ADVANCED C AND D TECHNIQUES AND APPLICATIONS STUDY

FINAL
REPORT

PREPARED FOR:

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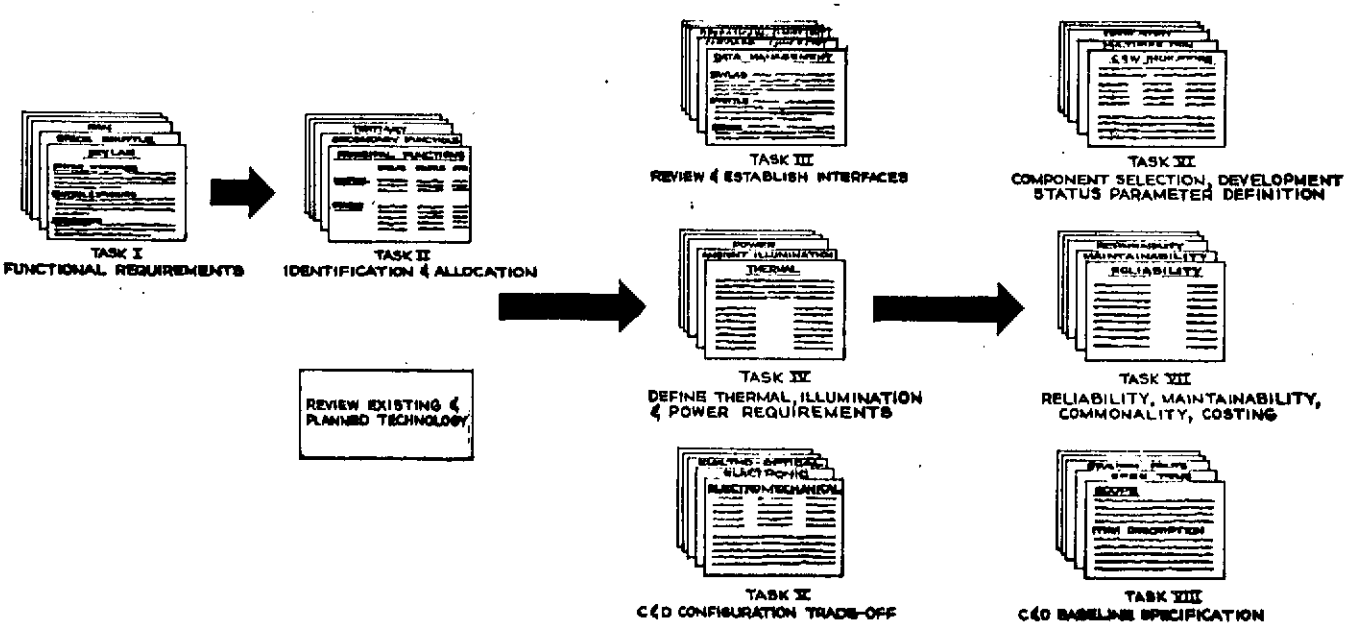

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ABSTRACT

The Final Report documents and summarizes results of a study performed under Contract No. NAS8-28657. A broad base of payload control and display requirements for future space missions have been identified. These requirements have been analyzed to define future C and D device requirements.

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SECTION 1

INTRODUCTION

1.1 SCOPE

This Final Report is prepared by the Navigation and Control Division of The Bendix Corporation, Teterboro, New Jersey for the George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Alabama in accordance with Paragraph VIII, Exhibit A of Contract No. NAS8-28657.

1.2 PURPOSE

The purpose of this study is to define the control and display requirements for future manned space experiments. The role of control and display consoles in future spacecraft is evolving into new and complex areas such as scientific experiment instrumentation, subsystem management, remote manipulation, mission planning and consummables management. The requirements of this new and expanded role must be identified to assure the development and availability of hardware with sufficient flexibility to adapt to changing needs and varied missions. The objective of this study is thus to define the control and display functional requirements of a comprehensive sampling of future manned space experiments, to identify the allocation of the control and display variables, and to analyze the C and D functional requirements to define generic devices necessary for implementation.

1.3 APPROACH

A broad base of payload control and display functional requirements necessary to perform future manned space experiments has been developed. These samples chosen encompass experiments and instrumentation in the following disciplines.

Astronomy	Life Sciences
Earth Resources	Advanced Technology
Physics	Support Instrumentation

This data, presented in Section 2 of this report, provides in essence a description of C and D functions necessary to conduct the scientific experiments considered.

Section 3 of this report, using a family of generic control and display devices, selects which generic device is appropriate for each requirement identified in Section 2. For example, in the Dual White Light Coronagraph experiment it was determine that one of the C and D functions is "Alignment Mode Select". In Section 3 a lasting switch is selected to control this function and correspondingly panel nomenclature is adequate to display the status. A summary of all device selections is given in Table 3-7.

To gain further insight into device requirements, device preference is considered using only dedicated controls and displays in Section 4. Thus, Sections 3 and 4 identify a family of generic devices which satisfy the requirements identified in Section 2.

Finally, it is possible to conclude from this analysis C and D device requirements, a generic family of devices, and certain console or workstation requirements. These conclusions are presented in Section 5.

SECTION 2

FUNCTIONAL REQUIREMENTS AND ALLOCATION ANALYSIS

2.1 GENERAL

This section develops a broad base of payload control and display functional requirements necessary to perform future manned space experiments. The experiment selection is based on projected payloads as defined in the Research Applications Module (RAM) Phase B Study, the Astronomy Sortie Mission (ASM) Phase A Definition Study and the Reference Earth Orbital Research and Applications Investigations (Blue Book) documents. Where experiment similarity existed, the requirements identified and implemented in the Skylab program were reviewed and utilized as aids in the definition of advanced payload C and D requirements. The samples chosen encompass Astronomy (ASM and Skylab), Earth Resources (RAM, Skylab and Blue Book), Physics (RAM and Blue Book), Life Sciences (RAM and Blue Book), Advanced Technology (Blue Book) disciplines, and support instrumentation. While not all instruments within a particular discipline are included in this report, those included exhibit functional requirements which represent the significant demands of the majority of the instruments and experiments reviewed. Additionally a general overview of subsystems C and D requirements is provided. These subsystems include: Attitude and Pointing Control (ASM, Skylab); Data Management (RAM, Skylab); Environmental Control (RAM, Skylab); and Electrical Power (RAM).

The experiment functional requirements, the control and display variables and significant characteristics are presented in tabular form. A functional allocation analysis has been performed based upon qualitative application to each experiment of the following criteria: criticality, frequency of use, resolution, response time and dwell time.

The control and display functional requirements for the five scientific disciplines investigated are listed in Tables 2-1 through 2-5 and subsystems in Tables 2-6 thru 2-9. The functional requirements and the C and D functions required are listed in the first three columns of the tables. The next five columns list the criteria and ratings upon which the functional allocation (column nine) has been based. Significant characteristics, which have been established, are presented in the Remarks/Notes column.

The function allocation was based upon qualitative application to each experiment of the following criteria: criticality, frequency of use, resolution, response time and dwell time. The criticality assignment is a measure of the impact upon the particular instrument of operator delay or failure to interface with the elements satisfying the C and D functional requirements. Four levels of criticality were defined and coded as follows:

C - Catastrophic, results in injury or loss of life

H - High, results in equipment damage

M - Medium, results in loss of or degradation of data

L - Low, impacts housekeeping function (no equipment degradation or hazard condition)

Frequency of use presents an assessment of the relative number of operator interactions with a particular control and display within the group of C and D defined for an individual instrument/subsystem. The coding used in the tables is defined as follows:

H - High, more than once per data cycle

M - Moderate, about once per data cycle

L - Low, infrequently used - often initial setup

Resolution is a measure of the degree of accuracy required of the control and display elements to satisfy the functional requirement. Resolution consideration has down stream impact on the device selection, presentation format and panel layout. The coding used in the tables is as follows:

H - High, numeric readout required or greater than 1% FS

M - Moderate, about 1% FS

L - Low, gross or coarse

D - Discrete (Status)

Response is assessed in terms of the degree of rapidity with which the operator is required to address the particular C and D function in response to instrument signals. Operator response was listed as follows:

H - High, immediate response required

M - Moderate operator response required, functions are primarily associated with instrument setup

L - Low, operator response not time critical

Dwell time is an estimate of the amount of time the operator interacts with the C and D during each usage as follows:

H - High, continuous operator interaction during instrument/subsystem operation

M - Medium, extensive operator time required each interaction with the C and D

L - Low, brief operator time required each C and D interaction

The resulting allocation of C and D functions into three categories, Primary (P), Secondary (S) and Tertiary (T), constitutes functional grouping based upon operator need. The primary C and D functions are required as a concurrent group to operate the subsystem or instrument in its normal modes and to enable recognition and corrective action to be taken in the event of a high criticality malfunction. The secondary C and D functions are required on an individual basis to provide a specific added capability or backup capability in support of the primary group. The tertiary C and D functions have low

frequencies of use and minimum interplay with the primary and secondary groups. Whereas the primary and secondary groups are associated with instrument operation in the data acquisition modes, the tertiary group provides housekeeping functions principally.

2.2 MISSION PLANNING C AND D

Onboard mission planning for advanced manned spacecraft flights will tend towards greater autonomy, with emphasis on crew participation. It is considered that a major objective of mission planning is to predict and provide for those activities which contribute to experimental data acquisition. Thus non-experiment systems, e.g. life support and electrical power, must be included in mission planning due to their direct support of the primary mission objective-experimentation. These systems have obvious criticality with respect to crew safety and therefore are prominent in the decision process to continue or terminate the mission, to initiate orbital maneuvers, and to enter particular data acquisition modes.

Use of a computer oriented onboard Data Management System (DMS) will permit the crew to have access to historical information, stored in computer memory, and to predictions with respect to the attainment of overall mission goals. A check list, displaying mission/experiment objectives completed and the priorities of those remaining is essential to onboard experimentation planning; The status of consumables and the projected rate of consumption as a function of mode of operation and vehicle attitude are also required.

The C and D requirements defined in the tables of this document allow the crew to assess present status. These displays include ECS, EPS and experiment consumables, CMG momentum storage and TACS pressure. Historical displays such as activity history plotter, tape recorders and log books are also provided. These displays provide the basic information inputs to the crew to aid in their participation in mission planning.

2.3 MATRIX TABLES

The functional requirements and allocation analysis of the comprehensive sampling described previously is presented in Tables 2-1 through 2-9. The experiment and instrumentation categories covered are as follows.

TABLE 2-1 ASTRONOMY GROUP

Photoheligraph
Dual White Light Coronagraphs
X-Ray Telexcope
XUV Spectroheliograph
IR Telescope
Stratoscope III
High Energy Arrays

TABLE 2-2 EARTH OBSERVATION GROUP

Cameras
Scanners
Microwave Radar
Multispectral Radiometer
Altimeter/Scatterometer/Radiometer
Multispectral Spectrometer
Polarimeter
Optical Radar
Observation Telescopes

TABLE 2-3 PHYSICS GROUP

Proton Sensors
EM Radiation Detectors/Transmitters
Ambient Measurement Instruments
Particle Sensors

TABLE 2-4 LIFE SCIENCE GROUP

Vertebrate Cage Module
Biomedical Measurements Unit
Life Support Test Unit

TABLE 2-5 ADVANCED TECHNOLOGY GROUP

Thermal Control Coating Refurbishment
Oxygen Recovery/Biowaster Resistojet
Liquid/Vapor Interface Stability

TABLE 2-6 EXPERIMENT ATTITUDE AND POINTING CONTROL

TABLE 2-7 DATA MANAGEMENT SUBSYSTEM

TABLE 2-8 ENVIRONMENTAL CONTROL SUBSYSTEM

TABLE 2-9 ELECTRICAL POWER SUBSYSTEM

A portion of Table 2-1 is given below as a typical example. In this case the control and display requirements for the Photoheliograph experiments are considered.

Table 2-1. Astronomy Group: Photoheliograph

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION
TELESCOPE								
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T
APERTURE DOOR	OPEN/CLOSE	STATUS					L	S
LAUNCH LOC								

The function "Telescope Main Power ON/OFF" has a criticality of M (Medium) since improper operation would result in loss of data. Note that this would not cause injury or loss of life (C) or equipment damage (H). The frequency of use is low (L) since activation is only once per mission. Resolution is obviously discrete (D) and operator response is not time related (L). Operator interaction (dwell time) is low or brief limited to only the time necessary for switch activation and confirmation of power status. Allocation is tertiary due to the combination of low frequency of use, resolution , dwell time, response and that the function is not critical to life or equipment.

Table 2-1. Astronomy Group: Photoheliograph

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
ELESCOPE									
AIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
ERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	M	L	S	
ENCH LOCK SYSTEM	LOCK/UNLOCK	STATUS	H	L	D	L	L	T	
ERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
ERMAL MONITORING	SELECT (1-12 TYP)	TEMPERATURE MEASUREMENTS	L	L	M	L	L	T	
CUS CONTROL:									
MODE SELECT	AUTO/MAN	STATUS	M	L	D	L	L	T	Auto focus failure alert required. Manual focus controls and displays provides backup to auto system.
MANUAL FOCUS	IN/OUT	NULL DETECTOR	M	L	H	M	M	T	0.1% resolution required.
IGNMENT	TRANSLATE/ROTATE X/Y AXES	TWO AXIS NULL DETECTION	M	L	M	M	M	S	1% resolution required.
AGE MOTION COMPENSATION OVERRIDE	NORMAL/RESET	STATUS	M	M	D	M	L	T	
GH VOLTAGE		STATUS	M	M	D	M	L	P	
	1-10	STATUS	M	H	D	M	L	P	
ELD MONITOR	(SELECT)	VIDEO	M	H	H	N/A	M	P	1000 line resolution required for simultaneous camera operation.
STER DATA ACQUISITION	START/STOP	READY/OPR	M	M	D	H	L	P	
	ON/OFF	STATUS	M	L	D	L	L	T	
MERA POWER	ON/OFF	STATUS	M	H	D	M	L	P	
DE CONTROL	SELECT 1-4	STATUS	M	H	D	M	L	P	
TA ACQUISITION	START/SET/STOP	READY/SET/OPR	M	H	D	H	L	P	
AME RATE	SELECT 1-3	STATUS	M	H	D	M	L	P	
AMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	1 count in 20000.

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: Photoheliograph (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
BROADBAND CAMERA									
CAMERA POWER	ON/OFF	STATUS	M	H	D	M	L	P	
MODE CONTROL	SELECT 1-6	STATUS	M	H	D	M	L	P	
DATA ACQUISITION	START/SET/STOP	READY/SET/OPR	M	H	D	H	L	P	
FRAME RATE	SELECT 1-3	STATUS	M	H	D	M	L	P	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 20,000.
DUAL RANGE SPECTROGRAPH									
CAMERA POWER	ON/OFF	STATUS	M	H	D	M	L	P	
MODE CONTROL	SELECT 1-4	STATUS	M	H	D	M	L	P	
DATA ACQUISITION	START/STOP	READY/OPR	M	H	D	H	L	P	
FRAME RATE	SELECT 1-3	STATUS	M	H	D	M	L	P	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 2,000.
GRATING SELECT	IN/OUT	STATUS	M	H	D	M	L	P	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: Dual White Light Coronagraphs (Inner and Outer Coronagraphs Provided)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
MAIN POWER	ON/STBY/OFF	STATUS	M	L	D	L	L	T	
THERMAL POWER	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL MONITORING	SELECT (1-7 TYP)	TEMPERATURE MEASUREMENTS	L	L	M	L	L	T	
MIRROR POSITION	SELECT TV/CAMERA	STATUS	H	H	D	M	L	P	
GIMBAL POINTING MANUAL CONTROL	SELECT MAN/AUTO	STATUS	M	L	D	L	L	T	Initial target acquisition and backup to auto alignment scheme. Dual range null detector required. Ranges: ±300 arc sec and ±30 arc sec.
	DUAL AXIS ROTATION CONTROL	TWO AXIS NULL DETECTION	M	L	M	M	M	T	
SCALE SELECT	COARSE/FINE	STATUS	M	L	D	M	L	T	
INTERNAL ALIGNMENT MANUAL OVERRIDE	SELECT AUTO/MAN	STATUS	M	L	D	L	L	T	Backup to auto centering system.
	DUAL AXIS TRANSLATION CONTROL	TWO AXIS NULL DETECTION	M	L	M	M	M	T	Range ±30 arc sec.
VIDICON HIGH VOLTAGE	ON/OFF	STATUS	L	H	D	M	L	P	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 10,000.
TARGET MONITOR	(SELECT)	VIDEO	L	H	M	M	M	P	Monochromatic display. Characteristics as for Skylab ATM TV monitors.
APERTURE DOOR	OPEN/CLOSE	STATUS	H	M	D	M	L	S	Door closure normally controlled by instrument. Door open alert status required.
APERTURE DOOR AUTO CLOSE	NORMAL/OVERRIDE	STATUS	L	L	D	M	L	S	Overrides normal automatic control of doors. Manual close command required.
MODE CONTROL	SELECT 1-5 (TYP)	STATUS	M	H	D	M	L	P	
LAUNCH LOCK SYSTEM	LOCK/UNLOCK	STATUS	H	L	D	L	L	T	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: X-Ray Telescope

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
GENERAL									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
APERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	M	L	S	
LAUNCH LOCK SYSTEM	LOCK/UNLOCK	STATUS	H	L	D	L	L	T	
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL MONITOR	SELECT (1-12 TYP)	TEMPERATURE MEASUREMENTS	L	L	M	L	L	T	
FILTER SELECT	1-6	STATUS	M	H	D	M	L	P	
INSTRUMENT SELECT	IMAGE SYS/SPECT/ PROPORTIONAL COUNTER	STATUS	M	H	D	M	L	P	
IMAGING SYSTEM									
FRAME RATE	SELECT 1-4	STATUS	M	H	D	M	L	P	
EXPOSURE RANGE	SELECT 1-6	STATUS	M	H	D	M	L	P	
HIGH VOLTAGE	ON/OFF	STATUS	M	H	D	M	L	P	
GRATING SELECT	IN/OUT	STATUS	M	H	D	M	L	P	
DATA ACQUISITION	START/STOP	READY/OPR	M	H	D	H	L	P	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 10,000.
SPECTROMETER									
DATA ACQUISITION	START/STOP	READY/OPR	M	H	D	H	L	P	
SLIT SIZE	SELECT 1-4	STATUS	M	H	D	M	L	P	
SCAN RANGE	SELECT 1-10	STATUS	M	H	D	M	M	P	
SCAN RATE	SELECT 1-4	STATUS	M	H	D	M	L	P	
SCAN STEP SIZE	SELECT 1-6	STATUS	M	H	D	M	L	P	
SCAN SEQUENCE	SELECT 1-3	STATUS	M	H	D	M	L	P	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: X-Ray Telescope (Continued)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
SCANS COMPLETE	-	SCAN COUNT	L	H	H	N/A	L	P	
CRYSTAL POSITION	UP/DOWN	LINE COUNT	M	H	H	M	M	P	Resolution 1 count in 1,000.
CALIBRATION	INITIATE	STATUS	L	M	D	L	L	S	
SPECTRUM MONITOR	RECORD/REVIEW	ANALOG RECORD	L	H	M	L	M	P	CRT display or strip chart display of counts detected as function of crystal position (energy).
DETECTOR RATE		COUNT RATE	L	H	M	M	M	P	1% resolution required.
PROPORTIONAL COUNTER SYSTEM									
HIGH VOLTAGE	ON/OFF	STATUS	M	H	D	M	L	P	
DATA ACQUISITION	START/STOP	READY/OPR	M	H	D	H	L	P	
CALIBRATION	INITIATE	STATUS	L	M	D	L	L	S	
PC SPECTRUM	RECORD/REVIEW	ANALOG RECORD	L	H	M	L	M	P	
DETECTOR RATE	-	COUNT RATE	L	H	H	M	M	P	1% resolution required.
APERTURE MODE	AUTO/MANUAL	STATUS	L	L	D	H	L	S	Manual aperture control provided as backup to automatic system. Excessive PC count rate alert required to cue operator to possible auto system malfunction.
	INCREASE/DECREASE	APERTURE POSITION	L	L	D	H	L	S	
PULSE HEIGHT ANALYZER GAIN	SELECT 1-32	STATUS	L	L	TBD	L	M	S	Used during calibration in conjunction with PC spectrum display.
FILTER HEATER	ON/OFF	STATUS	L	L	D	L	L	T	
HIGH VOLTAGE	ON/OFF	STATUS	L	H	D	M	L	P	
FIELD MONITOR	(SELECT)	VIDEO	L	H	M	N/A	M	P	Monochromatic display. Characteristics as for Skylab ATM TV monitor.
PHOTOMULTIPLIER DETECTOR									
HIGH VOLTAGE	ON/OFF	STATUS	M	H	D	M	L	P	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: X-Ray Telescope (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
TECTOR RATE	-	COUNT RATE	L	H	H	M	M	P	1% resolution required.
SCRIMINATOR LEVEL	SELECT 1-25	STATUS	M	M	D	M	L	P	
ARE ALERT	ENABLE/INHIBIT	STATUS	L	H	D	L	L	P	
		ALERT STATUS	L	H	D	H	L	P	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: XUV Spectroheliograph

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
IN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
ERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	M	L	S	
UNCH LOCKS	LOCK/UNLOCK	STATUS	H	L	D	L	L	T	
ERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
ERMAL MONITOR	SELECT (1-12 TYP)	TEMPERATURE MEASUREMENTS	L	L	M	L	L	T	
DE CONTROL	SELECT 1-3	STATUS	M	H	D	M	L	P	
VELENGTH SELECT	LONG/NORMAL/SHORT	STATUS	M	H	D	M	L	P	
POSURE DURATION	LONG/NORMAL/SHORT	STATUS	M	H	D	M	L	P	
ARE MODE	ENABLE/INHIBIT	ENALBE/INHIBIT/ACTIVE	M	M	D	L	L	S	
TA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
AMES REMAINING		FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 2,000.

