

Questions regarding the organization and contents of the Shuttle Crew Operations Manual should be directed to one of the SCOM representatives listed below:

NASA

U

Winston Scott, CB	244-8718
Alan Bachik, DF	483-8428
Ed Gonzalez, DM	483-1927
SA	
Bill Todd, DT	244-7311
Project Manager	
Dave Pitre, DT	244-7416

Hernandez Engineering Inc.

Vicki Atkins	283-0278
--------------	----------

PREFACE

The Shuttle Crew Operations Manual (SCOM) is a unique document containing information about each Shuttle system and every phase of a generic space shuttle mission.

The SCOM is a reference document for space shuttle crewmembers. The complexity of the Shuttle systems and the unique operational environment, coupled with the numerous malfunction/emergency procedures, necessitated some departures from a Dash1/NATOPS approach. Nonetheless, the SCOM is the only single source document, written specifically for shuttle astronauts, with comprehensive data about shuttle systems and operations.

This document contains condensed information from a large number of space shuttle publications, including the Flight Data File (FDF), Crew Training workbooks, Flight Procedure Handbooks (FPH), Flight Rules, Shuttle Operational Data Book, and Shuttle Performance Assessment Data Book. The SCOM is not a replacement for any of these documents. It has been carefully reviewed by FCOD and MOD personnel to ensure accuracy of information. In all cases, should a conflict arise between the SCOM and FDF or Flight Rules, the FDF and Flight Rules will govern. If conflicts arise between the SCOM and workbooks or FPH, the conflicts should be resolved with the appropriate book manager or system representative.

Information contained in the SCOM is current as of May 1997 and OI-26. CRT displays documented in the text and in Appendix B are the CRT displays documented in the Level C Functional Subsystem Software Requirements Display and Controls Specification, STS 83-0020H dated February 10, 1992, effectivity OI-25 and subs. It should be noted that several CRT displays provided in the body of this document are for illustrative purposes only; certain CRT displays contain data combined in one illustration that do not appear simultaneously in operational use. Additional information or clarification is presented in three formats: notes, cautions, and warnings. Notes provide amplifying information of a general nature. Cautions provide information and instructions necessary to prevent hardware damage or malfunction. Warnings provide information and instructions necessary to ensure crew safety. The formats in which this material appears are illustrated below.

NOTE

A barberpole APU/HYD READY TO START talkback will not inhibit a start.

CAUTION

After an APU auto shutdown, the APU FUEL TK VLV switch must be taken to CLOSE prior to inhibiting auto shutdown logic. Failure to do so can allow the fuel tank isolation valves to reopen and flow fuel to an APU gas generator bed that is above the temperature limits for safe restart.

WARNING

The FUEL CELL REAC switches on panel R1 are in a vertical column with FUEL CELL 1 REAC on top, FUEL CELL 3 REAC in the middle, and FUEL CELL 2 REAC on the bottom. This was done to allow the schematic to be placed on the panel. Because the switches are not in numerical order, it is possible to inadvertently close the wrong fuel cell reactant valve when shutting down a fuel cell.

The SCOM will be updated according to the process described in the Configuration Control Plan.

SFOC-FL0884

Configuration Control Plan

Your inputs are vital for the SCOM to remain a useful document. Changes may be submitted via the SCOM Change Request (CR) Form. Corrections, additions, deletions, or other constructive suggestions should be submitted to mail code CB-SCOM on the SCOM CR form. The form should be filled out in its entirety except for the Disposition blocks and the Control Number block. CB-SCOM will assign a control number. The initiator should clearly explain the correction or modification and list the applicable page number(s). Additional pages or annotated copies of the applicable SCOM pages may be submitted with the CR. Each CR should contain only corrections or modifications.

CRs containing recommended corrections will be verified by CB designated personnel and incorporated through pen and ink changes or page change notifications (PCNs). The CB representative will determine whether the number of verified corrections warrant a PCN prior to a semiannual review.

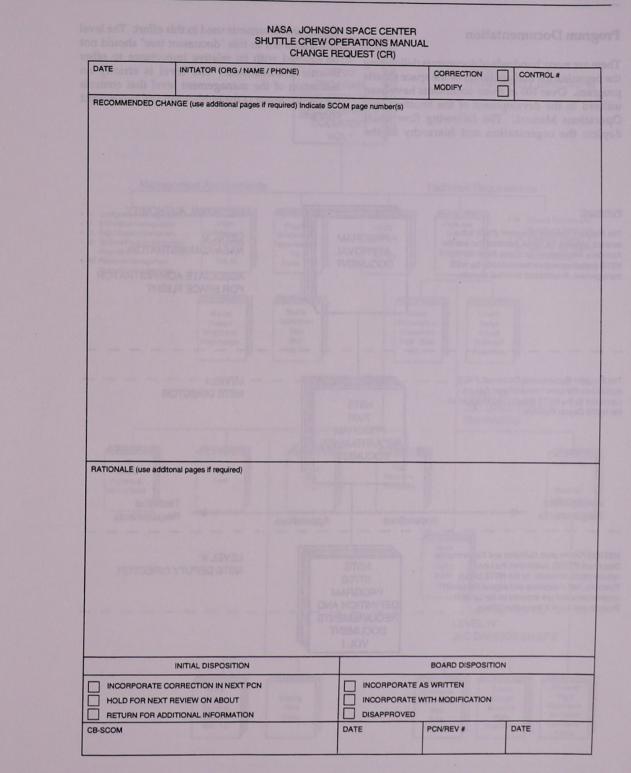
WARNER

As we way yet a column with FURL CELL 1 REAC as top, FURL CELL 3 REAC in the model, and FURL CELL 3 REAC in the bounces. This was done to allow the shamair to be placed in the pase. Because the switches are notice out in the pase. Because precisite to intelvention of the the theory precisite to intelvention of the the theory as and real.

The SCOM with he updated according to the process described in the Configuration Semiannual reviews will be conducted by a Change Board to consider changes to the SCOM. The CB representative (or his designee) will chair the reviews. CRs recommending modifications will be reviewed and incorporated (with or without additional modification) or disapproved. Disapproved CRs will be returned to the initiator with a brief explanation. Initiators may resubmit the CR at a future review. Approved changes will be promulgated via PCNs subsequent to the reviews or at the direction of CB. Revisions (Rev's) will be published at the direction of CB if substantial changes to the manual are made.

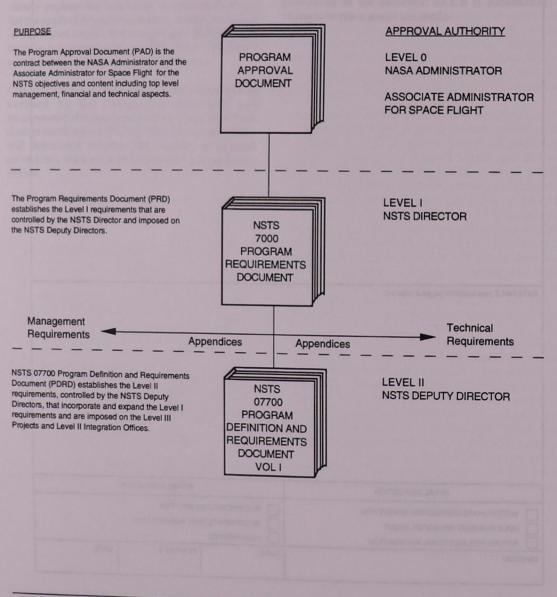
True accument contains contained by bitching for the state of a part of a part of the Physics of

Information contriand in the SOOM is current as of his 1997 and Ol-26. CRT displays documented in the text and in Appendix B are the CRT displays documented in the Level C Functional Subsystem Software Requirements Display and Controls Specification, STS 63-0000H dated Rebrary 10, 1992 effectivity Ch-28 and solts. If should be mited that asyveral CRT displays provided in the body of one document are for illustrative proposts of body of one document are for illustrative proposts of body of one document are for illustrative proposts of body of one illustration that do not appear diminimizations in conselication that do not appear diminimization in one



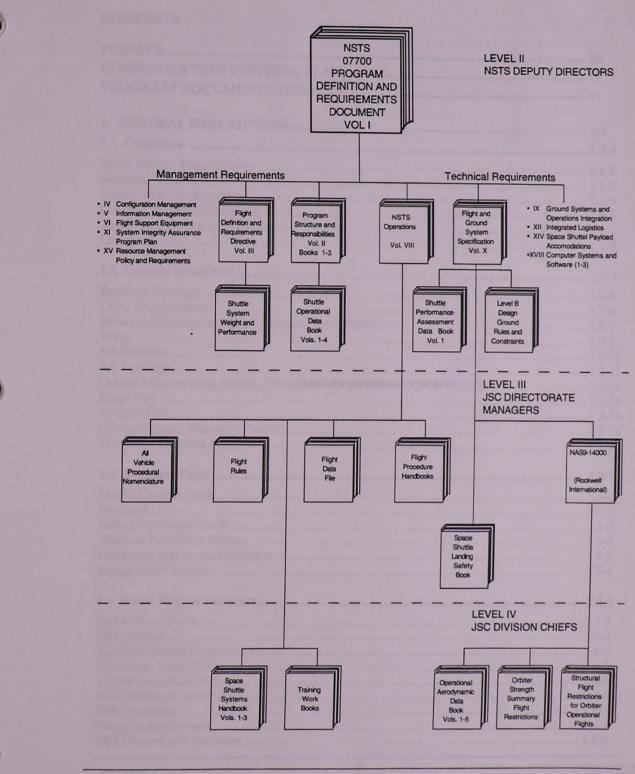
Program Documentation

There are many hundreds of documents delineating the organization and operation of the space shuttle program. Over 100 of these documents have been utilized in the development of the Shuttle Crew Operations Manual. The following flow chart depicts the organization and hierarchy of the significant documents used in this effort. The level of a document in this "document tree" should not be equated with its relative importance to other Shuttle publications. The level is strictly an indication of the management level that controls the development of the publication and subsequent changes.



05/12/97

SFOC-FL0884



PREFACE

CONTENTS

PREFACE	:::
CONFIGURATION CONTROL PLAN	im
PROGRAM DOCUMENTATION	1V
	V1
1 CENERAL DESCRIPTION	
1. GENERAL DESCRIPTION	1-1
1.1 Overview	1.1-1
Space Shuttle Requirements	1.1-1
Nominal Mission Profile	1.1-2
Launch and Landing Sites	1.1-5
Orbiter Ground Turnaround	1.1-5
Space Shuttle Coordinate Reference System	1.1-7
Location Codes	1.1-8
12 Orbitan Structure	Open
1.2 Orbiter Structure	
Forward Fuselage	
Crew Compartment	1.2-3
Forward Fuselage and Crew Compartment Windows	
Wing	1.2-8
Midfuselage	1.2-10
Aft Fuselage Orbital Maneuvering System/Reaction Control System (OMS/RCS) Pods	1.2-11
Body Flap	1.2-13
Vertical Tail	
Orbiter Passive Thermal Control	
Thermal Protection System	
	1.2 10
1.3 External Tank	1.3-1
Liquid Oxygen Tank	
Intertank	
Liquid Hydrogen Tank	
Thermal Protection System	
Hardware and Instrumentation	
Range Safety System	
1.4 Solid Rocket Boosters	1.4-1
Hold-Down Posts	1.4-3
SRB Ignition	1.4-4
Electrical Power Distribution	1.4-5
Hydraulic Power Units	
Thrust Vector Control	1.4-6
SRB Rate Gyro Assemblies	1.4-6
SRB Separation	1.4-6
Range Safety System	1.4-7
SRB Descent and Recovery	1.4-8





2. SYSTEMS	2-1
2.1 Auxiliary Power Unit/Hydraulics (APU / HYD)	2.1-1
Description	2.1-1
Fuel System	2.1-2
Gas Generator and Turbine	2.1-5
Lubricating Oil Electronic Controller	2.1-5
Injector Cooling System	2.1-10
APU Heaters	2.1-11
Water Spray Boilers	2.1-12
Main Hydraulic Pump	
Hydraulic Reservoir	
Hydraulic Accumulator Circulation Pump and Heat Exchanger	
Hydraulic Heaters	
Operations	
Addier Similare communication and a second	
2.2 Caution and Warning System (C/W)	2.2-1
Description	2.2-1
Alarms	2.2-2
Smoke Detection and Fire Suppression	2.2-5
Rapid Cabin Depressurization	2.2-10
Operations	2.2-11
SPEC 60, SM Table Maintenance	2.2-14
F7 Light Summary Fault Message Summary	2.2-20
2.3 Closed Circuit Television (CCTV)	2.3-1
Description	2.3-1
video Processing Equipment	222
CCTV Cameras	207
CCTV Camera Lens Control	2.3-11
Pan/Tilt Units (PTUs) Cabin Cameras	2.3-12
raco rape recorders (v rrs)	00 15
	2.3-17
- Jour Day Cantera Operations	2.3-20
	2.3-21
2.4 Communications	
Description	
Description S-Band Phase Modulation S-Band Frequency Modulation	
S-Band Frequency Modulation Ku-Band System	2.4-2
	2.4-12

Payload Communication System	2 4-20
Ultrahigh Frequency System	2 4-23
Audio Distribution System	2 4-25
Instrumentation	2 4-35
Thermal Impulse Printer System	2.4-40
2.5 Crew Systems	
Description	
Crew Clothing/Worn Equipment	2.5-1
Personal Hygiene Provisions	2.5-1
Sleeping Provisions	2.5-1
Exercise Equipment	2.5-4
Housekeeping Equipment	
Restraints and Mobility Aids	2.5-5
Stowage Containers	2.5-5
Reach and Visibility Aids	2.5-6
Photographic Equipment	2.5-8
Sighting Aids	2.5-10
Window Shades and Filters	2.5-10
Shuttle Orbiter Medical System	2.5-11
Operational Bioinstrumentation System	2.5-12
Radiation Equipment	2.5-14
Air Sampling System	2.5-15
2.6 Data Processing System (DPS)	2.6-1
2.6 Data Processing System (DPS)	
Description	2.6-1
Description General Purpose Computers (GPCs)	2.6-1
Description General Purpose Computers (GPCs) Data Bus Network	
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers	2.6-1 2.6-2 2.6-7 2.6-7
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers Mass Memory Units	2.6-1 2.6-2 2.6-7 2.6-7 2.6-11 2.6-13
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers Mass Memory Units Multifunction CRT Display System	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers Mass Memory Units	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers Mass Memory Units Multifunction CRT Display System Master Timing Unit	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-19
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers Mass Memory Units Multifunction CRT Display System Master Timing Unit Software Operations	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-19 2.6-25
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers Mass Memory Units Multifunction CRT Display System Master Timing Unit Software Operations 2.7 Dedicated Display Systems	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-19 2.6-25 2.6-25
Description	2.6-1 2.6-2 2.6-7 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-15 2.6-19 2.6-25 2.6-25
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-15 2.6-19 2.6-25 2.7-1 2.7-1 2.7-2
Description General Purpose Computers (GPCs) Data Bus Network Multiplexers/Demultiplexers Mass Memory Units Multifunction CRT Display System Master Timing Unit Software Operations 2.7 Dedicated Display Systems Description Display Driver Unit Attitude Director Indicator (ADI)	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-19 2.6-25 2.6-25 2.7-1 2.7-1 2.7-2 2.7-4
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-15 2.6-19 2.6-25 2.7-1 2.7-1 2.7-2 2.7-4 2.7-8
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-15 2.6-19 2.6-25 2.7-1 2.7-1 2.7-2 2.7-4 2.7-8 2.7-13
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-19 2.6-25 2.7-1 2.7-1 2.7-2 2.7-4 2.7-8 2.7-13 2.7-15
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-13 2.6-14 2.6-15 2.6-15 2.6-19 2.6-25 2.7-1 2.7-2 2.7-4 2.7-4 2.7-8 2.7-13 2.7-15 2.7-17
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-14 2.6-15 2.6-19 2.6-25 2.6-19 2.6-25 2.7-1 2.7-1 2.7-2 2.7-4 2.7-8 2.7-13 2.7-15 2.7-17 2.7-19
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-14 2.6-15 2.6-19 2.6-25 2.6-25 2.7-1 2.7-2 2.7-4 2.7-4 2.7-8 2.7-13 2.7-15 2.7-17 2.7-19 2.7-20
Description	2.6-1 2.6-2 2.6-7 2.6-11 2.6-13 2.6-14 2.6-15 2.6-19 2.6-25 2.6-19 2.6-25 2.7-1 2.7-1 2.7-2 2.7-4 2.7-8 2.7-13 2.7-15 2.7-17 2.7-19 2.7-20 2.7-20 2.7-20



2.8 Electrical Power System (EPS)	. 2.8-1
Description	. 2.8-1
Power Reactants Storage and Distribution System	2.8-1
Fuel Cell System	. 2.8-10
Electrical Power Distribution and Control	2.8-20
Operations	2.8-30
-1	
2.9 Environmental Control and Life Support System (ECLSS)	
Description	2.9-1
Pressure Control System	2.9-4
Atmospheric Revitalization System	
Active Thermal Control System	
Supply and Waste Water Systems	
Operations	2.9-42
2.10 Escape Systems	2.10-1
Description	
Launch Pad Egress Systems	
Launch and Entry Suits	2.10-1
Personal Parachute Assembly	2 10-4
Crew Escape System Pyrotechnics	2 10-10
Egress Pole System	2 10-12
Emergency Egress Slide	2.10-12
Secondary Emergency Egress	2.10-13
Procedures for Bailout, Water Survival, and Rescue	2-10-15
2.11 Extravehicular Activity (EVA)	0 11 1
Description Extravelicular Mobility Unit	2.11-1
Extravehicular Mobility Unit Airlock	2.11-3
EVA Support Equipment	2.11-11
Simplified Aid for EVA Rescue	2.11-15
Operations	2.11-17
2.12 Galley/Food	2.12-1
Description	
Volume A - Pantry	2.12-1
2.13 Guidance, Navigation, and Control (GNC)	2.12 0
Description	2.13-1
Digital Autopilot Operations	2.13-44
Operations	2.13-50

2.14 Landing/Deceleration System	2.14-1
Description	
Landing Gear	
Drag Chute	
Main Landing Gear Brakes	2.14-6
Nose Wheel Steering	2.14-10
Operations	2.14-11
215 Lighting System	2.20 8,040
2.15 Lighting System	
Description	2.15-1
Interior Lighting	2.15-1
Exterior Lighting	2.15-12
2.16 Main Propulsion System (MPS)	2 16-1
Description	
Space Shuttle Main Engines (SSMEs)	
Space Shuttle Main Engine Controllers	
Propellant Management System (PMS)	
Helium System	
MPS Hydraulic Systems	
Malfunction Detection	
Operations	
Post Insertion	
Orbit	
Deorbit Prep	2.16-36
Entry	
RTLS Abort Propellant Dump Sequence TAL Abort Propellant Dump Sequence	
2.17 Mechanical Systems	2.17-1
Description	2.17-1
Active Vent System	
External Tank Umbilical Doors	
Payload Bay Door System	2.17-9
Drag Chute	(see 2.14-5)
2.18 Orbital Maneuvering System (OMS)	2.18-1
Description	
Engines	
Helium System	2.18-9
Propellant Storage and Distribution	2.18-12
Thermal Control	2.18-18
Thrust Vector Control (TVC)	2.18-19
Fault Detection and Identification	2.18-21
Operations	



xiii

2.19 Payload Deployment and Retrieval System (PDRS)	2.19-1
	2.19-1
Description Remote Manipulator System (RMS)	2.19-1
Remote Manipulator System (RMS) Manipulator Positioning Mechanism	2.19-11
Payload Retention Mechanisms	2.19-14
Operations	2.19-18
Operations	
2.20 Reaction Control System (RCS)	2.20-1
Description	2.20-1
Int System	2.20-3
Propellant System	2.20-4
Helium System	2.20-9
Thermal Control	2.20-11
RCS Redundancy Management	2.20-12
Operations	2.20-17
2.21 Spacelab	2.21-1
Description	
Module	2.21-3
Pallet	2.21-5
Instrument Pointing Subsystem (IPS)	
Flight Deck Interfaces	
Electrical Power	2.21-6
Command and Data Management System	
Module Environmental Control and Life Support (ECLS)	2.21-14
2.22 Spacehab	2.22-1
Description	
Configurations	
Flight Deck Interfaces	2.22-1
Command and Data Subsystem	2 22-3
Caution and Warning	2 22-3
Electrical Power Subsystem	2 22-3
Environmental Control Subsystem	2 22-4
Audio Communication Subsystem	2.22-4
Fire Suppression Subsystem	2.22-4
Closed Circuit Television Subsystem	2.22-4
2.23 Orbiter Docking System	2 22 1
Description	. 2.25-1
Description External Airlock	. 2.23-1
Truss Assembly	. 2.23-2
Androgynous Peripheral Docking System	. 2.23-2
The booperational bequences (OPS)	2 22 E
Operational Notes of Interest	. 2.23-5
	. 2.23-1

2.24 Stowage	2.24-1
Description	2.24-1
Rigid Containers	2.24-1
Flexible Containers	2.24-4
Middeck Accommodations Rack	2.24-6
2.25 Waste Management System (WMS)	2.25-1
Description	2.25-1
Operations	
2.26 Payload and General Support Computer	2.26-1
Description	2.26-1
Equipment	
Production and a second s	
3. FLIGHT DATA FILE	. 3-1
3.1 Control Documents	. 3.1-1
Ascent Checklist	
Post Insertion Book	. 3.1-1
Flight Plan	
Deorbit Preparation Book	
Entry Checklist	. 3.1-2
22 Connect Deservate	2 2 1
3.2 Support Documents	. 5.2-1
Orbit Operations Checklist	. 3.2-1
Photo/TV Checklist	. 3.2-1
Payload Deployment and Retrieval System Operations Checklist Extravehicular Activity Checklists	3 2-1
Rendezvous Checklist	32-1
Payload Operations Checklist	. 3.2-2
Deploy Checklist	. 3.2-2
Additional Support Documents	. 3.2-2
appeed Limitations announcement and the second seco	
3.3 Off-Nominal Documents	. 3.3-1
Pocket Checklists	
Ascent/Entry Systems Procedures Book	. 3.3-1
Systems Abort Once Around Book	. 3.3-1
Malfunction Procedures Book	. 3.3-1
In-Flight Maintenance Checklist	. 3.3-1
Payload Systems Data and Malfunction Procedures Book	. 3.3-2
Medical Checklist	. 3.3-2
Contingency EVA Operations Checklist	. 3.3-2
Contingency Deorbit Preparation Book	0.5-2

CONTENTS

	3.4-1
3.4 Reference Documents	34-1
3.4 Reference Documents	3.4-1
Data Processing System Dictionary Payload Systems Data/Malfunction Book	3.4-1
Payload Systems Data/Mairunchon Book Maps and Charts Book	2.25
3.5 Operational Use	3.5-1
3.5 Operational Use	3 5-1
FDF Fabrication	3.5-1
Preliminaries	3.5-1
Basic	35-2
482	35-3
402 Final	3.5-3
Flight	
4. OPERATING LIMITATIONS	4-1
4. OPERATING LIMITATIONS	111
4.1 Instrument Markings	4.1-1
Description	4.1-1
Panel F6 Indicator	4.1-1
Panel F7 Meters	4.1-2
Panel F8 Meters	4.1-5
Panel F9 Meters	4.1-7
Panel O1 Meters	4.1-8
Panel O2 Meters	4.1-13
Panel O3 Meters	4.1-16
4.2 Engine Limitations	4 2-1
Space Shuttle Main Engines	
Orbital Maneuvering System	
Reaction Control System	. 4.2-3
4.3 Airspeed Limitations	4.3-1
Ascent	
Entry	
Landing	
	. 4.3-1
4.4 Angle of Attack Limitations	. 4.4-1
Entry	
Approach and Landing	4.4-1
11	. 4.4-1
4.5 Sideslip Limitations	4.5-1
4.6 Dynamic Pressure Limitations	4.6-1
Ascent	46-1
Entry	46-2
Approach and Landing	. 4.6-2

4.7 Crosswind Limitations	4.7-1
4.8 Landing Weight Limititions	
4.9 Dynamic Pressure Limitations	A Det Modes
Entry	
Main Gear Touchdown	4.9-1
Nose Gear Touchdown	4.9-1
4.10 Center of Gravity Limitations	
4.11 Acceleration Limitations	4.11-1
Ascent	
Entry	4.11-1
4.12 Weather Limitations	
5. NORMAL PROCEDURES SUMMARY	
5.1 Pre-Launch	
Pre-Launch Procedures	
5.2 Ascent	5.2-1
Powered Flight	
OMS Burns	
Post Insertion	5.2-4
5.3 Orbit	
Orbit Operations	
OMS (RCS) Burns	
Rendezvous	5.3-4
Proximity Operations	
Last Full On-Orbit Day	5.3-10
5.4 Entry	5.4-1
Deorbit Preparation	
Deorbit Burn	
Entry Interface	5.4-5
Terminal Area Energy Management	
Approach and Landing	5.4-8





5.5 Post Landing	5.5-1
6. EMERGENCY PROCEDURES	6-1
6.1 Launch Abort Modes and Rationale	6.1-1
Made 1 Unsided Foress / Escane	6.1-1
Made 2 Aided Escane	0.1-1
Mode 3 - Aided Escape	0.1-2
Mode 4 - Aided Escape	6.1-2
6.2 Ascent Aborts	6.2-1
Performance Aborts	6.2-1
Systems Aborts	6.2-3
Range Safety	6.2-4
6.3 Return To Launch Site	
Powered RTLS	636
Gliding RTLS	
6.4 Transoceanic Abort Landing	6.4-1
Nominal Transoceanic Abort Landing	6.4-1
Post MECO Transoceanic Abort Landing	6.4-4
6.5 Abort Once Around	6.5-1
Powered Flight OMS-1	6.5-1 6.5-1
Powered Flight OMS-1 OMS-2	6.5-1 6.5-1 6.5-3
Powered Flight OMS-1	6.5-1 6.5-1 6.5-3
Powered Flight OMS-1 OMS-2	6.5-1 6.5-1 6.5-3 6.5-4
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit	6.5-1 6.5-1 6.5-3 6.5-4 6.6-1
Powered Flight	6.5-1 6.5-3 6.5-4 6.6-1 6.6-1
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit Powered Flight	6.5-1 6.5-3 6.5-4 6.6-1 6.6-1
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit OMS-1 Powered Flight OMS-1 OMS-2 OMS-2	6.5-1 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit OMS-1 Powered Flight OMS-1 OMS-2 OMS-1 OMS-2 OMS-1 OMS-3 OMS-4 OMS-4 OMS-4 OMS-5 OMS-4	6.5-1 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.6-1 6.7-1
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit OMS-1 Powered Flight OMS-1 OMS-2 OMS-1 OMS-1 OMS-2 6.7 Contingency Abort OMS-1	6.5-1 6.5-1 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.6-1 6.7-1
Powered Flight	6.5-1 6.5-3 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.6-1 6.7-1 6.7-1 6.7-2
Powered Flight	6.5-1 6.5-3 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.6-1 6.7-1 6.7-2 6.7-2
Powered Flight	6.5-1 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.6-1 6.7-1 6.7-1 6.7-2 6.7-2 6.7-3
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit Powered Flight OMS-1 OMS-2 6.7 Contingency Abort Powered Flight Three Engine Out Automation ET Separation Entry 6.8 Systems Failures	6.5-1 6.5-3 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.7-1 6.7-1 6.7-2 6.7-2 6.7-3 6.8-1
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit Powered Flight OMS-1 OMS-2 6.7 Contingency Abort Powered Flight Three Engine Out Automation ET Separation Entry 6.8 Systems Failures APU/Hydraulics	6.5-1 6.5-3 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.7-1 6.7-2 6.7-2 6.7-2 6.7-3 6.8-1 6.8-2
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit Powered Flight OMS-1 OMS-1 OMS-2 6.7 Contingency Abort Powered Flight Three Engine Out Automation ET Separation Entry 6.8 Systems Failures APU/Hydraulics Communications	6.5-1 6.5-3 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.7-1 6.7-2 6.7-2 6.7-2 6.7-3 6.8-1 6.8-2 6.8-5
Powered Flight OMS-1 OMS-2 Entry 6.6 Abort to Orbit Powered Flight OMS-1 OMS-2 6.7 Contingency Abort Powered Flight Three Engine Out Automation ET Separation Entry 6.8 Systems Failures APU/Hydraulics	6.5-1 6.5-3 6.5-3 6.5-4 6.6-1 6.6-1 6.6-1 6.7-1 6.7-2 6.7-2 6.7-2 6.7-3 6.8-1 6.8-2 6.8-5

Environmental Control and Life Support System	(0.0
Electrical Power System	6.8-8
Guidance, Navigation, and Control	6 9 12
Mechanical	6.8-12
Main Propulsion System	6.8-12
Orbital Maneuvering System/Reaction Control System	6 8-14
6.9 Multiple Failure Scenarios	. 6.9-1
MPS He Leak with APC/ALC Failures	
Set Splits During Ascent	. 6.9-1
Stuck Throttle in the Bucket	. 6.9-1
Second Hydraulic Failure and 1 SSME Failed	. 6.9-2
Two APUs/Hydraulic Systems	. 6.9-2
APU 1 and Multiple Prox Box Failures	. 6.9-2
Two Freon/Water Loops	. 6.9-2
Total Loss of FES	. 6.9-2
Total Loss of FES with BFS Failure	
Two Fuel Cells	
Both OMS	
OMS/RCS Leak with DPS/EPS Failures	. 6.9-3
Cryo Leak with Failed Manifold Valve	. 6.9-3
BFS Self Engage	. 6.9-3
Curs	(nonine)
6.10 Switch and Panel Cautions	
MPS Switches	
Fuel Cell Reactant Valves	
CRT Power Switch	. 6.10-1
GPC/MDM	
PLB Mech Power/Enable	. 6.10-1
HYD Press and APU Controller Power Switches	
OMS Kit	. 6.10-1
thing with Mission Control	32.340
6.11 Systems Failure Summary	. 6.11-1
7. TRAJECTORY MANAGEMENT AND FLIGHT CHARACTERISTICS	7-1
7.1 Ascent	
Powered Flight	. 7.1-1
Insertion OMS Burns	. 7.1-7
Backup Flight System	7.1-8
Sensory Cues	7.1-9
7.2 Orbit	7.2-1
Attitude Control	72-5
Translation	72-6
Rendezvous/Proximity Operations	1.2-0



7.3 Entry	7.3-1
Overview of Entry Flying Tasks	7.3-1
Deorhit Burn	7.3-1
Entry	7.3-6
Backup Flight System	7.3-17
Sensory Cues	7.3-17
Ground Controlled Approach	7.3-17
7.4 Terminal Area Energy Management, Approach, Landing, and Rollout	7.4-1
Definition and Overview	7.4-1
Terminal Area Energy Management	7.4-2
Heading Alignment Cone	7.4-7
Outer Glide Slope	
Preflare	
Inner Glide Slope	
Touchdown	
Derotation	
Handling Qualities	
Wind Effects on Trajectory	
Backup Flight System	
Off-Nominal Approaches	7.4-23
Sensory Cues	7.4-23
Autoland	7.4-24
8. INTEGRATED OPERATIONS	8-1
8. INTEGRATED OPERATIONS 8.1 Flight Crew Duties and Coordination	
8.1 Flight Crew Duties and Coordination	8.1-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases	8.1-1
8.1 Flight Crew Duties and Coordination	8.1-1 8.1-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol	8.1-1 8.1-1 8.1-1 8.1-2
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control	8.1-1 8.1-1 8.1-1 8.1-2 8.2-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources	8.1-1 8.1-1 8.1-2 8.2-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-1 8.2-2
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-1 8.2-2 8.2-3 8.3-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch Flight Crew	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-1 8.2-2 8.2-3 8.2-3 8.3-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch Flight Crew Mission Control Center	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-1 8.2-2 8.2-3 8.3-1 8.3-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch Flight Crew Mission Control Center	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-1 8.2-2 8.2-3 8.3-1 8.3-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch Flight Crew Mission Control Center Launch Control Center	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-1 8.2-1 8.2-2 8.2-3 8.3-1 8.3-1 8.3-1 8.3-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch Flight Crew Mission Control Center Launch Control Center 8.4 Launch	8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-2 8.2-3 8.3-1 8.3-1 8.3-1 8.3-1 8.3-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch Flight Crew Mission Control Center Launch Control Center Flight Crew	 8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-2 8.2-3 8.3-1 8.3-1 8.3-1 8.3-1 8.3-1 8.4-1
8.1 Flight Crew Duties and Coordination Dynamic Flight Phases Orbit Phase Intercom Protocol 8.2 Working with Mission Control MCC Resources Operations Monitoring and Control Air to Ground Voice Communications Telemetry Uplink 8.3 Pre-Launch Flight Crew Mission Control Center Launch Control Center	 8.1-1 8.1-1 8.1-1 8.1-2 8.2-1 8.2-1 8.2-2 8.2-3 8.3-1 8.3-1 8.3-1 8.3-1 8.4-1

8.5 Ascent	8.5-1
Flight Crew	8 5-1
Mission Control Center	8.5-1
8.6 Orbit	
Flight Crew	8.6-1
Mission Control Center	8.6-1
8.7 Entry	8 7-1
Flight Crew	
Mission Control Center	8.7-1
forformation about the orbiter, its continuous and	0.7 1
8.8 Post Landing	8.8-1
Flight Crew	8.8-1
Mission Control Center	8.8-1
Launch Control Center	8.8-1
9. PERFORMANCE	0.1
9.1 Ascent	
Payload	
Launch Window Squatcheloids	
Main Engines	
Altitude, Velocity, and Dynamic Pressure	
MECO Targets	
ET Impact	9.1-8
Abort Mode Boundaries	
Minimum Safe Orbit	9.1-10
9.2 Orbit	9.2-1
Drag	9.2-1
Period	9.2-1
Perturbations	9.2-1
OMS/RCS	9.2-2
9.3 Entry	9 3-1
Downrange/Crossrange Trajectory	9.3-2
Entry History	9.3-2
Entry RCS Use Data	9.3-6
Rollout/Braking	9.3-6
Rollout History).3-8



CONTENTS

APPENDIX A: Panel Diagrams	A-1
APPENDIX B: CRT Displays	B-1
APPENDIX C: Study Notes	C-1
APPENDIX C: Study Notes	D-1
APPENDIX D: Rules of Thund	E-1
APPENDIX E: Cockpit Resource Management	E_1
APPENDIX F: OI Updates	
Index	
List of Effective Pages	LOEP-

.

1. GENERAL DESCRIPTION

Contents	
1.1 Overview	1.1-1
1.2 Orbiter Structure	1.2-1
1.3 External Tank	1.3-1
1.4 Solid Rocket Boosters	1.4-1

The section provides general background information about the orbiter, its configuration and coordinate systems, the nominal mission profile, and general procedures followed during a Shuttle mission. It also briefly discusses components, such as the external tank and solid rocket, that are no;t included in the next section on orbiter systems. pace Shuttle Requirements

ar around simultie system turning of hor primary mounts an orbiter spatement, nor solid ruched corres (Scillie, an external task (EI) is beause find of extention, and three Spate Shiftle mate contains SMES). The Shiftle can be appear system of the Barth orbit 100 to 112 cause is context above fine on Barth orbit 100 to 122 cause is context above fine orb. Physics is are carried in a key 15 feet in annexes and 35 feet long. Manor system primaries are the orbiter and the two Solid remarks.

to define the correled a flight or to of up to sight means. The neurinal mission is a to be despection of up to sight area in acc. The crow acceptarization is a situation of the relevant flight flight for the second sec

1.1 OVERVIEW

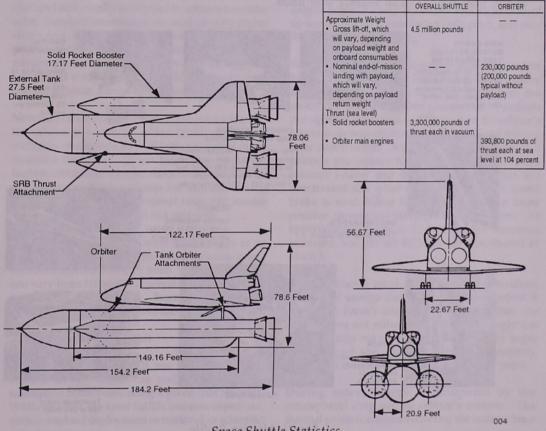
CONTENTS

Space Shuttle Requirements	1.1-1
Nominal Mission Profile	1.1-2
Launch and Landing Sites	1.1-5
Orbiter Ground Turnaround	1.1-5
Space Shuttle Coordinate	
Reference System	1.1-7
Location Codes	1.1-8

Space Shuttle Requirements

The Space Shuttle system consists of four primary elements: an orbiter spacecraft, two solid rocket boosters (SRBs), an external tank (ET) to house fuel and oxidizer, and three Space Shuttle main engines (SSMEs). The Shuttle can transport payloads into near Earth orbit 100 to 312 nautical miles above the Earth. Payloads are carried in a bay 15 feet in diameter and 60 feet long. Major system requirements are that the orbiter and the two SRBs be reusable.

The orbiter has carried a flight crew of up to eight persons. The nominal mission is 4 to 16 days in space. The crew compartment has a shirtsleeve environment, and the acceleration load is never greater than 3 g's. In its return to Earth, the orbiter has a cross-range maneuvering capability of about 1,100 nautical miles.



Space Shuttle Statistics

1.1-1



Nominal Mission Profile

Launch

In the launch configuration, the orbiter and two SRBs are attached to the ET in a vertical (nose-up) position on the launch pad. Each SRB is attached at its aft skirt to the mobile launcher platform by four bolts.

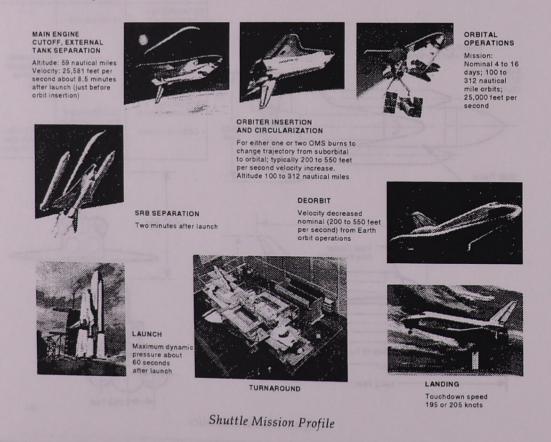
The three SSMEs, fed liquid hydrogen fuel and liquid oxygen oxidizer from the ET, are ignited first. When it has been verified that the engines are operating at the proper thrust level, a signal is sent to ignite the SRBs. At the proper thrust-to-weight ratio, initiators (small explosives) at eight hold-down bolts on the SRBs are fired to release the Space Shuttle for liftoff. Elapsed time is a few seconds.

Maximum dynamic pressure is reached early in the ascent, nominally 30 to 60 seconds after liftoff.

Approximately 1 minute later (2 minutes into the ascent phase), the two SRBs have consumed their propellant and are jettisoned from the ET. This is triggered by a separation signal from the orbiter.

The boosters briefly continue to ascend, while small thrusters fire to carry them away from the Space Shuttle. The boosters then turn and descend, and at a predetermined altitude, parachutes are deployed to decelerate them for a safe splashdown in the ocean. Splashdown occurs approximately 141 nautical miles from the launch site. The boosters are recovered and reused.

The orbiter and ET continue to ascend, using the thrust of the three SSMEs. Approximately 8 minutes after launch and just short of orbital velocity, the three engines are shut down (main engine cutoff or MECO), and the ET is jettisoned on command from the orbiter.



The forward and aft reaction control system (RCS) jets provide attitude control, translate the orbiter away from the ET at separation, and maneuver the orbiter to burn attitude prior to the orbital maneuvering system (OMS) burn.

The ET continues on a ballistic trajectory and enters the atmosphere, where it disintegrates. Its nominal impact is in the Indian Ocean for a 28 degree inclination launch.

Orbit Insertion and Circularization

One type of mission profile, called a standard insertion because it was the standard early in the Shuttle program, uses two OMS burns for orbital insertion. The first OMS burn (OMS 1) raises maximum altitude and occurs just a few minutes after MECO. The second OMS burn (OMS 2) occurs at the highest point of the trajectory after MECO/ OMS 1. OMS 2 raises the lowest point of the orbit (perigee) and usually is targeted to achieve a circular orbit. Standard insertions were used on early flights when less information was available on SSME performance and targeting precision. At present, a standard insertion would only be used for flights to low orbital altitudes where the ET impact point is outside of limits using a direct insertion.

Normally, only one OMS burn is required to place the orbiter in a circular orbit. Missions planned with only one insertion OMS burn are called direct insertion missions. Direct insertions allow the highest orbital altitudes by maximizing the amount of OMS propellant available for altitude raising while ensuring that the external tank will reenter the atmosphere and impact in a safe area.

The direct insertion OMS burn is referred to as an OMS 2 burn since it performs the same function as a standard insertion OMS 2 burn. Orbital altitudes can vary from 100 to 312 nautical miles, depending on mission requirements. Insertion OMS burns typically add 200 to 550 fps to the orbiter's velocity.

Orbit

The forward and aft RCS jets provide attitude control of the orbiter as well as any minor translation maneuvers along a given axis on orbit. While on orbit, the crew fulfills mission objectives, such as payload deployment or retrieval, or scientific experiments.

Deorbit

At the completion of orbital operations, the RCS is used to orient the orbiter in a tail first attitude. The two OMS engines are burned to slow the orbiter for deorbit. The deorbit burn usually decreases the orbiter's velocity 200 to 550 feet per second depending on orbital altitude. When the deorbit burn is complete, the RCS is used to rotate the orbiter's nose forward for entry. The RCS controls the orbiter until atmospheric density is sufficient for the pitch, roll, and yaw aerodynamic control surfaces to become effective.

Entry

Entry interface is considered to occur at 400,000 feet altitude approximately 4,200 nautical miles from the landing site and at approximately 25,000 feet per second velocity. The orbiter is maneuvered to zero degrees roll and yaw (wings level) and a 40degree angle of attack for entry. The flight control system issues the commands to roll, pitch, and yaw RCS jets for rate damping.

Without forward RCS programmed test inputs, the forward RCS jets are inhibited prior to entry interface, and the aft RCS jets maneuver the spacecraft until a dynamic pressure of 10 pounds per square foot is sensed. This is when the orbiter's ailerons become effective. The aft RCS roll jets are then deactivated. At a dynamic pressure of 2 pounds per square foot, the orbiter's elevators become active, and the aft RCS pitch jets are deactivated at a q-bar of 40. The orbiter's speed brake is used below Mach 10 to induce a more positive downward elevator trim deflection. At approximately Mach 5, the rudder becomes activated at Mach 1.

Entry guidance must dissipate the tremendous amount of energy the orbiter possesses when it enters the Earth's atmosphere to assure that the orbiter does not either burn up (entry angle too steep) or skip out of the atmosphere (entry angle too shallow) and that the orbiter is properly positioned to reach the desired touchdown point.

During entry, energy is dissipated by the atmospheric drag on the orbiter's surface. The thermal protection system covering the entire orbiter provides the protection necessary for the orbiter to survive the extremely high temperatures encountered. Higher atmospheric drag levels enable faster energy dissipation with a steeper trajectory.

Normally, the angle of attack and bank angle enable the atmospheric drag of any flight vehicle to be controlled. However, for the orbiter, angle of attack was rejected because it creates surface temperatures above the design specification. The angle of attack scheduled during entry is loaded into the orbiter computers as a function of relative velocity, leaving bank angle for energy control. Increasing the bank angle decreases the vertical component of lift, causing a higher sink rate and energy dissipation rate. Increasing the bank angle does raise the surface temperature of the orbiter, but not nearly as drastically as an equal angle of attack increase.

If the orbiter is low on energy (current range-to-go much greater than nominal at current velocity), entry guidance will command lower than nominal drag levels. If the orbiter has too much energy (current range-to-go much less than nominal at the current velocity), entry guidance will command higher-than-nominal drag levels to dissipate the extra energy.

Bank angle is used to control cross range. Azimuth error is the angle between the plane containing the orbiter's position vector and the heading alignment cone tangency point and the plane containing the orbiter's position vector and velocity vector. When the azimuth error exceeds a computer-loaded number, the orbiter's bank angle is reversed.

Thus, descent rate and downranging are controlled by bank angle. The steeper the bank angle, the greater the descent rate and the greater the drag. Conversely, the minimum drag attitude is wings level. Cross range is controlled by bank reversals. The entry thermal control phase is designed to keep the backface and surface temperatures within the design limits. A constant heating rate is established until below 19,000 feet per second.

The equilibrium glide phase transitions the orbiter from the rapidly increasing drag levels of the temperature control phase to the constant drag level of the constant drag phase. The equilibrium glide flight is defined as flight in which the flight path angle, which is the angle between the local horizontal and the local velocity vector, remains constant. Equilibrium glide flight provides the maximum downrange capability. It lasts until the drag acceleration reaches 33 feet per second squared.

The constant drag phase begins at that point. The angle of attack is initially 40 degrees, but it begins to ramp down to approximately 36 degrees by the end of this phase.

In the transition phase, the angle of attack continues to ramp down, reaching the approximately 14degree angle of attack at the entry terminal area energy management (TAEM) interface, at approximately 83,000 feet altitude, 2,500 feet per second, and 60 nautical miles from the landing runway. Control is then transferred to TAEM guidance.

During the entry phases described, the orbiter's bank commands keep the orbiter on the drag profile and control cross range.

TAEM guidance steers the orbiter to one of two 18,000-ft radius heading alignment cones (HAC), which are located tangent to and on either side of the runway centerline on the approach end. In TAEM guidance, excess energy is dissipated with an S-turn. This increases the ground track range as the orbiter turns away from the HAC until sufficient energy is dissipated to allow a normal approach and landing guidance phase capture, which begins at 10,000 feet altitude. The orbiter also can be flown near the velocity for maximum lift over drag or wings level for the range stretch case. The spacecraft slows to subsonic velocity at approximately 49,000 feet altitude, about 26 nautical miles from the landing site.

At TAEM acquisition, the orbiter is turned until it is aimed at a point tangent to the HAC and continues until it reaches way point (WP) 1. At WP-1, the TAEM heading alignment phase begins. The HAC is followed until landing runway alignment, \pm 20 degrees, has been achieved. In the TAEM prefinal phase, the orbiter pitches down to acquire the steep glide slope, increases airspeed, banks to acquire the runway centerline, and continues until on the runway centerline, on the outer glide slope, and on airspeed. The approach and landing guidance phase begins with the completion of the TAEM prefinal phase and ends when the spacecraft comes to a complete stop on the runway.

Landing

The approach and landing trajectory capture phase begins at the approach and landing interface and continues to acquition of the steep outer glide slope. The approach and landing phase begins at about 10,000 feet altitude at an equivalent airspeed of 290 knots for lightweight orbiters (220 k lbs or less) and 300 KEAS for heavyweight orbiters (greater than 220 k lbs) and 6.0 or 6.6 nautical miles (for -19 or -17 degree glide slopes respectively) from touchdown. Approach and landing guidance is initiated at this point to guide the orbiter to the -19 or -17 degree glide slope aimed at a target 7,500 feet short of the runway. The speed brake is modulated to hold the reference velocity. The descent rate in the later portion of TAEM and approach and landing is greater than 10,000 feet per minute.

At 2,000 feet above ground level (AGL), a preflare maneuver is started to position the spacecraft for a 1.5-degree glide slope in preparation for landing with the speed brake positioned to control touchdown energy. The flight crew deploys the landing gear at 300 feet AGL. The final phase reduces the sink rate of the spacecraft to a target value of 3 feet per second. Touchdown occurs approximately 2,500 feet past the runway threshold at a speed of 195 KEAS (light weight orbiters) or 205 KEAS (heavy weight orbiters).

Launch and Landing Sites

The Kennedy Space Center (KSC) in Florida is used for all Shuttle launches.

Edwards Air Force Base in California and KSC are the primary landing sites. The incorporation of a drag chute and carbon/carbon brakes will now allow more missions to land at KSC. Contingency landing sites are also provided in the event the orbiter must return to Earth in an emergency.

A 035-degree azimuth launch places the spacecraft in an orbital inclination of 57 degrees. This inclination means the spacecraft in its orbital trajectories around Earth will never exceed an Earth latitude higher or lower than 57 degrees north or south of the equator. A launch path from KSC at an azimuth of 090 degrees (due east from KSC) will place the spacecraft in an orbital inclination of 28.5 degrees.

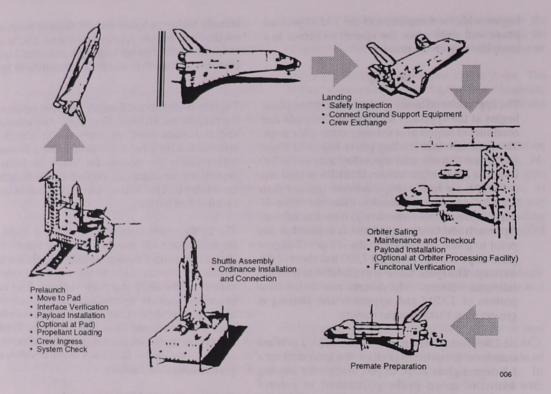
These two azimuths, 035 and 090 degrees, represent the current launch limits from KSC. Any azimuth angles further north or south would launch a spacecraft over a habitable land mass, adversely affect safety provisions for abort or vehicle separation conditions, or present the undesirable possibility that the SRB or external tank could land on inhabited territory.

The Earth rotates from west to east at a speed of approximately 900 nautical miles per hour. For due east launches (090 degrees azimuth), the Earth's rotational velocity adds to the velocity increase caused by the SRBs and main engines. Due east launches provide the maximum payload and altitude capability. Launches on azimuths other than due east benefit less and less from Earth's rotation as the launch azimuth approaches north or south. Westerly launches would decrease performance even further.

Orbiter Ground Turnaround

Spacecraft recovery operations at the nominal endof-mission landing site are supported by approximately 160 Space Shuttle Launch Operations team members. Ground team members wearing self-contained atmospheric protective ensemble suits that protect them from toxic chemicals approach the spacecraft as soon as it stops rolling. The ground team members take sensor measurements to ensure the atmosphere in the vicinity of the spacecraft is not hazardous. In the event of propellant leaks, a wind machine truck carrying a large fan is moved into the area to create a turbulent airflow that will break up gas concentrations and reduce the potential for an explosion.





Kennedy Space Center Ground Turnaround Sequence

A ground support equipment (GSE) airconditioning purge unit is attached to the righthand orbiter T-0 umbilical so cool air can be directed through the orbiter's aft fuselage, payload bay, forward fuselage, wings, vertical stabilizer, and OMS/RCS pods to dissipate the heat of entry.

A second GSE ground cooling unit is connected to the left-hand orbiter T-0 umbilical spacecraft Freon coolant loops to provide cooling for the flight crew and avionics during the postlanding and system checks. The spacecraft fuel cells remain powered up at this time. The flight crew then exits the spacecraft, and a ground crew powers down the spacecraft.

At KSC, the orbiter and GSE convoy move from the runway to the Orbiter Processing Facility (OPF). If the spacecraft lands at Edwards Air Force Base in California, the same procedures and GSE are used after the orbiter has stopped on the runway. The orbiter and GSE convoy move from the runway to the orbiter mate and demate facility. After detailed inspection, the spacecraft is prepared to be ferried atop the Shuttle Carrier Aircraft from Edwards Air Force Base to KSC. For ferrying, a tail cone is installed over the aft section of the orbiter.

In the event of a landing at an alternate site, a crew of about eight will move to the landing site to assist the astronaut crew in preparing the orbiter for loading aboard the Shuttle Carrier Aircraft for transport back to KSC. For landings outside the U.S., personnel at the contingency landing sites will be provided minimum training on safe handling of the orbiter with emphasis on crash rescue training, towing the orbiter to a safe area, and prevention of propellant conflagration. Upon its return to the OPF at KSC, the orbiter is safed (ordnance devices safed), the payload (if any) is removed, and the orbiter payload bay is reconfigured for the next mission. Any required maintenance and inspections are also performed while the orbiter is in the OPF. A payload for the orbiter's next mission may be installed in the orbiter's payload bay in the OPF or when the orbiter is at the launch pad.

The spacecraft is then towed to the Vertical Assembly Building and mated to the external tank. The external tank and SRBs are stacked and mated on the mobile launcher platform while the orbiter is being refurbished. Space Shuttle orbiter connections are made, the integrated vehicle is checked, and ordnance is installed.

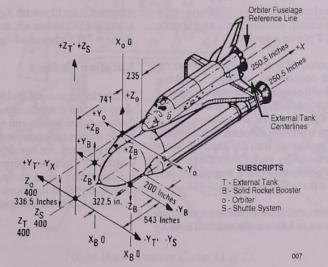
The mobile launcher platform moves the entire Space Shuttle system on a crawler transporter to the launch pad, where connections are made, and servicing and checkout activities begin. If the payload was not installed in the OPF, it is installed at the launch pad followed by prelaunch activities.

KSC Launch Operations has responsibility for all mating, prelaunch testing, and launch control ground activities until the Space Shuttle vehicle clears the launch pad tower. Responsibility is then turned over to NASA's Johnson Space Center Mission Control Center. Mission Control's responsibility includes ascent, on-orbit operations, entry, approach, and landing until crew egress, at which time the orbiter is handed over to the postlanding operations at the landing site for turnaround and relaunch. At the launch site, the SRBs and ET are processed for launch, and the SRBs are recycled for reuse.

Space Shuttle Coordinate Reference System

The Space Shuttle coordinate reference system is a means of locating specific points on the orbiter. The system is measured in inches and decimal places; X_0 designates the longitudinal axis, Y_0 the lateral axis, and Z_0 the vertical axis. The subscript "o" indicates orbiter; similar reference systems are used for the ET (T), SRB (B), and overall Space Shuttle system (S).

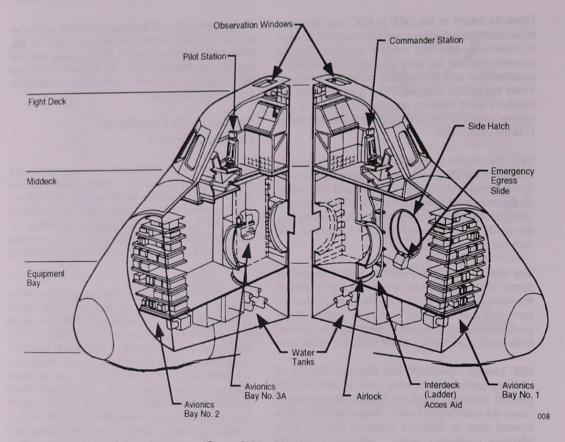
In each coordinate system, the X-axis zero point is located forward of the nose tip; that is, the orbiter nose tip location is 236 inches aft of the zero point (at $X_0 = 236$), the ET nose cap tip location is at $X_T = 322.5$, and the SRB nose tip location is at $X_B = 200$. In the orbiter, the horizontal X_0 , Y_0 reference plane is located at $Z_0 = 400$, which is 336.5 inches above the external tank horizontal X_T , Y_T reference plane located at $Z_T = 400$. The solid rocket booster horizontal X_B , Y_B reference plane is located at $Z_B = 0$ and coincident with the external tank horizontal plane at $Z_T = 400$. The solid rocket booster vertical



e criw members to locate by compartments and all time pass, equipment from the colder crew and because part of the weat is flows. Because

1. GENERAL DESCRIPTION

1.1 Overview



Crew Cabin (Cutaway View)

 X_B , Z_T planes are located at + Y_S = 250.5 and - Y_S = 250.5. Also, the orbiter, external tank, and Shuttle system center X, Z planes coincide.

From the X = 0 point, aft is positive, and forward is negative for all coordinate systems. Looking forward, each Shuttle element Y-axis point right of the center plane (starboard) is positive and each Yaxis point left of center (port) is negative. The Z axis of each point within all elements of the Shuttle except the SRBs is positive, with Z = 0 located below the element. In the SRBs, each Z-coordinate point below the X_B, Y_B reference plane is negative, and each point above that plane is positive.

The Shuttle system and Shuttle element coordinate systems are related as follows: the external tank X_T

= 0 point coincides with $X_S = 0$, the SRB $X_B 0$ point is located 543 inches aft, and the Y_O , Z_O reference plane is 741 inches aft of $X_S = 0$.

Location Codes

Orbiter location codes enable crewmembers to locate displays and controls, stowage compartments and lockers, access panels, and wall-mounted equipment in the orbiter crew compartments. The orbiter crew compartments are the flight deck, middeck, and airlock. A fourth compartment becomes part of the configuration when the Spacelab is flown. Because of compartment functions and geometry, each has a unique location coding format.

Flight Deck Location Codes

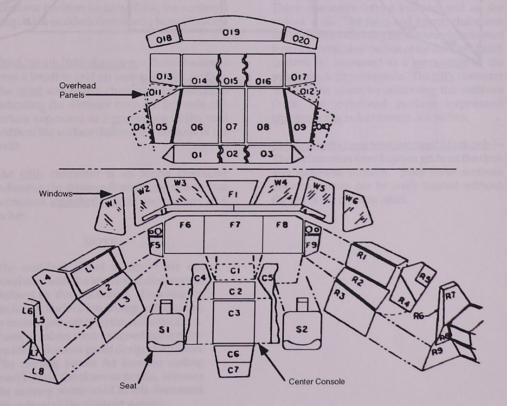
A flight deck location code consists of two or three alphanumeric characters. The first character is the first letter of a flight deck surface as addressed while sitting in the commander/pilot seats. The characters are:

- L Left
- R Right
- F Forward
- A Aft
- C Center Console
- O Overhead
- S Seats
- W- Windows

	SURFACES	GENERAL NUMBERING PHILOSOPHY
	L – Left R – Right C – Center console	Numbered from top to bottom, forward to aft
l	0 - Overhead	Numbered from left to right, forward to aft
	F – Forward A – Aft	 Numbered left to right, top to bottom (facing the surface)
	W – Windows	The forward windows are numbered left to right (W1 through W6) facing forward
		The overhead windows are numbered left to right (W7 and W8) facing aft
	1	The aft windows are numbered left to right (W9 and W10) facing aft
	S – Seats	 The CDR's seat is <u>S1</u> and the PLT's seat is <u>S2</u>

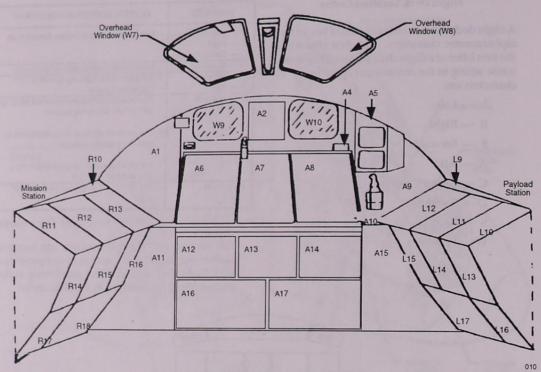
General Numbering Scheme for Flight Deck Surfaces

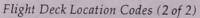
The second and third characters are numerics identifying the relative location of components on each flight deck surface. The numbering system philosophy is summarized in the table above.



Flight Deck Location Codes (1 of 2)







SCOM 1.0 November 1991

Middeck Location Codes

The middeck location codes have five characters specifying the following:

First character - M for middeck

<u>Second character</u> – The first letter of a middeck surface; the characters and surfaces are:

L – Left	A – Aft
R – Right	D – Deck
F-Forward	O-Overhead

SURFACES	REFERENCE POSITION
L, R, F, A	Standing on deck facing the surface
D	Standing on deck facing forward (+X) looking down
0	The overhead location grid matches the grid on the deck; i.e., a point on the overhead has the same third, fourth, fifth characters as a point directly below it on the deck

Middeck Location Codes (2 of 2)

The reference position for identifying the surface is standing on the middeck floor (deck) facing forward (+X).

<u>Third/fourth/fifth characters</u> – These characters form a location grid on each middeck surface. The <u>third</u> and <u>fourth</u> characters are numerics indicating the distance from the <u>left</u> side of a surface expressed as a <u>percentage</u> of the total width of the surface (follows the contour of the wall).

The <u>fifth</u> character is an alpha character indicating the distance from the <u>top</u> of a surface expressed <u>alphabetically</u> in increments of 6 inches.

NOTE

The middeck panel numbers are not consistent with the location coding system defined by this document. However, in each case, the location coding, as indicated, is in close proximity to the actual location. Panel numbers were assigned prior to the middeck closeout panel design definition. The starting points for location coding were behind the closeout panels, whereas the starting points used in this document are in front of the closeout panels.

Airlock Location Codes

An airlock code consists of four or five alphanumeric characters, which specify the following:

First character – A for airlock

<u>Second character</u> – The first letter of an airlock surface; the characters and surfaces are:

W-Wall

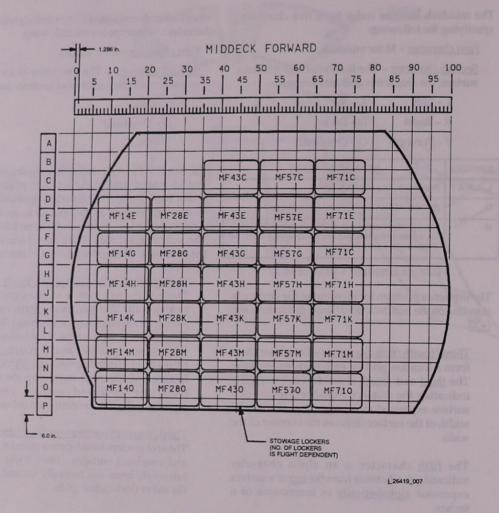
O-Overhead

D-Deck

The "wall" is the inner wall of the cylindrical airlock. The "overhead" and "deck" are flat surfaces at each end of the cylinder. The airlock is oriented upside down with respect to the middeck, so that the airlock <u>overhead</u> corresponds to the middeck floor. The wall location codes have five characters, and the overhead/deck codes have four characters.

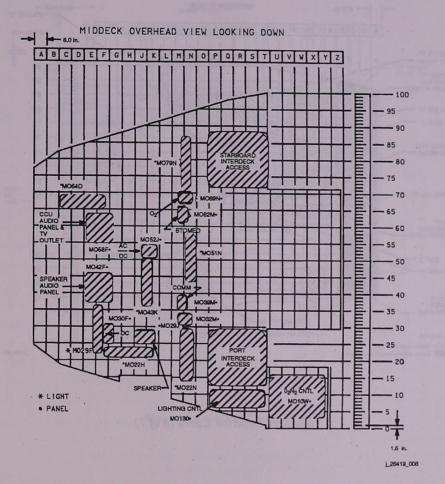
<u>Third/fourth/fifth characters (wall only)</u> – These characters form a location grid on the airlock wall. The <u>third</u> and <u>fourth</u> characters are numerics indicating the distance (clockwise) from the vertical centerline of the forward hatch (airlock in) expressed as a <u>percentage</u> of the total airlock circumference. The <u>fifth</u> character is an alpha character indicating the distance from the overhead surface expressed <u>alphabetically</u> in increments of 6 inches.

Third/fourth characters (overhead/deck only)– These characters form location grids on the deck and overhead surfaces. Since these surfaces are small, items can be easily located without the aid of the location grids. 1.1 Overview

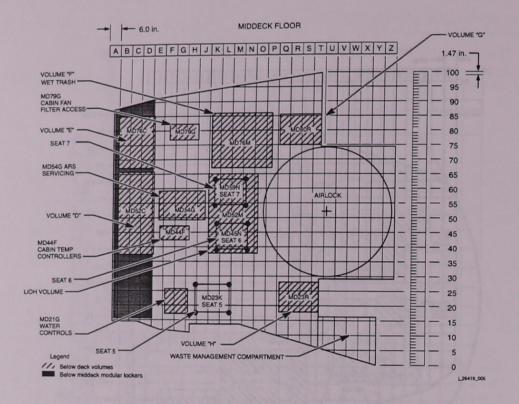


Middeck Location Codes (1 of 7)

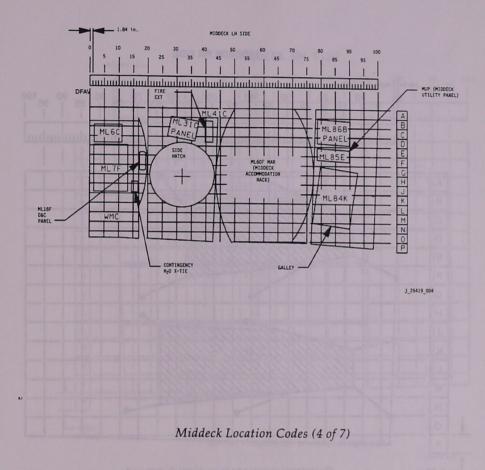
The mutdack panel numbers are not consistent with the location coding system defined or this doctinent. However, in each case, the incritic nulling, mindicalled is in disterpresenting to the actual location muddack doctors assigned prior to the muddack doctors panel design definition The summing points for location coding were behind the doctors panels, vibured the summing points used in the documents



Middeck Location Codes (2 of 7)

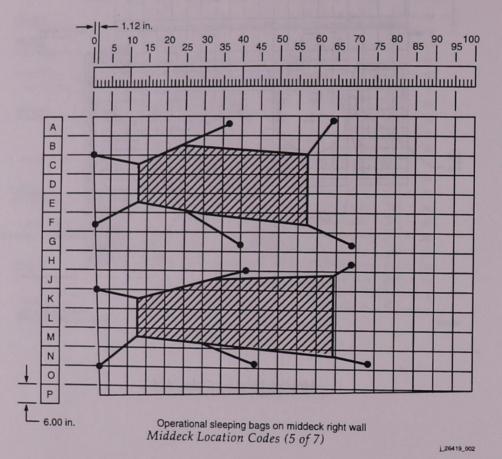


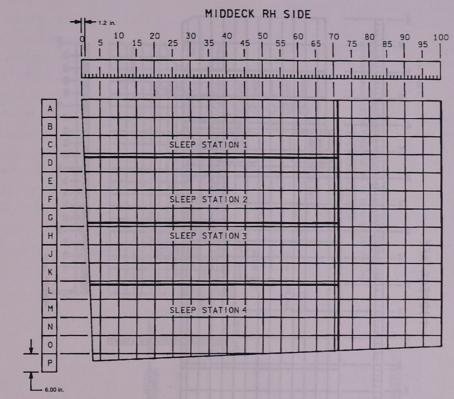
Middeck Location Codes (3 of 7)



1.1 Overview

MIDDECK RH SIDE



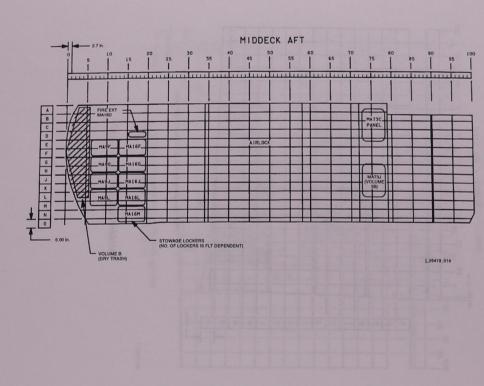


Four-tier sleep station on middeck right wall

L26419_013

Middeck Location Codes (6 of 7)

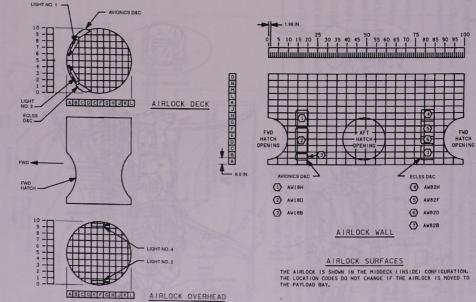
SCOM 1.6 August 1996



Middeck Location Codes (7 of 7)

1.1-18

SCOM 1.0 November 1991 1.1-19

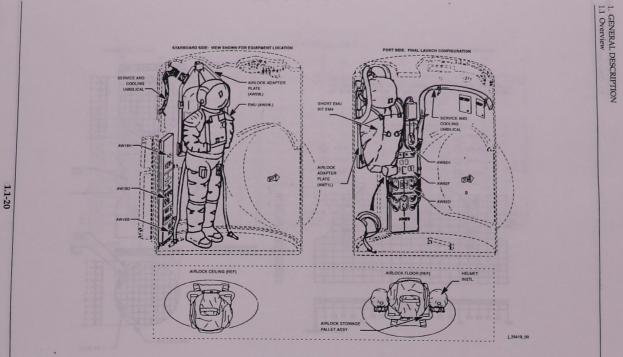


Airlock Location Codes

L26419_017

rlock Equipment and Associated Location Codes

1. GENERAL DESCRIPTION 1.1 Overview



Airlock Equipment and Associated Location Codes

SCOM 1.0 November 1991

1.1

1.2 ORBITER STRUCTURE

CONTENTS

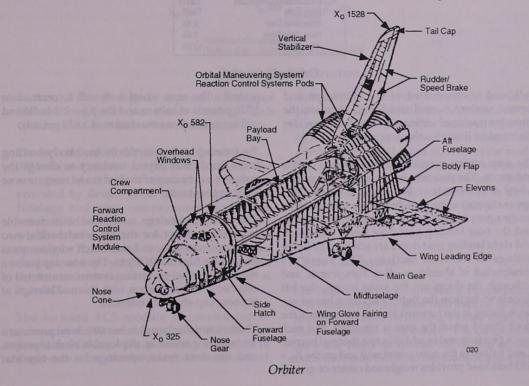
CONTENTS	
Forward Fuselage	1.2-1
Crew Compartment	1.2-3
Forward Fuselage and Crew	
Compartment Windows	1.2-7
Wing	1.2-8
Midfuselage	1.2-10
Aft Fuselage	1.2-11
Orbital Maneuvering System/	
Reaction Control System Pods	1.2-13
Body Flap	1.2-14
Vertical Tail	1.2-15
Orbiter Passive Thermal Control	1.2-16
Thermal Protection System	1.2-16

The orbiter structure is divided into nine major sections: (1) forward fuselage, which consists of upper and lower sections that fit clamlike around a pressurized crew compartment, (2) wings, (3) midfuselage, (4) payload bay doors, (5) aft fuselage, (6) forward RCS, (7) vertical tail, (8) OMS/ RCS pods, and (9) body flap. The majority of the sections are constructed of conventional aluminum and protected by reusable surface insulation.

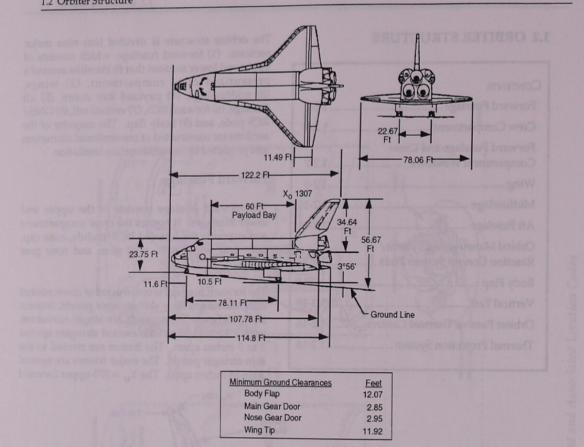
Forward Fuselage

The forward fuselage consists of the upper and lower fuselages. It houses the crew compartment and supports the forward RCS module, nose cap, nose gear wheel well, nose gear, and nose gear doors.

The forward fuselage is constructed of conventional 2024 aluminum alloy skin-stringer panels, frames, and bulkheads. The panels are single curvature, stretch-formed skins with riveted stringers spaced 3 to 5 inches apart. The frames are riveted to the skin-stringer panels. The major frames are spaced 30 to 36 inches apart. The Y_O = 378 upper forward



1. GENERAL DESCRIPTION 1.2 Orbiter Structure



Orbiter Deminsions

bulkhead is constructed of flat aluminum and formed sections riveted and bolted together; the lower is a machined section. The bulkhead provides the interface fitting for the nose section.

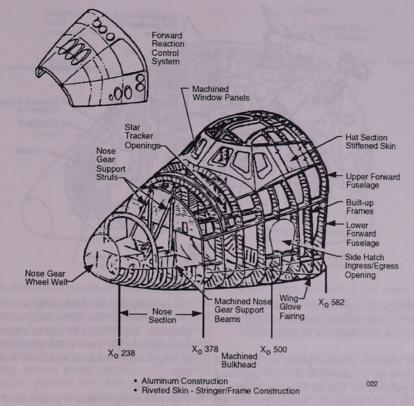
The nose section contains large machined beams and struts. The structure for the nose landing gear wheel well consists of two support beams, two upper closeout webs, drag-link support struts, nose landing gear strut and actuator attachment fittings, and the nose landing gear door fittings. The left and right landing gear doors are attached by hinge fittings in the nose section. The doors are constructed of aluminum alloy honeycomb, and although the doors are the same length, the left door is wider than the right. Each door has an uplatch fitting at the forward and aft ends to lock the door closed when the gear is retracted, and each has a pressure seal in addition to a thermal barrier. Lead ballast in the nose wheel well and on the $X_0 =$ 293 bulkhead provides weight and center-of-gravity

control. The nose wheel well will accommodate 1,350 pounds of ballast, and the $X_0 = 293$ bulkhead will accommodate a maximum of 1,971 pounds.

The forward fuselage carries the basic body-bending loads (loads that have a tendency to change the radius of a curvature of the body) and reacts to nose landing gear loads.

The forward fuselage is covered with reusable insulation, except for the six windshields, two overhead windows, and side hatch window areas around the forward RCS jets. The nose cap is also a reusable thermal protection system constructed of reinforced carbon-carbon with thermal barriers at the nose cap-structure interface.

The forward fuselage skin has structural provisions for installing antennas, deployable air data probes, and the door eyelet openings for the two star



Forward Fuselage Structure

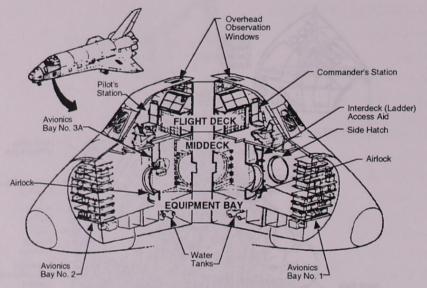
trackers. Two openings are required in the upper forward fuselage for star tracker viewing. Each opening has a door for environmental control.

The forward orbiter/ET attach fitting is at the $X_0 = 378$ bulkhead and the skin panel structure aft of the nose gear wheel well. Purge and vent control is provided by flexible boots between the forward fuselage and crew compartment around the windshield windows, overhead observation window, crew hatch window, and star tracker openings. The forward fuselage is isolated from the payload bay by a flexible membrane between the forward fuselage and crew compartment at $X_0 = 582$.

The forward RCS module is constructed of conventional 2024 aluminum alloy skin-stringer panels and frames. The panels are composed of single-curvature, stretch-formed skins with riveted stringers. The frames are riveted to the skin-stringer panels. The forward RCS module is secured to the forward fuselage nose section and forward bulkhead of the forward fuselage with 16 fasteners, which permit the installation and removal of the module. The components of the forward RCS are mounted and attached to the module, which has a reusable thermal protection cover, in addition to thermal barriers installed around it and the RCS jet interfaces and the interface-attachment area to the forward fuselage.

Crew Compartment

The three-level crew compartment is constructed of 2219 aluminum alloy plate with integral stiffening stringers and internal framing welded together to create a pressure-tight vessel. The compartment has a side hatch for normal ingress and egress, a hatch into the airlock from the middeck, and a hatch



Crew Compartment and Arrangement

from the airlock through the aft bulkhead into the payload bay for extravehicular activity and payload bay access. The side hatch can be jettisoned.

Redundant pressure window panes are provided in the six forward windshields, the two overhead viewing windows, the two aft viewing windows, and the side hatch windows. Approximately 300 penetrations in the pressure shell are sealed with plates and fittings. A large removable panel in the aft bulkhead provides access to the interior of the crew compartment during initial fabrication and assembly and provides for airlock installation and removal. The compartment supports the ECLSS, avionics, GNC equipment, inertial measurement units, displays and controls, star trackers, and crew accommodations for sleeping, waste management, seats, and an optional galley.

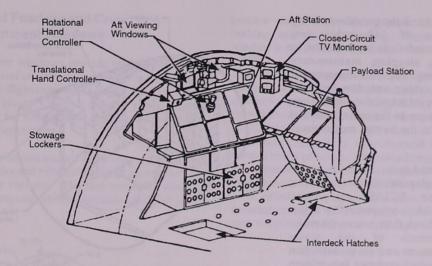
The crew compartment is supported within the forward fuselage at only four attach points to minimize the thermal conductivity between them. The two major attach points are located at the aft end of the crew compartment at the flight deck floor level. The vertical load reaction link is on the centerline of the forward bulkhead. The lateral load reaction is on the lower segment of the aft bulkhead. The compartment is configured to accommodate a crew of four on the flight deck and three in the middeck. In OV-102, four can be accommodated in the middeck. The crew cabin arrangement consists of a flight deck, middeck, and lower level equipment bay.

The crew compartment is pressurized to 14.7 ± 0.2 psia and is maintained at an 80-percent nitrogen and 20-percent oxygen composition by the ECLSS, which provides a shirt-sleeve environment for the flight crew. The crew compartment is designed for 16 psia.

The crew compartment's volume with the airlock in the middeck is 2,325 cubic feet. If the airlock is in the payload bay, the crew compartment's cabin volume is 2,625 cubic feet.

Flight Deck

The flight deck is the uppermost compartment of the cabin. The commander's and pilot's work stations are positioned side by side in the forward portion of the flight deck. These stations have controls and displays for controlling the vehicle throughout all mission phases. Directly behind and to the sides of the commander and pilot centerline are the mission specialist seats.



Aft Flight Station

The aft flight deck has two overhead and aft viewing windows for viewing orbital operations. The aft flight deck station also contains displays and controls for executing attitude or translational maneuvers for rendezvous, stationkeeping, docking, payload deployment and retrieval, payload monitoring, remote manipulator system controls and displays, payload bay door operations, and closed-circuit television operations. The aft flight deck is approximately 40 square feet.

The forward flight deck, which includes the center console and seats, is approximately 24 square feet. However, the side console controls and displays add approximately 3.5 more square feet. If the center console is subtracted from the 24 square feet, this would amount to approximately 5.2 square feet.

Middeck

Directly beneath the flight deck is the middeck. Access to the middeck is through two interdeck openings, which measure 26 by 28 inches. Normally, the right interdeck opening is closed, and the left is open. A ladder attached to the left interdeck access allows easy passage in 1-g conditions. The middeck provides crew accommodations and contains three avionics equipment bays. The two forward avionics bays utilize the complete width of the cabin and extend into the middeck 39 inches from the forward bulkhead. The aft bay extends into the middeck 39 inches from the aft bulkhead on the right side of the airlock. Just forward of the waste management system is the side hatch. The completely stripped middeck is approximately 160 square feet; the gross mobility area is approximately 100 square feet.

The side hatch in the middeck is used for normal crew ingress/egress and may be operated from within the crew cabin middeck or externally. It is attached to the crew cabin tunnel by hinges, a torque tube, and support fittings. The hatch opens outwardly 90 degrees down with the orbiter horizontal or 90 degrees sideways with the orbiter vertical. It is 40 inches in diameter and has a 10inch clear-view window in the center of the hatch. The window consists of three panes of glass. The side hatch has a pressure seal that is compressed by the side hatch latch mechanisms when the hatch is locked closed. A thermal barrier of Inconel wire mesh spring with a ceramic fiber braided sleeve is installed between the reusable surface insulation tiles on the forward fuselage and the side hatch. The total weight of the side hatch is 294 pounds.

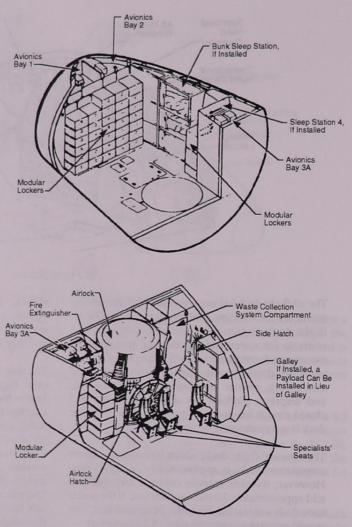
Depending on the mission requirements, bunk sleep stations and a galley can be installed in the middeck. In addition, three or four seats of the same type as the mission specialists' seats on the flight deck can be installed in the middeck. Three seats over the normal three could be installed in the middeck for rescue missions if the bunk sleep stations were removed. The middeck also provides a stowage volume of 140 cubic feet. Accommodations are included for dining, sleeping, maintenance, exercising, and data management. On the orbiter centerline, just aft of the forward avionics equipment bay, an opening in the ceiling provides access to the inertial measurement units.

The middeck floor contains removable panels that provide access the ECLSS equipment. to The middeck equipment bay below the middeck floor houses the major components of the waste management and air revitalization systems, such as pumps, fans, lithium hydroxide carbon dioxide absorbers, heat exchangers, and ducting. This compartment has space for stowing lithium hydroxide canisters and five separate spaces for crew equipment stowage with a volume of 29.92 cubic feet.

Modular stowage lockers are used to store the flight crew's personal gear, mission-necessary equipment, personal hygiene equipment, and experiments. There are 42 identical boxes, which are 11 by 18 by 21 inches.

An airlock located in the middeck is composed of machined aluminum sections welded together to form a cylinder with hatch mounting

flanges. The upper cylindrical section and bulkheads are constructed of aluminum honeycomb. Two semicylindrical aluminum sections are welded to the airlock's primary structure to house the ECLSS and electrical support equipment. Each semicylindrical section has three feedthrough plates for plumbing and cable routings from the orbiter to the airlock.



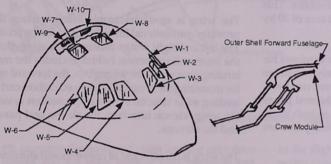
Crew Compartment Middeck

Normally, two extravehicular mobility units are stowed in the airlock.

Forward Fuselage and Crew Compartment Windows

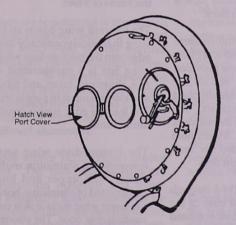
The orbiter windows provide visibility for entry, landing, and on-orbit operations. For atmospheric flight, the flight crew needs forward, left, and right viewing areas. On-orbit mission phases require visibility for rendezvous, docking, and payloadhandling operations.

The six windows located at the forward flight deck commander and pilot stations provide forward, left, and right viewing. The two overhead windows and two payload-viewing windows at the aft station



3 Panes and 2 Cavities per Window

Flight Deck Windows



Side Hatch (Interior View)

1.2-7

location on the flight deck provide rendezvous, docking, and payload viewing. There is also a window in the middeck side hatch.

The six platform-shaped forward windows are the thickest pieces of glass ever produced in the optical quality for see-through viewing. Each consists of three individual panes. The innermost pane, which is 0.625 of an inch thick, is constructed of tempered aluminosilicate glass to withstand the crew compartment pressure. Aluminosilicate glass is a low-expansion glass that can be tempered to provide maximum mechanical strength. The exterior of this pane, called a pressure pane, is coated with a red reflector coating to reflect the infrared (heat portion) rays while transmitting the visible spectrum.

The center pane is constructed of lowexpansion, fused silica glass because of its high optical quality and excellent thermal shock resistance. This pane is 1.3 inches thick.

The inner and outer panes are coated with a high-efficiency, anti-reflection coating to improve visible light transmission. These windows withstand a proof pressure of 8,600 psi at 240° F and 0.017 relative humidity.

The outer pane is made of the same material as the center pane and is 0.625 of an inch thick. The exterior is uncoated, but the interior is coated with high-efficiency, anti-reflection coating. The outer surface withstands approximately 800° F.

Each of the six forward windows' outer panes measures 42 inches diagonally, and the center and inner panes each measure 35 inches diagonally. The outer panes of the six forward windows are mounted and attached to the forward fuselage. The center and inner panes are mounted and attached to the crew compartment. Redundant seals are employed on each window. No sealing/bonding compounds are used.

The two overhead windows at the flight deck aft station are identical in construction to the six forward windows except for thickness. The inner and center panes are 0.45 of an inch thick, and the outer pane is 0.68 of an inch thick. The outer pane is attached to the forward fuselage, and the center and inner panes are attached to the crew compartment. The two overhead windows' clear view area is 20 by 20 inches. The left-hand overhead window provides the crew members with a secondary emergency egress. The inner and center panes open into the crew cabin, and the outer pane is jettisoned up and over the top of the orbiter. This provides a secondary emergency exit area of 20 by 20 inches.

On the aft flight deck, each of the two windows for viewing the payload bay consists of only two panes of glass, which are identical to the forward windows' inner and center panes. The outer thermal panes are not installed. Each pane is 0.3 of an inch thick. The windows are 14.5 by 11 inches. Both panes are attached to the crew compartment.

The side hatch viewing window consists of three panes of glass identical to the six forward windows. The inner pane is 11.4 inches in diameter and 0.25 of an inch thick. The center pane is 11.4 inches in diameter and 0.5 of an inch thick. The outer pane is 15 inches in diameter and 0.3 of an inch thick.

During orbital operations, the large window areas of transparency expose the flight crew to sun glare; therefore, window shades and filters are provided to preclude or minimize exposure. Shades are provided for all windows, and filters are supplied for the aft and overhead viewing windows. The window shades and filters are stored in the middeck of the orbiter crew compartment. Attachment mechanisms and devices are provided for their installation at each window on the flight deck.

The forward station window shades (W-1 through W-6) are rolled up and stowed at the base of the windows. Solid metal shades are used on overhead windows (W-7 and W-8). The overhead window filters are fabricated from Lexan and are used interchangeably with the shades.

The aft window shades (W-9 and W-10) are the same as the overhead window shades except that a 0.63-inch-wide strip of Nomex Velcro has been added around the perimeter of the shade. The shade is attached to the window by pressing the Velcro strip to the pile strip around the window opening. The aft window filters are the same as the overhead window filters except for the addition of the Velcro hook strip. The filters and shades are used interchangeably.

The side hatch window cover is permanently attached to the window frame and is hinged to allow opening and closing.

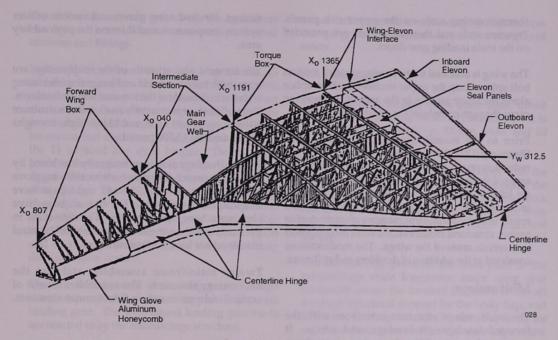
Wing

The wing is an aerodynamic lifting surface that provides conventional lift and control for the orbiter. The left and right wings consist of the wing glove, the intermediate section (which includes the main landing gear well), the torque box, the forward spar for mounting the reusable reinforced carbon-carbon leading edge structure thermal protection system, the wing/elevon interface, the elevon seal panels, and the elevons.

The wing is constructed of conventional aluminum alloy with a multirib and spar arrangement with skin-stringer-stiffened covers or honeycomb skin covers. Each wing is approximately 60 feet long at the fuselage intersection and has a maximum thickness of 5 feet.

The forward wing box is an extension of the basic wing that aerodynamically blends the wing leading edge into the midfuselage wing glove. The forward wing box is a conventional design of aluminum ribs, aluminum tubes, and tubular struts. The upper and lower wing skin panels are stiffened aluminum. The leading edge spar is constructed of corrugated aluminum.

