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March 8, 1972

VEHICLE MANAGEMENT AND MISSION PLANNING SYSTEMS WITH SHUTTLE APPLICATIONS

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HOUSTON, TEXAS

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CONTENTS

Section		Page
1.0	SUMMARY	1
2.0	INTRODUCTION	4
3.0	SYMBOLS	7
4.0	TOTAL SYSTEM OVERVIEW	9
	4.1 System Requirements	10
	4.1.1 General	10
	4.1.2 VMMPS requirements	11
	4.2 System Operation Modes	12
	4.3 System Description	14
5.0	SUBSYSTEM DESCRIPTION	20
	5.1 Mission Design and Analysis Subsystem (MDAS	22
	5.1.1 Introduction	22
	5.1.2 Objective	22
	5.1.3 Functions	23
	5.1.4 Requirements	24
	5.1.5 Subsystem description	25
	5.2 Flight Scheduler Subsystem (FSS)	30
	5.2.1 Introduction	30
	5.2.2 Objective	30
	5.2.3 Functions	30
	5.2.4 Description of current capability	32
	5.3 Launch Operations Subsystem (LOS)	35
	5.3.1 Intoruction	35
	5.3.2 Objectives	35
	5.3.3 Functions	35
	5.3.4 Requirements	36

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Section Page

5.4 Vehicle Operations Subsystem (VOS) 39

5.4.1 Introduction 39
5.4.2 Objectives 39
5.4.3 Functions 39
5.4.4 Subsystem description 40

5.5 Payload Operations Support Subsystem (POSS) . . . 44

5.5.1 Introduction 44
5.5.2 Objectives 44
5.5.3 Functions 44
5.5.4 Requirements 45
5.5.5 Subsystem description 45

5.6 Crew Support Subsystem (CSS) 49

5.6.1 Introduction 49
5.6.2 Objectives 49
5.6.3 Functions 49

5.7 Information Management Subsystem (IMS) 52

5.7.1 Introduction 52
5.7.2 Objectives 53
5.7.3 Functions 53
5.7.4 Requirements 54
5.7.5 Basic elements 57

5.8 Flight Operations Support Subsystem (FOSS) . . . 60

5.8.1 Introduction 60
5.8.2 Objectives 61
5.8.3 Functions 61
5.8.4 Requirements 63
5.8.5 Subsystem descriptions 64

6.0 SYSTEM DEVELOPMENT 68

6.1 Introduction 68

6.2 Gathering and Generation System Requirements 69

Section Page

6.3 Design of a Bench Program Prototype Planning System 70

6.4 Implementation of the Bench Program Prototype Planning System 71

6.5 Generation of Operating System Concept 72

6.6 Utilization of Prototype System to Test System Concepts and Carry Out Preliminary Shuttle Planning 73

6.7 Design of the Operating System 74

6.8 Implementation of the Operating System 75

FIGURES

Figure		Page
1-1	VMMPS concept	3
2-1	Mission planning for five typical flights	5
4-1	Shuttle management and planning room	17
4-2	Vehicle management and mission planning interfaces	18
4-3	Vehicle management and mission planning system . . .	19
5-1	Mission design process	27
5-2	Mission analysis capability used for long range flight scheduling	28
5-3	Launch operation subsystem	37
5-4	Vehicle operation subsystem	42
5-5	Payload operations subsystem	47
5-6	Flight operations support interfaces	65
5-7	Flight operation support software system	
	(a) Software System	66
	(b) Telemetry data processing	67
6-1	VMMP system development phases	76

VEHICLE MANAGEMENT AND MISSION PLANNING

SYSTEMS WITH SHUTTLE APPLICATIONS

By Mission Analysis Branch

1.0 SUMMARY

This document presents a preliminary definition of a concept of an automated system that will support the effective management and planning of space shuttle operations. It is called the Vehicle Management and Mission Planning System (VMMPS). In addition to defining the system and its functions, this document identifies some of the software requirements of the system and recommends a phased and evolutionary method of software design, development, and implementation. In accordance with this phased approach, the purpose of this document is to present the current concept in sufficient detail so as to elicit an initial round of constructive criticism from all interested parties.

The proposed VMMPS (fig. 1-1) would provide the operational shuttle program with an automated centralized program planning capability. Although it will also possess the capability for real-time support, its primary functions will be the management and planning of shuttle operations. To perform these functions it would be operated in an interactive mode by engineers and various levels of management.

To define the VMMPS, this document identifies conceptually the shuttle operation planning functions, describes the required decision-making processes, and categorizes the organizational interfaces. Computer software subsystems required to support shuttle planning are postulated and correlated to the various planning functions. The presentation of these elements - planning functions, decision processes, organizational interfaces, and supporting software - represents the shuttle operations planning and management concept.

The concept is composed of eight software subsystems supervised by an executive system. These subsystems are

/

a. Mission design and analysis

b. Flight scheduler

c. Launch operations

d. Vehicle operations

e. Payload support operations

f. Crew support

g. Information management

h. Flight operations support

Each of these is defined in this document. Of the eight subsystems, the first two, mission design and analysis and flight scheduler, already currently exist in initial prototype coded forms and are being used to support the MSC shuttle program office with traffic model analysis. The remaining six subsystems are in various degrees of preliminary definition but are generally just in the idea stage requiring future coordination with other MSC and NASA organizations for their interim and final definition.

In addition to presenting the proposed system, this report contains a discussion of the evolutionary software development philosophy that the Mission Planning and Analysis Division (MPAD) would propose to use in developing the required supporting software. Included in the discussion is a preliminary software development schedule.

As proposed in the development plan, existing software components will be used to construct the initial version of the prototype VMMPS. From this base, the more sophisticated total system will be developed in phases or directed evolutionary stages. An initial hard-and-fast VMMPS design will not exist; rather, the design will be generated and solidified in logical stages. The prototype system will be available for use at each stage of development. It will thus provide an early capability for performing some shuttle planning and analysis and will allow the evolutionary nature of the development to be most effective.

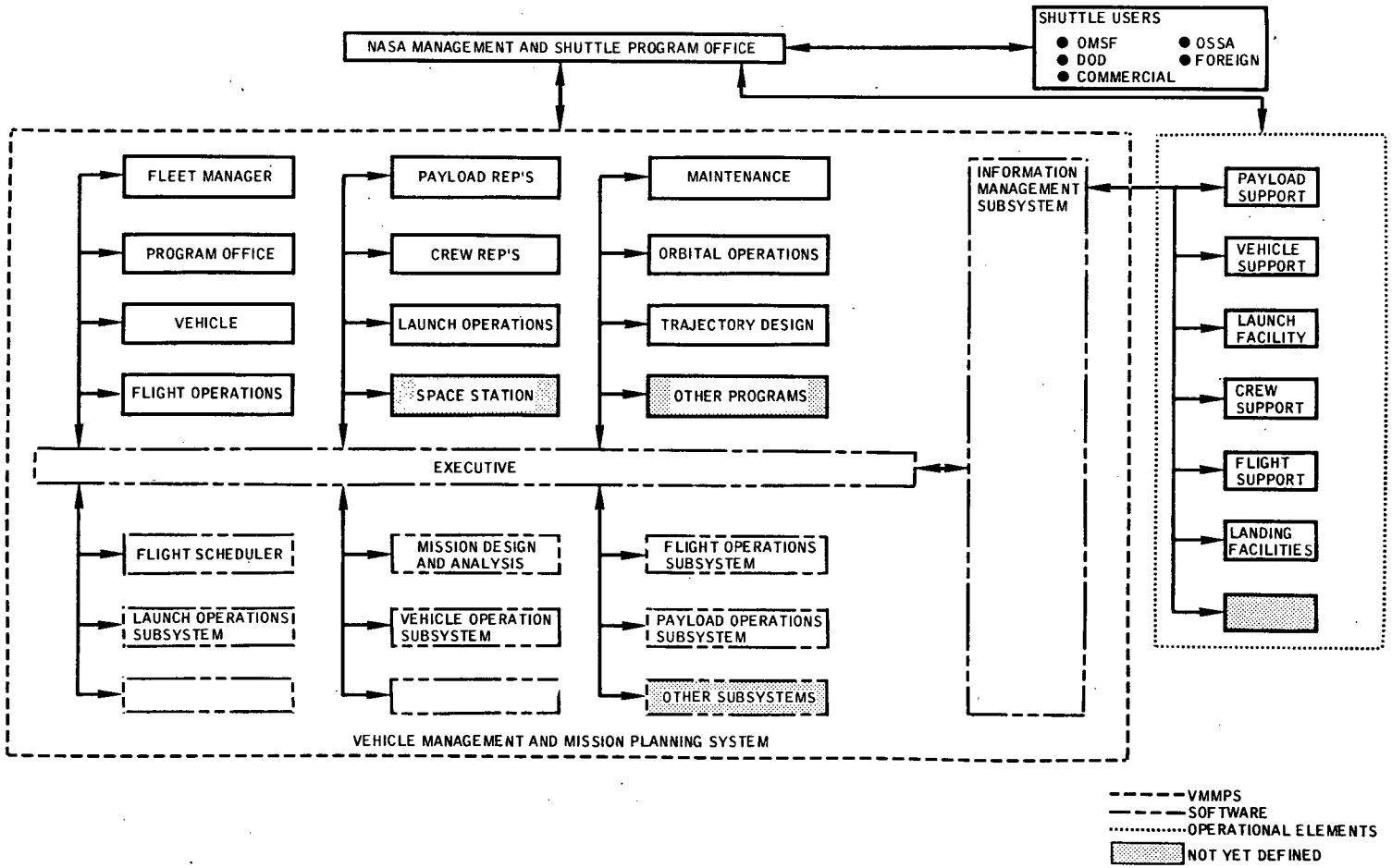


Figure 1-1.- VMMPS concept.

2.0 INTRODUCTION

The concept of a reusable shuttle has been accepted as a method to deliver man and cargo to earth orbit. Because of major differences between it and past programs, however, the shuttle program will require new methods of planning and operating manned space flight missions.

For instance, the shuttle should reduce payload delivery cost and increase space flight capability. Thus, the number of flights per year should increase. The projected rate of 20 to 50 flights per year will require a compression of the present mission planning cycle. The number of iterations or mission plans beginning from the preliminary mission profile through the reference trajectory and to the operational trajectory must either be eliminated or greatly reduced. Another difference, perhaps the most significant, that affects mission planning is the development of multiple payload missions. In the past each agency responsible for a particular payload has either developed mission plans in house or through their payload contractor. The combination of payloads on a single mission requires the integrated planning of the entire mission, and this cannot be done by independently planning individual missions and hoping for compatibility. Over 50 percent of all presently proposed shuttle flights require multiple payload deployment. Therefore, a central organization that is responsible for the planning of all shuttle missions seems essential. Figure 2-1 is a pictorial representation of the complexity of mission planning associated with five typical shuttle flights. On mission 1 are three payloads (PL). Two require a kick stage (KS) and the third is deployed by the shuttle. Each PL is developed by a different contractor (CONT) in support of various agencies. The integration of these payloads into one mission plan and the repetition of these types of missions indicate that one organization must be responsible for the development of these integrated plans.

The use of kick stages is another major difference. From 40 to 50 percent of the present shuttle traffic models require kick stages. The definition of the payload combinations (preliminary mission definition) defines the kick stage requirements. A natural result of long-range flight schedules would be kick stage requirements.

Another major difference is the reusability of the vehicles (orbiter, booster, RAM, and tug). The repeated use of major systems results in performance change that affects the mission planning (e.g., the I_{SP} of engines changes with each burn). This information must be taken into account during the mission planning for future use of these vehicles.

An apparent solution for coping with these complex management and planning problems is the use of a centralized mission planning system. This document gives a preliminary definition of such an automated management and planning system. Its objective is to propose this automated concept in sufficient detail as to elicit consideration and constructive criticism.

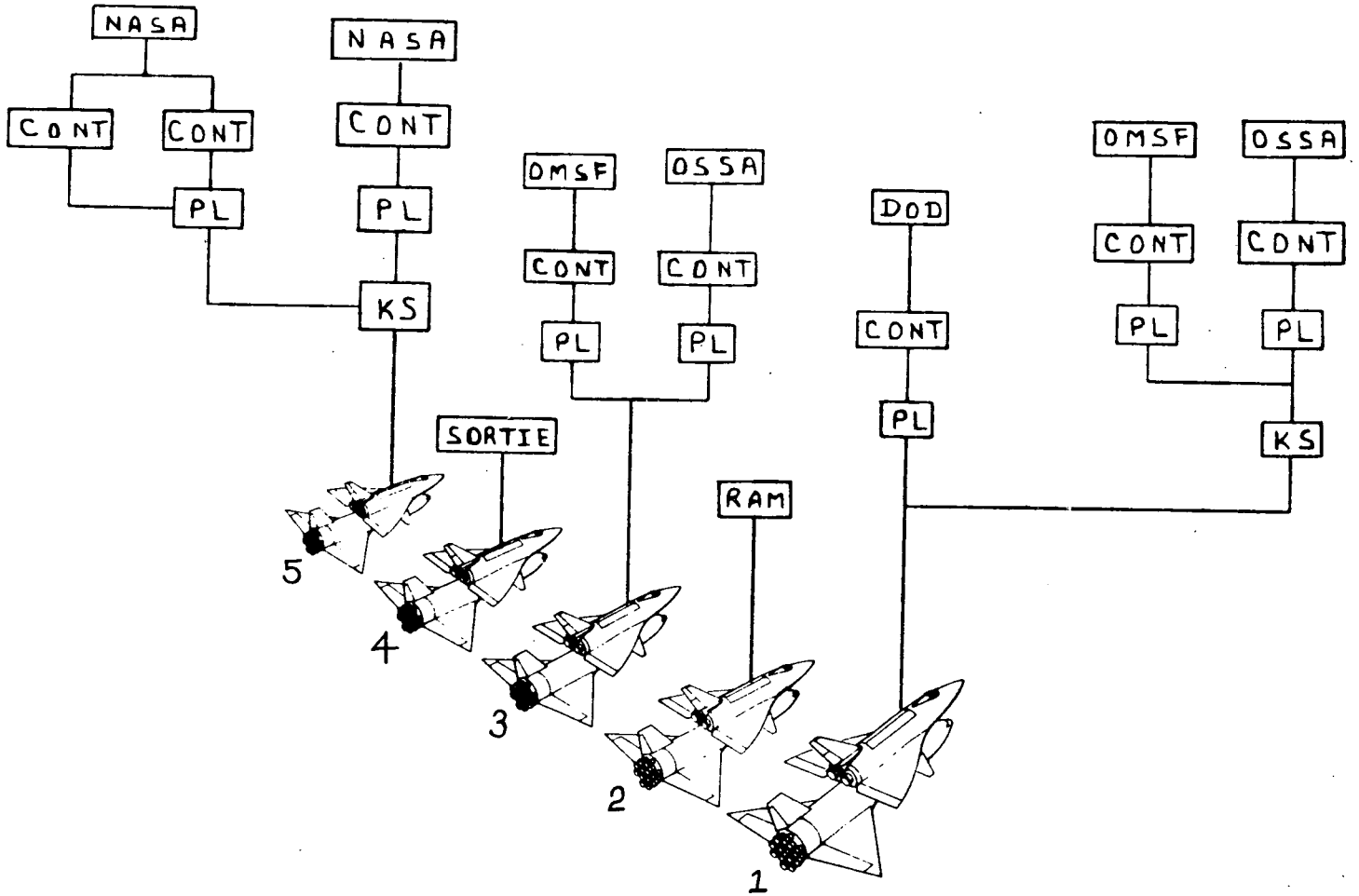


Figure 2-1.- Mission planning for five typical flights

3.0 SYMBOLS

ACS	attitude control system
CONT	contractor
DOD	Department of Defense
FAA-ATC	Federal Aviation Administration-Air Traffic Control
FOSS	flight operations support subsystem
FSS	flight scheduler subsystem
g.e.t.	ground elapsed time
GSE	ground support equipment
IMS	information management subsystem
I.O.	input/output
I_{SP}	specific impulse
KS	kick stage
KSC	Kennedy Space Center
LOS	launch operations subsystem
LRU	line replacement units
MDAS	mission design and analysis subsystem
MPAD	Mission Planning and Analysis Division
MSC	Manned Spacecraft Center
MSPS	maintenance and system performance subsystem
NASA	National Aeronautics and Space Administration
OMSF	Office of Manned Space Flight
OSSA	Office of Space Sciences and Applications

PL	payload
PSOS	payload support operations subsystem
RTCC	Real-Time Computer Complex
VMMPS	Vehicle Management and Mission Planning System
VOS	vehicle operations subsystems

4.0 TOTAL SYSTEM OVERVIEW

In general, the VMMPS is a non-real-time operation. Telemetry data from the actual flight in progress are not required. The overall concept originated from an attempt to automate (conceptually) the time-consuming mission planning and decision-making mechanism used for the Apollo program. The iterations between decisions and analyses must be decreased and the time between them must approach zero if an effective and efficient shuttle management program is to be instituted. The solution proposed by this document is that the required decision-making entity be supplied with software in support of the required functional areas. Then, through interactive capabilities, analyses can be performed and decisions made more rapidly.

Another objective of the VMMPS is to eliminate reference trajectories, operational trajectories, flight plans, consumables budgets, and so on. Crew training and simulations would not depend on actual mission event times. This can be accomplished by the development of mission types. Preliminary analyses have indicated that the 400 flights of the proposed traffic model can be categorized into eight to twelve mission types. Crews could be trained and simulations performed according to these mission types. (The definition of crew here includes the experimenters, payload handlers, etc.) Parametric data could be generated so that the crew can do onboard mission planning within the constraints of the mission type defined. The differences between missions within these standard types are a result of requirements and on-orbit activities directly associated with the individual payloads or individual mission objectives. By classifying missions into types and then into phases, standardized profiles, crew training data, procedures, and techniques can be developed which can be used for most flights, thus, eliminating the need for much of the detailed mission-by-mission analysis that is now required and reducing the need for publication of individual mission documents.

Figure 4-1 is a pictorial concept of this proposed system. It currently has no single counterpart; rather, its functions are being performed for Apollo and Skylab in a fragmented way by the various NASA panels. The concept of performing these functions in an integrated flight operations planning facility is new, but the role of such a system is a direct and logical extension of the MSC mission planning and analysis activities currently being performed for Apollo and Skylab.

4.1 System Requirements

4.1.1 General.- The VMMPS concept presented in this document is based on the assumption that the shuttle will be a transportation service for a variety of users. Each user will impose requirements related to his payload objectives. The VMMPS function, then, will consist of translating the user requirements into specific missions, directives, schedules, operation plan, and instructions needed to carry out the shuttle transportation function.

