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FORMULATION OF CONSUMABLES MANAGEMENT MODELS

30 MAY 1977

CONTRACT NO. NAS9-14264

TEST PLAN FOR THE MISSION PLANNING PROCESSOR WORKING MODEL

Prepared by

L. C. Connelly

Systems Analysis Section

TRW
DEFENSE AND SPACE SYSTEMS GROUP

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1.0 INTRODUCTION AND SUMMARY

The purpose of this report is to document the test plan and test procedures to be used in the verification and validation of the software being implemented in the Mission Planning Processor Working Model program. The Mission Planning Processor is a user oriented tool for consumables management and is part of the total consumables subsystem management concept presented in Reference 1. The detailed requirements for the Mission Planning Processor are presented in Reference 2. The working model will be developed from a subset of these requirements. An overview of the working model is presented in Section 2.

Execution of the test plan will comprehensively exercise the working model software. An overview of the test plan, including a testing schedule, is presented in Section 3. The test results will be published on completion of testing.

The working model will be tested at the unit, module, and system levels. The test plan for each level is discussed in Sections 4, 5, and 6, respectively.

The working model results will be validated using known consumables requirements previously generated by NASA/JSC/MPAD personnel using detailed consumables analysis models. The criteria used to validate the working model results for each consumables subsystem are presented in Section 6.2.

2.0 OVERVIEW OF THE WORKING MODEL

2.1 PURPOSE

The working model of the Mission Planning Processor will be developed in order to:

a) Demonstrate the validity of the consumables subsystem management concept as presented in Reference 1.

b) Demonstrate the validity of the Mission Planning Processor algorithms presented in Reference 2.

c) Provide a tool for consumables analysis flight planning of scheduled Space Shuttle missions.

2.2 SCOPE

The detailed requirements for the Mission Planning Processor are presented in Reference 2. The working model will be developed from a subset of these requirements. Table I summarizes the scope of the working model through comparison of Mission Planning Processor and working model capabilities.

The working model can be executed only in the ACTIVE (i.e., interactive flight activity scheduling) MODE. The EVENT (i.e., generation of the long range planning consumables worksheet) MODE does not demonstrate interactive capability and will not be implemented in the working model. Therefore, Flight Data File 0 (event data) will not be implemented.

Flight Data Files 1 (minimum data set to operate in the ACTIVE MODE) and 2 (usage profiles for each consumables subsystem) will be implemented in the working model. Flight Data File 3 (data for individual elements of the consumables storage and distribution network for each subsystem) is not required at this time and will not be implemented in the working model.

The working model will not include the capability to display detailed usage rate profiles. These profiles would be used for detailed analysis too time consuming for on-line interactive operations. The data will be generated and output via the line printer on user request.

Table I. Mission Planning Processor Working Model Scope

PROGRAM CAPABILITIES	MISSION PLANNING PROCESSOR	WORKING MODEL
RUN MODES	EVENT MODE, ACTIVE MODE	ACTIVE MODE for interactive scheduling with immediate feedback of scheduling conflicts and rate violations
FLIGHT DATA FILES	FILES 0, 1, 2, and 3	Files 1 and 2
CRT DISPLAYS	USER INTERFACE, SCHEDULING CONFLICT, RATE VIOLATION, CONSUMABLES QUANTITIES AND MARGINS, EVENT TIMELINE, and CONSUMABLES PROFILES (RATE VS. TIME) FOR EACH CONSUMABLES SUBSYSTEM	USER INTERFACE, SCHEDULING CONFLICT, RATE VIOLATION, CONSUMABLES QUANTITIES AND MARGINS, and EVENT TIMELINE
PRINTED OUTPUT	CRT TERMINAL HARDCOPY CAPABILITY	CONSUMABLES PROFILES (RATE VS. TIME) FOR EACH CONSUMABLES SUBSYSTEM

Figure 1 illustrates the working model routine tree. The EVENT MODE routines (IV INPUT, FILE ZERO, and EVENT CHART) will not be implemented in the working model. The OUTPUT routine associated with detailed usage rate profiles (CONSUM HISTORY) will be implemented with printed output not display capability.

