NASA CONTRACTOR
REPORT

N72-24853

NASA CR-61386

# SKYLAB EXPERIMENT PERFORMANCE EVALUATION MANUAL

By J. E. Meyers
Teledyne Brown Engineering Company
Huntsville, Alabama

January 1972



Prepared for

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

TECHNICAL REPORT STANDARD TITLE PAGE

| 1. REPORT NO. | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |
|---|---|---|
| NASA CR-61386 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Skylab Experiment Performance Evaluation Manual | January 1972 |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT # |
| J. E. Meyers | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. WORK UNIT NO. |
| Teledyne Brown Engineering Company<br>Huntsville, Alabama | 11. CONTRACT OR GRANT NO.<br>NAS8-21804 |
| | 13. TYPE OF REPORT & PERIOD COVERED |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>National Aeronautics and Space Administration<br>Washington, D.C. 20546 | Contractor Report |
| | 14. SPONSORING AGENCY CODE |

15. SUPPLEMENTARY NOTES

Prepared for Astronautics Laboratory
Science and Engineering

16. ABSTRACT

This document contains a series of preparation analyses used for evaluating the performance of the Skylab corollary experiments under pre-flight, in-flight, and post-flight conditions. Experiment contingency plan work-around procedure and malfunction analyses are presented in order to assist in making the experiment operationally succesful.

| 17. KEY WORDS | 18. DISTRIBUTION STATEMENT |
|---|---|
| Skylab Experiments | Un-Classified-Unlimited |

| 19. SECURITY CLASSIF. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. NO. OF PAGES | 22. PRICE |
|---|---|---|---|
| Unclassified | Unclassified | 29 | $3.00 |

MSFC - Form 3292 (May 1969)

## TABLE OF CONTENTS

TABLE OF CONTENTS (Concluded)

## LIST OF ILLUSTRATIONS

## DEFINITION OF SYMBOLS

| | |
|---|---|
| DOL | Department of Labor |
| DRF | Data Request Forms |
| DRS | Data Requirements Summary |
| ECR | Engineering Change Request |
| EOH | Experiment Operations Handbook |
| ERD | Experiment Requirements Document |
| ES | Evaluation Sequence |
| HOSC | Huntsville Operations Support Center |
| IBD | Interface Block Diagram |
| ICD | Interface Control Document |
| IP&CL | Instrumentation Program and Components List |
| IR | Instrumentation Requirements |
| KSC | Kennedy Space Center |
| L | Lift-off |
| LaRc | Langley Research Center |
| MA | Malfunction Analysis |
| MCPO | Malfunction and Contingency Plan Outline |
| MRD | Mission Requirements Document |
| MSC | Manned Spacecraft Center |
| MSFC | Marshall Space Flight Center |
| NASA | National Aeronautics and Space Administration |
| O | Operation |
| OA | Orbital Assembly |
| P | Preparation |
| POEA | Pre-flight Operations Evaluation Analysis |
| SD | Systems Diagram |
| SFP | Single Failure Point |

## DEFINITION OF SYMBOLS (Concluded)

| | |
|---|---|
| SL | Skylab |
| SRFP | Skylab Reference Flight Plan |
| T | Termination |
| USAF | United States Air Force |

## SUMMARY

This document presents the results of a Systems Engineering experiment evaluation study concerned primarily with defining carrier/experiment interface requirements, uncovering experiment faults, measuring operational performance, and deriving contingency plans.

Personnel knowledgeable about a particular experiment can use the information and data contained in the appropriate appendix to assist in evaluating the experiment performance. The information presented in this report will provide personnel with a general understanding of the functions and objectives of the experiment, a procedural sequence of events used by evaluation personnel to follow the performance of the experiment, contingency plans, and malfunction analyses used to assist in evaluating and minimizing expected experiment operating problems. The report also contains various other forms of information that may be useful for experiment evaluation.

# SECTION I. INTRODUCTION

The Mission Development Branch, S&E-ASTN-SD, has devised an integrated method for evaluating the performance of Skylab module carrier and corollary experiment interfaces. The method presented in this report will be used by S&E-ASTN-SD to develop the necessary information to perform an integrated evaluation of 18 MSFC-developed or proxy-developed experiments and 2 MSC-developed experiments. This effort is required so that the S&E-ASTN-SD Branch may fulfill its experiment operations support responsibilities, as defined by the Astronautics Laboratory Evaluation Support Plan.

Prior to the actual flight of the experiment, the adequacy of design and expected performance compliance between the flight carrier and corollary experiment interface requirements will be determined. During flight operation, the emphasis will be shifted from the requirements to the performance of the carrier and experiment systems insofar as meeting their functional objectives. The measurement of carrier/experiment performance will provide the necessary knowledge and data to determine if the flight hardware is functioning as intended and meeting its objectives. If the objectives of the carrier and the experiment are met, the carrier and the experiment can be assumed to be successful and will be so reported after each Skylab flight mission. If the experiment is a success, the interface requirements were adequate. The above arguments are time-related (pre-flight, in-flight, and post-flight) and, therefore, impose a severe operational constraint on an evaluator (the in-flight response time will probably be stated in terms of seconds and minutes). The evaluator must be highly knowledgeable about the design and systems with which he is working and be prepared to interpret and respond rapidly to requests for operating performance status. If the carrier/experiment operating performance is not within the design specification limits, the evaluator must be prepared to recommend a contingency work-around procedure to minimize the problem. The objective of this manual is to aid an evaluator in fulfilling all of the above requirements within a time interval dictated by the Skylab Program and Mission schedule.

As each corollary experiment is analyzed using the methodology presented herein, to develop the necessary performance evaluation criteria, the results will be forwarded to all holders of this manual. The pages should be inserted as an appendix to the manual (Table of Contents). Appendix updates will be prepared and distributed on an as-required basis.