The user requirements on the shuttle will be defined in terms of

a. Physical description of the payload, such as size, weight, shape, interfaces with cargo container or vehicle, and so on

b. Desired orbital parameters and schedule requirements

c. Ground testing, calibration, access, special handling, and launch checkout requirements

d. Orbital support requirements

e. Recovery and refurbishment requirements

To accomplish the transportation function, the VMMPS must transform the multiple user requirements into

a. Specific shuttle missions, traffic models, and flight schedules

b. Flight trajectories, time lines, procedures, and onboard software

c. Ground support plans, including vehicle, facilities, and utilization schedules

d. Integrated launch schedules

e. Crew training and scheduling plans

f. Logistics operations plans

This system will also allocate and schedule the necessary resources, identify and resolve conflicts, and form alternatives for management. This process may become a highly interactive exchange, requiring extensive modification of basic assumptions and objectives before a workable schedule is developed.

4.1.2 VMMPS requirements.- The basic VMMPS functional requirements that have been identified are

a. Provide a central operations facility for planning and scheduling shuttle missions. Such a facility would provide

   1. Nominal support to detailed planning of shuttle missions within a time-constrained operations environment as established by flight densities

   2. An analysis tool for investigating simulated operations flows and modifications to existing schedules and payload makeup

   3. Detailed trajectory analysis of specific mission or mission types as identified by mission loads and operations planning

   4. A means of assessing and evaluating changes in the status of any operations subsystem (contingencies)

b. Provide a planning and scheduling tool capable of long-range time flow development on each of several operations subsystems

   1. Maintenance and turnaround schedules

   2. Mission loads planning

   3. Payloads integration flow

   4. Mission type analysis and mission launch date assignments

c. Plan and simulate the ground operations activities to a detail necessary for effective mission scheduling and fleet management. (This might be a constant which represents turn around time)

d. Provide sufficient inputs from remote operations facilities, such as launch or maintenance areas, for planning of shuttle missions.

e. Provide cost analysis and tradeoff capability to be applied to various operations and missions plans.

f. Be at all times capable of supporting multiple missions in series and parallel.

g. Provide software and planning support for crew training and for onboard software verification.

4.2 System Operation Modes

The present concept is that during high flight-rate periods (1-2 per month), a facility similar to that shown in figure 4-1 will exist and will be manned by individuals with the responsibility and authority to change mission objectives (affect what payloads are taken or retrieved on proposed flights), to change vehicle utilizations, establish launch dates, and so on. Whether this facility would be fully manned at all times or would only be manned during planning sessions has not been established. It would, however, be able to operate in any one of three modes.

In the first operating mode the VMMPS would be able to satisfy program office preliminary planning requirements, that is, develop traffic models; perform cost trade studies on the number of vehicles, pads, etc.; define requirements for the kick stage or tug or both; and provide mission planning to the detail necessary to insure the feasibility of the missions defined in the traffic model.

The second mode of operations would be more detailed and would include the following activities:

a. Support payload development with mission planning information

b. Define candidate mission types, requirements, and characteristics

c. Develop and provide information necessary for training and simulations

d. Establish mission sequence and priorities

e. Develop long-range schedules

f. Develop short-range schedules

g. Assign vehicles for each mission

h. Estimate resource, facility, and crew requirements

i. Do cost analysis

j. Evaluate payload compatibility with mission plans

The third mode of operations, the most detailed, begins after the shuttle becomes operational. It would include not only the development of long- and short-range plans and schedules but the analysis of day-to-day variations of these plans as well. Some other activities of the third mode would be

a. Developing detailed mission sequences by phase

b. Providing anomalies of mission types to simulation personnel

c. Providing schedules for launch, landing, maintenance, payload development, mission support, FAA, and other areas of activity

d. Defining onboard software (mission peculiar) requirements

e. Rescheduling after anomalies

f. Providing detailed cost analyses and budget forecasts

4.3 System Description

To accomplish the activity within each operational mode, the planning system will interface with the required planning software through an executive system. As envisioned, the interfaces with other agencies and organizations would be through the Shuttle Program Office and the information management subsystem. Those interfaces are depicted in figure 4-2. Although all the software required to support the functional areas has not yet been completely defined, eight subsystems have been identified to various levels of detail and are discussed in section 5.0. Their conceptual roles and relationships and their functional and software interfaces are shown in figure 4-3. This figure is only an attempt to relate the elements of the VMMPS to various planning and analysis activities which the system is intended to support. The boxes in the upper half of the figure are meant to represent how related activities could be grouped into functional areas. The boxes in the lower half of the figure represent the major software elements of the VMMPS which will be required to support these activities. This figure is intended to illustrate the computational support role of the VMMPS and is in no way a recommendation of the organization or functional structure of the overall shuttle mission management and planning effort. For clarity, figure 4-3 is repeated before each subsystem discussion, with the appropriate subsystem and its primary interfaces outlined.

The following items briefly explain the functions of each of the proposed software subsystems:

a. Mission design and analysis subsystem (MDAS) - This software subsystem will be capable of several levels of mission design trajectory processing, depending upon the level of detail needed. It will be operable both in an online interactive or batch mode or in an offline batch mode. Its modules will be linkable for sequenced processing or will be singly executable for special applications. This subsystem will be used primarily by the mission design element, and its primary software interface will be the information management subsystem (IMS). It will interface other software subsystems through the IMS. It will also be directable by the real-time support element for real-time computational trajectory support.

b. Flight scheduler subsystem (FSS) - This software subsystem will be the integration element of the VMMPS and as such will be responsible for the generation of long- and short-range mission planning and scheduling. It will also have the capability to generate launch, maintenance, payload integration, and mission load design schedules. Its prime software interfaces will be with the information, mission design and analysis, and vehicle operations subsystems.

c. Launch operations subsystems (LOS) - This subsystem will be used to simulate the activities from the beginning of launch preparation to lift-off and the temporal relationship involved in pad refurbishment, scrub/relaunch cycles, and launch failure modes. The subsystem will also discern and respond to real-time conditions which require monitoring and statusing in the IMS. Interface will be with the IMS and the flight scheduler software subsystem.

d. Vehicle operations subsystem (VOS) - The purpose of the VOS is to use test, design, and flight data to determine during mission planning what the predicted vehicle performance will be. This model will fulfill its purpose by making trend analyses on all appropriate subsystems. A large interface with maintenance activities will be required to insure update of those system parameters that affect mission planning.

e. Payload operations support subsystem (POSS) - Long-range planning of missions with several payloads will require logistic support information, development schedules of payloads, probability of deliveries, interface constraints, priorities, and other considerations. An automated method of updating the status of several hundred payloads will be part of this software subsystem. Short-range planning will require the rapid evaluation of payload changeout, addition of new payload, or off-loading of payloads. Constraints associated with these functions will be modeled in this subsystem. The subsystem will also support the payloads officer in real time when he needs to evaluate candidate flight schedules in terms of retrieval and refurbishment of payloads.

f. Crew support subsystem (CSS) - The purpose of the CSS is to provide the VMMPS with information regarding crew status to insure that the shuttle flight schedule is compatible with crew resources and constraints. The CSS primarily interfaces with the flight scheduler subsystem.

g. Information management subsystem (IMS) - This will be a dynamic storage and retrieval system with multilevels of data protection. It will maintain formatted output storage of results from the other software subsystem operations and storage for basic data describing all aspects of the shuttle operations. The IMS software will allow liberal questioning and data retrieval from numerous remote terminals. It will have complex interfaces and automatic linkage with all other subsystems for status, storage, and input supply to those subsystems by the various users.

h. Flight operations support subsystem (FOSS) - This software subsystem will provide contingency control and computational support plus real-time status and monitoring of flight operations. It will also provide rapid response to failure and contingency conditions in the launch operations or vehicle operations. Its prime software interfaces will be the real-time status and response files of the IMS and the detailed processors of the mission design and analysis subsystem.

