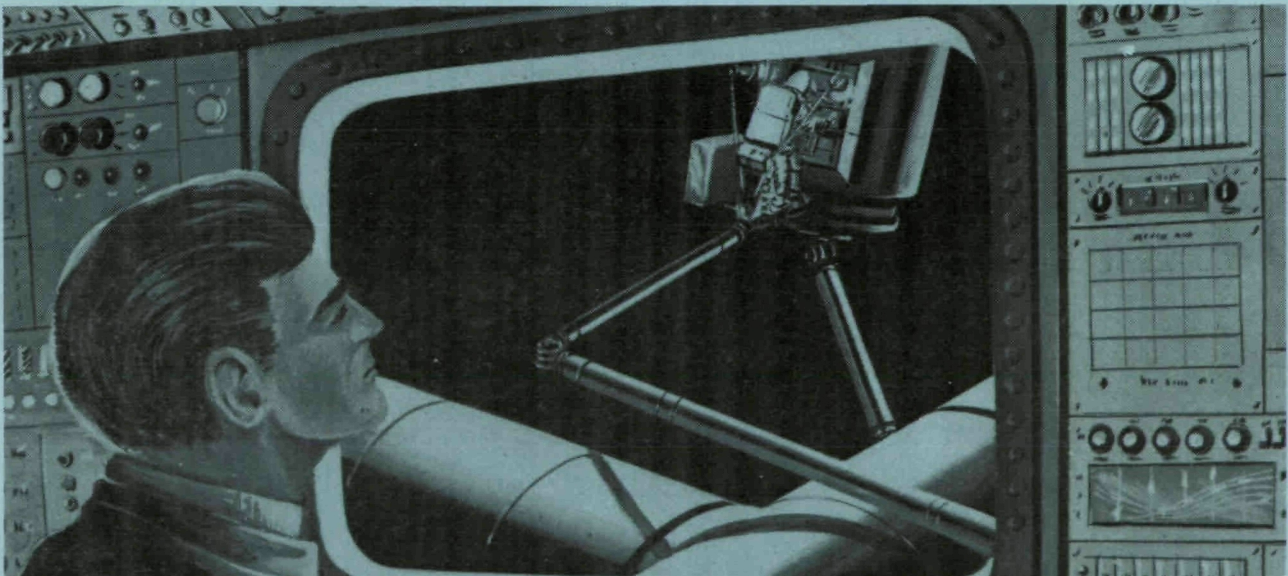
N84-18301

final technical report

SPACE STATION NEEDS, ATTRIBUTES, AND ARCHITECTURAL OPTIONS

volume II - book 2

part II — information management system



COMSAT GENERAL

GRUMMAN

GENERAL ELECTRIC

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volume II - book 2

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prepared for

National Aeronautics and Space Administration
Headquarters
Washington, D.C. 20546

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Space Station Task Force
Contracting Study Project Manager — E. Brian Pritchard

by

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- FINAL REPORT -

SPACE STATION
NEEDS, ATTRIBUTES AND ARCHITECTURAL OPTIONS STUDY

TASK 2
MISSION IMPLEMENTATION CONCEPTS
(INFORMATION MANAGEMENT SYSTEM)

SPACE SYSTEMS DIVISION
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GENERAL ELECTRIC

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H. Kraiman, Project Manager
Space Station IMS

Glossary

ACS - Attitude Control Subsystem
BER - Bit Error Rate
C&C - Command and Control
CDMF - Command Data Evaluation Facility
CIU - Communication Interface Unit
CMD - Command
CMOS - Complimentary Metal Oxide Silicon
COMSEC - Communications Security
CRC - Cyclic Redundancy Code
DBMS - Data Base Management System
DBS - Docking/Berthing Subsystem
DCSF - Data Collection and Storage Facility
DDF - Data Distribution Facility
DMS - Data Management System
DPEF - Data Planning and Evaluation Facility
ECLSS - Environmental Control and Life Support System
ELOS - Experimental Land Observation System
EPS - Electrical Power Subsystem
EVA - Extra Vehicular Astronaut/Extra Vehicular Activity
FDM - Frequency Division Multiplexing
FF - Free Flyer
GN&C - Guidance Navigation and Control
GOPS - Giga Operations Per Second
GPS - Global Positioning System
GS - Ground Station
H/W - Hardware
HOL - Higher Order Language
I/F - Interface
IMS - Information Management System
IR - Infra-red
ISL - Intersatellite Relay Link
KB - Kilobytes
KM - Kilometers
LI - Loop Interface

Glossary (Cont.)

MA	-	Multiple Access
MB	-	Megabytes
MCF	-	Mission Control Facility
MILCOM	-	Military Communications
MMI	-	Man/Machine Interface
MMU	-	Manned Maneuvering Unit
MOPS	-	Mega Operations Per Second
MOTV	-	Manned Orbital Transfer Vehicle
MTBF	-	Mean Time Between Failures
MTTR	-	Mean Time to Repair
NPF	-	NASA Program Facility
OB	-	On-board
OPS	-	Operations
OTV	-	Orbital Transfer Vehicle
PI	-	Principal Investigator
POV	-	Proximity Operations Vehicle
RIU	-	Remote Interface Unit
RMS	-	Remote Manipulation Subsystem
S/W	-	Software
SS	-	Space Station
STS	-	Space Transportation System
TBD	-	To Be Determined
TCS	-	Thermal Control Subsystem
TDAS	-	Tracking and Data Acquisition System
TDM	-	Time Division Multiplexing
TDRSS	-	Tracking and Data Relay Satellite System
TGS	-	TDRSS Ground Station
TLM	-	Telemetry
TMS	-	Teleoperator Maneuvering System
TWT	-	Travelling Wave Tube
VSS	-	Versatile Service Stage
WDM	-	Wavelength Dimension Multiplexing

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INTRODUCTION

SECTION 1
INTRODUCTION

During the period from September 1982 to March 1983, the General Electric Company was under subcontract to the Grumman Aerospace Corporation for implementation of several tasks for the "Space Station Needs, Attributes and Architectural Options Study." (Figure 1-1) This report summarizes the work performed under that subcontract for Task 2 - Mission Implementation Concepts for the Data Management System (DMS), Internal Communications and Ground Segment areas. It also includes the results of additional effort expended by the General Electric Co. in the External Communications area (Figure 1-2 and 1-3).

Although specific conclusions have been reached and discussed herein, it should be recognized that these conclusions are contingent upon many factors, some of which will undoubtedly change. Some of the more significant but variable factors are:

1. Definition of missions to be flown, as determined by potential PI's, commercial, industrial and DoD users and other interested parties;
2. Architectural concepts of the overall space station;
3. Assessment of the technologies that may be available in the time frame under question;
4. Built-in and automatic capabilities of the various subsystems;
5. Mix and skill of crew members.

Consideration of the above items has led to the conclusions reached herein. We have attempted to de-couple some of the more significant drivers (e.g., high data rates derived from earth observation sensors) from station operations, so that the final result is as in-sensitive to those factors, as possible at this stage of development. However, it is entirely possible that some of our conclusions would be different, given a different set of factors. Regardless, the methodology described in this report is sufficiently flexible so that changes in drivers and requirements can be handled with a minimum of perturbation. While the conclusions resulting from a different set of drivers may differ, the method by which they are handled, will not.

- SUB-CONTRACT TO GRUMMAN AEROSPACE CORP.
- GE PARTICIPATION
  - TASK 1: MISSION REQUIREMENTS
    - EARTH RESOURCES
    - GLOBAL ENVIRONMENT
    - MATERIALS PROCESSING
    - LIFE SCIENCES
    - NATIONAL SECURITY
  - TASK 2: MISSION IMPLEMENTATION CONCEPTS
    - DATA MANAGEMENT SYSTEM (DMS)
  - TASK 3: DMS PROGRAMMATIC ANALYSIS
  - TASK 4: DoD COMMUNICATION, COMMAND AND CONTROL

Figure 1-1. Space Station Needs Attributes and Archetictural Options Study

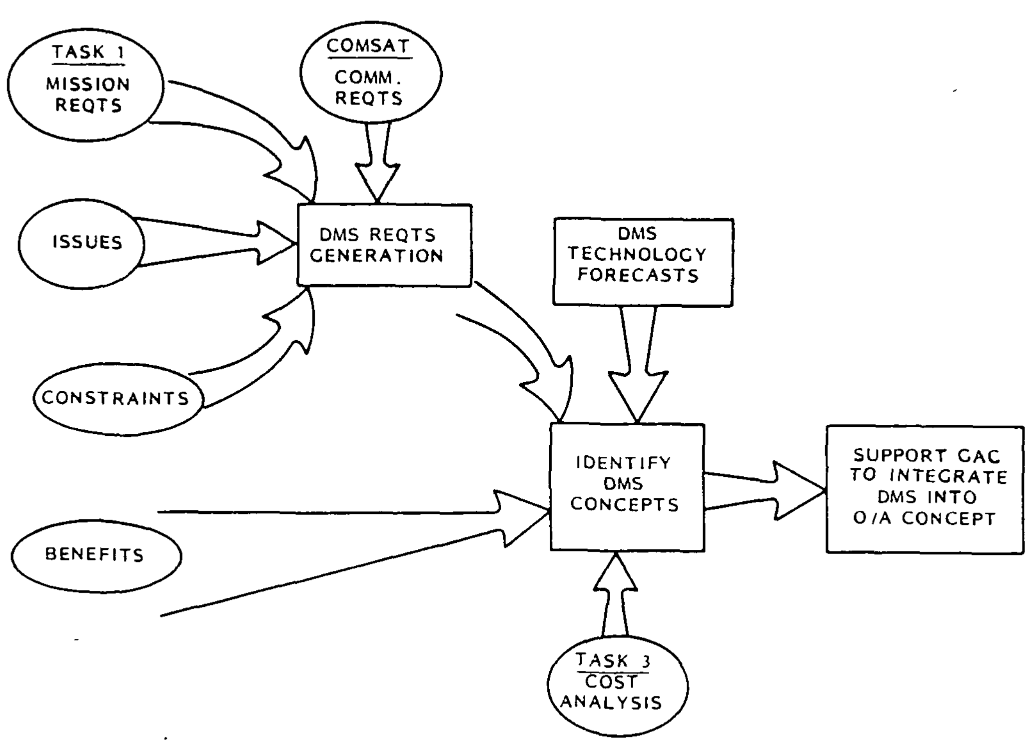


Figure 1-2. Mission Implementation Concepts (Task 2) Support to Grumman

As with the other Space Station Subsystems, the Information Management System (IMS) will play a major role in helping to make the Space Station an operational realization. Unlike other subsystems, however, the IMS must play a key role in making operations, housekeeping and the conduct of various missions, a reality. It must provide the mechanism whereby operations personnel can control the well-being of their environment, while carrying out those missions that have been relegated to it. Further, it must permit unmanned operations to occur during those periods of time when a manned presence is not required. It must initially satisfy the objective of maintaining control of all on-board and ground activities, yet be expandable to provide the capability to command, control and monitor the most sophisticated project yet undertaken by man in space. In short, the IMS must play the role of nerve center for both station operations and mission conduct, while permitting growth in all areas, including itself.

The question now, is how do we proceed? How do we get a handle, so to speak, on the potentially powerful, yet undefined entity known as the "IMS". Perhaps the best place to start is with a definition - just what is the IMS?

In our purvue, the IMS consists of three major elements, each of which are addressed in this report (see Figure 1-4). First, there is the Data Management System (or DMS), which consists of that on-board computer related hardware and software required to assume and exercise control of all activities performed on the Space Station. Secondly, there are the communication aspects of the IMS which must be determined. In order to direct our attention to the appropriate aspects of the Communication System, we have divided it into two areas, external and internal. The external communications consists of those capabilities and facilities that will allow the station to communicate with external entities, such as the ground, free flyers, shuttle, EVA, MOTV, etc. The internal communication elements are those facilities which will allow the transmission of data, voice, TV etc. within the confines of the station, even though those facilities may not be physically connected.

Put another way, the external communications systems are concerned with RF, laser or "wireless communications, while internal communications are primarily concerned with fibre optics or "wire" type communication. Finally, the third major element of the IMS that we have addressed is the Ground Segment.

These three elements, the DMS, the Communications System and the Ground Segment constitute the IMS. Using these definitions, we can proceed to define the methodology that we used to drive out preliminary requirements.

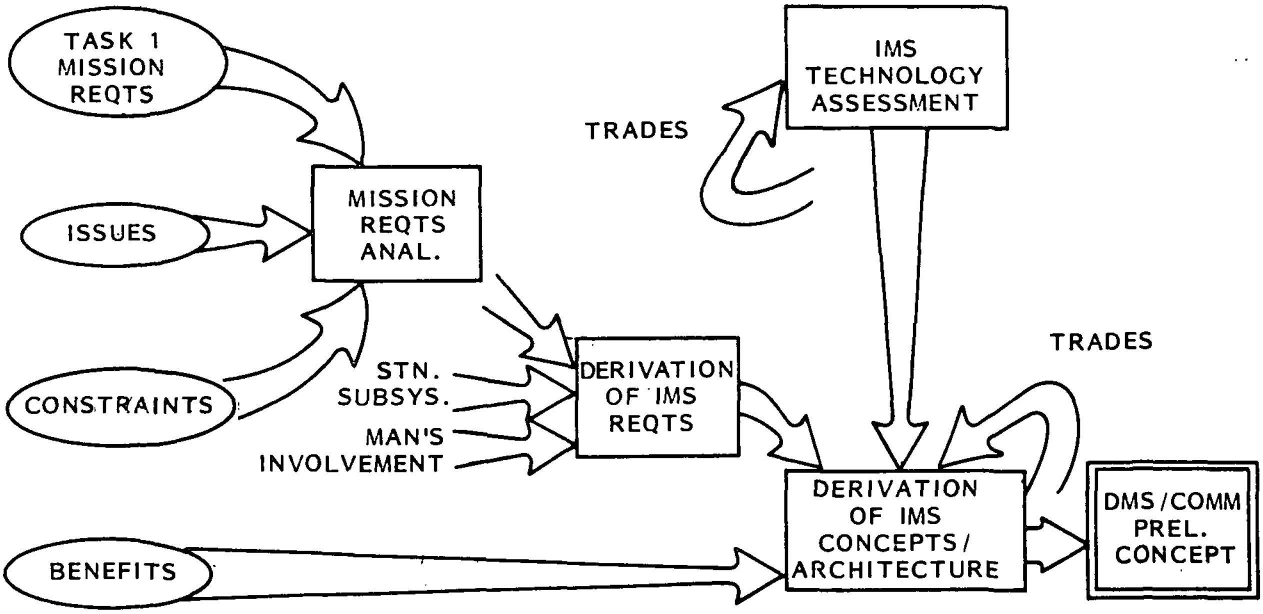


Figure 1-3. In-House Effort to Develop IMS

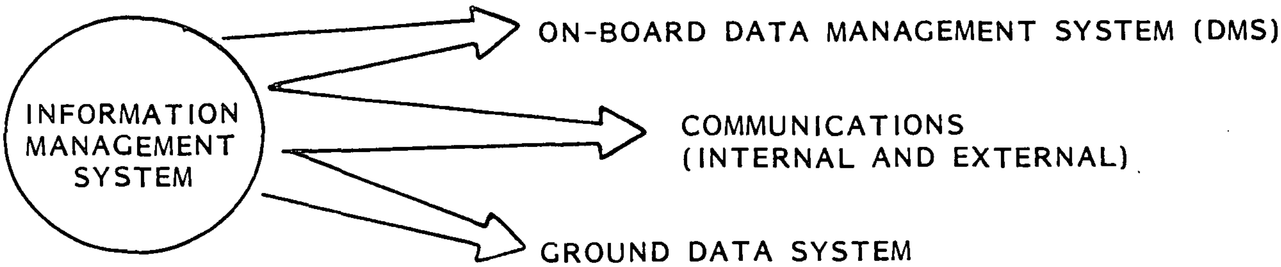


Figure 1-4. Space Station Information Management System (IMS)

1.1 METHODOLOGY

In order to derive the architectural concepts of the IMS, a three pronged approach was undertaken (see Figure 1.1-1). Each of the "prongs", which provided an insight into the overall concept are:

1. The missions to be performed;
2. The station operations and the functions to be carried out;
3. The technologies anticipated during the time frame of the space station.

These elements were addressed in a fashion that allowed us to formulate the requirements, architectures, concepts and technology drivers in such a way so as to drive out the issues of importance as well as determine the scope of the overall IMS.

Specifically, each of the areas were addressed as described below:

1.1.1 MISSION REQUIREMENTS ANALYSIS

Each of the 81 missions in the nine basic categories were examined to determine the restrictions placed upon them by their originators. Such elements as orbital altitude, inclinations, on-board sensors, operational constraints, environments, support vehicles, etc. were examined. These parameters were inserted into a computer program generated for the purpose of deriving commonality, and the resultant was several sets of compatible missions; that is, each subset of the 81 missions that could be operated from a common platform, due to commonality of restrictions. (See Figure 1.1-2)

The next step was to insert each mission subset into a second computer program and apply a set of algorithms to allow us to generate the IMS performance requirements. These requirements (i.e. acquisition data rates, storage capacities, processing speeds and communication rates) would enable us to place bounds on the size of the IMS.

It is interesting to note that for other than a few earth resources type missions, which require exceedingly large storage capacities, processing, speeds and communication rates, the majority of missions place a rather modest

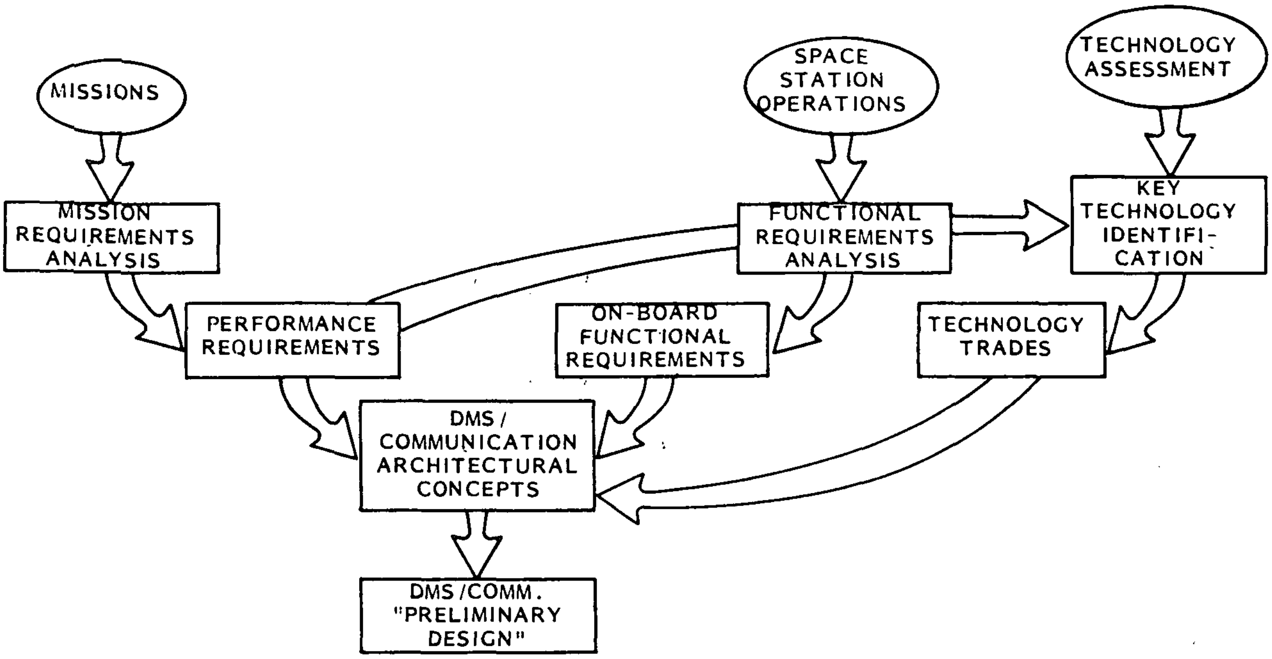


Figure 1.1-1. Study Methodology

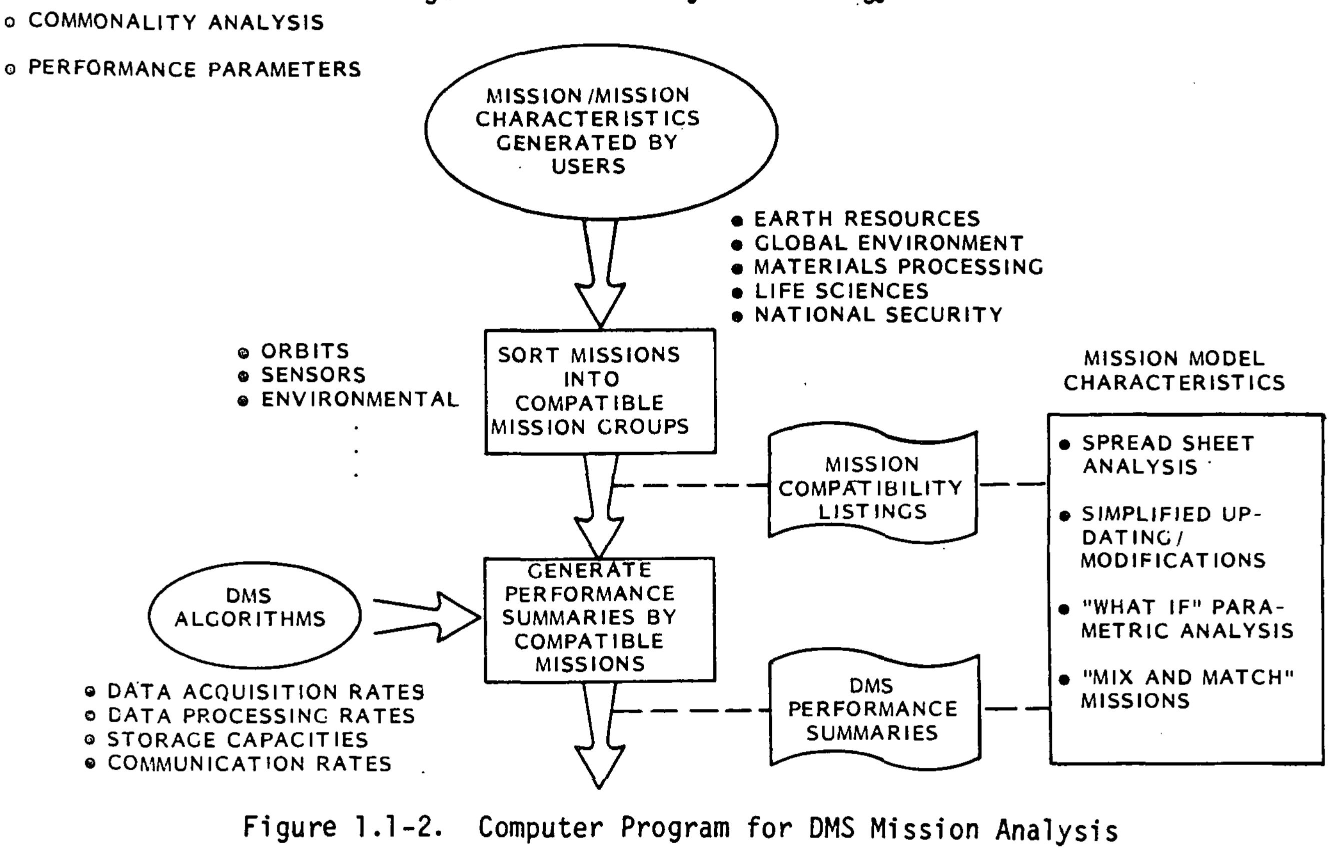


Figure 1.1-2. Computer Program for DMS Mission Analysis

load on the IMS. (See Table 1.1-1) Also, it is recognized that the missions that were used to "size" the IMS are subject to modification. It is further recognized that new missions or capabilities may be added, deleted or otherwise altered and that new commonalities and performance requirements could result. With this realization in mind, we generated the Commonality Analyses and Performance Requirements computer programs. These programs will allow us to factor in new missions with a minimum of effort, and to regenerate a new set of performance requirements. It is important to note however, that the architectural concepts derived herein are based on the initial set of missions supplied to us by Task 1 (Mission Requirements) of this study. As new missions are generated, it is quite likely that minor changes to the derived architecture will be required. However, we have taken action to minimize that eventuality by de-coupling the missions from the operation of the Space Station. This will become evident during our discussion of the DMS architecture contained in Section 2.2 of this report.

1.1.2 FUNCTIONAL REQUIREMENTS ANALYSIS

Whereas the Mission Requirements Analysis aided us in determining "how big" the IMS should be, the Functional Requirements Analyses give us an insight into "what" it should be doing. It assisted us in deriving the IMS architecture as well as the software requirements.

The functional requirements analysis consisted of three aspects (Figure 1.1-3)

- derivation and assessment of on-board and ground functions
- determination of those functions performed by the on-board subsystems
- identification and evaluation of man's participation.

1.1.2.1 On-board vs Ground Fucntions

A set of 18 major functions that would have to be performed by the IMS were identified and further sub-divided into 84 lower level functions. Each of the 84 functions were analyzed to determine where they should be performed (i.e. on-board, on the ground or shared). An evaluation was then made to assess the criticality of each on-board function to serve as a guide in deriving the DMS architecture (Table 1.1-2).

1.1.2.2 Subsystem Functions

A second analysis evaluated the operations performed by each of the major subsystems. It also estimated the quantity and type of data required to

Table 1.1-1. DMS Performance Requirements

KEY PARAMETERS		HABITAT	MILITARY FACILITY	SPACE TEST FACILITY	SATELLITE SERVICE FACILITY	INDUSTRIAL PARK	OBSER-VATORY	TRANSPORT HARBOR
*DATA RATES (KPS)	MISSION	11.6	704	1875	0.5	1.9	3300	-
	OPERATIONS	45	23	6	6	6	15	15
*STORAGE (X 10^9 CAPACITY BPD)	MISSION	1	61	86	0.04	0.17	280	-
	OPERATIONS	0.6	0.6	0.2	0.2	0.2	0.2	0.2
*PROCESSING SPEED (X 10^6 OPS)	MISSION	0.005	1.4	0.5	0.0003	0.0004	2.1	-
	OPERATIONS	1.3	1.3	0.1	0.1	0.1	1	0.2
*COMMUNICATION RATES (X 10^6 BPS)		0.008	4.2	7.5	0.001	0.001	13	0.1

* AVERAGED OVER A 24 HOUR PERIOD

Table 1.1-2. Allocation Summary

	ON-BOARD	GROUND	SHARED
USER/PI INTERFACE	0	3	2
SYSTEM COMMAND AND CONTROL	4	2	0
MISSION SUPPORT	2	1	0
S/S HARDWARE MAINTENANCE	3	0	3
S/S SOFTWARE MAINTENANCE	1	0	4
CREW HEALTH MONITORING/MAINTENANCE	2	0	4
SPACEBORNE EXPERIMENTATION	2	1	3
S/S ONBOARD SUPPORT	13	0	1
S/S SUPPORT SUBSYSTEM C&C	2	0	0
S/S MISSION SUBSYSTEM C&C	2	1	0
S/S SUPPORT SUBSYSTEM MONITORING	4	1	0
S/S MISSION SUBSYSTEM MONITORING	4	1	0
MISSION DATA DISTRIBUTION	1	3	1
ENTERTAINMENT	3	0	1
DATA STORAGE	1	1	1
PERFORMANCE EVALUATION	2	2	0
MILITARY SUPPORT	1	0	0
TRAINING AND SIMULATION	1	0	0
	48	16	20

- DERIVATION AND ASSESSMENT OF ON-BOARD AND GROUND FUNCTIONS
- CREW OPERATIONS
  - FUNCTIONS PERFORMED DURING
    - (1) MONITORING AND CONFIGURING OF SUBSYSTEMS
    - (2) MISSION SUPPORT
    - (3) HOUSEKEEPING ACTIVITIES
    - (4) SCHEDULING
    - (5) DOCKING
    - (6) EMERGENCY OPERATIONS
    - (7) OFF-DUTY
- DMS INTERFACES WITH OTHER SUBSYSTEMS
  - FUNCTIONS PERFORMED
  - COMMAND
  - TELEMETRY

Figure 1.1-3. Functional Requirements Analysis control the subsystem, as well as the quantity of telemetry data anticipated from each subsystem. These data were summarized and enabled us to size the DMS, from a "housekeeping" point of view (Figure 1.1-4).

1.1.2.3 Manned Operations

Finally, an operations analysis was performed to determine and assess man's involvement with the DMS. It identified potential tasks that might be performed by the crew members in order to determine the type of capabilities that the DMS should possess.

1.2 GROUND RULES/CONSTRAINTS

Although the quantity and extent of the Ground Rules and Constraints imposed upon the Space Station in general and the IMS in particular are few, there are several which guided our analyses. These are identified below:

1. TDRSS shall be used to communicate with the ground.
2. Autonomy shall be maximized.
3. Housekeeping and operations data processing shall be separate from mission applications data processing (this ground rule permitted us to decouple the missions to be performed from the basic housekeeping functions, thereby making the conclusions reached herein independent of missions to be performed).
4. On-board pre-processing only of mission data; extensive processing and analysis of mission data done on ground (This ground rule limited the need for special purpose processing equipment on-board the Space Station. It also reduced or eliminated the need for having a large number of PI's on-board).

1.3 ISSUES

A number of issues of major importance to the DMS surfaced prior to and during the course of the study. These issues (summarized in Table 1.3-1) could conceivably have a significant impact on the DMS architecture as well as its implementation. In order to assure that we selected the "proper" approach in the key areas, a number of trade studies and analyses were performed. The details of these studies are contained elsewhere in this report; however the conclusions reached are summarized below:

Table 1.3-1. Key Issues Impacting Data Management System

ISSUE	IMPACT	OPTIONS
AUTONOMY	• COST • CREW SAFETY/RISK • HARDWARE/SOFTWARE RELIABILITY • CREW SIZE	• MINIMUM DEPENDENCE ON GROUND • TRADITIONAL GROUND INVOLVEMENT • "MIDDLE GROUND"
STATE-OF-THE-ART	• COST • EVOLUTION VS. RISK • AVAILABILITY OF APPLICABLE HARDWARE	• SPACE QUALIFIED (NEW) • SPACE QUALIFIED (EXISTING) • COMMERCIAL
AUTOMATION OF SUBSYSTEMS	• DEFINITION • DMS ARCHITECTURE • SELF DIAGNOSIS • FAULT TOLERANCE	• DISTRIBUTED DMS TO CONTROL/MONITOR EACH SUBSYSTEM/OPERATION • SUPERVISORY CONTROL • HYBRID • SELF CONTROL
COMMERCIAL VS. MILITARY MISSION	• COMSEC/TRANSEC • COMPUTER SECURITY • DMS ISOLATION/ARCHITECTURE • COMMUNICATIONS INDEPENDENCE • HARDNESS; RAD, EMP	• COMMON DMS • SEPARATE DMS • SOME COMBINATION

SUBSYSTEM	COMMAND RATES (KBS)	TELEMETRY RATES (KBS)
ELECTRICAL POWER	0.02	0.08
ECLSS	0.2	0.3
GN&C	10	90
ATTITUDE CONTROL	2	6
PROPULSION	0.4	0.6
THERMAL	0.4	1.6
RADAR	0.4	0.6
DOCKING	0.4	0.6
REMOTE MANIPULATION	0.4	0.6
STRUCTURAL	0.02	0.08
COMM	0.2	1
DMS	0.1	0.1
	14.5 KBS	101.5 KBS

Figure 1.1-4. Preliminary Estimates of Subsystem Command and Telemetry Rates

1.3.1 AUTONOMY

This key issue is addressed in depth in Section 2.1; our preliminary conclusion is that the space station should have minimum dependence on the ground. However, as indicated in the study, there are various costs concerned with achieving the different degrees of autonomy. It is therefore recommended that this issue be re-visited at a later date when a more realistic mission profile and a more precise on-board DMS configuration can be determined.

1.3.2 STATE OF THE ART

The technologies identified for the initial and evolutionary IMS have been assessed, and the conclusions reached are as follows: all technologies either exist or are presently being developed by the private sector, NASA or the military. The major challenges in using these technologies are (1) to extend their use in such a manner so as to lower overall life cycle costs and (2) to cleverly functionalize the system design so that new technology can be introduced without requiring a major re-design. It is our opinion, that both space qualified and commercial hardware will find a place in the space station IMS design.

1.3.3 AUTOMATION OF SUBSYSTEMS

It is anticipated that each of the Space Station subsystems will have microprocessors embedded in their design, enabling them to perform some of the more repetitive calculations that may be required. However, each of these subsystems will have to interface with the DMS for overall command control, monitoring and performance evaluation. A preliminary analysis (see Section 2.2 has shown that a distributed DMS architecture can best perform this function. Since there are other functions that must also be performed, but do not fall into the realm of traditional spacecraft subsystems, our analysis has also indicated that some sort of supervisory control will be required. This distributed architecture can serve a two-fold purpose; first, it can best provide those operations required by each of the subsystems and secondly, it will easily permit modifications, expansions, deletions, etc. to be made in operating philosophies or technology advances.

1.3.4 COMMERCIAL VS MILITARY MISSIONS

Concerns regarding National Security and mission classification (from a security point of view) have led to the conclusion that a separate DMS will be required for most military missions. This does not include technology R&D missions, but does include missions in which operational type data is collected or acted upon.

1.4 SPACE STATION ARCHITECTURE

Although no final architectural concepts for the Space Station have evolved at this time, several potential features and facilities have been identified. These features have aided us in deriving some viable architectural options that could be assumed by the IMS. The facilities tend to be separate manned or unmanned elements co-located in a common orbital plane, and either physically attached or separated by some nominal distance. Each serves a different function, but all are necessary for minimum or full up operation of the Space Station. A brief summary of each is contained below (the terminology and concepts used herein is that derived by Grumman Aerospace Corp):

1. Habitat - that facility in which man resides, works (short sleeve environment), rests, etc. His/her "home in space", so to speak.

2. Space Test Facility - a separate facility where space tests for data accumulation or proof of concept can be carried out. Such functions as manned interaction for various tests, or use as a test range would be carried out here.

3. Transportation Harbor - the facility used as docking and/or support of Space Shuttle, upper stage refueling operations, etc. It would also provide for emergency repair and/or refurbishment of docked spacecraft.

4. Satellites Servicing/Assembly Station - this facility would provide for the service, repair, check-out and assembly of unmanned satellites.

5. Observatory - an extremely stable facility for earth viewing or astronomical experiments. Could conceivably be a free-flyer associated with the Spate Station.

6. Industrial Park - an eventual capability and/or facility in which mature commercial/industrial type operations would be carried out. Could include such operations as space manufacturing, materials processing, etc.

The configurations, attributes, and architecture of each of the above facilities is yet to be determined. However, using them as a baseline, we assumed an evolution of the Space Station (See Figure 1.4-1) to enable us to proceed with the analysis and concept derivation of the IMS. The remaining sections of this report will discuss the analysis and studies performed and the specific conclusion reached in each of the three major areas of the IMS, i.e. the Data Management System, the External and Internal Communications, and the Ground Segment.

INITIAL (HABITAT)

- BASIC ON-BOARD OPERATIONS, HOUSEKEEPING, ETC.
- MINIMUM OF ON-BOARD EXPERIMENTS

FIRST EVOLUTIONARY GROWTH (NON-DEFENSE)

- TRANSPORTATION HARBOR
- SATELLITE SERVICING & ASS'Y
- SPACE TEST FACILITY
- INDUSTRIAL PARK
- OBSERVATORY - LOW DATA RATE

FIRST EVOLUTIONARY GROWTH (NATIONAL SECURITY)

- TRANSPORTATION HARBOR
- SATELLITE SERVICING & ASS'Y
- SPACE TEST FACILITY
- LOW DATA RATE MILITARY MISSIONS

SECOND EVOLUTIONARY GROWTH (NON-DEFENSE)

- ALL ABOVE
- OBSERVATORY - HIGH DATA RATE

SECOND EVOLUTIONARY GROWTH (NATIONAL SECURITY)

- ALL ABOVE
- HIGH DATA RATE MILITARY MISSIONS

Figure 1.4-1. Assumed Space Station Evolution

SECTION 2
TECHNICAL DESCRIPTION

SECTION 2
TECHNICAL DESCRIPTION

As indicated in Section 1, a number of technical trades, studies and analyses were performed to enable us to derive the IMS concepts. This section discusses each of these studies in detail.

The first section, 2.1, Requirements Analysis, consists of those activities that allowed us to "scope" the IMS, from a "functional" as well as a "performance" point of view. Section 2.2 describes the analyses that we performed to derive the architecture for both the on-board DMS and the communications system (internal and external). We then used these architectures to generate a conceptual design (Section 2.3) of the on-board elements in order to get a "handle" on the physical parameters (i.e., size/weight/power, etc.) of the hardware and software. This section also contains a summary of the ground segment elements.

Finally, Section 2.4 discusses the technologies that might be used to implement the IMS.

2.1 REQUIREMENTS ANALYSIS

The requirements analysis consisted of a number of studies that were performed to drive out those elements that impact the IMS. The Mission Requirements analyses helped us to determine the effects that the missions to be performed would have on the IMS. It also aided us in determining the quantity of data we could be expected to handle. The Functional Requirements Analysis indicated which functions should be performed on-board by the DMS, as well as the criticality of those functions. The Operational Requirements Analysis performed the same function as the Mission Requirements Analysis, but concentrated on station operations (i.e., housekeeping) as opposed to missions. Finally, the Autonomy analysis provided us with a parametric view of the impact of doing things in space, as opposed to doing them on the ground.

2.1.1 MISSION REQUIREMENTS

Eighty one candidate missions have been identified for the Space Station. These 81 missions are broken down into nine major categories as shown in Table 2.1.1-1. Each of these missions places unique processing, storage, and communication requirements on the DMS. A rather simplistic method of deriving DMS performance requirements would be to determine and sum the individual requirements of all 81 potential missions. This methodology generates an extremely conservative, worst case set of requirements.

The approach taken in this study derives much more realistic requirements by performing a commonality analysis, identifying missions that could be supported concurrently by the Space Station, and factoring in time phasing of missions, anticipated duty cycles, and communication link availability.

2.1.1.1 Commonality Analysis

Definition of sets of compatible missions can be performed on many different bases. Some of the criteria considered in this analysis included:

1. Orbit requirements.
2. Operational requirements.
3. Support vehicle requirements.
4. Sensor requirements.
5. Physical requirements (weight, power, volume).

DATA MANAGEMENT SYSTEM
PERFORMANCE REQUIREMENTS ESTIMATE -- APPLICATION MISSIONS
MODIFIED MISSIONS LIST

	MISSION	REFERENCE DATA: SPACE STATION FACILITY	REFERENCE DATA: GRUMMAN MISSION NUMBER	MISSION REQUIREMENTS: DATA RATE, BPS	ACQ DUR, SEC	ACQ / DAY	OPS / BIT	COMM UTILIZ FACTOR	DATA CONV FACTOR	DMS PERFORMANCE: ACQ. RATE, KBPS	PROC. RATE, KOPS	STORAGE RATE, MBPD	COMM. RATE, KBPS
1.0	LIFE SCIENCES												
1.1	CARDIOVASCULAR EX	HAB	151	5000	3600	24	.5	.25	.1	5.00	2.50	432.00	2.00
1.2	METABOLISM STUDY	HAB	152	5000	3600	24	.5	.25	.2	5.00	2.50	432.00	4.00
1.3	HEMATOLOGY EXP	HAB	153	5000	3600	24	.5	.25	.2	5.00	2.50	432.00	4.00
1.4	BIOLAB	HAB	154	5000	3600	24	.5	.25	.1	5.00	2.50	432.00	2.00
1.5	MEDICAL OPERATION	HAB	155	5000	3600	8	.5	.25	.1	1.67	0.83	144.00	0.67
	LIFE SCIENCES	-	5	25000	-	-	-	-	-	21.67	10.83	1872.00	12.67
2.0	MILITARY												
2.1	C/C S/B WEAPONS	MIL	0	132000	3600	24	2	.25	1.5	132.00	264.00	11404.80	792.00
2.2	C/C US MILSATS	MIL	0	132000	3600	24	2	.25	1.5	132.00	264.00	11404.80	792.00
2.3	S/T COMM ROUTING	MIL	0	132000	3600	24	2	.25	1.5	132.00	264.00	11404.80	792.00
2.4	S/T FORCE CONTROL	MIL	0	132000	3600	24	2	.25	1.5	132.00	264.00	11404.80	792.00
2.5	S/T WARNING	MIL	0	132000	3600	24	2	.25	1.5	132.00	264.00	11404.80	792.00
2.6	PROTO WEAPON TEST	MIL	0	1000000	3600	8	2	.25	1	333.33	666.67	28800.00	1333.33
2.7	SPEC OTV/CRUISERS	MIL	0	132000	3600	8	2	.25	1.5	44.00	88.00	3801.60	264.00
	MILITARY	-	7	1792000	-	-	-	-	-	1037.33	2074.67	89625.60	5557.33
3.0	MATERIALS PROC.												
3.1	VAC VAPOR DEP	TEST	175	1000000	3600	24	.5	.25	1	1000.00	500.00	86400.00	4000.00
3.2	CHEM REACT STUDY	TEST	176	1000000	3600	7	.5	.25	1	291.67	145.83	25200.00	1166.67
3.3	U/COOLED SOLIDIF	TEST	177	1000000	3600	7	.5	.25	1	291.67	145.83	25200.00	1166.67
3.4	THERMOPHY MEAS	TEST	178	1000000	3600	7	.5	.25	1	291.67	145.83	25200.00	1166.67
3.5	R&D MATERIAL PROC	IND	1100	5	3600	24	.2	.25	.1	0.01	0.00	0.43	0.00
3.6	HgCdTe PRODUCTION	IND	1101	1	3600	24	.2	.25	.1	0.00	0.00	0.09	0.00
3.7	BULK GaAs PROD	IND	1102	1	3600	24	.2	.25	.1	0.00	0.00	0.09	0.00
3.8	FILM GaAs PROD	IND	1103	1	3600	18	.2	.25	.1	0.00	0.00	0.06	0.00
3.9	PROTEIN CRYSTALS	IND	1104	1	3600	24	.2	.25	.1	0.00	0.00	0.09	0.00
3.10	ISOENZYME SEP	IND	1105	100	3600	14	.2	.25	.1	0.06	0.01	5.04	0.02
3.11	CONT FLOW ELECTRO	IND	1106	400	3600	23	.2	.25	.1	0.38	0.08	33.12	0.15
3.12	X-RAY TARGET PROD	IND	1107	1000	3600	24	.2	.25	.1	1.00	0.20	86.40	0.40
3.13	LATEX REACTOR	IND	1108	500	3600	24	.2	.25	.1	0.50	0.10	43.20	0.20
	MATERIALS PROC.	-	13	4002009	-	-	-	-	-	1876.95	937.89	162168.5	7500.78
4.0	EARTH OBSERVATION												
4.1	ADV LAND OBS SYS	FF	400	32000	360	14	1	1	1	1.87	1.87	161.28	1.87
4.2	ADV LAND OBS SYS	FF	401	32000	360	14	1	1	1	1.87	1.87	161.28	1.87
4.3	ADV LAND OBS SYS	FF	402	32000	360	14	1	1	1	1.87	1.87	161.28	1.87
4.4	STEREOSAT	FF	1200	32000	360	14	1	1	1	1.87	1.87	161.28	1.87
	EARTH OBSERVATION	-	4	128000	-	-	-	-	-	7.47	7.47	645.12	7.47
5.0	GLOBAL ENVIRO												
5.1	ATMOSPHERIC CIRC	TEST	125	400000	3600	4	.5	.25	.5	66.67	33.33	5760.00	133.33
5.2	METEOR PAYLOAD	OBS	250	16000	600	24	1	.25	1	2.67	2.67	230.40	10.67
5.3	ATMOS RES PAYLOAD	OBS	251	300000	600	24	1	.25	1	50.00	50.00	4320.00	200.00
5.4	TROP METRO SUPT	OBS	252	1800000	600	22	2	.25	1	275.00	550.00	23760.00	1100.00
5.5	OCEAN PAYLOAD	OBS	254	10000000	600	8	.5	.25	1	555.56	277.78	48000.00	2222.22
5.6	ADV THERMAL MAP	OBS	255	2500000	600	24	1	.25	1	416.67	416.67	36000.00	1666.67
5.7	SOIL&SNOW RES	OBS	256	40000000	600	8	.5	.25	1	2222.22	1111.11	192000.0	8888.89
5.8	ADV METEOR SYS	FF	376	32000	360	14	1	1	1	1.87	1.87	161.28	1.87
5.9	OCEAN CIR MISSION	FF	377	32000	360	14	1	1	1	1.87	1.87	161.28	1.87
5.10	WINDSAT	FF	378	32000	360	14	1	1	1	1.87	1.87	161.28	1.87
	GLOBAL ENVIRO	-	10	55112000	-	-	-	-	-	3594.38	2447.16	310554.2	14227.38
6.0	ASTROPHYSICS												
6.1	IR TELE FACILITY	OBS	201	200	3600	8	.2	.25	1	0.07	0.01	5.76	0.27
6.2	STARLAB	OBS	202	4200	3600	8	.2	.25	1	1.40	0.28	120.96	5.60
6.3	ORBIT INTERFEROM	OBS	203	1200	360	8	.2	.25	1	0.04	0.01	3.46	0.16
6.4	MODULAR ARRAY	OBS	204	125000	1800	4	.5	.25	.1	10.42	5.21	900.00	4.17
6.5	X/G-RAY SPECTRO	OBS	205	30000	3600	8	.2	.25	1	10.00	2.00	864.00	40.00
6.6	COSMIC RAY OBS	OBS	207	5000	1800	6	1	.25	.1	0.63	0.63	54.00	0.25
6.7	SPACE TELESCOPE	FF	301	8000	600	6	2	1	1	0.33	0.67	28.80	0.33
6.8	G-RAY OBS	FF	302	32000	240	14	1	.25	1	1.24	1.24	107.52	4.98
6.9	EXTREME UV EXPL	FF	303	32000	360	24	1	.25	1	3.20	3.20	276.48	12.80
6.10	X-RAY TIMING EXPL	FF	304	32000	360	24	1	.25	1	3.20	3.20	276.48	12.80
6.11	GRAVITY PROBE B	FF	305	5000	1800	24	1	.25	.1	2.50	2.50	216.00	1.00
6.12	ADV X-RAY ASTRO F	FF	306	132000	600	12	.5	.25	1	11.00	5.50	950.40	44.00
6.13	EXTREME UV SPECT	FF	307	32000	360	24	1	.25	1	3.20	3.20	276.48	12.80
6.14	LONG DUR EXP FAC	FF	311	132000	600	12	.5	.25	1	11.00	5.50	950.40	44.00
	ASTROPHYSICS	-	14	570600	-	-	-	-	-	58.23	33.15	5030.74	183.15
7.0	SOLAR/TERRESTRIAL												
7.1	SOLAR OPT TELE	FF	224	8000	600	6	2	1	1	0.33	0.67	28.80	0.33
7.2	ADV SOLAR OBS	FF	225	42000	600	1	.1	.25	1	0.29	0.03	25.20	1.17
7.3	SOLAR TER OBS	FF	226	6000000	600	24	.25	.25	1	1000.00	250.00	86400.00	4000.00
7.4	RENU RES PAYLOAD	FF	227	2500000	600	1	.25	.25	.5	17.36	4.34	1500.00	34.72
7.5	GEOLOGY PAYLOAD	FF	228	300000	600	24	2	.25	1	50.00	100.00	4320.00	200.00
7.6	CRUSTAL DYN STUDY	FF	229	10000	600	24	1	.25	1	1.67	1.67	144.00	6.67
7.7	AURORAL MAN OBS	FF	230	1000000	600	8	.5	.25	1	55.56	27.78	4800.00	222.22
7.8	HEV NUCLEI EXPL	FF	231	500	3600	24	1	.25	1	0.50	0.50	43.20	2.00
7.9	LIDAR AIR MEAS	OBS	232	500000	600	24	.5	.25	.5	83.33	41.67	7200.00	166.67
7.10	EVENTS DETECTION	OBS	235	10000	3600	8	1	.25	1	3.33	3.33	288.00	13.33
7.11	EARTH PLASMA	FF	350	6000	600	14	.25	.25	1	0.58	0.15	50.40	2.33
7.12	SUBSATELLITE FAC	FF	351	100000	600	14	.5	.25	1	9.72	4.86	840.00	38.89
7.13	STARPROBE	FF	352	32000	600	14	1	.25	1	3.11	3.11	268.80	12.44
7.14	SOLAR INT DYN	FF	353	32000	240	2	1	.25	1	0.18	0.18	15.36	0.71
7.15	ADV INTPLAN EXPL	FF	354	32000	240	2	.1	.25	1	0.18	0.02	15.36	0.71
7.16	SOLAR CORONA EXPL	FF	355	32000	240	2	.1	.25	1	0.18	0.02	15.36	0.71
	SOLAR/TERRESTRIAL	-	16	10604500	-	-	-	-	-	1226.32	438.31	105954.5	4702.91
8.0	PLANETARY												
8.1	SPECTRO TELE	OBS	275	50000	600	8	1	.25	1	2.78	2.78	240.00	11.11
8.2	IR SPECTRO	OBS	276	1000000	600	4	1	.25	1	27.78	27.78	2400.00	111.11
8.3	SATURN ORB DUAL P	FF	325	132000	3600	8	1	.5	1	44.00	44.00	3801.60	88.00
8.4	URAN/NEPT/PLU P	FF	326	132000	3600	8	1	.5	1	44.00	44.00	3801.60	88.00
8.5	ASTR.MULT REND.	FF	327	132000	3600	8	1	.5	1	44.00	44.00	3801.60	88.00
8.6	LUNAR POLAR ORBIT	FF	328	132000	3600	8	1	.5	1	44.00	44.00	3801.60	88.00
8.7	IF SUBMIL TELE	FF	329	1000	100	8	.1	.25	1	0.01	0.00	0.80	0.04
	PLANETARY	-	7	1579000	-	-	-	-	-	206.56	206.56	17847.20	474.26
9.0	COMMUNICATIONS												
9.1	LANDSAT SERVICE	SAT	400	200	3600	8	1	.5	1	0.07	0.07	5.76	0.13
9.2	COMM R&D LAB	SAT	1000	200	3600	8	1	.5	1	0.07	0.07	5.76	0.13
9.3	QUAL & ACC LAB	SAT	1001	200	3600	12	1	.5	1	0.10	0.10	8.64	0.20
9.4	DEPLOY & SERVICE	SAT	1002	200	3600	16	1	.5	1	0.13	0.13	11.52	0.27
9.5	HF BROADCAST SAT	SAT	1003	200	3600	16	1	.5	1	0.13	0.13	11.52	0.27
	COMMUNICATIONS	-	5	1000	-	-	-	-	-	0.50	0.50	43.20	1.00
SUMMARY	BY MISSION CATEGORY												
	LIFE SCIENCES	LS	5	25000	-	-	-	-	-	21.67	10.83	1872.00	12.67
	MILITARY	MIL	7	1792000	-	-	-	-	-	1037.33	2074.67	89625.60	5557.33
	MATERIALS PROC.	MAT	13	4002009	-	-	-	-	-	1876.95	937.89	162168.5	7500.78
	EARTH OBSERVATION	EO	4	128000	-	-	-	-	-	7.47	7.47	645.12	7.47
	GLOBAL ENVIRO	GE	10	55112000	-	-	-	-	-	3594.38	2447.16	310554.2	14227.38
	ASTROPHYSICS	ASTRO	14	570600	-	-	-	-	-	58.23	33.15	5030.74	183.15
	SOLAR/TERRESTRIAL	S/T	16	10604500	-	-	-	-	-	1226.32	438.31	105954.5	4702.91
	PLANETARY	P	7	1579000	-	-	-	-	-	206.56	206.56	17847.20	474.26
	COMMUNICATIONS	COM	5	1000	-	-	-	-	-	0.50	0.50	43.20	1.00
	TOTAL	-	81	73814109	-	-	-	-	-	8029.41	6156.53	693741.1	32666.95
SUMMARY	BY FACILITY												
	HABITAT FACILITY	HAB	5	25000	-	-	-	-	-	21.67	10.83	1872.00	12.67
	MILITARY FACILITY	MIL	7	1792000	-	-	-	-	-	1037.33	2074.67	89625.60	5557.33
	TEST FACILITY	TEST	5	4400000	-	-	-	-	-	1941.67	970.83	167760.0	7633.33
	SATELLITE FAC	SAT	5	1000	-	-	-	-	-	0.50	0.50	43.20	1.00
	INDUSTRIAL FAC	IND	9	2009	-	-	-	-	-	1.95	0.39	168.52	0.78
	OBSERVATORY FAC	OBS	16	56341600	-	-	-	-	-	3661.88	2491.91	316386.6	14441.11
	MICRO-G FACILITY	U-G	0	0	-	-	-	-	-	0.00	0.00	0.00	0.00
	FREE-FLYERS	FF	34	11252500	-	-	-	-	-	1364.41	607.39	117885.2	5020.73
	TOTAL	-	81	73814109	-	-	-	-	-	8029.41	6156.53	693741.1	32666.95

Table 2.1.1-1. Space Station Candidate Missions

6. Environmental requirements.
7. Pointing/Tracking requirements.
8. Date acquisition requirements.
9. Data processing requirements.
10. Data storage requirements.
11. Communication requirements.
12. Location/Control requirements.
13. Logistics requirements.

In the context of the Space Station, the primary commonality criteria is orbital requirements of the mission. Technology projections, and the evolutionary growth of the station over a ten year period, make all the other factors listed above design rather than compatibility issues. In the case of factors 2 through 13, all 81 missions could be supported concurrently with projected technology.

The orbital requirements of the candidate missions fall into two basic categories: low inclination and high inclination. Orbital factors such as synchronism (geo or sun), altitude (low or high), and orbit shape (circular or elliptical) have only a minor effect on commonality. Therefore two commonality groups were chosen:

1. Low inclination, low altitude, circular orbit.
2. High inclination, low altitude, sun synchronus, circular orbit.

Table 2.1.1-2 shows a summary of the missions in each commonality group.

2.1.1.2 Mission Performance Requirements

Given the mission commonality groups, DMS performance requirements are derived by determining the performance requirements of each function within a commonality group, and projecting those requirements over the anticipated time phasing of missions.

The basic data performance requirements are derived from consists of:

1. Data rate generated by the experiment/mission. The raw data rate generated by sensors in the mission.

2. Acquisition duration. This parameter recognizes the fact that many missions (including high data rate earth observation missions) only operate during a small fraction of an orbit. Therefore, with adequate buffering, the average performance of the DMS may be scaled down by this "duty cycle."

3. Number of acquisitions per day. The expected number of duty cycles per day.

4. Operations per bit. This parameter is based upon pre-processing requirements for similar missions currently in operation.

5. Communications utilization factor. This factor accounts for the fact that most data communication links are scarce resource and must be block scheduled and shared. It has generally been assumed that the Space Station would be allocated no more than 25% of the available link time.

6. Data conversion factor. This factor accounts for the fact that given missions may have significant data reduction/compression from input to communication output. Unique factors have been estimated for each factor.

The DMS performance requirements considered in this analysis consist of Data Acquisition Rate, DMS Processing rate, DMS Storage Rate, and DMS Communication Rate. Figure 2.1.1-1 illustrates the algorithms used to derive these requirements.

A time phase analysis of the mission phasing for each commonality group was performed using a computer program. Automation of requirements derivation allows simple re-analysis when algorithm inputs are more well known. Figure 2.1.1-2 summarizes the concurrent missions for the low inclination commonality group. As shown, only 28 of the 51 missions are expected to operate concurrently, and the DMS need only be sized for 28 missions.

Figures 2.1.1-3 through 2.1.1-8 illustrate the DMS performance requirements over the life of the station. Tables 2.1.1-3 and 2.1.1-4 are the output of the automated analysis program and show in detail the time phasing and actual requirements for each mission.

Table 2.1.1-2. Mission Commonality Groups

MISSION CATEGORY	NUMBER OF MISSIONS								
	LOW INCLINATION			HIGH INCLINATION			TOTAL		
	SS	FF	TOTAL	SS	FF	TOTAL	SS	FF	TOTAL
LIFE SCIENCES	5	-	5	-	-	-	5	-	5
MILITARY	7	-	7	-	-	-	7	-	7
MATERIALS PROCESSING	13	-	13	-	-	-	13	-	13
EARTH OBSERVATIONS	-	-	-	-	4	4	-	4	4
GLOBAL ENVIRONMENT	-	-	-	7	3	10	7	3	10
ASTROPHYSICS	6	8	14	-	-	-	6	8	14
SOLAR/TERRESTRIAL	-	-	-	2	14	16	2	14	16
PLANETARY	2	5	7	-	-	-	2	5	7
COMMUNICATIONS	5	-	5	-	-	-	5	-	5
TOTAL	38	13	51	9	21	30	47	34	81

$$\text{ACQUISITION RATE, BPS} = \left[\begin{matrix}\text{DATE}\\ \text{RATE,}\\ \text{BPD}\end{matrix}\right] \left[\begin{matrix}\text{ACQ.}\\ \text{DUR.}\\ \text{SEC}\end{matrix}\right] \left[\frac{\text{\# ACQ.}}{\text{DAY}}\right] \left[\begin{matrix}\text{OPS}\\ \text{MODE}\\ \text{FACT}\end{matrix}\right] \div \left[\frac{\text{\# SEC}}{\text{DAY}}\right]$$

$$\text{PROCESSING RATE, MOPS} = \left[\begin{matrix}\text{ACQUISITION}\\ \text{RATE, BPS}\end{matrix}\right] \left[\frac{\text{\# OPS}}{\text{BIT}}\right] \div \left[10^6\right]$$

$$\text{STORAGE RATE, BPD} = \left[\begin{matrix}\text{ACQUISITION}\\ \text{RATE, BPS}\end{matrix}\right] \left[\frac{\text{\# SEC}}{\text{DAY}}\right]$$

$$\text{COMMUNICATION RATE, BPS} = \left[\begin{matrix}\text{ACQUISITION}\\ \text{RATE, BPS}\end{matrix}\right] \left[\begin{matrix}\text{DATE}\\ \text{CONVERSION}\\ \text{FACTOR}\end{matrix}\right] \div \left[\begin{matrix}\text{COMM}\\ \text{UTILIZATION}\\ \text{FACTOR}\end{matrix}\right]$$

Figure 2.1.1-1. Performance Requirements Derivation Algorithm

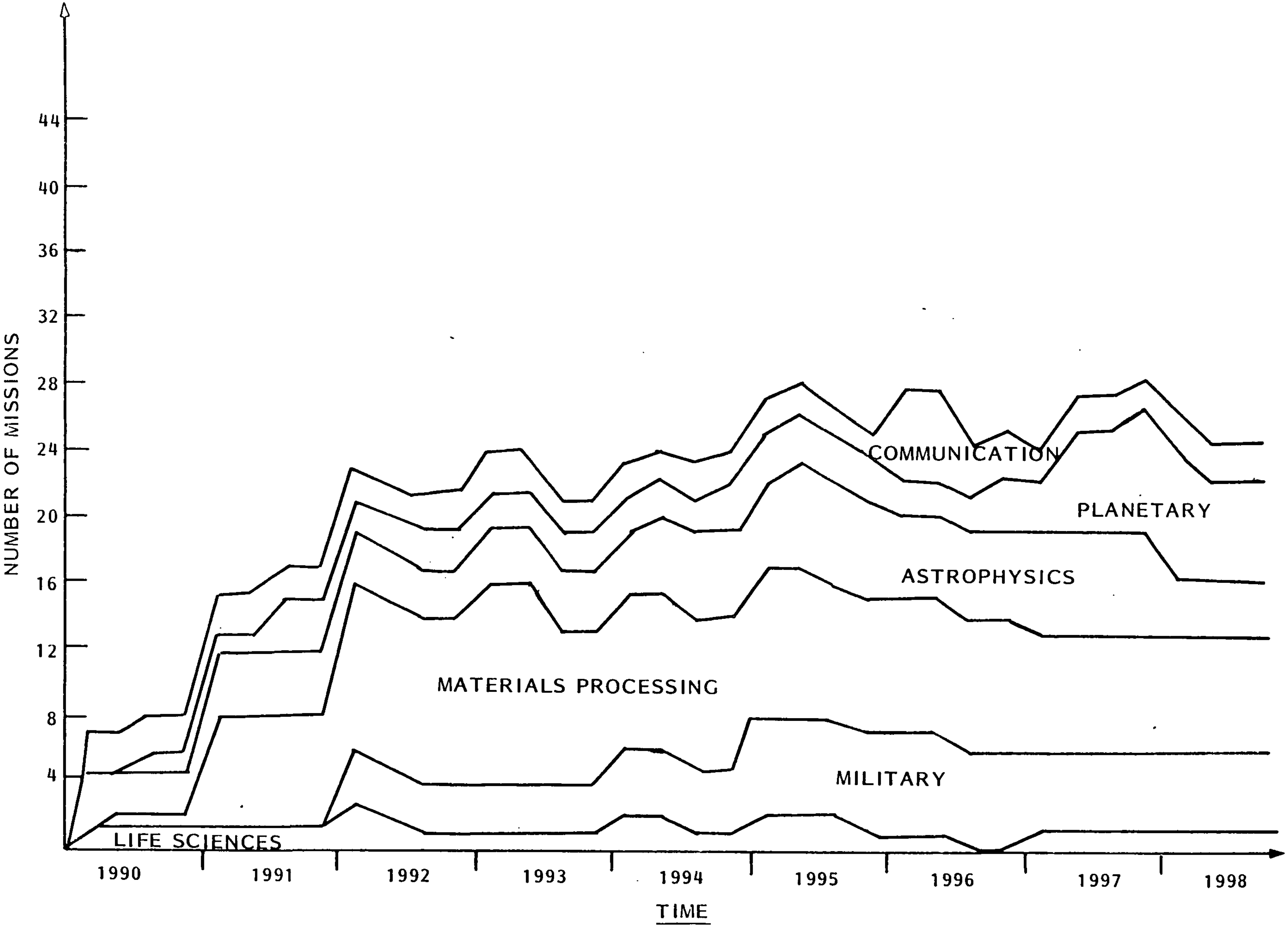


Figure 2.1.1-2. Low Inclination Group-Mission Phasing

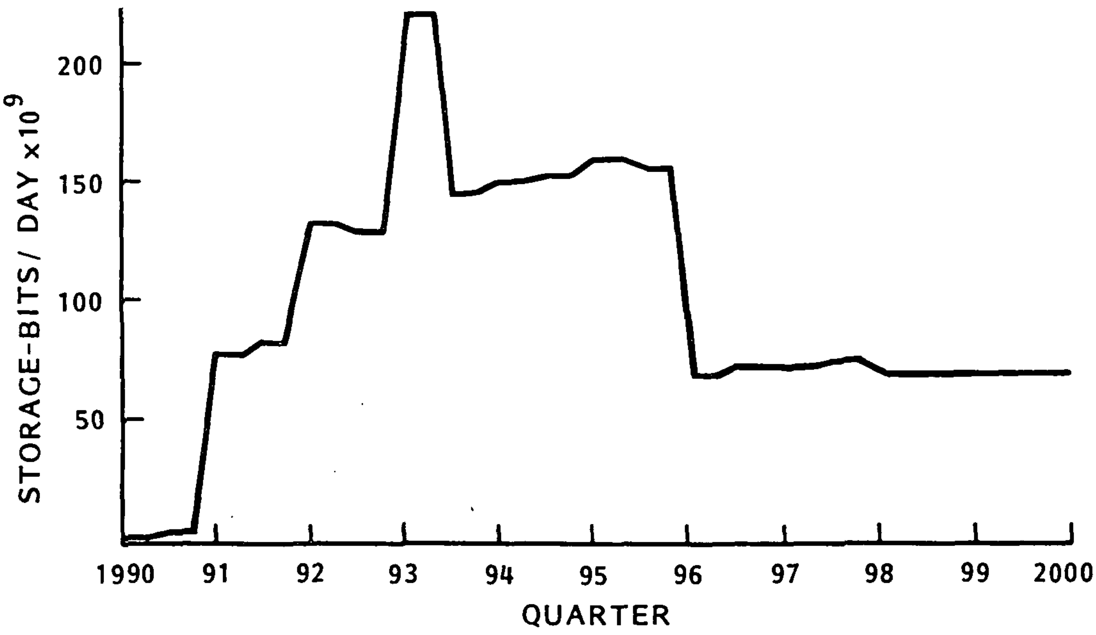


Figure 2.1.1-3. DMS Storage Requirements-Low Inclination Group

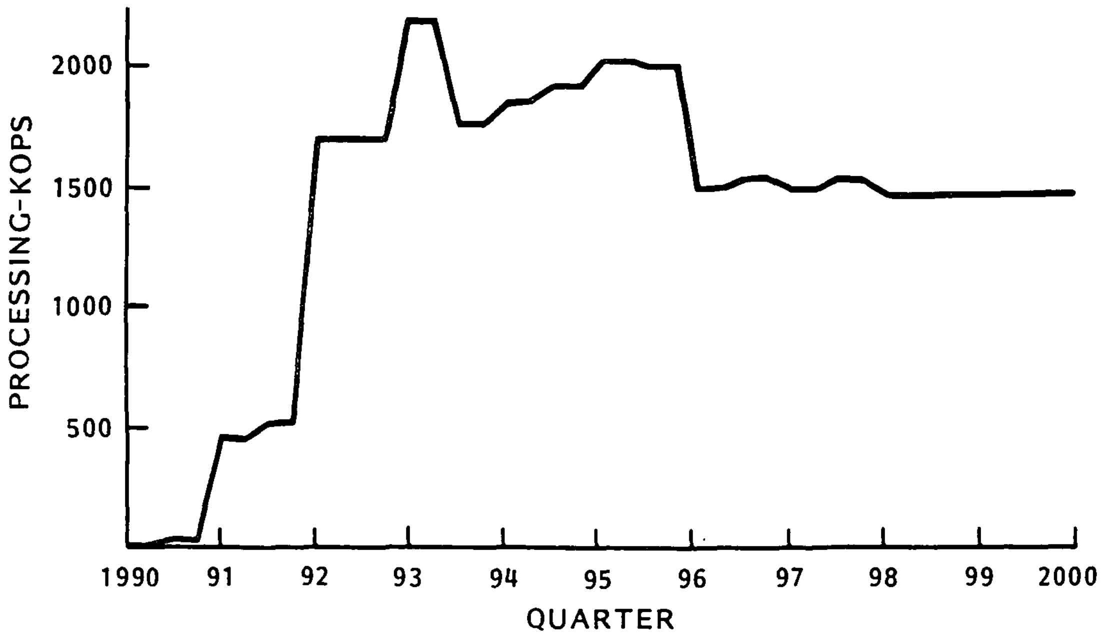


Figure 2.1.1-4. DMS Processing Requirement-Low Inclination Group

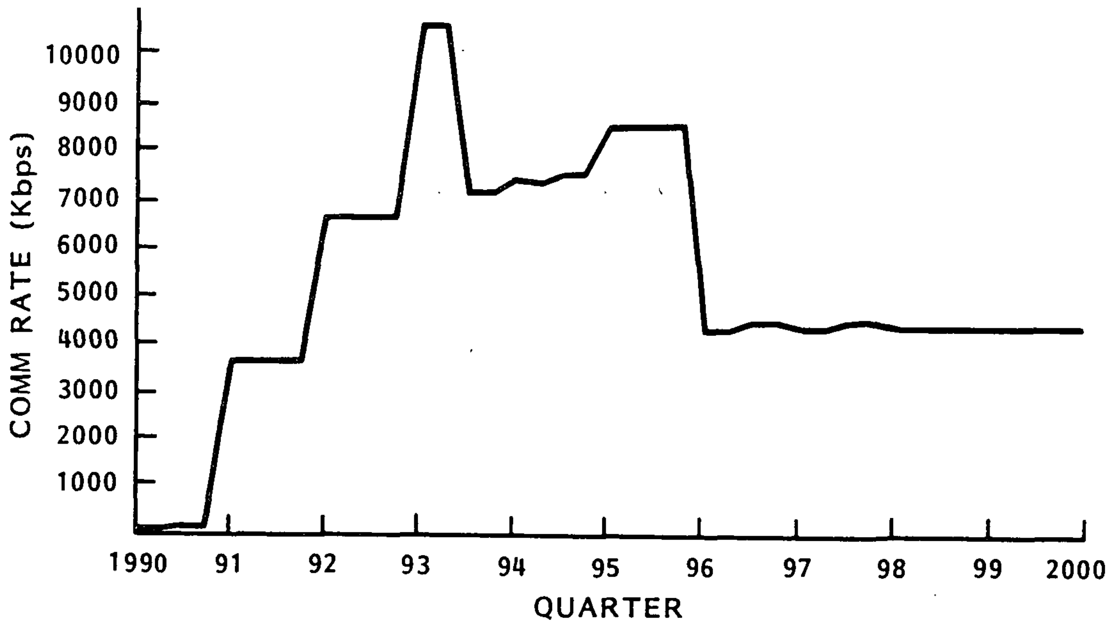


Figure 2.1.1-5. DMS Data Communication Requirements-Low Inclination Group

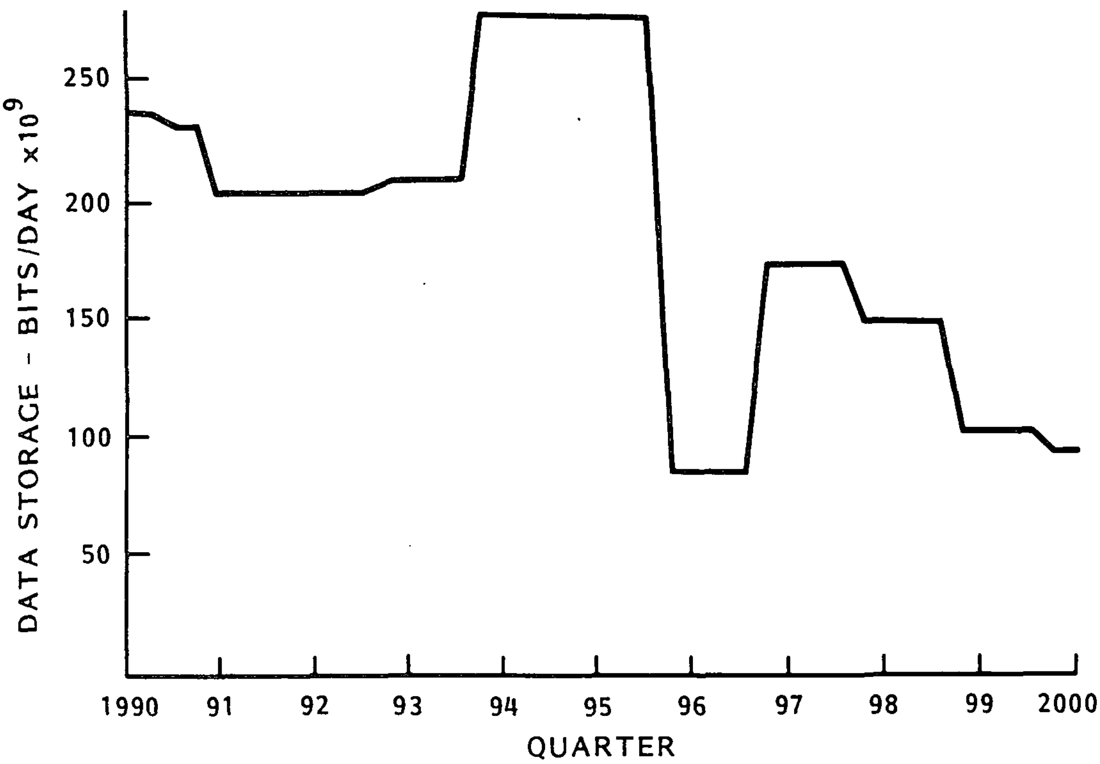


Figure 2.1.1-6. DMS Data Storage Requirements-High Inclination Group

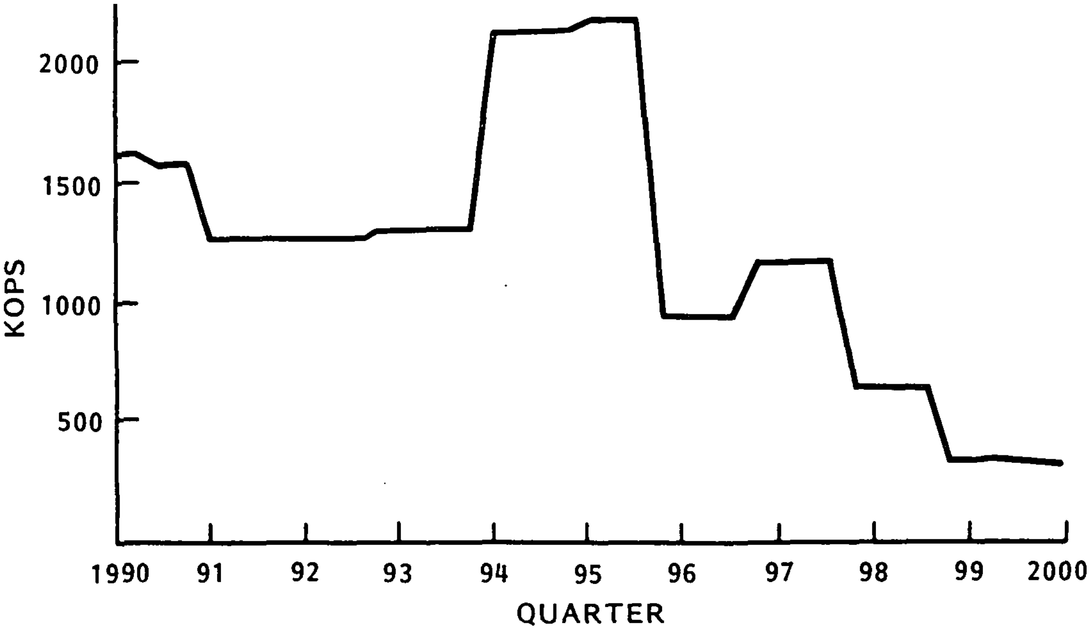


Figure 2.1.1-7. DMS Processing Requirement-High Inclination Group

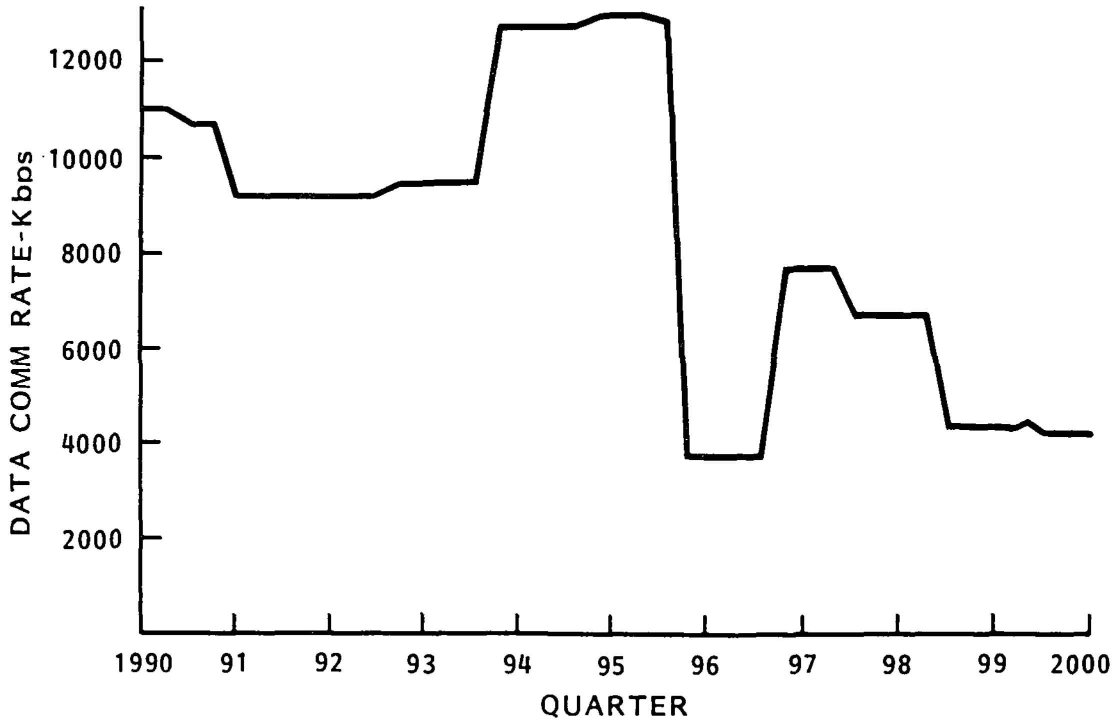


Figure 2.1.1-8. DMS Communication Requirement-High Inclination Group

Table 2.1.1-3. DMS Performance Requirements-Low Inclination Group
(In Attached Envelope)

Table 2.1.1-4. DMS Performance Requirements-High Inclination Group
(In Attached Envelope)

2.1.2 FUNCTIONAL REQUIREMENTS

A preliminary functional requirements analysies and allocation was performed to drive out those functions which due to a variety of reasons, should be carried out on board the Space Station. The definition of the on-board functions aided us in deriving both the on-board Data Management System architecture (Section 2.2.1) as well as the on-board software requirements (Section 2.3.2). The conclusion reached herein were reviewed and re-evaluated during the conduct of the Autonomy Study (Section 2.1.4).

