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MODIFICATION AND UPDATING OF THE MANNED ACTIVITY SCHEDULING SYSTEM (MASS) FOR SHUTTLE AND SHUTTLE PAYLOADS ANALYSIS

VOLUME II
SPACE SHUTTLE SORTIE PAYLOAD ANALYSIS

By R. C. Huyett
R. C. Ring

April 1973

Prepared under Contract No. NAS1-11674 by
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
San Diego, California
for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

During the very early stages in planning experiment payloads appropriate for a space shuttle sortie mission, the designers of the experiments and the supporting payload carrier work more or less independently. The principal investigator for an individual experiment has limited capability in predicting the impact that his experiment has on its support vehicle; and the vehicle design is, of necessity, based on a requirements analysis for a broad range of complete payloads and missions. When several experiments are grouped to form a payload, the overall compatibility of experiments and facility should be established as early as possible in the payload planning stage. Knowledge of time-dependent factors (e.g., crew activities, profiles of power use, ground target contacts, etc.) is required at the payload level to assist both the payload and support-vehicle designers. This report discusses the application of scheduling models to this problem.

The scheduling models used in this study are part of a system of mathematical models called the Manned Activity Scheduling System (MASS). These models are the result of a continuing effort by the Langley Research Center to develop and update a tool to meet the changing requirements associated with NASA manned space activities. The work described here was done under Langley Research Center Contract NAS 1-11674, Modification and Updating of the Manned Activity Scheduling System for Shuttle and Shuttle Payloads Analysis.

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General Dynamics Corporation, Convair Aerospace Division

SUMMARY

Space shuttle operations include a significant number of launches with a sortie laboratory serving as a facility for manned experimentation in space. Planning a program of space experiments for a facility of this type requires that both the composition of the laboratory payload and the schedule of experiment operations for each payload be carefully selected. In the current study, experiment operations are investigated using the Manned Activity Scheduling System (MASS) developed by Langley Research Center. Schedules provided by these models assist in selecting experiment groups that efficiently use the laboratory resources and yield the desired experiment accomplishment at the program level. An alternate use of the MASS models provides for establishing the time-dependent supporting resources required for a specified candidate payload.

A procedure for defining and analyzing shuttle sortie payloads was developed. This procedure was then applied to the definition of mixed-discipline experiment payloads for an Advanced Technology Laboratory (ATL) supported by two-man and three-man experiment crews. The experiments represent the research evolving at Langley that can operate beneficially in near-earth orbit. ATL payloads, including schedules of experiment operations, were defined to realize a high percentage of experiment accomplishment. The study considers the sensitivity of experiment accomplishment rate to variations of system parameters such as crew cross training, crew operations, shuttle and laboratory resources, ground target systems, and operational orbits.

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1 INTRODUCTION

This report discusses the problem of grouping manned experiments into shuttle sortie mission payloads. The necessity for experiment grouping arises when there exist a number of more or less independent experiments that are candidates for sortie mission payloads but which individually cannot efficiently use all the available supporting resources. This situation should occur with increasing frequency as world-wide attempts to exploit the shuttle sortie mission grow.

The current study concentrates on grouping Langley Research Center technology experiments into payloads suitable for an Advanced Technology Laboratory (ATL). Key elements of this study are:

(a) Advanced Technology Laboratory (ATL) — An orbiting laboratory for conducting manned space experiments; also a sortie mission payload for the shuttle. The ATL includes a pressurized volume and a pallet.

(b) ATL Experiments — Thirty experiments in six scientific disciplines representing the space oriented research evolving at Langley Research Center. These Langley experiments are defined to a Phase A level of detail in Reference 1. Two of the 30 experiments use common experiment equipment and the data acquired during one common operation can meet the experiment objectives of each experiment. For this reason these two experiments are combined in this study to yield a total of 29 experiments.

The ATL experiments are mostly independent, so that they may be grouped in a variety of ways to form ATL payloads. Most of the ATL experiments are structured so that the operational phase of the experiment is repeated several times throughout the sortie mission. Although all repetitions of these experiments are desired, meaningful results are obtained when only a fraction of the desired repetitions are actually completed.

The term payload definition as used in this report refers to the identification of the ATL experiments on a particular flight, and the schedule of operations for each individual experiment. This definition process considers the many interrelated system parameters that serve to constrain the payload. Some of these parameters are shown in Figure 1.

Once the experiment complement of a candidate payload is identified, the experiment operations can be scheduled throughout the mission, taking into consideration the desired activity cycles for the individual experiments. These time-dependent operations provide a means for establishing supporting resource requirements for the payload, or for establishing permissible schedules of experiment operations

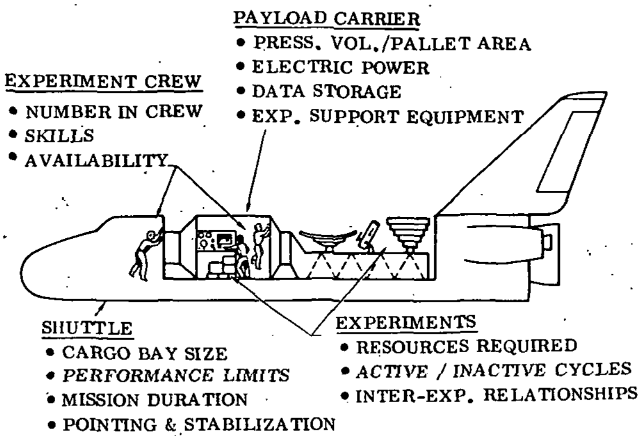


Figure 1. Major System Parameters in Shuttle Sortie Mission Payload Analysis

under specified resource constraints. Schedules of crew and experiment activities are provided from the Manned Activity Scheduling System (MASS) models. Background on the MASS models and a summary of model modifications accomplished on this contract are contained in Volume I of this report.

Succeeding sections in this volume are organized as follows. First the procedure used to define and evaluate sortie mission payloads is presented, together with an illustrative example. Then the analysis of specific ATL payloads is presented. Also included in that section is a discussion of some of the more important problem variables considered in this study. Detailed data on the ATL experiments and payload schedules are presented in Appendixes.

2 SYMBOLS

Identification code of experiments

CN.1	Microwave interferometer navigation and tracking aid
CN.2	Microwave radiometric measurements
CN.3	Precision laser ranging and altimetry
CN.4	Autonomous navigation
CN.5	Microwave altimetry
CN.6	Search and rescue aids
CN.7	Multipath measurements
CN.8	Imaging radar
CN.9	RF noise
EO.1	LIDAR measurement of cirrus clouds and lower stratospheric aerosols
EO.2	Tunable lasers for high resolution studies of atmospheric constituents
EO.3	Multispectral scanner for coastal zone oceanography
EO.4	Shuttle delivery atmospheric and oceanographic ground truth payloads
PH.1	Spacecraft wake dynamics
PH.2	Barium plasma cloud release on sunward side of earth
PH.3	Optical property of aerosols
PH.4	Mapping of upper atmosphere neutral gas parameters
PH.5	Spacecraft radiation environment
PH.6	Ultraviolet meteor spectroscopy from near-earth orbit
MB.1	Colony growth in zero gravity
MB.2	Interpersonal transfer of micro-organisms in zero gravity
MB.3	Electrical field opacity in biological cells
MB.4	Electrical characteristics of cells
MB.5	Spec. properties of biological cells
CS.1	Carbon deposition and transport in zero gravity
CS.2	Zero gravity steam generator
EN.1	Sampling airborne particles in space cabin
EN.2	Orbital fatigue experiment
EN.3	Environmental effects on nonmetallic materials
EN.4	Fluids in zero gravity

3 PROCEDURE FOR PAYLOAD DEFINITION AND EVALUATION

A procedure for defining and evaluating sortie mission payloads consisting of manned experiments is described in this section. This procedure starts with gross estimates and logically proceeds to detailed analysis of the relationships between experiment groupings, the payload carrier, and the shuttle. The Manned Activity Scheduling System (MASS) is ideally structured for application to this type of problem and is used extensively. The procedure is described separately since it is apparent that some of the procedural steps, especially those involving the MASS models, could benefit a variety of problems in the general area of sortie payload analysis. The particular application depends on which system parameters are fixed and which are still flexible, and whether the definition of a single payload or a program involving several payloads is involved. Table 1 illustrates various aspects of the sortie payload analysis problem.

TABLE 1.— PROBLEM CATEGORIES IN SORTIE PAYLOAD ANALYSIS

Problem	Fixed	Variable
Payload definition and evaluation	Space shuttle Payload carrier Experiments Experiment crew	Experiment assignment to payload No. flights in program Schedules of experiment completions
Design requirements shuttle and payload carrier	Experiments Experiment assignments Experiment crew	Supporting resources: Space shuttle Payload carrier
Crew system studies	Space shuttle Payload carrier Experiment assignments	No. experiment crew Crew crosstraining Crew availability Crew shifts and nonexperiment tasks
Experiment design	Space shuttle Payload carrier Experiment crew	Experiment support requirements Experiment activity cycles

In payload definition and evaluation, the tendency is to fix the experiments and the experiment support facility while adjusting the assignment of experiments to individual payloads and specifying the schedule of experiment operations. Payloads are constrained in a number of ways, including the physical limits of the payload carrier (e.g., laboratory), shuttle performance, crew availability, supporting subsystem resources, etc. In a broad sense, the payload definition process entails a series of compatibility checks, culminating in detailed schedules of experiment operations fully compatible with system constraints. Evaluation is based on the degree to which experiment program objectives are met, and the efficiency with which the laboratory resources are used. Major steps in the analysis are shown in Figure 2.

Detailed steps in the procedure are described in the following paragraphs, first in general terms, followed by an illustrative example based on the ATL payload analysis. A summary of each step in the definition and evaluation procedure is given in Table 2.

Step 1 — Statement of the Problem and Groundrules

General Considerations. — A clear statement of the problem will scope the analysis effort, give initial direction to the study, and provide a basis for quantitative evaluations

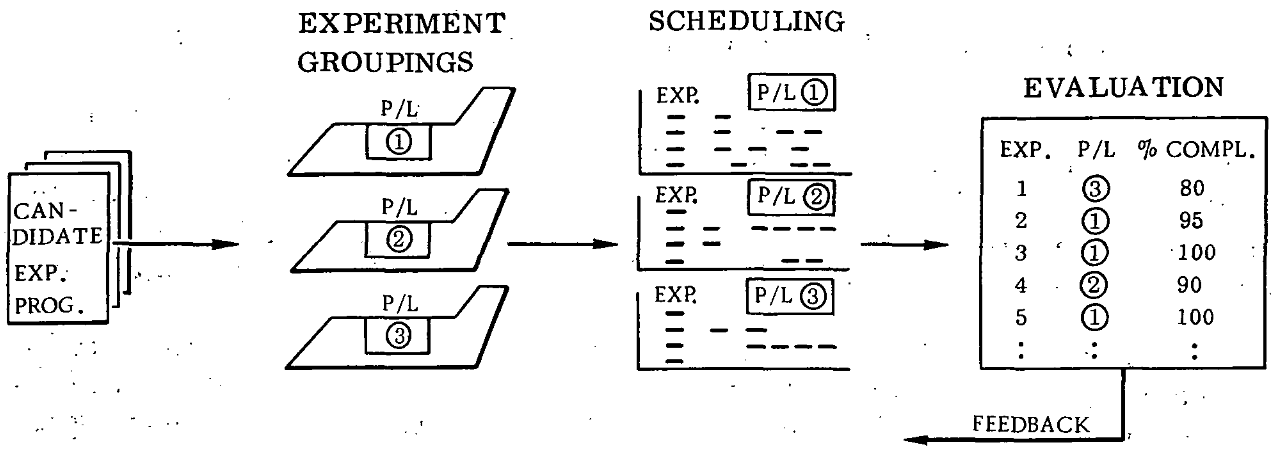


Figure 2. Major Steps in Sortie Mission Payload Analysis

TABLE 2. – STEPS IN PAYLOAD DEFINITION AND EVALUATION PROCEDURE

Step		Factors considered	Output
1	State problem and groundrules	• Program data • Hardware elements • Priorities • Experiment repeats	• Define problem variables and study objectives
2	Estimate number of payloads and orbits	• Total program resource requirements • Orbit preferences of experiments	• Minimum number of payloads in program • Orbit for each payload
3	Select nucleus experiments	• Inter-experiment relationships • Experiment availability	• Identification of nucleus experiments each payload
4	Gross compatibility check on nucleus experiments	• Potential constraint for nucleus experiments – weight, volume, pallet area, etc.	• Tentative OK to payloads or corrective feedback
5	Complete payload packaging	• Cumulative resource requirements for experiments on each payload • Desired distribution of experiments across all payloads	• Tentative groupings of experiments for all payloads in program
6	Inter-experiment compatiblity check	• Environment – contamination g level, EMI, etc. • Pointing	• Specific requirements to suppress concurrent experiment operations
7	Scheduling	• Experiment operations over mission • Experiment operations selected mission days	• Schedules of experiment operations • Resources used
8	Payload analysis	• Experiment completions – all payloads • Use of available resources	• Acceptance of payloads or corrective feedback

(see Table 1). Major system parameters should be identified and the availability of required input data established, consistent with the problem under consideration.

Key study groundrules also should be identified at this time if known. For example, constraints on the experiment crew workday, the availability of the shuttle crew to participate in experiment activities, or the acceptability of partially completed experiments can impact analysis results and should be stated at the outset.

ATL Example. — The 30 ATL experiments of mixed disciplines represent the "early years" program of space experimentation at Langley. Payloads, composed of groups of these ATL experiments, are to be defined so that all objectives of the experiments are met subject to the constraints imposed by the space shuttle, sortie laboratory with 9m (30 ft) pallet, two-man experiment crew and a 7-day sortie mission. More than one flight is required to accomplish all 30 ATL experiments at least once, so that a set of ATL payloads is to be defined and evaluated. Consistent with minimum cost, however, the set of ATL payloads is to be as small as possible. Partial completion was assumed to be acceptable for most experiments, so that there is no reason per se to prevent an experiment from appearing on more than one payload.

In the absence of specific programmatic information concerning the number of repeats (flights) desirable for each experiment, a uniform number of repeats for all experiments was selected as an objective. Other programmatic groundrules (e.g., twice as many flights for a specified subset of experiments compared to the remaining experiments), would lead to entirely different results; indeed a satisfactory problem solution in terms of overall experiment objectives and efficient resource use may be impossible to achieve for a given problem formulation. In such a case the problem can be restated in terms that may permit a satisfactory solution. Such is the iterative nature of the payload definition and evaluation problem. Figure 3 illustrates the key features of the ATL problem. Further discussion of this problem is found under the heading "Analysis of ATL Payloads."

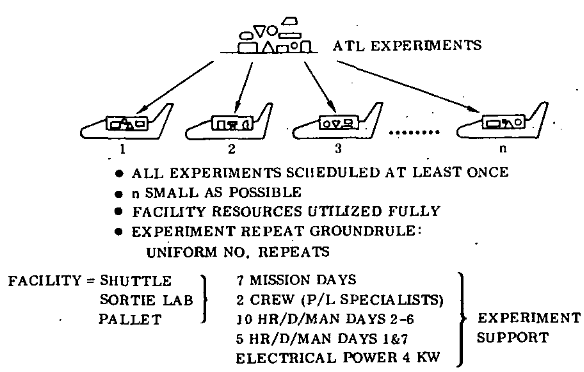


Figure 3. Schematic Representation of ATL Problem

Step 2 — Estimate the Number of Payloads and Orbits

General Considerations. — This step is problem dependent and is required when a population of experiments must be packaged into distinct payloads. An estimate of the minimum number of payloads needed to accommodate all the experiments is readily made by ignoring the inefficiencies associated with scheduling experiment operations. Total resources required by the total experiment program are first obtained then divided by the appropriate resource constraint, if applicable, of the supporting vehicles; e.g., shuttle and Sortie Laboratory.

ATL Example. — The total resources required by the ATL experiment program indicate a requirement for at least three payloads, as determined by crew time and pallet area constraints (Table 3). These payloads are designated as payloads 1, 2, and 3. Orbits are assigned to each of the payloads to best meet the desired orbit requirements of the experiments. Crew time available per flight reflects a 10-hour workday for each crewman for experiment activities for mission days 2-6 and a 5-hour workday for experiments on mission days 1 and 7. The electrical energy available is based on an assumed 4.0 kW continuous power available to the payload from the Sortie Laboratory for seven mission days. Tape storage for experiment-generated data and shuttle pointing in support of experiments were assumed to be more than adequate to meet all experiment requirements.

TABLE 3. — ESTIMATE OF MINIMUM NUMBER OF ATL PAYLOADS IN PROGRAM

System resource	Total program resource requirement	Resource availability each payload	Minimum number of ATL payloads
Crew hours for experiments	244	120	3
Pallet area	92.9m^2 (1000 ft^2)	38.6m^2 (415 ft^2)	3
Pressurized volume	15.9m^3 (561 ft^3)	17.0m^3 (600 ft^3)	1
Electrical energy	556 kWh	672 kWh	1

Estimated minimum number of ATL payloads in program = 3

Payload	Orbit assignments
1	370 km (200 n. mi.) × 60°
2	556 km (300 n. mi.) × 60°
3	185 km (100 n. mi.) × 90°

The three ATL payloads are evaluated as a set in terms of meeting the objectives of the ATL experiment program, as outlined in Step 1.

Step 3 — Select Nucleus Experiments

General Considerations. — Specification of nucleus experiments has the effect of forcing (or excluding) one or more experiments on the same payload. Experiment placement by this method may reflect: a) the favorable or unfavorable relationship of some experiments, b) the desire to distribute certain key experiments across the set of payloads, c) the requirement to account for the delayed development schedule of some experiments, d) provision for the orbit preferences of some experiments.

ATL Example. — Nucleus experiments for the ATL payloads are exclusively in the Com/Nav and Earth Observation area, since these were the only experiments in which the mutually supportive nature of the experiments was identified. Figure 4 contains a matrix identifying these requirements and identifies the resulting nucleus experiments. All nucleus experiments in this case use pallet-mounted experiment equipment. The ATL experiments in Figure 4 are listed by alphanumeric code; e.g., CN.1 = first Com/Nav experiment, EO.1 = first Earth Observation experiment, etc. A complete list of the Langley experiments and the associated alphanumeric codes used throughout this text are found in the table of symbols.

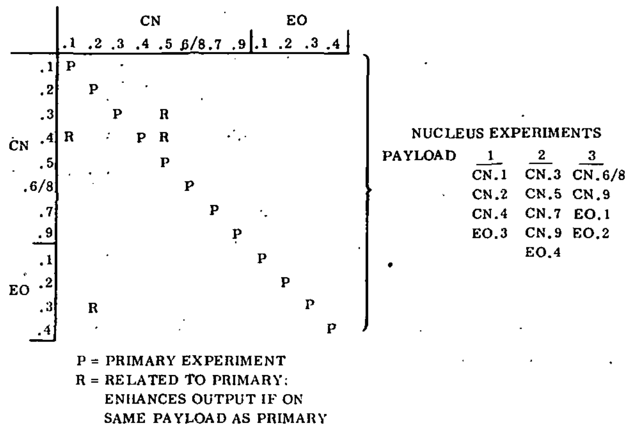


Figure 4. Nucleus Experiments for ATL Example

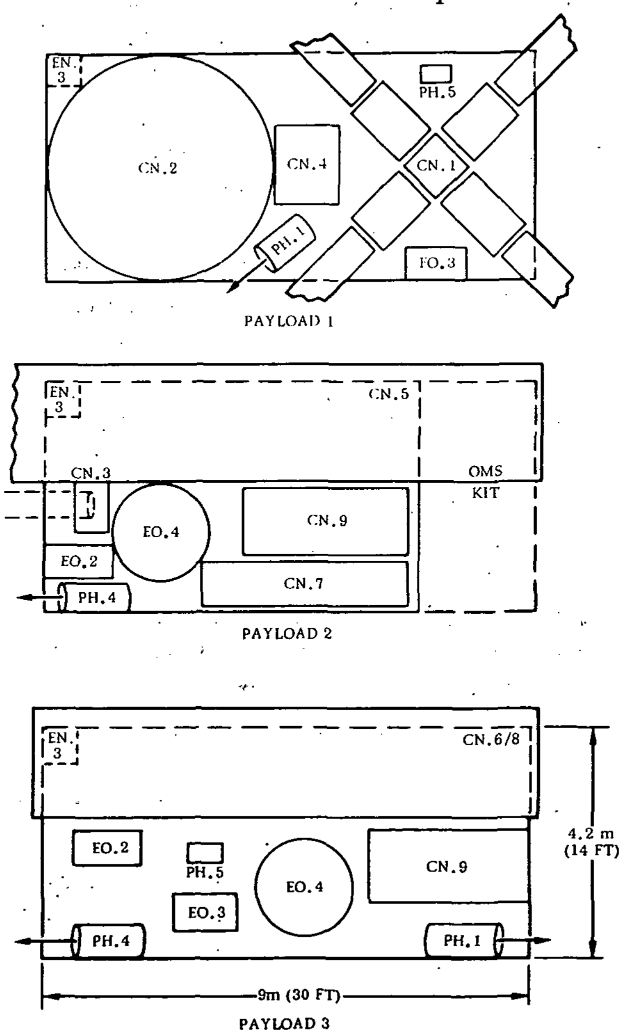


Figure 5. Pallet Area Layouts for Example ATL Payloads

Step 4 — Gross Compatibility Check on Nucleus Experiments

General Considerations. — This step provides for the identification of a possible no-go situation relatively early in the payload definition process by checking the supporting resources required for each group of nucleus experiments. The characteristics of the nucleus experiments and associated problem constraints should suggest the most meaningful checks to make at this point.

ATL Example. — Since the nucleus experiments on these payloads all have pallet mounted experiment equipment, a gross check on the pallet equipment layouts is indicated. Plan views of these layouts are shown in Figure 5, and indicate that the nucleus experiment equipment is compatible with a 9m (30 ft) pallet for the three example payloads. Projected areas shown are for the deployed antennas, some of which are stowed in a folded position for ascent to and descent from the operational orbits. Allowance is made for an Orbit Maneuvering Subsystem (OMS) kit in the shuttle cargo bay for the increased orbit maneuver requirements associated with the 556 km (300 n. mi.) altitude of the second payload.

Step 5 — Complete Payload Packaging

General Considerations. — Payload packaging is completed by adding experiments to the nucleus group of experiments of each payload. The objective of this step is to assign experiments to each payload so that the total resource requirements of the unscheduled experiments are roughly equal to, and slightly in excess of, the critical resources provided by the shuttle, payload carrier, and experiment crew. The excess in requirements prior to scheduling is provided to ensure as full resource use as possible after scheduling. It is anticipated that experiment accomplishment and resource use will be slightly degraded under scheduling. The cumulative total of critical resources required for each payload is adjusted with the addition of each experiment to a particular payload. At the time the experiments are assigned to each payload of the set, an attempt should be made to adhere to the groundrule for desired experiment repeats. In other words, the experiments are distributed among the payloads in such a way that the overall record of experiment completions will approach the program objective.

At this stage the experiment assignments are considered tentative and subject to scheduling later. After scheduling is accomplished and experiment completions are analyzed, it is usually necessary to return to this step and modify the original experiment assignments to improve the overall distribution of scheduled completions. This process is usually accomplished by adjusting the scheduling priority of selected experiments, although in some cases certain experiments may be eliminated from (or added to) the payload. The scheduling priority controls the sequence in which the experiments are selected for scheduling; this process will be explained in later steps.

Experience has shown that the success in defining a set of payloads with a desired distribution of experiment completions and high use of critical resources is largely dependent on accepting partial completions of some experiments on some flights.

