and also eliminates the coupled accelerations (due to lever arm effects) on the pointing control system.

Figure 4.1.6-1 illustrates the ATM and ECU arrangement in the Orbiter cargo bay. The location selected puts the ATM canister/SPAR CG as close to the Orbiter-combined CG as possible. With this configuration, the ATM CG is five feet forward of the nominal Orbiter combined CG.

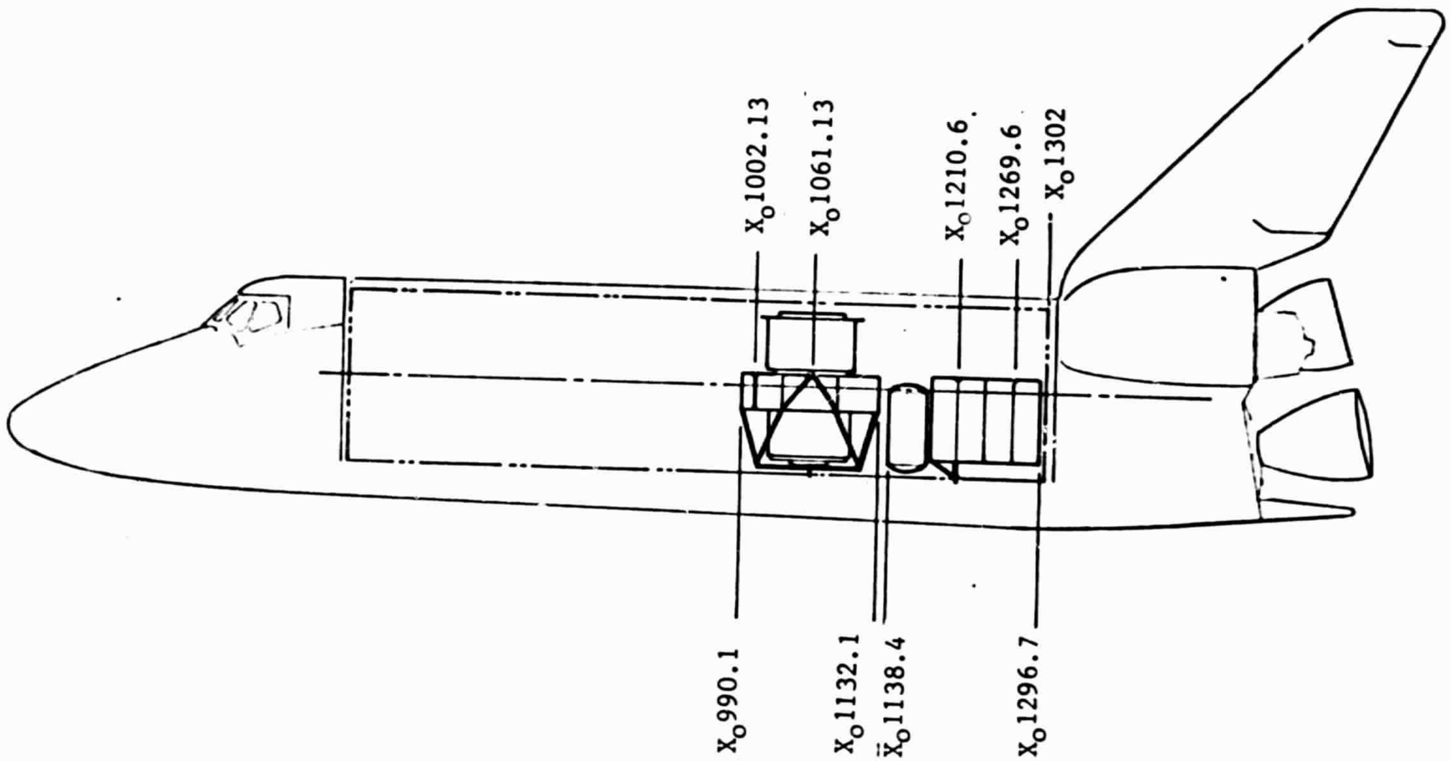

Figure 4.1.6-1 ATM + ECU Cargo Element

ATM/CSS to Orbiter interfaces are at attachment fittings $X_0$1061.13 (keel and primary longeron) and $X_0$1002.13 (stabilizing longeron). The Spacelab pallet has been located in its most aft location and the proper clearance between the Igloo and the ATM has been provided. Thirty-four (34) feet of cargo bay space is available forward of the ATM for additional payloads.

The arrangement using the Spacelab module is shown in Figure 4.1.6-2. Here the ATM and pallet are in the identical locations as the previous sketch. Removal of the Igloo from the pallet does not allow the ATM to move aft (nearer the CG) due to a lack of Orbiter attachment points in this region. The module is shown in one of the standard positions. It is apparent from the figure, that no additional cargo can be flown with this configuration.

An Integrated ATM cargo is depicted in Figure 4.1.6-3. Here the ATM has been located as close as possible to the region of the Orbiter-combined CG. Lack of keel attachment fittings again prohibits a nominal combined CG range location. This configuration provides thirty (30) feet of available space for shared payloads.

The ATM/IPS and the ATM/AGS concepts result in almost identical cargo geometries and CG's. For this reason, a single STS integration figure is used to represent either the ATM/IPS or the ATM/AGS. Figures 4.1.6-4, 4.1.6-5, and 4.1.6-6 represent STS integration as far forward as possible, as far aft as possible, and with the cargo CG located at the STS combined CG, respectively.

Loading the cargo in the forward location leaves 5 feet forward and 30 feet aft of the assembly. In the aft location, the space forward of the cargo is 27 feet, with 7 feet aft. When the ATM pallet train is loaded at the CG location, 30 feet of space is left forward and 4 feet is left aft. All cases result in the cargo element being within the Orbiter longitudinal CG envelope.

4.1.7 <u>Mass Properties</u> - The mass properties effort has been limited to top level weight and CG assessments due to the preliminary

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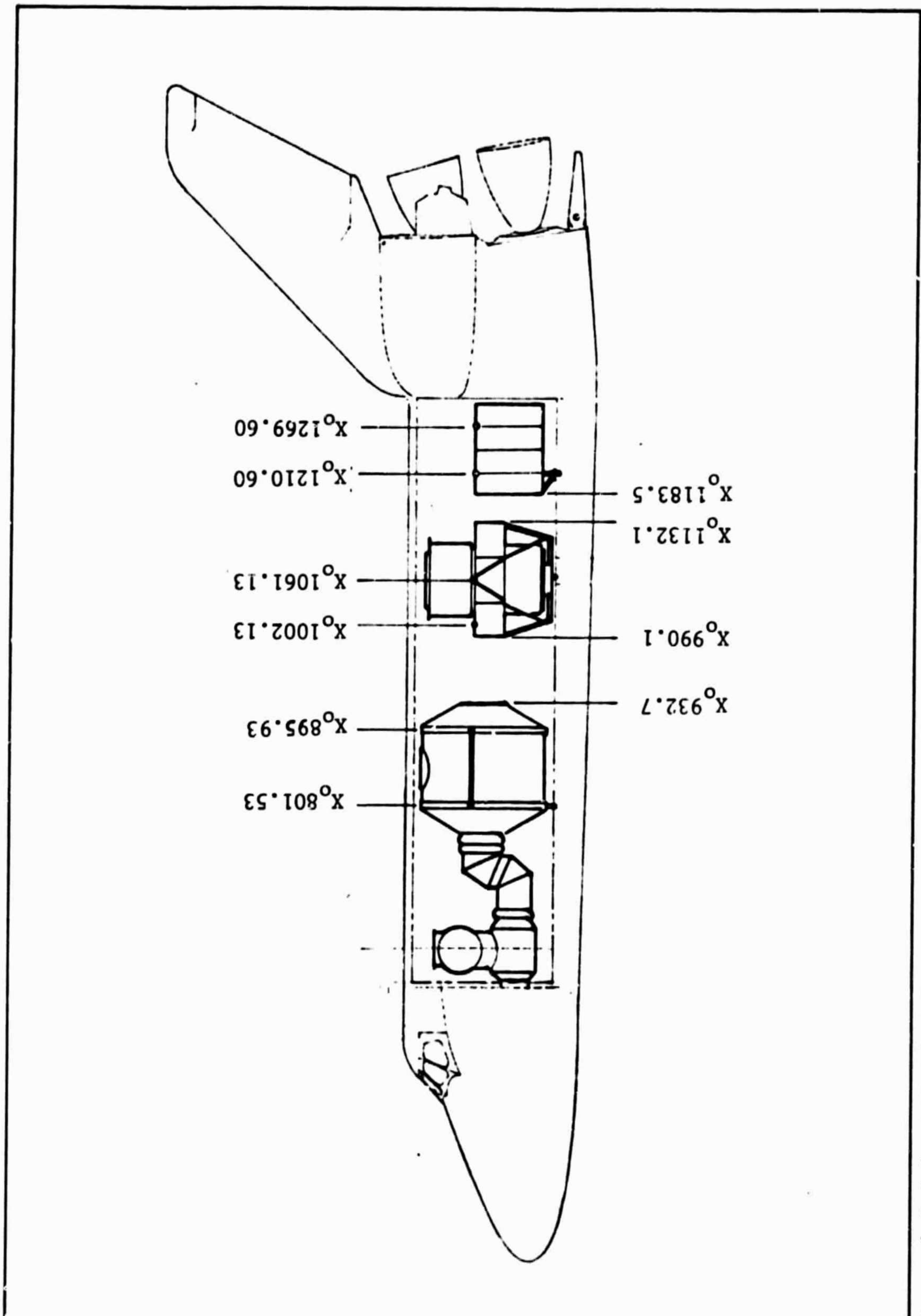

Figure 4.1.6-2 ATM + Module + ECU Cargo Element

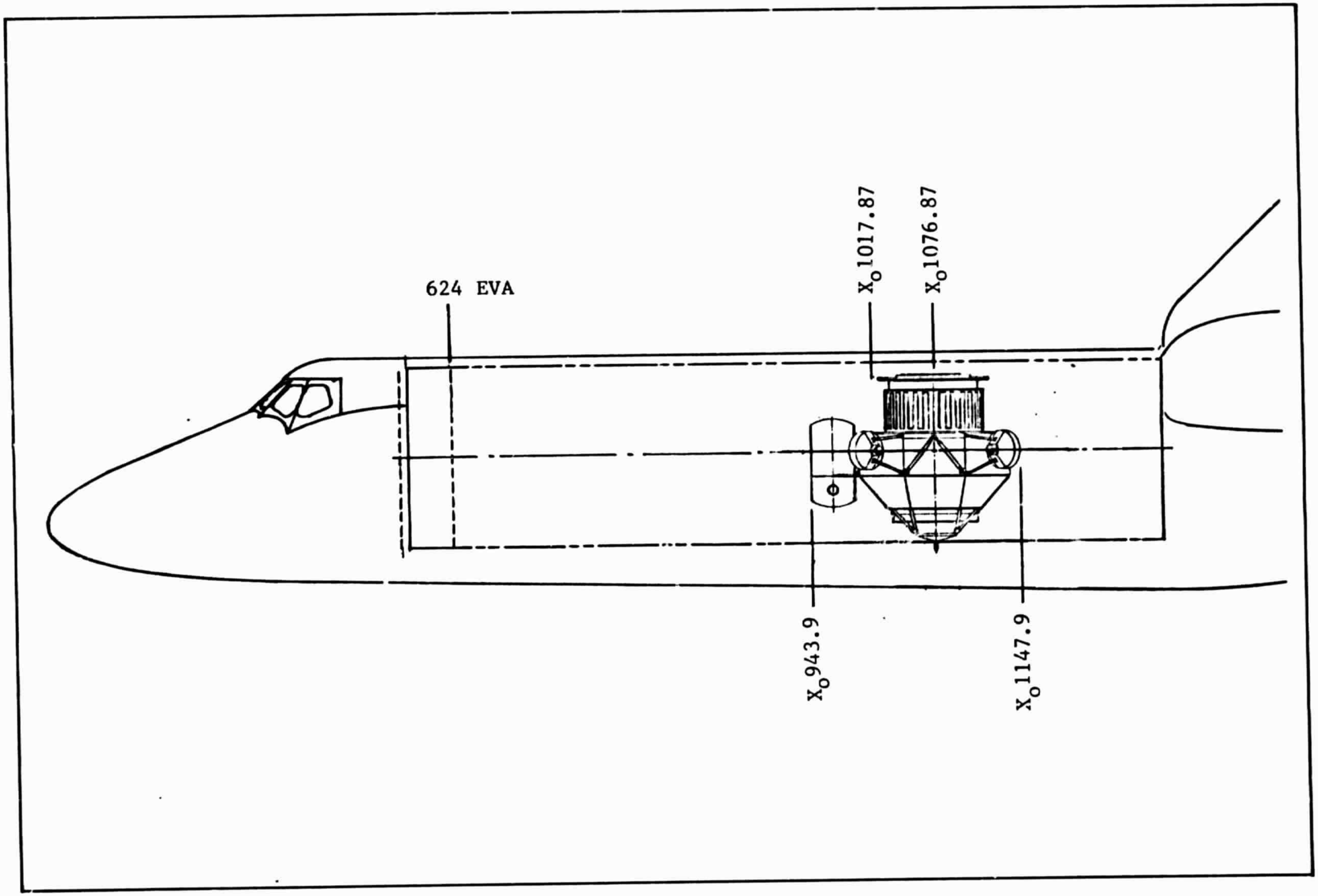

Figure 4.1.6-3 Integrated ATM Cargo Element

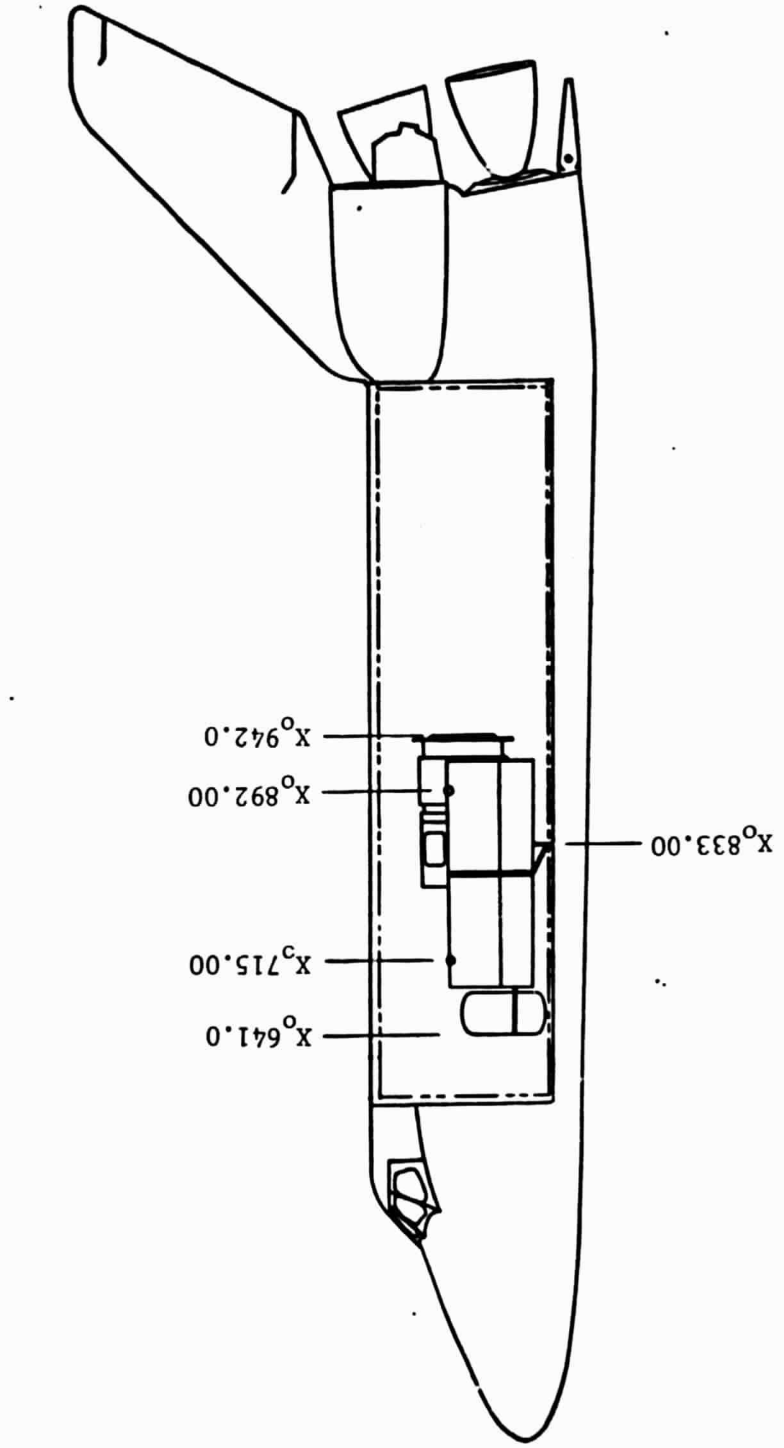

Figure 4.1.6-4 ATM/Pointing Platform Cargo Element, Forward Location

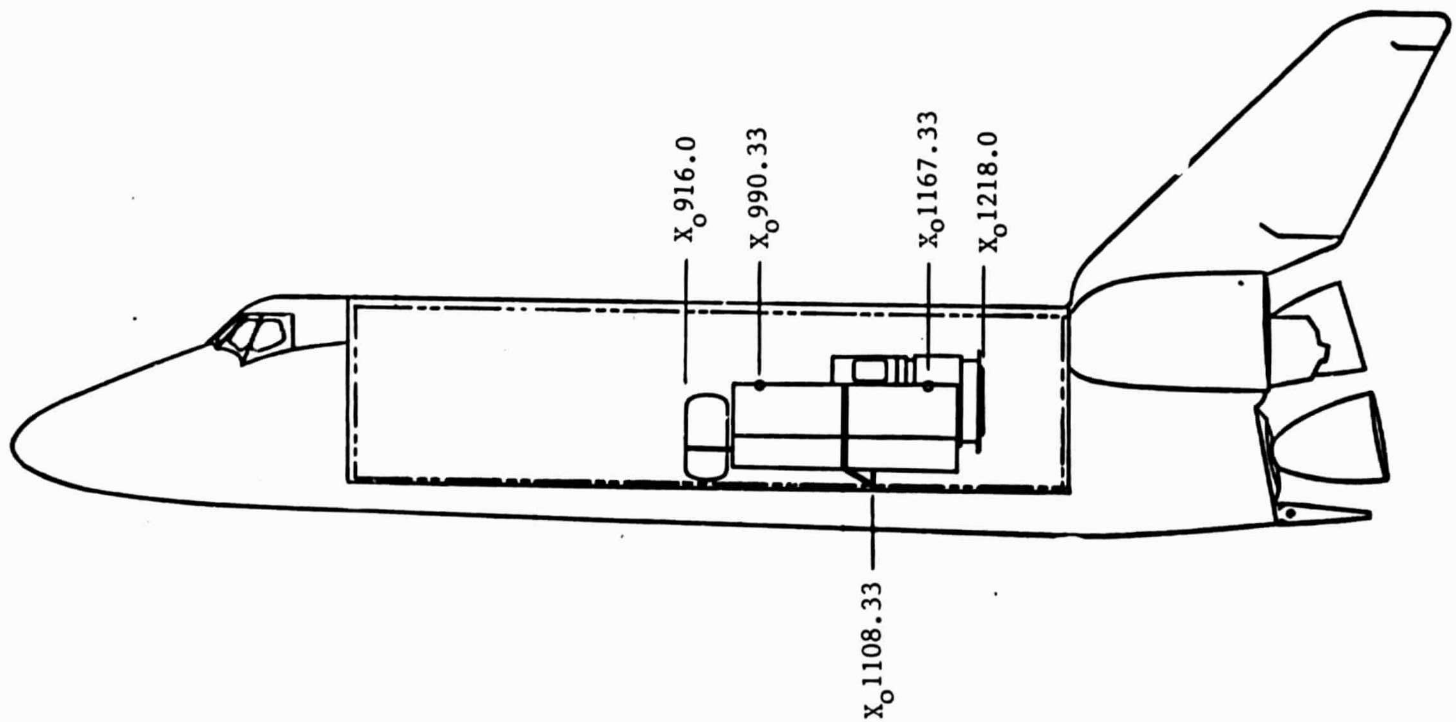

Figure 4.1.6-5 ATM/Pointing Platform Cargo Element, Aft Location

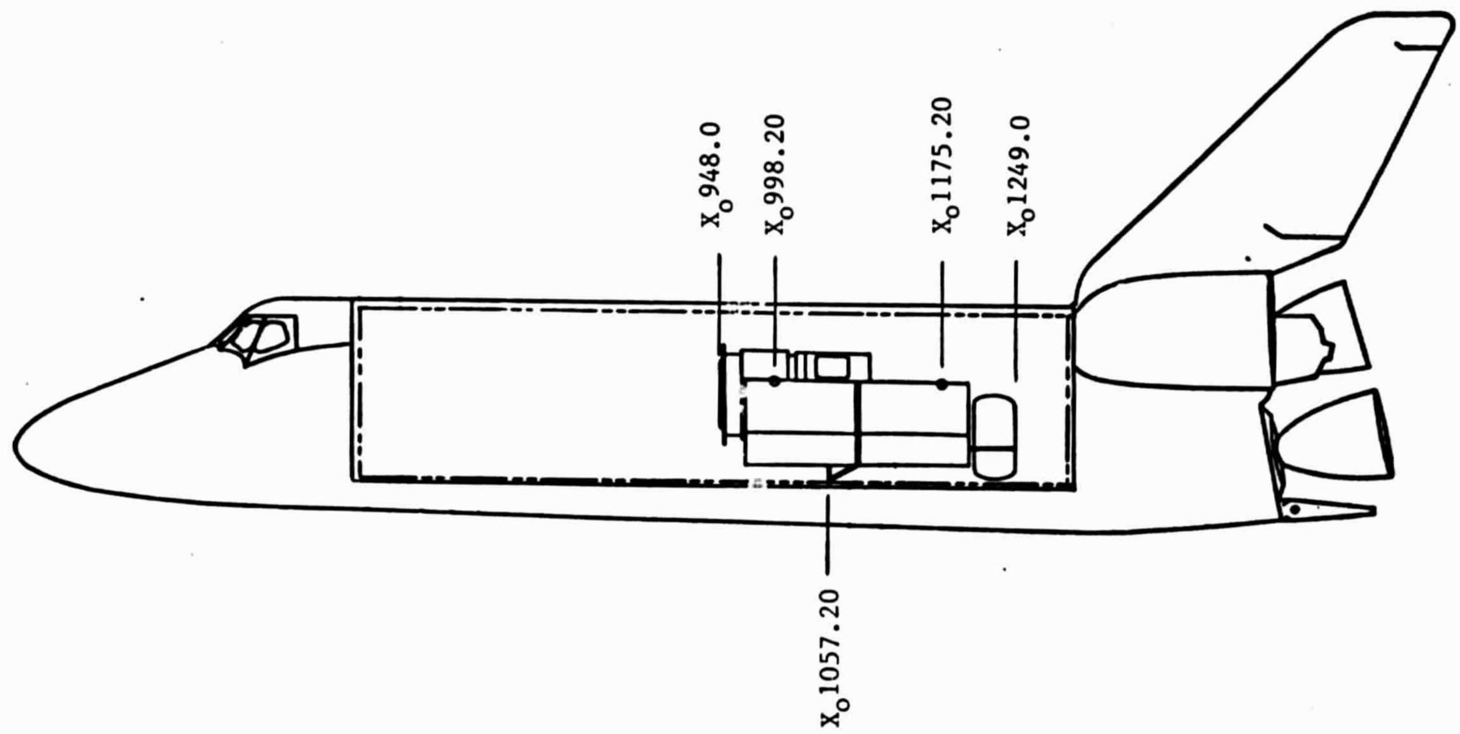

Figure 4.1.6-6 ATM/Pointing Platform Cargo Element, CG Location

nature of the study. Table 4.1.7-1 provides a weight comparison of the five pointing system options investigated in the course of the study. Most of the entries are self-explanatory; however, the growth and STS chargeable numbers can use some clarification.

The growth or weight margin number is based only on new structure and new equipment weight and therefore, may appear small when compared to the total cargo element weight. The margin is actually greater than 20% of the new equipment weight.

The STS chargeable weight includes; one EPS kit, the complete SMCH, and the retention/attachment hardware. ECU options include a larger STS chargeable weight because they include retention hardware for both pallet and CSS. The module option includes airlock and tunnel plus retention hardware for module, CSS, and ECU.

The CG row at the bottom of the table provides the total cargo element CG location, in Orbiter coordinates, for the five approaches. The capability entry, presents a weight comparison of the maximum payload weight for shared cargo. This weight comparison is based on an assumed 32,000 pound sortie mission. A CG location is also given for the shared payload. This number represents the most forward CG location of the shared payload weight such that, the total cargo remains within the Orbiter longitudinal CG curve.

4.1.8 Summary - The study results show that the ATM hardware has the potential for reuse in either the ATM Pointing System mode or the NASA-provided pointing platform options. Additional study effort is required, for any of the hardware usage options, in the areas of; Instrument size (both cross section and length) versus canister envelope, aperture door configuration (universal door versus dedicated doors for each mission), and overall instrument accessibility.

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Table 4.1.7-1 Mass Properties Summary, ATM Configuration

	ATM + ECU	PM+ATM+ECU	INTEG.ATM	ATM/IPS[1]	ATM/AGS[1]
PM	--	9,457	--	--	--
ATM	8,770	8,770	13,575	5,562	5,562
ECU	6,595	5,184	--	--	--
Pointing Platform System[2]	--	--	--	6,069	5,686
Growth	1,237	1,237	1,091	200	200
STS Chargeable	3,782	6,676	2,727	1,216	1,216
Total	20,384 lbs.	31,324 lbs.	17,393 lbs.	13,047 lbs.	12,664 lbs.
CG	X_o1040	X_o1004	X_o1069	X_o1078	X_o1078
Additional P/L Capability[3]	11,616 lbs.	--	14,607 lbs.	18,953 lbs.	19,336 lbs.
Forward CG Location	X_o825	--	X_o834	X_o882	X_o886

1 Calculations are for the "CG Location" option (Figure 4.1.6-6)

2 Includes pallets, PCA, pointing platform, etc.

3 Based on a 32,000 pound max. return payload

4.2 Command and Data Handling (C&DH)

C&DH aspects of integrating the pointing systems into the Shuttle payload bay will be discussed in this section. Payload instrument and support system telemetry and command requirements will first be defined. Data system concepts which accommodate these requirements in conjunction with the pointing systems under evaluation will then be explored. Finally, recommendations will be made for onboard multiplexing, recording, and eventual recovery of these data using the Shuttle RF system.

4.2.1 Previous Study Conclusions - In reviewing the C&DH conclusions reached during the earlier ATM feasibility study, it should be noted that the scientific payload then consisted of the ATM solar instruments flown previously on Skylab. For that payload, it was concluded that the ATM data system flown on Skylab, and presented in Figure 4.2-1, be fully utilized. Obviously, this eliminated any questions of compatibility between the instruments and data system; but did present some compatibility problems with the Orbiter data system. The 72 kbps ATM telemetry consisting of 10 bit words had to be converted to a PCM signal containing 8 bit words with a rate less than the 64 kbps limit for Orbiter payloads. It was further recommended that the ATM command system presented in Figure 4.2-2 be used. Using this approach, onboard control of the payload was to be achieved by locating ATM control and display panels in the Orbiter aft flight deck.

4.2.2 Payload C&DH Requirements - Data and command requirements were extracted from the instrument ERDs; and similar support system requirements were obtained from the earlier ATM study report. The instrument telemetry requirements are summarized in Table 4.2-1. Sample rates for the individual analog and discrete channels identified in the ERDs were assumed based on the data available or past experience with similar payloads. The serial PCM signals were defined in the ERDs. The 1 Mbps serial PCM rate used for SEUTS was based on data provided by the GSFC project office.

