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FORMULATION OF CONSUMABLES MANAGEMENT MODELS

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TECHNICAL REPORT

VOLUME I

MISSION PLANNING PROCESSOR DEVELOPMENT

Prepared by

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Operational Systems Section

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PREFACE

Future manned space programs that will have increased launch frequencies and reusable systems require an implementation of new consumables and systems management techniques that will relieve both the operations support personnel and flight crew activities. These techniques must be developed for the optimum combination of an onboard and ground support consumables management system consistent with the goals of the program. Effective operational performance of the consumables management techniques of a total system requires that a very explicit definition of the time, place, and method of performance of each function be determined by trade studies to ascertain that the operational methods do, indeed, meet these goals. This requires that the complete consumables management cycle be considered by including the mission planning and scheduling functions, prelaunch activities, onboard mission functions, ground mission support functions, and postmission activities.

Formulation of models required for the mission planning and scheduling function and establishment of the relation of those models to prelaunch, onboard, ground support, and postmission functions for the development phase of advanced spacecraft was conducted under Contract NAS9-14264.

Analytical models and techniques were developed which consist of a Mission Planning Processor (MPP) with appropriate consumables data base, methods of recognizing potential constraint violations in both the planning and flight operations functions, and Flight Data Files for storage/retrieval of information over extended periods interfacing with Flight Operations Processors for monitoring of the actual flights. Consumables subsystems considered in the MPP were electrical power, environmental control and life support, propulsion, hydraulics and auxiliary power.

Development of Space Transportation System (STS) interactive computer program MPP Working Model was conducted under Part IV of this Research and Technology Objectives and Plans (RTOP) and is based on studies conducted during the preceding Parts I, II and III. The period of performance for Part IV was 1 November 1976 through 31 August 1978.

The final report for Part IV of this contract is presented in an Executive Summary and two technical volumes. The technical volumes are: Volume I-Mission Planning Processor Development and Volume II-Mission Planning Processor User Guide.

Several formal reports were issued during the period of performance of Part IV and are so noted in the References of the Executive Summary and Volume I.

This particular report presents information on development of the Consumables Mission Planning Processor.

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TABLES

1.0 INTRODUCTION

Development of an STS interactive computer program MPP working model was conducted under Part IV of this RTOP and is based on studies conducted during the preceding Parts I, II and III. This report presents a summary of the computer program development and those supporting tasks conducted under Part IV. Development of the MPP Computer Program is discussed in Section 2.1. This development was supported by several parallel tasks. These tasks, discussed in Sections 2.2 through 2.10, either directly supported the program development, or provided information for future application and/or modification to the program in relation to the flight planning and flight operations of the STS and advanced spacecraft. The supporting tasks also include development of a Space Station MPP to demonstrate the applicability of the analytical methods developed under this RTOP to more advanced spacecraft than the STS. More detailed information on the individual tasks is included in the References issued during the execution of the RTOP.

2.0 PROGRAM DEVELOPMENT AND SUPPORTING TASKS

2.1 STS MPP WORKING MODEL

Analytical models and techniques were developed which consist of an MPP with appropriate consumables data base and a Flight Data File for storage/retrieval of information over an extended period which interfaces with a Flight Operations Processor for monitoring of the actual flights. The MPP provides a method for detecting activity scheduling conflicts and also for recognizing potential constraint violations in both the planning and flight operations functions.

A working computer model of the MPP for the STS was developed under Part IV of the RTOP. The program is structured as defined by the detailed requirements of Reference 1. The working model, however, does not incorporate the EVENT MODE nor the FILE 3 options. The EVENT MODE of operation is equivalent to a computerized version of the Long Range Planning Worksheet. The FILE 3 option is a detailed output of consumables-related parameters for flight monitoring and control. Neither of these options were considered necessary to the development of a working and demonstration model of the MPP. They may be incorporated at a later date.