ATL Example. — Experiment assignments to each of the three ATL payloads are shown in Table 4. These assignments reflect the results of several iterations in an attempt to achieve a goal of a uniform number of experiment repeats. Scheduling priorities shown at the left control the order in which experiments are scheduled and therefore roughly determine the probability that a particular experiment will be scheduled at all on a given payload. In the example, all Com/Nav and Earth Observation experiments were given high scheduling priorities to maximize their chances of being scheduled. This was especially important for the Com/Nav experiments, since pallet-area limitations prevented repeating these experiments on different payloads. The cumulative crew hours and electrical energy associated with the experiments for each priority level on each payload are noted in the table. The lower-priority experiments drive the total resource requirements above those provided by the experiment crew and orbit facility; they are included to provide a substitute in case a higher-priority experiment cannot be scheduled. The experiment groupings must survive later scheduling analysis, so the final groupings may not contain all the experiments in Table 4.

Step 6 — Inter-Experiment Compatibility Check

General Considerations. — Incompatible experiments were eliminated from the same payload in Step 3. However, it may be necessary to preclude the simultaneous

TABLE 4. — COMPLETING PAYLOAD PACKAGES FOR THREE EXAMPLE ATL PAYLOADS

Schedule Priority	Payload 1 Assigned exp	Payload 1 Cumulative Resources crew hrs	Payload 1 Cumulative Resources kWh	Payload 2 Assigned exp	Payload 2 Cumulative Resources crew hrs	Payload 2 Cumulative Resources kWh	Payload 3 Assigned exp	Payload 3 Cumulative Resources crew hrs	Payload 3 Cumulative Resources kWh
10,000	CN.1 .2 .4 EO.3	72	30	CN.3 .5 .7 .9 EO.4	55	169	CN.6/8 .9 EO.1 .2	39	156
1,000	PH.5 .6 MB.2 .4 CS.1 EN.1 .3	90	143	PH.2 MB.1 .3 EN.4	63	197	PH.1 .2 .3 MB.5 CS.2 EN.3	104	192
100	PH.4 .1 .3 MB.5 CS.2 EN.4	135	189	EO.1,.2 PH.6 MB.2,.4 CS.1 EN.2 .3	115	285	EO.3 .4 PH.4 .5 MB.2,.3 EN.1	126	321
1	PH.2 MB.1 .3 EN.2	167	232	PH.1 .3 .4 CS.2	153	312	PH.6 MB.1 CS.1 EN.3	132	337

operation of certain experiments on the same payload. This situation may arise when conflicting demands are made on the shuttle orientation, or because the environment (cleanliness, g-level, EMI, etc.) required by one experiment is violated by another. In this step an analysis is made of the experiment groupings on each payload to determine such conflicts.

ATL Example. — Figure 6 shows an example of certain combinations of ATL experiments that are to be prevented from operating simultaneously. The matrix defines a need to accomplish the following:

a. Prevent scheduling experiment PH.2 during the period in which any Com/Nav or Earth Observation experiment is operating.

b. Prevent scheduling experiment EO.2 during the operation of experiments CN.1, CN.2, CN.3, CN.6/8.

c. Prevent scheduling experiments CN.1 and CN.3 at the same time.

	PH.2	CN.1	CN.2	CN.3	CN.4	CN.5	CN.6/8	CN.7	CN.9	EO.1	EO.2	EO.3	EO.4
PH.2		C	C	C	C	C	C	C	C	C	C	C	C
CN.1	C			C							C		
CN.2	C										C		
CN.3	C	C									C		
CN.4	C												
CN.5	C												
CN.6/8	C										C		
CN.7	C												
CN.9	C												
EO.1	C												
EO.2	C	C	C	C			C						
EO.3	C												
EO.4	C												

C = CONFLICT

Figure 6. Simultaneous Scheduling Conflicts for ATL Payloads

The physical basis for identifying the conflicts shown in Figure 6 is that certain experiments require the exclusive use of the single observation window in the Sortie Laboratory, while other experiments can share this window using a common camera. A mechanization of these conflicts in the MASS model input will force experiments to timeshare the observation window when appropriate.

Step 7 — Scheduling

General Considerations. — The purpose of scheduling experiment activities is to provide an additional check on the compatibility of various system elements. Up to this point, the experiment packages have been structured to meet the desired level of program accomplishment and remain within gross resource limits of the crew, payload carrier, and shuttle. Scheduling will provide a check on whether or not the activity profile and resource requirements of the experiments on a given payload are compatible with each other, with ground support (viewing opportunities for ground targets and communication stations), and with facility resources. The desired schedules are produced as outputs of the MASS models, as previously mentioned. Two models are used to provide schedules at two levels of detail. The General Scheduling Model (GSM) provides a schedule of experiment activity over the entire mission. The One Day Model (ODM) schedules activities over the 24-hour period of a selected mission day. Experiment activities scheduled by the ODM are those previously scheduled by the GSM for that day, and are therefore known to be consistent with the total daily resource constraints considered by the GSM. The way in which these two models are used to check on the consistency among experiment activities at various levels is shown in Figure 7.

ATL Example. — Inputs for operating the GSM and ODM are described in the respective user's manuals, References 2 and 3. Experiments are typically described by a sequence of separate events describing the setup, calibration, operation, shutdown, etc., of the experiment in question. Appendix B describes the way in which experiments are coded for the MASS scheduling models and summarizes the experiment data bank developed for the ATL experiment program.

The GSM schedules each experiment separately, adhering to the desired experiment activity profile, but subject to the limited resources available to the experiment at the time it is scheduled. The resource constraints checked by the GSM are:

a. Daily Constraints:

Crew hours/day
Electrical energy - kWh/day
Digital data storage - MB/day
TV and voice transmission - hr/day

b. Total Mission Constraints:

Experiment equipment weight
Experiment equipment volume
Shuttle pointing duration

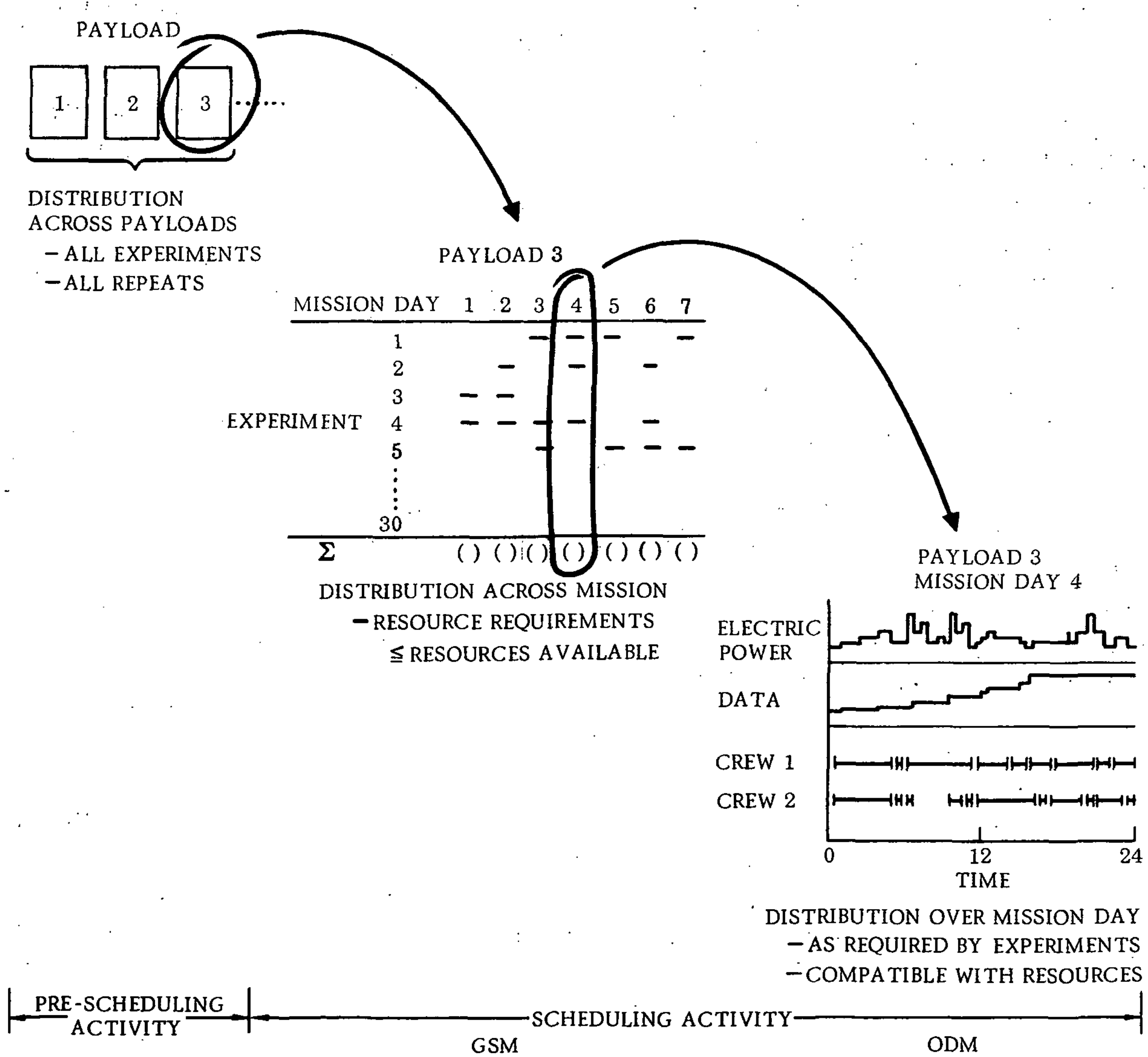


Figure 7. Levels of Payload Operations Analysis

After each experiment has been considered for scheduling, the GSM outputs the schedule for each mission day.

A sample of this output for one mission day of one of the example ATL payloads is shown in Figure 8. Scheduled events are identified by a six-character name, shown in the left-most column of the printout. For each event, the GSM outputs the hours worked by each crewman, the power source used (LB: laboratory, M1: module 1, etc.), the electrical energy used (ac and dc); voice communications hours, TV hours, and pointing hours used; and the digital data generated. Daily resource totals are given at the bottom of the page, where the indicator "ALL" under power source means the total energy for all power sources used by events that day.

A separate output of the GSM indicates the resources still available for each mission day after all scheduling opportunities have been checked. Necessary information for running the ODM is processed by the GSM and passed on to the ODM.

The ODM schedules both experiment and housekeeping activities throughout the mission day consistent with the desired experiment activity profile but subject to the following constraints:

Crew availability
Peak power level
Digital data storage
Experiment support equipment availability
Opportunities for viewing earth or celestial targets
Nonconflicting shuttle orientation requirements
Experiment work area location and volume

The housekeeping activities (including eating, personal hygiene, etc.) performed by the experiment crew are called tasks. Tasks are subdivided into events and input to the scheduling models in exactly the same format as experiments. Unless instructed to the contrary, both the GSM and ODM schedule all tasks before the start of experiment scheduling. Output of the ODM provides the start and finish times of all experiment activities, the timelines of resources used, and daily totals. Also noted are activities that were not scheduled and the constraints involved.

An optional output of the ODM is available for systems having either a Cal Comp or SC-4020 plot capability. An example of the latter is shown in Figure 9. On the crew activity profile, a heavy dark horizontal line between two short heavy vertical lines indicates that a crewman is working, eating, or sleeping during this time interval. The specific activity the crewman is performing is identified by a six-character label.

GENERAL SCHEDULING MODEL   DATE 12/09/72   TIME 05.37.23.   PROBLEM 02572027   PAGE 43

10 TASK EVENTS AND 25 EXPERIMENT EVENTS SCHEDULED ON DAY 4

EVENT ID	HOURS WORKED BY MAN 1	HOURS WORKED BY MAN 2	POWER SRC	POWER DC KWH	POWER AC KWH	VOICE HOURS	T.V. HOURS	POINT HOURS	DIGITAL MEGABITS
S.H.1	1.00								
S.H.2		1.00							
M.P.1	1.00								
M.P.2		1.00							
P.H.1	.75								
P.H.2		.75							
EAT.1	3.00								
EAT.2		3.00							
M.C.1	.25								
M.C.2		.25							
EN.4B			LB	.00					43.2000000
MB.3B			LB	1.44					
MB.4D			LB	1.44					
CN.9B	1.50		LB	.18				1.50	
CN.9C		1.50	LB	.18				1.50	
CN.5B	.50		LB	14.40				.50	
CN.5C	2.00							2.00	432000.000
CN.3B		.50	LB	14.40				.50	
CN.3C		2.00						2.00	75600.0000
CN.7B	1.00		LB	3.60				1.00	36400.0000
EN.7A		1.00							
EN.3B			LB	2.00					
EN.3C		1.00							
MB.1B			LB	1.49					
EO.1B	.25		LB	2.75				.50	
EO.1C	.25		LB	.35				.50	
MB.2	.25	.25	LB	3.36					
PH.6B	.33		LB	.24				.33	
EO.2B	.25								983.000000
EO.2C			LB	.02				1.00	
PH.3	4.00		LB	.27					43.2000000
EN.3D		1.00							
EN.3E			LB	1.00					
EN.3F		1.00							
PH.1		2.00	LB	.40					3640.00000
TOTALS	16.33	16.25	ALL	47.52				11.33	603709.400

Figure 8. Sample of General Scheduling Model Output

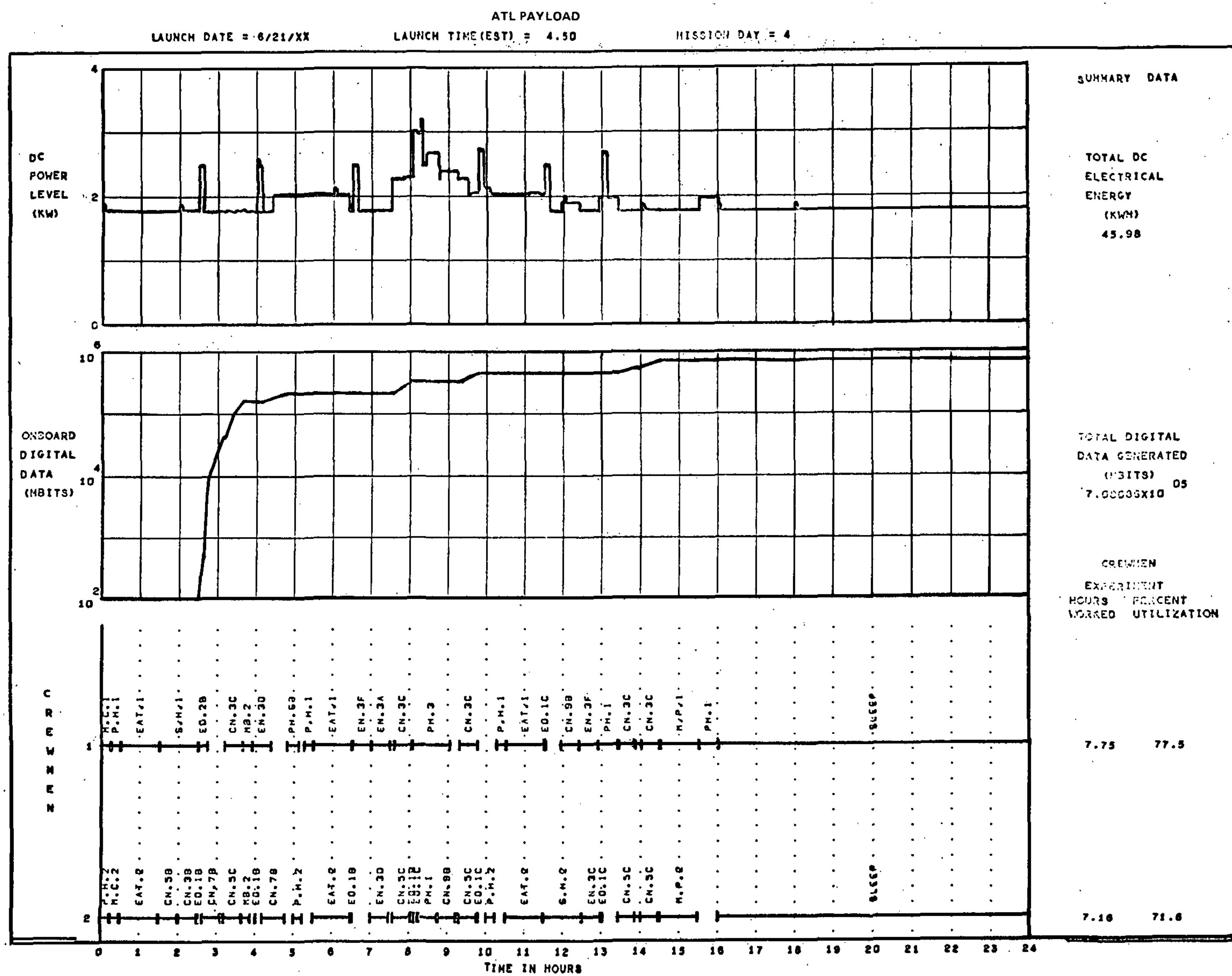


Figure 9. Sample One Day Model Output

Step 8 — Payload Analysis and Evaluation

General Considerations. — The purpose of this step is to evaluate the set of payloads previously defined to determine if the scheduled experiment operations meet the overall objectives of experiment accomplishment and if the resources provided to the payload are efficiently used. Feedback is used when the evaluation is unfavorable, and the appropriate procedural steps are repeated. As mentioned in Step 1, there is no assurance beforehand that a given problem has an acceptable solution under the problem constraints and groundrules adopted. The required feedback may extend to the point of payload carrier redesign or redefinition of experiments.

For a given problem, experience gained through the trial and error process of modifying model inputs and noting the effect on the resulting experiment accomplishment will indicate when further iterations are unproductive. The interrelationship between the GSM and ODM with the major feedback loops is shown in Figure 10. Experience to date has shown that revisions to the scheduling priorities have been effective and the most frequently used method for changing the distribution of experiment completions across the payloads in a given set of payloads. At other times it is advantageous to change the way the experiment is coded for the MASS models; i.e., change the selection of descriptors used to simulate the experiment. The procedure for summarizing the experiment completions for all payloads may vary; one method is illustrated in the ATL example that follows:

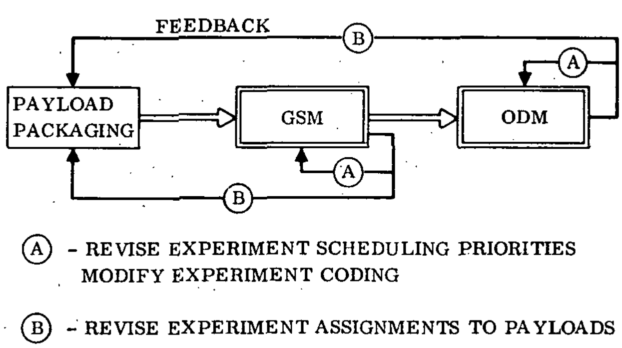
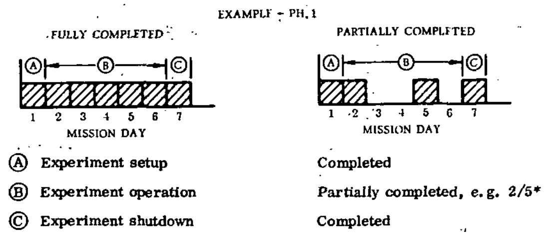


Figure 10. Interrelationship Between General Scheduling Model and One Day Model

ATL Example. — The results of scheduling the three example payloads on the GSM are shown in Table 5. The fractions refer to the number of daily operations scheduled on experiments with requirements for repeated operations. For example, an operational cycle of experiment PH. 1 was accomplished five of the five days desired on Payload 1, on two of the five days desired on Payload 2, and five of the five days desired on Payload 3, for a cumulative completion of 2-2/5 times the nominal required operations. Effectively, experiment PH. 1 was completed slightly more than two times over the three flights of the three example payloads.

A problem objective was to obtain a uniform number of repeats for all experiments, to the extent permitted by system constraints. For the example problem this amounted to a single repeat of all experiments. The data shown in Table 5 are the results of

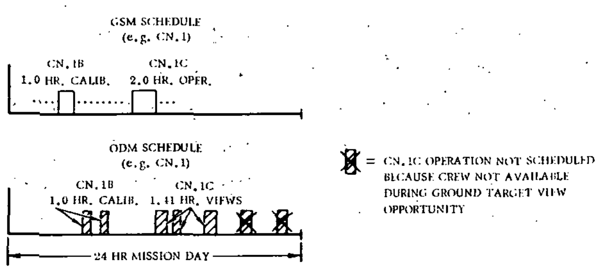
TABLE 5. — SUMMARY OF GSM SCHEDULES FOR EXAMPLE ATL PAYLOADS



Experiment	Experiment Completions P/L 1	P/L 2	P/L 3	Σ3 P/L
PH.1	1	*2/5	1	2 2/5
.2		1		1
.3	3/7	4/7	5/7	1 5/7
.4	6/7		6/7	1 5/7
.5	1		1	2
.6	1	1	5/7	2 5/7
CN.1	1			1
.2	1			1
.3		1		1

* 2/5 = Scheduled on 2 days of desired 5 days operation

TABLE 6. — SUMMARY OF ODM SCHEDULES FOR EXAMPLE ATL PAYLOADS



Payload 1 Exp.	GSM Sched.	ODM Sched.	Payload 2 Exp.	GSM Sched.	ODM Sched.	Payload 3 Exp.	GSM Sched.	ODM Sched.
CN.1B	1.0 hr	1.0	CN.3B	0.5 hr	0.5	CN.6/8	2.0 hr	1.31
CN.1C	2.0 hr	1.41	CN.3C	2.0 hr	1.17	CN.9B	3.0 hr	2.60
CN.2C	0.67 hr	0.67	CN.7B	1.0 hr	0.57	EO.2B	0.3 hr	0.3
CN.2D	0.67 hr	0.67	CN.9B	1.5 hr	0.96	EO.3	1.0 hr	0.4
CN.4B	2.0 hr	2.4						
CN.4C	0.52 hr	0.26						

several iterations through the GSM and represent what was judged to be the nearest approach to a uniform number of repeats that was practical to achieve under the problem groundrules. Thus, the single performance obtained with the Com/Nav group of experiments was a result of limited pallet area and consequent restriction of these experiments to only one payload. Attempts to increase the number of scheduled operations of experiment PH.2 generally resulted in fewer completions of other experiments to the overall degradation of the set of payloads.

As a general procedure, before final payload selection, the One Day Model is used to examine and timeline typical mission days. Then when the desired set of payloads is finally defined, each day of the mission can be examined on the ODM. There is a tendency for the ODM to schedule fewer experiment activities than the GSM has scheduled for that day. This reduction is a result of the additional scheduling constraints imposed by the ODM, including the requirement to view specific ground targets. Some reduction in crew activities was anticipated by relaxing the crew time constraints on the GSM. For the example payloads, a crew constraint of 11 hours/day/man was used in the GSM and 10 hours/day/man in the ODM. Table 6 shows typical ODM schedule results for mission day four for the example payloads. The required resources to complete the experiments for that day are shown for comparison. Data of this type are used to establish final estimates of experiment accomplishment, or alternatively, to provide feedback for additional MASS model runs with altered payload composition or scheduling priorities.

After the above steps have been completed and the overall schedule of experiment completions determined to be satisfactory, then the definition process is considered complete. Other payload groupings may be equally acceptable, but all should be defined using the same general procedure. The steps described here were used to derive baseline ATL payloads, as described in the next section, "Analysis of ATL Payloads."

4 ANALYSIS OF ATL PAYLOADS

Discussion of ATL Problem

ATL Concept. – The Advanced Technology Laboratory (ATL) uses a standard payload carrier equipped with ATL-peculiar experiment equipment, and is made ready for a shuttle sortie flight. Initial studies of the ATL are based on a Sortie Laboratory design adapted for use with Langley experiment equipment (see Reference 1). Planning, developing, and flight preparation of the ATL payloads would be under Langley control.