Our interpretation of ERD statements indicates that there is a similarity of data content in the SAROS video signal and the 524.3 kbps

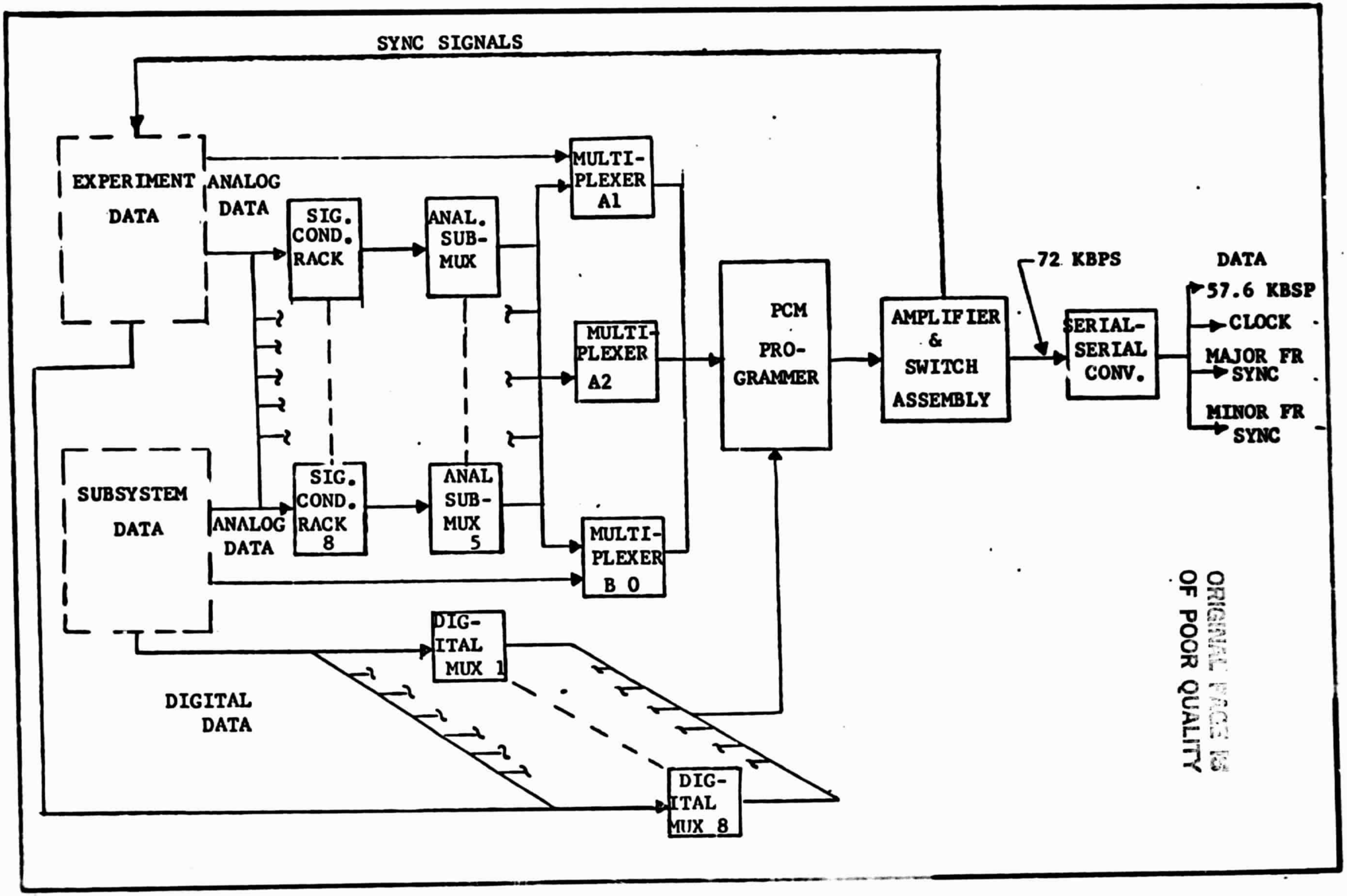

Figure 4.2-1 ATM Data System, Previous Study

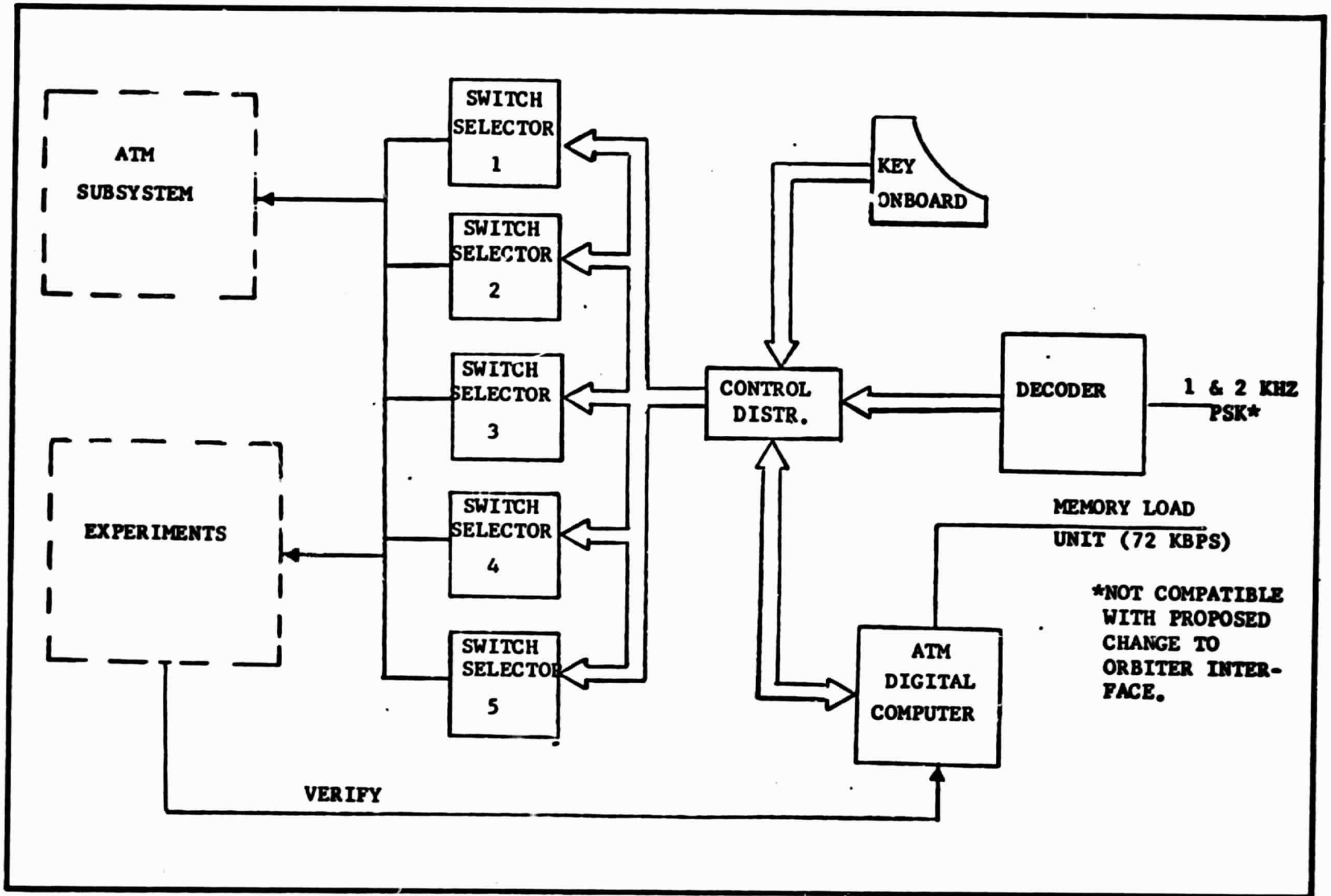

Figure 4.2-2 ATM Command System, Previous Study

Table 4.2-1 Instrument Data Requirements

INSTRUMENT	RAU CHANNELS							HRM CHANNELS (KBPS)	VIDEO	CONTROL & DISPLAY
	ANALOG			DISCRETE			SERIAL PCM (BPS)			
	1 SPS	10 SPS	100 SPS	1 SPS	10 SPS	100 SPS				
SAROS	10	5	—	16	—	—	6400 400	524.3	1	PRIMARY: MODULE OR AFD
SEUTS	10	5	—	40	24	—	512	1000	1	
SLAC	12	6	—	—	—	—	320	25-50	—	SECONDARY: POCC
WLC	9	—	—	24	3	—	123	—	—	
TOTALS	41	16	—	80	32	—	—	—		

signal. The video is intended for onboard display and the digital signal is transmitted to the POCC, and both are used simultaneously by ground and onboard personnel for correlated instrument setup. ERD statements indicate a desirability for some video transmission to the POCC, but this is not specifically a requirement. Finally, it should be remembered that the primary payload data is recorded on film, and the data listed in Table 4.2-1 is intended for status monitoring, instrument setup, and subsequent data analysis.

Estimated telemetry required for the ATM subsystems e.g. the APCS, TCS, and S&M, were extracted from the previous ATM study, and are listed in Table 4.2-2, with no modification since the APCS and TCS subsystems remain intact and similar S&M monitoring is assumed. ATM telemetry for the C&DH (previously referred to as Instrumentation and Communication) and EPS have been deleted since we plan on using available Spacelab capabilities in these areas. However, to assess data bus loading, estimates of data were made for these Spacelab subsystems. As indicated in Table 4.2-2, a rather low level of experiment and subsystem data bus loading is anticipated.

In evaluating the uplink command and control requirements of the payload, consideration was given to potential uplink operational constraints identified by previous GSFC studies. These constraints on uplink command capability are introduced by the fact that these command data flow through numerous facilities, equipment, and interfaces associated with the POCC, GSFC, NASCOM, MCC, TDRSS, Orbiter, and Spacelab. The result is a considerably reduced effective command rate on the order of 10 to 100 bps rather than the 2 kbps published capability, due to compounded processing and communication delays, numerous verification loops, and communication interruptions. These constraints could result in an average command processing time of 1-2 seconds. With these limitations in mind, the payload command requirements tabulated in Table 4.2-3 were analyzed. Except for updating stored command pages associaged with SAROS, and the SLAC memory update; the estimated uplink times required are quite manageable and should not adversely affect payload

Table 4.2-2 Data Bus Loads

SOURCE	RAU CHANNELS							BUS DATA RATE
	ANALOG			DISCRETE			SERIAL PCM (BPS)	
	1 SPS	10 SPS	100 SPS	1 SPS	10 SPS	100 SPS		
ATM SUBSYS:								SCIENCE: 9800
APCS	24	62	—	7	131	20	TBD	
TCS	33	—	—	—	17			
S&M				30				
SUB-TOTAL	112	62	—	37	148	20	TBD	
INSTRUMENT DATA	41	16	—	30	32	—	7760	SUBSYSTEM: 19,000 - 24,000
SPACELAB C&DH TM EPS ECS	ESTIMATE 10,000 - 15,000 BPS							

Table 4.2-3 Payload Command Requirements

Payload Component	Commands: Discretes	Commands: Serial	Control Source	Uplink Activity	Uplink Time (Estimated)
SAROS	22		POCC,KB	• Discretes control start-up used infrequently	10-20 sec/day
		1	POCC,KB	• Update stored command pages (16) once/day-2 or 3 pages every orbit at about 30 commands/page	3 min/orbit
		1	COMP	• Auxiliary data	
SEUTS	44		POCC,KB	• Estimate several discretes /orbit	20 sec/orbit
		1	COMP	• 32 words (16 bit), once/sec	—
SLAC	8		POCC,KB	• Infrequent use	Neg
		1	POCC,KB	• 32 words message, several/hr	1 min/(3/hr)
		1	KB	• " " " " "	—
		1	COMP,POCC	• DEP memory load, 4000 words	30 min
WLC	54		POCC,COMP	• Configuration control every 3 hours	20 sec/hr
		1	TBD	• TBD	—
ATM SYSTEMS	125	-	KB,POCC	• Controls APCS, TCS, S&M COMM, EPS	1 min/orbit

operations.

4.2.3 Data System Concepts - A decision was made early in this study to utilize the Spacelab C&DH subsystem rather than the ATM data and command system indicated in Section 4.2.1. The factors affecting this decision are listed in Figure 4.2-3 and offer very compelling reasons for the decision. It should be noted that the previous study evaluated a payload consisting of the Skylab ATM instruments with which the ATM data system was very compatible. Current instrument concepts are more oriented toward a Spacelab-type system.

Our evaluation of data system concepts was initiated with a definition of the detail interface between each of the instruments and the Spacelab data system components, basically the Remote Acquisition Unit (RAU). These interfaces are illustrated for each instrument in Figures 4.2-4 and 4.2-5. It should be noted in Figure 4.2-5 that separate interfaces are shown for the WLC and SLAC although these are physically recognized as a single instrument package. They have been shown separately because, in reality, there are two separate data systems.

It can be seen from the summary of spare channels on each figure that each of the instrument pairs requires a substantial part of an RAU's capacity, without giving any consideration to spare or redundant channels. Redundant command channels would probably be quite desirable. For either of the instrument combinations presented in Section 4.1, two RAUs will be required, and will provide adequate spare and redundant channel capability.

Referring to Tables 4.2-2 and 4.2-3, it can be seen that the ATM support subsystems require about 380 RAU channels for telemetry and up to 125 channels for command. It seems safe to assume that these requirements could probably be reduced by a more detailed requirements analysis if it became necessary to reduce the RAUs required. At least 4 RAUs are required to satisfy these subsystem requirements, and it would be desirable for one of these RAUs to be located on the ATM Canister to support the TCS and some APCS components. However, the thermal

- ORIGINAL ATM HAD NO SERIAL DIGITAL DATA
- ATM RECORDER HAD VERY LIMITED CAPABILITY
- 72 KBPS TM FORMAT NOT COMPATIBLE WITH ORBITER INTERLEAVING
- EXTENSIVE ATM TV SYSTEM NOT REQUIRED
- ATM DATA SYSTEM IS SATURN VINTAGE
- DEDICATED CONTROLS & DISPLAYS APPROACH USED ON ATM
- CURRENT INSTRUMENTS ARE SPACELAB COMPATIBLE
- CAN RETAIN ATM COMPUTER/WCIU FOR APCS

Figure 4.2-3 ATM Vs. Spacelab Data System

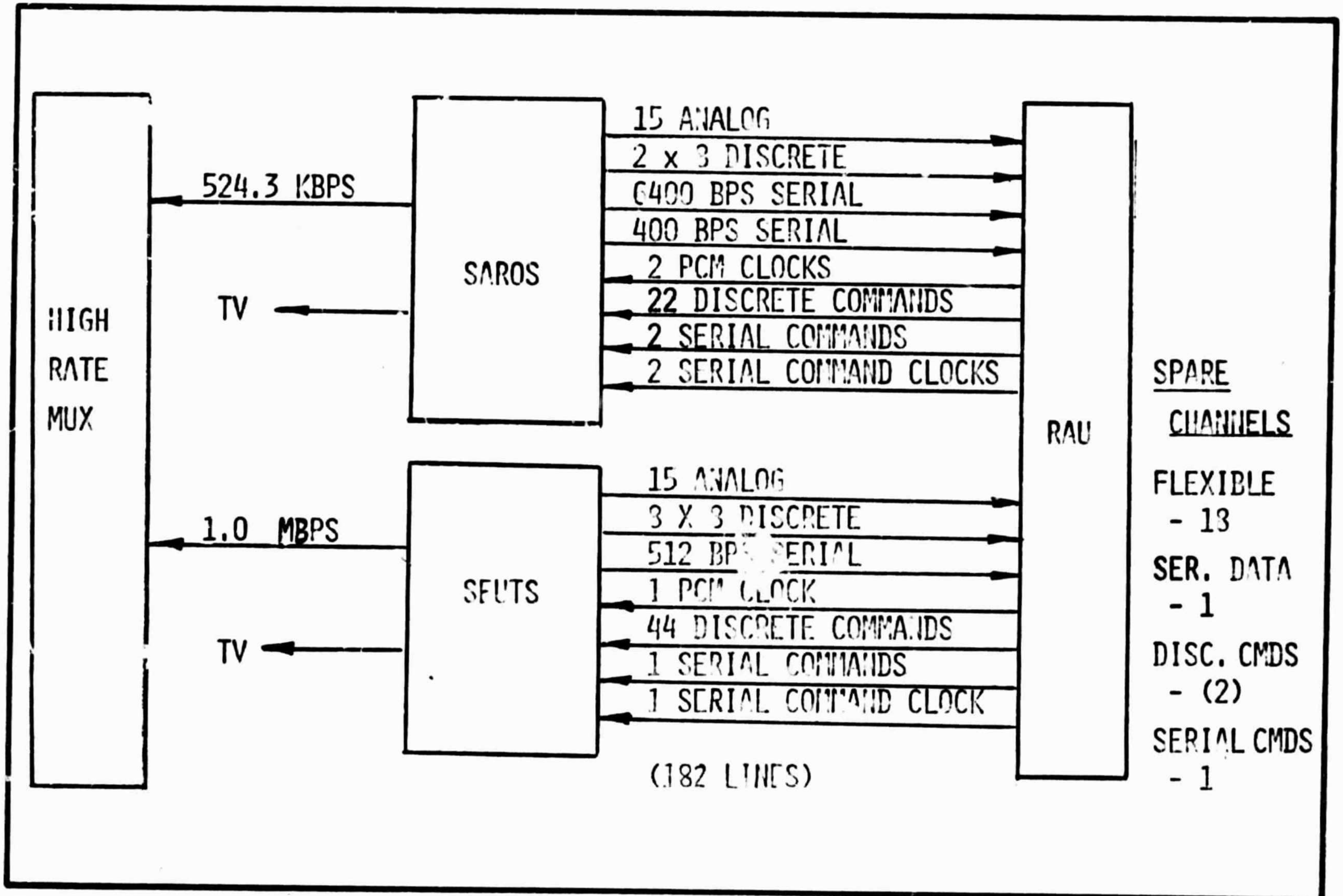

Figure 4.2-4 Instrument Data Interfaces

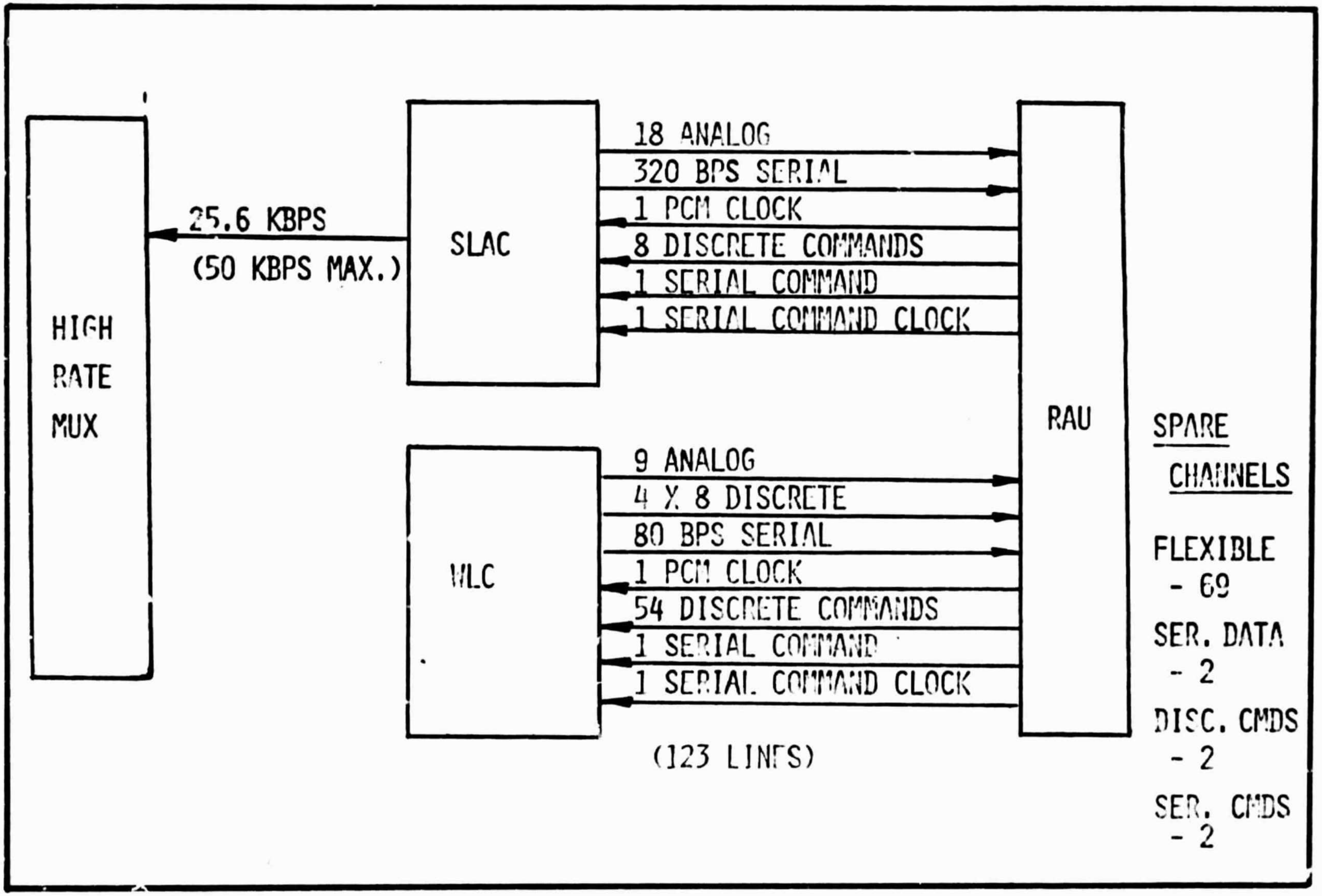

Figure 4.2-5 Instrument Data Interfaces

analysis presented in Section 4.3 will suggest an insufficient thermal margin to accommodate any RAUs on the canister. In this event, all the RAUs will be located on the CSS. This, or course, implies that the instrument and support system telemetry and command leads, a total of about 450 signals, will cross the ATM gimbals. Because of the limited canister movement, this should not be a serious problem as substantiated by Skylab performance where more than a thousand leads crossed this interface.

4.2.3.1 ATM Approach - The C&DH configuration recommended for integration of the ATM and its payload with the Spacelab and Orbiter data systems is shown in Figure 4.2-6. Major data system equipment within the Payload, Spacelab module and Orbiter is indicated. The Payload part of the diagram shows the instruments, the TCS and some APCS components, and 3 or 4 RAUs located on the ATM canister. If necessary, because of thermal limitations, the RAUs can be located on the CSS with the remaining 2 subsystem RAUs. Approximately 100-110 telemetry parameters from the TCS and APCS require low level signal processing and amplification before interfacing with an RAU. This signal processing is provided by 3 or 4 ATM Signal Conditioning Racks (SCR), each of which can accommodate 40 low level signals. These 100-110 conditioned, low level (20 millivolt) signals must then be amplified to the 5 volt level for compatibility with the RAUs. This will require design of a new amplifier package consisting of about 120 parallel, integrated circuit amplifiers.

The RAUs interface with the Spacelab experiment and subsystem data busses and computers within the module. The bus data plus the high rate serial digital signals from the payload are combined in the high rate multiplexer (HRM) and transferred to the Orbiter Ku-band system for transmission, or stored on the high data rate recorder (HDRR). Payload video is available for display in the module or the Orbiter aft flight deck (AFD). Payload control is possible from the module keyboard, the AFD keyboard, or from the ground POCC.

Figure 4.2-7 shows the C&DH configuration when the Spacelab module is not used, and the data system hardware is housed in the Igloo. Pay-

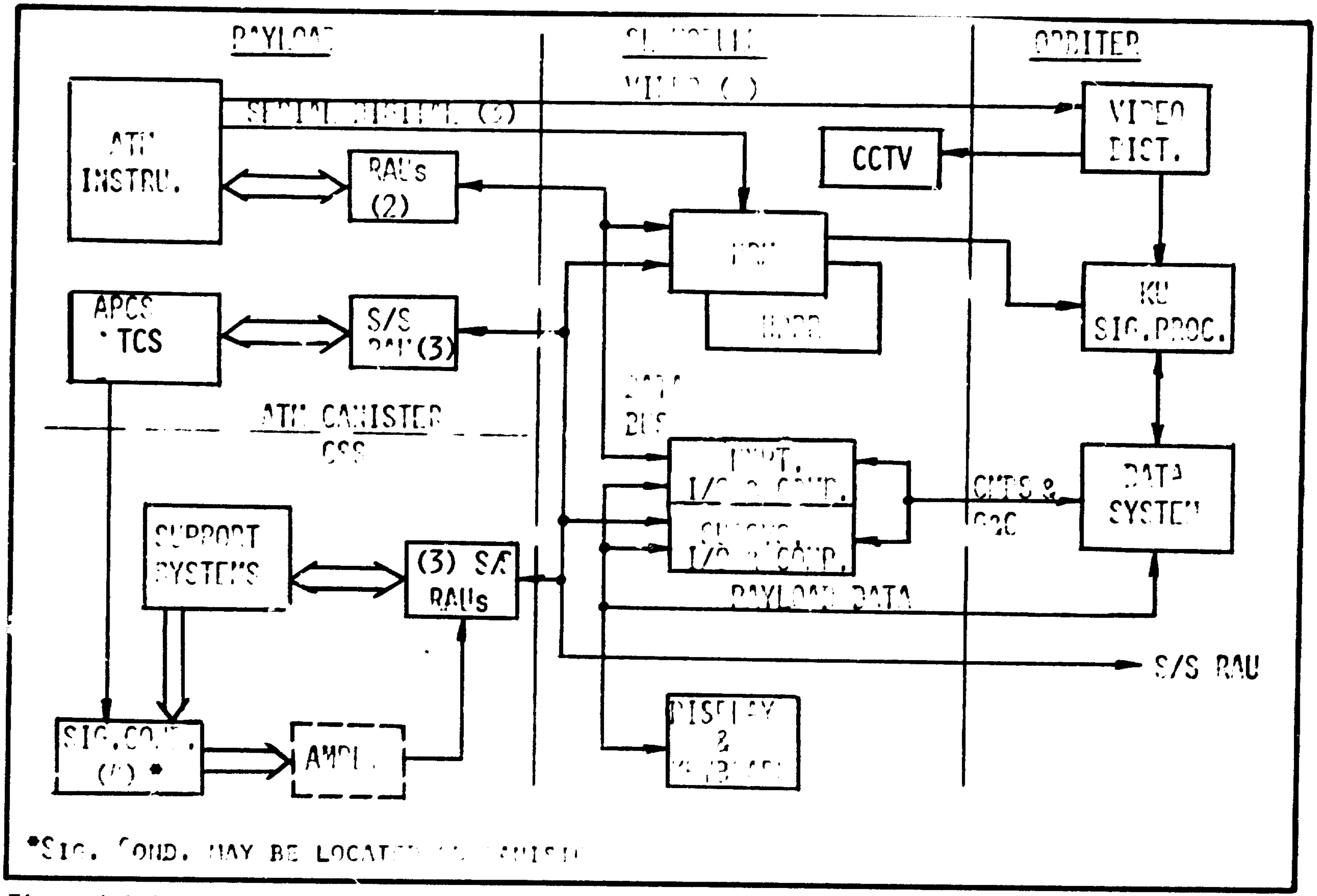

Figure 4.2-6 ATM C&DH Diagram (Module)

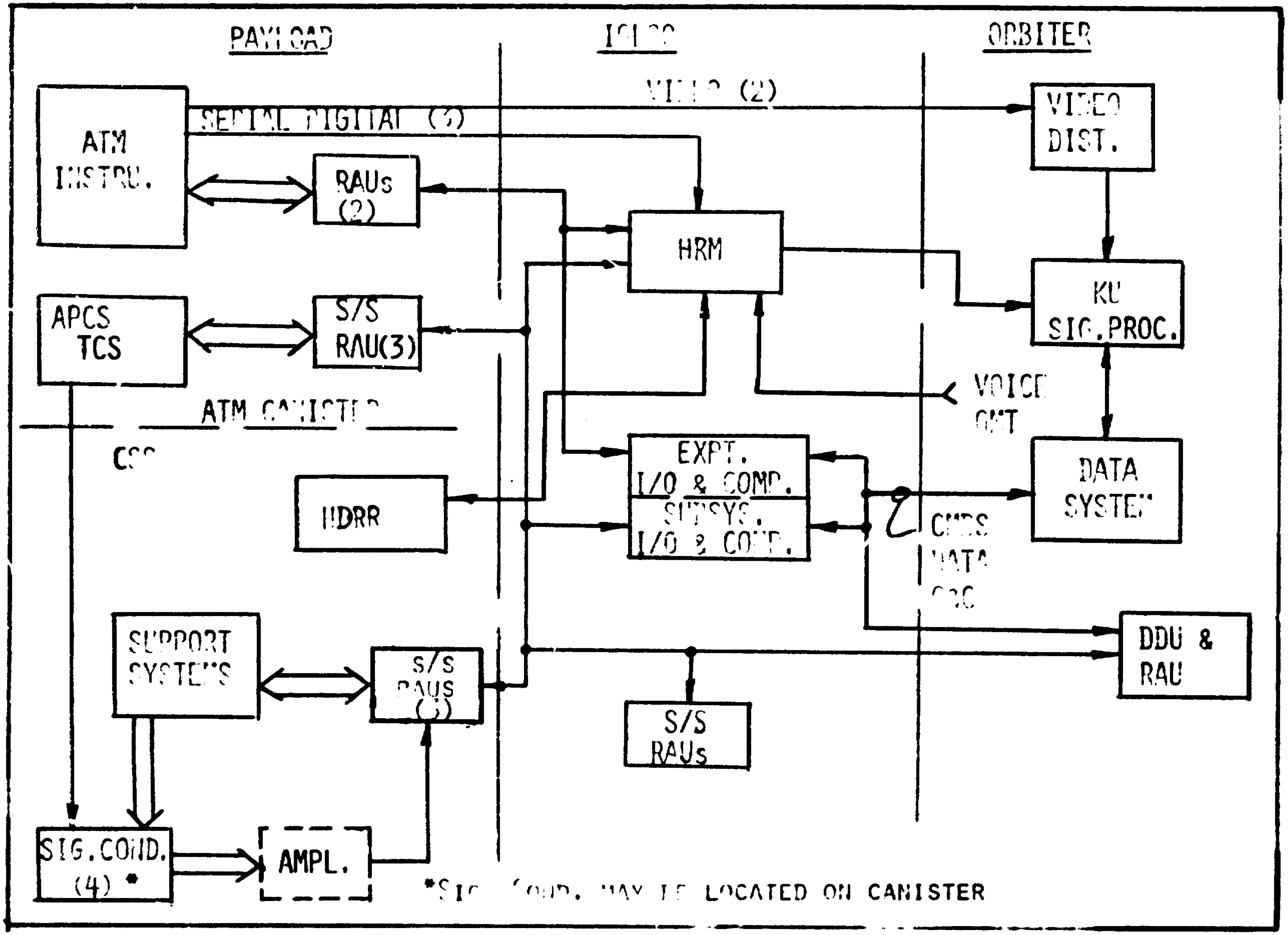

Figure 4.2-7 ATM C&DH Diagram (Igloo)

load control is then effected from either the AFD or POCC. The other change of significance is the fact that the HDRR does not fit in the Igloo, and will, therefore, be located on the CSS.