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: IR Telescope

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
TELESCOPE									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
APERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	M	L	S	
LAUNCH LOCK SYSTEM	LOCK/UNLOCK	STATUS	H	L	D	L	L	T	
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL MONITOR	SELECT (1-12 TYP)	TEMPERATURE MEASUREMENTS	L	L	M	L	L	T	
FOCUS	IN/OUT	NULL DETECTOR	M	M	M	M	M	S	1% resolution required.
ALIGNMENT:	X/Y AXES	TWO AXIS NULL DETECTOR	M	M	M	M	M	S	1% resolution required.
TRANSLATE									
ROTATE									
INSTRUMENT SELECT	RADIOMETER/ SPECTROMETER	STATUS	M	H	D	M	L	P	
HIGH VOLTAGE	ON/OFF	STATUS	M	H	D	M	L	P	
FIELD MONITOR	-	VIDEO	M	H	M	M	M	P	Monochromatic display. Characteristics as Skylab ATM TV monitor.
RADIOMETER									
DETECTOR ELEMENT SELECT	SELECT 1-21	STATUS	M	L	D	L	L	T	1% resolution required.
DETECTOR ELEMENT GAIN	ANALOG	GAIN MONITOR	M	L	M	L	M	T	
DETECTOR ELEMENT BIAS	ANALOG	BIAS MONITOR	M	L	M	L	M	T	1% resolution required.
DETECTOR TEMPERATURE	ANALOG	TEMPERATURE MONITOR	M	M	M	L	M	T	1% resolution required.
DETECTOR SELECT	SELECT 1-3	STATUS	M	H	D	M	L	P	
MODE	SELECT 1-6	STATUS	M	H	D	M	L	P	
CRYOGEN COOLING	ON/OFF	STATUS	M	L	D	L	L	T	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: IR Telescope (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
CALIBRATION	INITIATE	STATUS	M	M	D	M	L	S	
DATA ACQUISITION	START/STOP	READY/OPR	M	H	D	H	L	P	
SPECTROMETER									
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
DETECTOR GAIN	ANALOG	GAIN MONITOR	M	L	M	L	M	T	1% resolution required.
DETECTOR BIAS	ANALOG	BIAS MONITOR	M	L	M	L	M	T	1% resolution required.
DETECTOR TEMPERATURE	ANALOG	TEMPERATURE MONITOR	M	M	M	L	M	T	1% resolution required.
DETECTOR SELECT	SELECT 1-3	STATUS	M	H	D	M	L	P	
CALIBRATION	INITIATE	STATUS	M	M	D	M	L	S	
DATA ACQUISITION	START/STOP	STATUS	M	H	D	H	L	P	
SCAN RANGE	SELECT 1-6	STATUS	M	H	D	M	L	P	
SCAN RATE	ANALOG	RATE MONITOR	M	H	M	M	M	P	1% resolution required.
ZERO OFFSET	ANALOG	SCAN RANGE ZERO MONITOR	M	H	M	M	M	P	1% resolution required.

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: Stratoscope III

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
TELESCOPE									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
APERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	M	L	S	
LAUNCH LOCK SYSTEM	LOCK/UNLOCK	STATUS	H	L	D	L	L	T	
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL MONITOR	SELECT (1-12 TYP)	TEMPERATURE MEASUREMENTS	L	L	M	L	L	T	
FILTER SELECT	SELECT 1-6	STATUS	M	H	D	M	L	P	
ALIGNMENT	TRANSLATE/ROTATE X/Y AXES	TWO AXIS NULL DETECTOR	M	L	M	M	M	S	1% resolution required.
FOCUS	IN/OUT	NULL DETECTOR	M	M	H	M	M	S	0.5% resolution required.
HIGH VOLTAGE	ON/OFF	STATUS	M	H	D	M	L	P	
FIELD MONITOR	(SELECT)	VIDEO	M	H	H	N/A	L	P	1,000 line resolution. Monochromatic display.
DETECTOR SELECT	SELECT 1-9	STATUS	M	H	D	M	L	P	
FIELD CAMERA (4 PROVIDED)									Four field cameras may operate simultaneously or individually.
CAMERA POWER	ON/OFF	STATUS	M	H	D	M	M	P	
EXPOSURE DURATION	SELECT 1-6 (TYP)	STATUS	M	H	D	M	M	P	
MODE SELECT	SELECT 1-6	STATUS	M	H	D	M	M	P	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	M	P	Resolution 1 count in 20,000.
DATA ACQUISITION	START/STOP	READY/OPR	M	H	D	H	M	P	
SPECTROGRAPHS (4 PROVIDED)									Imaging, high speed, echelle, and near IR spectrographs provided.
INSTRUMENT POWER	ON/OFF	STATUS	M	H	D	M	M	P	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: Stratoscope III (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
EXPOSURE DURATION	SELECT 1-6 (TYP)	STATUS	M	H	D	M	L	P	
SLIT SELECT	SELECT 1-4	STATUS	M	H	D	M	L	P	Imaging spectrograph only.
GRATING SELECT	SELECT 1-2	STATUS	M	H	D	M	L	P	
MODE SELECT	SELECT 1-6	STATUS	M	H	D	M	L	P	
GRATING POSITION	STEP UP/DOWN	STEP COUNT	M	H	H	M	M	P	Imaging spectrograph only. Resolution 1 count in 6,000.
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	S	
DATA ACQUISITION	START/STOP	READY/OPR	M	H	D	H	L	P	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 2,000.
SPECTROMETERS (2 PROVIDED)									Lyman and middle IR spectrometers are provided.
INSTRUMENT POWER	ON/OFF	STATUS	M	H	D	M	L	P	
MODE SELECT	SELECT 1-6 (TYP)	STATUS	M	H	D	M	L	P	
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	S	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
POLARIMETERS (2 PROVIDED)									Wollaston and reflective polarimeters are provided.
INSTRUMENT POWER	ON/OFF	STATUS	M	H	D	M	L	P	
MODE SELECT	SELECT 1-6 (TYP)	STATUS	M	H	D	M	L	P	
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	S	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: High Energy Arrays

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
LARGE AREA X-RAY DETECTOR									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
HIGH VOLTAGE	ON/OFF 1-6	STATUS	M	L	D	L	L	T	
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	M	L	P	
DETECTOR RATE	SELECT 1-6	COUNT RATE	L	M	M	M	M	P	2% resolution required. Range: 10^2 to 10^5 counts/second.
PULSE HEIGHT ANALYZER MONITOR		SPECTRUM OF SOURCE	L	M	TBD	L	L	S	32 channels per detector module. Auxiliary calibration method. Video, oscilloscope or X-Y plotter can satisfy display requirement.
GAS PURGE	AIRLOCK OPEN/CLOSE	STATUS	H	L	D	L	L	T	
SAMPLING DURATION	SELECT 1-10	STATUS	M	M	D	M	L	P	
LOW BACKGROUND GAMMA RAY DETECTOR									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
HIGH VOLTAGE	ON/OFF 1-30	STATUS	M	L	D	L	L	T	30 high voltage supplies requiring individual activation in prescribed sequence.
	SELECT 1-128 LEVELS	STATUS	M	L	D	L	L	S	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	M	L	P	
DETECTOR RATE	SELECT 1-4	COUNT RATE	L	M	H	M	M	P	2% resolution required. Range: 1 thru 10^3 counts/second.
PULSE HEIGHT ANALYZER MONITOR		SOURCE SPECTRUM	L	M	TBD	L	L	S	128 channels. Auxiliary calibration method. Video, oscilloscope or X-Y plotter can satisfy display requirement.
DISCRIMINATOR CONTROL	LEVEL 1-16	STATUS	M	L	D	L	L	T	
LARGE MODULATION COLLIMATOR									

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: High Energy Arrays (Continued)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
HIGH VOLTAGE	ON/OFF 1-6	STATUS	M	L	D	L	L	T	
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	M	L	P	
RATE MONITOR	SELECT DETECTOR MODULE 1-6	DETECTOR COUNT RATE	L	M	M	M	M	P	Range 10 to 10^4 counts/second. 2% resolution required.
GAS PURGE	AIRLOCK OPEN/CLOSE	STATUS	H	L	D	L	L	T	
SAMPLING DURATION	SELECT 1-10	STATUS	M	H	D	M	L	P	
SCAN RATE	SELECT 1-6	STATUS	M	H	D	M	L	P	
SCAN RANGE	SELECT 1-6	STATUS	M	H	D	M	L	P	
PULSE HEIGHT ANALYZER GAIN	SELECT 1-32	PULSE HEIGHT	M	M	M	M	M	S	Voltage readout, 5% resolution adequate. Used during calibration sequence.
GAMMA RAY SPECTROMETER									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
HIGH VOLTAGE	ON/OFF (14)	STATUS	M	L	D	L	L	T	14 high voltage supplies requiring individual activation in prescribed sequence.
CALIBRATION	SOURCE SELECT 1-4	STATUS	M	L	D	L	L	T	
	INITIATE	STATUS							
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	M	L	P	
DETECTOR SPECTRUM		SOURCE SPECTRUM	L	M	H	L	L	S	1,024 channels. Auxiliary calibration method. Video, oscilloscope or X-Y plotter can satisfy display requirement.
WIDE COVERAGE X-RAY DETECTOR									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: High Energy Arrays (Continued)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
HIGH VOLTAGE	ON/OFF (154)	STATUS	M	L	D	L	L	T	Sequence of activation not defined. Individual off controls required. Auto malfunction detection and shutdown required.
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	L	D	L	L	T	
THRESHOLD ADJUST	SELECT 1-32	STATUS	M	L	D	L	M	S	Required for each of 154 detectors.
X-RAY ALERT		STATUS	M	H	D	H	L	P	Master alert required indicating one or more detectors have exceeded threshold setting.
		SOURCE COORDINATES	M	L	H	M	M	S	Coordinates of alert source. Situation display is an alternative, allowing observer to direct high resolution arrays to source via joy stick type pointing controller.
FLAT CRYSTAL SPECTROMETER									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
HIGH VOLTAGE	ON/OFF (3)	STATUS	M	L	D	L	L	T	
MODE SELECT	SELECT 1-6	STATUS	M	M	D	M	L	S	
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	M	L	P	
RATE MONITOR	SELECT 1-3	COUNT RATE	L	M	M	M	M	P	Range 1 to 10^4 counts/second. Resolution 2%.
SPECTRUM MONITOR	RECORD/REVIEW	SOURCE SPECTRUM	L	M	M	L	L	S	CRT, oscilloscope or strip chart display of counts detected as a function of crystal powition (energy).
SCAN RATE	SELECT 1-4	STATUS	M	M	D	M	M	S	
SCAN RANGE	SELECT 1-100	STATUS	M	M	D	M	L	S	
ASPECT SYSTEM POWER	ON/OFF	STATUS	M	L	D	L	L	T	
SOURCE CENTERING (GIMBAL POINTING)	DUAL AXIS ROTATION CONTROL	TWO AXIS NULL DETECTION	M	L	M	M	M	T	Used when acquiring source. Control may be part of main pointing system.

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-1. Astronomy Group: High Energy Arrays (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
NARROW BAND SPECTROMETER/ POLARIMETER									
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
HIGH VOLTAGE	ON/OFF (9)	STATUS	M	L	D	L	L	T	
CALIBRATION	INITIATE	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	M	L	P	
RATE MONITOR	SELECT 1-9	COUNT RATE	L	M	M	M	M	P	Range 1 to 10^4 counts/second
SAMPLING DURATION	SELECT 1-10	STATUS	M	M	D	M	L	P	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Cameras

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
METRIC CAMERA									
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 10,000.
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
CAMERA SPEED	SELECT 1-4	STATUS	M	H	D	M	L	P	
F STOP	SELECT 1-7	STATUS	M	H	D	M	L	P	
IMAGE MOTION COMP	ON/OFF	STATUS	M	M	D	L	L	T	
TEMPERATURE MONITOR	SELECT 1-3	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL SHIELD	OPEN/CLOSE	STATUS	M	M	D	H	L	S	
STELLAR CAMERA									
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
FRAMES REMAINING	SELECT 1-4	FRAME COUNT	L	H	H	N/A	L	P	Resoltuion 1 count in 10,000.
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
CAMERA SPEED	SELECT 1-4	STATUS	M	H	D	M	L	P	
TEMPERATURE MONITOR	SELECT 1-12	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL SHIELD	OPEN/CLOSE	STATUS	M	M	D	H	L	S	
CAMERA(S) SELECT	SELECT 1-6	PAIR SELECTION	M	H	D	M	L	T	
MULTISPECTRAL CAMERA									
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
FRAMES REMAINING	SELECT 1-6	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 1,000.

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Cameras (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
CAMERA SPEED	SELECT 1-4	STATUS	M	H	D	M	L	P	
F STOP	SELECT 1-7	STATUS	M	H	D	M	L	P	
IMAGE MOTION COMP	ON/OFF	STATUS	M	M	D	L	L	T	
TEMPERATURE MONITOR	SELECT 1-18	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL SHIELD	OPEN/CLOSE	STATUS	M	M	D	H	L	S	
FILTER SELECT	SELECT 1-3	STATUS	M	H	D	M	L	P	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Scanners

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
MULTISPECTRAL SCANNER									
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
IMAGE MOTION COMP	ON/OFF	STATUS	M	M	D	L	L	T	
DETECTOR CURRENT	SELECT 1-10	STATUS	M	M	D	M	L	P	
POWER SUPPLY VOLTAGE	SELECT 1-10	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 300 V, resolution .3 mV.
TEMPERATURE MONITOR	SELECT 1-15	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
THERMAL SHIELD	OPEN/CLOSE	STATUS	M	M	D	H	L	S	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
DETECTOR OUTPUT	SELECT 1-10	INTENSITY MEASUREMENT	M	M	H	L	L	P	
CALIBRATION	-	IN/OUT	M	M	M	L	L	T	
PASSIVE MICROWAVE SCANNER									
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
CALIBRATION MODE	AUTO/MAN	STATUS	L	M	D	L	L	T	
MANUAL CALIBRATION RATE	RATE HIGH/LOW	STATUS	M	M	D	L	L	T	
POWER SUPPLY VOLTAGE	SELECT 1-4	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 5 - 12 V, resolution 5 mV.
TEMPERATURE MONITOR	SELECT 1-2	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
THERMAL CONTROL	ON/OFF	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
ANTENNA STEERING COMMAND	UP/DOWN/L/R	X, Y COORDINATES	M	H	H	M	M	P	Range 90°, resolution 0.5°.

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Microwave Radar

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
WER	ON/OFF	STATUS	M	L	D	L	L	T	
AGE MOTION COMP	ON/OFF	STATUS	M	M	D	L	L	T	Resolution 1%.
WER SUPPLY VOLTAGE	SELECT 1-5	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 12 V - 1 kV, resolution 0.5%.
MPERATURE MONITOR	SELECT 1-2	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
NGE SWEEP SELECT	SELECT 1-3	STATUS	M	H	D	L	L	P	
IN CONTROL	CONTINUOUS	POSITION	L	H	H	M	M	S	
TENNA TILT	SELECT 1-10	POSITION READOUT	M	H	D	M	M	P	
CEIVER SENSITIVITY	-	S/N READOUT	L	M	D	L	L	P	
ANSMITTER POWER	-	POWER MEASUREMENT	M	M	H	L	L	P	Resolution 1%.
DAR DISPLAY	VIDEO GAIN	"A" SCOPE	M	H	M	M	L	P	
TA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	

- Catastrophic
- High
- Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Multispectral Radiometer

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
POWER SUPPLY VOLTAGE MONITOR	SELECT 1-5	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 12 - 300 V, resolution 1%.
CALIBRATION	ON/OFF	STATUS	M	M	D	L	L	T	
MIRROR ANGLE POINT	RATE	POSITION	M	H	H	M	M	P	
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
DETECTOR SIGNAL	SELECT 1-3	VOLTAGE MEASUREMENT	M	M	H	L	L	P	Range 1 V, resolution .05 V.
APERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	H	L	S	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Altimeter/Scatterometer/Radiometer

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
POWER SUPPLY VOLTAGE	SELECT 1-10	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 12 V to 1 kV, resolution 0.1%.
AIRFLOW TEMPERATURE	SELECT 1-2	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
TRANSMITTER POWER	-	POWER MEASUREMENT	M	M	H	C	L	P	
RECEIVER SENSITIVITY	-	READOUT	L	M	D	L	L	P	
RECEIVER GAIN	CONTINUOUS	POSITION	L	H	H	M	M	P	Resolution 1%.
RANGE AND ALTIMETER SWEEP	SELECT 1-5	STATUS	M	H	D	L	L	P	
ANTENNA TILT	SINGLE AXIS CONTROLLER	POSITION	M	M	D	L	L	P	Range ±48°, resolution ±0.15°.
AUTO SCAN	SELECT 1-2	STATUS	L	M	D	L	L	P	
INSTRUMENT COMBINATION	SELECT 1-4	STATUS	M	H	D	L	L	P	
ALTIMETER MODE	SELECT 1-5	STATUS	M	H	D	L	L	P	
ALTIMETER	-	HEIGHT MEASUREMENT	L	H	H	H	M	P	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Multispectral Spectrometer

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
POWER SUPPLY VOLTAGE	SELECT 1-5	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 12 - 300 V, resolution .1%.
TEMPERATURE MONITOR	SELECT 1-4	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
CALIBRATION	ON/OFF	STATUS	M	M	D	L	L	T	
MIRROR ANGLE POINT	UP/DOWN	POSITION	M	M	H	L	L	P	Range 30°, resolution 0.1 mrad.
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
DETECTOR SIGNAL	SELECT 1-4	VOLTAGE MEASUREMENT	M	M	H	L	L	P	Range 1 V, resolution 1 mV.
APERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	H	L	S	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Polarimeter

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
POWER SUPPLY VOLTAGE	SELECT 1-5	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 12 - 300 V, resolution 0.1%.
TEMPERATURE MONITOR	SELECT 1-16	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
CALIBRATION	ON/OFF	STATUS	M	M	D	L	L	T	
MIRROR ANGLE POINT	UP/DOWN	POSITION	M	M	H	L	L	P	Range 120°, resolution 0.3°.
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
DETECTOR SIGNAL	SELECT 1-16	VOLTAGE MEASUREMENT	M	M	H	L	L	P	Range 1 V, resolution 1 mV.
APERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	H	L	S	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Optical Radar

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
POWER SUPPLY VOLTAGE	SELECT 1-5	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 12 - 300 V, resolution .1%.
TEMPERATURE MONITOR	SELECT 1-3	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
TRANSMITTER POWER	-	POWER MEASUREMENT	M	M	H	C	L	T	Resolution .1%.
RANGE SWEEP	SELECT 1-3	STATUS	M	H	D	L	L	P	
DATA ACQUISITION	START/STOP	READY/OPERATE	M	H	D	H	L	P	
RANGE	-	HEIGHT MEASUREMENT	L	H	H	H	M	P	Range 200 n mi, resolution 0.1 ft.
MIRROR TILT	UP/DOWN	POSITION	M	M	H	L	L	P	Range 30°, resolution 0.1 mrad.
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
APERTURE DOOR	OPEN/CLOSE	STATUS	M	M	D	H	L	S	

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H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-2. Earth Observations Group: Observation Telescopes

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
TEMPERATURE MONITOR	SELECT 1-4	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 366° K, resolution ±.2° K.
ANGLE LOW POWER	SELECT 1-2	ANGLE MEASUREMENT	M	H	H	M	M	P	Range 45°, 90°. Resolution .01 mrad.
ANGLE HIGH POWER	SELECT 1-2	ANGLE MEASUREMENT	M	H	H	M	M	P	Range 45°, 90°. Resolution .002 mrad.
MAGNIFICATION	SELECT 1-5	STATUS	M	H	D	L	L	P	
FRAMES REMAINING	-	FRAME COUNT	L	H	H	N/A	L	P	Resolution 1 count in 10,000.
HIGH VOLTAGE	ON/OFF	STATUS	M	L	D	L	L	T	
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
TV/CAMERA	SELECT 1-3	STATUS	M	H	D	L	L	P	
EXPOSURE DURATION	SELECT 1-4	STATUS	M	H	D	M	L	P	
F STOP	SELECT 1-7	STATUS	M	H	D	M	L	P	
CAMERA TRIGGER	START/STOP	READY/OPERATE	M	H	D	H	L	P	
IMAGE MOTION COMP	ON/OFF	STATUS	M	M	D	L	L	T	
TARGET MONITOR	SELECT 1/2	VIDEO	M	H	M	M	M	P	

Observational Telescopes (2) with TV Camera used with:

- Multispectral Radiometer
- Altimeter
- Scatterometer
- Radiometer
- Multispectral Spectrometer
- Polarimeter
- Optical Radar

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-3.. Physics Group: Photon Sensors

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
PHOTOMETRIC CLUSTER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	SELECT 1-12	TEMPERATURE MEASUREMENTS	L	L	H	L	L	T	Range 250° K to 300° K. Resolution ±0.2° K.
HIGH VOLTAGE	ON/OFF 1-12	STATUS	M	H	D	M	L	P	
HIGH VOLTAGE MONITOR	SELECT 1-12	VOLT MEASUREMENTS	L	H	H	M	M	P	Range 1,000 V to 3,000 V. Resolution IV. Used in conjunction with gain select.
GAIN	SELECT (12)	STATUS	M	H	H	M	M	P	Frequency of use twice/orbit.
CALIBRATION	ON/OFF	STATUS	M	M	D	L	L	S	
DETECTOR SIGNAL	SELECT 1-12	INTENSITY MEASUREMENT	L	H	H	M	M	P	Range 0-5 V. Resolution 5 mV.
INTERFEROMETER SPECTROMETER									
POWER	ON/OFF 1-4	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	SELECT 1-4	TEMPERATURE MEASUREMENTS	L	L	H	L	L	T	Range 250° K to 300° K. Resolution 0.2° K.
POWER SUPPLY VOLTAGE MONITOR	SELECT 1-4	VOLT MEASUREMENTS	L	L	H	L	L	T	Range 0-300 V. Resolution IV.
IMAGE MOTION COMPENSATION	ON/OFF	STATUS	M	H	D	M	L	P	
SIGNAL SELECT	SELECT 1-6	STATUS	M	H	D	M	L	P	Twice/orbit.
DETECTOR SELECT	SELECT 1-4	STATUS	M	H	D	M	L	P	Twice/orbit.
SCAN SELECT	MODE 1-6	STATUS	M	H	D	M	L	P	Twice/orbit.
DETECTOR SIGNAL	-	INTENSITY MEASUREMENT	L	H	H	M	M	P	Range 0-5 V. Resolution 2.5 mV.
SCANNING GRATING SPECTROMETER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.