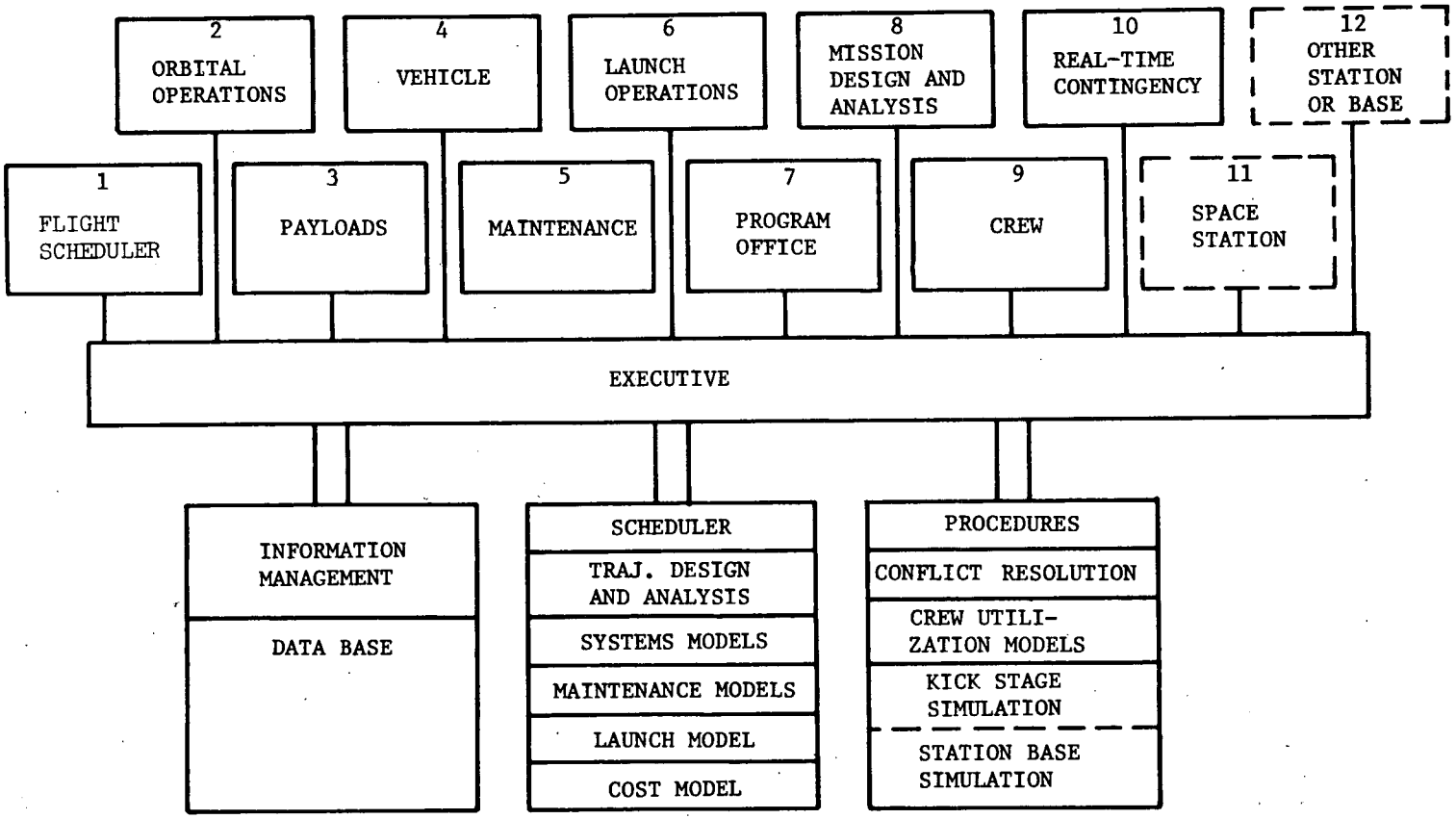


FIGURE 4-1. SHUTTLE MANAGEMENT AND PLANNING ROOM

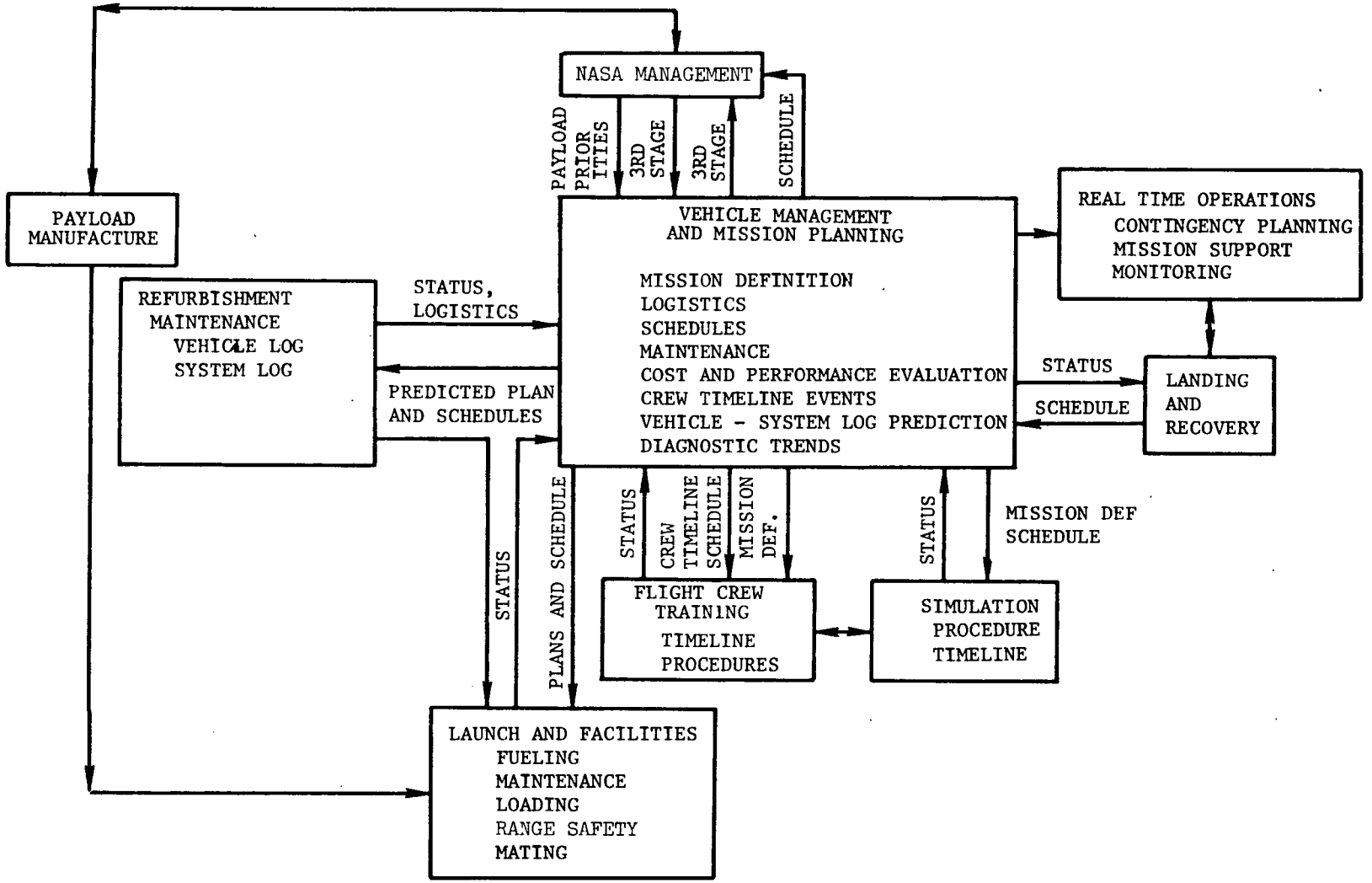


FIGURE 4-2. VEHICLE MANAGEMENT AND MISSION PLANNING INTERFACES

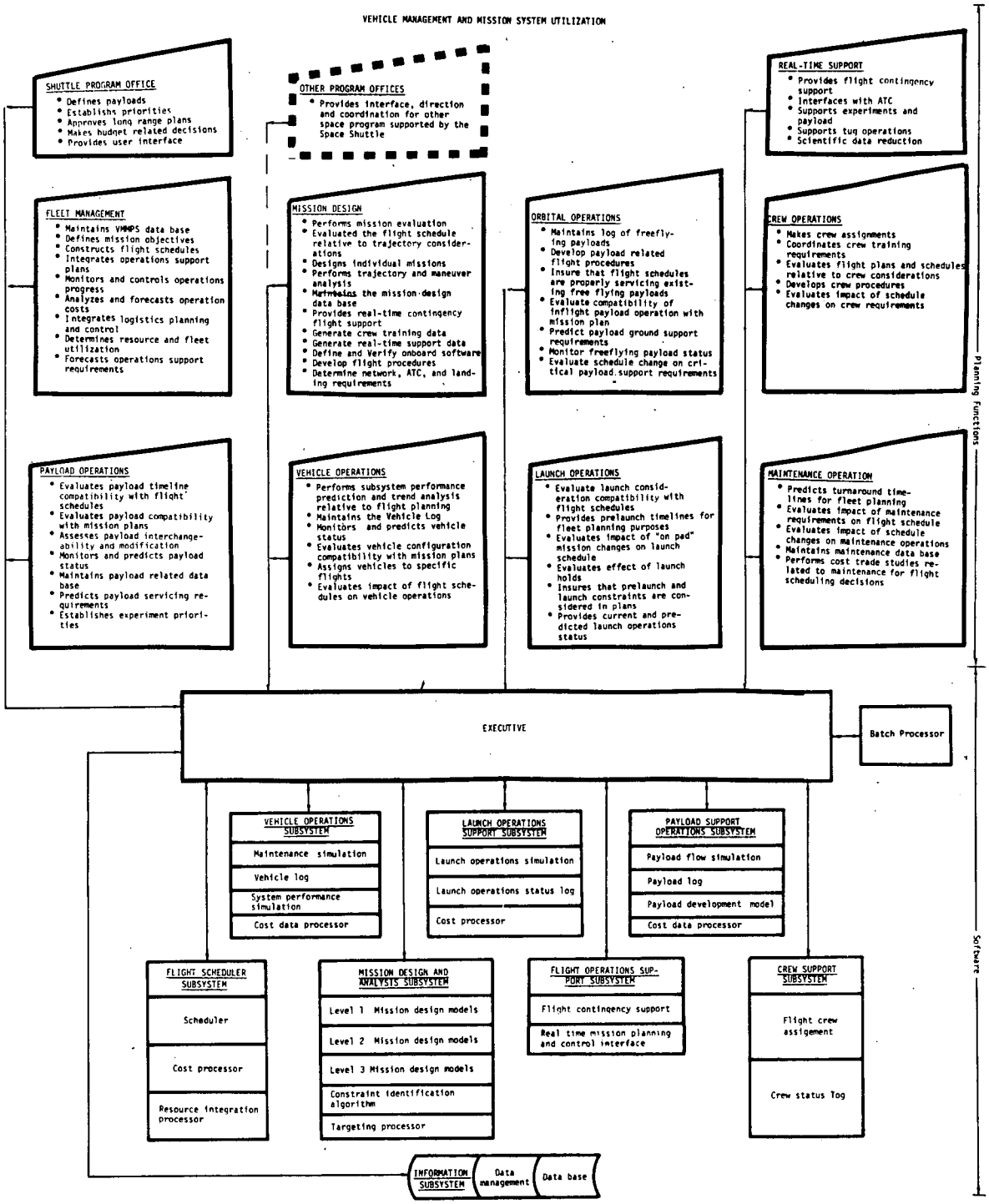
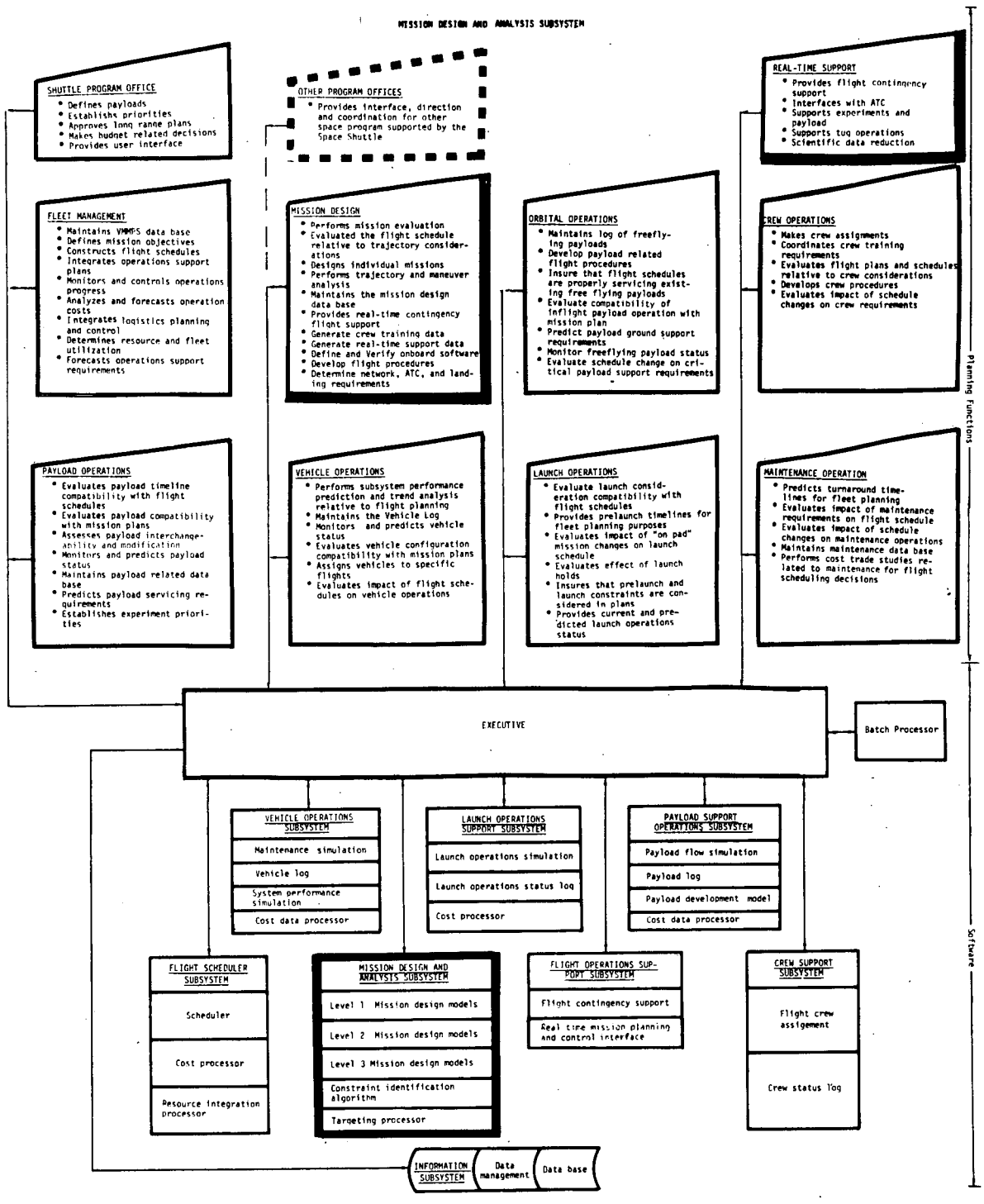


FIGURE 4-3. VEHICLE MANAGEMENT AND MISSION PLANNING SYSTEM

5.0 SUBSYSTEM DESCRIPTION

This section describes each of the distinct subsystems currently envisioned for the VMMPS. The subsystem breakdown used is not intended to imply equal levels of importance, size, or degree of utilization. In fact, the primary individual subsystems are the flight scheduler, mission design and analysis, and information management subsystems. The launch operations, vehicle operations, payload operations, and crew support subsystems are intended to provide the overall planning elements of the flight scheduler subsystem with sufficient information to accurately predict operations status. The predictions will be used in the development of the long-range and short-range launch schedules. The flight support subsystem is the real-time support element of the VMMPS. The FOSS is an integral part of the VMMPS, so that the planning can be coordinated with the real-time operations. The planning of orbital maneuvers of a kick stage may require real time support and therefore must be evaluated before launch commitment. Actual real-time payload contingencies will also affect the upcoming plans and must be integrated with the planning function.



Vehicle Management and Mission Planning System

5.1 Mission Design and Analysis Subsystem (MDAS)

5.1.1 Introduction.- By the time the shuttle becomes operational, much of the detailed trajectory design and analysis work for the standard shuttle missions will have been accomplished. This will mean that much knowledge about the vehicle, its behavior, and detailed plans for the standard shuttle mission will have been accumulated. Nominal mission plans for the standard shuttle missions will have been generated; the most common mission phases and activities for the standard shuttle missions will have been identified, and procedures for accomplishing these activities will have been developed and standardized. The software (onboard and ground) required to support these activities will be available for training flight crews and ground support teams. For most shuttle flights, then, the mission planning activity will become one of arranging these standardized shuttle activities or phases into a mission plan which will meet the mission objectives while minimizing the penalty from constraint violations.

The overall efficiency of the shuttle program will be increased if mission specialization can be minimized. Therefore, every attempt should be made to force conformity to standard mission types, even to the extent of reducing the efficienty of a particular flight or canceling a flight and rescheduling its payloads. A few missions, however, may pose special operational requirements for the mission planner, and may not conform to any mission type. For such missions, the mission design process will be much more like that currently performed; even so, these missions will still have some phases in common with the standard types and can thus be planned in a more timely manner than is currently required.

5.1.2 Objective.- For the VMMPS concept developed in this report, the MDAS is the primary trajectory design element. Its objective will be the integration of a significant portion of the software required for trajectory design, evaluation, and analysis into one software subsystem compatible with the total VMMPS. The subsystem is expected to

a. Reduce the overall mission planning cycle time

b. Reduce the number of formal organizational interfaces required during mission planning

c. Reduce the paper work and number of formal reports

d. Permit concurrent consideration of mission, vehicle, payload, crew, and ground support requirements during the mission planning process

e. Permit concurrent consideration of more than one trajectory design to satisfy a given set of objectives

f. Reduce the alternate mission planning effort

g. Reduce the contingency analysis effort

h. Provide a general engineering analysis capability (related to space flight) which will be readily adaptable to other programs

5.1.3 Functions.- The function of this proposed subsystem will be to provide the VMMPS with all the trajectory design and analysis capability required to support shuttle mission planning. The complexity of the computational support required will, of course, depend on the phase of mission planning underway in the VMMPS. As currently envisioned, the MDAS will be able to support at least the following three levels of mission planning (fig. 5-1).

The level 1 capabilities of the MDAS will be able to answer preliminary inquiries concerning the capabilities of the shuttle system, generating candidate event sequences for mission developed by the flight scheduler and the traffic model program, and performing cursory evaluation of these missions from a trajectory and operational standpoint. This level of analysis should discern some of the more obviously desirable and undesirable features of each proposed shuttle flight and provide the following type of answers to management.

YES: The shuttle has the capability (time, ΔV, etc.) to fly a specified mission.

NO: The shuttle does not have the capability to fly a particular mission as specified.

MAYBE: The MDAS needs to know more about the requirements and constraints for this mission, or a more thorough analysis is required before an answer can be given.

Level 2 capabilities will be used to refine the conceptual plans developed in level 1. This level of support includes performing detailed analyses of the mission phases, assisting in the development of new onboard software and procedures, and developing detailed launch schedules, alternate mission plans, and contingency plans. This level of support would also assist in the establishment of crew training needs, real-time software requirements, and support procedures.

Level 3 capabilities will be used to verify that the plan developed by the other two levels can be flown by the shuttle and that it will satisfy most of the mission objectives. It will also be used to generate crew and ground support team training data, and complete the mission time schedule.

Some elements of the level 2 and level 3 capability could be used to provide real-time backup support. The support that is provided, of course, will depend on the particular mission requirements and the degree of autonomy achieved by the shuttle itself.

Figure 5-2 shows how the MDAS level 1 capabilities would be used to support the development of long- and short-range launch schedules and plans. First, the mission objectives, payload information, and system status are defined by management and the flight scheduler. Then the flight scheduler would allocate the payloads to a specific flight and develop a preliminary traffic model. The MDAS supports this effort, using level 1 capabilities, by performing a preliminary performance evaluation for each mission (blocks A and B). If the vehicle is incapable of flying one or more of the desired missions, the payloads are reallocated and a refined traffic model is generated. If it is capable, the analysis continues.

The next function is to determine if any of the missions in the traffic model contains any unique or marginal phases (block C). A launch time is established for the missions which do not possess unique or marginal phases (block G). The missions which do possess such phases are evaluated in more detail in the MDAS (blocks D and E). If, after this evaluation, these missions are not acceptable, the traffic model is refined once again (block F). A launch time is established for the missions that are acceptable (block G).

After each mission is assigned a launch time, the total launch schedule is evaluated for conflicts. If conflicts arise which cannot be resolved by the analyst, the traffic model is refined once again (block H). If the launch times are then acceptable, a launch schedule is established and is presented to management for approval (block I).

5.1.4 Requirements.- The primary requirements for such a subsystem are

a. To support the development of long- and short-range shuttle launch schedules and the integration of payloads into definable missions

b. To develop mission plans

c. To perform detailed analysis on critical, marginal, or unique mission phases

d. To support payload development

e. To generate new procedures (onboard or ground) for new missions or mission phases

f. To develop simulation data for flight crew and ground support team training

g. To develop real-time support data required by the flight crews (crew charts) or the ground support team

h. To verify onboard software required for a particular mission

i. To maintain and update the mission design and analysis information

j. To perform mission planning support of any phase of a mission

k. To evaluate any new or updated hardware

l. To develop trajectories and mission profiles in any level of detail required for any mission or unique mission phase.

5.1.5 Subsystem description.- The MDAS can best be visualized as a fully integrated Mission Planning Laboratory. Such a facility will consist of a set of interactive consoles manned by trajectory design specialists, an integrated software system, and a common data base. This data base may be just one part of the larger VMMPS data base or a separate system tied to the larger one; but, in any case, the MDAS data will be updated every time the VMMPS data base is changed or expanded and will be accessible to the other elements of the VMMPS and vice versa.

The software library in the MDAS will be comprised of two levels of capabilities - computational modules and segments.

The computational modules will be the smallest elements in the library and will consist of things like powered flight models, targeting models, coasting flight models, reference system transformations, planetary ephemerides, and so on. The segments will be composed of a group of these modules developed relative to standardized mission phases or activities (rendezvous, deorbit, deployment, etc.). Most of the modules and segments will be developed from a selected set of the simulation capabilities now possessed by MPAD and from the simulation capability developed during the shuttle development phase. All onboard

targeting and guidance software will be completely simulated, and all software will be integrated into one software system under the control of the VMMPS executive program. This will permit the user to use a limited set of the total system capability or any compatible set of the computational elements of the total software system. These modules and segments can be linked to do sequenced processing or can be executed alone for special applications.

The software will be operable in an online interactive or batch mode or in an offline batch mode. The primary users in the online interactive mode will be the personnel in the VMMPS who have the responsibility of supporting the generation of schedules and plans and personnel of the flight operations support who have the responsibility for real-time computational support. In the offline batch mode, the software in this subsystem will be used for performing detailed trajectory design and analysis tasks for the more unique shuttle missions or for analysis and evaluation of new hardware and software.