An option exists to control ATM pointing using either the ATM Digital Computer (ATMDC) or the Spacelab subsystem computer. Availability of both the ATMDC and the required software makes this the cost effective approach. It is therefore necessary to interface the ATMDC with the Spacelab data system for control and monitoring purposes. An approach to achieving this interface is presented in Figure 4.2-8. One problem is presented by the telemetry data generated by the computer, which is a 50 bit word format occurring 24 times per second. Serial digital inputs to the RAU must be in a 16 bit word format up to a maximum of 32 words per message, at a clock rate of 1 Mbps. This incompatibility can be resolved by providing a Buffer consisting of a 50 bit register to receive the ATMDC telemetry, which is then clocked out in 16 bit words at a 1 Mbps rate. The Buffer would also process the User Time Code (UTC) signals to provide the 1 and 24 pulse per second signals required by the ATM. For on-off commands, the ATMDC requires a minimum 28 millisecond pulse and the RAU generates a 100 millisecond pulse. There may be some pulse level or drive current processing required, which would also be included in the Buffer package.

Figure 4.2-8 also shows an ATMDC interface with the Workshop Computer Interface Unit (WCIU) via dual parallel 16 line interfaces. The WCIU provides signal conditioning for two-way data exchange between the ATMDC and components of the APCS, as indicated in Figure 4.2-9. Even if a decision is made not to use the ATMDC, it will probably be desirable to retain the WCIU, and therefore, an interface with the data bus must be provided for two-way data exchange. The 16 line input to the WCIU can be provided by adding a serial-to-parallel converter to accept the 16 bit serial words from the RAU. The 16 line output from the WCIU can be directly introduced to the RAU discrete inputs.

4.2.3.2 IPS Approach - The C&DH configuration recommended for interfacing an IPS mounted payload to the Spacelab data system is presented

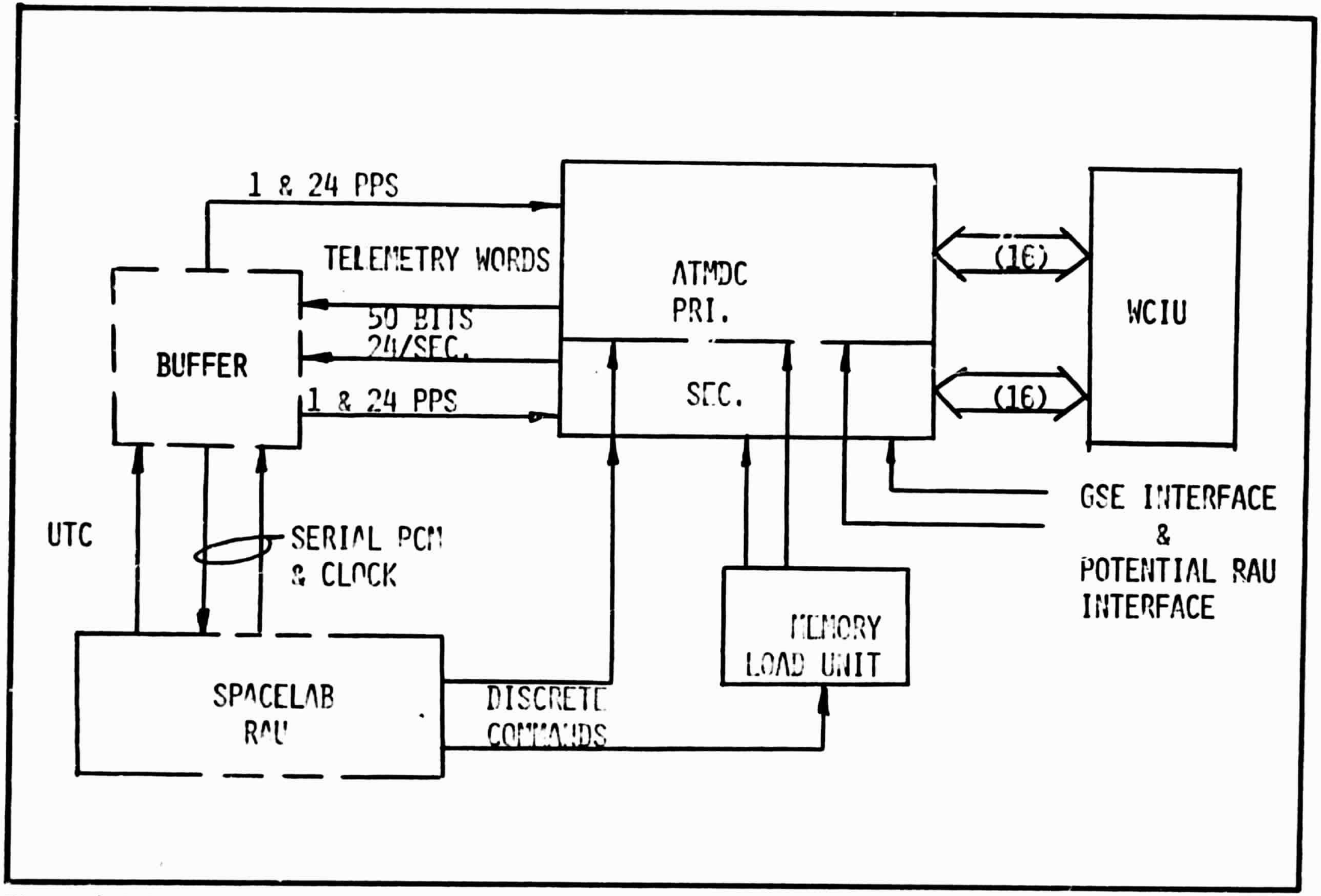

Figure 4.2-8 ATM Digital Computer Data Interfaces

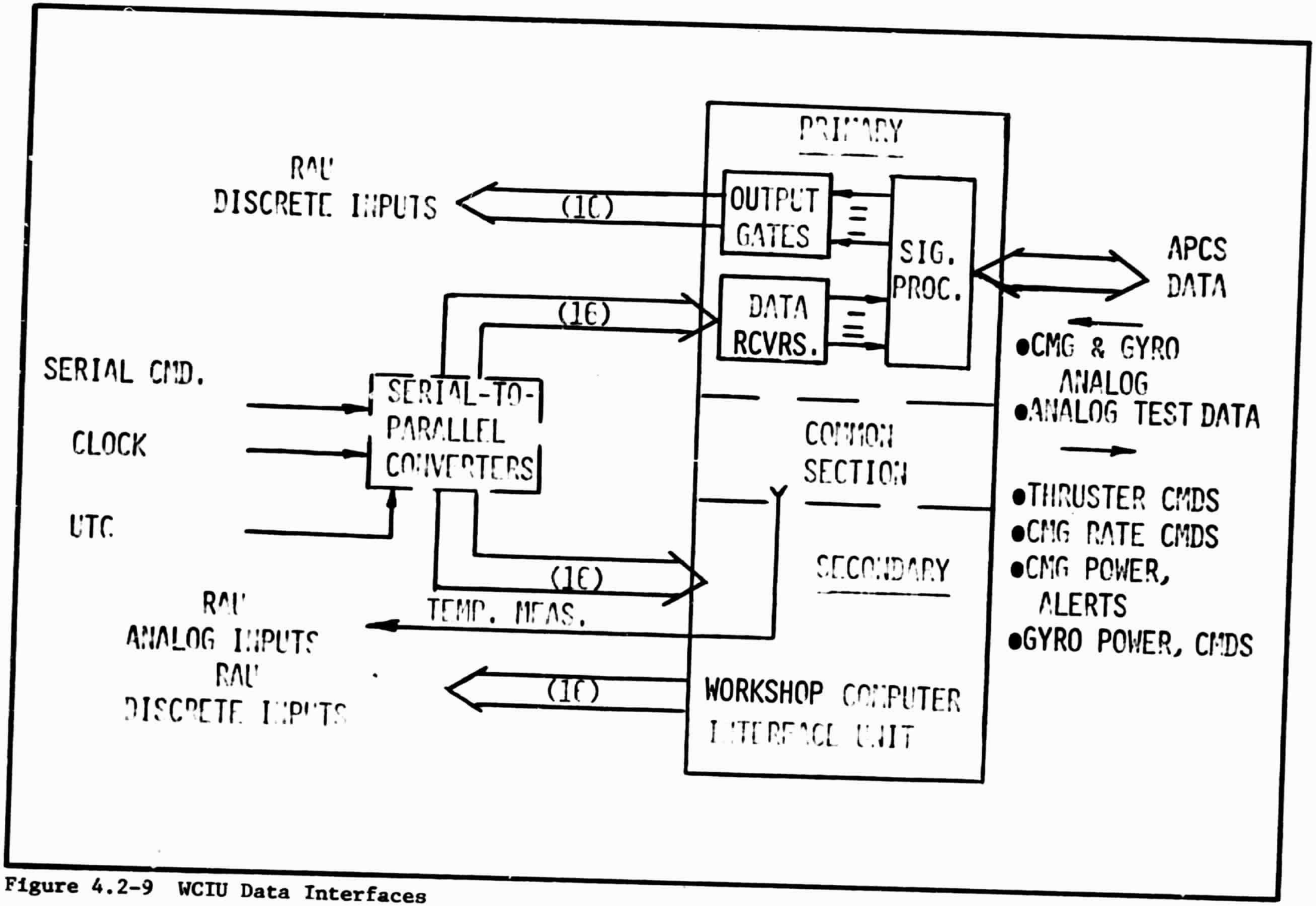

Figure 4.2-9 WCIU Data Interfaces

in Figure 4.2-10, which assumes use of the Spacelab module. The overall configuration and data interfaces are very similar to those required for the ATM. Some constraints do exist with the number of wires crossing the IPS gimbal interface. A cabling harness accommodates wiring for three RAUs mounted on the IPS attachment ring, which would be adequate to support the instruments considered in this study. The harness also includes wiring for three HRM channels, which again is adequate; but provides wiring for only one video cable, whereas our instruments generate two video signals.

Some consideration has been given to mounting the ATM canister plus instruments on the IPS. The numerous TCS telemetry channels and commands could be accommodated by a single RAU, but a problem would be encountered in processing the approximately 40 low level measurements. One possible solution would be to mount the required Signal Conditioning Racks and associated Amplifier stages external to the ATM canister so the low level data could be conditioned and fed into the RAU before crossing the gimbals.

Figure 4.2-11 illustrates the C&DH configuration for the Spacelab Igloo configuration, which indicates the same impact as for ATM with respect to the HDRR.

4.2.3.3 <u>AGS Approach</u> - The typical C&DH configuration and data interfaces associated with an AGS mounted payload are depicted in Figure 4.2-12. The diagram clearly shows two data bus interfaces with the platform-mounted components. One bus interface is typical for a science payload interfacing with the Spacelab data system. The other bus interface controls and monitors pointing control hardware on the platform under control of a dedicated NSSC-II computer located on a pallet.

As in the case of the IPS, a limited wiring interface across the AGS gimbals is provided for payload power and signals. An adequate number of twisted-shielded pairs are available to accommodate data bus wiring to several RAUs plus high rate digital channel inputs to the HRM. A possible problem appears to be the lack of any capability to carry

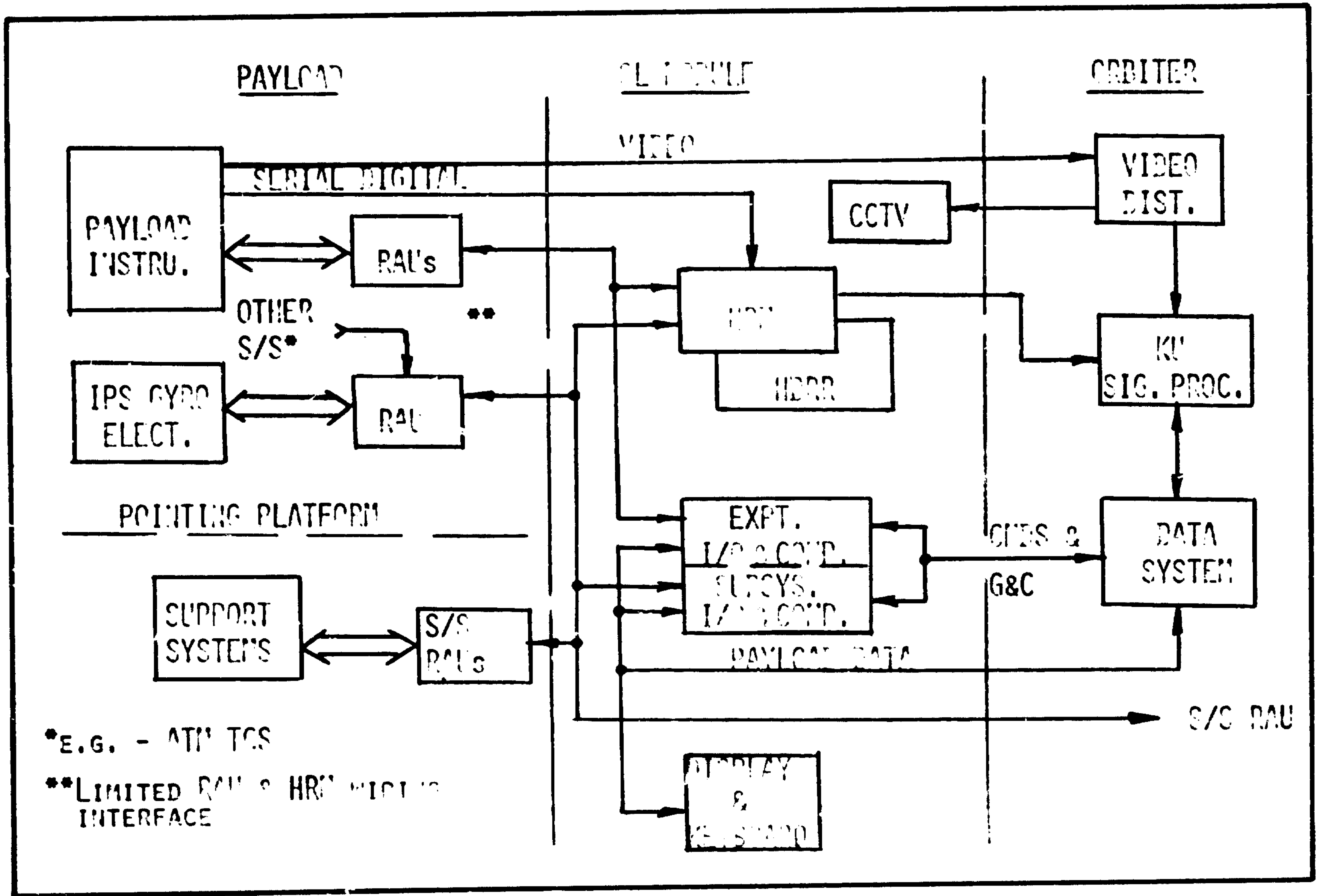

Figure 4.2-10 IPS C&DH Diagram (Module)

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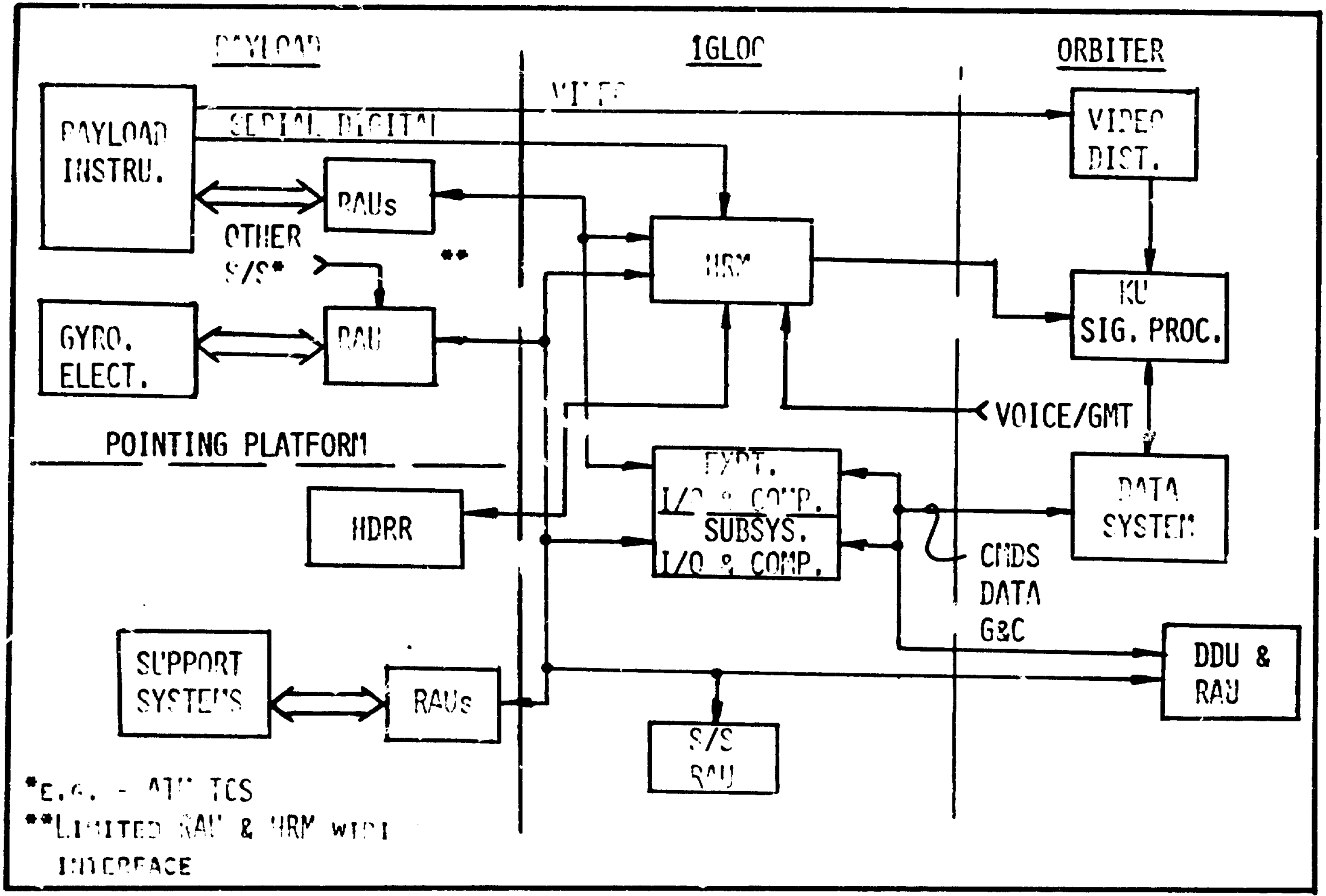


Figure 4.2-11 IPS C&DH Diagram (Igloo)

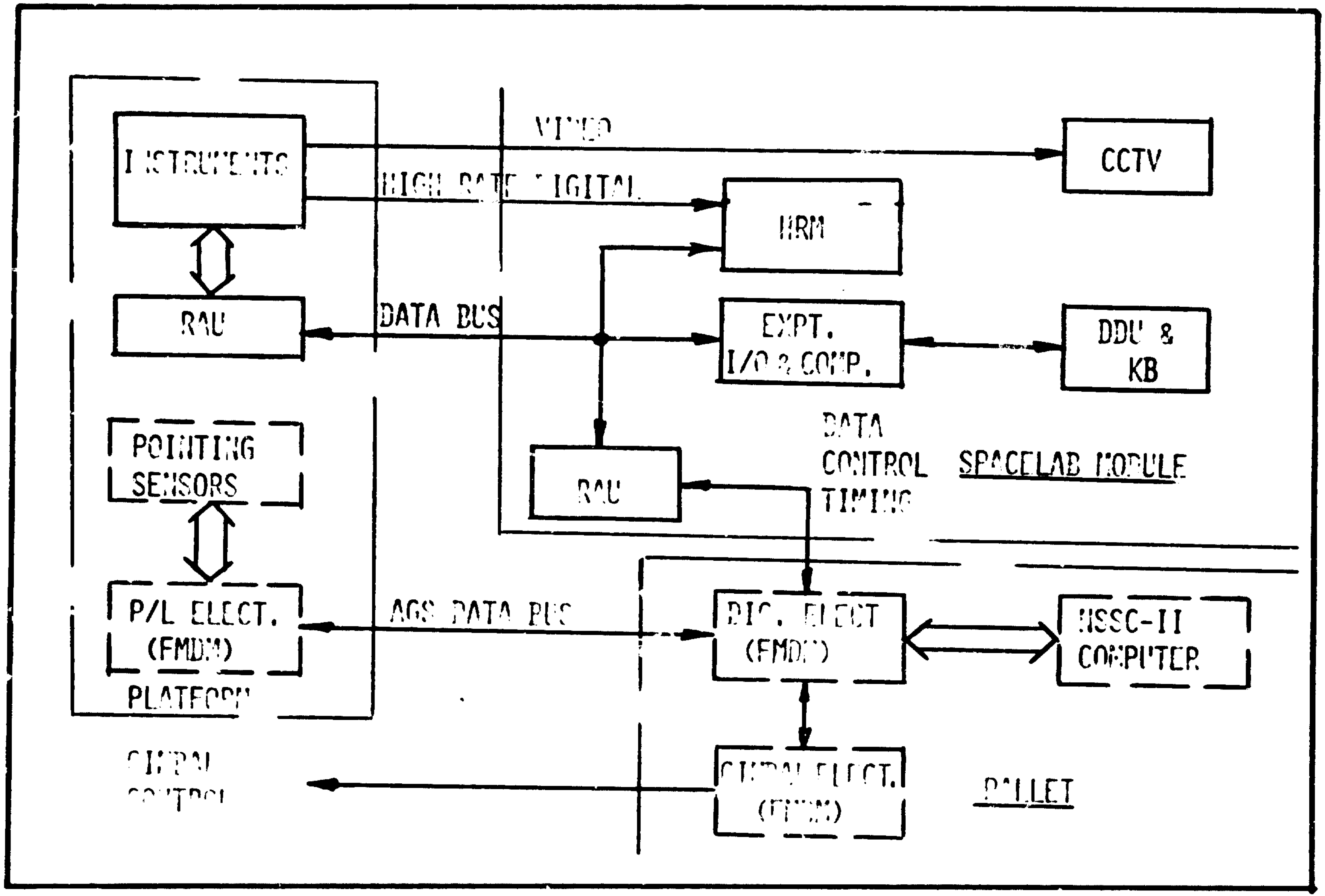


Figure 4.2-12 AGS C&DH Diagram

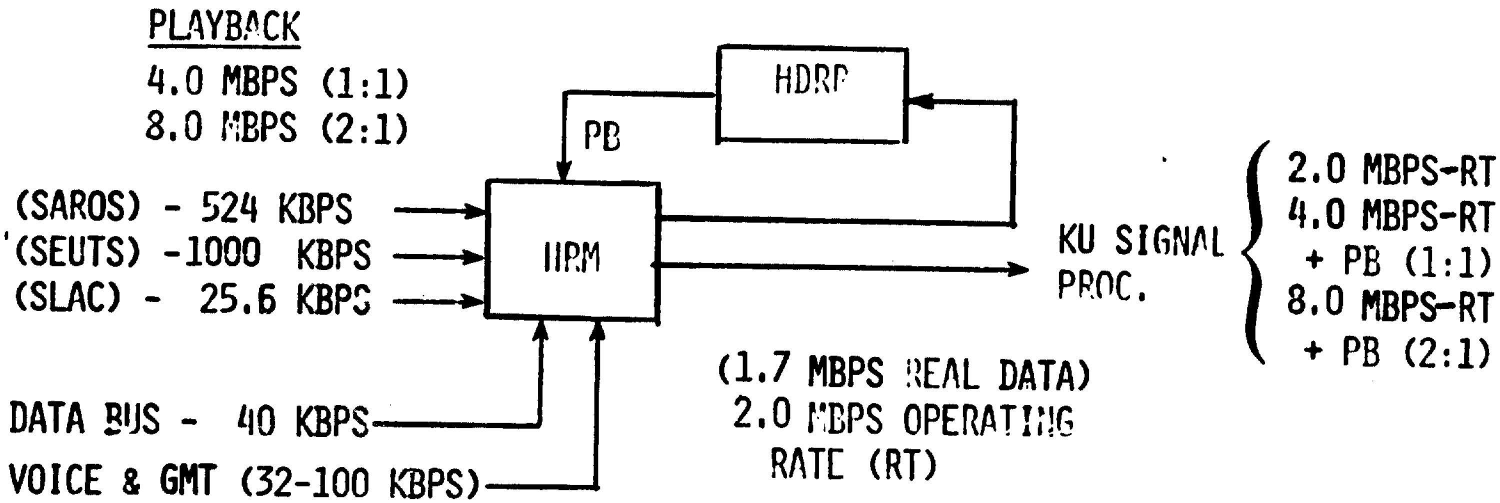
payload video signals across the gimbals.

4.2.3.4 Payload Data Handling - The primary components within the Spacelab data system which process the scientific data are the HRM and HDRR, regardless of the pointing platform involved. The HRM combines the high rate digital signals from the payload, as shown in Figure 4.2-13, with the data bus, digitized voice, and timing signals. The HRM has the capability to combine up to 48 Mbps of data, so any combination of the instruments in question utilizes only a small part of that capability. The combined rate of the three instrument data signals, as indicated in the figure, is about 1.7 Mbps. Since the HRM and HDRR operate at binary multiples with respect to 1.024 Mbps, the HRM would generate a 2 Mbps signal to accommodate the peak payload data rate. For a combination of only the SAROS and SLAC instruments as an example, a 1 Mbps HRM rate would be adequate.

During those periods when RT transmission is not possible, the HDRR is available to store the 2 Mbps for extended periods if required. Playback of this data is possible at a 1:1 rate or in binary multiples. As presented in Figure 4.2-13, the data is played back through the HRM and combined with any Ku data being generated. The figure also includes a table of Ku-band link capability, which shows a PM mode capacity to handle digital rates up to 50 Mbps. Also interesting is the FM mode capability used to recover video data simultaneous with a digital signal up to 2 Mbps. This means that RT payload digital data of 1.7 Mbps could be transmitted at the same time as a payload video signal.

The approach used to combine the various data signals within the HRM is clarified somewhat by the format diagram illustrated in Figure 4.2-14. The basic HRM format consists of a 96 word (16 bit) frame generated by sequencing through 16 columns of 6 lines each, and resulting in 1536 bits/frame.

The 2 Mbps HRM rate is produced by repeating this sequence 1330 times per second. Since the SEUTS produces a 1 Mbps signal, this will consume about half the format or 48 words, with 25 required for SAROS,



KU LINK CAPABILITY

MODE	CHANNEL 1	CHANNEL 2	CHANNEL 3
PM	192 KBPS	2 MBPS	50 MBPS
FM	192 KBPS	2 MBPS	4 MBPS OR 4.5 MHZ

Figure 4.2-13 Payload Data Handling

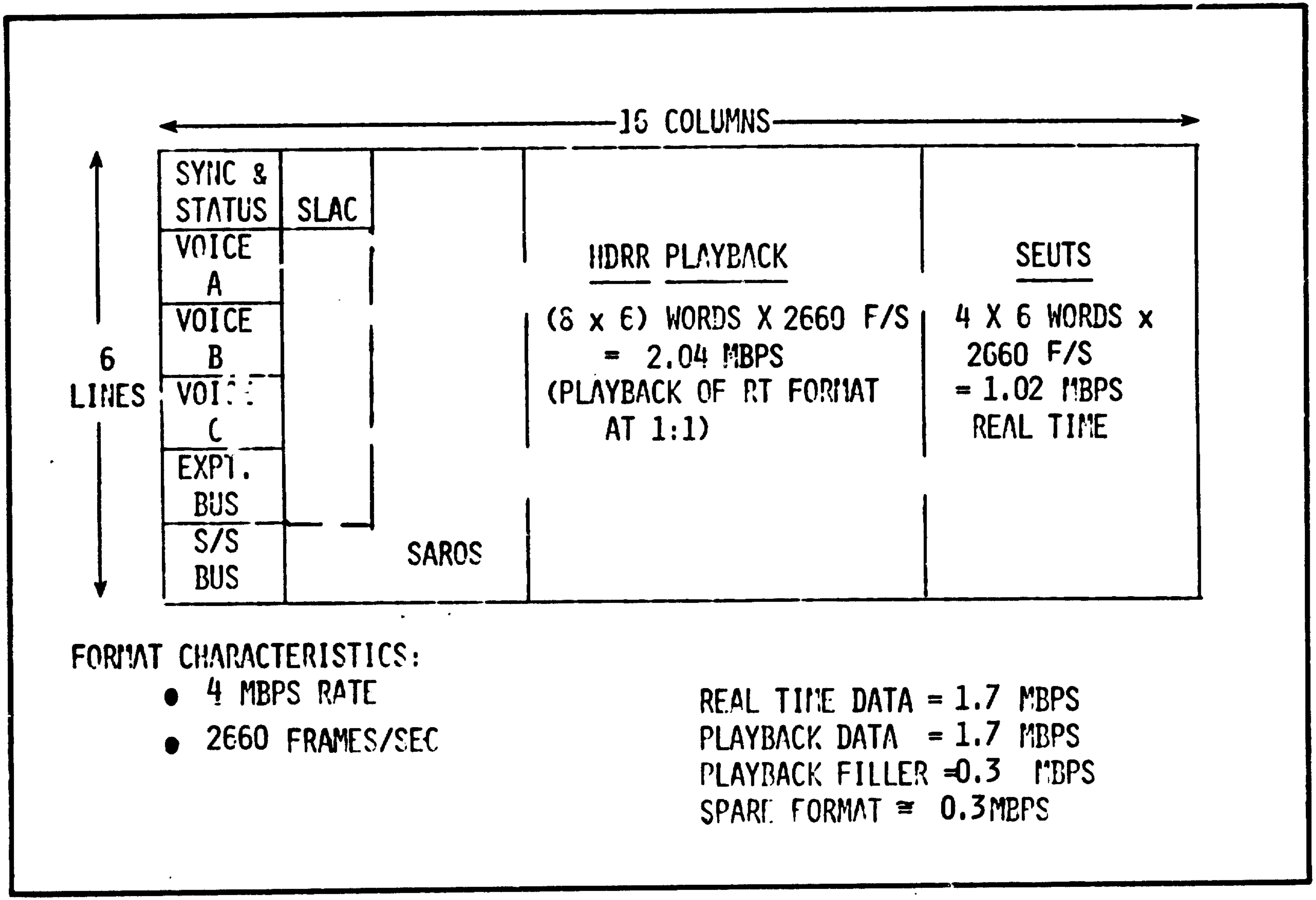


Figure 4.2-14 Real Time HRM Format

and 1 or 2 for SLAC. The synchronization, voice, timing, and bus data require less than 10 format words. This format will then produce about 1.7 Mbps of multiplexed payload data plus 0.3 Mbps of spare or filler bits.