## SECTION II. METHODOLOGY

### A. Discussion

The Skylab Experiment Performance Evaluation effort explained in this report is designed to aid the Astronautics Laboratory (S&E-ASTN) in assessing the adequacy and determining the operational success of carrier/experiment interfaces during orbital flight. The adequacy of interfaces is determined by carefully analyzing and matching up the design, operational, and supporting requirements between the carrier and experiment. Knowledge is desired concerning both how well these requirements are fitted together and the outcome of their performance under nominal and abnormal operating conditions. The above requirements are analyzed and evaluated for compliance, compatibility, human factors, safety, expected performance, and control. A requirement usually dictates a desired input/output function that may or may not be constrained. A requirement may be considered as the cement that joins the experiment to the flight carrier and dictates the criticality of the interface. If improper bonding occurs, it can preclude the successful operation of the carrier and experiment. The operational success of a carrier/experiment interface can be ascertained by measuring how well the hardware and supporting operations achieve their functional objectives. The measurement will be both qualitative and quantitative in nature.

The methodology is based on a Systems Engineering approach that allows an evaluator to make timely decisions based on his extensive knowledge of operating carrier/experiment systems and their expected performance output. The method of this plan is structured so that an evaluator is provided useful experiment input/output performance data during pre-flight, in-flight, and post-flight operational phases. Furthermore, the plan can be adapted to changing operational phases; it thereby permits the evaluator to handle the performance data as he sees fit. If the model is used properly, an evaluator can:

- Ensure that the flight carrier and experiment design and operating requirements are adequate, safe, and properly matched
- Comprehend the carrier/experiment interfaces and understand their peculiarities
- Help manage system performance requirements for the carrier and the experiment

- Troubleshoot operating carrier/experiment systems when abnormalities occur
- Make real-time decisions based on qualitative and quantitative data with a high level of confidence
- Devise contingency plans based on astronaut and carrier/ experiment hardware malfunction cues
- Process large quantities of technical information for carrier/ experiment performance evaluation.

## B. Process

Figure 1 depicts a functional model of the Skylab Experiment Performance Evaluation method. The model is designed for operation within the framework of the Mechanical and Crew Systems Integration Division (S&E-ASTN-S). It can be easily adapted to the work processes of the Huntsville Operations Support Center (HOSC) during actual and simulated Skylab mission data acquisition modes.

There are 15 system level functional steps (steps and functional blocks are used synonymously) that an evaluator would follow to use the model. Steps 1 through 6 are concerned with carrier/experiment pre-flight evaluation. Steps 8 through 13 are concerned with carrier/ experiment in-flight evaluation. Step 15 is concerned with post-flight evaluation of the carrier and experiment. Step 7 may be considered as an overlap of pre-flight and in-flight evaluation, while Step 14 may be considered as an overlap of in-flight and post-flight evaluation.

## C. Pre-Flight Evaluation

By following Steps 1 through 3 the problem of expected mission, system, and experiment performance can be solved. Knowledge of expected performance permits an evaluator to understand what systems interact; what engineering elements and variables are essential; and what magnitude, range, and tolerances of the variables are permissible for nominal operation. Furthermore, knowledge is required concerning the performance limitations of the systems in addition to nominal situations. General performance specifications and baseline requirements for the Skylab mission and subsystems are searched out and scrutinized in Steps 1 and 2. Specific performance specification and baseline requirements for corollary experiments are searched out and considered in Step 3. It is important to understand that Steps 1 and 2 constrain the final output of Step 3. Step 3 cannot be readily understood until Steps 1 and 2 are thoroughly comprehended. A considerable