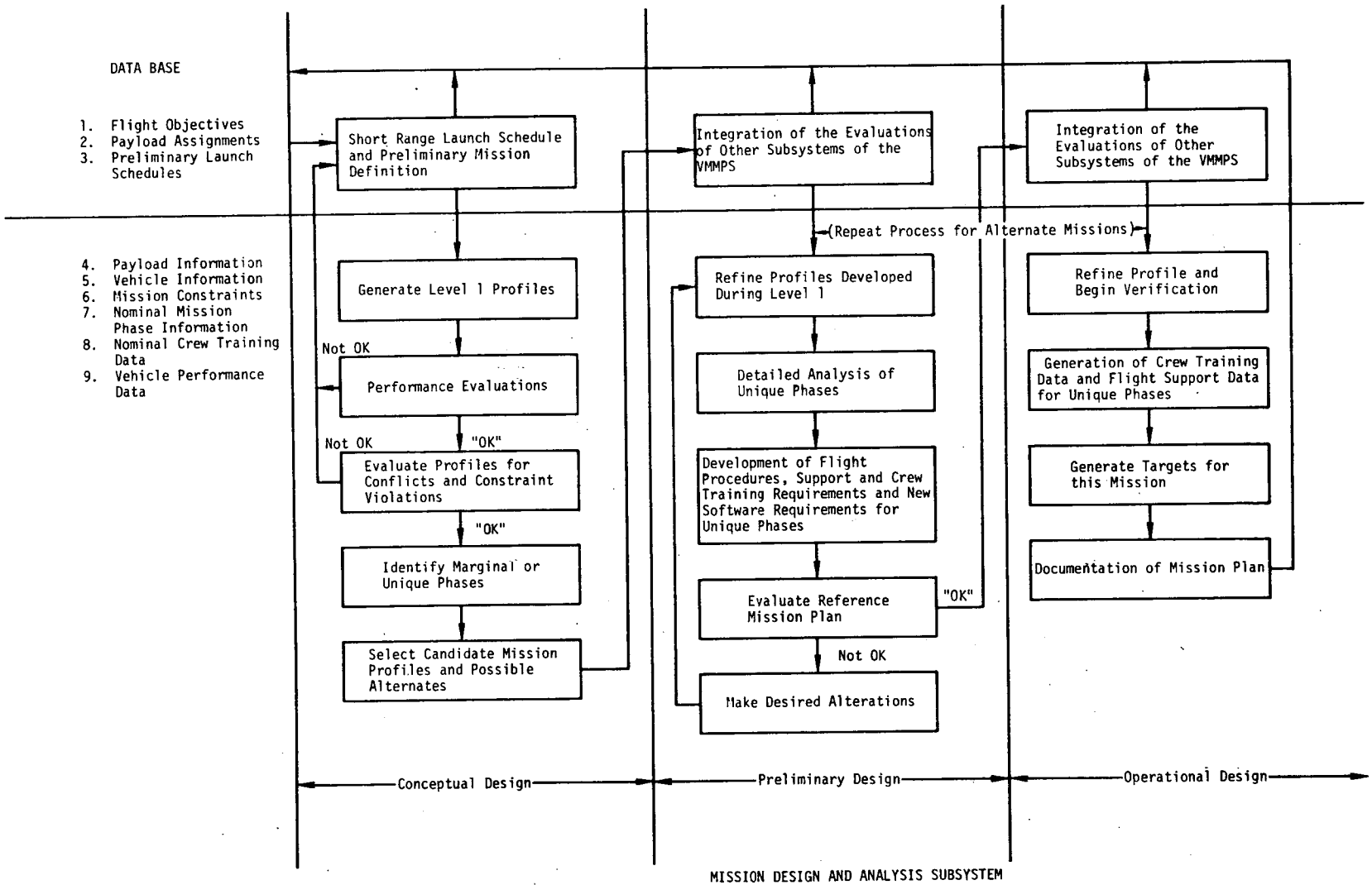


Figure 5-1. Mission Design Process

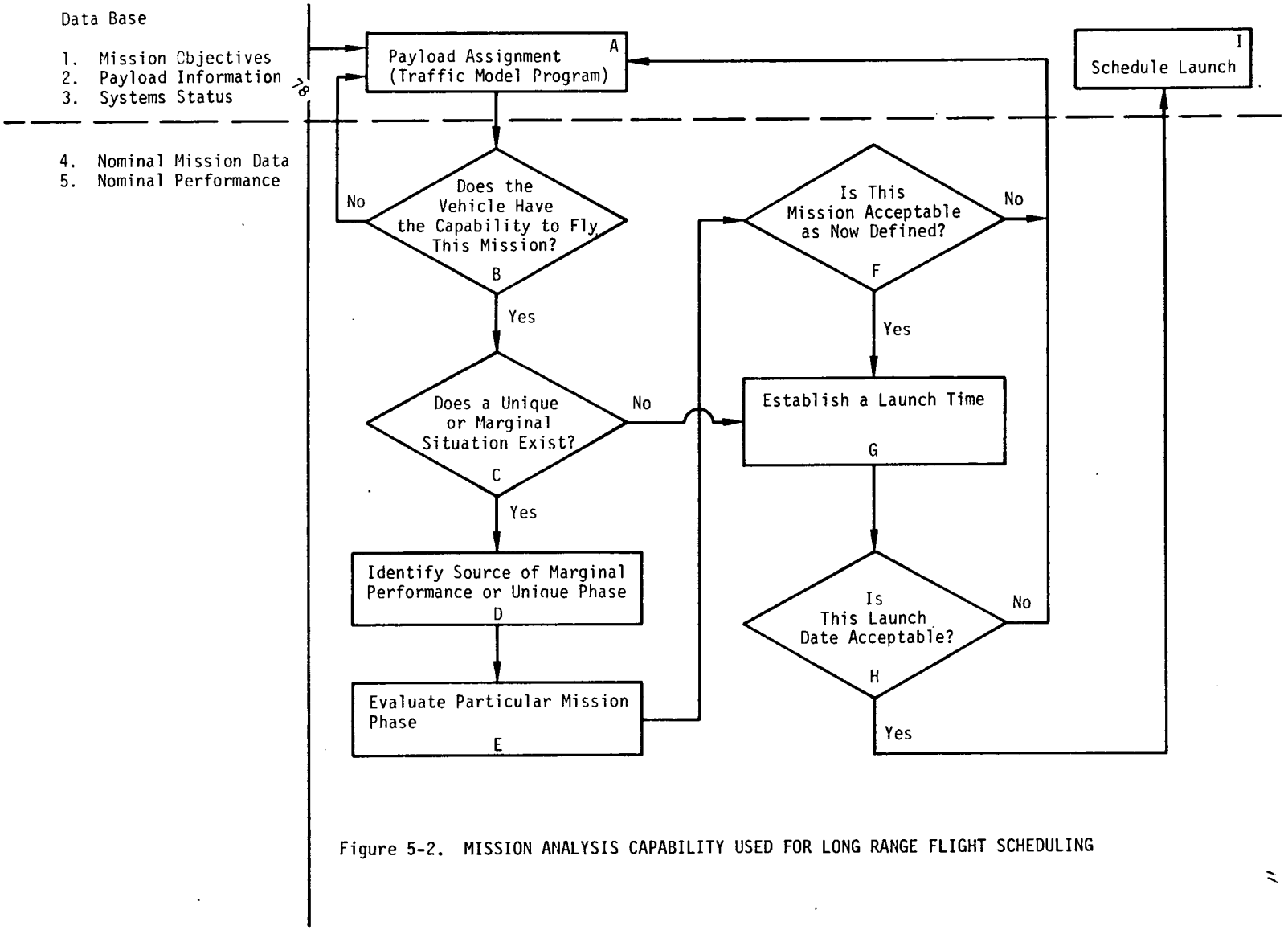


Figure 5-2. MISSION ANALYSIS CAPABILITY USED FOR LONG RANGE FLIGHT SCHEDULING

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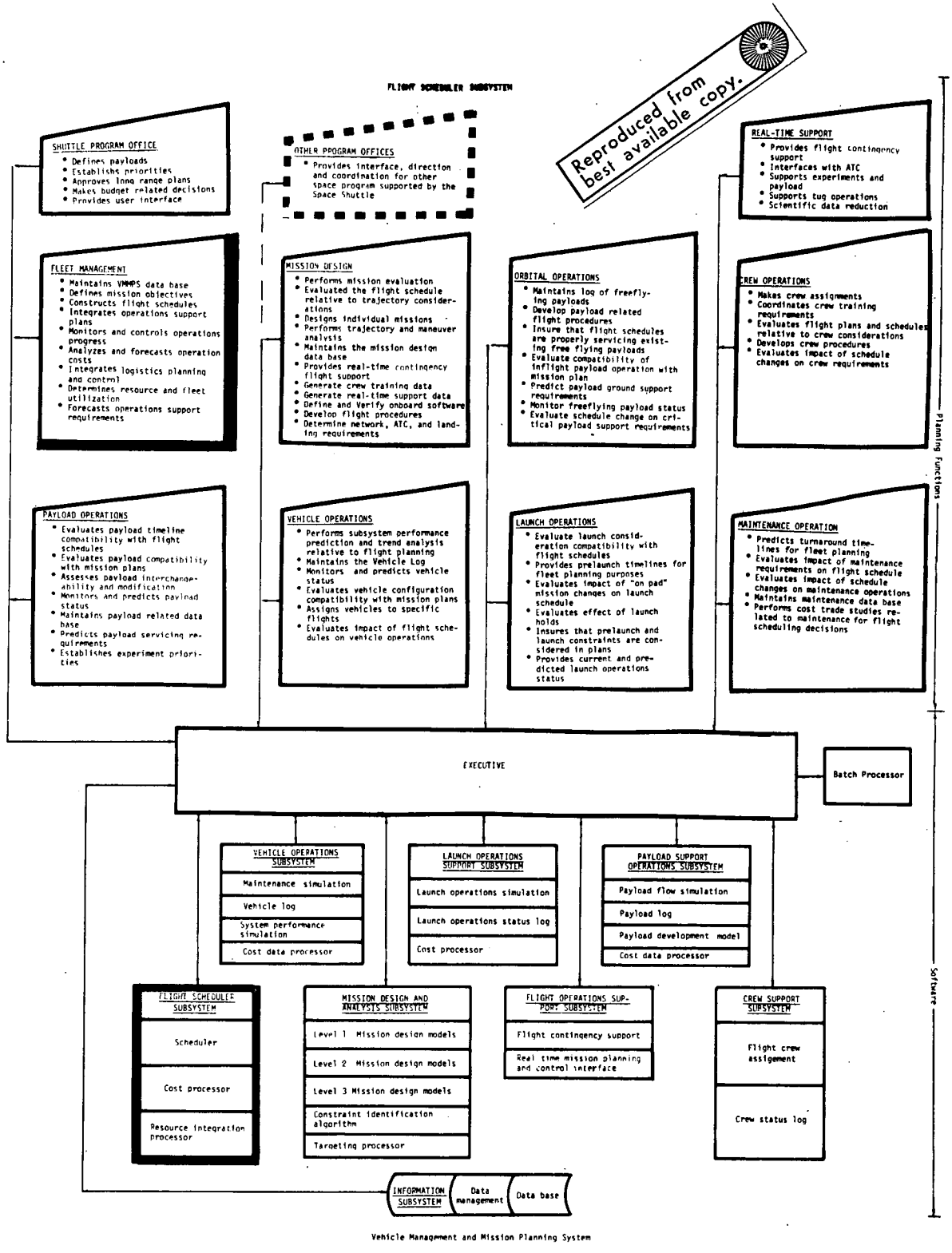


Vehicle Management and Mission Planning System

5.2 Flight Scheduler Subsystem (FSS)

5.2.1 Introduction.- The flight scheduler subsystem is the integration element of the VMMPS. It is the central planning and scheduling element of the VMMPS and supports the management and integration of launch, payload, and mission loads schedules. Other elements of the VMMPS, with the exception of the information management subsystem, are technical subsystems providing models and simulations of specific shuttle operations. Each of these subsystems provides the necessary data, evaluations, and so on for use by the FSS in the performance of its functions of supporting fleet scheduling and resource allocation decisions and cost trade-off studies.

In normal operation, the FSS provides vehicle management personnel with a detailed overview of current and future status of shuttle operations. It provides a means to evaluate the effect of changes or modifications to the basic shuttle operations cycles, which provides quick response information, thus minimizing reaction time to changing events.

The FSS is able to assist in the assessment of shuttle operations sensitivities to status changes by rescheduling activities and generating alternative plans when status changes are introduced. This process, while supported by FSS software, will rely heavily on the planners decision making capabilities being in an interactive environment.

5.2.2 Objective.- The purpose of the FSS is to assist in translating NASA shuttle program directives into crew, vehicle, payload, logistics, launch, mission, landing, and resource requirements. These requirements are issued in the form of long- and short-range plans and schedules for all ground and mission sequencing activities required for support of each shuttle flight.

5.2.3 Functions.- The overall function of the FSS is to provide a tool for generating integrated plans and schedules for the entire shuttle program, including launch, maintenance, payload integration and mission load operations. The FSS should be able to provide data to management for the evaluation of the cost impact on the shuttle program of schedules, plans, and resource implementation. To provide this information relating to schedules and plans, some of the specific functions to be performed by the FSS are as follows.

a. Monitor status of VMMPS data base - The FSS should at all times be aware of changes in the VMMPS data base that might have an impact on flight schedules or operations planning.

b. Define mission objectives - The FSS will take multiple user requirements, payload data, priorities, and so forth, and, with a knowledge of shuttle operational constraints and guidelines, define objectives of specific shuttle missions. Collectively, these missions will make up a traffic model which is evaluated by the mission design and analysis and other VMMPS subsystems.

c. Construct flight schedules - The FSS will generate both long- and short-range flight schedules that reflect an integration of user schedule requirements, payload buildup, vehicle maintenance, and trajectory launch constraints. For a given number of shuttle vehicles, there will be conflicts in schedules between user agencies. The FSS will identify these conflicts and assist in their resolution. With an awareness of the total problem through the other VMMPS subsystems the FSS will be able to use an iteration process to relieve these conflicts and arrive at flight schedules that are a feasible solution to the conflict.

d. Integrates operation support plans - The FSS will support the development of integrated top level operations plans that reflect a method for accomplishing program objectives as reflected in the flight schedule. By combining individual VMMPS subsystem functional plans, the FSS can assist in the formulation of the overall plan and create a feedback mechanism for review and evaluation of past performance.

e. Analyze and forecast operations cost - The FSS will be able to translate shuttle program objectives and resulting schedules and plans into cost data. Cost tradeoff studies can be performed to determine feasibility of alternate plans and schedules. The FSS provides data for analysis of financial aspects of these plans and identify less obvious indications. For example, a request for an inventory change must be analyzed to determine if it provides an efficient use of funds.

f. Determine resource and fleet utilization - The FSS will be able to assist in the assignment of specific vehicles and cargo loads to each shuttle flight. Keeping track of the number of uses and current status of each vehicle and payload will be a function of other VMMPS subsystems, but the FSS must use these data to assign vehicles and payloads in an optimum manner with regard to total resource allocations and utilization.

g. Forecast operations support requirements - In performance of the previous functions, the FSS will have available the software and data to assist in the analysis required to answer operational support requirement questions.

5.2.4 Description of current capability.- Presently, the initial core elements of the FSS exist in preliminary form and have been used to produce several shuttle mission models. Specifically, the payload loader and the resource allocation modules are already functioning and undergoing evolutionary changes and are expected to provide the more sophisticated models required by the VMMPS. The cost data module is in the conceptual stage of development.

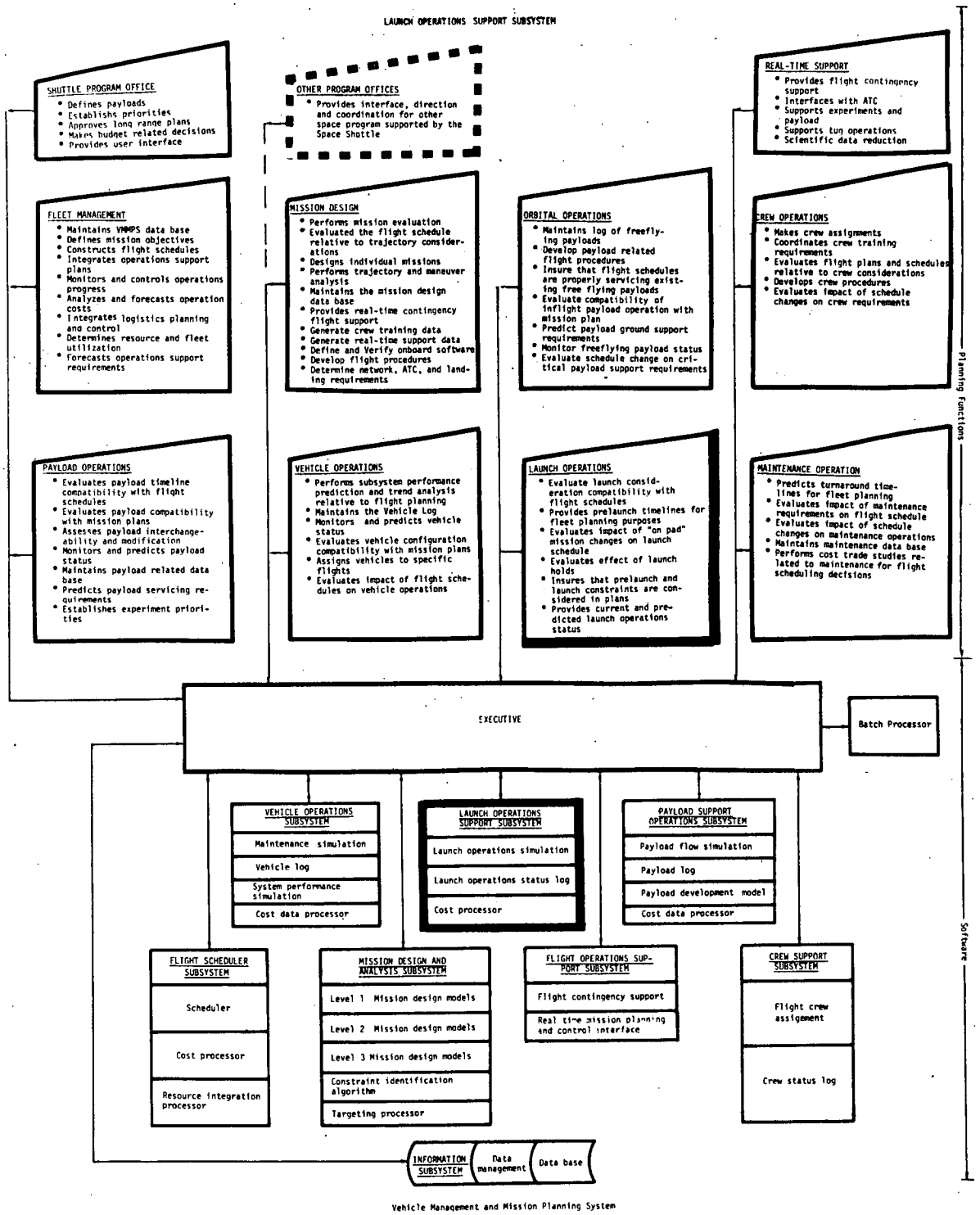
a. Automated payload - The payload loader module simulates the efficient combining of payload to be flown in the shuttle. Candidate payload pieces from various sources are integrated into a time line and traded off against each other using criteria such as weight, size, priority, mission compatibility, and schedule flexibility. The module attempts to accomplish this function in such a way as to minimize the demands in terms of flights, vehicles, payloads, and so forth.

The payload loader assesses the compatibilities of all payloads against each other over the entire array of candidate flights. The solution sought is the assignment of each payload to a flight in such a way that all pieces will fit the area and performance restrictions of the payload kick stage. The payload loader, when completely developed, will allow studies and tradeoffs on the effects of payload changes on the traffic model and fleet scheduling to be made. A large array of variables will have to be considered in the cargo loading capability. Among these are

1. Optimal loading methods
2. Performance characteristics of vehicles
3. Priority definition system
4. Center of gravity effects of loading configurations
5. Comprehensive and accurate data definition of payload
6. Detailed down cargo requirements must be identified
7. The effect of changing payload delivery dates must be modeled
8. Mission design
9. Automatic loading to incorporate all of the above

b. Resource allocation module - The resource allocation module assigns particular orbiter and booster stages, pads, and so forth to each mission. It uses vehicle, launch operations, and payload log data provided by the other VMMPS subsystems. The payload support subsystem will provide the earliest and latest times for each payload and the payload loader will determine payloads having common time intervals. A specific orbiter, booster, and pad is assigned to each load based on the earliest time associated with all loads. The number of loads that can be allocated depends on the distribution of the earliest and latest times, pad, booster, and orbiter turnaround times, mission duration, time interval between launches, the number of pads, orbiters and boosters available, and maintenance cycles and unscheduled events. In order to effectively schedule payloads and vehicles, considerable information about the status of each will have to be continuously updated and monitored. This implies, for example, that the vehicle and payload flight logs will have to keep track of where a particular stage is in its usage cycle.

c. Cost data module - The function of providing cost data for management evaluation can be satisfied by including expected costing algorithms which evaluate the operations plans and schedules provided by the VMMPS. As a schedule or plan is formulated, the cost information could be output on request. Likewise, segments of a plan could be analyzed from a cost standpoint so that various alternate plans can be evaluated against each other.



Vehicle Management and Mission Planning System

5.3 Launch Operations Subsystem (LOS)

5.3.1 Introduction.- The flight scheduling functions that are performed by the VMMPS will require a gross software simulation of the launch operations. Questions concerning number of pads, crews, and resulting cost for various flight rates can be evaluated by simple models of the operations. The effects that a single payload malfunction during checkout will have on the pending multi-payload mission will have to be evaluated. The decision of whether to launch with one dead payload or to delay and offload or change out a payload could be made if a simple model of the launch operations is developed for the VMMPS.

The effects of launch anomalies become more significant as launch rates increase. These must be evaluated during the long-range fleet scheduling activity, and the resulting flight schedule should reflect these anomalies.

5.3.2 Objectives.- The objectives of the launch operations subsystem are to evaluate long-range traffic models for cost effectiveness, using stochastic models where necessary. It will provide short-range evaluation of anomalies in the launch operations or of changes in program plans or priorities. The objectives can be met by providing simulation capability for the period from mating to launch. This simulation, if in sufficient detail, allows the prediction of the status of launch system elements any time downstream with an accuracy acceptable to VMMPS requirements. A means for imposing launch operations anomalies and failures for supporting planning tradeoffs may be necessary. At the same time, real-time status information will be supplied to the FOSS for operations monitoring. Consumables loads and subsystem performance information will be reviewed by the VMMPS when anomalies exist.

5.3.3 Functions.- The LOS, a closed-loop simulation of a given activity period, will ascertain in a gross sense the preliminary feasibility of a proposed sequence of launch dates and will allow programatic changes to adjust to a dynamic situation during near-real-time planning. The subsystem will interface with the IMS for storage and retrieval of current status of data and detailed launch operations plans as developed by detailed models at the support facility. The subsystem may be accessed from any of the functional areas through the executive (fig. 5-3). It will be used primarily to support the launch operations, flight operations, and flight scheduler areas, but it will also interact with the payload operations and vehicle operations subsystems to evaluate proposed schedules, to input probabilistic launch anomalies, and so on. Basically, this subsystem will relate the launch and launch facility recycle capability to mission planning.

5.3.4 Requirements.- The LOS will have the following requirements:

a. Provide the flight scheduler with nominal predictions of launch operations, given a series of launch dates

b. Provide flight operations with current status on the launch operations flow for upcoming flights

c. Provide the vehicle support subsystem with trend and system status information based on checkout results

These requirements can be met by the development of the following software packages:

a. Cost tradeoff model

b. Dynamic status data storage and retrieval

c. Probabilistic simulation

d. Facilities refurbishment processor; this may be satisfied in item b.

