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**ASTRONAUT/COMPUTER  
COMMUNICATION STUDY**

**Phase A Task 3 and  
Intermediate Report**

**MCDONNELL DOUGLAS AERONAUTICS COMPANY**

**MCDONNELL DOUGLAS**



**CORPORATION**

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# **ASTRONAUT/COMPUTER COMMUNICATION STUDY**

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NOVEMBER 1970

MDC G0852

## **Phase A Task 3 and Intermediate Report**

Prepared for the National  
Aeronautics and Space Administration  
Huntsville, Alabama Under  
Contract NAS8-25701



## PREFACE

This report documents the results of Phase A of the Astronaut/Computer Communication Study. It was prepared in compliance with the requirements of Contract NAS8-25701.

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## Section 1

### INTRODUCTION AND SUMMARY

This report documents Phase A of the Astronaut/Computer Communications Study contract, NAS8-25701. The main objective of this contract is to identify the onboard crew functions which can be performed or assisted by an onboard graphic-display computer system. To achieve this objective, methods for onboard function execution must be devised and a crew/computer communication's language must be developed. At the completion of this contract the following products will have been generated:

- A. A list of onboard spaceborne functions that can be performed or assisted by an onboard graphic-display computer system.
- B. Methods by which the space vehicle crew can perform the identified function.
- C. A vocabulary structure for use by a space vehicle crew in communicating function requirements to the onboard computer.

In performing this contract a two phase study approach was adopted; for simplicity, phases are designated as "A" and "B". Phase A was restricted to analyzing and evaluating existing and near-term space vehicles for state-of-the-art onboard computer capability and technology development, to identifying current and proposed onboard crew functions, and to devising preliminary methods and language requirements to be utilized in performing the onboard functions. Phase B could then concentrate on developing and refining a structured vocabulary suitable for performing onboard, spaceborne crew functions and also give consideration to the hardware and software requirements imposed by the methods devised and language recommended. The detailed and related tasks comprising each of these phases are herein listed for the convenience of the reader:

- A. Phase A
  1. Task 1--Document crew-computer (onboard) communication methods on existing and near-term space vehicles. (Completed May 1970, Report No. MDC-G0388.)

2. Task 2--Establish crew functions to be performed with an onboard computer for space station and space shuttles. Define the extent to which the crew will participate in these functions. (Completed 11 September 1970, Report No. MDC-GO388A.)
3. Task 3--Devise methods by which the crew can communicate with the onboard computer to perform the functions determined in Task 2 with special emphasis upon the software and hardware required to support these functions. (Contained in this report.)

B. Phase B

1. Task 1--Formulate a structured vocabulary which will allow the crew to communicate easily with the computer by means of graphic-displays.
2. Task 2--Perform a requirement analysis, based upon the crew functions and the vocabulary, to establish the software operating system necessary to accomplish crew-computer interaction.
3. Task 3--Perform a requirements analysis, based upon the results from Task 1 and 2 above, to establish the hardware operating system necessary to accomplish crew-computer interaction.

1.1 PHASE A TASK 1

After commencing Phase A Task 1, the absence of onboard graphic display capability on historic and existing manned space vehicles became immediately apparent. For this reason, and because of the relatively young age of the manned space effort, the scope of this task was expanded to include selected representative aircraft. Rational supporting this decision is based on the larger number of on-going aircraft projects and high-degree of onboard aircraft computer applications that are applicable to spacecraft usage (i.e., the automation trends established by aircraft manufacturers provide a convenient foundation for developing and proving spacecraft onboard computer requirements).

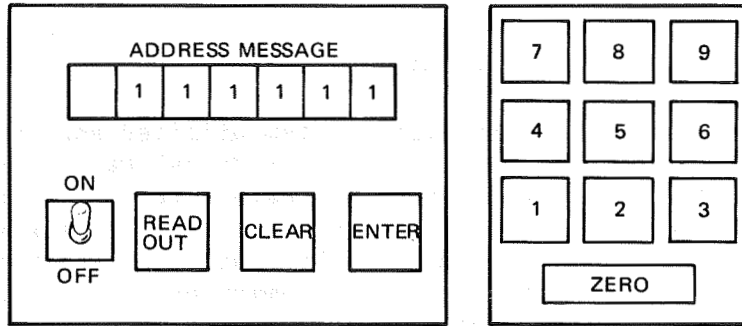
In summarizing the results of this task the following statements are of particular significance:

- A. No manned spacecraft programs were found to utilize onboard graphic-display computer systems (i.e., Mercury, Gemini, or Apollo).
- B. Project Mercury was found to have no onboard crew/computer interface capability at all.
- C. Project Gemini's interactive system utilized segmented light registers for displaying data and a Manual Data Insertion Unit (MDIU) for entering commands and data into the computer. A computer mode selector switch was also used to signal computational modes to the computer. The astronaut via numerical encoded language was capable of communicating commands and data to the onboard computer through the MDIU and computer mode selector switch (see Figure 1-1).
- D. Apollo vehicles utilize a display and keyboard (DSKY) to provide a media for crew/computer communication. The keyboard is digital with nine functions and the display panel consists of five segmented light registers and a computer operating status panel. The language selected for crew/computer communications is referred to as a VERB/NOUN language. Briefly, the astronaut simply reduces the function he wishes to perform to a descriptive verb (action to be performed) and noun (object to which action is to be directed), converts the verb and noun to their predefined two digit numeric codes, and enters the codes into the computer via the DSKY for subsequent computer processing (see Figure 1-2).
- E. The primary functions of onboard spaceborne computers are guidance, navigation and control (i.e., maintaining desired trajectory and vehicle attitude required to achieve mission objectives).
- F. Automation trends for future manned space missions are being directed toward onboard checkout, mission control, mission planning, etc. The underlying ground rule promoting the increase in onboard computer compatibility is vehicle autonomy for future manned space vehicles.
- G. Manned aircraft projects substantiate the feasibility of the automation direction selected for future manned space missions.

## 1.2 PHASE A TASK 2

In performing Task 2, determining onboard crew function requirements for future spacecraft, an assumption was made that future spacecraft would be as autonomous as state-of-the-art technology would permit. Ground support

MANUAL DATA INSERTION UNIT



COMPUTER MODE SELECTOR SWITCH POSITIONS

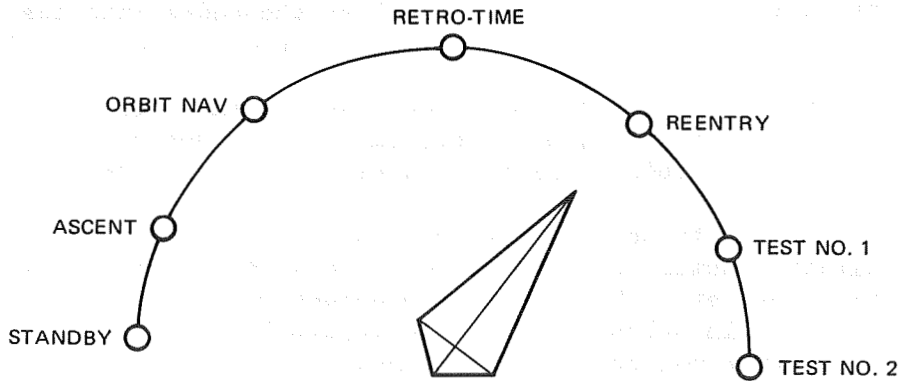
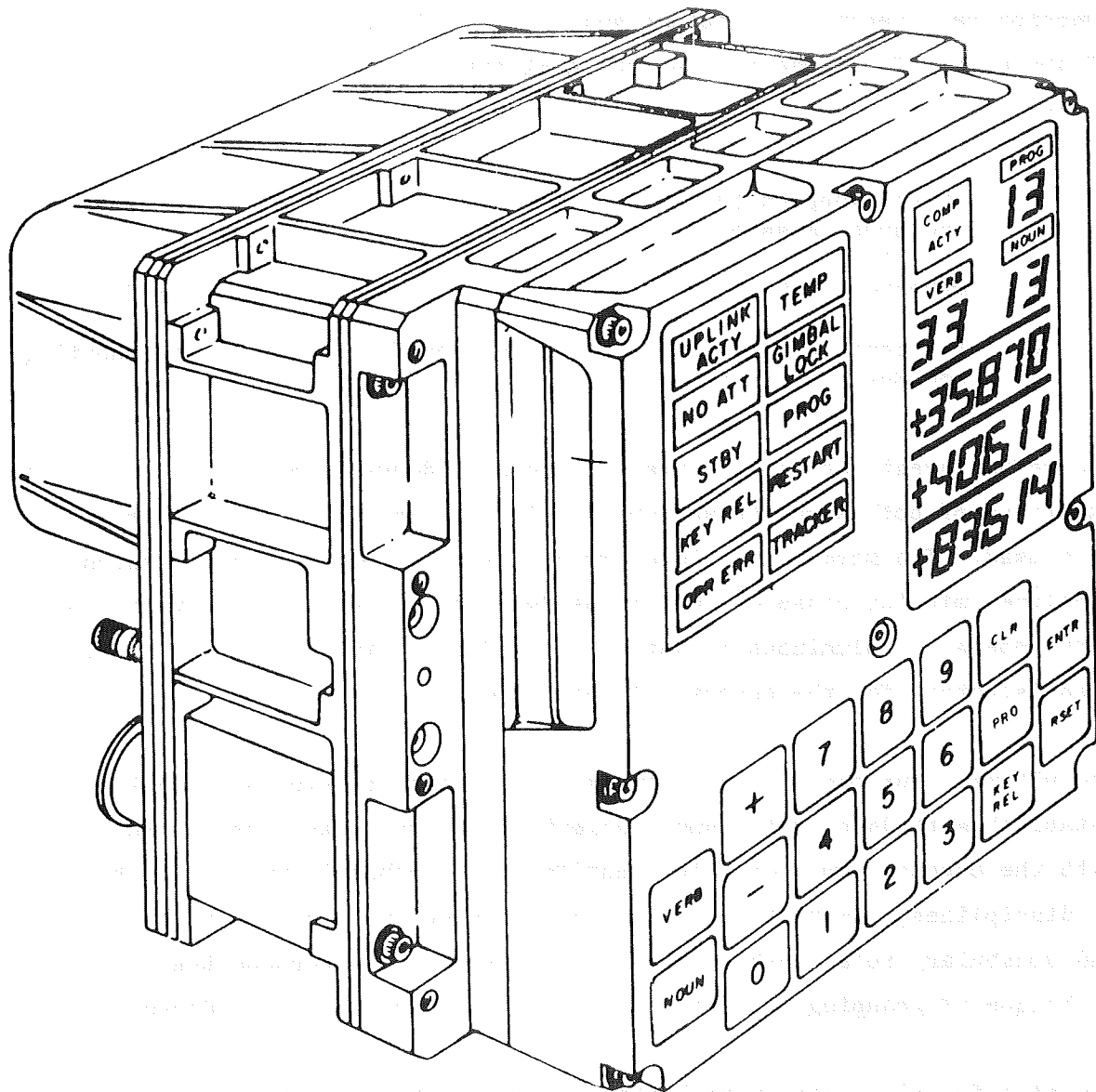


Figure 1-1. Gemini Computer Communications Equipment



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Figure 1-2. Display Keyboard

functions performed for Gemini and Apollo missions were considered as onboard function requirements for future spacecraft. To compile a composite list of spacecraft functions an in-depth analysis was conducted into the following areas:

- A. Ground support functions required by existing and past spacecraft and space missions.
- B. Onboard functions required by existing and past spacecraft.
- C. Proposed functions for future spacecraft (Skylab, Space Shuttle, and Space Station).

A careful investigation of current methods of documenting or listing onboard functions of both aircraft and spacecraft disclosed that several techniques were used. The more conventional methods were oriented toward mission timeline, mission phase or vehicle hardware subsystems. These techniques were generally voluminous in nature and redundant in content and therefore unsatisfactory for the purpose of this study.

The ultimate purpose of the study is to define a structured vocabulary and establish methods by which space scientists or astronauts can communicate with the onboard computer. In identifying the onboard function by technology or disciplines, a structure is thus established and a direct function, method and vocabulary relationship defined. It is for this purpose that the technique of grouping related functions into categories was adopted.

The nine function categories listed below have been established as a result of the analyses conducted as Task 2 of this study.

Mission Control--Functions required to monitor and evaluate actual versus planned mission data, and to adjust mission plan or correct vehicle performance as required to achieve desired mission goals.

Data Management--Functions required to acquire, process, store, maintain and retrieve data as required to support the vehicle and related mission functions.

Communications--Functions required to select the desired communications media (i.e., radio, television, radar, etc.) and related frequency/channel, antenna, and route of communications.

Flight Control--Functions required to maintain vehicle attitude and trajectory as required by the flight plan.

Guidance and Navigation--Functions required to acquire and reduce G&N data so that the vehicle's current versus planned position and trajectory can be determined and the degree of deviation and compensating control functions can be computed.

Experiments--Functions required to perform, monitor, and control experiments being performed from space vehicle.

Maneuver Management--Functions required to initiate, execute, and evaluate success of a vehicle maneuver.

Operational Status--Functions required to monitor and maintain vehicle and crew operational status.

Mission Independent Crew Functions--Functions required to maintain crew proficiency and efficiency during long space missions.

The results of this task support the philosophy that each function category will have its own interactive hardware and language requirements. This is not unreasonable to expect when considering that individual ground disciplines have unique computer/communication requirements and that future space languages will, by necessity, have to be easy to learn and easy to use. Future space missions will find the onboard computer user performing his job functions using language and tools normally associated with his job function and/or discipline.

### 1.3 PHASE A TASK 3

After beginning Phase A Task 3, it became evident that no one man-machine communication method could be devised to satisfy the requirements of all functions in all function categories. For this reason the decision was made that any method devised for performing onboard spaceborne crew functions should be:

- A. Flexible in Design--Methods must be "open-ended" for future enhancements and readily susceptible to change for ease in modification.
- B. "Straight-Forward" in Use--Methods must be easy to learn and easy to apply so as to minimize the training process requirements.
- C. Consistent in Approach--Methods must be similar in performance requirements for different functions in different function categories, and methods for performing identical functions for different space vehicles must be similar even though the function requirement may vary greatly.

Methods devised applying the preceding rationale were found to have basic communication hardware and language similarities. In general interfacing communications hardware will require a minimum configuration of a general purpose Cathode Ray Tube (CRT) with light pen and/or automatic cursor capability; a multipurpose keyboard consisting of selected predefined function (i.e., on/off, clear, enter, etc.) keys, general purpose command keys, CRT line select keys and a numeric digital keyboard.