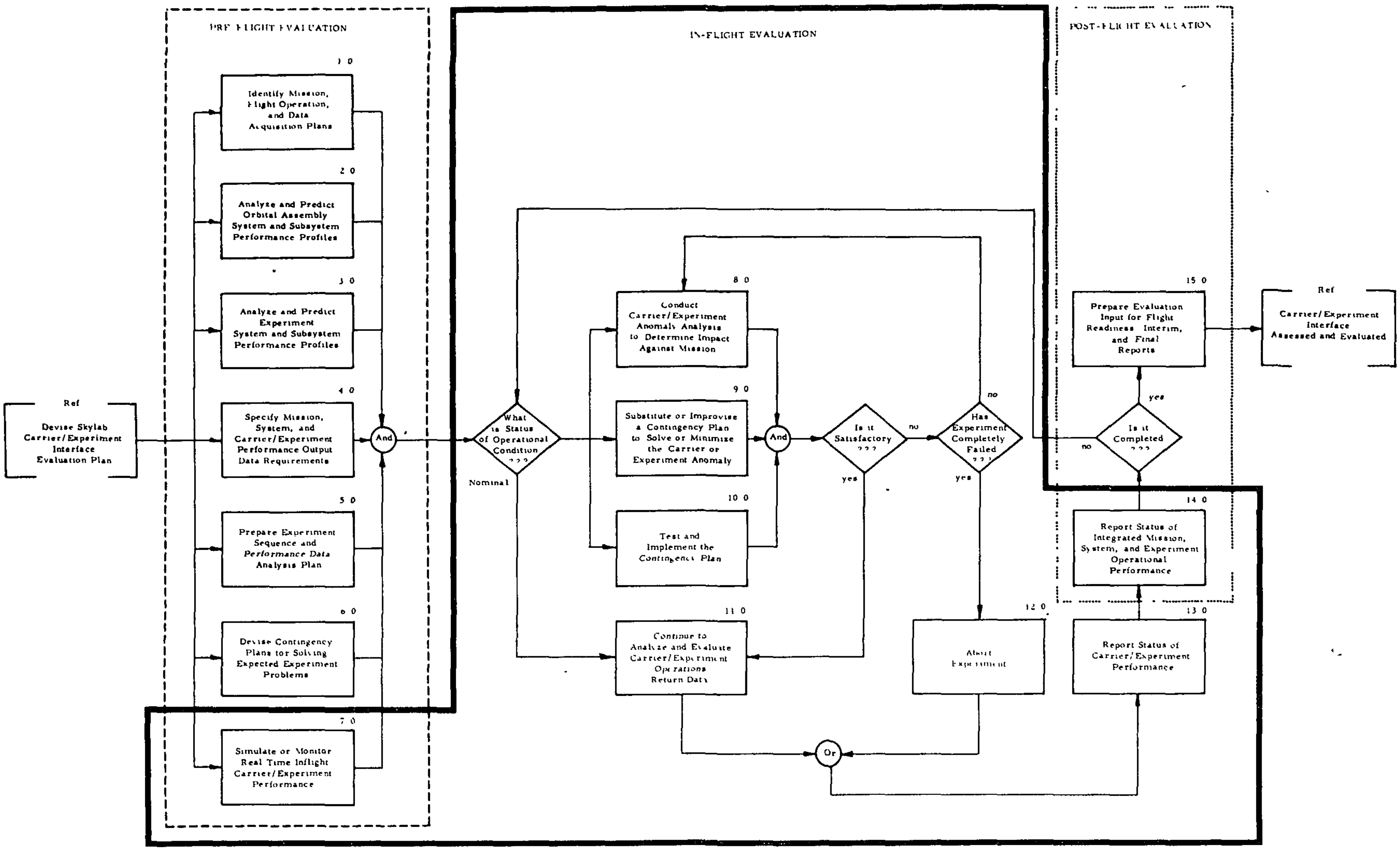


FIGURE 1. SKYLAB CARRIER/EXPERIMENT EVALUATION MODEL

quantity of technical information exists that describes the Skylab mission, Orbital Assembly (OA) modules, and subsystems expected performance. S&E-ASTN-SD uses Reference 1 to trace, review, and gain insight into Skylab mission, module, and experiment subsystem operations.

The result of following Step 1 should yield technical information in the form of gross expected performance profiles for the Skylab missions (SL-1 through SL-4). In particular, we are interested in mission, flight operation, and data acquisition plans; and how they constrain an experiment's design, operation, performance, and evaluation.

Following Step 2 should yield technical data in the form of discrete expected performance profiles for the OA modules and associated subsystems (Orbital Workshop, Multiple Docking Adapter, Airlock Module, and Apollo Telescope Mount). We are highly interested in those sequences of events that lead up to experiment initiation, occur during the experiment, and immediately follow experiment operations. Thus, when the OA module subsystem operates and supports a corollary experiment, it is desired to know how well it performed, since it could ultimately degrade the experiment's performance. The following OA operational performance characteristics are searched out and acquired for each subsystem when applicable:

- Natural and Induced Environments--temperature, humidity, pressure, radiation, shock, vibration, contamination, etc.
- Data Acquisition Properties--signal space, time, information, content, physical, etc.
- Orbital and Ephemeral--altitude, velocity, angle, attitude, tracking, position, epoch, etc.
- Power--standby, average, peak, total wattage, etc.
- Control--crew effort and presence, timeline, communications, etc.
- Consumable Scheduling--life support, power, materials, food, film, etc.

It is necessary to understand the ranges of operational performance and response of the OA subsystems so that the experiment can be matched to the interfaces (carrier), thereby determining if they are compatible and adequate.

The corollary experiments require extensive investigation, and in many cases expected performance data are not available, because, until recently, useful experiment information was not readily accessible. Moreover, the corollary experiment information and data change frequently. Some of the data must be interpreted and related to the Skylab mission. It is understandable, therefore, that most of the pre-flight carriers/experiment evaluation effort is focused on functional blocks 3.0 through 6.0.

To gain an insight into the performance of the corollary experiments (functional block 3.0), a somewhat rigorous analysis is needed, depending on Astronautics Laboratory's viewpoint and emphasis. A rigorous support effort is being made on behalf of the MSFC-responsible corollary experiments (18 total at present), and a less rigorous effort will be made for the MSC-responsible experiments (approximately 35 at present). Three end items are prepared so that expected performance profiles for the MSFC corollary experiments may be realized.

1. Pre-Flight Operations Evaluation Analysis (POEA). A POEA is prepared for each experiment (Section I, Appendices A through U). Almost every important facet of the experiments' design, operation, and expected performance is critically interrogated and analyzed. The analysis is conducted from a carrier/experiment interface compliance or malfunction premise. Thus, whenever an experiment has an operating input requirement dependent upon an external source, the requirement is determined to be adequately or inadequately met, based upon the carrier, scientific phenomena, power, human presence, ground support, etc. If the experiment input requirement cannot be furnished, either a design oversight or malfunction has occurred. Viewed within the context of the above stated premise, the POEA provides a mechanism for:

- Delineating the experiment's value in terms of its objectives, success criteria for meeting the objectives, and priority with respect to other experiments (a measure of emphasis)
- Defining and comprehending the functional elements that constitute the experiment
- Stating or projecting expected performance ranges and values for critical functional elements
- Denoting the criticality of each experiment's functional element, and how it could impact the mission and/or system operation

- Anticipating possible design faults, operational malfunction, and failures of the functional elements so that the consequences can be assessed

- Uncovering carrier/experiment design, operational, and performance problems, and recommending approaches for solving the problems.

The POEA considers only essential experiment functional elements and interfaces that are most susceptible to fault, malfunction, and failure. Only selected experiment functional elements that are considered critical are followed to determine their probability of failure. This is why the functional block number indentures beyond 3.5 are not listed consecutively. Moreover, the interfaces are assessed for impact when they are deemed pertinent to the experiment element. The carrier/experiment interfaces are:

- Physical--mechanical, electrical, communications, telemetry data, and support

- Environmental--natural and induced

- Operational--flight/crew safety, pointing, control, and human factors.