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Table 2-3. Physics Group: Photon Sensors (Continued)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	WELL TIME	ALLOCATION	REMARKS/NOTES
TEMPERATURE MONITOR	SELECT 1-4	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 250° K to 300° K. Resolution 0.2° K.
POWER SUPPLY VOLTAGE MONITOR	SELECT 1-3	VOLT MEASUREMENT	L	L	M	L	L	T	Range 0-300 V. Resolution 3 V.
DETECTOR SELECT	SELECT 1-6	STATUS	M	M	D	M	L	S	Once/orbit.
GRATING SCAN	MODE 1-12	STATUS	M	M	D	M	L	S	Once/orbit.
WAVELENGTH SCAN		WAVELENGTH/GRATING POSITION	L	H	H	H	M	P	Continuous monitor during operation.
SLIT WIDTH	SELECT 1-12	STATUS	M	M	D	M	L	S	Once/orbit.
DETECTOR SIGNAL	-	INTENSITY MEASUREMENT	L	H	H	H	M	P	Range 0-5 V. Resolution 2.5 mV.
EUV SPECTROMETER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	SELECT 1-4	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 250° K to 300° K. Resolution 0.2° K.
POWER SUPPLY VOLTAGE MONITOR	SELECT 1-2	VOLT MEASUREMENT	L	L	M	L	L	T	Range 0-300 V. Resolution 3 V.
GRATING SELECT	MODE 1-6	STATUS	M	M	D	M	L	S	Once/orbit.
WAVELENGTH SCAN	-	WAVELENGTH/GRATING POSITION	L	H	H	H	M	P	Continuous monitor during operation.
DETECTOR SIGNAL	-	INTENSITY MEASUREMENT	L	H	H	M	M	P	Range 0-5 V. Resolution 50 mV.
TELESCOPE									
APERTURE DOOR	OPEN/CLOSE	STATUS	M	L	D	M	L	S	
TEMPERATURE MONITOR	SELECT 1-8	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 77° K. Resolution 0.1° K.
DETECTOR	ON/OFF	VIDEO	M	H	H	M	M	P	1,000 line resolution. Frame rate 1/minute.
VIDEO REQUIREMENTS									
IMAGE ISOCON TV (NARROW FOV)	ON/OFF	STATUS	M	M	M	M	M	P	500 line resolution. Frame rate 2/second.

C - Catastrophic
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T - Tertiary

Table 2-3. Physics Group: Photon Sensors (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
IMAGE ISOCON TV (WIDE FOV)	ON/OFF	STATUS	M	H	M	M	M	P	500 line resolution. Frame rate 2/second.
SELECT	NARROW FOV/WIDE FOV	STATUS	M	M	D	M	L	S	

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Table 2-3. Physics Group: EM Radiation Detectors and Transmitters

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
VLF TRANSMITTER									
MAIN POWER	ON/OFF	STATUS	M	M	D	M	L	S	
TRANSMITTER POWER	CONTINUOUS	STATUS	M	L	H	M	L	S	Range 1-10,000 W. Resolution 30 W.
FREQUENCY	CONTINUOUS	STATUS	M	L	H	M	M	S	Range 0.1-200 KHz, resolution 1%.
TRANSMITTER TEMPERATURE	SELECT 1-4	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200-350° K. Resolution 0.2° K.
VLF RECEIVERS									
1-100 KHZ OUTPUT	-	VOLTAGE MEASUREMENT	L	H	H	L	L	P	Range 1 V, resolution 0.01 V.
1-3 KHZ BW OUTPUT	SELECT 1-6	VOLTAGE MEASUREMENT	L	H	H	L	L	P	Range 1 V, resolution 0.01 V.
100 HZ BW OUTPUT	SELECT 1/2	VOLTAGE MEASUREMENT	L	H	H	L	L	P	Range 1 V, resolution 0.01 V.
TEMPERATURE MONITOR	SELECT 1-9	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200-350° K, resolution 0.2° K.
GAIN	CONTINUOUS (9)	STATUS	M	M	H	M	M	S	Range 30 db, resolution 0.3 db.
CENTER FREQUENCY	CONTINUOUS (8)	STATUS	M	M	D	M	L	S	Resolution 1%.
3 KHZ BW CONTROL	CONTINUOUS (6)	STATUS	M	M	D	M	L	S	Range 1 Hz-3 KHz, resolution 1%.
100 HZ/3 KHZ INTERCONNECT	SELECT 1-6	STATUS	M	M	D	M	L	S	
RF TRANSMITTER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	
TRANSMITTER TEMPERATURE	-	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200-300° K. Resolution ±0.2° K.
TRANSMITTER POWER	CONTINUOUS	STATUS	M	M	H	M	L	S	Range 0-500 W, resolution 1.5 W.
FREQUENCY	CONTINUOUS	STATUS	M	M	H	M	M	S	Range 0.1 - 20 MHz.
PLASMA RESONANCE ELECTRONICS									
MAIN POWER	ON/OFF	STATUS	M	M	D	M	L	S	

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Table 2-3. Physics Group: EM Radiation Detectors and Transmitters (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
0.1 - 10 MHZ OUTPUT	-	VOLT MEASUREMENT	L	H	H	M	L	P	Range 1 V, resolution 0.01 V.
CENTER FREQUENCY	SELECT 1-3	STATUS	M	M	D	M	L	S	
BW CONTROL	CONTINUOUS	STATUS	M	M	H	M	L	S	Range 1 - 100 KHz.
TEMPERATURE MONITOR	SELECT 1-3	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200° - 350° K, resolution $\pm 0.2^{\circ}$ K.

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Table 2-3. Physics Group: Ambient Measurement Instruments

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
ELECTRON DENSITY AND TEMPERATURE MEASUREMENT									
MAIN POWER	ON/OFF	STATUS	M	M	D	M	L	S	
COLLECTOR CURRENT MODULATION DEPTHS	-	OSCILLOSCOPE	L	H	H	M	M	P	Range 0 - 100%, resolution 0.5%.
CARRIER LEVEL	-	OSCILLOSCOPE	L	H	H	M	M	P	Range 10^{-10} -3 x 10^{-6} A, resolution 0.5%.
SWEEP	-	OSCILLOSCOPE	L	H	H	M	M	P	Range -2.7 - 3.5 V; resolution 30 mV.
GRID POTENTIAL	CONTINUOUS	VOLT MEASUREMENT	M	H	H	M	M	P	Range -5 - 4V, resolution 45 mV.
COLLECTOR POTENTIAL	CONTINUOUS	VOLT MEASUREMENT	M	H	H	M	M	P	Range 0 - 25 V, resolution 0.5%.
POWER SUPPLY VOLTAGE MONITOR	SELECT 1-5	VOLT MEASUREMENT	L	L	H	L	L	T	Range 12 - 100 V, resolution 0.12 V.
TEMPERATURE MONITOR	ON/OFF	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 350° K, resolution 0.2° K.
SPHERICAL ION PROBE									
MAIN POWER	ON/OFF	STATUS	M	M	D	M	L	S	
TEMPERATURE MONITOR	ON/OFF	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 250° K to 300° K, resolution 0.02° K.
POWER SUPPLY VOLTAGE MONITOR	SELECT 1-5	VOLT MEASUREMENT	L	L	H	L	L	T	Range 12 V to 100 V, resolution 1%.
COLLECTOR CURRENT MODULATION	-	OSCILLOSCOPE	L	H	H	M	M	P	Range 0 - 100%. Resolution 0.5%.
CARRIER LEVEL	-	OSCILLOSCOPE	L	H	H	M	M	P	Range 10^{-11} to 10^{-7} A. Resolution 0.5%.
SWEEP	-	OSCILLOSCOPE	L	H	H	M	M	P	Range -4.0 to 11 V. Resolution 75 mV.
GRID POTENTIAL	CONTINUOUS	STATUS	M	H	H	M	M	P	Range 0 to 6.4 V. Resolution 0.5%.
COLLECTOR POTENTIAL	CONTINUOUS	STATUS	M	H	H	M	M	P	Range 0 - 25 V. Resolution 0.5%.

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Table 2-3. Physics Group: Ambient Measurement Instruments (Continued)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
QUADRUPLE MASS SPECTROMETER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	
TEMPERATURE MONITOR	ON/OFF	TEMPERATURE MEASUREMENT	L	L	D	L	L	T	Range 200 - 350° K, resolution 0.2° K.
ION COLLECTOR SIGNAL CURRENT	-	CURRENT MEASUREMENT	L	H	H	M	M	P	Range 10^{-18} - 10^{-10} A, resolution 0.5%.
DC FIELD VOLTAGE	-	VOLTAGE MEASUREMENT	L	M	H	M	L	S	Range 0 - 5 V, resolution 0.25 V.
RF FIELD FREQUENCY	-	FREQUENCY MEASUREMENT	L	M	H	M	L	S	Range 2 - 4 MHz, resolution .025 MHz.
OPERATION MODE	SELECT 1-15	STATUS	M	M	D	M	L	P	
FILAMENT CURRENT	-	CURRENT MEASUREMENT	L	M	H	M	L	S	Range 0 - 2 A, resolution 20 mA.
FLUXGATE MAGNETOMETER									
MAIN POWER	ON/OFF	STATUS	M	M	D	M	L	S	
TEMPERATURE	SELECT 1-4	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 350° K, resolution .2° K.
POWER SUPPLY VOLTAGE MONITOR	-	VOLTAGE MEASUREMENT	L	L	H	M	L	T	Range 0 - 28 V, resolution 1%.
CALIBRATION	SELECT 1-4	STATUS	M	M	D	M	L	S	
SIGNAL VOLTAGE	-	VOLTAGE MEASUREMENT	M	H	H	M	M	P	Range 0 - 5 V, resolution 0.1%.
RANGE COMMAND	SELECT 1-6	STATUS	M	H	D	M	L	P	
SUPRATHERMAL ELECTRONS									
MAIN POWER	ON/OFF	STATUS	M	M	D	M	L	S	
TEMPERATURE	-	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 350° K, resolution 0.2° K.
SHIELD GRID	-	VOLTAGE MEASUREMENT	M	M	M	M	L	S	Range 0 - 10 V, resolution 1%.
COLLECTOR	-	VOLTAGE MEASUREMENT	M	M	M	M	L	S	Range 0 - 25 V, resolution 1%.

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Table 2-3. Physics Group: Ambient Measurement Instruments (Continued)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
RETARDING GRID	-	VOLTAGE MEASUREMENT	M	M	M	M	L	S	Range 0 - 2,000 V. Resolution 1%.
COLLECTOR	-	AMP MEASUREMENT	M	H	H	M	M	P	Range 10^{-10} - 10^{-6}. Resolution 0.5%.
PLANAR THERMAL ION TRAP									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	-	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 350° K. Resolution 0.2° K.
GRID VOLTAGE	SELECT 1-3	VOLTAGE MEASUREMENT	L	L	H	L	L	T	Range 0 to ±20 V. Resolution 0.5%.
COLLECTOR VOLTAGE	-	VOLTAGE MEASUREMENT	L	L	L	L	L	T	Range 0 to -2 V. Resolution 5%.
COLLECTOR CURRENT	-	AMP MEASUREMENT	L	H	H	M	M	P	Range 10^{-10} to 10^{-6} A. Resolution 0.5%.
CYLINDRICAL ELECTROSTATIC PROBE									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	-	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200° K to 350° K, resolution 0.2° K.
GRID VOLTAGE	-	VOLTAGE MEASUREMENT	M	L	M	L	L	T	Range -3 V to 3 V. Resolution 1%.
COLLECTOR VOLTAGE	-	VOLTAGE MEASUREMENT	M	L	M	L	L	T	Range 0 - 25 V. Resolution 1%.
COLLECTOR CURRENT	-	AMP MEASUREMENT	M	H	M	M	M	P	Range 0 - 1 A. Resolution 1%.
SEARCH COIL MAGNETOMETER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	-	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 350° K. Resolution 0.2° K.
GAIN CONTROL	SELECT 1-4	ANALOG	M	M	M	M	M	S	Range 40 db. Resolution 1%.
SPECTRAL CHANNEL VOLTAGE	SELECT 1-15	VOLTAGE MEASUREMENT	L	H	H	M	L	P	Range 0 - 5 V. Resolution 0.5%.
WAVEFORM CHANNEL VOLTAGE	SELECT 1-3	VOLTAGE MEASUREMENT	L	H	H	M	L	P	Range 0 - 5 V. Resolution 0.5%.

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Table 2-3. Physics Group: Ambient Measurement Instruments (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
BANDPASS CONTROL	-	ANALOG	M	M	M	M	L	S	Range 40 db. Resolution 1%.
HEMISPHERICAL ANALYZER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	-	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200 - 350° K. Resolution 0.2° K.
HIGH VOLTAGE	CONTINUOUS	VOLTAGE MEASUREMENT	M	M	N	L	M	S	Range 5 - 6,000 V. Resolution 1%.
SCAN CONTROL	SELECT MODE 1/2	STATUS	M	H	D	M	L	P	
DETECTOR VOLTAGE	-	VOLTAGE MEASUREMENT	L	L	M	L	L	T	Range 2,500 - 4,000 V. Resolution 1%.
DETECTOR SIGNAL	-	ANALOG	L	H	M	M	M	P	Range 10^{-14} - 10^{-7} A. Resolution 1%.
DETECTOR SIGNAL	-	COUNT RATE	L	H	H	M	M	P	Range 10^{2} - 10^{5} counts/second. Resolution 1%.
AC ELECTRIC FIELD MEASUREMENT DEVICE									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
FIELD VOLTAGE	SELECT 1-15	VOLTAGE MEASUREMENT	M	H	H	M	M	P	Range 0.6 V to 6,000 V. Resolution 0.5%.
TEMPERATURE MONITOR	SELECT 1-2	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200° K to 350° K. Resolution 0.2° K.
DC ELECTRIC FIELD MEASUREMENT DEVICE									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
TEMPERATURE MONITOR	SELECT 1-2	TEMPERATURE MEASUREMENT	L	L	H	L	L	T	Range 200° K to 350° K. Resolution 0.2° K.
POWER SUPPLY VOLTAGE	-	VOLTAGE MEASUREMENT	L	L	L	L	L	T	
GRID VOLTAGE	-	VOLTAGE MEASUREMENT	M	M	M	M	L	S	Range 0 - 50 V. Resolution 1%.
ACCELERATION VOLTAGE	-	VOLTAGE MEASUREMENT	M	M	M	M	L	S	Range 400 - 600 V. Resolution 1%.
FILAMENT CURRENT	-	AMP MEASUREMENT	M	M	M	M	L	S	Range 0 - 5 A. Resolution 50 mA.
BEAM DEFLECTION SIGNAL	-	DIGITAL	M	H	M	M	L	P	

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Table 2-3. Physics Group: Particle Sensors

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
PARTICLE SENSOR CLUSTER									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	
TEMPERATURE	SELECT 1-8	TEMPERATURE MEASUREMENT	L	L	D	L	L	T	Range 200 - 350° K. Resolution 0.2° K.
GRID VOLTAGE	SELECT 1-5	VOLTAGE MEASUREMENT	M	L	M	L	L	T	Range 0 - 2,000 V. Resolution 0.5%.
ELECTRON MULTIPLIER COUNTING RATE	SELECT 1-29	COUNT RATE	M	H	H	M	M	P	Range 10 to 10^5 counts/second. Resolution 0.1%.
ION MASS SPECTROMETER									
MAIN POWER	ON/OFF	STATUS	M	M	D	M	L	S	
TEMPERATURE	ON/OFF	STATUS	L	L	D	L	L	T	Range 200 - 350° K. Resolution 0.2° K.
RF FREQUENCY	SELECT 1-2	FREQUENCY MEASUREMENT	M	L	H	L	L	T	Range 2 - 3 MHz. Resolution 10 KHz.
SAWTOOTH VOLTAGE	SELECT 1-2	VOLTAGE MEASUREMENT	M	L	H	L	L	T	
GRID VOLTAGE	SELECT 1-7	STATUS	M	L	H	L	L	T	Range 0 - 50 V. Resolution 0.5%.
COLLECTOR VOLTAGE	SELECT 1-7	STATUS	M	L	H	L	L	T	Range 0 - 50 V. Resolution 0.5%.
COLLECTOR CURRENT	-	CURRENT MEASUREMENT	M	H	H	M	M	P	Range 10^{-13} - 10^{-8} A. Resolution 0.5%.

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L - Low
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S - Secondary
T - Tertiary

Table 2-4. Life Science Group: Vertebrate Cage Module

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
ELECTROCARDIOGRAM									
MAIN POWER	ON/OFF	STATUS	M	H	D	M	L	P	Twice/orbit.
RECORD SPEED	SELECT 1-5	STATUS	M	H	D	M	L	P	
CALIBRATION	SELECT 1-5	STATUS	M	H	D	M	L	P	
POWER SUPPLY VOLTAGE MONITOR	-	VOLT MEASUREMENT	L	L	M	L	L	T	Range 12 V. Resolution 1%.
SIGNAL VOLTAGE	SELECT 1-16	CRT	M	H	M	M	M	P	Range 0-5 V. Resolution 1%. Hard copy and/or interactive graphics display required.
ELECTROENCEPHALOGRAM									Same C&D required as for electrocardiograph.
ELECTROMYOGRAM									Same C&D required as for electrocardiogram except 32 channels of signal voltage to be monitored.
BLOOD PRESSURE									Same C&D required as for electrocardiograph except hard copy and interactive graphics not required. Numeric display instead of CRT display.
RESPIRATORY RATE									Same as Blood Pressure.
BODY TEMPERATURE									
POWER SUPPLY VOLTAGE MONITOR	-	VOLT MEASUREMENT	L	L	M	L	L	T	Range 12 V. Resolution 1%.
CALIBRATION	ON/OFF	STATUS	M	M	D	L	L	S	
SIGNAL	SELECT 1-16	TEMP MEASUREMENT	L	H	L	M	M	P	Range 33-39° C. Resolution 1° C.
CAGE ENVIRONMENT									
TEMPERATURE CONTROL	ON/OFF	STATUS	H	L	D	L	L	T	
TEMPERATURE MONITOR	SELECT 1/2	TEMP MEASUREMENT	L	L	L	L	L	T	Range 25±1° C. Resolution 1° C. Primary alert status required.
ECS FLOW RATE	SELECT 1/2	STATUS	H	L	D	L	L	T	
ECS FLOW RATE MONITOR	SELECT 1/2	FLOW MEASUREMENT	L	L	L	L	L	T	Range 0-5 V. Resolution 2%.

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T - Tertiary

Table 2-4. Life Science Group: Vertebrate Cage Module (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
RELATIVE HUMIDITY	SELECT LEVEL 1/2	STATUS	M	L	D	L	L	T	
RELATIVE HUMIDITY MONITOR	SELECT 1/2	HUMIDITY MEASUREMENT	L	L	L	L	L	T	Range 60±10%. Resolution 2%.
pCO_2 CONTROL	SELECT 1/2	STATUS	H	L	D	L	L	T	
pCO_2 MONITOR	SELECT 1/2	CO_2 MEASUREMENT	L	L	M	L	L	T	Primary Alert Status required.
pO_2 CONTROL	SELECT 1/2	STATUS	H	L	D	L	L	T	
pO_2 MONITOR	SELECT 1/2	O_2 MEASUREMENT	L	L	M	L	L	T	Primary Alert Status required.
TOTAL PRESSURE CONTROL	SELECT 1/2	STATUS	M	L	D	L	L	T	
TOTAL PRESSURE MONITOR	SELECT 1/2	PRESSURE MEASUREMENT	L	L	M	L	L	T	Primary Alert Status required.
WATER SUPPLY CONTROL	SELECT 1/2	STATUS	M	L	D	L	L	T	
WATER SUPPLY MONITOR	SELECT 1-16	DISCRETE LEVELS 1-12	H	L	D	L	L	T	Primary Alert Status required.
FOOD WHEEL CONTROL	SELECT 1-24 (16 CHANNELS)	DISCRETE POSITION 1-24	L	L	D	L	L	T	
ILLUMINATION	SELECT 1-10 LEVELS	STATUS	L	H	D	M	L	P	
MONITOR	SELECT	VIDEO	L	H	M	M	M	P	Monochromatic on-board monitor. Color TV camera may be desireable for video transmitted to ground in support of total Life Sciences Group.
CAGE ENVIRONMENT									Same C&D requirements as for Vertebrate Cage Environment except Food Wheel Control not required.