The communications's language being developed to support the interactive methods will be a technology oriented structured vocabulary (i.e., each onboard discipline will have an indigenous vocabulary for communicating respective function requirements to the computer). Individual discipline languages will be accessible through the use of function and CRT line select keys that provide a conversational means for selecting the desired language level. The conversational approach to obtaining a language allows time for preprocessing software and hardware initialization. Many objections appear when manned space flights are discussed along with conversational



crew/computer communications. One must remember that each discipline is being handled separately, and preplanning should solve any critical timing problems.

The vocabulary structure being developed will permit onboard computer users to select the language working level conducive to solving the particular problem of interest. A language will have a function, command and procedural levels of problem solving capability. The "function" level will perform gross task (e.g., display current G&N measurement data); the "command" level performs a more controlled task (e.g., display the vehicle's current attitude using the inertial reference system); and the procedural level will permit finer control over the task being performed (e.g., determine the vehicle's current attitude by using telescopes "A" and "B" to sight celestial bodies "C" and "D" respectively). The flexibility generated using this technique centers around the users ability to obtain the exact data he desires and to chain vocabulary segments to perform even more sophisticated tasks.

In addition to the user vocabulary described, this study did reveal a future requirement to modify onboard software. This too is a controversial subject which is challenged by the onboard programming and software (i.e., compilers, assemblers, etc.) support requirements. The need for this requirement is outside the scope of this contract and will not be discussed further. It will suffice to say that the requirement has been identified and that its solution must be treated as the subject of a future study.

## Section 2

### FUNCTION CATEGORIES

This section will discuss the nine function categories determined in Phase A, Task 2. The intent is to define the functions comprising each function category and to emphasize the requirement(s) for said functions. The format for this discussion will be to present a pictorial overview of the function category being described with accompanying prose citing examples for clarity. Many of the functions described herein are proposed or anticipated to be operational on manned spacecraft during time frame of this study contract, 1973 to 1980. For this reason all functions are discussed collectively as if they were operational today.

#### NOTE

Figure 2-1 is presented to show the functions which must be performed by the pilot and/or copilot of the proposed Space Shuttle orbiter. It also provides emphasis on the control and display capability needed to perform the onboard functions.

#### 2.1 MISSION CONTROL (Figure 2-2)

Mission control encompasses all functions and subfunctions that must be performed to assure crew safety and mission success. Basic functions associated with this category are: (1) mission planning, (2) mission performance monitoring, and (3) commanding. Currently, the performance of these functions is a ground support responsibility, but to achieve the degree of vehicle autonomy being proposed for Space Shuttle and Space Station and to accomplish future manned space missions (e.g., Mars Fly-by, Grand Tour, etc.), mission control functions will be required to be performed onboard the in-flight vehicle. This is substantiated by the economics and logistics involved in maintaining a dedicated ground support mission control center.

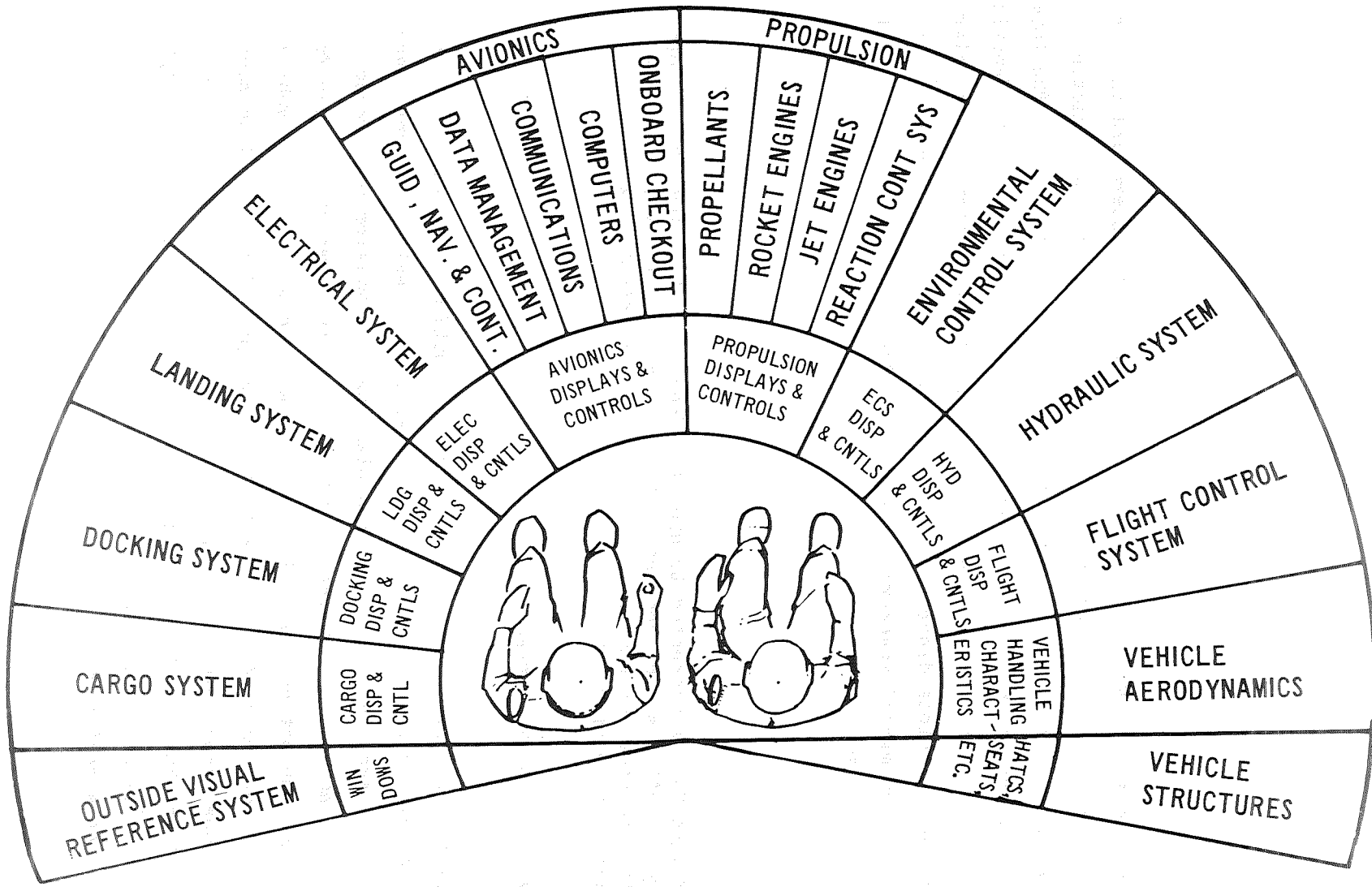


Figure 2-1. Crew Systems

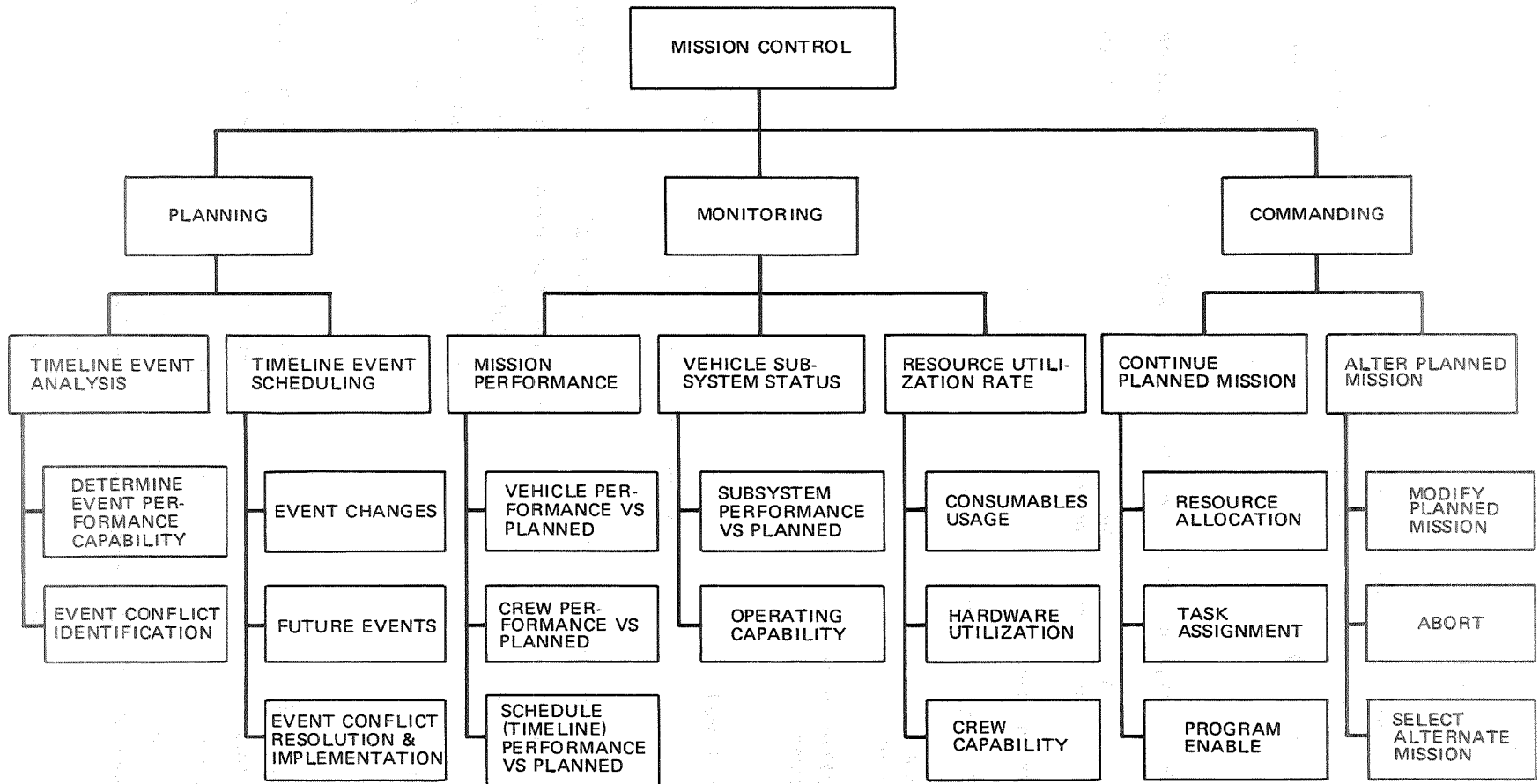


Figure 2-2. Mission Control Function Breakdown

### 2.1.1 Mission Planning

Mission planning functions are primarily concerned with the generation and maintenance of the mission timeline, a chronological list of mission events to be performed. The mission timeline also contains the following data related to event performance requirements:

- A. Event support requirements (i.e., subsystems, resources, etc.).
- B. The estimated status of the vehicle and subsystem before and after an event is performed.
- C. Resources and expendables required by the event.
- D. Crew participation requirements.
- E. Ephemeris data associated with the vehicle prior to event execution.
- F. Other necessary data required for judgment decision involving event execution.

The mission timeline is also used as a "yardstick" for measuring mission performance (i.e., actual requirements versus planned).

Timeline Event Analysis--Before scheduling a timeline event the event requirements must be identified to establish the capability of the vehicle to perform the event. Once this is established, an analysis is conducted of other events already scheduled to identify conflicts which could effect event scheduling and performance (i.e., computing for resources, counter-acting events, etc.).

Timeline Event Scheduling--Once the vehicle is found capable of performing the event, and the timeline can accommodate the event, the event is scheduled. Event scheduling is a tedious task for any event change. A critical analysis must be made of the timeline to determine exact times available for event execution and should the event being scheduled require a specific time, scheduling conflicts (i.e., resource and subsystem availability) must be resolved via predefined shifting or rescheduling algorithms.

### 2.1.2 Mission Monitoring

The vehicle "commander" must continuously monitor mission performance, vehicle subsystem status and resource utilization rates. In this manner he is able to make decisions concerning the mission. For past manned space programs (Gemini and Apollo) this activity was performed on the ground with the assistance of a large mission control staff. For future manned space programs this function will be performed onboard with the assistance of the onboard computer and computer software.

Mission Performance--The performance of the mission is determined by comparing actual data generated by the mission in progress with planned data generated prior to the mission and predicting mission success based on timeline event requirements and new data rates. These functions are performed automatically by the onboard computer by comparing the mission timeline with data obtained directly from vehicle subsystems. In this manner vehicle, crew and schedule performance are determined statistically and displayed for information and action by the flight commander.

Vehicle Subsystem Status--Monitoring vehicle subsystem status is another function automatically performed by the computer for the "flight commander."

Resource Utilization Rates--The flight commander will monitor the utilization rates of vehicle hardware and consumables for statistics generated by the computer. The raw data used in computing these statistics is obtained directly from hardware sensors. Interpretation of the computed statistics provides visibility of resource utilization performance. Crew capability and availability will be maintained in the computer's data base of skills inventory and duty rosters.

### 2.1.3 Mission Commanding

Commanding functions are those decisions made by the "flight commander" in determining the future of the mission being performed. The commander makes the final decision whether or not to continue or alter the planned mission

and implements his decision by issuing commands to effected areas. Commands can be verbal orders to crew members, but in many instances commands will be computer oriented functions which are initiated by the commander from the control and display panel on the mission control console. (Figure 2-3 depicts a version of the proposed Space Station mission control console.)

Continue Planned Mission--Decisions made to continue the planned mission will be of the more routine type commanding functions that allocate resources, assign tasks and enable computer programs required to maintain the planned mission.

Alter Planned Mission--If the "flight commander" decides a mission change is required, he must determine: (1) if a modification to the planned mission is adequate; (2) if an alternate mission is possible; or (3) if an abort situation exists? The ultimate decision will be made by the commander assisting the mission change requirement and the capability of the vehicle and crew to perform.

## 2.2 DATA MANAGEMENT (Figure 2-4)

Onboard manned spacecraft data management is concerned with the computer functions executed in acquiring, dissemination, storing and retrieving data. These functions are stimulated at the request of executing software (i.e., application's programs or operating system) or interrupting hardware. The significance of this statement and the point intended to be emphasized is that no direct crew interface is identified with data management functions. Onboard data management functions are analagous to a sophisticated "input/output" control system with all crew requests being made through interfacing software.