The intermediate wing section consists of the conventional aluminum multiribs and aluminum tubes. The upper and lower skin covers are constructed of aluminum honeycomb. A portion of the lower wing surface skin panel includes the main landing gear door. The intermediate section houses the main landing gear compartment and reacts to a portion of the main landing gear loads. A structural



Crew Compartment Middeck

rib supports the outboard main landing gear door hinges and the main landing gear trunnion and drag link. The support for the inboard main landing gear trunnion and drag link attachment is provided by the midfuselage. The main landing gear door is conventional aluminum honeycomb.

The four major spars are constructed of corrugated aluminum to minimize thermal loads. The forward spar provides the attachment for the thermal protection system reusable reinforced carbon-carbon leading edge structure. The rear spar provides the attachment interfaces for the elevons, hinged upper seal panels, and associated hydraulic and electrical system components. The upper and lower wing skin panels are stiffened aluminum.

The elevons provide orbiter flight control during atmospheric flight. The two-piece elevons are conventional aluminum multirib and beam construction with aluminum honeycomb skins for compatibility with the acoustic environment and thermal interaction. The elevons are divided into two segments for each wing, and each segment is supported by three hinges. The elevons are attached to the flight control system hydraulic actuators at points along their forward extremities, and all hinge moments are reacted to at these points. Each elevon travels 33 degrees up and 18 degrees down (software limits).

The transition area on the upper surface between the torque box and the movable elevon consists of a series of hinged panels that provide a closeout of the wing-to-elevon cavity. These panels are of Inconel honeycomb sandwich construction outboard of wing station $Y_W = 312.5$ and of titanium honeycomb sandwich construction inboard of wing station $Y_W = 312.5$. The upper leading edge of each elevon incorporates titanium rub strips. The rub strips are of titanium honeycomb construction and are not covered with the thermal protection system reusable surface insulation. They provide the sealing surface area for the elevon seal panels.

Except the elevon seal panels, the exposed areas of the wings, main landing gear doors, and elevons are covered with reusable surface insulation thermal protection system materials. Thermal seals are provided on the elevon lower cove area along with



thermal spring seals on the upper rub panels. Pressure seals and thermal barriers are provided on the main landing gear doors.

The wing is attached to the fuselage with a tension bolt splice along the upper surface. A shear splice along the lower surface in the area of the fuselage carry-through completes the attachment interface.

Prior to the manufacturing of the wings for Discovery (OV-103) and Atlantis (OV-104), a weight reduction program resulted in a redesign of certain areas of the wing structure. An assessment of wing air loads was made from actual flight data that indicated greater loads on the wing structure. As a result, to maintain positive margins of safety during ascent, structural modifications were incorporated into certain areas of the wings. The modifications consisted of the addition of doublers and stiffeners.

Midfuselage

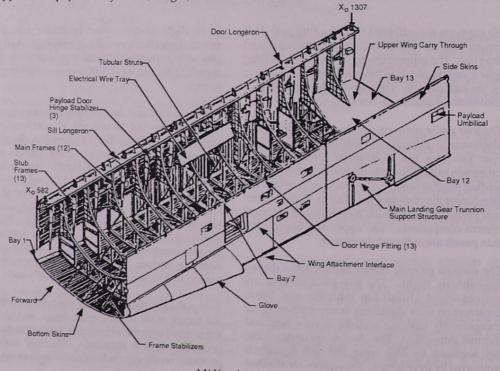
The midfuselage structure interfaces with the forward fuselage, aft fuselage, and wings. It supports the payload bay doors, hinges, tie-down

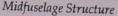
fittings, forward wing glove, and various orbiter system components, and it forms the payload bay area.

The forward and aft ends of the midfuselage are open, with reinforced skin and longerons interfacing with the bulkheads of the forward and aft fuselages. The midfuselage is primarily an aluminum structure 60 feet long, 17 feet wide, and 13 feet high. It weighs approximately 13,502 pounds.

The midfuselage skins are integrally machined by numerical control. The panels above the wing glove and the wings for the forward eight bays have longitudinal T-stringers. The five aft bays have aluminum honeycomb panels. The side skins in the shadow of the wing are also numerically control machined but have vertical stiffeners.

Twelve main-frame assemblies stabilize the midfuselage structure. The assemblies consist of vertical side elements and horizontal elements.





1.2-10

The side elements are machined; the horizontal elements are boron/aluminum tubes with bonded titanium end fittings.

In the upper portion of the midfuselage are the sill and door longerons. The machined sill longerons not only make up the primary body-bending elements, but also take the longitudinal loads from payloads in the payload bay. The payload bay door longerons and associated structure are attached to the 13 payload bay door hinges. These hinges provide the vertical reaction from the payload bay doors. Five of the hinges react to the payload bay door shears. The sill longeron also provides the base support for the payload bay manipulator arm (if installed) and its stowage provisions, the Kuband rendezvous antenna, the antenna base support and its stowage provisions, and the payload bay door actuation system.

The side wall forward of the wing carry-through structure provides the inboard support for the main landing gear. The total lateral landing gear loads are reacted to by the midfuselage structure.

The midfuselage also supports the two electrical wire trays that contain the wiring between the crew compartment and aft fuselage.

Plumbing and wiring in the lower portion of the midfuselage are supported by fiberglass milk stools.

The other exposed areas of the midfuselage are covered with the reusable surface insulation thermal protection system.

Because of additional detailed analysis of actual flight data concerning descent stress thermal gradient loads, torsional straps were added to the lower midfuselage stringers in bays 1 through 11. The torsional straps tie all stringers together similarly to a box section, which eliminates rotational (torsional) capabilities to provide positive margins of safety.

Also, because of additional detailed analysis of actual flight data during descent, room-temperature vulcanizing silicone rubber material was bonded to the lower midfuselage from bay 4 through 12 to act as a heat sink and distribute temperatures evenly across the bottom of the midfuselage, which reduces thermal gradients and ensures positive margins of safety.

Aft Fuselage

The aft fuselage consists of an outer shell, thrust structure, and internal secondary structure. It is approximately 18 feet long, 22 feet wide, and 20 feet high.

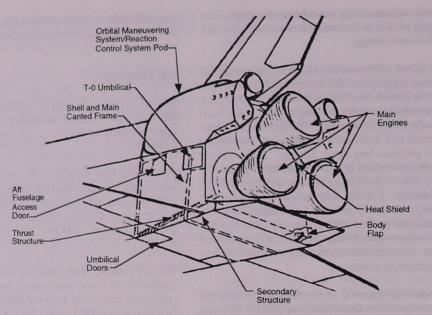
The aft fuselage supports and interfaces with the left-hand and right-hand aft OMS/RCS pods, the wing aft spar, midfuselage, orbiter/external tank rear attachments, main engines, aft heat shield, body flap, vertical tail, and two T-0 launch umbilical panels.

The aft fuselage provides the load path to the midfuselage main longerons, main wing spar continuity across the forward bulkhead of the aft fuselage, structural support for the body flap, and structural housing around all internal systems for protection from operational environments (pressure, thermal, and acoustic) and controlled internal pressures during flight.

The forward bulkhead closes off the aft fuselage from the midfuselage and is composed of machined and beaded sheet metal aluminum segments. The upper portion of the bulkhead attaches to the front spar of the vertical tail.

The internal thrust structure supports the three SSMEs. The upper section of the thrust structure supports the upper SSME, and the lower section of the thrust structure supports the two lower SSMEs. The internal thrust structure includes the SSMEs, load reaction truss structures, engine interface fittings, and the actuator support structure. It supports the SSMEs and the SSME low-pressure turbopumps and propellant lines. The two orbiter/ external tank aft attach points interface at the longeron fittings.

The internal thrust structure is composed mainly of 28 machined, diffusion-bonded truss members. In diffusion bonding, titanium strips are bonded together under heat, pressure, and time. This fuses the titanium strips into a single hollow, homogeneous mass that is lighter and stronger than



Aft Fuselage Structure

a forged part. In looking at the cross section of a diffusion bond, no weld line is visible. It is a homogeneous parent metal, yet composed of pieces joined by diffusion bonding. (In OV-105, the internal thrust structure is a forging.) In selected areas, the titanium construction is reinforced with boron/ epoxy tubular struts to minimize weight and add stiffness.

The upper thrust structure of the aft fuselage is of integral-machined aluminum construction with aluminum frames except for the vertical fin support frame, which is titanium. The skin panels are integrally machined aluminum and attach to each side of the vertical fin to react to drag and torsion loading.

The outer shell of the aft fuselage is constructed of integral-machined aluminum. Various penetrations are provided in the shell for access to installed systems. The exposed outer areas of the aft fuselage are covered with reusable thermal protection system.

The secondary structure of the aft fuselage is of conventional aluminum construction except that titanium and fiberglass are used for thermal isolation of equipment. The aft fuselage secondary structures consist of brackets, buildup webs, truss members, and machined fittings, as required by system loading and support constraints. Certain system components, such as the avionics shelves, are shockmounted to the secondary structure. The secondary structure includes support provisions for the auxiliary power units, hydraulics, ammonia boiler, flash evaporator, and electrical wire runs.

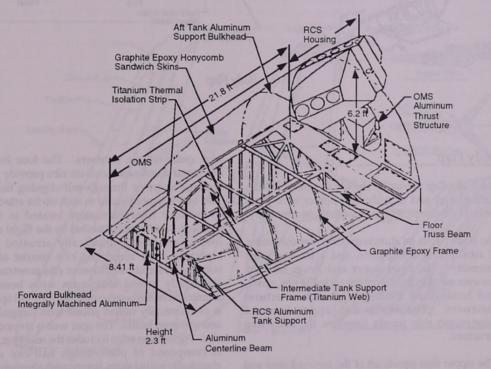
The two ET umbilical areas interface with the orbiter's two aft ET attach points and the ET's liquid oxygen and hydrogen feed lines and electrical wire runs. The umbilicals are retracted, and the umbilical areas are closed off after ET separation by an electromechanically operated beryllium door at each umbilical. Thermal barriers are employed at each umbilical door. The exposed area of each closed door is covered with reusable surface insulation.

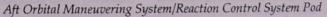
The aft fuselage heat shield and seal provide a closeout of the orbiter aft base area. The aft heat shield consists of a base heat shield of machined aluminum. Attached to the base heat shield are domes of honeycomb construction that support flexible and sliding seal assemblies. The enginemounted heat shield is of Inconel honeycomb construction and is removable for access to the main engine power heads. The heat shield is covered with a reusable thermal protection system except for the Inconel segments.

Orbital Maneuvering System/Reaction Control System (OMS/RCS) Pods

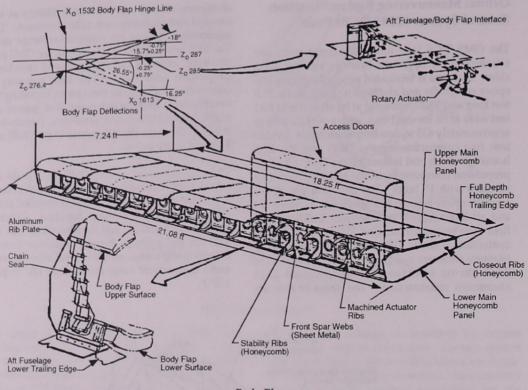
The OMS/RCS left- and right-hand pods are attached to the upper aft fuselage left and right sides. Each pod is fabricated primarily of graphite epoxy composite and aluminum. Each pod is 21.8 feet long and 11.37 feet wide at its aft end and 8.41 feet wide at its forward end, with a surface area of approximately 435 square feet. Each pod is divided into two compartments: the OMS and the RCS housings. Each pod houses all the OMS and RCS propulsion components and is attached to the aft fuselage with 11 bolts. The pod skin panels are graphite epoxy honeycomb sandwich. The forward and aft bulkhead aft tank support bulkhead and floor truss beam are machined aluminum 2124. The centerline beam is 2024 aluminum sheet with titanium stiffeners and graphite epoxy frames. The OMS thrust structure is conventional 2124 aluminum construction. The cross braces are aluminum tubing, and the attach fittings at the forward and aft fittings are 2124 aluminum. The intermediate fittings are corrosion-resistant steel. The RCS housing, which attaches to the OMS pod structure, contains the RCS jets and associated propellant feed lines. The RCS housing is constructed of aluminum sheet metal, including flat outer skins. The curved outer skin panels are graphite epoxy honeycomb sandwich. Twenty-four doors in the skins provide access to the OMS and RCS and attach points.

The exposed areas of the OMS/RCS pods are covered with a reusable thermal protection system, and a pressure and thermal seal is installed at the OMS/RCS pod aft fuselage interface. Thermal barriers are installed, and they interface with the RCS jets and reusable thermal protection system. The pods will withstand 162-decibel acoustic noise and a temperature range from minus 170° to plus 135° F.









Body Flap

Body Flap

The body flap thermally shields the three SSMEs during entry and provides the orbiter with pitch control trim during its atmospheric flight after entry.

The body flap is an aluminum structure consisting of ribs, spars, skin panels, and a trailing edge assembly. The main upper and lower forward honeycomb skin panels are joined to the ribs, spars, and honeycomb trailing edge with structural fasteners. The removable upper forward honeycomb skin panels complete the body flap structure.

The upper skin panels aft of the forward spar and the entire lower skin panels are mechanically attached to the ribs. The forward upper skin consists of five removable access panels attached to the ribs with quick-release fasteners. The four integralmachined aluminum actuator ribs provide the aft fuselage interface through self-aligning bearings. Two bearings are located in each rib for attachment to the four rotary actuators located in the aft fuselage, which are controlled by the flight control system and the hydraulically actuated rotary actuators. The remaining ribs consist of eight stability ribs and two closeout ribs constructed of chemically milled aluminum webs bonded to aluminum honeycomb core. The forward spar web is of chemically milled sheets with flanged holes and stiffened beads. The spar web is riveted to the ribs. The trailing edge includes the rear spar, which is composed of piano-hinge half-cap angles, chemically milled skins, honeycomb aluminum core, closeouts, and plates. The trailing edge attaches to the upper and lower forward panels by the pianohinge halves and hinge pins. Two moisture drain lines and one hydraulic fluid drain line penetrate the trailing edge honeycomb core for horizontal and vertical drainage.

The body flap is covered with a reusable thermal protection system and an articulating pressure and thermal seal to its forward cover area on the lower surface of the body flap to block heat and air flow from the structures.

Vertical Tail

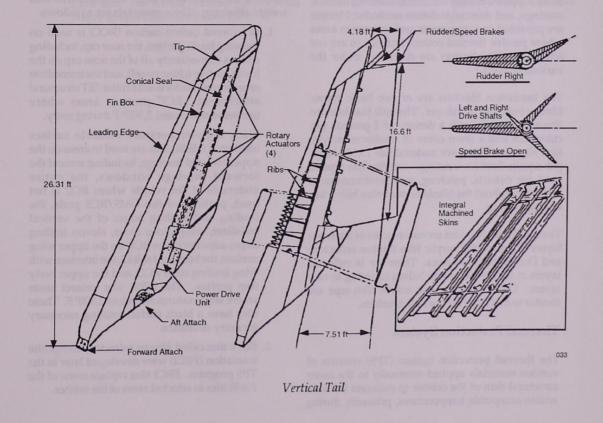
The vertical tail consists of a structural fin surface, the rudder/speed brake surface, a tip, and a lower trailing edge. The rudder splits into two halves to serve as a speed brake.

The vertical tail structure fin is made of aluminum. The main torque box is constructed of integralmachined skins and strings, ribs, and two machined spars. The fin is attached by two tension tie bolts at the root of the front spar of the vertical tail to the forward bulkhead of the aft fuselage and by eight shear bolts at the root of the vertical tail rear spar to the upper structural surface of the aft fuselage.

The rudder/speed brake control surface is made of conventional aluminum ribs and spars with aluminum honeycomb skin panels and is attached through rotating hinge parts to the vertical tail fin.

The lower trailing edge area of the fin, which houses the rudder/speed brake power drive unit, is made of aluminum honeycomb skin.

The hydraulic power drive unit/mechanical rotary actuation system drives left- and right-hand drive shafts in the same direction for rudder control of plus or minus 27 degrees. For speed brake control, the drive shafts turn in opposite directions for a maximum of 49.3 degrees each. The rotary drive actions are also combined for joint rudder/speed brake control. The hydraulic power drive unit is controlled by the orbiter flight control system.



The vertical tail structure is designed for a 163decibel acoustic environment with a maximum temperature of 350° F.

All-Inconel honeycomb conical seals house the rotary actuators and provide a pressure and thermal seal that withstands a maximum of 1,200° F.

The split halves of the rudder panels and trailing edge contain a thermal barrier seal.

The vertical tail and rudder/speed brake are covered with a reusable thermal protection system. A thermal barrier is also employed at the interface of the vertical stabilizer and aft fuselage.

Orbiter Passive Thermal Control

A passive thermal control system helps maintain the temperature of the orbiter spacecraft, systems, and components within their temperature limits. This system uses available orbiter heat sources and sinks supplemented by insulation blankets, thermal coatings, and thermal isolation methods. Heaters are provided on components and systems in areas where passive thermal control techniques are not adequate. (The heaters are described under the various systems.)

The insulation blankets are of two basic types: fibrous bulk and multilayer. The bulk blankets are fibrous materials with a density of 2 pounds per cubic foot and a sewn cover of reinforced acrylic film Kapton. The cover material has 13,500 holes per square foot for venting. Acrylic film tape is used for cutouts, patching, and reinforcements. Tufts throughout the blankets minimize billowing during venting.

The multilayer blankets are constructed of alternate layers of perforated acrylic film Kapton reflectors and Dacron net separators. There are 16 reflector layers in all, the two cover halves counting as two layers. Covers, tufting, and acrylic film tape are similar to that used for the bulk blankets.

Thermal Protection System

The thermal protection system (TPS) consists of various materials applied externally to the outer structural skin of the orbiter to maintain the skin within acceptable temperatures, primarily during the entry phase of the mission. The orbiter's outer structural skin is constructed primarily of aluminum and graphite epoxy.

During entry, the TPS materials protect the orbiter outer skin from temperatures above 350° F. In addition, they are reusable for 100 missions with refurbishment and maintenance. These materials perform in temperature ranges from minus 250° F in the cold soak of space to entry temperatures that reach nearly 3,000° F. The TPS also sustains the forces induced by deflections of the orbiter airframe as it responds to the various external environments. Because the TPS is installed on the outside of the orbiter skin, it establishes the aerodynamics over the vehicle in addition to acting as the heat sink.

Orbiter interior temperatures also are controlled by internal insulation, heaters, and purging techniques in the various phases of the mission.

The TPS is a passive system consisting of materials selected for stability at high temperatures and weight efficiency. These materials are as follows:

- Reinforced carbon-carbon (RCC) is used on the wing leading edges, the nose cap, including an area immediately aft of the nose cap on the lower surface (chine panel), and the immediate area around the forward orbiter/ET structural attachment. RCC protects areas where temperatures exceed 2,300° F during entry.
- 2. Black high-temperature reusable surface insulation (HRSI) tiles are used in areas on the upper forward fuselage, including around the forward fuselage windows, the entire underside of the vehicle where RCC is not used, portions of the OMS/RCS pods, the leading and trailing edges of the vertical stabilizer, wing glove areas, elevon trailing edges adjacent to the RCC on the upper wing surface, the base heat shield, the interface with wing leading edge RCC, and the upper body flap surface. The HRSI tiles protect areas where temperatures are below 2,300° F. These tiles have a black surface coating necessary for entry emittance.
- 3. Black tiles called fibrous refractory composite insulation (FRCI) were developed later in the TPS program. FRCI tiles replace some of the HRSI tiles in selected areas of the orbiter.

- 4. Low-temperature reusable surface insulation (LRSI) white tiles are used in selected areas of the forward, mid-, and aft fuselages, vertical tail, upper wing, and OMS/RCS pods. These tiles protect areas where temperatures are below 1,200° F. These tiles have a white surface coating to provide better thermal characteristics on orbit.
- 5. After the initial delivery of Columbia, an advanced flexible reusable surface insulation (AFRSI) was developed. This material consists of sewn composite quilted fabric insulation batting between two layers of white fabric that are sewn together to form a quilted blanket. AFRSI was used on Discovery and Atlantis to replace the vast majority of the LRSI tiles. Following its seventh flight, Columbia also was modified to replace most of the LRSI tiles with AFRSI. The AFRSI blankets provide improved producibility and durability, reduced fabrication and installation time and costs, and a weight reduction over that of the LRSI tiles. The AFRSI blankets protect areas where temperatures are below 1,200° F.
- 6. White blankets made of coated Nomex felt reusable surface insulation (FRSI) are used on the upper payload bay doors, portions of the midfuselage and aft fuselage sides, portions of the upper wing surface, and a portion of the OMS/RCS pods. The FRSI blankets protect areas where temperatures are below 700° F.
- 7. Additional materials are used in other special areas. These materials are thermal panes for the windows, metal for the forward RCS fairings and elevon seal panels on the upper wing to elevon interface, a combination of white- and black-pigmented silica cloth for thermal barriers and gap fillers around operable penetrations, such as main and nose landing gear doors, egress and ingress flight crew side hatch, umbilical doors, elevon cove, forward RCS, RCS jets, midfuselage vent doors, payload bay doors, rudder/speed brake, OMS/RCS pods, and gaps between TPS tiles in high differential pressure areas, and room-temperature vulcanizing material for the thick aluminum T-0 umbilicals on the sides of the orbiter aft fuselage.

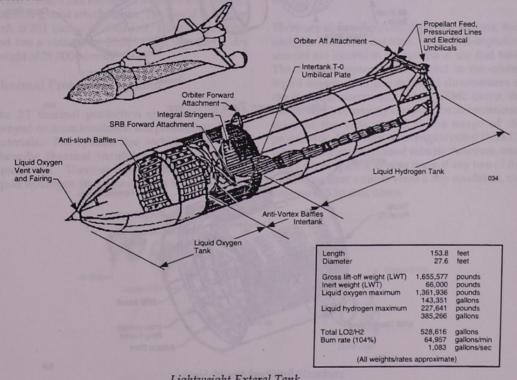
1.3 EXTERNAL TANK

Contents	
Liquid Oxygen Tank	1.3-2
Intertank	1.3-2
Liquid Hydrogen Tank	1.3-3
Thermal Protection System	1.3-3
Hardware and Instrumentation	1.3-3
Range Safety System	1.3-4

The external tank (ET) contains the liquid hydrogen fuel and liquid oxygen oxidizer and supplies them under pressure to the three SSMEs in the orbiter during lift-off and ascent. When the SSMEs are shut down, the ET is jettisoned, enters the Earth's atmosphere, breaks up, and impacts in a remote ocean area. It is not recovered. ET impact zones for direct and standard insertion are discussed in Section 1.1. The largest and heaviest (when loaded) element of the space shuttle, the ET, has three major components: the forward liquid oxygen tank, an unpressurized intertank that contains most of the electrical components, and the aft liquid hydrogen tank.

Since the STS-6 mission, a lightweight external tank (LWT) has been used. This tank weighs approximately 66,000 pounds inert. To help increase payload capability, a new super lightweight external tank (SLWT) has been developed, which is the same size as the LWT but weighs approximately 7500 pounds less. The first flight of the SLWT is scheduled for late 1997.

The ET is attached to the orbiter at one forward attachment point and two aft points. In the aft attachment area, there are also umbilicals that carry fluids, gases, electrical signals, and electrical power between the tank and the orbiter. Electrical signals and controls between the orbiter and the two SRBs also are routed through those umbilicals.



Lightweight Exteral Tank



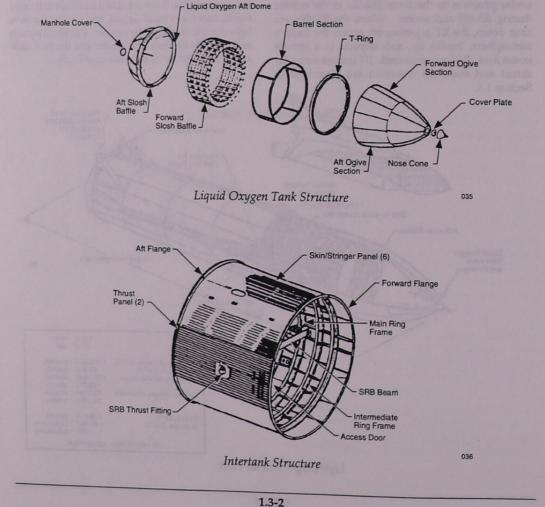
Liquid Oxygen Tank

The liquid oxygen tank is an aluminum monocoque structure composed of a fusion-welded assembly of preformed, chem-milled gores, panels, machined fittings, and ring chords. It operates in a pressure range of 20 to 22 psig. The tank contains anti-slosh and anti-vortex provisions to minimize liquid residuals and damp fluid motion. The tank feeds into a 17-inch-diameter feed line that conveys the liquid oxygen through the intertank, then outside the ET to the aft right-hand ET/orbiter disconnect umbilical. The 17-inch-diameter feed line permits liquid oxygen to flow at approximately 2,787 pounds per second with the SSMEs operating at 104 percent or permits a maximum flow of 17,592 gallons per minute. The liquid oxygen tank's double-wedge

nose cone reduces drag and heating, contains the vehicle's ascent air data system (for nine tanks only) and serves as a lightning rod. The liquid oxygen tank's volume is 19,563 cubic feet. It is 331 inches in diameter, 592 inches long and weighs 12,000 pounds empty.

Intertank

The intertank is a steel/aluminum semimonocoque cylindrical structure with flanges on each end for joining the liquid oxygen and liquid hydrogen tanks. The intertank houses ET instrumentation components and provides an umbilical plate that interfaces with the ground facility arm for purge gas supply, hazardous gas detection, and hydrogen gas boiloff during ground operations. It consists of



mechanically joined skin, stringers, and machined panels of aluminum alloy. The intertank is vented during flight. The intertank contains the forward SRB-ET attach thrust beam and fittings that distribute the SRB loads to the liquid oxygen and liquid hydrogen tanks. The intertank is 270 inches long, 331 inches in diameter, and weighs 12,100 pounds.

Liquid Hydrogen Tank

The liquid hydrogen tank is an aluminum semimonocoque structure of fusion-welded barrel sections, five major ring frames, and forward and aft ellipsoidal domes. Its operating pressure range is 32 to 34 psia. The tank contains an anti-vortex baffle and siphon outlet to transmit the liquid hydrogen from the tank through a 17-inch line to the left aft umbilical. The liquid hydrogen feed line flow rate is 465 pounds per second with the SSMEs at 104 percent or a maximum flow of 47,365 gallons per minute. At the forward end of the liquid hydrogen tank is the ET/orbiter forward attachment pod strut, and at its aft end are the two ET/orbiter aft attachment ball fittings as well as the aft SRB-ET stabilizing strut attachments. The liquid hydrogen tank is 331 inches in diameter, 1,160 inches long, and has a volume of 53,518 cubic feet and a dry weight of 29,000 pounds.

Thermal Protection System

The ET thermal protection system consists of sprayed-on foam insulation and premolded ablator materials. The system also includes the use of phenolic thermal insulators to preclude air liquefaction. Thermal isolators are required for liquid hydrogen tank attachments to preclude the liquefaction of air-exposed metallic attachments and to reduce heat flow into the liquid hydrogen. The thermal protection system weighs 4,823 pounds.

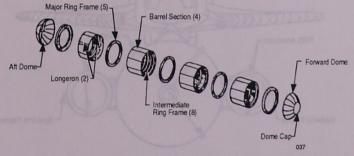
Hardware and Instrumentation

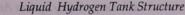
The external hardware, ET/orbiter attachment fittings, umbilical fittings, electrical, and range safety system weigh 9,100 pounds.

Each propellant tank has a vent and relief valve at its forward end. This dual-function valve can be opened by ground support equipment for the vent function during prelaunch and can open during flight when the ullage pressure of the liquid hydrogen tank reaches 38 psig, or the ullage pressure of the liquid oxygen tank reaches 25 psig.

The liquid oxygen tank contains a separate, pyrotechnically operated, propulsive tumble vent valve at its forward end. At separation, the liquid oxygen tumble vent valve is opened, providing impulse to assist in the separation maneuver and more positive control of the entry aerodynamics of the ET.

There are eight propellant-depletion sensors, four each for fuel and oxidizer. The fuel-depletion sensors are located in the bottom of the fuel tank. The oxidizer sensors are mounted in the orbiter liquid oxygen feed line manifold downstream of the feed line disconnect. During SSME burns, the orbiter GPCs constantly compute the instantaneous mass of the vehicle due to the usage of the propellants. Normally, main engine cutoff (MECO) is based on a predetermined velocity; however, once past a flight-specific arming mass, if any two of the fuel or oxidizer sensors sense a dry condition, the engines will be shut down.





.

The locations of the liquid oxygen sensors allow the maximum amount of oxidizer to be consumed in the engines, while allowing sufficient time to shut down the engines before the oxidizer pumps cavitate (run dry). In addition, 1,100 pounds of liquid hydrogen are loaded over and above that required by the 6:1 oxidizer/fuel engine mixture ratio. This assures that MECO from the depletion sensors is fuel-rich; oxidizer-rich engine shutdowns can cause burning and severe erosion of engine components.

Four pressure transducers located at the top of the liquid oxygen and liquid hydrogen tanks monitor the ullage pressures.

Each of the two aft ET umbilical plates mate with a corresponding plate on the orbiter. The plates help maintain alignment among the umbilicals. Physical strength at the umbilical plates is provided by bolting corresponding umbilical plates together. When the orbiter GPCs command external tank separation, the bolts are severed by pyrotechnic devices.

The ET has five propellant umbilical valves that interface with orbiter umbilicals: two for the liquid oxygen tank and three for the liquid hydrogen tank. One of the liquid oxygen tank umbilical valves is for liquid oxygen, the other for gaseous oxygen. The liquid hydrogen tank umbilical has two valves for liquid and one for gas. The intermediatediameter liquid hydrogen umbilical is a recirculation umbilical used only during the liquid hydrogen chill-down sequence during prelaunch.

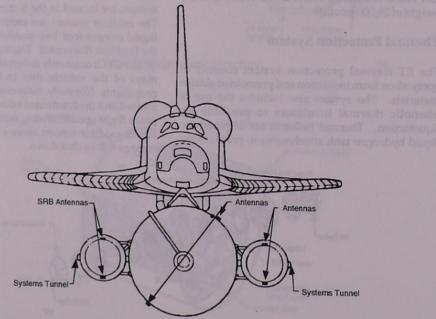
The ET also has two electrical umbilicals that carry electrical power from the orbiter to the tank and the two SRBs and provide information from the SRBs and ET to the orbiter.

A swing-arm-mounted cap to the fixed service structure covers the oxygen tank vent on top of the ET during the countdown and is retracted about two minutes before lift-off. The cap siphons off oxygen vapor that threatens to form ice on the ET, thus protecting the orbiter's TPS during launch.

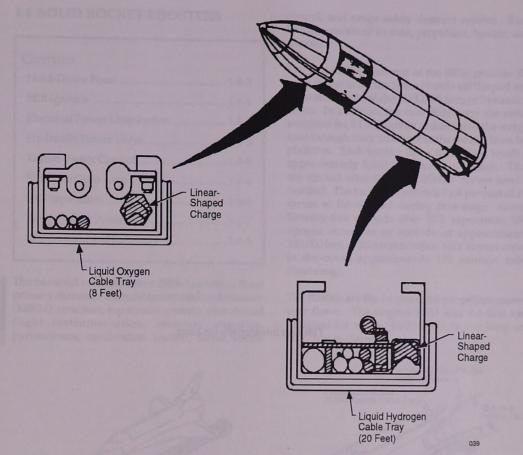
Range Safety System

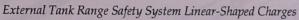
A range safety system provides for dispersing tank propellants if necessary. It includes a battery power source, a receiver/decoder, antennas, and ordnance.

Various parameters are monitored and displayed on the flight deck display and control panel and are transmitted to the ground.



External Tank Range Safety System Antennas





1.4 SOLID ROCKET BOOSTERS

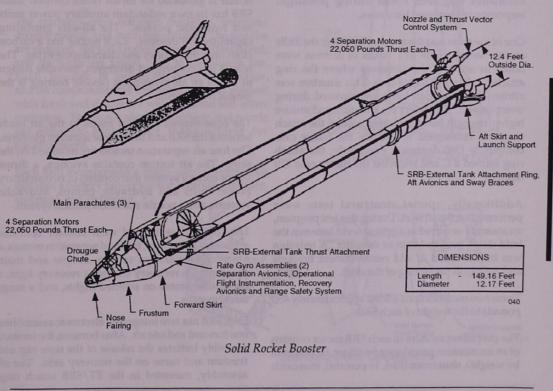
CONTENTS

Hold-Down Posts	1.4-3
SRB Ignition	1.4-4
Electrical Power Distribution	1.4-5
Hydraulic Power Units	1.4-5
Thrust Vector Control	1.4-6
SRB Rate Gyro Assemblies	1.4-6
SRB Separation	1.4-6
Range Safety System	
SRB Descent and Recovery	1.4-8

The two solid rocket boosters (SRBs) consist of these primary elements: the redesigned solid rocket motor (RSRM), structure, separation systems, operational flight instrumentation, recovery avionics, pyrotechnics, deceleration system, thrust vector control, and range safety destruct system. Each RSRM consists of its case, propellant, igniter, and nozzle.

The two RSRM elements of the SRBs provide the main thrust to lift the Space Shuttle off the pad and up to an altitude of about 150,000 feet, or 24 nautical miles. In addition, the two SRBs carry the entire weight of the ET and orbiter and transmit the weight load through their structure to the mobile launcher platform. Each booster has a thrust (sea level) of approximately 3,300,000 pounds at launch. They are ignited after the three SSMEs' thrust level is verified. The two SRBs provide 71.4 percent of the thrust at lift-off and during first-stage ascent. Seventy-five seconds after SRB separation, SRB apogee occurs at an altitude of approximately 220,000 feet, or 35 nautical miles. SRB impact occurs in the ocean approximately 122 nautical miles downrange.

The RSRMs are the largest solid-propellant motors ever flown. The original SRM was the first ever designed for reuse. Each is 149.16 feet long and 12.17 feet in diameter.



1.4-1

Each SRB weighs approximately 1,300,000 pounds at launch. The propellant for each motor weighs approximately 1,100,000 pounds. The inert weight of each SRB is approximately 192,000 pounds.

Primary elements of each booster are the motor (including case, propellant, igniter, and nozzle), structure, separation systems, operational flight instrumentation, recovery avionics, pyrotechnics, deceleration system, thrust vector control system, and range safety destruct system.

Each booster is attached to the ET at the SRB's aft frame by two lateral sway braces and a diagonal attachment. The forward end of each SRB is attached to the external tank at the forward end of the SRB's forward skirt. On the launch pad, each booster also is attached to the mobile launcher platform at the aft skirt by four bolts and nuts that are severed by small explosives at lift-off.

During the downtime following the Challenger accident, detailed structural analyses were performed on critical structural elements of the SRB. Analyses were primarily focused in areas where anomalies had been noted during postflight inspection of recovered hardware.

One of the areas was the attach ring where the SRBs are connected to the ET. Areas of distress were noted in some of the fasteners where the ring attaches to the SRB motor case. This situation was attributed to the high loads encountered during water impact. To correct the situation and ensure higher strength margins during ascent, the attach ring was redesigned to encircle the motor case completely (360 degrees). Previously, the attach ring formed a C and encircled the motor case 270 degrees.

Additionally, special structural tests were performed on the aft skirt. During this test program, an anomaly occurred in a critical weld between the hold-down post and skin of the skirt. A redesign was implemented to add reinforcement brackets and fittings in the aft ring of the skirt.

These two modifications added approximately 450 pounds to the weight of each SRB.

The propellant mixture in each SRB motor consists of an ammonium perchlorate (oxidizer, 69.6 percent by weight), aluminum (fuel, 16 percent), iron oxide (a catalyst, 0.4 percent), a polymer (a binder that holds the mixture together, 12.04 percent), and an epoxy curing agent (1.96 percent). The propellant is an 11-point star-shaped perforation in the forward motor segment and a double-truncated-cone perforation in each of the aft segments and aft closure. This configuration provides high thrust at ignition and then reduces the thrust by approximately a third 50 seconds after lift-off to prevent overstressing the vehicle during maximum dynamic pressure.

The SRBs are used as matched pairs, and each is made up of four solid rocket motor segments. The pairs are matched by loading each of the four motor segments in pairs from the same batches of propellant ingredients to minimize any thrust imbalance. The segmented-casing design assures maximum flexibility in fabrication and ease of transportation and handling. Each segment is shipped to the launch site on a heavy-duty rail car with a specially built cover.

The nozzle expansion ratio of each booster beginning with the STS-8 mission is 7-to-79. The nozzle is gimbaled for thrust vector control. Each SRB has its own redundant auxiliary power units and hydraulic pumps. The all-axis gimbaling capability is 8 degrees. Each nozzle has a carbon cloth liner that erodes and chars during firing. The nozzle is a convergent-divergent, movable design in which an aft pivot-point flexible bearing is the gimbal mechanism.

The cone-shaped aft skirt reacts to the aft loads between the SRB and the mobile launcher platform. The four aft separation motors are mounted on the skirt. The aft section contains avionics, a thrust vector control system that consists of two auxiliary power units and hydraulic pumps, hydraulic systems, and a nozzle extension jettison system.

The forward section of each booster contains avionics, a sequencer, forward separation motors, a nose cone separation system, drogue and main parachutes, a recovery beacon, a recovery light, a parachute camera on selected flights, and a range safety system.

Each SRB has two integrated electronic assemblies, one forward and one aft. After burnout, the forward assembly initiates the release of the nose cap and frustum and turns on the recovery aids. The aft assembly, mounted in the ET/SRB attach ring, connects with the forward assembly and the orbiter avionics systems for SRB ignition commands and nozzle thrust vector control. Each integrated electronic assembly has a multiplexer/ demultiplexer, which sends or receives more than one message, signal, or unit of information on a single communication channel.

Eight booster separation motors (four in the nose frustum and four in the aft skirt) of each SRB burn for 1.02 seconds at SRB separation from the ET. Each solid rocket separation motor is 31.1 inches long and 12.8 inches in diameter.

Location aids are provided for each SRB, frustum/ drogue chutes, and main parachutes. These include a transmitter, antenna, strobe/converter, battery, and salt water switch electronics. The location aids are designed for a minimum operating life of 72 hours and when refurbished are considered usable up to 20 times. The flashing light is an exception. It has an operating life of 280 hours. The battery is used only once.

The SRB nose caps and nozzle extensions are not recovered.

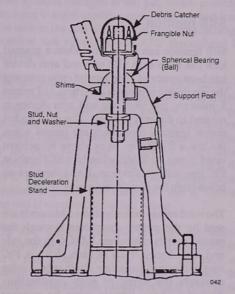
The recovery crew retrieves the SRBs, frustum/ drogue chutes, and main parachutes. The nozzles are plugged, the solid rocket motors are dewatered, and the SRBs are towed back to the launch site. Each booster is removed from the water, and its components are disassembled and washed with fresh and deionized water to limit salt water corrosion. The motor segments, igniter, and nozzle are shipped back to the manufacturer for refurbishment.

Each SRB incorporates a range safety system that includes a battery power source, receiver/decoder, antennas, and ordnance.

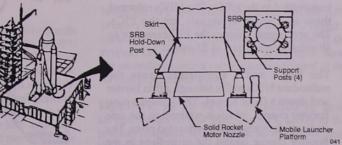
Hold-Down Posts

Each SRB has four hold-down posts that fit into corresponding support posts on the mobile launcher platform. Hold-down bolts hold the SRB and launcher platform posts together. Each bolt has a nut at each end, but only the top nut is frangible. The top nut contains two NASA standard detonators (NSDs), which are ignited at solid rocket motor ignition commands.

When the two NSDs are ignited at each hold-down, the hold-down bolt travels downward because of the release of tension in the bolt (pretensioned before



SRB Support/Hold-Down Post



SRB Hold-Down Configuration

launch), NSD gas pressure, and gravity. The bolt is stopped by the stud deceleration stand, which contains sand. The SRB bolt is 28 inches long and is 3.5 inches in diameter. The frangible nut is captured in a blast container.

The solid rocket motor ignition commands are issued by the orbiter's computers through the master events controllers to the hold-down pyrotechnic initiator controllers (PICs) on the mobile launcher platform. They provide the ignition to the hold- down NSDs. The launch processing system monitors the SRB hold-down PICs for low voltage during the last 16 seconds before launch. PIC low voltage will initiate a launch hold.

SRB Ignition

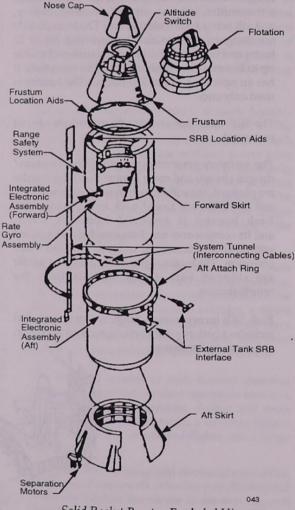
SRB ignition can occur only when a manual lock pin from each SRB safe and arm device has been removed. The ground crew removes the pin during prelaunch activities. At T minus 5 minutes, the SRB safe and arm device is rotated to the arm position. The solid rocket motor ignition commands are issued when the three SSMEs are at or above 90-percent rated thrust, no SSME fail and/or SRB ignition PIC low voltage is indicated, and there are no holds from the launch processing system.

The solid rocket motor ignition commands are sent by the orbiter computers through the master events controllers (MECs) to the safe and arm device NSDs in each SRB. A PIC single-channel capacitor discharge device controls the firing of each pyrotechnic device. Three signals must be present simultaneously for the PIC to generate the pyro firing output. These signals, arm, fire 1, and fire 2, originate in the GPCs and are transmitted to the MECs. The MECs reformat them to 28-volt dc signals for the PICs. The arm signal charges the PIC capacitor to 40 volts dc (minimum of 20 volts dc).

The fire 1 and 2 commands cause the redundant NSDs to fire through a thin barrier seal down a flame tunnel. This ignites a pyro booster charge, which is retained in the safe and arm device behind a perforated plate. The booster charge ignites the propellant in the igniter initiator, and combustion products of

this propellant ignite the solid rocket motor initiator, which fires down the length of the solid rocket motor igniting the solid rocket motor propellant.

The GPC launch sequence also controls certain critical main propulsion system (MPS) valves and monitors the engine-ready indications from the SSMEs. The MPS start commands are issued by the GPCs at T minus 6.6 seconds (staggered start—engine 3, engine 2, engine 1—all approximately within 0.25 second), and the sequence monitors the thrust buildup of each engine. All three SSMEs must reach the required 90-percent thrust within 3 seconds; otherwise, an orderly shutdown is commanded, and safing functions are initiated.



Solid Rocket Booster-Exploded View

Normal thrust buildup to the required 90-percent thrust level will result in the SSMEs being commanded to the lift-off position at T minus 3 seconds as well as the fire 1 command being issued to arm the SRBs. At T minus 3 seconds, the vehicle base bending load modes are allowed to initialize (movement of approximately 25.5 inches measured at the tip of the external tank, with movement towards the external tank).

At T minus 0, the two SRBs are ignited, separation of the four frangible nuts on each SRB hold down bolt is initiated, the two T-0 umbilicals (one on each side of the spacecraft) are retracted, the onboard master timing unit, event timer, and mission event timers are started, the three SSMEs are at 100 percent, and the ground launch sequence is terminated.

The solid rocket motor thrust profile is tailored to reduce thrust during the maximum dynamic pressure region.

Electrical Power Distribution

Electrical power distribution in each SRB consists of orbiter-supplied main dc bus power to each SRB via SRB buses A, B, and C. Orbiter main dc buses A, B, and C supply main dc bus power to corresponding SRB buses A, B, and C. In addition, orbiter main dc bus C supplies backup power to SRB buses A and B, and orbiter bus B supplies backup power to SRB bus C. This electrical power distribution arrangement allows all SRB buses to remain powered in the event one orbiter main bus fails.

The nominal dc voltage is 28 volts dc, with an upper limit of 32 volts dc and a lower limit of 24 volts dc.

Hydraulic Power Units

There are two self-contained, independent hydraulic power units (HPUs) on each SRB. Each HPU consists of an auxiliary power unit (APU), fuel supply module, hydraulic pump, hydraulic reservoir, and hydraulic fluid manifold assembly. The APUs are fueled by hydrazine and generate mechanical shaft power to a hydraulic pump that produces hydraulic pressure for the SRB hydraulic system. The two separate HPUs and two hydraulic systems are located on the aft end of each SRB between the SRB nozzle and aft skirt. The HPU components are mounted on the aft skirt between the rock and tilt actuators. The two systems operate from T minus 28 seconds until SRB separation from the orbiter and external tank. The two independent hydraulic systems are connected to the rock and tilt servoactuators.

The APU controller electronics are located in the SRB aft integrated electronic assemblies on the aft external tank attach rings.

The APUs and their fuel systems are isolated from each other. Each fuel supply module (tank) contains 22 pounds of hydrazine. The fuel tank is pressurized with gaseous nitrogen at 400 psi, which provides the force to expel (positive expulsion) the fuel from the tank to the fuel distribution line, maintaining a positive fuel supply to the APU throughout its operation.

The fuel isolation valve is opened at APU startup to allow fuel to flow to the APU fuel pump and control valves and then to the gas generator. The gas generator's catalytic action decomposes the fuel and creates a hot gas. It feeds the hot gas exhaust product to the APU two-stage gas turbine. Fuel flows primarily through the startup bypass line until the APU speed is such that the fuel pump outlet pressure is greater than the bypass line's. Then all the fuel is supplied to the fuel pump.

The APU turbine assembly provides mechanical power to the APU gearbox. The gearbox drives the APU fuel pump, hydraulic pump, and lube oil pump. The APU lube oil pump lubricates the gearbox. The turbine exhaust of each APU flows over the exterior of the gas generator, cooling it, and is then directed overboard through an exhaust duct.

When the APU speed reaches 100 percent, the APU primary control valve closes, and the APU speed is controlled by the APU controller electronics. If the primary control valve logic fails to the open state, the secondary control valve assumes control of the APU at 113-percent speed.

Each HPU on an SRB is connected to both servoactuators on that SRB. One HPU serves as the primary hydraulic source for the servoactuator, and the other HPU serves as the secondary hydraulics



for the servoactuator. Each servoactuator has a switching valve that allows the secondary hydraulics to power the actuator if the primary hydraulic pressure drops below 2,050 psi. A switch contact on the switching valve will close when the valve is in the secondary position. When the valve is closed, a signal is sent to the APU controller that inhibits the 100-percent APU speed control logic and enables the 113-percent APU speed control logic. The 113-percent APU speed enables one APU/HPU to supply sufficient operating hydraulic pressure to both servoactuators of that SRB.

The APU 100-percent speed corresponds to 72,000 rpm and 113-percent to 81,000 rpm.

The APUs/HPUs and hydraulic systems are reusable for 20 missions.

Thrust Vector Control

Each SRB has two hydraulic gimbal servoactuators: one for rock and one for tilt. The servoactuators provide the force and control to gimbal the nozzle for thrust vector control.

The Space Shuttle ascent thrust vector control (ATVC) portion of the flight control system directs the thrust of the three SSMEs and the two SRB nozzles to control attitude and trajectory during lift- off and ascent. Commands from the guidance system are transmitted to the ATVC drivers, which transmit signals proportional to the commands to each servoactuator of the main engines and SRBs. Four independent flight control system channels and four ATVC channels control six main engine and four SRB ATVC drivers, with each driver controlling one hydraulic port on each main and SRB servoactuator.

Each SRB servoactuator consists of four independent, two-stage servovalves that receive signals from the drivers. Each servovalve controls one power spool in each actuator, which positions an actuator ram and the nozzle to control the direction of thrust.

The four servovalves in each actuator provide a force-summed majority voting arrangement to position the power spool. With four identical commands to the four servovalves, the actuator force-sum action prevents a single erroneous command from affecting power ram motion. If the erroneous command persists for more than a predetermined time, differential pressure sensing activates a selector valve to isolate and remove the defective servovalve hydraulic pressure, permitting the remaining channels and servovalves to control the actuator ram spool.

Failure monitors are provided for each channel to indicate which channel has been bypassed. An isolation valve on each channel provides the capability of resetting a failed or bypassed channel.

Each actuator ram is equipped with transducers for position feedback to the thrust vector control system. Within each servoactuator ram is a splashdown load relief assembly to cushion the nozzle at water splashdown and prevent damage to the nozzle flexible bearing.

SRB Rate Gyro Assemblies

Each SRB contains two rate gyro assemblies (RGAs), with each RGA containing one pitch and one yaw gyro. These provide an output proportional to angular rates about the pitch and yaw axes to the orbiter computers and guidance, navigation, and control system during first-stage ascent flight in conjunction with the orbiter roll rate gyros until SRB separation. At SRB separation, a switchover is made from the SRB RGAs to the orbiter RGAs.

The SRB RGA rates pass through the orbiter flight aft multiplexers/ demultiplexers to the orbiter GPCs. The RGA rates are then interchangeable midvalue-selected in redundancy management to provide SRB pitch and yaw rates to the user software. The RGAs are designed for 20 missions.

SRB Separation

SRB separation is initiated when the three solid rocket motor chamber pressure transducers are processed in the redundancy management interchangeable middle value select, and the headend chamber pressure of both SRBs is less than or equal to 50 psi. A backup cue is the time elapsed from booster ignition.

The separation sequence is initiated, commanding the thrust vector control actuators to the null position and putting the main propulsion system into a second-stage configuration (0.8 second from sequence initialization), which ensures the thrust of each SRB is less than 100,000 pounds. Orbiter yaw attitude is held for 4 seconds, and SRB thrust drops to less than 60,000 pounds.

The SRBs separate from the external tank within 30 milliseconds of the ordnance firing command.

The forward attachment point consists of a ball (SRB) and socket (ET) held together by one bolt. The bolt contains one NSD pressure cartridge at each end. The forward attachment point also carries the range safety system cross-strap wiring connecting each SRB and the ET range safety systems with each other.

The aft attachment points consist of three separate struts: upper, diagonal and lower. Each strut contains one bolt with an NSD pressure cartridge at each end. The upper strut also carries the umbilical interface between its SRB and the external tank and on to the orbiter.

There are four booster separation motors (BSMs) on each end of each SRB. The BSMs separate the SRBs from the external tank. The solid rocket motors

in each cluster of four are ignited by firing redundant NSD pressure cartridges into redundant confined detonating fuse manifolds.

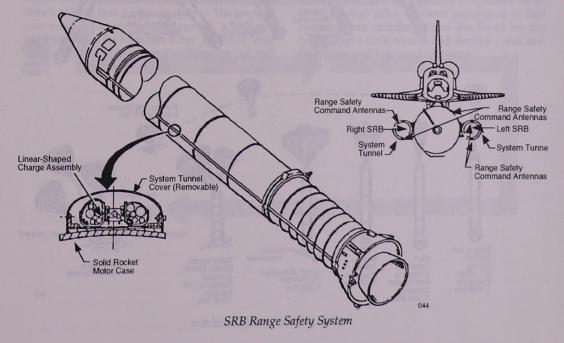
The separation commands issued from the orbiter by the SRB separation sequence initiate the redundant NSD pressure cartridge in each bolt and ignite the BSMs to effect a clean separation.

Range Safety System

The Shuttle vehicle has three range safety systems (RSSs). One is located in each SRB and one in the external tank. Any one or all three are capable of receiving two command messages (arm and fire) transmitted from the ground station. The RSS is used only if the Shuttle vehicle violates a launch trajectory red line.

An RSS consists of two antenna couplers, command receivers/ decoders, a dual distributor, a safe and arm device with two NSDs, two confined detonating fuse (CDF) manifolds, seven CDF assemblies, and one linear-shaped charge (LSC).

The antenna couplers provide the proper impedance for radio frequency and ground support equipment commands. The command receivers are tuned to



RSS command frequencies and provide the input signal to the distributors when an RSS command is sent. The command decoders use a code plug to prevent any command signal other than the proper command signal from getting into the distributors. The distributors contain the logic to supply valid destruct commands to the RSS pyrotechnics.

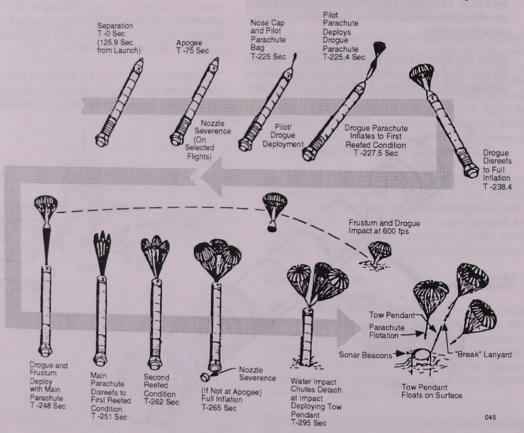
The NSDs provide the spark to ignite the CDF, which in turn ignites the LSC for Shuttle vehicle destruction. The safe and arm device provides mechanical isolation between the NSDs and the CDF before launch and during the SRB separation sequence.

The first message, called arm, allows the onboard logic to enable a destruct and illuminates a light on the flight deck display and control panel at the commander and pilot station. The second message transmitted is the fire command. The SRB distributors in the SRBs and the ET are cross-strapped together. Thus, if one SRB received an arm or destruct signal, the signal would also be sent to the other SRB and the ET.

Electrical power from the RSS battery in each SRB is routed to RSS system A. The recovery battery in each SRB is used to power RSS system B as well as the recovery system in the SRB. The SRB RSS is powered down during the separation sequence, and the SRB recovery system is powered up. Electrical power for the ET RSS system A and system B is independently supplied by two RSS batteries on the ET.

SRB Descent and Recovery

The recovery sequence begins with the operation of the high-altitude baroswitch, which triggers the functioning of the pyrotechnic nose cap thrusters.



SRB Descent and Splashdown

SCOM 1.0 November 1991 This ejects the nose cap, which deploys the pilot parachute. This occurs at 15,704 feet altitude 225 seconds after separation. The 11.5-foot-diameter conical ribbon pilot parachute provides the force to pull the lanyard activating the zero-second cutter, which cuts the loop securing the drogue retention straps. This allows the pilot chute to pull the drogue pack from the SRB, causing the drogue suspension lines to deploy from their stored position. At full extension of the twelve 95-foot suspension lines, the drogue deployment bag is stripped away from the canopy, and the 54-foot-diameter conical ribbon drogue parachute inflates to its initial reefed condition. The drogue disreefs twice after specified time delays, and it reorients/stabilizes the SRB for main chute deployment. The drogue parachute can withstand a load of 270,000 pounds and weighs approximately 1,200 pounds.

After the drogue chute has stabilized the vehicle in a tailfirst attitude, the frustum is separated from the forward skirt by a charge triggered by the lowaltitude baroswitch at an altitude of 5,975 feet 248 seconds after separation. It is then pulled away from the SRB by the drogue chute. The main chutes' suspension lines are pulled out from deployment bags that remain in the frustum. At full extension of the lines, which are 204 feet long, the three main chutes are pulled from the deployment bags and inflate to their first reefed condition. The frustum and drogue parachute continue on a separate trajectory to splashdown. After specified time delays, the main chutes' reefing lines are cut, and the chutes inflate to their second reefed and full open configurations. The main chute cluster decelerates the SRB to terminal conditions. Each of the 136-foot-diameter, 20-degree conical ribbon parachutes can withstand a load of 180,000 pounds and weighs 2,180 pounds. The nozzle extension is severed by pyrotechnic charge either at apogee or 20 seconds after low baroswitch operation.

Water impact occurs 295 seconds after separation at a velocity of 81 feet per second. The water impact range is approximately 140 miles off the eastern coast of Florida. Because the parachutes provide for a nozzlefirst impact, air is trapped in the empty (burned out) motor casing, causing the booster to float with the forward end approximately 30 feet out of the water.

The main chutes are released from the SRB at impact using the parachute release nut ordnance system. Residual loads in the main chutes deploy the parachute attach fittings with the redundant flotation tethered to each fitting. The drogue and frustum, each main chute with its flotation, and the SRB are buoyant. The SRB recovery aids are the radio beacon and flashing lights, which become operable at frustum separation. The radio transponder in each SRB has a range of 8.9 nautical miles, and the flashing light has a nighttime range of 4.9 nautical miles. Various parameters of SRB operation are monitored and displayed on the orbiter flight deck control and display panel and are transmitted to ground telemetry.

2. SYSTEMS

CONTENTS

2.1	Auxiliary Power Unit/Hydraulics (APU/HYD)2.1-1
2.2	Caution and Warning System (C/W)2.2-1
2.3	Closed Circuit Television (CCTV)2.3-1
2.4	Communications 2.4-1
2.5	Crew Systems 2.5-1
2.6	Data Processing System (DPS) 2.6-1
2.7	Dedicated Display Systems 2.7-1
2.8	Electrical Power System (EPS) 2.8-1
2.9	Environmental Control
	and Life Support System (ECLSS) 2.9-1
	Escape Systems 2.10-1
	Extravehicular Activity (EVA) 2.11-1
	Galley/Food2.12-1
2.13	Guidance, Navigation, and Control (GNC)2.13-1
~ ~ ~ ~	
	Landing/Deceleration System 2.14-1
	Lighting System 2.15-1
	Main Propulsion System (MPS) 2.16-1
	Mechanical Systems 2.17-1
2.18	Orbital Maneuvering System (OMS)2.18-1
2.19	Payload Deployment
	and Retrieval System (PDRS) 2.19-1
	Reaction Control System (RCS) 2.20-1
	Spacelab 2.21-1
	Spacehab 2.22-1
	Orbiter Docking System 2.23-1
	Stowage 2.24-1
	Waste Management System (WMS)2.23-1
2.26	Payload and General Support Computer 2.26-1

This section discusses in detail each of 26 orbiter systems as listed here in the Table of Contents. The subsections are organized alphabetically, with a detailed internal table of contents provided for each.

Each system subsection begins with descriptive information covering general purpose, function, and location. Relevant elements of each system are then provided in some detail. Where orbiter panels or CRT displays apply, an illustration of such appears as near the reference as possible. In the case of large panels, appropriate fragments are placed in the text, with full panel diagrams provided in Appendix A.

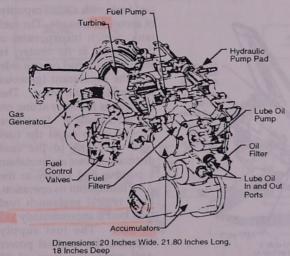
Most system subsections conclude with a summary. Caution and warning summaries and rules of thumb are also provided where appropriate.

2-1

2.1 AUXILIARY POWER UNIT / HYDRAULICS (APU / HYD)

CONTENTS

Description	.2.1-1
Fuel System	.2.1-2
Gas Generator and Turbine	2.1-5
Lubricating Oil	2.1-5
Electronic Controller	2.1-6
Injector Cooling System	2.1-10
APU Heaters	2.1-11
Water Spray Boilers	
Main Hydraulic Pump	2.1-16
Hydraulic Reservoir	2.1-18
Hydraulic Accumulator	2.1-18
Circulation Pump and Heat	
Exchanger	2.1-19
Hydraulic Heaters	2.1-21
Operations	2.1-21



Auxiliary Power Unit

Description

The orbiter has three independent hydraulic systems. Each consists of a main hydraulic pump, hydraulic reservoir, hydraulic bootstrap accumulator, hydraulic filters, control valves, hydraulic/Freon heat exchanger, electrical circulation pump, and electrical heaters.

Each system provides hydraulic pressure to position hydraulic actuators for:

- 1. Thrust vector control of the main engines by gimbaling the three SSMEs
- 2. Actuation of various control valves on the SSMEs
- 3 Movement of the orbiter aerosurfaces (elevons, body flap, rudder/speed brake)
- 4. Retraction of the external tank/orbiter 17-inch liquid oxygen and liquid hydrogen disconnect umbilicals within the orbiter at external tank jettison
- 5. Main/nose landing gear deployment (system 1)/(system 1 or 2)
- 6. Main landing gear brakes and anti-skid
- 7. Nose wheel steering (system 1 with backup from system 2).

Each hydraulic system is capable of operation when exposed to forces or conditions caused by acceleration, deceleration, normal gravity, zero gravity, hard vacuum, and temperatures encountered during on-orbit dormant conditions.

Three identical, but independent, improved auxiliary power units (APUs; also called IAPUs) provide power for the orbiter hydraulic systems. The APU is a hydrazine-fueled, turbine-driven power unit that generates mechanical shaft power to drive a hydraulic pump that produces pressure for the orbiter's hydraulic system. Each unit weighs approximately 88 pounds and produces 135 horsepower.

Each APU consists of a fuel tank, a fuel feed system, a system controller, an exhaust duct, lube oil cooling system, and fuel/lube oil vents and drains. Redundant electrical heater systems and insulation thermally control the system above 45° F to prevent fuel from freezing and to maintain required

2.1-1

046

lubricating oil viscosity. Insulation is used on components containing hydrazine, lube oil, or water to minimize electrical heater power requirements and to keep high surface temperatures within safe limits on the turbine and exhaust ducts.

The three APUs and fuel systems are located in the aft fuselage. Each APU fuel system supplies storable liquid hydrazine fuel to its respective fuel pump, gas generator valve module, and gas generator, which decomposes the fuel through catalytic action. The resultant hot gas drives a single-stage, dual pass turbine. The turbine exhaust flow returns over the exterior of the gas generator, cooling it, and is then directed overboard through an exhaust duct at the upper portion of the aft fuselage near the vertical stabilizer.

The turbine assembly provides mechanical power through a shaft to drive reduction gears in the gearbox. The gearbox drives a fuel pump, a hydraulic pump, and a lube oil pump. The hydraulic pump supplies pressure to the hydraulic system. The fuel pump increases the fuel pressure at its outlet to sustain pressurized fuel to the gas generator valve module and gas generator. The lube oil system supplies lubricant to the gearbox reduction gears

and uses the reduction gears as scavenger pumps to supply lube oil to the inlet of the lube oil pump to increase the pressure of the lube oil system.

The lube oil of each APU is circulated through a heat exchanger in a corresponding water spray boiler. Three water spray boilers (WSBs), one for each APU, cool the lube oil systems. The hydraulic fluid of each hydraulic pump driven by an APU is also circulated through a hydraulic heat exchanger in the corresponding water spray boiler to cool hydraulic fluid during hydraulic system operation. The three WSBs are also located in the aft fuselage of the orbiter.

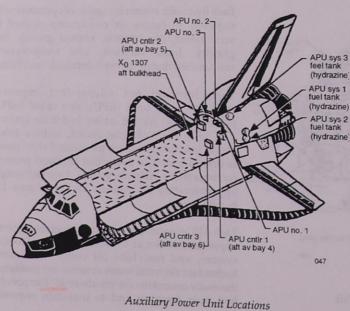
Fuel System

The APU fuel system (one for each of the three APUs) includes the fuel tank and fuel isolation valves, the fuel pump, and fuel control valves. The improved APUs use passive heat sinks and heat shields to minimize the effects of heat soakback.

Fuel Tanks

The APU fuel tanks are mounted on supports cantilevered from the sides of the internal portion of the aft fuselage. The fuel is storable liquid anhydrous hydrazine. The hydrazine is stored in a

> fuel tank with a total capacity of about 350 pounds. The fuel tank, which incorporates a diaphragm at its center, is serviced with fuel on one side and the pressurant (gaseous nitrogen) on the other. The nitrogen is the force acting on the diaphragm (positive expulsion) to expel the fuel from the tank to the fuel distribution lines and maintain a positive fuel supply to the APU throughout its operation. Each typical prelaunch fuel tank load is approximately 325 pounds. The fuel supply supports the nominal power unit operating time of 90 minutes in a mission or any defined abort mode, such as an abort once around, when the APUs run continuously for

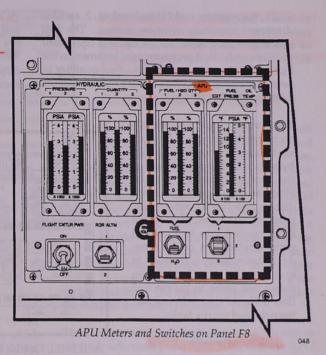


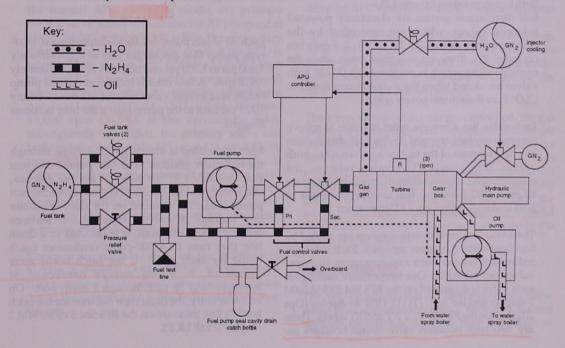
2.1-2

approximately 110 minutes. Under operating load conditions, an APU consumes approximately 3 to 3.5 pounds of fuel per minute.

The fuel tanks are 28-inch-diameter spheres. Fuel tanks 1 and 2 are located on the port side of the orbiter's aft fuselage, and tank 3 is located on the starboard side. Each fuel tank is serviced through its respective fill and drain service connections, located on the corresponding side of the aft fuselage. The gaseous nitrogen servicing connection for each fuel tank is located on the same panel as the fuel servicing connections on the corresponding side of the aft fuselage. The fuel tank is pressurized to 365 psi prelaunch.

Each fuel tank's temperature and gaseous nitrogen pressure are monitored by the APU controller and transmitted to the GPC, where quantity is calculated and transmitted to the APU FUEL/H2O QTY meters on panel F8. When the switch below the meters on panel F8 is positioned to





Improved APU Fuel System Schematic



SCOM 1.4 November 1993



FUEL, the quantity in APU fuel tanks 1, 2, and 3 is displayed simultaneously in percent. The fuel quantity of 100 percent on the meter is equivalent to 350 pounds. Fuel pressure (psia) is shown on the FUEL PRESS meter on panel F8. Fuel quantity in percent is also displayed on the BFS SM SYS SUMM 2 display (FUEL QTY).

The gaseous nitrogen pressure in each fuel tank exerts a force on the tank's diaphragm to expel the hydrazine fuel under pressure to the fuel distribution system. Filters are incorporated into each distribution line to remove any particles. The fuel distribution line branches into two parallel paths downstream of the filter. An isolation valve is installed in each parallel path, providing redundant paths to permit fuel flow to the APU or to isolate fuel from the fuel supply tanks.

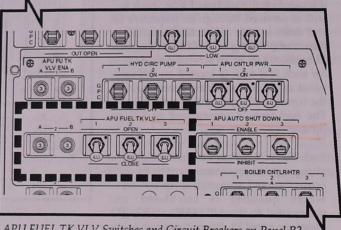
Fuel Tank Isolation Valves

Both isolation valves in each APU fuel distribution system are electrically powered solenoid valves, which are controlled by the corresponding APU FUEL TK VLV 1, 2, 3 switches on panel R2. They are energized open when the corresponding switch is positioned to OPEN; both valves are closed when the switch is positioned to CLOSE, or if electrical power is lost.

Each valve has a reverse relief function to relieve pressure on fuel trapped in the fuel distribution line downstream of the fuel tank valves when both valves are closed. The valve relieves the downstream pressure when the pressure increases 40 psi to 200 psi above fuel tank pressure due to heat soakback following APU shutdown.

The IAPU fuel tank isolation valves are cooled by fuel flow when the valves are open. Each valve has redundant temperature measurements (two per valve, four per APU). One temperature reading for each valve is displayed on the BFS SM SYS SUMM 2 display and the APU/HYD, DISP 86 display (Ops 201) beside the FU TK VLV AT and BT labels. There are two tank isolation valve circuit breakers per

APU (one per valve) located on panel R2. These can be pulled to disconnect electrical power from the solenoid if a valve fails open or shorts. The valve heating profile, when the fuel is stagnant, is gradual and, in the event of a failed open valve or short, permits adequate time for corrective action.



APU FUEL TK VLV Switches and Circuit Breakers on Panel R2

Fuel Pump

Each APU fuel pump is a fixed-displacement, geartype pump that discharges fuel at approximately 1,400 psi to 1,500 psi and operates at approximately 3,918 rpm. A fuel filter is located at the fuel pump outlet, and a relief valve relieves at approximately 1,725 psi back to the pump inlet if the filter becomes clogged.

Each fuel pump is driven by the turbine through the reduction gearbox. The fuel pump reduction gear is located in the lube oil system gearbox, and a shaft from the reduction gear drives the fuel pump. Seals are installed on the shaft to contain any leakage of fuel or lube oil. If leakage occurs through the seals, it is directed to a drain line that runs to a 500-cubic centimeter catch bottle for each APU. If the catch bottle were overfilled, it would relieve overboard at approximately 28 psia through a drain port. On ascent or entry, the flight crew can monitor the catch bottle's line pressure on the BFS SM SYS SUMM 2 display (PMP LK P).

SCOM 1.4 November 1993

theta ATAK pelteta	O2 PRESS X HTR T1 4 T2 4	1 XXXXS XXXXS X	2 XXXS XXXS XXXS	3 XXXS XXXS XXXS X ±XXXS ± ±XXXS ±	4 5 XXXS XXXS XXXS XXXXS XXXS ±XXXS		s x	
	APU TEMP EGT	1 XXXXS	2	3	HYD	1	2	3
	B/U EGT		XXXXS	XXXXS		XXXXS	XXXXS	
Course and		XXXXS	XXXXS	XXXXS		XXXXS	XXXXS	XXXXS
1000		XXXS	XXXS	XXXS	RSVR T	XXXS	XXXS	XXXS
1. 10.00	TUO OUT	XXXS		and the second	and the second second			
	GG BED		XXXS	and the second second second	QTY	XXXS	XXXXS	XXXS
	CONTRACTOR NO. 2. TO A STATE	XXXS	XXXS		and the second			
22 34	SPEED %	XXS	XXS	XXS				
1000	FUEL QTY	XXXS	XXXS	and the second second		XXXS	XXXS	XXXS
223	PMPLK P	XXS	XXS	XXS	BYP VLV	XXXS	XXXS	XXXS
Sec. 1	OIL OUT P	XXXS	XXXS	XXXS	1			
	FU TK VLV				THERM CN	ITL	1	2
	AT	XXXS	XXXS	XXXS	H20 PUMP P		XXXS	XXXS
	BT	XXXS	XXXS	XXXS	FREON FLOW	1	XXXXS	XXXXS
	AV BAY	1	2	3	EVAP OUT T		XXXS	XXXS
	TEMP	XXXS	XXXS	XXXS	and the second second			
	FAN AP	X.XXS	X.XXS	X.XXS	and the second			(XX)

APU Information on BFS SM SYS SUMM 2 Display

Fuel Control Valves

The APU's operating speed is controlled by the primary and secondary fuel control valves, which are installed in series downstream of the fuel pump. These are solenoid-operated pulser-type valves. In the normal APU operating mode, the primary control valve pulses to maintain the APU's speed at about 74,000 rpm (103%), while the secondary control valve is powered fully open. If the APU is taken to high via the APU SPEED SELECT switch on panel R2, the primary valve is unpowered and goes to fully open, while the secondary valve begins pulsing, and controls APU speed at about 81,000 rpm (113%). If the secondary valve subsequently fails open, the primary valve will begin pulsing to maintain APU speed at about 83,000 rpm (115%) in the backup speed control mode. If the secondary valve loses power, it goes to the closed position and shuts down the APU. As noted above, the primary valve goes to full open if it loses power, allowing the secondary valve to take over automatically and control at high speed (113%).

The crew can see APU speed on the BFS SM SYS SUMM 2 display (APU SPEED %) in percent (100 percent = 72,000 rpm). The speed fluctuates due to the nature of the pulse-modulated fuel flow system.

For safety reasons, each APU has an automatic shutdown feature that will shut the APU down if the speed falls below 80 percent (57,600 rpm) or rises above 129 percent (92,880 rpm).

Gas Generator and Turbine

Each gas generator consists of a bed of Shell 405 catalyst in a pressure chamber, mounted inside the APU exhaust chamber. When the hydrazine fuel comes into contact with the catalyst, it undergoes an exothermic reaction, decomposing into a hot gas at approximately 1,700° F. The gas expands rapidly and makes two passes through a single-stage turbine wheel, passes over the outside gas generator chamber and exits overboard through its own independent exhaust duct, located near the base of the

vertical stabilizer. The temperature of the hot gas at the exhaust duct is approximately 1,000° F.

The shaft power from the spinning turbine is sent to the hydraulic main pump associated with the APU via a speed reduction gearbox. It is also used to drive the APU's fuel pump and lubrication oil pump.

The normal speed of the hydraulic main pump, APU fuel pump, and APU lube oil pump are 3,918 rpm, 3,918 rpm, and 12,215 rpm respectively. The lube oil system is necessary to lubricate the APU gearbox and the fuel pump.

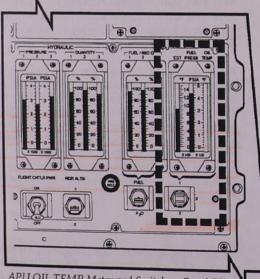
The temperatures of the gas generator bed, the gas generator fuel injector, and the turbine exhaust gas are visible on the BFS SM SYS SUMM 2 CRT display (GG BED, INJ, TEMP EGT). While the APU is running, the gas generator bed temperature transducer goes off-scale high at approximately 500° F. On orbit, when the APU is shut down, the gas generator bed temperature transducer is useful for monitoring the bed temperature when the bed is kept warm by heaters.

Lubricating Oil

The APU lube oil system is a scavenger-type system with a fixed-displacement pump. Each APU turbine through its gearbox drives a lube oil pump at 12,215 rpm. The system is pressurized with gaseous nitrogen to provide adequate suction pressure to start the lube oil pump under zero-gravity conditions. Each lube oil system has its own nitrogen gas storage vessel, which is pressurized to approximately 140 psia. The pressurization system for each lube oil system has a valve controlled by its corresponding APU controller. The gaseous nitrogen pressurization valve for each power unit is energized open by its corresponding controller when the gearbox pressure is below 5.2 psi, plus or minus 1.3 psi, to ensure that gearbox pressure is sufficiently above the requirements for proper scavenging and lube pump operation.

The pump increases the lube oil pressure to approximately 60 psi, directs the lube oil system through the corresponding water spray boiler for cooling, and returns the lube oil to the accumulators and gearbox. The two accumulators in each lube oil system allow thermal expansion of the lube oil, accommodate gas initially trapped in the external lube circuit, maintain lube oil pressure at a minimum of approximately 15 psia, and act as a zero-gravity, all-altitude lube reservoir.

The following information is transmitted to the BFS SM SYS SUMM 2 display by the APU controller via the GPC: lube oil pump outlet pressure (OIL OUT P)



APU OIL TEMP Meter and Switch on Panel F8 (NOTE: EGT indication on meter is driven by "TEMP EGT" transducer seen on BFS SYS SUMM 2 CRT display.)

at approximately 45 psia, outlet temperature at approximately 270° F and return temperature from the water spray boiler (OIL IN, OUT) at approximately 250° F for each APU. The lube oil temperature of each APU is also monitored on the APU OIL TEMP meter on panel F8. The APU is selected by the switch below the meter.

Electronic Controller

Each APU has its own digital controller. The controller detects malfunctions, controls turbine speed, gearbox pressurization, and fuel pump/gas generator heaters. Each controller is controlled by its corresponding *APU CNTLR PWR* switch on panel R2. When the switch is positioned to *ON*, 28-volt dc power is sent to that controller and APU. The controllers are redundantly powered via dual internal remote power controllers. When the switch is positioned to *OFF*, electrical power is removed from that controller and APU.

APU Start

An APU/HYD READY TO START talkback indicator for each APU is located on panel R2. The talkback signals gray when that APU hydraulic system is ready to start; that is, when the APU gas generator temperature is above 190° F, APU turbine speed is less than 80 percent, WSB controller is ready, corresponding APU fuel tank isolation valves are open, and corresponding hydraulic main pump is depressurized. When the APU is started, and its turbine speed is greater than 80 percent of normal speed, the corresponding indicator shows barberpole.

NOTE

A barberpole APU/HYD READY TO START talkback will not inhibit a start.

APU OPERATE 1, 2, 3 switches are located on panel R2. When the switches are positioned to *START/ RUN*, the corresponding APU controller activates the start of that unit and removes electrical power automatically from the unit's gas generator and fuel pump heaters.

To start the APU, fuel expelled from the hydrazine tank flows through the open tank valves and filter to the gas generator valve module, which contains a primary and secondary fuel control valve in series. The primary pulse control valve is normally open, and the secondary pulse control valve is energized open. Fuel flowing through the pump bypass valve is directed to the gas generator, because the fuel pump is not being driven at that moment by the APU turbine.

The fuel in the gas generator decomposes through catalytic reaction, creates hot gas, and directs the hot gas to the single-stage turbine, which begins to rotate. The turbine's mechanical shaft drives the reduction gears, rotating the fuel pump, lube oil pump, and hydraulic pump. The fuel pump increases the fuel pressure at its outlet and sustains pressurized fuel to the gas generator valve module and gas generator.

The startup logic delays the APU underspeed logic check for 10.5 seconds after the start command is issued. This allows the APU to reach normal operating speed before the shutdown logic begins checking for a speed lower than 80 percent. The auto shutdown capability of the controller can be disabled by taking the APU AUTO SHUT DOWN switch on panel R2 to INHIBIT.

The startup logic does not delay the APU overspeed logic. If an overspeed is detected at any time by the controller, the F7 and MASTER ALARM will annunciate. If the *AUTO SHUT DOWN* on panel R2 is *ENABLED*, the controller will automatically close the tank isolation valves and close the secondary control valve.

CAUTION

After an APU auto shutdown, the APU FUEL TK VLV switch must be taken to CLOSE prior to inhibiting auto shutdown logic. Failure to do so can allow the fuel tank isolation valves to reopen and flow fuel to an APU gas generator bed that is above the temperature limits for safe restart.

APU Speed Control

When the APU turbine speed exceeds the control target (103 percent for NORMAL and 113 percent for HIGH) the appropriate control valve closes. The fuel is then diverted through a bypass line back to the fuel pump inlet. When the turbine speed drops below the control target, the appropriate valve opens directing fuel to the gas generator and closing off the bypass line. The primary fuel valve pulses to maintain APU speed. The frequency and duration of the primary fuel control valve pulses are functions of the hydraulic load on the unit.

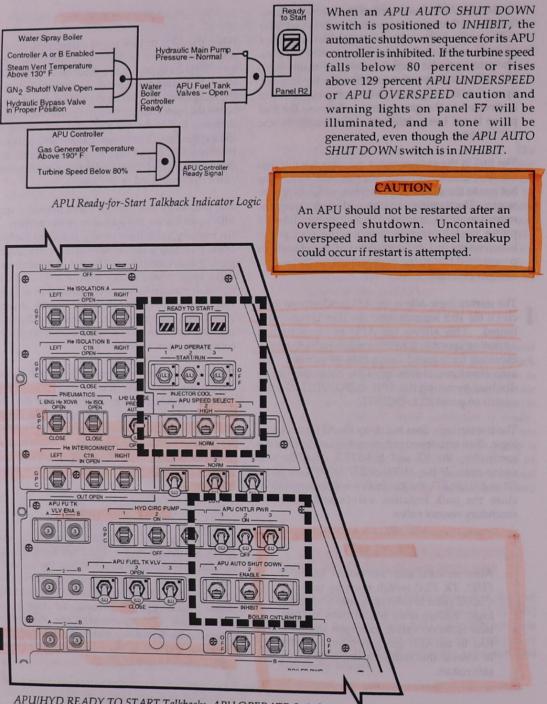
The secondary fuel control valve normally stays fully open during the operation of the primary. If the primary valve loses power, it goes to the fully open position, and the secondary valve begins pulsing and controlling APU speed. If the secondary valve loses power at any time, the APU is shut down. If the auxiliary power unit is taken to a high speed (by the *APU SPEED SELECT* switch on panel R2), the primary valve is unpowered and goes to the fully open position while the secondary valve controls the unit's speed.

Each APU controller controls the speed of each unit upon the activation of the APU SPEED SELECT switch for each APU on panel R2. The NORM position controls the speed at 74,160 rpm, 103 percent, plus or minus 8 percent. The HIGH position controls the speed at 81,360 rpm, 113 percent, plus or minus 8 percent, with a second backup of 82,800 rpm, 115 percent, plus or minus 8 percent.

APU Auto Shutdown

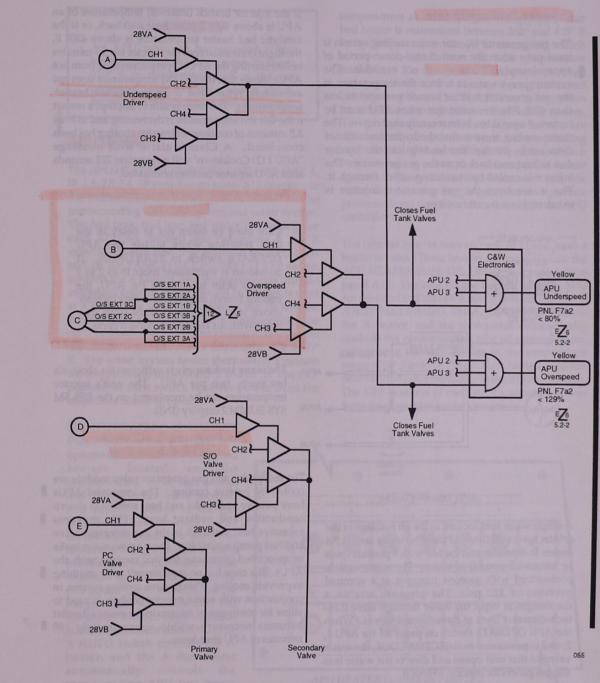
The APU AUTO SHUT DOWN switches on panel R2 enable the automatic shutdown feature in the associated APU controllers. When the switch is positioned to ENABLE, each controller monitors its corresponding APU speed. If that APU speed falls below 57,600 rpm (80 percent) or rises above 92,880 rpm (129 percent), the controller automatically shuts down that unit. Each shutdown command closes that unit's secondary fuel valve and the tank isolation valves.

2. SYSTEMS 2.1 Auxiliary Power Unit/Hydraulics



APU/HYD READY TO START Talkbacks, APU OPERATE Switches, APU SPEED SELECT Switches, APU CNTLR PWR Switches, and APU AUTO SHUT DOWN Switches on Panel R2

SCOM 1.1 July 1992 2.1-8

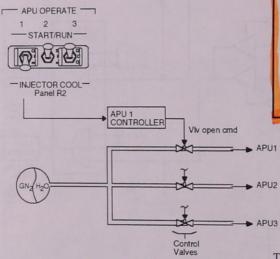


APU Overspeed/Underspeed Detection



Injector Cooling System

The gas generator injector water cooling system is used only when the normal cool-down period of approximately **180 minutes is** not available. The system sprays water to reduce the temperature of the gas generator injector branch passages to less than 400° F in the event that a hot APU must be restarted after it has been recently shut down. The water cooling ensures that the hydrazine will not detonate in the fuel line leading into the injector due to heat soakback from the gas generator. The injector is cooled by circulating water through it. The water from the gas generator injector is exhausted into the aft fuselage.



APU Injector Cooling

A single water tank located in the aft fuselage of the orbiter serves all three APUs. The water tank is 9.4 inches in diameter and loaded with 9 pounds (plus or minus 0.5 pound) of water. The water tank is pressurized with gaseous nitrogen at a nominal pressure of 120 psi. The pressure acts on a diaphragm to expel the water through three 0.25-inch-diameter lines to three control valves. When the *APU OPERATE* switch on panel R2 for APU 1, 2, or 3 is positioned to *INJECTOR COOL*, the water valve of that unit opens and directs the water into the gas generator injector to cool it.

If the injector branch (internal) temperature of an APU is above 400° F from heat soakback, or if the catalytic bed heater temperature is above 430° F, the flight crew must cool the injector for 3.5 minutes before starting the APU. Operational data from hot APUs shows that the GG INJ temperature does not accurately reflect the drop in injector branch temperatures. The crew is safe to attempt a restart if the GG INJ temperature is decreasing and at least 3.5 minutes of continuous injector cooling has been completed. A Class 3 alarm with messsage "APU 1 (2) Cooldown" will annunciate 225 seconds after APU injector cooling is initiated.

CAUTION

Care must be taken not to delay in the *OFF* position when taking the *APU OPERATE* switch to *START/RUN*. If cooldown is terminated more than 2 to 3 seconds prior to starting the APU, the injector branch temperatures may increase above start limits, and detonation may occur without another cooldown cycle.

The water tank supply is sufficient for about six hot starts, two per APU. The unit's injector temperature can be monitored on the BFS SM SYS SUMM 2 display (INJ).

Fuel Pump and Gas Generator Valve Module Cooling

The fuel pump and gas generator valve module are cooled by passive cooling. The improved APUs have passive heat sinks and heat shields to absorb conductive and radiant heat. This prevents excessive heat soakback in the gas generator valve and fuel pump assemblies. There are no water tanks or associated plumbing for this module with the APUs. The crew has no requirement to do anything to provide cooling. This passive cooling system, in conjunction with active injector cooling, is used to allow for contingency restarts in the event a deorbit becomes necessary within approximately 180 minutes of APU shutdown.

CAUTION

An APU may not be restarted if the temperature of the fuel pump is above 210° F or the temperature of the gas generator valve module is above 200° F, because hydrazine detonation may occur.

APU Heaters

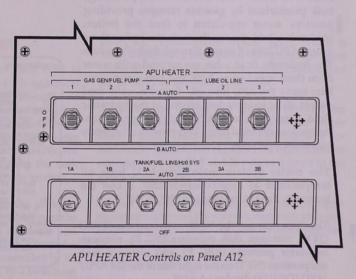
The APUHEATER TANK/FUEL LINE/H2O SYS1A, 1B, 2A, 2B, 3A, 3B switches on panel A12 operate the thermostatically controlled heaters located on the corresponding APU fuel system and water system. The fuel tank, fuel line, and water line heaters for each APU are divided into redundant A and B systems for each unit. For example, for APU 1, 1A and 1B, the TANK/FUEL LINE/H2O SYS 1A switch controls the A heaters, and the thermostats provide automatic control. Only one set of heaters is used at a time. The 1B switch controls the 1B heaters, and the thermostats provide automatic control. The APU fuel tank and line heater thermostats maintain the temperatures between a nominal 55° F and 65° F. The water system heater thermostats maintain the temperatures between 55° F and 65° F. The OFF position of each switch removes power from the respective heater circuits.

The APUHEATER GAS GEN/FUEL

PUMP1, 2, 3 switches on panel A12 operate thermostatically controlled heaters located on the corresponding APU, fuel pump, and gas generator valve module, and provide power to the gas generator bed heater. The thermostats control a series of heaters on the gas generator valve module, fuel pump, and all the fuel lines and the water lines from the fuel pump spray manifold to the gas generator valve module. The heaters are divided into redundant A and B systems for each APU. The A AUTO switch controls the A heater, and the A thermostat automatically controls the corresponding APU fuel pump heater, mintaining fuel pump and gas generator valve module

temperatures at about 100° F. The gas generator bed heater is maintained between 360° and 425° F by a comparator in the APU controller, which receives its signal from the bed temperature transducer. The gas generator temperature range ensures efficient APU startup through efficient catalytic reaction. The B AUTO switch position provides the same capability for the B heater system. The gas generator and fuel pump heaters are automatically deactivated by the corresponding controller at APU start. The OFF position of each switch removes power from the respective heater circuits. These heater switches also provide redundant power to the gas generator and gearbox pressure signal conditioners for use while the APU controller is off.

The lube oil system lines on each APU also have a heater system. These heaters are controlled by the *APU HEATER LUBE OIL LINE 1, 2, 3* switches on panel A12. The lube oil line heaters for each APU are also divided into an A and B system: e.g., for 1, *A AUTO* and *B AUTO*. The *A AUTO* switch controls the A heater, and the thermostat automatically controls the corresponding lube oil system heater, maintaining the lube oil line in the temperature range of 55° F to 65° F. The *B AUTO* switch position provides the same capability to the B heater system. The *OFF* position of each switch removes power from the respective heater circuits.