Figure 4.2-15 presents a possible HRM format capable of accommodating 2 Mbps of RT data at the same time as 2 Mbps of recorded data is played back through the HRM.

4.2.4 RF Link Support - RF support to the payload will be provided by the Shuttle RF systems, principally the Ku-band system. A summary of predicted RF link circuit margins for the Shuttle communication links is provided in Figure 4.2-16. It can be seen that the Ku link provides a +3.3dB margin for a 50 Mbps signal, which indicates that strong margins in excess of 10 dB can be expected for payload rates on the order of 10 Mbps or less. The margin for a video signal is predicted to be +5.5 dB, which should be adequate for the intended use of these data to support onboard instrument setup. A good uplink margin of +7.3 dB is predicted for command and voice transmission to the Shuttle. Only very limited support is provided by the S-bank Shuttle-to-TDRSS system. As the figure indicates, this link can only handle the Shuttle engineering data at a 192 kbps rate, which can contain up to 64 kbps of payload engineering data. This link should not be considered for recovery of payload science data.

4.2.5 C&DH Conclusions - The following conclusions are drawn from the C&DH study effort:

a) It is both performance and cost effective to use the Spacelab data system rather than the ATM data system, which has some serious incompatibilities.
b) The ATM payload instrument and support system data and command requirements can be satisfied efficiently in either the Spacelab module or Igloo configuration.
c) It is probably cost effective to use the ATM digital computer and available software for control of the pointing system. Only minor interface problems will be

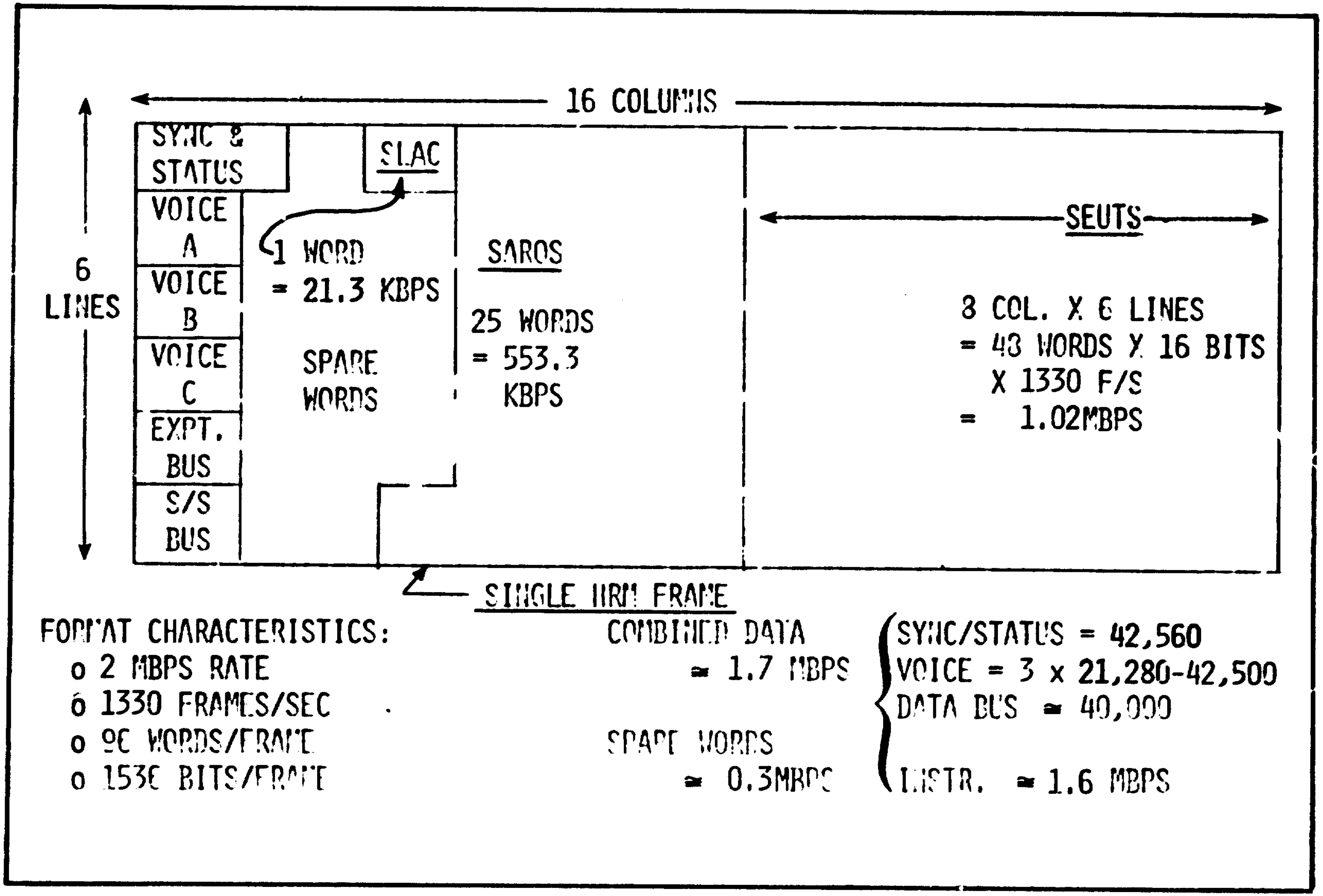


Figure 4.2-15 Playback HRM Format

FREQ. BAND	TERMINAL	RETURN (TELEMETRY)			FORWARD (COMMAND)	
		MODE	RATE (KBPS)	MARGIN (DB)	RATE (KBPS)	MARGIN (DB)
KU	TDRSS	QPSK	192	12.7	216	7.3
			50,000	3.3		
		FM	VIDEO	5.5		
S	TDRSS	PSK	192	1.5	32	3.4
S	GSTDN (9.1M SITE)	PM	192	13.5	72	>40
		FM	VIDEO	4.0		
		FM	5,000	2.7		

MARGIN DATA EXTRACTED FROM "SPACE SHUTTLE COMMUNICATIONS AND TRACKING RF LINK CIRCUIT MARGIN SUMMARY", JSC

Figure 4.2-16 RF Circuit Margins Summary encountered between the ATM computer and the Spacelab data system.

d) The instrument payload under consideration can be supported satisfactorily by the Spacelab data system when mounted on either the IPS or AGS, if a way is found to carry the two video signals across the gimbals. Use of the ATM canister for thermal and structural support of the payload on either the IPS or AGS will require mounting of 2 or 3 RAUs on the ATM to avoid wiring problems across the gimbals.

4.3 Thermal Control System

This section describes the solar scientific instruments thermal requirements, ATM canister thermal environment, instrument combinations and ATM/STS design concepts. The main objective is to illustrate thermal compatibility if possible of the configurations (Integrated ATM, IPS/ATM and AGS/ATM) introduced in Section 4.1.

4.3.1 Instrument Thermal Control Requirements and Descriptions - The scientific instruments thermal control requirements and descriptions are summarized in Table 4.3-1. The operating temperatures and acceptable thermal gradients of the instruments are within the design capability of the ATM thermal canister provided environment. It may be required to coordinate localized instrument hot spots with view ports in the instrument support structure to the ATM canister cold plates to obtain the instrument thermal gradient requirement. The internal scientific instrument thermal control systems are all compatible with the provided ATM canister thermal environment, (i.e., designed to operate in an enclosed thermal environment).

4.3.2 ATM Thermal Canister - The ATM canister incorporates an active thermal control system to provide the instruments with acceptable non-operational and operational thermal environments. The system incorporates a closed fluid loop (methanol/water) with a 900 $\pm$ 50 lb/hr flow rate. The fluid loop splits prior to the cold plates, therefore, there are two parallel flow paths with eight cold plates in series per path, for a total of sixteen (16) cold plates. One path removes heat from the sun end of the canister and the other from the MDA end. The flow then combines and is directed to a modulation flow control valve. This control determines the percent of fluid flow to be directed to the 500 watt capacity in-line heaters and the balance of the fluid is directed to the radiators for fine temperature control. The fluid loop is then completed. The ATM canister thermal control system provides $50^{o} \pm 1.5^{o}F$ ($10^{o} \pm 0.6^{o}C$) cold plate temperatures and a 500 watt heat transport capacity. The thermal control system is illustrated on Figure 4.1.

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Table 4.3-1 Instrument Thermal Control Requirements and Description

SCIENTIFIC INSTRUMENT	OPERATING TEMPERATURE	TEMPERATURE CONSTRAINTS	SCIENTIFIC INSTRUMENT THERMAL CONTROL SYS.
APC	21 ± 3°C	THERMAL GRADIENT NOT TO EXCEED 5°C FRONT TO BASE PLATE & 2°C SIDE-TO-SIDE	-COLD STRAP LINK COLD PLATE TO ELECTRONICS -HIGH EMITTANCE COATING -MULTILAYER INSULATION -INTERNAL HEATERS
SEUTS	22°C	SENSITIVE TO LONGITUDINAL DISPLACEMENT	-VARIABLE HEAT PIPES -SPECIAL COATINGS -MULTILAYER INSULATION -INTERNAL HEATERS
SAROS	20 ± 3°C	MAINTAIN THERMAL GRADIENTS IN PRIMARY STRUCTURE LESS THAN .01°C/CM	-COLD STRAP LINK COLD PLATE TO ELECTRONICS -SPECIAL COATINGS -INTERNAL HEATERS

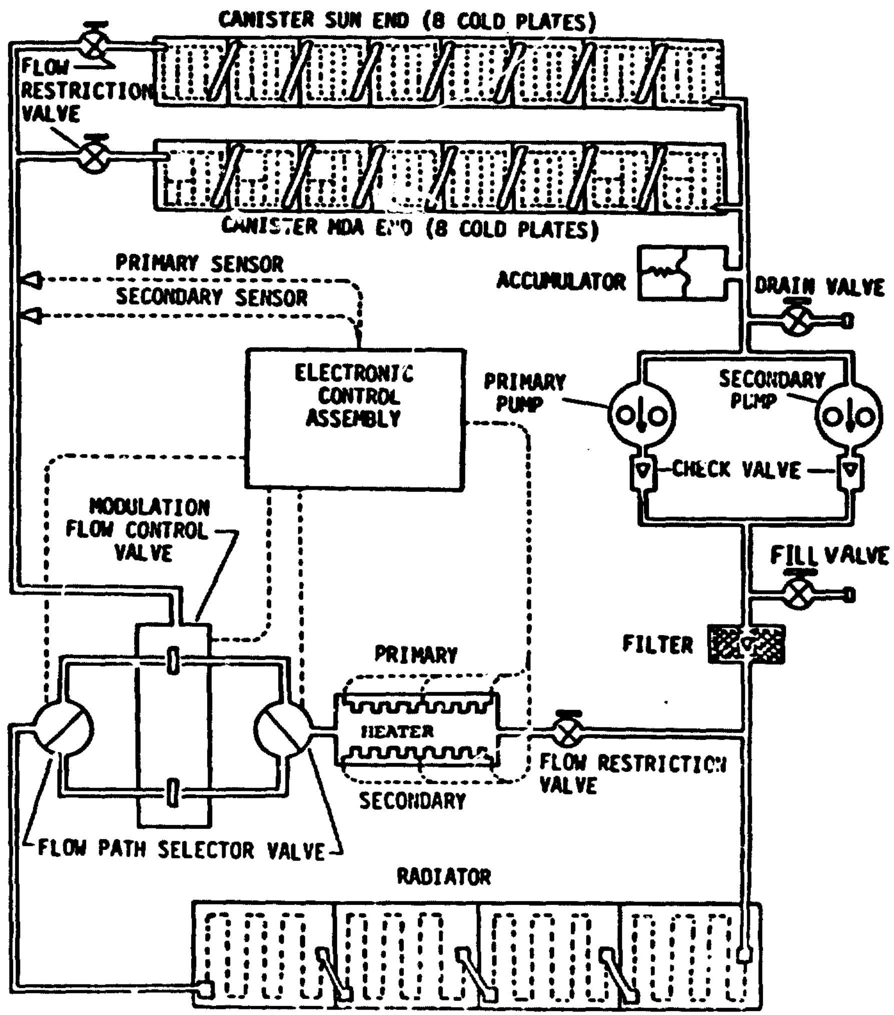

Figure 4.3-1 ATM Active Thermal Control System

4.3.3 Two Instrument Concept - Both ATM/Instrument concepts analyzed incorporated two instrument combinations. These two configurations are illustrated in Figures 4.3-2 and 4.3-3. The maximum power dissipation for the two instrument concepts and available power design margin provided by the ATM canister are illustrated in Table 4.3-2. This table was generated based on a 500 watt heat load with a 3°F temperature rise across the cold plates. A heat load of up to 800 watts can be handled by the system if a 5°F temperature rise is acceptable to the scientific instruments.

4.3.4 ATM/STS Design Concepts - The three design concepts considered are Integrated ATM, IPS/ATM and AGS/ATM. Each concept will be discussed separately.

4.3.4.1 Integrated ATM - The Integrated ATM configuration is illustrated on Figure 4.3-4. There are a number of thermal considerations to be addressed for this configuration.

a) The aft end of the canister provides mounting surface for experiment and TCS components. The components are thermally isolated from the surface by fiberglass standoff mounts and multilayer insulation. The components' temperature limit range is -12° to 50° C. An exposed payload (P/L) bay would provide a sink temperature of approximately 105° C which is unacceptable to the components. By shielding the P/L bay from the sun around the canister support structure with a silverized Teflon coated shade, it would provide a sink temperature of approximately -4° C. Passive thermal control of aft mounted components is feasible in this environment. It is important that the sun shield be tilted away from the ATM radiator surface to prevent additional heat load on the ATM canister TCS.

b) The components that were originally mounted on the Skylab ATM rack will be mounted on the canister support structure. An all-passive TCS would not be adequate for a number of

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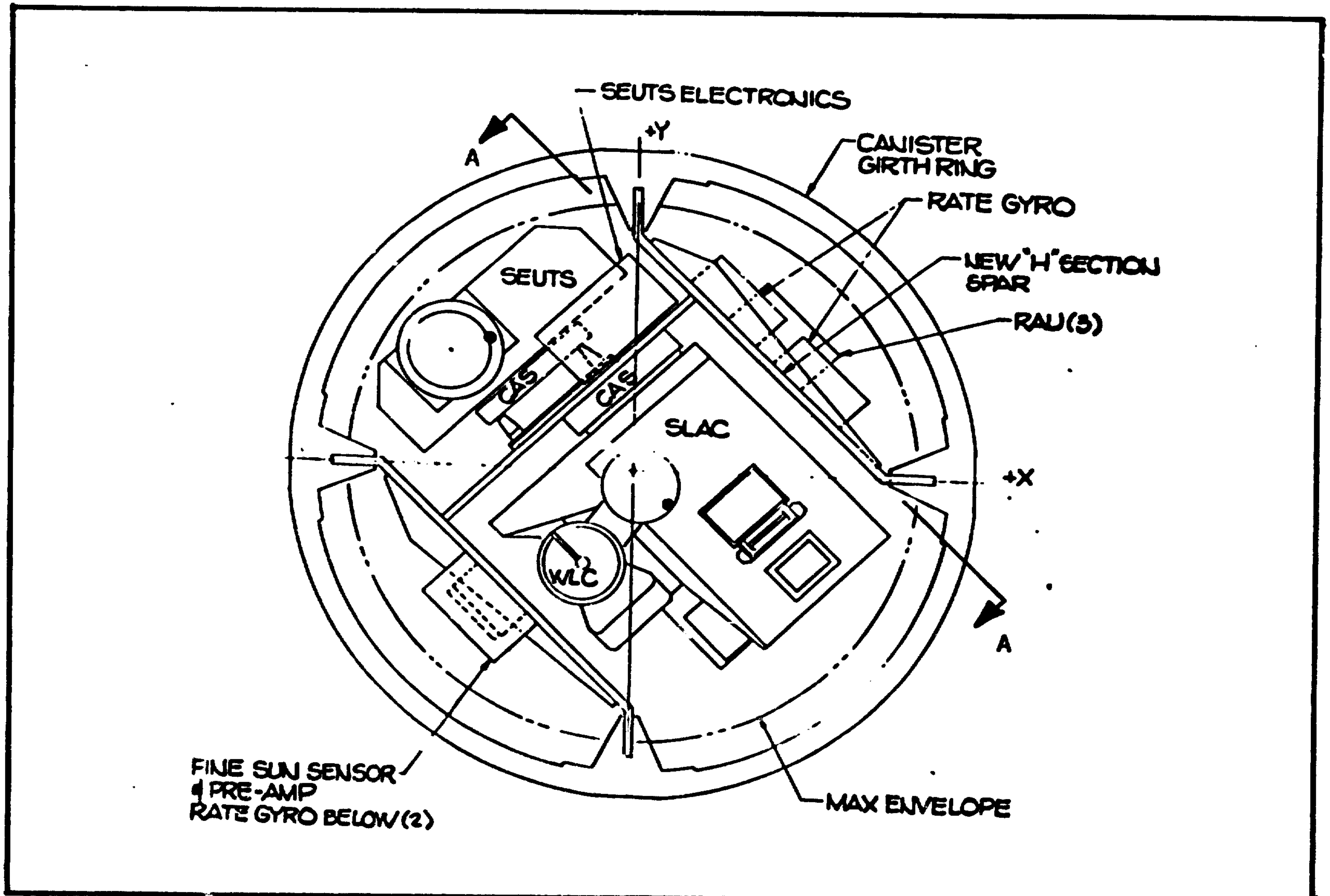

Figure 4.3-2 Two Instrument Configuration - SEUTS + ARC

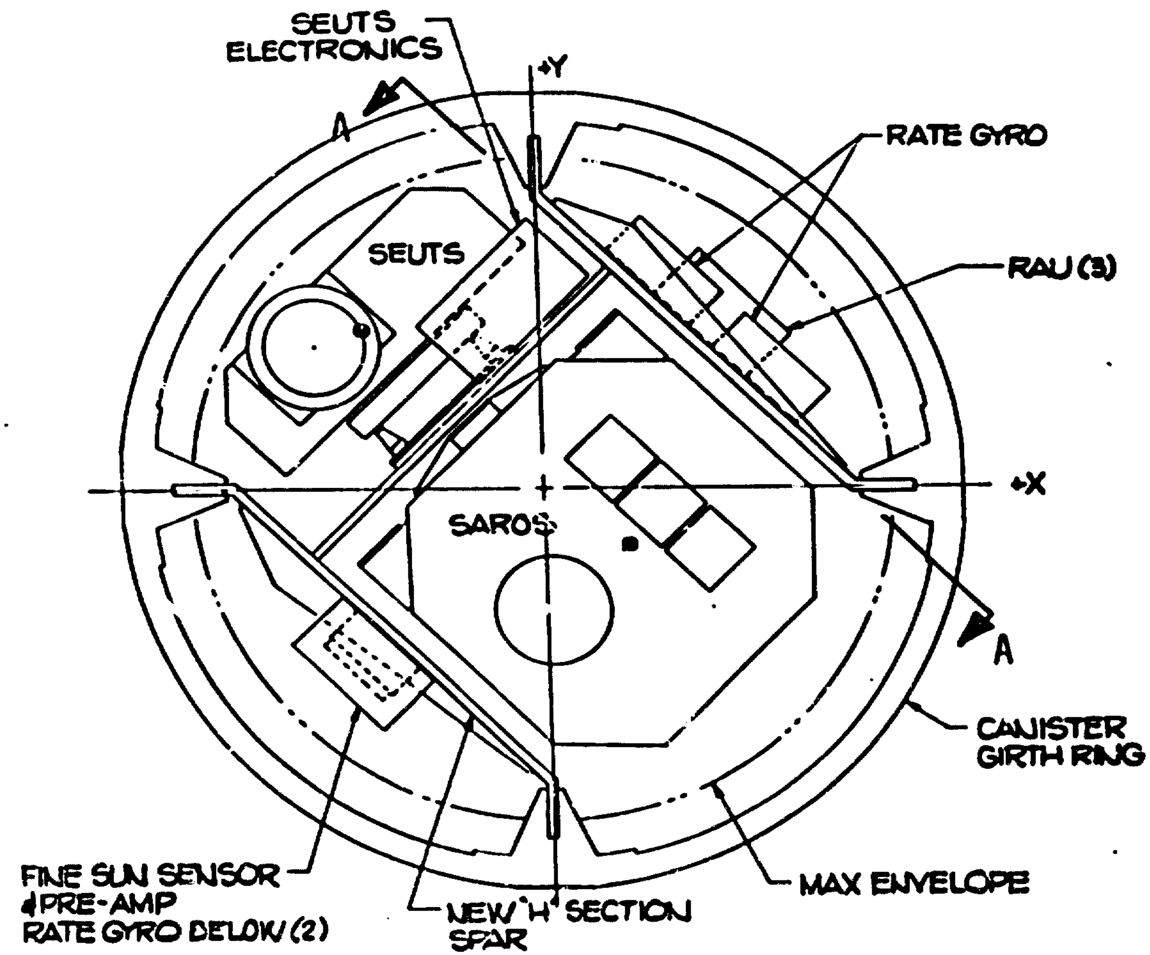

Figure 4.3-3 Two Instrument Configuration - SEUTS + SAROS

Table 4.3-2 Instrument Power Dissipation - Requirements and Margins

TWO INSTRUMENT CONCEPTS	COMBINED MAXIMUM POWER DISSIPATION	POWER DESIGN MARGIN
SEUTS & ARC	355 WATTS (SEUTS - 160 WATTS) (ARC - 195 WATTS)	145 WATTS (INST.'S ONLY) 35 WATTS (WITH PCS HARDWARE)
SEUTS & SAROS	440 WATTS (SEUTS - 160 WATTS) (SAROS - 280 WATTS)	60 WATTS (INST.'S ONLY) 0 WATTS (WITH PCS HARDWARE)

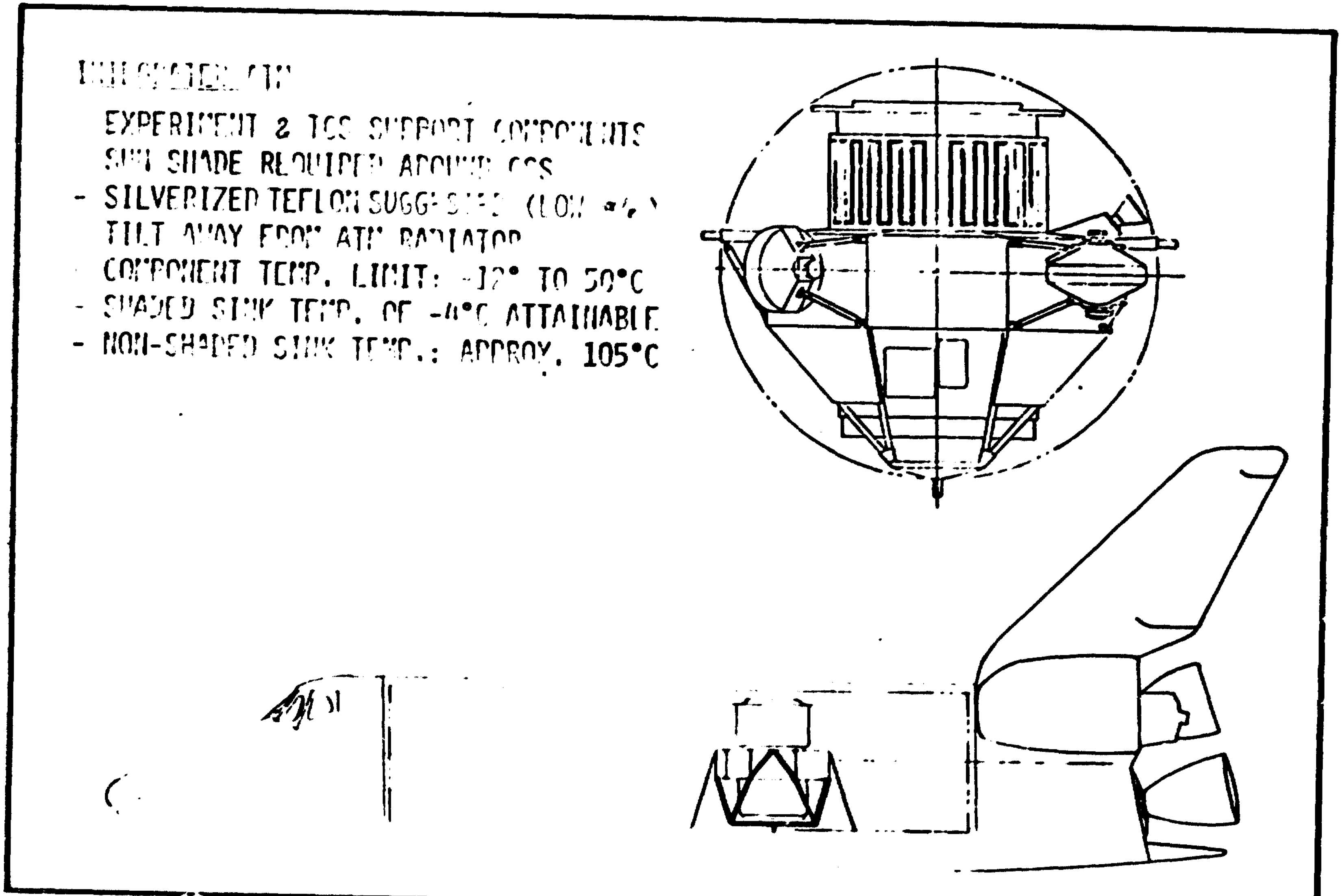

Figure 4.3-4 ATM Canister Support Structure - Passive TCS

these components, therefore, the utilization of the Spacelab active thermal control system is recommended.

The system, by means of cold plates and a Freon 21 fluid loop, is capable of transferring to the Orbiter radiator via the payload heat exchanger up to 6.3 kw of thermal energy. The proposed components to be cold plated are three CMG Inverter Assemblies, two ATM Digital Computers, one Workshop Computer I/F Unit, and two High Data Rate Recorders.

4.3.4.2 IPS/ATM and AGS/ATM - From a thermal viewpoint, the IPS and AGS systems are similar and will be discussed as one. The IPS/ATM configuration is illustrated on Figure 4.3-5. One ATM thermal control system component was moved into the canister environment and provides an additional 25 watt heat load for these two concepts. To reduce parasitic heat load on the ATM thermal control system, the support housing to the IPS and AGS mounting rings are lined with multilayer insulation. Additionally, since the TCS is self-contained in the canister, no fluid lines need to cross the gimbals.

4.3.5 Conclusions

The following conclusions were derived from the thermal analysis:

- The ATM TCS is compatible with instrument temperature limits and constraints,
- The ATM TCS is compatible with power dissipation requirements of both instrument combinations, and
- All the thermal problems related to Integrated ATM, IPS/ATM and AGS/ATM are workable.