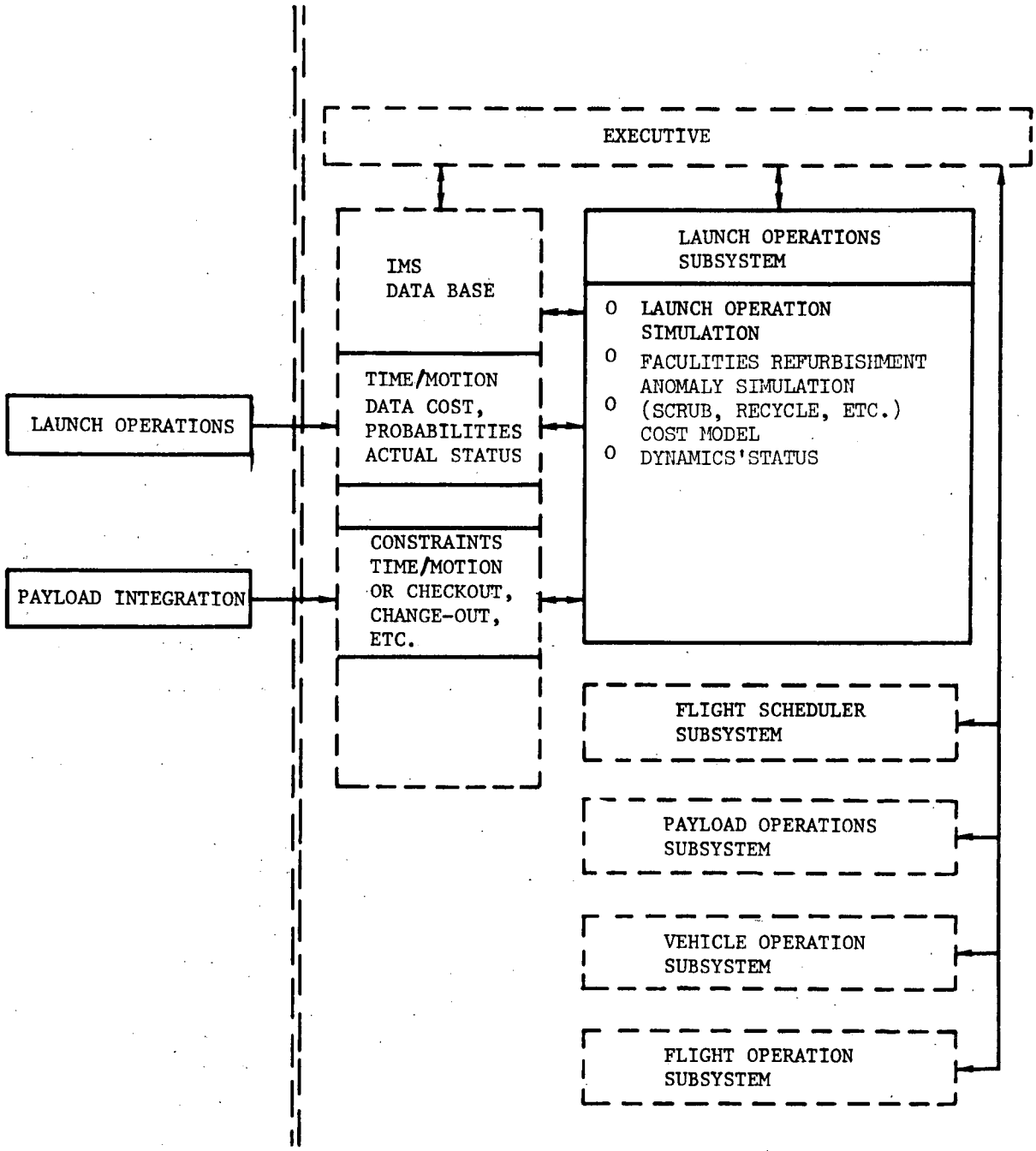
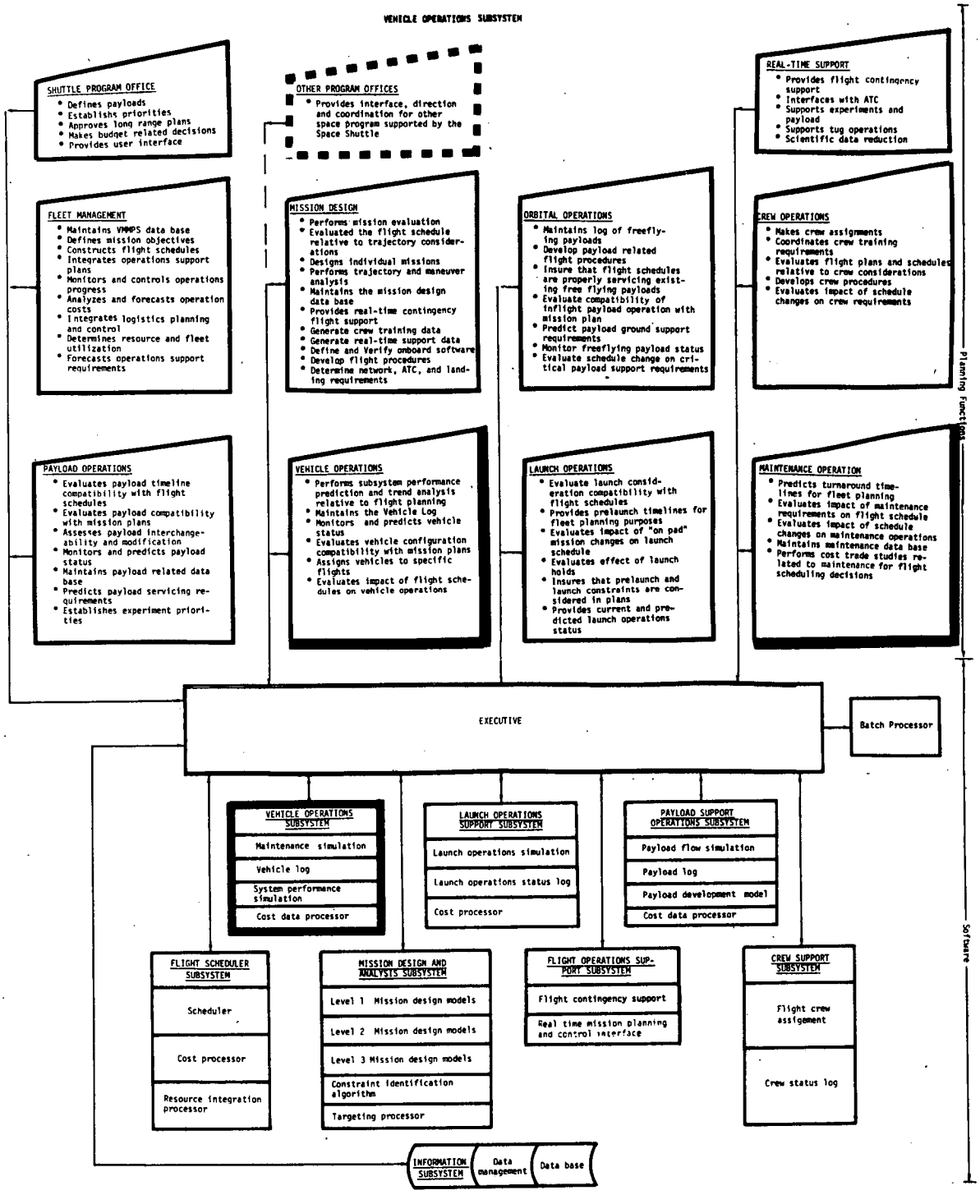


FIGURE 5-3. LAUNCH OPERATION SUBSYSTEM



Vehicle Management and Mission Planning System

5.4 Vehicle Operations Subsystem (VOS)

5.4.1 Introduction.- An onboard malfunction detection and fault isolation system will be required if the shuttle is to satisfy the operational readiness requirement. Moreover, system performance analyses (consumable analyses) cannot be performed as on past programs and should, in fact, be an integral part of any malfunction detection and fault isolation system. The depth of onboard systems performance analyses has not been decided; however, the maintenance (ground and onboard), malfunction detection and fault isolation, system performance, and trend analyses must all place requirements on the design of the systems so that appropriate sensors can be planned during the design of the systems to satisfy all requirements. Much effort on Apollo systems performance evaluation could have been eliminated by implementation of appropriate sensors during the design stages. Therefore, it is assumed that the maintenance and systems performance requirements, both ground and onboard, will be integrated during the design phase.

5.4.2 Objectives.- The objectives of the vehicle operations subsystem are to provide the overall planning system with sufficient information to accurately predict the vehicle utilization for both short-range and long-range planning. Maintenance cycles must be predicted, and the effects of both scheduled and unscheduled maintenance evaluated. Since the shuttle is a reusable vehicle, the systems performance will change from mission to mission. The I_{SP} of engines will vary and must be updated and the effects evaluated for future missions. Many systems will have similar inputs into the planning systems. One objective of this subsystem is to simulate these and evaluate the effects on mission planning.

5.4.3 Functions.- The purpose of the vehicle operations subsystem is to use test data, design data, and flight data to determine during mission planning the predicted vehicle performance and maintenance requirements. This model will fulfill its purpose by making trend analyses on all appropriate system components and line replaceable units (LRU). The results of the trend analysis will be the prediction of system performance. The following systems will be analyzed by the trend indicator:

a. Electrical power system

b. Propulsion system

c. Environment control/lift support systems

d. Cryogenics system

e. Guidance system

f. Auxiliary power unit

g. Thermal protection system

The data used to analyze the trends of the systems performance will be obtained through an interface with the information management subsystem through the VMMP system executive. These data, when used in conjunction with the system design, test data, past performance and trend data, and the simplified system performance prediction models, will determine when operational limits will be reached and what their effects on future flight schedules will be.

5.4.4 Subsystem description.- Other centers will have software models of the logistics associated with their prime areas of responsibility - launch operations, maintenance, and payload integration. The models will be complicated and detailed. The Manned Spacecraft Center must communicate with these models, which can be done by building grossly simplified models in the VMMPS or accepting input constants. The following sections discuss the maintenance data, vehicle log, and system performance simulation of figure 5-4.

5.4.4.1 Maintenance: To evaluate the feasibility of proposed flight schedules, the maintenance turnaround must be simulated to some degree. Initially, flight schedules will be limited by maintenance crew proficiency. Their learning curve is simulated in present analyses. Eventually, the maintenance will be both driven by and will drive the flight scheduling, and project management will be required to evaluate proposed missions and maintenance impact. The maintenance model developed for the VMMPS should satisfy the following capabilities:

a. Define the time required for maintenance cycles

b. Stochastic simulation of major events

c. Learning curves for major events

d. Major systems status update

e. Unscheduled maintenance update capability

f. Vehicle log update

With this simplified model, project management will be capable of making cost-trade feasibility studies and fleet scheduling decisions without time-consuming interface and review by other centers. The final schedule would then be reviewed by detailed simulation at various centers for final confirmation, but significantly different results should seldom arise.

5.4.4.2 Vehicle log: The vehicle log will contain past, present, and predicted information on each vehicle. Based on the current traffic model, total hours on each vehicle, maintenance projection, and systems utilization by serial number will be logged and modified as the schedules change from day to day and mission to mission. For example, actual heat loads on the thermal protection system will differ from the predicted; operating time on ACS thruster will vary; and, while original maintenance schedules are based on predicted system utilization, actual maintenance schedules may change. The vehicle log, therefore, will be updated after each mission. It will satisfy the following requirements:

a. Past history of vehicle utilization

b. Configuration status

c. System identification by serial number

d. Predicted modifications

e. Predicted maintenance schedule

f. Predicted systems utilization

5.4.4.3 Systems performance simulation: Onboard sensor information could be stored on magnetic tape and transmitted by high-speed data lines to MSC when the vehicle lands. These data should be sufficient to allow evaluation of critical system performance and to do sufficient trend analyses so that the predicted use of the vehicle can be validated. The simulation then could be updated during the maintenance, if system failure is noted. The system models in the VMMPS should be relatively simple and result primarily in trend analyses. Historical information by subsystem may be required in the data base for predicting accurate trends. This system shall satisfy the following requirements:

a. Real-time update capability

b. Simulate all critical systems for performance evaluation and trend analyses

c. Interface with maintenance simulation on predicted subsystem maintenance

d. Update vehicle log for system status

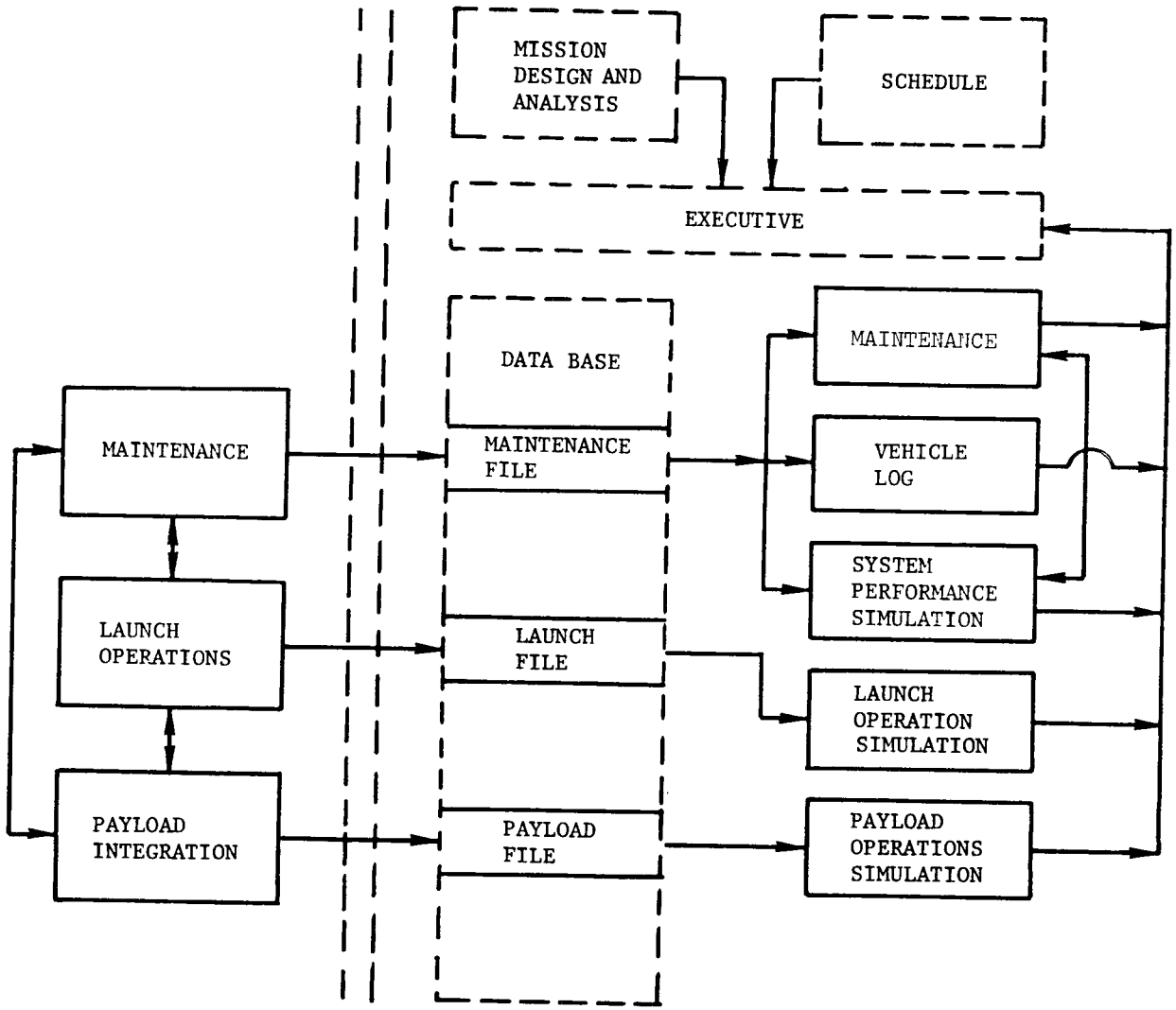
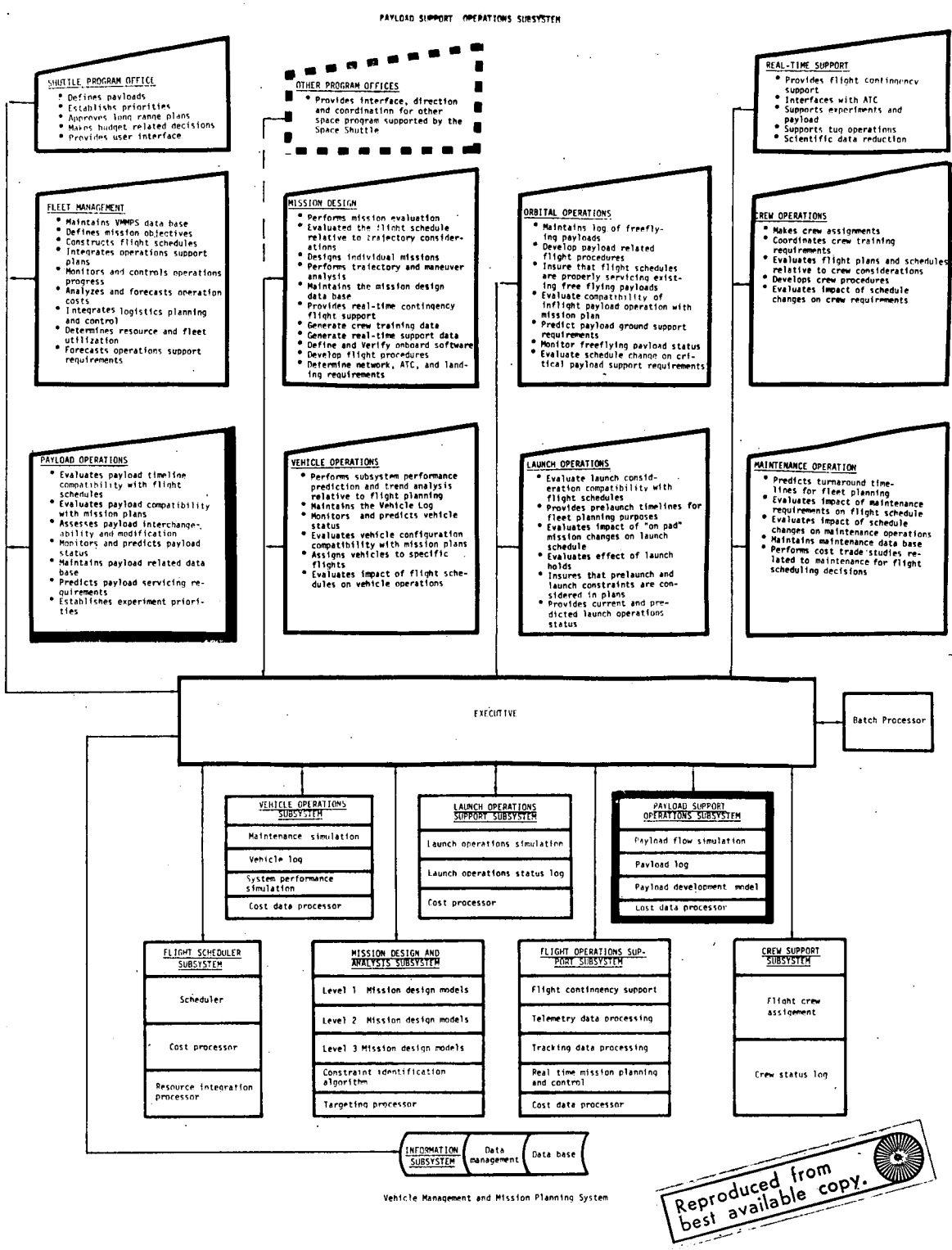


FIGURE 5-4. VEHICLE OPERATION SUBSYSTEM



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5.5 Payload Operations Support Subsystem (POSS)

5.5.1 Introduction.- Planning a particular shuttle mission begins with the definition of a payload and an expected launch date. A shuttle payload in this document includes the specific satellite or experiments (payload) and the attendant payload module and supporting equipment. Payload development, module production, experiment development, and participation of the scientist/user must be scheduled so that integration of payloads with the module, preflight preparation of instrumentation and test specimens, preflight checkout and testing, and installation of the payload module in the shuttle will coincide with the scheduled launch date. In instances when the shuttle returns a payload or module to earth, the module will generally need to be refurbished and the payload updated. In instances when the payload or module contains stored data, experiment-peculiar instruments, and specimens, they must be removed, attended, and returned to the user in a timely manner.

