W. C. GASS

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proposal for Apollo Mission Simulator Supplemental Equipment

GENERAL PRECISION INC

LINK GROUP

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J. DIONNE

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Proposal for APOLLO MISSION SIMULATOR SUPPLEMENTAL EQUIPMENT

Prepared
for
North American Aviation
Space and Information Systems Division
Downey, California

GENERAL PRECISION INC
LINK GROUP

FOREWORD

Link Group, Systems Division, General Precision, Inc., is pleased to submit this technical proposal to North American Aviation, Space and Information Systems Division, in response to NAA/S&ID RFQ M5MA3-22-6083, dated 15 January 1965, for Supplemental Equipment and Delta's to the Apollo Mission Simulator.

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1. INTRODUCTION

This proposal presents technical tasks to be supplied in developing the Supplemental Equipment to the Apollo Mission Simulator (AMS). The specific items proposed are as follows:

1) Phase I efforts for Block I Airframes 014, 017, and 020, and for Block II Airframes 102 through 112, inclusively

2) Phase I and Phase II efforts for the Block I Airframe 012, and the Block II Airframe 101

3) Incremental capabilities identified as Delta's (Δ's) to the delivered AMS, which are to be implemented and incorporated into the delivered simulator

1.1 PROPOSAL PHILOSOPHY

Link is cognizant that this proposal is to present firm estimates for the efforts to be accomplished in designing Supplemental Equipment to update the Apollo Mission Simulator to specific spacecraft mission configurations. Link considers the data provided insufficient to develop firm estimates in the required detail, except for Airframe 012. Nevertheless, Link assumes that North American Aviation (NAA) has provided all data that is currently available. Therefore, we have prepared this proposal on the basis of a number of prime assumptions and considerations:

1) Link has based this proposal, particularly for scheduling of manpower, on the implementation schedule received in the data package accompanying the Request for Quotation (RFQ) (see Figure 1). This schedule necessitates precise planning, all of which is reflected in this proposal, and must be considered in judging the merit of Link's approach. Any change to the implementation schedule will affect all preceding and succeeding Supplemental Equipment estimates.

2) Figure 2 illustrates Link's interpretation of the typical Supplemental Equipment implementation schedule. Note that since the Preliminary Design Review (PDR) occurs in the first half of the fifth month, Link has split fifth month efforts; half of the estimates have been included in Phase I, and half in Phase II. This interpretation is only reasonable since Link cannot be expected to stop all efforts while awaiting preliminary design approval.

3) The requirements of MC 901-0115A are considered applicable to the AMS delivered configuration and the Supplemental Equipment.

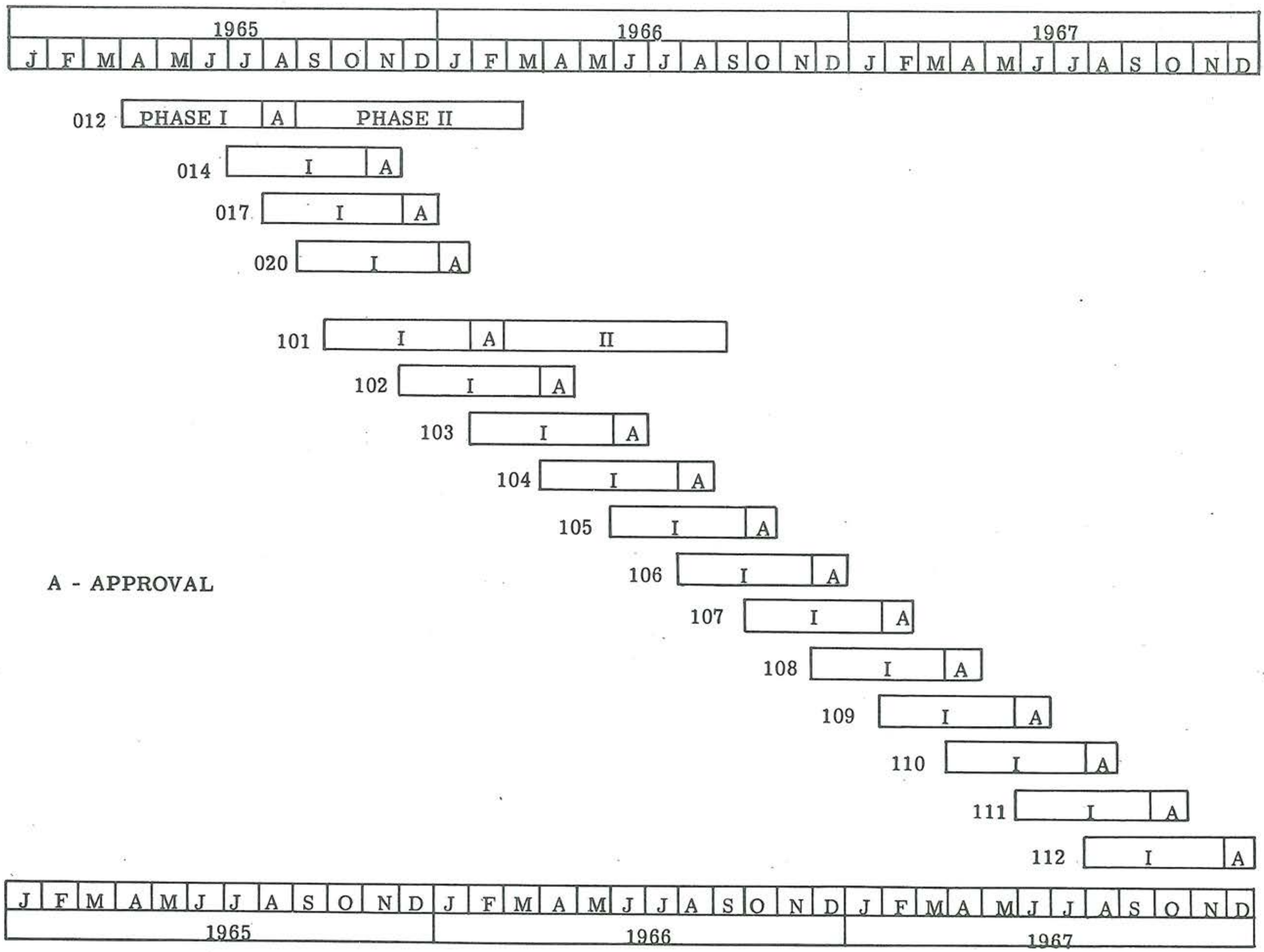

Figure 1 SUPPLEMENTAL EQUIPMENT IMPLEMENTATION SCHEDULE

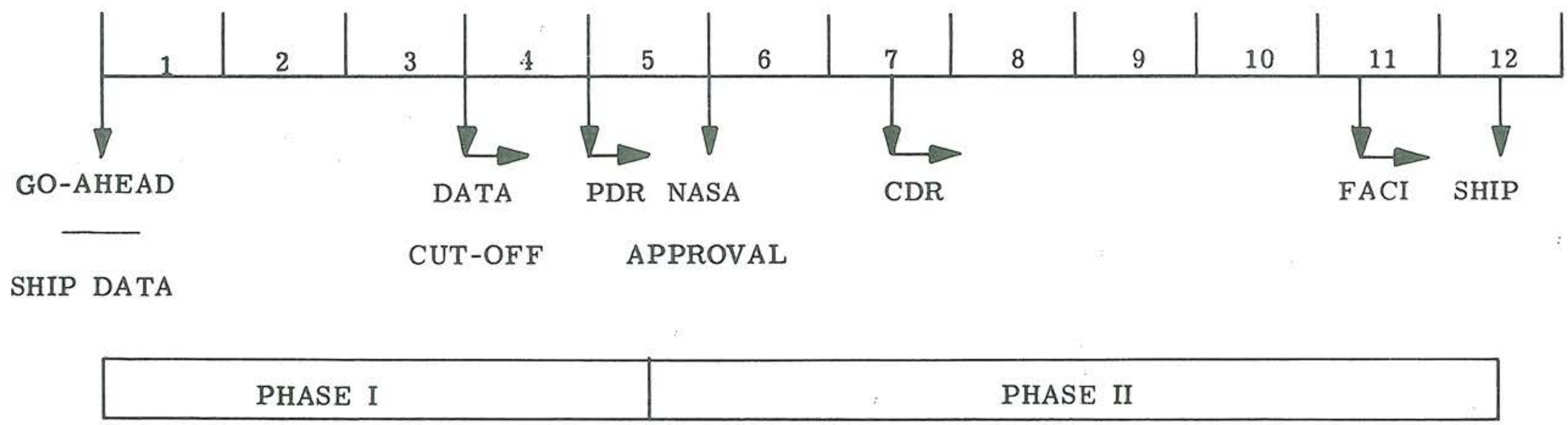

Figure 2 TYPICAL SUPPLEMENTAL EQUIPMENT SCHEDULE

4) It is Link's intent to design Supplemental Equipment for updating the training capabilities of the AMS to the specified mission and equipment requirements, and not to provide performance accuracies beyond those of the AMS delivered configuration.

5) Link has planned for an orderly incremental increase in simulator training capabilities, particularly for those intermediate Block I and II airframes that are proposed only as Phase I effort and for which there is little more available data than generalized mission descriptions. The intent is to provide Supplemental Equipment adequate for the required mission training.

6) Although only Phase I effort is being proposed for the intermediate Block I airframes (specifically, 014, 017, and 020), Link has assumed that each preceding Supplemental Equipment will be implemented (fabricated and installed) successively into the AMS. Hence, Airframe 020 is assumed to be the base from which the first Block II Airframe (101) will be designed; airframe 101 will be incorporated prior to incorporation of 102, 102 prior to 103, etc.

7) Link is providing estimates on the premise that all Preliminary Design Reviews (PDR's), Critical Design Reviews (CDR's), and First Article Configuration Inspections (FACI's) for Airframes 012 and 101 will be performed at Link's facilities in Binghamton, N.Y. Preliminary Design Reviews for all other proposed airframes will alternate between Link, Binghamton, N.Y., and NAA, Downey, Calif., as follows:

a. Airframe 014 - at NAA
b. Airframe 017 - at Link
c. Airframe 020 - at NAA
d. Airframes 102, 104, 106, 108, 110, and 112 - at NAA
e. Airframes 103, 105, 107, 109, and 111 - at Link

8) Link has assumed that the AMS' delivered on-site at Houston and Cape Kennedy will remain unchanged after on-site acceptance. Link, on this basis only, can be responsible for the compatibility of Supplemental Equipment with the delivered AMS configuration, and meet the schedule requirements.

9) Link has assumed that Supplemental Equipment are to be designed and fabricated, when required, for two Apollo Mission Simulators, and that the Supplemental Equipment for each simulator are to be identical.

10) Estimates do not include efforts for simulating exposed cabling on Apollo Spacecraft.

11) Available mission data for Airframes 014, 017, 020, 101, 102, etc., indicate that each spacecraft configuration may be used for one or more alternate missions. In the proposal for each airframe, Link has based its estimates on the primary mission only. For example, Airframe 017's primary mission is for unmanned flight (includes DART), while the alternate mission is described as a manned mission; Link has based its estimate on the unmanned (primary) mission.

12) No motion picture photography is required for Supplemental Equipment.

1.2 IMPLEMENTATION REQUIREMENTS

The requirements imposed by direction of NPC 500-1 and the extremely tight time schedules necessitate promptness by NAA in all areas in which delivery and response are critical, such as availability of design data, review and comments to approval-required documentation, and direction for go-ahead on long-lead items. In order for Link to perform preliminary design, for example, within the first 4 months, it is essential that the largest portion of available data be received prior to data cutoff. Excessive delays in receipt of review and comments to submitted documentation can only delay incorporation of the comments into the documents, and could conceivably affect the requisite approvals necessary for go-ahead on the next plateau of effort. These facts are presented to NAA and are indicative of Link's intent to comply with the required time schedules; however, because of the brief spans of time involved, there is a lack of flexibility, and every requirement is critical.

1.3 FACILITIES REQUIREMENTS

Link is fully aware of the space requirements inherent in the AMS Supplemental Equipment efforts. In order to provide for facility requirements and to extend the philosophy of flexibility to meet these requirements, Link is currently in process of planning space allocations. The Link Computation Center, Pleasantville, New York, Aerospace Systems Division (a GPI sister division), Little Falls, New Jersey, and the Link Engineering Center, Houston, Texas, have readily available, utilizable facility space. Liaison and communication links with each of these facilities are already firmly and effectively established. In summary, Link will plan facilities utilization to provide optimum application without jeopardizing implementation schedules.

Furthermore, the above plan ensures an availability of more than sufficient facility space at Link, Binghamton, for Supplemental Equipment requirements. The completion of a new engineering facility in Binghamton by December 1965, will increase the Binghamton floor space by still another 110,500 square feet. Thus, the proposed plan for facilities more than satisfies requirements.

1.4 PROPOSAL CONTENT

In Part I, Link presents its plan for implementing Supplemental Equipment into the existing Link and Apollo Mission Simulator Program Office (AMSPO) organization, and for performing in accordance with the NASA, NPC 500-1, Apollo Configuration Management Manual, 18 May 1964, and Supplement I, dated 18 May 1964.

Part II contains the technical discussions applicable to Supplemental Equipment. Part III contains the technical discussions relative to the Delta's (Δ's) to be added to the delivered simulator, while a detailed breakdown of the costs concerned with each element of this proposal will be depicted in the cost proposal.

PART I

MANAGEMENT

2. PROJECT MANAGEMENT

2.1 MANAGEMENT ORGANIZATION

Considerable forethought has gone into development of a Supplemental Equipment organization that will provide: 1) optimum use of available talents and experience, 2) expeditious application of these talents and experience at minimum cost, and 3) a flexibility to program each incremental Supplemental Equipment into the overall operation without disruption.

Factors that were considered in developing the Supplemental Equipment organization are as follows:

1) Supplemental Equipment will be initiated and carried out in parallel with continuing efforts on the delivered configuration.

2) Supplemental Equipment must be organized to enable implementation of a configuration control program in accordance with NASA NPC 500-1, each project to have separate identity, yet each to be compatible with the delivered AMS configuration, and with the preceding Supplemental Equipment.

3) Supplemental Equipment for airframes will overlap one another; hence, the project management organization must have a facility for maintaining continued and concurrent monitoring and control of progress and configuration of each individual implemented Supplemental Equipment Project.

With these factors as criteria and with full consideration of the previously-mentioned provisions, the Supplemental Equipment Organization (Figure 3) was developed. Note that the Supplemental Equipment Manager reports directly to the AMS Program Manager. Figure 4 illustrates the integrated relationship of the Supplementary Equipment Organization with the extant AMS Program Office and with other elements of the Link Organization.

2.1.1 Additional Advantages

Link believes that the organization presented will provide the advantages previously identified as essential to effective, expeditious implementation of Supplemental Equipment. In addition, principal support will be received from AMSPO, which is fully capable of handling all program/project requirements and exigencies. For example, AMSPO provides available data control capability for handling of incoming Apollo design data. Procedures have been established for receipt of Supplemental Equipment

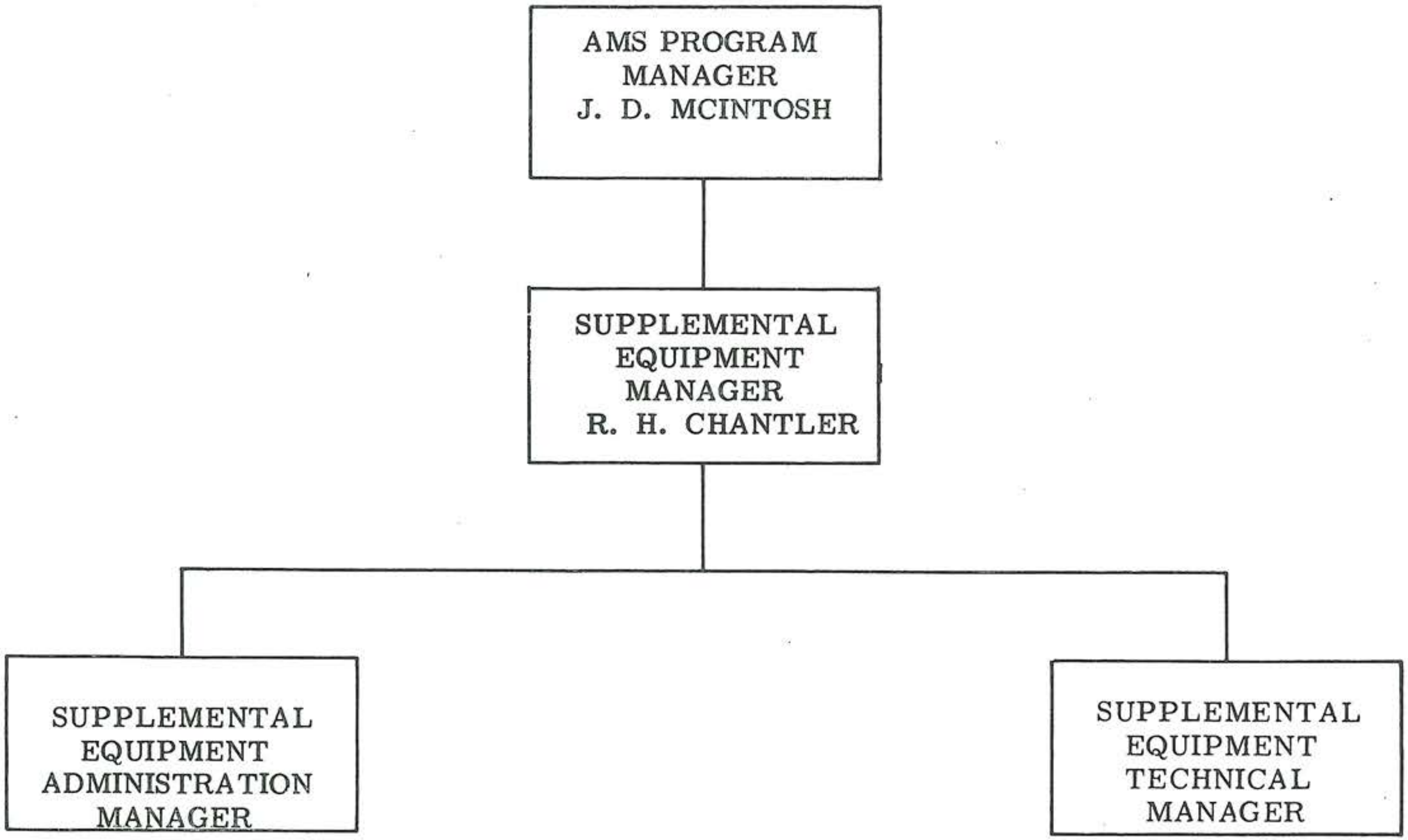

Figure 3 SUPPLEMENTAL EQUIPMENT PROJECT OFFICE

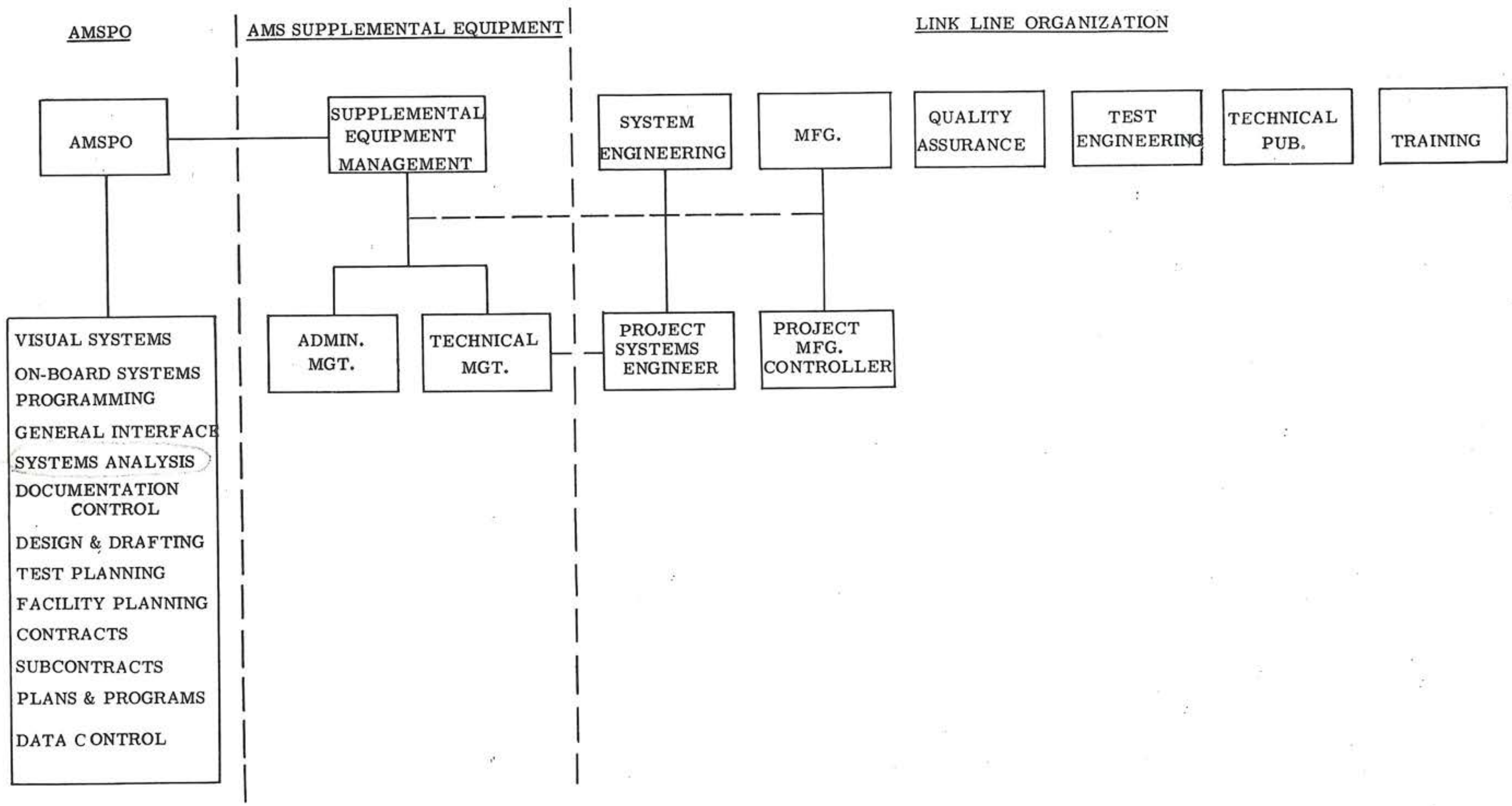

Figure 4 RELATIONSHIP BETWEEN SUPPLEMENTAL EQUIPMENT PROJECT OFFICE AND EXISTING ORGANIZATION

design data in such a manner that all incoming data will be identified with its applicable Apollo airframe number. This identifying number will appear on the data control master inventory list. The procedures also establish the flow of design data so that it will be received in the shortest possible time by the proper recipient for analysis and use in designing the particular airframe Supplemental Equipment.