ATL Experiments. – The ATL experiments considered here represent the space-oriented portion of research evolving at Langley. Thirty experiments in six different disciplines have been defined. All are candidates for sortie missions during the early years of shuttle operation. Descriptive data on each experiment is given in Reference 1. A condensed summary of experiment resource requirements is given in Appendix A. The scope of the ATL experiment program is indicated in Table 7.

TABLE 7. – ATL EXPERIMENT PROGRAM SCOPE

Discipline	No. Exp.	Mounting Pressurized	Pallet
Communications/Navigation	9	X	X
Earth Observations	4	X	X
Physics and Chemistry	6	X	X
Microbiology	5	X	
Components and Systems	2	X	
Environmental Effects	4	X	X

The total of 30 ATL experiments was reduced to 29 by combining the search and rescue and imaging radar experiments (common equipment) in the Comm/Nav discipline; the reduced total was used as a basis for this ATL analysis.

Problem Structure. – The objective of this analysis is to define a minimum number of ATL payloads that collectively meet all experiment objectives within system constraints. The 29 experiments are mostly independent so that many combinations of experiment groupings are possible; but no one payload can accommodate all experiments. Another objective is to ensure that the experiment groupings (payloads) are efficient in the sense that full use is made of the available resources, especially the experiment crew. It is reasoned that fully using critical resources will minimize the number of flights (and therefore costs) to accomplish the program.

The importance of two additional considerations became evident as the study progressed. First, it was recognized that partial completions of some experiments were desirable on some flights to achieve a high level of crew use. It was also recognized that meaningful experiment results could usually be obtained in these cases, since the operational phase of the experiment was structured as a one-day activity, repeated several times throughout the mission. Thus partial completions were judged to be acceptable if the required procedures for setup and shutdown of the experiment equipment were completed.

Second, it was recognized that some groundrule relative to experiment repeats (on successive flights) was necessary. This groundrule would prevent the attainment of a high resource use with a large number of repeats of smaller, easily scheduled experiment operations at the expense of a single performance of the remaining experiments. An equal number of repeats for all experiments measured across the set of ATL payloads was selected as a goal, since specific ATL mission models were not available.

The analysis culminates in the definition of a set of ATL payloads, the resources used, and a schedule of experiment operations. These payloads are designated as baseline payloads. They are reasonably good payloads for the set of input conditions used in the study. They are not unique, and it is unreasonable to expect that the input conditions will remain unchanged for long. Therefore, a second objective of the analysis was to gain insight to the potential impact that various problem variables might have on the results. A discussion of these variables follows the section on baseline payloads.

Baseline Payloads

A bank of experiment data was prepared to conduct the analysis of ATL payloads. A set of baseline payloads was derived, using the data bank, for the case of a two-man experiment crew. Midway in the study, the data bank was revised and updated to include new data from additional experiment definition studies at Langley. The revised data bank incorporated significant changes to experiment resource requirements, particularly extended crew times. A second set of baseline payloads was then derived, using the revised data bank, for the case of a three-man experiment crew.

The six baseline payloads defined by the ATL analysis are numbered as follows:

Payload No.	
1, 2, 3	2-man crew – original data
4, 5, 6	3-man crew – revised data

Input Data. – Problem input data for the ATL baseline analyses is now addressed. Similarities and differences in input data for the two- and three-man experiment crews are noted. Variations to these baseline inputs are discussed separately in the next section.

(1) Crew: Both the two- and three-man experiment crews were completely cross trained in all skills required to support the experiments. In other words, any available crewman can work on any experiment.

(2) Tasks: Tasks refer to non-experiment activities performed by the experiment crew. Tasks and sleep occupy most of the crew's time and are given priority over all experiment activities; i.e., scheduled first. Figure 11 shows how the sleep periods and tasks were positioned during mission days 2-6. Table 8 summarizes the daily task times for each case.

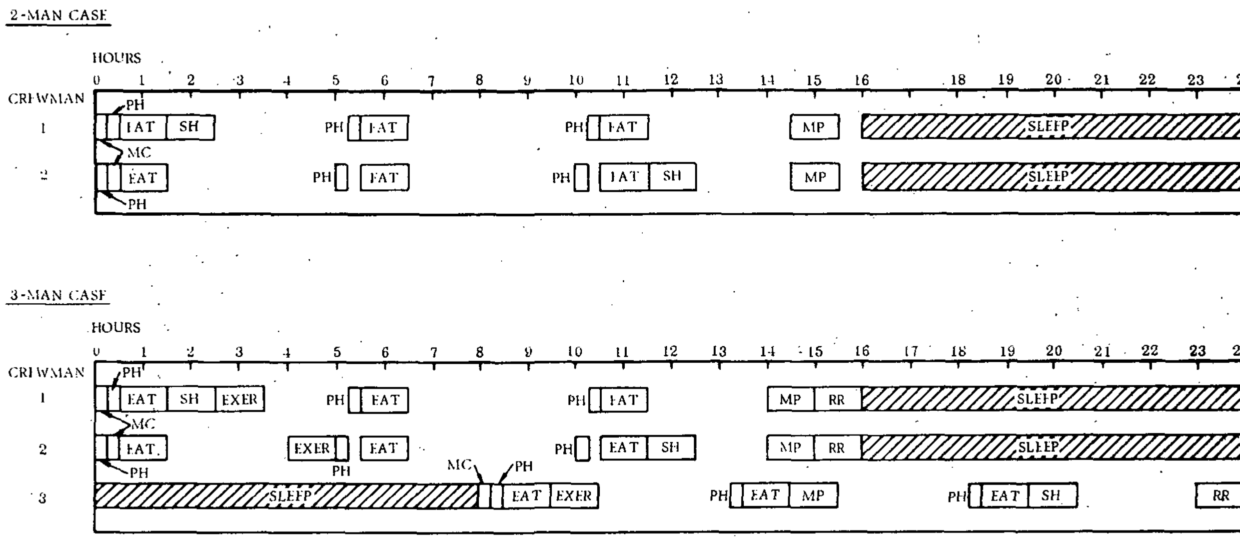


Figure 11. Sleep and Task Inputs for Scheduling Analysis

TABLE 8. – DAILY TASK SUMMARY, 2- AND 3-MAN ATL EXPERIMENT CREW

	2-man crew, hours	3-man crew, hours
Eating (EAT)	3	3
Personal Hygiene (PH)	0.75	0.75
Housekeeping (SH)	1.0	1.0
Medical Check (MC)	0.25	0.25
Mission Planning (MP)	1.0	1.0
Rest & Recreation (RR)	–	1.0
Exercise (EXER)	–	1.0
Sleep	8	8
Total task time	14	16

(3) Experiments: As noted earlier, the experiment requirements for the two- and three-man cases are different. Appendix A summarizes the supporting resource requirements for each case. Experiment activities must be scheduled during those times not blocked out by sleep or tasks as shown in Figure 11. Total time available for experiments in the two-man case is 10 hours per day for mission days 2-6. For the three-man case, 8 hours per day were available for experiment scheduling. Maximum time available for experiments on mission days 1 and 7 for the two cases was assumed to be 5 and 4 hours respectively.

(4) Payload Carrier: A standard Sortie Laboratory with a 9m (30 ft) pallet was used in both cases. Pressurized volume available for stowing experiment equipment

was assumed to be 17 m^3 (600 ft^3), and pallet area for unpressurized experiment equipment installation 35.6 m^2 (415 ft^2). Two airlocks, three viewing ports, and one optical window are available to the experiments in the Sortie Laboratory. Initial schedules were made with a 2 kW electrical power constraint, corresponding to the currently published capability of the Sortie Laboratory to support experiments. When it appeared that the 2 kW constraint was not firm, the scheduling constraint was relaxed to 4 kW to prevent an unrealistic constraint from affecting the results. Experiment scheduling was not constrained by the electrical power or digital data capability of the payload carrier.

(5) Space Shuttle: A standard shuttle as defined in Reference 4 was used as a basis for this analysis. Mission duration was fixed at seven days with reduced time for experiment operations on the first and last mission days.

Estimates made early in the study of shuttle performance to orbit and landing load limits indicated that there was no practical constraint relative to experiment grouping or ATL orbit assignments. Sufficient performance margin existed to provide for the inevitable growth in experiment equipment weight and ATL/pallet weights. At the time this report is written, however, there is some indication that the landing load limit may be reduced from 18,160 kg (40,000 lb) to 11,350-13,620 kg (25,000-30,000 lb). If this occurs, the landing load limit will be a constraint to ATL payload design with an, as yet, unevaluated impact. For a more complete discussion of this problem, see the discussion below under "Mission Operations."

Since the shuttle provides pointing for some of the space experiments, the shuttle capabilities in this area become a potential constraint to experiment schedules. A nominal pointing duration of 12 hours per mission at ±0.5° is provided by the shuttle. However, a number of ways are possible in which this capacity could be increased, and for this reason an arbitrarily set limit of 100 hours of pointing per mission was used as a constraint to experiment scheduling. This limit had the effect of eliminating this resource as a scheduling constraint. However, since most of the payloads considered require more than 12 hours per mission of pointing at ±0.5°, this shuttle resource should be re-examined when more definite limits are known.

(6) Ground Targets: Many of the ATL experiments require the viewing of earth ground targets from orbit to satisfy experiment objectives. Several sets of ground targets were identified to support the analysis:

a. World-wide distribution of truth sites to support experiments CN. 1, CN. 3, CN. 4, CN. 5, EO. 2.

b. Coastal regions for experiment EO. 3.

c. United States truth sites for experiment CN. 6/8.

d. Satellite subpoint for experiment CN. 7.

e. RF noise sources for experiment CN. 9 (two-man case only).

Opportunities for viewing these targets from the orbits of interest — and under such viewing constraints as mission day, elevation angle, and sun angle — were obtained using the GDCA opportunity generator. Actual view times were then modified by the addition of a 20-minute buffer time before the start of a view and a 5-minute buffer time following the end of the view, simulating crew operations ancillary to the actual view operations. Edited versions of these buffered views were then used as input to the One Day Model.

Two-Man Experiment Crew. -

Summary: A set of three ATL payloads is required to accomplish the experiment objectives. Specific groupings of these experiments were established to provide a high level of crew use and a desirable distribution of experiment completions across the set of three payloads. One of the 29 ATL experiments, MB. 4 (Electrical Characteristics of Cells), was not scheduled at all. This experiment requires a four-hour setup period and a 24-hour operational duration, a crew activity profile that is inconsistent with the study groundrules on the availability of a two-man experiment crew. A second experiment, CS. 1 (Carbon Deposition), can be scheduled only with difficulty. Usually it is necessary to adjust the computer-generated schedules to attain a reasonable level of completion of this experiment. The scheduling difficulty can be traced to the rigid activity schedule for this experiment. Both these experiments are candidates for possible restructuring to facilitate crew scheduling.

The three ATL payloads as defined show reasonably good schedules of experiment completions on all experiments except those mentioned in the preceding paragraph. Most experiments were repeated sometime during the three flights. The exception is the Com/Nav group of experiments which, because of their requirements for relatively large pallet areas, could be flown on only one payload and therefore could only be scheduled one time. In addition to being constrained by the pallet area available, the three payloads were also constrained by the opportunities to view supporting ground targets and by the availability of the two-man experiment crew. The payloads were constrained in the sense that if the available views and/or crew time were increased, the overall experiment completions would increase.

The relatively high crew use (78% of the available time spent on experiment activities) is in a large part attributable to the acceptability of partially completed experiments. Twenty-five percent of the experiments had fewer than the specified number of daily repeats on at least one flight, but were repeated on subsequent flights to meet the desired level of accomplishment.

The shuttle and Sortie Laboratory characteristics used as inputs (see preceding section) were judged to provide adequate support to the experiment payloads. Electrical power required to support the most demanding payloads averaged about 2 kW with peaks slightly greater than 3 kW. Although these requirements are in excess of the nominal 2 kW power originally adopted as a study input, they are well within the estimated capacity of the shuttle-Sortie Laboratory combination at this point of definition. The capacity for the shuttle to provide pointing for the experiments should be explored further, when the shuttle Reaction Control System (RCS) is better defined. Shuttle pointing in excess of the nominal 12 hours per mission will probably be required for support to the experiment payloads.

TABLE 9. – COMPOSITION OF EXPERIMENT PAYLOADS FOR TWO-MAN EXPERIMENT CREW

Payload	Orbit	Experiments					Tot. exp. wt, kg (lb)	Tot. press. vol., m^3 (ft^3)
1	370 km	CN.1*	PH.1*	PH.6	MB.2	EN.1	2640	11.1
	(200 n.mi.)	.2*	.4*	CS.1	.3	.2		
	× 60°	.4*	.3	.2	.4	.3*	(5825)	(393)
		EO.3*	.5*	MB.1	.5	.4		
2	556 km	CN.3*	EO.1	PH.1*	MB.1	EN.2	4960	12.2
	(300 n.mi.)	.5*	.2*	.2	.2	.3*		
	× 60°	.7*	.4*	.3	.3	.4	(10,930)	(430)
		.9*	CS.2	.6	.4			
3	185 km	CN 6/8*	EO.1	PH.1*	PH.6	MB.1	4235	13.3
	(100 n.mi.)	.9*	.2*	.3	EN.1	.2		
	× 90°	CS.1	.3*	.4*	.2	.3	(9335)	(468)
		.2	.4*	.5*	.3*	.5		

* Pallet-mounted

Payload Definition: The experiment complement of the baseline payloads is shown in Table 9. The payload orbit assignments are in general accordance with the orbit preferences of the experiments; e.g., the nucleus experiments (Com/Nav and Earth Observations) of payload 3 prefer a polar orbit for greater earth coverage. Payload 3 is thus assigned to polar orbit to introduce orbit variety, even though the required polar launch from WTR will probably not be available during the early years of the shuttle program.

Equipment weight totals in Table 9 reflect the experiment equipment weight only and not that of experiment interface or support equipment. Pallet layouts for the pallet-mounted experiment equipment for each of the three payloads are shown in Figure 12.

Resources Used: Resources used by scheduled experiments for each payload are summarized in Table 10. Shown are the resources used over the seven-day sortie mission (GSM) and the resources used on mission day 4 (ODM). Crew use shown for these payloads is considered to be about the maximum that can be achieved on an experiment program of this type. Unused crew time available for experiments is generally the accumulation of many small time intervals that occur between different experiment operations.

Schedule Summaries: Schedules were obtained for the baseline payloads using the procedures described in Section 3. Iterations were made using the GSM until an acceptable distribution of experiment completions was obtained, then each payload was examined on mission day 4 using the ODM. Finally, the remaining mission days were scheduled, using the ODM, for the first payload of the set. A summary of the GSM schedules is given in Table 11. The GSM completions include experiment MB.4, although this experiment dropped out of ODM schedules. Resource and activity timelines for each ODM run for each baseline payload are found in Appendix C.

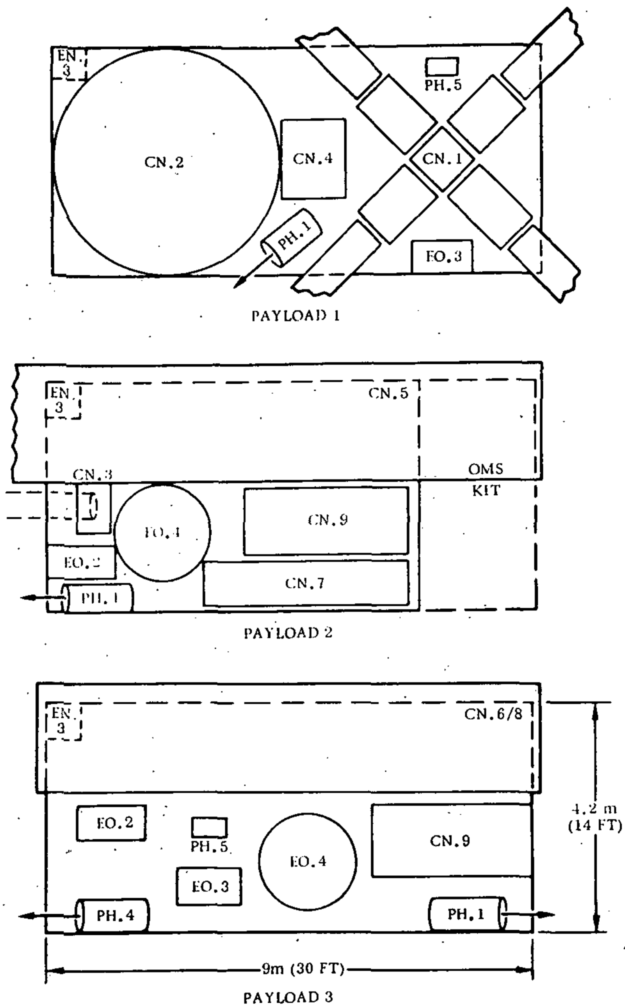


Figure 12. Pallet Layouts for Baseline ATL Payloads

TABLE 10. – SUMMARY OF RESOURCES SCHEDULED ON BASELINE ATL PAYLOADS WITH TWO-MAN CREW

	GSM				ODM (Day 4)			
Payload	Total crew hours	Total kWh	Total digital data stored, 10^6 MB	Total pointing hours	Average crew hr/d/man	Average crew use, %	Peak power, kW	Total kWh
1	120.7	214	2.68	51.6	8.1	81	1.7	29.7
2	123.2	267	2.99	63.5	8.0	80	3.2	46.1
3	123.0	330	2.22	48.0	8.1	81	3.1	49.4

TABLE 11. – EXPERIMENT COMPLETIONS FOR BASELINE ATL PAYLOADS WITH TWO-MAN CREW

	Payload					Payload			
Exp ID	1	2	3	Σ3 P/L	Exp ID	1	2	3	Σ3 P/L
CN.1	1			1	EO.1		1	1	2
.2	1			1	.2		1	1	2
.3		1		1	.3	1		1	2
.4	1			1	.4		1	1	2
.5		1		1					
.6/8			1	1	MB.1	1	1	1	3
.7		1		1	.2	1	5/7	1	2 5/7
.9		1	1	2	.3	1	1	1	3
					.4	1	1		2
PH.1	1	2/5	1	2 2/5	.5	1		1	2
.2		1		1					
.3	3/7	4/7	5/7	1 5/7	EN.1	1		1	2
.4	6/7		6/7	1 5/7	.2	4/14	10/14	12/14	1 6/7
.5	1		1	2	.3	1	1	1	3
.6	1	1	5/7	2 5/7	.4	1	1		2
CS.1	1		1	2	Average completions: Com/Nav = 1.0				
.2	1	1/2	1	2 1/2	Non-Com/Nav = 2.2				

Three-Man Experiment Crew. –

Summary: A set of three ATL payloads is required to accomplish the experiment objectives for a three-man experiment crew. The experiment groupings that were established are very similar to those in the set of payloads derived for the two-man experiment crew. For the three-man experiment crew analysis, the data bank of experiment characteristics was updated, and the time available for crewmen to work on experiments was reduced from ten to eight hours per day due to the addition of one-hour exercise and rest/recreation tasks. Increased crew-hour requirements for experiments, together with the shorter time available for each crewman to support experiments, resulted in an overall experiment completion record very similar to that for the two-man analysis.

Reasonably good schedules of experiment completions were obtained for all experiments. Except for the Com/Nav group and experiments PH. 2 and MB. 5, all experiments were repeated at least once during the three flights. The Com/Nav group, as discussed earlier, is pallet-area constrained and thus limited to one flight each. Experiments PH. 2 and MB. 5 are one-day experiments with large crew activity requirements that tend to prevent completion of other experiments conducted over the entire mission. On a daily basis, experiments CS. 1 and MB. 4 were difficult to schedule because of a rigid experiment activity schedule (CS. 1) and a long duration and large crew support requirement (MB. 4). In general, the three payloads were ultimately constrained by the opportunities to view ground targets and by the availability of the three-man experiment crew. As for the two-man case, if the available views and/or crew time were increased, overall experiment completions would increase.

TABLE 12. – COMPOSITION OF EXPERIMENT PAYLOADS FOR THREE-MAN CREW

Payload	Orbit	Experiments	Tot. exp. wt., kg (lb)	Tot. press. vol., m^3 (ft^3)
4	370 km (200 n. mi.) × 60°	CN.1* PH.1* PH.6 MB.2 EN.1 .2* .3 CS.1 .3 .2 .4* .4* .2 .4 .3* EO.3* .5* MB.1 .4	2500 (5510)	10.6 (375)
5	556 km (300 n. mi.) × 60°	CN.3* EO.1 PH.1* MB.3 EN.4 .5* .2* .6 .4 CS.1 .7* .4* MB.1 EN.2 .9* CS.2 .2 .3*	4030 (8880)	12.5 (440)
6	185 km (100 n. mi.) × 90°	CN 6/8* EO.2* PH.2 PH.6 MB.1 CS.1 .3* .3 EN.1 .2 .2 .4* .4* .2 .3 EO.1 PH.1* .5* .3* .5	4090 (9015)	12.9 (458)

* Pallet mounted

The overall crew use was 80% on experiments for the mission days analyzed in detail. Electrical power required to support the most demanding payloads averaged about 2. 1 kW with peaks slightly less than 3 kW. The power requirements are well within the estimated capacity of the shuttle-Sortie Laboratory combination as currently defined. As with the two-man analysis, shuttle pointing in excess of 12 hours per mission will probably be required to support the payloads.

TABLE 13. – SUMMARY OF RESOURCES SCHEDULED ON BASELINE ATL PAYLOADS WITH THREE-MAN CREW

	GSM				ODM (Day 4)			
Payload	Total crew hours	Total kWh	Total digital data stored, 10^6 MB	Total pointing hours	Average crew hr/d/man	Average crew use, %	Peak power, kW	Total kWh
4	148.8	187.3	2.35	55.3	5.83	72.9	1.53	28.6
5	144.8	273.8	2.98	91.8	6.69	83.5	2.93	47.9
6	144.9	306.7	2.03	49.7	6.81	85.0	2.69	50.2

Payload Definition: The composition of the baseline payloads is shown in Table 12. Equipment weight totals are for actual experiment equipment only. The pallet layouts for the pallet-mounted experiment equipment are the same as those shown for the two-man experiment crew in Figure 12. (The layouts for payloads 1, 2, and 3 correspond to payloads 4, 5, and 6 respectively.)

Resources Used: Table 13 summarizes the resources used by scheduled experiments for each payload over the seven-day sortie mission (GSM) and the resources used on mission day 4 (ODM). The results for mission day 4 include manual adjustment (maintaining rigid task structure) of ODM computer schedules. Typically, a 0-10% increase in crew use is achievable with manual adjustment.

TABLE 14. – EXPERIMENT COMPLETIONS FOR BASELINE PAYLOADS WITH THREE-MAN CREW

Exp ID	Payload 4	Payload 5	Payload 6	Σ 3 P/L
CN.1	1			1
.2	1			1
.3		1		1
.4	1			1
.5		1		1
.6/8			1	1
.7		1		1
.9		1		1
PH.1	3/5	1/5	4/5	1 3/5
.2			1	1
.3	3/7		4/7	1
.4	3/7		5/7	1 1/7
.5	6/7		6/7	1 5/7
.6	1	4/7	4/7	2 1/7
CS.1	1	1/2	1	2 1/2
.2	1		1	2

Exp ID	Payload 4	Payload 5	Payload 6	Σ 3 P/L
EO.1		5/6	1	1 5/6
.2		4/7	1	1 4/7
.3	6/7		1	1 6/7
.4	1		1	2
MB.1	1	1	1	3
.2	6/7	6/7	4/7	2 2/7
.3	1	1	1	3
.4	1	1		2
.5			1	1
EN.1	1		1	2
.2	4/14	10/14	11/14	1 11/14
.3	1	1	1	3
.4	1	1		2

Average completions: Com/Nav = 1.0
Non-Com/Nav = 1.93

Schedule Summaries: The procedures described in Section 3 were used to obtain schedules for the baseline payloads. After attaining an acceptable distribution of experiment completions over the mission using the GSM, the ODM was used to examine mission day 4. For payload 4, the remaining mission days were also scheduled. A summary of the GSM schedules is given in Table 14. Timelines for each ODM run are found in Appendix C.