The user interface was a prime consideration in the development of the MPP analytical tool. The user interface is designed to afford routine processing of the consumables aspect of mission planning and flight operations by personnel not specifically skilled in consumables technology. This particular design goal influenced the concept in several considerations. First, all operational requirements of a flight which impact consumables, regardless of particular mission requirements are included in the execution. The system has an update/edit capability such that the fidelity of the resulting consumables data can be increased as the user knowledge of that particular flight increases or replanning is necessary over a span time of approximately ten years from the long-range planning stage through flight operations. In addition, the user input/control uses mission related variables rather than consumables variables.

These goals are accomplished by use of an on-line/demand mode computer terminal Cathode Ray Tube (CRT) display. The process is such that the user merely adds specific mission/flight functions to a skeleton flight and/or alters the skeleton. The skeleton flight includes operational aspects from prelaunch through Ground Support Equipment (GSE) connect after rollout as required to place the STS in a parking orbit, maintain the spacecraft and crew for the stated on-orbit period and return.

The system uses a set of standard flight/mission components, representing portions of a flight which are to be combined to satisfy a particular mission.

The MPP consists of the following elements:

a) The displays/user interface
b) The Flight Data Files
c) The consumables analysis data base
d) The control and support routines
e) The computational routines.

The MPP performs the following functions:

a) Provides user interface through interactive CRT displays
b) Generates total mission consumable requirements
c) Acts as a scheduler for mission events that affect consumable usage
d) Provides immediate feedback of scheduling conflicts
e) Provides immediate feedback of consumable usage rate violations
f) Generates and displays detailed consumable analysis data on user request
g) Stores selected generated data in the Flight Data Files on user request.

Application of the program is explained in Volume II of this report which familiarizes the user with the operating system. The program is user-prompted through the displays such that the subject familiarization should be sufficient to qualify a potential user to operate the program. Detailed operating information which the user may wish to use as reference in actual mission planning application is included in the Appendices of Volume II.

The program is in operation on the Univac 1110 - Exec 8 system accessible through the Mission Planning Laboratory terminals in Building 30 at the Johnson Space Center (JSC). The program may be operated either from tape or secured files.

Demonstration of the file/retrieval and update/edit capability of the MPP was conducted via preparation of data files for operational flights past Orbital Flight Test (OFT)-6. The efforts demonstrate the preparation of early-stage flight planning data files based on the best information available on each individual flight and the techniques for updating the data as the flight planning process progresses. The MPP was exercised for 27 flights categorized as Single Payload Deployable, Multi-Payload Deployable, Department of Defense (DOD), Spacelab, or Other Flights and the File 1 data (input) has been placed in secured files for retrieval. The files can be retrieved for update/edit and/or generation of consumables data on the flights as currently planned. The preparation of these files provide JSC with a system for training personnel as well as initializes the operational era consumables management system.

Consumables analysis for STS operational Flights 7 throught 33 were performed and the corresponding File 1 information was created and stored for each of the 27 flights.

Mission/flight data was derived from the following major sources:

a) Payload/carrier information was obtained from the Flight Assignment Baseline Document 13000-0-6F (Planning Option) provided by Mr. E. Dupnik of the Utilization Planning Office at JSC.

b) Flight description, payload requirements and configuration were obtained from available Payload Integration Plans (PIP's) furnished by Mr. J. Llewellyn of the STS Operations Office at JSC.

c) Spacelab requirements/configuration was obtained from Reference 2.

A summary of the operational flights is given in Table I. The secure File Identification (ID) is also included.