The AMSPO Time/Cost Controls Group will be responsible for development, maintenance, and reporting of schedules in accordance with requirements established by the Supplemental Equipment Project Office. A task matrix will be developed on the basis of these schedules that will define responsibilities and schedule assignments. The assigned tasks will be introduced into the functional organizations by design work order, which will be accompanied by a clear, precise statement of work. Other support efforts, such as Design & Drafting, Planning, and Documentation, will remain within the scope of AMSPO control. All other AMSPO functions will operate as before, but will respond to requirements and direction of the Supplemental Equipment Office, as needed. Thus, with an organization that consists of only three functions or personnel, the Supplemental Equipment Office has capability to accomplish all the functions of the larger AMSPO organization. Furthermore, the Supplemental Equipment Office has an inherent capability for expansion in parallel with the initiation of additional Supplemental Equipment. The addition of only two or three personnel would about double the size of the Supplemental Equipment Office without reducing effectiveness, but would more than double the management and control potential.

2.1.2 Management Functions

The Supplemental Equipment Office will have responsibilities parallel to those of AMSPO. While it will have the same overall responsibility for configuration control as AMSPO, particular procedures will be established to enable conformity with the requirements of NPC 500-1.

The Supplemental Equipment Office will conduct internal design and status audits periodically. These audits will ensure design and schedule integrity, identify and define interface responsibilities, promote discussion and resolution of problem areas, and permit assignment of and response to action items.

The Supplemental Equipment Manager will have principal responsibility for the conduct and successful accomplishment of all initiated projects. He will direct all project efforts and maintain continual awareness of status at all times. To provide the capabilities needed, Robert H. Chantler has been assigned as Supplemental Equipment Manager. He has had extensive managerial experience on several simulation programs both with Link and with the Northrop Corporation. During his association with Northrop, he initially acted as Project Manager for the Type II Periscope Star Tracker and Drive System for the Polaris. More recently, he was Program Manager for the Launch Phase Simulator Program, a large centrifuge simulating the various environments experienced by spacecraft during launch.

In his earlier Link experience, Mr. Chantler undertook various assignments, chiefly as Manager of Engineering Administration. He received a B. S. B. A. from Ithaca College and has received post-graduate instruction in PERT, Value Analysis, Government Contracting, and related areas of engineering management.

The Supplemental Equipment Administration Manager will be responsible for planning and scheduling of all projects and of related program office activities.

The Supplemental Equipment Technical Manager will be responsible for conduct of the technical program. His functions will be parallel to those of the AMS Technical Director, with similar responsibilities as applicable to Supplemental Equipment. In addition, he will be responsible for application of a configuration control program in accordance with the requirements of NPC 500-1.

A Project Systems Engineer will be assigned from the Link Systems Engineering Group to function as central contact between all engineering operations and the Supplemental Equipment Office. Within the engineering organization, he will coordinate all line departments to provide for expeditious communication and integration of activities. In this capacity, he will serve as a central source aware of all technical requirements and activities associated with the Supplemental Equipment organization.

2.2 SCHEDULING/PERT

PERT networks, line-of-balance, and other planning and scheduling techniques currently in use on the AMS Program will also be employed for the Supplemental Equipment. PERT networks will be developed by the responsible AMS Management Controls Group under Supplement Equipment Office direction, utilizing inputs received from Engineering, Manufacturing, and other support activities. The individual PERT diagrams will be analyzed by the Supplemental Equipment Office for logic and compatibility with contract schedules. Preliminary networks will be submitted to NAA 30 days after Phase I go-ahead, and PERT updating information will be transmitted as a separate section of the AMS biweekly report. The final network will be presented at, and be the subject of discussion during, the Preliminary Design Review (PDR).

Second level working schedules based on PERT major events will be developed for each major area of effort, such as the Visual System, and G & N. These will be developed from task matrices generated for each Supplemental Equipment.

2.3 MANAGEMENT DOCUMENTATION

Link management reporting on Supplemental Equipment Projects will be in compliance with the requirements of MR-3 (1 February 1963), and MC 999-0025 (8 November 1962), as presently applied to NAA Purchase Order M3J8XA-406035, by Statement of Work, SID 62-1277 (1 July 1963), and currently accepted practice. Link will report status and progress on Supplemental Equipment Projects as separate sections, or appendices to, the above-referenced reporting documents. Each Supplemental Equipment project will require a separate section, which will be identified by the applicable Supplemental Equipment number.

3. CONFIGURATION CONTROL

3.1 NPC 500-1

Link intends to comply with the configuration control requirements as specified in NPC 500-1, NASA Configuration Management Control Manual, and Supplement # 1, dated 6 October 1964, including appendices. Link's effort will conform to the task requirements as reiterated in the following description, with the exception that it will continue to use its existing document and drawing numbering systems as permitted by Para. 6.0 of Supplement # 1.

3.2 PHASE I TASKS

The following listing of Phase I tasks fully describes the efforts to be performed by Link for the Definition Phase and is applicable to each proposed Supplemental Equipment.

3.2.1 Program Plan

A program plan and associated schedules will be prepared, including planning and scheduling for Phases I and II, for each Supplemental Equipment. The program plan will be submitted to NAA for the Preliminary Design Review (PDR). A PERT chart will be prepared, updated, and periodically reported during Phase I, and will be in final form for the PDR. ICD, CFE, and GFE requirements, data and approval requirements, and the documentation cycle will also be incorporated into the program plan and PERT chart.

3.2.2 Preliminary Design

Preliminary design of the specific Supplemental Equipment will be performed during Phase I. This will consist of the following:

1) Evaluation of all changes to be incorporated into the Supplemental Equipment, as analyzed from the design data provided by NAA

2) Preliminary design of the hardware and software required to satisfy the changes (This will involve generation of sketches, schematics, block diagrams, and preliminary math models from which initial programming can be started. These sketches, schematics, etc., will support and establish compatibility of design with the AMS and facilities, and the producibility of the design as determined necessary for the PDR.)

3) Identification of required long lead items as early as possible to ensure meeting required schedules and, when vendors are required, preparation of procurement specifications, and initiation of procurement

3.2.3 CEI Specification, Part I

A CEI Specification, Part I, will be prepared during this phase to identify Supplemental Equipment design and performance requirements, as defined by NPC 500-1 and Supplement # 1. First submittal of prepared portions of the CEI Specification, Part I, will be made 30 days after the start of Phase I, with a continuing release on a monthly basis until submittal of the completed document by the time of PDR. Following approval at the PDR, the CEI Specification, Part I, will be submitted as a Type I Document within 30 days following said approval.

3.2.4 Design Data Manual

A Design Data Manual (DDM) will be prepared containing all spacecraft data used in meeting preliminary design requirements. The DDM will identify all data used in design and development of the Supplemental Equipment. Submittal of the DDM will be identical with that of the CEI Specification, Part I.

3.2.5 Preliminary Design Review

All specified documentation will be prepared and submitted for the PDR. This includes the Program Plan, PERT Chart, CEI Specification, Part I, and the Design Data Manual. Link will also provide the minutes of the PDR, and such presentation materials and displays as it considers necessary to fully describe Link's preliminary design.

3.2.6 Other Tasks

Although implied, but not specifically described, there will also be support required from:

1) Design and Drafting - Mechanical and electrical design and drafting

2) Programming - Preparation of preliminary programs from math models

3) AMSPO - Management reporting, PERT charting, data and documentation control, subcontracts administration, etc.

4) Documentation - Preparation, coordination, and reproduction

5) Quality Assurance

3.3 PHASE II TASKS

The following subparagraphs fully describe the Phase II tasks to be performed by Link for the Acquisition Phases of Airframes 012 and 101.

3.3.1 Final Design

Preliminary design, completed for the PDR, will be made final during Phase II and presented at the Critical Design Review (CDR). Final design will consist of the following:

1) Determination of final configuration

2) Final design data identification

3) Preparation and completion of required documentation, as defined below

3.3.2 Program Plan

The Program Plan submitted for the PDR will be maintained and updated to reflect such program changes as may be required. The PERT chart will also be maintained current to reflect critical areas for application of specific effort, when and where needed.

3.3.3 Design Data Manual

The Design Data Manual will be updated as required during the period of final design to accurately identify the data used in designing the AMS. The DDM, classed as a Type I document after PDR approval, will be submitted monthly after PDR approval, and prior to CDR, at which time it will be reviewed for final approval and acceptance.

3.3.4 Preparation of Interface Control Drawings (ICD's)

The ICD's identified during Phase I will be prepared and submitted to NAA prior to the CDR, and accompany the documentation to be reviewed for approval by NAA at the CDR.

3.3.5 Contract End Items Specification, Part II

Part II of the CEI Specification, Sections 1 through 4, will be prepared at the outset of Phase II, and completed and submitted to NAA for the CDR. The CEI Specification, Part II, (Sections 1 through 4) will also become a Type I document after the CDR, at which time preparation of the balance of Part II will commence. During the period of Phase II following the CDR, the CEI Specification will continue to be expanded and revised as required with monthly submittals to NAA for review and comment until First Article Configuration Inspection (FACI).

3.3.6 Critical Design Review (CDR)

All specified documentation will be prepared and submitted for the CDR. This includes the Design Data Manual (in final approved form), the CEI Specification, Part II (Sections 1 through 4), Interface Control Drawings, and such other items as may be required to establish integrity of the final design. Link will prepare the minutes of the CDR, and all other necessary presentation material.

3.3.7 Equipment Fabrication

Fabrication of equipment will commence as soon after NASA approval of preliminary design as possible. Exceptions to this will be such long lead items as have been earlier approved by NAA.

3.3.8 Test and Acceptance Specification

A Test and Acceptance Specification will be prepared for Link in-house testing to establish verification of the performance and design requirements previously included in CEI Specification, Part I, and within the constraints presented by testing of the Supplemental Equipment prior to installation in the AMS. The test equipment will be Link supplied, and the Test and Acceptance Specification will be used as a guide for acceptance testing during the Sell-Off at Link, Binghamton, N. Y.

3.3.9 Installation and Checkout Procedures

Installation and Checkout Procedures for the Supplemental Equipment will be prepared and submitted as part of Sell-Off requirements.

3.3.10 First Article Configuration Inspection (FACI)

Principal requirement for FACI will be the completed and approved CEI Specification, Part II. Link will provide such material, displays, documentation, and test and measuring equipment as are required to establish the validity of the delivered equipment as described in the CEI Specification. Link will also prepare the minutes of the FACI.

3.3.11 Sell-Off

Final Sell-Off of the Supplemental Equipment will take place at Link. Link will perform acceptance testing in accordance with the Test Procedures, although management of the testing is understood to be provided by NAA. Installation and Checkout Procedures and the Supplemental Equipment Maintenance Manual will be provided as part of Sell-Off.

3.3.12 Packing and Shipping

The Supplemental Equipment will be readied for shipment to the using sites, FOB, Binghamton, N. Y., in accordance with the terms of the current AMS contract.

3.3.13 Other Tasks

Although implied, but not specifically identified, there will also be support provided from:

1) Design and Drafting - Mechanical and electrical design and drafting

2) Programming - Preparation, debugging, and finalization of software programs

3) AMSPO - Management reporting, PERT reporting, data and documentation control, subcontracts, etc.

4) Logistics - Preparation of Spare Provisioning, Maintenance Manuals, Installation and Checkout Procedures, Photography, and Reproduction

5) Quality Assurance

6) Test Engineering

PART II

TECHNICAL DESCRIPTION

4. TECHNICAL PROPOSAL CONTENT

Figure 5 is a block diagram of the AMS delivered configuration complex identifying the specific areas for which growth capability had been planned. The technical discussions describe the increments of growth and how and when they will be incorporated into the AMS to enable training for each succeeding airframe mission. Separate technical discussions are presented for each of the requisite airframe Supplemental Equipment, and these have been organized so that consideration of whether Phase I only or both phases are involved is irrelevant. The entire content of Part I, Para 3., Configuration Control, has described in detail the activities to be performed during the two phases: Para 3.2 (Phase I) is applicable to Airframes 014, 017, 020 and 102 through 112; and both Para 3.2 (Phase I) and Para 3.3 (Phase II) are applicable to Airframes 012 and 101. Thus, the contents of the paragraphs that follow are concerned only with the specific technical changes and added capabilities to be incorporated into each Supplemental Equipment.

4.1 SUPPLEMENTAL EQUIPMENT TEST PHILOSOPHY

The test plan and equipment description necessary for testing the Airframe 012 Supplemental Equipment are described in detail in Para 5.7. It must be understood that, although the costs and description for these are included with the AFRM 012 costs, the plan and equipment were developed for overall application to testing for all Supplemental Equipment from AFRM 012 to AFRM 112.

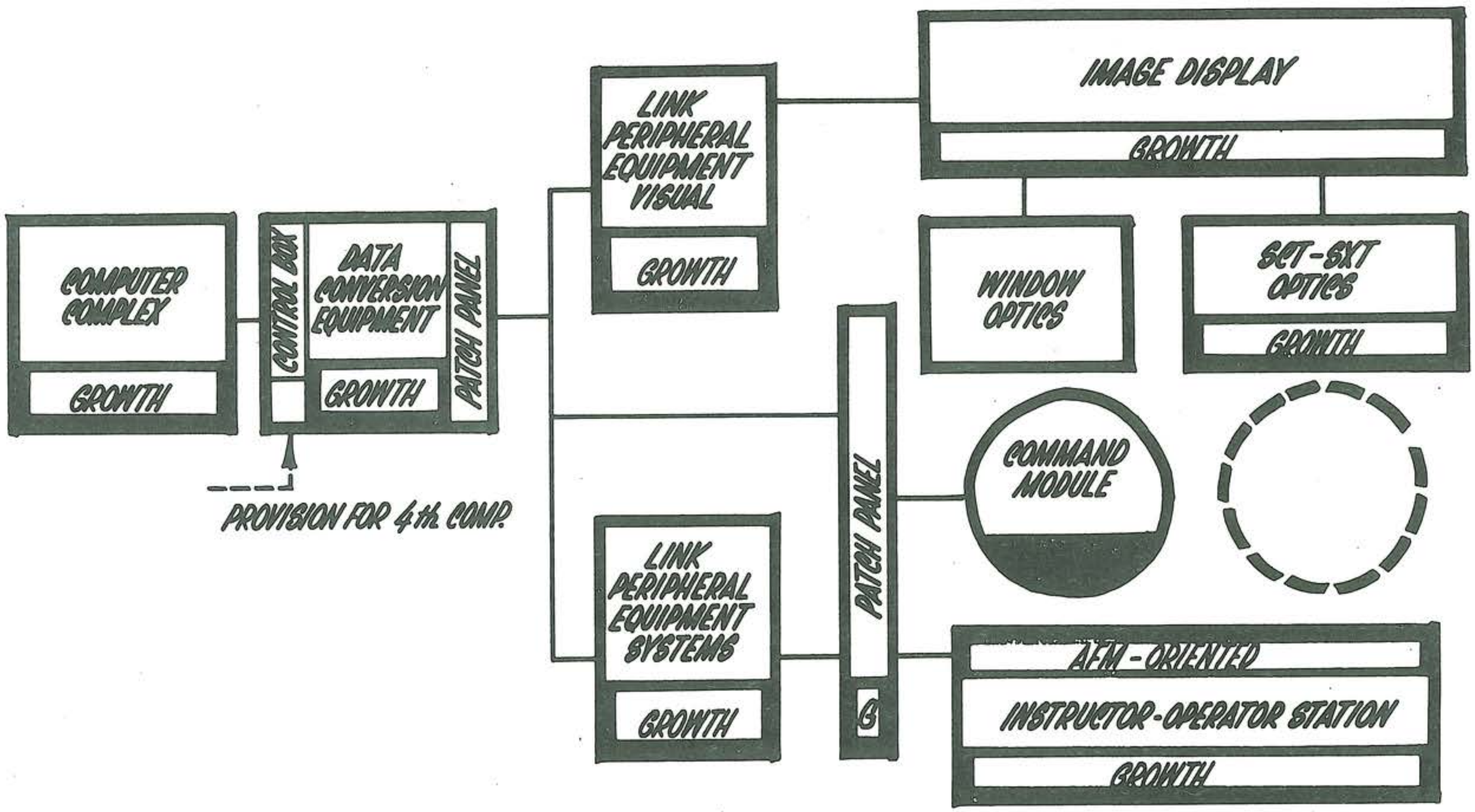

Figure 5 APOLLO MISSION SIMULATOR COMPLEX

5. AIRFRAME 012 SUPPLEMENTAL EQUIPMENT (PHASES I AND II)

5.1 GENERAL

This subsection presents the technical considerations required to provide the Supplemental Equipment essential to update the AMS for capability to simulate the Apollo Airframe 012 mission.

5.1.1 Mission Description

The technical changes presented in the next section are based upon the mission presented in Enclosure 2 of NAA letter M5MA3-22-6083, 15 January 1965, and are briefly summarized below:

Launch Vehicle	S-IB, Earth Only	
Launch Date	September 1966 (T-60 seconds)	1969
Launch Point	Cape Kennedy	
Launch Time	Dawn to 4 hours after	
Launch Azimuth	72°	
Insertion into Orbit	31°16'N, 297°30'	28.5°N, 80°W
Orbit Inclination	31.8°	32.
Orbits	1) 105 N.M. Circular for 13 orbits	
	2) 120 N.M Circular during 13th orbit for 24 orbits	
	3) 120-450 N.M. Elliptical for 75 orbits	
	4) 120 N.M Circular for 38 orbits	
Plane Change	2° (31.8° to 29.8°) during 24th orbit	
Rendezvous & Transposition	500 Yds.	
Entry Point	29.8°N, 174.48°E	

Entry Target	25.84°N, 156.6°W, Water Landing
Entry Altitude	400,000 ft.
Drogue Chutes	24,000 ft. Reefed
Main Chutes	11,000 ft.