### 2.2.1 Data Acquisition

Onboard data acquisition deals with data as it is received from the data buses. As there is no absolute way of predicting the exact type, amount,

DEDICATED D&C  
• SUBSYSTEM  
• EXPERIMENT

ALPHANUMERIC  
READOUTS

WARNING  
MATRIX

CAUTION  
DISPLAY

INTERCOM / ALERT  
LOUD SPEAKER

MICROFILM  
VIEWER

OCS DISPLAY

MULTIPURPOSE  
DISPLAY

MODE SELECT  
PUSHBUTTON SWITCH

REDUNDANT KEYBOARD  
AND HAND CONTROLLER

PRIMARY  
KEYBOARD

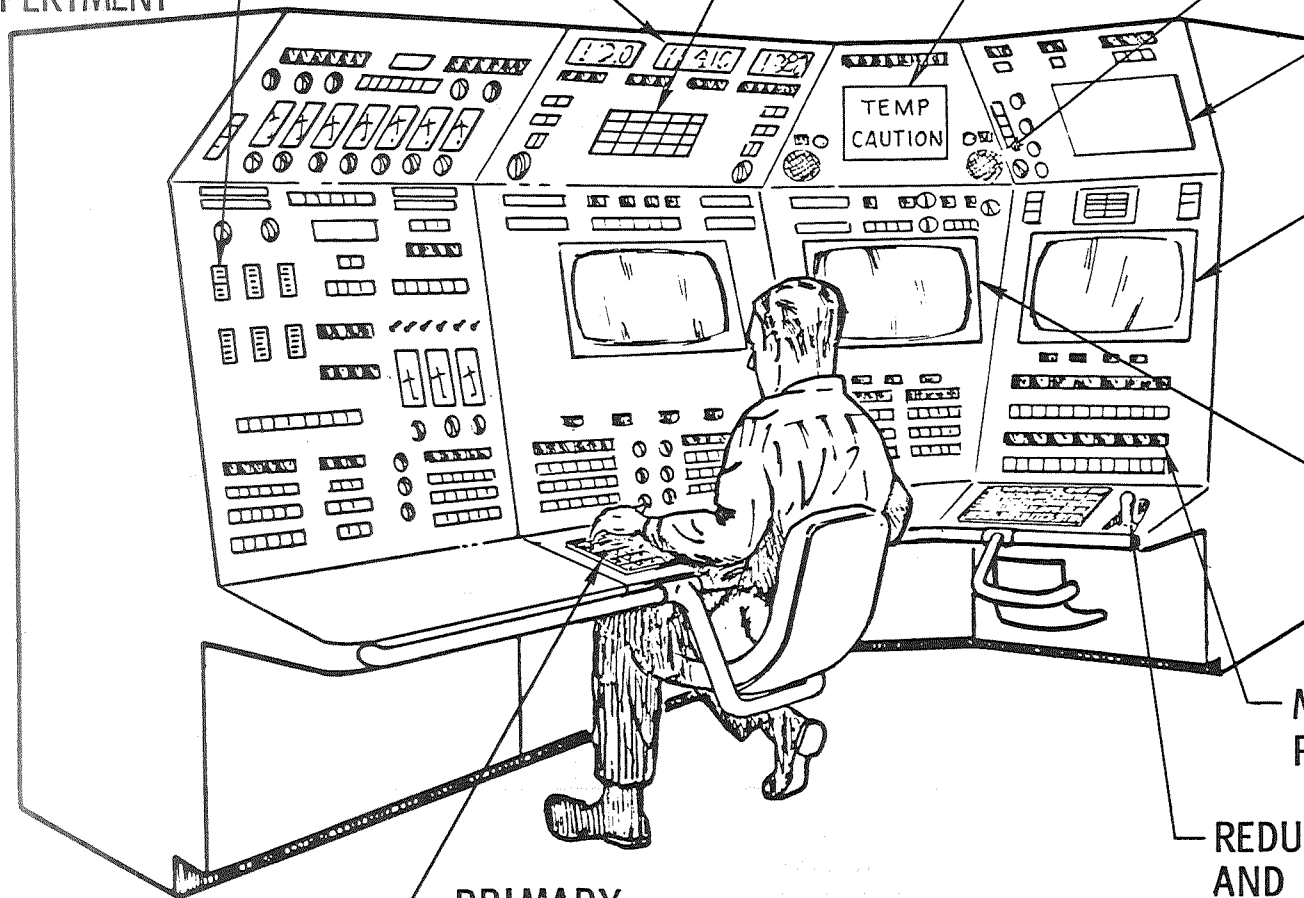


Figure 2-3. Secondary Command and Control Center



DATA MANAGEMENT

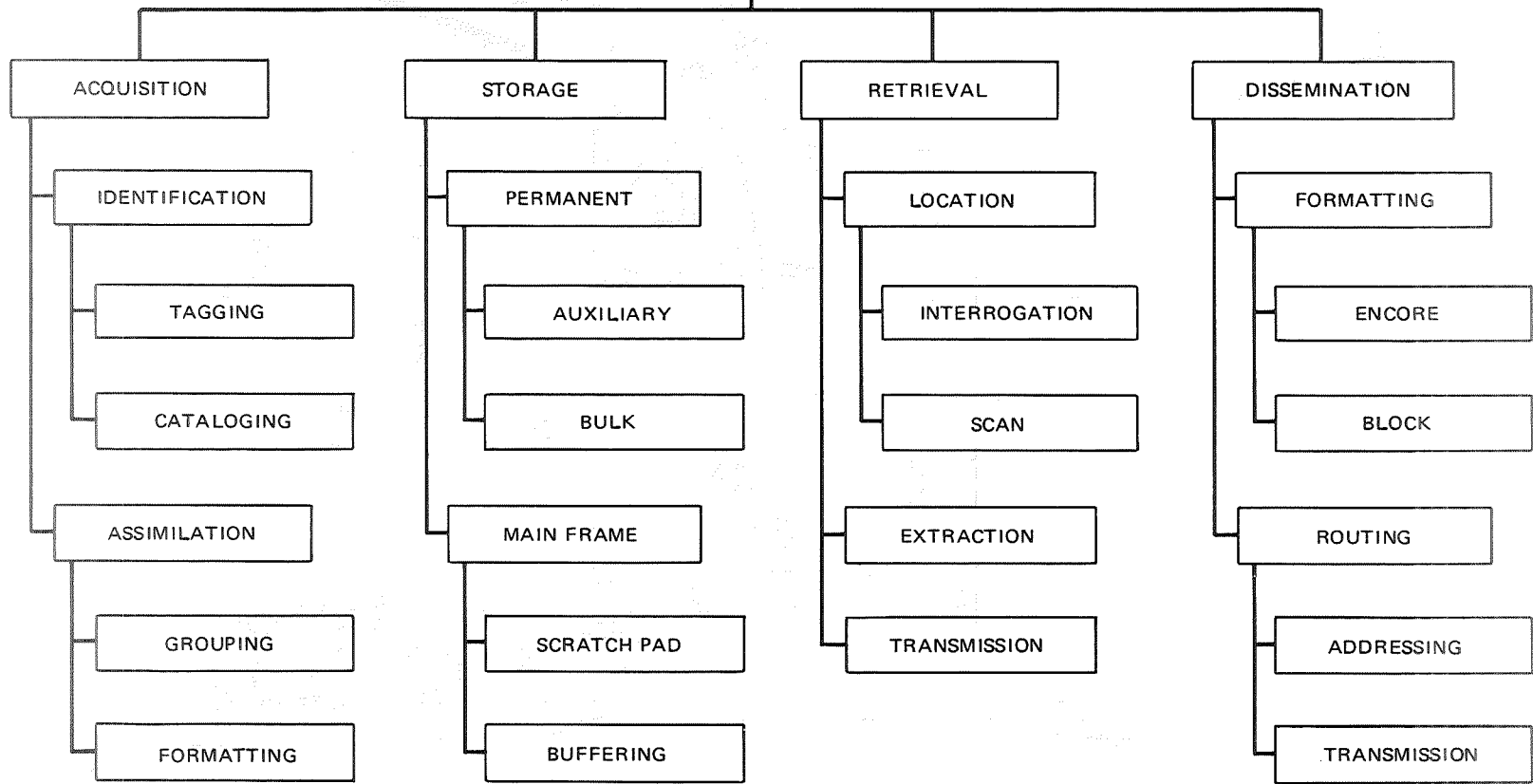


Figure 2-4. Data Management Function Breakdown

or sequence of data that will be obtained from the data bus(es), the responsibility of data identification and assimilation is assigned to the data acquisition procedures.

Data Identification--As incoming data is identified, a data management identification code is generated and "tagged" to the data for internal processing use by data management procedures. To minimize data location problems and to optimize data retrieval processing problems, an entry is made in the data availability index. This is referred to as cataloging.

Data Assimilation--Due to the random and sporadic manner in which data is received from the data bus(es), assimilating data in a working area of storage becomes a necessary function. This provides a convenient and simple method for grouping and formatting data without interfering with other processing functions. Data grouping functions assure data integrity by verifying reception of the total message, while data formatting optimizes data core requirements for efficient internal computer processing.

### 2.2.2 Data Storage Functions

Data storage functions are required to manage the variety of storage media supporting the onboard computer. Future onboard computers are expected to have auxiliary and bulk storage capabilities as well as increased main frame storage. Data storage tasks must maintain a continuance inventory of storage utilization and allocate remaining storage as required.

Permanent--Permanent storage will be provided in various forms (i.e., discs, tapes, etc.). Auxiliary storage is the faster access storage which is expected to accommodate the operating system, subroutine library, and frequently used data parameters and/or files. Bulk storage will store large volumes of data with limited access requirements and will be slow access storage.

Main Frame--Main frame storage will provide "scratch-pad" memory for intermediate processing by application programs and buffering areas for file blocking and processing functions.

### 2.2.3 Data Dissemination

Data dissemination is the term associated with the computer functions that process all requests for the computer to transmit data to remote stations on a data bus. Such a request can originate from the remote station itself, from a different remote station, or from functions performed by the operating system. Data dissemination functions analyze the transmission request to determine format and routing tasks to be performed. Example: A message is originated as a G&N function to display current G&N data on mission control and flight control displays. Data dissemination functions interpret the request, format the message for line transmission, and route the message (i.e., add the hardware address of the remote station(s) place the message in a data transmission buffer, and initiate hardware transmission).

Data Formatting--Data encoding and message blocking are performed by the software to ensure hardware and line compatibility, respectively.

Data Routing--Data dissemination functions provide the message hardware and line addressing data and initiate transmission sequence.

### 2.2.4 Data Retrieval

Data retrieval functions perform the more obvious data management tasks of locating, extracting, and transmitting data for subsequent computer processing.

Location--Data location involves interrogating the data availability catalog for rapid determination of data existences and scanning the data location index for absolute data address should the data exist.

Extraction--Once the desired data has been located, it must be extracted from the data file as requested.

Transmission--The data is then transmitted to a working area of main core for applications program processing.

## 2.3 COMMUNICATIONS (Figure 2-5)

Data management discussed one type of onboard communication, online computer communication with remote stations located on a data bus. This section discusses the remaining types of communication which deal with the more conventional communication techniques (i.e., radio, television, telemetry, etc.). Examples of this type of communication's requirement would be:

- A. Performing coordinated crew task onboard.
- B. Performing landing/docking maneuvers.
- C. Ground support communication.
- D. Performing external vehicle activities.

For discussion and study purposes onboard communications are divided into two functions, transmission and reception.

### 2.3.1 Message Transmission

The onboard computer is expected to perform most of the intricate and time consuming functions associated with message transmissions. The communications operator determines that transmission should occur and the messages to be transmitted. The computer will assist with message formatting, hardware selection, and message routing. The communications operator selects from a menu of options presented by the computer the communications method for performing his task.

Message Formatting--One of the major problems confronting future manned space missions is infinite data generation capability existing onboard future space vehicles versus the limited storage and transmission capability

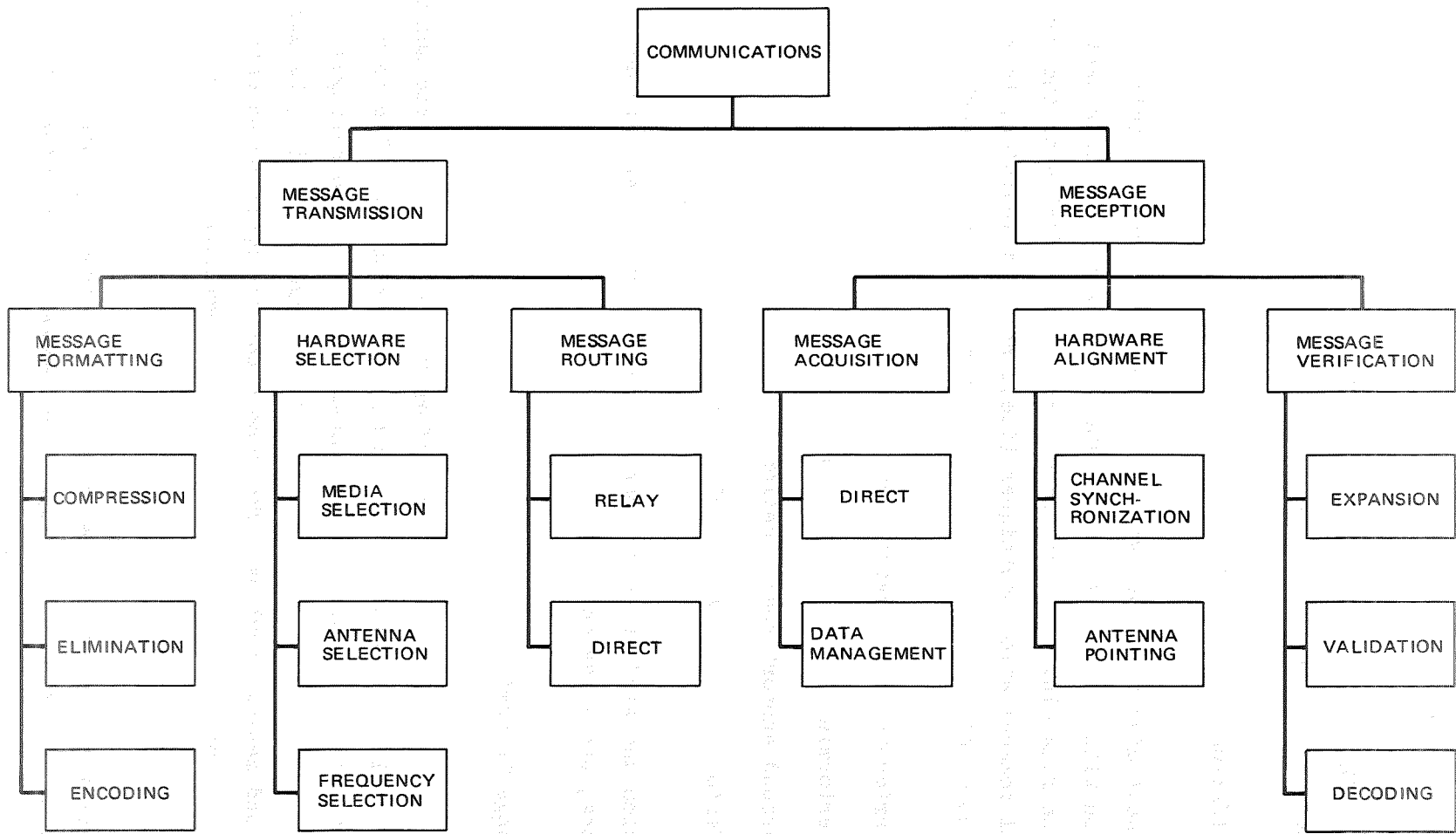


Figure 2-5. Communications Function Breakdown

for saving data. Communications software will of necessity require data compression, elimination and encoding algorithms for limiting the amount of data being transmitted. These terms may appear to connote similar meanings but each algorithm performs a unique task.