Table I. Operational Flight Summary

FLIGHT NUMBER	PAYLOAD	CARRIER	CREW COMPLEMENT	DURATION (DAYS)	FILE I ID
		Single Payload Deployable Flights			
7	TDRS-A	IUS-2 STAGE	3	2	OPS07
10	TDRS-B	IUS-2 STAGE	3	1	OPS10
18	GALILEO	IUS-3 STAGE	3	1	OPS18
		Multi-Payload Deployable Flights			
8	SBS-A	SSUS-D	3	3	OPS08
	GOES-D	SSUS-A			
	ANIK-C/1	SSUS-D			
12	INSAT-1A	SSUS-D	3	3	OPS12
	SBS-B	SSUS-D			
	RCA-C	SSUS-D			
13	TDRS-C	IUS-2 STAGE	3	2	OPS13
	ANIK-C/2	SSUS-D			
14	INTELSAT V	SSUS-A	3	2	OPS14
	GOES-E	SSUS-A			
24	ZOHREH-2	SSUS-A	3	2	OPS24
	GOES B/U	SSUS-A			
28	SBS-C (B/U)	SSUS-D	3	2	OPS28
	ANIK-C3 (B/U)	SSUS-D			
30	(SAME AS FLIGHT 14)		3	2	OPS30

Table I. Operational Flight Summary (Continued)

FLIGHT NUMBER	PAYLOAD	CARRIER	CREW COMPLEMENT	DURATION (DAYS)	FILE I ID
		DOD Flights			
9	STP-P80-1	UNIQUE STAGE	3	3	OPS09
	SME	SSUS-D			
	SPAS-01	1-1/2 M PLATFORM			
22*	DOD 82-1	IUS	3	1	OPS22
26*	DOD 82-2	IUS	3	1	OPS26
		Spacelab Flights			
11	SL 1	LM+P	6	7	11SL1A
16	SL 2	3 P+COSMIC RAY	5	9	16SL2
19	SL 3	LM+P	5	8	19SL3
21	SL 4	SM+P; PHYSICS & ASTRO	5	7	21SL4
23	SL 5	LM+P; LIFE SCIENCE	6	10	21SL5
25	SL 6	SM+2P	5	10	25SL6
29	SL 7	LM+P	5	10	29SL7
31	SL 8	4P	5	7	31SL8
33	SL 9	SM+3P	5	7	33SL9
		Other Flights			
15	LDEF-DEPLOY	LDEF	3	3	OPS15
	SMM-RETRIEVAL	MMS FLIGHT SUPPORT SYSTEM			

*DOD Dedicated

Table I. Operational Flight Summary (Continued)

FLIGHT NUMBER	PAYLOAD	CARRIER	CREW COMPLEMENT	DURATION (DAYS)	FILE I ID
		Other Flights (Continued)			
20	ZOHREH-1	SSUS-A	3	3	OPS20
	INSAT-1B	SSUS-D			
	INDUSTRIAL MOD B	RI 3 FT PLATFORM			
17	TDRS-D	IUS-2 STAGE	3	2	OPS17
	INDUSTRIAL MOD A	RI 3 FT PLATFORM			
27	INTELSAT V	SSUS-A	4	7	OPS27
	MATERIAL SCIENCE	S/L PALLET WITH IGLOO			
	INDUSTRIAL MOD C	RI 3 FT PLATFORM			
32	LDEF RETRIEVAL	LDEF	3	7	OPS32
	P/L OF OPPORTUNITY	OFT PALLET			

2.2 STS MPP VALIDATION STUDY

A study was conducted to determine accuracy of the MPP as a consumables analysis tool in relation to detailed consumables studies conducted by the Mission Planning and Analysis Division (MPAD) at JSC. Consumables requirements for several OFT flights were developed on the MPP and compared with similar data from the MPAD/JSC studies. The study was conducted with the following ground rules and goals for the completed MPP program:

1. Maximum difference between consumables requirements calculated by the two models should be less than five (5) percent.
2. The average difference for the five flights analyzed should be less than one (1) percent to minimize skewness.
3. The mean deviation should be less than four (4) percent consistent with items 1 and 2.