The balance of this subsection discusses the hardware and software changes to the various AMS subsystems in order to provide updating to Airframe 012. The technical discussion does not distinguish between Phase I and II efforts although this distinction is made in the Cost Proposal. Instead, the paragraphs that follow indicate Link's preliminary analysis of the necessary changes from the available data, and describe the known technical tasks to be implemented.

5.1.2 Mission Objectives

The primary objectives of the AFRM 012 mission are to check the operation of all on-board systems and the performance of the flight crew with these systems over a long time period. In addition, opportunity will be provided to verify launch, ground station, and astronaut performance during orbital navigation, simulated transposition using the S-IVB, and manual control of reentry. During reentry, equipment performance will be checked under high heat rate conditions for a specified entry path. Landing stresses produced by delayed opening of the drogue chutes will also be investigated. The individual subsystem design changes, which will also be verified on this flight, are described in the individual subsystem descriptions later in this section.

5.1.3 New Visual Simulation Provisions

In addition to providing revised panel displays, window and telescope scenes as required for the defined mission and equipment changes, the following new simulation features have been added for the AFRM 012 mission:

1) Landing scenes have been added for the rendezvous and landing windows. The drogue chutes will be shown reefed, followed by opening of the main chute at the specified altitude, approximately 11,000 feet.

2) The new mission will provide for viewing all of the earth between approximately ±40° latitude. Therefore, a revised catalog of landmarks is required. The Supplemental Equipment will be furnished with a list of landmarks, which can be selected by the instructor in accordance with the needs of specific mission objectives.

3) The field of view of the telescope will be increased from the present 90° to approximately 104° - 110°. This is desirable to pro-

vide a longer period for the astronaut to identify landmarks and to "MARK" the required number of times.

4) Self-verification operation of the sextant will be incorporated by providing autocollimation display for 90° and for a star displacement display for the zero degree trunnion angle condition.

5) Visual displays will be provided for the launch period. These will only show water/sky displays, but will be adapted for use for abort during injection.

5.1.4 New Environmental Simulation Provisions

Simulation of sounds to include approximately 35 additional elements or time periods have been incorporated. It is assumed that approximately this number of new items will be defined by NAA for incorporation during this period.

5.1.5 On-Board Systems Simulation Provisions

Link will review the data for AFRM 012 to determine where this data introduces new information in the areas in which Link has made design assumptions. In cases where the resulting system is adversely affected by the assumptions, Link will redesign the spacecraft systems to remove these assumptions and make the systems compatible with the new data.

5.1.6 Modification Philosophy

The Apollo Mission Simulator delivered configuration will be modified in both configuration and in operational capability to enable astronaut training in the Airframe 012 mission previously identified and to retain identity of the Simulated C/M with that of the Spacecraft C/M. Link's extensive experience in supplying supplemental equipment will be applied to this purpose.

The Airframe 012 Supplemental Equipment will include completely assembled and wired panels to replace the changed panels in the Command Module. On the Instructor/Operator Stations, similar panels corresponding to those in the C/M will be changed on a one-for-one basis. For example, the replacement of a component on a C/M panel will necessitate a new C/M panel to retain identity with the spacecraft being simulated and a similar change to the corresponding IOS panel.

Supplemental Equipment peripheral equipment changes will be provided for by inclusion of added components and wiring. These will require installation in the simulator peripheral cabinets on-site.

The Data Conversion Equipment will require seven new cabinets. (Para 5.5 presents a detailed discussion of AFRM 012 DCE requirements.) The new cabinets plus 128 associated cables will be included in the

Supplemental Equipment package. In addition, components and wiring will be provided for installation in the original DCE cabinets on-site.

All rework components, installation and checkout procedures, and new drawings will be provided with the Supplemental Equipment package.

5.2 SUBSYSTEMS AFFECTED

5.2.1 Stabilization and Control Subsystem (SCS)

Revision to the Stabilization and Control Subsystem (SCS) will incorporate additional malfunction capabilities. A tabular listing of the SCS malfunctions appears in Table 5.1. Although the major portion of this effort will be restricted to the performance of boolean operations on the existing equations, additional system analysis will be required in certain areas. One area in particular is that of Thrust Vector Control, where attitude and rate loop failures will be introduced. In order to reproduce these failures with fidelity, and thereby increase the training value, it is anticipated that preliminary studies of Thrust Vector Control (in both SCS and G & N Δ modes) will be required. This effort must be accomplished prior to incorporation of the additional malfunction capabilities into the present Stabilization and Control Subsystem software.

Although hardware design changes to the present SCS configuration are fairly obvious, the ramifications of these changes to the existing software are far reaching. For example, hardware changes to the SCS control panel require the change from pushbutton-type switch to toggle action-type switch, but the resulting effect on the software will necessitate a major change in the approach to "mode selection." It is anticipated that the entire "mode selection" logic and the associated equations will be revised in order to accommodate the panel change.

In addition to the above, software changes are also required to accommodate new telemetry signals.

5.2.1.1 Telemetry Inputs

The following changes will be incorporated to satisfy the T/M requirements of the Stabilization and Control Subsystem for AFRM 012.

1) Analog Inputs

Add:

(H0024V)	Pitch Rate
(H1024V)	Yaw Rate
(H2024V)	Roll Rate
(H2030T)	Combined Attitude Gyro Temp

2) Discrete Event Input

Add:

(H0087X)	+ Pitch + X Solenoid Driver Out
(H0088X)	- Pitch + X Solenoid Driver Out
(H0089S)	+ Pitch - X Solenoid Driver Out
(H0090X)	- Pitch - X Solenoid Driver Out
(H1087X)	+ Yaw + X Solenoid Driver Out
(H1088X)	- Yaw + X Solenoid Driver Out
(H1089X)	+ Yaw - X Solenoid Driver Out
(H1090X)	- Yaw - X Solenoid Driver Out
(H2087X)	+ Roll + Z Solenoid Driver Out
(H2088X)	- Roll + Z Solenoid Driver Out
(H2089X)	+ Roll - Z Solenoid Driver Out
(H2090X)	- Roll - Z Solenoid Driver Out
(H2091X)	+ Roll + Y Solenoid Driver Out
(H2092X)	- Roll + Y Solenoid Driver Out
(H2093X)	+ Roll - Y Solenoid Driver Out
(H2094X)	- Roll - Y Solenoid Driver Out

5.2.1.2 Hardware Changes

The following defines the hardware additions and/or deletions required to implement the SCS revision effort.

AREAS	HARDWARE CHANGE ADDITIONS	DELETIONS
C/M		
Panel 2	Potentiometer (1) Switch (1)	
Panel 8	Toggle switch (9)	
Panel 9		Toggle switch (3) Light (8)
Panel 16		Toggle switch (1)
Panel 24	Rotary switch (6)	
Panel 25	Toggle switch (1)	Rotary switch (5)
IOS	Meter (1) Switch/indicator (31) Rotary switch (15) Switch (5) Light (2)	Rotary switch (10) Switch (4)
PERIPHERAL	Relay (25) Resistor network (1)	Relay (18)
DCE	Channel (1) DBI (23)	DBI (10) DBIM (8) DBO (8)

5.2.2 Communications and Instrumentation Subsystem (CIS)

The changes necessary in the CIS for Airframe 012 are based on the following:

1) The Data Package

2) The Airframe 012 Main Display Panel

3) Past Technical Knowledge

A detailed examination of the data package and airframe 012 Main Display Panel revealed that the following CIS changes are required:

1) Communication and Data Subsystem

a. Deletion of the High Gain Antenna

b. Addition of a High-Frequency Communications Loop

c. Addition of an independent volume control capability for the S-Band and VHF/AM Voice Loops

2) Addition of a test message capability to the Up Data Link Subsystem

3) Changes in the Telemetry Subsystem dynamic output requirements

4) Deletions and additions necessary to satisfy the Instructor-Operator Station and Telemetry Console repeat capability of the Command Module Panels

5) Telemetry Inputs

6) Addition of Manfunctions

5.2.2.1 Communication and Data Subsystem (C & DSS)

5.2.2.1.1 High Gain Antenna

Since Airframe 012 is an earth orbital mission, it does not require the deep space communications capability; however, the C & DSS has the High Gain Antenna as part of the delivered configuration. To further complicate the foregoing fact, it appears that the High Gain Antenna will be required on Airframe 101 if is not on Airframe 017 or 020. This means that any peripheral hardware necessary for deep space communications should be retained, but disconnected for Airframe 012 modified AMS usage.

In determining the software change estimate, an assumption has been made concerning the S-Band meter, located on the Antenna Control Panel (1A19), that the meter functionally performs the same operation for the S-Band Notch Antenna as the AGC meter or "Tune for Max" meter did on the delivered configuration Antenna Control Panel. Based upon this assumption, it has been determined that the Antenna Effects math model has to be revised to delete the High Gain Antenna computation but retain the SCIN antenna software.

5.2.2.1.1.1 Hardware Changes

The following defines the hardware additions and deletions required to implement the High Gain Antenna deletion:

AREAS	HARDWARE CHANGE ADDITIONS	DELETIONS
C/M Panel 1A19		Bat-wing microswitch assembly (5) Rotary switch assembly (1) Light unit (2) Meter (2) Potentiometer (2) Resistor (2)
IOS Panel 18A30		Light unit (14) Diode (28)
T/M CONSOLE Antenna Control Panel		Light unit (14) Diode (28)
PERIPHERAL		Relay (7)
DCE		DBI (11)

5.2.2.1.2 High Frequency Communications Loop

Based upon past technical knowledge and the information contained in HF Transceiver Equipment Specification MC-478-0022C, it has been determined that the High Frequency Communications Loop is an added requirement for Airframe 012. This change has a considerable effect on the voice system hardware. The DCE hardware is affected to a lesser extent. Included as a part of the High Frequency Communications Loop addition is the independent HF volume control As a result of the on-board systems logic, the software area is affected in generating the necessary equations for cutting the HF voice on and off.

5.2.2.1.2.1 Hardware Changes

The following defines the deletions and additions necessary to implement the addition of the High Frequency Communications Loop into the AMS. Hardware previously added to the C/M panels and IOS repeats is not included in this listing.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M Panel 1A20		Rotary switch assembly (1) Bat-wing toggle switch assy. (1)
IOS Panel 20A3	Noise control switch - light potentiometer assy.(1) Garble control switch-light potentiometer assy.(1)	
PERIPHERAL	Preamplifier (4) Transformer (1) Relay (6) Voltage controlled attenuator (8) T-Pad (1)	
DCE	DBO (2)	

5.2.2.1.3 Independent Volume Control Capability for the S-Band and VHF/AM Voice Loops

This change provides each astronaut with a separate volume control for each RF receiving system, and is in addition to the existing master volume control. The change consists of hardware additions to the existing voice system.

5.2.2.1.3.1 Hardware Changes

The following defines the deletions and additions necessary to include the independent volume control for the S-Band and VHF/AM Voice Loops. Hardware previously added to the C/M pannels and IOS repeats is not included in this listing:

HARDWARE CHANGE

AREA	ADDITIONS	DELETIONS
C/M Panel 1A13	Volume control and potentiometer assembly (3) Resistor (3)	

Panel 1A23	Volume control and potentiometer assembly (3) Resistor (3)
Panel 1A26	Volume control and potentiometer assembly (3)
IOS	
Panel 1A13	Meter (3) Potentiometer (3) Resistor (3)
Panel 1A23	Meter (3) Potentiometer (3) Resistor (3)
Panel 1A26	Meter (3) Potentiometer (3) Resistor (3)

5.2.2.2 Up-Data Link (UDL) - Test Message Capability

According to Procurement Document Change No. 1 to Up-Data Link Specification MC470-0014D, the UDL System must be capable of receiving, decoding, and verifying through the telemetry link that one of two type test messages have been received and verified.

5.2.2.2.1 Hardware Changes

The following defines the UDL Test Message Capability changes:

AREA	HARDWARE CHANGE ADDITIONS	HARDWARE CHANGE DELETIONS
PERIPHERAL	Relay (8) Toggle switch (8)	
DCE	Printed circuit card (2)	

5.2.2.3 Telemetry Subsystem - Output Requirements

Based upon the supplied information for the dynamic telemetry outputs, a precise count of the hardware and software changes can be made. Of special consideration in the CIS portion are 16 discrete outputs from the SCS system to the T/M hardware. A sampling rate of 200 per second is required for this T/M information. The simulator PCM will provide the proper sampling rate, however, the computer can only update the discretes at 20 time per second.

For the proposed change, the following approach will be used:

1) Generate 16 Boolean outputs for the 16 solenoid drivers

2) Compute these Boolean outputs at a rate of 20 per second, where a "one" will indicate that a specific driver has been operated during some part of the 50-millisecond computing cycle

3) The PCM T/M will sample the Boolean outputs in 2) above at a rate of 200/sec. as in the spacecraft

5.2.2.3.1 Hardware Changes

The following defines the hardware deletions and additions to implement the Telemetry Dynamic Output requirements:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
PERIPHERAL	Resistor (72)	
DCE	D/A channel (36) DBO (16)	DBO (3)

5.2.2.4 IOS and Telemetry Console Repeat Capability Changes

These revisions include those changes necessary to satisfy the requirement that all C/M panels have a similar repeat panel on the IOS. In two instances, repeat panels are necessary on the Telemetry Console.

The following changes relate only to panel configuration. The degree of component changes are described under the various functional CIS additions and deletions. The following CIS panels are affected:

C/M	IOS	T/M Console
1A13	17A5	
1A23	18A26	

1A26	19A3	
1A19	18A30	Antenna Control Repeat Panel
1A20	18A33	Telecomm Repeat Panel
	20A3	
1A17	New IOS Panel to repeat 1A17	

5.2.2.5 Telemetry Inputs

The following changes will be incorporated to satisfy the T/M requirements of the Communications and Instrumentation Subsystem of AFRM 012:

1) Analog Inputs - Add the following:

(T0015V)	Sig Cond Pos Supply Volts
(T0016V)	Sig Cond Neg Supply Volts
(T0017V)	Sensor Excitation 5 volts
(T0018V)	Sensor Excitation 10 Volts
(T0089V)	C-Band Xmtr Output Monitor
(T0098V)	C-Band Decoder Out Normalized
(T0125V)	PCM Hi Level 85 Percent Ref.
(T0126V)	PCM Hi Level 15 Percent Ref.
(T0127V)	PCM Lo Level 85 Percent Ref.
(T0128V)	PCM Lo Level 15 Percent Ref.
(T0191V)	VHF/AM Rec AGC Voltage
(T0215V)	S-Band Xmtr Detected RF Output
(T0222V)	S-Band PA Detected RF Output
(T0261V)	UDL Receiver Signal Strength

5.2.2.6 Malfunction Additions

A tabulation of the applicable C&D malfunctions appears in Table 5.2. These malfunctions have a direct interface with the voice system hardware and the MIU capability. Thus, both hardware and software changes are required.

5.2.2.6.1 Hardware Changes

The following additional hardware is required:

AREA	HARDWARE CHANGES ADDITIONS	DELETIONS
PERIPHERAL	Relay (27) Voice-operated relay (2)	
DCE	DBO (27)	

5.2.3 Service Propulsion Subsystem (SPS)

Revision of the Service Propulsion Subsystem simulation will be accomplished by the following changes:

1) Addition of two engine prevalves

2) Addition of C/M engine chamber pressure readout capability

3) New simulation of the thermodynamics of the gaseous-nitrogen, pneumatic-pressurization system used for propellant-valve actuation

4) Complete revision of the simulated engine equations in order to provide the SPS ablative chamber "burn-out" malfunction

5) Incorporation of a malfunction capability to indicate a leak between the helium regulators and the system check valves

6) Incorporation of a malfunction capability to indicate clogging of the propellant lines

7) Incorporation of malfunction capabilities to indicate a "failed-open" condition in the secondary of the various helium regulators

It should be noted that the incorporation of item 7) will require analysis of the effects on regulator characteristics. In addition, since both primary and secondary sections of the helium regulators will possess this "failed-open" capability, an analysis of this condition on the simulated propellant tanks must be performed. Also, item 4) will necessitate complete revision of the simulated SPS engine characteristics. Finally, in order to attain the requirements of item 6), it will be necessary to simulate flow restrictions, which will result in propellant quantity unbalances in the propellant plumbing. A tabular listing of the SPS malfunctions appears in Table 5.3.

5.2.3.1 Telemetry Inputs

The following changes will be incorporated to satisfy the T/M requirements of the Service Propulsion System of AFRM 012:

1) Analog Inputs

Add:

(P0022H)	Position Fuel/Oxidizer Valve 1
(P0023H)	Position Fuel/Oxidizer Valve 2
(P0024H)	Position Fuel/Oxidizer Valve 3
(P0025H)	Position Fuel/Oxidizer Valve 4
(P0050T)	Temp. Nozzle Outer Skin 1

5.2.3.2 Hardware Changes

The following defines the hardware additions and/or deletions required to implement the SPS revision effort:

AREA	HARDWARE CHANGE ADDITIONS	DELETIONS
C/M	Toggle Switch (3)	
	Meter (1)	
IOS	Switch/Indicator (4)	
	Meter (1)	

AREA	HARDWARE CHANGE ADDITIONS	DELETIONS
PERIPHERAL	Relay (3)	
	Resistor Network (2)	
DCE	DBI (4)	
	D/A Channel (2)	

5.2.4 Reaction Control Subsystem (RCS)

The engineering effort involved in updating the C/M and S/M RCS software is described below. The changes are based on Reference No. 1 — NAA/SID Letter No. M5MA3-22-6083, Enclosure (2) and (3); Reference No. 2 — NAA/SID Letter No. M4MA1-22-2-1961, Block I Changes; and Reference No. 3 — Airframe 012 Display/Control Panel.

1) S/M equations must consider passive thermal control for reaction jet quads (Reference No. 2). Quad temperature will be generated as a function of spacecraft orientation. Existing equations will be modified. The space radiator math model can provide some of the required inputs. It will be necessary to establish the vector position of each quad with associated logic.

2) Reference No. 2 stated that six additional RCS quantities will have outputs for intermittent monitoring; a definition of the six quantities has not been included. The estimate considers the possibility that some of these parameters are not available in the Airframe 011 math model.

3) Addition of four malfunctions (Reference No. 1), whose effect would be to cause a loss of manifold pressure for S/M Systems A, B, C, and D.

4) A malfunction will be added (Reference No. 1) to create an unusually high package temperature to either S/M, A, B, C, or D quads. This malfunction is interpreted as a meter or sensor failure.

5) Malfunctions will be added to obtain S/M fuel and oxidizer tank leakage from either S/M System A, B, C, or D. (Reference No. 1.)

6) The capability of having an unbalance propellant flow rate will be incorporated in either S/M System A, B, C, or D. (Reference No.1.) To include this capability, the instructor will have the ability to vary the propellant flow rate of the selected system.

7) Additional malfunctions that provide the capability for propellant leakage between shutoff valve and reaction jets for S/M System A, B, C, or D (Reference No. 1) will be required. Additional propellant flow rate equations and logic will be provided. A tabular listing of the RCS malfunctions appears in Table 5. 4.

8) As stated in Reference No. 1, helium reservoir temperature outputs will no longer be provided to the CWS.

9) A new basis for development of propellant consumption rates will be employed (Reference No. 1).

10) The propellant gaging system is assumed to be that referenced in NAA Letter 1L 697-44-130-435, Enclosure No. 1 dated 10/24/64.

11) Panel 8 of Reference No. 3 shows the S/M Reactant Jets circuit breakers. Since Reference No. 1 states that Airframe 012 includes only passive thermal control for the S/M quads, these circuit breakers will not be considered in the simulation.

5.2.4.1 Telemetry Inputs

The following changes will be incorporated to satisfy the T/M requirements of the Reaction Control System of AFRM 012.