5.5.2 Objectives.- The objectives of the payload operations support subsystem are to provide the VMMPS with the necessary information about shuttle payload operations processes. The VMMPS can then evaluate the feasibility of proposed flight schedules and plans. It should provide the VMMPS with simulated payload integration and handling, including time predictions, real-time status reports of payload flows, and an evaluation of payload compatibility with flight schedules and mission plans.

Many components of shuttle payloads will be reusable. For example, the payload modules and supporting equipment, even payloads themselves, will be recycled. The POSS, therefore, must identify the payload components that are common to several missions, and evaluate the effect both of scheduled and unscheduled maintenance (just as must be done for the shuttle itself).

Shuttle payloads may impose unique requirements on the shuttle systems. This will result in varying degrees of modification to the vehicle and systems, thus affecting specific vehicle availability.

5.5.3 Functions.- The purpose of the POSS is to model and maintain status data on payload operations and thus provide the following:

a. An evaluation of payload compatibility with flight schedules

b. Payload flow status, prediction, and an assessment of schedule impact

c. An evaluation of payload compatibility with mission plans

d. Payload interface constraints

e. Payload development schedules and predicted delivery dates

f. Identification of common payload components between shuttle missions, status data on the refurbishment of these components, and predicted utilization

g. An assessment of the impact of short-range experiment or payload changeout and availability of alternate payloads

5.5.4 Requirements.- The POSS will have the following general requirements:

a. Access to the information management subsystem for storage and retrieval of status data from various elements of payload operations

b. A probabilistic model of payload component development and deliveries

c. A simulation of payload integration and handling flow

d. A payload status log which contains past, present, and predicted information on each payload component

5.5.5 Subsystem description.- The payload operations facility should have detailed software models of the logistics associated with the payload integration, preparation, and refurbishment. The VMMPS, however, will have to communicate with these models by maintaining a payload data base and grossly simplified simulation of the payload integration flow.

The proposed POSS is illustrated in figure 5-5. Principal internal VMMPS interfaces will be with the flight scheduler subsystem, the mission design and analysis subsystem, and the vehicle operations subsystem. External interfaces are with payload module manufacturing, user agencies, payload integration and installation, and payload refurbishment. Both external and internal interfaces will occur principally through the VMMPS data base under control of the overall executive.

The basic POSS modules are the following: payload log, payload flow simulation, and payload development model.

5.5.5.1 Payload log: The payload log will contain past, present, and predicted information on each payload and payload module. Information on payloads will consist primarily of current development status and a payload integration flow history. These payload histories will enable refinement of the payload flow simulation models for those payloads and mission types that are repeatable over the long-range plan.

5.5.5.2 Payload flow simulation: As perturbations to the payload integration flow occur, the feasibility of proposed flight schedules must be evaluated and both long- and short-range schedules must be altered. Likewise, the impact that proposed flight schedule changes will have on the payload integration flow must be evaluated. This simplified model will give project management the capability of providing feasible fleet schedules without time-consuming and costly interface and review by each user agency and other centers. The final schedule can then be reviewed by appropriate centers with their detailed simulations for final confirmation.

5.5.5.3 Payload development: This model (may be input constants) will be used to predict payload development cycle times for each payload class, to predict the availability of payloads for integration into short-range shuttle flight schedules and missions, and to understand the impact that schedule changes will have on payload development and user agencies.

The payload log will contain payload development history and status data required for updates to the development model. The payload development model will provide delivery schedules and probabilities and payload interface constraints to the payload flow simulation.

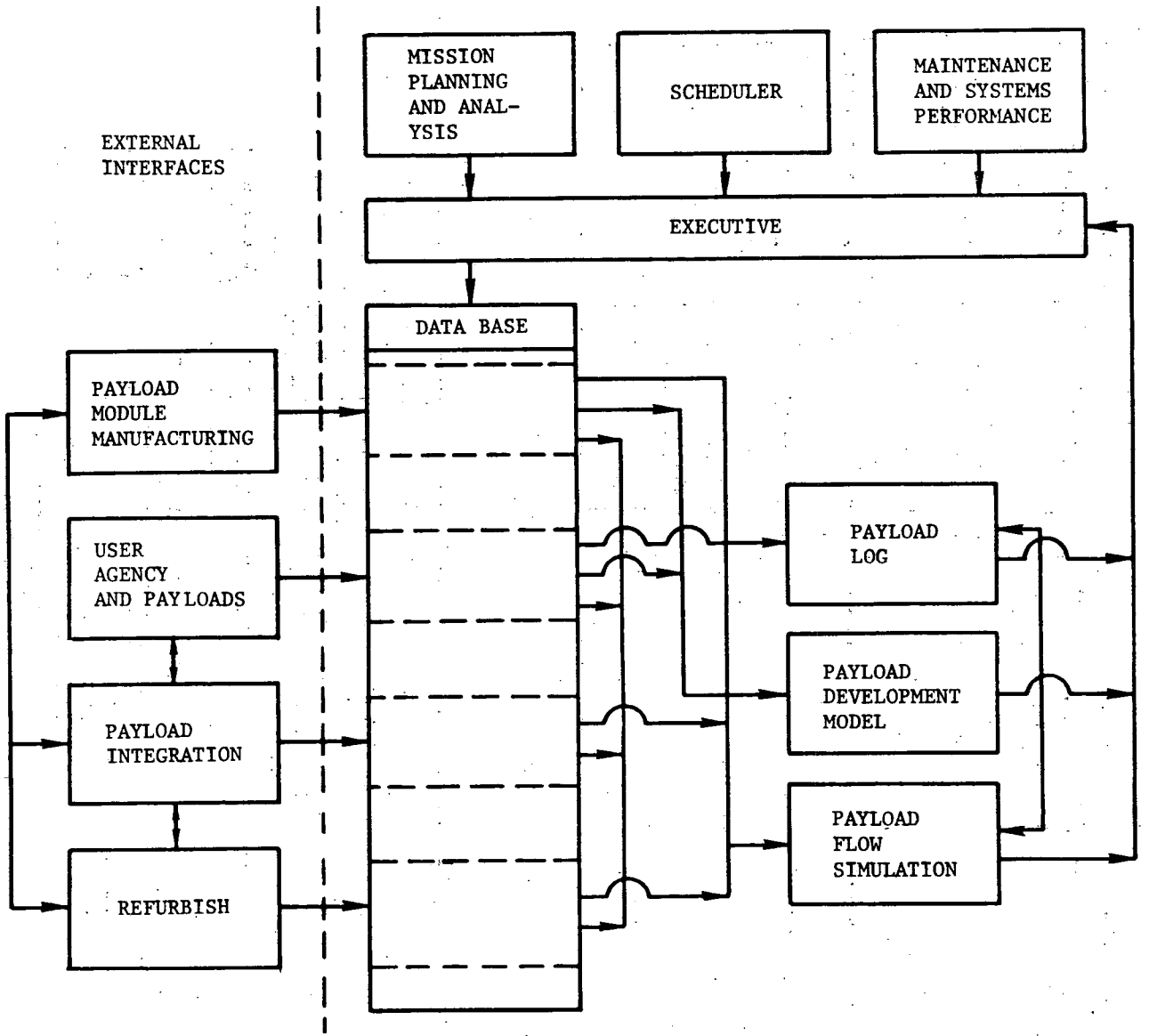
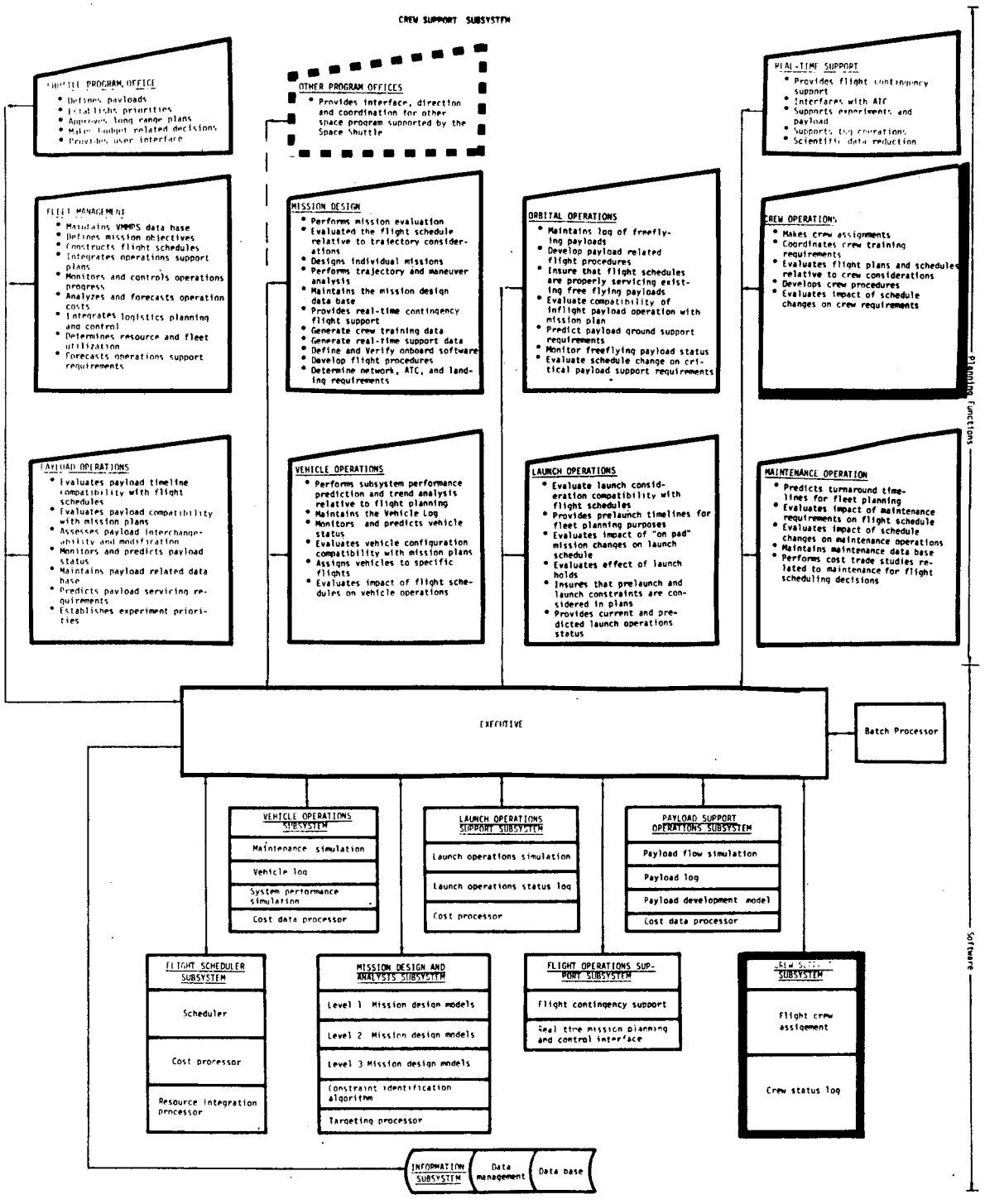


FIGURE 5-5. PAYLOAD OPERATIONS SUBSYSTEM



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5.6 Crew Support Subsystem (CSS)

5.6.1 Introduction.- Because shuttle missions are divided into different types, different shuttle crewmen will be trained for different purposes. Thus, certain crewmen will have specialized training and experience for particular types of missions. (The term crewmen includes the payload handler, experiment operators, etc.). Since crews will be operating in an environment more similar to aircraft operations, the flight scheduling and crew scheduling functions will have to be closely coupled to insure that the right type of crew is available to satisfy the mission requirements of the flight schedule.

5.6.2 Objectives.- The objective of the crew support subsystem is to provide the VMMPS with sufficient information regarding crew status to insure that the shuttle flight schedule is compatible with crew resources and constraints.

5.6.3 Functions.- The crew support subsystem has three functions:

a. Flight crew scheduling

b. Maintenance of flight crew log

c. Identification of training requirements (unique mission requirements)

This subsystem will provide an automated means for shuttle flight crew scheduling. An important aspect of this function is the evaluation and iteration of preliminary flight schedules in light of crew scheduling constraints. The constraints will be established at some later date but are likely to consider such items as

a. Interval between assignments

b. Training requirements

c. Previous training and experience

d. Accumulated flight time within a fixed period of time

e. Flight duration

f. Crew preference

g. Availability of a backup crew

h. Other established crew rotation guidelines

The subsystem will maintain a crew status log which will supply data to the crew scheduler and management about the current predicted status of individual crews and crewmen. The log will reflect such information as

a. Experience and training

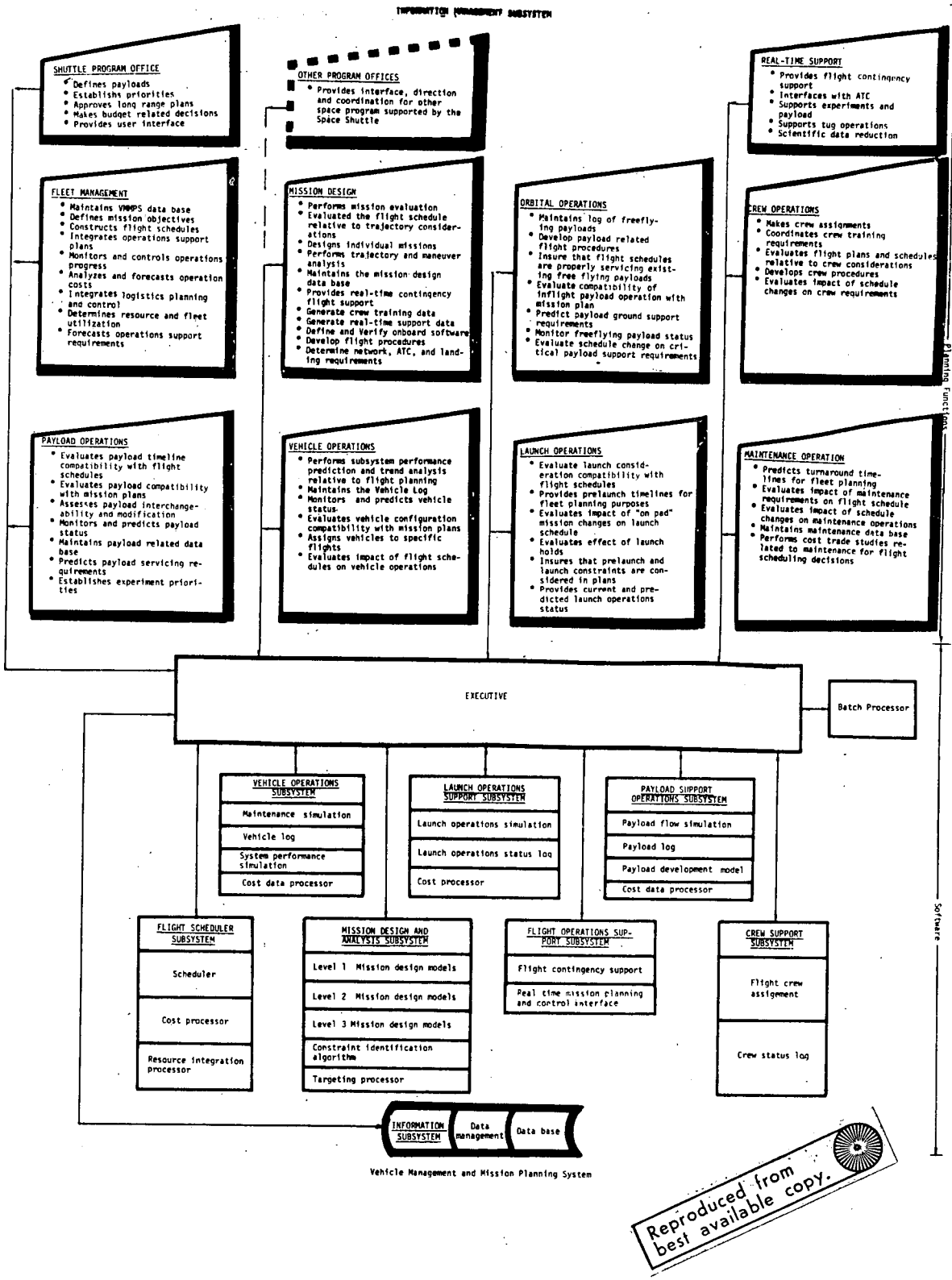
b. Projected flight assignments

c. Projected training schedules

d. Periods of nonavailability

e. Specialized capability

Additional training requirements will be identified by comparing existing and projected crew proficiency and experience against the requirements of the flight schedule.



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5.7 Information Management Subsystem (IMS)

5.7.1 Introduction.- The information management subsystem can automatically provide data to any other subsystem as input for software computations or can operate in a storage and retrieval mode for direct user access to the data. The IMS will maintain the integrity of all data which the other VMMPS subsystems will draw upon to accomplish their respective management and planning functions. It will contain allocated sections for the storage of output plans, schedules, mission phase designs, and other information resulting from subsystem computations and decisions during the planning system operations. Some output will use a working storage area so that other subsystems will have subsequent access for refinement, redesign, or alternate approach analysis. The final output products, representing accepted plans, schedules, mission designs, and operations activity, will be saved in protected locations, which can be changed only by certain codes and after clearing the proper management channels.

The stored data can be classified into several broad types. Within each of these types, some data will be frequently updated, such as the dynamic status of various shuttle refurbishment operations at the launch site; other data will be constant in nature, such as payload physical characteristics and management guidelines. The types of data include

a. Payload characteristics

b. Shuttle capabilities and configurations

c. Maintenance operations

d. Vehicle systems

e. Plans and schedules

f. Mission types and designs

g. Cost application parameters

h. Decision ground rules and tradeoff criteria

i. Launch operations

Each of the other subsystems of the VMMPS will have direct access to the IMS in a multiuser environment. Various application subsystems will have data sections which are peculiar to their function, while other data will be shared with other elements of the VMMPS. The IMS will be accessible by automatic calls from subsystem processors and

will be updated by processor- and man-initiated commands in a remote terminal or batch input mode. The IMS is thus very closely related to the other subsystems through various channels of data communication and through their command linkage to subsystem software. In accomplishing this linkage and providing channels of communication, the IMS will have a very complex executive processor linked to its data files. This processor will direct traffic in and out of the IMS and will maintain the data files structure.

5.7.2 Objectives.- The information management subsystem is intended to provide the VMMPS with a central dynamic storage and retrieval system with multilevels of data protection. It will maintain formatted output storage of results from other software subsystem operations and storage for basic data describing relevant aspects of the shuttle vehicles and shuttle operations.