2.1-11

Water Spray Boilers

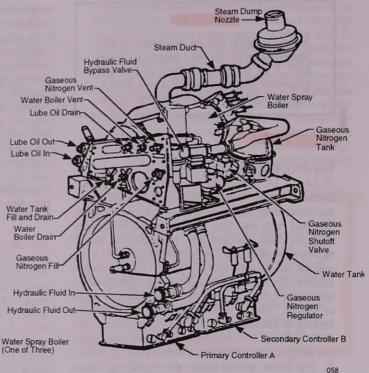
The water spray boiler (WSB) system consists of three identical independent water spray boilers, one for each APU and hydraulic system. The boilers are located in the aft fuselage of the orbiter. Each WSB cools the corresponding APU lube oil system and hydraulic system by spraying water onto their lines; as the water boils off, the lube oil and hydraulic fluid are cooled. The steam that boils off in each water spray boiler exits through its own exhaust duct, located on the starboard side of the vertical stabilizer.

Each WSB is 45 by 31 inches long by 19 inches wide, and including controller and vent nozzle, weighs 181 pounds. They are mounted in the orbiter aft fuselage between X_0 1340 and 1400, at Z_0 488 minus 15, and at Y_0 plus 15. Insulation blankets cover each boiler. The boiler's water capacity is 142 pounds.

Each WSB stores water in a bellows-type storage tank pressurized by gaseous nitrogen providing positive water expulsion to feed the boiler. Hydraulic fluid passes through the boiler twice. The hydraulic fluid tubes are sprayed with water from three water spray bars, and two water spray bars spray the APU lube oil. Separate water feed valves allow independent control of the hydraulic fluid spray bars and APU lube oil spray bars. Redundant electrical controllers provide completely automatic operation.

The boiler system maintains APU lube oil temperature at approximately 250° F and the hydraulic fluid in the range of 210° to 220° F.

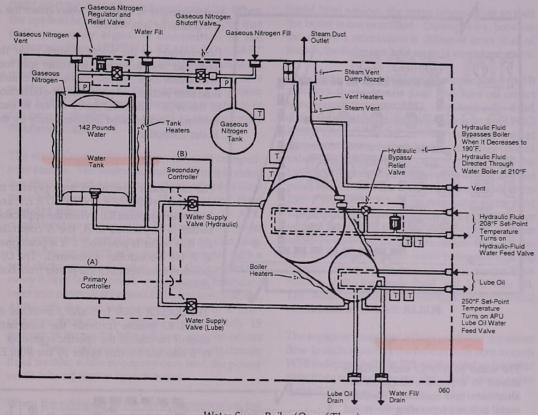
The crew can see the WSB water quantity (H2O QTY), nitrogen tank pressure (N2 P), nitrogen regulator pressure (REG P), and nitrogen tank temperature (N2 T) on the right side of the SM APU/ HYD (DISP 86) display on orbit.



Water Spray Boiler Unit

XXXXXXXXXX	/086		APU/	HYD		XX X DDD/HH:MM:SS DDD/HH:MM:SS			
APU	1	2	3	HYD		1	2	3	
B/U EGT	XXXXS	XXXXS	XXXXS	B/U	P	XXXXS	XXXXS	XXXXS	
EGT	XXXXS	XXXXS	XXXXXS	RSVR	Т	XXXS	XXXS	XXXS	
SPEED %	XXXS	XXXS	XXXS		P	XXXS	XXXS	XXXS	
FUEL QTY	XXXS	XXXS	XXXS	Q	TY	XXXXS	XXXXXS	XXXXS	
TK P	XXXS	XXXS	XXXS	ACCUM	P	XXXS	XXXS	XXXS	
OUTP	XXXS	XXXS	XXXS						
TK VLV A	XXXS	XXXS	XXXS						
AT	XXS	XXS	XXS						
В	XXS	XXS	XXS						
ВТ	XXXS	XXXS	XXXS	W/B		1	2	3	
OIL T	10010	XXXS	XXXS						
T TUO	XXXS	XXXS	XXXS	CNTLR		XXX	XXX	XXX	
OUT P	XXXS	XXXS	XXXS	H20 Q	TY	XXXS	XXXS	XXXS	
GBX P	XXXS	XXXS	XXXS	N2	P	XXXXS	XXXXXS	XXXXS	
N2 P		XXXS	XXXS		т	XXXS	XXXS	XXXS	
BRG T		XXXS	XXXS	REG	Ρ	XXXS	XXXS	XXXS	
GG BED T	XXXS	XXXS	XXXS	BYP V	LV	XXXS	XXXS	XXXS	
PUMP/VLV	1			VENT	T	±XXXS	±XXXS	±XXXS	
PMP T	10010	XXXS	XXXS	TANK	Т	±XXXS	±XXXS	±XXXS	
VLV T	XXXS	XXXS	XXXS	BLR	т	±XXXXS	±XXXS	±XXXS	
								(XX)	

SM APU/HYD Display (DISP 86)



Water Spray Boiler (One of Three)

Nitrogen Supply System

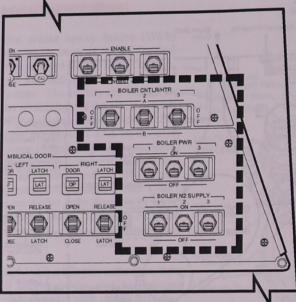
The gaseous nitrogen pressure for each WSB is contained in a corresponding 6-inch spherical pressure vessel. The pressure vessel contains 0.77 pound of nitrogen at a nominal pressure of 2,400 psi at 70° F. The gaseous nitrogen storage system of each WSB is directed to its corresponding water storage tank. Each storage vessel contains sufficient nitrogen gas to expel all the water from the tank and allow for relief valve venting during ascent.

The nitrogen shutoff valve between the pressure valve and water storage tank of each boiler permits the pressure to reach the nitrogen regulator and water tank or isolates the nitrogen supply from the water tank. Each nitrogen valve is controlled by its respective *BOILER N2 SUPPLY 1, 2, or 3* switch on

panel R2. The nitrogen shutoff valve, which is latched open or closed, consists of two independent solenoid coils that permit valve control from either the primary or secondary controller.

A single-stage regulator is installed between the nitrogen pressure shutoff valve and the water storage tank. The gaseous nitrogen regulator for each water spray boiler regulates the high-pressure nitrogen between 24.5 and 26 psig as it flows to the water storage tank.

A relief valve is incorporated inside each nitrogen regulator to prevent the water storage tank pressure from exceeding 33 psig. The gaseous nitrogen relief valve opens between 30 to 33 psig.



BOILER Switches on Panel R2

Water Supply System

The water supply for each boiler is stored in a positive-displacement aluminum tank containing a welded metal bellows separating the stored water inside the bellows from the nitrogen expulsion gas.

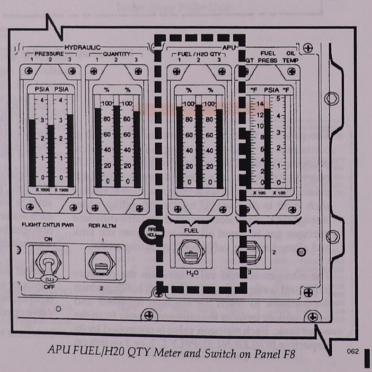
Redundant pressure and temperature sensors located downstream from the gaseous nitrogen pressure vessel and on the water tank for each boiler transmit the pressures and temperatures through each controller to the systems management generalpurpose computer. The computer computes the water tank quantity from the pressure, volume, and temperature, and transmits the water tank quantity to panel F8 for each boiler. The switch below the meter on panel F8 is positioned to H2O to allow the water quantity of each boiler to be displayed on the APU FUEL/H2O QTY 1, 2, or 3 meter. Water quantity is available when either the A or B controller is powered.

Downstream of the water storage tank, the feedwater lines to each water boiler split into two parallel lines: one line goes to the hydraulic fluid flow section and one to the lube oil section of the WSB. The H2O spray valves in each feedline are controlled independently by the boiler controller.

Temperature Control

The two boiler controllers are operated by the respective *BOILER CNTLR/HTR 1, 2,* and 3 switches on panel R2. When the applicable switch is positioned to *A*, the A controller for that boiler is powered; if it is positioned to *B*, the B controller is powered. The *OFF* position removes electrical power from both controllers.

The *BOILER PWR 1, 2,* and 3 switches on panel R2 enable (provide the automatic control functions) the specific controller A or B selected for that boiler by the *BOILER*



CNTLR/HTR 1,2, and 3 switches on panel R2. When the applicable controller A or B is enabled for that boiler, a ready signal is transmitted to the corresponding *APU/HYD READY TO START* indicator on panel R2 if the following additional conditions are met: gaseous nitrogen shutoff valve is open, steam vent nozzle temperature is greater than 130° F, and hydraulic fluid bypass valve is in the correct position with regard to the hydraulic fluid temperature.

The core of each WSB is a stainless steel crimpedtube bundle. The hydraulic fluid section is divided into three 17-inch-long passes of smooth tubes (first pass-234 tubes, second pass-224 tubes, and third pass-214 tubes). The lube oil section of the APU comprises two passes with 103 crimped tubes in its first pass and 81 smooth tubes in the second pass. The tubes are 0.0125 of an inch in diameter with a wall thickness of 0.010 of an inch. Crimps located every 0.24 of an inch break up the internal boundary layer and promote enhanced turbulent heat transfer. Although the second pass is primarily a lowpressure drop return section, approximately 15 percent of the unit's lube oil heat transfer occurs there. Three connected spray bars feed the hydraulic fluid section, while two spray bars feed the power unit's lube oil section in each boiler.

When the orbiter is in the vertical position on the launch pad, each boiler is loaded with up to 3.5 pounds of water, which is referred to as "pool mode" operation. When each APU/hydraulic system and WSB are in operation 5 minutes before lift-off, the APU lube oil tube bundle is immersed in the boiler water precharge. Liquid level sensors in each water boiler prevent the water feed valves from pulsing to avoid water spillage or loss. As the vehicle ascends during launch, the lube oil system of the APU heats up, eventually the boiler water precharge boils off, and the boiler goes into the spray mode about 8 minutes after launch. The hydraulic fluid usually does not heat up enough during ascent to require spray cooling.

When the APU/hydraulic combination is started for atmospheric entry, the hydraulic fluid and power unit lube oil flow commences, fluid temperatures rise, and spraying is initiated as required. During the lower part of entry, when the boiler temperature reaches 188° F, the water spray boiler returns to the pool mode. The spray bars begin discharging excess water to fill the boiler. When the water reaches the liquid level sensors, the spray is turned off so that the boiler is not overfilled. During entry, because the orbiter's orientation is different from that of launch, the boiler can hold up to 14 pounds of water.

The enabled controller of the operating WSB monitors the hydraulic fluid and lube oil outlet temperature from the APU. The hydraulic fluid outlet temperature controls the hydraulic fluid H2O spray control valve, and the lube oil outlet temperature controls the lube oil water spray control valve. Signals are based on a comparison of the hydraulic system fluid temperature to its 208° F set point and of the lube oil of the power unit to its 250° F set point. When the respective water feed valve opens, instantaneous flows of 10 pounds per minute maximum through the hydraulic section and 5 pounds per minute maximum through the lube oil section enter the water boiler through the corresponding spray bars to begin evaporative cooling of the hydraulic fluid and APU lube oil. The steam is vented out through the overboard steam vent.

The separate water feed valves modulate the water flow to each section of the tube bundle core in each WSB independently in 200-millisecond pulses that vary from one pulse every 10 seconds to one pulse every 0.25 of a second.

Because of the unique hydraulic system fluid flows, control valves are located in the hydraulic system fluid line section of each WSB. Normally, hydraulic system fluid flows at up to 21 gallons per minute; however, the hydraulic system experiences 1- to 2second flow spikes at up to 63 gallons per minute. If these spikes were to pass through the boiler, pressure drop would increase ninefold and the boiler would limit the flow of the hydraulic system. To prevent this, a relief function is provided by a spring-loaded poppet valve that opens when the hydraulic fluid pressure drop exceeds 48 psi and is capable of flowing 43 gallons per minute at a differential pressure of 50 psi across the boiler. A temperature controller bypass valve allows the hydraulic fluid to bypass the boiler when the fluid temperature decreases to 190° F. At 210° F, the controller commands the bypass valve to direct the fluid through the boiler. When the hydraulic fluid cools to 190° F, the controller again commands the valve to route the fluid around the boiler. Bypass



valve (BYP VLV) status is available on the following displays: SM SYS SUMM 2 (PASS AND BFS) and PASS DISP 86 APU/HYD.

Heaters

Each water boiler, water tank, and steam vent is equipped with electrical heaters to prevent freezeup in orbit. The water tank and boiler electrical heaters are activated by the corresponding BOILER CNTLR/HTR 1, 2, and 3 switches on panel R2. The A or B position of each switch selects the A or B heater system and is automatically controlled by the corresponding A or B controller. The steam vent heaters are also activated by the BOILER CNTLR/HTR 1, 2 and 3 switches but only if the BOILER PWR 1, 2 or 3 switch on panel R2 is ON. The water tank and boiler heaters are cycled on at 50° F and off at 55° F. The steam vent heaters are not operated continuously in orbit; they are activated approximately two hours before APU startup. The steam vent heaters are cycled on at 150° F and cycled off at 175° F.

Main Hydraulic Pump

The main hydraulic pump for each hydraulic system is a variable displacement type. Each operates at approximately 3,900 rpm when driven by the corresponding APU.

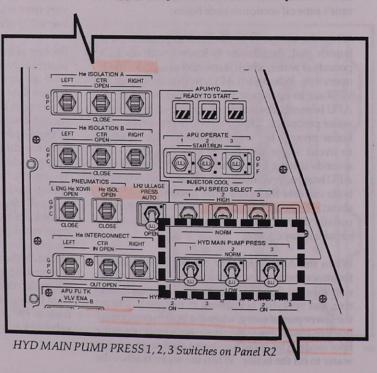
Each main hydraulic pump has an electrically operated depressurization valve. The depressurization valve for each pump is controlled by its corresponding HYD MAIN PUMP PRESS 1, 2, or 3 switch on panel R2. When the switch is positioned to LOW, the depressurization valve is energized to reduce the main hydraulic pump discharge pressure from its nominal range of 2,900 to 3,100 psi output to a nominal range of 500 to 1,000 psi to reduce the APU torque requirements during the start of the APU. "APU Press Low" is one of the inputs required to get a gray *READY* TO START talkback.

NOTE

An APU cannot be successfully started with *HYD MAIN PUMP PRESS* positioned to *NORM*.

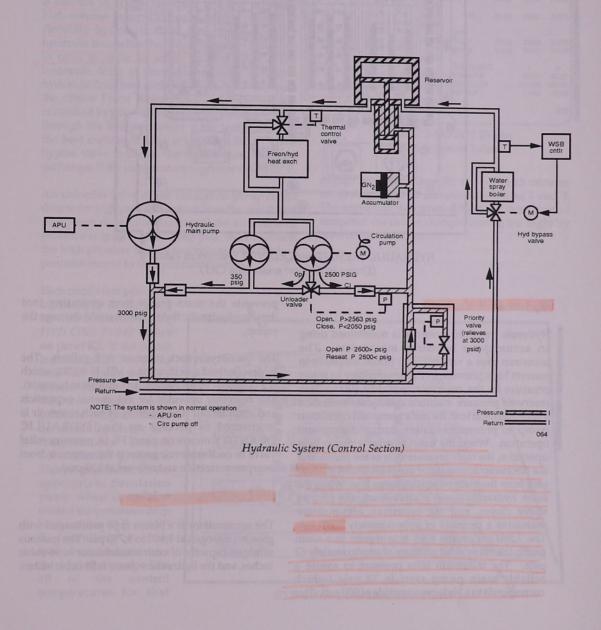
After an APU has been started, the corresponding *HYD MAIN PUMP PRESS* switch is positioned from *LOW* to *NORM*. This de-energizes the respective depressurization valve, allowing that hydraulic pump to increase its outlet pressure from 500 to 1,000 psi to 2,900 to 3,100 psi. Each hydraulic pump is a variable displacement type that provides 0 to 63 gallons per minute at 3,000 psi nominal with the APU at normal speed and 69.6 gallons per minute at 3,000 psi nominal with the APU at high speed.

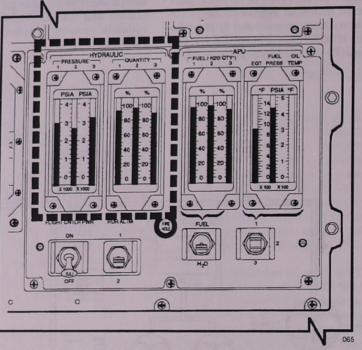
Main pump outlet pressure (HYD PRESS) can be seen by the crew on the BFS SM SYS SUMM 2 or PASS DISP 86 APU/HYD displays. A high-pressure relief valve in the filter module for each hydraulic system also relieves the hydraulic pump supply line pressure into the return line in the event the supply line pressure exceeds 3,850 psid.



A separate pressure sensor (sensor A) in the filter module for each hydraulic system monitors the hydraulic system source pressure and displays the pressure on the HYDRAULIC PRESSURE 1, 2, and 3 meters on panel F8. This hydraulic pressure sensor

also provides an input to the yellow *HYD PRESS* caution and warning light on panel F7 if the hydraulic pressure of system 1, 2, or 3 is below 2,400 psi.





HYDRAULIC PRSSURE and QUANTITY Meters on Panel F8 (Driven by different sensor than CRT)

Hydraulic Reservoir

Hydraulic reservoir pressure is maintained using an accumulator bootstrap mechanism. The bootstrap uses a variable area piston assembly to convert high pressure to the accumulator to lower pressure in the reservoir (roughly 40:1). This reservoir pressure maintains adequate hydraulic inlet pressure at both the main pump and circulation pump to prevent cavitation during startup and operation. When the main hydraulic pump is in operation, the high-pressure side of the piston and the bootstrap accumulator are pressurized to 3,000 psig from the main pump discharge line. When the main hydraulic pump is shut down, the priority valve closes, and the bootstrap accumulator maintains a pressure of approximately 2,500 psi. The 2,500 psi on the high side results in a main pump inlet (low side) pressure of approximately 62 psia. The minimum inlet pressure to assure a reliable main pump start is 20 psia (which corresponds to a high-pressure side of 800 psi). This

prevents the main pump from cavitating (not drawing hydraulic fluid), which could damage the pump.

The quantity in each reservoir is 8 gallons. The hydraulic fluid specification is MIL-H-83282, which is a synthetic hydrocarbon (to reduce fire hazards). The reservoir provides for volumetric expansion and contraction. The quantity of each reservoir is monitored in percent on the HYDRAULIC QUANTITY meters on panel F8. A pressure relief valve in each reservoir protects the reservoir from overpressurization and relieves at 120 psid.

Hydraulic Accumulator

The accumulator is a piston type precharged with gaseous nitrogen at 1,650 to 1,750 psi. The gaseous nitrogen capacity of each accumulator is 96 cubic inches, and the hydraulic volume is 51 cubic inches.

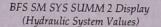
Circulation Pump and Heat Exchanger

The circulation pump is actually two fixeddisplacement gear-type pumps in tandem, driven by a single motor. One is a high pressure, lowvolume pump (2,500 psig), which is used to maintain accumulator pressure while the hydraulic system is inactive in orbit. The other is a low pressure, high-volume pump (350 psig), which is used to circulate hydraulic fluid through the orbiter hydraulic lines while the hydraulic system is inactive in orbit in order to warm up cold spots. The hydraulic fluid is circulated through a Freon/ hydraulic fluid heat exchanger to pick up heat from the orbiter Freon coolant loops. A temperaturecontrolled bypass valve directs the hydraulic fluid through the heat exchanger if the temperature at the heat exchanger inlet is less than 105° F. The bypass valve bypasses the fluid around the heat exchanger if the temperature is greater than 115° F.

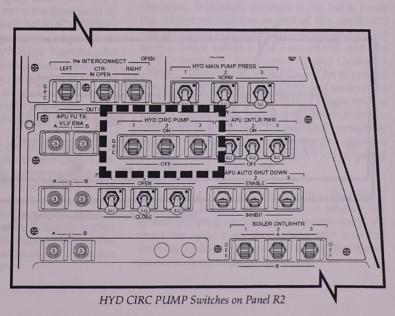
An unloader valve at the circulation pump outlet directs the high pressure output from the circulation pump into the accumulator until the accumulator pressure is greater than 2,563 psia, then redirects the high pressure output to combine with the low pressure output to the hydraulic lines.

Each circulation pump can be manually turned on or off with the corresponding HYD CIRC PUMP switch on panel R2. If the switch is placed in GPC, the pump will be activated and deactivated by the SM GPC according to a control software program based on certain hydraulic line temperatures and/or accumulator pressure. This program activates the appropriate circulation pump when any of the control temperatures drop below either 0° F, or -10° F, depending on their locations, and deactivates the circulation pump when all of the control temperatures for that

XXXXX		/079	SM	I SYS SU	JMM 2	1626		DDD/HH:	
CRYO H2 PRES O2 PRES HTR T1 T2	SS SS)	±XXXS	±XXXS	3 XXXS XXXS X ±XXXS ± ±XXXS ±	XXXS	5 XXXS XXXXS ±XXXS ±XXXS ±XXXS	MANF XXX XXXX	s x	MM:SS NF 2 XXS XXS
APU	and a	1	2	3	H	(D	1	2	3
100000000000000000000000000000000000000	EGT	XXXXXS		XXXXS	PRE	SS	XXXXS	XXXXS	XXXXS
a second second second	EGT	XXXXS	100000	XXXXS	ACU	MP	XXXXS	XXXXXS	XXXXS
	IN	XXXS	XXXS	XXXS	RSV	TF	XXXS	XXXS	XXXS
(TUC	XXXS	XXXS	XXXS	102.00				
	BED	XXXS	XXXS	XXXS	Sere The	QTY	XXXS	XXXS	XXXS
INJ		XXXS	XXXS	XXXS					
SPEED	%	XXS	XXS	XXS	W/	В			
	QTY	XXXS	XXXS	XXXS	H20 0	TY	XXXS	XXXS	XXXS
PMPLK	(P	XXS	XXS	XXS	BYP	VLV	XXXS	XXXS	XXXS
OIL OUT	P	XXXS	XXXS	XXXS	15.03				1584
FU TK	VLV				TH	ERM CN	ΠL	1	2
1000	AT	XXXS	XXXS	XXXS		UMPP		XXXS	xxxs
	ВТ	XXXS	XXXS	XXXS		N FLOW		XXXXS	XXXXS
AV B	AY	1	2	3		OUTT		XXXS	XXXS
TEMP		XXXS	XXXS	XXXS					
FAN AP		X.XXS	X.XXS	X.XXS	1311				(XX)



system are greater than 20° F, or after 15 minutes for system 1 and 10 minutes for systems 2 and 3. The activation/deactivation limits for these control temperatures can be changed during the flight by crew or Mission Control.



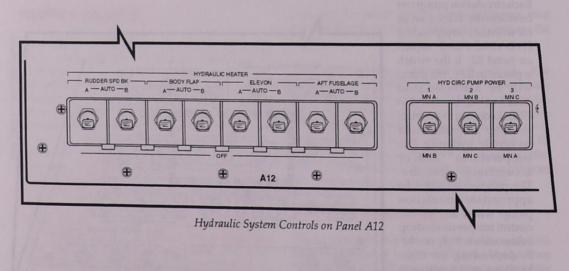
The program also includes a timer to limit the maximum time a circulation pump will run, and a priority system to assure that only one circulation pump is on at a time (because of excessive power usage if more than one circulation pump is on). Each circulation pump uses 2 kW of electrical power. This software will also automatically provide for the repressurization of the hydraulic accumulator when the pressure lowers to a value of 1,960 psi. In this contingency, the circulation pump will first receive the highest priority to operate and will be turned ON while other circulation pumps are operating in thermal mode (this means that two pumps can be operating simultaneously). After the pump has been repressurized, the accumulator above 1,960 psi, or a period of 2 minutes (this value can be changed by Mission Control Center uplink) has elapsed, the circulation pump will be commanded to OFF. It is possible to run all three circulation pumps at the same time to repressurize accumulators.

The circulation pump is automatically disconnected when its corresponding APU Run command is issued by the APU controller. Each circulation pump can be powered by one of two orbiter main electrical buses, selectable by the HYD CIRC PUMP POWER switches on panel A12. The crew can see circulation pump outlet pressure as well as the hydraulic line and component temperatures on the PASS SM HYD THERMAL display, DISP 87.

XXXXXXXXXX	087	н	D THEF	RMAL		XX X DDD/HH:MM:SS DDD/HH:MM:SS			
					CIRC	PUMP	CON	TROL	
HYD	1	2	3	LINET	EMPS	1 1	2	3	
CIRC PUMP P	XXXS			ELEVON			XXXS		
PMP BDY T	±XXXS	±XXXS	±XXXS	Carl Charles	LIB	±XXXXS			
RSVR T	±XXXS	±XXXS	±XXXS	1.15.10	RIB	±XXXXS			
ACCUM P	±XXXS	±XXXS	±XXXS		ROB	±XXXXS			
HX IN T	±XXXS	±XXXS		RD/SB					
OUT T	±XXXS	±XXXS	±XXXS	and the second second	FUS	±XXXS	±XXXS	±XXXS	
and the second		100000	1000	BDYFLP	PDU	±XXXS	±XXXS		
SW VLV	PR	S1	S2		FUS	±XXXS			
ELEV L OB	3XS	1XS	2XS	L BRAKE	WHL		±XXXS		
IB	2XS	1XS	3XS		FUS		±XXXS		
R IB	3XS	1XS	2XS	RBRAKE	WHL	±XXXS	±XXXS	±XXXS	
OB	2XS	1XS	3XS		FUS	±XXXXS	±XXXXS	±XXXS	
RUD/SPDBK	1XS	2XS	3XS	NG	UPLK	±XXXS			
				M	FUS 1	±XXXS			
TIRE PRESS			192111	M	FUS 2	±XXXS			
MG LEFT		RIGHT		MG L	UPLK	±XXXXS			
IB XXXS X	xxs x	xxs xx	CXS	MG R	UPLK	±XXXXS			
OB XXXS X	xxs x	xxs x	cxs .		FUS	±XXXS			
NG XXXS X	xxs x	xxs x	cxs					(XX)	

SM HYD THERMAL Display (DISP 87)

The SM APU/HYD display (DISP 86) shows the hydraulic system pressure, reservoir temperature, reservoir quantity (in percent), and hydraulic accumulator pressure.



Hydraulic Heaters

Areas of the hydraulic lines that cannot be warmed by fluid circulation while the system is inactive onorbit are warmed by heaters. These heaters are automatically controlled by thermostats to maintain the hydraulic line temperatures in a specified range. Each heated area has redundant heaters (A and B), which are controlled by the *HYDRAULIC HEATER* switches on panel A12.

Operations

The WSB controllers are powered up at launch minus 8 hours, and the boiler water tanks are pressurized in preparation for APU activation. The controllers activate heaters on the water tank, boiler, and steam vent to assure that the water spray boiler is ready to operate for launch.

APU start is delayed as long as possible to save fuel. At T minus 6 minutes 15 seconds, the pilot begins the prestart sequence. The pilot confirms that the WSB is activated, then activates the APU controllers and depressurizes the main hydraulic pump. Depressurizing the main pump reduces the starting torque on the APU. The pilot then opens the fuel tank valves and looks for three APU ready-to-start indications (gray talkbacks). At T minus 5 minutes, the pilot starts the three units by setting the APU OPERATE switches to START/RUN and checks the hydraulic pressure gauges for an indication of approximately 800 psi. Then the pilot pressurizes the main pump and looks for approximately 3,000 psi on the gauges. All three hydraulic main pump pressures must be greater than 2,800 psi by T minus 4 minutes, or the automatic launch sequencer will abort the launch.

The APUs operate during the ascent phase and continue to operate through the first OMS burn. At the conclusion of the main engine purge, dump, and stow sequence, the APUs and WSBs are shut down. The same sequence applies for a delayed OMS-1 burn. If an abort once around is declared, the APUs are left running, but the hydraulic pumps are depressurized to reduce fuel consumption. The units are left running to avoid having to restart hot APUs for deorbit and re-entry. Six hours after liftoff, or as soon as they are required, depending on the environment, the gas generator / fuel pump heaters are activated and are in operation for the remainder of the orbital mission. The fuel and water line heaters are activated immediately after APU/HYD SHUTDN in the post OMS-1 timeframe to prevent the lines from freezing as the APUs cool down.

Two hours after liftoff, the steam vent heaters of the WSBs are turned on and left on for about 1.5 hours to eliminate all ice from the steam vents.

Two hours and twenty minutes into the flight, while in the Post Insertion Checklist, the hydraulic thermal conditioning is enabled by taking the hydraulic circulation pumps to GPC. Further, the HYD CIRC PUMP POWER switch(es) on panel A12 will be configured to distribute electrical loads when appropriate.

While the vehicle is in orbit, the hydraulic circulation pumps are in the GPC mode—automatically activated when hydraulic line temperatures become too low and automatically deactivated when the lines warm up sufficiently.

On the day before deorbit, one APU is started to supply hydraulic pressure for flight control system checkout. (Hydraulic pressure is needed to move the orbiter aerosurfaces as part of this checkout.) The associated WSB controller is activated, landing gear isolation valves 2 and 3 are closed, and one APU (selected by the Mission Control Center) is started. The hydraulic main pump is set to normal pressure (approximately 3,000 psi), and aerosurface drive checks are made. After about 5 minutes, the checks are complete, and the APU is shut down. Normally, the unit does not run long enough to require WSB operation. The landing gear isolation valves on hydraulic systems 2 and 3 are reopened after the APU is shut down.

At 2.5 hours before the deorbit burn, the boilers' steam vent heaters are activated to prepare the system for operation during atmospheric entry. At about the same time, the landing gear isolation valves on hydraulic systems 2 and 3 are closed, and the circulation pumps are turned off.

At 45 minutes before deorbit, the WSB water tanks are pressurized, the APU controllers are activated. and the main hydraulic pumps are set to low pressure. The pilot opens the fuel tank valves and looks for three gray APU/HYD READY TO START talkbacks. The pilot then closes the fuel tank valves. This procedure takes place while the crew is in contact with the ground so that flight controllers can observe APU status. Five minutes before the deorbit burn, one APU (selected by Mission Control) is started to ensure that at least one unit will be operating for entry. The hydraulic pump is left in low-pressure operation. The APU operates through the deorbit burn. At 13 minutes before entry interface (400,000-foot altitude), while the orbiter is still in free fall, the other two APUs are started, and all three hydraulic pumps are pressurized to normal. Two main engine hydraulic isolation valves are cycled open and then closed to ensure

At 24 hours become 2, 5, 221 hours, its 5 hours stand very last to and are inited to proper the second of a performance and a mospheric outre. A sheat the same more that is an any hour schedule. Values on hole asks average and have been and an arrest from pion resum innext off that the engines are stowed for entry. Two minutes later, if required, the aerosurfaces are put through an automatic cycle sequence to make sure warm hydraulic fluid is available in the aerosurface drive units.

After touchdown, a hydraulic load test may be done to test the response of the auxiliary power units and hydraulic pumps under high load (i.e., high flow demand) conditions. This test cycles the orbiter aerosurfaces with one hydraulic system at a time in depressed mode (the remaining two APUs and hydraulic pumps have to drive all the aerosurfaces). This is typically done on the first flight of a new vehicle. Then the main engine hydraulic isolation valves are opened again, and the engines are set to the transport position. At this point, the hydraulic systems are no longer needed; the APUs and WSBs are shut down.

Fiber and the Well interference, the many parts are 470 sectors for the well of the sector parts and the sector parts are set of the sector parts and the sector parts are set of the set of the sector parts are set of the set of the sector parts are set of the sector parts are set of the sector parts are set of the set of the sector parts are set of the set of the sector parts are set of the se

The AC User or the second second of the second place and continue to opposite through the metric OVS burn At the conclustion of the continuous second second and abow sequence ets Ar Us and Visba are sho observed by a second second second to defend the APUs are left running, but the potentific compotion are depresented to reduce tracic analogical for units are left running to avoid having to restantific that the APUs are left running to avoid having to restantific

APU/HYD Caution and Warning Summary

- The yellow APU TEMP caution and warning light on panel F7 is illuminated if the APU 1, 2, or 3 lube oil temperature is above 290° F.
- The yellow APU OVERSPEED light is illuminated if APU 1, 2, or 3 turbine speed is more than 92,880 rpm (129%). If the APU AUTO SHUT DOWN switch on panel R2 is in ENABLE, an automatic shutdown of that APU will occur.
- The yellow APU UNDERSPEED light is illuminated if APU 1, 2, or 3 turbine speed is less than 57,600 rpm (80%). If the APU AUTO SHUT DOWN switch for that APU is in ENABLE, an automatic shutdown will occur.
- Placing the APU AUTO SHUT DOWN switch in INHIBIT only inhibits the automatic shutdown of that APU if its turbine speed is less than 80% or more than 129%. The APU UNDERSPEED or APU OVERSPEED light will always illuminate, and a tone will be generated.
- The yellow HYD PRESS light illuminates when hydraulic system 1, 2, or 3 drops below 2,400 psi for any reason.
- The blue *SM ALERT* illuminates, and the C/W tone is sounded if turbine speed falls below 80% or rises above 129%.
- The red BACKUP C/W ALARM illuminates if hydraulic pressure of system 1, 2, or 3 drops below 2,400 psi.

CABIN ATM (R) O2 HEATER TEMP MAIN BUS UNDERVOLT AC AC FREON LOOP AV BAY/ CABIN AIR IMU FWD RCS RCS JET H20 LOOP RGA/ACCEL AIR DATA LEFT RCS RIGHT RCS	
H20 LOOP RGA/ACCEL AIR DATA LEFT RCS RIGHT RCS	
H20 LOOP RGA/ACCEL AIR DATA LEFT RCS RIGHT RCS	
LEFT RHC (R) RIGHT/AFT LEFT OMS (R) RIGHT OMS	1
PAYLOAD WARNING (R) GPC SATURATION OMS KIT OMS TVC (0
PAYLOAD PRIMARY C/W FCS MPS (R)	
BACKUP C/W APU APU APU APU APU HYD PRESS	

atte hot sectory intector

14 all all the sprage batter ecology is toot to the halo oil after an APU reaches full operating compensatives, only 2 to 3 minutes of operating (inverses available before bearing secture)



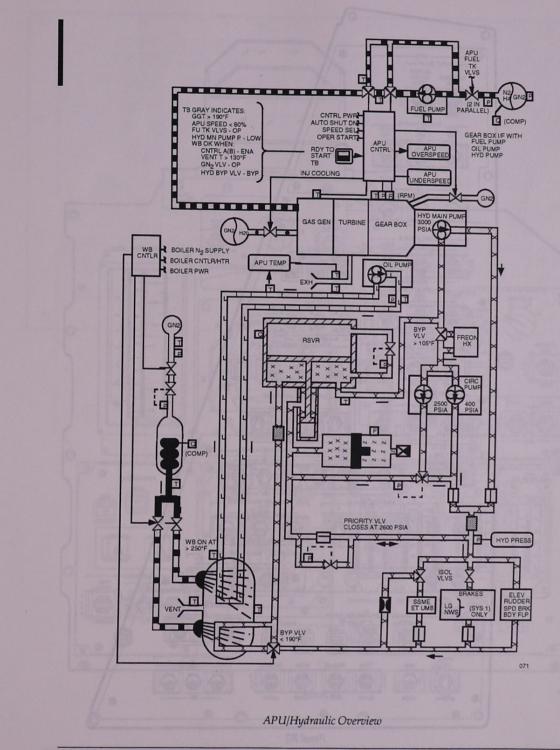
APU/HYD Summary Data

- The APU is a hydrazine-fueled, turbine-driven power unit that generates mechanical shaft power to drive a hydraulic pump that produces pressure for the orbiter's hydraulic system.
- The three orbiter hydraulic systems provide pressure to position hydraulic actuators for: gimbaling SSMEs, actuating SSME control valves, moving orbiter aerosurfaces, retracting ET disconnect umbilicals, deploying landing gear, and providing brake power, anti-skid, and nose wheel steering.
- The APUs are located in the aft fuselage of the orbiter.
- Each APU/HYD system has an independent water spray boiler for APU lube oil and hydraulic fluid cooling. Water is used after APU shutdown for injector cooling if a hot restart is required. The APUs share a central supply tank for injector cooling.

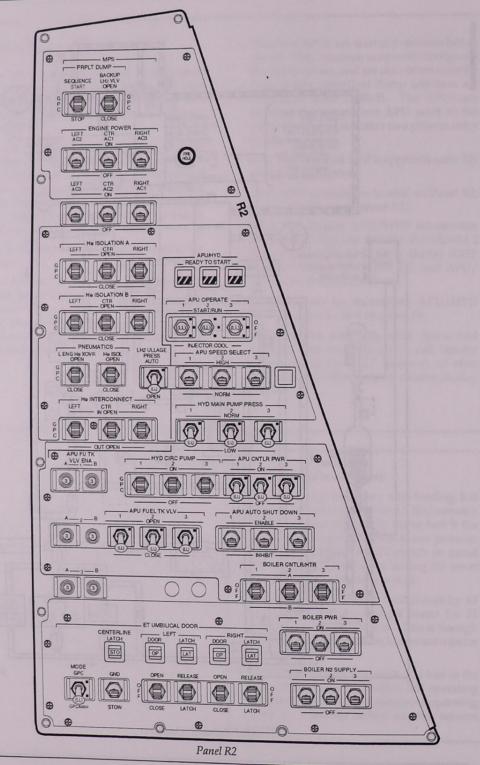
- The three APUs are started 5 minutes before lift-off. They continue to operate throughout the launch phase, and are shut down after the main engine propellant dump and stow are completed (post OMS-1). The APUs are restarted for entry: one APU prior to the deorbit burn, and the other two prior to entry interface.
- Each APU fuel tank load is approximately 325 pounds of hydrazine.
- APU/HYD controls are located on Panel R2; heater controls are on panel A12.
- CRTs that display APU/HYD information include the PASS and BFS SM SYS SUMM 2 display (DISP 79), APU/HYD display (DISP 86), HYD THERMAL (DISP 87), and APU/ ENVIRON THERM (DISP 88).
- Several meters for monitoring APU/HYD parameters are located on panel F8.
- APUs can be manually shut down and restarted after completion of a full injector water cooling cycle (3.5 minutes), or after approximately 180 minutes of passive cooling on orbit.

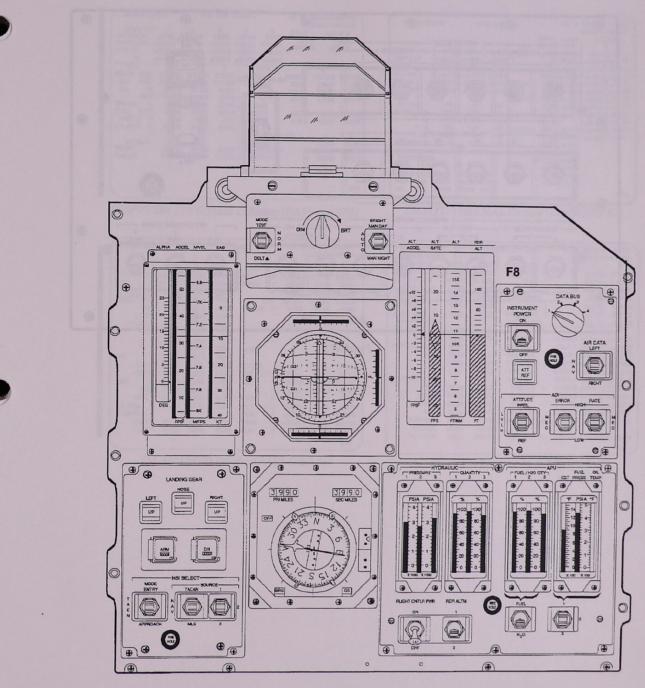
APU/HYD Rules of Thumb

- APU fuel usage rates vary with loading, but average 1% per minute (3 to 3.5 lbs/minute). Usage rates are reduced by about half if the hydraulic main pump is taken to low pressure (HYD MAIN PUMP PRESS switch on panel R2 set to LOW), as is done during the abort once around deorbit coast period.
- The APU injector cooling tank shared by all three APUs contains enough water for 21 minutes of continuous flow. This is enough for six complete 3.5-minute hot restart injector cooling cycles.
- If all water spray boiler cooling is lost to the lube oil after an APU reaches full operating temperatures, only 2 to 3 minutes of operating time are available before bearing seizure occurs.



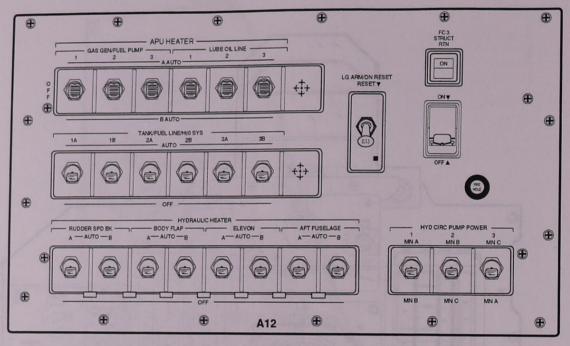




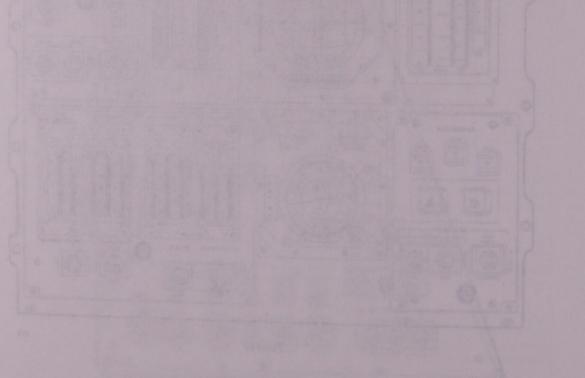


Panel F8

073



Panel A12



SCOM 1.1 July 1992

			M SYS S	UMM 2	xx x	DDD/HH:	MM:SS	1
HTR T1 T2	XXXXS XXXXXS ±XXXXS ±XXXXS	XXXXS XXXXXS ±XXXXS ±XXXXS	±XXXS :	XXXS XXXS XXXS XXXXS XXXXS ±XXXS	MANF XXX XXXX	DDD/HH: 1 MA S X S XX	NE 2	
APU	1	2	3	HYD		2	3	1. A
EMP EG	XXXXS	XXXXXS	XXXXS	PRESS	XXXXXS	XXXXS	mms	
B/U EG	XXXXS	XXXXXS	XXXXXS	RSVR T	XXXXS	XXXS	XXXS	1000
OIL IN		XXXS	XXXS	P	YYYC	XXXS		
OUT	XXXXS	XXXS	XXXS	QTY		XXXS		
PEED %	> XXXS	XXXXS	XXXS	W/B		10010	~~~~	
UEL QT	XXXXS	XXXS	XXXS	H20 QTY	XXXS	XXXS	xxxs	1000
PMPLK P	XXS XXXS	XXS	XXS XXXS	BYPVLV	XXXS	XXXXS		
			10010	THERMO	NTI	1	2	1
AV BAY				HOO DUMAD D		10010	10010	
EMP	XXXS	XXXS	XXXS	EREON ELOIA	1	MANA	100010	1000
ANAP	X.XXS	XXXS	X.XXS	EVAP OUT T		XXXS	XXXS	
							10010	
							1000	1000
							000	

XXXXXXXXXXX	87	HY	D THER	MAL			DDD/HH DDD/HH	
					CIRC		COL	
HYD	1	2	3	LINET	EMPO	-	2	3
CIRC PUMP P	XXXS	XXXS	XXXS	FLEVON	LOP	ma	xxxs	
PMP BDY T	±XXXS	±XXXS	±XXXS		LIB	+YYYS	±XXXS	
RSVR T	±XXXS	±XXXS	±XXXS	LLLVON	PID	+YYYO	±XXXXS	
ACCOM M	±XXXS	±XXXS	+0005	1	ROB		±XXXS	
HX IN T	±XXXS	±XXXS	+XXXS	RD/SB	PDU	EAAAS	±XXXS	TANAS
OUT T	±XXXS	±XXXS	+XXXS	NU/3B	FUO	TAXAS	±XXXS	ELLAS
SW VLV	PR	S1	S2	BDYFLP				
	3XS	1XS	2XS			±XXXS		
IB		1XS	3XS	L BRAKE			±XXXS	
		1XS	Same and		FUS			±XXXS
	2XS	1XS		RBRAKE			±XXXS	
	1XS		3XS			±XXXS	±XXXS	±XXXS
HOUSPUBK	IAS	2XS	3XS			±XXXS		
TIPE PORCO						±XXXS		
TIRE PRESS			25.25			±XXXS		
MG LEFT		RIGHT		MGL	UPLK	±XXXS		
			XXS	MG R				
		DOXS X	xxs			±XXXS		
NG XXXXS X	XXS X	oxs x	xxs					
-								(XXX)

DISP 79 SM SYS SUMM 2 Display (PASS and BFS)

F

x	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX					XX X DDD/HH:MM:S DDD/HH:MM:S			
A	PU	1	2	3	HY	D	1	2	3
B/U		XXXXXS	XXXXXS	XXXXS	B/U	P	xxxxs		XXXXXX
EGT		XXXXXS	XXXXXS	XXXXS	RSVR	Т	XXXS	XXXS	XXXXS
SPE		XXXS	XXXS	XXXS		P	XXXS	XXXS	XXXXS
FUE	L QTY	XXXS	XXXS	XXXS		QTY	XXXXXS	XXXXXS	XXXXXS
	TKP	XXXS	XXXS	XXXS	ACCL	M P	XXXS	XXXS	XXXXS
	OUTP	XXXS	XXXS	XXXS				10010	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Т	KVLVA	XXXS	XXXS	XXXXS					
	AT	XXS	XXS	XXS					
	В	XXS	XXS	XXS					
	ВТ	XXXS	XXXS	XXXS	W/B		1	2	3
OIL	т	XXXXS	XXXS	XXXS				01 0	
	OUTT	XXXXS	XXXS	XXXS	CNTL	R	XXX	XXX	XXX
	OUTP	XXXXS	XXXXS	XXXS	H20	QTY	XXXS	XXXS	XXXS
GBX	P	XXXS	XXXS	XXXS	N2	P	XXXXXS	XXXXXS	XXXXXX
	N2 P	XXXXS	XXXS	XXXS		т	XXXS	XXXS	XXXS
	BRG T	XXXXS	XXXS	XXXS	REG	P	XXXS	XXXXS	XXXXS
GGE	BED T	XXXS	XXXS	XXXS	BYP	VLV	XXXS	XXXS	XXXS
PUM	P/VLV				VENT	Т	±XXXS	±XXXS	±XXXS
	PMPT	XXXS	XXXS	XXXS	TANK	Ť	±XXXS	±XXXS	±XXXS
	VLV T	XXXS	XXXS	XXXS	BLR	Ť	±XXXS	±XXXS	±XXXXS
								20010	
-									(XXX)

SM APU/HYD Display (PASS DISP 86)

SM HYD THERMAL Display (PASS DISP 87)

FREON LOO	88 P 1	APU/EN	VIRON THERM	XX X DDD/HH:MM:SS
ACCUM QTY	xxxs	Z		DDD/HH:MM:SS
FREON FLOW	and the state of the state of the	XXXS	H2O LOOP	1 2
PL HX FLOW	XXXXXX	XXXXXS	PUMP OUT P	XXXXXS XXXXXS
	XXXXXS	XXXXXS	T TUO	XXXXXS XXXXXS
AFT CP FLOW	XXXS	XXXS	ΔP	XXXXXXX XXXXXXXX
RADIN T	XXXXS	XXXS	ICH FLOW	XXXXXS XXXXXS
RAD OUT T	XXXXS	XXXS	OUT T	XXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
EVAP OUT T	XXXS	XXXS	CAB HX IN T	XXXXXS XXXXXS
EVAP TEMP			ACCUMOTY	XXXXXS XXXXXS
HI LOAD INBD	XXXS		APU FUEL	1 2 3
OUTBD	XXXS	XXXS	TK SURF	±XXXXXS ±XXXXXS ±XXXXXS
TOPPING FWD	XXXS		TK HTR	±XXXXXS ±XXXXXS ±XXXXXS
AFT	XXXXS		TEST LN 1	±XXXXXS ±XXXXXS ±XXXXXS
L	XXXXS	XXXS	TEST LN 2	±XXXXXS ±XXXXXS ±XXXXXXS
R	XXXXS	XXXS	FEEDLN	±XXXXXS ±XXXXXS ±XXXXXS
EVAP FDLN T	A	В	PUMPIN	±XXXXXS ±XXXXS ±XXXXXS
FWD	XXXS	XXXS	DRN LN 1	±XXXXXS ±XXXXS ±XXXXXS
MID 1	XXXS	XXXXS	DRN LN 2	±XXXXXS ±XXXXS ±XXXXXS
MID 2	XXXXS	XXXXS	OUT	±XXXXXS ±XXXXXS ±XXXXXS
AFT	XXXS	XXXXS	BYPIN	±XXXXS ±XXXXS ±XXXXS
TOPPING	XXXXS	XXXXS	GG SPLY LN	
ACCUM	XXXXS	XXXS	GOSPLY LN	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
HILOAD	XXXXS	XXXXS	-	
TH LOAD	s	ALLS	H2O LN INJ	±XXXXXS ±XXXXXS ±XXXXXS
				(XXX)

APU/ENVIRON THERM (PASS DISP 88)

2.1-29

2.2 CAUTION AND WARNING SYSTEM (C/W)

Contents	
Description	2.2-1
Alarms	2.2-2
Smoke Detection and Fire	
Suppression	2.2-5
Rapid Cabin Depressurization	2.2-10
Operations	2.2-11
SPEC 60, SM Table Maintenance	2.2-14
F7 Light Summary	2.2-20
Fault Message Summary	2.2-23

Description

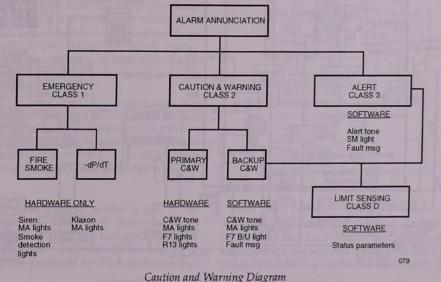
The caution and warning system warns the crew of conditions that may create a hazard to orbiter operation and/or crew. Under certain circumstances, the system also alerts the crew to situations that require time-critical (under 5 minutes) procedures to correct them. The system uses data such as temperature, pressure, flow rates, and switch positions to determine whether an alarm situation exists.

The system consists of software and electronics that provide the crew with visual and aural cues when a system exceeds predefined operating limits. Visual cues consist of four red *MASTER ALARM* lights, a 40-light array on panel F7, a 120-light array on panel R13U, and CRT messages. The aural cue is sent to the communications system for distribution to flight crew headsets or speaker boxes.

The crew interfaces with the C/W system through panel R13U, panel C3, CRT displays, panel F7, panel L1, and the four red *MASTER ALARM* push button indicators on panels F2, F4, A7, and MO52J.

The C/W system interfaces with the auxiliary power units, data processing system, environmental control and life support system, electrical power system, flight control system, guidance and navigation, hydraulics, main propulsion system, reaction control system, orbital maneuvering system, and payloads.

Inputs enter the software C/W logic circuitry from the onboard computers through multiplexers/ demultiplexers (MDMs) to activate alarm tones and the BACKUP C/WALARM. Some of these are used to turn on the BACKUP C/WALARM light on panel F7 while crew input resets the MASTER ALARM lights and tones.





Alarms

Four alarm classes constitute the C/W system.

Class 1 - Emergency

There are two alarms in this class: (1) smoke detection/fire suppression and (2) rapid cabin depressurization. (These systems are discussed in more detail later in this section.) Class 1 is a hard ware system only; its input is not processed by any MDMs or software. The system uses hardware, such as hard-wired sensors, to monitor parameters and to issue alarms. Because of the nature of the class 1 alarms, they always receive the highest priority for resolution.

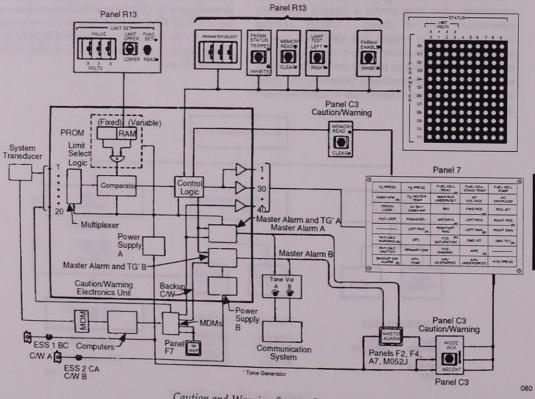
The emergency (class 1) aural alarms consist of a siren (activated by the smoke detection system) and a klaxon (activated by the delta pressure/delta time sensor that recognizes a rapid loss of cabin pressure), and they are annunciated by hardware. The siren's frequency varies from 666 to 1,470 hertz and returns

at a five-second-per-cycle rate. The klaxon is a 2,500hertz signal with an on/off cycle of 2.1 milliseconds on and 1.6 milliseconds off, mixed with a 270-hertz signal with a cycle of 215 milliseconds on and 70 milliseconds off.

The emergency alarm visual cues consist of illumination of the four *MASTER ALARM* pushbutton indicators on panels F2, F4, A7, and MO52J. The smoke detection system also illuminates *SMOKE DETECTION* lights on panel L1, displays information on the SM SYS SUMM 1 display (SMOKE), and issues a backup C/W "smoke alarm" message. Similarly, cabin pressure information can be seen on the SM SYS SUMM 1 display (CABIN).

Class 2 - C/W

This class also consists of two subclasses: primary C/W, which is a hardware system, and backup (B/U) C/W, which is a software system.



Caution and Warning System Overview

2.2-2

The primary C/W system has the capacity to monitor 120 inputs, which are received from transducers through either signal conditioners or flight forward MDMs. Baselined limit values are stored in the C/W electronics unit located in avionics bay 3. These values can be changed by the crew, after the parameters' engineering units are converted to a standard voltage value, through switches on panel R13U; however, if power is lost, the limits will return to their original values. The majority of the original stored values are identical to the backup C/W (software) values. Thirty-nine lights on the panel F7 annunciator matrix are dedicated to the primary C/W; the exception is the *BACKUP C/W ALARM*.

When a primary C/W alarm is issued, the appropriate lamp on the panel F7 annunciator matrix is illuminated, all four *MASTER ALARM* indicators are illuminated, the C/W tone sounds, and the appropriate lamp on the panel R13U parameter status light matrix is illuminated. No CRT fault message is generated by the primary C/W.

The primary C/W system receives power from power supply A from the C/W A circuit breaker powered by ESS 1BC on panel O13, and power supply B from C/W B circuit breaker powered by ESS 2CA on panel O13.

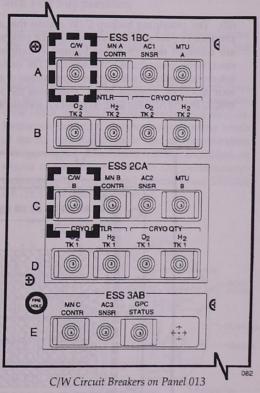
A loss of power supply A will cause all panel F7 lights except *BACKUP C/W ALARM* to illuminate. It will also cause a loss of panel R13U status lights and function, smoke detection via circuit test A, the *CAUTION/WARNING MEMORY READ* switch, lower bulbs of the *MASTER ALARM* light (except for lamp test), primary C/W limit sensing, and tones to the middeck.

A loss of power supply B causes the *BACKUP C/W ALARM* light to come on in addition to the primary *C/W* light, a loss of smoke detection via circuit test B, upper bulbs of the *MASTER ALARM* lights (except during a lamp test), and sleep station headset tones.

The backup C/W (class 2) system is part of the systems management fault detection and annunciation (FDA), GNC, and backup flight system software programs. Only the 69 backup C/W alarms that are produced by FDA (software that

		and the second second		A CONTRACTOR
O2 PRESS	H2 PRESS	FUEL CELL REAC	FUEL CELL STACK TEMP	FUEL CELL PUMP
	02 HEATER TEMP	MAIN BUS UNDERVOLT	AC VOLTAGE	AC OVERLOAD
FREON LOOP	AV BAY/ CABIN AIR	MU	FWD RCS	RCS JET
H20 LOOP	RGA/ACCEL	AIR DATA	LEFT RCS	RIGHT RCS
	LEFT RHC	RIGHT/AFT RHC	LEFT OMS	RIGHT OMS
PAYLOAD WARNING (F)	GPC	FCS (R) SATURATION	OMS KIT	OMS TVC
PAYLOAD CAUTION	PRIMARY C/W	FCS CHANNEL	MPS (P)	Part 101
BACKUP C.W ALARM	APU TEMP	APU OVERSPEED	APU	HYD PRESS
TE TE	TEMP	OVERSPEED	UNDERSPEED	

Caution and Warning Annunciator Matrix on Panel F7 (The 39 lights shown are dedicated to the primary C/W system. The BACKUP C/W ALARM light is dedicated to the entire backup C/W system. (R) sigmifies a red warning light. Red lights take precedence over yellow.)



monitors parameters and initiates alarms) have limits that can be changed and displayed in engineering units accessed through the SM TABLE MAINTENANCE specialist function display (SPEC * Channel not used

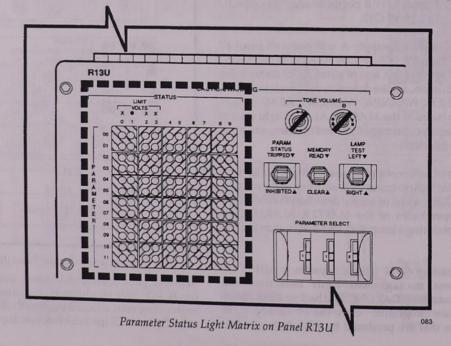
COM/	PARAMETER	T C/W	PARAMETER	T C/W	PARAMETER	C/W	PARAMETER	CNV	PARAMETER
C/W CH	NAME	CH	NAME	CH	NAME	CH	NAME	CH	NAME
	CRYO O2 P TK1	25		50	CRYO H2 P TK1	•75		100	
0	CRYO O2 HTR1 TK1	26		51	CRYO O2 HTR 2 TK3	76	RCS TK P FU- R	101	
1	FC1 REAC O2	27	OMS ENG - L	52	FC3 REAC H2	•77	and have and	102	
2	DC VOLT MAIN A	28		53	AC3 VOLT (\$A, B, C)	78		103	
3	CAB PRESS	20	MPS HE TK P - R	54	CAB N2 FLOW 1	79		104	
4	GPC 1	30	CRYO O2 P TK 4/5	*55		80	CRYO H2 P TK 4/5	105	
0	RCS TK P OX - F	31	CRYO O2 HTR 2 TK2	56	RCS LEAK/TK P - L	*81	And the second of the second	106	
07	OMS TK POX-L	32	FC2 REAC H2	57	OMS ENG - R	82	FC3 STACK T	107	
6	APU 1 EGT	33	AC1 VOLT (AA, B, C)	58	APU 3 OIL T	83		108	
°.	MPS HE TK P - C	34	CAB PPO2 A	59	MPS HE REG P - R	84	AV BAY 1 TEMP	109	
10	CRYO O2 P TK2	35	GPC 4	60	CRYO H2 P TK2	*85		110	
11	CRYO O2 HTR 2 TK1	36	RCS TK P OX - L	61	CRYO O2 HTR 1 TK4	86	RCS LEAK/TK P - R	111	FCS CH BYPASS
12	FC1 REAC H2	37	OMS TK POX - R	62	FC1 STACK T	*87	I want a support of the second	112	FC3 COOL PUMP
	DC VOLT MAIN B	38	APU 1 OIL T	63	AC1 OVLD	88	APU 3 OVERSPEED	*113	
14	CAB O2 FLOW 1		MPS HE REG P - C	64	CAB N2 FLOW 2	*89	Conceptions Party of the		CAB HX OUT T
15	GPC 2	*40		*65		•90			H2O LOOP 2 PUMP OUT P
	RCS TK P FU - F		CRYO O2 HTR 1 TK3	66	RCS TK P OX - R	91			FREON LOOP 2 FREON FLOW
	OMS TK P FU - L		FC3 REAC O2	67	OMS TVC	92			FREON LOOP 2 EVAP OUT T
	APU 2 EGT	43	AC2 VOLT (&A, B, C)	68	APU 1 OVERSPEED	93			APU 3 UNDERSPEED
	MPS HE TK P - L		CAB PPO2 B	69	MPS MANF PL O2		AV BAY 2 TEMP	119	HYD 3 P
	CRYO O2 P TK3	45	GPC 5	70	CRYO H2 P TK3	95	PL WARNING		
21	CRYO O2 HTR 1 TK2	46	RCS TK P FU - L	71	CRYO O2 HTR 2 TK4			19-22	A DECEMBER OF A DECEMBER OF
	FC2 REAC O2		OMS TK P FU - R	72	FC2 STACK T	97	PL CAUTION		
	DC VO MAIN C	48	APU 2 OIL T		AC2 OVLD			1000	
24	CAB O2 FLOW 2	49	MPS HE REG P - L	74	CAB FAN AP	99	HYD 1 P	Section of	THE REAL PROPERTY AND A DESCRIPTION OF THE READ A DESCRIP

Hardware Caution and Warning Table

60). The remaining backup C/W alarms that are produced by the guidance and navigation program are accessed through general-purpose computer read/write procedures. A backup C/W out-of-tolerance condition will trigger illumination of the four *MASTER ALARM* lights, illuminate the red *BACKUP C/W ALARM* light on panel F7, and display

a message on the fault message line and fault summary page.

The class 2 (C/W) aural master alarm is activated by the primary (hardware) system, the backup (software) system, or both. The C/W tone is an alternating 375 hertz and 1,000 hertz at a 2.5 hertz rate. The alternating C/W alarm tone is generated



SCOM 1.0 November 1991 when the hardware system detects an out-of-limit condition on any of the 120 parameters it monitors or when the software (backup) system detects a parameter that is out of limits.

Class 2 primary and backup C/W visual cues include a 40-light annunciator matrix on panel F7. This matrix annunciates various system or functional failures. Each light is driven by one or more parameters. With the exception of the *BACKUP C/W ALARM* light, once a lamp has been illuminated, it will not be extinguished until all parameters driving that light are back within limits. THE *BACKUP C/W ALARM* light is extinguished once a MSG RESET key is pushed.

Panel R13U is the crew's interface with the primary C/W system. It includes a parameter status light matrix that is used to check the status of a parameter and also to check parameter limits. When used to check the status of parameters, the numbers on the left side of the matrix are read first to obtain the first two numbers of the parameter (row), then the number on the top is read to obtain the third number of the parameter. The matrix can display all 120 parameters (numbered from 000 to 119) of the primary C/W system.

Class 3 - Alert

This class is a software system operated by the SM software. It would generally receive lower priority than a class 1 or 2 alarm. Class 3 alert is designed to inform the flight crew of a situation leading up to a class 2 alarm or one that may require a long procedure (over 5 minutes) in order to rectify the problem. When an alert parameter exceeds its limits, the blue *SM ALERT* light on panel F7 is illuminated, a discrete is sent to the primary C/W system to turn on the alert tone, and the software displays a fault message on the fault message line and fault summary page.

Both guidance, navigation, and control (GNC) and systems management (SM) software sense out-oflimit conditions. These software systems also serve some less critical parameters and annunciate the systems management alert tone. The SM alert tone is a steady tone of 512 hertz of predefined duration generated in the C/W electronics when activated by inputs from the onboard computers.

Class 0 - Limit Sensing

Class 0 is a software system consisting of up and down arrows on the CRT displays next to a parameter. It provides no aural annunciation.

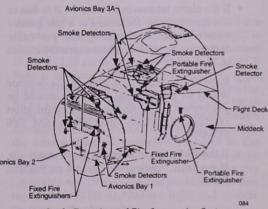
A down arrow displayed next to a parameter would indicate that the low limit for that parameter had been met or violated. In addition, the down arrow is used to indicate a state that does not agree with the nominal state; for example, a fan that is nominally on (e.g., HUM SEP fan) is off.

An up arrow displayed next to a parameter would indicate that the upper limit for that parameter has been exceeded.

Smoke Detection and Fire Suppression

This emergency class 1 alarm is hardware driven. The crew is alerted to emergency situations by use of visual and audio alarms.

Smoke detection and fire suppression capabilities are provided in the crew cabin avionics bays, the crew cabin, and the Spacelab pressurized module. Ionization detection elements, which sense levels of smoke concentrations or rate of concentration change, trigger alarms and provide information on smoke concentration levels to the performancemonitoring CRT system and an array of red SMOKE DETECTION lights on panel L1.



Smoke Detection and Fire Suppression System

The ionization detection system is divided into two groups: group A and group B. Group A ionization detection elements are located in the environmental control and life support system cabin fan plenum outlet beneath the crew cabin middeck floor and in the left return air duct on the crew cabin flight deck, and one element is located in each of the three forward avionics bays (1, 2, and 3A). Group B ionization detection elements are located in the right return air duct on the crew cabin flight deck and in avionics bays 1, 2, and 3A. On Spacelab missions, ionization detection elements are located in the Spacelab module.

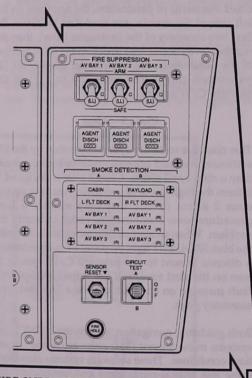
If an ionization detection element senses a smoke particle concentration of 2,000 (\pm 200) micrograms per cubic meter for at least 5 seconds and/or a rate of smoke increase of 22 micrograms per cubic meter per second for eight consecutive counts in 20 seconds, a trip signal illuminates the applicable red *SMOKE DETECTION* light on panel L1, illuminates the four red *MASTER ALARM* lights on panels F2, F4, A7, and MO52J, and sounds the siren in the crew cabin. The normal reading on the SM SYS SUMM 1 display for the smoke detection elements is 0.3 to 0.4 milligram per cubic meter. A reading on the CRT of 2.0, plus or minus 0.2, corresponds to 2,000 (\pm 200) micrograms per cubic meter.

After an alarm and a reset of the detector, the following conditions may be observed:

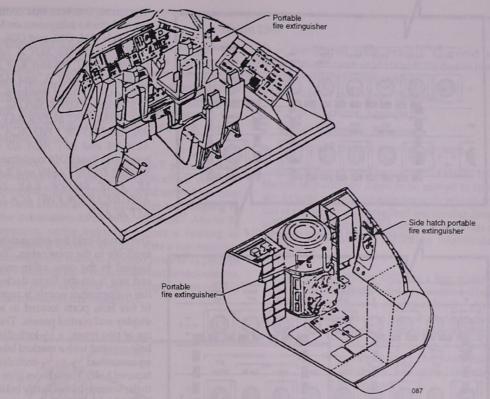
- If the alarm returns in 5 seconds, it is due to the concentration exceeding 2,000 ± 200 micrograms per cubic meter for 5 seconds.
- If the alarm returns in 20 seconds, it is due to the concentration increasing at a rate greater than or equal to 22 micrograms per cubic meter per second for eight consecutive counts in 20 seconds.
- If the alarm returns immediately, the detector would be suspect, and a self test should be performed. If available, the concentration readout should be observed on SM SYS SUMM 1.
- If the alarm does not return, perform self test. If available, check concentration on SM SYS SUMM 1.

0001/ /078 SM	SYS SUMM 1			:13:09
SMOKE 1/A 2/B	1			
CABIN - 0.9	DC VOLTS	1/A	2/B	3/C
L/R FD - 0.4 0.2	FC	31.1	31.1	31.1
AV BAY 1- 1.2 - 0.0	MAIN	31.0	31.1	31.0
2 - 0.6 0.3 3 - 0.1 - 0.9	CNTL AB BC	29.3	29.3	29.3
CABIN	CA	29.3	29.3	29.3
PRESS 14.7	ESS	29.8	29.8	29.8
dP/dT +.00	AC			
BU/EQ00 +.00	VOLT ¢A	117	117	117
PP02 3.02 3.02	¢Β	117	117	117
FAN P 5.79	¢C	117	117	117
HX OUT T 49	AMPS ØA	4.4	4.1	2.7
02 FLOW 0.0L 0.0L	¢Β	3.9	4.2	3.2
NZ FLOW 0.0L 0.0L	¢C	2.4	3.2	4.8
IMU FAN AP 4.62	FUEL CELL	PH		
AV FC1 FC2 FC3	AMPS	172	167	178
SS1 15 18 18	REAC VLV		OP	OP
SS2 16 20 11	STACK T	+204	+203	+203
SS3 22 26 26	EXIT T	150	150	151
TOTAL AMPS 510 KW 15	COOL P PUMP	61	61	61
KW 15	PUMP			/

SM SYS SUMM 1 (DISP 78)



FIRE SUPPRESSION Switches and Push Buttons and SMOKE DETECTION Lights on Panel L1

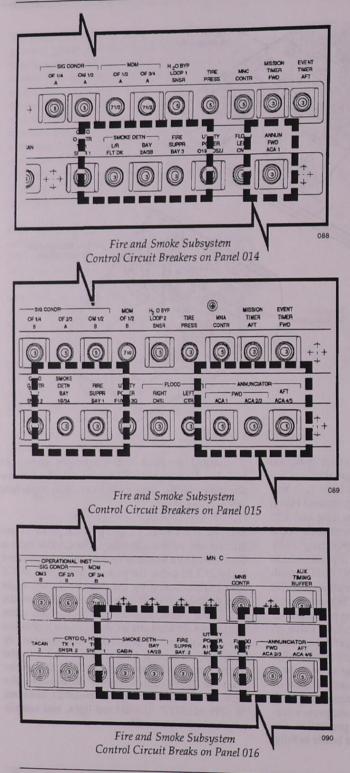


Fire Extinguisher Locations

Fire suppression in the crew cabin avionics bays is provided by three Halon extinguisher bottles permanently mounted in avionics bays 1, 2, and 3A. Each bottle contains 3.74 to 3.8 pounds of Halon in a pressure vessel that is 8 inches long and 4.25 inches in diameter. To activate the applicable bottle in an avionics bay, the corresponding FIRE SUPPRESSION switch on panel L1 is positioned to ARM, and the corresponding AGENT DISCH push button indicator on panel L1 is depressed for at least 2 seconds. The AGENT DISCH push button indicator activates the corresponding pyro initiator controller, which initiates a pyrotechnic valve on the bottle to discharge the Halon into the avionics bay. The discharge of Halon will produce a noise of approximately 130 decibels in the avionics bay. The discharge will give a Halon concentration in the avionics bay of 7.5 to 9.5 percent. A 4 to 5 percent concentration is required to suppress a fire. This concentration will provide protection for approximately 72 hours. When the bottle is fully

discharged, the push button indicator white light will be illuminated. The white light will be illuminated if the pressure in an avionics bottle falls below 60 ± 10 psig.

Red *SMOKE DETECTION* lights on panel L1 are illuminated by the following: the *CABIN* light is illuminated by a smoke detection ionization element in the ECLSS cabin fan plenum, the *L FLT DECK* light is illuminated by the crew cabin left flight deck return air duct smoke ionization element, the *R FLT DECK* light is illuminated by the crew cabin right flight deck return air duct smoke ionization element, and the *PAYLOAD* light is illuminated by the smoke detection ionization elements in the Spacelab pressurized module. The applicable smoke detection ionization element illuminates the applicable red *AV BAY* light on panel L1, activates the *C/W MASTER ALARM* red light, and sounds the siren in the crew cabin.



The circuit breakers that control the fire and smoke subsystem are located on panels O14, O15, and O16. Panel O14 contains the MN A SMOKE DETN L/R FLT DK and BAY 2A/3B, FIRE SUPPR BAY 3, and ANNUN FWD ACA 1 circuit breakers. Panel O15 contains MN B SMOKE DETN BAY 1B/3A, FIRE SUPPR BAY 1, and ANNUNCIATOR FWD ACA 1 and ACA 2/3 and AFT ACA 4/5 circuit breakers. Panel O16 contains MN C SMOKE DETN CABIN and BAY 1A/ 2B, FIRE SUPPR BAY 2, and ANNUNCIATOR FWD ACA 2/3 and AFT ACA 4/5.

Three hand-held fire extinguishers are available in the crew cabin. Two are located in the crew cabin middeck, and one is on the flight deck. Each fire extinguisher nozzle is tapered to fit fire hole ports located in several display and control panels. The holes are of two types: a 1/2-inch diameter hole covered with a marked label, and an unmarked 1/2- to 1/4-inch diameter tapered hole. These holes give access to the volume immediately behind the individual panel. To suppress a fire behind a panel or within an avionics bay, the extinguisher nozzle should be inserted into the fire hole and the actuating mechanism depressed for 15 seconds. This will ensure a complete discharge. The extinguishing agent is Halon-1301 (monobromotrifluoromethane). Halon-1301 minimizes the major hazards of a conflagration: smoke, heat, oxygen depletion, and formation of pyrolysis products such as carbon monoxide. The fire extinguishers are 13 inches long. The portable fire extinguishers can also be used as a backup for extinguishers in the avionics bays. Consideration should be given to the reactive force on the crewmember when discharging the extinguishers on orbit.

Halon 1301

Halon 1301 is used as the extinguishing agent for all fire suppression devices. It is colorless and odorless. Discharge of the agent may create a light mist in the vicinity of the discharge nozzle. Therefore, visibility is not adversely affected. Once the Halon is discharged into an enclosure, it is difficult to detect its presence through normal human senses.

Exposure to Halon in the 5 to 7 percent range produces little, if any, noticeable effect. At levels between 7 and 10 percent, mild central nervous system effects such as dizziness and tingling in the extremities have been reported. Above 10 percent, some subjects report a feeling of impending unconsciousness after a few minutes, although test subjects exposed to up to 14 percent for 5 minutes have not actually lost consciousness. These types of effects were completely reversible upon removal from exposure. It is considered good practice to avoid all unnecessary exposure to Halon 1301 and to limit exposures to the following times:

- 7 percent and below: 15 minutes
- 7 to 10 percent: 1 minute
- 10 to 15 percent: 30 seconds
- Above 15 percent: prevent exposure.

Anyone suffering from toxic effects of Halon 1301 should immediately move or be moved to fresh air. In treating persons suffering toxic effects, the use of epinephrine (adrenaline) and similar drugs must be avoided. These drugs may produce cardiac arrhythmias, including ventricular fibrillation.

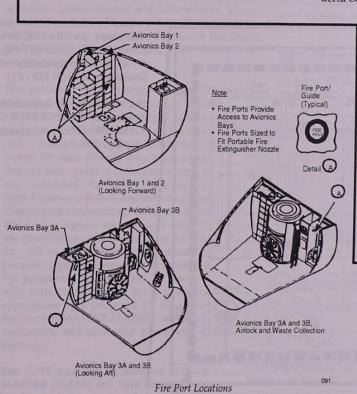
> Although Halon 1301 has a low toxicity, its decomposition can be hazardous. These products have a characteristically sharp acrid odor, even in minute concentrations

of only a few parts per million. This smell provides a warning system but at the same time creates a noxious, irritating atmosphere.

The accepted theory is that Halon must decompose before it is effective in suppressing fire. The decomposition takes place on exposure to a flame or to a hot surface of approximately 900° F.

Depending on the severity of the fire, length of time Halon is exposed to flame, and concentration of Halon, the decomposition products may be extensive or minimal.

The SMOKE DETECTION CIRCUIT TEST switch on panel L1 tests the smoke detection system, lights, and alarm circuitry. When the switch is positioned to A or B, electrical power is applied to the ACA channels controlling the AGENT DISCH lights, and the white lights are illuminated. Two tests are



completed for both the A and the B circuits to test the complete logic circuitry of the smoke detection system. In the first test, after approximately a 20second delay, the *SMOKE DETECTION A* or *B* lights are illuminated, and the siren is triggered. In the second test, the *SMOKE DETECTION CIRCUIT TEST* switch is turned off in 5 to 10 seconds, bypassing the 20-second time delay and immediately annunciating a siren and a *SMOKE DETECTION* light (A or B).

Once the alarm system has been triggered, it remains latched until the *SMOKE DETECTION SENSOR* switch on panel L1 is positioned to *RESET*. When the system is latched, the emergency alarm system will not activate an alarm in case of another fire in the same or any other avionics bay.

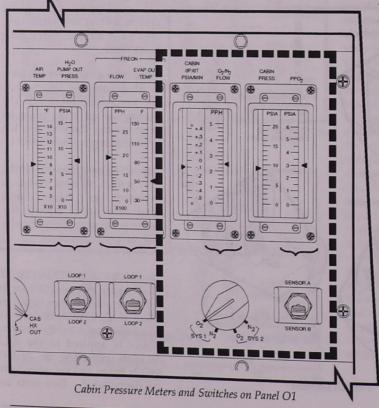
Various parameters of the smoke detection system and remote fire extinguishing agent system are provided to telemetry.

Rapid Cabin Depressurization

The cabin pressurization rate, dP/dT, senses the rate at which atmospheric pressure is changing in the orbiter (in psi/min). There will be an alarm issued only for a rapid cabin depressurization. If a dP/dT alarm was issued, it would indicate that air was leaking at a rate much higher than normal. The system alerts the crew to a rapid pressure change with respect to time by annunciation of the four MASTER ALARM push button indicators and sounding of the klaxon (class 1 alarm).

A dP/dT alarm will be issued if the change in pressure versus change in time decreases at a rate of 0.08 psi per minute or greater. The normal cabin dP/dT is zero psi per minute (\pm 0.01 psi for all normal operations.

In addition, a class 3 alarm will annunciate for a decrease in pressure greater than or equal to 0.12 psi per minute, based on equivalent dP/dT or backup dP/dT.



2.2-10

Values for dP/dT can be monitored on the SM SYS SUMM 1 (dP/dT, dP/dT-EQ, dP/dT-BU), and the dedicated display on panel O1 (dP/dT).

The rapid dP/dT detector is powered by the MN B PPO2 C CABIN DP/DT circuit breaker on panel O15.

2. SYSTEMS
 2.2 Caution and Warning System

	VIRONMENT	-	4 000/02	
dP/dT +.01 CABIN P	14.7 TEMP	BAY	1 2	3
	14.8 FAN		90 90 80 3.77	
		PPLY H2		3.92
B 3.04 HX OUT T	45L OTY	A 67	PRESS	32
C 3.04 CABIN T PPC02 1.9	71	B 18		
1	2	C 94 D 94	NOZ T	A 64
02 FLOW 0.0L	0.0L WAS		0	B 64
REG P 100	100 QTY	1 15		17
N2 FLOW 0.0L REG P 202	0.0L 202		DMP LN	T 58
02/N2 CNTL VLV N2	02		102 1	B 82
H20 TK N2 P 17	17		C VT NOZ	T 224
N2 QTY 131		CNTLR	1	2
EMER 02 OTY 1 REG P 4L	FILT	2	and the second	.00L
A B C	AP BED	A PRES		2.0L
IMU FAN *	4.5 BEU	B PRES		
HUMID SEP *		AP		L 0.00
Contrac Distant	VAC	PRESS		0.0L

ENVIRONMENT Display (DISP 66)

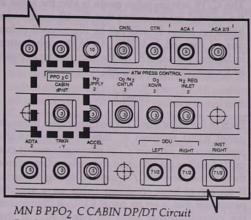
Operations

Primary C/W System

The primary C/W system has three modes of operation: ascent, normal, and acknowledge. These modes are controlled by the CAUTION/WARNING MODE switch on panel C3. The switch has three settings: ASCENT, NORM, and ACK. The normal mode is discussed first.

The primary C/W system receives 120 inputs directly from transducers through signal conditioners, or from the flight forward multiplexer/demultiplexers, and are fed into a multiplexing system. Of these 120 inputs, 95 come directly from transducers, five are from input/output processors, 18 are provided through multiplexer/ demultiplexer software, and two are spares. These inputs can be either analog or bilevel. The analog signals are zero to 5 volts dc; the discretes are either zero, 5, or 28 volts dc. All of these inputs are designed to provide upper or lower limit detection. If the parameter has exceeded its limits, it will turn on the C/W tone, light the appropriate light on panel F7, illuminate the four red MASTER ALARM push button indicators, and store the parameter in memory.

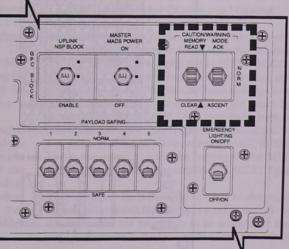
The C/W tone can be silenced and the *MASTER ALARM* red light extinguished by depressing any one of the *MASTER*



Breaker on Panel O15

ALARM push button indicators; however, the C/W light on panel F7 will remain illuminated until the out-of-tolerance condition is corrected. Any one of the MASTER ALARM push button indicators will reset all tones, including the systems management tone.

The C/W ascent mode is the same as the normal mode, except that the commander's red MASTER ALARM push button indicator will not be illuminated.



CAUTION/WARNING MEMORY and MODE Switches on Panel C3

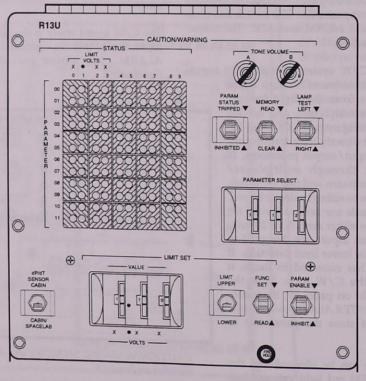
The C/W acknowledge mode is also the same as the normal mode, except that the 40 annunciator lights on panel F7 will not be illuminated unless one of the red *MASTER ALARM* push button indicators (on panel F2 for the commander or panel F4 for the pilot) is depressed.

Panel R13U

Each of the 120 status C/W red parameter lights on panel R13U receives an input from a specific parameter. A primary C/W parameter matrix cue card identifies the 120 input channels and correlates them to the panel F7 C/W annunciator light matrix. If an out-of-limit condition exists on a specific parameter that is set on panel R13U, it illuminates the corresponding light on panel F7. If the *CAUTION/WARNING PARAM STATUS* switch on panel R13U is held in the *TRIPPED* position when an out-of-limit parameter light on panel F7 is illuminated, the corresponding light on panel R13U will also be illuminated. Some limits, and the list of parameters monitored, change with flight phase. The crew uses the *PARAM ENABLE/INHIBIT* and *LIMIT* switches on panel R13U to tailor the C/W system for their current configuration.

The three *CAUTION/WARNING PARAMETER SELECT* thumbwheels on panel R13U provide signals to the C/W electronics unit and define the specific parameter for enabling and inhibiting the parameter and setting and reading the parameter's limits.

The CAUTION/WARNING LIMIT SET switch grouping on panel R13U is used to change limits or to read a parameter's limits. The three VALUE thumbwheels provide the signals to the C/W unit, defining the voltage value setting of a parameter's upper or lower limit, X.XX.



Panel R13U

2.2-12

The UPPER setting of the CAUTION/WARNING LIMIT SET LIMIT switch on panel R13U provides a signal to the C/W electronics unit, which modes the electronics to set or read the upper limit of a parameter specified by the settings on the PARAMETER SELECT thumbwheels for that parameter. The CAUTION/WARNING LIMIT SET FUNC switch is cycled to set or read the upper limit of that parameter. The LOWER setting functions in the same manner, except for the lower limit for a parameter.

The CAUTION/WARNING LIMIT SET FUNC SET switch position on panel R13U provides a signal to the C/W electronics unit, which sets the value specified by the LIMIT SET VALUE thumbwheels into the parameter as specified by the PARAMETER SELECT thumbwheels and LIMIT SET LIMIT switch. The LIMIT SET FUNC READ switch position on panel R13U provides a signal to the C/W electronics unit, which illuminates the lights under the STATUS LIMIT VOLTS X.XX columns on panel R13U that correspond to the voltage parameter limit specified by the PARAMETER SELECT thumbwheels and the LIMIT SET LIMIT switch. The value read corresponds to the parameter's full-scale range on a scale of zero to 5 volts dc. The LIMIT SET FUNC switch center position disables the set and read functions.

The ENABLE position of the CAUTION/WARNING PARAM switch on panel R13U provides a signal to the C/W electronics unit to enable the parameter indicated on the PARAMETER SELECT thumbwheels, which allows the parameter to trigger the primary C/W alarm when out of limits. The INHIBIT position operates the same as ENABLE, except it inhibits the parameter from triggering the primary C/W alarm. The center position of the switch disables the enable and inhibit functions.

The *TRIPPED* position of the *CAUTION/WARNING PARAM STATUS* switch on panel R13U provides a signal to the C/W electronics unit, which illuminates the C/W status lights that correspond to the parameters that are presently out of limits, including those that are inhibited. The *INHIBITED* position illuminates those C/W lights on panel R13U that have been inhibited. The center position disables the tripped and inhibited functions.

The CAUTION/WARNING MEMORY READ switch position on panel R13U provides a signal to the C/W electronics unit, which illuminates the C/W status lights on panel R13U that correspond to the parameters that are currently out of limits and that have been out of limits since the last positioning of this switch or the CAUTION/WARNING MEMORY switch on panel C3 to CLEAR. The CLEAR position on panel R13U or panel C3 provides a signal to the C/W electronics unit that clears from the memory any parameters that are presently within limits, but any parameters that are out of limits during this action remain in memory. The center position of the switch on panel R13U or panel C3 disables the clear and read functions.

The CAUTION/WARNING TONE VOLUME A knob on panel R13U, when adjusted clockwise, increases the system A siren, klaxon, C/W, and SM tone generator output signals to the audio central control unit. The B switch functions the same as the A switch for system B tone generators.

The CAUTION/WARNING LAMP TEST switch on panel R13U, when positioned to LEFT, provides a signal to the C/W electronics unit, which illuminates the left five columns of the C/W status matrix lights on panel R13U. The RIGHT position functions the same as the LEFT, except for the right five columns of lights. This allows the verification of all 120 lights, making sure that none have burned out.

Software (Backup) Caution and Warning

When the software caution and warning system detects an out of limits condition, it sounds an aural tone or master alarm, lights the *MASTER ALARM* or *SM ALERT* light, and issues a fault message that is displayed flashing on the CRT fault message line. The master alarm light and tones are reset by depressing a *MASTER ALARM* light push button. The fault message will flash until acknowledged by a depression of the ACK key or until the MSG RESET key is depressed to erase the message. The MSG RESET key will also extinguish the *SM ALERT* light.

The displayed fault message is used to diagnose system failures and frequently is used as the title of the flight data file procedure to be worked by the crew in response to the failure. The text of the fault message identifies the system where limits are being exceeded. A list of individual fault messages is presented in the summary at the end of this section.

For some general classes of fault messages, the first part of the text contains the SPEC number to be consulted to determine the specific parameter that is out of limits. The GPCs declaring the fault are enumerated after the message text. In parentheses at the end of the fault message, software will display the number of other fault messages generated while the current message was being displayed. To view these messages and the time at which they were annunciated, the crew must look at the fault summary page, or scroll through them using the *ACK* key.

After reset of the displayed fault message, the message line will be blank until another new message is generated by the software. To avoid missing messages in a multi-failure scenario, crews should occasionally review all messages on the fault summary page and try to reset messages on the fault line as quickly as possible after reviewing them.

Fault messages for some parameters are issued every time the software completes the required number of data counts with the parameter out of limits. This can result in a steady stream of fault messages and *MASTER ALARMS* that may obscure other important fault messages. If this situation is encountered, the crew or Mission Control can inhibit the affected parameter to prevent nuisance messages and alarms in OPS 2 or OPS 4. In OPS 1, 6, or 3, the crew generally has to tolerate the extra alarms/ fault messages and pay extra close attention to the fault summary display.