The approach taken was to first identify top level functions (18) and then break these down into 84 first level subfunctions. Since the ultimate objective was to allocate functions between flight and ground, and since this could not be done at the top level, the 84 subfunctions were derived.

Functions were allocated as being On-board, On Ground or Shared. Also, to support onboard data system architecture analyses, a criticality measure was assigned to each function.

2.1.2.1 Methodology

Our first step was to compile a comprehensive list of major functions for the space station. To accomplish this we began by considering those functions that were deemed necessary for the support of a manned space mission. Our primary model was Skylab, but consideration was also given to the Apollo missions as well as the Space Shuttle. Next we considered the myriad of support functions needed to operate a satellite. Here we drew on our knowledge of the Landsat-4 system to enumerate the ground control and processing needed. Along with the functions needed for satellite support, we also considered the functions needed for the various missions that would be conducted on a space station. The mission applications considered were those derived in Task 1 of this study. Here again we relied on our knowledge of Landsat-4, as well as such studies as ELOS (Experimental Land Observation System) and discussions with Earth resources personnel, in the compilation of a function list.

Finally, to complete our list of major functions, we considered those unique requirements that would be required to operate a space station. Here we considered the support needed for such activities as on board experiments, operation, military support, extra vehicular activities (EVA), orbital transport vehicles (OTV), etc.

Having compiled all the functions, an integration was done which resulted in a list of 18 major functions. In order to allocate functions to the on board or ground (or shared) components, it was necessary to break down the 18 major functions. This was done by considering the first level subfunctions of each major function. The result was a collection of 84 first level subfunctions. Of course each of these can be further broken down to form thousands of lower level functions, and that must be done as the system develops. For our purpose here however, the first level breakdown was sufficient to allow the allocation of each to a component of the IMS (i.e. on-board, ground or shared).

2.1.2.2 Assumptions

To establish a reasonable set of system functions and to intelligently allocate these functions, the following assumptions were made:

1. Space station is manned with at least five crew members
2. Principle investigators and mission users are numerous and are on the ground
3. Initial operations in 1990
4. Design objective is to maximize autonomy (i.e. minimize ground support)
5. Personnel onboard are primarily operations oriented

2.1.2.3 Allocation Criteria

The allocation of the first level functions, to either ground, on board, or shared, was made based on a set of criteria that are considered extensive though not necessarily exhaustive. These criteria were derived from past experience with manned missions, as well as unique considerations for the space station.

The major criteria used in the allocation of IMS functions are as follows:

1. Autonomy - The ability of the space station to function on its own without (or reduced) ground support. Autonomy is a desired goal since it would lead to reduced support crews on ground. (As previously indicated, a separate study was performed to examine the impact of autonomy.)

2. Health and Safety of crew and station - The maintenance of well being and prevention of hazards to crew and station.

3. Crew capability - Although the crew will probably be astronaut qualified, they are not expected to be experts in every field of technology.

4. Crew functional load - There are limits to the number of tasks that a crew can be expected to perform.

5. Cost - Related to both the cost of space qualified equipment and to life cycle costs.

6. National security - The space station is expected to support military missions.

7. Reliability/availability - The amount of time that a function is available for normal use. This considers such issues as mean time between failures (MTBF) and mean time to repair (MTTR).

8. Maintainability - The ease of upkeep of a system.

9. Communication load - There are limits to the time available on communication links such as TDRSS, and to the volume that such links can handle.

10. Technical risk - there are risks associated with the development of technology both in the areas of performance and in schedules.

11. On board processing load - refers to limitations of on-board data processing.

12. Applicability - some functions' locations are determined by their nature, e.g., entertainment for the crew belongs on board.

13. User accessibility - The ability of users of a function to have ready access to it.

14. Location of related functions - some functions should be colocated with others for simplicity and economy.

15. Back-ups - necessary for many functions and hence impact the allocations of the primary functions.

2.1.2.4 Allocation Methodology

Using the allocation criteria just enumerated, each of the 84 functions were assigned as (1) on board, (2) ground, or (3) shared. We accomplished this allocation by first determining which criteria were applicable, and then examining the function in light of the criteria and the assumptions made. This allowed us to determine the pros and cons of a particular allocation. Finally, the pros and cons were evaluated and the function was allocated to a particular location.

2.1.2.5 Criticality Methodology

To support the onboard data system architecture synthesis, the criticality of the 84 subfunctions was addressed. To do this, the following criticality code was established.

1. High - effects Health and Safety of Crew or Station or National Security
2. Medium - degrades performance
3. Low - no immediate impact

To establish criticality for each function, the function was reviewed and a criticality was assigned. This was done by assessing the impact of the failure of each function.

2.1.2.6 Functional Allocation

The following tabulation of functions constitutes the results of this functional analysis. For each function the allocation and criticality is given (Allocation, Criticality). Appendix E provides the analysis performed for each function, providing the rationale and allocation criteria.

Legend:

G	Ground	H	High Criticality
OB	On-Board	M	Medium Criticality
SH	Shared	L	Low Criticality

First Level IMS Functional Breakdown and Allocation

User/PI Interface	Process Experiment/Mission Rqmts.	G, L
	Preliminary Requirements Approval	G, L
	Input Requirements to Planning	G, L
	User/PI to Crew Voice Comm	SH, M
	User/PI to S/S Data Comm	SH, L
System Command and Control	Flight Operations Long Term Planning	G, L
	Mission Operations Long Term Planning	G, L
	Flight Operations Scheduling	OB, H
	Mission Operations Scheduling	OB, L
	Flight Operations	OB, H
	Mission Operations	OB, L
Mission Support	Mission Data Collection	OB, L
	Mission Data Preprocessing	OB, L
	Mission Data Processing	G, L

First Level IMS Functional Breakdown and Allocation (Cont.)

Mission Data Distribution	Data Downlinking	SH, M
	Free Flyer Relay	OB, M
	Data Routing to User/PI	G, M
	TDRSS Link Scheduling	G, M
	MILSATCOM Link Scheduling	G, M
S/S Hardware Maintenance	Preventive Maintenance	OB, H
	Fault Detection	OB, H
	Fault Isolation/Diagnosis	SH, H
	Corrective Action	OB, H
	SS/Ground Voice Comm	SH, H
	TV Monitoring	SH, M
S/S Software Maintenance	Fault Detection	OB, H
	Fault Isolation/Diagnosis	SH, H
	Corrective Action	SH, H
	SS/Ground Voice Comm	SH, H
	SS/Ground Data Comm	SH, H
Crew Health Monitoring/ Maintenance	Routine Check Up	OB, M
	Health Data Collection	OB, M
	Diagnosis/Treatment Det.	SH, H
	SS/Ground Voice Comm	SH, H
	SS/Ground Data Comm	SH, H
	TV Monitoring	SH, H
Spaceborne Experimentation	Conduct Experiment	OB, L
	Record Data	OB, L
	Analyze Data	G, L
	Crew/PI Voice Comm	SH, L
	SS/PI Data Comm	SH, L
	TV Monitoring	SH, L
S/S Onboard Support	Environmental Control and Life Support	OB, H
	Electrical Power	OB, H
	Thermal Control	OB, H
	Guidance, Nav. and Attitude Control	OB, H
	SS/Ground Communications	SH, M, L, H
	SS Interior Communications	OB, M
	Surveillance (Radar)	OB, H
	Rendezvous and Docking Support	OB, H
	Remote Manipulation Support	OB, M
	EVA Support	OB, H
	OTV Support	OB, H
	Free Flyer Support	OB, M
	Structure Control/Monitoring	OB, H
	Logistics	OB, L

First Level IMS Functional Breakdown and Allocation (Cont.)

S/S Support Subsystem C&C	Subsystem Commanding	OB, H
	Procedure Display/Processing	OB, H
	Backup Commanding	G, H
S/S Mission Subsystem C&C	Mission Subsystem Commanding	OB, M
	Procedure/Display Processing	OB, M
S/S Support Subsystem Monitoring	Telemetry Processing	OB, H
	Telemetry Display	OB, H
	Trend Analysis	G, L
	C&W Alarms	OB, H
	TV Monitoring	OB, M
S/S Mission Subsystem Monitoring	Telemetry Processing	OB, M
	Telemetry Display	OB, M
	C&W Alarms	OB, H
	Trend Analysis	G, L
	TV Monitoring	OB, L
On-Board Entertainment	Library	OB, L
	Movies	OB, L
	TV	SH, L
	Games	OB, L
Data Storage	On-Board Data Base	OB, H
	Support Data Base	G, M
	Long Term Data Storage	SH, H
Performance Evaluation	Long Term System PE	G, M
	Short Term System PE	OB, H
	Long Term Mission PE	G, L
	Short Term Mission PE	OB, M
Military Support	Interface	OB, H
Training and Simulation		SH, L

2.1.3 OPERATIONAL REQUIREMENTS

Having determined the functions that should be performed on-board the station, we proceeded to analyze the impact on the DMS caused both by man's interaction as well as by the space station subsystems. This analyses, along with the mission requirements analysis (Section 2.1.1) aided us in sizing the on-board DMS.

2.1.3.1 Crew Operations Requirements

The basic crew operation and interaction was determined by first developing a set of strawman activities and then deriving the basic data management requirements which result from those activities. In addition, a crew activities time line was generated to illustrate the relative durations of the various activities. (Figure 2.1.3-1.)

2.1.3.1.1 Crew Activities

Crew activities have been broken down into the following categories:

A) Monitoring and configuring of Space Station Subsystems.

B) Payload Mission Operations (Generic).

C) "Housekeeping" Activities.

D) "Crew Scheduling" Activities.

E) "Docking" Operations.

F) "Emergency" Operations.

G) "Off-Duty" Operations.

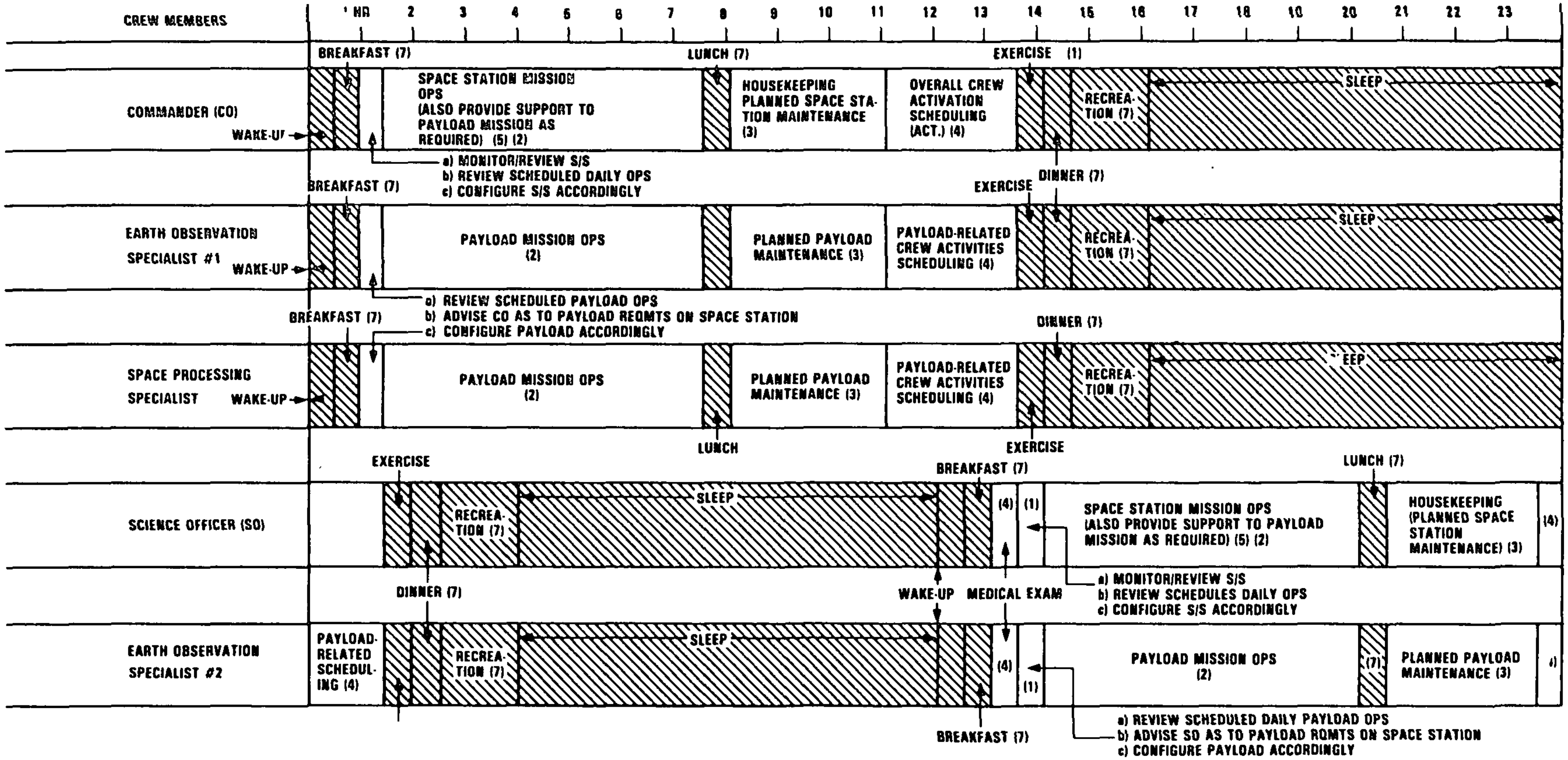
Tables 2.1.3-1 through 2.1.3-7 provide a detailed breakdown of these activities.

2.1.3.1.2 Daily Crew Activities Timeline

The basic assumptions used for constructing the preliminary daily crew activities timeline were as follows:

A) 5 men on the Space Station.

B) 2 men always on duty (one of which is the space station systems operations expert).



NOTE 1 - SHADED PERIODS DENOTE OFF-DUTY OPERATIONS
NOTE 2 - NUMBERS IN PARENTHESIS REFER TO CREW ACTIVITY TABLES 2.1.3-1 THRU 2.1.3-7.

Figure 2.1.3-1. Crew Timeline

Table 2.1.3-1. Daily Monitoring and Configuration of Space Station Subsystems

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
A) MONITOR SPACE STATION SUB-SYSTEMS AND OVERALL SPACE STATION STATUS	ONE ASTRONAUT MONITORING SUBSYSTEM STATUS ON CRT. ASTRONAUT WOULD ALSO ROUTINELY MONITOR RADAR SCOPE, AND CONDUCT VISUAL INSPECTION OF BOTH INTERIOR AND EXTERIOR OF SPACE STATION USING REMOTE TV.	CRT-9600 BIT/SEC RADARSCOPE-2400 BIT/SEC TV-6 MEGAHERTZ
B) MONITOR PAYLOAD SUBSYSTEM	ONE ASTRONAUT MONITORING PAYLOAD SUBSYSTEM STATUS ON CRT. ASTRONAUT MAY ALSO CONDUCT VISUAL INSPECTION OF EXTERIOR-MOUNTED PAYLOAD USING REMOTE TV.	CRT-9600 BIT/SEC TV - 6 MEGAHERTZ
C) REVIEW SCHEDURED DAILY OPS	ONE OR TWO ASTRONAUTS REVIEWING ON CRT SCHEDULED DAILY OPS (BOTH SPACE STATION MISSION OPS AND PAYLOAD MISSION OPS). MAY ALSO REQUIRE EXTERNAL COMM-LINK WITH GROUND FOR FURTHER DISCUSSION OF SCHEDULE.	CRT-9600 BIT/SEC TV - 6 MEGAHERTZ TV/VOICE-TO GROUND
D) CONFIGURE SPACE STATION SUB-SYSTEMS ACCORDING TO DAILY MISSION REQUIREMENTS (INCLUDING PAYLOAD REQUIREMENT ON SPACE STATION).	ONE ASTRONAUT CONFIGURING SUBSYSTEMS ON CRT, WITH ASTRONAUT UTILIZING CRT (WITH REMOTE TV) FOR CONFIRMATION.	CRT-9600 BIT/SEC TV-6 MEGAHERTZ
E) CONFIGURE PAYLOAD SUBSYSTEMS ACCORDING TO DAILY MISSION REQUIREMENTS.	SAME AS D)	SAME AS D)

Table 2.1.3-2. Payload Mission Operations (Generic)

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
A) PERFORM SPECIFIED PAYLOAD MISSION (OR CONTINUE MISSION FROM PREVIOUS WORK PERIOD).	IN THE COURSE OF PERFORMING MISSION ONE ASTRONAUT MAY REQUIRE ACCESS TO CRT, LIBRARY, TV	CRT-9600 BIT/SEC LIBRARY-2400 BIT/SEC TV - 6 MEGAHERTZ
B) REVIEW MISSION RESULTS WITH GROUND.	ONE ASTRONAUT MAY REQUIRE EXTERNAL COMM-LINK (RADIO, TV)	VOICE GROUND - TV BROUND
C) IF MISSION RESULTS ARE SATISFACTORY, REVIEW FUTURE MISSION ACTIVITIES AND APPROPRIATE PROCEDURES.	ONE ASTRONAUT MAY REQUIRE ACCESS TO CRT, LIBRARY, TV AND RADIO COMM-LINK WITH GROUND.	CRT-9600 BIT/SEC VOICE-GROUND TV GROUND
D) IF MISSION RESULTS ARE UNSATISFACTORY, DECIDE ON CORRECTIVE ACTION (WITH GROUND CONCURRENCE).	ONE ASTRONAUT MAY REQUIRE ACESS TO CRT, LIBRARY, TV AND RADIO COMM-LINK WITH GROUND.	CRT-9600 BIT/SEC LIBRARY-2400 BIT/SEC TV GROUND RADIO GROUND
E) PERFORM CORRECTIVE ACTION	ONE (OR MORE ASTRONAUTS) MAY BE REQUIRED FOR: 1) COMMANDS VIA CRT. 2) PHYSICALLY REPLACING/REPAIRING/RECALIBRATING PAYLOAD WHICH MAY REQUIRE CONSULTING LIBRARY. 3) EXTERNAL ACTION USING: a. EVA (TV, CRT, RADIO, LIBRARY) b. RMS (TV, CRT, ON-BOARD COMPUTER, LIBRARY).	CRT-9600 BIT/SEC LIBRARY-2400 BIT/SEC TV - 6 MEGAHERTZ RADIO -

Table 2.1.3-3. Housekeeping Activities

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
A) EXPENDABLES, LOGISTICS (FOOD, WATER, AIR, FUEL, ETC.).	ONE ASTRONAUT MONITORING EXPENDABLES LEVELS ON CRT. REPLACEMENT LOGISTICS MAY TAKE THE FORM OF ADJUSTMENTS VIA: 1) COMMANDS VIA CRT 2) PHYSICALLY REPLACING EXPENDABLES, WHICH MAY REQUIRE CONSULTING SYSTEMS LIBRARY.	CRT-9600 BIT/SEC LIBRARY - 2400 BIT/SEC
B) PLANNED SPACE STATION SUBSYSTEM MAINTENANCE/RECALIBRATION (INCLUDING SPARE PARTS LOGISTICS)	ONE ASTRONAUT ASSESSING THE NEED FOR SUBSYSTEM MAINTENANCE/RECALIBRATION USING: THE CRT, ON-BOARD COMPUTER, TV (FOR REMOTE AREAS), AND ACCESS TO THE LIBRARY AS REQUIRED. IF ACTION IS REQUIRED, IT MAY REQUIRE: 1) COMMANDS VIA CRT 2) PHYSICALLY REPLACING/REPAIRING/RECALIBRATING SYSTEMS, WHICH MAY REQUIRE CONSULTING LIBRARY 3) EXTERNAL ACTION USING: a. EVA (TV, CRT, RADIO, LIBRARY). b. RMS (TV, CRT, ON-BOARD COMPUTER, LIBRARY)	CRT-9600 BIT/SEC TV - 6 MEGAHERTZ LIBRARY - 2400 BIT/SEC RADIO -
C) DISPOSAL OF WASTE MATERIAL (FOOD, ETC)	COLLECTION AND DISPOSAL OF WASTE MAY BE DONE AUTOMATICALLY (AT CREW COMMAND), OR PHYSICALLY BY CREW	CRT - 9600 BIT/SEC
D) PLANNED PAYLOAD SUBSYSTEM MAINTENANCE/RECALIBRATION (INCLUDING SPARE PARTS LOGISTICS)	SAME AS B)	SAME AS B)

Table 2.1.3-4. Crew Scheduling Activities

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
A) DAILY SCHEDULING (OVERALL SPACE STATION ACTIVITIES AND PAYLOAD-RELATED ACTIVITIES).	ONE OR MORE ASTRONAUTS OPERATING A CRT.	CRT - 9600 BIT/SEC
B) CREW TRAINING (FOR BOTH SPACE STATION ACTIVITIES AND PAYLOAD RELATED ACTIVITIES).	ONE OR MORE ASTRONAUTS PERFORMING GENERAL INFORMATION REVIEW USING CRT AND LIBRARY, OR PRACTICE SIMULATORS	CRT - 9600 BIT/SEC LIBRARY - 2400 BIT/SEC
C) BIO-MEDICAL MONITORING/CHECKUP.	ONE ASTRONAUT MONITORING EACH CREW BIO-CONDITION ON CRT, AND POSSIBLY UTILIZING IN DIAGNOSIS PROCESS THE LIBRARY, TV	CRT - 9600 BIT/SEC LIBRARY - 2400 BIT/SEC TV - 6 MHz

Table 2.1.3-5. Docking Operations

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
A) TRACKING OF INCOMING SPACECRAFT ON SPACE STATION RADAR	ONE ASTRONAUT MONITORING ON CRT, RADAR SCOPE	RADAR - 2400 BIT/SEC CRT - 9600 BIT/SEC
B) ESTABLISH COMM-LINK WITH INCOMING SPACECRAFT.	IF SPACECRAFT IS UNMANNED, ONE ASTRONAUT MAY ONLY MONITOR PROGRESS. IF SPACE CRAFT IS MANNED, ONE ASTRONAUT MAY INITIATE COMM-LINK ESTABLISHMENT.	COMM: a. VOICE b. SPACECRAFT - 20 BIT/SEC TELEMETRY (CRITICAL FUNCTION STATUS)
C) ESTABLISH VISUAL CONTACT VIA LONG RANGE TV WHEN POSSIBLE.	SECOND ASTRONAUT WATCHING ON TV SCREEN.	TV - 6 MEGAHERTZ
D) REVIEW CONDITION OF INCOMING SPACECRAFT. a. SAFETY CONDITION OF CRITICAL SPACECRAFT FUNCTION b. OTHER CONSIDERATIONS (DANGEROUS SPACE STATION ENVIRONMENT).	ONE ASTRONAUT MONITORING ON CRT, RADAR SCOPE, TV. MAY ALSO REQUIRE USE OF LIBRARY, AND AUDIOVISUAL ALARMS IN DECISION PROCESS	RADAR - 2400 BIT/SEC CRT - 9600 BIT/SEC TV - 6 MEGAHERTS LIBRARY - 2400 BIT/SEC AUDIOVISUAL ALARM
E) IF SPACECRAFT IS SAFE FOR DOCKING, SPACECRAFT IS ALIGNED FOR FINAL APPROACH TO DOCKING (SPACE STATION SHOULD BE IN AUTO-HOLD ATTITUDE MODE)	ONE ASTRONAUT MONITORING ON CRT, RADAR SCOPE, TV. IF EMERGENCY DEVELOPS, ASTRONAUT MAY ACTIVATE MANUAL/REMOTE FLIGHT CONTROL.	CRT - 9600 BIT/SEC RADAR - 2400 BIT/SEC TV - 6 MEGAHERTZ EMERGENCY: MANUAL FLIGHT CONTROL
F) SPACECRAFT DOCKING	ONE ASTRONAUT MONITORING CAPTURE (AND EQUALIZING OF SPACECRAFT/SPACE STATION DOCKING PORT ENVIRONMENT) ON CRT, TV.	CRT - 9600 BIT/SEC TV - 6 MEGAHERTZ

Table 2.1.3-5. Docking Operations (Cont.)

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
G) TRANSFER OF CREW/MATERIALS VIA AIRLOCK.	ONE ASTRONAUT POSSIBLY MONITORING ON TV. OTHERWISE ONLY PHYSICAL ASSISTANCE REQUIRED).	TV - 6 MEGAHERTZ
H) TRANSFER OF CREW/MATERIALS EXTERNALLY VIA EVA OR SPACE STATION RMS.	IF EXTERNAL TRANSFER IS DONE BY EVA: 1) ONE ASTRONAUT MONITORING PROGRESS OF 2 EVA ASTRONAUTS ON CRT, TV, RADIO, LIBRARY ALSO REQUIRED) IF EXTERNAL TRANSFER IS DONE BY RMS: 1) ONE OR TWO ASTRONAUTS OPERATING RMS, TV, CRT, LIBRARY.	CRT - 9600 BIT/SEC TV - 6 MEGAHERTZ VOICE COMM - LIBRARY - 2400 BIT/SEC RMS -
I) REFUELING/RECONDITION OF SPACECRAFT FOR MISSION USE (VIA ASSISTANCE OF EVA CREWMAN OR RMS).	SAME REQUIREMENTS AS IN H)	SAME REQUIREMENTS AS IN H)
J) SPACECRAFT UNDOCKING AND DEPARTURE (CREW REMAINS IN SPACE STATION)	SAME REQUIREMENTS AS IN E), F).	SAME REQUIREMENTS AS IN E), F)
K) REVIEW AND ASSESS THE NEED TO BRING BACK SPACECRAFT TO REPAIR MALFUNCTION.	SAME REQUIREMENTS AS IN D).	SAME REQUIREMENTS AS IN D).
L) COMMAND SPACECRAFT IF REQUIRED AT SAFE DISTANCE FROM SPACE STATION a. SPACECRAFT MOTOR FIRING, DEPLOYMENT OF SPACECRAFT BOOMS, ETC.	SAME REQUIREMENTS AS IN D).	SAME REQUIREMENTS AS IN D).

Table 2.1.3-5. Docking Operations (Cont.)

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
M) IF SPACECRAFT IS NOT SAFE FOR DOCKING: a. SPACECRAFT IS ABORTED COMPLETELY b. SPACECRAFT IS ABORTED TO SAFE HOLDING AREA NEAR SPACE STATION	SAME REQUIREMENTS AS IN E).	SAME REQUIREMENTS AS IN E)
N) NEXT, SPACECRAFT IS EITHER: a. CREW/CARGO UNLOADED AND TRANSFERRED VIA EVA TO SPACE STATION b. REPAIR SPACECRAFT BY EVA CREWMAN TO MAKE IT SAFE FOR DOCKING AT SPACE STATION.	SAME REQUIREMENTS AS IN H).	SAME REQUIREMENTS AS IN H)

Table 2.1.3-6. Emergency Operations

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
A) EMERGENCY WARNING	ASTRONAUT(S) ARE NOTIFIED OF EMERGENCY SITUATION VIA: 1) AUDIOVISUAL ALARM(S) 2) CRT DISPLAY 3) EXTERNAL COMMUNICATION WITH GROUND OR OTHER SPACECRAFT (RADIO,TV)	AUDIOVISUAL ALARMS - CRT - 9600 BIT/SEC EXTERNAL COMM: a. RADIO - b. TV - 6 MEGAHERTZ RADAR - 2400 BIT/SEC
B) EMERGENCY ASSESSMENT	ASTRONAUT(S) PERFORM: 1) SPACE STATION SUBSYSTEM MALFUNCTION USING CRT, LIBRARY, TV, ON-BOARD COMPUTER. 2) CREW MEDICAL DIAGNOSIS USING CRT, LIBRARY, ON-BOARD COMPUTER, TV (MICROSCREEN). 3) EXTERNAL THREAT ASSESSMENT FOR THREATS SUCH AS COLLISION UTILIZING TRACKING RADAR, CRT, TV, OR -- GROUND-UP-LINKED DATA (RADIO, TV) CONCERNING SOLAR FLARE ACTIVITY, ECT).	CRT - 9600 BIT/SEC LIBRARY - 2400 BIT/SEC TV - 6 MEGAHERTZ RADIO - RADAR - 2400 BIT/SEC TV - 6 MHz
C) EMERGENCY REMEDY ACTION	ASTRONAUTS PERFORM: 1) ASTRONAUT COMMANDED AUTO-REPAIR USING CRT, ON-BOARD COMPUTER, TV 2) RMS (TV, CRT, LIBRARY). 3) MEDICAL OPERATION USING CRT, LIBRARY, TV 4) NO ACTION - CONTINUE TO MONITOR 5) SPACE STATION MISSION ABORT USING: a. ALREADY DOCKED ESCAPE CAPSULES. b. STS OR OTHER S/C	CRT - 9600 BIT/SEC TV - 6 MEGAHERTZ RADIO - LIBRARY - 2400 BIT/SEC TV - 6 MHz RADAR - 2400 BIT/SEC

Table 2.1.3-7. Off-Duty Operations

ACTIVITY	SPACE STATION ASTRONAUT PARTICIPATION	DATA RATES INVOLVED
A) RECREATION	ASTRONAUT USING LIBRARY, TV, VIDEO GAMES	LIBRARY - 2400 BIT/SEC TV - 6 MEGAHERTZ CRT - 9600 BIT/SEC

C) All medical evaluations should be done by science officer, and at the same time (for scheduling ease).

D) 8 hour sleep periods.

E) 12 hour work periods.

The table numbers referenced on Figure 2.1.3-1 correspond to the general areas of crew activities identified in Section 2.1.3.1.1.

2.1.3.2 DMS Interfaces with Space Station Subsystems

A second analysis was performed for the purpose of deriving the functional interfaces between the DMS and the following Space Station Subsystems.

1. Environmental Control and Life Support Subsystem (ECLSS) - Table 2.1.3-8.
2. Electrical Power Subsystem (EPS) - Table 2.1.3-9.
3. Guidance Navigation and Control Subsystem (GNCS) - Table 2.1.3-10.
4. Thermal Control Subsystem (TCS) - Table 2.1.3-11.
5. Communications Subsystem (COMM) - Table 2.1.3-12.
6. Radar Subsystem - Table 2.1.3-13.
7. Docking/Berthing Subsystem (DBS) - Table 2.1.3-14.
8. Remote Manipulator Subsystem (RMS) - Table 2.1.3-15.
9. Extra-Vehicular Activity Subsystem (EVA) - Table 2.1.3-16.
10. Facility Support Subsystem (FSS) - Table 2.1.3-17.
11. Safety Subsystem (SS) - Table 2.1.3-18.
12. Structural Subsystem (STRUC) - Table 2.1.3-19.
13. Mission Interface Subsystem (MIS) - Table 2.1.3-20.

Each of the tables identified above was constructed using the following acronyms.

1. Standard Process I/F Control - SPI(C)
2. Standard Process I/F Monitor - SPI(M)

Table 2.1.3-8. DMS/ECLSS Interfaces

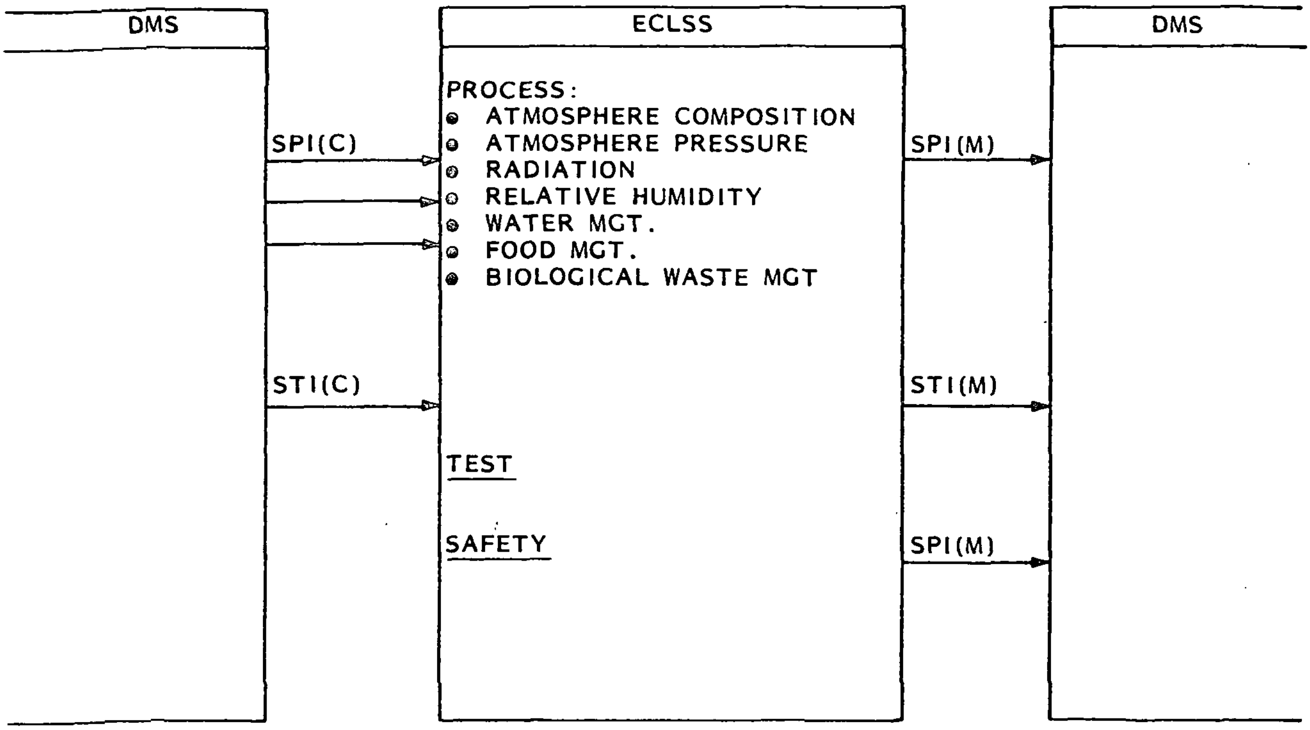
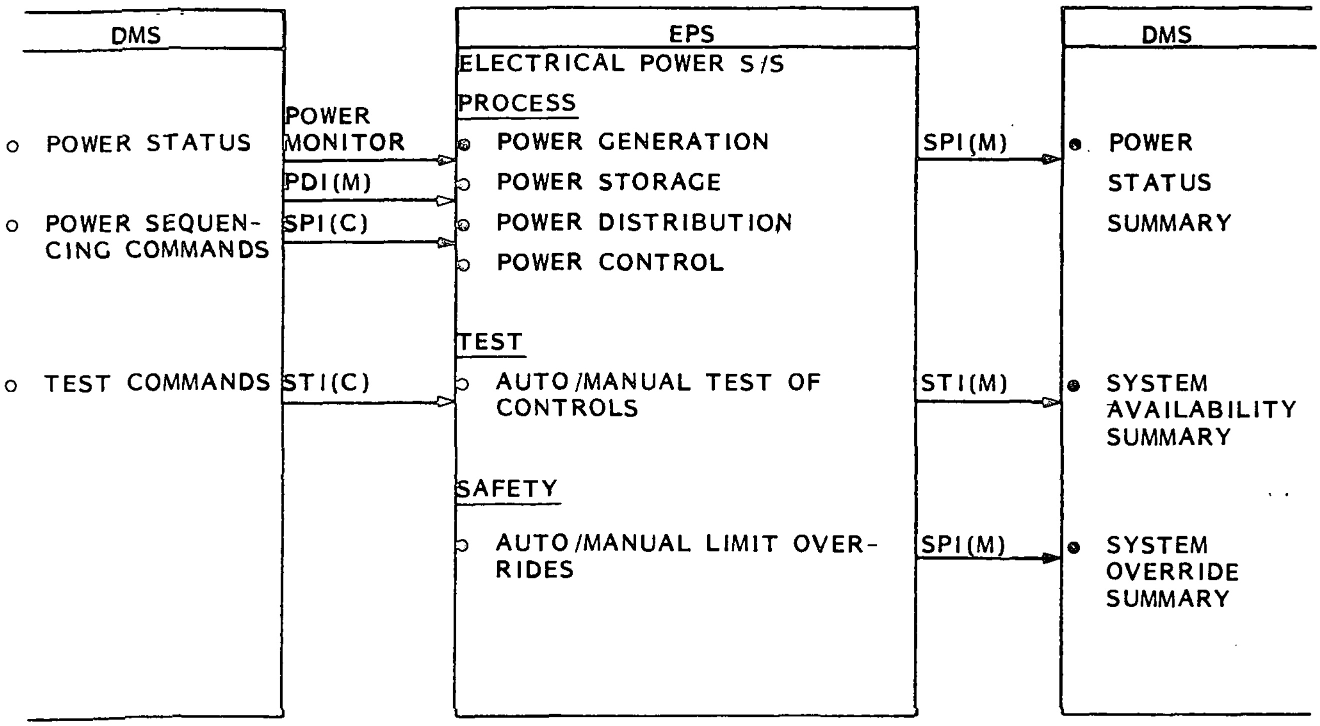


Table 2.1.3-9. DMS/EPS Interfaces



WPC-0352M-52M

Table 2.1.3-10. DMS/GNCS Interfaces

DMS		GNCS		DMS
• ORBIT DETERMINATION CALCULATIONS	SPI(C) →	GUIDANCE NAVIGATION & CONTROL S/S PROCESS • ATTITUDE CONTROL • ORBIT ADJUST • PROPULSION	SPI(M) →	• GNCS STATUS SUMMARY
• TEST COMMANDS	STI(C) →	TEST • AUTO/MANUAL TEST OF PROCESS	STI(M) →	• SYS. AVAIL. SUMMARY
		SAFETY • AUTO/MANUAL LIMIT OVERRIDES	SPI(M) →	• SYS. OVERRIDE SUMMARY

Table 2.1.3-11. DMS/TCS Interfaces

DMS		TCS		DMS
• TEMPERATURE STATUS • MISSION SPECIFIC TEMP. COMMANDS	SPI(C) →	THERMAL CONTROL SYSTEM PROCESS • ACTIVE SPACE STATION TEMPERATURE CONTROL • MONITOR TEMPERATURES	SPI(M) →	• TEMPERATURE SUMMARY
• TEST COMMANDS	STI(C) →	TEST AND MONITOR • AUTO/MANUAL TEST OF CONTROLS	STI(M) →	• SYSTEM AVAILABILITY SUMMARY
		SAFETY • AUTO/MANUAL LIMIT OVERRIDES	SPI(M) →	• OVERRIDE SUMMARY

Table 2.1.3-12. DMS/COMM Interfaces

DMS		COMM		DMS
o CCTV POINTING o ORBIT POSITION DATA	SPI(C) →	COMMUNICATION S/S PROCESS: • EXTERNAL COMM - ANTENNA POINTING	SPI(M) →	• LINK STATUS • COMM SAFETY STATUS
o COMM BUFFER	SPI(C) →			
o ALARM DET	SPI(C) →	• INTERNAL - INTERCOM - CCTV (INT. & EXT) - ALARMING	SPI(M) →	• COMM BUFFER • CCTV IMAGE ARCHIVE
o GROUP TESTING/REPORT CMDS	STI(C) →	TEST • COMM S/S TESTING	STI(M) →	• COMM AVAILABILITY STATUS
		SAFETY • LINK STATUS		

Table 2.1.3-13. DMS/Radar Interfaces

DMS		RADAR		DMS
o RADAR POINTING DETERMINATION o CONFIGURATION COMMANDS	SPI(C) →	RADAR S/S PROCESS • RADAR DRIVE - CONTINUOUS SWEEP - TARGET POINTING	SPI(M) →	• POINTING DATA
o GROUP TEST/REPORT COMMANDS	SPI(C) →	TEST o RADAR S/S TESTING	STI(M) →	• TEST STATUS
		SAFETY o COLLISION AVOIDANCE/ALARMING		

Table 2.1.3-14. DMS/DBS Interfaces

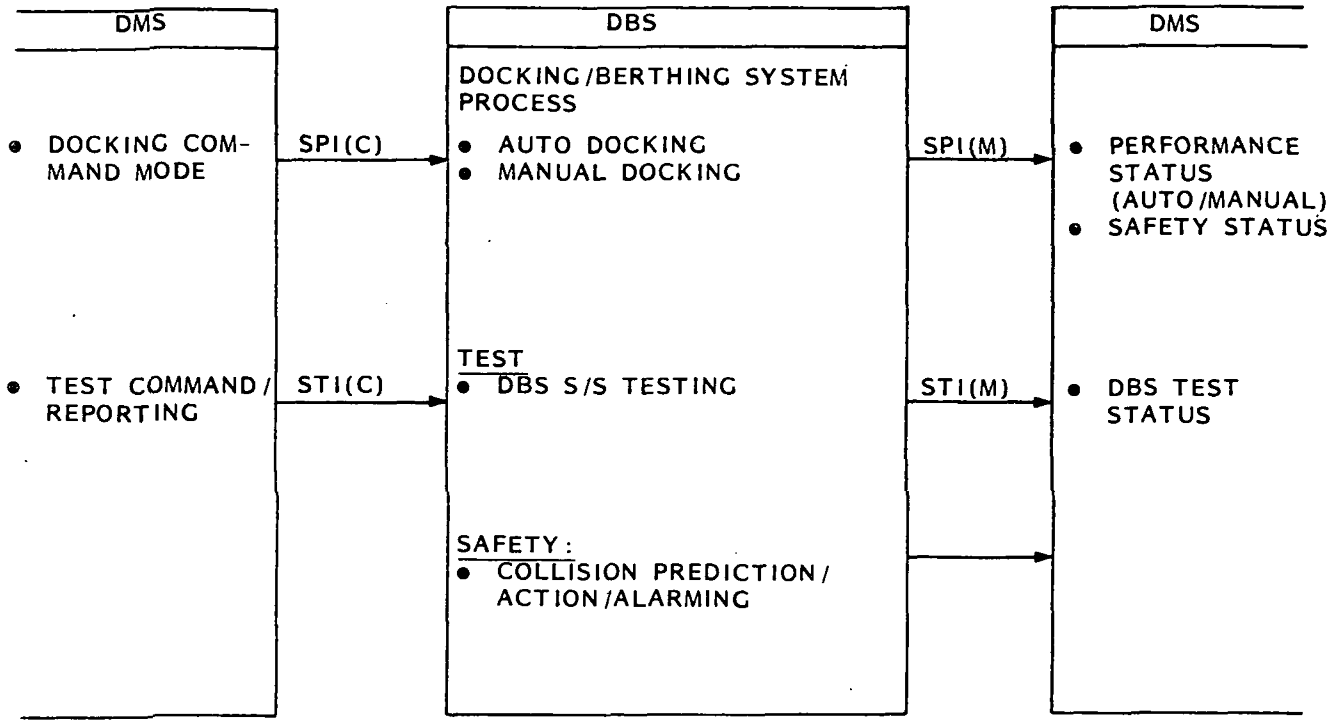


Table 2.1.3-15. DMS/RMS Interfaces

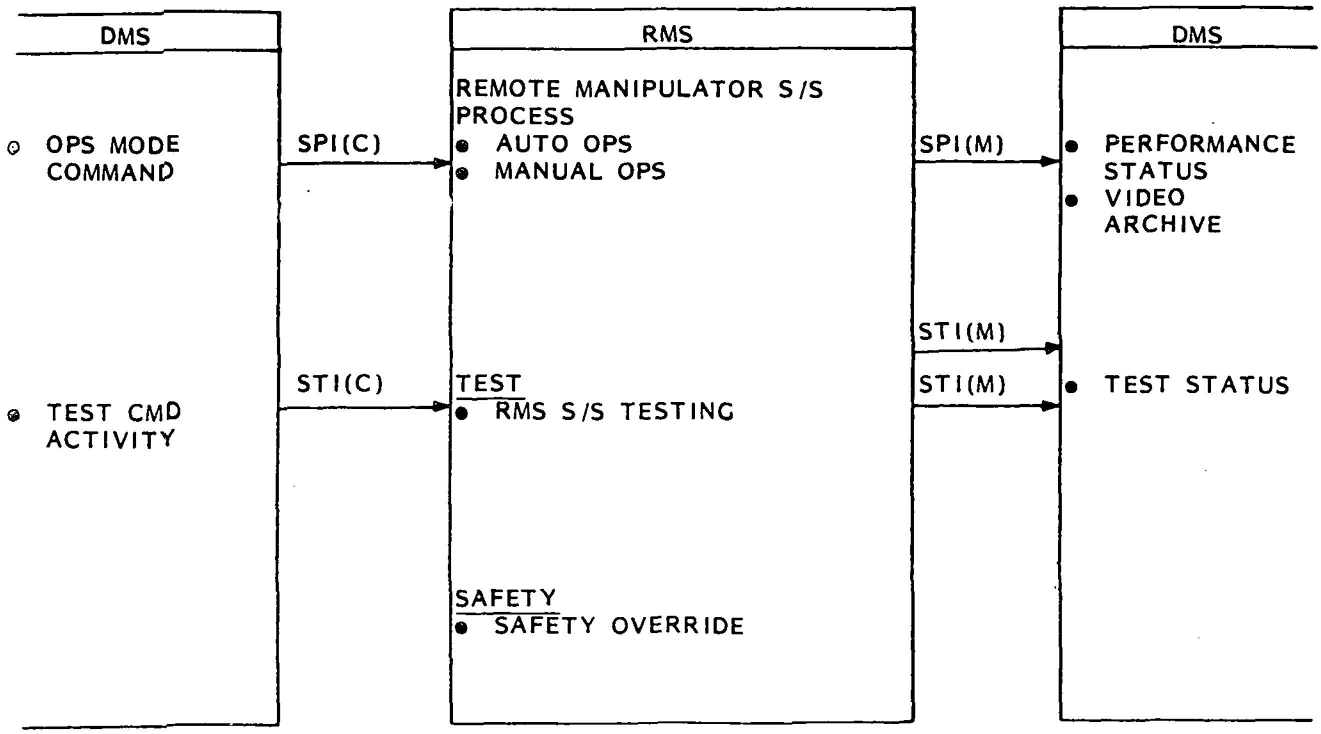


Table 2.1.3-16. DMS/EVA Interfaces

DMS		EVA		DMS
o EXTERNAL MODE DETERMINATION/ CMDS	SPI(C) →	EXTRA VEHICULAR ACTIVITY S/S PROCESS • EXTERNAL OPS	SPI(M) →	• PERFORMANCE STATUS • VIDEO ARCHIVE
o TEST CMD/ REPORT	STI(C) →	TEST • EVA S/S TESTING	STI(M) →	• TEST STATUSING
		SAFETY: • EVA HAZARD/ALARMING • HAZARD DETERMINATION/ ALARMING		

Table 2.1.3-17. DMS/FSS Interfaces

DMS		FSS		DMS
o STATION SYSTEMS LEVELS STATUS	SPI(C) →	FACILITY SUPPORT S/S PROCESS • INVENTORY CONTROL • INVENTORY ORDERING • INVENTORY ISSUING	→	• INVENTORY STATUS • SAFETY STATUS
o TEST COMMAND/ REPORT	STI(C) →	TEST: • FSS S/S TESTING	→	• TESTING STATUSING
		SAFETY: • TBD		

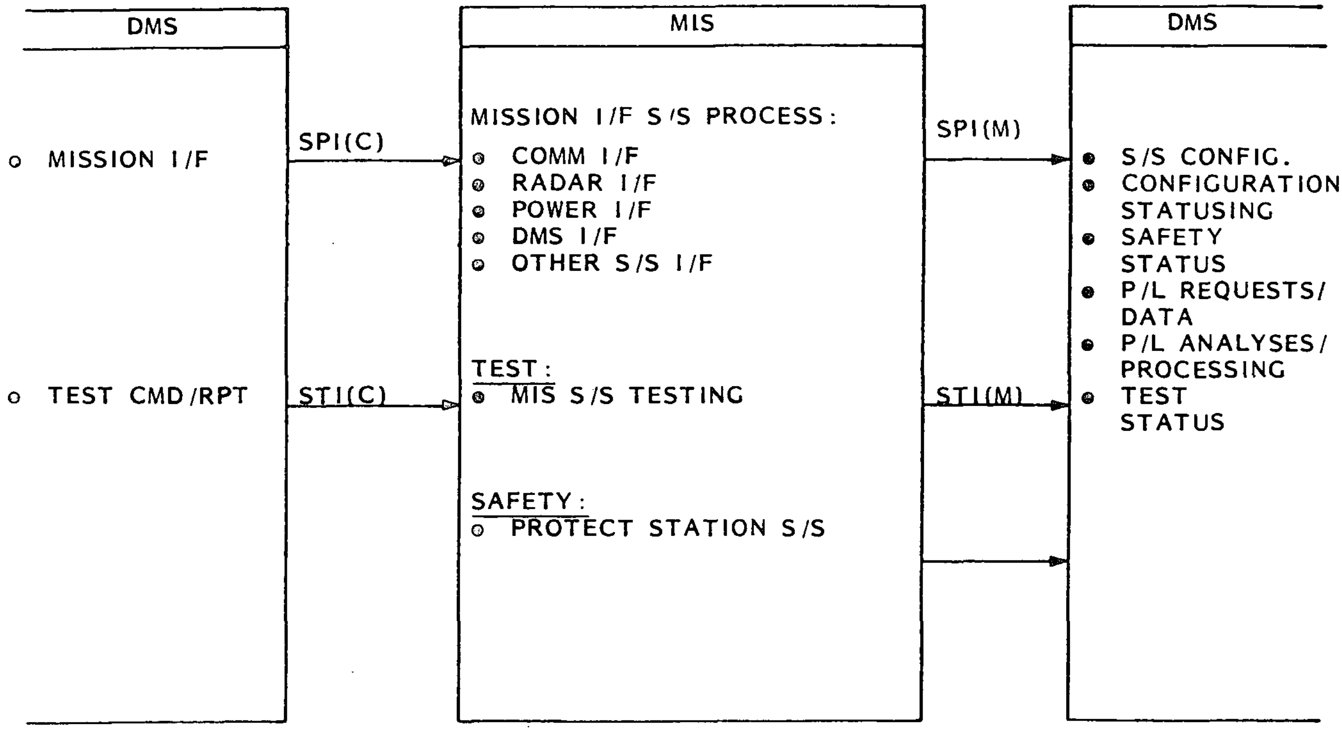
Table 2.1.3-18. DMS/SS Interfaces

DMS		SS		DMS
• INTEGRATED SAFETY REPORT	SPI(C) →	SAFETY S/S PROCESS: • CHECK DMS AGAINST S/S REPORTS	SPI(M) →	• ALL PROCESSES SAFETY CONCUR. • SAFETY S/S STATUS • DMS PROCESS COMMANDS • STATUS STOR-AGE • TEST STATUS
• TEST COM-MAND/REPORT	STI(C) →	TEST • SAFETY S/S TESTING	STI(M) → STI(C) →	
	SSI(C) →	SAFETY: • S/S OVERLAY	SSI(C) → SSI(M) →	• DMS SAFETY COMMANDS • SAFETY S/S REPORTS

Table 2.1.3-19. DMS/Structure Interfaces

DMS		STRUC		DMS
• OPS MODE CMDS	SPI(C) →	STRUCTURAL S/S PROCESS: • SERVO CONTROLS ON STRUCTURAL MEMBERS, DOORS, LOCKS • MONITOR STRUCTURE INTEGRITY	SPI(M) →	• STRUCTURE STATUS
• TEST CMD/ REPORT	STI(C) →	TEST: • STRUC S/S TESTING	STI(M) →	• TEST STATUS
		SAFETY: • LIMIT DETECTION & SAFING	→	

Table 2.1.3-20. DMS/Mission Interfaces



3. Standard Test I/F Control - STI(C)
4. Standard Test I/F Monitor - STI(M)
5. Standard Safety I/F Control 0 SSI(C)
6. Standard Safety I/F Monitor - SSI(M)

2.1.3.3 Command/Telemetry Interfaces

Finally, we assessed the command and telemetry interfaces with the various subsystems. Specifically, we addressed:

1. DMS functional commanding to other subsystems.
2. DMS command rates associated with the DMS command functions.
3. DMS command requirements.
4. DMS functional telemetry monitoring of the other subsystems.
5. DMS telemetry rates.
6. DMS telemetry requirements.

The results of this analysis are summarized in Table 2.1.3-21.

It should be noted that the command and telemetry rates are only estimates based upon assumptions of the sizes and capabilities of the generalized Space Station subsystems.

Concerning duty cycles, those DMS functions which are primarily on auto-control (with periodic crew commanding/monitoring) will probably have near-continuous duty cycles, while those DMS functions which are primarily manually commanded/monitored (such as docking and RMS subsystems) will likely have duty cycles which are dependent upon mission-specific requirements.

2.1.4 AUTONOMY ANALYSIS

The functional requirements analysis performed in Section 2.1.2 identified the major functions necessary for support of a manned space station and broke them down to first level subfunctions. Each first level subfunction identified for the Space Station Program has been previously allocated for residence either on the ground or on-board except for those cases in which the function is shared.

Table 2.1.3-21. Command/Telemetry Interfaces

SPACE STATION SUBSYSTEM	FUNCTIONS PERFORMED BY EACH SUBSYSTEM	DMS COMMANDING FUNCTIONS TO EACH SUBSYSTEM	DMS COMMAND RATES	DMS COMMAND REQUIREMENTS	DMS TELEMETRY MONITORING FUNCTIONS FROM EACH SUBSYSTEM	DMS TELEMETRY RATES	DMS TELEMETRY REQUIREMENTS
EPS	• POWER GENERATION • POWER STORAGE • POWER DISTRIBUTION AND CONTROL	• POWER SEQUENCING COMMANDS o TEST COMMANDS	0.01 KB/S 0.01 KB/S	• PRIMARILY AUTO-CONTROL WITH PERIODIC CREW COMMANDING	• POWER STATUS SUMMARY • TEST STATUS	0.04 KB/S 0.04 KB/S	• PRIMARILY AUTO-MONITORING WITH PERIODIC CREW STATUS CHECKS
ECLS	o ENVIRONMENTAL MONITORING • ACTIVE ENVIRON. CONTROL • STORAGE, PREPARATION AND DISPOSAL OF BIO-CONSUMMABLES	o ECLS SEQUENCING COMMANDS • TEST COMMANDS	0.1 KB/S 0.1 KB/S	SAME AS ABOVE	• ECLS STATUS SUMMARY • TEST STATUS	0.2 KB/S 0.1 KB/S	SAME AS ABOVE
G N+C	o ORBIT POSITIONING (ADJUST) o COMMANDING OF PROPULSION SUBSYSTEM	• ORBIT DETERMINATION CALCULATIONS • TEST COMMANDS	5 KB/S 5 KB/S	SAME AS ABOVE	• GNC STATUS SUMMARY • TEST STATUS	45 KB/S 45 KB/S	SAME AS ABOVE
ATTITUDE CONTROL	o ATTITUDE CONTROL • COMMANDING OF PROPULSION SUBSYSTEM	• ATTITUDE CONTROL SEQUENCING COMMANDS o TEST COMMANDS	1 KB/S 1 KB/S	SAME AS ABOVE	• ACS STATUS SUMMARY • TEST STATUS	3 KB/S 3 KB/S	SAME AS ABOVE
PROPULSION	o CONTROL OF ORBIT ADJUST AND ATTITUDE CONTROL THRUSTERS	o THRUSTER SEQUENCING COMMANDS o TEST COMMANDS	0.2 KB/S 0.2 KB/S	SAME AS ABOVE	• PROP S/S STATUS SUMMARY o TEST STATUS	0.2 KB/S 0.3 KB/S	SAME AS ABOVE
THERMAL	o THERMAL MONITORING o ACTIVE THERMAL CONTROL	o TEMPERATURE COMMANDS o TEST COMMANDS	0.2 KB/S 0.2 KB/S	SAME AS ABOVE	• TEMPERATURE STATUS SUMMARY • TEST STATUS	0.8 KB/S 0.8 KB/S	SAME AS ABOVE
RADAR	o CONTINUOUS WARNING SWEEP o TARGET TRACKING	o RADAR SEQUENCING COMMANDS o TEST COMMANDS	0.2 KB/S 0.2 KB/S	SAME AS ABOVE	• RADAR STATUS SUMMARY • TEST STATUS	0.3 KB/S 0.3 KB/S	SAME AS ABOVE
DOCKING	o SPACECRAFT CAPTURE AND LATCHING o AIRLOCK PREPARATION	o DOCKING MODE COMMANDING o TEST COMMANDS	0.2 KB/S 0.2 KB/S	• PRIMARILY MANUAL CONTROL (WITH AUTO-BACKUP)	o DOCKING S/S STATUS SUMMARY • TEST STATUS	0.3 KB/S 0.3 KB/S	• PRIMARILY MANUAL MONITORING (WITH AUTO-BACKUP)
RMS	o EXTERNAL, MECHANICAL SUPPORT FOR MANIPULATIVE TASKS	o OPERATIONAL MODE COMMANDING o TEST COMMANDS	0.2 KB/S 0.2 KB/S	• PRIMARILY MANUAL CONTROL (WITH AUTO-BACKUP)	• RMS S/S STATUS SUMMARY • TEST STATUS	0.3 KB/S 0.3 KB/S	• PRIMARILY MANUAL MONITORING (WITH AUTO-BACKUP)
STRUCTURAL	o STRUCTURAL CONFIGURING PER OPS/MISSION RQMT'S	o STRUCTURAL CONFIGURATION COMMANDING o TEST COMMANDS	0.01 KB/S 0.01 KB/S	• PRIMARILY AUTO-CONTROL WITH PERIODIC CREW COMMANDING	• STRUCTURAL S/S STATUS SUMMARY • TEST STATUS	0.04 KB/S 0.04 KB/S	• PRIMARILY AUTO-MONITORING WITH PERIODIC CREW STATUS CHECKS
COMM	o INTERNAL COMMUNICATION o EXTERNAL COMMUNICATION	o COMM CONFIGURATION COMMANDING (INCLUDING ALARMS) o TEST COMMANDS	0.1 KB/S 0.1 KB/S	• PRIMARILY AUTO-CONTROL WITH PERIODIC CREW COMMANDING	o COMM S/S STATUS SUMMARY o TEST STATUS	0.5 KB/S 0.5 KB/S	• PRIMARILY AUT MONITORING WITH PERIODIC CREW STATUS CHECKS
* DMS	o DATA MANAGEMENT SUPPORT	o DMS SELF-TEST CMD	0.1 KB/S	• PRIMARILY AUTO-CONTROL (CREW CMD)	• SELF-TEST STATUS	0.1 KB/S	• PRIMARILY AUTO-MONITORING (PERIODIC CREW STATUS CHECKS)
			TOTAL 14.5 KB/S			TOTAL 101.5 KB/S	

Twenty-one of these (84) functions were soft allocations, insofar as they represented judgemental allocations based primarily on the objectives of, autonomy, cost and/or health and safety of the crew and the station. These functions were re-evaluated in weighted trade-off fashion by considering all applicable criteria, such as autonomy, health and safety of the crew, crew capability, crew load, cost reliability, etc. Weights were assigned to each criteria based on the criticality of the criteria with respect to the overall mission objectives, as related to that function. The algorithm was designed to be very flexible and essentially all the computations are automated for ease in modification.

It must be noted that for the purpose of this analysis the assumption was made to treat all the tradeable functions as if the alternative selection was available for all the applicable missions and ignore the fact that some of the missions will be performed on Free Flyers.

2.1.4.1 Tradeable Functions

The following functions have been selected for re-evaluation based on their characteristics. A detailed analysis of each of these functions is contained in Appendix E. Next to each of the functions are found the pre-allocation code; the second letter (H, M or L) refers to the criticality code.

Mission Oriented Functions

- Mission Operations Scheduling — OB, L
- Mission Subsystem Commanding — OB, M
- Mission Operation — OB, L
- Short-Term Mission Performance Evaluation — OB, M
- Long-Term Trend Analysis — G, L
- Mission Data Pre-Processing — G, L
- Data Analysis Space Borne Experiments — G, L

Support Operations Function

- Hardware Fault Detection — OB, H
- Hardware Corrective Action — OB, H

o	Software Fault Detection	OB, H
o	Subsystem Support Logistics	OB, L
o	Support Subsystem C&C S/S Commanding	OB, H
o	Support Subsystem C&C Procedure Display/Processing	OB, H
o	Mission Subsystem C&C Procedure Display/Processing	O , M
o	Support Subsystem Trend Analysis	G, L
o	Long-Term Sys. Performance Evaluation	G, M
o	Short-Term Sys. Performance Evaluation	OB, H
o	Long-Term Mission Performance Evaluation	G, L

2.1.4.2 Allocation Criteria

The definitions and rationale for the principal allocation criteria are as follows:

Autonomy is the ability of the space station to function without ground support. Autonomy is only of value if its absence hampers or weakens the capability to perform the mission of the station.

Health and Safety of the crew and the station concerns itself with maintaining the well-being and prevention of hazards to the crew and the station.

Cost - Refers to the overall cost in personnel and materials required to develop and operate those portions of hardware and software required to perform each function as specified.

Reliability/Availability - Refers to the amount of time that a function, in the form of the hardware and software required, is available for its intended use.

Communication Load - Insofar as the limitations in accessibility to the communication links and the volume of data that the links can handle.

Back-Ups are necessary for many functions, if the primary allocation is made for onboard residence.

2.1.4.3 Cost Criteria

There are two principal components of cost, the development cost and the cost of operations. The first covers all the elements of cost from inception of the system, through design, fabrication, coding, integration and testing and includes all administrative and facilities cost associated with development and implementation to a level that is acceptable for operation. The cost of Operations herein, contains all the programmatic, technical, operational materials and maintenance costs associated with the day-by-day operation of that portion of the system necessary to perform the function.

Given that the (ten) mission oriented functions listed in 2.1.4.1 above are similar to functions performed by NASA's Landsat-4 Ground Segment, we elected to use the detailed cost records from the Landsat-4 Program as the baseline reference cost/function. These records represent a meaningful baseline from which to extract the cost elements that make up the cost components for each of the functions.

The onboard manpower cost of Operations was based on the figure of $10.2M per astronaut-year.