**Data compression**--those algorithms reduce the bit requirements for digital character representation. Example: If a transmission were known to contain all numeric data, a character could be represented in four bits as opposed to eight or the binary representation of the numeric field could be transmitted.

**Data elimination**--algorithms eliminate similar or redundant data. Example: If a thermometer were being sampled and a constant reading was being obtained, the first and last samples with respective times would suffice for data reconstruction purposes.

**Data encoding**--algorithms abbreviate data. Example: If a limited number (10) of data parameters are being transmitted in random sequence, a single unique character would adequately identify the data.

**Hardware Selection**--Selection of data transmission hardware is contingent on the type of data to be transmitted and the receiving capability of the station being contacted. For this reason and the uncertain attitude of the vehicle when message transmission occurs, message transmission systems must be coordinated. This means the communication media, compatible antenna and transmission frequency for data transmission must be selected and aligned before successful transmission can occur. The computer performs many of these tasks at the direction of the communications operator.

**Message Routing**--Message routing functions determine the route a message must take to reach the addressee. Messages will be sent directly to the station for which the message intended, but there will be times when contact is required with stations not in transmission range of the vehicle. For this type of transmission, message routing will determine the message relay route for transmission. This route may utilize one or a combination of data relay satellites, ground support stations, or other manned space vehicles.

### 2.3.2 Message Reception

Message reception functions are required for message reception, communications hardware alignment and message verification. These functions are initiated prior to station contact and continue until all data received has been evaluated/interpreted either by crew members or the computer system.

Message Acquisition--Message acquisition can be performed directly by the crew or by the computer data management system (i.e., teleprocessing techniques) providing a requirement for a wide range of interactive tasks. Direct message acquisition could either be visual or data obtained for immediate action or information. Even though the actual data communication is coordinated with the assistance of the computer, the text of the message travels directly to the addressee. Data management, on the other hand, intercepts messages for computer interpretation prior to disseminating the data.

Hardware Alignment--Onboard message reception requires hardware alignment interactive functions. The communications operator must synchronize the receiving channel with that of the transmitting station and optimize the position of the receiving antenna for "static free" reception. Hardware alignment functions are accomplished via the onboard computer at the direction of the communications operator.

Message Verification--Message verification functions are performed by the data receiving station to verify the integrity of the message being received. Messages received directly (i.e., bypassing the computer system) are verified by the receiver at the time of reception or inspection. Message received by the data management system are routed to communications software applications programs for processing. Software procedures analyze the message and perform the following functions as required:

- A. Expand the data by reversing the data compression and elimination algorithms applied prior to transmission.
- B. Validate the data by computing and comparing data check words transmitted as a part of the message text.
- C. Decode data by replacing predefined data abbreviations with respective meaningful data parameters.

## 2.4 FLIGHT CONTROL (Figure 2-6)

Flight control encompasses those functions performed in flying a space vehicle from launch to landing. Flight control interfaces closely with functions described under mission control, guidance and navigation, and maneuver management. The distinction between these functions and those described herein is that flight control functions are concerned with the immediate and near-future problems associated with maintaining a given flight trajectory to achieve the mission objective. The major functions identified with flight control are:

- A. Performing trajectory/flightpath analysis.
- B. Implementing trajectory changes.
- C. Evaluating trajectory changes.

### 2.4.1 Trajectory Flightpath Analysis

In the course of maintaining a given flightpath/trajectory continuous analysis must be made of the vehicle's actual position versus required position. Should a flightpath deviation of a magnitude requiring corrective action be detected, an in-depth study of the course change requirements must be made with particular consideration given to resource requirements and subsystem availability.

Course Change Analysis--Course change analysis is instigated to determine the corrective action required. Inquiries are made of the guidance and navigation, mission control, and maneuver management functions in determining course correction requirements. After determining course correction requirements, a further study is performed to determine the optimum time to execute the corrective functions. Such optimization must take full advantage of the vehicle's position, external vehicular forces, and percent probability of success.



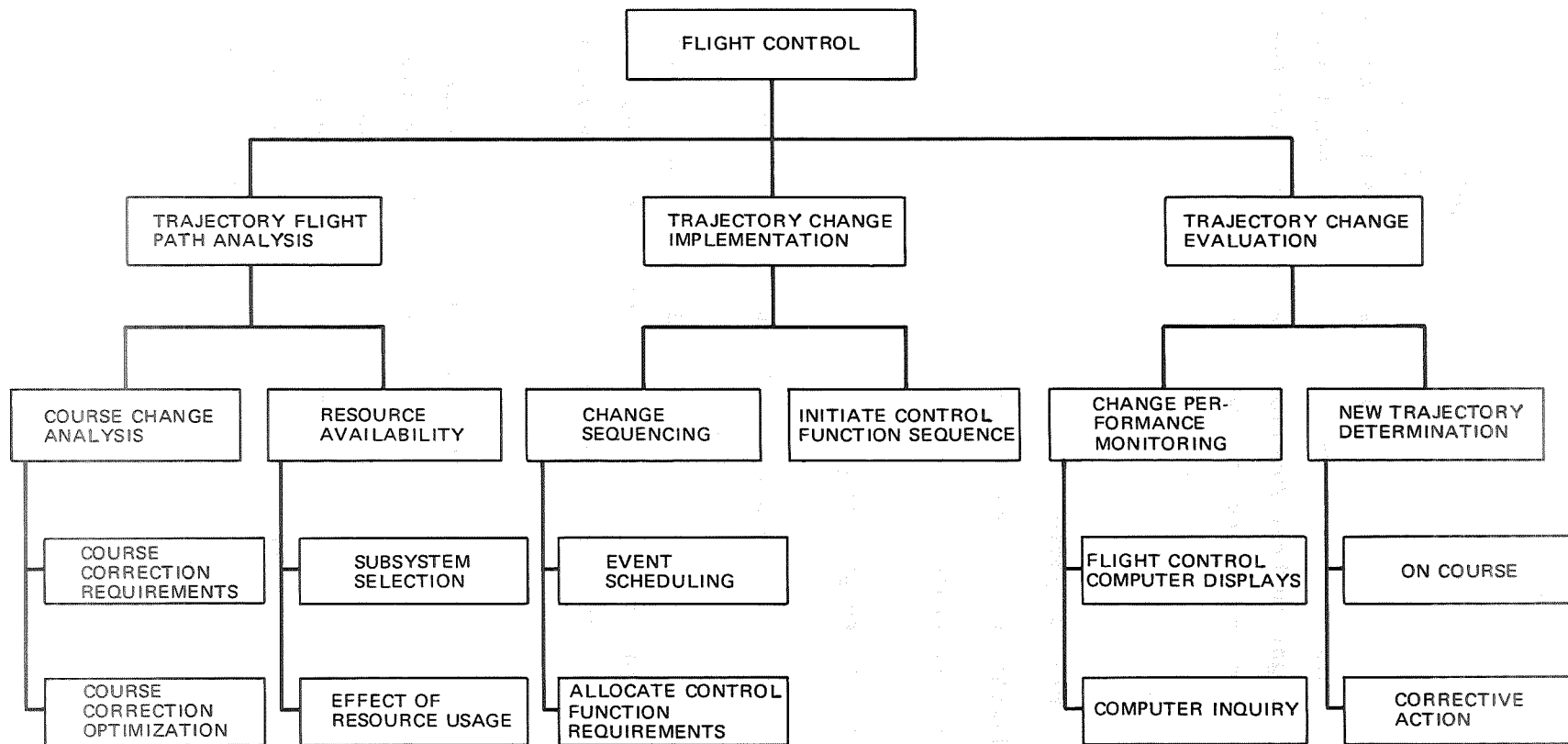


Figure 2-6. Flight Control Function Breakdown

Resource Availability--In conjunction with the analysis performed to determine course change requirements, functions must be executed to ascertain subsystem and resource utilization. It is important that the subsystem selected be capable of performing the required maneuver and not consume excessive quantities of valuable resources. The effects of resource usages must be considered in determining ability of the vehicle to complete the mission without endangering the crew.

#### 2.4.2 Trajectory Change Implementation

After determining a trajectory change is to be implemented, sequencing functions must be determined and initiated for performing the change. Sequencing determination is essential and requires careful planning to assure no step will be overlooked. In some instances a "dry-run" of the planned sequence will be required.

Change Sequencing--A major function in establishing a change sequence is event scheduling. Event scheduling coordinates all subsystem and resource requirements to assure availability and timely execution. Event execution timing is critical. As event scheduling is accomplished, control function requirements are allocated. Control function allocation may be performed by the flight controller in indicating to the onboard computer the sources of control data (i.e., auto pilot, hand controls, rudders, etc.).

Initiate Control Function Sequence--The flight controller performs the minimum function of initiating the control function sequence that starts the trajectory change maneuver. From that point on the flightpath change is performed by the computer under the auspices of the flight controller. The degree of interaction required by the flight controller during the execution of a trajectory change is a discretionary decision made by the flight controller based on trajectory change requirements.

#### 2.4.3 Trajectory Change Evaluation

The initiation of a trajectory change sequence signals the time to begin trajectory change evaluation. The flight controller, utilizing the onboard

computer, monitors the performance of the change being executed by viewing critical flight control data displayed on the control and display panel. Features of the control and display panel permit manual control of the changes in progress, if required. At completion of the trajectory change the flight controller makes a detailed evaluation of the new trajectory. Many of the tasks performed evaluating the vehicle's new trajectory are identical to those discussed in Subsection 2.4.1.

Change Performance Monitoring--One of the major tools available to the flight controller is the onboard computer and its display capability. Utilizing this tool the flight controller can monitor the performance of the vehicle. He does this by directing the computer to display and keep current that information of interest. He also queries the computer to obtain data from the computer's data base as required in performing his job duties.

New Trajectory Determination--The flight controller determines the vehicle's trajectory, as altered by the change, by interrogating the guidance and navigation system. If he has achieved the desired course, he enters a flight trajectory monitoring mode, but if he has not, he begins again the sequence of functions to implement a trajectory change.

## 2.5 GUIDANCE AND NAVIGATION (G&N) (Figure 2-7)

Guidance and navigation functions determine the trajectory and guidance requirements for flying a manned space vehicle to a predetermined destination. To perform these functions measurement data indicating the vehicle's attitude and position must be determined. This data, in turn, is reduced and processed to compute the vehicle's velocity and estimated/actual trajectory. Continued processing yields the trajectory deviation, if any, and control requirements for deviation compensation. The results of G&N calculations are used by mission control, flight control, and maneuver management in performing their respective functions.

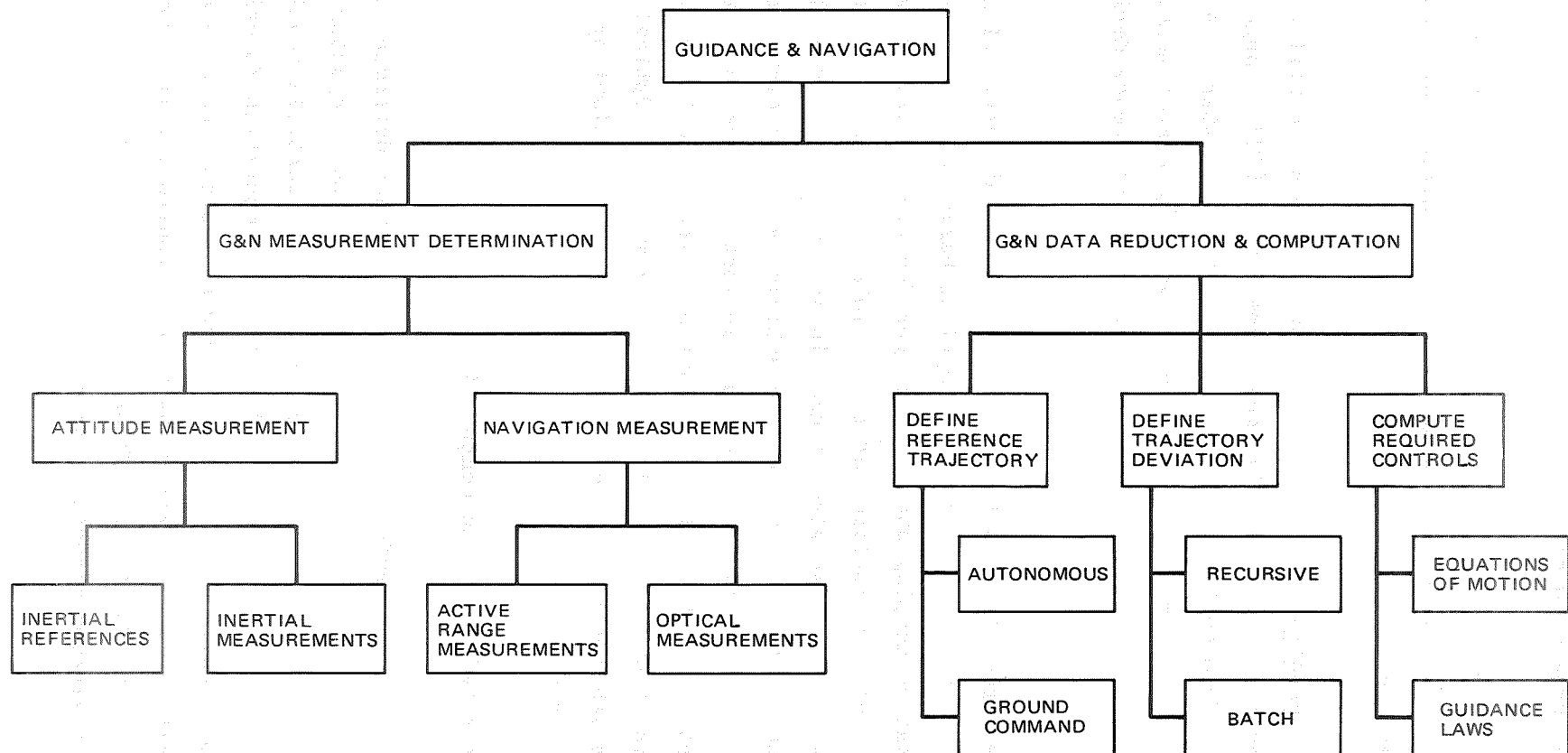


Figure 2-7. Guidance & Navigation Function Breakdown

### 2.5.1 G&N Measurement Determination

One of the first functions to be performed is determining the vehicle's attitude. This data is used in stabilizing the vehicle's attitude so that navigation measurement functions can be initiated.

Attitude Measurements--Attitude measurements are obtained utilizing both an inertial reference and an inertial measurement unit (IMU). Angular measurements are made from optical sightings of predetermined stars. An IMU is a gyro system, either gimballed or strap-down, which generates measurement data of the attitude of the vehicle with respect to the reference derived from the stars.