Major Variables in Payload Analysis

Following the definition of baseline payloads, several trade studies were carried out to establish the sensitivity of the payload analysis to variations in system parameters. This section discusses the results of studies to evaluate scheduling efficiency as a function of changes to parameters in the areas of:

Mission operations	Crew operations
Target view opportunities	Number of crewmen
Payload carrier design	Programmatic ground rules

In some cases (e.g., target view opportunities, pallet-only payloads, and crew cross training) the discussion of the system parameter is based on separate parametric analyses conducted during this study and supported by computer runs. In other cases, the discussions are based on experience obtained during the process of establishing the set of baseline ATL payloads described in the preceding section.

Mission Operations. – The operational orbit and mission duration are key mission operations parameters for payload analysis.

Operational Orbit: Requirements of the payload experiments drive the selection of the operational orbit, subject to the capability of the shuttle to deliver the payload to orbit. Currently estimated shuttle payload capability for sortie missions (no rendezvous) is shown in Figure 13. Preliminary estimates of ATL weight, including the heaviest ATL experiment grouping identified in this study, are shown in Table 15. The total payload weight is well within the range of estimated shuttle delivery performance for the orbits of interest:

a. 370 km (200 n. mi.) altitude x 60° inclination.

b. 556 km (300 n. mi.) altitude x 60° inclination.

c. 185 km (100 n. mi.) altitude x 90° inclination.

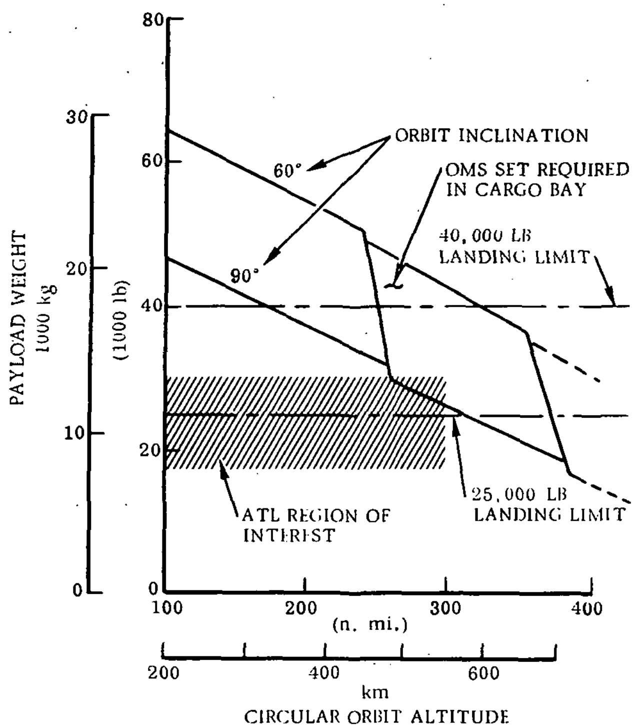


Figure 13. Space Shuttle Payload Capability, No Rendezvous

TABLE 15. – ESTIMATED ATL WEIGHTS

Sortie Laboratory (with systems) –		5450 kg	(12,000 lb)
9 m (30 ft) Pallet		545 kg	(1200 lb)
Payload Adapter		1360 kg	(3000 lb)
Experiment Equipment		5000 kg	(11,000 lb)
Integration Equipment		910 kg	(2000 lb)
	Total	13,265 kg	(29,200 lb)

The shuttle landing load limit could become a significant constraint to ATL. The currently estimated landing limit, 18,200 kg (40,000 lb), provides a margin of about 4935 kg (10,800 lb). Should this limit be lowered, a careful analysis of ATL weight would be required. A detailed weight analysis of ATL payload configurations was not made in this study.

The operational orbit can affect payload composition or payload operations in other ways. To achieve higher altitude orbits (e.g., above 370 km (240 n. mi.) at 60° inclination), at least one *Orbital Maneuvering Subsystem (OMS)* set must be included in the orbiter cargo bay to provide the required thrust. An OMS set in the cargo bay reduces the amount of the bay available to the experiment payload, and thus can influence the payload composition. This factor was taken into account in the ATL payload analysis.

The on-orbit operation of the payload is affected by the time available for experiment operations on the first and last mission days. These times are influenced by the sequence of orbit maneuvers required to achieve operational orbit and subsequently to deorbit and land. Sortie missions combined with payload delivery, service, or retrieval missions would have significantly less on-orbit time for experiments.

The operating orbit influences opportunities to view ground targets. This subject is discussed in detail below.

Mission Duration: Extending the mission duration has a potentially large payoff in terms of experiment accomplishment. Crew time for supporting experiments and view time over ground targets increase nearly linearly with extended duration. However, to fully exploit extended mission durations the required activity profiles of the ATL experiments should be redefined, and the weight chargeable to the payload for extending the mission should be established. This was not done in the current study.

View Opportunities For Ground Targets. – Certain Com/Nav and Earth Observation experiments require views of specific, fixed-position ground targets to meet the experiment objectives. Frequently, the opportunity to view supporting ground targets is the limiting factor in meeting the overall objectives of this class of experiments.

Opportunities to view fixed ground targets are determined by the number and location of the ground targets, the spacecraft orbit, and view constraints such as minimum elevation angle or solar illumination at the target. Earth target views from low-altitude earth orbit are typically short (less than 10 minutes long). It is unreasonable to assume that the crew can be ready, and that equipment can be turned on and off instantaneously to accommodate these short bursts of activity. A "buffer" time associated with crew readiness and equipment warmup, calibration, and standby was therefore added to the front end of the earth target view opportunities. Similarly a buffer time was added to the end of the view opportunities to represent equipment shutdown and crew standdown. The situation is shown in Figure 14.

For the ATL analysis, target sets were selected in collaboration with the experiment principal investigators. View opportunities were then obtained for these targets under a variety of orbit parameters and viewing constraints. Table 16 lists the ground targets with the associated view opportunities used in the ATL payload analysis. The average number of viewing opportunities per day was derived by processing opportunity generator data to eliminate redundant or overlapping views. The edited viewing opportunity data was then input to the One Day Model for detailed analysis of selected payloads and mission days.

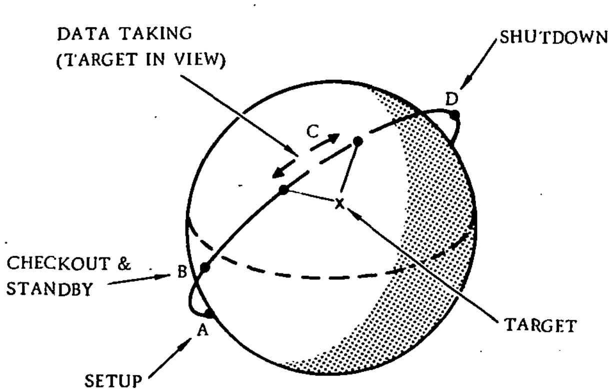


Figure 14. Buffer Time for Earth Target Views

The viewing opportunity analysis for the ATL experiment targets established the desirability for a world-wide set of ground targets. Viewing opportunities for a world-wide target set are distributed

TABLE 16. - GROUND TARGETS FOR ATL EXPERIMENTS

Target set	Related ATL experiments	Buffer time, min	Opportunity generator runs: Orbit km/deg (n. mi./deg)	Mission day	Average number views/ day
World-wide targets 25 selected point targets	CN.1 .3 .4 .5 EO.2	20/5 (1) 20/5 20/5 20/5 16/16 (2)	370 × 60 (6) (200 × 60)	2 - 6	18 or (10) (3)
			185 × 90 (7) (100 × 90)	4	15 or (8) (3)
Coastal regions U.S. east coast U.S. west coast	EO.3	20/5	370 × 60 (200 × 60)	2 - 6	3 (3)
			185 × 90 (100 × 90)	4	3 (3)
CONUS/Hawaii/Alaska	CN.6/8	20/5	185 × 90 (100 × 90)	4	7
Satellite Subpoint (4) 0° latitude 180° longitude	CN.7	15/15	370 × 60 (200 × 60)	4	2
			185 × 90 (100 × 90)	4	2
RF noise sources (5) 25 selected point targets	CN.9	20/5	370 × 60 (200 × 60)	4	24
			185 × 90 (100 × 90)	4	14

(1) Minutes prior to view/minutes following view.
(2) Automated.
(3) High sun angle required for EO.2 and EO.3.
(4) Viewing satellite in synchronous orbit.
(5) Used in two-man experiment crew analysis only; 8 hrs/day continuous noise search for three-man analysis.
(6) Launch is north from ETR.
(7) Launch is south from WTR.

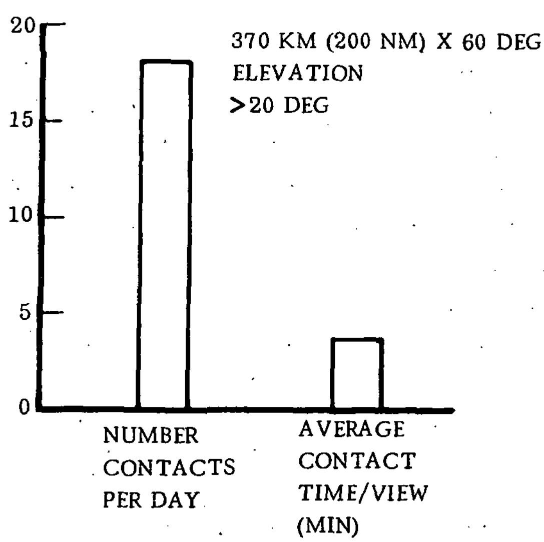


Figure 15. View Parameters for World-Wide ATL Target Set

throughout each mission day, giving a high probability that enough views can be scheduled to satisfy experiment objectives. On the other hand, view opportunities for more constrained target sets (e.g., targets within CONUS) are much more restricted. Typically, for the ATL orbits, there are five to six views per day for the targets in CONUS. Moreover, views occur in two groups of two or three views each (on successive orbits), separated by several hours. It is more difficult to accumulate the required viewing time for such a constrained target set than it is for world-wide set, particularly when views must be accommodated during periods when the crew is not asleep or working on tasks. This was a major consideration in defining the target sets for ATL experiments.

Figure 15 shows the view characteristics of the world-wide target set for the 370 km (200 n. mi.) x 60° orbit. An average of 18 non-overlapping contacts per day can be obtained (includes consideration of buffer times). The average time per contact is only 3.42 minutes.

The ability to communicate with ground stations (while operating on orbit) for the purpose of dumping experiment data or coordinating experiment operations will be a key factor in the definition and evaluation of some payloads. For ATL, a basic groundrule is to store all experiment data on board, communications being required only for payload status readouts and limited coordination of experiments. ATL communication contacts with the 14-station STDN ground network were analyzed for the 370 km (200 n. mi.) altitude x 60° inclination orbit. A

TABLE 17. – ATL COMMUNICATIONS SUMMARY, TYPICAL MISSION DAY

Communication network	14-station STDN
Orbit	370 km (200 n. mi.) x 60°
Total number of contacts	36
Average contact time	6 minutes
Total contact time	3.6 hours
Maximum time between contacts	2.3 hours

minimum elevation angle (ground to ATL) of 5° was assumed.

Table 17 summarizes the results for a typical mission day. If an analysis of experiment data dump capability is required, the MASS computer models have the capability to account for data dumps over the specific ground targets.

Payload Carrier Design. – Shuttle and payload carrier design characteristics relating to experiment payload support are discussed below.

Pressurized Volume/Pallet Area Split: The current (as of this report date) shuttle design and the MSFC Sortie Laboratory, including a 9 m (30 ft) pallet, were used as a basis for deriving the baseline ATL payloads. Division of the shuttle cargo bay in this manner provides for the following experiment equipment accommodations: 17 m^3 (600 ft^3) pressurized volume in the Sortie Laboratory and 38.6 m^2 (415 ft^2)unpressurized equipment mounting area on the pallet. This cargo bay split provides a reasonable configuration for accommodating mixed-discipline payloads based on Langley experiments. Pallet area requirements for the total ATL experiment program are roughly equivalent to the area provided by two pallets; pressurized volume requirements for all the ATL experiments are less than provided by one Sortie Laboratory. Actually, two pallets are insufficient to accommodate all the pallet-mounted experiments, since it is assumed that no combination of the antennas for CN. 2, CN. 5 and CN. 6/8 can exist on the same pallet. Thus a minimum of three 9 m (30 ft) pallets are required to accommodate all ATL experiments at least once; and for the same reason, the Com/Nav experiments can be repeated only by extending the number of baseline payloads in the program. In that sense, the baseline ATL payloads are pallet-area limited. No limitation exists as to repeating those experiments that require only pressurized volume for the experiment equipment. Table 18 shows the use of these resources for the baseline payloads, taking into consideration the experiment repeats. Refer to Figure 12 for schematics of the pallet area layouts for the baseline payloads. Relatively large increases in pallet length (at the expense of pressurized volume) are required to accommodate repeats of the CN. 2, CN. 5, and CN. 6/8 group of experiments. These longer pallets would preclude the use of a Sortie Laboratory of any reasonable length. Moreover, there is a limit to the gains to be derived

TABLE 18. – USE OF PRESSURIZED VOLUME AND PALLET AREA BY BASELINE ATL PAYLOADS

Payloads	Percent used	
	Pressurized volume	Pallet area
1 and 4	49	63
2 and 5	63	86
3 and 6	72	82

by adding pallet experiments that require the support of ground targets because of the limited opportunities to view these targets. The baseline payloads are at this limit, so that additional experiments competing for the same ground targets would not increase experiment accomplishment (under assumed problem input conditions).

The case of pallet-only payloads, i.e., payloads supported by mission specialists located in the orbiter, was investigated. Since the pressurized volume requirements are relatively small, there may be a possibility that the orbiter could provide the space for such equipment.

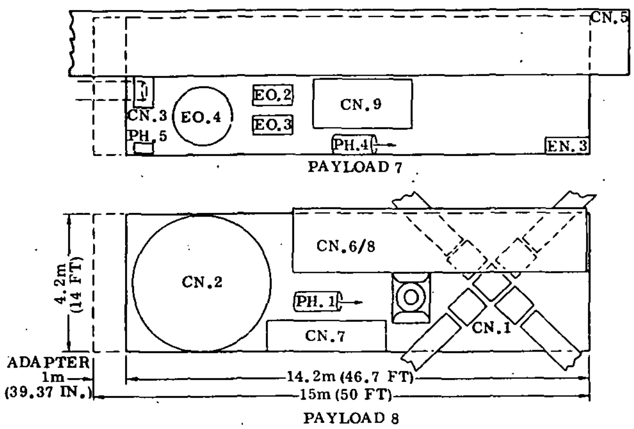


Figure 16. Pallet Layouts for Pallet-Only ATL Payloads

Two pallets, approximately 15 m (50 ft) long, were selected for mounting the pallet experiments. These are designated ATL Payloads 7 and 8 (Figure 16).

Each experiment appears one time on the two pallets. The revised experiment data bank was used in the analysis of pallet-only payloads. The supporting crew consisted of two men, completely cross trained in all skills required to support the pallet experiments. For this investigation only, the ground viewing requirements of experiment CN. 9 were halved (from eight to four hours per day) to give this experiment a reasonable chance of being scheduled. The sleep and task inputs, defined for the baseline case with two experiment crewmen, were used for the pallet-only analysis.

A summary of schedules produced by the General Scheduling Model (GSM) for the pallet-only payloads is shown in Table 19. The number of experiment completions (based on daily operational cycles) achieved over a seven-day sortie mission is indicated.

TABLE 19. – EXPERIMENT COMPLETIONS FOR PALLET-ONLY PAYLOADS

Exp. ID	Payload 7	Payload 8	Exp. ID	Payload 7	Payload 8
CN.1		1	PH.1		1
.2		1	.4	1	
.3	4/5		.5	1	
.4		1			
.5	1		EO.2	1	
.6/8		1	.3	1	
.7		1	.4	1	
.9	1				
			EN.3	1	
Total crew hours				86.9	113.8
Total kWh				217.4	179.5

Schedules produced by the One Day Model highlight the potential problem associated with payloads of this type; namely, the difficulty in obtaining the required views of the ground targets supporting the pallet-mounted experiments. This difficulty is basically due to the unavailability of the experiment crew when the view opportunity occurs. A summary of ODM results is given in Table 20. The data shown is the result of several iterations in pallet layouts in an attempt to maximize the experiment completions for experiments requiring target views.

These payloads are acceptable from the experiment accomplishment and crew use points of view. The marginal completion rate for experiments on the second payload requiring ground target views could be improved by scheduling view opportunities *more equitably between experiments* and/or by defining new targets.

TABLE 20. – ONE DAY MODEL SCHEDULE RESULTS FOR PALLET-ONLY PAYLOADS

Exp. ID	Percent operations accomplished	Ground targets	Exp. ID	Percent operations accomplished	Ground targets
CN.1	0	yes	PH.1	75	no
.2	56	no	.4	75	no
.3	119	yes	.5	100	no
.4	112	yes			
.5	95	no	EO.2	107	yes
.6/8	70	yes	.3	85	yes
.7	100	yes	.4	100	no
.9	100	no			
			EN.3	100	no
Average use of crew on experiments: 62.5%					

Payload Carrier Subsystems: Two payload carrier subsystem support requirements are of primary interest: electrical power for experiment operations and storage capacity for digital data generated by the experiments. All baseline payloads were derived with the levels of subsystem support in these areas selected so as not to constrain the schedule of experiment activities. This procedure was considered to be better than producing a large volume of schedule information based on questionable subsystem support levels. The payload electrical power and data storage profiles are thus the requirements placed on the laboratory subsystems. These requirements are believed to be within reason, especially if a certain amount of the resources (i.e., peaking batteries and tape storage) can be charged to the payload.

TABLE 21. – ELECTRICAL POWER REQUIREMENTS FOR ATL PAYLOADS

Payload			Mission day 2	3	4	5	6
	1	av (kw)	1.2	1.2	1.2	1.2	1.4
		pk (kw)	1.8	1.6	1.7	1.7	3.2
2-man case	2	av (kw)	–	–	1.2	–	–
		pk (kw)	–	–	3.2	–	–
	3	av (kw)	–	–	1.2	–	–
		pk (kw)	–	–	3.1	–	–
	4	av (kw)	1.1	1.3	1.2	1.3	1.5
		pk (kw)	1.5	1.6	1.5	2.1	2.5
3-man case	5	av (kw)	–	–	2.0	–	–
		pk (kw)	–	–	2.9	–	–
	6	av (kw)	–	–	2.1	–	–
		pk (kw)	–	–	2.7	–	–

A summary of the electrical power requirements for the baseline payloads is given in Table 21. Average powers of approximately 2 kW and peak powers of approximately 3 kW would adequately support these payloads as they are now defined. Detailed timelines of the electrical power requirements for these payloads appear in Appendix C.

Digital data storage required to support the baseline payloads is summarized in Table 22. In the operational mode selected for these payloads, all the digital data generated by the experiments is stored on tape. Assuming the capacity

TABLE 22. – DIGITAL DATA STORAGE REQUIREMENTS FOR ATL PAYLOADS

Payload			Mission day 2	3	4 (ODM Schedule)	5	6	Total data (GSM)
2-man case	1	($MB \times 10^6$)	0.319	0.274	0.329	0.269	0.240	2.68
	2	($MB \times 10^6$)	–	–	0.708	–	–	2.99
	3	($MB \times 10^6$)	–	–	0.320	–	–	2.22
3-man case	4	($MB \times 10^6$)	0.201	0.221	0.213	0.218	0.269	2.35
	5	($MB \times 10^6$)	–	–	0.657	–	–	2.98
	6	($MB \times 10^6$)	–	–	0.319	–	–	2.03

TABLE 23. – TOTAL POINTING DURATION OF BASELINE PAYLOAD EXPERIMENTS (HOURS AT ±0.5°)

Payload	1	2	3	4	5	6
Total pointing hours	51.6	63.5	48.0	55.3	91.8	49.7

of a single tape to be 6.2×10^{10} bits, the worst-case payload would require approximately 50 reels of tape. This is a sizeable, but not unreasonable, quantity of tape.

Space Shuttle Pointing: A pointing constraint to the experiment payloads considered in this study is the capacity of the shuttle to provide the duration and activity cycle of pointing required by the experiments. Although total pointing duration can be used as a scheduling constraint in the GSM, this resource was selected sufficiently large so that experiment scheduling would not be constrained. Table 23 shows the total pointing duration associated with the experiments on each of the baseline ATL payloads. These durations are excessive, since no provision is made for the concurrent operation of experiments requiring pointing. Although nominal pointing accuracy of ±0.5° is shown in Table 23, demands for shuttle pointing in support of those experiments having gimbal-mountings may be reduced significantly. Finally, neither the maximum shuttle capability to provide pointing, nor the possible extension of this maximum capability via payload-supplied propellants, is firmly fixed at this time. For these reasons, it is concluded that pointing requirements of the ATL payloads appear reasonable, but that the question of the adequacy of this type of support should be re-examined when the shuttle RCS system design is known in greater detail.

Crew Operations. — The influence of crew operations on payload analysis is discussed below under the following headings: Task and Sleep Flexibility, Crew Shifts, Cross Training, and the Number of Crewmen.

Task and Sleep Flexibility: A significant increase in experiment accomplishment is possible if some flexibility is permitted in scheduling sleep periods and tasks. As shown previously (Figure 11), the ATL payload analysis employed a rigid sleep and task structure as inputs to the computer scheduling models. Experiment scheduling was then constrained to the times during the day not blocked out by tasks or sleep. However, computer results could often be adjusted manually to provide a definite payoff in experiment accomplishment; for example, picking up one more view of a ground target. A complete sleep/task flexibility analysis was not made. Only certain task schedules (mission planning, exercise, rest and recreation) were adjusted. Task adjustment consisted primarily of shifting tasks – not reducing task time. Sleep periods were not adjusted. In some cases a 5-10% increase in total experiment hours scheduled could be obtained by shifting individual tasks.

It should be noted that computer scheduling (ODM) yielded an average crew use on experiments of 76% (a range of 69-91%) for both the 2- and 3-man baseline analyses. Manual adjustment of experiment schedules, while maintaining the rigid sleep/task structure, resulted in a 5-10% improvement in crew use in many cases. With these high use factors, opportunity is limited for improving overall experiment accomplishment. The real value in permitting some flexibility in task and sleep scheduling for the ATL analysis was to obtain better accomplishment on specific experiments; e.g., high priority earth-viewing events.

Crew Shifts: Standardized crew shifts were used throughout the ATL payload analysis. Work/rest cycles for the mid-mission days (2 through 6) were those shown previously in Figure 11. For the case of two experiment crewmen, sleep periods are scheduled concurrently. This schedule provides for support of two-man experiments and concurrent meal and mission planning activities. For the case of three experiment crewmen, the third man was scheduled to sleep at the start of the day, while the other two crewmen were awake. Then, at the end of the day, when the first two crewmen were sleeping, the third man was awake and available to support experiments. This crew shift structure provides:

a. Extended crew availability to support long-duration experiments, such as those requiring earth-target view opportunities that are distributed throughout the day,

b. Support for two-man experiments.

TABLE 24. – SKILLS REQUIRED BY ATL EXPERIMENTS

Skill level	Skills	No. of experiments	Crew hours*
Professional	Electronics engineer	2	51.5
	Physicist	2	23.2
	Meteorologist	1	28.0
Technical	Electronics	14	126.8
	Electronics with microwave training	4	69.6
	Biological	2	19.3
	Photo	1	1.0

* Revised data bank. Support from unspecified skills = 14.6 hours.