2.3 FUNCTIONS

The working model will perform all the Mission Planning Processor functions except display detailed consumables profiles. As noted in Section 2.2 of this report, these data will be generated and output via the line printer on user request. The working model will perform the following functions.

a) Provide user interface through interactive CRT displays

b) Generate total mission consumable requirements

c) Act as a scheduler for mission events that affect consumable usage

d) Provide immediate feedback of scheduling conflicts

e) Provide immediate feedback of consumable usage rate violations

f) Generate detailed consumable analysis data on user request for output on line printer

g) Store selected generated data in Flight Data Files 1 and 2 on user request.

2.4 ELEMENTS

The working model will consist of the following elements:

a) The displays/user interface

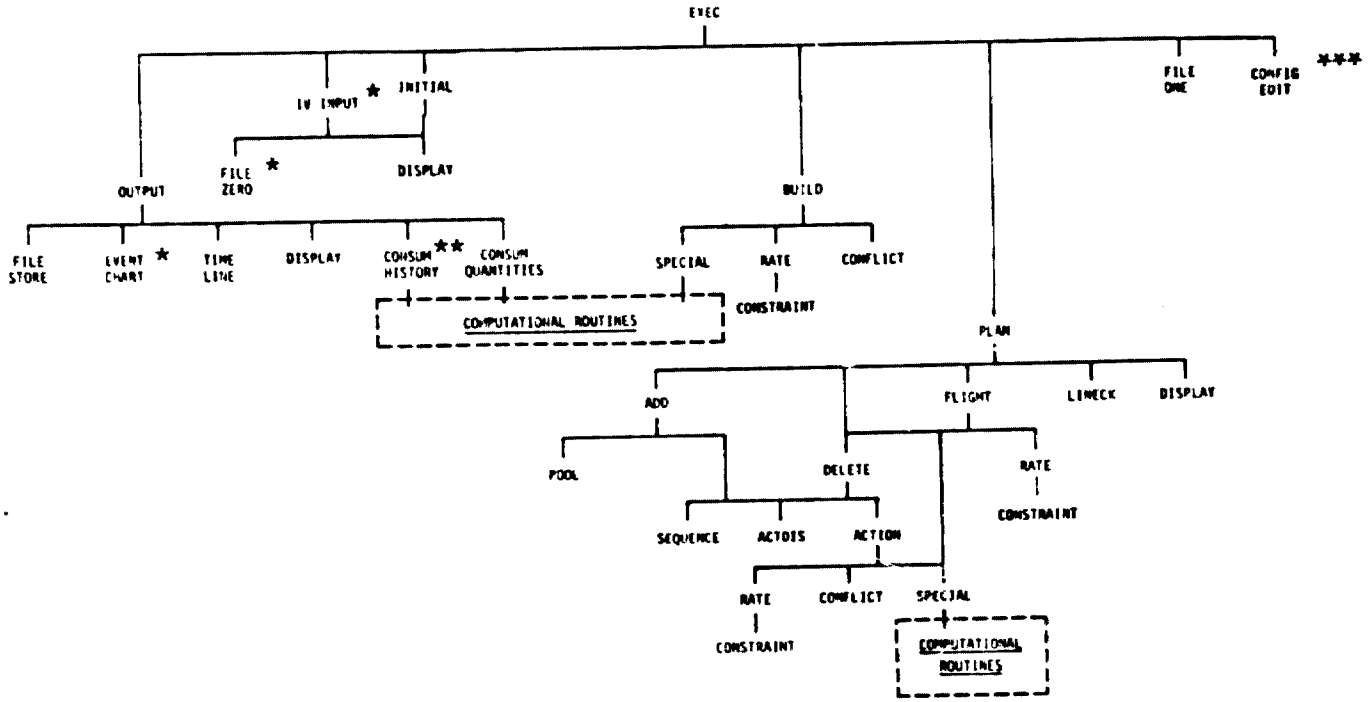
b) The Flight Data Files 1 and 2

c) The consumables analysis data base

d) The control and support routines for the ACTIVE MODE

e) The computational routines

f) The search, integration, and other utility routines.