Navigation Measurements--Functions performed to obtain navigation measurements utilize active range (i.e., radar) or optical hardware. Radar is used in performing station keeping and docking type functions (i.e., radar is used to determine the relative position of the vehicle with respect to other free flying bodies). Radar can also be used in determining the vehicle's position relative to the earth when the vehicle achieves adequate distance at which a meaningful measurement can be obtained. In most instances an optical system is used to determine the vehicle's position relative to the earth or any other celestial body sufficiently close to the vehicle. Optical techniques determine the vehicle's relative position from optical sightings of earth land marks or celestial bodies.

### 2.5.2 G&N Data Reduction and Computation

Data obtained from the performance of G&N measurement determination functions is reduced and processed to determine: (1) the actual trajectory of the vehicle, (2) the trajectory deviation, and (3) the controls required to correct the deviation. G&N data reduction and computation functions are executed automatically by the onboard computer system, and maintain current data parameters for use in performing mission control, flight control, and maneuver management functions. These functions can also be interactively controlled for mission planning. An example would be to establish a new trajectory for an alternate mission not contained in the mission timeline.

Define Reference Trajectory--Establishing the vehicle's reference trajectory can be performed, in most cases, either onboard, an autonomous function, or on the ground, a ground command function. Little differences will exist in the interactive functions required in obtaining the needed trajectory data. The significance of this function is that the capability of determining the vehicle's reference trajectory must reside onboard to supply trajectory data when ground contact is neither possible nor feasible.

Define Trajectory Deviation--"Recursive" and "batch" are terms applied to techniques used in computing a space vehicle's trajectory deviation (i.e., the difference between the reference and planned trajectory). The "recursive" technique is interactive in approach and lends itself nicely to a real-time environment with limited computing resources. The "batch" technique accumulates data points and increases in computation time requirements with the addition of each data point. The "recursive" technique is adequate for the job that must be accomplished and is recommended for limited onboard computer facilities. This technique can also be used in a non-real time mode to assist in defining trajectories in support of mission planning.

Compute Required Controls--Once the vehicle's reference trajectory has been computed and the trajectory deviation established, the G&N functions apply the equations of motion and guidance laws in computing the control requirements for achieving the planned trajectory. Since all G&N functions are educated guesses based on scientific computation, the calculation of control requirements becomes an interactive technique with the flight controller in the "loop".

## 2.6 EXPERIMENTS (Figure 2-8)

Onboard space experimentation is one of the more interactive functions to be performed on future manned space vehicles. The nature of experimentation prohibits discussion of unique functions required in performing individual experiments.

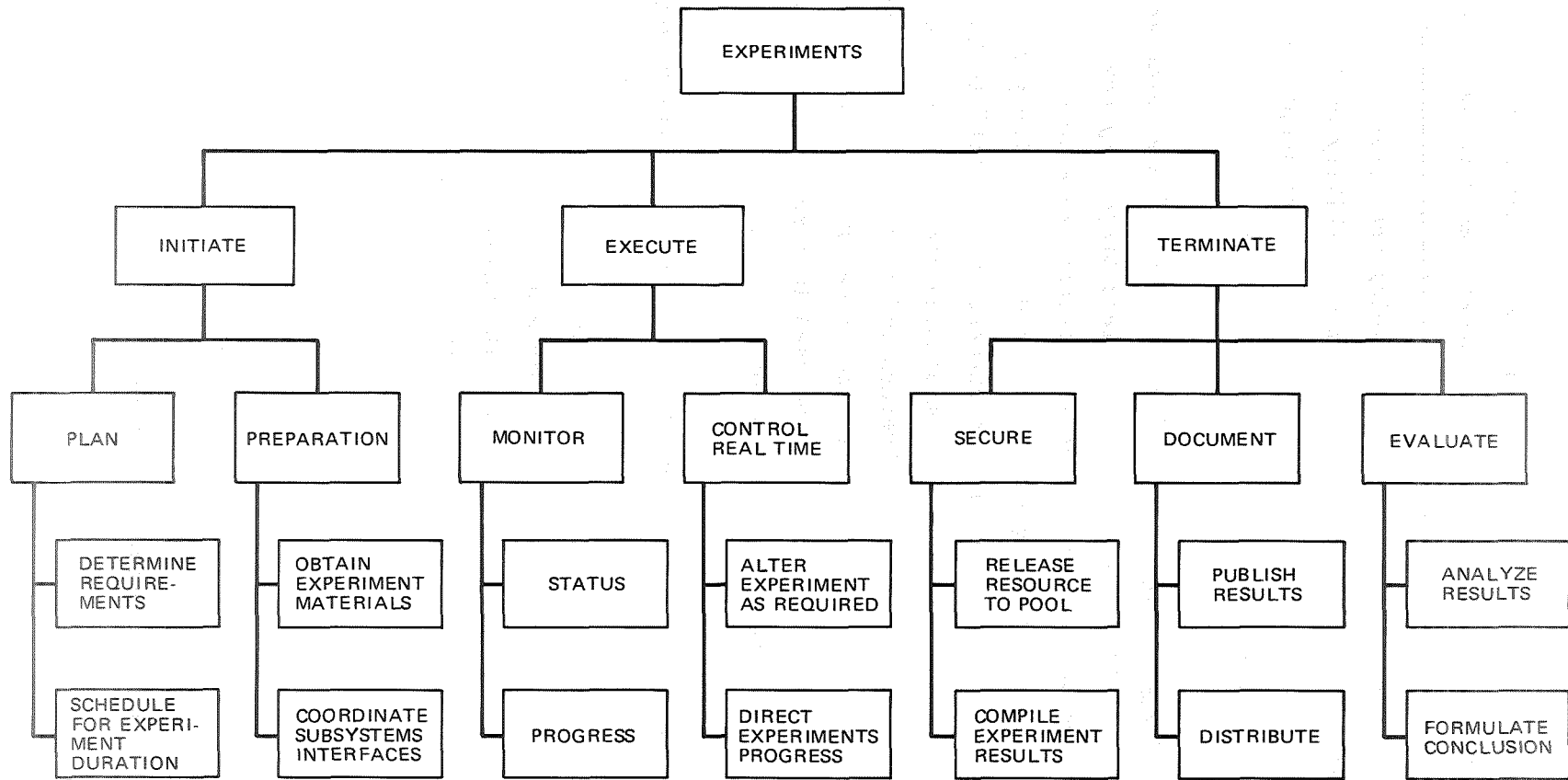


Figure 2-8. Experiments Function Breakdown

This is due to the current number of planned space experiments, the continuous identification of new experiments, and to the unique solution requirements of each experiment. For this reason experiments are discussed collectively so as not to prohibit growth or limit solution requirements. Basic experiment functions are to initiate, execute and terminate the experiment within the constraints of the mission environment. These functions are clearly separated from other mission functions and are considered by some organizations the responsibility of a mission director. This report does not intend to argue this point, but to discuss the functions named above.

### 2.6.1 Initiate

This interactive function assists the space scientist in planning and preparing his experiment. This function assures a coordinated effort and that the experiment can be completed once started.

Plan--Experiment planning calls for a detailed determination of the experiment requirements (i.e., subsystem support, expendables, hardware, etc.) and scheduling needs. An experiment must be scheduled considering the total onboard requirements with respect to the limited resources. Gross scheduling requirements are performed by the space scientist with the computer determining detail schedule requirements and conflicts.

Preparation--Once the experiment is planned the space scientist obtains experiment materials and prepares his laboratory area for execution. He coordinates subsystem interface requirements by verifying connection and the operating status of his experiment related equipment.

### 2.6.2 Execute

The space scientist must monitor and maintain real time control over his experiment during execution. These functions provide him with the visibility he needs in deciding the direction of his experiment.



Monitor--Monitoring the experiment's status and progress is a computer assisted function which frees the experimenter for other duties. While monitoring the experiment the computer records pertinent data for reference at future times.

Control Real Time--Real time control of onboard experiments will provide the space scientist with a "computerized" approach executing his experiment. He will be able to direct or alter his experiment's progress by initiating stimuli from his experiment computer control panel.

### 2.6.3 Terminate

Experiment termination is an important phase of experiment processing. The basic functions involve securing the experiment, documenting the experiment, and evaluating the experiment results. The space scientist will find the onboard computer a valuable tool in performing these functions.

Secure--As the experiment is completed the space scientist will release his hardware interfacing subsystem and unused resources to the availability pool for use by other experiments. He also organizes his experiment data for documentation and evaluation purpose by compiling experiment results and indexing for easy access.

Evaluate--Experiment evaluation becomes a simplified task since the computer has recorded the data during execution monitoring. The space scientist can now analyze experiment results by automatically messaging the computerized data to formulate experiment conclusion for publication.

Document--Documenting will be a manual task with exception of statistics and charts which can be automatically generated from the computerized data. Once documented the experiment results are distributed for consideration and interpretation by other space scientists having similar interest.

## 2.7 MANEUVER MANAGEMENT (Figure 2-9)

Maneuver management is a unique category of functions established to coordinate the various interfacing functions required to identify, define, and execute

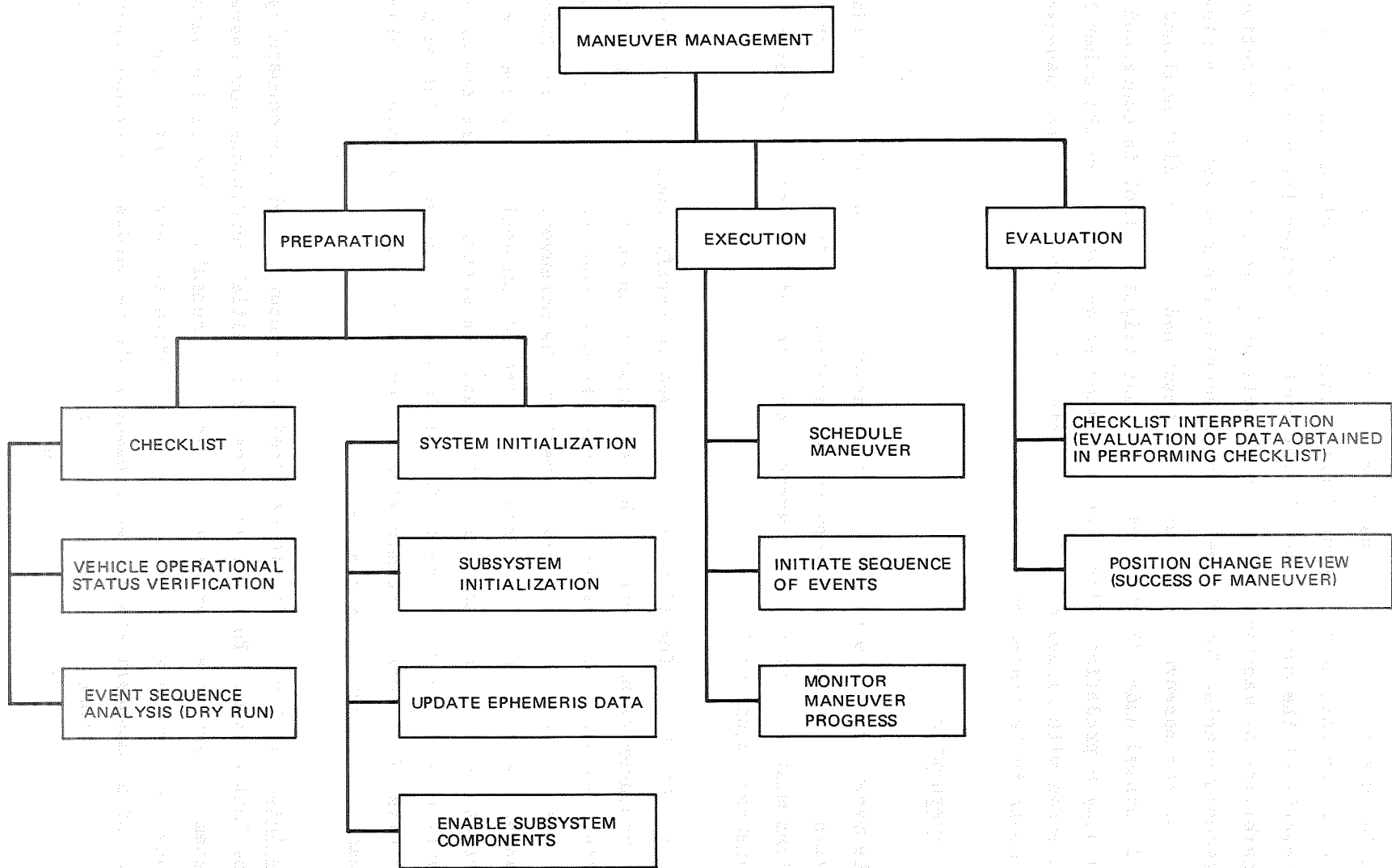


Figure 2-9. Maneuver Management Function Breakdown

a vehicle maneuver. In many instances a maneuver requirement will be identified by mission control, in others by flight control. G&N determines the control requirements of the maneuver and flight control performs the maneuver. The responsibility of maneuver management functions is to coordinate function interfaces preparing for the maneuver, executing the maneuver, and evaluating success of the maneuver. The functions described here are distinguished from those discussed under flight control in that flight control is concerned with maintaining a predefined flight path. Maneuver management on the other hand is concerned with rendezvous, docking, station keeping, and other maneuvers which cease to be trajectory oriented.

### 2.7.1 Preparation

Vehicle maneuvers are scheduled on the mission timeline at sufficient time intervals to allow for the extensive preparation requirements. A checklist of functions must be performed and systems must be initialized in anticipation of the maneuver requirements.

Checklist--Checklist functions are performed to verify condition requirements of the maneuver being planned. The checklist is an accepted technique for reminding crewmen of the tasks which must be performed in verifying the vehicle's operational status and readiness to perform the maneuver. Checklist functions for manned space vehicles are expanded to include an analysis of the events required to perform the maneuver. This analysis establishes the timing and interactive function requirements for performing the maneuver. The purpose of checklist functions is to minimize, if not eliminate, operating problems once maneuver execution is started.

System Initialization--Prior to performing a maneuver, vehicle onboard systems must be initialized. This requires that the initial conditions for respective subsystems be set to accommodate maneuver requirements. Some of the subsystems will have components which must be enabled before the components respond. (An example of a component enable requirement would be hardware settings required for abort situations. This enabling technique requires double consideration be given the task being performed.) Software as well as hardware conditions

must be initialized. G&N ephemeris parameters must be updated to reflect current status of the vehicle so that any accumulated G&N data errors are corrected prior to the maneuver.

### 2.7.2 Execution

Maneuver execution functions actually schedule the maneuver, initiate the sequence of events which perform the maneuver, and monitor the maneuver's progress to completion.