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-4. Life Science Group: Biomedical Measurements Unit

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
LOWER BODY NEGATIVE PRESSURE									
PRESSURE DIFFERENCE	VALVE	PRESSURE METER	C	L	M	M	M	P	Required at experiment location. Emergency relief valve available to subject must also be provided.
LBG VOLUME MEASURING SYSTEM	-		M	H	H	M	H	P	Two required: left and right leg. Range -1 to +5% change.
	NULL ADJUST	STATUS	M	M	M	M	M	P	Null and gain controls used with Leg Volume Measuring System △volume display.
	GAIN ADJUST	STATUS	M	M	M	M	M	P	
	-		M	M	M	M	H	P	Alert indicator required.
CABIN TEMPERATURE	-	TEMPERATURE MONITOR	M	L	M	L	M	S	
CHAMBER TEMPERATURE	-	TEMPERATURE MONITOR	M	L	M	L	M	S	
BODY TEMPERATURE	-	TEMPERATURE MONITOR	C	H	H	H	M	P	Provides indication of subject status.
BLOOD PRESSURE	-	PRESSURE MONITOR	C	H	H	H	M	P	Provides indication of subject status.
BICYCLE ERGOMETER									
RESPIRATION RATE	-	FLOW METER	M	H	M	M	H	P	
FLOW METER CALIBRATION	SELECT 1-6	STATUS	M	L	D	M	L	S	
HEART RATE	-	BEATS/MIN	C	H	M	M	H	P	Provides indication of subject status.
BODY TEMPERATURE	-	TEMPERATURE MONITOR	M	H	H	M	M	P	
BLOOD PRESSURE	-	PRESSURE MONITOR	C	H	M	M	M	P	Provides indication of subject status.
ERGOMETER OUTPUT	-	WATT METER	M	H	M	M	M	P	
ERGOMETER SPEED	-	RPM INDICATOR	M	H	M	M	M	P	
ERGOMETER MOTOR CONTROL	SELECT 1-12	STATUS	M	M	D	L	L	S	
ELECTROOCULAGRAM									
POWER	ON/OFF	STATUS	M	M	D	L	L	S	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-4. Life Science Group: Biomedical Measurements Unit (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
POWER SUPPLY VOLTAGE MONITOR	SELECT 1/2	VOLT MEASUREMENT	L	L	M	L	L	T	Range 12 V. Resolution 1%.
AMPLIFIER GAIN/ CALIBRATE	SELECT 1-6	STATUS	M	M	D	M	L	S	
SIGNAL VOLTAGE	SELECT 1/2	CRT	M	H	M	M	M	P	Range 0-5 V. Resolution 1%.
BODY MASS MEASUREMENT DEVICE									
POWER	ON/OFF	STATUS	M	M	D	L	L	S	
OSCILLATION OUTPUT	-	FREQUENCY	M	H	H	M	M	P	
OSCILLATION CALIBRATION	SELECT 1-6	STATUS	M	M	D	L	L	S	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-4. Life Science Group: Life Support Test Unit

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
POWER	ON/OFF (4)	STATUS	M	L	D	L	L	T	
VOLTAGE MONITOR	SELECT POWER SUPPLY/TEST SPECIMEN (4)	VOLT MEASUREMENT	M	L	M	L	L	T	
TEST SPECIMEN CURRENT	SELECT 1-4	AMP MEASUREMENT	M	L	M	L	L	T	
PRESSURE MONITOR	SELECT O_2 (1-4)/N_2 (1-4)	PRESSURE METER	M	L	M	L	M	T	O_2 and N_2 pressure alerts required (primary).
FLOW MONITOR	SELECT O_2 (1-4)/N_2 (1-4)	FLOW METER	M	L	M	L	M	T	
O_2/H_2 FLOW CONTROL	SELECT 1-16	STATUS	M	L	D	L	L	T	
TEST SPECIMEN TEMPERATURE	SELECT 1-24	TEMPERATURE MEASUREMENT	M	H	H	M	M	P	
TEST SPECIMEN PRESSURE	SELECT 1-24	PRESSURE MEASUREMENT	M	H	M	M	M	P	
TEST SPECIMEN WATER FLOW	SELECT 1-8	FLOW RATE	M	H	M	M	M	P	Analog voltage display. Range 0-5 V. Resolution 1%.

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-5. Advanced Technology Group: Thermal Control Coating Refurbishment

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
SPECTROREFLECTOMETER									Portable instrument, self-contained.
POWER	OFF/STANDBY/ON	STATUS	M	M	D	L	L	(P)	
SPACING	-	CONTACT/NO CONTACT	M	M	D	L	L	(P)	
WAVEBAND SELECT	1-4	STATUS	M	M	D	L	L	(P)	
REFLECTANCE		DETECTOR OUTPUT	M	M	M	L	L	(P)	Resolution 1% required.
CAMERA									Portable instrument used to record EVA operations.
POWER	OFF/STANDBY/ON	STATUS	M	L	D	L	L	(P)	
LIGHTS	OFF/ON	STATUS	M	L	D	L	L	(P)	Interlocked with above.
FILM	-	FILM REMAINING	M	L	M	L	L	(P)	Resolution 5 ft/500 ft.
COATING MONITORS									
CALORIMETER	OFF/ON/SHUTTER (4)	STATUS	M	L	D	L	L	P	
CALORIMETER	SELECT 1-4	SOLAR FLUX (4)	M	M	M	L	M	P	Resolution 1%.
SAMPLES	SELECT 1-32	TEMPERATURE	M	M	H	L	M	P	Range 150 - 350 K, resolution 1 K.
COATING REFURBISHMENT EQUIPMENT									
VACUUM VENT VALVE	OPEN/CLOSED/LATCHED	STATUS	C	L	D	H	L	P	
CHAMBER	-	PRESSURE	M	M	M	L	M	P	Range 10^{-6} - 10^{-3} torr.
METERING SYSTEM	FLOW OFF/ON	STATUS	M	M	D	L	L	P	
HIGH VOLTAGE	OFF/ON		M	M	D	M	L	P	
	VOLTAGE CONTROL	VOLTAGE	M	M	M	L	L	P	Range 0 - 3,000 V, resolution 10 V.
HEATER	CONTROL	CURRENT	M	M	M	M	L	P	Range 0 - 10 A, resolution 0.1 A.

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-5. Advanced Technology Group: Oxygen Recovery and Biowaste Resistojet

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
TANK PRESSURE	VALVE	PRESSURE METER	M	M	M	M	M	P	
MAIN POWER	ON/OFF	STATUS	M	L	D	L	L	T	
MOLECULAR SIEVE	INPUT POWER	POWER MONITOR	M	M	M	L	M	S	Analog controls required for all input power. Monitoring may be implemented by single display with select function.
CATALYTIC REACTOR	INPUT POWER	POWER MONITOR	M	M	M	L	M	S	
ELECTROLYSIS	INPUT POWER	POWER MONITOR	M	M	M	L	M	S	
RESISTOJET	INPUT POWER	POWER MONITOR	M	M	M	L	M	S	
PUMP	ON/OFF (3)	STATUS	M	L	D	M	L	S	
WATER QUANTITY	SELECT 1-6	STATUS	M	L	D	M	L	S	
		FLOW MONITOR	M	L	M	M	L	S	
RESISTOJET CONTROL	FIRE	STATUS	M	L	D	M	L	S	Thrust developed monitored by orbitor attitude monitors.
METHANE FLOW	SELECT 1-6	FLOW METER	M	M	M	M	M	P	
GAS COMPOSITION	-	pCO_2 MONITOR (2)	M	M	M	M	M	P	
		METHANE/HYDROGEN MONITOR	C	H	M	H	M	P	Caution and warning required to monitor status of combustible gas concentration.
PRESSURE MONITOR	SELECT 1-9	PRESSURE MONITOR	M	L	M	M	L	S	
TEMPERATURE MONITOR	SELECT 1-15	TEMPERATURE MONITOR	M	L	M	M	L	S	

C - Catastrophic
H - High
M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-5. Advanced Technology Group: Liquid/Vapor Interface Stability (Fluid Management)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
									A graphic display is suggested providing a system diagram including status of valves, pumps, vibrator and slosher, and heaters.
FLUID TRANSFER	VALVES (10)	STATUS	M	M	D	M	M	P	
PUMPS	ON/OFF (3)	STATUS	M	M	D	M	L	P	
VIBRATOR AND SLOSHER	SELECT 1-4	STATUS	M	M	D	M	L	P	
EXPERIMENT MONITORS	SELECT TV 1-6	VIDEO (2)	M	H	M	H	M	P	Two monochromatic monitors required. Commercial quality resolution adequate.
	ZOOM, PAN, TILT	-	M	M	M	M	M	P	
FILM CAMERA	PAIR SELECT 1-3	STATUS	M	M	D	L	L	P	
FRAME RATE	SELECT 1-4	STATUS	M	M	D	L	L	P	
FILM REMAINING	SELECT 1-3	FRAME COUNTS	M	M	M	N/A	L	S	
ILLUMINATION	ON/OFF (3)	STATUS	M	M	D	L	L	P	
TEMPERATURE	ON/OFF (8)	STATUS	M	M	D	L	L	P	
TEMPERATURE MONITOR	SELECT 1-15	TEMPERATURE MONITOR	M	M	M	L	M	P	
PRESSURE	SELECT 1-9	PRESSURE MONITOR	M	M	M	L	M	P	
FLOW RATE	SELECT 1-9	FLOW MONITOR	M	M	M	L	M	P	
PRESSURE AND FLOW HISTORY	SELECT 1-9	ACTIVITY HISTORY RECORDER	M	M	M	L	M	P	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-6. Experiment Attitude and Pointing Control Subsystem

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
MAIN POWER	ON/OFF	STATUS							Alert status required to monitor redundancy schemes or malfunction status of control elements (i.e., sensors, actuators, etc.).
EXPERIMENT/VEHICLE ATTITUDE	THREE AXIS CONTROLLER	VEHICLE ATTITUDE	M	H	TBD	TBD	M	P	Assumes payload pointing accomplished by vehicle attitude changes.
		EXP/VEHICLE DISPLACEMENT	M	H	H	H	M	P	Required when additional experiment pointing system employed.
		EXPERIMENT ATTITUDE	M	H	H	H	M	P	Required if additional experiment pointing system employed or for vehicle mounted experiments having skewed coordinates.
STABILIZATION		EXPERIMENT AND VEHICLE RATES	M	M	H	M	M	S	
		STABILIZATION ALERT	M	H	D	M	H	P	Provides alert to excessive rate or attitude error conditions.
VEHICLE ATTITUDE MODE	SELECT 1-6 (TYP)	STATUS	M	H	D	M	L	P	
CMG SYSTEM									
POWER	ON/AUTO/OFF	STATUS	M	L	D	L	L	T	Alert status of malfunctions required.
WHEEL SPEED	-	RPM	M	L	M	L	L	T	
WHEEL CURRENT	-	AMPS	M	L	M	L	L	T	
WHEEL BEARING TEMPERATURE	-	TEMPERATURE MONITOR	M	L	M	L	L	T	
MOMENTUM (H) MONITOR	-	H_X, H_Y, H_Z, H_T	M	M	M	M	M	S	Momentum storage alert required.
MOMENTUM MANAGEMENT	MODE SELECT 1/2 (TYP)	STATUS	M	M	D	M	L	S	
THRUSTER ATTITUDE CONTROL SYSTEM									
THRUSTER INHIBIT	ENABLE/INHIBIT	STATUS	M	L	D	H	L	P	Alert status required of thruster malfunction.
TACS PRESSURE	-	PRESSURE MONITOR	L	M	M	N/A	L	S	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-6. Experiment Attitude and Pointing Control Subsystem (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
THRUST DURATION	SELECT DISCRETE DURATION	STATUS	M	L	D	L	L	T	
RESOLUTION SELECT	DEADBAND SELECT DISCRETES	STATUS	M	M	D	M	L	S	

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H - High
M - Moderate
L - Low
D - Discrete
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S - Secondary
T - Tertiary

Table 2-7. Data Management Subsystem

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
TELEMETRY									
POWER	ON/OFF	STATUS	M	L	D	L	L	T	
TRANSMITTER INPUT	SELECT TAPE RECORDER/ REAL TIME	STATUS	M	H	D	M	L	P	
TRANSMITTER OUTPUT	ANTENNA SELECT	STATUS	M	H	D	M	L	P	
RECORDER POWER	ON/OFF	STATUS	M	H	D	M	L	P	
RECORDER MODE	RECORD/PLAYBACK	STATUS	M	H	D	M	L	P	
RECORDER TAPE REMAINING	-	FOOTAGE REMAINING	M	L	M	L	L	S	Alert status required to monitor low footage and recorder malfunction.
ONBOARD CHECKOUT SUBSYSTEM									
MONITOR CAUTION AND WARNING PARAMETERS	-	ORBITER FIRE, LAB FIRE, RAPID PRESSURE LOSS, FUEL CELL VOLTAGE, BATTERY PRESSURE, COMPUTER, WATER PUMP, WATER FLOW, pO_2, pCO_2, pN_2, O_2 PRESSURE, N_2 PRESSURE, H_2 PRESSURE, BUS VOLTAGES, FUEL CELL TEMPERATURE, ETC.	C	N/A	D	H	L	P	Continuous display of C&W parameters required. Dedicated, hardwired system recommended.
MONITOR SUBSYSTEM STATUS	-	ALERT INDICATION OF SUBSYSTEM MALFUNCTION	H	N/A	D	M	L	P	Continuous automatic checkout performed by DMS computer. RAM program recommended readout on CRT display in lieu of dedicated alert indicators.
SUBSYSTEM DIAGNOSIS	SELECT OCS MEASUREMENTS LIST	PARAMETRIC DISPLAY OF SUBSYSTEM STATUS	M	L	M	M	M	T	
MONITOR EXPERIMENT STATUS	INITIATE SELF TEST SUBROUTINE	PARAMETRIC DISPLAY OF EXPERIMENT RESPONSE TO STIMULI	M	L	M	M	M	T	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
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S - Secondary
T - Tertiary

Table 2-7. Data Management Subsystem (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
PROCEDURES	SELECT EXPERIMENT/ SUBSYSTEM	PROVIDE DESCRIPTIVE DISPLAY OF OPERATIONAL, BACKUP, AND FAULT ISOLATION PROCEDURES	M	H	H	H	M	P	

C - Catastrophic
H - High
M - Moderate
L - Low
D - Discrete
P - Primary
S - Secondary
T - Tertiary

Table 2-8. Environmental Control Subsystem

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION		REMARKS/NOTES
BIN PRESSURE	-	PRESSURE MONITOR	L	L	M	M	L	T	*	NOTE: The criticality assignments in this table are applicable to the C&D usage during normal housekeeping operations. Critical functions, denoted by *, are monitored continuously by the C&W subsystem.
BIN TEMPERATURE	-	TEMPERATURE MONITOR	L	L	M	M	L	T		
2	VALVE	PRESSURE MONITOR	L	L	M	M	L	T	*	
O_2	-	PRESSURE MONITOR	L	L	M	M	L	T	*	
BIN GAS SUPPLY MPERATURE	-	TEMPERATURE MONITOR	L	L	M	M	L	T		
2	-	PRESSURE MONITOR	L	L	M	M	L	T	*	
NIFOLD PRESSURE	-	PRESSURE MONITOR	L	L	M	M	L	T		
D PRESSURE	-	PRESSURE MONITOR	L	L	M	M	L	T		
TABLE H_2O SUPPLY	-	PERCENT MONITOR	L	L	M	M	L	T		
STE H_2O SUPPLY	-	PERCENT MONITOR	L	L	M	M	L	T		
OCIDE TANK QUANTITY	-	PERCENT MONITOR	L	L	M	M	L	T		
CUMULATOR PRESSURE OOLANT)	-	PRESSURE MONITOR	L	L	M	M	L	T		
MP DISCHARGE PRES-RE (COOLANT)	-	TEMPERATURE MONITOR	L	L	M	M	L	T		
DIATOR OUTLET MPERATURE	TEMPERATURE CONTROL	TEMPERATURE MONITOR	L	L	M	M	L	T		
DIATOR MIX MPERATURE	-	TEMPERATURE MONITOR	L	L	M	M	L	T		
BLIMATOR OUTLET MPERATURE	TEMPERATURE CONTROL	TEMPERATURE MONITOR	L	L	M	M	L	T		
TERCOOLER INLET MPERATURE	-	TEMPERATURE MONITOR	L	L	M	M	L	T		
EL CELL HEAT EX-ANGER INLET MPERATURE	-	TEMPERATURE MONITOR	L	L	M	M	L	T		

C - Catastrophic
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M - Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-8. Environmental Control Subsystem (Concluded)

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
UMULATOR PRESSURE O)	-	PRESSURE MONITOR	L	L	M	M	L	T	
P DISCHARGE PRES-E (H_2O)	-	PRESSURE MONITOR	L	L	M	M	L	T	
P DISCHARGE PERATURE (H_2O)	-	TEMPERATURE MONITOR	L	L	M	M	L	T	
IN HEAT EXCHANGER ET TEMPERATURE	-	TEMPERATURE MONITOR	L	L	M	M	L	T	
TION RETURN PERATURE	-	TEMPERATURE MONITOR	L	L	M	M	L	T	

- Catastrophic
- High
- Moderate

L - Low
D - Discrete

P - Primary
S - Secondary
T - Tertiary

Table 2-9. Electrical Power Subsystem

FUNCTION	CONTROL	DISPLAY	CRITICALITY	FREQUENCY OF USE	RESOLUTION	RESPONSE	DWELL TIME	ALLOCATION	REMARKS/NOTES
									NOTE: The criticality assignments in this table are applicable to the C&D usage during normal housekeeping operations. Critical functions, denoted by *, are monitored continuously by the C&W subsystem.
FUEL CELL VOLTAGE	-	VOLTS	L	M	M	M	L	S	*
FUEL CELL CURRENT	-	AMPS	L	M	M	M	L	S	*
COOLANT TEMPERATURE	-	^{o}F	L	M	M	M	L	S	*
WATER SEPARATOR TEMPERATURE	-	^{o}F	L	M	M	M	L	S	*
O_2 PRESSURE	-	PSIA	L	M	M	M	L	S	
H_2 PRESSURE	-	PSIA	L	M	M	M	L	S	
O_2 FLOW RATE	-	LB/HR	L	M	M	M	L	S	
H_2 FLOW RATE	-	LB/HR	L	M	M	M	L	S	
BATTERY VOLTAGE	-	VOLTS	H	M	M	M	L	S	Alert status required.
BATTERY TEMPERATURE	-	^{o}F	H	M	M	M	L	S	Alert status required.
BATTERY CURRENT	-	AMPS	H	M	M	M	L	S	Alert status required.
REGULATOR VOLTAGE	-	VOLTS	H	M	M	M	L	S	Alert status required.
REGULATOR CURRENT	-	AMPS	L	M	M	M	L	S	

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H - High
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S - Secondary
T - Tertiary

SECTION 3

C AND D GENERIC DEVICE MATRIX

3.1 PURPOSE

The purpose of the following C and D generic device matrix, based on Tables 2-1 through 2-9 of Section 2, is to identify general categories of C and D types which are candidates for use in performing experiments onboard advanced spacecraft. No attempt is made to select specific hardware, but rather to define general device types which could satisfy the functional requirements.

3.2 DESCRIPTION

The C and D generic devices are tabulated for each of the five scientific disciplines and support instrumentation in Tables 3-1 through 3-6.

The Function column contains those functions for which control or display requirements exist, e.g., "Main Power On/Off." The Use column is subdivided into specific experiments within a disciplinary area, e.g., for Astronomy Group (Tables 3-1) "Photoheliograph." This column contains the number of instances where the control or control requirement in question will be used within that experiment subgroup. For example, an entry of "7" in the "High Energy Arrays" column, opposite "Main Power On/Off," means that there are seven separate instances wherein main power control must be implemented for the high energy arrays.

The "Control" column is subdivided to reflect generic control devices which can be considered to implement the functional requirements, as follows:

Switch, lasting
Switch, momentary
Switch, rotary
Keyboard
Multi-axis proportional controller
Continuous controller

Entries in this column represent preference of the control device for a given function, "1" denoting first preference, "2" denoting second preference, and "3" denoting third preference.

The "Display" column is subdivided to reflect generic display devices which can be considered to implement the functional requirements, as follows:

Switch position (panel nomenclature)
Status indicator
Multifunction display
Numeric readout
Analog readout
2 axis null detector (cross-pointer)
History recorder
CRT monitor

Corresponding numbers in the "Display" column list the recommended display for each control device specified, e.g., a control type which is rated "2" goes with a display type which is also rated "2."

