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ATMOSPHERIC SCIENCE FACILITY

PALLET-ONLY MODE

SPACE TRANSPORTATION SYSTEM PAYLOAD

(FEASIBILITY STUDY)

INTERIM TECHNICAL REPORT

VOLUME 1

BY

EXPERIMENT SYSTEMS DIVISION

National Aeronautics and Space Administration
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FOREWORD

This study presents the interim results of an on-going evaluation study at the Johnson Space Center (JSC) of the pallet-only mode for Atmospheric, Magnetospheric, and Plasmas-in-Space (AMPS) payloads on the Space Transportation System (STS). The complete study is to address payload configurations for all AMPS disciplines, and also for payloads configured for selected disciplines. The configurations discussed in this interim report include the provisions for selected atmospheric science missions. The AMPS payload is being designed to conduct experiments in areas of global remote sensing of the atmosphere, the ionosphere and the magnetosphere. Active perturbation by laser emissions, chemical reactions, or gas releases of the stratosphere, ionosphere, and magnetosphere will answer fundamental scientific questions. Such answers are considered keys to a better understanding of man's total natural environment, his effects upon it, and its effects upon him.

In the summer of 1973, the Space Science Board of the National Academy of Science convened a study at Woods Hole, Massachusetts, to explore the scientific uses of the Orbiter which is a part of the STS. In this study, the discipline groups were asked to describe the scientific objectives of their respective disciplines, to identify experiments or instruments that are both scientifically desirable and suitable for Orbiter operations, to determine which mode of Orbiter use would be best suited to the operation of these instruments, to outline a mission model, and to make recommendations concerning their science and the Orbiter.

Discussion in the Woods Hole study report indicated that in the attempt to choose the best-suited Orbiter mode, almost all discipline groups were limited by the lack of detailed information being available at that time, which would enable them to determine cost-effectiveness for the various modes.

Although the presence of scientists in a pressurized Spacelab module appeared to be the preferred mode of operation for AMPS experiments which require manned control in real time, based on real time analysis of observational data, there were also experiments to be considered which might preclude the presence of the habitable Spacelab module and would require monitoring and control from the Orbiter cabin (pallet-only mode).

One of the recommendations by the Atmospheric and Space Physics Group in the Woods Hole study report indicated the need for the National Aeronautics and Space Administration (NASA) to study the relative merits of the two modes of operation: (1) pressurized habitable module with pallets; and (2) the pallet-only mode without the habitable Spacelab module. The recommended study was to include: (1) scientific payload weight, cost, available data rate, and (2) system coverage using active experiment control based on real time data evaluations. The current on-going study at JSC is partly the indirect result of this recommendation.

The Woods Hole study report also noted that suitable instrumentation for the AMPS payload could be available for the Orbiter missions if a program was to be started right away in certain crucial areas, and recommended that scientists should be selected as soon as possible to participate in the detailed scientific definition and development of the planned programs and instrumentation.

The 49-member AMPS Science Definition Working Group (herein referred to as AMPS SDWG) was formed by NASA in the summer of 1974. Definition and development studies by the working group, and also those being monitored by the working group, are being conducted in parallel with the definition and development of associated Orbiter systems because of the long lead time required for some of these, and so that AMPS payloads can be included on early STS operational missions.

The on-going AMPS study at JSC was begun in the Fall of 1974 to: (1) support the AMPS SDWG (2) to perform an evaluation of the potential of the pallet-only mode for AMPS payloads, and (3) to define details of an atmospheric science payload configuration for the AMPS program.

The JSC study required the establishment of a baseline which could be used for analysis for the evaluation of the pallet-only mode by specialists in the areas of systems hardware and software, instrumentation and sensors, data handling and processing, mission planning, crew procedures and timeline development, etc. It was necessary that the baseline be developed on criteria from the AMPS SDWG and include science objectives, candidate experiments, mission models, sensors and instrument definitions, and payload systems configurations. These criteria were representative of, and compatible with, the plans and concepts being developed by the AMPS SDWG scientists and by the Orbiter and Spacelab designers. This interim report includes the results of that part of the study which is establishing this representative configuration baseline.

The JSC study team has worked with members of the AMPS SDWG, Marshall Space Flight Center (MSFC), Goddard Space Flight Center (GSFC) AMPS personnel, with JSC personnel who are associated with the definition and development of the Orbiter, and with other Orbiter and Spacelab related activities so that adjustments can be considered as the definition and development of each progresses.

The cutoff date for technical input documentation to this Interim Report was June 1, 1975. Changes are to be expected during the course of the study which may affect the presentations in subsequent reports.

ACKNOWLEDGMENTS

During the study to evaluate the feasibility of a Spacelab pallet-only configuration with which the AMPS Experiments Program could be conducted from the Orbiter, considerable background data were required. Numerous individuals in the scientific disciplines very generously answered the inquiries made of them and, in many instances, offered pertinent suggestions and provided detailed documentation on the program, the experiments, and the instruments involved.

The members of the JSC AMPS feasibility study project wish to acknowledge the following individuals who provided the answers to many basic questions.

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ACRONYMS AND ABBREVIATIONS

A	ampere(s)
Å	angstrom(s)
A&A	alarm and advisory
ac	alternating current
A/D	analog to digital
AE	Atmosphere Explorer
AGC	Automatic Gain Control
Ah	ampere-hour
AIM	AMPS Instrument Module
AMPS	Atmospheric, Magnetospheric, Plasmas in Space
AMS	Attitude Measurement System
AMU	Atomic Mass Unit
A/N	alpha-numeric
ANK	alpha-numeric keyboard
APS	AMPS Pointing System
APCS	Attitude Pointing and Control System
ASF	Atmospheric Science Facility
ASTP	Apollo Soyuz Test Project
ASPO	Apollo Spacecraft Program Office
ATCS	Active Thermal Control Subsystem
ATS	Application Technology Satellite
AZ	azimuth
BI-STEM	Bi (dual) Storable Tubular Extendable Member
bpm	bits per minute
bps	bits per second
Btu	British Thermal Unit
B/U	backup
C	Centigrade
CCIG	Cold Cathode Ion Gauge
CCTV	closed circuit television
CDMS	Command and Data Management Subsystem
CEP	langmuir probe
CDU	control and display unit
CG	center of gravity
cm	centimeters
COAS	crewman optical alignment system

CRT	cathode ray tube
CSS	core segment simulator
C&W	caution and warning
CUM	cubic meter
CW	carrier wave
D&C	displays and controls
D/A	digital to analog
dB	decibel
dc	direct current
deg/sec	degrees per second
DEU	display electronics unit
DSKY	display and keyboard assembly
ECS	environmental control system
ED	experiment description
e.g.	for example
EGSE	electrical ground support equipment
ELF	extremely low frequency
EL	elevation
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPDS	electrical power and distribution subsystem
ERNO	Entwickelung Ring Nord (Engineering firm of the north)
ESD	Experiment Systems Division
ESRO	European Space Research Organization
ESTEC	European Space Technical Center
EUV	extreme ultraviolet
eV	electron volt
EVA	extra vehicular activity
F	farad
FCS	flight control system
FFK	fixed function keyboard
FHST	fixed heat star tracker
FM	frequency modulation (or modulated)
FOV	field-of-view
fps	feet per second
ft	feet
GARP	Global Atmospheric Research Program

GEOS	Geodetic Earth Orbiting Satellite
GFE	government furnished equipment
GHz	gigahertz
GMT	Greenwich Mean Time
GN_2	gaseous nitrogen
GN&C	guidance, navigation and control
GPC	general purpose computer, or ground payload computer
GRA	gyro reference assembly
GSE	ground support equipment
GSFC	Goddard Space Flight Center
GST	gimballed star tracker
HEPD	high energy particle detector
HF	high frequency
HPI	high performance insulation
hr	hour
HV	high voltage
Hz	hertz
IC	integrated circuit
ID	instrument description
i.e.	that is
IEP	instrument electronics package
IFOV	instantaneous field-of-view
IFRD	Instrument Functional Requirements Document
IMU	inertial measurement unit
in	inch(es)
I/O	input/output
IPS	Instrument Pointing System
ips	inches per second
IR	infrared
ISIS	International Satellite for Ionospheric Studies
J	Joule
JSC	Johnson Space Center
K	degrees Kelvin
kb	kilobit
kbps	kilo bits per second
keV	kilo electron volt
kg	kilogram(s)

kHz	kilohertz
KJ	kilojouk
km	kilometer(s)
KSC	Kennedy Space Center
kW	kilowatt(s)
kWh	kilowatt hour(s)
kwds	kilo words (digital) data per second
LCC	Launch Control Center
LEE	low energy electron probe
LIED	low energy ion detector
LH_e	liquid helium
LH_2	liquid hydrogen
LN_e	liquid nitrogen
LH_2	liquid oxygen
LLTV	low light television
LM	lunar module
LN_2	liquid nitrogen
LOS	line-of-sight (loss-of-signal)
Ly-α	Lymman-Alpha
m	meter(s)
MA	multiple access
MAG	triaxial fluxgate
MAIL	Mockup and Integration Laboratory
Mbps	mega bits per second
MCC	Mission Control Center
MCDS	multifunction CRT display system
MECO	main engine cutoff
MET	mission elapsed time
MeV	mega electron volts
MGSE	mechanical ground support equipment
MHz	Megahertz
MJ	megajoule
mm	millimeter(s)
mmHg	millimeters of mercury
MPD	magnetoplasmadynamic
MPS	magnetospheric and plasmas-in-space
mrad	milliradian(s)
ms	millisecond

MS	Mission Specialist
mV	millivolt
µm	micrometer
µF	microfarad
µs	microsecond
µv	microvolt
MSFC	Marshall Space Flight Center
MSS	mission specialist station
MW	megawatt
N	Newtons
N/A	not applicable
NACE	neutral mass spectrometer
NASA	National Aeronautics and Space Administration
NATE	neutral atmosphere temperature
Ne	Neon
NFFK	numeric fixed function keyboard
nH	nanohenry
NIR	near infrared
N/m^2	Newtons per square meter
NRL	Naval Research Laboratory
NIMBUS	NIMBUS Spacecraft
N_2	Nitrogen
ns	nanosecond
OBIPS	Optical Band Imager and Photometer System
OGO	Orbiting Geophysical Observatory (Spacecraft)
OMS	Orbital Maneuvering System
OSO	Orbiting Solar Observatory (Spacecraft)
OPF	Orbiter Processing Facility
OSSA	Office of Science and Space Applications
PBI	push button indicator
PCM	pulse code modulation
PCSS	Pointing Control and Stabilization Subsystem
PDS	Particle
PES	photoelectron spectrometer
PI	Principal Investigator
PM	phase modulation (or modulated)
PMS	Performance Monitoring System (or Payload Mission Simulator)

POK	page overlay keyboard
ppm	parts per million
pps	pulses per second
PPU	power processing unit
PS	Payload Specialist
p.s.	power supply
psi (a)(g)	pounds per square inch (absolute) (gauge)
PSS	Payload Specialist Station
QED	Quick and Easy Design
RAU	Remote Acquisition Unit
R&D	rendezvous and docking
RCA	Radio Corporation of America
RCS	reaction control system
rf	radio frequency
rms	root mean square
RMS	remote manipulator system
RPA	retarding potential analyzer (planar ion trap)
rpm	revolutions per minute
rps	revolutions per second
R&QA	reliability and quality assurance
RTOP	Research and Technology Objectives and Plans
SA	single access
S&AD	Science and Applications Directorate
SAIL	Shuttle Avionics Integration Laboratory
SCATHA	spacecraft charging at high altitudes
SCMR	Surface Composition Mapping Radiometer
SDWG	Science Definition Working Group
sec	second
SEMIS	Solar Energy Monitor in Space
SHP	standard hardware program
SIPS	Small Instrument Pointing System
SOLRAD	SOLRAD Spacecraft (Explorer 44)
sps	samples per second
SPS	Solar Physics Satellite
sq cm	square centimeter
sq m	square meter
sr	steradian
S/S	Subsystem (sample/seconds)

STA	Star Tracker Assembly
STDN	Space Tracking and Data Network
STEM	Storable Tubular Extendable Member
STS	Space Transportation System
ST	star tracker
TBD	to be determined
T&C/O	test and checkout
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
Te	temperature of electrons
TM	telemetry
T/R	transmitter/receiver
TSMS	thermal structural and mechanical subsystem
TV	television
ULF	ultra low frequency
UV	ultraviolet
V	volt
VA	voltampere
VAB	Vertical Assembly Building
Vac	volts alternating current
VAE	airglow photometers
Vdc	volts direct current
VIS	visible
VLF	very low frequency
W	watt(s)
XUV	extreme ultraviolet
Y-POP	y/perpendicular to orbiter plane
ZVV	z/velocity vector

SYMBOLS

Ar	argon
BeCu	beryllium copper
B_o	magnetic field strength
C	carbon
CH_4	methane
CO	carbon monoxide
dE/dX	energy loss per unit length
E/Q	energy per unit charge
H	atomic hydrogen
He	helium
HNO_3	nitric acid
H_2O	water
k	wave number
N	nitrogen
N_2	gaseous nitrogen
Ni^{63}	nickel 63
NO	nitric acid
NO_2	nitrogen dioxide
N_2O	nitrous oxide
O	atomic oxygen
O_3	ozone
OH	hydroxyl radical
P	phosphorus
Rb	budidium
Z	atomic number
o	degree
$\leq$	less than or equal to
$\geq$	greater than or equal to
$\Delta E/E$	energy resolution
$\Delta M/M$	mass resolution
$\Delta(M/Q)/(M/Q)$	resolution or ratio of mass to charge
$\Delta\lambda/\lambda$	wavelength resolution
λ	wavelength
γ	10^{-5} gauss
π	pi

1.0 INTRODUCTION

1.1 AUTHORIZATION

The NASA, Johnson Space Center (JSC) was requested by the Office of Space Science (OSS) to submit a Research and Technology Operating Plan (RTOP) entitled "Atmospheric, Magnetospheric, and Plasmas-In-Space (AMPS) Payload Definition Studies" which included the study of the potential of the pallet-only mode for the AMPS project and the provision of conceptual designs for the AMPS Atmospheric Science Facility (ASF) payload which can be flown in the pallet-only mode. This report is submitted in response to that RTOP.

1.2 STUDY OBJECTIVES

1.2.1 ASSESSMENT

Assess the potential of a 1981 AMPS mission in a pallet-only mode aboard the STS. This particular RTOP objective was interpreted as requiring a study to address the following questions:

a. Is it technically feasible to fly an AMPS mission in a pallet-only mode aboard the STS?

b. If the pallet-only mode is feasible for AMPS, of what would the AMPS flight system consist and how would it be integrated and operated? What facilities would be required to support the AMPS program?

c. What impact would AMPS pallet-only missions have on NASA resources such as cost, schedule, facilities?

d. What major trade-off considerations would be applicable, and what options would be presented to Level I NASA management for assessment of overall potential. For example, schedule/resources vs. scientific objectives/benefits.

1.2.2 IDENTIFICATION

Identify instrument designs and operational requirements for satisfying scientific objectives set forth by the NASA AMPS SDWG.

1.2.3 DEFINITION

Define a conceptual ASF system design in sufficient depth to serve as a baseline for both a Level I management start decision (cost/schedule/merit) and a final design study.

1.2.4 PREPARATION

Prepare a JSC study report containing results, conclusions, and recommendations for transmittal to NASA Headquarters.

1.3 END PRODUCTS

The end products of the study are two reports. The first is an Executive Summary document that presents an assessment of the potential of the Orbiter pallet-only mode to satisfy AMPS requirements. The summary will include:

a. Conclusions and recommendations.

b. Description of the study baseline system.

c. Significant technical and operational trade-off factors.

d. Representative AMPS payload instrument complements.

e. Payload development costs and schedules.

f. Identification of experiment classes not applicable to pallet-only operation.

g. Identification of significant problem areas that need resolution.

h. Recommendations for further study.

The second document is a technical report in two parts. The first part presents conceptual designs and specifications for an ASF and includes findings which disclose that an ASF can be fl wn in the pallet-only mode. The second part is a feasibility udy on the subject of flying a complete AMPS mission using the pallet-only mode.

2.0 STUDY APPROACH

2.1 NATURE AND SCOPE OF THE STUDY

As previously mentioned, the principal objective of the study is to assess the economic and technical feasibility of employing a pallet-only mode for conducting AMPS experiments. The study plan is to develop a baseline incorporating the experiment and instrument descriptions provided by the AMPS SDWG. This baseline will be augmented by assumptions and judgments of scientists and engineers knowledgeable in the various phenomena and state-of-the-art instrumentation. That baseline, which includes experimental objectives, methodologies, instrumentation, experiment timelines, development schedules and costs is then used to assess the feasibility of a pallet-only mode. The results may be used for advance planning and decision-making that will preclude false starts and wasted resources in a stringent economic environment.

The AMPS system, of course, incorporates much more than the ASF payload, as depicted in figure 2-1. It includes not only the Orbiter with its scientific payload but also space-to-ground and ground-to-space communication and data link systems, interfaces with other satellites, and supporting ground facilities. The scope of this study, however, primarily addresses the payload; giving substantive consideration only to those other system facets that are significantly impacted by the pallet-only mode operation. Cursory consideration is given to all system aspects to ascertain whether or not there may be such significant impacts.

2.2 TECHNICAL APPROACH

The approach employed, in essence, started with a set of Instrument Functional Requirements Documents (IFRD's) defined from inputs by the AMPS SDWG. Experiments were then defined by the

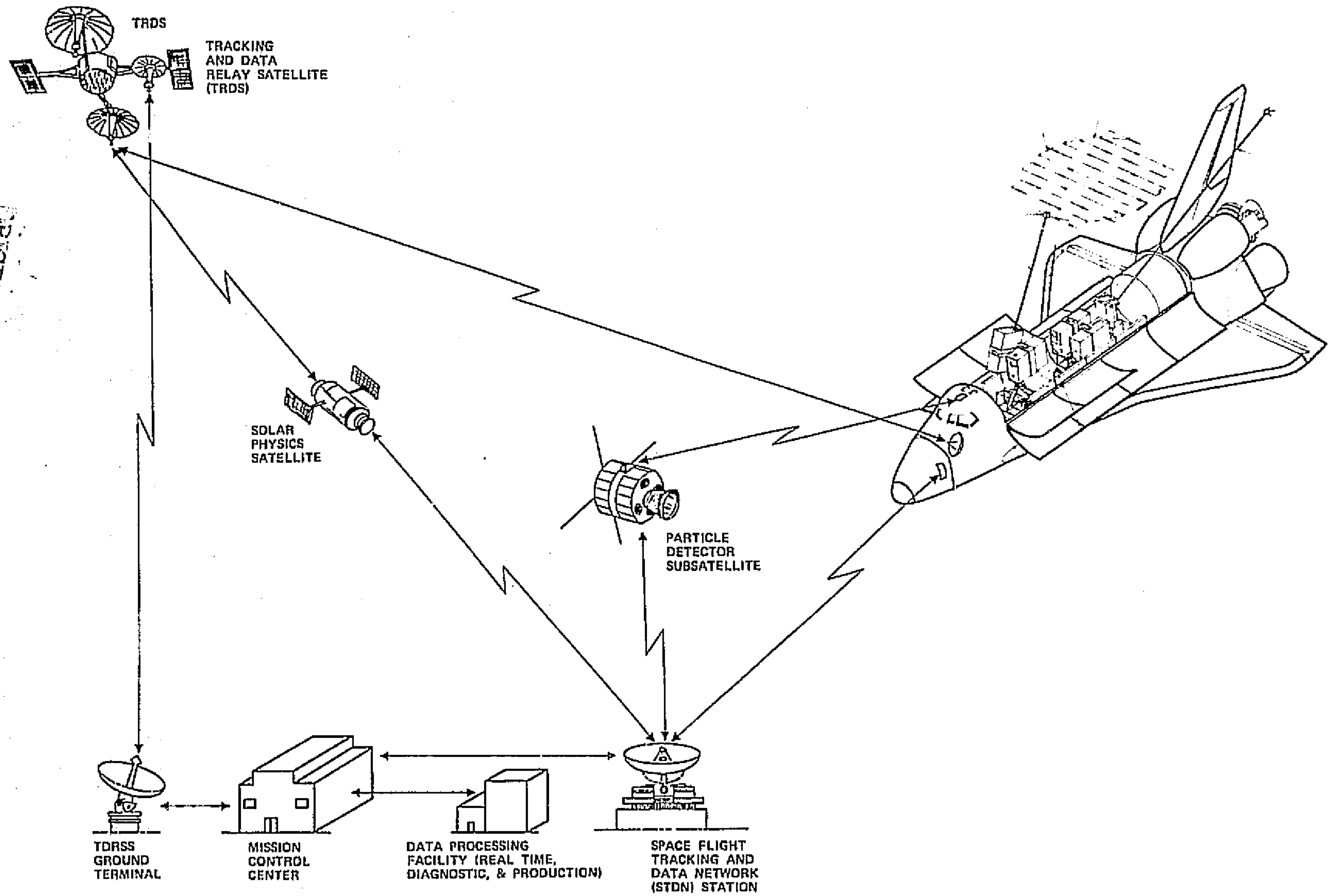

Figure 2-1 ASF mission system

JSC study group. The instrument characteristics and experiment requirements allowed definition of support subsystem requirements and subsequent translation into operational requirements which were integrated into a conceptual system and mission. This conceptual system was used as a baseline upon which to base a feasibility assessment.

Close communications were maintained with many of the scientific investigators of the AMPS SDWG to assure a correct understanding of their experimental objectives and preferences in experiment operations and data handling. Their inputs were augmented by JSC engineering expertise to define a conceptual system considered feasible, realizeable within a reasonable time frame, and capable of meeting a maximum portion of the ASF scientific objectives.

The Magnetospheric and Plasmas-in-Space (MPS) portion of the total AMPS concept is not addressed in this ASF report because of the unavailability of information and study schedule limitations. A separate report will be prepared at a later date.

2.3 STUDY BASELINES

2.3.1 JOHNSON SPACE CENTER ORGANIZATIONAL RESPONSIBILITIES

For the conduct of the program, areas of responsibility were established as detailed below:

a. The Shuttle Payload Integration and Development Program Office will be responsible for project management of the AMPS pallet-only study activities and related inter-NASA Center interface functions.

b. The JSC Science and Applications Directorate (S&AD) will be responsible for defining and interpreting science and experiment requirements and interfacing with the AMPS SDWG.

c. The JSC Experiment Systems Division (ESD) will be responsible for:

(1) Instrument definition.

(2) Systems aspect of pallet(s) requirements, integration, and hardware interfaces.

(3) Overall study objectives.

2.3.2 DEFINITIONS

2.3.2.1 Experiment

Experiment as used in this report is an orderly operation performed to acquire data that will provide certain desired scientific information.

2.3.2.2 Prime Instrument

An instrument which has been ascribed by the Scientific Investigator on the AMPS SDWG for a particular experiment or group of experiments.

2.3.2.3 Substitute Instrument

An instrument that is functionally similar to, but with different capability than, the prime instrument. It will be substituted for the prime instrument when the latter is not available for flight due to technical problems, schedule, cost, failure, or other reasons.

2.3.2.4 Alternate Instrument

That instrument which is dedicated to different experiment objectives (i.e., another experiment) for which it is the prime (or substitute) instrument. It will be used as an alternative when the previous experiment's instrument(s) is not available for flight or priority status has changed.

2.3.2.5 Core Instruments

That set of instruments that is used for experiments in all three scientific disciplines, i.e., atmospherics, magnetospherics, and plasmas-in-space.

2.4 REFERENCE DOCUMENTATION AND BIBLIOGRAPHY

During the course of this study, a great number of documents, reports, papers, and texts were used as reference material. In general, the material fell into three categories as follows.

2.4.1 AUTHORITATIVE DOCUMENTS

Documents which provide direct technical and programmatic information relative to the Space Shuttle Program, including publications such as JSC-07700, Volume XIV, JSC-09310 through JSC-09325, and JSC Specification SL-E-0001. The information provided by those documents and publications is intrinsic to all phases of this study, and no effort was made to cite the numerous references which were made.

2.4.2 REFERENCE DOCUMENTS

Reference documents include those documents and publications published by NASA, NASA contractors, and by or for other Government agencies, and which provide information and background data on spacecraft, projects, instruments, experiments, etc., including publications such as the various user's guides prepared for the unmanned spacecraft and satellites. In some instances, the publication used was one prepared by the prime contractor for the vehicle, such as the Radio Corporation of America (RCA) publication on the Atmosphere Explorer (AE) satellite. Except in the rare case where a reference was made on a specific aspect, no effort was made to cite the many areas from which the information was derived.

2.4.3 INFORMATION DOCUMENTS

Information documents include journals and other sources for scientific papers written on the theory and practice of experiments in the disciplines with which this report has been concerned. Many of the papers perused represented the work of the scientists who are members of the various working groups of the AMPS Program.

All of the documents used have been listed in the Bibliography, section 10.0, under one of the three headings previously mentioned.

2.5 ASSUMPTIONS

A number of assumptions were made at the outset of the study to establish guidelines and common bases of reference for all study participants. These assumptions are listed below:

a. The pallet-only mode may utilize up to five Spacelab pallets. As many as three pallets can be rigidly joined together.

b. The study will define the instruments, support subsystems interfaces, and Orbiter related operational requirements for any free-flying, maneuverable satellites/subsatellites, and tethered satellites required to support the AMPS pallet-only project.

c. Control of free-flying, maneuverable satellites, and tethered satellites necessary to support the ASF/AMPS payload will be effected from the Orbiter.

d. Earth and/or sun synchronous satellites may be considered, if necessary, to support the ASF/AMPS pallet-only payload. When required, the instrument complement, supporting subsystems and applicable interface requirements therewith will be defined during this study.

e. The ASF/AMPS payload will be automated to the maximum extent possible. However, the design approach will not preclude man-in-the-loop when hardware complexity and/or cost prohibit the automatic mode.

f. Each experiment, instrument, and support subsystem will utilize standard modular equipment for display and control mounting in the aft crew station payload console. Real time data displays, both onboard and downlink, will be provided as required.

g. Extravehicular Activity (EVA) operations to service the cargo bay payload equipment will not be considered normal operating procedure. However, the equipment design will not preclude EVA operations.

h. Utilization of Rendezvous and Docking (R&D) and Remote Manipulator System (RMS) capabilities will be normal procedure for the ASF/AMPS payload.

i. Existing NASA Shuttle/Spacelab document guidelines will be followed where applicable. Programmed Spacelab equipment, excluding the manned modules, will be utilized wherever possible. All European Space Research Organization/Entwickelung Ring Nord (ESRO/ERNO) supplied equipment will meet schedule, fit, and function requirements.

j. The first flight opportunity for ASF/AMPS payload(s) equipment will be mid-1981. Although all prime instruments may not be available for several years, the ASF/AMPS pallet-only basic design will provide experiment instruments for the first flight opportunity.

k. Wherever specific information is lacking, the study report will so state.

l. Configuration management, safety, reliability, and quality control guidelines will be established to NASA specifications for all ASF/AMPS equipment. Specifications tailored to environment, contractor history, experience, and development status of hardware will also be established.

m. The ASF/AMPS project plan will be based on hardware requirements of one engineering model, one qualification model, one training model (control panels), one flight model, and critical component spares.

n. ASF and/or AMPS will be considered the prime payload in terms of priority for the use of Orbiter payload accommodations during any ASF/AMPS mission.

o. A TV system for scanning within the Orbiter payload bay will be supplied on the Orbiter.

p. Many lower level, detailed technical assumptions relating to design approaches and operational philosophy necessary during this study are identified in appropriate sections of this report.

3.0 SUMMARY

3.1 GENERAL

This study was initialized with a preliminary set of IFRD's developed by the AMPS SDWG from which Experiment Descriptions (ED's)(appendix A) and Instrument Descriptions (ID's)(appendix B) were derived. The ED's and ID's are summarized in section 4.0. The prime instruments are packaged into four pallets in a physical and functional manner compatible with the STS capabilities and/or constraints and an Orbiter 7-day mission timeline (section 5.0). In section 6.0 operational compatibility is verified between the Orbiter/payload and supporting facilities (Particle Detector Subsatellite (PDS), Solar Physics Satellite (SPS), Tracking and Data Relay Satellite System (TDRSS), Space Tracking and Data Network (STDN), Mission Control and Ground Data Processing facilities). Section 7.0 treats the development status and schedule requirements applicable to the ASF mission. Sections 8.0 and 9.0 contain detailed treatments of the conclusions and recommendations resulting from this study. The abbreviations and acronyms used in this report are defined in a listing which is in the front matter of this report.

3.2 CONCLUSIONS

Many meaningful conclusions may be derived from results of this study; a study oriented toward assessing the potential of a 1981 ASF pallet-only mode STS mission. The study involved much more than a go-no-go determination of scientific and technical feasibility. This mission-level approach, as opposed to merely evaluating a "flight package" concept, necessitated many tangential studies into facility-level interface requirements. The study exposed programmatic factors not only of extreme significance to realistic management planning but also applicable to almost all missions utilizing the STS as a platform for scientific payloads. These factors influence each facet of this summary.

The scope of the ASF study is depicted in figure 2-1 which illustrates the major facility interfaces.

3.2.1 FEASIBILITY

In general, feasibility conclusions can be summarized as follows, but qualifications are in order subject to other factors presented in this summary section.

The data required to satisfy the preliminary set of definitions of the atmospheric science objectives can be obtained, utilizing the pallet-only mode with the proper instrumentation. However, much refinement in the scientific requirements may significantly impact programmatic considerations, primarily in the areas of cost and schedule.

Although the programmatic feasibility factors of cost, schedule, etc., can allow a wide latitude in trade-off considerations, the cost and schedule requirements to deliver certain prime instruments by 1981 are almost prohibitive. In addition, the costs to develop some instruments, considered prime at this time, could prove to be economically unfeasible.

If the global coverage requirement is interpreted literally, the polar orbit missions required to accomplish this will not be possible until at least 1983 because of present schedules for availability of the western launch facility. However, partial global coverage would be possible, in the interim period, utilizing the eastern launch facility.

Although schedule and costs are a major factor, it is technically feasible to conduct an ASF mission in the pallet-only mode. Two of the technical factors which may affect technical feasibility in some areas are: (1) contamination from the STS, and (2) payload computer sizing. These factors influence the unresolved issues, follow-up requirements, and trade-off considerations as treated in this summary.

3.2.2 MAJOR UNRESOLVED ISSUES

During the course of this study, initial concepts and approaches were selected in the development of a pallet-only mode ASF mission utilizing the STS. Preliminary mission timelines resulting from limited definition of the experiment and instrument requirements were developed and subsequently updated. As appreciation of the Orbiter contamination environment developed, a particle detector subsatellite and boom-mounted equipment design were implemented. This resulted in a conceptual functional design considered technically feasible, but with certain qualifications because of key assumptions developed along the way. Validity of some assumptions could not be fully verified. As a result, several potentially significant issues remain which warrant identification and require future investigation.

a. Upon receipt of the updated and upgraded sets of AMPS/ASF experiment/instrument requirements from the SDWG, revised mission timelines will be needed to establish operational boundaries. These boundary timelines will then be used to complete the task of sizing the ASF system, followed by a reassessment of the ASF design concepts relative to the new timeline. Particular emphasis will be given to the aft crew station, command and data management, power, and thermal subsystems for probable impacts.

b. There is need to operate the particle detector instruments a relatively short distance away from the Orbiter to avoid an excessive contamination environment. The AE satellite was chosen to carry these instruments because it is operationally ready and the normal AE instrument complement requires minimal change. There are obviously many unresolved problems associated with this approach:

   (1) How do the above impacts compare with those of a tethered satellite or boom-mounted module?

(2) Would it be feasible to modify the proposed subsatellite to remain in orbit and possibly be used for other scientific missions?

(3) How practical is the boom concept to implement in view of the requirement for Orbiter attitude changes?

Potential boom dynamics problems warrant further investigations related to technical, scientific, and operational factors.

c. The AMPS/ASF pallet-only mode of operation has more instruments, more experiments, more automation and a much greater emphasis on data processing than any previous space payload. This presents the need for a more detailed investigation of the Orbiter payload computer capability versus the forthcoming, upgraded requirements for AMPS/ASF experiments; more detailed than was possible within the scope of this study. This issue is addressed at length in paragraph 8.4.

3.2.3 TECHNICAL FOLLOW-UP REQUIREMENTS

Although study results indicate functional feasibility of this conceptual ASF payload design, more accurate capacity and sizing definitions are required in most areas. In order to refine the definitions, many details (not known originally) of the design and operation of the various instruments are required (i.e., detector and housing design for cryo-cooled instruments, and total payload data characteristics and timelines affecting data processing). A summary identification and priority of technical follow-up efforts resulting from this study are listed below. Details are contained in paragraph 8.3.

a. Define in greater detail a comprehensive set of requirements for experiments, instruments, subsatellite and support subsystems. This effort should include defining more detailed mission timelines for experiment, instrument and subsystem operations than that developed to date.

b. Provide better and more comprehensive design and operational definitions for instruments and subsystems.

c. Perform various analyses and trade-off studies to verify the preliminary selections or to update the design and operations with more optimum approaches.

d. Generate preliminary design and operational specifications to be used as a basis for downstream development.

e. Develop programmatic factors such as estimates of total program development, production, and operational costs; funding plans including expenditures by phases, allocation of resources, funding constraints and optional expenditure approaches; development, production and operational schedules including expected critical paths and availability of non-ASF support such as the Orbiter, the SPS, the TDRSS, etc.; development, production and operational plans for each major program element (e.g., flight hardware, flight software, ground support facilities and ground support software); and an analysis of the technical, cost, and schedule risks involved with full scale development.

3.2.4 TRADE-OFF CONSIDERATIONS

3.2.4.1 Scientific

The preliminary nature of the present scientific requirements plus the advanced state-of-art of many prime instrument concepts, present many potential trade-off areas. A detailed treatment is contained in paragraph 8.2.1 of this report. They can be broadly categorized in this summary as follows.

a. Different techniques to derive the desired scientific information.

b. Postponement of experiments requiring the instruments.

c. Substitute instrument(s) which may affect optimized scientific goals.

3.2.4.2 Technical

Table 3.2.4-1 summarily lists the technical trade-off parameters which are comprehensively treated in paragraph 8.2.2 of this report.

3.2.4.3 Programmatic

Many major trade-off considerations of a programmatic nature are evident from this ASF pallet-only mode study. Information is available now for some; additional information is required for many others. Paragraph 8.2.3 and appendix C (4 parts) address this subject in more detail. The two major trade-off areas center around the STS contamination environment and the practicality of a 1981 launch requirement as opposed to a 1983-1985 launch date.

3.3 RECOMMENDATIONS

3.3.1 ASF PAYLOAD SYSTEM DESIGN

Paragraph 9.1 of the text presents a detailed treatment and listing of specific recommendations for each major subsystem comprising the ASF pallet-only mode payload design. These recommendations incorporate an extensive use of Spacelab and Orbiter equipment and approaches. Although follow-on efforts are required to better refine the design concepts, the recommended configuration establishes a feasible baseline from which to initiate a preliminary system design study.

3.3.2 FOLLOW-ON STUDIES

Several unresolved major issues, identified above, must be addressed because they not only constrain technical effectiveness of this conceptual payload but they also involve major cost and schedule impacts to an ASF pallet-only mission(s). These issues and follow-on studies are treated in detail in paragraph 9.2. They are summarily listed as follows.

TABLE 3.2.4-1. — CANDIDATE SUBSYSTEM OPTIONS

Item	Selected Approach	Candidate Options
1. Cryogenic cooling	Open loop	Closed loop
2. Thermal dissipation	Payload coolant loop, Orbiter ATCS, Heat Radiator Kit	Payload unique radiators
3. Large structural assembly installation	Mounted on pallets	Use Orbiter primary payload attachment points
4. Circuit breakers	Remotely controlled	Direct access (at crew station)
5. High current transmission media	Large gauge (4/0) wires	Copper bus bars
6. Attitude measuring system	Centralized on Pallet 1, attitude transfer via optics	Distributed star tracker, GRA on each AIM or APS
7. Payload Specialist work station	Aft flight deck standard Orbiter PSS	Standard PSS plus mid-deck work station
8. Experiment sequence initiation	Onboard control	Ground control
9. Data processing	Onboard computer	Ground facilities
10. Mass memory operational programs	Temporary storage-reload from ground as programs are utilized	Permanent full mission programming capacity
11. Data compression (subsatellite and fixed payload to Orbiter)	Conventional Bi-Phase Manchester II PCM and tape recorders	Various high density systems
12. Computer, processor	Centralized experiment and subsystem (with backup)	Distributed microprocessors plus less complex central processor
13. Subsatellite retrieval	Retrieve subsatellite for subsequent reuse	Leave subsatellite in orbit. Consider trade-offs between economics and operation complexity, safety. Consider using on-station subsatellite for multiple ASF missions.
14. Orbiter and payload EMI environment	Minimize payload generation and susceptibility through conventional design techniques	Reduce Orbiter generation (e.g. change from structure to two wire return, increase shielding); adjust experiments to adverse environment
15. Support subsystem equipment selection	Primarily Space Shuttle, Orbiter, Apollo	Other existing or in development advanced, cost effective systems and hardware; standardized modular designs

3.3.2.1 Scientific

a. Using the upgraded ED's forthcoming from the AMPS SDWG, develop upgraded ASF mission timelines. The new timelines, utilizing the new ED's and revised ID's, should be analytically exercised by the conceptual payload system to verify continuing feasibility of the payload concept with a more realistic ASF pallet-only mode mission.

b. Choice of Instruments. Because of the unavailability of some ASF instruments for a mid-1981 launch date, it is recommended that a study be conducted with the following objectives:

   (1) Search for availability of instruments that can be used in lieu of those prime instruments presently described that cannot meet launch date and for which substitutes are not identified. Such instruments could be currently under development by either Government or industry, and could be completed in time to meet the scheduled launch date. Assess the impact to scientific value from the use of substitute and/or alternate instruments.

   (2) Explore alternate means of acquiring desired scientific information without the use of those instruments that cannot meet launch date and for which there are no substitutes.

   (3) Assess scientific and cost impacts of flying certain experiments during 1981 and deferring others until requisite instruments are available.

3.3.2.2 Technical

The specific follow-on studies recommended for the ASF payload system design (described in paragraphs 9.2.1 and 9.2.2) are listed on the following page.

a. EMI assessment.

b. Particle contamination evaluation.

c. Electrostatic charge assessment.

d. Study the overall issue of the use of booms, subsatellites, tethered satellites, or other concepts to cope with problems posed by the operation of AMPS particles instruments. This study should encompass the following factors:

   (1) All Orbiter interfaces (physical, operational, etc.).

   (2) Gross cost factors.

   (3) Scientific merit.

   (4) Program schedules.

   (5) Boom structural analyses.

e. Those analyses, trade-offs, assessments, and definitions related to each subsystem and described in paragraphs 9.2.2.1 through 9.2.2.5.

f. Concept of standardizing (paragraph 9.2.3).

3.4 COST

All cost considerations related to this study are contained in the Executive Summary.

4.0 SCIENTIFIC REQUIREMENTS

4.1 ORBITER PAYLOAD

4.1.1 INTRODUCTION

Exploratory studies of the thermosphere during the last decade have provided the necessary information to describe gross features of structure, composition and variability of the region above 250 km. The region between about 120 km and 200 km, where most of the extreme-ultraviolet (EUV) solar photons are absorbed, had not been studied extensively by in-situ satellite experiments until the flight of Atmosphere Explorer C (AE-C). The AE satellites are equipped to measure, simultaneously, the physical and chemical parameters of the neutral and ionized constituents, some of the airglow emissions, and the incident solar photon flux down to an altitude of 120 km. A significant improvement in our understanding of the structure and photochemistry of this region is expected to result from these missions, leading to reasonably successful theoretical models of the structure of the upper thermosphere, and the upper E region and F region of the ionosphere. Most of the uncertainties in such models will likely be due to input parameters, such as reaction rates, cross sections, and absolute solar flux intensity. Improvement in our very limited present-day knowledge of the absolute intensity and variability of the solar EUV flux will result from the EUV spectrophotometer carried by the AE satellites, but a much needed increased data base, necessary for quantitative thermospheric and ionospheric calculations, will not be obtained before the Orbiter flights.

The AMPS missions, and particularly the ASF mission, will provide a unique opportunity to study the basic processes in the areas of photochemistry, chemical kinetics, and atomic and molecular physics, that are of fundamental importance to the understanding of the evolution of planetary atmospheres as well as comet and interstellar cloud formation. Experiments which cannot be performed in terrestrial laboratories can be conducted in the medium of space, for the unattenuated solar ultraviolet (UV) and x-ray flux can be utilized in excitation and ionization studies. Gas releases, either directly from the Orbiter or from a container some distance away, will permit the study of molecules and radicals found in the atmospheres of the planets or the major planets as well as the more complicated molecules suspected of being the parents of the commonly observed cometary species. In addition to photo excitation, electron excitation produced by the onboard electron accelerator can be used to produce multiple ionization and excitation of atomic species found in planetary nebulae. Laser fluorescence can then be used for the detection of long-lived metastable species. Electron impact cross sections, photo absorption cross sections, probabilities, ion and neutral-neutral reaction rates are examples of the type of atomic parameters which can be determined. Photodissociation and photoionization lifetimes of cometary species can also be determined using either gas releases or an artifical comet (snowball) released in the vicinity of the Orbiter.

Since a detailed knowledge of photochemistry, dynamics, and energetics is essential to understanding the interrelationship of the atmospheric regions, it will be possible, for the first time, to treat the atmosphere in a unified manner. It will be of special interest to establish the relative importance of different energy sources to the behavior of the atmosphere, e.g., solar radiation, wave energy from the lower atmosphere, and magnetospheric input including joule and energetic particle heating. The underlying troposphere is a source of natural and anthropogenic chemical species that enter into photochemical chains which are believed to have significant control over the composition of the stratosphere. A knowledge of the relationship between the minor constituent photochemistry and the energetics and dynamics of the stratosphere and mesosphere is essential for any significant improvement in our understanding of these regions.

The Orbiter provides an unparalleled opportunity to conduct an investigation of the earth's atmosphere in the regions above the tropopause. These regions, the stratosphere, the mesosphere, and the thermosphere as far above the orbit as the Orbiter instrumentation can acquire useful information, are very important to the understanding of atmospheric behavior. A large portion of the energy that originates from outside the atmosphere and becomes involved in the earth's atmospheric chemistry, physics, and mechanics is trapped, absorbed, or otherwise utilized in the regions above the tropopause. Probing directly into these regions has been done only with difficulty and for brief periods of time. Therefore, these regions are not well understood. However, the advent of the Orbiter provides the means to rectify the paucity of information about these regions that have such profound influence on the general terrestrial climate.

The troposphere has been the subject of operational and research observations for many years and is currently being studied extensively as part of the Global Atmospheric Research Program (GARP). Operational instruments have been flown at altitudes up to 30 km above the land areas of the northern hemisphere and measurements have provided sufficient wind and temperature data to enable a meaningful understanding of the region. Satellite soundings, especially from the Nimbus satellites, have mapped stratospheric temperature to about 50 km and ozone distribution from 30 to 50 km. These data have contributed to a more detailed understanding of the dynamics of the stratosphere and are beginning to elucidate the overall ozone photochemistry scheme and the controlling transport processes. Experiments on the Nimbus F satellite are expected to map temperatures up to the lower mesosphere, and ozone and water vapor distributions to the stratopause. Later experiments on the Nimbus G satellite are expected to measure a number of trace species from the tropopause into the mesosphere, although not always with the desirable vertical or horizontal resolution.

It is now known that a very close coupling exists within the neutral atmosphere ionosphere-magnetosphere system, and that very complex interactive and feedback processes are present which involve mass, momentum, and energy transport, mostly along magnetic field lines. Knowledge and understanding of these processes is minimal and will probably be so at the time of the Orbiter flights.

4.1.2 OBJECTIVES

The fundamental objectives of the ASF mission are to investigate the following.

a. Composition and structure of the upper atmosphere.

b. Dynamic and physical processes of the upper atmosphere.

c. Interrelationships between the upper atmosphere and magnetosphere.

d. Interrelationships between solar phenomena and the upper atmosphere.

Fulfillment of the scientific objectives will require application of a number of instruments, including optical instruments, lasers, accelerators, and gas release devices. The ASF mission will use an array of such instruments operating concurrently, or in programmed sequences, to perform the observations and produce the data for studies of the upper atmosphere and of the correlation between upper atmosphere conditions and external influences. The instruments will permit separation of the temporal and spatial aspects of the observed conditions and, t ough use of the accelerators and gas release instruments, will initiate artificial or controlled perturbations of the ambient atmospheric constituents for observation and measurement.

4.1.3 EXPERIMENTS

4.1.3.1 Background

A series of fifteen atmospheric science experiments have been described.

a. Group D — Dynamics — Experiments to measure winds, temperature, and diffusion of atmospheric constituents.

b. Group C — Chemistry — Experiments to investigate photochemical reactions in the upper atmosphere.

c. Group S — Structure — Experiments to investigate particle interactions in the upper atmosphere.

Source data for the descriptions were obtained from papers and presentations by the scientists of the Atmospheric Science Section of the AMPS SDWG. The ED's are incorporated as appendix A of this report and include a statement of objective, a method of accomplishment, a list of instruments required, and the operational timing for collection of data.

The ED's are preliminary and, as a result, will undergo refinement and perhaps change as additional data becomes available. Nonetheless, these descriptions have been adequate for the purpose of establishing a baseline for performance of the ASF mission.

4.1.3.2 Experiment Summaries

The fifteen ASF experiments are listed below and each is summarized in the subsequent paragraphs.

Experiment	Title
AS-1	Identify Properties of Natural Tracers
AS-2	Measure Winds and Temperature Fields
AS-3	Profile the Atmosphere Temperature in the Region of 15 to 120 km Altitude

Experiment	Title
AS-4	Determine the Thermal Structure and Dynamics of the Mesospheric and Lower Thermospheric Regions
AS-5	Determine the Eddy Diffusion Between the Altitudes of 85 km and 120 km
AS-6	Determine Atmospheric Interactions of Excited Radicals
AS-7	Determine Atomic and Molecular Oxygen Densities Between 90 to 120 Kilometer Altitude
AS-8	Determine Solar Radiation Interaction with the Ambient Atmosphere
AS-9	Determine the Atmospheric Constituent Abundance Below 120 Kilometer Altitude
AS-10	Determine the Atmospheric Constituent Abundance Above 120 Kilometer Altitude
AS-11	Determine Change in the Ionospheric D Region Due To Seasonal Anomalies and Magnetic Storms
AS-12	Determine the Metallic Constituents in the Upper Atmosphere
AS-13	Evaluate Deposition of Meteoric Dust and Metallic Constituents
AS-14	Determine the Meteoric Production of Nitric Oxide
AS-15	Investigate the Excitation Exchange Between Metastable Species and the Ambient Environment

a. Experiment AS-1 — Identify Properties of Natural Tracers:

(1) Scientific Objective — To identify the properties of constituents which occur naturally in the atmosphere in order to determine suitability for scientific measurement and analysis.

(2) Method — Radiation spectroscopy in the downward and horizon looking directions will be used as a source of data. Wavelengths shorter than approximately 3 micrometers will require a sunlit air column against a dark background, or active probing with a laser beam. Release of trace gases in the vicinity of the Orbiter will be investigated to determine the desirability for providing controlled concentrations of known tracers for calibration of instruments.

(3) Instruments Required —

Instrument No.	Title
118	Limb-Scanning Infrared Radiometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder
532	Gas Release Module

b. Experiment AS-2 — Measure Winds and Temperature Fields:

(1) Scientific Objective — To measure winds and temperature fields in the upper atmosphere, on a global scale, using natural tracers determined, in Experiment AS-1, to be suitable.

(2) Method — Temperatures of gases may be derived from doppler broadening of emission lines, while scalar flow may be found from the doppler shifting of the same emission lines.

(3) Instruments Required —

Instrument No.	Title
118	Limb-Scanning Infrared Radiometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder

c. Experiment AS-3 — Profile the Atmosphere Temperature in the Region of 15 to 120 km Altitude:

(1) Scientific Objective — To measure the vertical temperature profile to differentiate from the horizontal temperature distributions found in Experiment AS-2. The resolution should be 1 km to 2 km of altitude.

(2) Method — Horizon scanning will be used to collect data. Temperatures of gases will be derived from doppler broadening of emission lines. Active vertical sounding may be possible through use of laser probing to excite atmospheric sodium emissions. A nadir-pointing infrared spectrometer will provide similar data by measurements of the shifts in the line of a carbon dioxide absorption edge.

(3) Instruments Required —

Instrument No.	Title
118	Limb-Scanning Infrared Radiometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder

d. Experiment AS-4 — Determine the Thermal Structure and Dynamics of the Mesospheric and Lower Thermospheric Regions:

(1) Scientific Objective — To develop a relationship between the wind and temperature fields derived in experiments AS-2 and AS-3, and the inputs from excitation due to the solar radiation.

(2) Method — The wind and temperature profiles derived through experiments AS-2 and AS-3 will be combined with measurements of the solar flux, Birkeland current, and particle precipitation. Energy balance calculations will be made through measurement of long wavelength infrared emissions. Estimates of the contribution of the albedo will be made from data collected by instruments carried on the Orbiter and the PDS.

(3) Instruments Required —

Instrument No.	Title
118	Limb-Scanning Infrared Radiometer
122	UV-VIS-NIR Spectrometer
126	Infrared Interferometer
1002	Pyrheliometer/Spectrometer

Supporting data from PDS.

e. Experiment AS-5 — Determine the Eddy Diffusion Between the Altitudes of 85 km and 120 km:

(1) Scientific Objective — To determine the rates of eddy diffusion, winds, and turbulence in atmospheric mixing phenomena.

(2) Method — Measurements of winds and temperatures will be based on the doppler techniques used in experiments AS-2 and AS-3. Diffusion will be measured by vertical profiling of selected constituents. Measurements of gas

release data and of data from the PDS instruments will be used as baseline for the reduction of data in this experiment.

(3) Instruments Required —

Instrument No.	Title
118	Limb-Scanning Infrared Radiometer
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder
532	Gas Release Module

Supporting data from PDS.

f. Experiment AS-6 — Determine Atmospheric Interactions of Excited Radicals:

(1) Scientific Objective — Significant portions of the total thermal energy in the upper atmosphere are believed to be held in molecular levels which do not possess radiative transitions. Excitation transfer by intermediates such as carbon dioxide and hydroxyl radicals leads to radiative transfers. This experiment will ascertain the importance of the transfer mechanism in the overall thermal budget.

(2) Method — Measurements of the hydroxyl vibrations levels will be made through induced fluorescence in the near UV spectral region. Collision excitation transfer will be estimated by comparing the measured level populations to theoretical populations in the absence of energy transfer. Principal measurements will be made through laser probing, supported by passive UV spectrography.

(3) Instruments Required —

Instrument No.	Title
116	Airglow Spectrograph
122	UV-VIS-NIR Spectrometer/Photometer
213	Laser Sounder
1011	Ultraviolet Occultation Spectrograph

g. Experiment AS-7 — Determine Atomic and Molecular Oxygen Densities Between 90 to 120 Kilometer Altitude:

(1) Scientific Objective — To determine to a very high precision the densities of atomic and molecular oxygen as a function of geographic position (both global and small scale), season, time, solar dissociating flux, and other parameters (e.g., low-level auroral inputs, wind fields, etc.).

(2) Method — Airglow emissions induced by the sun, particle precipitation, and laser probing will be used. Solar and stellar occultation will assist in determining the density of atomic oxygen, and possibly of molecular oxygen. A precise determination of solar flux is essential for this experiment. The use of the SPS and PDS will provide data required to make a complete analysis.

(3) Instruments Required —

Instrument No.	Title
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
213	Laser Sounder
1011	Ultraviolet Occultation Spectrograph

Supporting data from SPS and PDS.

h. Experiment AS-8 — Determine Solar Radiation Interaction with the Ambient Atmosphere:

(1) <u>Scientific Objective</u> — To identify spectral transitions of long-lived metastable states which are pressure-quenched in ground based experiments. Baseline data will be provided for other experiments in the ASF.

(2) <u>Method</u> — Clouds of neutral molecules of gas will be released from the Orbiter, and pre-ionized species may be released by the onboard accelerator instruments. Additional excitation may be produced by the onboard accelerator instrument, or may be provided by laser probing and through use of electron beams.

(3) <u>Instruments Required</u> —

Instrument No.	Title
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
213	Laser Sounder
303	Electron Accelerator
304	Magnetoplasmadynamic (MPD) Arc
532	Gas Release Module
534	Optical Band Imager and Photometer System
536	Triaxial Fluxgate
549	Gas Plume Release
550	Level II Beam Diagnostics Group

Supporting data from SPS.

i. Experiment AS-9 — Determine the Atmospheric Constituent Abundance Below 120 Kilometer Altitude:

(1) Scientific Objective — To synoptically map the geographic distributions and vertical profile of atomic, molecular, and ionic abundance between the altitudes of 15 km and 120 km.

(2) Method — Airglow measurements will be used in the determinations for oxygen, nitrogen, and their compounds. Measurements in the UV and infrared regions may be required for determinations of ions and polyatomic species. Laser excitation may be useful in creating a promptly radiating state from weakly emitting species.

(3) Instruments Required —

Instrument No.	Title
118	Limb-Scanning Infrared Radiometer
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder
1011	Ultraviolet Occultation Spectrograph

Supporting data from SPS and PDS.

j. Experiment AS-10 — Determine the Atmospheric Constituent Abundance Above 120 Kilometer Altitude:

(1) Scientific Objective — To synoptically map the geographic distributions and vertical profiles of atomic, molecular, and ionic abundance above the altitude of 120 km.

(2) Method — Data will be gathered primarily by occultation and by upward looking spectroscopy. The van Rhyn technique of estimating spherical shell contributions based on changing angular absorption will be used to determine constituent distribution.

(3) Instruments Required —

Instrument No.	Title
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
1011	Ultraviolet Occultation Spectrograph

Supporting data from SPS and PDS.

k. Experiment AS-11 — Determine Change in the Ionospheric D Region Due to Seasonal Anomalies and Magnetic Storms:

(1) Scientific Objective — To correlate the change in neutral composition, neutral species, temperature, ions, and particle flux to D Region propagation.

(2) Method — Measurements of nitric oxide, water vapor, hydrated ions, ozone, and atomic oxygen abundance and temperature will be taken by spectrographic instruments and by laser probing techniques as used in experiments listed heretofore. Simultaneous measurements will be made of particle fluxes for correlation purposes and to assess their import to regions of high precipitation, such as the South Atlantic Anomaly.

(3) Instruments Required —

Instrument No.	Title
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder

Supporting data from PDS.

1. Experiment AS-12 — Determine the Metallic Constituents in the Upper Atmosphere:

(1) Scientific Objective -- To provide baseline data on the quantity and distribution of metals in the upper atmosphere on a global basis.

(2) Method — Spectrographic data will form the primary source of information. Resonant backscatter from laser probing is a promising data source. Available techniques will probably measure only a limited portion of the total inventory of metals in the atmosphere.

(3) Instruments Required —

Instrument No.	Title
116	Airglow Spectrograph
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder
1011	Ultraviolet Occultation Spectrograph

Supporting data from SPS and PDS.

m. Experiment AS-13 — Evaluate Deposition of Meteoric Dust and Metallic Constituents:

(1) Scientific Objective — To determine changes in the metallic content of the upper atmosphere due to meteor showers. This experiment will use the data resulting from Experiment AS-12.

(2) Method — As in Experiment AS-12, spectrographic data will form the primary source of information, with resonant backscatter from the laser probing, if found to be a useful data source. The determination requires the advent of a substantial meteor shower subsequent to the results obtained in Experiment AS-12, with the measurements being made at the shower location.

(3) Instruments Required —

Instrument No.	Title
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder

Supporting data from SPS and PDS.

n. Experiment AS-14 — Determine the Meteoric Production of Nitric Oxide:

(1) Scientific Objective — To determine the amount of nitric oxide formed in the altitude region of 90 to 120 km by ionizing tracks of meteors. The measurements will be made after detecting the tracks with an onboard low light level television (LLTV) system.

(2) Method — Laser-induced fluorescence will be used for the quantitative determination of nitric oxide. It may be possible to quantitatively monitor the reactants spectroscopically during the meteor shower.

(3) Instruments Required —

Instrument No.	Title
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder
534	Optical Band Imager and Photometer System

o. Experiment AS-15 — Investigate the Excitation Exchange Between Metastable Species and the Ambient Environment:

(1) Scientific Objective — To study the quenching cross sections of metastable species at pressure levels and instrument volumes not available in ground laboratories.

(2) Method — Gas clouds will be released as plumes or plasmoids and the energy transfer by the ambient photons and particle fluxes, or by active probing with electron beams, will be evaluated. Fluorescent decay will be observed with imaging devices and with the complement of spectrographic instruments aboard the Orbiter.

(3) Instruments Required —

Instrument No.	Title
116	Airglow Spectrograph
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer

Instrument No.	Title
126	Infrared Interferometer
303	Electron Accelerator
304	Magnetoplasmadynamic (MPD) Arc
532	Gas Release Module
534	Optical Band Imager and Photometer System
536	Triaxial Fluxgate
549	Gas Plume Release
550	Level II Beam Diagnostics Group

4.1.4 INSTRUMENTS (PRIME)

4.1.4.1 General

Fifteen instruments have been described in sufficient detail to evaluate the feasibility of their construction. The basis for the ID's was the IFRD's prepared by the Atmospheric Science Section during meetings of the AMPS SDWG at MSFC. Preliminary information in the IFRD's was supplemented by discussions with the scientists who drafted them and with scientists at the JSC. These instruments have been termed "prime instruments" for the purpose of this report, and the ID's have been incorporated as appendix B.

The 15 prime instruments are listed in table 4.1.4-1 in numerical order with the names derived from the IFRD's. The matrix in table 4.1.4-2 relates the prime instruments to the experiments described in appendix A. Performance parameters are listed in table 4.1.4-3 and interface parameters are listed in table 4.1.4-4.

TABLE 4.1.4-1. — ASF INSTRUMENT IDENTIFICATION

Instrument Number	Instrument Name
116	Airglow Spectrograph
118	Limb-Scanning Infrared Radiometer
122	UV-VIS-NIR Spectrometer/Photometer
124	Fabry-Perot Interferometer
126	Infrared Interferometer
213	Laser Sounder
303	Electron Accelerator
304	Magnetoplasmadynamic Arc
532	Gas Release Module
534	Optical Band Imager and Photometer System
536	Triaxial Fluxgate
549	Gas Plume Release
550	Level II Beam Diagnostics Group
1002	Pyrheliometer/Spectrophotometer
1011	Ultraviolet Occultation Spectrograph

TABLE 4.1.4-2. — INSTRUMENTS ASSIGNED TO EXPERIMENTS

Experiment	Instrument Number														
	116	118	122	124	126	213	303	304	532	534	536	549	550	1002	1011
AS-1		X		X	X	X			X						
AS-2		X		X	X	X									
AS-3		X		X	X	X									
AS-4		X	X		X									X	
AS-5		X	X	X	X	X			X						
AS-6	X		X			X									X
AS-7			X	X		X									X
AS-8			X	X		X	X	X	X	X	X	X	X		
AS-9		X	X	X	X	X									X
AS-10			X	X											X
AS-11			X	X	X	X									
AS-12	X		X	X	X	X									X
AS-13			X	X	X	X									
AS-14			X	X	X	X				X					
AS-15	X		X	X	X		X	X	X	X	X	X	X		

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TABLE 4.1.4-3. — ASF PRIME INSTRUMENT PERFORMANCE PARAMETERS

Instrument		Instrument Range			Resolution			
No.	Name	Frequency Spectral	Energy	Dynamic	Spatial	Spectral	Sensitivity	S/N Ratio
116	Airglow Spectrograph	300 Å to 2000 Å			CONFA-1° CONFA-5°	0.5 to 2.0 A		
118	Limb Scanning IR Radiometer	3 to 40 micrometers		10^9		(TBD)	5×10^{-12} w cm^{-2} SR^{-1} m^{-1}	(TBD)
112	UV-VIS-NIR Spectrometer-Photometer	10,000 Å to 10 micrometers			12°×12°	10 Å	2 Photoelectrons Raleigh $^{-1}$ Sec $^{-1}$	
124	Fabry-Perot Interferometer	1 to 150 micrometers			3 km	1 Å	5×10^{6} detected photons $Raleigh^{-1}$ Sec^{-1}	
126	Infrared Interferometer	1 to 150 micrometers		10^5	0.5 cm^{-1}	0.5 cm^{-1}	10^{-11} w cm^{-2} SR^{-1} micrometer	100:1
213	Laser Sounder	1000 Å to 30000 Å			1 km 0.1 mrad	.001 Å		
303	Electron Accelerator		1 to 30 keV	0 to ? Amp	10° Divergence	≤10%		
304	Magnetoplasmadynamic Arc		100 to 500 V	10^3 to 2×10^5 Amp	40° Divergence	≤50%		
534	Optical Band Imager and Photometer System	Depends upon experiment	NA	(TBQ)	*	NA	(TBD)	(TBD)
536	Triaxial Fluxgate	<0.1 Hz	Passive	$\pm10^6$			5×10^{-7} Gauss	
532	Gas Release Module	300 Å- 1.2 micrometers			2 to 3 Degrees	0.2 Å @ 1200 Å	(TBD)	(TBD)
549	Gas Plume Release			0-0.5 moles fac.	60°			
550 550	Level II Beam Diagnostics		0 to 30 keV	10^{-6} amp/cm^2 →0 amp/cm^2			10^{-6} Amp cm^{-2}	(TBD)
1002	Pyrheliometer/ Spectrometer	0.2-5.0 micrometers 0.25-2.6 micrometers	NA	125-145 $\times10^{-3}$w cm^{-2}	NA	Δλ/λ 60 to 200	0.1%	1000
1011	UV Occultation Spectrograph	0.03-0.2 micrometers	NA	(TBD)	NA	0.4 Å	(TBD)	(TBD)

*Depends on experiment

TABLE 4.1.4-4. — ASF INSTRUMENT INTERFACE PARAMETERS

Instrument		Physical dimensions (metric)					Power			Pointing		Data (see note)			
												Scientific		Housekeeping	
No.	Name	Length	Width	Height	Volume	Weight	Vac	Vdc	Watts	Error	Stability	D, A, F	Rate	D, A, Dis.	Rate
116	Airglow Spectrograph	2.0m	0.6m		0.56 m^3	30 kg		28	1	≤0.5°	≤15 arc sec	F	700 frames	A	480 bps
118	IF Limb Scanning	1.8m	0.8m		4.52 m^3	115 kg	115 400 cycle		100	≤0.5	≤15 arc sec	D	12 kbps	A	480 bps
122	UV-VIS-NIR Spectrometer/ Photometer	0.5m	0.2m	0.2m	0.02 m^3	16 kg		28	16	≃0.1	≤6 arc min	D	8 kbps	A	320 bps
124	Fabry-Perot Interferometer	0.6m 0.4m 0.3m	0.3m 0.5m 0.2m	0.4m	0.6 m^3 0.08 m^3 0.18 m3	45 kg		28	14	≤1.0°	TBD	D	1.6 kbps	A	560 bps
126	Infrared Interferometer	0.7m	0.9m		0.45 m^3	114 kg	115 400 cycle		25	≤0.1°	≃3 arc min	D	1 kbps	A	200 bps
213	Laser Sounder	(4 subsystems)			9.3 m^3	415 kg	115 400 cycle		1.08 kw	≤1.0°	TBD	D	16 kbps	D	1 kbps
303	Electron Accelerator				6.1 m^3	740 kg		28	5kW avg 10kW max	6°	1° sec^{-1}	D	5 kbps	A	16 bps
304	Magnetoplasma-dynamic Arc				2.5 m^3	630 kg		28	5kW avg 10 kW max	2°	1° sec^{-1}	D	1 kbps	A	16 bps
534	Optical Band Imager and Photometer System	0.9m	0.9m	3.1m	3 m^3	100 kg			30	2°	1° min^{-1}	A D	4 MHz 2 kbps	D	TBD
536	Triaxial Fluxgate	Boom or subsatellite mounted sensor			0.005 m^3	5 kg		28	4			D	600 bps	Combined w/scientific	
532	Gas Release Module				1.24 m^3	49 kg		28	140	1°	0.15° sec^{-1}	D,A	77.5 kbps	Combined w/scientific	
549	Gas Plume Release				0.12 m^3	9		28	5-10	N/A	N/A	Video tape ~3 sec/release		A	16 bps
550	Level II Beam Diagnostics	3 Subsystems			0.005	23		28	20	N/A	N/A	D	6.5 kbps	A	12 bps
1002	Pyrheliometer/ Spectrometer	0.3m	0.1m	0.3m	0.01 m^3	<10 kg			10	2.5°	N/A	D	320 bps	Combined w/scientific	
1011	UV Occultation Spectrograph	3m	1m	1m	3 m^3	128 kg		28	100	1 arc µm	10-15 arc sec	F	1fps	A	TBD

NOTE: D = Digital; A = Analog; F = Film; Dis = Discrete

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The ID's for several of the prime instruments call for attributes which will require advancement of the start-of-the-art with an appropriate development program. The practicability of using more readily available instruments, termed "substitute instruments," was assessed in the light of scientific and program requirements, and the options for use of the substitute instruments are described in section 7.0 of this report.

4.1.4.2 Summary Descriptions

The 15 ASF prime instruments derived from the IFRD's are summarized below, and detailed technical descriptions are contained in appendix B.

a. Airglow Spectrograph, Instrument 116. The Airglow Spectrograph is used to collect data for the study of upper atmosphere emissions and absorptions in the vacuum UV range of 300 Å to 2000 Å. The instrument provides high spectral and spatial resolution in the collection of data, which is recorded on film in the form of spectrograms. The range of observations extends from zenith to nadir. The instrument has two configurations, either of which can be selected in flight, with one configuration having a field-of-view (FOV) of 5° square, and the second having a FOV 1° square. The operating volume of the instrument is 0.56 cubic meters, and the operating weight is 30 kilograms.

b. Limb Scanning Infrared Radiometer, Instrument 118. The Limb Scanning Infrared Radiometer is a cryogenic multi-channel instrument which acquires data to permit measurement of trace species and evaluation of the vertical distribution of trace gases in the altitudes up to approximately 120 kilometers. The spectral range of operation is from 3 to 40 μm. Twelve detectors are incorporated into the instrument which is completely encased in a dewar housing to maintain the cryogenic operating temperature of 77 K; the detectors are cooled to

4 K for operation. The operating volume of the instrument is is 0.9 cubic meters, and the operating weight is 115 kilograms plus 185 kg for cryogen dewar and associated plumbing.

c. UV-VIS-NIR Spectrometer/Photometer, Instrument 122. The UV-VIS-NIR Spectrometer is used to obtain measurements of natural and induced atmospheric and ionospheric emissions in wavelengths ranging from 0.11 μm to 1 μm. The instrument is comprised of four small spectrometers of Ebert-Fastie configuration, although as many as eight such instruments can be incorporated into the main spectrometer. The use of multiple spectrometers permits the simultaneous observation of several spectral features. Photomultiplier tubes are used as detectors. The operating volume of the spectrometer is 0.02 cubic meters and the operating weight is 16 kilograms.

d. Fabry-Perot Interferometer, Instrument 124. The Fabry-Perot Interferometer collects data which enable measurements to be made of doppler velocity and of temperature in the mesosphere and thermosphere using selected atomic line emissions in the UV, visible, and near infrared spectral regions. The large size of the etalons (i.e., 25 cm in diameter) permits high resolution and high etendue photometric studies of line and band emissions between the wavelengths of 0.2 μm and 10 μm. The overall spectral range of the instrument is 2000 Å to 10 μm. The instrument operates in one of three different modes, interferometer, photometer, or radiometer, each providing different sensitivity and different FOV. Mechanization of the instrument allows selection of operating mode during flight. The operating volume of the interferometer is 0.1 cubic meters and the operating weight is 45 kilograms.

e. Infrared Interferometer, Instrument 126. The Infrared Interferometer acquires data in the spectral region ranging from 1 μm to 150 μm, in three descrete intervals. The instrument incorporates interchangeable filter/beam-splitter/detector combinations to cover each of the three spectral ranges; the combinations are assembled into the instrument prior to flight and are not changeable during flight. The instrument is cryogenically cooled to 77 K, and all components are enclosed within a dewar structural casing to maintain the requisite temperature during operation. The detector units are further cooled to 4 K for maximum sensitivity. The telescope is pointed at areas between the nadir and the horizon for collection of data. The operating volume of the instrument is 0.45 cubic meters and the operating weight is 114 kilograms plus 186 kg for cryogen dewar and plumbing.

f. Laser Sounder, Instrument 213. The Laser Sounder enables studies to be made of the composition, structure, and dynamics of the atmosphere through backscattering and absorption of the laser beam. The primary area of concern is the upper atmosphere in the nadir direction from the Orbiter. The instrument consists of the laser emitter and the receiving interferometer, as major components. The laser is a tunable dye laser which operates over the spectral range of 1000 Å to 30000 Å, and which has an output energy of one joule, a pulse duration of ten nanoseconds, and a pulse rate of one per second. The interferometer section receives the returned energy through a 2-meter aperture Cassegrain telescope, which directs the energy to an array of ten Fabry-Perot etalons which separate the beam into discrete spectral bands which then impinge on the photomultiplier tube detectors.

The size of the interferometer telescope, i.e., 2-meter aperture, presents a serious problem in the accommodation array of instruments in the Orbiter payload bay, for the dimension far exceeds the available envelope for the Laser Sounder. The aperture has been reduced to ~0.8 meter diameter for accommodation purposes. The operating volume of the instrument is 9.21 cubic meters, and the operating weight is

415 kilograms; with the reduction of telescope aperture, the operating volume is reduced to 5.51 cubic meters, and the operating weight is 395 kilograms.

g. Electron Accelerator, Instrument 303. This instrument is a subsystem of the AMPS Particle Accelerator System and will be used to: (1) study the excitation of upper atmospheric and ionospheric constituents, (2) map the magnetic field lines of the earth, (3) determine ionospheric electric field magnitude and direction, and (4) study the plasma wave excitation in the ionosphere. It consists of an electron gun with variable energy and current output up to 30 keV and 7 amperes respectively. Operation of the electron beam can be continuous direct current (dc), pulsed, or modulated (up to 10 MHz). Energy storage for high intensity pulsed operation is accomplished with a 10^5 joule, 500 volt capacitor bank. The operating volume for this instrument is 6.1 cubic meters and the operating weight is 740 kilograms.*

h. Magnetoplasmadynamic (MPD) Arc, Instrument 304. The MPD Arc is a subsystem of the AMPS Particle Accelerator System. It will be used to: (1) study the excitation of upper atmospheric and ionospheric components, (2) trace and map the earth's magnetic field lines, (3) modify the conductivity in certain regions of the ionosphere, and (4) generate plasma waves in the very low frequency/extremely low frequency (VLF/ELF) regimes. The instrument consists of a low voltage plasma gun (up to 500 volts) with a discharge current up to 2×10^5 amperes. Energy storage for high intensity pulses is accomplished with a 10^5 joule, 500 volt capacitor bank. The operating volume of this instrument is 2.77 cubic meters and the operating weight is 630 kilograms.*

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*NOTE: Weights indicated apply if either instrument is flown without the other instrument. If both instruments 303 and 304 are flown, the combined weights will approximate 781 kilograms due to the common usage of certain power components.

i. Gas Release Module, Instrument 532. This instrument will be used to study photoexcitation and photoionization of various species exposed to solar radiation. In addition, it will be utilized to study the decay of excited species including metastable states. Gas will be admitted to an excitation chamber which is viewed by a monochromator and a quadrupole mass analyzer. The chamber will be exposed to the full unattenuated solar flux. Ion masses in the range of 1 atomic mass unit (amu) to 100 amu can be measured and by the use of three monochromators (one selected and mounted before flight), wavelengths in the ranges 300 Å to 1500 Å, 1100 Å to 4500 Å and 4000 Å to 1.2 μm will be measured. Metastable states will be measured by a free gas release to space which is viewed by the monochromator. The operating volume of this instrument is 1.42 cubic meters and the operating weight is 49 kilograms.

j. Optical Band Imager And Photometer System (OBIPS), Instrument 534. The OBIPS obtains monochromatic images of airglows due to natural aurora and atmospheric perturbation experiments such as chemical releases and high energy electron injections. The optical bandwidth is just sufficient to pass the radiation of a particular molecular band. The configuration depends upon the mission. The typical configuration has two LLTV's and two photometers operating at two different wavelengths. The TV's are used to point the narrow field photometers and the latter give accurate radiometric readings. A very large baffling system precedes the lens in order to block extraneous radiation and obtain data of faint airglows despite sunlight scattered by the earth's atmosphere. The optical band is determined by filters which are interchangeable. The operating volume of this instrument is 0.52 cubic meters and the operating weight is 100 kilograms.

k. Triaxial Fluxgate, Instrument 536. The objectives of this instrument are to: (1) study the natural hydromagnetic wave propagation, (2) probe the ultra low frequency (ULF) noise generated by the Orbiter, (3) study noise generated by controlled discharge from the ULF antenna, and (4) determine the magnetic environment of the Orbiter as a safety measure during accelerator operation. Because of low electromagnetic field interference requirements, the instrument will be sub-satellite or boom mounted. The sensors are orthogonally mounted coils on high permeability cores. Sensors will require about 0.003 cu m volume. The operating weight of this instrument is 5 kilograms.

l. Gas Plume Release (AMPS Particle Accelerator System Level I Diagnostic), Instrument 549. The Gas Plume Release will be used for optical tailoring and alignment of the particle beam from the Electron Accelerator (Instrument 303). The Gas Plume Release system resides within the volume of the electron accelerator and consists of a gas storage system from which gas can be released from four jets. Interaction of either the ion or electron beam with the gas will allow a visual observation of the profile of the beam. The operating volume of this instrument is 0.12 cubic meters and the operating weight is 9 kilograms.

m. Faraday Cup Probe/Retarding Potential Analyzer/Cold Plasma Probe/(AMPS Particle Accelerator System Level II Diagnostic Group), Instrument 550. This group of instruments will be utilized to define the energy, beam intensities and profiles of the Electron Accelerator (Instrument 303) and to determine the rise in potential of the Orbiter with respect to the ambient plasma during accelerator firing. The Faraday Cup Probe is a cylindrical cavity current collector and will be utilized to determine the spatial profiles and intensities of the beams. The retarding potential analyzer will determine beam energy and will operate up to 30 keV. The cold plasma probe is a passive floating potential probe and will be used to measure Orbiter charge build-up. The operating volume of this instrument is 0.005 cubic meters and the operating weight is 23 kilograms.

n. Pyrheliometer/Spectrophoto... r, Instrument 1002. The two instruments are combined in one small package with a single data output. The design is called the Solar Energy Monitor in Space (SEMIS). The system is optimized for accurate quantitative measurements. The pyrheliometer is the thermopile type, modified from a commercially available design which is used as a standard radiation detector. The range of radiation detected is 0.2 μm to 5.0 μm. The spectrophotometer views solar radiation reflected from a diffuse plate, thus no scanning of the sun is necessary. The radiation is dispersed by a quartz Littrow monochrometer. A beamsplitter divides the radiation into two spectra which are detected with a photomultiplier and lead sulfide detector. Ten minutes is required for a scan. The spectral range is 0.25 μm to 2.6 μm, but by changing to sapphire optics it is expected to go to 4 μm. The operating volume of this instrument is 0.01 cubic meters and the operating weight is 10 kilograms.

o. Ultraviolet Occultation Spectrograph, Instrument 1011. As the sun or a star appears to approach the limb of the earth, at certain wavelengths molecules and free radicals absorb radiations. This instrument measures the absorption, so the concentration as a function of altitude may be calculated. The initial value of the radiation is obtained when the sun or star is at a distance from the limb. A series of spectra are obtained with the sun or star at different distances from the limb. Two configurations are used, one for stellar and the other for solar occultation. Stars have a better continuum but the sun has a stronger signal. A Cassegrain telescope focuses on the slit of the spectrograph. For stellar occultation, the telescope is large. A concave grating focuses the spectrum on an opaque photocathode. The photoelectrons are emitted in the direction of the incident radiation, accelerated by an electric field, focused by a magnetic field and impinged upon film with a thick emulsion of the type made for recording nuclear particles. The spectral range is 300 Å to 2000 Å. The resolution is approximately 0.4 Å. The operating volume of this instrument is 1.66 cubic meters and the operating weight is 125 kilograms.

4.1.5 OVERVIEW, ASF MISSION TIMELINE

Operational timing of the instrument in each experiment is included in the ED's, and graphically depicted for the ASF payload in the timeline shown in figure 4.1.5-1. Although the timeline was developed without regard to whether the mission would be polar or low inclination orbit, global coverage from high inclination as well as low inclination orbits is required to satisfy the ASF experimental objectives. Since the west coast launch site which is required for polar orbits will not be completed until after 1981, the early ASF flights will be flown in low inclination orbits with the result that not all of the experiment objectives will be achieved on early flights. The objectives of many experiments may, however, be completely achieved on orbits of low inclination.

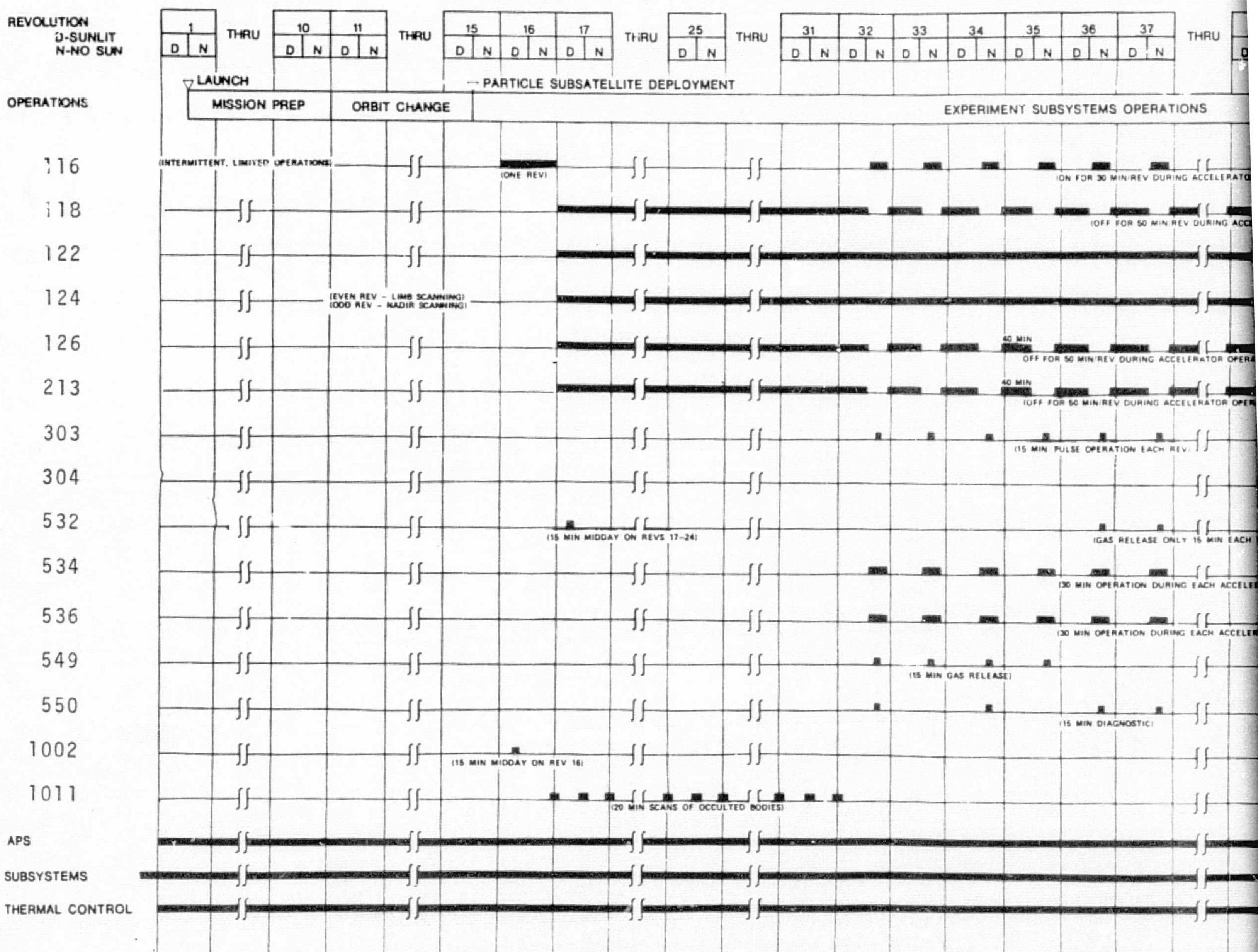
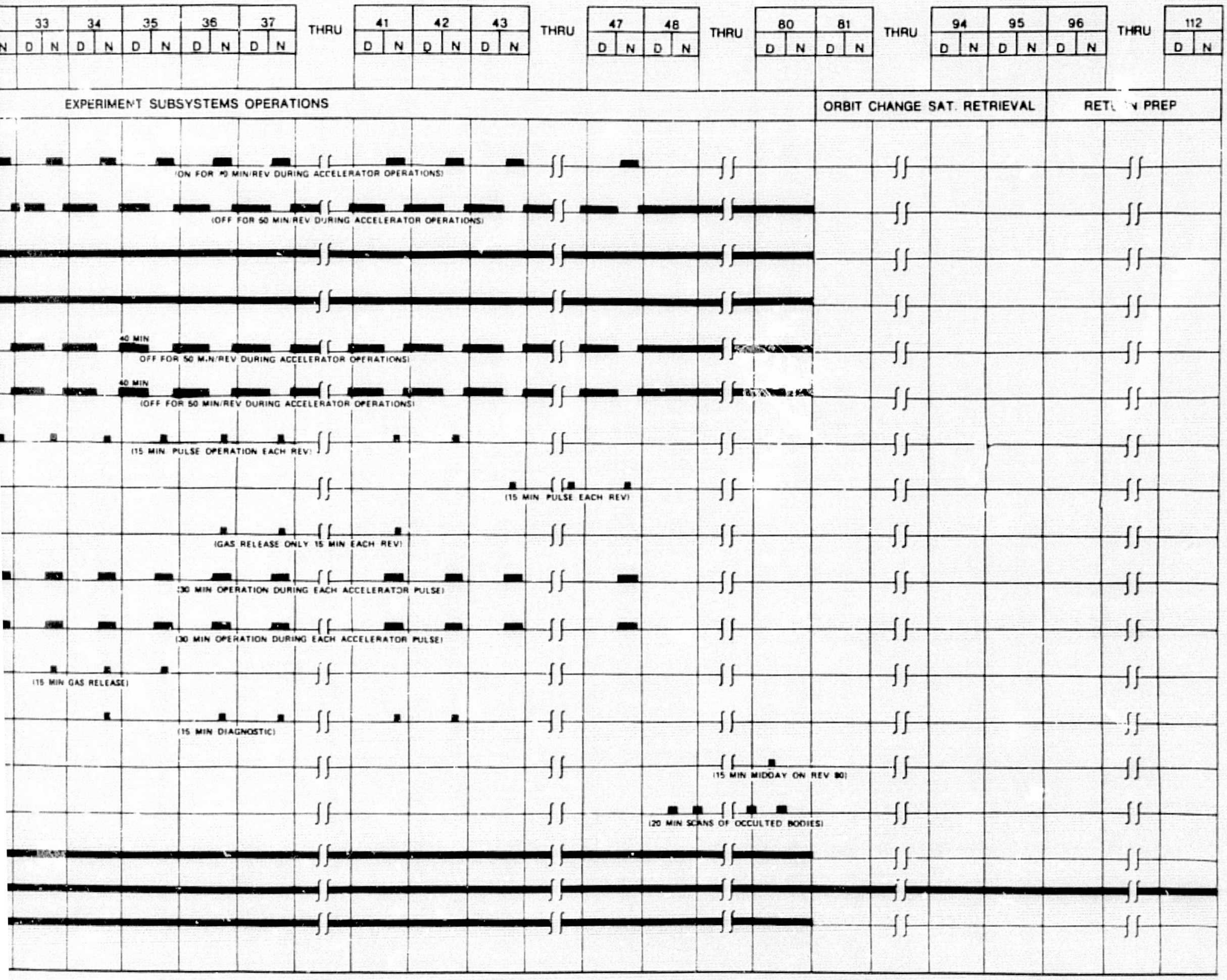


Figure 4.1.5-1. — ASF mission timel



4.1.5-1. — ASF mission timelines.

FOLDOUT FRAME 2

4.2 PARTICLE DETECTOR SUBSATELLITE (PDS) REQUIREMENTS

4.2.1 INTRODUCTION

A subsatellite will be used as the platform on which the particle detection instruments will be mounted. The instruments will provide the necessary particle data in support of the experiments being conducted by the ASF. This subsatellite will be of the AE type. The subsatellite configuration and a description of the subsatellite are contained in paragraph 5.2.6 of this report. Operations of the subsatellite are contained in section 6.0.

4.2.2 REQUIREMENTS

The functional requirements of the PDS are the following.

a. Measure energy of electrons, protons and plasma potentials.

b. Measure energy levels, drift velocities, temperature, mass and quantity of ions.

c. Measure mass of neutral particles.

d. Measure gas temperature and density.

e. Detect upper atmosphere emissions in spectral lines at specific wavelengths and within ranges of wavelengths.

f. Measure the instantaneous components of the magnetic field vector.

4.2.3 INSTRUMENT SUMMARY DESCRIPTIONS

The subsatellite instrument complement required to support the ASF experiments is listed in this section with comments on their use. The instruments are described in Radio Science, Volume 8, Number 4, April, 1973, Special Issue: The Atmosphere Explorer Satellite. Interface and performance parameters are listed in tables 4.2.2-1 and 4.2.2-2.

a. <u>(CEP) Cylindrical Electrostatic Probe</u> — Low energy electrons and plasma potentials at levels from 0 to 20 eV.
b. <u>(RPA) Planar Ion Trap</u> — Ion drift velocities, temperature, mass and quantity.
c. <u>(PES) Photoelectron Spectrometer</u> — Electrons with energy ranges from 2 eV to 500 eV.
d. <u>(LEID) Low Energy Ion Detector</u> — H^+, He^+, and O^+ with energy levels ranging up to 10 KeV.
e. <u>(LEE) Low Energy Electron Detector</u> — Electrons with energy ranges from 200 eV to 25 KeV.
f. <u>(NACE) Neutral Mass Spectrometer</u> — Mass values for neutral particles from 1 to 47 amu.
g. <u>(NATE) Neutral Atmosphere Temperature</u> — Gas temperature measurement using Nitrogen (N_2).
h. <u>(HEPD) High Energy Particle Detector</u> — Covering the ranges of energetic electrons and protons in the range from 25 up to 10 MeV.
h. <u>(VAE) Airglow Photometer</u> — Detecting the upper atmosphere emissions in the spectral lines at 3371, 4278, 5200, 5577, and 6300 Å, and in the band from 7319 to 7330 Å.
i. <u>(CCIG) Cold Cathode Ion Gauge</u> — Gas density measurement.
j. <u>(MAG) Triaxial Fluxgate Magnetometer</u> — Measure the instantaneous vector components of the local magnetic field.

The data obtained by the above instruments will provide all the information concerning the particle, electron and ion, environment that is of direct concern in the analysis of the data from the atmospheric science experiments.

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TABLE 4.2.2-1. – INTERFACE PARAMETERS

No.	Name	Quantity	Total weight (kg)	Total power (watts)	Total data rate (bps)
CEP	Cylindrical Electrostatic Probe	1	1.9	5	2.2K
RPA	Planar Ion Trap	1	5.1	6	2.5K
PES	Photoelectron Spectrometer	2	8.2	5	5.0K
LEID	Low Energy Ion Detector	2	12	10	5.0K
LEE	Low Energy Electron Detector	2	8.4	5	4.6K
NACE	Neutral Mass Spectrometer	1	8.3	18	2.2K
NATE	Neutral Atmosphere Temperature	1	9.2	17.5	1.5K
HEPD	High Energy Particle Detector	2	14	6	5.0K
VAE	Airglow Photometer	1	8.6	4.5	3.2K
CCIG	Cold Cathode Ion Gauge	1	2.5	1.5	0.8K
MAG	Triaxial Fluxgate Magnetometer	1	1.2	3	.4K

TABLE 4.2.2-2. — PDS PERFORMANCE PARAMETERS

Instrument		Instrument Range	
No.	Name	Frequency/Spectral	Energy
CEP	Cylindrical Electrostatic Probe	NA	0 to 20 eV
RPA	Planar Ion Trap	1 to 40 amu	
PES	Photoelectron Spectrometer	NA	2 to 500 eV
LEID	Low Energy Ion Detector	H^+,He^+,O^+	up to 10 KeV
LEE	Low Energy Electron Detector		200 eV to 25 KeV
NACE	Neutral Mass Spectrometer	1 to 64 amu	
NATE	Neutral Atmosphere Temperature	500 to 5000 K	
HEPD	High Energy Particle Detector		25 KeV to 10 MeV
VAE	Airglow Photometer	3371,4278,5208, 5577,6300,7519-7330 Å	
CCIG	Cold Cathode Ion Gauge	10^{-3} to 10^{-9} torr	
MAG	Triaxial Fluxgate Magnetometer	NA	

4.3 SOLAR PHYSICS SATELLITE

4.3.1 ASF SUPPORT INSTRUMENTS

Solar radiation, both wave and particulate matter, into the atmosphere is the prime energy input to which the atmosphere dynamics respond. The particulate input can be measured by instrumentation on the PDS discussed in the preceding section. This instrumentation is needed for measuring other experimental parameters.

In the case of electromagnetic energy emanating from the sun, however, all necessary data can be obtained from a SPS which is planned for late 1970's deployment. This effort, which is being planned by the Solar Physics Working Group, has as an objective; the detailed investigation of solar phenomena on an instantaneous, as well as multi-year basis. Use of the data from this satellite will eliminate the need for extensive solar instrumentation on the Orbiter, leaving space and support facilities for other needed instrumentation. All that is required on the Orbiter is relatively simple instrumentation to be used to calibrate the data from the SPS. A Pyrheliometer/Spectrometer (Instrument 1002), provides this capability.

4.3.2 INTERFACES

Data from the SPS can either be received and processed on the Orbiter in real time, or received and processed on the ground for subsequent correlation with other experimental data.

The sampling rate from the satellite is not critical. One sample of data at all wavelengths each minute appears sufficient. However, the optimum sampling rate can be found only by examining experimental data to determine how rapidly the changes occur. The data rate depends upon the number of wavelengths and energy intervals sampled.

5.0 ASF SYSTEM DESCRIPTION AND INTEGRATION

5.1 GENERAL

5.1.1 ASF SYSTEM ELEMENTS

The ASF System elements are the flight, ground, and support systems. The flight system consists of: (1) the instruments, (2) the PDS, and (3) the support subsystems. For the purpose of this study, the ASF ground system consists of: (1) the ASF payload and ground support equipment, and (2) the ASF unique data handling facility. The support systems are part of the national space program inventory of facilities shared by all payloads. These include: (1) the Orbiter, (2) the TDRSS, (3) the SPS, and (4) the STS ground facilities.

Figure 5.1.1-1 shows the interrelationship among the major ASF system elements discussed in this report during each operational phase of the ASF flight system.

Test and integration of the ASF payload will occur at various levels (pallet, integrated payload, and integrated Orbiter). The basic ASF ground support hardware and software will be required together with simulators at each level. The ASF ground support equipment (GSE) will be utilized at both Kennedy Space Center (KSC) and at the western launch facility to support the prelaunch and launch activities. For prelaunch support, the ASF GSE will be integrated into the Orbiter Processing Facility (OPF) and the Vertical Assembly Building (VAB). For launch support, the ASF GSE will be integrated into the Launch Control Center (LCC). After the payload is returned from orbit, it is removed from the Orbiter at the OPF and is refurbished and retested in an ASF dedicated facility. The ASF GSE will be required to support operations during this phase.

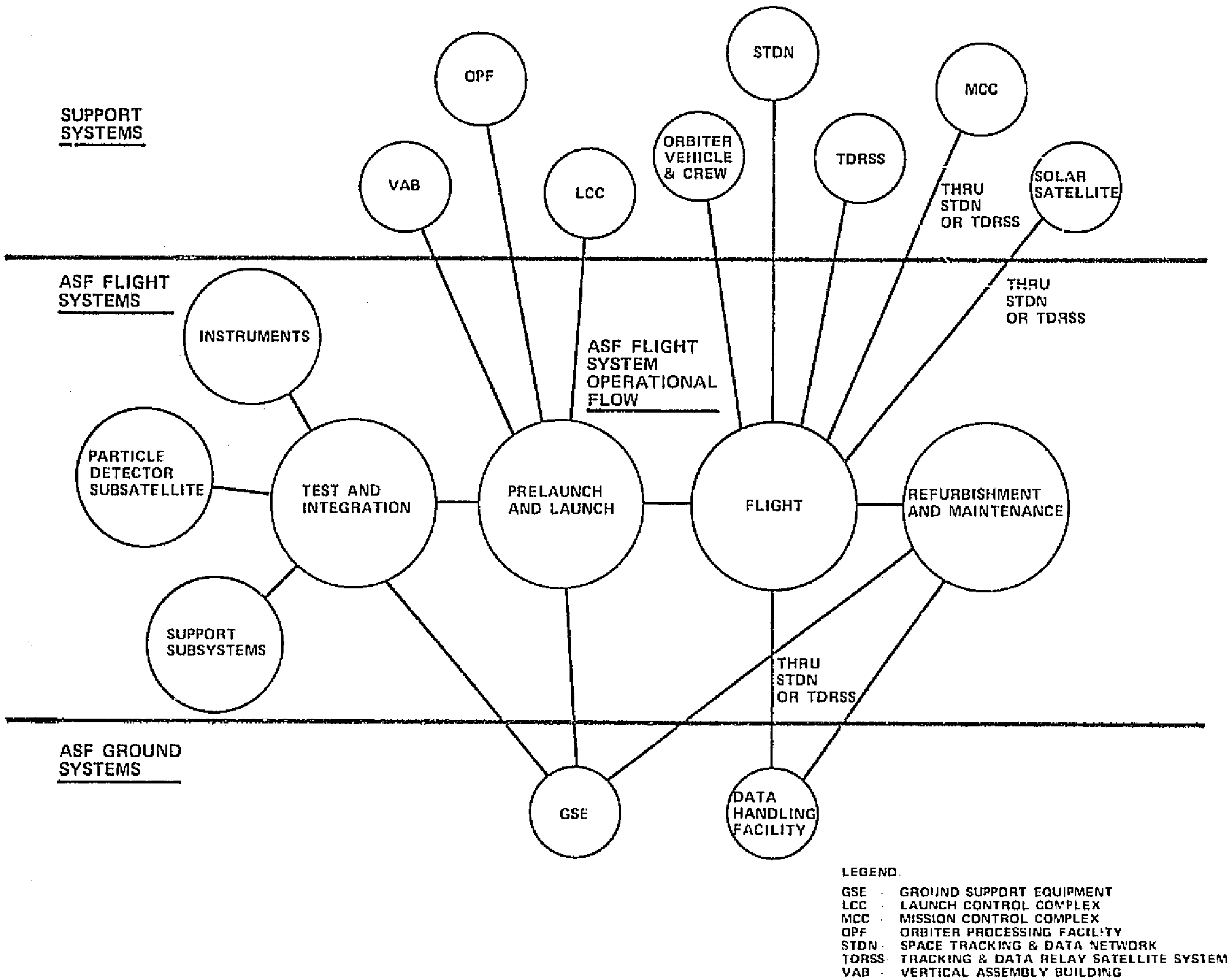

Figure 5.1.1-1. — ASF systems operational relationship.

During the flight phase, the ASF payload primarily operates automatically, sequencing the experiment and support subsystem operations and processing the instrument data through the onboard ASF computers. However, Orbiter vehicle and crew operations are required to support the missions. The Orbiter vehicle will orient the payload to approximately the right direction, providing a stable platform from which the payload pointing and tracking system can operate, and will change the orbit to rendezvous with the subsatellite for retrieval operations. The payload specialist (PS) will initiate and interrupt preprogrammed experimental sequences, check initial conditions, perform manual operations, make decisions for off-nominal conditions, and perform real time updat_ and changes to sequences.

The ASF flight system depends upon: (1) Support of the SPS to provide critical correlative experimental data, (2) Mission Control Center (MCC) to provide monitoring and diagnostic support, and (3) ASF ground facilities to provide the required data cataloging, segregating, storage and dissemination required for billions of bits of data. The communication links between the ASF payload onboard the Orbiter, or the SPS, and the ground facilities will be provided by the STDN and the TDRSS. The communication between the ASF and the Orbiter is provided through the attached payload interface. These interfaces are shown in figure 2-1.

5.1.2 ASF SYSTEM CONFIGURATION

a. Configuration - Figure 2-1 shows the ASF flight system configuration including the instruments onboard the Orbiter and the PDS.

Instrument placement in the ASF pallet-only mode study is based on the optical sensor pointing requirements which are too severe for the Orbiter reaction control system (RCS), on the necessity of avoiding mutual interference between instruments, and on the desire to keep similarly operating instruments together. The order of the platforms in the Orbiter payload bay is dictated by the clearances required to permit full articulation of the pointing structures.

The instruments for the ASF mission are arrayed in the payload bay in four groups, each on a separate pallet. Two pallets are fitted with an AMPS Pointing System (APS), while the remaining pallets have the instruments or facilities mounted on non-maneuverable accommodations. The pallets are identified (for the purposes of this report) numerically from the forward end of the payload bay. The forward edge of Pallet A-1 is at Station X_0 685.5 and the aft edge of Pallet A-4 is at Station X_0 1157.5. Figure 5.1.1-2 depicts the general pallet arrangement within the payload bay.

The first pallet has a steerable platform carrying instruments 213 (Laser Sounder), 532 (Gas Release Module), 534 (Optical Band Image and Photometer System), 1002 (Pyrheliometer/Spectrometer), 1011 (Ultraviolet Occultation Spectrograph) and 550 (Level II Beam Diagnostic). Instrument 1002 will be used to verify calibrations of an identical device on the sun-synchronous SPS. Only one revolution should be required for data acquisition to verify the calibration. Instrument 532 will require only one revolution for each of the types of gas to be released. Instrument 534 will be used with the accelerator package when it is being operated. Instrument 213 is the principal sensor on the platform operating for as much of the time as possible. Instrument 1011 is used on a time available basis when either the sun or a UV rich star is in the proper orientation.

The second pallet carries the PDS. This location is a compromise between the desired forward location of a light package,

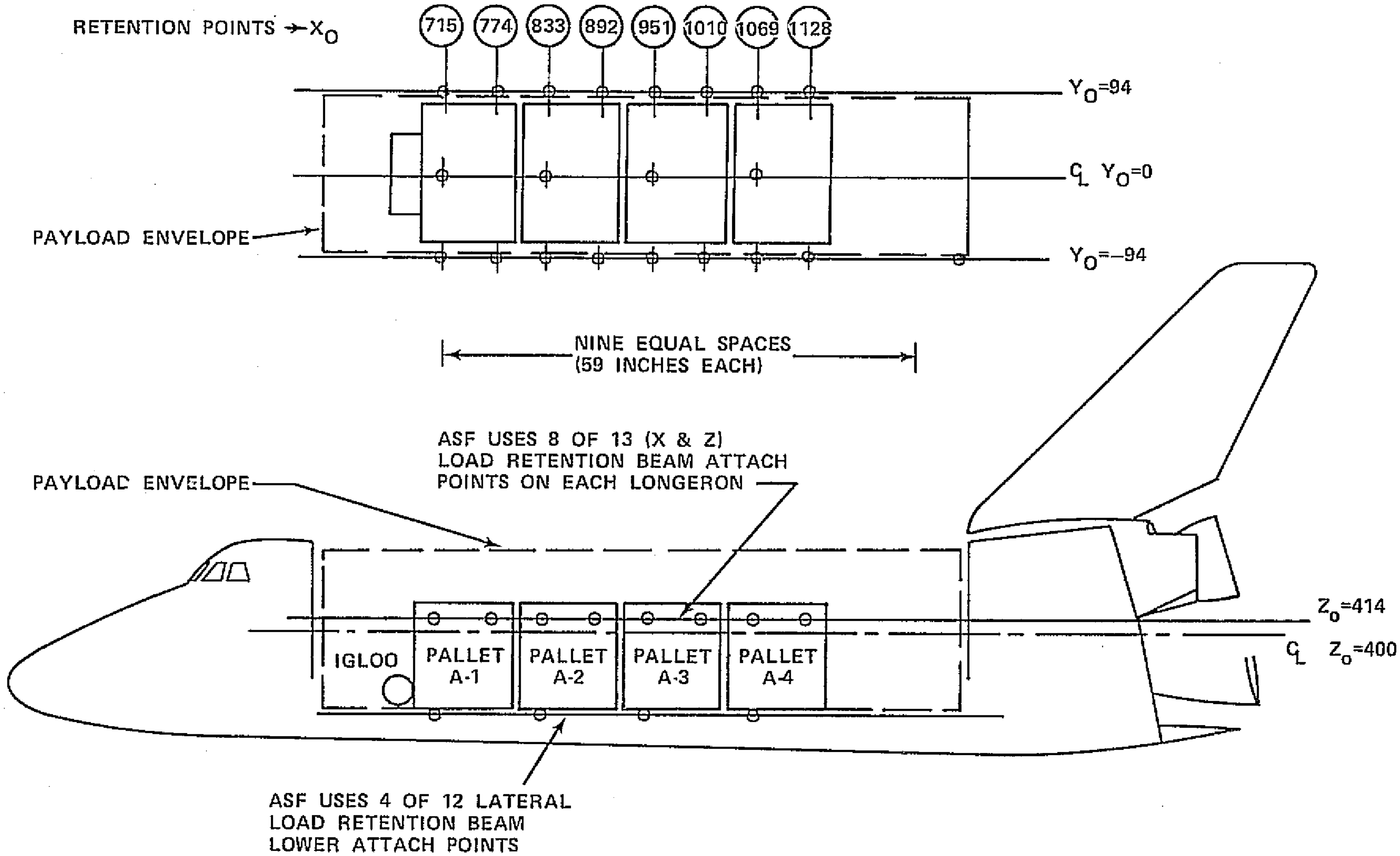

Figure 5.1.1-2. – ASF pallet attachment locations.

platform maneuvering requirements, and access by the vehicle RMS which is required for subsatellite recovery.

The third pallet has a second steerable platform which carries instruments 116 (Airglow Spectrograph), 118 (Limb Scanning Infrared Radiometer), 122 (UV-VIS-NIR Spectrometer/Photometer), 124 (Fabry-Perot Interferometer), and 126 (Infrared Interferometer). With the exception of Instrument 116, this package will generally be pointed at the same atmospheric feature for simultaneous data collection. Instrument 116 will be used less frequently than the others and would have been assigned to the first pallet/platform, if mounting space were available in that position.

The fourth pallet contains the particle accelerators, an accelerator beam diagnostic, a magnetometer for pointing, instruments 303 (Electron Gun), 304 (Magnetoplasmadynamic Arc), 536 (Triaxial Fluxgate), and 549 (Gas Plume Release). These instruments are assigned to the rearmost pallet because of their total weight, so that a favorable vehicle center of gravity (CG) may be maintained.