Results of the study are shown in Table II. Initial evaluation was conducted on the validation MPP model as shown on the referenced table. The resulting data indicated a difference in the models with a negative skew. The Orbital Maneuvering Subsystem (OMS) propellant differences were attributed to an older, lower specific fuel consumption used in the MPP. Cryogenic requirement differences were traced to both an absence of baseline heater power and improper data for the spacecraft power during crew daytime activities. The Environmental Control and Life Support Subsystem (ECLSS) nitrogen differences were the result of a lower cabin leakage rate than currently specified for STS.

Appropriate corrections reflecting the above considerations were applied to the validation model to develop the updated model. Re-evaluation of the consumables requirements based on the updated model are shown in Table II also. The differences are within the desired five (5) percent. For all flights analyzed, the average differences ($\bar{X}$) and mean deviation (σ) are shown in Table III using the updated model. These values are within the desired range stated in the goals.

Table II. Validation Study Results - Individual Flights

FLIGHT	CONSUMABLE	MPAD REQMT'S. DATA LBS.	MPP DATA (VALIDATION MODEL)		MPP DATA (UPDATED MODEL)	
			REQMT'S. LBS.	DIFF. %	REQMT'S. LBS.	DIFF. %
OFT 6	OMS PROP.	22171.0	20806.0	-6.2	21321.0	-3.8
	CRYO (H_2/O_2)	2226.7	1965.9	-11.7	2280.4	+2.4
	ECLSS N_2	62.2	60.3	-3.1	61.7	+2.3
OFT 5		22714.0	22448.0	-1.7	23003.6	+1.3
		2196.6	1929.1	-12.2	2241.5	+2.0
		53.7	52.2	-2.8	53.7	.0
OFT 4		28003.0	27573.0	-1.5	28255.5	+0.9
		2179.7	1825.8	-16.2	2109.1	-3.2
		49.7	48.3	-2.8	49.7	.0
OFT 3		21279.0	20580.0	-3.3	21089.4	-0.9
		2351.8	1976.6	-15.9	2291.7	-2.6
		54.2	52.8	-2.6	54.3	+0.2
OFT 2		13007.0	12995.0	-0.1	13316.7	+2.4
		1670.2	1500.7	-10.1	1737.1	+4.0
		40.7	40.2	-1.2	41.3	+1.5

Table III. Validation Study Results, Updated Model, All Flights

CONSUMABLE	$\bar{X}$	σ
OMS PROP	.0	2.4
CRYO (H_2/O_2)	.5	3.2
ECLSS N_2	.8	1.0

2.3 DATA BASE UPDATE FOR STS MPP

The Consumables Data Base associated with the performance of the mission activities and required as input to the STS MPP for the consumables calculations had been prepared under Part III of this RTOP. Under Part IV the information was updated to reflect current data. The updated information is given in Reference 3.

The activity data is defined in terms of discrete time periods having a distinct rate for each consumable required to support the performance of a given operation. The data is structured in a series of "Consumables Data Worksheets" for each activity that includes a profile of its operations and the rate of each consumable required to support the given activity. Data worksheets provide for the uniform specification of consumables data, allow for the ready identification of the consumables affected by a given activity, and facilitate the updating process.

2.4 PAYLOAD INTERFACE REQUIREMENTS

A study defining the payload interface to the MPP was conducted. The study is documented in Reference 4 which:

1. Defines the impact of payload functions on Orbiter operations.
2. Provides a guide to assessing this impact via reference to a typical payload data source and the related input to the MPP.
3. Identifies modifications to the MPP which will improve the interface of the payload data source and the processor.

4. Identifies the data and format for payload data sources which would improve the interface of that source and the MPP.

The review of payload interface to the MPP results in the recognition of several features which are suggested as modifications to future versions of the processor for improved interface.

1. The Extravehicular Activity (EVA) and Intravehicular Activity (IVA) activities represent situations in which the life support consumables for the subject(s) are provided by the Orbiter. There are no provisions for transfer to or from a payload which provides such life support such as a manned Tug. Provisions for such a payload interface should be incorporated.