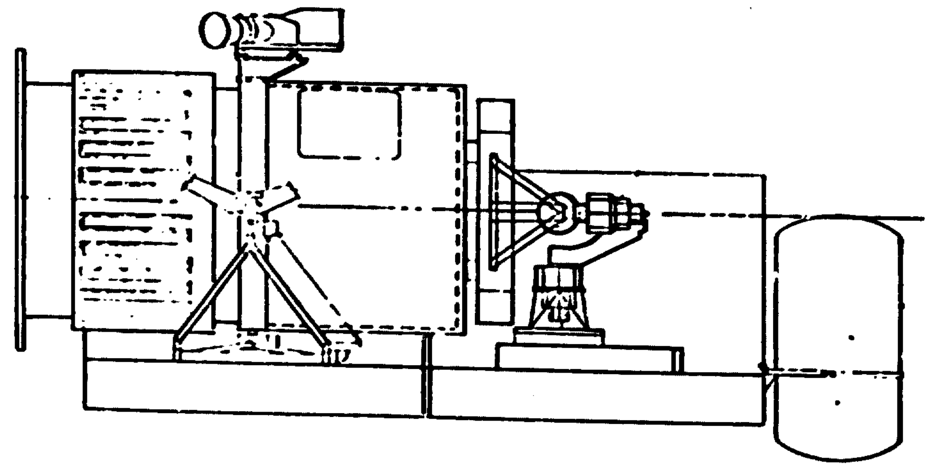

Figure 4.3-5 ATM/IPS Pallet Installation

4.4 Electrical Power System

The ATM, IPS, or AGS have no active power systems and must receive all of their electrical power from the Orbiter/Spacelab power system. Therefore, the power analysis consisted of an evaluation to determine if the Orbiter/Spacelab could supply the power required by each of the concepts discussed earlier in this section. The availability of power for the analysis was obtained from the Spacelab Accommodations Handbook.

4.4.1 Power/Energy Constraints - The electrical energy for ATM is supplied by fuel cells located in the Orbiter and is, therefore, dependent on availability of fuel cells dedicated to payload use. The normal configuration of the Orbiter power system provides 50 kw hours to the payload and a dedicated fuel cell provides 840 additional kw hours. The power available from the fuel cells is limited by the heat rejection capability of the Orbiter and is 7 kw for normal maximum continuous operation and 12 kw for pulse load operation.

4.4.2 Power/Energy Usage - The power levels required for each instrument considered for the ATM program are given in Table 4.4-1. "SLAC" and "WLC" are combined into a single instrument designated as "ARC". The only feasible combination of instruments due to physical constraints are "ARC" + "SEUTS" and "SEUTS" + "SAROS". Peak power refers to the worst case peak having a duration of less than approximately 1 minute in duration. Average power is power averaged over the mission and maximum continuous power is continuous power exclusive of peaks.

Figure 4.4-1 demonstrates the load requirements for each power user that makes up the total load requirement. The total load that comes out of the 7 kw allotment consists of the ATM instruments, mission dependent C&DH components, ATM support (subsystems) and basic Spacelab power. The basic Spacelab power requirement depends on equipment configuration. If the pressurized Spacelab module is used, 655 watts are required. If the pallet/Igloo or integrated ATM Igloo configuration is used, only 235 watts are required. Both the power limit of

Table 4.4-1 Experiment Power Requirement

	POWER (WATTS)		
	PEAK (1)	AVE. (2)	MAX. CONT. (3)
SLAC	161	150	153
WLC	90	47	42
ARC (SLAC + WLC)	241	197	195
SEUTS	190	160	160
SAROS	340	212	280
ARC + SEUTS	291	357	355
SEUTS + SAROS	390	372	440

(1) PEAK POWER MUST MEET PEAK POWER CAPABILITY
(2) AVE. POWER FOR ENERGY CALCULATIONS
(3) MAX. CONTINUOUS POWER TO EVALUATE POWER REQT.

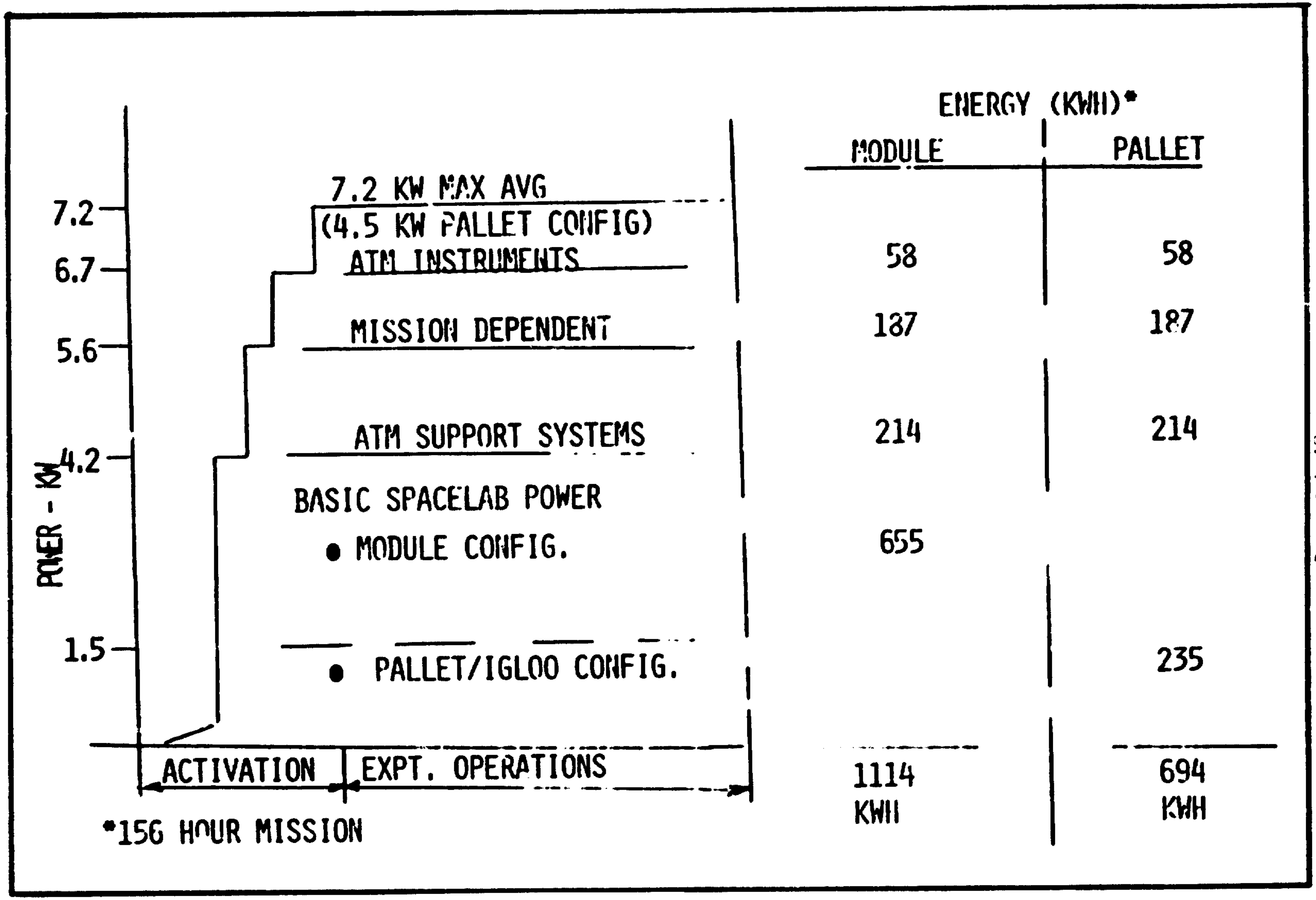

Figure 4.4-1 ATM Payload Power/Energy Requirements

seven (7) kw and the energy limit of 890 kwh are exceeded for the module configuration, whereas considerable margin exists for the other configurations.

4.4.3 Electrical Power Distribution - The simplified block diagram of the electrical power distribution system is shown in Figure 4.4-2. Electrical power is routed from the Orbiter fuel cells to either the Spacelab module or to the pressurized Igloo where C&DH components requiring pressurization are located. Power is then routed to either the pallets or to the canister support structure (CSS) where C&DH components are mounted and then to the subsystems and experiments in the ATM canister. The emergency box power has limited usage for equipment designated as warning and caution. The primary DC bus from the Orbiter provides subsystem and experiment power in the module by way of distribution boxes and distribution panels for the module configuration. In the pallet/Igloo configuration subsystem C&DH power is supplied in the Igloo and experiment power is supplied by way of the Igloo to the pallet for experiments and subsystems (IPS and AGS configuration).

In the integrated ATM configuration, the Igloo is physically mounted to the CSS. Power is supplied to the subsystems and experiments through the Igloo to a power distribution box also mounted on the CSS.

4.4.4 Conclusions - The Orbiter/Spacelab systems provide and distributes the power required by the ATM subsystems and experiments. There is, however, an operational constraint associated with the use of the Spacelab module configuration. Power management would be required in this configuration to limit both power and energy to the constraints of the Orbiter. No new hardware is required by the Power system except interconnecting power distribution harnesses.

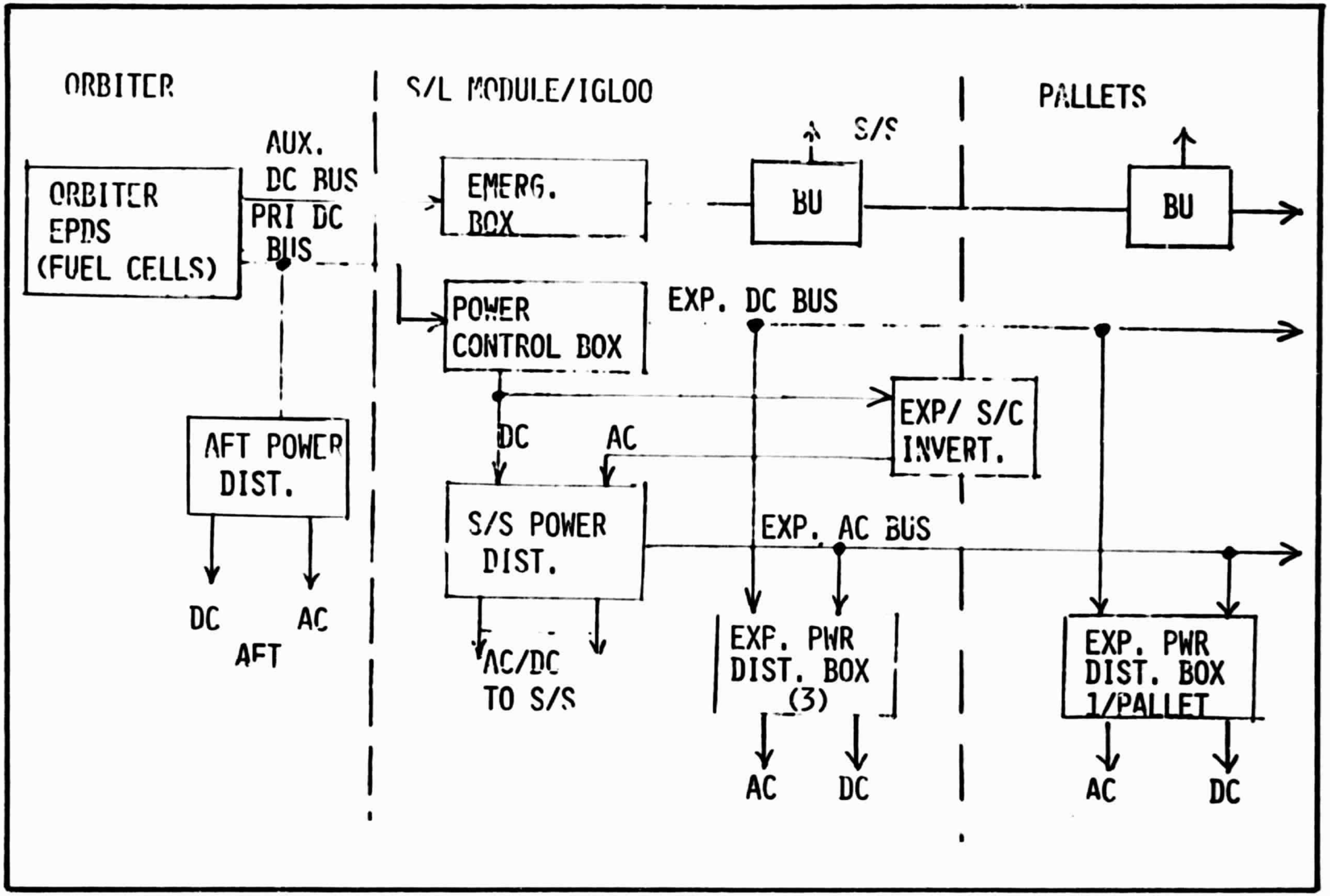

Figure 4.4-2 Electrical Power Distribution

4.5 Attitude and Pointing Control

Three systems for attitude and pointing control of the Solar Scientific Instruments in the Shuttle Orbiter/Spacelab were reviewed. The first system identified as the "ATM Integrated" maximizes the re-use of the ATM control system hardware and software from the past Skylab Program. The second and third systems reviewed utilized the Spacelab Instrument Pointing System (IPS) and the Annular Suspension and Pointing System Gimbal System (AGS). In both the IPS and AGS concepts, the ATM canister, with instrument payload was attached directly to the pointing platform's payload mounting rings. See Figures 4.1.4-1 and 4.1.5-1.

The payload instruments used for each review consisted of the SAROS, SEUTS and ARC as defined in Section 2.0. Pointing requirements with respect to pointing accuracy, knowledge of accuracy, stability, jitter and roll range were extracted from the GSFC furnished Experiment Requirements Documents (ERDs). These extracted requirements are listed in Table 4.5-1. Also listed in the last column of this table are the performance characteristics of the ATM/CMG system as demonstrated during Skylab. Discussion on this subject is covered in Section 4.5.8.

There are some areas of ambiguity with respect to these requirements. For example; the stability requirement is usually related to an exposure or integration period of the experiment during which the movement is not to exceed some specified value. For the SAROS, the line-of-sight stability requirement fits this definition, but the roll stability does not and requires some further interpretation from the experimenter.

The notes pertaining to roll range requirements (Table 4.5-1) bring out the conflicting requirements among the three experiments with respect to control of the roll axis of the pointing system.

More specifically:

a) The SAROS experiment requires the roll setting to remain fixed through a sun-side pass in order that a programmed sequence of observation points can be

Table 4.5-1 Experiment Pointing Requirements Comparison to ATM Capabilities

POINTING PARAMETER	AXIS (AXES)	EXPERIMENT POINTING REQUIREMENTS			SHUTTLE/ATM PREDICTED CAPABILITY (4)
		SAROS (1)	SEUTS (2)	ARC (3)	
ACCURACY	LOS	±2.5	±10	±10	±2.5
(arc sec)	ROLL	±1080	±1800	±7200 ±300	±540
KNOWLEDGE OF ACCURACY	LOS	±1	±1	±4	±2.5
(arc sec)	ROLL	±360	±180	±900 ±300	±540
STABILITY	LOS	±5.4/60 min.	±1/10 min. ±0.3/5 min.	10/60 min.	±1/15 min.
(arc sec/time)	ROLL	±0.5/sec. ?	±180/10 min.	±360/15 min. ±72/15 min.	±30/25 min.
JITTER	LOS	±0.25 ?	TBD	±2	±1
(arc sec/sec)	ROLL	±450	TBD	±150	±10

(1) NO REQUIREMENT ON ROLL RANGE. ROLL TO BE HELD CONSTANT DURING SOLAR SIDE PASS.

(2) REQUIRES ±180° ROLL RANGE TO ALIGN SPECTROMETER SLIT PARALLEL WITH LONG DIMENSION OF SOLAR FEATURE UNDER OBSERVATION. ROLL ORIENTATION TO BE HELD CONSTANT DURING TOTAL OBSERVING TIME ON A GIVEN FEATURE UP TO A SOLAR SIDE PASS.

(3) REQUIRED ±180° ROLL RANGE TO SURVEY SOLAR CORONA - REQUIRES 14 INCREMENTS OF ROLL TO PROVIDE 360° COVERAGE. ASSUMPTION THAT COMPLETION WITHIN A SOLAR PASS IS DESIRABLE.

(4) ATM ROLL CAPABILITY IS ±120° RANGE. ROLL CONTROL IS NOT PART OF FINE POINTING SYSTEM CONTROL LOOP.

observed during the pass. There are no stated requirements on roll range.

b) The SEUTS experiment requires alignment of the instrument slit parallel to the long dimension of the solar feature under study. Once a feature has been selected and the roll setting made, the setting is to be held during the remainder of the pass. A requirement for ± 180 roll range is stated in the ERD, however, it should be noted that a $\pm 90^{\circ}$ range would allow the slit to be aligned parallel to any given angle on the sun disc.

c) ARC desires to carry out a survey of the solar corona at 14 increments of roll (i.e., 26 degrees) to provide 360° coverage. The assumption has been made that this 360° mapping should be completed during one sun side pass.

These requirements are derived from the primary operating mode of each of the experiments.

The conclusion to be drawn is that only one of these three experiments can operate in its primary objective mode at any given time. Concurrent operation by a second experiment would of necessity be in some secondary objective mode.

4.5.1 Integrated ATM in Shuttle Orbiter - Similar to the Skylab application, the ATM Control Moment Gyro (CMG) System is used in the integrated system to point and stabilize the Shuttle Orbiter to a coarse alignment in three axes. The Experiment Pointing and Control System then provides the fine pointing accuracy and stability to the ATM canister mounted instruments. This concept yields several performance features:

a) The system has operated successfully in the similar Skylab application during spaceflight for an extended period of time.

b) The system provides control which has potential for future payload precise pointing applications.

c) The system minimizes exposure to payload contamination from the Orbiter VCS thrusters.

4.5.2 Control Moment Gyro Subsystem - Orbiter pointing attitude information is derived in a strapdown reference computation in the ATM Digital Computer (ATMDC). Sensors for the computation are mounted on the Canister Support System (CSS). Rate gyros, as shown in Figure 4.5-1, provide three axis rate information for stabilization and inner loop position. The Acquisition Sun Sensor is used for updating of vehicle attitude information for the pitch and yaw pointing system control. The Star Tracker is used to update the pointing system roll attitude computation. The ATMDC processes the sensors signals with a CMG control law to generate CMG gimbal rate commands. Momentum management computations are also performed by the ATMDC.

Three double-gimballed CMGs orthogonally hardmounted to the vehicle through the ATM Integrated Support Structure are shown in Figure 4.5-2. They are oriented with their gimbal axes as shown in Figure 4.5-3 such that any two can control all three axes in the event one fails. They provide the torques required for vehicle control. Each CMG has an angular momentum storage capability of 2300 ft-lb-sec at torques up to 160 ft-lb. Inner gimbal freedom is ± 75 degrees and outer gimbal freedom is +215 degrees to -125 degrees. The rotor runs at approximately 9000 rpm.

The three-CMG cluster requires periodic desaturation of its momentum buildup due to noncyclic components of gravity gradient (GG), aerodynamic, venting, and other disturbance torques. To minimize the bias components of the GG torques, the vehicle's principal axis of minimum inertia (X-axis) must be maintained in or near the Orbital plane attitude. Periodic firing of the Orbiter's VCS thrusters will be required to counteract the residual momentum buildup. This technique will eliminate the need to perform vehicle GG maneuvers on a per orbit basis to de-

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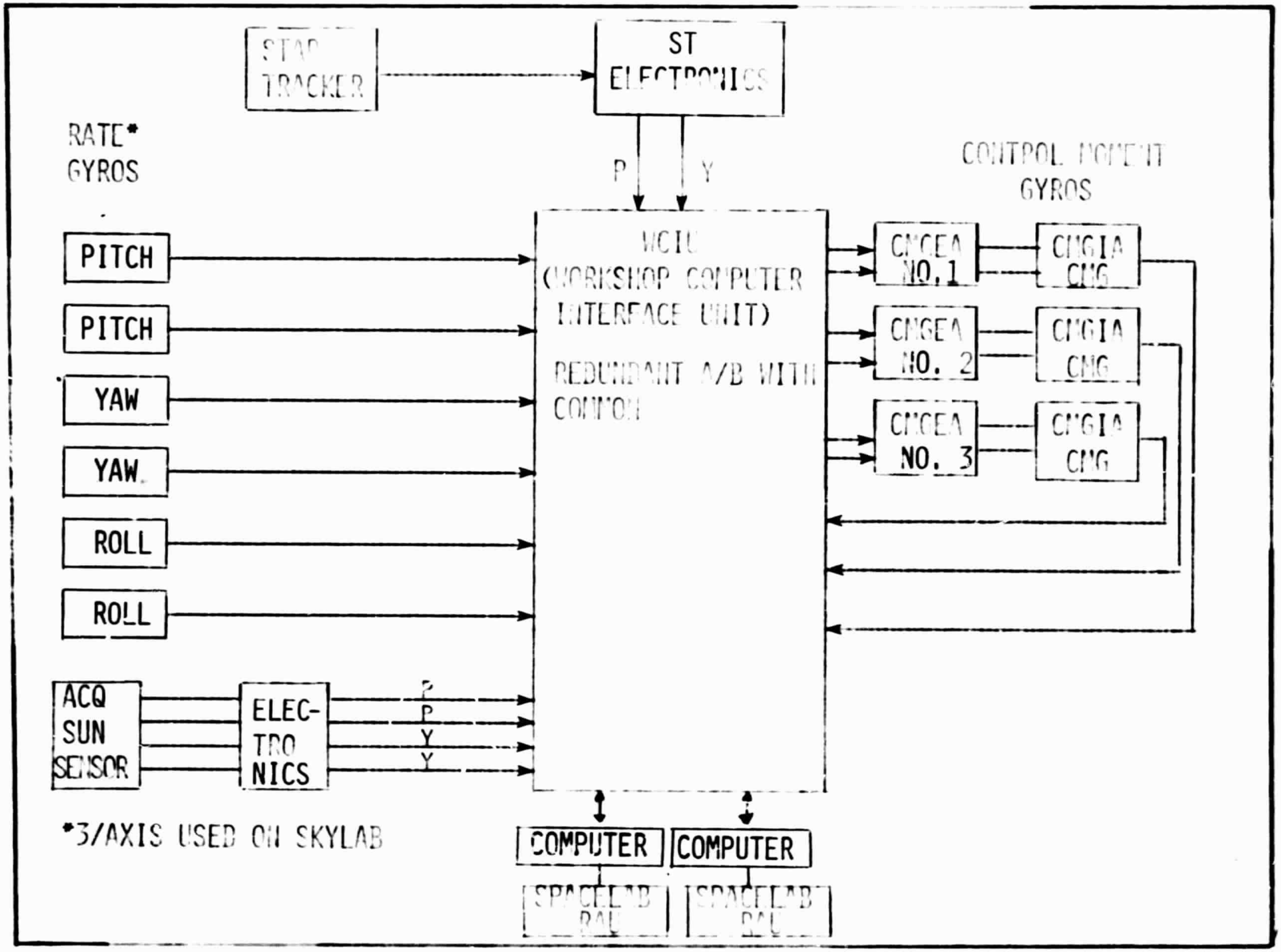

Figure 4.5-1 Control Moment Gyro Subsystem

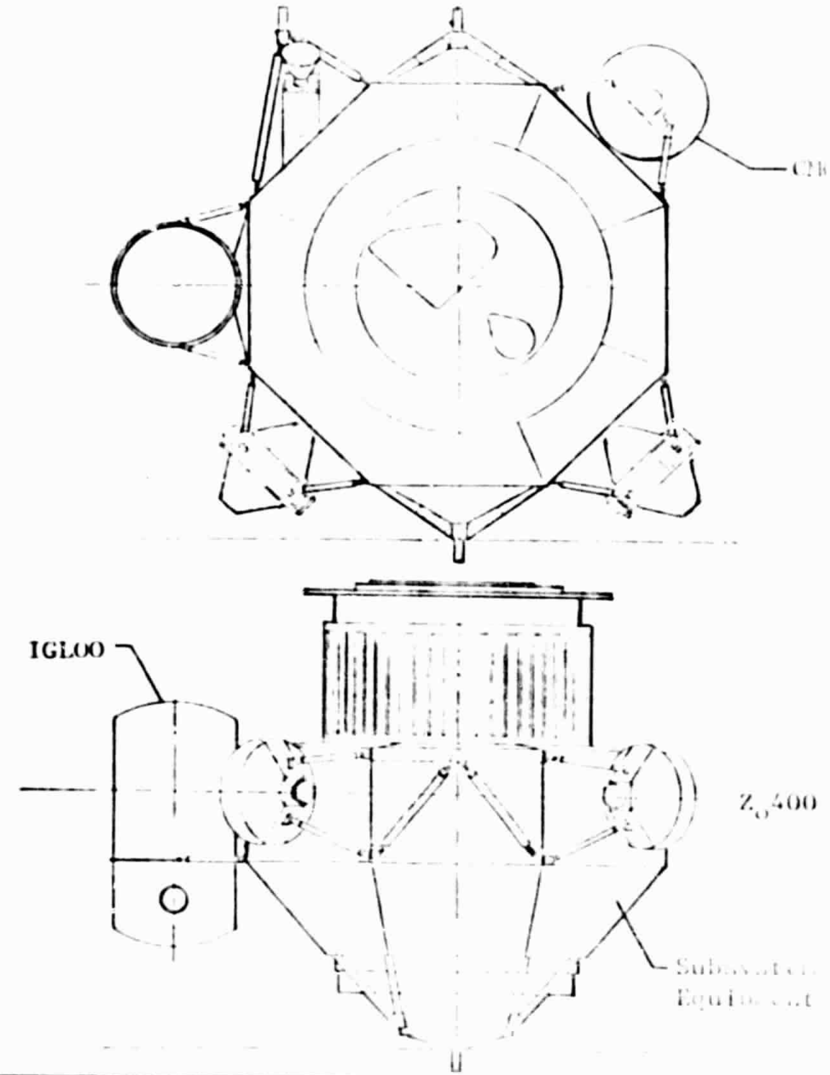

Figure 4.5-2 Gimbal Hardmounting to ATM Integrated Structure

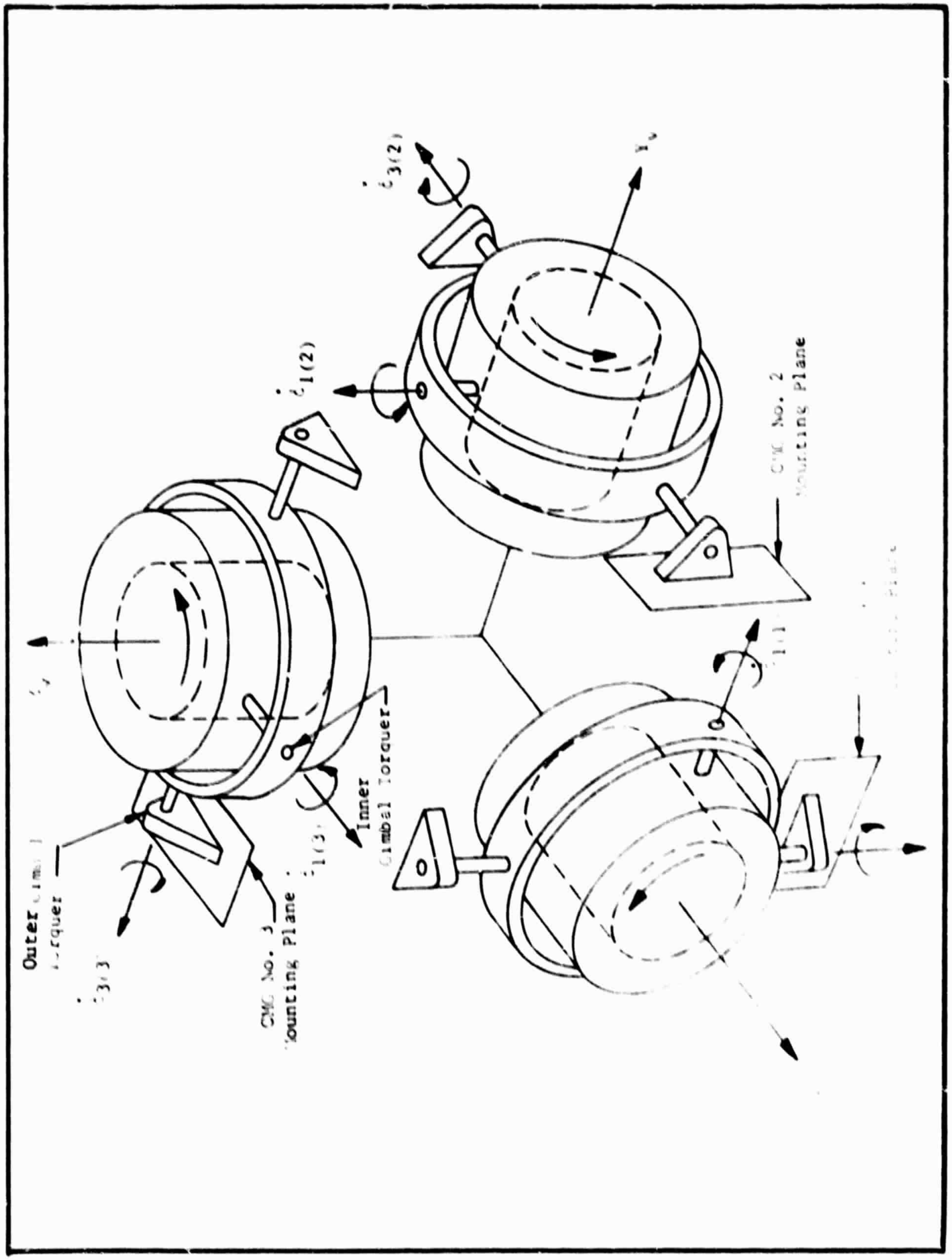

Figure 4.5-3 CMG Gimbal Axes Orientation

saturate the CMG subsystem, and thus allow for long term experiment viewing time.