The APS, which is symmetrically located on the floor of pallets A-1 and A-3 has a central column which contains the mechanism for the deployment and retraction of the instrument modules and which forms the axis for the coarse azimuthal rotation of the modules. At the upper end of the central column, two identical yokes accommodate the ASF Instrument Modules (AIM), one on each side of the column. The yokes pivot to provide vertical rotation of the modules and have the capability for almost full-circle rotation. One AIM is installed in each yoke, on provisions which allow for fine azimuthal rotation of up to five degrees either side of the nominal. The yoke-mounting provision is the primary interface of the AIM with the APS.

Figure 5.1.1-3 depicts the concepts of the APS and the AIM. The detailed descriptions of APS and AIM are contained in paragraph 5.2.3 of this report.

Figure 5.1.1-4 shows the instruments installed in the stowed condition and figure 5.1.1-5 shows the instruments in the operational configuration.

The ASF support subsystems consist of the following:

a. Thermal, Structural and Mechanical Subsystem (TSMS).

b. Electrical Power and Distribution Subsystem (EPDS).

c. Pointing Control and Stabilization Subsystem (PCSS).

d. Command and Data Management Subsystem (CDMS).

The support equipment and operations required at the aft crew station are also discussed in later sections of this report.

The ASF flight system instrument complement onboard the Orbiter and onboard the PDS, and the support subsystems onboard the Orbiter are listed in tables 5.1.1-1 through 5.1.1-3. The support subsystems onboard the PDS are the basic AE subsystems and will not be discussed in great detail in this report. Instruments are discussed in detail in section 4.0 and appendix B of this report.

5.1.3 ASF SYSTEM INTERFACES

The ASF flight system interfaces are illustrated in figure 5.1.1-6. These interfaces include those within the ASF payload, those between the ASF payload and the Orbiter, and those between the ASF payload and other systems which are linked with the ASF

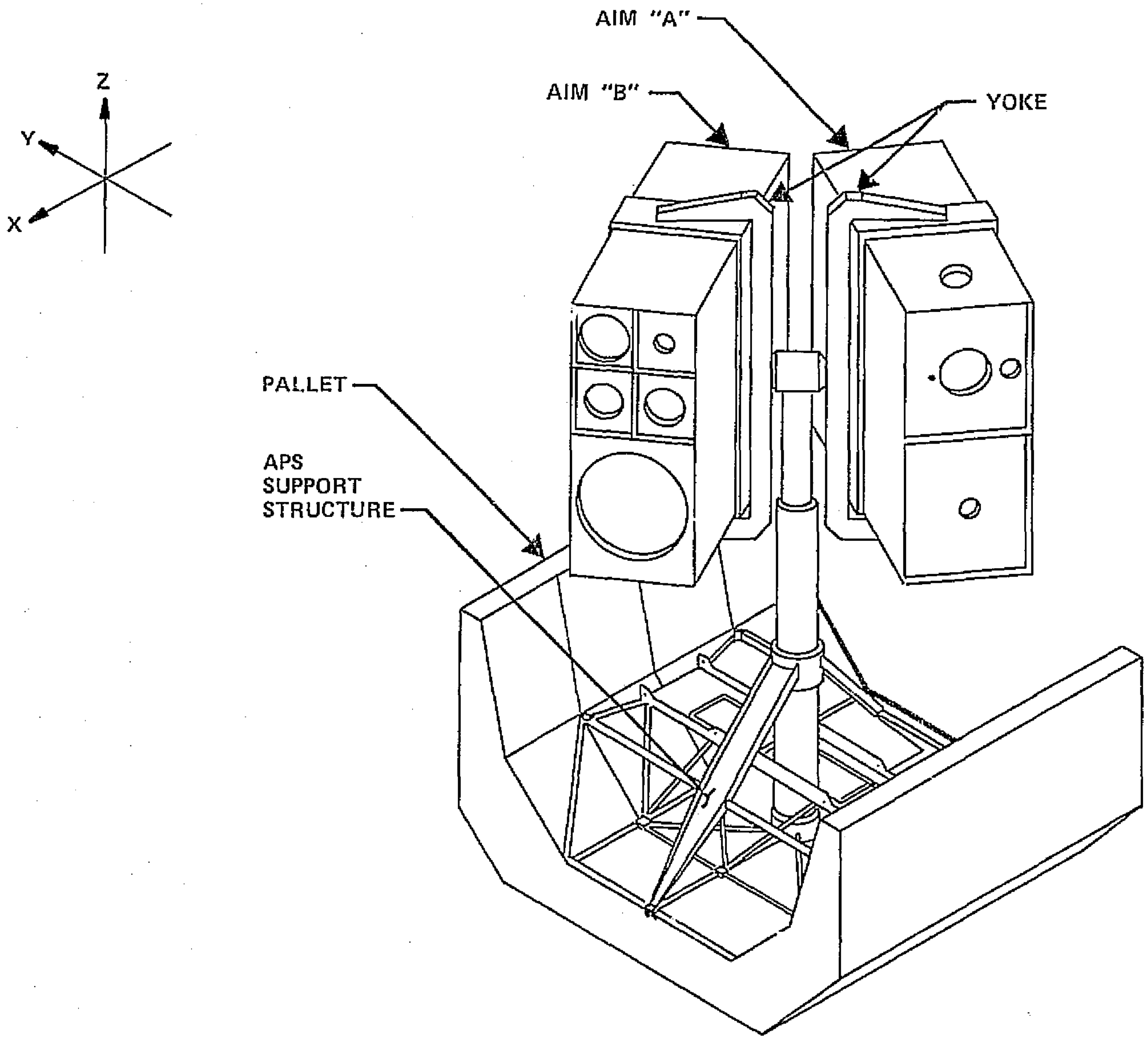

Figure 5.1.1-3. – ASF pointing system (concept).

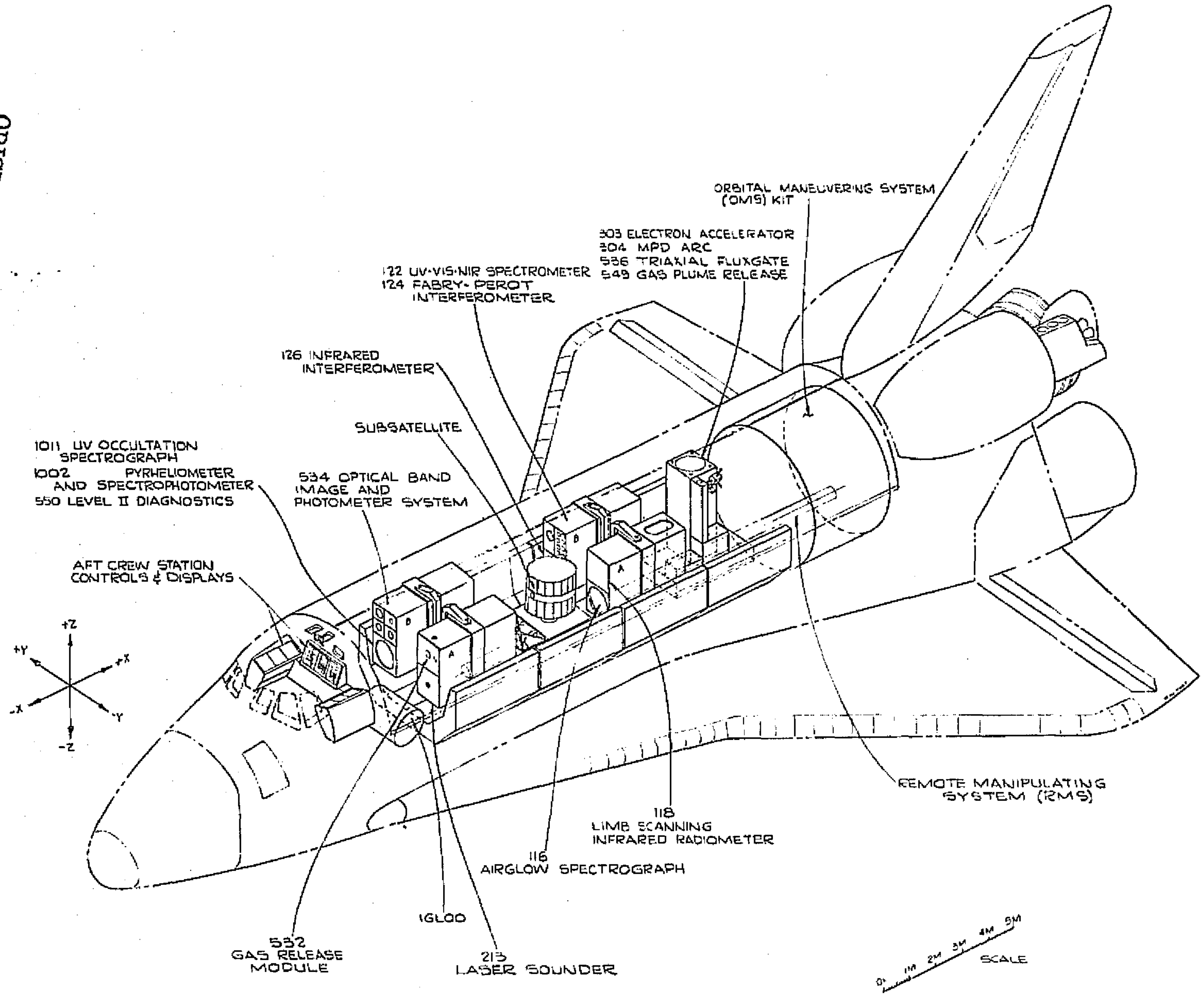

Figure 5.1.1-4. — ASF Pointing System Stowed.

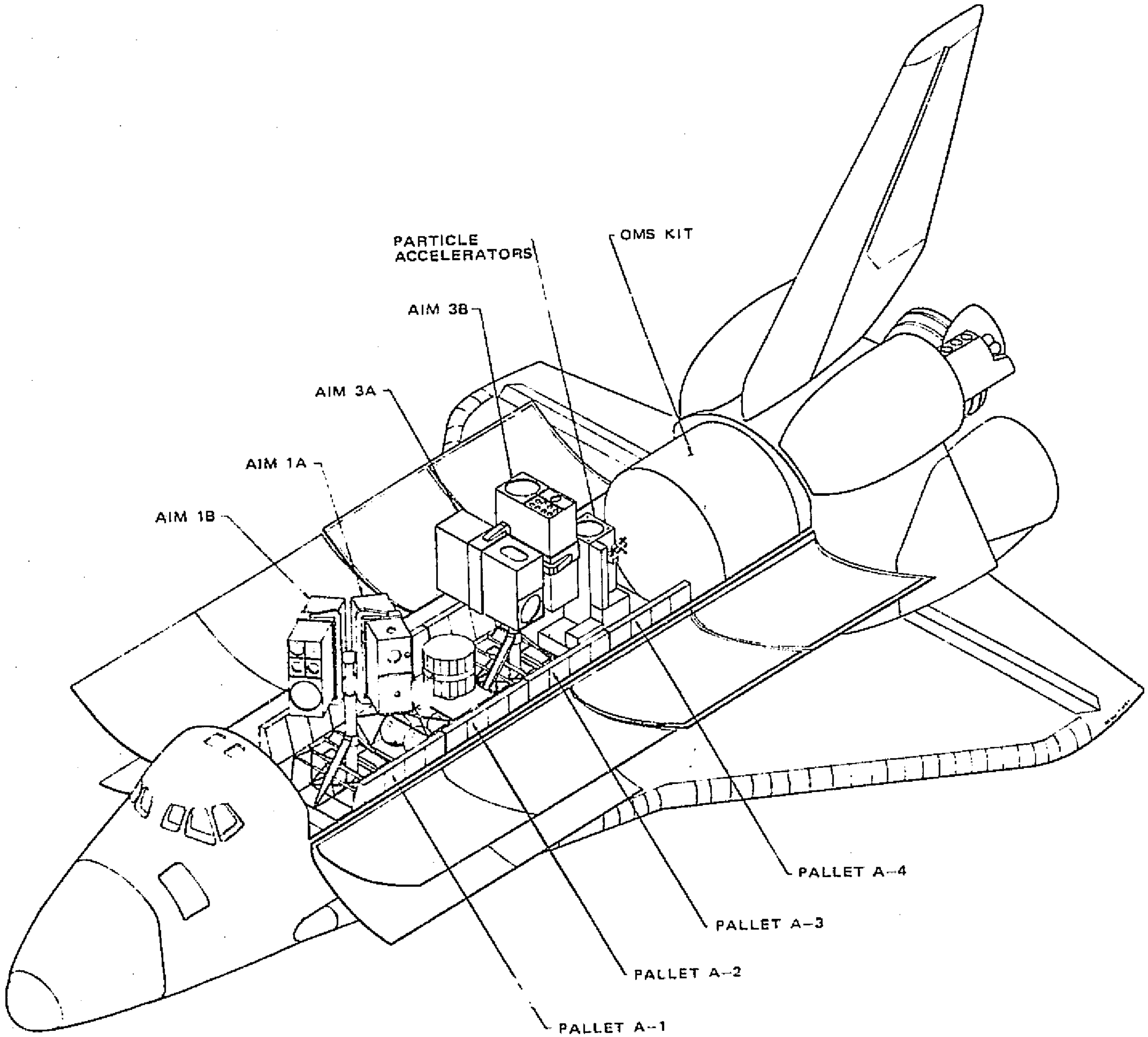

Figure 5.1.1-5. — ASF pointing system deployed.

TABLE 5.1.1-1. — ASF PALLET INSTRUMENT CHARACTERISTICS

Instruments/Item	Qty	Total Weight kg(LB)	Operating Power (Watts-Ave)	Unit Size-L(or D)xWxH or Diam x L Meters (Ft.)
Instruments				
116-Airglow Spectrograph	1	30(66)	10	0.6 Diam x 2.0 L (0.32 Diam x 6.46 L)
118-Limb Scanning IR Radiometer*	1	300(662)	100	0.8 Diam x 1.8 L (2.58 Diam x 5.83 L)
122-UV-VIS-NIR Spectrometer	1	16(35)	16	0.5 × 0.2 × 0.2 (1.62 × 0.65 × 0.65)
124-Fabry-Perot Interferometer	1	45(99)	14	0.3 Diam x 0.6 L (0.97 Diam x 0.94 L)
126-IR Interferometer*	1	300(662)	25	0.9 Diam x 0.7 L (2.91 Diam x 2.26 L)
213-Laser Sounder				
• Emitter/collimator	1	100(221)	1k	1.0 × 1.0 × 2.0 (3.23 × 3.23 × 6.46)
• Capacitor Bank	1	250(552)	-	1.0 × 1.0 × 1.0 (3.23 × 3.23 × 3.23)
• Interferometer	1	50(110)	25	2.0 Diam x 1.0 L (6.46 Diam x 3.23 L)
• Electronics	1	15(33)	50	0.2 × 0.2 × 0.2 (0.65 × 0.65 × 0.65)
303-Electron Accelerator			5k	
• Power Unit 1	1	45(99)		0.5 × 1.0 × 0.5 (1.62 × 3.23 × 1.62)
• Capacitor Bank	1	540(1193)		0.5 × 3.0 × 1.5 (1.62 × 9.69 × 4.84)
• Power Unit 2	1	110(243)		1.0 × 1.0 × 0.5 (3.23 × 3.23 × 1.62)
• Accelerator	1	41(91)		3.0 × 1.0 × 1.0 (9.69 × 3.23 × 3.23)
304-Magnetoplasmadynamic (MPD) Arc			5k	
• Power Unit (share with 303)		–		
• Capacitor Bank(share with 303)		–		
• Arc Generator	1	41(91)		2.0 × 0.3 × 0.5 (6.46 × 0.97 × 1.62)
532-Gas Release Module			140	
• Gas System	1	23(51)		1.0 × 0.5 × 0.3 (3.23 × 1.62 × 0.97)
• Excitation Chamber	1	2(5)		0.5 × 0.3 × 0.1 (1.62 × 0.97 × 0.32)
• Monochromator	1	11(25)		1.8 × 1.0 × 0.5 (5.82 × 3.23 × 1.62)
• Mass Filter	1	9(20)		0.5 Diam x 0.8 L (1.62 Diam x 2.58 L)
• Electronics	1	3(7)		0.3 × 0.3 × 0.3 (0.97 × 0.97 × 0.97)
534-Optical Band Imager and Photometer System		2×50(221)		
• TV Cameras	2		20(ea)	0.2 × 0.2 × 1.3 (0.65 × 0.65 × 4.27)
• Photometers	2		5(ea)	Within camera envelope
536-Triaxial Fluxgate	1	3(7)	4	0.1 × 0.1 × 0.1 (0.32 × 0.32 × 0.32)
549-Gas Plume Release	1	9(20)	5	Contained within 303 envelope
550-Faraday Cup Retarding Potential Analyzer, (RPA) Cold Plasma Probe			10	
• Faraday Cup Probe	1	9(20)		0.1 × 0.1 × 0.1 (0.32 × 0.32 × 0.32)
• RPA	1	9(20)		0.2 × 0.2 × 0.2 (0.65 × 0.65 × 0.65)
• Cold Plasma Probe	1	5(11)		0.1 × 0.1 × 0.1 (0.32 × 0.32 × 0.32)
1002 Pyrheliometer and Spectrophotometer	1	10(22)	10	0.3 × 0.3 × 0.1 (0.97 × 0.97 × 0.32)
1011 UV Occultation Spectrograph				
• Telescope	1	100(221)	-	1.0 Diam x 2.0 L (3.23 Diam x 6.42 L)
• Spectrograph	1	20(44)	1	1.0 × 0.3 × 0.3 (3.23 × 0.97 × 0.97)
• Solenoid	1	5(11)	100	Within telescope envelope
Total Instruments		2203(4858)		

*Includes dewars

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TABLE 5.1.1-2. — ASF PARTICAL DETECTOR SUBSATELLITE
SYSTEM CHARACTERISTICS

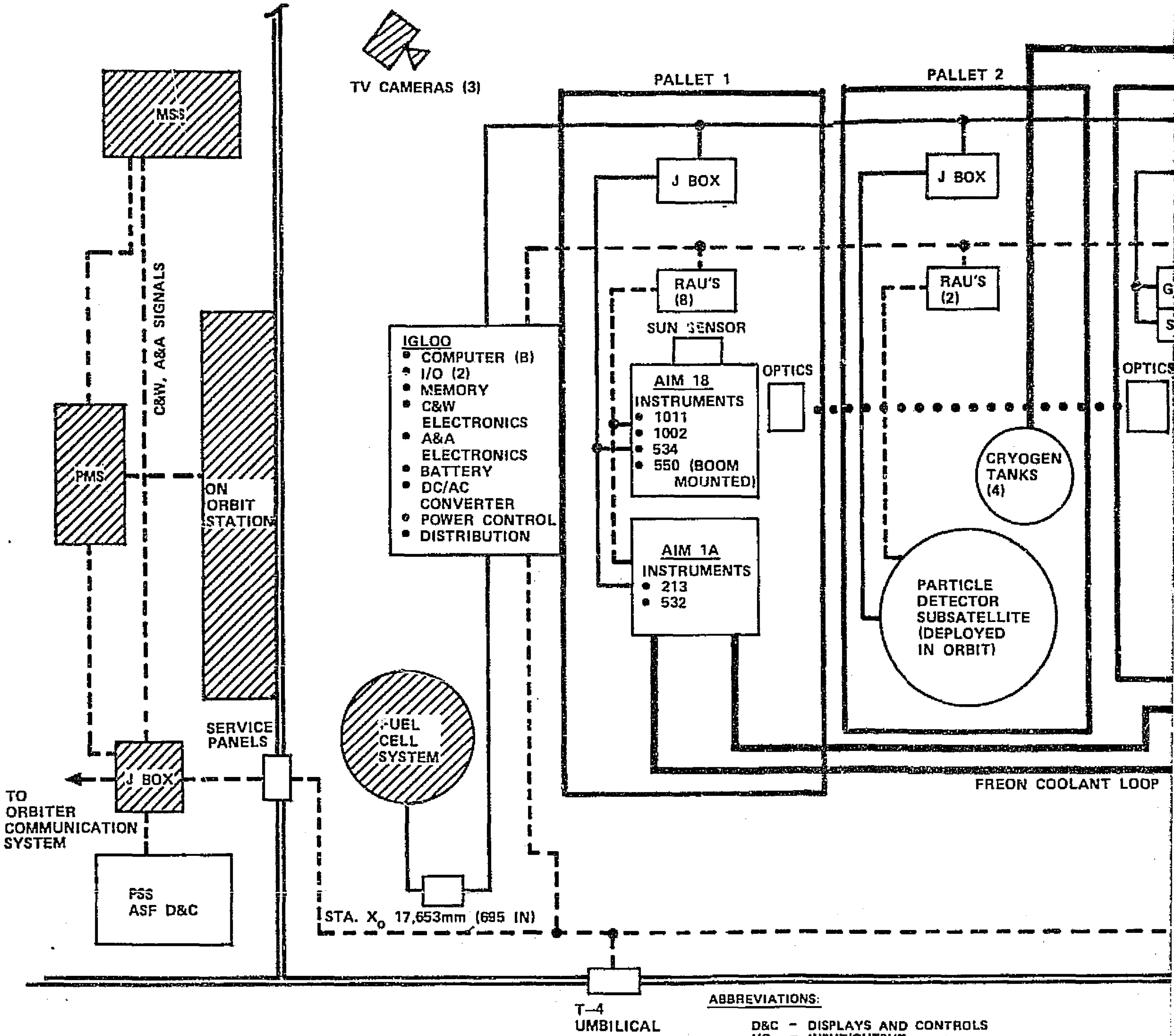
Item	Qty	Total weight kg (lb)	Operating power (Watts-Ave)	Physical Layout
1. Cylindrical Electrostatic Probe (CEP)	1	1.9 (4.2)	5	
2. Photoelectron Spectrometer (PES)	2	2x4.1 (18.2)	5	
3. Low Energy Ion Detector (LEID)	2	2x6.0 (26.5)	10	
4. High Energy Particle Detector (HEPD)	2	2x7.0 (30.8)	6	
5. Low Energy Electron Detector (LEE)	2	2x4.2 (18.4)	5	See Figure 5.2.6-3
6. Airglow Photometer (VAE)	1	8.6 (19.0)	4.5	
7. Triaxial Fluxgate Magnetometer (MAG)	1	1.2 (2.6)	3.1	
8. Planar Ion Trap (RPA)	1	5.1 (11.2)	6	
9. Neutral Mass Spectrometer (NACE)	1	8.3 (18.3)	18	
10. Neutral Atmospheric Temp. (NATE	1	9.2 (20.3)	17.5	
11. Cold Cathode Ion Gauge	1	2.5 (5.5)	1.5	
Total Instruments		79.3 (175.0)	81.6	
Satellite Structure and Support Equipment		662.8 (1372.9)	150	
Total Subsatellite		702.1 (1547.9)	231.6	

TABLE 5.1.1-3. — ASF SUPPORT SUBSYSTEM CHARACTERISTICS

Item	Qty	Total weight kg (lb)	Operating power (Watts-Ave)	Unit size - meters (ft) L = length, W = width, D = depth diam = diameter, H = height
1. Thermal, Structural, Mechanical Subsystem				
a. Pallet A-1				
(1) Pallet Structure	1	428 (945)	-	See figure 5.2.1-1
(2) APS	1	1100 (2426)	200	See figure 5.2.1-6
(3) Boom & mechanism	1	28 (62)	4	Boom - 0.079 diam x 18.0L (0.26 diam x 59.10L)
(4) Cold plate, thermal capacitor	1 set	39 (86)	-	See figure 5.2.1-3
b. Pallet A-2				
(1) Pallet structure	1	428 (945)	-	See figure 5.2.1-1
(2) Subsatellite launch platform	1	10 (22)	-	
c. Pallet A-3				
(1) Pallet Structure	1	428 (945)	-	See figure 5.2.1-1
(2) APS	1	1100 (2426)	200	See figure 5.2.1-6
d. Pallet A-4				
(1) Pallet Structure	1	428 (945)	-	See figure 5.2.1-1
(2) Boom & mechanism	1	3 (7)	4	Boom - 0.013 diam x 20.0L (0.043 diam x 65.6L)
(3) Cold plate, thermal capacitor	1 set	39 (86)	-	See figure 5.2.1-3
e. Active thermal control loop, pump, coolant	1 set	105 (232)	200	
f. Cryogenic coolant storage and distribution system				
(1) Tank, plumbing, valves	4	4x52 (456)		0.76 diam (2.5 diam)
(2) Cryogen		93 (204)		
g. Igloo Structure	1	55 (121)		0.95 diam x 1.5L (3.12 diam x 4.92L) (internal)
Total TSMS		4494 (9909)		
2. Electrical Power & Distribution Subsystem				
a. Emergency battery (igloo)	1	78 (172)	-	0.46Lx0.37Wx0.24H (1.50Lx1.20Wx0.80H)
b. DC/AC inverter (igloo)	1	6 (13)	500	0.40Lx0.25Wx0.15H (1.31Lx0.82Wx0.49H)
c. Power control box (igloo)	1	5 (11)	20	0.31Lx0.15Wx0.13H (1.00Lx0.50Wx0.42H)
d. Secondary power dist. box (igloo)	1	6 (13)	10	0.31Lx0.15Wx0.13H (1.00Lx0.50Wx0.42H)
e. Pallet distribution box (pallets)	8	8x4.5 (102)	8x10	0.25Lx0.15Wx0.13H (0.83Lx0.50Wx0.42H)
f. Harnesses				
(1) 4/0 gauge		290 (640)	-	183L (600L)
(2) 4 gauge		40 (88)		183L (600L)
(3) 10 gauge		55 (122)	-	1097L (3600L)
(4) 20 gauge		41 (90)	-	8,536L (28,000L)
Total EPDS		567 (1251)		
3. Pointing Control & Stabilization Subsystem				
a. Gyro reference assembly (pallet A-3)	1	30 (66)	100	0.18Lx0.25Wx0.20H (0.59Lx0.82Wx0.66H)
b. Star tracker assembly (pallet A-3)	3	3x11 (73)	75	0.60Lx0.21Wx0.21H (1.97Lx0.69Wx0.69H)
c. Sun sensor (pallet A-1)	1	13 (29)	10	0.15Lx0.30Wx0.20H (0.49Lx0.99Wx0.66H)
d. Optical alignment measuring device (pallet 1/pallet A-3)	1 set	12 (26)	30	0.10Lx0.25Wx0.10H (0.33Lx0.82Wx0.33H)
e. Signal processing electronics (pallet 1/pallet A-3)	2	20 (44)	40	0.15Lx0.40Wx0.35H (0.49Lx1.31Wx1.15H)
Total PCSS		108 (239)		

TABLE 5.1.1-3. — ASF SUPPORT SUBSYSTEM CHARACTERISITCS - Concluded

Item	Qty	Total weight kg (lb)	Operating power (Watts-Ave)	Unit size - meters (ft) L = length, W = width, D = depth diam = diameter, H = height
4. Command & Data Management, Subsystem, Displays and Control				
a. Computer (igloo)	3	3x32 (210)	3x245	0.50Lx0.26Wx0.20H (1.64Lx0.85Wx0.65H)
b. I/O unit (igloo)	2	2x32 (140)	2x210	0.50Lx0.26Wx0.20H (1.64Lx0.85Wx0.65H)
c. Mass memory (igloo)	1	27 (60)	35	0.46Lx0.31Wx0.24H (1.50Lx1.00Wx0.8H)
d. C&W electronics unit (igloo)	1	4 (8)	25	0.23Lx0.13Wx0.10H (0.75Lx0.42Wx0.33H)
e. A&A electronics unit (igloo)	1	4 (8)	40	0.23Lx0.13Wx0.10H (0.75Lx0.42Wx0.33H)
f. Remote acquisition unit				
(1) aft crew station	3	3x3 (20)	3x30	0.23Lx0.12Wx0.09H (0.71Lx0.39Wx0.30H)
(2) igloo	3	3x3 (20)	3x30	0.23Lx0.12Wx0.09H (0.71Lx0.39Wx0.30H)
(3) pallet A-1	8	8x3 (53)	8x30	0.23Lx0.12Wx0.09H (0.71Lx0.39Wx0.30H)
(4) pallet A-2	2	2x3 (13)	2x30	0.23Lx0.12Wx0.09H (0.71Lx0.39Wx0.30H)
(5) pallet A-3	7	7x3 (46)	7x30	0.23Lx0.12Wx0.09H (0.71Lx0.39Wx0.30H)
(6) pallet A-4	6	6x3 (40)	6x30	0.23Lx0.12Wx0.09H (0.71Lx0.39Wx0.30H)
g. Tape recorder (aft crew station)	2	2x11 (50)	45	0.33Lx0.33Wx0.15H (1.08Lx1.08Wx0.49H)
h. Cathode ray tube (aft crew station)	2	2x12 (54)	2x90	0.26Wx0.19Hx0.30D (0.85Wx0.62Hx0.99D)
i. Keyboard (aft crew station)	1(+1 space)	2x3 (12)	210	0.48Wx0.18Hx0.33D (1.57Wx0.59Hx1.08D)
j. Control & display unit (aft crew station)	1	16 (36)		0.46Lx0.25Wx0.20H (1.50Lx0.83Wx0.67H)
k. PSS control & display panel (aft crew station)	3	3x36 (240)	260	0.48Wx0.53Hx0.15D (1.57Wx1.74Hx0.49D)
Total CDMS & D&C		459 (1010)		
5. Mission Kits				
a. Radiator panels	2	87 (193)	-	
b. Electrical energy	2			
(1) O_2 tank + O_2	2	2x511 (2254)	-	1.22 diam (4.00 diam)
(2) H_2 tank + H_2	2	2x198 (874)	-	1.32 diam (4.33 diam)
c. OMS Kit	1	1351 (2978)	-	
Total — ASF Flight System		11,389 (25,113)		



ABBREVIATIONS:

- D&C – DISPLAYS AND CONTROLS
- I/O – INPUT/OUTPUT
- C&W – CAUTION AND WARNING
- A&A – ALARM AND ADVISORY
- MSS – MISSION SPECIALIST STATION
- PSS – PAYLOAD SPECIALIST STATION
- PMS – PERFORMANCE MONITORING SYSTEM
- RAU – REMOTE ACQUISITION UNITS
- GRA – GYRO REFERENCE ASSEMBLY
- SPE – SIGNAL PROCESSING ELECTRONICS
- STA – STAR TRACKER ASSEMBLY

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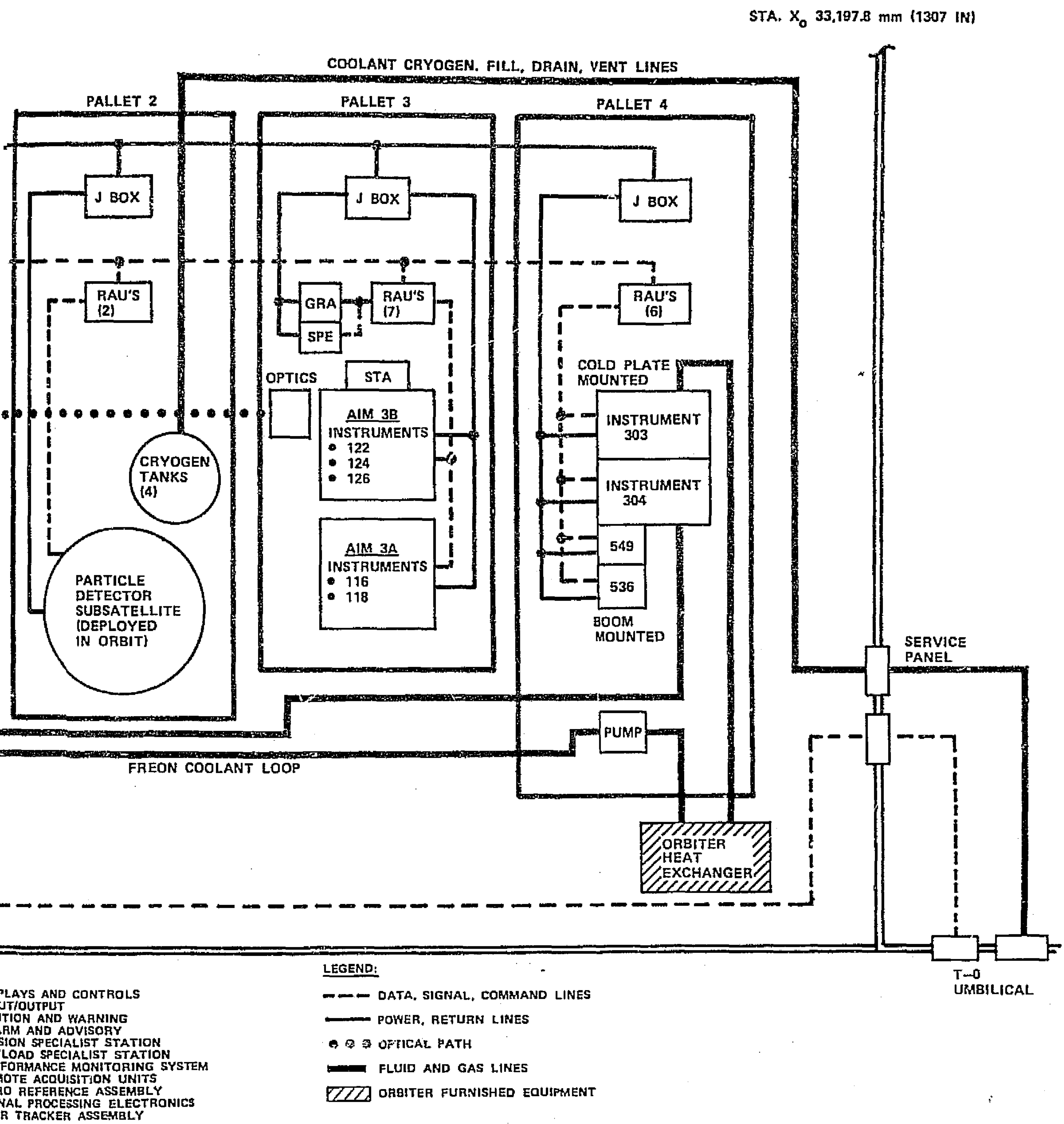
Figure 5.1.1-6. – ASF Flight System

FOLDOUT FRAME 1



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1-6. — ASF Flight System Interfaces

FOLDOUT FRAME 2

payload through the Orbiter rf communication link or, prior to launch, through the landline umbilicals.

a. Payload Interfaces. The interfaces within the payload include the following.

   (1) The structural and mechanical interfaces for the hard-mounted instruments and support equipment.

   (2) The structural and mechanical interfaces for the APS and the instruments mounted on the APS.

   (3) The structural and mechanical interfaces for the booms, the boom actuators and the instruments mounted on the booms.

   (4) The structural and mechanical interfaces for the stowed PDS.

   (5) The thermal interfaces for active thermal dissipation and for cryogenic cooling.

   (6) The avionics interfaces between the instruments/support equipment and the data and command system.

   (7) The avionics interfaces between the attitude measuring system and the APS.

   (8) The interfaces between the electrical power distribution points and the instrument/support subsystems.

b. Hardware, Software and Operational Interfaces. The hardware, software, and operational interfaces between the ASF payload and the Orbiter include those for the following.

   (1) Orbiter maneuvering.

   (2) Orbiter orbit change.

   (3) Subsatellite range and range rate measurements.

   (4) Subsatellite retrieval using Orbiter RMS.

   (5) Installation of pallets to Orbiter standard payload attach points.

(6) Fluid lines to and interconnects with the T-0 umbilical through the station Xo 33,197.8 mm (1307 in) bulkhead service panel.

(7) Fluid lines to and interconnects with the T-4 umbilical at station Xo 21,209 mm (835 in).

(8) Active thermal control heat exchanges interface.

(9) Electrical power from Orbiter fuel cells through the station Xo 17,653 mm (695 in) interfaces.

(10) Data and command interfaces between the ASF payload igloo and the PS and MS stations, and the Orbiter Performance Monitoring System (PMS) through the station Xo 14,630.4 mm (576 in) bulkhead service panels.

(11) Caution and Warning (C&W) and Alarm and Advisory (A&A) interfaces between the payload igloo and the Orbiter C&W electronics and the PMS through the station Xo 14,630.4 mm (576 in) service panels.

(12) Closed circuit television (CCTV) monitor and control interfaces between payload bay cameras and the aft flight deck through station Xo 14,630.4 mm (576 in) bulkhead service panels.

(13) Audio communication interface between the PS and other Orbiter crew members at the aft crew station.

c. ASF Flight System/STDN/TDRSS Interfaces. The interface between the ASF flight system and STDN or TDRSS is provided by the Orbiter by interleaving the data presented to the Orbiter rf communication signal processors through the station Xo 14,630.4 mm (576 in) bulkhead service panels.

Communication with the MCC and other mission control and data processing facilities are provided through these interfaces.

d. Fluid, Avionics and Power Interfaces (Ground). The fluid, avionics and power interfaces between the ASF flight system and the ground facilities after the ASF payload is mated with the Orbiter are provided through the T-4 prelaunch and T-0 launch umbilicals.

5.1.4 MAJOR SYSTEMS INTEGRATION ISSUES

a. Payload. Within the payload element, the major integration issues were as follows.

   (1) How best to install all the instruments on the pallets such as to meet the ASF experimental and operational requirements within the known constraints.

   (2) How a practical system could be developed to provide the required pointing for the instruments.

   (3) How a practical cryogenic cooling system could be developed for instruments 118 and 126.

   (4) How payload data could be processed to the maximum extent possible onboard.

   (5) How to maximize subsatellite, and support subsystem operations.

   (6) How the payload could minimize the EMI, electrostatic buildup, and contamination generated to allow valid experiment measurements to be made.

b. Payload/Orbiter/Crew. The integration issues between the payload and the Orbiter vehicle and crew were as follows.

   (1) Whether the Orbiter vehicle attitude control accuracy would be adequate for instrument pointing.

(2) How the payload thermal dissipation could be kept within the Orbiter Active Thermal Control Subsystem (ATCS) capability.

(3) Whether the EMI generated by the Orbiter could prevent valid experiment measurements to be made.

(4) Whether the payload specialist station (PSS) space allocation would be adequate for ASF displays and controls.

(5) Whether one PS could perform the required functions without overload.

(6) The number of PS's required to provide 24 hours/day coverage.

(7) Whether the data rate handling capability of the Orbiter communication system was adequate to handle the onboard experiments and the deployed PDS.

(8) The ASF payload failures, which could create a safety problem, and the best way to handle these failures.

c. Payload/MCC. The issues between the ASF payload and the MCC, ground data handling facilities included the following.

(1) The functions to be performed by MCC to support ASF data processing and mission operations.

(2) The best way to handle the large quantity of data transmitted to the ground.

d. Payload/Test, Integration and Launch. The major integration issue between the ASF payload and the test, integration and launch base facilities was the practicality of providing meaningful test and calibration of these extremely sensitive instruments under earth environments.

Each of the integration issues identified, which was unique to the ASF payload, was evaluated to determine functional feasibility (i.e., can the required function be performed?) and as many as possible within the study constraints were evaluated further to determine implementation feasibility (i.e., can all these functions be implemented by practical hardware and software?). The issues of how best to install all instruments on the pallets and how to provide an ASF pointing system were evaluated in detail. The other issues involving the payload elements alone were addressed only from a functional feasibility standpoint. Based on existing systems which have proven to be capable of performing the same or similar types of functions, it was concluded that these functions could be performed for the ASF payloads. The impact of sizing and capacity will be established during the next phase of study.

e. Instrument Arrangement. A number of factors were weighed in the determinations which resulted in the instrument arrangement depicted in figure 5.1.1-4. For each instrument, the factors included the following.

(1) Operating weight.

(2) Operating volume.

(3) Instantaneous Field-Of-View (IFOV).

(4) Pointing requirements.

(5) Scanning requirements.

(6) Temperature control requirements.

Certain instruments do not have a requirement for maneuvering, for either pointing or stabilization. Accordingly, those instruments were grouped to be mounted directly to a pallet instead of on an APS. Similarly, certain instruments must operate at a distance from the Orbiter, which dictated mounting on the subsatellite. The two groupings can be noted in figure 5.1.1-4. The remaining instruments were grouped in the four AIM units installed on Pallet A-1 and Pallet A-3.

f. Selection of Pallets. The selection of pallets for installation of the two APS assemblies was based on two factors.

(1) The swept volume of an AIM while it is maneuvered.

(2) The need for visibility of, and access to, the subsatellite during the separation and retrieval operations.

g. Overall Arrangement of Pallets. The overall envelope through which an AIM unit is maneuvered precluded the use of Pallet A-4 for an APS, for the envelope of the Orbital Maneuvering System (OMS) kit was encroached under certain combinations of the AIM azimuth and elevation settings. Similarly, the maneuvering space required by the AIM units precluded locating the APS assemblies on adjacent pallets, i.e., A-1 and A-2, or A-2 and A-3. These considerations alone seemed to dictate use of the first and third pallets for installation of the APS assemblies. The requirement for visibility of the subsatellite was the final determinant in locating the ASF instruments since placement of the subsatellite on Pallet A-2 permitted continuous viewing of that vehicle while the RMS was manipulated in the separation and retrieval operations. The final arrangement, as depicted in figure 5.1.1-4, is:

Pallet A-1 - ASF Pointing System
Pallet A-2 - Subsatellite
Pallet A-3 - ASF Pointing System
Pallet A-4 - Non-maneuverable Instruments

h. Selecting Pointing System. On the issue of selecting a practical pointing system, the Instrument Pointing System (IPS) was evaluated due to the ground rule that Spacelab equipment was to be used, if possible. However, several operational features made the use of the IPS unsuitable. The primary objections were the necessity of decoupling the pointing system payload for the vehicle launch and recoupling after attaining orbit and the lack of multiple pointing from the one system. It was not considered feasible to initially hard mount the experiment instrumentation and then attempt to install it, either with the RMS or a special, volume consuming apparatus on the pointing system,after the Orbiter was in orbit. Further, the need for more than one pointing direction for the various instrument clusters would have required more pallet space than was available if the IPS were used. Also, the IPS cannot be tested under one g conditions due to its gimbal suspension design.

The two APS assemblies have equal capability from the standpoints of instrument accommodation and operating precision and accuracy. Because of this, the requirements of the individual instruments for accuracy of pointing and tracking did not greatly influence the location of instruments in one AIM or another. A facet of the pointing requirement which did receive consideration was that of co-alignment of instruments for participation in the experiments. Where a high order of co-alignment precision has been specified, the instruments have been co-located in the same or adjacent AIM units.

The capabilities of the APS to provide accurate pointing, tracking, and stabilization are described more fully in paragraph 5.2.3 of this report.

i. Overall System Considerations. In the area of the interface between the ASF payload and the Orbiter vehicle and crew, detailed assessments were made of most of the issues mentioned. These are discussed in paragraphs 5.2.1 through 5.2.5. The one major issue which was not resolved was whether the EMI generated by the Orbiter would allow meaningful experimental results. Preliminary assessment of instrument susceptibility and expected Orbiter EMI background indicates that conventional Electromagnetic Compatibility (EMC) design approaches should be adequate to prevent EMI problems. (See section 5.5). However, this issue is one which could impact not only the ASF pallet-only mode but could raise feasibility questions with every payload which has instruments and equipment sensitive to high levels of electrical and magnetic interference fields. Further study is planned in this area after the sensitivities of the instruments are further defined.

In the area of interface between the ASF payload and the ground facilities, the full functional role of the MCC and other mission control facilities was not fully evaluated since the approach taken for the study was to perform as much of the data processing and mission operations onboard the payload as was considered practical. The question of the best way to handle the large amount of data handled on the ground was also not fully addressed from an implementation standpoint and should be further assessed during the next study phase.

The major issue for the area of interface between the ASF payload and the test, integration and launch base facilities is one which is not unique to the ASF program. All payloads which have sensitive, precision instruments with thresholds far below the background levels of magnetic or electric fields, particle contamination, etc., created by the earth-bound environment, or which cannot operate in the sea level atmosphere, will be subject to the same test and verification problems. Comprehensive analyses to identify the error sources which can affect the precision and thresholds of these instruments, and great care in selecting design to minimize these error sources, can assure successful experimental results.

5.2 FLIGHT SYSTEMS

5.2.1 THERMAL, STRUCTURAL AND MECHANICAL SUBSYSTEM (TSMS)

5.2.1.1 Introduction

The objective of this phase of the study was to show the feasibility of installing and servicing all ASF instruments, subsatellite, and support equipment on multiple ESRO furnished equipment pallets within the operational and environmental requirements and constraints imposed by the instruments and support equipment.

To meet the objective it was necessary: (1) that the instruments be grouped according to complementary operations and other specific experimental requirements, (2) that an IPS be developed, (3) that boom and actuation concepts be selected, (4) that a subsatellite retention and ejection concept be defined, and (5) that instrument, subsatellite and support equipment installation and layout design be performed.

Analyses were conducted, alternative candidate concepts were assessed, and a baseline conceptual configuration was established. The instrument pointing, boom and boom deployment, and subsatellite retention and ejection systems received greater emphasis than did other areas since the more significant questions of feasibility involve these areas. Also, the implementation techniques for these areas differ significantly from the ERNO approach where similar requirements apply.

5.2.1.2 Requirements

The following functional requirements apply to the ASF TSMS.

a. Thermal Control. The subsystem will provide for the ASF instruments and support equipment the capabilities for:

(1) active thermal dissipation, (2) passive thermal control, (3) heating, and (4) cryogenic cooling.

The active thermal control system must have the capability of dissipating payload thermal energy resulting from the use of the following levels of electrical power.

(1) 5.3 kW average over the entire mission.

(2) A maximum average of 6.9 kW during any given orbit.

(3) 9.0 kW maximum for 15 minutes each orbit from revolutions 32 through 47.

Instruments 213, 303 and 304 impose the greatest demand on the active thermal control system since they use the highest level of power (1.1 kW, 5.0 kW and 5.0 kW, respectively).

The detectors for instruments 118 and 126 must be cooled to 4K and portions of the instrument housings must be cooled to at least 77K. Although the instruments will be designed to be compatible with the cryogenic cooling requirements (e.g., the housings will be of dewar construction), the TSMS must provide cryogen storage, distribution and gas exhaust facilities.

b. Structural and Mechanical. The subsystem will provide for the installation of 15 ASF instruments on the equipment pallets. In addition, the subsystem will provide for the installation of the following support equipment on one or more of the pallets in the payload bay.

(1) An APS capable of pointing instruments in the desired direction with a high degree of accuracy.

(2) One APS control electronics for each APS.

(3) An Attitude Measuring System (AMS) consisting of a gyro-reference assembly, three star tracker assemblies (fixed

head), or one gimballed star tracker assembly and a processing electronics assembly.

(4) Autocollimators, porro prisms, optical flats and twist sensors for precise attitude transfer between pallets.

(5) Booms and boom actuator mechanisms.

(6) Subsatellite retention, ejection mechanisms.

(7) A thermal coolant loop pump and heat exchanger on one or more pallets.

(8) Up to 8 remote acquisition units (RAU's) per pallet.

(9) A power distribution box on each pallet.

(10) A pressurized equipment module (igloo).

Special installation requirements for instruments are included in the ID's and include individual instrument pointing and tracking accuracy, and requirements for accurate co-alignment of two or more instruments. These are summarized in table 5.2.1-1. In addition, requirements exist to have one diagnostic (Instrument 550) scan particle accelerator output to determine beam characteristics, and one instrument (Instrument 536) to be located such that the influence of the Orbiter in relationship to the earth's magnetic field is within acceptable limits as defined in the ID's.

No special requirements exist for installation or location of support equipment other than AMS equipment. The gyro-reference assembly and star tracker assembly reference axes must be aligned within a few seconds of arc to each other and to the APS reference axes. Optical attitude reference transfer media (porro prisms, twist sensor and optical flats) must also be aligned within a few seconds of arc to each other and the APS and AMS reference axes.

TABLE 5.2.1-1.— AIM PACKAGING PARAMETERS FOR ASF

AIM No.	Instrument No.	Size (m)	Weight (kg)	Temperature	FOV	Pointing Accuracy	Coalignment
1A	213	1.0 × 1.0 × 2.0 1.0 × 1.0 × 1.0 2.0 diam × 1.0 0.2 × 0.2 × 0.2	100.0 250.0 50.0 15.0 Total 415.0		Collimated	±1°	±0.1 (B)
	532	1.0 × 0.5 × 0.3 0.5 × 0.3 × 0.1 1.8 × 1.0 × 0.5 0.5 diam × 0.8 0.3 × 0.3 × 0.3	23.0 2.3 11.4 9.1 3.0 Total 48.8 AIM Total 464.0	5C to 35C	NA	±1°	NA
1B	534	0.2 × 0.2 × 1.3 0.9 × 0.9 × 1.8	100.0		0.5° to 160°	±2°	NA
	550 Boom	0.1 × 0.1 × 0.1 0.2 × 0.2 × 0.2 0.1 × 0.1 × 0.1	9.0 9.0 5.0 28.0 Total 51.0		NA	±0.6°	NA
	1002	0.3 x 0.3 x 0.1	10.0		5°	±2.5°	NA
	1011	1.0 diam x 2.0 1.0 x 0.3 x 0.3	100.0 25.0 Total 286.0 AIM 1A + B Total 750.0		.017° × 1/2°	±0.1°	±0.017° (A)
3A	116	0.6 diam × 2.0	30.0		1° to 5°	±0.5°	NA
	118	0.8 diam × 1.8	300.0* Total 330.0	4K to 28K	0.02°	±0.5°	±0.1° (B)
3B	122	0.5 × 0.2 × 0.2	16.0	-20C to +50C	12°	±0.1°	±0.017° (A)
	124	0.3 × 0.5 × 0.7	45.0		0.1° to 3°	±0.1°	±0.017° (A)
	126 Startracker and Gyro	0.9 diam × 0.7	300.0* 63.0 Total 424.0 AIM 3A + B Total 754.0	4K to 28K	0.1°	±0.1°	±0.1° (B)

NOTE: Instruments marked (A) or (B) are respectively coaligned with each other.

*Includes weight of cryogenic dewar.

The equipment will be in close proximity to instruments being serviced. This factor is especially critical for the high voltage, high power converters, the cryogenic coolant systems, and the AMS. Physical and environmental interference of instrument or other support equipment will be minimized and those requiring active cooling will be located on cold plates.

The subsatellite installation must provide for reliable separation while providing mechanical integrity during the launch and the reentry environments. The separation mechanism must impart a relative rate of 20 cm/sec to the subsatellite.

The extended booms with instruments attached must be capable of withstanding Orbiter maneuvering accelerations and decelerations without damage. The booms must also maintain instrument attitudes within 0.5 degrees during orbit limit cycling operation and during instrument scanning operations.

Safety considerations dictate that any part of the payload which could fail is to be securely latched or any part which could prevent closure of the payload doors is to be capable of being jettisoned.

5.2.1.3 Guidelines and Assumptions

In addition to the general guidelines and assumptions listed in paragraph 2.3.4, the following guidelines and assumptions unique to the TSMS were used in this study.

a. ERNO designed, ESRO furnished equipment including the equipment pallets will be utilized to the maximum extent possible.

b. The Orbiter attitude control system will be capable of providing coarse pointing to an accuracy of within 2°.

c. Normal Orbiter orientation during ASF missions will be the X-X axis tilted 45° to the earth's radius vector (nose up or down) with the payload bay forward in the direction of flight. Attitude changes will be made from this position for specific experiments.

5.2.1.4 Capabilities and Constraints

The following capabilities and constraints apply to the ASF TSMS.

a. Orbiter. The ATCS for the Orbiter and payload consists of:

   (1) Radiators mounted on the interior of the payload bay doors which deploy upward when the doors are open.

   (2) Heat exchangers and coolant pumps provided in the Orbiter.

   (3) Heat exchangers, thermal capacitors, and coolant pumps provided on the pallets for the experiment payload. The ATCS is available to the payload during all mission phases, including ground operations.

The Orbiter ATCS will provide a baseline on-orbit payload heat rejection of up to 21,500 Btu/hr (6.3 kW) with the payload bay doors open and coolant temperatures of 7.2°C maximum to the payload and 54.4°C returned from the payload (see table 5.2.1-2).

The on-orbit heat rejection capability can be increased to 29,000 Btu/hr (8.5 kW) by the addition of payload chargeable radiator kits provided that the Orbiter cabin is appropriately powered down. Coolant temperatures will be 7.2°C to the payload and 40°C returned from the payload. The ATCS will provide an ascent (after main engine cutoff (MECO)), on-orbit, entry and post-landing heat rejection capability of 5,200 Btu/hr (1.2 kW) with

TABLE 5.2.1-2.— ATCS CONTROL CAPABILITY

Mission Phase	Payload Heat Rejection Btu/hr (kW)	Coolant Temperature °F (°C)	
		In	Out
Payload doors open	21,500 (6.3)	45 (7.2)	130 (54.4)
(with additional radiator kits)	29,000 (8.5)	45 (7.2)	104 (40.0)
Ascent (post MECO) in-orbit, entry and post landing	5,200 (1.2)	45 (7.2)	100 (37.8)
Ground cooling with four thermal capacitors- 15 min/3 hours	29,000 (8.5) (12.4)	45 (7.2)	104 (40.0)
Cold plates	(1.0)		(10 to 30)

the payload bay doors closed and coolant temperatures of 7.2°C to the payload and 37.8°C returned from the payload. Within 15 minutes following touchdown, ground cooling will be available to the Orbiter; with ground cooling and with the Orbiter cabin appropriately cooled down, the ATCS will provide a payload heat rejection capability of 29,000 Btu/hr (8.5°kW) with the payload bay doors closed and coolant temperatures of 7.2°C maximum to the payload and 40°C returned from the payload.

The payload heat exchanger will be designed so that any of the following can be selected (by the payloads) as a payload coolant: water, Freon 21, Flutec PP50.

The payload side of the payload heat exchanger is being designed with two coolant passages. The payload may use either or both of these passages. Each of the payload coolant passages is being sized for a maximum delta pressure of 6 psia with 9,072 kg/hr (2,000 lb/hr) of Freon 21 and a maximum operating pressure of 200 psia.

b. Payload. The physical accommodation capability of a single pallet segment is as follows:

   (1) The overall payload carrying capability of a single pallet segment is about 3500 kg (5500 kg, multiple pallets) (uniformly distributed over the pallet) with a c.g. limitation between 250 mm above the pallet floor line and the Orbiter bay horizontal centerline at station Z_0 = 1016 cm (400 in.).

   (2) A single pallet provides 36 m^3 volume above the floor.

   (3) The floor panel of a single pallet segment provides about 17.0 m^2 (183 ft^2) of mounting area, which is available for mounting payload equipment.

If the equipment exceeds the floor panel load capability, it can only be mounted on standard equipment hard points. Provisions for 24 such hard points are located on each pallet segment on the inner surface at the intersections of the frames and longitudinal members (figure 5.2.1-1).

Each hard point provides a spherical nut with 36 mm or 45 mm diameter metric thread. They are bolted to the pallet structure and have a dynamic load carrying capability of:

X_0	direction	28,547 N	(6,418 lb)
Y_0	direction	18,443 N	(4,146 lb)
Z_0	direction	75,046 N	(16,871 lb)

Load carrying capability is equal for all hard points regardless of their locations.

The ESRO furnished coldplates are designed for 1 kW maximum. The coolant temperature will be between 10°C and 32°C for a pallet-only configuration depending on total heat load on the loop and the location of the coldplate. The coldplates are connected in series.

5.2.1.5 Subsystems Description

5.2.1.5.1 Thermal Control System

The thermal control system consists of: (1) an active thermal control, (2) a passive thermal control, and (3) instrument cryogenic cooling systems.

5.2.1.5.1.1 Active Thermal Control Subsystem (ATCS)

a. Cooling. The present instrument definition is not refined to the point that exact heating or cooling requirements can be defined. Some instrument designs may use direct radiation to space for cooling, others may have minimal cooling requirements such that heat may be directly coupled into the pallet

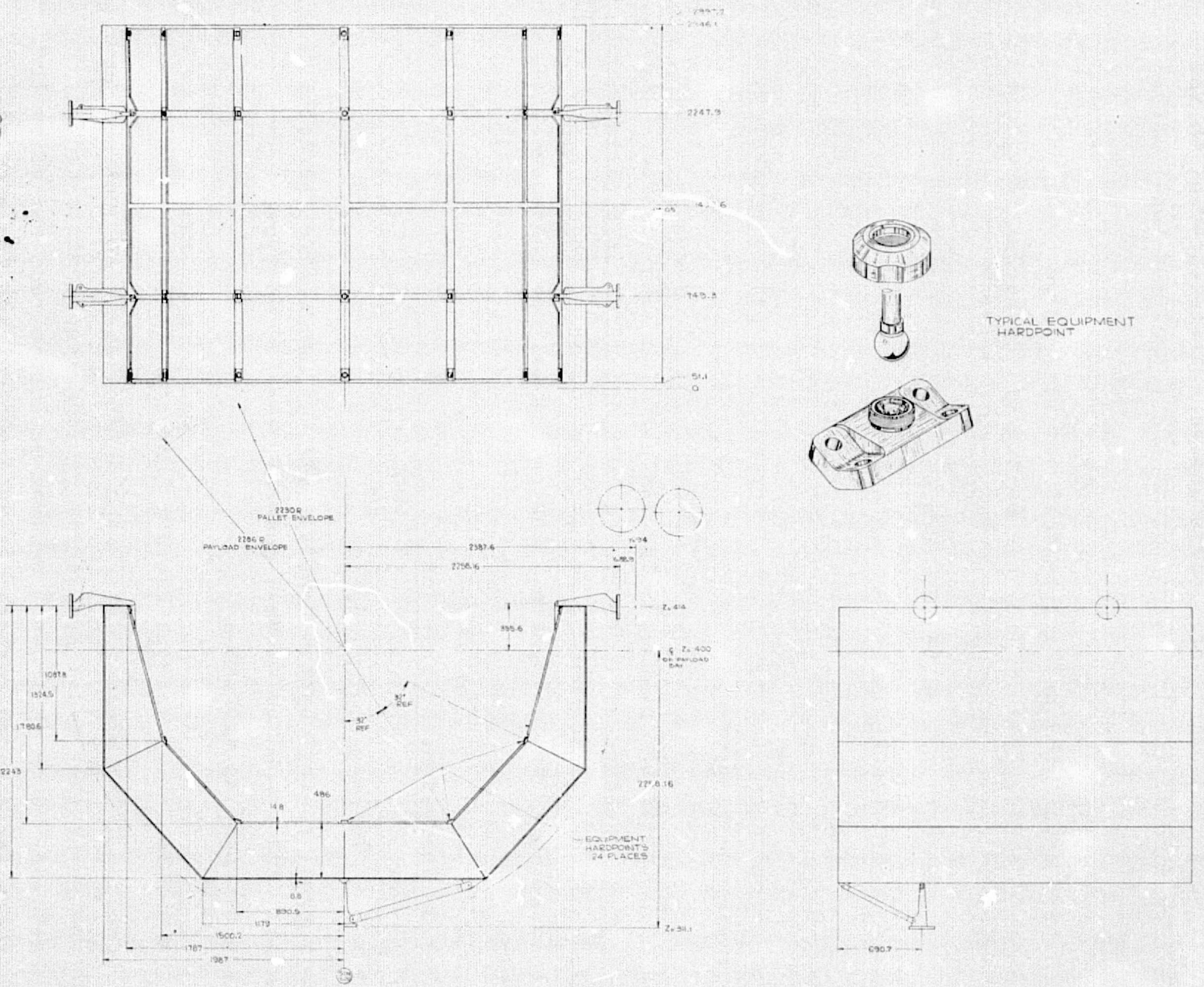


Figure 5.2.1-1. — Pallet equipment hardpoints.

structure. For those requiring significant thermal dissipation, the ATCS may be used. The Orbiter ATCS will include a heat exchanger to allow transfer of payload thermal energy to the Orbiter system.

Fluid circulation through the payload side of the heat exchanger will be provided by a pump kit chargeable to the payload (figure 5.2.1-2). The freon coolant loop is designed to accommodate up to eight cold plates and up to four thermal capacitors to take up peak heat loads. The cold plates and thermal capacitors used for ASF missions will be those furnished by ESRO for Spacelab.

The cold plates are mounted to the pallet floor panels as shown in figure 5.2.1-3. These panels fit the 48° section of the pallet. It is thus possible to mount all eight cold plates on one pallet segment or to distribute them over several pallet segments in (TBD) configuration. Since the coolant loop plumbing can be changed at the integration site, it is in principle also possible to mount cold plates in other positions. Isolators are used to thermally isolate cold plates from the pallet panels. All cold plates are connected in series.

Thermal capacitors can be mounted to cold plates to accomodate peak heat loads. It is not necessary, however, to mount peak load generating equipment directly to a thermal capacitor. The thermal capacitor can also be mounted to a different cold plate in the coolant loop. The size of a thermal capacitor is 750 x 500 x 52 mm. The capacitors are designed to accommodate the maximum permissible peak heat load of 12.4 kW for 15 minutes every three hours when all four are used.

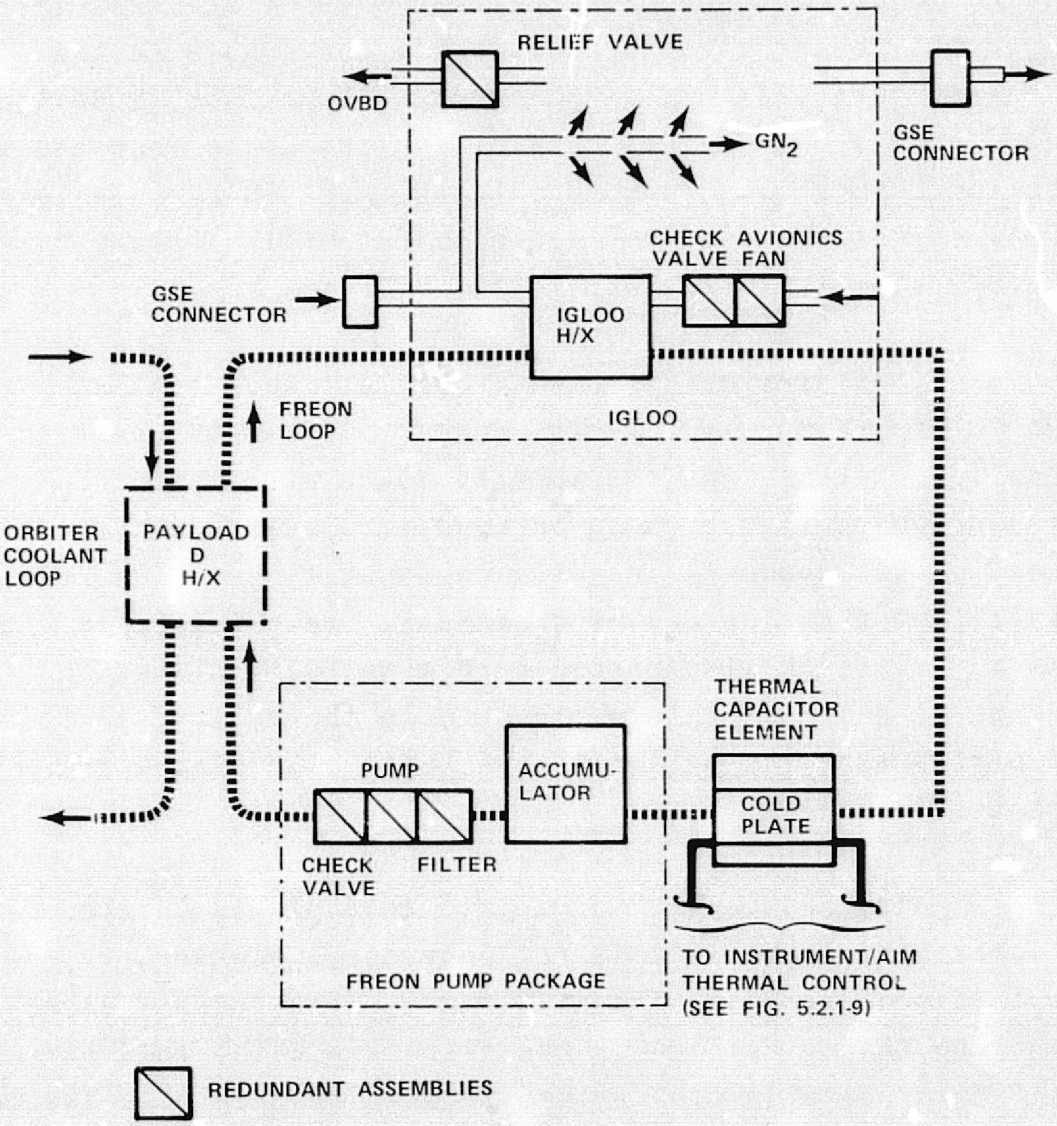


Figure 5.2.1-2. — Active thermal control system (ATCS).

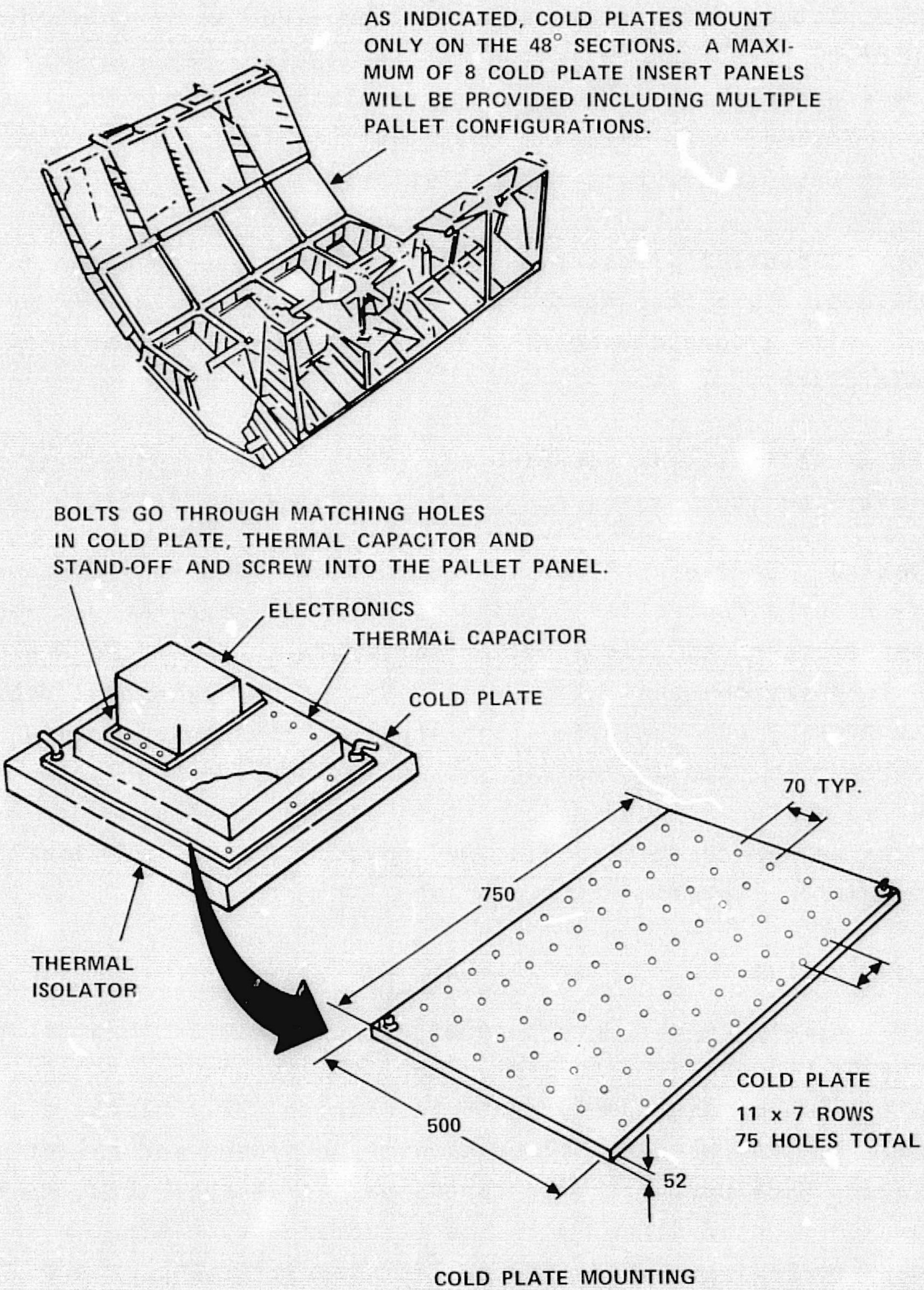


Figure 5.2.1-3. — Pallet cooling.

Cold plates and thermal capacitors provide the same standard mounting hole pattern as the pallet panels. Payload equipment are mounted to the pallet and cold plates (and thermal capacitor if used) with titanium bolts with isolating washers to limit heat transfer to the pallet panels.

Thermal contact is established in the area around the bolts. The design provides heat transfer capability of 13 W/°C per bolt with a conductance of 1 W/°C. The maximum capability per cold plate is 1 kW.

The mechanical load carrying capability of cold plates is limited by the load carrying capability of the pallet panels.

b. Heating. Some of the ASF instruments and subsystem equipment may require controlled heating to maintain temperatures above the structure to which they are attached or above the ambient payload bay environment. Each instrument or equipment requiring heating will provide it internal to its package using conventional techniques (thermistor bridges, proportional or pulsed drivers, wound wire heating element). The power required for these circuits are included in the individual equipment allocations.

5.2.1.5.1.2 Passive thermal control

Passive thermal control may be necessary to minimize temperature extremes of the pallet structure. Control techniques include thermal coatings, high performance insulation (HPI) blankets and thermal isolation between pallet-mounted equipment and pallet structure. When heat transfer to the pallet is desirable, equipment can be mounted directly to the structure, resulting in the equipment following closely the pallet structure temperature.

The thermal covers for the top surfaces of the pallet are flat HPI blankets the same size as the pallet structural panels. They are designed to be easily installed and removed so that the amount of exposed surface may be varied from mission to mission.

5.2.1.5.1.3 Cryogenic cooling system.

Two sensors, the Limb Scanning Infrared Radiometer (Instrument 118) and the Infrared Interferometer (Instrument 126), require cryogenic cooling of the instrument and optical telescopes. Specific heat loads are not defined at this time and further development will be required before a systems analysis can be performed. However, the requirement to cool large optical telescopes in the range of 60 to 100 cm diameter and the complete instrument housing rules out the feasibility of using state-of-the-art closed loop refrigerant systems at the required temperature of 4K. Therefore, looking only at the detector array heat load and estimating this to be in the order of 2 watts, a supercritical helium cryogenic system will suffice for these sensors. The 0.83 m (33") diameter, 74.8 kg (165 lb.) storage tank system used on the Apollo program for the lunar module (LM) vehicle will provide an adequate supply of helium if expanded through a joule Thompson expander to provide the 4 K temperature.

Multiples of these tankage systems could provide the additional cooling capacity for the instrument enclosure and optical telescopes. Liquid nitrogen or solid Ne may be better cryogens for the 77K and 20K temperatures of the telescopes and enclosures. However, these could be stored in the available tankage designs.

5.2.1.5.2 Structural/Mechanical System

The structural/mechanical system consists of the following standard items which will be supplied by ESRO:

a. Pallets.

b. Pallet panels with threaded inserts as required.

c. Cold plates with standard mounting holes for sensors.

d. Thermal capacitors.

e. Hard point mounting provisions for large instruments, cryogenic storage systems, and APS as required.

f. Igloo.

In addition to the ESRO items, the following items are included in the structural/mechanical system:

a. The APS and its truss structural mount.

b. The satellite mounting and deployment system.

c. The booms and boom mounting system.

d. All auxiliary brackets and mounting provisions plus restraint systems as required to provide structural integrity to the system.

The pallet cross section is U-shaped and of aeronautic-type construction. It provides for hard points for mounting heavy experiments and a large panel surface area to accommodate lighter payload elements. Pallet segments are modular (3 m nominal length) and can be flown independently or interconnected. As many as three pallets can be interconnected and supported by one set of retention fittings.

The pallet structure accommodates experiment and equipment for direct exposure to space. The general structural configuration at the pallet is shown in figure 5.2.1-4. The pallet provides mounting support for the experiments either directly on the inner skin panels, or as mission-dependent equipment through specific hard points for better dispersion of concentrated loads.

5.2.1.5.2.1 Pallets A-1 and A-3

The structural and mechanical configuration of pallets A-1 and

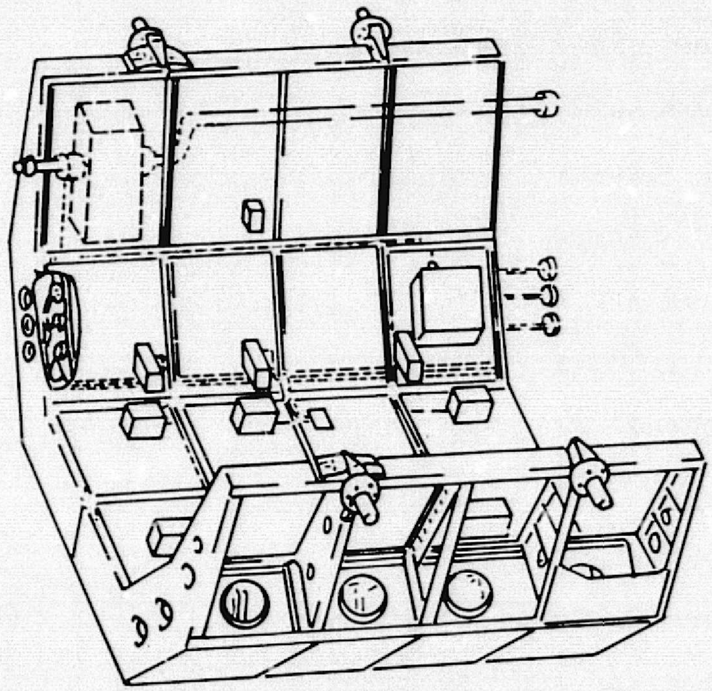


Figure 5.2.1-4. — Standard pallet configuration.

A-3 are similar. Each has an APS mounted to the basic structure to provide precision pointing for the ASF instruments. The instruments installed on the APS are contained in AIM's to provide a convenient integrated package which can be gimballed about two axes as shown in figure 5.2.1-5. Each APS is comprised of two AIM's, independently controlled. Table 5.2.1-3 lists the instruments contained in each AIM for each of the APS's. Other equipment installed on pallets A-1 and A-3 are as follows.

a. Pallet A-1

(1) Four experiment RAU's.

(2) Four subsystem RAU's.

(3) Sun Sensor.

(4) APS control electronics.

(5) Boom and boom actuation mechanisms.

(6) Power distribution box.

(7) Optical alignment transfer devices.

b. Pallet A-3

(1) Four experiment RAU's.

(2) Three subsystem RAU's.

(3) Porro prisms and optical flats for attitude reference transfer from the AMS on pallet A-1.

(4) APS control electronics.

(5) Power distribution box.

(6) Attitude measuring system including a gyro reference assembly, 3 star tracker assemblies, AMS processing electronics, and optical sensors for attitude reference transfer.

c. AMPS Pointing System. Each APS consists of two pointing platforms each mounted on a separate pallet as shown in figures 5.1.1-3, 5.1.1-4, 5.1.1-5 and 5.2.1-6. These may

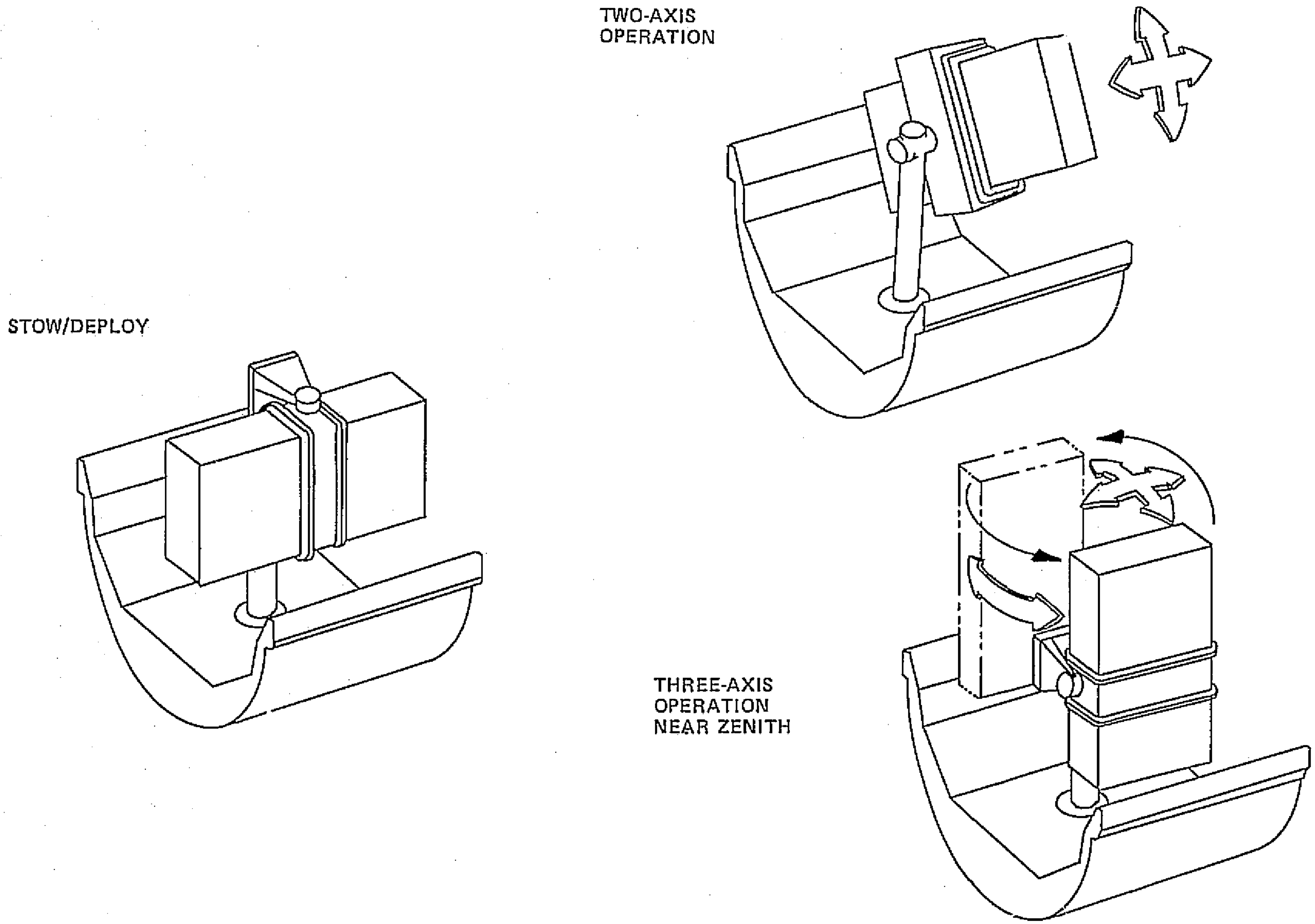


Figure 5.2.1-5. — AMPS pointing system operation.

TABLE 5.2.1-3.– SCIENTIFIC INSTRUMENT LOCATIONS

APS 1 (Pallet A-1)	
AIM 1A	AIM 1B
213 - Laser Sounder	1011 - Ultraviolet Occulation Spectrograph
532 - Gas Release Module	534 - Optical Band Imager and Photometer System
	1002 - Pryheliometer/Spectrophotometer
	550 - Level II Diagnostics (on boom)

APS 3 (Pallet A-3)	
AIM 3A	AIM 3B
116 - Airglow Spectrograph	122 - Ultraviolet-Visible-Near IR Spectrometer
118 - Limb Scanning Infrared Radiometer	124 - Fabry-Perot Interferometer
	126 - Infrared Interferometer

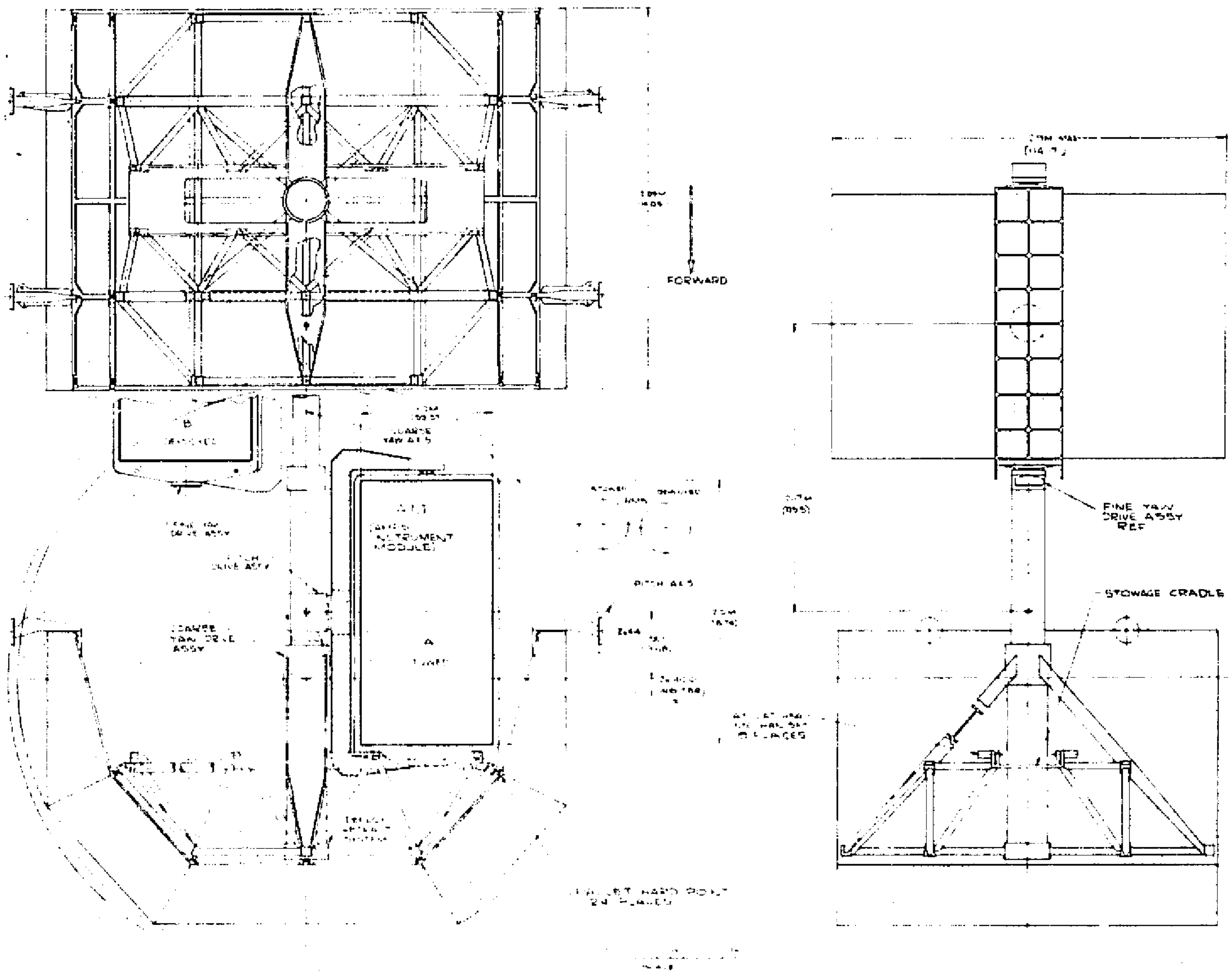


Figure 5.2.1-6. — AMPS pointing system (APS) mount.

cperate independently or in unison with each other. In addition, each of the two AIM's on each platform may operate at different pitch angles to one another and may point within 10 degrees of one another in yaw. All four AIM's are of the same size, therefore instruments may be interchanged as pointing requirements change.

The primary characteristics that dictate the instrument grouping are the instruments' weight, envelope, FOV, pointing accuracy, scanning requirements, and temperature control. These are tabulated in table 5.2.1-1. The AIM's housing these instruments provide thermal control, and contamination and acoustic protection. End covers are remotely operated to provide protection against contamination of optics and sensors. Each heated AIM is lined with multilayer aluminized kapton insulation. Heaters to maintain instrument temperatures to within ±2° C are mounted to the inner surface of the blankets. For those instruments requiring cooling, cold plates are mounted to the inner side of the AIM's. These in turn interface with the payload bay heat exchanger fluid loop (figure 5.2.1.7). The exterior surfaces of the AIM's are finished according to the thermal control desired. The coolant lines pass through the gimbals before interfacing with the payload bay heat exchanger fluid loop.

The experiment AIM's are attached to the yoke which provides the interface to the APS (figure 5.2.1-8). The yoke will accept AIM's of variable length and width. However, at the present all AIM's are 1 x 2 x 3 meters (3.28 x 6.56 x 9.84 feet). Lugs are provided to accept takeoff and landing restraint latches. The AIM's, with their associated sensors, are attached to the frame. Each of the two yokes are attached to the up-down (pitch) fine pointing drive. The two drives allow each AIM to be pointed independently of each other from 0 to 90° in pitch orientation with an accuracy

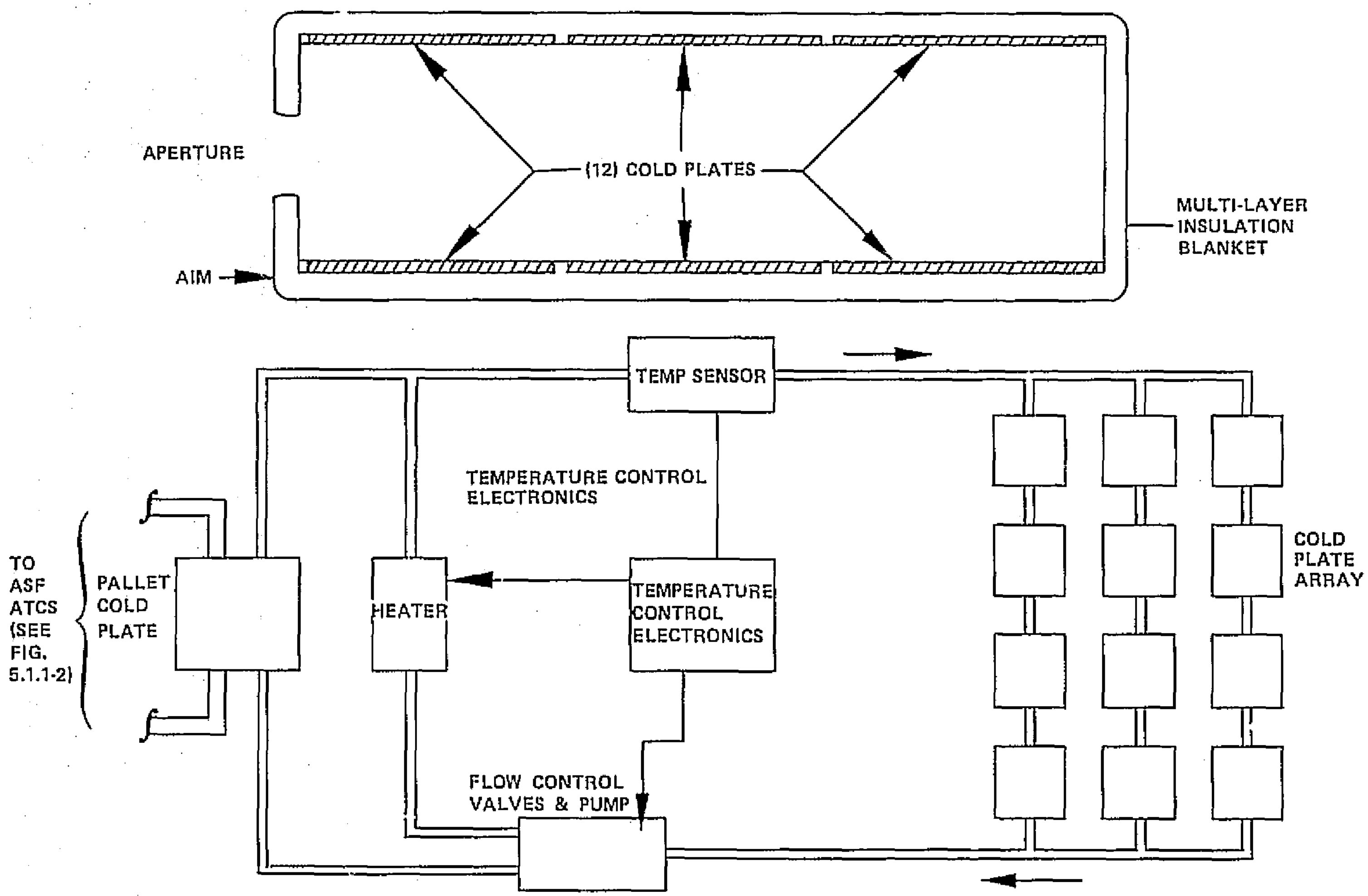


Figure 5.2.1-7. — Instrument/AIM thermal control.

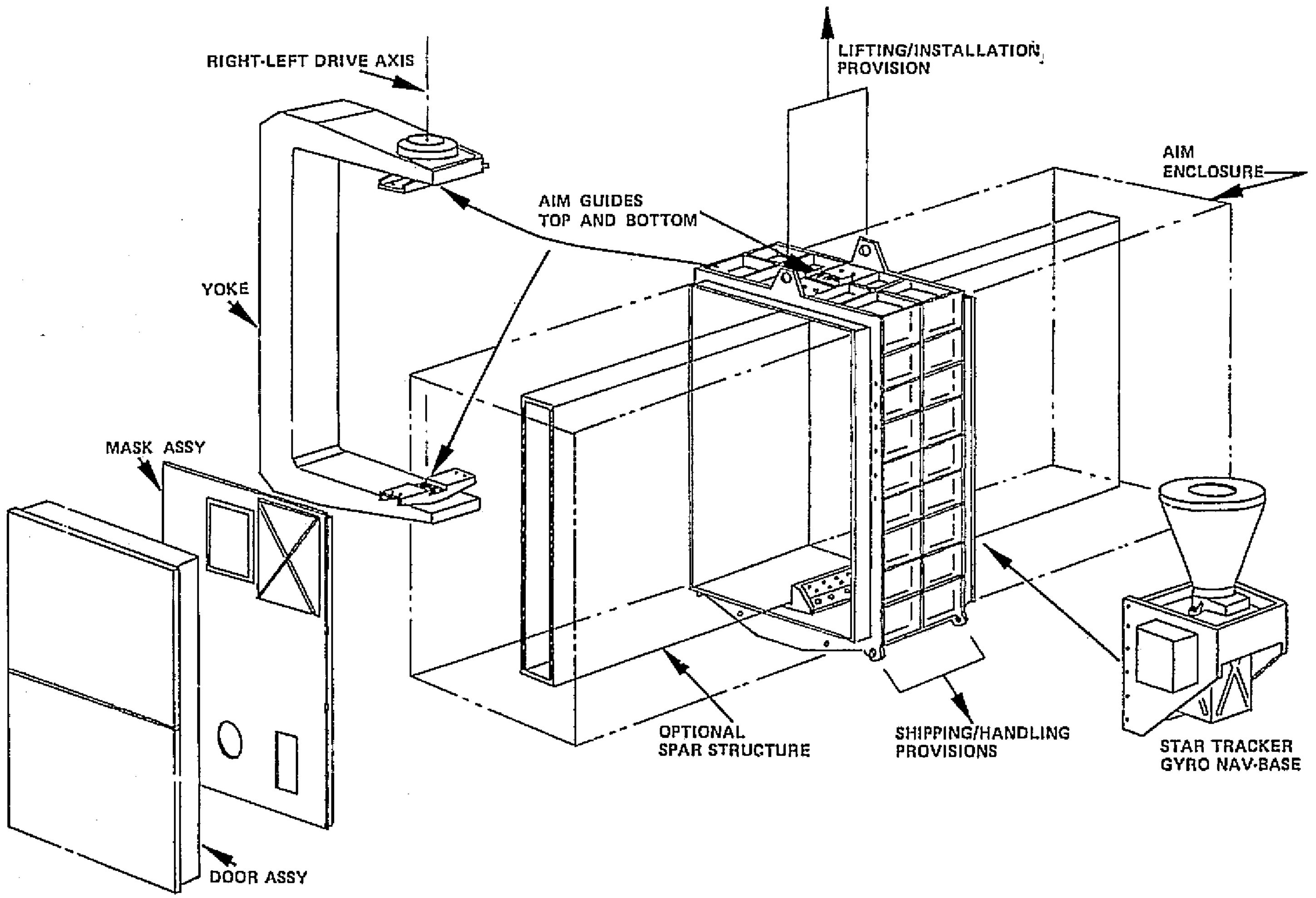


Figure 5.2.1-8. — AMPS instrument module (AIM).

potential better than one arc second. This capability would require sensors with greater accuracy than those planned for ASF. The two yokes revolve as a unit about the axis of the deploy-retract column to provide a coarse pointing maneuverability of 180° and an accuracy of six arc minutes. The slew rate of the combined gimbal system is 2 degrees/second.

The deploy-retract system elevates (figure 5.2.1-9) the telescoping central column through a ball screw jack from the stowed position to the fully extended position 2.15 meters (7.05 ft) high. This position allows the AIM's to be slewed within the gimbal envelope without Orbiter dimensional interference. Microswitches indicate full extension and retraction of the column. In the retracted position, eight solenoid actuated mechanical latches between the yoke and pallet mount prevent motion. Individual microswitches indicate latch position. In the event a latch fails in the extended position (gimbal frame locked) the individual latch may be separated with an explosive squib. Conversely, if one latch fails in the retracted position, two of the four are sufficient to enable the AIM to survive landing loads.

Direct drive brushless "pancake" dc torque motors are selected for the fine pointing gimbals because of their inherent frictionless characteristic and reliability. Brush type motors are selected for coarse pointing because of their high torque/weight and volumetric efficiency.

The total weight of the entire pointing system, not including instruments, is 1,100 kg (2,420 lbs). Each platform is capable of mounting two AIM's with instruments weighing 465 kg (1025 lb) per AIM.

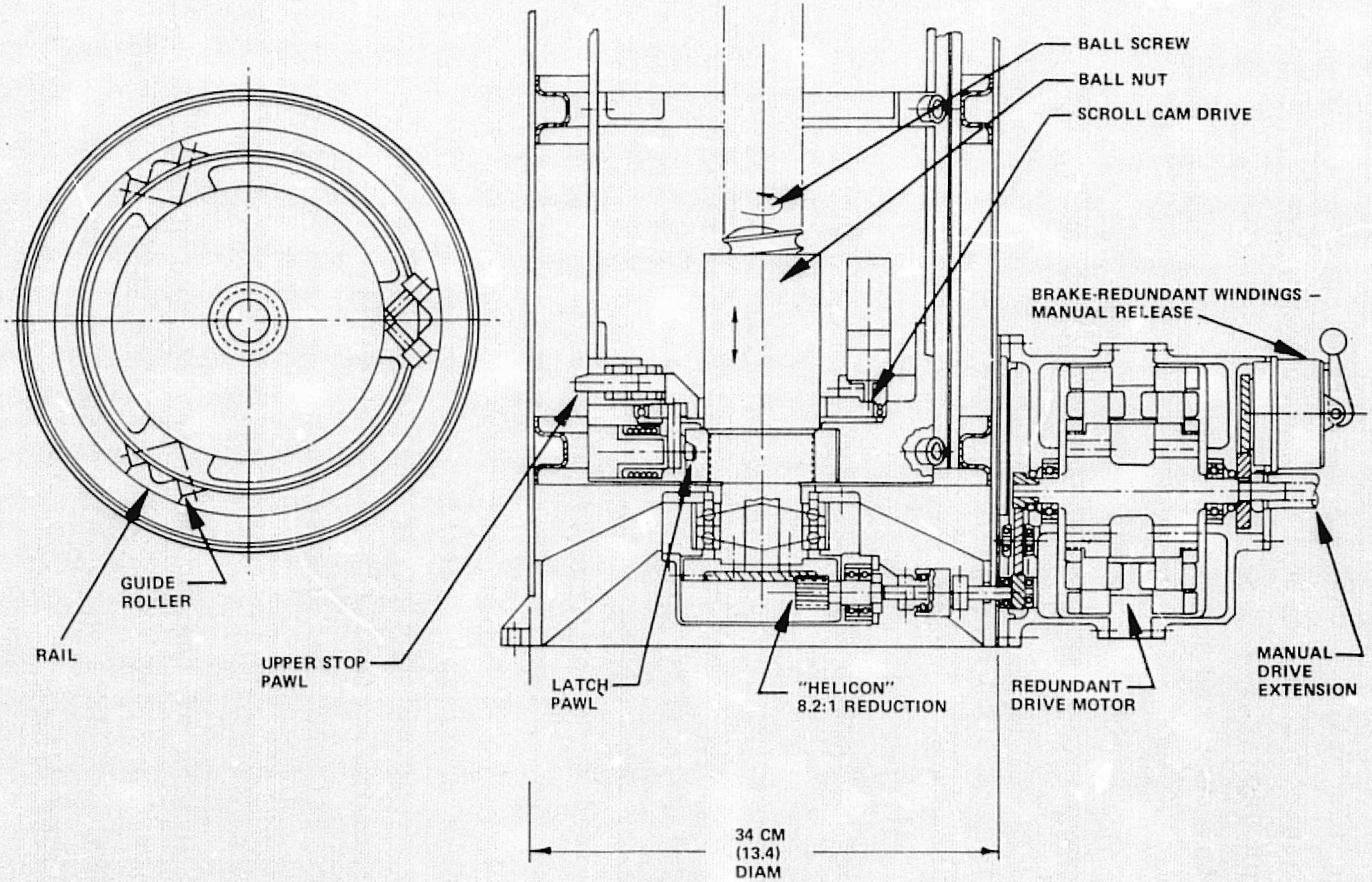


Figure 5.2.1-9. — Deploy-Retract system.

In the event a malfunction occurs in the pointing system which prevents the column from being retracted and/or locked in the landing position, the column may be separated from the mounting structure with explosive bolts and ejected from the payload bay through a spring mechanism.

The following three modes of operation are possible with the APS.

(1) The AIM's may be pointed using acquisition and fine tracking sun or star trackers.

(2) A preprogrammed subroutine may be initiated in the igloo payload computer through a PS keyboard entry. This is typically used to drive the APS in performing a raster scan utilizing the boom mounted Level II Diagnostics (Instrument 550).

(3) A two-axis displacement "joystick" provides a manual fine pointing capability. The attitude of the APS will be displayed on the cathode ray tube (CRT) at the PSS.

d. Instrument 550 Boom. Instrument 550 (Faraday cup, retarding potential analyzer, cold plasma probe) is installed on a furlable boom which is attached to the AIM 1B as shown in figure 5.2.1-10. The purpose of this boom is to allow the instrument to measure the particle energies and the exhaust beam plasma potential to establish Instrument 303 beam characteristics. These data will be used to support experiments using Instrument 303. In use, after the boom is extended, Instrument 550 is positioned by the APS at the desired elevation above the particle accelerator. Initiation of a preprogrammed subroutine accomplishes a raster scan of the accelerator beam field by yawing of the APS while the boom is extended or retracted to maintain the desired elevation.

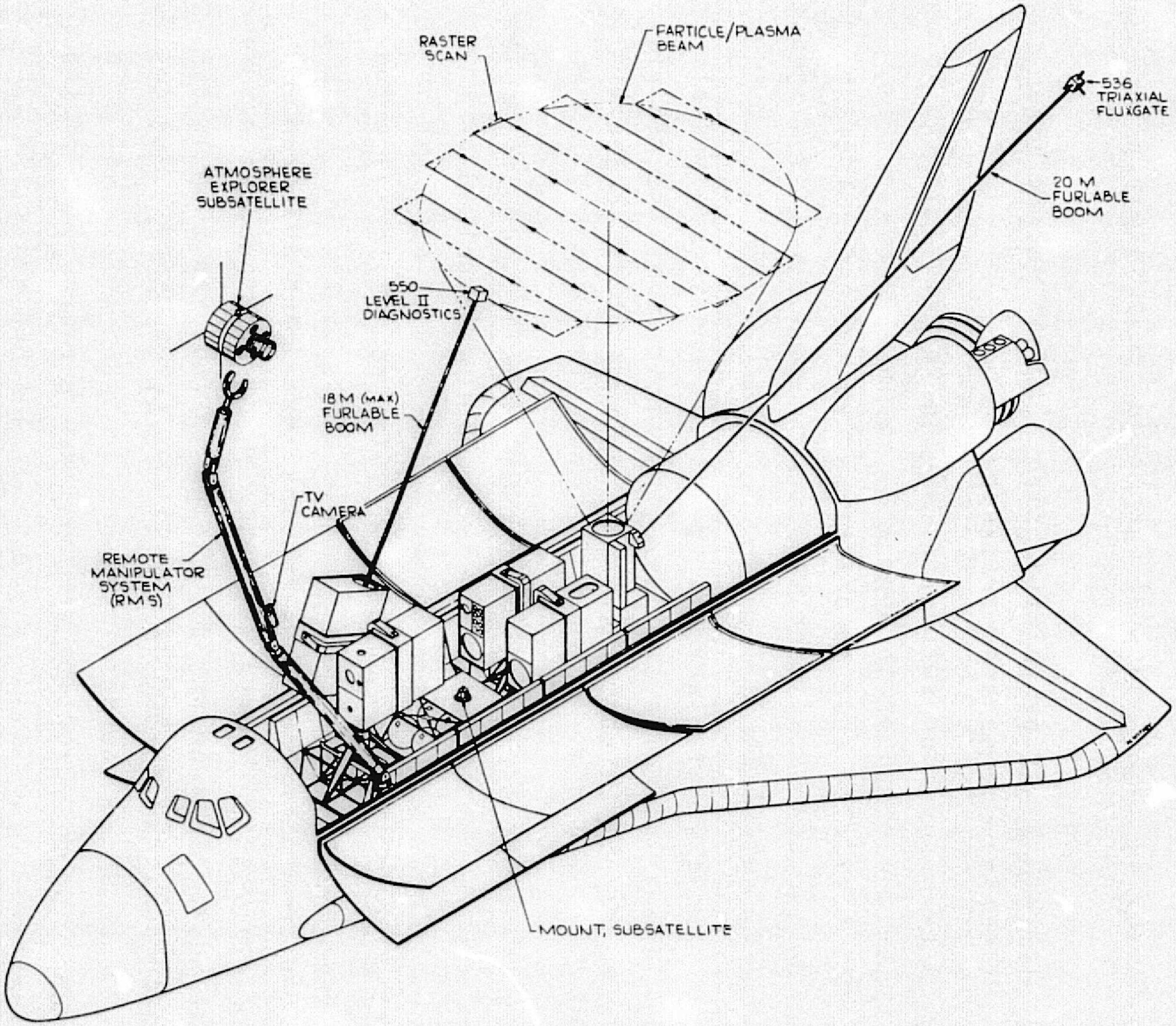


Figure 5.2.1-10. — Subsatellite retrieval and boom deployment.

The instrument must be capable of being completely removed from the accelerator beam except when calibration is being performed. Also the structure used to mount Instrument 550 must have minimum impact on accelerated particle beam characteristics.