Determination of the cost elements for each of the functions was achieved by allocating a weighted fraction of the cost elements associated with the implementation and operation of the applicable systems and Landsat-4 Ground Segment facilities. These weighted cost allocations were determined at the WBS cost element level. Table 2.1.4-1 lists these Landsat-4 Ground Segment costs per function for each of the two cost components, and the total cost (1983 dollars) based on 15 years of Operations and 5% inflation rate.

2.1.4.3.1 Cost Model

Figure 2.1.4-1 outlines the methodology and Fig. 2.1.4-1A indicates the algorithm used to derive the costs of performing each of the tradeable functions either on the ground or onboard the station.

2.1.4.3.2 Explanation Of The Model

A) SSGS COST/FUNCTION - MISSION

The cost per function (i) for each Mission (j) incurred when the function is performed by the SS GS is obtained by multiplying each LS4 (MSS) GS cost component times the applicable Complexity Cost Factor, one for development

Table 2.1.4-1. LS4 (MSS) GS Cost/Function

COST ELEMENT MISSION ORIENTED TRADEABLE FUNCTION	DEVELOPMENT COST $ (M) GCF = 2	OPERATIONS COST $ (M) GCF = 2	OPERATIONS COST $ (M) GCF = 5	TOTAL COST, 15 YEARS $ (M) GCF 2	 3
MISSION OPERATIONS SCHEDULING	2.67	0.29	0.65	5.15	8.23
MISSION OPERATIONS	4.84	0.44	0.83	8.61	11.94
MISSION S/S COMMANDING	4.84	0.44	0.83	8.61	11.94
LONG-TERM TREND ANALYSIS	0.25	0.29	0.65	2.73	5.81
SHORT-TERM MISSION PERFORMANCE EVALUATION	0.25	0.29	0.65	2.73	5.81
MISSION DATA PROCESSING	18.6	1.18	2.75	28.7	42.14
MISSION DATA PREPROCESSING	4.8	0.27	0.58	7.11	9.76
ANALYSIS OF DATA - SPACE BORNE EXPERIMENT	0.5	0.10	0.20	1.36	2.21

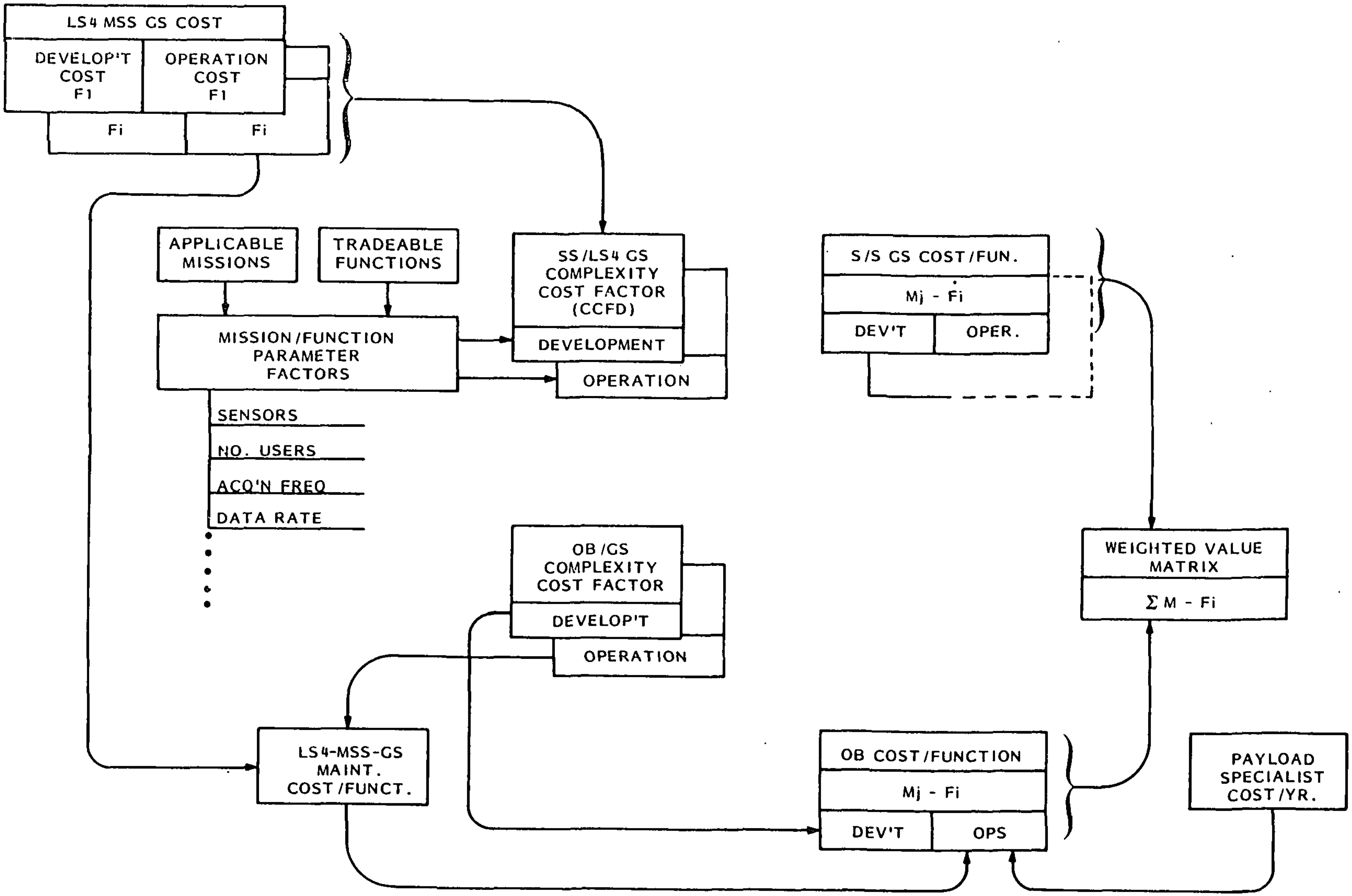


Figure 2.1.4-1. Cost Model Methodology

A) SPACE STATION GS COST MODEL - FUNCTION MISSION

CONSTANTS

CD4(i,j)	LS4 Development Cost - (F)unction i, (M)mission j
CO4 (i, j)	LS4 Operations Cost - Fi, Mj
CCFD(i,j)	SS GS/LS4 GS Development Complex Cost Factor, Fi, Mj
GCFD	Government and Facility Cost Factor for Development
CCFO(i,j)	SS GS/LS4 GS OP's Complexity Cost Factor, Fi, Mj
GCFO	Government and Facility Cost Factor for Development
PVF VARIABLES	Present Value Factor (5%, 15 yrs = 10.38)

VARIABLES

CT(i,j)	Total Cost (15 yrs) Fi, Mj
CT(i)	Total Cost (15 yrs) Fi
CT(i,j)	(CD4(i,j) *CCFD (k,j) *GCFD) + (CO(i,j) *CCFO(i,j) *GCFO *PVF)
CT(i)	CT(i,j)

B) SPACE STATION ONBOARD (OB) COST MODEL/(F)UNCTION - (M)ISSION CONSTANTS (Same as GS Cost Model Plus)

CMS	Cost of Mission Specialist/ANUM
CFMS(i,j)	Mission Specialist Cost Allocation Factor, Fi, Mj
CM4(i,j)	LS4 Maintenance Cost, Fi, Mj
CCFD(i,j)	O-B/GS Development Complexity Cost Factor Fi, Mj
CCFM (i,j)	O-B/GS Maintenance Complexity Cost Factor Fi, Mj

VARIABLES

CT'(i,j)	O-B Total Cost (15 yrs), Fi, Mj
CT'(i,j)	CD4(i,j) * CCFD(i,j) * GCFD * CCFD' (i,j) + ((CMS*CFMS(8,j)) + (CM4(8,j) * CCFO(i,j) *CCFM(i,j))) *PVF
CT'(i)	CT'(i,j)

Figure 2.1.4-1A Cost Model Algorithm

(CCFD) and another for operations (CCFO), then multiplying each SSGS cost component times the GCF. The total cost requires the additional computation of the present cost based on the base year cost of operations, the number of years of operations and the average inflation rate.

The SS/LS4 Complexity Cost Factor

The Complexity Cost Factors were derived through simple proportionalities between the projected demand for resources created by the function in both the space station and LS4. These proportionalities were based on the characteristic driving parameters for each of the development and operations cost components.

As shown in Table 2.1.4-2, the first ten parameters are grouped into mission operations oriented functions, mission performance evaluation functions and mission data operations related functions.

The mission operations oriented functions development costs are driven by the number of users, the number of sensors and the required frequency of acquisition. Their cost for operations is only driven by the last two parameters. For this reason the Complexity Cost Factor for development (CCFD) is modeled by:

$$
\begin{aligned}
CCFD &= (RU * .33 + RS * .33 + RA * .33) \\
&= .33 * (RU + RS + RA)
\end{aligned}
$$

where the ratios (R) apply to those of the users (RU) and the number of sensors (RS) and frequency of acquisition. Conversely, the Complexity Cost Factor (CCFO) for operations is:

$$CCFO = .5\ (RS + RA)$$

In the same fashion, CCFD and CCFO for performance evaluation oriented functions is obtained from:

$$CCFD = CCFO = RS$$

The last group of functions, related to the collection processing and analysis of mission data, are modelled by

$$CCFD = CCFO = (RR * RD)$$

Table 2.1.4-2. Space Station/LS4 GS Cost Driving Parameters (Mission Operations)

Mission Oriented Tradeable Function	Development Driving Parameters	Operations Driving Parameters
Mission Operations Scheduling	No. of Users No. Of Sensors Acq'n Frequency	No. of Sensors Acq'n Frequency
Mission S/S Commanding	No. of Users No. of Sensors Acq'n Frequency	No. of Sensors Acq'n Frequency
Mission Operations	No. of Users No. of Sensors Acq'n Frequency	No. of Sensors Acq'n Frequency
Short-Term Mission Performance Evaluation	No. of Sensors	No. of Sensors
Long-Term Trend Analysis	No. of Sensors	No. of Sensors
Mission Data Preprocessing	Data Rate Duration	Data Rate Duration
Mission Data Processing	Data Rate Duration	Data Rate Duration
Data Analysis - Space Borne Experiments	Data Rate Duration	Data Rate Duration

where RR and RD being the mission data rate and duration of acquisition respectively.

The Support Operations functions shown in Table 2.1.4-3 are driven by simpler ratios, as shown in that table.

B) S/S ONBOARD COST/FUNCTION

The cost/function incurred when the function is performed more autonomously in orbit was developed principally from the cost to perform said function on the ground times an additional component to the complexity cost factor to account for the inherent restrictions of orbital operations, such as packaging, environment, weight, power and manpower.

Table 2.1.4-3. Space Station/LS4 GS Cost Driving Parameters (Support Operations)

Support Operations Tradeable Functions	Development Driving Parameters	Operations Driving Parameters
H/W Fault Detection	Fault Detection Radio	H/W Qty Ratio
H/W Corrective Action	Corrective Action Ratio	H/W Qty Ratio
S/W Fault Detection	Lines of Code Ratio	Lines of Code Ratio
S/S Support Logistics	H/W Qty Ratio Lines of Code Ratio	H/W Qty Ratio Lines of Code Ratio
Support S/S C&C Commanding	S/S Numbers Ratio	S/S Numbers Ratio
S/S C&C Procedure Display/ Processing	S/S Numbers Ratio	S/S Numbers Ratio
Mission C&C Processing Display/Processing	Composite Missions Ratio	Composite Missions Ratio
S/S Trend Analysis	S/S Numbers Ratio	S/S Numbers Ratio
Long-Term Sys PE	Sys Numbers Ratio	Sys Numbers Ratio
Short-Term Sys PE	Sys Numbers Ratio	Sys Numbers Ratio
Long-Term Mission PE	Composite Missions Ratio	Composite Mission Ratio

Development Cost/(In-Orbit Function)

The development cost per function was obtained by multiplying the GS development cost per function times an Orbit/Ground Complexity Cost Factor. General Electric Company's experience in the implementation of current programs involving orbital data management systems indicates relative cost factors of one order of magnitude (10x) between orbital and ground system for major hardware items and for the software. A detailed evaluation of individual development labor and material cost elements on their merits yielded an average CCFD equal to 5 for these elements during development.

Operations Cost/(In Orbit) Function

The two principal cost components that make up the cost of operations are the maintenance cost and the Payload Specialist.

The maintenance cost was generated using the hardware and the software maintenance cost elements used in the calculation of the GS cost for Operations. These costs were multiplied by the orbital operations complexity cost factor of 10*CCFO, as shown in Table 2.1.4-4.

The Payload Specialist cost was generated by charging that portion of the annual cost of an operational astronaut that can be applied to the performance of the function. This cost includes all cost elements such as training, transportation to and from orbit, consumables and general mission support.

It is worthwhile noting that the fraction of an astronauts cost charged to the function bears no relation to the number of astronauts currently being projected to man the station and the number of functions to be performed onboard the station.

2.1.4.3.2 Space Station Tradeable Functions Costs Matrix

Table 2.1.4-4 lists all cost components projected for the costs of developing and operating the twenty-one functions in the Ground Segment (GS) or onboard (OB) the station (SS). The table lists all constants, independent variables and derived variables that make up the final costs of each of six (6) SS groups of mission and for the Support Operations functions. These missions fit into the SS facilities as follows:

	SS Mission	Facility(ies)
1.	Earth Resources	Observatory and Free flyers
2.	Materials Processing	Industrial and Test
3.	Life Sciences	Habitat
4.	Global Environment	Observatory and Free Flyers
5.	Astrophysics	Free Flyers and Observatory
6.	Solar, Terrestrial and Planetary	Free Flyers and Observatory

2.1.4.3.3 Allocation Matrix

The tradeable functions listed above were examined below for their comparative allocation value in either of the two options available, Ground Segment or Onboard residence. The comparative allocation value is achieved by assigning weight factors (W) to each of the relevant criteria and then

Table 2.1.4-4. Tradeable Functions Costs Matrix (in attached envelope) distributing these weights between the selection of GS residence and SS residence via selection value distribution factors. These selection value factors (V) describe in decimal percentage form, the relative effectiveness with which each criteria is met with each of the two selections.

A) THE DISTRIBUTED WEIGHT VALUE

The distributed weight value (WV) for each criteria is therefore the product of the weight (W) allocated for that criteria times the selection value factor, V, for the value of the GS residence selection and V' for the OB selection. It follows that the sum of WV and WV' must be equal W, in which case V' = 1-V.

B) THE SELECTION VALUE FACTOR

The selection value factors V, V', serve to describe in decimal percentage form the relative effectiveness with which each criterion is met with each of the two residence selections for that function. It follows then that in some cases the criteria for the particular function is only met with one of the two selections, in which case the selection value factor will be one (1.0) for the correct selection, and zero (0.0) for the incorrect selection. This is why V is always zero for the autonomy criteria, under the GS selection for any tradeable function, and V' always zero for the processing load criteria under the OB selection for any tradeable function.

2.1.4.3.4 Function Allocation Summary

Table 2.1.4-5 summarizes the OB/GS weighted value ratios derived with the allocation matrix algorithm described in Paragraph 2.1.4.3.3 above. Tables 2.1.4-6 through 2.1.4-13 show the weights and selection value factors assigned to the applicable criteria for each of the functions. These tables affirm most of the previously defined ground versus on-board allocations. Eight of the pre-allocations were strongly confirmed, while eight wre too close to determine. Only five pre-allocations were revised relating to performance evaluation and mission data pre-processing. Since the distinction between mission data pre-processing and processing was unclear, and since performance evaluation is not a design driver, these reversals do not significantly affect the other DMS analyses.

Table 2.1.4-5. Space Station Function Summary Value Allocation

Mission Functions	Pre-Allocation (Criticality)	Weighted Value Ratio	Remarks
Mission Ops Scheduling	OB(L)	52/48	Maintain Pre-allocation
Mission Subsys Commanding	OB(M)	50/50	Maintain Pre-allocation
Mission Operations	OB(L)	51/49	Maintain Pre-allocation
Short-Term Mission PE	OB(M)	69/31	Confirm Pre-Allocation
Long-Term Mission Trend Analysis	G(L)	69/31	Reverse Pre-Allocation
Mission Data Collection	OB(L)	32/68	Reverse Pre-Allocation
Mission Data Preprocessing	OB(L)	34/66	Reverse Pre-Allocation
Mission Data Processing	G(L)	37/63	Confirm Pre-Allocation
Data Recording - SS Experiments	OB(L)	27/73	Reverse Pre-Allocation
Data Analysis - SS Experiments	G(L)	22/79	Confirm Pre-Allocation
Support Operations			
H/W Fault Detection	OB(H)	63/37	Confirm Pre-Allocation
H/W Corrective Action	OB(H)	63/37	Confirm Pre-Allocation
S/W Fault Detection	OB(H)	63/37	Confirm Pre-Allocation
S/S Support Logistics	OB(L)	58/42	Confirm Pre-Allocation
Support S/S C&C Commanding	OB(H)	48/52	Maintain Pre-Allocation
Support S/S C&C Procedure Display/Processing	OB(H)	48/52	Maintain Pre-Allocation
Mission C&C Procedure Display/Processing	OB(M)	50/50	Maintain Pre-Allocation
S/S Trend Analysis	G(L)	53/47	Maintain Pre-Allocation
L/T Sys Performance Evaluation	G(M)	52/48	Maintain Pre-Allocation
S/T Sys Performance Evaluation	OB(H)	50/50	Confirm Pre-Allocation
L/T Mission Performance Evaluation	G(L)	40/60	Reverse Pre-Allocation

Table 2.1.4-6. Allocation Weighted Value Matrix (1)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
MISSION OPS SCHEDULING					
1.0 AUTONOMY	20	0.00	1.00	0.00	20.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	60	0.57	0.43	34.20	25.80
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
MISSION OPS SCHEDULING	-	-	-	48.20	51.80
MISSION S/S COMMANDING					
1.0 AUTONOMY	20	0.00	1.00	0.00	20.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	60	0.60	0.40	36.00	24.00
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
MISSION S/S COMMANDING	-	-	-	50.00	50.00
MISSION OPERATIONS					
1.0 AUTONOMY	20	0.00	1.00	0.00	20.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	60	0.59	0.41	35.40	24.60
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
MISSION OPERATIONS	-	-	-	49.40	50.60

Table 2.1.4-7. Allocation Weighted Value Matrix (2)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
S/T MISSION PERF. EVAL.					
1.0 AUTONOMY	20	0.00	1.00	0.00	20.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	60	0.28	0.72	16.80	43.20
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
S/T MISSION PERF. EVAL.	-	-	-	30.80	69.20
L/T TREND ANALYSIS					
1.0 AUTONOMY	20	0.00	1.00	0.00	20.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	60	0.28	0.72	16.80	43.20
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
L/T TREND ANALYSIS	-	-	-	30.80	69.20

Table 2.1.4-8. Allocation Weighted Value Matrix (3)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
MISSION DATA PRE-PROC.					
1.0 AUTONOMY	12	0.00	1.00	0.00	12.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	38	0.85	0.15	32.30	5.70
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	10	0.00	1.00	0.00	10.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	10	1.00	0.00	10.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	10	1.00	0.00	10.00	0.00
MISSION DATA PRE-PROC.	-	-	-	66.30	33.70
MISSION DATA PROCESSING					
1.0 AUTONOMY	12	0.00	1.00	0.00	12.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	38	0.76	0.24	28.88	9.12
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	10	0.00	1.00	0.00	10.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	10	1.00	0.00	10.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	10	1.00	0.00	10.00	0.00
MISSION DATA PROCESSING	-	-	-	62.88	37.12

Table 2.1.4-9. Allocation Weighted Value Matrix (4)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
DATA ANAL. S/B EXPERIMENTS					
1.0 AUTONOMY	15	0.00	1.00	0.00	15.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	45	0.98	0.02	44.10	0.90
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	10	1.00	0.00	10.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	10	1.00	0.00	10.00	0.00
DATA ANAL. S/B EXPERIMENTS	-	-	-	78.10	21.90
SUMMARY					
MISSION OPS SCHEDULING	-	-	-	48.20	51.80
MISSION S/S COMMANDING	-	-	-	50.00	50.00
MISSION OPERATIONS	-	-	-	49.40	50.60
S/T MISSION PERF. EVAL.	-	-	-	30.80	69.20
L/T TREND ANALYSIS	-	-	-	30.80	69.20
MISSION DATA PRE-PROC.	-	-	-	66.30	33.70
MISSION DATA PROCESSING	-	-	-	62.88	37.12
DATA ANAL. S/B EXPERIMENTS	-	-	-	78.10	21.90

Table 2.1.4-10. Allocation Weighted Value Matrix (5)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
H/W FAULT DETECTION					
1.0 AUTONOMY	15	0.00	1.00	0.00	15.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	10	1.00	0.00	10.00	0.00
5.0 COST	45	0.30	0.70	13.50	31.50
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	10	0.00	1.00	0.00	10.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
H/W FAULT DETECTION	-	-	-	37.50	62.50
H/W CORRECTIVE ACTION					
1.0 AUTONOMY	12	0.00	1.00	0.00	12.00
2.0 HEALTH & SAFETY	20	0.20	0.80	4.00	16.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	-	-	-	0.00	0.00
5.0 COST	38	0.34	0.66	12.92	25.08
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	10	0.60	0.40	6.00	4.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
H/W CORRECTIVE ACTION	-	-	-	36.92	63.08
S/W FAULT DETECTION					
1.0 AUTONOMY	7	0.00	1.00	0.00	7.00
2.0 HEALTH & SAFETY	20	0.20	0.80	4.00	16.00
3.0 CREW CAPABILITY	10	0.60	0.40	6.00	4.00
4.0 CREW LOAD	10	0.60	0.40	6.00	4.00
5.0 COST	23	0.31	0.69	7.13	15.87
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	10	0.00	1.00	0.00	10.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
S/W FAULT DETECTION	-	-	-	37.13	62.87

Table 2.1.4-11. Allocation Weighted Value Matrix (6)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
S/S SUPPORT LOGISTICS					
1.0 AUTONOMY	15	0.00	1.00	0.00	15.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	10	0.80	0.20	8.00	2.00
4.0 CREW LOAD	10	0.80	0.20	8.00	2.00
5.0 COST	45	0.27	0.73	12.15	32.85
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
S/S SUPPORT LOGISTICS	-	-	-	42.15	57.85
S/S C/C COMMANDING					
1.0 AUTONOMY	10	0.00	1.00	0.00	10.00
2.0 HEALTH & SAFETY	20	0.20	0.80	4.00	16.00
3.0 CREW CAPABILITY	10	0.60	0.40	6.00	4.00
4.0 CREW LOAD	10	0.60	0.40	6.00	4.00
5.0 COST	30	0.72	0.28	21.60	8.40
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
S/S C/C COMMANDING	-	-	-	51.60	48.40
S/S C/C DISP/PROC.					
1.0 AUTONOMY	15	0.00	1.00	0.00	15.00
2.0 HEALTH & SAFETY	10	0.20	0.80	2.00	8.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	10	0.60	0.40	6.00	4.00
5.0 COST	45	0.67	0.33	30.15	14.85
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
S/S C/C DISP/PROC.	-	-	-	52.15	47.85

Table 2.1.4-12. Allocation Weighted Value Matrix (7)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
MISSION C/C DISP/PROC.					
1.0 AUTONOMY	15	0.00	1.00	0.00	15.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	10	0.60	0.40	6.00	4.00
5.0 COST	45	0.67	0.33	30.15	14.85
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	10	0.00	1.00	0.00	10.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	-	-	-	0.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
MISSION C/C DISP/PROC.	-	-	-	50.15	49.85
S/S TREND ANALYSIS					
1.0 AUTONOMY	10	0.00	1.00	0.00	10.00
2.0 HEALTH & SAFETY	20	0.20	0.80	4.00	16.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	10	0.80	0.20	8.00	2.00
5.0 COST	30	0.36	0.64	10.80	19.20
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	10	1.00	0.00	10.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
S/S TREND ANALYSIS	-	-	-	46.80	53.20
L/T SYS PERF.EVAL.					
1.0 AUTONOMY	15	0.00	1.00	0.00	15.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	-	-	-	0.00	0.00
4.0 CREW LOAD	10	0.80	0.20	8.00	2.00
5.0 COST	45	0.36	0.64	16.20	28.80
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	10	1.00	0.00	10.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
L/T SYS PERF.EVAL.	-	-	-	48.20	51.80

Table 2.1.4-13. Allocation Weighted Value Matrix (8)

MISSION FUNCTION	ASSIGNED VALUES: ASSIGNED WEIGHT	ASSIGNED VALUES: ON GND VALUE	ASSIGNED VALUES: ON BRD VALUE	WEIGHTED VALUES: ON GND VALUE	WEIGHTED VALUES: ON BRD VALUE
S/T SYS PERF. EVAL.					
1.0 AUTONOMY	7	0.00	1.00	0.00	7.00
2.0 HEALTH & SAFETY	20	0.20	0.80	4.00	16.00
3.0 CREW CAPABILITY	10	0.60	0.40	6.00	4.00
4.0 CREW LOAD	10	0.80	0.20	8.00	2.00
5.0 COST	23	0.36	0.64	8.28	14.72
6.0 REL./AVAILABILITY	10	0.70	0.30	7.00	3.00
7.0 MAINTAINABILITY	10	0.70	0.30	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	10	1.00	0.00	10.00	0.00
11.0 USER ACCESS	-	-	-	0.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
S/T SYS PERF. EVAL.	-	-	-	50.28	49.72
L/T MISSION PERF.EVAL.					
1.0 AUTONOMY	10	0	1	0.00	10.00
2.0 HEALTH & SAFETY	-	-	-	0.00	0.00
3.0 CREW CAPABILITY	10	.6	.4	6.00	4.00
4.0 CREW LOAD	10	.8	.2	8.00	2.00
5.0 COST	30	.39	.61	11.70	18.30
6.0 REL./AVAILABILITY	10	.7	.3	7.00	3.00
7.0 MAINTAINABILITY	10	.7	.3	7.00	3.00
8.0 COMM. LOAD	-	-	-	0.00	0.00
9.0 TECHNICAL RISK	-	-	-	0.00	0.00
10.0 PROCESSING LOAD	10	1	0	10.00	0.00
11.0 USER ACCESS	10	1	0	10.00	0.00
12.0 CO-LOCATION	-	-	-	0.00	0.00
13.0 BACK-UPS	-	-	-	0.00	0.00
L/T MISSION PERF.EVAL.	-	-	-	59.70	40.30

SUMMARY					
H/W FAULT DETECTION	-	-	-	37.50	62.50
H/W CORRECTIVE ACTION	-	-	-	36.92	63.08
S/W FAULT DETECTION	-	-	-	37.13	62.87
S/S SUPPORT LOGISTICS	-	-	-	42.15	57.85
S/S C/C COMMANDING	-	-	-	51.60	48.40
S/S C/C DISP/PROC.	-	-	-	52.15	47.85
MISSION C/C DISP/PROC.	-	-	-	50.15	49.85
S/S TREND ANALYSIS	-	-	-	46.80	53.20
L/T SYS PERF.EVAL.	-	-	-	48.20	51.80
S/T SYS PERF. EVAL.	-	-	-	50.28	49.72
L/T MISSION PERF.EVAL.	-	-	-	59.70	40.30
TOTAL	-	-	-	512.58	587.42

In conclusion it must be noted that while the function resident allocation model used herein has some merit in describing relative cost values, there are additional long-term considerations within the growth capability of the station and the H/W and S/W growth potential, that need to be taken into account.

2.2 ARCHITECTURE

Based on the requirements derived in Section 2.1, studies were undertaken to develop the architectures for both the Data Management System and the Communications Systems. The following paragraphs address the studies performed and the conclusions reached.

2.2.1 DATA MANAGEMENT SYSTEM

Development of the DMS architecture must consider three major design factors: distributed processing, fault tolerance, and network topology. The following section presents a methodology for addressing these factors with respect to functional requirements, performance requirements, and other design goals. Also presented is a preliminary DMS architecture which was derived using this methodology.

2.2.1.1 Requirements

The DMS manages all functions involved in the daily operation of the space station, support of the crew and operation of the missions. These functions, which are described in detail in Section 2.1.2 are summarized in Appendix A. Also included in Appendix A are the criticality, thruput and communication requirements for each function.

The DMS architecture supports the aggregate processing rate, which is estimated to be in excess of 8 million operations per second (MOPS), and an aggregate communications rate of 25 Mbits/sec. High processing and communication rates are primarily mission data pre-processing functions. Station operation functions typically require much lower processing and communications speeds.

In addition to the functional and performance requirements identified, the following features are also required for the DMS:

1. Automatic fault tolerance. Fault tolerance includes automatic fault detection, isolation and recovery. Since the space station will be manned, highly critical functions involving crew safety and health are required to exhibit "fail operational, fail safe" performance. This means that highly critical functions must perform correctly in the presence of any system failure. If a second failure is detected and recovery is not possible, the system must revert to a fail safe mode. Non-critical functions require "fail safe".

2. Flexibility to add, modify and delete mission and station operation functions. The Space Station is an extremely long life project, and is expected to change significantly over time. Figure 2.2.1-1 illustrates the expected evolutionary growth of the station. Many missions planned for the station are of short duration and will be phased in and out of the project. As the station itself evolves, different habitation, observatory, and materials processing modules will be added and deleted significantly changing operational aspects of the DMS. The DMS architecture must be supported by these configuration changes with relatively minor system impact and cost.

3. Technology transparency. As the station evolves, it will be highly desirable to replace obsolete technology with new technology. The DMS architecture must allow these upgrades to occur with minimal impact on the system as a whole.

2.2.1.2 Architecture Development

The DMS architecture includes three major aspects: the degree of distributed processing, network topology, and the approach to fault tolerance for different levels of criticality. These three aspects will be addressed sequentially and systematically with respect to key DMS design drivers including:

1. Performance of the DMS in terms of communications and processing rates. The large number of missions, and the potentially high communication and processing rates for each mission strongly suggest individual processing units for each mission.

2. Safety and reliability. One of the foremost DMS architecture design drivers. Highly critical functions should be as autonomous as possible, allowing them to operate regardless of faults in other DMS functions. Isolation of highly critical functions from less critical functions in the architecture precludes interference in critical functions from non-critical functions.

3. Flexibility. As the station changes throughout its ten to twenty year life, missions will be added and deleted. Operational elements will also be changed to support these changing missions. These changes should be accommodated at minimal system cost and operational impact.

4. Technology transparency. The DMS architecture must allow graceful upgrades in technology. Technology upgrades are expected in software, particularly fault tolerant software, as well as processor hardware and communication equipment.

5. Cost. The total life cycle cost of the DMS should be considered. In terms of DMS architectural options, this cost reflects the additional cost one DMS implementation requires over another. For example, application software to implement the majority of individual functions is not included in this differential cost since it is

relatively constant for any DMS architecture. Software to interface between functions in different processors is included since it varies from one implementation to another. Total cost includes hardware, software, integration, operations, maintenance, and planned expansions.

The sequential methodology involves first determining the degree of distributed processing appropriate for the DMS through an analysis of all low level functions. Functional interfaces, computational requirements, and the critical nature of functions were considered in the analysis.

After a basic distributed DMS architecture was designed, methods for interconnecting the distributed processors was determined through an analysis of the characteristics of network topologies and the interfaces to be implemented.

Finally, an approach to fault tolerance (for different levels of criticality) was determined and overlaid onto previously defined distributed network.

2.2.1.2.1 Centralized Vs. Distributed Architectures

Centralized and distributed architectures have distinct advantages and disadvantages, as shown in Figure 2.2.1-2.

Centralized systems offer straightforwared control of processes, less complex architectures, generally less software, and few places for faults to occur. Distributed systems are more applicable to systems where ease of expandability, higher thru-put and isolation of critical functions are required.

The most cost effective approach to many systems is to find a middle ground between the fully centralized system (having one large processing element) and the fully distributed system (where each function is performed by an individual processor). The following approach was used to systematically locate the most cost effective middle ground.

2.2.1.2.1.1 Distribution Methodology. Distributed processing involves three elements: computation, control and data management. The methodology used for the DMS considers these aspects sequentially, first defining the distributed processing elements, then addressing control, and finally determining an approach to data management.

INITIAL (HABITAT)

- BASIC ON-BOARD OPERATIONS, HOUSEKEEPING, ETC.
- MINIMUM OF ON-BOARD EXPERIMENTS

FIRST EVOLUTIONARY GROWTH (NON-DEFENSE)	FIRST EVOLUTIONARY GROWTH (NATIONAL SECURITY)
• TRANSPORTATION HARBOR • SATELLITE SERVICING & ASS'Y • SPACE TEST FACILITY • INDUSTRIAL PARK • OBSERVATORY - LOW DATA RATE	• TRANSPORTATION HARBOR • SATELLITE SERVICING & ASS'Y • SPACE TEST FACILITY • LOW DATA RATE MILITARY MISSIONS
SECOND EVOLUTIONARY GROWTH (NON-DEFENSE)	**SECOND EVOLUTIONARY GROWTH (NATIONAL SECURITY)**
• ALL ABOVE • OBSERVATORY - HIGH DATA RATE	• ALL ABOVE • HIGH DATA RATE MILITARY MISSIONS

Figure 2.2.1-1. Assumed Space Station Evolution

CENTRALIZED	DISTRIBUTED
o STRAIGHT-FORWARD CONTROL o LESS COMPLEX ARCHITECTURE o LESS COMPLEX DATA MANAGEMENT o FEWER PLACES FOR FAULTS	• EASILY EXPANDED • HIGHER THRU-PUT (VIA PARALLEL PROCESSING) • MORE FLEXIBLE (TO NEW APPLICATIONS) • MORE AMENABLE TO FAULT TOLERANCE • INHERENT GRACEFUL DEGRADATION

BOTH APPROACHES HAVE ADVANTAGES

NEEDED: A SYSTEMATIC APPROACH THAT ANALYZES CENTRALIZED, DISTRIBUTED AND HYBRID ARCHITECTURES WITH RESPECT TO DESIGN GOALS.

Figure 2.2.1-2. Centralized Vs. Distributed Architectures

Figure 2.2.1-3 illustrates an iterative approach which leads to an optimal degree of distributed processing in a system.

This approach uses the fully distributed implementation (one processing element for each low level function) as a starting point, establishes an evaluation of merit for this implementation, and considers increasingly centralized approaches evaluating the merit of each. After all iterations are complete, the implementation with the highest merit value is selected as the optimal degree of distribution.

The evaluation of merit is the key aspect of this method. The evaluation must balance cost against performance characteristics in a manner consistent with DMS design goals. The merit function was calculated by assigning weights to the following criteria:

1. Cost - 20%. The cost criteria is divided into three aspects: hardware (10%), software (5%), and integration (5%). These weights are based upon the differential costs between architectural options. Overall, software and integration costs are expected to be far higher than hardware costs, however the differential software and integration cost imposed by distributed processing are expected to be a small fraction of the total cost. Costs implied by different network topologies and fault tolerant implementations are addressed in following sections and are not included here.

2. Expansion potential - 20%. This criteria is an evaluation of the system impacts of adding and deleting missions and operational elements. Generally, the distribution of elements that are likely to change, and the facility to add new elements increase expansion potential. Costs associated with adding elements to centralized control nodes and integration of new elements is included in this criteria.

3. Technology transparency - 20%. This criteria is similar to expansion potential except it applies to replacing existing technology (including software) with new technology. Technology transparency is achieved by distributing processing and minimizing interprocessor connections.

4. Isolation/autonomy of critical functions - 20%. One of the DMS design goals is to isolate critical functions such that failures in unrelated functions do not impair the critical function (as listed in Appendix A). Autonomy includes segregation of critical functions in independent processors, capable of operating in a fail safe mode in the event of a failure of the rest of the DMS.

5. Feasibility - 20%. This criteria is a qualitative measure of the risk associated with a given implementation. For example, implementations which require processors with capabilities beyond the

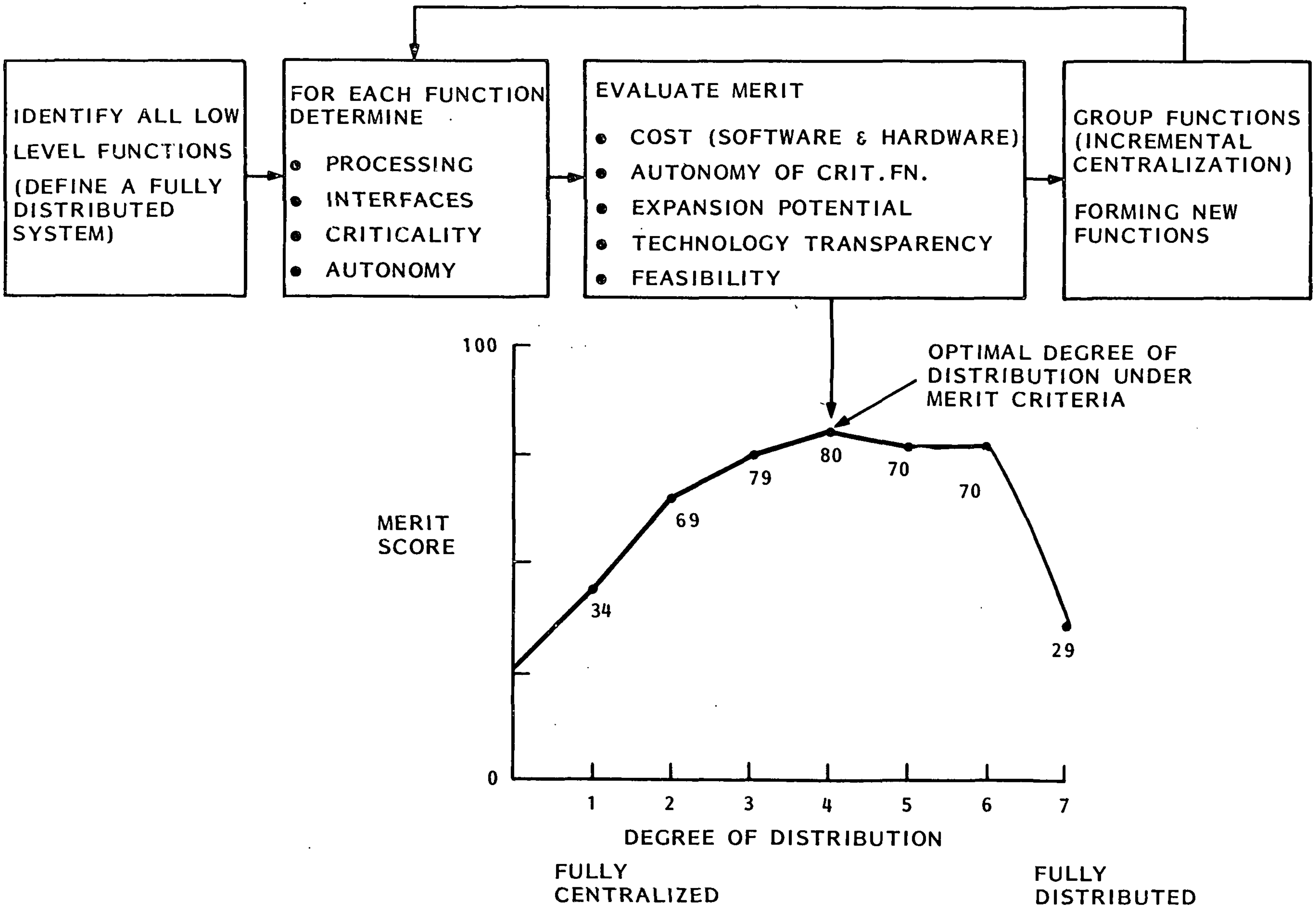


Figure 2.2.1-3. Distribution Methodology

projected space qualified technology have a higher risk than implementations that require projected available technology. Similarly, implementations which have a high number of complex functional interfaces involve a high degree of risk due to potential development and integration problems.

The merit of a particular implementation is calculated by summing the score for each of the above criteria. The maximum score possible is 100.

Alternative implementations (after the original fully distributed approach) are individually established by grouping low level functions into units that could be performed by a single processing element. The merit of each grouping considered is evaluated as described above. The ultimate grouping of all functions will result in a fully centralized system.

This method can be automated to test many alternatives, or applied manually to test a few intelligently selected alternatives.

2.2.1.2.1.2 <u>Applying the Method</u>. This method was applied for several implementations including fully distributed (which scored 34), fully centralized (which scored 29), and various other levels of distributed processing. Table 2.2.1-1 illustrates the results of the analysis. A more detailed explanation of the scoring is provided in Appendix B.

Alternative architectures were selected by preparing a matrix of all possible interfaces between functions and looking for patterns in the interfaces. Table 2.2.1-2 illustrates the first level matrix showing all functions on each axis. The large unoccupied sections in the matrix suggest a separation of operational and mission functions.

Analysis of the interface matrix leads to grouping functions that must communicate frequently into a single processor. The processing requirements of this single processor must be checked to insure that it does not required technology beyond that available in the 1990 time frame. Autonomy of critical functions must also be considered.

The matrix also illustrates functions that should be distributed to each processor, such as hardware and software maintenance. Leaving these as stand-alone functions greatly increases system complexity and cost with little benefit.

Table 2.2.1-1. Distribution Alternatives Summary

DEGREE OF DISTRIBUTION	COST 20%	AUTONOMY 20%	EXPANSION 20%	TECHNOLOGY TRANS. 20%	FEASIBILITY 20%	TOTAL 100%
CENTRALIZED	17.5	0	2	4	6	29
DEDICATED STATION OPS PROCESSOR	17	10	10	10	12	69
DISTRIBUTED STATION OPS	11	18	16	18	16	79
MODIFIED DISTRIBUTED STATION OPS	14	16	16	16	18	80
INTEGRAL COMMUNICATIONS	14	14	12	14	16	70
SINGLE NETWORK	14	14	16	10	16	70
FULLY DISTRIBUTED	0	20	6	6	2	34

Table 2.2.1-2. S/S DMS Functional Interfaces (In Attached Envelope)

2.2.1.2.1.3 Processor Distribution. The implementation shown in Figure 2.2.1-4 illustrates the highest rated implementation (which scored 80).

This implementation consists of two primary subsystems, Station Operations and Mission Support. These systems, as well as the Personnel Support and Military Interface are connected together via the Communications and Data Routing subsystem. The Entertainment system stands alone. Appendix C contains a complete list of all low level functions contained in each processor.

The Station Operations subsystem consists of five processors, Station Operations, Orbit/Radar, Attitude Control/Propulsion/Rendezvous-Docking, Environmental Control/Thermal, Control/Power and Remote Manipulator/OTV/EVA/ Structural Monitoring. The station operations processor itself consists of command and control of the operations functions, telemetry processing, and other functions which interface to the station operations functions frequently.

Communications and Data Routing consists primarily of controlling the internal and external communications systems. All voice, and TV communications with the ground (for critical and non-critical functions) are routed throughout the station by this function.

Personnel Support consists of crew health monitoring, training and simulation, and other semi-independent functions. These functions could be centralized to reduce the overall system cost with a minor impact on autonomy of critical function as and expansion potential.

Mission support consists of all functions common to the missions. It includes mission operations scheduling and resource allocation. It also provides a central point for the communication of all mission data to the ground.

Each mission is conducted by its own unique mission processor. This facilitates mission unique processing and provides an easily expandable system.

The military interface is isolated for security reasons.

The entertainment system consists of the library, movies and games, and does not have an interface with any other DMS function.

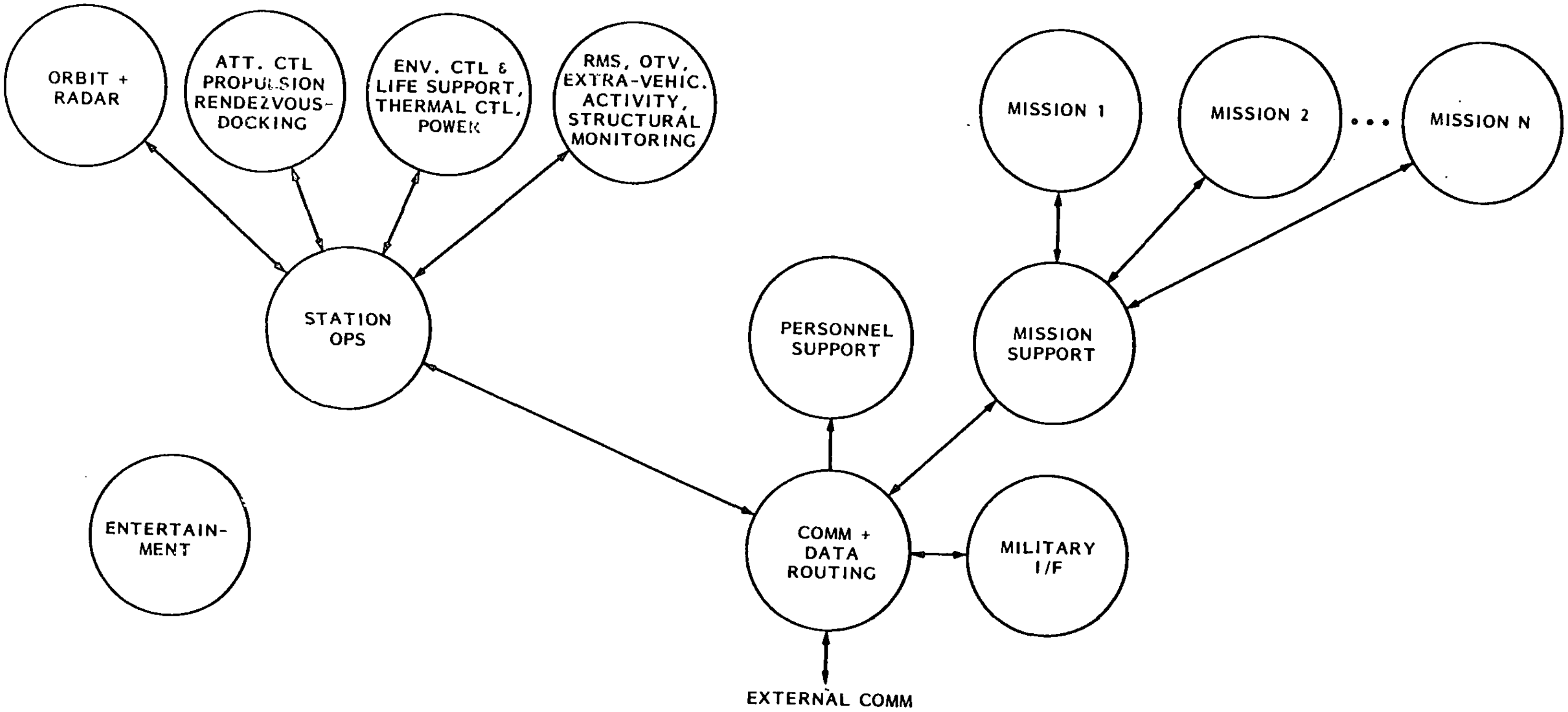


Figure 2.2.1-4. DMS Processor Distribution

2.2.1.2.1.4 <u>Control Distribution</u>. Distribution of control in the DMS applies to control within the station and mission operations subsystems and control of the major subsystems themselves.

The issue of distributed control evolves around the degree of autonomy desired for each function, the interfaces and relationships between functions, and the anticipated operational environment.

The major subsystems in the DMS are highly autonomous, linked primarily by the need to share a single communication link to the ground. For this reason, control at the major subsystem level is distributed. The central node (Communication and Data Routing) simply acts as an intelligent switch, routing addressed messages from the TDRSS antenna to the appropriate major subsystem. The Communication and Data Routing processor itself does not provide any control functions to the DMS. In those rare instances in which communication between major subsystems is required, the Communication and Data Routing node passes the message from one subsystem to another.

In the Station Operations subsystem, individual processors are moderately autonomous, however the general station operation is monitored and directed by a single operator with access to information from each of the individual processors. This necessitates a moderate degree of centralized control by the Station Operations processor. This control occurs at a very high level. Each of the other processors contains considerable internal control, and is able to maintain a stable, fail safe situation should all communication with the Station Operations node fail.

The Mission Operations subsystem is characterized by mission nodes performing extremely diverse missions. Control of the individual missions at a central node would be very complex, and is therefore distributed to each mission node. The mission operations node simply schedules missions and resolves conflicts for shared resources, such as communication to the ground.

2.2.1.2.1.5 <u>Data Base Distribution</u>. The centralized versus distributed data base issue is similar to the centralized versus distributed computation issue in that both approaches have certain advantages, and the most appropriate approach for a given system is usually some degree of distributed data.

Centralized data bases are appropriate when:

1. Data is generated, updated and accessed by multiple processors. Situations where two independent processors attempt to update a single common data element are most easily managed by a central system.

2. Complex relationships between data generated in different processors must be computed and maintained. Links between distributed data bases to compute and support these relationships can become complex.

3. Data is accessed and controlled at a single processing element.

Distributed data bases are most appropriate when:

1. Data is generated and used by a single processor.

2. Immediate access to data is required. Requests for data from a centralized data base can be impeded by communication network problems or loading problems at the central data base manager.

3. Autonomy of functions is required. Centralization of data makes remote processors dependent upon the central node. In the case of a failure of the central node or communication network, the remote node must have all data to maintain operations locally.

4. Data interfaces do not exist between processors. Distribution of data bases can be used to isolate processors and subsystems, making them more independent. Coupling of independent systems by centralizing data bases increases system integration costs and impact of component failures.

5. Data security is an issue. Access of data by an unauthorized processor is more simple in distributed data base systems.

Applying these factors to the DMS, a general philosophy of locally managing data unique to a single processor, i.e., data required for the routine operations, and centralizing data required for higher level station or mission management has been adopted.

Data management in the DMS consists of three major data bases: Station Operations, Mission Operations and Personnel Support. This configuration was preferred over a single centralized data base due to the functional independence of the subsystems and the advantages of completely decoupling station operations from mission operations. These data bases do represent centralized data bases within the subsystems. Centralized data bases at the subsystem level were chosen due to the interrelated nature of data from the individual processors (used for telemetry processing) and to support centralized station and mission planning. Local data bases, supporting routine operations, are also included at each processor. These data bases increase the autonomy of the individual processors and the ability of each processor to operate independently in the presence of system failures.

The Station Operations data base contains high level processed data from each of the remote processors. This data supports the flight operations planning and scheduling functions and maintains the long term data on the status of the station. This data base does not directly manage the data required for the routine operation of the remote processors, but may contain backup or initialization data. Backups of the Station Operations data base are maintained in the Information Management System Ground Segment.

The Mission Operations data base contains all data required to support mission planning and scheduling. Mission unique data, except a list of the resources required to accomplish a mission, is not stored in this data base. Data common to all missions includes station parameters such as observatory attitude and ephemeris data, environmental telemetry, and the status of all shared resources such as the TDRSS communication link.

The Personnel Support data base contains health and personnel data concerning the crew.

Figure 2.2.1-5 illustrates the distributed processing in the DMS.

2.2.1.2.2 Network Topology

Once the appropriate level of distributed processing has been determined, the method for interconnecting processors must be defined. Selection of an appropriate network topology is designed to: minimize interference between highly critical functions, minimize number and length of communication links, minimize complex network routing software, and accommodate new technology and missions. Generic topologies considered were multidrop, fully connected,ring, and star. Figure 2.2.1-6 illustrates these basic configurations.

Observing the processing element definition and the required functional interfaces, a hierarchical network configuration is appropriate. Three unique subnetworks are identifiable: Station Operations, Mission Support, and Data

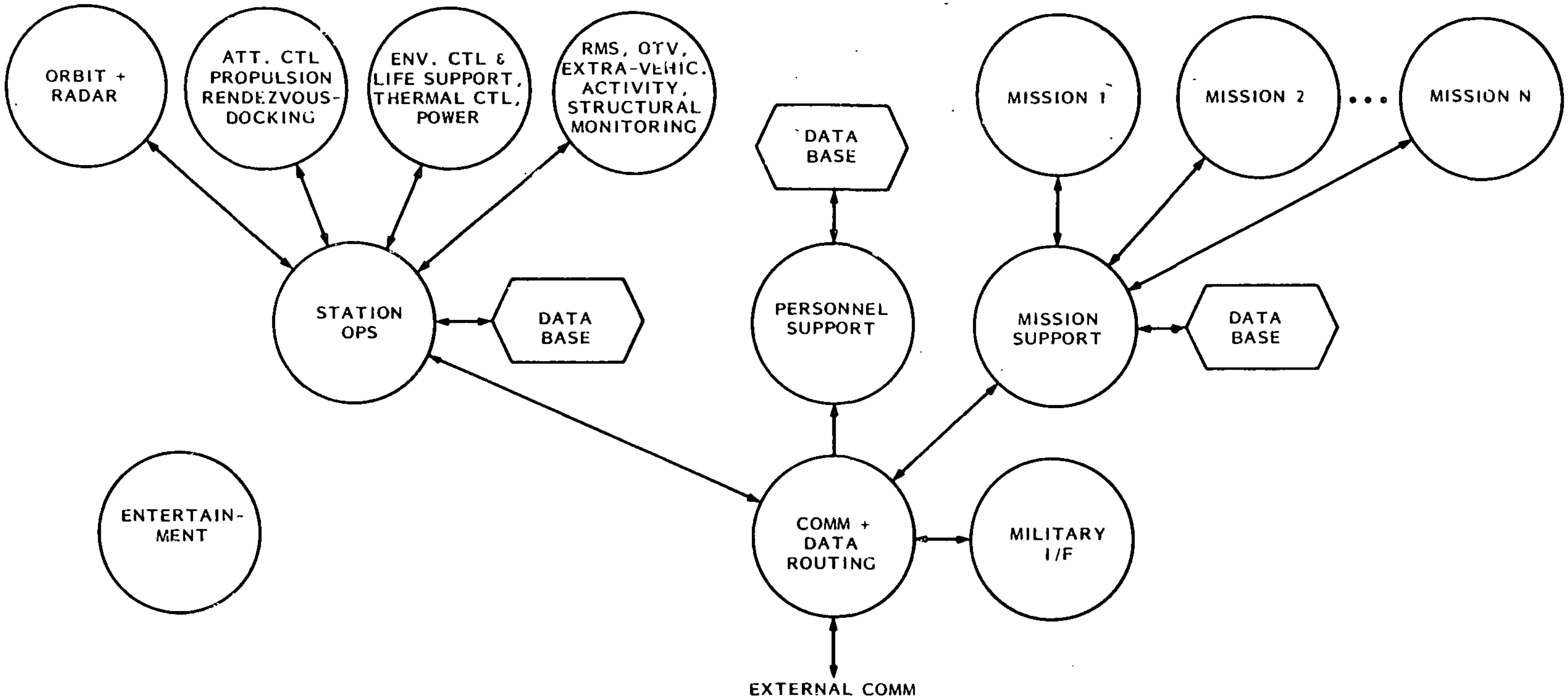


Figure 2.2.1-5. DMS Processor Architecture (with Data Bases)

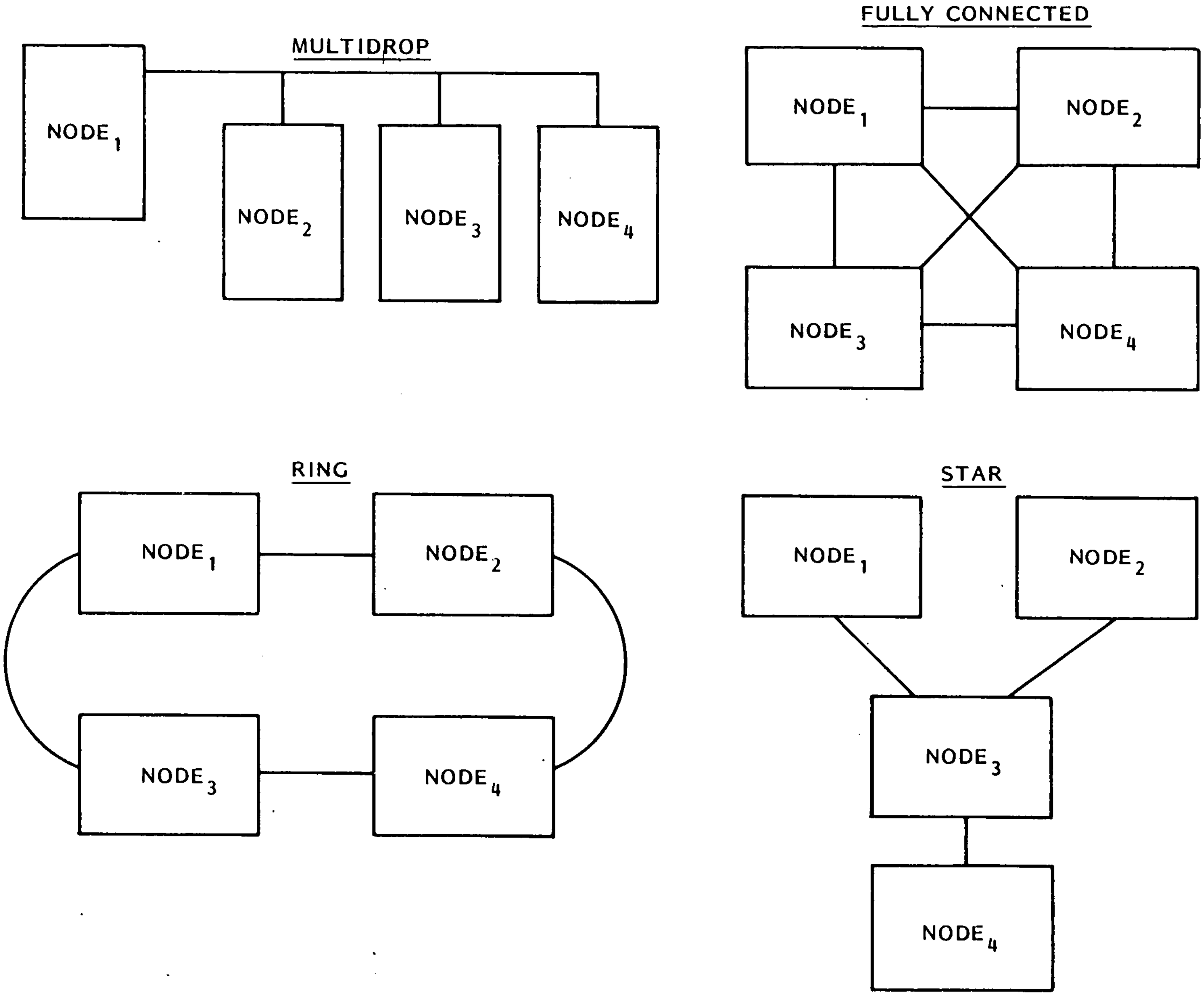


Figure 2.2.1-6. Network Topologies

Routing (which provides the interface to the ground communications system as well as a low volume interface between Station Operations and other subsystems.)

Appropriate network connections for each of the subnetworks are determined by analyzing the characteristics of different network topologies and the functional characteristics of the subnetworks.

2.2.1.2.3 Network Characteristics

The following network characteristics provide a basis for comparison:

1. Fault tolerance. This indicates the ability to operate in the presence of faults without special redundant circuits. Only topologies which provide multiple paths to each node provide natural fault tolerance. Multiple, non-redundant paths to each node, such as the ring and fully connected networks provide, are also capable of tolerating "chatty node" failures. Chatty nodes are processor failures where the processor continuously transmits data on the network. This is a serious problem in multidrop networks since the entire network can be tied up with erroneous messages.

2. Complexity of routing. Network topologies which require complex routing algorithms at some or all nodes are difficult to implement and maintain. Generally, networks with large numbers of paths to each node require more complex network routing algorithms.

3. Fiber optic implementations. The fiber optic communication links between nodes on the Space Station impose certain restrictions on the network topology. Anticipated technology for couplers limits the number of connections on a single link to less than ten, which precludes multidrop for networks or more than ten nodes. Technical problems encountered in demultiplexing wave division multiplexed signals on single links could present problems for full duplex operation.

4. Operation in physically distributed systems. Over long distances, the large number of links required by fully connected networks can become burdensome.

5. Performance with many nodes. When sharing communication links, bandwidth of single communication links can limit system performance.

6. Expansion potential. This provides an measure of how easily new nodes can be added to the network.

Table 2.2.1-3 illustrates the attributes of each network topology with respect to the above selection criteria.

Table 2.2.1-3. Network Topologies Comparison

	REDUNDANT LINKS REQUIRED	VULNERABILITY TO "CHATTY" NODES	COMPLEXITY OF ROUTING	FIBER OPTIC IMPLICATIONS	OPERATION IN PHYSICALLY DISTRIBUTED SYS.	PERFORMANCE WITH MANY NODES	EXPANSION (AND/DELETE NODES)
RING (UNIDIRECTIONAL)	YES	MODERATE	LOW	ALL-POINT TO POINT-SIMPLEX	GOOD - FEW LINKS	GOOD	FAIR
RING (BIDIRECTIONAL)	NO	LOW	MODERATE	ALL-POINT TO POINT. FULL DUPLEX	GOOD - FEW LINKS	GOOD	FAIR
MULTIDROP	YES	HIGH	MODERATE	# OF DROPS LIMITED BY COUPLING LOSSES, FULL/HALF DUPLEX	GOOD - FEW LINKS	GOOD (WIRE LINKS)	FAIR
STAR	YES	LOW	--	ALL-POINT TO POINT SIMPLEX/HALF DUPLEX	POOR - FOR LARGE # OF NODES	POOR	GOOD
FULLY CONNECTED	NO	LOW	HIGH	ALL-POINT TO POINT. FULL DUPLEX	POOR FOR LARGE # OF NODES	FAIR	POOR

2.2.1.2.3.1 Network Selection. The selection of a topology for each subnetwork is based on the specific functional characteristics of that network.

Due to the small number of nodes (five), the differences in criticality and bandwidth of communications, the low potential for changes (at this level of the architecture), and the short physical communication links, a star network is recommended for the communication subnetwork.

Station operations is characterized by five critical nodes communicating at a relatively low rate. In this subnetwork, fault tolerance is the key selection criteria. Fully connected and ring networks are best suited to fault tolerance. The ring topology has significant cost expansion potential advantages over the fully connected. These advantages are especially important in light of the expected changes to the Station operations subnetwork over the life of the station.

Mission support is characterized by a very large number of nodes sharing a single communication link to the ground. The high bandwidth required for this communication will require fiber optic communication among 13 nodes. Anticipated technology will not support a 13 node multidrop, hence a ring network is preferred for this also.

Figure 2.2.1-7 illustrates the DMS distributed processing network, showing the selected network topologies.

2.2.1.2.4 Fault Tolerance

The design of the DMS architecture is driven significantly by the degree of reliability required by different functions. In this regard the ability of various systems to execute functions regardless of failures, play an important role in the development of candidate DMS architectures. This fault tolerance occurs automatically. All detected faults are immediately reported to the crew and corrective maintenance scheduled. Mechanisms to automatically and manually test and report the status of the system are required.

The operational requirements for the DMS are:

1. Prompt fault detection.

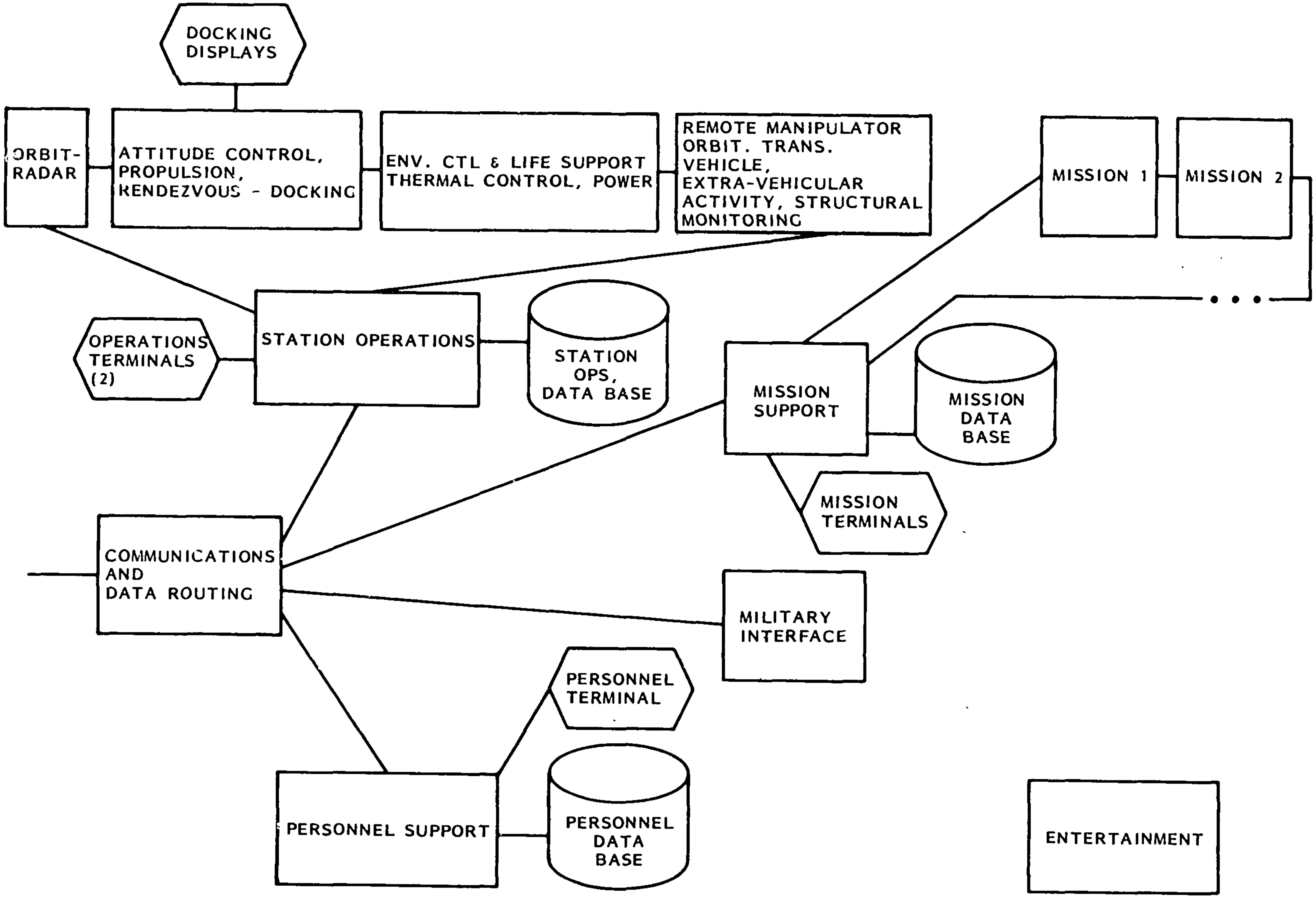


Figure 2.2.1-7. DMS Architecture

2. Immediate fault isolation.

3. Automatic fault recovery.

4. Operator notification of faults.

5. Automatic diagnostic to the replaceable item level (i.e., processor or board).

6. Machine prompted corrective maintenance.

7. Machine controlled retest.

The hardware requirements for operating in a fault tolerant environment are:

1. Modularity.

2. Accessibility.

3. Identifiability.

4. Interchangeability.

2.2.1.2.4.1 Methods for Achieving Fault Tolerance. There are many methods for achieving fault tolerance for processors communication links, and networks. Table 2.2.1-4 illustrates those considered in this study. Each of these approaches involves additional cost (cost for additional redundant processors and in system complexity) for a specific level of fault tolerance.

Redundancy in the data transmitted through a communication network (cylical redundancy codes, CRCs) can be used to detect and correct errors in communication links without redundant hardware. However, to guard against complete failure of communication links redundant communication paths are required.

The interconnection of redundant processors to redundant communications links has implications on system complexity, maintainability, and general system architecture. Figure 2.2.1-8 illustrates potential interconnection schemes. Generally system complexity can be reduced and maintainability enhanced by performing redundancy checks at a local level. This simplifies isolation of faults and reduces system complexity, and reduces overall cost by avoiding integration problems.