2. Deployment or retrieval of a payload of significant weight affects the propulsion consumables requirement to accomplish subsequent ΔVs of the Orbiter. Provision for such a weight change on-orbit should be incorporated in the MPP. It is suggested that this feature be incorporated in the manipulator operations activity as an additional input specifying the magnitude and sense of the weight change.

3. The terminology "downlink" and "uplink" imply communication with the ground only. In view of the requirements for Orbiter communications to or from the ground, Tracking and Data Relay Satellite (TDRS) and/or an automated payload, the respective activities would be more descriptive if renamed "transmit" and "receive". In addition, an indication of attitude hold requirements for these communications activities should be incorporated in the input and reflected in the associated consumables usage. Incorporation of this feature would eliminate the current multiple activity entry requirement on the part of the user.

4. The waste management activity as currently defined in the MPP is not an activity that can be scheduled. In this view, and with respect to the magnitude of the associated consumables, it is suggested that this activity be incorporated in the baseline (common) data base and eliminated from the activity menu.

The MPP is a phase/activity block oriented system with simple input as to when the phases and/or activities start and stop. Such a system is not only applicable to consumables planning, but may be viewed as the final form of any mission planning function. Regardless of the structure, format, manipulation requirements, or data flow, the information, whether Orbiter of payload data, ultimately ends up as a timeline of when various activities occur. Information in this form is then converted to response of spacecraft

measurable consumables related parameters in support of flight operations. The consumables MPP is designed to perform this latter conversion with the view that the end object of mission planning is support of flight operations.

The defined process and end item should be considered in the establishment of an authoritative payload data base, not only for the consumables MPP but also with respect to other mission planning functions. Steps and generic contents of a payload data base system which would satisfy this goal are:

1. Establish a standardized set of operational phases and activities.

2. Develop a payload data base format which contains user input requirements and a timeline of associated phases and activities.

3. Develop a data control and manipulation process which converts user defined requirements (Principal Investigator input) to the subject timeline of associated phases and activities. (Store in data base).

4. Provide access to the timeline data to various mission planning functions. These data should reflect the best estimate of this timeline at any stage of the planning cycle so that the respective function's operational parameters may be established.

5. Provide feedback to the principal investigator through a combination of items 3 and 4 to reflect conflicts and possible modifications of requirements.

2.5 CREW SIMULATOR REQUIREMENTS

A study was conducted to define the crew training simulations requirements relating to consumables management for advanced spacecraft systems. The Space Shuttle requirements were examined in detail as a specific example of such an advanced system.

The support role to the simulators during past programs including data requirements, interfaces, products and methods was reviewed. This review was required to evaluate past methodology and establish its applicability to the new flight planning/flight readiness environment for advanced spacecraft stressing repetitive operations and minimum available resources. Principal findings of this survey indicated that:

a) The developmental nature of past programs required a customized approach to the planning, training and analysis of every flight. These functions were accomplished with the use of specialized detail analysis tools.

b) Some aspects of the consumables simulator data generation and data transfer mechanism of past programs were burdensome and inefficient. The effect of these deficiencies was minimized by the ample manpower availability and less stringent schedule requirements of those programs.

Based on specialized requirements of advanced spacecraft systems, the experience gained in past programs, and economic considerations, the study concluded that generalized, simplified methods must be developed to support the training and simulations of advanced systems. To this end the study recommended development of a "Consumables Reset Point Generator" program for inclusion in the simulator software package. This program could be used at the simulator in conjunction with existing Flight Activities and Consumables Data Base to generate required consumables data, virtually eliminating the inefficiencies observed in the past. In addition, by providing the appropriate data, this program will afford the flexibility to simulate individual Flight Activities and/or any combination of Flight Activities to form Flight Phases, Flights, or Missions to suit the training requirements.