The Storable Tubular Extendable Member (STEM) design has been selected for the ASF application. The STEM is a thin strip of metal heat treated into a circular overlapped cross section (figure 5.2.1-11). The bending strength of a STEM element is almost equivalent to that of a seamless tube to the same diameter and wall thickness. The element is stored on a drum by a flattening and rolling process, and very long lengths of tubular structure may be extended or retracted by rotating the drum in the appropriate direction.

A further development of this principle is a mechanism that employs two diametrically opposed "underlapped" elements as shown in figure 5.2.1-12. These BI-STEM elements are stored on two drums instead of one. This configuration offers several advantages over the STEM; the natural tendency of the STEM to warp because of the high compressive stresses built in during fabrication is eliminated and two drums instead of one allows a more compact deployment package (figure 5.2.1-13). The perforated BI-STEM boom is fabricated from precision rolled beryllium copper chosen for its excellent heat transfer characteristic combined with high strength-to-weight ratio. For Instrument 550, the 0.036 cm (.014") thick x 22.1 cm (8.7") wide strip is rolled and heat treated to form a 7.92 cm (3.12") diameter x 18 meters (59 ft) long tube. The tubes are then flattened back into strips and wound on spools for maximum compactness.

The geometric and thermal configuration controls the rate of absorption of heat on opposite sides of the boom, thus pro-

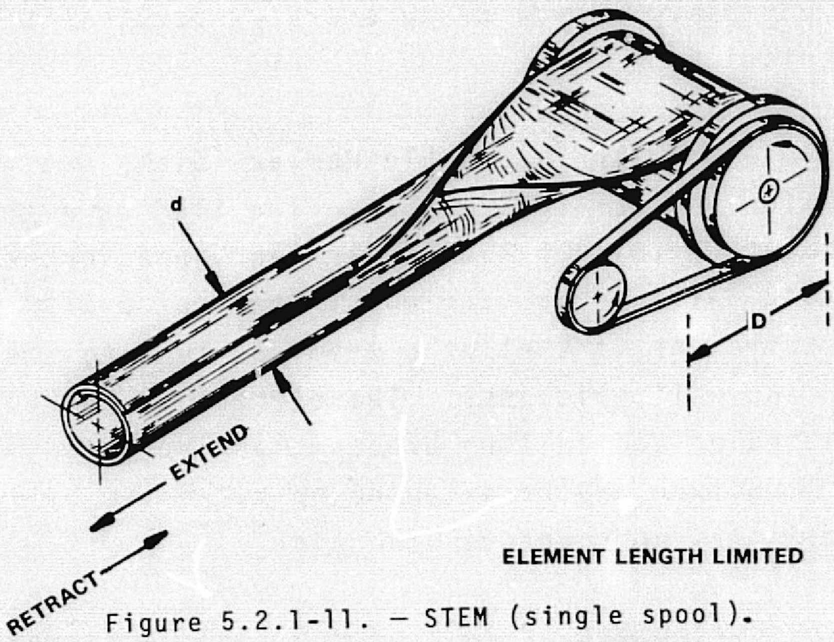


Figure 5.2.1-11. — STEM (single spool).

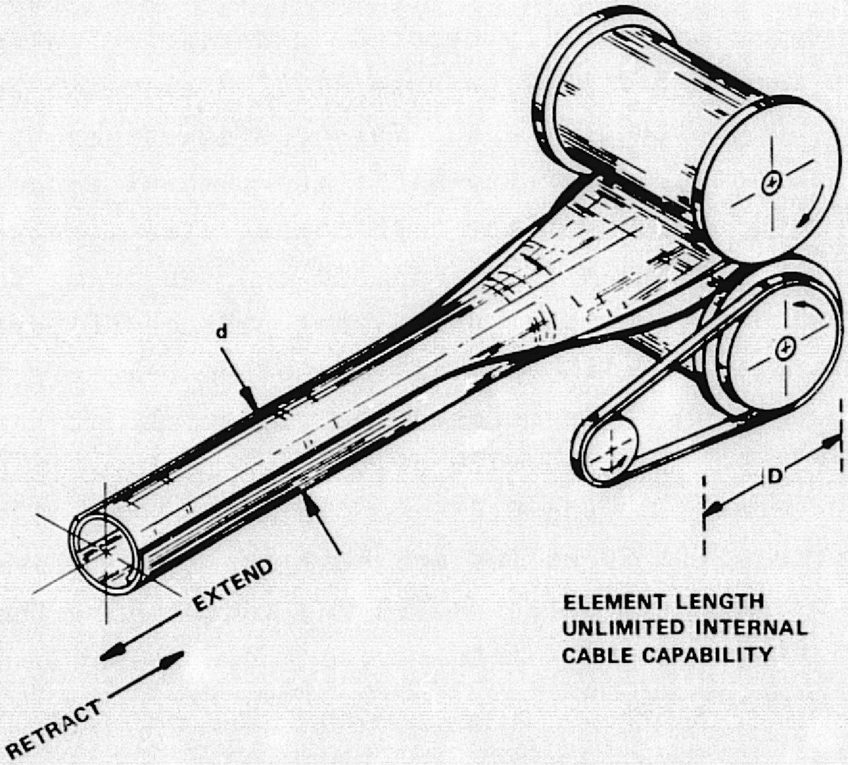


Figure 5.2.1-12. — BI-STEM (twin-spool).

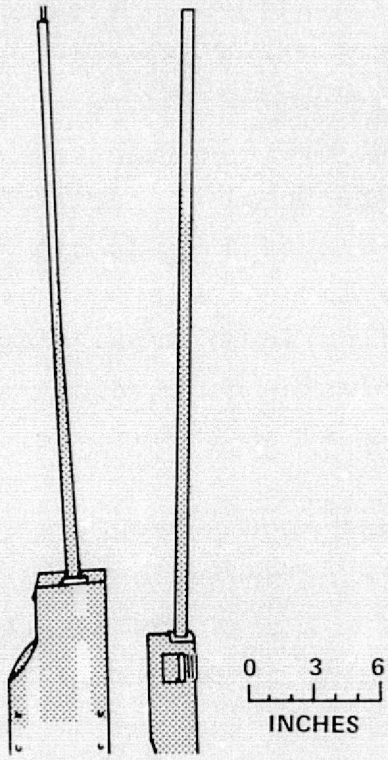


Figure 5.2.1-13. — STEM/BI-STEM element deployment comparison.

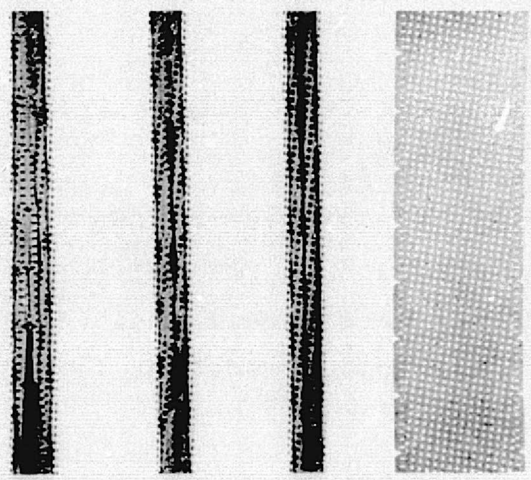


Figure 5.2.1-14. — Chemically milled strip.

ducing equal thermal expansions on opposite walls and avoiding thermal bending. A unique perforation pattern produced by chemical milling allows a selected amount of solar radiation to pass through the near wall of the boom and impinge on the far wall. This produces the same proportionality of inside to outside exposure for all incident angles of the sun. The perforation pattern consists of small circular holes arranged in a double helix pattern (figure 5.2.1-14). The ratio of absorptivities (outside to inside) is equal to the fractional area of wall cut out for windows. Polished silver plating is used on the outside while a black oxide coating is used on the inside.

The deployment mechanism provides a positive drive for both extension and retraction and contains a simple mechanism for joining the seams. A position potentiometer allows the boom for Instrument 550 to be precisely extended during raster scanning (figure 5.2.1-10). The wire harness is simultaneously deployed or retracted through the center of the boom. The combined weight of boom plus deployer is 28 kg (61.7 lb) for Instrument 550.

In the event the boom cannot be retracted, an explosive device is used to separate and eject the boom and allow closure of the payload bay doors.

Perforated BI-STEMS, similar to the one previously described, have been manufactured and successfully flown on various spacecraft by several aerospace firms. Therefore minimal time and effort are necessary to produce a flight-qualified unit meeting the desired specifications.

5.2.1.5.2.2 Pallet A-2

The PDS, which is deployed soon after mission orbit is achieved, is installed on Pallet A-2. In support of the subsatellite, the following equipment are also mounted on Pallet A-2.

a. Experiment RAU.

b. Subsystem RAU.

c. Power distribution box.

d. Deployment mechanisms.

e. Latch/unlatch mechanisms.

The following discussion is limited to the mounting, deployment, and latch/unlatch mechanisms for the subsatellite. The subsatellite is discussed in section 5.2.6 and the other equipment installed on Pallet A-2 are discussed in their respective sections.

Since the subsatellite is to be reused it is imperative that the deploy/retrieval/retention operations present a minimal possibility of damaging the subsatellite. Therefore, the subsatellite mount and grab ring must be designed with this objective in mind. Also, the retrieval operation must be as simple and foolproof as possible to prevent damage to adjacent structures by the subsatellite and remote manipulator arm while allowing retrieval to be accomplished in a minimum time period.

The configuration of a collet containing a cold gas velocity separation device is depicted in figures 5.2.1-15 and 5.2.1-16. The mechanism carries the tensile load of the subsatellite in the locked position. When the system is "armed" an explosive squid shears out a metal slug in the isolation valve and admits 25.8×10^6 N/m^2 (3750 psig) GN_2 to the inlet of the pilot valve. Energizing the "eject" switch fires the electrical harness guillotine and separates the wiring which was used to power and monitor the subsatellite. One hundred milliseconds later, gas pressure is introduced into the cylinder bore through the energized solenoid actuated pilot valve, causing the piston to move toward the collet and allowing the collet fingers to spring

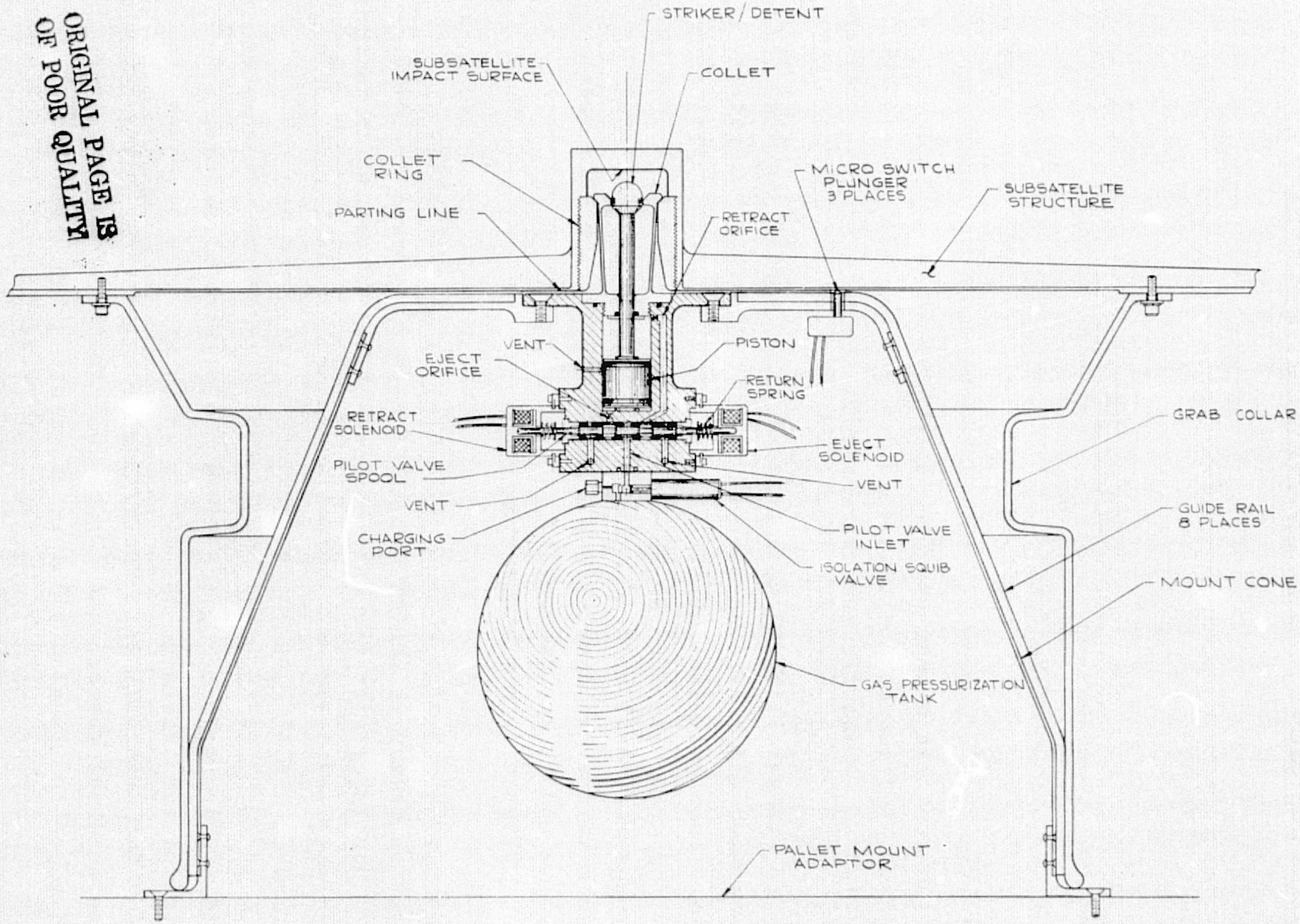


Figure 5.2.1-15. — Subsatellite retention/ejection mechanization.

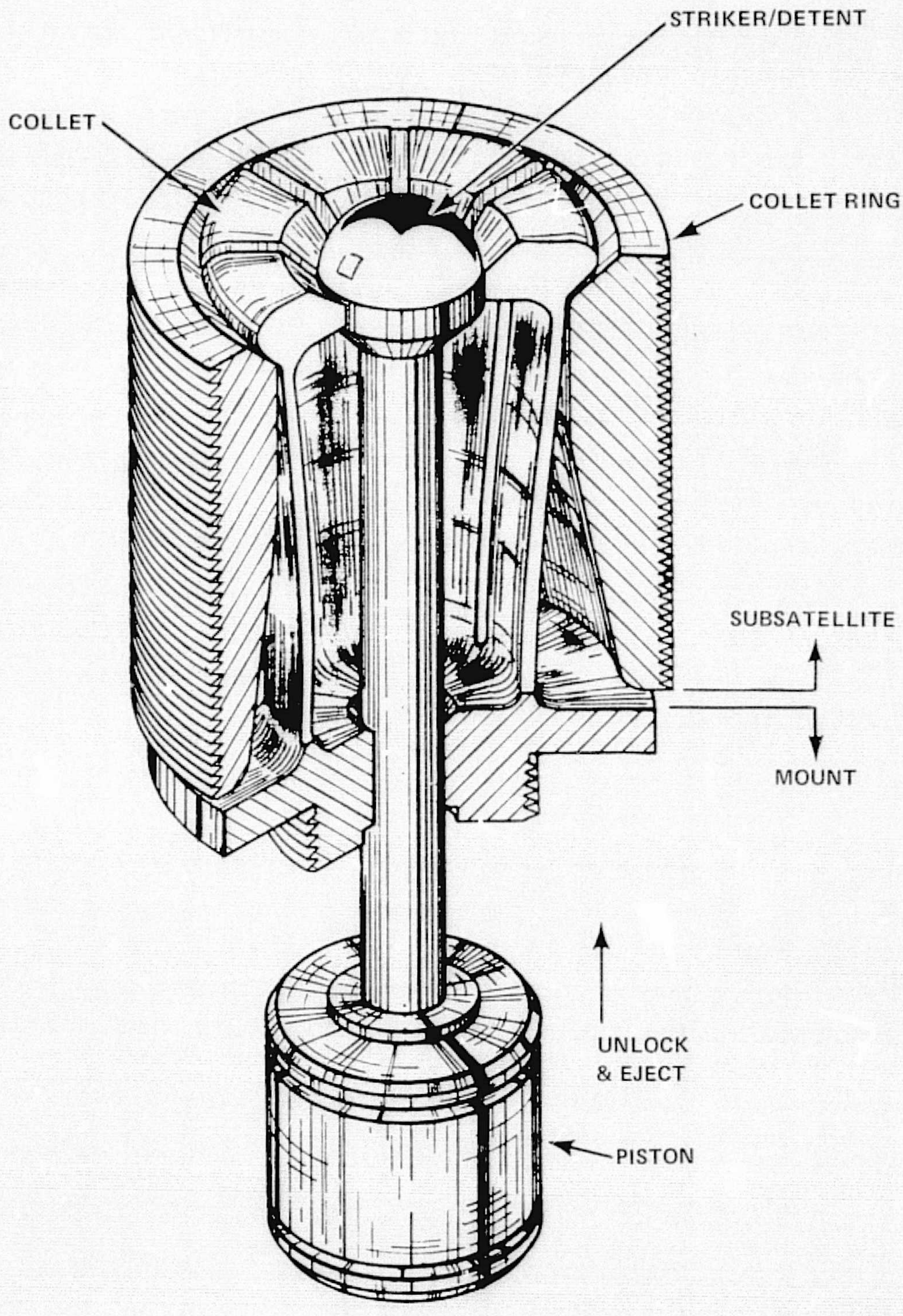


Figure 5.2.1-16. — Subsatellite retention/ejection mechanism.

inward due to their stored strain energy. The piston continues forward until it contacts the surface of the subsatellite where further expansion of the trapped gas causes the subsatellite to separate at the required velocity of 20 cm/sec. The subsatellite grab collar continues on teflon guide rails until free of the mount. The rails assure liftoff in a precise direction. The vent hole uncovered by the piston allows the trapped gas to escape.

During retrieval, the subsatellite grab collar is grasped with the remote manipulator claw and positioned on the mount cone. The tapered mount cone assists in maneuvering the subsatellite to the proper location on the pallet. When the three sensors at the top of the mount are simultaneously contacted, the grab cone is fully seated on the mount. Gas is then automatically admitted to the retract side of the piston through the solenoid pilot valve, retracting the collet piston and expanding the collet fingers, thereby locking the subsatellite on the mount. A.micro-switch indicates piston positions assuring that the piston is fully retracted and the collet locked.

5.2.1.5.2.3 Pallet A-4

Pallet A-4 is utilized to mount the Electron Accelerator (Instrument 303), MPD Arc (Instrument 304), Triaxial Fluxgate (Instrument 536), and the Gas Plume Release (Instrument 549).

In addition to the instruments, the following support equipment are installed on Pallet A-4.

a. Four experiment RAU's.

b. Two subsystem RAU's.

c. Power distribution box.

d. Boom and boom actuator mechanism.

Instruments 303 and 304 are hard mounted to the pallet. Since these instruments are high power users (5 kW, average) provisions will be made to install these instruments on cold plates and on thermal capacitors.

The Gas Plume Release (Instrument 549) is located internal to the Electron Accelerator and is used for the determination of accelerator-produced electron and ion beam flux densities and emergence angles by means of optical observations of the excitation of the released gas.

In order to map the earth's magnetic field it is necessary to extend the Triaxial Fluxgate (Instrument 536) a sufficient distance from the Orbiter to negate the magnetic interference of the vehicle. A furlable boom is used to accomplish this task. The boom is hard mounted to allow deployment at a 45° angle from the Orbiter Z axis in the Y-Z plane as shown in figure 5.2.1-10.

The basic design of the boom for Instrument 536 is similar to that described in paragraph 5.2.1.5.2.1 for Instrument 550. The boom for Instrument 536 utilizes the same BI-STEM technique and material (beryllium copper). The material is 0.005 cm (0.002") thick x 3.56 cm (1.4") wide and forms a 1.27 cm (0.5") diameter x 20 meters (66 ft) long tube. The combined weight of the boom and deployment mechanism is 2.4 kg (5.3 lb).

Automatic limit switches indicate full extension and retraction of the boom. As with the boom for Instrument 550, explosive devices are used to separate and eject the boom if the retraction mechanism fails.

5.2.1.5.2.4 Igloo

The igloo is a pressurized vessel containing support equipment for experiments on pallet-only mode Spacelab missions.[1] It is being

[1]Spacelab Payload Accommodations Handbook. ESTEC SLP/2104, May 1975.

developed by the ERNO consortium under the direction of ESRO/ESTEC with the intent that it also be provided as a standard off-the-shelf module for other pallet-only mode users.

The igloo provides a convenient centralized location for those equipment which must service all of the pallet-mounted instruments. It is mounted off the edge of the front pallet, therefore does not take up pallet space required by the instruments. It also provides a pressurized environment for laboratory type equipment not designed to operate in vacuum. Most, if not all, interfaces between the pallet-mounted equipment and the Orbiter interfaces at station Xo 14,630.4 mm (576 in) will be provided through the igloo.

For ASF mission applications, the following CDMS and EPDS equipment will be mounted within the igloo for the pallet-only mode:

a. CDMS equipment.

    (1) 3 computers.

    (2) 2 Input/Output (I/O) units.

    (3) 1 mass memory.

    (4) 3 subsystems RAU's.

    (5) 1 payload C&W logic electronics.

    (6) 1 experiment A&A electronics.

b. EPDS equipment.

    (1) Experiment inverters.

    (2) 1 emergency battery.

    (3) 1 power control box.

    (4) 1 secondary power distribution box.

The design of the igloo is such that no changes are necessary for ASF missions. Necessary wiring and ducting are permanently installed and the built-in environmental control system will provide an environment of 15 to 30°C with a heat rejection capability of 1.5 kW (5,115 Btu/hr).

Connectors for power supply and data lines are provided at the removable bulkhead.

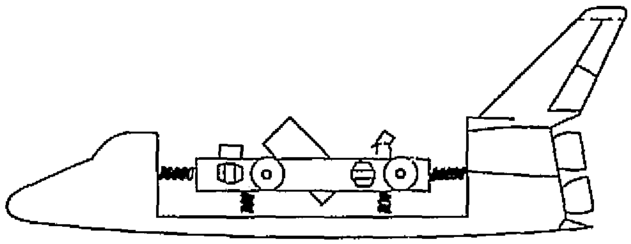
The usable volume for equipment accommodation is approximately 0.7 cu. m. (20.6 cu ft) and equipment weights up to 290 kg (641 lb) can be accommodated. The equipment will be mounted on platforms which are adjustable in their relative position to accommodate various sizes of equipment.

5.2.1.6 Analyses and Trade Studies

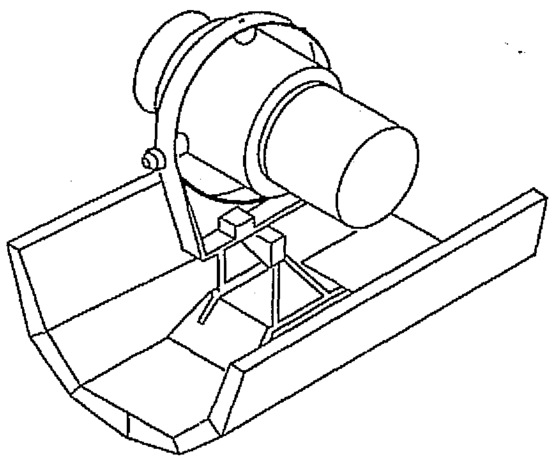
5.2.1.6.1 AMPS Pointing System

Several different concepts were investigated for pointing platforms. Among these was the ERNO IPS utilizing ring gimbal versus inside out and suspended control moment gyro controlled platforms (figure 5.2.1-17), the Ball Brothers, Small Instrument Pointing System (SIPS) was used only for the purpose of establishing conceptual feasibility, mainly because of its versatility. Other systems available in the time frame for ASF missions (1981) will be considered during subsequent phases.

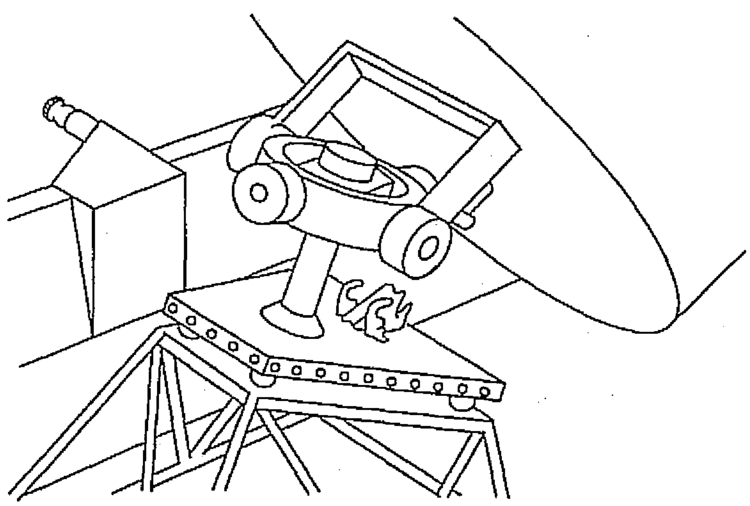
Instruments contained within AIM 1A may be pointed at different elevation angles to those contained within AIM 1B. In addition, APS 1 (AIM's 1A and 1B) may be pointed independent of APS 3 (AIM's 3A and 3B). The variety of pointing choices between instruments is obvious using this method. Also since the AIM modules are of the same size, instruments may be interchanged as requirements vary. Figure 5.1.1-5 shows the wide range of pointing which can be accomplished with the AIM's.



SOFT MOUNTED, CMG-CONTROLLED PALLET



TYPICAL RING GIMBAL SYSTEM



INSIDE–OUT GIMBAL SYSTEM

Figure 5.2.1-17. — Candidate pointing platform study concepts.

5.2.1.6.2 Booms

The BI-STEM boom configuration was chosen over the Quasi-Biconvex, fiberglass coilable lattice, and articulated lattice because of its inherent thermal bending stability. One of the design requirements is a static deflection angle of less than 0.5 degree to allow determination of the position of the Instrument 550 through the interrogation of the attitude of the boom base. Solar radiation on one side of the boom combined with the deep space view on the other creates a severe differential thermal bending problem. The geometric and thermal configuration of the perforated BI-STEM allows solar radiation to pass through the near wall of the boom and impinge on the far wall thus producing equal thermal expansion of opposite walls and avoidance of thermal bending. Table 5.2.1-4 compares candidate materials.

The boom payload (Instrument 550) will deviate from its theoretical position while being scanned because of the acceleration force imposed on it. If the error angle is limited to 0.5 degree, the actual position of Instrument 550 may differ 15.7 cm (6.2") from the position measured by the pointing platform (APS). In a weightless environment the acceleration causing this force and thus the deflection is 0.152 m/sec^2, 0.5 ft/sec^2.

The scan period is defined as the time to traverse the maximum accelerator beam field. The boom is accelerated at the maximum rate which will not exceed the 0.5 degree allowable deviation error to a point midway across the 10 meter scan field where it will then be decelerated at the same rate to zero for the completion of one scan line. The total traverse time for one scan line is found to be 29.6 sec. Therefore, the beam may be accurately scanned in either of two methods:

a. Since acceleration is theoretically constant, deflection is constant and may be calibrated out.

b. The boom may be positioned and the accelerator discharged. The boom is then moved to a new position and the accelerator

TABLE 5.2.1-4.— BOOM CANDIDATE MATERIALS

Materials	Yield Strength/ Density @ 70°F in X 10^3	Yield Strength/ Density @ 400°F in X 10	Thermal Conductivity BTU in/Ft^3 -Hr°F	Thermal Expansion (in/in°F)X10^{-6}	Magnetic
Beryllium Copper 25	(605)	(537)	(750)	(9.3)	No
Stainless Steel					
17-7 PH	(656)	(585)	(146)	(9.5)	Yes
PH15-7Mo	(710)	(656)	(146)	(8.5)	Yes
Maraging Steel 300	(1003)	(865)	(138)	(5.6)	Yes
Titanium Ti-6Al4V	(938)	(812)	(50)	(4.9)	No
Inconel-X	(419)	(386)	(83)	(7.0)	No
Aluminum 7075-T6	(660)	(300)	(1580)	(13.1)	No

again discharged. This will provide a dot matrix rather than a line matrix.

No time period has been allowed for a boom settling-out period because of the unknown damping characteristics of the boom.

The curvature of the boom is found by writing an expression for the strain energy due to bending and thermal gradients and finding the curvature required to make it a minimum.

Assumptions:

(1) Window pattern distributes radiation to back side of boom regardless of orientation.

(2) Axial temperature variation along boom surface is < 10°F at any instant.

(3) Inside surface coating reflects diffusely.

(4) Conductivity along seam is same as elsewhere.

$$\frac{1}{R_s} = \frac{erJs}{2K't}(1-A_W)(\alpha_o - A_W\alpha_i)\sin\theta$$

where:

R_s = radius of curvature due to solar irradiation

e = coefficient of thermal expansion

r = radius of boom

J_s = solar radiation flux

K' = effective conductivity of boom considering effect of hole pattern

t = strip thickness

A_W = fractional window area of holes

α_o = solar absorptivity of outer surface

α_i = solar absorptivity of inner surface.

θ = angle between boom axis and solar flux.

If a perforation or window area is chosen such that

$A_w = \frac{\alpha_o}{\alpha_i}$ then thermal bending can be eliminated.

α_o for outer surface = 8 percent for polished silver.

α_i for inner surface = 95 percent for flat black

then A_w = 8 percent.

But, assume half the radiation passes through holes in the backside of the boom,

then A_w = 16 percent.

Test results have shown actual thermal bending to be very close to theoretical calculations, especially if degradation of the silver plating is accounted for.

5.2.1.6.3 Subsatellite Separation

The devices normally used for separation include linear explosives (flat linear shaped charge, mild detonating fuse, primer cord, and various encapsulated designs), explosive bolts and nuts, V-band clamps, ball locks, pin pullers, and cable cutters. The devices normally used to perform an ejection function and/or obtain separation velocity include springs, thrusters, retro-rockets, and hot or cold gas systems. A limited evaluation of the advantages and disadvantages of these candidate systems as related to the subsatellite mount requirements is presented in table 5.2.1-5. The selection of separation devices quickly narrows down to the ball-lock and the collet mechanisms which are the only mechanisms which can be reused. The obvious advantage is the combination of

TABLE 5.2.1-5.– SEPARATION AND EJECTION DEVICES

	Separation Devices								Ejection Devices				
	Linear Explosive	Contained Linear Explosive	Explosive Bolts/Nuts	Ball Lock	V-Band	Pin Puller	Cable Cutter	Collet Mechanism	Springs	Thruster	Rockets	Hot/Cold Gas	Contained Cold Gas
Load capability	E	G	E	G	E	G	G	E	-	-	-	-	-
Uniform load	E	E	G	G	E	P	P	G	-	-	-	-	-
Minimum shock	P	P	G	E	E	P	G	E	P	G	E	E	E
Minimum impulse	P	P	P	E	E	E	E	E	-	-	-	-	-
Minimum tipoff	P	P	G	E	G	E	E	E	G	P	G	E	E
No contamination	P	E	G	E	E	E	E	E	E	G	P	G	E
No debris	P	E	G	E	G	E	E	E	E	E	P	E	E
Maintainability	P	P	G	E	E	G	G	E	E	P	P	P	G
Reusability	P	P	P	E	P	P	P	E	E	P	P	P	G
Safety	P	P	G	E	E	E	E	E	E	P	P	P	G
High reliability	G	G	E	E	E	E	P	E	E	P	E	G	G
Minimum weight	P	P	E	G	G	E	G	G	P	G	E	G	G
Minimum volume	G	G	E	G	G	G	E	G	P	P	E	G	G
Survival of temp extremes	P	P	G	E	G	G	G	E	G	G	P	P	G
Survival of radiation	P	P	G	E	E	E	E	E	E	P	G	G	G
Minimum ΔV	-	-	-	-	-	-	-	-	E	E	E	E	E
Predictable ΔV	-	-	-	-	-	-	-	-	P	P	G	E	E

Note: E = Excellent
G = Good
P = Poor

separation and retrieval/retention mechanisms in one unit. Of these two, the collet offers the higher load bearing capability. This factor is significant in that only one mechanism in the center of the mount is necessary for separation/retention.

Selection of an ejection device eliminated thruster, rockets, and expelled hot/cold gas because of debris and contamination. Contained cold gas was chosen over a spring because of the spring's higher weight and shock characteristics and lesser ΔV predictability. Furthermore, a device to retract the spring prior to retrieval would be necessary with this concept.

The fingers of the collet are analyzed as a cantilevered beam with an initial deflection and an axial load equivalent to controlled crash conditions.

The equation for the total stress for a trapezoidal finger cross section is found to be:

$$S_{total} = S_{axial} + S_{initial}$$

$$S_{total} = \left[\frac{WG}{\pi t(D_o - t - 0.019 \text{ in})}\right] + \left[\frac{3ES}{L^2}\left(\frac{2\sin\left(\frac{\pi}{n}\right)\left(R_o^{\,3} - R_i^{\,3}\right)}{3\left(\frac{\pi}{n}\right)R_o^{\,2} - R_i^{\,2}} - R_i \cos\frac{\pi}{n}\right)\right]$$

where

W = weight of the satellite

G = crash "G" load in +X direction = 9

D_o = outside diameter = 2.54 cm (1")

D_i = inside diameter = 2.22 cm (0.875")

E = modulus of elasticity = 19.3×10^{10} N/M^2 (28×10^6 psi)

n = number of fingers = 8

L = finger length = 5.08 cm (2")

S = initial finger deflection = 0.254 cm (0.100")

The stress analysis of the collet fingers for a 6,124 kg (13,500 pound) load shows a stress of 7.5 x 10^8 N/M^2 (108 kpsi). Using 4340 steel with ultimate strength 12.6 x 10^8 N/M^2 (182 kpsi), the margin of safety is:

$$M.S. = \frac{128}{76} - 1$$

$$= \underline{\lfloor 0.69}$$

This margin of safety is more than adequate considering the fact that the finger was analyzed as a perfect cantilever neglecting the effect of the collar.

The collet mechanism, compressed gas and actuator are analyzed in three steps:

a. Isentropic expansion of gas after pilot valve actuation.

b. Unlocking collet mechanism (initial 0.635 cm (0.250") movement of piston).

c. Power stroke (continued movement of piston against satellite surface).

The subcritical mass flow of a perfect gas is:

$$w = 8.02\ A\left\{\left(\frac{Pt}{V_t}\right)\left(\frac{K}{K-1}\right)\left[\left(\frac{2}{K+1}\right)^{\left(\frac{2}{K-1}\right)} - \left(\frac{2}{K+1}\right)^{\left(\frac{K+1}{K-1}\right)}\right]\right\}^{\frac{1}{2}}$$

where:

A = piston area - 5.08 cm^2 (0.785 in^2)

V_t = tank volume - 0.0018 m^3, D = 15.2 cm (113 in^3, D=6")

P_t = tank pressure - 2.58 x 10^6 N/M^2 (3750 psig)

w = gas mass flow-gram/sec (pounds/sec)

K = gas constant

The piston velocity using the impulse-momentum relationship is:

$$\overline{V}_p = \frac{P_r A \Delta t + I_o}{M_s}$$

where:

Δt = time for satellite separation, sec

I_o = initial impulse of piston, N sec (pound sec)

M_s = satellite mass, kg (slugs)

P_r = pressure at release conditions, N/M^2 (pounds/inch^2)

V_p = velocity of piston, m/sec (ft/sec)

The pneumatic analysis shows that operating from a 25.8 x 10^6 N/M^2 (3750 psi), 12.5 cm (6") diameter sphere, the desired separation velocity of 20 cm/sec is achieved.

Adequate GN_2 pressure remains for approximately 10 latchings after satellite retrieval.

5.2.1.6.4 Mass Properties

Tables 5.2.1-6 and 5.2.1-7 show the overall mass properties of the ASF payload. All pallet-mounted hardware is included. Items of relatively small mass (RAU's, heat exchangers, etc.) have been included in the mass properties of the pallet.

TABLE 5.2.1-6.- WEIGHT AND BALANCE

Component	Weight		Orbiter Coordinates							
			X		Y		Z		Z* (Deployed)	
	lb	kg	in	mm	in	mm	in	mm	in	mm
Pallet 1 + Igloo	1,065	483.0	743.9	18,895	5.6	142.0	359.1	9,121		
Igloo electronics**	702	318.3	668.8	16,998	0	0	344.0	8,738		
APS	2,426	1100.0	744.5	18,910	0	914.0	387.0	9,830	412.0	10,465
AIM 1A	1,023	464.0	744.5	18,910	-36.0	914.0	419.7	10,660	493.7	12,540
AIM 1B	631	286.0	744.5	18,910	+36.0	914.0	419.7	10,660	493.7	12,540
RAU (8)	48	21.6	744.5	18,910	0	0	419.7	10,660	493.7	12,540
J-Box (2)	9	4.0	691.5	17,564	0	0	347.0	8,814		
Coldplates, thermal capacitors (2)	86	39.0	786.8	19,985	0	0	358.0	9,093		
Sun sensor	55	25.0	796.0	20,218	24	610.0	351.0	8,915		
Totals	6,044	2740.9	736.6	18,710	-1.1	-28.0	385.5	9,792	416.4	10,577
Pallet 2	944	428.0	862.5	21,908	5.7	145.0	359.1	9,121		
Subsatellite	1,548	702.0	892.0	22,657	0	0	410.0	10,414		
Launch mechanism	22	10.0	892.0	22,657	0	0	381.5	9,690		
RAU (2)	12	5.4	875.0	22,225	0	0	347.0	8,814		
J-Box (2)	9	4.0	809.5	20,561	0	0	347.0	8,814		
Cryogenic Tanks (4)	650	295.0	845.0	21,463	0	0	360.5	9,157		
Structure	100	45.0	864.5	21,958	0	0	364.5	9,258		
Totals	3,285	1489.4	873.1	22,177	1.6	41.0	382.7	9,721		
Pallet 3	944	428.0	980.5	24,905	5.7	145.0	359.1	9,121		
Coldplates, thermal capacitors (2)	86	39.0	1022.8	25,979	0	0	358.0	9,093		
J-Box (2)	9	4.0	927.5	23,559	0	0	347.0	8,814		
RAU (7)	42	18.9	980.5	23,905	0	0	419.7	10,660	493.7	12,540
APS	2,426	1100.0	980.5	24,905	0	0	387.0	9,830	412.0	10,465
AIM 3A	728	330.0	980.5	24,905	-36.0	-914.0	419.7	10,660	493.7	12,540
AIM 3B	796	361.0	980.5	24,905	36.0	914.0	419.7	10,660	493.7	12,540
Star Tracker, gyros, etc.	183	83.0	977.5	24,829	52.5	1334.0	400.5	10,173	465.4	11,821
Totals	5,214	2363.9	981.0	24,917	3.3	85.0	391.7	9,949	427.8	10,867
Pallet 4	944	428.0	1098.5	27,902	5.7	145.0	359.1	9,121		
Coldplates, thermal capacitors (10)	428	194.0	1098.5	27,902	0	0	358.0	9,093		
J-Box (2)	9	4.0	1045.5	26,566	0	0	347.0	8,814		
RAU (6)	36	16.2	1104.2	28,047	-9.5	-241.0	347.0	8,814		
Power unit	99	45.0	1066.0	27,076	19.7	-500.0	374.8	9,520		
Capacitor bank	1,191	540.0	1104.4	28,052	9.0	229.0	355.5	9,030		
High voltage	243	110.0	1104.4	28,052	-19.7	-500.0	385.0	9,779		
Instrument 304	89	40.5	1089.8	27,681	-19.7	-500.0	443.7	11,270		
Instruments 303/549	89	40.5	1104.4	28,052	10.2	259.0	423.6	10,759		
Instrument 536	17	7.5	1118.2	28,402	-37.4	-950.0	463.8	11,781		
Totals	3,144	1425.7	1100.1	27,943	-1.0	-25.4	364.7	9,263		
Pallet 1	6,044	2740.9	736.6	18,710	-1.1	-28.0	385.5	9,792	416.4	10,577
Pallet 2	3,285	1489.4	873.1	22,177	1.6	41.0	382.7	9.721		
Pallet 3	5,214	2363.9	981.0	24,917	3.3	85.0	391.7	9,949	427.8	10,867
Pallet 4	3,144	1425.7	1100.1	27,402	-1.0	-25.4	364.7	9,263		
ASF Totals	17,687	8019.9	898.6	22,825	0.7	18.0	383.1	9,731	404.3	10,269

**This includes: 3 computers (31.8 kg each), 2 I/O units (31.8 kg each), Mass Memory (27.3 kg), 3 RAU (2.7 kg each), C&W logic (3.6 kg), Power distribution (6.0 kg), Power control (5.0 kg), Emergency battery (78 kg), 400 Hz inverter (110.3 kg), and A&A logic (3.6 kg).

TABLE 5.2.1-7. — WEIGHT AND BALANCE, PAYLOAD ON PALLETS AND PAYLOAD CHARGEABLE SUPPORT HARDWARE

Component	Weight		Orbiter Coordinates							
			X		Y		Z		Z'	
	lb	kg	in	mm	in	mm	in	mm	in	mm
ASF Pallets	17,687	8,019.9	898.6	22,825	0.7	18	383.1	9,731	404.3	10,269
Radiator Panels*	193	87.5	1213.1	30,813	0	0	472.8	12,009	404.7	10,279
Mission Kit-O_2 Tanks	2,254	1,022.2	1115.5	28,334	0	0	300.8	7,640		
-H_2 Tanks	874	396.3	949.3	24,112	0	0	300.8	7,640		
OMS Kit	2,978	1,350.6	1249.5	31,737	0	0	388.0	9,855		
Payload Specialist Station	405	185.0	540.5	13,729	-53.5	1359	446.0	11,328		
ASF Mission Total	24,391	11,061.5	959.8	24,379	-0.4	-10	374.9	9,523	389.7	9,899

*This includes the two aft panels only.

Note: Total weight does not include cable harnesses.

The Orbiter imposes strict CG location constraints to allow an aborted launch condition, in addition to enabling a safe landing. Figures 5.2.1-18, 5.2.1-19, and 5.2.1-20 show the location of the composite CG within the CG limitations imposed by the Orbiter. The shaded areas of each envelope indicate the launch condition constraints when overall Orbiter mass is greater than the landing mass (expendables, non-returnable satellites, etc.)

The coordinate system utilized in tables 5.2.1-6 and 5.2.1-7 and figures 5.2.1-18, 5.2.1-19 and 5.2.1-20 is that of the Orbiter; Station Z_0 = 1016 cm (400 in) is the geometric centerline of payload bay envelope and the Station X_0 - 1478.3 cm (582 in.) is the forward edge of the envelope.

As shown in the three figures, the ASF composite payload CG falls well within the Orbiter constraints.

5.2.1.7 Conclusions and Recommendations

5.2.1.7.1 Conclusions

Study results indicate that in the area of active thermal control, the capabilities of the ASF coolant system and the Orbiter ATCS exceed the expected ASF thermal dissipation (29,500 Btu/hr capability versus 24,000 Btu/hr expected). The ASF coolant system will utilize the ERNO designed cold plates, thermal capacitors, pumps and the Orbiter heat exchanger. Conventional passive thermal control techniques will provide greater flexibility in the design and allow better control of dissipation paths.

Cryogenic cooling of instruments 118 and 126 presents the greatest challenge for thermal control. The study results indicate that a closed loop cryogenic system is not practical on the basis of electrical power required if the instruments' housings are to be cooled (more than 5 kilowatts of power are estimated to be required). An open loop system requires considerably less

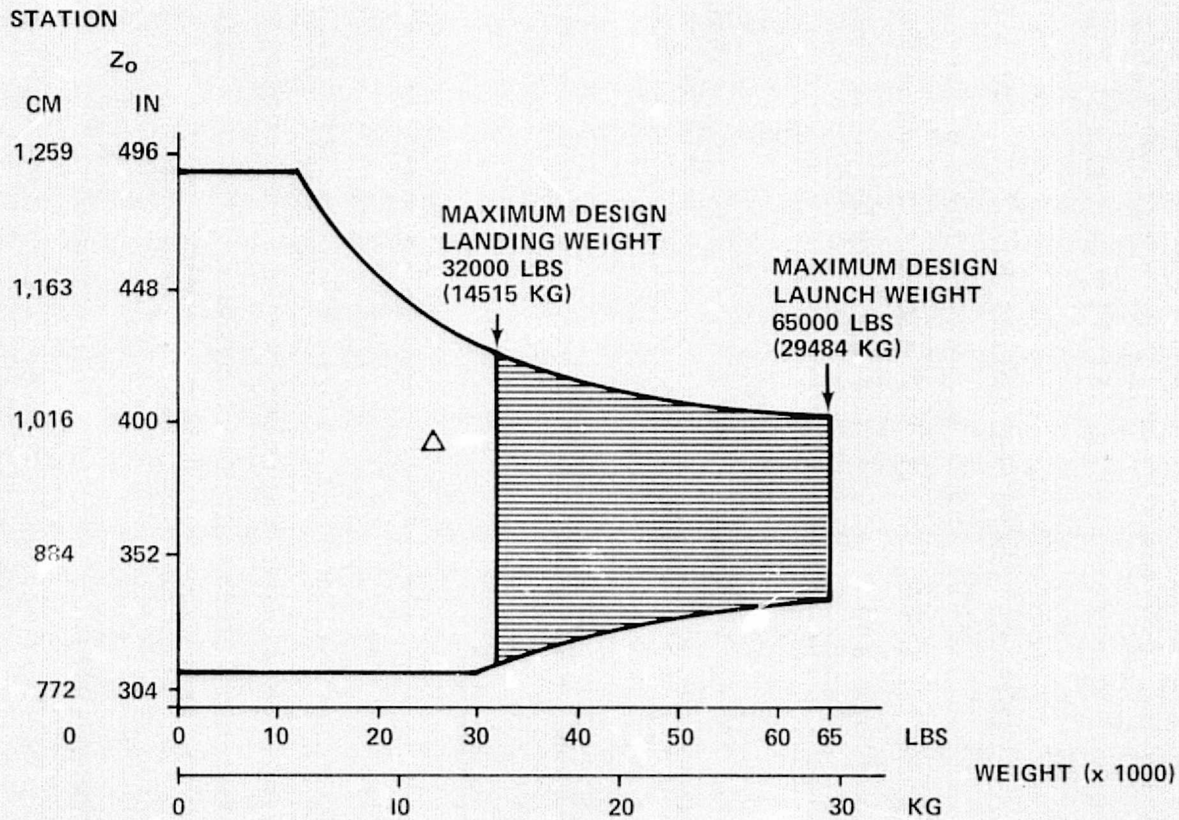


Figure 5.2.1-18. — Z-axis CG location.

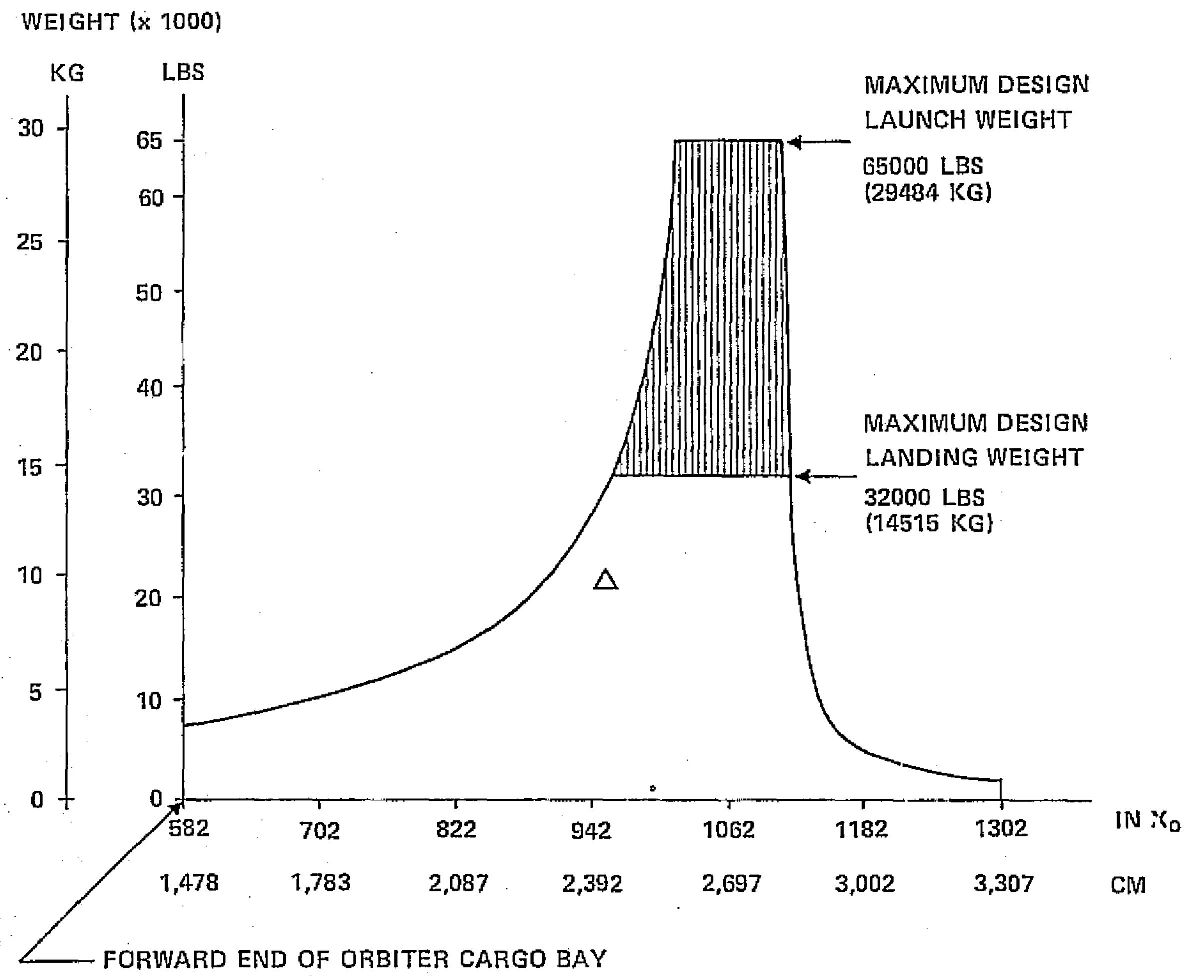


Figure 5.2.1-19. — X-axis CG location.

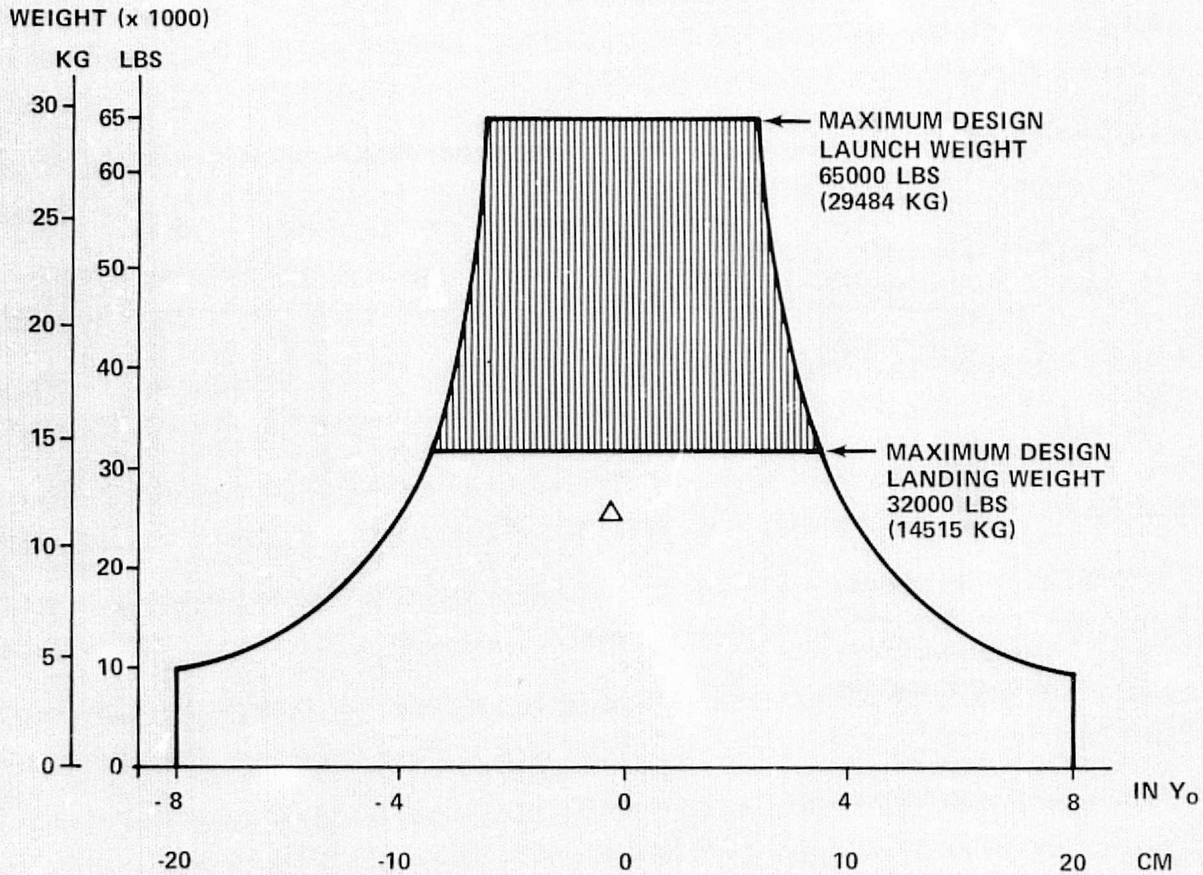


Figure 5.2.1-20. — Y-axis CG location.

electrical power but will require significantly greater quantities of cryogen. The amount of cryogen required depends on the heat load and the duration of the operation. Further effort is required to establish heat loads when the instrument designs are established.

The mechanical and structural aspects of the ASF payload were evaluated to some considerable depth with preliminary designs being established for instrument pointing, boom and boom actuation and subsatellite retention and ejection. Results indicate that the ASF instruments, subsatellite and support equipment can be installed and serviced within the operational and environmental requirements and constraints defined using the modified Ball Brothers pointing system, the perforated BI-STEM boom configuration and the integral collet/GN_2 subsatellite retention/ejection system.

5.2.1.7.2 Recommendations

The following recommendations apply to the TSMS:

a. Perform a detailed thermal analysis establishing heat loads for instruments 118 and 126 when instrument designs are further defined. Calculate the flow rate of cryogen required to cool the detectors and the housings and determine the volume and weight of cryogen required from the flow rate required and the instrument operating time.

b. Analyze the effect of the cryogen discharge cloud from the open loop cooling system on the operation of ASF instruments. Evaluate methods of reducing the effects of the discharge (e.g., use of Orbiter vent or dump lines to route exhaust gases away from instruments). Alternative means of cooling may have to be evaluated if contamination from open loop cooling cannot be tolerated.

c. Perform a trade study on installing the APS directly to the Orbiter payload attach trunions instead of using the equipment pallets. Weight would be reduced but structural and mechanical design and development cost might be increased and some versatility sacrificed since the pallets would no longer be available for installing other equipment.

5.2.2 ELECTRICAL POWER AND DISTRIBUTION SUBSYSTEM (EPDS)

5.2.2.1 Introduction

The study objective for the ASF EPDS was to determine if the power needs of the ASF payload could be met within the power, energy and thermal dissipation constraints of the Orbiter electrical power and ATCS.

Using the mission operational timeline and the power requirements for the individual instruments, support subsystems and the subsatellite, average and maximum operational power levels were defined and total electrical energy required for a 7-day mission was established. A conceptual ASF EPDS utilizing ERNO designed equipment to the maximum extent possible was developed.

Study results show that utilizing two Orbiter energy kits and time phasing the high power users, the total energy and maximum power required for the ASF payload can be provided (with substantial margin) within the Orbiter energy, power and thermal dissipation constraints.

5.2.2.2 Requirements

The power and energy requirements used to size the EPDS were derived from the following sources.

a. ID's (appendix B).

b. AE satellite descriptions (used to size ASF subsatellite requirements).

c. Support subsystem descriptions.

d. ASF mission timelines (see figure 4.1.5-1 in section 4.0).

5.2.2.2.1 Functional

The EPDS will provide the following functions to the ASF instruments and the support subsystems from prelaunch to postlanding.

a. Primary electrical power.

b. Secondary electrical power.

c. Emergency electrical power.

d. Power conversion, inversion and conditioning.

e. Power distribution, control and overload protection.

f. Data for subsystem status verification, test, maintenance, and diagnostic support.

The EPDS will provide full operational capability before and after the first failure with no degradation of power quality. Levels and time duration of power dropouts and transients during switchover from primary to secondary power sources will be minimized. After a second power source failure, the EPDS will provide sufficient power to maintain the ASF payload in a safe condition.

5.2.2.2.2 Performance

Power requirements for the ASF scientific instruments, subsatellite (before deployment) and the support subsystems were identified. Table 5.2.2.-1 lists the power required by each of the instruments and the subsatellite. The column titled "System Input" lists the levels and types of voltages required of the Orbiter or ASF primary power sources by each of the instruments. The basic elements (emitter, cathode) of the Laser Sounder (Instrument 213), Electron Accelerator (Instrument 303), and the Magnetoplasmadynamic (MPD) Arc (Instrument 304) instruments require high voltage; high power not directly available from the Orbiter or ASF primary power sources. These special power requirements are listed under the heading "Element High Voltage/Power Input".

TABLE 5.2.2-1. — ASF INSTRUMENT/SUBSATELLITE POWER

Instrument	Voltage		Power (Watts)(1)		
	System(1) Input	Element(2) High Voltage/Power Input	Standby	Operating Average	Operating Peak
116	28 Vdc		10	10	10
118	115 Vac, 400 Hz		15	100	100
122	28 Vdc		16	16	16
124	28 Vdc		14	14	14
126	115 Vac, 400 Hz		10	25	25
213	115 Vac, 400 Hz	5kV pulses (10^{-8} to 10^{-5} sec)	110	1.1 K	TBD
303	28 Vdc	30 kV dc	400	5 K	10 K
304	28 Vdc	500 V pulses (TBD sec)	50	5 K	10 K
532	28 Vdc		120	120	140
534	28 Vdc		10	50	190
536	28 Vdc		4	4	4
549	28 Vdc		5	5	10
550	28 Vdc		5	10	20
1002	28 Vdc		3	10	10
1011	28 Vdc		100	100	100
Subsatellite(3)	28 Vdc		200	300	300

(1)Input required from Orbiter or ASF primary power source.

(2)Special high voltage, high power input not available directly from Orbiter or ASF primary power source.

(3)Predeployment power only.

Standby power represents that required for instrument warmup and preoperational status checks. Many of the instruments do not operate continuously during the mission as discussed subsequently in this section. The power listed under the heading "Average" represents the average power over only the time the instrument is actually performing its experimental operations. Thus, the average and peak power for many instruments are identical. The peak power differs from the average operating power for some of the instruments since they are operated in a pulsed or modulated mode, or periodic control of devices and elements such as relays, solenoids, motors, actuators, valves, etc. is required.

The subsatellite utilizes the Orbiter primary power sources until shortly before deployment. The power requirement listed reflects only this predeployment power.

Table 5.2.2-2 lists the voltages and power required by support subsystems; the APS and the thermal control systems. The support subsystems will require power during virtually the entire mission from prelaunch to postlanding. A peak power of 700 watts for each APS is required for only one or two minutes during the reorientation of the platforms. An average of 400 watts is required for the remainder of the operations to maintain tracking and stabilization. A continuous level of 200 watts for the thermal control system (including cryogenic cooling and the freon coolant systems) is required from mission start to experiment completion.

5.2.2.3 ASF Timelines and Power Usage

The ASF timelines shown in figure 4.1.5-1 in section 4.0 are used in this study to determine worst case energy requirements. During the first 15 revolutions, the instruments will require little or no power. The only power which might be required during this period for the instruments is the standby power during revolution

TABLE 5.2.2-2.— ASF SUPPORT SYSTEM POWER

Support Systems	Input Voltage	Power (Watts)	
		Average	Peak
Pointing, Control and Stabilization	28 Vdc	230	230
AMPS Pointing System (2 systems)	28 Vdc	400 ea.	700 ea.
Command and Data Management	28 Vdc	1915	3805
Aft Crew Station*	28 Vdc	610	610
Electrical Power and Distribution	28 Vdc	580	580
Cryogenic Cooling and Active Thermal Control System	28 Vdc	200	200
		4335	6825

*Power to payload unique equipment at the aft crew station including display and control equipment is not charged to payload but must not exceed that allocated. Energy used by these equipment, however, is charged to payload.

15 for preparation and status checks. The experiments will be performed from revolution 16 through revolution 80 with some instruments powered continuously during this period and others sequenced as shown.

The support subsystems will be powered continuously in the time span shown in figure 4.1.5-1.

The pointing systems will require peak power only during reorientation for 1 to 2 minutes. During the tracking or hold mode a constant level of power is required.

The instruments which use the greatest amount of power are the Laser Sounder (Instrument 213), the Electron Accelerator (Instrument 303) and the Magnetoplasmadynamic Arc (Instrument 304). The Laser Sounder will operate over much of the orbit to provide maximum global coverage. The voltage pulse applied to the emitter is 10 nanosecond minimum in duration and is applied at a one pulse per second rate. The Electron Accelerator operates in either a dc, a pulsed, or a modulated mode. The voltage applied to the cathode will be 1 to 30 K Vdc and the electron current will be controlled by controlling the grid voltage. The MPD Arc will operate in a pulsed mode with the voltage applied to the cathode being 1 to 10 milliseconds in duration. The duty cycle will be determined by the maximum allowable Orbiter power drain.

Instruments 118 and 126 require cryogenic cooling. Cooling starts some period prior to initial use of the instruments and continues as long as the instruments are operating. Instruments 213, 303 and 304 will require active thermal control using the freon loop and cold plates. Other equipment may also be tied in to this coolant system.

5.2.2.4 Guidelines and Assumptions

In addition to the general guidelines and assumptions listed in para. 2.3.4, others unique to the EPDS were used during the study. These are the following.

a. The ASF EPDS will provide centralized processing and distribution for both instrument and support subsystem primary power. A single point ground will be provided for the instruments. Subsatellite power will be provided from this centralized system until just prior to deployment.

b. Primary input power to the ASF will be 28 Vdc $\pm$ 4 Vdc, and three phase 115 Vac, 400 Hz.

c. Special power conditioning (conversion, inversion, regulation) will be provided by the using equipment.

d. In addition to the primary power source, backup and emergency sources will be provided. The emergency source will be used only in safing the ASF payload in the event both primary and backup sources fail.

5.2.2.5 Capabilities and Constraints

The Orbiter will provide electrical power to the ASF payload during all phases of the mission. The primary constraints are; (1) maximum power capability of the Orbiter fuel cell, (2) available energy, and (3) heat dissipation.

5.2.2.5.1 Interfaces

Four interfaces for payload access to Orbiter power will be provided. Primary and secondary interfaces are located at station X_o 17653 (695 in) on the right hand side just below the longeron. Two interfaces will be provided at station X_o 33197 (1307 in) at the aft bulkhead. Power will normally be supplied to only one of the four interfaces at a time. However, more than one outlet can be used by the payload at the same time as long as these separate outlets are not tied together within the payload and provisions are made such that no single failure or series of failures within the payload systems can cause loss or degradation of Orbiter power.

5.2.2.5.2 Orbiter Fuel Cells

Each of the three Orbiter fuel cells will provide up to 12 kW of power. However, the maximum power available to the payload depends on which fuel cell is used and what phase of operation is involved. Table 5.2.2-3 shows the power levels available at each outlet for each operational phase, and the constraints imposed on the payload and the Orbiter.

5.2.2.5.3 Baseline Orbiter Power

The baseline Orbiter power system can provide 50 kWh of energy to the payload for a 7-day mission. Energy above 50 kWh from the Orbiter power subsystem may be available without adding kits if the mission duration is less than seven days. As figure 5.2.2-1 shows, for a 6.5-day mission, the Orbiter can supply the payload with 1 kW of continuous power (156 kWh). For energy levels exceeding these, up to five cryogenic energy kits which are payload chargeable can be utilized. Each of these kits consists of one O_2 tank and one H_2 tank.

5.2.2.5.4 Kits

Up to five kits can be installed in the payload bay below the payload and outside the payload envelope. Full installation provisions for the first kit are allocated in the baseline Orbiter although the weight of this first kit (and every other kit) is chargeable to the payload. Additional kits can be installed within the payload envelope if this becomes necessary.

TABLE 5.2.2-3. — PAYLOAD POWER INTERFACE CHARACTERISTICS

Interface	X_o Sta	Mission Phase	Voltage Range-Volts	Power - kW Ave	Power - kW Peak	ATCS Payload Heat Rejection Configuration	Comments
Dedicated Fuel Cell Connector	695	Ground Operation (GSE Pwr)	24-32	1	1.5	21,500 or 29,500 Btu/hr	Normal Checkout
			27-32	7	12		Orbiter Powered Down
Main Bus Connector	695		24-32	1	1.5		Normal Checkout
				5	8		Orbiter Power Down
Aft (Bus B)	1307		24-32	1.5	2		
Aft (Bus C)	1307		24-32	1.5	2		
Dedicated Fuel Cell Connector	695	Ascent/ Descent	27-32	1	1.5		Power is limited to a total of 1 kW average and 1.5 kW peak for 2 minutes
Main Bus Connector	695		27-32	1	1.5		
Aft (Bus B)	1307		24-32	1	1.5		
Aft (Bus C)	1307		24-32	1	1.5		
Dedicated Fuel Cell Connector	695	On-Orbit Payload Operations	27 min.	7	12	29,500 Btu/hr	Peak power is limited to 15 minutes once every 3 hours.
				6	(TBD)	21,500 Btu/hr	
Main Bus Connector	695		27-32	5	8	21,500 or 29,500 Btu/hr	
Aft (Bus B)	1307		24-32	1.5	2		Power may be utilized from both interfaces simultaneously. Busses must be isolated on the payload side of the interface.
Aft (Bus C)	1307		24-32	1.5	2		
Aft Crew Station Payload Unique							See text.

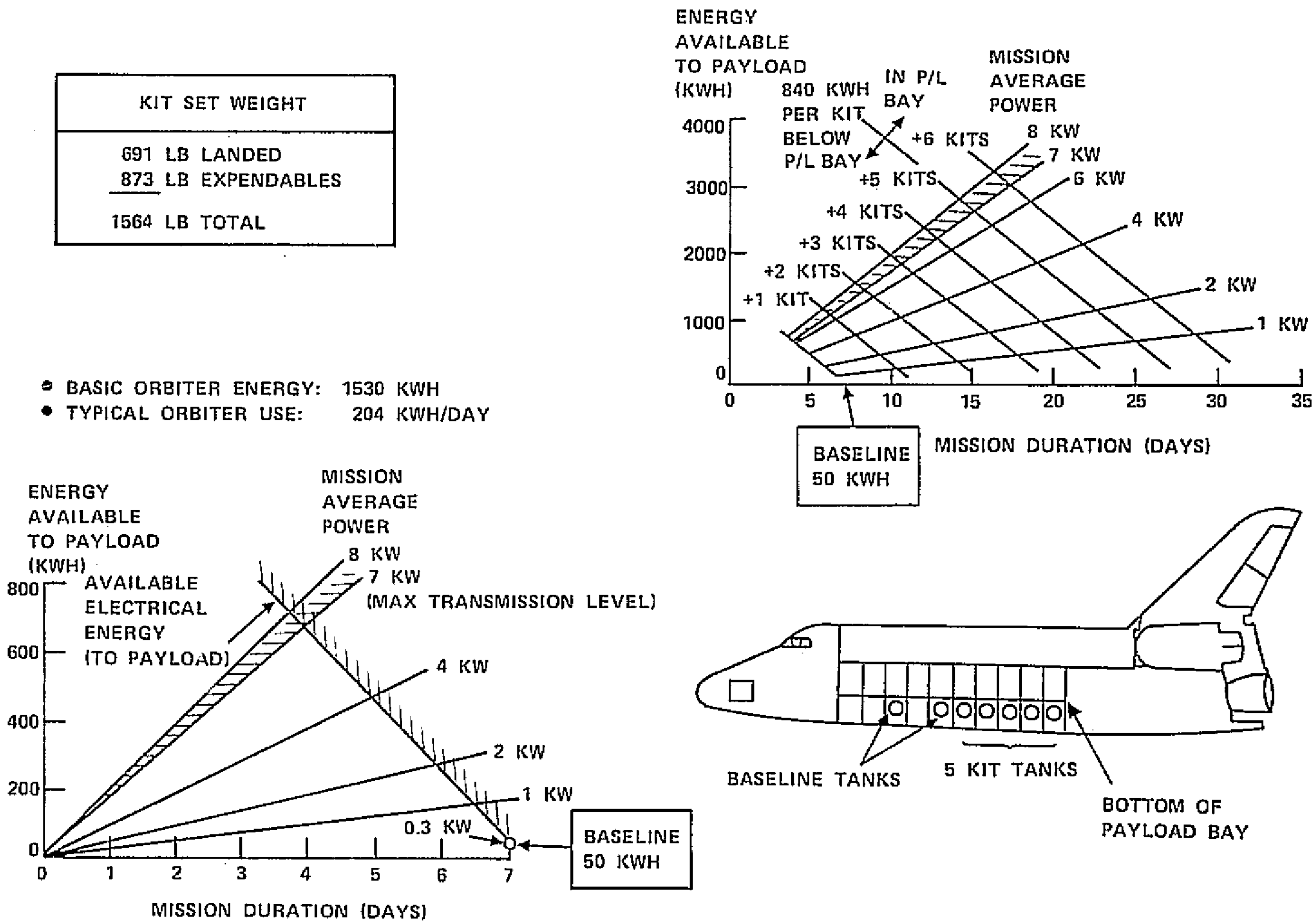


Figure 5.2.2-1. — Energy/power available to payload.

5.2.2.5.5 Orbiter Power Dissipation

The maximum allowable Orbiter power dissipation is constrained by the heat rejection capability of the radiators. The baseline Orbiter ATCS provides a capability of 21,500 Btu/hr heat rejection for the payload on-orbit with the doors open. This limits the payload to a power level of 6.3 kW. This capability can be increased to approximately 29,000 Btu/hr (8.5 kW) by the addition of a payload chargeable radiator kit. If the dedicated fuel cell is used with the Orbiter in a powered down condition, the payload can use up to 12 kW peak power for a maximum duration of 15 minutes every 3 hours. The electrical potential at the primary payload interface (dedicated fuel cell interface at X_o 17653 (695 in) will be a minimum of 27 volts with a 12 kW load.

5.2.2.5.6 Backup Mode

In a backup mode (one of the three Orbiter fuel cells inoperative), the backup interface at station X_o (695) from the main Orbiter bus will supply a minimum of 27 volts at 8 kW peak power and 5 kW average power during on-orbit payload operations. The aft payload power interfaces located at station X_o (1307) are supplied by the Orbiter aft local buses. The minimum potential at these interfaces will be 24 volts at 1.5 kW average power and 2.0 kW peak power per bus.

5.2.2.5.7 Aft Flight Deck Equipment

For payload unique equipment located at the aft flight deck (within the crew compartment) such as displays and control panels, tape recorders, etc., the power required is not included in the allocations shown in table 5.2.2-3. This power is included in the Orbiter baseline allocations. However, the electrical energy required by these equipment at the aft flight deck is chargeable to the payload. The power allocations for these payload unique aft flight deck equipment by phases are:

a. Ground operations (GSE power) and on-orbit operations - 750 watts average, 1000 watts peak.

b. Prelaunch (Orbiter internal power), ascent, descent and postlanding (Orbiter internal power) - 350 watts average, 420 watts peak. Peak power is limited to two minutes each phase.

5.2.2.5.8 Other Orbiter Systems

Other Orbiter power system characteristics are:

a. Peak-to-peak ripple for Orbiter electrical power is 0.9 volts or less over a broadband of frequencies for both aft flight deck and payload bay interfaces.

b. Orbiter fuel cells have no voltage control requirements for loads up to 2 kW except that the voltage will not exceed 40 volts.

c. A two wire power/return interface is provided to payloads. However, the Orbiter uses a distributed structure return system for its own loads. Up to 400 amperes of dc current can flow through Orbiter structure during on-orbit operations.

5.2.2.6 Subsystem Description

Figure 5.2.2-2 describes the ASF EPDS equipment and interfaces with the Orbiter power system and with the ASF payload.

5.2.2.6.1 Energy Sources

The ASF EPDS utilizes the Orbiter fuel cells as the primary source of its power. Preliminary assessment indicates that the ASF energy requirement (897 kWh) far exceeds the 50 kWh energy allocated by the baseline Orbiter electrical power system under worst case

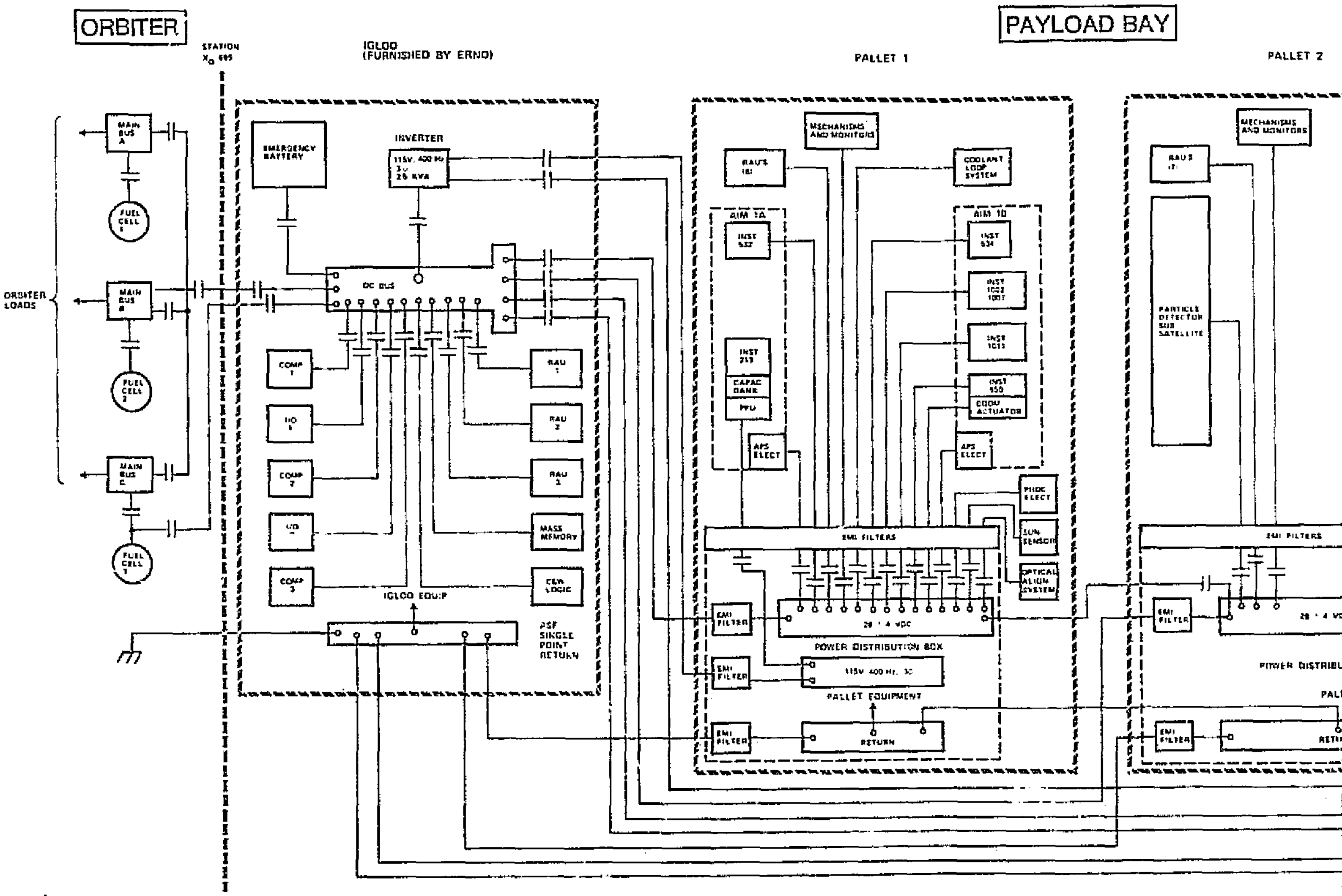


Figure 5.2.2-2. — ASF electrical power distrib

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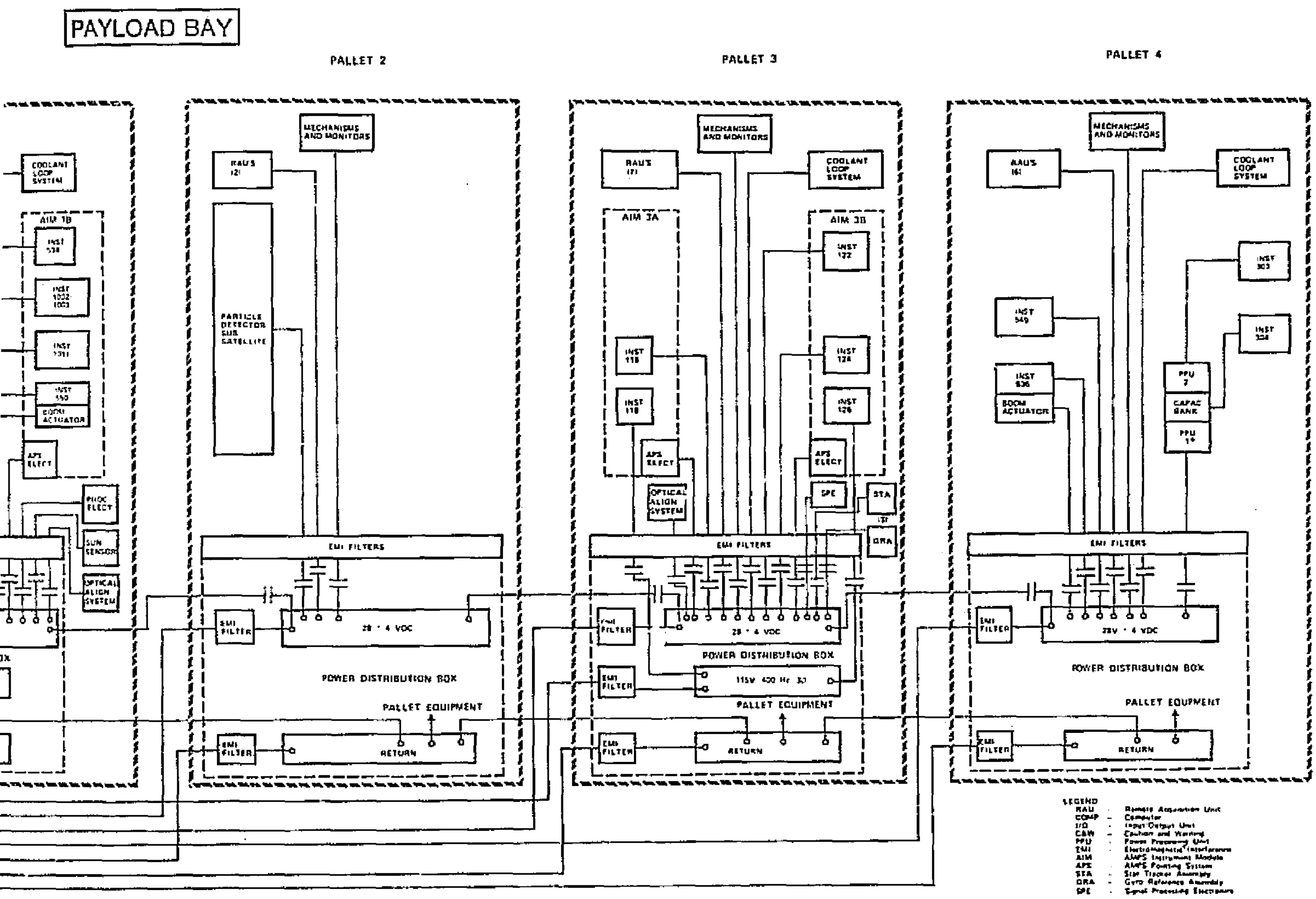


ASF electrical power distribution system (EDPS).

FOLDOUT FRAME 2

conditions. Therefore two energy kits (two O_2 and two H_2 tanks) are included in the ASF baseline EPDS configuration. Primary power is obtained from the dedicated fuel cell (cell 3) and the second outlet at station X_0 17653 (695 in) is used to provide a backup power source. In the event power is lost from both Orbiter outlets, an emergency source will be available to provide power to the ASF payload safety critical functions such as the cryogenic tank pressure monitors. The energy required for these functions is expected to be a small fraction of that required for normal operation and relatively inefficient sources such as silver-zinc batteries can be considered. A 28 Vdc silver-zinc battery of the same type used on Spacelab (and also on a number of space-crafts and boosters) has been selected for the baseline ASF EPDS.

5.2.2.6.2 Power Conversion, Inversion and Distribution

The baseline ASF EPDS includes the 2.5 kVA, 3Ø, 115 V, 400 Hz inverter provided for Spacelab. Instruments 118, 126 and 213 presently require this ac power source. However, the final instrument designs could include individual inverters with little impact on total development or unit cost since qualified, flight proven power supply designs are available.

Centralized dc to dc converters and regulators are not included in the EPDS baseline since the current approach is that power conversions and regulation requirements will be satisfied by using equipment with internal provisions. However, the ERNO designed dc to dc converter will meet most of the ASF regulated dc power requirements and is considered an acceptable option. These converters would be located on the individual pallets in the standard Spacelab location or under the pallet floor if available floor space becomes a factor and the converters do not require active cooling. Overall program cost and weight differentials between the two approaches should be minor. A variety of available converter designs can be used for ASF applications, therefore little development cost is involved. Some weight and unit cost savings may accrue if centralized rather than dedicated converters are used. However, due to the relative conversion efficiencies, the overall programmatic trade-offs are not expected to be significant.

The Laser Sounder (Instrument 213), the Electron Accelerator (Instrument 303), and the Magnetoplasmadynamic Arc (Instrument 304) all require high level voltage sources to operate (see table 5.2.2-1). These high level voltages will be provided to the accelerator and the MPD arc through the special high voltage power supply shown in figure 5.2.2-3. A separate power source will be required for the Laser Sounder due to the distance between the two groups of instruments. Orbiter 28 Vdc power is converted to 500 Vdc by power processing unit 1 and this voltage is used to charge a large (10^5 joule, 0.8 Farad) capacitor bank. The output of the capacitor bank is converted by a second power processing unit to the high voltages (30 kV) required to operate the Electron Accelerator. The MPD Arc will use the 500 Vdc output of the capacitor bank directly through a solid state switch.

Fundamental issues involving the development and utilization of the high voltage, high power system are how best to accomplish the following.

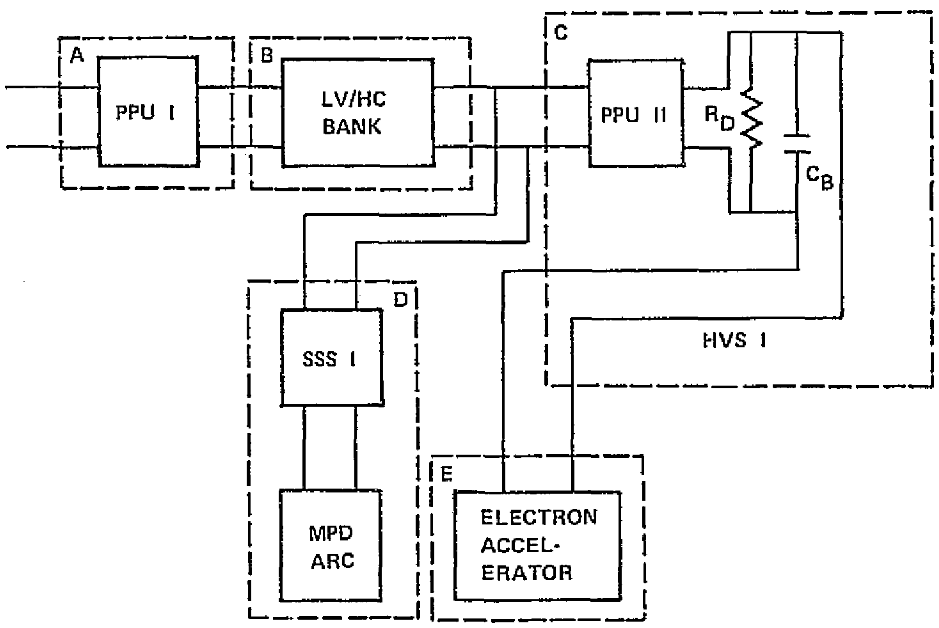
a. Generate required voltages.

b. Minimize voltage attenuation and power losses within power conversion and transmission media.

c. Provide required insulation, minimize corona effects.

d. Contain generated conducted and radiated EMI.

Circuit breakers and power switches will be provided to isolate the ASF central bus from the Orbiter power sources and the ASF power busses from the individual instruments and equipment. As shown in figure 5.2.2-3, circuit breakers are also provided in the baseline Orbiter to protect the Orbiter power sources.



SUBSYSTEM	ELEMENTS
A	POWER PROCESSING UNIT (PPU) I (28V/400A/ /500V/23A)
B	LOW VOLTAGE/HIGH CAPACITANCE (LV/HC) BANK (500V/.8F)
C	PPU II (500V/400A/ /30,000V/10A), DRAINAGE RESISTOR (R_D), BUFFER CAPACITOR (C_B), HIGH VOLTAGE SWITCH
D	SOLID STATE SWITCH (SSS I), MAGNETOPLASMADYNAMIC (MPD) ARC (500V/200,000A)
E	ELECTRON ACCELERATOR (30,000V 7A)

Figure 5.2.2-3. — ASF Particle Accelerator High Voltage Power System.

These circuit breakers and those in the ASF igloo will be used to provide redundant means of isolating the two Orbiter power outlets used by the ASF payload.

Further effort is required to establish the criteria for selection of circuit breakers over a combination of relays and fuses for overload protection and to determine the operational and safety requirements that dictate which circuit breakers can be remotely controlled and which should be located at the aft crew station. In addition to the circuit breakers, the need for overload protection within each equipment or instrument should be assessed.

The EMI filters will be required to protect the Orbiter and ASF power systems from conducted interference effects and to reduce the effect of Orbiter power and ground system noise and transients on the ASF system.

The two wire power/return interface provided by the Orbiter will be utilized by the ASF power system. A single point return bus for the ASF payload will be provided in the igloo. Each pallet power distribution bus will have a return bus dedicated to the instruments and equipment on the pallet. The Orbiter power system uses vehicle structure as its dc return. It is expected that as much as 400 amperes of dc current can flow through the Orbiter structure during mission operations. As part of the on-going EMC evaluation, the possibility of structure noise feeding into the ASF power system through the by-pass capacitors and its impact on the payload operations must be assessed.

Each power and return bus in the individual pallet power distribution boxes interfaces directly with the respective centralized busses in the igloo. In addition, the individual pallet dc power busses are connected in series (as are the return busses) for redundancy purposes.

The connections between the dc power busses are made through normally opened switches to provide isolation, if required.

Preliminary assessments indicate that to keep line voltage drops to less than 10 percent of power voltage (2 to 3 volts for dc power) wire sizes of up to 4-0 (0.04 ohms/310 m (1000 ft)) will have to be used for the primary Orbiter-to-payload interface and for the high power users such as instruments 303 and 304 assuming individual harness runs (to load and back) are less than 62 meters (200 ft). Together with insulation, this size of wire will measure about 1/2 inch in diameter and weigh over 1.5 kg/meter (1 lb/ft). Other wires used will range in size from 4 to 20 gauge.

5.2.2.6.3 EPDS Equipment Characteristics

Table 5.2.2-4 summarizes pertinent characteristics of the ASF EPDS equipment.

5.2.2.7 Analyses

Worst case analyses of the total ASF payload power and energy levels were performed using the power and timeline requirements discussed in paragraph 5.2.2.2. Table 5.2.2-5 shows the power level required for each major phase of the mission requiring significant changes in instrument or associated equipment operations. Two hours before lift-off, a transfer is made from ground support power to internal Orbiter power. From insertion into mission orbit until orbit revolution 16, the crew makes preparation for the start of the experimental operations. During this period, only the support subsystems are assumed to be powered. During revolution 15, the power to instruments other than those associated with the particle accelerators is turned on and the platform pointing closed loop servo system is powered. The cryogenic cooling systems for instruments 118 and 126 are turned on during revolution 7. During revolutions 16 through 80, the experiments are conducted.

TABLE 5.2.2.-4. – EPDS EQUIPMENT

Item	Quantity	Weight kg (lb)	Power (watts)	Prior Use	Modifications Required
1. Dc-ac 3Ø, 2.5 kva, 115 V, 400 Hz Inverter	1	28 (62)	500 (1)	Spacelab	None
2. Power Distribution Box	5	30 (66)	5x10	Spacelab	(TBD)
3. Energy Battery	1	78 (172)		Spacelab	
4. Power Control Box	1	5 (11)	20	Spacelab	(TBD)
5. Harnesses (including connectors)				New	
a. 4-0 Gauge-183m (600 ft)		290 (640)			
b. 4 Gauge-183m (600 ft)		40 (88)			
c. 10 Gauge-109m (3600 ft)		55 (122)			
d. 20 Gauge-8536m (28,000 ft)		41 (90)			
6. Energy Kit				Orbiter Mission Kits	None
a. O_2 and H_2 tanks (and fittings)	2 each	626 (1381)			
b. Cryogenic Reactants					
• O_2		708 (1564)			
• H_2		82 (182)			
ASF EPDS TOTAL		1983 (4378)			

NOTE: Capacitor bank and power processing unit weights included in instruments 303 and 213 weights.
(1) Inverter inefficiency

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TABLE 5.2.2-5. — ASF AVERAGE POWER BY FLIGHT PHASE

Instrument/Subsystem	Ave standby power (watts)	Power during operational (watts)	Mission prep and orbit change Revs. 1-15 Ave power (w)	Experiments Operation: Rev. 16 Operation duty cycle	Rev. 16 Ave[1] power (w)	Revs 17-25 Operation duty cycle	Revs 17-25 Ave[1] power (w)	Revs 26-31 Operation duty cycle	Revs 26-31 Ave[1] power (w)	Revs 32-35 Operation duty cycle	Revs 32-35 Ave[1] power (w)	Revs 36-42 Operation duty cycle	Revs 36-42 Ave[1] power (w)	Revs 43-47 Operation duty cycle	Revs 43-47 Ave[1] power (w)	Revs 48-80 Operation duty cycle	Revs 48-80 Ave[1] power (w)	Subsatellite retrieval and return preparations Revs. 81-112 Ave power (w)
Instruments																		
1 116	10	10	10	1.00	10	Standby	10	Standby	10	0.33	10	0.33	10	0.33	10	Standby	10	-
2 118	15	100	15	Standby	15	1.00	100	1.00	100	0.55	62	0.55	62	0.55	62	1.00	100	-
3 122	16	16	16		16	1.00	16	1.00	16	1.00	16	1.00	16	1.00	16	1.00	16	-
4 124	14	14	14		14	1.00	14	1.00	14	1.00	14	1.00	14	1.00	14	1.00	14	
5 126	10	25	10		10	1.00	25	1.00	25	0.55	18	0.55	18	0.55	10	1.00	25	-
6 213	110	1,100	110		110	1.00	1,100	1.00	1,100	0.55	655	0.55	655	0.55	655	1.00	1,100	
7 303	400	5,000	400		400	Standby	400	Standby	400	0.17	1,182	0.17	1,182	Standby	400	Standby	400	-
8 304	50	5,000	50		50	Standby	50		50	Standby	50	Standby	50	0.17	897		50	-
9. 532	120	120	120		120	0.16	120		120	Standby	120	0.17	120	Standby	120		120	-
10 534	10	50	10		10	Standby	10		10	0.33	23	0.33	23	0.33	23		10	-
11 536	4	4	4		4		4		4	0.33	4	0.33	4	0.33	4		4	-
12 549	5	5	5		5		5		5	0.33	5	Standby	5	Standby	5		5	
13. 550	5	10	5	Standby	5		5		5	0.17	5	0.05	5	Standby	5	Standby	5	
14 1002/1003	3	10	3	0.01	3	Standby	3	Standby	3	Standby	3	Standby	3		3	<0.01	3	
15 1013	100	100	100	0.11	100	0.45	100	0.45	100	Standby	100	Standby	100	Standby	100	0.45	100	
Instruments Total	872		872		872		1,962		1,962		2,267		2,267		2,347		1,962	
Support Subsystems	3335	3335	3335	1.00	3335	1.00	3335	1.00	3335	1.00	3335	1.00	3335	1.00	3335	1.00	3335	3335
AMPS Pointing Systems	800	800	800	1.00	800	1.00	800	1.00	1.00		800	1.00	800	1.00	800	1.00	800	-
Thermal Control Systems	200	200	200	1.00	200	1.00	200	1.00	200	1.00	200	1.00	200	1.00	200	1.00	200	200
Subsatellite	300	300	300												-		-	
ASF Total			5507		5207		6297		6297		6607		6602		6882		6297	3535

[1](Ave. during operation minus standby) x duty cycle + standby. Assumes instruments are on standby between experiment operations.

From revolution 81 through 95, power to the instruments are turned off. Orbiter maneuvers are performed, the orbit is changed for rendezvous with the PDS. The subsatellite is retrieved on about revolution 95. During revolutions 95 through 112, the Orbiter and payload systems are prepared for the return phase.

From the timelines and the power requirements of the individual instruments and the support systems, average power levels required by flight phase were established as shown in table 5.2.2-5. The maximum power required is 6882 watts during revolutions 43 through 47 which is 42 percent less than the 12 kW maximum available from the dedicated fuel cell.

The average power by phase was integrated over the entire mission as illustrated in figure 5.2.2-4 to establish the total energy required. The 1730 kWh (50 basic and 1680 kit) of energy available from the Orbiter provides a 48 percent margin over the 897.3 kWh required by the ASF payload for the 7-day mission.

The heat dissipation capability of the Orbiter using the payload chargeable radiator kit limits power levels to 8.5 kW average during the mission and a peak of 12 kW for 15 minutes every 3 hours. Figure 5.2.2-4 shows that the ASF average power required over periods greater than 15 minutes (6.9 kW during revolutions 43 through 47) results in a 19 percent power margin. Figure 5.2.2-5 shows the peak power required by the ASF payload during a typical orbit. The maximum power required by the ASF payload is approximately 9 kW for a period of about 15 minutes every 1-1/2 hours (one revolution).

Although the integration time for the ASF peak power is one-half that used to define Orbiter constraints (1-1/2 hours compared to 3 hours) as indicated earlier, the total integrated power (energy) over each orbit is well within the 8.5 kW specified.

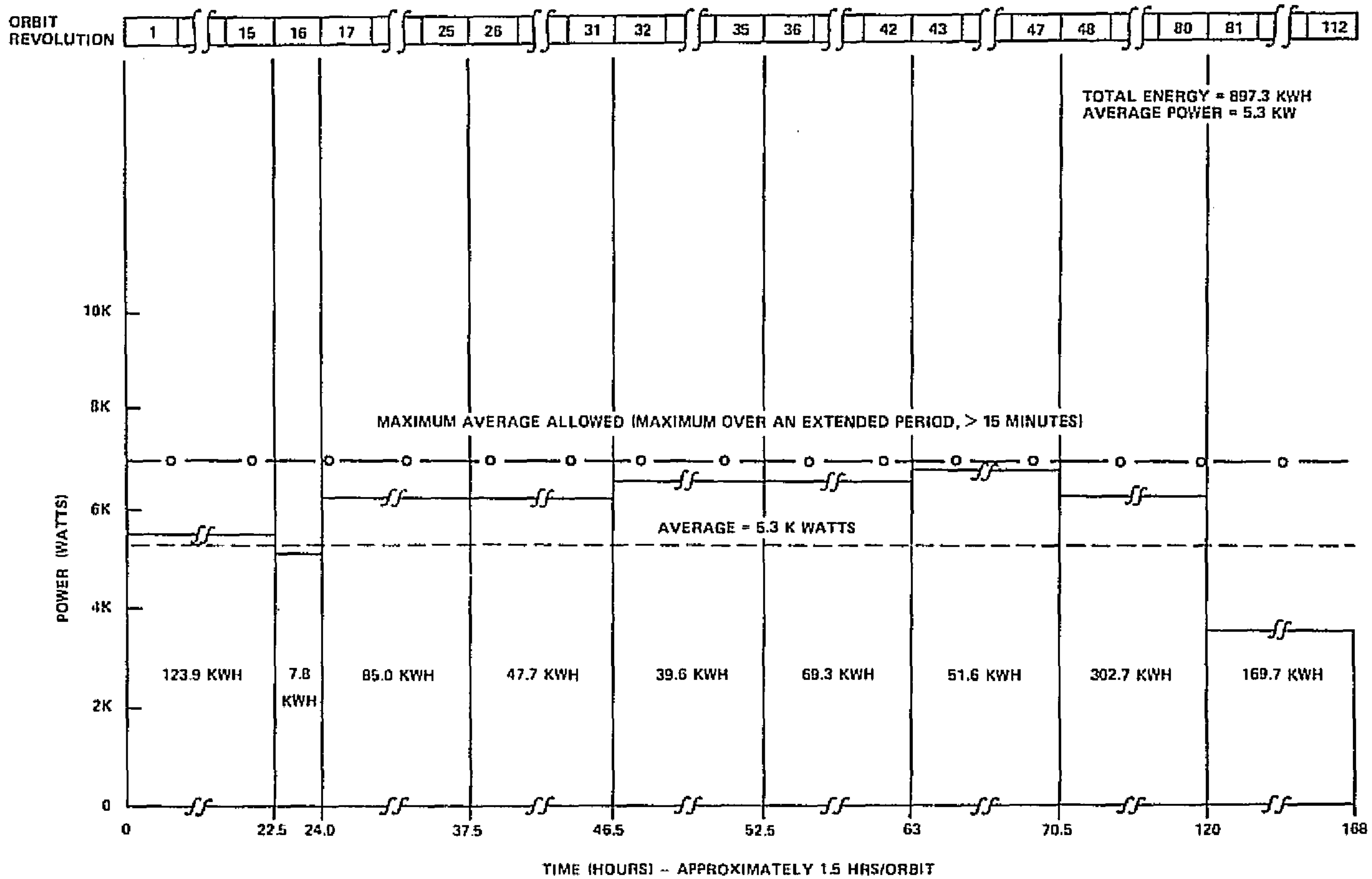


Figure 5.2.2-4. – ASF system power profile.

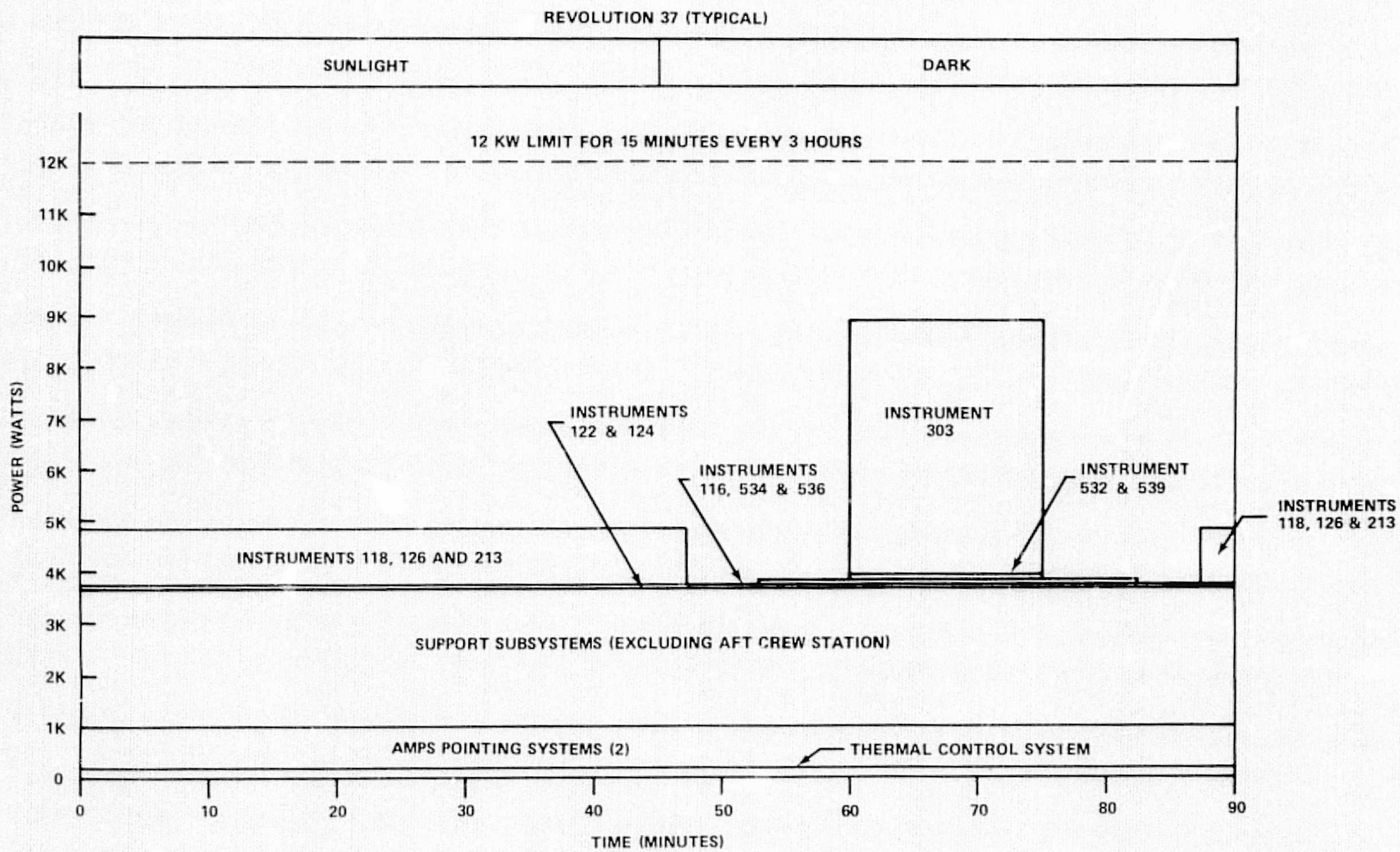


Figure 5.2.2-5.— Typical orbit revolution for peak electrical power.

5.2.2.7.2 High Voltage Source Efficiency

The particle accelerators baselined for the ASF mission are an Electron Accelerator (Instrument 303) and a Magnetoplasmadynamic Arc (Instrument 304). Both of these instruments require high power and high voltage levels. The required power is provided through the use of a 0.8 Farad 500 volt dc capacitor bank fed by a dc converter (see figure 5.2.2-3).

A capacitor bank with these characteristics is capable of an energy storage of 10^5 joules and would weigh approximately 540 kg, and have a volume of approximately 2 cu m.

Although the total storage capability of the capacitor bank is 10^5 joules, all of this energy is not available for useful energy in the accelerator beams. In the case of both the Magnetoplasmadynamic Arc and the Electron Accelerator, efficiency losses in both the power conversion and in the guns need to be considered.

Analysis performed on this study indicates that with a power converter interval impedance of 4 ohms, and the capacitor bank value of 0.8 Farads, the time required to charge the capacitor bank is 14.6 seconds and the efficiency of the high voltage source is above 70 percent.