Table 2.2.1-4. Fault Tolerance

LEVEL	METHOD	FAULT DETECTION	FAULT ISOLATION	AUTOMATIC RECOVERY	COST	COMPLEXITY	RECOMMEND FOR
MODULE	5 PROCESSOR MAJORITY VOTING	EXCELLENT	GOOD	EXCELLENT	VERY HIGH	HIGH	
	4 PROCESSOR CROSS CHECK	EXCELLENT	GOOD	EXCELLENT	VERY HIGH	HIGH	
	3 PROCESSOR, MAJORITY VOTING	GOOD	GOOD	GOOD	HIGH	MODERATE	CRITICAL
	2 PROCESSOR, HOT STANDBY	FAIR	FAIR	FAIR	MODERATE	LOW	
	2 PROCESSOR, COLD STANDBY	FAIR	FAIR	FAIR	MODERATE	LOW	
	RECONFIGURABLE SPARES	POOR	POOR	NONE	LOW	LOW	ALL
	REDUNDANT INFORMATION	FAIR	FAIR	FAIR	HIGH	HIGH	
COMMUNICATION	REDUNDANT INFORMATION (CRC)	GOOD	GOOD	FAIR	LOW	MODERATE	ALL
	REDUNDANT LINKS	GOOD	GOOD	GOOD	LOW	LOW	CRITICAL
NETWORKS	FUNCTIONAL REASSIGNMENT BETWEEN PROCESSORS	GOOD	GOOD	FAIR	HIGH	HIGH	
	FAULT TOLERANCE AT MODULE LEVEL	GOOD	GOOD	GOOD	MODERATE	LOW	ALL
	FAULT TOLERANCE AT SYSTEM LEVEL	FAIR	POOR	FAIR	MODERATE	HIGH	

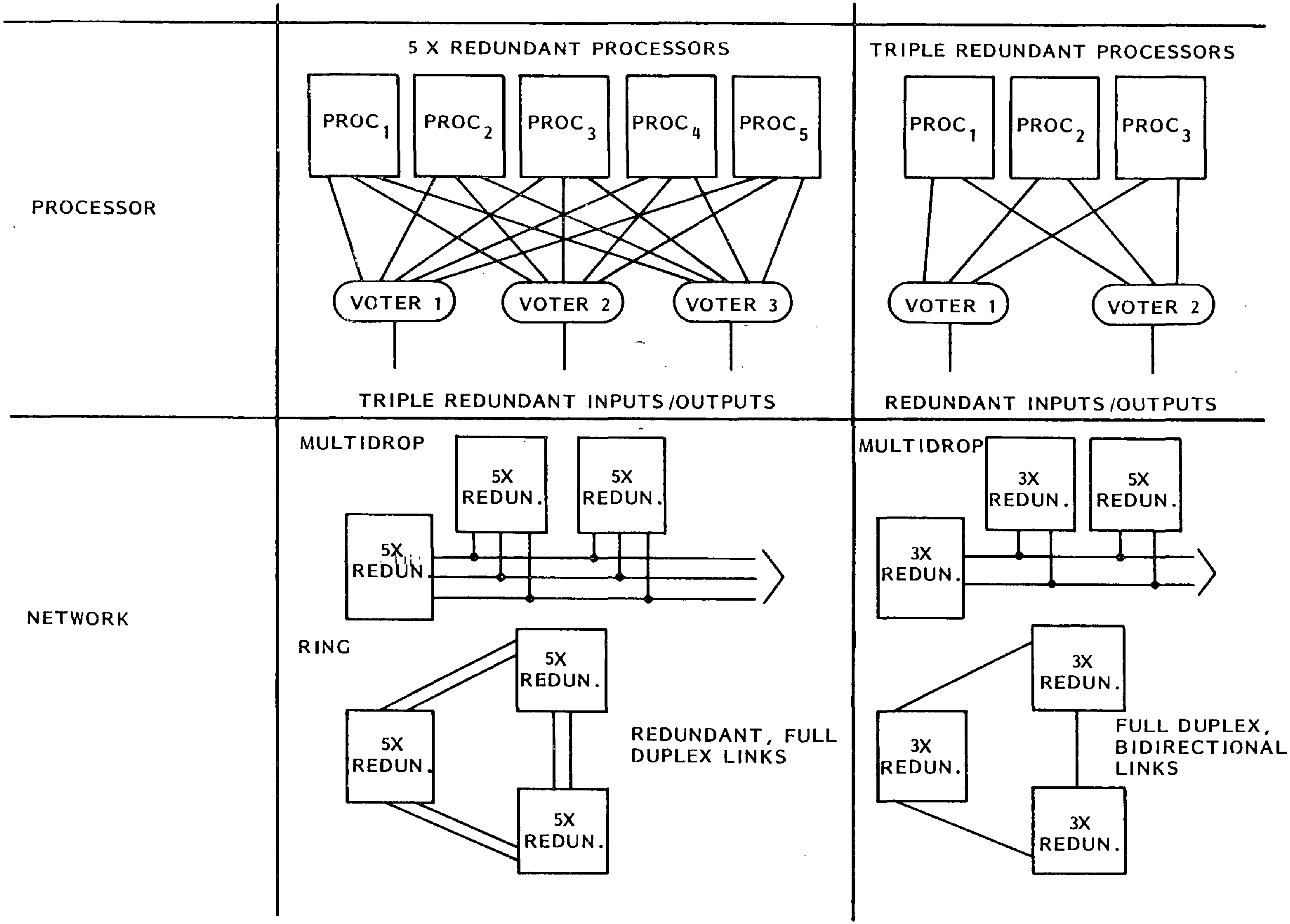


Figure 2.2.1-8. Fault Tolerant Implementations

2.2.1.2.4.2 Software Considerations. Software reliability is harder to model, predict and design into systems. Nevertheless, some predictive models have evolved in the last few years (Musa, Selinski-Moranda, Shooman, Littlewood-Verrall, etc.) that promise improvements in capability to predict the reliability of software systems.

The use of these and future models, parallel development of redundant (non-equal) software, automatic testing, and the inclusion of error detecting/correcting codes need to be evaluated in terms of cost versus performance.

2.2.1.2.4.3 Fault Tolerance Implementations. In order to minimize the overall cost of the system, a modular approach fault tolerance was taken. Fault tolerance at the module level is tailored to the critical nature of the function. This minimized initial cost, and allows the flexibility to upgrade to different technology in the future.

A static redundancy 3-modular network has been selected to provide zero-degradation fault tolerant redundancies for critical functions. Failures in non-critical functions are detected by self tests operating in a background mode. Recovery is achieved by manual reconfiguration of spares by the operator. This is anticipated to consist of board replacement. This approach to fault tolerance was selected over methods such as automatic system reconfiguration using on-line spares, or reassignment of functions to other processors for reasons of overall system cost. Approaches that require fewer physical processors to achieve the same level of reliability generally increase system complexity, and therefore increase system integration cost. The reassignment of functions to other processors in the DMS is further complicated by the numerous and diverse remote equipment controlled by each processor. For one processor to assume functions of another, it would require connection to all the physical equipment of the other.

In network operation, the voted output of all redundant processors is simultaneously imposed on all communication links. If any processor fails, all voters for that function detect the error and report it back to all processors. In all cases of failed processors, correct data is imposed on all communication lines. Each processor of a receiving function receives three copies of each message (one across each communication link). Each redundant processor can independently verify the validity of each message with the CRC code, and can detect the complete failure of a communication link or voter by receiving less than three copies of each message.

Tolerance to hard faults in the Data Routing network is achieved by parallel redundant communications links. In the station operations ring network, redundancy is best achieved using two unidirectional rings. The use of unidirectional rings avoids full-duplex/wave division multiplexing problems and simplifies control. The redundant rings operate in opposite directions, thus avoiding "chatty node" problems.

2.2.1.2.4.4 Fault Tolerant Technology. Technology advances in processors and fault tolerance techniques are expected in the space station time frame. Approaches to fault tolerance that could not be cost justified in the initial station configuration are likely to become economical in later stages of the program. The fault tolerance approach taken in the DMS design with technology available in the 1986 time frame and upgrade to more advanced technology as it becomes available. Anticipated advances include software fault tolerant techniques and methods for automatic system reconfiguration.

2.2.1.3 Conclusion

Figure 2.2.1-9 illustrates the DMS architecture. The station operations subsystem is a distributed processing network of five nodes, providing autonomy, expansion potential, and technology transparency to critical functions. The elements in this subsystem are three times redundant and communicate over a redundant uni-directional ring. Isolation of these critical functions precludes interference from non-critical mission functions.

The mission support subsystem includes all functions required to operate the missions. All common functions (primarily scheduling, resource allocation, and telemetry processing) are performed in the mission support processor. All mission unique functions are performed by special mission processors (using reconfigurable spares as backup) connected by a ring. Taps for new missions are included to minimize the impact of station reconfiguration.

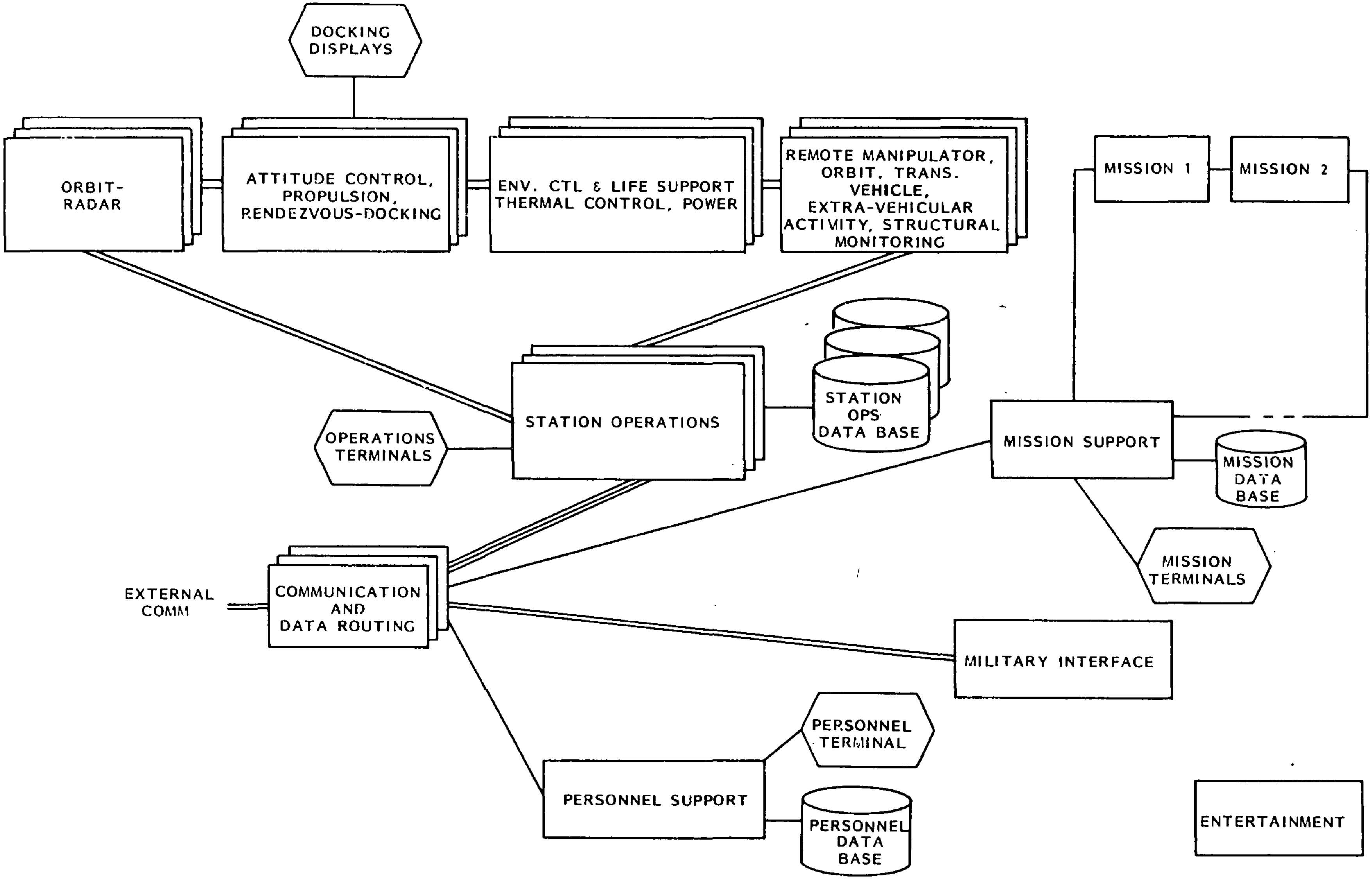


Figure 2.2.1-9. Space Station DMS Architecture

The Communications/Data Routing and Military Interface processors are critical and therefore are implemented as three times redundant processors. These, station operations, personnel support, and mission support are connected in a redundant star network with Communications/Data Routing at the center.

Entertainment (library, movies and games) is implemented as a separate, standalone system.

This configuration achieves safety/reliability and technology transparency goals in a cost effective system.

2.2.2 COMMUNICATIONS

The space station communications system comprises both internal and external communications subsystems. The system overview is given in Figure 2.2.2-1. The external communications subsystem provides communications between the space station and external users (such as manned and unmanned spacecraft and the Ground Data System) as well as navigation, tracking and surveillance capability. The internal communications subsystem provides intercompartment voice communications, closed circuit TV, and audio/video/digital data transmission. Local communications is a subset of internal communications where modules of the space station are physically detached and thereby require an RF or optical transmission link. The Data Management System (DMS) links internal and external communications by configuring the communication interfaces and by performing overall command and control.

Tables 2.2.2-1 and 2.2.2-2 summarize, respectively, the communications and tracking service requirements and capability requirements. Table 2.2.2-2 also shows the anticipated growth in the capabilities requirements. These service and capability requirements provide the basis for the communication subsystem architecture discussed in this section and the conceptual designs of Sections 2.3.3 and 2.3.4.

2.2.2.1 External Communications

(This section is contained under separate cover.)

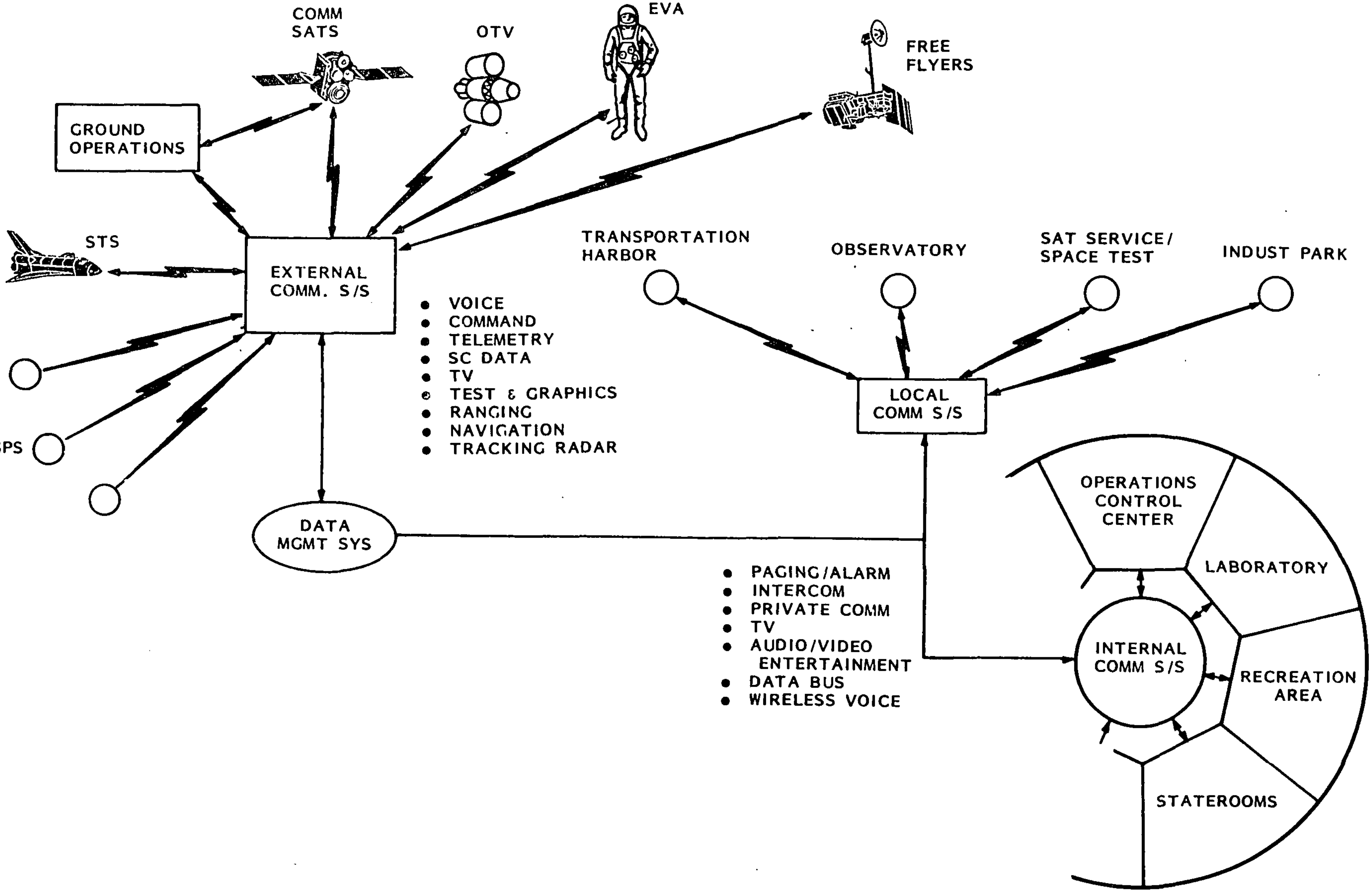


Figure 2.2.2-1. Communication Subsystem Overview

Table 2.2.2-1. Communication Subsystem Functional and Service Requirements

COMMUNICATION FUNCTION SUPPORT BETWEEN SPACE STATION AND –	COMMUNICATION SERVICES REQUIRED
CO-ORBITING FREE FLYERS - FF	TELEMETRY, COMMANDS, TRACKING, RETURN TV, MISSION DATA
UNMANNED ORBIT TRANSFER VEHICLES - OTV	TELEMETRY, COMMANDS, TRACKING, RETURN TV
MANNED ORBIT TRANSFER VEHICLES - MOTV	TELEMETRY, COMMANDS, TRACKING, DUPLEX TV, DUPLEX VOICE
TELEOPERATOR MANEUVERING SYSTEM - TMS	TELEMETRY, COMMANDS, TRACKING, RETURN TV
MANNED MANEUVERING UNIT - MMU	TELEMETRY, COMMANDS, DUPLEX TV, DUPLEX VOICE
SPACE TRANSPORTATION SYSTEM - STS	TELEMETRY, COMMANDS, TRACKING, RETURN TV, DUPLEX VOICE
EXTRAVEHICULAR ASTRONAUT - EVA	TELEMETRY, RETURN TV, DUPLEX VOICE
VERSATILE SERVICE STAGE - VSS	TELEMETRY, COMMANDS, TRACKING, RETURN TV
PROXIMITY OPERATIONS VEHICLE - POV	TELEMETRY, COMMANDS, TRACKING, RETURN TV
GROUND OPERATIONS CENTER VIA TDRS OR TDAS	TELEMETRY, COMMANDS, TRACKING, DUPLEX TV, DUPLEX VOICE, DUPLEX COMPUTER DATA, GRAPHICS, TEXT
GLOBAL POSITIONING SYSTEM - GPS	SPACE STATION ELEMENTS' POSITION, VELOCITY, ACCELERATION, TIMING
ALL PROXIMITY OPERATIONS	RANGE, RANGE RATE, ANGLE, ANGULAR VELOCITY, PLUS ORIENTATION FOR RENDEZVOUS

Table 2.2.2-2. Communication Subsystem Capabilities Requirements

COMMUNICATION FUNCTION SUPPORT BETWEEN SPACE STATION AND -	MAX NUMBER OF VEHICLES SUPPORTED BY TIME PERIOD		
	1990	1995	2000
CO-ORBITING FREE FLYERS - FF	3	4	5
UNMANNED ORBIT TRANSFER VEHICLES - OTV	1	2	2
MANNED ORBIT TRANSFER VEHICLES - MOTV	NONE	2	2
TELEOPERATOR MANEUVERING SYSTEM - TMS	1	1	1
MANNED MANEUVERING UNIT - MMU	2	3	4
SPACE TRANSPORTATION SYSTEM - STS	2	2	2
EXTRAVEHICULAR ASTRONAUT - EVA	2	2	2
VERSATILE SERVICE STAGE - VSS	1	1	1
PROXIMITY OPERATIONS VEHICLE - POV	1	1	1
GROUND OPERATIONS CENTER VIA TDRSS OR TDAS	1	1	1
GLOBAL POSITIONING SYSTEM - GPS	4	4	4
ALL PROXIMITY OPERATIONS	3	4	5

2.2.2.2 Internal Communications

Requirements

The Space Station will be capable of many different forms of internal communications and will be designed so that the systems as a whole will be completely flexible. Each compartment will be able to communicate with any other over a variety of transmission media. Figure 2.2.2.2-1 shows the various types of internal communications along with their required data rates. As shown, the data rate capacity of any particular station should be 47 Mb/s or greater.

The most important communication link is the computer. All compartments and modules will be linked to the Data Management System. Digital data on this link requires data rate of 25 Mb/s.

Telemetry will be gathered in all compartments and modules, and monitored by the DMS. Analog and digital telemetry from transducers (pressure, temperature, etc.) will be appropriately converted and encoded into a digital form by Remote Interface Units (RIU's), then sent to the DMS. The data rate capacity for telemetry is 110 Kb/s.

The Space Station will be capable of caution and warning during emergency or potentially dangerous situations. Caution and warning will consist of audible and visible alarms, emergency control of critical subsystems, and instructions or information that would be displayed audibly or visibly. Caution and warning information requires 10 Khz of bandwidth.

All compartments and modules will be linked by a private communications network. Private communications will take the form of plug-in headsets or wireless remote units utilizing radio-frequency to allow freedom of movement. All private communication will be digitally converted. The number of simultaneous voice conversations is selected to be 24. Current telephone systems use 1.54 Mb/sec T1 carriers to accommodate 24 digitized voice signals.

Television aboard the Space Station will serve a variety of communications functions. It will be used to monitor Space Station activities in all the various compartments and modules. In conjunction with the intercomm system, TV will provide a means of two-way audio-video communications. Entertainment channels can be displayed over monitors distributed throughout the Space Station. Associated with each TV monitor will be a video player/recorder (VCR) used for entertainment, information or data storage. TV, converted to a digital form has the highest data rate requirement of 20 Mb/s. The audio portion of entertainment requires a bandwidth of 20 Khz.

The Space Station will possess an intercomm system implemented in each compartment by a combination wall-speaker and microphone. The intercomm system will allow for multi-compartment, conference communications. The intercomm system requires a bandwidth of 10 Khz.

Since it is possible that some modules of the Space Station will be physically disconnected and co-orbiting, the Space Station will possess a local communication network. Information of the type already discussed will be transmitted to these unconnected modules via an optical or RF link.

Compartmental or Modular Requirements

Figure 2.2.2.2-2 shows the internal communication requirements for each compartment or module. As shown, all compartments and modules have links to the DMS, telemetry, caution/warning, private communication and TV channels. In addition, any module which contains a shirtsleeve environment will have access to the intercomm channels. Because of their functions, some compartment have special internal communication requirements.

The mission/operations control center, which resides in the Habitat module, the heart of the Space Station's functional control, is where all activities, operations and missions are monitored and controlled. Activities are divided into two groups: operations (those functions which deal with the Space Station itself) and missions (those functions which deal with experiments, production, observation, etc.). Each group will require its own console, TV monitors and cameras, private comm system and intercomm. Both groups require multiple TV monitors for docking procedures, mission control etc. In addition, mission operations control has several hand held TV cameras associated with it, used for monitoring EVA's. Another important feature of mission operations control is that external communication are routed through and controlled by mission operations.

FUNCTION	BANDWIDTH/ DATA RATE
CAUTION/WARNING	10 kHz
INTERCOM	10 kHz
PRIVATE COMM	1.5 MB/s
TV	5 MHz/20 MB/s
AUDIO ENTERTAINMENT	20 kHz
TLM	110 kB/s
DIGITAL DATA	25 MB/s

TYPICAL DATA RATE/COMMUNICATION INTERFACE UNIT ≤ 47 MB/s

Figure 2.2.2.2-1. Internal Communication Performance Requirements

	COMPUTER	TLM	CAUTION WARNING	PRIVATE COMM	TV	AUDIO VIDEO ENTERTAIN	INTERCOM
HABITATION MODULE							
STATEROOMS (3)	X	X	X	X	X	X	X
MISSION/OPS	X	X	X	X	X		X
SUPPORT	X	X	X	X	X		X
REC/DINING	X	X	X	X	X	X	X
LAB	X	X	X	X	X		X
TRANSPORT HARBOR	X	X	X	X	X		
OBSERVATORY	X	X	X	X	X		
INDUSTRIAL PARK	X	X	X	X	X		X
SAT/SERV SPACE TEST	X	X	X	X	X		X

Figure 2.2.2.2-2. Internal Communication Requirements

It is assumed that there are three staterooms on the Space Station where crew members sleep and relax. In addition to the normal internal communication capabilities, staterooms will possess an audio/video entertainment unit which contains high-fidelity audio speakers, an audio tape unit and a video game unit. The recreational/dining compartment has the same capabilities with the addition of a wide-screen TV.

The support area contains Space Station's housekeeping functions and repair accesses. It is assumed to be a shirtsleeve environment and possesses all normal internal communication capabilities as indicated in Figure 2.2.2.2-1. The lab compartment is assumed to be a shirtsleeve environment used for experimentation and data processing not associated with any of the other modules. It will possess all normal internal communication capabilities.

The transport harbor is a docking and airlock facility. It is assumed to be a non-shirtsleeve environment and therefore has no intercom system. It does have a private communication system so that astronauts may communicate via wireless RF or plug-in units. Because of critical docking procedures, the transport harbor will possess multiple TV cameras for adequate visual coverage. These cameras can be controlled remotely by the ops center.

The observatory is assumed to be a non-shirtsleeve facility for remote sensing and data acquisition. It possesses all normal internal communication capabilities except for intercomm.

The industrial park is a facility used for commercial production and experimentation. It requires multiple camera coverage, controlled and monitored remotely be the mission control center. It is assumed that part of the industrial park will be a shirtsleeve environment and so requires all normal internal communication capabilities.

The satellite service/space test facility is responsible for preparation, repair and refurbishment of satellites as well as space environment testing. It is similar to the industrial park in that it requires multiple camera coverage and part of it will be a shirtsleeve environment.

Technology Tradeoffs

Technology tradeoffs which affect the internal communication system were performed based on the following criteria:

1. Size, weight and power.
2. Reliability/Maintainability.
3. Bandwidth
4. Compatibility with existing/future systems.
5. Security.

The first tradeoff, shown in Figure 2.2.2.2-3, considered hardwire versus fiber optics for the transmission medium of the internal communication system. Fiber optics is chosen primarily for its high data rate capacity and low size, weight and power. It should be noted that the data rate capacity of fiber optics (10 Gb/s) is well in excess of the predicted requirement (47 Mb/s).

Figure 2.2.2.2-4 shows the tradeoffs considered for various methods of multiplexing information within a particular station. As shown, time division multiplexing is considered best because of its simplicity and data rate capacity.

The next tradeoff performed is for the method of multiplexing information among the various stations. Frequency division multiplexing is not considered here for the same reasons that it was rejected in the previous tradeoff study. As shown in Figure 2.2.2.2-5, the optimum choice for this case is wavelength division multiplexing for the reasons indicated.

It should be noted that WDM systems are currently being constructed, so the technology is existing.

Figure 2.2.2.2-6 shows the various types of internal communications architectures considered and Figure 2.2.2.2-7 contains the corresponding tradeoffs. The best choice is the star configuration mainly because of moderate coupling losses and low complexity. Up to 50 stations can be interconnected with this approach with an adequate signal to noise ratio. The optical star coupler combines data from all transmitters, each at a different location, and distributes all data to all receivers.

OPTIONS	CRITERIA	ADVANTAGES	DISADVANTAGES	RATIONALE
HARDWIRE	TECHNOLOGY	EXISTING		
	RELIABILITY	EXCELLENT MECHANICAL INTEGRITY		
	BANDWIDTH		LIMITED CAPACITY	
	SIZE, WEIGHT		BULKY	
	SECURITY		NOT SECURE DUE TO RF LEAKAGE	
	INTERFERENCE		RFI OR CROSSTALK POSSIBLE	
	ENVIRONMENT	WILL WITHSTAND RADIATION ENVIRONMENT		
FIBER OPTICS	BANDWIDTH	WIDE BANDWIDTH (1-10 Gb/s)		FIBER OPTIC SHOULD BE USED STARTING WITH FIRST MISSION BECAUSE TECHNOLOGY EXISTS NOW
	SIZE, WEIGHT	VERY SMALL AND LIGHT		
	SECURITY	NO DATA LEAKAGE		
	INTERFERENCE	NO PICKUP, RFI OR CROSSTALK. LOW SUSCEPTIBILITY TO EMP, SHORTS OR STATIC DISCHARGE.		
	RELIABILITY	HIGH TENSILE STRENGTHS. NO RINGING PROBLEMS. FIBER DOES NOT SHORTEN WHEN DAMAGED.		
	FLEXIBILITY	NONCONTACTING ROTATING JOINT POSSIBLE		
	ENVIRONMENT		SOME FIBERS AGE WITH RADIATION	

Figure 2.2.2.2-3. Hardwire vs. Fiber Optics Tradeoff

OPTIONS	CRITERIA	ADVANTAGES	DISADVANTAGES	RATIONALE
FREQUENCY DIVISION MULTIPLEXING	COMPATIBILITY	COMPATIBLE WITH STANDARD TELEPHONE HARDWARE, BASE-BAND TV AND FM MODULATED IF CARRIERS		
	SENSITIVITY		LOW SENSITIVITY REQUIRED SNR = 70 dB	
	BANDWIDTH		LIMITED TO <100 MHz	
TIME DIVISION		BEST SENSITIVITY REQUIRED SNR=20 dB COMPATIBLE WITH HIGH DATA RATES (1-3 Gb/s) POSSIBLE. COMPATIBLE WITH STANDARD TELEPHONE MODEMS (24 CHANNELS)		SIMPLER SYSTEM, HIGHER DATA RATES POSSIBLE. PREFERRED CHOICE.
	COMPLEXITY		TV SIGNALS HAVE TO BE DIGITIZED TO 20 Mb/s BIT STREAMS	
	DATA RATES CAPACITY	1-2 Gb/s		
WAVE DIVISION MULTIPLEXING	COMPLEXITY		NEEDS SEPARATE LASER FOR EACH DATA CHANNEL	

Figure 2.2.2.2-4. Internal Communications Multiplexing Trade-Off

OPTIONS	CRITERIA	ADVANTAGES	DISADVANTAGES	RATIONALE
TIME DIVISION MULTIPLEXING	BANDWIDTH		INVERSELY PROPOR-TIONAL TO NUMBER OF STATIONS	
	RELIABILITY		IN CASE OF FAILURE STATIONS CAN INTERFERE	
	HARDWARE COMPLEXITY		NEEDS DISCONNECT SWITCHES	
	SOFTWARE COMPLEXITY		NEEDS PROTOCOL FOR FAULT TRACING AND REROUTING	
WAVELENGTH DIVISION MULTIPLEXING	BANDWIDTH	INDEPENDENT OF NUMBER OF STATIONS		PREFERRED CHOICE. LARGEST BANDWIDTH. HIGHEST RELIABILITY.
	RELIABILITY	COMPLETE ISOLATION BETWEEN STATIONS, NO INTERFERENCE POSSIBLE		
	HARDWARE COMPLEXITY		NEED ONE DETECTOR FOR EACH STATION ON BUS, NEED WAVELENGTH DEMUX.	
	SOFTWARE COMPLEXITY	NONE NEEDED		

Figure 2.2.2.2-5. Interstation Multiplexing Tradeoff

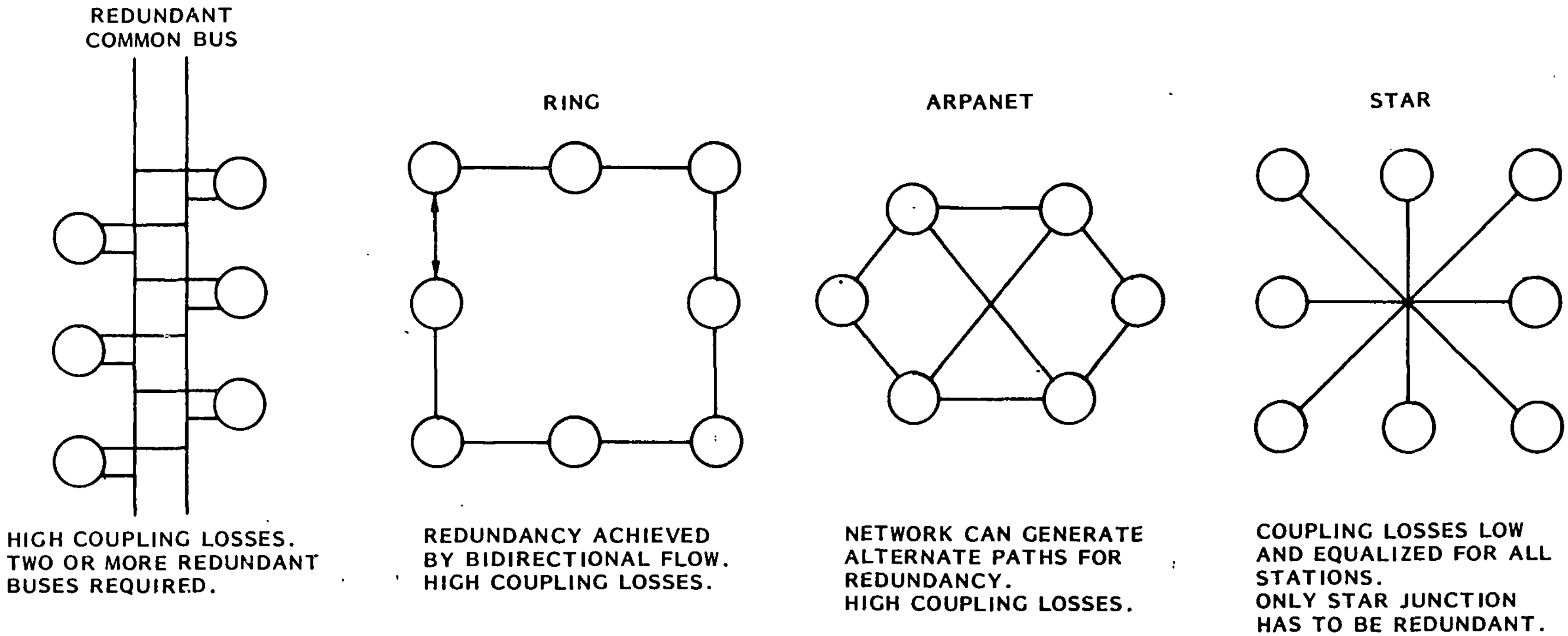


Figure 2.2.2.2-6. Candidate Internal Communication Fiber Optic Architecture

OPTIONS	CRITERIA	ADVANTAGES	DISADVANTAGES	RATIONALE
COMMON REDUNDANT BUS AND/OR RING	RELIABILITY		ONE NOISY STATION DISABLES WHOLE BUS.	
	COMPLEXITY	LOW, SINGLE RECEIVER PER STATION		
	BANDWIDTH		RESTRICTED BY NUMBER OF CHANNELS.	
	SENSITIVITY		POOR, HIGH COUPLING LOSSES	
ARPANET	RELIABILITY	BYPASSES DEFECTIVE PATH	SOFTWARE FOR FAULT DETECTION. ISOLATION AND BYPASS ROUTE	
	SENSITIVITY		POOR, HIGH COUPLING LOSSES	
	COMPLEXITY		ELABORATE PROTOCOL REQUIRED FOR ROUTING	
STAR WITH WDM	RELIABILITY	NO FAULT ELIMINATION PROTOCOL. NOISY STATION DOES NOT AFFECT ANY OTHER STATION		OFFERS BEST RELIABILITY, SENSITIVITY AND BANDWIDTH
	COMPLEXITY	NO DESIGNATOR PROTOCOL	ONE DETECTOR FOR EACH TRANSMITTER REQUIRED AT ALL STATIONS	
	BANDWIDTH	INDEPENDENT OF NUMBER OF STATIONS		
	SENSITIVITY	GOOD, COUPLING LOSSES 10-20 dB		

Figure 2.2.2.2-7. Internal Communication Link Architecture Tradeoff

Finally, the local communication technology characteristics are considered and the choice is between RF and optical transmission. An optical system is considered best because of its high data rate capacity and easy interface with internal communication optics. Preliminary link estimates show that ranges up to 1000 Km are possible using lasers with beam widths smaller than one degree.

The results of these tradeoffs are summarized in Figure 2.2.2.2-8. Using these technology choices, a general structure for the Space Station internal communication system emerges. All compartments or modules of Space Station are interconnected by devices known as Communication Interface Units CIU's. For reasons of criticality, there are three types of CIU's: A, B and C, each responsible for different types of communications. Type A CIU's are all linked to the main computer and carry digital data, commands and control. Type B CIU's carry caution/warning signals and telemetry information. Type C CIU's are responsible for the balance of Space Station's internal communications: private communications, TV, entertainment and intercomm.

There are three CIU's in each compartment or module (one of each type) and all CIU's of the same type are commonly linked by a star junction as shown in Figure 2.2.2.2-9. Information from any particular CIU sent into the star junction is distributed to all CIU's connected to it. It is therefore possible for any compartment or module of Space Station to communicate directly with any other.

Figure 2.2.2.2-10 shows a diagram for a typical CIU with redundancy. Information from a module is first converted to a digital form and encoded by Remote Interface Units (RIU's). This information is then mixed onto a binary laser using TDM and then sent to the star junction. Each laser has a discrete, unique wavelength so information from many compartments may be placed on the same optical fiber. Information from the star (which is the combined information from all other compartments) enters the CIU and is demultiplexed into separate channels using WDM. Each of these channels is received and demultiplexed, using TDM, onto the output lines of the CIU. The information out of the CIU is then decoded and converted by a RIU into the appropriate form for an output device (e.g., a TV camera).

STUDY AREA	OPTIONS	CRITERIA	COMMENTS
• INTERNAL COMM TECH	• FIBER OPTICS • HARD WIRE	• BANDWIDTH/DATA RATE • EXPANDABILITY • TECH. TRANSPARENCY • COMPLEXITY • RELIABILITY • LIFE CYCLE COST • SIZE, WT, POWER	• FIBER OPTICS IS BEST APPROACH IN ALL CATEGORIES.
• MULTIPLEXING	• FREQ DIV MUX (FDM) • TIME DIV MUX (TDM) • WAVELENGTH DIV MUX (WDM)	• DATA RATE • SNR/BER • EXPANDABILITY • TECH. TRANSPARENCY • COMPLEXITY • RELIABILITY • LIFE CYCLE COST	• TDM SELECTED FOR MUXING FUNCTIONS AT COMM INTERFACE UNIT. • WDM SELECTED FOR MUXING STATIONS (CIU'S)
• ARCHITECTURE	• REDUNDANT COMMON BUS • BIDIR. RING • ARPANET • STAR	• RELIABILITY • COMPLEXITY • EXPANDABILITY • COUPLING LOSSES	• COUPLING LOSSES LOW AND EQUAL FOR ALL STATIONS • ONLY STAR JUNCTION REQUIRES REDUNDANCY
• LOCAL COMM	• RF • OPTICAL	• BANDWIDTH/DATA RATE • SNR/BER • SIMPLICITY OF INTERNAL COMM INTERFACE • RELIABILITY • LIFE CYCLE COST	• OPTICAL (IR) XMISSION DIRECTLY COUPLES TO FIBER OPTICS

Figure 2.2.2.2-8. Initial Space Station Deployment-Internal/Local Communications Technology Trade Studies

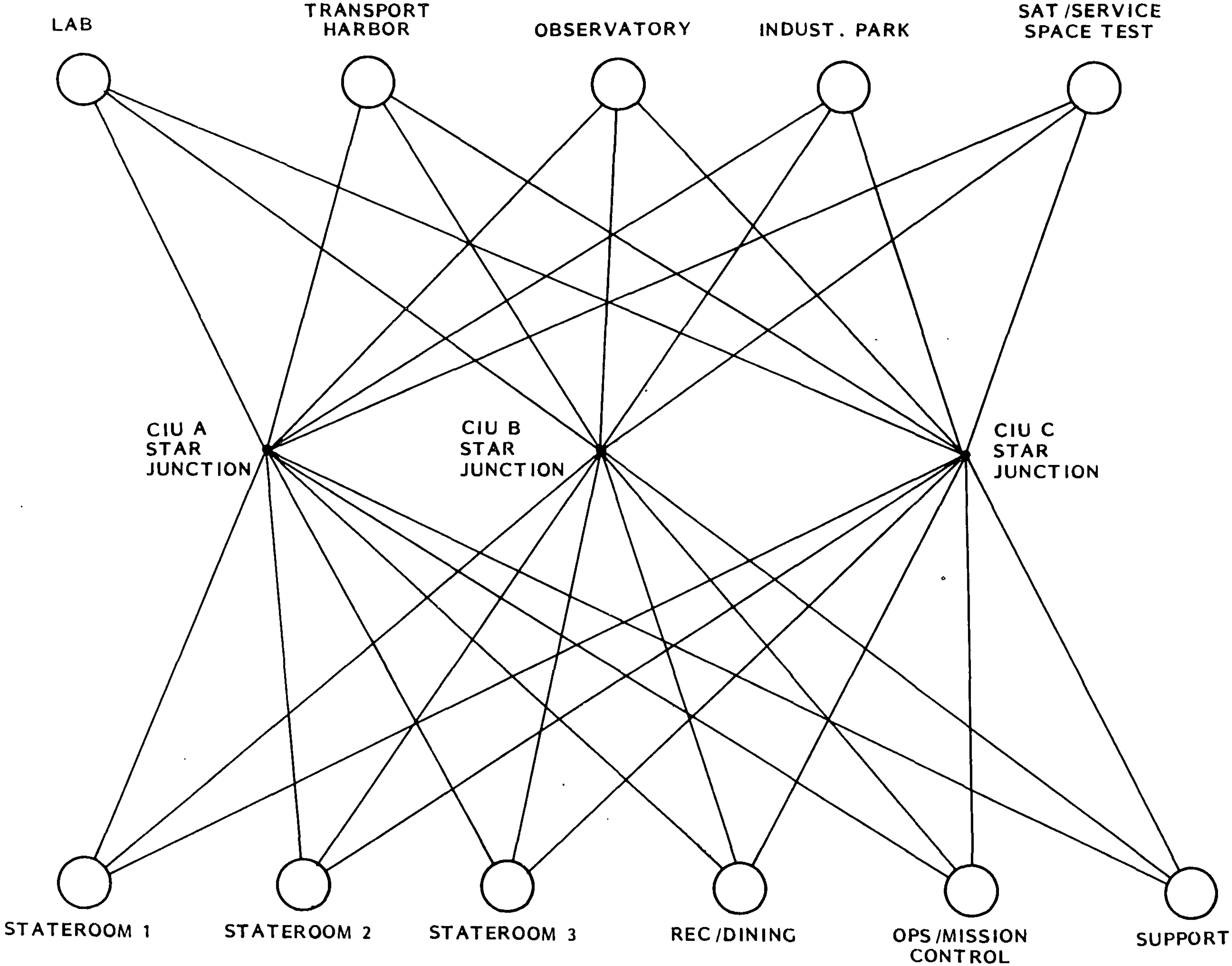


Figure 2.2.2.2-9. Space Station Internal Communications Star Configuration

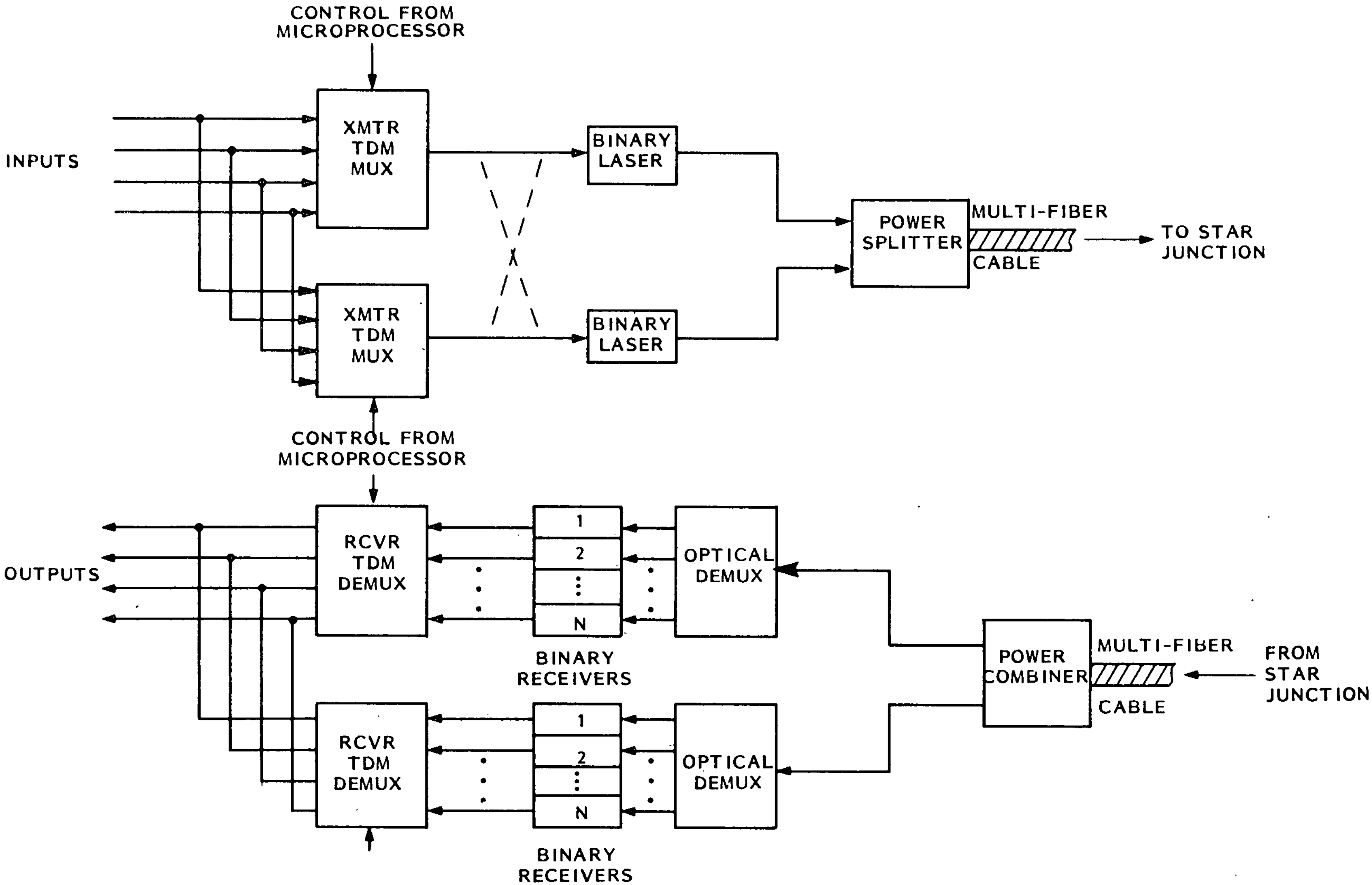


Figure 2.2.2.2-10. Typical CIU

2.3 CONCEPTUAL DESIGN

Having arrived at an architectural configuration, we proceeded to translate it into a conceptual design. This allowed us to estimate some of the more significant physical parameters that might be involved in IMS design. This section discusses those conceptual designs.

2.3.1 ON-BOARD DMS HARDWARE

The DMS, which consists of three major subsystems (i.e., Station Operations, Mission Operations and Data Routing) is illustrated in Figure 2.3.1-1.

As shown, the Data Routing Subsystem connects the Station Operations and Mission Operations subsystems. Data Routing acts primarily as a buffer between the TDRSS link to the Ground Segment and all other DMS processors. Additionally, it controls the Space Station internal communications system. The Data Routing subsystem consists basically of a star network with five nodes (representing the three major subsystems, Personnel Support, and Military Interface).

The Station Operations subsystem performs all functions necessary to operate and maintain the system. This includes such functions as flight scheduling, environmental control, thermal control, docking, etc. The Station Operation subsystem is comprised of five highly critical processing elements connected by a ring network. All processing elements are triply redundant with voting elements arbitrating the outputs.

The Mission Operations subsystem consists of a central mission support processor which communicates to individual ring networks of mission processors. One mission processor ring network exists in each of the Space Station physical compartments that performs missions. Missions are not considered critical, and are therefore not redundant.

2.3.1.1 DMS Components

The DMS consists of processing, data storage, communication, and interface elements. The distributed architecture of the DMS insures that microprocessors with the capability to operate at 700 thousand instructions per second (KIPS) and main memory units of one million bytes (Mbyte) are sufficient for all processing elements. Technology forecasts indicate that

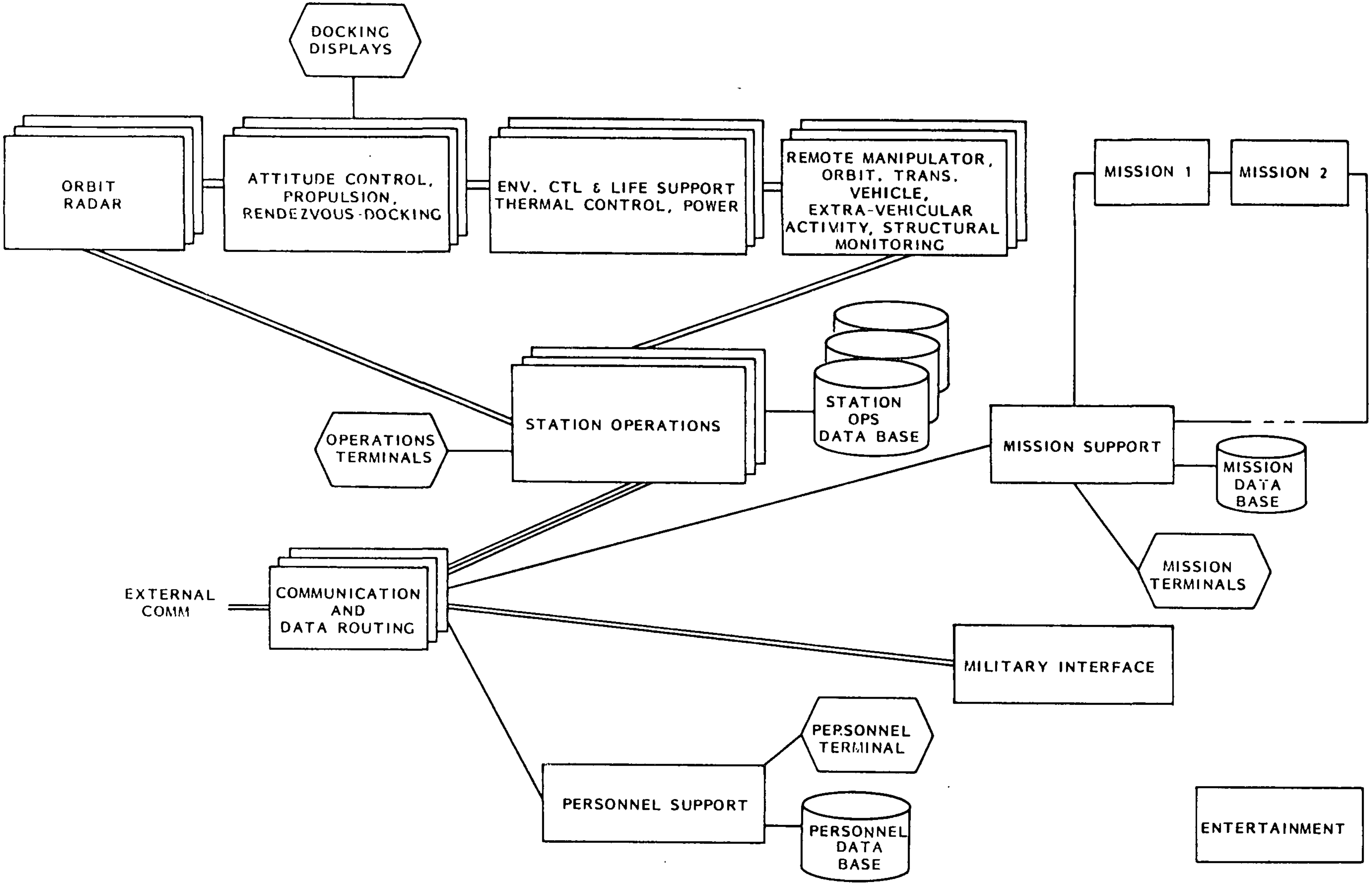


Figure 2.3.1-1. Space Station DMS Architecture

processors with these capabilities will be available as single board units in the space station time frame. In order to increase system maintainability, it is anticipated that all processors in the DMS will be implemented as identical single board microcomputers.

Data storage in the DMS consists of two types of storage: data base, which requires random access read/write capabilities, and mission data collection, which requires extremely high sequential write rates. Magnetic disk technology is the most appropriate for the data base applications. Although magnetic disks are not currently space qualified, it is reasonable to assume that due to the stable environment and the ability to assemble the disks on-board, the Space Station could support such devices. The high data rate storage devices recommended for mission data collection are optical disks. Optical disks offer significant cost and reliability advantages over high density magnetic tapes. Furthermore, the missions that require such high data rates do not occur until the second evolutionary growth, which allows time for technology development.

Communications throughout the DMS is via optical fiber links, for compatibility with the space station internal communication system.

Interface elements consist of human interfaces, network interfaces, and remote interfaces to sensors, actuator, etc. Human interfaces in the DMS consists primarily of keyboard/CRT units. These units have full color graphic capabilities. As technology advances in voice input and speech output it is expected that the keyboard/CRT units will be supplemented.

Network interface units in the DMS, interface processing units to ring networks. The interfaces (labeled "loop interface" or LI), interface to fiber optic communication links, one input and one output. Loop interfaces monitor address information in data circulating on the ring. Data addressed to the processor attached to the loop interface is forwarded to the processor; all other data is relayed to the next node on the ring. The LI has the capability to block data from nodes known to be faulty. In the Station Operations sub-network, the LIs also function as voters. That is, they accept three inputs from the redundant Station Operations processors, compare the data, and pass on data from two agreeing processors. If an error is detected, the two correct processors are informed that the third is in error.

Remote interfaces to actual sensors, actuators and other field equipment contain standard interfaces to the processor, and specialized interfaces to the remote equipment.

2.3.1.2 Data Routing Subsystem

A block diagram of the Data Routing Subsystem is shown in Figure 2.3.1-2. The central node, Communications and Data Routing is shown as a triply redundant processor. Connections A, B and C are redundant links to the Station Operations subsystem.

2.3.1.3 Station Operations Subsystem

Figure 2.3.1-3 illustrates the Station Operations Subsystem. Each processor in the system is triply redundant. The network is connected by two unidirectional ring networks. Data is passed around the rings in opposite directions, avoiding "chatty node" faults described in Section 2.2.1. The loop interface units act as voters, and detect processor errors by matching the output of three identical processors. The loop interface also provides all three processors with identical inputs to each of the three processors. Since each processor receives data from two loop interfaces, communication around the ring can be validated. CRC codes appended to data transmissions are used to detect most errors, the redundant links allow errors of ommission to be detected.

In the case of two failures in the communication system each of the processors will operate in a standalone mode.

2.3.1.4 Mission Operations - Initial

The initial space station will include only a few, low data rate missions. The simple ring network shown in Figure 2.3.1-4 illustrates the design of this subsystem. Since none of the operations are critical, redundancy is not included. The loop interfaces do not contain voting elements.

2.3.1.5 Mission Operations - First Evolution

Figure 2.3.1-5 illustrates the first evolution of the Mission Operations subnetwork. The system consists of two ring networks, one physically located in the habitat module, and one physically located in the transport harbor. The physical proximity of the rings to the experiments themselves greatly reduces demands on the internal communications system.

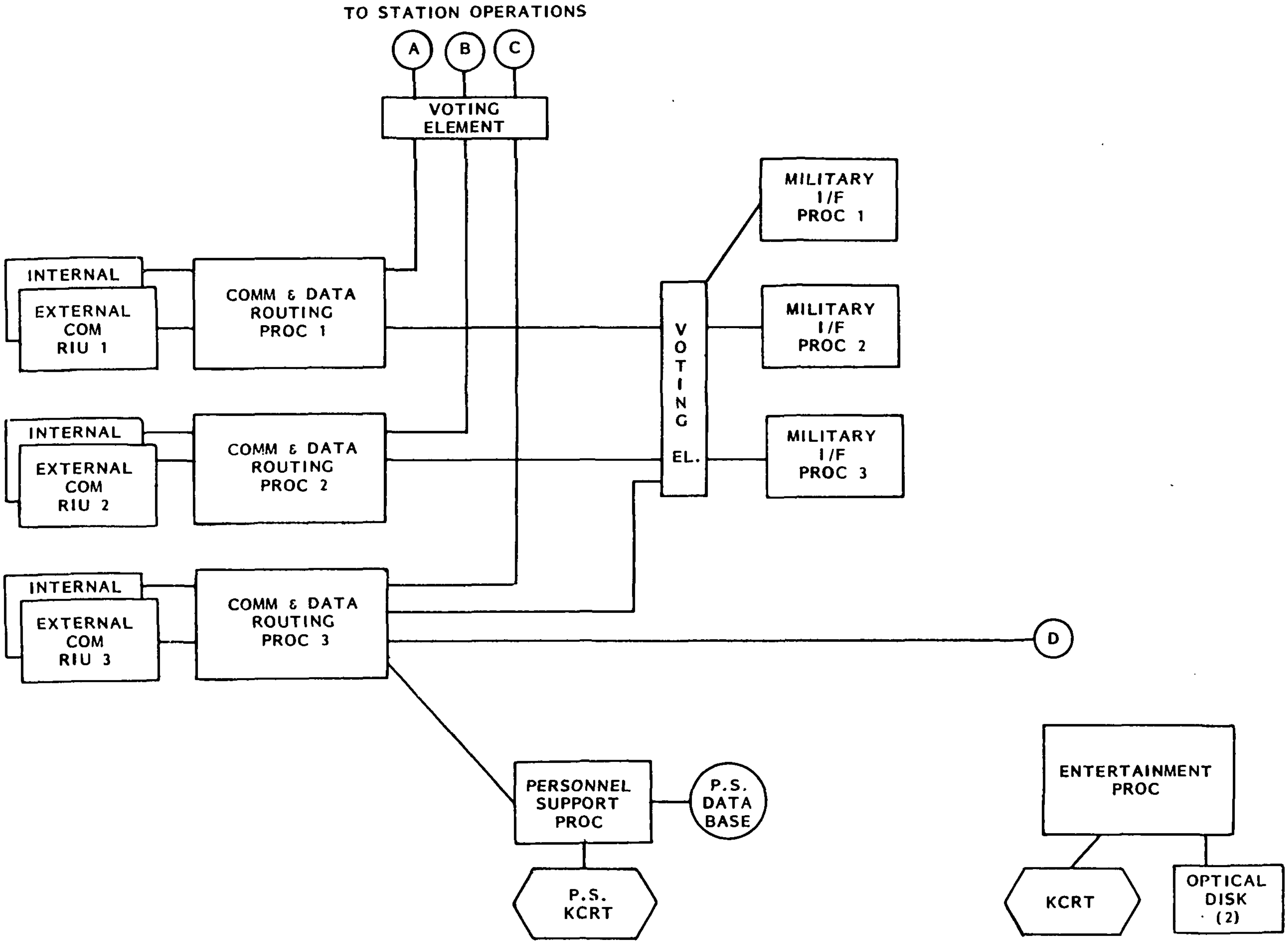


Figure 2.3.1-2. Data Routing Subsystem

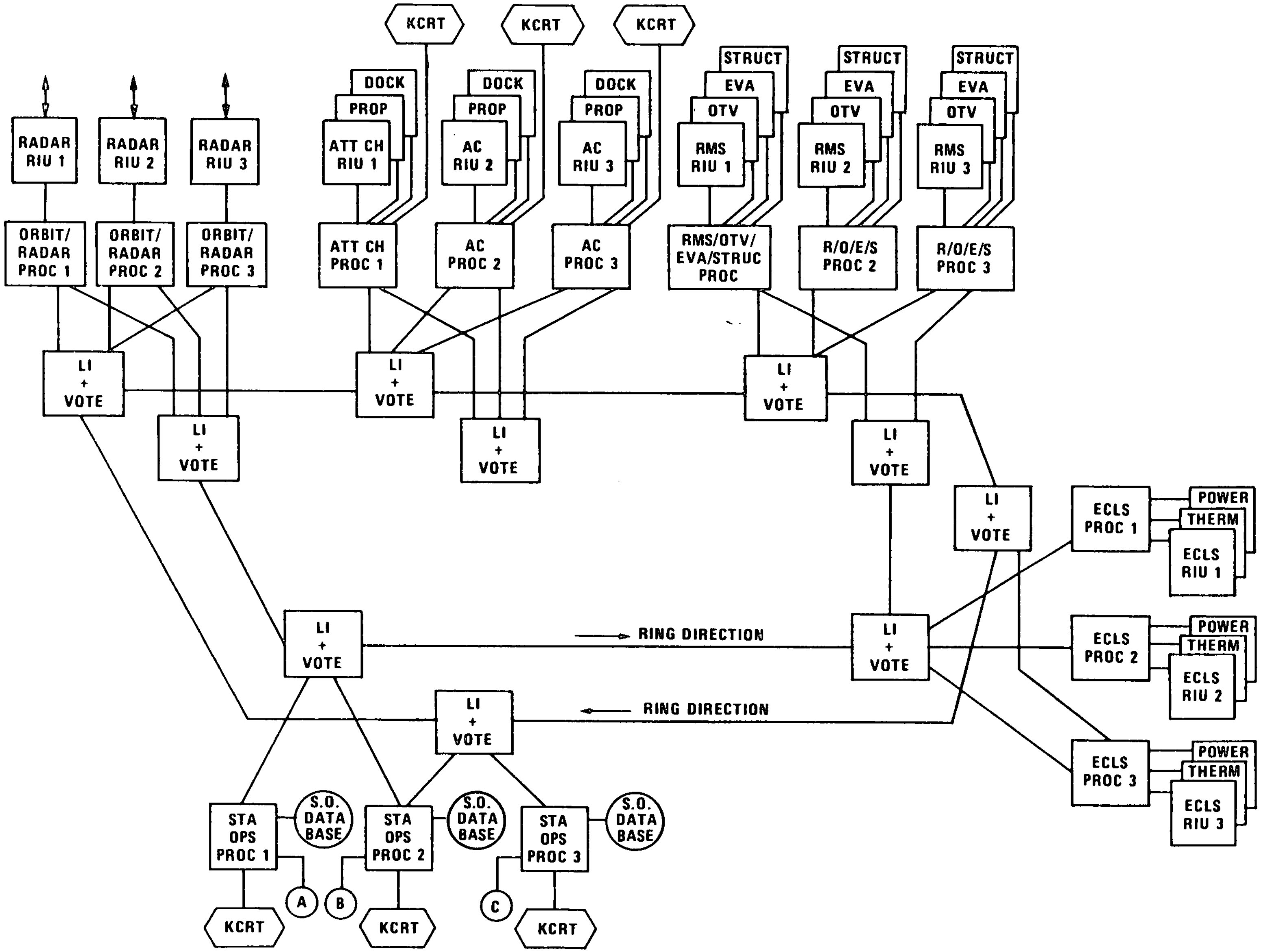


Figure 2.3.1-3. Station Operations Subsystem

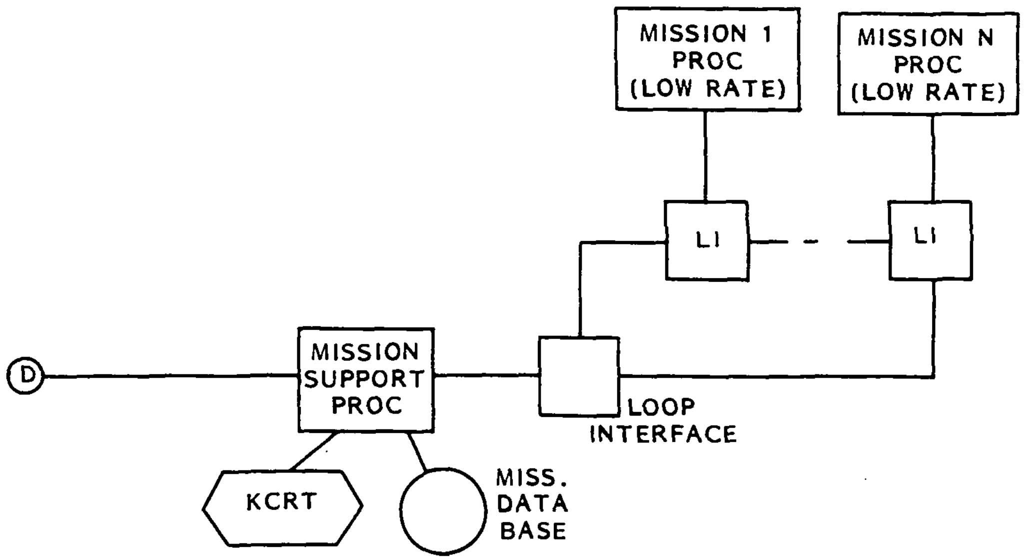


Figure 2.3.1-4. Mission Subsystem - Initial

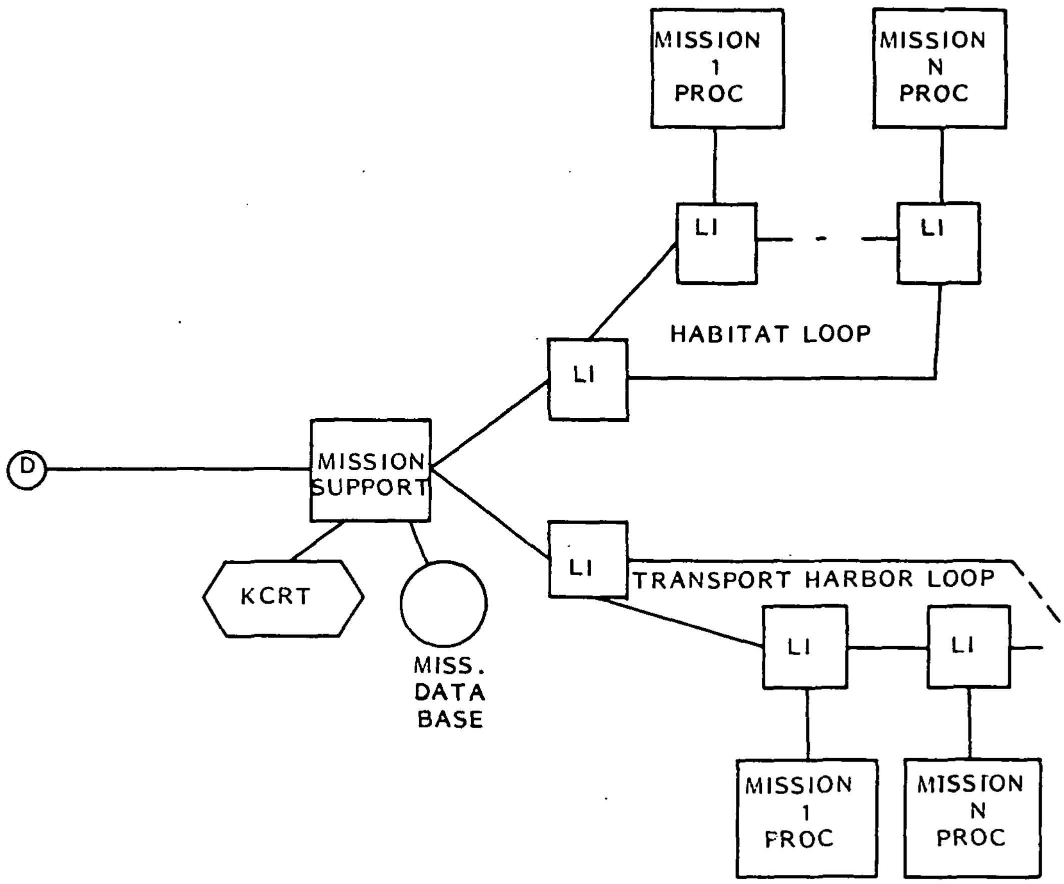


Figure 2.3.1-5. Mission Subsystem - First Evolution

2.3.1.6 Mission Operations - Second Evolution

Figure 2.3.1-6 illustrates the second evolution of the Mission Operations subnetwork. A third ring network for the observatory module is included with optical disk storage for high data rate experiments. Three disks are indicated with separate loop interfaces so that these resources can be time shared among several experiments. An optical disk is also included in the habitat module to support data collection for life sciences experiments.

2.3.1.7 Weight Power and Volume

Based upon the design stated above, weight, power and volume estimates were made. Table 2.3.1-1 shows the weight, power and volume for the second evolution of the entire space station. Tables 2.3.1-2, 2.3.1-3 and 2.3.1-4 show weight power and volume by physical module.

2.3.2 DMS SOFTWARE

Assessment of the requirements derived in Section 2.1 and the DMS Architecture derived in Section 2.2, enabled us to define on-board software requirements. This section contains a description of those major software elements, as well as some preliminary sizing and timing parameters.

Figures 2.3.2-1a and 2.3.2-1b depict the top level overview of the DMS applications software. As can be seen, there are six major areas titled: Station Operations, Personnel Support, Mission Operations, Communications Management, Astronaut Entertainment, and Military Systems Interface. More detail on each of these areas is presented herein. Also shown are the operations and mission networks. Our current approach is that these will be ring networks. The dashed lines leading to Astronaut Entertainment indicate that there is no direct link between this area and the rest of the DMS system. It is only a logical link. One could argue that television is considered part of entertainment,but this can really be supplied through proper configuration of the communications network in the Communications Management area. These six major areas reflect the current defined architecture of DMS, each area actually being a separate set of processors connected via a star network with the data routing node (the center node) containing the Communication Management software.