The Acquisition Sun Sensor has a ± 20 degree field of view in each axis. Unit accuracy is approximately ± 2 arc minutes. Two of these acquisition sun sensors are used for redundancy.

The Star Tracker has a tracking accuracy (gimbal position readout) of ± 30 arc seconds (1 sigma) with outer gimbal freedom of ± 87 degrees and inner gimbal freedom of ± 40 degrees. It can operate to within about 5 degrees of the earth albedo and to within about 45 degrees of the sun. One star tracker is used. Backup roll attitude is obtained from Orbiter state vector data and CMG subsystem roll rate. The Rate Gyro Packages measure vehicle rates in one of two modes: coarse is up to ± 1 degree per second and fine is up to ± 0.1 degree per second. Compensated drift rate is ± 0.1 degree per hour. Two Rate Gyro Packages are orthogonally mounted in each of the three pointing axes, i.e., the gyro system is fully redundant.

4.5.3 ATM Digital Computer/Workshop Computer Interface Unit - The ATM Digital Computer/Workshop Computer Interface Unit (ATMDC/WCIU) subsystem provides high speed general purpose computing capabilities along with a multi-purpose, flexible input/output capability. It accepts analog and discrete signals from several sources which are used to perform calculations under the direction of a stored program, and also provides analog and discrete outputs to several devices. The subsystem consists of two identical ATMDC units and a single WCIU unit. The WCIU is divided into two identical sections and a common section. One ATMDC unit and one corresponding section of the WCIU along with the WCIU common section are always used. The other ATMDC and corresponding WCIU section are powered down and kept in a standby mode to provide redundant operation.

The ATMDC/WCIU subsystem is recommended for use because most of the software modules are available and proven and the hardware interfaces are simpler than multiple interfaces to RAU's for Spacelab computation.

The subsystem will be connected to the Spacelab computers through redundant RAU's for uplink of commands and to obtain telemetry and housekeeping data.

The software requirements of the Spacelab ATM payload are similar to, but less demanding than those of the Skylab program. Modification of the Skylab program consists of deleting those routines no longer required, and simplification of those remaining routines, where appropriate. The Spacelab ATM APCS redundancy management philosophy is quite different from that of Skylab. For the Spacelab ATM mission, the APCS redundancy management will consist of failure detection of the CMG subsystem with maintenance of sufficient information to allow ground or crew detection and isolation of failures in the Acquisition Sun Sensor and RGP's subsystems.

4.5.4 Experiment Pointing and Control Subsystem - The Experiment Pointing and Control Subsystem (EPCS) consists of the Experiment Pointing System and the Roll Positioning Mechanism, implemented in an identical fashion as on the Skylab. A block diagram of EPCS is shown in Figure 4.5-4. The experiment package and EPC sensors are mounted to a three-degree-of-freedom spar that is contained in the CSS.

The spar-mounted Fine Sun Sensor (FSS) provides experiment package position information and the spar-mounted RGPs provide rate information. In the Experiment Pointing Electronics Assembly (EPEA), the position and rate signals are summed after passing through bending mode filters and then amplified by a current amplifier to drive actuator (DC torquer) pairs. One pair is located on the pitch gimbal and the other on the yaw gimbal. The two actuators of a pair operate in parallel for redundancy and power reduction purposes, and provide a total torque output of 14 lb-ft. Should a single amplifier or torquer fail, the loop can operate with the remaining amplifiers and torquer.

The experiment package can be offset pointed in the pitch and yaw axes over a range of ± 24 arc-minutes, with the center of the solar disk being the zero position. The solar disk measures approximately 32 arc-

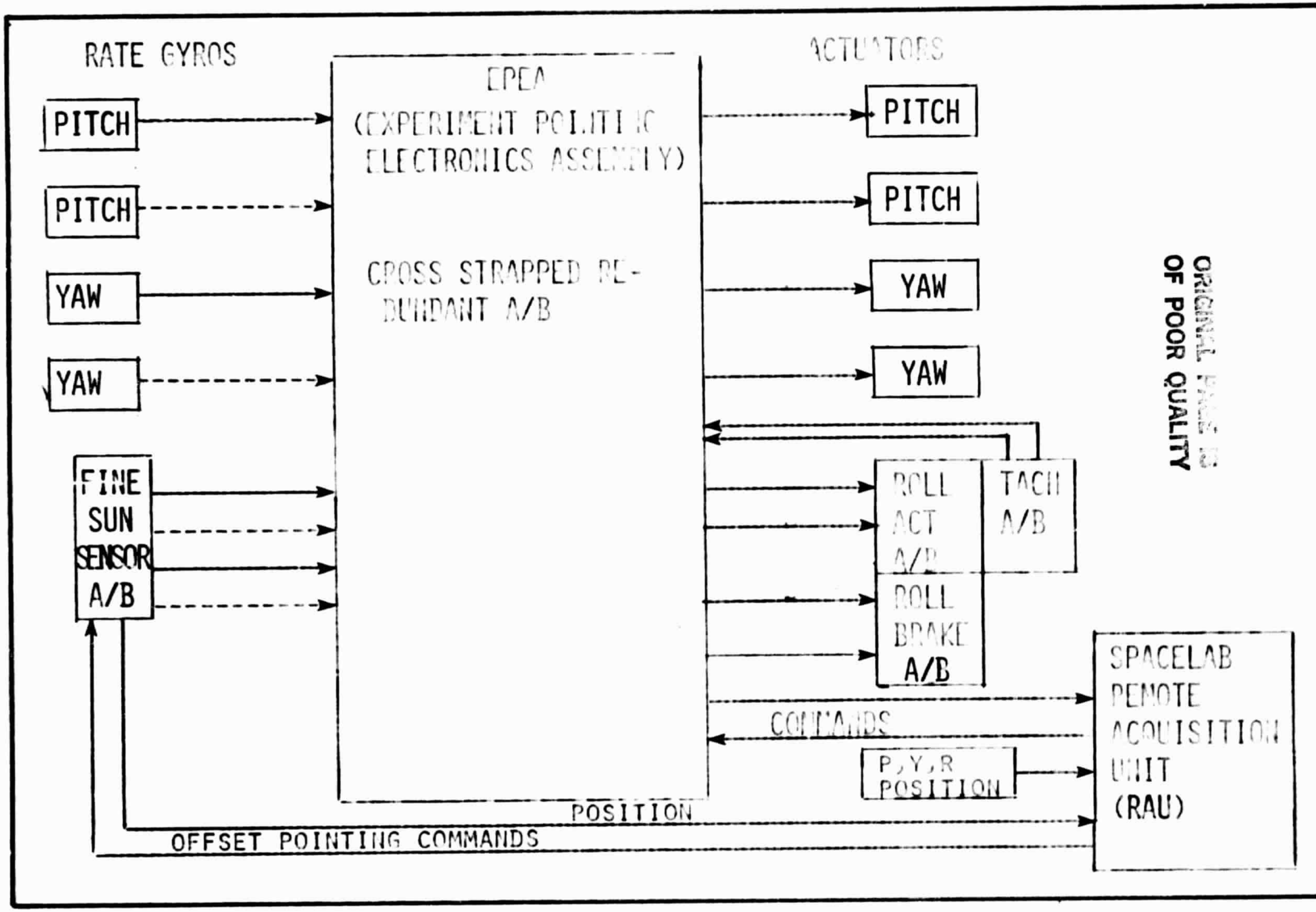

Figure 4.5-4 Experiment Pointing Control System

minutes from limb to limb. Offset pointing is accomplished by positioning an optical wedge located in each channel of the FSS. The wedge is mounted in the path of the sunlight passing through the FSS optics, and can be rotated to refract the sunlight a fixed angle in a controlled direction. The wedges are positioned by a drive mechanism controlled by an astronaut operator via the Manual Pointing Controller. A wedge offset produces a FSS output error voltage that causes the spar to rotate about the appropriate axis and point the FSS, and thereby the experiment package, in a direction that will drive the FSS output voltage to null. Stability is then automatically re-established at the offset position and maintained by the EPC subsystem.

Two RGPs are mounted with their input axes aligned in the pitch axis; two additional RGPs are aligned in the yaw axis. One gyro per axis is redundant and may be activated by ground command or by the astronaut. All spar-mounted gyros are identical to the CSS-mounted units.

The Fine Sun Sensor has a field of view of about ±5 degrees in each of two axes. Full scale electrical output is about ±1 arc-minute. Pointing accuracy is ±2.25 arc-seconds (2 sigma) and short term stability is ±0.1 arc-second. Offset pointing range capability is ±24.21 arc-minutes in both pitch and yaw. The FSS consists of a single optical system with redundant position sensors.

The EPEA is an analog electronics assembly which performs the entire EPCS closed loop computation to control the actuators utilizing the RGP and FSS sensors inputs. It is cross strapped redundant. Connection through a RAU to the Spacelab computer provides for uplink commands and transmission of telemetry data. A minor change to the EPEA is required to tune the bending mode filters to the EPCS mass distributions.

The electromechanical system consists essentially of three large concentric rings; a pitch gimbal ring, a yaw gimbal ring and a roll ring. This gimballing system as shown in Figure 4.5-5 is free to pivot ±2 degrees in pitch and yaw and ±120 degrees in roll. Compensated flexure

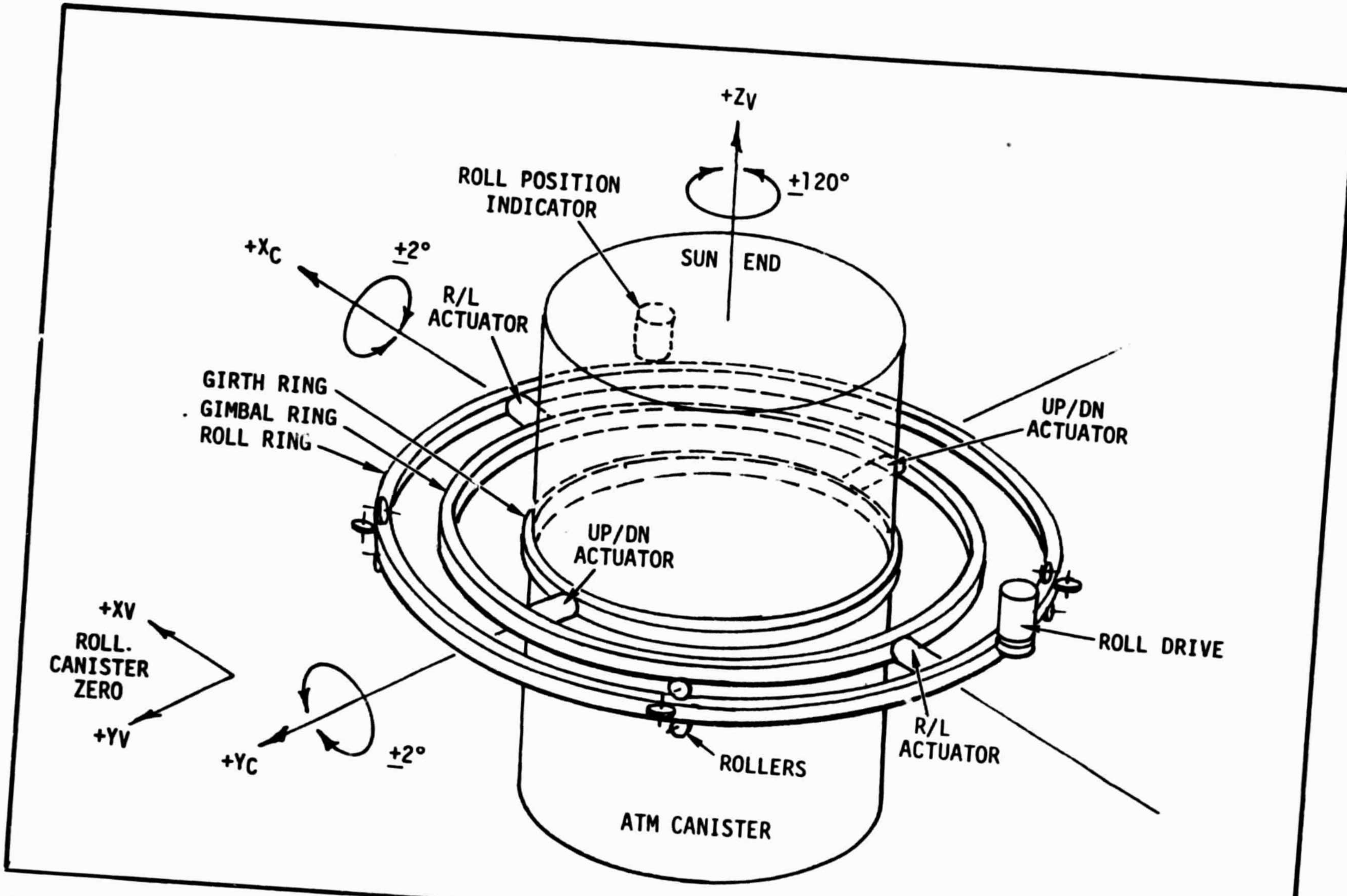

Figure 4.5-5 Experiment Pointing Control System Gimballing System

pivot actuators operating in parallel provide the required motion about the two pointing axes; motion about the roll axis is provided by a single roll actuator. The caging system, i.e., launch locks, will be redesigned to constrain the pitch and yaw rings under vehicle launch and re-entry conditions. The existing system is released on orbit and cannot be recaged. Orbital locks provide on-orbit caging of the pitch of yaw gimbal ring as required.

4.5.5 <u>Orbiter Reaction Control System</u> - The Orbiter Reaction Control System (RCS) is the propulsion system used mainly for vehicle control during on-orbit maneuvering and initial re-entry control. It is also used, to a limited extent, during ascent. The Orbiter Vernier Control System (VCS), which is a part of the RCS, is a candidate for base stabilization in lieu of the CMG system or as a backup. The VCS is a mass expulsion system composed of six 25-pound thrusters which can be used for on-orbit Orbiter-payload pointing and stability purposes. The VCS will be used to perform the CMG momentum desaturation for the Spacelab ATM missions.

4.5.6 <u>Pointing and Stability Capabilities</u> - The CMG Subsystem (Orbiter vehicle base pointing) and EPC Subsystem (Fine pointing) pointing and stability capabilities are tabulated in Table 4.5-2. These APCS stabilities, achieved during the Skylab mission, were established from analysis of flight data for selected mission time periods. The feasibility of the Spacelab ATM APCS to achieve these levels of stability is a critical function of the disturbance environment for the Spacelab ATM mission. Crew motion, Orbiter and payload venting, and the solar experiment package operations must be controlled if the Spacelab ATM APCS is to attain the quoted stability margins. Figure 4.5-6 is a pictorial description of Pointing Accuracy, Stability, and Jitter.

4.5.7 <u>Alternate Approaches</u> - Three alternate subsystem applications of ATM versus Orbiter/Spacelab hardware and software were reviewed. These reviews were conducted to determine if portions of the ATM capability could be used in conjunction with the Orbiter/Spacelab capability to enhance experiment operation and performance. The trades conducted

Table 4.5-2 ATM Capabilities Based on Skylab Data

CMG SUBSYSTEM POINTING AND STABILITY - THE CMG SUBSYSTEM POINTING, STABILITY AND JITTER CAPABILITIES ARE:

AXIS	POINTING	STABILITY	JITTER
PITCH	±6 ARC-MIN	±1.8 ARC-MIN/25 MIN	±0.6 ARC-MIN/1 SEC
YAW	±6 ARC-MIN	±0.5 ARC-MIN/25 MIN	±0.45 ARC-MIN/1 SEC
ROLL	±9 ARC-MIN	±0.5 ARC-MIN/25 MIN	±0.5 ARC-MIN/1 SEC

EPC SUBSYSTEM POINTING AND STABILITY - THE EPC SUBSYSTEM POINTING, STABILITY AND JITTER CAPABILITIES ARE:

AXIS	POINTING	STABILITY	JITTER
PITCH, YAW	±2.5 ARC-SEC	±1ARC-SEC/15 MIN	±1ARC-SEC/1 SEC

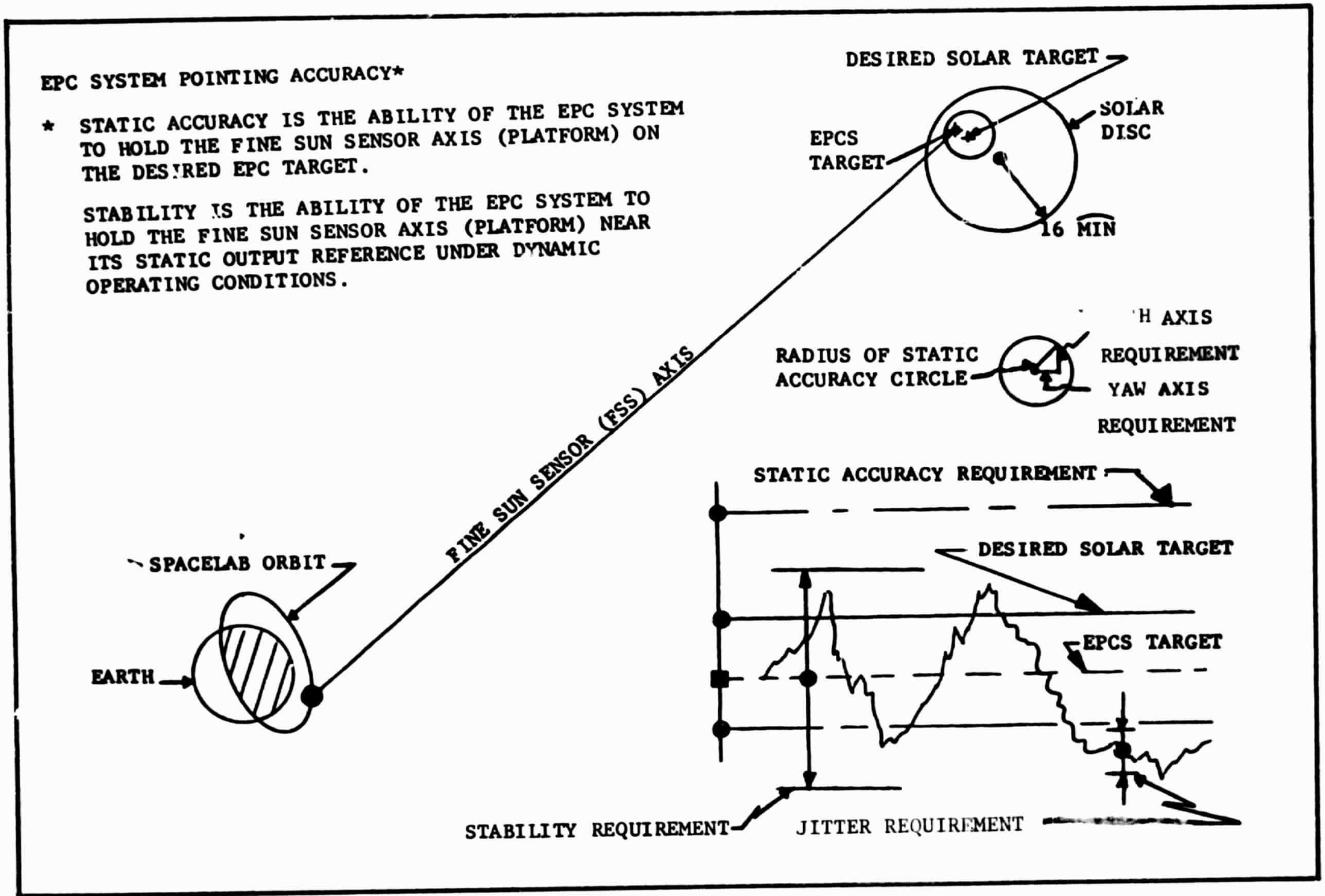

Figure 4.5-6 APCS Pointing and Stability Nomenclature

were:

a) The ATM CMG Subsystem versus Orbiter VCS control for base pointing.

b) The ATM versus Orbiter sensors for rate/attitude inputs.

c) The ATMDC versus Orbiter/Spacelab computers for CMG control.

Table 4.5-3 lists the conclusions along with salient reasons for employing the complete complement of ATM control system hardware and software.

4.5.8 Assessment of ATM/CMG Performance - The predicted Shuttle/ATM performance characteristics of the ATM/CMG system, based on Skylab data have been listed in the last column of Table 4.5-1.

Those areas where the predicted ATM performance does not meet the experiment ERD requirement have been highlighted with asterisk marks in the upper left hand corner of the block.

The first area of deficiency is "knowledge of accuracy" where the SAROS and SEUTS requirement of ± 1 arc second relates to the ± 2.5 arc second capability of the ATM, and the corresponding roll axis requirements of ± 370 and ± 180 arc seconds relates to the ± 540 arc seconds capability. The roll performance of the ATM is not integrated into the fine control guidance loop and is basically set by the roll control capability of the CMG system. Better "knowledge of accuracy" performance could be attained by use of the ATM star tracker to indicate the roll angle at any given time. The performance in LOS knowledge is basically set by the fine sun sensor of the ATM. Significant improvement in this area would require a more sophisticated angle reference system be incorporated to supplement the pointing knowledge derived from the ATM fine sun sensor.

The second area of deficiency is the roll stability requirement of SAROS. As was noted earlier, this requirement is suspect of being misinterpreted because of the apparent inconsistency with the associated

Table 4.5-3 Conclusions

<u>CMG VS. ORBITER VCS</u> FOR BASE POINTING AND STABILITY UTILIZE ATM CMG SYSTEM	• STABILITY PERFORMANCE IS PROVEN • INHERENTLY GREATER POTENTIAL DUE TO FINE CONTROL ABOUT THE CENTER OF GRAVITY • ROLL STABILITY NOT ACCEPTABLE WITH VCS • VCS CONTAMINATION COULD AFFECT EXPERIMENTS
<u>ATM VS. ORBITER SENSORS</u> USE ALL ATM ATTITUDE AND RATE SENSORS	• TRANSFER OF THE ORBITER INERTIAL BENCH DATA TO THE PAYLOAD INVOLVES ALIGNMENT AND BENDING ERRORS UP TO $\pm 3°$. DYNAMICS IS ALSO A PROBLEM. • ATM STAR TRACKER MOUNTING IS OPTIMIZED FOR SUN POINTING. • ATM IS PRIMARILY A SUN POINTER AND INCLUDES A FINE SUN SENSOR.
<u>ATM VS. ORBITER/SPACELAB COMPUTERS</u> USE REDUNDANT (2) ATM DIGITAL COMPUTERS.	• MOST SOFTWARE MODULES ARE AVAILABLE AND PROVEN • HARDWARE INTERFACES ARE SIMPLER.

LOS stability requirement for the same experiment.

The third area of deficiency is the ±0.25 arc second limit requirement on jitter for SAROS which compares to the ±1 arc second performance of ATM.

The final area of deficiency is the 360° roll range requirement of ARC as compared to the $\pm120^{\circ}$ roll range capability of ATM.

4.5.9 Dornier IPS and Sperry AGS Pointing and Stability - Specification values for pointing and stability performance of the Dornier IPS and Sperry AGS were extracted from the latest published documentation and are shown in Table 4.5-4. The figures are indicative of the capability of these systems with the instruments mounted in the ATM canister, which in turn is end mounted to the payload attachment ring (IPS) or payload adapter plate (AGS). However, the published data was insufficient to draw any conclusions as to the capability of these systems to provide the pointing knowledge, stability, and jitter required by the solar instruments used in this study.

Table 4.5-4 IPS and AGS Specification Pointing and Stability

	POINTING ACCURACY (SEC)		STABILITY (SEC)		STABILITY (SEC) MAN MOTION OR VCS	
	LOS	ROLL	LOS	ROLL	LOS	ROLL
IPS	2	40	1	5	5	10
ASPS	0.1	60	0.01	1		

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5.0 COST ANALYSIS

This section presents the costing groundrules, methodology and cost estimates derived for each of the three configurations baselined during the study. As will be noted; cost estimates were provided only for the new and modified equipment required for each configuration. Total cost for implementing each of the configurations, will in addition to the tabulated costs in this section, include the costs for:

- Removal and transportation of the ATM equipment from bonded storage to the place of rework:
- Disassemblying, inspecting and testing the hardware;
- Replacement of time critical hardware items;
- Software check-out and modification; and
- Re-assembly and systems check-out of the hardware.

Further technical studies must be conducted to determine the costs associated with these tasks.

5.1 Costing Groundrules - The groundrules listed below were used in this costing exercise:

A) Constant 1981 dollars.
B) Estimates are contractor costs including G & A and excluding fee.
C) All individual estimates are for an end item quantity of one protoflight unit.
D) Estimates exclude all system level assembly and test costs.
E) All existing ATM drawings and hardware are GFE to contractor.

5.2 Methodology - Cost data and estimates were derived from the following sources:

A) Parametric Cost Analysis

1) RCA Price Model
2) NASA-JPL Cost Prediction Model for Unmanned Spacecraft Exploration Missions.
3) Martin Marietta Aerospace Division data base and cost estimating relationships.

The RCA Price Model is an appropriate estimating tool for concept identification cost studies and has been extensively in use at Martin Marietta since 1977. Recently developed algorithms enabled us to examine cost sensitivities to variations in such structural cost drivers as material type, part tolerance, number of parts per assembly, and reliability (man rating versus lesser requirements). Further, technology improvement features of the model provide declining cost curves through time allowing for improved processes to reduce cost from that otherwise extrapolated from existing hardware. Other variables deal with weight, degrees of new design, engineering experience, calculation of schedules and prototype quantity and cost relationships.

The use of this model will also enable the data from the study to be more readily employed by Goddard's own analysts as well as provide a common baseline and vocabulary for inter-organizational discussion. The Cost Prediction Model for Unmanned Spacecraft Exploration Missions developed by NASA/JPL was used in this study to substantiate the RCA Price Model cost estimates. This dollar per pound analysis was based on an aluminum structure of an advanced spacecraft. This analysis substantiated the RCA Price Model cost estimates. In addition, reasonableness checks were made by utilizing the Martin Marietta Aerospace Division data base and cost estimating relationships.

5.3 <u>Cost Estimates</u> - The cost estimates for the three configurations defined in this study are summarized in Tables 5-1 and 5-2. Table 5-1 (Cost Comparison Summary by Configuration), identifies cost by line item for each of the three configurations. Table 5-2 (Cost Breakdown Summary by Configuration) gives a breakdown of costs for all three configurations.

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Table 5-1 Cost Comparison Summary by Configuration (1981 $'s in 1000's)

	Integrated Configuration	IPS Configuration	ACS Configuration
Spar Assembly (H Section)	$ 370	$ 370	$ 370
Spar Assembly Launch Lock Fitting	21	-	-
Spar Assembly Lock Interface Fitting and Sensor Fitting	-	24	24
Canister Sun End Plate and Aperture Cover Ramps	308	308	308
Support Structure and Insulation, Sun Shield and Aperture Covers	243	243	243
Aft Canister Modification to Launch Locks	31	-	-
Improvement Modification to Aperture Door	76	-	-
Redesign Cable Drum of MDA End Canister	194	-	-
Canister Support Structure*	3,745	118	118
Launch/Landing Locks	77	-	-
Truss Structure	-	-	130
Invert Roll Ring	26	-	-
Instrument Mounting Adapters	83	-	-
RAU Pre Amp	30	30	30
C & DH Buffer	194	194	194
Fluid Loop Hose (TCS)	112	112	112
Cold Plates (TCS)	48	48	48
Electrical System Harness*	17	19	19
PUMP (TCS)	49	-	-
Accumulator (TCS)	12	-	-
Total Cost	$5,636	$1,466	$1,596

* The integrated configuration for this item is different from the IPS or ACS configuration.

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Table 5-2 Cost Breakdown Summary by Configuration (1981 $'s in 1000's)

	Integrated Configuration		IPS Configuration		AGS Configuration	
Design and Drafting	$3,534		$835		$908	
Systems Engineering	1,109		284		308	
Subtotal (Engineering)		$4,643		$1,119		$1,216
Build/Test	880		311		340	
Tool-Test Equipment	111		35		41	
Subtotal (Manufacturing)		991		346		381
Total Cost		$5,634		$1,465		$1,597

The same methodologies were used to estimate each configuration. Therefore, a comparison of the costs of these three configurations allows analysis of the effect of decisions envolving the same design parameters on cost. For further detail into the estimated costs or input variables used in modeling, see Appendices B, C and D which contain the RCA Price Model Reports.

6.0 CONCLUSIONS

The concept of utilizing the back up ATM hardware for Shuttle/ Spacelab flights appears to be both feasible and economical. The specific study results, although preliminary indicate:

- The ATM hardware should be used unchanged or with only slight modifications for maximum cost effectiveness to Spacelab. That is, scientific payloads should be selected that fit within the physical and performance capabilities of the hardware---thereby eliminating much of new and modified equipment dictated by the straw man payload used in this study;
- The ATM hardware exists, therefore, no new hardware design, development, testing or fabrication is required;
- The hardware reliability and safety has been established since a like set of the existing ATM hardware and software was flight tested during Skylab;
- The ATM canister assembly has a complete self-contained thermal control system capable of maintaining close thermal tolerance on the payload. The assembly can be easily mounted to the IPS and AGS eliminating the need to cross the gimbals with fluid lines;
- The ATM attitude and pointing control capability has been flight tested; eliminates much of the contamination associated with VCS base stabilization; and although additional analysis is required, it appears to be capable of satisfying instruments requiring very accurate pointing and stability;
- Either concept; the "ATM Integrated" or "IPS" or "AGS" can be integrated into the Shuttle/Spacelab as a payload of opportunity with other payload elements;

- Very little new of modified C & DH equipment is necessary to establish compatibility of the three baselined concepts with existing capabilities; and
- The "ATM Integrated" concept eliminates ever having to eject a costly attitude pointing and control system, and scientific payload, since it always remains within the Shuttle payload envelope.