5.7.3 Functions.-

a. The IMS will primarily maintain, coordinate, and provide rapid access/update to an approved, verified, and highly structured set of resource data related to the space shuttle program. These data will be of sufficient detail to allow all mission designs, schedules, and resource assignments to be made, by using the various interactive subsystems of the VMMPS, within a response period consistent with the planned launch frequencies. To accomplish this, the IMS must contain resource data describing all aspects of shuttle operations, including booster, orbiter, space stations, launch, maintenance, mission design, management, support systems, and hardware/software development. All data will be monitored and their status maintained.

b. Data will be acquired, structured, and stored continuously as the space shuttle program proceeds through its design, development, testing, and operations/support phases. During each phase, the IMS will maintain and provide access to data of the detail required by the VMMPS. During all phases of the shuttle system design, the IMS will function as an exchange terminal for flow of information at various frequencies and in numerous formats between the VMMPS subsystem processors and the IMS, on one hand, and between the IMS and various users and the planners on the other.

c. The IMS will function as a singular centralized information system. It will be self-sufficient in its ability to supply the data needs of the subsystems calling upon it for information. All data requests from users, whether subprocessors or individuals, will have rapid response and accurate communication, thus eliminating excessive time delays inherent in any noncentralized and unprotected data supply network.

d. As much as possible the IMS will use automated file inversion and cross-file indexing for storage and for maximum economy and performance. The system will have numerous internal conversion and referencing capabilities; therefore, the number of structured files is small but without the danger of unprotected modifications of data content during usage and update of the data.

e. The IMS will provide information files for maintaining schedules, operation plans, mission designs, inventory logs, and other data generated by the various VMMPS subsystems processors in the planning cycle. These data will become accessible to the other system elements as needed for sequential planning of missions and schedules. To accomplish this, portions of the subsystem-generated output will be used as working data for that system or processor only; other outputs will be placed in common data for use, dissemination, or additional analysis and tradeoff studies.

f. The IMS will basically function on two levels. First, it will serve as a general question-and-answer system for obtaining visual or printed information from the system. The IMS can be used for generating reports and for item-by-item quizzing. Second, the IMS will support the flight scheduler and other subsystems as a formatted and automatic means of transferring data from storage to subsystem processors for planning computations. Initial capabilities to support scheduling, statusing, and configuration control of the shuttle shall be provided. During the operations phase, this support will be broadened and will be adapted to rapid response and dynamic update and planning requirements.

g. The IMS will provide all services to users and subsystem processors in a multiuser, re-entrant environment. It will be capable of supporting approximately 20 users simultaneously. This support will have no visible time delay from data acquisition. Data transmission and data processing will be as rapid as possible to enchance the man-in-the-system environment being used.

5.7.4 Requirements.- The IMS objectives and functions will require numerous software capabilities. Some of these requirements can be identified, but detailed, subsystem-interrelated requirements will be available only after the design phase is in progress.

a. The IMS will use standardized data accessing structures and English language user control for defining, updating, and accessing information. The IMS will correctly interpret a wide range of inputs, including precise formats for computer-generated requests and near-free-form user requests. Abbreviations and symbols will minimize the size of input request streams while retaining phrase meaning. Format of the input may vary depending upon the application, but, in general, requests for data will be accompanied by the following:

   1. User and subsystem terminal identification

   2. Inquire, update, or computational mode

   3. Data file access pointers

   4. Data requested or to be input as update

   5. Processing required before display or other output

   6. Output specifications or options

b. The IMS must be able to save data at specified intervals and restore the data in case of hardware or software failures. A transaction log will be maintained with the capability of restoring the data to any transaction point until the log is released.

c. A security system will be required to determine who will be allowed to update and access certain portions of the data. Since different individuals may be responsible for different portions of the data, the security should allow for securing individual elements of the data as well as the entire data base. The security system will protect any of the following:

   1. Individual data items

   2. Logical groupings of data items

   3. Subsystem characteristic data and output

   4. User commands

   This protection will include security updates both on data and on access to the data.

d. To support an English-language-oriented syntax, the IMS will provide capability to distinguish various types of words, including

   1. Commands

   2. Names

   3. Connectives

   4. Restrictors

      (a) Equal to

      (b) Greater than

      (c) Less than

      (d) Not

      (e) Combinations of the above

e. Data access, update, and retrieval requirements will include the capability to accomplish the following actions.

   1. The IMS will use related storage, so that the user will not be required to input the same data more than once when the data or functionally dependent data exist in several locations.

   2. The system will create and verify data using data within other files.

   3. The user will be allowed to obtain any subset of data within the data base by the use of qualifiers and selection criteria.

   4. The system will automatically generate and store current data when items are updated.

   5. The system will support terminal or batch input loading in both free, English-type formats and fixed field format. Inputs from terminals will allow the user to add new items to the data base; to change, delete, or reformat items contained in the data base; and to create relationships between data elements in the system. The system will be able to bulk load data from files, tapes, or from drum into the data system. This capability will be used for data transfers from other organizations to the IMS and for processor-to-processor transfers within the VMMPS.

f. The IMS will be required to provide a useful set of tutorial and system status support to aid the user in accessing the system and in using its capabilities correctly. This support will include the providing of various progress reports, request formats, terminal usage descriptions, data file update transaction logs, available output formats in the system, subsystem usage instructions, and distribution of data requirements.

g. The IMS will support various formats for output of data. In general, most output will be predefined and referenced in the request or implied by the type of operation being done. However, format specifications at the time of request will be allowed and guidelines for that formatting provided.

h. The IMS will provide certain software which will allow some conventional postprocessing of data being brought out of the system. Typical of these operations is the ability to alphabetize, count, total, sequence by some parameter value, and so on.

i. The IMS will provide executive software, whereby subsystem processors may automatically access and update the IMS in the normal functioning of the VMMPS during all phases of planning.

5.7.5 Basic elements.- In fulfilling the software requirements which have been identified, several processor elements can be discerned, at least at a functional level. Other software may be needed, and some of the functions may be satisfied by software external to the IMS: however, these software elements will be required either internal to or as support elements for the IMS:

a. An input validation processor - To examine buffered inputs for data completeness, valid source codes, proper format, correct storage pointers, and receipt on acknowledgement input back to the sources. If errors in input are detected, the processor will explain the error to the user and advise him of corrective action.

b. An input routine processor - To direct traffic within the IMS and to properly route requests from various subsystems to the appropriate IMS software or data locations.

c. A file management processor - To accept the verified input codes and parameters, to form data file control commands, and to file linkage indexes and pointers. It will then execute the update by access and location of the data being specified.

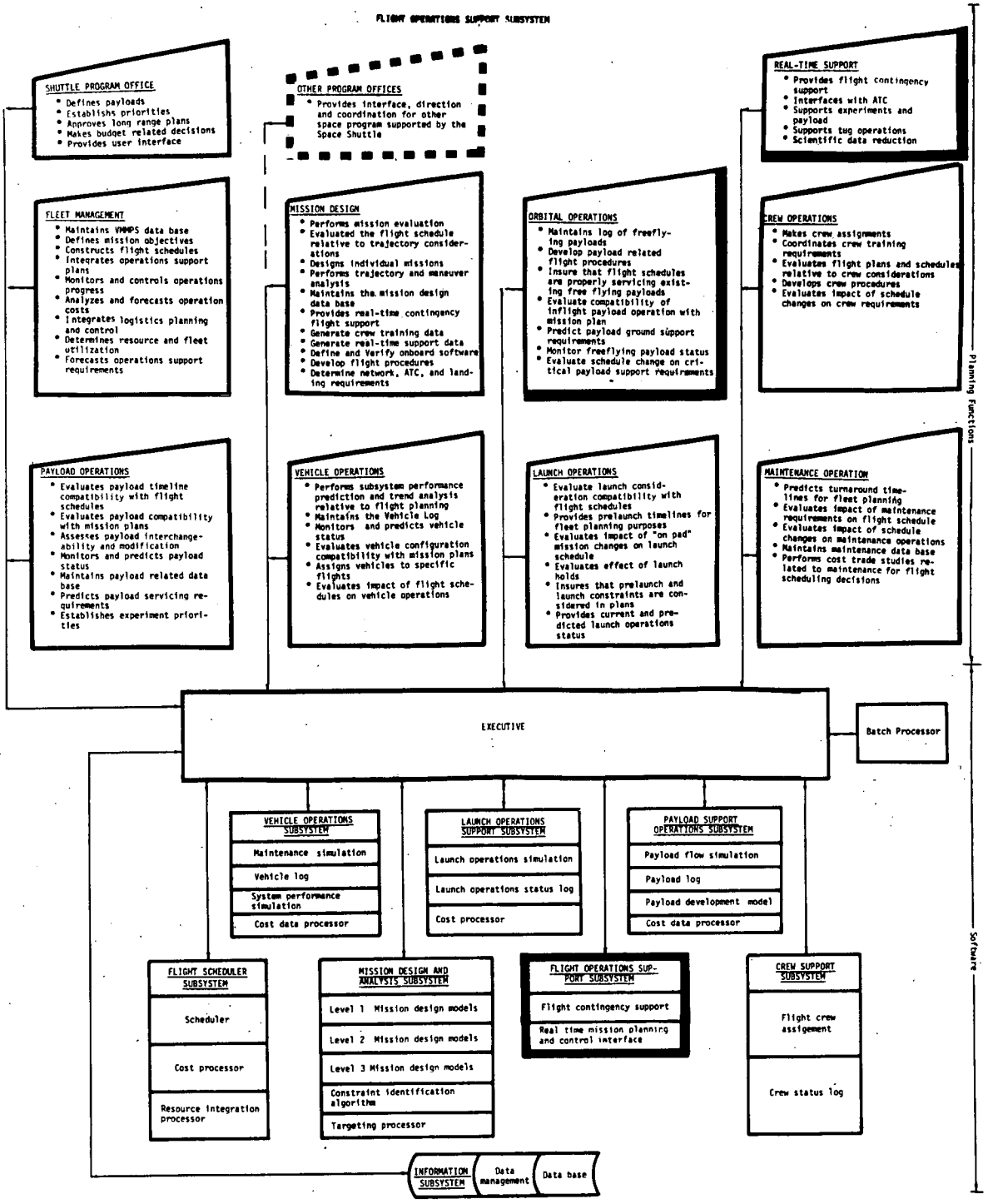
d. A request processor - To satisfy all commands for data retrieval. It will examine the request from the data input routine processor and establish control parameters. It will then perform information retrieval, processing, and distribution to other processors for further formatting and usage.

e. A tutorial processor - To assist the user in responding to error conditions from the input routine processor and other processors providing diagnostics. It will also provide general system usage guidelines and input/access mode capabilities.

f. A storage processor - In conjunction with the file management processor, to structure, format, link, edit, index, position, audit, and execute the additions and changes to data. It will be responsible for interpreting the various security and hierarchy codes which will be used.

g. An information processing processor - To accept the data from the request processor and assist that processor in satisfying the logical and comparative requirements of the original request. Once data is obtained which meets the input requests, it will be routed to the format and distribution processor.

h. A format and description processor - To accept the data which has been retrieved and format it to meet the requirements of various subsystem processors or direct access users who initiated the request. It will then route the data to subsystems, processors, terminals, input/output devices, and IMS internal files in the final execution of the input request. A transaction log will be kept at this point, and all appropriate subsystems will be polled for a go-ahead for data transmission.



Vehicle Management and Mission Planning System

5.8 Flight Operations Support Subsystem (FOSS)

5.8.1 Introduction.- The flight operations support subsystem is an integral part of the VMMPS.

The primary goal of the flight operations support subsystem as adopted for this proposed system is to reduce the ground support activity to a minimum. The elements that will affect the level of ground support required during a shuttle mission are

a. Degree of shuttle onboard autonomy

b. Operational flight philosophy

c. Standardization of flight profiles and procedures

d. Crew proficiency and training

e. Nature of the individual mission

f. Support software system

g. Stage of evolution of the shuttle from development program to operational status

The most important of these is the degree of onboard autonomy attained by the operational shuttle vehicle. Even for a highly autonomous vehicle, certain ground support functions will have to be provided. The shuttle, however, will perform on board many tasks currently done on the ground, and many other current tasks will probably not be performed to the degree they are today. Of the remaining tasks, those which cannot or should not be performed on board for whatever reason will be relegated to the ground support element.

A reasonable flight philosophy for the operational shuttle would be to accomplish the primary mission objectives of each specific flight. For example, if a failure of an onboard system occurs during the course of a flight which jeopardizes the success of the mission, the standard procedure might be to terminate the mission and return to earth. The affected mission objectives could then be rescheduled on a later flight. Such an approach to shuttle utilization would be characterized by

a. Little or no alternate mission planning

b. Onboard evaluation of the system status

c. Decisions made on board as to what flight objectives to try to accomplish

d. No significant deviation from flight plan

e. Lower level of ground support required

As in the mission design function, a key element for reducing ground support requirements is the standardization of flight profiles and flight procedures relative to mission type and common flight phases and events. This standardization coupled with a high density flight schedule will allow more routine flights, with individual crews becoming more proficient in specific types of missions. This would lead to fewer requirements for flight-crew-related support as the shuttle program progresses.

In general, then, the factors which have an effect on the degree of flight operations ground support should decrease as the program matures. In fact, the requirement for ground support should reach an almost static level during the early stage of operational phase.

5.8.2 Objective.- The FOSS, as envisioned in this report, should provide the shuttle with all normal ground software support required for interfacing with the real-time operation during the flight phase of a shuttle mission. The subsystem would be integrated into the VMMPS so that it can use the capability of other subsystems as required.

5.8.3 Functions.- To keep the majority of the inflight operations on board the shuttle, the normal flight operations ground support for the operational phase have been reduced to five major functions.

a. Flight contingency support

b. Network interface and communication

c. FAA and air traffic control interface

d. Tug/kick stage support

e. Real-time experiment and payload support

The interfaces for these functions are depicted on figure 5-6.

More complex, unique, or very costly missions may require a higher level of ground support than the standard-type missions. For such missions, the usual ground support activity could be augmented by elements of the mission design team who are specially qualified in the type of support required. In this case, the FOSS could be augmented by the MDAS to provide additional capability where required.

If a serious problem occurs during flight which cannot be handled on board, the FOSS would be capable of providing assistance through its own software and through the MDAS. The requirement for such assistance, however, should be infrequent if a flight philosophy of return-and-try-again is adopted as the governing procedure for such inflight problems.

During the flight test and qualification phase, the ground support activity would consist mainly of evaluating and verifying all onboard systems and vehicle performance in a manner similar to the present Apollo system monitoring function. In fact, the ground-based flight operations activity is likely to base a large part of the test activities on real-time engineering evaluation. As the shuttle becomes operational, the monitoring function of the vehicle systems should diminish to a level compatible with the degree of shuttle onboard autonomy and the flight philosophy.

5.8.3.1 Flight contingency support: When a contingency situation occurs, the FOSS would assist to the degree required by the nature of the specific problem. The action taken may range from the coordination of an early landing to the coordination of a crew rescue mission. Some of the flight contingency support functions are

a. Coordinate landing activities for early deorbit

b. Computation of orbiter maneuvers

c. Plan and direct crew rescue missions

d. Launch abort support

5.8.3.2 Network interface and communication: As envisioned by this report, the FOSS would provide the ground support interface with the network for the following functions:

a. Tracking data utilization - Tracking data from the tracking network would be used to generate ephemerides for the orbiter and other vehicles and targets related to a specific flight. These data could be used to provide site acquisition information for communication requirements and to evaluate the trajectory if required.

b. Telemetry data utilization - If required, the subsystem could be capable of receiving and processing telemetry from the tracking network for use in updating system performance.

5.8.3.3 FAA and air traffic control coordination: Such a subsystem could have the responsibility for coordinating all projected schedules with the FAA and air traffic control. These activities could include

a. Alerting ATC of flight schedule status and changes which may have an effect on the current landing plans

b. Requesting landing clearance from ATC, alerting the landing site, and coordinating landing plans in the event that the nominal flight plan is altered

5.8.3.4 Tug/kick stage support: How much of the capability for providing computational support for tug/kick stage operation will reside on board the shuttle is currently not clear. At times, however, ground control of the tug would probably be desirable or even required, such as during interplanetary missions. For such support, this subsystem could provide the following functions:

a. Trajectory determination

b. Targeting and maneuver planning[a]

c. Acquisition and coverage computation[a]

5.8.4 Requirements.- The specification of detailed requirements and capabilities of the FOSS is premature at present. This subsystem will not be immdeiately required and will have an evolutionary development. Much of its capability will be a direct outgrowth of the MDAS and of the nature of its real-time experiment and payload support role; however, many of the basic characteristics and requirements for the subsystem can be currently defined in general terms as follows:

a. Support multiple ongoing missions

b. Require a minimum of personnel during normal operations

c. Be able to support the shuttle flight test program in a cost-effective manner

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[a]Software capability to be used may reside in the MDAS.

d. Provide automated training aids for FOSS personnel

e. Assist in the coordination of all flight support through integrated linkup with other software elements of the mission operations management and planning system

f. Accept and use tracking data to generate ephemerides for the orbiter and any other designated orbiting vehicle

g. Monitor the launch phase so as to provide support in the event of launch abort

h. Support inflight modification of premission plans

i. Provide backup maneuver computation and targeting as required

j. Generate entry and landing information and plans which are adequate for the needs of the ATC for landing clearance and area air control and transmit such data to the ATC

5.8.5 Subsystem descriptions.- Figure 5-6 depicts the interfaces between the FOSS and other elements of the shuttle support system. Figure 5-7 depicts a gross concept and structure for this software subsystem. Not all elements shown in figure 5-7 may be required to support a specific flight. The degree to which these elements are used will depend, in a large part, on the degree of shuttle vehicle autonomy.