5.2.2.8 Conclusions and Recommendations

5.2.2.8.1 Conclusions

The most significant conclusion relative to the ASF EPDS is that with logical time sharing by the high power users, there is every indication that the Orbiter power and energy constraints can be met with adequate margin. The heat radiator kit provided by the Orbiter will probably be required.

On a worst case basis, the total energy required by the ASF payload is 897 kWh. Since the baseline Orbiter payload support is only

50 kWh of energy, two energy kits with 1680 kWh additional energy capability will be included as part of the EPDS baseline.

5.2.2.8.2 Recommendations

Results of the study have led to the following recommendations.

a. More fully develop the EPDS concepts in the areas of power control, conditioning, conversion and inversion. Establish whether ac power should be provided from a central ASF bus or if it can be more effectively provided by the using equipment. Establish criteria defining the use of circuit breaker vs. relays, remote vs. aft flight deck circuit breakers, fuses or other overload protection in individual loads.

b. Identify the safety critical functions which require power redundancy. Establish power levels required and perform trades/studies to select the most effective power source.

c. Evaluate the total impact of using extremely high power levels on EMC, heat dissipation, required sizes for power and return lines, common impedances and conducted interference effects, insulation, etc.

d. Evaluate the possible impact on payload operations of Orbiter vehicle structure noise coupling through the EMI by-pass capacitors into the ASF system.

C.3

5.2.3 POINTING/CONTROL AND STABILIZATION SUBSYSTEM (PCSS)

5.2.3.1 Introduction

The objective of this phase of the study was to establish the conceptual feasibility of providing precision pointing, tracking and stabilization for the ASF instruments. The approach was to evaluate the Orbiter attitude accuracy capability relative to the instrument requirements and to develop a dedicated ASF/PCSS concept if the Orbiter capability fell short of these requirements.

The scope of this phase was limited to: (1) defining the techniques for pointing and control, (2) defining a conceptual design approach, and (3) determining the hardware requirements and functional interfaces required for pointing/control and stabilization. No attempt was made during this study to perform dynamic simulations and evaluations of the control laws or to analyze the PCSS performance. A secondary goal was to research the state-of-the-art hardware that can meet the pointing and stability requirements thus minimizing development time and cost. Other studies for advanced pointing systems are being conducted for payloads that require a high degree of pointing accuracy and [illegible]ability. However, these are not included in this study.

The study showed that the Orbiter attitude control and stabilization capabilities are not adequate to meet experimental needs. A PCSS concept was developed which consists of two major elements: (1) the AMS, and (2) the APS. This section discusses the AMS in detail and describes the integrated AMS/APS operations. The details of the APS configuration are provided in Section 5.1.

5.2.3.2 Requirements

The ASF payload consists of instruments that require stellar, solar, and earth pointing. The ASF experiments require the pointing of one or more FOV's at a target such as the solar disc, the nadir, or along a specific direction. In addition, the FOV or line-of-sight (LOS) must have pointing stability that permits experiment measurements to be made without distortion.

Pointing accuracy requirements are usually functions of the instrument FOV and of target and experiment data characteristics. Stability requirements, however, depend on the resolution capability of the experiment instruments; that is, the sensitivity of these instruments to a LOS rate.

In general, the stellar instruments usually require large gimbal angles, long exposure times, and stringent pointing and stability accuracies. The solar instruments remain sun-centered or search the surface of the solar disk. The earth looking instruments usually require high gimbal rates for tracking earth based targets and the use of the Orbiter for maintaining an earth oriented attitude with the payload bay toward the nadir. Thus, the attitude control and pointing system must be capable of meeting these various types of requirements.

5.2.3.2.1 Functional

Assessment of the Orbiter pointing and stabilization capabilities (see paragraph 5.2.3.4) indicates that an independent pointing/control and stabilization system is required for the ASF payload. The prime mission functions which this system must perform to support the experiments are payload reference axes attitude determination, pointing/control (target tracking) and stabilization. Other functions include providing data for downlink telemetry and for onboard display and processing, power conditioning and control within PCSS equipment, and data to be used for failure detection and isolation.

5.2.3.2.2 Performance

The principal source for the pointing accuracy, pointing stability, and rate stability requirements is the ASF ID documents (see appendix B). A summary of these requirements is listed in table 5.2.3-1. The definition of these errors and a graphical presentation is illustrated in figure 5.2.3-1. The justification for the pointing accuracy and stability rate requirement lies with the scientific community and/or payload users. The remainder of the study is based on that data as defined by the users in the ID's.

The instrument stability requirements defined in the ID's vary from .003°/sec. to 36°/sec. The instruments pointing accuracy requirements vary from 1 minute of arc to 6°.

5.2.3.3 Guidelines and Assumptions

Following are the guidelines and assumptions used for this phase of the study.

a. Pointing accuracy knowledge of better than 0.1° must be provided by the payload AMS.

b. Those instruments which have a requirement of 2° but whose operations (such as TV monitors) are controlled by the crew can be hard mounted to the pallet. The crew will use visual means to keep instrument LOS on target.

c. The Orbiter will be operating within its minimum deadband (±0.1°) and minimum rate (0.01°/sec) to provide the payload with the least vehicle motion.

d. The AMS will be placed on the reference base requiring the greatest accuracy and stability.

e. The LOS of the cluster of instruments on a given platform will be boresighted to a common LOS.

TABLE 5.2.3-1. — ASF POINTING AND STABILITY REQUIREMENTS

	Instrument Requirements[1]		Orbiter Capability[2]		
	Accuracy	Stability Rate	Accuracy	Stability	Stability Rate
AMPS Pointing System (APS): Pallet A-1			±2°	±0.1°	0.01°/sec
<u>AMPS Instrument Module (AIM) 1A</u>					
<u>Instrument No.</u> — <u>Title</u>					
213 Laser Sounder	±1.0°	(TBD)			
532 Gas Release Module	±1°	0.15°/sec			
<u>AMPS Instrument Module (AIM) 1B</u>					
1011 UV Occultation Spectrograph	±0.017°	0.003°/sec			
1002 Pyroheliometer/spectrophotometer	±2.5°	(TBD)			
534 Optical Band Imager and Photometer System	±2.0°	0.017°/sec			
550 Level II Beam Diagnostics	N/A	N/A			
Subsatellite: Pallet A-2					
<u>Instrument No.</u> — <u>Title</u>					
(TBD)					
AMPS Pointing System (APS): Pallet A-3			±2°	±0.1°	0.01°/sec
<u>AMPS Instrument Module - AIM 3A</u>					
<u>Instrument No.</u> — <u>Title</u>					
116 Airglow Spectrograph	±0.5°	(TBD)			
118 Limb Scanning IR Radiometer	±0.5°	0.004°/sec			
<u>AMPS Instrument Module - AIM 3B</u>					
122 UV/VIS/NIR Spectrometer	±0.1°	(TBD)			
124 Fabry-Perot Interferometer	±1.0°	(TBD)			
126 Infrared Interferometer	±0.1°	0.05°/sec			
Hard Mounted: Pallet A-4			±2°	±0.1°	±0.01°/sec
<u>Instrument No.</u> — <u>Title</u>					
303 Electron Accelerator	±6°	1°/sec			
304 Magnetoplasmadynamic (MPD) Arc	±2°	1°/sec			
536 Triaxial Fluxgate	±0.5°	ROLL <36°/sec			
549 Gas Plume Release	N/A	N/A			

[1] ID Requirements

[2] JSC-07700, Vol. XIV, Rev. C, dated July 3, 1974

ASF - Atmospheric Science Facility
N/A - Not applicable

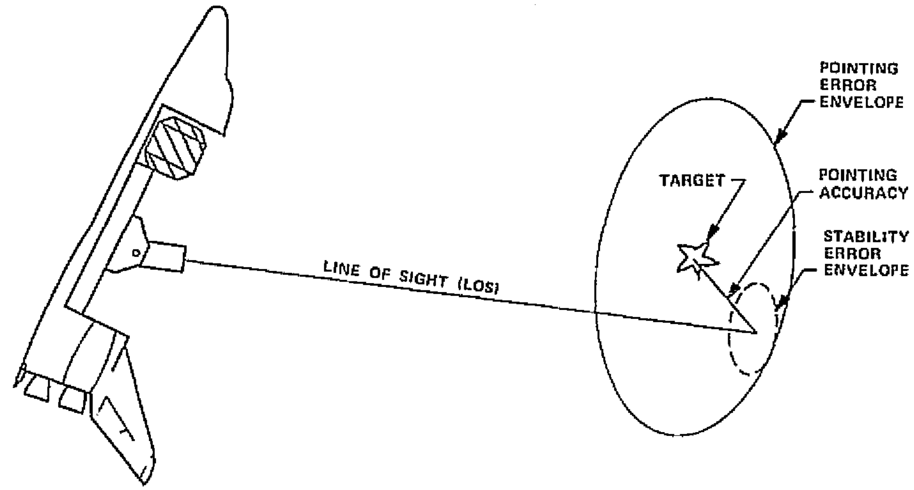
POINTING DEFINITIONS

POINTING ERROR – DEFINES THE TOTAL ERROR THAT CAN BE TOLERATED BY THE INSTRUMENT OR PAYLOAD. IT NORMALLY IS THE RSS OF THE POINTING ACCURACY AND POINTING STABILITY.

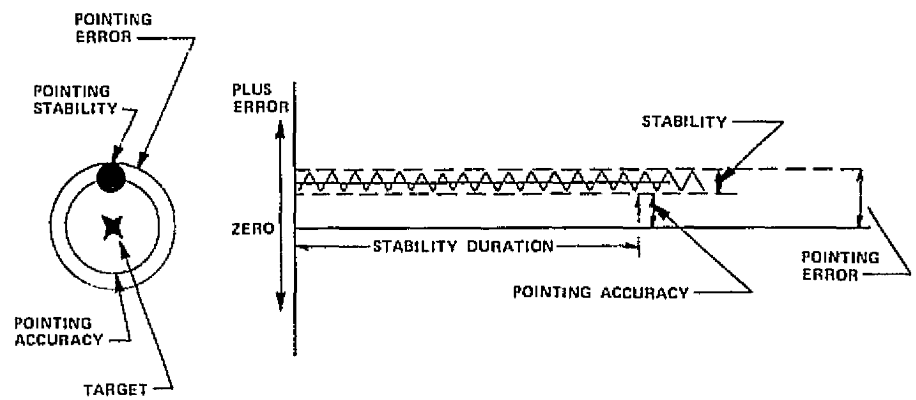
POINTING ACCURACY – DEFINES HOW CLOSE TO THE DESIRED TARGET THE INSTRUMENT MUST INITIALLY POINT. IT USUALLY IS ASSOCIATED WITH AN INSTRUMENT FIELD-OF-VIEW (FOV), OR A PARTICULAR AREA AROUND THE INSTRUMENT CENTERLINE. ERRORS THAT CONTRIBUTE TO POINTING ACCURACY ARE USUALLY OF THE STATIC TYPE AND RESULT FROM ITEMS SUCH AS MISALIGNMENT, ENCODER READOUT, ETC. AND CONSEQUENTLY, POINTING ACCURACY IS OFTEN REFERRED TO AS A BIAS.

POINTING STABILITY – DEFINES HOW CLOSE THE INSTRUMENT MUST STAY TO THE POINT AT WHICH IT WAS INITIALLY POINTED. ERRORS THAT CONTRIBUTE TO THE STABILITY ARE NORMALLY OF THE DYNAMIC TYPE SUCH AS VIBRATION DISTORTIONS, ELECTRONIC DRIFT, VEHICLE DRIFT, GIMBAL MOUNT DRIFT, ETC.

STABILITY DURATION – DEFINES TIME DURATION DURING WHICH STABILITY MUST BE HELD. IT USUALLY IS ASSOCIATED WITH INSTRUMENT EXPOSURE TIME OR EXPERIMENT SEQUENCE OBSERVATION TIME.



GLOBAL ILLUSTRATION OF DEFINITIONS



TIME ILLUSTRATION OF DEFINITIONS

Figure 5.2.3-1. – Pointing definitions.

f. The AMS will have to be updated once per orbit in order to maintain the 60 arc second accuracy. Time of update will be approximately five minutes.

g. The operation of the APS will be primarily computer controlled; however, the fine pointing of certain instruments will be manually performed by the crew. The crew will have to activate the system operations through keyboard-entered computer programs such as:

   (1) Initial alignments.

   (2) Update or realignments.

   (3) Tracking programs.

   (4) Calibration, etc.

h. The solar instrument group will use a sun sensor.

i. Instrument 1011 should have a sensor (star or sun) in the optical train. The output of this sensor would be available as an input into the control loop and operate as a closed loop sensor around the target star or sun.

5.2.3.4 Capabilities and Constraints

The Orbiter avionics system provides pointing and control capability through the use of its guidance, navigation, and control (GN&C) subsystem. The Orbiter GN&C subsystem consists of an inertial measurement unit (IMU), star trackers, and a flight control system (including vernier and large reaction control system thrusters).

The Orbiter vehicle has the capability of attaining and maintaining desired inertial, local vertical, and earth surface pointing attitude within the accuracy defined in table 5.2.3-2 and Orbiter thermal attitude constraints defined in table 5.2.3-3. The Orbiter IMU may be initially aligned to 0.1° with a drift rate of 0.1° per hour while other errors in the flight control subsystem contribute

TABLE 5.2.3-2. — ATTITUDE POINTING ACCURACY — ORBITER REFERENCE SYSTEM

Reference	Attitude accuracy (3σ)	Attitude degration (3σ)	Duration between alignments
Inertial	±0.4°	0.1°/Hr	1.5 Rev
Celestial	±0.24°	0	Not Applicable
Earth Target	±0.4°	0.1°/Hr	1 Rev

*Does not include errors associated with vehicle flexure.

TABLE 5.2.3-3. — ORBITER THERMAL ATTITUDE CONSTRAINTS

β Range (Degrees)	Orbiter Orientation	Hold capability (Hours)	Pre-entry thermal conditioning requirement (Hours)
0 – 60	Any	≥160	≤12
	A. Other than inertial hold	Cycles of 6-hour holds followed by 3 hours of thermal conditioning for worst thermal attitudes	≤7
60 – 90	B. 3-axis inertial holds	≥160	≤12

Source: JSC 07700, Volume XIV, Rev. C, July 3, 1974

0.25°. Table 5.2.3-2 shows that after 1.5 orbits the inertial attitude error of the Orbiter as related to its reference system is ±0.5°. Using the Orbiter star tracker continuously for attitude reference, the vehicle reference system error relative to the celestial reference can be held to within 0.25° indefinitely. In using the Orbiter IMU to point to an earth target, additional errors are introduced due to the Orbiter position and velocity uncertainties. In order to maintain a 0.5° error, the Orbiter IMU must be updated once in orbit. These errors are Orbiter reference axes errors relative to inertial or earth target references. For the purposes of payload pointing using the Orbiter IMU, an error source (>2°) can accrue due to vehicle flexure, payload structure, and payload mounting misalignments.

The Orbiter flight control system (FCS) is capable of providing stability (deadband) of ±0.1°/axis and a stability rate of ±0.01°/sec/axis utilizing the Orbiter IMU and the vernier RCS thrusters, provided that all vernier thrusters are operational. When using the large RCS thrusters, the Orbiter FCS is capable of providing stability of ±0.1°/sec/axis.

5.2.3.5 Subsystem Description

Comparison of the Orbiter pointing and stability capabilities and the ASF experiment requirements indicates a need for an accurate ASF attitude reference and pointing system for some of the instruments. The system defined in this section is an inertial system with optical updates. It consists of a three axis strap-down inertial system with star trackers and/or a sun sensor to provide updates to compensate for gyro drifts and computer errors. This is potentially the most versatile system and is equally effective for solar, stellar, and/or earth pointing missions.

5.2.3.5.1 Configuration

The ASF pointing and control requirements defined in table 5.2.3-1 dictate the need of a subsystem that can provide a pointing accuracy of 60 arc seconds. This requirement is considered to be within the state-of-the-art of existing hardware and can be achieved using several techniques. Two approaches that can be used are:

a. A central or master inertial reference system with optical updates.

b. A distributed inertial reference system with optical updates.

The master reference system can be placed on a separate gimbal system or incorporated with the instruments on a given pallet platform. This scheme introduces errors because of the required transfer of the reference error signals through the gimbals, however, these are manageable by design and calibration. Because of mechanical errors between pallet segments, optical links between gimbal systems for alignment control are required. This subsystem approach is illustrated in figure 5.2.3-2.

The distributed attitude reference system places a star tracker assembly (STA) and a gyro reference assembly (GRA) on each pointing system in the payload bay. Table 5.2.3-4 discusses the merit of each approach. Both approaches can fulfill ASF pointing and stability needs. For this study, the initialized inertial reference system with optical updates (star and sun sensors) augmented with an optical alignment transfer device was chosen (reference figure 5.2.3-3). This system was selected because of the large range of pointing requirements (0.017° to 6.0°) and the non-severity of the pointing accuracy (0.017°) needed for ASF.

The selected ASF PCSS configuration is shown in figure 5.2.3-4. It consists of the following hardware:

a. Digital computer (part of CDMS).

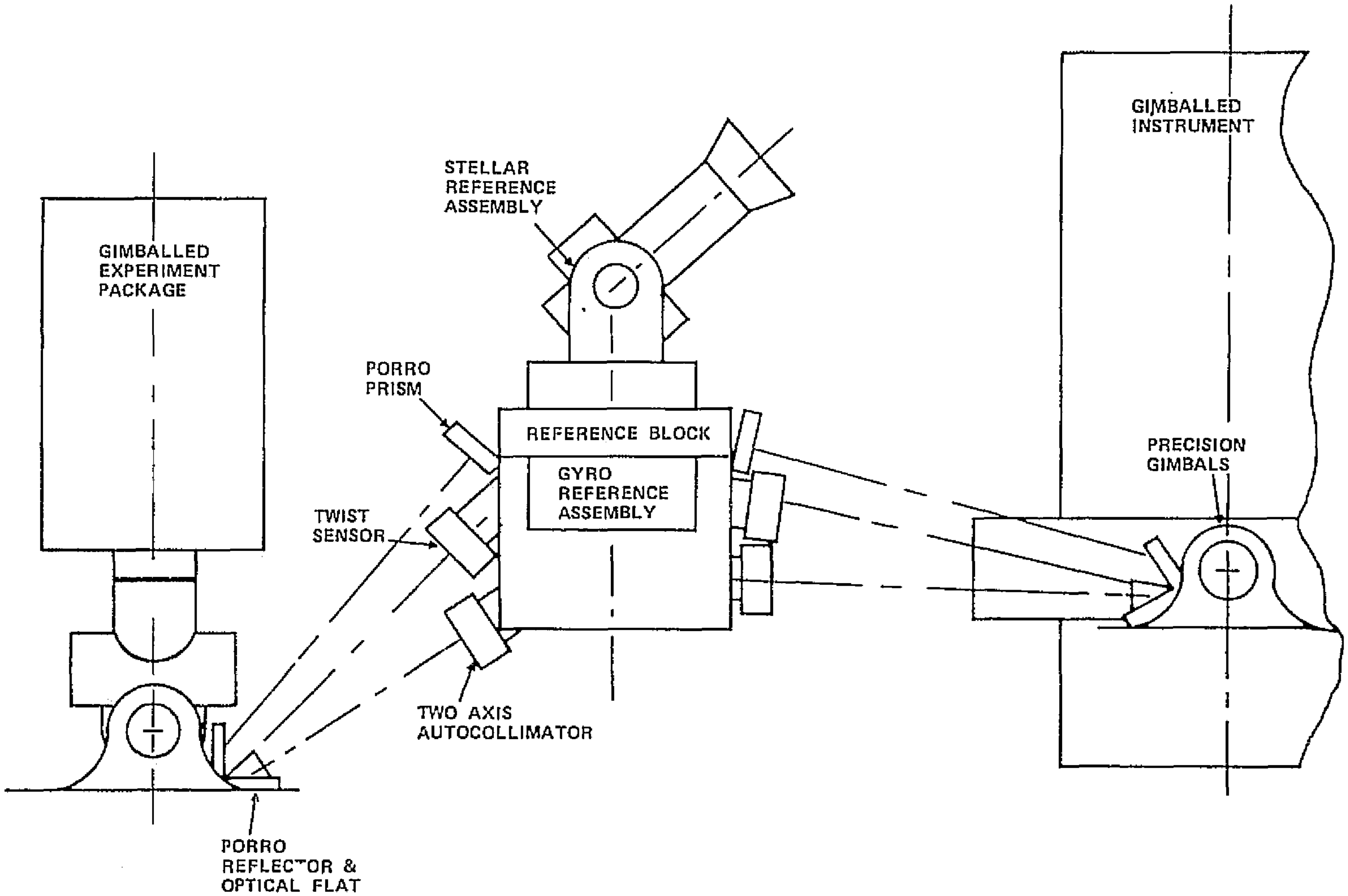


Figure 5.2.3-2. — Central attitude reference concept.

TABLE 5.2.3-4 — CENTRAL VS DISTRIBUTED ATTITUDE REFERENCE SYSTEM

Central	Distributed
<u>Advantages</u>	<u>Advantages</u>
• Only one star tracker and gyro reference assembly required.	• Experiments are more flexible and autonomous.
• Relative cost appears to be less	• Reduces computer involvement in the control loop.
• Weight requirement is less.	• Gimbal precision requirements are less stringent.
<u>Disadvantages</u>	<u>Disadvantages</u>
• Computer requirements are higher.	• Need one star tracker and gyro reference assembly for each gimbal.
• Need optical links between gimbal systems.	• Weight is increased.
• Precision gimbal sets are required to minimize errors.	• Apparent increase in relative costs.

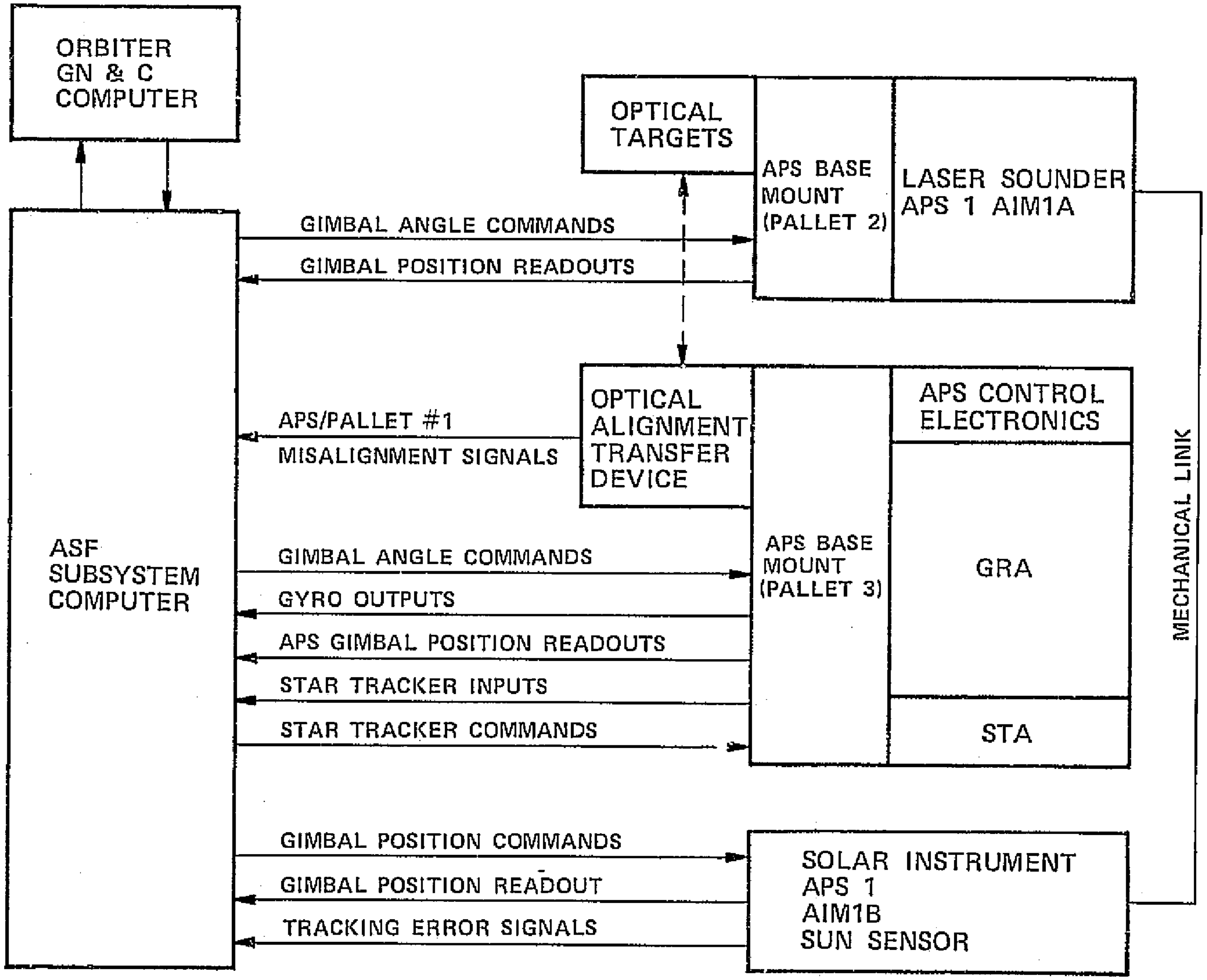


Figure 5.2.3-3. — Centralized AMS signal plan.

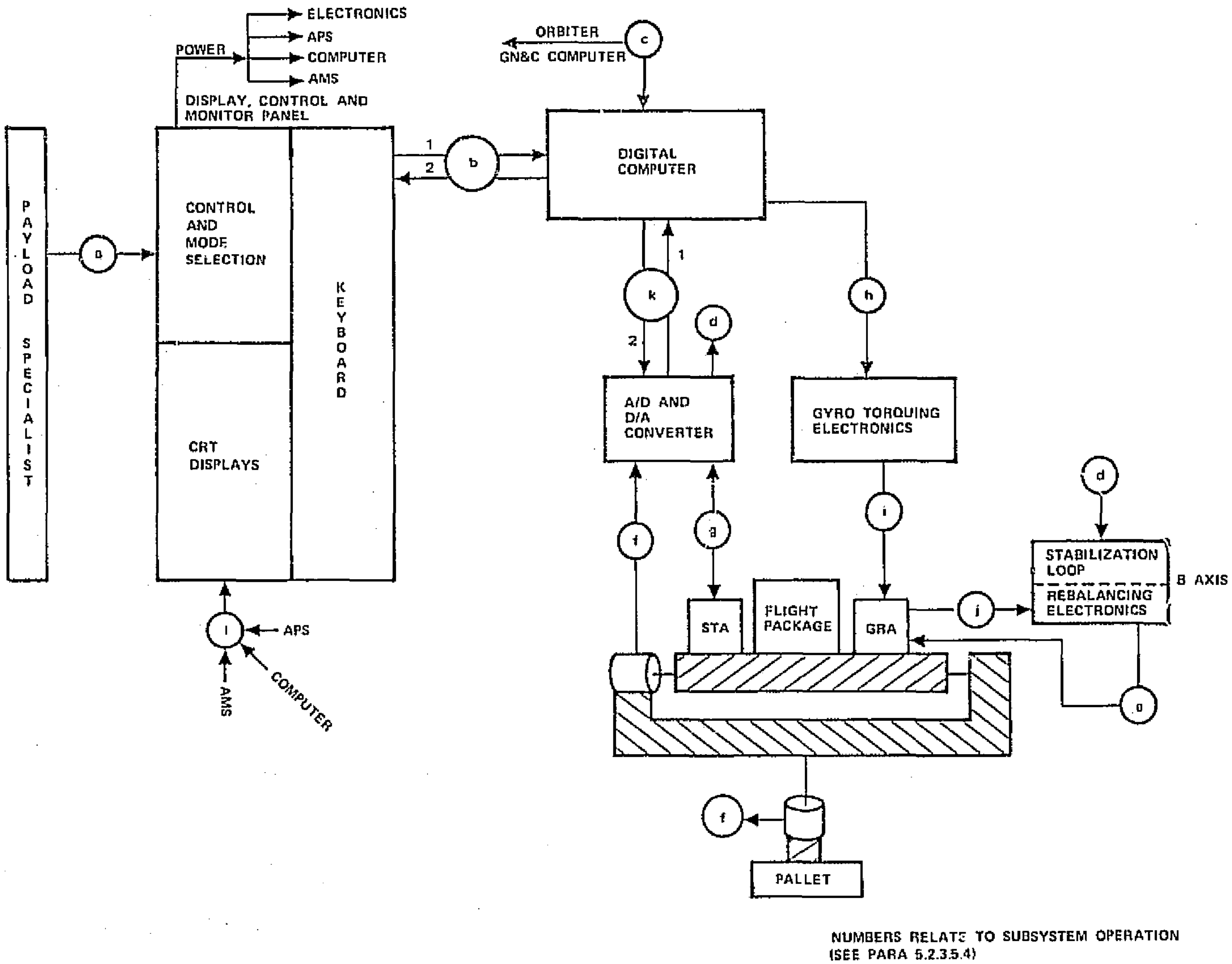


Figure 5.2.3-4. — Altitude reference & pointing control functions.

b. Gyro reference assembly.

c. Star tracker assembly.

d. Processing electronics.

e. APS.

5.2.3.5.1.1 Digital Computer

The digital computer is part of the CDMS described in paragraph 5.1.4. The general pupose computer is used to support the ASF support subsystems. The computer is a major functional element of the PCSS providing coordinate transformations, gyro commands, gimbal commands, a star catalog, star identification processing, Orbiter GN&C inputs, and other related functions required for achieving the pointing, control and tracking necessary for the payload sensors operations.

5.2.3.5.1.2 Gyro Reference Assembly

The gyro reference assembly consists of three orthogonally mounted gyros on the AIM of the APS. The gyros provide stability error signals to the support subsystem computer. Attitude data are obtained from readouts at the APS gimbals.

Available gyro units have a drift rate of 0.01°/hour. The selection of the gyro unit will be dependent on bias stability, power, weight, cost and gimbal drive rate requirements. Listed below are examples of current state-of-the-art gyros in the 0.01° to 0.1°/hour drift range:

Honeywell GG 248	Apollo
A. C. Electronics IRIG 25	Apollo, Skylab, ASTP
Kearfott 2519	Skylab

5.2.3.5.1.3 Star Tracker Assembly

Star trackers are usually classified as gimbaled or strap-down with a variety of detectors ranging from solid state to photomultiplier tubes. State-of-the-art trackers are available with an accuracy of 10 to 30 arc seconds. There are star trackers advertised with an accuracy potential of 0.5 arc sec., such as the ITT or Nortronics trackers, but these are still in the development stages. Table 5.2.3-5 is a sample of state-of-the-art star trackers that have been developed and have been qualified for the respective programs.

Strap-down trackers are less complex from a hardware standpoint to implement. They can be mounted on the same platform as the GRA and payload instruments. In order to achieve the accuracy requirements desired, a narrow FOV is needed, thus requiring a lower star threshold and requiring the scanning of the entire gimbal system in order to conduct star searches. A minimum of two trackers are required in order to determine the attitude reference if large Orbiter maneuvering angles are to be avoided.

The gimbaled tracker adds complexity to its design but can be operated independently of the main gimbal system when searching for stars. Star threshold levels for gimbaled systems are higher because of the large area of celestial sphere available by the gimbal system. Usually, one star tracker is needed to determine the desired attitude reference.

Either type of star tracker discussed has the accuracy needed for the ASF payload. The selection will be influenced by such factors as weight, cost, power, etc.

5.2.3.5.1.4 Processing Electronics

The processing electronics contains amplifiers, analog-to-digital (A/D) and digital-to-analog (D/A) converters, multiplexing equipment,

TABLE 5.2.3-5. — TYPICAL STAR TRACKER PERFORMANCE CHARACTERISTICS

Performance Data	Kollsman Oao	ITT Federal Labs	Hughes** Tracker	Kollsman* KS-199	Shuttle Tracker BBRC	ATM Star Tracker
Field-of-view	1° × 1°	8° × 8°	2° × 2°	1.2° diam	10° × 10°	1° × 1°
Star magnitude sensitivity	+2	+3	+3	+2.4	+3	+3
Operational accuracy	15 sec	5 sec	30 sec	10 sec	60 sec	22 sec
Weight - kg (lb)	19.5 (43)	4.3 (9.5)	13.6 (30)	13.6 (30)	7.3 (16)	32.6 (72)
Power (watts)	15 watts	8 watts	40 watts	19 watts	23 watts	15 watts
Gimbal freedom	2 AXIS	STRAP-DOWN	2 AXIS	2 AXIS	Strap-down	2 AXIS
Dimensions - meters (ft)	0.86×.30×0.40 (2.8×1.0×1.3)	0.12×0.27×0.12 (0.4×0.9×0.4)	16"×18"×12"	0.43×0.30×0.30 (1.4×1.0×1.0)	Unavailable	0.40×0.28×0.10 (1.3×0.9×0.3) (electronics) 0.45×0.28×0.40 (1.5×0.9×1.3) (Mechanical/ optics)

*Developed for JSC under the cognizance of the Guidance and Control Division (EG). Unit has been qual tested and performance verified by testing.

**Developed during Apollo for JSC as a Lunar Optical and Rendezvous System and has been qual tested and performance verified by testing.

processing electronics, switching logic, input and output signals, processing, routing and gyro rebalancing electronics for the operations of the PCSS. Included in the attitude measuring subsystem are the status indicator circuits for monitoring key system parameters for proper operation during the mission and ground self-testing. These include both hardware circuitry and software-aided programs.

The pointing system control electronics as well as the torque motors, resolvers, etc., are considered part of the APS.

5.2.3.5.1.5 AMPS Pointing System (APS)

The type of pointing system selected and the system design features are discussed in Section 5.2. The general approach is to standardize the design for both systems. A particular gimbal arrangement or order is not necessary to meet pointing requirements. This is usually a function of mechanical obstruction in the desired FOV and gimbal range necessary to cover all desired targets. Each gimbal axis will have torque motors and an angular readout device such as a resolver for torquing the platform to its desired position and providing position data.

On some instruments, stability about the instrument LOS is critical. Therefore, this may dictate the need of a three-axis gimbal system.

5.2.3.5.2 PCSS Equipment Characteristics

Excluding the APS and the digital computer which are described in other sections of this report, the equipment for the PCSS described in this section weighs approximately 100 kg and uses 210 to 255 watts of electrical power. The estimated size, weight and power breakdown by subsystem equipment are shown in table 5.2.3-6.

TABLE 5.2.3-6. — SIZE, WEIGHT, AND POWER SUMMARY
POINTING/CONTROL AND STABILIZATION SUBSYSTEM

End Item	Size W×H×D-meters (ft)	ght-kg (lb)	Power (watts)
AMPS Pointing System	This data is provided in section 5.1.1		
Digital Computer	The general purpose digital computer will be discussed in the data system section of this report		
Gyro Reference Assembly	0.25 × 0.20 × 0.18 (0.8 × 0.7 × 0.6)	30 (66)	100
Signal Processing Electronics	0.40 × 0.35 × 0.15 (1.3 × 1.1 × 0.5)	20 (44)	40
Star Tracker Assembly	FHST-0.60 × 0.21 × 0.21* (2.0 × 0.7 × 0.7)	33 (73)	75
	GST-0.58 × 0.45 × 0.42** (1.9 × 1.5 × 1.4)	20 (44)	30
Sun Sensor	0.30 × 0.20 × 0.15 (1.0 × 0.7 × 0.5)	13 (29)	10
Optical Alignment Measuring Device	0.25 × 0.10 × 0.10 (0.8 × 0.3 × 0.3)	12 (26)	30
Total		95*/108** (209/238)	210*/ 255*

*GST — Gimbaled Star Tracker
**FHST — Fixed Head Star Tracker

5.2.3.5.3 Interfaces

Figure 5.2.3-5 describes the interface data flow within the ASF payload and to/from the Orbiter. The primary interface areas are power, data management, and Orbiter GN&C subsystem. The following paragraphs will describe in general the attitude pointing and control interfaces.

a. PCSS-to-Orbiter. The primary interface with the Orbiter is the GN&C subsystem. The Orbiter GN&C will provide to the payload initialization data such as vehicle attitude, timing, clock synchronization, etc., necessary for monitoring the attitude position of the Orbiter. The interface will allow for the transfer of pointing vector information to the Orbiter GN&C so that the payload attitude can be assessed by the Orbiter. Further, the interface requires the transmittal to the Orbiter GN&C of a pointing vector for reorienting he payload through use of the Orbiter RCS or vernier RCS. The Orbiter will have the capability through the interface to transmit override commands from the payload control panel to disable the payload attitude pointing system if required.

   The requirement exists to interface the payload attitude sensor (star tracker) through the ASF support subsystem computer with the Orbiter GN&C computer so that the basic error between the payload attitude measuring system and the Orbiter reference system resulting from structural deformation can be established during flight.

b. PCSS-to-Support Subsystems. The pointing and control discipline involves the management of several pointing systems. Figure 5.2.3-6 shows typical inter-relationships of the various elements of the payload system and briefly describes the functions of the major interface subassemblies. The PCSS must interface with the support subsystem computer. This

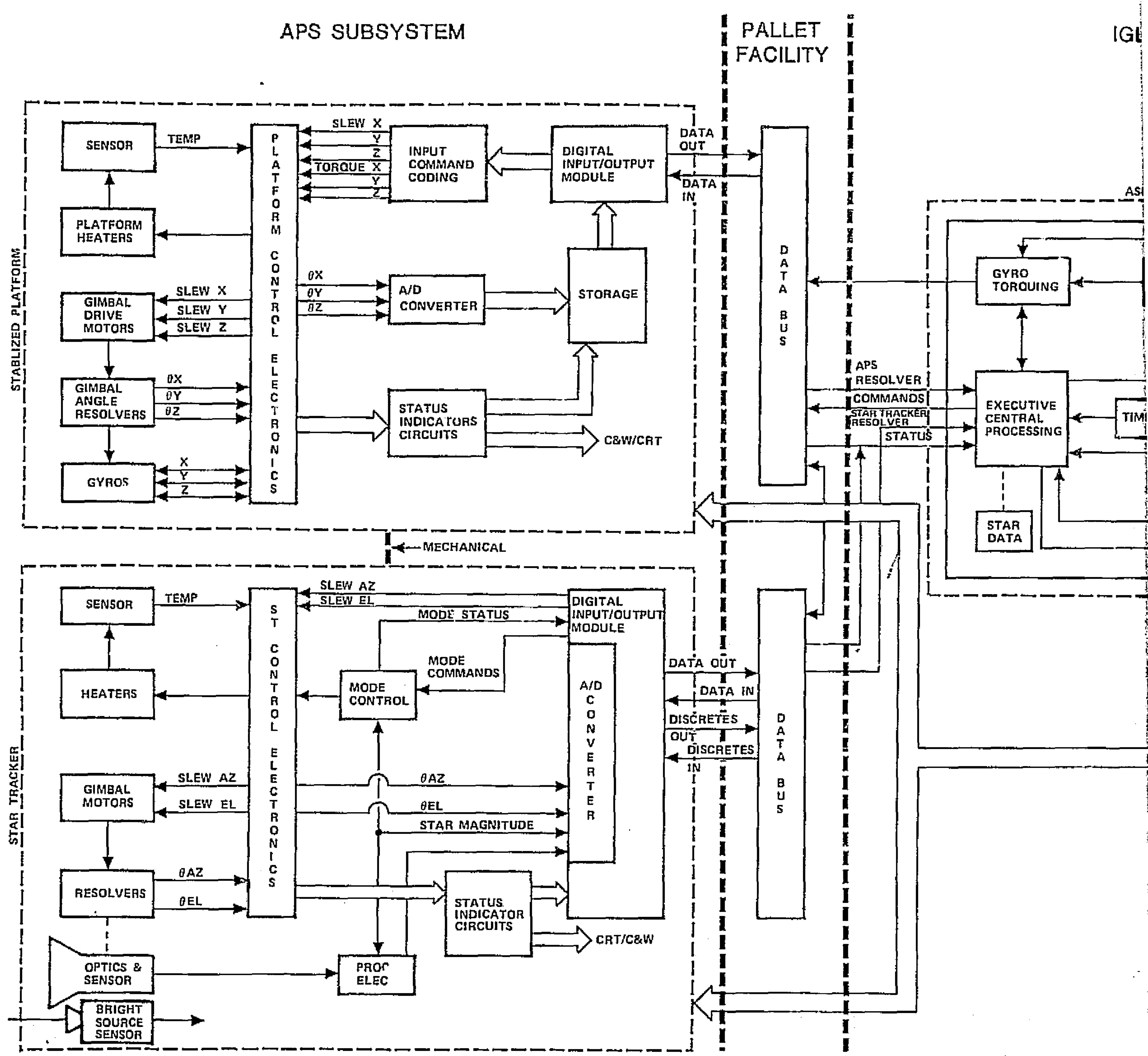
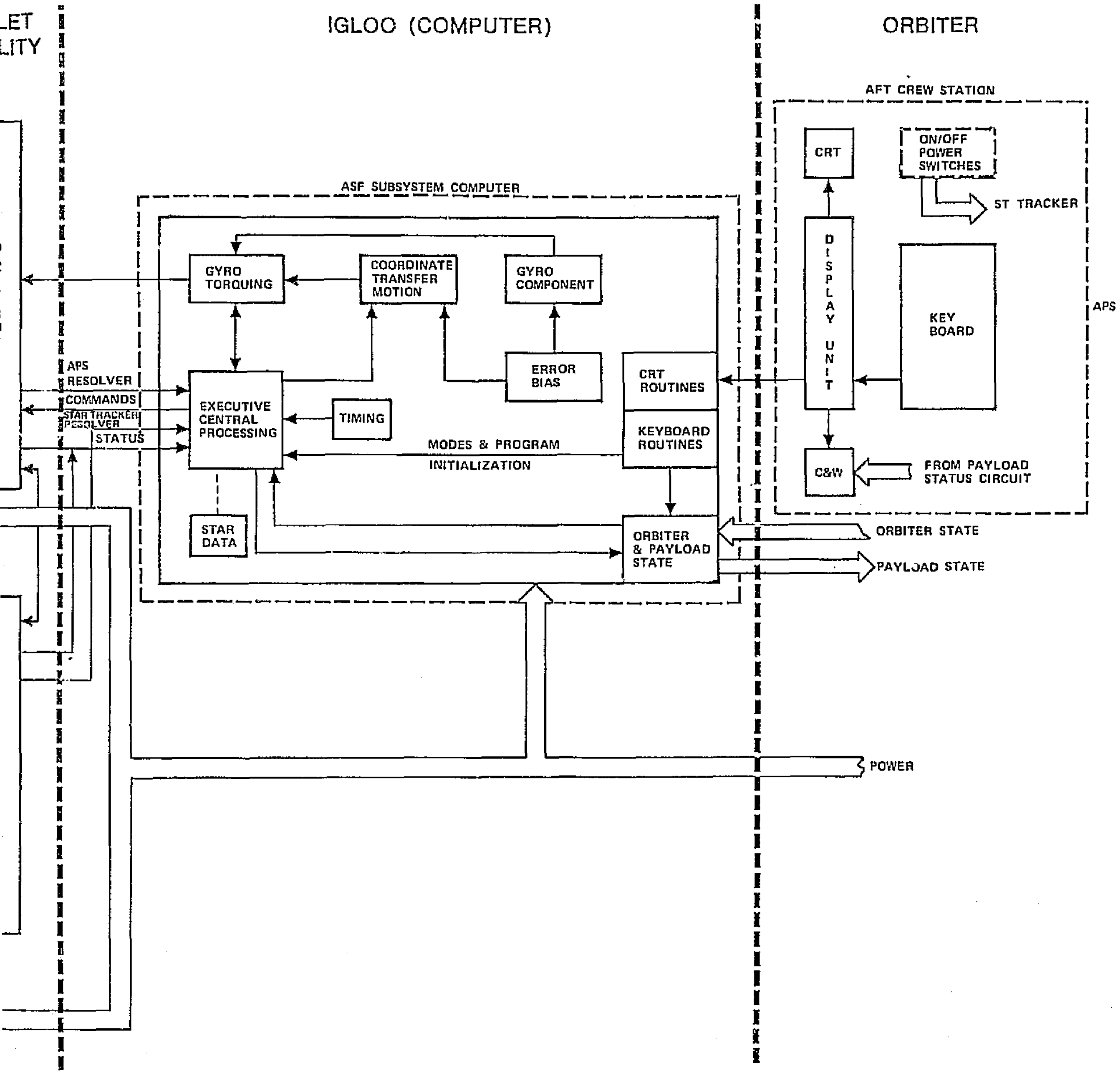


Figure 5.2.3-5. — Interface and Data Flow Dia

FOLDOUT FRAME



Interface and Data Flow Diagram

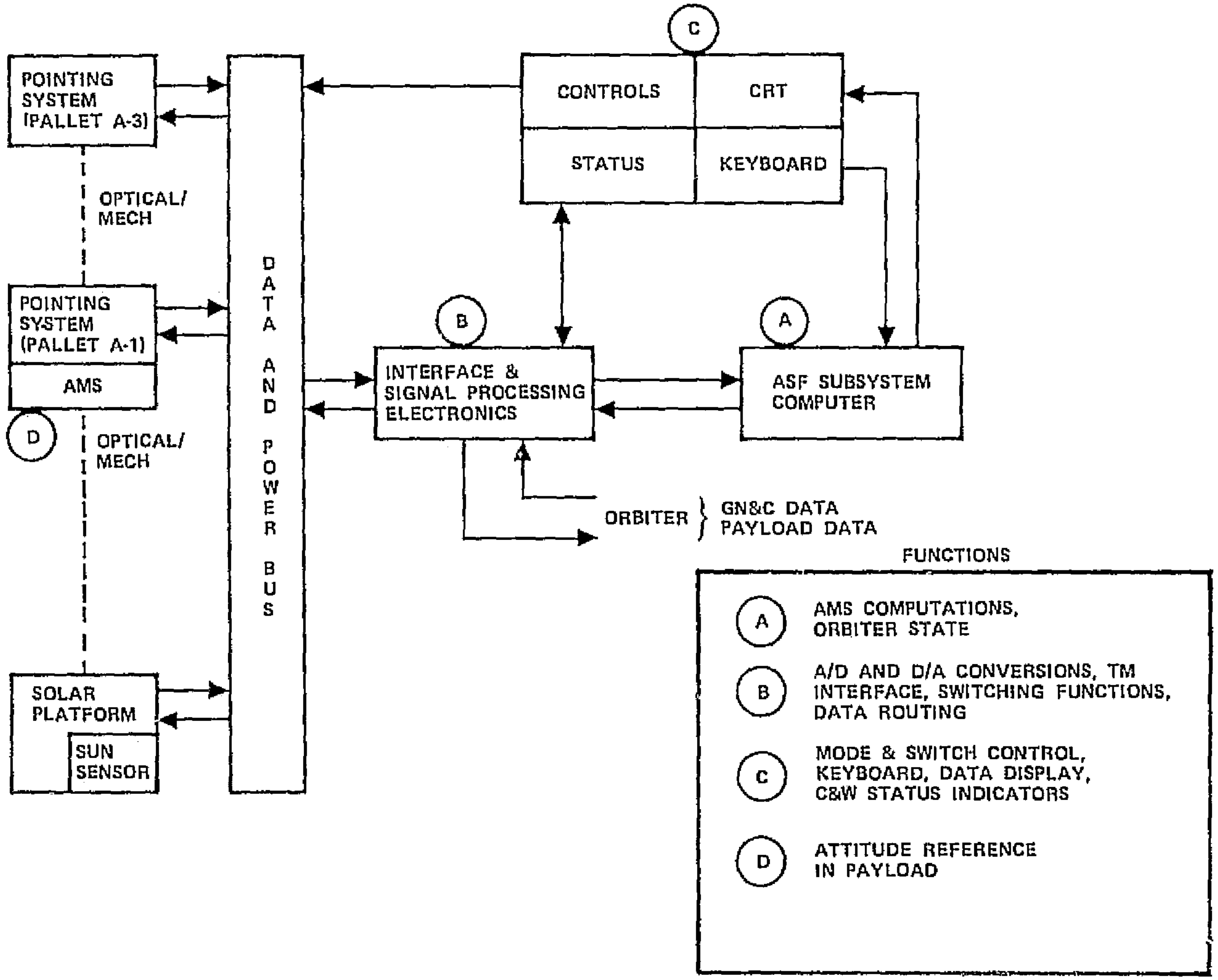


Figure 5.2.3-6. — Pointing and control interface and data flow chart.

relationship and data and command flow is reflected in figure 5.2.3-5. A summary of the command and data requirements is reflected in table 5.2.3-7. Power interfaces are discussed in paragraph 5.2.2.

5.2.3.5.4 Operations

In reference to figure 5.2.3-3 and 5.2.3-7 a and b, the PCSS operations are summarized below. Item letters below correspond to the item numbers contained in those two figures.

a. The PCSS is activated by the PS. The PS has the option of operating the APS either automatically through the computer or manually through the fine pointing control lever at the PSS.

b. The PS prepares the APS for alignment as follows:

   (1) The PS selects the proper program, mode, etc., and commands are transferred to the payload subsystem computer.

   (2) PCSS status and data are displayed on the CRT at the PSS during the alignment operation.

c. The data link between the Orbiter GN&C and the payload support subsystem computer is activated. The ASF support subsystems computer receives the following information from the Orbiter GN&C for use in computation: Orbiter position (crosstrack, downtrack, altitude), velocity, attitude (3-axis), target coordinates, time reference, etc. The ASF support subsystems computer will update the Orbiter with the same data as required.

d. Using Orbiter data, the payload is coarse aligned. The computer sends out commands via path k. The gimbal angles orientation is controlled by the computer and APS is positioned to an

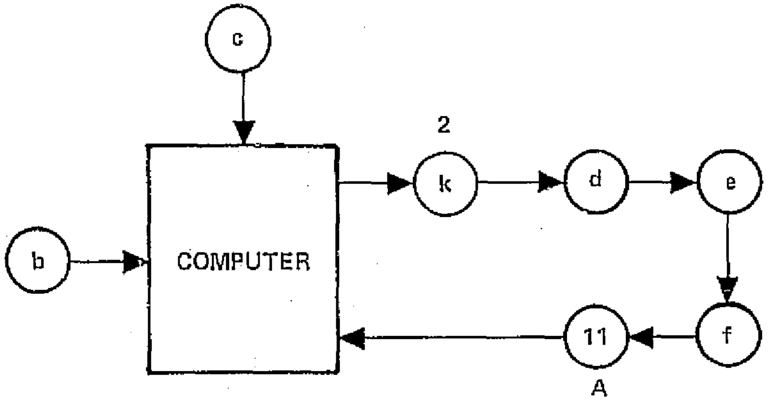
TABLE 5.2.3-7. — SUMMARY OF POINTING AND CONTROL SUBSYSTEM PRELIMINARY DATA REQUIREMENTS

Signal Name	Source	Signal Type	Sample Rate (samples per second)
APS 1 and 2			
APS Temperature	Gimbal Platform Electronics Temp Sensor	Housekeeping	1 S/S
Gimbal Resolver Axis 1	Gimbal Position	Output Data Word	25 S/S
Gimbal Resolver Axis 2	Gimbal Position	Output Data Word	25 S/S
Gimbal Resolver Axis 3	Gimbal Position	Output Data Word	25 S/S
APS Power on Command	Keyboard/Display	Discrete	1 S/S
APS Mode Status	Keyboard/D&C	Discrete	1 S/S
APS Gimbal Slew Axis 1	Subsystem Computer	Input Data Word	25 S/S
APS Gimbal Slew Axis 2	Subsystem Computer	Input Data Word	25 S/S
APS Gimbal Slew Axis 3	Subsystem Computer	Input Data Word	25 S/S
APS A/D Axis 1 Fail	Gimbal Platform Electronics	Housekeeping	1 S/S
APS A/D Axis 2 Fail	Gimbal Platform Electronics	Housekeeping	1 S/S
APS A/D Axis 3 Fail	Gimbal Platform Electronics	Housekeeping	1 S/S
Coolant Input Temp	Pallet Sensors	Housekeeping	1 S/S
Coolant Output Temp	Pallet Sensors	Housekeeping	1 S/S
APS Torquer Current Axis 1	Gimbal Elect	Housekeeping	1 S/S
APS Torquer Current Axis 2	Gimbal Elect	Housekeeping	1 S/S
APS Torquer Current Axis 3	Gimbal Elect	Housekeeping	1 S/S
Gyro Package Temp	Temp Sensor	Housekeeping	1 S/S
Gyro Electronics Temp	Temp Sensor	Housekeeping	1 S/S
Gyro Torque Command X	Subsystem Computer	Input Data Word	25 S/S
Gyro Torque Command Y	Subsystem Computer	Input Data Word	25 S/S
Gyro Torque Command Z	Subsystem Computer	Input Data Word	25 S/S
Gyro Torque Rate X	Subsystem Computer	Input Data Word	25 S/S
Gyro Torque Rate Y	Subsystem Computer	Input Data Word	25 S/S
Gyro Torque Rate Z	Subsystem Computer	Input Data Word	25 S/S
Gyro Warm-Up Time	Keyboard/D&C	Discrete	1 S/S
Gyro Power Present	Keyboard/D&C	Discrete	1 S/S
X Gyro Fail	Gyro Package and Electronics	Output/Housekeeping	1 S/S
Y Gyro Fail	Gyro Package and Electronics	Output/Housekeeping	1 S/S
Z Gyro Fail	Gyro Package and Electronics	Output/Housekeeping	1 S/S

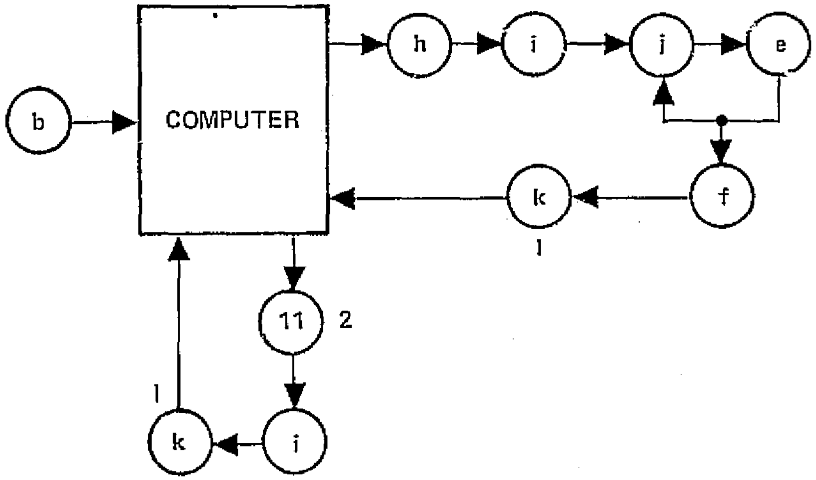
TABLE 5.2.3-7. — SUMMARY OF POINTING AND CONTROL SUBSYSTEM PRELIMINARY DATA REQUIREMENTS - Concluded

Signal Name	Source	Signal Type	Sample Rate
Star Tracker Temp	ST Temp Sensor	Housekeeping	1 S/S
Star Tracker Elect Temp	Electronics Temp Sensor	Housekeeping	1 S/S
ST AZ Resolver	ST Gimbal Position	Output Data Word	25 S/S
ST EL Resolver	ST Gimbal Position	Output Data Word	25 S/S
ST AZ Slew	Subsystem Computer	Input Data Word	25 S/S
ST EL Slew	Subsystem Computer	Input Data Word	25 S/S
ST AZ Torquer Current	ST Gimbal Electronics	Housekeeping	1 S/S
ST EL Torquer Current	ST Gimbal Electronics	Housekeeping	1 S/S
ST Search Command	Subsystem Computer	Input/Command	1 S/S
Star Presence	ST Selector Output	Output/Housekeeping	1 S/S
Star Tracker Engage	Star Tracker	Output/Housekeeping	1 S/S
Star Tracker Power Present	Keyboard/D&C	Housekeeping	1 S/S
Star Magnitude	ST Electronics	Output/Housekeeping	1 S/S
ST A/D AZ Channel Fail	ST Electronics	Housekeeping	1 S/S
ST A/D EL Channel Fail	ST Electronics	Housekeeping	1 S/S
Bright Source Sensor	ST Electronics	Output Data Word	1 S/S
Optics Shutter Status	Star Tracker	Output Data Word	1 S/S

Note: Three fixed-head star trackers or one gimbaled star tracker required. Measurement list for each tracker is the same.



a. PLATFORM ERECTION



b. ALIGNMENT AND UPDATING

Figure 5.2.3-7. — PCSS operational sequence.

accuracy of ≈2°. Certain instruments such as the Optical Band Imager and Photometer system require manual fine pointing using the "joystick".

e. Signals are generated to torque the gimbals to a coarse align orientation.

f. Resolver outputs which are proportional to the gimbal angles (position data) are provided to the payload computer (A/D conversion) via k.

g. Star position data (optical angles) are provided and transformed by the computer into inertial reference frame for positioning gyros. Sighting of at least two stars (non-colinear) are required. These data are provided to computer via k. Status data are provided and can be displayed on the CRT if requested by the PS.

h. The computer transforms optical measurements into inertial coordinates and compares desired coordinates with actual coordinates. The computer selects gyro(s) to be torqued and gates the required pulses through the gyro torquing electronics.

i. Each gyro is positioned as commanded by the computer until the PCSS is aligned.

j. Stabilization loop is established. This loop holds the stabilized system inertially referenced as determined by star sensor and commanded by computer. Gyros generate error signals (i) to indicate any change with respect to inertial space resulting in the gimbal torque motors being repositioned (e).

k. PCSS data is routed through the system via:

   1. A/D data provided to computer as status and/or position indication.

   2. D/A commands provided by computer to perform required functions.

Data to the CRT at the PSS are provided depicting the health of the system.

5.2.3.5.4.1 Operational Modes

The operational modes of the pointing and control subsystem can generally be classified into the following categories: initial alignment and updates, attitude determination, stabilization, and tracking/pointing. Each are described below.

a. Initial Alignment and Updating. This mode utilizes the star tracker to establish the common reference frame for the payload experiments. In this mode, the gimbals can be slewed to zero or the Orbiter GN&C computer can transfer appropriate data to the ASF support subsystem computer for aligning the gyro system to a coarse reference frame. In order to perform the fine alignment, sightings on a minimum of two non-colinear stars are required. The ASF support subsystem computer accepts the angular data received from these optical measurements along with star catalog data stored in memory and transforms it into an inertial reference frame for precisely aligning the GRA. The same procedure is repeated to update the system to correct errors that are usually accrued from gyro drift.

b. Attitude Determination. Outputs from the three gyros mounted on the gimbal system are used to maintain an updated attitude reference for the payload sensors and determination of the LOS with respect to the inertial reference frame established by star tracker sightings. The attitude data defining payload position is transferred to the Orbiter GN&C computer to maintain that the Orbiter spacecraft attitude is properly positioned during the payload operation.

c. Stabilization. In the stabilization mode, the stabilized platform inertially referenced is isolated from spacecraft motion. The three gyros generate error signals to indicate any change in orientation with respect to inertial space and these signals are supplied to the gimbal torque motors which reposition the APS.

d. Tracking and Pointing. This mode allows the LOS to be pointed to a target and track the target in the presence of Orbiter motion. The Orbiter position and target position are transferred into inertial coordinates and a command vector is determined. This command vector is then transformed into payload LOS coordinates and the gimbals are aligned to point the sensor(s) LOS to the desired pointing direction.

5.2.3.5.4.2 Operational Functions

a. In-Flight Alignment. The in-flight alignment of the PCSS requires use of the Orbiter GN&C to maneuver the vehicle to an attitude where target visibility is obtained and to transmit star tracker pointing vectors to the support subsystem computer. The computer generates gimbal commands to point the star tracker along the star vector. Due to the potential misalignments between the star tracker and the Orbiter GN&C, it will be necessary to scan the star tracker LOS over a predetermined field to insure star acquisition.

Prior to star acquisition, the gyro reference is initialized with an approximation to the desired inertial attitude for target tracking and placed in the inertial mode. Using this approximate alignment, simultaneous star tracker and APS gimbal angle readouts are taken by the subsystem computer for two non-colinear stars.

Using this data the ASF support subsystem computer solves for the refined final pointing system gimbal angles and establishes a true inertial reference based on the desired pointing vector and gyro reference assembly outputs. It is possible to update this alignment in a similar manner on a periodic basis, or, if desired, near-continuous updating may be performed utilizing optimal optional estimation techniques and continuous tracking of a single star. The sequence of operation discussed above is described in figure 5.2.3-8.

b. Target Pointing and Tracking. This mode provides the capability to track a target in the presence of Orbiter motion after initial alignment and/or acquisition has occurred. This operation requires that outputs of the GRA and the STA be combined by the subsystem computer to form an inertial frame in the APS. The present inertial attitude is compared to that desired, and appropriate gimbal torque commands are generated to position the platform(s) to maintain the desired inertial pointing vector. This vector may be fixed with respect to the earth; however, its position is always referenced instantaneously to an inertial frame and appropriate bias rates are introduced by the ASF support subsystems computer to enable tracking as desired. If it is desired to track a non-inertially fixed target, the support subsystems computer must be given the orbit ephemeris on a continuous basis to yield the desired tracking accuracy. Use of the star tracker in conjunction with the gyro reference assembly will allow for periodic updating of gyro drifts.

In order to meet the pointing accuracy requirements utilizing a centralized AMS, it will be necessary to establish and monitor relative base motion of the various mounts. This may be accomplished by optical transfer techniques. These alignment errors will be provided to the support subsystems computer to establish the relative location to the various mounts. The Laser Sounder (Instrument 213) pointing and tracking operation will require near continuous updating from the support subsystems computer. The following

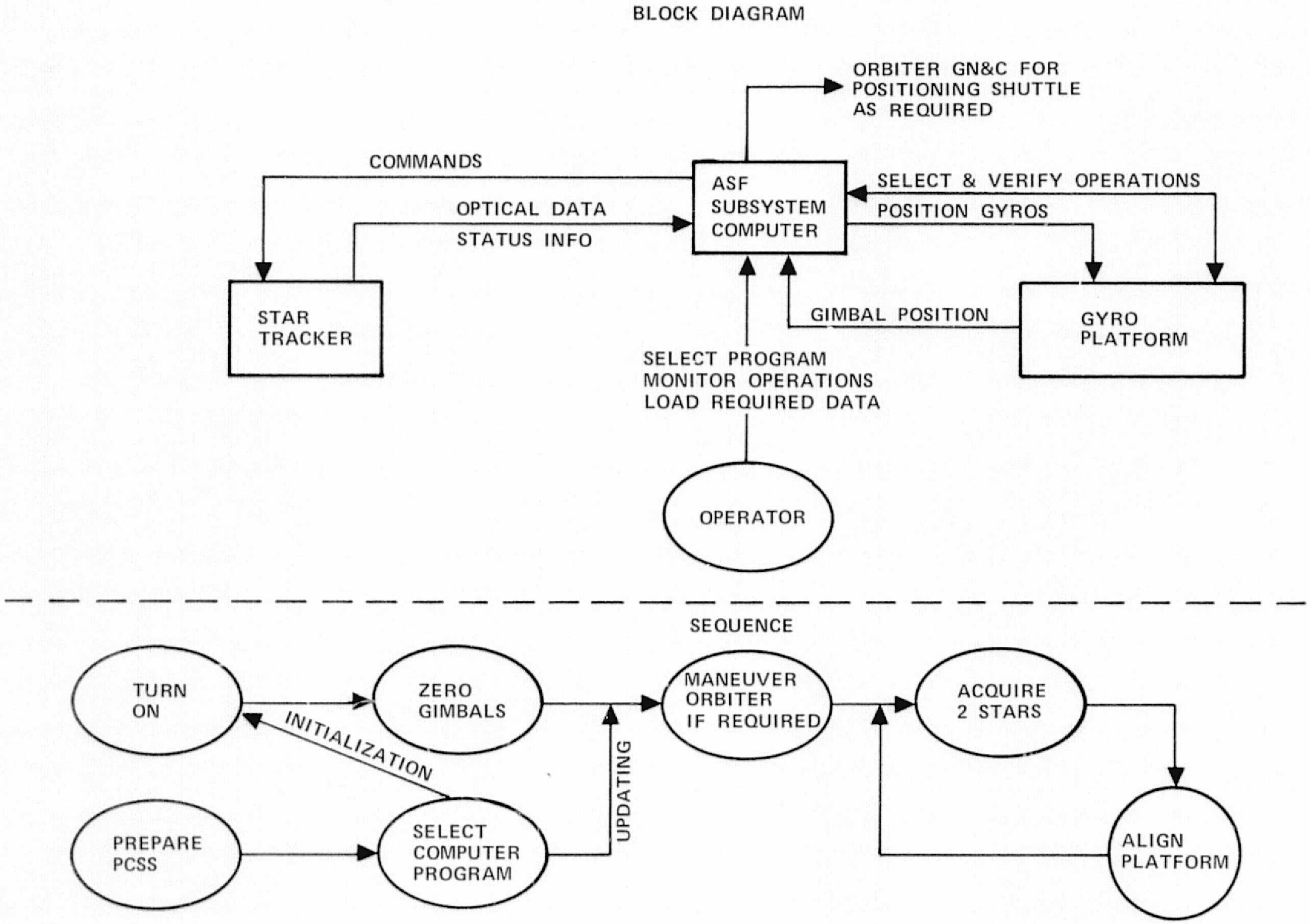


Figure 5.2.3-8. — Inflight alignment sequence.

sequence of events is envisioned in the performance of target pointing and tracking.

(1) The ASF support subsystems computer generates the desired pointing vector. Body fixed axis and inertial pointing is desired.

(2) This vector is transferred to the Orbiter computer.

(3) The Orbiter computer determines the necessary inputs to the Orbiter flight control system.

(4) The RCS maneuvers the Orbiter to the desired orientation.

(5) Once there, the Orbiter is placed in attitude hold with desired deadband.

(6) The ASF support subsystems computer transforms the desired pointing vector into the payload LOS coordinates in terms of gimbal angles. The gimbal errors represent the rotation required to position the LOS to the desired direction.

(7) The payload gimbals converge to the desired target using the payload attitude sensors.

(8) During tracking, calculations for positioning the gimbals must be performed repeatedly to maintain the desired pointing direction while both the target and Orbiter are moving.

Figure 5.2.3-9 illustrates a block diagram for performing the pointing and tracking requirements. Tracking aids, such as a TV camera system, could be advantageous to the PS for those targets that require open loop fly-by tracking. This requires that the TV camera be boresighted to the flight package and slaved to the flight package gimbal electronics.

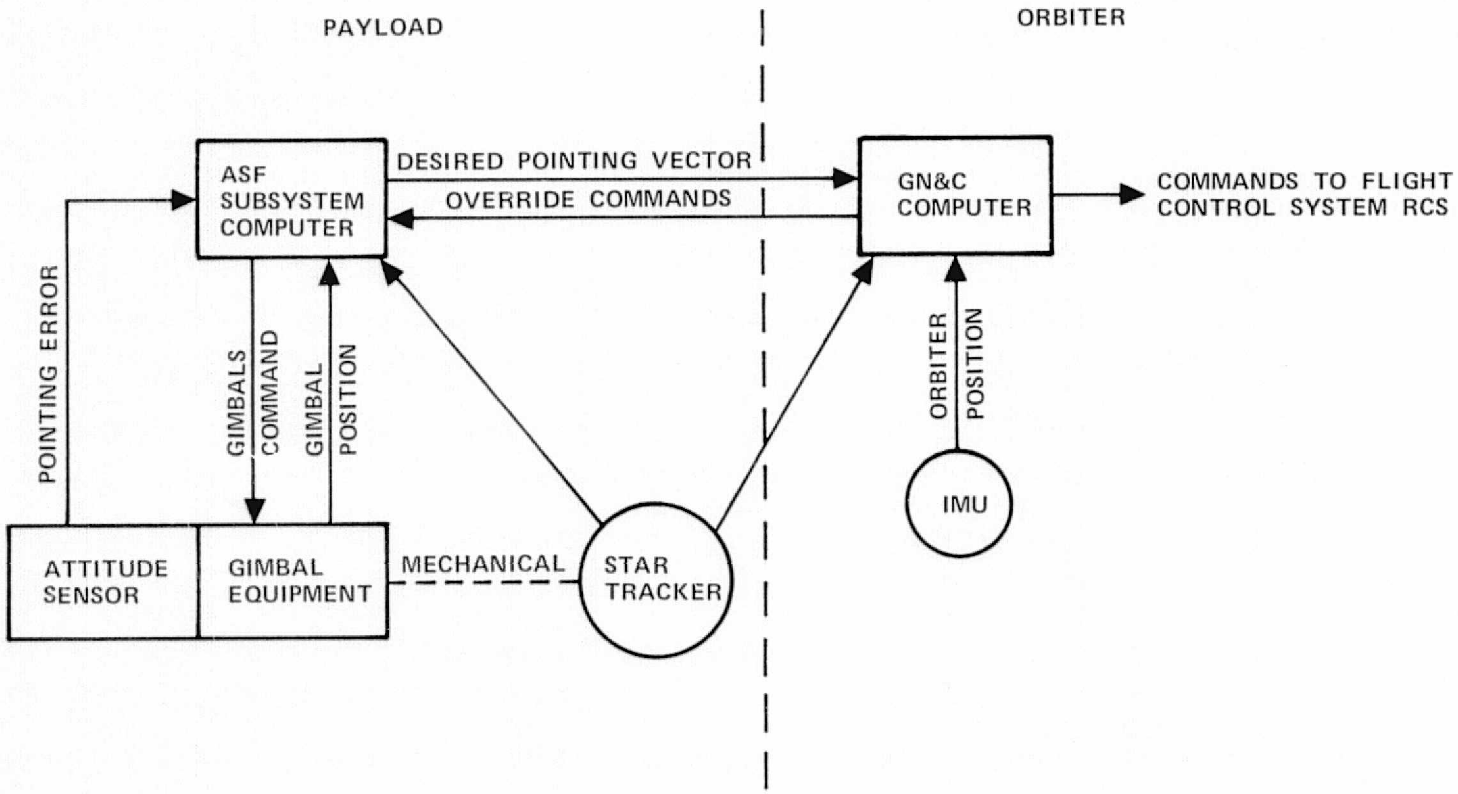


Figure 5.2.3-9. — Block diagram for pointing and tracking simplified.

c. Solar Pointing and Tracking. For solar pointing and tracking, sun sensors can be used to provide error signals to reposition the LOS. The AMS can be used along with the subsystems computer to generate the desired pointing vector for the solar monitoring platform LOS. This can serve as a coarse alignment for the solar platform. Once the sun is in the solar tracker FOV, the error signal is supplied to the solar monitor gimbal system and the gimbals are torqued until the output error signal from the solar tracker is nulled. This is illustrated in figure 5.2.3-10.

For those instruments that require scanning the sun disk or examining sections of the solar disk other than the center, offset signals can be introduced into the control loop. Another approach is to use optical wedge offset pointing.

The fine sun sensor optical wedge subassembly is rotated to vary the angle of the incoming sunlight and produce an offset of the experiment platform. This technique was utilized with a high degree of success during the Skylab mission.

Sun sensors are available, such as that used on Skylab, that have an accuracy capability of approximately four arc seconds.

5.2.3.5.4.3 Operations Management

The ASF subsystem computer and the APS with its associated GRA and STA form the nucleus of the central reference system. Pointing and control of any subsystem will involve management of the subsystem together with the APS. The outputs of the GRA and STA are combined by the ASF support subsystems computer to yield a constant APS inertial attitude. Gimbal drive commands for one or all payload subsystems are generated by the computer as required. Gimbal angle readouts together with other tracking

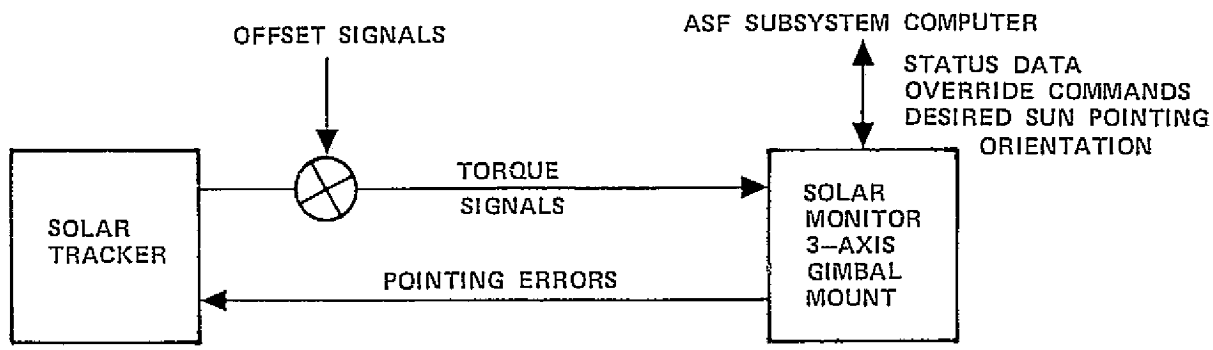


Figure 5.2.3-10. — Solar monitoring pointing and control.

sensor outputs are accepted by the computer and used to generate a continuous update of pointing vector coordinates. These coordinates are compared to the desired coordinates (after suitable transformation) in the inertial frame defined by the APS and suitable gimbal torque commands are generated to null any existing tracking errors.

Orbiter attitude must also be factored into the pointing and control tasks. Initial attitude when alignment of the APS takes place will require crew coordination. Thereafter, the support subsystems computer will monitor attitude through the APS. If particular experiments require Orbiter attitude changes for tracking or to prevent occultation, appropriate desired payload bay pointing vectors must be furnished to the GN&C computer or displayed to the crew.

The pointing and control operations for the ASF payload involve two AMPS pointing systems plus a flight package that is hard mounted to the pallet. In general, the simultaneous operation of all pointing systems is not required; however, there will be occasions for the simultaneous operation of these systems. A typical example of this is the simultaneous operation of the Laser Sounder on module 1A and the optical instruments on module 1B. The experiment requirements will govern the need for multiple operations.

The management of the APS will be performed by the support subsystems computer and the payload attitude reference system.

In the previous paragraphs, two subsystem approaches were discussed for an AMS, central and distributed. Since the pointing accuracy requirements for the APS vary from .01° to 6°, a central attitude reference system with the capability of transferring alignment data for alignment control could be implemented for the operations and management of the APS. Therefore, this approach is suggested for the pointing and control aspects of the ASF payload. Since the optical instruments module requires the most stringent stability and pointing accuracy, the AMS will be placed on the pallet with this module.

Pallets A-1 and A-3 contain the two ASF APS.

a. Pallet A-1. Module 1A on pallet A-1 contains the Laser Sounder (Instrument 213) and the Gas Release Module (Instrument 532). Module 1B contains optical instruments for investigating the atmosphere (Instrument 534), solar monitoring instruments (1002 and 1011) and particle beam diagnostic (Instrument 550). The pointing and stability requirements for the individual instruments within these flight modules are shown in table 5.2.3-1.

   The operational modes for the laser sounder system are pointing and tracking. The pointing accuracy for this sytem is 1°. Its reference base will be monitored and provided by the AMS located on pallet 3. The tracking mode provides the capability of maintaining lock on the target in the presence of Orbiter motion. The technique required is described in the previous section. The Laser Sounder pointing control will be provided by the computer. Resolvers provide position readouts for use by the computer in generating both the initial and update pointing commands.

   The minimum pointing and stability requirements for the solar flight package are 60 seconds of arc and 0.01° per second, respectively. The solar instruments will be mounted together and boresighted to a common LOS. The solar pointing and tracking technique were discussed previously. A solar tracker is employed to provide the necessary tracking and maintaining lock on the solar disk during instrument operations.

b. Pallet A-3. Pallet A-3 also contains two AMPS instrument modules. Module 3A is configured with the Airglow Spectrograph (Instrument 116) and the Limb Scanning IR Radiometer (Instrument 118), while module 3B contains the UV-VIS-NIR Spectrometer (Instrument 122), the Fabry-Perot Interferometer (Instrument 124), and the Infrared Interferometer (Instrument 126). The pointing and stability requirements for the individual instruments within these flight packages are shown in table 5.2.3-3.

The primary function of this platform is to point and control the orientation of the common LOS of each flight module on the pallet. The minimum pointing and stability requirements dictated by the instruments on this platform are 0.1 degrees and 30 seconds of arc per second, respectively. An additional function of this platform is to provide the single ASF attitude reference. Therefore, the present scheme is to mount the AMS on this pallet. Alignment data and control will be transferred through optical links to the other APS on pallet A-1. To accomplish these two functions, the operational modes are:

(1) initial alignment and update mode.

(2) attitude determination and control mode.

(3) target pointing and tracking mode.

These three modes of operation are discussed in detail in previous sections.

c. Pallet hard-mounted platform. This flight package consists of the particle accelerator instruments. Because of the gross pointing and stability requirements (i.e., 2° to 6° and 1°/sec., respectively), there is no need for a gimbal mount. These requirements can be achieved utilizing the Orbiter GN&C subsystem. Therefore, the Orbiter will be positioned in order to point the LOS of this flight package to its desired target.

d. Boom system. Instrument 550 (Faraday cup, Retarding Potential Analyzer, Cold Plasma Probe) is mounted on an extendable boom which is attached to AIM 1B on pallet A-1. The instrument must be extended generally above pallet A-4 during the accelerator operations. The instrument must raster scan an area covering the accelerator beam width. (See paragraph 5.2.1). The scanning motion is provided by the APS for AIM 1B. Instrument 536 (Triaxial Fluxgate) must be extended about 20 meters (66 feet) out of the payload bay. No special provisions other than holding to mechanical tolerances are required to meet the ±0.6° pointing accuracy for this instrument.

e. Subsatellite. Some of the ASF experiments require the use of the PDS to obtain supporting data. When the subsatellite is deployed, the Orbiter is used to point the subsatellite in the proper direction for ejection. No other requirement has been identified for orientation of the Orbiter relative to the subsatellite except during recovery of the subsatellite. Subsatellite attitude and rates can be of significant importance to ASF experiments and the compatibility of the AE satellite (used as baseline for the PDS) control system should be evaluated in the next study phase.

5.2.3.6 Analyses

Pointing error sources discussed in this section fall within two categories: (1) errors resulting from structural misalignments, and (2) errors related to the attitude pointing and control system (APCS). These two types of error directly affect the development of pointing techniques and system impelementation.

Structural errors result from the multitude of structural interfaces separating the attitude reference sensors and experiments, structural assembly errors, thermal deflection, etc. Systems errors are a function of the attitude sensors, gyro drift, quantization of signals, noise, etc.

In the candidate PCSS described in the previous paragraphs, the misalignment between the STA and GRA and the transformation of error signals from the gyros through the gimbals are manageable by design and calibration techniques. However, the misalignment between gimbal systems can have a significant impact. This can be reduced by the arrangement of the gimbal platforms on the pallet. More sophisticated methods such as optical links for alignment control (reference figure 5.2.3-2) or a gyro package for each gimbal system may be required to satisfy the pointing accuracy for the payload sensors. Until the design approach matures sufficiently to perform an error analysis, the pointing technique cannot be finalized. The selection of attitude sensors as well as the type of subsystem (central vs. distributed) is also dependent on the error analysis.

The numerical values appearing in table 5.2.3-8 are typical errors of related sensors that were used on Apollo and Skylab programs.

5.2.3.7 Conclusions and Recommendations

5.2.3.7.1 Conclusions

A significant result of reviewing the Orbiter capability versus payload requirements for pointing and stability is that the uncertainties or errors in pointing knowledge of the Shuttle reference system will exceed the requirements of many payload sensors. Since the Orbiter GN&C cannot satisfy all of the ASF instrument pointing accuracy and stability requirements, it is

TABLE 5.2.3-8. — SYSTEM ERROR BUDGET (1σ)

Equipment	Error
Star tracker gimbal accuracy	15 arc sec
Star tracker noise	5 arc sec
Star tracker quantization	1 arc sec
Star tracker bias error	4 arc sec
Star tracker to mount	10 arc sec
Gyro package to mount	10 arc sec
Gimbal resolver	5 arc sec
Gyro drift (time dependent)	10 arc sec
Gyro quantization	1 arc sec
Total	24.33 RSS*
Pallet deformation	Unknown
Pallet misalignments	Unknown

*Root Mean Square

concluded that one or more gyro stabilized platforms for stability and star trackers for pointing accuracy will be required to provide the pointing accuracy and stability desired by the payload instruments.

A centralized reference system utilizing a gyro reference assembly and one or more star trackers can provide a common attitude reference frame for all pointing subsystems. However, mounting of individual gimbal systems, pallet segment flexures, and pallet segment misalignments may result in sufficiently large errors that the addition of optical links between the individual gimbaled platforms and the reference system may be required for alignment control. An alternate concept is to provide a separate gyro/star tracker attitude reference unit to serve each gimbaled system that requires a high degree of accuracy and stability.

To summarize, the pointing/control and stabilization subsystem conclusions are as follows:

a. The ASF pointing and stability requirements are more exacting than that provided by the Orbiter GN&C system; therefore, a payload attitude reference sensor and/or system is required.

b. The error budget for the attitude measuring system demonstrates analytically that the ASF requirements can be met with state-of-the-art hardware consisting of a precision strap-down gyro-reference assembly and a star tracker to provide attitude alignment and update. A solar sun sensor will be needed for the solar platform to maintain the stability and offset pointing requirements.

c. Either a gimbal or strap-down star tracker can provide the necessary attitude reference for the payload.

d. A central reference system can provide a common reference system for all gimbal systems but may require optical links for alignment control.

e. For open loop fly-by targets, the use of a TV system for monitoring the instrument LOS pointing could be useful.

f. An interface between the payload star tracker and the Orbiter GN&C computer is mandatory so that an inflight calibration between the payload AMS and Orbiter reference system can be performed to determine the basic error resulting from structural deformation.

5.2.3.7.2 Recommendations

PCSS recommendations resulting from the study are as follows.

a. A detailed error analysis must be completed early in the follow-on study so that the pointing techniques and attitude sensors selection can be solidified.

b. Based on the error analysis, the type of subsystem, i.e., central or distributed, should be selected during the follow-on study.

c. The sensors for the AMS can be selected after the follow-on study is completed.

d. At the time this study was performed, studies for instrument pointing systems with an accuracy capability of 1 arc second were being conducted. During the follow-on study an assessment of these systems should be performed to determine applicability to the ASF missions.

5.2.4 COMMAND AND DATA MANAGEMENT SUBSYSTEM (CDMS)

5.2.4.1 Introduction

The objective of this phase of the study was to determine the conceptual feasibility of acquiring, processing, displaying, storing and transmitting the scientific and engineering data generated by the ASF payload and to define a candidate CDMS.

Data rate and total data capacity requirements were derived from ASF ID's (see appendix B) and a conceptual CDMS was established using ESRO/ERNO designed equipment where possible. Boundary conditions for data acquisition, processing, storage, and transmission were established and determined to be within existing ERNO equipment and Orbiter facility capabilities.

Due to the ASF approach of providing complete onboard processing capability for scientific data and control of experiments, many areas of uncertainties in the data processing area exist. These areas have been identified for further study considerations.

5.2.4.2 Requirements

The CDMS performs executive functions for the entire payload system including the instruments and the support subsystems. The functional requirements for the ASF CDMS are to provide the following.

a. Data acquisition.

b. Data monitoring.

c. Data formatting.

d. Data processing which includes:

   (1) Instrument/subsystem checkout.

   (2) Sequencing and control of experiments and subsystems.

   (3) Data compression.

(4) Filtering, averaging, histogramming.

(5) Computing.

(6) Encoding and decoding.

(7) Data display.

(8) C&W display.

(9) Data recording.

(10) Data transmission.

5.2.4.3 Guidelines and Assumptions

The CDMS, as defined for ASF, does not deviate from the ESRO baseline system. Through the use of the igloo and its command and data management components, and the extensive use of RAU's for controlling instruments and acquiring data, the CDMS is capable of performing the total ASF command and data management tasks as currently defined.

Since certain details of the ESRO design are lacking, assumptions have been made regarding the CDMS baseline capabilities. These assumptions are listed as follows.

a. The maximum number of RAU's per pallet segment is four. It is assumed that this figure is representative of each data bus; i.e., that four RAU's per pallet segment can be used for both the experiment bus and the subsystem bus, yielding a total of eight RAU's per pallet.

b. The serial pulse code modulated (PCM) input to each RAU can be used simultaneously with the analog and discrete inputs. This is a critical assumption for ASF.

c. Both experiment and subsystem RAU's can be mounted in the aft crew station. The ESRO documentation states that RAU's are mounted in the manned module for interfacing with the CDMS. In the pallet-only mode, these RAU's are required in the aft crew station.

d. The software resident in the CDMS mass memory may be altered during the course of the ASF mission by crew input. Changes may be in the form of different data processing routines on punched tape. These changes can be read into the mass memory as certain experiments are completed and their associated processing routines are no longer required. This mode of operation is required if the mass memory is unable to house in residence all required software for the 7-day mission. Software inputs to the mass memory may be uplinked from the ground as a secondary mode of operation. However, this will be done only if unexpected situations warrant such changes.

5.2.4.4 Additional General Assumptions

In addition to the assumptions made based on preliminary ESRO descriptions, the following general assumptions are made.

a. Data processing, to the maximum extent possible, will be performed onboard.

b. Ground control over certain aspects of the ASF mission will be standard procedure if required.

c. Adequate space will be available in the aft crew station to house two wideband analog recorders and associated electronics. The tape transports will be accessible in flight for tape changes.

d. The primary communications link for PDS data and control will be with the Orbiter, although a direct link with the STDN will be available to complement the primary link if required. Data from the PDS will be routed to the CDMS via the attached payload interface. The primary communications link with the SPS will be with the ground through TDRSS. These data may be uplinked to the Orbiter if required.

e. Communications links between the Orbiter and the ground, either through the TDRSS or STDN, and between the Orbiter and the PDS can be accomplished simultaneously.

f. The subsystem computer will have adequate speed and computational capacity to control the two APS required for ASF.

5.2.4.5 Capabilities and Constraints

The ASF instruments and support subsystems will utilize the Orbiter avionics resources through the CDMS. The CDMS will share the use of the Orbiter C&W system to process and display safety critical data, the Orbiter PMS to process engineering data for both statusing and to back up the primary C&W system, the mission specialist station (MSS) PCM recorder for data storage, the Orbiter mass memory and general purpose computer (GPC) for constants and utility storage (for state vector, orbit ephemeris, and attitude data determination) and the FM and Ku band signal processors to process scientific data for downlink STDN or TDRSS transmission.

The Orbiter payloads are limited to using 10K words of resident GPC memory and 35K words of mass memory storage capability. Hardline engineering data transmission is limited to five channels and up to 64 kbps data rate and the hardline command rate for unmanned payloads is 2 kbps.

The data rate from deployed payloads to the Orbiter is limited to 16 kbps and the command rate to payloads is 2 kbps.

Orbiter capability to handle scientific data is as follows.

a. MSS PCM recorder - Analog, 2.0 MHz bandwidth
- Digital, 1.024 Mbps rate

b. S band FM downlink - Analog, 4.0 MHz bnadwidth
- Digital, 5.0 Mbps rate

c. Ku band downlink - Analog, 4.2 MHz bandwidth
- Digital, 50 Mbps rate
uplink - 1 Mbps, max.

The number of C&W annunciators at the forward crew station dedicated to payloads is limited to two at this time. The status panel at the MSS will accept up to five payload C&W parameters.

5.2.4.6 Subsystem Description

A functional block diagram of the ASF CDMS is shown in figure 5.2.4-1, which depicts the total command and data flow, with all instruments, pallets, subsystems, and subsatellites defined.

The CDMS consists of the following.

a. Three computers:

(1) Subsystem computer.

(2) Experiment computer.

(3) Backup computer (has capability to replace either experiment or subsystem computer, but not both simultaneously).

b. Two I/O units:

(1) Subsystem.

(2) Experiment.

c. Mass memory (shared by both computers).

d. Keyboard.

e. Data displays.

f. C&W electronics.

g. Wideband analog tape recorders.

h. RAU's.

i. CDU.

j. A&A Electronics.

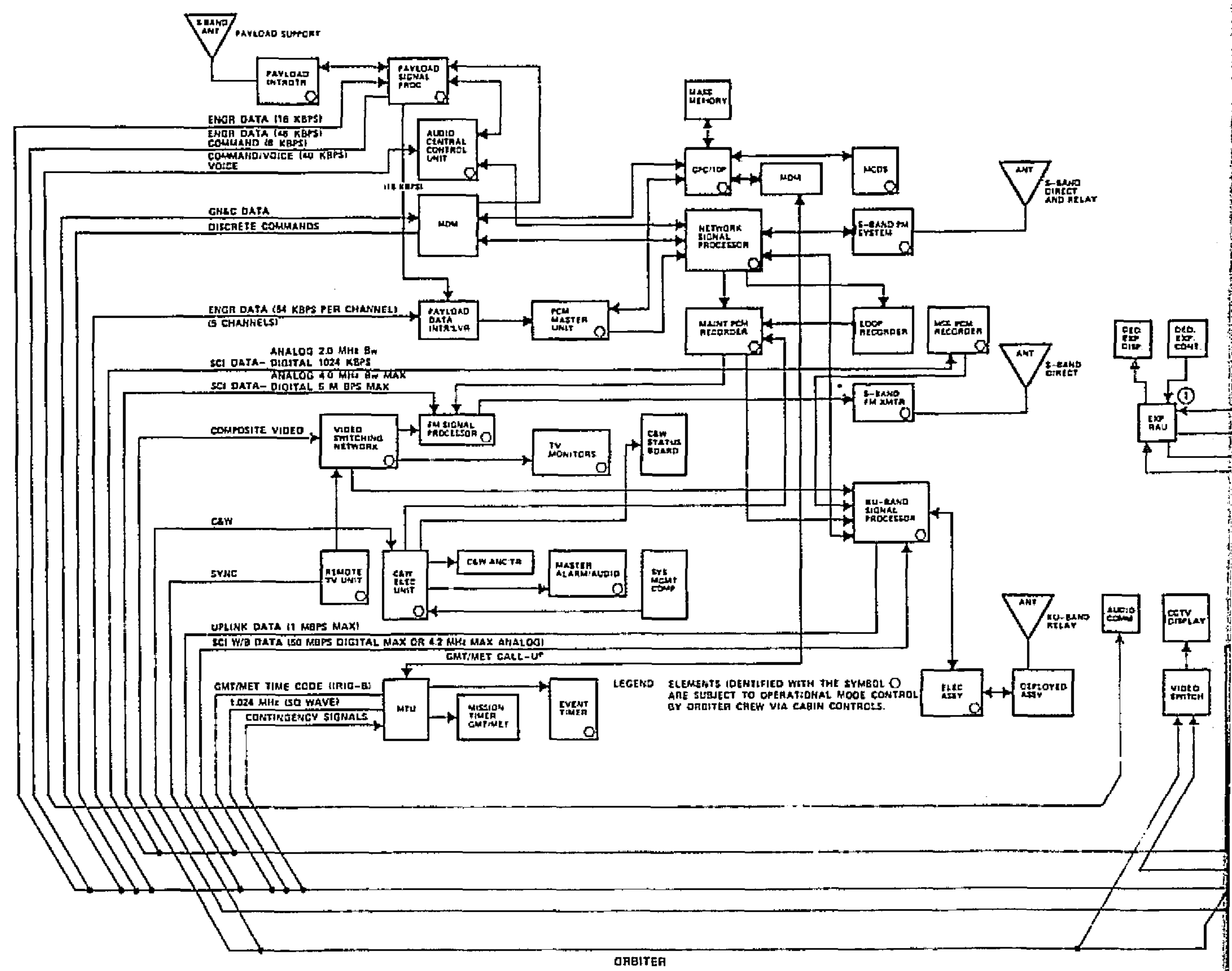


Figure 5.2.4-1. — CDMS F
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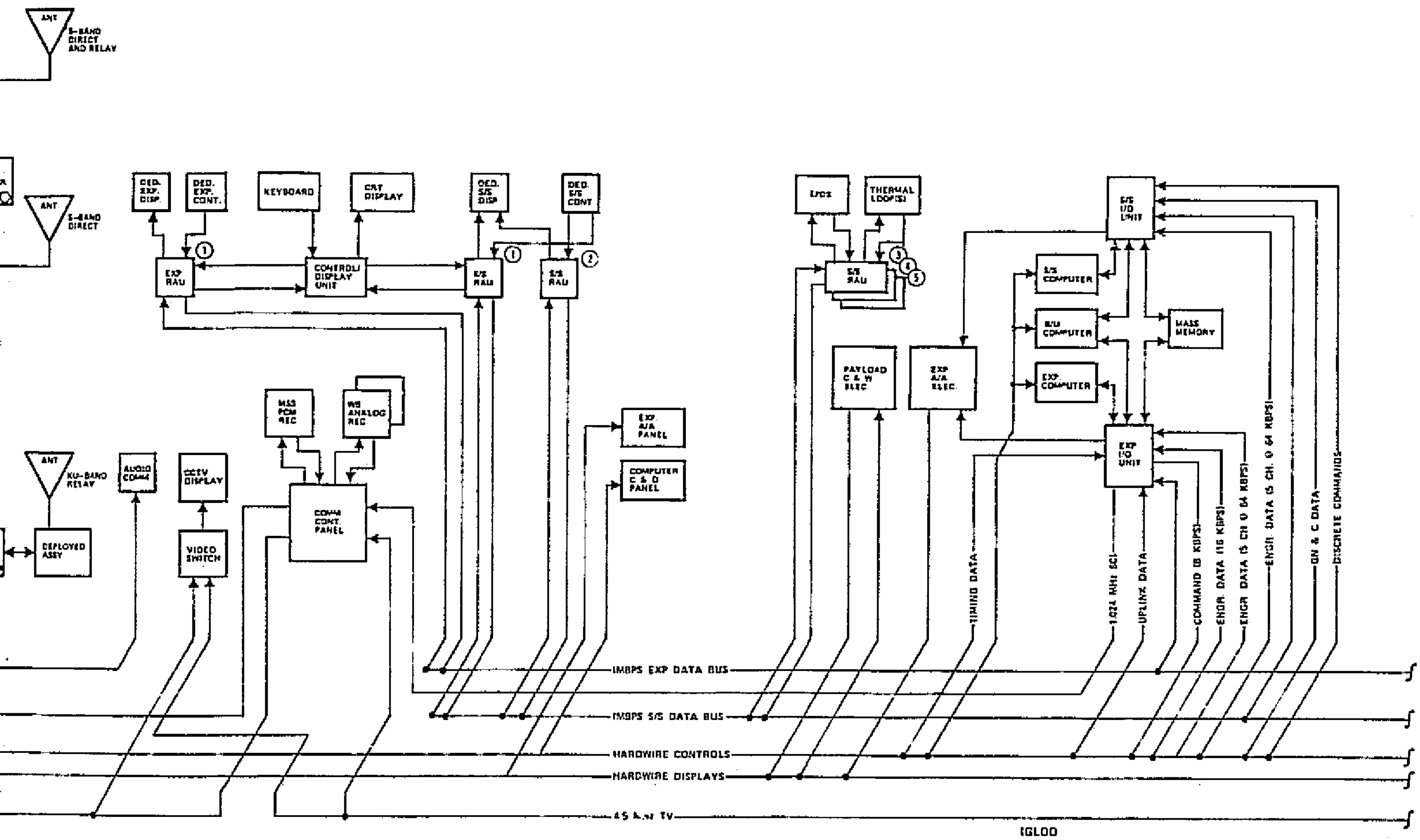
FOLDOUT FRAME



.2.4-1. — CDMS Functional Block Diagram.
(Sheet 1)

FOLDOUT FRAME 2

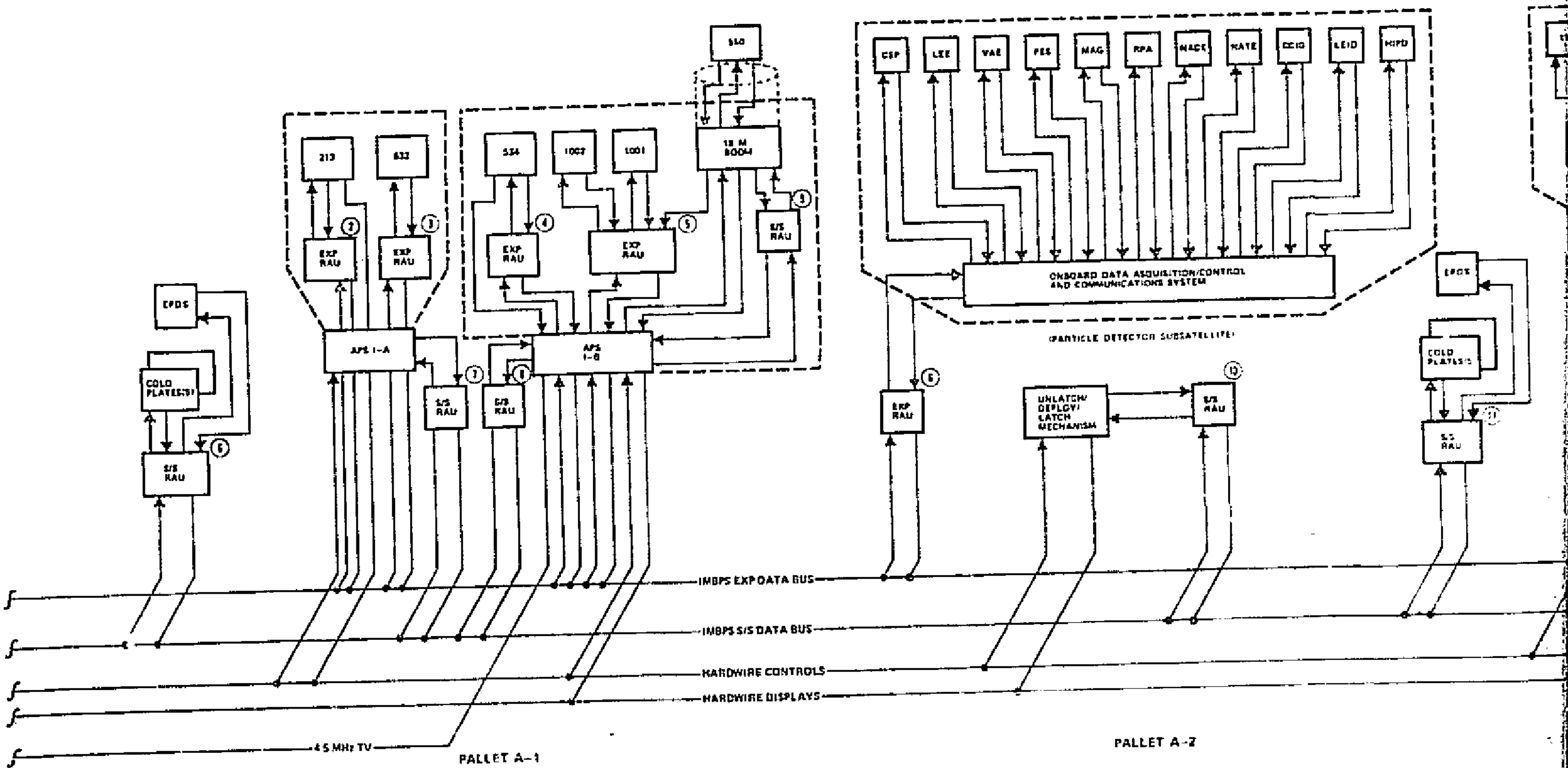
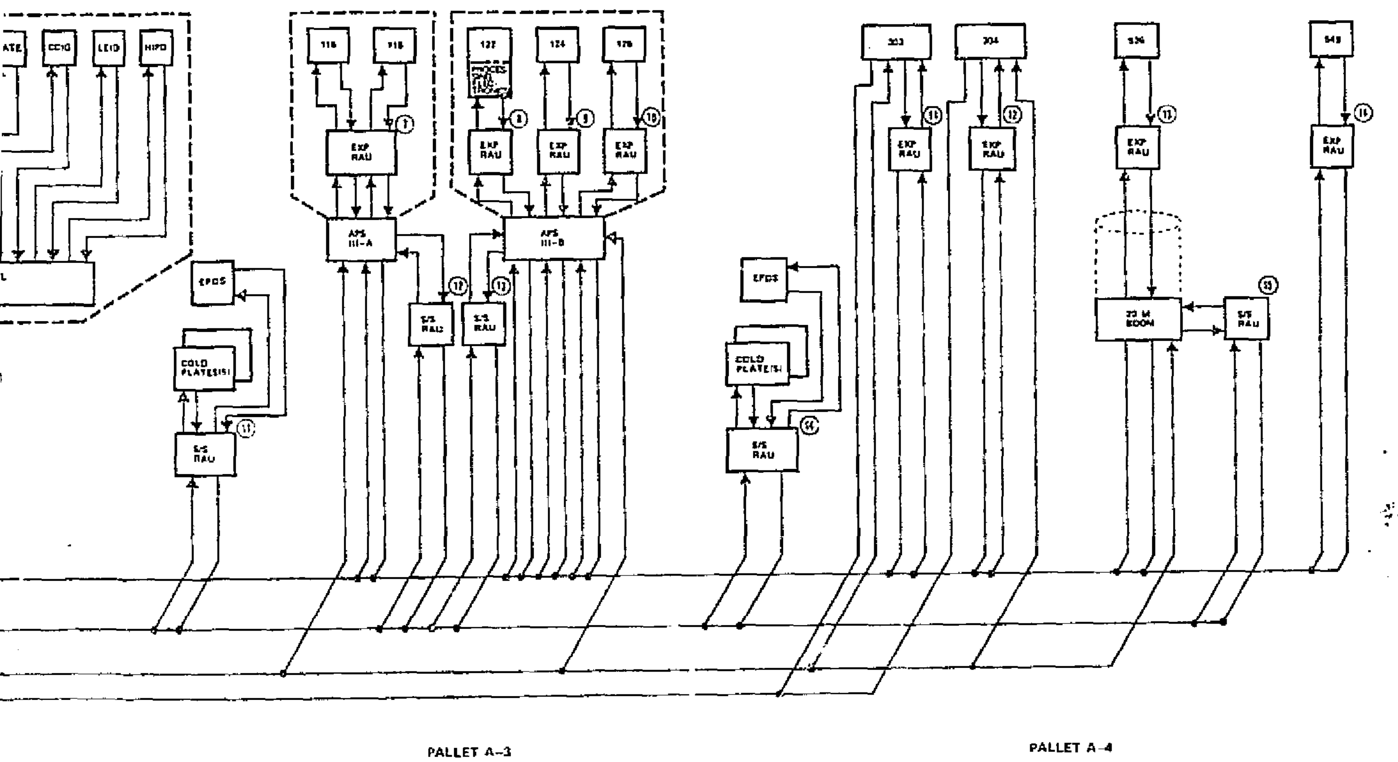


Figure 5.2.4-1. – CDMS Functional Bloc
(Sheet 2)



DMS Functional Block Diagram
(Sheet 2)

FOLDOUT FRAME 2

The CDMS provides to the ASF payload all services associated with the command and control of each instrument, as well as data acquisition, preprocessing, compression and transmittal of all data generated during the conduct of each ASF mission.

The command subsystem executes all ASF instrument command information in real time either by remote command from the ground, or from the Orbiter aft crew station, or by a stored program regulating the orbit operational schedule. The command subsystem has the capability to check validity of each command generated, regardless of its source.