Cross Training: The degree to which astronauts and payload specialists can be cross trained in the skills required to support the experiments is very important to payload planning, especially for mixed-discipline payloads such as ATL. Cross training has significant impact on astronaut training and the extent to which a principal investigator accompanies his own experiment.

A limited study of the cross training problem with a three-man experiment crew was conducted during the ATL payload analysis. The skills required to support the ATL experiments are summarized in Table 24. Nearly two-thirds of the total crew hours required by the package of experiments can be satisfied by technician-level skills, while approximately a third of total crew support requirement is from the professional skill level. A small part of the crew support (14.6 hours total) does not require a particular skill. Appendix A contains a list of the skills required by each of the ATL experiments.

TABLE 25. – SKILL CROSS TRAINING FOR ATL ANALYSIS

	Skills		
	Mix Ⓐ	Mix Ⓑ	Mix Ⓒ
Crewman 1	Electronics engineer Electronics technician Electronics technician with microwave training Photo technician	Electronics engineer Electronics technician Electronics technician with microwave training Photo technician	Electronics engineer Electronics technician Electronics technician with microwave training
Crewman 2	Physicist Meteorologist Biological technician Electronics technician	Physicist Biological technician Electronics technician Electronics technician with microwave training	Physicist Biological technician
Crewman 3	Photo technician Electronics technician Electronics technician with microwave training Biological technician	Meteorologist Biological technician Electronics technician Photo technician	Meteorologist Photo technician

All baseline ATL payloads were established on the assumption that the supporting experiment crewmen were universally skilled; i.e., any available crewman can work on any experiment. Three alternate levels of cross training, defined in Table 25, were investigated. In skill mix Ⓐ, crewmen 1 and 2 are trained in professional skills and cross trained in certain additional technical skills. Crewman 3 is a technician cross trained in all technician-level skills. For skill mix Ⓑ, all three crewmen are trained in professional skills and selectively cross trained in technical skills. Skill mix Ⓒ has only limited cross training, corresponding to the case where the principal investigator accompanies his own experiment and is not extensively trained in other areas.

The starting point for the skill cross training analysis was the baseline set of payloads derived for a universally skilled three-man crew. A series of GSM runs was made, following the procedures of Section 3, to derive a reasonable set of payloads, adjusted from the baseline set to account for the specific cross training in skill mix Ⓐ. Table 26 shows the required adjustments to the baseline payloads. Experiment CN.9 was shifted from the second to the third payload in the set in exchange for experiments PH.2 and PH.3. Experiment PH.1 was deleted from the first payload in the set. These adjustments were made to better distribute experiments requiring professional skills. The payload set derived for skill mix Ⓐ was then examined using skill mixes Ⓑ and Ⓒ.

TABLE 26. – EFFECT OF SKILL CROSS TRAINING ON PAYLOAD COMPOSITION

Baseline payloads	Adjustments for skill cross training	Rationale
4	Deleted PH.1	Reduced requirement for professional skill
5	Deleted CN.9; added PH.2, PH.3	Better distribution of professional skills
6	Deleted PH.2, PH.3; added CN.9	Better distribution of professional skills

Table 27 gives the results of the scheduling analysis of crew cross training. Experiment completions, obtained from GSM schedules, are shown for each payload

TABLE 27. EXPERIMENT COMPLETIONS WITH CROSS TRAINED CREW

Experiment	Payload 4 skill mix				Payload 5 skill mix				Payload 6 skill mix				Total 3 payloads			
	BL	Ⓐ	Ⓑ	Ⓒ	BL	Ⓐ	Ⓑ	Ⓒ	BL	Ⓐ	Ⓑ	Ⓒ	BL	Ⓐ	Ⓑ	Ⓒ
CN.1	1	1	1	4/5									1	1	1	4/5
.2	1	1	1	1									1	1	1	1
.3					1	1	1	4/5					1	1	1	4/5
.4	1	5/6	5/6	0									1	5/6	5/6	0
.5					1	1	1	1					1	1	1	1
.6/8									1	1	1	4/5	1	1	1	4/5
.7					1	1	1	3/5				*	1	1	1	3/5
.9					1	—	—	—	—	1	1	0	1	1	1	0
EO.1					5/6	4/6	5/6	0	1	1	1	5/6	1 5/6	1 4/6	1 5/6	5/6
.2					4/7	1	6/7	0	1	1	1	6/7	1 4/7	2	1 6/7	6/7
.3	6/7	1	1	5/7					1	1	1	6/7	1 6/7	2	2	1 4/7
.4				*	1	1	1	1	1	1	1	1	2	2	2	2
PH.1	3/5	—	—	—	1/5	3/5	3/5	2/5	4/5	0	0	0*	1 3/5	3/5	3/5	2/5
.2					—	1	1	1	1	—	—	—	1	1	1	1
.3	3/7	3/7	3/7	6/7	—	0	3/7	1	4/7	—	—	—	1	3/7	6/7	1 6/7
.4	5/7	5/7	4/7	1					5/7	5/7	5/7	1	1 3/7	1 2/7	1 1/7	2
.5	6/7	6/7	6/7	0					6/7	4/7	4/7	0	1 5/7	1 3/7	1 3/7	0
.6	1	6/7	1	0	4/7	5/7	5/7	0	4/7	2/7	3/7	0	2 1/7	1 6/7	2 1/7	0
MB.1	1	1	1	1	1	1	1	1	1	1	6/7	1	3	3	2 6/7	3
.2	6/7	1	1	1	6/7	1	1	6/7	4/7	6/7	5/7	1	2 2/7	2 6/7	2 5/7	2 6/7
.3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3
.4	1	1	1	1	1	1	1	1					2	2	2	2
.5									1	1	1	1	1	1	1	1
CS.1	1	1	1	0	1	1	1	0	1	1	1	0	3	3	3	0
.2	1	1	1	1/2	1/2	1/2	1/2	0	1	1	1	1/2	2 1/2	2 1/2	2 1/2	1
EN.1	1	1	1	1					1	1	1	1	2	2	2	2
.2	4/14	7/14	8/14	0	10/14	12/14	13/14	8/14	11/14	10/14	10/14	5/14	1 11/14	2 1/14	2 3/14	13/14
.3	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3
.4	1	1	1	0	1	1	1	1					2	2	2	1
Total crew hours	148.8	140.9	141.6	98.5	144.8	125.8	138.8	98.9	144.9	144.6	144.4	79.6	438.5	411.3	424.8	277.0
Total kWh	187.3	187.7	187.3	106.3	273.8	272.8	277.4	209.2	306.7	296.5	291.9	234.7	767.7	757.0	756.6	550.1

*Note slight difference in payload composition for skill mixes Ⓐ, Ⓑ, Ⓒ.

and skill mix combination analyzed. For each skill mix, the results are summed across the set of three payloads, giving an overall view of experiment accomplishment as affected by cross training.

The GSM results for skill mix Ⓐ show a sharp reduction in accomplishment (compared with the baseline) for experiments PH. 1 and PH. 3. These experiments require different professional skills (physicist and meteorologist respectively), both possessed by a single crewman. The results illustrate the relative unavailability of this particular man after the nucleus experiments (Com/Nav and Earth Observations) have been scheduled. (In the iterations to obtain acceptable schedules, the performance of the nucleus experiments was not sacrificed; i. e., the nucleus experiments were given high priority and scheduled first.) Also, for the analysis of alternate skill mixes, experiment PH. 1 was deleted from the first payload in the group, giving PH. 1 fewer chances to be scheduled. In skill mix Ⓑ, the physicist and meteorologist professional skills were distributed between two crewmen, providing more scheduling flexibility. A significant increase in the percentage accomplishment of experiment PH. 3 (meteorologist) was obtained.

The results for the highly constrained skill mix Ⓒ show a very significant degradation in experiment accomplishment. Scheduling is chiefly constrained by the unavailability of the electronics technician skill, which as shown in Table 24, is required by almost half of the ATL experiments.

The total crew hours and electrical energy scheduled for the set of three payloads for each skill mix is also shown in Table 27. For the baseline payload set, the total experiment hours input for scheduling was 545. 1. The total input hours for the alternate skill mix cases was 525. 1 due to the slight difference in payload composition. From these numbers and the totals in Table 27, the relative scheduling efficiency for each case can be determined (Table 28).

As mentioned previously in the discussion of the analysis procedure, experiment hour inputs to the General Scheduling Model (GSM) were in excess of available crew time. In the seven-day sortie mission, according to groundrules, a total of 432 crew hours are available to support experiments.

TABLE 28. – SCHEDULING EFFICIENCY AS A FUNCTION OF SKILL MIX

Skill mix	Scheduling efficiency, %
BL	80.5
Ⓐ	78.2
Ⓑ	80.9
Ⓒ	51.4

Skill mix Ⓐ was analyzed on the One day Model for mission day 4. Only the first payload exhibited a significant degradation in crew use compared with the baseline case. This resulted from the unavailability of the crewman with physicist/meteorologist skills to support experiment PH. 3 and PH. 4 for the six hours (total) required. In the three payloads, the overall degradation in crew use on experiments was six percent.

As the results show, cross training of the experiment crew in the various skills required is of critical importance for mixed-discipline payloads. For ATL, cross training of the crew in technical skills is mandatory. Although the cross training analysis was conducted for the case of three experiment crewmen, the conclusions are applicable to the case of two experiment crewmen, where cross training requirements would be even more severe. In the case of a three-man crew, some specialization in the professional level skills is acceptable.

Number of Crewmen. – The crew is the critical resource for experiment accomplishment. Two- and three-man experiment crews were discussed as ATL baselines above. For ATL, a three-man crew is preferable to a two-man crew, since the additional man, working the "swing shift," provides continuing support for experiments extending over the entire mission day, while the two crewmen on the standard shift can provide experiment support only over 16 hours of the mission day.

For a crew severely constrained in cross training, more than three crewmen would be required to achieve reasonable overall experiment accomplishment. In such a case, however, the use of individual crewmen would be low. For a three-man shuttle crew (in addition to the three experiment specialists), the third shuttle crewman may be a source of experiment support on a part-time basis.

Programmatic Groundrules. – Some of the more important groundrules used in the current study are discussed below. Groundrules of this type are significant drivers of analysis results.

Experiment Repeat Rules: Most experiments can benefit from repeated orbit flights because of the accumulation of additional experiment trials or the systematic variation in orbit parameters (e.g., altitude). In the current study, the repeated experiments made possible a more equitable distribution of experiment resource requirements over a series of flights. A uniform number of repeats was specified as an overall objective in the experiment program, but this could not be achieved because of other system constraints. Although variations in the experiment repeat rule were not explored, it was apparent that a highly structured repeat rule, in which a maximum number of repeats is associated with each experiment, would greatly complicate the payload analysis problem. A specified matrix of experiment repeats may or may not be consistent with efficient crew resource use.

Partial completions: Scheduling results are greatly enhanced if experiments can be partially completed. This, in effect, provides a degree of flexibility in the experiment definition so that available resources (but less than the full experiment requirement) can be used. The disadvantage is that the experiment objective is totally realized only after more than one flight. Approximately 25% of the experiments on the ATL payloads were partially completed on one or more flights.

Payload Changeovers: No restrictions were made relative to payload changeovers in the current ATL analysis. As a result each payload in a set of ATL payloads is different. This mode of operation was considered reasonable for the relatively low launch rates associated with the ATL. Any constraints of this nature would significantly impact the payload definition process.

5. CONCLUDING REMARKS

A procedure for analyzing sortie mission payloads was developed that incorporates consideration of schedules of crew and experiment operations in overall payload evaluation. This procedure was used to define mixed-discipline ATL payloads consisting of Langley experiments that a) meet experiment program objectives and b) use the experiment crew and other resources efficiently. Other, equally acceptable, ATL payload definitions may be possible. But failure to consider the implications of scheduled experiment operations generally results in unacceptable levels of either experiment accomplishment or crew use. This consideration of scheduled experiment operations early in the payload design process is made practical using the Manned Activity Scheduling System (MASS).

Some of the more significant findings in this study of ATL payloads are noted below.

Experiments. — The ATL experiments can usually be incorporated into efficient crew schedules if partial completions of the repetitive operational phase of some experiments can be tolerated. Two experiments, CS. 1 (Carbon Deposition) and MB. 4 (Electrical Characteristics of Cells), are especially difficult to schedule as originally structured. These experiments should be re-examined to determine whether more easily scheduled experiment activity cycles would be acceptable.

Many of the ATL experiments require support from specific ground targets. Most ATL payloads are marginal with respect to fulfilling the desired opportunities to view these targets. Sleep and other non-experiment activities of the experiment crew eclipse many of the view opportunities that would otherwise be available.

Experiment Crew. — Cross training of the experiment crew in the various skills required by the experiments is of critical importance for mixed-discipline payloads. In the case of ATL a large part of the experiment program is conducted with technician-level skills and a high degree of cross training of the crew in these skills is mandatory. In the case of a 3-man crew some specialization in the professional-level skills is acceptable. A 3-man crew also provides for a split shift and 24-hour coverage.

Sleep and other non-experiment activities (tasks) of the experiment crew were positioned in a rigid framework throughout the mission day, and only the remaining time slots were available for experiment activities. In general, this situation is satisfactory. Varying the task structure can improve isolated scheduling conflicts, but the overall impact of this added degree of flexibility is relatively small.

Payload Carrier. — The ATL was based on the MSFC Sortie Laboratory with a 9m (30 ft) pallet. This configuration is satisfactory for the mixed-discipline payloads of the ATL. These payloads are pallet-area limited, but reasonable extensions in pallet length would not significantly aid in experiment accomplishments, especially considering the limited view opportunities associated with the pallet-mounted experiments.

Pallet-only payloads based on a subset of ATL experiments were examined and found to be feasible if the orbiter can provide the pressurized volume required by the pallet-mounted experiments. Two payloads using 15m (50 ft) pallets provide the pallet area to accommodate the appropriate ATL experiment equipment. Crew use on these payloads is acceptable, but opportunities to view ground targets in support of the pallet-mounted experiments are less than desired. This results from the relatively high concentration of experiments using ground targets on each payload and the limited view opportunities in only two flights.

Subsystem resources used by the worst-case ATL payloads are: electrical power 2 kW average, 3 kW peak, and 3×10^6 MB digital data storage. These are within the limits of the Sortie Laboratory with payload assist.

Shuttle. — Many ATL experiments require pointing and stabilization support by the shuttle at the times these experiments are scheduled throughout the mission. Rough estimates of pointing support requirements indicate this to be an area requiring additional analysis when the shuttle Reaction Control System (RCS) is better defined.

Shuttle payload performance to orbit is sufficient to meet ATL requirements for the operational orbits selected in this study. However, if landing load considerations limit shuttle payloads to less than 18,200 kg (40,000 lb) then this factor could be an added constraint in ATL payload design.

6. REFERENCES

1. The Study of a Shuttle Compatible Advanced Technology Laboratory (ATL), Phase A Report, Langley Research Center (To Be Published).

2. User's Manual for the General Scheduling Model (GSM), Vol. I, 18 March 1973, Prepared for NASA, Langley Research Center, Contract NAS1-11674.

3. User's Manual for the One Day Model (ODM), Vol. II, 18 March 1973, Prepared for NASA, Langley Research Center, Contract NAS1-11674.

4. Space Shuttle Baseline Accommodations for Payloads, June 27, 1972, MSC Report MSC-06900.

APPENDIX A

ATL EXPERIMENT PROGRAM

The tables included in this appendix list the ATL experiments and the resources they require (as defined at the time of this study). Descriptive material on each of the thirty ATL experiments may be found in Reference 1. Two experiments, CN. 6 and CN. 8, are combined for the purpose of this study. Both use a common side-looking radar, and data acquired during one common operation can meet the experiment objectives of each experiment. The experiment ID is coded to represent the general scientific discipline as follows: CN - Communications/Navigation, EO - Earth Observation, PH - Physics and Chemistry, MB - Microbiology, CS - Components and Systems, and EN - Environmental Effects. Separate listings are given for the experiments as defined for the two- and three-man experiment crew analyses. (Tables 29 and 30 respectively). Crew skill requirements used in studies of cross training in a three-man experiment crew are included in Table 31.

TABLE 29. — EXPERIMENT RESOURCE REQUIREMENTS, TWO-MAN CREW ANALYSIS

ID no.	Name	No. crew	Tot. crew hr	Tot. kWh	Days dur.	Point. hr	Equip. wt kg (lb)	Press. vol. m^3 (ft^3)
CN. 1	Microwave interferometer	1	16.5	1.7	7	15.0	136 (300)	0.57 (20)
.2	Microwave radiometric meas.	1	15.4	6.2	7	11.9	136 (300)	1.24 (44)
.3	Prec. laser ranging	1	13.1	72.6	7	12.5	182 (400)	1.70 (60)
.4	Autonomous navigation	1	18.6	22.1	7	15.1	91 (200)	0.34 (12)
.5	Microwave altimetry	1	14.5	73.2	7	12.5	1500 (3300)	0.34 (12)
.6/8	Search & rescue/imaging radar	1	12.5	129.6	7	10.0	817 (1800)	0.45 (16)
.7	Multipath meas.	1	6.0	18.1	7	5.0	45 (100)	0.85 (30)
.9	RF noise	1	19.0	3.6	7	15.0	54 (120)	0.17 (6)
EO. 1	Lidar meas. cirrus clouds	1	4.1	21.7	7	7.0	318 (700)	1.41 (50)
.2	Tunable lasers	1	2.5	0.2	7	7.0	91 (200)	0.08 (3)
.3	Multispectral scanner	1	7.0	0.3	7	7.0	45 (100)	0.28 (10)
.4	Delivery ground truth P/Ls	1	2.0	0.5	1	---	908 (2000)	---- --
PH. 1	Spacecraft wake dynamics	1	2.0	0.4	5	---	418 (900)	0.25 (9)
.2	Barium plasma cloud rel.	1	2.3	0.1	1	1.8	23 (50)	0.08 (3)
.3	Optical properties aerosols	1	28.0	0.3	7	---	159 (350)	0.82 (29)
.4	Mapping upper atmos.	1	6.2	25.3	7	---	658 (1450)	3.14 (111)
.5	Spacecraft radiation environ.	1	1.8	57.1	7	---	318 (700)	0.42 (15)
.6	UV meteor spectroscopy	1	2.6	1.7	7	2.6	45 (100)	0.23 (8)
MB. 1	Colony growth - zero g	1	0.5	10.5	7	---	13 (29)	0.11 (4)
.2	Xfer of micro-organisms	2	3.5	23.5	7	---	14 (30)	0.11 (4)
.3	Elec. field opacity in cells	1	1.0	10.7	1	---	34 (75)	0.42 (15)
.4	Elec. characteristics of cells	1	6.8	14.6	1	---	20 (45)	0.23 (8)
.5	Spec. properties bio. cells	1	2.5	12.9	5	---	30 (65)	0.34 (12)
CS. 1	Carbon deposition	1	2.3	3.6	1	---	24 (52)	0.14 (5)
.2	Steam generator	1	2.0	1.0	2	---	52 (114)	0.08 (3)
EN. 1	Sampling airborne part.	1	0.3	12.1	4	---	23 (50)	0.11 (4)
.2	Orbital fatigue	1	28.0	21.0	7	---	91 (200)	0.08 (3)
.3	Environ. effects nonmetals	1	0.5	0.1	7	---	23 (50)	---- --
.4	Fluids in zero g	1	4.0	6.0	1	---	211 (465)	1.84 (65)
Σ			225.5	550.7		122.4	6,470 (14,245)	15.9 (561)

TABLE 30. – EXPERIMENT RESOURCE REQUIREMENTS, THREE-MAN CREW ANALYSIS

ID No.	Name	No. crew	Tot. crew hr	Tot. kWh	Days dur.	Point. hr	Equip. wt kg (lb)	Press. vol. m^3 (ft^3)
CN. 1	Microwave interferometer	2	18.5	1.7	7	15.0	136 (300)	0.57 (20)
.2	Microwave radiometric meas.	1	24.6	6.2	7	21.1	136 (300)	1.24 (44)
.3	Precision laser ranging	1	15.0	72.6	7	12.5	182 (400)	1.70 (60)
.4	Autonomous navigation	1	24.6	22.1	7	15.1	91 (200)	0.34 (12)
.5	Microwave altimetry	1	16.0	74.1	7	12.5	1500 (3300)	0.34 (12)
.6/8	Search & rescue/imaging radar	2	14.5	129.6	7	10.0	817 (1800)	0.45 (16)
.7	Multipath measurements	1	9.0	18.1	7	5.0	45 (100)	0.85 (30)
.9	RF noise	1	42.5	5.0	7	40.0	54 (120)	0.17 (6)
EO. 1	Lidar meas. cirrus clouds	1	9.0	24.2	7	12.0	318 (700)	1.41 (50)
.2	Tunable lasers	1	6.5	0.3	7	10.5	91 (200)	0.09 (3)
.3	Multispectral scanner	1	10.5	0.4	7	10.5	45 (100)	0.28 (10)
.4	Delivery ground truth P/Ls	1	2.0	0.5	1	----	908 (2000)	---- --
PH. 1	Spacecraft wake dynamics	2	20.0	2.0	5	----	418 (900)	0.25 (9)
.2	Barium plasma cloud release	2	8.7	0.1	1	6.7	23 (50)	0.08 (3)
.3	Optical properties aerosols	1	28.0	0.3	7	----	159 (350)	0.82 (29)
.4	Mapping upper atmosphere	1	13.2	25.2	7	----	658 (1450)	3.14 (111)
.5	Spacecraft radiation environ.	1	4.8	57.1	7	----	318 (700)	0.42 (15)
.6	UV meteor spectroscopy	1	5.3	1.7	7	4.3	45 (100)	0.23 (8)
MB. 1	Colony growth - zero g	1	0.5	10.5	7	---	13 (29)	0.11 (4)
.2	Xfer of micro-organisms	2	3.5	23.5	7	---	14 (30)	0.11 (4)
.3	Elec. field capacity of cells	1	1.0	10.7	1	---	34 (75)	0.42 (15)
.4	Elec. characteristics of cells	1	6.8	14.6	1	---	20 (45)	0.23 (8)
.5	Spec. properties bio. cells	1	12.5	12.9	5	---	30 (65)	0.34 (12)
CS. 1	Carbon deposition	1	2.3	3.6	1	---	24 (52)	0.14 (5)
.2	Steam generator	1	2.0	1.0	2	---	52 (114)	0.08 (3)
EN. 1	Sampling airborne part.	1	0.3	12.1	4	---	23 (50)	0.11 (4)
.2	Orbital fatigue	1	28.0	21.0	7	---	91 (200)	0.08 (3)
.3	Environ. effects nonmetals	1	0.5	0.1	7	---	23 (50)	--- --
.4	Fluids in zero g	1	4.0	6.0	1	---	211 (465)	1.84 (65)
Σ			334.1	557.2		175.2	6,470 (14,245)	15.9 (561)

TABLE 31. – CREW SKILL REQUIREMENTS FOR ATL EXPERIMENTS

Skill	Skill code	Experiment																											
		CN. 1	CN. 2	CN. 3	CN. 4	CN. 5	CN. 6/8	CN. 7	CN. 9	CS. 1	CS. 2	EN. 1	EN. 2	EN. 3	EN. 4	EO. 1	EO. 2	EO. 3	EO. 4	PH. 1	PH. 2	PH. 3	PH. 4	PH. 5	PH. 6	MB. 1	MB. 2	MB. 3	MB. 4	MB. 5
Biology technician	1																												X	X
Electronics technician with microwave trng.	6	X	X			X	X																							
Electronics technician	7			X	X					X	X		X	X	X	X	X	X		X	X			X	X					
Photo technician	8																											X		
Meteorologist	10																					X								
Electronics engineer	14							X	X																					
Physicist	19																			X			X							
Crewman 1	21																										X			
Crewman 2	22																										X			
Any	27	X					X					X							X		X					X				

APPENDIX B

MASS DATA BANK

The procedure for simulating an experiment in terms of descriptors acceptable as input to the MASS models is given in this appendix. The ATL experiment program so described constitutes the experiment data bank used in the current analysis effort.