Schedule Maneuver--Maneuver scheduling functions allocate the actual time and time duration for the maneuver, ensuring subsystem and resource availability requirements.

Initiate Sequence of Events--Initiating the sequence of events as described as that function(s) which are required to issue the control command(s) that will execute the events which perform the maneuver.

Monitor Maneuver Progress--Future manned maneuver progress functions will be restricted, almost entirely, to computer interpreted and displayed data. There will be television personnel viewing of maneuvers but decisions will be based on performance evaluation and data being displayed by the onboard computer system.

### 2.7.3 Evaluation

Maneuver management requires both pre and post evaluation of maneuvers.

Checklist Interpretation--Pre-evaluation of the maneuver is limited to the interpretation of data obtained as a result of performing checklist functions.

Position Change Review--Post-evaluation of a maneuver entails a review of the maneuver objectives (i.e., position change) and an interpretation of the success of the maneuver (i.e., were objectives achieved).

## 2.8 OPERATIONAL STATUS (Figure 2-10)

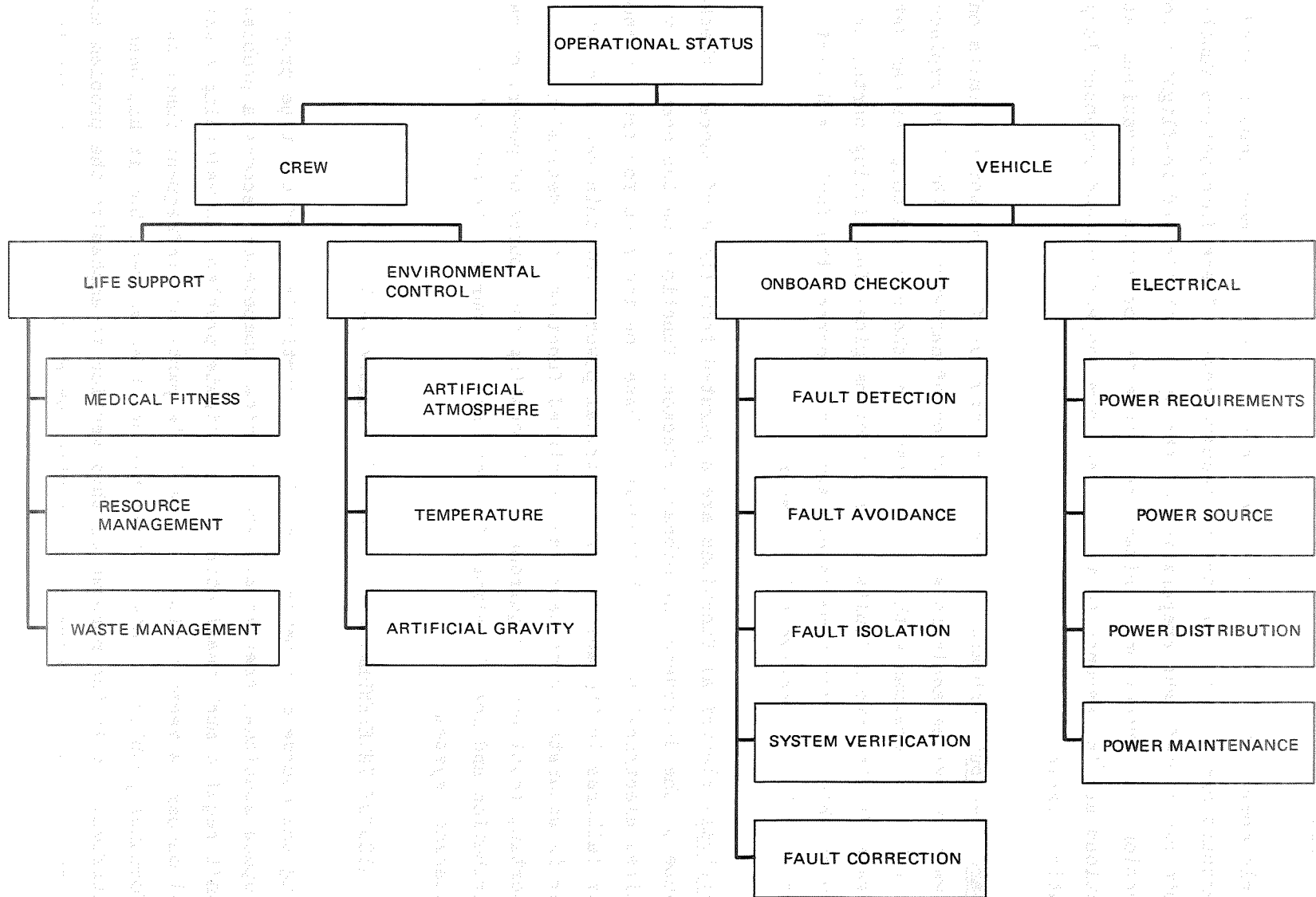
Operational status is the term applied to the interactive functions which are performed onboard the in-flight vehicle to maintain the vehicle's and crew's operating capability. The requirement for this type of function can be attributed to the proposed long duration mission and vehicle autonomy. To achieve these objectives the capability must reside onboard the in-flight vehicle to detect, diagnose and correct sub-performing systems. This requirement is satisfied by the capability provided by the operational status functions.

### 2.8.1 Crew

Maintaining the operational capability of the flight crew is the concern of the life support and environmental control functions performed to sustain life in a space environment. Crew safety is the major factor in manned space flights, and crew operational status functions are designed to detect and identify for corrective action any symptoms which could prove hazardous to human life. These functions also provide a means for making life in space as comfortable as possible considering the imposed limitations.

Life Support--Life support encompasses those functions which are concerned with the physical needs of the body. Specifically, (1) is the body medically fit to perform (i.e., mental or physical); (2) are adequate resources available to sustain life (i.e., food, water, oxygen, etc.); and (3) is the waste management system sufficient and operational?

Environmental Control--Environmental control functions maintain cabin environment as well as space suit environment. These functions maintain a "shirt-sleeve" environment in the space vehicle by controlling the temperature, pressure, and atmosphere within the cabin. Future spacecraft are being proposed to support an artificial gravity system. This function when defined will be considered an environmental control function.



2-29

Figure 2-10. Operational Status Function Breakdown

## 2.8.2 Vehicle

Vehicle operational maintenance functions deal with the more popular subjects of onboard checkout and electrical requirements. These interactive functions permit rapid preflight preparation of the space vehicle and in-flight error detection and correction. Primary requirements for vehicle operational status functions are in response to vehicle autonomy objectives and proposed long duration mission.

Onboard Checkout--Onboard checkout is an obvious function which permits onboard hardware subsystem analysis and correction of hardware to the line replaceable unit (LRU). A crewman with the assistance of the onboard computer can detect hardware faults, avoid faults by detecting marginal functioning parts, isolate failures which are not immediately apparent, correct the fault, and verify the success of the corrective action taken.

Electrical--Electrical functions are separated from those of onboard checkout because of the dependence of onboard checkout functions on the computer which requires electrical power. Rationale is based on the need for trouble shooting power failures in the absence of electrical power. For this reason electrical power is separately considered and assigned functions for determining and supporting total power requirements, allocating the source of power, overall distribution and load leveling of power, and of course, its own optional maintenance system.

## 2.9 MISSION INDEPENDENT CREW FUNCTIONS (Figure 2-11)

During the course of a manned spaceflight, particularly of the type proposed for space stations, crew morale and technical competence becomes a problem. It doesn't require much imagination to anticipate problems in maintaining a skills level onboard a vehicle with high reliable parts and infrequent function performance problems. This problem has not been solved, but it has been identified. It is the purpose of this section to emphasize the problem and discuss training and recreation functions which will alleviate the problem.

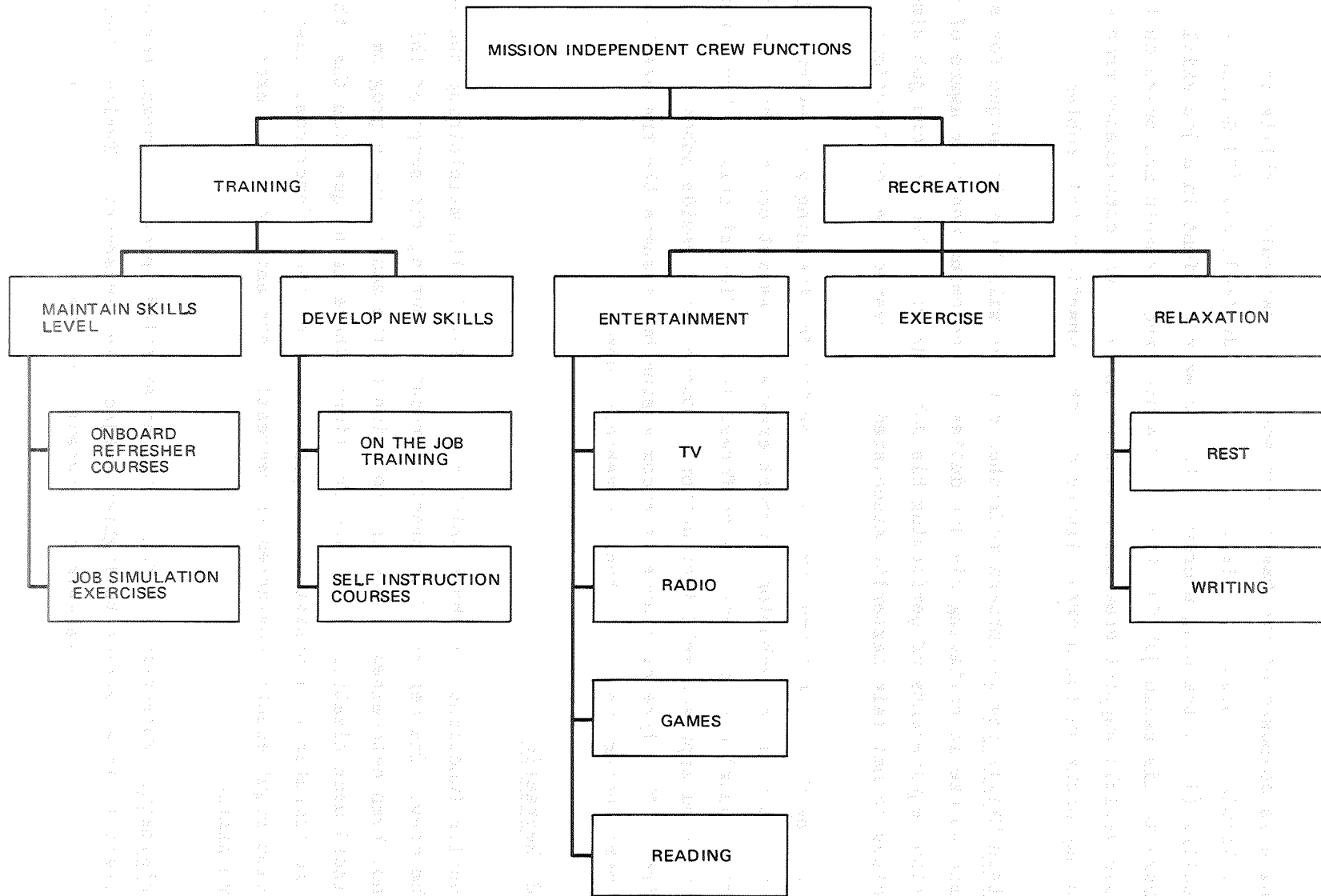


Figure 2-11. Mission Independent Crew Function Breakdown



### 2.9.1 Training

Training is composed of two basic problems: (1) maintain a skills level (i.e., keeping crewmen proficient in their job duties), and (2) developing new skills (i.e., training a crewman to become proficient in a job skill contrary to his basic job function). Training requirements are based on the limited vehicle support crew which will be onboard, and contingency problems which may occur during a crew illness or other unanticipated problem.

Maintain Skills Level--Onboard refresher courses will be a technique for a crewman to use in reviewing his job duties and becoming mentally aware of the function requirements of performing his job. He will also perform job simulation exercises to maintain dexterity associated with respective job functions.

Develop New Skills--A formal program of on-the-job training will exist. This will permit vehicle technology support crewmen to assist one another, and thus become acquainted with functions performed in a different skill. For a more concentrated approach self-instructional courses will reside onboard for use as required. This type of course is encompassing but assumes the trainee has a reasonable background on technology vehicle support.

### 2.9.2 Recreation

Recreation functions are those which are associated with maintaining the morale of the crew. The degree of interaction required during the scope of this study has not been determined, but with evolution of the manned space program and continued mechanization of onboard functions, there is no question that the onboard computer will assist in the performance of these functions. Basic function requirements considered as recreation are entertainment, exercise, and relaxation.

Entertainment--Entertainment functions, as expected, provide a means for crewmen to divert their attention to lighter subjects and amusement. Typical functions would include watching television, listening to the radio, reading and/or playing games.

Exercise--Exercise is a required function for maintaining physical fitness in a space environment. A need will exist for tracking crew performance and adherence to predefined physical fitness programs.

Relaxation--A hard requirement exists for each crewman to spend time relaxing (i.e., sleeping, resting, writing, etc.). This function will be a crew timeline function and strictly enforced. The rationale is to have each crewman capable of performing when required, not as he desires.

### Section 3

#### CREW/COMPUTER COMMUNICATION METHODS

The primary purpose of this study is to formulate a structured vocabulary for onboard manned spacecraft crew/computer communications. In arriving at this end, an analysis of onboard crew/computer interactive functions and methods was conducted. The functions identified as a result of this analysis are documented in Section 2 of this report, and the methods are discussed in this section.

The ultimate method suggested for future onboard crew/computer communications is voice communications with self-educating computer systems. This was the most common response received when the obvious question was asked. The methods devised as a consequence of this study are not that exotic and are considered as intermediate solutions to the onboard crew/computer communications problem. The term "intermediate" is intended to connote a necessary evolutionary step in achieving the ultimate solution not to infer that better solutions exist. The methods described in this section are feasible and advanced over the conventional systems and reflect proposed hardware and software technology advances anticipated for the period 1973 to 1980. Although the crew/computer interactive methods described herein do not eliminate the needs for knobs and switches as a part of future spacecraft cockpit configurations, they do provide a technique for considerably reducing the present day requirement. Briefly, the crew/computer communication methods devised from this study utilized remote graphic displays for entering data and a technology oriented vocabulary for describing tasks to the computer.

As one scans the function categories described in Section 2, it is not difficult to pick out those functions which can best be performed by the onboard computing facility and controlled by the crew from an interactive terminal. Not all categories will require the same degree of crew participation but the functions

listed are felt to be the most conducive to crew/computer interaction. A list of the following methods identified for each function category will substantiate this premise:

Mission Control--This function category is one of the better suited categories for crew/computer communication interaction. The mission planning, monitoring and commanding subfunctions require continuous interaction on the part of the flight commander. The mission timeline with its dynamic characteristics require continuing event analysis, changes, and updating. Utilizing the conversational mode of the graphic display terminal the flight commander will call for status information from the monitoring routines for mission timeline evaluation. From his terminal keyboard he can then key in the required update and changes to comply with the new mission requirements.