The "Remarks" column is provided for inclusion of pertinent remarks, references to notes, and similar entries. Initial numbers, e.g., "2:" refer to the preference rating numbers in the "Control" and "Display" columns.

3.3 DEVICE MATRIX TABLES

The C and D generic device matrices, which identify general categories of C and D types considered candidates for use in scientific experiments and support instrumentation, are as follows.

TABLE 3-1 ASTRONOMY GROUP

TABLE 3-2 EARTH OBSERVATION GROUP

TABLE 3-3 PHYSICS GROUP

TABLE 3-4 LIFE SCIENCE GROUP

TABLE 3-5 ADVANCED TECHNOLOGY GROUP

TABLE 3-6 SUPPORT GROUP

A portion of Table 3-1 is given below as a typical example. In this case the Astronomy Group experiments are considered.

Table 3-1. C&D Generic Devices: Astronomy Group

FUNCTION	USE REQUIREMENT									CONTROL							DISPLAY									
	PHOTOHELIOGRAPH	DUAL WHITE LIGHT CORONAGRAPHS	X-RAY TELESCOPE	XUV SPECTROHELIOGRAPH	IR TELESCOPE	STRATOSCOPE III	HIGH ENERGY ARRAYS			SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER			SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR			
MAIN POWER ON/OFF	1	1	1	1	1	1	7			1	3		2					1	3	2							2:
DOOR OPEN/CLOSE	1	1	1	1	1	1	-				2		1							1							
LAUNCH LOCKS LOCK/UNLOCK	1	1																									

The function "Main Power On/Off" is used once in each of the first six experiments. An entry of seven for the High Energy Arrays appears since the function occurs once for each of seven different array experiments.

A lasting switch is indicated as first preference in the control column. The primary reason for this preference is due to the criticality of the function, which was ranked M (medium, results in loss of or degradation of data) in Section 2. As the loss of this function results in the operational loss of an entire experiment, a redundant dedicated hardwire interface is preferred. This interface is most readily satisfied at the C and D Console through the use of a toggle switch, employing redundant bus feeds, switching contacts and interface wiring. Further, considering the low ranking in terms of Frequency of Use, Response and Dwell Time indicates that this function does not warrant inclusion in the primary command interface area of the Console. The use of a switch

in lieu of a dedicated function key allows this function to be accommodated in the peripheral area of the Console or on a remote console dedicated to infrequently used payload activation and housekeeping monitoring functions.

The alternative of a keyboard command is acceptable as the primary control source, provided adequate system level reliability is incorporated. This reliability may be implemented through redundant keyboards (or on-board replaceable plug-in keyboards) and redundant interface wiring as may be inherent to the design of a multi-operator crew station. A keyboard may also be used as backup to a non-redundantly wired switch command, thereby minimizing interface wiring complexity while maintaining system reliability through command redundancy.

The use of a momentary type switch was also considered and ranked last. This type switch provides equal reliability, through redundant wiring, as the lasting type switch but has no built-in memory and therefore requires an additional status indicator. The penalties in terms of additional panel space, power and interface complexity were considered to override the advantage of positive feedback.

Table 3-1. C&D Generic Devices: Astronomy Group

FUNCTION	USE REQUIREMENT										CONTROL										DISPLAY										REMARKS
	PHOTOHELIOGRAPH	DUAL WHITE LIGHT CORONAGRAPHS	X-RAY TELESCOPE	XUV SPECTROHELIOGRAPH	IR TELESCOPE	STRATOSCOPE III	HIGH ENERGY ARRAYS				SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER					SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR				
MAIN POWER ON/OFF	1	1	1	1	1	1	7				1	3		2							1	3	2								2: See Note 1
DOOR OPEN/CLOSE	1	1	1	1	1	1	-					2		1								2	1								1: See Note 1
LAUNCH LOCKS LOCK/UNLOCK	1	1	1	1	1	1	-				1			2							1		2								2: See Note 1
THERMAL CONTROL ON/OFF	1	1	1	1	2	1	-				1	3		2							1	3	2								2: See Note 1
THERMAL MONITORING	1	1	1	1	1	1	-						1	2									2		1						2: See Note 2
FOCUS MODE AUTO/MANUAL	1	-	-	-	-	-	-				1	3		2							1	3	2								2: See Note 1
MANUAL FOCUS CONTROL	1	-	-	-	1	1	-					1													1						
ALIGNMENT MODE SELECT	1	1	-	-	-	-	-				1	3		2							1	3	2								
ALIGNMENT MANUAL CONTROL	1	1	-	-	1	1	-					1A			1B																
IMC OVERRIDE	1	-	-	-	-	-	-				1	3		2							1	3	2								2: See Note 1
HIGH VOLTAGE ON/OFF	1	1	4	-	1	1	7				1	2		3							1	2	3								
	-	-	-	-	-	-	222					2	2	1								2	1								3: See Note 1
WAVELENGTH SELECT	1	-	-	-	-	-	-						1	2							1		2								
	-	-	-	1	-	-	-					1		2								1	2								2: See Note 1
MONITOR	1	1	1	-	1	1	-																				1				
MASTER DATA START/STOP	1	-	-	-	-	-	-					1		2								1	2								2: See Note 1
INSTRUMENT POWER ON/OFF	3	-	-	-	-	4	1				2	3		1							2	3	1								1: See Note 1
MODE CONTROL SELECT	3	1	-	1	1	4	1					3	2	1							2	3	1								1: See Note 1
DATA ACQUISITION START/STOP	3	1	3	1	2	4	7					2		1								2	1								1: See Note 1
FRAME RATE SELECT	3	-	-	-	-	-	-				2	3		1							2	3	1								
	-	-	1	-	-	-	-					3	2	1							2	3	1								1: See Note 1
FRAME COUNT	3	1	2	1	-	2	-																1	2							
GRATING SELECT IN/OUT	1	-	1	-	-	1					2			1							2		1								1: See Note 1

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-1. C&D Generic Devices: Astronomy Group (Continued)

FUNCTION	USE REQUIREMENT							CONTROL						DISPLAY								REMARKS
	PHOTOHELIOGRAPH	DUAL WHITE LIGHT CORONAGRAPHS	X-RAY TELESCOPE	XUV SPECTROMETER	IR TELESCOPE	STRATOSCOPE III	HIGH ENERGY ARRAYS	SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER	SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO-AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR	
MIRROR POSITION SELECT	-	1	-	-	-	-			2		1				2	1						1: See Note 1
GIMBAL POINTING MODE SELECT	-	1	-	-	-	-		1	2					1	2							
GIMBAL POINTING MANUAL CONTROL	-	1	-	-	-	-	1				2	1				2	1					2: Three 4 digit numeric indicators required on MFD
DOOR AUTO CLOSE NORMAL OVERRIDE	-	1	-	-	-	-	-	1	2		3			1	2	3						3: See Note 1
FILTER SELECT	-	-	1	-	-	1	-			2	1			2		1						2: See Note 1
INSTRUMENT SELECT	1	-	1	-	1	-	-	2			1			2		1						1: See Note 1
EXPOSURE RANGE SELECT	-	-	1	-	-	-	-			2	1			2		1						1: See Note 1
SLIT SIZE SELECT	-	-	1	-	-	1	-			2	1											1: See Note 1
SCAN RANGE SELECT	-	-	1	-	1	-	2			2	1			2		1						1: See Note 1
SCAN RATE SELECT	-	-	1	-	-	-	2			2	1			2		1						1: See Note 1
SCAN STEP SIZE SELECT	-	-	-	-	1	-	-						1					1				
SCAN SEQUENCE SELECT	-	-	1	-	-	-	-			2	1			2		1						1: See Note 1
SCAN COUNT	-	-	1	-	-	-	1	2			1			2		1						1: See Note 1
CRYSTAL/GRATING POSITION UP/DOWN	-	-	1	-	-	1	-									1	2					1: Five digit numeric indicator required on MFD
CALIBRATION INITIATE	-	-	2	-	2	3	6		1		1					1A	1B					1A: Four digit numeric indicator required on MFD
SPECTRUM MONITOR RECORD/ REVIEW	-	-	2	-	1	-	4		2		1				2	1						1: See Note 1
DETECTOR COUNT	-	-	3	-	-	-	5													1		Paper tape recorder required. Two channels minimum.
APERTURE MODE SELECT AUTO/MANUAL	-	-	1	-	-	-	-	2	3		1			2	3	1						1: See Note 1

Note 1: Discrete status indication required on multifunction display.

Table 3-1. C&D Generic Devices: Astronomy Group (Continued)

FUNCTION	USE REQUIREMENT										CONTROL										DISPLAY										REMARKS
	PHOTOHELIOGRAPH	DUAL WHITE LIGHT CORONAGRAPHS	X-RAY TELESCOPE	XUV SPECTROMETER	IR TELESCOPE	STRATOSCOPE III	HIGH ENERGY ARRAYS				SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER					SWITCH POSITION (PANEL MOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO-AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR				
APERTURE MANUAL CONTROL INCREASE/DECREASE	-	-	1	-	-	-	-					2		1								2	1								1: See Note 1
PHA GAIN SELECT	-	-	1	-	-	-	-				2		2	1							2		1								1: See Note 1
FILTER HEATER ON/OFF	-	-	1	-	-	-	-				1			2							1		2								2: See Note 1
DISCRIMINATOR LEVEL SELECT	-	-	1	-	-	-	1				2		2	1							2		1								1: See Note 1
FLARE ALERT ENABLE/ INHIBIT	-	-	1	-	-	-	-				1			2								1	2								1: See Note 1
EXPOSURE/SAMPLING DURATION	-	-	-	1	-	-	-					2		1								2	1								1: See Note 1
	-	-	-	-	-	2	2						2	1							2		1								
FLARE MODE ENABLE/ INHIBIT	-	-	-	1	-	-	-					2		1								2	1								1: See Note 1
DETECTOR GAIN	-	-	-	-	2	-	-									1					1										
	-	-	-	-	-	-	1						2	1							2		1								1: See Note 1
DETECTOR RATE	-	-	-	-	-	-	2						2	1							2		1								1: See Note 1
DETECTOR BIAS	-	-	-	-	2	-	-									1					1										
DETECTOR TEMPERATURE					2											1								1							
DETECTOR SELECT					2		1				2			1							2		1								1: See Note 1
						1	4						2	1							2		1								
ZERO OFFSET	-	-	-	-	1	-	-									1					1										
DETECTOR ELEMENT SELECT	-	-	-	-	1	-	-				2		2	1							2		1								1: See Note 1
CRYOGEN COOLING ON/OFF	-	-	-	-	1	-	-				1			2							1		2								2: See Note 1
HIGH VOLTAGE LEVEL SELECT	-	-	-	-	-	-	1						2	1							2		1								1: See Note 1
AIRLOCK OPEN/CLOSE	-	-	-	-	-	-	1				1	3		2							1	3	2								2: See Note 1
CALIBRATION SOURCE SELECT	-	-	-	-	-	-	1						2	1							2		1								1: See Note 1

Note 1: Discrete status indication required on multifunction display.

Table 3-1. C&D Generic Devices: Astronomy Group (Concluded)

FUNCTION	USE REQUIREMENT										CONTROL							DISPLAY										REMARKS
	PHOTOHELIOGRAPH	DUAL WHITE LIGHT CORONAGRAPHS	X-RAY TELESCOPE	XUV SPECTROMETER	IR TELESCOPE	STRATOSCOPE III	HIGH ENERGY ARRAYS				SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER CONTINUOUS CONTROLLER			SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)		HISTORY RECORDER		CRT MONITOR		
THRESHOLD SELECT	-	-	-	-	-	-	1						2	1				2		1								1: See Note 1
X-RAY ALERT	-	-	-	-	-	-	1												1	2								

Note 1: Discrete status indication required on multifunction display.

Table 3-2. C&D Generic Devices: Earth Observation Group

FUNCTION	USE REQUIREMENT									CONTROL							DISPLAY								REMARKS
	CAMERAS	SCANNERS	MICROWAVE RADAR	MULTISPECTRAL RADIOMETER	ALTIMETER/SCATTEROMETER/RADIOMETER	MULTISPECTRAL SPECTROMETER	POLARIMETER	OPTICAL RADAR	OBSERVATION TELESCOPES	SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER		SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR		
POWER ON/OFF	3	2	1	1	1	1	1	1	1	2	3		1				2	3	1						1: See Note 1
FRAME COUNT	3	-	-	-	-	-	-	-	1										1	2					1: See Note 1 2: 5 digit numeric display
DATA ACQUISITION START/STOP	3	2	1	1	-	1	1	1	1		2		1					2	1						1: See Note 1
CAMERA SPEED SELECT	3	-	-	-	-	-	-	-	1		3	2	1				2	3	1						1: See Note 1
f-STOP SELECT	2	-	-	-	-	-	-	-	1			2	1				2		1						1: See Note 1
IMC ON/OFF	2	1	1	-	-	-	-	-	1	1	3		2				1	3	2						2: See Note 1
THERMAL CONTROL ON/OFF	3	2	-	-						1	3		2				1	3	2						2: See Note 1
THERMAL MONITOR	3	2	1	-	1	1	1	1	1			1	2						2	1B	1A				2: See Note 2
DOOR OPEN/CLOSE	3	1	-	1	-	1	1	1		3	2		1				3	2	1						1: See Note 1
INSTRUMENT(S)/CAMERA(S) SELECT	1				1				1			2	1				2		1						1: See Note 1
FILTER SELECT	1									2			1				2		1						1: See Note 1
DETECTOR CURRENT SELECT	-	1										2	1				2		1						1: See Note 1
POWER SUPPLY VOLTAGE MONITOR	-	2	1	1	1	1	1	1				1	2						2		1				2: See Note 2
CALIBRATION STATUS	-	1	-	1	-	1	1			2			1					2	1						1: See Note 1
CALIBRATION MODE SELECT AUTO/MANUAL		1		1			1			2	3		1				2	3	1						1: See Note 1
MANUAL CALIBRATION RATE SELECT HIGH/LOW		1								2			1				2		1						1: See Note 1
ANTENNA STEERING -Z AXES		1											2	1					2	1					2: See Note 2
RANGE SWEEP SELECT			1		1			1		2			1				2		1						1: See Note 1
GAIN CONTROL	-	-	1	-	1										1		1								

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-2. C&D Generic Devices: Earth Observation Group (Concluded)

FUNCTION	USE REQUIREMENT										CONTROL						DISPLAY									REMARKS
	CAMERAS	SCANNERS	MICROWAVE RADAR	MULTISPECTRAL RADIOMETER	ALTIMETER/SCATTEROMETER/RADIOMETER	MULTISPECTRAL SPECTROMETER	POLARIMETER	OPTICAL RADAR	OBSERVATION TELESCOPE		SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER	SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR		
ANTENNA TILT SELECT			1		1							2	2	1			2		1							1: See Note 1
														1					1	2						
RECEIVER SENSITIVITY MONITOR	-	-	1	-	1														1	3	2					1: See Note 2
TRANSMITTER POWER MONITOR	-	-	1	-	1	-	-	1											1	3	2					1: See Note 2
RADAR DISPLAY			1																					1		"A" Scope Display
MIRROR POINTING			-	1		1	1	1	1			1		2	1				2	1						2: See Note 2
														2					2	1						Observation telescope requires display only.
DETECTOR VOLTAGE MONITOR				1	-	1	1						2	1					1	2						1: See Note 2
MODE SELECT					1						2			1			2		1							1: See Note 1
					1				1				2	1			2		1							
RANGE MONITOR								1											1	2						1: See Note 2
HIGH VOLTAGE ON/OFF	-	-	-	-	-	-	-	-	1		1	3		2			1	3	2							2: See Note 1
EXPOSURE DURATION SELECT									1			3	2	1			3	2	1							1: See Note 1
TARGET MONITOR									1		2			1										1		

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-3. C&D Generic Devices: Physics Group

FUNCTION	USE REQUIREMENT										CONTROL										DISPLAY										REMARKS
	PHOTON SENSORS	RF RADIATION DETECTORS & TRANSMITTERS	AMBIENT MEASUREMENT INSTRUMENTS	PARTICLE SENSORS							SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER					SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR					
MAIN POWER ON/OFF	4	3	11	2							2	3		1							2	3	1								1: See Note 1
THERMAL MONITOR	5	4	11	2									1	2									2	1E	1A						2: See Note 2
HIGH VOLTAGE ON/OFF	1		1								1	3		2		1					1 1	3	2								2: See Note 1
POWER SUPPLY VOLTAGE MONITOR	3	4	4										1	2									2		1						2: See Note 2
GAIN CONTROL	1	9	1										2	1		1					2 1		1								1: See Note 2
CALIBRATION MODE	1		1								2	3	2	1 1							2 2	3	1 1								1: See Note 1 1: See Note 1
CALIBRATION STATUS	1		1										2	1								2	1								1: See Note 1
DETECTOR SELECT	3												2	1							2		1								1: See Note 1
DETECTOR MONITOR	4		2 1	1							2		2	1 1									1 1	2	2						5 digit numeric readout
IMC ON/OFF	1										1	3		2							1	3	2								2: See Note 1
SIGNAL SELECT	1												2	1							2		1								1: See Note 1
SCAN SELECT	3												2	1							2		1								1: See Note 1
SLIT SIZE SELECT	1												2	1							2		1								1: See Note 1
GRATING POSITION	2																						1	2							1: See Note 1 5 digit numeric readout
DOOR OPEN/CLOSE	1										3	2		1							3	2	1								1: See Note 1
SPACE IMAGE TUBE MONITOR	1																										1				Resolution: 1000 TV lines Frame Rate: 1/min
IMAGE ISOCON TV MONITOR	2																										1				Resolution: 500 TV lines Frame Rate: 2/sec
TRANSMITTER POWER		2														1					1										

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-3. C&D Generic Devices: Physics Group (Concluded)

FUNCTION	USE REQUIREMENT										CONTROL										DISPLAY										REMARKS
	PHOTON SENSORS	EM RADIATION DETECTORS & TRANSMITTERS	AMBIENT MEASUREMENT INSTRUMENTS	PARTICLE SENSORS							SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER					SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR					
FREQUENCY CONTROL		10 1									1					1					1 1										
BANDWIDTH CONTROL		7														1					1										
INSTRUMENT SELECT		1											2	1							2		1								1: See Note 1
COLLECTOR CURRENT MODULATION MONITOR			2																									1			Oscilloscope Display
CARRIER LEVEL CURRENT MONITOR			2																									1			Oscilloscope Display
SWEEP MONITOR			2																									1			Oscilloscope Display
GRID POTENTIAL			2	2												1									1						
COLLECTOR POTENTIAL			2													1									1						
SENSOR VOLTAGE MONITOR			16	4									2	1									1	2							1: See Note 2
SENSOR CURRENT MONITOR			6	1									2	1									1	2B	2A						1: See Note 2
SENSOR FREQUENCY MONITOR			1	1																			1	2							1: See Note 2
RANGE SELECT			1										2	1							2		1								1: See Note 1
BANDPASS MONITOR																							1		2						1: See Note 2
MODE SELECT			1								2	3		1							2	3	1								1: See Note 1

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-4. C&D Generic Devices: Life Science Group

FUNCTION	USE REQUIREMENT										CONTROL							DISPLAY										REMARKS
	VERTEBRATE CAGE MODULE	BIOMEDICAL MEASUREMENTS UNIT	LIFE SUPPORT TEST UNIT								SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER		SWITCH POSITION (PANEL MOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR			
MAIN POWER ON/OFF	5	2	1								2	3		1				2	3	1								1: See Note 1
RECORD SPEED SELECT	5												1	2				1		2								2: See Note 1
CALIBRATION COMMAND	6	1											2	1				2		1								1: See Note 1
POWER SUPPLY VOLTAGE MONITOR	6	1	1																	1		2						1: See Note 2
SIGNAL VOLTAGE	3 2	1	1																	1	2			1	1			1: See Note 2 Hard copy and/or interactive graphics display required for Vertebrate Cage Module
TEMPERATURE MONITOR	2 1										2		2	1 1						1		2						1: See Note 2
TEMPERATURE CONTROL ON/OFF	2										1	3		2				1	3			2						
ECS FLOW RATE CONTROL	2		1								2	3	2	1				2 2	3	1 1								1: See Note 1 1: See Note 1
ECS FLOW RATE MONITOR	2		1																	1		2						1: See Note 2
RELATIVE HUMIDITY CONTROL	2										2	3		1				2	3	1								1: See Note 1
RELATIVE HUMIDITY MONITOR	2																			1		2						1: See Note 2
pCO_2 CONTROL	2										2	3		1				2	3	1								1: See Note 1
pCO_2 MONITOR	2																			1		2						1: See Note 2
pO_2 CONTROL	2		1								2	3		1				2	3	1								1: See Note 1
pO_2 MONITOR	2		1																	1		2						1: See Note 2
TOTAL PRESSURE CONTROL	2		1								2	3		1				2	3	1								1: See Note 1
TOTAL PRESSURE MONITOR	2		1																	1		2						1: See Note 2
WATER SUPPLY CONTROL	2										2	3		1				2	3	1								1: See Note 1
WATER SUPPLY MONITOR	2		1										2	1						1		2						1: See Note 2

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-4. C&D Generic Devices: Life Science Group (Concluded)