*RUN MODE=EVENT routines will not be included in the working model.

**Consumables profiles will have printed output only.

***CONFIG EDIT routine will not be included in the working model.

Figure 1. The Mission Planning Processor Working Model Routine Tree

2.5 INITIATION

The working model will be initiated in the same manner as the Mission Planning Processor in the ACTIVE MODE. In the ACTIVE MODE, the Mission Planning Processor requires a mission timeline as input. There are two methods to introduce the mission timeline into the program as a function of where the mission lies in the planning cycle;

a) The first time the mission is executed, the timeline is entered event by event through keyboard entry. Even this mode is semi-automatic. Many standardized events (eat and sleep periods, etc.) are automatically scheduled as a function of the mission configuration.

b) In subsequent executions the mission timeline is entered from the FILE 1 data set stored in the Flight Data Files.

2.6 EXECUTION

The working model will execute in the same manner as the Mission Planning Processor in the ACTIVE MODE. Mission timeline creation or modification is accomplished by user input through a set of interactive displays. The user may change the start and stop times of mission phases, schedule new events, modify existing events, or unschedule existing events. For each change in the mission timeline, consumable usage rate blocks are built for each consumable subsystem affected by the change. Any scheduling conflicts or rate violations will be fed back to the user and stored in conflict tables for later assessment.

2.7 OUTPUT

At this time in the execution, the user may elect to generate and display the following:

a) A scheduling conflict table listing the time of conflict and the conflicting scheduled events.

b) A rate violation table for each consumable subsystem listing the time and rate of the violation and the limit that was violated.

c) A timeline listing scheduled events versus mission time without reference to consumables usage.

d) The total consumables used and end-of-mission quantities for each consumables subsystem.

On user request, the detailed profiles (usage rate versus time) for each consumables subsystem will be generated via the line printer.

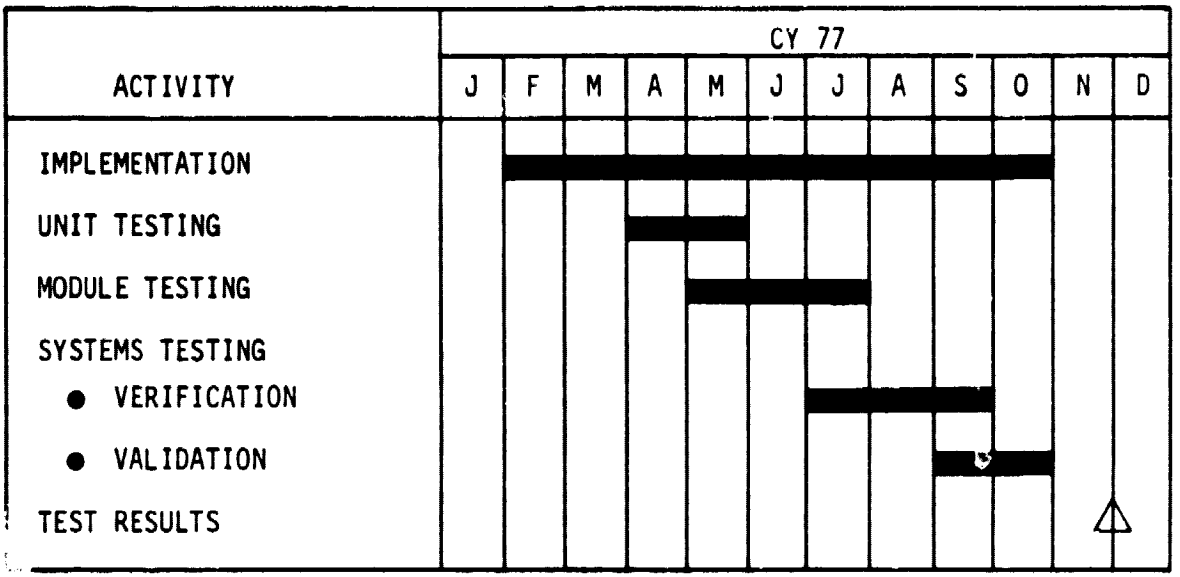
3.0 OVERVIEW OF THE TEST PLAN

The test plan execution will comprehensively exercise the software to verify and validate the working model. Verification implies that the software will execute and perform the functions specified in Reference 2 and addressed in Section 2.0 of this report. Validation implies that the working model results will be accurate.