7.0 RECOMMENDATIONS

Preliminary results of this study indicated that there may be many advantages for utilizing the leftover ATM Skylab hardware and software for Shuttle/Spacelab missions, both from the standpoint of performance capability and cost. To substantiate these findings, several additional tasks should be performed. These tasks are:

- ATM Hardware/Software Status/Condition Definition
  This task would determine the status of each of the hardware and software items; where they are located; what life critical hardware requires change out; the additional testing required; problems identified during Skylab that must be fixed; and so on.
- Structural/Mechanical Analysis
  This task would accomplish the detailed designs and analysis to determine the design requirements for modifying the ATM hardware for the "ATM Integrated" concept and also for mounting the ATM canister onto the IPS and AGS mounting rings.
- Attitude and Pointing Control Analysis
  Detail analysis and modeling would be accomplished under this task to verify the capability of the ATM to control the Shuttle/Spacelab as well as providing the fine pointing required by the experiments. The tasks would further evaluate the effects that the ATM canister (with active thermal control system) has on the IPS and AGS pointing and stability capabilities.

- Program Definition/Cost Analysis

  This task would prepare a detailed program plan and schedule and perform a detailed bottoms-up cost analysis. The cost analysis would consider all costs associated with the program, so that cost comparisons with other approaches could be made.

8.0 ACRONYMS AND ABBREVIATIONS

AFD	-	Aft Flight Deck
AGS	-	Annular Suspension and Pointing System Gimbal System
ARC	-	Acceleration Region Coronographs
ASPS	-	Annular Suspension and Pointing System
ATM	-	Apollo Telescope Mount
ATMDC	-	ATM Digital Computer
ATMDC/ WCIU	-	ATMDC/Workshop Computer Interface Unit
C&DH	-	Command and Data Handling
CG	-	Center of Gravity
CMG	-	Control Moment Gyro
CSS	-	Canister Support Structure
DEP	-	Dedicated Equipment Processor
ECU	-	Electronic Components Unit
EPCS	-	Experiment Pointing and Control Subsystem
EPEA	-	Experiment Pointing Electronics Assembly
ERDs	-	Experiment Requirements Documents
EUV	-	Extreme Ultraviolet
FSS	-	Fine Sun Sensor
G&A	-	General and Administrative
GFE	-	Government Furnished Equipment
GSE	-	Ground Support Equipment
HAO	-	High Altitude Observatory
HDR	-	High Data Rate
IPS	-	Instrument Pointing System
MDA	-	Multiple Docking Adapter
MTM	-	Multiple Telescope Mount
PAP	-	Payload Adapter Plate
PAR	-	Payload Attachment Ring
PCA	-	Payload Clamp Assembly
PMS	-	Payload Mounting System
POCC	-	Payload Operations Control Center

RAU	-	Remote Acquisition Unit
RCS	-	Reaction Control System
SAA	-	South Atlantic Anomaly
SAO	-	Smithsonian Physical Observatory
SAROS	-	Solar Active Region Observations from Spacelab
SCR	-	Signal Conditioing Racks
SEUTS	-	Solar Extreme Ultraviolet Telescope & Spectrograph
SLA	-	Spacelab Lyman Alpha
SLAC	-	Spacelab Lyman Alpha - White Light Coronograph
SMCH	-	Standard Mixed Cable Harness
STS	-	Space Transportation System
VCS	-	Vernier Control System
WLC	-	White Light Coronograph

APPENDIX A

SPACELAB ATM FEASIBILITY STUDY DRAWING AND HARDWARE STATUS

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 1 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Sun End Canister Assy/10M24020	Canister	1	1	0			MSFC
MDA End Canister Assy/10M24010	Canister	1	1	0	X		MSFC
Spar Assy./10M24008	Canister	1	1	0	X		MSFC
CSS Solar Shield	CSS	1				X	
ECU Solar Shield	ECU	1				X	
Canister Support Structure	CSS	1				X	
Electronic Component Unit	ECU	1				X	
Launch/Landing Locks	CSS	5				X	
Aperture Doors	Canister	7				X	
Aperture Door Mechanism	Canister	7				X	
Temperature Sensor Assy./20M42500-1	Canister	1	1	1			LTV
Electronic Control Assy./20M42500-7	Canister	1	1	1			LTV
Liquid Heater Assy./20M42500-5	Canister	1	1	0			LTV
5 Micron Filter/20M42500-21		1	1	1			Vacco
Valve Assy. Flow Path Selector 20M42517-1	Canister	2	1	1			Avco
Accumulator Assy. Methanol/Water 20M42512	Canister	1	1	1			Metal

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 2 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Pump Package/20M42514	Canister	1	1	1			Air Research
Valve Assy. Flow Restricting/20M42519	Canister	1	5				Honer-Tucker-ling
Canister Panel, Thermal Condition 20M2527 thru 35	Canister	16	16	0			MSFC
Radiator ATM/20M42633/20M32545	Canister	4	4	0			MSFC
Modulating Flow Control Valve Assy. 20M42500-3	Canister	1	1	1			LTV
ECS Pump Inverter Assy./40M26550	Canister	1	1	2			MSFC
400 Nicron Filter/20M2500-21	Canister	1	1	1			LTV
HCO Micron Filter/20M42500-19	Canister	1	1	1			LTV
Thermal Cold Plates (ECU)	ECU					X	
Memory Load Unit/50M39050	ECU	1	1				IBM
Tape Recorder (MLU)/50M39051	ECU	1	1				B/W
Camera Control Unit/50M12730-5	Canister	2	1		X		MSFC
Camera Control Unit/50M12730-1	Canister	1	1		X		MSFC
Camera Control Unit/50M12730-3	Canister	1	1		X		MSFC

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 3 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Switcher/Processor/50M17348	Canister	2	1		X		MSFC
Backup Inverter Lighting Control Assy.	Crew Station	1					
Camera Control Unit	Canister	2				X	
DC-DC Converter 29± Vdc	Crew Station	1				X	
Control and Display Console	Crew Station	1				X	
Sync Generator	Canister	1				X	
Master Measuring Voltage Supply/ 40M26271	ECU	2	1		X		Gulton Indus.
Main Power Distributor/40M37381	ECU	1	1		X		MSFC
Auxiliary Power Distributor/40M37382	ECU	1	1		X		MSFC
Power Transfer Distributor/40M37380	ECU	1	1		X		MSFC
Switch Selector/50M67864-7	ECU	5	1		(4)X	(1)X	IBM
Control Distributor/40M37383	ECU	1	1		X		IBM
Control Distributor/40M37384	ECU	1	1		X		IBM
Control Distributor/40M37387	ECU	1	1		X		IBM
Control Distributor/40M37388	ECU	1	1		X		IBM

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 4 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Control Distributor/40M37393	ECU	1	1		X		IBM
Measuring Distributor/40M37385	ECU	1	1		X		IBM
Measuring Distributor/40M37386	ECU	1	1		X		IBM
Measuring Distributor/40M37389	ECU	1	1		X		IBM
NRL/HAO Power Supply/40M26580	ECU	3	1				MSFC
J Box Assembly/40M33680	ECU	1	1		X		MSFC
J Box Assembly/40M33681	ECU	11	11		X		MSFC
C&D Logic Distributor/40M37390	ECU	1	1		X		MSFC
Control Distributor/40M37394	ECU	1	1				MSFC
Transient Filter/40M38547-1	ECU	4	1				MSFC
J Box Assembly/40M33691	Canister	1	1		X		
Thermal Control System Monitor/ 50M16129	Canister	1	1				LTV
Control Distributor/40M37XXX	ECU	1				X	IBM
Voltage Regulator/61B769005	ECU	4				X	Engineered Magnetics
<u>Command System</u>							
Command Decoder/50M12746	ECU	2	1		X		Spacecraft

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 5 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Measuring System							
Signal Conditioning Rack/50M12724-1	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-3	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-5	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-7	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-9	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-11	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-13	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-15	ECU	1	1		X		MSFC
Signal Conditioning Rack/50M12724-17	ECU	1	1		X		MSFC
Telemetry System							
Multiplexer Assy. Mod. 270/50M12989-7	ECU	1	1				Teledyne
Multiplexer Assy. Mod. 270/50M12989-3	ECU	1	1				Teledyne
Multiplexer Assy. Mod. 270/50M12989-1	ECU	1	1				Teledyne
Multiplexer Assy. Mod. 270/50M12989-5	ECU	1	1				Teledyne
Remote Analog Sub Multiplexer Mod. 103/50M13970-1	ECU	1	1				MSFC

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 6 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Remote Analog Sub Multiplexer Mod. 103/50M12970-3	ECU	1	1				Teledyne
Remote Analog Sub Multiplexer Mod. 103/50M12970-5	ECU	1	1				Teledyne
Remote Analog Sub Multiplexer Mod. 103/50M12970-7	ECU	1	1				Teledyne
Remote Analog Sub Multiplexer Mod. 103/50M12970-9	ECU	1	1				Teledyne
Remote Analog Sub Multiplexer Mod. 103/50M12970-11	ECU	1	1				MSFC
Remote Digital Multiplexer Mod. 410/50M12990-1	Canister MDA	1	1		X		Spacecraft
Remote Digital Multiplexer Mod. 410/50M12990-3	Canister MDA	1	1		X		Spacecraft
Remote Digital Multiplexer Mod./ 50M12990-5	ECU	1	1		X		Spacecraft
Remote Digital Multiplexer Mod./ 410/50M12990-7	ECU	1	1		X		Spacecraft
Remote Digital Multiplexer Mod./ 410/50M12990-9	ECU	1	1		X		Spacecraft
Remote Digital Multiplexer Mod./ 410/50M12990-11	ECU	1	1		X		Spacecraft

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LISTS & HARDWARE STATUS (Sheet 7 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
PCM/DDAS Assy. Mod. 301 Primary/ 50M13991-1	ECU	2	1		X		Spacecraft
Filter Signal Conditioning Rack/ 50M17211-1	ECU	9	1				MSFC
Amplifier & Switch Assy./50M1272[illegible]-1	ECU	1	1		X		Teledyne
Serial to Serial Converter	ECU					X	
<u>Attitude Control System</u>							
Control Moment Gyro/50M22136	ECU	3	3	1			Bendix
CMG Inverter Assy./50M22137	ECU	3	3				Bendix
Acquisition Sun Sensor/50M22140	ECU	2	1				BBRC
Acquisition Sun Sensor Electronics/ 50M22141	ECU	2	1				BBRC
ATM Rate Gyro/50M37700-13	ECU	9		1			MMC
Exp. Pointing Elect. Assy./ 50M38500	ECU	1	1				Bendix
Digital Computer/50M36755	ECU	2	1		X		IBM
Radial Roller Assy./640-0106	ECU	2	2		X		Perkin/ Elmer

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 8 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Workshop Computer Interface Unit/ 50M37938	ECU	1	1				IBM
Experiment Pointing System							
Star Tracker Opto-Mech. Assy./ 50M22145	ECU	1	1				Bendix
Star Tracker Elect./50M22146	ECU	1	1				Bendix
FSS Signal Conditioner/50M22147	ECU	1	1				Motorola
Roll Axis Stop Assy./640-0105	CSS	1	1				P/E
Fine Sun Sensor Pre-Amp Assy./ 50M22142	SPAR	1	1		X		Honeywell
Fine Sun Sensor Opto-Mech./50M22138	SPAR	1	1		X		Honeywell
ATM Rate Gyro/50M37700-13	SPAR	4		1			MMC
Roll Actuator Drive/640-0400	CSS	1	1				P/E
Pitch Actuator/640-0207	CSS	1	1				P/E
Pitch Actuator/640-0290	CSS	1	1				P/E
Yaw Actuator/640-0208	CSS	1	1				P/E
Yaw Actuator/640-0207	CSS	1	1				P/E

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 9 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
Orbital Lock/640-0206	CSS	2	1		X		P/E
Ring Gear Assy./640-0102	CSS	1	1				P/E
Radial Roller Assy., Type B/640-0107	CSS	2	2				P/E
Bottom Axial Roller Assy.,/640-0109	CSS	4	4				P/E
Gimbal Ring Assy./640-0006	CSS	1	1				P/E
Top Axial Roller Assy./640-0108	CSS	1					P/E
Fine Sun Sensor Control Elect. Assy./ 50M22139	Canister	1	1		X		Honeywell
Main Electronics Assy. (S054) ASE-102-512	ECU	1	1		X		AS&E
AS&E X-Ray Spectrographic Telescope (S054) ASE-102-512	SPAR	1	1		X		AS&E
Temp. Control Assy. (S054) ASE 102-1359	SPAR	1	1		X		AS&E
X-Ray Event & Analyzer Assy./ 50M16633	SPAR	1	1		X		GSFC
Camera Control Elect. Assy./ 50M16034 (S056)	SPAR	1	1		X		GSFC

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 10 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
GSFC X-Ray EUV Telescope (S056)/ 50M16500	SPAR	1	1		X		GSFC
HCO Hydrogen Alpha Telescope/ 647-0001	SPAR	1	1		X		HCO/ASTR
NRL-A-XUV (S082) Spectroheliograph/ 29300-1	SPAR	1	1		X		NRL
NRL-B-XUV Spectroheliograph (S082)/ 29301-1	SPAR	1	1		X		NRL
HAO-White Light Coronograph (S052)/ 23594	SPAR	1	1		X		HAO
HCO-A UV Scanner Polochromator Spectro-heliograph/27024	SPAR	1	1		X		HCO
HCO Electronic Mounting Bracket/ 29231-1	SPAR	1	1		X		HAO
Aperture Door Torque Motor/NT-2950	Canister	10	10				Inland
Motor Transient Suppressor/40M38697-1	Canister	4	4				MFFC
NRL-A Camera, Film 36360-501		4	0				BBRC
NRL-B Camera, Film 36361-501		4	1				BBRC
NRL-A Canister, Camera 26852		4	1				BBRC
NRL-B Canister, Camera 26852		4	1				BBRC

SPACELAB ATM FEASIBILITY STUDY DRAWING/PARTS LIST & HARDWARE STATUS (Sheet 11 of 11)

DRAWING/DRAWING NO.	LOCATION	NO. REQ'D	ATM	SPARES (STORAGE)	MOD. REQ'D	NEW HARDWARE	ORIGINAL VENDOR
HAO Camera Film 38420-503		4	1				BBRC
Film Magazine Assy. GSFC/50M73658		4					MSFC
Film Camera Magazine AS&E 481-202001		4					Hycon
TV Camera (Vidicon)/50M12731-1	Canister	1			X		MSFC
TV Camera (LLL)/50M12729-1-5	Canister	1					MSFC
TV Camera (LLL)/50M12729-9	Canister	1					MSFC
TV Camera	Canister	4				X	
Quarts Crystal Micro Balance/ 50M18270	Sun Shield	2	0	1			Atlantic Research

APPENDIX B

ATM INTEGRATED CONFIGURATION

PRICE MODEL REPORT

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- - PRICE 84 -
MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:3? (281058)

SPAR ASSY (H)

PROTOTYPE QUANTITY	1.0	UNIT WEIGHT	[illegible]	[illegible]
		UNIT VOLUME	[illegible]	[illegible]

PROGRAM COSTS ($1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	48.	-	[illegible]
DESIGN	106.	-	[illegible]
SYSTEMS	5.	-	[illegible]
PROJECT MGMT	33.	-	[illegible]
DATA	53.	-	[illegible]
SUBTOTAL(ENG)	245.	-	[illegible]
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	116.	-	[illegible]
TOOL-TEST EQ	10.	-	10.
SUBTOTAL(MFG)	126.	-	[illegible]
TOTAL COST	370.	-	370.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	1400.000	ENGINEERING COMPLEXITY	[illegible]
DENSITY	6.635*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.308	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.400	PLATFORM	2.0
DESIGN REPEAT	0.150	YEAR OF TECHNOLOGY	1783*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	48669*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 83	(2)	FEB 83*	(0)	FEB 83*	(2)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		

DEV COST MULTIPLIER 1.10

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	320.	-	320.
CENTER	370.	-	370.
TO	445.	-	445.

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MECHANICAL [illegible]

DATE 12-MAR-81 TIME 20:33 (281058) FILENAME: [illegible]

SPAR ASSY LAUNCH LOCK FITTTING

		UNIT WEIGHT	[illegible].00	MODE	[illegible]
PROTOTYPE QUANTITY	[illegible]	UNIT VOLUME	0.04	QUANTITY/[illegible]	[illegible]

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	2.	-	[illegible]
DESIGN	6.		6.
SYSTEMS	1.		[illegible]
PROJECT MGMT	2.		[illegible]
DATA	0.	-	0.
SUBTOTAL(ENG)	11.	-	11.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	8.	-	[illegible]
TOOL-TEST EQ	1.		[illegible]
SUBTOTAL(MFG)	9.	-	9.
TOTAL COST	21.	-	[illegible]1.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	.000	ENGINEERING COMPLEXITY	[illegible]
DENSITY	100.000*	PROTOTYPE SUPPORT	[illegible]
MFG. COMPLEXITY	5.830	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	PLATFORM	2.0
DESIGN REPEAT	0.750	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	[illegible]08987*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(8)	NOV 83*	(6)	MAY 84*	(14)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	18.	-	18.
CENTER	21.	-	21.
TO	25.	-	25.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:34 (281058) FILENAME: [illegible]

END PLATE & APERTURE COVER RAMPS OF SEC

		UNIT WEIGHT	80.00	MODE	[illegible]
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.30	QUANTITY/NHA	[illegible]

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	61.	-	[illegible]
DESIGN	149.	-	149.
SYSTEMS	18.	-	18.
PROJECT MGMT	28.	[illegible]	[illegible]
DATA	13.	-	13.
SUBTOTAL(ENG)	269.	-	269.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	34.	-	[illegible]
TOOL-TEST EQ	4.	-	[illegible]
SUBTOTAL(MFG)	38.	-	[illegible]
TOTAL COST	308.	-	308.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	80.000	ENGINEERING COMPLEXITY	0.700
DENSITY	266.667*	PROTOTYPE SUPPORT	[illegible]
MFG. COMPLEXITY	5.918	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	[illegible]
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	61094*

SCHEDULE	START	FIRST ITEM	FINISH
DEVELOPMENT	JUL 83 (6)	DEC 83* (0)	DEC 83* (6)

SUPPLEMENTAL INFORMATION
- YEAR OF ECONOMICS 1981
- ESCALATION 0.00
- DEV COST MULTIPLIER 1.10

TOOLING & PROCESS FACTORS
- DEVELOPMENT TOOLING 1.00

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	271.	-	271.
CENTER	308.	-	308.
TO	359.	-	359.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:34 (281058) FILENAME: INT.PI

SUP. STR.,SUN SHIELD & APERTURE COVERS

		UNIT WEIGHT	100.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	2.50	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	47.	-	47.
DESIGN	113.	-	[illegible]
SYSTEMS	14.	-	14.
PROJECT MGMT	22.	-	[illegible]
DATA	10.	-	10.
SUBTOTAL(ENG)	208.	-	208.
MANUFACTURING			
PRODUCTION	-	-	[illegible]
PROTOTYPE	29.	-	29.
TOOL-TEST EQ	7.	-	[illegible]
SUBTOTAL(MFG)	35.	-	[illegible]
TOTAL COST	243.	-	[illegible]

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	100.000	ENGINEERING COMPLEXITY	0.700
DENSITY	40.000*	PROTOTYPE SUPPORT	1.[illegible]
MFG. COMPLEXITY	5.670	PROTO SCHEDULE FACTOR	.25[illegible]*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.200	YEAR OF TECHNOLOGY	1982*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	[illegible]
INTEGRATION LEVEL	[illegible]	MTBF(THOU HR)	[illegible]

SCHEDULE	START	FIRST ITEM	FINISH
DEVELOPMENT	JUN 83 [illegible]	DEC 83* [illegible]	DEC 83* [illegible]

SUPPLEMENTAL INFORMATION			
YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	[illegible]
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	211.	-	[illegible]
CENTER	243.	-	243.
TO	253.	-	[illegible]

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:34 (231058) FILENAME: [illegible]

AFT CANISTER MOD TO LAUNCH LOADS

PROTOTYPE QUANTITY	1.0	UNIT WEIGHT	0.00	NOA
		UNIT VOLUME	[illegible].05	QUANTITY/NHA

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	5.	-	[illegible]
DESIGN	12.	-	[illegible]
SYSTEMS	[illegible]	-	[illegible]
PROJECT MGMT	2.	-	[illegible]
DATA	[illegible]	-	[illegible]
SUBTOTAL(ENG)	23.		[illegible]
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	7.	-	7.
TOOL-TEST EQ	1.		[illegible]
SUBTOTAL(MFG)	8.		[illegible]
TOTAL COST	31.	-	31.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	70.300	ENGINEERING COMPLEXITY	1.000
DENSITY	400.000*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.520	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.400	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	153590*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JUN 84	(8)	JAN 85*	(0)	JAN 85*	(8)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	.750
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	27.	-	27.
CENTER	31.	-	31.
TO	37.	-	37.

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MECHANICAL ITEM

DATE [illegible]-MAR-81 TIME 20:[illegible] FILENAME [illegible]
(281058)

IMPROVE. MOD TO APERTURE DOOR

		UNIT WEIGHT	15.00	MODE
PROTOTYPE QUANTITY	[illegible]	UNIT VOLUME	0.40	QUANTITY [illegible]

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	11.		[illegible]
DESIGN	[illegible]		[illegible]
SYSTEMS	5.		[illegible]
PROJECT MGMT	[illegible]	-	[illegible]
DATA	[illegible]	-	[illegible]
SUBTOTAL(ENG)	[illegible]		[illegible]
MANUFACTURING			
PRODUCTION	-		
PROTOTYPE	17.	-	[illegible]
TOOL-TEST EQ	[illegible]	-	[illegible]
SUBTOTAL(MFG)	[illegible]	-	[illegible]
TOTAL COST	76.	-	[illegible]6.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	15.000	ENGINEERING COMPLEXITY	[illegible]
DENSITY	37.500*	PROTOTYPE SUPPORT	[illegible]
MFG. COMPLEXITY	5.520	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.550	PLATFORM	[illegible]
DESIGN REPEAT	0.500	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	[illegible]
INTEGRATION LEVEL	1.0	MTBF(FIELD)	[illegible]41350*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 83	(8)	AUG 83*	(3)	NOV 83*	(11)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	67.	-	67.
CENTER	76.	-	76.
TO	89.	-	89.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:35 FILENAME: INT.MI
(281058)

REDESIGN CABLE DRUM OF MTA END CAN.

	[illegible]	UNIT WEIGHT	20.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.30	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	35.	-	35.
DESIGN	98.	-	98.
SYSTEMS	25.	-	25.
PROJECT MGMT	16.	-	16.
DATA	8.	-	8.
SUBTOTAL(ENG)	182.	-	182.
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	10.	-	10.
TOOL-TEST EQ	3.	-	3.
SUBTOTAL(MFG)	13.	-	13.
TOTAL COST	194.	-	194.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	20.000	ENGINEERING COMPLEXITY	1.200
DENSITY	66.667*	PROTOTYPE SUPPORT	1.2
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.800	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	1.0	MTBF(FIELD)	145015*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JUN 83	(10)	MAR 84*	(0)	MAR 84*	(10)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	168.	-	168.
CENTER	194.	-	194.
TO	236.	-	236.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:35 FILENAME: INT.PI
(281058)

CANISTER SUPPORT STR

		UNIT WEIGHT	2300.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	2384.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	658.	-	658.
DESIGN	1784.	-	1784.
SYSTEMS	346.	-	346.
PROJECT MGMT	262.	-	262.
DATA	122.	-	122.
SUBTOTAL(ENG)	3172.	-	3172.
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	505.	-	505.
TOOL-TEST EQ	68.	-	68.
SUBTOTAL(MFG)	573.	-	573.
TOTAL COST	3745.	-	3745.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	2300.000	ENGINEERING COMPLEXITY	1.000
DENSITY	0.965*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.884	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.250	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	30158*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 83	(8)	AUG 83*	(0)	AUG 83*	(8)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	3321.	-	3321.
CENTER	3745.	-	3745.
TO	4333.	-	4333.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:36 (281058) FILENAME: INT.PI

LAUNCH/LANDING LOCKS

		UNIT WEIGHT	4.00	MODE	2
PROTOTYPE QUANTITY	4.0	UNIT VOLUME	3.00	QUANTITY/NHA	4

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	11.	-	11.
DESIGN	35.	-	35.
SYSTEMS	8.	-	8.
PROJECT MGMT	8.	-	8.
DATA	3.	-	3.
SUBTOTAL(ENG)	64.	-	64.
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	12.	-	12.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	13.		13.
TOTAL COST	77.	-	77.

DESIGN FACTORS MECHANICAL PRODUCT DESCRIPTORS

WEIGHT	4.000	ENGINEERING COMPLEXITY	1.300
DENSITY	1.333*	PROTOTYPE SUPPORT	1.5
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	1.0	MTBF(FIELD)	235019*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 83	(10)	OCT 83*	(6)	APR 84*	(16)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	68.	-	68.
CENTER	77.	-	77.
TO	90.	-	90.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:36 FILENAME: INT.PI
(281058)

INVERT ROLL RING

		UNIT WEIGHT	10.00	MODE	2
PROTOTYPE QUANTITY	0.0	UNIT VOLUME	0.13	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	5.	-	5.
DESIGN	14.	-	14.
SYSTEMS	3.	-	3.
PROJECT MGMT	2.	-	2.
DATA	1.	-	1.
SUBTOTAL(ENG)	25.	-	25.
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	0.	-	0.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	1.	-	1.
TOTAL COST	26.	-	26.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	10.000	ENGINEERING COMPLEXITY	1.000
DENSITY	76.923*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	PLATFORM	2.0
DESIGN REPEAT	0.500	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0

INTEGRATION LEVEL 0.5 MTBF(FIELD) 178534*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 84	(8)	AUG 84*	(0)	AUG 84*	(8)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00*
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	23.	-	23.
CENTER	26.	-	26.
TO	32.	-	32.

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MECHANICAL ITEM

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INSTRUMENT MOUNTING ADAPTERS

		UNIT WEIGHT	10.00	MODE	2
PROTOTYPE QUANTITY	10.0	UNIT VOLUME	0.07	QUANTITY/NHA	10

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	9.	-	9.
DESIGN	28.	-	28.
SYSTEMS	4.	-	4.
PROJECT MGMT	7.	-	7.
DATA	2.	-	2.
SUBTOTAL(ENG)	51.	-	51.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	30.	-	30.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	32.	-	32.
TOTAL COST	83.	-	83.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	10.000	ENGINEERING COMPLEXITY	1.000
DENSITY	142.857*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.520	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	PLATFORM	2.0
DESIGN REPEAT	0.300	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	189092*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 84	(8)	AUG 84*	(9)	MAY 85*	(17)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00*
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	70.	-	70.
CENTER	83.	-	83.
TO	104.	-	104.

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ELECTRONIC ITEM

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RAU PRE AMP

		UNIT WEIGHT	2.50	MODE	1
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.03	QUANTITY/NHA	2

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	11.	-	11.
SYSTEMS	2.	-	2.
PROJECT MGMT	2.	-	2.
DATA	1.	-	1.
SUBTOTAL(ENG)	18.	-	18.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	10.	-	10.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	11.	-	11.
TOTAL COST	30.	-	30.

DESIGN FACTORS	ELECTRONIC	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	0.500*	2.000	ENGINEERING COMPLEXITY	1.200
DENSITY	54.000	66.667*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	9.410	5.770	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	0.500	ELECT VOL FRACTION	.309*
DESIGN REPEAT	0.980	0.500	PLATFORM	2.0
EQUIPMENT CLASS	*****	*****	YEAR OF TECHNOLOGY	1983*
INTEGRATION LEVEL	0.5	0.5	RELIABILITY FACTOR	1.0
			MTBF(FIELD)	1361537*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(16)	JUL 84*	(0)	JUL 84*	(16)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	.500
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	26.	-	26.
CENTER	30.	-	30.
TO	35.	-	35.

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ELECTRONIC ITEM

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C&DH BUFFER

		UNIT WEIGHT	3.00	MODE	1
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.03	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	33.		33.
DESIGN	108.	-	108.
SYSTEMS	17.	-	17.
PROJECT MGMT	11.	-	11.
DATA	5.	-	5.
SUBTOTAL(ENG)	175.	-	175.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	17.	-	17.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	19.	-	19.
TOTAL COST	194.	-	194.

DESIGN FACTORS	ELECTRONIC	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	1.000*	2.000	ENGINEERING COMPLEXITY	1.200
DENSITY	48.000	66.667*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	9.410	5.770	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	0.500	ELECT VOL FRACTION	.694*
DESIGN REPEAT	0.500	0.66	PLATFORM	2.0
EQUIPMENT CLASS	*****	*****	YEAR OF TECHNOLOGY	1983*
INTEGRATION LEVEL	0.5	0.5	RELIABILITY FACTOR	1.0
			MTBF(FIELD)	690271*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(16)	JUL 84*	(0)	JUL 84*	(16)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	.500
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	172.	-	172.
CENTER	194.	-	194.
TO	223.	-	223.