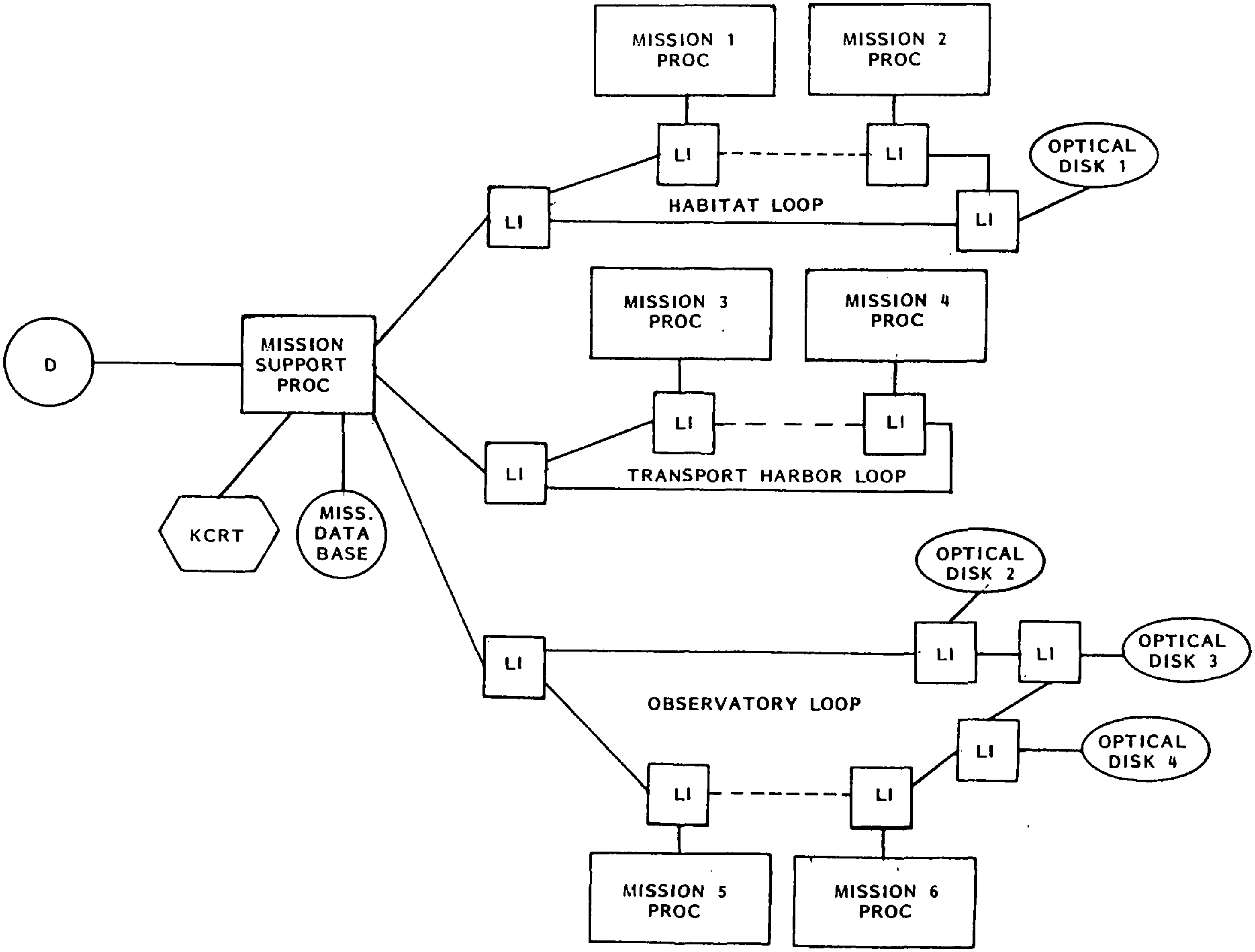


Figure 2.3.1-6. Mission Subsystem Second Evolution

Table 2.3.1-1. Space Station DMS Weight, Power and Volume Characteristics

Device	Quan.	Wt. (lbs.)	Total Wt. (lbs.)	Power (watts)	Total Power (watts)	Vol. cu. ft.	Total cu. ft.
Optical Disk	6	30	180	50	300	0.75	4.5
KCRT	9	35	315	51	459	1.7	15.3
Mag. Disk	5	140	700	300	1500	3	15
Processors	51	.332	16.9	.332	16.9	0.01	.51
Interface Units	150	.332	49.8	.332	49.8	0.01	1.5
Total			1261.7 lbs.		2325.7 watts		36.81 cu. ft.

Table 2.3.1-2. Space Station DMS Habitat Module Weight, Power and Volume Characteristics

Device	Quan.	Wt. (lbs.)	Total Wt. (lbs.)	Power (watts)	Total Power (watts)	Vol. cu. ft.	Total cu. ft.
Optical Disk	3	30	90	50	150	0.75	2.25
KCRT	6	35	210	51	306	1.7	10.2
Mag. Disk	5	140	700	300	1500	3	15
Processors	32	.332	10.6	.332	10.6	0.01	.32
Interface Units	109	.332	36.2	.332	36.2	0.01	1.09
Total			1046.8 lbs.		2002.8 watts		28.86 cu. ft.

Table 2.3.1-3. Space Station DMS Transport Harbor Weight, Power and Volume Characteristics

Device	Quan.	Wt. (lbs.)	Total Wt. (lbs.)	Power (watts)	Total Power (watts)	Vol. cu. ft.	Total cu. ft.
Optical Disk	0	-	0	-	0	0	0
KCRT	3	35	105	51	153	1.7	5.1
Mag. Disk	0	-	0	-	0	-	0
Processors	6	.332	2	.332	2	0.01	0.06
Interface Units	12	.332	4	.332	4	0.01	0.12
Total			111 lbs.		159 watts		5.28 cu. ft.

Table 2.3.1-4. Space Station DMS Observatory Weight, Power and Volume Characteristics

Device	Quan.	Wt. (lbs.)	Total Wt. (lbs.)	Power (watts)	Total Power (watts)	Vol. cu. ft.	Total cu. ft.
Optical Disk	3	30	90	50	150	0.75	2.25
KCRT	0	-	0	-	0	-	0
Mag. Disk	0	-	0	-	0	-	0
Processors	13	.332	4.3	.332	4.3	0.01	0.13
Interface Units	29	.332	9.6	.332	9.6	0.01	0.29
Total			103.9 lbs.		163.9 watts		2.67 cu. ft.

A top level DMS software partitioning is presented in Figure 2.3.2-2. As can be seen the software is divided into two major categories: system software and applications software. The application software has been derived from the space station functional requirements, while the support software is generic to all the application areas and used by each. It provides all support required for the applications software to perform their job properly. The support software will also be described in more detail.

A high level interface for the DMS software is shown in Figure 2.3.2-3. This diagram dictates that all data base access be performed through the Data Base Management System, to assure that rigid control is maintained over the various data base files in DMS. Another point is that all operator input and all output to the operator (both hardcopy and displays) is performed by the Man/Machine Interface software. A final consideration is that all communications between the major areas are done via the Network Control software. The Network Control software also supports all communication between processors for the Station and Mission Operations areas.

2.3.2.1 System Software
(See Figure 2.3.2-3A)

2.3.2.1.1 Operating System
An important part of any software system is the operating system (Figure 2.3.2-4). An important feature of this operating system is that it must be fault tolerant. This is especially true in a Space Station environment. It is intolerable to have the system crash when a problem occurs. If possible the fault tolerant operating system should be an off-the-shelf vendor product with as few modifications as possible. It should also support multi-tasking features. It must be possible to assign some level of priorities to the various application software tasks, more critical tasks having higher priorities than non-critical tasks. The operating system must be able to effectively manage its resources. This includes memory management as well as management of any peripherals connected to the system. Support should be provided for interrupt handling and data security.

2.3.2.1.2 Man/Machine Interface (MMI)
An important aspect of any software tasks is its method of interfacing with human beings. The purpose of the MMI is to create a user friendly interface.

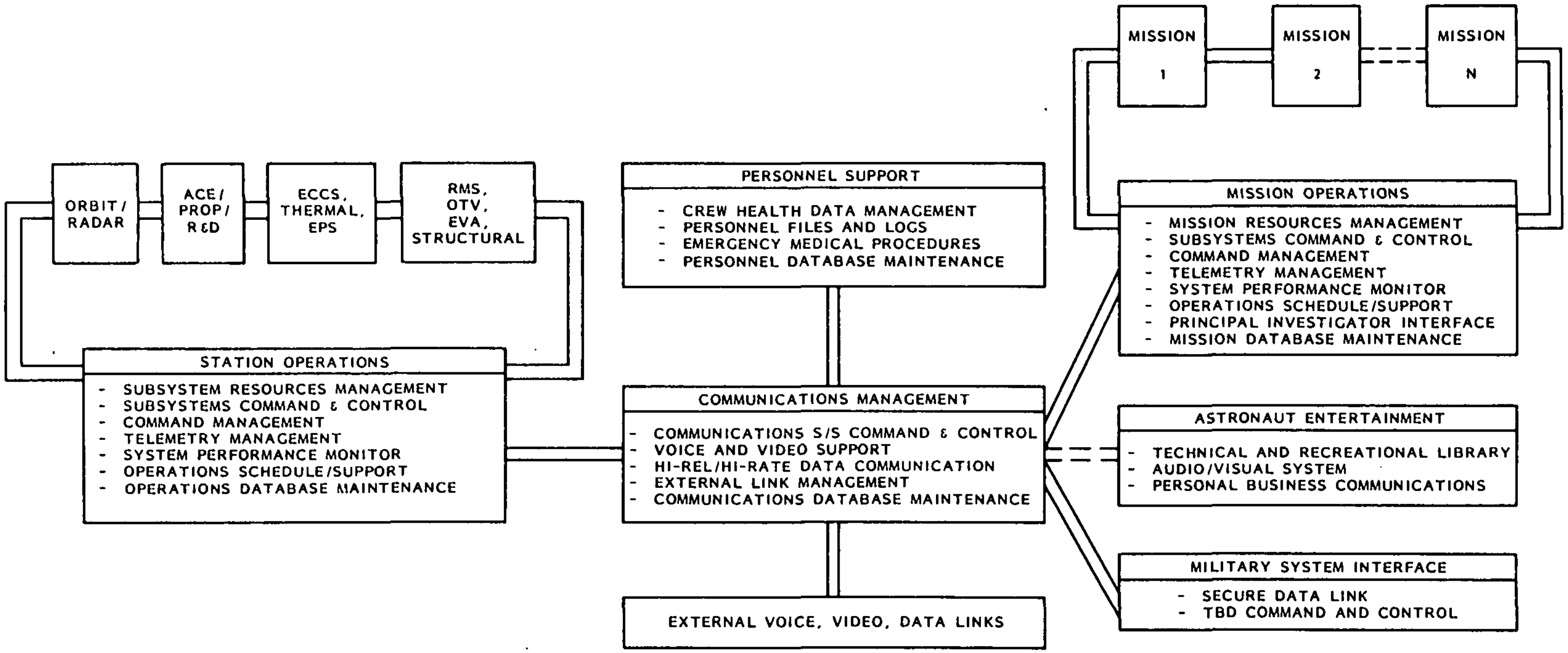


Figure 2.3.2-1a. DMS Applications Software Overview

STATION OPERATIONS (CRITICAL/NON-CRITICAL)

- SUBSYSTEM RESOURCE MANAGEMENT (C)
  - PRIORITIZED ADVANCE SCHEDULING
  - R/T RESOURCE ARBITRATION/REALLOCATION
  - SUBSYSTEM COMPUTATIONAL SUPPORT
- SUBSYSTEMS COMMAND AND CONTROL (C)
  - ELECTRICAL POWER
  - ENVIRONMENTAL CONTROL/LIFE SUPPORT
  - GUIDANCE AND NAVIGATION/ATTITUDE CONTROL
  - RADAR (COLLISION AVOIDANCE)
  - RENDEZVOUS AND DOCKING
  - STRUCTURAL CONTROL
  - THERMAL CONTROL
  - PROPULSION
- COMMAND MANAGEMENT (C)
  - SEQUENCE GENERATION, VALIDATION, STORAGE
  - SEQUENCE TRANSMISSION AND SAFETY INTERLOCK
  - COMMAND VERIFICATION
- TELEMETRY MANAGEMENT (C)
  - TLM ACQUISITION
  - S/S REAL-TIME DATA DISPLAYS
  - S/S ALARMS RECOGNITION/RESPONSE
  - TLM STORAGE AND RETRIEVAL
  - PLAYBACK PROCESSING
- SYSTEM PERFORMANCE MONITORING/EVALUATION (NC)
- STATION OPERATIONS SCHEDULING/SUPPORT (NC)
  - PROCEDURES AND TIMELINES
  - LOGISTICS
- OPERATIONS DATABASE MAINTENANCE (NC)

ENTERTAINMENT (ALL NON-CRITICAL)

- TECHNICAL AND RECREATIONAL LIBRARIES
- AUDIO/VISUAL SYSTEM
  - CABLE-TYPE TV AND GAMES
  - EDUCATIONAL PROGRAMMING
  - RECORDING AND PLAYBACK
- PERSONAL/BUSINESS COMM. INTERFACE

PERSONNEL SUPPORT (ALL NON-CRITICAL)

- CREW HEALTH DATA COLLECTION AND EVALUATION
- EMERGENCY MEDICAL PROCEDURES
- PERSONNEL FILES AND LOGS
- PERSONNEL SUPPORT DATABASE

COMMUNICATIONS MANAGEMENT (CRITICAL)

- VOICE AND VIDEO SUPPORT
  - PRIVATE LINES, CONFERENCING
  - TAPING AND PLAYBACK
- HI-REL/HI-RATE DATA COMMUNICATIONS
  - MESSAGE SWITCHING
  - DATA BUFFERING
  - PRIORITIZED CHANNEL SCHEDULING
- EXTERNAL LINK MANAGEMENT
  - REMOTE OPERATORS, OTV/S, FREE FLYERS, ETC
  - TDRSS
  - GROUND-DIRECT
  - OTHERS
- COMMUNICATIONS SUBSYSTEM COMMAND AND CONTROL
- COMMUNICATIONS MANAGEMENT DATABASE MAINTENANCE

MISSION OPERATIONS (NON-CRITICAL)

- MISSION RESOURCES MANAGEMENT
  - PRIORITIZED ADVANCE SCHEDULING
  - R/T RESOURCE ARBITRATION/REALLOCATION
  - SUBSYSTEM COMPUTATIONAL SUPPORT
- MISSION SUBSYSTEMS CONTROL AND SUPPORT
  - GENERIC MISSION SUPPORT PACKAGES
  - MISSION-SPECIFIC SUBSYSTEMS
  - INTERFACE TO OTHER STATION RESOURCES
- COMMAND MANAGEMENT
  - SEQUENCE GENERATION, VALIDATION, STORAGE
  - SEQUENCE TRANSMISSION AND SAFETY INTERLOCK
  - COMMAND VERIFICATION
- TELEMETRY MANAGEMENT
  - TLM ACQUISITION
  - MISSION STATUS AND PERFORMANCE MONITORING
  - MISSION REAL-TIME DATA DISPLAYS
  - MISSION ALARMS RECOGNITION/RESPONSE
  - TLM STORAGE AND RETRIEVAL
  - PLAYBACK PROCESSING
- MISSION SYSTEM PERFORMANCE MONITORING/EVALUATION
- MISSION OPERATIONS SCHEDULING/SUPPORT
  - PROCEDURES AND TIMELINES
  - LOGISTICS
- PRINCIPAL INVESTIGATOR VOICE/VIDEO/DATA INTERFACE
- MISSION SUPPORT DATABASE MAINTENANCE

MILITARY SYSTEMS INTERFACE (ALL CRITICAL)

- SECURE, HIGH-RATE DATA INTERFACE
- TBD SUPPORT

Figure 2.3.2-1b. Major Nodes - DMS Functional Allocation

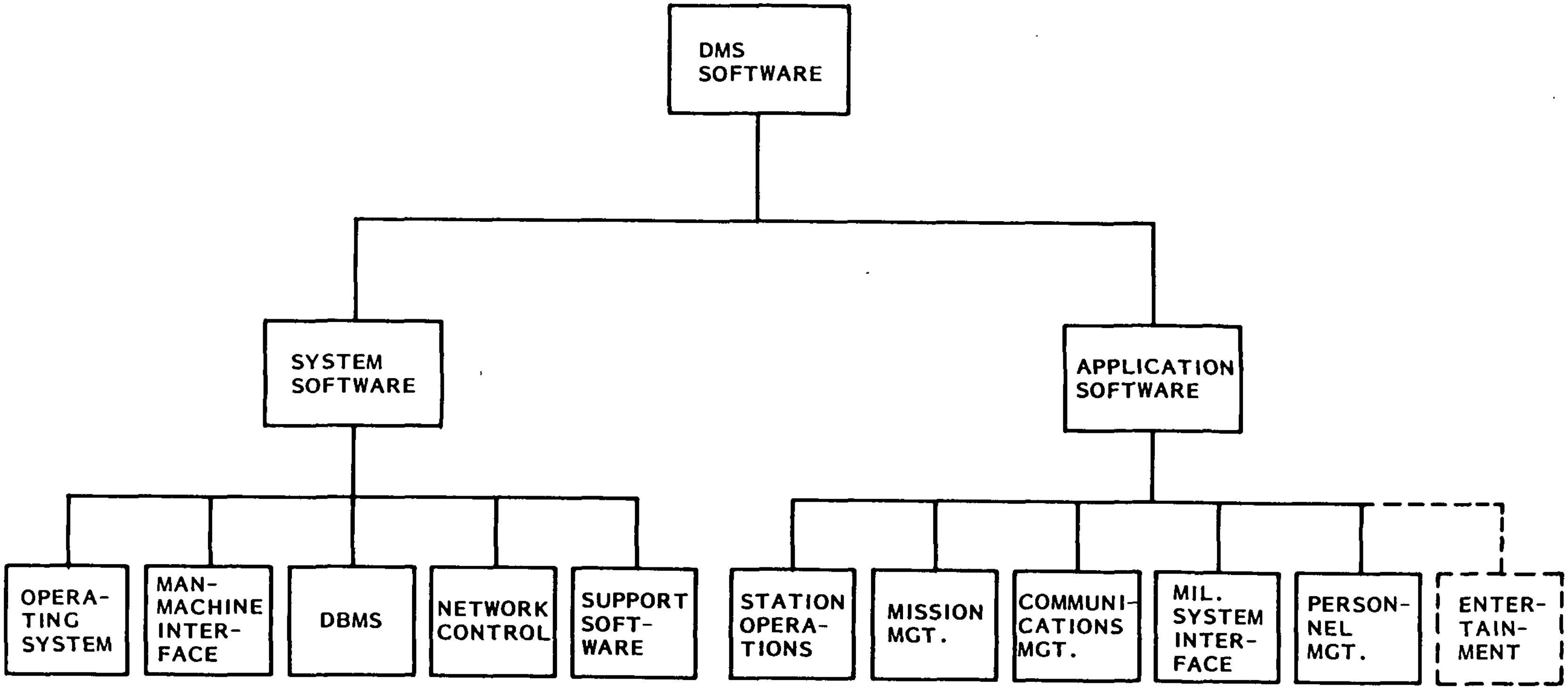


Figure 2.3.2-2. DMS Software Partitioning

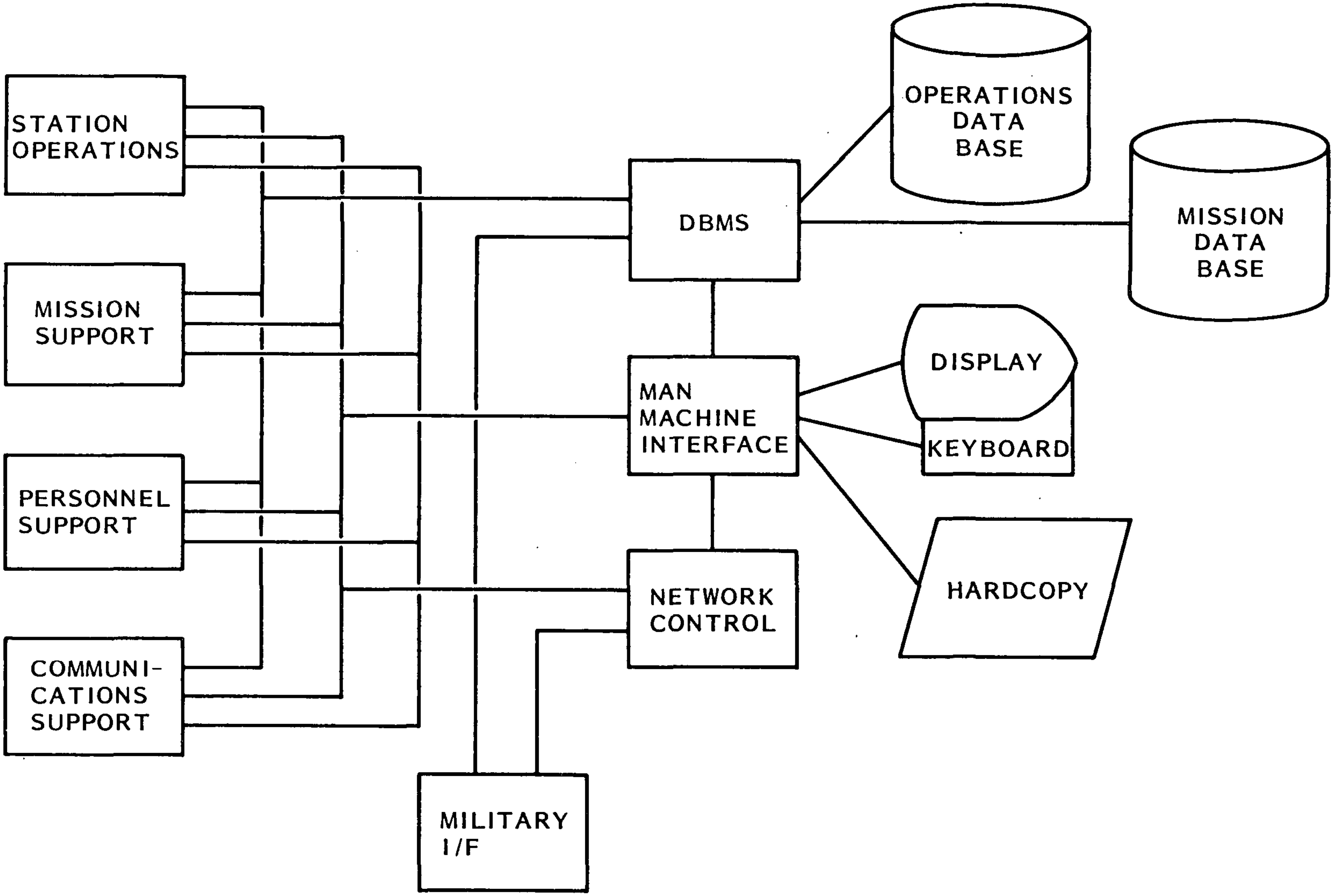


Figure 2.3.2-3. DMS Software Interface

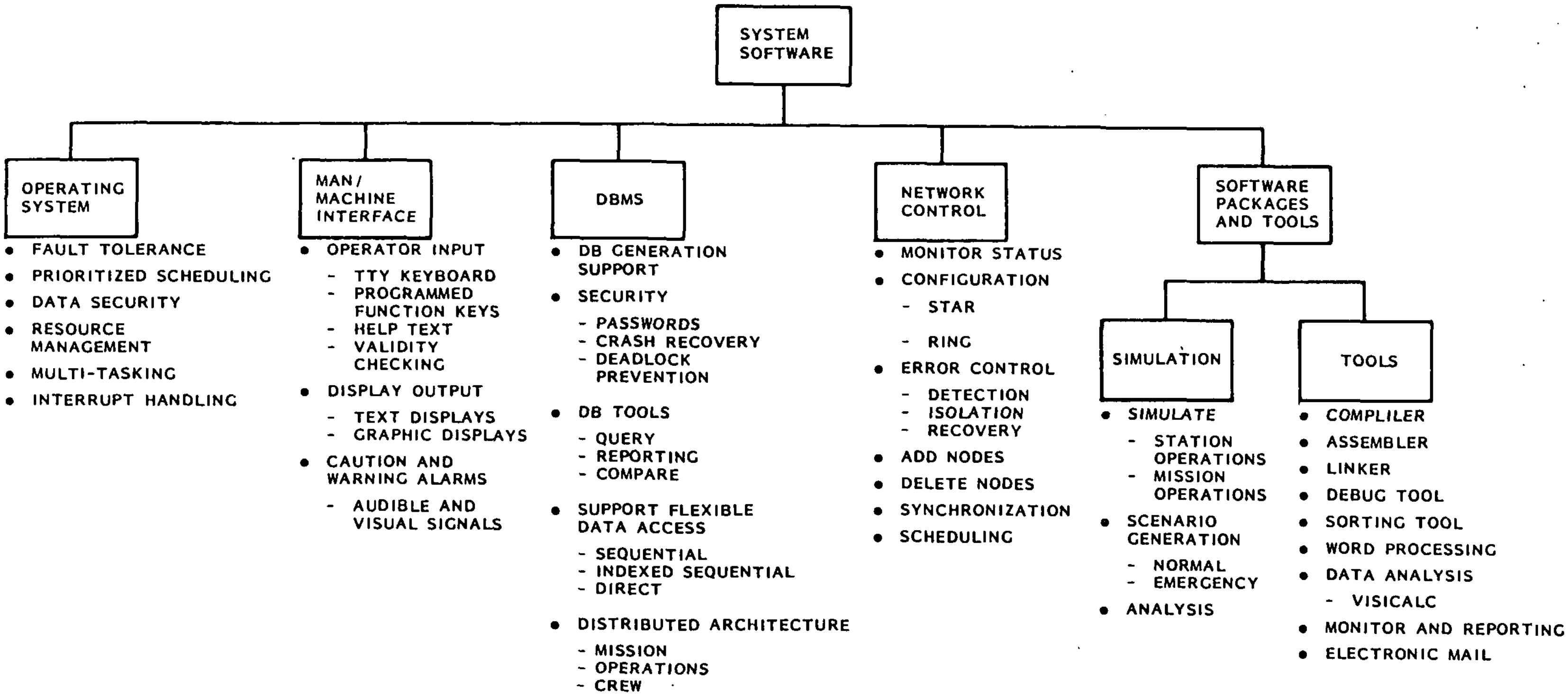


Figure 2.3.2-3A. System Software Overview

OPERATING SYSTEM

- FAULT TOLERANT
- PRIORITIZED TASK SCHEDULING
- DATA SECURITY
- RESOURCE MANAGEMENT
- MULTI-TASKING
- INTERRUPT HANDLING
- INTERPROCESS COMMUNICATION
  - QUEUE
  - EVENTS

Figure 2.3.2-4. System Software - Operating System

All software modules which must display information or get information from the operator must do so through support routines supplied by the MMI segment. This enforces consistency of input/output from/to terminals and hardcopy devices. Figure 2.3.2-5 summarizes the MMI requirements and is explained in more detail in the following sections.

A. Operator Input

Of primary importance to the system is an MMI that simplifies the input of information from the operator as much as possible. This simplification should be done in a manner which will reduce the number of operator errors. Good operator prompts and help facilities aid the operations procedures. When the operator is prompted for an input, the display of "help" information, will make the operators job easier, and can reduce the number of errors the operator will make during data entry. It is important that these help displays do not interfere with the current information being displayed on the screen. It is acceptable to overlay the current display as long as that display can be redisplayed after the help information is read. Another method of reducing the number of operator errors is to give the operator a limited number of choices (when applicable) in the form of menus. Menus will be used whenever possible. If the operator is prompted for numeric information, the range of acceptable inputs must be displayed. While the operator is entering information into the system, the ability to edit his input before entry must be provided. All operator input must be validated whenever possible. This checking must consist of at least range checking for all numeric inputs and menu selection validation. If an error is detected during validation, the operator should be informed of the error and be given the opportunity to make a valid reentry to correct the invalid input. Input could be obtained from either terminal keyboards or from programmed function keys (PFK). PFKs allow the operator to perform the equivalent of several keystrokes or commands via one PFK keystroke. This is useful in reducing the number of operator errors and increasing the speed at which the operator can utilize the system by reducing keystrokes.

B. Display

A second major area of MMI is that of display output to the operator. An objective of MMI in displays is that of making the displays as readable as possible. This can be achieved by consistency, proper use of color, and in general proper formatting of the displays themselves. All displays should

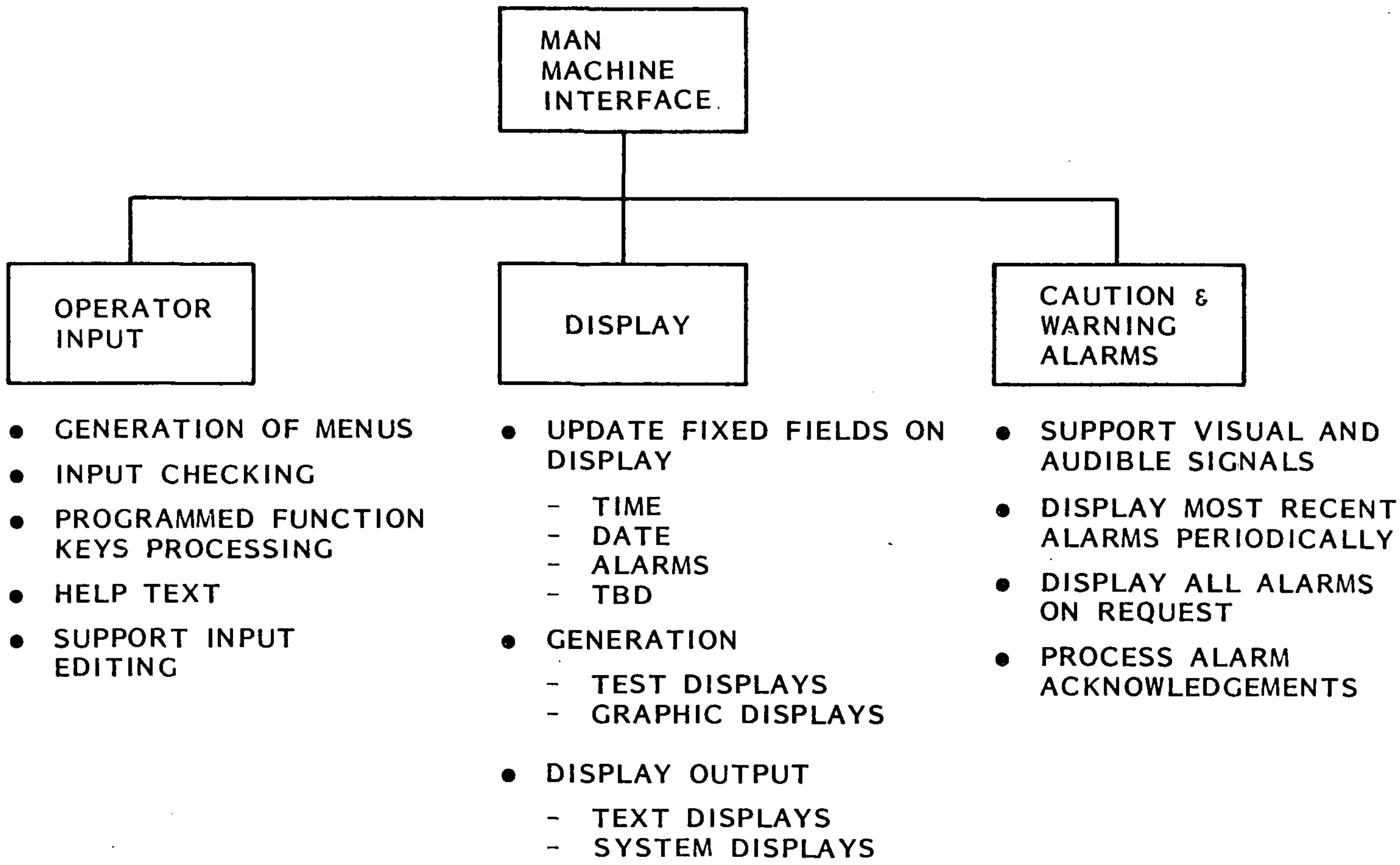


Figure 2.3.2-5. System Software - MMI

contain at least the current time and date. These fields should always be in the same location on the screen and must be updated to assure currency. Displays shall consist of but are not limited to: text displays, graphic displays, menus, prompts, alarms, error messages, status messages, procedures, help messages, etc. The ability to easily move though a series of displays should be provided (for example by paging forward/backward). It should be possible to output and update the same display page on more than one screen as might be the case when display terminals are located in different facilities on-board the station. In general all displays can be directed to a hardcopy printer.

C. Caution and Warning Alarms

The last area to be discussed in MMI is that of display of alarms. The most recent high priority alarms must always be displayed. This requires a dedicated area on the display screen for these alarms. As new alarms come in, they would be displayed at the top of the display alarm area. Alarms must be supported by both audible and visual signals to make the operator aware of the problem. It should be possible to categorize alarms by criticality. A means should be provided to inhibit/uninhibit alarms from occurring on an alarm by alarm basis. Upon request all current alarms could be displayed on the screen. Once an alarm occurs, it should not be removed from the alarm queue until it has been acknowledged by the operator. The operator should be informed when an alarm returns to a normal state. The possibilities of several levels of alarm should also be considered.

2.3.2.1.3 Data Base Management System (DBMS)

Figure 2.3.2-6 depicts the software requirements for a DBMS.

A. Generation

In general, generation of the data base should be performed on the ground. Modification of the data base is considered a maintenance function and is covered below.

B. Maintenance

Data base maintenance can be divided into two sections, archiving and modification. An archive tool should be provided which can be used to archive all or part of the data base to an external media. It should be possible to

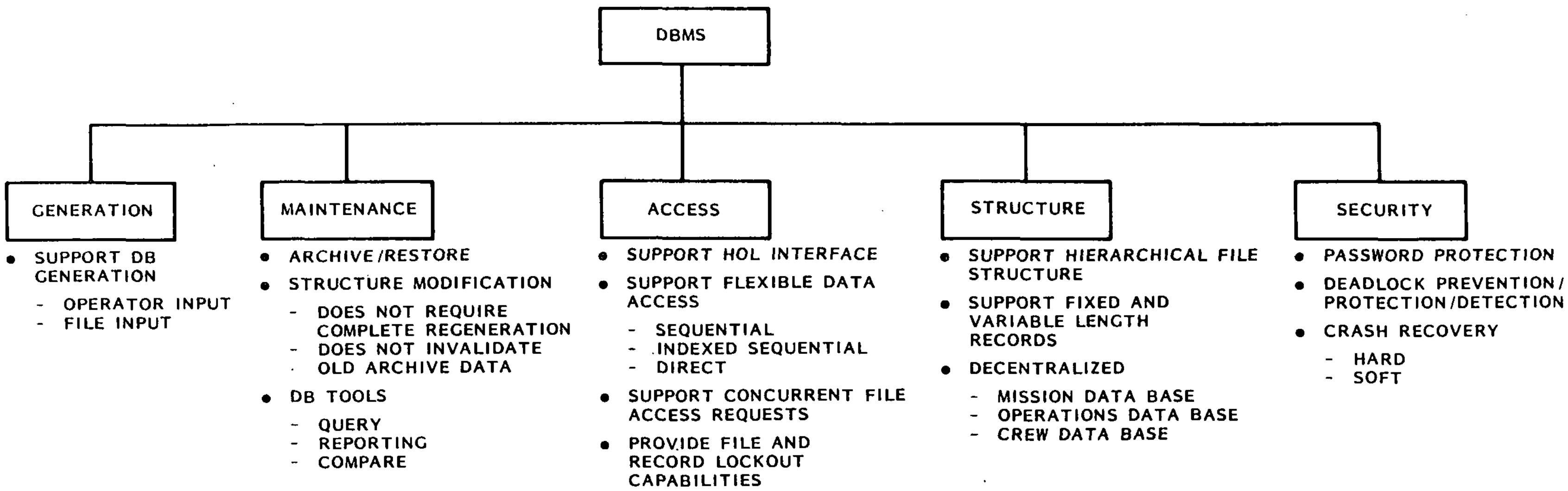


Figure 2.3.2-6. System Software - DBMS

qualify which files or records are to be archived based on date, type, and whether or not any changes have been made since the last archive. It should be possible to list the contents of or restore part or all the contents of an archive media to the data base upon request, and to compare the contents of an archived media to the contents of the data base.

Tools should be provided to facilitate structure modifications to the data base. A modification to the structure of the data base should not require a complete regeneration of the data base. It is also required that structure modifications do not invalidate those archives which were performed before the modification took place.

C. Access

All access to the data base must be performed through the DBMS. The DBMS must provide a high level language (HOL) interface for the selected language to assure that all access is indeed performed via the DBMS. The DBMS should provide an interactive mode of access which can be used to display the structure, current values, and modify the values in the data base. The ability to access a data base in a processor other than the one in which the task resides must be provided.

At least three types of access must be available through the HOL interface. They are: sequential, indexed sequential, and direct. Three access modes must be available for file access. They are: read only, write only, and read/write (update). The DBMS must be able to coordinate concurrent requests from different tasks in the same processor and from tasks in different processors. It must also allow for a file to be accessed from two different tasks at the same time when it is opened for read only. Provisions must be made for file and record lock capabilities.

D. Structure

The DBMS should support a hierarchical type file structure. This hierarchical structure should be at least TBD levels deep and shall be easily accessible from the applications software. The use of a data dictionary should be considered to support DBMS operations. As a minimum, both fixed and variable length records will be supported. The DBMS should also be capable of being decentralized. There could be at least six major divisions in the data base corresponding to the six major nodes in the star network. There could also be several small data bases in the station operations network, to provide autonomy.

E. Security

An important feature in any DBMS is that of security. File access security should be provided via file protection codes and file password protection. The operating systems file manager will provide the file protection codes. It will be the DBMS's responsibility to assure that any file which is defined to require a password for access is accessed using that password. This applies to both HOL access and interactive access.

Another consideration in security is that of crashes. All efforts must be made to assure that if a soft or hard crash occurs the data base is not left in an inconsistent intermediate state. If a crash occurs during the middle of an update, it is possible that the data base will be left in a state where only half of the update occurred. Provisions should be made to assure that this does not happen, of if it does that a convenient method of recovery is available.

A final consideration in security is that of deadlock control. If two tasks both have a file open, and they both need the file the other has open, they may wait forever for each to release the other's file. Some mechanisms of deadlock prevention/detection/protection must be provided to prevent such deadlocks from occurring.

2.3.2.1.4 Network Control

Since the DMS for the space station has a distributed architecture, software is required for monitoring, controlling, and operating the networks. Figure 2.3.2-7 depicts the requirements for that software and is described in more detail in the following paragraphs.

A. Monitor

Software must be provided for monitoring the network. This will involve some type of polling activity. All nodes in the network must report their current status to the monitoring activity. Any changes in node status, such as faults (hardware and software), must be reported to the operator.

B. Control

A second part of the network software area is that of control of the network. Support must be provided to assure that all parts of the network are in synchronization with each other. Methods for display and modification of schedules required for node transmission must be provided. Tools should be provided for initial definition, display, and modification of the configuration of the network. At least two types of configuration must be supported. They are star networks and ring networks. A means of adding and deleting nodes in the network without adverse affect on the rest of the nodes in that network must be provided.

An important part of control is error control. Software must be provided for the detection of both hard and soft errors in the network. After the error is detected, it should be possible to isolate the node in error, and to recover from the error without adverse affects on the rest of the network. Isolation and recovery may simply be node deletion and addition. All errors detected must be recorded for the operator. If a node detects that it has a problem this fact must be sent to the monitor software described above.

C. Operations

The real purpose of a network is to transfer data from one node to another. A method of initiating this process must be provided by some initialization procedure. After the network is initialized, transfer of information can commence. A data transfer protocol must be defined and implemented in order to support this process. This could be a multi-layered hierarchical protocol with the application software at the highest level and the data transfer media (bus) at the lowest level. It is not required that the processors be of the same type, only that they use the same protocol for communication. It is important that fault detection be provided at this level. If an error in transmission is detected during operations, the opportunity for retransmission should be provided. The number of retrys should be adjustable on a node basis. All error detected must be recorded for the operator.

2.3.2.1.5 Software Packages and Tools

Figure 2.3.2-8 depicts the software packages and tools requirements.

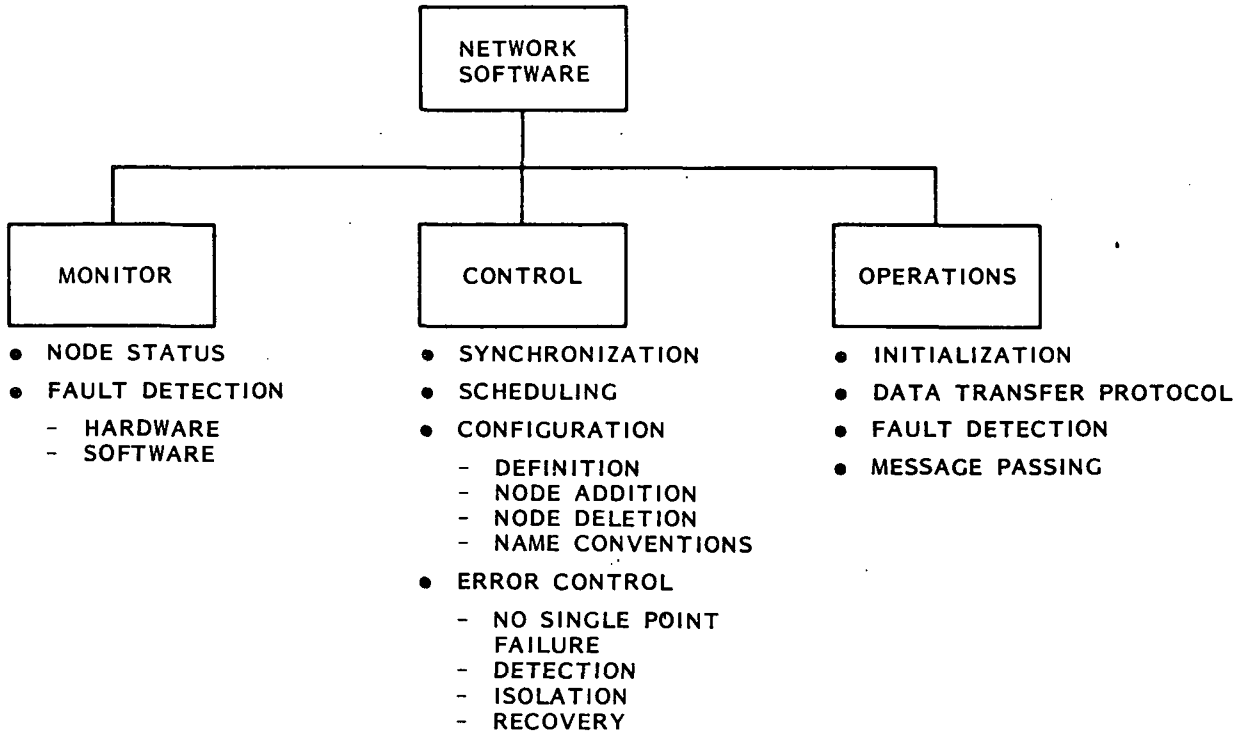


Figure 2.3.2-7. System Software - Network

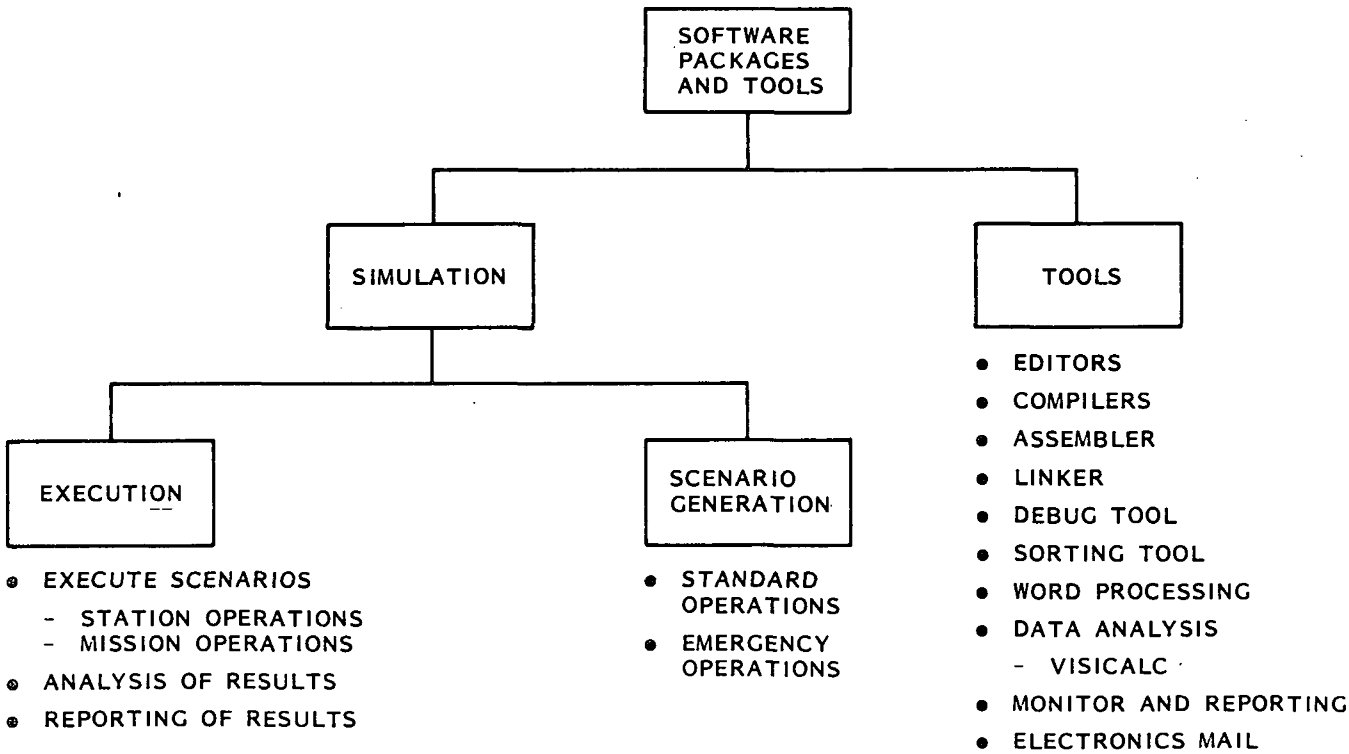


Figure 2.3.2-8. System Software - Software Packages and Tool

A. Simulation

It is assumed that some training will be done on-board the space station. To support this training, simulation software is required. The simulation software is divided into two categories: scenario generation and environment simulation. It should be possible to accurately simulate all station operations and mission operations. This simulation should not adversely affect actual operations. Tools will be provided to perform analysis of responses and to report the results of the simulation. The simulation should be able to use real time data, archived data, or simulated data as input to the simulation.

In order to support simulation, scenario generation is required. These scenarios can be used to simulate both standard operations and emergency operations and can be stored for repeated use, as required.

B. Tools

The space station software may require the following tools:

1. Editors
2. Compilers
3. Assembler
4. Linked
5. Debug Tool
6. Sorting Tool
7. Word Processing
8. Data Analysis
9. Monitor and Reporting Tools
10. Electronic Mail

2.3.2.2 Applications Software

2.3.2.2.1 Station Operations

Station Operations Software is responsible for the planning, support and evaluation of all Space Station operations. Included functions are Flight Operations Command and Control, Station Operations Support, and Remote Operations Command and Control.

A. Flight Operations, Command, and Control

Flight Operations Command and Control functions, depicted in Figure 2.3.2-9, include Telemetry and Command Management, Scheduling and Allocation of Station Resources, and Command and Control of the Major Station Subsystems.

Telemetry Management

Telemetry Management involves the collection, preprocessing, analysis, and storage of Space Station Telemetry. Telemetry Management's key responsibility is to monitor the status and performance of critical Space Station Subsystems. This provides support for the real-time allocation of scarce station resources and the timely recognition and resolution of alarm conditions. Telemetry Management is also responsible for station data storage and retrieval, extended subsystem analysis support, and transmission of station data to the ground.

Command Management

Command Management involves the preparation, validation, transmission, and verification of Flight Operations commands and command sequences. A major responsibility of the Command Management function is the provision of safety interlock processing during the command transmission activity. All commands are screened for a number of conditions prior to being passed on to the relevant subsystems including: commanding of dangerous system configurations, attempts to command unavailable resources, and transmission of commands that require special reconfirmation and/or validation processing. A command history detailing all station commanding activity should also be maintained.

Subsystem Resource Management

Subsystem Resource Management is responsible for scheduling station resource usage in a prioritized manner that supports both flight and mission operations. The Resource Manager must recognize conflicting requests for station resources in real-time and reallocate such resources on a priority basis heavily biased towards flight and emergency operations. It logs the results of the arbitration/reallocation activity and keeps track of subsystem usage and availability to aid in the rescheduling (automatic or manual) of activities that were denied the appropriate resources when they were initially scheduled to run.

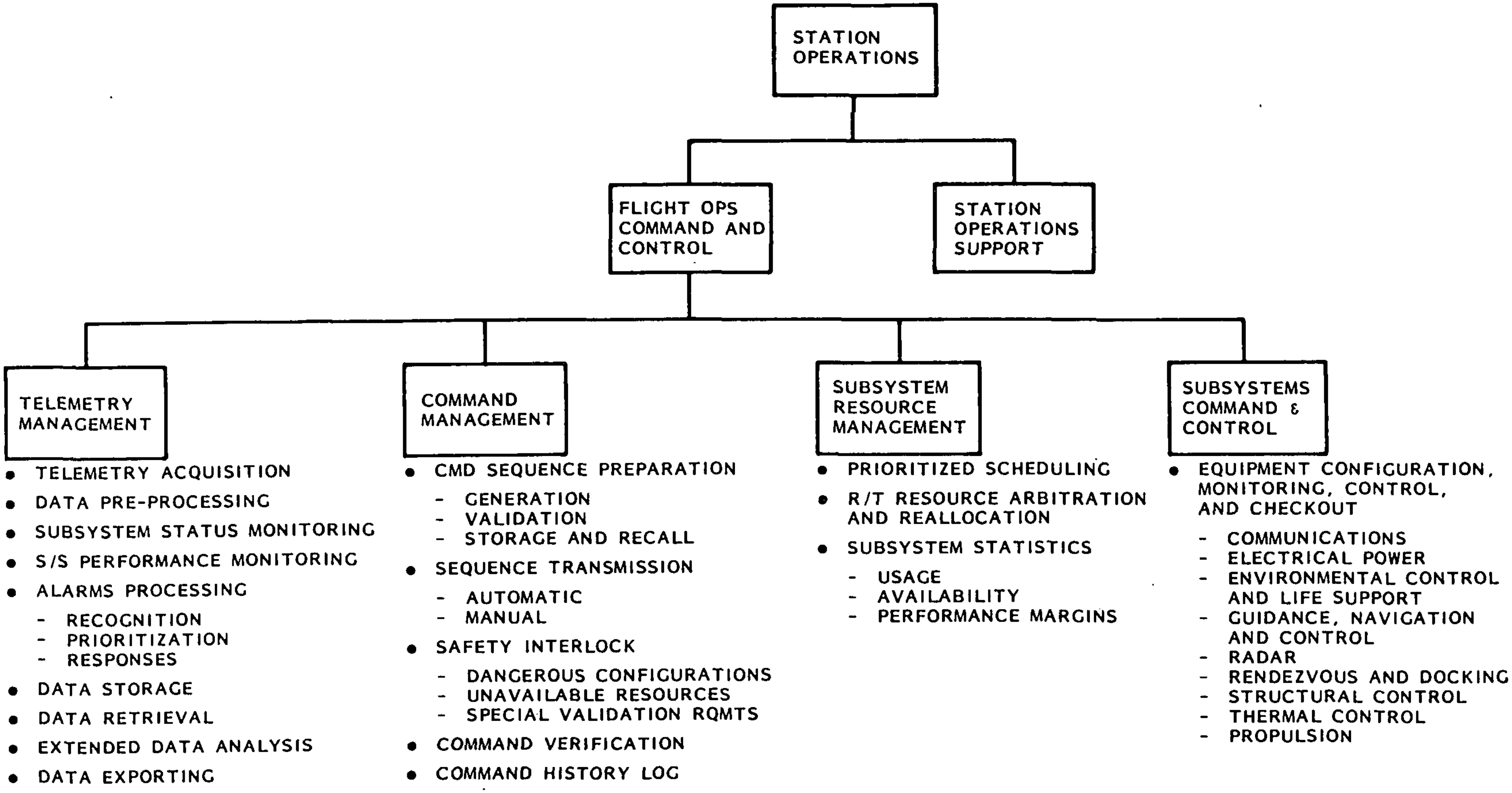


Figure 2.3.2-9. Station Operations - Flight Ops Command & Control

Subsystem Command and Control

The Subsystem Command and Control Function provides a central control point for the Configuration, Monitoring, Control, and Checkout of key Space Station Subsystems.

Major software functions for the Station Operations subsystem are presented in Figure 2.3.2-10. The requirements presented in this figure are those which relate to each of the currently defined Space Station Subsystems and will, of course, change as the overall system baseline design is refined and upgraded. They are presented here primarily as a means of "scoping out" the magnitude of computational support required for each subsystem as an input to preliminary memory space, timing, and cost studies.

B. Station Operations Support

Station Operations Support functions, depicted in Figure 2.3.2-11 include Scheduling and Support Processing for both Station Operations and Remote Operations, System Performance Evaluation, and Station Operations Database Maintenance.

Operations Scheduling and Support

Station Operations and Remote Operations Scheduling and Support Functions are nearly identical differing only in the areas of control that they service. The major activities of each are to provide scheduling support in terms of task lists, timelines, and logistics and then to support real-time activities with pre-operation checklist preparation, checklist check-off, and post operation evaluation. Station Operations supported by this function include Station Maneuvers, Station Reconfiguration, Preventative Maintenance, etc.

System Performance Evaluation

The System Performance Evaluation function is responsible for statistical determinations of the Space Station's effectiveness in performance of its missions. It tracks such characteristics as system usage, system availability, and system margins, and highlights trends in order that timely remedial action can be taken in cases of degrading performance of any of the key station subsystems.

ATTITUDE CONTROL SUBSYSTEM

- SENSOR DATA PROCESSING
  - SENSOR SELECTION
  - PRE-PROCESSING
- CONTROL ALGORITHMS
  - THRUSTER COMMANDS
  - OTHER
- ACE ELECTRONICS CONFIGURATION
- MISSION SUPPORT
  - SUN POINTING
  - EARTH POINTING
  - HIGH-PRECISION POINTING
- SUBSYSTEM SELF-TEST

RADAR SUBSYSTEM

- RADAR DRIVE CONTROL
  - TARGET DETECTION (SWEEP)
  - TARGET TRACKING (TRACK)
- RENDEZVOUS AND DOCKING SUPPORT
  - TRACKING
  - MOVEMENT FORECASTING
- COLLISION AVOIDANCE
  - SINGLE AND MULTIPLE THREATS
  - THREAT ALARMING
  - THREAT TRACKING
  - MOVEMENT FORECASTING
  - TARGET ELIMINATION
    - LASERS
    - MANEUVERS
    - REMOTE MANIPULATORS
- SUBSYSTEM SELF-TEST

REMOTE OPERATIONS

- EVA
- OTV
- FREE FLYER
- RMS
- EQUIPMENT CONFIGURATION, MONITORING, CONTROL, AND CHECKOUT
- S/S PERFORMANCE STATS
- ANOMALLY RESPONSES
  - ROUTINE
  - EMERGENCY
- COMMUNICATIONS MONITOR/CONTROL
- LOGISTICS MONITORING
- MANIPULATOR PROGRAM LOADING

GUIDANCE AND NAVIGATION S/S

- ORBIT DETERMINATION
  - QPS DATA
  - COMPUTED COEFFICIENTS
- MISSION SUPPORT
  - STATIONKEEPING
  - REMOTE OBJECT TRACKING
  - SUN/MOON/PLANETS MODELLING
- ORBIT ADJUST COMPUTATIONS
  - DRAG MAKE-UP
  - ORBIT MODIFICATION
  - RENDEZVOUS AND DOCKING SUPPORT
- SUBSYSTEM SELF-TEST

PROPULSION SUBSYSTEM

- THRUSTER MANAGEMENT
  - ATTITUDE CONTROL
  - ORBIT ADJUST
  - COLLISION AVOIDANCE
  - THERMAL CONTROL
- THRUSTER CONTROL
  - FIRING SEQUENCES
  - DUTY CYCLES
  - ELECTRONICS SAFE/ARM
- LOGISTICS SUPPORT
  - PROPELLANT USAGE
  - TANK TEMPERATURES
  - TANK PRESSURES
- SUBSYSTEM SELF-TEST

RENDEZVOUS AND DOCKING S/S

- AUTO-DOCKING CONTROL
  - APPROACH PROCESSING
  - ATTITUDE ADJUSTMENT
  - COLLISION AVOIDANCE
  - DOCKING SEQUENCING
- MANUAL DOCKING SUPPORT
  - ORBIT MATCHING AND APPROACH
  - ATTITUDE ADJUSTMENT
  - COLLISION AVOIDANCE
  - DOCKING SEQUENCING
- SUBSYSTEM SELF-TEST

ELECTRICAL POWER SUBSYSTEM

- POWER MANAGEMENT
  - GENERATION
  - STORAGE
  - CONDITIONING
  - DISTRIBUTION
- LOGISTICS SUPPORT
  - FUEL USAGE
  - AVAILABLE POWER RESERVES
  - SOLAR ARRAY OUTPUT LEVEL
- SUBSYSTEM SELF-TEST

STRUCTURAL SUBSYSTEM

- MONITORING
  - PHYSICAL (DOORS, LOCKS, ETC)
  - ELECTRICAL (SERVOS, ETC)
  - STRUCTURAL INTEGRITY
  - STRUCTURAL STRESSES
- CONTROL
  - MANUAL (SAFETY INTERLOCK)
  - AUTOMATIC
- TESTING
  - SUBSYSTEM SELF-TEST
  - DRILLS

THERMAL SUBSYSTEM

- TEMPERATURE MONITOR
  - SUBSYSTEMS
  - CREW AREAS
- TEMPERATURE CONTROL
  - ACTIVE (HEATERS, A/C)
  - PASSIVE (S/S ORIENTATION)
- SUBSYSTEM SELF-TEST

ENVIRONMENT CONTROL/LIFE SUPPORT

- AIR MIXTURE CONTROL
  - OXYGEN, NITROGEN, TRACE GASES PARTIAL PRESSURE MANAGEMENT
  - CO_2 REMOVAL
- AIR CONDITIONING/DISTRIBUTION
  - TEMPERATURE
  - HUMIDITY
  - PRESSURE
  - FILTRATION
- RADIATION MONITORING
  - CURRENT LEVELS
  - CUMULATIVE DOSAGES
- WATER MANAGEMENT
  - WATER QUALITY
  - RECLAMATION
  - DISTRIBUTION
- FOOD MANAGEMENT
  - SPOILAGE CONTROL
  - PREPARATION
  - GARBAGE DISPOSAL
- BIOWASTE MANAGEMENT
  - RECLAMATION
  - DISPOSAL
- LOGISTICS SUPPORT
  - QUANTITIES USED
  - QUANTIES AVAILABLE
  - TRENDS
- FIRE AND "FLOOD" CONTROL
- SUBSYSTEM SELF-TEST

Figure 2.3.2-10. Software Requirements by Subsystem

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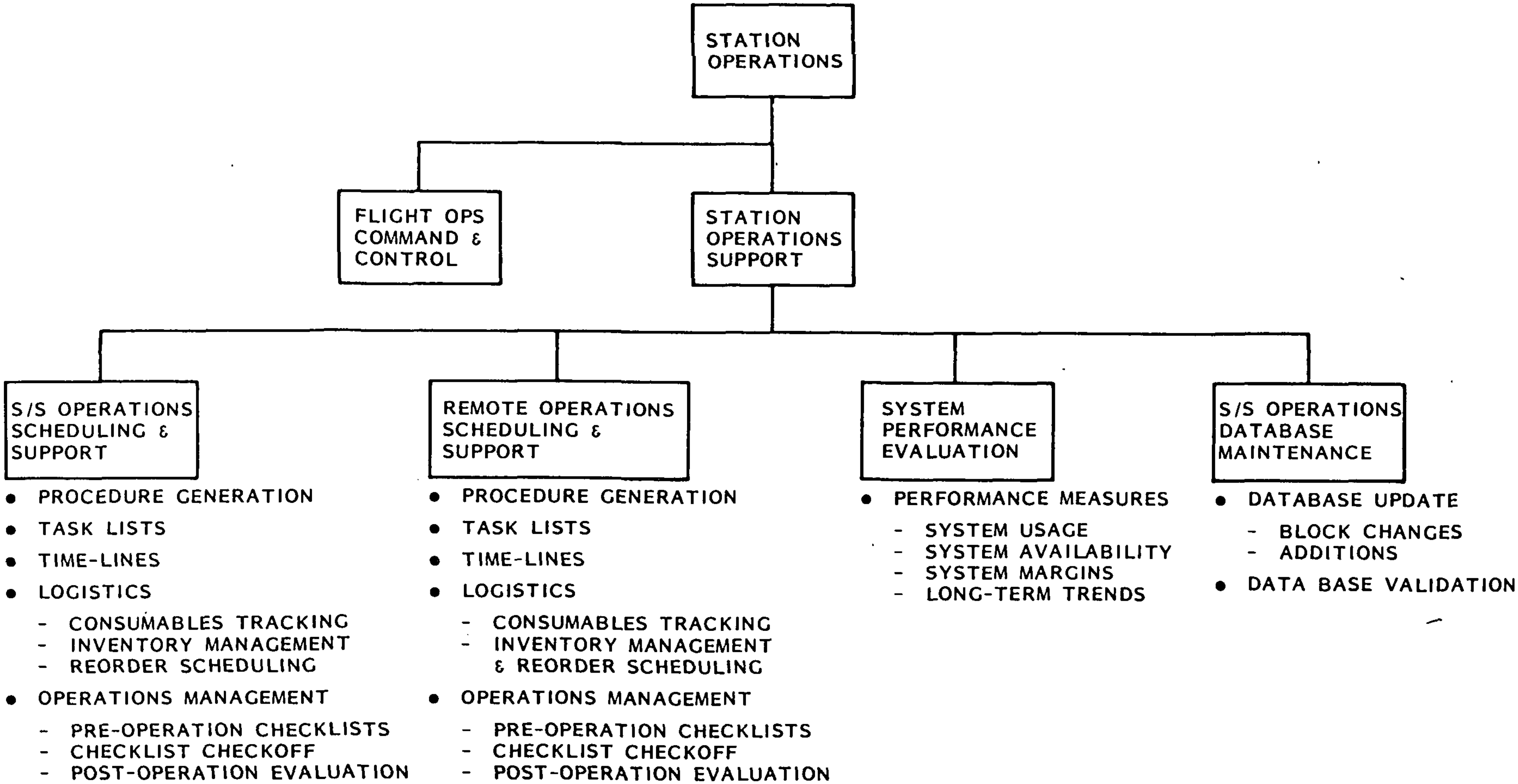

Figure 2.3.2-11. Station Operations - Station Operations Support

Data Base Maintenance

The Data base Maintenance function is primarily responsible for the installation and validation of Space Station operations database changes uplinked from the ground. Other capabilities in this area would allow some troubleshooting and correction of data base problems on-board.

2.3.2.2.2 Mission Generic Software

This section describes the mission generic software. The word "mission" in this context refers to experiments that are to be executed on-board the space station, or on a free-flyer under control of the space station. The term "mission generic software" refers to that software which is common to all missions that might be executed. Any software for a specific mission is not considered part of the generic software. Figure 2.3.2-12 summarizes the software requirements for the mission generic software and is explained in more detail in the following paragraphs.

A. Mission Support Software

In general missions are going to require files of parameters for execution. The actual files and parameters are mission specific, but the need is generic. Software should be provided which can be used to create, display, modify, and destroy these files.

Software should also be provided to maintain a library support function. This library could contain as a minimum, subroutines to support the following:

1. Operations data base access (read only).
2. Missions data base access.
3. Command generation.
4. Command transmission.
5. Command verification.
6. Telemetry processing.

Tools should also be provided for definition, generation, display and modification of mission procedures.

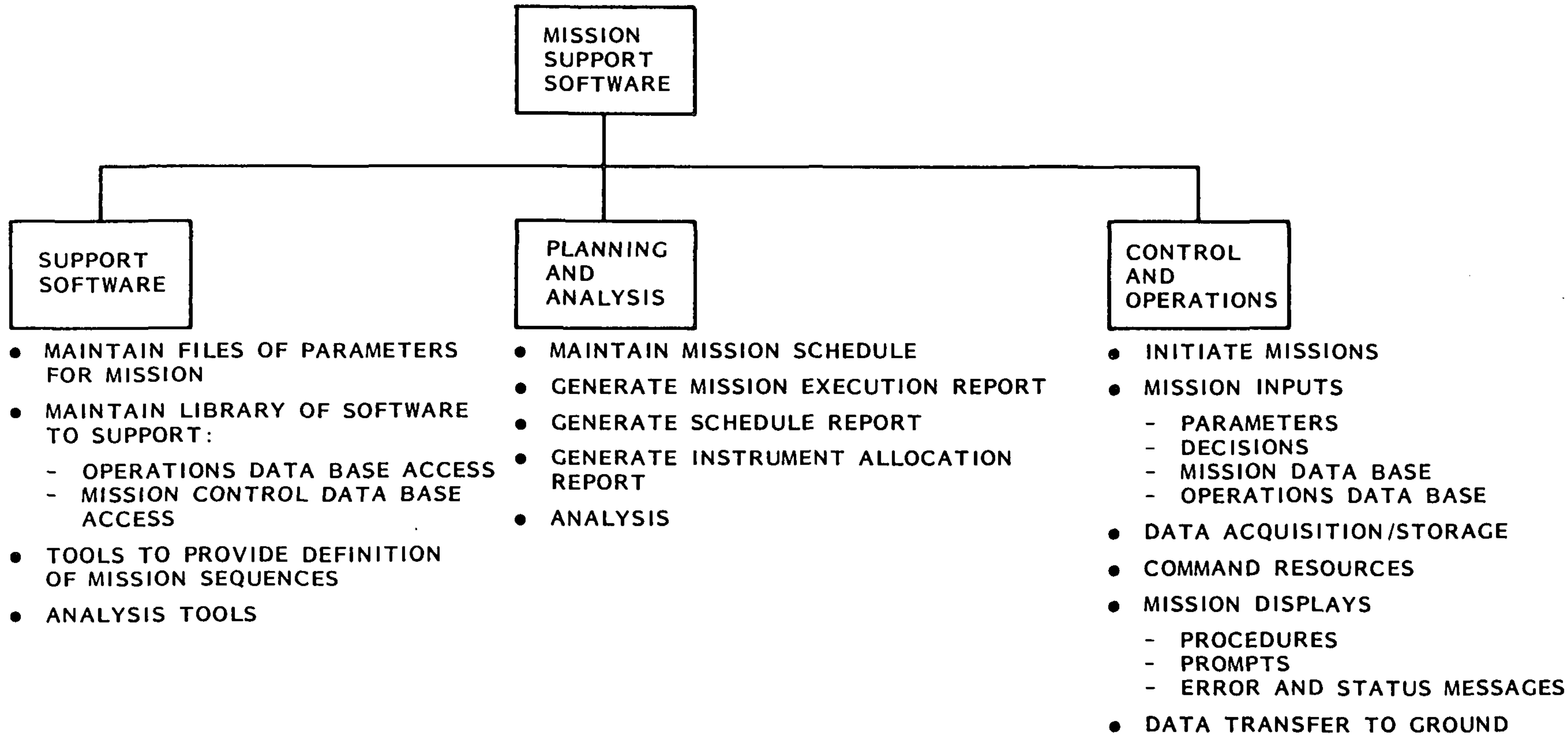

Figure 2.3.2-12. Mission Support

B. Mission Planning and Analysis

In order to support operations, a mission schedule must be maintained in the mission data base. This schedule should contain a list of all missions on-board with information specific to each mission such as: initiation date and time, execution frequency, required resources, description, data acquisition rates, etc. The mission control software should be aware of what resources are available for missions to use. Tools should be provided for generation, display, and modification of this information. The ability to add and delete missions should be part of this tool. When a mission is added to the schedule, conflicts in required resources will be detected. If any problems are detected the operator should be informed and the schedule can be modified accordingly.

Various reports should be provided to assist with planning. These reports could consist of at least the following:

1. Mission execution report.
2. Schedule report.
3. Instrument allocation report.

Tools should be provided to assist in performing analysis on generic mission scheduling and execution data. The results of the analysis could be a part of the above reports.

C. Mission Control and Operations

Generic operations for control of missions is basically the ability to initiate missions manually and automatically. When a mission is initiated it is based upon the mission schedule maintained in mission planning. If an attempt is made to initiate a mission not yet due by the schedule, an error message should be displayed. The ability to cancel a mission, put a mission in a hold state, and to resume a mission from a hold state should also be provided.

Support for missions operations is also required. During execution, a mission will require various types of inputs. These inputs will consist of both operator inputs for either parameters or decisions, and data base inputs from both the mission data base and the operations data base. Note that missions software has read-only permission for operations data base access. Missions will require support for allocation of and commanding of available resources. During the mission, data will be collected. Software is required to support the generic aspects of data collection and storage. After the mission is complete the data collected might require some preprocessing. Support will be required for packaging and transference of the collected data to the ground. During mission execution various displays might be required. These displays could consist of mission procedures, prompts for parameters or decisions, error messages, and status messages.

2.3.2.2.3 Personnel Support

Figure 2.3.2-13 depicts the software requirements for personnel support.

A. Health

Software may be required for monitoring the health of the crew. This software should provide the ability to setup, maintain, and display a crew health checkup schedule. Some on-board evaluation of the collected data from the checkups may be required.

Another important part of the health software is the ability to display emergency procedures. An emergency may arise that prohibits waiting for direction from the ground. Emergency procedures should be supplied for such situations and could assist the science officer in treatment of any problems.

B. Miscellaneous

Support should be provided to setup, maintain, and display various miscellaneous files such as personnel files, personnel logs, and skill requirements files.

2.3.2.2.4 Communications Management

Communications Management Functions, depicted in Figure 2.3.2-14 currently include Data and Message Switching, Voice and Video Subsystem Support, External Communications Link Scheduling and Support, and Data Base Maintenance.