A timeline of the desired activity throughout the mission of each experiment is the first step in constructing the data bank. The format shown in Figure 17 has been found to be useful for this purpose. Resources needed to support the experiment are defined for each stage of the experiment activity. Figure 17 shows the case of a Communications/ Navigation experiment, CN. 1, for illustration.

The next step entails the breakdown of the experiment activity into one or more events. An event is a subactivity of an experiment. For example, the CN. 1 experiment shown in Figure 18 has an equipment setup event on mission day 1, repeated calibration and operation events on mission days 2-6, and an equipment shutdown event on mission day 7. Activities within a mission day arealso defined. In the CN. 1 example the 1. 0 hour (total) calibration activity is set up as two 0. 5-hour activities spaced one orbit apart. The 2. 0 hours daily operation is then accumulated when within view of one of a specified set of ground targets. View opportunities constitute a separate model input and are obtained from an opportunity generator model.

The final step in experiment data bank preparation requires that the experiment events, previously defined, be coded in computer input format using the specific experiment descriptors acceptable to the MASS. One set of descriptors is required for General Scheduling Model (GSM) runs; this set and an additional set are required for One Day Model (ODM) runs. These descriptors are shown in Figure 19, with the data representing the CN.1 experiment example. In this example the daily operation was coded as a one-day operation to be repeated four times. During any one day, the operating event can be scheduled any time following the completion of the calibration event. With the particular coding used in this example, the MASS models would attempt to schedule all the operations shown, but would, if necessary, permit the omission of the operation on one or more mission days, or permit the omission of one or more views on a given mission day. Various options are available to the user of the MASS models in the way a given experiment can be coded. The reader is directed to References 2 and 3 for a discussion of these options.

A summary of events used in the revised ATL experiment data bank is given in Table 32. The data is based on the 29 ATL experiments defined for the baseline three-man experiment crew analysis.

EXPERIMENT OPERATIONS DATA

Expt. No. CN.1

Operating Mode Sortie

Title MICROWAVE INTERFEROMETER NAVIGATION AND TRACKING AID

Rev. ______ Date ______

	Support Requirements / Experiment Operating Sequence	Initial	Repeated	Termination
		Initiate, Deploy, Checkout, Test	EXPERIMENT OPERATIONS (Crew Monitor Signals, Coordinate with Targets)	Shutdown, Stow Equip.
		Day 1	Time ⟶ Hours — Repeat for 7 days	DAY 7
Crew Requirements	Code No. Skill Type		Calibrate (30 min./orbit, 2 orbits)	
	Elec. Tech.	→ (0.5 hr)	→ → ; → → → → → → → → → → → →	→ (1.0 hr)
			(1.0 hr/day) ; (10 min./target, 12 targets/day)	
Equipment Requirements	Inv. No. Nomenclature			
	Deploy	→ (100 W 0.5 hr)		
	Calibrate		→ (100W 1 hr/day)	
	Electronics		→ 2 hr/day - 100 W operating power	
	Retract			→ (1.0 hr)
Time - Dependent Functions	Power Profile	Day 1 – 100 W 0.5 hr	100 W 3 hr/day	Day 7 - 100 W, 1.0 hr
	Data Profile		10 min./target, 12 targets/day ; 3 MBPS (based on 10 bits/sample)	
	Target Type - Point Targets	Earth looking		
	Stability	Booms - static position within 2° - rate within 10^{-5} rad/sec		
	Remarks	No thermal dump in boom area; development time < 1 yr.		

Figure 17. Example of Experiment Operations Data for MASS Data Bank

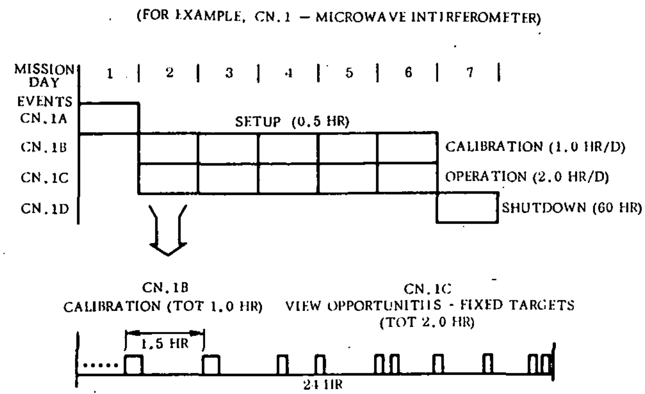


Figure 18. Data Bank Preparation – Breakdown of Experiment into Events

Table 32. Revised ATL Experiment Data Bank Descriptors

Experiment ID	Total no. of events	Total no. of active days	Can experiment be partially completed?	Specific support equipment	Pallet-mounted	Ground targets
CN. 1	4	7	Yes		Yes	World-wide
.2	7	7	Yes	Obs. window	Yes	-
.3	4	7	Yes	Obs. window	Yes	World-wide
.4	5	7	Yes		Yes	World-wide
.5	4	7	Yes		Yes	World-wide
.6/8	3	7	Yes	Obs. window	Yes	CONUS
.7	4	7	Yes		Yes	Satellite subpoint
.9	3	7	Yes		Yes	World-wide
EO. 1	4	7	Yes	Airlock	No	-
.2	4	7	Yes	Obs. window	Yes	World-wide
.3	2	7	Yes		Yes	Coastal zones
.4	1	1	Yes		Yes	-
PH. 1	1	5	Yes	Boom	Yes	-
.2	3	1	No	Obs. window	No	-
.3	1	7	Yes		No	-
.4	4	7	Yes	Boom	Yes	-
.5	3	7	Yes		Yes	-
.6	3	7	Yes	Airlock	No	-
MB. 1	3	7	Yes		No	-
.2	1	7	Yes		No	-
.3	2	1	No		No	-
.4	4	1	Yes		No	-
.5	2	5	Yes		No	-
CS. 1	4	1	Yes		No	-
.2	1	2	No		No	-
EN. 1	3	4	No		No	-
.2	6	7	Yes	Airlock	No	-
.3	3	7	Yes	Boom	Yes	-
.4	1	1	Yes		No	-

EXPLIB/TSKLIB

1–6	7–12	13–18	19–24	25–30	31–36	37–42	43–48	49–54	55–60
EVENT ID	ALPHA NUMERIC DESCRIPTOR			PREDECESSOR/ SUCC. OPTION	PARTIAL COMP OPTION	OUTPUT SUM OF PHASES	ATTITUDE REQUIRED		ACTIVITY PROFILE FLAG
CN. 1C	MICROWAVE INTERFER			0	0	0	-1		0
EVENT DURATION	NUMBER ACTIVE DAYS	NUMBER ACTIVE PERIODS	NUMBER INACTIVE DAYS	FIRST DAY ACTIVE/INACTIVE	FORCE START DAY	PREDECESSOR OR SUCC. DELAY	PREDECESSOR	PREDECESSOR OR SUCCESSOR	
1	1	1	0	1	0	0	CN. 1B	0	
NUMBER TIMES TO REPEAT	MIN. DELAY TO NEXT REPEAT	MAX. DELAY TO NEXT REPEAT			CONSECUTIVE EVENTS TO REPEAT	SUCCESSOR TO REPEAT REFER.	POINTING HOURS		
4	1	4			0	0	2. 0		
NUMBER SKILLS	1ST SKILL TYPE	1ST SKILL HOURS	2ND SKILL TYPE	2ND SKILL HOURS	3RD SKILL TYPE	3RD SKILL HOURS	4TH SKILL TYPE	4TH SKILL HOURS	5TH SKILL TYPE
2	6	2. 0	27	0. 4					
5TH SKILL HOURS	6TH SKILL TYPE	6TH SKILL HOURS	AC STAND BY POWER WATTS	AC OPERATING POWER WATTS	AC OPERATING POWER HOURS	AC PEAK POWER WATTS	AC PEAK POWER HOURS	AC PEAK POWER DELAY HOURS	DC STAND BY POWER WATTS
0	0								
DC OPERATING POWER WATTS	DC OPERATING POWER HOURS	DC PEAK POWER WATTS	DC PEAK POWER HOURS	DC PEAK POWER DELAY HOURS	VOICE HRS/DAY	TV HRS/DAY	DIGITAL DATA MEGA BIT/DAY	LOGISTICS WEIGHT UP	LOGISTICS VOLUME UP
100	2. 0						21600		

EPRLIB/TPRLIB

1–6	7–12	13–18	19–24	25–30	31–36	37–42	43–48	49–54	55–60
EVENT ID	PREDECESSOR WITHIN CHAIN	SUCCESSOR WITHIN CHAIN	SUCCESSOR DELAY HOURS	EVENT LØCATION	EQUIPMENT ITEM 1	EQUIPMENT ITEM 2	EQUIPMENT ITEM 3	EQUIPMENT ITEM 4	EQUIPMENT ITEM 5
CN. 1C	CN. 1B				9003	9004	9005	9006	9007
EQUIPMENT ITEM 6	EQUIPMENT ITEM 7	EQUIPMENT ITEM 8	EQUIPMENT ITEM 9	EQUIPMENT ITEM 10	EQUIPMENT ITEM 11	EQUIPMENT ITEM 12	SKILL 1 DELAY HOURS	SKILL 2 DELAY HOURS	SKILL 3 DELAY HOURS
9008	9009	9015	7001					0. 33	
FIRST EVENT OF PREDECESSOR CHN			FIXED TIME - POSITION FLAG	FIXED START TIME HOURS				PARTIAL COM- PLETION FLAG	WORK AREA VOLUME FT 3
0			1					0. 1	
CHN DELAY FROM PREDECESSOR HRS			NUMBER OF REPEATS	MINIMUM REPEAT DELAY HOURS	EARLIEST START TIME HOURS		SKILL 4 DELAY HOURS	SKILL 5 DELAY HOURS	
0									

Figure 19. MASS Input Descriptors for CN. 1 Operational Event

APPENDIX C

DETAILED SCHEDULES FOR BASELINE PAYLOADS

Detailed timelines of scheduled experiment activities are shown for each of the following:

2-Man Crew:	Payload 1 - mission days 2-6, Figure 20-24
	Payload 2 - mission day 4, Figure 25
	Payload 3 - mission day 4, Figure 26
3-Man Crew:	Payload 4 - mission days 2-6, Figure 27-31
	Payload 5 - mission day 4, Figure 32
	Payload 6 - mission day 4, Figure 33

The timelines presented in Figures 20-33 are produced by an SC-4020 plot routine, which is an optional output of the One Day Model (ODM). Extensive printed output of the ODM serves to back up the crew timelines and resource profiles shown in these figures. Detailed schedules are not shown for mission days 1 or 7, since the non-experiment crew activities for these days have not yet been completely defined. For the purposes of this study, it is assumed that the setup and shutdown events scheduled by the General Scheduling Model for these days can in fact be accomplished by the crew when the additional constraints imposed by the ODM are considered.

The crew activities shown in Figures 20-24 and 27-31 are summed at the experiment event level in Tables 33 and 34. Event times passed on by the General Scheduling Model (GSM) to the ODM are also given in these tables. In general, there is some degradation in overall experiment completions scheduled in the ODM compared to the GSM because of the additional scheduling constraints introduced by the ODM. The data shown in Tables 33 and 34 differ slightly from the respective timelines shown in the figures. The differences are caused by manually adjusting the ODM schedules to obtain a better distribution of scheduled completions and/or increase total scheduled experiment time. Increased crew use obtained by manually adjusting the ODM schedules usually amounts to less than 10 percent.