FOLLOWING DATA CHANGES MADE:
DMULT=1.36,PMULT=1.36

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 20:38 (281058) FILENAME: INT.PT

FLUID LOOP HOSE(TCS)

		UNIT WEIGHT	120.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.11	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	15.	-	15.
DESIGN	29.	-	29.
SYSTEMS	1.	-	1.
PROJECT MGMT	14.	-	14.
DATA	6.	-	6.
SUBTOTAL(ENG)	66.	-	66.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	44.	-	44.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	46.	-	46.
TOTAL COST	112.	-	112.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	120.000	ENGINEERING COMPLEXITY	0.300
DENSITY	1090.909*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	6.100	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	65173*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(3)	JUN 83*	(0)	JUN 83*	(3)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	.500
ESCALATION	0.00		
DEV COST MULTIPLIER	1.36		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	97.	-	97.
CENTER	112.	-	112.
TO	132.	-	132.

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MECHANICAL ITEM

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COLD PLATES(TCS)

		UNIT WEIGHT	6.00	MODE	2
PROTOTYPE QUANTITY	8.0	UNIT VOLUME	0.11	QUANTITY/NHA	8

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	5.	-	5.
DESIGN	14.	-	14.
SYSTEMS	2.	-	2.
PROJECT MGMT	4.	-	4.
DATA	1.	-	1.
SUBTOTAL(ENG)	27.	-	27.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	19.	-	19.
TOOL-TEST EQ	2.	-	[illegible]
SUBTOTAL(MFG)	21.	-	21.
TOTAL COST	48.	-	48.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	6.000	ENGINEERING COMPLEXITY	0.900
DENSITY	54.545*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.520	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	220408*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(7)	OCT 83*	(8)	JUN 84*	(15)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00*
DEV COST MULTIPLIER	1.36		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	41.	-	41.
CENTER	48.	-	48.
TO	58.	-	58.

FOLLOWING DATA CHANGES MADE:

DMULT=1.1,PMULT=1.1

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MECHANICAL ITEM

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(281058)

EL SYSTEM HARNESS

		UNIT WEIGHT	25.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	1.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	5.	-	5.
SYSTEMS	0.	-	0.
PROJECT MGMT	3.	-	3.
DATA	2.	-	2.
SUBTOTAL(ENG)	12.	-	12.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	4.	-	4.
TOOL-TEST EQ	0.	-	0.
SUBTOTAL(MFG)	4.	-	4.
TOTAL COST	17.	-	17.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	25.000	ENGINEERING COMPLEXITY	0.200
DENSITY	25.000*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.200	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.0	MTBF(FIELD)	173894*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	MAY 84	(1)	MAY 84*	(0)	MAY 84*	(1)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	14.	-	14.
CENTER	17.	-	17.
TO	21.	-	21.

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ELECTRONIC ITEM

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PUMP (TCS)

		UNIT WEIGHT	35.00	MODE	1
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.50	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	7.	-	7.
DESIGN	14.	-	14.
SYSTEMS	0.	-	0.
PROJECT MGMT	6.	-	6.
DATA	3.	-	3.
SUBTOTAL(ENG)	30.	-	30.
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	18.	-	18.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	20.	-	20.
TOTAL COST	49.	-	49.

DESIGN FACTORS	ELECTRONIC	MECHANICAL
WEIGHT	1.000*	34.000
DENSITY	50.000	68.000*
MFG. COMPLEXITY	9.410	5.640
NEW DESIGN	0.250	0.250
DESIGN REPEAT	0.000	0.000
EQUIPMENT CLASS	*****	*****
INTEGRATION LEVEL	0.7	0.5

PRODUCT DESCRIPTORS	
ENGINEERING COMPLEXITY	0.200
PROTOTYPE SUPPORT	1.0
PROTO SCHEDULE FACTOR	.250*
ELECT VOL FRACTION	.040*
PLATFORM	2.0
YEAR OF TECHNOLOGY	1983*
RELIABILITY FACTOR	1.0
MTBF(FIELD)	690271*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(3)	JUN 83*	(0)	JUN 83*	(3)

SUPPLEMENTAL INFORMATION	
YEAR OF ECONOMICS	1981
ESCALATION	0.00
DEV COST MULTIPLIER	1.10

TOOLING & PROCESS FACTORS	
DEVELOPMENT TOOLING	1.00*

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	42.	-	42.
CENTER	49.	-	49.
TO	60.	-	60.

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MECHANICAL ITEM

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ACCUMULATOR (TCS)

		UNIT WEIGHT	5.00	MODE	[illegible]
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.20	QUANTITY/NHA	[illegible]

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	2.	-	2.
DESIGN	5.	-	5.
SYSTEMS	1.	-	1.
PROJECT MGMT	1.		1.
DATA	0.		0.
SUBTOTAL(ENG)	10.	-	10.
MANUFACTURING			
PRODUCTION	-	-	
PROTOTYPE	2.	-	2.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	2.	-	2.
TOTAL COST	12.	-	12.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	5.000	ENGINEERING COMPLEXITY	0.700
DENSITY	25.000*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.520	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	232799*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	MAY 83	(5)	SEP 83*	(0)	SEP 83*	(5)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	10.	-	10.
CENTER	12.		12.
TO	14.	-	14.

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SYSTEM COST SUMMARY

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TOTAL COST, WITH INTEGRATION COST

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	971.	-	971.
DESIGN	2563.	-	2563.
SYSTEMS	455.	-	455.
PROJ MGMT	449.	-	449.
DATA	205.	-	205.
SUBTOTAL(ENG)	4643.	-	4643.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	880.	-	880.
TOOL-TEST EQ	111.	-	111.
PURCH ITEMS	0.	-	0.
SUBTOTAL(MFG)	991.	-	991.
TOTAL COST	5634.	-	5634.

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	4966.	-	4966.
CENTER	5634.	-	5634.
TO	6585.	-	6585.

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*****************************************************************************
* SYSTEM  UT                    4333.00          SYSTEM  WS           4330.00  *
* SYSTEM SERIES MTBF HRS.        3759            AV SYSTEM COST             0  *
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APPENDIX C

IPS CONFIGURATION

PRICE MODEL REPORT

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MECHANICAL ITEM

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SPAR ASSY (H)

		UNIT WEIGHT	1400.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	211.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	58.	-	58.
DESIGN	106.	-	106.
SYSTEMS	5.	-	5.
PROJECT MGMT	53.	-	53.
DATA	23.	-	23.
SUBTOTAL(ENG)	245.	-	245.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	116.	-	116.
TOOL-TEST EQ	10.	-	10.
SUBTOTAL(MFG)	126.	-	126.
TOTAL COST	370.	-	370.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	1400.000	ENGINEERING COMPLEXITY	0.300
DENSITY	6.635*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.308	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.400	PLATFORM	2.0
DESIGN REPEAT	0.150	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	**.**	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	48669*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 83	(2)	FEB 83*	(0)	FEB 83*	(2)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	320.	-	320.
CENTER	370.	-	370.
TO	445.	-	445.

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MECHANICAL ITEM

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SPAR ASSY LOCK INTERFACE FITTING & SENSOR FITTING

		UNIT WEIGHT	5.00	MODE	2
PROTOTYPE QUANTITY	4.0	UNIT VOLUME	0.03	QUANTITY/NHA	4

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	8.	-	8.
SYSTEMS	1.	-	1.
PROJECT MGMT	2.	-	2.
DATA	1.	-	1.
SUBTOTAL(ENG)	15.	-	15.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	8.	-	8.
TOOL TEST EQ	1.	-	1.
SUBTOTAL(MFG)	9.	-	9.
TOTAL COST	24.	-	24.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	5.000	ENGINEERING COMPLEXITY	1.000
DENSITY	166.667*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.750	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	219801*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 84	(8)	AUG 84*	(5)	JAN 85*	(13)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	21.	-	21.
CENTER	24.	-	24.
TO	28.	-	28.

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MECHANICAL ITEM

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END PLATE & APERTURE COVER RAMPS OF SEC

		UNIT WEIGHT	80.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.30	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	61.	-	61.
DESIGN	149.	-	149.
SYSTEMS	18.	-	18.
PROJECT MGMT	28.	-	28.
DATA	13.	-	13.
SUBTOTAL(ENG)	269.	-	269.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	34.	-	34.
TOOL-TEST EQ	4.	-	4.
SUBTOTAL(MFG)	38.	-	38.
TOTAL COST	308.	-	308.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	80.000	ENGINEERING COMPLEXITY	0.700
DENSITY	266.667*	PROTOTYPE SUPPORT	1.3
MFG. COMPLEXITY	5.918	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	81094*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JUL 83	(6)	DEC 83*	(0)	DEC 83*	(6)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	271.	-	271.
CENTER	308.	-	308.
TO	359.	-	359.

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MECHANICAL ITEM

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(281058)

SUP. STR.,SUN SHIELD & APERTURE COVERS

		UNIT WEIGHT	100.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	2.50	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	47.	-	47.
DESIGN	113.	-	113.
SYSTEMS	14.	-	14.
PROJECT MGMT	22.	-	22.
DATA	10.	-	10.
SUBTOTAL(ENG)	208.	-	208.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	29.	-	29.
TOOL-TEST EQ	7.	-	7.
SUBTOTAL(MFG)	35.	-	35.
TOTAL COST	243.	-	243.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	100.000	ENGINEERING COMPLEXITY	0.700
DENSITY	40.000*	PROTOTYPE SUPPORT	1.2
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.200	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	89479*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JUL 83	(6)	DEC 83*	(0)	DEC 83*	(6)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.30
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	211.	-	211.
CENTER	243.	-	243.
TO	293.	-	293.

MECHANICAL ITEM

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CANISTER SUP STR

		UNIT WEIGHT	100.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	232.00	QUANTITY/NHA	1

PROGRAM COST($ 10E3)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	17.	-	17.
DESIGN	44.	-	44.
SYSTEMS	9.	-	9.
PROJECT MGMT	8.	-	8.
DATA	3.	-	3.
SUBTOTAL(ENG)	81.	-	81.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	30.	-	30.
TOOL-TEST EQ	6.	-	6.
SUBTOTAL(MFG)	37.	-	37.
TOTAL COST	118.	-	118.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	100.000	ENGINEERING COMPLEXITY	1.000
DENSITY	0.431*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.703	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.600	PLATFORM	2.0
DESIGN REPEAT	0.750	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.5	MTBF(FIELD)	85378*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 84	(8)	AUG 84*	(0)	AUG 84*	(8)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00*
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	103.	-	103.
CENTER	118.	-	118.
TO	139.	-	139.

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ELECTRONIC ITEM

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(281058)

RAU PRE AMP

		UNIT WEIGHT	2.50	MODE	1
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.03	QUANTITY/NHA	2

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	11.	-	11.
SYSTEMS	2.	-	2.
PROJECT MGMT	2.	-	2.
DATA	1.	-	1.
SUBTOTAL(ENG)	18.	-	18.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	10.	-	10.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	11.	-	11.
TOTAL COST	30.	-	30.

DESIGN FACTORS	ELECTRONIC	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	0.500*	2.000	ENGINEERING COMPLEXITY	1.200
DENSITY	54.000	66.667*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	9.410	5.770	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	0.500	ELECT VOL FRACTION	.309*
DESIGN REPEAT	0.980	0.500	PLATFORM	2.0
EQUIPMENT CLASS	*****	*****	YEAR OF TECHNOLOGY	1983*
INTEGRATION LEVEL	0.5	0.5	RELIABILITY FACTOR	1.0
			MTBF(FIELD)	1361537*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(16)	JUL 84*	(0)	JUL 84*	(16)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	6.00	DEVELOPMENT TOOLING	.500
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	26.	-	26.
CENTER	30.	-	30.
TO	35.	-	35.

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C&DH BUFFER

		UNIT WEIGHT	3.00	MODE	1
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.03	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	33.	-	33.
DESIGN	108.	-	108.
SYSTEMS	17.	-	17.
PROJECT MGMT	11.	-	11.
DATA	5.	-	5.
SUBTOTAL(ENG)	175.	-	175.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	17.	-	17.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	19.	-	19.
TOTAL COST	194.	-	194.

DESIGN FACTORS	ELECTRONIC	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	1.000*	2.000	ENGINEERING COMPLEXITY	1.200
DENSITY	48.000	66.667*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	9.410	5.770	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	0.500	ELECT VOL FRACTION	.694*
DESIGN REPEAT	0.500	0.001	PLATFORM	2.0
EQUIPMENT CLASS	*****	*****	YEAR OF TECHNOLOGY	1983*
INTEGRATION LEVEL	0.5	0.5	RELIABILITY FACTOR	1.0
			MTBF(FIELD)	690271*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(16)	JUL 84*	(0)	JUL 84*	(16)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	.500
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	172.	-	172.
CENTER	194.	-	194.
TO	223.	-	223.

FOLLOWING DATA CHANGES MADE:
DMULT=1.36,PMULT=1.36

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MECHANICAL ITEM

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FLUID LOOP HOSE(TCS)

		UNIT WEIGHT	120.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.11	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	15.	-	15.
DESIGN	29.	-	29.
SYSTEMS	1.	-	1.
PROJECT MGMT	14.	-	14.
DATA	6.	-	6.
SUBTOTAL(ENG)	66.	-	66.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	44.	-	44.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	46.	-	46.
TOTAL COST	112.	-	112.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	120.000	ENGINEERING COMPLEXITY	0.300
DENSITY	1090.909*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	6.100	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	65173*

SCHEDULE	START	FIRST ITEM	FINISH
DEVELOPMENT	APR 83 (3)	JUN 83* (0)	JUN 83* (3)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	.500
DEV COST MULTIPLIER	1.36		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	97.	-	97.
CENTER	112.	-	112.
TO	132.	-	132.

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MECHANICAL ITEM

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COLD PLATES(TCS)

		UNIT WEIGHT	6.00	MODE	2
PROTOTYPE QUANTITY	8.0	UNIT VOLUME	0.11	QUANTITY/NHA	8

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	5.	-	5.
DESIGN	14.	-	14.
SYSTEMS	2.	-	2.
PROJECT MGMT	4.	-	4.
DATA	1.	-	1.
SUBTOTAL(ENG)	27.	-	27.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	19.	-	19.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	21.	-	21.
TOTAL COST	48.	-	48.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	6.000	ENGINEERING COMPLEXITY	0.900
DENSITY	54.545*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.520	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	220408*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(7)	OCT 83*	(8)	JUN 84*	(15)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.36		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	41.	-	41.
CENTER	48.	-	48.
TO	58.	-	58.

FOLLOWING DATA CHANGES MADE:
DMULT=1.1,PMULT=1.1

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MECHANICAL ITEM

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EL SYSTEM HARNESS

		UNIT WEIGHT	30.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	1.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	5.	-	5.
SYSTEMS	0.	-	0.
PROJECT MGMT	4.	-	4.
DATA	2.	-	2.
SUBTOTAL(ENG)	14.	-	14.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	4.	-	4.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	5.	-	5.
TOTAL COST	19.	-	19.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	30.000	ENGINEERING COMPLEXITY	0.200
DENSITY	30.000*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.200	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.0	MTBF(FIELD)	164638*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	MAY 84	(-1)	MAY 84*	(0)	MAY 84*	(1)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	16.	-	16.
CENTER	19.	-	19.
TO	24.	-	24.

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SYSTEM COST SUMMARY

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(281058)

PI I&T

TOTAL COST, WITH INTEGRATION COST

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	246.	-	246.
DESIGN	589.	-	589.
SYSTEMS	70.	-	70.
PROJ MGMT	148.	-	148.
DATA	66.	-	66.
SUBTOTAL(ENG)	1119.	-	1119.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	311.	-	311.
TOOL-TEST EQ	35.	-	35.
PURCH ITEMS	0.	-	0.
SUBTOTAL(MFG)	346.	-	346.
TOTAL COST	1465.	-	1465.

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	1278.	-	1278.
CENTER	1465.	-	1465.
TO	1735.	-	1735.

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**************************************************************************
* SYSTEM  WT                  1906.00        SYSTEM  WS           1906.00 *
* SYSTEM SERIES MTBF HRS.       7411         AV SYSTEM COST             0 *
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APPENDIX D

AGS CONFIGURATION

PRICE MODEL REPORT

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MECHANICAL ITEM

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SPAR ASSY (H)

		UNIT WEIGHT	1400.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	211.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	58.	-	58.
DESIGN	106.	-	106.
SYSTEMS	5.	-	5.
PROJECT MGMT	53.	-	53.
DATA	23.	-	23.
SUBTOTAL(ENG)	245.	-	245.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	116.	-	116.
TOOL-TEST EQ	10.	-	10.
SUBTOTAL(MFG)	126.	-	126.
TOTAL COST	370.	-	370.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	1400.000	ENGINEERING COMPLEXITY	0.300
DENSITY	6.635*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.308	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.400	PLATFORM	2.0
DESIGN REPEAT	0.150	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	48669*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 83	(2)	FEB 83*	(0)	FEB 83*	(2)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	-1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	320.	-	320.
CENTER	370.	-	370.
TO	445.	-	445.

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MECHANICAL ITEM

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SPAR ASSY LOCK FITTING ON GR

		UNIT WEIGHT	5.00	MODE	2
PROTOTYPE QUANTITY	4.0	UNIT VOLUME	0.03	QUANTITY/NHA	4

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	8.	-	8.
SYSTEMS	1.	-	1.
PROJECT MGMT	2.	-	2.
DATA	1.	-	1.
SUBTOTAL(ENG)	15.	-	15.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	8.	-	8.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	9.	-	9.
TOTAL COST	24.	-	24.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	5.000	ENGINEERING COMPLEXITY	1.000
DENSITY	166.667*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.750	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	219801*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 84	(8)	AUG 84*	(5)	JAN 85*	(13)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	21.	-	21.
CENTER	24.	-	24.
TO	28.	-	28.

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MECHANICAL ITEM

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END PLATE & APERTURE COVER RAMPS OF SEC

		UNIT WEIGHT	80.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.30	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	61.	-	61.
DESIGN	149.	-	149.
SYSTEMS	18.	-	18.
PROJECT MGMT	28.	-	28.
DATA	13.	-	13.
SUBTOTAL(ENG)	269.	-	269.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	34.	-	34.
TOOL-TEST EQ	4.	-	4.
SUBTOTAL(MFG)	38.	-	38.
TOTAL COST	308.	-	308.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	80.000	ENGINEERING COMPLEXITY	0.700
DENSITY	266.667*	PROTOTYPE SUPPORT	1.3
MFG. COMPLEXITY	5.918	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	81094*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JUL 83	(6)	DEC 83*	(0)	DEC 83*	(6)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	271.	-	271.
CENTER	308.	-	308.
TO	359.	-	359.

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MECHANICAL ITEM

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(281058)

SUP. STR.,SUN SHIELD & APERTURE COVERS

		UNIT WEIGHT	100.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	2.50	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	47.	-	47.
DESIGN	113.	-	113.
SYSTEMS	14.	-	14.
PROJECT MGMT	22.	-	22.
DATA	10.	-	10.
SUBTOTAL(ENG)	208.	-	208.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	29.	-	29.
TOOL-TEST EQ	7.	-	7.
SUBTOTAL(MFG)	35.	-	35.
TOTAL COST	243.	-	243.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	100.000	ENGINEERING COMPLEXITY	0.700
DENSITY	40.000*	PROTOTYPE SUPPORT	1.2
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.750	PLATFORM	2.0
DESIGN REPEAT	0.200	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	89479*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JUL 83	(6)	DEC 83*	(0)	DEC 83*	(6)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.30
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	211.	-	211.
CENTER	243.		243.
TO	293.	-	293.

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MECHANICAL ITEM

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CANISTER SUP STR

		UNIT WEIGHT	100.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	232.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	17.	-	17.
DESIGN	44.	-	44.
SYSTEMS	9.	-	9.
PROJECT MGMT	8.	-	8.
DATA	3.	-	3.
SUBTOTAL(ENG)	81.	-	81.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	30.	-	30.
TOOL-TEST EQ	6.	-	6.
SUBTOTAL(MFG)	37.	-	37.
TOTAL COST	118.	-	118.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	100.000	ENGINEERING COMPLEXITY	1.000
DENSITY	0.431*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.703	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.600	PLATFORM	2.0
DESIGN REPEAT	0.750	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.5	MTBF(FIELD)	85378*

SCHEDULE	START	FIRST ITEM	FINISH
DEVELOPMENT	JAN 84 (8)	AUG 84* (0)	AUG 84* (8)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00*
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	103.	-	103.
CENTER	118.	-	118.
TO	139.	-	139.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 13:35 FILENAME: AGS.PI
(781058)

TRUSS STR

		UNIT WEIGHT	100.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	125.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	20.	-	20.
DESIGN	53.	-	53.
SYSTEMS	11.	-	11.
PROJECT MGMT	9.	-	9.
DATA	4.	-	4.
SUBTOTAL(ENG)	96.	-	96.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	29.	-	29.
TOOL-TEST EQ	6.	-	6.
SUBTOTAL(MFG)	35.	-	35.
TOTAL COST	130.	-	130.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	100.000	ENGINEERING COMPLEXITY	1.000
DENSITY	0.800*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.620	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.600	PLATFORM	2.0
DESIGN REPEAT	0.700	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.7	MTBF(FIELD)	89479*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	JAN 83	(8)	AUG 83*	(0)	AUG 83*	(8)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	115.	-	115.
CENTER	130.	-	130.
TO	152.	-	152.

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ELECTRONIC ITEM

DATE 12-MAR-81 TIME 13:35 FILENAME: AGS.PI
(281058)

RAU PRE AMP

		UNIT WEIGHT	2.50	MODE	1
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.03	QUANTITY/NHA	2

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	11.	-	11.
SYSTEMS	2.	-	2.
PROJECT MGMT	2.	-	2.
DATA	1.	-	1.
SUBTOTAL(ENG)	18.	-	18.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	10.	-	10.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	11.	-	11.
TOTAL COST	30.	-	30.

DESIGN FACTORS	ELECTRONIC	MECHANICAL
WEIGHT	0.500*	2.000
DENSITY	54.000	66.667*
MFG. COMPLEXITY	7.410	5.770
NEW DESIGN	0.500	0.500
DESIGN REPEAT	0.980	0.500
EQUIPMENT CLASS	*****	*****
INTEGRATION LEVEL	0.5	0.5

PRODUCT DESCRIPTORS	
ENGINEERING COMPLEXITY	1.200
PROTOTYPE SUPPORT	1.0
PROTO SCHEDULE FACTOR	.250*
ELECT VOL FRACTION	.309*
PLATFORM	2.0
YEAR OF TECHNOLOGY	1983*
RELIABILITY FACTOR	1.0
MTBF(FIELD)	1361537*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(16)	JUL 84*	(0)	JUL 84*	(16)

SUPPLEMENTAL INFORMATION	
YEAR OF ECONOMICS	1981
ESCALATION	0.00
DEV COST MULTIPLIER	1.10

TOOLING & PROCESS FACTORS	
DEVELOPMENT TOOLING	.500

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	26.	-	26.
CENTER	30.	-	30.
TO	35.	-	35.

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ELECTRONIC ITEM

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(281058)

C&DH BUFFER

		UNIT WEIGHT	3.00	MODE	1
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.03	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	33.	-	33.
DESIGN	108.	-	108.
SYSTEMS	17.	-	17.
PROJECT MGMT	11.	-	11.
DATA	5.	-	5.
SUBTOTAL(ENG)	175.	-	175.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	17.	-	17.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	19.	-	19.
TOTAL COST	194.	-	194.

DESIGN FACTORS	ELECTRONIC	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	1.000*	2.000	ENGINEERING COMPLEXITY	1.200
DENSITY	48.000	66.667*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	9.410	5.770	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	0.500	ELECT VOL FRACTION	.694*
DESIGN REPEAT	0.500	0.001	PLATFORM	2.0
EQUIPMENT CLASS	*****	*****	YEAR OF TECHNOLOGY	1983*
INTEGRATION LEVEL	0.5	0.5	RELIABILITY FACTOR	1.0
			MTBF(FIELD)	690271*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(16)	JUL 84*	(0)	JUL 84*	(16)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	.500
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	172.	-	172.
CENTER	194.	-	194.
TO	223.	-	223.

FOLLOWING DATA CHANGES MADE:
DMULT=1.36,PMULT=1.36

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 13:36 (281058) FILENAME: AG5.PI

FLUID LOOP HOSE(TCS)

		UNIT WEIGHT	120.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	0.11	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	15.	-	15.
DESIGN	29.	-	29.
SYSTEMS	1.	-	1.
PROJECT MGMT	14.	-	14.
DATA	6.	-	6.
SUBTOTAL(ENG)	66.	-	66.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	44.	-	44.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	46.	-	46.
TOTAL COST	112.	-	112.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	120.000	ENGINEERING COMPLEXITY	0.300
DENSITY	1090.909*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	6.100	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.3	MTBF(FIELD)	65173*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(3)	JUN 83*	(0)	JUN 83*	(3)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	.500
ESCALATION	0.00		
DEV COST MULTIPLIER	1.36		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	97.	-	97.
CENTER	112.	-	112.
TO	132.	-	132.

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MECHANICAL ITEM

DATE 12-MAR-81 TIME 13:36 (281058) FILENAME: AGS.PI

COLD PLATES(TCS)

		UNIT WEIGHT	6.00	MODE	2
PROTOTYPE QUANTITY	8.0	UNIT VOLUME	0.11	QUANTITY/NHA	8

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	5.	-	5.
DESIGN	14.	-	14.
SYSTEMS	2.	-	2.
PROJECT MGMT	4.	-	4.
DATA	1.	-	1.
SUBTOTAL(ENG)	27.	-	27.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	19.	-	19.
TOOL-TEST EQ	2.	-	2.
SUBTOTAL(MFG)	21.	-	21.
TOTAL COST	48.	-	48.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	6.000	ENGINEERING COMPLEXITY	0.900
DENSITY	54.545*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.520	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.250	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1983*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0

INTEGRATION LEVEL 0.3 MTBF(FIELD) 220408*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	APR 83	(7)	OCT 83*	(8)	JUN 84*	(15)

SUPPLEMENTAL INFORMATION

YEAR OF ECONOMICS	1981	TOOLING & PROCESS FACTORS	
ESCALATION	0.00	DEVELOPMENT TOOLING	1.00*
DEV COST MULTIPLIER	1.36		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	41.	-	41.
CENTER	48.	-	48.
TO	58.	-	58.

FOLLOWING DATA CHANGES MADE:
DMULT=1.1,PMULT=1.1

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MECHANICAL ITEM

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EL SYSTEM HARNESS

		UNIT WEIGHT	30.00	MODE	2
PROTOTYPE QUANTITY	1.0	UNIT VOLUME	1.00	QUANTITY/NHA	1

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	3.	-	3.
DESIGN	5.	-	5.
SYSTEMS	0.	-	0.
PROJECT MGMT	4.	-	4.
DATA	2.	-	2.
SUBTOTAL(ENG)	14.	-	14.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	4.	-	4.
TOOL-TEST EQ	1.	-	1.
SUBTOTAL(MFG)	5.	-	5.
TOTAL COST	19.	-	19.

DESIGN FACTORS	MECHANICAL	PRODUCT DESCRIPTORS	
WEIGHT	30.000	ENGINEERING COMPLEXITY	0.200
DENSITY	30.000*	PROTOTYPE SUPPORT	1.0
MFG. COMPLEXITY	5.200	PROTO SCHEDULE FACTOR	.250*
NEW DESIGN	0.500	PLATFORM	2.0
DESIGN REPEAT	0.000	YEAR OF TECHNOLOGY	1984*
EQUIPMENT CLASS	*****	RELIABILITY FACTOR	1.0
INTEGRATION LEVEL	0.0	MTBF(FIELD)	164638*

SCHEDULE	START		FIRST ITEM		FINISH	
DEVELOPMENT	MAY 84	(1)	MAY 84*	(0)	MAY 84*	(1)

SUPPLEMENTAL INFORMATION		TOOLING & PROCESS FACTORS	
YEAR OF ECONOMICS	1981	DEVELOPMENT TOOLING	1.00*
ESCALATION	0.00		
DEV COST MULTIPLIER	1.10		

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	16.	-	16.
CENTER	19.	-	19.
TO	24.	-	24.

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SYSTEM COST SUMMARY

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(281058)

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TOTAL COST, WITH INTEGRATION COST

PROGRAM COST($ 1000)	DEVELOPMENT	PRODUCTION	TOTAL COST
ENGINEERING			
DRAFTING	266.	-	266.
DESIGN	642.	-	642.
SYSTEMS	81.	-	81.
PROJ MGMT	157.	-	157.
DATA	70.	-	70.
SUBTOTAL(ENG)	1214.	-	1214.
MANUFACTURING			
PRODUCTION	-	-	-
PROTOTYPE	340.	-	340.
TOOL-TEST EQ	41.	-	41.
PURCH ITEMS	0.	-	0.
SUBTOTAL(MFG)	381.	-	381.
TOTAL COST	1595.	-	1595.

COST RANGES	DEVELOPMENT	PRODUCTION	TOTAL COST
FROM	1393.	-	1393.
CENTER	1595.	-	1595.
TO	1887.	-	1887.

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* SYSTEM  WT                2006.00        SYSTEM  WS          2006.00   *
* SYSTEM SERIES MTBF HRS.    6844          AV SYSTEM COST         0      *
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