The command subsystem controls the operation of the full ASF instrument payload, which includes the pallet, the APS, the subsatellite, and the boom-mounted instruments. The proper sequences of turn-on, warmup, operate, standby, and turn-off for individual instruments or groups of instruments, consistent with the mission timeline requirements, are controlled through the command subsystem.

Commands are sent to the pallet-mounted or boom-mounted instruments and igloo mounted subsystems through the 1 Mbps data bus. Again, these commands are initiated in real time by the flight crew, the ground controllers, or by preprogrammed command sequences in response to externally sensed conditions.

Commands are sent to the subsatellite through the S band Phase Modulated (PM) link. These commands may be generated in the same manner as those generated for pallet and boom-mounted instruments.

The data management subsystem provides acquisition capability for all data generated by ASF payloads. Data may be acquired from subsystems, pallet and boom-mounted instruments, and from subsatellites. All data, with the exception of subsatellite data, are managed through the 1 Mbps data bus, utilizing RAU's, or by wideband analog or TV data lines. Subsatellite data are received through the Orbiter S band PM communications system and routed to the CDMS as digital and/or analog inputs.

The data management subsystem, after acquiring data from the various data sources, formats the data for compatibility with the I/O units, thus allowing the onboard computers to perform preprocessing and data compression. This processing is dependent on the particular experiment(s) being conducted, the mission timeline, complexity of processing algorithms required, computer availability, etc. The data will be processed to the highest degree possible within the constraints imposed. Experiment end products are not defined to an extent which will allow details of processing to be defined at this time.

The processed data will be stored on magnetic tape or downlinked in either real time or delayed depending on the experiment requirements, detailed elsewhere in this report.

5.2.4.6.1 <u>Command Subsystem</u>

5.2.4.6.1.1 <u>Command Generation</u>

Commands generated on the ground are generally in response to evaluations performed on downlinked data. Changes to the resident software for data processing may be uplinked through the Orbiter communications system. These changes are made and verified on the ground, and uplinked only on a programmed basis in accordance with the mission timeline. This technique of updating software will only be used if required, however, and is further described in section 5.2.4.6.4. The primary mode of software update/change will be by crew input.

Commands generated by the crew are primarily entered through the keyboard input. These commands are limited to calling certain displays and diagnostic information to the monitors, and to initiating sequences for the conduct of certain experiments consistent with the mission profile. The crew, through the keyboard, has the capability of overriding preprogrammed sequences and of altering the resident software to a limited degree. The keyboard is the primary crew interface with the computers. Other commands generated by the crew consist of discrete and potentiometric inputs for selection of operating modes and instrument/subsystem tuning adjustments. The majority of these commands are routed to the igloo where they are converted to coded commands prior to insertion into the data bus.

In addition to ground generated commands based on evaluation of downlinked data, ground controllers have the capability of controlling certain aspects of the ASF experiment, supplementing crew control, as required. Details regarding the crew-ground responsibilities are not treated in this report, and are greatly dependent on currently undefined aspects of the mission objectives.

The majority of commands for ASF payload and subsystems operation are preprogrammed and stored in the CDMS mass memory. These software routines consist primarily of sequences of commands needed to conduct a specific experiment involving a number of instruments, pallets, stable platforms, etc. These routines are transferred from the mass memory into the appropriate computer by command from the crew or the ground. The computer then controls the conduct of the experiment or experiments, until completion, or until an override command is received. Following completion of the particular experiment, or experiments, the subject computer is reloaded with the next control program for subsequent experiments.

5.2.4.6.1.2 Command Transmittal

As previously stated, all commands, whether generated by the flight crew, the ground controller, or the flight computers, must interface with the total ASF system at the applicable I/O unit within the igloo. Those commands affecting the TSMS, the pointing and control subsystem, the EPDS or the displays and controls (D&C) subsystem are routed to the subsystem I/O unit. Commands affecting instrument operation are routed to the experiment I/O unit.

Within the applicable I/O unit, the command, whether discrete or analog, is converted to a PCM code compatible with the RAU's and is routed through the 1 Mbps data bus to the RAU associated with the instrument/subsystem being commanded. This RAU converts the coded command into either discrete 0 to 5 Vdc outputs or serial bi-phase L PCM outputs, and routes the command to the instrument/subsystem. A full description of the RAU output capabilities and characteristics is provided in table 5.2.4-1.

The subsatellite may be controlled by the payload or subsystem computer through the Orbiter S band PM link. These commands may be generated as preprogrammed sequences by the applicable computer or may be generated by the flight crew. Ground control of the subsatellites is yet to be assessed. In general, however, the subsatellite will operate in a continuous mode, and will have self-contained control sequences for such control functions as spin rate, stabilization, etc. Orbiter supplied commands to the subsatellite will primarily consist of initiating the preprogrammed sequences and operational control overrides.

TABLE 5.2.4-1. — REMOTE ACQUISITION UNIT (RAU) DATA OUTPUT CHARACTERISTICS

Discrete Outputs	
Number:	16
Type:	Single-ended, positive with respect to 0 Vdc RAU common
Output Logic States:	"1" -(on) +5 ± 1.0 Vdc "0" -(off) 0 ± 0.5 Vdc
Output Power:	10 mA dc minimum at +4 Vdc
Output Impedance:	1 k ohms for "0" logic state 2 k ohms for "1" logic state
	PCM Outputs
Number:	8 (data plus clock)
Type:	Manchester II bi-phase L code
Logic States:	"1" -(true) +5 ± 2 Vdc "0" -(false) 0 ± 1 Vdc

5.2.4.6.2 Data Management Subsystem

5.2.4.6.2.1 Remote Acquisition Units (RAU's)

The majority of data generated by ASF experiments is handled through the RAU's. A maximum of 32 RAU's is available to accommodate payload data. Each RAU has data acquisition characteristics as described in table 5.2.4-2.

The maximum of four RAU's can be located on each pallet segment for payload data acquisition. Three RAU's can be located within the igloo to manage subsystem data. Additional subsystem RAU's may be located in the payload bay.

Each RAU is capable of managing data from 64 analog sources, sampling the sources at 1, 10, or 100 times per second, under preprogrammed computer control. The analog samples are converted to 8-bit digital words and are introduced into the 1 Mbps data bus, where they are routed to the applicable I/O unit for additional processing, if required. The 64 analog inputs require data levels of 0 to 5.12 Vdc and are divided into 32 single-ended inputs and 32 differential inputs.

In addition to the 64 analog inputs, each RAU can accommodate a single bi-phase L PCM serial input of up to 1 Mbps (see table 5.2.4-2). This capability exists to accommodate those payloads which generate data not compatible with the low sampling rates of the analog inputs.

Eight 8-bit discrete inputs are also available on each RAU to accommodate "mode" or "flag" data which is generated by certain instruments as housekeeping information.

The mechanical configuration of a RAU is shown in figure 5.2.4-2.

TABLE 5.2.4-2. — REMOTE ACQUISITION UNIT DATA INPUT CHARACTERISTICS

Analog Inputs	
Number:	64
Type:	32 0 to 5.12 Vdc single-ended, positive with respect to 0 Vdc RAU common 32 0 to 5.12 Vdc differential
Resolution:	8 bits
Source Impedance:	100 ohms
Input Impedance:	500 k ohms with power on 100 k ohms with power off
Sampling Rate:	Selectable - 1, 10, or 100 samples per second
	Discrete Inputs
Number:	64
Logic States:	"1" -(true) +5 ± 1.0 Vdc "0" -(false) 0 ± 0.5 Vdc
Type:	Single-ended
	Digital PCM Inputs
Number:	1
Source Code:	Manchester II bi-phase L
Logic States:	"1" -(true) +2 to +5 Vdc "0" -(false) 0 to +1 Vdc
Input Data Rate:	1 Mbps (mean rate of all RAU's will be ≈ 300 kbps)

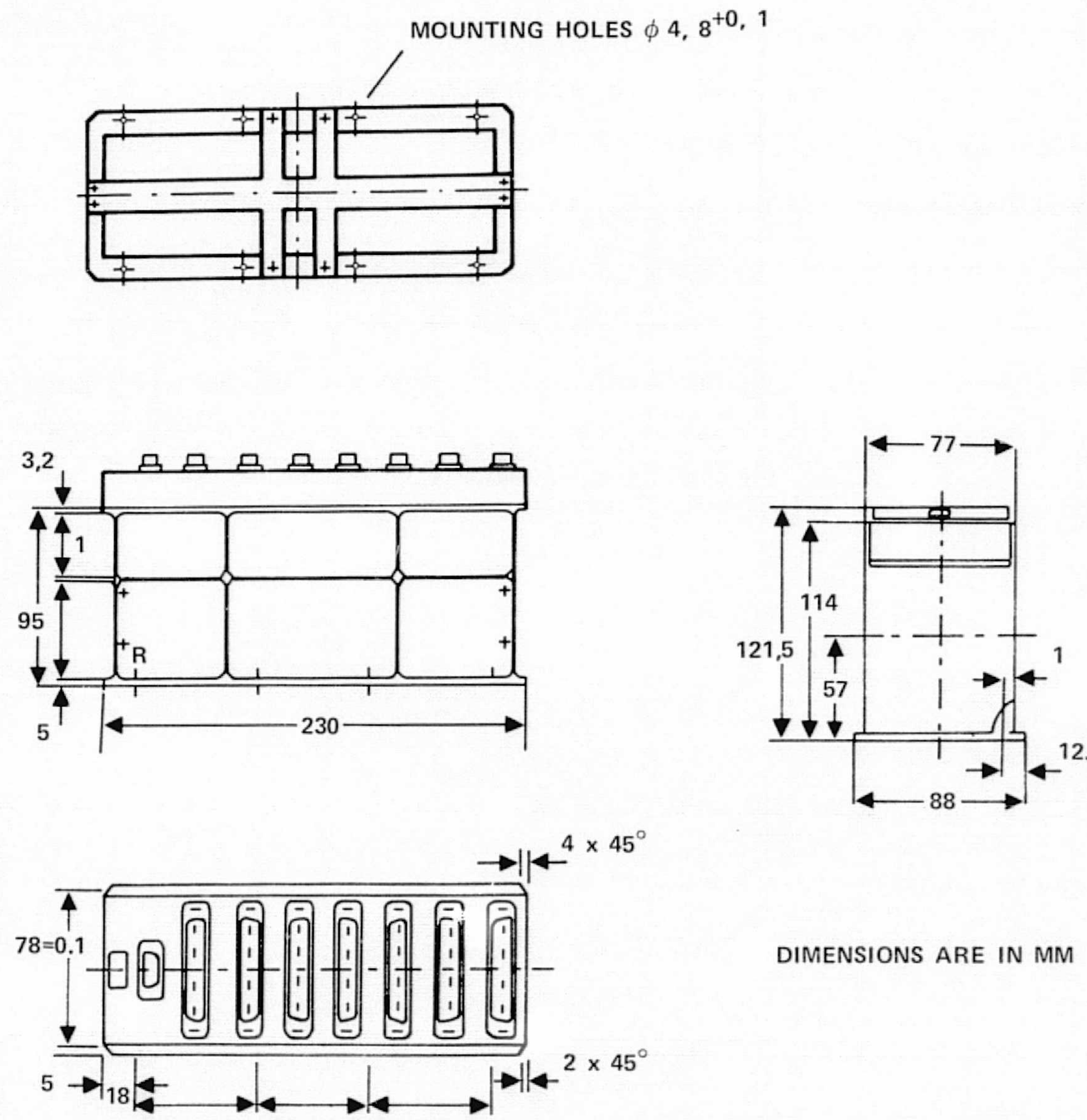


Figure 5.2.4-2. — RAU mechanical configuration.

5.2.4.6.2.2 High Frequency Analog Data Lines

Analog data which have bandwidths in excess of the analog data handling capabilities of the RAU are accommodated through the high frequency analog data lines. These lines, having one input terminal per pallet segment, can manage bandwidths to 6 MHz.

The high frequency analog data lines are routed directly to the aft crew station, where the data are either recorded on the 6 MHz analog recorder (paragraph 5.2.4.6.2.5) or interfaced with the Orbiter avionics via the FM signal processor for downlink transmission.

No significant data processing is performed onboard the vehicle with respect to high frequency analog data.

5.2.4.6.2.3 Television Data Lines

Wideband analog video data are generated by certain of the ASF instruments utilizing TV cameras. These data are accommodated by the 4.5 MHz TV data lines. One input to this system is located on each pallet segment.

These lines are routed directly to the aft crew station where they are interfaced with the Orbiter CCTV system. The video data may then be displayed on the TV monitors in real time, or may be recorded for later display.

Downlinking in either real time or in a delayed mode is also available depending on downlink availability and the ASF mission timeline.

Certain ASF instruments supply their own TV cameras. These instruments will utilize the TV input on their respective pallets. Multiple cameras required for the conduct of certain experiments must be sequentially operated with output switching, as there is only one TV input available per pallet.

Other ASF instruments do not supply TV cameras but require TV coverage of the phenomenon being observed. The Orbiter payload bay camera may be used in these cases, and the resulting video information displayed, recorded, and/or downlinked as required.

5.2.4.6.2.4 Data Processing

Onboard data processing to the maximum degree possible consistent with ASF mission timeline and economic constraints is a primary goal of the ASF pallet-only mode CDMS.

General purpose processing is supplied for experiment checkout, sequencing and control, data compression, data reduction, etc. Processing is accomplished in the igloo through the use of the experiment computer and the subsystem computer. The characteristics of these computers are shown in table 5.2.4-3.

The basic software for execution and management of data processing is resident in the mass memory and is supplied by Spacelab. Application software for individual experiments is also resident in the mass memory, being supplied by the investigator.

The purpose of onboard data processing is to deliver to the ground data dissemination center a product which can be rapidly reformatted into computer-compatible tapes and forwarded to each investigator for detailed analysis. The reformatting procedure would not include any manipulation, merging, curve-fitting or algorithm applications, as these functions would have been performed on the vehicle prior to delivery of the data to the dissemination center.

While the detailed processing software will not be defined for some time due to the many external variables currently existent in the ASF mission profile, a conceptual description of the processing sequence is provided in paragraph 5.2.4.6.4.

TABLE 5.2.4-3. — COMPUTER CHARACTERISTICS

Formats

Operands: 8, 16, 32 and 24 +8 (floating points) bits

Instructions: 16 bits

Control Unit

Micro-programmed control unit

Cycle time 300 NS

Micro-interrupt capability

Micro-instructions 4 K words of 16 or 20 bits

Instruction Set

- Number of instructions 128
- Format 16 bits
  - Immediate 8 bits
  - Direct 256 Bytes
  - Indirect memory double word
  - Relative 512 bytes
  - Based 256 bytes
  - Indexed 64 K bytes
- Type
  - Call and store
  - Logic and comparison operations
  - Shift operations
  - Fixed-to-floating and floating-to-fixed conversions
  - Conditional and unconditional jumps

Addressing Modes

Immediate, direct, indirect, relati e to a base, indexed, relative to a program counter, half word, word, character, double word

- Addressing capability

  Byte, word, double word

Number of addressable Registers

4 Specialized registers

62 Dedicated registers

7 Base registers

Computing Speed

Fixed Point 16 Bits

Add/Sub	Direct	2	μ sec
	Indirect	3	μ sec
Mul/Div	Direct	4	μ sec
	Indirect	5	μ sec

Fixed Point 32 Bits

Add/Sub	Direct	5.5	μ sec
	Indirect	6.5	μ sec
Mul/Div	Direct	8.3	μ sec
	Indirect	9.3	μ sec

Floating Point 32 Bits (24 + 8)

Add/Sub	Direct	5	μ sec
	Indirect	6	μ sec
Mul/Div	Direct	6	μ sec
	Indirect	7	μ sec

Input/Output

• Interrupts	
- Number of external	8 Levels
- Number of internal	5 Levels
- Number of software	Program dependent
- Interrupt control	Microprogram + Software
- Priority scheduler	Software
• Data transfer mode	
- Program controlled	
data rate	60 μS/word
no of addressable periferals	65 K
- Direct memory access	
data rate	400 to [illegible]00 K word/sec
control	direct
• Word length	16 bits plus 1 parity +1 protection
• Discretes	8 inputs and 8 outputs
• Real time work	1 μS to 2^{32} MS

Memory

• Type:	18 mil ferrits cores 2 1/2 D, configuration
• Capacity:	64 K 16-bit words (plus 1 parity bit and 1 protection bit) extendible to 512 K 16-bit words
• Modularity:	16 K words
• Cycle time:	920 NS
• Appressing, Quantum:	Byte, word
• Access time:	420 NS
• Ports:	2

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5.2.4.6.2.5 Data Recording

There are two payload dedicated analog magnetic tape recorders in the ASF CDMS located in the aft crew station. Specifications for these recorders are shown in table 5.2.4-4.

The primary function of these recorders is to store high rate data during periods when the Orbiter data downlink capability is not available, or to store the data for delivery to the ground data dissemination center following the conclusion of the mission. The capability to store onboard the vehicle all PCM data from a 7-day mission exists. The capability to downlink data either in real time or in a delayed mode remains and can be accomplished as a complementary action.

The recorders are designed to act as permanent or short term storage devices, or to be bypassed entirely if real time data downlink is available and the need to store data onboard the vehicle does not exist.

These recorders must be located in the aft crew station (or other crew accessible areas). Tape changes will be required daily in order to provide a recording medium for raw and/or processed data for the 7-day mission.

The MSS recorder is also available as a short term storage device for processed payload data. Its operation and interface with the data downlink system is very similar to that of the high rate recorders.

5.2.4.6.2.6 Data Downlink

The ASF payload is visualized as being totally dependent on the Orbiter communications system for transmittal of data to the ground either directly to the STDN or via the TDRSS. Details of the Orbiter communication system utilized by the ASF payload are shown in figure 5.2.4-1.

TABLE 5.2.4-4. — TAPE RECORDER CHARACTERISTICS

Capacity:	2.4×10^9 Bits	
Data tracks:	14	
Minimum bit rate:	5.25×10^3 bps	
Maximum bit rate:	5.90×10^6 bps	
Record/playback ratios:	160:1 to 1:160	
Power:	15 - 30 Watts	
Weight:	13.6 kg (30 lbs)	
Dimensions:	Transport	Electronics
Height:	12.7 CM (5")	15.2 CM (6")
Width:	33.0 CM (13")	33.0 CM (13")
Depth:	33.0 CM (13")	15.2 CM (6")
Volume:	0.045 M^3 (0.489 cu. ft.)	0.025 M^3 (0.271 cu. ft.)

Notes:

Mounting technique will include provision for stacking.

Recorders must be modified for reel change capability.

5.2.4.6.3 CDMS Equipment Characteristics

Some of the characteristics of interest for the CDMS equipment are listed in table 5.2.4-5.

5.2.4.6.4 Interfaces

The CDMS comprises the system through which all experiments are commanded, controlled, and through which data are acquired. These interfaces are shown in figure 5.2.4-1.

The CDMS interfaces with the pallet segments, where a maximum of four RAU's per data bus per pallet are located. These RAU's distribute command and control functions to various instruments and subsystems located on each pallet segment. They acquire data generated by these instruments, format the data, and route it to processing equipment located in the igloo.

The heart of the CDMS is the igloo, where the experiment I/O unit and computer, the subsystem I/O unit and computer, the backup computer, and RAU's for monitoring subsystem performance are located.

The CDMS interfaces with the subsatellite through the pallet A-2 RAU's prior to subsatellite deployment and via the Orbiter communications system after deployment.

All ASF subsystems interface with the CDMS through subsystem RAU's. The subsystems include the TSMS, the PCSS, the EPDS and the D&C subsystem.

TABLE 5.2.4-4. — CDMS EQUIPMENT CHARACTERISTICS

CDMS Hardware	Dimensions cm (in.)*	Location	Power *			Weight *	
			Ave.	Peak	Supplier	kg	(Lbs)
Experiment RAU 1	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Aft Crew Sta.	30	60	ESRO	2.7	(6)
Experiment RAU 2 APS 1-A	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Experiment RAU 3	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Experiment RAU 4 APS 1-B	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Experiment RAU 5	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Experiment RAU 6	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-2	30	60	ESRO	2.7	(6)
Experiment RAU 7 - APS III-A	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-3	30	60	ESRO	2.7	(6)
Experiment RAU 8	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-3	30	60	ESRO	2.7	(6)
Experiment RAU 9 - APS III-B	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-3	30	60	ESRO	2.7	(6)
Experiment RAU 10	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-3	30	60	ESRO	2.7	(6)
Experiment RAU 11	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-4	30	60	ESRO	2.7	(6)
Experiment RAU 12	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-4	30	60	ESRO	2.7	(6)
Experiment RAU 13 - 20m Boom	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-4	30	60	ESRO	2.7	(6)
Experiment RAU 14	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-4	30	60	ESRO	2.7	(6)
Subsystem RAU 1	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Aft Crew Sta.	30	60	ESRO	2.7	(6)
Subsystem RAU 2	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Aft Crew Sta.	30	60	ESRO	2.7	(6)
Subsystem RAU 3	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Igloo	30	60	ESRO	2.7	(6)
Subsystem RAU 4	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Igloo	30	60	ESRO	2.7	(6)
Subsystem RAU 5	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Igloo	30	60	ESRO	2.7	(6)
Subsystem RAU 6	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Subsystem RAU 7	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Subsystem RAU 8	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Subsystem RAU 9	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-1	30	60	ESRO	2.7	(6)
Subsystem RAU 10	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-2	30	60	ESRO	2.7	(6)
Subsystem RAU 11	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-2	30	60	ESRO	2.7	(6)
Subsystem RAU 12	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5	Pallet A-3	30	60	ESRO	2.7	(6)
Subsystem RAU 13	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-3	30	60	ESRO	2.7	(6)
Subsystem RAU 14	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-4	30	60	ESRO	2.7	(6)
Subsystem RAU 15	23.1 x 12.2 x 8.9 (9.1 x 4.8 x 3.5)	Pallet A-4	30	60	ESRO	2.7	(6)
Computer, Experiment	19.6 x 25.9 x 49.7 (7.7 x 10.2 x 19.6)	Igloo	245	350	ESRO	31.8	(70)
Computer, Subsystem	19.6 x 25.9 x 49.7 (7.7 x 10.2 x 19.6)	Igloo	245	350	ESRO	31.8	(70)
Computer, Backup	19.6 x 25.9 x 49.7 (7.7 x 10.2 x 19.6)	Igloo	35	350	ESRO	31.8	(70)

*Estimated

TABLE 5.2.4-4. — CDMS EQUIPMENT CHARACTERISTICS (Concluded)

CDMS Hardware	Dimensions cm (in.)*	Location	Power *			Weight *	
			Ave.	Peak	Supplier	kg	(Lbs)
I/O Unit, Experiment	19.6 x 25.9 x 49.7 (7.7 x 10.2 x 19.6)	Igloo	210	300	ESRO	31.8	(70)
I/O Unit, Subsystem	19.6 x 25.9 x 49.7 (7.7 x 10.2 x 19.6)	Igloo	210	300	ESRO	31.8	(70)
Mass Memory		Igloo	35	350	ESRO	27.3	(60)
Payload C&W Electronics Unit		Igloo	25	25	ESRO	3.6	(8)
Experiment A&A Electonics Unit		Igloo	40	40	NASA	3.6	(8)
Computer D&C Panel		Aft Crew Sta.	40	40	NASA	28.0	(62)
Experiment A&A Panel		Aft Crew Sta.	30	30	NASA	3.6	(8)
Audio Communications Unit		Aft Crew Sta.	15	15	ESRO	3.6	(8)
Video Switch Assembly		Aft Crew Sta.	25	25	NASA	3.6	(8)
CCTV Display		Aft Crew Sta.	--	--	Orbiter	19.2	(42)
Communications Control Panel		Aft Crew Sta.	60	60	NASA	7.0	(15)
Wideband Analog Recorder 1	15.3 x 33.0 x 33.0 (6.0 x 13.0 x 13.0)	Aft Crew Sta.	45	45	NASA	13.6	(30)
Wideband Analog Recorder 2	15.3 x 33.0 x 33.0 (6.0 x 13.0 x 13.0)	Aft Crew Sta.	45	45	NASA	13.6	(30)
Control/Display Unit	Aft Crew Sta.	Aft Crew Sta.	200	200	NASA	28.0	(62)
Ded. Experiment Display Unit	Aft Crew Sta.	Aft Crew Sta.	30	30	NASA	24.0	(53)
Ded. Experiment Control Unit	Aft Crew Sta.	Aft Crew Sta.	15	15	NASA	8.0	(17)
Keyboard/CRT Display		Aft Crew Sta.	60	60	NASA	28.8	(63)
Ded. Subsystem Display Unit		Aft Crew Sta.	30	30	NASA	24.0	(53)
Ded. Subsystem Control Unit		Aft Crew Sta.	15	15	NASA	8.0	(17)
				2525 W		484.8	(1068)

*Estimated

5.2.4.6.4.1 Orbiter Aft Crew Station

The CDMS interface with the Orbiter aft crew station is depicted in the functional block diagram, figure 5.2.4-1. The diagram provides details regarding interfaces between various components comprising the CDMS and major D&C's required for their proper functioning. Many details regarding specific operational conditions are yet to be assessed, but should be compatible with this functional concept.

The aft crew station also provides basic interfaces with the Orbiter communications sytem. These interfaces are depicted on the block diagram as being a part of the aft crew station. This is functionally correct; although the actual location of the Orbiter communications components may be elsewhere in the Orbiter.

The primary CDMS components located in the aft crew station are subsystem dedicated D&C's, experiment dedicated D&C's, and the computer keyboard and CRT.

All subsystem dedicated D&C's are routed to and from the igloo mounted subsystem I/O unit through subsystem RAU's located in the aft crew station. These RAU's convert all subsystem command and control fu ctions generated by the crew into a format compatible with the subsystem data bus. The data bus then routes the command functions to the applicable subsystem where, through another RAU, the command is decoded and routed as a discrete word or as a PCM word to the subsystem. The D&C's required for proper control and monitoring of each subsystem are described in subsequent paragraphs. The display of required subsystem parameters is accomplished through monitor devices driven from the subsystem computer through the same RAU which receives the control inputs.

All experiment dedicated D&C's are accommodated in the identical manner described for subsystems. The experiment data bus, I/O unit, computer, and RAU's are used, however, in lieu of subsystem components.

The computer keyboard is used for generating all instructions which do not require the use of manually-operated switches and tuning adjustments. The keyboard addresses both the subsystem and experiment RAU's located in the aft crew station. Thus, through the keyboard, both instruments and subsystems can be controlled. All of the various computer controlled experiment sequences which are initiated by the crew are entered through the keyboard. The data processing programs are transferred from mass memory into the experiment computer after keyboard instruction. Similarly, all computer driven displays are called through the keyboard.

The aft crew station mounted subsystem and experiment RAU's interface with the keyboard and the computer driven display by the D&C unit - a device which has preprogrammed control recognition logic and display logic in residence. This unit is very similar to the Orbiter display electronics unit (DEU) and serves the same purpose.

As stated previously, the aft crew station provides basic interfaces between the CDMS and the Orbiter communications system. These interfaces are detailed in the functional block diagram, figure 5.2.4-1, which illustrates the various components within the Orbiter avionics system. A discussion of the total Orbiter communications system is not included in this report, but may be found in the reference documents.

5.2.4.6.4.2 Igloo

In the ASF pallet-only mode, the igloo houses the major portion of the CDMS. A description of the igloo is found in paragraph 5.2.1 of this report; hence, this section is limited to the CDMS functions of the igloo.

The igloo houses the mass memory, the subsystem and experiment computers plus a backup computer, two I/O units, subsystem RAU's, the A&A electronics, and the C&W electronics. The igloo is also used to route wideband analog and payload dedicated TV lines to the aft crew station.

The mass memory houses the executive and application software for both the control of experiments and data acquisition and processing. The applicable software routines are transferred to the subsystem and experiment computers through their respective I/O units. The I/O units serve as the interface point between the 1 Mbps data busses and the computers.

The subsystem RAU's located in the igloo are used to monitor housekeeping parameters from the EPDS power supplies and the active thermal control loop. These subsystems are also controlled through the subsystem RAU's.

The A&A and C&W electronics units monitor both the subsystem and experiment I/O units for potential crew hazards and out-of-tolerance conditions existing within the total ASF system. Conditions recognized as being outside nominal tolerances are conditioned and forwarded to the aft crew station C&W and A&A panels.

5.2.4.6.4.3 Pallet Segments

The CDMS has identical interfaces with each of the four pallets. Data busses for both experiments and subsystems are routed from the igloo-mounted I/O units to RAU's located in each pallet. The RAU locations within the individual pallets are flexible to accommodate the various instruments located in each segment. Those pallets having instruments mounted to the pallet structure itself will have hard-mounted RAU's in close proximity to the instruments. Those pallets having pointing systems will have RAU's mounted on the platforms.

Each pallet has inputs available for one wideband analog line (paragraph 5.2.4.6.2.2) and one TV line (paragraph 5.2.4.6.2.3).

5.2.4.6.4.4 Pallet-Mounted Instruments

The CDMS interfaces with the pallet-mounted instruments through the RAU's for control functions, and one or more of the three data acquisition components described in paragraph 5.2.4.6.2.

5.2.4.6.4.5 Subsatellite

The CDMS has a dual interface with the subsatellite mounted on Pallet A-2. For checkout of the various subsatellite sensors and subsystems prior to deployment, a RAU hard-mounted to Pallet A-2 is used. After deployment, the detached payload S band link is used.

Subsatellite data composition is not yet defined, but will be generated to fit within the data bandwidth limitations imposed by the communications link available.

5.2.4.6.4.6 ASF Support Subsystems

a. TSMS. The CDMS will control and monitor the TSMS through the subsystem computer, I/O unit, and RAU's.

   Since the ASF pallet-only mode has no life support requirements, the function of the thermal subsystem is reduced to instrument cooling or heating as required.

The Freon loop is controlled via the subsystem RAU located in the igloo. The primary and backup Freon pumps will be turned on and off as required and the interloop heat exchanger inlet and outlet temperatures will be monitored. The pump status will be continuously monitored, as will the inlet and outlet temperatures of the igloo heat exchanger. The inlet and outlet temperature of the cold plates will be monitored by pallet-mounted RAU's.

The temperature and pressure of the internal environment of the igloo will be monitored, as will the status of the GN_2 fans.

Thermal conditions in the payload bay will be monitored as required.

b. PCSS. The PCSS consists of three hardware groups with their associated electronics. These groups are:

(1) Star tracker assembly.

(2) Gyro reference assembly.

(3) Pointing systems.

Each of the platforms communicates with the CDMS subsystem computer through a dedicated RAU. In addition, the CDMS subsystem computer communicates directly with the Orbiter GN&C computer.

The APS provides instrument positioning and tracking capabilities which exceed those of the Orbiter vehicle. The operational modes of the subsystem are: (1) initial alignment and updates, (2) attitude determination, (3) stabilization, and (4) tracking.

During the initial alignment, a minimum of two non-colinear star sightings are made by the star tracker. This angular data is transferred to the subsystem computer, which has access to the star catalog stored in the Orbiter mass memory. The angular information is transformed to an inertial reference frame and the resulting data is used to align the gyro reference assembly. The procedure is repeated for periodic updates.

The outputs from the gyro are sent to the subsystem through the GRA RAU, where a determination of the LOS with respect to the inertial reference frame established by star tracker sightings is made. The data are then transferred to the Orbiter GN&C computer for Orbiter positioning.

Stabilization is maintained through the monitoring of error signals by the subsystem computer. The error signals are generated by the GRA. Signals are then sent to the gimbal torque motors to reposition the instruments.

During periods when the Orbiter is changing attitude but the APS's must remain in stable pointing modes, the Orbiter position and the target position are both sent to the subsystem computer. All information is transformed into inertial coordinates and command vectors are calculated. These data are transformed to target LOS coordinates, which are sent to the gimbal torque motors to align the APS.

Because of the complexity of the CDMS/APS interfaces, the large interchange of information between the ASF subsystem computer and the Orbiter GN&C computer, and the operational computations required for proper APS operation, the practicality of the subsystem computer accommodating the total load is questionable. It is impossible to determine this factor without performing a software analysis effort. Details are too preliminary at this time to initiate such an effort. An extensive follow-on to this report is needed to evaluate this situation.

Should the computer be inadequate for the task, the use of APS dedicated microprocessors, which will perform operational calculations dedicated to each platform, will be investigated. These devices would receive Orbiter GN&C data through the subsystem data bus and perform the required computations. This technique would free the subsystem computer of the additional computation load.

c. EPDS. The CDMS provides the basic controls over the switching and monitoring of electrical power throughout the aft crew station, the igloo, and the payload bay.

Monitoring of both voltage and load is accomplished through subsystem RAU's located at the power input point to the igloo, at the power converters, and throughout the payload bay at power distribution points.

Control of power distribution is accomplished through the same subsystem RAU's. Remote circuit breakers and switches respond to commands generated by the crew or the computer and distributed by the subsystem data bus.

Those instruments requiring capacitor banks for operation are automatically monitored by the subsystem computer to insure adequate capacitor charge prior to activating the discharge sequence.

d. D&C subsystem. The CDMS interfaces with the D&C subsystem are described earlier in this section. A complete description of the D&C subsystem is found in paragraph 5.2.5.

5.2.4.6.4.7 Instrument Interface Listing

The control, data and display interface requirements imposed on the pallet RAU's are listed in table 5.2.4-6 (for Pallet A-1) and table 5.2.4-7 (for pallets A-3 and A-4).

5.2.4.6.5 Operations

The operation of the ASF CDMS involves continuous support of payload engineering (status, etc.) functions and on-demand support of the scientific instruments.

As previously discussed, not all instruments operate simultaneously. Instruments are divided into groupings of those which operate together. The controlling information and data handling requirements are preprogrammed to manage the operation of these sensor groupings.

During the first day of the mission, following successful establishment of the orbit, the instrument checkout sequence is performed. This command or series of commands may be generated by the crew or by ground controllers. During this operation, the executive routine and application routine for one group of instruments are transferred from the mass memory to the experiment and subsystem computers. The validity of the program is then verified. Following the validity check, each instrument is powered and the operational parameters are limit-checked to verify "in tolerance" conditions.

Following this validation of software transfer and the checkout of all instruments and subsystems required to support the particular sensor grouping, the entire sequence is repeated for the remaining sensor groups. This includes a verification of subsatellite systems prior to deployment. The subsatellite is then deployed and stabilized.

TABLE 5.2.4-6. — INSTRUMENT/CDMS INTERFACE LISTING
(PALLET A-1)

Instrument	CDMS Interfaces
Pallet A-1	
213	Control: RAU 2 - Discrete Outputs 1 through 9 Display: RAU 2 - Discrete Input 1 - Analog Input 1 - Hardwire Displays 1 and 2 Data : RAU 2 - Digital PCM Input - Analog Inputs 2 and 3 - Discrete Inputs 2, 3, and 4
532	Control: RAU 3 - Discrete Outputs 1 through 7 - PCM Outputs 1, 2, and 3 Data : RAU 3 - Discrete Input 1 - Digital PCM Input - Analog Inputs 1 through 24
534	Control: RAU 4 - PCM Output 1 Display: RAU 4 - Discrete Input 1 Data : RAU 4 - Digital PCM Input - Discrete Inputs 2 through 7 4 MHz TV Video Input
1002	Control: RAU 5 - Discrete Outputs 1, 2, 3, and 4 Data : RAU 5 - Discrete Inputs 1, 2, and 3 - Analog Inputs 1, 2, 3, and 4
1011	Control: RAU 5 - Discrete Outputs 5 through 10 - PCM Output 1 Data : RAU 5 - Discrete Inputs 4 through 8 - Analog Inputs 5 through 8
550	Control: Hardwire Controls 1 through 5 Display: Hardwire Displays 3 through 7 RAU 5 - Analog Inputs 9 through 28 Data : RAU 5 - Digital PCM Input - Analog Inputs 29 through 43

TABLE 5.2.4-7. — INSTRUMENT CDMS INTERFACE LISTING (PALLETS A-3 AND A-4)

Instrument	CDMS Interfaces
Pallet A-3	
116	Control: RAU 7 - Discrete Outputs 1, 2, 3, and 4 Display: RAU 7 - Discrete Input 1 Data : RAU 7 - Discrete Input 2 - Analog Input 1
118	Control: RAU 7 - Discrete Outputs 5 through 10 - PCM Output 1 Data : RAU 7 - Digital PCM Input - Analog Inputs 2 through 6
122	Control: RAU 8 - Discrete Outputs 1 through 9 - PCM Output 1 Data : RAU 8 - Digital PCM Input - Discrete Input 1 - Analog Inputs 1 and 2
124	Control: RAU 9 - Discrete Outputs 1 through 9 Data : RAU 9 - Digital PCM Input - Discrete Input 1 - Analog Inputs 1, 2, 3, and 4
126	Control: RAU 10 - Discrete Outputs 1 through 10 Display: RAU 10 - Analog Input 1 Data : RAU 10 - Digital PCM Input - Analog Inputs 2, 3, and 4 - Discrete Input 1
Pallet A-4	
303	Control: Hardwire Controls 1 through 10 RAU 11 - Discrete Outputs 1, 2, and 3 Display: Hardwire Displays 1 through 5 Data : RAU 11 - Analog Inputs 1 through 20 - Digital PCM Input
304	Control: Hardwire Controls 11 through 14 RAU 12 - Discrete Output 1 Display: Hardwire Displays 6 through 10 RAU 12 - Analog Inputs 1 through 10 Data : RAU 12 - Digital PCM Input - Analog Inputs 11 through 25
536	Control: RAU 13 - Discrete Output 1 - PCM Output 1 Data : RAU 13 - Digital PCM Input - Analog Inputs 1, 2, 3, and 4
549	Control: RAU 14 - Discrete Outputs 1 through 5 Data : RAU 14 - Analog Inputs 1 and 2

Stabilization of the subsatellite is automatic, activated by command from the flight crew following deployment. Deployment is accomplished by command rom the flight crew through the RAU located on the subsatel, e pallet (Pallet A-2). This command actuates the hold down c vice, allowing the subsatellite to be ejected from the payload bay. Communication with the subsatellite is accomplished via the Orbiter S band PM communications link. The subsatellite range is monitored through the Orbiter tracking system until operational range (1 to 10 km) is obtained. By crew command, the spin stabilization sequence is initiated. All further stabilization adjustments to the subsatellite are automatic, being sensed and controlled by the internal stabilization system of the subsatellite. Crew override capability exists for repositioning, if required, and rendezvous following the completion of all experiments.

The data from the subsatellite is complementary to that generated by the pallet-mounted instruments; i.e., the subsatellite dat is used in real time or stored onboard the Orbiter for delayed use in processing and analyzing data from pallet-mounted instruments. The processing routines for this operation are entirely dependent on experiment definition, and will be addressed when mission requirements are finalized. The capability to transfer subsatellite data to the CDMS via the attached payload interface needs to be further assessed.

Prior to the start of the first data acquisition sequence, the subsystem and experiment command and processing routines are transferred from the mass memory into the experiment and subsystem computers. Following validation of the software transfer, the preoperate sequence will be manually initiated by the crew. This operation will command all required subsystems and instruments to sequence through their preoperate modes; i.e., to warm up, cool down, orient platforms, etc. Each stage of this operation is monitored automatically for out-of-tolerance conditions, with the status being presented to the crew, if required, of each instrument or subsystem.

Any instrument or subsystem which does not come within operational tolerances within a preprogrammed time interval following initiation of the warm up sequence will be flagged to the crew automatically through the split-screen CRT. Diagnostic information on that instrument or subsystem may then be called up to determine the validity of the out-of-tolerance flag. Should the flag be false, the crew simply proceeds with the data acquisition, as the flag is only a monitor having no control over instruments or subsystem operation. Should the flag be true, i.e., the instrument or subsystem is malfunctioning, the capability exists to instruct the malfunctioning system to power down and to proceed with the experiment. This procedure, however, is entirely dependent on the system in question and the mission requirements.

Any instrument or subsystem which demonstrates a malfunction which may affect crew or vehicle safety is immediately presented to the crew through the C&W system described in the preceding section.

Assuming all systems accomplish the preoperate sequence successfully, the total CDMS is then ready to initiate the operate sequence. This sequence is initiated by the experiment computer in response to a preprogrammed time label, which is recognized by the computer as it monitors the Greenwich Mean Time (GMT) and Mission Elapsed Time (MET) clocks. The sequence may also be initiated by the crew or by the ground, however, if required.

The entire operation; i.e., subsystem operation, including pointing and control, stabilization, thermal control, instrument operation, data acquisition, processing, and recording are conducted under the control of the CDMS. The operational sequence is ended, with all systems being commanded to "standby" or "off" by the CDMS automatically, provided the preprogrammed "stop time" label exists. Again, the operate sequence may be terminated by crew or ground input.

Certain instruments cannot be operated in a totally automatic mode, but require the man-in-the-loop capability to "fine tune" the instrument as the experiments progress. In these experiments, the command and processing routines transferred from mass memory to the computer include the automatic routing of observed phenomena to the various display devices required by the crew. The crew inputs are then routed to the instrument through the 1 Mbps data bus, and the required adjustment is made.

Following completion of one data acquisition sequence, the CDMS awaits the initiation of a second sequence by the crew. This is accomplished in the same manner as was the first sequence.

The CDMS is able to conduct a number of experiments simultaneously, being limited only by the speed and software capabilities of the computers. These limits are TBD and are dependent on the definition of experiment control and processing requirements, and on the definition of the mission profile.

Data processing is accomplished in near real time. The limitation here is the complexity of the processing required. Where data rates exceed the capability of the computer for real time processing, the data will be stored on magnetic tape and played into the computer for processing during mission phases where the full capability of the computer is not required.

As stated in paragraph 5.2.4.3.d, if the mass memory is unable to house in residence all software required for a 7-day mission, updating of the mass memory during the course of the mission will be required. Thus, the mass memory becomes a system of temporary storage, and the flexibility required to assure on-board processing to the greatest degree possible is not restricted by the mass memory size. The data processing routines will be developed and verified on the ground prior to the start of the mission, and will be written on a punched tape format, taken on the flight, and loaded into the mass memory as required.

5.2.4.7 Analyses

Based on the overall ASF system timelines, data timelines for the instruments and the PDS were defined. Figure 5.2.4-3 shows the periods during the mission for revolutions 15 through 80 for each instrument requiring CDMS support. Based on these timelines and the data requirements defined in the ID's (in appendix B), data bit rate requirements during each minute of experiment operations from revolution 16 through revolution 80 were established. These levels are illustrated in figure 5.2.4-4 through 5.2.4-12. These figures show that the maximum data rate for the ASF complement of instruments required is 123.192 kbps during revolutions 17 through 25 when Instrument 532 (Gas Release Module) with its requirement for over 77 kbps operates for 15 minutes each revolution. If these data were to be transmitted directly to the TDRS or to the ground station, the data rate is well within the capability of the Orbiter S band FM downlink system and the Ku band TDRS system.

The total quantity of data required by the ASF instruments for the 7-day mission was determined by integrating the data rates over the total experimental operating period. The result is shown in figure 5.2.4-13. A total of 15.931×10^9 bits of data will be processed by the onboard data management subsystem. At 2.4×10^9 bits per reel, it would require seven reels to accommodate onboard storage. The extent of data compression which will

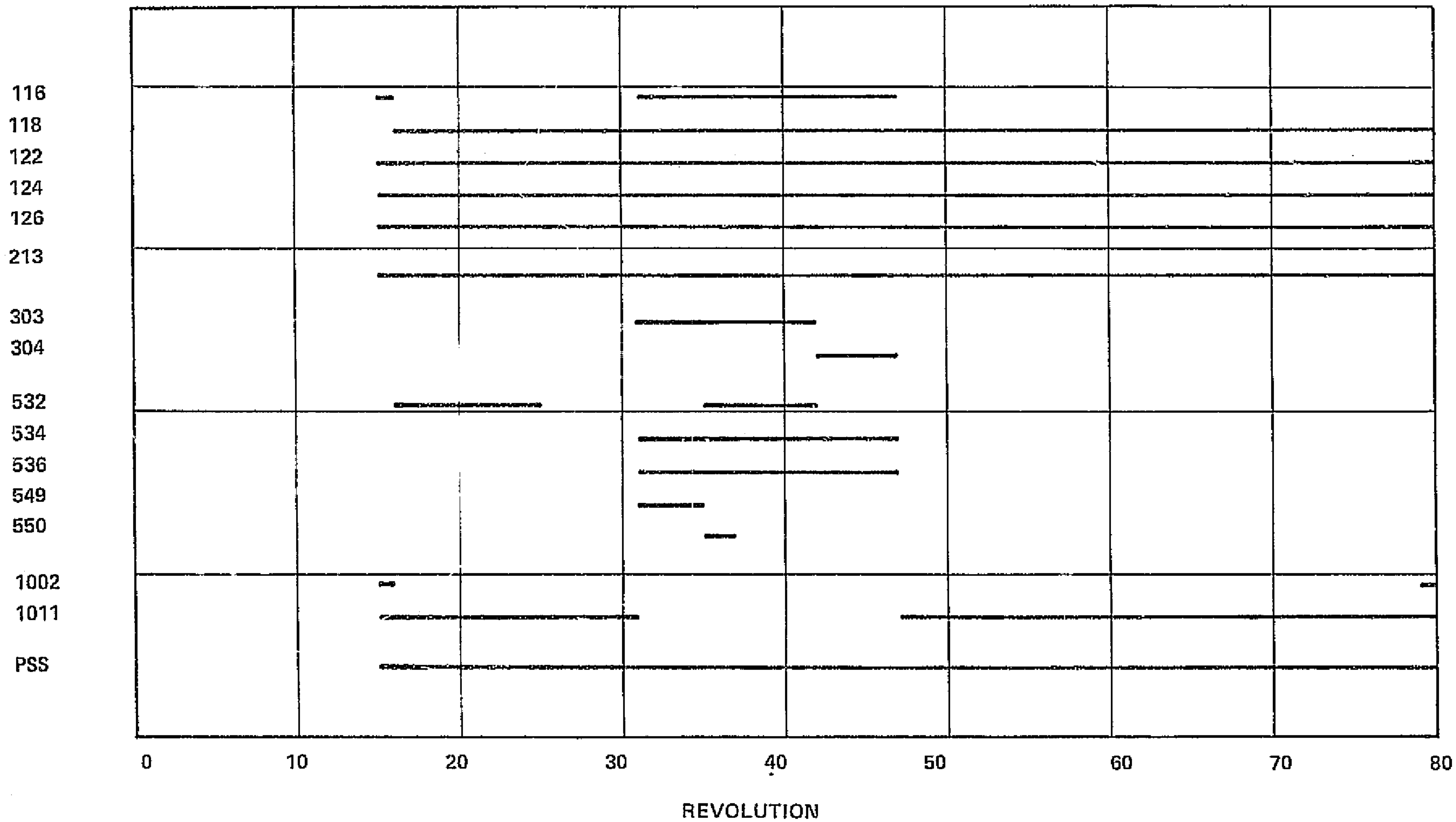

Figure 5.2.4-3. — ASF Data time-lines.

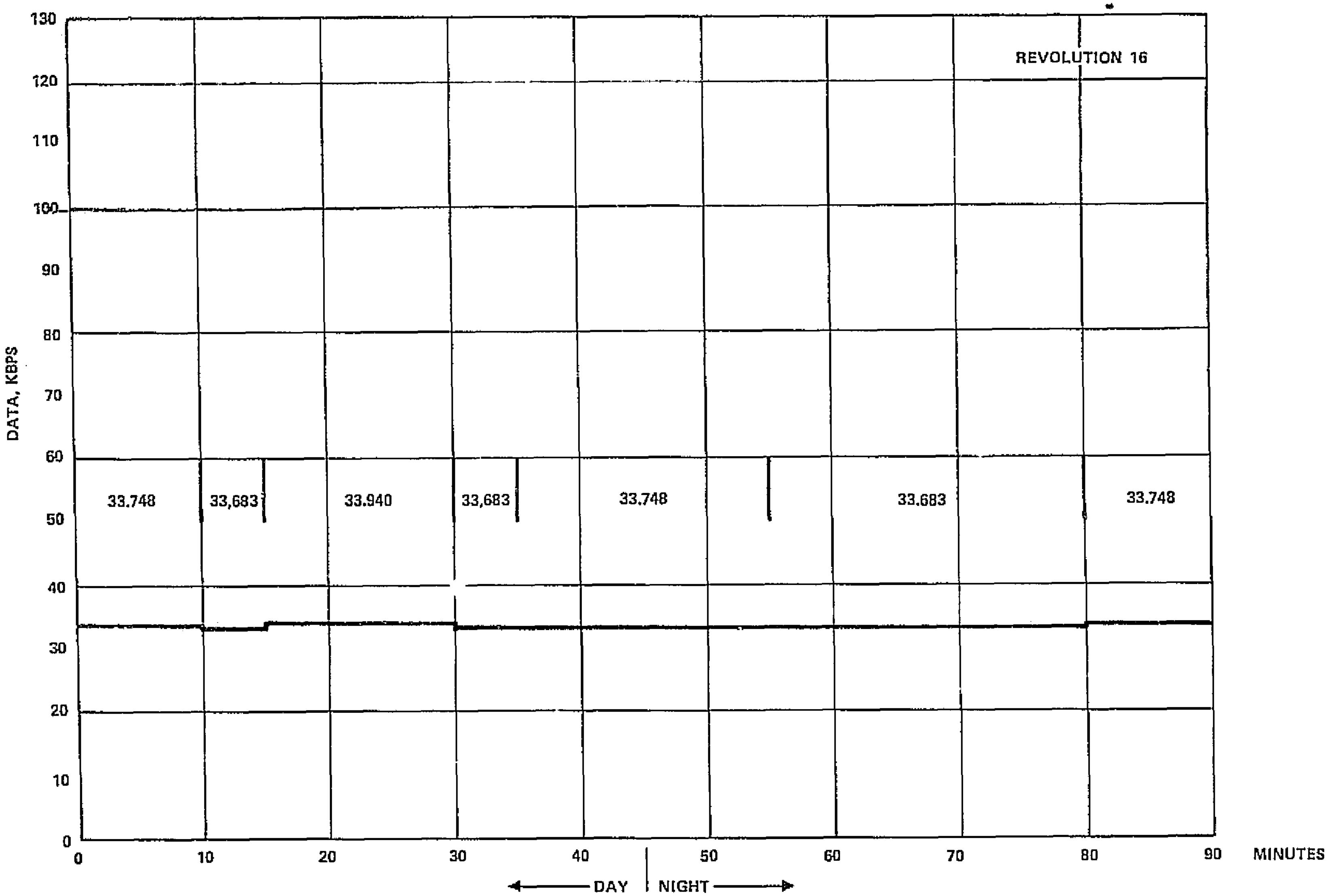

Figure 5.2.4-4. — ASF data rate requirements revolution 16.

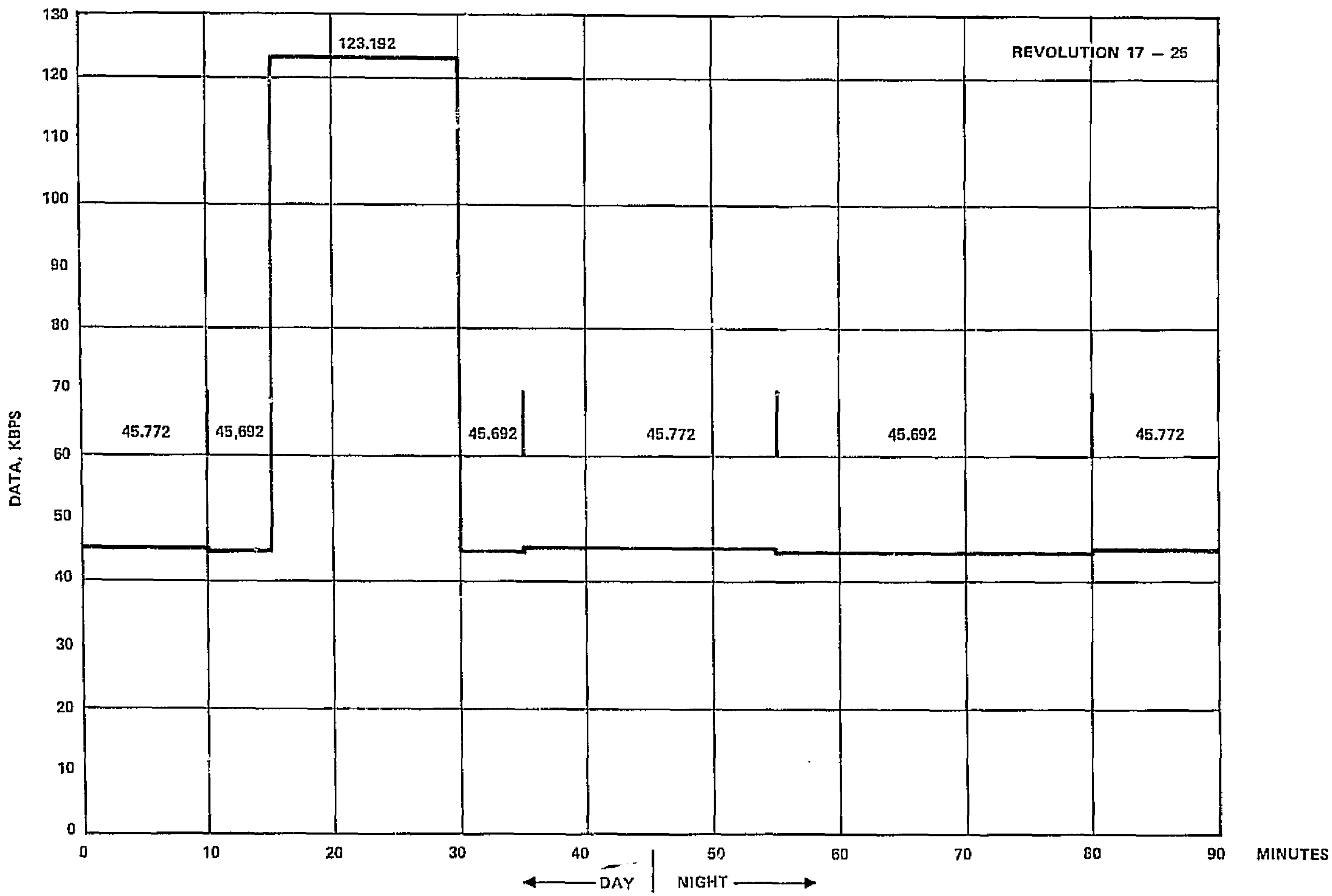

Figure 5.2.4-5. — ASF data rate requirements revolution 17-25.

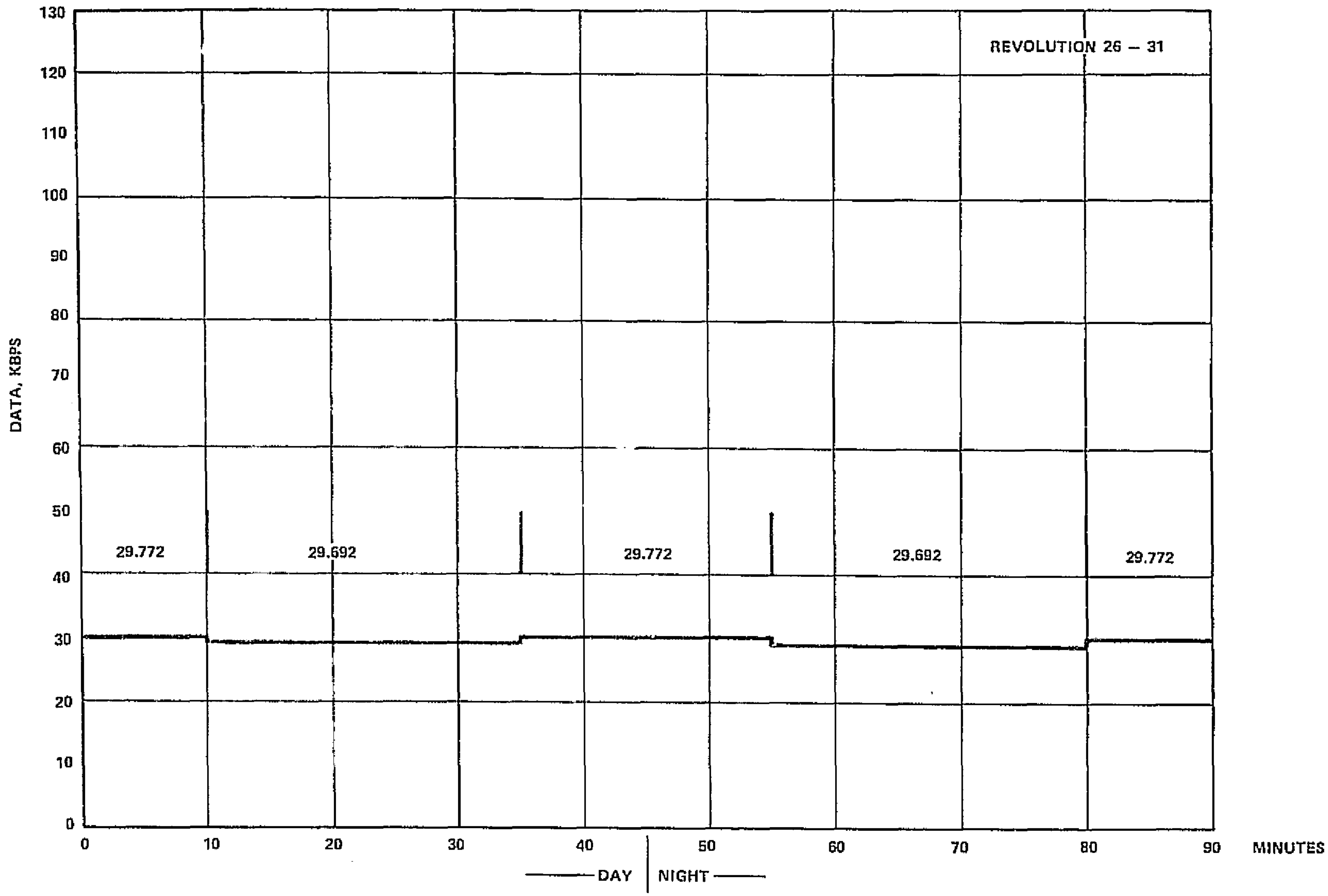

Figure 5.2.4-6. — ASF data rate requirements revolution 26-31.

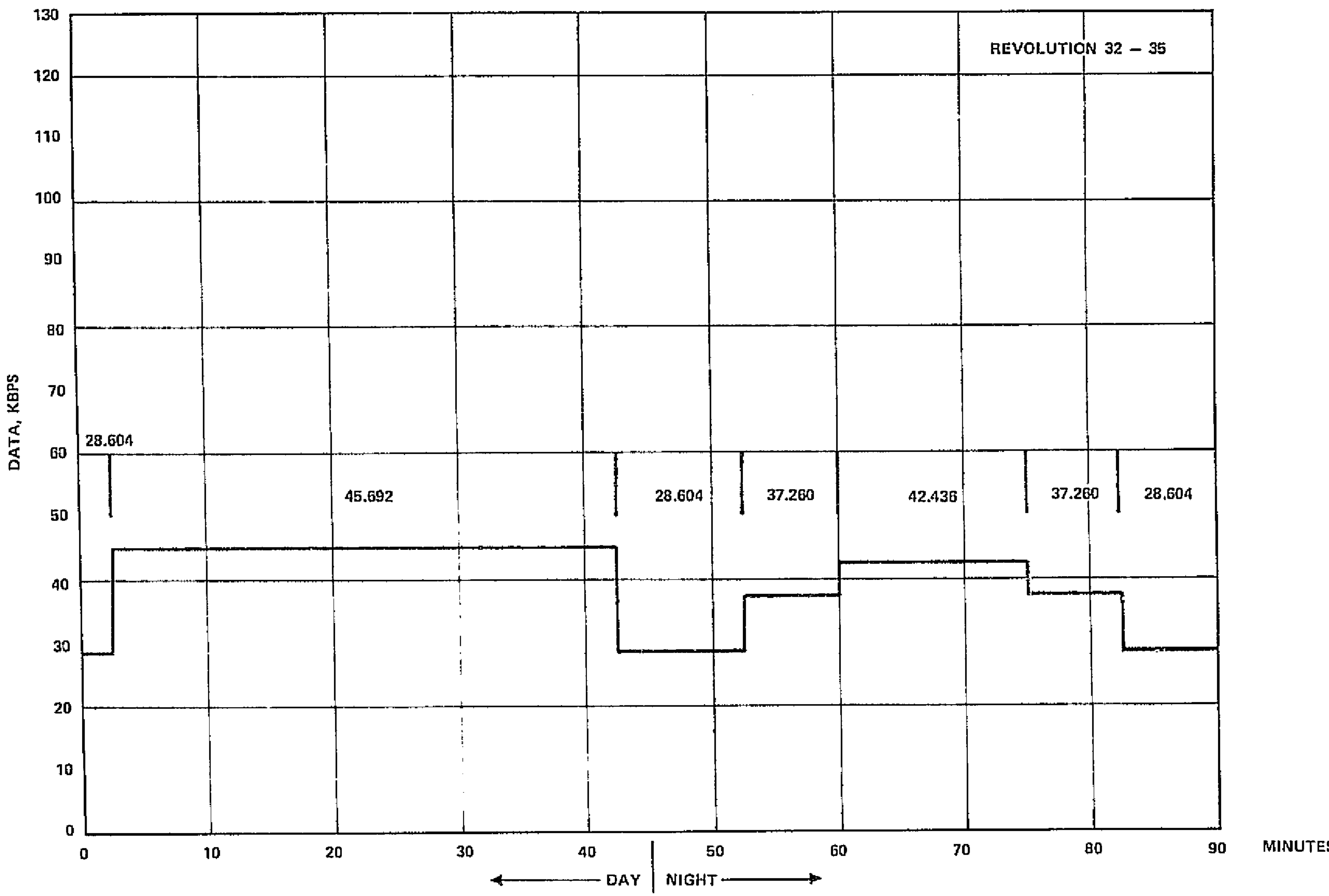

Figure 5.2.4-7. – ASF data rate requirements revolution 32-35.

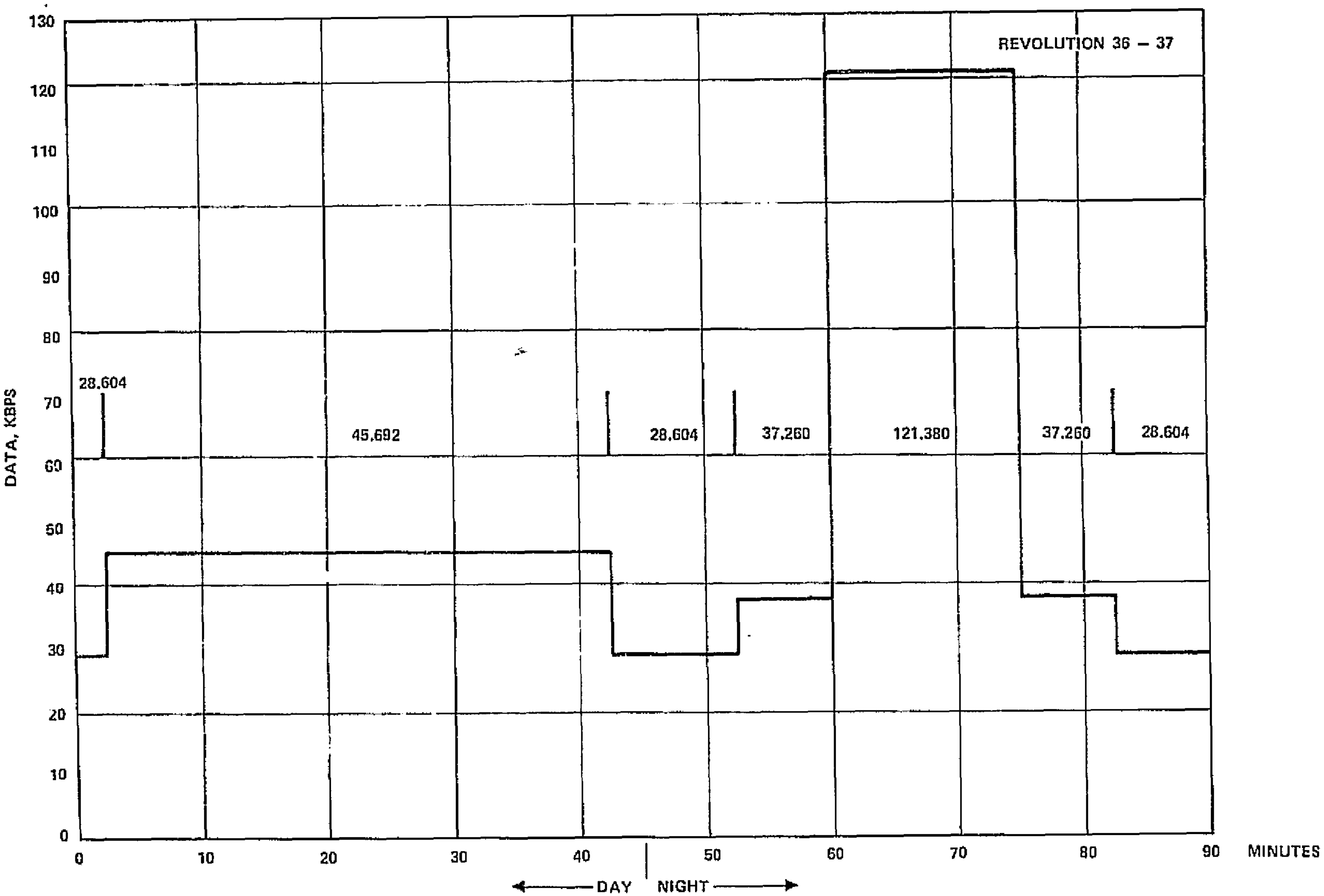

Figure 5.2.4-8. – ASF data rate requirements revolution 36-37.

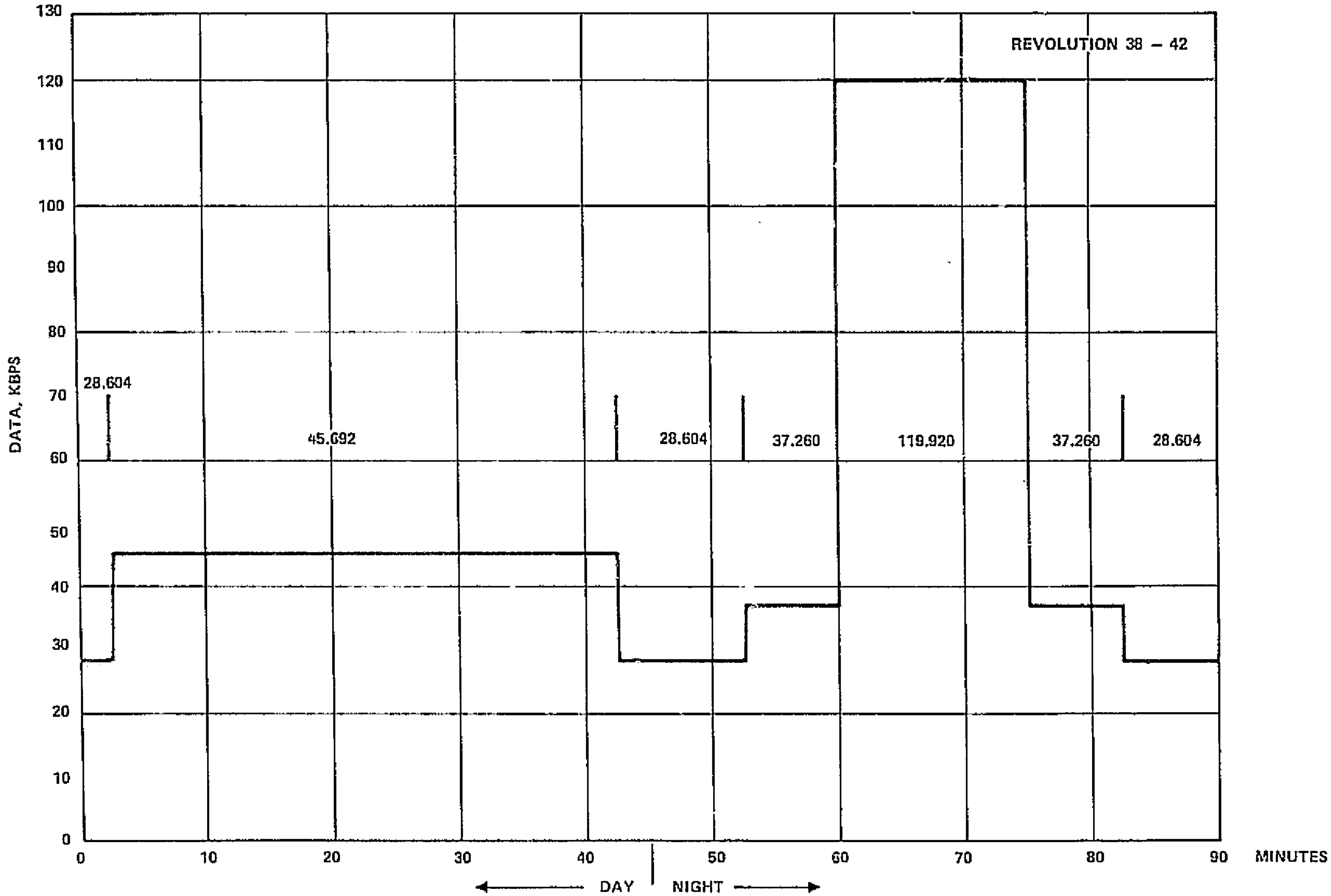

Figure 5.2.4-9. – ASF data rate requirements revolution 38-42.

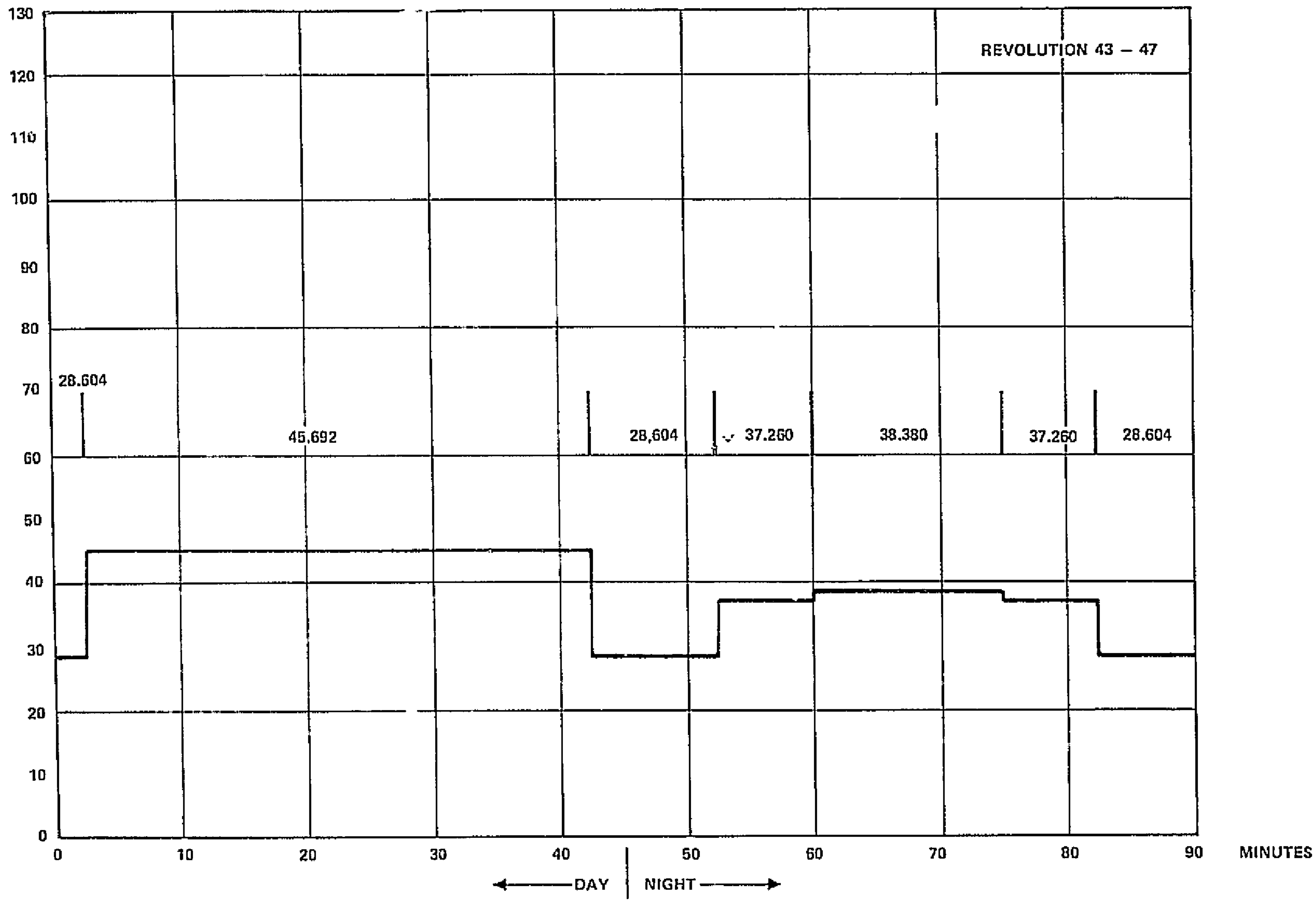

Figure 5.2.4-10. — ASF data rate requirements revolution 43-47.

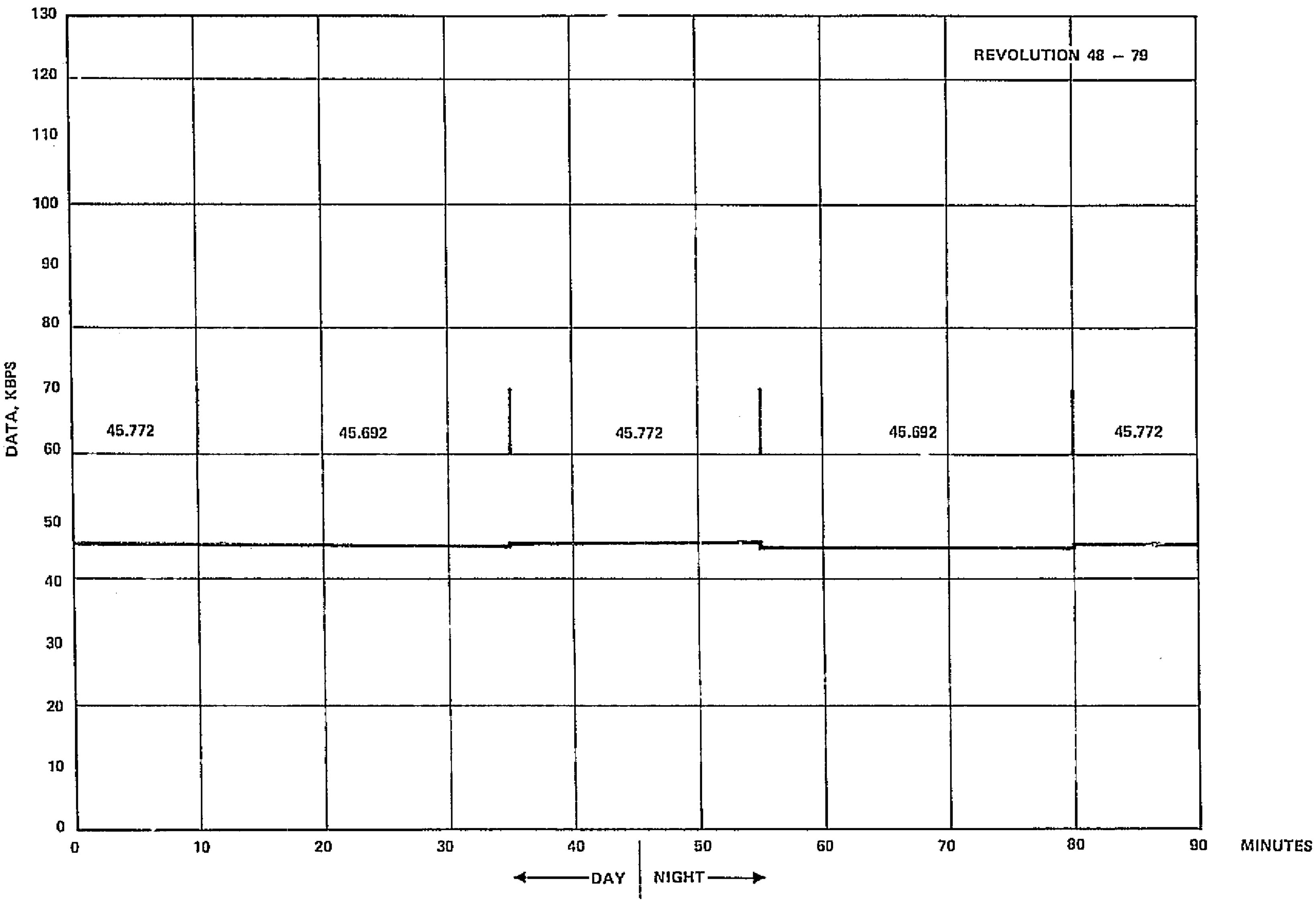

Figure 5.2.4-11. – ASF data rate requirements revolution 48-79.

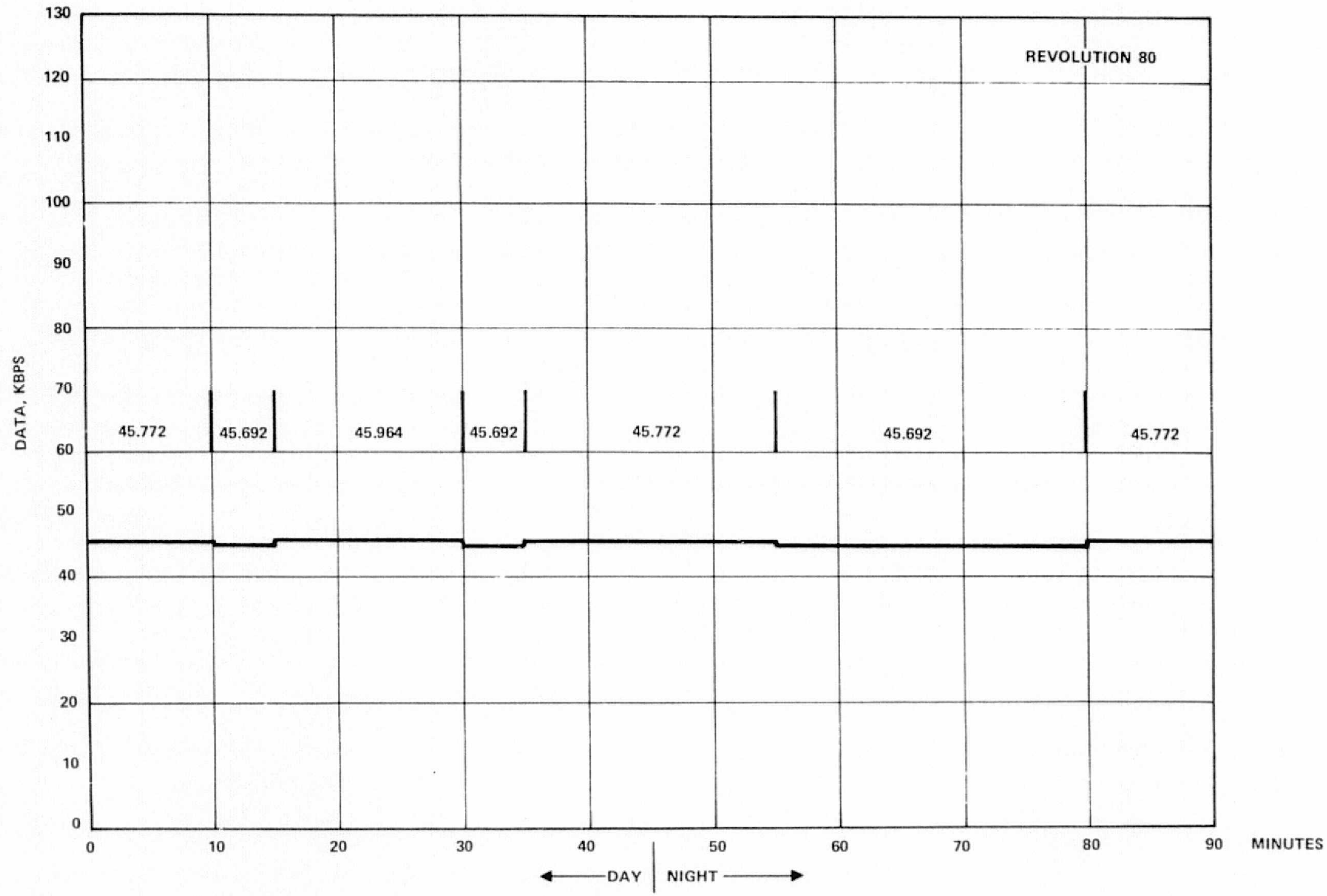

Figure 5.2.4-12. – ASF data rate requirements revolution 80.

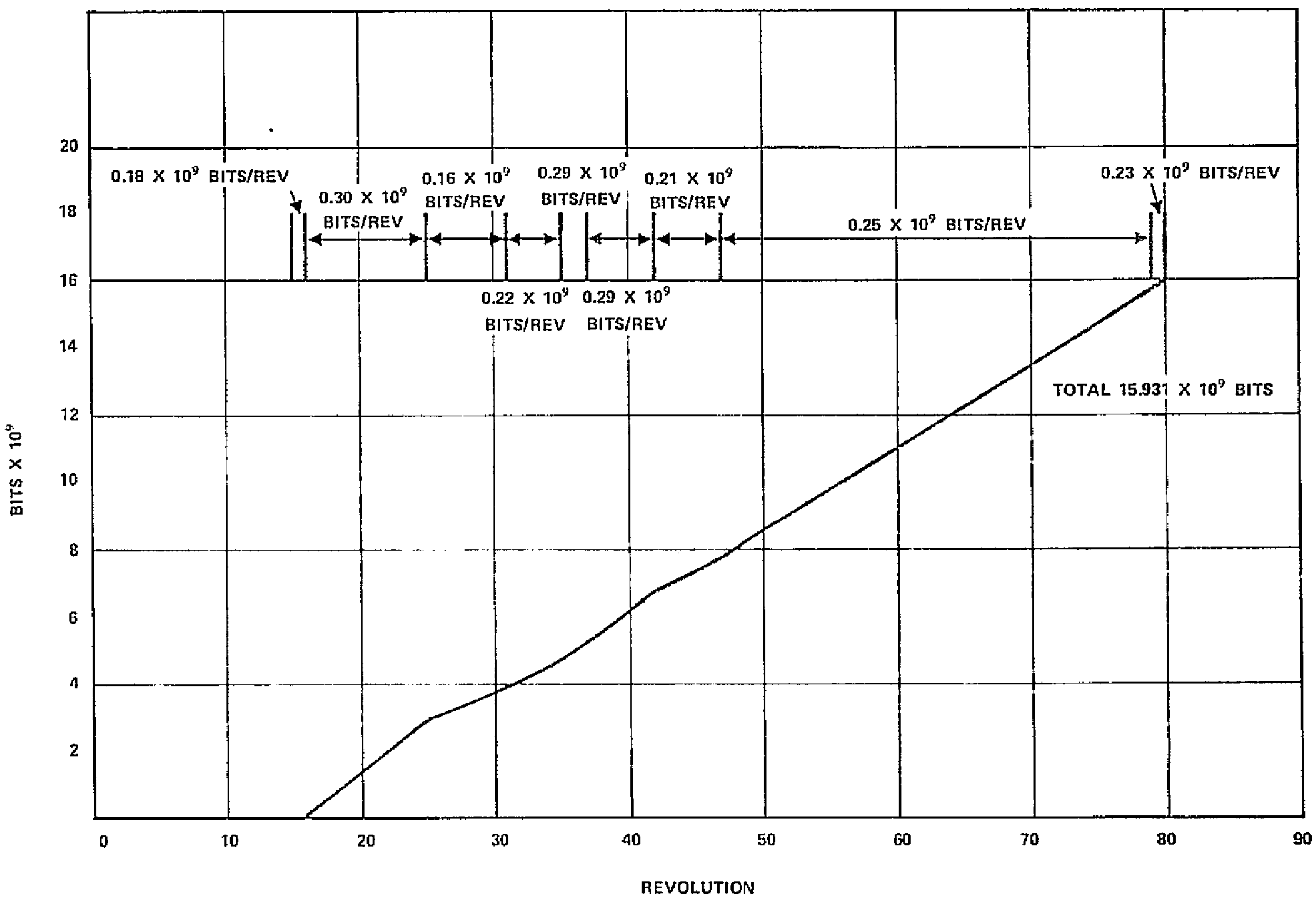

Figure 5.2.4-13. — ASF data rate requirements revolution 0 to 90.

be performed, the real time versus stored data processing and transmission planned, and other related operations need to be further assessed to determine the full impact on onboard processing and storage capability and the ground facilities.

The 4 MHz TV requirement (Instrument 534) is not included in this analysis.

This analysis does not address the recent developments regarding Instrument 126, the Infrared Interferometer. The original data rate was calculated at 1.2 kbps, and this figure was used in all analyses regarding data management. Recent developments place the data rate as high as 6 Mbps. Accommodation of this data rate with the currently defined CDMS can easily be made, although the RAU's and I/O units would be bypassed. This technique, while an inherent feature in the CDMS, is not discussed as part of this report.

5.2.4.8 Conclusions and Recommendations

5.2.4.8.1 Conclusions

The CDMS appears to be one of the most significant drivers in a Spacelab Manned Module versus pallet-only ASF approach. The capability to control a full complement of instruments by remote means and the requirement to perform a high degree of data processing onboard the vehicle present unique problems over the manned module approach.

The study results indicate that, functionally, the ASF approach for onboard processing of scientific data is feasible with still-to-be-resolved issues being the computer executive, memory and throughput capacity and processing speeds, the application software sizing, and the possible need for advanced data compression techniques.

5.2.4.8.2 Recommendations

The study has resulted in the following recommendations.

a. Establish firm data processing requirements.

b. Define computer hardware and software required for the extensive onboard processing required.

Onboard data processing has been defined as one of the major goals of the ASF pallet-only mode. The degree of processing to be performed is dependent on many factors, most of which have not been adequately defined. Primary among these is the mission operating timeline. Since the requirement exists to operate one or more instruments continuously throughout the mission, the experiment and subsystems computers will be occupied in controlling instrument operation and will possibly be unavailable for data processing. The use of the backup computer as a data processing tool during these periods, i.e., when the primary computers are unavailable, should be investigated. This would relieve the problem of having one computer perform both controlling and processing functions, and would assist greatly in the pallet-only mode _ .al of onboard processing to the maximum extent possible.

Complete definitions of experiments will not be available for some time, making sizing of software for applications routines undefinable at present. Processing routines cannot be defined until experiment end products are defined, making a determination of the adequacy of onboard computer capabilities for the total task impossible. The use of the backup computer and remotely located microprocessors must be considered.

The ability of the subsystem computer to control and supply the required computational support for two APS's as well as control and monitor the electrical and thermal subsystems, cannot be determined without performing a software design effort. Therefore, the use of APS dedicated microprocessors, capable of performing the high speed calculations and reference transformations needed for instrument pointing, thus reducing the computational load on the subsystem computer, is being explored.

c.4

5.2.5 AFT CREW STATION CONFIGURATION

5.2.5.1 Introduction

The primary objective of this phase of the study was to determine the feasibility of operating the ASF instruments from the Orbiter aft crew station. The purpose was to establish a baseline for future ASF and AMPS pallet-only mode analyses.

Requirements were established using inputs from the scientific ID's and the support subsystem conceptual definitions. Guidelines and assumptions were established and Orbiter and other constraints were established. A full scale mockup of the Orbiter aft flight deck, constructed for this study, was configured to accommodate standup operation by a crewman in a zero-g erect position using only foot restraints.

An operational D&C philosophy was developed from the results of a preliminary analysis which considered the following.

a. ASF D&C requirements.

b. Payload dedicated D&C area in aft crew station.

c. PS workload for operating ASF instruments.

d. One or two-man operating capability at the PSS.

e. Support hardware (D&C units, recorders, etc.) stowage requirements in the aft crew station area.

f. The number of PS's required to perform an ASF mission.

g. Support requirements for Orbiter supplied D&C (RMS, R&D CCTV, etc.)

Study results indicate that some manual control is required but that most operations can be automatically controlled through the ASF payload CDMS. Sufficient space is available at the PSS console to accommodate ASF instrument D&C requirements. Stowage for support

ASF hardware is required in the aft crew station. No attempt was made to assign a location to this hardware since Orbiter has not yet assigned dedicated aft crew station stowage volume to payloads.

It was determined that only one PS at a time can operate at the PSS. For 24 hour/day operations of the ASF, two PS's will be required, each operating on a 12 hour/day shift.

5.2.5.2 Requirements

5.2.5.2.1 Instruments

Instrument requirements were defined using the latest available information. These requirements are outlined in table 5.2.5-1. The table is organized by instrument packaging per pallet and associated parameters. The parameters cover data collection, preparation time, controls, displays, forced A&A, C&W and other parameters such as provisions for data filming .

5.2.5.2.2 Support Subsystems

Functional D&C requirements for the support subsystems are minimal. These are the following.

a. Equipment power control.

b. Boom extension and retraction.

c. Platform latching and unlatching.

d. Tape recorder control.

e. Fine pointing control.

5.2.5.2.3 Orbiter Support

a. MSS Panels R-12 and R-13 (figure 5.2.5-1) are dedicated to the mission station. Included in this area are the D&C for

TABLE 5.2.5-1. — AMPS/ASF INSTRUMENT DISPLAY AND CONTR

PLATFORM	APS PLATFORM #1						PLATFORM #2	APS PLAT			
PARAMETERS / INSTRUMENT AND TYPE	213 LASER SOUNDER	532 GAS RELEASE MODULE	534 OPTICAL BAND IMAGE AND PHOTOMETER SYSTEM	550 (BOOM) FARADAY CUP RETARDING COLD PLASMA PROBE POTENTIAL ANALYZER (DIAGNOSTIC LEVEL II)	1002/1003 PYRHELIOMETER SPECTROPHOTOMETER	1011 ULTRAVIOLET OCCULTATION SPECTROGRAPH	SUBSATELLITE	116 AIRGLOW SPECTROGRAPH	118 (CRYO) LIMB SCANNING INFRARED RADIOMETER	122 UV-VISIBLE NEAR INFRARED SPECTROMETER	
DATA COLLECTION							SEE ASF MISSION TIMELINES (FIGURE 4.1.5-1)				
PREPARATION TIME							SEE ASF MISSION TIMELINES (FIGURE 4.1.5-1)				
CONTROLS	POWER (ON,OFF,STBY) POINTING TUNE Å PULSE RATE DOORS (OPEN,CLOSE)	POWER GAS BOTTLES (4) GAS PRESSURE (PSI) GAS MODE (2 SPACE, BOX) GRATING (5 DIGITS) DOORS MASS FILTER (5 DIGITS)	POWER POINTING FILTER SELECT MODE APERTURE 2 CAMERAS (CCTV, UV) START, STOP RECORD DOORS	POWER BOOM-EXTEND, RETRACT INCRE- MENTS JETTISON SCAN DOORS	POWER DATA SEQUENCE INITIATION CALIBRATION DOORS	POWER POINTING EXPOSURE CONTROL DOORS	POWER UNLATCH, EJECT, STOW, LATCH RCS CONTROL COVERS	POWER CONFIGURATION SELECT (SPECTRAL RANGES) POINTING EXPOSURE DOORS	POWER POINTING-SCAN RATE FILTERS SCAN MODE DOORS	POWER MODE SPECTRAL (4 BANDS) SCAN RATE (GRATING) DOORS	POWE ETAL POIN FILT WAVE DOOR
	PLATFORM #1 JETTISON REQUIREMENT — TO ORBITER									PLATFORM #3 JETTISO	
DISPLAYS	WAVE LENGTH (VARIANCE) PULSE RATE RELATIVE POINTING ANGLE BEAM REFLECT MEDIA RANGE STATUS	BOTTLES (4) GAS MODE (2) CHAMBER TEMPERATURE GAS PRESSURE CHAMBER PHOTODIODE (VOLTAGE) WAVELENGTH-X INTENSITY-Y STATUS MASS COUNT-X INTENSITY-Y	INDICATOR LIGHTS TV MONITORS (2) VIDEO TAPE STATUS	VARIABLE SAMPLING RATES (3) STATUS PULSE SHAPES (NEAR REAL TIME) STATUS	INDICATOR LIGHTS STATUS SPECTRAL RANGE SCAN	FILM COUNTER STAR, SUN TRACKER INDICATORS STATUS TRACES EXPOSURE SPECTRAL RANGES TRACKER, ACQUISITION	RANGE, RANGE RATE INDICATORS ORIENTATION RUNNING LIGHTS ST· BE A ·ISITION LIGHT ON, OFF STATUS	INDICATORS FILM COUNTER RELATIVE POINTING ANGLE SPECTROGRAM EXPOSURES START-STOP SCOPE TRACES (2 RANGES) STATUS	TV MONITOR SCOPE TRACES (4-12) RELATIVE POINTING ANGLE STATUS TEMPERATURE SCAN RATE	SCOPE TRACES (8 RANGES) STATUS MODES (1-8) RELATIVE POINTING ANGLE DETECTOR COUNTS	STAT SCOP SCAN RELA POIN
FORCED ALARM/ ADVISORY	LASER HEAD OVER TEMPERATURE WAVE LENGTH VARIANCE	CHAMBER TEMPERATURE		OUT OF SEQUENCE					COOLING CRYO SUPPLY LOW		DET TEM
OTHERS						FILM		FILM			

/ASF INSTRUMENT DISPLAY AND CONTROL REQUIREMENTS

	PLATFORM #2	APS PLATFORM #3					PLATFORM #4 (HARD MOUNT)			
...ROGRAPH	SUBSATELLITE	116 AIRGLOW SPECTROGRAPH	118 (CRYO) LIMB-SCANNING INFRARED RADIOMETER	122 UV-VISIBLE NEAR-INFRARED SPECTROMETER	124 FABRY-PEROT INTERFEROMETER	126 (CRYO) INFRARED INTERFEROMETER	303 ELECTRON ACCELERATOR	304 MAGNETOPLASMADYNAMIC (MPD) ARC	536 (BOOM) TRIAXIAL FLUXGATE	549 GAS PLUME RELEASE AMPS PARTICLE ACCELERATOR (SYSTEM LEVEL I DIAG)
SEE ASF MISSION TIMELINES (FIGURE 4.1.5-1)										
SEE ASF MISSION TIMELINES (FIGURE 4.1.5-1)										
POWER UNLATCH, EJECT, STOW, LATCH RCS CONTROL	POWER CONFIGURATION SELECT (SPECTRAL RANGES) POINTING EXPOSURE	POWER POINTING-SCAN RATE FILTERS SCAN MODE	POWER MODE SPECTRAL (4 BANDS) SCAN RATE (GRATING)	POWER ETALON SELECT POINTING FILTERS WAVELENGTH	POWER POINTING MODES SCAN PULSE RATE	POWER POINTING MODES (3) HIGH VOLTAGE (4) TYPE ADJUST INITIATE SEQUENCE	POWER POINTING PRESSURE RELEASE INITIATE SEQUENCE	POWER BOOM- EXTEND RETRACT JETTISON SAMPLING RATES	POWER GAS SUPPLY RELEASE INITIATE WITH 303
COVERS	DOORS	DOORS	DOORS	DOORS	DOORS	DOORS	DOORS	DOORS	DOORS	
			PLATFORM #3 JETTISON REQUIREMENTS TO ORBITER (PULSE PROGRAM BOX→COMPUTER							
RANGE, RANGE RATE INDICATORS ORIENTATION RUNNING LIGHTS STROBE ACQUISITION LIGHT ON, OFF STATUS	INDICATORS FILM COUNTER RELATIVE POINTING ANGLE SPECTROGRAM EXPOSURES START-STOP SCOPE TRACES (2 RANGES) STATUS	TV MONITOR SCOPE TRACES (4-12) RELATIVE POINTING ANGLE STATUS TEMPERATURE SCAN RATE	SCOPE TRACES (8 RANGES) STATUS MODES (1-8) RELATIVE POINTING ANGLE DETECTOR COUNTS	STATUS SCOPE TRACE SCAN RATE RELATIVE POINTING ANGLE	TV MONITOR INTERFEROGRAM SCOPE TRACE INDICATORS STATUS VERTICAL TEMPERATURE PROFILE RELATIVE POINTING ANGLE	STATUS RELATIVE POINTING ANGLE MODE ADJUST DUAL TRACE PULSE SHAPES	STATUS RELATIVE POINTING ANGLE DISCHARGE CURRENT VOLTAGE TRANSIENT PULSE WAVE FORMS STORAGE GAS PRESSURE (TBD TANKS)	STATUS POWER SPECTRA FREQUENCY BANDS	STATUS STORAGE PRESSURE (TBD TANKS) RELEASE BURST VIDEOTAPE REPLAY
		COOLING CRYO SUPPLY LOW		DETECTOR TEMPERATURE	COOLING CRYO SUPPLY LOW LOW DETECTOR TEMPERATURE			ELECTRONIC TEMPERATURES POWER SAFETY	
	FILM									

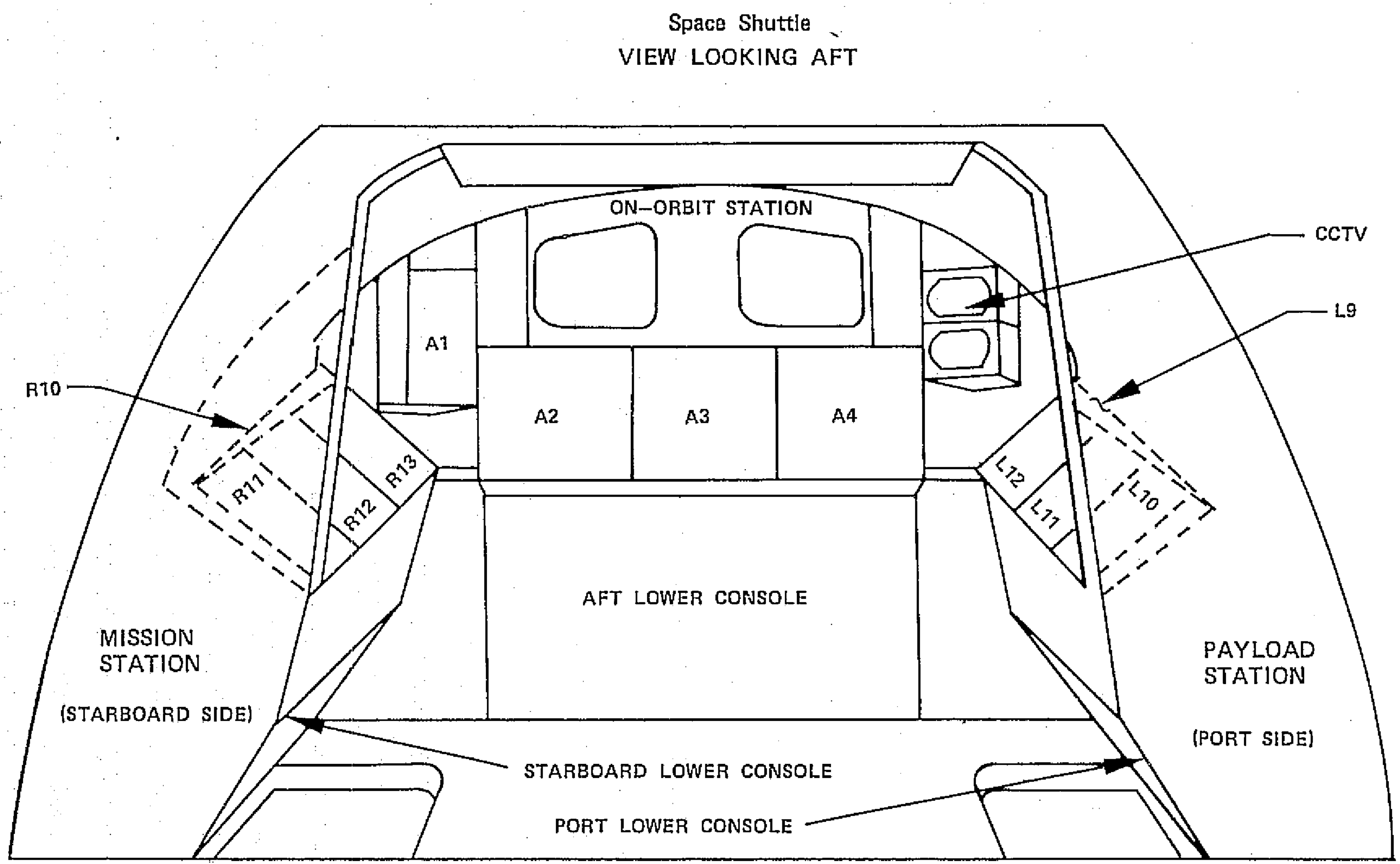

Figure 5.2.5-1. – Orbiter aft flight deck panel location code.

general payload subsystem operations. Panel R-11 will contain all unique D&C required by the MS to support ASF payload subsystem operation. The functions identified at this time are:

(1) Subsatellite monitoring and control.

(2) Experiment computer D&C.

b. At the on-orbit station, Panel A2 is the R&D panel. The ASF support requirements are for retrieval of the subsatellite and include the following:

(1) Range/range rate indicators.

(2) Control and monitoring of subsatellite, if it plays active role during retrieval.

Panel A2 is the CCTV panel. The ASF support requirements will include switching capability to allow the scientific TV cameras to utilize the onboard TV monitors.

Panel A4 is the RMS panel. The ASF support requirements will include:

(1) An indicator for stowed/unstowed status of the subsatellite.

(2) A control to activate the latch/unlatch mechanism.

(3) An indicator for latch/unlatch status.

Additional panel assignments at the on-orbit station are required to support ASF for the following:

(1) APS jettison control.

(2) Boom(s) jettison control.

(3) Subsatellite jettison control.

These will be controlled by guarded switches and will be required if the APS, booms, or subsatellite tiedown latching mechanism should fail.

5.2.5.3 Guidelines and Assumptions

a. The ASF experiments will operate 24 hours/day.

b. The inflight calibrations for the ASF instruments will be automatic.

c. The Orbiter-provided RMS, CCTV, and R&D capabilities will be required.

d. An AMPS/ASF dedicated computer will be provided.

e. EVA will not be considered as a normal operational requirement.

f. The ASF will be considered the prime payload and the dedicated payload D&C area, lower console volume and allocated payload stowage space will be dedicated to it.

g. There will be no audible alarms required for the operation of the ASF. An exception will be if the simultaneous crew sleep constraint is enforced.