1) Analog Inputs

Add:

(R0003T)	H_e Temp Tank A
(R0004T)	H_e Temp Tank B

5.2.11 Caution Warning Subsystem (CWS)

The CWS will require expansion to incorporate the additional detection, display, and control capabilities imposed because of changes to other subsystems. The effects of all other added subsystem malfunctions are included in the revision to the CWS.

5.2.11.1 Hardware Changes

The following defines the hardware additions and/or deletions required to implement the CWS revision.

AREA	HARDWARE CHANGES ADDITIONS	DELETIONS
C/M		
Panel 10	Light assembly (10)	Light assembly (3)
Panel 11	Light assembly (4) Toggle switch (4)	Light assembly (4)
Panel 12		Light assembly (1)
Panel 13	Toggle switch (1)	
IOS	Switch/indicator (10) Light assembly (14)	Switch/indicator (4) Light assembly (7)
PERIPHERAL	Relay (8)	
DCE	DBO (10) DBI (8)	DBO (4)

5.2.12 Visual System

The changes in the visual system are primarily associated with changes in the flight path and increases in simulation capability. The equipment and software changes required for both are described below.

5.2.12.1 Mission Changes

Films have been provided for the specified mission. These films will also be capable of accommodating any number of orbits within the altitude ranges of 100 to 465 NM. Software will be provided to permit variations in inclination within the specified range at the time of launch or during any orbit. The additional films, MEP cassettes, and Data Conversion Equipment (DCE) required for this are tabulated below.

5.2.12.2 Additional Training and Simulation Capability

The following depicts additional training and simulation capabilities:

1) The central field of view of the simulated telescope will be increased from the present 90°, centered on the nadir, to 104° - 110°. It is desired to increase the 90° angle as much as possible to provide a longer time for the trainee to acquire landmarks. Marking can then be accomplished as soon as the landmark is within 45° of the nadir. This change will be accomplished by changes in the optical system of the MEP associated with the SCT system. It may also be necessary to change the scaling of the films associated with telescope. This will require unique films for the telescope but will not require new artwork.

2) Visual displays have been added for the periods from lift-off to insertion and for the landing from 30,000 feet to a water touchdown. Because of the attitude and altitude of the C/M during these phases, the landing and rendezvous windows must present different scenes. The telescope will not be active during these phases.

The launch scene will show sky and water, the sky gradually turning dark and stars appearing as the orbital attitude is reached. As the attitude is changed, the orbital scene will be shown. These scenes will be programmed to permit visual simulation during aborts. Equipment changes will provide the horizon scenes desired to assist manual stabilization during aborts, however, they will not provide full simulation of the lower altitude effects.

The landing scene in the rendezvous window will show deployment of the drogue chutes followed by the main chutes, while the landing window scene will show a water-sky horizon.

3) It is understood that a self-check procedure has been incorporated to permit checking of the alignment of the Sextant in the 012 Spacecraft. The zero point will be checked by viewing the same star by way of both the landmark and star paths. When this is accomplished, the images must be aligned within certain limits (value undefined). Likewise the 90° trunnion mirror position is checked by observing the mirrored image of the reticle.

It is proposed to simulate this by providing a single star slide and a mirror image slide of the reticle in the landmark image carrousel. These will be selected and positioned in accordance with a computer program so that normal operation and malfunctions can be simulated. The major effort is expected to be the addition of special landmark type slides, the improvement of the accuracy of the reticle attitude control capabilities, and the development of software to automatically select and position these images.

5.2.12.3 Visual System Software Change and Additions

The following depicts changes and additions to the visual system:

1) Increase in visual system software will be added to accommodate the additional MEP cassettes, orbital films, and landing and launch films (This will include storage for the additional landmarks on the new ground track area.)

2) Changes to the simulated telescope system Math Model and program are necessitated by changes in the characteristics of the MEP

3) Add SXT self-verification test program

4) Modify SXT and SCT software to accommodate the defined malfunctions

5) Changes as required to provide launch abort displays

5.2.12.4 Hardware Changes

The following revisions will be required to update the Visual System.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
PERIPHERAL	Signal cable from DCE to MEP cabinet (10)	
MEP	Films as follows: 1) Range 1, 100 to 215 NM with 22.5° node regression: a. Orbits 1 thru 8 normal node position (10) b. Orbits 8 thru 16 normal position (10) c. Orbits 1 thru 8 offset node (10) 2) Range 2, 215 to 465 NM with 24° node regression:	Films as follows: 1) Range 1, three-orbit mission (1)

a. Orbits - 1 thru 15
normal node position (20)

3) Landing (8)

4) Insertion (8)

Cassettes as follows:

Range 1 and 2 (4)

	HARDWARE CHANGES	
AREA	ADDITIONS	DELETIONS
DCE	DBO (90) D/A channel (65) A/R (30) D/R (15) DWOD (60)	

5.2.13 Booster Simulation

5.2.13.1 Launch Boost Tapes (Nonintegrated)

The new tapes being computed by MSCC will require additional information in the data format because of the added Aural Cue capability. The additional data will be stored on the tape in spare words, which were intentionally left open for this purpose. There will be no change in the general data format.

5.2.13.2 Trajectory Link (Integrated)

To accommodate the Aural Cue capability, the trajectory link will require additional information in the message format. This additional data will be transmitted by using the spare words, which were intentionally left open for this purpose. Again, no change in the general data format will be required.

5.2.14 Aeromechanics

5.2.14.1 Aerodynamics

Data on the canard surfaces will be added to the Launch Escape Vehicle (LEV) configuration. Simulation of "Canards folded-power on" will conform to the present "total angle" concept. The form of the "total angle" equations will not change, only the functions that describe the new LEV configuration. It is anticipated that simulation of "Canards deployed-power off" will be based on the angle of attack and sideslip concept. The addition of at least four 2-variable functions will be required for each force equation, plus an expression for determing the sideslip angle.

5.2.14.2 Weight and Balance

Canard surfaces data, such as center of gravity, moments of inertia, etc., will be added. The form of the present equations, as they appear in math model ER642, will not change, only the values of the various constants.

5.2.14.3 Equations of Motion

The transposition equations and the S-IVB limit cycle will be programmed as they appear in math model ER640 Revision D.

5.2.15 Other Subsystems

Revision required to update the 011 airframe to the 012 configuration necessitates the addition of a new "test system" and the deletion of the old IFTS (In-Flight Test System). The new test system will provide for the C/M display of 24 parameters. These parameters are specified in the various subsystems. Additionally, changes to the simulation of C/M lighting and a new C/M clock will be incorporated.

5.2.15.1 Telemetry Inputs

The following changes will be incorporated to satisfy the T/M requirements of the Crew Safety System of AFRM 012:

1) Analog Inputs

Delete:

(S0085V) EDS Abort Signal Man A
(S0086V) EDS Abort Signal Man B

2) Discrete Event Inputs

Add:

(S0150X) Master Caution - Warning ON

Delete:

(S0101X) CM-SM Phys Sep Man B

5.2.15.2 Hardware Changes

The following defines the miscellaneous hardware changes required.

AREA	HARDWARE CHANGE ADDITIONS	DELETIONS
C/M Panel 3		Toggle switch (1)
Panel 12	Clock (1)	Clock (1)
Panel 18		Toggle switch (1)
Panel 26	Toggle switch (1)	
Panel 97	Rotary switch (2) Meter (1)	
IOS	Switch/indicator (2) Meter (1) Switch (1) Switch position indicator (14)	Switch/indicator (4)
PERIPHERAL	Relays (4) Resistor network (2)	Relays (4)
DCE	D/A channel (2) DWI (2) DBI (2)	DBI (4)

5.3 MALFUNCTIONS

The malfunctions listed in the following tables will be incorporated into the Airframe 012 simulation effort; however, some of these malfunctions have been previously incorporated and are so annotated. The majority of these malfunctions were discussed during the NAA/NASA/Link Malfunction Meeting of October 28-30, 1964. It must be emphasized that the effect of these additions, on the applicable subsystems, is necessarily dependent on whether the affected math model will require rewriting and the extent to which the failure is reflected in the real hardware subsystem.

In addition to the listed malfunctions, it is anticipated that subsequent requirements for the Airframe 012 will increase the overall effort by a factor of 25%. This additional effort is reflected in the cost proposal.

Each table contains, where available, the NAA catalog number, the corresponding Link identification number, and a brief description of the malfunction. The tables are arranged by subsystems as follows:

Table	Subsystem
5.1	Stabilization and Control
5.2	Communication and Data
5.3	Service Propulsion
5.4	Reaction Control
5.5	Electrical Power
5.6	Electrical Power (Fuel Cells)
5.7	Environmental Control
5.8	Guidance and Navigation
5.9	Sequence Control Group
5.10	Cryogenic Storage
5.11	Structures

TABLE 5.1

STABILIZATION AND CONTROL SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
019, 020, 021	-	Rotational controller # 2
089	013	Minimum Impulse Enable Switch (*)
040	029	Attitude Deadband-Switching (at maximum) (*)
-	005, 006, 007	Rotational hand-control, direct control fail, # 1 controller, 3 axes (*)
001, 002, 003	-	Switching Amplifier, fails "off" (pitch, roll, and yaw)
004, 005, 006	-	Reaction jet solenoid-driver (1 of 4 in pitch, roll, and yaw)
010, 011, 012	-	Rate gyro fails "hand-over" (pitch, roll, and yaw)
013, 014, 015	-	Pseudo rate feedback, fails "open" (pitch, roll, and yaw)
016, 017, 018	-	Pseudo rate feedback, fails "on" (pitch, roll, and yaw)
022, 023, 024	-	Rotational controller demodulator failure (pitch, roll, and yaw)
025, 026, 027	-	G&N demodulator failure (pitch, roll, and yaw)
028, 029, 030	-	BMAG demodulator failure (pitch, roll, and yaw)
034, 035, 036	-	Rate command and feedback amplifier (pitch, roll, and yaw) (**)
037, 038, 039	-	Attitude-error DC Amplifier (pitch, roll, and yaw) (**)
041, 042, 043	-	Switching amplifier (pitch, roll, and yaw) (**)

048, 049, 050	-	BMAG fails "hand-over" (pitch, roll, and yaw)
058	-	Thrust "on" logic
066	-	Pitch rate demodulator, during thrusting
067	-	Attitude-to-rate limits (pitch, during thrusting)
072	-	Yaw rate demodulator, during thrusting
073	-	Attitude-to-rate limits failure (yaw), during thrusting
076	-	Pitch TVC fails "open" during thrusting
077	-	Yaw TVC fails "open" during thrusting
080, 081	-	Gimbal position feedback demodulator (pitch and yaw)
082, 083	-	Gimbal drive velocity-generator demodulator (pitch and yaw)
084, 085	-	TVD-error, DC Amplifier (pitch and yaw)
088	-	Rotational-hand-controller detent-switch
099	-	SCS Power Switch (***)
104, 105, 106	-	G&N Command demodulator fails "on" (pitch, roll, and yaw)
110	-	SCS delta V-thrust "on" logic, fails "off" (pitch, yaw, and roll)
112	-	Channel disable switch fails "gen" (pitch and yaw)
114	-	Translational controller micro-switch fails open (1 of 6)
115	-	Translational controller micro-switch fails, "shorted" (1 of 6)

NOTES:
(*) - These malfunctions have been previously incorporated.
(**) - Deleted with IFM (in-flight maintenance) deletion
(***) - This malfunction has been relocated. It now appears in the EPS listing.

TABLE 5.2

COMMUNICATIONS AND DATA SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
001 (*)	-	One or more C-Band receiver
002	043 (**)	Complete C-Band
015 (***)	-	Main recovery antenna
017 (***)	-	HF/VHF diplexer
022	-	VOX function of audio panel - no transmission
023	-	VOX function of audio panel - continuous transmission
024	-	Push-to-talk portion of audio panel
025	-	S-Band (or HF or VHF) transmit-receive or receive function
-	-	VHF Ommi antenna (****)

NOTES:

(*) - It has been determined that 001 is a malfunction that can best be implemented by ground crew response and should not be added.

(**) - The malfunctions with assigned Link identification numbers have been previously incorporated.

(***) - Malfunctions 015 and 017 concern the recovery phase of the mission. The recovery phase is not simulated.

(****) - Malfunction is already provided.

TABLE 5.3

SERVICE PROPULSION SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
-	-	Helium regulator A, secondary section fails "open"
-	-	Helium regulator B, secondary section fails "open"
-	-	Helium leak
-	-	SPS Albative chamber burn-out, variable thrust
-	-	Propellant flow unbalance

TABLE 5.4

REACTION CONTROL SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
005, 006, 007, 008	-	S/M system (A, B, C, &D), loss of manifold pressure
009	-	S/M jet-quad temperature high (interpreted as a meter or sensor failure) (1 of 4)
-	-	C/M system A and B oxidizer fails to dump automatically
-	-	S/M/CM transfer system A
-	-	SM/CM transfer system B
-	-	SM propellant flow unbalance (1 of 4)
-	-	SM propellant unbalance indicator
-	-	SM fuel tank leak (1 of 4)
-	-	SM oxidizer tank leak (1 of 4)
-	-	SM fuel leak (1 of 4)
-	-	SM oxidizer leak (1 of 4)

TABLE 5.5

ELECTRICAL POWER SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
029	-	Inverter # 1, undervoltage
030	-	Inverter # 2, undervoltage
032	-	Generator # 2, undervoltage
036	-	AC Bus # 1, overload
040	-	Inverter # 2, frequency out of tolerance
041	-	Inverter # 3, frequency out of tolerance
078	-	Helium tank pressure indicator, fails minimum
079	-	Helium tank temperature indicator, fails minimum
080	-	Oxidizer tank pressure indicator, fails minimum
-	-	Switching motor
-	-	Battery change switch fails "closed"
-	-	Inverter # 1, component failure
-	-	Inverter # 2, overtemperature
-	-	Inverter # 3, overvoltage
-	-	Inverter # 3, undervoltage
-	-	Inverter # 3, overtemperature

NOTE:

These malfunctions will be incorporated in the manner presently employed in the AFRM - 011 simulation for corresponding malfunctions.

TABLE 5.6

ELECTRICAL POWER SUBYSTEM (FUEL CELLS)

NAA Catalog No.	Link Identification No.	Malfunction Description
013	-	Contamination of electrodes, F/C (fuel cell) # 1
014	-	Contamination of electrodes, F/C # 2
015	-	Contamination of electrodes, F/C # 3
016	-	Skin temperature high, F/C # 1
018	-	Skin temperature high, F/C # 3
020	-	H_2 regulator out pressure high, F/C # 2
021	-	H_2 regulator out pressure high, F/C # 3
023	-	H_2 flow exceeds .090 lbs/hr, F/C # 2
024	-	H_2 flow exceeds .090 lbs/hr, F/C # 3
025	-	Water contamination, F/C # 1
027	MC 111	Water contamination, F/C # 2 (*)
044	-	Skin temperature low, F/C # 1
046	-	Skin temperature low, F/C # 3
047	-	H_2 regulator out pressure low, F/C # 1
048	-	H_2 regulator out pressure low, F/C # 2
049	-	H_2 regulator out pressure low, F/C # 3
051	-	O_2 regulator out pressure high, F/C # 1
052	-	O_2 regulator out pressure high, F/C # 3

053	-	O_2 regulator out pressure low, F/C # 1
054	-	O_2 regulator out pressure low, F/C # 2
055	-	O_2 regulator out pressure low, F/C # 3

NOTE:

(*) Previously incorporated. These malfunctions will be incorporated in the manner presently employed in the AFRM 011 simulation for corresponding malfunctions.

TABLE 5.7

ENVIRONMENTAL CONTROL SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
002 (*)	-	Cabin pressure relief valve leak
009	-	Wetness control amplifier
011 (*)	-	Surge tank relief valve
012 (*)	-	Water pressure relief valve
042 (*)	-	Pressure suit bypass valve
050 (*)	-	Waste water tank leak
065	-	O_2 surge tank, slow leak
067 (*)	-	Emergency O_2 inflow control valve, slow leak
-	-	Tank pressure relief valve fails open

NOTE:

(*) These malfunctions were deleted by NAA/NASA/Link AMS Malfunction Meeting held October 28-30, 1964; however, they are hereby incorporated in AFRM -012 Supplemental Equipment as requested in Data Package Enclosure (2).

TABLE 5.8

GUIDANCE AND NAVIGATION SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
007 (*)	MG042	AGC interrupted for 30 msec. (Reworded by Link to cause "Warning Light" indication only.)
008 (*)	MG043	Computer in endless control loop (reworded by Link to cause "Warning Light" indication only.)
009 (*)	MG044	Word incorrectly transferred from memory. (Reworded by Link to cause "Warning Light" indication only.)
013 (*)	MT756, MT760, MT761, MT762, MT763	Loss of T/M sync pulses
-	-	SCT trunnion manual input gear train fails to function (**)
-	-	SXT reticle lamps fail
-	-	25° offset mode fails
-	-	Slave mode failure, SXT-to-SCT and SCT-to-SXT
-	-	Resolved-mode failure
-	-	Direct-mode failure
-	-	Illegal-program-order alarm failure
-	-	SCT trunnion failure, LOS cannot be changed
-	-	SCT LOS fails to rotate
-	MG047 (*)	SXT LOS rotational failure

NOTE:

(*) - Previously incorporated.
(**) - Link exercises option to choose where the gear train will fail.

TABLE 5.9

SEQUENCE CONTROLS GROUP SUBSYSTEM

NAA Catalog No.	Link Identification No.	Section	Malfunction Description
-	-	ELS	Apex cover jettison lamp fails to "on"
008	-	LES	Translational controller will not initiate on abort
011	-	LES	Adapter fails to separate
052 (*)	-	LES	Escape tower fails to jettison
017 (**)	-	EDS	Auto abort not armed at liftoff
-	-	EDS	Translational control fails to function in providing manual abort initiation (***)
-	-	EDS	Angle-of-attack indicator failure
-	0200 (****)	EDS	0-999 second timer

NOTES:

(*) - This malfunction has been deleted due to the removal of the "NO SEP" lamps and "TWR JETT" switch.

(**) - Not a malfunction.

(***) - Same as ELS 008 malfunction.

(****) - This malfunction has been deleted due to an equipment change.

TABLE 5.10

CRYOGENIC STORAGE SUBSYSTEM

NAA Catalog No.	Link Identification No.	Malfunction Description
002	-	Q_2 tank 2 pressure fail (Heater element failure)
003	-	Q_2 tank 2 pressure fail (Auto press. control failure)
005	-	H_2 tank 1 pressure fail (Heater element failure)
006	-	H_2 tank 2 pressure fail (Heater element failure)
007	-	H_2 tank 2 pressure fail (Auto press control failure)
008	-	H_2 tank 1 pressure fail (Auto press control failure)
011	-	H_2 tank 2 pressure fail (Tank failure)
012	-	H_2 tank 1 pressure fail (Tank failure)
-	-	O_2 tank 1 shutoff valve fails closed
-	-	H_2 pressure switch fails open
-	-	H_2 tank 1 shutoff valve fails closed
-	-	Fan heater malfunction

TABLE 5.11

STRUCTURES

NAA Catalog No.	Link Identification No.	Malfunction Description
001, 002, 003, 004	-	Couch support-structures, locks failure (See Note)

NOTE:

Inclusion of these malfunctions will not be considered since the crew couches are CFE and data is totally lacking. Link will submit estimates to incorporate them at such time as data is provided.