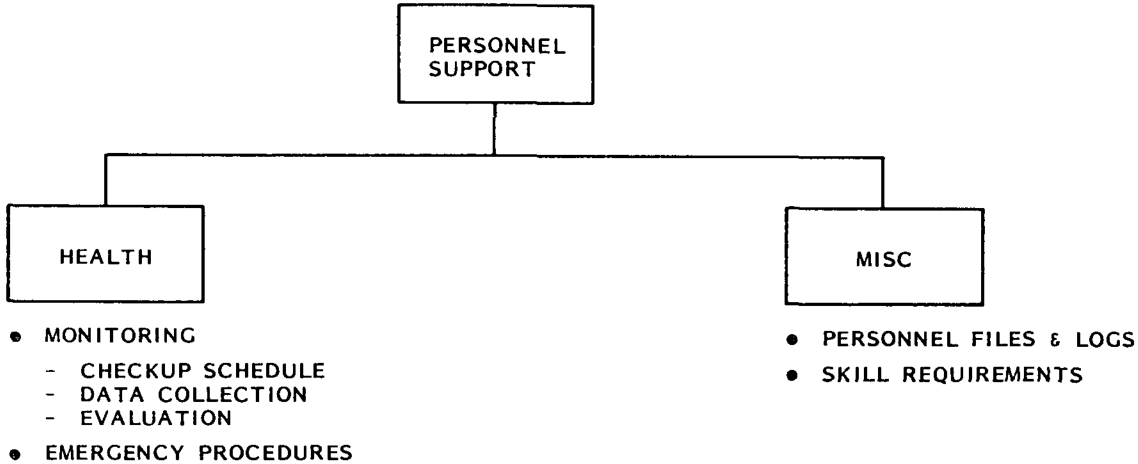

Figure 2.3.2-13. Personnel Support

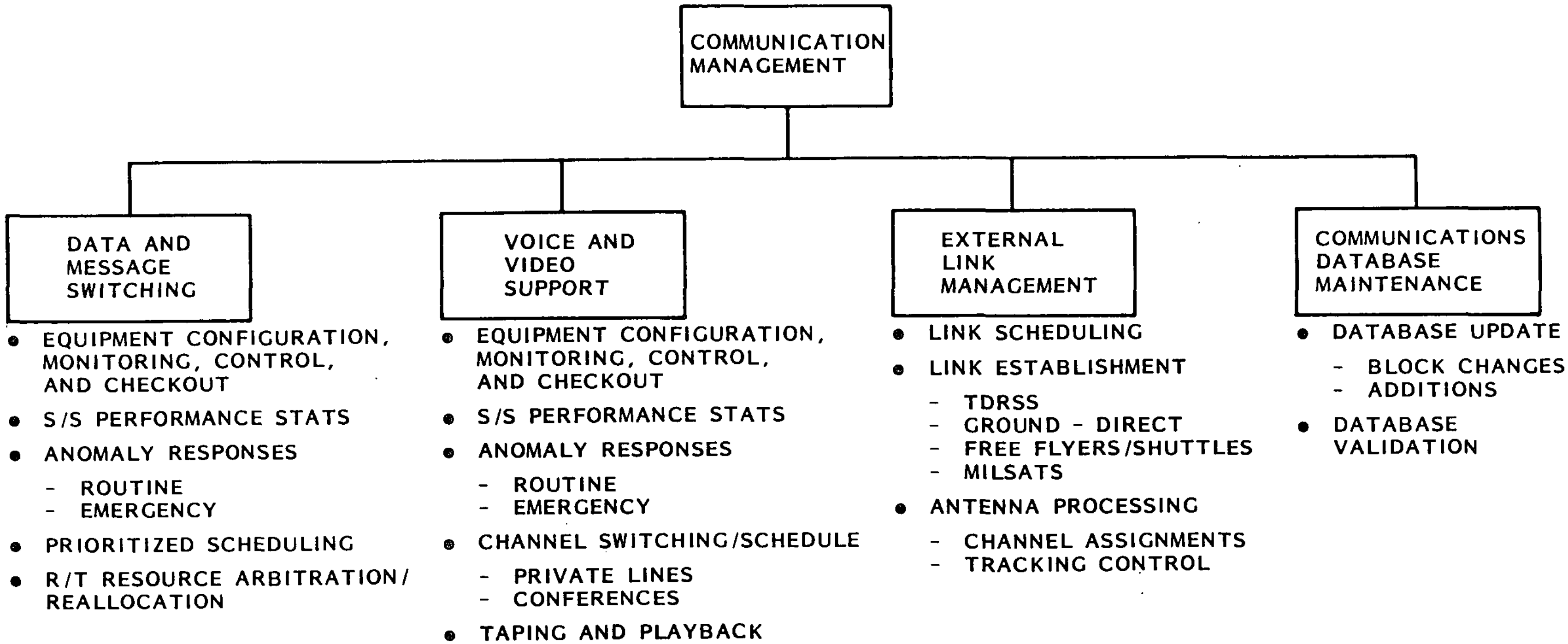

Figure 2.3.2-14. Communication Management

A. <u>Data and Message Switching</u>

The Data and Message Switching function provides the prioritized scheduling and support of high rate, highly reliable data communications. It provides for all channel allocations, message switching, buffering and requeing as required. It acts as the controller for the on-board data network.

B. <u>Voice and Video Subsystem Support</u>

The Voice and Video Subsystem Support function provides the necessary channel interconnects to provide for private lines and "conference calls" as requested by the users. It can also provide taping, storage, and playback of voice and video communications.

C. <u>External Link Management</u>

The External Link Management function provides the on-board capability to configure the Communications Subsystem to support any external communications required by either Station Operations or Mission Operations. It is responsible for configuration, monitoring, control, and checkout of the on-board equipment as well as for the scheduling, initiation, and data routing for any of the external communications links (Remote Manipulators, OTV's, Free-Flyers, EVA, TDRSS, Shuttle, Ground, GPS, etc.).

D. <u>Data Base Maintenance</u>

The Data Base Maintenance function is primarily responsible for the installation and validation of Communications Subsystem data base changes uplinked from the ground. Other capabilities in this area would allow some trouble-shooting and correction of data base problems on-board.

2.3.2.2.5 Software Sizing and Timing

Once we determined the functional capabilities that the on-board software should possess, we turned our attention to estimating its size. The approach that we used to make those estimates was to compare the Space Station function with similar functions performed by other space systems (both manned and unmanned), through the use of a "sizing algorithm". This algorithm was used as follows:

1. For each function with a subsystem or partition in the system, a number (1 - 10) was generated. This number is based upon the estimated relative complexity of the function.

2. Rules for size-as-a-function-of-complexity were established:

   a. In major partitions the largest subfunction was alloted 100,000 bytes and the smallest was allotted 10,000 bytes.

   b. Within subsystems the largest subfunction uses 10,000 bytes, while the smallest was allotted 1,000 bytes.

3. The subfunction sizes were estimated based on relative complexities and a total size for the function was derived.

   Example: ACS Subsystem

Function	Complexity	Size
Sensor Data Processing	3	3 KB
Control Algorithms	5	5 KB
Electronics Configuration	1	1 KB
Mission Support	5	5 KB
Self-Test/Checkout	1	1 KB
TOTAL:		15 KB

4. Minimum lines-of-code were estimated assuming 2 bytes for a machine instruction and 5 machine instructions being generated for each of the high-order-language statements in a function. The exceptions to this procedure are in the support software areas - sizings for the EXEC, DBMS and the network software packages were derived from existing software systems.

Based on the previously derived functions, and the guidelines imposed by the "sizing algorithm", we proceeded to estimate the lines of code, main and mass memory capacities. These results are depicted in Figures 2.3.2-15 to 2.3.2-21, while Figure 2.3.2-22 summarizes the seven major functions.

In interpreting those numbers, it should be recognized that all values include a 100% growth factor for overhead and expansion. As more details become available and a more precise design evolves, the estimates contained herein will be re-examined and modified, as required.

2.3.3 INTERNAL COMMUNICATIONS

Based on the requirements given in Section 2.2.2.2, a table of equipment requirements per compartment was produced. The results are presented in Table 2.3.3-1. Using these figures, another Table, 2.3.3-2 indicating size, weight and power requirements with the corresponding totals was prepared. Estimates of size, weight and power were made using equipment used aboard the Space Shuttle and otherwise based on today's technology.

FUNCTION	*MAIN MEMORY DATA	PROG	MASS STORAGE	ASSUMPTIONS
S/S RESOURCE MGMT	40KB	40KB	5MB	10 SUBSYSTEMS, RT
S/S CMD & CNTL	40KB	80KB	5MB	AUTO/MANUAL MIX
CMD MANAGEMENT	80KB	120KB	20MB	5K CMD SEQUENCES
TLM MANAGEMENT	80KB	120KB	100MB	RT TLM PROCESSING
PERF. MONITOR	40KB	40KB	5MB	BACKGROUND, NON-RT
OPER. SUPPORT	40KB	40KB	5MB	INTERACTIVE, NON-RT
REMOTE CMD&CNTL	40KB	80KB	5MB	AUTO/MANUAL MIX
DB MAINTENANCE	40KB	80KB	5MB	INTERACTIVE, NON-RT
TOTALS	1MB		150MB	

ESTIMATED LINES OF CODE - 25K

Figure 2.3.2-15. Software Sizing Estimate - Station Operations

FUNCTION	*MAIN MEMORY DATA	PROG	MASS STORAGE	ASSUMPTIONS
MIS RESOURCE MGMT	40KB	40KB	5MB	25 EXPERIMENTS, RT
MIS CMD & CNTL	40KB	80KB	5MB	AUTO/MANUAL MIX
CMD MANAGEMENT	80KB	120KB	20MB	10K CMD SEQUENCES
TLM MANAGEMENT	80KB	120KB	100MB	RT TLM PROCESSING
PERF. MONITOR	40KB	40KB	5MB	BACKGROUND, NON-RT
OPER. SUPPORT	40KB	40KB	5MB	INTERACTIVE, NON-RT
P/I INTERFACE	40KB	80KB	5MB	LOW RATE DATA DUMPS
DB MAINTENANCE	40KB	80KB	5MB	INTERACTIVE, NON-RT
TOTALS	1MB		150MB	

ESTIMATED LINES OF CODE - 25K

Figure 2.3.2-16. Software Sizing Estimate - Mission Operations

FUNCTION	MAIN MEMORY DATA	PROG	MASS STORAGE	ASSUMPTIONS
COMM CMD & CNTL	30KB	80KB	2.5MB	10 EXTERNAL LINKS
VOICE/VIDEO SUPPT	20KB	40KB	1.0MB	LINK MANAGEMENT ONLY NO SIGNAL PROCESSING
DATA TRANSMISSION	30KB	80KB	2.5MB	RT MSG SWITCH/BUFFER
EXTERN. LINK MGMT	30KB	80KB	2.5MB	10 ACTIVE LINKS
DB MAINTENANCE	30KB	80KB	1.5MB	INTERACTIVE, NON-RT
TOTALS	0.5MB		10MB	

ESTIMATED LINES OF CODE - 15K

Figure 2.3.2-17. Software Sizing Estimate - Communication Management

FUNCTION	MAIN MEMORY DATA	PROG	MASS STORAGE	ASSUMPTIONS
CREW HEALTH DATA	40KB	45KB	20MB	INTERACTIVE, NON-RT
PERSONNEL FILES	80KB	30KB	20MB	INTERACTIVE, NON-RT
EMERGENCY MEDICAL	80KB	120KB	100MB	1K PROCEDURES, FAST KEYWORD SEARCH
DB MAINTENANCE	35KB	60KB	10MB	INTERACTIVE, NON-RT
TOTALS	0.5MB		150MB	

ESTIMATED LINES OF CODE - 15K

Figure 2.3.2-18. Software Sizing Estimate - Personnel Support

FUNCTION	*MAIN MEMORY DATA	PROG	MASS STORAGE	ASSUMPTIONS
TECH/REC LIBRARY	160KB	160KB	100MB	INTERACTIVE, NON-RT FAST CATALOG SEARCH DOCUMENT ORDERING
AUDIO/VISUAL LINK	30KB	60KB	25MB	LINK SCHEDULE ONLY
PERS. BUS. LINK	30KB	60KB	25MB	LINK SCHEDULE ONLY
TOTALS	0.5MB		150MB	

ESTIMATED LINES OF CODE - 15K

Figure 2.3.2-19. Software Sizing Estimate - Astronaut Personal Business

SUBSYSTEM	*MAIN MEMORY DATA	PROG	HARD RAM	TOTAL RAM	LINES-OF-CODE
ATTITUDE CONTROL	5KB	15KB	1KB	32KB	2K
ELECTRICAL POWER	5KB	10KB	1KB	32KB	2K
ENV. CONTROL AND LIFE SUPPORT	5KB	25KB	1KB	64KB	2K
GUIDANCE AND NAVIGATION	20KB	50KB	2KB	128KB	2K
PROPULSION	5KB	10KB	1KB	32KB	1K
RADAR/COLLISION AVOIDANCE	20KB	50KB	2KB	128KB	2K
RENDEZVOUS AND DOCKING	20KB	50KB	2KB	128KB	2K
STRUCTURAL	5KB	10KB	1KB	32KB	1K
THERMAL	5KB	10KB	1KB	32KB	1K
TOTALS	90KB	200KB	12KB	608KB	15K

ESTIMATED LINES OF CODE - 15K

Figure 2.3.2-20. Software Sizing Estimate - Station Subsystem Processing

PACKAGE	LINES-OF-CODE	NOTES
EXECUTIVE	15K	SUBSETTABLE, TAILORED TO EACH APPLICATION
DBMS	15K	SUBSETTABLE, TAILORED TO EACH APPLICATION
NETWORK CONTROL S/W	15K	SUBSETTABLE, TAILORED TO EACH APPLICATION
OPERATOR INTERFACE	15K	SUBSETTABLE, TAILORED TO EACH APPLICATION
SOFTWARE PACKAGES	15K	ESTIMATES FOR STATION SIMULATION PACKAGE ONLY, ANTICIPATE THAT ANY OTHER SOFTWARE PACKAGES WILL BE PURCHASED OFF-THE-SHELF.
TOTALS:	75K	

Figure 2.3.2-21. Software Sizing Estimate - Support Software

FUNCTION	LINES-OF-CODE	MAIN MEMORY	MASS MEMORY
STATION OPS	25K	1MB	150MB
MISSION OPS	25K	1MB	150MB
COMMUNICATIONS MGMT	15K	0.5MB	10MB
PERSONNEL SUPPORT	15K	0.5MB	150MB
ASTRONAUT (PERSONAL)	15K	0.5MB	150MB
STATION SUBSYSTEMS	15K	1MB	N/A
SUPPORT SOFTWARE	75K	(--- INCLUDED IN ABOVE ESTIMATES ---)	
TOTAL	185K	4.5MB	610MB

Figure 2.3.2-22. Software Sizing Estimate - Summary

Table 2.3.3-1. Number of Units Per Compartment

	STATEROOMS (3)	MISSION/OPS CTRL	SUPPORT	REC/DINING	LAB	TRANSPORT HARBOR	OBSERVATORY	INDUSTRIAL PARK	SAT/SERV SPACE TEST	TOTAL
CIU	9	3	3	3	3	3	3	3	3	33
AUDIO/VIDEO UNIT	3	1	1	1	1	1	1	1	1	11
TV MONITOR	3	6	1	1	1	1	1	1	1	16
WIDE-SCREEN TV	0	0	0	1	0	0	0	0	0	1
TV CAMERA	3	2	1	1	1	6	1	3	3	21
TV REMOTE CONTROL	0	2	0	0	0	0	0	0	0	2
HAND-HELD CAMERA	0	4	0	0	0	0	0	0	0	4
ENTERTAIN. UNIT	3	0	0	1	0	0	0	0	0	4
TLM MUX	3	1	1	1	1	1	1	1	1	11
VIDEO RECORDER	3	6	1	1	1	1	1	1	1	16
MICROPROCESSOR	3	1	1	1	1	1	1	1	1	11
ALARM UNIT	3	1	1	1	1	1	1	1	1	11
RIU	12	4	4	4	4	4	4	4	4	44

NUMBER OF UNITS PER COMPARTMENT

INTERNAL COMM ARCHITECTURE

Table 2.3.3-2. Internal Comm Physical Parameter Estimation

COMPONENT	QTY	UNIT WEIGHT lbs	TOTAL WEIGHT lbs	UNIT PWR WATTS	TOTAL PWR WATTS	UNIT VOL ft^3	TOTAL VOL ft^3
CIU	33	25	825	25	825	1.5	49.5
AUD/VIDEO UNIT	11	5	55	10	110	.15	1.65
TV MONITOR	16	22	352	40	640	.5	8
WIDE SCREEN TV	1	50	50	200	200	7	7
TV CAMERA	21	27	567	43	1343	1.6	33.6
TV REMOTE CONT	2	40	80	67	134	1	2
HAND-HELD CAM	4	21.7	86.8	62	248	.4	1.6
ENTERTAIN. UNIT	4	25	100	75	300	3	12
TLM MUX	11	3	33	5	55	.1	1.1
VID. RECORDER	16	15	240	40	640	.3	4.8
MICROPROCESSOR	11	.33	3.63	.33	3.63	.01	.11
ALARM UNIT	11	1	11	10	110	.1	1.1
RIU	44	.5	22	5	220	.02	.88
TOTALS			2425		4829		122

	WEIGHT	PWR	VOL
HABITATION MOD			
STATEROOMS (3)	526	955	31.02
MISSION/OPS	529	1068.33	15.10
SUPPORT	150.33	243.33	7.34
REC/DINING	225.33	518.33	17.34
LAB	150.33	243.33	7.34
TRANSPORT HARBOR	285.33	835.83	15.34
OBSERVATORY	150.33	306.23	7.34
INDUST. PARK	204.33	329.33	10.54
SAT/SEN SPACE TEST	204.33	329.33	10.54
	2425	4829	122

Figure 2.3.3-1 shows the conceptual design for a typical compartment or module. Input/output devices (TLM, speakers TV monitors, etc.) are connected to the appropriate CIU where information is either distributed or received. The transmit and receive multiplexers and demultiplexers within each CIU (as shown in Figure 2.2.2.2-10) are configured by a microprocessor associated with each compartment so that each CIU transmits and receives only the information it needs. Commands are delivered to the microprocessor by the user or the DMS regarding a desired communication scenario (e.g., private communications between stateroom 1 and the industrial park). The microprocessor confers with the DMS to decide communication priorities. The microprocessor receives appropriate instructions from the DMS and configures the appropriate CIU multiplexers accordingly so that the desired communication scenario is achieved. This system achieves maximum interconnectivity between compartments.

Figure 2.3.3-2 shows the Operations/Mission Control Center and the link between external and internal communications. Antenna and channel selection is performed by the microprocessor in collaboration with the DMS (CIUA). Information from the external communications channels is routed to the appropriate CIU's using the Comm Switching Unit, which is itself a microprocessor. The Comm Switching Unit is configured by the microprocessor with direction from the DMS. Once information is sent to a CIU, it becomes available to the entire Space Station via the star junction. Similarly, the Comm Switching Unit gathers information from the CIU's and routes it to an appropriate transponder for external transmission.

2.3.4 EXTERNAL COMMUNICATIONS

(This section is contained under separate cover.)

2.3.5 GROUND SEGMENT

The ground segment has been scoped to perform the functions allocated to it by the functional analysis performed in Section 2.1.2. It also includes several test and simulation operations.

The total set of functions allocated to the ground complex were grouped by commonality and assigned phases of the Space Station evolution in which they need to exist. Next a functional view of the ground complex was derived, and each function was allocated to a compartment. The result of the activity is a

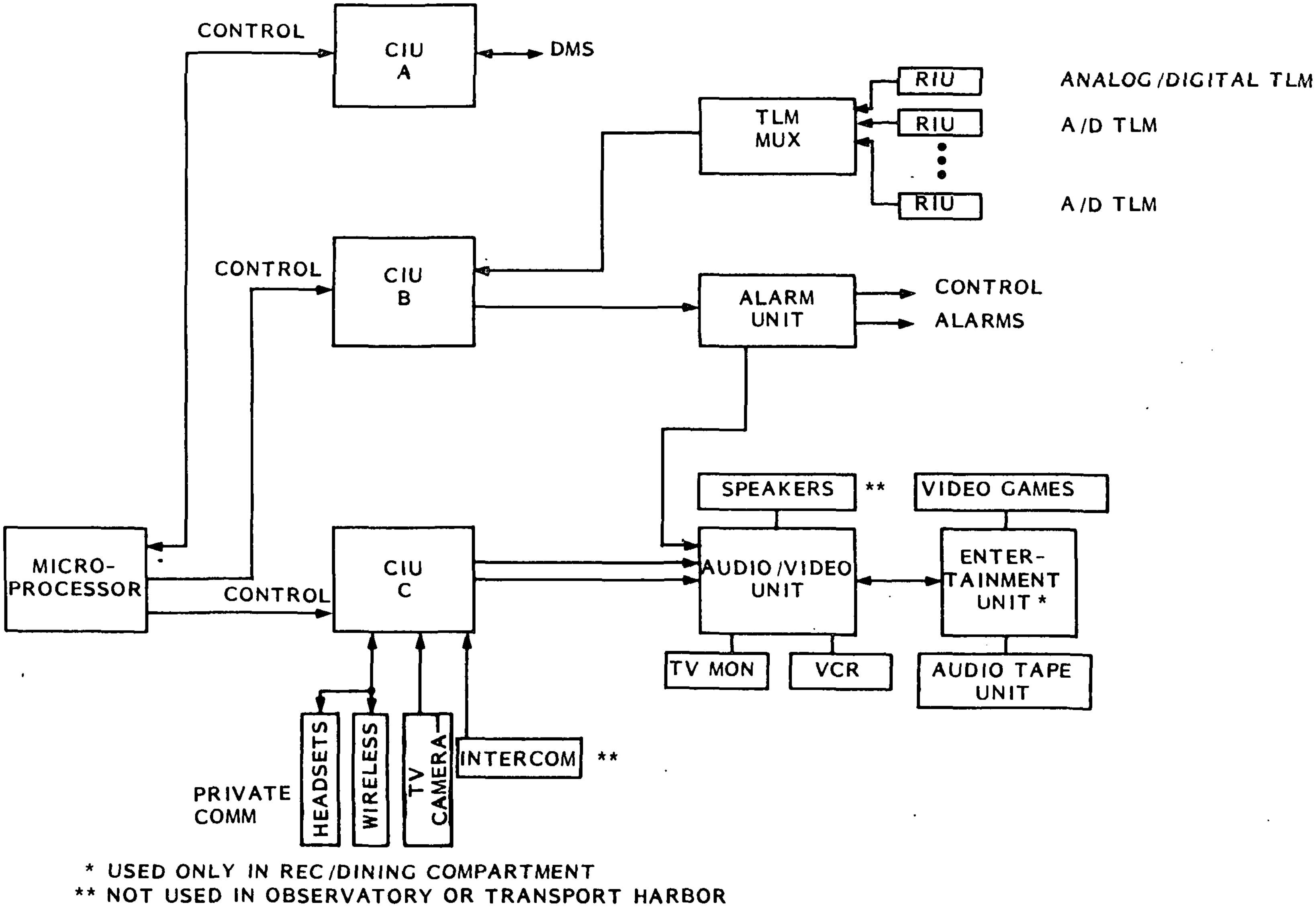

Figure 2.3.3-1. Typical Space Station Compartment or Module

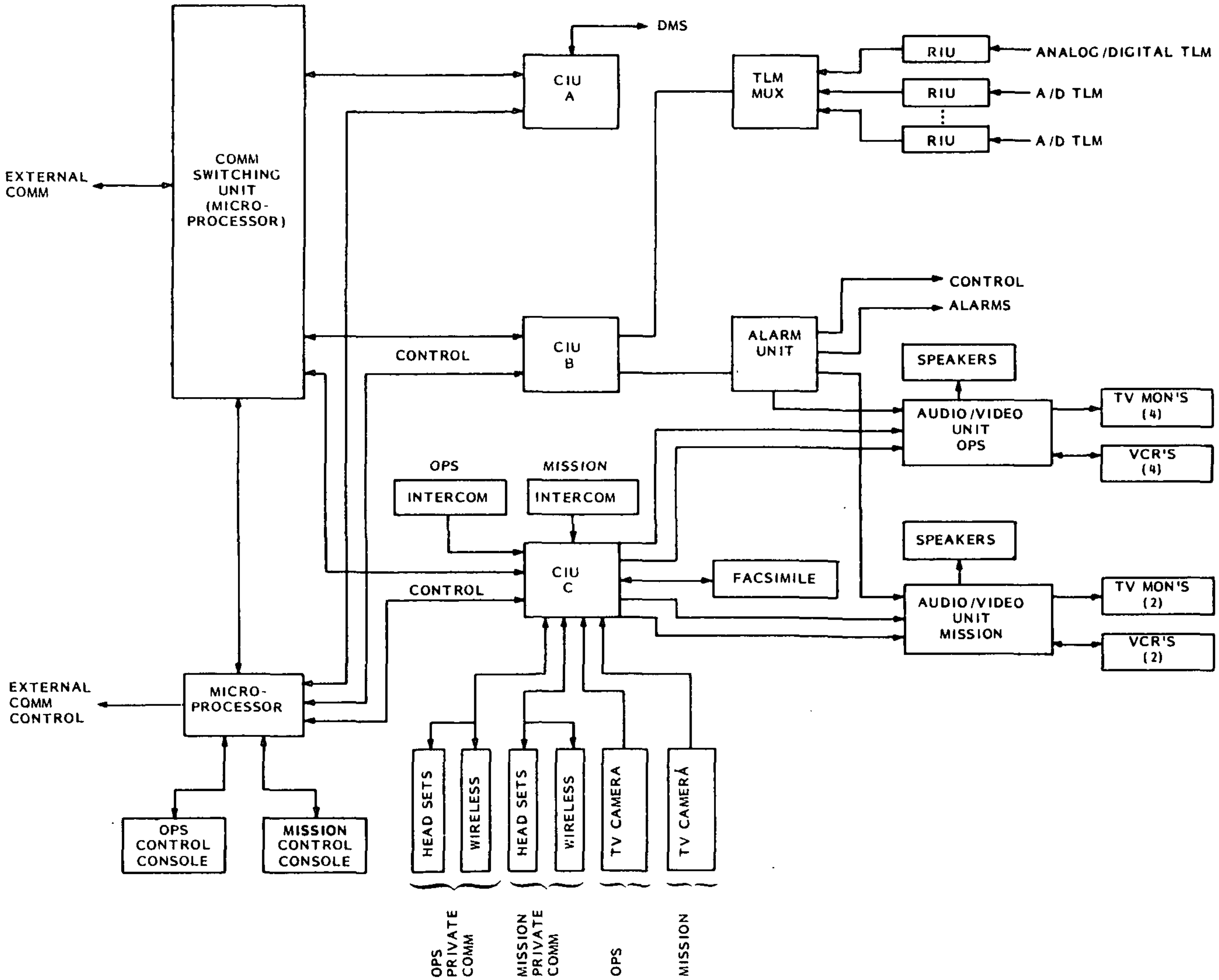

Figure 2.3.3-2. OPS/Mission Control Center and External Communication

high level software representation. Having derived a functional representation, of the ground, a hardware configuration was then developed.

Finally, functional criticality and the Space Station evolutionary phases were considered, to develop the evolution of the ground segment. Our main objectives in the design of the ground complex were: expandability, cost, DMS compatibility, evolution, and flexibility.

Several other factors were taken as given in this development. To begin with, the space station is assumed to evolve according to the phases of Figure 2.3.5-1. We have termed the initial phase as Phase 1. First evolutionary growth (non-defense) as Phase 2, second evolutionary growth (non defense) as Phase 3, first evolutionary growth (defense) as Phase 4, and second evolutionary growth (defense) as Phase 5. We assumed that there exists a separate military mission that can be detached from the space station (or takes command of it) in national emergencies.

Another assumption was that the hardware and software needed to support communications stations, such as TDRSS ground stations, will be provided and are not part of the IMS ground segment.

A final major assumption was that the space station will be launched via the Shuttle. This implies that no special launch facilities and capabilities are needed since they exist for the Shuttle and its payloads. We have provided a test bed for the OB DMS though, and the training and simulation functions can be used for some other tests.

Aside from the above assumptions, the ground complex needed to be compatible with the OB DMS and meet certain objectives. The major objectives were: a cost effective design with low maintenance; flexibility and expandability for easy future adjustments; and an evolutionary design to follow the expansion of the space station.

With these ground rules, we proceeded to fashion the functional view of the ground complex.

ASSUMED SPACE STATION EVOLUTION

INITIAL (HABITAT) (PHASE 1)

- BASIC ON-BOARD OPERATIONS, HOUSEKEEPING, ETC.
- MINIMUM OF ON-BOARD EXPERIMENTS

FIRST EVOLUTIONARY GROWTH (PHASE 2) (NON-DEFENSE)

- TRANSPORTATION HARBOR
- SATELLITE SERVICING & ASS'Y
- SPACE TEST FACILITY
- INDUSTRIAL PARK
- OBSERVATORY - LOW DATA RATE

SECOND EVOLUTIONARY GROWTH (PHASE 3) (NON-DEFENSE)

- ALL ABOVE
- OBSERVATORY - HIGH DATA RATE

FIRST EVOLUTIONARY GROWTH (PHASE 4) (NATIONAL SECURITY)

- TRANSPORTATION HARBOR
- SATELLITE SERVICING & ASS'Y
- SPACE TEST FACILITY
- LOW DATA RATE MILITARY MISSIONS

SECOND EVOLUTIONARY GROWTH (PHASE 5) (NATIONAL SECURITY)

- ALL ABOVE
- HIGH DATA RATE MILITARY MISSIONS

Figure 2.3.5-1. Assumed Space Station Evolution

2.3.5.1 Conceptual Design

The functional view of the Ground complex was arrived at by a two pronged approach. The first avenue examined the Space Shuttle complex and the LANDSAT-4 complex for their ground support facilities. These two were combined and modified to develop "functional" facilities for the space station ground complex. A "functional" facility is defined to be a collection of related functions, not necessarily a physical entity or hardware related. The results of that development are presented in Figures 2.3.5-2 to 2.3.5-7. The second avenue collected the functions that were assigned to either ground or shared, and added to them some of the on-board allocated functions that require ground backup. The derived list was then broken into similar groups to form "functional" facilities. The two prongs were then compared for completeness and consistency and then combined to form a unified functional (software) view, with each function assigned to a "functional" facility.

In addition to the above, each function was assigned a set of phases (1-5, as previously defined) in which that function needs to be available. Table 2.3.5-1 list the functions of the space stations, along with the assigned facilities and phases. In this table, OB means that the function exists on-board only, and OB/(FAC) means that the function is primarily on-board with backup in facility (FAC).

The separation of the ground complex into the three centers: Military Mission Center (MMC), Mission Control Center (MCC), and Commercial Daa Center (CDC), is a very natural one. The Military Mission Center, by the nature of its functions' relation to national security, is isolated not only relationally, but physically as well. The Mission Control Center (MCC) has responsibility for the station and crew (as well as all the missions) and thus performs highly critical functions; therefore it probably should be isolated from facilities concerned with less critical functions. The last is the Commercial Data Center (CDC) which consists of functions related to payloads. The above rationale filters down to the subdivisions of the MCC and the CDC in the "functional" facility view. Although the MCC and CDC are relationally separated, there are good arguments for having centers colocated. These arguments include economics and the facilitation of communications.

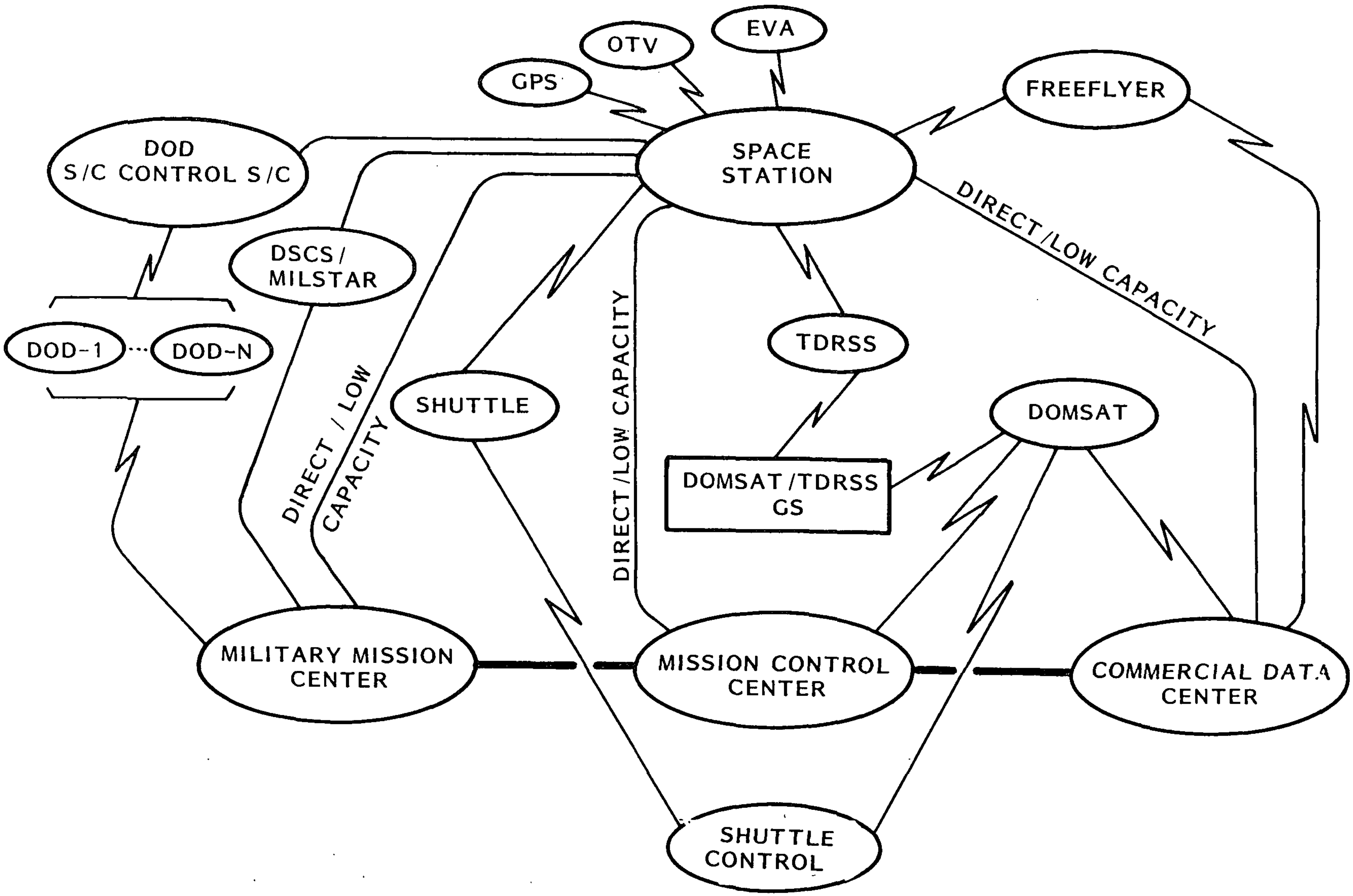

Figure 2.3.5-2. Space Station Ground Complex

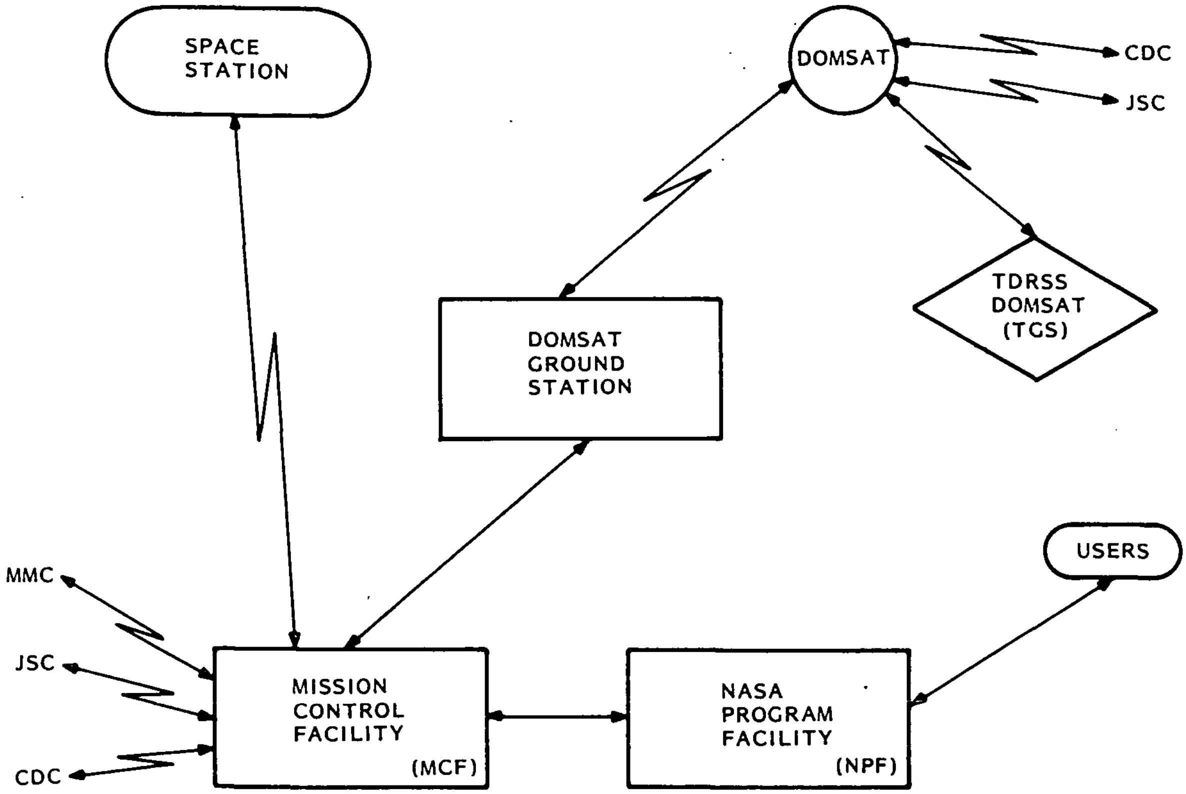

Figure 2.3.5-3. Mission Control Center (Phase 1 - 5)

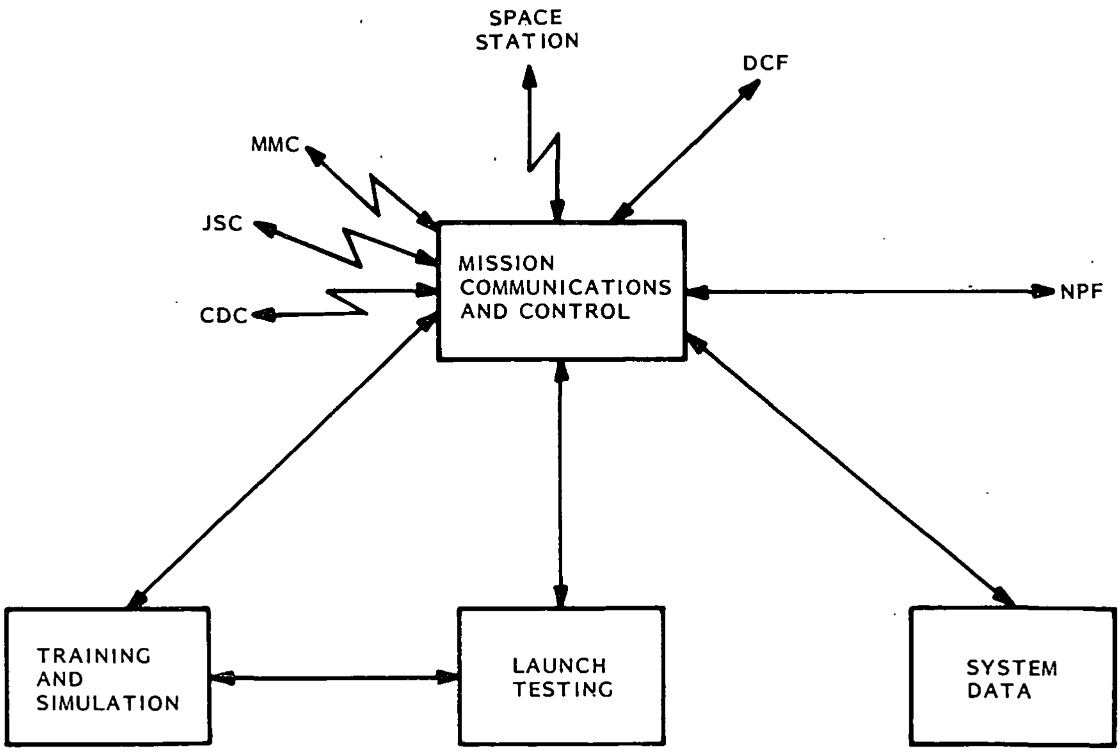

Figure 2.3.5-4. Mission Control Facility

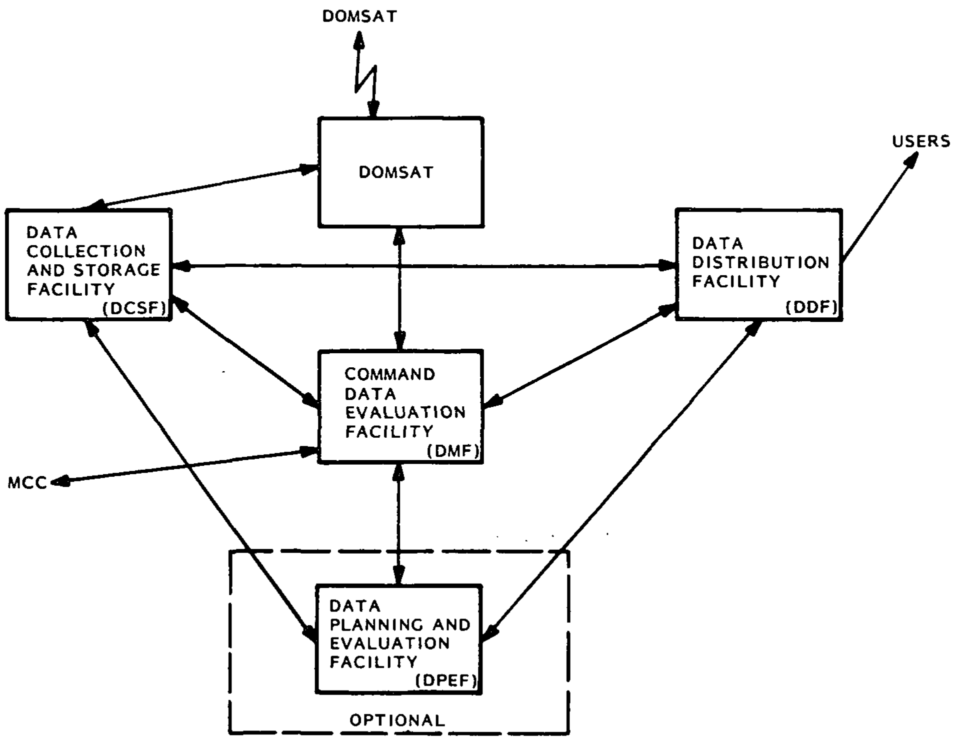

Figure 2.3.5-5. Commercial Data Center (Phase 2 and 3)

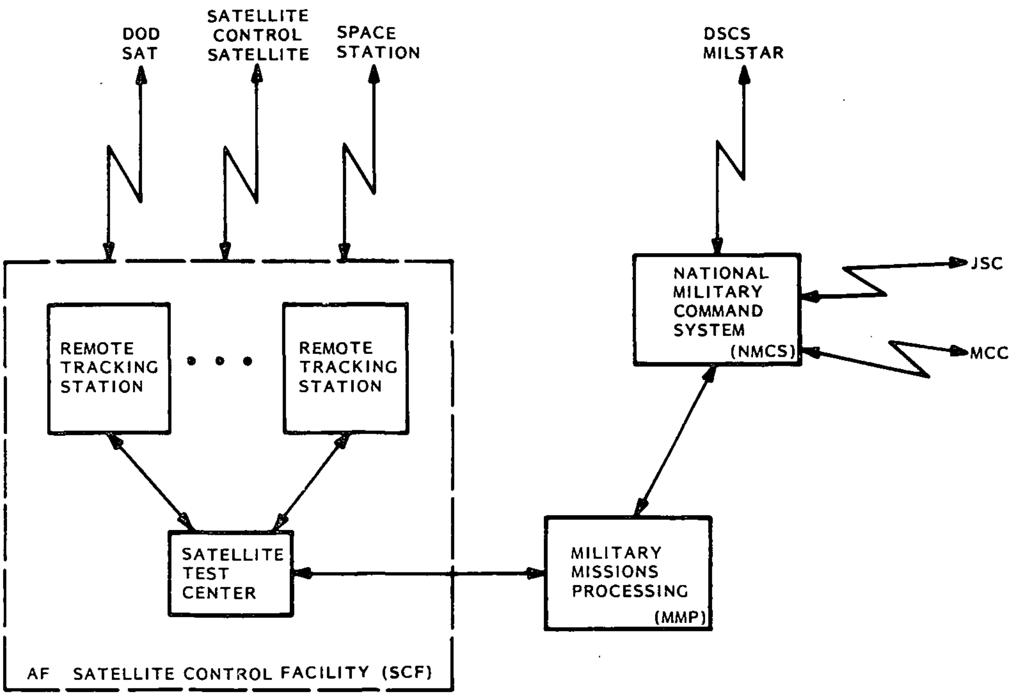

Figure 2.3.5-6. Military Mission Center (Phase 4 and 5)

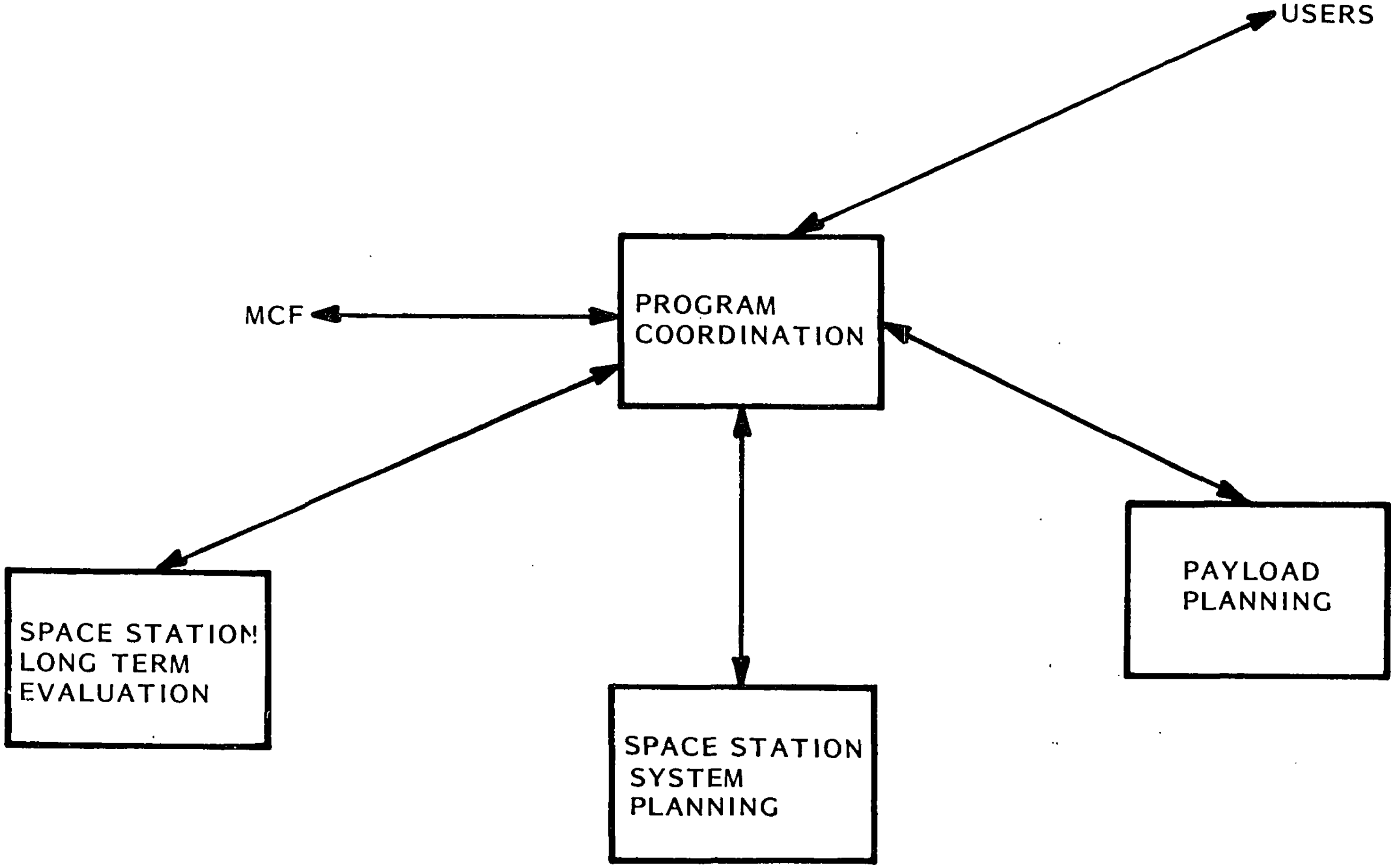

Figure 2.3.5-7. NASA Program Facility

Table 2.3.5-1A. Ground Segment Functional Allocation

		PHASE 1	2	3	4	5	FACILITY
USER/PI INTERFACE							
PROCESS EXPERIMENT/MISSION REQUIREMENTS	G, L		X	X	X	X	NPF
PRELIMINARY REQUIREMENTS APPROVAL	G, L		X	X	X	X	NPF
INPUT REQUIREMENTS TO PLANNING	G, L		X	X	X	X	NPF
USER/PI TO CREW VOICE COMM	SH, M		X	X	X	X	CDMF
USER/PI TO S/S DATA COMM	SH, L		X	X	X	X	CDMF
SYSTEM COMMAND AND CONTROL							
FLIGHT OPERATIONS LONG TERM PLANNING	G, L	X	X	X	X	X	NPF
MISSION OPERATIONS LONG TERM PLANNING	G, L		X	X	X	X	NPF
FLIGHT OPERATIONS SCHEDULING	OB, H	X	X	X	X	X	OB/MCF
MISSION OPERATIONS SCHEDULING	OB, L		X	X	X	X	OB/MCF
FLIGHT OPERATIONS	OB, H	X	X	X	X	X	OB/MCF
MISSION OPERATIONS	OB, L		X	X	X	X	OB/MCF
MISSION SUPPORT							
MISSION DATA COLLECTION	OB, L		L	H	L	H	OB/DCSF
MISSION DATA PREPROCESSING	OB, L		L	H	L	H	OB/DPEF
MISSION DATA PROCESSING	G, L		L	H	L	H	DPEF
MISSION DATA DISTRIBUTION							
DATA DOWNLINKING	SH, L		L	H	L	H	TGS
FREE FLYER RELAY	OB, M			X		X	OB
DATA ROUTING TO USER/PI	G, M		X	X			DDF
TDRSS LINK SCHEDULING	G, M	X	X	X			TGS/MCF
MILSATCOM LINK SCHEDULING	G, M				X	X	MMC
S/S HARDWARE MAINTENANCE							
PREVENTIVE MAINTENANCE	OB, H	X	X	X	X	X	OB
FAULT DETECTION	OB, H	X	X	X	X	X	OB/MCF
FAULT ISOLATION/DIAGNOSIS	SH, H	X	X	X	X	X	MCF

Table 2.3.5-1B. Ground Segment Functional Allocation

		PHASE 1	2	3	4	5	FACILITY
CORRECTIVE ACTION	OB, H	X	X	X	X	X	OB
SS/GROUND VOICE COMM	SH, H	X	X	X	X	X	MCF
TV MONITORING	SH, M	X	X	X	X	X	MCF
S/S SOFTWARE MAINTENANCE							
FAULT DETECTION	OB, H	X	X	X	X	X	OB/MCF
FAULT ISOLATION/DIAGNOSIS	SH, H	X	X	X	X	X	MCF
CORRECTIVE ACTION	SH, H	X	X	X	X	X	MCF
SS/GROUND VOICE COMM	SH, H	X	X	X	X	X	MCF
SS/GROUND DATA COMM	SH, H	X	X	X	X	X	MCF
CREW HEALTH MONITORING/MAINTENANCE							
ROUTINE CHECK UP	OB, M	X	X	X	X	X	OB
HEALTH DATA COLLECTION	OB, M	X	X	X	X	X	OB
DIAGNOSIS/TREATMENT DET.	SH, H	X	X	X	X	X	MCF
S/S/GROUND VOICE COMM	SH, H	X	X	X	X	X	MCF
S/S/GROUND DATA COMM	SH, H	X	X	X	X	X	MCF
TV MONITORING	SH, H	X	X	X	X	X	MCF
SPACEBORNE EXPERIMENTATION							
CONDUCT EXPERIMENT	OB, L	X	X	X	X	X	OB
RECORD DATA	OB, L	X	X	X	X	X	OB/DCSF/MCF
ANALYZE DATA	G, L	X	X	X	X	X	DPEF
CREW/PI VOICE COMM	SH, L	X	X	X	X	X	MCF
SS/PI DATA COMM	SH, L	X	X	X	X	X	MCF
TV MONITORING	SH, L	X	X	X	X	X	MCF
S/S ONBOARD SUPPORT							
ENVIRONMENTAL CONTROL & LIFE SUPPORT	OB, H	X	X	X	X	X	OB
ELECTRICAL POWER	OB, H	X	X	X	X	X	OB

Table 2.3.5-1C. Ground Segment Functional Allocation

		PHASE 1	2	3	4	5	FACILITY
THERMAL CONTROL	OB, H	X	X	X	X	X	OB
GUIDANCE, NAV & ATTITUDE CONTROL	OB, H	X	X	X	X	X	OB
SS/GROUND COMMUNICATIONS	SH, M, L, H	X	X	X	X	X	MCF
SS INTERIOR COMMUNICATIONS	OB, M	X	X	X	X	X	OB
SURVEILLANCE (RADAR)	OB, H		X	X	X	X	OB
RENDEZVOUS AND DOCKING SUPPORT	OB, H		X	X	X	X	OB
REMOTE MANIPULATION SUPPORT	OB, M		X	X	X	X	OB
EVA SUPPORT	OB, H		X	X	X	X	OB
OTV SUPPORT	OB, H		X	X	X	X	OB
FREE FLYER SUPPORT	OB, M		X	X	X	X	OB
STRUCTURE CONTROL/MONITORING	OB, M		X	X	X	X	OB/NPF
LOGISTICS	OB, L	X	X	X	X	X	OB
S/S SUPPORT SUBSYSTEM C&C							
SUBSYSTEM COMMANDING	OB, H	X	X	X	X	X	OB/MCF
PROCEDURE DISPLAY/PROCESSING	OB, H	X	X	X	X	X	OB/MCF
BACKUP COMMANDING	G, H	X	X	X	X	X	MCF
S/S MISSION SUBSYSTEM C&C							
MISSION SUBSYSTEM COMMANDING	OB, M		X	X	X	X	OB/MCF
PROCEDURE/DISPLAY PROCESSING	OB, M		X	X	X	X	OB/MCF
S/S SUPPORT SUBSYSTEM MONITORING							
TELEMETRY PROCESSING	OB, H	X	X	X	X	X	OB/MCF
TELEMETRY DISPLAY	OB, H	X	X	X	X	X	OB/MCF
TREND ANALYSIS	G, L	X	X	X	X	X	NPF
C&W ALARMS	OB, H	X	X	X	X	X	OB/MCF
TV MONITORING	OB, M	X	X	X	X	X	MCF

Table 2.3.5-1D. Ground Segment Functional Allocation

		PHASE 1	2	3	4	5	FACILITY
S/S MISSION SUBSYSTEM MONITORING							
TELEMETRY PROCESSING	OB, M		X	X	X	X	OB/MCF
TELEMETRY DISPLAY	OB, M		X	X	X	X	OB/MCF
C&W ALARMS	OB, H		X	X	X	X	OB/MCF
TREND ANALYSIS	G, L		L	H	L	H	NPF
TV MONITORING	OB, L		X	X	X	X	MCF
ON-BOARD ENTERTAINMENT							
LIBRARY	OB, L	X	X	X	X	X	OB
MOVIES	OB, L	X	X	X	X	X	OB
TV	SH, L	X	X	X	X	X	OB
GAMES	OB, L	X	X	X	X	X	OB
DATA STORAGE							
ON-BOARD DATA BASE	OB, H	X	X	X	X	X	OB
SUPPORT DATA BASE	G, M	X	X	X	X	X	MCF/DCSF
LONG TERM DATA STORAGE	SH, H	X	X	X	X	X	MCF/DCSF
PERFORMANCE EVALUATION							
LONG TERM SYSTEM PE	G, M	X	X	X	X	X	NPF
SHORT TERM SYSTEM PE	OB, H	X	X	X	X	X	OB/MCF
LONG TERM MISSION PE	G, L		L	H	L	H	
SHORT TERM MISSION PE	OB, M		L	H	L	H	OB/MCF
MILITARY SUPPORT							
INTERFACE	OB, H				X	X	NMCS/SCF
TRAINING AND SIMULATION							
TRAINING AND SIMULATION SUPPORT	OB, M	X	X	X	X	X	OB/MCF

Several factors were considered in the conceptual design of the ground complex and its relation to the OB DMS. The OB architecture has the DMS connected to a large network of subsystems and sensors which would be very costly to duplicate in the MCC. There is a need to consider conflicting and overlapping signals between ground and OB when designing backups. The OB DMS was designed for very high reliability, with redundancy and manual overrides on-board for most subsystems. For these reasons, it was determined to tie the Mission Control Center (MCC) backup functions into the OB DMS, as opposed to bypassing it directly to the subsystems. In this mode, the ground will build (using the training and simulation functions) the commanding sets that would have been generated on-board by the crew, and transfer them to the OB DMS. In a backup mode, if the OB DMS is operating in a reduced mode, the ground can use the training and simulation functions to do the appropriate calculations, and uplink them to the crew. Note, that if both OB DMS and crew are unable to operate properly, it is envisioned that the space station will go into a safe-hold.

A major component of the Mission Control Center is the training and simulation section. This component is envisioned to service a multitude of functions. To begin with, it could be used as a training site for future crew members. As such it will resemble the on-board configuration and be able to generate scenarios for the crew to practice on. It will contain a complete copy of the OB DMS hardware and software and hence will respond exactly as the real one would, to trainee inputs. Another purpose of this component will be to act as a test bed for the DMS. Here, the initial DMS can be checked and all updates and changes can be tested before being sent up. A final purpose of the training and simulation section is to serve as a backup to on-board functions. In cases of emergencies, this section can be reconfigured through the mission control facility and act as a live backup. The Military Mission Center performs functions analogous to those done by both the Mission Control Center and the Commercial data center combined.

2.3.5.2 Ground Segment Hardware

The top level hardware view of the ground complex that is presented in this section was scoped to perform the functions as allocated in Section 2.3.5.1. The hardware for performing commercial data processing and evaluation was not identified at this point in time because it is highly dependent on the missions being performed, their processing requirements and the aggregate number being handled simultaneously. However, the present concept allows for the addition of such a facility at Phase 2 and expansion of it in Phase 3.

Figure 2.3.5-8 shows the hardware configuration of the mission control center. The left side of the figure consists of a copy of the DMS along with a special purpose interface unit to allow for simulation of the multitude of inputs to it. That section also has a minicomputer system which includes disk memory and terminal(s). The combination of the above hardware is intended to handle the training and simulation functions, act as a test bed for DMS updates, and be used for backup command and control functions, as detailed earlier.

The central portion of Figure 2.3.5-8 is the heart of the mission control center. This is the section that handles all communications with the space station, performs all the ground monitoring functions, controls backup operations, processes telemetry, etc. This portion consists of: the receiving equipment for data, voice and TV communications; a NASCOM link with an A-channel preprocessor for telemetry; a mini-computer system and fixed disc packs. This section is triply redundant since it is involved in processing many highly critical functions that are shared with the OB DMS. Higher redundancy is not deemed necessary at this point since all the high criticality functions are shared with OB DMS which could take part of the load (an exception may be the communication links). The final section, the right portion of Figure 2.3.5-8 consists of a minicomputer system. This equipment is to handle the planning and evaluation functions of the NASA Programs Facility. These are mostly low criticality functions which were separated from the highly critical ones of the Missions Control Facility.

Figure 2.3.5-9 depicts the hardware of the Commercial Data Center. The left side consists of a minicomputer system with a DBMS and a disk farm for its online data base. This section is designed to handle the commercial data management functions along with the data distribution activities. It will also act as a controller of processing and an interface to the data processing and evaluation section should it become appropriate. The right side of Figure 2.3.5-9 is intended to support the data collection and storage functions. this section consists of: a minicomputer system, for some control of the recording processes and for the coupling of IRIG time with space station time;

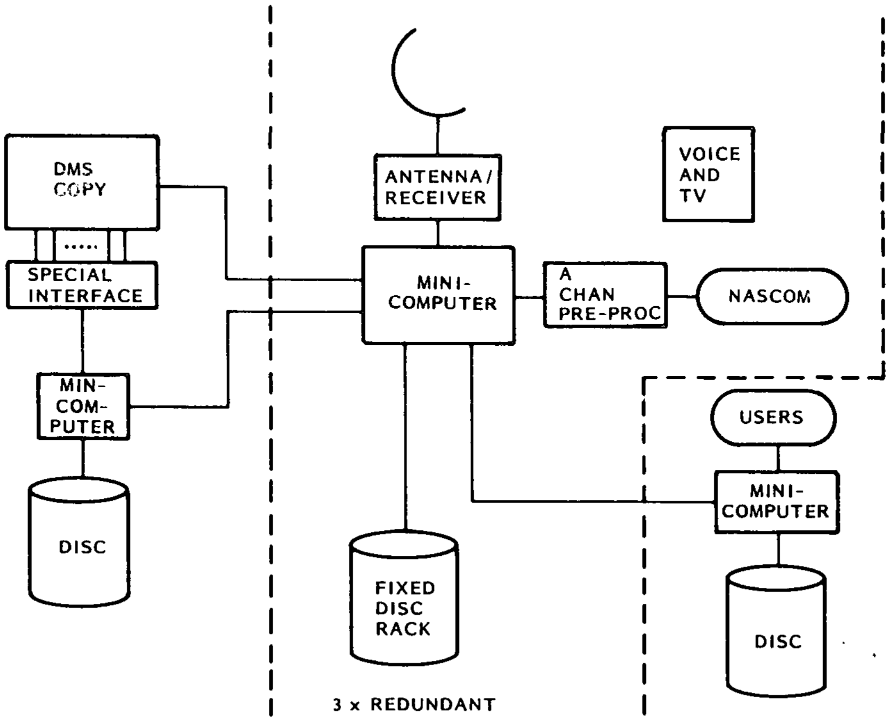

Figure 2.3.5-8. Mission Control Center H/W

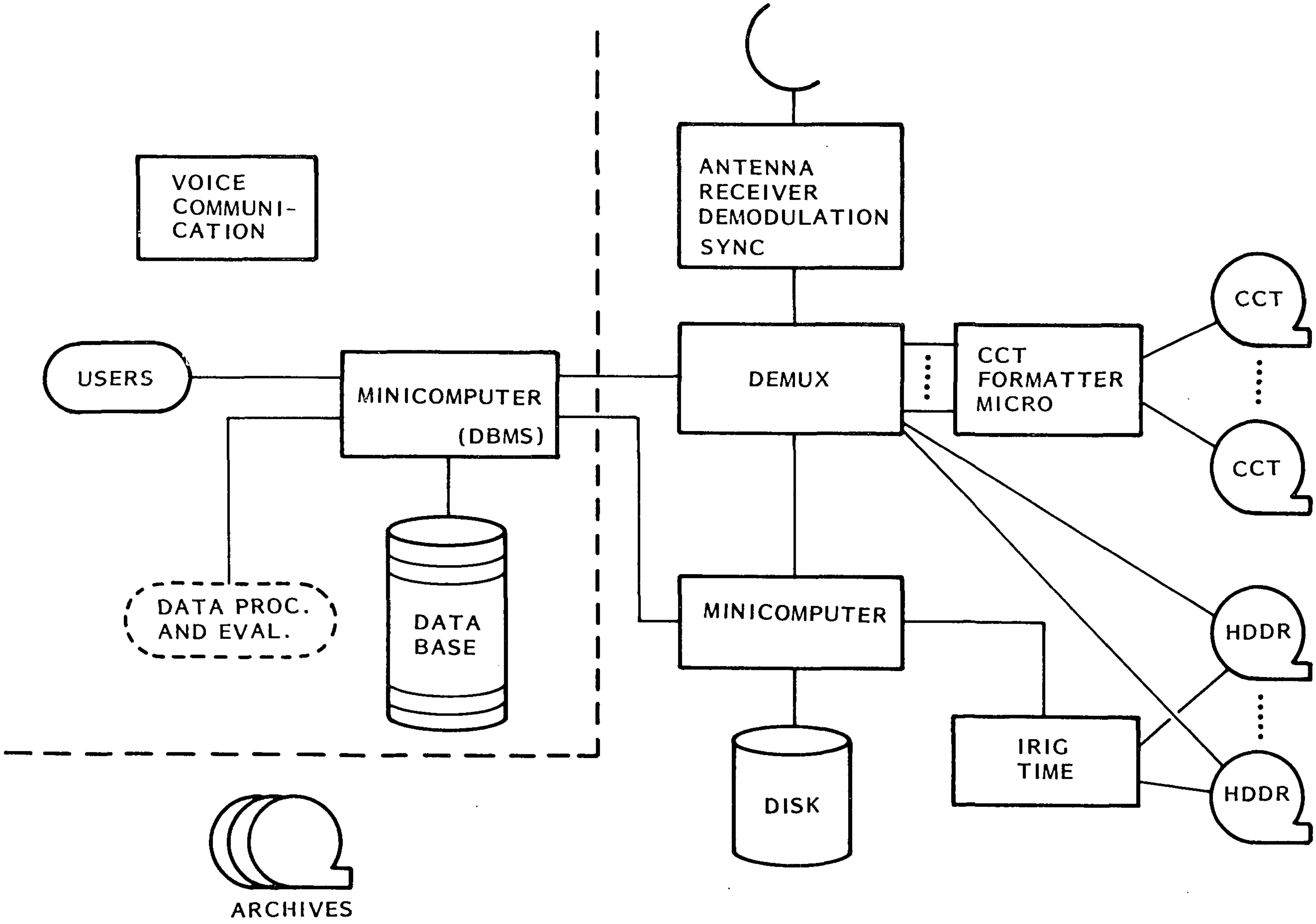

Figure 2.3.5-9. Commercial Data Center H/W

a demultiplexer for separating the various payload streams; a CCT formatter for the lower data rates; several high density data recorders (HDDR) for large data volume missions; and several magnetic tape drives (CCT) for lower data volume missions. The number of HDDR and CCT records is expandable with the growth in the mission load of the space station.

The design of the ground complex is fairly simple. This is possible to accomplish since much has been assigned to the on-board data management system, thus reducing the ground complex load.

B. Commercial Data Center

This center is responsible for the handling of all commercial/scientific mission data. Here, payload data is: collected and recorded; stored, indexed and archived; if applicable processed and evaluated; and distributed to users.

The components of the commercial data center are: 1) data collection and storage facility, 2) commercial data management facility, 3) data processing and evaluation facility, and 4) data distribution facility.

The data processing and evaluation facility performs the following functions:

Mission data preprocessing
Mission data processing
Spaceborne experiment data analysis
Evaluations of processed data

The data distribution facility has been folded into the commercial data management facility, and thus is shown as part of Table 2.3.5-4. Table 2.3.5-5 shows the data collection and storage facility.

A. Mission Control Center

This center acts as a hub for communication, control, planning, and serves as a backup to the on-board data management system. It consists of the Mission Control Facility (Table 2.3.5-2) and the NASA program facility (Table 2.3.5-3).

C. Military Mission Center

This center handles all information related to national security and military payloads on the space station. It is endowed with most of the functions of the mission control center (in case of national emergencies) and of the commercial data center. This center comes into existance in Phase 4 and is

Table 2.3.5-2a. Mission Control Facility - Phase 1

Function	Criticality
Flight operations scheduling	H
Flight operations	H
TDRSS link scheduling	M
SS H/W fault detection	H
SS H/W fault isolation/diagnosis	H
SS S/W fault detection	H
SS S/W fault isolation/diagnosis	H
SS S/W corrective action	H
Health diagnosis/treatment determination	H
SS Subsystem commanding	H
SS procedures display/processing	H
Backup commanding	H
SS telemetry processing	H
SS telemetry display	H
SS C&W alarms	H
Support data base	M
Long term storage	H
Short term system performance evaluation	H
Training and simulation support	M
For all function support:	
SS/ground voice communication	H
SS/ground data communication	H
TV monitoring	H

Table 2.3.5-2B. Mission Control Facility - Phase 2 and 3

Function	Criticality
Missions operations scheduling	L
Missions operations	L
Missions subsystem commanding	M
Missions procedures display/processing	M
Missions telemetry processing	M
Missions telemetry display	M
Missions C&W alarms	H
Short term missions performance evaluation	M

Table 2.3.5-3a. NASA Program Facility - Phase 1

Function	Criticality
Flight operations long term planning	L
Trend analysis (S/S telemetry)	L
Long term system performance evaluation	M

Table 2.3.5-3b. NASA Program Facility - Phase 2 and 3

Function	Criticality
Process experiment/mission requirements	L
Preliminary requirements approval	L
Input requirements to planning	L
Missions operations long term planning	L
SS structure control/monitoring	M
Trend analysis (mission telemetry)	L
Long term mission performance evaluation	L

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Table 2.3.5-4. Commercial Data Management Facility - Phase 2 and 3

Function	Criticality
User/PI to crew voice communication	M
User/PI to SS data communication	L
User request handling	M
Data base management support software	M
Processing control	M
Data routing to user/PI	M

Table 2.3.5-5. Data Collection and Storage Facility - Phase 2 and 3

Function	Criticality
Mission data collection	L
Spaceborne experimental data recording	L
Support data base	M
Long term data storage	M

Note: Spaceborne experiments data recording needs to be available in Phase 1. However, the data rates and volumes for these are so low that they can be done elsewhere and do not warrant the creation of this facility at that stage.

nearly unchanged through Phase 5. Its components could be the Satellite control facility which performs tracking command and control and a separate facility which handles mission data processing.