In order to clear messages from the fault summary page, the crew enters a SPEC 99 PRO on the keyboard. If the fault summary (DISP 99) is called up using a SPEC 99 PRO instead of the FAULT SUMM key, the fault summary page will appear, and then immediately clear itself.

Software caution and warning limits for some parameters change depending on the phase of flight. These changes can be entered by the crew via the SPEC 60 TABLE MAINTENANCE display or uplinked from the ground. The ground uplink for limits changes is called a Table Maintenance Block Uplink (TMBU).

SPEC 60, SM Table Maintenance

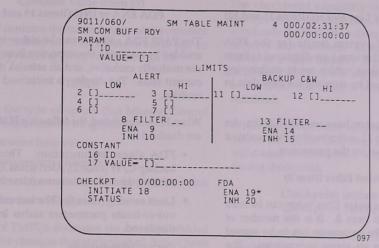
The primary avionics software system (PASS) includes three types of applications software, called major functions. The first, systems management (SM), is the function that is active on orbit. The second, guidance, navigation, and control (GNC), is active during all flight phases. The third, payload software, provides operations support to payloads. The backup flight system (BFS), normally used only during ascent and entry, also contains both SM and GNC software.

Modules within both SM and GNC software monitor parameters and initiate alarms. To change the characteristics of the PASS GNC, BFS GNC, and BFS SM parameters, the crew would have to perform a GPC memory read/write procedure. (This procedure is described in the DPS HW/SW 2102 Training Manual.)

However, PASS SM parameters <u>can</u> be accessed directly by the crew. Within PASS SM is a module called fault detection and annunciation. This module monitors the backup C/W and alert parameters and initiates alarms.

SPEC 60 SM TABLE MAINT is the crew interface with the PASS SM parameters. Using SPEC 60, the crew can read and change the following for each PASS SM backup C/W or alert parameters: (1) lower and upper limits, (2) noise filter value, and (3) enable/inhibit status. Additionally, the crew can read and change SM program constants, initiate a checkpoint, and enable or inhibit the entire fault detection and annunciation software module.

SPEC 60, which is a PASS SM SPEC, is available during SM OPS 2 and SM OPS 4. When the SM TABLE MAINT display is called up by its SPEC number (SPEC 60 PRO), each field will be blank except CHECKPT time and FDA ENA. When SPEC 60 is called by pressing RESUME, the fields that were previously in use will retain their data. When a legal item entry is made, the new data will be displayed in the appropriate field and will overwrite any previous data.



SM TABLE MAINT CRT (SPEC 60)

Any backup C/W parameter may be accessed by entering its software ID number (see page 2.2-4) in item 1 of the SM TABLE MAINT display. The limits, noise filter value, and enable/inhibit status of alert parameters may be changed with items 2 through 10. The same characteristics of backup C/W parameters are available through items 11 through 15. These CRT parameters are discussed in more detail below.

PARAM ID (Item 1) and PARAM Value

The software ID number for the desired fault detection and annunciation (FDA) parameters is entered in item 1. The software IDs are located in the C/W and FDF TABLE of the Flight Data File Reference Data Book.

When a valid ID is entered, the ID number will be displayed in the PARAM ID space, and the current value of the parameter will be displayed in the PARAM VALUE field. The status of the parameter is indicated by the presence or absence of an up or down arrow. The appropriate ALERT or BACKUP C/W data will appear in the LIMITS portion (items 2 through 10 or items 11 through 15 respectively). If the parameter is monitored by both the Alert and B/U C/W systems, then both sections will contain the proper data. Otherwise, one of the LIMITS sections will be blank. If the PARAM ID is not valid, all associated data fields will be blank, and an ILLEGAL ENTRY message will be displayed.

Limits Alert Low and Hi (Items 2 through 7)

These fields contain the upper and lower alert limits of the FDA parameter identified in item 1. The limit values are displayed in engineering units and can be changed by entering the desired data in the appropriate items.

Alert parameters that are preconditioned may have two or three limits sets. All other alert parameters have only one limit set. The SM software selects which set of limits is currently active and places an asterisk next to that set (before item 2, 4, or 6). (There is no item entry that allows the crew to move the asterisk to directly select which set of limits is active. This is done exclusively by software.) If only one set of limits exists for the parameter, this set will be displayed in the first limit set location, and the asterisk will be placed by item 2. If a value is entered in a limit set that does not exist for the selected parameter, an illegal entry message will be displayed.



Limits Backup C/W Low and Hi (Items 11 and 12)

The backup C/W system limits for the FDA parameter identified in item 1 are displayed in these fields. The limit values, which are in engineering units, can be changed by entering the new data in the desired item.

Backup C/W parameters have one set of limits. An asterisk next to item 11 indicates that there exists a backup C/W limit set for the parameter.

Limits Alert Filter (Item 8)

The Alert parameter noise filter value can be read or changed through item 8. It is the number of consecutive times the parameter has to be sensed out of limits before an alarm annunciates. The reverse is true for returning back into limits. The range of valid values is 1 through 15.

Limits Backup C/W Filter (Item 13)

The backup C/W filter functions similarly to the Alert filter (item 8).

Limits Alert ENA or INH (Items 9 and 10)

The annunciation of an out-of-limits Alert parameter may be either enabled or inhibited by executing the respective item. The items are mutually exclusive, and an asterisk indicates the current annunciation status by appearing after the more recently selected item.

The class 0 status indicators (up and down arrows) and transducer data symbols (H, L, M, ?) are not affected by this item.

Limits Backup C/W ENA or INH (Items 14 and 15)

These backup C/W items operate similarly to the Alert items 9 and 10.

FDA ENA or INH (Items 19 and 20)

The PASS FDA software can be either inhibited or enabled by executing the respective item. The items are mutually exclusive, and an asterisk denotes the current state. The display is initialized with FDA enabled.

When FDA is inhibited, the following FDA functions are disabled:

- FDA alarm annunciation. This includes backup C/W (class 2), Alert (class 3), and limit sensing up or down arrows (class 0).
- Limit sensing (class 0). The last value of each out-of-limits parameters status indicator is displayed.
- Precondition steering.
- False alarm avoidance noise filters.

Other parameter status indicators (H, L, M, ?) are not affected because they are not generated by the FDA software.

Constants

SM constants may be accessed through items 16 and 17. These constants are primarily involved in SM special processes such as water loop pump cycling, alert preconditioning, and payload deployment.

Constant ID (Item 16)

When a constant ID number is entered in item 16, both the CONSTANT ID and VALUE fields are filled. If the ID was illegal, both data fields are blanked.

The constant IDs and values are not typically carried onboard the orbiter, although various malfunction procedures contain occasional constants. If a constant must be changed, Mission Control will either provide the crew with the data or directly change the constant through a TMB Uplink. (See TMBU description in this section.)

Constant Value (Item 17)

This field contains the current value of the constant identified in item 16. The constant value can be changed by entering the new data in item 17.

TMBU

TMBU is the type of uplink that Mission Control uses to change the following data:

- Parameter limit values
- Parameter noise filter values
- Parameter annunciation enable/inhibit status
- SM constant values.

The use of TMBUs decreases the crew's workload because the changes that are uplinked do not have to be entered on SPEC 60.

SPEC 60 operations and TMBUs are interlocked such that TMBU loads are rejected if SPEC 60 is active. If a TMBU is in progress when SPEC 60 is called, the flashing words UPLINK and UL will be displayed on the display, and all item entries will be prohibited by an ILLEGAL ENTRY message.

Uplink

The flashing word UPLINK is displayed in the top center of SPEC 60 to indicate that a TMBU is in progress.

UL

When any two-stage command (including a TMBU) is uplinked, a flashing UL is displayed in the upper right corner of all CRTs associated with the GPC(s) that are being commanded.

Checkpoints

When a checkpoint is performed, the following information is saved in a mass memory unit:

- · Parameter limit values
- Parameter noise filter values
- Parameter annunciation enable/inhibit status
- SM constant values
- Checkpoint timetags.

The checkpoint capability is valuable because changes made through item entries on SPEC 60 affect only the SM GPC software and not the mass memory unit software. If these changes are not saved in a mass memory unit, and the SM GPC fails, flight software will lose the changes that have been made. The changes would then have to be reentered.

When checkpoint retrieval is enabled, the software loaded into an SM GPC from a mass memory unit will contain the most recent version of changes saved during checkpoint.

Checkpoint Initiate (Item 18), Checkpoint Status, and Time

When item 18 is executed, the STATUS field will go blank. While the checkpoint is being performed, a flashing BSY will be displayed next to SM COMM BUFF at the top left of SPEC 60. This indicates that the SM communications buffer is in use. When the checkpoint is completed, the CHECK PT STATUS field will contain GOOD. If the SM common buffer was not available, CHECK PT STATUS will be FAIL, and item 18 should be executed again.

The mission elapsed time (MET) of the most recent successful checkpoint will be displayed as DD/HH:MM:SS, in the checkpoint time field.

SM COMM BUFF - BSY, or RDY

Either a flashing BSY or a status RDY is displayed after SM COMM BUFF to indicate the status of the SM Common Buffer. BSY (busy) indicates that the SM COMM BUFF is being used; RDY (ready) means the buffer is available.

Keypad entries are rejected if BSY is flashing.

CKPT RETRV ENA (SPEC 1, Item 12)

Executing this item will alternately select or deselect CKPT RETRV ENA. An asterisk appears next to item 12 when checkpoint retrieval is enabled.

MMU Assignment (DPS Utility – SPEC 1, Items 3 and 4)

A checkpoint saves the changes in the mass memory unit assigned to the SM software by item 3 or 4. In order to save the checkpoint in both, two checkpoints must be performed.

And the second process of a second state of a se

A FERRING TO THE MORE THE

realized provide the second second second

· Far and a surrent for the second second second

The car of TMDL's demonstration orbital workload accurate the character stati attorn plinked do not have to be entered on MTPL' 60.

SPEC of report them and " ADD as released of the design of the design

Church potents

יאותיה אינרייתי סומר העבולייבע לי ליר ולולי יותר מילוישימלותי ערצע יצול ועברוקרי עליכולי שוור אילוישימלותי ערצע יצול ועברוקרי עליכולי

- · Parameter sed arrively vanies.
- + Formester and monthing antiple information +
 - · SM o ustant valpes
 - · Checkpeint Emerge

2.2 - 18

C/W Summary Data

- The C/W system consists of four alarm classes: emergency (class 1), C/W (class 2), alert (class 3), and limit sensing (class 0).
- Emergency alarms cover two situations: smoke detection/fire suppression and cabin pressure.
- Smoke detection and fire suppression capabilities are provided in the crew cabin avionics bays, the crew cabin, and the Spacelab pressurized module.
- Increased smoke particle concentration will illuminate SMOKE DETECTION lights on panel L1, illuminate four red MASTER ALARM lights on panels F2, F4, A7, and MO52J, and sound the siren in the crew cabin.
- Fire suppression in the crew cabin avionics bay is provided by one permanent Halon extinguisher bottle in avionics bays 1, 2, and 3A. The bottle is operated by switches on panel L1.
- Three portable hand-held extinguishers in the crew cabin are operated by inserting them into fire holes located in several display and control panels.
- A class 1 alarm (four MASTER ALARM pushbutton indicators and the sounding of the klaxon) is triggered when there is a rapid change in cabin pressure with respect to time.

- Class 2 alarms include primary (hardware) and backup (software) systems. The crew interfaces with the system primarily through the 40-light annunciator matrix on panel F7 and a 120-parameter monitor on panel R13U.
- Class 3 alerts warn the crew of a situation leading up to a class 2 alarm or of one that may require a long procedure.
- Class 0, a software system, consists of up and down arrows displayed on the CRT displays next to a parameter.
- The SPEC 60 TABLE MAINT display allows the crew to change limits, noise filter values, and status of backup C/W or alert system parameters.
- C/W information can be seen on the SM SYS SUMM 1 (DISP 78), and ENVIRONMENT (DISP 66) displays.
- Pressing the MASTER ALARM light will silence the alarm and reset the light.
- Pressing the ACK key will stop the fault messages from flashing. Subsequent pressing of ACK key will scroll through fault messages.
- Pressing the MSG RESET key will erase fault messages and extinguish the SM ALERT light.

C/W Rules of Thumb

- The SENSOR RESET switch on panel L1 shourld be pressed when smoke concentration goes below 1.8. This prevents masking of alarms.
- When panel R13U is not in use, the PARAMETER SELECT thumbwheels should be set to a value greater than 119.
- Crewmembers should reser fault messages as quickly as possible after review to avoid covering other messages.
- The fault summary should be reviewed regularly to avoid missed fault messages.

F7 Light Summary

NOTE

A Class 2 audible tone and *MASTER ALARM* lights accompany the appropriate C/W light. Most lights are hardwaredriven, but many parameters are also software-sensed by the PASS or BFS GPCs. The software provides a CRT message and illuminates the *BACKUP C/W ALARM* light. The hardware channels listed below are the same as the channels on the C/W STATUS light matrix on panel R13U. The color of each light is indicated by (R) for red and (Y) for yellow.

*O*₂ *PRESS* (*Y*): Indicates an O2 tank 1, 2, 3, or 4 pressure or the O2 kit (Tank 5) pressure out of limits. The hardware channels are 0, 10, 20, 30, and 40 for Tanks 1, 2, 3, 4, and 5, respectively.

 H_2 *PRESS* (Y): Indicates either an H2 Tank 1, 2, 3, or 4 pressure or the H2 kit (Tank 5) pressure out of limits. The hardware channels are 50, 60, 70, 80, and 90 for Tanks 1, 2, 3, 4, and 5, respectively.

FUEL CELL REAC (R): Indicates an O2 or H2 Fuel Cell 1, 2, or 3 reactant valve is closed. The hardware channels are 2, 22, 32, 42, and 52 for FC 1, 2, and 3 O2 and H2 respectively.

FUEL CELL STACK TEMP (Y): Indicates a Fuel Cell 1, 2, or 3 stack temperature out of limits. The hardware channels are 62, 72, and 82 for FC 1, 2, and 3, respectively.

FUEL CELL PUMP (Y): Indicates a Fuel Cell 1, 2, or 3 pump P out of limits. The hardware channels are 92, 102, and 112 for FC 1, 2, and 3 respectively.

CABIN ATM (R): Indicates either cabin pressure, PPO2, O2 flow rate, or N2 flow rate out of limits. The hardware channels are 4, 14, 24, 34, 44, 54, and 64 for cabin press, O2 SYS 1 and 2 flow rate, PPO2 A and B, and N2 SYS 1 and 2 flow rate respectively.

O₂ HEATER TEMP (Y): Indicates an O2 Tank 1, 2, 3, or 4 heater temp or O2 kit (Tank 5) heater temp out of limits. The hardware channels are 1, 11, 21, 31, 41, 51, 61, 71, and 81 for O2 Tank 1 HTR 1 and 2, Tank 2 HTR 1 and 2, Tank 3 HTR 1 and 2, Tank 4 HTR 1 and 2, and Tank 5 respectively.

Ē			1	1	
	O2 PRESS	H ₂ PRESS	FUEL CELL REAC	FUEL CELL STACK TEMP	FUEL CELL PUMP
	CABIN ATM	O ₂ HEATER TEMP	MAIN BUS UNDERVOLT	AC VOLTAGE	AC OVERLOAD
	FREON LOOP	AV BAY/ CABIN AIR	IMU	FWD RCS	RCS JET
L	H ₂ O LOOP	RGA/ACCEL	AIR DATA	LEFT RCS	RIGHT RCS
		LEFT RHC (R)	RIGHT/AFT RHC		RIGHT OMS
	PAYLOAD WARNING (R)	GPC	FCS (R) SATURATION	OMS KIT	OMS TVC
	PAYLOAD CAUTION	PRIMARY C/W	FCS CHANNEL	MPS (R)	
	BACKUP C/W ALARM (R)	APU TEMP	APU OVERSPEED	APU UNDERSPEED	HYD PRESS
)	114 Shilterpu	en distribut			

F7 Light Summary (continued)

MAIN BUS UNDERVOLT (R): Indicates main bus A, B, or C voltage low. The hardware channels are 3, 13, and 23 for main bus A, B, and C respectively.

AC VOLTAGE (Y): Indicates AC bus 1, 2, or 3 phase A, B, or C out of limits. The hardware channels are 33, 43, and 53 for AC bus 1, 2, and 3 respectively.

AC OVERLOAD (Y): Indicates an inverter 1, 2, or 3 phase A, B, or C output of 225 percent overload for 20 sec or 300 percent for 4 to 6 sec. The hardware channels are 63, 73, and 83 for inverter 1, 2, and 3 respectively.

FREON LOOP (R): Indicates a low Freon loop 1 or 2 flow rate or a temperature out of limits. The hardware channels are 106, 116, 107, and 117 for loop 1 and 2 flow rate, and loop 1 and 2 temp respectively.

AV BAY/CABIN AIR (Y): Indicates out of limits condition on cabin fan P, AV Bay 1, 2, or 3 air out temp, or cabin heat exchanger air temp. The hardware channels are 74, 84, 94, 104, and 114 for cabin fan P, AV Bay 1, 2, or 3 Temp, and CAB HX temp respectively.

IMU (Y): Indicates detection of an inertial measurement unit (IMU) failure or dilemma. The hardware channel is 103 and is a discrete driven from the GNC software.

FWD RCS (R): Indicates detection of an out of limits condition on a forward RCS oxidizer tank ullage pressure, fuel tank ullage pressure, or forward oxidizer or fuel leak. The hardware channels are 6, 16, and 26 for oxidizer tank press, fuel tank press, and leak respectively.

RCS JET (Y): Indicates detection of an RCS jet failed on, failed off, or leaking. The hardware channel is 96 and is a discrete driven from the GNC software.

 H_2O LOOP (Y): Indicates an out of limits condition on H_2O loop 1 or 2 pump out pressure. The hardware channels are 105 and 115 for loop 1 and 2 respectively.

RGA/ACCEL (Y): Indicates detection of a rate gyro assembly (RGA) 1, 2, 3, or 4 failure, or an accelerometer 1, 2, 3, or 4 failure. The hardware channel is 93 and is a discrete driven from the GNC software.

AIR DATA (R): Indicates detection of an air data transducer assembly (ADTA) dilemma. The hardware channel is 91 and is a discrete driven from the GNC software.

LEFT RCS (R): Indicates detection of a left RCS oxidizer, fuel tank ullage pressure out of limits, or left oxidizer or fuel leak. The hardware channels are 36, 46, and 56 for oxidizer tank press, fuel tank press, and leak respectively.

RIGHT RCS (*R*): Indicates detection of a right RCS oxidizer, fuel tank ullage pressure out of limits, or right oxidizer or fuel tank leak. The hardware channels are 66, 76, and 86 for oxidizer tank press, fuel tank press, and leak respectively.

SPARE: Available for future warning parameter growth.

LEFT RHC (R): Indicates detection of a left rotational hand controller (RHC) pitch, roll, and yaw disagree. The hardware channel is 100 and is a discrete driven from the GNC software.

RIGHT/AFT RHC (R): Indicates detection of a right or aft RHC pitch, roll, or yaw disagree. The hardware channel is 110 and is a discrete driven from the GNC software.

LEFT OMS (R): Indicates detection of a left OMS pod oxidizer, fuel tank ullage pressure out of limits, or an engine abnormal (OMS engine fail to cutoff, fail to ignite, or early shutdown) condition. The hardware channels are 37, 47, and 57 for the oxidizer, fuel tank press, and engine abnormal respectively. The hardware channels are 7, 17, and 27 for the oxidizer, fuel tank press, and engine abnormal respectively.

F7 Light Summary (continued)

RIGHT OMS (R): Indicates detection of a right OMS pod fuel tank ullage pressure out of limits, or an engine abnormal (OMS engine fail to ignite, or early shutdown) condition.

PAYLOAD WARNING (*R*): Indicates detection of up to five payload parameter inputs out of limits. The hardware channels are 55, 65, 75, 85, and 95.

GPC (*Y*): Indicates GPC 1, 2, 3, 4, or 5 has determined itself failed and issued a self-fail discrete. The hardware channels are 5, 15, 25, 35, and 45 for GPC 1, 2, 3, 4, and 5 respectively.

FCS SATURATION (Y): Indicates detection of elevon position or hinge moment saturation. The channel is 101 and is a discrete driven from the GNC software.

OMS KIT (Y): Indicates detection of an OMS kit oxidizer or fuel tank ullage pressure out of limits. The hardware channels are 77 and 87 for oxidizer and fuel respectively.

OMS TVC (R): Indicates detection of an OMS pitch or yaw gimbal failure. The hardware channel is 67. An OMS TVC failure may also result in a *LEFT* or *RIGHT OMS* light.

PAYLOAD CAUTION (Y): Indicates detection of a payload parameter input out of limits. The hardware channel is 97 and is not presently implemented.

PRIMARY C/W (Y): Indicates detection of a C/W system self-test failure internal to the C/W EU. The failures include the loss of power supply A or B, loss of A or B timing, or the inability of a C/W self-test parameter to pass limit check. No channel number. The parameter is internal to the C/W unit hardware itself. The light also illuminates each time the ESS 1BC C/W A circuit breaker is closed after being opened and extinguishes when the MASTER ALARM push button indicator is depressed. *FCS CHANNEL (Y)*: Indicates detection of an elevon, rudder, or speedbrake actuator failure, SRB rock or tilt actuator failure, or MPS engine pitch and yaw actuator failure. The hardware channel is 111 and is a discrete driven from the GNC software.

MPS (R): Indicates detection of an MPS engine He tank press, He regulator out press, LO2 manifold press, or LH2 manifold press out of limits. The hardware channels are 9, 19, 29, 39, 49, 59, 69, and 79 for Engine 1, 2, and 3 He TK, He reg, and LO2 and LH2 pressure respectively.

SPARE (R): Available for future warning parameter growth.

BACKUP C/W ALARM (R): Indicates detection of a C/W alarm via SM, GNC, or BFS software monitoring. In OPS 2 SM parameter limits can be accessed, changed, enabled, and inhibited through the Table Maintenance display.

APUTEMP (Y): Indicates an APU1,2, or 3 exhaust gas temp or lube oil temp out of limits. The hardware channels are 8, 18, 28, 38, 48, and 58 for APU 1, 2, and 3 EGT and lube oil temp respectively.

APU OVERSPEED (Y): Indicates an APU 1, 2, or 3 speed greater than a specified percentage of the designed speed. The hardware channels are 68, 78, and 88 for APU 1, 2, and 3 respectively.

APU UNDERSPEED (Y): Indicates an APU 1, 2, or 3 speed less than a specified percentage of the designed speed. The hardware channels are 98, 108, and 118 for APU 1, 2, and 3 respectively.

HYD PRESS (Y): Indicates a hydraulics system 1, 2, or 3 supply pressure out of limits. The hardware channels are 99, 109, and 119 for APU 1, 2, and 3 respectively.

Fault Message Summary

MESSAGE		OPS	AVAIL	CAUSE	and a second of the second
medande		PASS	BFS	CAUSE	COMMENTS
S86 APU FUEL	1(2,3)	S2,4	1953	APU FUEL QTY ↓ APU FUEL TK P ↑↓	
S86 APU GBX P	1(2,3)	S2,4	100.1	● GBX P↓ ● OIL OUT P↑↓	
т	1(2,3)	S2,4		OIL OUT T †↓ GBX BRG T †	
S88 APU H2O T	1 (2,3)	S2,4	-	APU H2O LN INT T ↑↓	
SM2 APU SPD HI 1 (2,3)		1 1471	SM	TURBINE OVERSPEED	NO MAL
SM2 APU SPD LO 1 (2,3)			SM	TURBINE UNDERSPEED	NO MAL
S86 APU TEMP	1(2,3)	S2,4	0.000	BACKUP EGT †	
SM2 APU TEMP			SM	• OIL TEMP 1	
S88 APU TK T	1(2,3)	S2,4	1000	APU TK SURF T↓ APU TK SKIN T↑↓	1 2814
S66 AV BAY 1(2,3)	FAN	S2,4	THERE IS	• AV BAY 1 (2,3) FAN ΔP ↑↓	The State State
SM2 AV BAY FAN			SM	A DOTAL A ALL OPEN DECEDITED IN	BUE STRUE STRUE
S66 AV BAY 1 (2,3)	TEMP	S2,4	mage	• AV BAY 1 (2,3) FAN AIR OUT T 1	
SM2 AV BAY TEMP			SM	IN TANK CHREATENET TUNH	
BCE BYP	FLEX	S2,4		BCE BYPASS ON FLEX/FLEX PAIR	
BCE BYP	κυ	S2,4		PL1 KU COMM/RADAR S10 FAIL	RADAR: GPC MODE NOT VALID UNLESS TRACKING, AUTO-TRACK MODE IS VALID
BCE BYP	MCIU	S24		GPC DETECTED I/O LOSS WITH MCIU	NO MAL

MESSAGE		OPS	AVAIL	CAUSE	00111/0170	
		PASS	BFS	CAUSE	COMMENTS	
S62 BCE BYP	OA	S2,4		OA1, OA2, OR OA3 MDM OR MDM CARD FAIL		
	OFA	S2,4		OF1 OR OF2 MDM OR MDM CARD FAIL	AT A PROPERTY OF PROPERTY PROPERTY	
	OFB	S2,4	Constant of the second	• OF3 OR OF4 MDM OR MDM CARD FAIL	1.00 2012	
	PDI	S2,4	- Nor	PDI INTERFACE TO SM GPC FAIL	MSG OCCURS AT SM OPS TRANSITION IF PDI POWER OFF	
	PL	S2,4		PDI SSC OR EXC INTERFACE TO PCMMU FAIL	MSG OCCURS AT SM OPS TRANSITION IF PDI POWER OFF OR IF SPACELAB AND SSC OR EXC POWER OFF	
PS	SP 1(2)	S2,4		PSP 1(2) TO PL 1(2) MDM SERIAL I/O FAIL		
BCE BYP F	PL1(2)	S2,4	a land	BCE BYPASS ON PL BUSES	1001A 6000 8.4	
BCE BYP	SCA	S2,4	BOY CON	BCE BYPASS ON SCA	NO MAL	
BCE STRG 1	A	G1,2,3, 6,8	G0,1,2, 3,6	ALL GPCs DETECTED PROBLEM RECEIVING DATA FROM INDICATED	 BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO 	
	ADTA	G1,3,6, 8	G0,1,3, 6	BCE ELEMENT OF STRING 1 AND HAVE BYPASSED THAT ELEMENT	ANNUNCIATE	
	В	G1,2,3, 6,8	G0,1,3, 6			
	с	G1,2,3,	G0,1,3, 6			



		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE		PASS			
BCE STRG 1	D	G1,2,3, 6,8	G0,1,3, 6	ALL GPCs DETECTED PROBLEM RECEIVING DATA FROM INDICATED BCE ELEMENT OF STRING 1 AND HAVE BYPASSED THAT ELEMENT	BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO ANNUNCIATE
	IMU	G1,2,3, 6,8	G0,1,3, 6	HAVE BYPASSED THAT ELEMENT	A A A A A A A A A A A A A A A A A A A
	MLS	G1,3,6, 8			A TRACTOR AND
	MTU	G1,2,3, 6,8,0	G0,1,3, 6		a fear
	NSP	G1,2,3, 6,8,0	G0,1,3, 6	The set of the set of the	Trantings
	STKR	G2,3,8			
	TAC	G1,3,6, 8	G0,1,3, 6	ALL GPCs DETECTED PROBLEM RECEIVING DATA FROM INDICATED BCE ELEMENT OF STRING I AND HAVE BYPASSED THAT ELEMENT	BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO ANNUNCIATE RADAR ALTIMETER DATA ALSO LOST
	PASS		G0,1,3, 6	BFS FAIL TO TRACK STRING 1	NO MAL I/O RESET MAY RESTORE PASS/BFS COMM
BCE STRG 2	A	G1,2,3, 6,8	G0,1,3, 6	ALL GPCs DETECTED PROBLEM RECEIVING DATA FROM INDICATED BCE ELEMENT OF STRING 2 AND	 BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO ANNUNCIATE
	ADTA	G1,3,6, 8	G0,1,3, 6	HAVE BYPASSED THAT ELEMENT	ANNUNGIATE

MESSAGE	10.0	OPS	AVAIL	CAUSE	COMMENTS	
MECONCE		PASS	BFS	CROSE	COMMENTS	
BCE STRG 2 (Cont)	B	G1,2,3, 6,8	G0,1,3, 6	ALL GPCs DETECTED PROBLEM RECEIVING DATA FROM INDICATED	BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO	
	С	G1,2,3, 6,8	G0,1,3, 6	BCE ELEMENT OF STRING 2 AND HAVE BYPASSED THAT ELEMENT	ANNUNCIATE	
	D	G1,2,3, 6,8	G0,1,3, 6			
	IMU	G1,2,3, 6,8	G0,1,3, 6	A MERINAN CARANTER ST. A.	A REAL PROPERTY AND A REAL	
1201-0 12000000	MLS	G1,3,6, 8	1	LOW TO REAL PROVIDENCE LINE	100	
,	MTU	G1,2,3, 6,8,0	G0,1,3, 6	amon and a proprietant	The second s	
	TAC	G1,3,6, 8	G0,1,3, 6	ALL GPCs DETECTED PROBLEM RECEIVING DATA FROM INDICATED BCE ELEMENT OF STRING 2 AND HAVE BYPASSED THAT ELEMENT	BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO ANNUNCIATE BADAR ALTIMETER DATA ALSO LOST	
	PASS		G0,1,3, 6	BFS FAIL TO TRACK STRING 2	NO MAL I/O RESET MAY RESTORE PASS/BFS COMM	
BCE STRG 3	A	G1,2,3, 6,8	G0,1,3, 6	RECEIVING DATA FROM INDICATED	BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO	
A	DTA	G1,3,6, 8	G0,1,3, 6		ANNUNCIATE	

MESSAGE	OPS	AVAIL	Service Landstree	
MEGGAGE	PASS	BFS	CAUSE	COMMENTS
BCE STRG 3 B	G1,2,3, 6,8	G0,1,3, 6	RECEIVING DATA FROM INDICATED	BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO
C	G1,2,3, 6,8	G0,1,3, 6	BCE ELEMENT OF STRING 3 AND HAVE BYPASSED THAT ELEMENT	ANNUNCIATE
D	G1,2,3, 6,8	G0,1,3, 6	The case of the second	
IMU	G1,2,3, 6,8	G0,1,3, 6	THE REAL PROPERTY OF	AN CAR AS AN ANY ANY ANY ANY ANY ANY
MLS	G1,3,6, 8		A CHER CHERT AND ACTION	10 170 01 BMA
MTU	G1,2,3, 6,8,0	G0,1,3,	The state of the s	a sar out to to own
NSP	G1,2,3, 6,8,0	G0,1,3,	And the second s	2 2 014 24 00 A D A D A D A D A D A D A D A D A D
STKR	G2,3,8	and and a state of the	(* PHONE 1	BAR CAR PROOF
TAC	G1,3,6, 8	G0,1,3, 6	 CADIN PRESIDENT OF L CADIN FAN APTROPHY 	
PASS		G0,1,3, 6	BFS FAIL TO TRACK STRING 3	NO MAL I/O RESET MAY RESTORE PASS/BFS COMM

MESSAGE	OPS	AVAIL	0.1105	
MESSAGE	PASS	BFS	CAUSE	COMMENTS
BCE STRG 4	A G1,2,3 6,8	, G0,1,3, 6	RECEIVING DATA FROM INDICATED	BFS PRE-ENGAGED MUST BE IN SYNC WITH (TRACKING) PASS TO
AD	G1,3,6	G0,1,3,	BCE ELEMENT OF STRING 4 AND HAVE BYPASSED THAT ELEMENT	ANNUNCIATÈ
	B G1,2,3 6,8	G0,1,3,	LAND THE	SCALE REPORT AND IN
CARD - MERLIN LEARN	C G1,2,3 6,8	G0,1,3, 6	THE SOLONNER CONTROL OF	
	D G1,2,3 6,8	G0,1,3, 6	CONTRACTOR OF COMMENTS	CETONO MERO IN
PA:	S	G0,1,3, 6	BFS FAIL TO TRACK STRING 4	NO MAL I/O RESET MAY RESTORE PASS/BFS COMM
BDY FLP SW L(R) G3,6		BODY FLAP DN(UP) SW DISAGREE	NO MAL DEFAULT TO NO OUTPUT
BODY FLAP CY	CL G1,3,6		BODY FLAP LIMIT CYCLING BUT USABLE	NO MAL
FA	IL G1,3,6		. BODY FLAP STALLED OR RUNAWAY	1.55 C
HOL	D G1,3,6	ME 24 VIIIVI	BODY FLAP ONE CH FAILED BUT USABLE	CHERNE SEY GATTRUS A SE
SMO BRAKE P 1/3	in L	G0,1,3, 6	PRESSURE >180 PSI IN BRAKES DRIVEN BY HYDRAULIC SYSTEM 1/3	e artiste
2/3		G0,1,3, 6	PRESSURE >180 PSI IN BRAKES DRIVEN BY HYDRAULIC SYSTEM 2/3	



		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE		PASS	BFS		
S66 CAB AIRLK	PRES	S2,4		AIRLOCK P 1	AP AIRLOCK TO AMB (PL)
S66 CAB HX OUT	TEMP	S2,4		CAB HX OUT T	NO MAL (NO LIMITS)
S66 CAB H20 N2	P1(2)	S2,4		H2O TK N2 P ↓	
S66 CAB N2 FLO	1(2)	S2,4		N2 FLOW †	
SM1 CABIN N2			SM		
S66 CAB N2 QTY	1(2)	S2,4		N2 SPLY QTY	
S66 CAB N2 REG	P1(2)	S2,4		N2 REG P ↑↓	
S66 CAB O2 EMR	SPLY	S2,4		EMER 02 QTY AND REG P	EMER 02 MSG ONLY WHEN EMER 02 TK MANIFESTED
S66 CAB O2 FLO	1(2)	S2,4		• 02 FLOW †	a contraction of the contraction
SM1 CABIN 02		01	SM		
S66 CAB O2 REG	P 1(2)	S2,4		• O2 REG P †	
S66 CAB PPCO2		S2,4		PPCO2 †	
S78 CABIN	DP/DT	S2,4		CABIN PRESS RATE OF CHANGE	
S66 CABIN	FAN	S2,4		CABIN FAN ∧P ↑↓	
SM1 CABIN FAN			SM	TAXANT COMPANY AND ALL STOR	A REAL
S66 CABIN	PRES	S2,4		• CAB P 11	
SM1 CABIN PRES			SM		
S66 CABIN	TEMP	S2,4		• CAB T †	
S78 CABIN O2	CONC	S2,4		• 02 CONC 1	NO MAL

MESSAGE		OPS	AVAIL	CAUSE	COMPLETE	
MESSAGE			BFS	CAUSE	COMMENTS	
S66 CABIN PPO2	A(B,C)	S2,4		PPO2 ↑↓	NO MAL	
SM1 CABIN PPO2			SM			
SM1 CABN DP/DT	BU		SM	. S/W CAB P RATE OF CHANGE COMP 1	. NOT IN PRELAUNCH OPS 0	
S78 CABN DP/DT	EQ	S2,4		• EQ CABIN PRESS RATE OF CHANGE		
SM1 CABN DP/DT EQ			SM		That is	
S60 CHECKPT FAIL		S2,4		SM CHECKPOINT FAILED ON WRITE OR RESTORE DUE TO AN I/O FAILURE BETWEEN THE GPC AND MMU, OR MMU WAS OFF/BUSY	ATTEMPT RECOVERY USING MMU MALS	
CIRC PUMP	and the second	S2,4		CIRC PUMP FAILS TO TURN OFF	INHIBITS CONTINUATION OF PUMP CYCLING SEQ	
S87 CIRC PMP P	1(2,3)	S2,4		CIRC PUMP P t		
S67 CNTL BUS	v	S2,4		DC CNTL VOLT		
RPC		S2,4	-	DC CNTL BUS RPC = OFF		
CM BUF BSY	CRT1(2,3,4)	S2,4		DEU IPL REQUEST WHEN THE SM COMMON BUFFER IS CURRENTLY BUSY	NO MAL WAIT FOR CONTENDING OPERATION TO COMPLETE, THEN RETRY THE SN DEU IPL	
SM1 CNTL/ESS V			SM	DC VOLT CNTL DC VOLT ESS		
S66 CO2 RL SYS	MALF	S2,4		EDO CO2 CNTLR 1(2) MALFUNCTION	(0V102 ONLY) MALFUNCTION SIGNAL DURATION IS 6 SEC; RESULTING SPEC 66' 'J' WILL ONLY APPEAR FOR SEC (PNL M051F CONTROLLER FAIL LIGHT WILL REMAIN LATCHED)	

2.2 Caution and Warning System

MESSAGE		OPS	AVAIL	Landa a		
		PASS	BFS	CAUSE	COMMENTS	
S66 CO2 RL SYS	PCO2	S2,4		EDO CO2 RCRS CO2 PARTIAL PRESS †	OV102 ONLY	
S66 CO2 RL SYS	VACP	S2,4			(OV102 ONLY) CURRENTLY NO FDA ANNUNCIATION	
S66 CO2 RL SYS	FAN	S2,4		CHAR REPORT TOOL 400	ANNONCIATION	
S76 COMM CAM	TEMP	S2,4		• TV CAMERA OVERTEMP - YES ↓	CAM TEMP MSG VALID ONLY WHEN CCTV IN SYNC MODE	
PA1	TEMP	S2,4	1000	PWR AMP 1 TEMP 1		
PA2	TEMP	S2,4		PWR AMP 2 TEMP †		
S76 COMSEC 1	BITE	S2,4	7 030.	. COMSEC XMIT AND/OR RCV FAILED		
S76 COMSEC 2	BITE	S2,4		. COMSEC XMIT AND/OR RCV FAILED	COLUMN COLUMN	
CRT BITE	1(2,3,4)	ALL	ALL	A BITE ERROR DETECTED IN INDICATED DEU		
SM2 CRYO H2 MANF			SM	• MANEP ↓	· · · · · · · · · · · · · · · · · · ·	
PRES		2	SM	• TK CNTL P 1		
SM2 CRYO O2 HTR			SM	• TKHTRT †	-	
MANF		1-1-1	SM	■ MANEP↓		
PRES			SM	• TK CNTL P 1	PROPERTY OF THE PROPERTY OF	
DAP RECONF	400 10041 512.00	G2,8		DESELECTION OF ONE OR MORE DOWNFIRING VERNIER JETS	NO MAL IF USING PRI RCS, MSG INDICATES FAILURE OF DOWNFIRING VERN JET W/O DOWNMODING IF USING VERN RCS, OR UPON TRANS FROM PRI TO VERN RCS, DA WILL DOWNMODE TO FREE DRIFT	

MESSAGE	OPS	AVAIL		COMMENTS
MESSAGE	PASS	BFS	CAUSE	
SM1 DC VOLT FC 1(2,3)		SM	• FC VOLT 11	
S69 DELTA AMPS 1(2,3)	S2,4	-	• FC AAMPS 11	
> 3 DEU	ALL	-	• TOO MANY DEUS IN COMMON SET	NO MAL
DISPLAY SW A	G2,8		AFT ADI ERROR/RATE SW AFT ADI ATT SEL SW	NO MAL MAY BE TRIGGERED BY COMM FAULT OR I/O RESET
	G1,2,3, 6,8		LH ADI ERROR/RATE SW H ADI ATT SEL SW LH AIR DATA SW LH AIR DATA SW LH HSI MODE/SOURCE/TRAN SW LH RADAR ALT SW	MOVE APPROPRIATE SW TO GREEN DOT DEFAULT POS AIR DATA/RADAR ALT SW NOT READ IN OPS 1,2 OR 8 FOR PASS
R	G1,2,3, 6,8		RH ADI ERROR/RATE SW RH ADI ATT SEL SW RH AIR DATA SW RH AIR DATA SW RH HSI MODE/SOURCE/TRAN SW RH RADAR ALT SW	
DK XMTR 1(2,3,4)		ALL	BFS DK TRANSMITTER FAILED HIGH ON A PASS CONTROLLED CRT	NO MAL BFS WILL DOWNMODE AFFECTED DK BUS - NO COMMAND/LISTEN CAPABILITY ON THAT BUS ASSIGN BFS TO AFFECTED CRT TO RECOVER BFS COMMAND/LISTEN CAPABILITY BFS IS STILL ENGAGEABLE WITH FULL CAPABILITY
S67 ESS BUS V 1BC(2CA,3AB)	S2,4		DC VOLT ESS	

		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE		PASS	BFS	102 0	
ET SEP	AUTO	G6		ET SEP MODE SW FAIL	NO MAL SW DEFAULTS TO AUTO IN G6
	INH	G1,6	G1,6	• AUTO SEP INH G1 = BODY RATES & FDLN DISC VLVS G6 = BODY RATES, α AND β	NO MAL USE CUE CARDS FOR DISC VLVS
	MAN	G1		• ET SEP SW FAIL (RM)	NO MAL USE SPEC 51 OVERRIDE
S77 EVA-MMU T	PORT	S2,4		MMU/FSS TEMP OUT OF LIMITS	te sust int
S88 EVAP FDLN	TA(B)	S2,4		FDLN FWD,MID,AFT, TOPPING,ACCUM LINE A(B) AND HI LOAD LINE A(B) T 11	FES FEEDLINE TEMPS
S88 EVAP HI LD	TEMP	S2,4	Sec. 1	 FES HI LOAD NOZ AND DUCT T ↑↓ 	• HI LOAD IB/OB DUCT T AND NOZ T
S88 EVAP OUT T	1(2)	S2,4		• OUT T 1	and the state of the second
SM2 EVAP OUT T			SM		The second s
S88 EVAP TOP	TEMP	S2,4		FES TOPPING NOZ AND DUCT T	TOPPING EVAP L(R) FWD(AFT) DUCT T AND L(R) NOZ T
167 EXT A/L	PRES	S2,4		EXT AIRLOCK P	EXTERNAL AIRLOCK ONLY
F RCS	JET		G1,3,6	• F JET MANF 1(2,3.4) FAIL ON/OFF	NO FAIL LK DETECTION IN BFS
	DJET	G1,2,3, 6,8		• F DOWN JET 1(2,3,4) FAIL ON/OFF/LK	FAIL OFF DETECTION NOT PERFORMED IN MM101 & 012 FOR PASS
	FJET	G1,2,3, 6,8		• F FWD JET 1 (2,3) FAIL ON/OFF/LK	
	WET	G1,2,3, 6,8		• F LEFT JET 1(3,5) FAIL ON/OFF/LK	

MESSAGE		OPS	AVAIL	CAUSE	COMMENTS	
MEGGAGE		PASS BFS		CAUSE	COMMENTS	
F RCS (Cont)	RJET	G1,2,3, 6,8		• F RIGHT JET 2(4,5) FAIL ON/OFF/LK	FAIL OFF DETECTION NOT PERFORMED IN MM101 & 102 FOR	
	UJET	G1,2,3, 6,8		• F UP JET 1(2,3) FAIL ON/OFF/LK	PASS	
	He P	G2,8	G1,3,6	• F He (FU OR OX) TK P 2 LOW	PKT C/L - RCS LEAK ISOL	
	LEAK	G2,3,8	G1,3,6	PROP/He LEAK	• OX/FU ∆ QTY > 9.5%	
	PVT	G2,3,8		LOSS OF P OR T DATA FOR RCS QTY CALC	NO MAL QTY CALC SUSPENDED	
Charles of the second	TKP	G2,8	G1,3,6	FWD RCS (FU OR OX) TK ULL PRESS HI/LOW	QTY CALC SUSPENDED	
S69 FC AMPS	1(2,3)	S2,4		• FC AMPS † ↓	and the second of the second second	
SM1 FC AMPS 1(2,3)			SM	AND THE PARTY OF THE REAL PROPERTY OF	ID DATE:	
S69 FC COOL P	1(2,3)	S2,4		• FC COOL P 1	and the second sec	
SM1 FC COOL P 1(2,3)		1.23	SM			
S69 FC DELTA V	1(2,3)	S2,4	-	 FC SUBSTACK ΔV > 150 MV 		
SM1 FC DELTA V 1(2,3)	and the second	No.	SM	in the second second second second	and a second second second second	
S69 FC EXIT T	1(2,3)	S2,4	1000000	• FC EXIT T 1 1		
SM1 FC EXIT T 1 (2,3)		A A A	SM	and the second se	and the second s	
S69 FC H2 FLOW	1(2,3)	S2,4		. FC H2 FLOW †		
S69 FC H2 PUMP	1(2,3)	S2,4		FC H2 PUMP STATUS 1		

MESSAGE		OPS AVAIL		CAUSE	COMMENTS
		PASS	BFS	CAUSE	
S69 FC H2O ALT	1 (2,3)	S2,4	Color a	• FC ALT H2O LN T † 1	A REAL PROPERTY OF THE REAL PR
PRI	1 (2,3)	material and the second		• FC H2O LN T 1 J	and places and a second second second second
RLF	and the second sec	S2,4	hazar	FC H2O RLF VLV T †	LIAI BTM
	HTR	S2,4		• FC H2O RLF HTR STATUS A,B 1	BOTH HTRS OFF OR BOTH HTRS INDICATING AUTO WILL ANNUNCIATE ALARM
	LINE	S2,4	A Course of	FC H2O RLF LN T †	
1.	NOZ	S2,4		FC H2O RLF NOZ T A(B) †	
S69 FC O2 FLOW	1(2,3)	S2,4		FC 02 FLOW †	T MUR
S69 FC PH	1(2,3)	S2,4	Carter of	FC PH – PH↓	PH > BILEVEL
SM1 FC PH 1 (2,3)		- Hereit	SM	• FC PH HIGH	LIATE
S69 FC PRG LN	H2	S2,4	C Palan	• FC H2 PURGE LN T 1(2) †	ATE E
	02	S2,4		FC 02 PURGE LN T †	- 44411
S69 FC PUMP	1(2,3)	S2,4	- Anna Parto	 FC COOL PUMP △P↓ 	1. 1. 1 P
SM1 FC PUMP 1 (2,3)	1441	he we a	SM	Press Brichmann Andrew Mart	I have the second second second second
FC PURGE	1(2,3)	S2,4	001	FAILS FLOW CHECK AT PURGES AT END OF PURGE	USE MAN FC PURGE PROC
	SEQ	S2,4	1 and a	LOSS OF PWR TO PURGE LN HTRS AFTER AUTO SEQ INIT OR LOSS OF SWITCH FUNCTION	USE MAN FC PURGE PROC SEQ FAIL FLAG TERMINATES AUTO PURGE SEQ
	TEMP	\$2,4	The second	FC PURGE LINE TEMP TOO LOW TO PERFORM AUTO PURGE	TERMINATES AUTO PURGE USE MAN FC PURGE PROC
S69 FC REAC	1(2,3)	S2,4	malania	• FC REAC ↓	FC REAC VLV - CL
SM1 FC REAC 1(2,3)			SM		
S69 FC READY	1(2,3)	S2.4	-	• FC READY L	and the second second of the second second

MESSAGE		OPS	AVAIL	CAUSE	0011115150
WESSAGE		PASS	BFS	CAUSE	COMMENTS
S69 FC STACK T	1(2,3)	S2,4	10.00	FC STACK T ↑↓	
SM1 FC STACK T 1(2,3)		Stand -	SM	when the set of the set of the set of the	The seal of the se
S69 FC VOLTS	1(2,3)	S2,4		FC VOLT	The seal work of the second seal and
FCS CH	1(2,3,4)	G1	G1	SRB CHANNEL BYPASS	NO MAL ROCK & TILT ACT A(B,C,D) CH FAIL
		G1,3,6	G1,6	MPS CHANNEL BYPASS	NO MAL MPS ENG PITCH(YAW) CH FAIL
		G1,3,6	G1,3,6	AERO CHANNEL BYPASS	NO MAL ELEV (RUD,S/B) ACT CH FAIL
FCS SAT	POS	G3,6	G3,6	L/R IB/OB ELEVON POSITION SATURATION	NO MAL ELEVON SAT (>+12 OR <-15 DEG)
	MOM	G3,6	G3,6	L/R IB/OB PRI DELTA PRESS	NO MAL IN RTLS EXPECT HINGE MOM > 2400 PSI (80% SYS MAX)
S67 FPC/FLC	1(2,3)	S2,4		• FWD PCA V ↓	Sector Se
S88 FREON FLOW	1(2)	S2,4	124000	• FLOW ↓	FCL ICH FLOW
SM2 FREON FLOW			SM	H VIDENSE M	8 Page 10 granting
S88 FREON QTY	1(2)	S2,4		· ACCUM QTY 1	FREON LOOP ACCUM QTY
S88 FREON RAD	T1(2)	S2,4	and the second second	CNTL OUT T 1(2) ↓	RAD CONTROLLER OUT TEMP
S88 FRN AFT CP	1(2)	S2,4		AFT CP FREON FLOW	AFT CP FLOW
S88 FRN PL HX	1(2)	S2,4		PL HX FREON FLOW	PL HX FLOW
S86 FU TK VLV	1(2,3)	S2,4		APU FUEL TANK VLV TEMP	
SM2 FU TK VLV APU			SM		



		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE		PASS	BFS	0,000	
S76 GCIL	FAIL	S2,4	-	GCIL CONFIG FAILED TO PNL	Carlos Contra
S86 GG/FU PMP	1(2,3)	S2,4		APU GG BED T	
GPC	BITE	ALL	ALL	S/W FORCED CLOSED PROCESS DUE TO GPC H/W (S/W) FAULT	• IN PASS
		State Provide		BFS RESTART INDICATION	IN BFS
	CONF	ALL		NBAT TGT GPCs NOT IN RUN OR NOT SPECIFIED	NO MAL PROCEDURAL ERROR OR SWITCH ERROR
	SUM	-	ALL	BFS GPC FAIL: CHECKSUM	10 10 10 10 10 10 10 10 10 10 10 10 10 1
	1	ALL		INDICATED GPC HAS FAILED	The second se
	2	ALL		ALL PROPERTY AND	
	3	ALL		a set of the set of the set of the set	Stat SH HJ LASS DAVE
	4	ALL			1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
	5	ALL		GPC 5 HAS FAILED	NO MAL
GPC PWR	and the second	lin	ALL	PWR TRANSITIONS TO BFS GPC	NO MAL BFS WILL DISENGAGE S/W DOES AUTO RESTART
668 H2 CNTL P	1 (2,3,4,5)	S2,4		• CNTL P †↓	Entrance (and) have the
HTR T	1 (2,3,4,5)	S2,4		• HTR T †	
MANF	PRES	S2,4		● MANF P↓	THE MARTY
	VLV	S2,4		MANF VLV = CL	
TKP	1 (2,3,4,5)	S2,4		• TK P †↓	

MESSAGE		OPS AVAIL PASS BFS		041105	
				CAUSE	COMMENTS
168 H2 CNTL P	6(7,8,9)	S2,4		CNTL P †	the second se
HTR T	6(7,8,9)	S2,4		• HTR T †	
TKP	6(7,8,9)	S2,4		• TKP †↓	and the second second second second second
S69 H2O LN PH		S2,4	-	• H2O LINE PH ↓	PH > 9 BILEVEL
S88 H20 LOOP 1 (2)	FLOW	S2,4		● ICH FLOW ↓	ACTIVE LOOP ONLY
	QTY	S2,4		· ACCUM QTY 11	
DISTURDED AND A	TEMP	S2,4		PUMP OUT T 14 CAB HX IN T 1 ICH OUT T1	H2O LOOP TEMPS
S88 H2O PUMP P	1(2)	S2,4		• P 1(2) ↑↓ OR △P 1(2) ↑↓	● ΔP HIGH ONLY FOR INACTIVE LOOP
SM2 H2O PUMP P			SM		• ΔP HIGH OR LOW FOR ACTIVE LOOP
HIGH G	77611001	G3,6		• HIGH G	NO MAL
S66 HUMID SEP	A(B)	S2,4		• HUM SEP SPEED J	
SM2 HYD ACUM P 1(2,3)			SM	ACCUM P	
S86 HYD PRESS	1(2,3)	S2,4	-	. HYD SYS SPLY P 1	NO MAL
SM2 HYD PRESS			SM		- NO MAL
SM2 HYD QTY 1 (2,3)			SM	• RSVR QTY 1	WOLFRED WOLFER
S86 HYD RSVR Q	1(2,3)	S2,4		• RSVR QTY 1	2 1930 19 19 19 19 19 19 19 19 19 19 19 19 19
S86 HYD RSVR T	1(2,3)	S2,4		• RSVR T Lt	Statistics and statistics and statistics
SM2 HYD RSVR T 1 (2,3)		1000	SM		A PARTICIPAL CARLING

CAUSE COMMENTS

MESSAGE				CALICE	TO REAL PROPERTY AND A DECIMAL OF A DECIMA OF A DECIMAL OF A DECIMAL O
·		PASS BFS		CAUSE	COMMENTS
ILLEGAL ENTRY		ALL	L ALL	ILLEGAL KYBD ENTRY WITH RESPECT TO OPS SELECT/TRANSITION, DATA LOAD, INITIALIZATION, MEM RECONFIG, GPC ASSIGN, KYBD SYNTAX, FREEZE DRY LOAD, ETC	NO MAL IF APPROPRIATE, KYBD INPUT SHOULD BE REENTERED
S66 IMU FAN	DP :	S2,4		 IMU FAN ΔP ↑↓ 	
SM1 CABIN IMU		-	SM		
S66 IMU FN SPD	A(B,C)	S2,4	XLARK	IMU FAN SPEED ↓	
I/O ERROR	CRT1	ALL	ALL	• ERROR IN DEU 1 (2,3,4) MSG (I/O OR	
	CRT2	ALL	ALL	CHECKSUM)	
	CRT3	ALL	ALL		
	CRT4	ALL	ALL		
	D/L	ALL		I/O ERROR ON DOWNLIST INTERFACE WITH PCMMU	
	FA1	G1,2,3, 6,8	G0,1,3, 6	INDICATED UNIT HAS BEEN	BFS PRE-ENGAGE MUST BE IN SYNC WITH (TRACKING) PASS TO
	FA2	G1,2,3, 6,8	G0,1,3, 6	DETECTED	ANNUNCIATE
	FA3	G1,2,3, 6,8	G0,1,3, 6	man see the lot	DALAY SER MAN NAS
CALL THE REPORT	FA4	G1,2,3, 6,8	G0,1,3, 6	Assessment of the second	

OPS AVAIL

MESSAGE

MESSAGE		OPS	AVAIL	04105	
MESSAGE		PASS	BFS	CAUSE	COMMENTS
ITEM RJCT PSP) MAL	S2,4	1014 M 10	PCP CC CMD REJECTED DUE TO PSP CMD DATA TRANSMISSION IN PROGRESS	• NO MAL
S76 KU-GMBL A	TEMP	S2,4		KU GMBL A TEMP †	a second and a second as a
GMBL B	TEMP	S2,4		KU GMBL B TEMP †	no Pago
GYRO	TEMP	S2,4	-	KU GYRO TEMP †	
XMTR	TEMP	S2,4		KU XMTR TEMP †	C- on on another second
LOMS	GMBL	G1,2,3	G1,3	 PITCH (YAW) CMD/FEEDBACK Δ2° FOR 3.8 SEC 	• NO MAL
	PC	G1,2,3, 6	G1,3,6	ENG CHAMBER PRESS LOW	
	QTY	G1,2,3, 6,8		ENG FU OR OX TK LEVEL LOW	
	TEMP		G1,3	ENG FU INJ T HI	and a second second second
	TKP	G2,8	G1,3	• FU OR OX TK ULLAGE P HI/LOW	Service Proved and Loss
	A ALL		G1,3,6	He OR N2 TK P LOW N2 REG P HI/LOW	
	VLV	G2	the many	He P/VAP ISOL VLV MISMATCH	• NO MAL
S89 L OMS	TEMP	S2,4	10	ENG FU INJ T HI/LOW	NO MAL



		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE	MESSAGE		BFS	2245 224	
L RCS	JET	1000	G1,3,6	LEFT JET MANF 1(2,3,4) FAIL ON/OFF	NO FAIL LK DETECTION IN BFS
The set of the state	AJET	G1,2,3, 6,8	1	LAFT JET 1(3) FAIL ON/OFF/LK	FAIL OFF DETECTION NOT PERFORMED IN MM101 & 102 FOR PASS
	DJET	G1,2,3, 6,8	-2 040	L DOWN JET 2(3,4,5) FAIL ON/OFF/LK	PASS
	LJET	G1,2,3, 6,8		• L LEFT JET 1(2,3,4,5) FAIL ON/OFF/LK	The contract of the
	UJET	G1,2,3, 6,8		L UP JET 1(2,4) FAIL ON/OFF/LK	RD-MARKEN CONTRACTOR
	He P	G2,8	G1,3,6	 L RCS AFT He (FU OR OX) TK PRESS – 2 LOW 	• PKT C/L - RCS LEAK ISOL
	LEAK	G2,3,8	G1,3,6	PROP/He LEAK	 OX/FU AQTY > 9.5%
	PVT	G2,3,8		LOSS OF P OR T DATA FOR RCS QTY CALC	NO MAL QTY CALC SUSPENDED
	TKP	G2,8	G1,2,3, 6	L RCS AFT (FU OR OX) TK ULL PRESS HI/LOW	19 mg
	XFEED	G1,3,6		L RCS PROP TANK LOW PRESS	FAILURE ON LEFT SIDE, AUTO XFEED FROM RIGHT
67 MAIN BUS V	A(B,C)	S2,4		• MN VOLTS †↓	
SM1 MAIN BUS V A(B,C)			SM		AT ANY

MESSAGE		OPS	AVAIL	01105	00111151150
		PASS BFS		CAUSE	COMMENTS
MPS DATA	C(L,R)	G1,6	G1,6	DATA PATH FAIL	NO MAL REF AESP CUE CARDS
MPS ELEC	C(L,R)	G1,6	G1,6	ELECTRONIC LOCKUP MODE FAIL	NO MAL REF AESP CUE CARDS
MPS H2 OUT P C(L,R)	-		G1,6	PREMATURE SSME SHUTDOWN MPS GH2 OUT P ↓	NO MAL REF AESP CUE CARDS
MPS HYD	C(L,R)	G1,6	G1,6	HYD LOCKUP MODE FAIL	NO MAL REF AESP CUE CARDS
MPS He P C(L, R)			G1,6	MPS He TK P HI/LOW HI LEAK RATE dP/dT	NO MAL REF AESP, APCL
			G1,3,6	INDICATED REG P HI/LOW	NO MAL REF AESP, APCL, EPCL
MPS LH2/02 MANF			G1,6	MPS LH2 ENG MANF P HI MPS LOX ENG MANF P HI	NO MAL REF AESP CUE CARDS
ULL	-		G1,6	• ET ULL P HI/LO	
MPS O2 OUT T C(L,R)			G1,6	PREMATURE SSME SHUTDOWN MPS GO2 OUT T ↓	NO MAL REF AESP CUE CARDS
MPS PNEU ACUM			G1,6	MPS PNEU ACUM PRESS LOW	NO MAL REF AESP CUE CARDS
REG			G1,3,6	MPS PNEU REG PRESS HI/LOW	NO MAL REF AESP, APCL, EPCL
ТК	- Maria	Ra	G1,6	MPS PNEU TANK PRESS LOW	NO MAL REF AESP CUE CARDS
NAV EDIT		G2		RNDZ NAV EDIT	• NO MAL
			G3,6	DRAG H, ADTA, OR TACAN NAV EDIT	BFS DOES NOT SUPPORT MLS NO MAL

MESSAGE NAV EDIT ALT (Cont)		OPS AVAIL		MARKING MARKING	
		PASS	BFS	CAUSE	COMMENTS
		G3,6		ADTA ALT DATA NOT PROCESSING AD2.5 DRAG H DATA NOT PROCESSING 85.2K FT < H < 140K FT	NO MAL MLS NAV EDIT MESSAGE (MLSNV) SEEN ONLY ON HUD
IP FAIL	TAC	G3,6		TACAN DATA NOT PROCESSING < 140K FT	NO MAL
S76 NSP 1	BITE	S2,4	1	NSP A/G 1 OR 2 XMIT AND/OR RCV VOICE MUX FAILED	
S76 NSP 2	BITE	S2,4	P. (PCA)	NSP A/G 1 OR 2 XMIT AND/OR RCV VOICE MUX FAILED	
S68 O2 CNTL P	1 (2,3,4,5)	S2,4		• CNTL P 1	1.1.1.1.1.1
HTR T	1 (2,3,4,5)	S2,4	12000	• HTR T †	- 198
TRP	1 (2,3,4,5)	S2,4		HTR CUR SNSR = TRIP	
MANF	PRES	S2,4	1	• MANF P L	CALL OF THE OWNER OF
	VLV	S2,4		MANF VLV = CL	a sea water and the second second second
TK P	1 (2,3,4,5)	S2,4	Sec.	• TKP 1	
168 O2 CNTL P	6(7,8,9)	S2,4	1. 10 10	• CNTL P 1	1-
HTRT	6(7,8,9)	S2,4	1	• HTR T †	
TRP	6(7,8,9)	S2,4	and the second second	HTR CUR SNSR = TRIP	
TKP	6(7,8,9)	S2,4	- Andrews	• TKP 1	
OFF/BUSY MMU	1(2)	ALL	TA OK	AN MMU TRANSACTION IS REQUESTED WHEN THE MMU IS OFF/BUSY, FAILED OFF, OR SELECTED FOR IPL	

MESSAGE	OPS	AVAIL			
MESSAGE	PASS	BFS	CAUSE	COMMENTS	
G23 OMS/RCS Q	TY G2		L(R) OMS TO RCS PROP TRANSFER EXCEEDS LIMIT	NO MAL	
OTT ST IN	G3,6	G3,6	INDICATED E/W LVL LESS THAN LVL REQD FOR OVHD APPROACH	NO MAL MSG TERMINATES < 45 NM FROM LD OR E/W LVL AGAIN MATCHES PROFILE	
S76 PA1 OUTPUT LC	W \$2,4	State of	PWR AMP OUTPUT	THE PARTY OF THE PARTY	
S76 PA2 OUTPUT LC	W S2,4	and the second second	PWR AMP OUTPUT		
168 PALLET H2 PRES		\$3,6	• H2 TK 6 (7,8,9) CNTL P 1		
TK P	NC 124.50	S3,6	• H2 TK 6 (7,8,9) TK P ↑↓	-	
O2 HTR	- Sinner	S3,6	• O2 TK 6 (7,8,9) HTR T †		
PRES		S3,6	• O2 TK 6 (7,8,9) CNTL P ↑↓		
TK P		S3,6	• O2 TK 6 (7,8,9) TK P ↑↓		
T	S2,4	Contraction of the	PALLET T	TENTEDAL THE TOTAL STREET	
V	A S2,4		PALLET V A	The open	
	B S2,4	-	• PALLET V B L		
PBD CONFIG	S2,4		PLBD OUT-OF-SEQUENCE CONFIG	CAUSES TERMINATION OF AUTO	
S63 PBD CONFIG	a la la	SM	PACIFIC PROPERTY AND A	SEQUENCE	
PBD CONFIG	S2,4	1	PLBD AUTO SEQ FAIL	CAUSES TERMINATION OF AUTO	
S63 PBD CONFIG		SM		SEQUENCE	

		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE		PASS	BFS	UNCOL	
S62 PDI DECOM FAIL		S2,4		DECOM 1 FMT 1 DECOM 2 FMT 1 DECOM 3 FMT 1 DECOM 3 FMT 1 DECOM 4 FMT 1	MSG OCCURS IF DECOM FDA ENA AND PL TLM FAIL OR PDI DECOM FAILS MSG ALSO OCCURS IF PL DEPLOYED PI FAIL, OR PSP FAIL
S96 PDRS ABE	COMM	S2,4		ABE/MCIU MISCOMPARE	
	JPC1	S2,4		SHOULDER JPC FAIL	A large aces
	JPC2	S2,4		WRIST JPC FAIL	
	SP EP WP WR	S2,4		SPA PWR (COMMUTATOR, MDA) FAIL TACH/PHASE LOCK LOOP FAIL	AUTO BRAKES APPLIED
S96 PDRS CKCRT	D	S2,4		D&C COMM FAIL	AUTO BRAKES APPLIED
SY SP EP WP WY WR EE	SP EP WP WY	S2,4		TACH/ENCODER DATA FAIL JOINT ENCODER FAIL	DNMODE TO IDLE IF IN AUTO MODE
	EE	S2,4		• EE CMDS ↓, EE FLAG ↓, EEEU FAIL ↓	the second se
	TCK	S2,4		MCIU TEMP MONITOR CIRCUIT FAIL	and the second se
	FS	S2,4		MCIU EXTERNAL FRAME SYNC BITE OR BITE VERIFICATION FAILURE	
	нс	S2,4		RHC (THC) HARDOVER (ANY AXIS) MCIU HC ↓ (MULTIPLEXER MISMATCH)	S/W DOWNMODE TO IDLE IF IN MANUAL (TEST)

MESSAGE		OPS AVAIL		CAUSE	
	PASS	BFS	COMMENTS		
PDRS TEST	BRK C/W NMI FS LOSS	S2,4		MCIU BITE VERIFICATION TEST FAILURE	4 TE 10
PDRS CNTL	SYP EPP WPY WR	S2,4		CONSISTENCY CK – JOINT RUNAWAY TACH DATA FAIL	AUTO BRAKES APPLIED
PDRS DERIG		S2,4		UNCOMMANDED DERIGIDIZE	POSSIBLE EE STRUCT FAIL
S94 PDRS GPC		S2,4		MCIU-DETECTED GPC COMM FAIL	MCIU SAFING COMMANDED S/W DNMODE TO 'SUSPEND'
S96 PDRS MCIU	MADC	S2,4		MADC REF VOLT TEST FAIL	AUTO BRAKES APPLIED
	MCPC	S2,4		MCPC REF VOLT TEST FAIL	AUTO BRAKES APPLIED
	ICF	S2,4		• ICF FAIL	AUTO BRAKES APPLIED (MAY NOT BE IND)
PDRS RCH	SP EP WP WR	S2,4		JOINT EXCEEDS POS OR NEG RCH LIMIT	APPROX 2° PRIOR TO S/W STOP APPROX 4° PRIOR TO HARDSTOP
PDRS REL		S2,4		UNCOMMANDED P/L RELEASE	POSSIBLE EE STRUCT FAIL

2.2 Caution and Warning System

MESSAGE	OPS	AVAIL	OPS A SAL	
MECOAGE	PASS	BFS	CAUSE	COMMENTS
PDRS SING SY	S2,4	214	• SY/WY WITHIN 3 FT OF COALIGNMENT	LOSE ±Y DEG OF FREEDOM AT SINGULARITY
EP	S2,4		• EP > -7.6°	LOSE -X DEG OF FREEDOM AT SINGULARITY
WY	S2,4	9-0.7 9	• WY WITHIN ±15° OF ±90° SING	LOSE ROLL DEG OF FREEDOM AT SINGULARITY
S96 PDRS SLIP SY SP EP WP WY WR ALL	S2,4	200	JOINT SLIPPAGE WITH THE BRAKES ON AND NOT IN DIRECT MODE	SLIPPAGE GREATER THAN 0.5° PER JOINT OR SUM OF 2.0° FOR ALL JOINTS
PDRS TEMP PORT STBD	S2,4	52563	JOINT/EE TEMP OUT OF LIMITS	
S94 PDRS WR R	S2,4	REIN	PDRS WRIST ROLL RANGE CHECK FAILURE	a ave
206 PL CL2	7	SM		SEE ASCENT/ENTRY SYSTEMS PROCEDURES (SPACELAB MODULE CONFIGURATION ONLY)
PL CL3	10-11	SM	AUX BUS A/B U/V ↓ SS INV IN AMPS 1 SS TEMP 1 EXP INV IN AMPS 1 EXP TEMP 1 SS AC ΦA(B,C) V 1↓ MAIN BUS V	SEE ASCENT/ENTRY SYSTEMS PROCEDURES

MESSAGE		OPS	AVAIL	011105		
a had not been a loss many similar		PASS	BFS	CAUSE	COMMENTS	
PNLTRIM	L(R)	G3,6		• LH(RH) +/- P/R/Y TRIM SW DISAGREE	NO MAL	
PROBES	VA JADOG	G3,6		EITHER ADTA PROBE NOT DEPLOYED DURING 1 < M < 2.5	• NO MAL	
S89 PRPLT THRM	OMS	S2,4	ARISON	OX(FU) LN STRUCT T HI/LOW		
	POD	S2,4		PROP AND STRUCT T HI/LOW	0 2.04	
VERO DE CIPCE D'ALL	RCS	S2,4		• FWD AND L/R RCS STRUCT T HI/LOW	1	
ROMS	GMBL	G1,2,3	G1,3	• PITCH (YAW) CMD/FEEDBACK 12° FOR 3.8 SEC	• NO MAL	
	PC	G1,2,3, 6	G1,3,6	ENG CHAMBER PRESS LOW		
	QTY	G1,2,3, 6,8	Toran	• FU OR OX TK LEVEL LOW	TRA	
	TEMP		G1,3	• ENG FU INJ T HI		
	TKP	G2,8	G1,3	• FU OR OX TK ULLAGE P HI/LOW		
		-	G1,3,6	He OR N2 TK P LOW N2 REG P HI/LOW	ROLL NO.	
	VLV	G2		OMS R POD He/P VAP ISOL VLV MISMATCH	• NO MAL	
S89 R OMS	TEMP	S2,4	FELINIS	ENG FU INJ T HI/LOW	NO MAL	



		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE			BFS	CAUSE	COMMENTO
R RCS	JET		G1,3,6	• RIGHT JET MANF 1(2,3,4) FAIL ON/OFF	NO FAIL LK DETECTION IN BFS
	AJET	G1,2,3, 6,8		RAFT JET 1(3) FAIL ON/OFF/LK	FAILED OFF DETECTION NOT PERFORMED IN MM101 & 102 FOR PASS
	DJET	G1,2,3, 6,8		R DOWN JET 2(3,4,5) FAIL ON/OFF/LK	
	RJET	G1,2,3, 6,8		• R RIGHT JET 1(2,3,4,5) FAIL ON/OFF/LK	No You And And And
	UJET	G1,2,3, 6,8		• R UP JET 1(2,4) FAIL ON/OFF/LK	A State Street & Frank
	He P	G2,8	G1,3,6	 R RCS AFT He (FU OR OX) TK PRESS – 2 LOW 	• PKT C/L - RCS LEAK ISOL
	LEAK	G2,3,8	G1,3,6	PROP/He LEAK	• OX/FU ΔQTY > 9.5%
	PVT	G2,3,8		LOSS OF P OR T DATA FOR RCS QTY CALC	NO MAL QTY CALC SUSPENDED
Т	TKP	G2,8	G1,3,6	• R RCS AFT (FU OR OX) TK ULL PRESS HI/LOW	
and when the	XFEED	G1,3,6		R RCS PROP TANK LOW PRESS	FAILURE ON RIGHT SIDE, AUTO XFEED FROM LEFT
23 RCS SYSTEM F(L,F	F(L,R)	G2,8		• F(L,R) RCS FU OR OX TK TEMP	the second s
		G2,8		• F(L,R) RCS FU OR OX TK OUT PRESS	
RCS PWR	FAIL	G1,2,3, 6,8		LOSS OF VLV LOGIC PWR TO MANF ISOL VLVs	 OMS/RCS VLVs WITH tb - bp STUCK IN CURRENT POSITION

MESSAGE		OPS	AVAIL	04105	
		PASS	BFS	CAUSE	COMMENTS
RM FAIL	ACC	G1,3,6		• FAIL	NO MAL DES/SEL AVAILABLE
	ADTA	G3,6	G3,6	• FAIL	NO MAL DES/SEL AVAILABLE
	IMU	G1,2,3 6,8	G1,3,6	FAIL COMM FAULT CAUSES BFS RM FAIL	NO MAL DES/SEL AVAILABLE
		G3,6		• FAIL	NO MAL DES/SEL AVAILABLE OPS 8 ONLY NO CRT DATA OPS 3
		G1,3,6		• FAIL	NO MAL DES/SEL AVAILABLE
		G3,6		• FAIL	NO MAL DES/SEL AVAILABLE
	XFER		G1,3,6	BFS NOT RECEIVE STATE VECTOR OR REFSMAT	• NO MAL
G33 RNDZ RADAR		G2		KU-BAND BREAKS TRACK WITH RADAR TARGET (GPC ANT STEERING MODE ONLY)	• NO MAL
ROLL REF		G3	G3	REF ROLL STATUS FAIL	• NO MAL
S86 RSVR/ACC P	1(2,3)	S2,4		RSVR P ↓ ACCUM P ↓	• NO MAL
SBTC/THC	A	G2,8		AFT THC POS/NEG X/Y/Z OUTPUT A/B/C FAIL AFT THC POS/NEG X/Y/Z OUTPUT DISAGREE	• NO MAL
	L	G3,6		L SBTC CMD A(B,C) FAIL L SBTC CMD A(B,C) DISAGREE	

MESSAGE	OPS	AVAIL		- VECTOR CONTRACTOR OF AND
	PASS	BFS	CAUSE	COMMENTS
SBTC/THC L	G2,3,8		FWD THC POS/NEG X/Y/Z OUTPUT A/B/C FAIL FWD THC POS/NEG X/Y/Z OUTPUT DISAGREE	• NO MAL
R	G3,6		R SBTC CMD A(B,C) FAIL R SBTC CMD A(B,C) DISAGREE	The second s
SEL AUTO	G2		UNIV PTG MNVR T-30 & NOT AUTO	NO MAL
SENSE SW	G2		AFT SENSE SW DEFAULT	NO MAL DEFAULT POS IS '-Z'
212 SL LINK ERR	S2,4		ANY OF THE FOLLOWING MDM SERIAL I/O LINK EAROR CONDITIONS OCCURRED FOR SSC OR EXC: NO SL RESP GPC NO MATCH SL LENGTH AR NO MATCH SR NO MATCH MSG REJECT (ITEM OR GNC) MSG LINK BUSY MSG LINK DSBL	• SL MAL, <u>CDMS</u> , MDM/MTU/PCMMU
212 SL LINK TERM	S2,4	TAT	MDM SERIAL I/O LINK TO SPACELAB TERMINATED. CAUSED BY ANY OF THE FOLLOWING FOR SSC OR EXC: NOP IND COMM UNK INTRPT	 SL MAL, <u>CDMS</u>, MDM/MTU/PCMMU
SM1 SMOKE ALRM		SM	ANY SMOKE CONC †	

MESSAGE		OPS	AVAIL	041105		
CONNERSION		PASS	BFS	CAUSE	COMMENTS	
SM1 SMOKE BAY	1A	S2,4		AV BAY 1 SENSOR A CONC †	• NO MAL	
	1B	S2,4		AV BAY 1 SENSOR B CONC †		
	2A	S2,4		AV BAY 2 SENSOR A CONC †		
	2B	S2,4		AV BAY 2 SENSOR B CONC †		
	AE	S2,4		AV BAY 3 SENSOR A CONC †	and the rest of the second sec	
	3B	S2,4		AV BAY 3 SENSOR B CONC †	A A A A A A A A A A A A A A A A A A A	
SM1 SMOKE CAB	LFD	S2,4		LEFT FLT DECK SMOKE CONC †	NO MAL	
	RFD	S2,4	100	RIGHT FLT DECK SMOKE CONC †	1	
and the second sec	HX	S2,4		• RETURN AIR CAB HX SMOKE CONC †	La l'une	
SPD BRK		G3,6		SPEED BRAKE POSITION > 20% FROM AUTO SCHEDULE DURING 0.95 < M < 9.8	NO MAL	
S66 SPLY H2O	PRES	S2,4		SUPPLY H2O IN P 11		
	QTY	S2.4		• SUPPLY QTY TK A(B,C,D) \$ C(D) \$	22 Y 19 CT 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
	TEMP	S2,4		SPLY DUMP LINE T ↑↓ SPLY NOZ T A(B) ↑		
SSME FAIL	C(L,R)	G1,6	G1,6	PREMATURE ME SHUTDOWN	 IN MM101, MSG ANNUNCIATED BY BFS ONLY 	
SSME REPOS FAIL		G3	G3	MORE THAN ONE MPS/TVC ISOL VLV FAILED TO INDICATE OPEN LESS THAN TWO APU/HYD SYSTEMS INDICATED GOOD	NO MAL SSME REPOSITIONING FOR DRAG CHUTE DEPLOY IS NOT COMPLETE MM304 AND 3.5 < MACH < 8	



	OPS	AVAIL	CAUSE	COMMENTS
MESSAGE	PASS	BFS		
SUMWORD ICC 1(2,3,4,5)	ALL		SUMWORD MISCOMPARE IN DATA FROM INDICATED GPC	
SW TO MEP	G3,6	G3	MEP ALERT	NO MAL
TFL LOAD FAIL	S2,4	ALL	READ COMPARE ERROR UNSUCCESSFUL LOAD	NO MAL MAY BE RESULT OF GROUND UPLINK
τστ Δτ	G2		REQUESTED TRANSFER TIME CAUSED SINGULARITY IN TARGETING ALGORITHM	00000000 Wid Samo
TGT EL ANG	G2		EXCEEDED MAX NUMBER OF ITERATIONS ON TPI TIG FOR GIVEN ELEVATION ANGLE	• NO MAL
TGT ITER	G2		LAMBERT TGT TRANSFER ANGLE NEAR SINGULARITY POINT PARABOLIC TRANSFER MAX NUMBER OF ITERATIONS	
S87 THERMAL HYD	S2.4		• HX OUT T L	
S87 THERMAL CNTL 1(2,3)	S2,4		LN T ELEV RD/SPBK/BDY FLP ↑↓	HYD CIRC PUMP NOT MAINTAINING HYD THERMAL ENVIR
SMOTHRM APU		SM	• GG BED 1, APU INJ T 1	APCL, EPCL - THERM HTR
APU		SM	APU FU FEED LN T † 1, PUMP IN T † 1, PUMP OUT T † 1, FU TEST LN T † 1, FU SERVICE LN T † 1, PUMP DAN LN T † 1, PUMP BYP LN T † 1, GGVM SPLY LN T † 1, H2O LN INJ † 1	
EVAP		a	• FES NOZ, DUCT OR FDLN T 1	ONLY SELECTED DUCTS AND FDLN Ts ARE SENSED FOR STATUS

MESSAGE		OPS	AVAIL	CAUSE	COMMENTS
MESSAGE		PASS BFS		CAUSE	COMMENTS
SM0 THRM FRN (Cont)			SM	ACCUM QTY I BAD OUT T † I	NO ASC/ENT PKT C/L
H2O			a	H2O SPLY IN P 11	
HYD			a	• H2O BLR T † I	NO MAL APCL, EPCL - THERM HTR
PRPLT			a	OMS FU/OX BLD/DRAIN LN T OMS POD RCS HOUSING OMS RCS STRUCT T OX ENG IN OR ENG FU FDLN T	
TIME	MTU	ALL		AUTOMATIC TIME SOURCE CHANGE	
	TONE	ALL		TIME MGT TIME TONE	NO MAL
SM0 TIRE PRESS			G3,6	NOSE GEAR/MLG TIRE PRESS ↓	
S66 VAC VNT NZ	TEMP	S2,4		VACUUM VENT NOZ T	NO MAL (NO LIMITS)
SM2 W/B QTY 1 (2,3)			SM	. HYD SYS H20 BOILER FLUID QTY 40%	
S66 WASTE H2O	PRES	S2,4		WASTELIQP 1	CONTRACT.
	QTY	S2,4	1000	WASTE QTY 11	NO MAL FOR QTY HIGH
and the second second second	TEMP	S2,4		WASTE NOZ T 11 DUMPLINE T 11	
S86 WSB P	1(2,3)	S2,4		• REG P 11 • N2 P 1	
Q	1(2,3)	S2,4		• H20 QTY	
Т	1(2,3)	S2,4		• TKT J • BLRT †J	

2.3 CLOSED CIRCUIT TELEVISION (CCTV)

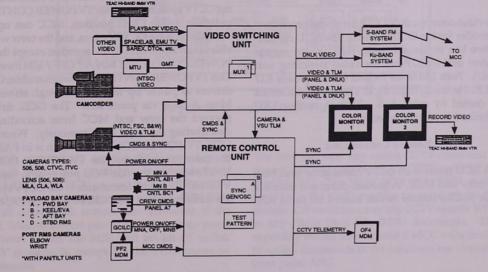
Contents	
Description	2.3-1
Video Processing Equipment	2.3-2
CCTV Cameras	2.3-7
CCTV Camera Lens Control	2.3-11
Pan/Tilt Units (PTUs)	2.3-12
Cabin Cameras	2.3-12
Video Tape Recorders (VTRs)	2.3-15
Special Purpose Video	2.3-17
Monitors	2.3-18
Payload Bay Camera Operations	2.3-20
CCTV Accessories	2.3-21
CCTV System Summary	2.3-22

Description

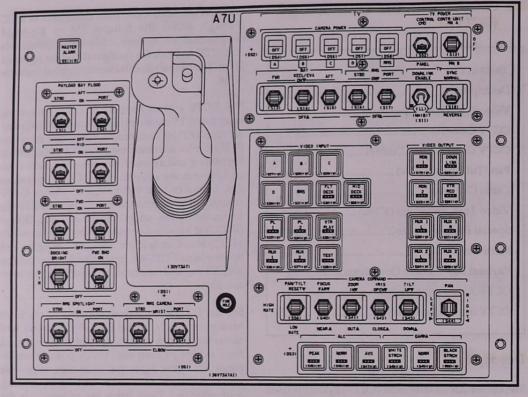
The closed circuit television (CCTV) system is used on orbit to provide support to orbiter and payload activities. This support includes transmitting realtime and recorded video from the orbiter to MCC through either the S-band FM or Ku-band communications systems. Mission requirements for CCTV and camera configurations are specified in the Flight Requirements Document for each shuttle flight.

The CCTV system consists of video processing equipment, TV cameras (and lens assemblies), pan/ tilt units (PTUs), camcorders, video tape recorders (VTRs), color television monitors (CTVMs), and all the cabling and accessories required to make thesecomponents work together. All CCTV operations can be controlled by the crew. Most CCTV configuration commands can be executed by the Instrumentation and Communications Officer (INCO) at Mission Control. Among the commands MCC cannot uplink are those to configure and operate loose CCTV equipment, such as camcorders and VTRs, and selection of inputs to the color monitors.

Standard CCTV components are powered via circuit breakers located on panel R14. Flight specific keel cameras (prox ops or berthing) are usually powered from a cabin payload bus. CCTV pushbuttons on panel A7U have lights that illuminate to provide visual feedback on camera and CCTV routing configuration. These lights are powered via the ANNUNCIATOR light switches located on panel A6U.



CCTV System Overview



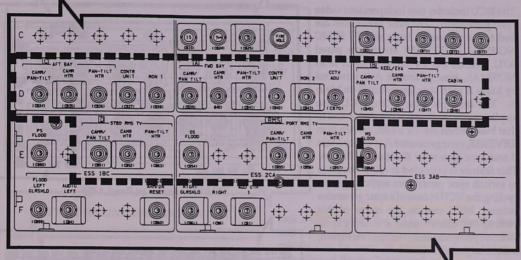
Panel A7U

Video Processing Equipment

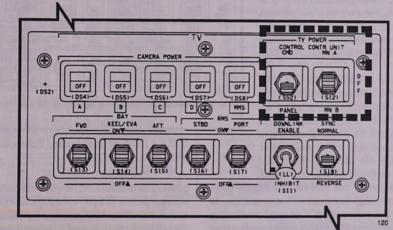
The video control unit (VCU) is the central processor/ controller for the CCTV system. The VCU consists of two line replaceable units (LRUs): the remote control unit (RCU) and the video switching unit (VSU). Both LRUs are located behind panels R17 and R18 in the aft flight deck. These units are forced air cooled by cabin fans, although neither LRU includes a temperature sensor.

Remote Control Unit

The RCU receives all CCTV commands from both the crew and MCC. A ground command interface logic (GCIL) control switch located on panel A7U determines whether MCC can send commands to the CCTV system. When the TV POWER CONTROL switch is in the CMD position, MCC can uplink commands to the CCTV system, and the crew will be able to use all panel A7U TV switches except the TV POWER CONTRUNITMINA / OFF / MNB switch. This TV POWER CONTRUNIT switch enables GCIL drivers to power up the VCU through either DC Main A or B via panel R14. The GCIL drivers prevent the crew and MCC from activating or deactivating the VCU simultaneously. When the GCIL TV POWER CONTROL switch is in PANEL, the crew can configure the TV POWER CONTR UNIT switch to provide VCU power or to turn the VCU off. All uplink commands to the CCTV system are inhibited when the GCIL switch is in PANEL.



CCTV Circuit Breaker on Panel R14



TV POWER Controls on Panel A7U

Uplink commands to the RCU must pass through payload 2 mutiltiplexer/demultiplexer (PF2 MDM). The VCU power MN A / OFF / MN B commands to the GCIL drivers use PF1 or PF2 MDM like all other GCIL commands. However, if the GCIL Main C circuit power provided from panel R14 were to fail, the RCU will inhibit all uplink CCTV commands, except for the VCU power-on commands.

The crew can send any uplink CCTV command by executing a real-time command (RTC) on SPEC 1 of the SM GPC. The TV POWER CONTROL switch must be in the CMD position for crews to use this feature. Crews do not carry any CCTV specific RTCs in any Flight Data File (FDF) documents. This capability would only be used if MCC were unable to uplink commands or for functions not available from panel A7U.

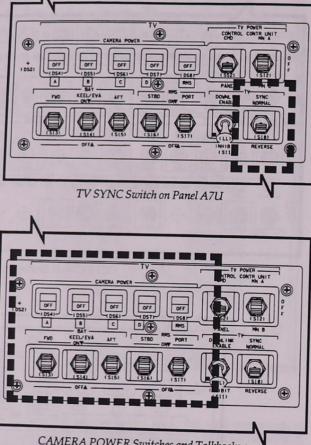
The RCU includes two independent video sync generators. The sync generators are tied to the power on logic and TV SYNC NORMAL/ REVERSE switch on panel A7U. When the TV SYNC switch is in NORMAL, sync generator A is powered by Main A with sync generator B on Main B. The bus that powers the VCU also applies power to the sync generator tied to that bus. When the TV SYNC switch is in REVERSE, sync generator A is tied to Main B and sync generator B is tied to Main A. This feature is provided to allow the crew to switch sync generators without power cycling the VCU in case of a sync generator failure. MCC can see the status of this switch, but cannot send a command to switch sync generators without switching main bus power sources.

In addition to generating master sync signals, the RCU also generates a full-field test signal, better known as a test pattern. The test pattern is black and white. The test pattern can be selected as a video source from panel A7U or via an uplink command.

The sync signal is distributed to CCTV cameras and the VSU for synchronization purposes. Commands to the cameras are embedded in the sync signal. Each camera has a unique address. This address is sent out with the command in the sync signal. Therefore, only the correctly addressed camera will respond to the command.

Uplinked commands are sent on a different sync (horizontal scanning) line than A7U commands. It is possible for the crew and MCC to send conflicting commands to a camera at the same time; coordination between crew and MCC is very important to prevent potential conflicts. Usually, the crew configures cameras and MCC selects cameras for downlink. Prior to launch, each crew should talk with the lead INCO for their flight to work out CCTV responsibilities during crew activity and sleep shifts.