5.4 PROGRAMMING

Programming tasks for the Airframe 012 Supplemental Equipment include revisions and additions to the following software programs:

1) Simulator Control

    a. Executive and Control System
    b. On-Line I/O
    c. Real Time I/O
    d. Malfunction Insertion Unit
    e. Utilities
    f. Data Retrieval (Symbol Dictionary)

2) Diagnostics

    a. Command Module
    b. Instructor/Operator Station
    c. Telemetry
    d. Visual System
    e. Data Conversion Equipment

3) MSCC Interface

    a. Launch Boost
    b. Communications and Instrumentation (Antenna Effects and Power Switching)
    c. MSCC
    d. Telemetry

4) Mechanics

    a. Equations of Motion
    b. Aerodyanmic Forces and Moments
    c. Weight and Balance

5) Visual System

    a. Sextant
    b. Telescope
    c. Rendezvous
    d. Mission Effects Projector
    e. Occultation Mask

6) On-Board Systems

a. Propulsion System
b. Electrical Power System
c. Fuel Cell System
d. Sequence Controls Group
e. Caution Warning System
f. Environmental Control System (Water, Water-Glycol)
g. Cryogenic Storage System
h. Stabilization and Control System
i. Guidance and Navigation System (IMU, IMU-Temp., Optics CDU, Exec I/O, and Earth Orbit)

5.5 DATA CONVERSION EQUIPMENT (DCE)

In summary of the Data Conversion Equipment, described in part in the subsystems breakdown of paragraph 5.2, the following DCE are considered necessary for the Airframe 012 Supplemental Equipment:

DCE	Remarks
A/D	Add 2 channels (plug-in new cards)
A/R	Add 30 channels (plug-in new cards)
DBI	Add 45 channels (plug-in new cards)
DBO	Add 123 channels (new hardware)
DWI	Add 2 channels (no hardware change)
DWOD	Add 15 channels (new hardware)
D/A	Add 175 channels (new hardware)
D/R	Add 15 channels (new hardware)

The following assumptions, conditions, and philosphy are applicable to the above summary of DCE:

1) Channel deletions are treated as no change (cards are not eliminated).

2) The most efficient method of adding the extra equipment will be such that any equipment already present, need not be removed to be worked upon in order to minimize downtime.

3) New cabinets will be built and assembled and tested at Link, Binghamton, and then shipped ready for plug-in.

4) Each new cabinet will be completely wired—sufficient to provide all needs. Circuit cards will be supplied only to the extent necessary to realize the actual number of needed channels.

5) New cabinets will be designed with a special control section and an extra set of control cable connectors. At installation, the original cabinet will be unplugged from the Data Conversion Control Unit and plugged into the new cabinet of the same type. Then, the new cabinet will be plugged into the Control Unit. This will accomplish installation, other than to connect the new cabinet to the patch panel.

6) The special control section in the new cabinets will accept data from the computers by means of the Control Unit; it will "decide" whether the data is meant for the "old" channels in the original cabinet or the "new" channels in the new cabinet; and will relay the data accordingly. To the computers it will appear only that there are more channels; it will not have to deal with the extra channels as if they were a separate device.

7) In all cases, a minimum of 20% expansion capacity has been provided for, either by addition of new cabinets or in the expansion area of the original cabinets. It is anticipated that this expansion capability will provide space for all subsequent Block I and Block II changes; however, as data becomes more definitive, it may be necessary to provide additional cabinets. These will be submitted to NAA under separate notification as they are determined.

5.6 SIMULATOR POWER DISTRIBUTION SYSTEM

The various hardware changes to the simulator subsystems have created increased power requirements in the simulator visual, computer complex, and data conversion equipment areas. In turn, the increased power requirements necessitate revisions in the existing power distribution hardware for these areas.

5.6.1 Hardware Changes

The hardware changes described in this document not only incorporate the increases due to AFRM 012, but include an increment to accommodate future expansion. It is considerably more economical to provide this increment now, rather than in the future.

5.6.1.1 Visual Area Distribution Equipment

System changes necessary to reflect this change will consist of replacement of the metering circuit (ammeter and current transformer), and upgrading of the distribution buses to handle the additional load.

5.6.1.2 Computer Complex Distribution Equipment

Additions in the computer area (DCE and Peripheral cabinets) cause an increase in distribution loading and necessitate a replacement of the associated 125-ampere circuit breaker with a 150-ampere circuit breaker and the addition of 27 subsystem breakers.

5.7 SPECIAL TEST EQUIPMENT

5.7.1 General

The magnitude of the software and hardware changes required to update the AMS delivered configuration to the Airframe 012 configuration necessitates a thorough in-house verification test for all systems. It is realized that integrated systems performance testing cannot be achieved without the use and expense of a duplicate Apollo Mission Simulator. It is, however, possible to verify individual systems performance. It is this type test that is premised.

Where possible, the individual systems performance will be evaluated with complete hardware/software integration. This, of course, will require additional hardware in systems necessitating only partial modification. Where the actual AMS hardware will not be available, this additional hardware will be used to simulate the missing hardware by using external stimuli and indicators. Where the C/M and IOS panels are available, these will be used to debug the software and hardware. In all cases, the hardware included in the supplemental equipment kit will be functionally and operationally checked.

In such a program, it is mandatory to perform as much verification testing of the computer programs and hardware as possible prior to the actual installation. By so doing, long shutdown periods of the simulator and, subsequently, loss of training time are avoided. Past experience has shown that installation of modification kits without prior verification can cause shutdowns of long duration.

The programs will be checked for programming errors and agreement with the appropriate math model prior to the individual system performance tests. Upon receipt of the program, further debugging will be required to assure interface compatibility. Once accomplished, a test setup will be prepared for the debugging and verification of the systems performance.

5.7.2 Test Setup

The hardware necessary for the above tests is shown in Figure 6. The test setup will be in the same general form as the AMS system and will perform the same operations as the AMS computer complex to avoid undue program modifications.

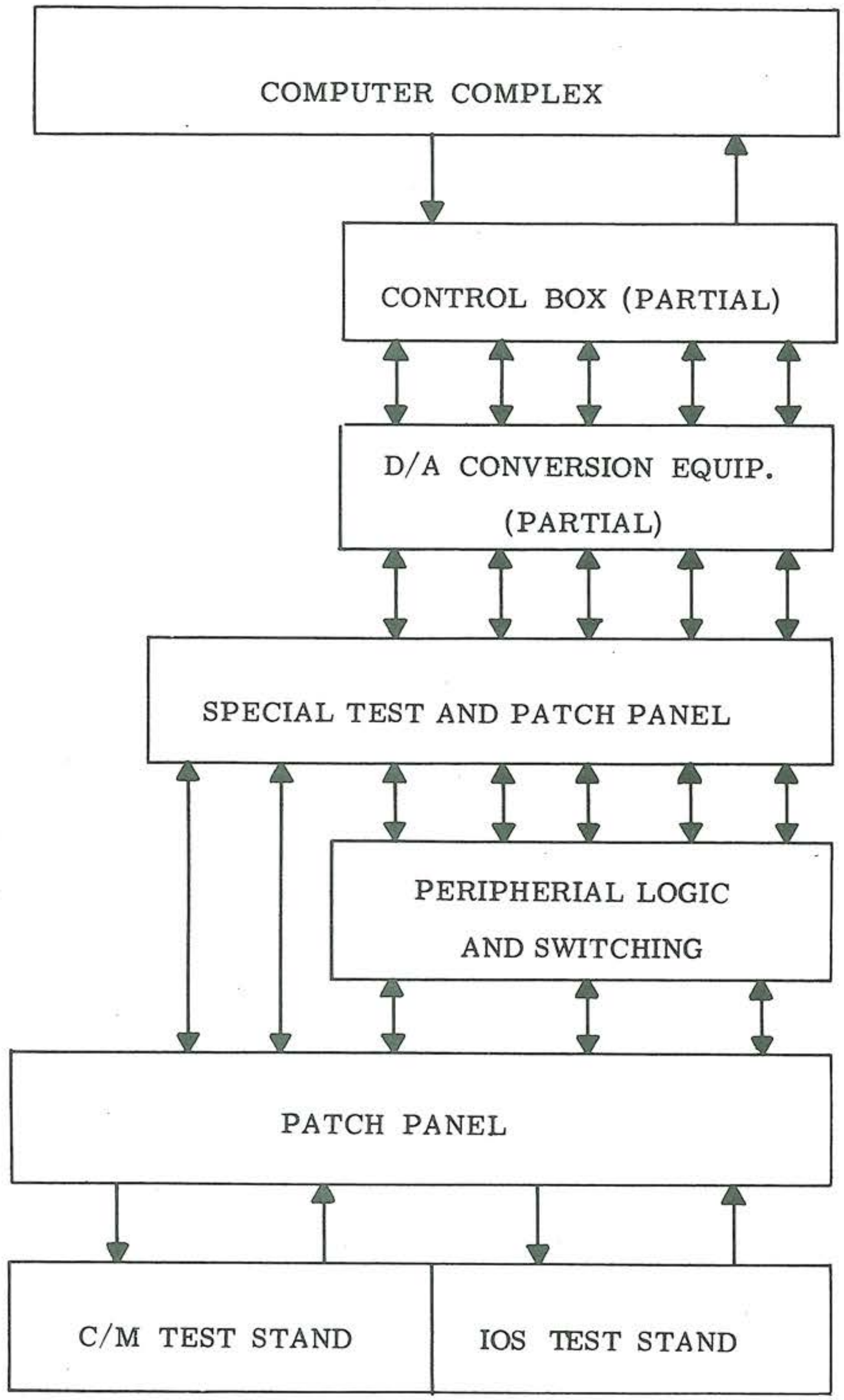

Figure 6 AIRFRAME 012 TEST SETUP

5.7.3 Special Equipment

5.7.3.1 Computer Complex

As mentioned previously, the computer complex depicted in Figure 6 must perform the same general operations as the AMS computer complex. To accomplish this, the following equipment will be required for this complex.

1) 1 each - DDP-224 (40K Memory)
2) 2 each - Magnetic tape units
3) 1 each - Paper tape punch
4) 1 each - Paper tape reader
5) 1 each - Card punch
6) 1 each - Card reader
7) 1 each - Line printer
8) 1 each - Fully buffered channel

In addition, DMA's and other necessary items, including the wiring and operational checkout, will be required.

5.7.3.2 Partial, Real-Time Input/Output Equipment Control Box

This device is similar in nature to that which was estimated for the UAMS.

5.7.3.3 Partial Data Conversion Equipment

This equipment will be necessary to enable signal conversion and communication between the C/M and IOS panels and the computer.

5.7.3.4 Special Test and Patch Panel

The special test and patch panel will consist of a large patch panel, switches, lights, meters, potentiometers, power supplies, 50-pin connectors, mounted on an independent castered frame. This equipment is necessary to simulate the AMS inputs and outputs not otherwise available.

5.7.3.5 Peripheral Logic and Switching

This cabinet will be used as a test stand and interconnect for peripheral equipment card mounting. It includes 10 wired bins in a single-bay cabinet rack in which the various logic and switching printed circuit cards will be mounted for system test.

5.7.3.6 Patch Panel

This panel is necessary to substitute for AMS cabinet No. 4. It will contain patching necessary to interconnect C/M and IOS panels to other units.

5.7.3.7 C/M and IOS Test Stand

This test stand, consisting of basic panel mounting framework, will be used for mounting the new command module and instructor/operator station panels during test.

5.7.3.8 Cables

Cabling will be provided, as necessary, for interconnecting the hardware units into the test setup system. The following is a list of the proposed cables:

1) 26 C/M panel cables
2) 26 IOS panel cables
3) 40 Patch panel/Periph.
4) 40 Patch panel/Special Test & Patch panel cables
5) 40 Peripheral/Special Test & Patch panel cables
6) 40 Special Test - Patch panel/DCE cables
7) 40 DCE/Control box cables
8) 20 Control box/Computer Complex cables

6. AIRFRAME 014 SUPPLEMENTAL EQUIPMENT (PHASE I ONLY)

6.1 GENERAL

The AFRM 014 mission is understood to be as follows:

1) Manned Earth Orbit

2) Launch T-180 minutes

3) 105 N. M. Circular orbit at 31.8 degrees inclination for one-three orbits

4) Hohmann transfer to 120 N. M. circular orbit at 31.8 degrees inclination for 48 orbits

5) Two-degree plane change to 29.8 degree inclination

6) Transfer to 120 N. M. — 2,640 N. M. elliptical orbit at 29.8 degree inclination for four orbits

7) Two-degree plane change to 31.8 degree inclination

8) Transfer to 120 N. M. circular orbit at 31.8 degrees inclination for 1/2-orbit reentry

6.2 MISSION OBJECTIVES

The primary objectives of this mission are expected to be as follows:

1) Evaluate portions of the new Series 100 G&N system

2) Evaluate mid-course type navigation including use of Telescope (SCT) and Sextant (SXT) navigation sighting procedures

3) Evaluate high velocity reentry guidance and control techniques

4) Evaluate normal reentry control using visual display

5) Evaluate transposition and docking procedures

6.3 VISUAL SYSTEM

6.3.1 New Simulation Provisions

In addition to providing revised panel displays, windows, and telescope and sextant scenes, as required by the defined mission and equipment changes, the following new simulation features have been added for this mission:

1) The prelaunch simulation has been extended from T-60 sec. to T-180 min.

2) Reentry scenes have been provided to complete the window displays from prelaunch until touchdown.

3) The degree-of-freedom of launch azimuth and insertion point has been greatly expanded in the visual displays.

4) Emergency eyepieces have been added to the SXT and SCT, permitting evaluation of performance under procedures associated with loss of pressure.

5) The loss of field of view in the SCT due to the S-IVB in the transposed mode has been provided.

6) Occultation of earth and moon images behind the S-IVB/ LEM has been provided.

7) A catalog of 56 navigational stars has been provided, permitting variation in the catalog assigned to a specific mission and the updating of these by the Up-Data Link.

8) Aural simulation will be expanded.

9) A catalog of higher altitude landmarks has been added for the G&N system.

6.3.2 Visual System Changes

The major changes in the visual system have been dictated by the specific mission requirements. These changes are as follows:

1) Higher altitude orbits, which, in turn, require new films and sextant slides.

2) Flight test of the star seeker and horizon photometer function of the sextant system and associated G&N procedures. It is anticipated that this will include the following new functions:

a. Mid-course type Landmark-Star navigation sightings from much lower altitude than previously considered.

b. Distant SCT and SXT Landmark-Star navigation sighting using the distant moon.

c. New SXT star tracker and horizon photometer equipment for automatic star-horizon measurements and star occultation measurements.

3) A reentry test of manual control with a high heat load.

4) Normal parachute display is now required, rather than furled as on AFRM 012, plus reentry scenes from 100 N. M. to 30,000 ft. These are planned to show horizon scenes replaced by decreasing degrees of incandescent air streaming by as the C/M attitude, velocity, and altitude vary prior to chute deployment.

6.3.3 Added Features

Additional features have also been added to provide an orderly growth in capabilities, as follows:

1) The hatch window, which had been previously cancelled, has been reinstated per the original concept, in accordance with Enclosure 1 to NAA letter 697-220-130-65-005.

2) The addition of window and SCT and SXT scenes for the T-180 minute prelaunch simulation capability. These will permit the alignment of the IMU and the checkout of the SCT and SXT and portions of the AGC and IMU systems during this period. It is assumed that functional fixed pylons will be available for this purpose.

3) Emergency eyepieces and eyepiece heating controls have been added to the SCT and SXT.

4) The navigational stars in the SXT have been increased to 56 with realistic background stars.

5) Additional software has been added to permit flexibility in launch azimuth from 72° to 110°, in insertion points from 27°N to 35°N, and from 50°W to 65°W with the fewest constraints, while at the same time not requiring additional films for most missions.

6) Provide for occulting the images of the earth or moon behind the S-IVB/LEM to provide more realistic simulation.

6.3.4 Implementation Tasks

The following major engineering tasks and equipment designs must be provided, to implement these features.

1) Define and initiate procurement of transition and mid-course films from 465 to 2,640 N. M. for 4 orbits over defined ground tracks and times.

2) Define requirement for the additional Infinity Image System (IIS), starfields, MEP's and solar simulators required for the addition of the hatch window.

3) Provide a design for occulting the image of the earth or moon behind the S-IVB/LEM. If it is determined that this should be incorporated within the MEP, it will be incorporated in the unit designed under 2) above and the two units interchanges with the MEP's in the rendezvous windows at the time of integration with the AMS. The displaced units would be modified and used in AMS No. 2. The units finally displaced would then be placed in the two hatch windows.

4) Provide a design for increasing the accuracy of the tracking or synchronization of the occulting of stars by the earth or moon. This is necessary to permit observation in the telescope of the tracking of the stars by the star tracker as the star approaches the earth or moon, as is assumed to be required by the procedures. While existing tolerance requirements in the occulting system, films, MEP, and software are qualitatively acceptable for the delivered configuration, the 014 Spacecraft procedural requirements will probably require added sophistication. If it is determined that changes are required in any hardware unit, they will be incorporated in the hatch window equipment and interchanged with SCT equipment in the field, or used as a prototype for the modification of the associated SCT equipment unit.

5) Prepare a film application plan to permit use of orbital film for the ranges of launch azimuth, inclinations, insertion point variations and altitudes shown, with minimum possible film length and number of cassettes. The results will be incorporated into the software.

6) Provide a design for a dummy star tracker for the SXT. It is planned to provide the star tracker and horizon photometer functions by means of a straight math model of their performance, but at the same time it will be necessary to provide a dummy head and cable, and to interlock the placement of the star tracker head with the associated software.

7) Provide design of emergency eyepieces for the Sextant and Telescope.

8) Define the landmarks to be used for superorbital flight, and develop the software for use of these in the Telescope and Sextant.

9) Provide design for modification of the Sextant for higher scan rates if required for lower altitude use.

10) Provide design to increase the number of stars in the sextant to 56.

11) Define the operation of the SXT and SCT with the new 100 series G&N procedures and the new optics panel. Provide proper software and DCE equipment.

12) Provide design for occultation of the field of view (FOV) by the S-IV B in the "transposed" position.

13) Define additional DCE equipment and software for all of above features and initiate procurement of equipment and development of software.

6.4 GUIDANCE AND NAVIGATION SYSTEM

The following efforts are assumed to be essential to update the G&N System for the airframe 014 training mission:

1) Revise the Launch Monitor Program to meet the spacecraft mission date

2) Provide design for addition of a horizon seeker and star seeker tracker

3) Provide for addition of Sextant software

4) Revise all G&N software as required for the specified mission operations

6.5 LAUNCH BOOST

Principal effort will be concerned with revision of the data on the launch boost tapes to include the 3-hour prelaunch period.

6.6 MSCC INTERFACES (TRAJECTORY DATA LINK)

Effort will consist of revision of initialization of all systems for the 3-hour prelaunch period.

6.7 EQUATIONS OF MOTION

The moon ephermeris will be added for positioning the moon into visual equations.

6.8 OTHER SUBSYSTEMS

Although data is unavailable, it has been assumed that there will be design effort necessary to incorporate changes to the following subsystems:

1) Launch-escape System

2) Communication and Instrumentation System (UDL, Antenna, Communication Voice).

3) Cryogenic Storage System

4) Emergency Detection System

5) Environmental Control System

6) Earth Landing System

7) Stabilization and Control System

8) Reaction Control System - S/M, C/M

9) Service Propulsion System

10) Sequence Controls Group

11) Electrical Power System

12) Aural Simulation System

13) Telemetry (Measurements for the Series 100 G&N)

6.9 SUMMARY

Although the scope of the proposal for this particular subsystem is concerned with Phase I only, it must be understood that even in the definition phase there are a great many task efforts that are associated with the system changes described in the previous section. The following list is indicative of the large number of work areas that have been considered in estimating requirements for the AFRM 014 Supplemental Equipment Program:

1) Engineering

   a. Hardware changes to the C/M for the indicated systems

   b. Mechanical changes to the C/M

   c. Hardware changes to the IOS

d. Electrical changes associated with all hardware changes

e. Software changes for all systems, and associated programming revisions

f. Launch boost tape revisions

g. Design and drafting of mechanical, hardware, and electrical changes

h. Changes to data conversion equipment

i. Changes to peripheral equipment

j. Simulator power requirement changes

2) Support

a. Documentation requirements

b. PDR requirements

c. Program management and AMSPO support requirements

This listing is not all-inclusive but indicates some of the many items that were considered in proposing this Phase I effort.

7. AIRFRAME 017 SUPPLEMENTAL EQUIPMENT (PHASE I ONLY)

7.1 GENERAL

The AFRM 017 Mission is understood to be as follows:

1) Unmanned 12-hour earth orbit
2) Mission sequences in C/M
3) S/C includes LEM flight test article
4) S-V launch vehicle
5) 100 N. M circular orbit for three orbits
6) 100 N. M. - 10,000 N. M. elliptical orbit and reentry
7) Fire S-IVB
8) Separate C/M from S-IVB
9) Fire SPS to obtain 36,000 ft./sec. reentry velocity
10) Closed-loop G&N
11) High heat rate reentry (undershoot)

7.2 TECHNICAL DISCUSSION

In consideration of available data, consisting principally of a generalized mission description; and in order to program an orderly incorporation of added training capabilities, the following paragraphs describe AMS system changes which have been assumed:

7.2.1 Launch Boost

Booster tapes will be revised for the S-V launch vehicle. Staging, Emergency Detection System, and Sequence Controls Group changes will require inclusion of revised data on the tapes.