Data Management, Communications and Guidance and Navigation--Data management, communications, and guidance and navigation are among those function categories that require minimum crew interaction. Methods utilized for such subfunctions as message verification and hardware alignment will require very discrete actions as well as channel and antenna assignments to the terminal keyboard input. Most all guidance and navigation subfunction problems will be handled automatically by the onboard guidance and navigation systems with resulting status displayed to the flight commander for evaluation. Any action taken by the flight commander will result in the maneuver management category.

Flight Control--The flight control function category is another category requiring crew decisions. The assistance of the onboard computing facility will be utilized to gather status information for making such decisions. Such subfunctions as trajectory flightpath analysis change implementation and change evaluation will be conducted by the flight commander. The display of predicted trajectory information will be utilized by the crew for implementation of change sequencing and events scheduling. Special image projection techniques can be utilized to overlay predicted versus actual information on the screen, and real-time updated information be played back immediately for evaluation of a change in course. This information can then be utilized in the maneuver management function category to initiate immediate vehicle attitude changes.

Experiments--The experiments category will require the most crew interaction of all categories. The initialization, execution and termination of experiments will require versatility in the experiment procedures.

### 3.1 CREW/COMPUTER COMMUNICATION HARDWARE

This study does not have as a purpose the design or construction of computer communications hardware, but hardware is an integral part of any method for communicating with a computer. For this reason, and to facilitate discussion of crew/computer communication methods, a minimum hardware configuration of a remote graphic-display terminal is presented (Figure 3-1). This particular configuration was selected after analyzing the common communication requirements of the functions listed in Section 2. Two factors which highlight the differences in function communication requirements follow:

- A. Manned space vehicles have common function requirements, but have different missions, objectives and configurations. All of which are influencing factors in devising interactive methods. Examples would be the difference in guidance and navigation, onboard checkout, and flight control requirements for Space Shuttle and Skylab. Both vehicles have a need to perform all the functions, but their requirements are very different.
- B. Interactive functions performed onboard manned space vehicles have a common requirement to communicate with the onboard computer, but each has unique data acquisition problems which prohibit a common hardware solution. Example: Manual control of the in-flight vehicle, a flight control function, enters data to the computer via remote sensors which transmit the position on the manual controls (i.e., yoke, translation and/or rotation devices, etc.). On the other hand, updating ephemeris data in the computer's data base, a G/N function, is accomplished by the graphic-display terminal keyboard. (Figures 3-2 and 3-3 show the stress the various display and control requirements for decks 2 and 4 respectively of the proposed Space Station.)

This graphic-display terminal configuration not only provides an instrument for discussion and developing a communications's vocabulary but a prototype for future designs. A discussion of the components which comprise the graphic-display terminal depicted in Figure 3-1 follows:

Cathode Ray Tube (CRT) Display--The CRT display is a multi-purpose device capable of receiving and displaying data from the computer, remote television cameras

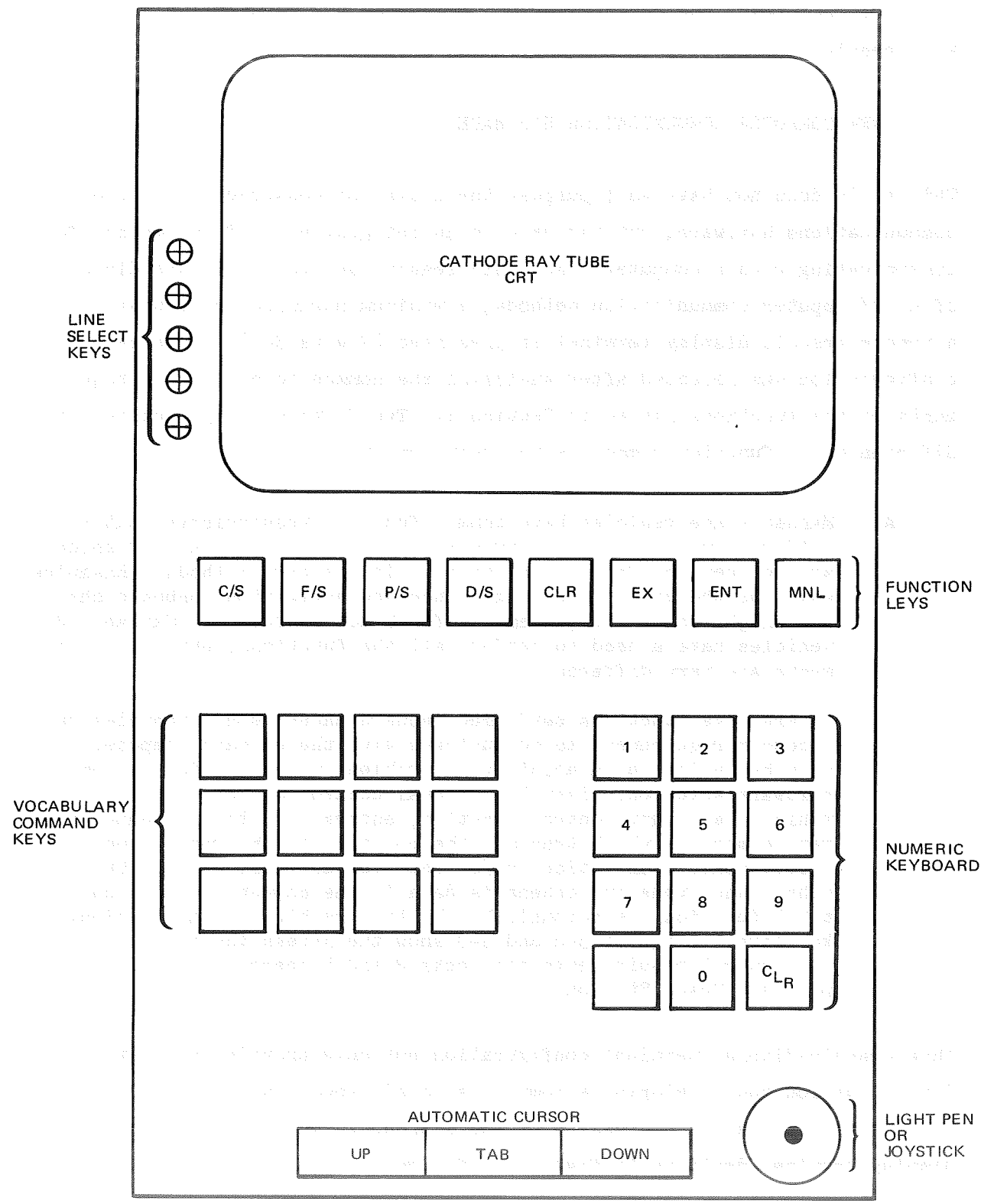


Figure 3-1. Remote Graphic Display Terminal

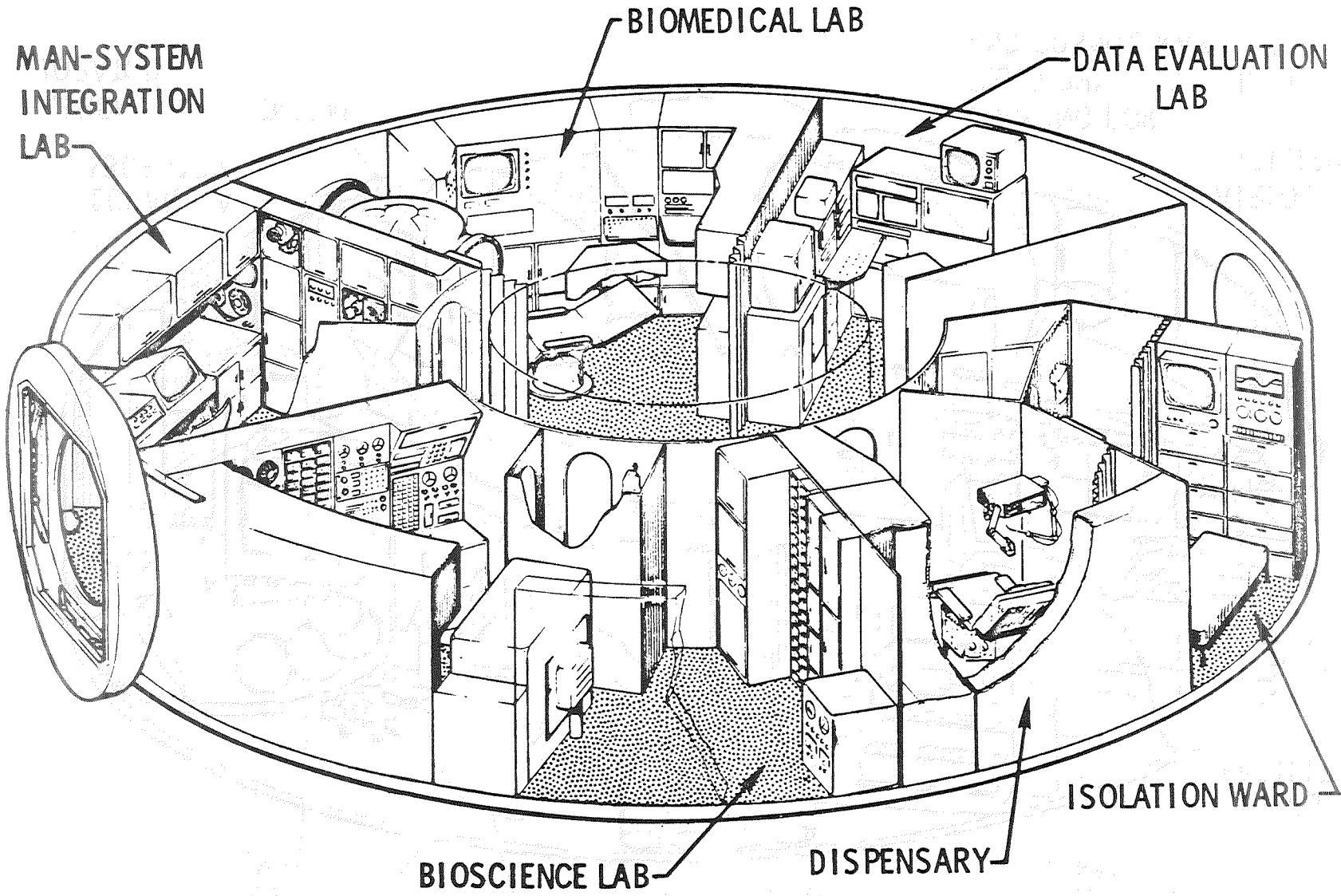


Figure 3-2. Experiments (Deck 2)

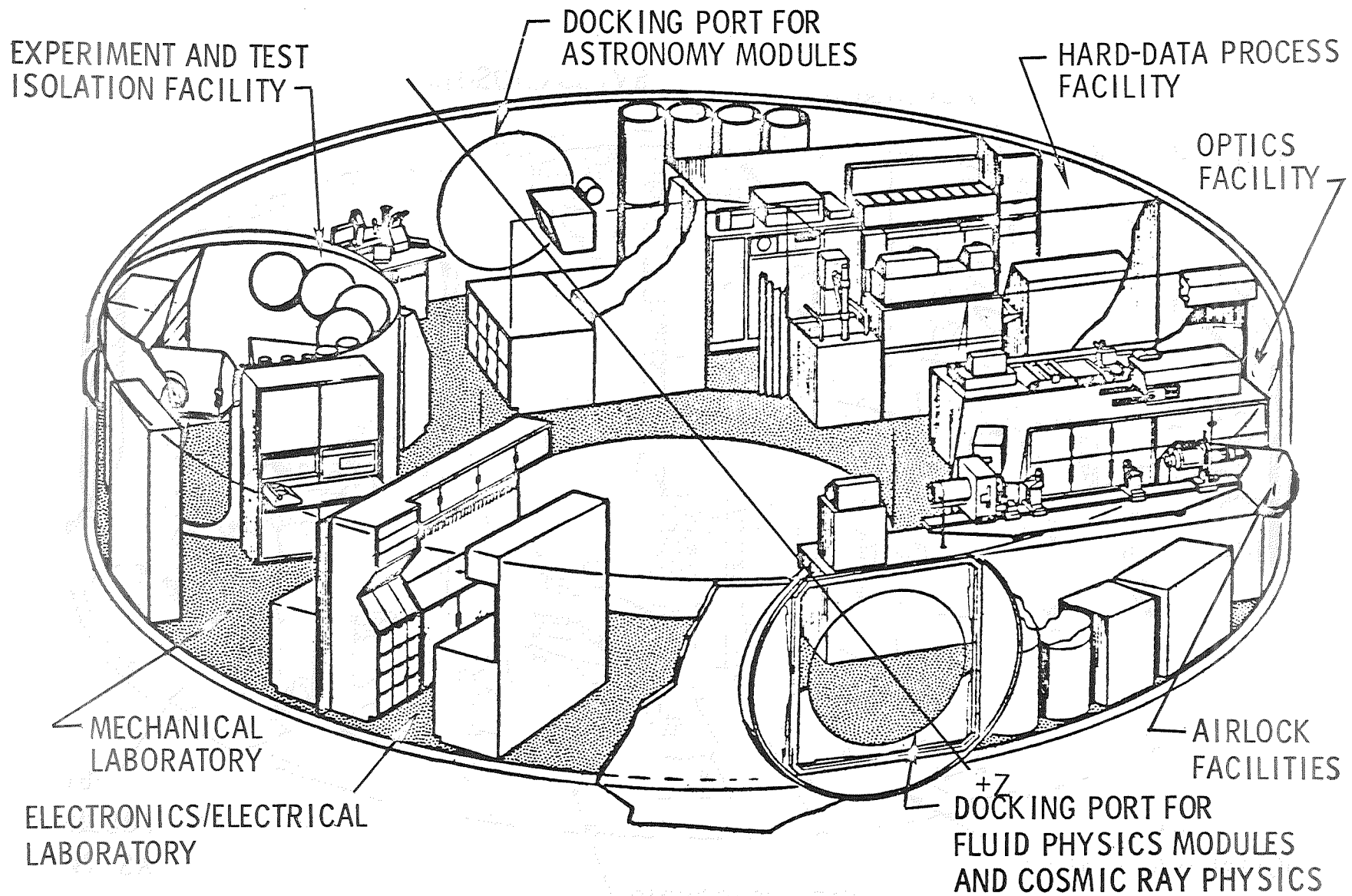


Figure 3-3. General Purpose Laboratory (Deck 4)



and/or mechanical projectors (i.e., microfilm projectors which display an image on the back of the CRT by projecting the image through a window in the rear of the tube). The CRT via a light pen or cursor position also provides a media for entering data into the computer.