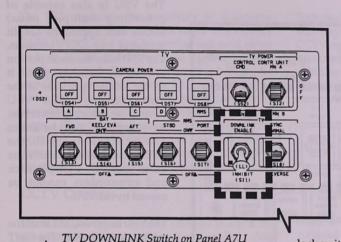
The crew activates payload bay cameras using the TV CAMERA POWER switches located at the top of panel A7U. These switches are momentary in both the ON and OFF positions. The ON/OFF talkbacks are set by the RCU. The talkbacks indicate the status of a 28 V dc discrete signal that enables a remote

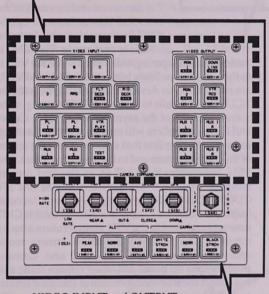


CAMERA POWER Switches and Talkbacks on Panel A7U

power controller (RPC) to provide panel R15 circuit breaker power to a payload bay camera and pan/tilt unit. The talkback status can be misleading because the talkback can indicate ON when the circuit breaker that provides power to the camera is out. Crews should always use these switches to power off the cameras prior to deactivating the VCU to ensure correct camera powerdown.

There are two remote manipulator system (RMS) camera switches to note. In additon to the RMS PORT TV CAMERA POWER switch, another RMS camera switch is located directly below the aft RHC on panel A7U. The RMS CAMERA WRIST/ELBOW selectswitches toggle between the wrist (end effector) and elbow cameras. Only the RMS CAMERA PORT WRIST/ELBOW switch is operational when the





VIDEO INPUT and OUTPUT Push Buttons on Panel A7U

RMS is flown. Only one RMS camera can be activated at a time. Cycling the switch powers off one camera and powers on the other. MCC cannot select between the wrist and elbow cameras nor can MCC identify the position of the switch using downlinked telemetry.

In addition to TV SYNC NORMAL/REVERSE and RMS CAMERA PORT WRIST/ELBOW switches, MCC is unable to configure the TV DOWNLINK ENABLE/INHIBIT SWITCH function. This lever lock switch inhibits the VSU output to the Ku-Band and S-Band FM communications systems. This switch can be used to ensure that no video is downlinked during "sensitive" mission operations. For the majority of mission operations, this switch should be in the ENABLE position. MCC receives telemetry that indicates the position of the TV DOWNLINK switch.

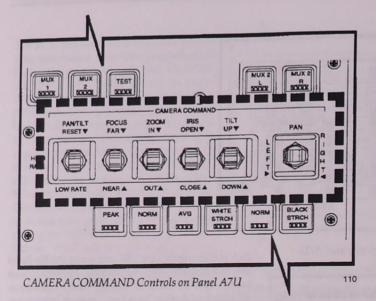
The RCU provides some telemetry to the pulse code modulation master unit (PCMMU) via OF4 MDM. This includes camera overtemp, downlink enable, VCU power source, sync normal/reverse, sync generator active, and "camera select." The camera select is the camera selected for downlink. This may be a different camera from the one the crew or MCC is commanding at the time. The crew and MCC can command different cameras at the same time. The ALC/Gamma status of the downlink camera will be included in the telemetry to the PCMMU.

Video Switching Unit (VSU)

The VSU can accommodate up to 13 video inputs and 7 outputs. However, panel A7U only provides for 10 inputs and 4 outputs. Adding pushbuttons to expand the VSU operational capability has been determined by the Space Shuttle Program (SSP) as being too expensive for the increase in capability and is not planned.

The VSU is used to route video from a source to a destination. All commands to the VSU are processed by the RCU before being sent to the VSU. Note that the crew routes video by selecting a destination and then a source, whereas MCC selects a





source and then a destination. When the crew selects a destination on panel A7U, that output pushbutton indicator (PBI) illuminates. Once an input is selected for that particular output, the input PBI will illuminate as well. If the input is a camera, the crew can select ALC/Gamma PBI settings and/ or send PTU/lens commands to that camera and pan/tilt unit.

The VSU is synchronized to the RCU via the sync generators. This allows the VSU to change video sources for a destination at the end of a video field to prevent visible picture distortion when the video switches engage. The synchronization of CCTV also allows the VSU to read CCTV camera telemetry. The VSU can read camera ID, temperature, and pan/tilt angles. If the VSU detects a camera temperature exceeding 45 degrees Celsius, an overtemp warning is sent to the RCU. The RCU sets a telemetry bit high so that the SM GPC will annunciate an SM Alert and an S76 COMM CAM TEMP message. The temperature limit is set in the VSU and cannot be changed by a table maintenance block update (TMBU). A TMBU can be used to inhibit the SM alert and message.

The VSU is also capable of generating multiplex (mux) scenes that appear as a split screen of two CCTV cameras. The VSU takes the center portion of a camera scene and places it on the left or right side of the The VSU mux picture. determines where to extract the center portion of the video source from the RCU's sync signals. The VSU can only mux synchronous video sources. VTR playback and camcorders cannot be muxed by the VSU.

The VSU receives GMT from the orbiter timing buffer. The GMT is formatted and inserted in the vertical retrace interval by the VSU, using sync timing from the RCU as a reference. This GMT is

inserted in all incoming video lines when the VSU is in the sync mode. Since both camcorders and VTRs are asynchronous devices (i.e., not in sync with the RCU), the VSU fails to insert the GMT timetag in the correct location of the asynchronous video. Crews and flight controllers will see this as a thin, flashing, segmented white line that scrolls accross the screen of the color monitors and in the downlink video. The VSU interpretes the GMT as an elevated camera temperature. This will produce a false SM S76 COMM CAM TEMP message. An asynchronous (async) mode command is available to inhibit GMT timetags and disable the VSU's temperature sensing circuits. The async mode affects camera mode sensing in the VSU. The ALC and Gamma pushbuttons on panel A7U may remain static and not reflect the true configuration of standard orbiter payload bay cameras. This async mode is usually enabled for VTR playback to downlink and for downlinking camcorder video. Otherwise, a white line will be visible in the scene.

The asynchronous mode does not mean that the CCTV system is no longer sync'd together. CCTV cameras are still slaved to the RCU, as is the VSU. Since almost all payload customers require a GMT timetag in recorded and real-time video, crews and flight controllers must coordinate the use of async mode.

The VSU includes the capability to interleave digitized voice in the downlink video. The PL BAY OUTLETS ICOM A and B switches will send either or both ICOM audio loops for digitization and interleaving with downlink video. This feature was provided in an effort to create lip sync between the audio and video. An uplinked command is required to enable the delta modulator to digitize these voice loops. This feature degrades the quality of the downlink video; the digital voice can been seen as distorted vertical color bands along the left side of the picture. This feature is no longer used.

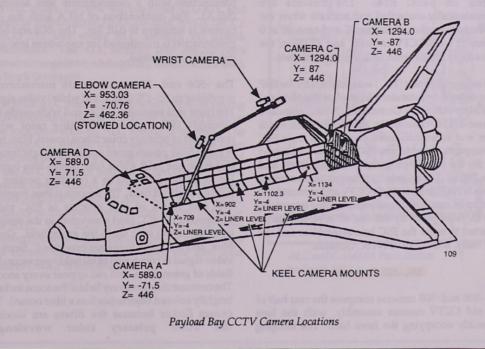
CCTV Cameras

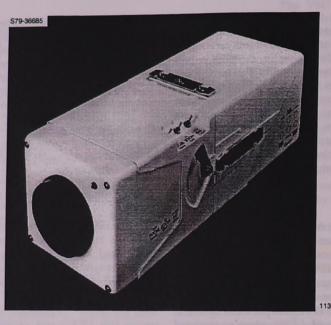
There are four types of CCTV cameras flown in the payload bay. The cameras are designated as -506, -508, color television camera (CTVC), and intensified television camera (ITVC). The first camera flown onboard the orbiter was the -506 camera. The -508 is an improved version of the -506. The CTVC first flew on STS-61. The ITVC is expected to fly first in mid-1995. The -506 and -508 cameras are expected to be phased out in 1996.

Each payload bay camera has two names associated with its position. Camera ports were labeled before CCTV operations were finalized. Crews insisted upon naming cameras in a manner where camera ID could be more easily identified with the camera's location in the payload bay. The two names for each camera location are listed below:

FWD BAY	А
KEEL/EVA BAY	В
AFT BAY	С
RMS STBD	D
RMS PORT WRIST	WRIST
RMS PORT ELBOW	ELBOW

Some missions require additional cameras in the payload bay. These keel cameras are usually positioned in one of four keel camera mounts. Occassionally, these cameras are mounted on payload support structures and are used to assist with berthing operations.





CCTV Lens (Color/Monochrome Lens Assembly Model)

All payload bay CCTV cameras have heaters for both the camera and the pan/tilt units. These heaters are independently powered from circuit breakers located on panel R14. The heaters are thermostatically controlled and activate when the temperature reaches -8 degrees C and turn off at 0 degrees C. All CCTV cameras and PTUs in the payload bay are covered with thermal blankets.

Field sequential color (FSC) was selected by the SSP as the color video standard instead of the National Television Standards Committee (NTSC) standard because NTSC cameras in the 1970s were much larger and consumed more power than their FSC counterparts. In addition, FSC cameras performed well for the Apollo program in the late 1960s and early 1970s. Today, miniaturization of electronics allows NTSC cameras (both CCTV and camcorders) to occupy a smaller volume and consume less power than in years past. By the end of 1994, the SSP is expected to retire the FSC lens assemblies and use only black and white or NTSC cameras.

-506, -508 Cameras

The -506 and -508 cameras compose the rear half of the old CCTV camera assembly, with the lens assembly occupying the front half. The imaging device within the camera is a silicon intensified target vidicon (tube). This vidicon provides excellent low-light performance, especially when used in conjunction with a monochrome lens assembly (MLA). The combination of MLA with the -508 camera is sensitive to 0.01 lux. The -508 and MLA combination is manifested for use where low-light capability is required.

The -506 and -508 cameras are monochrome, providing an RS-170 (black and white) video signal. The color lens assembly (CLA) and wide-angle lens assembly (WLA) have a rotating color wheel composed of primary color filters (green, blue, red). A green filter passes green component light into the camera in one field, a blue filter passes blue light on the next field, followed by a red filter passing red light on the third field. The process is then repeated. The end result of this process is FSC video. Equipment at MCC (and converters in the orbiter's color monitors) sync up to the green field. Green, blue, and red color fields are processed. Since the video signal is composed of 60 fields per second, 20 fields of green, blue, and red appear every second. The contrast changes every field if the scene includes brightly colored objects (such as a blue ocean). This causes flicker because the filters are blocking the other primary color wavelengths

on alternating fields. For video scenes of stationary objects, the color quality is quite good. As objects move relative to the camera, color quality and motion rendition degrade. The color along the perimeter of moving objects is not sharp (individual green, blue, and red lines are visible). Essentially, the only differences between the CLA and WLA are the field of view and zoom capabilities, as shown below.

Lens	Focal length (zoom)	Zoom ratio	Focus distance	F-stop (iris)
Monochrome	18mm to 108mm	6:1	2.5 ft to ∞	11.6 to 116
Color	18mm to 108mm	6:1	2.5 ft to ∞	11.6 to 116
Wide Angle	8.2mm to 25mm	3:1	2 ft to ∞	13.5 to 122

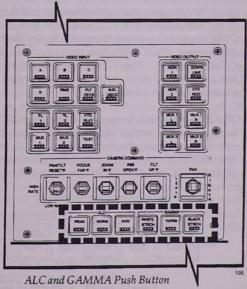
Zoom Focus	-	FOV (horizontal)		
	Focus	MLA & CLA	WLA	
Out	Far	40.9°	83.3°	
In	Far	6.6°	29.5°	

CCTV Lens Data

The -506 and -508 cameras have automatic light control (ALC) circuitry to provide control of the camera lens' iris and the camera's silicon target high voltage supply. There are three ALC settings for these cameras: peak, normal, and average. To select an ALC mode, the crew will use panel A7U ALC and Gamma pushbuttons (PEAK, NORM, AVG). MCC/ INCO can also select ALC settings via uplink commands. The ALC settings shift the camera's dynamic range from white (peak), to neutral (normal), to black (average).

The peak ALC setting is most sensitive to incoming light; therefore, the iris will allow less light to enter the lens than with an ALC setting of normal. The average ALC setting will command the iris to open more and increase the voltage gain when compared to the ALC setting of normal. When crews or MCC require direct control of the iris, the iris switch on panel A7U just above the ALC AVG PBI or an iris open/close command by MCC can be used to disable the ALC. This mode is called semi-manual. The camera operator has total control of the iris but does not control the vidicon gain since the auto gain control (AGC) is still enabled. Additional video processing circuits can be activated. Gamma correction circuits can be used to provide additional output gain (or attenuation). Gamma circuits provide an exponential gain as opposed to a constant gain. The white stretch is selected by the WHITE STRCH pushbutton on panel A7U. The white stretch exponent is less than one (0.667), thus providing an attenuation. This provides for better contrast and detail within brightly lit objects, such as a payload reflecting sunlight. The black stretch is selected by the BLACK STRCH pushbutton. The black stretch exponent is greater than one (2.0), thus the circiut provides additional gain. This setting provides for better detail and contrast of dimly lit objects and is best suited for applications such as star gazing or lightning observations at night. The gamma setting of normal is selected by the gamma NORM pushbutton. Gamma normal bypasses the gamma circuit, providing no additional gain or attenuation.

A semi-manual mode is available in both the -506 and -508 cameras. The camera operator can select semi-manual mode by executing a manual iris command. The -508 camera futher requires that gamma normal be selected. A full-manual mode is



on Panel A7U

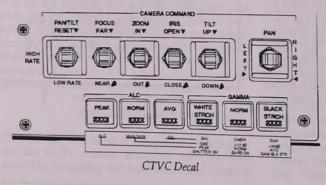
a feature of the -508 camera only. This is selected using white or black stretch gamma and having the ALC disabled by sending a manual iris command. The white and black stretch provides fixed voltage gain to the silicon target of the camera when the ALC setting is disabled. This feature provides for full control of the camera (iris and silicon target gain) by disabling the ALC and AGC. **CAUTION**: both semi- and full-manual modes leave the cameras vulnerable to damage by the Sun if sunlight passes through the viewing area of the camera. Crews and flight controllers must be aware of the Sun's position when using these manual modes. Do not leave a camera unattended in any manual mode!

Color Television Camera (CTVC)

Unlike the -508 and -506 cameras that employ a special lens assembly (CLA or WLA) to provide a color (FSC) video signal, CTVC provides an RS-170A (NTSC) color video signal that does not require additional processing in MCC prior to distribution to the media. NTSC is the color video standard in North America, Japan, and other areas. Great Britain and France are among nations with television standards other than NTSC.

The CTVC is approximately the same size and shape as the -508 camera with a CLA or MLA lens. The CTVC does not have interchangeable lenses like the -508 camera. The CTVC lens is encased within the CTVC housing. The CTVC has a maximum horizontal field-of-view of 77 degrees and a minimum of about 9 degrees.

The CTVC uses three charge-coupled devices (CCDs) to take discrete samples of light passing through a prism after entering the lens. The red, green, and blue (RGB) light separated by the prism are directed to (RGB) CCDs. The CCDs are strobed by the



2.3-10

camera's timing circuits to provide RGB component The RGB signals are processed signals. independently to provide color balancing. Payload bay floodlights, compact portable lights (CPLs) in the cabin, and sunlight are composed of different light spectra. The CTVC includes bay, cabin, and sun color balance settings to compensate for the different wavelength components of fluorescent, tungsten, and solar lighting, respectively. A colorcoded decal was created to assist crews in operating the CTVCs. The ALC options are coded red, MAN GAIN in green, BAL in blue, and miscellaneous in black. This menu system for configuring the CTVCs provides control of the CTVC's operating modes using existing PBIs and uplink commands.

The CTVCs have ALC settings essentially identical to the -508 and -506 cameras. ALC settings can be disabled by using the iris command switch on panel A7U or by selecting a manual gain setting. There are three manual gain settings with the CTVC: 0 dB; +12 dB; and +24 dB. The gain settings not only fix the output gain by the specified amount but also fix the iris to its current position. If the crew or MCC sends a manual iris command when in an ALC setting, the ALC is disabled, and the camera is moded to manual gain of 0 dB. The scene will immediately appear darker because the AGC will be disabled once the iris command is received by the camera.

The CTVCs also include some miscellaneous settings, sometimes referred to as the "all-off" menu. A shutter can be activated to reduce vertical smearing caused by bright light. Color bars can be generated for the crew to calibrate the color monitors. Since the color bars are generated within the camera (as opposed to the B&W test pattern of the VCU), the color bars could be used to inspect noise in the CCTV system if video appears degraded onboard. Gamma can be toggled between black stretch and linear.

> The power on defaults are manual gain of 0 dB, color balance of sun, and gamma black stretch. The CCTV activation cue card instructs crews to select the applicable color balance for the environment and then select ALC of average.

> The CTVCs provide full-level output at 20 lux and are designed to operate in a medium to bright light environment. These cameras operate poorly in low light.

Colors cannot be distinguished in low light, so there was no need to design these cameras for that environment. Because CCTV camera operations are required for a low-light environment, a black and white camera was designed to meet these needs and operate similarly to the CTVC.

Intensified Television Camera (ITVC)

The ITVC is essentially a black and white version of the CTVC. The ALC, manual gain, and gamma settings are exactly the same. However, the ITVC

only has one CCD (instead of the CTVC's three) and is optimized for a low-light environment. Instead of color balance, the ITVC includes day and night operating modes. The night mode provides additional gain, which can be used with any ALC setting as well as manual gain settings. This feature allows a high gain option without sacrificing the ALC protection, particularly around orbit sunrise. A combination of night mode and manual gain 24 dB will make the ITVC sensitive

down to 0.03 lux and provide a full-level output at around 0.2 lux. If the night mode is used with daylight, the video will appear granular (noisy). The daylight mode essentially deactivates the night mode.

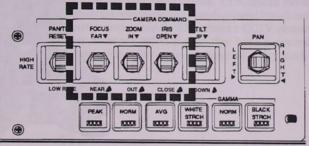
The ITVCs also include an aperature compensation that provides finer detail in low-light conditions. Although the ITVCs have been designed to work well in low light, these cameras are not quite as sensitive to light as are the -508 cameras coupled with the MLA. When the fleet inventory of ITVCs is sufficient, the -506 and -508 cameras are expected to be removed from service. Currently, there is no operations decal to assist in ITVC ALC/Gamma PBI operations.

Power-on defaults are similar to the ITVC. Manual mode of 0 dB is displayed on panel A7U and night operation mode and gamma black stretch are active in the background. The ITVCs will be configured using a menu based system that has ALC/Gamma PBI commands very similar to those of the CTVCs.

CCTV Camera Lens Control

Each CCTV camera type uses the same switches and command sequences to adjust the camera's field-ofview. Just above the six ALC/Gamma pushbutton indicators (PBIs) is a row of switches used to send commands to the cameras and pan/tilt units.

Lens commands are used to adjust the lens and iris settings. The focus, zoom, and iris commands provide the crew and MCC with direct control of



Focus, Zoom, and Iris control

lens settings. The CTVC and ITVC insert lens data into the video. The color monitors are able to display the lens data in the upper portion of the monitor's display. This data is also available to INCO in the MCC. In addition to changing the field-of-view, the zoom function can affect the apparent scene brightness when the camera is in an ALC mode. As bright objects increase or decrease in size, the ALC adjusts accordingly to increase or decrease the amount of light entering the lens. The -506 and -508 cameras tend to bloom in the presence of bright objects. Changing the field-of-view can usually reduce the blooming without changing the camera's auto or manual operating modes. The IRIS switch provides manual control of the iris to the user. Use of this switch disables ALC. When using this switch, crews must not leave the payload bay cameras Direct sunlight can permanently unattended. damage these cameras if a camera's iris remains open.





Pan/Tilt Unit with Camera Thermal Blankets

Pan/Tilt Units (PTUs)

The PTUs are used with cameras A, B, C, D, and RMS elbow. The PTUs are used to change the cameras field-of-view by moving a camera about two axes. The PTUs can pan and tilt 170 degrees in either direction, positive or negative, when any CCTV camera is attached. However, a -506 or -508 camera with a WLA will limit tilt to plus and minus 150 degrees.

The PAN/TILT RESET/HIGH RATE/LOW RATE switch on panel A7U is used to configure the rate of movement for the pan/tilt unit of the camera selected. The RESET position is momentary and resets the camera's pan/tilt coordinates to zero. The HIGH RATE position allows the PTU to pan and tilt at a rate of 12 degrees per second. The LOW RATE position allows the PTU to be commanded at a rate of 1.2 degrees per second. The TILT UP/DOWN and PAN LEFT/RIGHT momentary switches are used to initiate and maintain movement about the tilt and pan axis until the switches are released or a hardstop is encountered. Pan and tilt commands can be executed simultaneously. The PTUs may encounter clutch slippage during operation, particularly when configured for high rate. When the clutch slips, there is a temporary suspension in PTU movement. The camera will continue counting during this period because there is no feedback from the PTUs to the camera to suspend counting. This affects the accuracy of camera pointing in support of payload activities.

111

MCC is capable of configuring the pan/tilt rate to be different from what the crew has set. For uplinked commands, the rate defaults to high during CCTV activation. INCOs usually use the low rate for more effective management of CCTV camera movement because of the time delays in the orbiter's communications systems.

Cabin Cameras

Although all CCTV cameras are compatible with the TV outlets located on panels O19 and MO58F, there are no plans to regularly use these cameras in the flight deck or middeck areas. Camcorders have replaced the CCTVs in the orbiter's crew compartment. In addition to providing excellent

real-time video, the camcorders can also record and play back video without using an external video recorders.

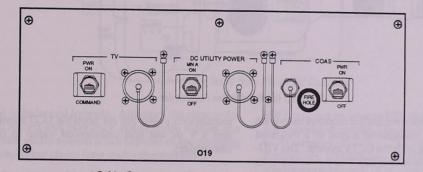
CCTV cameras will be used in the Spacelab module because these cameras can be remotely commanded by crews and MCC, unlike camcorders. If a CTVC is used in a Spacelab module, the crew should select a manual gain of +12 dB before manually adjusting the iris of the lens. Direct sunlight is not a concern, so crews should manually adjust the camera for the best possible picture.

Camcorders

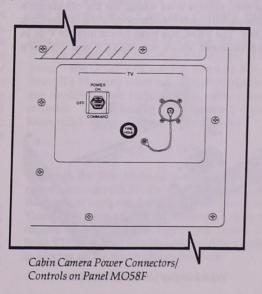
The Canon A1 Hi-Band 8mm camcorder was the first camcorder selected for use on the orbiters back in 1990. In 1992, the Canon L1 Hi-Band 8mm

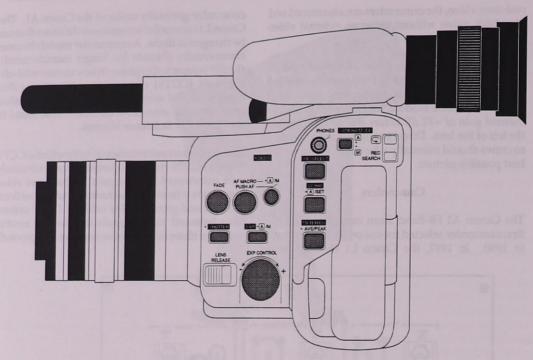
camcorder gradually replaced the Canon A1. The Canon L1 camcorder uses removable lenses that can be changed in flight. As camcorder models become commercially obsolete (no longer manufactured), the SSP is expected to phase-in new commercial-offthe-shelf (COTS) camcorders and other video equipment and accessories as necessary. Detailed model-specific camcorder features can be found in the Photo/TV Reference Manual.

Camcorders cannot interface directly with the CCTV system. COTS video equipment almost exclusively uses unbalanced video signals. Unbalanced video signals are referenced to a chassis ground (two lines, positive and ground). The orbiter's CCTV system uses balanced video signals that have a neutral reference (three lines: positive, negative, and ground).



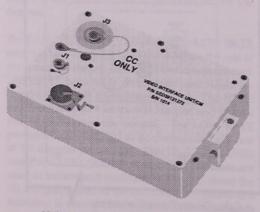
Cabin Camera Power Connectors/Control on Panel O19





Canon L1 Hi-Band 8 mm Camcorder

A VIU-C (video interface unit) is required to convert the camcorder's unbalanced signal to a balanced signal compatible with the CCTV system. The VIU-C also converts the orbiter's 28 V dc power to 6 volts in order to power the camcorders. The VIU-C adjusts the sync voltage level within the the camcorder's video signal to prevent overmodulation of downlink video. The VIU-C has three connectors: 28 V dc in and balanced video out (to O19 and MO58F);



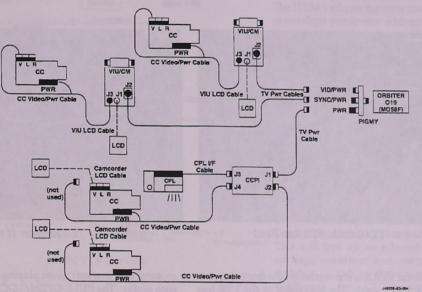
Video Interface Unit/CM (VIU/CM)

unbalanced video out (to portable LCD monitor); and 6 V dc out and unbalanced video in (from camcorder).

A transformer can be used with a camcorder to record video from a connector on the rear panel of the color monitors. The transformer is required to convert the balanced output video of the monitor to an unbalanced signal usable by the camcorder. This transformer is usually Velcroed to the side of the VIU-C. The combination of VIU-C and transformer is referred to as the VIU-CM.

In addition to providing real-time video like a CCTV camera, the camcorders have a built-in Hi-band 8mm video cassette recorder. The blank video cassettes flown have two-hour record duration. The camcorders can record or play back audio in addition to video. However, the camcorder's audio, like the video, is unbalanced and the orbiter audio is balanced. The audio signal level of the camcorder to and from the audio system creates a volume imbalance. The ICOM recorder (currently a Sony cassette recorder) is required to balance the signal values and to convert audio signals between balanced

CAMCORDER SCHEMATICS (Continued) MULTIPLE CAMCORDER W/PIGMY CABLE AND CCPI



Camcorder Setup from Photo/TV Checklist

and unbalanced formats. Although the camcorder can record and play back stereo audio signals, the orbiter audio system is not capable of transmitting or receiving stereo (one audio channel only).

The camcorders can be powered by the VIU-C or by two other means. A battery pack can be used, but battery power only lasts from 20 to 40 minutes, depending on how the camcorder is used. The camcorder power interface (CCPI) device can be connected to a TV camera port on either O19 or MO58F. The CCPI, using a different cable, can also draw power from a dc utility power outlet, freeing the camera ports. The CCPI only provides power, it cannot be used to route video. The CCPI can provide power to one or two camcorders plus a compact portable light (CPL).

Video Tape Recorders (VTRs)

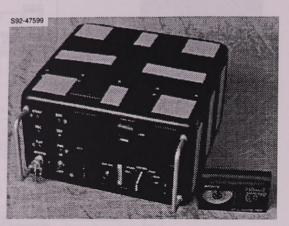
Video tape recorders have flown on every space shuttle mission to date. More than one video camera is flown and because the orbiter is unable to downlink video to MCC continuously, the CCTV system must be able to record video to document activities. The SSP has flown an interim VTR that uses U-Matic (3/ 4-inch) video cassettes. These tapes could record up to 30 minutes of video. The Office of Aerospace Technology (OAST) has supplied a similar VTR when more than one VTR was required for a mission. The VTRs were placed in a VTR bucket, which not only secured the VTR but also provided input/ output configuration and power. The VTR buckets were placed in an aft flight deck panel (usually R11 or L10). Each VTR bucket would occupy half a panel. The OAST VTR was last flown on STS-51. Since STS-53, every mission has manifested at least one modified Teac Hi-Band 8mm video cassette recorder. The payload video console will replace loose video taping equipment used onboard.

Teac 8mm VTR

Although the Teac Hi-Band 8mm VTR is a video cassette recorder (VCR), the term VTR is applied to this piece of equipment as a matter of convention. This VTR is loose equipment; therefore, it does not require securing in an aft flight deck panel. The 8mm VTR is stowed with its cables and accessories in a locker on the flight deck or middeck.



TEAC 8MM VTR Rear Panel



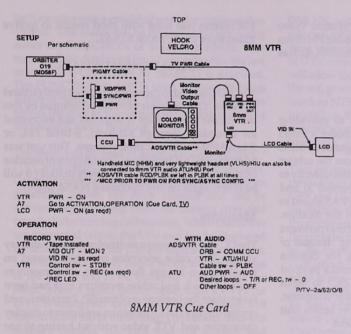
8 MM Video Tape Recorder (8 mm VTR)

The 8mm VTR has connectors on the front and rear of the VTR chassis. The rear panel of the VTR has three connectors. The POWER & VIDEO OUT receptacle is used to accept 28 V dc and output a video signal. The VIDEO IN connector receives a video signal from the J3 connector on the rear of a color television monitor. This allows the VTR to record video routed from the VSU to the color monitor. The AUDIO ATU/HIU connector provides an interface to an ATU via the ADS/VTR (audio distribution system) cable or a headset interface unit (HIU) in order to record or playback audio.

The MONITOR connector on the front faceplate provides video to an LCD monitor. Tape counter and VTR mode indications will appear on the LCD screen. Six LEDs are present on the front faceplate. VTR modes of standby (STBY), record (REC), and PLAY are indicated by the illuminated LED. A power-on LED will indicate if 28 V dc is reaching the VTR. An end-of-tape (EOT) LED will indicate when the video cassette has reached its limit. A humidity sensor can activate the DEW LED. If condensation is present inside the VTR, the VTR will unthread the tape and will not operate.

Two switches and two rotary knobs are also located on the front faceplate. The ON/OFF switch enables or disables power to the VTR. The EMK REC is a momentary switch that can be used to record a 1 kHz tone when recording video. This tone can be used as an aural cue (marker) when playing back the video with audio. The PULL OPEN/LOCK knob is used to secure a door that prevents contaminents from entering the VTR during operations. When the door is opened, the tape counter on the LCD monitor is zeroed. Finally, a mode select knob allows the user to select operating modes for the the VTR. The knob must be in the UNTHRD (unthread) position to remove a tape. All modes except unthread are indicated on the LCD monitor.

The 8mm VTR is powered from panel O19 or MO58F TV camera power port. The camcorders and VTRs have been using the source for power, so a pigmy cable was constructed to provide multiple power outlets. The pigmy cable plugs into the flight deck or middeck camera port and has three connectors with unequal cable extensions on the other end. The VID/PWR connector provides 28 V dc power and allows video to be routed to the VSU as flight deck or middeck video. The VID/PWR connector has the shortest cable extension. The SYNC/PWR connector provides 28 V dc power and provides a sync/ command signal that could be routed via a TV interface panel (TVIP) or a payload data interface panel (PDIP) for CCTV cameras in the payload bay that require synchronization with the CCTV system. This sync signal is usually required when more than one keel camera is used. The longest extension of the three has a PWR connector, which provides only 28 V dc power.





OPERATION (Concluded)

PLAYBACK NOTES For extended onboard playback of VTR or other async inputs, S76 COMM alens may be avoided by inhibiting Carr overtemp C&W SPC 60 ITM + 0.2 4 (9.4 2 EXEC, 10 EXEC Advise MCC of C/W Enable status

Alter playback completion, Camr overtemp detection must be enabled SPEC 60 ITEM 1 + $0.2.4\,0.8\,4.2\,$ EXEC, 9 EXEC Advise MCC of C/W Enable status

VIDE	EO PLAYBACK (DNLK)	- WIT	H AUDIO
VTR	Tape installed	ADS/VTR	Cable
	Rewind tape position (as regd)		ORB - COMM CCU
019	PIGMY - Vid/pwr if read		(if MHA: CCU Pwr - ON)
A7	VID OUT - MON 1(2)		VTR - ATU/HIU
	VID IN - FLT DECK		Cable sw - PLBK
	I-TV DNLK - ENAL	ATU	AUD PWR - AUD
	[VID OUT - DNLK]		Desired loops - T/R
	[VID IN - FLT DECK]		Other loops - Not T/R
VTR	Control sw - PLAY		AUD XMIT/ICOM MODE - VOX/VOX
	VPLAY - LED		AUDVOX SENS - MAX

DEACTIVATION

VTR	Control sw - UNTHRD
	Remove, mark, stow tape as regd
	PWR - OFF
LCD	PWR - OFF (as regd)
A7	Go to DEACTIVATION (Cue Card, IV)

ATU Reconfig as reqd

P/TV-20/62/0/8

Back of 8MM VTR Cue Card

as read

Camera overtemp alerts from the SM GPC can be inhibited by SM SPEC 60. The ITEM 1 allows the crew to enter a seven-digit parameter address. The current value of the term specified will be displayed underneath ITEM 1. ITEM 10 allows the crew to inhibit the caution and warning (C&W) system from annunciating alarms as a result of parameter violations. The sequence for inhibiting TV camera overtemperature sensing by SM is provided on the 8mm VTR cue card. MCC can also perform this task via a TMBU.

Payload Video Console (PVC)

The PVC is designed to mount two Teac Hi-band 8mm VTRs on panel R12. This will free up an inboard locker stowage container and reduce the number of cables the crew must configure for CCTV support. Configuration of the PVC, which includes what video to route, VTR operating modes, and audio configuration will be controlled by the crew using a portable computing device. Most recording and playback features can be commanded by MCC. This will allow for video recording and playback during crew sleep periods. The PVC is expected to first fly in 1996.

Special Purpose Video

On many missions, additional video sources are used above and beyond the payload bay, RMS, and cabin cameras (camcorders) in order to meet mission success. Keel (berthing and/ or prox ops) cameras will be installed on rendezvous missions. These cameras are usually stationary CCTV cameras (no PTU) although mission-unique video cameras have been flown in the payload bay. Pressurized modules (Spacelab and Spacehab) include camera ports that can provide cabin or experiment video from the module to the orbiter CCTV system. Video can also be received via RF carrier (S-band FM) from an EVA crewmember or a deployed satellite, such as SPAS.

Spacelab

The Spacelab module, in addition to providing camera ports for sending video, includes a video analog switch (VAS) that can be configured by MCC or the crew to route video to and from the orbiter CCTV. The VAS can also downlink video directly to the Ku-band system (PL analog, channel 3) and bypass the orbiter CCTV system. The VAS is used to route video and activate cameras in the module. Video recording equipment is installed in experiment racks for experiment video recording. Instead of using switches and pushbuttons for camera configuration and routing, the crew uses a payload and general support computer (PGSC) to input commands to the Spacelab experiment computer. Commands are then sent via a remote access unit (RAU) to the Spacelab video equipment.

The Spacelab module TV connectors include extra pins that are used to specify camera addresses not available in the orbiter. This provides for remote commanding of these cameras from MCC or from panel A7U. Therefore, cables designed for the orbiter cannot be used in Spacelab for use with standard orbiter CCTV cameras. Orbiter cables can be used with camcorders (with a VIU-C).

Addition information on the Spacelab CCTV system can be found in the S COMM 2102 training workbook.

EMU/Payload TV

The EVA crew can transmit television signals from an EMU suit if special equipment is attached to the helmet. The EMU camera is a CCD imaging device that sends its signal to an RF (S-band) transmitter. A receiver demodulates the TV signal from the carrier. This receiver uses one of the two orbiter S-band FM antennas to receive the EMU TV signal. The receiver will be located in the middeck. The output of the receiver will be routed to panel MO58F to be distributed as middeck video. EMU TV was last attempted on STS-49. The S-band

FM system was used with good results to receive video from the SPAS on STS-51.

Airborne Digitizer Unit (ADU)

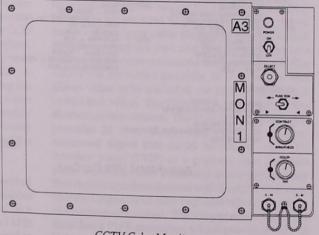
The ADU is used to capture a snapshot (still picture) of video. Once a frame of video is captured by this device, the video image is digitized and encrypted for downlink through Ku-band, S-band FM, or S-band PM communication systems. This unit was used during DOD missions. The equipment remains certified for flight, although it is very unlikely it will be flown again on any upcoming NASA flights.

Monitors

The CCTV system uses a varity of monitors to display video. Two color television monitors located on panel A3 are always flown. The color monitors replaced black and white monitors that had been flown since the beginning of the SSP. Portable liquid crystal display (LCD) monitors are flown to display camcorder and VTR video without having to use either CCTV color monitor.

Color Television Monitor (CTVM)

The CTVMs are the primary display equipment of the CCTV system. These 10-inch monitors display NTSC and FSC color. Rotary knobs are used to control the contrast, brightness, color, and tint of the video dispayed. The color and tint are only effective displaying NTSC video; they are not effective with FSC video.



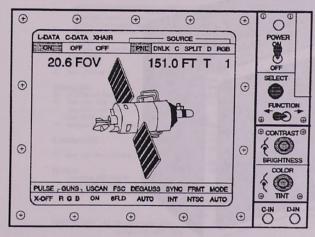
CCTV Color Monitor

2.3-18

Each monitor uses a graphical menu for configuration control. The menu can be displayed by activating either the FUNCTION or SELECT controls. The menu will be displayed for 10 seconds after the last command (FUNCTION or SELECT) is executed. The FUNCTION switch is used to move through different menu headings. The SELECT pushbutton allows the user to toggle between different options within each menu heading.

The menu can be used to enable viewing of CTVC/ ITVC lens data, CCTV camera data, and crosshairs. Data and crosshairs that appear green are characters generated within the color monitor and can be activated by selecting GRN for camera data and crosshairs by turning on lens data. White characters are generated within the VSU and can be displayed by selecting WHT for camera data and crosshairs. Lens data will display zoom, focus, and iris settings of the CTVC and ITVC cameras. These fields are static when a video source other than a CTVC or ITVC is displayed. Lens data, when activated, will appear at the top of the screen. The camera data will display camera ID, pan and tilt angles, and temperature, although the white data displays temperature of the camera only when the VSU detects a camera with an elevated temperature. Camera data is displayed in the lower portion of the screen.

Each color monitor can select from one of five independent video sources. PNL will display any video routed to the monitor using panel A7U. The



CCTV color monitor with menu and L-Data

DNLNK will allow the user to view any video selected for downlink. The C and D selections will view video from equipment connected to the C IN or D IN connectors on the front of the monitor. RGB will allow the user to view video that directly drives the red, green, and blue electron guns of the monitor (such as NTSC component). The RGB connector is located on the rear panel of the monitor. SPLT is another source available and provides a split screen image of C and D inputs.

Two ground checkout menu functions are located on the lower left portion of the menu (PULSE-XON/ OFF and GUNS R G B). USCAN ON/OFF enables or disables the underscanning feature. When ON, the underscan allows viewing of edge-to-edge video (horizontal and vertical) with no loss of image data. In other words, you see what the camera sees. When OFF, about 5 percent of each horizontal and vertical edge is lost. In addition, the top line of the upper menu and the bottom line of the lower menu cannot be seen when USCAN is OFF. The FSC function selects between 6FLD (6 field) and 3FLD (3 field). This feature determines how often FSC color will be updated to the screen. 6FLD is the default and preferred setting, except for viewing FSC video of objects in rapid motion. This function only applies to cameras with WLA or CLA lenses. The DEGAUSS function will dissapate magnetic fields that build up around the monitor as the orbiter moves at high speed through the Earth's magnetic field, but only when DEGAUSS is in the default AUTO position.

AUTO engages the degaussing circuitry every 10 minutes. OFF disables this feature.

The SYNC function of the monitor displays the source of sync used to display video and graphics (menu and green data). When no video is detected by the monitor, the field under SYNC will indicate EXT for external source. This means that the sync line from the RCU to the monitor is providing the sync pulses necessary to display the menu and data. This field can be useful for quick troubleshooting for loss of video (camera power fail vs. iris stuck closed).

Video format can be selected manually or automatically. The CTVMs default to AUTO MODE in which the monitor determines the video format from data embedded in the CCTV camera video. CTVCs will use the NTSC format, -506 and -508 cameras will use FSC, and ITVCs will use B&W decoding. Camcorders do not provide this data, hence the monitors will process the camcorder video using the default NTSC converter. The crew can override the AUTO selected format by taking MODE to MAN and then toggling the FRMT to select NTSC, FSC, or B&W. If a mux scene is routed to a monitor, the monitor will select FSC because of the nature of the video processing by the VSU in creating the mux scene. In order to display NTSC color from a CTVC in a mux scene, the user must manually override the format and select NTSC.

The CTVMs have a connector labeled J3 on the rear of the monitor. This connector provides a balanced video signal of whatever video is routed to the monitor output pushbutton on panel A7U. A Teac VTR or a camcorder (using a VIU-CM) can record this video. Any VSU (white) data requested by the monitor will be recorded by the Teac or camcorder. Monitor (green) data will not be recorded.

Portable LCD Monitor

Portable LCD monitors are flown to display video at a VTR or a camcorder. Sony XV-M30 and FDM-330 LCD monitors have been used by the SSP for those purposes. Some modifications have been made to these monitors, which makes disconnecting cables from the LCD monitor more difficult in an effort to reduce accidental cable disconnections.

Viewfinder Monitor

The viewfinder monitor is used with a CCTV camera within the cabin or a module, such as Spacelab. This monitor is a 3.8-inch (diagonal) black and white portable monitor that can be connected via a power cable to a CCTV camera. The monitor is used to adjust the camera when a CCTV color monitor is not available for the task. This usually applies to cameras in the Spacelab module or cabin middeck areas. The viewfinder monitor includes brightness and contrast controls. The viewfinder monitor is usually mounted to the top or side of the CCTV camera.

Payload Bay Camera Operations

The CCTV ACTIVATION cue card includes activation procedures for the CCTV system and payload bay cameras. This cue card also includes steps that can command the cameras to different operating modes. The steps indicated are good guidelines for setting up cameras in a safe (ALC active) configuration. However, crews should not hesitate to command cameras out of their normal operating modes. Since lighting conditions on orbit



LCD Color Monitor



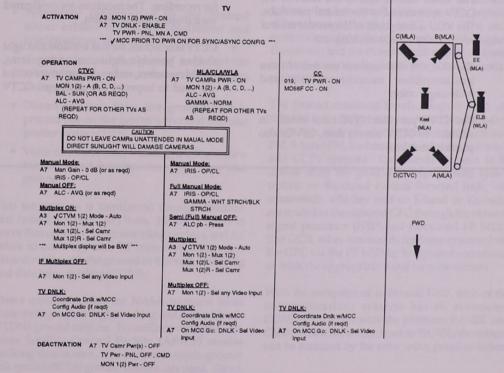
are quite dynamic, ALC modes, manual gain modes, and gamma settings may require changes. Crews should take the initiative and adjust the cameras to provide the best possible video of the object(s) in view. CCTV camera operation is more of an art than a science when it comes to minimizing blooming without sacrificing contrast and clarity. However, please note the caution block, as the CCTV cameras (in particular the -506 and -508) are susceptible to damage by direct sunlight while in a manual mode.

CCTV Accessories

The CCTV system has many accessories that aid in CCTV operations. Light shades are used to reduce the amount of sunlight entering the flight deck. Shades are also available for reducing glare caused by cabin lights. Portable lighting, such as the compact portable light (CPL), is used to brighten areas for short durations. The shuttle photoflood uses fluoroscent tubes powered by the orbiter 115 V ac 400Hz supply. The ICOM recorder is a Sony WM-DC6 stereo audio cassette recorder. This device is used to record and playback voice from the orbiter audio system and the camcorder. ICOM recorder procedures are located in the Orbit Ops FDF.

Camcorders can share the same mounts, arms, and clamps with the photo equipment. These portable structures provide a secure base to position the camcorders in a microgravity environment.

Crews work with the engineering and flight controller organizations to improve CCTV operations. These improvements usually result in new cables or interface units that increase the CCTV system's capabilities. This cooperation has helped make CCTV one of the most frequently changing orbiter systems. The monitors, camcorders, and VTRs flown today are different from those flown as recently as 1992. The CTVCs and ITVCs are expected to fully replace the -506 and -508 cameras sometime in 1995. The payload video console is expected to fly in 1996, and a high-definition television camera is expected to fly in 1998.



TV Cue Card From Photo/TV Checklist

CCTV System Summary

- The CCTV system is used on orbit to support payload and orbiter activities by using realtime and recorded video.
- The CCTV system is composed of CCTV cameras, pan/tilt units, color monitors, camcorders, video tape recorders, video processing equipment, and accessories.
- All CCTV functions can be controlled by the crew. Most CCTV functions can be configured by MCC via uplink commands. Both crew and MCC can command all CCTV camera functions.
- CCTV equipment is powered from circuit breakers located on panel R15.
- Crews use panel A7U to control the CCTV system.
- The video control unit is the heart of the CCTV system and is the central processor. The VCU is composed of the remote control unit and the video switching unit.
- The -506 and -508 cameras use one of three lens assemblies: monochrome, color, and wide-angle color.
- The CTVC provides NTSC color video. In addition to CCTV camera data, CTVCs also provide lens data.

- The ITVC generates black and white video. This CCTV camera is designed to operate in a low-light environment.
- The ALC and gamma PBIs on panel A7U perform different tasks with the CTVCs and ITVCs than with the -506 and -508 cameras.
- Camcorders are now used to provide cabin video. Camcorders require special interface equipment to operate in the orbiter.
- The Teac Hi-Band 8mm VTR is the VTR used by the SSP to record payload bay camera video. These VTRs are loose equipment and are stowed in lockers for ascent and entry. These VTRs record video from an output port on the color monitors and playback through flight deck and middeck camera ports.
- Two 10-inch color monitors display video onboard. The monitors are located on panel A3 and provide connectors for VTRs to use for recording. The monitors are configured via a display menu system.
- CCTV accessories, such as window and light shades, portable lights, mounting arms, ICOM recorders, and a wide variety of cables are used to improve the quality of CCTV video.



2.4 COMMUNICATIONS

CONTENTS

Description	2.4-1
S-Band Phase Modulation	2.4-2
S-Band Frequency Modulation	2.4-10
Ku-Band System	2.4-12
Payload Communication System	2.4-20
Ultrahigh Frequency System	2.4-23
Audio Distribution System	2.4-25
Instrumentation	2.4-35
Thermal Impluse Printer System	2.4-40

Description

The orbiter communication system transfers the following types of information:

- Telemetry information to the ground about orbiter operating conditions and configurations, systems, and payloads
- Commands from the ground to the orbiter systems to perform a function or configuration change
- Documentation from the ground that is printed out on the orbiter's thermal impulse printer system (TIPS)
- Voice communications among the flight crew members and between the flight crew and ground.

This information is transferred through hardline and radio frequency (RF) links. Hardline refers to wires that connect communicating devices, and RF refers to radio signals. RF communication takes place directly with the ground or through a tracking and data relay satellite (TDRS).

Direct communication for NASA missions takes place through space flight tracking and data network (STDN) ground stations. For military missions, Air Force Satellite Control Facility (AFSCF) remote tracking station sites, also known as space-ground link system (SGLS) ground stations, are used. Direct signals from the ground to the orbiter are referred to as uplinks (UL), and signals from the orbiter to the ground are called downlinks (DL).

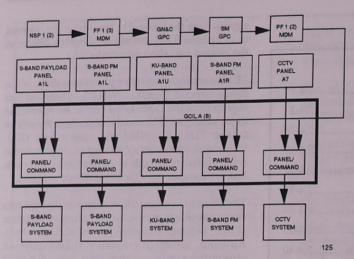
TDRS communication takes place through the White Sands Ground Terminal (WSGT). These indirect signals from the TDRS to the orbiter are referred to as forward links (FL), and the signal from the orbiter to the TDRS is called the return link (RL). Communication with a detached payload from the orbiter is also referred to as forward link, and return link is the signal from the payload to the orbiter.

The orbiter communication system is divided into several smaller systems: S-band phase modulation (PM), S-band frequency modulation (FM), Ku-band, ultrahigh frequency (UHF), payload communications, audio, and closed-circuit television. (Closed-circuit television is discussed separately in Section 2.3.)

The S-band FM, S-band PM, Ku-band, and UHF systems are used to transfer information between the orbiter and the ground. The payload communication system is used to transfer information between the orbiter and its payloads either through hardline or RF links. The audio systems transfer voice communications throughout the orbiter, and the closed-circuit television system is used for visually monitoring and recording activities.

The ground command interface logic (GCIL), also referred to as the ground command interface logic controller, controls selected functions of the S-band PM, S-band FM, Ku-band, payload communication, and CCTV systems. Commands are sent to the orbiter from the ground through S-band system uplink or Ku-band system forward link. All commands, whether sent on S-band or Ku-band, are routed to the onboard GPC through the network signal processor (NSP) and associated FF MDM. The GCIL takes commands for these systems from the GPC via the PF MDMs, for ground commands or from the appropriate panel for crew control.

With the exception of audio and UHF, each of the communications systems has an associated *CONTROL* switch with the positions *PANEL* and *CMD*. When the switch is set to *PANEL*, the system can be accessed by the crew using panel switches.



Ground Command Interface Logic

When the switch is set to *CMD*, control is by ground command via GCIL. The locations and operations of these switches are provided in the individual communications systems discussions that follow.

NOTE

Because of the large number of distinct elements of the Communications system, a separate Operations subsection is not included. Rather, this information is provided within the separate element discussions.

S-Band Phase Modulation

The S-band PM system provides two-way communication between the orbiter and the ground, either directly or through a relay satellite. It provides communication channels for five functions:

- Command channel: used to send commands from ground to orbiter.
- Voice channel(s): used for one-way and twoway voice communications between ground and orbiter. One of the two voice channels can be used for Thermal Impulse Printer System signals from ground to orbiter.
- Telemetry channel: carries real-time orbiter and payload operational telemetry data to ground.

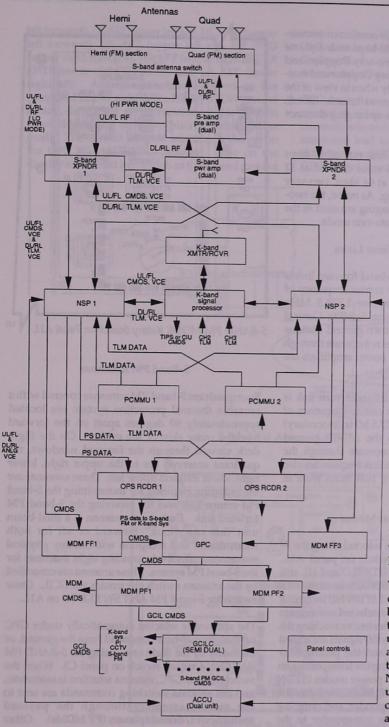
- Turnaround tone ranging channel: used to determine slant range from a known point to the orbiter. Tones are transmitted from the ground to the orbiter where they are "turned around" and transmitted back to ground from the orbiter on a coherent RF carrier. Slant range can be computed from net total two-way phase delay of the major tone for the "round trip."
- Two-way Doppler tracking: used to aid in tracking the orbiter. An RF carrier, of precisely known frequency, is transmitted to the orbiter.

A characteristic of RF signals in the S-band range is that "line-of-sight" must exist between transmitting and receiving antennas to permit communications. With the availability of the east and west TDRS, potential total S-band PM support time using direct and relay links will be as much as 80 percent of mission time. (For some missions, vehicle attitude constraints imposed by experiment requirements may cause the loss of portions of that potential support time because the required orbiter attitudes may at times be incompatible with orbiter S-band PM quad antenna patterns.)

A fully operational TDRS system provides east and west satellites that are both supported by the WSGT facility. The east and west satellites are approximately 130 degrees apart in geosynchronous orbits. In the S-band mode, the TDRS single access antenna is gimballed but does not automatically track the orbiter. It is sequentially commanded by the ground to follow the orbiter position. There is a zone of exclusion (ZOE) where the orbiter, operating at normal altitudes, will not be in line-of-sight with either satellite. The ZOE is geographically over the Indian Ocean region.

S-Band Forward Link

The S-band forward link operates through the STDN or TDRS. It is phase modulated on a center carrier frequency of either 2,106.4 MHz (primary) or 2,041.9 MHz (secondary) for NASA. The two frequencies would prevent interference if two users were in



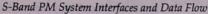
operation at the same time and place, since one user could select the high frequency, and the other could select the low frequency.

The forward link originates from Mission Control through the NASA STDN ground stations used for launch, lift-off, ascent, or landing, or through the WSGT via the TDRS system to the orbiter. The high data rate is 72 kilobits per second, consisting of two air-to-ground voice channels at 32 kbps each and one command channel at 8 kbps, two-way Doppler, and two-way tone ranging. The low data rate is 32 kbps, consisting of one air-to-ground voice channel at 24 kbps and one command channel of 8 kbps, two-way Doppler, and two-way ranging. The two-way ranging does not operate through the TDRS.

S-Band Return Link

The S-band return link operates through the STDN or TDRS. It is phase modulated on a center carrier frequency of 2,287.5 MHz (primary) or 2,217.5 MHz (secondary) for NASA. The two frequencies prevent interference if two users are in operation at the same time and place.

The S-band PM return link can originate from one of two Sband PM transponders aboard the orbiter, each of which can use one frequency, but not both at the same time. The link transmits the data through the NASA STDN ground stations used for launch, lift-off, ascent, or landing, or through the TDRS and TDRS system via the WSGT to Mission Control.



The high data rate of 192 kbps consists of two airto-ground voice channels at 32 kbps each and one telemetry link of 128 kbps, two-way Doppler, and two-way ranging. The two-way Doppler and twoway ranging are operative only when in view of the NASA STDN ground stations at launch, lift-off, ascent, or landing. The two-way ranging does not operate with the TDRS.

The S-band return link low data rate of 96 kbps consists of one air-to-ground voice channel at 32 kbps and one telemetry link at 64 kbps, two-way Doppler, and two-way ranging. As noted, the twoway Doppler and two-way ranging are used in the same manner as in the high-data-rate mode.

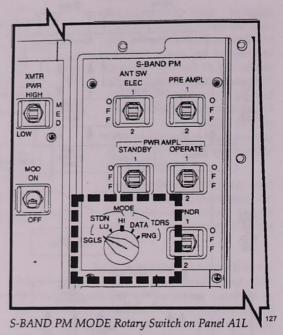
Department of Defense Links

The Department of Defense S-band forward link is phase modulated on a center carrier frequency of either 1,831.8 MHz (primary) or 1,775.5 MHz (secondary) from the Air Force Satellite Control Facility (AFSCF) through its own ground stations (SGLS ground stations). It does not operate through the TDRS because the S-band power amplifiers are not powered in the SGLS mode.

The Department of Defense S-band return link is phase modulated on a center carrier frequency of 2,287.5 MHz (primary) or 2,217.5 MHz (secondary) through the SGLS mode to the AFSCF ground stations, and also does not operate through the TDRS. The two S-band return link frequencies also would prevent interference if two users were in operation at the same time.

S-Band PM Power Modes

S-band PM power modes are selected using the *S*-*BAND PM MODE* rotary switch on panel A1L. Selectable modes are *SGLS*, *STDN LO* and *HI*, and *TDRS DATA* and *RNG* (*TDRS RNG* is not used). In high power modes (*TDRS* and *STDN HI*) incoming (received) signals from a quad-selected antenna are directed through a preamplifier before reaching the transponder. Outgoing (transmit) signals are routed through a power amplifier and the preamplifier assembly diplexer after leaving the transponder en route to an antenna. In low power modes (*STDN LO* and *SGLS*), incoming signals flow from the antenna directly to the transponder, and outgoing signals go directly from the transponder to the selected antenna without amplification.



S-Band PM Antennas

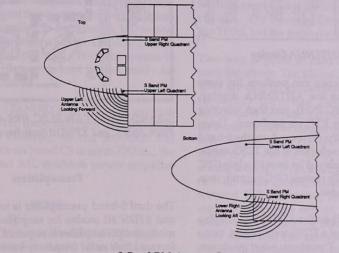
Four quadrant S-band PM antennas covered with a reusable thermal protection system are located approximately 90 degrees apart on the forward fuselage outer skin of the orbiter. On the flight deck viewed through the forward windows, the quadrant antennas are to the upper right, lower right, lower left, and upper left. These antennas are the radiating elements for transmitting the S-band PM return link and for receiving the S-band PM forward link. Each quad antenna is a dual-beam unit that can "look" forward or aft for both transmission and reception without any physical movement, effectively creating eight antennas for the S-band PM system. These antenna are controlled by the antenna switch electronics via GCIL. Crew switch for S-band PM ANT SW ELEC is on A1L.

The antenna is selected automatically under GPC control, by real-time command from the ground, or manually by the flight crew using the *S*-BAND PM ANTENNA rotary switch on panel C3. When the switch is set to *GPC*, antenna selection is automatic, and the antenna switching commands are sent to the switch assembly through the payload multiplexers/demultiplexers (PF MDMs). Other positions selectable by the switch are *LLFWD* (lower

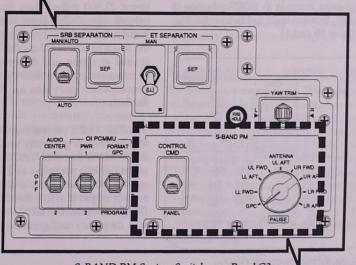
left forward), LL AFT (lower left aft), UL FWD (upper left forward), UL AFT (upper left aft), UR FWD (upper right forward), UR AFT (upper right aft), LR FWD (lower right forward), and LR AFT (lower right aft). Antenna selection is based on the computed line of sight to the NASA STDN ground station, the AFSCF ground station, or the TDRS in view, depending on the orbiter communication mode. The current antenna selection is shown on the OPS 201 ANTENNA display. Also on the display are related items such as the S-band ground

station in view, TDRS in line of sight, and whether GPC antenna selection is enabled or inhibited. Also displayed is the antenna electronics unit performing antenna selections.

GPC control can be inhibited to permit ground control to select an antenna other than the one currently selected by the GPC. The ground sends a command load to inhibit GPC control and a realtime command (RTC) to select the desired antenna. GPC control is restored by sending a load to enable

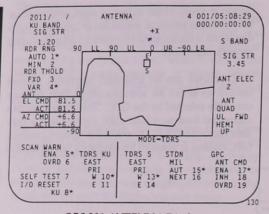


S-Band PM Antenna Locations



S-BAND PM System Switches on Panel C3

2. SYSTEMS 2.4 Communications



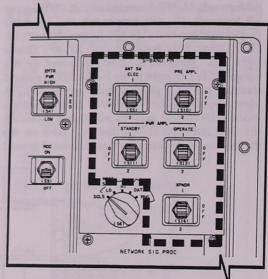
OPS 201 ANTENNA Display

the GPC mode. The crew can perform the same functions by selecting the ANTENNA display, executing Item 18 (GPC INH), and then selecting the desired antenna by RTC via keyboard. Using GPC OVRD (item 19), the crew can force the S-band antenna management software to the TDRS mode. An asterisk will be displayed by item 19 while GPC override is in effect. To restore GPC control, item 17 (GPC ENA) is executed.

Other S-band PM fields on the ANTENNA display allow prime selection of a TDRS west or east, items 13 and 14, respectively. These items select the chosen TDRS as prime; if this TDRS is not in view, it selects the other TDRS. If both are in view, the prime is selected. No change is made to TDRS selection if neither is in view. Similar logic holds true for Kuband system, items 10 and 11.

2011/ /076 S-BAND PM XPND	COMM/I	000/00.00.00
MODE FREQ PREAMP PWR AMPL OPER STBY	2 TDRS LO 2 2	KU-BAND 000700100100 PA TEMP +91 GMBL TEMP A +80 B +82 GYRO TEMP +146 PWR OUT 26 FR_SYNC YES
PWR OUT 1 2 TEMP 1 2 NSP	133 169	MODE COMM TV CAM OVER-TEMP NO GCIL CONFIG CHD RECORDERS
BIT/FR SYNC 1 NO 2 YES DATA XMIT RCV	NO YES ENA HI	MODE STBY RCDA STBY TRK DIR FWD FWD FWD \$TAPE 55 200 0
UL DATA CODING XMIT RCV BITE 1	HI ON GOOD GOOD	TAPE STOP RUN STOP TEMP 48 90 48 BITE <u>SCDE INPUT</u> D/YO COMSEC BITE 1 FAIL
2	GOOD	COMSEC BITE 1 FAIL 2 GOOD

COMM/RCDR (DISP 76) Display



S-BAND PM ANT SW ELEC, PRE AMPL, PWR AMPL, and XPNDR Switches on Panel A1L

Preamplifiers

The dual S-band preamplifier is used in the *TDRS* and *STDN HI* modes for amplification. In *TDRS* mode, the preamplifier is required full-time for the forward link radio frequency because of the much greater distance and, consequently, lower strength signal from the TDRS to the orbiter (minimum of about 22,300 miles) than from the STDN to the orbiter (typically, slant ranges are in the low hundreds of miles). The preamplifier is not used in the *SGLS* or *STDN LO* modes. One of the two units is used at a time, and the output of either unit can be cross-strapped to feed either transponder. The preamplifier provides an RF gain of about 25 decibels.

The PRE AMPL control switches are on panel A1L; this function is generally under ground control. If the S-BAND PM CONTROL switch on panel C3 is set to PANEL, preamp 1 or 2 is selected, depending on the position of the S-BAND PM PRE AMPL switch on panel A1L. The COMM/RCDR display (DISP 76) under SM OPS 201 shows preamp status and frequency configuration (PREAMP and FREQ).

Power Amplifiers

The S-band power amplifiers provide selectable amplification of transponder RF output for *STDN HI* and *TDRS* operational modes. The nominal power gain is about 17 decibels. There are two power amplifiers; one is used at a time, and the input of either can be cross-strapped with the output of either transponder. The output of the power amplifiers can also be routed through either frequency diplexer in the preamp assembly.

The power amplifiers use a traveling wave tube, which has a filament that must be warmed up before high voltage is applied to the tube. A 140-second timer provides the delay when the *OPERATE* mode is selected from a cold start. With the system in *STANDBY*, the filament is kept heated, ready for "instant on" operation.

The *PWR AMPL STANDBY* and *OPERATE* switches are on panel A1L; these functions are generally under ground control. If the *S-BAND PM CONTROL* switch on panel C3 is set to *PANEL*, the switches on panel A1L establish power amplifier configuration.

NOTE

Both the *PWR AMPL STANDBY* and *OPERATE* switches should be in the same position to avoid a reset of the 140-second timer when the standby system is selected.

The COMM/RCDR display, DISP 76, also shows power amplifier status (PWR AMPL OPER, STBY, and PWR OUT and TEMP).

Transponders

Two identical S-band PM transponders function as multipurpose, multimode transmitter/receivers. The transponder can simultaneously transmit and receive, transmit only, or receive only. Only one transponder operates at one time; the other is a redundant backup. The selected transponder transfers the forward link commands and voice to the network signal processor and receives the return link telemetry and voice from the network signal processor. The transponders may be cross-strapped. Transponder 1 or 2 may be used with network signal processor 1 or 2. The radio frequency sections of either transponder can be used with either preamplifier and power amplifier 1 or 2.

The selected transponders also provide a coherent turnaround of the PM forward link and PM return two-way Doppler and two-way tone ranging signals. The two-way Doppler and two-way ranging signals are operative when the orbiter is in view of the NASA STDN ground stations at launch, lift-off, ascent, or landing, or when it is in view of SGLS mode ground stations. The two-way Doppler operates through the TDRS, but the two-way ranging does not.

Two-way Doppler is used by ground stations to track the orbiter. The S-band PM forward and return links are directly proportional to the forward link frequency (two-way Doppler). The S-band transponder provides a coherent turnaround of the forward link carrier frequency necessary for the twoway Doppler data. The transponder operates only when in view of the NASA STDN ground stations during launch, lift-off, ascent, or landing, or in view of SGLS mode ground stations. By measuring the forward link and using return link frequencies expected from the orbiter, the ground tracking station can measure the double Doppler shift that takes place and can calculate the radial velocity (range rate) of the orbiter with respect to the ground station. Because these links are PM, the S-band carrier center frequency is not affected by the modulating wave. It would be impossible to obtain valid Doppler data of the S-band carrier center frequency if it were affected by the modulating technique.

The S-band transponder also provides a subcarrier for two-way tone ranging. The transponder is used to determine slant range from a known point to the orbiter and operates only when in view of the NASA STDN ground stations during launch, lift-off, ascent, or landing, or in view of SGLS mode ground stations. This capability does not operate through the TDRS. The ground station forward-links ranging tones at 1.7 MHz and computes vehicle slant range from the time delay in receiving the return link 1.7-MHz tones to determine the orbiter's range. The orbiter's azimuth is determined from the ground station antenna angles. A C-band skin-tracking mode also is provided from the ground station to track the orbiter and, again, is used only in view of the NASA STDN ground station associated with launch, lift-off, ascent or landing, or in view of SGLS mode ground stations. This capability does not operate through the TDRS.

The *S*-BAND PM XPNDR switch is located on panel A1L; this function is generally handled by ground command via the GCIL. If the *S*-BAND PM CONTROL switch on panel C3 is set to PANEL, the XPNDR selection is made from panel A1L.

The COMM/RCDR display, DISP 76 in OPS 201, gives transponder status (XPND and MODE). The OPS 201 ANTENNA display also shows the mode for active transponders.

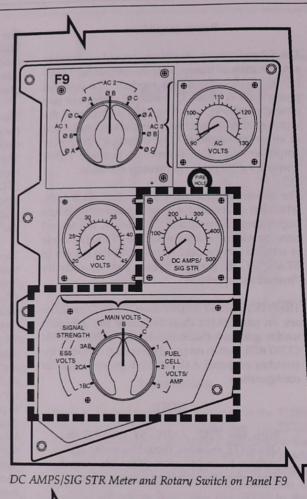
Received S-band PM RF signal strength is shown on the DC AMPS/SIG STR meter on panel F9 when the rotary switch below the meter is set to *SIGNAL STRENGTH*, and on the SIGNAL STRENGTH indicator on panel A1U when the switch to the left of the indicator is set to *S-BAND PM*. Signal strength is also shown on the OPS 201 ANTENNA DISPLAY (SIG STR); however, during launch and landing, the display is not available.

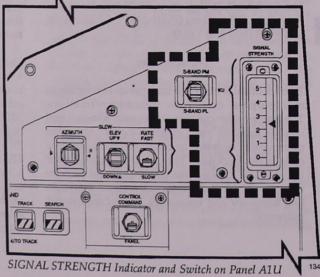
NOTE

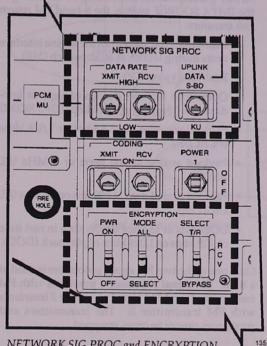
The panels F9 and A1U signal strength indications come from the transponder receiver, whereas OPS 201 ANTENNA display signal strength comes from OI MDM OF3 data.

Network Signal Processors

The two onboard network signal processors (NSPs) receive commands (forward link) and transmit telemetry data (return link) to the selected S-band transponder. Only one signal processor operates at a time; the other provides a redundant backup. The selected processor receives one or two analog







NETWORK SIG PROC and ENCRYPTION Switches on Panel A1L

voice channels from the onboard audio central control unit, depending on whether one (in the lowdata-rate mode) or both (in the high-data-rate mode) of the air-to-ground channels are being used. Both voice channels are downlinked only if the NSP is high data rate on both forward and return links. It converts them to digital voice signals, time-divisionmultiplexes them with the telemetry from the pulse

code modulation master unit, and sends the composite signal to the S-band PM transponder for transmission on the return link. On the forward S-band PM link. the NSP does just the reverse. It receives the composite signal from the S-band transponder and outputs it as either one or two analog voice signals to the audio central control unit. The composite signal from the S-band transponder and outputs it as either one or two analog voice signals to the audio central control unit. The composite forward link

also has ground commands that the NSP decodes and sends through the FF MDMs (nominally NSP 1 to FF 1 and NSP 2 to FF 3) to the onboard computers, which route the commands to the intended onboard systems. The NSP data routing / processing modes are controlled by the *NETWORK SIG PROC* switches on panel A1L.

NOTE

The NSP can also route return link (telemetry and voice) and receive forward link (commands and voice) via the Ku-band system.

Communications Security

Communications security (COMSEC) equipment provides the capability for encryption/decryption of operational data aboard the orbiter. The COMSEC equipment works with the NSPs to provide selectable transmit, receive, and record combinations under NSP mode control.

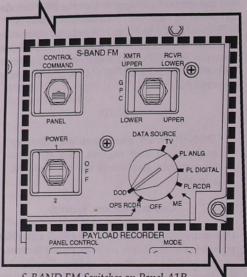
The NSP routes data of the indicated type through the COMSEC encryptor or decryptor as appropriate if "ENC" and gets the data back from the COMSEC line-replaceable unit encrypted/decrypted; if "CLR", the indicated data are handled directly by the NSP, and the COMSEC is bypassed.

The three *ENCRYPTION* switches on panel A1L provide power and routing control for encrypted data through the NSP.

NSP/COMSEC Link Functions

ISP ENCRYPTION	Switch MODES	Link function
ALL (DOD)	sate on panel -2 and of the S- cardbilleleded	Recorded Data Encrypted * Transmitted Data Encrypted Received Data Encrypted
SELECT	T/R	Recorded Data Clear (unencrypted) ** Transmitted Data Encrypted Received Data Encrypted
(NASA)' RCV	RCV	Recorded Data Clear (unencrypted) ** Transmitted Data Clear (unencrypted) Received Data Encrypted
	BYPASS	Recorded Data Clear (unencrypted) ** Transmitted Data Clear (unencrypted) Received Data Clear (unencrypted)

Data rate determined by NSP downlink DATA RATE switch.
 HDR only.



S-BAND FM Switches on Panel A1R

S-Band Frequency Modulation

The S-band FM system cannot receive information; it is used to downlink data from up to seven different sources, one at a time, directly to the ground when there is a line of sight between the orbiter and STDN or Air Force ground stations. The S-band FM return link can originate from two S-band transmitters aboard the orbiter. Both transmitters are tuned to 2,250 MHz. The S-band FM return link can be transmitted simultaneously with the S-band PM return link to the STDN ground station or Mission Control or to the Air Force ground station. The Sband FM return link does not operate through the TDRS system.

Controls for the S-band FM system are on panel A1R. Status and configuration control of the Sband FM system electronic elements can be selected either by panel switches or GCIL, depending on whether the CONTROL switch is set to COMMAND or PANEL. Set to PANEL, the switches allow rotary switch selection of the DATA SOURCE, and FM Power 1, Off, or 2.

The FM signal processor is commanded to select one of seven sources for output to the S-band FM transmitter, which transmits it to the S-band FM return link through the STDN ground station used for launch, lift-off, ascent, or landing, or the DOD AFSCF ground station. Depending on the setting of the DATA SOURCE switch, the S-band FM return link transfers:

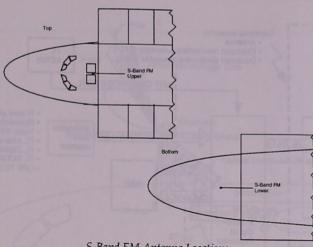
- Real-time SSME data from the engine interface units during launch at 60 kbps each (ME)
- Real-time video (TV)
- Operations recorder dumps of high- or lowdata-rate telemetry at 1,024 kbps (OPS RCDR)
- Payload recorder at 25.5 kbps or 1,024 kbps (PLRCDR)
- Payload analog at 300 hertz or 4 MHz (PL ANLG)
- Payload digital data at 200 bps or 5 Mbps (PL DIGITAL)
- DOD data at 16 kbps or 256 kbps in real time or 128 kbps or 1,024 kbps of playback (DOD).

Only one of the two FM signal processors is used at a time. FM signal processor 1 interfaces with FM transmitter 1, and FM signal processor 2 interfaces with FM transmitter 2. The transmitters and processors cannot be cross-strapped.

S-Band FM Antennas

Two hemispherical S-band FM antennas covered with a reusable thermal protection system are located on the forward fuselage outer skin of the orbiter approximately 180 degrees apart. On the flight deck, the hemispherical antennas are above the head (upper) and below the feet (lower) and radiate the S-band FM return link.

The S-band antenna switch assembly provides the signal switching among the two S-band FM transmitters and either of the two hemispherical antennas. The proper antenna is selected automatically by onboard or real-time command from the ground, computer control, or manual flight crew selection using the *S-BAND FM XMTR UPPER*, *RCVR LOWER* switch on panel A1R. In the *GPC* mode, the onboard SM computer selects the proper hemispherical antenna to be used whenever an S-band FM transmitter is active. The antenna selection is based on the computed line of sight to the NASA STDN ground station used for launch, lift-off, ascent, or landing, or the AFSCF ground stations.

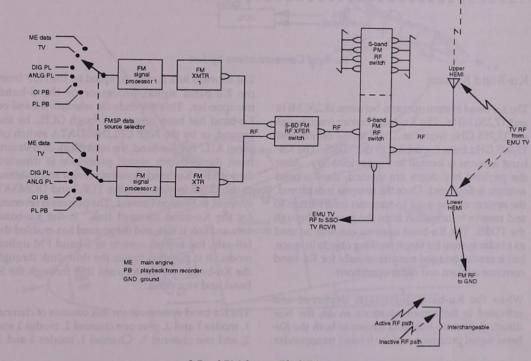


S-Band FM Antenna Locations

The basic difference between the quadrant and hemispherical antennas is that the hemispherical antennas have a larger beamwidth, whereas the quadrant antennas have a higher antenna gain. The hemispherical antennas are so named because there are two of them, one on the top of the orbiter and one on the bottom.

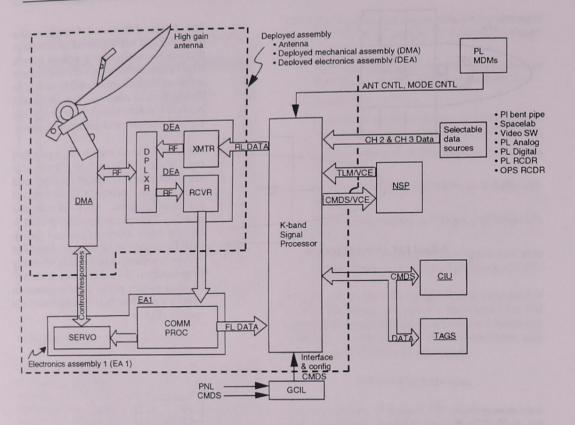
The hemi antenna switch has a port that can route RF television from the astronaut's extravehicular mobility unit (EMU) to the orbiter's closed-circuit television system. An extravehicular mobility TV unit can transmit television on one hemi antenna/antenna switch path to the orbiter while the S-band FM system is routing FM downlink telemetry to ground on the other hemi antenna/ antenna switch path. This requires an EMU TV receiver that is manifested for specific flights.

FM RF



S-Band FM System Block Diagram

2.4-11



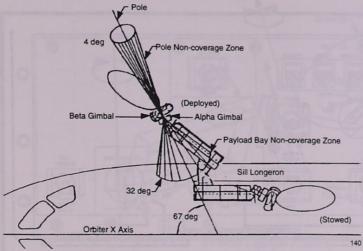
Ku-Band Communications System

Ku-Band System

The Ku-band system operates between 15,250 MHz and 17,250 MHz. The Ku-band carrier frequencies are 13,755 GHz from the TDRS to the orbiter and 15,003 GHz from the orbiter to the TDRS. The Kuband antenna is located in the payload bay. After the payload bay doors are opened, the Ku-band antenna is deployed. Once the antenna is deployed, the system can be used to transmit information to and receive information from the ground through the TDRS. The Ku-band antenna can also be used as a radar system for target tracking objects in space, but it cannot be used simultaneously for Ku-band communications and radar operations.

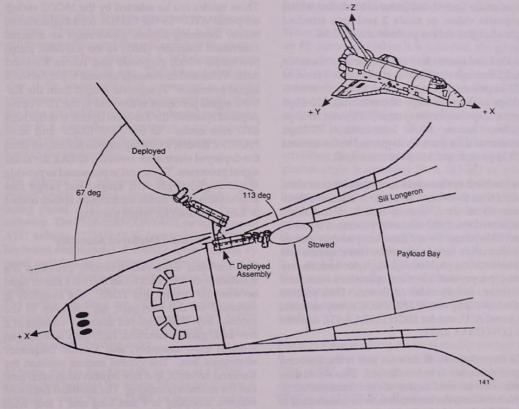
When the Ku-band antenna is deployed and activated in the communications mode, the NSP directs the return link data stream to both the Kuband signal processor and the S-band transponder. The forward link is only accepted by the NSP from the Ku-band signal processor or the S-band transponder. This depends on whether S-band or Ku-band has been selected through GCIL, by the ground, or by the NSP UPLINK DATA switch on panel A1L. For Ku-band, the return link data stream from the network signal processor is directed through the Ku-band signal processor and antenna to the TDRS in view, via the TDRS and DOMSAT systems, to Mission Control. The process is reversed for the Ku-band forward link. If the Ku-band forward link is lost, and the ground has enabled the fail-safe, the system reverts to S-band PM uplink mode. It is possible to run the downlink through the Ku-band and the forward link through the Sband, and vice versa.

The Ku-band system return link consists of channel 1, modes 1 and 2, plus one channel 2, modes 1 and 2, and one channel 3. Channel 1, modes 1 and 2,



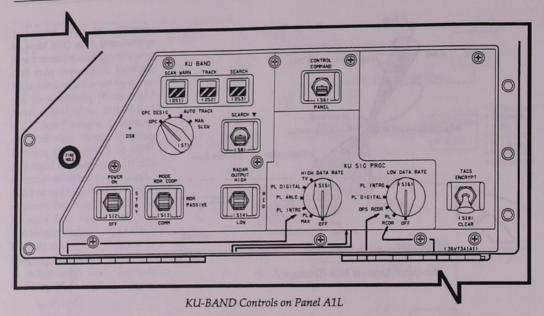
Ku-Band Antenna Non-Coverage Zones

consists of 192 kbps of operational data (128 kbps of operational data telemetry and payload interleaver plus two air-to-ground voice links at 32 kbps each) plus one of the following selections from channel 2, modes 1 and 2: (1) payload digital data from 16 kbps to 2 Mbps, (2) payload digital data from 16 kbps to 2 Mbps, (3) operations recorder playback from 60 kbps to 1,024 kbps, or (4) payload recorder playback from 25.5 kbps to 1,024 kbps. It also includes one of the following from channel 3: mode 1 attached payload digital data (real-time or playback) from 2 Mbps to 50



Ku-Band Deployed Assembly Location

2.4-13



Mbps, mode 2 television (color or black and white) composite video, or mode 2 real-time attached payload digital data or payload analog data.

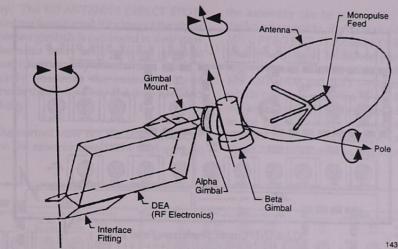
The Ku-band system forward link consists of a mode 1 and 2 through the TDRS in view. Mode 1 consists of 72-kbps data (two air-to-ground voice streams at 32 kbps each and 8 kbps of command), 128-kbps thermal impulse printer system (TIPS), and 16-kbps synchronization. Mode 2 consists of 72-kbps operational data (two air-to-ground voice streams at 32 kbps each and 8 kbps of command).

The Ku-band system can handle greater quantities of data than the S-band systems. It transmits three channels of data, one of which is the same interleaved voice and telemetry processed by the Sband PM system. Two of the seven possible sources of information sent on the other two channels are: payload analog, payload digital, payload interleaver bent-pipe, payload recorder, operations recorders, television, and Spacelab (if flown). Data sources are selectable by two KU SIG PROC rotary switches on panel A1U, one for HIGH DATA RATE and one for LOW DATA RATE.

The three channels of data are sent to the Ku-band signal processor to be interleaved. This signal then goes to the onboard deployed electronics assembly, which contains the transmitter, to be transmitted to the TDRS through the Ku-band antenna. Three modes can be selected by the MODE switch on panel A1U. In the COMM (communications) mode, incoming signals go through an internal electronics assembly (EA1) to the Ku-band signal processor, which processes and routes Ku-band data. Voice and commands are sent to the network signal processor. A separate output from the Kuband signal processor is directed to the TIPS or the payload system if the Ku-band uplink is in the high data rate mode. In the RDR COOP and RDR PASSIVE modes, incoming signals are routed from the deployed electronics assembly to EA2, the radar signal processor. The signal is processed to provide target angle, angle rate, range, and range rate information. This status information is then routed to EA1 to be used for target tracking.

Ku-Band Deployed Assembly

The Ku-band deployed assembly provides the interface with the TDRS when there is a line of sight between the orbiter and TDRS. The assembly is mounted on the starboard sill longeron in the payload bay. The deployed assembly consists of a two-axis, gimbal-mounted, high-gain antenna, an integral gyro assembly, and a radio frequency electronics box. The gimbal motors position the Ku-band antenna, and rate sensors determine how fast the antenna is moving. The Ku-band deployed antenna assembly is 7 feet long and 1 foot wide when stowed in the payload bay. The graphite



Ku-Band Deployed Assembly

epoxy parabolic antenna dish is 3 feet in diameter. The deployed antenna assembly weighs 180 pounds. The weight of the entire system is 304 pounds.

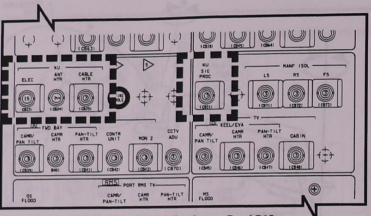
The antenna dish is edge-mounted on a two-axis gimbal. The alpha gimbal provides a 360-degree roll movement around the pole or axis of the gimbal. The beta gimbal provides a 162-degree pitch movement around its axis. The alpha gimbal has a stop at the lower part of its movement to prevent wraparound of the beta gimbal control cable. Since the beta gimbal has only a 162-degree movement, there is a 4-degree non-coverage zone outboard around the pole and a 32-degree non-coverage zone toward the payload bay.

The antenna can be steered in several selectable modes under manual control by the flight crew using panel A1U or automatically by the SM software. The KUBAND CONTROL switch on panel A1U selects COMMAND (control by GCIL or keyboard commands) or PANEL (crew control by panel switches and selectors). With the switch in PANEL, the antenna steering mode can be selected using the rotary switch on the left side of the panel. The switch positions are GPC (GPC pointing and auto track), GPC DESIG (GPC pointing only), AUTO TRACK (manual pointing and auto track), and MAN SLEW (manual pointing only).

At times, the Ku-band system, in view of a TDRS, is interrupted because the orbiter blocks the Ku-band antenna's view to the TDRS or because orbiter attitude requirements or payloads' radiation sensitivities prohibit its use. In addition, the Kuband antenna beta cabling may periodically require positioning to ensure that it does not become twisted in a way that could cause the antenna to bind.

When the Ku transmitter is enabled and outputting an RF carrier and when it is inhibited, the ground can control via ground uplink command to the SM GPC and Ku system. This control is called Ku antenna "masking." These masking modes are used to provide protection from Ku radiation for payloads and for crewmembers during EVAs and certain payload operations. The types of masking, commandable from the ground, include: 1) inhibiting the Ku transmitter when a specified beta gimbal angle is exceeded (beta MASK) or when both a specified beta gimbal angle and the orbiter hardware obscuration zone are exceeded (beta +MASK), 2) specifying an EVA protection zone, where the transmitter is disabled, within certain elevation and azimuth angle pointing of the antenna relative to a coordinate system, based on the orbiter's X, Y, and Z axes. New Ku software also modes the Ku system to standby mode, if the antenna remains near the beta stops for a certain period of time, to prevent excessive antenna gimballing and cable binding.

None of these masking modes is readily evident to the crew unless they monitor RF out power on SM GPC SPEC 76. Only the orbiter hardware obscuration zone is shown on the SM ANTENNA SPEC (see ANTENNA display on page 2.4-6).



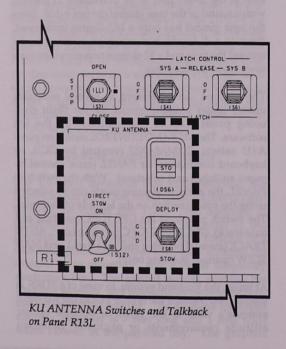
KU-BAND Circuit Breakers on Panel R15

Ku-Band Antenna Deployment and Stowage

When the Shuttle reaches orbit, before the Ku-band antenna is deployed, the KU ANT HTR circuit breaker on panel R15 is closed to energize thermostatically controlled heaters for the deployed electronics assembly, gimbals, and antenna assembly. During Ku-band activation, the KU ELEC and KUSIG PROC circuit breakers on panel R15 are closed. (There is also a CABLE HTR circuit breaker on panel R15. The Ku-band system was originally designed to have a cable heater, but it was never installed. Therefore, this circuit breaker is always left open.) These circuit breakers provide electrical power to the Ku-band electronic elements, electronics assemblies 1 and 2, the signal processor assembly, and Ku-band portions of panels A1U and A2. Actual deployment involves the KU ANTENNA controls and associated talkback on panel R13L. The antenna is locked in the stowed position to clear the adjacent payload bay doors and radiators when they are closed or moving.

Twenty-three seconds are normally required to deploy or stow the assembly. In the deployed position, the assembly forms a 67-degree angle with the orbiter X axis. Activating the Ku electronics and taking the KU BAND POWER switch on panel A1U to ON frees the antenna gimbals by removing the gimbal locking pins. The beginning of stow operations contains approximately 30 seconds of gimbal lock sequencing before assembly stow begins.

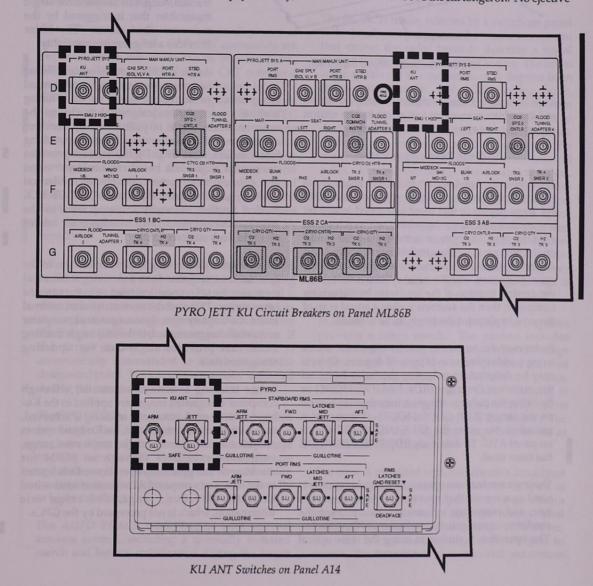
The Ku-band antenna must be stowed before the orbiter payload bay doors are closed in preparation for entry. This is done by setting the *KU ANTENNA* three-position switch on panel R13L to the *STOW* position. If the assembly does not respond to normal stow operations, the *KU ANTENNA DIRECT STOW* switch on panel R13L is used. Setting this switch to *ON* bypasses the normal stow control sequences and causes the assembly to be driven inside the



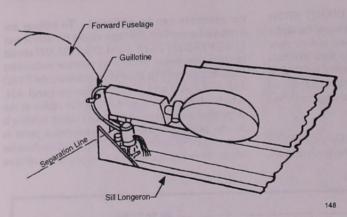
payload bay. The KU ANTENNA DIRECT STOW switch procedure is only used if locking of the alpha and beta antenna gimbals is successful in their stow position, because entry with antenna gimbals unlocked may cause unacceptable damage. DIRECT STOW merely positions the entire deployed assembly inside the payload bay and does not affect gimbal locking.