FUNCTION	USE REQUIREMENT										CONTROL										DISPLAY										REMARKS
	VERTEBRATE CAGE MODULE	BIOMEDICAL MEASUREMENTS UNIT	LIFE SUPPORT TEST UNIT								SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER					SWITCH POSITION (PANEL MOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR					
FOOD WHEEL CONTROL	1										2		2	1							2		1					1			1: See Note 1
ILLUMINATION CONTROL	2												2	1							2		1								1: See Note 1
VIDEO MONITOR	2																										1				Monochromatic display compatible with color camera system required.
LBNP ΔP MONITOR		1																					1		2						1: See Note 2
LBNP ΔP CONTROL		1														1									1						Valve type continuous controller required.
LWMS NULL AND GAIN CONTROL		2														1									1						
LEG VOLUME PLETHYSMOGRAPH																										1					
TEMPERATURE MONITOR		4																					1		2						1: See Note 2
			1										2	1									1		2						1: See Note 2
BLOOD PRESSURE MONITOR		2																					1		2						1: See Note 2
RESPIRATION RATE (FLOWMETER)		1																					1		2						1: See Note 2
FLOWMETER CALIBRATION		1											2	1									1		2						1: See Note 2
HEART RATE MONITOR		1																					1		2						1: See Note 2
ERGOMETER OUTPUT MONITOR		1																					1		2						1: See Note 2
ERGOMETER SPEED MONITOR		1																					1		2						1: See Note 2
ERGOMETER MOTOR CONTROL		1											1								1										1: See Note 1
BODY MASS MEASUREMENT DEVICE OSCILLATION CALIBRATION AND MONITOR		1											2	1									1	2A	2B						1: See Note 2
SIGNAL CURRENT MONITOR			1										2	1									1		2						1: See Note 2

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-5. C&D Generic Devices: Advanced Technology Group

FUNCTION	USE REQUIREMENT			CONTROL						DISPLAY								REMARKS
	THERMAL CONTROL COATING REFORB	OXYGEN RECOVERY AND BIONASTE RESISTOJET	LIQUID/VAPOR INTERFACE STABILITY	SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER	SWITCH POSITION (PANEL MOUNT)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR	
POWER ON/OFF	6	1	-	2			1			2		1						1: See Note 1
SPACING STATUS	1	-	-								2	1						1: See Note 1
WAVEBAND SELECT 1-4	1	-	-		3	2	1			2	3	1						1: See Note 1
REFLECTANCE MONITOR	1	-	-									1	2	3				1: Five digit numerical indicator required on MFD
LIGHTS/ILLUMINATION ON/OFF	1	-	3	1			2			1		2						2: See Note 1
FRAMES REMAINING	1		1	2			1					1		2				1: See Note 2
CALORIMETER SELECT	1	-	-		3	2	1			2	3	1	2					1: See Note 1
CALORIMETER MONITOR	1	-	-									1	2	3				1: Three digit numeric indicator required on MFD
TEMPERATURE MONITOR	1	1	1			2	1					1		2				1: See Note 2. Range 150 to 350° K, resolution 1%.
VACUUM VENT	1			3	2		1			3	2	1						1: See Note 1
VACUUM CHAMBER PRESSURE MONITOR	1											1		2				1: See Note 2. Range 10^{-6} to 10^{-3} torr.
FLOW RATE SELECT	1	2	1	2		2	1			2		1						1: See Note 1
FLOW RATE MONITOR	-	2	1			2	1					1		2				1: See Note 2
HIGH VOLTAGE ON/OFF	1	-	-	2			1			2		1						1: See Note 1
HIGH VOLTAGE CONTROL	1						1		2			1	2					1: Four digit numeric indicator required on MFD
HEATER CONTROL	1								1					1				0 - 10A ammeter required.
TANK PRESSURE	-	1	-						1					1				Valve control required.

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-5. C&D Generic Devices: Advanced Technology Group (Concluded)

FUNCTION	USE REQUIREMENT			CONTROL						DISPLAY								REMARKS
	THERMAL CONTROL COATING REFURB	OXYGEN RECOVERY AND BIOWASTE RESISTOJET	LIQUID/VAPOR INTERFACE STABILITY	SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER CONTINUOUS CONTROLLER		SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR	
POWER CONTROL		4							1					1				
PUMP ON/OFF		3	3	2	3		1			2	3	1						1: See Note 1
RESISTOJET CONTROL	-	1	-		1						1							
GAS COMPOSITION MONITOR		1				2	1					1		2				Caution and warning indicator required.
PRESSURE MONITOR	-	1	1			2	1					1		2				1: See Note 2
FLUID TRANSFER	-	-	1	2	3		1			2	3	1						1: See Notes 1 and 3
VIBRATOR AND SLOSHER	-	-	1		3	2	1			2	3	1						1: See Notes 1 and 3
EXPERIMENT MONITOR	-	-	2														1	Monochromatic video monitors (2) required. Commercial quality resolution and gray scales adequate.
TV CAMERA PAN AND TILT CONTROL	-	-	6		1					1								Five position momentary switch required.
TV CAMERA ZOOM CONTROL	-	-	6		1					1								
TV CAMERA SELECT 1-6	-	-	2			1				1								
FILM CAMERA PAIR SELECT 1-3	-	-	1	2			1			2		1						1: See Note 1
FRAME RATE SELECT 1-4	-	-	1		3	2	1			2	3	1						1: See Note 1
THERMAL CONTROL ON/OFF	-	-	8	2			1			2		1						1: See Notes 1 and 3
HISTORY RECORDER	-	-	1			1										1		Two channel paper tape recorder, monitoring pressure and flow required.

Note 3: Status of liquid/vapor interface stability experiment may be displayed as a signal flow type graphic display on a multifunction display. Status of valves, pumps, vibrator and slosher, and heaters may be displayed on signal flow diagram.

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-6. C&D Generic Devices: Support Group

FUNCTION	USE REQUIREMENT				CONTROL						DISPLAY								REMARKS
	EXPERIMENT A/PCS	DATA MANAGEMENT SUBSYSTEM	ENVIRONMENTAL CONTROL SUBSYSTEM	ELECTRICAL POWER SUBSYSTEM	SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER CONTINUOUS CONTROLLER		SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR	
MAIN POWER	1	1	-	-	1			2			1		2						2: See Note 1
EXPERIMENT ATTITUDE CONTROL	1	-	-	-				2	1				1	2					1: Four digit numeric indicators required on MFD providing the following information about 3 axes: rate, angular displacement, inertial reference, and angular displacement, vehicle reference.
VEHICLE ATTITUDE CONTROL AND STABILIZATION	1	-	-	-				1	2				1	2					1: Four digit numeric indicators required on MFD providing the following: vehicle rate and attitude.
ATTITUDE CONTROL MODE SELECT 1-6	1	-	-	-		2		1				2	1						1: See Note 1
MOMENTUM MANAGEMENT MODE SELECT	1					2		1				2	1						1: See Note 1
CMG POWER	3				2			1				2	1						1: See Note 1
CMG MONITOR	3						2	1					1		2				1: MFD to provide analog display of total momentum (H), 3 axis H, and for each CMG wheel speed, current and bearing temperature.
MOMENTUM ALERT	1											1	2						2: May require blink coding
BEARING TEMPERATURE ALERT	3											1	2						2: May require blink coding
THRUSTER INHIBIT	6	-	-	-	1			2				1	2						2: See Note 1
TACS PRESSURE	1	-	-	-									1		2				1: See Note 2
TACS THRUST DURATION	1							1					1						1: Four digit numeric indicator required
RESOLUTION SELECT	1							1					1						1: Four digit numeric indicator required
TRANSMITTER INPUT SELECT	-	2	-	-	3	2		1			3	2	1						1: See Note 1
TRANSMITTER OUTPUT SELECT	-	2	-	-	3	2		1			3	2	1						1: See Note 1
RECORDER POWER	-	2	-	-	3	2		1			3	2	1						1: See Note 1
RECORDER MODE	-	2	-	-	3	2		1			3	2	1						1: See Note 1

Note 1: Discrete status indication required on multifunction display.

Note 2: Analog readout required on multifunction display.

Table 3-6. C&D Generic Devices: Support Group (Continued)

FUNCTION	USE REQUIREMENT										CONTROL										DISPLAY											REMARKS
	EXPERIMENT A/PCS	DATA MANAGEMENT SUBSYSTEM	ENVIRONMENTAL CONTROL SUBSYSTEM	ELECTRICAL POWER SUBSYSTEM							SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER					SWITCH POSITION (PANEL MOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR					
RECORDER TAPE REMAINING	-	2	-	-																			1		2							1: See Note 2
CAUTION AND WARNING	-	40 (TYP)	-	-																		1										Brightness: 50 FL nominal Color: emergency - red caution - amber warning - amber
ALERT STATUS	-	80 (TYP)	-	-																		2	1									1: Tabular listing of alert status. Master alert indicator required to cur operator to investigate alert status. 2: Brightness - 15 FL nominal Color - blue
SUBSYSTEM DIAGNOSIS	-	(TBD)	-	-										1									1									OCS performs continuous automatic checkout. MFD provides parametric display of OCS measurements list as selected by keyboard command.
MONITOR EXPERIMENT STATUS	-	(TBD)	-	-										1									1									Manual checkout of experiments initiated by keyboard command. MFD provides parametric display of experiment response to self test routine.
PROCEDURES DISPLAY		(TBD)												1									1									1* A microfilm viewer addressable via the keyboard is recommended.
PRESSURE MONITOR, ECS			9																				1		2							1: See Note 2. Used in conjunction with C&W and alert status dedicated monitors. 2: Dedicated meter for each function located on ECS monitor panel.
PRESSURE CONTROL, ECS			1													1									1							Dedicated pO_2 analog meter required.
TEMPERATURE MONITOR, ECS			11																				1		2							Same as for pressure monitor.
TEMPERATURE CONTROL, ECS			2													1									1							Dedicated C&D required for radiator and sublimator outlet temperatures.
VOLTAGE MONITOR, EPS				3																			1		2							1: See Note 2. Used in conjunction with C&W and alert status dedicated monitors. 2: Dedicated meter for each function located on EPS monitor panel.

Note 2: Analog readout required on multifunction display.

Table 3-6. C&D Generic Devices: Support Group (Concluded)

FUNCTION	USE REQUIREMENT										CONTROL							DISPLAY										REMARKS
	EXPERIMENT A/PCS	DATA MANAGEMENT SUBSYSTEM	ENVIRONMENTAL CONTROL SUBSYSTEM	ELECTRICAL POWER SUBSYSTEM							SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER		SWITCH POSITION (PANEL NOMEN)	STATUS INDICATOR	MULTIFUNCTION DISPLAY	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR			
CURRENT MONITOR, EPS				3																1		2						Same as for voltage monitor.
PRESSURE MONITOR, EPS				2																1		2						Same as for voltage monitor.
FLOW RATE MONITOR, EPS				2																1		2						Same as for voltage monitor.
TEMPERATURE MONITOR, EPS				3																1		2						Same as for voltage monitor.

3.4 DISCUSSION

The material presented in Tables 3-1 through 3-6 reflects certain philosophy and assumptions required to select generic devices for a generalized application as follows:

extent of dedicated vs. universal C and D specification

primary control vs. secondary, or backup control

assignment of display types for associated controls

man-machine optimization

human factors consideration

cost

size/weight

reliability

maintainability

The criteria above has been applied to each requirement using a generalized C and D console/work station model. The device matrices are indicative of the general requirements for future manned space missions and are useful to perceive trends, commonality and new, unique device requirements. Careful, detailed analysis and trade studies are necessary for each specific C and D console/module/mission to arrive at optimized C and D device selection.

It is of interest in studying Tables 3-1 through 3-6 to summarize the use requirements per discipline for each generic control and display device. Such a summary is presented in Table 3-7. Use requirements have been summed across all experiments within a discipline, or group, for first choice (1) only. The table illustrates the versatility of a keyboard device in that most of the control functions (77% for the Astronomy Group) can be implemented using this device in lieu of dedicated switches. Further, the usefulness of a multifunction display is illustrated by noting that most display functions can be implemented using this device (83% for the Astronomy Group).

Table 3-7. Summary of C&D Device Matrix

GENERIC DEVICE / SCIENTIFIC DISCIPLINE	USE REQUIREMENTS PER DISCIPLINE													
	CONTROL						DISPLAY							
	SWITCH, LASTING	SWITCH, MOMENTARY	SWITCH, ROTARY	KEYBOARD	MULTI-AXIS PROPORTIONAL CONTROLLER	CONTINUOUS CONTROLLER	PANEL NOMENCLATURE	STATUS INDICATOR	MULTI-FUNCTION	NUMERIC READOUT	ANALOG READOUT	TWO AXIS NULL DETECTOR (X-PTR)	HISTORY RECORDER	CRT MONITOR
ASTRONOMY	51	11	7	331	2	8	58	5	340	2	12	4	7	5
EARTH OBSERVATION	10	3	19	65	3	2	13	1	73	6	19	0	0	2
PHYSICS	3	0	33	69	0	36	33	0	76	0	39	0	0	9
LIFE SCIENCE	2	0	6	43	0	3	8	0	77	0	3	0	5	6
ADVANCED TECHNOLOGY	4	13	3	44	0	6	18	1	49	0	6	0	1	2
SUPPORT	8	0	0	19	1	3	2	50	136	0	3	0	0	0
TOTALS	78	27	68	571	6	58	132	57	751	8	82	4	13	24

This summary matrix also suggest that although a multipurpose display and control device(s) satisfy most requirements a certain amount of dedicated devices must be included. Note that in addition to a keyboard nearly all other control functions require a dedicated switch (lasting, momentary, or rotary) or a continuous controller. Note that for displays a multifunction device is not sufficient, dedicated readout or talkback is necessary as well.

Thus, it appears that future control and display subsystems will consist of an optimum mix of conventional, dedicated type C and D devices and integrated, software oriented, multipurpose C and D devices.

SECTION 4

DEDICATED C AND D DEVICE MATRIX

4.1 GENERAL

The combination of dedicated and integrated, software oriented, multipurpose devices discussed in Section 3 is dependent on a multitude of variables such as:

Scientific experiments

Console size

Number of operators

Hardware interface

Mission

Module

It is not fruitful to attempt generalizations in order to arrive at a specific mix for all experiments/missions/modules. Careful analysis and trade studies must be performed for each specific C and D console to define the proper mix of dedicated and multipurpose devices.

To gain further insight into C and D device requirements, let us consider device preference using only dedicated devices.

4.2 DESCRIPTION

Tables 4-1 through 4-6 list C and D device preference using only dedicated devices. Once again the device preference is listed for each of the five scientific disciplines and support instrumentation as follows.

Astronomy

Earth Observation

Physics

Life Science

Advanced Technology

Support

C and D functions identified for each discipline are listed in the first column of each table. The second and third column list the recommended first and alternate choice, respectively, of interface between the control device and the functional element. Three choices have been considered: module, data management system or experiment. The next column lists the display talkback required for the primary choice of control device. The "Use Requirement" column lists the total usage of the C and D function listed for a given discipline (sum of all experiments requiring that function). The final major group of columns list generic control devices which can be considered to implement the functional requirements as follows:

Lasting Switch, 2 position, Lasting-Lasting (L-L)

Lasting Switch, 2 position, Locking, Locking (LK-LK)

Lasting Switch, 3 position, Lasting, Lasting, Lasting (L-L-L)

Momentary Switch, 3 position

Momentary Switch, 5 position

Rotary Switch, 6 position

Rotary Switch, 12 position

Rotary Switch, 18 position

The numbers in the switch type columns (1,2) represent the recommended device for each function, primary preference denoted by 1, secondary preference denoted by 2.

These tables assume the availability of an onboard data management system including a computer. Critical function control, e.g., Main Power On/Off, are dedicated rather than part of an integrated control console. Lasting type switches are preferred over momentary types except for short duration switching functions and for situations where ambiguous switch positions could result due to remote or automatic switching.

4.3 DEVICE MATRIX TABLES

The C and D dedicated device matrices which identify general categories of C and D types considered candidates for use in scientific experiments and support instrumentation, are as follows.

TABLE 4-1 ASTRONOMY GROUP

TABLE 4-2 EARTH OBSERVATION GROUP

TABLE 4-3 PHYSICS GROUP

TABLE 4-4 LIFE SCIENCE GROUP

TABLE 4-5 ADVANCED TECHNOLOGY GROUP

TABLE 4-6 SUPPORT GROUP

An example of Table 4-1 Astronomy Group is given below:

Table 4-1. Dedicated C&D Devices: Astronomy Group

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS						
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L	3-POS	5-POS	6-POS	12-POS	18-POS	
MAIN POWER	Module	DMS	NR	12	1			2					
			NR	1			1						2:
DOOR OPEN/CLOSE	Module	DMS	Status, 3 pos	6				1					
LAUNCH LOCKS			Status, 2 pos										

This function, as explained in Section 3, must be performed with high reliability. Thus, "hard-wiring" to the module is recommended as the preferred interface. An alternative as indicated would be the data management system. Talkback is not required (NR) in this instance since other indications of power status exist. The use requirement list twelve

occurrences for a 2 position lasting and one for a 3 position lasting switch. This latter application requires a standby position in addition to the on/off positions. A lasting, in lieu of a locking, switch for all thirteen uses is considered appropriate since no compelling need to avoid inadvertent activation exist. An alternative switch arrangement for the twelve applications, is the use of 3 position momentary (on, neutral, off). However, this configuration will require a status indication to assure positive talkback.

Table 4-1. Dedicated C&D Devices: Astronomy Group

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS						
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L	3-POS	5-POS	6-POS	12-POS	18-POS	
MAIN POWER	Module	DMS	NR	12	1			2					
			NR	1			1						2: Two position status indicator required.
DOOR OPEN/CLOSE	Module	DMS	Status, 3 pos	6				1					
LAUNCH LOCKS	Module	DMS	Status, 2 pos	6		1							
THERMAL CONTROL	Module	DMS	NR	7	1			2					
THERMAL MONITOR	DMS	Experiment	Analog Meter	7									2: Two position status indicator required.
FOCUS MODE SELECT	Experiment	DMS	NR	1	1			2			1		
MANUAL FOCUS CONTROL	Experiment	-	Analog Meter	3				1					2: Two position status indicator required.
ALIGNMENT MODE SELECT	Experiment	DMS	NR	4	1			2					Analog meter with zero center (null detection).
ALIGNMENT MANUAL CONTROL	Experiment	-	See Remarks						1*				2: Two position status indicator required.
													Two axis null detector (X Ptr) having 300 and 30 arc second ranges. * Two axis proportional controller may be desired.
IMC OVERRIDE	DMS	Experiment	NR	1	1			2					
MAIN HIGH VOLTAGE ON/OFF/RESET	DMS	Experiment	Malfunction Alert Indicator	15			1						
HIGH VOLTAGE ON/OFF	DMS	Experiment											
1-6			NR	2			1(6)	2		2			(Individual HV controls)
1-30			Status (2 pos)	1			1	1				1	
1-14			Status (2 pos)	1				1				1	
1-154			Status (2 pos)	1				1				1	
1-3			NR	1			1(3)	2		2	1	1	154 two position status indicators required.
1-9			Status (2 pos)	1			2(9)	1			1		
WAVELENGTH SELECT	DMS	Experiment	NR	1							1		
			Status (3 pos)	1				1					
MONITOR			TV Monitor										
MASTER DATA	DMS	-	Status (3 pos)					1					
INSTRUMENT POWER	DMS	Experiment	NR	8	1			2					2: Two position status indicator required.