7.2.2 Guidance & Navigation (G&N) System

A revised G&N system will be designed for incorporation, and programmed to control flight for the mission, which includes an undershoot entry. Software will require revision to accept the star tracker for alignment. In addition, the revised G&N will be designed to include control of the SPS in order to build up reentry velocity.

7.2.3 Equations of Motion

The equations of motion will require revised scaling to account for a 10,000 N. M. range.

7.2.4 Telemetry

The Telemetry will be added to reflect revised EDS, SCG, Staging, and effects of the mission sequencer. It is assumed that a new measurements list will be provided.

7.2.5 Communication & Instrumentation

The program related to the Up-Data Link will require revision to route commands to the mission sequencer.

7.2.6 Mission Sequencer

Although no data is available on the mission sequencer, it is assumed that some hardware changes, as well as major software changes, will be required for all affected systems — UDL, TM, G&N, SCS, etc.

7.2.7 MSCC Interfaces

Data messages will require revision to account for the S-V launch vehicle, as well as such systems as EDS, SCG, pyrotechnics and staging, LES, and ELS.

7.2.8 Emergency Detection System

Revision will be required to account for the S-V launch vehicle.

7.2.9 Sequence Controls Group

Revision will be required to allow for the S-V launch vehicle.

7.2.10 Malfunctions

Inclusion of the revised G&N and mission sequencer will require revision to AMS manfunctions.

7.2.11 Other Systems

Although specific data is unavailable, it is assumed that minor design effort will be required to revise the following subsystems:

1) Launch Escape System
2) Cryogenic Storage System
3) Electrical Power System
4) Environmental Control System
5) Earth Landing System
6) Stabilization & Control System
7) Reaction Control System
8) Service Propulsion System
9) Caution Warning System

7.3 SUMMARY

Although the scope of the proposal for this particular subsystem is concerned with Phase I only, it must be understood that even in the definition phase there are a great many task efforts that are associated with the system changes described in the previous section. The following list is indicative of the work areas that have been considered in estimating requirements for the AFROM017 Supplemental Equipment Program.

1) Engineering

a. Hardware changes to the C/M for the indicated systems

b. Mechanical changes to the C/M

c. Hardware changes to the IOS

d. Electrical changes associated with all hardware changes

e. Software changes for all systems, and associated programming revisions

f. Launch boost tape revisions

g. Design and drafting of mechanical, hardware, and electrical changes

h. Changes to data conversion equipment

i. Changes to peripheral equipment

j. Simulator power requirement changes

2) Support

a. Documentation requirements

b. PDR requirements

c. Program management and AMSPO support requirements

This listing is not all-inclusive but indicates some of the many items that were considered in proposing the Phase I effort.

8. AIRFRAME 020 SUPPLEMENTAL EQUIPMENT (PHASE I ONLY)

8.1 GENERAL

The Airframe 020 Mission is understood to be as follows:

1) Unmanned Earth Orbit

2) Exactly the same as the AFRM017 Mission, except for the following:

a. G&N Control of the S-IVB

b. High Heat Load Entry (Overshoot)

8.2 TECHNICAL DISCUSSION

The available data, consisting only of a generalized mission description, is the basis for assumption of the following changes.

8.2.1 Guidance & Navigation System

The G&N will require revision to include control of injection into the parking orbit and injection into translunar trajectory. In addition, revision of the entry control program will be required to account for the overshoot entry.

8.2.2 Other Systems

It is assumed that, in the absence of data, minor revisions will be required to the following systems:

1) Telemetry
2) Launch Escape System
3) Cryogenic Storage System
4) Electrical Power System
5) Emergency Detection System
6) Environmental Control System
7) Mission Sequencer
8) Communication & Instrumentation
9) MSCC Interfaces
10) Launch Boost

8.3 SUMMARY

The scope of the proposal for this particular subsystem is concerned with Phase I only; however, it must be understood that even in the definition phase there are a great many task efforts that are associated with the system changes described in the previous section. The following list is indicative of the large number of work areas that have been considered in estimating requirements for the AFRM020 Supplemental Equipment Program.

1) Engineering

a. Hardware changes to the C/M for the indicated systems

b. Mechanical changes to the C/M

c. Hardware changes to the IOS

d. Electrical changes associated with all hardware changes

e. Software changes for all systems, and associated programming revisions

f. Launch boost tape revisions

g. Design and drafting of mechanical, hardware, and electrical changes

h. Changes to data conversion equipment

i. Changes to peripheral equipment

j. Simulator power requirement changes

2) Support

a. Documentation requirements

b. PDR requirements

c. Program Management and AMSPO support requirements

This listing is not all-inclusive, but indicates some of the many items that were considered in proposing the Phase I effort.

9. AIRFRAME 101 SUPPLEMENTAL EQUIPMENT (PHASE I & II)

9.1 GENERAL

This subsection presents the technical considerations required to design the Supplemental Equipment essential to provide the AMS with the capability to simulate the Apollo Airframe 101 mission.

9.1.1 Mission Description

The technical changes presented herein are based upon the primary Airframe 101 mission described in NAA IOL II-03-022, dated 4 July 1964, and upon the data enclosed in NAA M5MA3-22-6083, dated 15 January 1965. The mission is summarized as follows:

1) Manned Earth Orbit (14 days)

2) Launch into Parking Orbit (105 N. M. circular orbit at 31.8° inclination for 1-1/2 orbits)

3) Insertion into Elliptical Orbit (105 N. M. to 2000 N. M. maximum) using S-IVB with G&N Control

4) Transposition and Docking

5) Separation of LEM from S-IVB

6) Hohmann transfer to 120 N. M. circular orbit using SPS

7) Separation of LEM from C/M and Rendezvous and Docking with CSM active

8) SPS lunar injection simulation resulting in plane change to 28° inclination and 120-2000 N. M. elliptical orbit (30 orbits)

9) Separation of LEM and Rendezvous and Docking with active LEM

10) SPS burn to circularize at 120 N. M. orbit

11) LEM-fire descent stage attached to CSM resulting in plane change (full burn)

12) LEM active separation, fire-in-the-hole, limited distance rendezvous using ascent stage

13) LEM separation, SPS burn, terminal ellipse to 30,000 ft./sec. entry velocity

14) G&N Reentry (Approx. 6G)

15) Water Landing

9.1.2 Assumptions

As stated in Paragraph 1, Introduction, Link has assumed that each Airframe Supplemental Equipment will be sequentially implemented, regardless of the fact that Phase I only is being estimated for many airframes. Thus, Airframe 101 changes are considered as being implemented after Airframe 020 changes have been incorporated into the AMS.

Link also assumes that Computer Complex capacity will necessarily be expanded after Airframe 012 and prior to AFRM 101 to the extent that no further computer expansion will be required for the Airframe 101 Supplemental Equipment.

9.1.3 Mission Objectives

The principal mission objectives of the AFRM 101 spacecraft are identified herein. The spacecraft will be inserted into a 100 N. M. circular earth orbit by a Saturn V. During the second revolution, a lunar mission S-IVB restart and translunar injection burn will be simulated. The burn will be oriented to result in an orbital plane change and in a near earth elliptical orbit (120 N. M. to 2000 N. M, maximum). The upper adapter will be deployed and the CSM will transpose, dock, and separate the LEM from the S-IVB. The service module SPS will then be used to insert the CSM-LEM into a 120 N. M. circular earth orbit.

The LEM will be pressurized from the CSM and manned for systems checkout. A CSM active rendezvous maneuver will be performed, followed by CSM-LEM docking. Following these maneuvers, an SPS lunar orbit insertion burn will be simulated resulting in an elliptical orbit with perigee of 120 N. M. and apogee of approximately 2000 N. M. Star-landmark sightings will take place at the apogees. An SPS burn will be used to circularize the spacecraft orbit at 120 N. M. This will be followed by LEM active separation and docking maneuvers.

The manned LEM will perform a full duration descent stage burn while attached to the CSM to impart a ΔV resulting in an orbital plane change. This maneuver will be followed by LEM active separation, fire-in-the-hole, limited distance rendezvous using the ascent stage, extra vehicular visual inspection of the LEM ascent stage, and continued exercise of primary and redundant mode of all systems to expendable depletion. After final separation from LEM, the SPS will place the CSM into a terminal ellipse followed by entry at a velocity of approximately 30, 000 ft./ sec. The closed-loop G&N entry will develop an entry load factor of approximately 6 G's. The entry will be followed by a sea recovery.

9.1.4 Constraints to Simulation

The following are the constraints to simulation of the mission objectives described above:

1) Visual simulation of the LEM will be limited to predesigned and taped maneuvers for the AMS operating independently of the LMS.

2) The LEM model will not be animated (e.g., to include visual display of thrusting, or leg operation, etc.).

9.1.5 Modification Philosophy

9.1.5.1 Command Module

Analysis of the structural changes to the Command Module as dictated by available data indicates that installation of the Supplemental Equipment into the on-site AMS would necessarily result in an inordinately long "out-of-service" period. This time would be necessary since almost the entire interior, and associated wiring, would have to be removed, and literally rebuilt. Therefore, Link's proposed Airframe 101 effort consists in part of a completely new Command Module including the primary structure (above $X_c = -3.0$). The life support systems that are suspended below the primary structure, and possibly the C/M conical sections will be reused. Available data does not indicate changes to the main hatch, window areas, and longerons, hence, no effort for their change is included.

The following summarize the C/M changes:

1) A new C/M primary structure is required. The forward bulkhead will remain the same size but the center will be revised by the addition of a new forward hatch.

2) The entire C/M interior including panels, skins, wiring, interface, secondary structures, instruments not on the main display panel and not equipped with quick-disconnect wiring, plumbing, ducting, etc., shall be new as a part of the Supplemental Equipment. Also, the new Main Display Panels will incorporate simulated electroluminescent lighting.

3) A new revised forward tunnel and associated attached hardware will be provided.

4) New outer skins below X_c = 42.665 to X_c = 0, including all soundproofing and insulation shall be provided.

5) Life support units and other equipment normally suspended beneath the C/M will not be supplied with the Supplemental Equipment but will be reused and transferred from the on-site simulator when the new C/M is installed. The conical sections shall likewise be reused.

9.1.5.2 On-Board Systems Simulation

The available AFRM101 data indicates that all spacecraft systems will be modified to include the new C/M structure and panel layouts. Link will review each S/C subsystem data package to determine the revisions required for AMS simulated subsystems, and incorporate only those changes that are required. The only simulated subsystems presently anticipated to require no revision are:

1) Aural Cue Simulation

2) Smoke Simulation

3) Simulator power

4) Simulator Control (except for LMS interface considerations)

9.2 SUBSYSTEMS AFFECTED

9.2.1 Stabilization and Control Subsystem (SCS)

The magnitude of the required simulation changes will necessitate a detailed analysis of the entire SCS subsystem. This detailed analysis will be required to determine the system behavior and vehicle characteristics. The results will be used to develop the simulator math model for digital implementation of the SCS. Component changes, additions, and deletions, as well as increased software requirements, will be necessary in addition to the deletion and addition of several malfunctions as listed in paragraph 9.4. The proposed areas of change are as follows:

1) Changes in jet select logic

2) Attitude Gyro Coupler Unit (AGCU) change

3) Deletion of one translational controller

4) Changes in Delta "V" Remaining and associated circuitry

5) Addition of three BMAG's

6) Addition of one FDAI

7) Addition of Gyro Display Coupler (GDC) to software

8) Addition of S-IV and S-II fuel indicator

9) Addition of Entry Monitor and change in Delta "V" Remaining systems

10) Manual translation through G&N

11) Addition of push-to-talk switch on rotational control

12) Additional controls

9.2.1.1 Hardware Changes

The following defines the hardware changes necessary to implement the SCS revision effort:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	FDAI (2) Indicator (3) Meter (3) Potentiometer (2) Switch (43) Entry Monitor Panel (1) Attitude Set Control Panel (1)	Existing panels

IOS	Indicator (116) Meter movement (3) Magnaline indicator (18) FDAI (2) Switch (7) Entry Monitor Panel (1)	Existing panels
PERIPHERAL	Resolver (6) Servo (2) Resistor network (17) Relay (41)	
DCE	DBI (45) DBO (3) D/A channel (17) A/D (2) Digital resolver (30)	

9.2.2 Communications and Instrumentation Subsystem (CIS)

Revisions to the CIS necessary to change the Airframe 020 Simulator to the Airframe 101 configuration are proposed as follows:

1) Hi-Gain Antenna Addition

2) Telemetry

   a. Output Requirements Revision
   b. LEM PCM Record Capability Addition

3) UDL

   a. Teleprinter Addition
   b. Dart Telemetry Deletion

4) Data Storage Equipment

5) Power and Switch Logic Changes

6) MSCC/LMS Interface Changes

7) Malfunction Additions

8) IOS and T/M Console Repeat Capability

9.2.2.1 Hi-Gain Antenna

This change required the addition of the steerable, deep-space Hi-Gain Antenna into Airframe 101. Associated with this change is the requirement to drive an AGC meter, which is indicative of the antenna orientation to an earthbound transmitting station. Also, during the automatic mode of operation, the antenna must be driven to look at the center of the earth by means of an IR sensor device.

The software effort for the Hi-Gain Antenna will include station selection routines and antenna drive equations. This will cause extensive changes in the Antenna Effects program.

9.2.2.1.1 Hardware Changes

The following changes will be necessary to implement the Hi-Gain Antenna function:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Toggle Switch (10) Meter (3) Talk-back indicator (1) Potentiometer (4)	Panel 1A19(1) (Hi-Gain antenna function will be incorporated on Airframe 101 panel No. 2)
IOS	Repeat panel (1) Light (11) Diode (22) Meter (5)	Panel 18A30 (1)

T/M CONSOLE	Repeat panel (1) Light (11) Diode (22) Meter (5)	Antenna Control panel (1)
DCE	A/D (6)	

9.2.2.2 Telemetry

Telemetry output requirements and capabilities are:

1) Output Requirements - The output requirements for the Block II Telemetry will be different from those of Block I. Although a 25 percent increase in the telemetered measurement requirements is anticipated, no change will occur in the subcontracted equipment assuming that a basic bit rate change or telemetry outputs beyond the present capacity are not required.

2) LEM PCM Record Capability - The examination of the Block II spacecraft main display console drawings has revealed that the Command Module/Service Module should receive LEM telemetry by way of the Command Module/Service Module VHF/AM receiver. This information shall be recorded on the Command Module/Service Module tape recorder (DSE) for playback to earth. The revision will require both hardware and software changes to the AMS.

9.2.2.2.1 Hardware Changes

The changes on the C/M, IOS, T/M Console, and peripheral equipment are included in the power and switch logic change (Paragraph 9.2.2.5). The following DCE changes are predicated upon a 25 percent increase in simulated telemetered measurements. The DCE changes are as follows:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
DCE	D/A channel (38) DBO (20)	

9.2.2.3 UDL

UDL changes are as follows:

1) Teleprinter - This change requires an addition of a teleprinter in the C/M. The teleprinter will print out the received UDL messages. This addition will create extensive software and hardware changes.

2) DART Telemetry - This change deletes the requirement for controlling the "mechanical boy," which was installed in some Block I unmanned spacecrafts.

9.2.2.3.1 Hardware Changes

The following defines the changes necessary to update the UDL subsystem:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Teleprinter (1)	
IOS	Teleprinter (1)	
PERIPHERAL	Relay (20)	
DCE	Printed circuit card (5) DWO (2)	

9.2.2.4 Data Storage Equipment (DSE)

The DSE will have to be repackaged to the Block II lower equipment bay configuration. The following design changes will be incorporated:

1) Humidity - proof unit with new power, signal, and coax connectors

2) Delete excess record and reproduce amplifiers

3) Add digital record and reproduce circuitry for LEM PCM recording

4) Redesign voice reproduce amplifier to accommodate 32:1 dump of CSM-LEM voice recordings

5) Provide capability for recording CSM and LEM voice on one track

6) Add automatic speed control circuitry to assure apparent 51.2 KBPS output

7) Delete and/or redesign the control logic to fit the requirements of the foregoing changes

8) Add tape motion monitor

9) Change access connectors

9.2.2.5 Power and Switch Logic

Extensive changes are required in this area due to the differences between the Block I panel No. 20 and the new Block II Telecommunications Control Panel. The added requirements necessitate the deletion of the existing Power and Switch Logic program and the generation of a new program. This program will cause all existing and added hardware to interface with the software.

9.2.2.5.1 Hardware Changes

The following changes will be necessary:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Toggle switch (8) Talk-back indicator (2)	Panel 1A20 (1) (The function of this panel will be added to Airframe 101 panel 3)
IOS	Telecomm Control Panel (To reflect Telecomm portion of Airframe 101 panel 3) Light (16) Diode (32) Talk-back indicator (2)	Panel 18A33 (1)

T/M CONSOLE	Telecomm Control panel (1) (To reflect Telecomm portion of Airframe 101 panel 3) Light (16) Diode (32) Talk-back indicator (2)	Telecomm Control panel
PERIPHERAL	Relay card (8) Voltage controlled alternator (3) Preamplifier (4)	
DCE	D/A channel (4) DBI (8) DBO (8)	

9.2.2.6 MSCC/LMS Interface

The Telecomm Control panel changes make it apparent that a LEM PCM hardline and additional hardlines are necessary for complete interfacing with both the MSCC and the LMS.

9.2.2.6.1 Hardware Changes

No C/M, IOS, T/M Console, or DCE changes are required. The following describes the necessary peripheral equipment changes:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
PERIPHERAL	Relay card (2)	

9.2.2.7 Malfunctions

Although additional malfunctions are not specified, it has been assumed that they will be required. A 50 percent change in existing malfunctions and a 25 percent addition of malfunctions is anticipated.

9.2.2.7.1 Hardware Changes

No C/M, IOS, or T/M Console changes are required. The following changes to the peripheral equipment and DCE are required:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
PERIPHERAL	Relay card (2) Voltage controlled attenuator (3)	
DCE	D/A channel (3) DBO (3)	

9.2.2.8 IOS and T/M Console

Since there is a requirement that the IOS and Telemetry Console repeat certain displays presented in the C/M, several IOS and Telemetry Console panel changes are required. With the exception of the hardware changes presented in Paragraph 9.2.2.8.1, all additional changes have been included in the preceding subsystem hardware changes.

9.2.2.8.1 Hardware Changes

The following changes are required:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Panel 6 (1) Panel 9 (1) Panel 10 (1)	Panel 1A13 (1) Panel 1A23 (1) Panel 1A26 (1)
IOS	Panel (3)	Panel (3)

9.2.3 Service Propulsion System (SPS)

Simulation of the new temperature characteristics of the propellant storage tanks will be provided. The programming effort anticipated was predicated on the availability of temperature characteristics of the real system.

Changes in the real system characteristics, such as mass volume, and plumbing, will necessitate analysis and revision of math models for the following: 1) propellant and helium flow characteristics, 2) propellant and helium volumetric characteristics, and 3) propellant-utilization-system point sensors. Additionally, changes in the structural integrity of the propellant storage tank will require changes in the simulation of the propellant tank relief valve characteristics.

The change from a pneumatic to an electrical injector valve, on the SPS engine, will require a change in the associated simulation as will the incorporation of the new electrical control system for this valve. The present pneumatic system will be removed. The effect of this new valve system on the real engine thrust characteristics will be analyzed and incorporated into the thrust simulation.

9.2.3.1 Hardware Changes

The following defines the hardware changes necessary to implement the SPS revision effort. The Command Module and the IOS are the only items effected.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Switch (4) Meter (7) Indicator (2) Panel (1)	Existing panel
IOS	Switch/indicator (23) Meter (4) Magnaline indicator (8) Meter movement (4)	Existing panel

9.2.4 Reaction Control Subsystem (RCS)

It is anticipated that changes in the propellant storage tanks will require revision of the associated heat-transfer and volume equations. Specific data is required to determine the surface area and internal volume of these tanks.