If neither the normal stow nor the *DIRECT STOW* can position the assembly inside the payload bay,

the assembly can be jettisoned. To jettison the deployed assembly, the crew closes the *MN A* and *MN C PYRO JETT SYS A* and *SYS B KU ANT* circuit breakers on panel ML86B to provide redundant jettison power. The crew then activates the *PYRO KU ANT ARM* and *JETT* switches on panel A14, which causes a guillotine to cut the cables to the deployed assembly and releases a clamp holding it to the pivot assembly. The separation point is between the assembly and deployment mechanism about 20 inches above the sill longeron. No ejective







Ku-Band Antenna Jettison Separation

force is imparted; the assembly is merely cut loose, and the orbiter maneuvers away from it. The jettison operation takes approximately 4 seconds.

Ku-Band Rendezvous Radar

The orbiter Ku-band system includes a rendezvous radar that skin-tracks satellites or payloads in orbit. For large payloads that must be carried into orbit one section at a time, the orbiter will rendezvous with the payload segment currently in orbit to add on the next section. The gimballing of the Ku-band antenna permits it to conduct a radar search for space hardware. The Ku-band system is first given the general location of the hardware by the orbiter computer; then the antenna makes a spiral scan of the area to pinpoint the target (in *GPC* mode).

Radar may also be used to search for space hardware using a wide spiral scan of up to 60 degrees. Objects may be detected by reflecting the radar beam off the surface of the target (*RDR PASSIVE MODE*) or by using the radar to trigger a transponder beacon on the target (*RDR COOP MODE*). These modes are selectable using the *KU BAND MODE* switch on panel A1U. To date, only RDR PASSIVE MODE has been used.

During a rendezvous operation, the radar system is used as a sensor that provides target angle, angle rate, and range rate information for updating the rendezvous navigation data in the GNC computer. The operation is similar to using the crew optical alignment sight or star trackers, except that the radar provides range data in addition to angle data. Angle tracking maintains appropriate antenna pointing to keep the target within the antenna beam. Range tracking is accomplished by electronically measuring the time between a transmitted pulse and a return pulse from the target. The return pulse may be reflected from a passive (skintracked) target or cooperative target transmitter that is triggered by the radar-initiated pulse. The latter provides a longer range capability.

Angle tracking can be accomplished in two ways: computer or manual designations or automatic (auto) servo. During manual or computer-designated tracking, the antenna beam angle is positioned by services external to the Ku-band system. Computer tracking (used in GPC and GPC DESIG modes) provides designated angle data based on combined target and orbiter state vector information. Manual tracking (used in MAN SLEW and AUTO TRACK modes) applies manually initiated rates to the antenna control system from switches at the orbiter aft flight deck station (A1U).

Automatic angle tracking applies error rates to the antenna control system from a receiving station that measures the target position relative to the antenna beam center. This closed-loop servosystem, internal to the Ku-band system, ignores external computer or manual designations. It is the only angle tracking mode that provides angle data for updating navigation data.

Range tracking is always automatic, although computer-designated ranges are applied to the Kuband system until automatic tracking is achieved. In the automatic tracking mode, the Ku-band system provides actual antenna angle, angle rate, range, and range rate data through an MDM for rendezvous and proximity operations. Data routed to the indicators on panel A2 represent hard-wired azimuth, elevation, range, and range rate information, which is not processed by the GPCs. Before any radar mode is used, the orbiter is normally maneuvered to an attitude with the minus Z axis pointing at the target location. In all modes, therefore, the radar antenna is normally maneuvered around the minus Z axis.

The Ku-band system provides for antenna steering modes, each with a different combination of capabilities for acquiring and tracking a target: *GPC*, *GPC DESIG*, *AUTO TRACK*, and *MAN SLEW*. All are mutually exclusive and crew selectable using the rotary switch on panel A1U.

The GPC mode is fully automatic in all phases of target acquisition. Two GPC CRT commands are required before this mode can be initiated (GNC SPEC 33, REL NAV DISP). One CRT command enables target position data to be routed from the GNC to the SM antenna management program through the intercomputer data bus (GNC SPEC 33, REL NAV DISP, item 1). The antenna management program converts the target position to antenna pointing angles and estimated orbiterto-target range data. Another CRT command enables the antenna management program to send designated antenna pointing and range data to the Ku-band system through the payload 1 data bus and the payload forward 1 MDM (GNC SPEC 33, item 2).

When the *GPC* mode is selected, the antenna points to the commanded angles and adjusts the ranging system to the specified range. If a receive signal is detected, the automatic closed-loop system tracks the target in angles and range and provides data for the SM and GNC computers and panel displays. If the target is not detected, the antenna is automatically commanded to search around the designated point. The antenna is inertially stabilized during the search operation.

The *GPC DESIG* mode provides the same designated pointing as the *GPC* mode without angle search or angle-tracking capabilities. No closed-loop angle tracking is provided. The designated angles are updated every 2 seconds. Range search and tracking are automatic. The antenna may be either inertially or body stabilized.

The AUTO TRACK mode begins with manual antenna control, including a manually initiated search and inertial stabilization during the target

acquisition phase. Once the target is detected, automatic angle and range tracking is initiated and manual control is inhibited until auto tracking is broken.

The *MAN SLEW* mode allows manual control of antenna movement with maximum automatic range search. Once the target is detected, an automatic range track is initiated, but angles are still under manual control. No angle search is available in this mode.

The SEARCH mode, selected by a switch on panel A1U, involves a programmed antenna movement that causes the radar beam to describe a spiral pattern starting at the designated angles. The beam angle spirals out to a maximum of 30 degrees from the designated angle. In the GPC steering mode, the variation of the maximum angle of search from the designated point is inversely proportional to designated range. The smallest search spirals outward to a maximum of 6.2 degrees from the designated point for ranges from 145 to 300 nautical miles. At minimum ranges (0 to 8 nautical miles), the spiral search is the maximum 30 degrees from the designated point. If the antenna drive system detects but overshoots the target during a spiral search, a miniscan program is automatically initiated near the point of detection. The miniscan searches to a maximum of 9 degrees from the starting point in 1 minute. In the auto track steering mode, only the manually initiated main 30-degree scan is available.

In addition to angle search, the Ku-band system provides a range search. The process includes electronically varying the timing within the range system until it coincides with the time interval between the transmitted and received radar pulses. Once the intervals coincide, radar tracking is established, and the range data output represents the range between the target and the orbiter. The crew can read the range and range rate values as panel and CRT parameters.

The crew is provided with two controls associated with range. Transmitter power output is automatically varied in proportion to range when a target is being tracked to keep the return signal relatively constant, regardless of range. If, however, the track is lost, and the range system begins to search, the transmitter may transmit maximum power during the search. The crew can limit the maximum transmitter power by using an aft station panel control. The other control is a CRT command that limits the range search in GPC steering mode to 2,400 feet.

The Ku-band system has body and inertial antenna stabilization modes. When the body is stabilized, the antenna beam remains in a fixed relationship to the orbiter X, Y, and Z axes during orbiter attitude changes. When the system is inertially stabilized, the antenna beam remains aligned to a point in inertial space, regardless of the orbiter attitude changes. Both of these modes are effective only when the radar angle-tracking system is not tracking a target. In the target angle-tracking mode, the system aligns the antenna beam to the target, and antenna movement is independent of orbiter attitude changes.

Each antenna steering mode, except the designate mode, has a specific stabilization mode. The designate mode selects either body or inertial stabilization on the basis of a real-time GPC command (not available to the crew). Since the designate mode provides range tracking only, inertial stabilization is effective during target tracking.

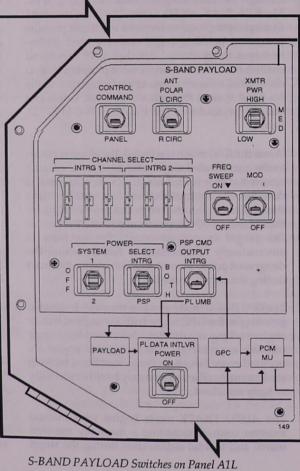
The COMM/RCDR display, DISP 76, provides the status of Ku-band temperatures (PA, GMBL, GYRO), power out (in watts), frame sync, and mode (COMM or RDR), to flight crews.

Payload Communication System

The payload communication system is used to transfer information between the orbiter and its payload or payloads. It supports hardline and radio frequency communications with a variety of payloads. The system is used to activate, check out, and deactivate attached and detached payloads.

Communication with an attached payload takes place through the payload patch panel at the crew compartment flight deck aft station, which is connected to payloads in the payload bay. All command and

telemetry signals that meet the payload communication system specifications can be processed on board. Incompatible signals can be sent to the ground through Ku-band or directly to payload ground stations. This method of transmission, referred to as bent-pipe telemetry, means that no onboard signal processing occurs before the telemetry is sent to the Ku-band system. Payload telemetry can go directly to the S-band FM or Ku-band systems for transmission to the ground, payload analog, or payload digital, to the payload recorder for later transmission, or to the payload data interleaver to be interleaved with other payload data. The system also processes commands and provides payload telemetry to the pulse code modulation master unit (PCMMU), where the data can be accessed for display on various payloadrelated controls and displays.



2.4-20

SCOM 1.5 July 1994 The S-band payload antenna is located on the top of the outer skin of the orbiter's forward fuselage, just aft of the S-band FM upper hemispherical antenna. The payload antenna is covered with reusable thermal protection system. This antenna is used as the radiating element for S-band transmission and reception to and from the orbiter to detached payloads through the forward and return links.

Communication problems involving antenna position relative to payload position are not evident while the payload is within a half mile of the orbiter, along the minus Z axis. However, to maintain good communication with the orbiter from distances of several miles, the payload must be within an 80degree beamwidth (with reference to the minus Z axis) of the orbiter's payload interrogator antenna. The boundary of the 80-degree beamwidth is the 3decibel point (or half-power point), which must be considered during communication with deployed payloads. This constraint is normally satisfied by the payload deployment and retrieval process.

The basic elements in the payload communication system are the payload interrogator (PI), payload signal processor (PSP), communication interface unit (CIU), payload data interleaver (PDI), pulse code modulation master unit (PCMMU), and payload recorder (PL RCDR). These elements are in the forward avionics bays. Commands to the payload communication system are routed through the

XXXX/062/ SM COM BUFF XX PCMMU BITE WORD XXXX FMT SEL FXD 1XS PCM 2XS PCM 1D 64 XXX 128 XXX		XX X DDD/HH: MM: SS DDD/HH: MM: SS PDI i/O RESET 8XX BITE WORD XXXXS 9 SEL DECOM XX 10 SEL FMT XXX LOAD 11 XXXX 12 SEL INPUT X
3 SEL ID XXX LOAD 4 XXXX I/O RESET PCM 5XX		LOAD 13 DECOM INPUT FMT 1 X XXS 2 X XXS 3 X XXS 4 X XXS 5-FPM XXX
PSP I/O RESET PSP1 6X PSP2 7X SYNC BIT XXXS FRAME XXXS LOAD XXXX XXXX	X PHASE LOCK XXX ERR ±XX	DECOM ENA ENA S FDA 1 14X 3 16X S 2 15X 4 17X S 18 TFL GPC SEL X S DOWNLIST S 19 SEL FMT ID XX

PCMMU/PL COMM Display (SPEC 62)

GCILC from the payload MDMs 1 and 2, although these MDMs are also used for orbiter commanding. Status and control of payload communication systems can also be accessed by the PCMMU/PL COMM display (SPEC 62).

Payload Interrogator

Detached payloads communicate with the orbiter on an RF signal through the payload antenna by the payload interrogator. The payload interrogator is a transmitter/receiver/transponder unit that provides full duplex RF communications between the orbiter and a detached payload. It transmits commands to and receives telemetry from NASAor DOD-compatible payloads through the payload antenna. Payload interrogator controls are located on panel A1L.

The main carrier frequency of the detached payload telemetry is demodulated by the payload interrogator. The telemetry is routed directly to the Ku-band system for transmission to the ground (bent-pipe telemetry) and to the payload signal processor. The payload signal processor demodulates the telemetry from the subcarrier and sends it to the payload data interleaver to be interleaved with other payload data. Hardline payload commands are routed through the payload signal processor and then output through the payload patch panel directly to an attached payload. Detached RF commands are routed through the payload signal processor and then through the payload interrogator for transmission to the payload through the payload antenna.

The payload interrogator receiver automatically sweeps to acquire and track an unmodulated or modulated RF signal. Payload interrogator telemetry is available through an operational instrumentation MDM to verify signal strength and frequency lock. If payload frequencies are near the orbiter S-band frequencies, care must be taken to prevent interference.

When the payload outputs a data rate that is not compatible with the payload signal processor or communication interface unit, payload telemetry is throughput to the PDI without processing.

10016. CRT. 1

Payload Signal Processor

The payload signal processor is the RF and hardline command interface between the ground or flight crew and the payload. It is also a detached payload telemetry interface to the payload data interleaver. The payload signal processor is controlled by the switches on panel A1L. The payload signal processor output is commanded or selected by the PSP CMD OUTPUT switch.

The PI and PSP are commanded through GCILC/ MCC or selected by the crew (AIL) using the two power switches.

Communication Interface Unit

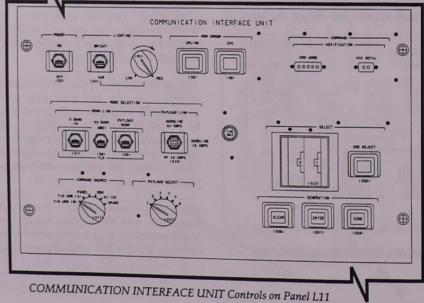
The communication interface unit sometimes replaces the payload signal processor. The payload signal processor may be retained to act as a backup. The communication interface unit is commonly used with the inertial upper stage, although it may be used with other payloads compatible with SGLS. The communication interface unit interfaces indirectly with the payload data interleaver through the patch panel because the communication interface unit is treated as an attached payload accessed through a patch panel input of the payload

data interleaver. The payload signal processor is hard-wired directly to the payload data interleaver. This provides a command and telemetry path between the orbiter guidance, navigation, and control, GPC, and an SGLS-compatible payload or between the flight crew and an SGLS-compatible payload. The communication interface unit passes commands and telemetry to either attached or COMMUNICATION detached payloads. INTERFACE UNIT controls are on panel L11.

Payload Data Interleaver

In the NASA mission configuration, the payload patch panel interfaces attached payloads to the PDI. The PSP acts as the interface for detached payloads. Attached payloads are wired to specific input channels of the PDI via the payload patch panel during prelaunch activities. When the PDI is reconfigured by the flight crew, programming procedures include assigning inputs in the PDI to one of four decommutators.

The PDI allows the payload communication system to interface with the rest of the orbiter communication system and computers. It receives up to six different inputs from attached or detached payloads and one ground support equipment input.





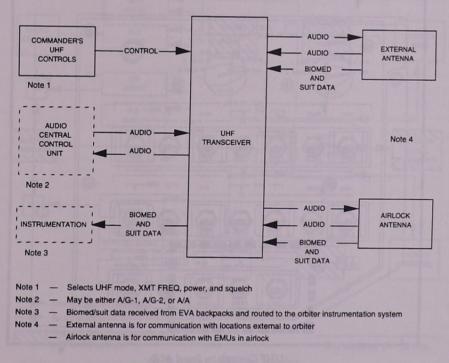
For missions using the payload signal processor, a maximum of five attached payloads can be accommodated on inputs 1 through 5. Input 6 is reserved for detached payload telemetry using the RF link through the payload signal processor. For missions using the communication interface unit, all data, attached or detached, are routed through input 5. The PDI has four decommutators that can process up to four payload data streams. The PDI ships the payload telemetry to the PCMMU, where it can be accessed by the SM GPC for display, and combined with orbiter telemetry for transmission to the ground. The *PL DATA INTLVR POWER* switch is on panel A1L.

Ultrahigh Frequency System

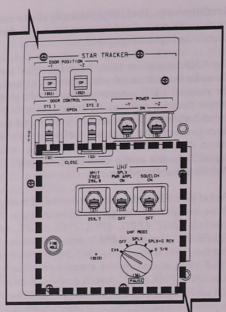
The UHF system is used as a backup for the S-band PM and Ku-band voice communications, and is primary during EVA operations. For communications with MCC through the STDN or SGLS ground stations, the UHF system operates in a simplex mode, which means that the orbiter flight crew can transmit or receive, but cannot do both simultaneously. The UHF system may also be used for air traffic control and two-way voice with chase aircraft during landing operations.

The UHF transceiver takes the voice signal from the audio central control unit and routes it through the external UHF antenna on the bottom of the orbiter forward fuselage for transmission to the ground station. The incoming UHF signal goes through the external antenna to the UHF transceiver, which demodulates it and routes it as an audio signal it to the audio central control unit for distribution in the orbiter.

Part of the UHF configuration is controlled through three two-position toggle switches on panel O6 labeled XMIT FREQ, SPLX PWR AMPL, and SQUELCH. The XMIT FREQ switch selects one of the two UHF frequencies, 296.8 MHz primary or 259.7 MHz secondary, for external transmission. The SPLX PWR AMPL switch enables or inhibits the UHF power amplifier circuit. When the switch is positioned to ON, the UHF system transmits 10 watts of power through the antenna. When the switch is positioned to OFF, the power transmission



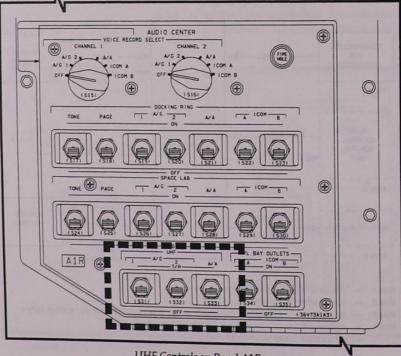
UHF Subsystem Functional Block Diagram



UHF System Controls on Panel 06

is reduced to 0.25 watts by bypassing the power amplifier circuit. (An airlock antenna is used by EVA astronauts in extravehicular mobility units to check out their transceivers before exiting the airlock.) The *SQUELCH* switch permits *ON* or *OFF* selection of UHF squelch.

A five-position UHF MODE rotary switch on panel O6 activates power to the UHF transceiver and is used to select any of the following modes of UHF transmission. When the rotary switch is positioned to EVA, EVA transmissions are made on one frequency selected by the XMIT FREQ switch. The return signal is received on two other frequencies. The OFF position removes all electrical power. When the rotary switch is positioned to SPLX, transmission and reception are both on the frequency selected by the XMIT FREQ switch. Positioned to SPLX + G RCV, transmission and reception are the same as in simplex except that reception of the UHF guard (emergency) frequency (243.0 MHz) also is possible. In the G T/R position, transmission and reception are both on the UHF guard (emergency) frequency.



UHF Controls on Panel A1R



Three two-position *UHF* toggle switches located on the bottom of the *AUDIO CENTER* portion of panel A1R control routing of audio from the audio central control unit to the UHF transceiver. The switches are labeled *T/R* for transmit/receive, *OFF* for blocking UHF audio to and from the UHF transceiver, *A/G* for the air-to-ground channels, and *A/A* for the air-to-air channel.

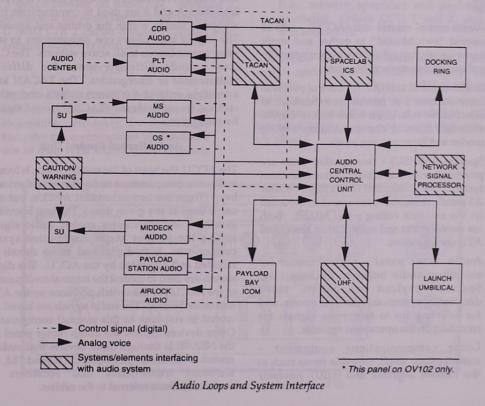
For normal EVA operations, the orbiter transmits 296.8 MHz and receives 259.7 and 279.0 MHz. The EVA astronauts are transmitting voice and biomedical/suit data on their respective frequencies. The biomedical/suit data is routed through the OI system once it is removed from the UHF carrier. The astronaut configured for mode A transmits on 259.7 MHz. The astronaut configured for mode B transmits on 279.0 MHz. Each of the two EVA astronauts receives the other on the respective transmitted frequencies. Every 2 minutes, biomedical data are replaced with suit telemetry data for 15 seconds. EVA conversations are routed to Mission Control via the S-band PM or Ku-band system on A/G 1 or A/G 2, depending on the

configuration of the *UHF A/G 1* and *A/G 2* switches on panel A1R. As a backup procedure only when the orbiter is over a UHF ground station, the EVA astronauts, orbiter, and ground can switch to the 259.7-MHz UHF, simplex.

The UHF system may be used after entry during the approach and landing phase of the mission. UHF air-to-ground voice communications may take place between the orbiter, the landing site control tower, and chase planes (if used).

Audio Distribution System

The audio distribution system gathers audio signals from multiple sources and routes them throughout the orbiter. It provides the means by which crew members communicate with each other and with external locations, such as Mission Control, through the S-band PM, Ku-band, and UHF systems. It also interfaces with the caution and warning system for reception of C/W (tone) signals and with the three tactical air navigation (TACAN) sets for monitoring the TACAN audio identification codes. The external



2.4-25

communications are facilitated by routing AG1/2 through the network signal processor. The audio distribution system outputs audio for one or both of the A/G loops to the network signal processor where it is digitized and sent to the S-band PM and Ku-band systems for downlink to MCC. Uplink digitized A/G audio is routed through the S-band PM or Ku-band systems and the network signal processor where it is converted to analog for use in the audio distribution system. This system also provides connections to the UHF transceiver via the AA loop for external communications with MCC through ground base sites which support UHF. As previously stated, UHF is also used as prime voice communications with EVA crewmembers. Normally in the EVA mode, the AG1 loop is routed to and from the audio distribution system. The audio distribution system routes audio signals to an onboard Spacelab module, docking ring, operations recorder, payload bay stations, and the video distribution system under control of switches on panel A1R.

The major elements of the audio distribution system include:

- Audio central control unit (ACCU) acts as central "switchboard" to gather and route audio signals throughout the orbiter; internally redundant line-replaceable unit.
- Audio terminal unit (ATU) control panels at crew stations that permit crewmembers to select audio talk/listen buses and to control external/internal communication keying modes and listen volume levels.
- 3. Speaker unit (SU) two speaker units are provided with the orbiter communications system. One is mounted on the flight deck aft A2 panel. A second speaker unit in mounted on the middeck ceiling panel MO29J. Both are connected to and subject to an associated ATU configuration.
- 4. Audio center panel control center for extending audio buses to docking ring, Spacelab, payload bay outlets, video distribution system, and the UHF system, and for selecting up to two voice signals for recording on the operations recorder.
- Loose communications equipment miscellaneous small, stowable items such as the headset interface unit (HIU), headset/

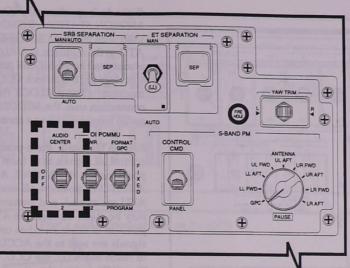
helmet cables, wireless crew communications unit (WCCU), and handheld or wireless handheld mic.

6. Crew communications umbilical (CCU) jack – individual panel-mounted jacks at crew stations where mating headset plugs give the crew access to audio buses. At each CCU location is an associated ON/OFF switch to control power to the headset interface unit or wireless communications unit utilizing that jack.

The eight loops in the audio system are (1) air-toground 1, (2) air-to-ground 2, (3) air-to-air, (4) intercom A, (5) intercom B, (6) paging, (7) C/W, and (8) TACAN. A/G 1 and A/G 2 are used to communicate with the ground through the S-band PM and Ku-band systems and UHF during EVA operations. (In the NSP low-data-rate mode or while used with other loose communications gear such as the thermal impulse printer system, A/G 2 is not available for voice communications.) A/A is used, by convention, to communicate with the ground and with EVA astronauts through the UHF system. Intercoms A and B are used to communicate from station to station within the orbiter and Spacelab. The paging loop allows one crewmember to send voice transmissions to all active stations. The C/W loop sounds different tones for different malfunctions or emergencies. The TACAN loop, accessible only at the commander's and pilot's stations, is used to identify TACAN ground stations for navigation.

Audio Central Control Unit

The ACCU, the heart of the audio system, is located in the crew compartment middeck forward avionics bay. (There are two redundant ACCUs, but only one is used at any given time.) The unit identifies, switches, and distributes analog audio signals among the various audio distribution system components. Both digital and audio signals are received and processed by the ACCU. The digital signals are used to control the internal configuration of the ACCU per the switch positions on the ATUs and other devices. The audio signals are keyed and routed in response to this internal configuration. Other devices include the audio center panel and the NSP. It is through these devices that audio is routed to the ultrahigh frequency, S-band PM, and Ku-band transmitters and receivers for communications external to the orbiter.



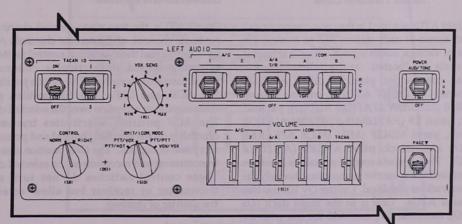
AUDIO CENTER Selection Switch on Paenl C3

The AUDIO CENTER selection switch is on panel C3. Setting the switch to 1 applies primary power to the control center unit from the ESS 2CA AUD CTR 1 circuit breaker on panel R14. Selecting 2 applies power to the secondary unit electronics from MN C AUD CTR 2 circuit breaker on panel R14. OFF removes all power from the ACCU.

NOTE

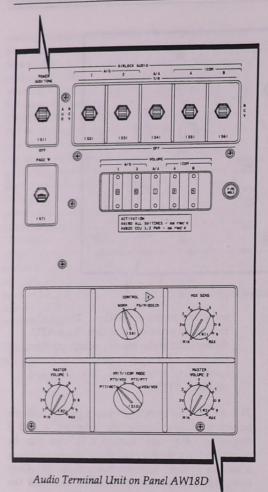
With the AUDIO CENTER selection switch OFF, all normal audio functions will be inoperative. However, the commander and pilot can communicate via headset if one of their ATU CONTROL switches is set to the alternate position. This is also true for any two stations that share ATUs through the audio control switch position (i.e., mission specialist and payload specialist, airlock CCU 1 and 2, and middeck ATU).

The ACCU circuitry activates signals from the launch umbilical connection intercom A and B channels. Any crew station ATU can then be configured to transmit and receive intercom signals from the ground through the umbilical. (Only intercom signals are processed through the umbilical.)



Commander's Audio Terminal Unit of Panel 05

2.4-27



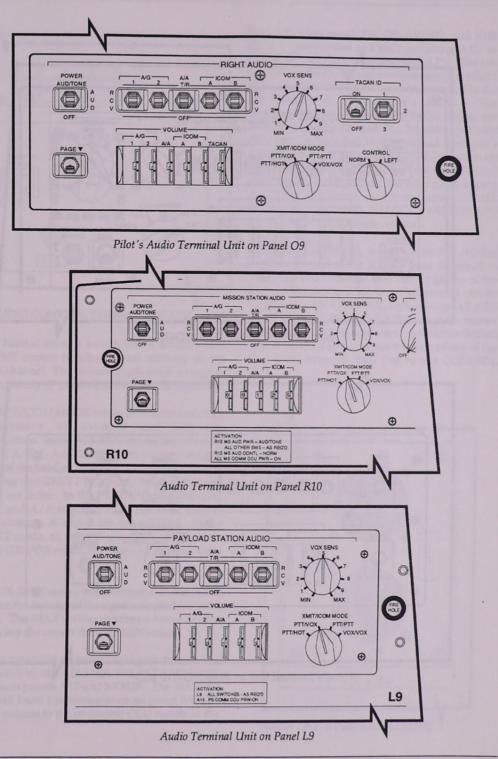
Audio Terminal Units

Up to eight ATUs are used in the crew compartment to select access at each station and to control the volume of various audio signals. Audio terminal unit panels are located at the following crew stations: commander, panel O5 (*LEFT AUDIO*); pilot, panel O9 (*RIGHT AUDIO*); mission station, panel R10 (*MISSION STATION AUDIO*); payload station, panel L9 (*PAYLOAD STATION AUDIO*); middeck, panel M042F (*MID DECK SPEAKER AUDIO*); and airlock, panel AW18D (*AIRLOCK AUDIO*). These panels control signals to headsets or communication carrier assemblies through the communications umbilical. Orbiter OV 102 has two additional ATUs. One is in the flight deck (*OS AUDIO*), mounted on panel A13 for use with the flight deck speaker unit. (On all other orbiters, the *MISSION STATION AUDIO* audio terminal unit is used with the flight deck speaker unit.) The second ATU, in the middeck, is *AIRLOCK 1 BACKUP*, which is mounted at the MO58F position and acts only as a backup for the airlock CCU1 headset CONTROL function. (The *AIRLOCK AUDIO* CCU 2 headset connection uses the *MIDDECK SPEAKER AUDIO* audio terminal unit as a control function backup.)

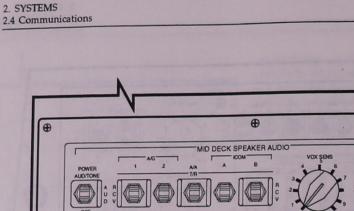
Each ATU has a three-position power switch to control all signals to or from the ATU. The switch positions are AUD/TONE, AUD, and OFF. In the AUD/TONE position, all available functions of the ATU are armed, and transmission and receptions may be made through the ATU, depending on the position of other switches on the ATU. C/W tone signals are sent to the ACCU to allow C/W audio to reach the ATU, the CCU, and the speaker unit. The AUD position has the same functions as AUD/ TONE except that C/W signals are blocked from the ATU. The OFF position shuts off power to the ATU power supply, for the ATU amplifiers. Klaxon (cabin air pressure) and siren (fire) C/W signals go directly to a speaker unit, even with the speaker power off.

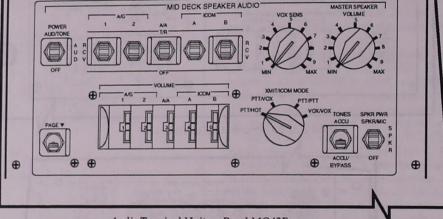
Each ATU has a two-position, spring-loaded-off *PAGE* switch that must be held in the *PAGE* position to activate the circuit. When activated, the circuit enables the ATU to transmit to all other ATUs, the EVA transceiver, and the attached payload circuit (e.g., Spacelab). Any number of stations may use the paging circuit simultaneously, and the circuit may be used regardless of the position of the other channel control switches.

On all ATUs, the two air-to-ground channels, the air-to-air channel, and intercom channels A and B have individual three-position control switches for selecting access to particular channels for transmission or reception. The switch positions are T/R, RCV, and OFF. The T/R position permits transmission or reception over the selected channel. The RCV position deactivates transmission capability on the selected channel and permits only reception of signals. The OFF position deactivates transmission and reception on the selected channel. These control switches do not turn on any transmitter or receiver but allow access to a transmitter or receiver.



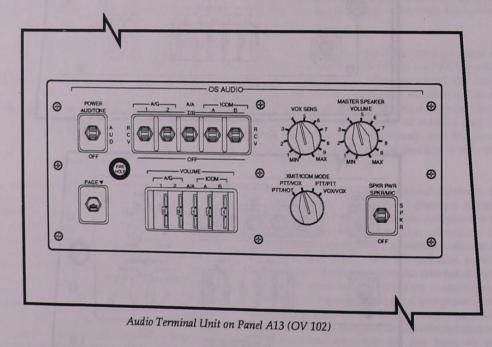




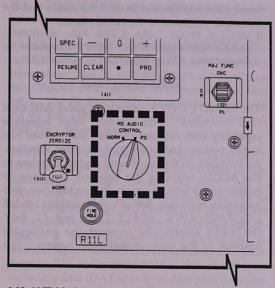


•

Audio Terminal Unit on Panel MO42F



2.4-30



MS AUDIO CONTROL Switch on Panel R11L

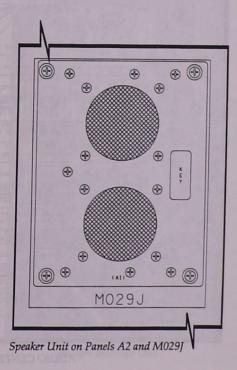
Each channel control switch has a thumbwheel *VOLUME* control to adjust signal intensity on the related channel. The thumbwheels cover a range of approximately 27 decibels in 3-decibel increments.

The XMIT/ICOM MODE rotary switch controls four combinations of external and intercom transmissions. In the PTT/HOT mode, transmission through A/G 1, A/G 2, and A/A requires manual keying of the headset interface unit, microphone, or WCCS leg unit XMIT PTT button; intercom A and B will be hot mike. In the PTT/VOX mode, A/G 1, A/G 2, and A/A require PTT of the XMIT button, while intercom A and B are voice keyed. In the PTT/PTT mode, all voice channels are voice keyed.

The VOX SENS rotary potentiometer on the ATUs regulates the volume of the signal required for voice keying. The MAX setting requires a lower decibel level to key the circuit than the MIN setting.

Volume control of all incoming signals to speakers is adjusted by the MASTER SPEAKER VOLUME controls on panels A13 and MO42F. The MASTER VOLUME 1 and 2 potentiometers on panel AW18D control volume to the respective CCU outlets in the airlock. Four ATUs (on panels O5, O9, AW18D, and R10) allow a crewmember at a malfunctioning ATU to switch the CCU jack to an alternate ATU. The left may be switched to the right (commander's to pilot's ATU), or right ATU control may be switched to the left (pilot's to commander's ATU). The commander's and pilot's CONTROL knobs are located on panels O5 and O9. Mission specialist ATU may be switched to the payload specialist's ATU using the MS AUDIO CONTROL switch on panel R11L. Airlock ATU control may be switched to the middeck and payload specialist's ATUs using the CONTROL rotary switch on panel AW18D. Orbiter OV 102 uses the AIRLOCK 1 BACKUP ATU for airlock CCU 1 alternate control.

When the CONTROL switch is in the NORM position, control of the ATU is from the panel to which the knob belongs. The other position of the knob indicates the ATU to which control can be transferred. The CONTROL knob changes all ATU functions to the alternative ATU except the master volume control. This redundancy protection is used in the event of a failure or malfunction of any of the four audio terminal units that have a CONTROL knob.



NOTE

If an ATU loses power, switching to the other *CONTROL* position will restore listen capability but not talk capability.

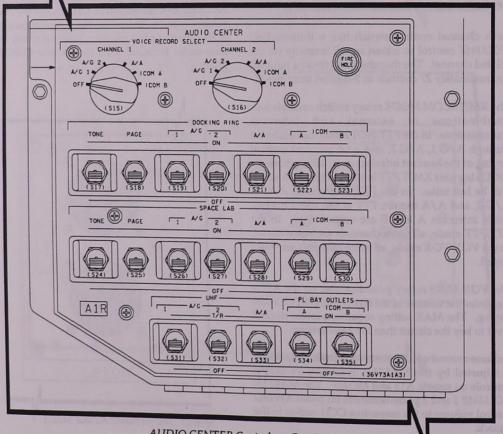
Speaker Units

An SU is located on panels A2 and MO29J. They are controlled by the ATU on panels R10, A13, and MO42F in orbiters OV 103, 104, and 105. They are controlled by the ATU on panels A13 and MO42F in orbiter OV 102. In addition to the features of the other ATUs, the speaker unit ATU has a threeposition *SPKR PWR* switch. Only the *OFF* and *SPKR* positions are used. In the *OFF* position, no signals go through the ATU. In the *SPKR* position, audio selected on the associated ATU, including C/W tones, are enabled. The *SPKR/MIC* position is not used. The top speaker is used for audio and the bottom is dedicated to the klaxon/siren.

The KEY light illuminates when a microphone on the associated ATU is keyed (PTT, VOX, etc.)

Audio Center Panel

The AUDIO CENTER controls on panel A1R have four functions: UHF control, voice interface capability with external vehicles, the payload bay comm outlets, and operations recorder selection. All switches on the panel send digital impulses to the ACCU, enabling the selected functions to communicate with Spacelab, the payload bay, and operations recorders. Sets of toggle switches labeled DOCKING RING, SPACE LAB, and PL BAY OUTLETS electrically connect the particular function to the audio distribution system. The



AUDIO CENTER Controls on Panel A1R

The DOCKING RING and SPACE LAB subpanels have seven switches to enable the following functions: A/A, A/G 1, A/G 2, ICOM A, ICOM B, PAGE, and TONE (C/W). The UHF switches control A/G 1, A/G 2, and A/A channels to the UHF transceiver. The PL BAY OUTLETS subpanel has two ON/OFF switches, one for intercom A and one for B. The PL BAY OUTLETS switches also route ICOM A and B to the CCTV system for interleaving with the video signals

Two rotary knobs labeled *VOICE RECORD SELECT* control various audio signals to be sent to the operational recorders through the NSP. A/G 1, A/G 2, A/A, and *ICOM* A or B audio can be sent to either recorder. Any two signals may be recorded at the same time, one on channel 1 and the other on channel 2. Either channel may be turned off. A recorder input (RCDR INPUT) parameter on orbiter display S76 indicates whether the recorder is recording data (DATA) only or data plus the voice selected on the *AUDIO CENTER* panel (D/VO).

Loose Communications Equipment

Launch and Entry Helmets

During launch and entry, each flight crewmember wears a launch and entry helmet to lessen the severe noise levels encountered at launch and to allow intelligible air-to-ground communications. A communications carrier assembly headset containing microphones and earphones fits over the crewmember's head, and a connector and cable interface with the headset interface unit, connected through communications cables to respective audio terminal units. The microphones can be positioned to suit the individual crewmember. For emergency egress, a pull-away connection is used between the communications carrier assembly and headset interface unit, in addition to the standard communications carrier assembly/headset interface unit twist-on connector.

The helmets have redundant noise-canceling microphones and electrically isolated earphones. When air is inhaled, the demand breathing regulator shuts off the microphones to avoid transmitting breathing sounds.

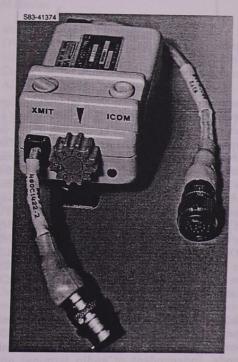
NOTE

An improper face seal will cause enough oxygen flow to cut off microphones.

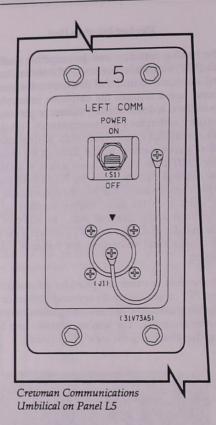
Headset Interface Unit

The headset interface unit has separate push-totalk (PTT) buttons for transmit and intercom modes and a volume control that determines the level of sound heard through the earphone (microphone sound level is determined by automatic gain control circuitry within the audio terminal unit). (Push-totalk means that a pushbutton must be depressed to allow a crewmember to talk through the system.) The XMIT push button allows access to intercom and external circuits, while the ICOM push button is for intercom only. The volume control knob acts in series with the loop volume controls on the associated audio terminal unit. In addition, the commander and pilot have PTT switches on their rotational hand controllers for transmit (XMIT) keying.

The headset interface unit provides volume control and PTT capabilities to the communications carrier assembly used for EVA, and to the communications carrier assembly. The headset interface unit has a clip that attaches to the crew's flight suits.



Headset Interface Unit



Cables

The communication cables vary in configuration depending on seat location. Each seat has two 4-foot communication cables or a 14-foot length, as required. One 4-foot cable is flown as a spare. The cables connect to crewman communications umbilical (CCU) outlets at various locations in the crew compartment. Each CCU has a specific audio terminal unit that controls communication loop configurations. The CCU associated with the ATU on panel O5 is located on panel L5 (*LEFT COMM*); for O9 on R6 (*RIGHT COMM*); for R10 on A11 (*MS COMM*), for L9 on A15 (*PS COMM*), and for MO42F on MO39M (*MID DECK COMM*); two others for the airlock ATU are located on panel AW82D (*CCU 1* and *CCU 2*).

Each CCU outlet has a power switch that controls the associated microphone power. Leaving CCU power off confines an individual to a listen-only mode, independent of audio terminal unit configuration.

Multiple Headset Adapter

A multiple headset adapter may be plugged into the CCU outlets. The three CCU outlets on the adapter allow up to three crewmembers to share one CCU outlet. When any one person connected to a multiple headset adapter keys (in PTT mode) or activates the voice-operated transmitter, all three individuals' microphones will be keyed, and individuals sharing the multiple headset adapter will hear each other talking on the side tone.

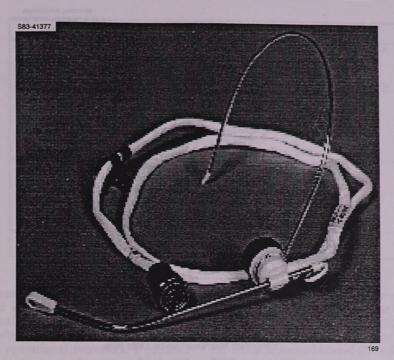
Wireless Communications Units

On orbit, the crew may use wireless communication units in place of communication cables. A wireless unit consists of one wall unit (audio interface unit) and two leg units (crew remote units) worn by crewmembers during orbital operations. The wall unit connects to a CCU outlet and remains attached to the crew compartment wall. Each wall unit transmits on a unique pair of UHF frequencies. Leg units may be configured to work with any wall unit. A leg unit may be converted into a wireless handheld microphone by attaching a noisecancelling mic at the headset connector. Each wall unit is identified by a letter enclosed in a box. Each unit is stowed with its cabling attached. The wall unit has a 23-inch cable to interface with the CCU outlet, and the leg unit has a 22-inch cable attached to a lightweight headset.

NOTE

If the two leg units are set to use the same frequency, one of the units' transmit signals will be muted.

When the wireless unit is unstowed, part of the assembly necessary is to insert and tighten the flexible antenna in the bottom of each wall and leg unit. The wall unit receives power from the CCU outlet. All other switches are set as required; typically, the individual communication loops are used. The leg unit is attached to the crewmember's leg with a wraparound elastic strap. The rotary *ON/OFF/VOLUME* knob (unlabeled) is turned clockwise past the *ON/OFF* detent, and the volume is set as desired. Each leg unit is powered by a replaceable lithium battery pack. A weak battery is identified by a continuous beeping sound when the leg unit is powered on. A single battery pack



Very Lightweight Headset

provides about 35 hours of service. Sliding a new battery pack into the unit causes both the electrical connector and mechanical connector to latch.

Very Lightweight Headset

The very lightweight headset is the interface between the leg unit and crewmember. A singlestrand wire headband holds the earphone against the ear and supports a thin boom holding a noisecancelling microphone near the mouth. A cable and connector are attached to the crewmember's leg unit. The lightweight headset cable and connector also can interface with the headset interface unit.

Handheld Microphone

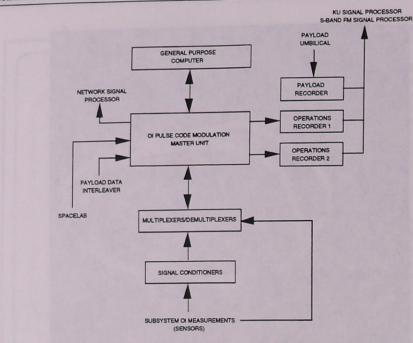
The handheld microphone is a noise-canceling microphone that connects directly to any CCU outlet. The microphone is used primarily with the SUs located at panels A2 and MO29J. To avoid feedback when using the speakers, one ATU and its corresponding CCU outlet on the aft flight deck and one ATU and associated CCU on the middeck

are equipped with a speaker muting capability. On OV103, OV104, and subsequent vehicles, muting is controlled through ATUs at panels R10 and MO42F. On OV102, the muting ATUs are located at panels A13 and MO42F.

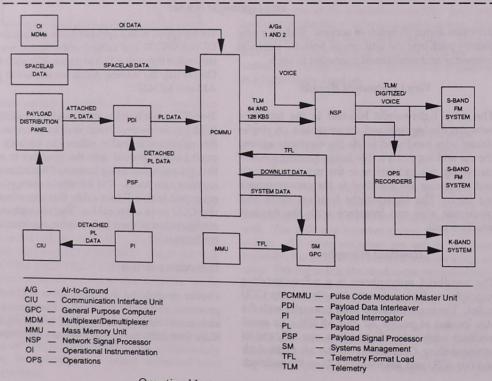
Two PTT push buttons are provided for XMIT and ICOM audio modes. When used to record audio on the videotape recorder, either can be used. The push buttons should face the operator to ensure that the noise-canceling feature of the microphone remains functional. The handheld microphone is equipped with a 7-foot cable that can connect at any CCU or to other cables. The microphone/SU configuration is used for on-orbit communication configurations.

Instrumentation

Orbiter operational instrumentation (OI) collects, processes, and routes information from transducers and sensors throughout the orbiter and its payloads. More than 3,000 data parameters are monitored.



Simplified Instrumentation Data Flow



Operational Instrumentation System Overview

AREA	CHARACTERISTICS				
Signal Conditioning	14 DSCs conditioning appoximately 1,200 channels, plus EDO DSCs (up to 4) 6 WBSC to MDM				
Conditioning	Approximately 45 high-level transducers				
1 million from the second	 Distributes data to PCM data system, panel displays, C/W, flight-critical MDMs 				
	 Acquires data through 7 OI MDMs, approximately 2,800 measurements 				
	Receives and provides data to 5 computers				
PCM Data System	Accepts payload data through PDI or payload data bus (Spacelab)				
	Provides output data in 64 and 128-kbps formats				
	Provides synchronization to PDI and NSP				
- I have a second	Provides data to NSP and T-0 umbilical				
	Receives data directly from payload or PLSP				
	Provides data to GPCs and PCM				
Payload Data Recorders	Stores 3 channels of engine data at 60-kbps rate				
	Stores interleaved voice and data at 96, 128, or 192-kbps rates				
	Stores payload data				
	Provides for playback of recorded data during and after mission				
	· Provides time reference to computers, OI PCM, display panel, and payload				
Master Timing	Provides synchronization to instrumentation and other subsystems				

The instrumentation system consists of transducers, 14 dedicated signal conditioners (additional dedicated signal conditioners (DSCs) for extended duration orbiter (EDO) missions), 7 MDMs, 2 PCMMUs, 2 operational recorders, 1 payload recorder, master timing equipment, and onboard checkout equipment.

The OI system senses, acquires, conditions, digitizes, formats, and distributes data for display, telemetry, recording, and checkout. It provides for pulse code modulation recording, voice recording, and master timing for onboard systems.

Instrumentation equipment, except sensors and selected dedicated signal conditioners, is located in the forward and aft avionics bays. Sensors and DSCs are located throughout the orbiter in areas selected on the basis of accessibility, minimum harness requirements, and functional requirements. Abbreviations used to designate the locations of equipment are as follows: OA refers to operational aft, OF to operational forward, OL to operational left, OR to operational right, and OM to operational mid.

Dedicated Signal Conditioners

Dedicated signal conditioners acquire and convert various sensor data from thousands of orbiter sensors into a 0-5 V dc pulse acceptable to MDMs. Sensors requiring DSCs include frequency, temperature, rate, voltage, current, and analog parameters.

OI System

There are 14 orbiter DSCs, 4 in forward avionic locations (OFs), 3 in the aft avionic bays (OAs), 3 under the payload bay (MID) (OMs), and 4 in the right and left tail sections (ORs and OLs). There can be up to four additional DSCs flown with the EDO.

Multiplexer/Demultiplexers (MDMs)

MDMs can operate in two ways. As multiplexers, they take data from several sources, convert the data to serial digital signals (a digitized representation of the applied voltage), and interleave the data into a single data stream. As demultiplexers, the MDMs take interleaved serial digital information, separate and convert it to analog, discrete, or serial digital, and send each separate signal to its appropriate destination.

The OI MDMs act only as multiplexers. Upon request from the pulse code modulation master unit (PCMMU), the MDMs send these interleaved streams to the PCMMU through the OI data buses. When the MDM is addressed by the PCMMU, the MDM selects, digitizes, and sends the requested data to the PCMMU in serial digital form. The PCMMU/OI MDM interface is based on demand and response; that is, the OI MDMs do not send data to the PCMMU until the PCMMU makes the request. There are seven OI MDMs, four OFs, and three OAs for forward and aft multiplexing of DSC and direct data signals.

Pulse Code Modulation Master Unit (PCMMU)

The PCMMU receives data from the OI MDMs, downlist data from the GPCs under control of flight software, and payload telemetry from the payload data interleaver and Spacelab. It then interleaves the data, formats data according to programmed instructions stored within the PCMMU (the telemetry format load, or TFL), and sends the interleaved data to the network signal processor to be combined with the analog air-toground voice data from the audio central control unit for transmission through the S-band PM downlink and Ku-band system return link, channel one. Telemetry from the PCMMU is also sent through the network signal

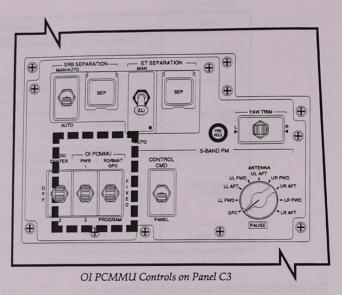
processor to the operational recorders for storage and subsequent downlink on the S-band FM or Kuband system. OI and payload data collected by the PCMMU are available to the GPCs for display and monitoring purposes upon request. All data received by the PCMMU are stored in memory and periodically updated.

The PCMMU has two formatter memories: programmable read only (PROM) and random access (RAM). The read-only memory is hard coded; the RAM is reprogrammed several times during flight. The PCMMU uses the formatters to load data from the computers and OI MDMs into PCM telemetry data streams for downlinking

NOTE

When the PCMMU is powered off (as when switching to the alternate unit), the TFL changes to the fixed format loaded in the PROM.

One of the two redundant PCMMUs and network signal processors operates at a time. The one used is controlled by the crew through the flight deck display and control panel. The primary port of each MDM operates with PCMMU 1 and the secondary port operates with PCMMU 2.



The PCMMUs receive a synchronization clock signal from the master timing unit. If this signal is not present, the PCMMU provides its own timing and continues to send synchronization signals to the payload data interleaver and network signal processor.

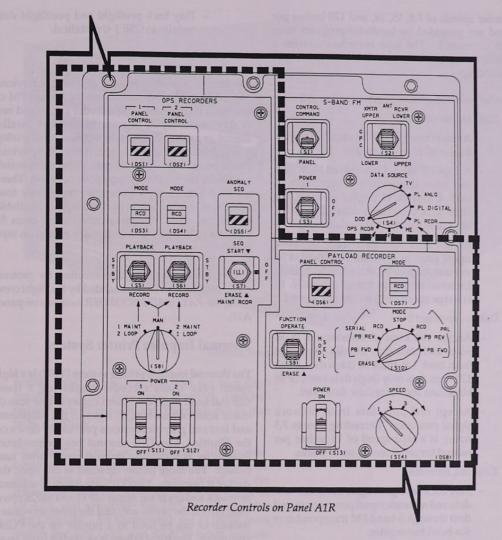
The OI PCMMU controls are located on panel C3.

Master Timing Unit

The master timing unit is a stable crystal-controlled timing source. It provides synchronization for instrumentation, payloads, and other systems. The master timing unit is described in more detail in Section 2.6.

Operations Recorders

Two recorders are used for serial recording and dumping of digital voice and pulse code modulation (PCM) data from the OI systems. The recorders normally are controlled by ground command, but they can be commanded by the flight crew through the flight deck display and control panel keyboard or through the OPS RECORDERS switches on panel A1R or commanded via uplink. The input to the recorders is from the network signal processor, in main engine data at 60 kbps.



The operations recorders can be commanded to dump recorded data from one recorder while continuing to record real-time data on the other. The dump data are sent to the FM signal processor for transmission to the ground station through the S-band FM transmitter on the S-band FM return link or to the Ku-band signal processor. When the ground has verified that the received data are valid, the operations recorders can use that track on the tape to record new data. If ground is controlling recorders, the crew cannot, unless ground sets a "crew reset" command or its equivalent from SPEC 1. Recorder speeds of 7.5, 15, 24, and 120 inches per second are provided by hardwire program plug direct command. The tape recorders contain a minimum of 2,400 feet of 0.5-inch by 1-mil magnetic tape.

Recorder functions can be summarized as follows:

- Data in, recorder 1
 - Accept three parallel channels of engine data at 60 kbps during ascent.
 - Accept 192 kbps of interleaved PCM data and voice that serially sequences from track 4 to track 14 (high data rate), 128 kbps data only (high data rate), or 96 kbps data and voice (low data rate).
 - Accept real-time data from network signal processor. Recording time is 32 minutes for parallel record and 5.8 hours for serial record on tracks 4 through 14 at a tape speed of 15 inches per second.
- Data in, recorder 2
 - Accept 192 kbps of interleaved PCM voice and data that serially sequences from track 1 to track 14 (high data rate), 128 kbps data only (high data rate), or 96 kbps data and voice (low data rate).
 - Accept real-time data from network signal processor. Recording time is 7.5 hours at a tape speed of 15 inches per second for serial record on 14 tracks.
- Data out, recorder 1
 - Play back in-flight engine interface unit data and network signal processor digital data through S-band FM transponder or Ku-band transmitter.
 - Play back in-flight anomaly PCM data for maintenance recording.
 - Play back data serially to ground support equipment to T-0 ground support equipment umbilical.
- Data out, recorder 2
 - Play back digital data through S-band FM transponder or Ku-band transmitter in flight.
 - Play back anomaly PCM data in flight for maintenance recording.

 Play back preflight and postflight data serially to GSE T-0 umbilical.

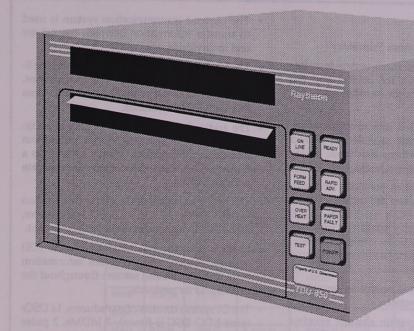
Payload Recorder

The payload recorder records and dumps payload analog and digital data through the S-band FM or Ku-band transmitter. The recorder can record one of three serial inputs or a maximum of 14 parallel digital or analog inputs or combinations of analog and digital data (up to 14 inputs) from the payload patch panel. In flight, all data dumps are serial; capability for parallel dumps does not exist. There are 14 selectable tape speeds; however, only four speeds, selectable by a program plug, are available per flight. Total recording time ranges from 56 minutes to 18 hours 40 minutes depending on tape speed.

The recorder normally is controlled by ground command, but can be commanded by the flight crew using the *PAYLOAD RECORDER* switches on panel A1R.

Thermal Impulse Printer System

The thermal impulse printer system (TIPS) is a high speed gray shade recorder employing a fixed thermal head to produce hard copies of line scan or raster scan information. It replaces the teleprinter and text and graphics systems previously flown on the Shuttle. The TIPS thermal head reproduces images by bombarding thermal paper with heat pulses. The more pulses directed at one spot, the darker it becomes. Two TIPS are flown in separate middeck lockers in the upper MF14 and MF28 rows. One TIPS is the prime unit and the other serves as a backup or can be used as a printer for the PGSC computer. Electrical power is provided from an ac outlet on panel ML85E (MUP). TIPS can receive text data over S-band PM or Ku-band (voice channel) via STDN or TDRS. TIPS can also receive text and graphics data through Ku-band mode one (128kbps) via TDRS. The voice channel input for TIPS is accomplished through the PS COMM outlet on panel A15 nominally via A/G 2. The voice channel data transfer rate of 600 baud requires up to 90 seconds per 11 inch page depending on the number of lines. The Ku-band mode 1 input is received through the Ku-band Data Uplink Port behind the old TAGS small compartment door. When the Kuband voice channel is used, it takes approximately 44 seconds to print 11 inches of text or dithered (laser



Thermal Impulse Printer System

printer style) graphics at 200 dots per inch (dpi) resolution. True gray scale graphics data will require about 4 minutes and 9 seconds per 11 inch page at 200 dpi.

To minimize crew workload, the TIPS power, communications, and Ku-band cables are routed and secured pre-launch. The procedures for connecting the three cables, reconfiguring the panel L9 ATU, and activating the TIPS are in the Orbit Ops Checklist. An illuminated red POWER push button and ON LINE and READY lights indicate the TIPS is ready to print. TIPS must be ready to print when an uplink is transmitted since the MCC has no ground command over TIPS. If TIPS is not ready to print when an uplink is initiated or if it runs out of paper prior to the end of a transmission, the data will have to be retransmitted when TIPS is back on-line. The unit does not have the capability to store data for printing at a later time. Three additional 165 foot rolls of thermal paper are stowed for changeout on orbit. The crew should replace the roll when the red warning strip appears along the edge of the paper.

Communications System Summary

- The orbiter communications system transfers information between the orbiter and the ground, either through hardline or radio frequency links.
- The system is divided into several smaller systems: S-band phase modulation, S-band frequency modulation, Ku-band, UHF, payload communications, audio, and CCTV.
- The S-band PM system provides two-way communication between the orbiter and the ground, through either an STDN/SGLS ground station or a relay satellite. It provides channels for five functions: command, voice, telemetry, turnaround tone ranging, and twoway Doppler tracking.
- Four quadrant S-band antennas provide a selection of eight directions.
- The S-band FM system cannot receive information. It is used to downlink data directly to the ground from seven different sources: SSME interface units, the video switching unit, the operations recorder, the payload recorder, payload analog, or payload digital.
- There are two hemispherical S-band FM antennas.
- The Ku-band system provides for on-orbit communication between the orbiter and the ground. It can also be used as a radar system for tracking objects in space.
- The Ku-band antenna is deployed when the payload bay doors are opened, and stowed when they are closed. The antenna is steerable.
- TV data can be downlinked over Ku-band and S-band FM only.

- The payload communication system is used to transfer information between the orbiter and its payloads.
- The UHF system is used as a backup for the Sband PM and Ku-band voice communications. UHF is used as the primary communications link with EVA astronauts.
- The audio distribution system gathers audio signals from multiple sources and routes them throughout the orbiter. It may be used as a means by which crewmembers communicate with each other.
- The major elements of the audio distribution system are: the ACCU, ATU, SU, audio center, CCU, and loose communications equipment.
- Orbiter operational instrumentation (OI) collects, routes, and processes information from transducers and sensors throughout the orbiter and its payloads.
- The OI system consists of transducers, 14 DSCs (plus EDO DSC if flown), 7 MDMs, 2 pulse code modulation master units, encoding equipment, 2 operations recorders, 1 payload recorder, master timing unit, and onboard checking equipment.
- Additional communication equipment includes the thermal impulse printer system.

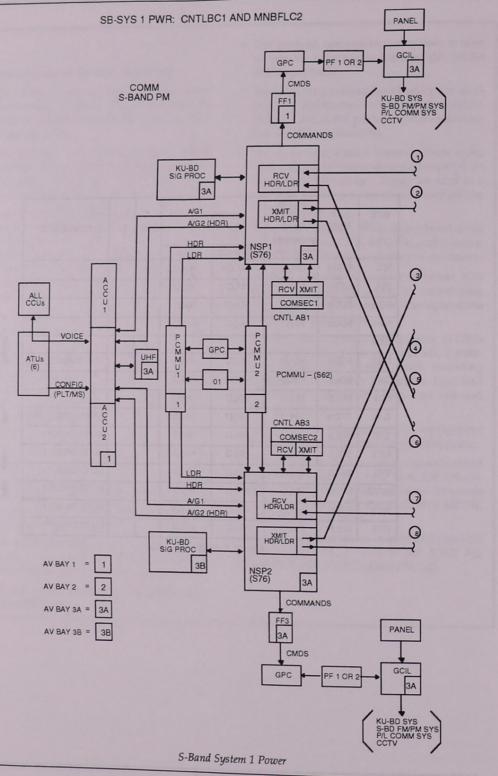
- Major communications equipment and control panels are A1R, A1U, A1L, R13L, O5, O6, O9, R10, L9, and R12. Others are found on panels A13, A14, A15, L5, F9, C3, R11L, R15, MO29J, MO42F, and AW18D.
- Specific communications system CRTs are OPS 201 ANTENNA, COMM/RCDR (DISP 76), and PC MMU/PL COMM (SPEC 62).

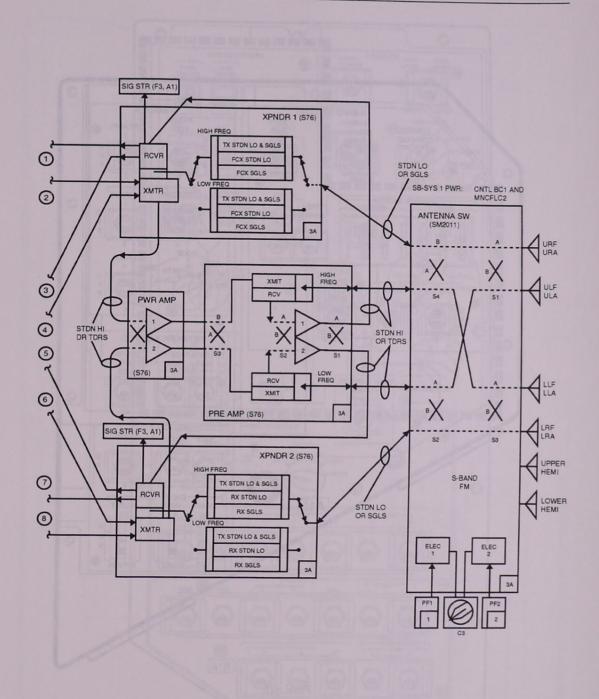
SCOM 1.5 July 1994

SITE	SITE TYPE	UPLINK DATA RATE ENCRYPTED	DOWNLINK DATA RATE		UHF	TV	COMMENTS
	1.1	OR CLEAR	ENCRYPTED	CLEAR			and an and a second and
MIL	STDN	HI/LO	HI/LO	HI/LO	V	V	N
PDL	STDN	HI/LO	HI/LO	HI/LO		1	
BDA	STDN	HI/LO	HI/LO	HI/LO	V		1 1 1 1 1 1 1 1 1 1
NHS	SGLS	HI/LO	HI/LO	HI/LO		Jung-	
DKR		195	2 2	1281	V	-	and a second sec
MAD	STDN	HI/LO	HI/LO	HI/LO		find	EMERGENCY USE
OAK	SGLS	HI/LO	HI/LO	HI/LO	V		Lando
IOS	SGLS	HI/LO	HI/LO	HI/LO	V	fra	Statisty Louise
CAN	STDN	HI/LO	HI/LO	HI/LO			EMERGENCY USE
GTS	SGLS	HI/LO	HI/LO	HI/LO			NO ID ON 2011
HTS	SGLS	HI/LO	HI/LO	HI/LO		1	NO ID ON 2011
VTS	SGLS	HI/LO	HI/LO	HI/LO	3/		NO ID ON 2011
DFRF	STDN	HI/LO	HI/LO	HI/LO	×	V	NO ID ON 2011
GDS	STDN	HI/LO	HI/LO	HI/LO		V	NO ID ON 2011
CTS	SGLS	HI/LO	HI/LO	HI/LO	-		NO ID ON 2011

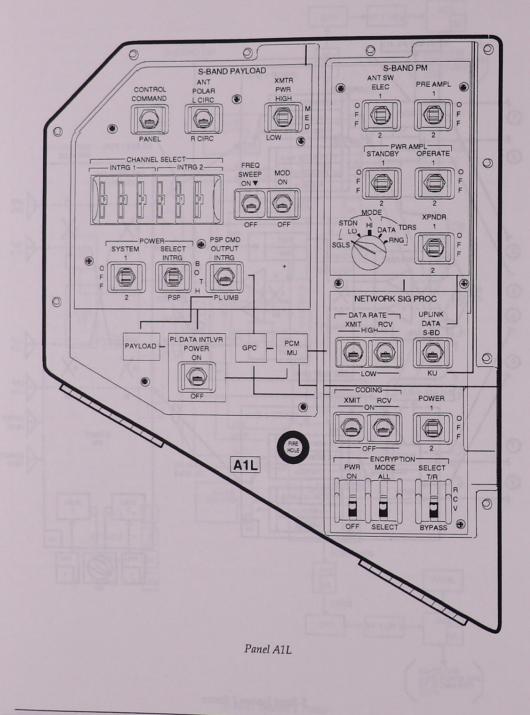
Comm S-Band PM Table

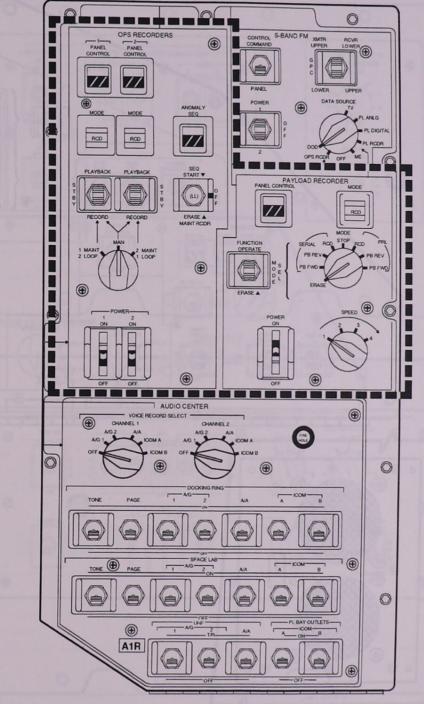
2.4-43





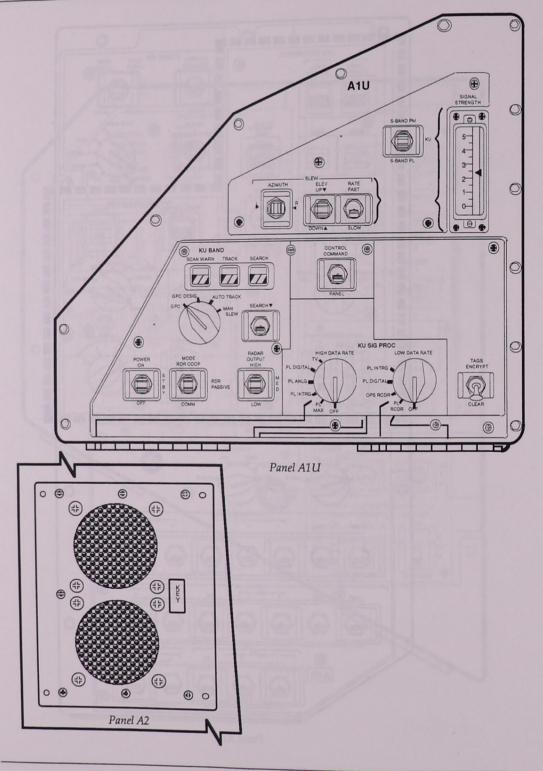
S-Band System 2 Power





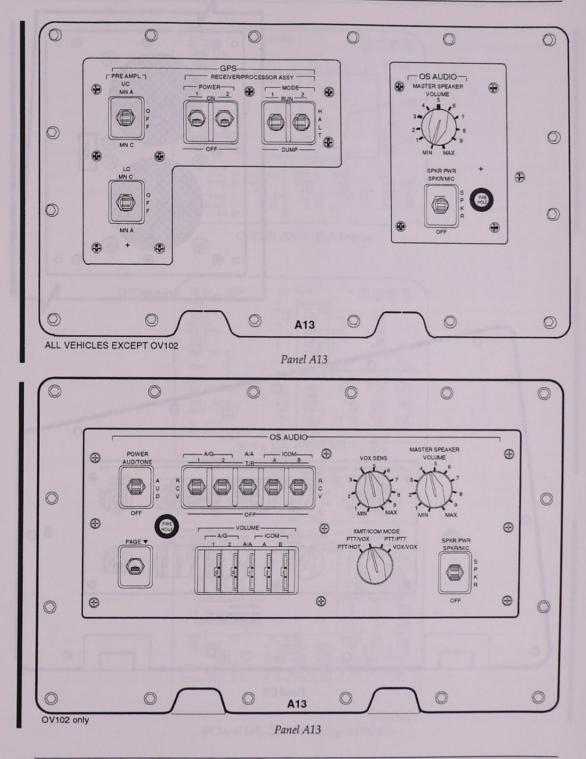
Panel A1R

2.4-47

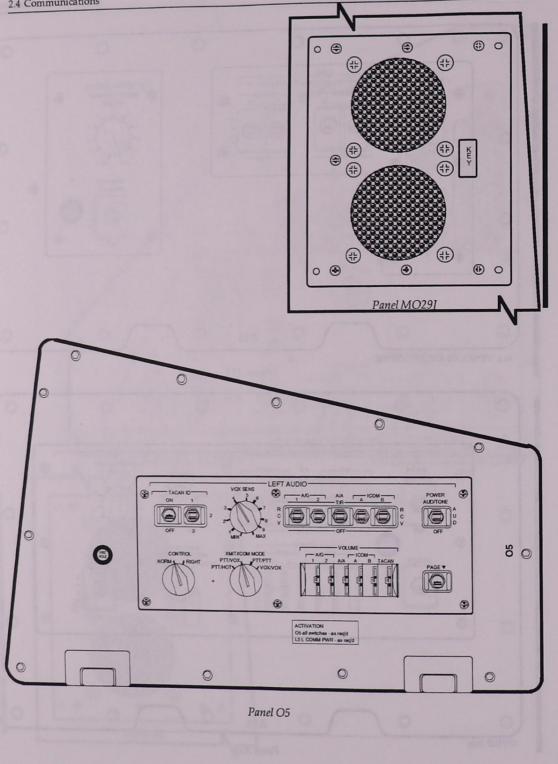


SCOM 1.1 July 1992

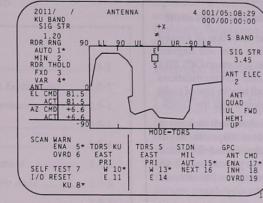
2. SYSTEMS 2.4 Communications

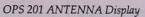


2.4-49



SCOM 1.1 July 1992





130

2011/ /076 S-BAND PM	COMM/I	RCDR		01/05:0	
XPND	2	KU-BAND		00700.0	00.00
MODE	TDRS	PA TEMP		+91	
FREQ	LO	GMBL TE			
PREAMP	2	and the second second	B	+82	
PWR AMPL		GYRO TE	MP	+146	
OPER	2	PWR OUT		26	
STBY	1	FR SYNC		YES	
PWR OUT 1	133	MODE TV CAM	AVED T	COMM	NO
TEMP 1	133	GCIL CON		EMP	
1EMP 1 2	169	RECORDER			CMD
NSP	103	RECORDER	OPS 1	OPS 2	PL
BIT/FR SYNC 1 NO	NO	MODE	STBY	RCDA	STBY
2 YES	YES	TRK		1	0.01
FAIL SAFE	ENA	DIR	FWD	FWD	FWD
DATA XMIT	HI	%TAPE	55	200	0
RCV	HIS	TAPE	STOP	RUN	STOP
UL DATA		TEMP	48	90	48
CODING XMIT	ON	BITE	19.223		
RCV	ON	RCDR INP		D/VO	
BITE 1	GOOD	COMSEC B	ITE .	E GOOD	

terrental hypers of a pulp rentw taken any portector instruction on the tony are found to convert efficiency in this particular. Where described with instruction

Crew Clothing/W

The crew clothing we items that provide for convenientless. Polor is select clothing and we required and optimal f

Crew clothing used a includer such Sensy or a shorts, and shores and

COMM/RCDR (DISP 76) Display

XXXX/062/ SM COM BUFF XXX PCMMU BITE WORD XXXX SEL FXD 1XS PCM 10 64 XXX 3 SEL 10 XXX 3 SEL 10 XXX 10 AD 4 XXXX LOAD 4 XXXX 1/0 RESET PCM 5XX	PCHMU/PL COMM	XX X DDD/HH:MH:SS DDD/HH:MH:SS DDD/HH:MH:SS 9 SEL DECOM X 10 SELFM XXX LOAD 11 XXXX LOAD 13 DECOM INPUT FMT 1 X XXS 3 X XXS 4 X XXS
PSP I/O RESET PSP1 6XX PSP2 7XX SYNC BIT XXXS FRAME XXXS LOAD XXXX XXXX	PL INTRC 1 CHANNEL XXXS 2 CHANNEL XXXS PHASE LOCK XXXS ERR 1XXS XMIT PWR XX.XXS PL SIG STR X.XXS	5-FPM XXX DECOM ENA ENA FDA 1 14X 3 16X 2 15X 4 17X 18 TFL GPC SEL X

^{10016.} CRT. 1

PCMMU/PL COMM Display (SPEC 62)

Communications System Rules of Thumb

- When the TDRS has an elevation of greater than +70 degrees or less than -60 degrees relative to the orbiter (as shown on OPS 201), there is a risk of degraded communications as the orbiter nose or tail blocks line of sight between the orbiter antenna and the TDRS.
- Power amplifiers are specified to have a minimum power output of 100 watts. Flight experience has shown that a good downlink can be sustained with a power out of 65 watts. Power amplifiers require 140 seconds to warm up if not in a standby state.
- Payload interrogator output power, when in low power mode, will read zero. This measurement is meaningless as the output power is too small to be output by the instrumentation system.

2.5 CREW SYSTEMS

CONTENTS

Description	2.5-1
Crew Clothing/Worn Equipment	2.5-1
Personal Hygiene Provisions	
Sleeping Provisions	2.5-1
Exercise Equipment	2.5-4
Housekeeping Equipment	2.5-4
Restraints and Mobility Aids	2.5-5
Stowage Containers	2.5-5
Reach and Visibility Aids	2.5-6
Photographic Equipment	
Sighting Aids	2.5-10
Window Shades and Filters	2.5-10
Shuttle Orbiter Medical System	2.5-11
Operational Bioinstrumentation	
System	2.5-12
Radiation Equipment	2.5-14
Air Sampling System	2.5-15

Description

Several types of equipment and systems that the crew uses are not covered in other sections of this manual, since they are not necessarily part of any of the larger systems. These items and systems, which focus on crew efficiency and comfort, are discussed in this section. Where appropriate, operations are described within each separate subject area.

Crew Clothing/Worn Equipment

The crew clothing/worn equipment consists of items that provide for the personal needs of all crewmembers. Prior to each flight, crewmembers select clothing and worn equipment from a list of required and optional flight equipment.

Crew clothing used during on-orbit activities includes such items as trousers, jackets, shirts, sleep shorts, soft slippers, and underwear.

Optional worn/carry-on equipment includes scissors, sunglasses, HP48 calculators, gray tape, flashlight, Swiss army knife, pens and pencils, and chronographs.

Personal Hygiene Provisions

Personal hygiene and grooming provisions are furnished for both male and female flight crewmembers. Ambient warm water for washing comes from a personal hygiene hose (PHH) attached to the galley auxiliary port. Other personal hygiene provisions are stowed in middeck lockers and/or the airlock stowage bag at launch and are removed for use on orbit.

A personal hygiene kit is furnished for each crewmember for brushing teeth, hair care, shaving, nail care, etc. Additional grooming and hygiene items are available for female crewmembers in the female preference bags.

Two washcloths and one towel per crewmember per day are provided. In addition, wet wipes, dry wipes, tissues, and Wash 'N Dri's are provided for personal hygiene. The Wash 'N Dri's are located in Volume G (spares), a middeck locker, and in the galley. Wet wipes and dry wipes are stowed in the waste managment compartment (WMC) and in a middeck locker. Rubber grommets in the waste management compartment allow crewmembers to restrain their towels and washcloths.

If the WMS becomes nonfunctional, contingency equipment is located in Volume G. This equipment consists of Wash 'N Dri's, urine collection devices, diapers, and Apollo fecal bags.

Sleeping Provisions

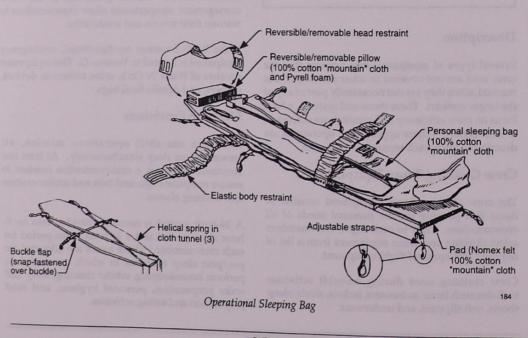
During a one-shift operations mission, all crewmembers sleep simultaneously. At least one crewmember wears a communication headset to ensure reception of ground calls and orbiter caution and warning alarms.

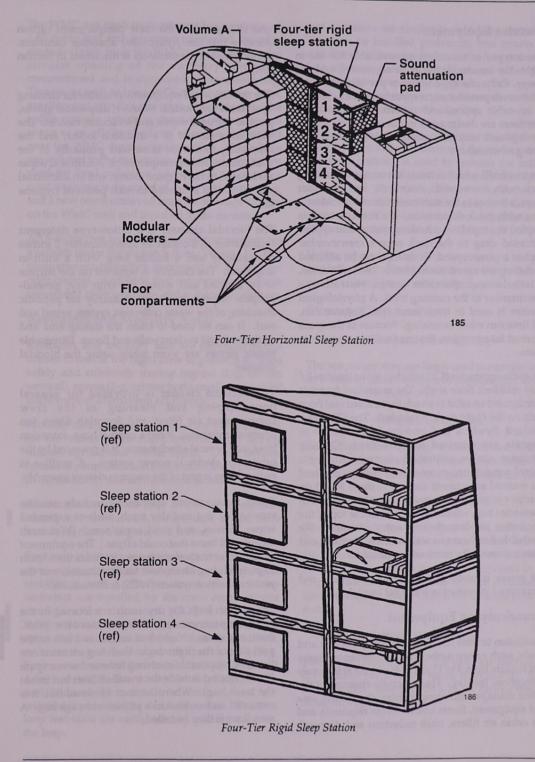
A 24-hour period is normally divided into an 8hour sleep period and a 16-hour wake period for each crewmember. Three hours are allocated for pre/post sleep activities in which crewmembers perform housekeeping, orbiter cleaning, sleep and wake preparation, personal hygiene, and food preparation and eating activities. Sleeping provisions for flight crewmembers consist of sleeping bags and liners, or rigid sleep stations with one sleeping bag and two liners per bunk. Sleeping bags are installed on the starboard middeck wall and relocated for use on orbit. Some sleeping bags can remain on the starboard wall, and some can be attached via pip pins to the middeck lockers. Others can be relocated to the airlock, Spacelab, or flight deck (crew preference). A sleeping bag is furnished for each crewmember and contains a support pad with adjustable restraining straps and a reversible/removable pillow and head restraint.

Six adjustable straps permit the sleeping bag to be adjusted to its proper configuration. Three helical springs above the adjustable straps on one side of the bag relieve loads exerted by the crewmember on the crew compartment structure. Six pip pins allow the bag to be attached to the middeck locker face in either a horizontal or vertical configuration. Two elastic adjustable straps restrain the upper and lower parts of the body in the bag. Velcro strips on the ends of both sides of the head restraint attach it to the pillow. A double zipper arrangement permits the sleeping bag to be opened and closed from the bottom to the top of the bag. One zipper on each side of the sleeping bag allows the bag to be attached to a support pad for better rigidity. A sleep kit is provided for each crewmember and is stowed in the crewmember's clothing locker during launch and entry. Each kit contains eye covers and ear plugs for use as required during the sleep period.

For 24-hour operations missions, the four-tier, rigid sleep station is flown. If manifested, it is installed on the starboard side of the middeck.

The four-tier rigid sleep stations contain a sleeping bag/liner, personal stowage provisions, a light, and a ventilation inlet and outlet in each of the tiers. The cotton sleeping bag is installed on the ground in each tier and held in place by six spring clips. The light in each tier is a single fluorescent fixture with a brightness control knob and an off position. The air ventilation inlet duct is an air diffuser similar to an automobile ventilation duct. It is adjusted by moving the vane control knob. The air ventilation outlet duct is located in the fixed panel at each tier and is opened or closed by moving the vane control knob. The air inlet is located at the crewmember's head. The outlet is at the feet. All crewmembers' heads are toward the airlock and their feet toward the avionics bay.





Exercise Equipment

Three types of exercisers are available for use in flight: the treadmill, the cycle ergometer, and the rower. Only one type is flown per mission, with selection dependent on crew preference, availability of on-orbit space, and science objectives. All exercisers are designed to minimize muscle loss in the legs and maintain cardiovascular fitness in a zero-g environment.

The treadmill, which consists of a conveyor running track with force cords, waistbelt, and shoulder straps, attaches to the starboard side of the middeck floor with quick disconnects. The running track is coupled to a rapid onset braking system that applies increased drag to the track once a crewmember reaches a preset speed. Resistance can be adjusted by dialing the speed control knob. The force cords, waistbelt, and shoulder straps restrain the crewmember to the running track. A physiological monitor is used to track heart rate, distance run, and time run while exercising. Because of the space required for operation, the treadmill is now seldom flown.

The cycle ergometer (CE) attaches to the treadmill/ entry middeck floor studs. The mounting frame is reconfigured on orbit to attach to standard seat floor studs on the flight deck or middeck. The CE uses a standard flywheel and braking band system to generate the required resistive force. Cycling resistance can be controlled electronically by a control panel or computer-driven exercise protocol or a manual adjustment similiar to those found on exercise cycles used at home or in gymnasiums. An accessories bag, which is strapped to the top of the ergometer for launch and entry, contains the attachable hardware as well as crew clothing and shoes necessary for nominal operations.

The rower is undergoing a design upgrade and operational information is not yet available.

Housekeeping Equipment

In addition to time scheduled for sleep periods and meals, each crewmember has housekeeping tasks that require from 5 to 15 minutes of time at intervals throughout the day. These include cleaning of the waste management compartment, the dining area and equipment, floors and walls (as required), and the cabin air filters; trash collection and disposal; and changeout of the crew compartment carbon dioxide (lithium hydroxide) absorber canisters. (Changeout of the canisters is discussed in Section 2.9.)

The materials and equipment available for cleaning operations are biocidal cleanser, disposable gloves, general-purpose wipes, and a vacuum cleaner. The vacuum is stowed in a middeck locker, and the remaining hardware is stowed primarily in the waste management compartment. Additional wipes are located in the hygiene locker, and an additional pair of gloves is located in each personal hygiene kit.

The biocidal cleanser is a lotion-type detergent formulation in a container approximately 2 inches in diameter and 6 inches long with a built-in dispenser. The cleanser is squirted on the surface to be cleaned and wiped off with dry, generalpurpose wipes. It is used primarily for periodic cleansing of the waste collection system urinal and seat. It can be used to clean the dining area and equipment and to clean walls and floors. Disposable plastic gloves are worn while using the biocidal cleanser.

The vacuum cleaner is provided for general housekeeping and cleaning of the crew compartment air filters and Spacelab filters (on Spacelab missions). It has a normal hose, extension hose, and several attachments. It is powered by the orbiter dc electrical power system. A muffler to reduce noise is part of the vacuum cleaner assembly.

Trash management operations include routine stowage of wet and dry trash, such as expended wipes, tissues, and food containers. (Wet trash includes all items that could offgas.) The equipment available for trash management includes three trash bags, trash bag liners, wet trash volumes, and the waste collection system (WCS) coffee canister.

Three trash bags for dry trash are located in the crew compartment: one on the inside of the WMC door, one on an aft middeck locker, and one on the port side of the flight deck. Each bag contains one installed disposable trash bag liner and seven spare liners (located outside the installed liner but inside the trash bag). When the liner becomes full, it is removed and stowed in a jettison stowage bag. A new liner is then installed. The WMC wet trash compartment has a volume of 1.85 cubic feet and is vented overboard for odor control. Trash from the WMC is inserted into the circular opening of the auxiliary wet trash compartment and is contained by an elbow bag. Tissues, as well as used WCS coffee canister bags, are disposed of in this wet trash compartment. The coffee canister, which is about the same size and shape as an off-the-shelf can of coffee, is installed near the WMC during post insertion. Trash bags are inserted in the canister and are filled with wipes used for fecal collection. After each WCS use, a used trash bag is disposed of in the Stowage volume on the WMC wall and installed in the canister.

An 8-cubic-foot wet trash stowage compartment is available under the middeck floor (Volume F). This compartment is vented overboard (3 lb/day) for odor control. Any item that can create an odor is considered to be wet trash and is disposed of there.

Restraints and Mobility Aids

Restraints and mobility aids are provided in the orbiter to enable the flight crew to perform all tasks safely and efficiently during ingress (1-g, orbiter vertical), egress (1-g, orbiter horizontal), and orbital flight (orbiter orientation arbitrary).

Mobility aids are located in the crew compartment for movement of the flight crewmembers during ingress, egress, and orbital flight. These devices consist of permanent and soft handholds, a platform in the middeck, and an interdeck access ladder.

Restraints consist of foot loop restraints, seat restraints, retention nets, Velcro, tape, snaps, cable restraints, clips, bungees, and tethers.

Foot loop restraints are cloth loops attached to the crew compartment decks by adhesive to provide stability in zero g. Before launch, the foot loop restraints are installed by the crew compartment configuration drawings (CCCD) or vehicle integration test team (VITT) personnel on the floor areas of the aft flight deck work stations, middeck, and near the waste management system and galley. Spares are stowed in the modular lockers. To install a foot restraint, the protective backing on the underside of the restraint is removed, and the restraint is placed in its desired location. The foot loop restraints are easily used by placing a foot in the loop. Seat restraints are similar to foot loop restraints. They can be installed prelaunch, and spares are manifested in the same locker as the foot restraints. One adhesive patch is placed on one side of the seat, and the other patch is placed on the opposite side. A restraint strap is placed over the seat back and attached to each patch via clips.

A brown mesh middeck retention net, attached to the forward middeck lockers and the starboard wall (no sleep station), is used to restrain the inflight stowage bags, as well as other hardware. The airlock stowage net, also made of brown mesh net, can restrain this equipment in the airlock if the sleep station is manifested, or if the crew determines they wish to stow this hardware in the airlock.

Velcro, tape, snaps, cable restraints, clips, bungees, and tethers are all manifested in the IFM locker and can be utilized for a variety of purposes.

Stowage Containers

Temporary Stowage Bag

The temporary stowage bag is used to restrain, stow, or transport loose equipment temporarily. One is installed on the flight deck.

Inflight Stowage Bags

Ten inflight stowage bags are manifested, one per crewmember plus spares. These brown mesh bags are used to stow suits, boots, and harnesses on orbit.

Flight Deck Stowage Bags

The flight deck stowage bags provide restraint for flight deck items when those items are not immediately returned to locker stowage compartments. These bags are manifested in the Flight Data File (FDF) locker and are installed on orbit on the back of the CDR and PLT seats (one per seat).

Jettison Stowage Bags

The jettison stowage bags are used for restraining dry trash or early return items, such as FDF, film, and cassettes. (See Section 2.24 for further details on all stowage bags.)

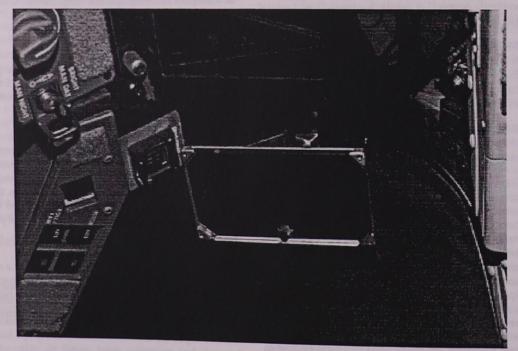
Reach and Visibility Aids

Reach and visibility aids are hardware items that assist the flight crew in monitoring and manipulating displays and controls throughout various phases of flight. These aids consist of CDR/ PLT adjustable mirrors, CDR/PLT two axis (Z and X) seat adjustment, wicket tabs, and an auxiliary reach mechanism.

The adjustable mirrors are installed at launch on handholds located between windows 2 and 3 for the CDR and windows 4 and 5 for the PLT. During ascent and entry, the CDR and PLT use the adjustable mirrors to facilitate seeing controls that are in the obscured areas of their vision envelope. On orbit, mirrors can be removed and stowed, if desired.

