CHECKOUT SYSTEM
TRADEOFF STUDY

Augmentation Task No. 41

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Section 1
SCOPE

1.1 INTRODUCTION

The selection of the system test complex to support factory, thermal vacuum and KSC prelaunch testing of the ATM involves many factors and can have a profound influence on the program cost, performance, and ability to meet the required schedules. This report is a review of the available documentation related to two candidate systems under consideration for the ATM testing. These are the ACE-S/C System manufactured by the General Electric Company, and a new manual system presently in the preliminary design phase at MSFC.

During the first six months of the AAP Phase C contract, LMSC conducted a thorough analysis of many candidate checkout systems being considered to support the total AAP program. Although there has been some change in schedule requirements since that study was conducted, much of the background and technical conclusions are considered valid and the results of that study are used extensively in this analysis.

The basic alternatives under consideration are:

- Use of the manual system
- Use of a modified ACE-S/C System
- Use of a standard ACE-S/C System with vehicle modifications to achieve compatibility

The only method of implementing an ACE-S/C System considered in this analysis is that of relocating one of the 12 existing systems to MSFC. It is anticipated that one of the systems presently located at Grumman Aircraft Engineering Corporation will be made available.

1.2 ASSUMPTIONS AND GROUNDRULES

The basic assumptions and groundrules applied to this analysis are summarized as follows:

- Two sets of manual ESE will be built
- Building 4708 will be used for ATM systems test at MSFC
- Vibration testing will be conducted in the P&VE Laboratory
- Interconnect between the System Test Complex and the ATM during vibration testing will be required
- Both the prototype unit and the flight unit will be in test at MSFC concurrently
- Similar systems will be used at all test locations. An exception to this is considered due to its apparent advantages (i. e., use of a simple manual system to support thermal vacuum testing) in conjunction with the ACE-S/C System for factory and prelaunch testing.

Section 2
SUMMARY

Section 5 of this report presents a detailed breakdown of the study results, conclusions and implementation considerations. A brief summary of these facts is presented here, indicating the major problem areas or considerations that appear to be of major significance.

2.1 SCHEDULE

For both the manual and the modified ACE-S/C System a decision to proceed must be made as soon as possible because both systems require a minimum of one year to implement and because ATM testing is scheduled to begin in August of 1968. The ACE-S/C System indicates a marginal schedule at best. The alternative of modifying the ATM to accommodate ACE-S/C if implemented immediately would incur a schedule slip.

2.2 COST

The cost of the relocated ACE-S/C System, the new software required, and the system modifications is considerably higher than the cost of the manual systems. (This is a one-time cost that can be written off against future vehicles; however, it does increase the first-use or ATM cost.)

2.3 THERMAL VACUUM TESTING

The use of ACE-S/C for factory, thermal vacuum, and KSC testing appears possible only if the MSC thermal vacuum chamber is used. The use of manual equipment, however, will enable the use of any of the candidate chambers. Use of a simplified manual system for thermal vacuum test support, in conjunction with ACE-S/C for factory and KSC testing, appears attractive.

2.4 AVAILABILITY

The present usage schedule of ACE-S/C systems does not indicate availability of a hardware system (to be installed at MSFC in time to support ATM testing) and a software development facility to allow sufficient machine time for software validation.

2.5 TECHNICAL ASPECTS

Required ACE-S/C modification is considered feasible and may provide an additional advantage by reducing the amount of experimenter-supplied equipment required for systems level testing since basic ACE-S/C capability can satisfy many of the simple experiment-command and data requirements. Manual equipment could easily be provided to satisfy the vehicle requirements since it will consist basically of a new design. It does appear extremely appropriate, however, to trailerize the manual equipment, which would simplify tear down and setup requirements, overcome KSC problems at LC 37, and facilitate meeting schedule requirements.

Section 3
MANUAL SYSTEM

3.1 SYSTEM DESCRIPTION

The concept of manual GSE to perform ATM checkout calls for two types of equipment: (1) experiment checkout equipment (ECE), supplied by principal investigators (PI), and (2) electrical support equipment (ESE), supplied by MSFC. ESE will be used for overall, system ATM testing, whereas the ECE will be used by the PI's for experiment testing, calibration, and troubleshooting. As ECE is common to both the automatic and manual approaches, the term "Manual Equipment" as used in this report is synonymous with ESE.

Two sets of ESE will be fabricated to a common design, with the possible exception of additional signal processing equipment required at LC-37 because of the long-run cabling required at that location.

Data available to LMSC indicates that Astrionics is proposing minimal ATM testing at the MSOB and maximum testing at the launch pad (Ref. 1). While this philosophy is dictated for most booster-type systems, it is contrary to the LMSC and KSC recommended approach for spacecraft checkout.

ATM system testing and LM/ATM mission module testing at the MSOB should be designed to establish flight readiness. Testing on the pad should revalidate launch readiness and ensure compatibility of the mission module with the launch vehicle. Thus, maximum testing is accomplished at the MSOB and reduced checkout performed at the launch site.