2. Interface Block Diagram (IBD). An IBD is prepared for each experiment (Section II, Appendices A through U). It shows in a simplified manner the physical, environmental, and operational interfaces that exist among the carrier, experiment, ground, astronaut, etc. Some of the interfaces are abstract in the sense that no physical connection exists between hardware components which could be controlled by signal intelligence or by the astronaut. Whenever an interface exists among two or more elements on the diagram, the blocks are appropriately coded so that they can be described and related to an existing measurement number. The IBD contains as many blocks as necessary to point out all of the physical and abstract interfaces, or to show the need to acquire an interface where one does not already exist.

3. Systems Diagram (SD). An SD is provided for each experiment (Section III, Appendices A through U). It displays a composite breakout of all operating equipment subsystems that make up the experiment. Usually, mechanical, electrical, fluid, instrumentation, telemetry, logic, and other subsystem descriptions are incorporated in the SD. Evaluation personnel use the SD for familiarization, experiment baseline monitoring, and engineering working papers in the development of malfunction assessment and contingency plans. The SD is acquired from whatever reliable baseline Skylab program documentation sources are currently available.

4. Data Management. Functional block 4.0 is designed to specify, acquire, and justify critical mission, system, and experiment data requirements. Critical data requirements are essential needs that must be met to provide knowledge of the operating status of the above cited program elements. The evaluator selects only those data measurements that measure carrier/experiment interface performance. The performance will be monitored over the duration of Skylab mission as necessary and the experiment will be evaluated for success at the end of the mission.

a. Data Requirements Summary (DRS). A DRS table is prepared for each experiment (Section IV, Appendices A through U). Each table is an aggregation of selected physical and operational data requirements and is intended for use by the evaluator so that he can analyze and evaluate the carrier/experiment performance parameters. The essential carrier/experiment data requirements are specified in the following manner:

- Measurement name
- Measurement range and dimension of variables
- Measurement number
- Telemetry assignment channel
- Data return
- Data time
- Remarks.

Much of the input data used to describe the above requirements can be found in the following carrier/experiment documentation:

- Instrumentation Program and Components List (IP&CL)
- Mission Requirements Document (MRD)
- Experiment Requirements Document (ERD)
- Instrumentation Requirements (IR)
- Interface Control Document (ICD).

Whenever the measurement and telemetry assignment channel column alphanumerics are missing from the DRS sheet for a specified measurement name, the requirement is assumed to be either existing but undefined (i.e., a measurement slot is provided by NASA), or new and not recognized by MSFC/MSC documentation (i.e., no measurement slot is provided by NASA). When this information is missing, an appropriate clarification will be made in the remarks column. The time constraints column is used to help organize the data requirements for requesting the information from MSFC Skylab Mission Operations Office (PM-MO-MGR).

b. Data Request Form (DRF). The carrier/experiment evaluator prepares a DRF for each corollary experiment as needed (Reference 2). The DRF's incorporate the essential data requirements used in the evaluation of the carrier/experiment performance, and are submitted to the PM-MO-MGR office for processing and approval. The DRF's are used as the administrative processing mechanism for acquiring carrier/experiment performance data from MSC and MSFC flight operation centers. The DRF's are found in Section V, Appendices A through U.

c. Engineering Change Request (ECR). An ECR is prepared for those data requirements that measure carrier/experiment interface performance when no measurement slot is provided, and it is thought that adequate justification can be made and submitted to the appropriate engineering organizations for disposition. The ECR is used for incorporating a measurement name and number into the IP&CL and ICD where none exists, or the ECR is used as a matter of record when a desired data evaluation measurement is rejected. The ECR's are found in Section VI, Appendices A through U, when applicable.

5. <u>Evaluation Sequence</u>. Step 5 (Figure 1) devises an efficient technique for acquiring operational carrier/experiment performance data and evaluating them in a timely manner. Previous efforts were aimed at uncovering and defining essential performance data requirements. This step takes the data requirements and organizes them into a sequence of procedural events that correspond to the expected operation of the Skylab mission.

An Evaluation Sequence (ES) is prepared for each experiment (Section VII, Appendices A through U). It is used for monitoring, tracking, and comparing carrier/experiment operation status; and troubleshooting expected carrier/experiment equipment and data malfunctions. The ES also relates contingency plans to experiment/crew task malfunctions, if they should occur, so that appropriate work-around action can be taken to minimize impacts against the mission. The ES organizes information obtained from Reference 1 (in particular, the SFP; IP&CL; ERD, Section 6.0; and EOH, Volume II) for rapid carrier/experiment interface performance evaluation with a minimum of paperwork. The ES is flexible enough to permit the evaluator to change, at will, from a real-time evaluation mode (in terms of seconds and minutes) to an all-time evaluation mode (in terms of hours and days). Two ES forms are used. One is used for those experiments or portions thereof that have little or no telemetry output data. The other ES form is used for those experiments that have considerable telemetry output data. The ES forms are designed to provide the evaluator with the following information:

- Operation Step Number. This entry indicates the sequence of experiment or crew task operation with respect to the experiment's three operating procedural modes: Preparation (P), Operation (O), and Termination (T). The numbers associated with these letters represent the sequential steps and/or crew cues taken to operate the experiment. For example, P 1.0 is the first step taken in preparing the experiment for operation, P 2.0 is the second step, and so on. Whenever a second or greater alphanumeric indenture is noted, it indicates a subclassification of the previous procedural event and may have a single callout or series of telemetry measurement callouts associated with it. A similar explanation is applicable for both the Operation and Termination modes. A fourth mode, Lift-off (L), is included to denote important mission flight time elements referenced against booster launch.

- Crewman. This entry identifies the personnel responsible for performing test procedure tasks.

- Test Procedure. This entry depicts a crewman task operation, an operational status, or procedures that are to be accomplished.

- Data Return Recorder Number. This entry is an alphanumeric code pertinent to recording and storing experiment data on various recorder systems. This identifier can refer to any type recording system used for displaying or storing data such as strip chart, tape, computer printout, etc.