To install the adjustable mirror, place the split clamp halves around the handhold, fit the handwheel stem into both clamp halves, and tighten the handwheel clockwise. To adjust the mirror, loosen the mirrorlock knob (counter-clockwise), move the mirror to the desired orientation, and tighten the mirror-lock knob. The CDR/PLT seats provide the CDR and PLT with the capability to move their seats along the orbiter Z- (vertical) and X- (longitudinal) axes to facilitate the reach and visibility of controls during the ascent and entry phase of flight. Seat movement for each axis is provided by a single ac motor. The total travel distances for the Z- and X-axes are 10 and 5 inches respectively. Seat adjustment controls are located on the left side of the seat pan. The controls consist of a three-position toggle switch for power bus selection and one spring-loaded, three-position toggle switch each for control of horizontal and vertical seat movement.

To operate the CDR/PLT seat, the crewmember must first assign ac power to his or her seat motors by moving the *POWER BUSS SEL* switch to *AC2* (up) or *AC3* (down). To move the seat along the horizontal axis, crewmembers must actuate the *HORIZ CONTR* toggle switch FWD to move the seat forward and *AFT* to move the seat aft. Similarly, to move the seat along the vertical axis, the crewmember must actuate the *VERT CONTR* toggle switch *UP* to move the seat upward and *DN* to move the seat downward.



Adjustable Mirror



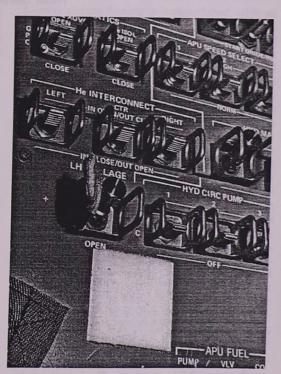


Seat Power and Controls

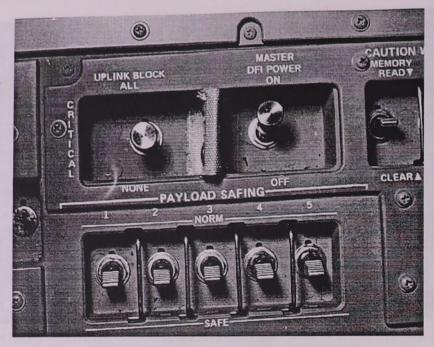
If the seat motors fail to work, and seat adjustment is needed, manual adjustment capability is provided. However, manual seat adjustment can take place only on orbit and is accomplished with a special seat adjustment tool provided in the in-flight maintenance tool kit. Manual horizontal and vertical seat adjustment control locations are under the seat pan cushion and on the aft side of the fixed seat structure.

The seat adjustment tool is a ratchet-driven, 3/16inch Allen wrench inserted into the vertical or horizontal manual adjustment to move the seat along the Z- or X-axis.

Wicket tabs are devices that help the crewmember activate controls when his or her vision is degraded. The tabs provide the crewmember with tactile cues to the location of controls to be activated as well as a memory aid to their function, sequence of activation, and other pertinent information. Wicket tabs are found on controls that are difficult to see on panels O8, C3, and R2 during the ascent and entry flight phases.



Wicket Tabs on Panel R2



Wicket Tabs on Panel C3

The auxiliary reach mechanism, sometimes known as the "swizzle stick," is a short adjustable bar with multipurpose end effectors that are used to actuate controls that are out of the reach of seated crewmembers. The reach aid is used to push in and pull out circuit breakers, move toggle switches, and turn rotary knobs. It is stowed on the inboard side of the PLT seat. It may be used during any phase of flight, but is not recommended for use during ascent because of the attenuation and switch-cuing difficulties resulting from acceleration forces.

Operation of the reach aid consists of extending it and actuating controls with the end effector. To extend the reach aid, the crewmember depresses the spring-loaded extension tab and pulls the end effector out to the desired length.

The reach and visibility envelope of each crewmember is limited by the LES. Tactile cues are restricted by the LES pressure glove. Visibility is reduced because of the helmet and neck ring, and reach is restricted by the bulk of the LES and the parachute and harness. Crewmembers should practice techniques that enable them to adjust their reach and visibility envelope. The helmet can be swiveled on the neck ring. The neck ring tie down may be adjusted to help open up downward field of view. Mirrors, the auxiliary reach mechanism (swizzle stick), and other crewmembers can aid in locating and actuating controls. Seat headrest pads and helmet pads may be used to adjust the position of the head in the seat and in the helmet. The CDR and PLT seats may be adjusted as necessary.

Photographic Equipment

Five still camera systems and one motion picture camera are used on orbit to document crew activities, meet payload requirements, and record Earth observations. Additional cameras can be stowed as required. Nikon 35 mm and Hasselblad 70 mm single lens reflex (SLR) cameras are flown for still photography. The Kodak/Nikon electronic still camera stores digital still images on removeable hard drives. Images can be downlinked for printing and distribution. An Arriflex 16 mm camera is used for motion picture photography. When stowage and weight provisions allow, an Aero Linhof 4X5 aerial photography camera or a NASAdeveloped electronic still camera may be flown. Additional camera systems may be flown for specific experiments or as part of an ongoing NASA evaluation of new cameras and technology. Periodically, the IMAX Corporation manifests its 70 mm motion picture camera aboard the shuttle as a commercial payload.

Two slightly modified Nikon professional 35 mm F4S autofocus SLR cameras are nominally manifested for each mission. The F4 provides stateof-the-art metering for automatic ambient light and flash exposure and exposures as brief as 1/8000 of a second. The camera incorporates a "full information" LCD viewfinder display. Interchangeable autofocus lenses of various focal lengths, including 28 mm f/2.8, 24-50 mm f/4.5 and 35-70 mm f/2.8 zoom are available. A 300 mm telephoto and 2X converter can be flown for photographing the shuttle external tank postjettison. Manual focus lenses can be used on the F4, with the camera indicating when proper focus is achieved. The camera motor drive advances the film after each exposure or permits continuous exposure at 3.4 or 5.7 frames per second. It operates on six AA batteries. The F4 flash (SB-24) operates on four AA batteries. The F4 cameras are used primarily for in-cabin crew activities and experiments. They may also be used for payload deployments and Earth observations. A wide variety of negative (print) and positive (slide) color 35 mm films can be manifested for a mission. The 36 exposure rolls run the gamut of ISOs (ASAs) from 50 to 1600. Special purpose IR and black and white films may be flown as required.

One or two factory modified Nikon F3 35 mm cameras are manifested for scheduled EVA missions or flights having a high probability of an EVA. A special camera thermal cover, sport finder eyepiece, and tabs to assist the EVA crew with camera operations are also manifested. This camera permits manual or automatic exposure. An EVA 35 mm camera is loaded with a 36 exposure roll of 100 ISO negative film. Two lenses have been qualified for the harsh EVA environment. They are a 28 mm f/2, and a 35 mm f/1.4.

Two 70 mm SLR medium format (2.25 in square) cameras are usually flown on each shuttle mission. The cameras are Hasselblad 500 EL/Ss (EL/Xs with minor modifications). Only manual exposure is available with the 70 mm cameras. Two Minolta

handheld reflected light spotmeters are manifested to provide exposure information as required. Interchangeable magazines provide approximately 95 exposures on Kodak 100 ISO Professional 70 mm perforated positive film. Occasionally, color infrared film is used for Earth observations. Each magazine has a detachable data recording device that prints flight-specific data on the edge of the film. Interchangeable lenses, including 40 mm f/4, 50 mm f/4, 100 mm f/3.5, and 250 mm f/5.6, are part of the standard complement. The camera motor drive operates on five AA batteries. It permits single frame automatic film advance or a continuous rate of about one frame per second. The 70 mm cameras are used exclusively for photography of payload bay activities and Earth observations. The Nikon flash can also be used with the 70 mm cameras via photographic "pc" cords.

The 70 mm camera can also be used EVA with a body lubricated especially for EVA usage. A 30 mm f/3.5 or 60 mm f/3.5 lens is available for EVA photography. A thermal cover encloses the camera, lens, and magazine.

Motion picture filming is accomplished with an Arriflex professional 16 mm through-the-lens viewing rotary shutter camera with integral light meter. The crystal-controlled camera motor transports film at 24 frames per second. The nominal shutter speed is 1/48 second. The camera utilizes an interchangeable 10 - 100 mm f/2 zoom or 5.9 mm f/1.8 wide angle lens. Both lenses permit manual exposure. The zoom lens aperture can be controlled by inputs from the camera light meter for automatic exposure as well. Interchangeable magazines are reloaded in flight with 380 ft rolls of 100 or 500 ISO Kodak tungsten light balanced color negative film. A full magazine will provide about 10.5 minutes of filming. Color correction filters must be used whenever sunlight is the main subject light. The camera is normally powered by a NASA developed 15 V dc battery containing 40 AA batteries. The camera may also be powered from the orbiter, via an adapter cable and the inflight maintenance (IFM) "breakout box." A rarely flown accessory provides variable frame rates for the Arriflex and bar code time data on the film. A photoflood light is available and is used during interior filming. The Arriflex is used primarily to document in-cabin and payload bay activities.

The Aero Linhof is a manual exposure 4X5 camera that is manifested approximately every other mission if stowage space and weight constraints allow. The camera produces large (4 in. by 5 in.) images on Kodak 100 ISO thin base positive film. Each removable magazine contains approximately 185 exposures. The camera uses a 90 mm f/5.6 wide angle and a 250 mm f/5.6 lens. Camera power is supplied by orbiter 28 V dc. An attachable viewfinder can be used to estimate the field-of-view (FOV) of the lens in use. The Linhof camera is used primarily for Earth observations photography.

Most of the photography and cinematography conducted in the orbiter are handheld. With the exception of flash photography, however, many of the images and scenes the crew captures on film can be improved through the use of the multiuse brackets, clamps, and baseplate adapter. Twenty two mounts throughout the flight deck, middeck, and airlock permit the crew to mount cameras and accessories. The baseplate adapters (crew installed) provide quick mounts in windows 9 and 10. The multiuse clamp is used on switchguards or other structures to provide an attachment base for a multiuse arm. The multiuse arm is a modified commercial device that attaches to a camera and a wall mount or clamp. The arm permits universal pointing of the camera until the center "elbow" knob is tightened. When the knob is secure, the camera is held rigidly at the selected orientation (zero g). Multiuse equipment is also used to mount the camcorder, and photo flood.

Sighting Aids

Sighting aids include all items used to aid the flight crew within and outside the crew compartment. The sighting aids include the crew optical alignment sight (COAS), binoculars, adjustable mirrors, and spotlights. (The COAS is discussed in detail in Section 2.13.)

Five models of binoculars are available for on-orbit use. Two models are routinely flown on each mission. Binocular models include the Zeiss 8X20, Fuji 10X40 gyro stabilized day/night, Fuji 14X40 gyro stabilized, Fuji 16X70, and the Zeiss 20X60 mechanically stabilized

The spotlight is a high-intensity, handheld flashlight powered by a battery pack consisting of five 1.2volt one-half D size nickel-cadmium batteries. The spotlight produces a 20,000-candlepower output with a continuous running time of 1.5 hours. The lamp is a 6-volt tungsten filament and cannot be replaced in flight.

The high intensity search light (HISL) is used in conjunction with the rangefinders during visual acquisition of satellites. It provides crewmembers with the capability to detect and maintain visual contact with a payload for effective rendezvous and station keeping at 700 to 1000 feet when on the dark side. The light is portable and has a stainless steel camera mounting rail on the handle that interfaces to the multiuse mounting brackets on the orbiter. The light is aimed out the aft, or overhead, windows of the flight deck.

Window Shades and Filters

Window shades and filters are provided for installation on the orbiter windows to minimize crewmember exposure to sunglare during ascent, entry, and orbital flight phases.

The window shades and filters are stowed in a compartmented bag attached to a mounting pallet on the starboard side of the aft middeck.

To install the W1 through W6 window shades, the crewmember unrolls the shade (white surface outboard) over the window and mates the Velcro with the Velcro on the window frame. Removal of the shades is accomplished by just the reverse. Demate the Velcro, and roll the shade up as compactly as possible (blue surface visible). Insert into window shade holders and close the holders by mating Velcro together.

Aft window shades and filters are installed simply by placing the correct shade or filter in the appropriate window (reflective side outboard) and securing it to the mating Velcro on the window ledges.

To remove a window shade from the window shade stowage container, the crewmember must unfasten the securing straps and pull the Velcro-restrained closure panel away from the desired stowage pouch.

Interdeck light shades are provided to minimize light leakage between the flight deck and middeck during in-cabin photography. The light shade is attached with Velcro to the flight deck floor around the interdeck access. Adjustable louvers are provided to regulate the amount of light between the flight deck and the middeck.

The side hatch viewport is the only optical-quality window on OV 102, 103, 104, and 105. Unlike the 10 windows on the flight deck, the side hatch viewport does not provide protection from solar ultraviolet (UV) rays, which can cause serious injury in as little as 10 seconds. Therefore, a removable UV filter must be placed on the side hatch viewport for on-orbit operations. The filter is held against the viewport by Velcro and is normally installed post insertion and removed during deorbit preparations.

Shuttle Orbiter Medical System

The shuttle orbiter medical system (SOMS) is required to provide medical care in flight for minor illnesses and injuries. It also provides support for stabilizing severely injured or ill crewmembers until they are returned to Earth.

The SOMS is provided in two separate packages: the medications and bandages kit (MBK) and the emergency medical kit (EMK). The MBK is blue with blue Velcro and a blue strap. The EMK is also blue with red Velcro and a red strap.

The medical kits are stowed in a middeck modular locker. If the kits are required on orbit, they are unstowed and installed on the locker doors with Velcro. The kits have a patch of Velcro on the bottom to match the Velcro on the outside of the doors.

Each kit contains pallets and a pocket inside the back. Pockets containing medications and equipment are mounted on each side of the pallets. The MBK pallet designators are E, F, and G. The E pallet contains pills, capsules, and suppositories. The F pallet contains bandage materials for covering or immobilizing body parts. The G pallet contains medications to be administered by topical application.

The EMK pallet designators are A, B, C, and D. The A pallet contains medications to be administered by injection. The B pallet contains emergency items and equipment for performing minor surgeries. The C pallet contains diagnostic/therapeutic items

consisting of instruments for measuring and inspecting the body. The D pallet contains dental items, injectables, and intravenous fluid/ administration sets.

The onboard medical checklist and medical checklist flight supplement specify the location of medications/equipment in the two medical kits by an alphanumeric code. The first character is the alphanumeric code of the pallet (A through G). The second character is the side of the pallet (1 or 2). The third and fourth characters are the number of the specific pocket on the pallet. The pallets are appropriately marked.

The medical accessory kit supplements the SOMS kit by providing additional storage capability for crew-specific and/or mission-specific medications, such as toxin antidotes, additional I.V. fluid, etc.

The SOMS also includes a resuscitator and patient/ rescuer restraints. The resuscitator consists of a mask with a retaining cap, a manually activated/ demand regulated oxygen supply valve, a 6-foot hose, and a quick disconnect fitting. The resuscitator assembly is stored in a middeck locker with the EMK and MBK.

The resuscitator is emergency hardware to be utilized, along with the patient/rescuer restraints, in the case of a crewmember becoming ill as called out for in JSC-17327, Medical Checklist – All Flights.

The resuscitator provides the capability to deliver 100 percent oxygen, control ventilation, and perform CPR for extended periods of time.

The resuscitator valve can supply 100 percent supplemental oxygen in two ways: (1) at 40 LPM positive pressure for unconscious patients, and (2) on demand flow for conscious patients.

The resuscitator, upon unstowage, can be connected to the orbiter oxygen supply on the middeck connections on panels MO32M and MO69M and the flight deck connection on panel C6. Oxygen flow can be checked by depressing the O_2 trigger arm. Following verification of O_2 flow, a crewmember will position and tighten the resuscitator mask over the crewmember's face using the head cap and elastic straps. The patient/rescuer restraints consist of one belt with two pip pins for the patient and two belts with two pip pins for the rescuer. They are designed to interface into the holes in the middeck locker latches.

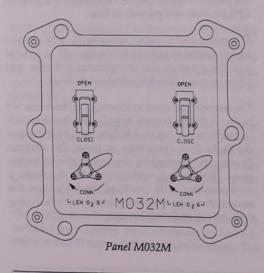
The patient/rescuer restraint system is emergency hardware to be utilized in the case of a crewmember becoming ill. The restraints are stored in a middeck locker with the EMK and MBK.

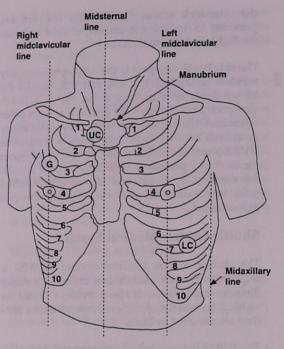
The patient restraints will restrain the patient in the mid-calf area and the chest area. The restraints can be easily tightened to fit the patient. The rescuer restraint will wrap around the rescuer's waist and will have two extensions from the waist belt with pip pins on the end to fasten into the locker latches. This will allow the rescuer and patient to remain stationary.

The diagnostic equipment on board and information from the flight crew will allow diagnosis and treatment of injuries and illnesses through consultation with flight surgeons in Mission Control.

Operational Bioinstrumentation System

The operational bioinstrumentation system (OBS) provides an amplified electrocardiograph (ECG) analog signal from any crewmember aboard the orbiter to the avionics system, where the signal is converted to digital signal and transmitted to the ground in real time or stored on tape for dump at a later time. On-orbit use is limited to crewmembers in EVA or to contingency situations (only at the request of the flight surgeon).

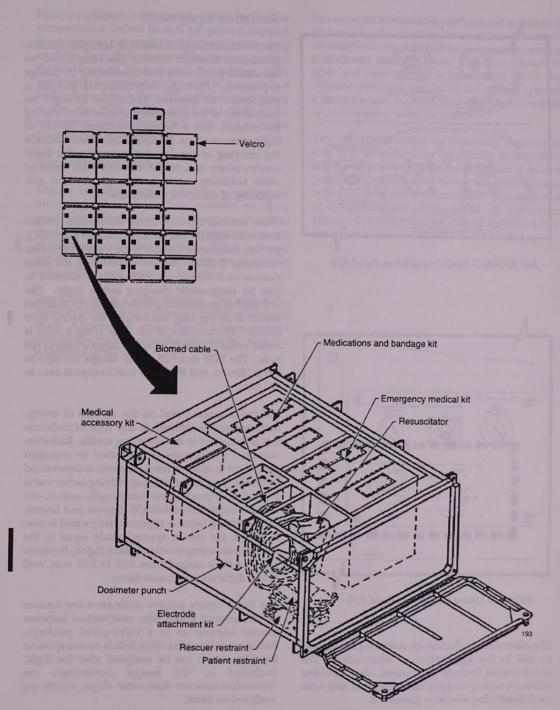




The OBS electrodes are attached to the skin with electrode paste to establish electrical contact. The electrode is composed of a plastic housing containing a non-polarizable pressed pellet. The housing is attached to the skin with double-sided adhesive tape, and the pellet contacts the skin. There are three electrodes on the harness, marked LC (lower chest), UC (upper chest), and G (ground).

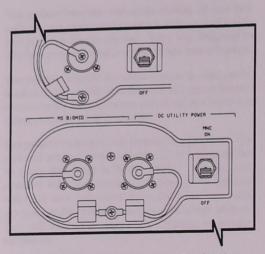
The ECG signal conditioner is a hybrid microcircuit with variable gain (adjusted for each crewmember before flight). It provides a zero- to 5-volt output and has an ON/OFF switch within the input plug, which is actuated when the intravehicular activity (IVA) biomed cable is plugged in. The unit has batteries that will not be replaced in flight.

The IVA biomed cable connects to the signal conditioner and is routed under the IVA clothing to connect to the biomed seat cable. The biomed seat cable is routed to one of the *BIOMED* input connectors located on panel A11, A15, or M062M. Rotary control switches on panel R10 provide circuits from the biomed outlets to the orbiter's network signal processor for downlink or recording. The two rotary switches on panel R10 are *BIOMED* CHANNEL 1 and CHANNEL 2. Extravehicular activity positions provide circuits from the EVA UHF transceiver.

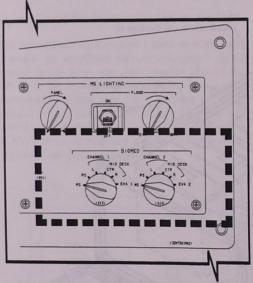


Modular Locker Equipment and Locations

2.5-13



MS BIOMED Input Connector on Panel A11



BIOMED Rotary Switches on Panel R10

The electrode application kit contains components to aid in the application of electrodes. The components include wet wipes, double-sided adhesive tape, overtapes, electrode paste, and a cue card illustrating electrode placement.

Radiation Equipment

The harmful biological effects of radiation must be minimized through mission planning based on calculated predictions and monitoring of dosage exposures. Preflight requirements include a projection of mission radiation dosage, an assessment of the probability of solar flares during the mission, and a radiation exposure history of flight crewmembers. In-flight requirements include the carrying of passive dosimeters by the flight crewmembers and, in the event of solar flares or other radiation contingencies, the readout and reporting of the active dosimeters.

There are four types of active dosimeters: pocket dosimeter high (PDH), pocket dosimeter low (PDL), pocket dosimeter FEMA (PDF), and high-rate dosimeter (HRD). All four function in the same manner and contain a quartz fiber positioned to zero by electrostatic charging before flight. The unit discharges according to the amount of radiation received; as the unit discharges, the quartz fiber moves. The position of the fiber along a scale is noted visually. The PDH unit's range is zero to 100 rads. The PDF and PDL units' range are zero to 200 millirads, and the HRD unit's range is zero to 600 rads.

The rad is a unit based on the amount of energy absorbed and is defined as any type of radiation that is deposited in the absorbing media. Radiation absorbed by humans is expressed in roentgen equivalent in man, or rems. The rem is determined by multiplying rads times a qualifying factor that is a variable depending on wavelength, source, etc. For low-inclination orbits (35 degrees and lower), the qualifying factor is approximately equal to one; therefore, the rem is approximately equal to the rad. In space transportation system flights, the doses received have ranged from 0.05 to 0.07 rem, well below flight crew exposure limits.

The flight crew's passive dosimeters are squares of fine-ground photo film sandwiched between plastic separators in a light-proof package. Radiation striking the silver halide causes spots on the film, which can be analyzed after the flight. Included in the badge dosimeters are thermoluminescent dosimeter chips, which are analyzed on Earth. Passive radiation dosimeters are placed in the crew compartment before launch by ground support personnel and removed after landing for laboratory analysis. Each flight crewmember carries a passive dosimeter at all times during the mission. The remaining dosimeters are stowed in a pouch in a middeck modular locker. If a radiation contingency arises, the PDL, PDH, HRD and PDF active dosimeters will be unstowed, read, and recorded for downlink to the ground.

Air Sampling System

The air sampling system provides a method for obtaining cabin atmosphere samples to allow postflight analysis of the gas environment within the crew module. The air sampling system consists of an air sample bottle. The air sampling system is stowed in a modular locker for ascent, unstowed for sampling, and restowed for entry.

The air bottle is a steel cylinder. The end of the cylinder is fitted with a valve operated by the valve knob. A screw cap covers the air inlet to prevent dust from contaminating the air sample. This cap is tethered to the valve.

The air bottle is evacuated preflight and is operated by removing the dust cap, turning the valve knob counterclockwise until full open, and then turning it clockwise until full close. The time it takes to open and close the valve is sufficient to fill the cylinder with cabin gas. When the valve is opened, a hissing sound may not always be heard because of cabin noise or valve variations.

Two air sample bottles are nominally manifested. One is to be utilized for fire/smoke in the cabin, and the other is used for air sampling during deorbit prep, of if a crewmember notices either an unusual odor and/or excessive sneezing and/or watery eyes in a particular area of the cabin. If this occurs, Mission Control should be notified for a microbial sample to be taken of that location post flight.

2.6 DATA PROCESSING SYSTEM (DPS)

CONTENTS

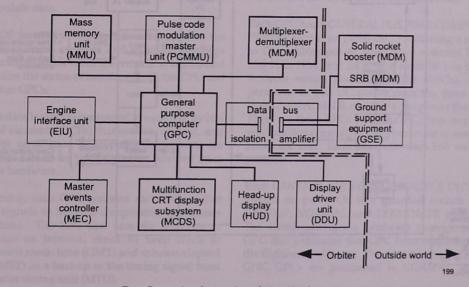
Description	2.6-1
General Purpose Computers	2.6-2
Data Bus Network	2.6-7
Multiplexers/Demultiplexers	2.6-11
Mass Memory Units	2.6-13
Multifunction CRT Display System	2.6-14
Master Timing Unit	2.6-15
Software	2.6-19
Operations	2.6-25

Description

The DPS, consisting of various hardware components and self-contained software, provides the entire Space shuttle vehicle with computerized monitoring and control. DPS functions are:

- Support the guidance, navigation, and control of the vehicle, including calculations of trajectories, SSME burn data, and vehicle attitude control data.
- Monitor and control vehicle subsystems, such as the electrical power system and the environmental control and life support system.
- Process vehicle data for the flight crew and for transmission to the ground, and allow ground control of some vehicle systems via transmitted commands.
- Check data transmission errors and crew control input errors; support annunciation of vehicle system failures and out-of-tolerance system conditions.
- Support payloads with flight crew/software interface for activation, deployment, deactivation, and retrieval.
- Process rendezvous, tracking, and data transmissions between payloads and the ground.

The DPS hardware consists of five general-purpose computers (GPCs), two mass memory units (MMUs) for large-volume bulk storage, and a network of serial digital data buses to accommodate the data traffic between the GPCs and vehicle systems. The



Data Processing System Interfacing Hardware

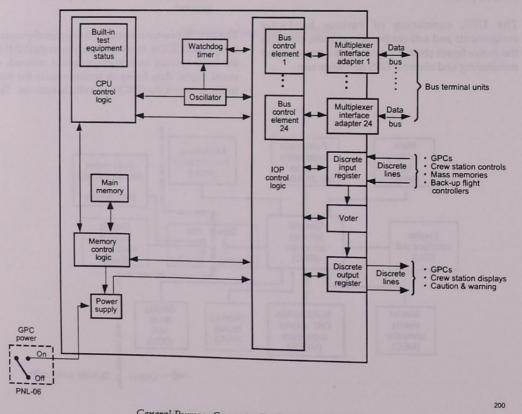
DPS also includes 20 orbiter and four SRB multiplexers/demultiplexers (MDMs) to convert and format data from the various vehicle systems, three SSME interface units to command the SSMEs, four multifunction CRT display systems used by the flight crew to monitor and control the vehicle and payload systems, two data bus isolation amplifiers to interface with the ground support equipment/launch processing system and the SRBs, two master events controllers, and a master timing unit.

DPS software accommodates almost every aspect of Space shuttle operations, including orbiter checkout, prelaunch and final countdown for launch, turnaround activities, control and monitoring during launch, ascent, on-orbit activities, entry, and landing, and aborts or other contingency mission phases. A multicomputer mode is used for the critical phases of the mission, such as launch, ascent, orbit, entry, landing, and aborts.

General Purpose Computers (GPCs)

The orbiter has five identical IBM AP-101S GPCs. The GPCs receive and transmit data to and from interfacing hardware via the data bus network. GPCs also contain the software that provides the main on-board data processing capability. Up to four of the systems may run identical software. The fifth system runs different software, programmed by a different company, designed to take control of the vehicle if an error in the primary software or other multiple failures cause a loss of vehicle control. The software utilized by the four primary GPCs is referred to as PASS (primary avionics software system); the fifth GPC is referred to as BFS (backup flight system).

GPCs 1 and 4 are located in forward middeck avionics bay 1, GPCs 2 and 5 are located in forward middeck avionics bay 2, and GPC 3 is located in aft middeck avionics bay 3. The GPCs receive forced-



General Purpose Computer Functional Block Diagram

air cooling from an avionics bay fan. (There are two fans in each avionics bay, but only one is powered at a time.)

CAUTION

If both fans in an avionics bay fail, the computers will overheat within 25 minutes (at 14.7 psi cabin pressure) or 17 minutes (at 10.2 psi) after which their operation cannot be relied upon. An operating GPC may or may not survive for up to an additional 30 minutes beyond the certifiable thermal limits.

Each GPC consists of a central processing unit (CPU) and an input/output processor (IOP) stored in one avionics box. The boxes are 19.55 inches long, 7.62 inches high, and 10.2 inches wide; they weigh approximately 68 pounds. The main memory of each GPC is volatile (the software is not retained if power is interrupted), but a battery pack preserves software contents when the GPC is powered off. The memory capacity of the GPCs is 256 k halfwords, but only the lower 128 k half-words are normally used for software processing.

The CPU controls access to GPC main memory for data storage and software execution and executes instructions to control vehicle systems and manipulate data.

The IOP formats and transmits commands to the vehicle systems, receives and validates response data transmissions from the vehicle systems, and maintains the status of interfaces with the CPU and the other GPCs.

The 24 data buses are connected to each IOP by bus control elements (BCEs) that receive, convert, and validate serial data in response to requests for available data to be transmitted or received from vehicle hardware.

For timing, each GPC contains an oscillator that sends signals to internal components to regulate operations. The GPC also uses the oscillator to maintain an internal clock to keep track of Greenwich mean time (GMT) and mission elapsed time (MET) as a backup to the timing signal from the master timing unit (MTU). Each GPC contains a watchdog timer. The watchdog timer is an incrementing clock register in the GPC that is reset about once every second by a signal from the CPU. If the register ever overflows, then a problem exists and is annunciated by a self-fail indication from that GPC. The PASS set does not utilize this hardware feature since it operates in synchronization with each of its GPCs to ensure proper functioning. Since the BFS operates essentially standalone relative to the PASS set synchronization, the BFS mechanization does utilize the watchdog timer function to serve as a check on its operation.

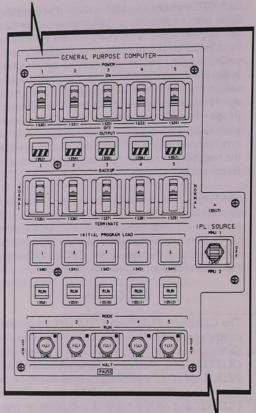
The PASS GPCs use a hardware "voter" to monitor discrete inputs from the other GPCs. Should a GPC receive a fail vote from two or more of the other GPCs, it will cause the GPC to annunciate a self-fail indication that also causes the GPC to inhibit any fail votes of its own against the other GPCs.

GPC Controls

The GENERAL PURPOSE COMPUTER hardware controls are located on panel O6. Each of the five GPCs reads the position of its corresponding OUTPUT and MODE switches and INITIAL PROGRAM LOAD push buttons from discrete input lines that go directly to the GPC. Each GPC has OUTPUT and MODE talkback indicators on panel O6 that are driven by GPC output discretes.

Each GPC has a GENERAL PURPOSE COMPUTER POWER switch on panel O6. Positioning a switch to ON enables power from three essential buses, ESS 1BC, 2CA, and 3AB. The essential bus power controls remote power controller (RPCs), which permit main bus DC power from the three main buses (MN A, MN B, and MN C) to power the GPC. There are three RPCs for each GPC; thus, any GPC will function normally, even if two main or essential buses are lost. Each computer uses 560 watts of power.

Each GENERAL PURPOSE COMPUTER OUTPUT switch on panel O6 is a guarded switch with BACKUP, NORMAL, and TERMINATE positions. The switch provides a hardware override to the GPC that precludes that GPC from outputting on the flight-critical buses. The switches for the PASS GNC GPCs are positioned to NORMAL, which



GENERAL PURPOSE COMPUTER Hardware Controls

permits them to output. The backup flight system switch (GPC 5) is positioned to *BACKUP*, which precludes it from outputting until it is engaged. The switch for a GPC designated on-orbit to be a systems management (SM) computer is positioned to *TERMINATE*, since the GPC is not to command anything on the flight-critical buses.

The talkback indicator above each OUTPUT switch on panel O6 indicates gray if that GPC output is enabled and barberpole if it is not.

Each GPC receives RUN, STBY, or HALT discrete inputs from its MODE switch on panel O6, which determines whether that GPC can process software. The MODE switch is lever-locked in the RUN position. The HALT position initiates a hardwarecontrolled state in which no software can be executed. A GPC that fails to synchronize with others is either powered *OFF* or moded to *HALT* as soon as possible to prevent the failed computer from outputting erroneous commands. The talkback indicator above the *MODE* switch for that GPC indicates barberpole when that computer is in *HALT*.

In *STBY*, a GPC is also in a state in which no PASS software can be executed, but it is in a softwarecontrolled state. The *STBY* mode allows an orderly startup or shutdown of processing. It is necessary, as a matter of procedure, for a PASS GPC that is shifting from *RUN* to *HALT* or vice versa to be temporarily (more than 3 seconds) in the *STBY* mode before going to the next state. The *STBY* mode allows for an orderly software cleanup and allows a GPC to be correctly initialized (when reactivated) without an initial program load. If a GPC is moded to *RUN* or *HALT* without pausing in *STBY*, it may not perform its functions correctly. There is no *STBY* indication on the talkback indicator above the *MODE* switch.

The *RUN* position permits a GPC to support its normal processing of all active software and assigned vehicle operations. Whenever a computer is moded from *STBY* to *RUN*, it initializes itself to a state in which only system software is processed (called OPS 0). If a GPC is in another operational sequence (OPS) before being moded out of *RUN*, that software still resides in main memory; however, it will not begin processing until that OPS is restarted by flight crew keyboard entry. The *MODE* talkback indicator always reads *RUN* when that GPC switch is in *RUN*, and no failures exist.

Placing the backup flight system GPC in *STBY* does not stop BFS software processing or preclude BFS engagement; it only prevents the BFS from commanding the payload buses used by BFS systems management software.

The PASS GPC/BUS STATUS display (DISP 6) indicates the current mode of each PASS GPC in the common set. The display does not differentiate between *STBY* and *HALT*; only *RUN* or *HALT* is displayed (GPC MODE).

The *INITIAL PROGRAM LOAD* pushbutton for a GPC on panel O6 activates the initial program load command discrete input when depressed. When the input is received, that GPC initiates an initial

GPCI		2	13	14	1 5	00:11:
MODE	RUN	RUN	HALT	RUN	HALT	
OPS	G2	G2	0	S2	0	1.3 0.00
STRING 1 FF	*	5 61	and the second	+	10000	
FA	*	1.	a state of the second se	+	and the second second	Contraction of the
2 FF		*	CORPORT	+	A BURN	Con Frank
FA		*		+		
3 FF	*			+	12021	120.2
FA	*	1000	- Aller and	+	1. 1. 1.	1.434
4 FF		*	A COLORED BY	+	11.000	-
FA		*	a find the	+	COR	1.1.1.1.1.1.1
PL 1	+	+	1 200		25.00	dina?
2	+	+	1	+		The second
LAUNCH 1	+	+			- Second	C. C. C. C.
2	+	+	in and	L	1 AL	
CRT 1	*		A CONTRACTOR OF THE OWNER OWNER OF THE OWNER OF THE OWNER OF THE OWNER	J J	1.	1000
			AND CON	J J	The second second	- manual a
23	T	J.			1 100	1.1
4	Ť	Ť	POT St.		10000	1000

GPC/BUS STATUS Display (DISP 6)

program load (IPL) from the MMU specified by the *IPL SOURCE* switch on panel O6. The talkback indicator above the *MODE* switch for that GPC indicates *IPL*.

During non-critical periods in orbit, only one or two GPCs are used for GNC tasks, and another is used for systems management and payload operations.

A GPC on-orbit can also be "freeze-dried"; that is, it can be loaded with the software for a particular memory configuration and then moded to *HALT*. Before an OPS transition to the loaded memory configuration, the freeze-dried GPC can be moded back to *RUN* and the appropriate OPS requested.

NOTE

Because all BFS software is loaded into the BFS GPC at the same time, the BFS GPC is sometimes referred to as being freeze-dried on orbit when it is placed in *HALT*. The BFS GPC can be moded to *RUN* prior to entry and will begin processing entry software following the OPS 3 request without having to access a mass memory unit. The term freeze-dry or freeze-dried is most often used with respect to the PASS GPCs.

GPC Modes of Operation

GPC modes of operation are redundant set, common set, and simplex. Redundant set operations refer to the mode in which two or more GPCs are concurrently receiving the same inputs, executing the same GNC software, and producing the same outputs. This mode uses a maximum amount of intercomputer communications, and the GPCs must maintain a high level of synchronization (called redundant set synchronization).

During redundant set operations, each GPC outputs only certain portions of its total software output to its interfacing hardware. Therefore, although each GPC "thinks" it is performing all its operations, only the GPC responsible for supporting a specific group of hardware will be able to actually transmit its data and commands. The redundant set GPCs compare all calculations to ensure that individual outputs are the same.

Common set operations occur when two or more GPCs communicate with one another while they are performing their individual tasks. They do not have to be performing the same major function (although they can be), but they do maintain common set synchronization. Any GPC operating as a member of the redundant set is also a member of the common set.

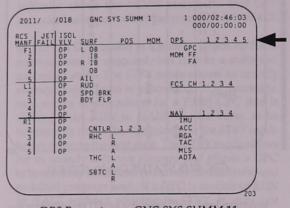
A simplex GPC is in *RUN*, but not a member of the redundant set. Systems management and payload major functions are always processed in a simplex GPC.

GPCs running together in the same GNC OPS are part of a redundant set performing identical tasks from the same inputs and producing identical outputs. Therefore, any data bus assigned to a commanding GNC GPC (except the instrumentation buses because each GPC has only one dedicated bus connected to it) is heard by all members of the redundant set. These transmissions include all CRT inputs and mass memory transactions, as well as flight-critical data. If one or more GPCs in the redundant set fail, the remaining computers can continue operating in GNC. Each GPC performs about 1.2 million operations per second during critical phases.

Each computer in a redundant set operates in synchronized steps and cross-checks results of processing hundreds of times per second. Synchronization refers to the software scheme used to ensure simultaneous intercomputer communications of necessary GPC status information among the PASS computers. If a GPC operating in a redundant set fails to meet any redundant synchronization point, the remaining computers will immediately vote it out of the redundant set. If a GPC has a problem with one of its multiplexer interface adapter receivers during two successive reads of response data, or does not receive data while other members of the redundant set do receive data, the GPC with the problem will fail-to-sync. A failed GPC is either powered OFF or moded to HALT as soon as possible by the crew.

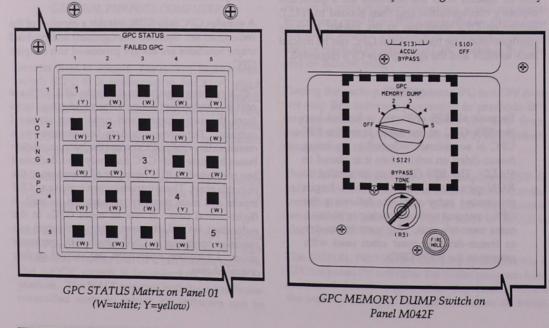
GPC Failure Indications

GPC failure votes are annunciated in a number of ways. Each GPC has discrete output lines for fail votes against each of the other GPCs that go to the other GPCs and the GPC status matrix. A GPC FAIL detection will cause a class 2 GPC fault message with illumination of the *MASTER ALARM*. Error indications may be displayed on DISP 18 GNC SYS SUMM 1 and DISP 6 GPC/BUS STATUS displays. The GPC STATUS matrix (sometimes referred to as the GPC fail CAM) on panel O1 is a 5-by-5 matrix of lights. Each light corresponds to a GPC's fail vote



DPS Parameters on GNC SYS SUMM 11 Display (DISP 18)

against another GPC or itself. For example, if GPC 2 sends out a failure vote against GPC 3, the second white light in the third column is illuminated. The off-diagonal votes are votes against other GPCs. The yellow diagonal lights from upper left to lower right are self-failure votes. Whenever a GPC receives two or more failure votes from other GPCs, it illuminates its own yellow light and resets any



failure votes that it made against other GPCs (any white lights in its row are extinguished). Any time a yellow matrix light is illuminated, the GPC caution and warning light on panel F7 is illuminated, in addition to MASTER ALARM illumination, and a GPC fault message is displayed on the CRT.

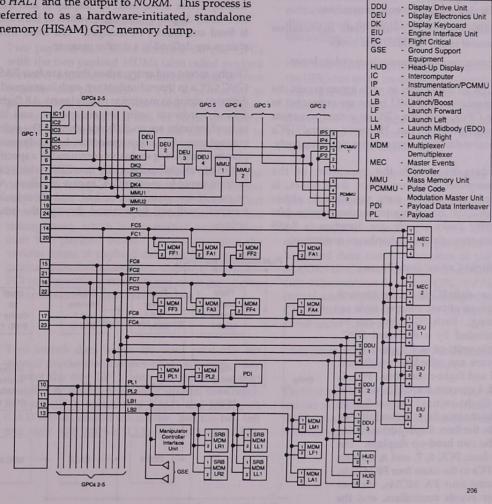
A failed GPC's memory contents can be dumped by powering ON, switching the computer to TERMINATE and HALT, and then selecting the number of the failed GPC on the GPC MEMORY DUMP rotary switch on panel M042F. The GPC is then moded to STBY to start the dump. After 2 to 8 minutes, the dump is stopped by moding the GPC to HALT and the output to NORM. This process is referred to as a hardware-initiated, standalone memory (HISAM) GPC memory dump.

Data Bus Network

The data bus network supports the transfer of serial digital commands and data between the GPCs and vehicle systems. The network is divided into seven groups that perform specific functions:

1. Flight-critical (FC) data buses that tie the GPCs to the flight-critical multiplexer/ demultiplexers (MDMs), display driver units, head-up displays, engine interface units, and master events controllers

Display Drive Unit Display Electronics Unit



Data Bus Network

2.6-7

- 2. Payload data buses that tie the GPCs to the payload MDMs and the payload data interleaver (PDI), and possibly missiondependent flex MDMs or sequence control assemblies
- 3. Launch data buses that tie the GPCs to ground support equipment, launch forward, launch aft, launch mid, and SRB MDMs, and the manipulator controller interface unit (MCIU) used by the remote manipulator system
- Mass memory data buses for GPC/MMU transactions
- 5. Display/keyboard data buses for GPC/ display electronics unit transactions
- 6. Instrumentation/pulse code modulation master unit (PCMMU) data buses
- 7. Intercomputer communication data buses.

Although all data buses in each group except the instrumentation/PCMMU buses are connected to all five GPCs, only one GPC at a time transmits commands over each bus. However, several GPCs may receive data from the same bus simultaneously.

Each data bus, with the exception of the intercomputer communication data buses, is bidirectional; that is, data can flow in either direction. The intercomputer communication data bus traffic flows in only one direction (a PASS software constraint, not a hardware restriction).

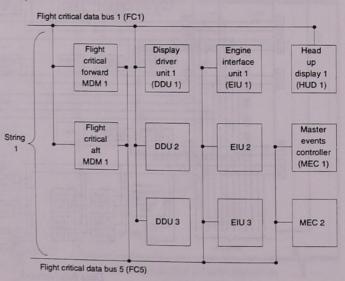
Flight-Critical Data Buses

There are eight FC data buses directed into groups of two, referred to as an FC string. Each FC string can be commanded by a different GPC. Multiple units of each type of GNC hardware are wired to a different MDM and flight-critical bus. FC1, 2, 3, and 4 connect the GPCs with the four flight-critical forward (FF) MDMs, the four flight-critical aft (FA) MDMs, the three display driver units, and the two head-up displays. The other four, FC5, 6, 7, and 8, connect the GPCs to the same four FF MDMs, the same four FA MDMs, the two master events controllers, and the three main engine interface units.

A string is composed of two FC data buses: one from the first group (FC1, 2, 3, or 4) and one from the second group (FC5, 6, 7, or 8). Vehicle hardware is segmented into these groups to facilitate GPC command of these components for redundancy, to allow for nominal mission operations in the event of a loss of one string caused by a GPC or MDM failure, and to allow for safe return to Earth in the event of the loss of a second string.

String 1 consists of FC data buses 1 and 5, MDMs FF1 and FA1 and their hard-wired hardware, controls, and displays, the three engine interface units, the two master events controllers, the three display driver units, head-up display 1, and their associated displays. This distribution of hardware is fixed and cannot be changed. The other three strings are defined in a similar manner.

During ascent and entry, when there are four PASS GNC GPCs in the redundant set, each is assigned a different string to maximize redundancy. All flightcritical hardware units are redundant, and the redundant units are on different strings. The string concept provides failure protection during dynamic phases by allowing exclusive command of a specific group of vehicle hardware by one GPC, which can be transferred to another GPC in case of failure. All or part of one string can be lost, and all avionics functions will still be retained through the other strings.



Components of String One

2.6-8

With four PASS GNC GPCs in a redundant set, each GPC is responsible for issuing commands over the string assigned to it; that is, it is the commander of that string. The other GNC GPCs will monitor or listen on this string. When the string's commanding GPC sends a request for data to the hardware on the string, all the other GNC GPCs will hear and receive the same data coming back on the string. This transaction (one commanding GPC and multiple listening GPCs) is occurring in parallel with the other three strings. Therefore, all GNC GPCs will get a copy of all of the data from all four strings. Once all the data are received from the string, the GPCs then agree (or disagree) that the data are consistent.

Payload Data Buses

Two payload data buses interface the five GPCs with the two payload MDMs (also called payload forward MDMs), which interface with orbiter systems and payloads. A PDI is connected to payload data bus 1. Additionally, on some flights, one or two flex MDMs and/or sequence control assemblies connect the payload data buses to communicate with other payload equipment.

Each payload MDM is connected to two payload data buses. Safety-critical payload status parameters may be hard-wired; then these parameters and others can be recorded as part of the vehicle's system management, which is transmitted and received over two payload buses. To accommodate the various forms of payload data, the PDI integrates payload data for transmission to ground telemetry. PDI configuration commands and status monitoring is accomplished via payload data bus 1.

Launch Data Buses

Two launch data buses are used primarily for ground checkout and launch phase activities. They connect the five GPCs with the ground support equipment/launch processing system, the launch forward (LF1), launch mid (LM1), and launch aft (LA1) MDMs aboard the orbiter, and the two left and right SRB MDMs (LL1, LL2, LR1, and LR2). Launch data bus 1 is used on orbit for interface with the remote manipulator system controller by the SM GPC.

Mass Memory Data Buses

Each of two MMUs interfaces with its data bus via a multiplexer interface adapter, which functions just like the ones in the GPCs. Each data bus is connected to all five GPCs. Each MMU is connected to only one mass memory data bus.

In addition, each MMU has a separate discrete line called the "ready discrete" that goes to each of the GPCs. If the discrete is on, it tells the GPC the mass memory unit is ready for a transaction. When the discrete is off, the MMU is either busy with another transaction or is powered off.

Note that all MMU operations and transmissions to the GPCs are on an on-demand basis only. There is no insight into the state of the MMU (other than the ready discrete) unless a specific transaction is requested. This includes the status of the MMU's built-in test equipment (BITE), which is only updated for MMU read or write.

Display/Keyboard Data Buses

The four display electronics unit keyboard (DK) data buses, one for each display electronics unit, are connected to each of the five GPCs. The computer in command of a particular display/keyboard data bus is a function of the current *MAJOR FUNC* switch setting of the associated CRT, current memory configuration, GPC/CRT keyboard entries, and the position of the backup flight control CRT switches. (These topics are discussed in more detail under "Operations.")

Instrumentation/Pulse-Code Modulation Master Unit (PCMMU) Buses

The five instrumentation/PCMMU data buses are unique in that each GPC has its own individual data bus to two PCMMUs. All the other data buses interface with every GPC. Flight controllers monitor the status of the vehicle's onboard systems through data transmissions from the vehicle to the ground. These transmissions, called downlink, include GPC-collected data, payload data, instrumentation data, and onboard voice. The GPC-collected data, called downlist, includes a set of parameters chosen before flight for each mission phase.

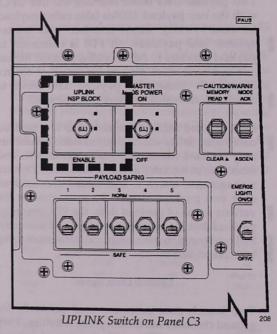
The system software in each GPC assimilates the specified GNC, systems management, payload, or DPS data according to the premission-defined format for inclusion in the downlist. Each GPC is physically capable of transmitting its downlist to the current active PCMMU over its dedicated instrumentation/PCMMU data bus. Only one PCMMU is powered at a time. It interleaves the downlist data from the different GPCs with the instrumentation and payload data according to the telemetry format load programmed in the PCMMU. The resulting composite data set, called the operational downlink, is transmitted to one of two network signal processors (NSPs). Only one NSP is powered at a time. In the NSP, the operational downlink is combined with onboard recorded voice for transmission to the ground. The S-band and Ku-band communications systems transmit the data either to the space flight tracking and data network remote site ground stations or through the Tracking and Data Relay Satellite (TDRS) system to Mission Control.

Uplink is the method by which ground commands originating in Mission Control are formatted, generated, and transmitted to the orbiter for validation, processing, and eventual execution by onboard software. This capability allows ground systems to control data processing, change modes in orbiter hardware, and store or change software in GPC memory and mass memory.

From Mission Control consoles, flight controllers issue commands and request uplink. The command requests are formatted into a command load for transmission to the orbiter either by the STDN sites or by the TDRS system. The S-band or Ku-band transponder receivers aboard the orbiter send the commands to the active NSP. The NSP validates the commands and, when they are requested by the GPCs through a flight-critical MDM, sends them on to the GPC. The GPCs also validate the commands before executing them. Those GPCs listening directly to the flight-critical data buses then forward uplink commands for those GPCs not listening to the FC buses over the intercomputer communication data buses.

The PCMMU also contains a programmable readonly memory for accessing subsystem data, a random-access memory in which to store data, and a memory in which GPC data are stored for incorporation into the downlink.

To prevent the uplink of spurious commands from somewhere other than Mission Control, the flight crew can control when the GPCs accept uplink commands, and when uplink is blocked. The *GPC BLOCK* position of the *UPLINK* switch on panel C3 inhibits uplink commands during ascent and entry when the orbiter is not over a ground station or in TDRS coverage.



Intercomputer Communication Data Buses

There are five intercomputer communication (IC) data buses. The following information is exchanged over these buses for proper DPS operation: input/ output errors, fault messages, GPC status matrix data, display electronics unit major function switch settings, GPC/CRT keyboard entries, resident GPC memory configuration, memory configuration table,

operational sequences, master timing unit, time, internal GPC time, system-level display information, uplink data, and state vectors.

All GPCs processing PASS software exchange status information over the IC data buses. During launch, ascent, and entry, GPCs 1, 2, 3, and 4 are usually assigned to perform GNC tasks, operating as a redundant set, with GPC 5 as the backup flight system. Each of the PASS GPCs acts as a commander of a given IC data bus and initiates all data bus transactions on that data bus.

The four PASS GPCs are loaded with the same software. Interconnecting the four IC buses to the four PASS GPCs allows each GPC access to the status of data received or transmitted by the other GPCs so that identical results among the four PASS GPCs can be verified. Each IC bus is assigned to one of the four PASS GPCs in the command mode, and the remaining GPCs operate in the listen mode for the bus. Each GPC can receive data from the other three GPCs, pass data to the others, and perform any other tasks required to operate the redundant set.

Multiplexers/Demultiplexers (MDMs)

The MDMs convert and format (demultiplex) serial digital GPC commands into separate parallel discrete, digital, and analog commands for various vehicle hardware systems. The MDMs also convert and format (multiplex) the discrete, digital, and analog data from vehicle systems into serial digital data for transmission to the GPCs. Each MDM has two redundant multiplexer interface adapters (MIAs), each connected to a separate data bus. The MDM's other functional interface is its connection to the appropriate vehicle system hardware by hardwired lines.

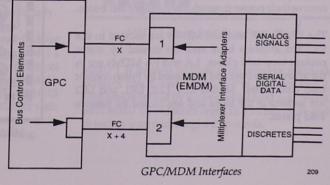
There are 20 MDMs aboard the orbiter; 13 are part of the DPS, connected directly to the GPCs and named and numbered according to their location in the vehicle and hardware interface. The remaining seven MDMs are part of the vehicle instrumentation system and send vehicle instrumentation data to the PCMMUs. (They are termed operational instrumentation (OI) MDMs.) The DPS MDMs consist of flight-critical forward (FF) MDMs 1 through 4, flight-critical aft (FA) MDMs 1 through 4, payload (PL) MDMs 1 and 2, and GSE/LPS launch forward (LF1), launch mid (LM1), and launch aft (LA1). One or two flex MDMs (FMDMs) may also be connected to the PL data buses, depending on the payload needs for a particular flight.

Of the seven operational instrumentation MDMs, four are located forward (OF1, OF2, OF3, and OF4), and three are located aft (OA1, OA2, and OA3).

Also recall, there are four SRB MDMs; i.e., SRB launch left (LL) MDMs 1 and 2 and launch right (LR) MDMs 1 and 2.

The system software in the redundant set GPC activates a GNC executive program and issues commands to authorized buses and MDMs to request a set of input data. Each MDM receives the command from the GPC assigned to command it, acquires the requested data from the GNC hardware wired to it, and sends the data to the GPCs.

Each FC data bus is connected to a flight forward and flight aft MDM. Each MDM has two MIAs, or ports, and each port has a channel through which the GPCs can communicate with an MDM; however, the GPCs can interface on the FC data buses with only one MIA port at a time. Port moding is the software method used to control the MIA port that is active in an MDM. Initially, these MDMs operate with port 1; if a failure occurs in port 1, the flight crew can select port 2. Since port moding involves a pair of buses, both MDMs must be port moded at the same time. The control of all other units connected to the affected data buses is unaffected by port moding. Port moding is a software-only process and does not involve any hardware changes.



Payload data bus 1 is connected to the primary MIA port of payload MDM 1, and payload data bus 2 is connected to the primary port of payload MDM 2. Payload data bus 1 is connected to the secondary MIA port of payload MDM 2, and payload data bus 2 is connected to the secondary port of payload MDM 1. Which bus is used to communicate with each MDM is controlled by port moding.

The two launch data buses are also connected to dual launch MDM multiplexer interface adapter ports. The flight crew cannot switch these ports; however, if an input/output error is detected on LF1 or LA1 during prelaunch, an automatic switchover occurs.

The hardware controls for the MDMs are the MDM PL1, PL2, PL3, FLT CRIT AFT, and FLT CRIT FWD power switches on panel O6. These ON/OFF switches provide or remove power for the four aft and four forward flight-critical MDMs and PL1 and PL2 MDMs. The PL3 switch is unwired and is not used. There are no flight crew controls for the SRB MDMs.

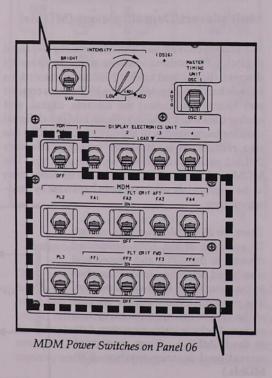
Each MDM is redundantly powered by two main buses. The power switches control bus power for activation of a remote power controller (RPC) for each main power bus to an MDM. The main buses power separate power supplies in the MDM. Loss of either the main bus or MDM power supply does not cause a loss of function because each power supply powers both channels in the MDM. Turning off power to an MDM resets all the discrete and analog command interfaces to subsystems.

The SRB MDMs receive power through SRB buses A and B; they are tied to the orbiter main buses and are controlled by the master events controller circuitry. The launch forward, mid, and aft MDMs receive their power through the preflight test buses.

The FF, PL, LF, and LM MDMs are located in the forward avionics bays and are cooled by water coolant loop cold plates. LA and FA MDMs are in the aft avionics bays and are cooled by Freon coolant loop cold plates. MDMs LL1, LL2, LR1, and LR2 are located in the SRBs and are cooled by passive cold plates. Module (or card) configuration in an MDM was dictated by the hardware components to be accessed by that type of MDM. A flight-critical forward and aft MDM are not interchangeable. However, flightcritical MDMs of the same type may be interchanged with another and the payload MDMs may be interchanged.

Each MDM is 13 by 11 by 7 inches and weighs about 38.5 pounds. MDMs use less than 80 watts of power.

Enhanced MDMs (EMDMs) were installed in OV 105. EMDMs will be installed in the other vehicles only as MDMs require replacement. The presence of EMDMs is transparent to the crew except in the case of an MDM OUTPUT message. With MDMs, the message means there is a problem with an MDM or a GPC. An MDM OUTPUT message with EMDMs means it is most likely a GPC problem. Crews flying with a combination of MDMs and EMDMs will receive assistance from flight controllers in interpreting an MDM OUTPUT message.



2. SYSTEMS 2.6 Data Processing System

Mass Memory Units

There are two mass memory units (MMUs) aboard the orbiter. Each is a coaxially mounted, reel-toreel read/write digital magnetic tape storage device for GPC software and orbiter systems data.

Computing functions for all mission phases requires approximately 600,000 half-words of computer memory. The orbiter GPCs are loaded with different memory configurations from the MMUs. In this way, software can be stored in MMUs and loaded into the GPCs when actually needed.

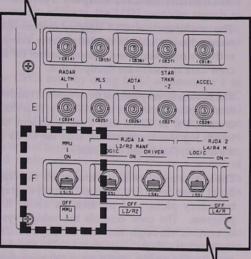
To fit the required software into the available GPC memory space, programs are subdivided into eight memory configurations corresponding to functions executed during specific flight and checkout phases. Thus, in addition to the central memory in the GPCs themselves, 34 million bytes of information can be stored in each of the two MMUs. Critical programs and data are loaded in both MMUs and protected from erasure.

The principal function of the MMU, besides storing the basic flight software, is to store background formats and code for certain CRT displays and the checkpoints that are written periodically to save selected data in case the systems management GPC fails.

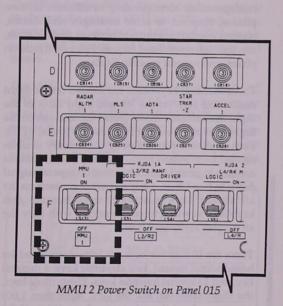
Operations are controlled by logic and the read and write electronics that activate the proper tape heads (read or write/erase) and validate the data.

Each MMU interfaces with its mass memory data bus through MIAs that function like the ones in the GPCs. Each mass memory data bus is connected to all five computers; however, each MMU is connected to only one mass memory data bus. All MMU operations are on an on-demand basis only.

The power switches are located on panel O14 for MMU 1 and panel O15 for MMU 2. The MMU 1 switch on panel O14 positioned to ON allows control bus power to activate an RPC, which allows MNA power to MMU 1. The MMU 2 switch on panel O15 positioned to ON operates in a similar manner with MNB power. An MMU uses 20 watts of power in standby and 70 watts when the tape is moving.



MMU 1 Power Switch on Panel 014



MMU 1 is located in crew compartment middeck avionics bay 1, and MMU 2 is in avionics bay 2. Each unit is cooled by water coolant loop cold plates. Each MMU is 7.6 inches high, 11.6 inches wide and 15 inches long and weighs 25 pounds.

Multifunction CRT Display System

The multifunction CRT display system allows onboard monitoring of orbiter systems, computer software processing, and manual control for flight crew data and software manipulation.

The system is composed of three types of hardware: four display electronics units (DEUs), four display units (DUs) or CRTs, and three keyboard units, which together communicate with the GPCs over the display/keyboard data buses.

The system provides almost immediate response to flight crew inquiries through displays, graphs, trajectory plots, and predictions about flight progress. The crew controls the vehicle system operation through the use of keyboards in conjunction with the display units. The flight crew can alter the system configuration, change data or instructions in GPC main memory, change memory configurations corresponding to different mission phases, respond to error messages and alarms, request special programs to perform specific tasks, run through operational sequences for each mission phase, and request specific displays.

Three identical keyboards are located on the flight deck: one each on the left and right sides of the flight deck center console (panel C2) and one on the flight deck at the side aft flight station (panel R11L). Each keyboard consists of 32 momentary double-contact push button keys. Each key uses its double contacts to permit communication on separate signal paths to two DEUs. Only one set of contacts on the aft station keys is actually used because this keyboard is wired to communicate with only the aft display electronics unit.

There are 10 number keys, six letter keys (used for hexadecimal inputs), two algebraic keys, a decimal key, and 13 special function keys. Using these keys, the flight crew can ask the GPC more than 1,000 questions about the mission and condition of the vehicle. (Keyboard operations are discussed in detail later in this section.)

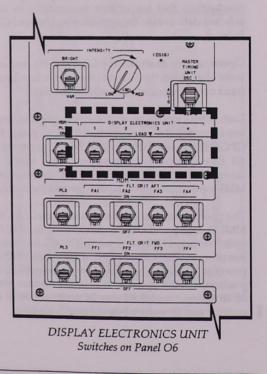
Each of the four DEUs responds to computer commands, transmits data, executes its own software to process keyboard inputs, and sends signals to drive displays on the CRTs (or display units). The units store display data, generate the GPC/keyboard unit and GPC/display unit interface displays, update and refresh on-screen data, check keyboard entry errors, and echo keyboard entries to the CRT.

There are three CRTs on flight deck forward display and control panel F7 and one at the side aft flight deck station on panel R11L. Each CRT is 5 by 7 inches.

The display unit uses a magnetic-deflected, electrostatic-focused CRT. When supplied with deflection signals and video input, the CRT displays alphanumeric characters, graphic symbols, and vectors on a green monochrome phosphorous screen activated by a magnetically controlled beam. Each CRT has a brightness control for ambient light and flight crew adjustment.

The DEUs are connected to the display/keyboard data buses by MIAs that function like those of the GPCs. Inputs to the DEU are from a keyboard or a GPC.

Positioning the DISPLAY ELECTRONICS UNIT 1, 2, 3, 4 switches on panel O6 to LOAD initiates a GPC request for a copy of DEU software stored in



mass memory before operations begin. If the GPC software in control of the CRT is designed to support a DEU load (or IPL) request, then information is sent from the mass memory to the GPC and then loaded from the GPC into the DEU memory.

It is possible to do in-flight maintenance and exchange CRT 4 with CRT 1 or 2. CRT 3 cannot be changed out because of interface problems with the orbiter jettison T-handle. Also, either individual keys or the entire forward keyboard can be replaced by the aft keyboard. The DEUs are located behind panels on the flight deck. DEUs 1 and 3 are on the left, and DEUs 2 and 4 are on the right. DEU 4 can replace any of the others; however, if DEU 2 is to be replaced, only the cables are changed because 2 and 4 are next to each other.

The display electronics units and display units are cooled by the cabin fan system. The keyboard units are cooled by passive heat dissipation.

Master Timing Unit

The GPC complex requires a stable, accurate time source because its software uses Greenwich mean time (GMT) to schedule processing. Each GPC uses the master timing unit (MTU) to update its internal clock. The MTU provides precise frequency outputs for various timing and synchronization purposes to the GPC complex and many other orbiter subsystems. Its three time accumulators provide GMT and mission elapsed time (MET), which can be updated by external control. The accumulator's timing is in days, hours, minutes, seconds, and milliseconds up to 1 year.

The MTU is a stable, crystal-controlled frequency source that uses two oscillators for redundancy. The signals from one of the two oscillators are passed through signal shapers and frequency drivers to the three GMT/MET accumulators.

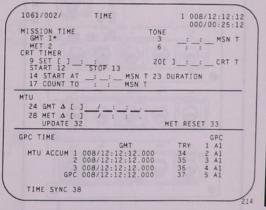
The MTU outputs serial digital time data (GMT/ MET) on demand to the GPCs through the accumulators. The GPCs use this information for reference time and indirectly for time-tagging GNC and systems management processing. The MTU also provides continuous digital timing outputs to drive the four digital timers in the crew compartment: two mission timers and two event timers. In addition, the MTU provides signals to the PCMMUs, COMSECs, payload signal processor, and FM signal processor, as well as various payloads.

The GPCs start by using MTU accumulator 1 as their time source. Once each second, each GPC checks the accumulator time against its own internal time. If the time is within tolerance (less than one millisecond), the GPC updates its internal clock to the time of the accumulator, which is more accurate, and continues. However, if the time is out of tolerance, the GPC will try the other accumulators and then the lowest numbered GPC until it finds a successful comparison.

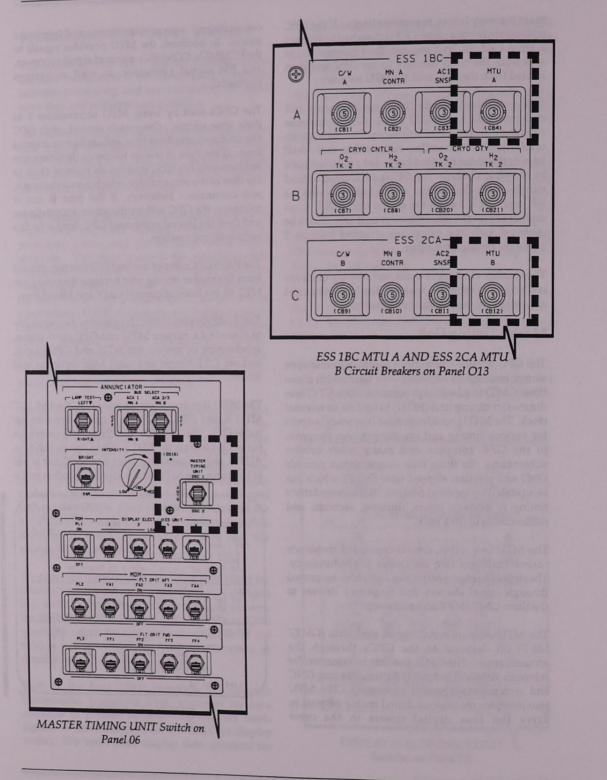
The PASS GPCs do not use the MET that they receive from the master timing unit because they compute MET on the basis of current GMT and lift-off time.

The TIME display (SPEC 2) provides the capability to observe the current MTU and GPC clock status, synchronize or update the MTU and GPC clocks, and set CRT timers and alert tone duration and timers.

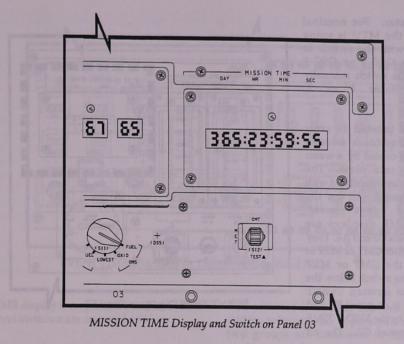
The MTU is redundantly powered by the ESS 1BC MTU A and ESS 2CA MTU B circuit breakers on panel O13. The MASTER TIMING UNIT switch on panel O6 controls the MTU. When the switch is in AUTO, and a time signal from one oscillator is out of tolerance, the MTU automatically switches to the



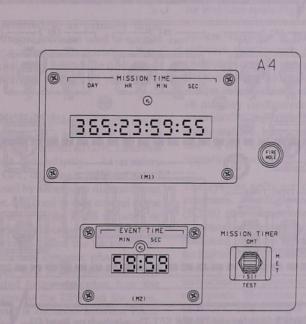
TIME Display (SPEC 2)



2. SYSTEMS 2.6 Data Processing System



Soffware

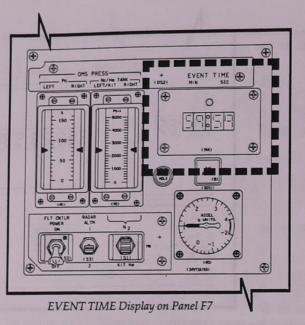


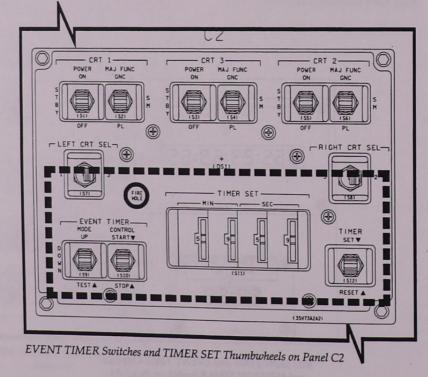
MISSION TIME and EVENT TIME Displays and MISSION TIMER Switch on Panel A4

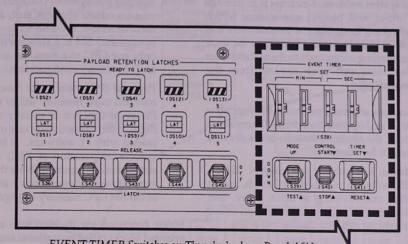
2.6-17

other oscillator. For nominal operations, the MTU is using oscillator 2 with the switch in *AUTO*. The OSC 1 or OSC 2 position of the switch manually selects oscillator 1 or 2, respectively.

The MTU is located in crew compartment middeck avionics bay 3B and is cooled by a water coolant loop cold plate. The hardware displays associated with the master timing unit are the mission and event timers. MISSION TIME displays are located on panels O3 and A4. They can display either GMT or MET in response to the GMT or MET positions of the switch below the displays. The forward EVENT TIME display is on panel F7, and it is controlled by the EVENT TIME switches on panel C2. The aft







EVENT TIMER Switches on Thumbwheels on Panel A6U

EVENT TIME display is on panel A4, and its EVENT TIME control switches are on panel A6U.

Software

Primary Avionics Software System (PASS)

The PASS (also referred to as primary flight software) is the principal software used to operate the vehicle during a mission. It contains all the programming needed to fly the vehicle through all phases of the mission and manage all vehicle and payload systems.

Since the ascent and entry phases of flight are so critical, four of the five GPCs are loaded with the same PASS software and perform all GNC functions simultaneously and redundantly. As a safety measure, the fifth GPC contains a different set of software, programmed by a company different from the PASS developer, designed to take control of the vehicle if a generic error in the PASS software or other multiple errors should cause a loss of vehicle control. This software is called the backup flight system (BFS). In the less dynamic phases of onorbit operations, the BFS is not required. The information provided below describes how the PASS software relates to the DPS and the crew. Much of the material is common between PASS and BFS; therefore, only BFS differences are discussed immediately after the PASS discussion.

DPS software is divided into two major groups, system software and applications software. The two groups are combined to form a memory configuration for a specific mission phase. The programs are written in HAL/S (high-order assembly language/shuttle) specifically developed for real-time space flight applications.

System software is the GPC operating system software that controls the interfaces among the computers and the rest of the DPS. It is loaded into the computer when it is first initialized. It always resides in the GPC main memory and is common to all memory configurations. The system software controls GPC input and output, loads new memory configurations, keeps time, monitors discretes into the GPCs, and performs many other DPS operational functions.

The system software consists of three sets of programs. The flight computer operating system (FCOS) (the executive) controls the processors, monitors key system parameters, allocates computer resources, provides for orderly program interrupts for higher priority activities, and updates computer memory. The user interface programs provide instructions for processing flight crew commands or requests. The system control program initializes each GPC and arranges for multi-GPC operation during flight-critical phases.

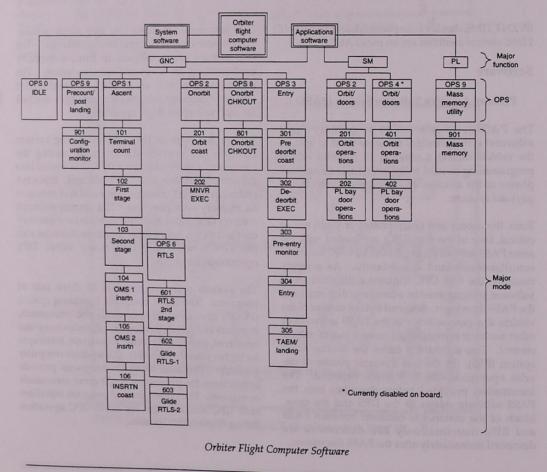
One of the system software functions is to manage the GPC input and output operations, which includes assigning computers as commanders and listeners on the data buses and exercising the logic involved in sending commands to these data buses at specified rates and upon request from the applications software.

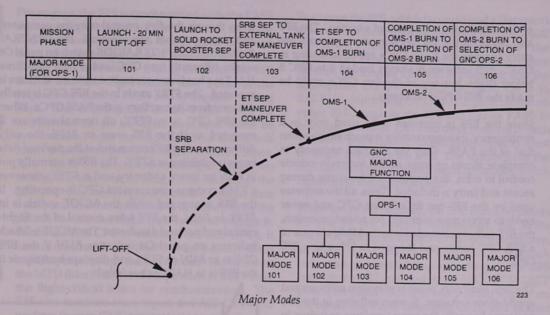
The applications software performs the functions required to fly and operate the vehicle. To conserve main memory, the applications software is divided into three major functions:

 Guidance, navigation, and control (GNC): specific software required for launch, ascent to orbit, maneuvering in orbit, entry, and landing. This is the only major function where redundant set synchronization can occur.

- Systems management (SM): tasks that monitor various orbiter systems, such as life support, thermal control, communications, and payload operations. SM is a simplex major function; only one GPC at a time can actively process an SM memory configuration.
- Payload (PL): this major function currently contains mass memory utility software. The PL major function is usually unsupported in flight, which means that none of the GPCs are loaded with PL software. It is only used in vehicle preparation at KSC, and is also a simplex major function. Note that software to support payload operations is included as part of the SM GPC memory configuration.

Major functions are divided into mission phase oriented blocks called operational sequences (OPS). Each OPS of a major function is associated with a





particular memory configuration that must be loaded separately into a GPC from the MMUs. Therefore, all the software residing in a GPC at any given time consists of system software and an OPS major function; i.e., one memory configuration. Except for memory configuration 1, each memory configuration contains one OPS. Memory configuration 1 is loaded for GNC at launch and contains both OPS 1 (ascent) and OPS 6 (RTLS), since there would be no time to load in new software for an return to launch site (RTLS) abort.

During the transition from one OPS to another, called an OPS transition, the flight crew requests a new set of applications software to be loaded in from the MMU. Every OPS transition is initiated by the flight crew. When an OPS transition is requested, the redundant OPS overlay contains all major modes of that sequence.

Major modes are further subdivisions of an OPS, which relate to specific portions of a mission phase. As part of one memory configuration, all major modes of a particular OPS are resident in GPC main memory at the same time. The transition from one major mode to another can be automatic (e.g., in GNC OPS 1 from precount MM 101 to first stage MM 102 at lift-off) or manual (e.g., in SM OPS 2 from on-orbit MM 201 to payload bay door MM 202 and back).

Each major mode has an associated CRT display, called a major mode display or OPS display, that provides the flight crew with information concerning the current portion of the mission phase and allows flight crew interaction. There are three levels of CRT displays. Certain portions of each OPS display can be manipulated by flight crew keyboard input (or ground link) to view and modify system parameters and enter data. The specialist function (SPEC) of the OPS software is a block of displays associated with one or more operational sequences and enabled by the flight crew to monitor and modify system parameters through keyboard entries. The display function (DISP) of the OPS software is a group of displays associated with one or more OPS. These displays are for parameter monitoring only (no modification capability) and are called from the keyboard. Display hierarchy and usage are described in detail later in this section.

Backup Flight System

Even though the four PASS GPCs control all GNC functions during the critical phases of the mission, there is always a possibility that a generic software failure could cause loss of vehicle control. Therefore, the fifth GPC is loaded with the BFS software. To take over control of the vehicle, the BFS monitors the PASS GPCs to keep track of the current state of the vehicle. If required, the BFS can take over control

of the vehicle upon the press of a button. The BFS also performs the SM functions during ascent and entry because the PASS GPCs are all operating in GNC. BFS software is always loaded into GPC 5 before flight, but any of the five GPCs could be made the BFS GPC if necessary.

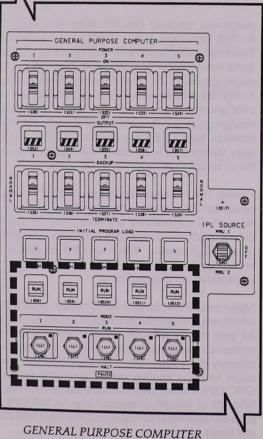
Since the BFS is intended to be used only in a contingency, its programming is much simpler than that of the PASS. Only the software necessary to complete ascent or entry safely, maintain vehicle control in orbit, and perform SM functions during ascent and entry is included. Thus, all the software used by the BFS can fit into one GPC and never needs to access mass memory. For added protection, the BFS software is loaded into the MMUs in case of a BFS GPC failure and the need to IPL a new BFS GPC.

The BFS, like PASS, consists of system software and applications software. System software in the BFS performs basically the same functions as it does in PASS. These functions include time management, PASS/BFS interface, multifunction CRT display system, input and output, uplink and downlink, and engage and disengage control. The system software is always operating when the BFS GPC is not in *HALT*.

Applications software in the BFS has two different major functions, GNC and systems management, but all its applications software resides in main memory at one time, and the BFS can process software in both major functions simultaneously. The GNC functions of the BFS, designed as a backup capability, support the ascent phase beginning at MM 101 and the deorbit/entry phase beginning at MM 301. In addition, the various ascent abort modes are supported by the BFS. The BFS provides only limited support for on-orbit operations via MM 106 or MM 301. Because the BFS is designed to monitor everything the PASS does during ascent and entry, it has the same major modes as the PASS in OPS 1, 3, and 6.

The BFS SM contains software to support the ascent and entry phases of the mission. Whenever the BFS GPC is in the *RUN* or *STBY* mode, it runs continuously; however, the BFS does not control the payload buses in *STBY*. The SM major function in the BFS is not associated with any operational sequence and is always available whenever the BFS is active.

Even though the five general-purpose computers and their switches are identical, the GENERAL PURPOSE COMPUTER MODE switch on panel O6 works differently for a GPC loaded with BFS. Since HALT is a hardware-controlled state, no software is executed. The STBY mode in the BFS GPC is totally different from its corollary in the PASS GPCs. When the BFS GPC is in STBY, all normal software is executed as if the BFS were in RUN; the only difference is that BFS command of the pavload data buses is inhibited in STBY. The BFS is normally put in RUN for ascent and entry, and in STBY whenever a PASS systems management GPC is operating. If the BFS is engaged while the MODE switch is in STBY or RUN, the BFS takes control of the flightcritical and payload data buses. The MODE talkback indicator on panel O6 indicates RUN if the BFS GPC is in RUN or STBY and displays barberpole if the BFS is in HALT or has failed.



GENERAL PURPOSE COMPUTER MODE Switches and Talkbacks on Panel O6

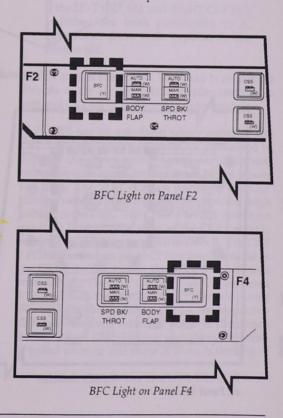
Pre-engage, the BFS is synchronized with the PASS set using flight-critical I/O so that it can track the PASS and keep up with its flow of commands and data. Synchronization and tracking take place during OPS 1, 3, and 6. During this time, the BFS listens over the flight-critical data buses to the requests for data by PASS and to the data coming back. The BFS depends on the PASS GPCs for acquisition of all its GNC data and must be synchronized with the PASS GPCs so that it will know when to receive GNC data over the FC buses. When the BFS is in sync and listening to at least two strings, it is said to be tracking PASS. As long as the BFS is in this mode, it maintains the current state vector and all other information necessary to fly the vehicle in case the flight crew needs to engage it. When the BFS GPC is tracking the PASS GPCs, it cannot command over the FC buses but may listen to FC inputs through the listen mode. The BFS uses the MTU (like PASS) and keeps track of GMT over the flight-critical buses for synchronization. The BFS also monitors some inputs to PASS CRTs and updates its own GNC parameters accordingly.

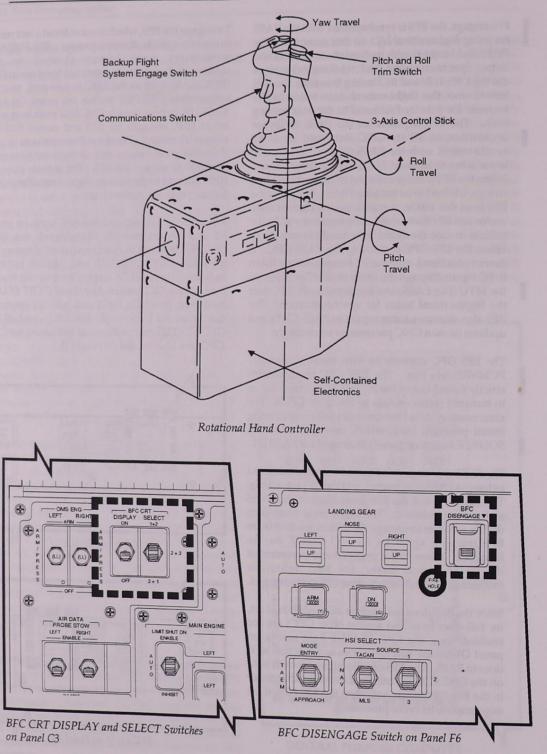
The BFS GPC controls its own instrumentation/ PCMMU data bus. The BFS GPC requirements strictly forbid use of the IC data bus to monitor or to transmit status or data to the other GPCs. The mass memory data buses are not used except during initial program load, which uses the same *IPL SOURCE* switch on panel O6 as used for PASS IPL.

The *BFC* lights on panels F2 and F4 remain unlighted as long as PASS is in control, and the BFS is tracking. The lights flash if the BFS loses track of the PASS and goes standalone. The flight crew must then decide whether to engage the BFS or try to initiate BFS tracking again by an I/O RESET on the keyboard. When BFS is engaged and in control of the flight-critical buses, the *BFC* lights are illuminated and stay on until the BFS is disengaged.

Since the BFS does not operate in a redundant set, its fail votes from and against other GPCs are not enabled; thus, the *GPC STATUS* light matrix on panel O1 for the BFS GPC does not function as it does in PASS. The BFS can illuminate its own light on the *GPC STATUS* matrix if the watchdog timer in the BFS GPC times out when the BFS GPC does not complete its cyclic processing. To engage the BFS, which is considered a last resort to save the vehicle, the crew presses a *BFS ENGAGE* momentary push button located on the commander's and pilot's rotational hand controllers (RHCs). As long as the RHC is powered, and the appropriate *OUTPUT* switch on panel O6 is in *BACKUP*, depressing the *ENGAGE* push button on either RHC engages the BFS and causes PASS to relinquish control. There are three contacts in each *ENGAGE* push button, and all three contacts must be made to engage the BFS. The signals from the RHC are sent to the backup flight controller, which handles the engagement logic.

When the BFS is engaged, the *BFC* lights on panels F2 and F4 are steadily illuminated, the BFS's *OUTPUT* talkback indicator on panel O6 turns gray, all PASS GPC *OUTPUT* and *MODE* talkback indicators on panel O6 display barberpole, the BFS controls the CRTs selected by the *BFC CRT SELECT* switch on panel C3, big X and poll fail appear on the remaining PASS-controlled CRTs, and all four *GPC STATUS* matrix diagonal indicators for PASS GPCs are illuminated on panel O1.





When the BFS is not engaged, and the *BFC CRT DISPLAY* switch on panel C3 is positioned to *ON*, the BFS commands the first CRT indicated by the *BFC CRT SELECT* switch. The *BFC CRT SELECT* switch positions on panel C3 are 1 + 2, 2 + 3, and 3+1. When the BFS is engaged, it assumes control of the second CRT as well.

If the BFS is engaged during ascent, the PASS GPCs can be recovered on orbit to continue a normal mission. This procedure takes about 2 hours, since the PASS inertial measurement unit reference must be reestablished. The BFS is disengaged after all PASS GPCs have been hardware-dumped and reloaded with PASS software. Positioning the *BFC DISENGAGE* switch on panel F6 to the *UP* position disengages the BFS. The switch sends a signal to the BFCs that resets the engage discretes to the GPCs. The BFS then releases control of the flight-critical buses as well as the payload buses if it is in *STBY*, and the PASS GPCs assume command.

After disengagement, the PASS and BFS GPCs return to their normal pre-engaged states. Indications of the PASS engagement and BFS disengagement are as follows: *BFC* lights on panels F2 and F4 are out, BFS's *OUTPUT* talkback on panel O6 displays barberpole, all PASS *OUTPUT* talkback indicators on panel O6 are gray, and BFS releases control of one of the CRTs.

If the BFS is engaged, there is no manual thrust vector control or manual throttling capability during first- and second-stage ascent. If the BFS is engaged during entry, the speed brake can be positioned using the speed brake/throttle controller, and the body flap can be positioned manually. Control stick steering (CSS) by either the commander or pilot is required during entry.

Pre-engage, the BFS supplies attitude errors on the CRT trajectory display, whereas PASS supplies attitude errors to the attitude director indicators; however, when the BFS is engaged, the errors on the CRT are blanked, and attitude errors are supplied to the attitude director indicators.

Operations

The crew interfaces with the five GPCs via four CRTs and various dedicated display instruments. This section first discusses crew operations using PASS, and then discusses crew operations using the BFS.

CRT Switches

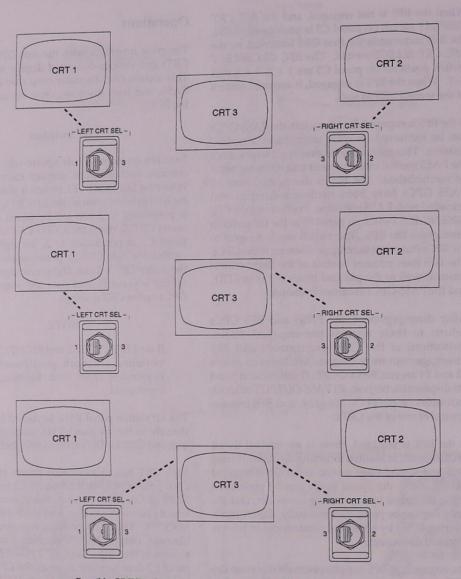
Switches on panel C2 designate which keyboard controls each forward display electronics unit. When the *LEFT CRT SEL* switch is positioned to 1, the left keyboard controls the left CRT 1; if the switch is positioned to 3, the left keyboard controls the center CRT 3. When the *RIGHT CRT SEL* switch on panel C2 is positioned to 2, the right keyboard controls the right CRT 2; if positioned to 3, it controls the center CRT 3. Thus, flight crew inputs are made on the keyboards, and data are output from the GPCs on the CRT displays.

NOTE

If the *LEFT CRT SEL* and *RIGHT CRT SEL* switches are both positioned to 3, keystrokes from both keyboards are interleaved.

The aft station panel R11L keyboard is connected directly to the aft panel R11L display electronics unit and CRT (or DU); there is no select switch.

Each CRT has an associated power switch. The CRT 1 POWER switch on panel C2 positioned to STBY or ON allows control bus power to activate remote power controllers and sends MN A power to CRT 1. The STBY position warms up the CRT filament, only. The ON position provides high voltage to the CRT. The CRT 2 POWER switch on panel C2 functions the same as the CRT 1 switch, except that CRT 2 is powered from MN B. The CRT 3 POWER switch on panel C2 functions the same as the CRT 1 switch, except that CRT 3 is powered from MN C. The CRT 4 POWER switch on panel R11L functions the same as the CRT1 switch, except that CRT 4 is powered from MN C. The respective keyboards receive 5 volts of ac power to illuminate the keys. Each DEU/DU pair uses about 290 watts of power when on and about 20 watts in standby.



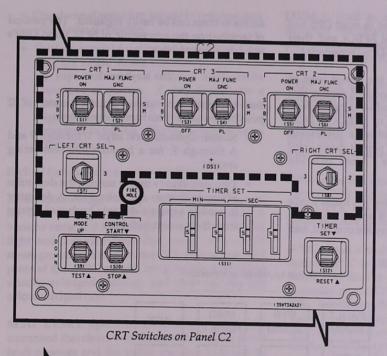
Possible CRT/Keyboard Assignments in the Forward Flight Station

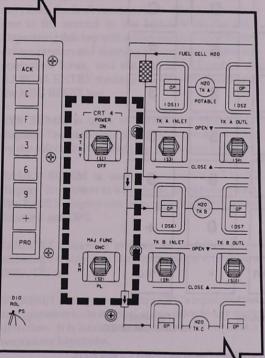
NOTE

Crewmembers should always check that keyboard information is accepted on the proper CRT prior to executing the item.