The recommendations were documented in Reference 5 and presented in a briefing on March 7, 1977, to representatives of the NASA/JSC Flight Simulations Division for their consideration.

2.6 FLIGHT DATA FILE III DEVELOPMENT

Consumables data generated by the MPP developed under this RTOP represents a time history of the consumables usage for a given mission. The data is contained in a multifile Flight Data File system consisting of four files. The first two files (Files 0 and I) consist of flight design/mission planning data, while the latter two files (Files II and III) present the consumables data in two levels of detail. File II gives the gross consumables quantities while File III presents the data for the individual elements of the consumable storage and distribution network for each subsystem including quantities, temperatures, pressures and flow rates. These data are required to interface with the launch, monitor, and postflight subprocessors for updating of loaded

quantities, inflight consumables management, and postflight evaluation and subsystems data revisions. In addition, File III data will be made available to the crew training and simulator activity to support their initialization and reset data points requirements. File III data can also serve the needs of any user requiring detail subsystems consumables information to establish trend and performance analysis.

Algorithms required for the preparation of the File III were developed under Part IV of this RTOP. The algorithms are documented in Reference 6. The File III data set is prepared from the consumables data calculated in the MPP and obtained from the File II data set of the Flight Data File. Consumables data generated by the MPP are stored in the File II. The function of the algorithms is to manipulate and convert the gross consumables data into a set of specific parameters associated with each of the storage and distribution networks, corresponding in turn to the various spacecraft subsystems.

The algorithms were used to formulate a File III Routine consisting of seven subroutines that simulate the consumables storage and distribution networks. A detailed description, interfaces, input/output data, processing equations, and computational flow is presented in Reference 6 for each of the seven subroutines.

2.7 OPERATIONS TRANSITION STUDY

A study to establish refinements to the consumables management mission planning process in the transition from the development to the operational era of the STS was performed and documented in Reference 7. The refinements address methods to minimize support effort on the basic delivery system (Orbiter) based on increased confidence gained during the development era, and shift the effort to Payload support during the operational era.

Those aspects where improvements could be realized were identified by a review of the overall Consumables Management activity. This review included examination of methodology and techniques employed during past and present programs as well as those developed under this RTOP. The results of this review suggested the input data function as a prime target for refinement as the operational era is approached. Consequently, this effort was primarily directed to the examination of the various input elements to the consumables management process in an attempt to establish the desired refinements.

To this end, the overall input data requirements and the procedural steps used in the definition and usage of these data were reviewed. Unique requirements arising from the projected high density operational flights were established along with simplifying methods which will provide adequate support for the Orbiter, and in addition, will allow the shifting of this support to the Payloads.

The study concludes with specific recommendations which include:

a) The simplication of the data specification process by the implementation of a Data Management System which can also be used in support of other mission planning groups such as Flight Control, Crew Procedures and Training, Flight Simulation, etc.

b) The consolidation of activity blocks for events scheduled on a routine basis, which will result in a considerable reduction in the time and effort required in the preparation of the timeline which is required for input to the consumables models.

2.8 SIMPLIFIED SPACE STATION MPP

Consumables management techniques developed under this RTOP were used to formulate a consumables model for the Space Station. This effort served the twofold purpose of: a) testing the applicability of techniques developed earlier for the STS to advanced spacecraft systems, and b) establishing the basis from where tools can evolve to support the Space Station consumables management.

The Space Station model development first addressed the establishment of the consumables data base as it affects the formulation of the consumables model. The data base includes the definition of the activities and related consumables data for the Space Station under its various operational models and configurations, from the initial Shuttle-tended, through the buildup phase by the addition of various models, and culminating with the permanently manned configuration. The consumables data was constructed as "Consumables Data Worksheets" for each activity and includes profiles of the rate of each affected consumables required to support the given activity, in the same format as that constructed for the STS (see Section 2.3).