- Measurement Name, Number, and Signal. This entry includes measurement nomenclature, alphanumeric identifier, and a description of the signal. The signal signature will incorporate the magnitude or range of the dependent variable (voltage, temperature, pressure, etc.) against a time increment.

- Telemetry Assignment Channel. This entry refers to appropriate IP&CL for definition.

- Function. This entry identifies the type of measurement data being interrogated, such as event, housekeeping, analog, and digital.

- Frequency. This entry indicates the number of times a task, measurement number, or data element is expected to be performed, repeated, or transmitted. It is an indication of how many times and/or how often the task is to occur.

- Range and Dimension of Variables. For Range, refer to an appropriate IP&CL for further definition. The Read term denotes the specific value or range that the evaluator is expected to acquire during actual experiment simulation or flight operations. If the actual experiment data return value or range is not as shown for the listed Read value or range, the experiment may have malfunctioned or experienced an anomalous condition. Conversely, if the actual experiment data return value or range is as shown for the Read value or range, the experiment probably performed satisfactorily.

- Limit of Concern. This entry indicates the maximum allowable limit of variable performance (in engineering units). If the maximum allowable limit is exceeded, an anomaly has occurred, thus indicating the seriousness of malfunction or failure. Whenever "over" and "under" limits can be determined for the carrier/experiment interfaces, they shall be so noted. The stated limit of concern indicates to the evaluator minimum and maximum capable operation limitation for the carrier/experiment equipment. This concept may be considered analogous to that of threshold operational efficiency and "redline" limits. In both cases, it is understood that the carrier/experiment can operate above or below its intended design capability for a duration of time without its performance being materially degraded. The concept of limit of concern can aid the evaluator in assessing the seriousness of a malfunction or failure, and help him to decide whether or not to implement a contingency plan.

- Data Evaluation Checkoff. This entry denotes the status of experiment operation, i.e., satisfactory or anomalous.

- Data Evaluation Remarks. This entry denotes the type of time frame (Real time, Near/Real time, and All time) in which experiment/crew task, measurement number, or data element was evaluated or looked at. Real time is stated in seconds-to-minutes interval, near/real time is stated in minutes-to-hours interval, while all time is stated in the hours-to-days interval. The time frame interval can be used to assess the relative importance of the data, when the data are needed, and the sensitivity or insensitivity of the data to affect the mission timeline and schedule. Actual carrier/experiment return data, used as a verification of the Read term, may be entered by the evaluator.

- Contingency Plan Number. This entry references specific contingency plans for an experiment/crew task element. The alphanumeric code shown in the column identifies a contingency plan for a particular malfunction or failure of an experiment/crew task (Section VII, Appendices A through U). It is envisaged and hoped that the malfunction or failure was considered prior to actual Skylab mission flight operations; and that the formulated contingency plan will provide the required work-around procedures to minimize the malfunction and failure. If the experiment/crew task is performed as scheduled and no malfunction occurs, the alphanumeric code is ignored.

- Contingency Plan Remarks. This entry provides appropriate comments and notes about the implementation of contingency plans, status of anomaly, and additional problems. Other entries might cover:
  - --Description of the anomaly, malfunction, or failure, time in mission when it occurred, and the trends that may have caused it
  - --Criticality of the anomaly, malfunction, or failure and the degree to which it compromises the experiment and mission objectives, and impacts subsequent missions
  - --Identification of any testing required in support of corrective action, changes that could impact the mission timeline, and procedural changes to experiment operation.

6. Malfunction and Contingency Plan Outline. Expected carrier/experiment malfunctions, failures, and contingencies are considered in functional block 6.0. A contingency plan is devised for each essential experiment/crew task that could impact the mission and experiment objectives. The Malfunction and Contingency Plan Outline (MCPO) provides a set of work-around procedures that are expected to minimize carrier/experiment malfunctions and failures. This does not mean that a contingency plan is all inclusive for any possible malfunction and failure, but rather considers only those malfunctions and failures that are considered most likely to occur. In addition, even though a contingency plan is proposed for a malfunction or failure, it does not necessarily follow that the plan will actually work the way it was intended, but rather the subjective probability of its working is high. This distinction is important because situations may arise where a given contingency plan can fulfill its intended purpose, while other situations could occur where a set of contingency plans cannot fulfill their intended purpose. When the latter situations arise, the evaluator will at least know what contingencies were considered unworkable. It is hoped, of course, that a contingency plan is devised to cover as many malfunctions and failures as possible. In fact, it is hoped that a contingency plan is never used, implying that the carrier/experiment is

functioning as required. If the situation occurs where no work-around procedure fulfills its purpose, the evaluator is required to improvise additional contingency plans based on his intimate knowledge and experience of the mission, system, and experiment.

Contingency plans for each experiment are found in Section VIII, Appendices A through U. The following information may be acquired from the MCPO:

- Operation Step Number. This entry indicates the step-by-step experiment or crew task operation as previously discussed for the ES sheet. A large background P, O, or T letter is centered on each contingency outline sheet and helps the evaluator to distinguish among the three experiment operating modes. Only essential carrier/experiment operation step numbers that require performance evaluation are correlated between the ES and MCPO. Other procedural events and astronaut cues will not be shown on the MCPO.
- Experiment/Crew Tasks. This entry presents only the essential carrier/experiment operations that require performance evaluation between the ES and MCPO and references the contingency plan to the Operation Step Number.
- Completed (check). This column may be used to double check the experiment/crew tasks in the ES as desired.
- Possible Malfunction. This entry denotes what carrier/experiment equipment and operational malfunctions can be expected to occur during actual mission flight conditions. Each malfunction has an alphanumeric code that is correlated to the MCPO Operation Step Number column, which, in turn, can be related to the ES.