2.3.5.3 Ground Segment Software

Based on the functions to be performed by the ground segment, the set of major software functions illustrated in Table 2.3.5-6 was determined. These software elements not only include the major ground functions to be performed, but on-board DMS backup as well. The ground backup could be performed in two ways (see Figure 2.3.5-10) by having the ground communicate directly with the Space Station subsystems via hardware cross-strapping or by software cross-strapping. At this point in time the hardware cross-strapping (method one on Figure 2.3.5-10) is preferred because it allows commonality in ground and flight software and eliminates the need for a special TLM/CMD interface module in the DMS.

Table 2.3.5-6. Major Ground Facility Software Functions

MILITARY MISSION CENTER

- SUBSYSTEM RESOURCE MANAGEMENT (C)
  - PRIORITIZED ADVANCE SCHEDULING
  - R/T RESOURCE ARBITRATION/REALLOCATION
  - SUBSYSTEM COMPUTATIONAL SUPPORT
- SUBSYSTEMS COMMAND AND CONTROL (C)
  - ELECTRICAL POWER
  - ENVIRONMENTAL CONTROL/LIFE SUPPORT
  - GUIDANCE AND NAVIGATION/ATTITUDE CONTROL
  - RADAR (COLLISION AVOIDANCE)
  - RENDEZVOUS AND DOCKING
  - STRUCTURAL CONTROL
  - THERMAL CONTROL
  - PROPULSION
- COMMAND MANAGEMENT (C)
  - SEQUENCE GENERATION, VALIDATION, STORAGE
  - SEQUENCE TRANSMISSION AND SAFETY INTERLOCK
  - COMMAND VERIFICATION
- TELEMETRY MANAGEMENT (C)
  - TLM ACQUISITION
  - S/S STATUS AND PERFORMANCE MONITORING
  - S/S REAL-TIME DATA DISPLAYS
  - S/S ALARMS RECOGNITION/RESPONSE
  - TLM STORAGE AND RETRIEVAL
  - PLAYBACK PROCESSING
- SYSTEM PERFORMANCE MONITORING/EVALUATION (NC)
- STATION OPERATIONS SCHEDULING/SUPPORT (NC)
  - PROCEDURES AND TIMELINES
  - LOGISTICS
- NATIONAL MILITARY COMMAND SYSTEM
- SPECIAL PURPOSE MILITARY MISSION PROCESSING
- DATA BASE MAINTENANCE

MISSION CONTROL CENTER

- SUBSYSTEM RESOURCE MANAGEMENT (C)
  - PRIORITIZED ADVANCE SCHEDULING
  - R/T RESOURCE ARBITRATION/REALLOCATION
  - SUBSYSTEM COMPUTATIONAL SUPPORT
- SUBSYSTEMS COMMAND AND CONTROL (C)
  - ELECTRICAL POWER
  - ENVIRONMENTAL CONTROL/LIFE SUPPORT
  - GUIDANCE AND NAVIGATION/ATTITUDE CONTROL
  - RADAR (COLLISION AVOIDANCE)
  - RENDEZVOUS AND DOCKING
  - STRUCTURAL CONTROL
  - THERMAL CONTROL
  - PROPULSION
- COMMAND MANAGEMENT (C)
  - SEQUENCE GENERATION, VALIDATION, STORAGE
  - SEQUENCE TRANSMISSION AND SAFETY INTERLOCK
  - COMMAND VERIFICATION
- TELEMETRY MANAGEMENT (C)
  - TLM ACQUISITION
  - S/S REAL-TIME DATA DISPLAYS
  - S/S ALARMS RECOGNITION/RESPONSE
  - TLM STORAGE AND RETRIEVAL
  - PLAYBACK PROCESSING
- SYSTEM PERFORMANCE MONITORING/EVALUATION (NC)
- STATION OPERATIONS SCHEDULING/SUPPORT (NC)
  - PROCEDURES AND TIMELINES
  - LOGISTICS
- FAULT DETECTION AND ISOLATION
- EXPERIMENT AND MISSION REQUIREMENTS DEFINITION, APPROVAL, PLANNING
- LONG TERM TREND ANALYSIS
- LONG TERM PERFORMANCE EVALUATION
- DATA BASE MAINTENANCE

COMMERCIAL DATA CENTER

- DATA COLLECTION AND STORAGE
  - OB MISSION DATA COLLECTION
  - FREE FLYER DATA COLLECTION
  - LONG TERM DATA STORAGE
- COMMERCIAL DATA MANAGEMENT
  - REAL-TIME VOICE, TV, DATA INTERFACE BETWEEN PI'S AND SPACE STATION
- DATA PROCESSING
  - OB MISSION/FREE FLYER DATA PREPROCESSING
  - OB MISSION/FREE FLYER DATA PROCESSING
  - OB MISSION/FREE FLYER DATA ANALYSIS
- DATA DISTRIBUTION
  - DISSEMINATION OF DATA TO REMOVE INVESTIGATORS

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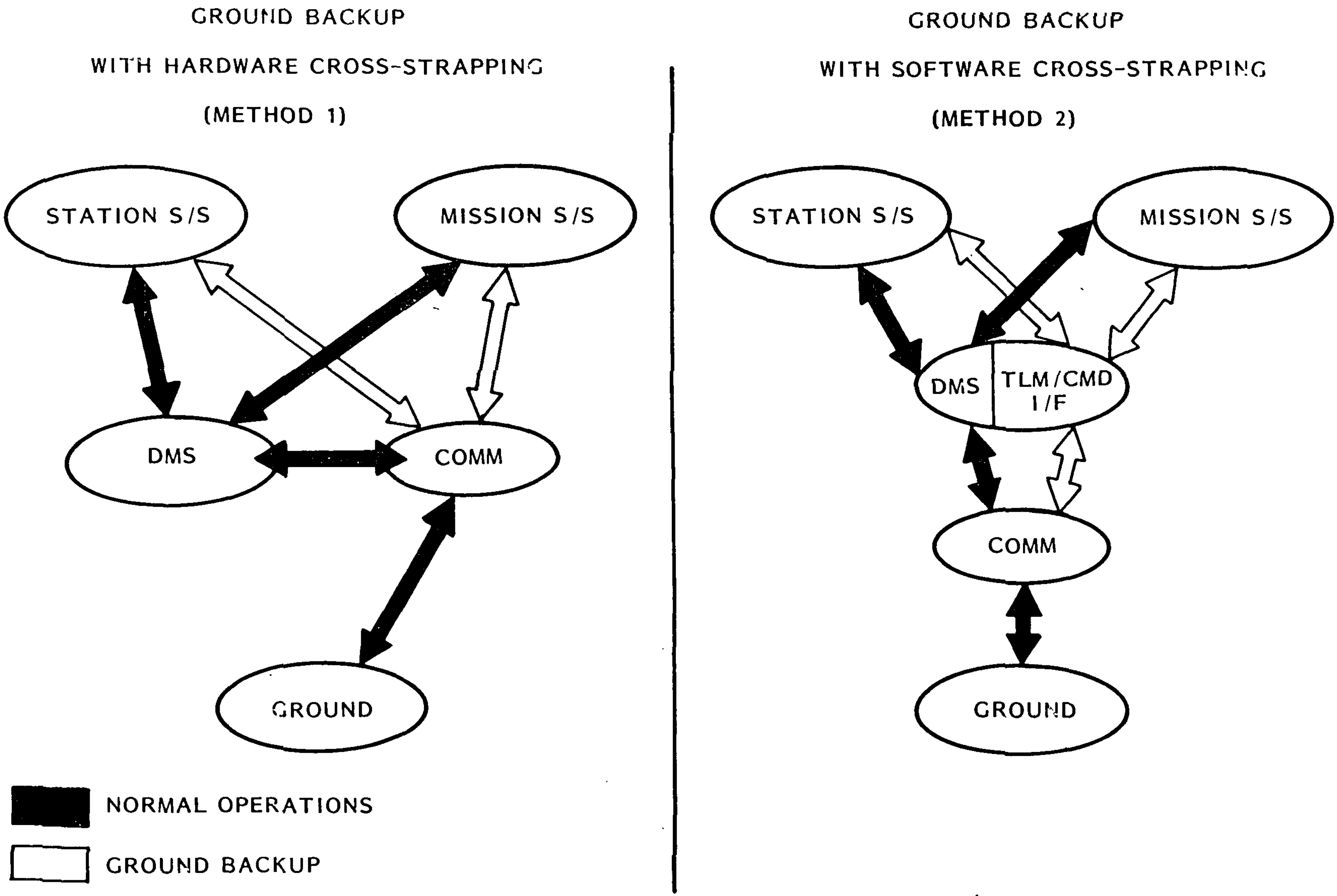

Figure 2.3.5-10. On-Board DMS Backup

2.4 TECHNOLOGY ASSESSMENT

Having determined the driving performance parameters for the IMS in terms of rates, capacities and throughputs, we turned our attention to assessing those technologies which would be required for implementation. Both major areas of Data Management System and Communication technologies were surveyed and trade studies were performed where deemed necessary. This section discusses the results of those surveys as well as the details involved in performing the trades.

In assessing the technologies, we were very cognizant of and concerned with "technology transparency". Technological Transparency is a philosophy that provides for a controlled upgrade approach to long life cycle systems. Long life cycle in this context is defined such that during fielded system lifetime it is economically advantageous to upgrade system hardware to take advantage of new technology not previously available.

A controlled approach to such upgrading calls for a methodology that minimizes upgrade cost, schedule, and risk through advanced planning for the introduction of new advancing technologies. A GE methodology which has been used successfully relies on modular system specification that makes it possible to introduce new technology modules without disturbing the remaining system modules - making the change "transparent" to the non-upgraded hardware.

Technological Transparency allows for advanced technology transitioning through a system specification method that requires functional module partitioning, input-output specification, and software specifications that facilitate technology upgrade with minimum impact of logistics and software. This is a hierarchical methodology that can be carried to the level of modularity required to accommodate the planned technology advancements. This approach has allowed us to use new integrated circuit technology capabilities to add function to existing modules, increase performance throughout, and/or reduce module size, weight, power, and cost. This has been achieved on many levels of transparency from box level modules such as the Modernized logic units of U.S. Navy patrol aircraft (P3C), to board level transparency to chip level transparency, on the F5G Fourier transform hardware using second generation (5 microns) LSI technology for enhanced speed performance. Life cycle system concepts utilizing technological transparency have been demonstrated to be a most effective means of providing for tomorrow's technology today. Conceptually, the Space Station is a large, complex, very long life program of major proportions. The space segment will probably consist of a multi-function space platform providing for a variety of space sensors and on-going manned subprograms. High technology will be employed throughout the program. A low risk conservative approach must be taken to insure successful initial operation of the station. It will be desirable to update various subsystems with more reliable and higher performance devices and architectures not previously available. Requirements will grow as expectations of the system are realized. In previous space programs this change due to growth of technology and growth of requirements has been handled on a block change basis. For the first time, upgrading a single space platform with improved, proven technology without bringing it back from orbit or without replacing the entire space vehicle shall be necessary. Therefore it is highly desirable to identify and provide for later technology updates at the outset of the program.

Early consideration and planning to minimize rework and life cycle costs to realize the advantages of technology transparency is as much a necessity in the architectural design and implementation of the IMS as it is with all other Space Station Subsystems.

2.4.1 DATA MANAGEMENT SYSTEM TECHNOLOGIES

The relevant DMS technologies (Figure 2.4.1-1) were determined by analyzing those functions performed by the on-board DMS. Each technology was analyzed with respect to each of the functions, to ascertain whether that technology constitutes:

1. A "driver" which is beyond the present state of the art.
2. An enabling technology, without which the particular function could not be performed.
3. An "enhancing" technology, the attainment of which will represent significant savings in system resources (e.g., man hours, material, time), translatable in terms of money saved.

The results are shown in Table 2.4.1-1 which correlates technologies with functions.

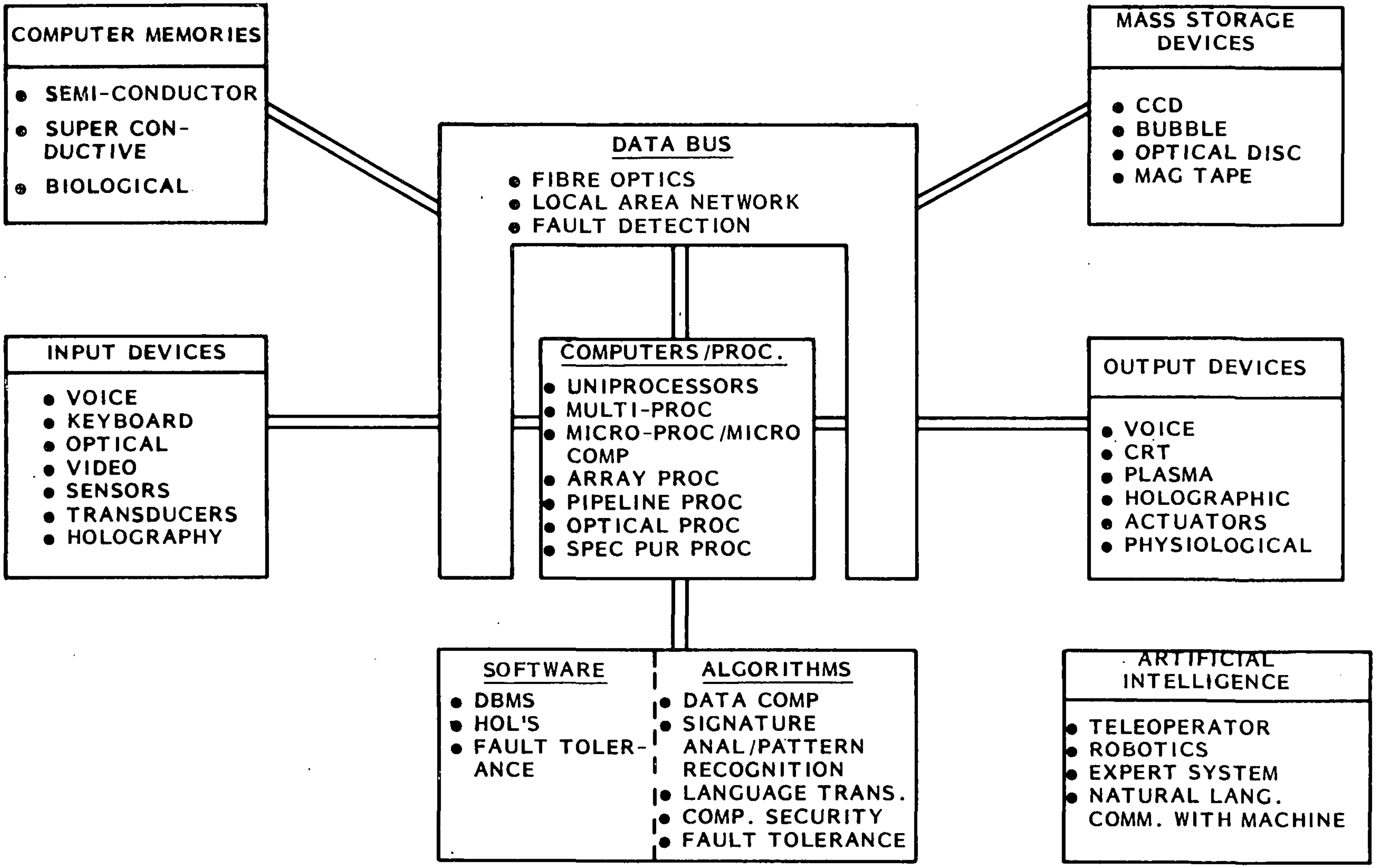

Figure 2.4.1-1. DMS Technologies

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Table 2.4.1-1. DMS Technologies vs. Functions

	TECHNOLOGIES \ FUNCTIONS	ACQUIRE DATA	AUTHENTICATE USER	ERROR DETECT/CORRECTION	VOICE INTERPRETATION	SEARCH DATA BASE	PATTERN RECOG/INFERENTIAL ANALYSIS/HEURISTIC PROC.	MULTI DATA CORRELATION	PROCESS DATA	MESSAGE ROUTING	MAINTAIN DATABASE	STORE DATA	SELF DIAGNOSIS/SELF REPAIR	FORMULATE/FORMAT RESPONSE	TRANSLATE TO REQUESTER'S LANG.	GENERATE VOICE RESPONSE	PRESENT DATA TO USER
INPUT/OUTPUT DEVICE	VOICE REQUEST	●	o														
	SENSOR	o															
	VOICE RESPONSE														o		
	VIDEO/DISPLAY																o
	HARD COPY (I.E., PRINTER/PLOTTER)																o
	FACSIMILE																o
	COMPUTERS/PROCESSORS					●	●	o		o					o	o	
	COMPUTER MEMORIES						o	o									
	MASS STORAGE DEVICES										●	●					
SOFT-WARE	DATABASE MGT/INFO STORE & RETRIEVAL	●				●	●	●	●		o	●					
	HIGHER ORDER LANGUAGE		o		o												
	FAIL SOFT OPERATION (RELIABILITY)												o				
ALGORITHMS	SIGNATURE ANALYSIS							●									
	DATA COMPRESSION			o				●	o								
	PATTERN RECOGNITION						●	●									
	LANGUAGE TRANSLATION				o									o	●		
	SELF DIAGNOSIS/SELF REPAIR			o									●				
	AUTHENTICATION		●											o			
ARTIFICIAL INTELLIGENCE	TELEOPERATOR												●				
	ROBOTICS												o				
	HUMAN/MACHINE COMMUNICATION				●											o	
	NATURAL LANGUAGE UNDERSTANDING				●				o							o	

o - ENHANCING

● - ENABLING

The intersections marked with an open circle are "driver" technologies which are enhancing, whereas the solid dots indicate the "driver" enabling technologies. For simplicity in presentation, Table 2.4.1-1 shows only those technologies and functions which are relevant to technology "drivers;" this does not imply that other intersections are not applicable to the DMS, only that they are considered to be within the projected state of the art capability.

A comparison between current technological capability and that projected for 1995 was then performed. The results of that analysis are shown in Tables 2.4.1-2 to 2.4.1-9.

2.4.1.1 <u>Discussion</u>

The space station DMS will consist of input and output devices, data bases, computers and processors (hardware and software), main memory and mass memory. The following discussion assesses all hardware (with the exception of the data bus, which is covered in Section 2.4.2), as to its capabilities in satisfying the previously derived requirements. It is anticipated that a hardware lead time of at least four years prior to launch will be required.

The objective of this analysis was to perform a survey of the technologies that can be expected in the period 1990 to 2000, to provide a time phase forecast of the technologies and to perform trade studies that select the technologies best suited for the DMS hardware. The trade study includes a forecast of the new developments expected to result in products for launch during the 1990-2000 time phase.

2.4.1.1.1 Input Devices

Input information can be acquired from sensors or from input devices operated by humans. The human inputs involve some form of interactive communications between man and machine. Table 2.4.1-9 contains a list of input modes and their availability.

The current devices will not show orders of magnitude improvement in the next twenty years but certain areas will grow at a considerably higher rate than others. Technology that assists supersonic aircraft pilots meet the critical minimum reaction time response needs or that free hands of astronauts and pilots will receive attention.

Table 2.4.1-2. Input Devices

	Present Capability	1995 Capability
Voice Recognition	o Threshold Technology: 30-100 Vocabulary o Carnegie-Mellon HAPPY	o 1000's Word Vocabulary o Adaptive Recognition from context
Keyboard Entry	o Full 128 ASCII Character K/B o 12 Digit Phone Pad (0-9, *, #) o Up to 80-100 wds/min.	o No significant increase in performance
Optical Character Recognition	o IBM 3886:280 Char/Sec — 4x9" Form, 5 lines per/form — Document Reader 8.5 x 11 in, 50 lines/form — Page Reader o 500-1500 Points/Char. stylized forms-OCR-A/ OCR-B — Journal Tape Reader	o Easy, convenient to use. No critical lighting or positioning requirements. All solid-state sensor, No sensor motion. Will read newsprint quality at 10K char/sec. Will not read longhand.
Optical Bar Code Reader	o Universal Product Code (UPC) - Used in supermarkets	o Cheap and widely available and used
Video Camera	o 525 Lines o Vidicon Input	o Commercial TV Cameras to be hand sized, solid-state o Commercial Format unchanged o Industrial or special-purpose video 4000 line, Digital I/F
Sensor	o Complete Earth Resources o Temperature/Pressure/Vacuum/Voltage (current)/ Flow/Sound/Smell/Acceleration/Light/Metal/ Seismic/Video Motion	

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Table 2.4.1-2. Input Devices

	Present Capability		1995 Capability
Magnetic Tape	o 200/556/800/1600/6250 bpr o 7 Track/9 Track o 1500 K Char/Sec Transfer Rate		o Industry Standard Computer Tape 1/2" Tape (However 2" tape will also be available) 150 Mbps
Interactive Display	o 80 Char x 40 Lines (Max) character alphanumeric/Graphic o Full ASCII Keyboard-Microprocessor as part of terminal permits interactive operation	o Communication interface (via Modem-600/1200/2400/4800/9600 Baud) o Joystick/Track Ball/Light Gun or other cursor permits operator identification of data on CRT o Special functions keys controlled by software	o Interactive High resolution-graphic and color input
Telephone	o Digital - 12 Button Phone-Pad; 3 KHz BW		o Cordless portable telephones. Inherent modem o Rotary dial obsolete o Available telephone-terminals, i.e. terminal with auxiliary telephone in it; also available, a telephone with a small keyboard and display

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Table 2.4.1-3. Output Devices

	Present Capability	1995 Capability
Voice Synthesis		o 1000's Word Vocabulary, easily "trained" and changed o "Human-Like" sound
Typewriter/Teletype		o 2000 Char/Sec Electro-optical print on paper (Laser, direct photo-sensitive paper) o CRT integral to system
Display - CRT - Plasma	o 4000 Char/Alphanumeric/Graphic/ASCII Character o 300 W/NeGAS No refresh required	o 25" Flat-Face, Color, light transmissive (similar to light valve) o 4096 x 4096 Resolution hard copy options.
Hard copy (i.e. Printer/ Plotter)	o 132 Characters/Line 1200 1 pm } Standard Input — Honeywell Page Printer System- 210 Pgs/min or 18,000 lns/ min o IBM 3800: 13,360 lpm using electroptic and laser technology	o Laser driven page printer, photo-sensitive paper 100 Pages/Sec
Facsimile	o 4/6 min per page/electronic newspaper	o 2 seconds/page

Table 2.4.1-3. Output Devices

	Present Capability	1995 Capability
Magnetic Tape	o 200/556/800/1600/6250 pbi o 9 Track o Transfer Rate - 200 K Chara/Sec	Same as Table 2.4.1-2.
Video	o TV Black and white and color o Home Video Recorders	o Same commercial TV standards but industrial and scientific video of high performance (see displays above)
Alphanumeric		o Same density as today's technology (1-10 char/ in^2) but LCD-type o (Low Power/High Contrast)

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Table 2.4.1-4. Computers/Processors

Large Scale General Purpose	o 500 KOPS o Vector Processors (or Super Computers o 10-50 sec instruction		o 40 GOPS using Gallium Arsenide o 1-2 Orders of Magnitude in performance
Mini-Computers	o Spaceborne: 10^5 OPS - 10^6 OPS 22 Watts (NAVY:AADC) 4.5 Kg		o 1-3 GOPS
Microprocessors	o Hand-held calculators o Home/Personal Computters o Games	o Process Control o Automotive / Industrial / Application { Wrist-Watch Size	o 6-8 Orders of Magnitude in computing power o (3-4 orders of Magnitude in performance with considerable decrease in cost)
Array Processors	o 70-8000 MOPS; Goodyear Staran IV Illiac IV		o JPL-STAR (Self-Testing And Repair) o 40 GOPS o 50 NSEC-Acces Time

Table 2.4.1-4. Computers/Processors

	Present Capability		1995 Capability
Parallel Pipeline Processors	o 10-50 M Floating Point Ops	o Cray-1 (800-138 MOPS) o Burroughs o BSP o CDC-STAR 100 o TI-ASC o GSFC-MPP o GSFC-TSE	o Arrays of processors, in which processors are organized to match either the structure of data or structure of algorithm
Adaptive Processors			
Associative Processors			
Optical Processors			
Special Purpose Processors	o Data Base Machines (Hsaiao) - 10^7-10^8 Bytes/Bubble Mem. o FFT o 15 GOPS		o Arrays of processors optimized to data format, i.e., 1 processor/pixel in imagery
Computer Networking/ Configurations	o Multi-Processing		o Federal Networks o Distributed Data Bases

II/2/II

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Table 2.4.1-5. Computer Memories

Magnetic Core	o 50 NS Access Time		
Semi-Conductor	o 16 K MOS RAM/0.1 ¢/BIT o 64 K Dynamic MOS RAM (1980)	- 100-200 NSEC Access Time - 5 x 10^5 Bits/In^2	o 256 K Dynamic RAM Chip o 90-150 N SEC - Access Time
CCD	o 64 K Bit o 1 M Sec Latency o 60 MB/SEC Transfer Rate	- 200-500 μ Sec Access Time - 1-5 MHz Transfer Rate - 0.1¢/Bit	o 10^6 Bit/Chip

Table 2.4.1-5. Computer Memories

	Present Capability		1995 Capability
Bubble	o 100 K Bit Chip (RI) o 0.01 ¢/Bits	- 1 MBS Transfer Rate - 4 Micron Bubble Size - 0.5 μSec Access Time	o 10^8 Bit/Chip
Plated Wire	o (Space Application)	10^4 - 10^6 Bits 1.5-2.5 μ Sec Cycle	
Super Conducting (i.e. Josephson Junction)	o 16 K Bit Chip o 15 N Sec - Access Time		o 10^6 Byte/Chip

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Table 2.4.1-6. Mass Storage Devices

	Head/Track	Moving Head Discs	
Disc	o 8.5-17 MS Access Time o 4-32 M Bytes o .002 ¢/Bit o 4-8 MBS Transfer Rate	o 1.2-38 MBS Tranfer Rate o 300-400 MB o 35-50 Ms Access Time o .002-.0007 ¢/Bit	o 10^{12} Bytes
Laser	o 10^{10}-10^{12} Bits/Tape o 150 MS Access Time Within Tape o 10 Sec to Select Tape		o 10^{11}-10^{13} Bits o 0.1-10 U Sec Access Time o 50 Mb/Sec Transfer Rate
Electron Beam	o 100 μ Sec-Access Time o 10 Mbs-Transfer Rate o 32 M-100 M Bits	o 10^{7}-10^{8} Bytes o Block Access Time- 5 μ Sec	o 10^{14} Bits/Plate
Magnetic Tape	o 125-6250 BPI x 9 Tracks x 2400 Ft = 10^{9} Bits o 10^{-6} ¢/Bit (Tape Only) o .003 ¢/Bit (Tape + Controller + Drive) o HDDT - 10^{11} Bits on 10,800 Foot Reel		

Table 2.4.1-6. Mass Storage Devices

	Present Capability	1995 Capability
CCD		o 10^9 Bits o 0.5 μ Sec Access Time o 6 M BPS - Transfer Rate
Bubble		o 10^9 Bits o 2 μ SEC Access Time o 1.5 M Bit/Sec Transfer Rate
Mass Storage Systems		

# Installations			Access Time	Transfer Rate	¢/Bit
-	CALCOMP 7110	8×10^{12} Bits	10 Sec	1.2 MB	.00002
4	CDC 385000	2.4×10^{11} Bits	7 Sec	800-900 KB	.00026
100	IBM 3850	3.8×10^{12} Bits	15 Sec	806 KB	.00017
-	SDC/AMPEX TBM	2.9×10^{12} Bits	15 Sec	700 KB	.00064

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Table 2.4.1-7. Software

Data Base Management/ Information Storage and Retrieval	- Hierarchial Representation - Relational Representation - Network Representation for Single Data Base	o Resiliency to Tolerate Detected Error o 10^{12} Bytes per Data Base o Structured to Minimize Access Operations o Multi User, Multi Data Base Capability
Higher Order	o FORTRAN o JOVIAL o CMS-2	o Syntax Approximating English o ADA o High Efficiency Coding o Customized H.O.L. will make computer language machine independent
Failsoft Operation/	o TANDEM Non-Stop Fault-Tolerant Operating System o Raytheon-Long Life Spacecraft Computer o GE-Distributed Control Kernal	o Computer will be more tolerant of "User Errors" o Self Diagnosis/Self-Correction o Fault Tolerant Algorithms

Table 2.4.1-7. Software

	Present Capability	1995 Capability
Language Translation	o Limited Vocabulary/Non-Real Time o English to Foreign Language (Single Case Only)	o Near Real Time o Any Language to any other (including multiple languages)
Self Diagnosis/Self Repair	o TANDEM Non-Stop Operating System o Triple Redundancy/Voting Logic o Bypass of Faulty Component	o Complete Self Repair and replacement of entire processing elements without any data loss o Fault detection, isolation, recovery

Table 2.4.1-7. Software

Human/Machine Communication	o .2-5 words/sec o Text Recognition o Speech Recognition limited o Image Analysis <u>Human</u> <u>Assimilation</u> <u>Rates</u> o <u>Visual</u> - 30-40 Char/Sec-10^6 bits/sec for pictorial data o <u>Aural</u> - 2-4 words/sec with 10-1000's of tonal pitch o <u>Manual</u> - Several digital bits/sec; simultaneous distinguishable sensing of pressure, temp., motion, texture	o Simulate Human Cognition and Preception o 2500 Word Vocabulary with 95% success rate
Natural Language Understanding	o Sentence Analysis "Several" Hundred Words o Generation o Memory and Interference o Representation o Control Structures o Speech Recognition	o "Relevance" Determination o Task Synthesis, Given Natural Language Descript-ion o Personal Secretaries to transcribe spoken natural language o Vocabulary of "several thousand" words

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Table 2.4.1-8. Algorithms

Signature Analysis	o Extraction of Spectral Signature using IR Optical Sensors	o World-Wide Signature Bank o Atmospheric Model o Extraction of Signal from Noise
Data Compression	o Primitive - Achieve same effect through increase of channel capacity compression ratio 5-10 (depending on type of data to be re-constructed)	o 10-1000 compression ratio
Heuristic Processing	o GPS-General problem solving (Newell Et. Al) uses Means-End analysis (i.e. reduces differences between state on step-by-step basis) - Elementary Logic - Chess - High School Algebra - Question/Answering for small data bases	o Problem solved for large data bases on interactive basis o Use of higher order logic based system o Expert Systems
Pattern Recognition	o Auto Correlation/Cross Correlation Techniques -	o Complete recognition of complex shapes under otation/magnification and topological distortions

Table 2.4.1-9. Interactive Communications Modes: Human to Machine

Input Modes	Availability
Keyboard	Numerous variations, sufficient standardization.
Pointing	Lightpen, data tablet, trackball, mouse and hardware cursor all readily available.
Hand Editing	Requires moderate resolution tablet, easily programmed.
Handwriting	High resolution tablet; good software is currently beyond state-of-the-art; should probably use software approach of speech-understanding research.
Limited Voice	About 500-100 isolated words or phrases are state-of-the-art; commercially available with about 95% accuracy.
Continuous Speech	Under development in ARPA sponsored projects; expected to be available in limited task domains in about 3 years.
Physiological Signals	Eye motion, muscle contraction, alpha waves, pulse, etc. at research stage.
Pictorial Data	Presently requires line scanning devices; picture interpretation still quite limited except for very narrow task domains.
Optical Character Recognition	Several commercially available high-speed devices, with limited type fonts and handprinted characters.
Low Density Text	Numerous commercially available hard and soft copy terminals; 25 lines typical. Ann Arbor displays 40 lines of 80 characters; typical full-graphics terminal displays 50-55 lines of 70-80 characters.
High-Density Text	Tektronix 4014 can display 64 lines of 133 characters, equivalent to one computer printout page.
Multi-font Text	Full graphic terminals allow programmable character generator; TV based terminals convenient for boldfaced type.
Low-resolution Graphics	Low resolution (256 x 256 to 512 x 512) TV based terminals plasma panel
High-resolution Graphics	Requires high resolution (1024 x 1024) TV or refreshed or storage directed-beam CRT; many available.

Table 2.4.1-9. Interactive Communications Modes: Human to Machine (Cont.)

Input Modes	Availability
High-Speed Graphics	IMLAC and GT40, IDIIOM, Vector General, Evans - Sutherland
Color Graphics	Data disc; RAMTEK
TV Images	Data disc: RAMTEK; other TV-based systems
Immediate Hardcopy	Tektronix in 18 sec; plasma panel hardcopy being developed; graphics printer + software in about 1 minute
Overnight Hardcopy	Commercially available devices produce publication quality
Voice	Several commercially available devices
Physiological	Research underway in biofeedback and "vision" devices for the blind
Half Tone Graphics	Evans-Sutherland "Watkins box" for surface shading: GE/NASA System
Feel	"Feelie box" investigated by A.M. Nool (Ph.D. thesis): also under development by Kent Wilson at U.C. San Diego

Voice recognition will provide the astronauts a means of issuing voice commands via the computer. This will be particularly useful when the astronauts are not at a terminal and/or do not have a free hand. The use of simple sentences will provide a degree of redundancy that can be used to achieve a predetermined error rate for voice recognition. By the year 1990, the software will be able to identify the speaker as well.

Optical character reader will provide a convenient method to enter printed material into the DMS storage. The terminal keyboard will continue to provide an acceptable method to enter limited amounts of data into the DMS storage.

2.4.1.1.2 Output Devices

The next generation output devices will find expanded use of teleoperators and voice synthesis. The use of displays will continue with improved resolution and thin CRTs.

Hardcopy printers and plotters can be expected to continue with improved quality of print and increased speed with outputs of greater than 100 pages per second.

Voice generation can provide a means for the DMS to communicate with the operators when they are not at a terminal. The 1995 time frame will have the capability to generate simple sentences, which include redundancy. This will increase the intelligibility of the voice generated message.

2.4.1.1.3 Computer Systems

The on-board DMS performance requirements indicate that an aggregate 8 MOP processing speed may be required. Although such processing speeds could be attained using single array processors or multiprocessors, the distributed DMS architecture makes these alternatives unnecessary. Use of simple, single processor technology lowers system development and maintenance cost while fully satisfying performance requirements.

Processor Technology

I^2L microprocessors are or soon will be hardened for application in space. A typical microprocessor has a 200 to 300 nanosecond cycle time and processing throughput of 700 KIPS with a 20 MHz clock. The current versions have a 16 bit word and a 16 bit address for the 64K direct address capability.

The 1995 time reference will see 32 bit computer words and a 24 bit address line which will give a direct memory addressing capability of 16 Megawords or 64 Megabytes. The chip will include fault tolerance and a throughput of 1.0 MOP.

A number of computer processors have been space qualified by the military for use aboard various spacecraft. A number of microcomputers are in the process of being hardened. The Fairchild 9445 I^3L microcomputer is an example of the computer processors that will be available in the 1990 time frame. This unit includes a "bussing capability" for use in a multiprocessor computer system.

Computer Processors - Trade Study (see Table 2.4.1-10)
The CMOS microprocessors can be space qualified and are the best choice for use onboard the space station. The standard computer mainframe bus should have a 32 bit word capability and a 24 bit memory address line. The 1990 computer processors will use a 16 bit word and a 24 bit memory address. This provides adequate direct memory address space and makes software transparent to the 1995 generation of computer processors.

2.4.1.1.4 Main Memory
A main memory is characterized by fast access times and fast read/write times. There are three types of main memory:

1. Dynamic memory is volatile and must be periodically refreshed or the data is lost.

2. Static memory is also volatile memory, but the content will be retained as long as the voltage supply remains on. A static memory with a battery back-up for the power is considered to be non-volatile main memory.

3. Non-volatile memory, which is magnetic core and plated wire.

Fault Tolerant Main Memory
Memory modules can be designed to have words with redundant bits and the redundant information to be used for error detection and correction.

Table 2.4.1-10. Processor-CPU Trade Study

CRITERIA	WEIGHT (Wi)	MICRO-COMPUTER		MINI-COMPUTER		LARGE SCALE	
		SCORE	WiS	SCORE	WiS	SCORE	WiS
FAULT TOLERANCE	5	3	15	1	5	1	5
COST	1	3	3	2	2	1	1
COMPLEXITY	2	3	6	2	4	1	2
ARCHITECTURE	3	2	6	2	6	1	3
TOTAL (Σ WiS)		20		17		11	

SCORE: 1 - FAIR
2 - GOOD
3 - EXCELLENT

WEIGHT: 1 - LEAST SIGNIFICANT
5 - MOST SIGNIFICANT

The memory can be grouped into blocks which can be switched to replace other blocks of memory. This grouping can be used in a fault tolerant memory system that detects failures and replace the failed blocks with spares.

Processor Main Memory (Non-Volatile)

A computer with non-volatile memory can be powered down and restarted without the need to reload the memory. A momentary interruption of power will not necessarily halt a computer with non-volatile memory. Both plated wire memory and magnetic core memory have been used in space. They require more power than CMOS memory but for applications that need non-volatile memory, the magnetic core memory would be a good choice.

Most development work is being done to improve the semi-conductor memory technology. For this reason no improvements in magnetic core or plated wire are forecast past the 1990 launch.

Processor Main Memory (Volatile)

The CMOS technology has produced hardened chip for applications in space. Most semiconductor companies believe that CMOS memory has good potential for both commercial and space applications. And the CMOS memory is a good choice for the space station. Current CMOS memory chips have 64K bits/chip, an access time of 360 nanoseconds and a read/write time of 480 nanoseconds. The 1990 forecast is for the 128K bits/chip, a 100 nanosecond access time and a 250 nanosecond read/write time. By year 2000 the speeds should be improved and the memory chips will include fault tolerance with self test and repair capability.

Plated Wire Main Memory

Plated wire memories have been space qualified and successfully used as the main memory in space. It provides a non-volatile memory with non-destructive readout.

Plated wire memory has the following performance characteristics:

Capacity	12 K bits/array
Access Time	150 nsec
Read/Write Times	250 nsec
Radiation Hardened	

Plated wire memories could be a good choice for non-volatile memory with fast access and bit transfer rates.

Semiconductor Main Memory

The semiconductor memory can be either dynamic or static memory. CMOS memory is "static" and will retain the memory content as long as the voltage remains within the specified limits. The technology is available to harden CMOS memory chips. The CMOS memory has been space qualified for use with three computers and CMOS is the obvious choice for semiconductors main memory applications aboard the space station.

The major development effort is to improve the speed and density of the CMOS memory chips. The currently available memory chips have the following performance parameters:

Capacity	12 K bits/chip
Access Time	350 nsec
Read/Write Times	480 nsec

The 1990 technology can be expected to have the following:

Capacity	128 K bits/chip
Access Time	100 nsec
Read/Write Times	250 nsec

The chip will include bits for the redundancy needed for error detection correction for memory transfer.

Magnetic Core Main Memory

Magnetic core is non-volatile memory with destructive read out and the read must also include an automatic rewrite. Magnetic core is intrinsically hard and has been successfully used on Landsat-4. The typical magnetic core memory would have the following performance characteristics:

Capacity	476 K bits/array
Access Time	350 nsec
Read/Write Times	850 nsec

The magnetic core should be selected for the space station for those applications that require fast access time and non-volatility.

2.4.1.1.5 Mass Memory

Computer mass memory is characterized by large bit storage capacity, slow access times and moderate to high bit transfer rates. The space station requires mass storage to be retained for long periods of time and non-volatile memory could be subject to a loss of memory content in the event it became necessary to remove power.

The computer industry believes that bubble memory is an effective mass memory technology with great potential and plan to offer new bubble memory products with improved performance. The bubble memory chips require no hardening (except for the drive electronics) and the new products now under development make bubble memory the best choice for use aboard the space station.

Charge coupled device are fast and offer good packing density. Radiation hardening has not been completed and a volatile mass memory could cause memory loss which would have to be reloaded from the ground.

Optical disks are now being developed for commercial applications. A single optical disk used for computer mass storage can store about one third the number of bits as a magnetic tape and the disk occupies about a one hundredth the volume of a comparable storage on magnetic tape.

Optical Disk Technology

The optical disk is expected to evolve into the major mass storage device for use to store large volumes of data. The primary commercial application to date has been for video disks that can be played back on TV sets. The computer industry expects to develop optical disks to supersede the magnetic disk.

The optical disk bit density is more than 100 times that of magnetic tape. The optical disks can be removed from the recorder and once removed the disk can be stored for 25 years and still retain the recorded data.

IBM expects to introduce an erase/rewrite optical disk in 1983 which could be available in time for a 1990 launch date.

Optical disks are expected to be on the commercial market by 1986 with the following projected performance characteristics:

	1986	1995	2000
Storage Capacity (bits)	50×10^9	100×10^9	200×10^9
Access Time (msec)	100	20	20
Transfer Rates (megabits/sec.)	50	100	150
Bit Error Rates	10^{-12} or less	10^{-13}	10^{-14}

Bubble Memory Technology

Bubble memory is expected to be used extensively for mass storage in future commercial and space applications. A number of computer companies are working to improve the bit density, the transfer rate and the access time. The currently available 16 Megabit bubble memory has an access time of 400 milliseconds and a bit transfer rate of 70 K bits per second. The 16 megabit unit weighs 19 pounds or 1.1875 pounds/megabit.

Current development work can by 1985, produce a bubble memory with 10^9 bits per chip and with a transfer rate of 1.5 megabits/second. The design of magnetic bubble memory limits the access times that can be achieved, and the reduction in access times will be achieved by going to a more complex chip design.

Charge Coupled Devices

Charge coupled devices are volitale memory and are radiation sensitive. CCD are not being developed for space applications.

Magnetic Disks

Winchester disks are being developed with storage capacity that warrant their consideration for application on the space station. The mechanical design would need to be able to survive a launch environment. The disks are not removable and Winchesters could not be used to read library disks.

Magnetic Tape Recorders

Magnetic tape recorders have performed well in previous space applications. The magnetic tape technology is well understood and reliable units could be manufactured for use on board the space station. The following performance could be achieved for launch by 1990:

Capacity	6.6×10^{10} bits
Transfer Rate	150 megabits/second

Main Memory Trade Study (see Table 2.4.1-11)

The CMOS memory technology is the best choice for use as the computer main memory for the space station DMS. New memory chips are now being developed for the commercial market and CMOS chips can be made radiation hard for space applications. Fault tolerance will give the reliability need for manned space flight.

Mass Memory (Electronic Media) Trade Study (see Table 2.4.1-12)

Mass memory technology is expected to improve the performance capability of mass memory systems that use bubble memory. The expected improvements and system transparency make bubble memory the best choice for electronic mass storage systems.

Mass Memory (Moving Media) Trade Study (see Table 2.4.1-13)

Mission data collection and large on-board data bases will require data storage capacities for greater than can be accommodated by electronic media mass memory. For these applications, magnetic tape, magnetic disk, and optical disk technologies are required. Each of these technologies presents unique problems in the Space Station content. Optical disks are clearly the mass storage device of the future, especially for data collection/archival purposes. However, read/write optical disks may not be available by 1990. Magnetic disks have not been space qualified and would have to be assembled in space to avoid launch stress problems. Magnetic tapes do not provide random access to data which is required for data base operation.

Optical disks are the preferred technology for moving media mass memory. In the initial station, magnetic disks may have to be used. These disks will be phased out as optical technology becomes available.

Table 2.4.1-11. Main Memory Trade Study

CRITERIA	WEIGHT (Wi)	CMOS		MAGNETIC CORE		PLATED WIRE*	
		SCORE	WiS	SCORE	WiS	SCORE	WiS
WGT/SIZE/POWER	2	3	6	1	2	1	2
COST	1	3	3	1	1	1	1
ACCESS TIME	4	2	8	2	8	3	1
TOTAL (ΣWiS)		17		11		13	

*POOR RAD HARDENING CHARACTERISTIC OF PLATED WIRE MEMORIES MAKE IT LESS DESIRABLE THAN CMOS

SCORE: 1 - FAIR
2 - GOOD
3 - EXCELLENT

WEIGHT: 1 - LEAST SIGNIFICANT
5 - MOST SIGNIFICANT

Table 2.4.1-12. Mass Memory - Electronic Media Trade Study

CRITERIA	WEIGHT (Wi)	BUBBLE MEMORY		CCD MEMORY	
		SCORE	WiS	SCORE	WiS
WGT/SIZE/POWER	5	1	5	2	10
CAPACITY	4	2	8	2	8
VOLATILITY	3	3	9	1	3
TOTAL (ΣWiS)		22		21	

SCORE: 1 - FAIR
2 - GOOD
3 - EXCELLENT

WEIGHT: 1 - LEAST SIGNIFICANT
5 - MOST SIGNIFICANT

Table 2.4.1-13. Mass Memory Mechanical Media Trade Study

CRITERIA	WEIGHT (Wi)	OPTICAL DISCS*		MAGNETIC DISCS		MAGNETIC TAPE	
		SCORE	WiS	SCORE	WiS	SCORE	WiS
STORAGE CAPACITY	5	3	15	1	5	2	10
SPACE QUALIFICATION	3	3	9	1	3	3	9
TOTAL (ΣWiS)		24		8		19	

* PROJECTED - ASSUMES THAT OPTICAL DISCS WILL BE SPACE QUALIFIED

SCORE: 1 - FAIR
2 - GOOD
3 - EXCELLENT

WEIGHT: 1 - LEAST SIGNIFICANT
5 - MOST SIGNIFICANT

2.4.1.1.6 Integrated Circuits

The status of integrated circuit development is summarized in the following (The material contained in Section 2.4.1.1.6, including Tables 2.4.1-14 to 2.4.1-22 and Figure 2.4.1-2 was extracted from Volume IIIA, Technology Trend Forecasts, Military Space Systems Technology Model).

IC Properties

A summary of current integrated circuit properties is provided in Tables 2.4.1-14 through 2.4.1-18 including performance and radiation hardness characteristics. The projected characteristics of CMOS and GaAs device technologies are shown for the 1985-1990 time period.

Current Development Effort

A comparison of presently available technology, technology now under engineering development and technology still in basic research are compared in Figure 2.4.1-2. The comparison is in terms of time delay versus power dissipation for a basic inverter circuit. As indicated, SSI (300 gates) and LSI (500 gates) GaAs devices are now in engineering development status with technology demonstration in the 1985 time frame (3500 gates/chips). High speed silicon MESFET technology has been under development since 1979 with LSI demonstrations in 1982 and 1985. GaAs technology promises the highest speed with lower power. The charts in this section illustrate ongoing efforts at AFWAL/AFAL in support of electronic warfare developments for avionics, with application to AF/SD needs. Table 2.4.1-19 gives the details of the high speed silicon MESFET effort.

Expected completion for the 8 x 8 multiplier using 1 um design rules was late 1982. A follow-on until July 1985 will fund the 16 x 16 multiplier to demonstrate LSI capability in silicon MESFET. Table 2.4.1-20 describes several devices of both depletion and enhancement modes showing threshold voltage shift under radiation test. A more complete summary of radiation test results of MESFET devices is given in Table 2.4.1-21 showing reasonable values in neutron flux, total dose and dose rate, while recognizing that these are engineering development devices from laboratory pilot lines.

GaAs Technology

GaAs radiation hardness for small scale ICs is shown in Table 2.4.1-22. Possible degradation with reduced design rules is not indicated, but the

Table 2.4.1-14. Summary of IC Properties (1)

PROPERTY	CURRENT TECHNOLOGY 1981				
	T^2L	LST^2L	ECL	I^2L	PMOS
1 RELATIVE PROCESS MATURITY (1-10)	10 (8)	9 (4 to 5)	8 to 9 (3 to 5)	4	10
2 PROCESS COMPLEXITY (No. processing steps)	18 to 22+	18 to 23+	19 to 23+	13 to 17	8 to 14
3 LOGIC COMPLEXITY (No. components 2-input gate)	12	12	8	3 to 4	3
4 PACKING DENSITY (gates/mm^2)	10 to 20	20 to 40	15 to 20	75 to 150	75 to 150
5 PROPAGATION DELAY (n/sec) (typical value)	6 to 30 (10)	2 to 10 (5)	0.7 to 2 (2)	7 to 50 (20)	30 to 200 (100)
6 SPEED-POWER PRODUCT (pj)	30 to 150	10 to 60	15 to 80	0.2 to 2.0	50 to 500

Table 2.4.1-15. Summary of IC Properties (2)

PROPERTY	CURRENT TECHNOLOGY 1981				
	T^2L	LST^2L	ECL	I^2L	PMOS
7 TYPICAL SUPPLY VOLTAGES (volts)	+5.0	+5.0	-5.2	+0.8 to +1.0	-15 to 20
8 SIGNAL SWING (volts)	0.2 to 3.4	0.2 to 3.4	-0.8 to -1.7	0.2 to 0.8	0.0 to -15.0
9 GUARANTEED NOISE MARGIN (volts)	0.3 to 0.4	0.3 to 0.4	0.125	<0.1	1 to 2
10 NEUTRON HARDNESS (n/cm^2) CAPABILITY	0.2 to 1×10^{15}	0.2 to 1×10^{15}	0.5 to 2×10^{15}	1 to 5×10^{13}	$>10^{15}$ to 10^{16}
11 TOTAL DOSE (γ) HARDNESS CAPABILITY (rads)	10^6 to 10^8	10^6 to 10^8	10^7 to 10^8	10^5 to 10^6	10^7
12 DOSE RATE ($\dot{\gamma}$) OR PHOTO-CURRENT HARDNESS CAPABILITY (rads/sec)	0.5 to 2×10^{10}	0.2 to 1×10^{10}	0.2 to 1×10^{10}	0.1 to 4×10^{10}	0.1 to 5×10^{9}

Table 2.4.1-16. Summary of IC Properties (3)

PROPERTY	CURRENT TECHNOLOGY			FUTURE 1985-1990	
	NMOS	CMOS		SOS	GaAs
		BULK	SOS		
1 RELATIVE PROCESS MATURITY (1-10)	9	8	4	2 (1980)	1 (E/D) (1980)
2 PROCESS COMPLEXITY (No. processing steps)	9 to 15	14 to 17	14 to 20	14 to 20	16
3 LOGIC COMPLEXITY (No. components) 2-input gate)	3	4	4	3 to 4	2
4 PACKING DENSITY (gates/ mm^2)	100 to 200	40 to 90	100 to 200	200 to 500	300 TO 1000
5 PROPAGATION DELAY (nsec) (typical value)	4 to 25 (15)	10 to 35 (20)	4 to 20 (10)	0.2 to 0.4 (0.3)	0.05 to 0.1 (0.07)
6 SPEED-POWER PRODUCT (pj)	5 to 50	2 to 40	0.5 to 30	0.1 to 0.2	0.01 to 0.1

Table 2.4.1-17. Summary of IC Properties (4)

PROPERTY	CURRENT TECHNOLOGY			FUTURE 1985-1990	
	NMOS	CMOS		SOS	GaAs
		BULK	SOS		
7 TYPICAL SUPPLY VOLTAGES (volts)	+5.0	+10.0	+10.0	+2.0	+1.2
8 SIGNAL SWING (volts)	0.2 TO 3.4	0.0 TO 10.0	0.0 TO 10.0	0.0 TO 2.0	0.0 TO 0.8
9 GUARANTEED NOISE MARGIN (volts)	0.5 TO 20	3.5 TO 4.5	3.5 TO 4.5	0.2 TO 0.8	0.2 TO 0.3
10 NEUTRON HARDNESS (n/cm^2) CAPABILITY	$>10^{15}$ TO 10^{16}	$>10^{15}$ TO 10^{16}	$>10^{15}$ TO 10^{16}	$>10^{15}$ TO 10^{16}	$>10^{15}$
11 TOTAL DOSE (γ) HARDNESS CAPABILITY (rads)	1 TO 5×10^6	10^6 TO 10^7	10^5 TO 10^6	10^5 TO 10^6	$>10^7$
12 DOSE RATE (γ) OR PHOTOCURRENT HARDNESS CAPABILITY (rad/sec)	0.1 TO 5×10^9	0.5 TO 2×10^9	0.2 TO 1×10^{11}	0.5 TO 1×10^{11}	$>10^{10}$

Table 2.4.1-18. Semiconductor Damage Threshold

RADIATION ENVIRONMENT	NEUTRONS n/cm^2	IONIZING TOTAL DOSE RAD (Si)	TRANSIENT DOSE RATE RADS (Si)/S	TRANSIENT DOSE RATE (Si)/S SURVIVAL	DORMANT TOTAL DOSE (zero bias)
BIPOLAR & JFET DISCRETES	$\sim 10^{12}$	$\sim 10^5$	--	10^{10}	$>10^4$
SCR	$\sim 10^{12}$	10^5	10^3 TO 10^5	10^{10}	10^4
TTL	10^{14}	10^6	5×10^7	$>10^{10}$	10^6
LSI TTL	10^{14}	10^6	5×10^7	$>10^{10}$	10^5
ANALOG IC	10^{13}	10^5	10^6	$>10^{10}$	10^5
CMOS	10^{15}	10^4	10^7 TO 10^8	10^9	10^6
NMOS	10^{15}	$>10^3$	10^5 TO 10^6	10^{10}	10^4
LED	10^{13}	$>10^5$	--	$>10^{10}$	$>10^5$
ISO N ECL	10^{15}	10^7	10^8	10^{11}	$>10^7$

Table 2.4.1-19. High Speed Silicon Mesfet Technology

8 X 8 HIGH SPEED, LOW POWER MULTIPLIER

- ON THE BASIS OF A NOVEL FULL ADDER CIRCUIT, AN 8 x 8 PARALLEL MULTIPLIER HAS BEEN SPECIFIED. THE SPECIFICATION INCLUDES (using 1 μm design rules):
  - 20 ns MULTIPLY TIME
  - 200 mW POWER DISSIPATION
  - TTL - COMPATIBLE I/O
- WITH OVER 800 LOGIC GATES, SUCH A CIRCUIT WILL DEMONSTRATE SILICON MESFET LSI CAPABILITY, AND HAS THE POTENTIAL TO FILL THE REQUIREMENTS OF MANY MILITARY SYSTEMS
- FUTURE DIRECTION
  - 16 x 16 MULTIPLIER WITH ACCUMULATOR
    - 40 NANOSECONDS MULTIPLY TIME
    - 1 WATT TOTAL POWER
  - CONTINUED TECHNOLOGY DEVELOPMENT
    - SHORT CHANNEL EFFECTS
    - PROCESS CONTROL/UNIFORMITY/REPRODUCIBILITY
    - RELIABILITY/YIELD

Table 2.4.1-20. Silicon Mesfet Technology

- DEVICE THRESHOLD VOLTAGE - 35 mV (max) ACROSS THREE WAFERS UNIFORMITY ACHIEVED

• DEVICE	GATE LENGTH	FREQ (MHz)	Tpd (nsec)	TxP (fJ)	Vt ENHANCEMENT	Vt DEPLETION	Vdd
E-BEAM, LOW POWER RING OSCILLATOR	1.0 μm		2.8 2.9	1.5 0.5			1.0 0.5
DIVIDE-BY-TWO (DMESFET)	1.9 μm	148.8	1.12	418		-1.0	1.5, -1.5
DIVIDE-BY-FOUR (EMESFET)	1.9 μm	40	4.2	29.5	0.173	-0.82	1.0
DIVIDE-BY-TWO (non inverting logic)		220 (1 GHz)					

- RADIATION TEST RESULTS
  - Vt SHIFT - 35 mV (max) AT 5×10^6 rads (SI)
  - DOSE RATE UPSET 2×10^6 rads/sec - 6×10^9 rads/sec (flip flops and memory cells)

Table 2.4.1-21. Summary Silicon Mesfet RAD Results

	BULK MESFET (TI)	SAPPHIRE MESFET (GE)
NEUTRONS n/cm^2	3×10^{14} - WEAPON LAB (discretes) NO CHANGE - WILL CONTINUE 10^{15} etc	3×10^{15} > 10 KeV - 20% DROP GM (GE) NO PROBLEM DIGITAL (MAYBE RF?)
TOTAL DOSE rad (SI)	> 10^6 CRANE, RADC - (ICs) 5×10^5 WEAPONS LAB - (discretes) WILL CONTINUE TO 10^6 etc	10^7 - NO CHANGE TEST DEVICES 2×10^8 - NO PROBLEM RF, SHOWED SOME LEAKAGE (not fully turning off) (digital problem?)
DOSE RATE rad/sec	2×10^6 - 5×10^9 - RADC FF/MEMORY CELL (Flash X-Ray) CONCERN OVER QUALITY OF DATA S/N PROBLEMS 2×10^{10} - CRANE-LASER SIMULATION DIVIDERS RING OSC (concern over source) 5×10^{11} - WEAPONS LAB - DISCRETES - NO PERMANENT DAMAGE - WILL CONTINUE TO CATASTROPHIC FAILURE	2×10^{10} - TEST DEVICES

Table 2.4.1-22. GaAs Radiation Hardness

- SMALL SCALE INTEGRATED CIRCUIT TEST DATA*
  - 1×10^{15} n/cm^2 (E >10 KeV) FAST NEUTRONS
  - 1×10^{7} RAD (GaAs) TOTAL DOSE
  - 5×10^{9} RAD (GaAs)/S DOSE RATE UPSET
  - 1×10^{11} RAD (GaAs)/S SURVIVAL DOSE RATE
- TECHNOLOGY ADVANCES SHOULD PROVIDE 2 TO 5 TIMES INCREASED TOLERANCE
- RADIATION PROPERTIES OF MESFET MAY BE SLIGHTLY LESS THAN JFET DUE TO SURFACE EFFECTS

*R. Zuleeg and K. LeHovec, "GaAs FET Technology" Artech-House (1981)

J. M. Borrego, IEEE Trans. Nucl. Sci. NS-25, 1436 (1978)

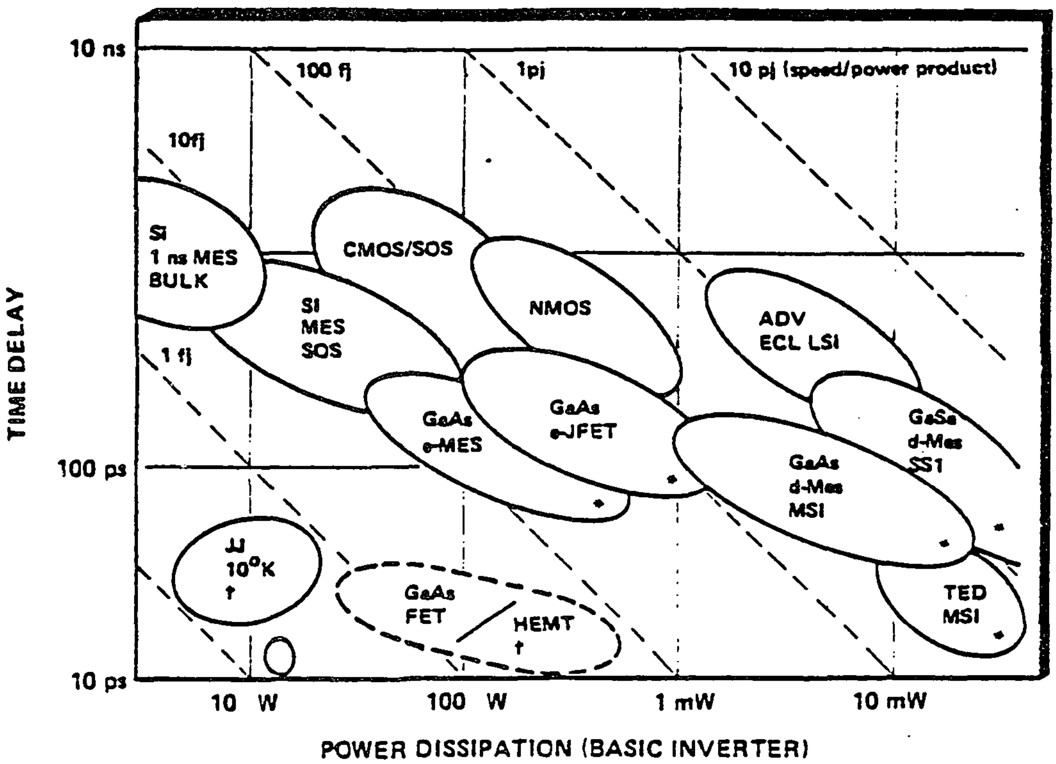


Figure 2.4.1-2. Power Dissipation (Basic Inverter)

expectation is that GaAs may be considered inherently hard and satisfy future spaceborne requirements, off-setting the lower power advantage that silicon exhibits with power hardness characteristics.

2.4.1.1.7 Software

There will be very significant progress made in the areas of software management, automated generation, validation, etc. but none of these advances will change the fundamental nature of software; so in this technology forecast, software progress is not relevant to on-board systems.

High Order Language (HOL) Trade Study

The objective of this trade study was to make a preliminary selection of an HOL for the space station software. The three languages considered are ADA, FORTRAN and JOVIAL. All three are DOD approved languages. Table 2.4.1-23 summarizes the results of the study. Shown are the evaluation criteria, the weighting factor applied for each criteria (1 to 5), and the assessed relative rating for each language for that criteria (1 to 3) where 1 is the lowest. The weighting factors of the criteria reflect current thinking on important factors required by the space station software. As understanding of these requirements evolve, it may be desirable to modify these weighting factors.

Currently, ADA received the highest score with a value of 80. It should be noted however, that the ADA column assumes that ADA does meet its design goals and has been in use to provide a reasonable level of maturity. Since ADA has not been in use, some of the ratings under ADA are subjective and might change before actual implementation of the space station software, possibly affecting the choice of the HOL to be used in its implementation.

2.4.1.1.8 Summary

DMS technologies selected for use on board the space station must be available by 1986 to be included in hardware for launch in 1990. The selected technologies must be available for the projected 1990 launch date, must meet the DMS storage and throughput requirements for the early 1990's and must be transparent to the technologies needed to update the DMS hardware to meet the DMS requirements for year 2000.

Table 2.4.1-23. High Order Language Trade Study

CRITERIA	WEIGHT (Wi)	ADA*		FORTRAN		JOVIAL	
		SCORE	WiS	SCORE	WiS	SCORE	WiS
LANGUAGE FEATURES	3	3	9	1	3	2	6
MATURITY OF LANGUAGE	4	1	4	3	12	2	8
MAINTAINABILITY	4	3	12	2	8	2	8
RELIABILITY	5	3	15	1	5	2	10
FAULT TOLERANCE	5	3	15	1	5	2	10
SUPPORT TOOLS	3	3	9	3	9	2	6
EFFICIENCY OF CODE GENERATION	5	3	15	2	10	2	10
TRAINING	1	1	1	3	3	1	1
TOTAL (Σ WiS)		80		55		59	

* PROJECTED - ASSUMES ADA MEETS DESIGN GOALS AND HAS BEEN IN USE

SCORE: 1 - FAIR
2 - GOOD
3 - EXCELLENT

WEIGHT: 1 - LESS SIGNIFICANT
5 - MOST SIGNIFICANT

The technologies selected are those that are either available now or in the development phase. And those fields where the current research is expected to make significant advances over the next ten years.

2.4.2 COMMUNICATIONS TECHNOLOGY ASSESSMENT

Technology issues associated with the internal and external communication subsystems are discussed here. The technology for implementing the internal subsystem is largely available currently. For the external subsystem projected increases in capability requirements and the introduction of the TDAS forces more extensive changes in the subsystem between the initial implementation and that expected to be required by the year 2000.

2.4.2.1 External Communications

(This section is contained under separate cover.)

2.4.2.2 Internal Communications

The technology required to implement the internal communications is largely available, the exception being the that required to implement the fiber optics interconnect network.

Other than the fiber optics equipment, all functions required are well within the current state-of-the-art. (See Figure 2.4.2.2-1). The major issues are weight, power and qualification of the technology for the Space Station application. The projected weight approaches 2500 pounds and the power 5000 watts. Except for essential mechanical portions of the equipment, such as the tape unit of the Video Recorder, significant weight and power reductions are possible through the mechanical integration of equipment the use of developing integrated circuit technology which promises an order of magnitude decrease in power consumption for a given function. These steps might make possible a 50% reduction in the projected weight an power requirements.

With regard to the fiber optics equipment, the essential technology is available. Development of space qualified equipment satisfying the Space Station requirements will require considerable effort. Particular issues of importance are the demonstration of the ability to maintain the close tolerances required in the wavelength multiplexers and the effect of the space radiation environment on the active devices, lasers and detectors and on the fiber optic materials. It is known that the attenuation rate of some fiber

Optical system digitizes, transmits six video signals

by Larry Waller, Los Angeles bureau

Experimental system from TRW modulates two laser beams with three channels each; data rate is 500 Mb/s

Researchers developing digital components for putting multiple light signals on and off an optical fiber are sure to have their heads turned by a new digital transmission link that crowds six multiplexed video signals onto a single fiber. Built and demonstrated at TRW Inc.'s Technology Research Center in El Segundo, Calif., it can move data at 500 megabits per second on a composite bandwidth of 25 megahertz.

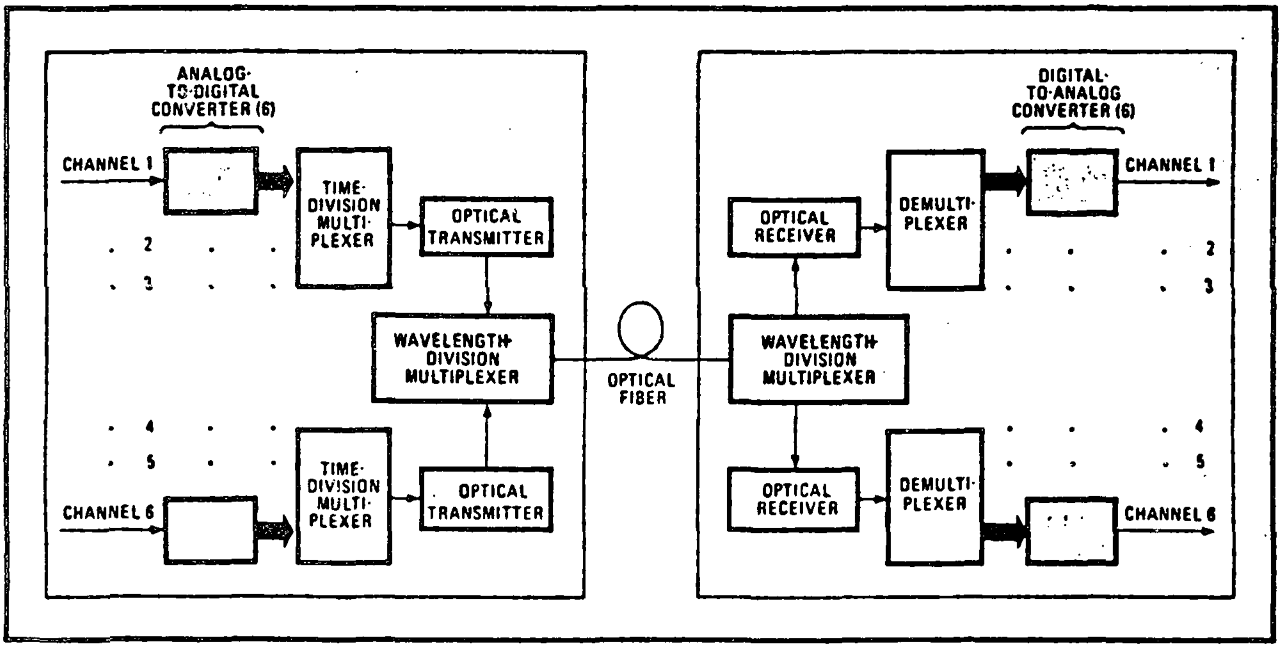
Furthermore, because they use light, studio-quality signals can be transported over more than 20 kilometers without a repeater. Conventional coaxial cable systems may require the expensive repeaters as often as every several hundred feet.

The TRW system combines "parts of the most advanced digital optical technology," notes Stewart D. Personick, who manages the advanced electronics systems laboratory at the research center. Putting together "wavelength multiplexing and the digitizing of six video channels moves optical technology ahead a step or so," in his opinion. All the equipment, including the analog-to-digital and digital-to-analog converters, the multiplexers, and the optical transmitters and receivers, was built by TRW.

TRW calls its link an "optical-fiber digital CATV superlink" and intends to demonstrate its performance to cable-TV companies, for example, which could use it to transmit programs from a studio to system distribution points. The highest signal quality is demanded in such point-to-point trunk transmissions.