The activities selected, the affected consumables and the data specification (input data) are summarized in Table IV.

Table IV. Space Station Activity Summary

ACTIVITY NO.	ACTIVITY NAME	PHASE	CONSUMABLES: EPS	CONSUMABLES: RCS	CONSUMABLES: ECLSS ATMO	CONSUMABLES: ECLSS H2O	CONSUMABLES: ECLSS LiOH	CONSUMABLES: ECLSS TOTAL	CONSUMABLES: CREW	DATA: START TIME	DATA: STOP TIME	DATA: CYCLIC	DATA: ΔV	DATA: ATTITUDE
-7	COMMON	I	X				1		X	X				
-8	PRELAUNCH TO ORBIT		X				1		X	X				
-9	ORBIT ACQUISITION		X	X			2		X	X				
-10	ORBIT ACQUISITION TO END OF MISSION	I	X	X	X	X	5	X	X	X				
1	RESUPPLY OPERATIONS	II	X				1		X	X				
2	WORKDAY		X		X	X	4	X	X	X	X			
3	RESTDAY		X				1	X	X	X	X			
4	EVA		X		X	X	4	X	X	X				
5	RCS MANEUVER		X	X			2		X	X		X	X	
6	IMU ALIGN		X	X			2		X	X	X			
7	COMMUNICATIONS DATA/MGMT		X				1		X	X				
8	SHOWER		X		X		2	X	X	X	X			
9	PROCESS SUPPORT		X	X	X	X	5		X	X				
10	CRANE OPERATIONS		X	X			2		X	X				X
13	ORBITER		X	X	X	X	5		X	X				
14	POWER MODULE		X	X			2		X	X				X
15	SPACE CONSTRUCTION		X	X			2		X	X				
16	TEST ARTICLE 1		X	X			2		X	X				X
17	STRONGBACK		X	X			2		X	X				
18	REACTION CONTROL PODS		X	X			2		X	X				
19	POWER PLATFORM		X	X			2		X	X				X
20	CONSTRUCTION SHACK		X	X	X	X	5	X	X	X				
21	100 METER RADIOMETER		X	X			2		X	X				X
22	MULTIBEAM LENS ANTENNA	II	X	X			2		X	X				X

The MPP was modified to incorporate the Space Station data base and revise the activity displays and input controls to reflect the Space Station activity menu.

The data base workbook for the Space Station model is documented in Reference 8. The operation of the Space Station program differs from the STS program only in the activity menu from which the user selects the timeline elements.

2.9 CONSUMABLES REDLINE GUIDELINES

Guidelines for the development of consumables subsystem redlines for advanced spacecraft systems were established and documented in Reference 9. Although the basic redline function remains unchanged, the methodology employed in past programs is inadequate to support future spacecraft requirements. Techniques developed for the Apollo missions, for example, characterized by the developmental nature of each of its flights, must be reoriented to serve the needs of the highly repetitive and routine earth orbit operations of advanced spacecraft systems such as the Shuttle Orbiter.

General redline concepts were developed with a twofold purpose. The first was an attempt to establish general redline criteria; the second, to establish the basis for the evaluation of work performed in past programs in order to fully utilize those aspects applicable to advanced systems. The redline activity of past programs was reviewed including their development and implementation.

Requirements of the operational Space Shuttle spacecraft as an example of an advanced spacecraft system were defined. These requirements, especially the projected high flight density, strongly suggest the development of simplified methods that would be both responsive and cost-effective in the new operating environment. Guidelines for the redline development process of the Space Shuttle were presented, and implementation of the function of a Redline Status Subprocessor was recommended as a substitute for the methods employed in the past programs. The algorithms of the Redline Status Subprocessor, a part of the MPP, are amenable for use in the Mission Control Center (MCC) at JSC, the Launch Processing System (LPS) under development at the Kennedy Space Center (KSC), or the Space Shuttle onboard computer system.