  The malfunction information is acquired by reviewing the Mission Level and Experiment Level Failure Modes and Effects Analysis and the Mission Operations Design Support documentation (Reference 1); and then anticipating possible malfunction outcomes based on expected carrier/experiment performance operation lifetime. Further, mission and experiment complexity will influence the number and types of malfunctions and failures that the evaluator considers. Generally, as the mission and/or the experiment becomes more complex, the probability of success decreases, and the chance that some element will fail increases. All of the above criteria are used to formulate possible malfunctions. It is envisaged that each experiment will be supported by a malfunction analysis and will be provided as background information (Section IX, Appendices A through S).

- Contingency Plan. This entry provides the necessary work-around procedures to be implemented whenever it is desired to minimize or eliminate a carrier/experiment malfunction or failure. The work-around procedures are assigned an alphanumeric code and are referenced to the Possible Malfunction and Operation Step Number columns.

  The contingency plan is designed to specify alternative work-around procedures for carrier/experiment equipment operations, crew operations, and data retrieval operations. The method for devising contingency plan work-around procedures, as used in this report, is shown in Figure 2. The model in Figure 2 is self-explanatory and will not be expanded in this write-up. It is sufficient to say that the model is adaptive to human, carrier, and experiment needs; and probably some changes or modifications to it can be expected in the future, whenever an evaluator or analyst deems it necessary.

- Remarks. This entry indicates whatever information or data the evaluator considers important.

a. Malfunction Analysis (MA). As previously indicated, MA's are used to help define or denote what possible malfunctions and failures might occur during carrier/experiment operations (Reference 3). Section IX, Appendices A through U presents the MA for the corollary experiments. The MA is one of the primary sources used in formulating contingency plan work-around procedures. It aids an evaluator in comprehending what malfunctions and failures should be assessed so that adequate contingency plans can be made.

7. Functional Block 7.0. This block is concerned with gaining a comprehensive understanding of how the carrier/experiment performance data are to be received, processed, evaluated, and acknowledged under simulated or actual in-flight conditions. It is envisaged that this effort will permit an experiment evaluation team to assess the usefulness and value of the ES and the MCPO under simulated conditions. An evaluation team can gain a high level of confidence during experiment operation simulation runs by:

- Measuring the evaluator's ability to monitor and follow the mission and carrier/experiment sequence of operations
- Recognizing the differences between nominal and abnormal carrier/experiment operations
- Determining when malfunctions and failures occur

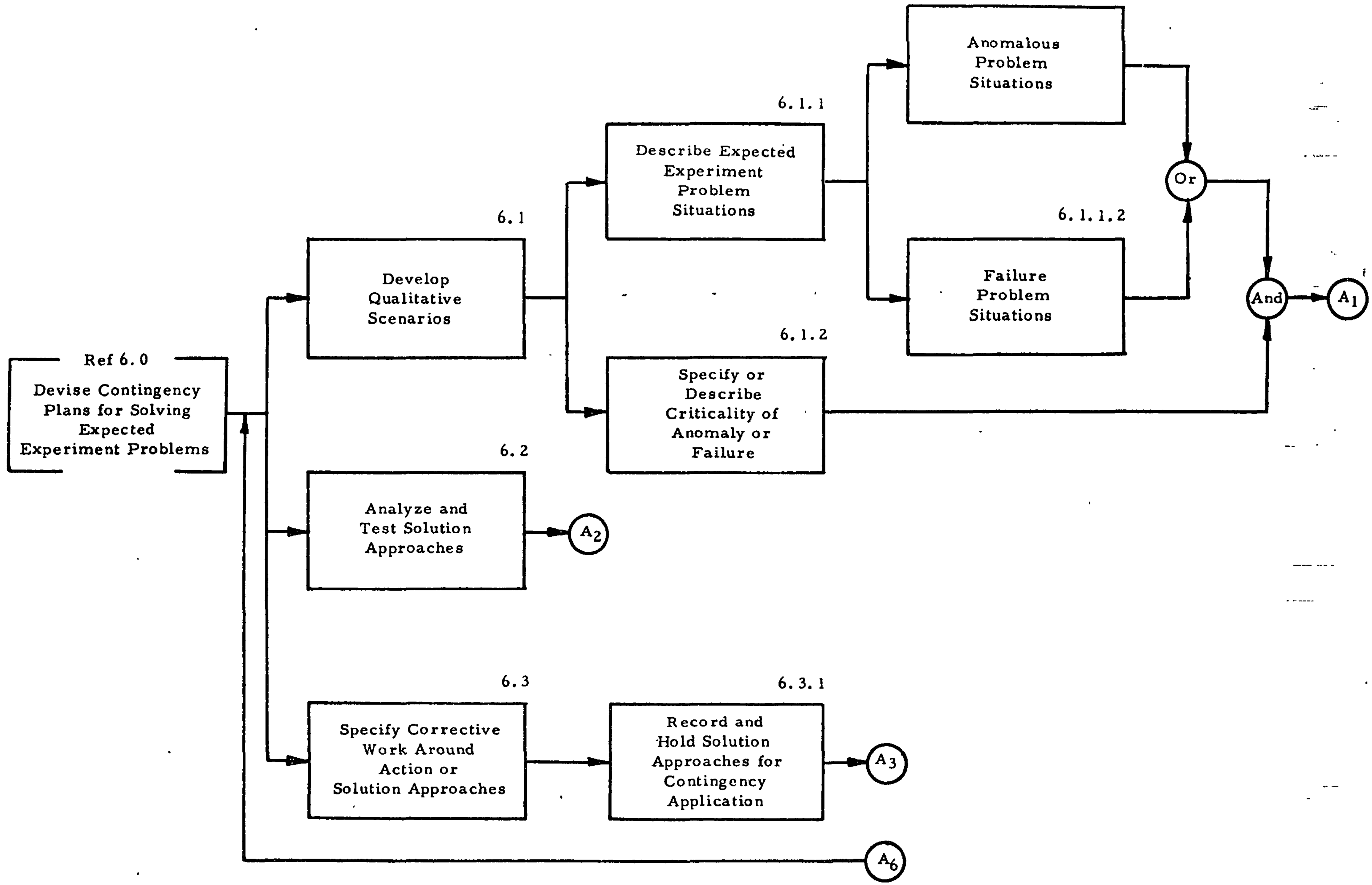


FIGURE 2. CONTINGENCY PLAN MODEL (Sheet 1 of 3)