The working model will be tested at the unit, module, and system levels. Each software routine (Control and Support, Computational, and Utility) will be coded and checked out as a unit. Units will be tested as each routine is coded. The units will be coded in a fashion to facilitate module development. Modules are a collection of units that perform a specific working model function. Modules will be developed in a "bottom-up" order to exercise the more complicated interfaces among Control and Support Routines, Computational Routines, Utility Routines, and the Consumables Analysis Data Base prior to the less complicated interfaces among Control and Support Routines alone. The modules will be integrated into a complete program. The program will be tested in a hands-on systems environment to verify all proposed working model capabilities and to validate all working model results.

The following Sections of this report describe the unit test, module test, and systems test procedures. Table II presents a test schedule. The test results will be published on completion of testing.

Table II. The Mission Planning Processor
Working Model Test Schedule



4.0 UNIT TEST

The working model software consists of the Control and Support Routines, the Computational Routines, and the Utility Routines. Each routine will be coded and checked out as a unit.

The steps to be followed in the coding and checkout of each unit are as follows:

a) Initial coding of the unit

b) Manual checking to detect and correct obvious errors

c) Compilation to detect syntax errors

d) Correction of compiler-detected errors

e) Recompilation to assure correction of all compiler-detected errors.

A top-down approach was applied to the design of the Mission Planning Processor and structured programming techniques will be used in the implementation of most of the working model software. One objective of top down/structured methodology is to produce small units of simplified code for ease of checkout. Therefore, the above five steps should be sufficient for unit testing.

5.0 MODULE TEST

After each unit has been accepted, the routines are to be collected into modules. Module construction is dictated by the functional paths through the working model illustrated in Figure 1. There are nine modules: RATE, ACTION, BUILD, ADD, DELETE, FLIGHT, PLAN, OUTPUT, and EXEC. The module name implies the controlling routine. Modules will be developed in a bottoms-up order to exercise the more complicated interfaces among Control and Support Routines, Computational Routines, Utility Routines, and the Consumables Analysis Data Base prior to the less complicated interfaces among Control and Support Routines alone.

A driver will be written to test each module. The RATE, ACTION, BUILD, ADD, DELETE, and FLIGHT modules can be completely tested in a batch mode environment. The PLAN, OUTPUT, and EXEC modules can only be partially tested by batch mode because of their "interactive" requirements. Therefore, the PLAN, OUTPUT, and EXEC module testing will be completed during the hands-on system test.

The modules are listed in Table III and described in the following subsections. The descriptions address the module objectives and the Control and Support Routines that make up each module. Although not directly addressed, the appropriate Computational and Utility Routines are included in each module.

5.1 THE RATE MODULE

The RATE module is the heart of the working model and consists of the RATE and CONSTRAINT routines. The RATE module constructs the consumables rate tables for each subsystem affected by a scheduled or unscheduled event and checks for rate constraint violations. These rate tables are internal tables used for constraint checking and consumables usage integration. The RATE module includes several utility routines to manipulate the consumables usage rates for each activity as stored in the Consumables Analysis Data Base.

A driver will be constructed to test all functions of the RATE module by itself. Then RATE module testing will continue because the RATE module is the basic part of the ACTION and BUILD modules.

Table III. The Mission Planning Processor
Working Model Modules

MODULE	UNITS	FUNCTIONAL FLOW*
RATE	RATE Routine	37/5-122
	CONSTRAINT Routine	23/5-48
ACTION	ACTION Routine	15/5-14
	RATE Module	
	CONFLICT ROUTINE	21/5-36
	SPECIAL Routine	39/5-137
BUILD	BUILD Routine	17/5-25
	SPECIAL Routine	39/5-137
	RATE Module	
	CONFLICT Routine	21/5-36
ADD	ADD Routine	16/5-19
	POOL Routine	35/5-117
	SEQUENCE Routine	38/5-130
	ACTDIS Routine	14/5-10
	ACTION Module	
DELETE	DELETE Routine	24/5-59
	SEQUENCE Routine	38/5-130
	ACTDIS Routine	14/5-10
	ACTION Module	
FLIGHT	FLIGHT Routine	29/5-79
	DELETE Module	
	SPECIAL Routine	39/5-137
	RATE Module	

*Figure/Page number of the Control and Support Routine flow chart in Reference 2.