5.2.5.4 Capabilities and Constraints

The ASF utilizes Orbiter facilities in accomplishing the required operations. The resources include space allocation at the PSS for D&C (figure 5.2.5-2) support equipment installation and stowage, and control, display, checkout, C&W, and other functions at the MSS and the on-orbit station. These stations are illustrated in figure 5.2.5-1. Figure 5.2.5-1 also shows the panel location codes which are as follows:

A2	R&D Panel	On-Orbit Station
A3	CCTV Panel	On-Orbit Station
A4	RMS Panel	On-Orbit Station
R11, R12 & R13	MSS Panels	
L10, L11 & L12	PSS Panels	

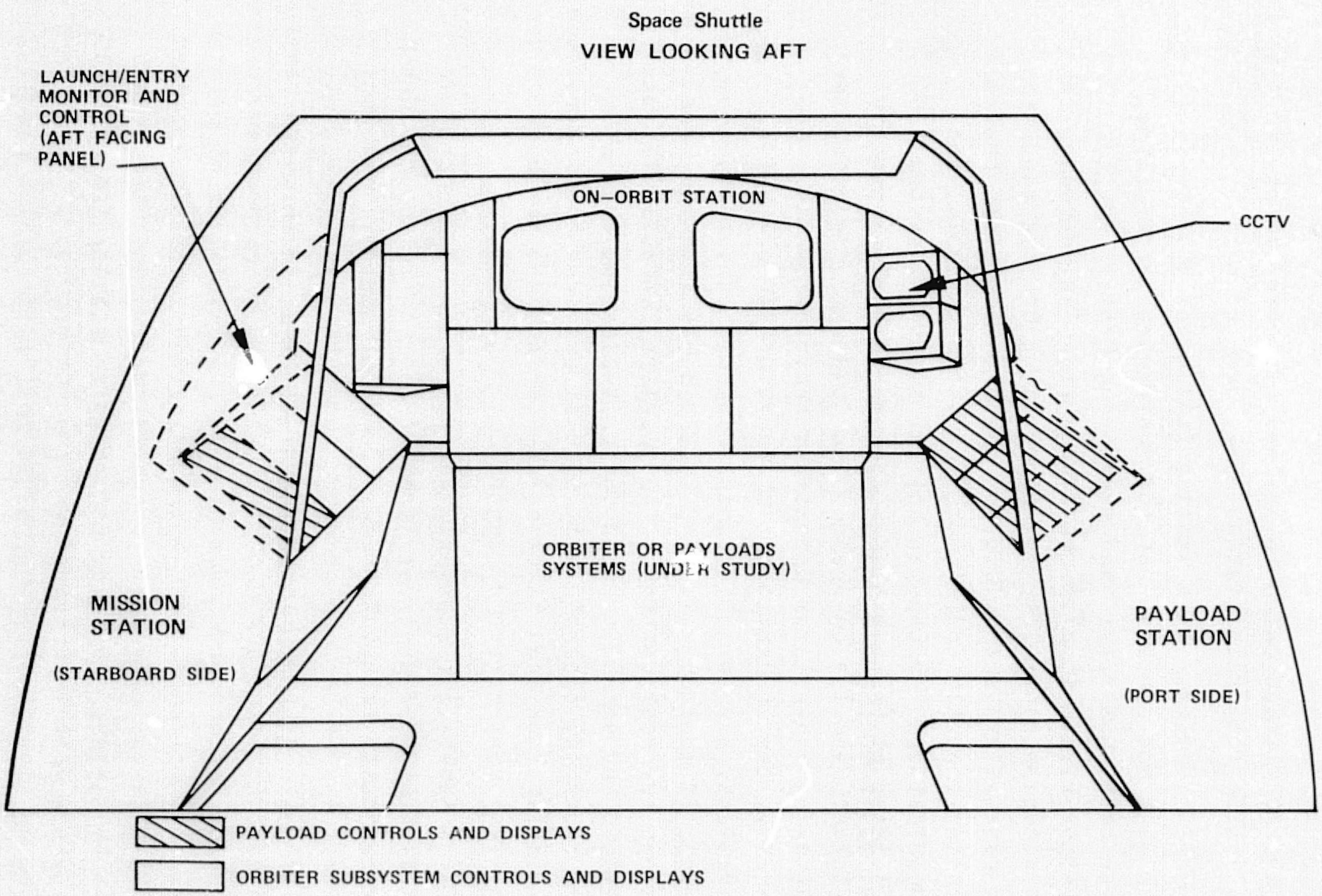

Figure 5.2.5-2. — Aft flight deck crew station.

R11 at the MSS is dedicated to payload use. Following are the descriptions of on-orbit station, MSS, and the PSS.

a. On-Orbit Station. This station is located at the aft flight deck wall and contains D&C for monitoring target range, range rate, LOS rates, and monitoring Orbiter attitude and attitude rate. It also contains a translation controller and rotation controller for controlling Orbiter maneuvers. The capability is provided for docking mechanisms control, lighting control, docking module system controls, and communications. A crewman optical alignment system (COAS) is located at the overhead window for visual alignment of target vehicles on-orbit. Two CCTV's are provided for monitoring manipulator operations and experiments. Additionally, the on-orbit station contains D&C for manipulator operations, D&C for CCTV camera control (pan, tilt, zoom, focus), TV monitor switching, payload bay lighting, and payload bay door controls. Appropriate controls will be provided for operating with one or two manipulator arms. When required, controls will also be provided for manipulator jettisoning, payload latching/unlatching, and payload/Orbiter umbilical connect and disconnect.

b. Mission Specialist Station. The MSS on the starboard side contains D&C for checkout, monitor and control of the Orbiter/payload subsystems interface. Command, control, and monitoring, via rf, of deployed and detached payload support systems are also provided. A CRT display and keyboard panel are used to interface with the Orbiter systems management computer for onboard checkout and fault isolation of Orbiter subsystem malfunctions. A communications panel is provided for management of voice, TV and telemetry (TM) data to and from the ground. Onboard recording of Orbiter and payload subsystem data is provided via the PCM recorder. A standard 48.26 cm (19-inch) wide by 53.34 cm (21-inch) high panel is provided for accommodating payload unique D&C. Mission and event timers and lighting controls will also be located at this station. During launch and entry, some payload experiment and payload subsystem C&W and other monitor and control capability is provided on a panel located on the starboard side and facing aft.

c. Payload Specialist Station. The PSS on the port side contains three standard panel spaces with required Orbiter-to-payload standardized electrical power connectors for accommodating government-furnished equipment (GFE) and/or user provided unique modules for command, control, and checkout of experiment instruments. A junction box will be provided for routing wire from connectors located in the payload bay to the equipment modules at the aft crew station. Standard Orbiter audio panel and lighting controls will be provided at this station.

5.2.5.5 Aft Crew Station Configuration Description

The ASF D&C consists of the following:

a. An alpha-numeric keyboard (ANK)(part of CDMS).

b. Two CRT's.

c. Two event timers.

d. A fine pointing control panel.

e. An Alarm/Advisory (A&A) display.

f. An analog tape recorder control and status panel.

g. A platform latch control and status panel.

h. A boom control and status panel.

i. Film status displays.

j. Power control panels.

k. A "scratch pad".

These D&C are located at the PSS on panels L10, L11 and L12 (see figure 5.2.5-1). Panels L10 and L11 comprise the "facility" D&C which are expected to support not only ASF but the full complement of AMPS missions. The D&C items located on L10 and L11 are shown in figures 5.2.5-3 and 5.2.5-4. The location of these D&C's is preliminary and will be updated as D&C requirements are better defined. Panel L12 (figure 5.2.5-5) is dedicated to discrete instrument D&C's. These are not high usage items and are primarily status displays such as film status, etc. Other discretes would be time critical items such as manual power cutoff to instruments in case of critical malfunction requiring computer override. These items will change with the various ASF/AMPS mission requirements. The ASF discrete D&C items identified to date are:

(1) Film status for instruments.

(2) Computer override power cutoff for all instruments.

(3) Latch/unlatch controls and status for pallets A-1 and A-3 APS's.

(4) Unlatch/latch, deploy/retract controls and status for booms.

5.2.5.5.1 Cathode Ray Tube

The CRT selected for ASF missions is the unit being developed for the Orbiter Multifunction CRT Display System (MCDS). The overall dimension is 26.06 cm × 18.75 cm (10.26" × 7.38") with a screen size of 17.8 cm × 12.7 cm (7" × 5"). The display has a split screen format capability. Character sizes can be either 0.318 cm (0.125") or 0.381 cm (0.150") in height. The 0.318 cm (0.125") size allows 26 lines of 51 characters-per-line formats. The 0.381 cm (0.150") size allows 25 lines of 41 characters-per-line formats. Figures 5.2.5-6 and 5.2.5-7 show the Orbiter CRT selected for the ASF program.

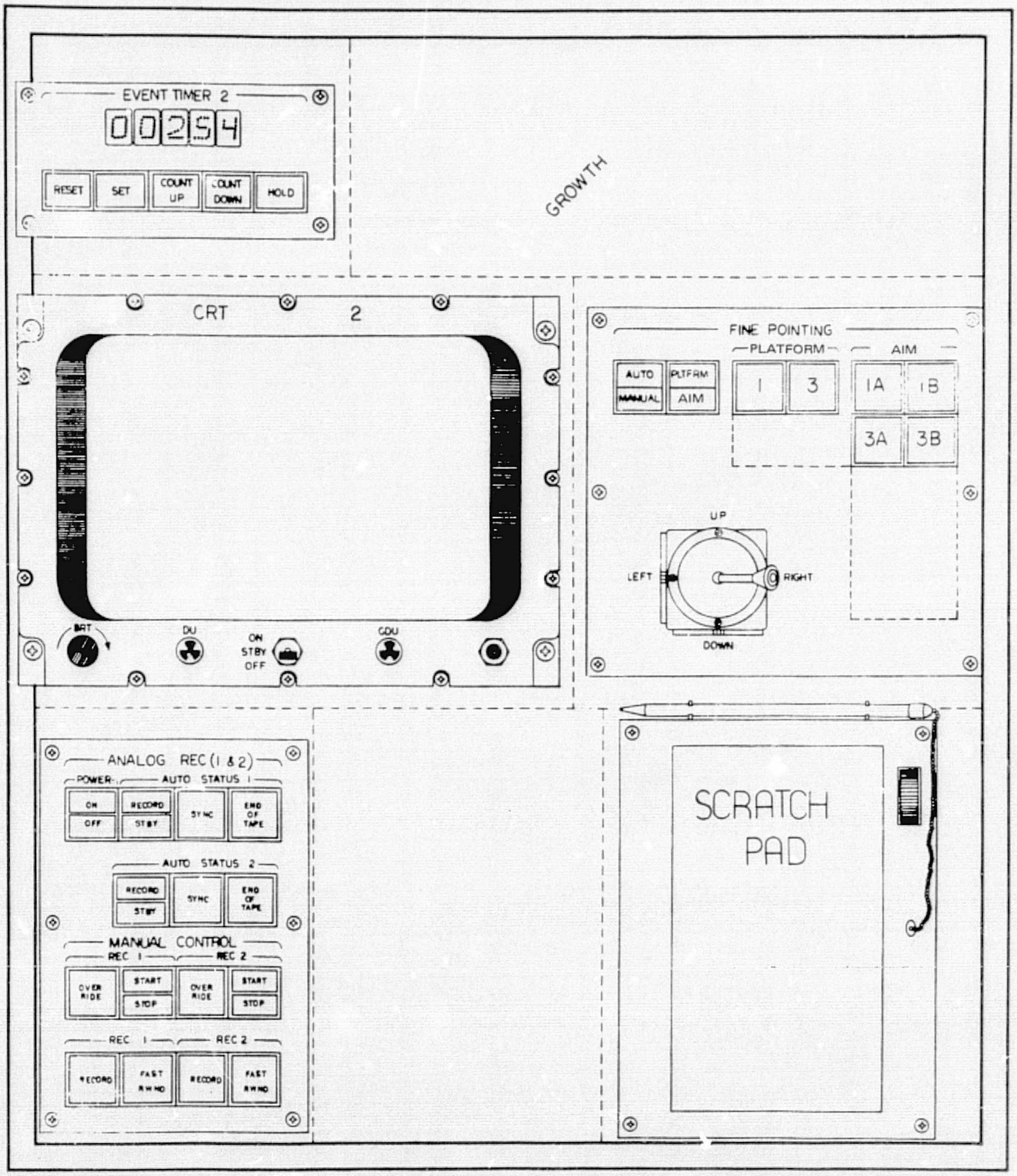

Figure 5.2.5-3. — Panel L10.

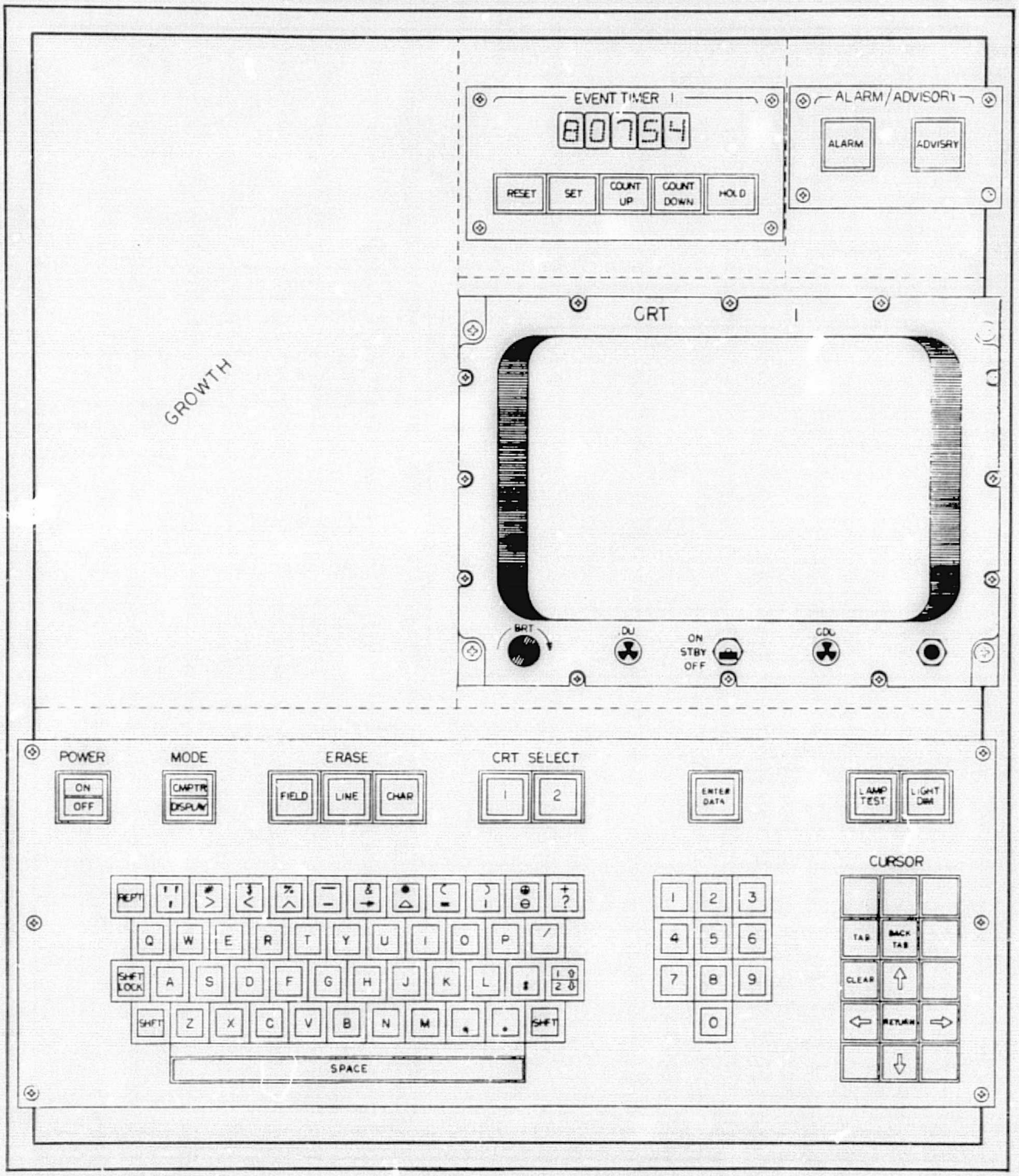

Figure 5.2.5-4. — Panel L11.

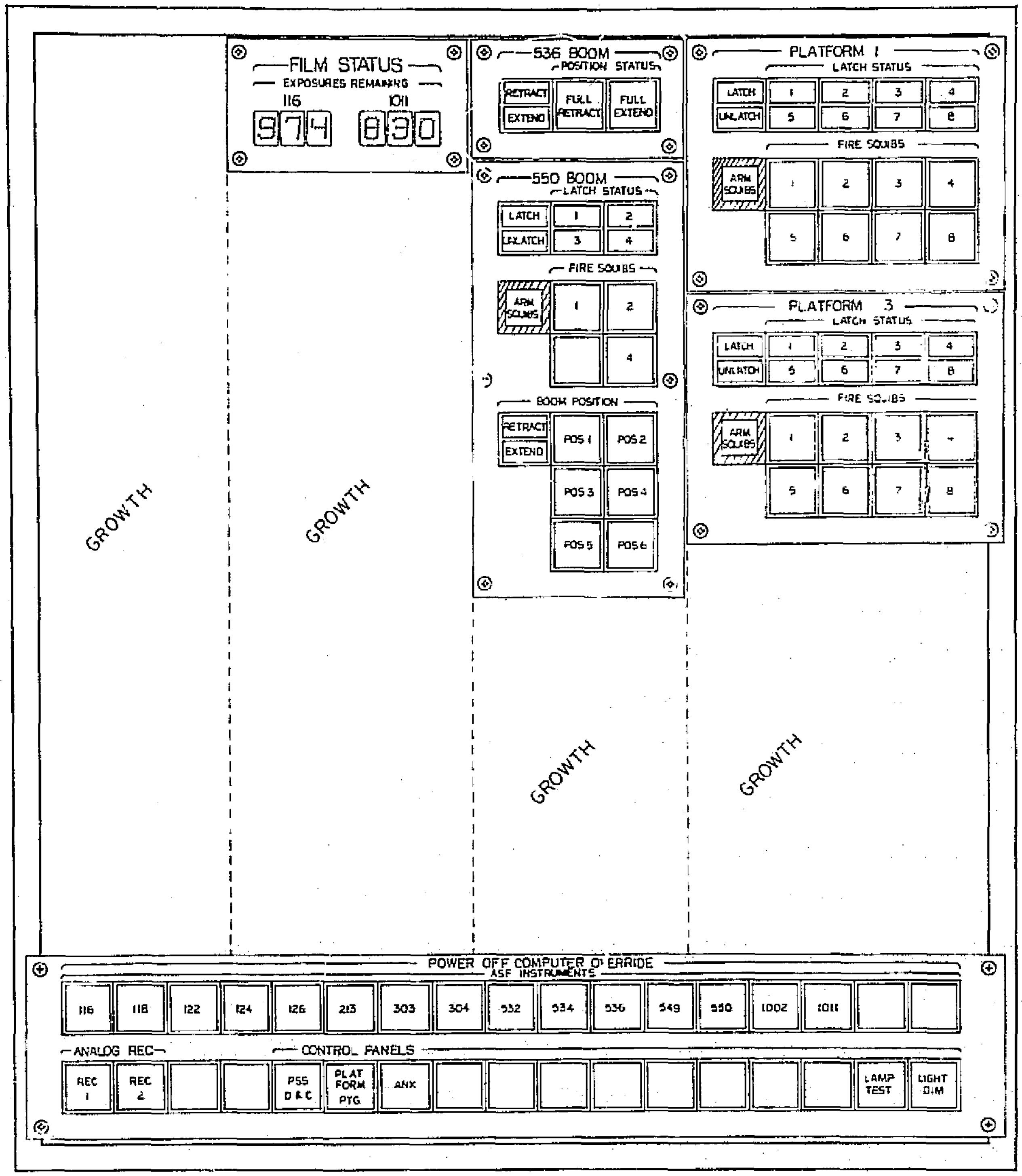

Figure 5.2.5-5. — Panel L-12 Payload Specialist station.

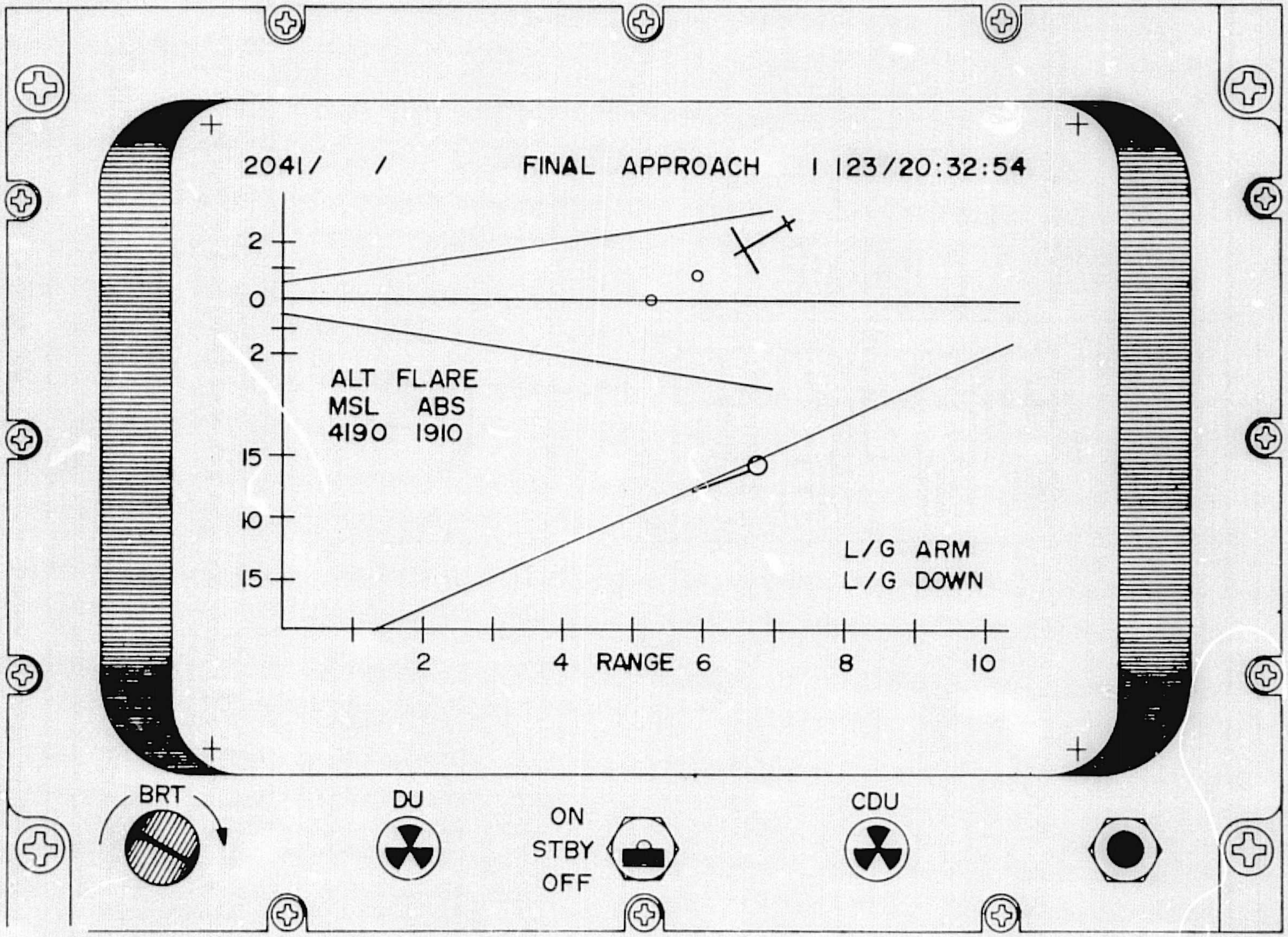

Figure 5.2.5-6.— CRT graphics display format.

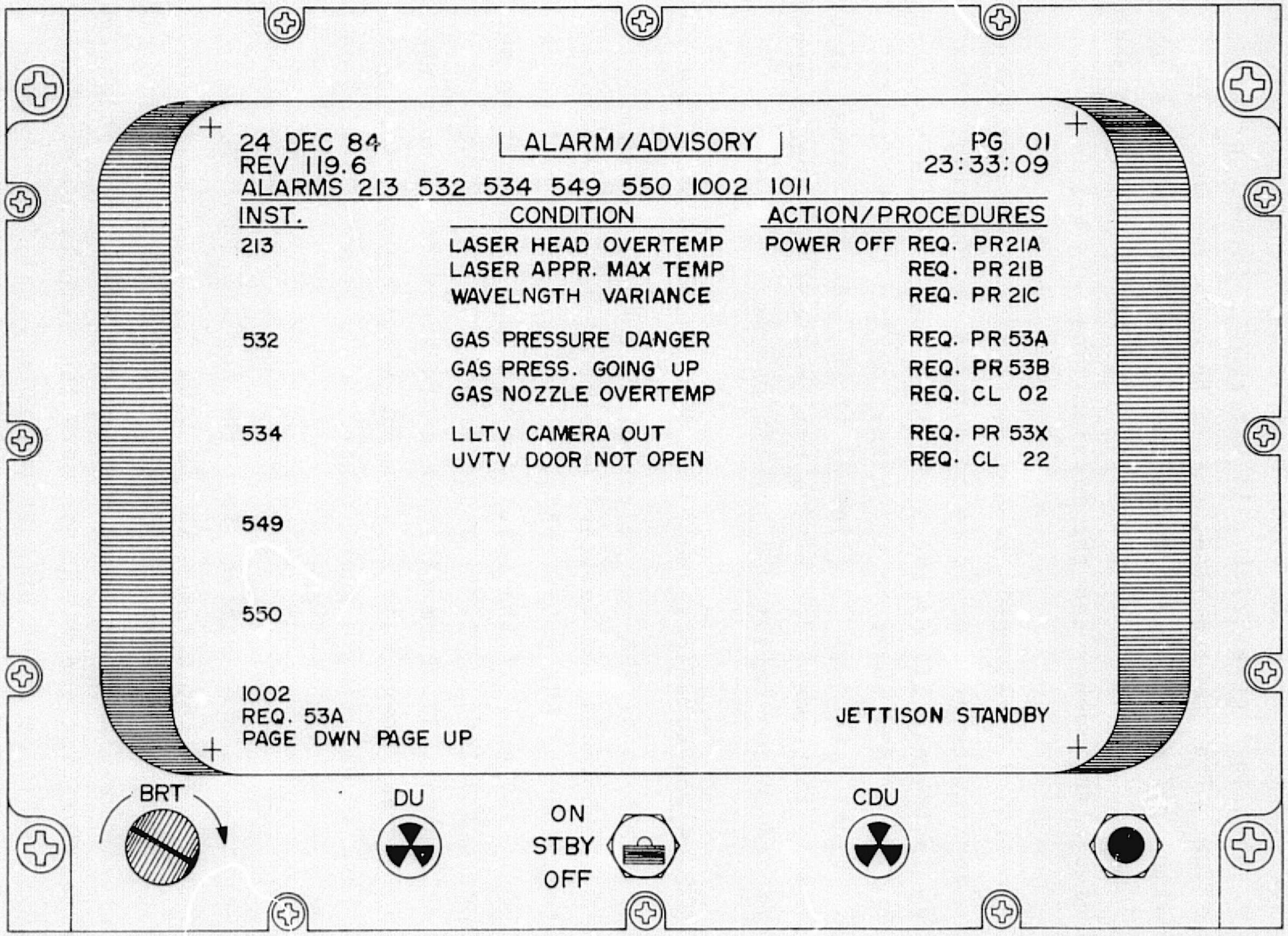

Figure 5.2.5-7. — CRT alphanumeric display format.

Figure 5.2.5-6 illustrates a sample split screen graphical display and figure 5.2.5-7 shows an alpha-numeric (A/N) page format. The example shown in figure 5.2.5-7 illustrates a format for A&A information. The top two lines should be reserved for header information. The format for these two lines will be the same for all pages. It includes the date, page heading, page number, orbit revolution number and the mission time.

The alarm (third line) would be unique to this series of displays and the particular area would be brightened or flashing. For example, Instrument 532 on the alarm line would be flashing and the top line of 532 would be brightened across the entire CRT screen. Lines 4 through 23 (line 24 if the 26-line format is used) will display instrument data. The bottom two lines are reserved for keyboard communication and scratch pad use.

5.2.5.5.2 Alpha-Numeric Keyboard

A typewriter type of ANK was selected for the ASF program. Figure 5.2.5-8 shows the keyboard panel containing pushbutton indicators and the ANK subassembly. It is a self-contained unit. Included in the back of the panel are control logic, gating shift register, and drivers. It is a standard 17.78 cm × 48.26 cm (7" × 19") panel, 33.02 cm (13") in depth excluding connectors with an internal power module. The power requirement for the ANK is 115 Vac, 60 Hz, single phase power. Lamp power (24 Vdc) is supplied from an external source.

The numerics have been removed from the top key line of the typewriter format and grouped at the side for input convenience. Additional symbols have been added to the top keys. An alternate configuration would be to leave the numeric keys in the standard typewriter location and reduce or move the symbols to other key locations. This decision will depend upon final instrument requirements.

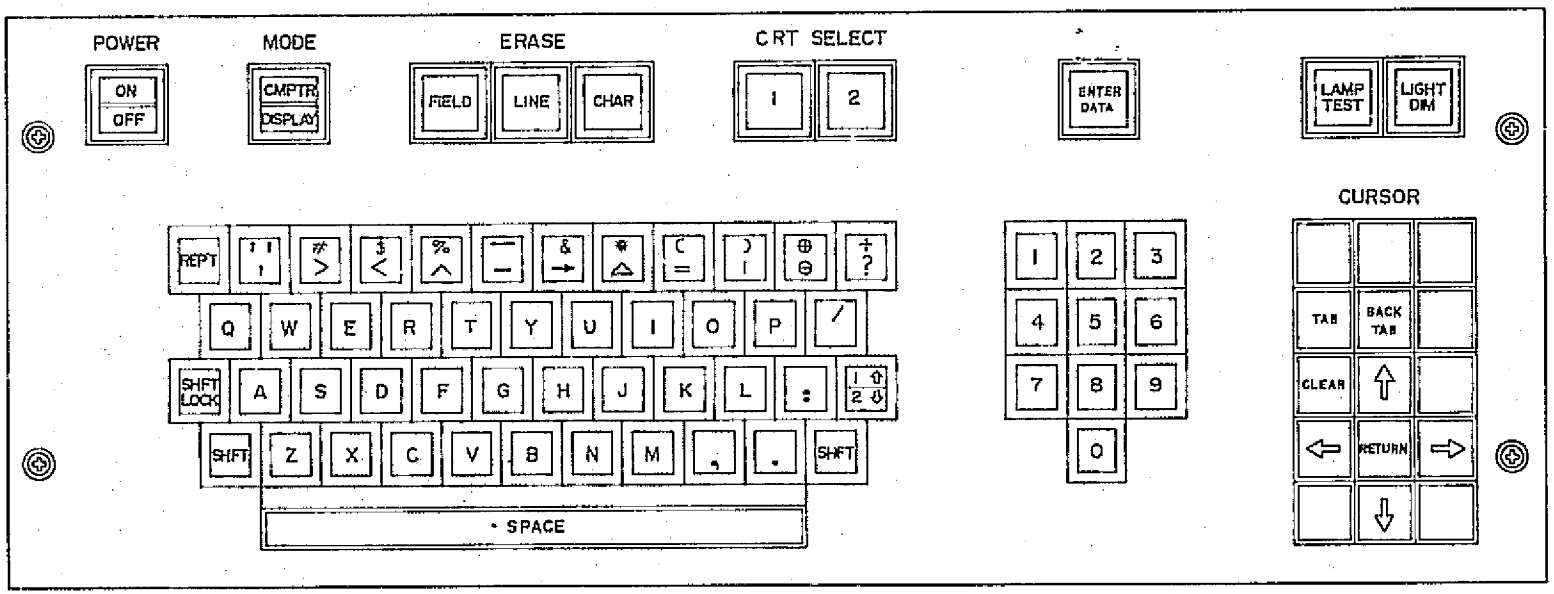

Figure 5.2.5-8. — Alphanumeric keyboard panel.

5.2.5.5.3 Fine Pointing Control

The ASF mission requires the capability for fine pointing control of the APS and modules. There are two directions of movements: (1) up-down, and (2) right-left. The two APS can be rotated right-left in the "platform" mode. The two instrument modules on each platform can be individually rotated up-down and right-left in the "AIM" mode. The control is a two-axis displacement "joystick" with provision for spring return to center in each axis. Third axis control is not required at this time.

The type of display to be provided to the crew in conjunction with the manual fine pointing control is subject to more detail study and will be considered in the follow-on AMPS study.

5.2.5.5.4 Alpha-Numeric Dot Matrix Displays (time, film status)

(TBD).

5.2.5.5.5 Discrete Switches

The type of switch selected for the ASF panels is the rack-mounted, plug-in, lighted pushbutton indicator (PBI) switch with full and split legend displays. Each contains four lamps with varied color capability. The lamps or legends can be removed from the panel front without tools. The majority of these PBI's are alternate action switches and are 2.54 cm (1") high, 2.54 cm (1") wide, and 7.62 cm (3") deep.

Using only one type of switch is more cost effective than mixing with toggles, thumbwheels, etc. Larger lots and simpler inventory requirements will result in low costs. Reasons for selecting this particular type of switch are as follows.

a. Flexibility and growth is excellent. Functions can be changed by removing and replacing legends and making the desired connections.

b. Visibility is excellent with a minimum scan time required for status information.

5.2.5.5.6 Scratch Pad

A scratch pad will be provided for recording remarks and notes. The design shown is conceptual.

5.2.5.5.7 Support Hardware

Support hardware for ASF requiring aft crew station lower console volume have been identified. No allocation of lower console volume to payload use has been made at this time. Therefore, the support hardware is identified as to requirements only, with no specific location assigned to them. ASF equipment located within the crew station envelope to support the ASF includes:

a. One control and display unit (CDU).

b. Three RAU's.

c. Two analog tape recorders.

These items are part of the CDMS.

The CDU is the interface between the keyboard and CRT's. It generates the necessary symbology and data formats. The CDU will service the keyboard and two CRT's. The CDU will be located in the PSS lower console a minimum distance from the keyboard CRT's. The unit is approximately 27.94 cm (11") in width, 19.55 cm (7-1/2") in height and 22.99 cm (8.1/2") in depth. It weighs 18.2 Kg (40 lbs), and requires 201 watts maximum power.

The analog tape recorders are used primarily to store high frequency scientific data. The stored data can be transmitted to the ground station through the Orbiter rf links. Two analog recorders will be required to operate in series. To allow uninterrupted data recording they will require crew access for changing tapes. It is recommended that a crew-accessible location be allocated with a pull-out drawer in the lower portion of one of the aft crew station consoles. These recorders are each approximately 33.02 cm (13") wide by 33.02 cm (13") deep by 15.24 cm (6") high.

Three RAU's will be required to interface pallet-located equipment with the D&C and Orbiter equipment. The MSS will require an experiment RAU and the PSS will require one experiment RAU and one subsystem RAU. RAU size is approximately 22.61 cm (8.9") in width, 11.94 cm (4.7") in depth, and 8.64 cm (3.4") in height.

5.2.5.5.8 Loose Equipment Stowage

The loose equipment requiring stowage volume are:

a. Tape recorder tapes (number and dimensions TBD).

b. Backup keyboard.

5.2.5.5.9 Interfaces

The ASF D&C has three primary interfaces. These are with; (1) the payload, (2) the Orbiter equipment, and (3) the Orbiter crew.

a. Payload. Interfaces with the ASF payload (instruments, subsatellite, and support systems) are made through the ASF CDMS RAU. These interface functions are discussed in section 5.2.4.

b. Orbiter Equipment. Orbiter equipment which interface with the ASF D&C include:

   (1) C&W electronics and displays.

   (2) MSS.

   (3) On-orbit station.

c. R and D Station. To retrieve the subsatellite, D&C capabilities at the R&D station are required. These are:

   (1) Orbiter/subsatellite relative range and range rate monitor.

(2) Subsatellite attitude and control and monitoring (if subsatellite plays an active role during retrieval).

d. RMS Station. The control and monitoring functions at the RMS station required during subsatellite retrieval are:

(1) Indication to the operator that the subsatellite is in the stowed position.

(2) Control to activate the latch/unlatch mechanism.

(3) Indicator to show latch/unlatch status.

In addition to the C&W status board, the MSS will provide control and monitor capability for the payload subsystem, payload computer, and the subsatellite.

e. CCTV. The CCTV display will be used by the ASF system. Instrument 534 contains two cameras, one for low light television (LLTV) and the other for UV display. A capability to select either or both of these cameras simultaneously for display on the CCTV is required.

f. On-Orbit Station. In the event the pointing systems or the boom cannot be retracted into their stowed position in preparing for Orbiter return to earth, the following capabilities must be provided at the on-orbit station:

(1) Jettison APS 1 and 3.

(2) Jettison boom (Instrument 536).

(3) Jettison boom (Instrument 550).

5.2.5.5.10 Operations

Utilization of keyboards, predefined CRT formats, operator interaction, and computer/software interfaces must have an operating philosophy as a foundation for decisions. The following paragraphs discuss such a philosophy.

Display design should be oriented toward ANK manipulation on a CRT. The CRT would present status, alarm message, attention coding, etc. Display request would be accomplished via ANK. Checklists and procedures will be incorporated into the ANK/CRT system (TBD). The following general characteristics would apply to most displays.

a. Function Codes. The ANK function codes would be graphic descriptor or mnemonic labels, displayed on the CRT and linked through a software program or routine. These function codes would be displayed only if applicable to the particular format and picture being presented. An individual function code would occupy a common location on all displays; however, it may not appear on all displays, i.e., it would be suppressed when not applicable to a particular display. These function codes would be designated and activated by underlining with the ANK cursor either of the first two characters of the respective function code. The normal sequence of use would require the operator to designate an entity - such as a data item - and the operation to be performed on it, such as ERASE, ENTER, REVERSE, PAGE UP, PAGE DOWN, etc., and enter the request. The result would be an observable change in display content or format.

b. Data Fields. Specified data fields would be intentionally protected and not subject to ANK manipulation. The data on some displays should be made impervious to change through the ANK to ensure the integrity of the display format designs. When the ANK cursor encounters such a field, it would automatically advance to the next eligible field.

5.2.5.5.11 Crew Requirements

ASF mission requirements dictate that several instruments operate simultaneously. Additional instruments may be activated as soon as some complete their data collecting cycles. Thus rapid and continuous monitoring, experiment initiation and data analysis are required. The present assessment indicates that an excessive workload would be imposed on the operator if he were to have to change or correct incoming data, initiate new experiments, and monitor several sets of data. Therefore, the selected D&C approach is for the ASF pallet-only mode to limit the PS operations to the following.

a. Initiate and interrupt preprogrammed sequences.

b. Check initial conditions (modes, filters, etc.).

c. Perform limited manual operations (pointing, TV monitoring, etc.).

d. Act as a decision maker in off-nominal conditions.

e. Perform real time updates and changes to sequences.

In a very few instances the PS will analyze data, if it is the only way to ensure that a given instrument is performing correctly.

Using the above as the PS's task definition and based on the operating philosophy discussed in 5.2.5.5.10, one PS per shift will be able to operate the PSS for an ASF-configured mission.

The ASF experiments will operate on a full time basis. It is recommended that two PS's, each working a 12-hour shift, be used. A clear definition of crew tasks is required to determine whether this payload will require a fifth crewman (chargeable to ASF) or whether the pilot or commander could serve as a PS on-orbit.

For any ASF mission requiring detailed real time onboard data analysis, a preliminary study was performed to look at the possibility of providing a data monitoring station in the mid-deck area where one or more principal investigators (PI's) could monitor experiments and make real time inputs to the instruments through communication with the PS. Figures 5.2.5-9 and 5.2.5-10 show the concept of a swing-out modular monitoring console in the mid-deck area. The console would be launched in position A. During on-orbit monitoring it would be moved to position B. The details of this concept will be supplied at a later time. Another possible location for this console is in the area of the airlock shown in positions A and B. This would require that the airlock be flown in the payload bay. Details of this concept will be the subject of further study.

5.2.5.5.12 Crew Training Requirements

Optimally, the crew training would be accomplished using a full scale, instrumented aft crew station simulator with all stations (PSS, MSS, and on-orbit) configured to the ASF mission.

Since many of the scientific objectives of the mission require the PSS and MSS (and in some cases, the commander and pilot) to perform simultaneous or interdependent functions, the training should be done with the entire crew training to perform the scientific requirements.

This simulator would be dedicated to payload requirements and should be located in close geographical proximity to the Shuttle Mission Simulator.

In addition to the Payload Mission Simulator, a flight configured mockup (non-instrumented) of the aft crew station should be provided for crew familiarization of D&C, stowage, etc.

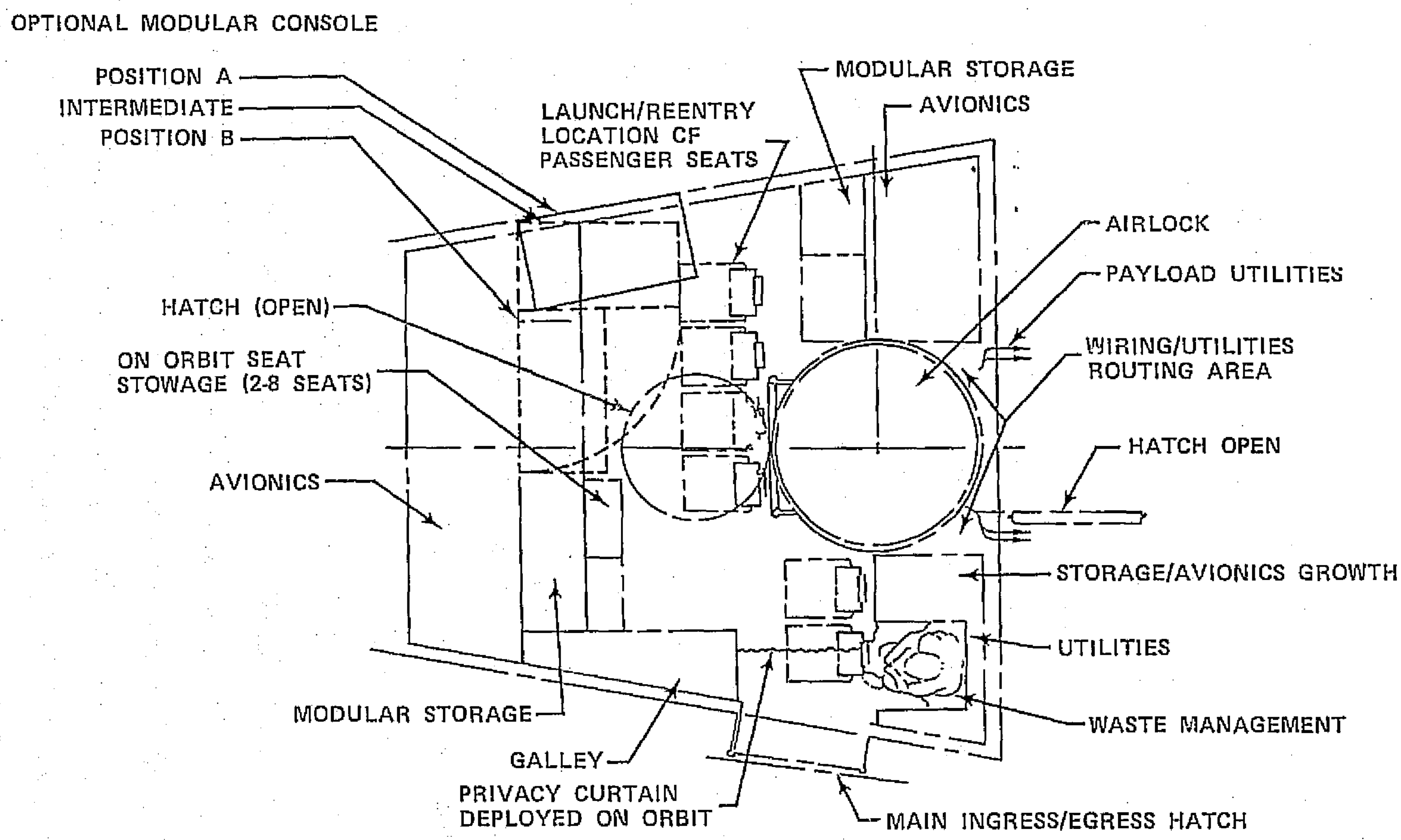

Figure 5.2.5-9. — Crew compartment, midsection plan view.

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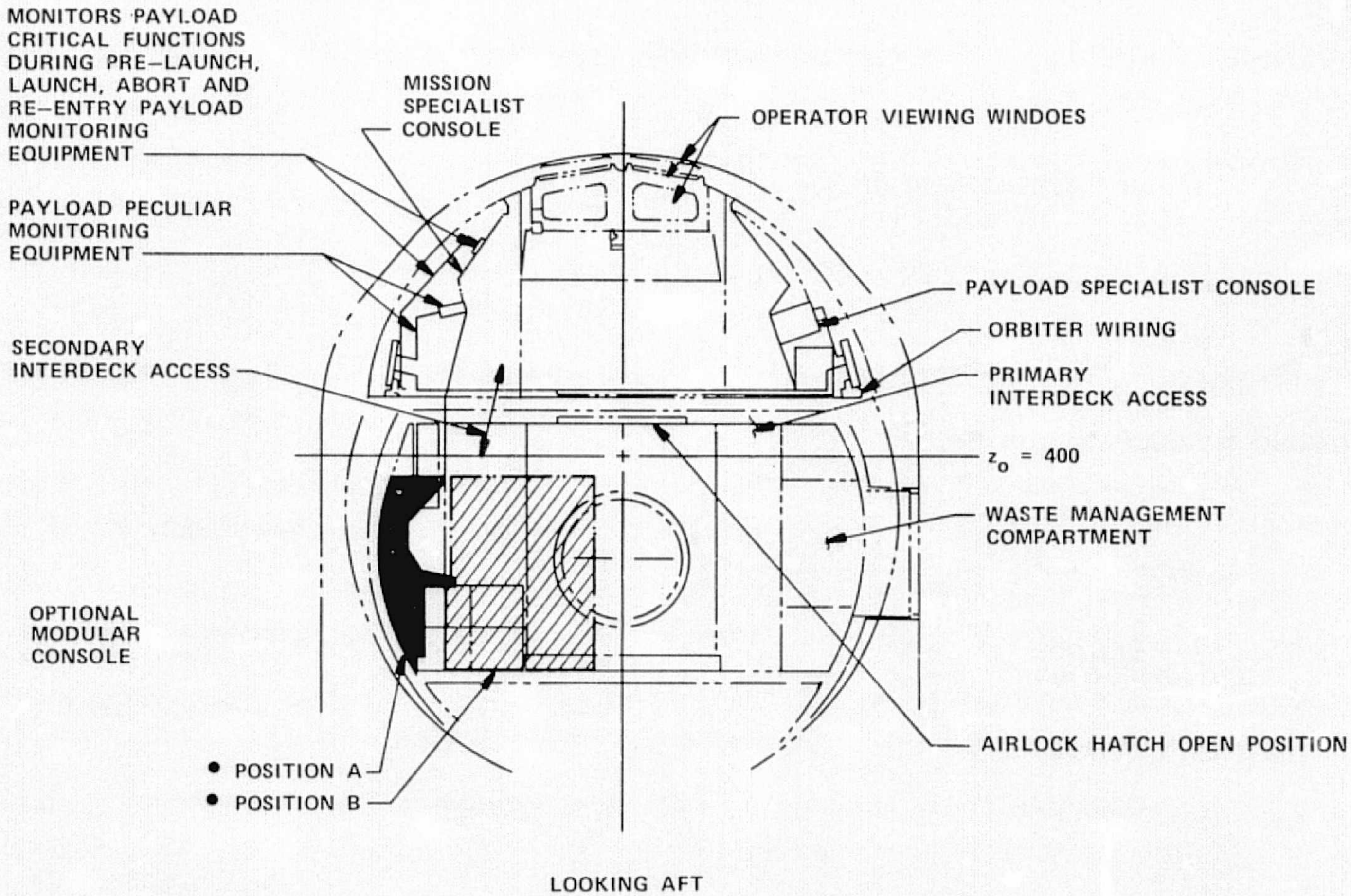


Figure 5.2.5-10. – Crew compartment, aft view.

It is assumed that a part task trainer will be provided for RMS and R&D training, using out-the-window simulations. The training would generally consist of the following.

a. Classroom briefings on scientific requirements. (The PI's would be greatly involved with this portion of the training.)

b. Mockup familiarization of D&C locations, stowage, velcro placements, etc.

c. Simulator training for timelines, off-nominal situations, etc. A Payload Mission Simulator should be provided to accomplish the crew training with personnel from the various payload areas acting as briefing and training personnel.

5.2.5.6 Analyses and Trade Studies

The functional requirements for D&C's defined by the instruments and support subsystems were evaluated. A key issue in establishing the ASF D&C approach was manual versus automatic (computer) control of the experiments, instruments, subsatellite, and the support subsystems. Using a full scale hard mockup, a preliminary layout evaluation was performed utilizing discrete switches, i.e., thumbwheels, windows, light indicators, pushbutton illuminators, etc., to ascertain the panel space required.

Results indicated that slightly more than one bay 48.26 cm × 53.34 cm (19" × 21") was required to accommodate these switches alone. This left less than two bays for CRT's, keyboards, timing devices, A/D recorder panels, etc., which was considered unacceptable.

Further analysis indicated that the panel space for D&C's could be reduced an order of magnitude with extensive automation utilizing keyboard interaction and display data formats for operator/computer communication.

The conceptual approach selected was to automate, to the maximum extent practical utilizing keyboard, CRT interaction and to use discrete switches or manual control elements where automatic control was unacceptable or impractical.

Equipment selections were based on limited evaluations of available candidates. The objective of these evaluations was primarily to verify that the selected equipment was compatible with the ASF D&C requirements and the Orbiter constraints. Evaluation of the keyboard concept went into somewhat more detail due to the importance of the man-machine interface and the impact of the keyboard concept on other segments of the D&C.

5.2.5.6.1 Cathode Ray Tube

The instrument requirements dictate that the display unit must generate A/N's, symbols, vectors, and circles for display on a predetermined format of static and/or variable data. A double brightening and flashing of a character or group of characters is a desirable feature. In addition, expansion and contraction of displayed data as well as rotation are probably required.

The viewing distance for the PS operator working in a zero-g erect position will range from 50.80 to 71.12 cm (20 to 28"). This will require a capability to present a character height of 0.318 cm (0.125") or more. This A/N and graphic capability is available in most CRT display units today, whether they use dot matrix, stroke writing, or plasma techniques. Recognition of some symbols in smaller size dot matrix configurations has been a problem in past studies so this type was not considered. Plasma displays have not been used operationally for a sufficient length of time so these display types were not investigated. The obvious candidate to investigate was the display unit being developed for the Orbiter MCDS.

The Orbiter CRT meets ASF display requirements. The symbols generated in the Orbiter display electronics unit are different from those required for the ASF system, as one might expect. However, this is a software change rather than one impacting hardware.

The Orbiter MCDS format samples demonstrate that two separate graphs could be adequately displayed on the CRT screen (figure 5.2.5-6). For ASF mission applications, the split screen format is a significant advantage because of the large amount of data required to be displayed. Therefore, this feature is retained.

5.2.5.6.2 Keyboard

There are several keyboard devices available and table 5.2.5-2 presents the types considered.

a. Alpha-numeric Keyboard. The ANK is considered to be a slow input device, when compared to other input devices, because a number of separate operator actions are required to initiate a computer input. Evaluation of ANK usage indicates that picture modification (changing data on a display) of 10 item changes will take approximately three minutes. Modification of three items containing 18 characters can be accomplished in approximately 32 seconds. The ANK is a highly versatile input device useful for all situations except those that are time critical.

b. Page Overlay Keyboard (POK). The POK is designed to be the most rapid and useful of all keyboard input devices. Proper functional programming of the creative instructions for folio design can make this input design perform as desired. Software for the folio and picture format is complex. Minimum

TABLE 5.2.5-2. — KEYBOARD TRADE-OFF COMPARISON

Comparative Factors / Keyboard Types	Alphanumeric (typewriter)	Fixed Function (grouped by function-redundant)	Fixed Function (non-redundant)	DSKY (numerical)	Page Overlay	Page Overlay plus Fixed Function
Error Potential	Very high	Very low	High due to lack of grouping	Very high. Inputs not user oriented	Very low	Very low
Operator Feedback	Requires extra display area	Very good (button, labels, lamps)	Fair (button, labels, lamps)	Very poor unless display is associated	Very good (button, labels, lamps)	Very good (button, labels, lamps)
Speed and Ease of Entry	Slow and difficult	Fast	Slow operator must search panel	Fast for single inputs. Slc.er for mul.i-inputs	Fast	Fast
Training and Skill	Extensive training plus constant practice	Minimum training	Moderate training constant use to retain skill	Minimum training	Minimum training	Minimum training
Addition and Modification	Easily modified via software	Must add new hardware	May require new hardwire	Easily modified via software	Easily modified via software	Easily modified via software
Functional Grouping	Does not exist	Excellent	Very poor	Does not exist	Excellent by page and folio	Excellent by page and folio
Operational Flexibility	Excellent. Poor in backup hardware logic mode	Very good in backup logic mode	Good	Good	Good	Good
A/N Capability	Best	Limited	Limited	None	Limited difficult	Some
Area	Medium	Medium	Extensive	Minimum	Minimum	Slight increase over POK
Discrete Capability	Very poor. Keys do not provide meaningful labels	Very good but redundant	Very good	None	Excellent but redundant between pages	Excellent

fixed functions (those that should be used on every page) should not be assigned to POK buttons. The major drawback of the POK is that its A/N capability is very limited.

c. Fixed Function/Numeric Fixed Function Keyboard (FFK, NFFK). The FFK is a design which contains a limited number of possible inputs, thereby being the fastest input device available. The concept would be to assign fixed functions to this device which would be similar for all instruments or experimental packages. Its drawback (as in the case of the POK) is that its A/N capability is limited.

d. Display/Keyboard, Computer (DSKY). This keyboard has utility when extensive growth is not required. Normally considered to be a noun-verb-numeric (Apollo type) type, it has advantages when the same population will always be the users. Its primary disadvantage is its lack of functional grouping and A/N capability. It also requires more panel space for growth than the other candidates.

The keyboard selected was the ANK because the A/N input capability is considered to be an important feature, the operational flexibility is highest of the candidates, functions and formats can be easily modified through software, and additional hardware is not required for future growth. Initial assessment indicates the speed of the ANK is adequate for the ASF application and that functional grouping is not necessary.

The capabilities of the keyboard and CRT candidates selected can be greatly expanded without adding additional hardware. This concept requires the layout of formats and a command language interface easily handled and understood by the user. This type of keyboard/display/computer interface is presently being used in many operating systems and will meet the ASF requirements according to preliminary assessment.

The one major disadvantage to this concept is its slow input capability even when meaningful abbreviations are used. Detailed task sequences and timelines which relate to the total instrument complement usage according to experiment objectives must be generated. It is only after these details are defined that a final assessment can be made to determine if the typewriter ANK can handle the data communication requirements within the time specified.

Because of the total reliance on the keyboard (and CRT) for mission success, an additional ANK should be stowed onboard as a backup in case of failure.

5.2.5.7 Conclusions and Recommendations

5.2.5.7.1 Conclusions

From the results of this study, the following conclusions have been made.

a. Sufficient space is available at the Orbiter aft crew station port side console to accommodate the ASF D&C requirements.

b. D&C panel area is available for future growth and for other ASF and AMPS configurations.

c. Volume in the lower console bays of the aft crew station will be required for ASF supporting hardware (recorders, CDU(s), etc.).

d. D&C space on the Orbiter C&W, R&D, RMS, MSS, and CCTV panels will be required to support the ASF missions.

e. Creative display format design and keyboard interaction will be required.

f. The operator-computer interaction will require complex software development.

g. Instrument scientific data collection must be accomplished by preprogrammed experiments initiated by the operator but executed by the computer.

h. The PS's primary functions are to operate the payload instruments and monitor the scientific data collection.

i. The ASF mission requires 24 hr/day operation. One operator per shift is adequate to operate the ASF instruments.

..2.5.2.7 Recommendations

Recommendations are as follows.

a. Lower console volume be assigned for dedicated payload use.

b. Dedicated panel space on the RMS, CCTV, and R&D panels be assigned for payload use.

c. ASF data display formats be designed and keyboard interaction defined for submittal to software analysis and computer storage requirements.

d. ASF task sequence/timelines be further detailed to complete the D&C arrangement/layout definition.

e. Complete AMPS requirements be defined to establish total D&C requirements.

f. A follow-on study be performed to define the details of the data monitoring station in the mid-deck area for scientific real time onboard data analysis by experiment PI's.

5.2.6 PARTICLE DETECTOR SUBSATELLITE (PDS)

5.2.6.1 Introduction

In defining the ASF pallet-only concept and feasibility, it was determined that a subsatellite was required to carry out the experiments previously described. The instruments required were similiar to those on the AE satellite and hence, this satellite was the baseline for the subsatellite described herein.

5.2.6.2 Requirements

The experiments AS-4, AS-5, AS-9, AS-10, AS-11, AS-12, and AS-13, described in section 4.1.3 and appendix A, require information that cannot easily be obtained using instruments mounted on the Orbiter vehicle. Other instruments are required on the vehicle and in the near vicinity (10 km) of the Orbiter vehicle. These two factors alone dictated a subsatellite and, since most of the instruments were particle detectors (ions, electrons, etc.), the name "particle detector subsatellite" was selected.

The instruments which were determined to be best suited for the subsatellite require the following engineering support functions onboard the subsatellite.

a. Provide for attitude control, maneuvering, and stabilization of the subsatellite.

b. Provide velocity change capability.

c. Provide attitude determination capability.

d. Provide downlink communication capability for scientific and engineering data.

e. Provide for data processing and formatting.

f. Provide for uplink command capability.

g. Provide for onboard experiment programming and control.

h. Provide power and power control for instruments and support systems.

i. Provide instrument and support system health status and diagnostic data.

5.2.6.3 Guidelines and Assumptions

The following guidelines and assumptions were made for the study.

a. The basic AE satellite instruments and support systems will be used to the maximum extent possible in their existing locations.

b. The AE satellite will be in production during the ASF time frame (beyond 1981).

c. The subsatellite will operate at or near the same orbital altitude as the ASF payload at a distance of about 10 km.

d. The subsatellite will be passive, cooperative (except for attitude control) for the rendezvous and retrieval operations.

e. Control of the subsatellite attitude and velocity will be provided from the Orbiter Mission Specialist Station (MSS).

f. Scientific and engineering data link will be primarily with the Orbiter.

5.2.6.4 Capabilities and Constraints

The capabilities and constraints of the basic AE satellite are shown in table 5.2.6-1.

5.2.6.5 System Description

The subsatellite will be used as the platform on which the particle detection instruments will be mounted. The instruments will provide the necessary particle data in support of the experiments being conducted by the ASF. This subsatellite will be of the AE type with the configuration shown in figure 5.2.6-1.

TABLE 5.2.6-1.— AE CAPABILITIES SUMMARY[1]

Parameter	Value
Spacecraft Weight (less payload)	560 kg
Payload Weight (typical)	100 kg
Projected Area	1.5 m^2
Experiment Footprint Available	0.8 m^2
Experiment Volume Available	0.2 m^3
Energy Available to Experiments (orbit average)	4000 watt minutes
Regulated Voltage	-24.5 v ±2%
Temperature Range (upper baseplate)	10° C to 15° C
Temperature Range (lower baseplate)	10° C to 28° C
Attitude Determination Accuracy	0.5°
Attitude Control Accuracy	1.0°
Spin Rates Available	1 revolution/orbit; 1 to 10 rpm
Minimum Operating Altitude	120 km → 150 km (depends on stabilization mode and apogee altitude)
Orbit Adjust Capability	∿610 m/sec
Maximum ΔV per Burn	7.6 m/sec
Memory Capacity	2 × 32 kilobits
Memory Delay Time (maximum)	72 hours maximum
Command Op-Codes Available to Experiments	260
Recorder Capability	2 × (1/2 × 10^8 bits) 2 × 2 hours record time
Maximum Playback Data Rate	∿130 kilobits/sec
Maximum Communication Rates	16 transmitted 8 received

[1]"A plan for the use of the Basic Atmosphere Explorer Spacecraft System as a Subsatellite of the Shuttle". Goddard Space Flight Center, May, 1973.

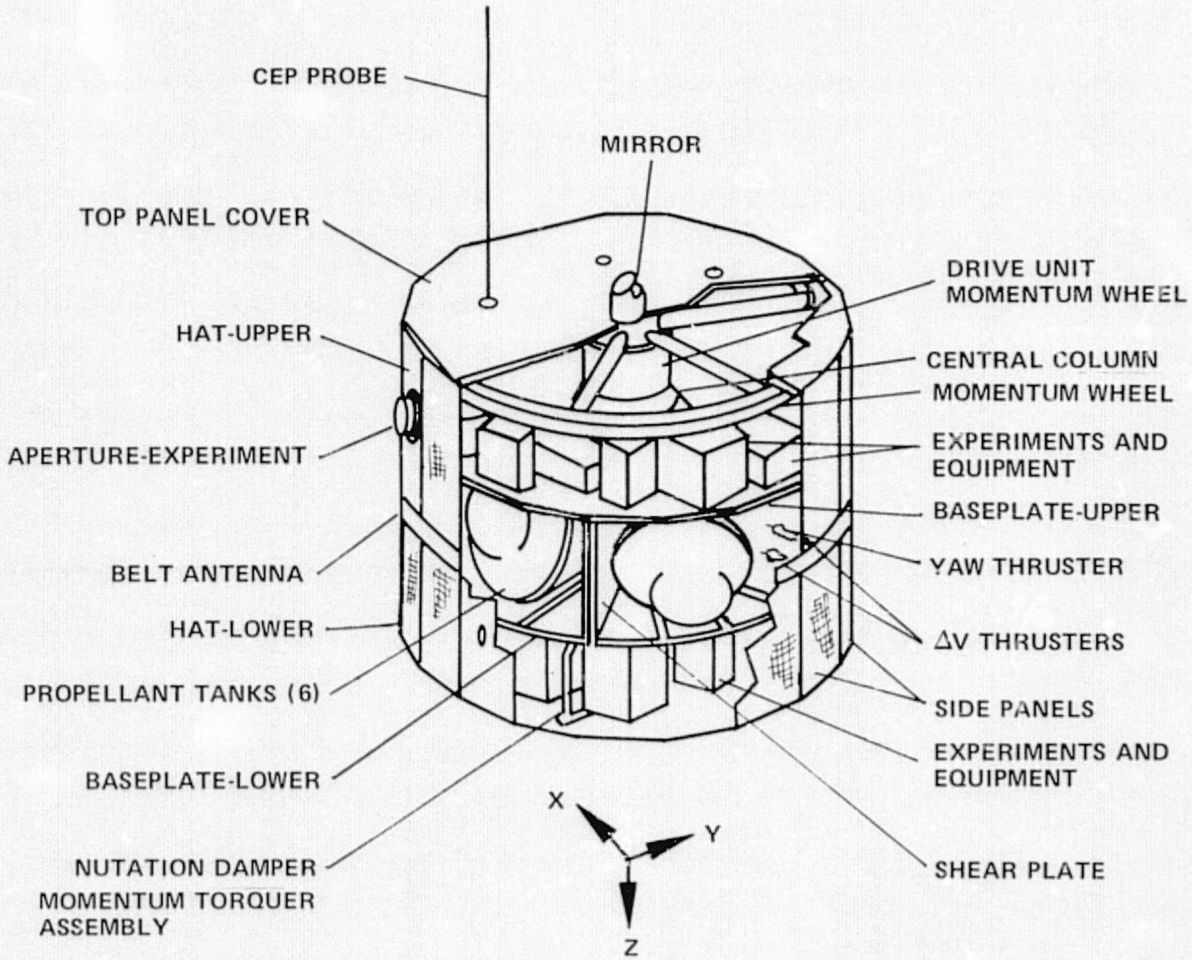


Figure 5.2.6-1. — Subsatellite configuration, component designations.

5.2.6.5.1 General Description

In general configuration, the AE subsatellite is a 16-sided polyhedron, 136 cm (53.5 inches) in outside diameter and 114 cm (45 inches) high, weighing 678 kg (1494 lbs). The subsatellite contains a 3-axis attitude control system utilizing a momentum wheel to provide roll-yaw stiffening and pitch orientation, and magnetic torque coils to maintain momentum axis orientation in inertial space. A combination of fluid-filled loops and a cage-tuned pendulum is used for nutation damping. A thruster and monopropellant hydrazine fuel supply is used to provide orbital adjust capability. An active thermal control system maintains subsatellite temperatures within operating limits. Command and communication systems are compatible with the Orbiter communication system. Power is obtained from a skin-mounted solar cell array and a battery pack. The subsatellite is designed to be launched by a system of pressurized gas thrusters to impart the small velocity increment necessary to achieve the desired separation between the subsatellite and the Orbiter. Recovery of the subsatellite will be accomplished using the remote manipulator system.

5.2.6.5.2 Internal Configuration

The internal configuration consists of two baseplates separated by a central column and connected by six shear ties. Spacecraft components and experiments are mounted to one side of each baseplate. Six cono-spherical shaped propellant tanks, carrying a total of 169 kg (373 lbs) of hydrazine propellant, are grouped symmetrically about the central column, sandwiched between the two baseplates. The momentum wheel assembly for spacecraft stabilization is mounted on one end of the central column within the spacecraft, with its attitude sensing mirror assembly projecting through a hole in the center of the upper surface.

5.2.6.5.3 Subsatellite Coordinate System

The subsatellite coordinate system is a right hand system as shown in figure 5.2.6-2. The origin is taken at the geometric center of the subsatellite, on the axial centerline midway between the end surfaces. The coordinate system is body fixed; the orbital directions shown are for reference only.

The coordinates are defined as follows.

a. Subsatellite top: -Z axis

b. Subsatellite bottom: +Z axis

c. Pitch: -Z axis

d. Roll: +X axis

e. Yaw: +Y axis

5.2.6.5.4 Instruments

The ASF experiment support instruments on the subsatellite are as follows:

a. Cylindrical Electrostatic Probe (CEP)

b. Low Energy Electron Probe (LEE)

c. Airglow Photometer (VAE)

d. Photoelectron Spectrometer (PES)

e. Triaxial Fluxgate Magnetometer (MAG)

f. Planar Ion Trap (RPA)

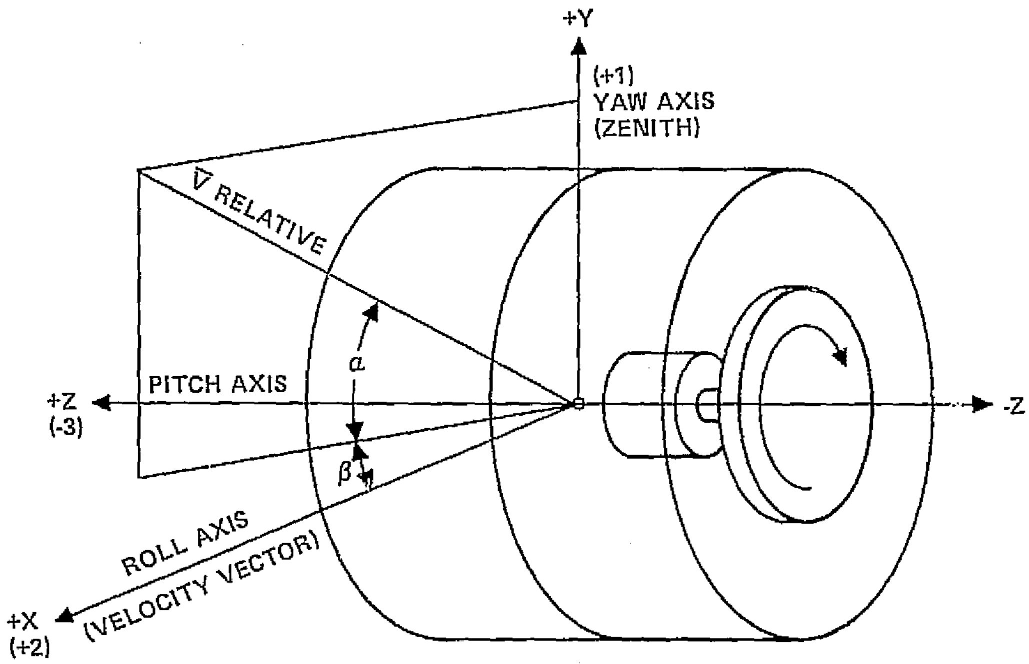
g. Neutral Atmospheric Composition (NACE)

h. Neutral Atmospheric Temperature (NATE)

i. Cold Cathode Ion Gauge (CCIG)

j. Low Energy Ion Detector (LEID)

k. High Energy Particle Detector (HEPD).



ITEM	AXIS SYSTEM	NUMERICAL AXIS
ROLL	X	2
YAW	Y	1
PITCH	Z	-3
WHEEL ROTATION	RIGHT HAND (CCW) ABOUT +Z	RIGHT HAND ABOUT -3
VELOCITY VECTOR	ALONG +X	ALONG +2
ZENITH	ALONG +Y	ALONG +1
ORBIT POSITIVE NORMAL	ALONG -Z	ALONG +3

α – ANGLE OF ATTACK

β – ANGLE OF SIDESLIP

Figure 5.2.6-2. — Spacecraft coordinate system.

The first nine instruments are existing AE devices. The last two (LEID and HEPD) are additional instruments required to meet ASF requirements.

The instruments providing the particle data and ancillary information are mounted along the outer edge of the baseplates as shown in figure 5.2.6-3. The particle detector instruments are oriented so that the primary axis of measurement is at a 67.5^0 angle to the spin axis of the subsatellite. Each of the electron and ion detectors is repeated. Each pair of instruments is placed so that the primary axes are in opposition. Thus, as the subsatellite spins, measurement of the particle flux is made in both directions along two lines near the orbit trajectory. Due to the spin, these lines sweep out conjugate cones and each instrument repeatedly scans above and below and to each side of the local magnetic field lines.

5.2.6.5.5 Support Subsystem

Except for the addition of three nickel-cadmium rechargeable batteries, and the deletion of the tape recorders, the support systems provided by the basic AE satellite remain basically unchanged for the ASF application.

5.2.6.6 Analysis

The AE[2,3] was used as the starting point for the ASF subsatellite. Comparing the basic AE scientific and engineering capabilities with the ASF support requirements led to changes. These changes include the following.

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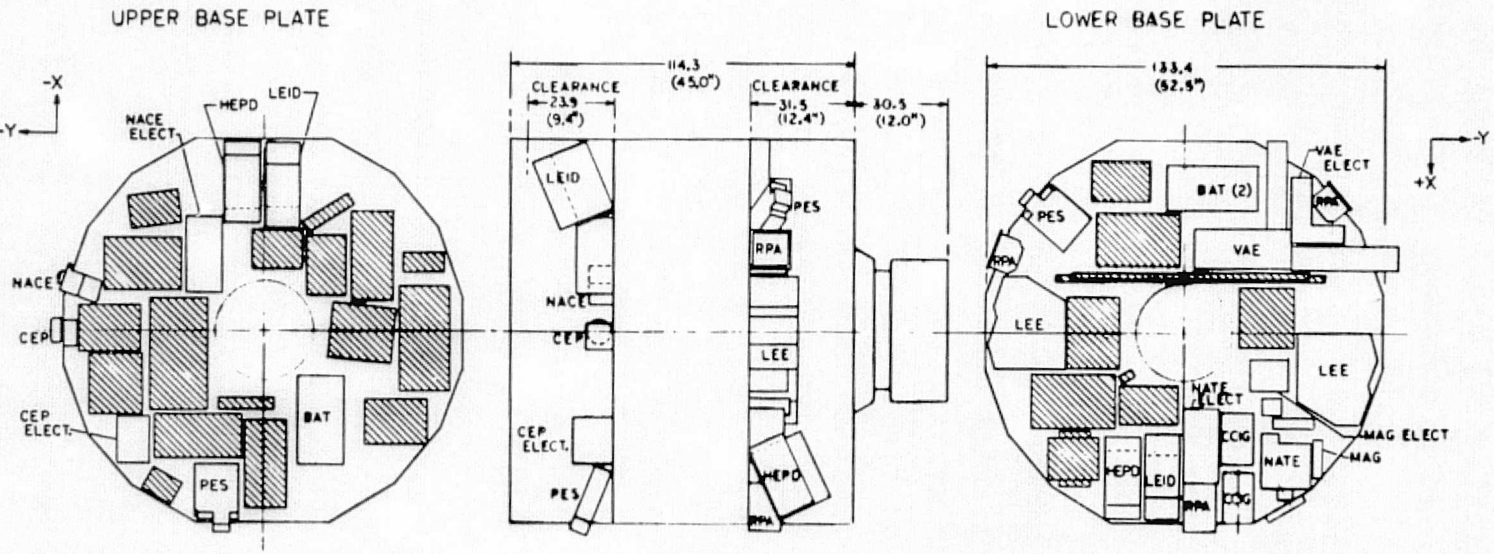
[2]"Atmosphere Explorer (AE Spacecraft System Description)"; RCA Government and Commerical Systems, Astro Electronics Division; AED R-3816F; March 30, 1972; Attachment B (updated August 8, 1974).

[3]GSFC Specification for Atmosphere Explorer (AE-C, D and E)"; Goddard Space Flight Center, S-620-P-1; September, 1973.



CEP-CYLINDRICAL ELECTROSTATIC PROBE
LEID-LOW ENERGY ION DETECTOR
HEPD-HIGH ENERGY PARTICLE DETECTOR
LEE-LOW ENERGY ELECTRON DETECTOR
VAE-AIRGLOW PHOTOMETER
PES-PHOTOELECTRON SPECTROMETER
MAG-MAGNETOMETER
RPA-PLANAR ION TRAP
NACE-NEUTRAL MASS SPECTROMETER
NATE-NEUTRAL ATMOSPHERIC TEMPERATURE
CCIG-COLD CATHODE ION GAUGE
BAT-BATTERY, ADDED

NOTE:
SHADED AREAS DENOTE EXISTING A E SATELLITE SUPPORT SYSTEMS.

Figure 5.2.6-3 — Subsatellite Instrument Layout.

a. Scientific. Of the 17 scientific instruments used on the combined AE-C, D and E satellites, eight will not be required for ASF experiments and will be removed. Two new instruments, the Low Energy Ion Detector (LEID) and the High Energy Particle Detector (HEPD) will be added to respectively provide H^+, He^+ and O^+ ion detection in the 0 to 10 keV range and to cover the energy range of from 25 keV to 10 MeV for electrons and protons.

b. Engineering. The total power required by the instruments and support systems for the ASF subsatellite remains at about the same level as that required by the AE satellite. However, three additional batteries will be added to increase the experiment duty cycle capability about 50 percent. The tape recorders are not required since the subsatellite will communicate continuously with the Orbiter, and data time compression is not required. The accuracy (about 1 km) achievable with ground tracking using pseudorandom noise techniques is not adequate for primary mission state vector determination due to Orbiter crew and vehicle safety considerations. Therefore, the range and range rate determinations will be made using the Orbiter rendezvous radar system. However, since the tracking system is a small part of the total communication transponder, these circuits will be left in the system. Provisions must be made to disable these circuits when Orbiter/subsatellite communication is required. For verification purposes, the ground tracking facility will then be able to use the subsatellite tracking system to determine approximate subsatellite position and velocity.

5.2.6.7 Conclusions and Recommendations

5.2.6.7.1 Conclusions

The conclusion resulting from the study is that the AE satellite is an acceptable candidate for use as the ASF remote subsatellite. Some moderate changes in the instrument complement and minor changes in the support systems will be required.

5.2.6.7.2 Recommendations

The following recommendations apply to the PDS definition:

a. Establish a subsatellite experiment and instrument timeline which is correlated with the overall ASF mission timelines.

b. Using the subsatellite timeline, determine power and data duty cycle requirements to be used in further defining support system needs.

c. Develop a detailed operational sequence including that for the rendezvous and retrieval phase. Establish the safest and most effective way of capturing and retrieving the subsatellite.

5.3 GROUND SYSTEM

The ASF ground systems are comprised of two major facilities: (1) one which processes the flight data and disseminates the results to the scientific community, and (2) the ground support, test, and checkout facilities which include both mechanical and electrical GSE.

5.3.1 GROUND PROCESSING OF FLIGHT DATA

5.3.1.1 Introduction

During an ASF mission, electronic data will be delivered to the ground data reduction complex in one or more of four forms, all of which are technically feasible within the concepts explored during this JSC study.

a. Unprocessed data transmitted from Orbiter to ground.

b. Unprocessed data on magnetic tape delivered to ground at completion of mission.

c. Processed data transmitted from Orbiter to ground.

d. Processed data on magnetic tape delivered to ground at completion of mission.

5.3.1.2 Considerations

The processed data as defined in (c) and (d) above represent the most desirable forms, and as such, are the types of data the CDMS is designed to produce. Because these data will have been processed onboard the Orbiter prior to transmittal or storage on tape, the ground-based operation is greatly simplified. As the transmitted data is received, it will be stored on ground-based tape recorders. These tapes will then be reformatted to computer-compatible tapes, screened, and forwarded to the scientists. Similarly, processed data delivered on magnetic tape at the end of the mission will be handled in like manner. There are numerous trade-offs to be considered regarding which of (c) and (d) represents the greatest advantage and is yet cost effective. A combination of these two data forms is recommended.

Data forms (a) and (b) represent the concept utilized in previous manned spacecraft experiments. Form (b) represents the worst case and is considered undesirable, although it is technically feasible. Analyses have indicated that all unprocessed digital PCM data generated during a 7-day ASF mission can be stored on seven reels of magnetic tape. This figure does not include wide-band analog video from instruments utilizing TV cameras. The degree of difficulty in transforming these seven reels of tape data into usable products for the scientific community is much greater than that applied to data forms (c) and (d).

It is anticipated that even though data will be processed on-board the vehicle, certain unprocessed data will be transmitted in real time to allow some recovery ability in the case of processing errors or malfunctions. Unprocessed data will also be required on the ground in near real time to allow diagnostic analyses of certain instrument operations. This data, however, would not be intended for dissemination to the data user.

5.3.2 GROUND SUPPORT, TEST AND CHECKOUT SUBSYSTEM

5.3.2.1 General

The objective for this phase of the study is to define the conceptual design and requirements for an overall ground-based hardware support system considered both feasible and practical for the AMPS/ASF pallet-only payload concept. The system must accomodate all levels of preflight and postflight payload hardware testing plus considerations of major transportation, storage, installation, and logistical requirements.

5.3.2.2 Requirements

The AMPS/ASF ground support, test, and checkout subsystem must satisfy the following functional, hardware/software, and data requirements.

a. Provide verification that scientific and engineering parametric requirements are met.

b. Provide diagnostic and evaluation capabilities beyond the performance verifications of a. above.

c. Incorporate optimized test flexibility, mechanical and structural support, and mobility concepts wherever possible within existing constraints (safety, reliability, quality assurance, programmatic, etc.).

d. Encompass test and/or checkout at all assembly levels of AMPS/ASF flight equipment. This includes both preflight and appropriate postflight calibrations and tests.

e. The ground support functions must encompass applicable transportation, storage, and logistical requirements.

5.3.2.3 Guidelines and Assumptions

The guidelines and assumptions in paragraph 2.3.4 were used where applicable to this portion of the study. The major items pertained to standardization of equipment and utilization of Spacelab facilities wherever practical.

5.3.2.4 Subsystem Description

The ground support, test and checkout subsystem is segregated into three general categories: (1) electrical GSE (EGSE), (2) mechanical GSE (MGSE), and (3) logistics.

5.3.2.4.1 Electrical Ground Support Equipment (EGSE)

5.3.2.4.1.1 General

The EGSE provides functional test and checkout of all physical parameters of the ASF instruments/experiments pertaining to electric, electronic, magnetic, electrostatic, and optical functions. It is made up of various types of test instruments, many varied readout and display devices, and numerous recording devices.

The EGSE design is based on the use of computer-controlled automatic test equipment augmented by simulators. Figures 5.3.2-1, 5.3.2-2, and 5.3.2-3 depict the equipment comprising the EGSE. It is designed to support the ASF pallet-only mode during the integration, prelaunch, launch, postflight, maintenance, and refurbishment phases. The primary purpose is to assure that the ASF instruments and subsystems are operating within their design limits.

The EGSE simulators support instrument integration at user sites and at the payload integration site. At the payload integration site the two-computer configuration shown in figure 5.3.2-2 allows for checkout of the ASF instrument pallets supported by payload subsystem simulators and Orbiter signal simulators.

The EGSE is used for payload final checkout at the launch site by interfacing with the ASF CDMS via hard lines and telemetry (see figure 5.3.2-3).

Overall test control is implemented via the EGSE GPC and checkout software and CDMS data acquisition capabilities. EGSE

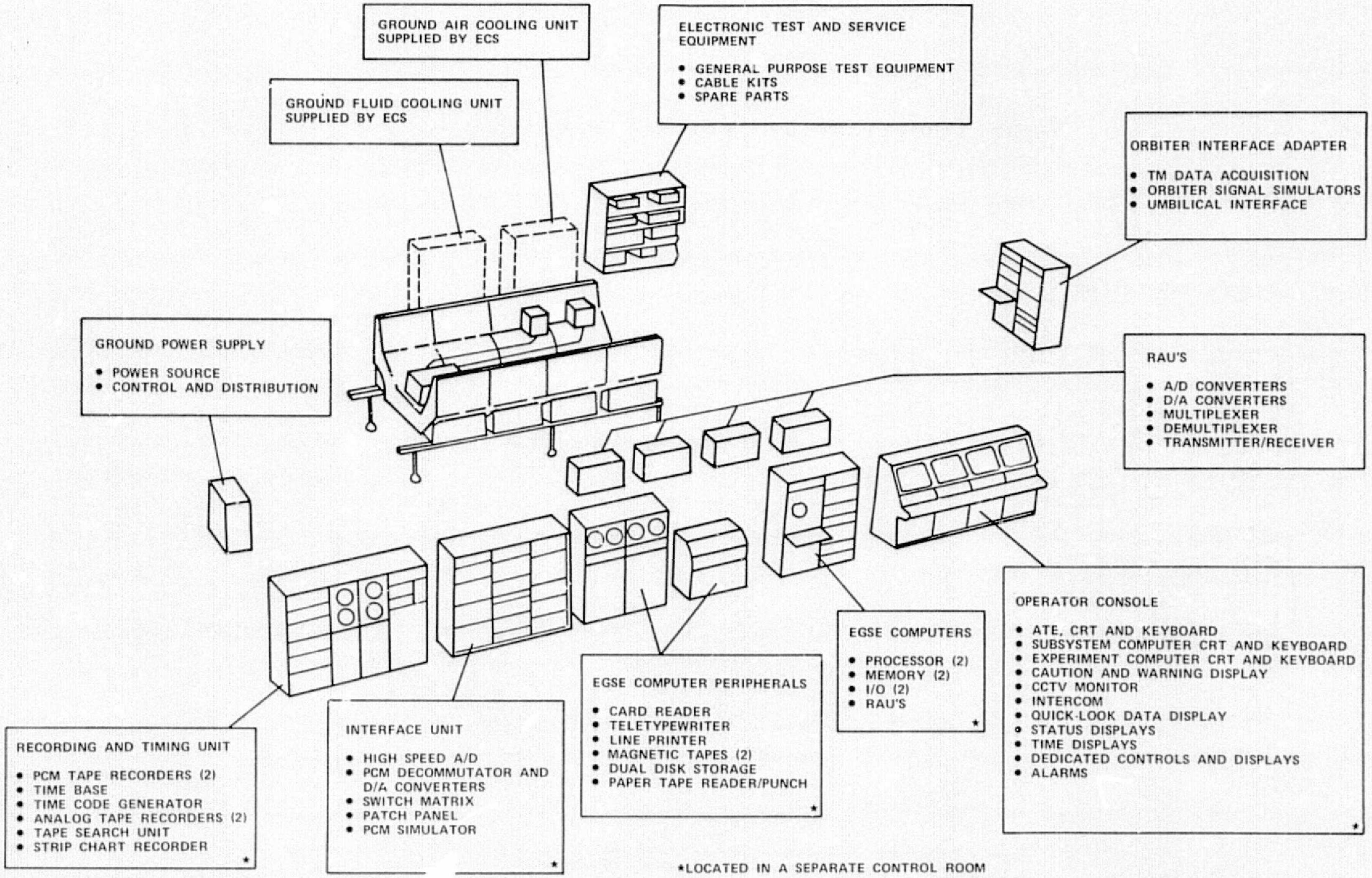


Figure 5.3.2-1. — AMPS EGSE assemblies.

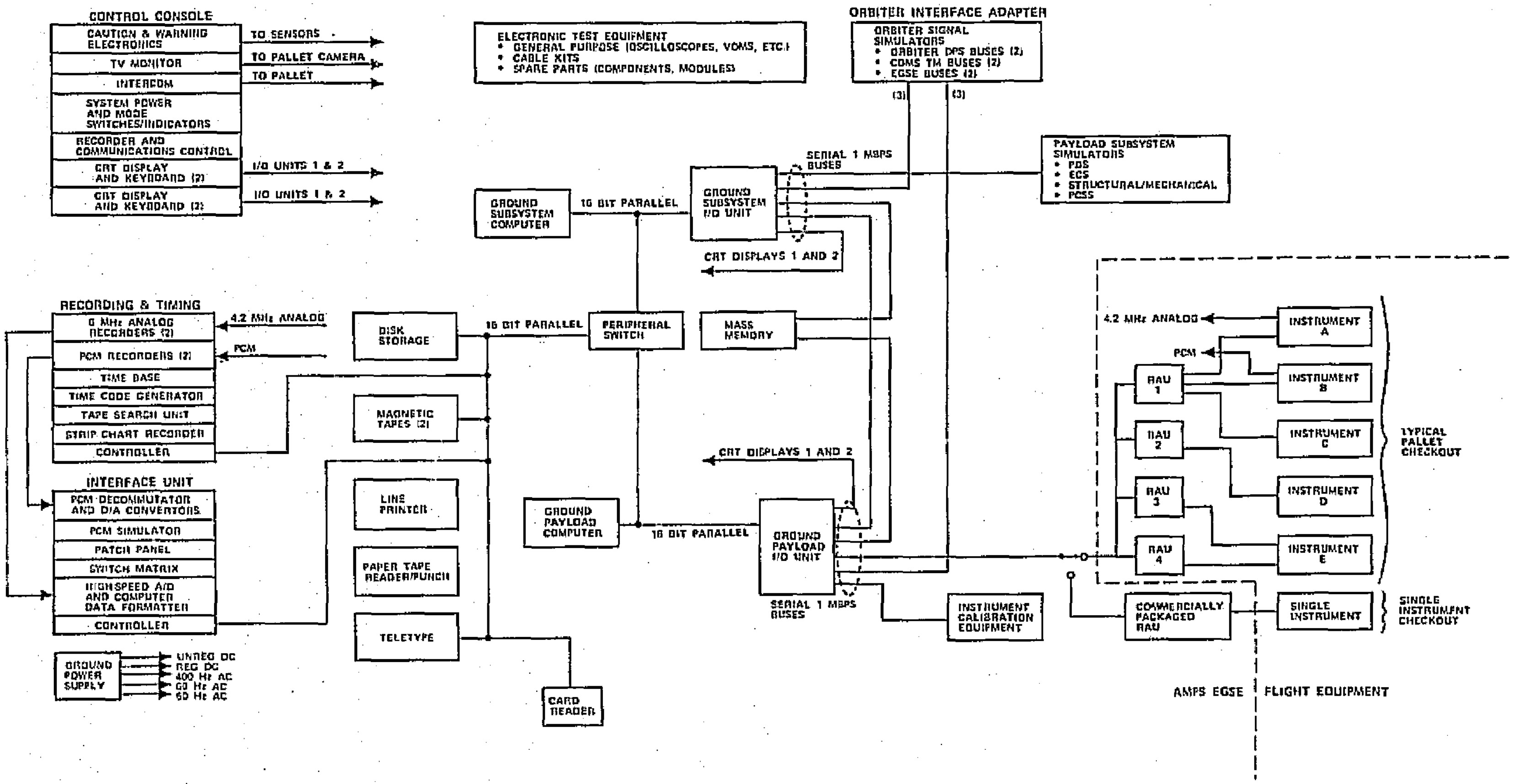


Figure 5.3.2-3. — AMPS EGSE (launch site).

control, measurement, stimuli, recording and processing capabilities allow detailed testing, fault isolation and tasks such as data reduction and test result display and printout. The control console controls the EGSE GPC and accesses the onboard payload and subsystem computers via CRT keyboard terminals connected to CDMS I/O units. Manual controls are also provided.

The EGSE Ground Subsystem Computer at the launch site will be used as a backup computer to the GPC. It will also perform off-line duties such as processing of TM tape dumps.

Additional EGSE equipment simulate ASF CDMS interfaces to facilitate payload preparation prior to integration into the Orbiter. Integration of instruments into the pallets is supported by the Spacelab Simulator for Experiments (optional, interface verification testing only) and the Core Segment Simulator (CSS). These items are discussed in later paragraphs.

5.3.2.4.1.2 <u>Utilization of EGSE</u>

Utilization of the ASF EGSE for four stages of instrument checkout is depicted in figure 5.3.2-4.

a. Early Interface Verification. Verification of instrument interfaces will be supported at any site by the portable ASF simulator for instruments (option), which allows for early interface verification.

b. Instrument Integration or Pallets. Integration and test of complex instruments will be supported by the CSS at any site. The CSS is a modular portion of the ASF EGSE and it simulates the flight CDMS and EPDS services provided for the payload. The CSS includes a payload computer and its associated peripherals.

c. Payload Integration for All Pallets. Integration and test of all pallets is supported at the payload integration site by the full complement of ASF EGSE, excluding the TM data

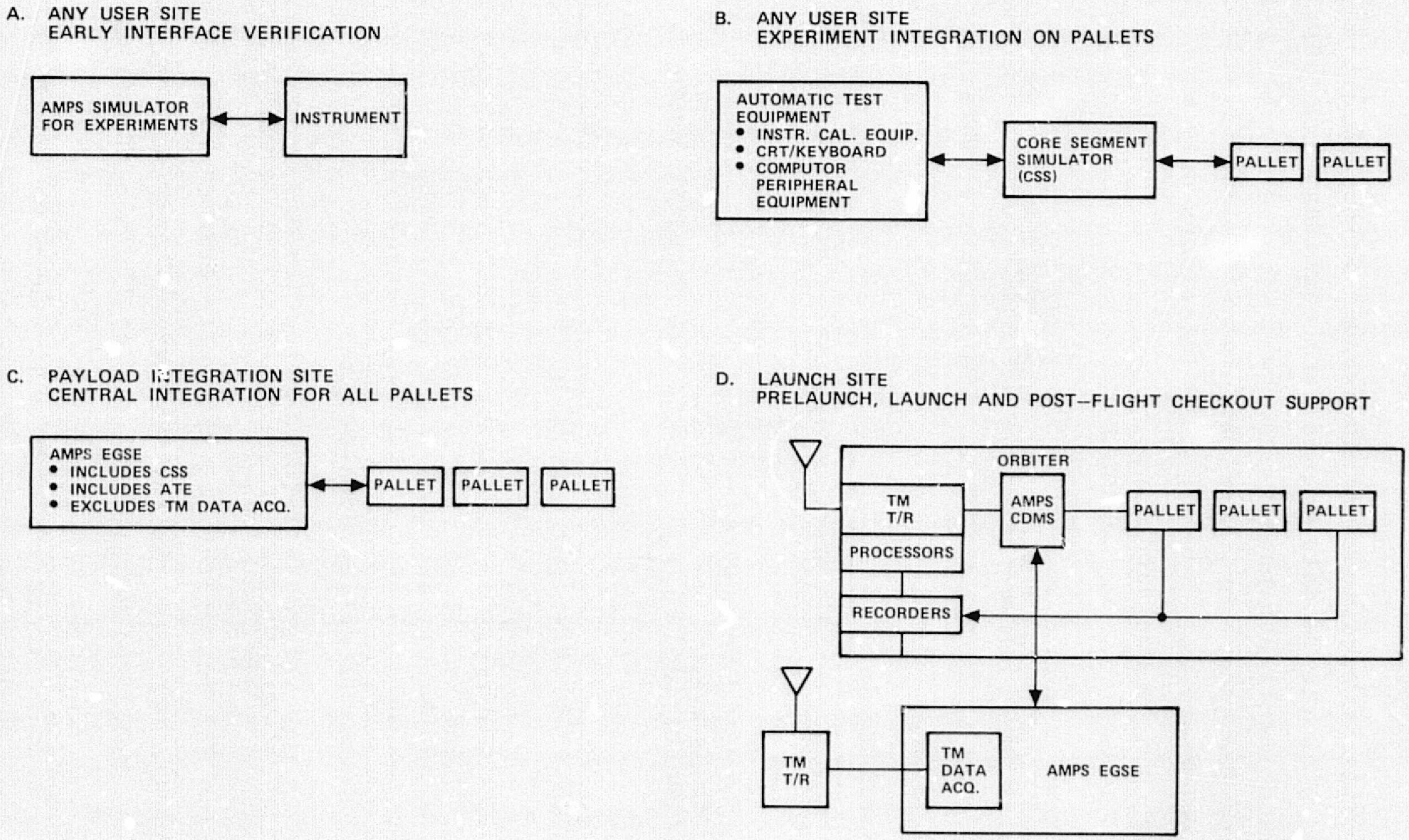


Figure 5.3.2-4. — EGSE utilization.

acquisition equipment. Flight-packaged instruments and RAU's are tested with actual flight software at this site.

d. Launch Site Integration. At the launch site, the ASF EGSE is used with the TM data acquisition equipment. During the prelaunch and launch phases, the EGSE is used for ASF payload and subsystem verifications, interface verifications, and final checkout. The ASF EGSE interfaces only with the ASF CDMS via TM and hard lines.

5.3.2.4.1.3 Interfaces and Functions

a. Simulator for Instruments. The ASF Simulator for instruments is depicted in figure 5.3.2-5. The interface characteristics are as follows:

(1) Facility Interfaces:

Weight:	(TBD)
Dimensions:	(TBD)
Power:	115 V, 60 Hz, (TBD) kW
Type of Connectors:	(TBD)
Environment:	22 ±5°C
(Operating):	40 to 80% relative humidity

(2) Instrument Interfaces:

(a) EPDS Interface Simulation:

Unregulated dc	- 26 to 32 Vdc	- (TBD) kW
Regulated dc	- 28 Vdc ±2%	- (TBD) kW
400 Hz ±1% ac	- 115 Vac ±5%	- (TBD) kW
60 Hz ±1% ac	- 115 Vac ±5%	- (TBD) kW
50 Hz ±1% ac	- 220 Vac ±5%	- (TBD) kW

(b) RAU Interface Simulation:

RAU interface technical requirements are identical to flight RAU.

b. CSS. The CSS interfaces are not fully determined. Essentially, the CSS will provide limited EPDS and CDMS simulation. Figure 5.3.2-4 (B) depicts the use of the CSS at any user site. Figure 5.3.2-6 shows the functional units of the CSS. The CSS would comprise several racks of equipment whose functional

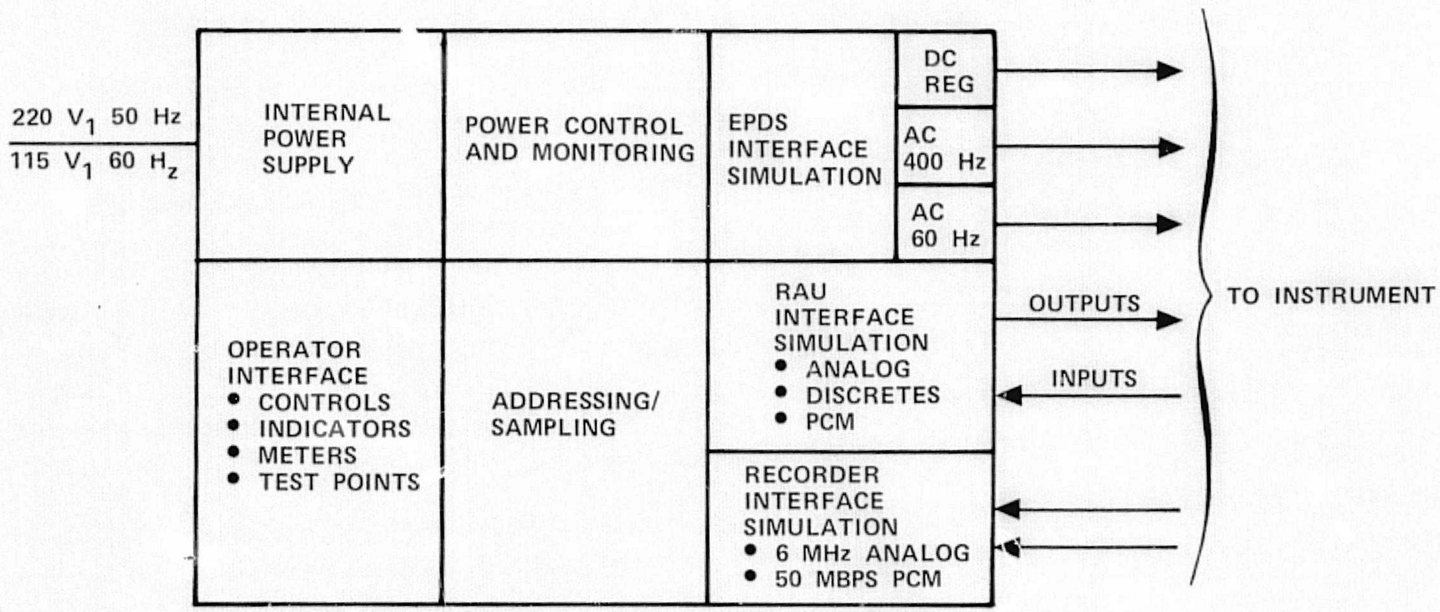


Figure 5.3.2-5. — AMPS simulator for experiments.

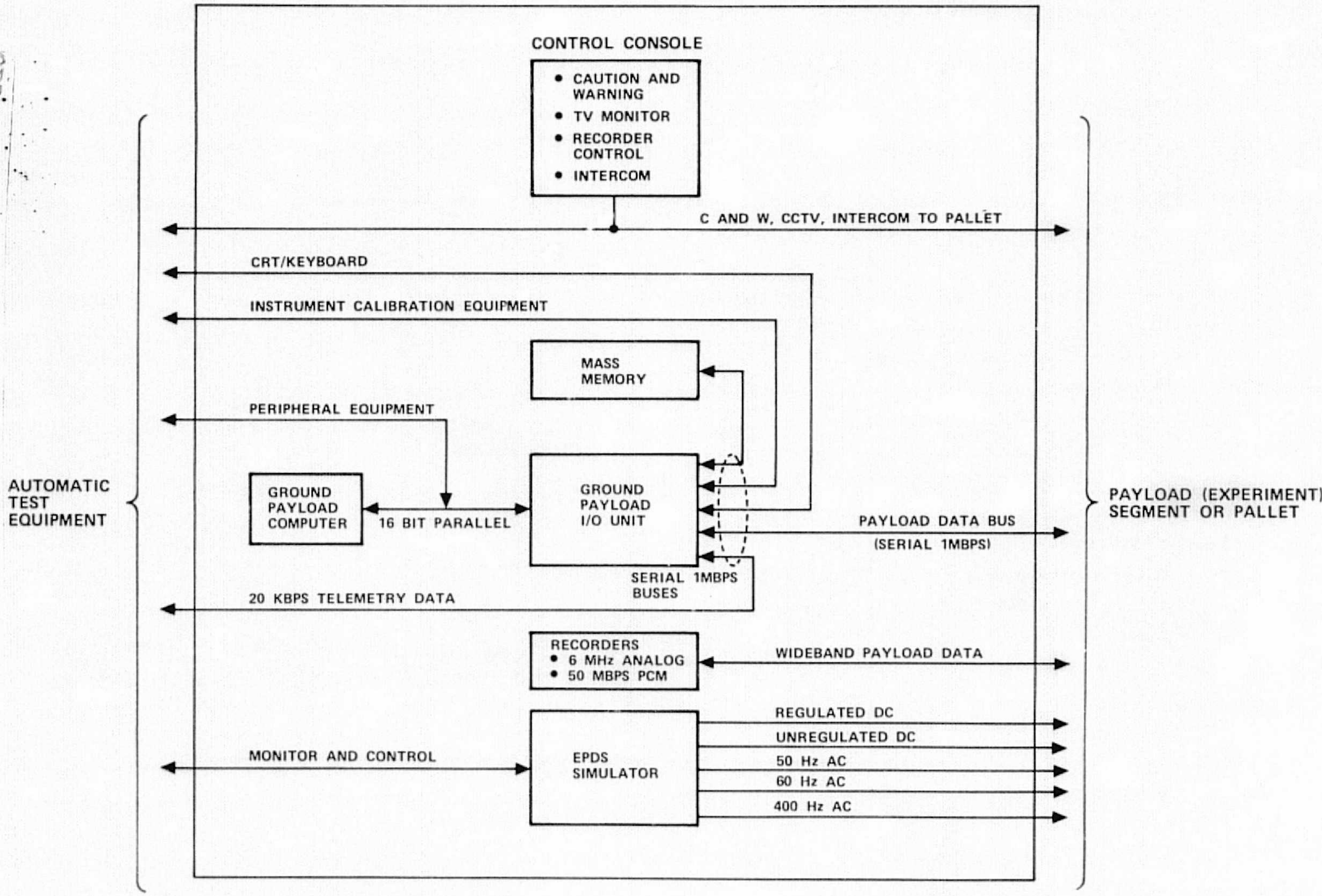


Figure 5.3.2-6. — Core Segment Simulator (CSS).

units are identical to those named in the full complement EGSE, and are described in the next section.

(1) Control Console. Provides operator control of automated checkout, contains C&W, TV monitor, recorder control, and intercom.

(2) Ground Payload Computer.

(3) Ground Payload I/O Unit.

(4) Mass Memory.

(5) Recorders.

(6) EPDS Simulator.

c. Payload Integration Site EGSE. A full complement of EGSE is required to integrate and test all of the ASF experiments (see figure 5.3.2-2). All equipment shown to the left of the vertical dotted line is commercially packaged.

Two modes of checkout will be used. The first is the single instrument checkout. A single flight-packaged instrument will be tested before it is mounted on a pallet by using a commercially packaged RAU, and the rest of the EGSE. The second mode is checkout of one or more pallets with flight packaged RAU's and instruments. Commands to the pallet RAU's are sent in PCM format at a 1 Mbps maximum rate. The RAU's send output discretes and PCM signals to control the attached instruments. Housekeeping and scientific data are sent from the instrument to the RAU's in PCM, discretes, or analog form. The RAU converts the data into PCM for return to the Ground Payload I/O Unit. The Ground Payload I/O Unit formats the data, buffers it, and sends it to the GPC for processing. Additional wideband scientific data from some instruments are recorded on analog and PCM tape recorders.

The operator uses the items in the control console to automatically perform extensive instrument checkouts using both computers, I/O units, mass memory, computer peripherals, recording and timing equipment and the interface unit. Use of computer-controlled instrument calibration equipment can help shorten instrument checkout time.

Recommended EGSE equipment:

(1) Ground Payload Computer.

(2) Ground Payload I/O Unit.

(3) Ground Subsystem Computer.

(4) Ground Subsystem I/O Unit.

(5) Mass memory.

(6) Peripheral switch.

(7) Disk storage.

(8) Magnetic tapes.