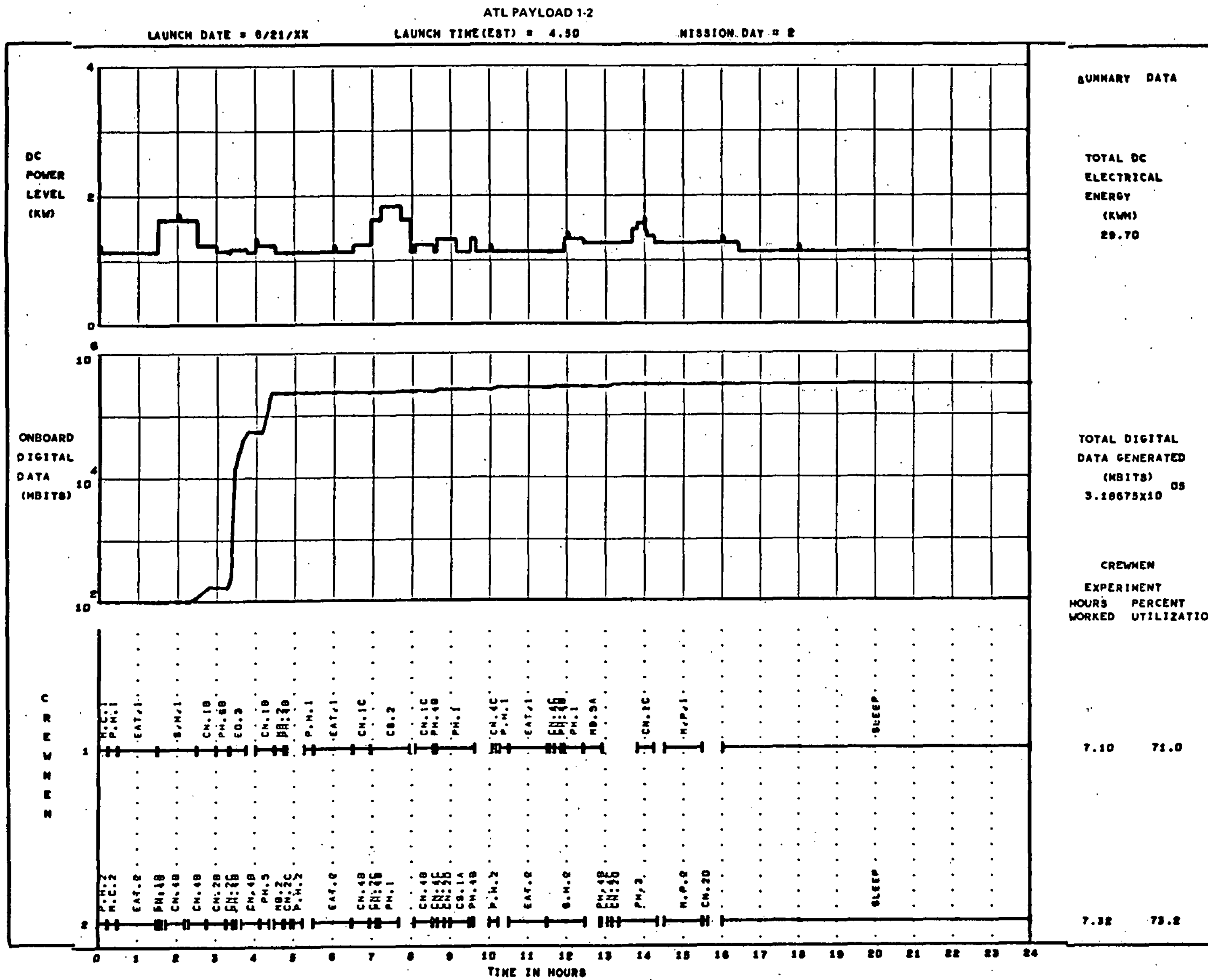


Figure 20. Schedule Timeline, ATL Payload 1, Day 2

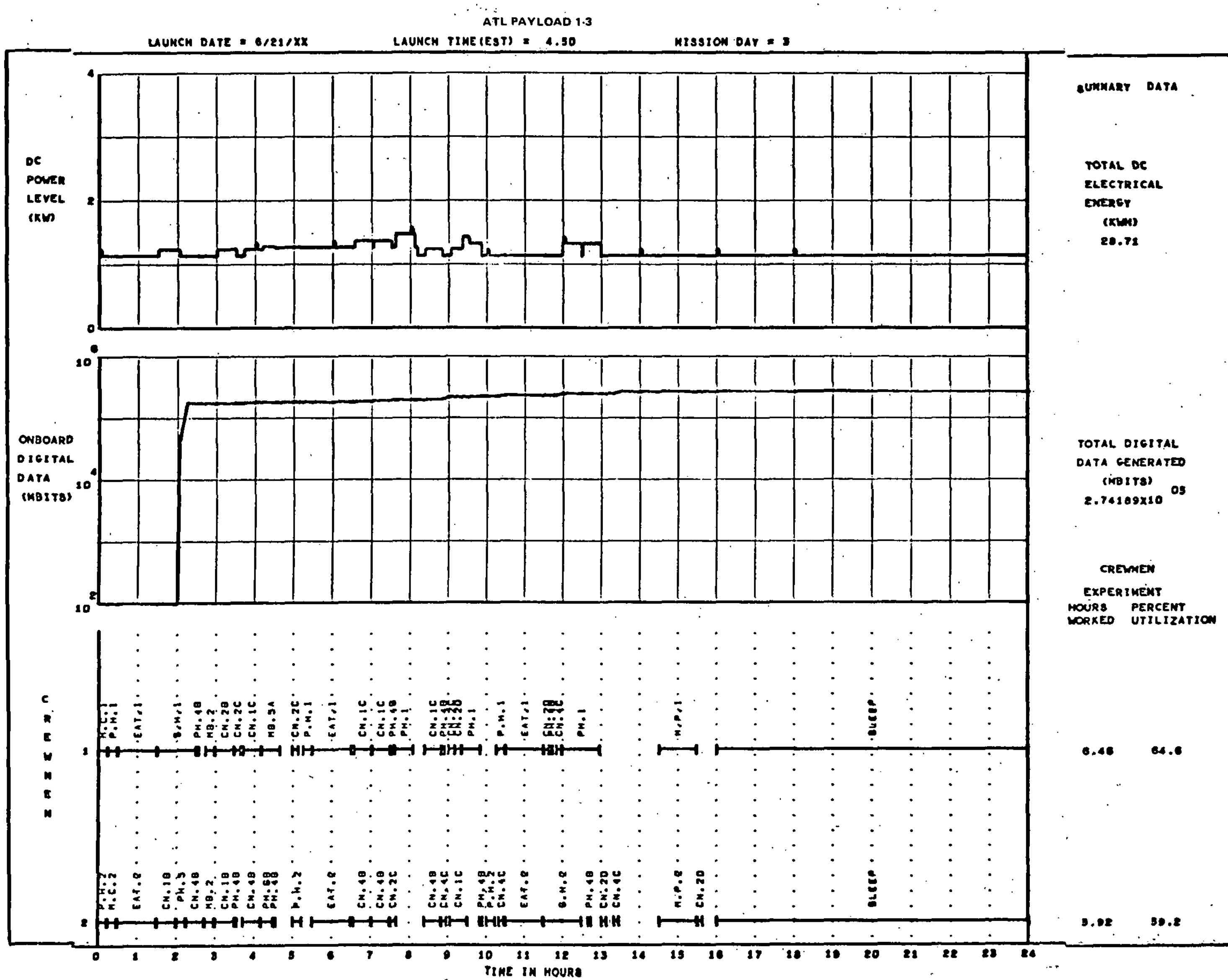


Figure 21. Schedule Timeline, ATL Payload 1, Day 3

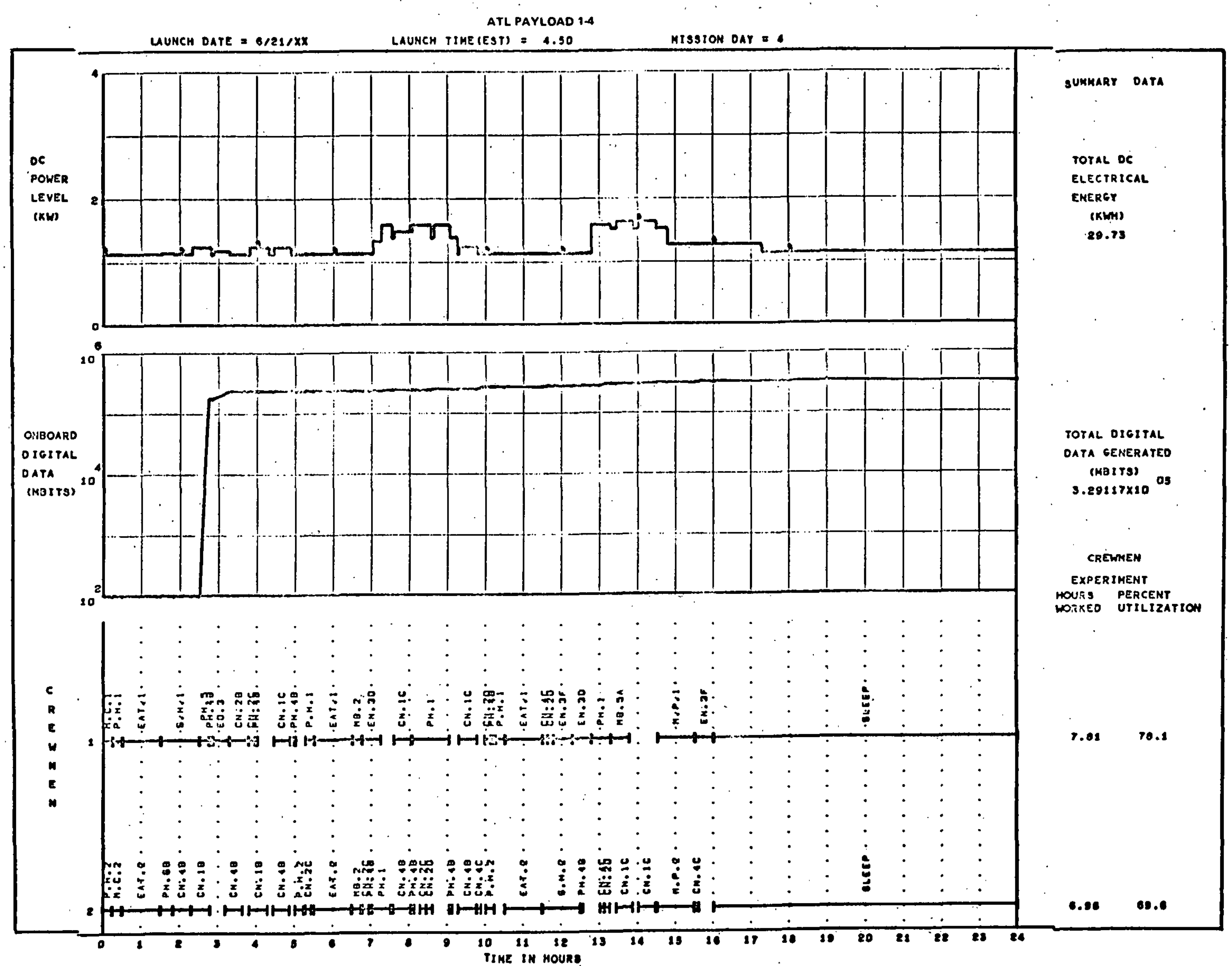


Figure 22. Schedule Timeline, ATL Payload 1, Day 4

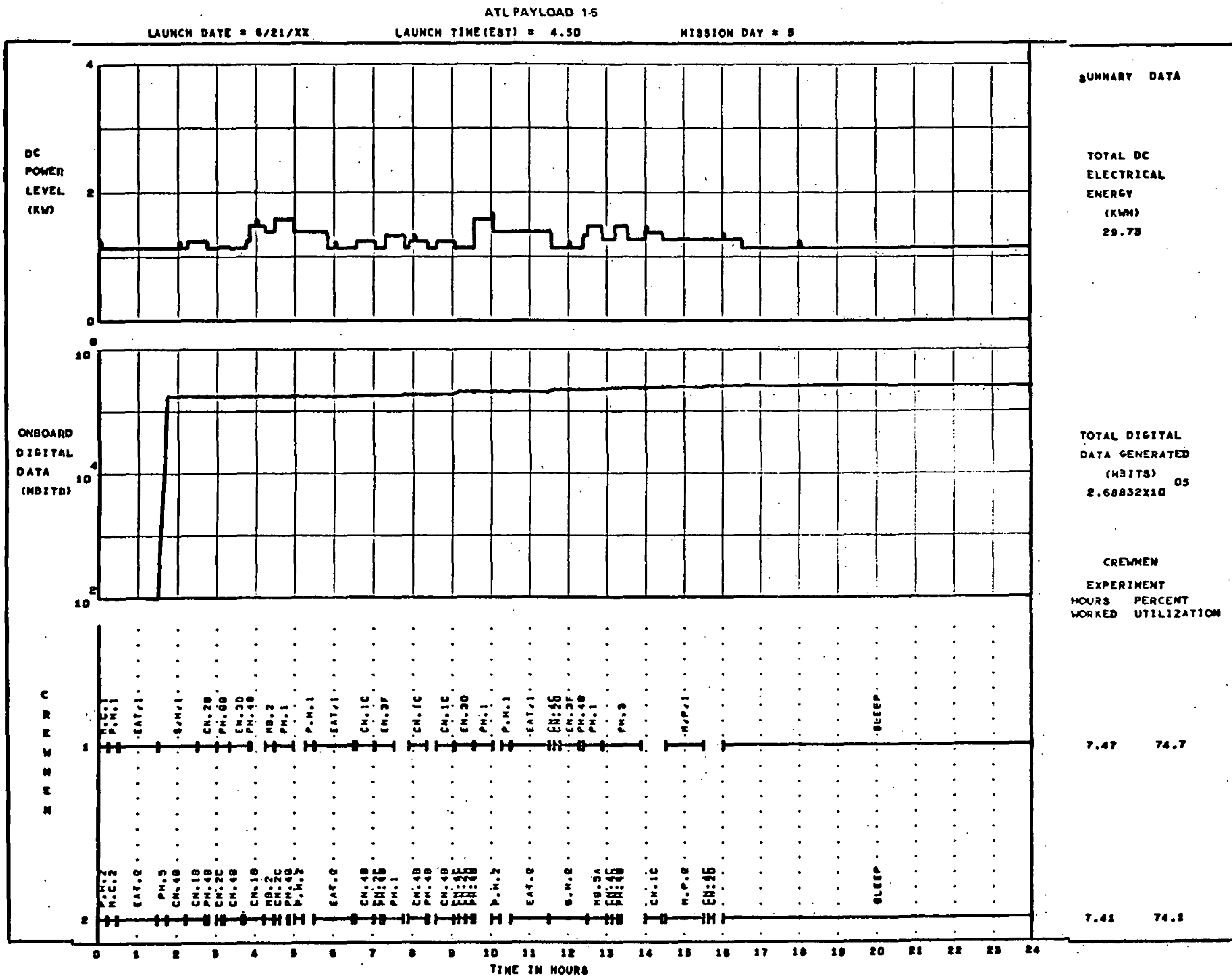


Figure 23. Schedule Timeline, ATL Payload 1, Day 5

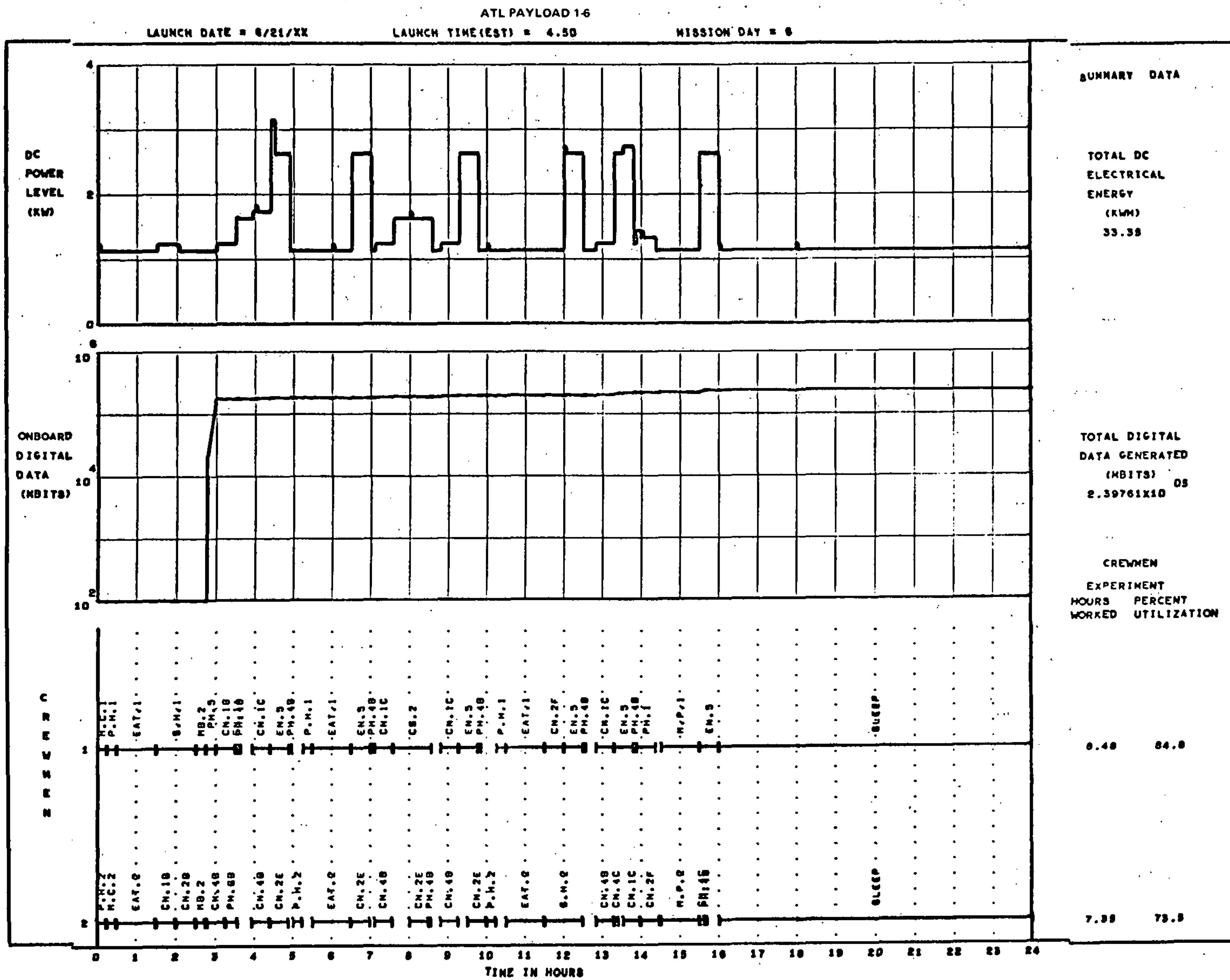


Figure 24. Schedule Timeline, ATL Payload 1, Day 6

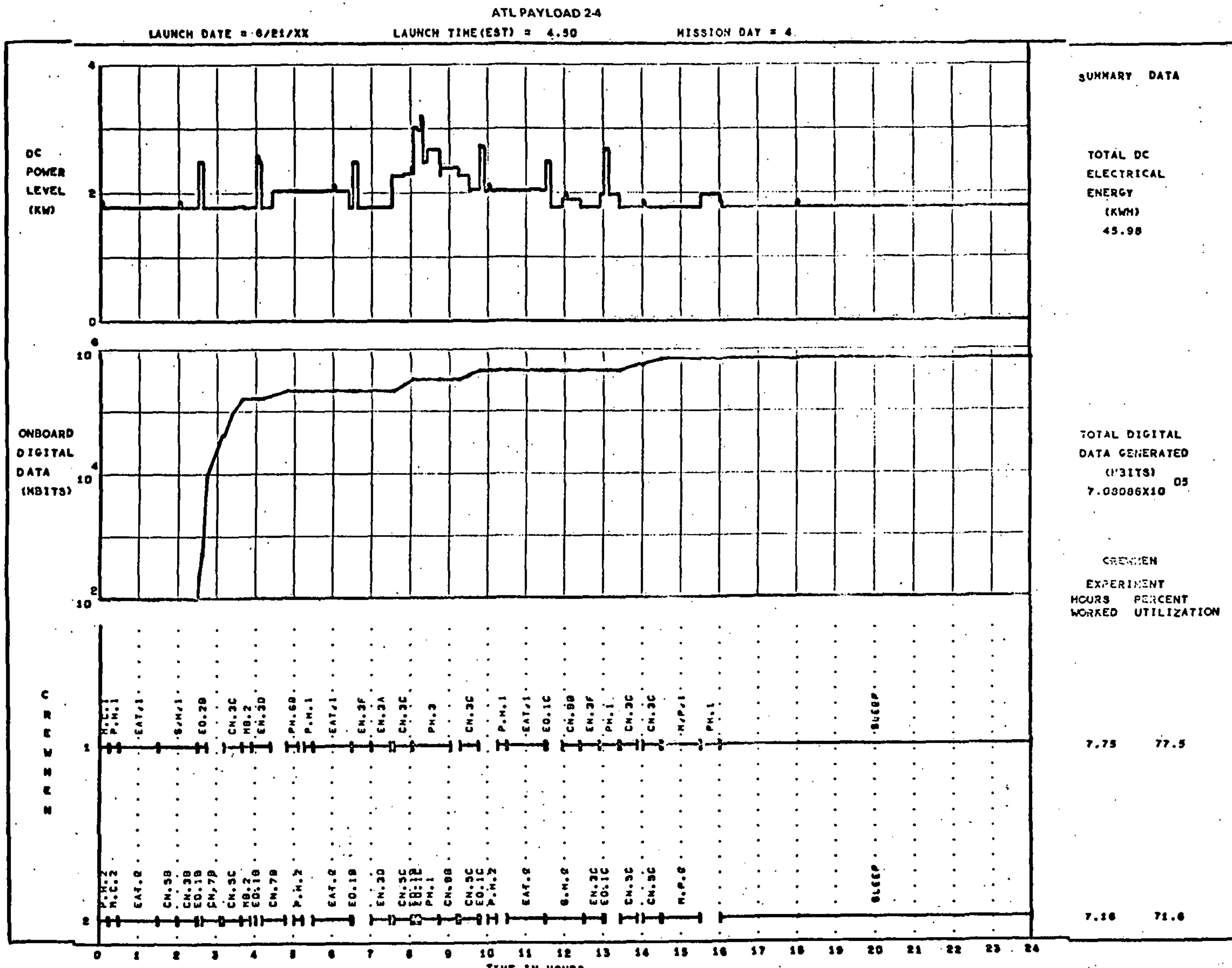


Figure 25. Schedule Timeline, ATL Payload 2, Day 4

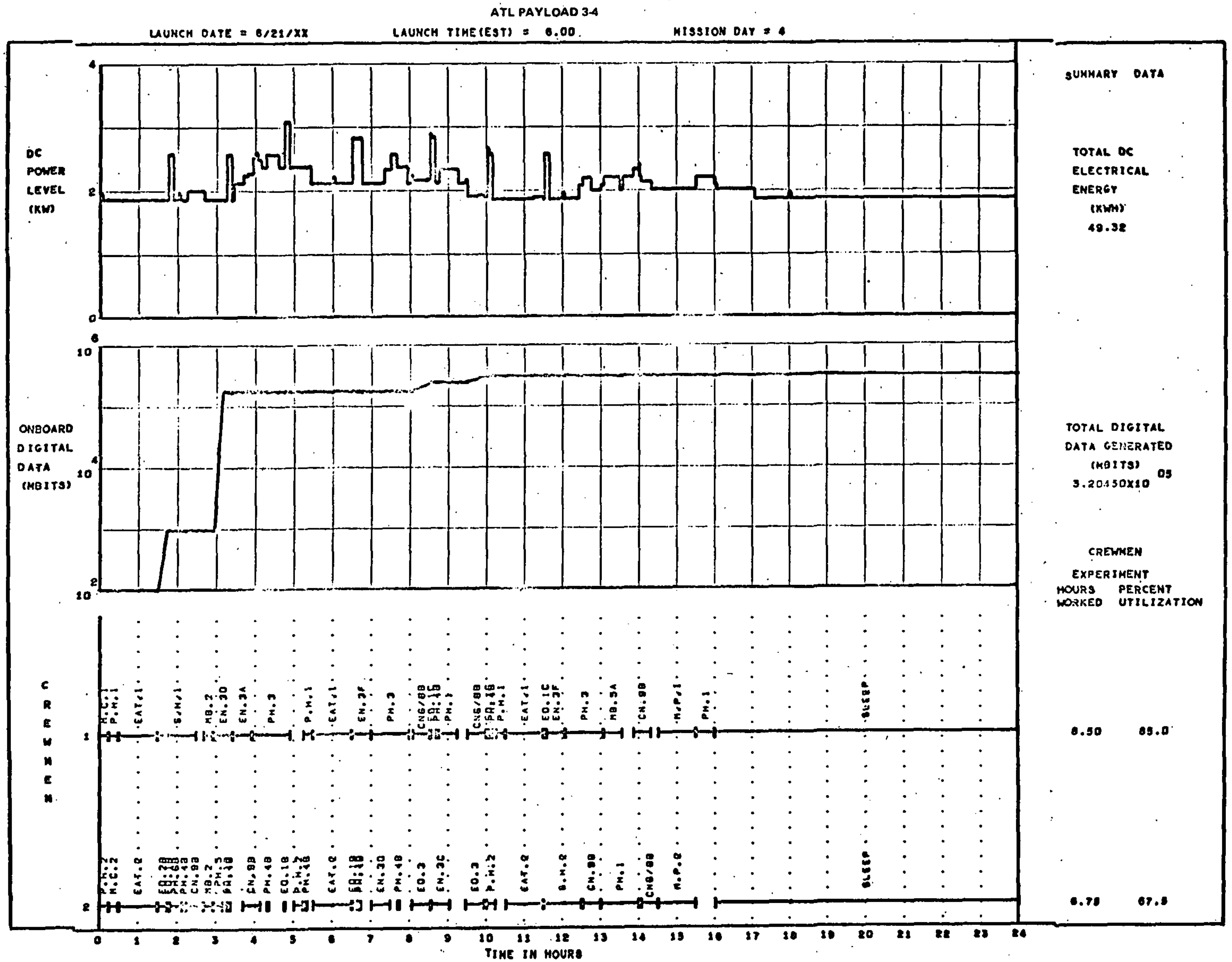


Figure 26. Schedule Timeline, ATL Payload 3, Day 4

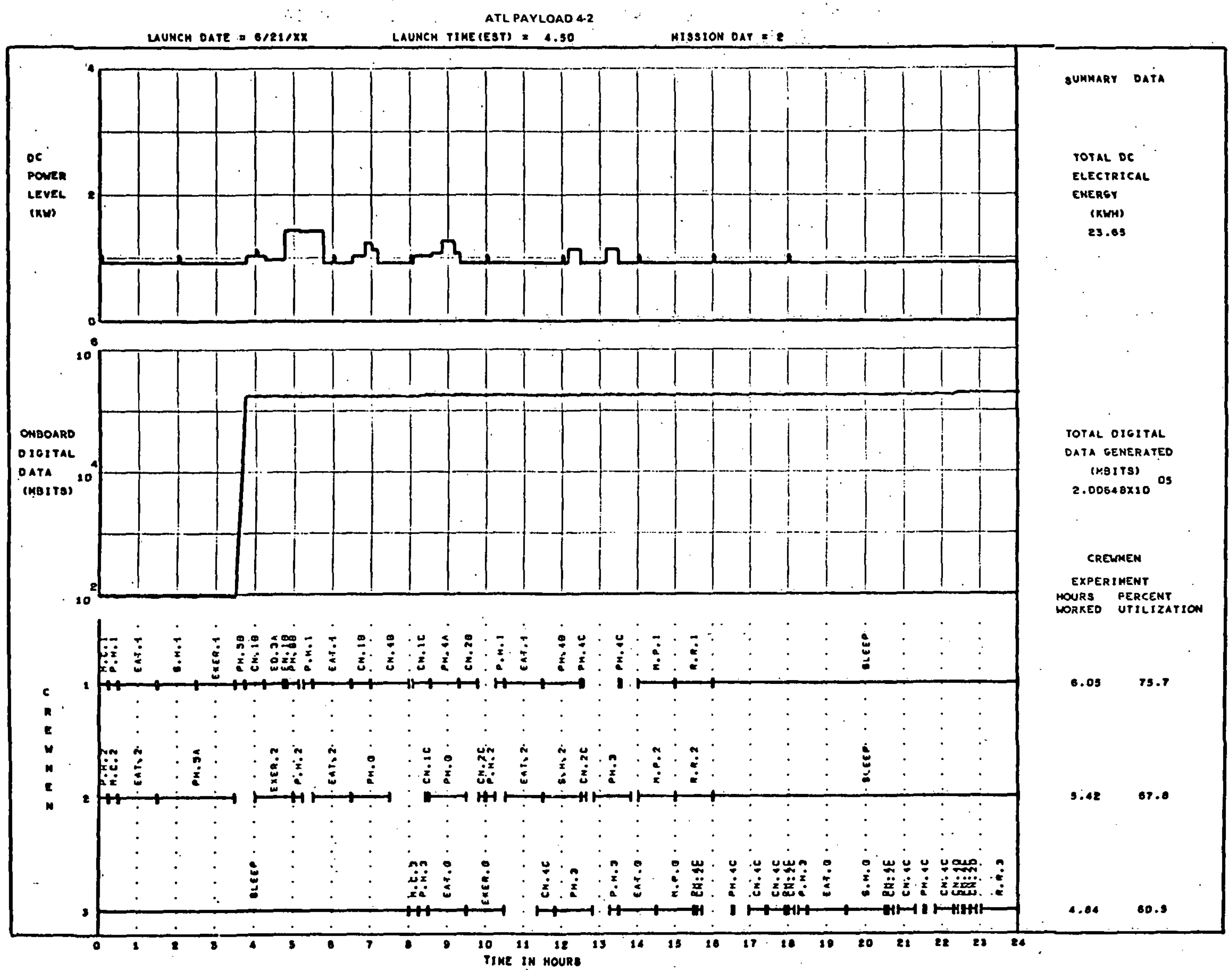


Figure 27. Schedule Timeline, ATL Payload 4, Day 2

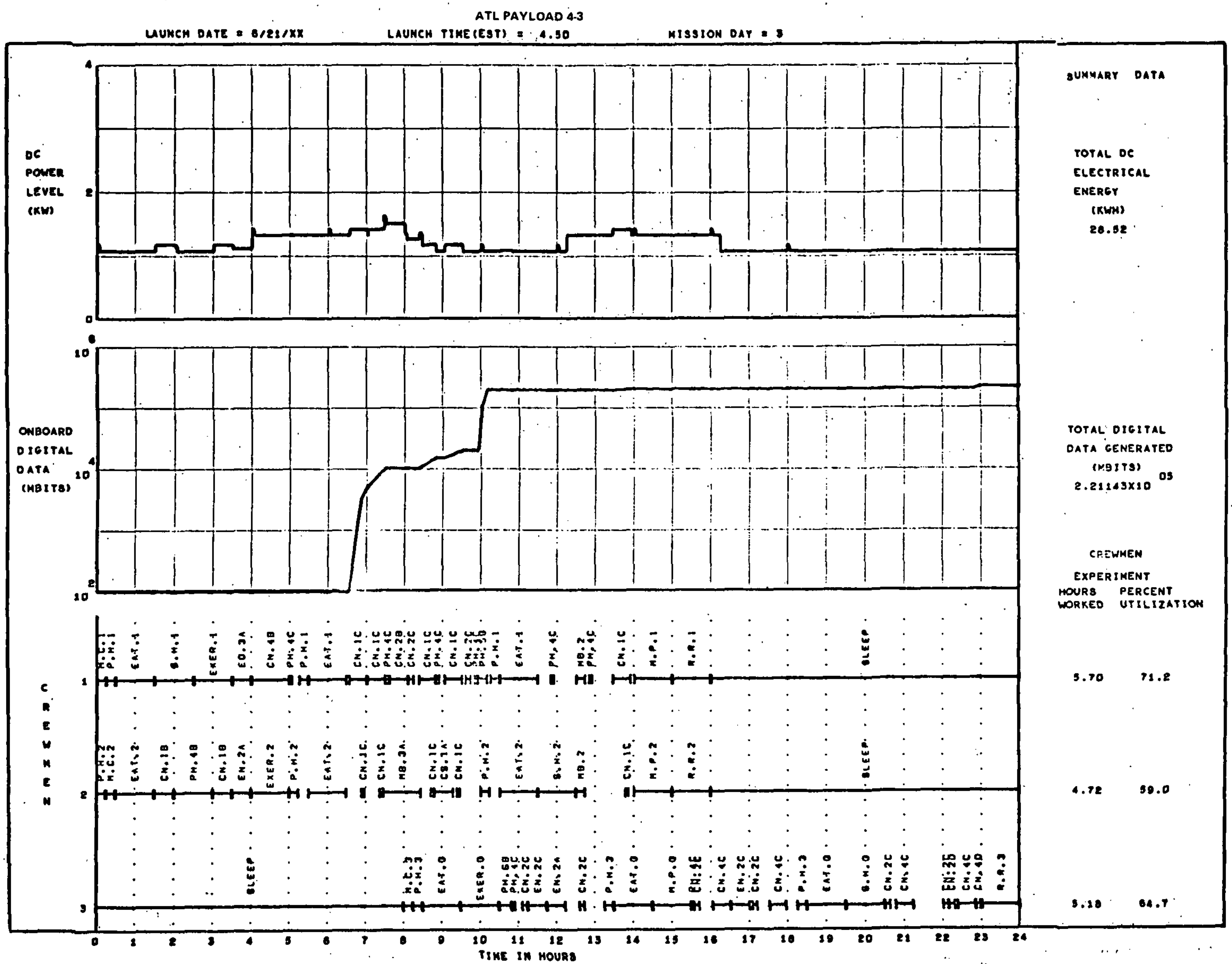


Figure 28. Schedule Timeline, ATL Payload 4, Day 3

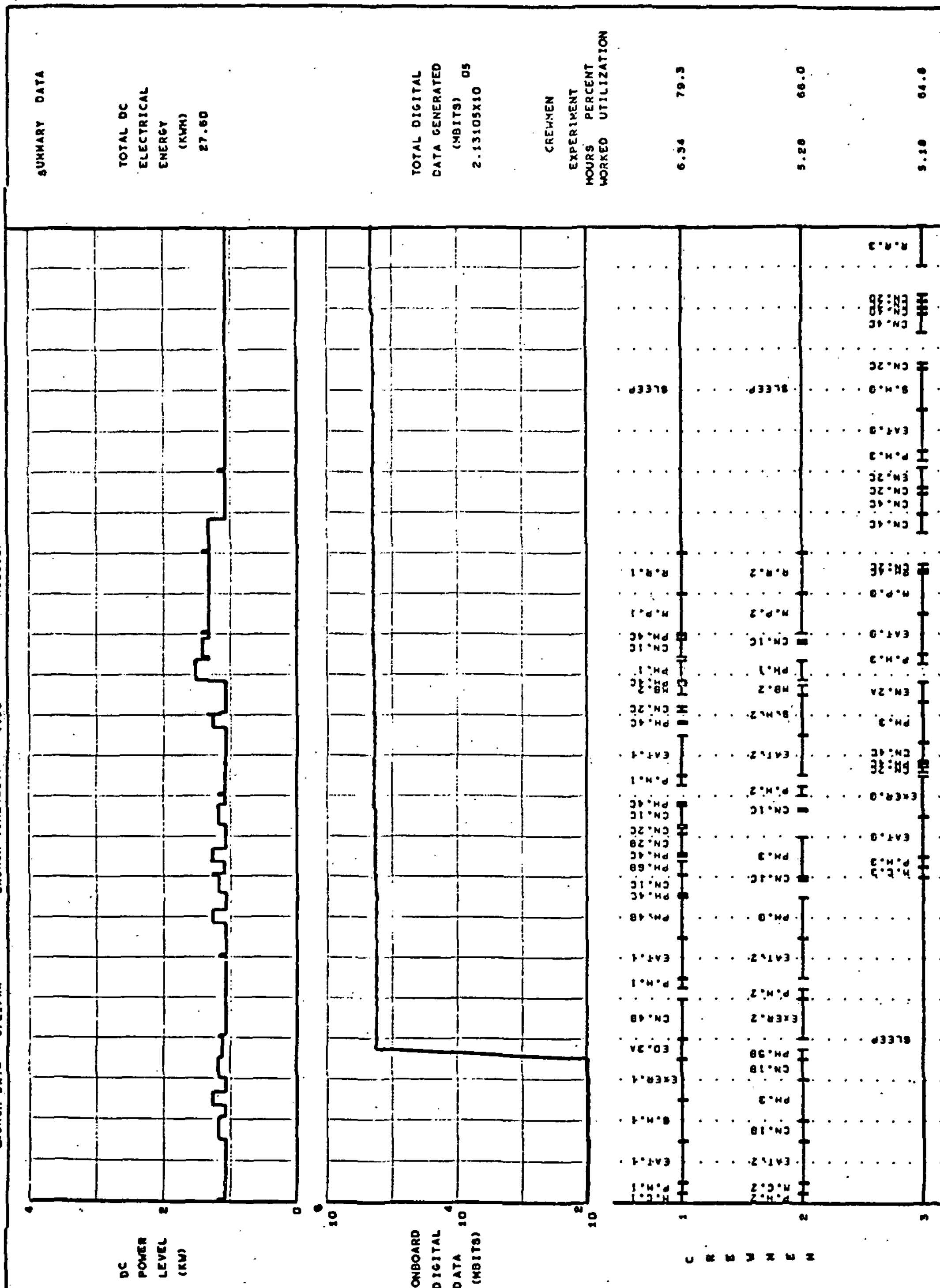


Figure 29. Schedule Timeline, ATL Payload 4, Day 4

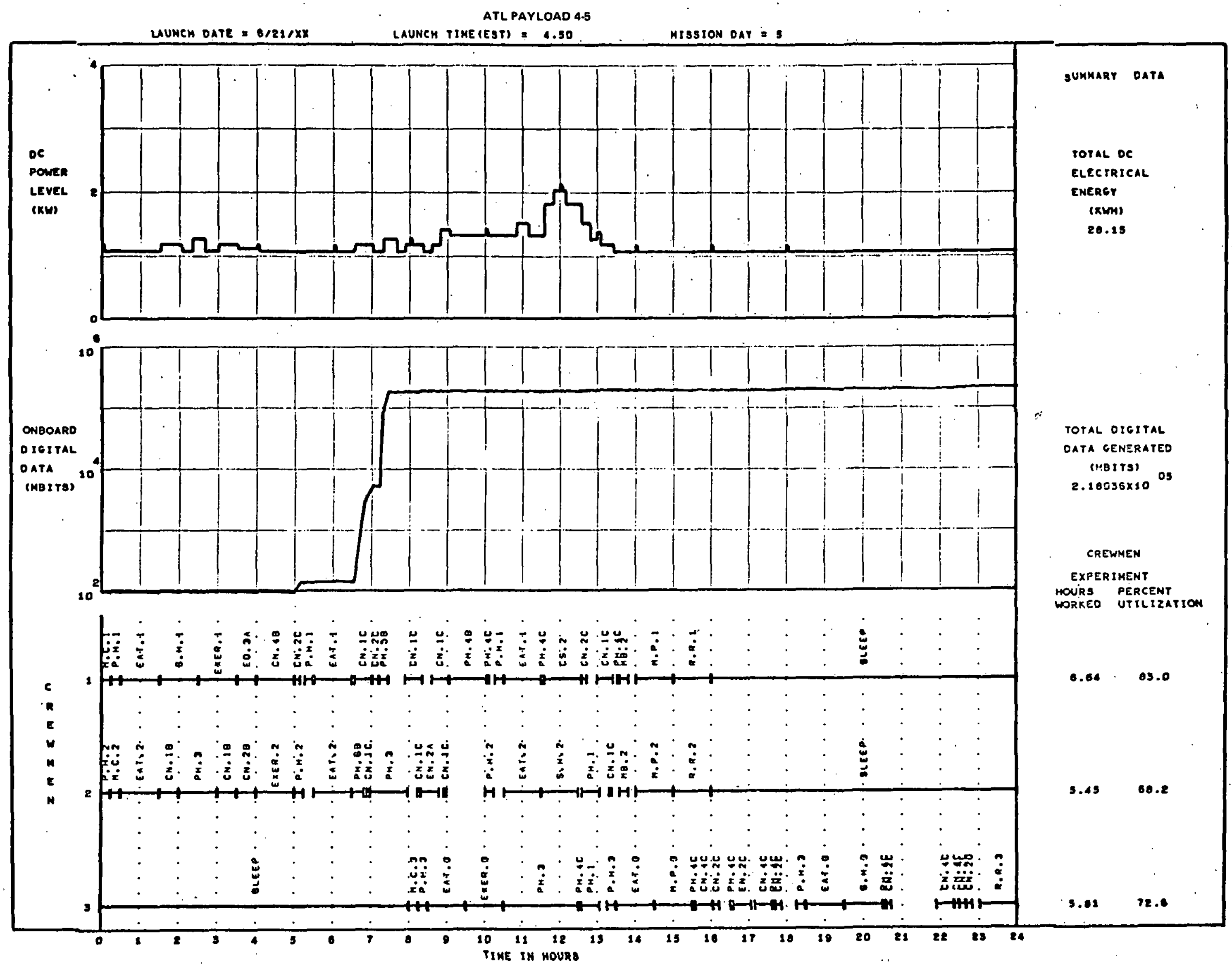


Figure 30. Schedule Timeline, ATL Payload 4, Day 5

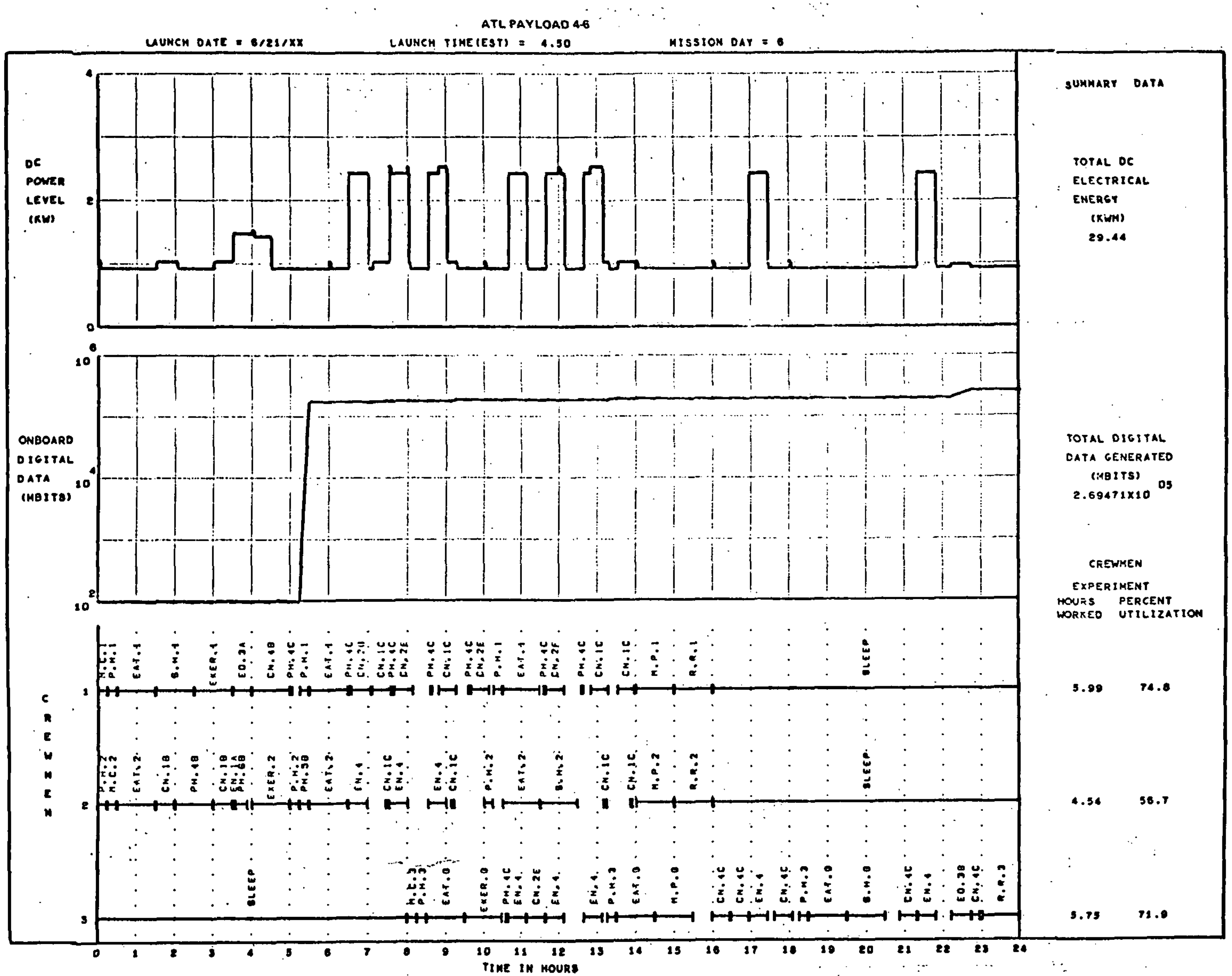


Figure 31. Schedule Timeline, ATL Payload 4, Day 6

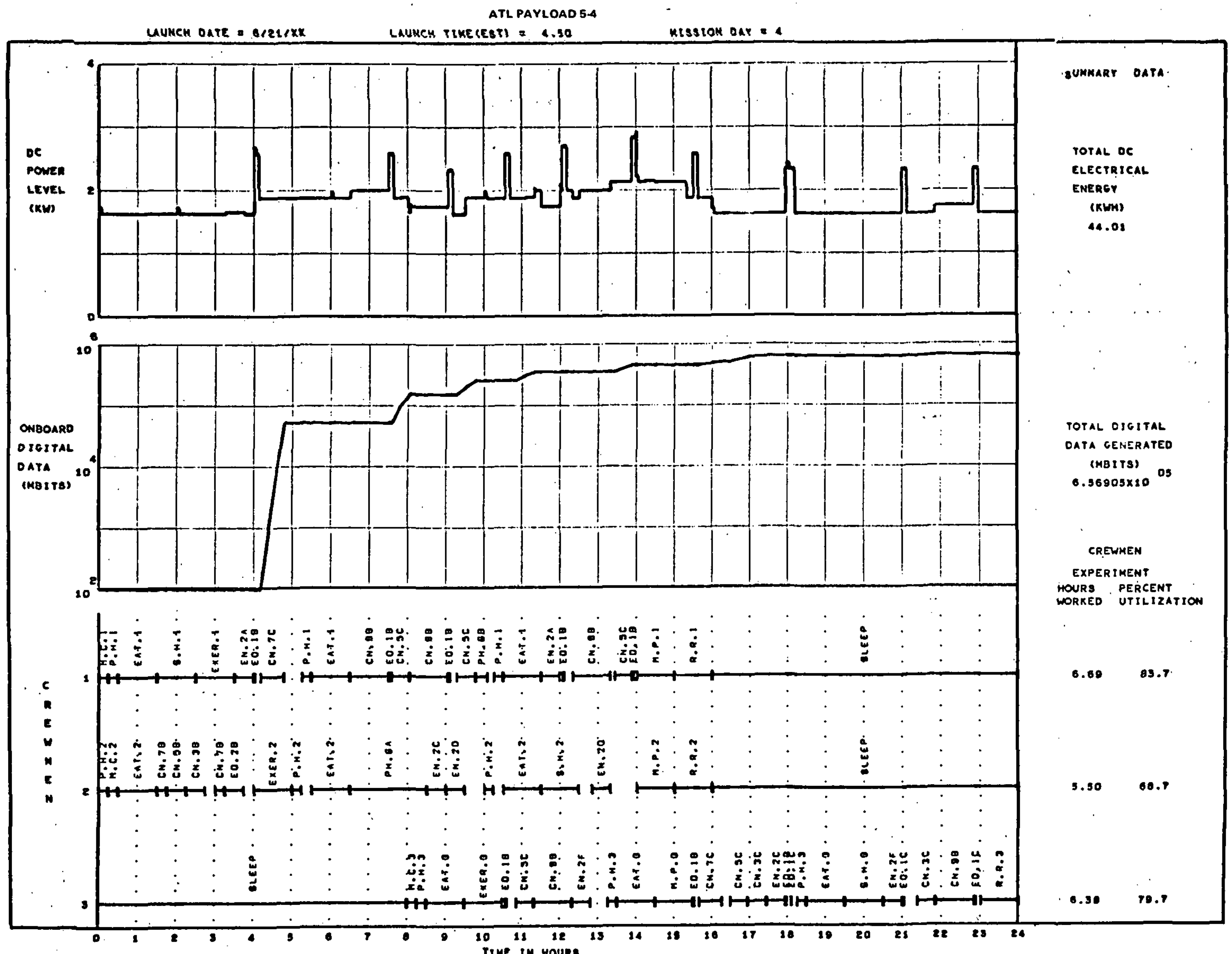


Figure 32. Schedule Timeline, ATL Payload 5, Day 4

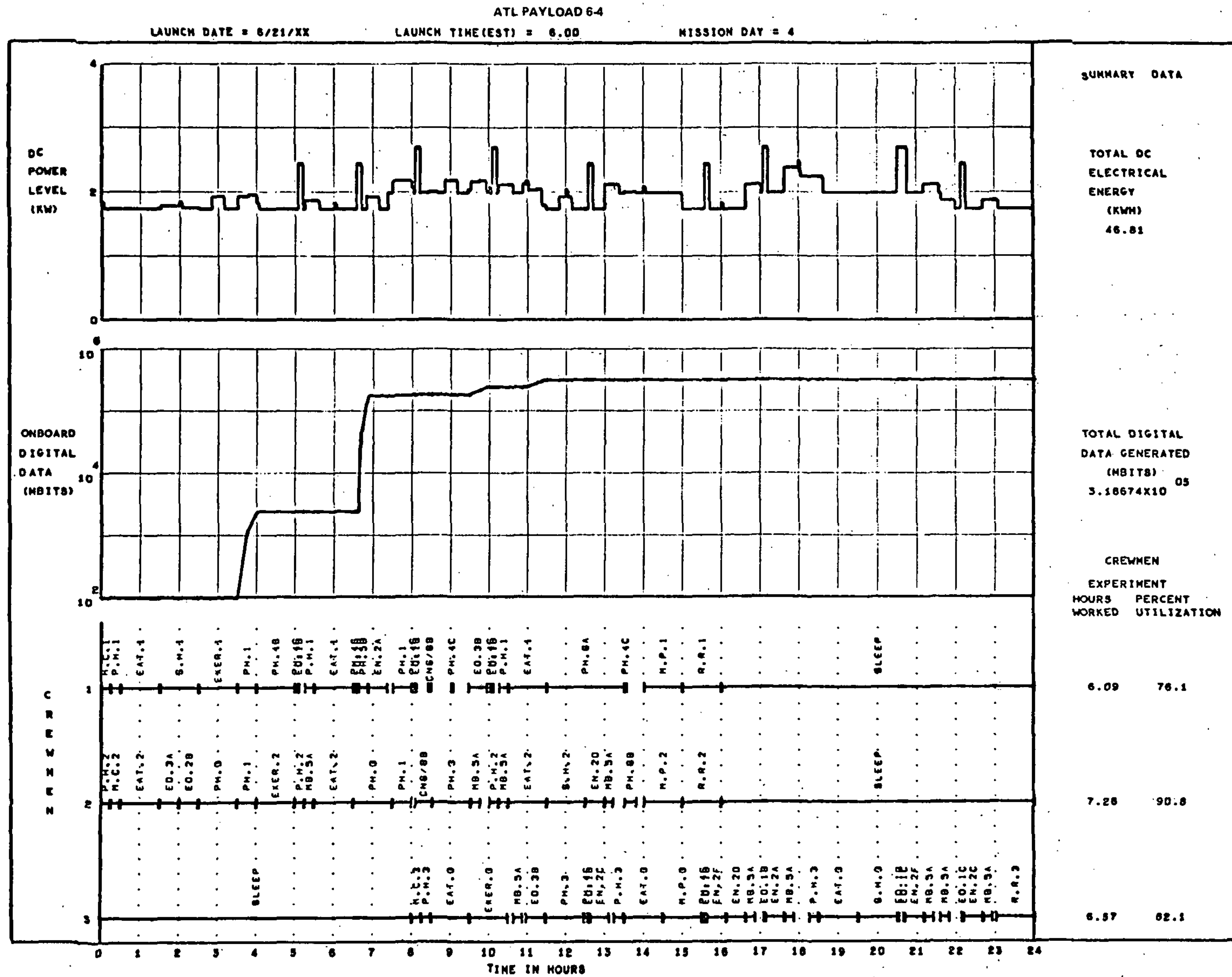


Figure 33. Schedule Timeline, ATL Payload 6, Day 4

TABLE 33. ODM SCHEDULES SUMMARY FOR TWO-MAN CASE, PAYLOAD 1

Experiment Event	Crew hours required/day	Crew hours scheduled on ODM				
		Day 2	Day 3	Day 4	Day 5	Day 6
CN. 1B	1.00	1.00	1.00	1.00	1.00	1.00
C	2.00	1.41	(1.90)†	2.37	1.90	2.37
CN. 2B	0.50	0.50	0.50	0.50	0.50	0.50
C	0.67	0.67	0.67	0.67	0.67	—
D	0.67	0.67	0.67	0.67	0.67	—
E	2.00	—	—	—	—	2.00
F	2.00	—	—	—	—	1.00
CN. 4B	2.00	(1.93)	(1.92)	2.40	(1.92)	(2.29)
C	0.52	0.52	0.52	0.52	0.52	0.26
EO. 3	1.00	(0.85)	(0.85)	(0.73)	(0.43)	0
PH. 1	2.00	2.00	2.00	2.00	2.00	(1.00)
PH. 2	2.33	—	(2.33)	—	—	—
PH. 3	4.00	1.00	—	(1.00)	(2.00)	—
PH. 4B	0.67	0.67	0.67	0.67	0.67	0.67
PH. 5	0.25	0.25	0.25	0.25	0.25	0.25
PH. 6B	0.33	0.33	0.33	0.33	0.33	0.33
MB. 1B	P‡	P	P	P	P	P
MB. 2*	0.50	0.50	0.50	0.50	0.50	0.50
MB. 3A	1.00	(1.00)	—	—	—	—
B	P	P	P	P	P	P
MB. 4A	4.00	—	0	—	—	—
B	2.50	—	0	—	—	—
C	0.25	—	0	—	—	—
D	P	P	P	P	P	P
MB. 5A	0.50	0.50	0.50	0.50	0.50	—
B	P	P	P	P	P	P
CS. 1A	0.50	0.50	—	—	—	—
B	0.50	0	—	—	—	—
C	0.75	0	—	—	—	—
D	0.50	0	—	—	—	—
CS. 2	1.00	1.00	—	—	—	1.00
EN. 1A	0.08	—	—	—	—	0.08
B	0.08	0.08	—	—	—	—
C	P	P	P	P	P	P
EN. 3A	1.00	—	—	0	0	—
B	P	P	P	P	P	P
C	1.00	—	—	0	0	—
D	1.00	—	—	1.00	1.00	—
E	P	P	P	P	P	P
F	1.00	—	—	1.00	1.00	—
EN. 4B	P	P	P	P	P	P
EN. 5	4.00	—	—	—	—	3.00
Σ Crew hours		15.4	14.6	16.1	15.8	16.2
Σ kWh		29.7	28.7	29.8	29.7	33.4

TABLE 34. ODM SCHEDULES SUMMARY FOR THREE-MAN CASE, PAYLOAD 4

Experiment Event	Crew hours required/day	Crew hours scheduled on ODM				
		Day 2	Day 3	Day 4	Day 5	Day 6
CN. 1B	1.00	1.00	1.00	1.00	1.00	1.00
C*	2.40	0.58	2.82	1.71	2.28	2.29