Table III. The Mission Planning Processor
Working Model Modules (Concluded)

MODULE	UNITS	FUNCTIONAL FLOW*
PLAN	PLAN Routine	34/5-103
	ADD Module	
	DELETE Module	
	FLIGHT Module	
	LINECK Routine	32/5-91
	DISPLAY Routine	25/5-63
OUTPUT	OUTPUT Routine	33/5-95
	FILE STORE Routine	
	TIMELINE Routine	
	DISPLAY Routine	25/5-63
	CONSUM HISTORY Routine	
	CONSUM QUANTITIES Routine	
EXEC	EXEC Routine	13/5-5
	OUTPUT Module	
	INITIAL Routine	30/5-85
	BUILD Module	
	PLAN Module	
	FILE ONE Routine	27/5-72

*Figure/Page number of the Control and Support Routine flow chart in Reference 2.

5.2 THE ACTION MODULE

The ACTION module consists of the ACTION routine, the RATE module, the CONFLICT and SPECIAL routines. The ACTION module will construct the File 1 schedule data set, detect scheduling conflicts, construct consumables rate tables, and detect consumables rate violations. Common block and on-orbit activities will be input to construct a pseudo Flight Data File 1.

5.3 THE BUILD MODULE

The BUILD module consists of the BUILD and SPECIAL routines, the RATE module, and the CONFLICT routine. The BUILD module reconstructs the scheduling conflict table, the consumables rate tables, and the rate violation table from a previously stored Flight Data File 1. A pseudo Flight Data File 1, including the common blocks and on-orbit activities required for a skeleton mission will be used as input to the BUILD module.

5.4 THE ADD MODULE*

The ADD module consists of the ADD, POOL, SEQUENCE, and ACTDIS routines and the ACTION module. The ADD module schedules an activity by establishing the activity number, setting the Flight Data File 1 cross reference parameters, and calling the ACTION module to complete the scheduling affects. Common block, single on-orbit activities, and cyclic on-orbit activities will be scheduled to test the ADD module.

5.5 THE DELETE MODULE*

The DELETE module consists of the DELETE, SEQUENCE, and ACTDIS routines and the ACTION module. The DELETE module unschedules an activity by erasing its effects for the Flight Data File 1 cross reference parameters, and calling the ACTION module to complete the unscheduling. Common block and single on-orbit activities will be unscheduled to test the DELETE module. Cyclic activities must be deleted one at a time the same way as single on-orbit activities.

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*The DELETE and ADD modules are used in sequence to modify a scheduled activity. This capability will be verified during the system test.

5.6 THE FLIGHT MODULE

The FLIGHT module consists of the FLIGHT routine, the DELETE module, the SPECIAL routine, and the RATE module. The FLIGHT module updates the common blocks if any flight phase times are changed during scheduling by calculating new phase times, and calling the RATE module to modify the scheduled usage rate data. If the on-orbit flight time is shortened, the FLIGHT module calls the DELETE module to erase all previously scheduled activities beyond the new end-of-flight time.

5.7 THE PLAN MODULE

The PLAN module consists of the PLAN routine, the ADD, DELETE, and FLIGHT modules, and the LINECK and DISPLAY routines. The PLAN module provides the interactive capability within the working model. The PLAN module acts as a middle manager calling on the other routines and modules to perform the basic working model functions of scheduling, modifying, or deleting consumables related flight activities. The capabilities of the PLAN module can only be completely tested during the hands-on system test.

5.8 THE OUTPUT MODULE

The OUTPUT module consists of the OUTPUT, FILE STORE, TIMELINE, DISPLAY, CONSUM HISTORY, and CONSUM QUANTITIES routines. The OUTPUT module provides the option to display, print, and store selected data generated by the working model. Only the CONSUM HISTORY capability to print detailed usage rate versus time data will be bench tested. The display and store capabilities will be tested during the hands-on system test.