(9) Line printer.

(10) Paper tape reader/punch.

(11) Teletype.

(12) Card reader.

(13) Instrument calibration equipment.

(14) Control console.

(15) Recording and timing equipment.

(16) Interface equipment.

(17) Orbiter interface adapter.

(18) PSS.

(19) Electronic test equipment.

d. Launch Site EGSE. The ASF EGSE required for the launch site is shown in figure 5.3.2-3. The GPC and checkout software communicates with the Orbiter AMPS CDMS via payload and I/O

GSE buses through the umbilical interface and via TM. In this configuration, the GPC requests the ASF CDMS computers to perform checkout of the instrument pallets and send the checkout results down to the EGSE for real time and post test analysis.

The Ground Subsystem Computer and Ground Subsystem I/O Unit may serve as backups. The computer will be used for processing TM tape dumps.

The same equipment shown in figure 5.3.2-3 has been previously specified in the paragraphs on the Payload Site EGSE, with the following exceptions:

(1) Orbiter Interface Adapter (Launch Site).

(2) Computer Test Equipment.

5.3.2.4.1.4 Software

a. Ground Checkout Software. The ASF ground checkout software is used with the EGSE computers at user sites, the Payload Integration Site, and at the Launch Site. The software will be additional application software added to the onboard CDMS subsystem and payload software such that certain additional standard routines may be utilized.

The software will provide for the ability to operate in both an automatic checkout sequence as well as manual mode. The onboard computer routines for formatting data, display, sequencing and initialization will be used to the maximum extent possible.

b. Support Software. The support software will provide the capability to develop, verify and maintain the ground checkout software. This software will be developed to operate on IBM 360/370 and/or CDC 6500 computers to assure its useability at various installations. The development process requires that all software must be coded in the GPC assembler or compiler language. The software is then assembled on an IBM 360/370 or CDC 6500 computer and verified with a simulator resident in the same computer. The simulator-verified software is then used with both computers in the EGSE to integrate and checkout the ASF instruments.

Provision will be made for an interpretive simulation for the onboard CDMS computers and functional simulations of external devices to provide a source of data for the software test functions. Main items in the support software package are:

(1) Program generation and maintenance.

(2) Simulation and program validation software.

(3) Utility software.

5.3.2.4.1.5 Packaging and Modularity

The ASF EGSE is designed to use commercially packaged equipment in a modular arrangement to reduce equipment and maintenance costs.

5.3.2.4.1.6 Quantitative Requirements

Equipment	Quantity Required
ASF Simulator for Experiments	(TBD)
Core Segment Simulator	(TBD)
Payload Integration Site EGSE	1 Set
Launch Site EGSE	1 Set
Payload Crew Training Simulator	1 Set

5.3.2.4.1.7 Payload Mission Simulator (PMS)

The PMS is comprised of two major subassemblies as follows:

a. A full scale, instrumented operating aft crew station co.sole simulator capable of utilizing flight (mission) software.

b. A programmable electronic payload simulatcr and operator's console.

The PMS will be designed to the applicable EGSE requirements. Software will be provided to program the PMS for ASF requirements. The PMS will be designed to be integrated into the Shuttle mission simulator.

5.3.2.4.2 Mechanical Ground Support Equipment (MGSE)

5.3.2.4.2.1 General

The ASF MGSE consists of operational equipment for the handling, transportation, servicing, measuring, aligning, and protection of ASF payload hardware instruments and experiment assemblies. The ASF payload is modular in its major subassemblies and therefore requires a highly flexible MGSE capability to acommodate all of the alternative configurations. The flexibility is provided by MGSE which includes the following.

a. Support for each instrument to enable bench handling and local transportation (see figure 5.3.2-7).

b. Support, with local mobility, for major subassemblies, experiments, and pallets. These support assemblies will be capable of interlocking for test and checkout purposes (see figure 5.3.2-8).

c. Instrument protective/shipping containers.

d. Servicing equipment to fill, leak check, and drain coolant loops of the thermal control system, provide adapters for nitrogen purge, and to provide experiment gas for instruments 304, 532 and 549.

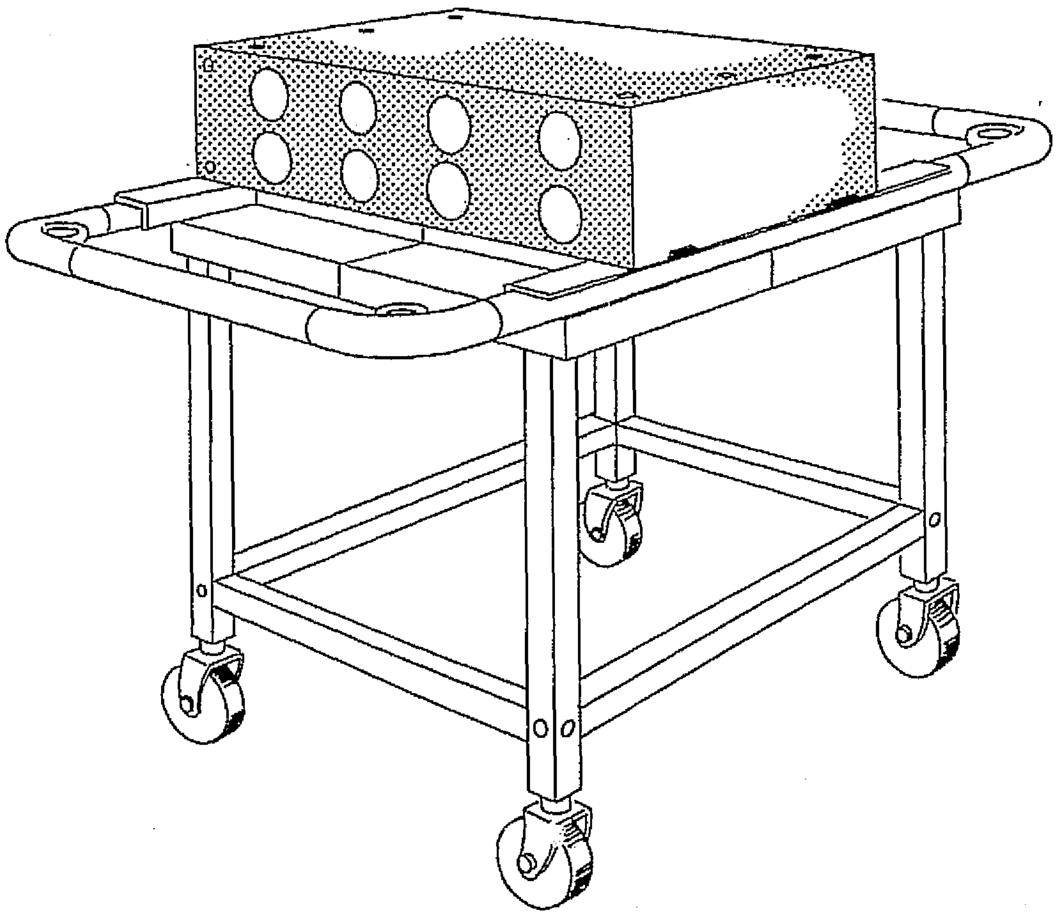


Figure 5.3.2-7. — Instrument handling concept.

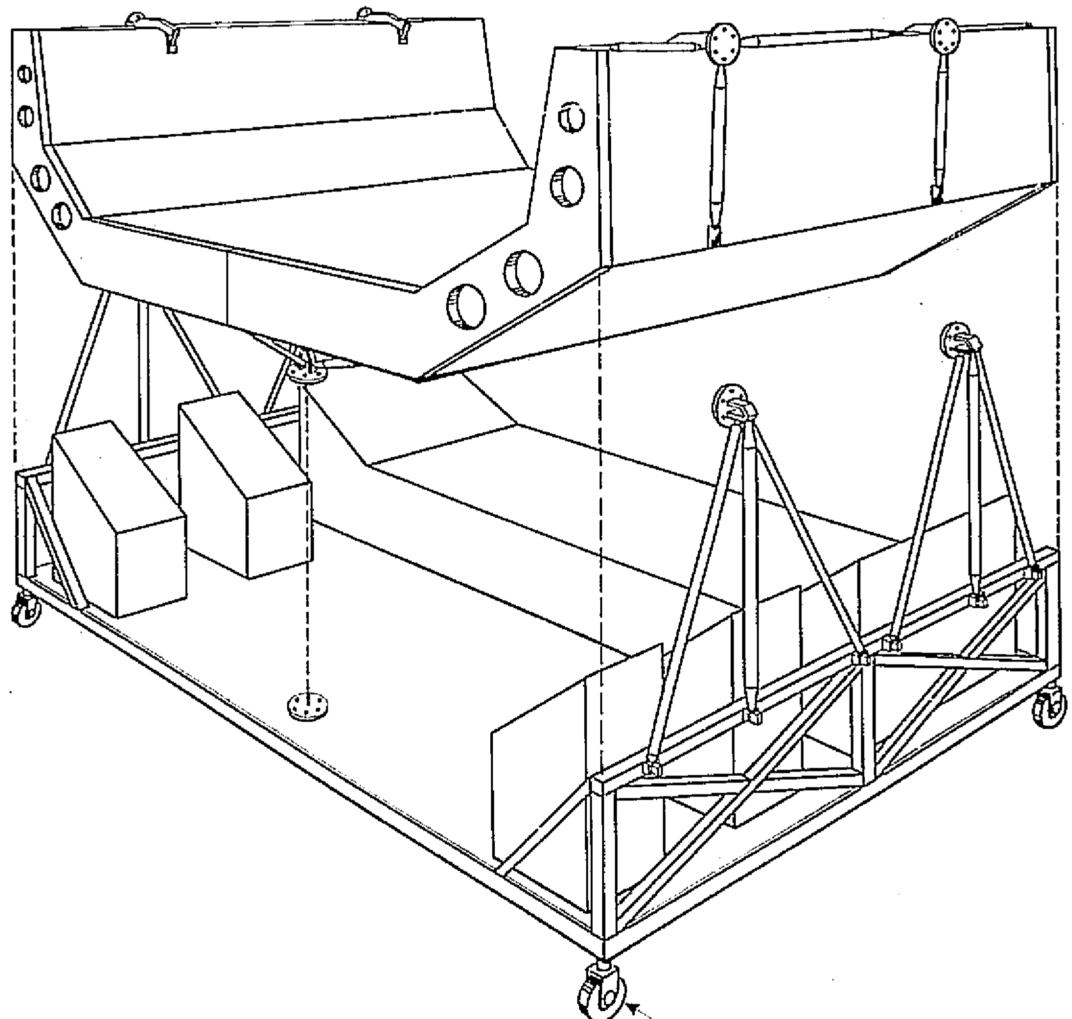


Figure 5.3.2-8. — Concept of AMPS pallet handling frame.

e. A matched rail assembly system with local mobility features which is capable of orienting experiments/pallets in any desired longitudinal pattern for checkout and/cr vehicle integration (reference ESTEC SLP/2104 - design coordination with ESRO in this regard is highly desirable).

5.3.2.4.2.2 Instrument/Instrument Cluster Support and Handling Equipment

Each instrument requires handling and servicing for test and checkout; therefore, a simple handling/interface assembly which permits positioning, alignment, functional test, and servicing of the instrument is required. The design of these handling fixtures provides that after the instrument is fabricated (or reworked), it will have minimal contact with human hands to minimize contamination during instrument/experiment test, checkout, and instrument cluster integration.

5.3.2.4.2.3 Instrument/Pallet Handling Equipment

The MGSE for pallet level test and checkout is made up of matched-rail handling and servicing equipment. This enables connecting the pallets or integrated instrument assemblies to each other in any order or sequence required, and connecting to the EGSE checkout complex for integration tests (see figure 5.3.2-8). The matched-rail pallet handling dolly has steerable, removable wheels and is provided with hoisting/sling loops and slots for fork-lift handling from either side. Manual handling of a pallet/cart must be limited to movement over the floor with the handling dolly wheels installed.

Pallet interface points are connected to and supported by MGSE support and lifting assemblies capable of supporting and orienting the pallet in both horizontal and vertical positions.

Orientation of a cluster in horizontal and vertical positions is accomplished with slings, hoists, and hydraulic positioners (see figures 5.3.2-9 and 5.3.2-10). The ASF payload is stabilized and supported during integration, Orbiter loading, and unloading operations. This is done with the hoist/sling assembly. Each segment (pallet) of the payload is spanned by interconnected structure which is assembled or connected for support of any ASF pallet or payload configuration (figure 5.3.2-11). Note that during Orbiter/pallet integration, the instrument cluster yoke will be retracted and the clusters will be in the launch positions.

The MGSE design provides for complete integration of the instrument/instrument clusters with the pallet(s) plus ASF payload integration prior to installation and integration with the Orbiter.

The instrument handling fixtures are designed of tubular support struts with angular interface frames to optimize the rigidity and strength of the assembly. This essentially single plane design provides, with the instrument attached, complete manual, sling/hoist and laboratory cart handling capability for an instrument. Further, the design provides, sling/hoist attach points (rings), round end pieces (handles) which have soft molded plastic or rubber covers for manual usage, instrument interface attach points compatible with instrument mechanical interface design, plus interface points on the bottom of the frame to mate with certain standard laboratory wheeled carts. See figure 5.3.2-7. This design is adaptive to adjustable configurations through the use of extension members. The adjustable design embodies handling capability through instrument cluster integration with the pallet instrument cluster support/positioning yoke.

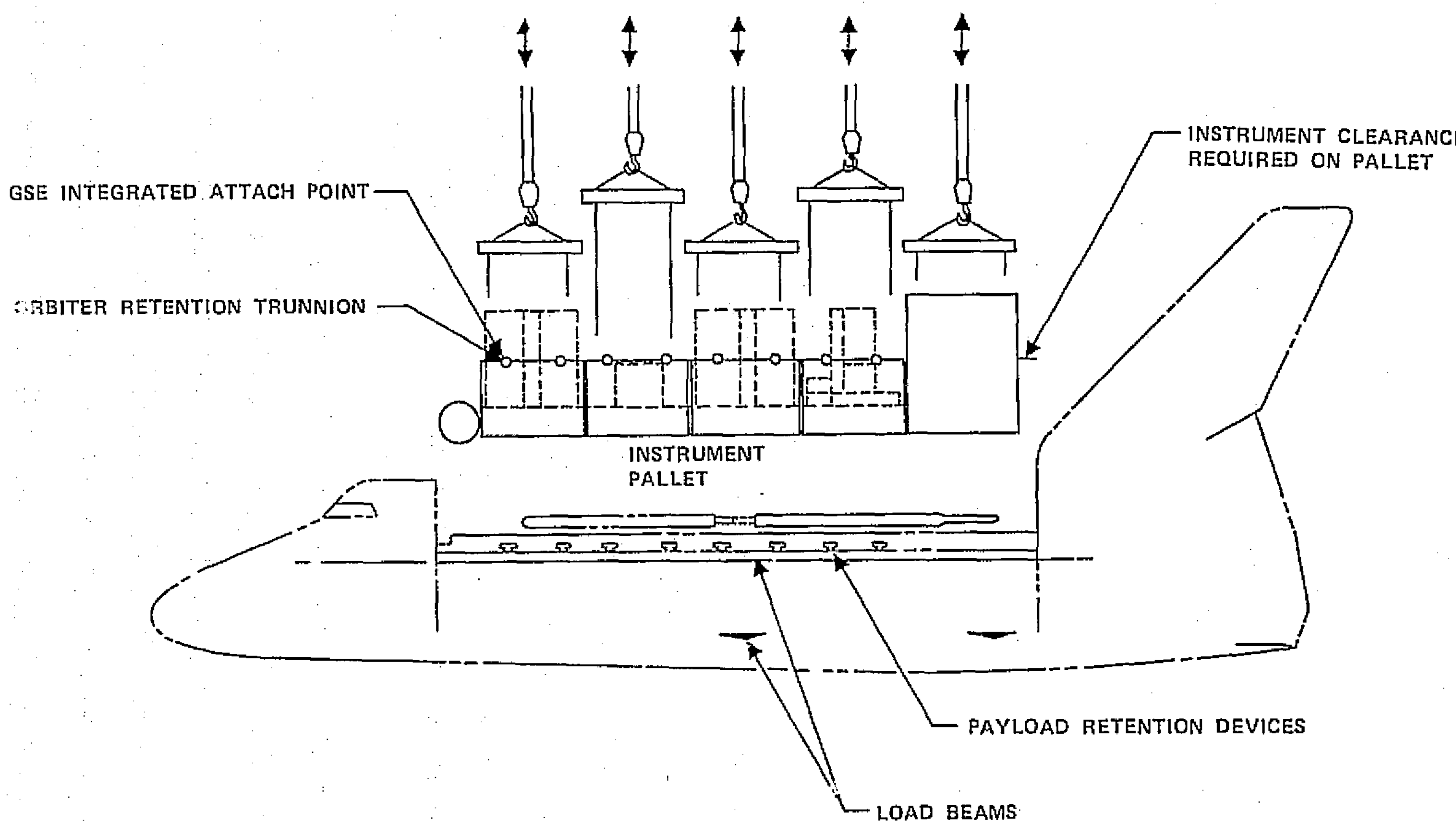


Figure 5.3.2-9. — Horizontal ASF/AMPS payload installation/removal (concept).

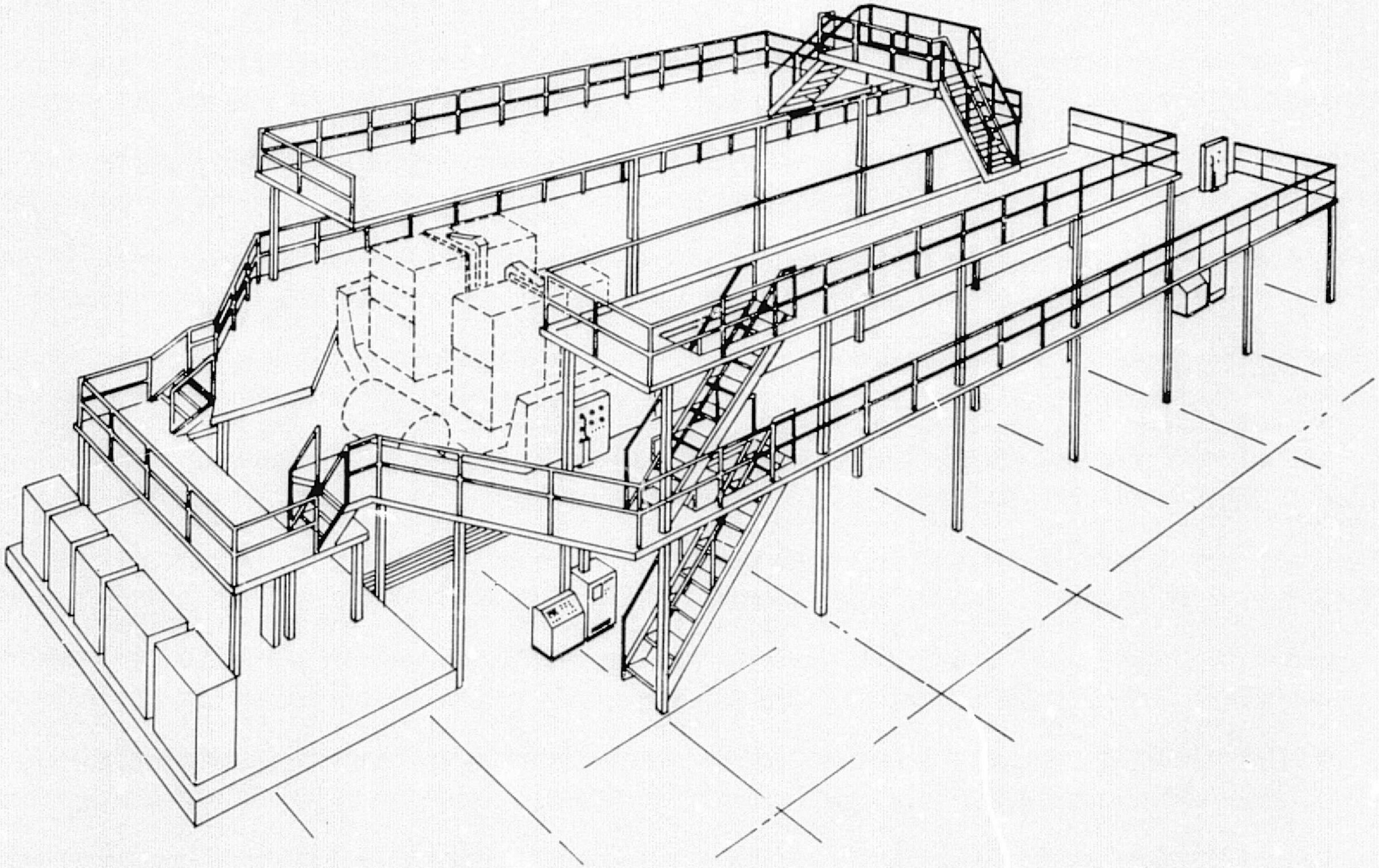


Figure 5.3.2-10. — Standard payload maintenance and checkout station.

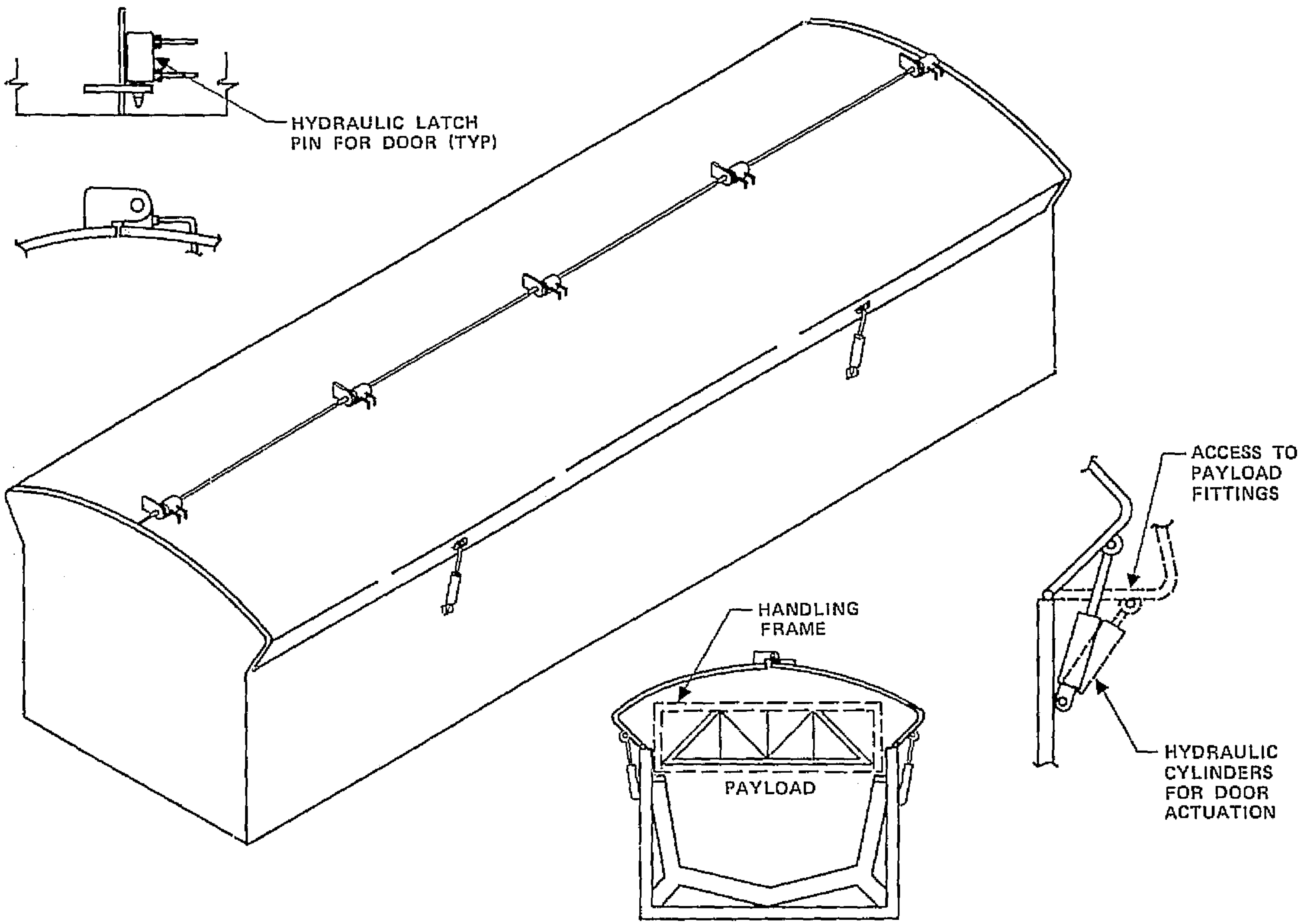


Figure 5.3.2-11. – Horizontal payload cannister concept.

5.3.2.4.2.4 Vertical Payload Installation/Removal (Contingency Operation)

Payload installation and removal from the Orbiter in the vertical position is a contingency operation. However, an ESRO concept has been reviewed and is considered acceptable, with minor changes, for ASF use. See figures 5.3.2-12, 13, 14 and 15.

5.3.2.5 Logistics and Transportation

Appendix E is a conceptual treatment of one set of fabrication and checkout flow requirements compatible with the section 5.3.2 ground support and test philosophy which in turn was derived for the ASF pallet-only mode payload. These requirements are not only a baseline for ASF hardware logistics but a driver for the definition of transportation requirements.

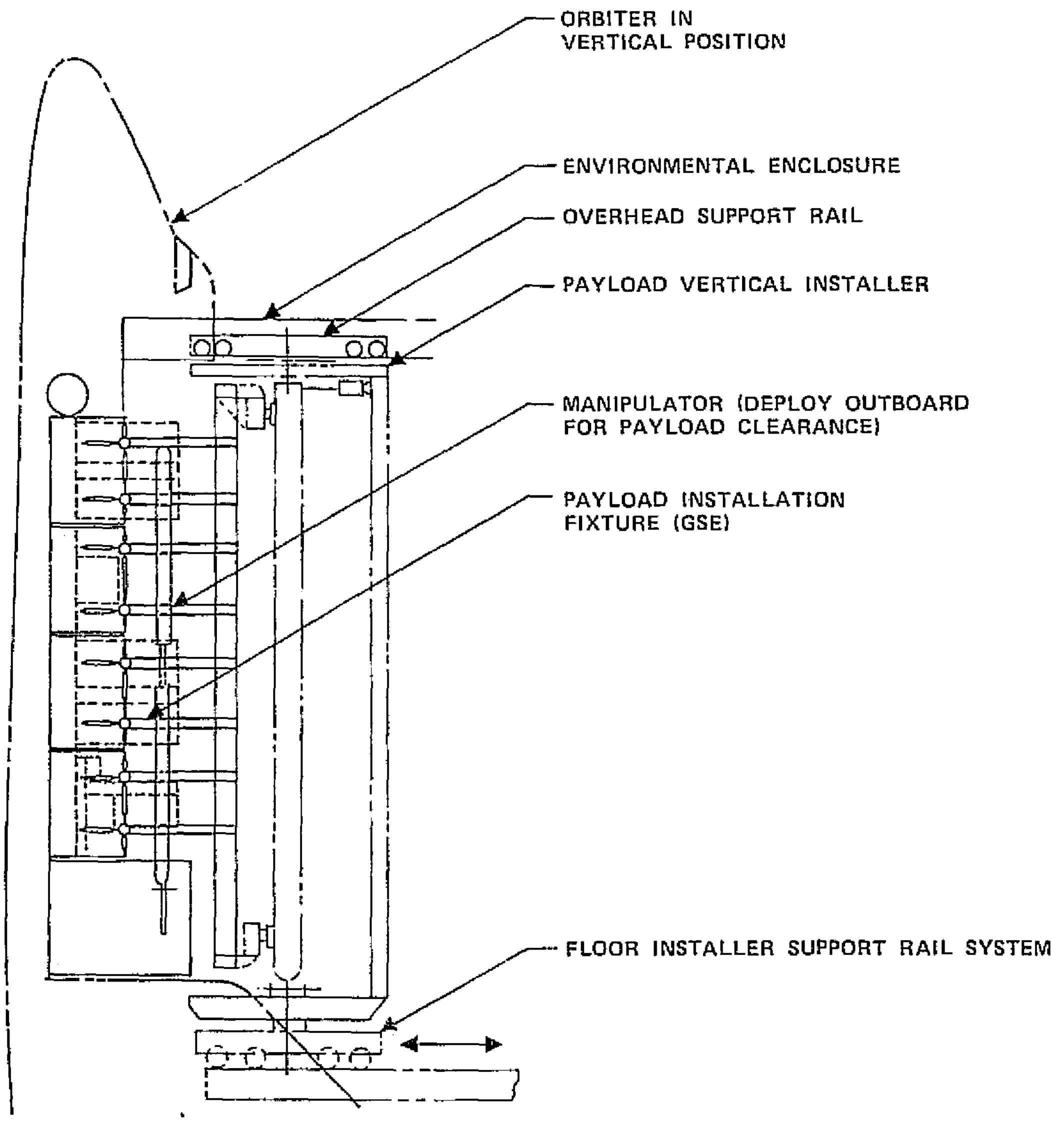


Figure 5.3.2-12. — AMP/ASF payload vertical handling concept.

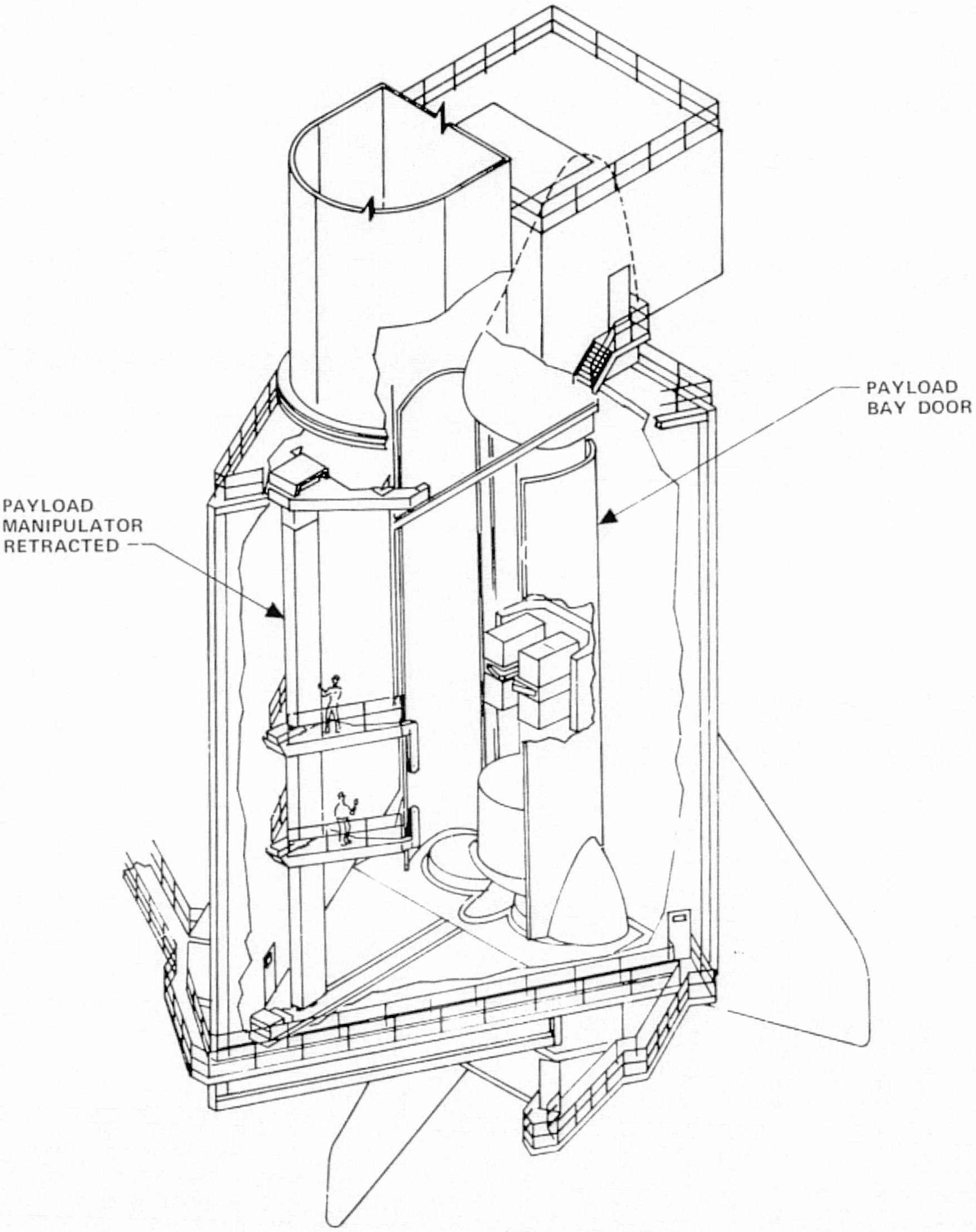


Figure 5.3.2-13. — Pad payload vertical handling.

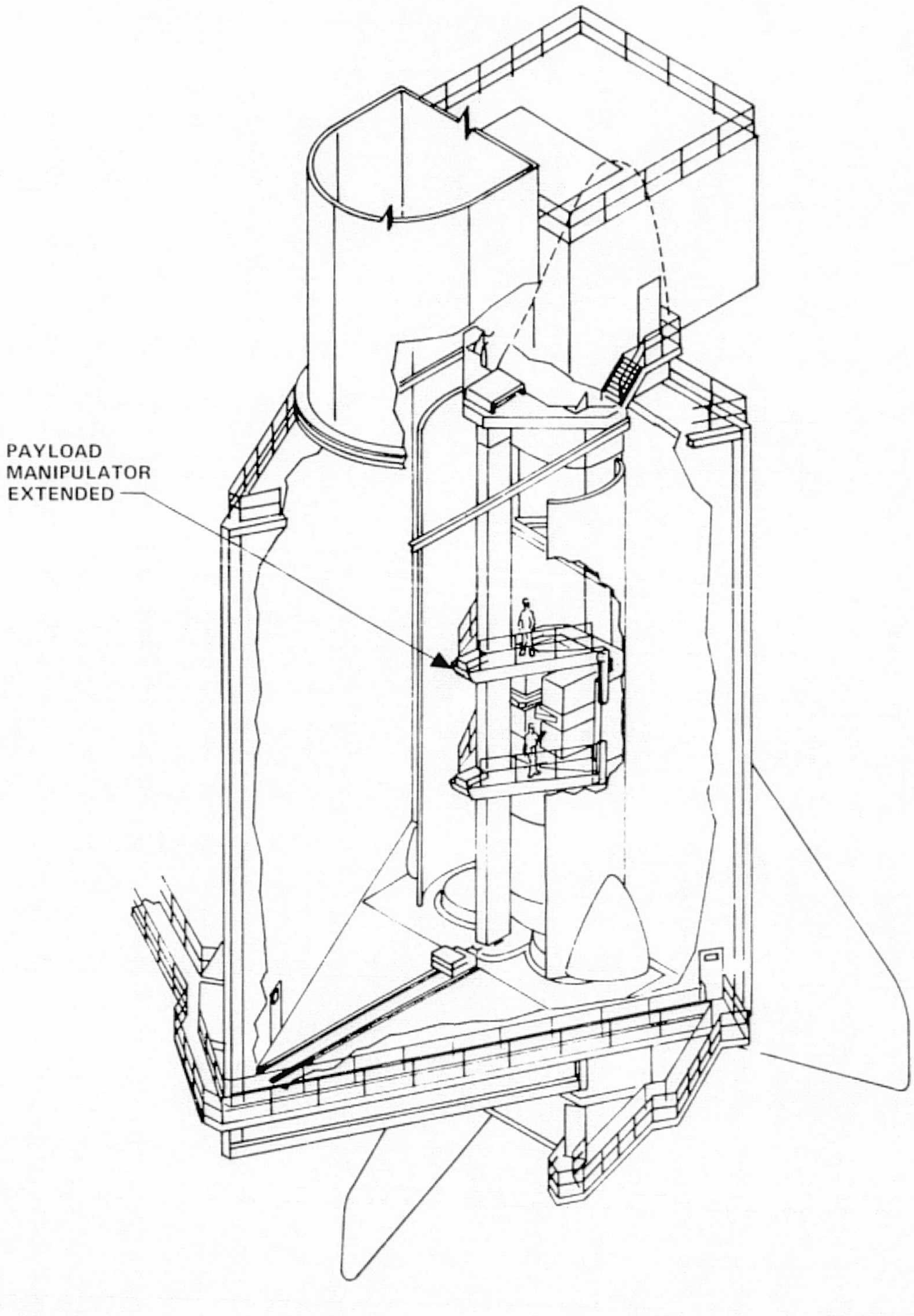


Figure 5.3.2-14. — Pad payload changeout.

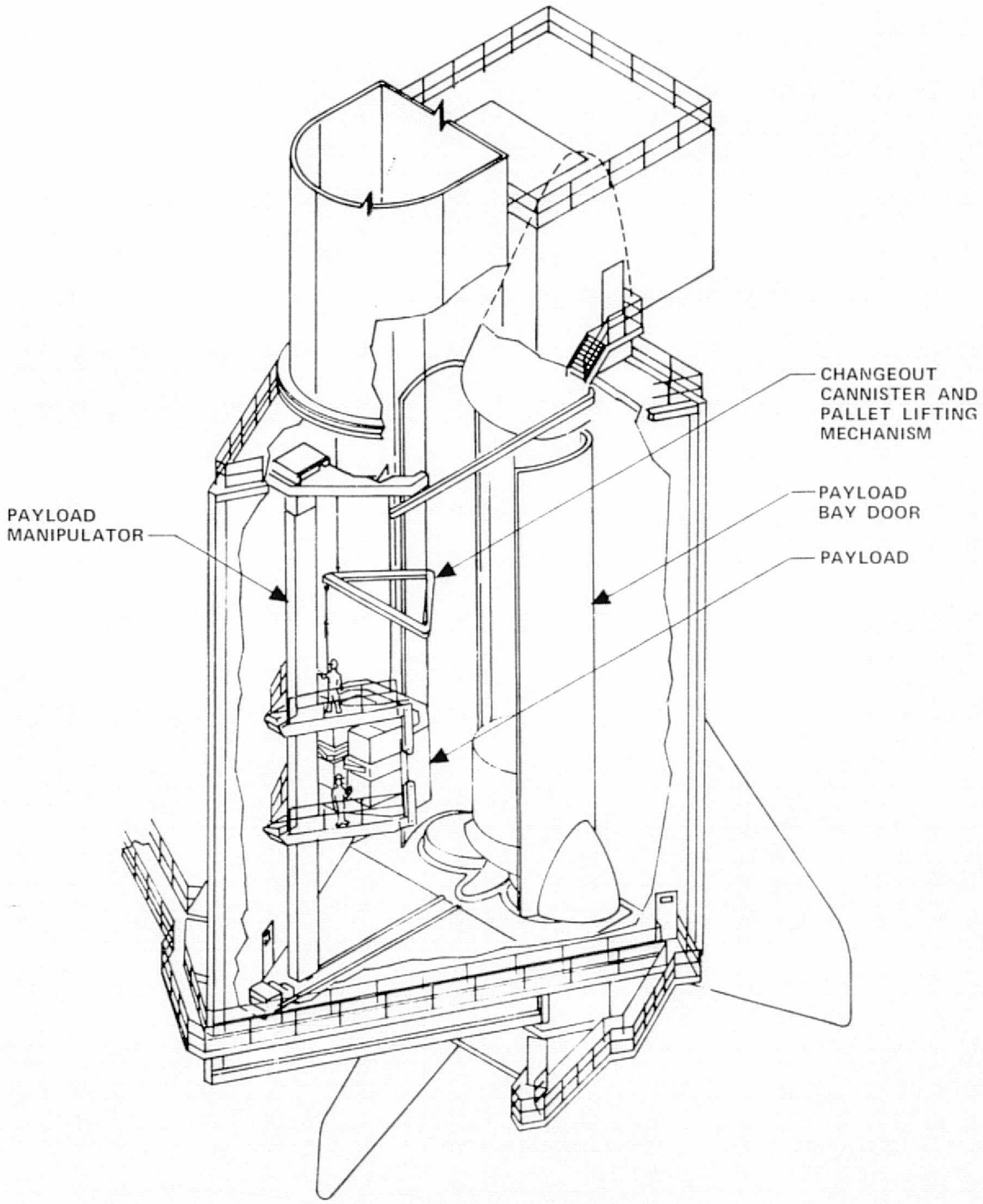


Figure 5.3.2-15. — Pad payload vertical handling.

5.4 SUPPORT SYSTEMS

In addition to the ASF unique flight and ground systems described in paragraphs 5.2 and 5.3, respectively, the accomplishment of each mission depends on support from other systems not dedicated to the ASF program but in operation as part of the overall national space program. These include the Orbiter and ground facilities within the STS inventory, the TDRSS and a SPS which are being planned for operational status in the late 1970's to early 1980's time period.

5.4.1 ORBITER

In the pallet-only mode, the ASF missions depend extensively on a number of Orbiter support facilities in the areas of structural/ mechanical, thermal control, avionics, and electrical power. In addition, Orbiter crew and vehicle operations support are required. The support functions required by the ASF payload are discussed in greater detail in paragraph 5.2 of this report. Details of the Orbiter vehicle facilities and operational capabilities are provided in the "Space Shuttle Systems Payload Accommodations," JSC 07700, Volume XIV, Rev. C, July 3, 1974, and the "Space Shuttle Flight and Ground System Specification," JSC 07700, Volume X, Rev. A, January 2, 1974.

5.4.1.1 Payload Placement

The first ASF launch will be from KSC in a 28.8° inclination, 400 to 500 km orbit. Polar orbit missions at the same altitude are also scheduled from the western launch facility.

Placement accuracy required for ASF missions are expected to be well within baseline Orbiter capabilities.

5.4.1.2 Orbit Changes

The PDS will be deployed at a distance of 1 to 10 km in front of the Orbiter at approximately the same altitude. The subsatellite will be ejected at 20 cm/sec and will continue to separate for the duration of the mission. At the end of tne mission, either the Orbiter or the subsatellite will provide the ΔV required to rendezvous and retrieve the subsatellite. Both vehicles have ΔV capability.

5.4.1.3 Attitude Control, Maneuvering and Pointing

The Orbiter will be maneuvered to some preselected attitude and will maintain payload attitude within an accuracy of 1 or 2 degrees. In this mode, the Orbiter will be operating at minimum deadband (0.1°) and at lowest rate (0.01°/sec). The ASF pointing system will decouple the instrument clusters installed in the AIM's from Orbiter motion and provide the precision accuracy required.

During the mission, a number of maneuvers each revolution may be required to reorient the vehicle for the different experiments.

5.4.1.4 Communications

a. Direct with STDN. The maximum real time downlink data rate for unprocessed data (worst case condition) is approximately 123 kbps. This condition exists only during the 15 minute bursts when Instrument 532 operates. During these periods, the Orbiter S band PM direct downlink system will be inadequate, forcing use of the S band FM link, if the direct link is required.

b. Relayed through TDRSS. The TDRSS S band PM downlink capability is limited to 96 kbps. The ASF missions will use the TDRSS Ku band PM link which has the capability of transmitting up to 50 Mbps. The Orbiter baseline provides a Ku band antenna on one side of the fuselage. A second payload chargeable antenna (available in kit form) will be required on the other side of the vehicle to provide near 4π steradian coverage.

c. PDS to Orbiter. The only communication link between the Orbiter and deployed payload is the S band PM link. The capacity of this link is 16 kbps.

5.4.1.5 Tracking

a. Orbiter state vector (position and velocity). The ASF payload will utilize the baseline Orbiter one-way doppler tracking capability to establish Orbiter/payload state vector.

b. PDS tracking. Tracking of the PDS, which will be deployed approximately 10 km from the Orbiter, will be performed using the baseline Orbiter rendezvous radar. This microwave radar is capable of detecting and tracking a passive target at ranges between 10 km (5.4 n.mi.) and 30 m (100 ft.)

5.4.1.6 Data/Command Interface and Processing

a. Engineering data to Orbiter performance monitoring system. Engineering data from the payload will utilize the 64 kbps, 5-channel interface provided by the baseline Orbiter.

b. Scientific data for downlink transmission. Scientific data will utilize the 5.0 Mbps digital interface with the Orbiter FM signal processor for data being transmitted direct to the ground stations. The 50 Mbps digital interface with the Orbiter Ku band signal processor will be used for data being relayed through TDRSS. The interface with the MSS recorder is optional.

c. Commands and data from the Orbiter. The ASF payload will interface with the 8 kbps Orbiter payload signal processor output for commands from the ground station (through the Orbiter rf link). The ASF payload will receive commands from the MSS and GN&C data through the Orbiter general-purpose computer and the multiplexer-demultiplexer.

d. C&W. The payload C&W interface is with the Orbiter baseline C&W electronics (primary) and with the PMS (backup).

e. Video. The ASF payload will utilize the Orbiter bay and RMS arm TV cameras provided in the Shuttle baseline configuration. The two TV monitors with their associated camera and monitor controls at the on-orbit station will be used during experiment preparation, instrument pointing, accelerator operation, and subsatellite operations.

f. Time codes. The mission elapsed time and GMT codes will be used by the ASF experiment and support subsystem computers and the timing displays at the PSS.

g. ASF unique interface. The PSS interconnects with the ASF payload through the patch board. The patch board is located in the Orbiter junction box which provides the interface among the MSS, PSS and the payload through the station X_o 14,630.4 (576 in) bulkhead electrical connector panels. The ASF PSS will use the Orbiter audio system for voice communication with the rest of the Orbiter crew and with mission control.

5.4.1.7 Displays and Controls

The ASF mission will utilize the Orbiter C&W annunciator at the forward station and the status board at the MSS. The CRT displays and keyboard control at the MSS which are part of the Orbiter CDMS will be used to monitor ASF instrument and support subsystems for health status, to perform failure diagnosis, and to control the deployed subsatellite.

5.4.1.8 Remote Manipulator System

The RMS will be used to retrieve the PDS at the end of the mission.

5.4.1.9 Electrical Power

As discussed in paragraph 5.2.2, the ASF payload will use the Orbiter dedicated fuel cell as its primary power source and the shared fuel cell as the secondary source in case of dedicated fuel cell failure. Two energy kits will also be required.

5.4.1.10 Structural/Mechanical

a. Payload attachment. The ASF program will utilize four of the ERNO designed, ESRO furnished standard equipment pallets to install instruments and support system equipment in the payload bay. (see paragraph 5.2.1 for details of pallet configuration and equipment installation). Each of the four pallets required for the ASF payload will be attached to the payload bay structure using the standard Orbiter primary payload structural attachment points as discussed in paragraph 5.2.1. No special provisions for these installations, or the vernier bridge fittings, are required.

b. Payload bay cabling and fluid line accommodations. The ASF payload will require electrical cable break-out points for signal, command and power outlets from the wiring tray to the four pallets and the igloo. The Orbiter wire tray will provide harness routing from the pallets and the igloo to the forward bulkhead station X_0 14,630.4 (576 in), the aft bulkhead station X_0 33,197.8 (1307 in) and to the prelaunch (T-4) umbilical.

   Fluid lines are required from the launch (T-0) umbilicals through the aft bulkhead at station X_0 33,197.8 (1307 in) for the following functions:

   (1) Cryogen (LNe or LN_2) fill, vent, dump and relief.

   (2) Energy kit (LO_2 and LH_2) fill, vent, dump and relief (part of Orbiter baseline).

c. Payload service panels. The ASF payload will require access to the following service panels:

(1) Station X_0 14,630 (576 in) for signal, data, and command interface with aft crew station facilities.

(2) Station X_0 33,197.8 (1307 in) for signal, data and command interfaces and fluids with the launch (T-0) umbilical.

(3) Station X_0 17,653 (695 in) for primary and secondary electrical power interfaces.

(4) Preflight (T-4) umbilical station X_0 20,688.3 (814.5 in) for functions (TBD).

(5) Launch (T-0) umbilical, left and right side, station X_0 26,444 (1435 in) to interface with the launch control complex for signal, data, commands, electrical power, ground cooling, and LH_2 and LO_2 fill, drain, and dump.

Fill and drain for the active thermal control freon and fill, vent and drain interface provisions for the GN_2 for the subsatellite ejection system are (TBD).

5.4.1.11 Thermal Control

The ASF payload requires the use of the Orbiter ATCS to dissipate up to 24,000 Btu's of thermal energy per hour generated by the use of about 6.9 kW of electrical power over prolonged periods of time (e.g., from orbit revolutions 43 through 47).

The baseline Orbiter ATCS coolant loop will provide the required support. Two additional heat radiator panels provided in a kit will be required.

5.4.2 TRACKING AND DATA RELAY SATELLITE SYSTEM

The ASF mission will utilize the forward and return link communication services of the TDRSS. The single access (SA) return link is planned for the scientific data since the multiple access (MA) link capability (50 kbps) is inadequate to handle the 123.192 kbps ASF data rate requirement. However, due to possible priority scheduling problems, a combination of multiple and single access system usage may be necessary with selective transmission of continuously acquired data being provided by the low data rate MA system. The forward link can be on either MA or SA services.

The standard tracking service will be utilized by the Orbiter to determine its position and velocity. The TDRSS will not be used for the primary tracking of the PDS since this function will be accomplished using the Orbiter microwave rendezvous radar. The TDRSS tracking capability could be utilized in a back-up mode if the TDRSS compatible transponder is incorporated into the subsatellite communication system.

5.4.3 SOLAR PHYSICS SATELLITE (SPS)

A SPS is scheduled for operational status in the late 1970 to early 1980 time period. The solar physics program is part of the overall scientific program for the NASA to investigate short and long term solar phenomena. The ASF missions which include solar measurements require data from the solar satellite to support experiments.

ASF optical instruments would be used to calibrate the satellite's optical instruments. The most logical arrangement is for the Orbiter to have optical instruments which duplicate those on the satellite. Both sets of instruments would have the identical spectral sensitivity and would eliminate one source of error in the calibration. This calibration by the Orbiter instruments is necessary because the responsivity of the optical instruments on the satellite would drift due to long term UV radiation, contamination, aging, and gamma rays affecting the optical surfaces.

The instrument planned for this purpose in the baseline system is the Pyrheliometer/Spectrometer, described as Instrument 1002 in appendix B. The solar calibration instrument complement in the ASF payload cannot be truly defined until the instrumentation that will be used on the SPS has been specified. However, the physical size, weight, pointing requirements, and data sampling rate of the Pyrheliometer/Spectrometer make the instrument representative of the Orbiter instrumentation that will ultimately be selected.

The Orbiter and the satellite need not be at the same altitude for optical calibration. If they are not, then atmospheric corrections must be made to the data before applying them to the calibration.

It is sufficient for the satellite optical instruments that the orbit be sun-synchronous at a sufficiently high altitude to require little correction, if any, for atmospheric absorption (such as may occur for H and O atoms). However, the particle detectors may need to be outside the earth's magnetic field, 25 or 30 earth radii from the earth in order to measure the particle flux and energy from the sun. The final altitude at which the satellite will operate is yet to be determined.

The data required by the ASF program will be provided by the solar physics program. To support the ASF experiments, the sampling rate from the satellite is not critical. The data rate depends upon the number of wavelengths and energy intervals sampled. The particle detection instruments may sample more often, possibly as rapidly as once every four seconds. However, the optimum sampling rate can be found only by examining experimental data to determine how rapidly the changes occur. The data rate of the instruments on the Orbiter should be at least as great as that on the satellite.

5.4.4 SPACE TRANSPORTATION SYSTEM (STS) GROUND FACILITIES

The STS ground operational facilities include the OPF, the VAB, and the LCC at KSC and the western launch site; mission controls at JSC; data monitoring and handling facilities at JSC, MSFC and GSFC; and the landing area facilities. Developmental ground facilities utilized by the ASF program will include the Shuttle Avionics Integration Laboratory (SAIL), the Mockup and Integration Laboratory (MAIL), the payload integration facilities, and instrument development and integration facilities.

The unique GSE required for ASF payload checkout and test are discussed in paragraph 5.2.

The four ASF pallets and the igloo will be installed into the Orbiter in the OPF. The ASF ATCS will be installed and connected to the Orbiter payload heat exchanger. The coolant loop will be filled with freon and checked for leakage. The pumps and valves will be checked for operation. Fluid connections between the payload and the station X_0 33,197.8 (1307 in) bulkhead service panel will be made and electrical connection at stations X_0 14,630.4 (576 in), 17,653 (695 in), 33,197.8 (1307 in) and at other harness breakout points will be made. Mated checkout requirements for the ASF payload at the OPF are yet to be assessed. The ASF unique GSE required to interface with the STS facilities is discussed in paragraph 5.2.

At the VAB, after the Orbiter has been erected and mated to the external tank, ASF payload test and checkout will be performed. The details of the ASF payload checkout operations at the VAB have not been established. However, the same type of ASF unique GSE used for OPF checkout operations would be available to interface with the VAB STS facilities, if required.

The prelaunch operations support required by the ASF payload through the LCC includes verification of the engineering level operation of ASF support subsystems and as much of the instrument operations which might be practical at this time. After the launch readiness checks are completed, the subsatellite ejection system gaseous nitrogen tank is filled to a pressure of 2.41×10^7 N/m^2 (3500 psig). After the countdown process is initiated at T-2 hours, the cryogenic coolant tank is filled with cryogen (LNe or LN_2). The electrical energy kit reactant tanks are filled with LO_2 and LH_2 as part of the Orbiter fuel cell reactant loading operations. During the countdown and through liftoff, the ASF payload data monitoring and operation checks are performed by the ASF unique GSE and the baseline LCC complex.

The flight operations approach selected for ASF missions requires most of the processing and experiment operations to be performed onboard the Orbiter. Data not processed by the payload will be processed by the ASF ground facility. Most of the processing and controls will be performed automatically using the experiment and support subsystem computers.

Using this approach, the support role for the MCC for the ASF payload is primarily to provide backup capabilities in the areas of experiment control and data processing analyses. It is expected that, as for most payloads, ASF unique stations will be required at the control center where engineering and scientific data monitoring will be conducted and non-safety related contingency decisions will be made. The stations will require support from the mission control complex for communications; data processing, stripping, storage, and routing; command and mission operational data (GN&C, attitude update maneuvering parameters, etc.) generation and other standard payload services.

The ASF payload will not require special operations during the period immediately after Orbiter landing except for normal safing operations. Tapes and films from the recorders and camera will be removed and transported to the data handling facilities within a short time of landing.

During the maintenance, refurbishment and repair cycle, the ASF payload will be removed from the Orbiter payload bay at the OPF and serviced in preparation for the next mission.

5.5 CONTAMINATION

5.5.1 INTRODUCTION

This section addresses the STS environments and provides a treatment of salient environmental susceptibilities and radiative characteristics of ASF/AMPS instruments. Appendix C (4 parts) presents results from various supporting tasks undertaken during the study of this most important subject.

5.5.2 STUDY APPROACH

The contamination portion of this study started with a summary definition of the STS environment (appendix C-1) as derived from authoritative documents listed in paragraph 2.3.3.a. An environmental analysis (appendix C-2) was performed which treated the EMI and dust/gas/particulate contamination characteristics of the ASF/AMPS instruments. The analyses encompassed EMI controls and effects of contamination upon the payload instruments. Specific interference problems for ASF/AMPS instruments were identified and presented in appendix C-3. The results of this study are in context with a June 1975 correspondence originated by the Space Shuttle Program Office (appendix C-4) which quotes an expected magnetic flux density of three orders-of-magnitude greater than the maximums specified for AMPS instruments.

5.5.3 CONCLUSIONS

The complexities of the environments and preliminary nature of information relating to characteristics of both the advanced scientific instruments and the Orbiter itself, result in obvious major problems requiring extensive, in depth study and analysis before either quantitative definitions or solutions can be expected. These same problems, in most cases, will confront pallet-mounted instruments comprising most scientific payloads presently conceived for the Shuttle era. The potential impact to Orbiter mounted scientific payloads presents important trade-off considerations relating to "cleaning up" the Orbiter design versus long range resource requirements to fortify the design of each instrument and payload subsystem to live with the Orbiter payload bay environment. Impact estimates, trade-off, and follow-on actions related to these environment problems will be addressed in paragraphs 8.1.1.1 (Problems), 8.1.1.2 (Impacts), 8.2 (Trade-Off Considerations), and 9.0 (Recommendations).

5.5.4 RECOMMENDATIONS

5.5.4.1 EMI Contamination

A number of areas related to electromagnetic and electrostatic compatibility remain to be evaluated in depth after the ASF instruments and the supporting subsystems are further defined. Some of these are the following.

a. Further definition of instrument susceptibility characteristics.

b. Further definition of Orbiter, support subsystem and instrument EMI generation characteristics.

c. Determination of the electrostatic potentials expected between the Orbiter and the surrounding plasma during particle discharge. Determination of the impact on experiments of these potentials and evaluation of possible solutions, if required.

d. Evaluation of the effect on instrument electromagnetic contamination of the Orbiter multipoint structural dc power return system.

e. Generation of a preliminary electromagnetic control plan.

5.5.4.2 Dust, Gas, Particulate Contamination

The following information may be considered as potential approaches toward improvements in the overall Orbiter contamination problem.

a. The raising of lens temperatures a few degrees to inhibit condensation.

b. The use of lens covers which are only opened shortly before sensor activation.

c. The use of "shades" to limit the angle from which particulates may impinge on the lens surfaces.

d. The use of clean inert gas to purge various areas periodically or create a slight positive pressure inside cameras, optical systems, etc.

If contamination of radiative coolers by condensibles cannot be avoided, the contaminants can be removed by periodic cleaning through evaporation. Heaters for this purpose may be incorporated into the cooler design and operated on ground command. This approach has been used effectively on the Surface Composition Mapping Radiometer (SCMR) on Nimbus E.

Contamination control/avoidance on sensor optics may be achieved by a number of preventive designs and operational countermeasures. The utilization of an Orbiter work shroud at the OPF during all open cargo bay operations and the maintenance of rigid clean room standards will help greatly to reduce the major source of contamination. Materials selection will obviously be controlled by the Shuttle Project Office, and this will also help.

For flight operations, there are a number of approaches which the Orbiter can use to limit contaminants. The most obvious is the control of Orbiter RCS/OMS thrusters, especially during periods when lens covers are opened. Without a high duty cycle use of the RCS, tight attitude control cannot be maintained by the Orbiter, and there might be some image smearing; however, this problem is not unique to the pallet-only mode configuration.

Another critical operational method to avoid contamination is the avoidance and/or control of venting. Since it would be impractical to prohibit venting, appropriate control measures are required. Quantities can be made low and vent ports should be located away from critical areas and designed to provide high velocity, short-duration, directional flow. Designing tankage to provide minimum duty cycle is also desirable.

5.6 STANDARDIZATION

Appendix D is a detailed treatment of the feasibility of standard-dized electronics for the AMPS/ASF pallet-only mode payload.

5.6.1 SUMMARY

Using the current AMPS/ASF ID's, a typical system was defined. Using this definition, a study was made to determine if it was feasible to remove from the individual instruments the supporting electronics and combine those for several instruments into a single instrument electronics package (IEP). The study also considered the cost savings that might be realized by standardizing and modularizing the sensor support electronics within the IEP. It further considered the possibility of utilizing existing packaging methods such as NIM-CAMAC, Navy QED, Navy SHP and ATR.

This study made a special application of this centralizing, standardizing, modularizing concept to ASF.

5.6.2 CONCLUSIONS

a. It is feasible to apply the centralized instrument electronics concept to AMPS/ASF.

b. Considerable cost savings can be realized in the areas of design, fabrication, and test.

c. Standardizing and modularizing the IEP offer a number of advantages in the areas of replaceability, maintainability, system expansion, and preflight checkout.

d. Although the concepts are good, the use of existing standardized electronics such as NIM-CAMAC, Navy QED, ATR, and others are not acceptable within the existing constraints for spaceflight type experiment hardware. This is largely because of the constraints on weight and volume and also the existing packaging technique is not suitable for spaceflight use.

6.0 MISSION OPERATIONS

6.1 INTRODUCTION

This section describes the ground and flight operations required to support ASF missions. These missions include both low inclination and polar flights to provide global coverage and to provide flight paths both parallel and normal to the earth's magnetic field.

The first launch will be into a 28.8° inclination orbit from KSC in 1981. Succeeding launches from the eastern launch facility (KSC) will be at orbital inclinations from 28.8° to 57°, depending upon individual mission requirements. Launches from the western launch facility sometime after it becomes operational will inlude 90° inclination (polar) orbits. Orbits will be at altitudes between 200 and 500 km.

The mission operations will be supported by the prelaunch checkout facilities at the launch site (both ASF dedicated and part of the STS), the launch pad checkout facilities, the Orbiter vehicle and crew, the STDN and TDRSS, the MCC at JSC, the ASF dedicated ground data handling and processing facility, the landing site facilities, and the ASF payload refurbishment and modification facilities. In addition, supporting data from a PDS deployed from the Orbiter and a SPS already in orbit will be required to accomplish the ASF missions. The in-flight mission system support facilities and the fundamental interfaces required are illustrated in figure 6.1-1.

6.2 GUIDELINES AND ASSUMPTIONS

The following guidelines and assumptions were utilized for the ASF study.

a. Normal Orbiter operation will be nose up and nose down Z/velocity vector (ZVV) and Y/perpendicular to Orbiter Plane (Y-POP) for least fuel consumption (figure 6.2-1).

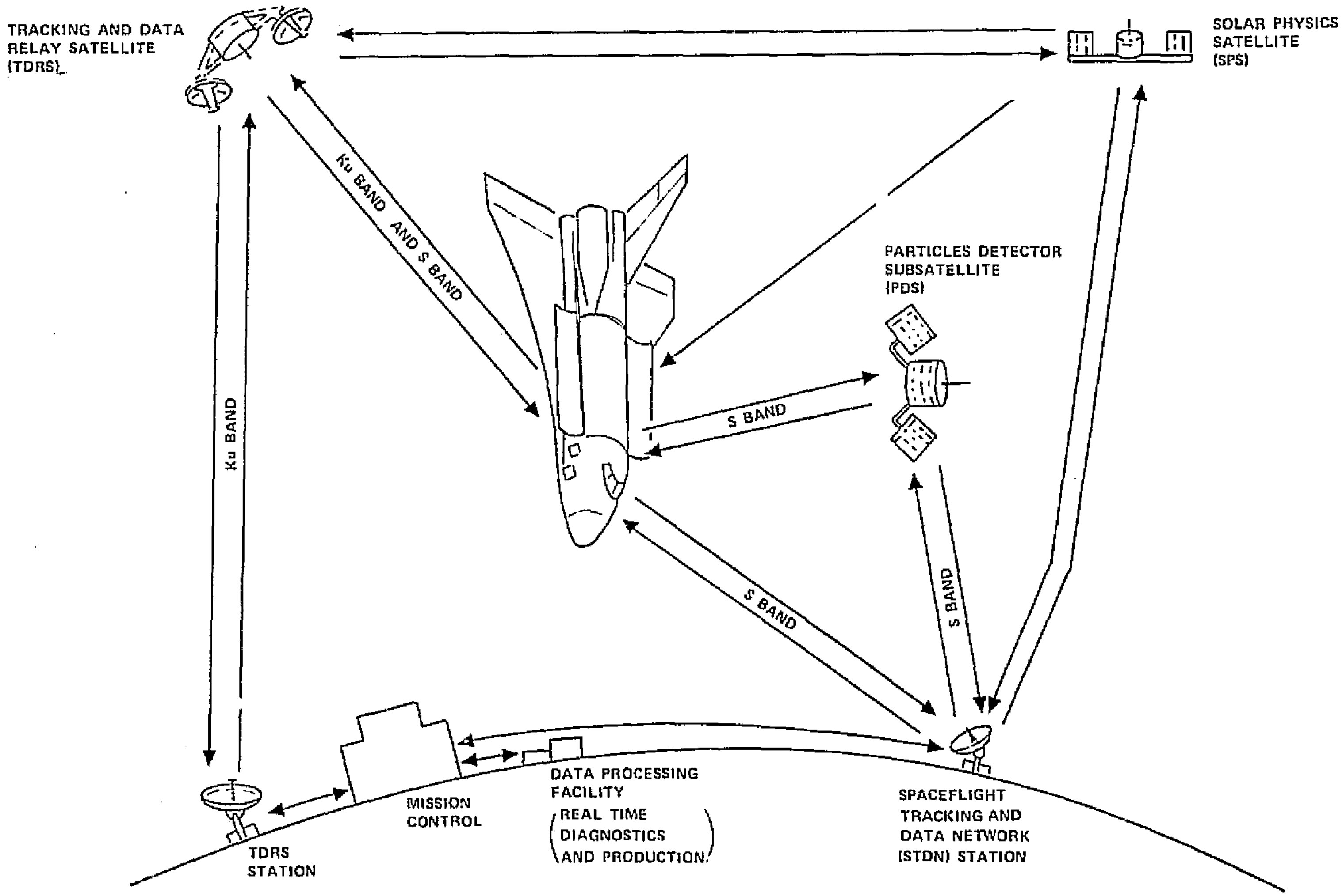


Figure 6.1-1. – ASF mission system.

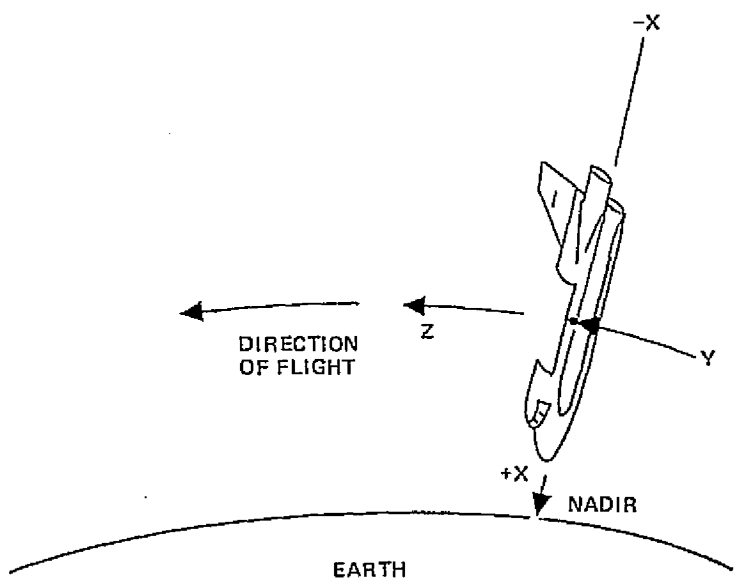


Figure 6.2-1. — Normal Orbiter operations.

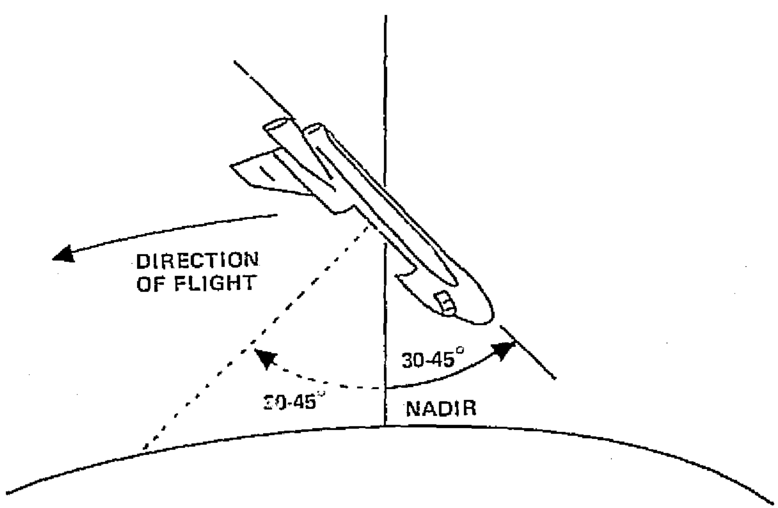


Figure 6.2-2. — ASF instrument pointing operations.

b. For each ASF mission, the Orbiter vehicle will be dedicated to the ASF payload.

c. ASF instrument pointing will be accomplished primarily from the Orbiter attitude shown in figure 6.2-2. Maneuvers from this position will be required to accomplish some experiment objectives.

d. SPS instrument data will be available at the time the ASF missions are flown, and the solar instruments on the Orbiter will be used for calibration only.

e. The identical instrument/experiment complement will be flown in polar as well as 28.8^{o} inclination orbits. Time in attitude hold angle will be limited for Beta angles greater than 60^{o}.

6.3 OPERATIONS DESCRIPTION

For each mission, the operations required will include the following.

6.3.1 PREFLIGHT OPERATIONS

a. Pallet level integration and test.

b. Payload level integration and test (SAIL).

c. Vehicle integration, test and launch preparation (launch base facilities).

6.3.2 FLIGHT OPERATIONS

a. Launch and mission orbit injection.

b. Orbiter/payload systems verification and experiment preparation.

c. Deploy subsatellite.

d. Perform experiments.

e. Retrieve subsatellite.

f. Re-entry preparation.

g. Re-entry, descent and landing.

6.3.3 POSTFLIGHT OPERATIONS

a. Onboard stored data recovery.

b. Data processing.

c. Distribution of data to users.

d. Payload refurbishment, change and preparation for storage or subsequent flight.

e. Logistic support.

6.4 PREFLIGHT OPERATIONS

6.4.1 PALLET LEVEL INTEGRATION AND TEST

Subsequent to delivery of the instruments, PDS, and the subsystem equipment to the pallet integration facility, the instruments and the PDS will be installed into handling fixtures. These handling fixtures (see paragraph 5.3.2 for further details) will allow instrument and PDS positioning, alignment, functional test and servicing with minimal manual contacts, thereby reducing possible contamination.

The instruments (or PDS) and support equipment will be installed directly onto the pallet in the case of pallets A-2 and A-4. For pallets A-1 and A-3, the instruments will be installed into the AIM's and the AIM's will be mounted on the APS. Support equipment for pallets A-1 and A-3 will be installed directly to the pallets or, in the case of the star tracker and sun sensor assemblies, on the AIM. Mechanical alignments will be checked and adjusted as necessary using optical alignment tools for the critical alignments.

One or more pallets with the complement of instruments (or PDS) and support subsystems (pallet packages) will be installed in the matched-rail handling and service fixture (see paragraph 5.3.2). The pallet packages will be mated with the EGSE described in paragraph 5.3.2 and comprehensive test and checkout will be performed using simulators to provide compatible support subsystem and Orbiter interfaces. The tests will be automatically controlled through the EGSE computer and test software. Power, signal, and data interfaces will be verified; complementary operation of instruments will be tested for compatibility; and the operation of the integrated pallet package will be checked for compatibility.

The precision of many of the instruments and the measurement thresholds or the sensitivity of instrument operations are such that under ground level environments, verification of instrument accuracy or operational capability may not be possible. The operation of these instruments will be checked, to the accuracy level possible, for functional compatibility and to verify that gross malfunctions have not occurred. The support subsystem equipment on the pallet including the APS will be checked for both functional operation and to verify in-limit performance.

After the pallet level tests are completed, the pallet (or pallets) together with the matched rail handling fixture will be installed into an enclosed transporter. The transporter will then be placed in temporary storage or shipped to the payload integration facility.

6.4.2 PAYLOAD LEVEL INTEGRATION AND TEST

If pallets are shipped individually, the four pallets comprising the ASF payload will be assembled at the payload integration and test site. The SAIL will be utilized for electrical and electronic integration verification. The MAIL will be used to verify the mechanical interfaces. The full complement of ASF EGSE will be available to be used at either integration laboratory, although the SAIL will require little additional ASF unique GSE.

Tests and checkout at the payload integration facility will be performed to verify: (1) compatibility among the different elements of the integrated payload, and (2) thermal, fluid, mechanical, electrical and electronic compatibility of the integrated payload with the Orbiter. As in the case of the pallet level test and checkout, precise verification of instrument accuracy or operational capability may not be possible at the integrated payload level. The same test approach utilized at the pallet level will apply at the integrated payload level.

After integration and tests are completed at the payload integration site, the payload will be loaded into the same type of enclosed transporter used for the individual (or combined) pallets and the transporter will either be placed into storage or will be shipped to the launch site.

6.4.3 VEHICLE INTEGRATION, TEST AND LAUNCH PREPARATION

At the launch site, the transporter will be delivered to the OPF. When the Orbiter is ready for payload installation, the pallets (and the handling dolly) will be removed from the transporter and inspected for possible damage. An integrated payload test will be performed using the ASF dedicated EGSE to verify operational integrity of the instruments and the support equipment. After tests are completed, the pallets will individually be installed into the Orbiter payload bay using the slings, hoists and hydraulic positioners discussed in paragraph 5.3.2. The pallets will be attached to the payload bay structure using the standard Orbiter attachment provisions (see paragraph 5.2). Mechanical alignment checks will be made, electrical connections will be made and verified. Fluid and gas lines will be connected and pressure checks will be made using helium or other inert gases to verify pressure integrity of the lines, valves and containers. After the lines are purged and cleaned, the ATCS coolant loop will be filled with freon and checked for leakage. The pump and valve operations will be verified. The pyrotechnics for latch actuation and boom and platform jettison will be installed and made safe using safe plugs or electrical safeing circuits.

Using the ASF EGSE, a payload functional test similar to those conducted at the pallet and integrated payload levels will be performed.

The Orbiter, with the ASF payload installed, will be transported to the VAB and will be erected and mated to the external tank and the solid rocket motors. The integrated Shuttle/payload will then be transported to the launch pad. At the launch pad, with the Shuttle in position, electrical and fluid interfaces with the launch complex will be made at the T-0 and T-4 umbilical connections.

A Shuttle system launch readiness test will be conducted to verify all Shuttle onboard and ground interfaces using command and test controls from the LCC. All payload functional electrical interfaces with the Orbiter will be verified and the payload and support subsystem computers and mass memory will be loaded with the final flight programs. The programs, as loaded into the computers, and the mass memory will be verified through memory dumps and a simulated flight sequence will be performed using the onboard computers and the mass memory.

After these launch readiness checks are completed, the pyrotechnic safe plugs will be removed (after the circuits are reverified to be in the safe conditions). The subsatellite

2.5

ejection system gaseous nitrogen tank will then be filled. The Orbiter payload bay doors will be closed at T-2 hours and the final countdown process will then be initiated. During the final countdown phase, the cryogenic coolant tanks will be filled with cyrogen and the electrical energy kit reactant tanks will be filled with LO2 and LH2 as part of the Orbiter fuel cell reactant loading operations. Power to the Orbiter will then be switched from the external ground support source to the internal fuel cells.

6.5 FLIGHT OPERATIONS

6.5.1 LAUNCH AND MISSION ORBIT INJECTION

During launch and until the Orbiter is in its operational orbit, the payload will basically be passive although the ATCS will be operational and the C&W parameters will be displayed onboard the Orbiter at the MCC.

6.5.2 ON-ORBIT OPERATIONS

The on-orbit operations will be separated into 5 phases. These will be: (1) payload preparation; (2) subsatellite deployment; (3) perform experiments; (4) subsatellite retrieval; and (5) re-entry preparation.

The ASF program approach for control of payload operations and for data processing will be to provide as much of these operations as possible through the payload or Orbiter systems. Dependence on ground stations will be minimized. Therefore, throughout the mission, the role of the MCC for payload operations control will be primarily one of backup. Also, data processing will be limited to that required to display the downlinked data at the MCC stations since an ASF dedicated ground data handling facility is currently planned.

Although the mission of the SPS will be independent of the ASF mission, coordination between the JSC and GSFC for the operation of these two systems in orbit will be required. The data obtained from the ASF payload and the deployed ASF PDS will be used to calibrate the instruments onboard the SPS and the data obtained from that satellite. These coordination factors will be established during subsequent ASF studies.

The on-orbit operations are shown in the ASF mission timelines presented previously in figure 4.1.5-1.

6.5.2.1 Payload Preparation (Revolutions 1 through 10)

After the Orbiter has achieved orbit insertion, the payload bay doors will be opened and the Orbiter system will be prepared to support the mission.

The ASF support subsystems, which have been powered through the launch and ascent phase, will be verified for mission readiness and safety. Power to the APS gimbal torque motors, the instruments and the subsatellite will be applied with the instruments in the standby mode. The cryogenic coolant systems for instruments 118 and 126 will be activated. After a short warm-up period (5 to 10 minutes), the APS and all instruments except instruments 118 and 126 will be checked to verify readiness status. After the temperature of the detectors for instruments 118 and 126 have stabilized (approximately 10 hours after coolant system is activated) the operational status of these two instruments will be verified.

By orbit revolution 10, all verification checks will be completed and the payload will be ready for operations.

6.5.2.2 PDS Deployment (Revolutions 11 through 15)

Between Orbit revolutions 10 and 15, the Orbiter will adjust its orbit, if required. The Orbiter will be maneuvered to the desired attitude for deployment and inertially stabilized to that attitude during the PDS deployment operations.

On or about revolution 15, the PDS deployment sequence will be initiated by the MS. Subsequent deployment operations will be controlled by the subsystem support computer.

The ejection system will be armed, preparing the GN_2 system for ejection operations. The command to eject the PDS will be manual and will actuate a solenoid pilot valve which will introduce the gas into a cylinder bore containing a piston. Under the action of the gas, the piston will move and the movement will allow the PDS holding mechanisms (collets) to unlatch the PDS. The piston will continue its movement until a striker fixture attached to the piston rod impacts the PDS and imparts to it a separation velocity of about 20 cm/sec. Teflon guide rails will be used to assure liftoff in the desired direction.

Details of this ejection system are provided in paragraph 5.2.1.

Subsystem support will be provided before, during and after PDS separation. Prior to ejection, the PDS communication system will be checked through hardline connections with the Orbiter. Operational data will be processed through the experiment RAU's on Pallet A-2 and the experiment computer in the igloo before the data is displayed at the aft crew station. Commands will be programmed by the subsystem computer in the igloo and transmitted to the PDS ejection system through the subsystem RAU located on Pallet A-2. Electrical power will be provided to the PDS from shortly after Orbiter insertion into orbit to PDS separation.

The PDS will be a modified AE satellite as discussed in paragraph 5.2.6. After separation from the Orbiter, the PDS thrusters will provide it with a spin rate of one revolution per minute (rpm) for spin stabilization. During this period the PDS communication link with the Orbiter will be verified. After about 14 hours the PDS will be at a separation distance of 10 km from the Orbiter and thrusters will be actuated automatically by the PDS control system to reduce its velocity relative to the Orbiter. The PDS will be reoriented to the desired attitude and will go into a stationkeeping mode at this distance from the Orbiter.

All operations on the PDS subsequent to separation (except stationkeeping velocity changes) will be autonomous although control can be exercised either from the ground stations or the Orbiter through the respective rf communication links. Orbiter control capability, if required, will be provided at the MSS.

After the PDS has been stabilized in the stationkeeping mode, it will begin to transmit data from its instruments (and support systems) to the Orbiter.

Payload attitude initialization and update will be performed during the latter stages of this phase. Commands will be given to the star tracker assemblies to start the star search. Since the tracker reference axes orientation will be known to within $\pm 2°$, the star search and recognition processes, and alignment of the APS, will be completed within a few minutes. The star angle data will be processed by the payload subsystem computer to align the APS inertial reference system.

Subsequent to this attitude initialization, updates will be required at least every 1-1/2 revolutions during the conduct of the experiments.

6.5.2.3 Experiment Operations (Revolutions 16 through 80)

The ASF experiments will be conducted during a period of about 4 days (64 revolutions). During this entire period, the support subsystems including the APS, the ATCS, and the cryogenic cooling system will be operational.

6.5.2.3.1 Revolution 16

Instrument 116 (Airglow Spectrograph) will be operated intermittently to study upper atmospheric emissions and absorptions and Instrument 1002 (Pyrheliometer) will operate for about 15 minutes during mid-daylight to measure the solar constant, the solar spectral irradiance, and to determine possible variations of total and spectral flux associated with changes in sun radiation. Instrument 1002 is used to calibrate solar instruments on the SPS.

6.5.2.3.1.1 Instrument 116

The frequency of operation of Instrument 116 will depend on the occurrence of discrete phenomena such as aurorae, by the existence of observable conditions such as noctilucent clouds, and the frequency of data required for normal day-glow and night-glow studies. The spectrogram exposure times will range from 1 second to 1000 seconds.

The subsystem support required will include the following.

a. Power, power control for standby and operate modes.

b. Instrument pointing using the APS to within 0.5°.

c. Computer controls to shift instrument collimating mirrors into and out of the energy path.

d. Exposure control to control the start and duration of the spectrogram exposure.

e. Displays for indication of the optical configuration of the instrument, relative pointing angle, indication of spectrogram exposure completion and indication of the exhaustion of the film supply.

f. Operational status monitor displays. Inflight calibration of Instrument 116 is not planned at this time.

6.5.2.3.1.2 Instrument 1002

This instrument will be pointed at the sun using the APS. The instrument has a door covering the opening for the optical input. The door will be opened before the data take and closed after the measurements are made. Scan frequency will be 2 or 3 times during this revolution and scan time will be 10 minutes. A light source will be used during flight to calibrate the instrument.

Subsystem support will include the following.

a. Power and power control.

b. Door opening and closure control.

c. Data sequence control.

e. Displays indicating control activation.

f. Data processing for data taken at one sample per minute for the Pyrheliometer and 270 pairs of samples per minute for the Spectrophotometer.

g. Operational status monitor displays.

h. APS pointing to within $\pm 2.5°$ of the sun line.

6.5.2.3.2 Revolutions 17 through 31

During revolutions 17 through 31 the following instruments are operated.

a. 118 - continuously scanning with scan periods between 40 and 66 seconds to measure trace gas concentrations in the spectral range of 3 to 40 μm.

b. 122 - continuously measuring atmospheric and ionospheric gaseous spectral emissions and absorptions in the range of 1100 to 10,000 Å.

c. 124 - continuously cycling at 2 minute intervals for durations up to 100 seconds. The instrument will be used to measure spectral or photo emissions in the range of 0.2 μm to 10 μm in the stratosphere, mesosphere and thermosphere.

d. 126 - continuously acquiring data in the 1 to 150 μm spectral region.

e. 213 - continuously cycling at a rate of one pulse per second. The laser will operate over the spectral range of 1000 Å to 30000 Å and will be used with other instruments to study the composition, structure and dynamics of the atmosphere through backscattering and absorption of the laser beam.

f. 532 - once for 15 minutes near mid-daylight during revolutions 17 through 25. The instrument will be used to release gases and to monitor orbital and solar effects on these gases.

g. 1011 - twenty or more exposures during 20 minute scans of earth limb during solar occultation. The instrument measures solar energy absorption by certain molecules and free radicals at different altitudes above the earth.

6.5.2.3.2.1 Instrument 118

The Limb Scanning IR Radiometer will scan the atmosphere vertically from the horizon upwards to 120 km and normal to the vertical up to 10° on either side of the nominal position using the APS.

The scanning operation will be provided by a preprogrammed routine in the subsystem computer which will drive the APS. Either the computer program or the crew manual control will provide the alignment of this instrument which will be on AIM 3A with Instrument 124, on AIM 3B with Instrument 213, and on AIM 1A when co-alignment operations are required.

a. Controls will include:

   (1) Power control.

   (2) Selection of scan rate and scan angle.

   (3) Selection of scan mode (sawtooth, zig-zag, sinusoidal).

   (4) Inflight calibration using internal black body source and space background.

   (5) Control of instrument temperature using cryogenic cooling system.

b. Displays required will include:

   (1) Scientific data from 4 to 12 spectral channels.

   (2) Verification of selected scan rate and angle.

   (3) Verification of scan mode.

   (4) Relative pointing angle of radiometer.

   (5) Detector temperature and bias voltage.

   (6) Telescope temperature.

   (7) Status of cryogen supply.

   (8) Instrument operational status monitor.

6.5.2.3.2.2 Instrument 122

The Ultraviolet-Visible-Near Infrared Spectrometer will be operated in both a fixed orientation mode and in an earth limb scanning mode. Tracking and scanning control will be provided by the APS. Covers will be used to protect the instrument optics from contamination when possible.

a. Controls will include:

   (1) Power control.

   (2) Selection of spectrometer mode.

   (3) Selection of grating scan rate.

   (4) Selection of wavelength to be measured.

   (5) Instrument pointing using the APS to within ±0.017° of the Instrument 1011 reference axes.

b. Displays will include:

   (1) Verification of scan rate, scan mode and wavelength.

   (2) Detector counts as function of integrated time.

   (3) Relative pointing angle of instrument.

   (4) Instrument operational status monitors.

6.5.2.3.2.3 Instrument 124

The Fabry-Perot Interferometer will operate in two modes; limb scanning (during even-numbered revolutions) and nadir scanning (during odd-numbered revolutions). During limb scanning operations, the instrument will scan the earth from side to side from the tangent point to a depression angle of about 20° below the tangent point. The scanning is provided internally to the instrument through a scan-driven planar mirror. However, the initial pointing is provided by the APS. Nadir scanning will occur when operating in conjunction with the Laser Sounder (Instrument 213) to measure resonance backscatter energy. For this operation, the instrument must be co-aligned with Instrument 213 to within 1 milliradian using the respective APS on pallets A-1 and A-3 and the optical transfer system between the two pallets to transfer the attitude reference.

Inflight calibration of this instrument will be performed throughout the mission using integral spectral/radiance calibration lamps.

a. Controls will include:

   (1) Power control.

   (2) Selection of operating modes (interferometer, photometer or infrared photometer).

   (3) Selection of scan rate.

   (4) Instrument pointing using APS to within $\pm 0.06°$ of the Instrument 213 reference axes.

b. Displays will include:

   (1) Scientific data (interferometer diagnostics and parameters for plotting intensity versus wavelength).

   (2) Verification of operating mode and scan rate.

   (3) Photomultiplier tube power supply voltage and dark current calibration data.

   (4) Detector temperature.

   (5) Relative pointing angle of instrument.

   (6) Integration time.

   (7) Instrument operational status monitors.

6.5.2.3.2.4 Instrument 126

The Infrared Interferometer will operate in two modes; limb scanning and nadir scanning. The scanning function will be provided by the APS. During operation with the Laser Sounder (Instrument 213), the two instruments must be co-aligned to within ±0.1°. Since Instrument 126 will be in AIM 3B and Instrument 213 will be in AIM 1A, the optical transfer between pallets A-1 and A-3 will be used to determine the attitude alignment. Instrument 126 will require cryogenic cooling of the detector to 4 K. A common set of storage tanks will supply make-up cryogen to both instruments 118 and 126.

Internally provided black body sources and the space background will be used for in-flight calibration.

a. Controls will include:

(1) Power control.

(2) Selection of scan rate.

(3) Selection of scan angle.

(4) Duration of data take.

(5) Inflight calibration.

(6) Control of instrument temperature using cryogenic cooling system.

(7) Initial pointing of instrument using APS to within ±0.1° of instruments 213 and 118 reference axes.

b. Displays will include:

(1) Spectrogram of observed data.

(2) Verification of spectral range.

(3) Verification of scan rate and angle.

(4) Relative pointing angle of instrument.

(5) Detector temperature and bias voltage.

(6) Instrument internal temperature.

(7) White light interferograms (for calibration).

(8) Instrument operational status monitors.

6.5.2.3.2.5 Instrument 213

The Laser Sounder will operate similar to a radar in which the laser beam will be directed towards the atmospheric mass under observation, generally toward the nadir using the APS. The receiver section will measure the reflected (backscatter) energy. The laser will be operated on both the dark side and the daylight side of the earth in conjunction with instruments 118, 124 and 126. Some question remains as to the effectiveness of the laser operation during the daylight, and this will be further assessed during the next phase of study.

a. Controls will include:

(1) Power control.

(2) Selection of wavelength to be emitted.

(3) Selection of pulse width and repetition rate.

(4) Instrument pointing using the APS to within ±0.1° of the reference axes of instruments 118, 124 and 126.

b. Displays will include:

(1) Indication of receipt of backscatter energy.

(2) Indication of pulse height and duration.

(3) Laser head temperature.

(4) Relative pointing angle of instrument.

(5) Instrument operational status monitor.

6.5.2.3.2.6 Instrument 532

The Gas Release Module will admit gases into the excitation chamber, and the gases will be elevated to an excited state by exposure to the solar flux introduced into the chamber. The excited gases will be observed by a monochromator. The ions produced in the chamber will be analyzed by a mass spectrometer. Gases will also be released into space and analyzed by the monochromator.

The LOS of the sun sensor on the excitation chamber will be pointed to within ±1° of the sun line such that sun sensor will be able to acquire the sun and control the reflection of the solar radiation into the chamber.

The monochromator will be calibrated in flight using a special light source attached to the system.

a. Controls will include:

   (1) Power control.

   (2) Selection of gas.

   (3) Selection of gas release mode (chamber or space release).

   (4) Gas release.

   (5) Control of gas pressure.

   (6) Monochromator grating control.

   (7) Mass filter control.

   (8) Instrument sun sensor pointing to within ±2.0° of sun line using APS.

b. Displays will include:

   (1) Verification of sun acquisition.

   (2) Verification of selected gas and gas mode.

   (3) Gas system pressure.

   (4) Chamber pressure.

   (5) Chamber photodiode signal.

   (6) Chamber temperature.

   (7) Monochromator intensity versus wavelength.

   (8) Mass filter ion intensity versus mass count.

   (9) Mass filter rf voltage.

   (10) Instrument operational status monitors.

6.5.2.3.2.7 Instrument 1011

The Ultraviolet Occultation Spectrograph will be pointed at the sun through the earth's atmosphere. The initial LOS will be at altitudes about 100 km or more above the point of tangency with the earth. The altitude will decrease as the Orbiter makes its revolution. A sun tracker will be used integral with this instrument to provide the control signal for sun tracking by the APS. Exposures will start just before detectable absorption. Ten or more one-second exposures will be made until the data is rendered useless by the reduced tangency altitude or the excessive absorption.

Inflight calibration will be achieved periodically using a calibrating source in front of the small telescope.

a. Controls will include:

   (1) Power control.

   (2) Exposure control and sequencing.

   (3) Opening and closing of protective door.

   (4) Film advance.

   (5) Calibration control.

   (6) Initial pointing of instrument to allow sun sensor to acquire the sun.

b. Displays will include:

   (1) Verification of door position.

   (2) Sun acquisition.

   (3) Verification of calibration source position and verification that it is on.

   (4) Film frame count.

   (5) Exposure timing.

   (6) Instrument operational status monitors.

6.5.2.3.3 Revolutions 32 through 47

During this span, the payload will operate as follows.

6.5.2.3.3.1 Instrument 116

This instrument will function in the same manner as it had during revolution 16 except that it will be operating in support of Instrument 303 (revolutions 32 to 42) and Instrument 304 (revolutions 43 to 47). The instrument will observe the effects of the accelerated particles on spectral emissions from the elements of the upper atmosphere. Subsystem support, control of the instrument and the displays required will be the same as that required during revolution 16 operations.

6.5.2.3.3.2 Instruments 118, 126, 213

These instruments will operate as they did during revolutions 17 through 31 except that operations will be at standby for about 50 minutes on the dark side of the earth. This period will begin about 17 to 18 minutes before the accelerators start to operate and will continue for 17 to 18 minutes after the accelerators are turned off.

The support subsystem operation will continue as before except processing and display of scientific data will not be required. Computer controls required will be the same as for revolutions 17 and 31 except that switching the instrument to and from the standby mode will be required.

6.5.2.3.3.3 Instrument 303

The Electron Accelerator will operate for 15 minutes each revolution, during revolutions 31 through 42, while on the dark side of the earth. At all other times, the instrument will be on standby status.

The accelerator will operate in a continuous dc, pulsed or modulated mode. When pulsed, the repetition rate and pulse duration will vary such that the duty cycle remains at 5 percent at maximum power. In the modulated mode, the amplitude of beam energy will vary from 0 to 100 percent at a frequency of 0 to 10 MHz with a 5 percent duty cycle at maximum power.

When energized, the accelerator will provide a beam of electrons with energies between 1 keV and 30 keV which will be used in conjunction with instruments 116 and 534 to study the excitation of the upper atmosphere and ionosphere elements, to map the magnetic field lines of the earth, to determine ionospheric electric field magnitude and direction, and to study plasma wave excitation in the ionosphere.

The instrument pointing requirement (< 2° error) will be provided by the Orbiter attitude control system.

a. Controls will include:

   (1) System power control.

   (2) Accelerating voltage control.

   (3) Control grid voltage and frequency control.

   (4) Diverging and converging lens voltages control.

   (5) X-Z and Y-Z sweep coil voltages control.

   (6) Control interlock with Triaxial Fluxgate (Instrument 536) to prevent accelerator operation when direction of earth's magnetic field could cause beam return.

b. Displays will include:

   (1) Power unit output voltage and current amplitude and wave shape.

   (2) Acceleration voltage and current amplitude and wave shape.

(3) Grid current amplitude and wave shape.

(4) Accelerator operational status monitors.

6.5.2.3.3.4 Instrument 304

The MPD Arc will operate for 15 minutes each revolution while on the dark side of the earth during revolutions 43 through 47. Simultaneous operation of instruments 303 and 304 are not planned because of the thermal dissipation constraint of the Orbiter ATCS.

The MPD Arc will operate in a pulsed mode with the pulse duration and rate controlled to keep the power drain on the Orbiter supply below 10 kW.

Instrument 304 is a plasma accelerator which will discharge currents up to 2×10^5 amperes. It will be used to study the excitation of the upper atmospheric and ionospheric elements, to trace and map the earth's magnetic field lines, to modify ionospheric conductivity in certain regions, and to generate plasma waves in the very low to extreme low frequency regimes.

The pointing requirement for this instrument ($< 2°$ error) will be provided by the Orbiter attitude control system.

a. Controls will include:

(1) System power control.

(2) MPD Arc plenum pressure control.

(3) Solid state switch (for high voltage) control.

(4) Interlock control with Magnetometer (Instrument 536) to prevent beam return due to direction of earth's magnetic field lines.

b. Displays will include:

(1) Discharge current and voltage pulse amplitude and waveforms.

(2) MPD Arc operational status monitors.

6.5.2.3.3.5 Instrument 532

The operation of the Gas Release Module during this span will be concurrent with the operation of the accelerators (instruments 303 and 304). The mode will be used to release the gases into space and this will occur during the dark phase of the orbit rather than during the daylight side. The mode for gas release into the excitation chamber will not be used during this phase and therefore the sun sensor and the spectrometer will not be required. All other operations will be the same as those described during revolutions 17 through 25. Controls and displays will not include those associated with the gas release into the excitation chamber.

6.5.2.3.3.6 Instrument 534

The OBIPS will operate for 30 minutes during each revolution from revolutions 32 through 47. The 30-minute span will start 7 or 8 minutes prior to the operation of the accelerator (instruments 303 and 304) and end about 7 or 8 minutes after accelerator operation terminates.

The OBIPS will be used to obtain images of faint, transient atmospheric energy phenomena such as artificial or induced aurorae and glows produced by chemical tracers. The electron and MPD Arc accelerator beams will be used to provide the energetic particles required for the excited states. The images produced by the beams will also be picked up by the Orbiter TV cameras.

The orientation of the OBIPS reference must be known to within 0.02° of the Orbiter reference. Initial pointing and subsequent target tracking will be provided by the APS.

A cover will be necessary to prevent contamination of the optics. This will be provided by a door located in front of the lens which will be opened just before data measurements are made and closed when the instrument is on standby status. The instrument can be damaged by direct sunlight and operational controls will be provided to prevent direct solar incidence onto the photometers through the lens.

An inflight calibration will be performed. The calibration source will be selected during the next study phase.

a. Controls will include:

   (1) Power control.

   (2) Opening and closing of door.

   (3) Aperture control.

   (4) Selection of filter (if turret is used).

   (5) Image processing gain control.

   (6) TV pointing and controls mode.

   (7) Calibrator source position and light control.

   (8) Instrument pointing control using APS.

b. Displays will include:

   (1) TV monitor.

   (2) Door position verification.

   (3) Filter selection verification (if turret is used).

   (4) TV camera direction indicator.

   (5) Calibrator position and light indicators.

   (6) Instrument operational status monitor.

6.5.2.3.3.7 Instrument 536

The Triaxial Fluxgate will be deployed on a boom during (or before) revolution 32. The instrument will be used to measure the direction and amplitude of the earth's local magnetic field.

Data from the instrument will be used to provide an interlock for accelerator operations if the earth's magnetic field direction is such that beam return might occur.

There are no special pointing requirements for this instrument but the knowledge of the reference axes orientation must be accurate to within 0.5°.

The boom will be retracted at the end of this phase. If the retraction mechanism malfunctions, the boom and instrument will be jettisoned.

a. Controls will include:

   (1) Power control.

   (2) Boom extension and retraction control.

   (3) Boom jettison control.

b. Displays will include:

   (1) Magnetic field lines direction relative to Orbiter reference axes and field strength.

   (2) Verification of boom extension and retraction.

   (3) Instrument operational status monitors.

6.5.2.3.3.8 Instrument 549

The Gas Plume Release instrument is a diagnostic tool used in conjunction with the Electron Accelerator (Instrument 303). It will be used to determine accelerator-produced electron beam flux density and emergence angles. This function will be performed by the release of gas into the electron beam which will allow visual observation of the beam profile OBIPS, or the Orbiter TV camera will be used to pick up the beam profile image.

The instrument will operate concurrently with Instrument 303 only during revolutions 32 through 35 since it is not expected that the beam characteristics will subsequently change from that initially observed.

a. Controls will include:

   (1) Power control.

   (2) TV camera angle and mode control.

   (3) Gas release sequence control (synchronized with Instrument 303 operation).

b. Displays will include:

   (1) TV display of images.

   (2) TV camera angle relative to Orbiter reference axes.

   (3) Instrument operational status monitors.

6.5.2.3.3.9 Instrument 550

The Faraday Cup Retarding Potential Analyzer Cold Plasma Probe is a diagnostic instrument which will be used to supplement the operation of Instrument 549 in determining the electron beam characteristics of Instrument 303. It will also be used to determine the exhaust potential of the Instrument 304 plasma. The instrument will be mounted on a boom installed in the AIM 1B. The instrument will scan the beam fields in a raster scan using the APS which will be controlled through a software program resident in the subsystem computer or loaded from mass memory.

There are no special pointing requirements other than that imposed on the boom system (< 0.5° knowledge of instrument reference axes). The boom will be retracted at the end of this phase. If the boom retraction mechanism malfunctions, the boom and instrument will be jettisoned.

a. Controls will include:

(1) Power control.

(2) Faraday cup inner and outer grid potential control.

(3) Retarding potential analyzer outer, retarding and suppressor grid potential control.

(4) Boom extension and retraction control.

(5) Instrument scan sequence control.

(6) Boom jettison control.

b. Displays will include:

(1) Faraday cup collector current amplitude versus instrument position.

(2) Retarding potential analyzer collector current and retarding potential versus instrument position.

(3) Cold plasma probe current and floating potential versus instrument position.

(4) Boom position relative to Orbiter reference.

(5) Boom extension and retraction verification.

(6) Instrument operational status monitors.

6.5.2.3.4 Revolutions 48 through 80

During this phase of the mission, the operations of instruments 118, 122, 124, 126 and 1011 will be identical to those conducted during revolutions 17 through 31. The controls and displays will also be the same.

Instrument 1002 will operate once at mid-daylight during revolution 80. Its operations will be identical to those conducted during revolution 16. The controls and displays will also be the same.

Instruments 116, 303, 304, 532, 534, 536, 549 and 550 will be on standby or powered down. The support subsystems will be operational during this period.

At the end of this phase, all experiments will have been completed.

6.5.2.3.5 Crew Operations Timeline (Revolutions 1 through 81)

A PS and a MS will operate and monitor the payload and payload subsystems from their respective consoles in the aft crew station. Since ASF requires 24-hour operation, two teams each consisting of a PS and a MS will operate on 12-hour shifts with the last hour of each 12-hour shift serving as a shift-over period for the new team.

The control of the instruments will be accomplished by grouping them into operating sequences based on the instrument operating timeline (table 6.5.2-1). These sequences will be preprogrammed in the payload computer and will be initiated by the PS. The initiation can be accomplished by inserting a "Δt" to initiate a sequence into the computer via the keyboard, thus allowing the PS and MS to check system status, set up parameters well in advance of the sequence initiate time, and allow for other setups and monitoring tasks.

Table 6.5.2-2 shows a preliminary crew task timeline for operating the ASF mission.

TABLE 6.5.2-1. — ASF INSTRUMENT OPERATING TIMELINE

Sequence	Sequence Duration	Instruments
1.	Rev. 16 to Rev. 81	Subsatellite
2.	Rev. 16 to Rev. 17	116
3.	a. Rev. 16 to Rev. 16-1/2 b. Rev. 80 to Rev. 80-1/2	1002
4.	Rev. 17 to Rev. 81	122, 124
5.	Rev. 17 to Rev. 32-1/2	118, 126, 213
6.	Rev. 32-1/2 to Rev. 48-1/2	116, 118, 126, 213, 303, 304, 534, 536, 549
7.	Rev. 36 to Rev. 36-1/2	550
8.	Rev. 48 to Rev. 81	118, 126, 213

TABLE 6.5.2-2. — CREWMAN TASK TIMELINE

Rev.	Mission Specialist (MS)	Payload Specialist (PS)
1-12	1. Set up payload subsystems: a. electrical b. thermal c. data management d. computers e. subsatellite	1. Set up payload D&C 2. Check out payload instruments 3. Set up APS
12-16	1. Deploy subsatellite 2. Monitor subsatellite data and payload subsystems	1. Set up for Seq. 2, Seq. 4 and Seq. 5
16-17	1. Monitor subsatellite data and payload subsystems	1. Initiate Seq. 2 and Seq. 3 2. Monitor Seq. 2 and Seq. 3
17-32-1/2	1. Monitor subsatellite data and payload subsystems	1. Initiate Seq. 4 and Seq. 5 2. Monitor Seq. 4 and Seq. 5 3. Set up for Seq. 6
32-1/2-36	1. Monitor subsatellite data and payload subsystems	1. Initiate Seq. 6 2. Monitor Seq. 4 and Seq. 6
36-36-1/2	1. Monitor subsatellite data and payload subsystems	1. Initiate Seq. 7 2. Monitor Seq. 4, Seq. 6 and Seq. 7
36-1/2-48	1. Monitor subsatellite data and payload subsystems	1. Monitor Seq. 4 and Seq. 6 2. Set up for Seq. 8
48-80	1. Monitor subsatellite data and payload subsystems	1. Initiate Seq. 8 2. Monitor Seq. 4 and Seq. 8 3. Set up for Seq. 3
80-81	1. Monitor subsatellite data and payload subsystems	1. Initiate Seq. 3 2. Monitor Seq. 3, Seq. 4, and Seq. 8
81	1. Retrieve subsatellite	

NOTE: Seq = Sequence

This preliminary timeline presents no crew overload periods for setting up and monitoring the instrument sequences.

6.5.2.3.6 <u>PDS Retrieval (Revolutions 81 through 95)</u>

At the beginning of this phase, power to the instruments will be turned off and the APS will be retracted and stowed in place. If either of the APS fails to return to its stowed position or if more than two of the redundant latching mechanisms fail, the entire APS will be jettisoned from the payload bay. Individual microswitches on the latches indicate the positive latch condition. After the APS are safely stowed, the Orbiter will rendezvous with the deployed PDS. Rendezvous can be automatic for the initial approach and manual for the last stage, or the entire rendezvous operation can be under manual crew control if visibility of the PDS is unimpaired. Relative range and range rate will be displayed at the on-orbit station.