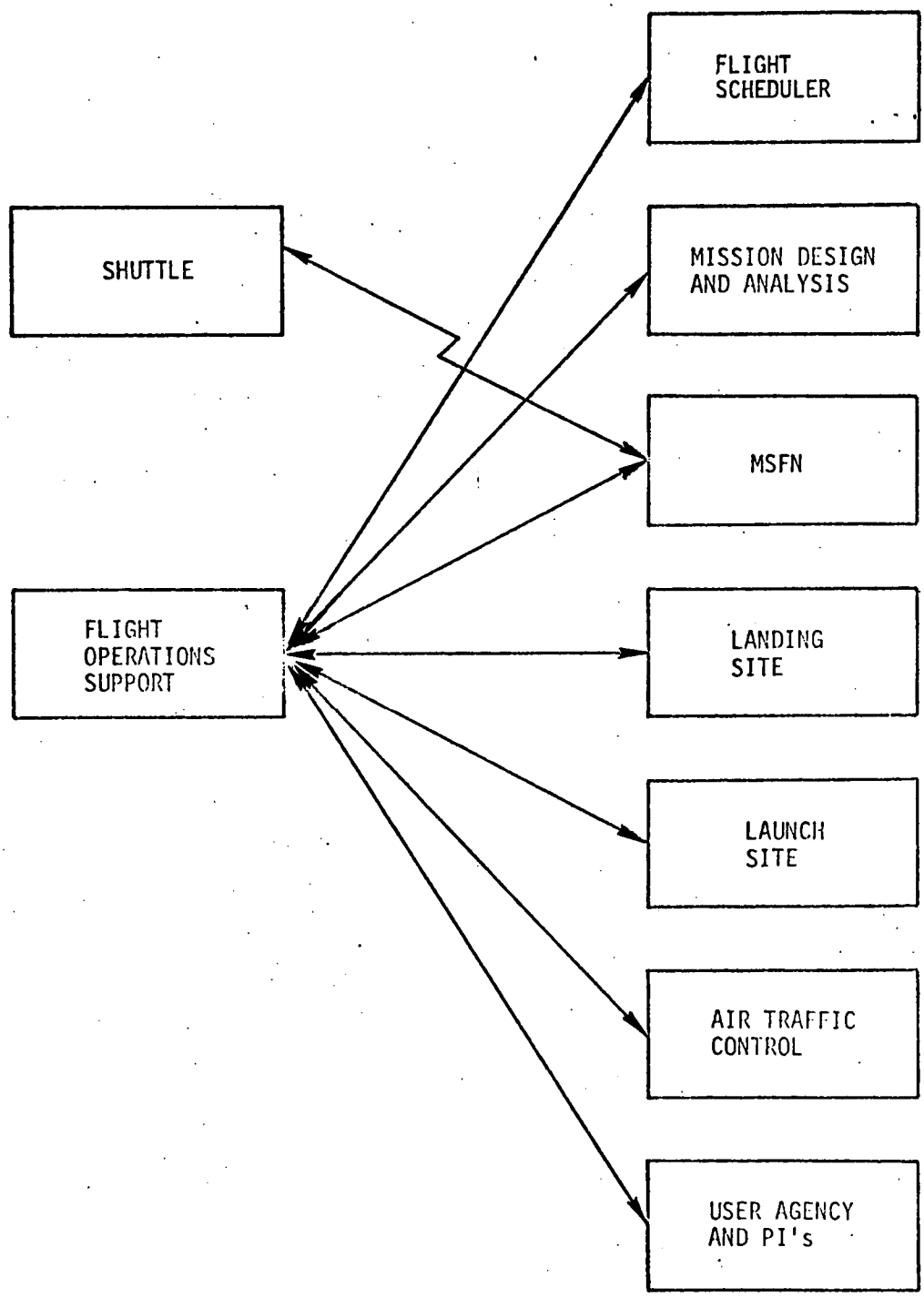
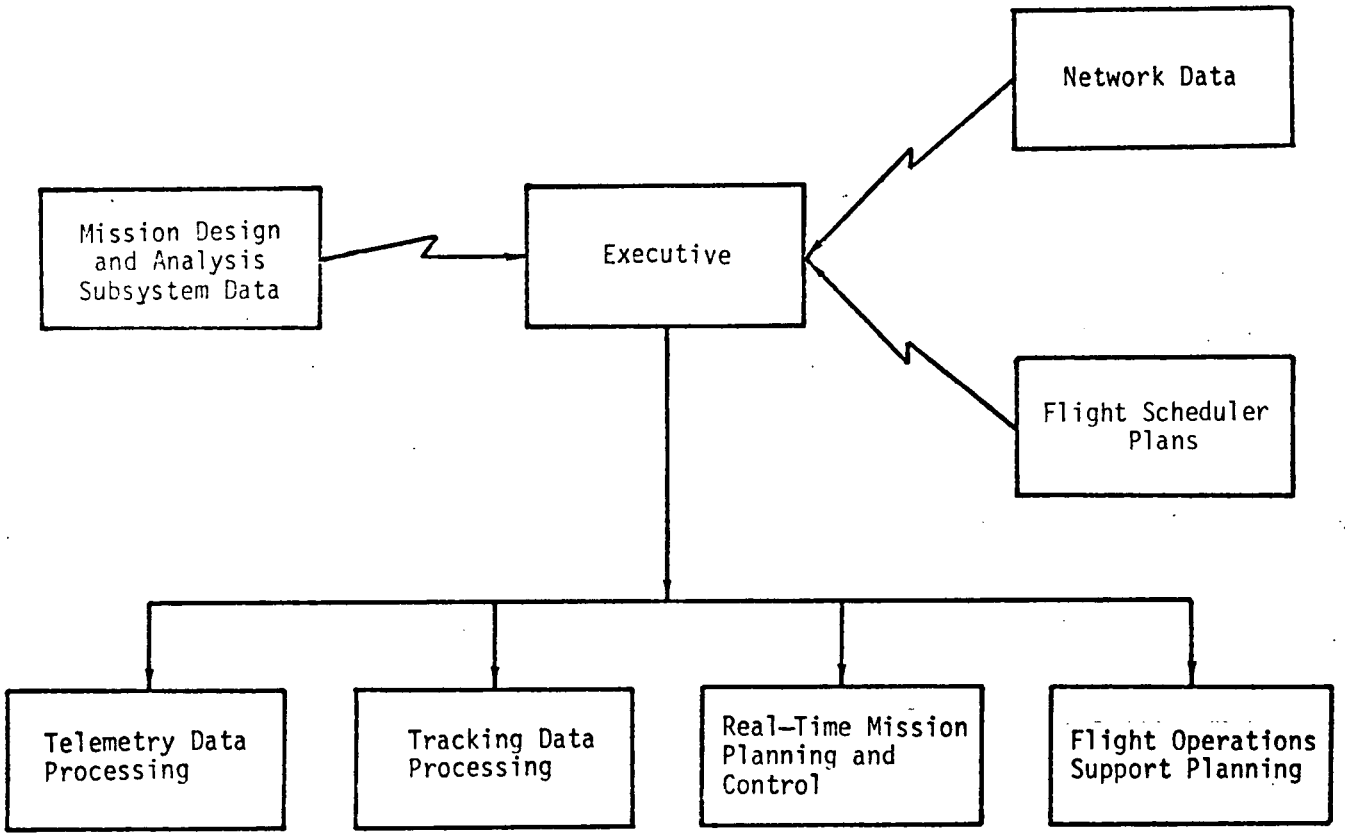


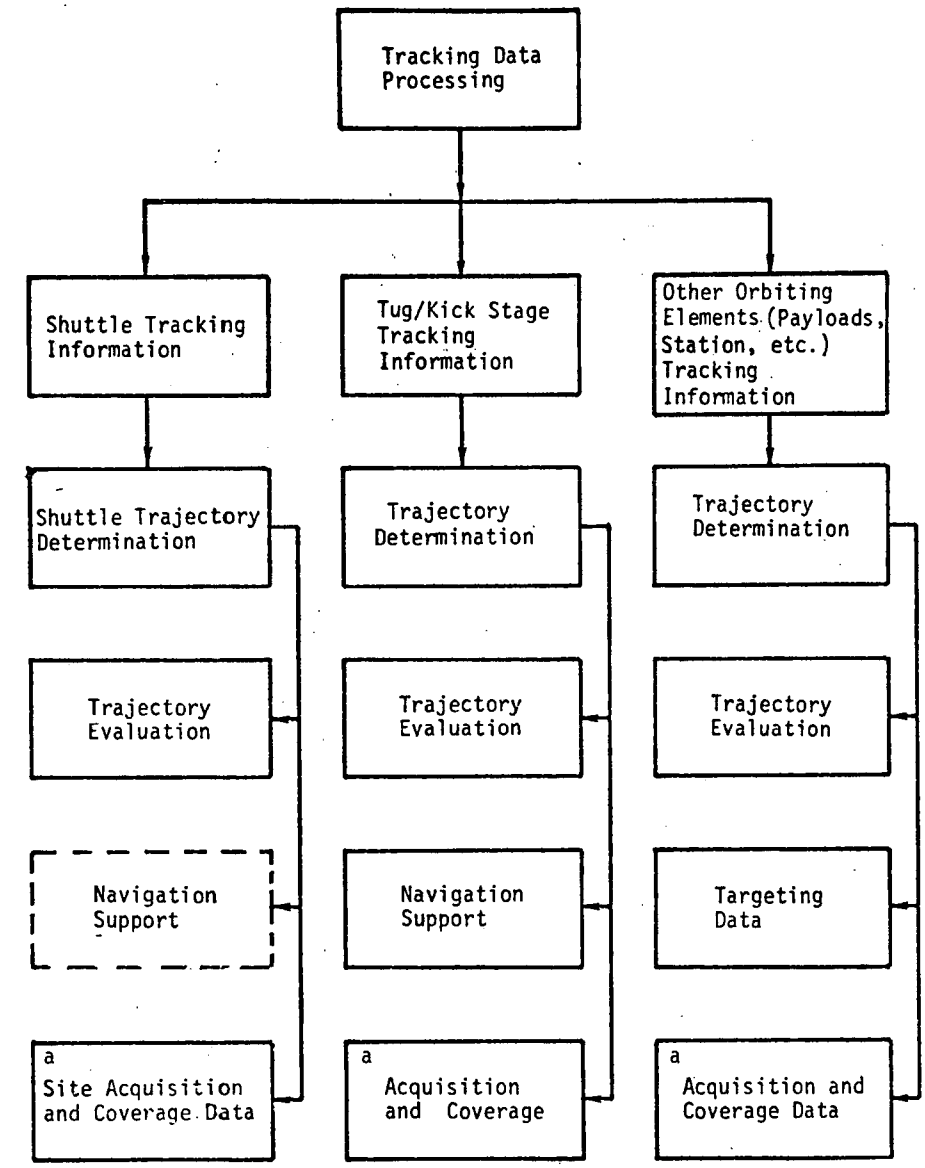
FIGURE 5-6. FLIGHT OPERATIONS SUPPORT INTERFACES

C



(a) Software system

Figure 5-7. Flight operation support software system



Notes: A Dashed Line Indicates That The Necessity is Dependent on Level of Shuttle Autonomy

[a] Software Capability To Be Used May Actually Reside In Mission Design Subsystem

(b) Tracking data processing

Figure 5-7. Flight operation support software system-Continued

6.0 SYSTEM DEVELOPMENT

6.1 Introduction

The development of the VMMPS will be both phased and evolutionary. As experience has proved, the development of such a large system should be flexible enough to respond to major requirements changes. Such a development effort, moreover, must smoothly reflect the ongoing education of the designers. For example, over several years, the designers will advance in the state of the art of the system component disciplines (scheduling, e.g.), but will also make some adverse feasibility determinations concerning planned capabilities. No initial, hard-and-fast shuttle VMMPS design will exist; rather, the design will be generated and solidified in stages.

This section presents the basic system concept and lays out a tentative development plan. This tentative development plan stresses flexibility, and is concrete only in the initial phase of development.

The following development plan reflects the considerable experience that the MPAD has had in software development and systems design (i.e., the formulation and systems design of the Real-Time Computer Complex and the Mission Operations and Planning Schedule). The shuttle VMMPS development plan will consist of these phases:

a. Gather and generate system requirements

b. Design of a bench program prototype planning system

c. Implementation of the bench program prototype planning system

d. Generation of operating system concept

e. Utilization of prototype system to test system concepts and carry out preliminary shuttle planning

f. Design of the operating system

g. Implementation of the operating system

Each of these phases will be discussed in the following sections.

6.2 Gathering and Generation System Requirements

Requirements will be generated by potential users, including MPAD, the shuttle program office, other MSC organizations, and other NASA centers engaged in shuttle activities. In building a system of this proposed complexity, the compilers and documenters of requirements must work in an environment of daily contact with the system designers. As the prime system design authority and system user, MPAD would coordinate the compilation and documentation of system requirements.

During 1972 MPAD will informally solicit requirements from all potential system users. Those informal requirements will be compiled and will form the basis formulating a system concept in 1973. While the informal requirements are being gathered, a procedure will be evolved for the formal solicitation of detailed requirements, for the submission of formal requirements, for the approval of requirements, and for the documentation of requirements. In conjunction with the system designers, the requirements compilers will establish schedules for requirements documentation milestones. Initial requirements will subsequently be modified and expanded; hence, the function of gathering and coordinating requirements must continue throughout the design phase.

6.3 Design of a Bench Program Prototype Planning System

Several considerations indicate the need for a rudimentary prototype shuttle fleet management planning system.

a. An early capability to perform some shuttle planning is needed.

b. Some of the software modules developed for the bench program would be integrated into the later system.

c. The exercise would be very educational for the designers of the followon system.

d. Problems encountered and ideas generated in designing the prototype system will feed back into requirements generation and modification.

Some components of the prototype system already exist within MPAD. The design process would include extending the capabilities of those tools, adding other tools, and integrating all components into a single shuttle planning bench program.

At a minimum, the prototype system would include the following components:

a. Shuttle, facilities, and payload data base and data retrieval system

b. A payload loading analyzer which generates compatible payload groups (candidate mission)

c. A resources allocation capability which generates an assignment of vehicles and facilities to missions

d. The capability to stochastically model shuttle operations from launch to launch

e. Mission design and analysis capability for mission-type evaluation

6.4 Implementation of the Bench Program Prototype Planning System

The prototype design must be implemented both because the capability of doing preliminary shuttle planning is needed and because the actual implementation exercise will uncover design errors and prevent the duplication of those errors in the later system design. In addition, an operating prototype system is needed to carry out validation of software modules which will eventually be implemented into the final system. The bench program will be mainly an inhouse MPAD project, and its implementation will provide vital education to the MPAD personnel who will be implementing and monitoring the more complex final system. It is proposed that the prototype system be implemented into the current facilities of the MPAD Mission Planning Laboratory.

6.5 Generation of Operating System Concept

Inevitably, the initial informal requirements submitted by the potential users of a shuttle VMMPS will assume or propose several different concepts of the system configuration (e.g., organizational interfaces, lines of authority, software capabilities, computer hardware, and system operating characteristics). A period of time will be allocated to the analysis of several possible configurations. In conjunction with the shuttle program office, the MPAD will evolve an overall system concept which will subsequently be used as a baseline for the detailed system design. The resultant system concept will identify the following items:

a. Organizational interfaces in the operation of the VMMPS

b. Organizational responsibilities for levying requirements

c. Electronic interfaces between centers involved in shuttle operation

d. Computer hardware capabilities

e. General operating characteristicst of the system (e.g., MOCR environment)

f. General software capabilities (e.g., payload integration, mission definition, resource allocation)

g. General guidelines as to the utilization of existing MSC computer facilities

6.6 Utilization of Prototype System to Test System Concepts and Carry Out Preliminary Shuttle Planning

While the overall system is being designed and implemented, the bench program shuttle planning system will be used by MPAD to support ongoing shuttle planning. The MPAD will be supporting the shuttle program office by generating shuttle traffic models, by performing fleet-sizing studies, by analyzing requirements for shuttle facilities, by performing analysis on the several mission types, by generating preliminary flight schedules, and by performing other studies as requested. By using the prototype system, MPAD will be able to test operations modeling and planning concepts. The experience gained in the practical utilization of the prototype system will be an invaluable aid for generating system requirements and designing the overall system.

6.7 Design of the Operating System

Definition of the detailed specifications of the VMMPS will tentatively start in 1974 and will be approximately a 2-year effort. According to MPAD experience in the design of large systems, requirements modifications, clarification, and expansion will frequently interrupt and redirect the system design. Too many requirements changes during the design phase can cause significant development cost overruns and cause significant slips in the delivery of the operating system. To minimize this impact, the design phase for the system will not begin until after a lengthy requirements gathering, requirements analysis, and the generation of an overall system configuration concept.

During the design phase, MPAD and possibly other NASA organizations will formulate detailed specifications for the system. Among these specifications will be the logic and equations for modeling the different aspects of shuttle operations, detailed interface specifications between the various software modules, display format specifications, and user-oriented input specifications. The result of the design phase will be a document or series of documents that will specify to the system implementors the detailed formulation of the software portion of the system.

6.8 Implementation of the Operating System

The system will be implemented either by the system designers or by contractor personnel whom the designers will monitor. Since several years are provided for requirements gathering, for generating a system configuration concept, and for designing the prototype system, the system implementation effort should not be significantly interrupted by requirements changes or major redesign. The implemented system will be tested, verified, and delivered as an operating system by the beginning of 1978.

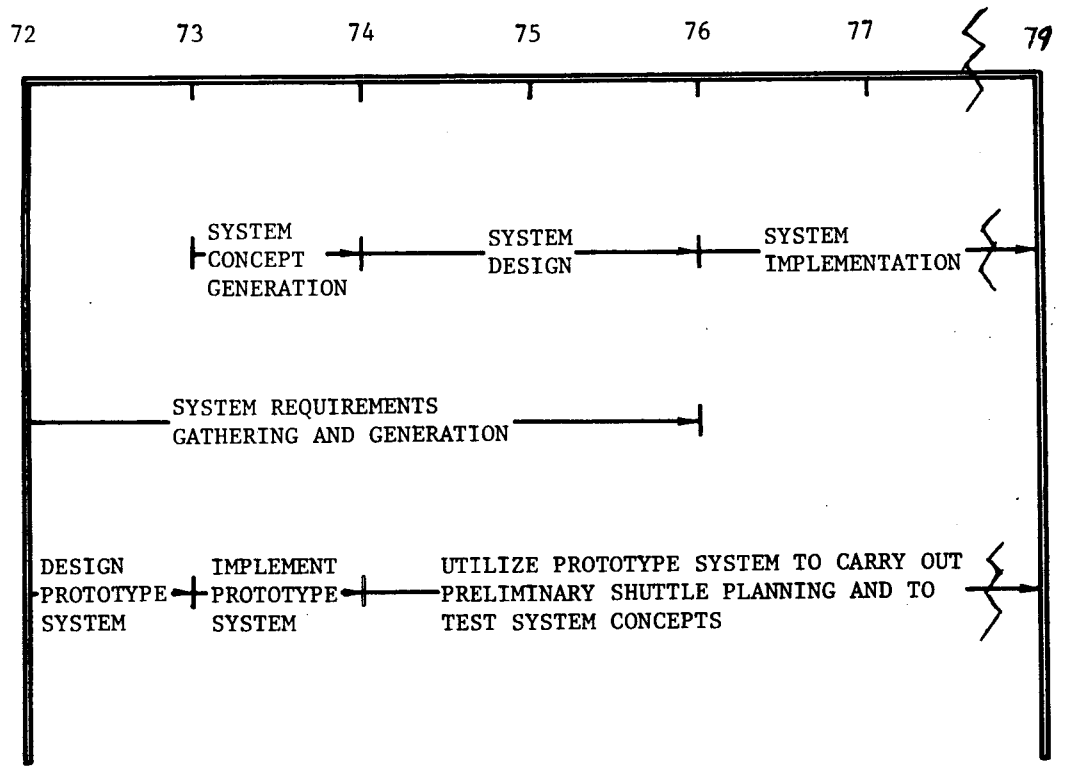


FIGURE 6-1. VIMP SYSTEM DEVELOPMENT PHASES

☆ U.S. GOVERNMENT PRINTING OFFICE: 1972—779-263/847