5.9 THE EXEC MODULE

The EXEC module consists of the EXEC routine, the OUTPUT module, the INITIAL routine, the BUILD and PLAN modules, and the FILE ONE routine. The EXEC module controls the working model and calls other modules, at user request, to execute the user directed working model functions. The EXEC module can only be completely tested during the hands-on system test.

6.0 SYSTEM TEST

On completion of module testing, the modules will be integrated into the working model. The system tests will be conducted in a hands-on environment on the UNIVAC 1110 EXEC 8 using test cases designed to verify all proposed working model capabilities and to validate all working model results.

6.1 VERIFICATION

At least four different cases will be designed and executed to test the total working model system. The test cases include, but are not limited to the following:

Case #1 - A cold start exercising interactive scheduling

Case #2 - A restart exercising interactive scheduling

Case #3 - Exercise all schedule conflict possibilities

Case #4 - Exercise all rate violation possibilities.

Other system test cases may evolve from module testing. The results expected from each systems test case will be calculated before execution. The test cases should verify all proposed working model capabilities. Those capabilities are:

Initiation

- That a cold start produces a skeleton profile before any activity is interactively scheduled.
- That a restart will reproduce a previously saved profile including all scheduling conflicts, rate tables, rate violations, and output displays before any other activity is interactively scheduled.

Execution

- That the user interface displays accept, transfer, and display data correctly.
- That the user interface displays sequence properly.
- That flight phase times can be altered and the changes properly reflected in all affected data sets.

- That the effects of all activities scheduled beyond a new (shortened) flight end time will be erased.

- That all single and cyclic activities can be added to, modified on, or deleted from a skeleton profile (i.e., Cold Start) or a scheduled (i.e., Restart) profile.

- That a scheduling conflict warning is displayed on all possible combinations of activity-to-activity conflicts.

- That a rate violation warning is displayed for all consumables subsystems when a rate violation occurs.

Output

- That all output displays (Scheduling Conflict, Rate Violation, Timeline, Consumables Quantities) can be properly generated for all consumables subsystems.

- That detailed profiles of consumables usage rate versus time can be generated for printed output for all subsystems.

- That a warning will be displayed if the user attempts to end execution prior to saving a Flight Data File 1.

- That Flight Data File 1 can be generated and saved at the end of an execution.

6.2 VALIDATION

On completion of system test verification, at least five different cases will be executed to validate the results of the working model. The cases encompass the OFT2 through OFT6 flights.

The activity timeline and consumables requirements for each of these flights have been generated by NASA/JSC/MPAD using detailed models and documented in References 3, 4, and 5. The activity timeline for each flight will be scheduled using the working model and the consumables requirements generated by the working model will be compared to the documented MPAD results. The criteria used to validate the working model results for each consumables subsystem are as follows:

EPS

- If valid, the working model generated energy requirement (KWH) should approximately equal the MPAD generated energy requirements. The usage rates are derived from the same source and the processing is simply rate multiplied by time.

- The quantity of EPS cryo required, however, will differ because of the processing differences between the simplified working model and the MPAD detailed models. If valid, the difference should be within ±5 percent.

OMS and RCS

- The working model generated OMS and RCS propellant requirements will differ from the MPAD generated requirements. The working model utilizes an average usage rate instead of a flight specific usage rate used by the MPAD detailed models. If valid, the difference should be within ±5 percent.

ECLSS

- If valid, the working model generated ECLSS consumables (H_2, O_2, LiOH, and H_2O) requirements should approximately equal the MPAD generated requirements. The usage rates are derived from the same source and the processing is simply rate multiplied by time.

APU

- If valid, the working model generated APU consumables (Fuel and H_2O) requirements should approximately equal the MPAD generated requirements. The usage rates are derived from the same source and the processing is simply rate multiplied by time.

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3. "Updated Conceptual Flight Profiles for OFT-2 and OFT-3," NASA/JSC IN76-FM-17, April 2, 1976.

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