L=Lasting
LK=Locking

Table 4-1. Dedicated C&D Devices: Astronomy Group (Continued)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS						
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L	3-POS	5-POS	6-POS	12-POS	18-POS	
MODE SELECT	DMS	Experiment											
1-4			NR	2				2(2)		1			2: Two 3-position status indicators required.
1-6			NR	6				2(3)		1			2: Two 3-position status indicators required.
1-5			NR	1						1			
1-3			NR	1			1	2					2: Three position status indicator required.
DATA ACQUISITION	DMS	Experiment	Status (3 pos)	21				1					
FRAME RATE SELECT	DMS	Experiment	NR										* Pulse or digital counter.
1-3				3			1	2					2: Three position status indicator required.
1-4				1				2(2)		1			2: Two 3-position status indicators required.
FRAME COUNT	DMS	Experiment	4 Digit Numeric Display	4									Pulse or digital counter required.
GRATING SELECT	DMS	Experiment	Status (3 pos)	3			1						
MIRROR POSITION SELECT	DMS	Experiment	NR	1				1					Talkback is provided by video display.
GIMBAL POINTING MODE SELECT	DMS	Experiment	NR	2	1			2					2: Two position status indicator required.
GIMBAL POINTING MANUAL CONTROL	Experiment	DMS	Three 4-Digit Numeric Readouts	2									Two axis proportional control required.
DOOR AUTO CLOSE NORMAL/OVERRIDE	DMS	Experiment	NR	1	1			2					2: Two position status indicator required.
FILTER SELECT 1-6	DMS	Experiment	3 Position Status Indicator (3)	2						1			
INSTRUMENT SELECT	DMS	Experiment	NR	3			1						
EXPOSURE RANGE	DMS	Experiment	NR	1						1			
SLIT SIZE SELECT	DMS	Experiment	3 Position Status Indicator (3)	2						1			
SCAN RANGE SEL	DMS	Experiment											
1-6			NR	2						1			
1-10			NR	1							1		
1-100			NR	1							1(2)		
SCAN RATE SELECT	DMS	Experiment	NR	2						1			
SCAN STEP SIZE SELECT	DMS	Experiment	NR	1						1			

L=Lasting
LK=Locking

Table 4-1. Dedicated C&D Devices: Astronomy Group (Continued)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS						
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L	3-POS	5-POS	6-POS	12-POS	18-POS	
SCAN SEQUENCE SELECT	DMS	Experiment	NR	1			1						
SCAN COUNT	DMS	Experiment	5 Digit Numeric Readout	2									Pulse or Digital Counter Required.
CRYSTAL/GRATING POSITION UP/DOWN	DMS	Experiment	4 Digit Numeric Readout	2				1					
CALIBRATION INITIATE	DMS	Experiment	3 Position Status Indicator	13				1					
SPECTRUM MONITOR RECORD/ REVIEW	DMS	Experiment	Paper Tape Recorder	6									
DETECTOR COUNT	DMS	Experiment	Numeric Display										
			3 Digit	5									This display used in communication with detector select control. Excessive count rate alert indicator (2-pos) required.
			4 Digit	2									
			5 Digit	1									
APERTURE MODE SELECT AUTO/MAN	DMS	Experiment	NR	1	1			2					2: Two position status indicator required.
APERTURE MANUAL CONTROL INCR/DECR	DMS	Experiment	3 Position Status Indicator (2)	1				1					
PHA GAIN SELECT (1-32)	DMS	Experiment	NR	1	1							1	
FILTER HEATER ON/OFF	DMS	Module	NR	1	1								
DISCRIMINATOR LEVEL SELECT	DMS	Experiment	NR										
1-16				1								1	
1-25				1	1							1	
FLARE ALERT ENABLE/INHIBIT	DMS	Experiment	Flare Alert Indicator (2 position)	1	1								
EXPOSURE/SAMPLING DURATION	DMS	Experiment											
1-3			3 Position Status Indicator	1				1					
1-6			NR	2						1			
1-10			NR								1		
FLARE MODE ENABLE/INHIBIT	DMS	Experiment	3 Position Status Indicator	1				1					

L=Lasting
LK=Locking

Table 4-1. Dedicated C&D Devices: Astronomy Group (Concluded)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
DETECTOR GAIN	Experiment	DMS	NR	2									Continuous gain controll is required. Discrete steps, implemented by rotary switches may be acceptable.
DETECTOR RATE SELECT 1-4	DMS	Experiment	NR	1						1			Excessive count rate alert status indicator (2 position) required.
SELECT 1-6			NR	1						1			
DETECTOR BIAS	Experiment	DMS	NR	2									Continuous bias control is required. Discrete steps, implemented by rotary switches may be acceptable.
DETECTOR TEMPERATURE	Experiment	DMS	Analog Readout (Scale TBD)	2									Continuous temperature control is required.
DETECTOR SELECT 1-6	DMS	Experiment	NR	3			1(6)	2		2			This control function may be shared with high voltage control.
1-30				1			1					1	
1-14				1								1	
1-154				1							1	1	
1-3				1			1	2		2			
1-9				1			2(9)	1			1		
ZERO OFFSET	Experiment	DMS	NR	1									Continuous control is required.
DETECTOR ELEMENT SELECT 1-21	DMS	Experiment	NR	1	1						1		
CRYOGEN COOLING ON/OFF	Module	DMS	NR	1	1								
HIGH VOLTAGE LEVEL SELECT 1-128	DMS	Experiment	NR	1							1(2)		
AIRLOCK OPEN/CLOSE	Experiment	DMS	NR	1	1			2					2: Two position status indicator required.
CALIBRATION SOURCE SELECT 1-4	DMS	Experiment	NR	1						1			
THRESHOLD SELECT 1-32	DMS	Experiment	NR							1(2)			
X-RAY ALERT	DMS	Experiment	Status, 2 Pos.										

L=Lasting
LK=Locking

Table 4-2. Dedicated C&D Devices: Earth Observation Group

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
POWER ON/OFF	Module	DMS	NR	12	1			2					2: Two position status indicator required.
FRAME COUNT	DMS	Experiment	Numeric Display										
			4 Digit	1						1			
SELECT 1-4			4 Digit	1						1			
SELECT 1-6			3 Digit	1						1			
DATA ACQUISITION	DMS	Experiment	3 Position Status Indicator	11				1					
CAMERA SPEED SELECT 1-4	DMS	Experiment											
			NR	2				2(2)		1			2: Two 3-position status indicators required.
			Four 2-Position Status Indicators	1				1(4)		2(4) 1(6)			2: No talkback required.
			NR	1									
f-STOP SELECT	DMS	Experiment											
SELECT 1-7			NR	2							1		
			NR	1							1(6)		
IMC ON/OFF	DMS	Experiment	NR	5	1			2					2: Two position status indicator required.
THERMAL CONTROL ON/OFF	Module	DMS	NR	5	1			2					2: Two position status indicator required.
THERMAL MONITOR SELECT	DMS	Experiment	Analog Meter										Analog temperature meter range 200°K to 366°K; Resolution 1%.
1-2				3	1								
1-3				2			1						
1-4				2						1			
1-12				1							1		
1-18				3								1	
DOOR OPEN/CLOSE	Module	DMS	Status (3 Pos.)	8	2			1					
INSTRUMENT(S)/CAMERA(S) SELECT 1-3	DMS	Experiment	NR	1			1						
1-4				1						1			
1-6				1						1			
FILTER SELECT	DMS	Experiment	NR	1			1						
DETECTOR CURRENT SELECT	DMS	Experiment	NR	1							1		

L=Lasting
LK=Locking

Table 4-2. Dedicated C&D Devices: Earth Observation Group (Continued)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
POWER SUPPLY VOLTAGE MONITOR	DMS	Experiment	Digital Readout										Digital readouts required as follows:
1-4				1						1			3 Digit - 6 required
1-5				5						1			4 Digit - 2 required
1-10				2							1		
CALIBRATION STATUS	DMS	Experiment	Status (2 Pos.)	4	1								
CALIBRATION MODE SELECT AUTO/MAN	DMS	Experiment	NR	3	1			2					2: Two position status indicator required.
MANUAL CALIBRATION RATE SELECT HIGH/LOW	DMS	Experiment	NR	1	1								
ANTENNA STEERING 2 AXES	Experiment	DMS	Two 4-Digit Numeric Readouts	1									Two axis proportional controller required.
RANGE SWEEP SEC.	DMS	Experiment											
1-3			NR	2			1	2					2: Three position status indicator required.
1-5			NR	1						1			
GAIN CONTROL	Experiment	DMS	NR	2									Continuous gain control is required.
ANTENNA TILT SELECT	Experiment	DMS	NR	1							1		
ANTENNA TILT CONTROL	Experiment		4 Digit Numeric Readout	1				1					Single axis joy stick control may be preferred.
RECEIVER, SENSITIVITY MONITOR			Analog Readout										
TRANSMITTER, POWER MONITOR			Analog Readout										
RADAR DISPLAY			"A" Scope Display										Continuous type video gain control required.
MIRROR POINTING	Experiment	DMS	4 Digit Numeric Readout										
				1									Multi-axis proportional controller required.
				1						1			Only display select 1-4 required.
				3				1					

L=Lasting
LK=Locking

Table 4-2. Dedicated C&D Devices: Earth Observation Group (Concluded)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
DETECTOR VOLTAGE MONITOR	DMS	Experiment	Numeric Readout										
			4 Digit	1								1	Range IV; Resolution 1mV
			4 Digit	1						1			Range IV; Resolution 1mV
			3 Digit	1			1						Range IV; Resolution 50mV
MODE SELECT	DMS	Experiment	NR										
1-2				1	1								
1-3				1						1			
1-5				1						1			
RANGE MONITOR	DMS	Experiment	5 Digit Numeric Readout	1									Range 200n miles: A resolution of .01n miles is considered adequate for on-board monitoring.
HIGH VOLTAGE ON/OFF	Experiment	DMS	NR	1	1			2					2: Two position status indicator required.
EXPOSURE DURATION SELECT	DMS	Experiment	NR	1				2(2)		1			2: Two 3-position status indicators required.
TARGET MONITOR	Experiment	---	Video Monitor	1	1								Monochromatic TV Display: Resolution: 525 lines Gray scales: 8-10

L=Lasting
LK=Locking

Table 4-3. Dedicated C&D Devices: Physics Group

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
THERMAL MONITOR SELECT	DMS	Experiment	Analog Readout										Analog meter range: 200°K - 350°K
ON/OFF				10	1								Resolution: 1%
1-2				2	1								
1-3				1			1						
1-4				5						1			
1-8				2							1		
1-9				1							1		
1-12				1							1		
HIGH VOLTAGE ON/OFF	Experiment	DMS	NR										
				1							1		
				1									Continuous control required.
POWER SUPPLY VOLTAGE MONITOR	Experiment	DMS	Analog Readout										Range 0-300V; Resolution 1%
SELECT 1-4				1						1			
SELECT 1-3				1			1						
SELECT 1-2				1	1								
POWER SUPPLY VOLTAGE MONITOR	Experiment	DMS	Analog Readout										Range 0-1V; Resolution 1%
SELECT 1				2	1								
SELECT 1-2				1	1								
SELECT 1-6				1						1			
POWER SUPPLY VOLTAGE MONITOR	Experiment	DMS	Analog Readout										Range 12-100V; Resolution 1%
SELECT 1-5				2						1			
POWER SUPPLY VOLTAGE MONITOR	Experiment	DMS	Analog Readout	2	1								Range 0-28V; Resolution 1%
GAIN CONTROL	Experiment	DMS	NR										
				1								1	
				10									Continuous control required.
CALIBRATION SELECT	Experiment	DMS	NR										
1				1	1		2						2: Two position status indicator required.
1-4				1						1			
MAIN POWER	Module	DMS	NR	20	1			2					2: Two position status indicator required.

L=Lasting
LK=Locking

Table 4-3. Dedicated C&D Devices: Physics Group (Continued)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
DETECTOR SIGNAL	Experiment	DMS	5 Digit Numeric Readout	5	2			2					2: Two position status indicator required. Analog readout range 0-5V; Resolution 1%
1				1					1				
1-4				1					1				
1-6			Analog Readout	1						1			
1-12				1									
IMC ON/OFF	DMS	Experiment	NR	1	1			2					2: Two position status indicator required.
SIGNAL SELECT	DMS	Experiment	NR	1						1			
SCAN SELECT	DMS	Experiment	NR	2						1			
1-6				1							1		
1-12											1		
SLIT SIZE SELECT	DMS	Experiment	NR	1									
GRATING POSITION	DMS	Experiment	5 Digit Numeric Readout	2									
DOOR OPEN/CLOSE	Module	DMS	Status 3 Pos.	1				1					
SPACE IMAGE TUBE MONITOR	Experiment	DMS	CRT	1									Resolution 1000 TV lines; frame rate 1/min.
IMAGE ISOCON TV MONITOR	Experiment	DMS	CRS										Resolution: 500 TV lines; frame rate 2/sec.
TRANSMITTER POWER	Experiment	DMS	M2	2									Continuous control required.
FREQUENCY CONTROL													Continuous control is required. Range 0.1 to 200 KHz; resolution 1%.
1	Experiment	DMS	NR	10									
SELECT 1-3	Experiment	DMS		1			1						
BANDWITH CONTROL	Experiment	DMS	NR	7									Continuous control is required.
INSTRUMENT SELECT	DMS	Experiment	NR	1			1						
COLLECTOR CURRENT MODULATION MONITOR			CRT	2									Range 0-100%; Resolution 0.5%.
CARRIER LEVEL CURRENT MONITOR			CRT	2									Range 10^{10} 3 X 10^{-6}A; Resolution 0.5%.
SWEEP MONITOR			CRT	2									Range -2.7 -3.5V. Resolution 1%.

L=Lasting
LK=Locking

Table 4-3. Dedicated C&D Devices: Physics Group (Concluded)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
GRID POTENTIAL	Experiment	DMS	4 Digit Numeric Readout	4									Continuous control is required.
COLLECTOR POTENTIAL	Experiment	DMS	4 Digit Numeric Readout	2									Continuous control is required.
SENSOR VOLTAGE MONITOR	DMS	Experiment	See Remarks										Includes the following ranges: -3 to +3V, 0 to -2V, 0 to 5V, 0 to 10V, [illegible] 60V, -20 to +20V, 0 to 25V, 0 to 200V, 5 to 6000V and 4Cd to 600V.
1				13									
1-2				1	1								
1-3				2			1						
1-5				1						1			
1-7				2							1		
1-15				1								1	
SENSOR CURRENT MONITOR	DMS	Experiment	See Remarks	7									Includes the following ranges: 10^{-18} to 10^{-10}A, 0 to 2A, 10^{-10} to 10^{-6}A, 0 to 1A, 0 to 5A, and 10^{-13} to 10^{-8}A.
SENSOR FREQUENCY MONITOR													
1	DMS	Experiment	NR	1									Range 2 to 4 MHZ.
1-2	DMS	Experiment	NR	1	1								Range 2 to 3 MHZ.
RANGE SELECT	DMS	Experiment	NR	1					1				
BAND PASS MONITOR	DMS	Experiment	Analog Readout	1									
MODE SELECT	DMS	Experiment	NR	1								1	

L=Lasting
LK=Locking

Table 4-4. Dedicated C&D Devices: Life Science Group

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
MAIN POWER	Module	DMS	NR	8	1			2					2: Two position status indicator required.
RECORD SPEED SELECT	Experiment	DMS	NR	5						1			
CALIBRATION COMMAND	DMS	Experiment	NR	6						1			
POWER SUPPLY VOLTAGE MONITOR	DMS	Experiment	Analog Meter										Range 0 to ±12V; Resolution 1%.
1				7									
1-4				1						1			
SIGNAL VOLTAGE	Experiment	DMS	CRT or Numeric Display										Of the seven experiments that employ this control, four require a CRT display with hard copy and/or interactive graphics display.
1-16				6								1	
1-32				1								1(2)	
TEMPERATURE MONITOR	DMS	Experiment	Analog Meter										Ranges of 33 to 39°C and 25±1°C. Resolution 1°C. Primary alert status required for 2 exp.
1-2				2	1								
1-16				1								1	
TEMPERATURE CONTROL ON/OFF	Experiment	DMS	NR	2	1			2					2: Two position status indicator required.
ECS FLOW RATE CONTROL	DMS	Experiment	NR										2: Two position status indicator required.
1-2				2	1			2					
1-16				1								1	
ECS FLOW RATE MONITOR	DMS	Experiment	Analog Readout	2									Range 0 to 5V.
RELATIVE HUMIDITY CONTROL	DMS	Experiment	NR	2	1			2					2: Two position status indicator required.
RELATIVE HUMIDITY MONITOR	DMS	Experiment	Analog Readout	2									Range 60 ±10%.
PCO_2 CONTROL	DMS	Experiment	NR	2	1			2					2: Two position status indicator required.
PCO_2 MONITOR	DMS	Experiment	Analog Readout	2									Primary alert status required.
PO_2 CONTROL	DMS	Experiment	NR	3	1			2					2: Two position status indicator required.
PO_2 MONITOR	DMS	Experiment	Analog Readout	3									Primary alert status required.
TOTAL PRESSURE CONTROL	DMS	Experiment	NR	3	1			2					2: Two position status indicator required.
TOTAL PRESSURE MONITOR	DMS	Experiment	Analog Readout	3									Primary alert status required.
WATER SUPPLY CONTROL	DMS	Experiment	NR		1			2					2: Two position status indicator required.

L=Lasting
LK=Locking

Table 4-4. Dedicated C&D Devices: Life Science Group (Concluded)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS						
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L	3-POS	5-POS	6-POS	12-POS	18-POS	
WATER SUPPLY MONITOR SELECT	DMS	Experiment	Analog Readout										Primary alert status required.
1-8				1							1		
1-16				2								1	
FOOD WHEEL CONTROL	DMS	Experiment	NR	1	1						1		
ILLUMINATION CONTROL	DMS	Experiment	NR	2							1		
VIDEO MONITOR			CRT	2									Monochromatic display compatible with color camera system required.
BNP P CONTROL	Experiment		Pressure Meter	1									
BNP P CONTROL	Experiment		NR	1									Valve type continuous controller required.
VMS NULL AND GAIN CONTROL	Experiment		Null Meter	2									Continuous gain control required. Range -1 to +5% change.
LEG VOLUME PLETHYSMO-GRAPH	Experiment			1									History recorder required.
TEMPERATURE MONITOR			Analog Readout										
1	DMS	Experiment		4									
1-24	DMS	Experiment		1	1						1		
BLOOD PRESSURE MONITOR	DMS	Experiment	Analog Readout										
RESPIRATION RATE	DMS	Experiment	Flow Meter	1									
FLOWMETER CALIBRATION	DMS	Experiment	NR	1						1			
HEART RATE MONITOR	DMS	Experiment	Beats/Min	1									
ERGOMETER OUTPUT MONITOR	DMS	Experiment	Watt Meter	1									
ERGOMETER SPEED MONITOR	DMS	Experiment	RPM Indicator	1									
ERGOMETER MOTOR CONTROL	DMS	Experiment	NR	1							1		
BODY MASS MEASUREMENT DEVICE OSCILLATION CALIBRATION AND MONITOR	DMS	Experiment	4 Digit Numeric Readout	1						1			
SIGNAL CURRENT MONITOR	DMS	Experiment		1						1			

L=Lasting
LK=Locking

Table 4-5. Dedicated C&D Devices: Advanced Technology Group

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS	3-POS	5-POS	6-POS	12-POS	18-POS	
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L						
POWER ON/OFF	Module		NR	7			1						
SPACING STATUS	Experiment	DMS	Status, 2 Position	1									
WAVEBAND SELECT 1-4	Experiment	DMS	NR	1				2(2)		1			2: Two 3-Position status indicators required.
REFLECTANCE MONITOR	DMS	Experiment	Two Digit Numeric Readout	1									Alternate: Analog meter - scale 0 to 100%. Resolution 1%.
LIGHTS/ILLUMINATION ON/OFF	Module		NR	4	1								
FRAMES REMAINING	DMS	Experiment	Four Digit Numeric Readout	1									
FILM REMAINING (Footage)	DMS	Experiment	Analog Meter	1									Scale 0 to 100%; Resolution 1%.
CALORIMETER SELECT 1-4	Experiment	DMS	NR	1				2(2)		1			2: Two 3-position status indicators required.
CALORIMETER MONITOR	DMS	Experiment	Analog Meter	1									Scale TBS; Resolution 1%.
TEMPERATURE MONITOR	DMS	Experiment	Analog Meter	2 1	 1							1 1	Scale 150 to 350°K; Resolution 1% typical.
VACUUM VENT	Experiment	DMS	Status, 3-Position	1	2			1					2: Panel nomenclature indicates command status.
VACUUM CHAMBER PRESSURE MONITOR	DMS	Experiment	Analog Meter	1									Programable scale required: X1, X10, X100. Range 10^{-6} to 10^{-3} Torr; Resolution 1%.
FLOW RATE SELECT	Experiment	DMS	NR	1 2 1	1					1	1		
FLOW RATE MONITOR	DMS	Experiment	Analog Meter	3									
HIGH VOLTAGE ON/OFF	Experiment	DMS	NR	1	1								
HIGH VOLTAGE CONTROL	Experiment		Four Digit Numeric Readout	1									Continuous control required.
HEATER CONTROL	Experiment		Analog Meter	1									Continuous control required. Analog meter - scale 0 to 10 Amp - Resolution 1%.
POWER CONTROL	Experiment		Analog Meter	4									Continuous control required. Analog meter - Scale (TBS) - Resolution 1%.

L=Lasting
LK=Locking

Table 4-5. Dedicated C&D Devices: Advanced Technology Group (Concluded)

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS						
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L	3-POS	5-POS	6-POS	12-POS	18-POS	
PUMP ON/OFF	Experiment	DMS	NR	6	1			2					2: Two position status indicator required.
RESISTOJET CONTROL	Experiment		Status, 2 Position	1									Two position, locking-momentary, switch required
GAS COMPOSITION MONITOR	DMS	Experiment	Analog Readout	1						1			Analog meter - Scale: 0 to 100% - Resolution: 1%
PRESSURE MONITOR	DMS	Experiment	Analog Readout	2							1		Analog meter - Scale: (TBD) - Resolution: 1%
FLUID TRANSFER	Experiment	DMS	NR	1	1			2					2: Three position status indicator required.
VIBRATOR AND SLOSHER SELECT 1-4	Experiment	DMS	NR	1				2(2)		1			2: Two 3-position status indicators required.
EXPERIMENT MONITOR	Experiment		Video Monitor	2									Monochromatic video monitors (2) required.
TV CAMERA PAN AND TILT CONTROL	Experiment		NR	6				2(2)	1				
TV CAMERA-ZOOM CONTROL	Experiment		NR	6				1					
TV CAMERA SELECT 1-6	Experiment	DMS	NR	2						1			
FILM CAMERA PAIR SELECT 1-3	Experiment	DMS	NR	1			1						
FRAME RATE SELECT 1-4	Experiment	DMS	NR	1				2(2)		1			2: Two 3-position status indicators required.
THERMAL CONTROL ON/OFF	Module	Experiment	NR	8	1								
HISTORY RECORDER	Experiment		Two Channel Paper Tape Recorder	1							1		

L=Lasting
LK=Locking

Table 4-6. Dedicated C&D Devices: Support Group

FUNCTION	INTERFACE		TALKBACK (PRIMARY CONTROL)	USE REQ'T	SWITCH TYPE								REMARKS
					LASTING			MOMENTARY		ROTARY			
					2-POS		3-POS						
	RECOMMENDED	ALTERNATE			L-L	LK-LK	L-L-L	3-POS	5-POS	6-POS	12-POS	18-POS	
MAIN POWER	Module	DMS	NR	2	1			2					2: Two-position status indicator required.
EXPERIMENT ATTITUDE CONTROL	Experiment	DMS	Multi-function Display (CRT)	1									Multi-axis proportional controller required.
THRUSTER INHIBIT	Module	DMS	Multi-function Display (CRT)	6	1								

L=Lasting
LK=Locking

4.4 DISCUSSION

Table 4-7 lists a summary of the use requirements per discipline for each dedicated switch device (for all rank orders). Each use requirement is further subdivided into primary and alternate interfaces.