Since the LM will not be present during ATM testing at MSFC and at the thermal vacuum test facility, the LM must be simulated. This simulation must include the ATM control and display panels which are normally mounted in the LM astronaut compartment. ATM/LM system testing at KSC, however, must be analyzed to determine the ATM manual ESE interface with LM and/or ACE-S/C.

The LM/ATM electrical interface, as described in report LMSC-A842239, consists of approximately 1,200 conductors of the following types:

Conductors, round	773
Conductors, flat	418
Conductors, coaxial	13
Total	1,204

These ATM conductors connect to the ATM control and display panel located in the LM astronaut compartment and do not interface with any LM electrical system. The LM and ATM astronaut control and display systems are separate and operate completely independently. However, a provision exists for supplying +28 VDC power from the ATM to the LM via the ATM solar array power system, and this does represent an electrical circuit interface bwteeen the ATM and the LM. This limited ATM/LM interface should result in a negligible interface between ACE-S/C and manual ATM ESE at KSC.

Verification of the +28 VDC ATM/LM interface power circuit can be done on a subsystem basis at KSC using an ATM ESE power source and LM/ACE-S/C monitoring capability. Precautions should be used during this test, or interlock circuitry provided, to prevent feeding the +28 VDC bus in the LM from two independent power sources simultaneously, and possibly damaging equipment. During integrated tests of the LM/ATM at KSC it will be necessary to provide a test-timing signal that is common to both LM/ ACE-S/C and the ESE to ensure a coordinated test sequence.

3.2 PRESENT STATUS

Preliminary design of the ESE is under way at Astrionics, MSFC. Their schedule (Ref. 2) as of 29 June 1967 shows that final design and fabrication of the first set of ESE will commence in October 1967, with the second set starting into manufacturing in December. It can be assumed that long-lead procurement activity will have been originated in some areas, but the most likely candidates would be those ATM peculiars that would be equally usable with ACE.

It is therefore concluded that efforts accomplished to date toward acquisition of a manual system for ATM checkout have not reached a point where cancellation of those efforts would present a significant cost factor. It is apparent, however, that the point is rapidly approaching when such a decision would cause an impact of economic significance.

3.3 COST TO IMPLEMENT

The LMSC trade study, document number 4,900,228A, specifies the following costs for manual ESE.

- One-time development costs $0.6M
- Single-system cost 1.4M

Based on these figures, two manual systems for ATM will cost approximately $3.4M.

To estimate what additional costs are involved in trailerizing these two systems, the following is appropriate. LMSC obtained a price quotation of $24,500 each from the Fruehauf Trailer Corp. for a 28-ft-long trailer. This trailer was a standard commercial type with reefer-type insulation. Included were a 3-ton air conditioner, 3-kw strip heaters, enclosed wiring, household-type interior lighting, vinyl corlon floor covering, and complete undercoating.

The trailers required for the manual ESE are approximately 35-ft long, require larger air conditioning systems, and should have a personnel access door on the side.

Based on the foregoing, it is estimated that the cost per trailer will be approximately $33,000 and each set of manual ESE (comprised of 3 trailers) would increase in cost by $100,000. Delivery time for such trailers is approximately 3 months. This includes factory time for the basic trailer and branch office time for air conditioning installation, etc.

To summarize, the total cost for two new manual trailerized ESE systems is:

Cost Item	Unit Cost	Total Cost
One-Time Development Cost	\$0.6M	\$0.6M
Hardware Cost	1.4M	2.8M
Trailers (3 per system)	0.1M	0.2M
Total Cost for Two Systems		\$3.6M

This cost will be reduced by utilizing existing equipment, which is available from the retired 500FS ESE.

3.4 OPERATIONAL REQUIREMENTS

In addition to initial acquisition considerations for candidate checkout systems, operational requirements from acquisition through launch of the mission module must be evaluated. For a manual system, this includes the following areas of support.

3.4.1 Engineering

A sustaining effort averaging approximately five equivalent men per month for ten months will be required to respond to ATM and GSE changes which impact ESE design, to analyze performance of the GSE, and to provide engineering field support at the test locations.

3.4.2 Manufacturing

A sustaining effort will be required to respond to engineering changes that result in new or modified hardware.

3.4.3 Test Operations

Based on comparable LMSC checkout experience, it is estimated that a sustaining effort averaging approximately 20 equivalent men per month will be required for 10 months for operation of the ESE (two sets).

3.4.4 Logistics Spares

Based on LMSC experience gained in supporting Agena checkout systems, the provision of spares for two identical manual test stations is estimated to cost approximately \$20,000. As the extent of existing spares for the 500FS ESE is unknown, and as two ESE systems will be located at KSC during the most critical phases of testing, it is conceivable that a lesser degree of spares support could result.

Various other required services such as Program Office, Configuration Management, and Quality Assurance are not anticipated to differ materially whether a manual or an ACE system is utilized.