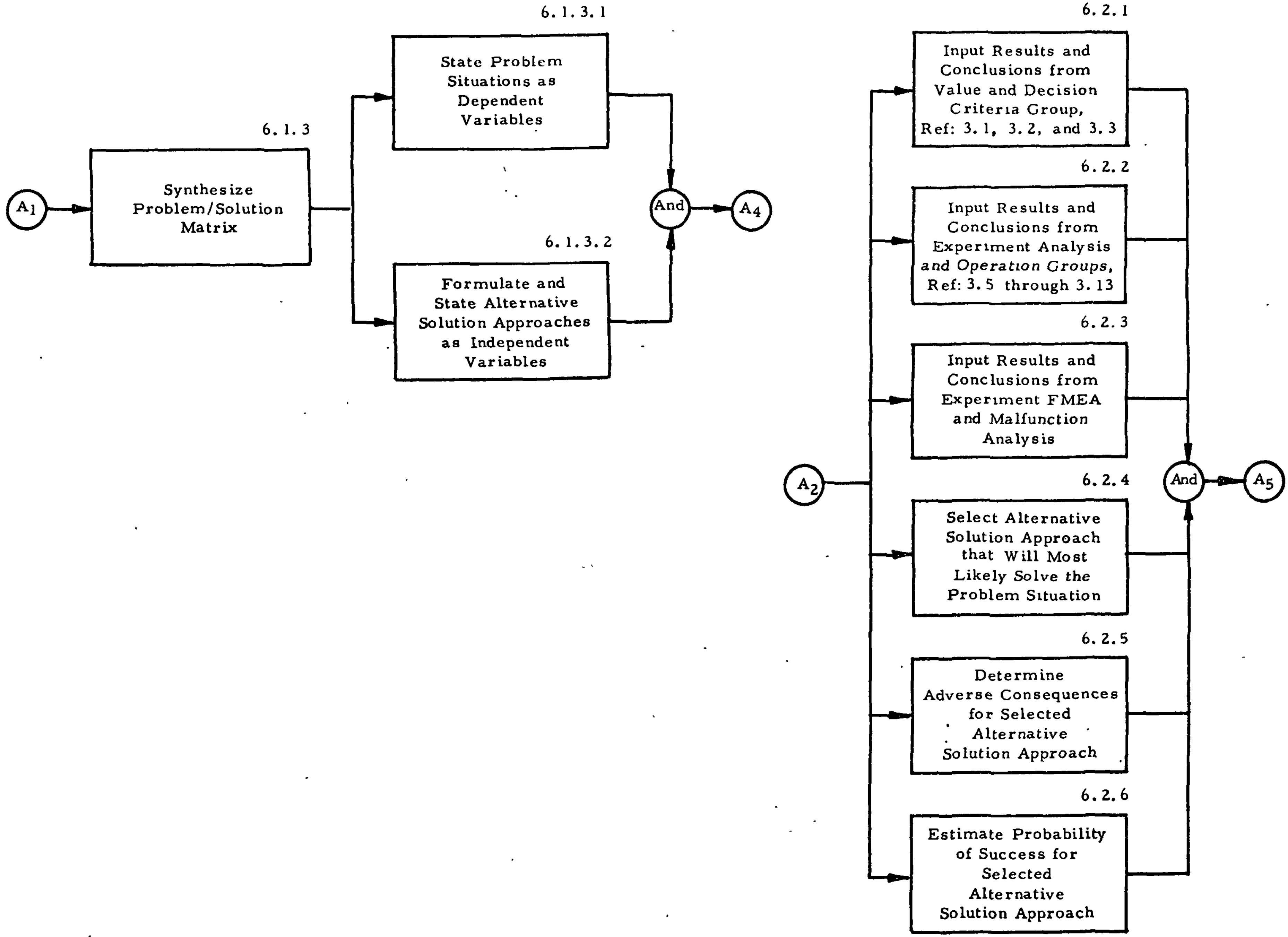


FIGURE 2. CONTINGENCY PLAN MODEL (Sheet 2 of 3)