Study of Table 4-7 reveals that all functions listed can be accommodated with the C and D devices considered. Note also that the usage of lasting, 2 position, locking-locking and momentary, 5 position switches is negligible. Other alternative arrangements can be considered. For example, a locking-locking switch function can be accomplished by using a standard lasting switch with an appropriate switch guard. The 5 position momentary (discrete joystick) can be implemented using two 3 position momentary switches.

Thus, it would appear that the following switch complement will satisfy nearly all of the functional requirements considered:

Lasting Switch, 2 position, lasting-lasting

Lasting Switch, 3 position, lasting-lasting-lasting

Momentary Switch, 3 position

Rotary Switch, 6 position

Rotary Switch, 12 position

Rotary Switch, 18 position

Review of rotary switch applications will reveal that there is a need for selection beyond 18 as noted in the dedicated device matrix tables. However, practical switch design limits the choice to a maximum of 18 positions. Actually, the limit is determined principally by the minimum angular separation of each position consistent with the required space for panel nomenclature. Applications for greater than 18 positions have been implemented using combinations of rotary and momentary switches. It is also interesting to note that a great majority of switches interface with the computer. Few functions require module or experiment interface.

A summary of dedicated display devices necessary to implement the C and D requirements identified for the experiments and support instrumentation is given in Table 4-8. This table reflects the control selections summarized in Table 4-7 since most of the display applications are related to the control device selected.

Table 4-7. Summary of Dedicated Devices: Switches

	INTERFACE		USE REQUIREMENT								
				SWITCH TYPE							
				LASTING			MOMENTARY		ROTARY		
				2-POS		3-POS	3	5	6	12	18
	RECOMMENDED	ALTERNATE	TOTAL	L-L	LK-LK	L-L-L	POS	POS	POS	POS	POS
ASTRONOMY	Module	Computer	11	3	1	1	6	0	0	0	0
	Experiment	Computer	7	3	0	0	3	1	0	0	0
	Computer	Experiment	135	18	0	32	38	0	26	12	9
EARTH OBSERVATION	Module	Computer	8	4	0	0	4	0	0	0	0
	Experiment	Computer	5	1	0	0	2	0	1	1	0
	Computer	Experiment	58	6	0	5	12	0	23	10	2
PHYSICS	Module	Computer	3	1	0	0	2	0	0	0	0
	Experiment	Computer	19	6	0	3	1	0	6	2	1
	Computer	Experiment	22	5	0	3	1	1	4	6	2
LIFE SCIENCE	Module	Computer	2	1	0	0	1	0	0	0	0
	Experiment	Computer	4	1	0	0	1	0	1	0	1
	Computer	Experiment	28	9	0	0	6	0	5	5	3
ADVANCED TECHNOLOGY	Module	Computer	1	1	0	0	0	0	0	0	0
	Experiment	Computer	23	4	0	1	11	0	6	1	0
	Computer	Experiment	7	3	0	0	0	0	1	1	2
SUPPORT	Module	Computer	4	2	0	0	2	0	0	0	0
	Experiment	Computer	0	0	0	0	0	0	0	0	0
	Computer	Experiment	0	0	0	0	0	0	0	0	0
		TOTALS	337	68	1	45	90	2	73	38	20

Table 4-8. Summary of Dedicated Devices: Displays

DISPLAY DEVICE	USE REQUIREMENT						
	ASTRONOMY	EARTH OBSERVATION	PHYSICS	LIFE SCIENCE	ADVANCED TECHNOLOGY	SUPPORT	TOTALS
Panel Nomenclature	56	13	33	8	2	0	112
Status, 2 Position	12	12	1	0	2	0	27
Status, 3 Position	53	19	1	0	5	0	78
Analog Meter	12	19	17	16	9	0	73
2 Axis Null Detector	4	0	0	0	0	0	4
History Recorder	7	0	0	0	1	0	8
Numeric, 3 Digit	5	8	0	0	1	0	14
Numeric, 4 Digit	14	9	6	1	2	0	32
Numeric, 5 Digit	3	1	3	0	0	0	7
CRT Monitor	5	2	8	1	0	2	18
Alert/Caution/Warning Indicator	15	0	0	2	0	0	17
TOTALS	186	83	69	28	22	2	390

SECTION 5

CONCLUSIONS

5.1 C AND D SUBSYSTEM DESIGN

The matrices in Section 3 and 4 of this report reveal application trends for future manned spacecraft experiment C and D specification. The analysis indicates that future control and display subsystems will consist of an optimum mix of conventional, dedicated type C and D devices and integrated, software oriented, multipurpose C and D devices. The dedicated components should be modularized and specification based on specific functional requirements levied by the experiment user. The integrated, or universal portion of the subsystem will comprise multifunction displays and appropriate control keyboards. Integrated displays will be interfaced with a central computer, and information display format flexibility will provide a great variety of presentation schemes.

Using a mix of dedicated and universal C and D devices a highly flexible cost expedient control and display system for a multitude of experiments becomes feasible. Because of the system inherent flexibility, one basic display system can accommodate most experiment C and D requirements without the necessity for complete system redesign between missions. System reconfiguration is limited primarily to software and replacement of mission/experiment peculiar modules.

The analysis also indicates that C and D consoles which employ keyboard data entry should include provisions for verification, editing, or correction. It may be desirable to design data entry consoles for this purpose. This specialized type of equipment would be used for visual verification of messages prior to transmission to the onboard computer and for subsequent display of an acknowledgment or reply message. It would consist of an alphanumeric keyboard, function/editing buttons and an alphanumeric display. The data entry console would operate off-line from the computer, that is, the "desired" message would be generated, checked, and edited independently of the computer. When the astronaut is satisfied that the message displayed is correct, he would initiate data transfer by activating the TRANSMIT button. (This approach requires local memory and character generation equipment). Data entry consoles lend themselves most to larger spacecraft with several operators who need independent access to the computer.

Extension of this concept to a basic interactive control-display unit is also worthy of consideration. This C and D subsystem would consist of a keyboard data entry device, the computer and a graphics display unit. It is entirely possible that larger spacecraft would contain several such units. Readout of the status of particular parameters could be commanded from any of several console locations. Similarly, conference type data handling could be available to the crew.

This study also suggest that with longer missions, larger spacecraft and vast instrumentation requirements that C and D consoles for future payloads utilize a degree of automatic monitoring and interactive display techniques. This is particularily relevant to subsystem and support instrumentation. The fundamental philosophy is management by exception. The crew members are provided with only the information required rather than a mass of data which then requires interpretation. Problem areas and out of tolerance conditions are shown with additional information concerning desired course of action. Using an interactive procedure problem isolation or more specific course of action could be indicated by proceeding through a hierarchy of display formats.

5.2 CONTROL FUNCTIONAL REQUIREMENTS

Control function requirement extrapolation, avoiding specific hardware description, is discussed in this section. A corresponding treatment of display characteristics will be found in Section 5.3.

As indicated in Table 3-7 (Summary of C and D Device Matrix) typical future consoles or workstations will consist of a mix of universal, i.e., flexible integrated controls and dedicated, or unifunction controls. The analysis indicates that the preponderence of control functions will be accomplished via keyboard (or in the general sense - a data entry device). However, for reasons discussed previously, there is a need for dedicated controls to complement the multifunction or keyboard type of controls.

Approximately 25 percent of all the analyzed control functions will be accomplished in a dedicated manner (exclusive of hand controllers, which account for a small percent of total control functions), as opposed to the remainder which will be accomplished in an integrated, or universal (keyboard) manner. These analytical results demonstrate a clear trend toward flexible, interactive man-machine combinations wherein the astronaut makes use of a multi-format display in conjunction with a flexible data entry device.

5.2.1 BINARY/TERNARY

Recommended dedicated switch devices for advanced space experiment control have been categorized in three groups: 1) lasting (or maintained position) toggle switch, 2) momentary position toggle switch, and 3) rotary selector (multi-position) switch.

Lasting type toggle switches have found wide application in contemporary spacecraft control. These switches have the desirable feature of furnishing visual feedback to the crew, concerning the most recently commanded switch position. Because of this feature the switch does not normally require additional visual feedback such as a status indicator. Additionally, panel nomenclature acts as a reinforcing agent in switch position identification, i.e., as a "memory". Sample control functions which are candidates are: 1) selection function, e.g., recording speed select, temperature control on/off; and 2) control functions, e.g. TV camera pan and tilt.

It will be noted that, where there is a functional need for rapid control, a toggle switch is preferred to keyboard entry, except where keyboard push-buttons are dedicated to that function and so labeled. The reason for this is that the need for code number lookup would introduce an undesirable delay in the response process.

A momentary toggle switch lacks the "memory" feature which is inherent in the lasting, or maintained position, toggle switch. Thus the momentary toggle switch requires the augmentation of a "talkback" display, e.g., status flag. Normally, momentary switches with talkback indicators are employed in situations where an ambiguous indicator, due to remote switching, would occur if a lasting type switch were utilized.

As indicated in Section 4.4 the following dedicated switch complement will satisfy all of the functional requirements where binary/ternary control is appropriate.

Lasting Switch, 2 position, lasting-lasting

Lasting Switch, 3 position, lasting-lasting-lasting

Momentary Switch, 3 position

Note also that, from Table 4-7, the recommended interface is most frequently (67%) with the computer or data management system.

5.2.2 MULTI-SELECTION

This class of controls comprises rotary selector switches, primarily. Table 3-7 shows that this type of control is foreseen in 68 of 808 cases, or 8.5%. This compares with the approximatedy 13% of cases which are accounted for by toggle switches (both lasting and momentary types) and the approximately 70% accounted for by keyboards. Thus, rotary selector switches represent a transition, or compromise between dedicated and integrated control demands.

Rotary selector switches find application where selection of several measurements within the same functional category is involved. Examination of the matrices shows that rotary selector switches have been prescribed for the following typical control functions:

thermal monitoring

wavelength selection

voltage monitoring

calibration selection

detector monitoring

ergometer motor control

TV camera selector

As described in Section 4.4 the recommended number of selector switch positions are: 6, 12 and 18. There is a need, as indicated in the device matrices, for selection beyond 18. These applications have been implemented using combinations of rotary and momentary switches.

5.2.3 MULTIFUNCTION

Multifunction controls are those control devices which are not dedicated to a single purpose. Within the context of this report these devices are considered keyboards or more generally data entry devices. As shown in Table 3-7 keyboards account for 571 of 808, or about 70% of all identified control functions. It is anticipated that the basic use of keyboards will be in conjunction with flexible format talkback displays. Thus, keyboards will furnish an integrated data entry, event command, and status request input device -- a vital part of the astronaut-computer-subsystem complex.

One of the fundamental problems to be solved in connection with keyboard specification is the determination of the desirable, or optimum, mix of dedicated and universal keys. The solution of this C and D problem is predicated on the expected astronaut workload in managing experiments and spacecraft subsystems. Dedicated push-buttons carry the name of a specific function and, in general, command the execution of that function only (or perhaps readout of data from that function). Universal push-buttons are the familiar alphanumeric arrays which can command or request data from many functions, using coded input commands. It should be noted that dedicated keys require no lookup in a handbook or directory, whereas integrated keys do.

5.2.4 ANALOG

The general class of analog controllers would include multi-axis controllers, joysticks, potentiometers, etc. This type of device provides the astronaut with proportional control of a variable with respect to mechanical motion of knob, lever, or stick. As indicated in Table 3-7 this device category accounts for 58 of the 808, about 7%, of the control requirements.

Multi-axis proportional controllers will be employed in such spacecraft experiment/subsystem control tasks as hardware pointing, e.g., mirror pointing and antenna steering; component alignment; experiment attitude control; vehicle attitude control and stabilization; and identification of specific data for the computer. The last application in particular, involves a class of controllers known as joysticks. In this case positioning signals will usually generate a special symbol, such as a box, to show the astronaut the current position of the joystick. The joystick can be operated in the slew, as well as the proportional, mode. In the slew mode the trace will move in the direction indicated at a constant rate of speed. This device category also includes controls which adjust or command an action, usually from a potentiometer, in a continuous analog manner. Typical control functions are detector gain, bias, temperature adjust, offset, transmitter power, etc.

An important design constraint utilizing analog control is that sufficient talkback must be furnished to the astronaut. Control specification must include consideration of the complete man-machine control system; that is, the feedback display is rightfully part of this system. Information must, be provided to inform the operator when, how much and how far to move the control. The display should provide true feedback of component status.

5.3 DISPLAY FUNCTIONAL REQUIREMENTS

Clearly advanced C and D consoles or workstations for future manned spacecraft will consist of a mix of dedicated and multifunction displays. Table 3-7 summarizes the different categories of display devices selected to implement the broad base of experiment and support functional requirements idenfified in Section 2. The majority of display requirements can be satisfied by panel nomenclature, status indicators, analog readout devices and multifunction displays. Specialized requirements, 4.5% of the total use requirements, can be satisfied using numeric readout devices, two axis null detectors, history recorders and CRT monitors.

It is conceivable that specific console designs could eliminate some of the specialized devices by implementing the display function using other more frequently used devices. For example, certain numeric readout, analog scale readout and two-axis null detector displays could be implemented using the multifunction display. An analysis of these trade-offs is beyond the scope of this study since specific console design requirements must be known.

The following sections summarize each display category of generic devices implementing the display requirements identified in Section 2.

5.3.1 ANNUNCIATORS

This display category consist of panel nomenclature in conjunction with control position and status or mode displays. Approximately 17% of all display requirements can be implemented using this type of device. Selection of annunciators for a display requirement is actually more dependent upon the control device selected than upon display characteristics desired. That is, selection of panel nomenclature for a particular requirement may be deemed appropriate since a toggle or rotary switch is employed for control. Obviously, if a keyboard is used, panel nomenclature would not be a viable display device.

Panel nomenclature acts as a reinforcing agent in switch position identification. In this sense panel nomenclature serves as a "memory" for the most recently commanded (lasting) switch position and is considered a type of display. The use of panel nomenclature shown in Table 3-7 is a direct consequence of the use selection of dedicated switches.

Status indicators will be used in conjunction with momentary action switches in order to reflect the most recently commanded position of such switches. As previously discussed, momentary switches possess no "memory" in this respect. However, it should be pointed out that in some instances the astronaut will be able to infer status from resulting subsystem action, e.g., lights coming on elsewhere, voltage readings increasing, etc. Status indicators are particularly attractive for support instrumentation, approximately 88% of all disciplines.

5.3.2 NUMERIC

Numeric indicators are expected to see very limited use in future C and D consoles (8 out of 1071 cases). This type of indicator is recommended for two experiments in the Astronomy Group and six experiments in the Earth Observations Group. These functions; gimbal pointing (Astronomy), antenna steering (Earth Observations), and mirror pointing (Earth Observation) can be readily implemented using a multifunction display.

5.3.3 ANALOG AND TWO-AXIS

This display category includes meters, X-Y plotters, cross pointers and similar types. As indicated in Table 3-7 two-axis null detectors (cross-pointers) represent a minute segment of all use requirements. This device is required strictly within the Astronomy Group for pointing control and display.

Analog readout devices represent a significant segment, about 7%, of all use requirements. Nearly all device requirements within this category are for scale or meter type presentation. It is not possible to generalize this category any further or develop standardized scales since not all ranges or indeed parameters are defined.

5.3.4 HISTORY RECORDER

History recorders provide the astronaut with permanent or stored data of parameters which are time related. Two, essentially different, recorders are required. The first type is used within the Astronomy Group experiments; namely in conjunction with the X-ray Telescope, IR Telescope and High Energy Arrays; to review and monitor spectral phenonenom. This type of recorder is used to record or log activity. The astronaut compares past history with current events to anticipate what will happen next. The recorder should provide nominally two channels, time markers and relative slow speed (about 25 cm/hr to 75 cm/hr).

The second type of history recorder is used for physiological experiments within the Life Science Group. This recorder function is required to perform electrocardiogram, electroencephalograph, electromyogram, blood pressure measurements and respiratory rate measurements. It is possible that these recorders may be part of a portable instrument which could be moved to an area where the measurements are to be taken and stored when not in use. If the physiological instrumentation is designed into a C and D console or work station, it should be modularized since it is unique to the Life Science discipline experiments.

5.3.5 MULTIFUNCTION

As a result of this study it is clear that multifunction displays should be employed to implement most of the display requirements. Table 3-7 reveals that 751 of 1071 use occurrences (70%) can be satisfied by the use of multifunction or universal (shared) type displays.

Advanced Control and Display systems will require an increasingly large number of complex parameters and functions to be observed and interpreted during various phases of a mission. Further, it seems most desirable to concentrate this information in an area immediately within the field of view of the operator. Since various parameters have different order of importance for different mission phases, it is difficult to place all dedicated instruments at their optimum location on the C and D panel. Further, it is common to encounter crucial parameters which must be observed during a specific phase which are not required at all for other mission phases. To alleviate this problem, there is a need for multifunction display devices which will present different information during different mission phases to the crew at centralized locations.

A Multifunction Display System is a general purpose, time-shared, electro-optical display driven by onboard data management systems. It must be capable, in the most flexible manner, of presenting information of many forms. The displays could consist of alphanumerics, symbolics, graphics separately or in combination. The most distinguishable feature of a Multifunction Display is its flexibility.

Since by functional definition it is possible that nearly any display format could be presented; the display system must be designed to provide the greatest display flexibility possible. Thus, the display system architecture is generally organized into generic symbol generation capability controlled by processing elements which execute a stored program. This concept allows display formats to be determined by software(the stored program).

5.3.6 CRT MONITOR

The need for a CRT Monitor exist in each of the five scientific disciplines studied. It is possible, although perhaps not desirable, to use Multifunction displays to satisfy some of these display requirements. This alternative can only be evaluated for specific cases.

It should be recognized that although the term CRT (cathode ray tube) monitor is used here, any generic device offering this function should be considered. Since cathode ray tubes are so widely used for this function, the term is deemed appropriate in the descriptive sense within this context.

The video requirements identified in Section 2 are summarized in Table 5-1. It can be seen that there is a considerable difference in terms of resolution and frame rate requirements. It should also be noted that the Life Science Group may employ color cameras. Color, in this instance, is considered desirable for at least transmission to the ground. However, onboard monitoring may not require color for astronaut purposes. In this case mono-chromatic CRT monitors for onboard use would be adequate.

TABLE 5-1

VIDEO REQUIREMENTS

GROUP	EXPERIMENT	RESOLUTION	FRAME RATE
ASTRONOMY	PHOTOHELIOGRAPH	>1000 LINES	0.1 TO 1.0 FR/SEC
	DUAL WLC	525 LINES	30 FR/SEC
	X-RAY TELESCOPE	525 LINES	30 FR/SEC
	IR TELESCOPE	525 LINES	30 FR/SEC
	STRATOSCOPE III	>1000 LINES	1 FR/ORBIT TO 1 FR/SEC
EARTH OBSERVATION	OBSERVATION TELESCOPE	525 LINES	30 FR/SEC
PHYSICS	PHOTO SENSORS	1000 LINES	TBD
	IMAGE ISOCON RFOV	500 LINES	2 FR/SEC
	IMAGE ISOCON WFOV	500 LINES	2 FR/SEC
LIFE SCIENCE	SPECIMEN MONITORS	525 LINES	30 FR/SEC
ADVANCED TECH.	LIQUID/VAPOR I/F	525 LINES	30 FR/SEC

Of the eleven video camera types identified eight have resolution requirements which may be satisfied by monitors comparable to those currently employed by the Skylab ATM. The remaining three, the Photoheliograph and Stratoscope III of the Astronomy group, and the Photon Sensor of the Physics group, require resolution on the order of 1000 lines TV or twice that provided by the Skylab ATM TV monitors. For these instruments the higher resolution must be provided by the onboard monitors if the operator is to be required to interact with the instruments as a function of the real time scientific data available. The high resolution cameras are provided primarily for transmission of quality scientific video to ground stations and thus the need for onboard high resolution monitors must consider the degree with which the crewman will interact with the instrument. The higher the degree of interaction based on evaluation of scientific data the greater the requirement for high resolution monitors.

The difference in frame rates, which vary from a low of one frame per orbit (on the order of one frame every 50 minutes) to a high of 30 frames per second, impose additional demands on the onboard viewing system. The 30 frame per second rate is compatible with the existing Skylab ATM TV monitors but, the lower frame rates require some form of image storage to allow display rates compatible with crew viewing. Methods include the use of monitors employing high persistance phosphors or the use of additional interface equipment, providing intermediate storage and scan conversion. Through the use of image storage and scan conversion the same monitors may be utilized to satisfy the viewing requirements of a wide range of cameras having different frame rates. The use of long persistance phosphor monitors may be applied on an individual basis.