Line Select Keys--Line select keys correspond to data lines on the face of the CRT. When a line select key is engaged, the computer receives a discrete impulse. This impulse is correlated to its respective data line, and the software, being cognizant of the data displayed, performs those preprogrammed functions required by the data on the line.

Function Keys--A graphic-display terminal is a general purpose device capable of performing or assisting in the performance of all onboard interactive functions. The function keys associated with the terminal are used to inform the operating system that the terminal is active and preparing to perform a specific task. As a crewman manipulates the function keys to assign meaning to the vocabulary/command keys, the operating system initializes the application program software. Function keys retain their predefined and preprogrammed identity and can be used to select and perform various tasks as required. Function keys are also used to initiate data transmission to the computer and indicate to the software end of data, begin execution.

Eight function keys are proposed to satisfy the structured vocabulary and execution requirements of crew/computer communication methods. The identified keys are listed for information:

- 1 C/S - Category Select
- 2 F/S - Function Select
- 3 P/S - Procedure Select
- 4 D/S - Data Select
- 5 ENT - Enter
- 6 EX - Execute
- 7 CLR - Clear
- 8 MNL - Manual

(Definition and usage of these keys can be found in Subsection 3.3.)

Vocabulary/Command Keys--Once the graphic-display terminal has been initialized, via the function keys, the vocabulary/command keys will display the instruction repertoire for performing the desired task(s). Each activated key represents a command for the computer to perform an associated task(s). The vocabulary/command keys are general purpose (i.e., will accommodate all onboard functions). Normally commands require arguments to control the function being performed. Arguments will be entered via the numeric keyboard.

Numeric Keyboard--The numeric keyboard provides the terminal user the capability of entering data to the computer. The data will be in the form of arguments to commands. Example: Point telescope 1, 20 degrees elevation and 5 degrees azimuth, focus 500 nmi. "Point" and "focus" are commands. "Telescope"1, 20, 5, and 500 are arguments entered by the terminal user.

Light Pen/Joystick--The light pen or joystick will be used for course cursor alignment and rapid answers to "binary" type conversational statements. The light pen is the preferred device and yields the greater capability.

Automatic Cursor--The automatic cursor keys are used for fine alignment of the cursor to the beginning of data fields.

In summary, the minimum hardware configuration discussed in this section is concerned with the general purpose components that can be utilized by all spacecraft and all functions. This study did reveal and does recognize the requirement for other general and special purpose communication's hardware in performing onboard interactive functions. Some of these components are identified in the discussion of methods in Subsection 3.3.

### 3.2 CREW/COMPUTER COMMUNICATION'S LANGUAGE

A crew/computer communication's language is required to overcome the man-machine interface barrier. Attributes of the language must satisfy the interactive requirements of the graphic-display terminal and computer without placing undue hardships on the crew. The approach adopted by this study as the solution to the above problem is to formulate a function oriented structured vocabulary. The objective being to provide each onboard discipline a unique

command vocabulary for performing related interactive functions and eliminate the need for all crewmen to learn a general purpose language and adapt it to their respective job duties.

The structured vocabulary has four distinct levels which parallel the breakdown of function categories presented in Section 2. Figure 3-4 shows the relationship of the levels and a description follows:

- A. **Category**--Refers to nine function categories described Section 2, e.g., Mission Control.
- B. **Function**--The function level is first level breakout of a function category, e.g., Mission Control Planning.
- C. **Subfunction**--Subfunction, as expected, in the next level breakout of a function, e.g., Mission Control Planning Timeline Event Analysis.
- D. **Vocabulary**--The vocabulary level is the detailed working level and is subdivided into two operating modes, to be discussed later.

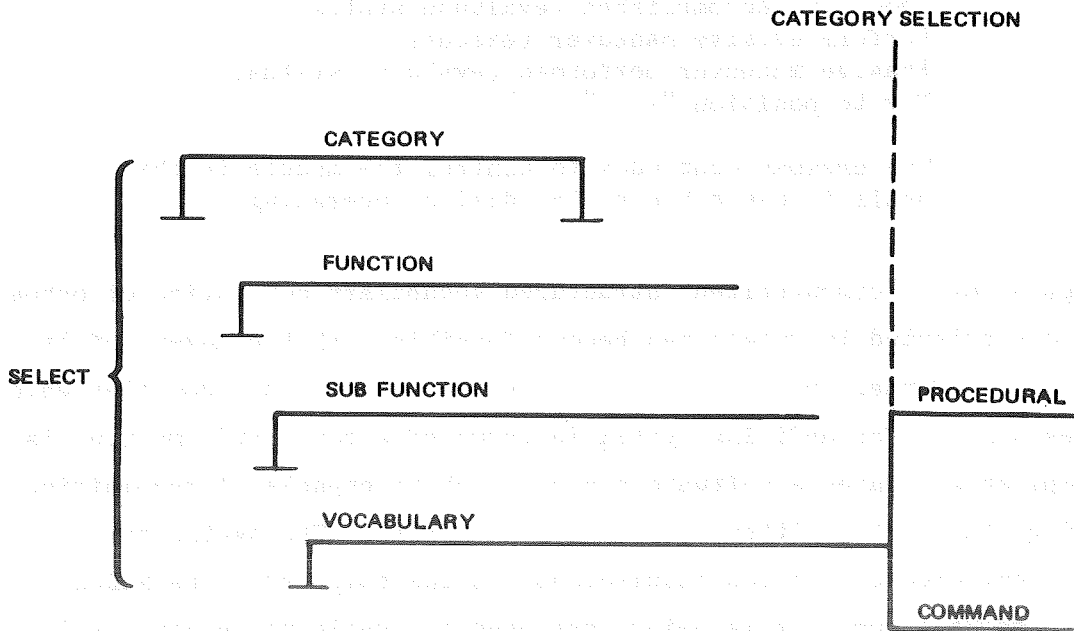


Figure 3-4. Vocabulary Structure Breakdown

The purpose of the structured vocabulary is to expedite the location and access of the desired function language. This is accomplished through keyword association of job functions to technology language. Another advantage of a structured vocabulary is that it's easy to program, and adapts to an interactive environment.

The vocabulary level operating modes, "procedural" and "command," permit the user the option of constructing a complete function for automatic execution or performing each task serially. The latter affords the user greater control over the function being performed by providing intermediate task results for analysis before proceeding to the next task.

Example:

Procedure Mode

Telescope Experiment

Point telescope 1 at star 4, track for 2 hours, photograph at 15 minute intervals. (execute)

Command Mode

Free Flying Module Experiment

Undock module from port 1 (execute)  
Undocking accomplished (evaluate status)  
Perform evasive maneuver (execute)  
Evasive maneuver performed (evaluate status)  
Fly to position "X," "Y," "Z"

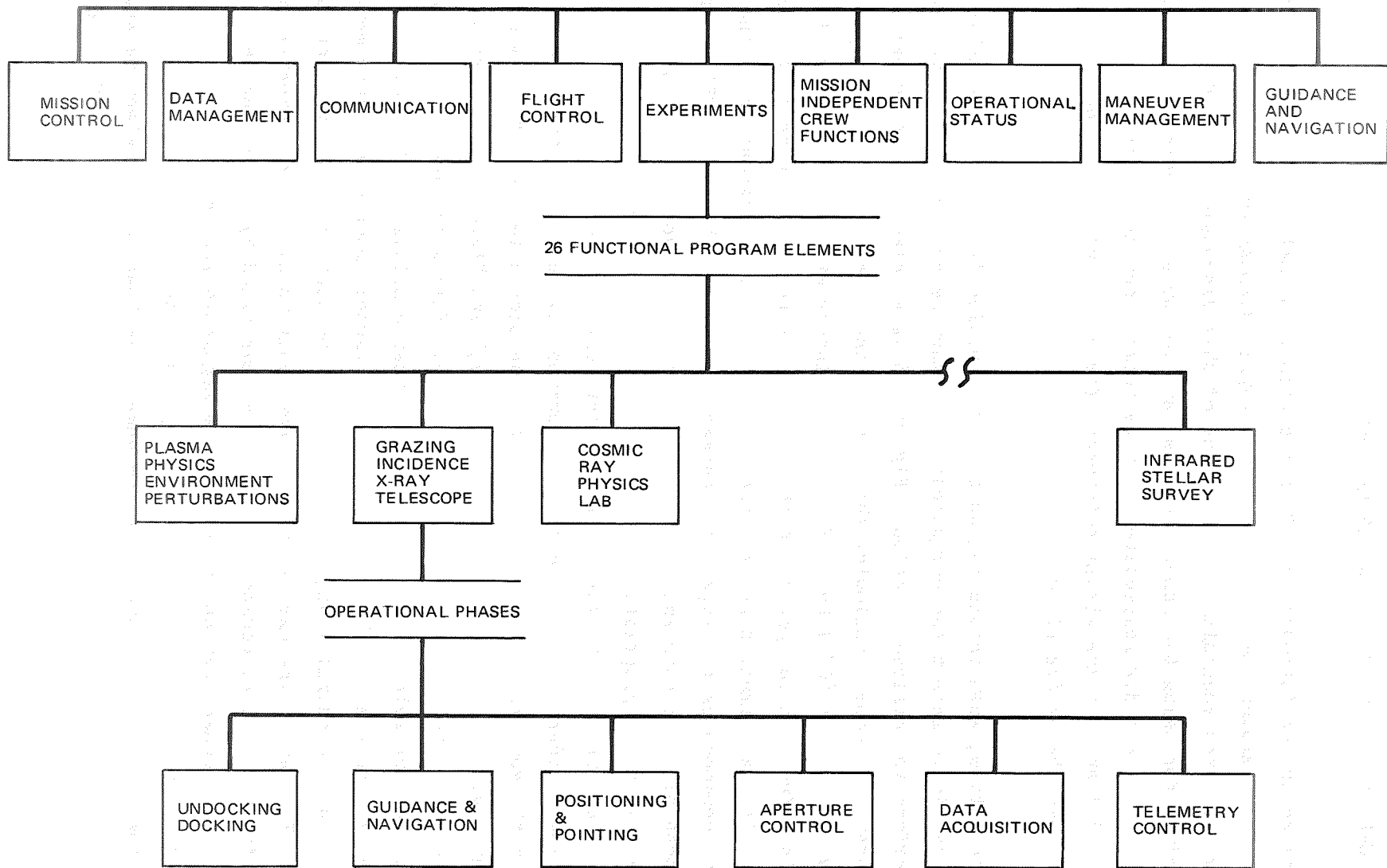
The crewman continues to control the module in this manner until it has achieved the desired operating state.

Development of a "computerized" structured vocabulary consisting of onboard technology oriented languages has become feasible with the advent of language compilers. McDonnell Douglas is currently producing such a compiler which provides a means for defining syntax in terms of a computer's machine language. The compiler generates a software system which is capable of recognizing and analyzing statements written in the defined syntax. The syntax can now be used to communicate function requirements to the computer. The McDonnell Douglas language compiler is being developed in Huntington Beach, California, and is referred to as a Syntax Directed Compiler (SDC). The significance of this technique is that individual languages can be expanded and/or changed without affecting other languages or the operating system.

### 3.3 CREW/COMPUTER COMMUNICATION METHODS

As stated in the introduction of this section, the methods devised from this study focus around the use of a remote graphic-display terminal and a technology oriented vocabulary. The intent of this discussion is to describe the procedure for using the remote terminal and vocabulary, documented in Subsections 3.1 and 3.2 respectively, in performing onboard interactive functions. Figures 3-1 and 3-5 are visual references for use in understanding the procedural tasks being described.

The objective, when initiating an onboard function from a remote graphic-display terminal is to select the communication's language and operating level required to perform the desired function. Figure 3-5 is an example of an experiment using an x-ray telescope. Following this example the experimenter first depresses the category - select (C/S) key. The computer interprets this signal and in turn displays function categories on the CRT. The experimenter wishing to perform a particular experiment depresses the line select key corresponding to the line which accommodates the experiment category. (Note: Should the CRT be incapable of containing all entries, in this case function categories, the user continues to depress the appropriate function key for the next screen of data.) The computer then presents the various experiments until the experimenter selects the "grazing incidence x-ray telescope" experiment by depressing the line select key in the same manner as he selected the function category. The computer now responds with functions "initiate," "execute," and "terminate." "Execute" was the selected function as shown in Figure 3-5. This selection was also made using the line select keys. The computer then displays the technology - command vocabulary on the vocabulary/command keys. (Note: Should the experimenter desire the procedural mode, he can select it by depressing the procedural select P/S key.) The experimenter is now ready to execute his experiment by entering the desired commands. This is accomplished by depressing the vocabulary/command key and supplying the arguments requested on the CRT. Arguments can be entered by selecting option using the line select keys, by positioning the cursor and using the numeric keyboard or by selecting arguments with the light pen. Regardless of the technique used the enter (ENT) key is used for partial data entries and the execute (EX) is used to signal command execution to the computer.



3-12

Figure 3-5. Function Categories

The manual (MNL) function key is used by the terminal operator to go directly to the desired vocabulary level without going through category and function select operations. This is accomplished by depressing the MNL key, the appropriate function key and entering control data through the keyboard, preferably an alphanumeric keyboard.

The data select (D/S) function key is used to engage the data management retrieval system. This is used to obtain general data from the computer data base.

The clear (CLR) function key is used to clear the last task signaled by the terminal operator so that it can be performed again (an error mode).

The clear (CLR) key on the numeric keyboard clears the last argument entered via the keyboard and position the cursor for reentry.

As can be seen, there is a need for additional general purpose as well as special purpose hardware in performing onboard functions. The alpha-keyboard is the most apparent general purpose component. The alpha-keyboard will be required by most functions in labeling data, but some functions will be unable to use it.

Examples of special purpose hardware can be identified with all functions but a few are listed below:

- A. Flight control will need to use yokes, rudders translation and rotation devices, etc. All of these hardware components will communicate with the computer.
- B. G/N could have a requirement to enter data base on optical settings of telescopes and/or sextants.
- C. Mission control and onboard checkout functions will require the use of dedicated and/or special purpose displays (i.e., electronic attitude direction indicator, map display, oscilloscope, etc.).

The point is, even though many functions will utilize special purpose hardware to communicate and control interactive functions via the onboard computer, modifications or changes to these functions can be accomplished using the procedural mode of the language described. This, of course, is assuming that the software is not hardwired.



Section 4  
CONCLUSION

Delivery of this document satisfies Phase A requirements for the Astronaut/Computer Communication's Study Contract, NAS8-25701. This phase of the study revealed the unprecedented role of the onboard computer in future manned space programs. The computer is no longer an afterthought; it is a major component around which the vehicle is designed. The identification of this fact emphasized the man-machine interface problem by the conspicuous absence of concern.

Phase B of this contract will continue to expand and develop the vocabulary/command language described in Section 3 of this report. Development of this language will offer a prototype from which a production model can be constructed.

Section 5

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