Automatic control of the S/M jet-quad temperature, by means of the added jet quad heaters, will require additional simulation. Included will be provisions for manual override of the quad heaters and the effects of quad heater circuit breakers. Also, revised jet quad temperature limits, for the CWS, will be provided. This part of the simulation effort is based on the assumption that the effects of environmental heating will be incorporated in the math model for Airframe 012; therefore, the only additional analysis will be that required to determine the effects of the heaters on the temperature rate and the thrust effects during quad freeze.

The addition of six malfunctions, as yet undefined, will also be incorporated.

9.2.4.1 Hardware Changes

The following defines the hardware changes necessary to implement the proposed RCS revision. The Command Module and the IOS are the only hardware items affected.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Switch (24) Indicator (16) Meter (2) Propellant Quantity indicator (1)	Existing panel
IOS	Switch/indicator (34) Meter movement (2) Magnaline indicator (7) Switch (1) Indicator (6)	

9.2.5 Electrical Power System (EPS)

Revisions to the spacecraft Electrical Power System will cause the following simulation effort:

1) Analysis of changes to simulated fuel cells to determine and simulate the effects of the redesigned fuel cells. The purpose of this redesign is to increase the fuel cell life from 400 hours to 1000 hours.

2) Analyze the effects of the removal of the Pyro battery from the S/M (service module), and revise the system simulation accordingly.

3) Ascertain the impact of the redesign of the Post-landing and Entry batteries on the current simulation, and revise the simulation accordingly.

4) Determine and simulate the effects of the EPS radiator changes on the fuel cell operation.

5) Provide any necessary changes in the electrical power distribution simulation resulting from changes in the various other subsystems.

9.2.5.1 Hardware Changes

The following defines the hardware changes necessary to implement the EPS revision effort.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Circuit breaker (160) Switch (40) Meter (5) Indicator (18) Switch (22) Meter (7) Potentiometer (1)	Existing panel
IOS	Switch/indicator (20) Indicator (11) Meter movement (5)	Existing panel
PERIPHERAL	Relay (3)	
DCE	DBI (3)	

9.2.6 Environmental Control Subsystem (ECS)

The addition of a redundant glycol-accumulator, a glycol pump and evaporator, and the associated electronic control circuitry will be simulated. A general analysis of the operation of the two glycol coolant devices will be completed to determine the effect of the additional functions. Specifically, a malfunction in one redundant branch may adversely effect the other branch; these effects must be determined prior to deriving the simulation math model.

The simulated cold-plate network in the water-glycol subsystem will be revised to incorporate the rendezvous radar and the redundant electronic-equipment cold plates. The glycol flow equations require extensive revision to provide for the new glycol flow paths.

Simulation of the added glycol valves and the alternate-mode temperature valve will also be provided. Analysis of the water-glycol cooling system will be performed to determine the effects of the selective-freezing aspect of the ECS radiator systems.

Simulation of the thermodynamic characteristics of the C/M-to-LEM transfer tunnel will be provided. Also, the effects of opening and closing the C/M-to-LEM interconnecting hatch will be determined and simulated for the cabin-air subsystem.

In addition, 17 new malfunctions, as yet undefined, will be incorporated in the ECS simulation.

9.2.6.1 Hardware Changes

The following defines the hardware changes necessary to implement revisions to the ECS:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Switch (22) Meter (7) Potentiometer (1)	Existing panel
IOS	Indicator (163) SCR module (160) Switch/indicator (54) Meter movement (5) Switch (24)	Existing panel
PERIPHERAL		Relay (2) Resistor network (1)
DCE	DBO (3) DBIM (8)	DBI (10) D/A channel (1)

9.2.7 Guidance and Navigation Subsystem (G&N)

Several math model and panel changes are required to update the G&N Airframe 020 configuration to the Airframe 101 configuration. The panel and associated hardware changes are described in Paragraph 9.2.7.1. The affected math models and their applicable changes are described below.

1) Math Model 3173-1, Inertial Measurement Unit - Incorporate new error analysis and control loop data. This revision is required due to the change in the spacecraft IMU from size 14 to size 12.5.

2) Math Model 3173-2, IMU Temperature - Complete revision of math model as a result of automatic mercury thermostat control system addition in S/C.

3) Math Model 3173-3, Error/Warning - Minor math model revision is anticipated due to the changes in the IMU and Optics systems and inclusion of the Rendezvous Radar System.

4) Math Model 3173-4, IMU-CDU - Math model to be revised due to incorporation of electronic CDU's and associated changes in CDU characteristics, e.g., transfer function change error analysis revision.

5) Math Model 3173-5, IMU-CDU Difference - Math model revision entails deletion of analog display functions.

6) Math Model 3173-6, Optics CDU - Math Model completely revised due to elimination of mechanical CDU's and the addition of direct line-of-sight velocity control of sextant. The Rendezvous Radar Antenna Control System will also interface with this model in the Block II configuration.

7) Math Model 3173-7, Executive - Mission control routines will require a complete revision for the time-line capabilities.

8) Math Model 3173-8, AGC Input/Output - Considerable revision of this math model is anticipated because of the following changes:

a. Inclusion of Block II CDU's
b. Removal of IMU-Mode Control Panel
c. Inclusion of Rendezvous Radar System

9) Math Model 3173-9, Prelaunch IMU Alignment - Changes in these routines are due to the IMU change and the incorporation of electronic CDU's.

10) Math Model 3173-10, Launch Boost Monitor - Math Model modification will incorporate new reference trajectory parameters and autopilot interface.

11) Math Model 3173-11, Navigation - This Math Model will be modified to incorporate new routines for rendezvous radar data processing and Block II star-tracker horizon photometer data processing.

12) Math Model 3173-12, Inflight IMU Alignment - Modification of these routines is anticipated due to changes in the IMU and inclusion of the electronic CDU's.

13) Math Model 3173-13, Guidance - Math Model will be revised to include requirements of CSM active rendezvous and (simulated) translunar injection.

14) Math Model 3173-14, Steering - Complete modification of the steering math model will be required to incorporate S-IVB control, Minimum Impulse Controller - AGC interface, closed-loop Rendezvous, and Digital Autopilot functions in the AGC simulation.

15) Math Model 3173-15, Reentry - Minor modification of this math model is required due to spacecraft changes in lift over drag and interface with the autopilot.

16) Math Model 3173-16, IMU-Mode Switching Logic - Complete revision of the math model is required due to the elimination of the IMU mode control panel and associated redundant IMU mode control.

17) Math Model 3173-17, Rendezvous Radar - A completely new math model is required for simulation of the Rendezvous Radar - Transponder system. This also includes the antenna control system and radar signal data processing.

18) Math Model 3173-18, Star Tracker - Horizon Photometer - This math model (originally used in Airframe 014) will require revision to incorporate Block II changes.

9.2.7.1 Hardware Changes

The following defines the changes necessary to implement to G&N revision effort:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	AGC panel, 1A43 (1) PSA panel, 1A35 (1) Dummy IMU unit (1) Dummy control-electronics unit (1) Dummy D&C electronics unit (1) CDU panel, 1A32 (1)	Existing panels

	IMU Mode Control panel, 1A29 (1) G&N Indicator Control panel, 1A31 (1) AGC DSKY panel, 1A24 (1) AGC DSKY panel, 1A33 (1) Rendezvous Radar Control Panel (1)	
IOS	Panel 16A9 (1) Panel 16A1 (1) Panel 16A10 (1) Panel 16A11 (1) Panel 16A12 (1) Panel 16A13 (1) Panel 16A14 (1) Panel 18A9 (1) Panel 18A24 (1) Panel 16A2 (1) Panel 16A17 (1) Panel 15A2 (1)	Existing panels
PERIPHERAL	Diode (92) Relay (3) Printed circuit cards (3)	D/R (5) Relay (19)
DCE	DBI (6)	D/A (fast) channel (5) D/R (5) DWI (7) DBI (7) DBIM (8) D/A channel (3) DBO (11)

9.2.8 Sequence Controls Group/Emergency Detection Subsystem

The major additions to the Sequence Controls Group in Block II give the Spacecraft a translunar capability, allow rendezvous and docking with the LEM, and allow LEM S-IVB separation, and LEM-C/M final separation. Analysis of Block II data will be performed to determine a malfunction philosophy consistent with the above capabilities. A math model addition will be generated and integrated with the existing SCG math model. AFRM 101 data will also be analyzed for changes in sequencing of events during normal launch/boost reentry and abort periods in order to determine the changes necessary to incorporate SCG malfunction list and the math model revisions.

Analysis of Block II data for the Emergency Detection System will be performed to determine the changes necessitated by a launch vehicle with lunar capability. The existing EDS malfunction list and math model will be updated accordingly.

The C/M Main Display Panel Changes will necessitate the generation of new cabling diagrams and the updating of the Sequence Controls Group and Emergency Detection System Hardware Functional Specifications.

9.2.8.1 Hardware Changes

The following defines the hardware changes necessary to implement the SCG/EDS revision effort.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Switch (39) Timer (1) Meter (1) Indicator (SCG) (8)	Existing panel
IOS	Switch/indicator (79) Meter (1) Magnaline indicator (8)	Existing panel
PERIPHERAL	Relay (16)	
DCE	DBI (16)	DBO (2)

9.2.9 Cryogenic Storage Subsystem (CSS)

Relocation of the cryogenic storage tanks and the changes in the hydrogen tanks insulation should not affect the existing CSS math model except that a revision will be required to incorporate the required malfunction. Hardware changes to the command module and the IOS will be necessary to update the AMS to the Airframe 101 configuration.

9.2.9.1 Hardware Changes

The following defines the changes necessary to update the CSS to the AFRM 101 configuration. The C/M and IOS are the only items affected.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Switch (9) Meter (4)	Existing panel
IOS	Meter movement (4) Switch/indicator (18)	Existing panel

9.2.10 Aural Simulation Subsystem

Although additional aural cues may be required for simulation of Airframe 101, it is presumed for purposes of this proposal, that any additional aural cues will be obtained from equipment existing prior to this modification.

9.2.11 Caution/Warning Subsystem (CWS)

The Caution/Warning Subsystem (CWS) will be expanded to incorporate the new C/M "on-board" system inputs and the additional detections, display, and control capabilities imposed by changes to other subsystems. Additional CWS outputs will also be incorporated in the simulation.

An analysis of the expanded AFRM 101 inputs and outputs will be performed to determine the requirements for the new malfunction capabilities.

9.2.11.1 Hardware Changes

The following defines the changes necessary to implement the CWS revision effort:

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Switch (6) Indicator (48) Alarm/indicator (2)	Existing panel

LEM MODEL LIGHTING	New requirement
STAR OCCULTING FOR LEM IN SCT	New requirement
DCE	D/A channel (20) D/R channel (5) DBO channel (10)

9.2.13 Other Subsystems

Revision required to update the Airframe 020 to the Airframe 101 configuration requires changes to the "test system," C/M and IOS instruments, and a complete revision of the C/M lighting control system. Panel lighting, flood lighting, and dimming controls will be incorporated. Analysis of the panel lighting control system and component surveys will be accomplished to determine the requirements imposed by the electroluminescent panel lighting.

Simulated loading of the EPS will be revised to incorporate the additional loading resulting from the C/M lighting changes.

9.2.13.2 Hardware Changes

The following defines the changes necessary to implement the revision effort.

HARDWARE CHANGES

AREA	ADDITIONS	DELETIONS
C/M	Clock and timer (1) Light dimmer (8) Switch (7)	Existing panels
IOS	Magnaline indicator (18) Indicator (9)	Existing panels
PERIPHERAL		Relay (2)
DCE		DBI (2)

9.3 SOFTWARE

Revision and/or additions to the AMS simulator software are required to update the AMS simulator from the airframe 020 configuration to the Airframe 101 configuration. The affected areas are as follows:

1) Space Radiators
2) Equations of Motion
3) Aerodynamics
4) Weight and Balance
5) Ephermeris
6) MSCC Interface
7) LMS/AMS Interface
8) Dynamic Launch

9.3.1 Space Radiators

A review of the AFRM 101 data indicates that a major modification of the existing space radiator software package will be required to update from Airframe 020 to Airframe 101. Changes will be necessary in all equations except the following: 1) equations concerned with vector components of the earth, with respect to the sun, 2) equations concerned with vector components of the vehicle, with respect to the earth, and 3) equations that determine whether or not the vehicle is in the shadow of the earth.

The spacecraft changes that necessitate these software changes can be divided into two groups: 1) ECS radiator changes, and 2) EPS radiator changes. The ECS radiator changes will be presented first.

9.3.2 ECS Radiators

The spacecraft changes and the resulting software changes are as follows:

1) Increase in radiator surface area - This change requires revision of the math model equation that is used to determine radiator area perpendicular to a vector from the earth to the vehicle, and the radiator area perpendicular to a vector from the sun to the vehicle.

2) Changes in radiator tube configuration - This change requires revision of that part of the math model concerned with the deviation of overall radiator flow resistance.

3) Additional control valves - This change required revision of the ECS logic, temperature rate, and flow equations. It is anticipated that additional temperature-rate equations, one for each coolant section that can be isolated, will be written.

4) Relocation of radiators - This change will require development of new unit normal vectors.

5) Incorporation of selective freezing capability - The revision required in this area is not firm. It is anticipated that the effective radiator area will not be a function of temperature as well as control valve status.

9.3.3 EPS Radiators

The spacecraft changes and the resulting software changes will be as follows:

1) Change in radiator tube wall dimensions - This change will necessitate revision of the heat transfer effects in the temperature rate equations.

2) Relocation of radiator - This change will necessitate the derivation of new unit normal vectors. Also, if the number of radiator sections is greater than two, new direction-cosine equations will be necessary.

3) Change in radiator area - This change requires substitution of the new area data into the existing area equations.

4) Addition of control valves - This change will necessitate a new flow-resistance equation, revision of the EPS logic, and new flow rate equations.

9.3.4 Equations of Motion (EOM)

The equations of motion will be revised to incorporate provisions for the physical docking of the Lunar Excursion Module (LEM). The effort will require Boolean equations for docking, and equations defining the time-distance between the center of gravity of the command/service module and that of LEM. The latter equations will be used to activate the former.

In addition, equations will be added to simulate the effects of the operation of the LEM descent engine with LEM attached to the command/service module. Ignition of the descent engine will be obtained upon receipt of a command signal from the IOS. Descent-engine thrust will be computed as a function of "time since ignition." The descent engine gimbal angle will be locked in the zero position.

9.3.5 Aerodynamics

This effort consists of the revision of ten 2-variable functions to obtain the new aerodynamic coefficients of the reentry vehicle. The form of the present equation will remain unchanged.

9.3.6 Weight and Balance

Although the form of the present equations will remain unchanged, several constants for the reentry vehicle will be revised. In addition, incorporation of the effects of LEM ascent and descent engines will be accomplished. Equations that calculate the reduction in propellant quantity, due to the firing of the LEM descent engine, will be added to the software package. Also to be added are equations to calculate the change in propellant quantity of the LEM ascent engine from the time of LEM separation from command/service module to the final LEM docking. These equations are based on the assumption that the LEM ascent engine will not be fired while LEM is attached to the command/service module.

9.3.7 Ephemeris

New ephemeris tapes will be supplied; however, the programs will be the same as those used for the Airframe 020 simulator.

9.3.8 Manned-Spacecraft Control Center (MSCC) Interface

The general message format of the trajectory-link message will be unchanged; however, the message will now contain additonal data associated with the following:

1) Added aural cues

2) Saturn V staging inputs (discretes)

3) Fuel pressure indicator for the second stage (S-II) of the Saturn V

Incorporation of the added message-data will be accomplished through the utilization of spare words in the message format.

9.3.9 Lunar Mission Simulator (LMS) - Apollo Mission Simulator (AMS) Interface

Interface of the LMS and AMS will place additional requirements on the executive program. Timing and message formating, for the

AMS-to-LMS output and LMS-to-AMS input will be required. Task complexity should be on the order of that experienced with the AMS/MSCC interface software.

9.3.10 Dynamic Launch

The following defines the software requirements for the dynamic launch program:

1) Revision of the equations of motion to include the Saturn V booster thrusts

2) Addition of 10 new 2-variable functions to provide the aerodynamic coefficient data required for the Saturn V booster stages

3) Incorporation in the existing equations of the Saturn V boosters weight and balance data

4) Incorporation of the Saturn V booster control system (This subsystem requires both math model development and programming of the SI-C and SII, gimbal steering logic, and for the engine gimbaling dynamics. Each booster requires four dynamic engine channels.)

5) Programming of the Saturn IVB thrust vector control (TVC) system (Programming of the Saturn IVB attitude control was previously completed for the S-IB mission and therefore will require no additional effort at this time.)

6) Simulation of the Saturn V, S-IC propulsion (This effort requires equations for the five F-1 engines and for the secondary rockets.) The equations for the F-1 engines will consider the following:

a. Fuel tanks (Hydrocarbon)
b. Oxidizer tanks (LOX)
c. Two pumps
d. Engine chamber pressure
e. Engine thrust
f. Sequence controls
g. Emergency Detection System (EDS) interface
h. Malfunction capabilities

The secondary rocket (eight solid rockets used for separation) equations will simulate engine chamber pressure and engine thrust.

7) Simulation of the Saturn V, S-II propulsion - This effort will require derivation of equations for the five J-2 engines and the eight secondary rockets, and the four ullage control rockets. Considerations

for the J-2 engines will be identical to those specified for the F-1 engines. The rocket equations will consider engine chamber pressure and thrust.

8) Simulation of the Saturn V, S-IVB, auxiliary-propulsion-system equations - These equations will consider the following:

a. Fuel tank
b. Oxidizer tank
c. Helium tank
d. Chamber pressure
e. Thrust
f. Control logic
g. Malfunction capabilities
h. Equations to simulate the J-2 engine of the Saturn V, S-IVB propulsion system. These equations will consider the following:

(1) Fuel tank (liguid hydrogen)
(2) Oxidizer tanks (LOX)
(3) Helium tank
(4) Heat exchangers
(5) Engine pump
(6) Engine chamber pressure
(7) Thrust
(8) CWS/EDS interface
(9) Malfunction capabilities

9.4 MALFUNCTIONS

The following table contains a summary list of the malfunctions to be added and deleted in accordance with Enclosure 4 of RFQ letter M5MA3-22-6083, dated 15 January 65. The effort reflected in the cost proposal is based on the assumption that firm data will be available prior to design start date.

MALFUNCTIONS

SUBSYSTEM	QUANTITY	AREA OF MALFUNCTION
ECS	6	Redundant glycol accumulator, glycol pump, glycol evaporator
ECS	2	Redundant coldplate system

ECS	2	Rendezvous radar coldplate in S/M
ECS	2	Shutoff-valve and disconnect
ECS	3	Pressure gage and control valve - C/M to S/M transfer tunnel
ECS	2	Alternate-mode, temperature control valve
ECS	2	Control valves for radiators
CSS	1	Hydrogen storage tanks
G&N	10	CDU display readout
G&N	2	IMU temperature control
G&N	2	S-IVB control
G&N	6	Star tracking
G&N	2	Minimum impulse
G&N	10	PSA interfaces
G&N	30	Digital autopilot in AGC
G&N	10	Rendezvous radar
G&N	4	AGC optics-drive interface
RCS	6	S/M - undefined
SCG	18	Undefined
SCS	9 (*)	AGCU
SCS	6 (*)	Translational controller
SCS	2 (*)	Delta "V" Display
SCS	6	Twelve, body mounted attitude gyros
SCS	12	Flight director-attitude indicator
SCS	9	GDC
SCS	2	S-IV and S-II fuel indicators

SCS	1	Push-to-talk switch on rotational controller
SCS	6	Manual translation through G&N
SCS	12	Entry monitor
SCS	40	SCS Controls & circuits

NOTES:
(*) To be deleted.