Each CRT has an associated *MAJ FUNC* switch. The *CRT 1, 3, 2, MAJ FUNC* switches on panel C2 tell the GPCs which of the different functional software groups is being processed by the keyboard units

and what information is presented on the CRT. The CRT 4 MAJ FUNC switch on panel R11L functions in the same manner. This three-position toggle switch allows the crew access to the GNC, SM, or PL software on a desired CRT. The GPC loaded with the desired major function applications software will then drive this CRT. Each major function accesses an independent set of display data and functional software.





CRT 4 POWER and MAJ FUNC Switches on Panel R11L

Display Hierarchy

CRT display organization consists of three levels of crew software displays within any given major function. The display types parallel the different types of modules used in the GPC software. The established display hierarchy within applications software is operational sequences (OPS), specialist functions (SPEC), and display (DISP) functions. Each has a type of CRT page associated with it.

The OPS is the highest level of crew software control within a major function. Each memory configuration contains one or more OPS. Each OPS allows the crew to accomplish an associated mission phase task. Several operational sequences are

defined, each covering some portion of the mission. For example, OPS 1 contains ascent software, OPS 2 contains on-orbit software, and OPS 3 contains entry software.

Each operational sequence is further divided into major modes. Each major mode has an associated display that allows direct crew interface with the software. These are OPS pages, and are also referred to as major mode pages.

Specialist functions (SPECs) are second in the hierarchy. A SPEC allows crew execution of other activities in conjunction with a particular OPS. SPEC displays, like major mode displays, allow direct crew interface with the software. Each SPEC has an associated display that will overlay the major mode display when called. When a SPEC is called, its display rolls in on top of the major mode display, which is still active underneath. The SPEC provides access to an associated portion of the software located in the GPC. Some SPECs are contained in systems software, whereas others are resident in the applications load. A SPEC can be associated with a major function or an OPS, but the systems software SPECs can be obtained in most OPS and major functions. (The list of SPECs and their availability can be found in the DPS Dictionary.)

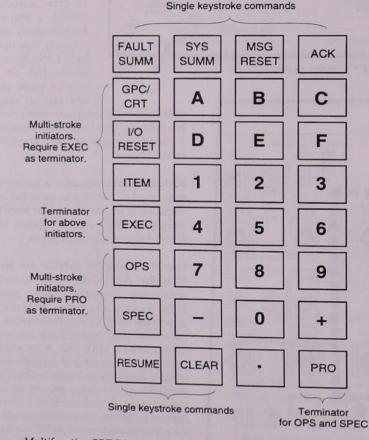
Display functions (DISPs) are the lowest level of software. Each DISP has an associated display that presents the status of a predefined set of parameters. Unlike major mode displays or SPECs, a DISP cannot initiate a change in software processing because DISP displays do not permit direct crew interface with the software. They provide information only.

When called, a DISP will overlay the major mode display and the SPEC, if one is active. Both the SPEC and the major mode display are overlaid, and access to them can be easily regained. The method of terminating the processing of SPECs and DISPs will be discussed later.

The Keyboard

Each keyboard is composed of a 4 x 8 matrix of 32 push button keys. This matrix consists of:

- Sixteen alphanumeric keys: 0 through 9 and A through F, for a hexadecimal numbering system
- Two sign keys (+ and -) serving the dual roles of sign indicators and delimiters. A delimiter is used to separate discrete keyboard entries from their associated data.



Multifunction CRT Display System Keyboard Unit Found on Panels C2 and R11L

- One decimal point key for use in entering data with decimal notation
- Thirteen special function keys: some of these keys are single stroke commands, and some are keys that start or finish a multi-stroke command sequence. A key that starts a command sequence is a command initiator and requires a command terminator key to be depressed to tell the DEU the keyboard entry is complete.

Each of these keys is discussed below.

ACK acknowledges receipt of a fault message on the fault message line by causing the message to become static and by extinguishing the *SM ALERT* light and software-controlled tones. If multiple messages are indicated on the CRT, each subsequent press of the ACK key will bring up the next oldest unacknowledged message and clear out the last acknowledged one.

MSG RESET operates as a single keystroke command that clears both the currently annunciated fault message and the buffer message indicator (if any) from the fault message line. The fault message line is the second to the last line on the CRT. Depressing this key will also extinguish all softwaredriven caution and warning annunciators, softwarecontrolled tones, and the *SM ALERT* light. An ILLEGAL ENTRY message can only be cleared with the MSG RESET key.

SYS SUMM is used to invoke the SYS SUMM display. The particular display called is determined by the selected major function and active OPS.

FAULT SUMM is used to invoke the FAULT display. It operates as a single keystroke command. The FAULT display can be accessed in every major function and OPS.

GPC/CRT initiates a multistroke keyboard entry, allowing the selection of a particular GPC to drive a DEU/DU set.

I/O RESET attempts to restore a GPC's input/output configuration to its original status prior to any error detection. It is a command initiator and requires a terminator keystroke.

ITEM is used as a multi-keystroke command initiator for changing the value of defined parameters or implementing configuration changes on a given display (OPS or SPEC).

EXEC acts as a multi-keystroke terminator to command the execution of the action specified on the scratch pad line. It is the terminator for the initiators above it (GPC/CRT, I/O RESET, and ITEM keys). EXEC may also be a single keystroke command to enable an OMS burn.

OPS serves as a multi-keystroke initiator to load a desired OPS load from mass memory into one or more GPCs. It is also used to transition from major mode to major mode within an OPS.

SPEC acts as a multi-keystroke initiator to select a defined SPEC or DISP display within a given OPS. In addition, this key provides the capability to freeze a display on the CRT. A single depression of the SPEC key freezes the display so it may be statically viewed. The display will remain frozen until another key (other than ACK, MSG RESET, or another SPEC) is entered.

PRO (Proceed) serves as a terminator to the OPS and SPEC keys. The completed command sequence initiates the selection of a desired OPS, SPEC, or DISP display.

RESUME is used to terminate a displayed SPEC or DISP. CRT control is restored to the underlying display upon depression of this key.

CLEAR clears the last echoed keystroke from the bottom line (scratch pad line) of the CRT. For each depression, one additional keystroke is removed, proceeding from right to left. After a command sequence is completed, a single depression of the CLEAR key will erase the static command from the scratch pad line.

Display Selection Procedures

The crew can select a variety of CRT displays. Some of the different ways to select an OPS display and its available SPEC and DISP displays are as follows:

 Selection of the major function is done by placing the *MAJ FUNC* switch (on panel C2) associated with the CRT in use in the *GNC*, *SM*, or *PL* position.

- An OPS is loaded from the MMU via a threestep keyboard entry. A new OPS is called from mass memory by its first major mode. The OPS is loaded into the GPC that is currently driving the DEU/DU on which the keyboard entry is done. Once the OPS is loaded, access is provided to major modes in that OPS. Major mode displays are advanced by the same keyboard command. The steps for selecting an OPS display are as follows:
 - 1. Depress the OPS key.
 - Key in the three numbers of the desired OPS. The first digit defines the OPS and the next two digits specify the major mode.
 - Depress the PRO key. Once the OPS is loaded into one or more GPCs, that software can be accessed at any time through any CRT in the proper major function.

Selection of a major mode does not involve a mass memory access. Advancing major modes is done by the same keyboard command as loading an OPS. The first digit will be the same as the OPS number, but the last two digits specify the major mode. For example, to go to GNC MM 202, enter OPS 2 0 2 PRO.

Within each OPS, certain SPEC and DISP displays are available. The steps for selecting a SPEC or a DISP are as follows:

- 1. Depress the SPEC key. The SPEC key is used in calling both SPEC and DISP displays.
- 2. Key in the SPEC or DISP number omitting all leading zeros. SPEC and DISP numbers have three digits. They are differentiated by their numbering scheme. The display is a DISP only if the first digit is a 9, or if the last digit is a 6 through 9. To illustrate the method for keying in SPEC and DISP numbers, DISP number 106 would be keyed in as "106"; SPEC number 034 would be keyed "34"; DISP number 066 would be keyed "66"; and SPEC number 001 would be keyed "1."
- 3. Depress the PRO key.

OPS and Major Mode Transitions

Transitions from major mode to major mode or to another OPS are accomplished by either automatic transitions or proper command entry.

- Automatic transitions: Some major mode transitions occur automatically, usually as a function of some mission event. Examples of automatic transitions are between major modes 101 and 102 (SRB ignition) and between major modes 102 and 103 (SRB separation). Selection of an RTLS abort also results in an automatic OPS transition.
- Command entry: Proper command entry (OPS XXX PRO) is almost always used to transition from one OPS to another. In most cases, it is also a legal transition operation for proceeding from one major mode to the next (e.g.; 301 to 302).

Display Sequencing, Overlaying, and Retention

Certain rules have been established for proceeding from one display to another. These can be categorized into treatment of proper display sequencing, the overlaying of current displays by new displays, and the display retention hierarchy.

SPEC and DISP Displays

The hierarchy of overlaying SPECs and DISPs makes sense if one remembers that a SPEC allows crew interaction and control of specialized operations, whereas a DISP provides display information only. Both SPECs and DISPs overlay the current major mode display when called.

A SPEC need not be previously selected in order to call a DISP. If a DISP is on the CRT, and another SPEC or DISP is called, the current DISP is terminated. The terminated DISP can only be viewed again by entering its calling command once more.

If a SPEC is selected, and a DISP is called to overlay it, the SPEC is retained underneath the DISP. If another SPEC is then selected, the underlying SPEC as well as the DISP over it is terminated. The terminated SPEC can only be viewed again if it is recalled.

The RESUME key is used as a single keystroke entry to terminate the SPEC or DISP currently being displayed and to restore the underlying display. If the display being terminated is a DISP, CRT control will be restored to the underlying SPEC, or to the OPS display if no SPEC has been selected. If a SPEC display is terminated, CRT control is restored to the major mode display. It is advisable to press RESUME after viewing any SPEC or DISP to avoid confusion and to decrease the possibility of attempting to retain more SPEC displays than the software allows. Also, certain ground command functions may not be possible when corresponding SPECs are active or underlying a DISP. The RESUME key cannot be used to transition from one major mode display to another or to page backwards through major mode displays.

Display Retention Hierarchy

- Major mode transitions: Both SPECs and DISPs are retained during a major mode transition. If a SPEC or DISP is overlaying the major mode display, the new major mode display can't be seen until the overlaying displays are terminated with the RESUME key.
- Major function change: OPS and SPEC displays on the CRT screen are retained within their major function when major function positions are switched. When the crew returns to the first major function, the SPEC last viewed will appear on the screen. Depression of the RESUME key will restore the underlying OPS. If no SPEC had been selected, return to a major function would restore the last major mode display. DISP displays are not retained at major function switch transitions.
- OPS transition: SPECs, DISPs, and major mode displays are not retained through an OPS transition, since this involves loading an entirely new module of applications software in the GPC. The SPECs may be called again if they are available in the new OPS.

Standard Display Characteristics

Standard Display Features

Two discrete brightness intensities for displayed characters are designated "bright" and "overbright." The bulk of all material is displayed in the "bright" intensity. Special messages and special characters, such as parameter status indicators, are displayed in "overbright" to direct the crew's attention during their display scan.

Certain words and messages are designed to flash on and off. Fault messages will flash, indicating a message that needs to be acknowledged. Command initiators are designed to flash until the command is completed, and an incorrect keyboard entry will result in a flashing "ERR" to the right of the erroneous entry.

Formatting Similarities

OPS number: The four-digit field in the upper left corner of the first line designates the number of the OPS display being processed. The first digit represents the OPS; the next two digits indicate the major mode. The last digit is always a "1," and it is not used when making keyboard entries.

SPEC number: Directly to the right of the OPS number is a three-digit field. This field displays the number of the SPEC overlaying the OPS. This field is blank if no SPEC is selected.

DISP number: The last field in the upper left corner represents the DISP number. It is a three-digit field. This field is blank if no DISP is currently being displayed.

Display title: Centered on the top line of the display is the title of the display. Portions of some titles are dynamic and will specify the mission phase.

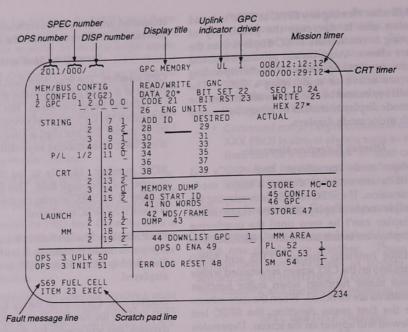
Uplink indicator: Directly to the right of the display title is a two-space field. When an uplink to the GPC is in progress, a flashing "UL" will be displayed. Otherwise this field is blank.

GPC driver: To the right of the uplink indicator is a one-digit field. A number in this field indicates the particular GPC (1, 2, 3, 4, or 5) that is commanding the CRT.

GMT/MET clock: This field displays time in days, hours, minutes, and seconds (DDD/HH:MM:SS). The field is updated every second. The time displayed may be either GMT or MET selectable via a keyboard entry to the SPEC 2 TIME display.

CRT timer: Directly below the GMT/MET clock is a CRT timer field also displayed in days, hours, minutes, and seconds (DDD/HH:MM:SS). This field is also updated every second, and can be set via a keyboard entry to the TIME SPEC display.

Fault message line: The second line from the bottom is reserved for fault messages. Illegal keyboard entry messages and systems fault messages are displayed on this line. In the case of system faults, a number in parentheses to the far right on this line indicates the number of fault messages that have



Formatting Conventions Common to All Displays

not been viewed and acknowledged (further discussion of fault messages is covered in a later section).

Scratch pad line: The bottom line of the display echoes keyboard entries made by the crew. Command initiators (OPS, SPEC, ITEM, GPC/CRT, and I/O RESET) will flash on the scratch pad line until the command is terminated. The keystrokes remain on the scratch pad line in a static mode until (a) a new command is initiated, (b) the CLEAR key is depressed, or (c) the MAJOR FUNC switch position is changed. Keyboard syntax errors detected by the DEU will result in a flashing "ERR" on the scratch pad line following the keyboard entry.

Specially Defined Symbols

These symbols include an asterisk and a set of parameter status indicators. Parameter status indicators are displayed in "overbright" intensity for quick recognition. These special symbols are defined as follows:

M: This symbol indicates missing data. It is displayed directly to the right of the affected parameter. The parameter value may be blanked,

or the last value received by the GPC may be displayed. If data are missing for a parameter that has no numerical value associated with it, then an M is used to indicate the parameter status.

H: This symbol indicates that a parameter is offscale high. This indicates a transducer limit has been reached, and the scale is registering its highest possible value. The actual parameter being measured may, in fact, be higher than the recorded data, but the instrument in use does not have the capacity to measure the value. Off-scale high indicators do not appear on the display until several (normally two) consecutive readings have verified this finding. This symbol is displayed to the right of the data affected.

L: This symbol indicates off-scale low parameters. This means that the parameter value displayed is the lowest possible reading due to transducer limitations. The actual value of the parameter may exceed the displayed value, but the range of the hardware is not defined to evaluate this reading. As with the "H," the off-scale low indicator is not displayed until a set number of consecutive readings have verified this status.

2. SYSTEMS 2.6 Data Processing System

Up arrow: This symbol, displayed to the right of the affected parameter, indicates a parameter driven out-of-limits high. The value displayed is a true reading but has equaled or exceeded the operational high limit established by the software. The fault detection and annunciation (FDA) software keeps track of the low and high limits for each parameter and annunciates any violation of these limits to the crew by displaying the appropriate "up arrow" or "down arrow" next to the parameter on the appropriate display.

In the case where the transducer limit is the same as the operational limit, the "H" symbol overrides the "up arrow" symbol. Several (normally two) consecutive readings verify this status before the "up arrow" symbol is displayed.

Down arrow: This symbol indicates that a parameter value is equal to or less than the operational low limit. The value displayed is outside the software limits placed upon the parameter. When the software limit established is the same as the transducer limit, the "L" symbol takes precedence over the "down arrow" symbol. A set number of consecutive readings verifies this indication before the "down arrow" is displayed.

In addition, the down arrow is used to indicate a discrete state that does not agree with the nominal state. For example, a high pressure gas supply valve state reading "closed" when its position is normally "open" would drive the "down arrow" symbol.

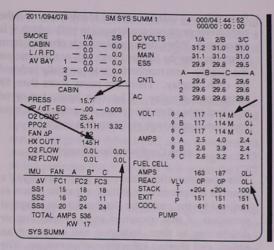
The down arrow is also used to indicate that a hardware unit has been declared failed by a GPC.

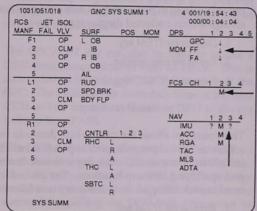
?: This symbol indicates a redundancy management dilemma. That is, if two hardware units measuring the same parameter disagree, and the software cannot isolate which of the two is failed, a "?" will be displayed in both places.

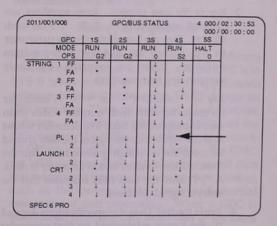
*: This symbol indicates an active state or the selected item of mutually exclusive items.

Item Operations

Within a given display, certain operations can be performed by the crew. Those items that may be altered are identified by an item number. The item number is a maximum of two digits and is placed







Specially Defined Symbols on CRT Displays

2.6-33

in such a way that it is readily identifiable with the parameter or status configuration with which it is associated. When item numbering is obvious, item numbers may be implied and will not appear on the display. Item numbering is sequentially ordered for each display. There are never more than 99 items per display. The two basic types of manipulations that the crew can perform are item configuration change and item data entry.

Item Configuration Change

This operation allows the crew to choose any of a number of options or to initiate a specific action as defined by the particular display format. Typical purposes of this operation include selecting or deselecting an item, initiating and executing an action, and altering software configurations. The procedure used in performing an item configuration change within a selected display is as follows:

- 1. Depress the ITEM key.
- 2. Key in the item number.
- 3. Depress the EXEC key.

Item Data Entry

This operation allows the crew to load data into the software. Typical purposes of this operation include initializing parameters, changing software limits, and specifying memory locations. The procedure used in performing an item data entry is as follows:

- 1. Depress the ITEM key.
- Key in the item number. Item numbers are ordered sequentially (1, 2, 3, . . .) on each display. They are located next to the parameter to which they are assigned. Some item numbers must be inferred by their surrounding item numbers.
- 3. Key in a delimiter ("+" or "-"). A delimiter serves to separate item number codes from their corresponding data. The delimiter whose sign corresponds to the sign of the data should be used, but if no sign is associated with the data, it doesn't matter which delimiter is used. A "[]" after the data field indicates that the entry is sign-dependent.
- Key in the data. Data size specifications depend on the format established for that particular data load. Usually, the data size will be indicated with an underline for each digit. As

a general rule, leading and trailing zeros need not be entered. Remember that the sign of the delimiter is the sign of the data.

5. Depress the EXEC key.

Multiple Data Entries

Multiple item configuration changes cannot be done; however, multiple item data entries can. Multiple data entries can be made with separate command strings, but because this is time-consuming, the software allows more than one data entry to be made with one command sequence. The procedure is the same as described above except step 4 (after data are keyed in). Add step 4a to make more than one item data entry at once.

4a. *Key in a delimiter*. Consecutive data entries may be loaded by using a delimiter to separate each parameter. Item entries are incremented sequentially so the item number need not be entered for each parameter following the one already entered. Just hit another delimiter, and the next item number will appear, ready to receive its associated data. To skip an item number, hit a delimiter twice. In this way, any amount of item numbers may be skipped until the desired item number is reached.

Both the "+" and the "-" keys may be used interchangeably as delimiters. However, when skipping item numbers, it is a good idea to use the delimiter corresponding to the sign of the next data entry if there is any sign associated with it. Using the sign key corresponding to the next data entry ensures that the GPC receives the proper data entry.

An example of a multiple item data keyboard entry is:

ITEM 7 + 2 + 1 + + 2 + - - 2 EXEC

In this example, Items 7, 8, 10, and 13 have no sign associated with them so the sign of the delimiters doesn't matter. Although there was room for four item entries here, the actual number allowed on the scratch pad line is a function of the size of the data.

This entry will appear on the scratch pad line of the corresponding CRT as:

ITEM (07) + 2 (08) + 1 (10) + 2 (13) - 2 EXEC.

All item operations will be one of these two basic manipulations. However, data size and form will differ for each display.

Remember, only OPS and SPEC displays allow item operations. A DISP display does not.

Special Operations and Displays

GPC/CRT Assignment

GPC assignment to a particular DEU/CRT set is determined via a predefined table of assignments. This table is stored in all the common set GPCs' systems software and can be manipulated by the crew. There is a table for each memory configuration (MC) that is valid when that MC is active (loaded in one or more GPCs), and the particular major function is selected. This table can be changed using the GPC MEMORY display (SPEC 0). The current GPC driver for a CRT is controlled by the MAJ FUNC switch. That is, the position of the MAJ FUNC switch (GNC, SM, or PL) will determine the GPC with which the DEU communicates. In some cases, a redundant set of GPCs is formed for GNC, and the GNC CRTs are normally split among them. This is done with the predefined table. The table is looked at by the GPCs when they are loaded with the applications software, and that is when the assignments take effect.

Another way to change the current GPC assignment logic is with the GPC/CRT key. The GPC/CRT key allows the crew to reassign a CRT to a different GPC commander. The steps for selecting a GPC to command a given DEU/CRT are as follows:

- 1. Depress the GPC/CRT key.
- 2. Key in the desired GPC number (1, 2, 3, 4, or 5)
- 3. *Key in the desired CRT number* (1, 2, 3, or 4). No delimiter is needed between the GPC and the CRT numbers.
- 4. Depress the EXEC key.

An assignment is not executed if the GPC being assigned doesn't have the applications software in memory to support the DEU/CRT in its current major function. If the GPC specified by a keyboard entry is not a valid assignment, the reassignment does not occur, and the current GPC driver retains the CRT. Thus, if a CRT is in *GNC*, and an attempt is made to assign a GPC that is not in the redundant set to drive it, a redundant set (or valid) GPC will drive the CRT instead of the invalid GPC. If GPC 4 is the SM machine (nominal configuration), then it is the only valid GPC to drive a CRT whose *MAJ FUNC* switch is in *SM*.

The payloads major function is usually *unsupported*. This means that none of the GPCs have payload applications software loaded in them. Any GPC can be assigned to drive a CRT in an unsupported major function. The GPC that was driving the CRT in the previous major function will retain the CRT when it is placed in *PL*.

If the keyboard entry specifies a valid GPC, it will override any assignment made by the software. The keyboard entry assignment will remain in effect whenever the *MAJ FUNC* switch is in a position supported by that GPC. A new assignment can be made via the keyboard.

The GPC/CRT key can also be used to isolate a DEU from communication with all GPCs. This is accomplished by using "0" for the number of the GPC. The PASS set can drive only three of the four CRTs at one time, so at least one DEU is always isolated from PASS.

The DEU drives a big X over an isolated CRT to remind the crew that the DEU is not receiving data. The DEU also annunciates a POLL FAIL message to inform the crew that the GPC is no longer successfully polling the DEU (not attempting to communicate with the DEU).

Memory Configurations

After a GPC has been IPL'd, the only software resident is the systems software, and the GPC is in OPS 0 when moded to RUN. Any applications software is loaded in from the MMU during an OPS transition. There are two levels of applications software: the major function base (MFB) and the OPS overlay. The MFB is that software common to all OPS in a particular major function. For GNC, the MFB contains flight-critical software and data that are retained from one mission phase to another. such as the current state vector and inertial measurement unit processing. When a GPC is transitioned from one OPS to another in the same major function (e.g., from GNC OPS 1 [ascent] to OPS 2 [orbit]), the MFB remains in main memory, and only the OPS overlay is loaded from the MMU

and written over the old OPS. Of course, when the major function changes (e.g., when GPC 4 is transitioned from GNC OPS 1 to SM OPS 2), a new MFB is loaded in from the MMU along with the OPS overlay.

The controls for performing an OPS transition (i.e., loading a new memory configuration into the GPC from the MMU) are on the GPC MEMORY display (SPEC 0), which is also the OPS 0 OPS display. Item 1 determines the memory configuration (CONFIG) to be loaded. Currently, there are eight different memory CONFIGs, besides memory CONFIG 0, which is post-IPL OPS 0 (no applications software loaded).

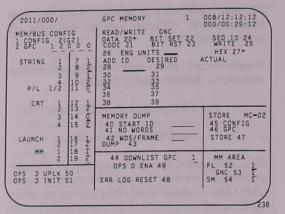
MC	ABBREV	DESCRIPTION
1	(G1)	GNC OPS 1 and 6 combined
		(ascent and aborts)
2	(G2)	GNC OPS 2 (on orbit)
3	(G3)	GNC OPS 3 (entry)
4	(S2)	SM OPS 2 (on orbit)
5	(S4)	SM OPS 4 (on orbit [not used])
6	(P9)	PL OPS 9 (preflight)
No MC 7	and the	STPC The PASS SECTOR STREET
8	(G8)	GNC OPS 8 (on orbit checkout)
9	(G9)	GNC OPS 9 (preflight/postflight)

Memory Configurations

Nominal Bus Assignment Table

Associated with each memory configuration is a nominal bus assignment table (NBAT). It is displayed via items 7-19 on SPEC 0 whenever a memory configuration is entered, and it tells which GPCs are in the target set and which GPCs are to be in command of each data bus. The nominal assignments are already loaded in GPC main memory preflight. However, these bus assignments may be changed any time, including when an OPS transition is performed.

An example of a typical nominal bus assignment table is shown below on SPEC 0 GPC MEMORY for GNC OPS 3.



Sample NBAT Data on GPC MEMORY Display (SPEC 0)

- Items 2-6 determine which GPCs will be in the OPS. They are referred to as the "target" GPCs. In this case, GPCs 1-4 are in a redundant set. If a GPC is not to be in that OPS, a 0 is entered in that GPC's item number, which is one more than the GPC number. (Item 2 is for GPC 1, etc.)
- The commanders of the flight-critical data buses or strings are entered in items 7-10. (String 1 is FF1 and FA1, etc.) In this case, each GPC is set to command its samenumbered string.
- The two PL buses are assigned together. For OPS 1 and 3 they are assigned to GPC 1 via item 11 in case the BFS fails. When the BFS is in *RUN* (as it is for entry), it commands the PL data buses.
- CRTs 1, 2, 3 are assigned to GPCs 1, 2, 3 respectively, via items 12-14. Since the PASS can only control three CRTs at a time, no GPC is assigned to CRT 4 during entry. Note that CRT assignments are for a particular major function only.
- The launch data buses are assigned via items 16 and 17. Since they have no function during entry, they are deassigned.
- Items 18 and 19 show that GPC 1 will command mass memory bus 1 for the OPS 3 transition, and GPC 2 will command mass memory bus 2, either if the transaction fails on mass memory bus 1 or if MMU 2 is prime selected on SPEC 1 DPS UTILITY.

MMU Assignment

Since there are two identical MMUs, there must be a method to tell the GPCs which one to use for a particular transaction. This is done on DPS UTILITY SPEC 1 display via items 1 through 8. Only one MMU (and its data bus) is assigned to each major function. A post-IPL OPS 0 GPC also has an MMU assigned to it for requesting freeze-dry software for a memory store. This display is initialized with all assigned to MMU 1, and execution of any of the item numbers causes the appropriate MMU to be assigned. Note that each of the pairs of item numbers is mutually exclusive.

When a GPC needs to access mass memory, this table tells it which MMU to use. For example, the SM GPC may need to call a roll-in SPEC or take a checkpoint (discussed later). In the case of OPS transitions, if the MMU selected is busy or fails twice, then the other is automatically tried. For a GNC OPS transition where a redundant set is involved, one GPC is assigned to each mass memory bus via items 18 and 19 on SPEC 0 GPC MEMORY. The indicated GPC will command the mass memory bus selected by item 1 or 2 on SPEC 1 DPS UTILITY, then the other GPC will command the next mass memory bus if the first transaction fails. Of course, all GPCs in the redundant set will be listening over both buses and receive the overlay.

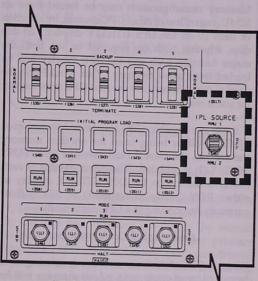
2011/001/	DPS UTILITY 1 008/12:12:1
MMU ASSIGN	PORT ASSIGN 000/00:25:1
GNC 1 * 2	STRING 1 15* 16 AUTO 25*
SM 3* 4	STRING 1 15* 16 AUTO 35* 2 17* 18 ENA 36
PL 5* 6	3 19* 20 INH 37
OPS 0 7* 8	4 21* 22
HHU CTATUS	P/L 1/2 23* 24 IPL SOURCE SW
MMU STATUS	MASK 38*
2 RDY	VAR PARAM ID LIST
	25 <u>9ABA</u>
MMU SOURCE/BUS	26 9ABB G3 ARCHIVE
GPC/MMU 9* MMU/MMU 10	27 9ABC LOAD 48 28 9ABD RETRIEVE 49
GPC/LDB 11	29 9ABE RETRIEVE 49
SS SPECEDERAL	30 9ABF GROUND OPS
CKPT RETRV	31 9ACA GSE POLL ENA 50
ENA 12	32 9ACB SM GSE INH 51 33 9ACC SM C/O FNA 52
RTC	
13	34 9ACD GNC C/O ENA 53 BFC C/O ENA 54
CMD 14	ALT PL9 TB 55

DPS UTILITY Display (SPEC 1)

Software Memory Source Selection

During an initial program load (IPL), an MMU is selected as the software source via the *IPL SOURCE*

switch on panel O6. This switch is a three-position toggle switch that will be either in the MMU 1 or MMU 2 position during the IPL sequence. At all other times, this switch will nominally be in the OFF position.



IPL SOURCE Switch on Panel 06

The controls for selecting the memory source for an OPS transition and the bus over which it is loaded into the GPCs are on SPEC 1 DPS UTILITY (items 9 through 11). The display is initialized with item 9 selected, which is almost always used. As part of the GPC status exchanged at common set sync, each GPC exchanges its current resident memory configuration. When a request is made for a memory configuration, the software determines whether or not another GPC already has the requested OPS or a current major function base. If another GPC already has any of the requested software, the lowest numbered such GPC will be used as a source for the other GPCs. Such a GPCto-GPC overlay of software will be done over the mass memory data buses. An overlay that is not available from a GPC will be loaded from an MMU. Note that the major function base may come from another GPC and the OPS overlay from mass memory. For transitions to OPS 3, the G3 archive (stored in the upper 128 k of main memory prelaunch) is simply copied to lower memory and executed.

If there is a problem with both of the mass memory data buses, then item 11 may be selected if there is a GPC source for both overlays. In this case, the GPC-to-GPC overlay is done over the launch data buses.

Memory reconfiguration may be forced from an MMU, regardless of other GPC sources, by selection of item 10 on the DPS UTILITY display. In this case, whether both are required or not, both the major function base and the OPS overlay will be loaded from mass memory. This would only be used if the software in a current GPC was suspect for some reason.

If there is no usable GPC source and the selected MMU is off or being used for another memory transaction, the class 3 fault message OFF/BUSY MMU 1 (2) is initiated. The current status of each MMU is shown on the DPS UTILITY display as either RDY (ready to respond) or BSY (off or currently responding to a GPC command).

Resetting I/O Configurations

When a GPC detects an error or is missing data from a piece of equipment, a fault message will be displayed on the CRTs, the SM ALERT light and tone will be activated, and further attempts by the GPC to communicate with the equipment will be terminated. Two common causes of detected errors or missing data are the powering down of equipment or an error in a data transmission. In these two cases, if the equipment is to be powered up, or if the error has been corrected, it is desirable to restore the GPC's data input to the nominal configuration. Restoring input is done through the I/O RESET key in the affected major function. If an I/O RESET is performed only on a GNC GPC, the entire redundant set of GNC GPCs will be restored to nominal I/O configuration. If it is performed on the SM GPC, only the SM GPC's I/O configuration will be restored to nominal. To reset I/O configurations, the procedure is as follows:

- Select desired MAJ FUNC.
- Depress the I/O RESET key.
- Depress the EXEC key.

If the powered down equipment has been powered on, or if a problem with a piece of equipment has been fixed, an I/O RESET will resume communication, and it will not cause another fault message annunciation. If the GPC still has a problem communicating with any piece of its assigned equipment, a fault message will reannunciate after an I/O RESET. This termination of attempts by the GPC to communicate with its assigned equipment is called a commfault (i.e., the input element has been bypassed by the GPC) and the resultant loss of input data to applications software is also referred to as a commfault.

Systems Summary Displays

Systems summary displays provide general systems status information that can be accessed quickly to aid immediate diagnosis of a problem. They are designed to support the caution and warning (C/W) matrix located on panel F7. When a C/W alarm occurs, the crew can call a systems summary display that has general information from several systems to pinpoint the problem to a specific system, then continue troubleshooting the problem on system-specific SPECs, DISPs, and hardware panels. The systems summary displays are DISPs and provide information only.

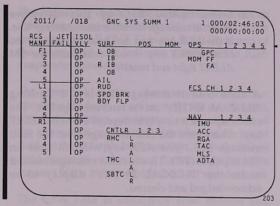
The systems summary displays are major functionspecific and are called with the SYS SUMM key. If a CRT's *MAJ FUNC* switch is in *GNC*, and the SYS SUMM key is pressed, then GNC SYS SUMM 1 will appear on that CRT. GNC SYS SUMM 1 is DISP 18 so it may also be called with a SPEC 18 PRO, but it is faster to use the SYS SUMM key.

There are four PASS systems summary displays: GNC SYS SUMM 1, GNC SYS SUMM 2, SM SYS SUMM 1, and SM SYS SUMM 2.

The SYS SUMM key is a toggle function in each major function. In SM on-orbit, hitting SM SYS SUMM will cause SM SYS SUMM (DISP 78) to appear on the CRT. If SYS SUMM is depressed again, SM SYS SUMM 2 (DISP 79) will appear, and if SYS SUMM is depressed once more, SM SYS SUMM 1 reappears.

The same toggle function exists in GNC between GNC SYS SUMM 1 (DISP 18) and GNC SYS SUMM 2 (DISP 19).

2. SYSTEMS 2.6 Data Processing System



PASS GNC SYS SUMM 2, available in GNC OPS 1, 6, 2, 8 and 3

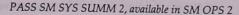
OMS A	AFT O	TY	L	R		OMS	;	0	00/00	:00:	R
	0			30.2			(P	HE	4070	40	170
		FU 3	0.2	30.2				OXID			:58
	1000	1	-	1.07	1.001	1		FU			260
RCS		OXID	FU	FAIL	ISOL	N.		REG P			260
FWD	HE P	3048	2968					PVL			C
	TK_P	247	248	1202	1222	EM	IG	IN	P	100	Ŭ
	OTY	67	67	1.00		23623		OXID			
MANF	1 P 2 P	248 248	242		OP OP			VLV	U 26	0 2	60
	3 P	250	246	10000	OP	1367		VLV	2	0 -	2
	4 P	246	246	10000	OP			10000	-	JET	IS
	5			1200	OP		_	OXID	FU	FAIL	V
AFT	HE P TK P	3200	3144	1986	1000	HE		3216	3160	C. C.	
L	OTY	245 82	249 83	100		R TK		251 84	249 84		
MANE	IP	246	246	222	OP	T	P	242	246	12.00	0
	2 P	246	250	38.3	OP	2	P	250	246	10000	
	2 3 4 2 3 4	250	250		OP	234	Ρ	246	258		0
	4 P	246	250	10000	OP OP	4	P	246	242	1000	0

GNC SYS SUMM 2, available in GNC OPS 2 and 8

2011/ /078 SM	SYS SUMM 1	4		4:44:12
SMOKE 1/A 2/B	DC VOLTS	1/A	2/B	3/C
CABIN 0.0 L/R FD 0.0 0.0	FC	30.6	30.1	31.0
AV BAY 1 0.3 0.3	ESS	30.6	30.1 29.6	31.0
2 0.3 0.4	and and the same	A	B	c
3 0.3 0.3	CNTL 1	29.4		29.6
PRESS 14.0	23	29.4	29.4	29.4
dP/dT-E0 +.00 +.000	AC	29.4	29.4	29.4
02 CONC	VOLT ¢ A	118	118	117
PP02 3.00 3.00	¢Β	117	117	118
FAN AP 5.00	¢ C	117	117	118
HX OUT T 46	AMPS ¢ A	4.3	6.3	2.1
02 FLOW 0.0 0.0	¢Β	5.5	6.6	2.2
N2 FLOW 0.0 0.0	¢C	3.1	5.0	3.2
IMU FAN A B C	FUEL CELL			
ΔV FC1 FC2 FC3 SS1 22 21 22	AMPS REAC VLV	180	232	146
SS2 22 22 23	STACK T	0P +202	0P +206	0P +200
SS3 23 21 21	EXIT T	150	152	149
TOTAL AMPS 557	COOL P	61	60	61
KW 17	PUMP			

PASS SM SYS SUMM 1, available in SM OPS 2

2011/ /	079	SM	SYS S	UMM 2	4 00	00/14:	44:52
	1 211 834 -221 -221	2 211 833 -221 -221	3 238 858 -212 -212	858	5 145L 515L -194 -194	MANF1 238 858	MANF2 238 858
APU TEMP EGT	1	2	3	HYD	1	2	3
B/U EGT	20	15 15	11 15	PRESS RSVR T	65 72	65	65
OIL IN	51	59	57	P	6	72	72
SPEED %	56	54	59	QTY W/B	55	55	55
FUEL QTY	89	88	85	H20 OTY	97	94	92
PMP LK P OIL OUT P	15 24	15 24	15 24	BYP VLV	BYP	BYP	BYP
AV BAY				THERM		1	2
TEMP	50	88	82	H20 PUM		50	50
	.59	3.64	3.67	FREON F		2000	2000



Fault Detection and Annunciation

Five classes of alarms have been established. Class 1, Emergency, has no interface with software. Class 2, Caution and Warning (C/W), is the second highest alarm class. It is divided into primary (hardware-driven) and backup (software-driven) systems. An alarm of the software-driven class will result in the annunciation of the BACKUP C/W ALARM light on the C/W matrix on panel F7, the MASTER ALARM lights, and an associated tone. In addition, a fault message will be displayed upon the fault message line of the CRT. Class 3, Alert, triggers the SM ALERT light and corresponding tone. A fault message is displayed upon the fault message line. Class 5, Operator Errors, is the lowest priority alarm and is caused only by a crew entry error. It results in an ILLEGAL ENTRY fault message being displayed. Class 0, Limit Sense, provides a status indicator (down arrow, up arrow) to the right of the affected parameter on an appropriate CRT. No fault message, tone, or light is triggered.

The output of a fault message to the fault message line results in several indications requiring crew interface. Although generally the crew keyboard responses are similar, the effects of these responses differ for each class alarm. The crew response to a class 2 backup fault message is:

- 1. Depress the MASTER ALARM push button indicator. This will extinguish the MASTER ALARM light and caution and warning tone.
- 2. Depress the ACK key (on the keyboard). The fault message will cease flashing. If the crewmember can examine the message while it flashes, this step is unnecessary. Depress the ACK key again to look at the next message in a stack if required.
- 3. Depress the MSG RESET key. Depression of this key removes the fault message from the fault message line. In addition, the BACKUP C/W light is extinguished. (Hardware-driven lights remain on until the problem is corrected.)

The crew response to a class 3 fault message is:

- 1. Depress the ACK key. This will cause the fault message to become static. Depression of the ACK key will also extinguish the SM ALERT light and tone. (The tone duration is set to a crew-selected length and may have stopped before the ACK key is pressed.) Depress the ACK key again to look at the next message in a stack if required.
- 2011/ /018 GNC SYS SUMM 1 1 000/02:46:03 000/00:00:00 ISOL MANE FAL SURF POS MOM DPS 12345 L OB IB R IB OB OP OP OP OP OP OP OP MDM AIL LI FCS CH 1 2 3 4 SPD BRK BDY FLP NAV R1 OP OP OP RHC ACC 123 RGA ADTA THC SBTC 203 S88 EVAP OUT T CRT Fault Minor C/W GPC ID Field

Major Field

2. Depress the MSG RESET key. This will remove the fault message from the fault message line. If the ACK key had not been depressed, the MSG RESET key would extinguish the SM ALERT light and tone.

A class 5 fault message displays a flashing "ILLEGAL ENTRY" on the fault message line. The crew response is simply to depress the MSG RESET key. This clears the fault message from the fault message line. The ACK key will not clear an "ILLEGAL ENTRY." It will cause messages stacked under the "ILLEGAL ENTRY" display to be acknowledged and cleared.

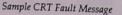
Some illegal keyboard entries are detected by the DEU before being sent to the GPCs. When this occurs, a flashing "ERR" appears immediately to the right of the erroneous entry on the scratch pad line. The crew response is simply to depress the CLEAR key. Upon depression of the CLEAR key, the "ERR" and the last keystroke will disappear. Subsequent depressions of the CLEAR key will remove single keystrokes, proceeding from right to left. This feature enables the crew to CLEAR back to the portion of the command that was incorrect. correct it, and proceed. This type of error is not identified by class, since it is not GPC-detected and is known simply as a DEU-detected error.

Fault Messages

Fault messages associated with alarm classes 2, 3, and 5 follow a standard format of five fields.

The major field is a 14-character field. The first three characters identify the display on which more information about the annunciated failure can be found. An Sor a G, followed by a two digit number, indicates the major function (G for GNC and S for SM) and the number of the SPEC or DISP. If no display is associated with the fault, this field is blank.

> In the example below, "S88" is the CRT ID and means that information on the fault can be found on SPEC 88 in SM.



4

19:54:01

Time

The remaining characters identify the problem or subsystem group associated with the fault. In the example, "EVAP OUT T" is the FAULT portion of the major field and indicates a fault in the flash evaporator subsystem.

The minor field is a four-character field that further identifies the fault. It will specify the subdivision, direction, location, parameter, or specific unit of the subsystem or problem identified in the major field. In the example fault message, "1" is the minor field message and means that the temperature sensor 1 is the area in which the fault was detected.

The C/W field is used only with caution and warning class 2 backup messages. An asterisk appears in this column across from the corresponding fault to denote that the condition is a class 2 backup alarm.

The GPC field identifies the GPC that detected this fault. This characteristic aids the crewmember in locating or identifying internal GPC or I/O errors.

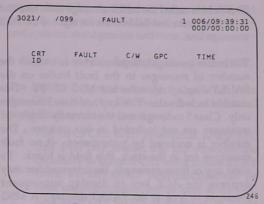
The far right field is the TIME field. This field indicates the time at which the fault occurred. The time is MET and is displayed in hours, minutes, and seconds (HH:MM:SS).

A complete listing of all possible fault messages can be found in the Flight Data File Reference Data Book and in Section 2.2.

A class 5 alarm is annunciated by an "ILLEGAL ENTRY" in the major field, and all other fault message fields are blank. When a class 5 message is received, it is displayed instantaneously on the fault message line of the CRT where the error occurred, rather than on all CRTs like class 2 and 3 errors. To get rid of the class 5 message, a MSG RESET must be done to the CRT where the error occurred. Class 2 backup and class 3 messages are extinguished by a MSG RESET on any CRT.

The Fault Summary Display

A historical summary of class 2 backup and class 3 fault messages is provided via the FAULT display (DISP 99). Class 5 errors are not displayed as they are caused by illegal crew entries to a *single* DEU. The FAULT display is a DISP available in all OPS. It is selected for viewing by depression of the FAULT SUMM key.



FAULT Display (DISP 99)

The PASS fault summary display consists of up to 15 fault message lines. They appear in reverse chronological order. The oldest message appears on the bottom line. When a new fault message is generated, it appears on the top line. The other messages are pushed down, and the 15th message (the oldest) disappears.

The only difference between the fault messages on the FAULT display and the fault message on the fault message line is the TIME field. On the FAULT display, the time field includes days as well as hours, minutes, and seconds (DDD/HH:MM:SS).

Sometimes, a subsystem failure or malfunction results in the output of several fault messages, some of which may be identical. The fault detection and annunciation logic can prevent the annunciation of identical fault messages. When a fault message is generated, its major and minor fields are compared to those of the top message of the display. If the fields are the same, and if the new fault message has occurred within a 4.8 second window, the new message is inhibited.

The last message displayed on the fault message line of any CRT is not necessarily the most recent fault message. Unless the fault message line was cleared with a MSG RESET, the crewmember will not see any new messages that came in after the flashing or frozen message. In that case, the crewmembers can see if a new message has been annunciated by looking at a two-character field. This field is called the buffer message indicator and is located in the last field on the far right of the fault message line.

The buffer message indicator serves to indicate the number of messages in the fault buffer on the FAULT display since the last MSG RESET. This number includes class 2 backup and class 3 messages only. Class 5 messages and the currently displayed messages are not included in this counter. The number is enclosed by parentheses. If no fault messages are in the stack, this field is blank. To view any of these messages, the crewmember may depress the *ACK* key to display subsequent messages or look at the FAULT display. A MSG RESET clears both the fault message line and the buffer message indicator.

In addition to using the FAULT SUMM key, the FAULT display may also be selected by the keyboard entry "SPEC 99 PRO." However, this command will clear all fault messages from the FAULT display and the fault message lines. This capability is useful if and when the fault messages displayed are no longer significant (i.e., they are old, or they have been dealt with).

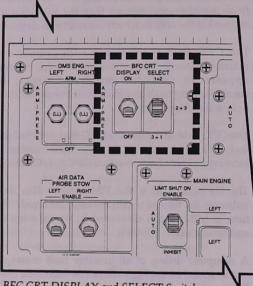
Crew Software Interface with the BFS

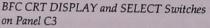
The crew software interface with the BFS is designed to be as much like PASS as possible, but there are some differences. This section covers the differences between the PASS's and BFS's crew and CRT interfaces. If something is not mentioned in this section, it can be assumed to operate the same as the PASS interface.

BFC CRT Switches

Panel C3 contains two switches relevant to BFS operations. The *BFC CRT DISPLAY* switch is a two-position *ON/OFF* switch. In the *ON* position, the CRT(s) specified by the *BFC CRT SELECT* switch is driven by the BFS computer. (The *BFC CRT SELECT* switch controls CRT assignment to the BFS computer.) The switch is read by the GPC only when the *BFC CRT DISPLAY* switch is in the *ON* position. The *BFC CRT SELECT* switch has three positions. In each position, the first digit is the CRT commanded by the BFS pre-engage. Post-engaged, the BFS also commands a second CRT indicated by the second number. For example, when the *BFC CRT SELECT* switch is in the *1* + 2 position, CRT 1 is

connected to the BFS GPC *prior* to engaging the BFS. After the BFS is engaged, this switch position allows the BFS computer to command both CRT 1 and CRT 2. In the 2 + 3 position, CRT 2 is commanded by the BFS GPC *prior* to engaging the BFS. Post-engaged, this switch allows CRT 2 and CRT 3 to be supported by the BFS computer. In the 3 + 1 position, CRT 3 is driven by the pre-engaged BFS GPC. Upon engaging the BFS, both CRT 3 and CRT 1 will be assigned to the BFS computer.





During ascent and entry, one CRT will normally be assigned to the BFS via the *BFC CRT SELECT* switch. The nominal position of the switch is the 3+ 1 position. However, this switch position may be changed at any time, pre-engage or post-engage. If the BFS is engaged with the *BFC CRT DISPLAY* switch *OFF*, the BFS will automatically assume command of CRTs 1 and 2.

No set of BFC CRT switches exists for the CRT in the aft station.

BFS Functions of the MAJ FUNC Switch

The *MAJ FUNC* switches on panels C2 and R11L are also functional for the BFS. However, the display data and functional software accessed by the three-

position switch are slightly different. The BFS functions of the *MAJ FUNC* switch are defined as follows:

- GNC: Flight critical software including limited guidance, navigation, and control software is contained in this major function. The BFS GNC major function contains only that software necessary for safe orbital insertion and return, including ascent abort logic.
- SM: This major function contains limited nonredundant systems management and payload software. There is no room in the BFS for the redundancy management found in PASS. When the MAJ FUNC switch is set in the SM position, the THERMAL display is invoked. This display is unique to the BFS.
- PL: This major function is not functional for the BFS. Should the MAJ FUNC switch be set in this position, no display change would occur. If the BFC CRT DISPLAY switch is turned on, allowing the BFS to drive a CRT already in the PL major function, the CRT will be blank except for time and GPC driver fields because the BFS has no software to support this major function. Backup Flight

BFS ENGAGE Push Button

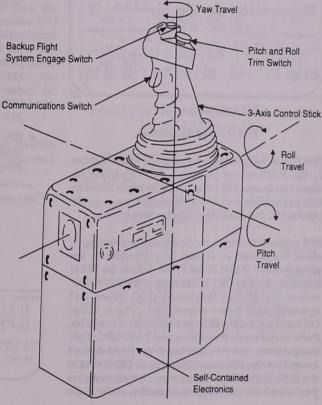
The BFS ENGAGE push button is located on the commander's and pilot's rotational hand controllers (RHCs). During the dynamic flight phases (ascent and entry), the commander and pilot usually rest a hand on or near the RHC. In this way, BFS engagement can occur as quickly as possible. If the crew delays engagement during these flight phases, they could lose control of the vehicle, or the BFS' navigation calculations could degrade very quickly so that control would be essentially lost after engagement.

Some force (8 lb) is required to depress this push button to prevent inadvertent engages. While on-orbit, the push button is essentially disabled by reconfiguring the *BFS OUTPUT* switch. The BFS cannot track PASS while it is in OPS 2 and is moded to *HALT* on-orbit. If the BFS needs to be engaged on-orbit, the BFS must be "awakened", and the only software that will be of any use is entry and systems management software.

Keyboard and Display Differences for the BFS

The keyboard operates exactly the same way for the BFS as for the PASS. A few additional capabilities need to be mentioned.

• The GPC/CRT key: In addition to the BFC CRT DISPLAY switch, this key provides the capability to assign a CRT to (or isolate a CRT from) the BFS GPC. Both methods can be used interchangeably, but as long as the BFC CRT DISPLAY switch is working, it is the fastest method of allowing the BFS to drive a CRT or to change BFS CRTs. The BFC CRT DISPLAY switch allows PASS to automatically begin driving the CRT again when the BFS is turned off. When the BFS is assigned a CRT with the GPC/CRT key, it is the same as



2.6-43

deassigning that screen from PASS with a GPC/CRT 0X EXEC. PASS must be reassigned to resume commanding of that CRT.

 The BFS INDICATOR: When the BFS is commanding a CRT, the BFS indicator will appear on the CRT being commanded. On the second line of every BFS display a threecharacter space field has been reserved for the message "BFS." This field is located directly below the GPC indicator. The BFS indicator is displayed in the overbright intensity and is intended to prevent possible confusion of a PASS display with a BFS display. Often the BFS display will be identical or very close to the corresponding PASS display.

				DPS 1234
SURF L OB IB R IB OB AIL	POS	MDM		DPS 1234 MDM FF FA PL
AIL RUD SPD BRK BDY FLP				FCS CH 1 2 3 4
MPS	L	с	R	NAV 1 2 3 4
HE TK P REG P A B dP/dT	4280 784 776	4230 768 766	4240 768 770	IMU TAC ADTA
arrai				MPS PNEU HE P
ULL P LH2 LO2	42.5	42.7 21.0	42.9 20.8	TK 4350 REG 798
GH2 OUT P GO2 OUT T	70↓ 79↓	50↓ 97↓	40↓ 70↓	ACUM 760 MANF P LH2 46 L02 110

BFS Indicator on CRT

BFS Display Sequencing

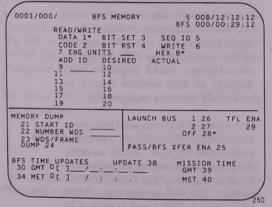
The BFS is designed to operate in the same manner as the PASS where possible. BFS requirements, however, demanded a distinction be made between BFS pre-engage and BFS post-engage major mode transitions and associated display sequencing.

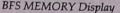
BFS pre-engage major mode display sequencing is either automatic, or it may be performed in the same manner as that of the PASS. Before the BFS is engaged, the BFS CRT is listening to the PASS CRT across the display/keyboard (DK) buses and updating its software accordingly. This is called DK listening and the BFS can hear PASS item entries, PASS major mode transitions, and PASS GPC/CRT assignments. On the other hand, the PASS doesn't know that the BFS exists, so it never DK listens to the BFS. Therefore, BFS major mode transitions are performed automatically as a function of the major mode transitions performed on a PASS keyboard. If the BFS does not follow the PASS major mode transitions, then the BFS must receive a manual OPS XXX PRO on its CRT.

BFS post-engage major mode display sequencing is the same as that of the PASS. After the BFS is engaged, the BFS GPC is on its own. It no longer listens to the PASS GPCs. Therefore, major mode display sequencing has been designed to be the same as that of the PASS.

Three operational sequences are defined for BFS GNC; one operational sequence is defined for the BFS SM. Transactions to and from these OPS displays differ considerably from the PASS. BFS keyboard and CRT peculiarities are outlined as follows:

- BFS GNC OPS 0 BFS MEMORY display: This display is forced to the CRT when BFS is not processing either GNC OPS 1 or 3. Nominally, this occurs prior to ascent and again prior to entry. This display corresponds to the PASS GPC MEMORY display and performs the same functions for the BFS. It also performs some of the same functions as PASS SPEC 2, the TIME SPEC, in that time updates can be performed along with selection of GMT or MET to be displayed. GPC MEMORY is the default display for PASS OPS 0, and the BFS MEMORY display is the default display for BFS GNC OPS 0.
- BFS GNC OPS 1 and 6 Ascent: This OPS must be manually selected via a keyboard assigned to the BFS prelaunch. BFS GNC OPS





1 is available for use during the ascent portion of the mission. The OPS 6 transition is automatic upon abort selection with the *ABORT* rotary switch and push button, or an OPS 601 PRO may be used.

 BFS GNC OPS 3 – Entry: This OPS must be manually selected from BFS GNC OPS 0 or BFS GNC OPS 1. BFS GNC OPS 3 is available for use during the entry portion of the mission. It is a legal transition to go from the BFS GNC OPS 1 to BFS GNC OPS 3 (for aborts), but nominally, the transition will be from BFS GNC OPS 0. In both cases, the manual keyboard entry "OPS 301 PRO" is required.

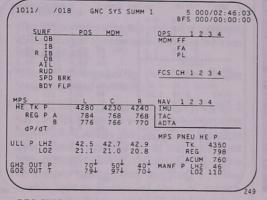
The major mode displays for BFS OPS 1, 3, and 6 are similar, if not identical, to their PASS counterparts. A complete listing of PASS and BFS displays can be found in the DPS Dictionary.

BFS Special Operations and Displays

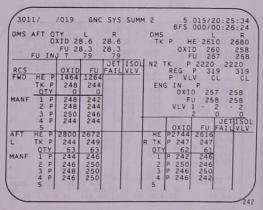
In the pre-engaged mode, the BFS GPC performs BCE and MDM bypasses when PASS data are bypassed, or it sets its own bypasses. The I/O RESET command when made via the BFS keyboard restores those I/O configurations set by the BFS GPC. That is, a BFS "I/O RESET EXEC" restores the bypasses set by the BFS GPC. In addition, the I/O RESET operation attempts to synchronize the BFS with the PASS GPC listen commands so the BFS can track PASS.

Post-engage, the only bypasses set are those detected by the BFS GPC. The "I/O RESET EXEC" command functions to restore those bypasses. The BFS systems summary displays operate the same way the PASS displays work. The BFS display numbers are the same as their PASS counterparts and some of the displays themselves are identical. However, three of the BFS SYS SUMM displays are unique to the BFS.

GNC SYS SUMM. The GNC SYS SUMM consists of two DISPs. GNC SYS SUMM 1 is display format and content unique to BFS. It is called via the SYS SUMM key or by the command "SPEC 18 PRO." GNC SYS SUMM 2 is identical to the GNC SYS SUMM 2 display available in the PASS OPS 2 and 8. It is called by the command "SPEC 19 PRO" or by depressing the SYS SUMM key twice.



BFS GNC SYS SUMM 1, available in GNC OPS 1, 6, and 3 (Unique to BFS)



BFS GNC SYS SUMM 2, available in GNC OPS 1, 6, and 3 (Identical to PASS GNC SYS SUMM 2 except shaded lines)

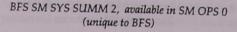
> SCOM 1.6 August 1996

- SM SYS SUMM. There are two SM SYS SUMM displays. SM SYS SUMM 1 is identical to the PASS SM SYS SUMM 1, while BFS SM SYS SUMM 2 is a unique display. They are called in the same manner as the PASS SM SYS SUMM displays.
- THERMAL. This is a systems summary DISP available as the SM OPS 0 display in BFS. It is forced to the screen anytime the *MAJ FUNC* switch is placed in the *SM* position (unless an SM SPEC is called up over it). This display is unique to the BFS. It cannot be obtained with a SPEC key, and it never requires a keyboard entry.

	SYS SUMM 1		000/03	
SMOKE 1/A 2/B CABIN - 0.9 L/R FD - 0.4 0.2 AV BAY 1- 1.2 - 0.0	DC VOLTS FC MAIN	1/A 31.1 31.0	2/B 31.1 31.1	31.1
2- 0.6 0.3 3- 0.1 - 0.9 CABIN	CNTL AB BC CA	29.3 29.3 29.3	29.3	29.3 29.3
PRESS 14.7 dP/dT +.00	ESS	29.8	29.8	29.8
BU/EQ00 +.00	VOLT ¢A		117	117
PP02 3.02 3.02 FAN P 5.79	ФВ ФС	117	117	117 117
HX OUT T 49	AMPS ØA	4.4	4.1	2.7
02 FLOW 0.0L 0.0L N2 FLOW 0.0L 0.0L	ФВ ФС	3.9	4.2	3.2
IMU FAN ΔP 4.62	FUEL CELL		3.2	4.0
ΔV FC1 FC2 FC3 SS1 15 18 18	AMPS REAC VLV	172 0P	167 0P	178 0P
SS2 16 20 11 SS3 22 26 26 TOTAL AMPS 510	STACK T EXIT T COOL P	+204 150 61	+203 150 61	+203 151 61
KW 15	PUMP	01	01	01

BFS SM SYS SUMM 1, available in SM OPS 0 (Unique to BFS)

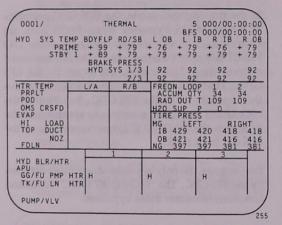
0001/ /	079	SM	SYS SU	IMM 2	S O	08/23:	29:22
CRYO TK	1	2	3	4	5		MANE
H2 PRESS	208	208	206	206	206		207
02 PRESS	816	815	814	814	814	815	815
HTR T1	-248	-248	-248	-248	-248		
T2	-248	-248	-248	-248	-248		
APU	1	2	3	HYD	1	2	3
TEMP EGT	942	942	942	PRESS	3064	3064	3064
B/U EGT	942	942	942	ACUM P	3080	3080	3080
OIL IN OUT	250	250	250	RSVR T	116	153	142
	264	264	264				
GG BED INJ	511H 1271	511H		QTY	72	74	71
SPEED %	99	1271 102	1271 101				
FUEL OTY	59	60		W/B			
PMP LK P	14	14	62 14	H20 QTY		73	78
OIL OUT P	42	42	41	BYP VLV	BYP	BYP	BYP
FU TK VLV		42	-1	1.			
AT	63	65	62	THERM	A CNT		
B T	63	65	62	H20 PU	AP P	23	28
AV BAY	1	2	3	FREON	FLOW	2384	63
TEMP	97	97	83	EVAP OI	IT T	39	2384
A4 14	27	.439	27.435	26.32	4 31	.873	18.48
							10.40



BFS Fault Messages

Several crew interface characteristics of fault annunciation in the BFS differ from those in the PASS.

- The BFS FAULT display. The BFS FAULT display functions in the same manner as the PASS. The BFS FAULT display is composed of 20 fault lines as compared to 15 in the PASS. The C/W field displays an asterisk when the message annunciated is a class 2 backup alarm. The BFS FAULT display provides a history of only class 2 backup and class 3 messages annunciated by the BFS GPC itself.
- BFS Unique CRT IDs. In BFS SM, all messages referring to SM SYS SUMM 1 or SM SYS SUMM 2 are indicated by the CRT IDs SM1 and SM2. Fault messages referring to the THERMAL display are indicated by the CRT ID SM0.



BFS THERMAL, available in SM OPS 0 (Unique to BFS)

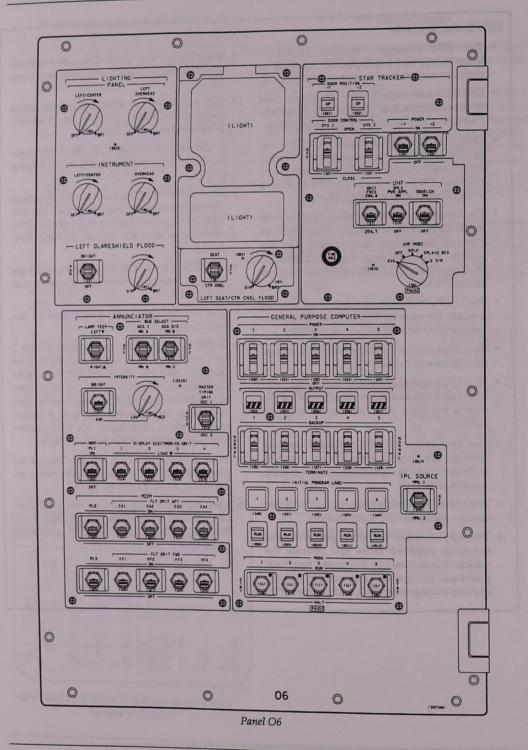
SCOM 1.6 August 1996

DPS Summary Data

- The DPS combines various hardware components and self-contained software to provide computerized monitoring and control.
- DPS hardware includes five GPCs, two mass memory units, a data bus network, 20 MDMs, four CRTs, and other specialized equipment.
- Each of the five GPCs consists of a CPU and an IOP stored in one avionics box. During ascent/entry, four of the GPCs are loaded with identical PASS software; the fifth is loaded with different software, the BFS.
- The data bus network transfers data between the GPCs and vehicle systems. There are seven types of data buses: flight-critical, payload, launch, mass memory, display/keyboard, instrumentation/PCMMU, and intercomputer communication.
- The 13 DPS MDMs convert data to appropriate formats for transfer between the GPCs and vehicle systems. OV 105 has all EMDMs.
- Two mass memory units provide bulk storage for software and data.
- Four CRTs (three on panel F7 and one on panel R11L) and associated keyboards provide the means for flight crew interaction with the GPCs.
- The two types of DPS software, system software and applications software, combine to form a memory configuration for a specific mission phase.
- The system software is operating software that always resides in GPC main memory.
- The applications software performs the functions required to fly and operate the vehicle. It is divided into three major functions: guidance, navigation, and control (GNC); systems management (SM); and payload (PL).

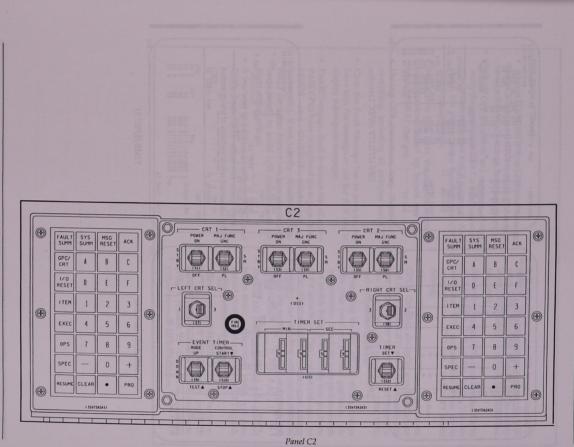
- Major functions are divided into mission phase oriented blocks called operational sequences (OPS).
- OPS are further divided into blocks called major modes (MM), which relate to specific portions of a mission phase.
- There are three levels of CRT displays: major mode or OPS, specialist (SPEC), and display (DISP).
- The four PASS GPCs control all GNC functions during ascent/entry mission phases; the fifth GPC is loaded with backup flight system (BFS) software to take over in case of PASS GPC failure.
- The BFS contains a limited amount of software; there are some operational differences between BFS and PASS.
- The BFS is engaged by pushbutton on the rotational hand controller.
- A GPC FAIL detection will display a class 2 GPC FAULT message with illumination of the MASTER ALARM. The GPC STATUS matrix (sometimes referred to as the computer annunciation matrix (CAM)) on panel O1 lights to indicate failure votes; any time a yellow matrix light is illuminated, the GPC caution and warning light on panel F7 also lights.
- Most DPS control switches are located on panels O6 and C2. Others may be found on panels C3, R11L, F2, F4, F6, and F7.
- CRT displays relevant to the DPS are: GPC/BUS STATUS (SPEC 6), GPC MEMORY (SPEC 0), DPS UTILITY (SPEC 1), and TIME (SPEC 2).

2.6-47



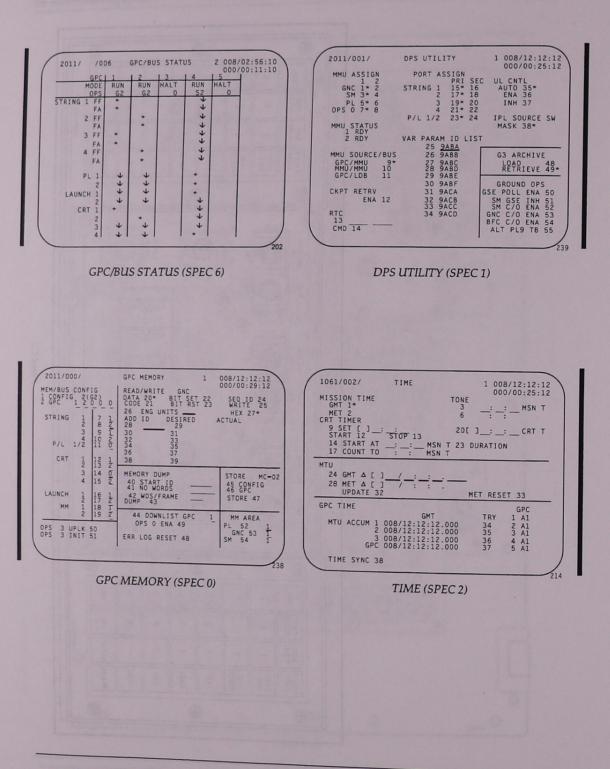
2.6-48

SCOM 1.0 November 1991 2.6-49



SYSTEMS
 Data Processing System

SYSTEMS Data Processing System



SCOM 1.6 August 1996

DPS Rules of Thumb

- Always HALT fail to sync GPCs and reassign their CRTs to good GPCs to avoid inadvertent entries (NBATs/restrings, burn targets, etc.).
- Before OPS transitions and restrings, always verify the appropriate NBAT is what you want it to be; never assume that it is correct! Also check the proper major function and GPC switch configuration.
- Make sure you have the correct memory configuration called up before you start making NBAT changes.
- During OPS transitions, keep "hands off" everything, including all switches and CRT entries.
- Clear the Fault Message line as soon as you have seen the message or use the ACK key to display subsequent messages.
- Post BFS engage, check to ensure that all active PASS GPCs have recognized the engage (both MODE and OUTPUT talkbacks are barberpole). If not, take the offending GPC to HALT (or if this doesn't work, power it OFF) immediately to avoid I/O problems on the flight critical strings.
- It is a very good idea to resume SPECs and DISPs from CRTs when not using them or before going to another major function on that CRT.

- It is important to be able to identify GPC failures. The information you provide will affect Mission Control analysis and its ability to plan for subsequent failures (both DPS and non DPS).
- Always hard assign CRTs (both PASS and BFS) via PASS CRTs (BFS will DK listen). You can cause dual CRT commanders if you try to assign BFS to a CRT that a PASS CRT is still driving.
- Always distribute your CRTs among different GPCs. On orbit, always be sure to minimize SM usage on all CRTs at the same time; if you lose SM, you also lose PASS CRT interface. The same is true if in single GPC GNC OPS, such as Spacelab missions.
- When using the *GPC MODE* switch, always take your hand off between positions. On past missions, there have been problems with the switch being in essentially two positions at the same time. This problem can occur on other orbiter switches too. It is a good idea to always pause slightly in each switch detent to ensure the contacts are made and recognized by the GPCs.
- The CRT SEL switch should always be checked before making a keyboard entry, and data should always be checked on the CRT scratch pad line before it is entered.
- When moding PASS GPCs into the common set (i.e., STBY to RUN), always pause 10 seconds before and after switch throws to avoid a possible fail-to-sync and to ensure proper common set initialization.

2.7 DEDICATED DISPLAY SYSTEMS

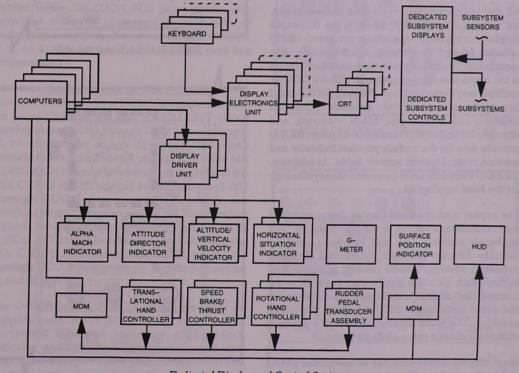
Contents	
Description	. 2.7-1
Display Driver Unit	
Attitude Director Indicator	. 2.7-4
Horizontal Situation Indicator	. 2.7-8
Alpha/Mach Indicator	. 2.7-13
Altitude/Vertical Velocity Indicator	. 2.7-15
Surface Position Indicator	. 2.7-17
Flight Control System Push Button	
Indicators	. 2.7-19
Reaction Control System Command	
Lights	
G-Meter	2.7-20
Head-Up Display	2.7-21

Description

Dedicated displays provide the flight crew with information required to fly the vehicle manually or to monitor automatic flight control system performance. The data on the dedicated displays may be generated by the navigation or flight control system software or more directly by one of the navigation sensors. The dedicated displays are located in front of the commander's and pilot's seats and on the aft flight deck panel by the aft-facing windows.

The dedicated displays are:

- Attitude director indicators on panels F6, F8, and A1U
- Horizontal situation indicators on panels F6 and F8
- Alpha/Mach indicators on panels F6 and F8
- Altitude/vertical velocity indicators on panels F6 and F8
- Surface position indicator on panel F7



Dedicated Display and Control System

- Reaction control system activity lights on panel F6
- G-meter on panel F7
- Head-up display on the glareshield in front of the commander's and pilot's seats.

Not all the dedicated displays are available in every operational sequence or major mode. Their availability is related to the requirements of each flight phase.

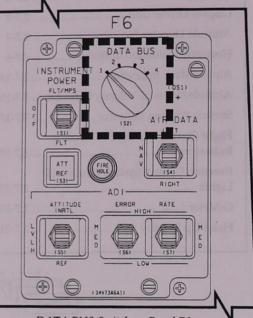
Display Driver Unit

The display driver unit (DDU) is an electronic mechanism that connects the GPCs and the primary flight displays. The display driver unit receives data signals from the computers and decodes them to drive the dedicated displays. The unit also provides dc and ac power for the attitude director indicators and the rotational and translational hand controllers. It contains logic for setting flags on the dedicated instruments for such items as data dropouts and sensor failures.

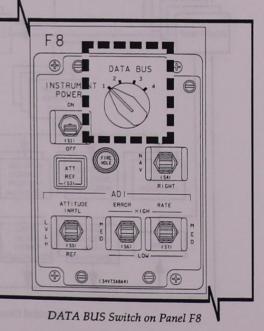
All display parameters, regardless of their origin, are ultimately processed through the dedicated display subsystem operating program (SOP) software (except the g-meter, which is totally selfcontained). The display parameters are then routed to the respective displays through either a DDU or multiplexer/demultiplexer (MDM); DDUs send data to the attitude director indicator, horizontal situation indicator, alpha/Mach indicator, and altitude/vertical velocity indicator displays; MDMs provide data for the surface position indicator and reaction control system activity lights. In addition, the HUD electronic units generate video symbology for the head-up display.

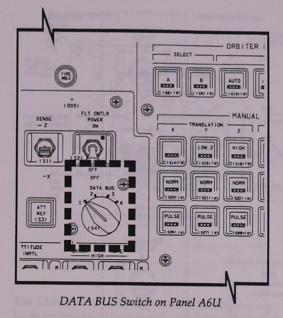
The orbiter contains three display driver units: at the commander's station, at the pilot's station, and at the aft station. One unit interfaces with the attitude director indicator, horizontal situation indicator, altitude/vertical velocity indicator, and alpha/Mach indicator displays on panel F6 at the commander's station, and the second interfaces with the same instruments on panel F8 at the pilot's station. The third interfaces with the attitude director indicator at the aft flight station.

Each display driver unit has an associated DATA BUS rotary switch. The commander's switch is on panel F6, and the pilot's is on panel F8. The switch for the aft flight station is on panel A6U. Switch positions 1, 2, 3, and 4 allow the flight crew to select any one of four forward flight-critical data buses (FC1 through 4) as the data source for that display



DATA BUS Switch on Panel F6

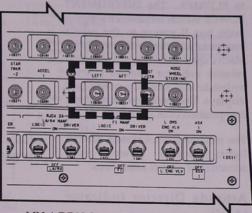




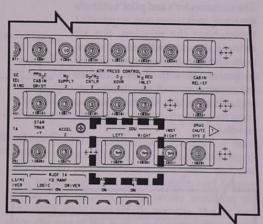
driver unit and its dedicated displays. (Because the flight-critical data buses are assigned to specific orbiter GPCs, the *DATA BUS* select switch also provides a means of assessing the health of individual computers, if they are assigned to FC1, 2, 3, or 4. See Section 2.6 for detailed data bus information.)

The commander's attitude director indicator is powered from the *MN A DDU LEFT* circuit breaker on panel O14 and the *MN B DDU LEFT* circuit breaker on panel O15 through DDU 1 power supply D, which provides ac and dc power. The pilot's attitude director indicator is powered from the *MN B DDU RIGHT* circuit breaker on panel O15 and the *MN C DDU RIGHT* circuit breaker on panel O16 through DDU 2 power supply D, which also provides ac and dc power. The aft flight station attitude director indicator is powered from the *MN A DDU AFT* circuit breaker on panel O14 and the *MN C DDU AFT* circuit breaker on panel O16 through DDU 3 power supply D, which provides ac and dc power.

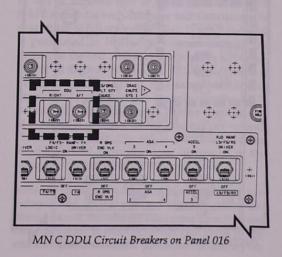
The INSTRUMENT POWER switch on panel F6 supplies main bus A power to the commander's horizontal situation indicator, alpha/Mach indicator, and altitude/vertical velocity indicator displays, the single surface position indicator, and the main propulsion instruments when positioned



MN A DDU Circuit Breakers on Panel 014



MN B DDU Circuit Breakers on Panel 015

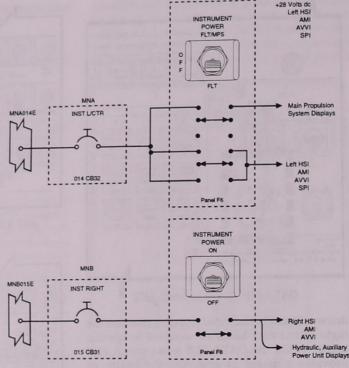


to *FLT/MPS*. The *INSTRUMENT POWER* switch on panel F8 supplies main bus B power to the pilot's horizontal situation indicator, alpha/Mach indicator, and altitude/vertical velocity indicator displays and the hydraulic and auxiliary power unit displays. The switch on panel F8 is a two-position *ON/OFF* switch.

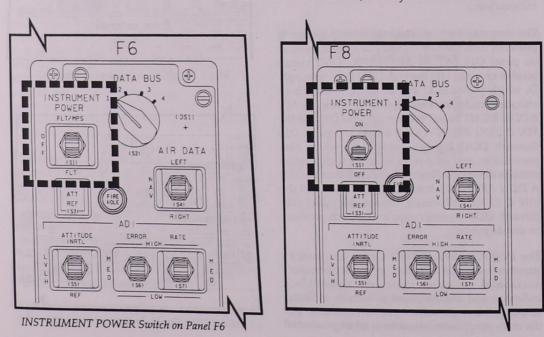
The reaction control system activity lights receive power from annunciator control assemblies.

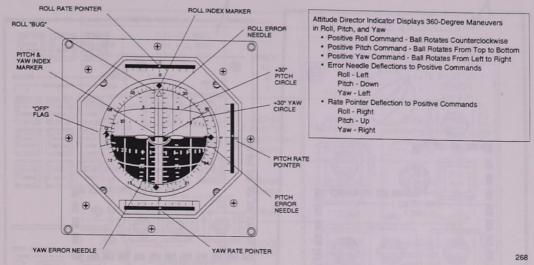
Attitude Director Indicator (ADI)

The commander's and pilot's attitude director indicators are supported throughout the mission; the aft attitude director indicator is active only during orbital operations. The indicators give the crew attitude information as well as attitude rate and attitude errors, which can be read from the position of the pointers and needles.



Power for Alpha/Mach Indicator, Altitude/Vertical Velocity Indicator, Horizontal Situation Indicator, and surface Position Indicator





Attitude Director Indicator

The orbiter's attitude is displayed to the flight crew by an enclosed ball (sometimes called the eight ball) that is gimbaled to represent 3 degrees of freedom. The ball, covered with numbers indicating angle measurements (a 0 is added as the last digit of each), moves in response to software-generated commands to depict the current orbiter attitude in terms of pitch, yaw, and roll.

Each attitude director indicator has a set of switches by which the crew can select the mode or scale of the readout. The commander's switches are located on panel F6, the pilot's on panel F8, and the aft switches on panel A6U.

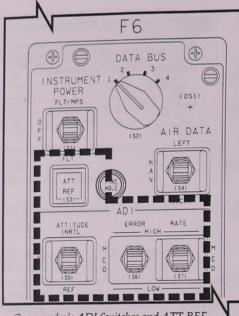
The ADI ATTITUDE switches determine the unit's frame of reference: INRTL (inertial), LVLH (local vertical/local horizontal), and REF (reference). The INRTL position allows the flight crew to view the orbiter's attitude with respect to the inertial reference frame, useful in locating stars. The LVLH position shows the orbiter's attitude from an orbitercentered rotating reference frame with respect to Earth. The REF position is primarily used to see the orbiter's attitude with respect to an inertial reference frame defined when the flight crew last depressed the ATT REF push button above the ADI ATTITUDE switch. The REF position is useful when the crew flies back to a previous attitude or monitors an OMS burn for attitude excursions. The switches on panels F6 and F8 are active during ascent, orbital, and transition flight phases but have no effect

during entry, the latter part of a return to launch site, or when the backup flight system is driving the attitude director indicators. The switch on panel A6U, like the aft attitude director indicator, is operational only in orbit.

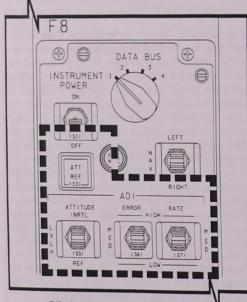
Each attitude director indicator has a set of three rate pointers that provide a continuous readout of vehicle body rotational rates. Roll, pitch, and vaw rates are displayed on the top, right, and bottom pointers respectively. The center mark on the graduated scale next to the pointers shows zero rates; the rest of the marks indicate positive (right or up) or negative (left or down) rates. The ADI RATE switch for each indicator unit determines the magnitude of full-scale deflection. When this switch is positioned to HIGH (the coarsest setting), the pointer at the end of the scale represents a rotation rate of 10 degrees per second. When the switch is positioned to MED, a full-range deflection represents 5 degrees per second. In the LOW position (the finest setting), a pointer at either end of the scale is read at a rate of 1 degree per second. These pointers are "fly to" in the sense that the rotational hand controller must be moved in the same direction as the pointer to null a rate.

Attitude director indicator rate readings are independent of the selected attitude reference. During ascent, the selected rates come directly from the solid rocket booster or orbiter rate gyros to the attitude director indicator processor for display on

2. SYSTEMS 2.7 Dedicated Display Systems

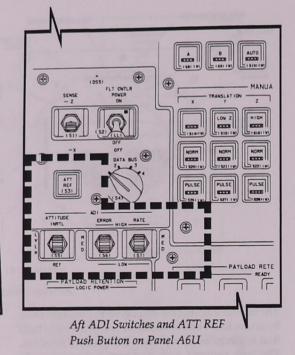


Commander's ADI Switches and ATT REF Push Button on Panel F6



Pilot's ADI Switches and ATT REF Push Button on Panel F8

the rate pointers. During entry, only the pitch rate follows the direct route to the attitude director indicator display. The selected roll and yaw rates



first flow through flight control, where they are processed and output to the attitude director indicator as stability roll and yaw rates. (This transformation is necessary because, in aerodynamic flight, control is achieved about stability axes, which in the cases of roll and yaw differ from body axes.) The rate needles strictly display vehicle rate information in all major modes except while in TAEM (MM 305, 603). For ascent, orbit, and most of entry, the HIGH position represents 10 degrees per second, MED represents 5 degrees per second, and LOW represents 1 degree per second. During TAEM, the ADI rate needles can be used to help fly the proper HAC profile as long as the rate switch is in MED (see table A).

Three yellow needles on each attitude director indicator display vehicle attitude errors. These needles extend in front of the attitude director indicator ball, with roll, pitch, and yaw arranged just as the rate pointers are. Like the rate indicators, each error needle has an arc-shaped background scale with graduation marks that allow the flight crew to read the magnitude of the attitude error. The errors are displayed with respect to the body axis coordinate system and, thus, are independent of the selected reference frame of the attitude display.

MISSION PHASE	ROLL	PITCH	YAW	
Ascent (101-106, 601) On-orbit (201, 202, 801) Transition/entry (301-304, 602) High Medium Low	(deg/s) 10 5 1	(deg/s) 10 5 1	(deg/s) 10 5 1	
TAEM to HAC intercept (305, 603) High Medium Low	10 (deg/s) Time to HAC intercept (10 sec) 1 (deg/s)	10 (deg/s) Altitude error (±5000 feet) 1 (deg/s)	10 (deg/s) Heading error to HAC (5 deg 1 (deg/s)	
HAC intercept to prefinal (305, 603) High Medium Low	10 (deg/s) Stowed 1 (deg/s)	10 (deg/s) Altitude error (±5000 feet) 1 (deg/s)	10 (deg/s) Radial error (±5000 feet) 1 (deg/s)	
Prefinal to 7000 ft (305, 603) High Medium Low	10 (deg/s) Stowed 1 (deg/s)	10 (deg/s) Altitude error (±1000 feet) 1 (deg/s)	10 (deg/s) Crosstrack (±2500 feet) 1 (deg/s)	
7000 ft to landing (305, 603) High Medium Low	(deg/s) 10 5 1	(deg/s) 10 5 1	(deg/s) 10 5 1	

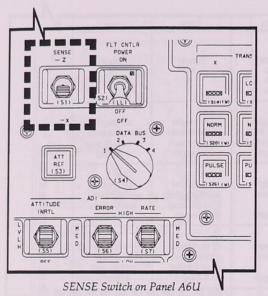
(A) ADI Rate Switch vs. Full Range Deflection

The attitude director indicator error needles are driven by flight control outputs that show the difference between the required and current vehicle attitude. These needles are also "fly to," meaning that the flight crew must maneuver in the direction of the needle to null the needle. For example, if the pitch error needle points down, the flight crew must manually pitch down to null the pitch attitude error. The amount of needle deflection indicating the number of degrees of attitude error depends upon the position of the ADI ERROR RATE switch for each attitude director indicator and the flight phase. For ascent, orbit, and transition, in the HIGH position, the error needles represent 10 degrees, MED represents 5 degrees, and LOW represents 1 degree. For entry, the needles signify different errors in different phases (see table B).

The SENSE switch on panel A6U allows the flight crew to use the aft attitude director indicator, rotational hand controller, and translational hand controller in a minus X or minus Z control axis sense. These two options of the aft attitude director indicator and hand controllers correspond to the visual data out of the aft viewing (negative X) or overhead viewing (negative Z) windows.

MISSION PHASE	ROLL	PITCH	YAW
(101-106, 601) Ascent/ (201, 202, 801) On orbit/ (301, 303) Transition High Medium Low	(Deg) 10 5 1	(Deg) 10 5 1	(Deg) 10 5 1
ENTRY (MM 304, 602) High Medium Low MM 603 IPH = 4,6	(Deg) 25 25 10	(Deg) 10 5 1	(Deg) 2.5 2.5 2.5
TAEM (MM 305, 603) High Medium Low IPH ≠ 4,5 WOWLON = 0	(Deg) 25 25 10	(g's) 1.25 1.25 0.5	(Deg) 2.5 2.5 2.5
WOWLON = 1 Rollout (MM 305, 603) High Medium Low	(Deg) 20 5 1	(Deg/s) 10 5 1	(Deg) 2.5 2.5 2.5

(B) ADI Error Switch vs. Full Range Deflection



Each attitude director indicator has a single flag labeled *OFF* on the left side of the display whenever any attitude drive signal is invalid. There are no flags for the rate and error needles; these indicators are driven out of view when they are invalid.

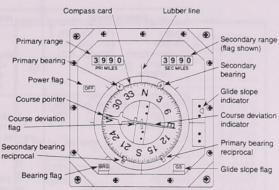
Horizontal Situation Indicator (HSI)

The horizontal situation indicator for the commander (panel F6) and pilot (panel F8) displays a pictorial view of the vehicle's position with respect to various navigation points and shows a visual perspective of certain guidance, navigation, and control parameters, such as direction, distance, and course/glide path deviation. The flight crew uses this information to control or monitor vehicle performance. The horizontal situation indicators are active during the entry and landing and ascent/ return to launch site phases.

Each horizontal situation indicator provides an independent source to compare with ascent and entry guidance, a means of assessing the health of individual navigation aids during entry, and information needed by the flight crew to fly manual ascent, return to launch site, and entry.

HSI Ascent Displays

During ascent major modes 102 and 103 (first and second stage) and return to launch site, the



Horizontal Situation Indicator

horizontal situation indicator provides information about the target insertion orbit. The compass card displays heading with respect to target insertion orbit, and north on the compass card points along the target insertion orbit plane. The heading of the body plus X axis with respect to the target insertion orbit is read at the lubber line.

The course pointer provides the heading of the Earth-relative velocity vector with respect to the target insertion orbit plane. The course deviation indicator deflection indicates the estimated sideslip angle, the angle between the body X axis and the relative velocity vector.

The primary bearing pointer during major modes 102 and 103 (pre-TAL abort) is fixed on the compass card at a predetermined value to provide a turnaround heading in the event of a return to launch site (RTLS) abort. During RTLS major mode 601, or post-TAL abort, MM103, the pointer indicates the heading to the landing site runway. The secondary bearing provides the heading of the inertial velocity vector with respect to the target insertion orbit plane.

HSI Entry Displays

The commander's horizontal situation indicator switches are on panel F6, and the pilot's are on panel F8. The HSI SELECT MODE switch selects the mode: ENTRY, TAEM, or APPROACH. These Area Navigation modes are different from the Guidance phases with virtually identical names (Entry, TAEM, and Approach and Landing). The ENTRY position enables HSI mode auto switching from Entry through Approach. The HSI SELECT

SCOM 1.6 August 1996