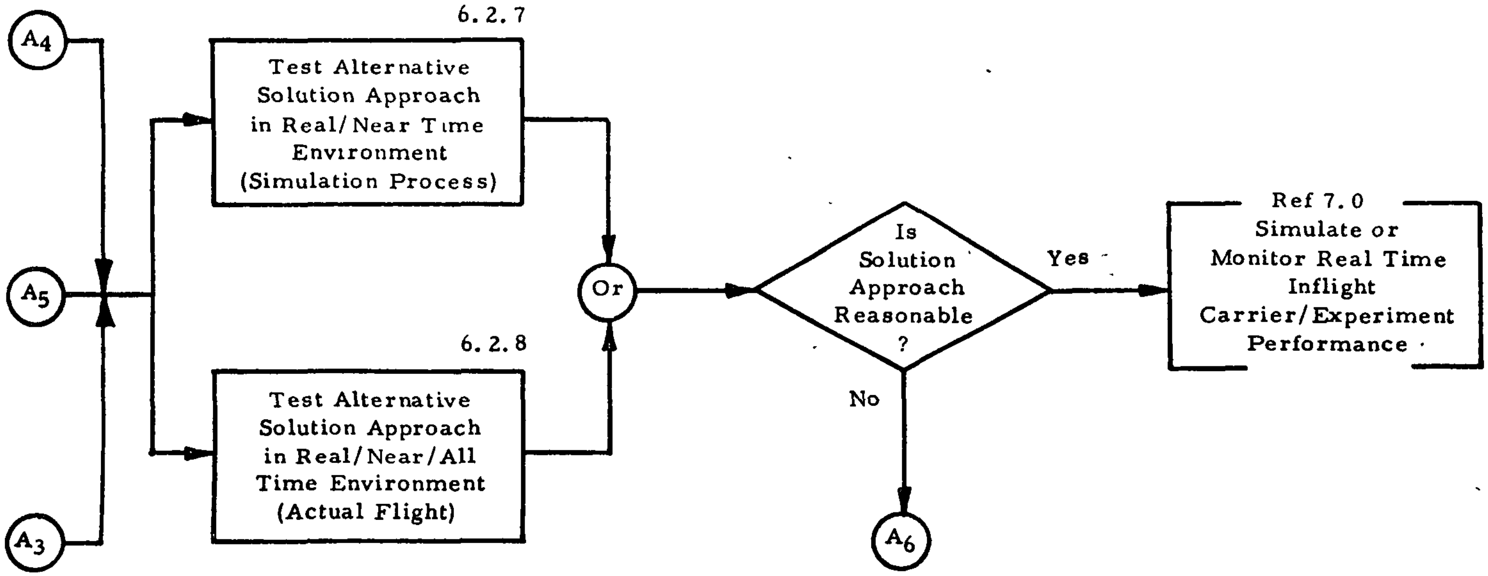


FIGURE 2. CONTINGENCY PLAN MODEL (Sheet 3 of 3)

- Selecting and knowing when to implement the appropriate contingency plan work-around procedures
- Measuring the evaluator's reaction time and response to simulated carrier/experiment faults
- Training an evaluator to expect the unexpected.

It is obvious that Step 7 does not have, at this time, a specific documentation output and is not referenced in the Appendices. However, future requirements may dictate the need for specific documentation.

Each experiment that is analyzed and verified for adequacy of carrier/experiment interface requirement compliance will have a Conclusion and Recommendation component stated at the end of each appendix (Section X, Appendices A through U).

### D. In-Flight Evaluation

Steps 8 through 13 (and probably 7 and 14) are concerned with the actual carrier and experiment during countdown, launch, and orbital operations (Figure 1). It is envisaged that the above operations will be monitored by appropriate evaluation teams located at various NASA centers (probably the HOSC for MSFC). All evaluation and contingency plan implementation efforts will be reported to KSC and MSC during pre-flight (countdown) and to MSC for in-flight (launch and orbit) operating modes. Steps 8 through 13 are designed to be integrated into any portion of the Skylab flight operation. However, Steps 8 through 10 and 12 are only implemented when the carrier/experiment experiences abnormal operating conditions; otherwise, they are ignored. Most of the carrier/experiment performance evaluation takes place during the in-flight portion of the Skylab mission. It is envisaged that the evaluator will closely follow the Skylab mission using an SRFP (Reference 1), the ES, and the MCPO documentation to support and evaluate carrier/experiment interface performance.

### E. Post-Flight Evaluation

Functional blocks 14.0 and 15.0 are self-explanatory insofar as functions are performed by the evaluator. However, an explanation of the actual information flow and of responsibility for the preparation of the final report would be premature. These tasks are still being negotiated among the laboratories at MSFC, as well as NASA; and will be discussed when better defined.

## REFERENCES


1. Meyers, J. E.: Skylab A Experiment Documentation Matrix. Teledyne Brown Engineering Company, Huntsville, Alabama, October 21, 1971, TL-14099.

2. Golden, H.: Support Requirements Submission for Skylab. PM-MO-I-102-70, October 9, 1970.

3. Wilcoxson, C. B., et al.: Mission Operations Design Support, Volume III–OWS Experiments Malfunction Analyses., MMC, June 30, 1971, ED-2002-1244.

BIBLIOGRAPHY


1. Suyemoto, L.: A Priority Model for Flight Operations Planning, ESD-TR-67-391. USAF, Electronic Systems Division, Bedford, Massachusetts, September, 1967.

2. Mesarovic, M. D., Macko, D., and Takahara, Y.: Theory of Hierarchical Multilevel Systems. Academic Press, New York, 1970.

3. Preliminary Considerations Leading to Development of a Contingency Plan for the Apollo Project, NASA TMX 54708. Office of Manned Space Flight, Washington, D. C., July 15, 1963, (Confidential).

4. Arabian, D. D.: Action on Mission Evaluation and Flight Anomalies, Astronautics and Aeronautics. March 1970, pages 72-75.

5. Corcoran, D. M., Sjoberg, S. A., and Day, R. E.: Flight and Ground Crew Operations. Astronautics and Aerospace Engineering, February 1963, pages 68-74.

6. Dorian, M. F.: A New Technique for the Scheduling and Simulation of Manned Orbital Operations. Paper presented at 3rd AIAA Annual Meeting, Boston, Massachusetts, November 29 - December 2, 1966, AIAA paper no. 66-907.

7. Boynton, J. H. and Kraft, Jr., C. C.: Flight Operations Planning and Preparation for Manned Orbital Missions. Paper presented at 3rd AIAA Annual Meeting, Boston, Massachusetts, November 29 - December 2, 1966, AIAA paper no. 66-904.

8. Purser, P. E., Faget, M. A., and Smith, N. F. (Editors): Manned Spacecraft Engineering Design and Operation. Fairchild Publications, New York, 1964.

9. Mesarovic, M. D.: Multilevel Systems and Concept in Process Control. Proceedings of the IEEE, January 1970, pages 111-125.

10. Brewer, A. C.: Interactive Scheduling System, IBM Systems Journal. November 1971, pages 62-79.

11. Systems Engineering Management. Military Standard MIL-STD-499 (USAF), Washington, D. C. July 1969.

12. Hall, A. D.: A Methodology for Systems Engineering. D. Van Nostrand Company, Inc., New York, N. Y., 1965.

13. Asimow, M.: Introduction to Design. Prentice-Hall, Englewood Cliffs, New Jersey, 1962 (Paperback).

NASA—MSFC