9.5 PROGRAMMING

Programming tasks for the Airframe 101 Supplemental Equipment will consist of revisions to the following computer program routines:

1) Simulator Control

   a. Executive and Control System
   b. On-Line I/O
   c. Real Time I/O
   d. Malfunction Insertion Unit
   e. Utilities
   f. Data Retrieval (Symbol Dictionary)

2) Diagnostics

   a. Command Module
   b. Instructor - Operator Station
   c. Telemetry
   d. Visual System
   e. DCE

3) MSCC Interface

   a. Communications and Instrumentation
   b. SIVB Control and Propulsion
   c. MSCC
   d. Up-Data Link
   e. Telemetry

4) Mechanics

   a. Equations of Motion
   b. Aerodynamic Forces and Moments
   c. Weight and Balance
   d. Ephemeris
   e. Rendezvous and Docking

5) Visual System

   a. Sextant
   b. Telescope
   c. Rendezvous
   d. Mission Effects Projector
   e. Occulation Mask
   f. Solar Simulation

6) On-Board Systems

   a. Propulsion System
   b. Electrical Power System
   c. Space Radiators
   d. Sequence Controls Group/Emergency Detection System
   e. Caution Warning System
   f. Environmental Control System
   g. Stabilization Control System
   h. Guidance and Navigation System

9.6 DATA CONVERSION EQUIPMENT

The following is a summation of the DCE hardware requirements for Airframe 101.

Description	Quantity
DWOR (Digital word output relay)	2 channels
A/R	3 channels
D/R	3 channels
A/D	14 channels
DBI	64 channels
DBO	35 channels
DWOD	3 channels
D/A	80 channels
D/AF	No change
DWI	No change
DBIM	No change

9.7 SIMULATOR POWER DISTRIBUTION EQUIPMENT

Although additional power distribution requirements will be necessary for simulation of Airframe 101, it is expected that these will have been provided by implementation of one or more of the airframes prior to Airframe 101.

9.8 CONTRACTOR FURNISHED EQUIPMENT

The lack of definition of Airframe 101 permissible from available data necessitates that Link assume the following equipment to be Contractor Furnished Equipment (CFE) until such time as sufficient data is made available:

1) Teleprinter (See Paragraph 9. 2. 2)

2) Data Storage Equipment (See Paragraph 9. 2. 2)

3) G&N AGC DSKY panels (See Paragraph 9. 2. 7)

4) All other items identified in Enclosure 4 to NAA Letter M5MA3-22-6083, 15 January 1965

10. AIRFRAME 102 SUPPLEMENTAL EQUIPMENT (PHASE I ONLY)

10.1 GENERAL

The Airframe 102 mission is understood to be as follows:

1) Manned earth parking orbit

2) S-V booster

3) LEM #3 incorporated

4) Translunar injection

5) Transposition and docking for normal lunar mission

6) Spacecraft translunar midcourse abort mode to be used to establish an elliptical orbit at sufficient altitude (approximately 100,000 N. M.) to obtain complete DSIF coverage

7) Check of communication equipment, and G&N tests, rendezvous and docking

8) Reentry - G&N closed loop

10.2 TECHNICAL DISCUSSION

10.2.1 Specific Tasks

On the basis of the above mission definition, the following tasks have been assumed a part of the effort on this particular Supplemental Equipment.

10.2.1.1 Visual System

1) Prepare film application plan, procurement specification, and software for midcourse films (2640 - 100,000 N. M.)

2) Define film handling changes, prepare procurement specification, and define DCE requirements

3) Modify rendezvous radar, and define interfaces with rendezvous radar

4) Modify star occultation (by earth and moon) software

5) Define new landmarks for earth and moon in accordance with distance (100,000 N. M.) requirements

6) Define new sextant landmark slides

7) Delete map and data viewer (replacement book assumed to be CFE)

8) Review requirements and prepare software for tape for relative LEM, as required for mission

9) Review and modify interfaces with G&N

10) Design for modification of sextant or telescope equipment simulation

11) Make software revisions to rendezvous radar, sextant, and telescope, as required in accordance with mission requirements

10.2.2 Additional Tasks

1) Rescale equations of motion to lunar range

2) Revise telemetry in accordance with new measurements list (assumed)

3) Revise G&N system for lunar range

4) Modify MSCC interface to conform with changes in data format

5) Revise guidance aiming parameters for specified mission

6) Other subsystems have been considered to require minor changes

11. AIRFRAME 103 SUPPLEMENTAL EQUIPMENT (PHASE I ONLY)

11.1 GENERAL

The Airframe 103 mission is understood to be as follows:

1) Manned lunar orbit

2) S-V booster

3) LEM #4 incorporated

4) Launch boost into earth parking orbit

5) Translunar injection

6) Transposition and docking

7) Translunar coast

8) Entry into lunar orbit as for normal lunar mission

9) LEM separation and injection into synchronous 50, 000 ft. clear pericynthion orbit. LEM to check radar and operational characteristics

10) LEM abort performed in regime of clear pericynthion after initiation of descent burn, near maximum rendezvous maneuver (burn continuous) followed by docking

11) LEM separation, transearth injection, and nominal return to earth

11.2 TECHNICAL DISCUSSION

11.2.1 Specific Tasks

Based upon the above mission definition, the following tasks have been assumed a part of the effort on this particular Supplemental Equipment.

11.2.1.1 Visual System

1) Prepare film application plan procurement specification and software for:

a. Midcourse films to lunar orbit

b. Lunar orbit films in ranges 58-127 N. M. and 127-273 N. M., both 32° wide.

2) Define film handling changes, prepare procurement specification, and define DCE requirements

3) Define new landmarks for sextant and telescope

4) Design for modification to sextant or telescope equipment simulation

5) Design for modification of rendezvous radar

6) Review requirements and prepare software for tape for relative LEM as per mission

7) Review G&N system changes for effects on interfaces with the visual system

11.2.2 Other Systems

1) Revise guidance parameters for specified mission

2) Revise telemetry in accordance with new measurements list (assumed)

3) Other systems will likely change although which systems and to what degree are presently unknown

12. AIRFRAME 104 SUPPLEMENTAL EQUIPMENT (PHASE I ONLY)

12.1 GENERAL

The Airframe 104 mission is understood to be a full lunar landing mission.

12.2 TECHNICAL DISCUSSION

In light of the above mission, which is almost the entire summation of available data, the only system that Link can be reasonably certain will change is the visual system. Anticipated visual system efforts are assumed as follows:

1) Prepare film application plan, procurement plan, and software for films to increase lunar orbit inclination ranges to include LEM pickup at 50,000 ft.

2) Define film handling changes, procurement specification, and DCE requirements. Cassettes will be modified in accordance with mission requirements, and analysis will be performed to determine the scope and feasibility of changes required to accommodate the new desired speed ranges

3) Define new landmarks for sextant and telescope

4) Design for modification to sextant or telescope equipment simulation

Other systems will probably change, although these cannot be determined from the available information. It is, however, expected that rework of the major subsystems will be required to make them compatible with the knowledge gained on earlier flights.

13. AIRFRAMES 105-112 SUPPLEMENTAL EQUIPMENT INCLUSIVE (PHASE I ONLY)

The limited available information confirms that the Airframe 105 mission is to be identical to the Airframe 104; and the Airframe 106 mission is unspecified, although it is expected to be used as a backup for previous missions. Missions for Airframes 107 through 112 are completely unspecified.

In consideration of the lack of data, but in full realization that estimates for these airframes are for the Definition Phase (Phase I) only, Link is including estimates based upon the experience gained in the course of development of the AMS. The review of the data for the earlier Supplemental Equipment indicates a progression of the design of the major subsystems, which can be expected to continue for these airframes.

Procedural changes are also expected to evolve, which will have an effect on the Link system engineering and the system software design.

PART III

DELTA'S TO DELIVERED CONFIGURATION

PART IV

ALTERNATE COMPUTER PLAN

14. DELTA'S TO DELIVERED CONFIGURATION

14.1 INTRODUCTION

This section describes the efforts involved in accomplishing the Delta's to the Delivered Configuration as per NAA request and as identified and defined herein.

The Delta's are applicable to the delivered AMS configuration; therefore, compliance with the requirements of NPC 500-1 is not considered. Hence, the Delta efforts will be accomplished in compliance with requirements of the AMS Delivered Configuration and NAA/SID Specification MC-901-0115A. This is true, although this effort will be expended in conjunction with an appropriate Supplemental Equipment effort.

15. WINDOW FILTERS

The window filters were not included in the delivered configuration due to lack of design data to permit their simulation. It is currently planned to add these filters to the four windows in conjunction with the AFRM 012 Supplemental Equipment effort. Performance of the filters will comply with NAA/SID Specification MC901-0115A. The exact design approach cannot be specified until data on the design of the on-board equipment is available. However, it will include the incorporation of window filter assemblies similar in appearance to those used on the spacecraft, and the adjustment of both C/M and visual display light levels to provide proper light-level ratios to obtain an overall satisfactory simulation. This will probably require modification of other math models in order to effect an overall design.

16. LEM RENDEZVOUS AND DOCKING TAPES AND SOFTWARE

This Delta includes the various deferred items relative to LEM rendezvous and docking. This Delta will be provided in conjunction with AFRM 104 Supplemental Equipment effort. Areas of concern are:

1) LEM time of descent
2) LEM descent
3) LEM ascent
4) LEM castoff

16.1 GENERAL

An off-line program will be written to generate the trajectory for the LEM vehicle when operating within a lunar reference. The required data, containing relative position and attitude information, will be stored on magnetic tape. The AMS program will be modified to accept these parameters, integrated with the equations of motion of the CSM, and will thus generate the visual equipment drive signals required to position the LEM vehicle image in the docking windows.

The tapes provided will include specific LEM trajectories from the docked position up to 20 miles out. The following quantities of tapes, and their applicable phase of the lunar landing mission activities, will be provided:

1) 1 - LEM separation and descent (LEM Active, C/M Passive)

2) 1 - LEM Castoff (C/M Active, LEM Passive)

3) 1 - Coplanar ascent to rendezvous and docking (LEM Active)

4) 4 - Non-coplanar ascent to rendezvous and docking (LEM Active)

5) 3 - Non-coplanar ascent to rendezvous (C/M Active to achieve docking)

The AMS "on-line" program to utilize the above data in conjunction with the CSM equations of motion to generate the visual equipment drive signals will also be provided.

16.2 TECHNICAL DISCUSSION

16.2.1 LEM Descent Time

The specification of a time for LEM separation from the C/M when in lunar orbit is instructor-controlled by using the typewriter. Consequently, no constraint or incremental change need apply to the AMS at the time of separation. The instructor will call up that section of magnetic tape containing the LEM descent data. This should not be preprogrammed to occur at a specified time in the mission, as separation could occur at an incorrect time. This could occur, if there were any changes in the mission time profile from lift-off to the time of separation in lunar orbit. LEM separation is normally initiated by the astronauts in the LEM vehicle; however, in the AMS, the instructor is the acting LEM controller and will initiate separation.

16.2.2 LEM Descent Tape

One tape will be provided which will allow positioning of the simulated LEM vehicle in the docking window during the separation and during the first 20-mile segment of the descent phase. The initiation of this phase will be instructor-controlled.

16.2.3 LEM Ascent Tapes

Eight tapes will be provided to allow simulation of the visual aspects of the final ascent phase during the rendezvous and docking mission. These tapes will be instructor-selected and initiated by use of the typewriter. Additional tapes, which are required to provide C/M pickup of the LEM vehicle at 50,000 ft., will be incorporated as part of the Supplementary Equipment for AFRM 104. Use of rendezvous radar or of G&N to achieve the rendezvous will have been included, per the AFRM 101 Supplementary Equipment Proposal.

16.2.4 LEM Castoff

One tape will be provided to include the LEM final separation from the CSM and departure from it. This differs from the LEM Descent tape only in respect to which vehicle performs the rendezvous and docking task. In this tape, the C/M will be maneuvered to effect a rendezvous and docking with a passive LEM vehicle. Additional tapes will be required for AFRM 101 to provide the relative LEM visual displays for operation within an earth reference. Where AFRM 101 is an earth orbit mission, LEM operations are not similar to those for the Lunar Mission, and therefore require these additional tapes which will be included as a portion of the Supplemental Equipment of AFRM 101.

Additional tapes may also be required for AFRM 102 and 103, if these missions differ substantially from those of AFRM 104. They will, however, be included as part of the respective Supplemental Equipment.

17. G&N CONTROL OF SIVB THRUSTING (BACKUP)

This Delta will provide the G&N backup mode of guidance to control the last stage of the booster (SIVB) for translunar injection. The math model for the thrust vector control of the SIVB has already been written but remains to be programmed. This feature is required for AFRM 020 and will be incorporated with its Supplemental Equipment effort.

The G&N steering equations will require modification to provide proper command signals to the S-IVB system (different from those to the SCS for the S/M-SPS drive signals) for the Series #100 Guidance Equipment. The navigation and guidance, and steering portions of the G&N programs are included in the G&N simulation for the earlier airframes. However, these programs will require revision for the specific mission to be flown.

18. MID-COURSE TRANSEARTH G&N

The equations for this mode are included in the delivered configuration (in the math model for the Block I G&N); however, prior to being utilized, the program must be changed to pickup the new aim points and must be rescaled for lunar ranges (presently scaled for G&N earth orbit range only). The lunar missions will be used in Block II G&N (lunar), which will be included in AFRM 101. As such, the only increment is that required to revise the G&N programs for the specified mission, which must be performed for each mission (load mission profiles, such as launch, reentry, and enroute aim points). Also, revision may be required for any portion of G&N that might have been revised since the last AMS G&N program was written.

19. ALTERNATE COMPUTER PLAN

19.1 PURPOSE

The modifications to software programs for Supplemental Equipment in a literal sense would require a complete Apollo Mission Simulator to enable their debugging and integration, but, time, economic, and geographical constraints do not allow such a plan. Therefore, Link has proposed the test plan discussed in Paragraph 5.7 of Part II of this proposal. In the proposed test plan, Link recommended the leasing of a DDP-224 computer, with a 40,000 word memory, and associated peripheral equipment. The leased computer would be required not only for duration of the Airframe 012 Supplemental Equipment effort, but throughout the entire period of all Supplemental Equipment efforts.

As a further consideration, Link also feels that as simulated mission complexity increases, the increase in required software program content will eventually result in exceeding the capacity of the present computer complex. Current estimates indicate that this situation will occur with the inclusion of the Airframe 014 Supplemental Equipment. By the time of inclusion of the fifth or sixth Block II Supplemental Equipment, the computer complex will require two DDP-24's (32K memory each), and two DDP-224's (40K memory each).

Therefore, Link proposes an alternate approach as described herein in order to: 1) satisfy AMS computer complex capacity requirements, 2) meet Supplemental Equipment test requirements, 3) provide for each of these requirements in the most expedient and economical manner, and 4) make the best possible use of available computers from the very beginning of simulator training implementation.

19.2 ALTERNATE APPROACH

The present AMS delivered configuration computer complex consists of the following:

AMS # 1	AMS # 2
2 - DDP-24's (designated as A_1 and B_1)	2 - DDP-24's (designated as A_2 and B_2)
1 - DDP-224 (designated as C_1)	1 - DDP-224 (designated as C_2)

The alternate proposed approach, as illustrated in Figure 7 and described below consists of the following:

1) Two DDP-224's (40K each), which are identified herein as D_1 and D_2, will be ordered for delivery to Link as soon as possible.

2) A_1, C_1, and C_2 will be shipped with AMS #1 to the specified site (one DDP-24 and two DDP-224's).

3) The remaining computers at Link— A_2, B_2, D_1, and D_2-- will be used for test of AMS #2 and of Supplemental Equipment.

4) A_2, D_1, and D_2 will be delivered with AMS #2 (one DDP-24 and two DDP-224's)

5) $B_1$and B_2 will be retained by Link for continued use in test of Supplemental Equipment until such time as the on-site AMS's require the added capacity.

19.3 PROVISIONS

This recommended approach is in keeping with NAA and NASA's foresightedness of planning, and provides several distinct advantages. First, this approach removes the requirement for computer leasing for program debugging and integration. From an economic standpoint, this is highly desirable since it relieves a requirement for nonrecoverable expenditure.

Second, the approach provides for increased and improved technical continuity resulting from the use of deliverable computers. This advantage will be manifested technically and economically since programs will be tested and integrated on equipment manufactured to the AMS specification, thereby alleviating any requirement for special programming techniques to provide compatibility with a leased computer. The use of deliverable equipment for programming prior to on-site delivery will assure a thorough checkout of Supplemental Equipment, including computers, prior to installation.

Third, the recommended approach will assure a smooth transition to the final computer complex configuration. As programs are modified for Supplemental Equipment changes, they can also be tailored to the computer configuration as it evolves, rather than making a major program revision in order to satisfy a revised computer configuration.

Finally, the approach will ensure that program hardware installation can be accomplished with greatest expediency and minimum out-of service time. This will assure minimum interruption to the astronaut training schedule.

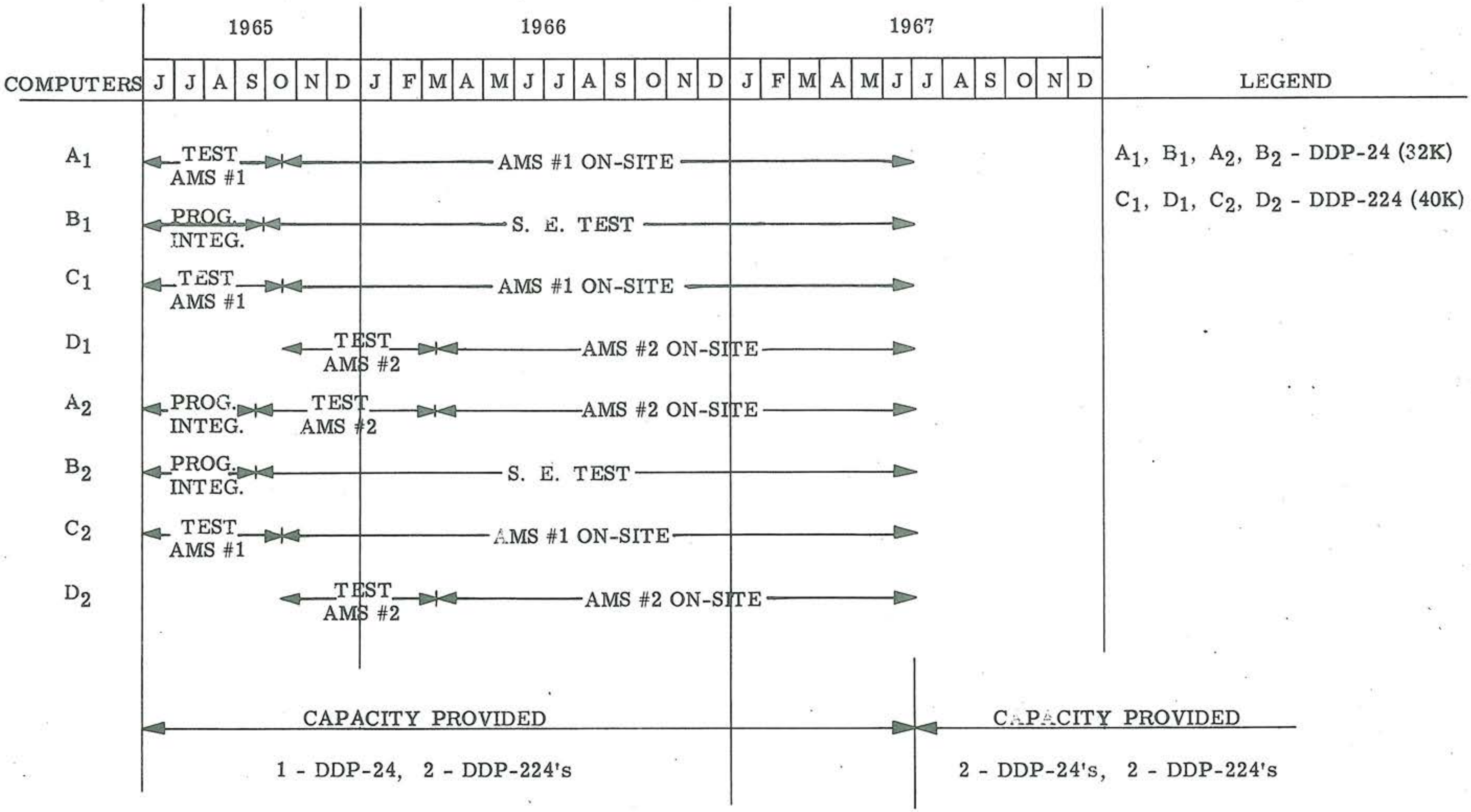

Figure 7 PROPOSED ALTERNATE COMPUTER IMPLEMENTATION SCHEDULE

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Pages 106
107
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