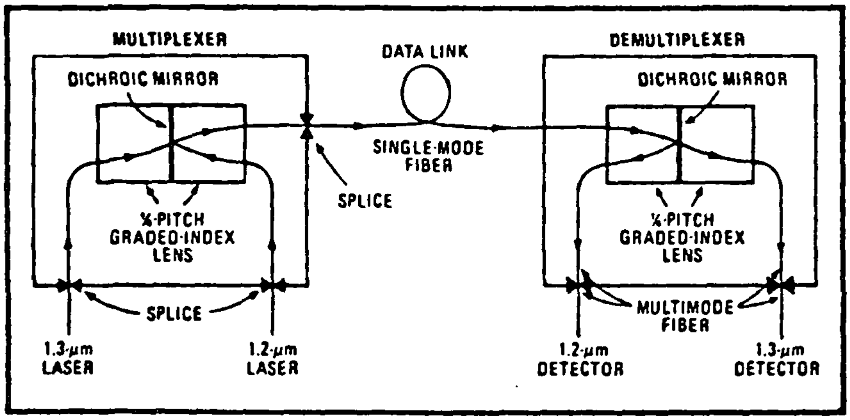
Fiber-optic links are already being used in such applications for their broad bandwidth and freedom from radio-frequency interference, and some systems typically put three or four channels on a single fiber. But they use analog techniques and the result is much lower quality than the digital technique offers, according to Personick.

In operation, video signals undergo preprocessing to limit their indi-



Six to one. A digital "supertrunk" passes six video channels (left) through 8-bit a-d conversion and multiplexes them so they modulate two laser transmitters. The laser outputs are multiplexed and fed into an optical-fiber cable. A reverse process takes place at the receiving end.

Figure 2.4.2.2-1



Waveform multiplexing. A dichroic mirror is the key to combining the outputs of the two lasers and sending a multiplexed signal along the same optical path into the single-mode fiber. A similar mirror at the receiving end demultiplexes the signals back into its components.

vidual bandwidth to 4.2 MHz before an 8-bit analog-to-digital conversion with 10.5 megasamples per second. Each signal occupies a composite date rate of 84 Mb/s, according to the TRW researcher. Three digitized video signals plus their associated audio feed into one time-division–multiplexed data stream at 252 Mb/s.

Laser pair. This stream, in turn, modulates one of two solid-state lasers, single-mode indium-gallium-arsenide-phosphide devices with outputs of 1.2- or 1.3-micrometer wavelengths. The modulated laser signals are then combined in a multiplexer and coupled to a single-mode fiber (see figure on p. 47).

A single laser might also have done the job, but speed was uppermost in TRW's considerations. "You can only modulate a single laser just so fast," Personick points out. "With two in parallel, we reach much higher data rates."

At the other end of the fiber, the video signal undergoes a reverse conversion to return it to its original analog form. The receiver has an indium-gallium-arsenide p-i-n diode detector and a high-impedance gallium arsenide field-effect-transistor preamplifier. Its sensitivity is –36 dBm; the bit-error rate is 10^{-9}.

Light signals to the optical wavelength multiplexer and demultiplexer are collimated by small Selfoc lenses and guided by graded-index lenses to a dichroic mirror, as shown in the figure above. The mirror transmits one wavelength and reflects the other along the same optical path so that the two signals are focused into the fiber. The core diameter of the single-mode fiber is only 10 μm, pointing up the tight tolerances that must be dealt with.

No timetable. Personick says there is no timetable right now for a Superlink product. "We want to show people the potential of the technology," he says. "The few who have seen the new system have been very impressed."

However, he views the equipment as only the initial step toward the big-payoff application: optical-fiber technology for local networks (less than 1 kilometer in range). To this end, TRW is considering how to convert the point-to-point link into a bus-link configuration, so that "user terminals can access [the link] at random points rather than only at the ends," he says.

Reaching this goal will not be a simple task, since the link's structure must be modified into a high-speed network configuration. Such a network would need a gigabit data rate, he notes.

Figure 2.4.2.2-1 (Cont)

optics materials increases in response to radiation exposure.

Integrated optics developments could substantially reduce the projected CIU size and weight.

APPENDIX A
FUNCTIONS ALLOCATED TO DMS

APPENDIX A

FUNCTIONS ALLOCATED TO DMS

	Crit	Thru	Comm
User/PI Interface			
User/PI to Crew Voice Comm	M	L	L
User/PI to S/S Data Comm	M	L	L
System Command and Control			
Flight Operations Scheduling	H	L	L
Mission Operations Scheduling	L	L	L
Flight Operations	H	L	L
Mission Operations	L	L	L
Mission Support			
Mission Data Collection	L	L	H
Mission Data Pre-Processing	L	H	H
Mission Data Distribution			
Data Downlinking	M	L	H
Free Flyer Relay	M	M	H
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
S/S Ground Voice Comm	M	L	L
TV Monitoring	M	L	M
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
SS/Ground Voice Comm	M	L	L
SS/Ground Data Comm	M	L	L
Crew Health Monitoring/Maintenance			
Routine Checkup	M	L	L
Health Data Collection	M	L	L
Diagnosis/Treatment Det.	H	L	L
SS/Ground Voice Comm	H	L	L
SS/Ground Data Comm	H	L	L
TV Monitoring	H	L	M
Spaceborne Experimentation			
Conduct Experiment	L	L	H
Record Data	L	L	M
Crew/PI Voice Comm	M	L	L
SS/PI Data Comm	M	L	M
TV Monitoring	M	L	M

II/2/II

S/S Onboard Support			
Environmental Control and Life Support	H	L	L
Electrical Power	H	L	L
Thermal Control	H	L	L
Guidance, Nav. and Attitude Control	H	M	L
SS/Ground Communications	M	L	H
SS Interior Communications	M	L	H
Surveillance (Radar)	H	M	L
Rendezvous and Docking Support	H	L	L
Remote Manipulation Support	M	L	L
EVA Support	H	L	L
OTV Support	H	L	L
Free Flyer Support	M	L	L
Logistics	L	L	L
S/S Support Subsystem C&C			
Subsystem Commanding	H	L	L
Procedure Display/Processing	H	L	L
S/S Mission Subsystem C&C			
Subsystem Commanding	M	L	L
Procedure Display/Processing	M	L	L
S/S Support Subsystem Monitoring			
Telemetry Processing	H	L	L
Telemetry Display	H	L	L
Caution and Warning Alarms	H	L	L
TV Monitoring	M	L	M
S/S Mission Subsystem Monitoring			
Telemetry Processing	M	L	L
Telemetry Display	M	L	L
Caution and Warning Alarms	H	L	L
TV Monitoring	L	L	M
Onboard Entertainment			
Library	L	L	L
Movies	L	L	M
TV	L	L	M
Games	L	L	M
Data Storage			
Onboard Data Base	H	L	M
Long Term Data Storage	H	L	M
Performance Evaluation			
Short Term PE	H	L	L
Short Term Mission PE	M	L	L
Military Interface	H	L	H
Training and Simulation	M	L	L

APPENDIX B
DISTRIBUTED PROCESSING ALTERNATIVES

APPENDIX B
DISTRIBUTED PROCESSING ALTERNATIVES

Presented below are seven architectural alternatives for distributed processing in the DMS. These seven were selected by analyzing the functional interfaces and processing loads of the functions itemized in Appendix A. The alternatives were evaluated on the following basis:

1. Cost - 20%. The cost criteria is divided into three aspects: hardware (10%), software (5%), and integration (5%). These weights are based upon the differential costs between architectural options. Overall software and integration costs are expected to be far higher than hardware costs, however the differential software and integration cost imposed by distributed processing are expected to be a small fraction of the total cost. Costs implied by different network topologies and fault tolerant implementations are addressed in following sections and are not included here.

2. Expansion potential - 20%. This criteria is an evaluation of the system impacts of adding and deleting missions and operational elements. Generally, the distribution of elements that are likely to change, and the facility to add new elements increase expansion potential. Costs associated with adding elements to centralized control nodes and integration of new elements is included in this criteria.

3. Technology transparency - 20%. This criteria is similar to expansion potential except it applies to replacing existing technology (including software) with new technology. Technology transparency is achieved by distributing processing and minimizing interprocessor interconnections.

4. Isolation/autonomy of critical functions - 20%. One of the DMS design goals is to isolate critical functions such that failures in unrelated functions do not impair the critical function (as listed in Appendix A). Autonomy includes segregation of critical functions in independent processors, capable of operating in a fail safe mode in the event of a failure of the rest of the DMS.

5. Feasibility - 20%. This criteria is a qualitative measure of the risk associated with a given implementation. For example, implementations which require processors with capabilities beyond the projected space qualified technology have a higher risk than implementations that require projected available technology. Similarly, implementations which have a high number of complex functional interfaces involve a high degree of risk due to potential development and integration problems.

B.1 ALTERNATIVE 1 - CENTRALIZED

Shown in Figure B-1, all functions (except mission unique, military interface and entertainment) in this alternative are performed in the DMS processor.

Criteria	Rational	Score (1-10)	Weighted Score
a. Cost	Hardware (3 processors)	10	10
	Software	10	5
	Integration	5	2.5
b. Autonomy	Potential Interference of non-critical functions, Failure of DMS implies all critical functions fall back to fail safe modes.	0	0
c. Expansion	DMS processor is heavily loaded in terms of thruput (approximately 3 MOPS) and interfaces to physical systems (e.g. life support sensors-actuators)	1	2
d. Tech. Trans.	If physical subsystems (e.g. radar) are upgraded the entire DMS is affected.	2	4
e. Feasibility	High thruput required at DMS node may not be achievable.	3	6
Total			29

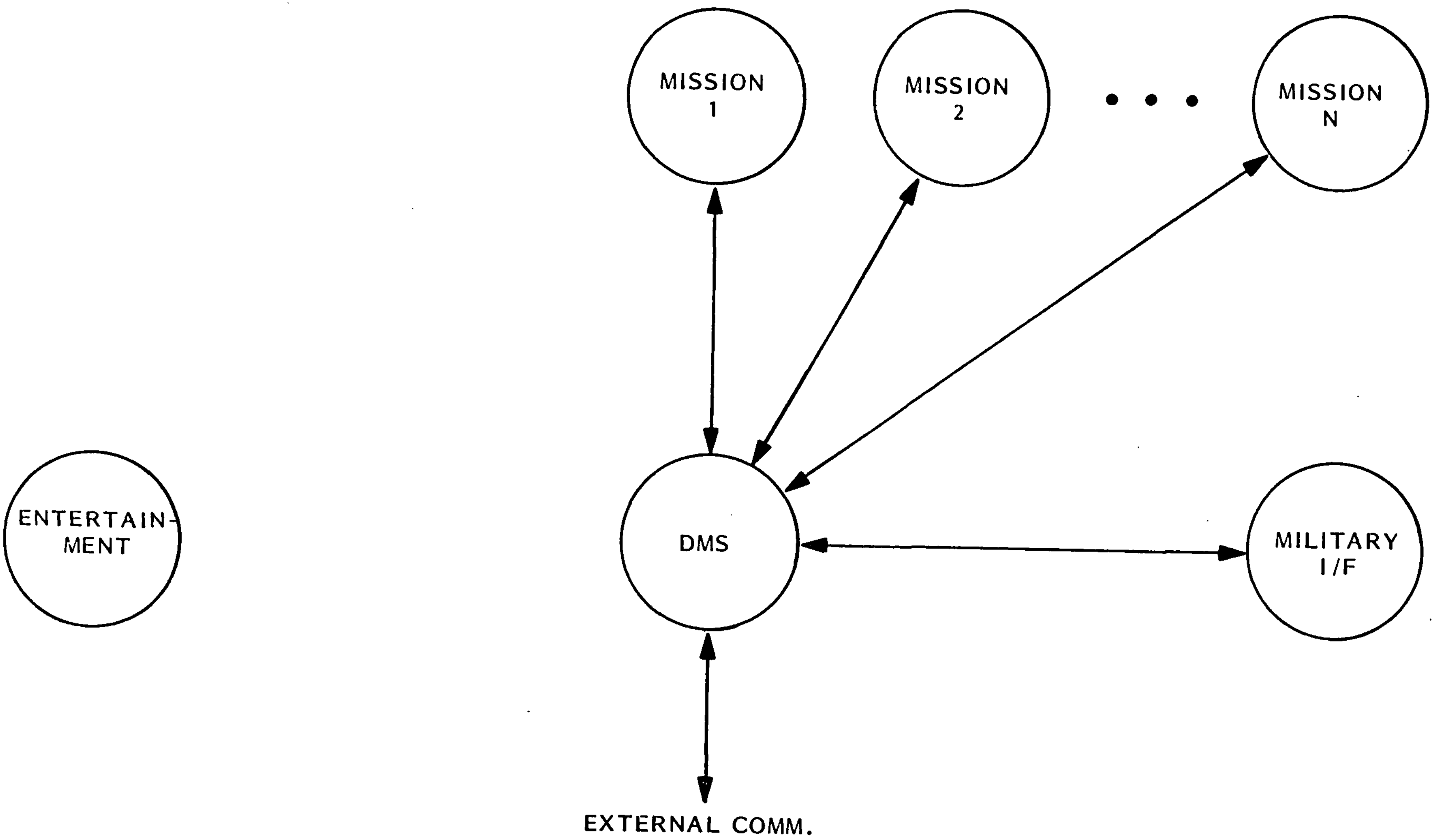


Figure B-1. Alternative 1 - Centralized

B.2 ALTERNATIVE 2 - CENTRALIZED STATION OPERATIONS

Addressing the issues of high thruput at the DMS processor, and autonomy of critical functions, station and mission operations can be separated as shown in Figure B-2. The communications and data routing node serves as a switch, routing messages from the ground to either station or mission operations, controlling the internal communication system, and buffering as required.

Criteria	Rational	Score (1-10)	Weighted Score
a. Cost	Hardware	9	9
	Software	9	4.5
	Integration	5	3.5
b. Autonomy	Failure of Station Operations node implies all critical functions fall back to fail safe modes.	5	10
c. Expansion	Station Operations is limited.	5	10
d. Tech. Trans.	If physical subsystems (e.g. radar) are upgraded, the all Station Operations are affected.	5	10
e. Feasibility	High thruput required at Station Operations (1210 KIPS) may require a multiprocessor configuration	6	12
Total			69

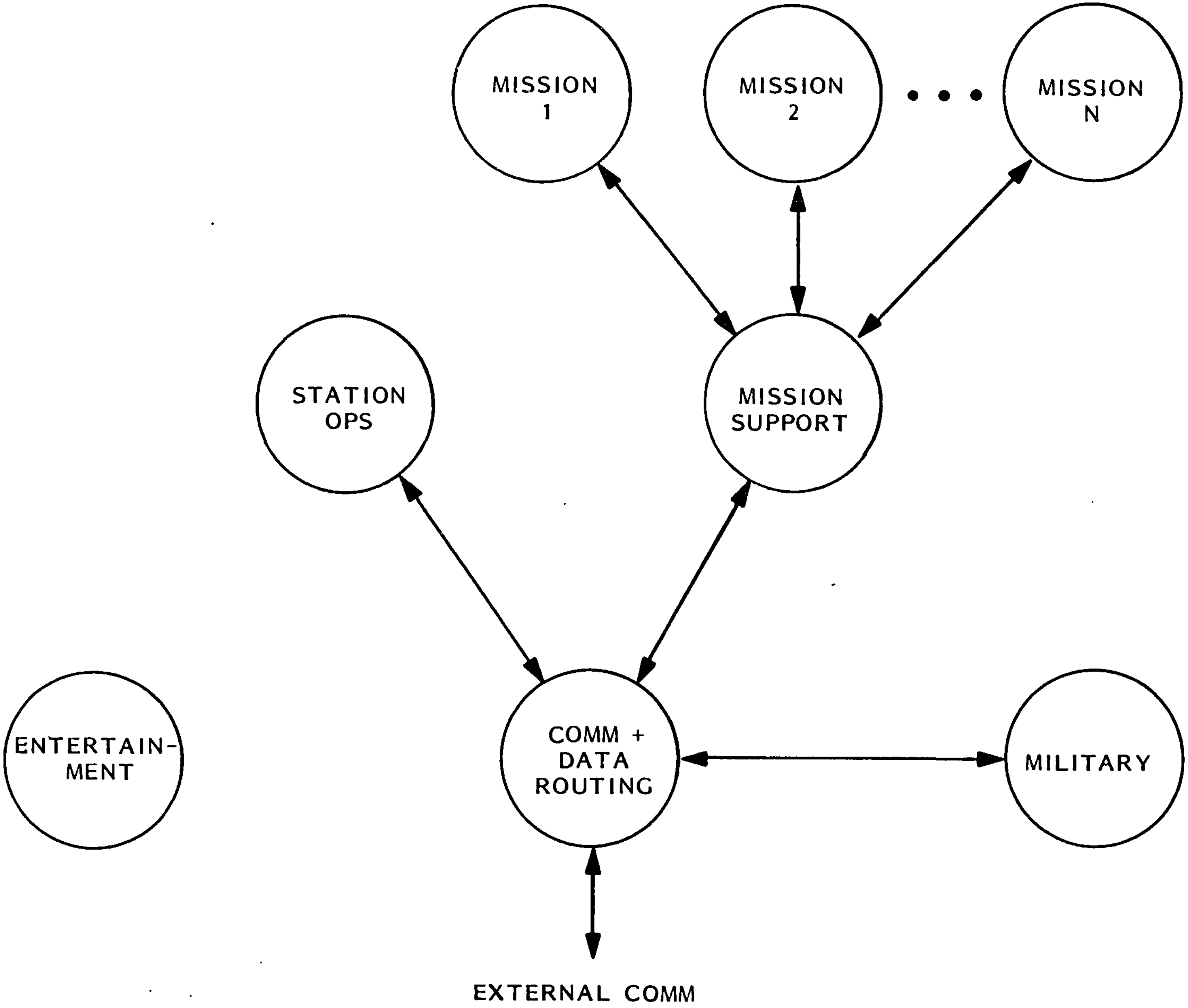


Figure B-2. Alternative 2 - Centralized Station Operations

B.3 ALTERNATIVE 3 - DECENTRALIZED STATION OPERATIONS

Extending the distribution concept of Alternative 2,the relatively high thruput requirement of the station operation node and the autonomy of critical functions can be addressed by creating an eight node subnetwork for station operations as shown in Figure B-3. In this configuration nearly all critical functions are performed by separate processors and no processor in the subnetwork exceeds 350 KIPS. These advantages are partially offset by higher cost.

	Criteria	Rational	Score (1-10)	Weighted Score
a.	Cost	Hardware	5	5
		Software	6	3
		Integration	6	3
b.	Autonomy	Only very low thruput critical functions (EVA, OTV Free Flyer support) and are performed in a central node	9	18
c.	Expansion	Each station operation and mission processor expansion	8	16
d.	Tech. Trans.	Subsystems (i.e. Radar) are isolated and can be upgraded with minimal impact on the DMS	9	18
e.	Feasibility	Thruput is not a problem for any processor. Some interfaces between independent station operations processors (orbit calculations to radar) could complicate the system	8	16
Total				79

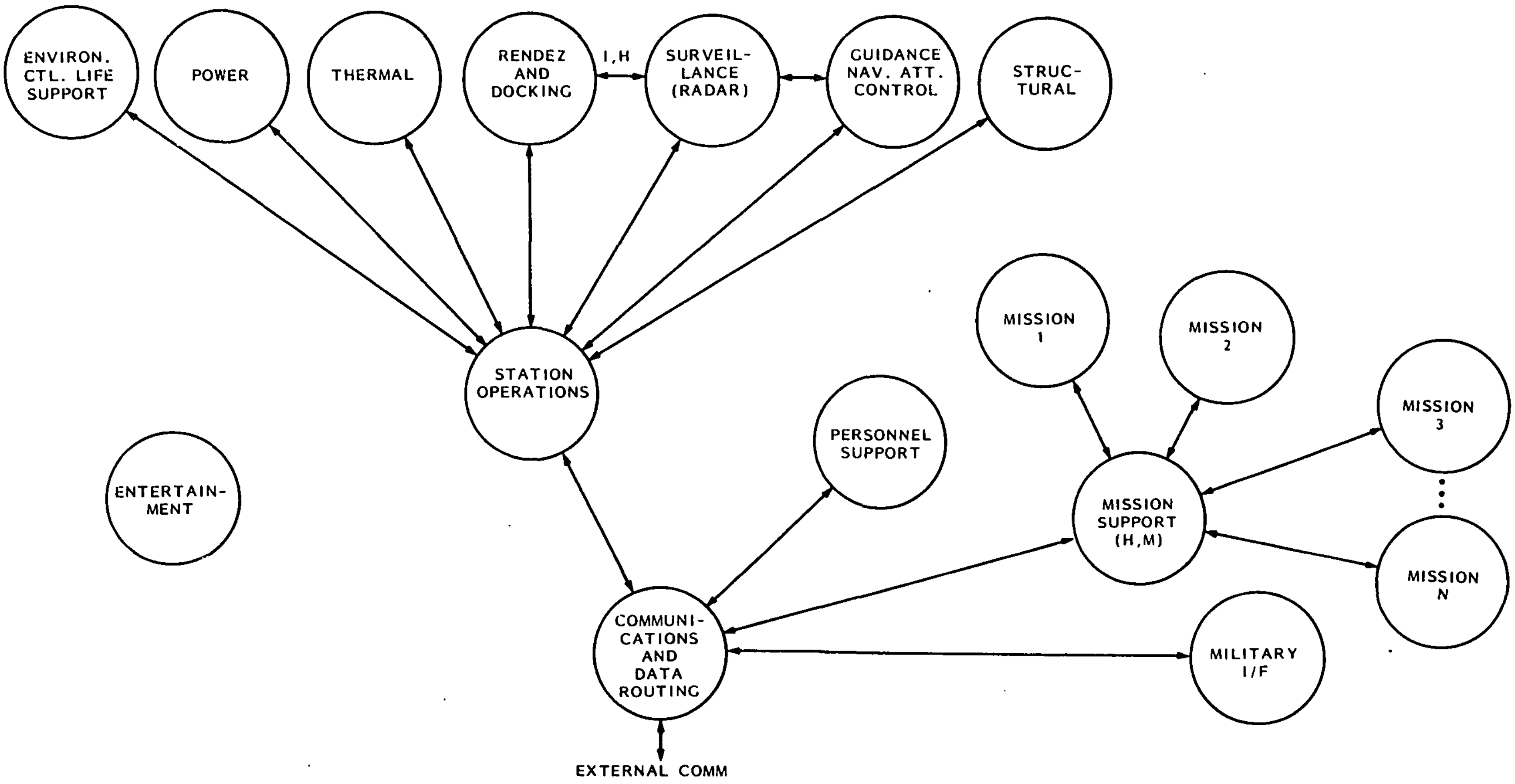


Figure B-3. Alternative 3 - Distributed Station Operations

B.4 ALTERNATIVE 4 - MODIFIED DECENTRALIZED STATION OPERATIONS

Alternative 4 is a cost optimization of alternative 3. Prosessors in the station operations subsystem were combined based upon thruput and interfaces. To allow for expansion potential, the required thruput of any processor does not exceed 55% of the 700 KIP maximum. Figure B-4 illustrates this configuration.

Criteria	Rational	Score (1-10)	Weighted Score
a. Cost	Hardware	7	7
	Software	7	3.5
	Integration	7	3.5
b. Autonomy	Critical functions are relatively independent but not as good as Alternative 3.	8	16
c. Expansion	No processor is more than 55% loaded.	8	16
d. Tech. Trans.	Changes to subsystems affect two or three functions.	8	16
e. Feasibility	Fewer interfaces than Alternative 3.	9	18
Total			80

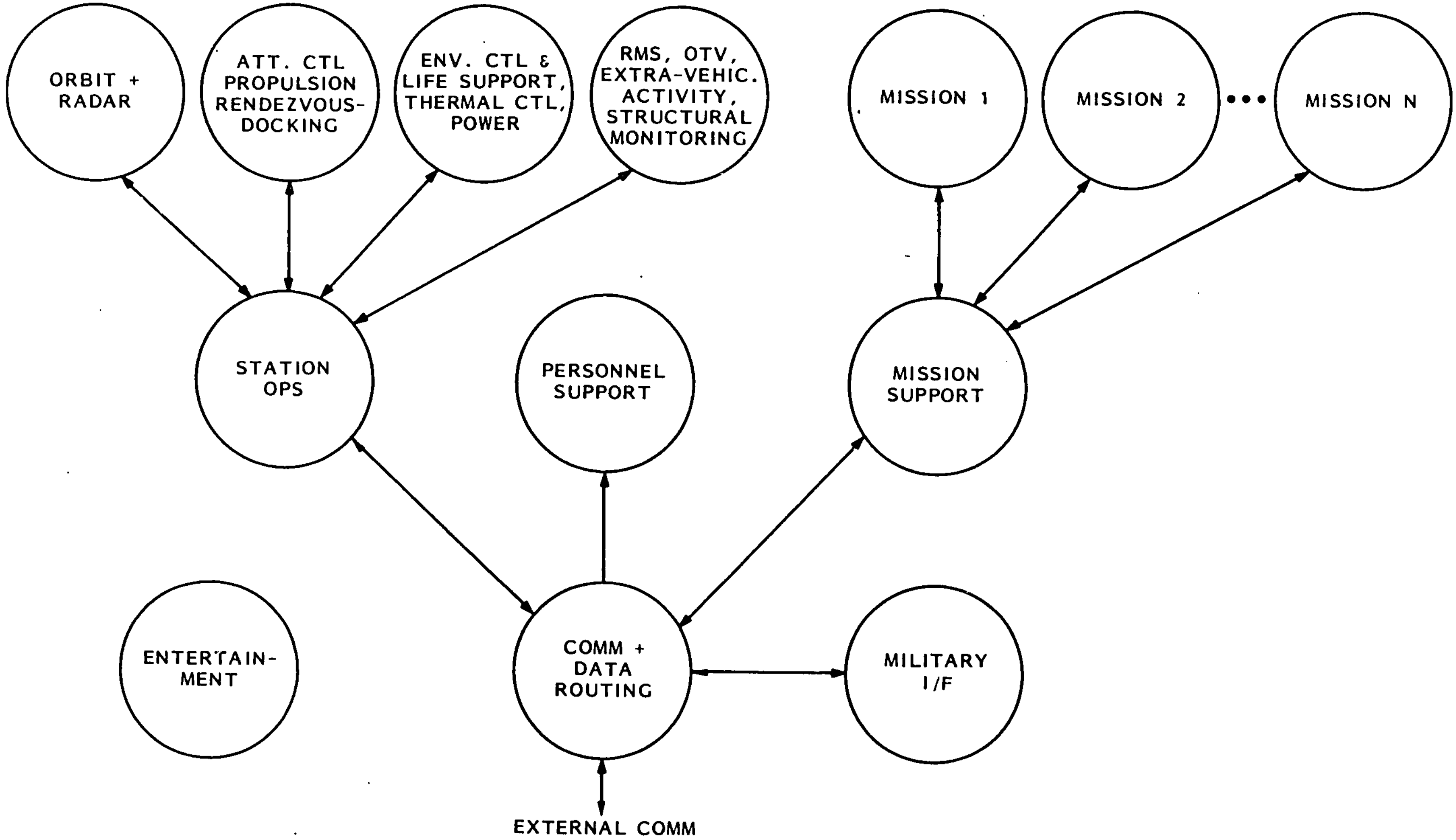


Figure B-4. Alternative 4 - Modified Decentralized Station OPS

B.5 ALTERNATIVE 5 - STATION OPERATIONS CONTROLLING COMMUNICATION

This alternative integrates the personnel support, communication, and data routing functions into the station operations function reducing the system cost, but possibly overloading the station operations function. This alternative is illustrated in Figure B-5.

Criteria	Rational	Score (1-10)	Weighted Score
a. Cost	Hardware	8	8
	Software	7	3.5
	Integration	5	2.5
b. Autonomy	Possible interference between mission and station operation functions.	7	14
c. Expansion	Station operations may become overloaded.	6	12
d. Tech. Trans.	Changes in communication are not isolated.	7	14
e. Feasibility	Station operations is a potential problem area.	8	16
Total			70

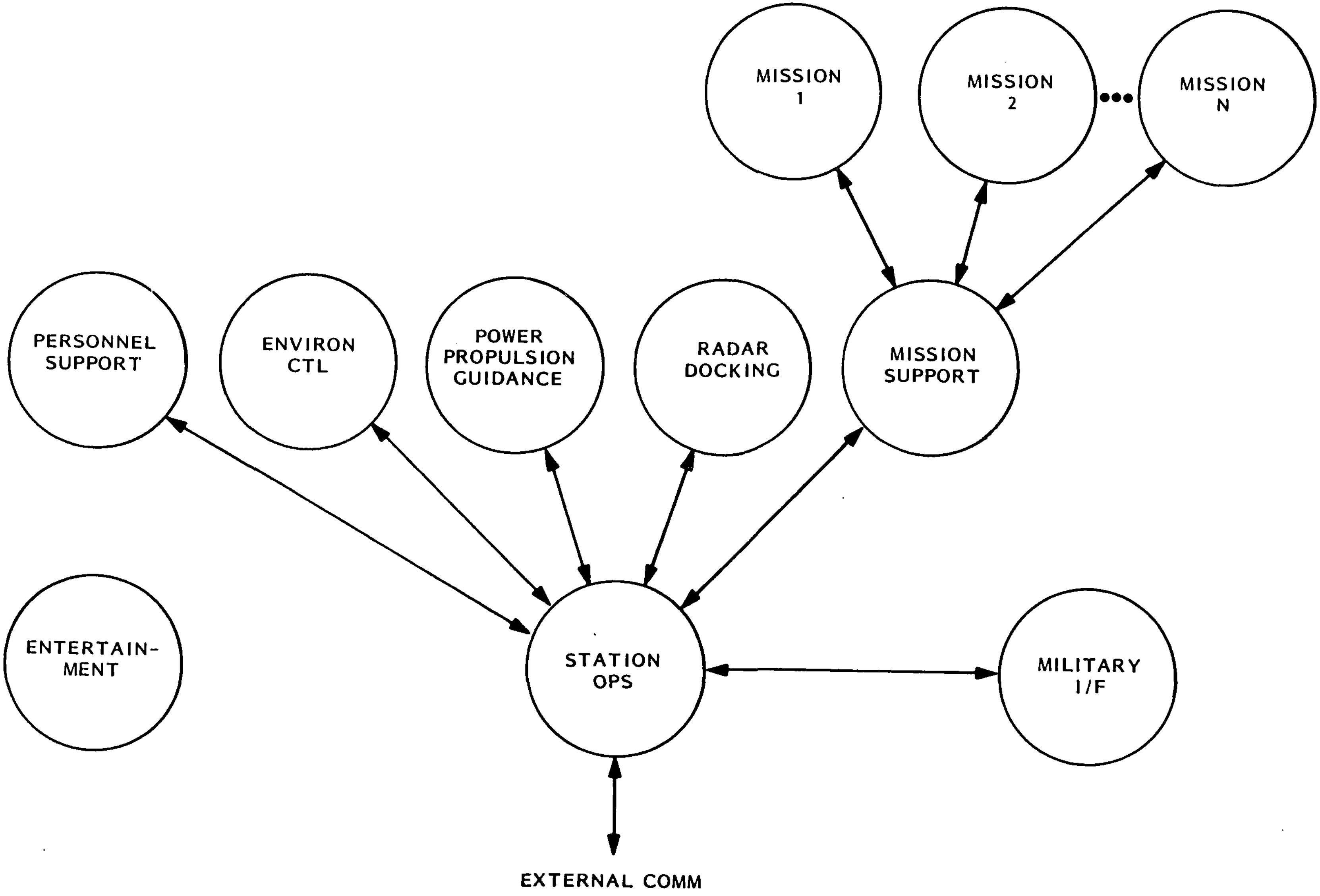


Figure B-5. Alternative 5 - Station OPS Controlling Comm

B.6 ALTERNATIVE 6 - SINGLE NETWORK

A single data network, rather than station and mission subnetworks, is suggested by the distribution shown in Figure B-6. This configuration may simplify networking.

Criteria	Rational	Score (1-10)	Weighted Score
a. Cost	Hardware	9	9
	Software	6	3
	Integration	4	2
b. Autonomy	Possible interference between mission and station operations.	7	14
c. Expansion	Since network capacity is not expected to be a problem, this alternative has good expansion potential.	8	16
d. Tech. Trans.	Changes to communication to support high data rate missions affect the entire DMS.	5	10
e. Feasibility	Station operations node may become overburdened.	8	16
Total			70

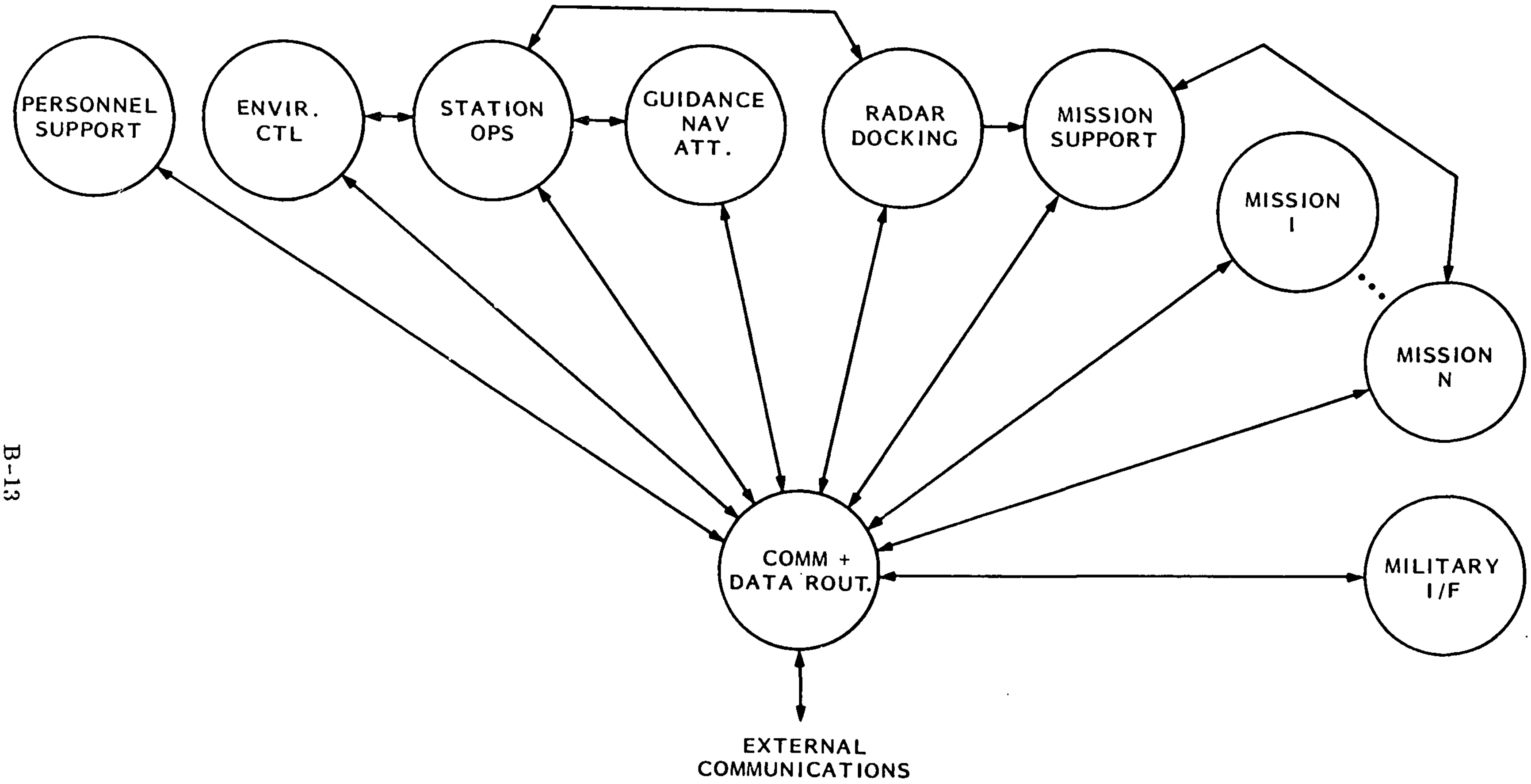


Figure B-6. Alternative 6 - Single Network

B.7 ALTERNATIVE 7 - FULLY DECENTRALIZED

Using the distribution method described in the text, the first alternative to evaluate is the fully distributed system, where each function is performed in a unique processor.

	Criteria	Rational	Score (1-10)	Weighted Score
a.	Cost	Hardware	0	0
		Software	0	0
		Integration	0	0
b.	Autonomy	Each critical function is independent.	10	20
c.	Expansion	Adding capabilities is complex due to large number of interfaces.	3	6
d.	Tech. Trans.	The large number of interfaces makes it difficult to upgrade modules.	3	6
e.	Feasibility	Too complex.	1	2
Total				34

APPENDIX C

THRUPUT REQUIREMENTS FOR SELECTED FUNCTIONS

APPENDIX C
THRUPUT REQUIREMENTS FOR SELECTED FUNCTIONS

Table C-1. DMS Thruput Requirements by Function

Function	Transportation	Data Rate Kbps	Thruput (KIPS)
Guidance and Navigation	Orbit Calc. (from GPS)	100	200
Attitude Control	Signal Process	8	100
Propulsion	RT control	1	50
Environmental Control and Life Support	Monitor/Ctl	0.5	100
Thermal Control	Monitor/Ctl	2	100
Power	Monitor/Ctl	0.1	25
Radar	Status Display	1	100
Rendez. and Docking	Status Display	1	100
Structural	Monitor	0.1	10
Remote Manip.	Monitor/Control	1	50
Orbit. Trans. Veh.	Monitor	1	25
Extra Veh. Activity	Monitor	2	25
Free Flyer Support	Monitor	8	25
Station Ops	Supervision Planning Modeling Data Base	-	300

APPENDIX D

LOW LEVEL FUNCTIONS ALLOCATED TO EACH DMS PROCESSOR

APPENDIX D

LOW LEVEL FUNCTIONS ALLOCATED TO EACH DMS PROCESSOR

D.1 Data Routing and Communications	Crit	Thru	Comm
User/PI Interface			
User/PI to Crew Voice Comm	M	L	L
User/PI to S/S Data Comm	M	L	L
Mission Data Distribution			
Data Downlinking	M	L	H
Free Flyer Relay	M	M	H
S/S Hardware Maintenance			
S/S Ground Voice Comm	M	L	L
TV Monitoring	M	L	M
S/S Software Maintenance			
SS/Ground Voice Comm	M	L	L
SS/Ground Data Comm	M	L	L
Crew Health Monitoring/Maintenance			
SS/Ground Voice Comm	H	L	L
SS/Ground Data Comm	H	L	L
TV Monitoring	H	L	M
Spaceborne Experimentation			
Crew/PI Voice Comm	M	L	L
SS/PI Data Comm	M	L	M
TV Monitoring	M	L	M
S/S Onboard Support			
SS/Ground Communications	M	L	H
SS Interior Communications	M	L	H
S/S Support Subsystem Monitoring			
TV Monitoring	M	L	M
S/S Mission Subsystem Monitoring			
TV Monitoring	L	L	M
Onboard Entertainment			
Movies	L	L	M
TV	L	L	M
Performance Evaluation			
Short Term PE	H	L	L

D.2 - Station Operations

	Crit	Thru	Comm
System Command and Control			
Flight Operations Scheduling	H	L	L
Flight Operations	H	L	L
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
S/S Onboard Support			
Logistics	L	L	L
S/S Support Subsystem C&C			
Subsystem Commanding	H	L	L
Procedure Display/Processing	H	L	L
S/S Support Subsystem Monitoring			
Telemetry Processing	H	L	L
Telemetry Display	H	L	L
Caution and Warning Alarms	H	L	L
Data Storage			
Onboard Data Base	H	L	M
Long Term Data Storage	H	L	M
Performance Evaluation			
Short Term PE	H	L	L

D.3 - Environmental Control and Life Support

	Crit	Thru	Comm
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
S/S Onboard Support			
Environmental Control and Life Support	H	L	L
Electrical Power	H	L	L
Thermal Control	H	L	L
Data Storage			
Onboard Data Base	H	L	M
Performance Evaluation			
Short Term PE	H	L	L

D.4 - Attitude Control/Propulsion/Docking

	Crit	Thru	Comm
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	h	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
S/S Onboard Support			
Attitude Ctl.	H	L	L
Rendezvous and Docking Support	H	L	L
Propulsion	H	L	L
Data Storage			
Onboard Data Base	H	L	M
Performance Evaluation			
Short Term PE	H	L	L

D.5 - Orbit/Radar

	Crit	Thru	Comm
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	h	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
S/S Onboard Support			
Guidance and Navigation	H	L	L
Surveillance (Radar)	H	L	L
Data Storage			
Onboard Data Base	H	L	M
Performance Evaluation			
Short Term PE	H	L	L

D.6 - RMS/EVA/OTV/STRUCTURAL

	Crit	Thru	Comm
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	h	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
S/S Onboard Support			
Remove Manipulation Support	M	L	L
EVA Support	H	L	L
OTV Support	H	L	L
Free Flyer Support	M	L	L
Structure Control/Monitoring	H	L	L
Data Storage			
Onboard Data Base	H	L	M
Performance Evaluation			
Short Term PE	H	L	L

PERSONNEL SUPPORT

D.7 - PERSONNEL SUPPORT

	Crit	Thru	Comm
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	h	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
Crew Health Monitoring/Maintenance			
Routine Checkup	M	L	L
Health Data Collection	M	L	L
Diagnosis/Treatment Det.	H	L	L
S/S Onboard Support			
Logistics	L	L	L
Data Storage			
Onboard Data Base	H	L	M
Performance Evaluation			
Short Term PE	H	L	L
Training and Simulation	M	L	L

D.8 - MISSION SUPPORT

	Crit	Thru	Comm
System Command and Control			
Mission Operations Scheduling	L	L	L
Mission Operations	L	L	L
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	h	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
S/S Support Subsystem C&C			
Subsystem Commanding	M	L	L
Procedure Display/Processing	M	L	L
S/S Mission Subsystem C&C			
Subsystem Commanding	M	L	L
Procedure Display/Processing	M	L	L
S/S Onboard Support			
Free Flyer Support	M	L	L
Logistics	L	\ L	L
S/S Mission Subsystem Monitoring			
Telemetry Processing	M	L	L
Telemetry Display	M	L	L
Caution and Warning Alarms	H	L	L
Data Storage			
Onboard Data Base	H	L	M
Long Term Data Storage	H	L	M
Performance Evaluation			
Short Term Mission PE	M	L	L

MISSIONS

D.9 - MISSIONS

	Crit	Thru	Comm
Mission Support			
Mission Data Collection	L	L	H
Mission Data Pre-Processing	L	H	H
Mission Data Distribution			
Free Flyer Relay	M	M	M
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
Spaceborne Experimentation			
Conduct Experiment	L	L	H
Record Data	L	L	M
S/S Mission Subsystem Monitoring			
Telemetry Processing	M	L	L
Telemetry Display	M	L	L
Caution and Warning Alarms	H	L	L
Data Storage			
Onboard Data Base	H	L	M
Long Term Data Storage	H	L	M
Performance Evaluation			
Short Term Mission PE	M	L	L

D.10 - MILITARY INTERFACE

	Crit	Thru	Comm
S/S Hardware Maintenance			
Preventive Maintenance	H	L	L
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
S/S Software Maintenance			
Fault Detection	H	L	L
Fault Isolation/Diagnosis	H	L	L
Corrective Action	H	L	L
Performance Evaluation			
Short Term Mission PE	M	L	L
Military Interface	H	L	H

APPENDIX E
ON-BOARD/GROUND FUNCTIONAL ALLOCATION

APPENDIX E

ON-BOARD/GROUND FUNCTIONAL ALLOCATION

E.1 System Command and control.

E.1.1 Flight Operations Long Term Planning

Definition:

Establish Long Term Flight Operations Activities such as Orbit Adjusts, Replenishment Flights and OTV flights. Output is list of Conflict Free Flight Operations Activities vs. time.

Allocation Criteria:

1. Crew Capabilities
2. Crew Functional Load
3. Flight/Ground Communications Load

Allocation:

Ground

Reasons and Comments:

1. S/S CO Primary responsibility in S/S operations including both flight operations and mission operations, additional responsibilities may result in overload, i.e., span of control too large.

2. Planning requires the resolution of conflicting requirements at the program level. S/S CO is not high enough in command structure to resolve multiprogram conflicts. This by itself is a full time job.

3. Would stress Onboard communications assets.

E.1.2 Mission Operations Long Term Planning

Definition:

Establish Long Term Mission Activities such as Experiments, Mission Instrument Utilization, Free Flyer Data Collection, etc. Output is list of Conflict Free Mission Activities vs. time.

Allocation Criteria:

1. Crew Capabilities
2. Crew Functional Load
3. Flight/Ground Communications Load

Allocation:

Ground

Reasons and Comments:

1. S/S CO Primary responsibility in S/S operations including both flight operations and mission operations, additional responsibilities may result in overload, i.e., span of control too large.

2. Planning requires the resolution of conflicting requirements at the program level. S/S CO is not high enough in command structure to resolve multiprogram conflicts.

3. Would stress Onboard communications assets.

E.1.3 Flight Operations Scheduling

Definition:

Convert uplinked Activity List (from planning function) into schedule containing crew directions and subsystem commands vs. time.

Allocation Criteria:

1. Autonomy
2. Performance

Allocation:

Onboard

Reasons and Comments:

1. Allows for S/S CO involvement in and cognizance of daily scheduling, planning/scheduling must involve CO.

2. Permits Onboard editing of Activities List in response to Real-Time considerations (i.e., add or delete activities).

3. Provides for semi-autonomous operations.

E.1.4 Mission Operations Scheduling

Definition:

Convert uplinked Activity List (from Mission Planning Function) into schedule containing crew directions and subsystem commands vs. time.

Allocation Criteria:

1. Autonomy
2. Performance

Allocation:

Onboard

Reasons and Comments:

1. Allows crew involvement in and cognizance of daily scheduling, resulting in more realistic schedules, takes advantage of first hand knowledge of crew.
2. Permits Onboard editing of Activities List in response to Real-Time considerations (i.e., add/delete mission activities).

E.1.5 Flight Operations

Definition:

Conduct daily flight activities such as orbit adjusts, OTV launch/docking, shuttle rendezvous, commanding and operation of support subsystems, monitoring support subsystems, etc.

Allocation Criteria:

1. Location of Related Functions
2. Space/Ground Communications Load
3. Availability
4. Autonomy

Allocation:

Onboard

Reasons and Comments:

1. Simplifies overall commanding function given that scheduling is done onboard.

2. Reduces Space/Ground Communications Load

3. Reduces Ground Support Requirements

4. Enhances Availability of Commanding Function by eliminating need for Space/Ground Communications

5. Enhances Autonomy

E.1.6 Mission Operations

Definition:

Conduct daily mission activities such as sensor activation/deactivation, experiment activation/deactivation. Monitor daily mission activities.

Allocation Criteria:

1. Availability
2. Location of Related Functions
3. Flight/Ground Communications Load
4. Autonomy

Allocation:

Onboard

Reasons and Comments:

1. Simplifies overall commanding function given that scheduling is done onboard.

2. Enhances function availability by eliminating need for Space/Ground Communications

3. Reduces Ground Support Requirements

4. Reduces Space/Ground Rommunications Load

5. Enhances Autonomy

E.2 User/PI Interface

E.2.1 Input Requirements to Planning

Definition:

Provide file containing compilation of validated requirements, covering a particular time span to planning computer.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Ground

Reasons and Comments:

1. Requirements Approval Function and Planning Function located on Ground.

E.2.2 Process Experiment/Mission Requirements

Definition:

Interface with user/PI to establish dynamic experiment and mission requirements (Preliminary). Output is compilation of requirements vs. time.

Allocation Criteria:

1. Crew Functional Load
2. Space/Ground Communications Load

Allocation:

Ground

Reasons and Comments:

1. Requires extensive communications with users/PIs at diverse locations.

2. Appropriate to Ground since planning is done on Ground.

3. If done onboard, it would involve crew in major, time consuming, non-operations task.

E.2.3 Preliminary Requirements Approval

Definition:

Establish validity of requirements based on Mission Level Criteria (e.g., is user an "authorized" user).

Output is compilation of approved requirements vs. time.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Ground

Reasons and Comments:

1. Request Processing and Planning done on Ground.

E.2.4 User/PI to Crew Voice Communications

Definition:

High quality voice communications service (full duplex) on a daily basis between any User/PI and crew.

Allocation Criteria:

1. Applicability.

Allocation:

Shared

Reasons and Comments:

1. Space/Ground communications is by definition a shared function.

E.2.5 User/PI to S/S Data Communications

Definition:

High quality data link to ground to provide mission/experiment data to user on a daily basis.

Allocation Criteria:

1. Applicability.

Allocation:

Shared

Reasons and Comments:

1. Space/Ground communications is by definition a shared function.

E.3 Mission Support

E.3.1 Mission Data Collection

Definition:

Recording of experimental/instrument data.

Allocation Criteria:

1. Autonomy
2. Communication load
3. User accessibility
4. Location of related functions

Allocation:

Onboard

Reasons and Comments:

1. Recording of data OB increases S/S autonomy.
2. Communication links may not always be available and might not be able to handle the data volume.
3. Some experiments may be done with PI on board only and thus accessibility to the data is needed.

4. Preprocessing will be done on board and would include data reduction, thus sending recorded data back up adds to complexity of the system

5. Back up recording on ground is assumed.

E.3.2 Mission Data Preprocessing

Definition:

Analysis of usefulness, quality checks, first level corrections, data reduction.

Allocation Criteria:

1. Autonomy
2. Communication load
3. Location of related functions
4. User accessibility

Allocation:

Onboard

Reasons and Comments:

1. Increases autonomy.

2. Data can be screened and reduced thus decreasing the communication load.

3. Data recording is OB.

4. Data is more accessible to PI's conduction to OB missions.

E.3.3 Mission Data Processing

Definition:

Conversion of raw mission data to useable products.

Allocation Criteria:

1. Crew functional load
2. Crew capabilities
3. Cost

4. Availability/maintainability
5. Technical risk
6. User accessibility

Allocation:

Ground

Reasons and Comments:

1. Crew are not experts in or able to handle the great number of missions planned for the S/S.
2. Equipment and software is easier to maintain and repair on ground.
3. There is a risk in the development of processors capable of handling the large data volumes envisioned.
4. Most users of mission data are located on the ground and will want accessibility to it.

E.3.4 Telemetry Processing (Mission)

Definition:

Documentation, Smoothing, Limit Checking, Conversion to Engineering Units and creation of files for display.

Allocation Criteria:

1. Location of Related Functions
2. Autonomy

Allocation:

Onboard

Reasons and Comments:

1. This function is closely coupled to subsystem Command and Control which is done Onboard.
2. Minimizes Ground Support.

E.3.5 Telemetry Display (Mission)

Definition:
Display selected measurands on CRT or Strip Chart. Provide capability to build special pages.

Allocation Criteria:
1. Location of Related Functions

Allocation:
Onboard

Reasons and Comments:

1. Telemetry Processing done onboard

2. Subsystem Command and Control done onboard.

E.3.6 Long Term Trend Analysis (Mission)

Definition:
Analysis/Observation of long term behavior of telemetry measurments.

Allocation Criteria:
1. Crew Capabilities

Allocation:
Ground

Reasons and Comments:

1. Crew will be concerned with real-time operations on a daily basis.

E.3.7 Generate C&W Alarms (Mission)

Definition:
Autonomated monitoring of selected measurands and generation of Alarms when measurand goes beyond safe limits.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Onboard

Reasons and Comments

1. Telemetry Processing done Onboard
2. Subsystem Command and Control done Onboard.

E.3.8 TV Monitoring (Mission)

Definition:

Visual monitoring.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Onboard

Reasons and Comments:

1. Subsystem Command and Control done Onboard.

E.4. Data Storage

E.4.1 Long Term Data Storage

Definition:

Off line storage of system backups, onboard mission data, S/S and crew historical data.

Allocation Criteria:

1. Safety and health of crew and station
2. Reliablity/availability
3. Autonomy
4. User accessibility

Allocation:
Onboard

Reasons and Comments:

1. It is assumed that such capabilities exist on ground
2. Must have system backups available for emergencies
3. Increases S/S autonomy
4. Needed for OB missions

E.4.2 Data Base and DBMS (S/S)

Definition:
Schematics, station history (modifications, repairs), operating parameters, OB mission data, inventories, medical DB.

Allocation Criteria:
1. Safety of crew and S/S
2. Autonomy
3. Location of related functions
4. User accessibility
5. Applicability

Allocation:
Onboard

Reasons and Comments:

1. Data bases needed OB for crew and s/S health maintenance
2. Increases S/S autonomy
3. Many OB functions need DB support
4. DB needed for some OB missions

E.4.3 Data Base and DBMS (on ground)

Definition:

Duplicate of OB data base, all missions related data for operations, historical data of S/S, historical data of missions.

Allocation Criteria:

1. Safety of crew and S/S
2. Reliability/availability
3. Location of related functions

Allocation:

On Ground

Reasons and Comments:

1. Assume backups are available in long term storage
2. Needed so support mission data processing
3. Backups for on board DB

E.5 Entertainment

E.5.1 Entertainment

Definition:

Libraries, TM, movies, games, etc., for crew entertainment

Allocation Criteria:

1. Health of crew
2. Applicability

Allocation:

Onboard

Reasons and Comments:

1. Crew are on board

E.6 Performance Evaluation

E.6.1 Long Term System Performance Evaluation

Definition:

Long term evaluations of S/S functional performance

Allocation Criteria:

1. Crew capabilities
2. Crew functional load
3. Cost
4. On board processing load
5. User accessibility

Allocation:

On Ground

Reasons and Comments:

1. These are long term specialized tasks
2. Might require specialized equipment
3. Large volumes of historical data need to be processed
4. The authorities that direct the S/S are probably on the ground

E.6.2 Short Term System PE

Definition:

The evaluations of daily operations of the station subsystems and functions.

Allocation Criteria:

1. Autonomy
2. Safety and health of crew and station
3. Reliability/availability

Allocation:

Onboard

Reasons and Comments:

1. Decreases ground dependence.

2. Some malfunctions may be easier to detect on board and may need immediate attention.

3. Crew is able to make some adjustments on the spot.

E.6.3 Long Term Mission Performance Evaluation

Definition:

Long term evaluations of intermediate and final products of missions

Allocation Criteria:

1. Crew capabilities
2. Crew functional load
3. Cost
4. User accessibility
5. On board processing load

Allocation:

Ground

Reasons and Comments:

1. There may be a large number and variety of specialized equipment needed.

2. These tasks required highly specialized knowledge.

3. There will be many missions on the S/S.

4. Users will be on the ground for most missions and need access to the data

5. Large data volumes will need to be processed.

E.6.4 Short Term Mission Performance Evaluation

Definition:

The daily evaluations of the various missions' operations and data quality

Allocation Criteria:

1. Autonomy
2. Communication load
3. Reliability/availability

Allocation:

Onboard

Reasons and Comments:

1. Decreases ground dependence.
2. Detected bad data need not be transmitted.
3. Some repairs/adjustments may be made OB.

E.7 Military Support

E.7.1 On Board Data Link

Definition:

Transmission fo OB data to military system onboard.

Allocation Criteria:

1. National security
2. Autonomy

Allocation:

Onboard

Reasons and Comments:

None at this time.

E.8 Spaceborne Experiments

E.8.1 Conduct Experiment

Definition:

DMS support for carrying out all steps of spaceborne experiments.

Allocation Criteria:

1. Location of related functions
2. Safety of crew and S/S
3. Autonomy
4. Communication load

Allocation:

Onboard

Reasons and Comments:

1. These experiments will be carried out OB and the crew need access to DMS to carry them out safely.
2. Increases S/S autonomy
3. Some data does not need to bounce between S/S and ground.

E.8.2 Record Data

Definition:

Recording and storage of data from onboard experiments.

Allocation Criteria:

1. Location of related functions
2. Communication load

Allocation:

Onboard

Reasons and Comments:

1. Communication links may not always been available

E.8.3 Analyze Data

Definition:

Conversion of raw data to meaningful products and analysis of these products.

Allocation Criteria:

1. User accessability
2. Reliability/availability
3. Maintainability
4. Crew capability
5. Crew functional load
6. Cost

Allocation:

Ground

Reasons and Comments:

1. The final users of mission data are on ground.
2. Analysis functions are numerous and are easier to maintain with ground facilities.
3. Crew are not experts in all experiments and cannot be expected to carry out all the analysis needed.
4. Many experiments need specialized equipment that is not space qualified.

E.8.4 Voice Communications

Definition:

Support of voice communications between crew and PI.

Allocation Criteria:

1. Safety of crew and S/S
2. Autonomy

Allocation:

Shared

Reasons and Comments:

1. Communications are shared functions.

E.8.5 Data Communications

Definition:

Transmission support for data between PI and S/S for spaceborne experiments.

Allocation Criteria:

1. Safety of crew and S/S
2. Autonomy

Allocation:

Shared

Reasons and Comments:

1. Communications are shared functions.

E.8.6 TV Monitoring

Definition:

Support for TV link to monitor experiments.

Allocation Criteria:

1. Safety of crew and S/S
2. Necessary for performance of some experiments

Allocation:

Shared

Reasons and Comments:

1. Communications are shared functions.

E.9 S/S DMS Software Maintenance

E.9.1 Fault Detection

Definition:

The recognition of the occurrance of errors in the DMS software and documentation thereof.

Allocation Criteria:

1. Autonomy
2. Health and safety of crew and station
3. Reliability/availability
4. Applicability

Allocation:

On board

Reasons and Comments:

1. Decreases ground dependence.
2. Some faults may be in high criticality functions and the crew would need to know immediately.
3. For some functions, detection OB may be easier since other signs could exist.
4. The DMS is on board and so is the crew.

E.9.2 Fault Isolation/Diagnosis

Definition:

The location and isolation of faults and the subsequent determination of their cause.

Allocation Criteria:

1. Autonomy
2. Safety and health of crew and station
3. Crew capabilities
4. Crew functional load
5. Reliability/availability
6. Maintainability

Allocation:

Shared

Reasons and comments:

1. OB part increases autonomy
2. Some functions may effect safety and health and will need immediate attention OB.
3. Crew are not experts and have full loads thus for most functions isolation/diagnosis can occur on ground.
4. Availability and maintainability are increased by sharing this function with experts on ground.

E.9.3 Corrective Action

Definition:

After an error is diagnosed, a correction must be found, tested and implemented.

Allocation Criteria:

1. Autonomy
2. Safety and health of crew and station
3. Crew capabilities
4. Crew functional load
5. Reliability/availability
6. Maintainability

Allocation:

Shared

Reasons and comments:

1. OB part increases autonomy
2. Some functions may effect safety and health and will need immediate attention OB.
3. Crew are not experts and have full loads thus for most functions isolation/diagnosis can occur on ground.
4. Availability and maintainability are increased by sharing this function with experts on ground.

E.9.4 S/S to Ground Voice and Data Communication

Definition:

The support of both voice and data messages between S/S and ground.

Allocation Criteria:

1. Applicability

Allocation:

Shared

Reason and Comments:

1. All communications are two sided and hence must be shared.

E.10 Training and Simulation

E.10.1 Support for Training and Simulation

Definition:

The continuous training of crew members in S/S operations and the simulation of activities for that purpose.

Allocation Criteria:

1. Autonomy
2. Safety and health of crew and station
3. Applicability

Allocation:

Onboard

Reasons and Comments:

1. Crew members are on board and need constant sharpening of capabilities.
2. It is assumed that similar functions exist on the ground for preflight training.

E.11 Misson Data Distribution

E.11.1 Free Flyer Relay

Definition:

Relay of Data Transmissions from a Free Flyer to the Ground.

Allocation Criteria:

1. Applicability

Allocation:

Onboard

Reason and Comments:

1. This function can only be performed Onboard i.e., the relay function.

E.11.2 Data Downlinking

Definition:

Transmission of Mission/Experiment Data to Ground on a daily basis.

Allocation Criteria:

1. Applicability

Allocation:

Shared

Reasons and Comments:

1. Space/Ground communications is by definition a shared function.

E.11.3 Data Routing to User/PI

Definition:

Transfer of Mission/Experiment data to individual users/PIs.

Allocation Criteria:

1. Space/Ground Communication Load
2. User Accessability
3. Performance

Allocation:

Ground

Reasons and Comments:

1. The concept envisioned is a wideband data "trunk" to the Ground via TDRSS/TDAS at which point links "fan-out" to users/PIs at various locations thus actual data routing to PIs will take place on the Ground.

2. In all likelihood the station will be low orbit with the corresponding limited visibility time dispersed users thereby limiting the mission data throughput if PIs were linked directly to the station. The communications load will be higher than permitted by this limited visibility.

3. It is not likely that every user/PI will be equipped with space communications equipment.

E.11.4 TDRSS Link Scheduling

Definition:
Obtain TDRSS/TDAS link allocation from TDRSS Network Control Center on a dynamic basis to support downlink communications.

Allocation Criteria:
1. Location of Related Functions
2. Performance

Allocation:
Ground

Reasons and Comments:

1. This function provides data for the planning function which is on the ground. To provide this data from the station would be inefficient.

2. No planned space communications interface with NCC.

E.11.5 MILSATCOM Link Scheduling

Definition:

Obtain MILSATCOM link allocations to support Military Mission downlink communications.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Ground

Reasons and Comments:

1. This function provides data to the planning function which is on the ground.

E.12 S/S Hardware Maintenance

E.12.1 Preventive Maintenance

Definition:

Conduct regular PM procedures on S/S hardware.

Allocation Criteria:

1. Applicability

Allocation:

Onboard

Reasons and Comments:

1. Hardware is Onboard thus PM is easier Onboard given that a trained crew member is available to do it.

E.12.2 Fault Detection

Definition:

Primarily Automated Fault Detection Processing. In addition to telemetry processing/monitoring.

Allocation Criteria:

1. Communications Load
2. Autonomy

Allocation:

Onboard

Reasons and Comments:

1. Minimizes Ground Support
2. Reduces Communications Load

E.12.3 Fault Isolation/Diagnosis

Definition:

Determine the cause of failure

Allocation Criteria:

1. Crew Capabilities

Allocation:

Shared

Reasons and Comments:

1. Crew members may require support from specialists on the ground.

E.12.4 Corrective Action

Definition:

Expedite repair.

Allocation Criteria:

1. Location of Related Functions
2. Applicability

Allocation:

Onboard

Reasons and Comments:

1. Commanding is done primarily Onboard
2. Boards cannot be changed from the Ground

E.12.5 SS/Ground Voice Communications

Definition:

Full Duplex voice communications between station and Ground with high probability of access to a link.

Allocation Criteria:

1. Applicability

Allocation:

Shared

Reasons and Comments:

1. Space/Ground Communications is by definition a shared function.

E.13 Crew Health Monitoring/Maintenance

E.13.1 Routine Check-up

Definition:

Regular vital sign tests such as Blood Pressure, Pulse Rate, Temperature, etc.

Allocation Criteria:

1. Autonmy

Allocation:

Onboard

Reasons and Comments:

1. Function is relatively simple thus involving the Ground is unnecessary.

E.13.2 Health Data Collection

Definition:

Collection and Tabulation/Storage of crew Health Data

Allocation Criteria:

1. Autonomy
2. Communication Load
3. Availability

Allocation:

Onboard

Reasons and Comments:

1. Eliminates need for Space/Ground Communications to perform function.

2. Elimination of Space/Ground Communications enhances availability (less facilities/links involved).

3. Reduces Ground Support required.

E.13.3 Diagnosis/Treatment Determination

Definition:

Determination of Illness and appropriate treatment.

Allocation Criteria:

1. Crew Capabilities

Allocation:

Shared

Reasons and Comments:

1. Crew requires support of specialists on Ground to properly perform this function.

E.13.4 SS/Ground Voice Communications

Definition:

Full Duplex voice link with high probability of link access.

Allocation Criteria:

1. Applicability

Allocation:

Shared

Reasons and Comments:

1. Space/Ground communications is by definition a shared function.

E.13.5 SS/Ground Data Communications

Definition:

High quality low data rate channel to ground with high probability of access.

Allocation Criteria:

1. Applicability

Allocation:

Shared

Reasons and Comments:

1. Space/Ground communications is by definition a shared function.

E.14 SS Onboard Support

E.14.1 SS/Ground Data Communications

Definition:

High quality low data rate channel to ground with high probability of access.

Allocation Criteria:

1. Shared

Reasons and Comments:

1. All First Level Subfunctions under this category with the exception of SS/Ground Communications are allocated onboard due to the fact that they do not apply to the Ground.

2. SS/Ground Communications by definition a shared function.

E.14.2 Environmental Control and Life Support

Definition:

Monitoring and control of environmental control, life support, and waste disposal systems.

Allocation Criteria:

1. Autonomy
2. Safety
3. Applicability

Allocation

Onboard

E.14.3 Electrical Power

Definition:

Management, Monitoring, and Control of electrical power generation.

Allocation Criteria:

1. Autonomy
2. Safety
3. Applicability

Allocation:

Onboard

E.14.4 Thermal Control

Definition:

Control, monitoring, trending of the station's thermal systems.

Allocation Criteria

1. Autonomy
2. Safety
3. Applicability

Allocation

Onboard

E.14.5 Guidance Navigation and Attitude Control

Definition:

Orbit modelling, orbit prediction, attitude monitoring, attitude adjustment.

Allocation Criteria

1. Autonomy
2. Applicability
3. Safety

Allocation

On-Board

E.14.6 S/S Internal Communications

Definition:

Monitoring, configuration, and control of the internal communications system.

Allocation Criteria

1. Applicability

Allocation

On-Board

E.14.7 Radar

Definition:

Display, processing of surveillance data. Collision avoidance, debris avoidance.

Allocation Criteria

1. Safety
2. Autonomy
3. Applicability

Allocation

On-board

E.14.8 Rendezvous and Docking

Definition:

Monitoring, display, and caution/warning for docking operations.

Allocation Criteria

1. Safety
2. Autonomy
3. Applicability

Allocation

Onboard

E.14.9 Remote Manipulator Support

Definition:

Monitoring, procedure/display generation and control for the remote manipulator system.

Allocation Criteria:

1. Applicability
2. Autonomy

Allocation

Onboard

E.14.10 Extra-Vehicular Support

Definition:

Monitoring and caution/warning of extra-vehicular activity.

Allocation criteria

1. Safety
2. Autonomy
3. Applicability

Allocation

On-Board

E.14.11 Orbital Transfer Vehicle Support

Defintion:

Monitoring and scheduling of orbital transfer vehicle activity.

Allocation Criteria

1. Safety
2. Autonomy
3. Applicability

Allocation

Onboard

E.14.12 Free Flyer Support

Definition:

Telemetry processing, experiment scheduling for free flyers.

Allocation Criteria

1. Autonomy

Allocation

On-Board

E.14.13 Structural

Definition:

Monitoring and configuration management of the station's physical structure.

Allocation Criteria

1. Autonomy

Allocation

On-Board

E.14.14 Logistics

Definition:

Management of all consumables on-board the station. Scheduling of replenishment and waste disposal.

Allocation Criteria

1. Autonomy

Allocation

On-Board

E.15 SS Support Subsystem C&C

E.15.1 Subsystem Commanding

Definition:

Transfer of commands compiled by scheduling function (or Real-Time Commands) to subsystems and monitoring for command verification.

Allocation Criteria:

1. Location of Related Functions
2. Autonomy

Allocation:

Onboard

Reasons and Comments:

1. Scheduling done Onboard therefore it would be grossly inefficient to then command from the Ground.
2. Minimizes Required Ground Support.

E.15.2 Procedure Display/Processing

Definition:

Capability to display commanding procedures and to build pages for special procedures.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Onboard

Reasons and Comments:

1. Commanding is done Onboard.

E.15.3 Backup Commanding

Definition:

Emergency Support Subsystem Commanding Backup Capability.

Allocation Criteria:

1. Reliability/Availability
2. Health and Safety of Crew and Station

Allocation:

Ground

Reasons and Comments:

1. Provide redundant capability to provide high availability.

E.16 SS Mission Subsystem Commanding

E.16.1 Mission Subsystem Commanding

Definition:

Transfer of commands compiled by scheduling function (or Real-Time Commands) to mission subsystems and monitoring for command verification.

Allocation Criteria:

1. Location of Related Function
2. Autonomy

Allocation:

Onboard

Reasons and Comments:

1. Scheduling done onboard therefore it would be grossly inefficient to then command from the Ground.

2. Minimizes Required Ground Support.

E.16.2 Procedure Display/Processing

Definition:

Capability to display commanding procedures and to build pages for special procedures.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Onboard

Reasons and Comments:

1. Commanding is done onboard.

E.17 SS Support Subsystem Monitoring

E.17.1 Telemetry Processing

Definition:

Decommutation, Smoothing, Limiting, Checking, Conversion to Engineering Units and creation of files for display.

Allocation Criteria:

1. Location of Related Functions
2. Autonomy

Allocation:

Onboard

Reasons and Comments:

1. This function is closely coupled to subsystem Command and Control which is done Onboard.

2. Minimizes Ground Support.

E.18 SS Support Subsystem Monitoring

E.18.1 Telemetry Display

Definition:

Display selected measurands on CRT or Strip Chart. Provide capability to built special pages.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Onboard

Reasons and Comments:

1. Telemetry Processing done onboard
2. Subsystem Command control done onboard.

E.18.2 Long Term Trend Analysis

Definition:

Analysis/Observation of long term behavior of telemetry measurments.

Allocation Criteria:

1. Crew Capabilities

Allocation:

Ground

Reasons and Comments:

1. Crew will be concerned with real-time operations on a daily basis.

E.18.3 Generate C&W Alarms

Definition:

Automated monitoring of selected measurands and generation of Alarms when measurand goes beyond safe limits.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Onboard

Reasons and Comments:

1. Telemetry Processing done Onboard
2. Subsystem Command and Control done Onboard

E.18.4 TV Monitoring

Definition:

Visual monitoring.

Allocation Criteria:

1. Location of Related Functions

Allocation:

Onboard

Reasons and Comments:

1. Subsystem Command and Control done onboard.