When the final approach is completed and the Orbiter is about 15 meters (50 feet) from the PDS, the RMS will be deployed. The PDS grab collar will be grasped by the RMS attach mechanism. Upon verification of positive capture, the PDS will be retracted into the payload bay and reseated onto the PDS retention structure on Pallet A-2. The tapered mount cone assists in guiding the PDS to the proper location on the structure. When the PDS is fully seated on the retention structure, the collet piston will be automatically actuated, setting the latches and locking the PDS to the structure. Microswitches will be used to indicate positive seating and locking of the PDS. If the PDS fails to seat or the locking mechanisms malfunction, the PDS will be lifted out of the payload bay and left clear of the Orbiter.

After the PDS is safely stowed and latched into place, the RMS will be disconnected from the PDS grab collar. The RMS will then be returned to its stowed position. The baseline Orbiter configuration has the provisions to jettison the RMS if safe stowage cannot be achieved.

6.5.2.3.7 Preparation for Re-Entry (Revolutions 96 through 112)

During this last on-orbit phase, high pressure gases and cryogens will be dumped from the payload systems using the dump lines provided by the Orbiter. Power to all payload systems except for those required to verify safety will be removed. The payload bay doors will be closed and the Orbiter systems readiness checks will be performed.

The Orbiter will be maneuvered to its retro-attitude and the Orbiter maneuvering system engines will be fired to provide the delta velocity required.

6.6 RE-ENTRY, DESCENT AND LANDING

During this phase, the payload will be passive.

6.7 POST-LANDING

After landing the Orbiter will be transported to the OPF to allow ground crew access, the payload bay doors will be opened and the films will be removed from the cameras. The tape recorders in the aft crew station will also be removed. The films and tapes will be transported to the ASF dedicated data handling facility.

The films and tapes will be catalogued, stripped, data reduced, processed, reformatted, re-recorded and stored or transferred to the responsible scientific centers.

The ASF payload will be removed from the Orbiter payload bay and loaded into the payload transporter. The transporter will then be sealed and shipped to the payload integration facility.

At the payload integration facility, full functional and performance tests will be performed to determine health status of the support subsystems and components. The instruments will be tested to the extent possible at this facility or will be removed and returned to the supplier for detail tests.

Damaged or marginal performance elements will be replaced and the payload will be reconfigured for the next mission.

The logistic aspects of operations are yet to be defined. Maintenance, repair, spares and inventory management, transportation and handling, and packaging requirements and approaches will be further defined in the next study phase.

7.0 ASF SYSTEM DEVELOPMENT STATUS AND REQUIREMENTS

7.1 INTRODUCTION

One objective of this study was to assess the potential of a 1981 ASF mission. Accordingly, three schedule hard point requirements relative to delivery of a flight-ready ASF payload were assigned for this phase of the study: (1) the launch date of July 1981, (2) the payload hardware delivered to KSC at T-6 months, and (3) the payload hardware to integration site at T-9 months.

These requirements are depicted in table 7.1-1. This firm requirement precipitated a comprehensive look at the design status and development lead times for all entities comprising the conceptual ASF payload system. The required program functions may be categorized as follows:

a. Development, test, and acceptance of individual instrument and subsystem blocks.

b. Development, test, and acceptance of software packages.

c. Assembly and test of a qualification ASF system (4 different pallet configurations).

d. Assembly and checkout of a flight model of the ASF system.

e. Initial installation/checkout of the ASF payload system with Orbiter.

f. Prelaunch activities. This category contains those functions which are spanned by the above T-9 months delivery requirement. Thus, category (a) through (f) functions must be accomplished between authority-to-proceed and T-9 months. The category (a) functions must be completed prior to start of category (b) or (c) functions, i.e., engineering models must be successfully tested prior to fabrication of the qualification of flight model hardware blocks. For realistic planning it is assumed that production of the qualification and flight units will not be sequential, and the flight model production will follow the

TABLE 7.1-1

SCHEDULE CONSTRAINTS

	CY 1977												CY 1978												CY 1979												CY 1980												CY 1981											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
LAUNCH DATE																																																						△						
PAYLOAD HDWRE TO KSC																																																△												
PAYLOAD HDWRE TO INTEGRATION SITE																																													△															

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qualification model. Another assumption made during this study was that the initial installation, checkout or integration of the ASF payload with the Orbiter will be performed with qualification units of the payload hardware (4 pallets) after completion of a qualification test program at the payload system level (4 pallet configurations).

With these assumptions, an estimate of nine months schedule block is programmed between delivery of the qualification model payload hardware and the T-9 months milestone. The nine months time block will optimistically provide time for the first assembly and qualification testing of four different pallet-mounted payload configurations. The block will also provide time for the initial installation, fit/functional test and checkout of the ASF payload (four different pallet configurations) in the Orbiter. This nine months will not be a serialized function; but rather, it is a planning provision for defining lead-time requirements to develop an overall ASF payload system. This nine months schedule requirement is referred to as a first-article integration time.

7.2 INSTRUMENTS

7.2.1 PRIME

A prime instrument is one which has been described by the scientist for a particular experiment or group of experiments.

The prime instruments are all treated in detail in section 2.0 and 4.0 and appendix B. It is sufficient at this point to reemphasize two points.

a. The ID's (appendix B) and ED's (appendix A) generated as part of this study are preliminary and require more refinement by the NASA AMPS SDWG.

b. Many of the preliminary ID's contain specifications which are beyond current state-of-art instrumentation technology.

7.2.1.1 Technical Considerations

This section summarizes the more obvious technical considerations (for each prime instrument) influencing development time required to produce instruments for the ASF payload.

a. Instrument 116 (Airglow Spectrograph). Similar instruments have been flown and used successfully on sounding rockets. Some development difficulty may be expected in achieving 300 Å with the normal incidence grating and with the focusing magnet coil required. Changing direction of view with the collimating mirror complicates pointing operation. Extreme care must be exercised in integrating into the ASF payload due to the instruments susceptibility to stray magnetic fields and EMI. Technical risks are low.

b. Instrument 118 (Limb Scanning IR Radiometer). A smaller non-cryogenic radiometer with lesser capability will operate on the Nimbus "F" spacecraft. Unmanned satellites in recent years have carried, as payloads, radiometers which are somewhat similar to the instrument described although they were of a lesser degree of sophistication. The cooling of the optics required by the instrument described is often quite risky. Problems are anticipated in protecting against off-axis interference in achieving suitable spectral rejection. Minimizing heat loss, cryogenic leaks, and maintaining proper cryogenic temperature pose difficult engineering problems. Technical risks are rated high.

c. Instrument 122 (UV-VIS-NIR Spectrometer). Several similar instruments have successfully flown on sounding rockets and a satellite version of the proposed instrument is scheduled to be flown on the Naval Research Laboratory (NRL) SOLRAD II Satellite in November 1975. The small grating in this instrument may make it difficult to obtain the desired dynamic range. Technical risks are low.

d. Instrument 124 (Fabry-Perot Interferometer). Fabry-Perot Interferometers with significantly less sophisticated components have flown successfully in rockets. These instruments used ruggedized Piezo-Electric scanning etalons of the type considered for this instrument but smaller in diameter. The large etalons required for this unit will be difficult to produce and keep in proper adjustment through a launch environment. To achieve the required degree of optical flatness over the large etalon diameters requires advancing the state-of-the-art in optical component fabrication. The necessity to maintain extreme optical flatness while under thermal and mechanical stress may also require significant advances in optical material. Technical risks are high.

e. Instrument 126 (IR Interferometer). Laboratory models of conceptually similar spectrometers have been developed and others with significantly reduced technical specifications have been developed for aircraft operation. However, significant development effort remains to be done on this instrument to achieve the full range of specifications and provide the cryogenic cooling required. Technical risks are medium.

f. Instrument 213 (Laser Sounder). Fixed wavelength lasers have been employed in both airborne and ground installations to detect and profile various atmospheric constituents. A reasonably high-powered tunable dye laser has been used in a mobile van for profiling sodium atoms. There has not been a forerunner instrument that has accomplished all the capabilities desired for this application. Significant advances must be made in energy output capability, laser efficiency, and operational lifetime of dye materials. Useful measurements can be achieved, however, of at least some of the constituents by using different laser heads and wavelengths for different applications. Technical risks are high.

g. Instrument 303 (Electron Accelerator). Similar devices with significantly lower capability have been flown on sounding rockets. Current devices have a maximum output energy capability of approximately 5,000 joules which is about a factor of 20 less than that envisioned for the proposed instrument. To achieve the desired output energy, voltage levels and current levels will present some difficult engineering problems in the design of the capacitor storage bank and the output switching circuitry. Technical risks are medium.

h. Instrument 304 (Magnetoplasmadynamic (MPD) Arc). A plasma accelerator somewhat similar to the one proposed but with significantly lower output capability has been flown on unmanned rockets. This device employs the same energy storage capacitor bank as that used for Instrument 303. Significant development problems other than those associated with the development of the capacitor bank and output switching circuitry are not anticipated. Technical risks are medium.

i. Instrument 532 (Gas Release Module). Development of this instrument is essentially a combining of subsystems that have flown successfully in space before. No particularly difficult development or integration problems are anticipated. Technical risks are low.

j. Instrument 534 (Optical Band Imager and Photometer System (OBIPS)). All major components of this instrument have been developed and employed in either spacecraft, aircraft, or field applications. The major significant problem remaining is the design of a suitable baffle and the integration of the various items into a unified assembly capable of meeting the pointing requirements. Technical risks are low.

k. Instrument 536 (Triaxial Fluxgate Magnetometer). Several fluxgates have been flown, however, further instrument development is required to achieve the desired sensitivity. Technical risks are low.

l. Instrument 550 (Particle Accelerator System Level II Diagnostics). This diagnostic instrument package comprises a Faraday cup, a Retarding Potential Analyzer, and a Cold Plasma Probe. Retarding potential analyzers have flown on several satellites. The Faraday cup and the Cold Plasma Probe are passive sensors used extensively in ground based ion and plasma studies. Significant engineering design effort will be required to increase the high voltage capability of the Retarding Potential Analyzer and to integrate the three units into a suitable packaging configuration. Technical risks are low.

m. Instrument 1002 (Pyrheliometer/Spectrometer). This instrument is currently under development. Major components have been built and are in use. No significant development problems are anticipated. Technical risks are low.

n. Instrument 1011 (Ultraviolet Occultation Spectrograph). The basic spectrograph has been designed and breadboarded. Subsystems used have all been developed and employed in previous applications. No uniquely difficult development problems are visible at this time. Technical risks are low.

7.2.1.2 Development Schedule Requirements

Table 7.2.1-1 depicts the estimated lead times required to produce each of the prime ASF instruments. The production of instruments encompasses all the necessary functions between project approval and delivery of a qualified and acceptance-tested flight instrument to a pallet integration facility. The following typical functions are performed in the production of a flight instrument.

a. Program start upon authorization-to-proceed.

b. Procurement cycle and preliminary design studies.

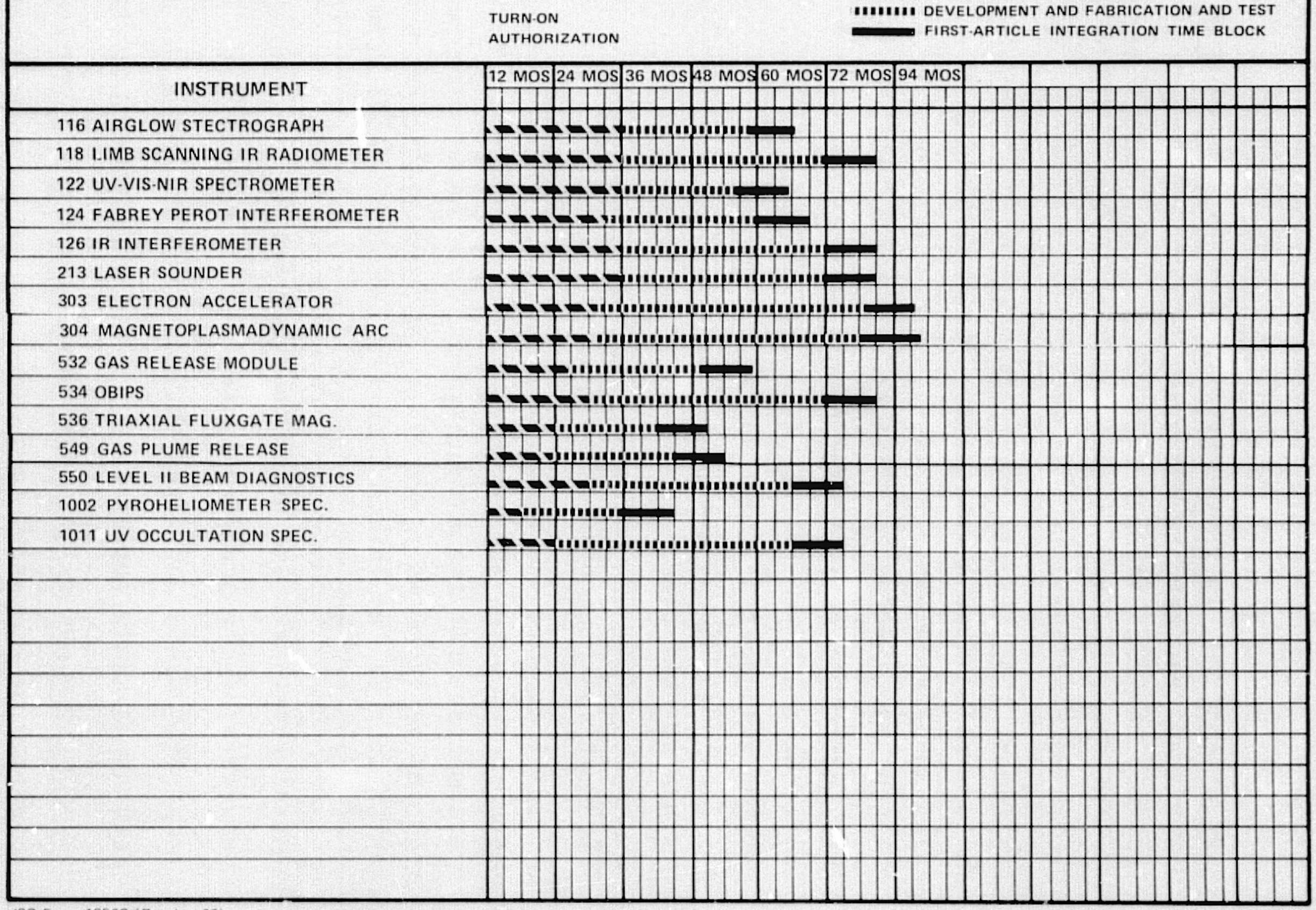
c. Procurement cycle and final design study.

d. Procurement cycle and prototype model development and test.

e. Qualification and flight model development and acceptance test.

f. Qualification testing.

TABLE 7.2.1-1 ASF PRIME INSTRUMENT DEVELOPMENT LEAD TIMES



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g. Flight model acceptance testing,

h. Government acceptance.

Table 7.2.1-1 shows a spread of from 24 to 66 months estimated for production of all ASF prime instruments. This is due to the diverse design schedules. One category is those instruments of current design, i.e., similar instruments have been produced for other uses. These instruments require some study to define minor modifications necessary to adapt them for ASF use. The second category is those instruments whose basic design is not current; they must be developed, and/or modified, and then fully qualified. These instruments are extremely complex and sophisticated. In many cases the design is pressing current state-of-the-art technology but can be developed with adequate funding. The third category encompasses those (futuristic) instrument concepts which could have major impact to flight schedules and financial resources.

Table 7.2.1-1 includes the nine months first-article integration time block which must be considered in planning the overall system development program.

7.2.1.3 Conclusions

The following schedule ground rules were directed for this study.

a. Assume project approval on January 1, 1977.

b. Deliver an assembled and checked-out ASF payload (4 individually configured pallet assemblies) to an integration site by October 1, 1980.

Table 7.2.1-2 depicted the results when payload development and qualification lead time requirements are superimposed on the January 1, 1977, and October 1, 1980, schedule hard points. They are grossly incompatible. This incompatibility necessitated consideration of substitute instruments and other trade-offs treated in the following sections of this report.

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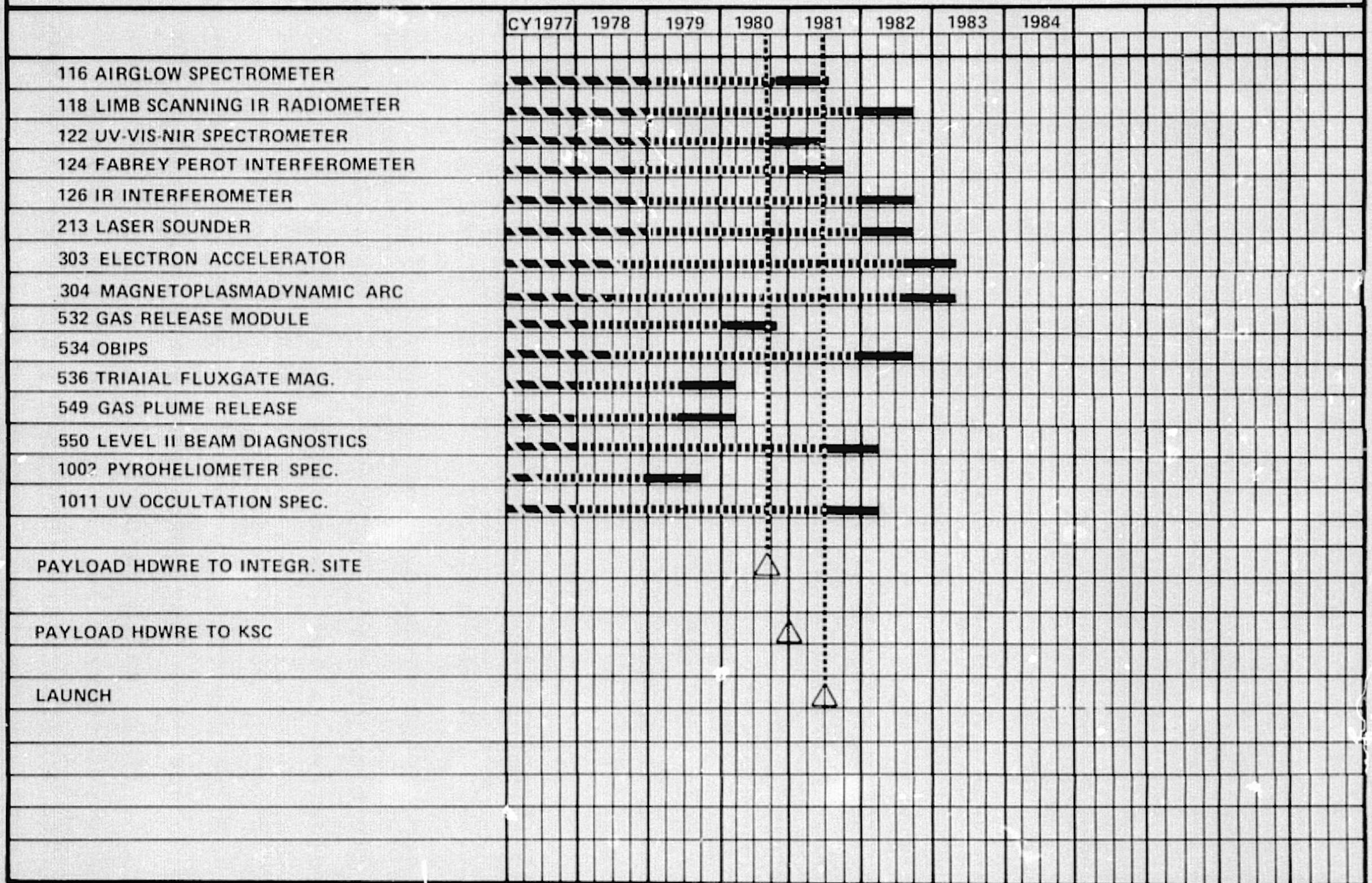
TABLE 7.2.1-2 ASF PAYLOAD DEVELOPMENT REQUIREMENTS
VERSUS PROGRAM SCHEDULE HARD POINTS

PROCUREMENT AND STUDY
DEVELOPMENT AND FABRICATION AND TEST
FIRST-ARTICLE INTEGRATION TIME BLOCK

TURN-ON AUTHORIZATION



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7.2.2 SUBSTITUTE INSTRUMENT CONSIDERATIONS

7.2.2.1 Introduction

The ASF experiments have been reviewed for suitability of existing instruments that may be considered for use in lieu of prime instruments for program schedule and/or economic trade-off considerations. Such instruments are referred to as substitute instruments in this report. They are defined as instruments that are fully developed and have been used to performed similar observations. While they may not provide the full degree of scientific fulfillment that is anticipated from those instruments described by scientists of the AMPS SDWG, they will nevertheless provide valuable and useful data.

Economics and time constraints require that the sensor portion of the instrument be complemented with the most cost effective off-the-shelf subsystems. Since weight is not a critical factor for the ASF pallet-only mode payload, considerable flexibility exists in the selection of support subsystem hardware which are already developed. In addition, equipment installation in the pressurized crew compartment and the igloo allow consideration of orbiter or even aircraft types of hardware. These factors should result in considerable reduction in the cost of support subsystems.

The Orbiter will have EMI, dust and gas environmental contamination which may be manifested as background noise. Therefore, the advanced state-of-the-art sensitivities desired of many of the prime instruments may not yield usable data that could not be acquired with sensors that are already developed. Instruments in existence which are less sensitive than those specified by the AMPS SWDG but which are adequate for measuring data above the Orbiter background noise and are readily available to fill many observational requirements.

7.2.2.2 Technical Considerations

The substitute instruments listed in table 7.2.2-1 for ASF are a collection of instruments from many other programs wherein weight was critical. As a result of the Orbiter's larger payload volume and weight capability, they can now be used simultaneously on the same mission. Key spacecraft are AE, Nimbus, ISEE, GEOS, OGO, OSO, ISIS, and ATS. Table 7.2.2-1 lists the prime instrument complement for the ASF payload and indicates whether a potential substitute has been identified by the study team. A candidate substitute has been identified for seven of the 15 prime instruments. More may be in existence or in development in the academic and/or industrial communities. A continuing search is recommended as follow-up action to this study.

The following pages present a technical comparison of each of the seven prime instruments for which a candidate substitute has been identified.

7.2.2.3 Development Requirements

Table 7.2.2-2 shows a comparison of development requirements for the ASF prime instruments and the potential substitutes identified to date. It must be emphasized that the scientific suitability of these candidate substitutes has not been assessed. Also the development lead times are estimates based on the preliminary information currently available. The purpose of this comparison is to indicate availability of possible substitutes and the impact that the use of these substitutes might have on schedules and costs. Therefore, these estimates are carried forward in subsequent sections as potential trade-off factors.

TABLE 7.2.2-1. — SUBSTITUTE INSTRUMENTS

Instrument	Substitute
116	No candidate substitute
118	118X Nine-channel radiometer
122	No candidate substitute
124	124X (Several possible candidates)
126	126X Instruments from Nimbus satellites
213	No candidate substitute
303	303X Accelerators flown on sounding rockets
304	No candidate substitute
532	No candidate substitute
534	534X Photometers flown on ISIS, DMSP satellites
536	536X Commercially developed magnetometers
549	No candidate substitute
550	No candidate substitute
1002	1002X Instrument from Nimbus satellites
1011	No candidate substitute

COMPARISON OF PRIME/SUBSTITUTE INSTRUMENTS

	Prime	Substitute
Instrument -	118-Limb Scanning Infrared Radiometer	Lower Atmosphere Composition and Temperature Experiment (LACATE)
Configuration -	Cryogenically cooled instrument in dewar construction; 60 cm to 100 cm clear aperture; detectors are copper-doped or gold-doped germanium; 12 channels.	Cryogenically cooled instrument in dewar construction; 20 cm clear aperture; detectors are Hg:Cd-Te; 10 channels.
Specifications -		
Physical measurements:	3 μm to 40 μm	6 μm to 18 μm
Resolution:	(TBD)	0.5 mr (spatial) (TBD) (spectral)
Sensitivity:	1 to 5 x 10^{-12} W cm^{-2} sr^{-1} μm^{-1}	(Not known)
Field-of-view:	0.02° desirable; 0.08° acceptable	0.04° x 0.11°
Power:	15 W (standby) 100 W (operating)	34 W
Physical dimensions:		
Size:	4.52 cu m	0.18 cu m
Weight:	115 kg	77 kg
Other:	Dynamic range=10^9, off-axis rejection=(TBD,10^{-6}); nutates and scans 10° each side; dewar operates at 28°K or 77°K; detector at 4°K	Methane/ammonia cooler, operates at 80°K; detector temp=80°K; cooler is mechanical.
Constraints -	Operation must be completed before cryogen is exhausted.	(Not known)
Procurement -		
Design status:	Conceptual only	Design has been flown in space
Delivery time:	36 months	18 months
Relative cost:	100 percent	12.5 percent
Remarks -		Detectors and filters would require change; nutating scanning system would be added. System has been flown in balloons.

COMPARISON OF PRIME/SUBSTITUTE INSTRUMENTS

	Prime	Substitute
Instrument -	124-Fabry-Perot Interferometer	Beamont Fabry-Perot Interferometer
Configuration -	Combination of 23 cm Fabry-Perot interferometer, photometer with variable frequency filter and an Infrared photometer.	(TBD)
Specifications -		
Physical measurements:	2000 Å to 10 μm	Selected wavelengths
Resolution:	1 Å (spectral) 3 km (spatial)	0.015 Å
Sensitivity:	25 detector photons 5^{-1} $Raleigh^{-1}$ (Mode I)	1° circle
Field-of-view:	2 mrad (Mode I) ranging to 50 μm (Mode II)	50 W
Power:	14 W	50 W
Physical dimensions:		
Size:	0.86 cu m	0.012 cu m } excluding telescope
Weight:	45 kg	10 kg } excluding telescope
Other:		
Constraints -	No specified constraints	Not known
Procurement -		
Design status:	Conceptual only; concept proven	Versions have flown on OGO-6
Delivery time:	24 months	12 months
Relative cost:	100 percent	28 percent
Remarks -	25 cm etalon	Requires attachment to larger telescope and adding selective filters for wavelengths of interest. Would only measure preselected discrete lines.

COMPARISON OF PRIME/SUBSTITUTE INSTRUMENTS

	Prime	Substitute
Instrument -	126-Infrared Interferometer	(Unnamed) Michelson Interferometer
Configuration -	Michelson configuration interferometer; encased in dewar housing; cryogenically cooled; 60 cm telescope; detectors; Hg:Cd-Te up to 50 μm; InSb above 50 μm; instrument has four ranges.	Double-pass interferometer; has solar tracker with 0.25° accuracy for absorption measurements; digitally stepped or continuous movement; can be used for emission measurements.
Specifications -		
Physical measurements:	1 μm to 150 μm, in four ranges	1 μm to 8 μm
Resolution:	0.05 cm^{-1}	0.25 cm^{-1}
Sensitivity:	10^{-11} W cm^{-2} sr^{-1} μm^{-1}	(Not specified)
Field-of-view:	0.1°	(Not specified)
Power:	10 W (standby); 25 W (operating)	∿30 W
Physical dimensions:		
Size:	0.45 cu m	0.3 cu m
Weight:	114 kg	100 kg
Other:	Dynamic range = 10^5; off-axis rejection = $>10^{-6}$; signal-to-noise ratio ratio = 100:1	
Constraints -	Protect against contamination; use before cryogen supply has been exhausted.	
Procurement -		
Design status:	Design concept only	Has been flown on Nimbus 4
Delivery time:	36 months	9 months
Relative cost:	100 percent	2.5 percent
Remarks -	Dewar and cryogen designed to maintain instrument at internal temperature of 77 K or 28 K depending on cryogen; detector operates at 4 K.	Non-cryogenic; designed for nadir observations from satellite; ruggedized for aircraft vibration; has been flown on Concorde. Does not have sufficient resolution for upper atmosphere wind speed measurements.

COMPARISON OF PRIME/SUBSTITUTE INSTRUMENTS

	Prime	Substitute
Instrument -	303-Electron Accelerator	Electron Echo Experiment
Configuration -	DC instrument; pulsed or modulated heated cathode electron gun with magnetic beam steering capability; beam modulation capability to 10 MHz.	Battery powered accelerator with ten electron guns; deployable collector screen to prevent build-up of charge on carrier vehicle.
Specifications -		
Physical measurements:	1 keV to 30 keV	9.5 keV
Resolution:	0.1 (max)	(Not known)
Sensitivity:	0-7 Amperes	0.5 Amperes
Field-of-view:	±5° (max)	(Not known)
Power:	400 W (standby); 5 kW (avg); 10 kW (max)	∿5 kW (average)
Physical dimensions:		
Size:	15.75 cu m	2.4 cu m (Collector screen folded)
Weight:	740 kg	∿300 kg
Other:	Shares some of its volume and weight with other accelerators, if they are flown.	
Constraints -	Cathode may be contamination sensitive. Pointing with respect to magnetic field restricted because of beam return to spacecraft. Operate above 200 km.	(Similar to those of Instrument 303)
Procurement -		
Design status:	This instrument not designed	Instrument has flown on Aerobee
Delivery time:	48 months	24 months
Relative cost:	100 percent	28 percent
Remarks -	Problems involving charge build-up and high voltage discharge and corona will require study.	(Same as Instrument 303)

COMPARISON OF PRIME/SUBSTITUTE INSTRUMENTS

	Prime	Substitute
Instrument -	534-Optical Band Imaging Photometer	Multifilter TV Camera
Configuration -	System has 2 TV camera-UV System, and Visible-NIR; 2 monochromatic radiometers, all on the same line-of-sight. Large light shields are used.	Wide angle (150°) TV camera with beam compression; filter wheel with 4 tilting filters; SEC time integrating TV tube; minicomputer for exposure cycling, image processing; digital image processing; B&W and color monitors.
Specifications -		
Physical measurements:	Monochromatic images are presented and spot monochromatic measurements made.	(Not specified)
Resolution:	0.02° (spatial)	(Not specified)
Sensitivity:	10^{-7} footcandles at TV faceplate	(Not specified)
Field-of-view:	16°	150°, with beam compression
Power:	50 W	550 W
Physical dimensions:		
Size:	2.5 cu m	2.8 cu m
Weight:	100 kg	318 kg
Other:		
Constraints -	Protect instrument from high light levels in field of view.	(Similar to those of prime instrument)
Procurement -		
Design status:	Conceptual only	Ground use; proposed for aircraft use
Delivery time:	24 to 36 months	9 months
Relative cost:	100 percent	50 percent
Remarks -	UV capability important in other AMPS missions, desirable in acclerator experiments.	Requirement for TV camera coverage of accelerator operation will be met by closed circuit camera installed as part of Orbiter baseline configuration.

COMPARISON OF PRIME/SUBSTITUTE INSTRUMENTS

	Prime	Substitute
Instrument -	536-Triaxial Fluxgate	Triaxial Fluxgate Magnetometer
Configuration -	Three sets of excitation and pick-off windings on high permeability core forms.	Essentially identical to prime instrument.
Specifications -		
Physical measurements:	Magnetic field vector	Magnetic field vector
Resolution:	N/A	N/A
Sensitivity:	±2 degree, $\pm 10^{-6}$ gauss	±2 degrees, $\pm 10^{-3}$ gauss
Field-of-view:	$4\ \pi$ sr	$4\ \pi$ sr
Power:	(TBD)	(TBD)
Physical dimensions:		
Size:	(TBD)	0.002 cu m
Weight:	(TBD)	
Other:		
Constraints -	Will only operate efficiently in EMI below 3×10^{-7} gauss RMS.	
Procurement -		
Design status:	(TBD)	Instruments are commercially available
Delivery time:	18 months	6 months
Relative cost:	100 percent	5 percent
Remarks -	Instruments have flown; some development may be required to achieve desired sensitivity. Requires space qualification.	Have flown on many spacecraft

COMPARISON OF PRIME/SUBSTITUTE INSTRUMENTS

	Prime	Substitute
Instrument -	1002-Pyrheliometer/Spectrophotometer	Pyrheliometer/Spectrophotometer
Configuration -	Pryheliometer and a spectrometer with parallel containers in a common package.	Pyrheliometer flown on NIMBUS R06 combined with quartz prism spectrometer.
Specifications -		
Physical measurements:	0.25 μm to 4 μm (spectrophotometer) 0.2 μm to 5 μm (pyrheliometer)	0.2 μm (min) to (TBD)
Resolution:	$\lambda/\Delta\lambda \sim 100$	(TBD)
Sensitivity:	0.5 percent (pyrheliometer) Spectrophotometer accuracy 2-5 percent	(TBD)
Field-of-view:	5°	5°
Power:	10 W	10 W
Physical dimensions:	30 x 30 x 10 cm	30 x 30 x 10 cu
Size:	9×10^2 cm^3	9×10^3 cm^3
Weight:	<10 kg	<10 kg
Other:		
Constraints -	Protection against contamination of calibrating radiation source is critical.	Same as 1002
Procurement -		
Design status:	Under development-models built	Pyrheliometer proven in space-nominal; development required.
Delivery time:	18 months	9 months
Relative cost:		
Remarks -		Will cover 99% of solar radiant energy.

TABLE 7.2.2-2. — DEVELOPMENT REQUIREMENTS PRIME INSTRUMENTS VERSUS CANDIDATE SUBSTITUTES

Prime Instrument/Substitute Instrument	Design Status	Development Time (MO) (see notes)	Relative Cost (%)
116 Airglow Spectrograph	10.0	67	100
No substitute identified	—	—	—
118 Limb Scanning Infrared Radiometer	5.0	80	100
118X Lower Atmosphere Composition & Temperature Experiment (LACATE)	10.0	30	12.5
122 UV-VIS-NIR Spectrometer/Photometer	5.0	18	100
No substitute identified	—	—	—
124 Fabry-Perot Interferometer	0.0	24	100
124X Blamont Fabry-Perot Interferometer	5.0	21	28
126 Michelson Infrared Radiometer	2.5	36	100
126X Michelson Interferometer	10.0	18	2.5
213 Laser Sounder	0.0	36	100
No substitute identified	—	—	—
303 Electron Accelerator	0.0	48	100
303X Electron Echo Experiment	10.0	33	38
304 Magnetoplasmadynamic Arc	0.0	48	100
No substitute identified	—	—	—
532 Gas Release Module	5.0	24	100
No substitute identified	—	—	—
534 Optical Band Imager & Photometer System	5.0	42	100
534X Multifilter TV Camera	7.5	21	50
536 Triaxial Fluxgate	TBD	18	100
536X Triaxial Fluxgate Magnetometer	10.0	15	5
549 Gas Plume Release	5.0	—	100
No substitute identified	—	—	—
550 Level II Beam Diagnostics Group	5.0	36	100
No substitute identified	—	—	—
1002 Pyrheliometer/Spectrophotometer	5.0	18	100
1002X Pyrheliometer/Spectrophotometer	5.0	18	30
1011 Ultraviolet Occultation Spectrograph	2.5	42	100
No substitute identified	—	—	—

NOTE: Design status and relative cost ratings are assigned as follows:

Concept state only	0
Laboratory breadboard exists	2.5
Operational componenets exist	5.0
Fully developed, not space operated	7.5
Operationally proven in space	10.0

Prime instrument costs are rated 100 percent. Substitute instrument costs are relative to prime costs.

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7.2.2.4 Conclusions

Estimated development times for the potential substitute and prime instruments (where no substitutes have been identified) are plotted in table 7.2.2-3 against the program schedule hard points. Incompatibility still exists for six of the ASF instruments. The table, when compared to 7.2.1-2, illustrates a trade-off potential significant enough to warrant a more detailed, follow-on investigation of possible substitute instruments; especially in view of a forthcoming refinement of ASF ED's and ID's from the NASA AMPS SDWG. The significance of this preliminary treatment is described in sections 8.0 and 9.0.

7.2.3 SUPPORT SUBSYSTEMS

The basic approach to developing the subsystem concept for the ASF pallet-only mode study was to utilize equipment planned for the Spacelab and Orbiter systems to the maximum extent possible.

The support subsystem equipment selection and development status are shown in table 7.2.3-1. Of the 33 major groups of elements listed, 13 are being developed by ERNO for the Spacelab program and seven are being developed by the NASA for the Orbiter. Five other items have been (or are being) used on various space vehicles and satellites. Only 8 of the major subsystem items require full scale development at this time. The major new development elements required for ASF are the following:

a. PCSS signal processing electronics.

b. A&A electronics.

c. PSS ASF unique C&D panels.

d. APS including gimbals, torques, and extendable column.

e. AIM or modules holding the instrument clusters.

f. Subsatellite retention/ejection mechanism.

TABLE 7.2.2-3 ASF DEVELOPMENT SCHEDULE REQUIREMENTS UTILIZING IDENTIFIABLE POTENTIAL SUBSTITUTE INSTRUMENTS

▬ ▬ ▬ PROCUREMENT AND STUDY
IIIIIIIIII DEVELOPMENT AND FABRICATION AND TEST
▬▬▬ FIRST-ARTICLE INTEGRATION TIME BLOCK

	CY1977	CY1978	1979	1980	1981	1982	1983	1984	1985
116 AIRGLOW SPECTROMETER									
118X LOWER ATMOS. COMPOS. & TEMP. EXPERIMENT									
124X BLAMONT FABREY PEROT INTERFEROMETER									
126X MICHELSON INTERFEROMETER									
213 LASER SOUNDER (NS)									
303X ELECTRON ECHO EXPERIMENT									
304 MAGNETO PLASMA DYNAMIC ARC (NS)									
532 GAS RELEASE MODULE (NS)									
534X MULTIFILTER TV CAMERA									
536X TRAXIAL FLUXGATE MAGNETOMETER									
550 LEVEL II BEAM DIAGNOSTICS GROUP (NS)									
1002X PYROHELIOMETER/SPECTROPHOTOMETER									
1011 UV OCCULATATION SPECTROGRAPH (NS)									
PAYLOAD HDWRE TO INTEG. SITE				△					
PAYLOAD HDWRE TO KSC					△				
LAUNCH					△				

NS = NO POTENTIAL SUBSTITUTE IDENTIFIED

TABLE 7.2.3-1. — SUPPORT SUBSYSTEM EQUIPMENT DEVELOPMENT STATUS

Equipment	Program	Supplier	Development Status
Pointing, Control and Stabilization			
1. Gyro Reference Assembly	Apollo, Skylab,	Honeywell, Delco, Kearfott	Existing, spaceflight proven
2. Star Tracker Assembly (3)	Shuttle	Ball Bros., Honeywell	In development
3. Sun Sensor			Existing, spaceflight proven
4. Optical Alignment Measuring Devices		ITT, Perkin-Elmer	Existing
5. Signal Processing Electronics	—	—	New
Command and Data Management			
1. Computer (3)	Spacelab	ESRO	In development
2. Input/Output Units (2)	Spacelab	ESRO	In development
3. Mass Memory (1)	Spacelab	ESRO	In development
4. Remote Acquisition Unit (29)	Spacelab	ESRO	In development
5. Caution and Warning Electronics Unit	Spacelab	ESRO	In development
6. Alarm and Advisory Electronics Unit	—	—	New
7. Analog Recorder (2)	Shuttle	Odetics	In development
8. Keyboard	Shuttle	IBM	In development
9. CRT	Shuttle	IBM	In development
10. PSS C&D Panel L10	—	—	New (existing switches, etc.)
11. PSS C&D Panel L11	—	—	New (existing switches, etc.)
12. PSS C&D Panel L12	—	—	New (existing switches, etc.)
13. Control and Display Unit	Modified Shuttle Display Electronic Unit (DEU)	IBM	DEU in development
Electrical Power and Distribution			
1. Emergency Battery	Spacelab	ESRO	In development
2. DC/AC Inverter	Spacelab	ESRO	In development
3. Power Control Box	Spacelab	ESRO	In development
4. Secondary Power Distribution Box	Spacelab	ESRO	In development
5. Pallet Power Distribution Box (4)	Spacelab	ESRO	In development
6. Energy Kit (2)	Shuttle	Beech Aircraft	In development
Thermal, Structural, Mechanical			
1. Pallet (4)	Spacelab	ESRO	In development
2. APS (2)	—	Ball Bros.	Goddard study conducted
3. AIM Structure (4)	—	Ball Bros.	Goddard study conducted
4. Boom and Actuator (2)	Thor, Agena, Delta, Titan and others	Astro Research Corp.	Existing, spaceflight proven
5. Igloo Container	Spacelab	ESRO	In development
6. Coolant Pumps, Heat Exchanger, Capacitors, Plates	Spacelab	ESRO	In development
7. Subsatellite Retention/Ejection Mechanism	—	—	New
8. Cryogenic Coolant Tank, Valve, etc.	Apollo		Existing, spaceflight proven
9. Heat Radiator Kit	Shuttle		In development

Some of these items, including the APS and AIM which are currently under study by GSFC, could be in development by 1981.

Table 7.2.3-2 shows the support subsystem development schedule assuming a contract start in January 1977. The schedule shows development completion including payload integration with the Orbiter in early 1981. This assumes that the scientific instruments will be available for the pallet level development and integration tests in early 1979.

Since the assessment of the instrument development schedule shows many of the prime instruments will not be available until late 1980 and early 1981, it is apparent that the critical development paths are those related to prime instrument rather than the support subsystem development.

7.2.4 GROUND SUPPORT AND TEST EQUIPMENT

The philosophy employed during conceptual definition of paragraph 5.3.2 requirements was that of utilizing equipment developed and/or planned for the Spacelab, Orbiter, or other sources to the maximum extent.

The only visible potential problem area related to status or development lead times is that of possible unique experiment and system test sets. It is unrealistic to address the potential impact at this time due to the conceptual status of all levels of instrument, subsystems, and system designs.

TABLE 7.2.3-2. — SUPPORT SUBSYSTEM DEVELOPMENT SCHEDULE

A. <u>ANALYSIS, DESIGN, INTEGRATION</u>

1. Thermal
   - a. Analyses
     - (1) Heat loads
     - (2) Nodes and paths
   - b. Design and integration
     - (1) ATCS collant loop
     - (2) Cryo storage and distribution
     - (3) Insulation, surfaces
2. Structural, Mechanical
   - a. Analyses
     - (1) Static, dynamic loads
     - (2) Mass properties
   - b. Design and integration
     - (1) Hardmount installation
     - (2) AIM & APS
     - (3) Booms
     - (4) Mockups
     - (5) Subsystem
3. Pointing Control and Stabilization
   - a. Analyses
     - (1) Error sources
     - (2) Closed loop control stability and dynamics
     - (3) Equipment trade studies
     - (4) Software requirements
     - (5) Hybrid simulation requirements
   - b. Design and Integration
     - (1) Hardware
     - (2) Subsystem
4. Command and Data Management
   - a. Analyses
     - (1) Data, command listing
     - (2) Data rates, quantities
     - (3) Algorithms generation
     - (4) Computer, I/O sizing, timing
     - (5) Equipment trade studies
     - (6) Software requirements
   - b. Design and Integration
     - (1) Hardware
     - (2) Software
     - (3) Subssystem
5. Electrical Power and Distribution
   - a. Analyses
     - (1) Power and energy levels
     - (2) Time lines
     - (3) Equipment trade studies
   - b. Design and Integration
     - (1) Hardware
     - (2) Wiring mockups
     - (3) Harnesses
     - (4) Subsystem

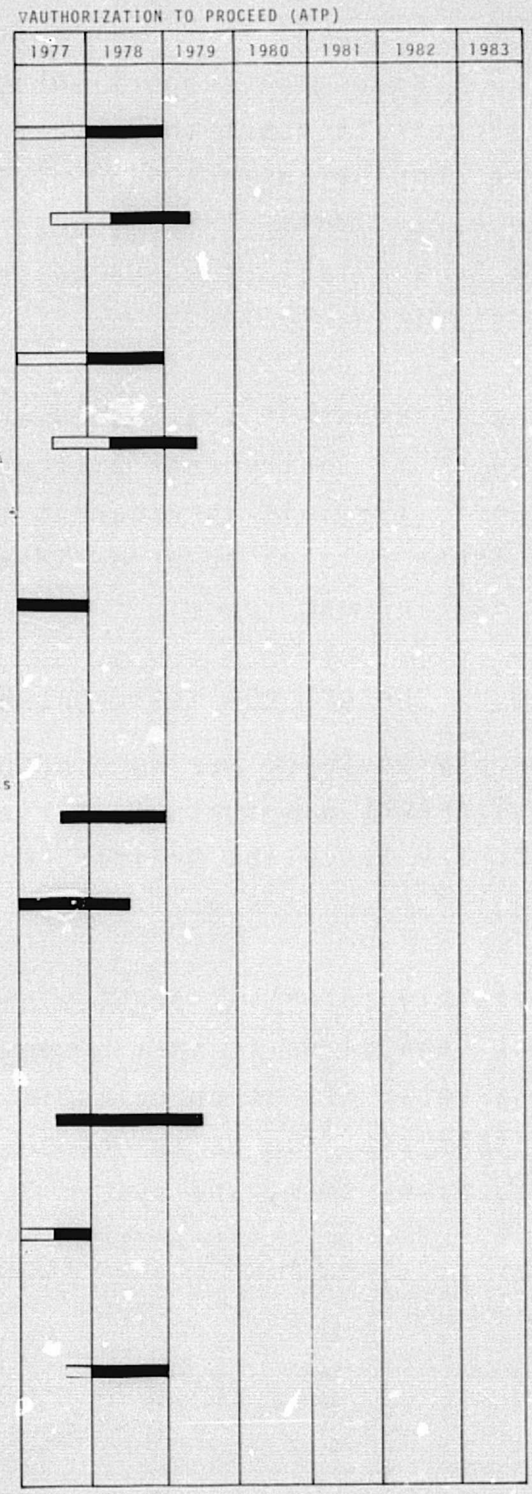

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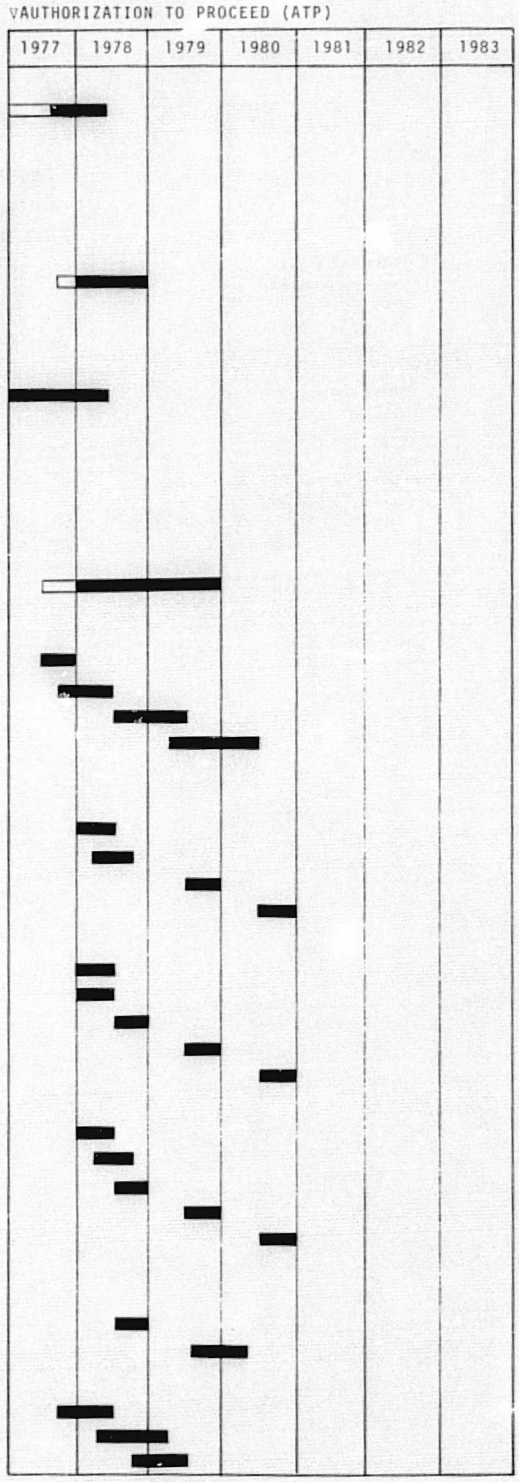
TABLE 7.2.3-2. — SUPPORT SUBSYSTEM DEVELOPMENT SCHEDULE (Continued)



6. Aft Crew Station Support
   a. Analyses
      (1) Displays and controls software requirements
      (2) Man-machine interface requirements
      (3) Crew wprk load
      (4) Equipment trade studies
   b. Design and Integration
      (1) PSS layout
      (2) Mockups
7. ASF Flight Systems
   a. Analyses
      (1) Mission operations
      (2) Time lines and sequences
      (3) Trajectory parameters
      (4) Orbiter performance
      (5) Orbiter RCS expenditure
      (6) EMC
   b. Design and Integration

B. <u>PARTS, MATERIAL, MECHANISMS PROCUREMENT</u>
   1. Mockups and Mass Simulators
   2. Structural Test and Prototypes
   3. Qualification Units
   4. Flight Units

C. <u>PRODUCTION</u>
   1. Equipment
      a. Mass simulators
      b. Prototypes
      c. Qualification Units
      d. First flight units
   2. AIM, APS
      a. Mass simulators
      b. Structural mockup
      c. Dev. Test. and integration unit
      d. Qualification units
      e. First flight units
   3. Pallets, Igloo
      a. Structural mockup
      b. Structural test units
      c. Dev. test and integration units
      d. Qualification units
      e. First flight units

D. <u>TEST AND INTEGRATION</u>
   1. Equipment
      a. Development
      b. Qualification
   2. Software
      a. Scientific simulation
      b. Interpretive computer simulation
      c. Hybrid simulation

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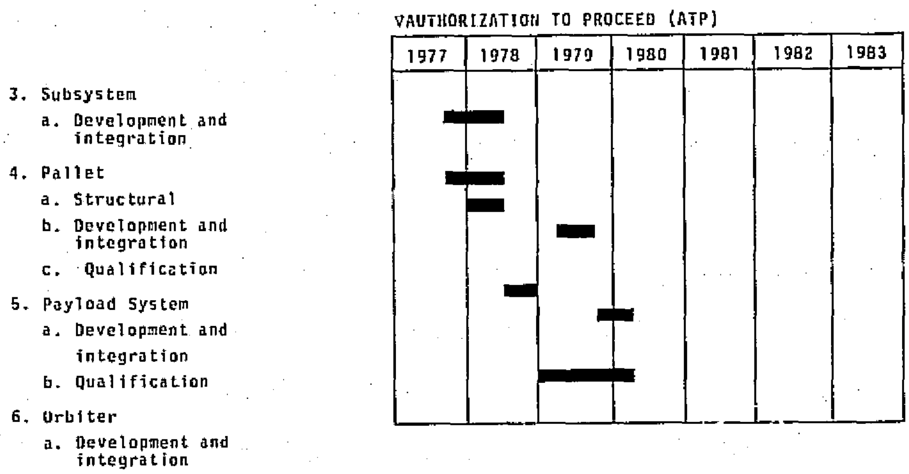
TABLE 7.2.3-2. — SUPPORT SUBSYSTEM DEVELOPMENT SCHEDULE (Concluded)



7.2.5 GROUND DATA HANDLING AND PROCESSING

The conceptual description of the types of ASF data expected for ground data processing is contained in paragraph 5.3 of this report. There are no identifiable handling or processing requirements that cannot be implemented with existing JSC equipment.

8.0 CONCLUSIONS

8.1 INTRODUCTION

Many worthwhile conclusions may be drawn from results of this study which was oriented towards assessing the potential of a 1981 ASF pallet-only mode STS mission. In this case, assessing the potential involved much more than a go-no-go determination of scientific and/or technical feasibility of the concept. The mission-level treatment, as opposed to only a flight package evaluation, precipitated many tangential studies into facility level interfaces exposing technical, scientific and programmatic factors of significant impact to STS missions planning. They extend beyond ASF or even AMPS missions to perhaps planning factors applicable to all STS missions dedicated to the use of the STS as a scientific platform.

The scope of this ASF study is depicted in figure 8-1 which illustrates the major spacecraft and facility interfaces.

The study was initialized with a preliminary set of IFRD's developed by the AMPS SDWG from which ED's and ID's were derived and are contained in appendix A and B, respectively. The prime instruments were then packaged into one of four pallets in a physical and functional manner compatible with an Orbiter 7-day mission timeline (section 5). In section 6, operational compatibility was verified between the Orbiter/payload and supporting facilities (PDS, SPS, TDRSS, STDN, Mission Control and Ground Data Processing facilities).

In the course of the study some problems were encountered, most of which were resolved. Some potential problems remain and will be summarized in the following trade-offs and recommendations sections. In general, however, the feasibility conclusions can be summarized as technical, scientific, and programmatic.

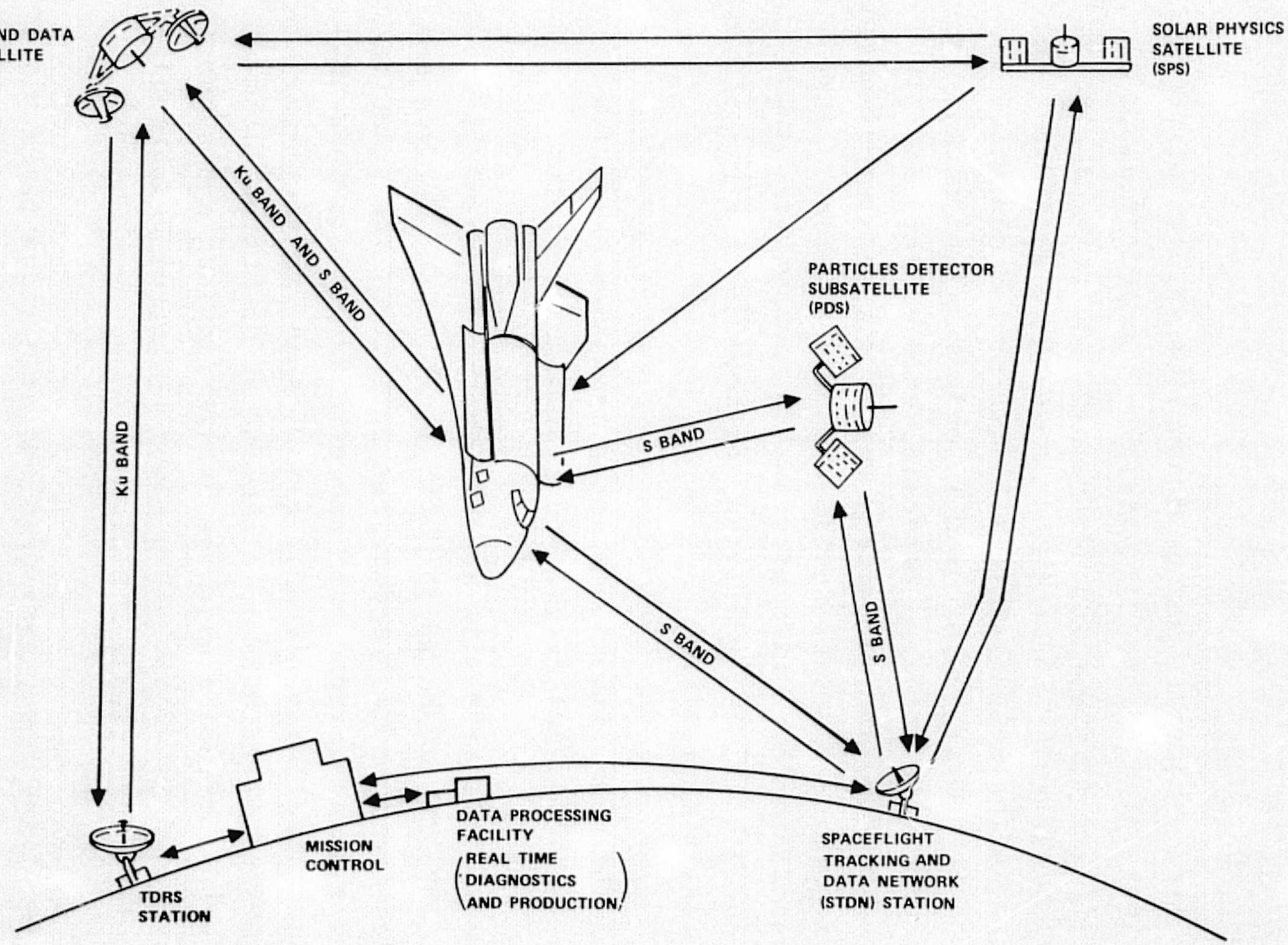


Figure 8-1. — ASF mission system.

8.1.1 TECHNICALLY FEASIBLE

It is technically feasible to conduct an ASF mission in the pallet-only mode aboard the STS. Only one factor remains which could conceivably negate technical feasibility. The Orbiter EMC environment as currently defined is not compatible with the full AMPS experiments and will have adverse effects on even the ASF missions. The EMC problem and a possible solution are addressed in detail in appendix C. Many areas require further indepth study. They are addressed in the technical feasibility section below.

8.1.2 SCIENTIFICALLY FEASIBLE

A pallet-only ASF mission aboard the STS is scientifically feasible. Much refinement is required in the area of scientific requirements. This subject is treated in detail in the scientific feasibility section below.

8.1.3 PROGRAMMATICALLY FEASIBLE

The programmatic feasibility factors (cost, schedule, etc.) for the ASF pallet-only mission are addressed in section 8.2. Many trade-off options have been identified; many others will be available from follow-on studies.

8.2 <u>FEASIBILITY ASSESSMENT</u>

8.2.1 SCIENTIFIC OBJECTIVES FULLFILLMENT

Results of the study show that all scientific objectives established for atmospheric science Orbiter missions can be met with a pallet-only payload. The added instruments made possible by the additional payload volume enables acquisition of much more scientific information in each mission than would otherwise be possible. This will reduce the necessity to time-phase operations over several missions, as would likely often be required with a smaller complement of instruments. This will permit more accurate determination of interacting time-variant parameters.

The baseline system established in the study is not fixed; however, it shows that a large complement of highly sophisticated instruments can be appropriately pointed, powered, and thermally controlled. Also, very importantly, the study shows the attendant data can be adequately handled and the instruments controlled and their outputs displayed in the limited volume of the aft crew station.

This system is not final. It is based on preliminary and sketchy information from the AMPS SDWG. Their requirements, conceptualizations, and experiment prioritization are still in progress and may result in some changes in the instrument complement. The modular approach taken, for packaging and pointing, readily accommodates changes in instruments and their configurations that may evolve as the AMPS SDWG continues its study.

There is also room for growth of instrument numbers or size. Pallets A-2 and A-4 have substantial space available that can accommodate additional instrumentation. Small instrumentation or electronics packages can also be located on pallets A-1 and A-3 if needed.

In summary, it appears highly probable that as scientific requirements are further defined, this baseline system will evolve into a complete ASF that need not be reconfigured for successive atmospheric science missions. It is also anticipated that only replacement of certain pallets and software packages will be required to convert to payloads suitable for other AMPS experiments.

8.2.1.1 Problems

The foremost cause for uncertainties related to scientific feasibility stems from the preliminary nature of the instrument and experiment descriptions. Although changes to these documents and additional information are forthcoming from the AMPS SDWG, only the preliminary versions of these documents were available during the study. As a result, the study had to contend with futuristic performance requirements for experiment objectives and procedures which in some cases were not fully defined or understood. Maximum emphasis is placed on the necessity for the forthcoming upgrading of the IFRD's and ED's. With a better definition of the instruments, the follow-on studies will result in improvements in cost effectiveness of the ASF pallet-only mission. The improvements will be manifested in both scientific return and cost/schedule factors.

Problems related to scientific feasibility of the ASF pallet-only mode concept can be categorized as follows.

a. Those scientific objectives requiring the operation of instruments in a low EMI/particle contamination environment may not be compatible with the contamination environment presently postulated for the Orbiter payload bay. However, this problem is not unique to pallet-only mode, but is of concern for all payload configuration on STS. The EMI portion of this potential problem is detailed in appendix C.

b. Many of the proposed prime instruments cannot be developed in time for the baseline 1981 launch. Also, there are questions as to whether or not they can be developed at all within realistic budget limits. This fact again points to the necessity for an upgraded set of instrument and experiment definitions against which the use of substitute instruments may be weighed. The following information presents more detailed insight into this type of problem.

Of the prime instruments treated in section 7.0, at least four will probably not be developed in time for a 1981 launch. Of the four, two substitute instruments have been identified that could be used to yield a good percentage of the desired scientific information. The two instruments that may not be ready are Instrument 304 (Magnetoplasmadynamic Arc) and Instrument 1011 (UV Occulation Spectrograph). Unless either substitute instruments or other means of acquiring the desired information are found, experiments using these instruments may have to be postponed for later missions.

The three instruments that represent high technical risks present problems that could adversely affect scientific fulfillment. These are: Instrument 124 (Fabry-Perot Interferometer), Instrument 118 (Limb Scanning IR Radiometer), and Instrument 213 (Laser Sounder). The technical difficulties delineated in the previous section may necessitate relaxing critical specifications in order to achieve a realistic unit. Substitutes which can be used in lieu of instruments 124 and 118 are identified. However, none is available for Instrument 213. This instrument presents operational problems in addition to technical problems that must be resolved before it can be used as it is currently envisioned, and for some of the purposes for which it is intended. Specifically, it is intended to measure the intensity and temperature of various atmospheric constituents by a laser fluorescence technique. Some of these measurements require energy and power levels far in excess of those considered possible by the early 1980's. Increasing the energy and power output to these levels exceeds safe allowable limits for ground personnel by at least three orders of magnitude.

As an example of the problem, an experiment was reported[1] which required accumulation of returns from 250 pulses, 0.5 joule each, 5 seconds apart, from a ground-based experiment to accumulate

[1] "Composition, Structure, and Dynamics of the Atmosphere," Sandford and Gibson, FATP, 32 1423 (1970)

statistics on the sodium layer. The Orbiter would travel 10,000 km while accumulating these data. To accumulate similar statistics at a range of 300 km above the Na layer would require approximately 1 kilo joule per second. The safe level from ground observe eye damage standpoint is 1 joule or about three orders of magnitude less than that required. This problem needs careful study to define operational usage and realistic design specifications for Instrument 213 to support any payload configuration, i.e., pallet-only, Spacelab, etc.

While there is no instrument that covers the broad range of wavelengths, power and energy requirements stipulated for Instrument 213, it is likely that further evaluation of requirements and instrument availability may reveal that operational lasers already developed for other applications can be modified to meet a majority of scientific requirements.

8.2.1.2 Impacts

As inferred above, there are areas of uncertainty which remain in assessing the potential of the pallet-only mode ASF mission. The potential involves not only scientific merit but also cost/schedule factors. The more obvious trade-offs will be summarized in paragraph 8.3.

8.2.2 SUPPORT SUBSYSTEMS

8.2.2.1 Conclusions

In general, the conclusion in the support subsystem area is that by using Spacelab, Orbiter and other proven equipment and approaches, the ASF subsystem concepts selected are compatible with the ASF requirements and constraints. Feasibility at the conceptual level has been assessed in each area and no major functional feasibility problem is anticipated. However, a number of areas require further definition as to sizing and capacity. These have been identified and are suggested for further study.

The particularly critical subsystem for pallet-only operations proved to be the CDMS. The conceptual designs for the CDMS, as developed during this study, were found to be adequate to support the additional instruments afforded by the pallet-only mode. The command and control functions intricately involve the crew and the ASF experiment and subsystem computer capabilities. Although adequacy of the control and command techniques herein developed may appear marginal, the question of feasibility only involves sizing (i.e., memory and processor size) which will be established during the follow-on studies.

The specific conclusions resulting from the study were as follows.

a. The Orbiter ATCS capability of 29,500 Btu/hr with the radiator kit is adequate for the ASF payload requirement of 24,000 Btu/hr.

b. Open loop cryogenic cooling appears to be the only practical approach to cooling instruments 118 and 126 to less than 4K. However, a detailed heat load analysis is required after the instrument designs are better defined.

c. The APS approach selected provides instrument pointing accuracy capability (0.007° 1 sigma) with adequate margins over requirements (0.017° 1 sigma).

d. The selected boom and boom deployment approach meets the ASF accuracy requirements of 0.6°.

e. The subsatellite retention/ejection mechanism meets both the Orbiter launch and landing static load requirements of 9 g with a capability of 17 g and provides a simple means of ejecting the subsatellite at the required 20 cm/sec separation rate.

f. The pallet loads and center-of-gravity locations are well within specified constraints. Considerable growth potential exists with the pallet-only mode since equipment and instruments can be relocated from pallet to pallet.

g. Two Orbiter energy kits with a capability of over 1700 kWh will supply, with sufficient margin, the 897.3 kWh of energy required by the ASF payload. The Orbiter provides for the addition of four energy kits. Therefore the growth potential is significant.

h. The maximum power level available from the Orbiter, 12 kW, is adequate for the 9 kW peak required by the ASF payload.

i. The Orbiter thermal constraint reflected by the 815 kW maximum average power capability is sufficient to handle the 6.9 kW average required over an extended (>1 Orbit) period of time.

j. An independent instrument pointing and attitude measuring system is required since the ±2.0° accuracy predicted for the Orbiter for pointing payload is inadequate to meet the 0.017° minimum instrument req irement.

k. The attitude measurement approach selected (gyro reference with star tracker update) provides an accuracy capability will within requirements (0.007° capability versus 0.017° required).

l. Onboard computer control of instruments, subsatellite and subsystem operations poses no fundamental issues of functional feasibility since the types of inputs, outputs, equations, and algorithms used will be similar to those currently being used on many commercial and space applications. The question of memory, executive, I/O and software capacity and timing remains to be resolved. These comments regarding onboard computer control apply also to onboard data processing.

m. The data transmission requirements of 16 kbps and 123.192 kbps from the deployed subsatellite and from the ASF instruments, respectively, to the Orbiter are within the capability of the Orbiter. Since the Orbiter capability of processing ASF instrument data located in the payload bay is 5.0 Mbps for

S band and 50 Mbps for Ku band data links, considerable growth margin exists for these data. Since the subsatellite to Orbiter data rate capability is 16 kbps, some data compression may be necessary or individual instrument data rates may have to be reduced if additional data growth occurs.

n. Available space at the aft crew station limits the number of PS's to one at any given time.

o. Due to the experiment timelines which require 24 hr/day operations, two crew members will be required to man the PSS; each on a 12 hour/shift basis.

p. The AE satellite appears to be an ideal carrier for the particle measurement support instruments required by the ASF experiments. Nine of the 17 existing instruments will be used and two new instruments will be added.

8.2.2.2 Assessment

Conceptual feasibility was established for the major support subsystem areas. The issues involved and the study results are discussed in some detail in each of the subsystem sections (paragraphs 5.2.1 through 5.2.6). The results are summarized in this section.

8.2.2.2.1 Thermal, Structural and Mechanical Subsystems (TSMS)

The major issues in the TSMS were as follows.

a. Installing all 15 ASF instruments and the support equipment on the ESRO furnished equipment pallets within the requirements and constraints of the ASF missions.

b. Providing accurate instrument pointing and tracking for massive (up to 691 kg) clusters of instruments.

c. Maintaining better than 5° reference axes accuracy relative to payload reference axes of instruments extended on long (20 m) booms under environmental conditions, Orbiter limit cycle operations, and boom scanning operations.

d. Maintaining retention integrity of subsatellite installation under launch and landing dynamic environments while providing a simple and effective means of ejecting the subsatellite at the desired separation rate.

e. Providing the required cryogenic cooling of instruments 118 and 126.

Table 8.2.2-1 summarizes the TSMS issues, approaches taken, and compares capabilities with requirements. The table indicates the growth potential of the ASF payload configuration in terms of weight, volume, and pallet-mounting space.

8.2.2.2.2 Electrical Power and Distribution Subsystem (EPDS)

The major feasibility issues in the EPDS area were the following.

a. The compatibility of the ASF power needs with Orbiter capability.

b. The ability of the Orbiter to provide the required energy levels.

c. The compatibility of the ASF thermal energy dissipation expected relative to the Orbiter ATCS capability.

d. The selection of a practical high voltage electrical power source for instruments 213, 303, and 304.

Table 8.2.2-2 summarizes the EPDS issues, approaches taken, and compares the capabilities of each approach to the ASF requirements or constraints.

8.2.2.2.3 Pointing, Control and Stabilization Subsystem (PCSS)

The major feasibility issues in the PCSS area were the following.

a. The conceptual approach to be taken for instrument pointing and tracking.

Table 8.2.2-1. — TSMS ISSUES

Item	Approach	Capability	Requirement
			Unused Space / Available Volume
1a. Installation space and volume	Install instruments and support equipment on 3 pallets, subsatellite on one pallet	Space: 4 x 17 m^2 Volume: 4 x 33 m^3	Pallet 1 0% / 0% Pallet 2 50% / 50% Pallet 3 0% / 0% Pallet 4 40% / 40%
1b. Installation weight (not including pallet).	Distribute total payload weight among four pallets	Maximum weight: 3,000 kg/pallet with igloo 3,500 kg/pallet without igloo	Pallet 1: 2449 kg (with igloo) Pallet 2: 721 kg Pallet 3: 1852 kg Pallet 4: 998 kg
2. Instrument pointing (APS)	Modified Ball Brothers SIPS	1 arc sec	Accuracy: <1 arc minimum
3. Instrument pointing (boom)	BI-STEM concept	Accuracy: < 0.6°	0.5°
4. Subsatellite retention/ejection	Collet/GN_2 activation	17 g 2 cm/sec	Launch and landing Loads: 9 g Ejection ΔV: 2 cm/sec
5. Cryogenic cooling (Instruments 118 and 126)	Open loop joules - Thompson Expansion Ne or N_2	4K (TBD depends on instrument design)	Detector: <+4K Housing: <+77K

TABLE 8.2.2-2. — EPDS ISSUES

Item	Approach	Requirement	Capability
1. Power level	Use Orbiter fuel cells	9 kW peak	Dedicated fuel cell -12 kW
2. Energy level	Use 2 Orbiter energy kits	897.3 kWh	1730 kWh
3. Thermal energy dissipation	Use Orbiter heat radiator kit	24,000 Btu/hr	29,500 Btu/hr
4. High voltage, high power source	Use capacitor bank (0.8 joules capacity and power converters)	Up to 30 kV	>30 kV at a >70% efficiency

b. The accuracy capability of the PCSS AMS relative to the APS requirements.

c. The question of a centralized versus distributed AMS.

Table 8.2.2-3 summarizes the PCSS issues, the selected approaches, and compares the capabilities of the selected approaches to the requirements.

8.2.2.2.4 Command and Data Management Subsystem (CDMS)

The main feasibility issues in the CDMS area were the following.

a. The ability to perform most of the ASF experiment operations automatically with the onboard computer.

b. The capability of performing most of the data processing automatically through the ASF computers.

c. The compatibility of ASF data transmission requirements with Orbiter downlink capability.

Table 8.2.2-4 summarizes the CDMS issues, the selected approaches, and the comparison between the capabilities of the selected approaches and the requirements.

8.2.2.2.5 Aft Crew Station

The main feasibility issues in the aft crew station support area were the following.

a. Crew control versus automatic computer control of experiments and instruments.

b. Adequacy of PSS space allocation.

c. Workload versus crew capability

Table 8.2.2-5 summarizes these issues, describes the selected approaches, and compares the capabilities of the selected approaches with the requirements.

TABLE 8.2.2-3. — PCSS ISSUES

Item	Approach	Requirement	Capability
1. Instrument pointing	ASF independent pointing system	<0.017°	Orbiter: +0.4° ASF system (including AMS): <0.007°
2. Attitude measurement	Three axes gyro referenced with star tracker updates	<0.017°	<0.007°
3. Centralized versus distributed AMS	Central using optical attitude reference transfer	Provide reference for 2 pointing systems with 0.017° accuracy	Provide attitude transfer accuracy of better than 0.001°

TABLE 8.2.2-4. — CDMS ISSUES

Item	Approach	Requirement	Capability
1. Onboard computer control versus crew control of experiments	Maximize onboard computer control	Control 15 experiments using 15 instruments	Conceptual feasibility of automatic experiment operations not an issue. Computer, I/O and software sizing and timing impact yet to be assessed.
2. Onboard computer data processing versus ground data processing	Onboard computer processing for most data	Processing of data from 15 instruments and 5 subsystems	Conceptual feasibility of extensive data processing onboard not an issue. Computer, I/O and software sizing and timing yet to be assessed.
3. Data transmission downlink (STDN or TDRSS)	Use Orbiter baseline S band FM with STDN and Ku band with TDRSS	123, 192 kbps data rate	S band FM: Analog 4.0 MHz bandwidth. Digital 5.0 Mbps Ku band: Analog-4.2 MHz bandwidth. Digital-50 Mbps
4. Data transmission from subsatellite to Orbiter	Use Orbiter baseline S band PM link	16 kbps data rate	16 kbps

TABLE 8.2.2-5 — AFT CREW STATION SUPPORT ISSUES

Item	Approach	Capability	Requirement
1. Crew control versus automatic, computer control of experiments and instruments	Automatic, computer control of most instrument.	Feasibility of controlling 15 or more experiments and 15 or more instruments through computer program is not an issue. The impact on computers, I/O and software sizing and timing is yet to be evaluated.	Control operations of 15 experiments and 15 instruments.
2. PSS space allocation	Minimum manual, direct control, minimum dedicated displays. Use key-board/CRT for control and display.	Using the computerized control and data processing approach, the standard panel allocations are adequate.	Three standard 48.26 x 53.34 cm (19 x 21 in) panels for control and display.
3. Workload versus crew capability	Two payload specialists each working a 12-hour shift. Use of a second specialist or possibility of pilot or commander sharing PS duties yet to be assessed.	Using the computerized control and data processing approach, two crew members, each working separate 12-hour shifts should be adequate.	24 hour/day mission coverage. Control 15 experiments and 15 instruments. Monitor instrument data.

8.2.2.2.6 Particle Detector Subsatellite (PDS)

The main issue in the PDS area was the question of adequacy of the AE satellite for ASF mission support. Results indicate that the AE satellite, with a few replacements and deletions of instruments, will meet ASF support requirements. Of the 15 AE instruments, eight are not applicable to ASF missions and two different instruments must be added. The AE support systems appear to be fully compatible with ASF mission requirements. However, the electrical energy storage capacity will be increased by 100 per cent to provide additional margin for instrument operation duty cycles.

8.2.2.2.7 Other Key Issues

Other major feasibility issues may exist which are not unique to the ASF pallet-only mode of operation, but should nevertheless be mentioned since they may be more fundamental to the question of feasibility than those related to ASF unique areas. These other issues include:

a. The impact of Orbiter background EMI on the practicality of performing experiments.

b. The impact of the electrostatic charge on the Orbiter and payload on accelerated electrons and ions.

c. Effect of Orbiter background contamination (e.g., water and other vapors) on experiments operations.

d. The capability of ground data handling facilities to store and segregate billions of bits of data.

These areas were not fully addressed during the study since they are common to all AMPS or ASF types of missions. Assessments must be made to determine if the ASF missions can be undesirably impacted by these issues and to determine if practical solutions exist.

8.2.3 PROGRAMMATIC FACTORS

8.2.3.1 Schedule

As described in section 7.0, there are no major constraints identified to date in meeting the program schedule milestones for delivery of a flight-ready ASF payload system on October 1, 1980, except in the case of prime instruments. An alternative approach involving consideration of existing substitute instruments offers potential relief to the overall instrument problem; but not a total solution. This prime versus substitute instruments approach is addressed in detail in paragraphs 8.3, 8.4, and 8.5

8.2.3.2 Costs

Detailed cost analyses are not included in this technical report. They are contained in the Executive Summary.

The major cost items for the ASF pallet-only mode are centered around development of the advanced state-of-art prime instruments and the costs associated with end-to-end testing (development, qualification, and flight acceptance) required for a scientific payload of this size and complexity.

8.3 TRADE-OFF CONSIDERATIONS

8.3.1 SCIENTIFIC

Scientific requirements are presently quite preliminary, hence hard instrument specifications are not feasible in many instances. Many of the prime instruments are very sophisticated and some require technological advances that cannot be accurately timed. The result is that lengthy development times may preclude their inclusion on earlier Orbiter flights, as shown in table 7.2.1-2. In such cases, it will be necessary to: (1) use a different technique to derive the desired scientific information; (2) postpone experiments that require the instrument; or (3) use a substitute instrument.

Consideration of different techniques that might provide requisite information requires scientific investigation that is beyond the scope of this study. The advisability of postponement of desired experiments is also beyond the scope of this study, however, it seems obvious that such a choice would only be made if there were no other alternative. The possibility of using substitute instruments on early ASF missions, however, is a likely choice.

Summarized development schedules and relative costs of prime versus candidate substitutes, depicted in figure 7.2.2-1, show that the schedule problem could be alleviated and substantial cost savings realized if substitute instruments could be used.

Throughout this study, it was assumed that those instruments described by the AMPS SDWG in the IFRD's are the best choice and will provide the highest yield of scientific information. Based on that assumption, using substitute instruments will, to some extent, reduce the degree of scientific fulfillment that might otherwise be obtained. The quantification of this reduction is hard to derive, because the full number and range of physical quantities to be measured is not known. They will not be known until they have been measured with instruments that have bandwidths and dynamic ranges greater than the quantities to be measured.

Nevertheless, useful and valuable information concerning atmospheric dynamics can be derived from spatial and temporal measurements made with instruments with less than the ultimate capabilities. Their use could preclude detection of some obscure phenomena or subtle effects; however, the global coverage of simultaneous measurements of interacting parameters afforded by the Orbiter should yield information that will be invaluable in characterizing and modeling the principal dynamic processes of the atmosphere.

Trade-off parameters that might influence whether or not a substitute instrument is selected include size, weight, power requirements, thermal requirements and operational constraints. There is insufficient information about both prime and substitute operational constraints to consider the latter further as a trade-off parameter. Regarding size, weight, power, and thermal requirements, the Orbiter can accommodate any but the most gross increases in these parameters. The brief comparative descriptions available at this time do not reveal any difference of such magnitudes, except for Instrument 534 versus Instrument 534X power requirements. In that case, the power required by the substitute instrument is about 500 watts greater than that estimated for the prime. The timeline developed during this study shows this instrument will be used only for a very small fraction of the mission time. Furthermore, the ASF payload power requirements are far below the full capacity afforded by the ASF configuration. The remaining trade-off factors, namely schedule and relative cost, are shown in tables 7.2.1-1 and 7.2.1-2. The assumed cost of each prime instrument is expressed as 100 percent and the cost of the corresponding substitute is expressed as a percentage of that cost. Generally, as would be expected, substitute instruments cost substantially less than the closest corresponding prime instruments. Many examples of potentially significant cost and schedule options can be derived from tables 7.2.1-1 and 7.2.1-2.

8.3.2 TECHNICAL

8.3.2.1 Approach

The primary approach to concept and design selection for this study was to make use of the ERNO designed Spacelab and the

Orbiter designs wherever possible. The purpose was to show conceptual feasibility and not necessarily the most cost effective or optimized performance or design approach. The issues identified and discussed are not related only to the pallet-only mode but are considerations that must be addressed for any payload configuration. Future studies should consider the impact of alternative approaches to cost, risk, schedules, performance, capability or capacity margins, reliability, weight, size, power, and other trade-off parameters considered to be of prime significance.

Table 3.2.4-1 summarizes the alternatives to the selected ASF approaches which should be considered in future studies.

8.3.2.2 Structural

Installation of large structural elements; mounting the APS or the subsatellite installation structure directly to the standard payload attach points provided by the Orbiter can result in significant weight savings since pallets A-1, A-2 and A-3, each weighing 428 Kg, would not be used. Additional attach structures would be required which would reduce the weight savings to some degree.

The pallets have great flexibility for installation of different sized equipment in different locations with standard provisions for active thermal control, if required. These capabilities would require considerable development effort if individual installation provisions were to be provided.

8.3.2.3 Thermal Control System

Current evaluations indicate that there is about a 14 percent margin between payload heat dissipation requirements and the Orbiter ATCS capability. If greater margin is required, additional heat dissipation capabilities can be provided through payload unique radiators. Considerable effort would be required for development of these radiators and they would result in additional payload weight. The alternative would be to constrain instrument operations to reduce · .rage power consumption, which might reduce the effectivene , of the experiments.

8.3.2.4 Remote vs. Direct Access Circuit Breakers

Direct access circuit breakers would be located at the aft crew station. They would provide direct means for manually controlling primary power to each instrument and equipment if individual power control was lost. Also, direct access provides a reliable way of resetting the circuit breaker switches. Remote circuit breakers reduce the weight of power lines since large wires (e.g. 4/0 gauge) carrying primary currents need not be routed to the aft crew station and back.

8.3.2.5 High Current Transmission Media

Large cross sectional area copper busses interconnecting the pallets with the central power distribution point would be the most efficient way of providing the high current capability required and would allow greater flexibility for reduction of common impedances. However, this approach will probably result in greater levels of magnetic field generation since the enclosed area of the total current loop will be increased. Two busses (power and return) adjacent to each other will not provide the same level of field cancellation as a two-wire twisted pair.

8.3.2.6 AMS

The distributed system is more accurate than the centralized system since optical transfer of attitude reference from one user to the next is not required and operations become more complex. However, distributed systems require more hardware and software.

8.3.2.7 Payload Specialist Work Station

An additional mid-deck data monitoring station will provide increased space such that additional displays could be provided. With the added space, real time onboard data analyses of the experiments could be provided. The added equipment and crew member will increase cost and weight.

8.3.2.8 Instrument Sequence Initiation

Control of instrument initiation from the ground station would reduce crew workload. It would, however, complicate ground operations.

8.3.2.9 Data Processing

Processing the scientific and engineering data at ground facilities would reduce the burden on the onboard computer and result in smaller, less complex hardware and software. However, the downlink data transmission requirements could be increased significantly and the ground facility software complexity would increase.

8.3.2.10 Mass Memory Operational Programs

Providing full end-to-end mission operational programming capability resident in the onboard mass memory reduces the uplink communication load and the dependence on timely ground support. However, a much larger mass memory capability is required.

8.3.2.11 Data Compression

High density data compression techniques can result in significant reduction of downlink communication data rate and quantity required. However, high compression systems with capability of reducing data quantities by a factor of 10 or more have not yet been developed to the operational stage. Considerable development effort would be required before such a system could be used on the ASF program.

8.3.2.12 Computer, Processor

The centralized computer results in a more efficient utilization of the machine since the executive, central processor, memory, I/O and power supplies can be time shared by the different users.

Dedicated distributed microprocessors are more flexible since any change in software programs or computational requirements affect only the processor directly involved. Problems of priority are reduced and faster processing is possible without the extensive time sharing required.

8.3.2.13 Subsatellite Retrieval

Recovery of the subsatellite and returning it for refurbishment to new mission requirements and reusing it is obviously a more economical approach than to provide a different subsatellite for each mission. The possibility of continued use of a single subsatellite with the capability of supporting many missions left in orbit after the first mission should be further explored. Spacecraft retrieval of the subsatellite increases Orbiter operational complexity.

8.3.2.14 Orbiter and Payload EMI Environment

The baseline Orbiter using structure as the return for electrical current will present a high background EMI environment to payloads.

If the levels are such as to affect the validity of the experiments, the trade-off considerations are: (1) provide extensive electrostatic and magnetic shields to protect the instruments, (2) operate the instruments on extended booms, (3) operate the instruments on deployed subsatellites, and (4) change Orbiter structure return to a two-wire system.

Extensive shielding around the instruments may not be adequate to reduce the EMI fields to acceptable levels. Booms complicate operations and reduce pointing accuracy. Two of the ASF instruments are already on booms, although only one, the Triaxial Fluxgate, is deployed because of the EMI effect of the Orbiter and payload. Operating instruments on deployed subsatellites is an expensive approach. Also, accurate co-alignment of instruments on the subsatellite with instruments onboard the Orbiter, if required, is more difficult to achieve. Changing the Orbiter structure return to a two-wire system will increase Orbiter wiring weight by about 317 Kg (700 lbs) but is probably the most cost effective approach for the ASF program.

8.3.2.15 Support Subsystem Equipment Trade-Off

In each subsystem area there are a number of alternative equipment approaches currently available. Others are almost certain to be available by 1981. These equipment include star trackers, gyro reference assemblies, computers, mass memories, tape recorders, high voltage supplies, power inverters, remote circuit breakers, and CRT's.

Each equipment area will have a number of trade-off considerations which must be assessed. The primary considerations will be those associated with direct support of the instruments, such as accuracy and data rates. Total power usage is also an important consideration due to the limitation of the Orbiter ATCS. Program cost is a prime consideration in any area. Weight, size and volume will probably not be critical factors although they may be the deciding factors if all else among the options are equal.

8.3.3 PROGRAMMATICS

Many major trade-off considerations of a programmatic nature are evident from this ASF pallet-only mode Orbiter mission. However, these considerations are not unique to the pallet-only mode and must be addressed for any ASF mission configuration. Information is available now for some; additional information is required for many others.

Perhaps the most important trade-off to be considered at this time is one related to a timely modification to the Orbiter electrical wiring design to reduce the EMI contamination to something more compatible with ASF and AMPS instrument requirements. Appendix D-4 addresses the problem and an improvement technique (for a price) which should reduce the Orbiter's ac magnetic field by about three orders of magnitude. This study has addressed the problem and derived a requirement for the use of an AE type subsatellite to remove the more critical instruments away from the Orbiter's EMI contamination environment. This concept also has a price, and there still remains a question of the remaining ASF instruments being operable in the cargo bay without an intolerable degradation of scientific return.

This problem will be magnified many times during planning for the MPS experiments because of the design and operation characteristics of the MPS particle instruments.

Candidate trade-offs appear productive in the following areas.

a. The price of rewiring power cables in the Orbiter cargo bay and the cost of analytical models of the resulting wideband EMI environment in which all future payload bay-mounted scientific instruments must operate.

b. The cost of analytically modeling the non-modified, wideband EMI environment throughout the bay; information which is required before the feasibility of future payloads can be established.

c. The projected costs of individually shielding, as applicable, each scientific and/or subsystem to be flown on future STS flights.

d. An overall assessment of the applicability of the STS as a platform for scientific payloads.

A major trade-off treatable at this time is that of the 1981 launch. Many major, prime instruments will not be available. One trade-off factor is a start date of January 1976 instead of 1977. However, this will not provide a satisfactory probability margin that all prime instruments will be ready. Quite obvious then, is the trade-off factor of substitute instruments. However, there are no adequate substitutes for some of the long lead, major instruments. The third factor in this area is the inadequacy of a 28° inclination orbit of the 1981 launch in satisfying the scientific requirement for global coverage. The final trade-off consideration is that of a 1983-85 launch which would achieve two goals: (1) higher probability of all prime instruments, and (2) a polar orbit which would result in one mission to achieve all ASF scientific objectives.

8.4 TECHNICAL FOLLOW-UP REQUIREMENTS

Although study results indicate functional feasibility of the conceptual ASF payload design, more accurate capacity and sizing definitions are required in most areas (e.g., the quantity of cryogen required to cool instruments to 4.0 K and the memory, executive, I/O and software capacity and timing capability required to perform extensive onboard data processing). In order for capacity and sizing to be further defined, many details of the design and operation of the various instruments are required (e.g., detector and housing design for cryo-cooled instruments, and total payload data characteristics and timelines affecting data processing).

Therefore, the first priority of follow-up efforts should be to define in greater detail a comprehensive set of requirements for experiments, instruments, subsatellite and support subsystems. This effort should include the generation of a more detailed mission timeline for experiment, instrument and subsystem operations then that developed to date.

The second priority for follow-on efforts is to provide better and more comprehensive design and operational definitions of the instruments and subsystems. For example, the detector holding structure and instrument housing for the cryogenically-cooled instruments should be defined in some detail and the complementary operations of two or more instruments, and the operational constraints of each instrument, should be defined.

The third priority is to perform various analyses and trade-off studies to verify the preliminary selections or to update the design and operations with more optimum approaches.

The fourth priority for the follow-on efforts is to generate preliminary design and operational specifications which will be used as a basis for downstream development.

The last priority is to develop programmatic factors such as estimates of total program development, production, and operational costs; funding plans including expenditures by phases, allocation of resources, funding constraints and optional expenditure approaches; development, production and operational schedules including expected critical paths and availability of non-ASF support such as the Orbiter, the SPS, the TDRS system, etc.; development, production and operational plans for each major program element (e.g., flight hardware, flight software, ground support facilities and ground support software); and an analysis of the technical, cost and schedule risks involved with full scale development.

8.5 UNRESOLVED MAJOR ISSUES

During the course of this study, initial concepts and approaches were selected in the development of a pallet-only mode ASF mission utilizing the STS which required modification at a later stage of the study. Some were major in scope and others minor. A preliminary mission timeline resulting from limited definition of the experiment and instrument requirements was developed and subsequently updated. As appreciation of the STS contamination environment developed, a PDS and a boom-mounted equipment design were implemented. This evolution did result in a conceptual functional design considered technically feasible, but with certain qualifications stemming from key assumptions developed along the way. The validity of some of the assumptions could not be fully verified. As a result, several potentially significant issues remain which warrant identification at this time and require future investigation. These issues are not unique to the pallet-only mode and must be resolved for any ASF mission configuration.

a. Upon receipt of the forthcoming upgraded set of AMPS/ASF experiment/instrument requirements from the SDWG, revised mission timelines will be required to establish operational boundaries. These boundary timelines will then be used to complete the task of sizing the ASF system, followed by a reassessment of the ASF design concepts relative to the new timeline. Particular emphasis should be given to the aft crew station, command and data management, power, and thermal subsystems for probable impacts.

b. There is need to operate the particle detector instruments at a relatively short distance away from the Orbiter contamination environment. The AE satellite was chosen for two primary reasons. It is presently operational and the instrument complement requires minimal change. There are obviously many unresolved problems associated with this approach:

(1) What is the overall impact to operational and safety aspects of the Orbiter during release, deployment, and retrieval of this subsatellite?

(2) How do the above impacts compare with those of a tethered satellite?

(3) Would it be feasible to modify the proposed subsatellite to remain in orbit and possibly be used for other scientific missions?

(4) How practical is the boom concept to implement in view of the requirement for STS attitude changes? Potential boom dynamics problems warrant further investigations related to safety and scientific, as well as the operational factors.

c. With the above instruments deployed away from the payload bay, a valid question exists as to the operation of the ASF instruments remaining in the cargo bay being compatible with the EMI and contamination environments. A comprehensive analysis is required for an answer to the question. If the answer is negative then this subject becomes a problem of the highest priority because there is a limit to how much of a sophisticated payload, such as the AMPS, can be deployed away from the Orbiter.

d. Several assumptions were made during this study related to the data management philosophy. The resulting subsystem is technically feasible but it does approach a marginal capability and flexibility. A detailed look at the philosophy provides insight to the situation which could very easily become a problem if even a slight increased demand were made of its function. However, this problem is not unique to the pallet-only mode and must be addressed for any ASF mission configuration.

e. The operational philosophy of data management for AMPS(ASF) pallet-only mode places a larger demand on automation of mission conduct than does the pressurized module approach. This automation is accomplished through the use of the experiment and subsystem computers located in the igloo. The practicality of providing computers of adequate capacity to accomplish the total task must be further assessed. In addition a mid deck monitoring station could be provided that would reduce the required level of automation approaching that of the pressurized module approach.

9.0 RECOMMENDATIONS

9.1 ASF PAYLOAD SYSTEM DESIGN

Results of this study warrant the following design recommendations for an ASF pallet-only mode payload system. These recommendations incorporate an extensive use of Spacelab and Orbiter equipment and approaches. Although follow-on efforts are required to better refine the design concept, the recommended configuration establishes a feasible baseline from which to initiate a preliminary system design study. These design recommendations are presented by subsystem.

9.1.1 TDRS

a. Use ESRO furnished pallets for instrument and support equipment installation.

b. Cluster instruments by pointing requirements.

c. Use independent instrument pointing systems to achieve desired accuracy.

d. Use open loop cryogenic cooling because of excessive power required by closed loop cooling systems.

e. Use Orbiter ATCS with the addition of the heat radiator kit and ESRO approach for active thermal control.

f. Use the BI-STEM configuration for the deployable booms.

g. Use the collet/cold gas velocity separation mechanization for the retention and ejection of the subsatellite.

9.1.2 EPDS

a. Use Orbiter dedicated fuel cell for primary power source.

b. Use two Orbiter energy sets to meet ASF requirements of 897.3 kWh.

c. Use ESRO furnished dc/ac inverter, power control box, primary and secondary power distribution boxes.

d. Use remotely controlled circuit breakers except where safety may be involved.

e. Use a high capacity capacitor bank and power converters to provide the 30 kV voltage required.

f. Use conventional heavy gauge wires for power and return lines.

9.1.3 PCS

a. Use an independent ASF AMS consisting of a gyro reference and star tracker update.

b. Use the centralized reference approach with optical transfer of attitude from Pallet A-3 to Pallet A-1.

c. Use Orbiter for only coarse instrument pointing.

9.1.4 CDMS

a. Use ESRO furnished computers, I/O's, mass memory, C&W electronics and RAU's. Use Orbiter designed tape recorder, keyboard and CRT display, and modified display electronics unit. Use Orbiter furnished TV cameras and monitors. Use additional ASF supplied, Orbiter designed TV cameras, if required. Use bi-phase L Manchester coded PCM data bus approach.

b. Perform as much of the data processing with the onboard computers as is practical.

c. Operate the instruments, subsatellite and subsystems with the onboard computers to the maximum extent possible.

d. Use Orbiter baseline S band FM link for communication with STDN and Orbiter Ku band for communication with TDRSS.

e. Use Orbiter baseline payload S band PM link for communication with subsatellite.

f. Use mass memory for temporary storage of operational sequences with real time reloading prior to next set of operational routines or programs.

9.1.5 AFT CREW STATION SUPPORT

a. Use all three standard panels at PSS to support ASF mission.

b. Use one PS at any given time. Support of two crew members will be required to man the station 24 hr/day.

c. Limit the PS functions primarily to initiating and interrupting programmed sequences, checking initial conditions, performing limited manual operations, analyzing and making decisions for off nominal conditions, and performing real time updates and changes to sequences.

d. Provide a limited number of manual controls at the PSS including a manual fine-pointing capability to point instruments and control power to equipment and instruments.

9.1.6 PDS

Use AE satellite as baseline. Delete eight of the 17 AE instruments and add two new ones (low energy ion detector and high energy particle detector). Add three rechargeable batteries to improve duty cycle capability. Delete the tape recorders.

9.2 FOLLOW-ON STUDY

The need for follow-on study efforts was addressed in paragraphs 8.4 and 8.5. Two major study areas were identified and rationale presented for follow-on study efforts. The first contained several unresolved major issues which must be addressed because they not only constrain technical effectiveness of this conceptual payload but they also involve major cost and schedule impacts to an ASF pallet-only mission.

The second category of recommended study efforts relate to certain facets of this conceptual design. These design features need more detailed definition since they too offer promise of increased technical efficiency and cost/schedule effectiveness in an ASF payload system.

9.2.1 UNRESOLVED MAJOR ISSUES

a. The preliminary nature of the ASF ID's and ED's used as a baseline for this study created an unresolved issue necessitating the following studies:

   (1) Using the upgraded ED's forthcoming from the AMPS SDWG, develop upgraded ASF mission timelines. The new timelines, utilizing the new ED's and revised ID's, should be analytically exercised by the conceptual payload system to verify continuing feasibility of the payload concept with a more realistic ASF pallet-only mode mission.

   (2) Choice of instruments. Because of the unavailability of some ASF instruments for a mid-1981 launch date, it is recommended that a study be conducted with the following objectives.

      - Search for availability of instruments that can be used in lieu of those prime instruments presently described that cannot meet launch date and for which substitutes are not identified. Such instruments could be currently under development by either Government or industry, and could be completed in time to meet the scheduled launch date. Assess the impact to scientific value from the use of substitute and/or alternate instruments.

      - Explore alternate means of acquiring desired scientific information without the use of those instruments that cannot meet launch date and for which there are no substitutes.

- Assess scientific and cost impacts of flying certain experiments during 1981 and deferring others until requisite instruments are available.

b. EMI assessment. Some of the ASF instruments are extremely sensitive to EMI (see paragraph 5.4). In order to assess the total impact of this problem, the levels of EMI expected to be generated by the Orbiter and the payload should be established. In parallel, the susceptibility levels (using conventional EMC design practices to reduce susceptibility) of instruments should be established. The effect on instrument measurements of the expected EMI levels should then be evaluated. If the effects are not acceptable, evaluation should be performed on the practicality of incorporating methods of reducing both EMI generation and susceptibility, including possible changes to existing Orbiter systems.

c. Electrostatic charge assessment. The amount of electrostatic charge expected on the surface of the Orbiter vehicle and the payload structures should be established. In parallel, the maximum charge acceptable for particle accelerator operations should be established. If the two are not compatible, various possible means of reducing the charge potential of the vehicle and payload should be evaluated. Reference is made to appendix C.

d. Particle contamination evaluation. The expected particle contamination from the Orbiter and from the payload should be established. Water vapor, cryogenic coolant gases, leaking fluids, subliming solids and other outgassing products can affect the validity of certain experiments. In a parallel effort, the susceptibility levels of instruments sensitive to each of the expected contaminants should be established. Depending on the seriousness of the problem, changes to materials, methods of reducing the production rate of contaminants, and the possible time sequencing of experiments, instruments and support equipment operation to minimize the impact of the contaminants should be assessed.

e. Study the overall issue of the use of booms, subsatellites, tethered satellites, or other concepts to cope with problems posed by the operation of AMPS particles instruments. This study should encompass the following factors:

(1) All Orbiter interfaces (physical, operational, etc.)

(2) Gross cost factors

(3) Scientific merit

(4) Program schedules

(5) Boom structural analyses.

9.2.2 ASF PAYLOAD SYSTEM DESIGN

For each of the support subsystems, those areas requiring follow-on primary emphasis were identified in section 8.0. The following specific studies are recommended as follow-up efforts.

9.2.2.1 TSMS

a. Cryogenic cooling system requirements definition. In order to define the cryogenic cooling system, requirements should be further defined. The designs of instruments 118 and 126 in the areas of detector installation, housing and associated structure should be defined in enough detail that a meaningful heat load analysis can be performed.

b. Cryogenic cooling system trade-offs. After the heat load analysis is completed, the open and closed loop cooling system design parameters (flow rates, quantity of cryogen, power required, system weight, size, etc.) should be established, environmental impacts such as contamination should be evaluated, and development risk and other programmatics should be assessed. Assuming both approaches meet basic ASF criteria, a trade-off study should be conducted to determine the most cost effective approach.

c. Payload static and dynamic loads analysis. The structural and mechanical provisions for instrument, APS equipment and pallet installation should be further defined. Preliminary static and dynamic loads analyses should be performed to determine design margins available. The results of ESRO/ERNO analyses should be utilized, as applicable.

d. ATCS definition. The thermal energy dissipation expected from instruments and support equipment should be further established. A thermal analysis should be performed to determine heat transfer characteristics and to determine the heat loads expected at the active thermal control interface. Thermal capacitors and cold plate requirements should be established and coolant loop characteristics including choice of fluid and flow rates should be established. The number of pumps, valves and heat exchangers, the routing of the coolant, the need for flexible conduits, and other design features should be defined at the preliminary design stage.

e. Boom dynamics analyses. The capability of the boom, and the instrument mounted at the end of the boom, to withstand vehicle dynamics and the Instrument 550 scanning operation on instrument alignment accuracy should be analyzed. If necessary, constraints on Orbiter maneuvering and limit cycle acceleration should be established.

9.2.2.2 EPDS

a. High voltage, high power source definition. There are many issues involved with the use of high voltage (up to 30 kV), high power (5 to 10 kW) sources. Each one of these should be evaluated in some detail since this capability is fundamental to three of the ASF instruments (213, 303, and 304). Trade-offs should be conducted to determine the most effective approach for the generation of the required voltages.

Design features such as best transmission media for the high current (200 amps), optimum location of the high voltage sources relative to the instrument, adequacy of available insulation techniques to eliminate breakdown and corona effects, and adequacy of EMC techniques to minimize effects of radiated and conducted EMI generated by the high voltages and current, should be fully evaluated.

b. Inverter trade-offs. The need for a centralized 400 Hz inverter should be evaluated. The effectiveness of a centralized system compared to individual inverters provided by the using instrument or equipment should be assessed.

9.2.2.3 <u>PCSS</u>

a. AMS trade-offs. Trade-offs should be performed on the effectiveness of a centralized versus distributed AMS. An AMS located on Pallet A-1 using optical media to transfer attitude reference to Pallet A-3 simplifies the system. Individual star trackers and gyro packages on each AIM or APS improve attitude accuracies.

b. Equipment trade-offs. Trade-off studies should be conducted on most applicable gyro packages, on selection of strapped down or gimballed star trackers, and the use of the Orbiter GN&C system to calibrate and improve the accuracy capability of the ASF system.

9.2.2.4 <u>CDMS</u>

a. Data processing requirements definition. The instrument and support subsystem data processing requirements should be further defined.

b. Experiment, instrument and subsystem operations definition. The payload operational functions and timelines should be defined in greater detail.

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c. Processing system definition. Based on better definition of the data processing and operations requirements, computer, I/O, and software sizing and timing analyses should be performed. The analyses results would be the basis for establishing computer and I/O design and selection criteria. Based on these criteria, trade-off studies should be conducted to compare effectiveness of centralized versus distributed processors, and to select the processors most compatible with ASF program requirements.

d. Mass memory utilization assessment. The issue of using the ASF mass memory for temporary processing routine storage or for permanent storage with full mission operational capability should be resolved. Based on the payload operational requirements previously established, an assessment should be made to determine mass memory storage capacity required to provide the full mission operational program capability without recourse to crew update. The memory size required for this approach should be assessed against the experiment, instrument, and support subsystem mission timelines and the possible constraints imposed by dependence on ground operations and availability of Orbiter or ground facilities for communications at the required time.

e. Data transmission compatibility assessment. Based on the data processing requirements established previously (including that for the fixed payload and the deployed subsatellite) a determination should be made as to whether the margins between the requirements and capabilities are adequate. If data compression is required, trade studies should be conducted to determine the most cost effective approach.

9.2.2.5 Aft Crew Station Support

a. C&D requirements definition. The C&D support required by the individual instruments for the subsatellite and the support subsystems should be further defined.

b. PS operations definition. The role of the PS in controlling the experiments and other payload operations and in monitoring and assessing the displayed data should be further evaluated with scientific community participation. The need for a second (mid-deck) work station to expand the aft flight deck capability should be examined. Based on the updated definition of the PS functions and responsibilities, the need for additional specialist/crew member support should be defined.

9.2.2.6 PDS

An assessment of the economic impact on the total ASF program should be made if the subsatellite was left in orbit rather than retrieved subsequent to each mission. Subsatellite retrieval significantly complicates mission operations and crew training and more importantly, increases the possibility of jeopardizing the safety of the crew and the vehicle. The total ASF (and AMPS) mission traffic should be analyzed to determine if a single deployed subsatellite might be able to support a number of separate ASF launches over an extended period of time.

9.2.3 CONCEPTS OF STANDARDIZING

The concepts of centralizing and standardizing described in appendix D of this report will be applied to the ASF configuration to determine the savings offered in areas of reliability, schedule, cost, etc.

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