CN. 2B	0.50	0.50	0.50	0.50	0.50	0.50
C	1.33	1.00	1.33	0.85	1.15	—
D	1.33	0.17	0.17	0.17	0.17	—
E	4.00	—	—	—	—	1.50
F	4.00	—	—	—	—	0.50
CN. 4B	1.00	1.00	1.00	1.00	1.00	1.00
C	2.00	2.39	1.88	1.89	1.44	2.14
D	0.52	0.13	0.13	0.13	0.13	0
EO. 3A	0.50	0.50	0.50	0.50	0.50	0.50
B	1.00	0	0	0	0	0.53
PH. 1*	4.00	(1.00)†	—	1.00	1.00	—
PH. 3	4.00	4.00	—	4.00	4.00	—
PH. 4A	0.75	0.75	—	—	—	—
B	1.00	1.00	1.00	1.00	1.00	1.00
C	0.67	0.67	0.67	0.67	0.67	0.67
PH. 5A	2.00	2.00	—	—	—	—
B	0.25	0.25	0.25	0.25	0.25	0.25
PH. 6B	0.33	0.33	0.33	0.33	0.33	0.33
MB. 1B	P‡	P	P	P	P	P
MB. 2*	0.50	(0.50)	0.50	0.50	0.50	(0.50)
MB. 3A	1.00	—	1.00	—	—	—
MB. 3B	P	P	P	P	P	P
MB. 4A	4.00	—	0	—	—	—
B	2.50	—	0	—	—	—
C	0.25	—	0	—	—	—
D	P	P	P	P	P	P
CS. 1A	0.50	—	0.50	—	—	—
B	0.50	—	0.50	—	—	—
C	0.75	—	(0.43)	—	—	—
D	0.50	—	0	—	—	—
CS. 2	1.00	—	—	—	1.00	—
EN. 1A	0.08	—	—	—	—	0.08
B	0.08	0.08	—	—	—	—
C	P	P	P	P	P	P
EN. 2A	1.00	—	1.00	1.00	(1.00)	(1.00)
B	P	—	P	P	P	P
C	1.00	—	1.00	1.00	(1.00)	(1.00)
EN. 3B	P	P	P	P	P	P
EN. 4	4.00	—	—	—	—	4.00
Σ Crew hours		17.8	16.5	17.5	18.9	18.8
Σ kWh		27.5	30.1	28.6	30.1	34.8

* Two-man experiment
† ( ) means manually adjusted
‡ Power-only event

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13. ABSTRACT Space shuttle operations include a significant number of launches with a sortie laboratory serving as a facility for manned experimentation in space. Planning a program of space experiments for a facility of this type requires that both the composition of the laboratory payload and the schedule of experiment operations for each payload be carefully selected. In the current study, experiment operations are investigated using the Manned Activity Scheduling System (MASS) developed by Langley Research Center. Schedules provided by these models assist in selecting experiment groups that efficiently use the laboratory resources and yield the desired experiment accomplishment at the program level. An alternate use of the MASS models provides for establishing the time-dependent supporting resources required for a specified candidate payload.

A procedure for defining and analyzing shuttle sortie payloads was developed. This procedure was then applied to the definition of mixed-discipline experiment payloads for an Advanced Technology Laboratory (ATL) supported by two- and three-man crews. The experiments represent the research evolving at Langley that can operate beneficially in near-earth orbit. ATL payloads, including schedules of experiment operations, were defined to realize a high percentage of experiment accomplishment. The study considers the sensitivity of experiment accomplishment rate to variations of system parameters such as crew cross training, crew operations, shuttle and laboratory resources, ground target systems, and operational orbits.

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