2.10 WORKSHEET UPDATE

The Consumables Flight Planning Worksheet is a tool developed earlier under this RTOP (Reference 10) for screening of flights to determine which flights require detailed consumables analysis. The worksheet was updated to reflect current available data along with minor modifications to its format.

An updated Worksheet User's Guide was developed (Reference 11) which included:

- The worksheet concept
- The updated and reformatted worksheet
- Detailed instructions in how to use the worksheet
- A sample application including a completed worksheet.

An accuracy study was performed to consummate the worksheet development process and to affirm the viability of the concept. The study is reported in Reference 12. The worksheet was used to determine the consumables requirements of the OFT flights. The worksheet results were compared to the consumables requirements established by MPAD detailed models. In general, the average deviation was within ± 5 percent.

ACRONYMS AND ABBREVIATIONS

CRT	Cathode Ray Tube
DOD	Department of Defense
ECLSS	Environmental Control and Life Support Subsystem
EVA	Extravehicular Activity
GSE	Ground Support Equipment
H_2	Hydrogen
ID	Identification
IVA	Intravehicular Activity
JSC	Johnson Space Center
KSC	Kennedy Space Center
LBS	Pounds
LPS	Launch Processing System
MCC	Mission Control Center
MPAD	Mission Planning and Analysis Division
MPP	Mission Planning Processor
N_2	Nitrogen
O_2	Oxygen
OFT	Orbital Flight Test
OMS	Orbital Maneuvering Subsystem

ACRONYMS AND ABBREVIATIONS (Concluded)

RTOP	Research and Technology Objectives and Plans
STS	Space Transportation System
TDRS	Tracking and Data Relay Satellite

REFERENCES

1. Connelly, L. C., "Formulation of Detailed Consumables Management Models for the Development (Preoperational) Period of Advanced Space Transportation System," Detailed Requirements for the Mission Planning Processor, TRW Report No. 26821-H002-R0-00, November 1976.

2. Spacelab "Payload Accommodations Handbook", SLP/2104, 30 June 1977.

3*. Zamora, M. A., "Formulation of Consumables Management Models," Consumables Data Base Workbook, TRW Report No. 26821-H008-R0-00, 7 January 1977.

4*. Torian, J. G., "Formulation of Consumables Management Models," Mission Planning Processor Payload Interface Definition, TRW Report No. 26821-H011-R0-00, 28 January 1977.

5*. Zamora, M. A., "Formulation of Consumables Management Models," Consumables Analysis/Crew Simulator Interface Requirements, TRW Report No. 26821-H015-R0-00, 29 April 1977.

6*. Zamora, M. A., "Formulation of Consumables Management Models," Flight Data File - File 3 Algorithms, TRW Report No. 26821-H020-R0-00, 30 September 1977.

7*. Zamora, M. A., "Formulation of Consumables Management Models," Development/Operational Transition Study, TRW Report No. 26821-H022-R0-00, 12 May 1978.

8*. Zamora, M. A., "Formulation of Consumables Management Models," Consumables Data Base Workbook Space Station, TRW Report No. 26821-H021-R0-00, 12 April 1978.

9*. Zamora, M. A., "Formulation of Consumables Management Models," Guidelines for the Development of Consumables Subsystem Redlines for Advanced Spacecraft, TRW Report No. 26821-H018-R0-00, 30 June 1977.

10. Torian, J. G., "Interim Report, A Consumables Analysis Technique in Support of Long Range Flight Planning," Contract NAS9-14269, dated May 1975.

11*. Newman, C. M., "Formulation of Consumables Management Models," Consumables Flight Planning Worksheet Utilization, TRW Report No. 26821-H013-R0-00, 25 February 1977.

12*. Newman, C. M., "Formulation of Consumables Management Models," Consumables Flight Planning Worksheet Accuracy Study, TRW Report No. 26821-H014-R0-00, 25 March 1977.

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