3.5 RELIABILITY

Two distinct and separate aspects of reliability are appropriate when evaluating a ground support system – the reliability of the equipment itself and the reliability of the performance of the system and the data it produces.

The manual test station envisioned for ATM is primarily composed of the same type of components as other aerospace manual test stations. Their relatively brute-force approach to test and checkout coupled with the basic simplicity and maximum use of standard commercial equipment provides a high MTBF figure. An estimated MTBF of 400 hr is considered feasible with this type of system. As shown in the recent LMSC Trade Study, this is an appreciably higher number than any alternate candidate system.

From a data reliability aspect, it is reasonable to assume that the greater involvement of operator personnel in test sequencing will materially decrease the dependability of acquired data compared with that of a system such as ACE-S/C.

3.6 THERMAL VACUUM TESTING

The proposed method of supporting thermal vacuum testing on the ATM prototype and flight articles is by relocating a checkout system to the test facility during the testing program. This is the reasonable approach, as the only practical alternative would be to fabricate another complete set of ESE. However, two additional factors should be considered.

- The double move of both sets of ESE (first item from MSFC to TV Test Facility, to MSOB; second item from MSFC, to TV Test Facility, to LC-37) could be reduced if compatible schedules can be achieved and if the prototype is functionally similar to the flight item. Then the first set of ESE could be relocated to the TV Test Facility and remain there for support of both ATM's. Upon completion of MSFC activity, the second unit would be relocated to the MSOB in time to receive the flight ATM, with the first unit being assigned to LC-37 at the end of TV testing.
- The physical dismantling, transportation, setup and validation of the proposed ESE manual system is a considerable task, particularly in terms of schedule time. The concept of mounting this equipment in trailers therefore offers a very real advantage. This approach offers minimum disruption of the system, thus saving relocation schedule and preserving a much greater degree of system confidence.

A further distinct advantage of a trailerized system can be realized at KSC LC-37. The problems associated with integration of a manual system are outlined by KSC letter to NASA Headquarters, dated 23 May 1967 (Ref. 5). Program-peculiar equipments of this quantity in the LCC and, to a lesser degree, in the Service Structure are not desirable. However, these objections can be overcome to a large extent if the ESE is housed in trailers close to the Service Structure. This system appears practical because the nature of the ATM suggests that a minimum of control and monitoring will be required during the final phases of countdown, and because the trailers can be withdrawn at a reasonable time prior to launch. The remaining functions would then be routed to minimal consoles in the LCC through the DDAS, augmented as necessary by essential hardlines.

3.7 FACILITY REQUIREMENTS

Each set of manual checkout equipment will comprise approximately 30 racks of equipment. Space requirements listed consider equipment placement and personnel accessibility for operation and maintenance.

The power requirements and the air conditioning requirements listed herein are necessarily approximations based on the status of the preliminary design.

3.7.1 Room Installation

Two areas are required, each of 700 – 1,000 sq ft, for a total requirement of 1,400 – 2,000 sq ft. It appears that Bldg 4708 at MSFC has sufficient space available to handle this requirement. Modifications to the area will be necessary but cannot be identified at this time. If the two planned sets of ESE are installed in Bldg 4708, hard-line cabling will be necessary to the P&VE Laboratory for the performance of vibration testing at that location. An alternative to this would be to move the set of ESE from Bldg 4708 to the P&VE Laboratory upon completion of the systems test and prior to performance of the vibration test.

To provide temperature control of the electronic equipment, approximately 3.5 tons of refrigerated air conditioning will be needed for each set of ESE. This estimate is based on similar systems presently used for system testing of Agena spacecraft.

Approximately 15,000 watts of 120/208-volt three-phase 60-Hz electrical power will be required for each set of ESE. This will be used to supply three-phase and single-phase power to the various racks of equipments.

3.7.2 Trailer Installation

A mobile, trailerized system will probably require three trailers approximately 35-ft long. For two complete sets of ESE, therefore, six trailers will be required. This will provide approximately 700 sq ft of floor space for each set of ESE.

It will be necessary to provide integrally mounted air conditioners on the trailers. The total air conditioning requirement will be approximately the same as for the room installations (3.5 tons per set) or somewhat higher due to the need for individual air conditioners on each trailer.

Power requirements will be essentially as required for the room installation. This requirement is for approximately 15,000 watts of 120/208-volt three-phase 60-Hz electrical power per set. For the trailer installation, conveniently located power receptacles will be necessary within reach of the trailer's interface cables at each location of usage.

Parking space must be provided for one set of ESE adjacent to each area of use. The ATM Project Master Schedule (ATM-1 dated 1 June 1967) indicates that no more than one set of ESE will be necessary at any location at any one time. The areas of usage are as follows:

MSFC Bldg. 4708 – Systems checkout
MSFC P&VE Laboratory – Vibration test
Thermal Vacuum Facility – Thermal vacuum test
KSC MSOB – Complete systems checkout
KSC LC-37 – Launch readiness

Section 4
ACE SYSTEM

4.1 SYSTEM DESCRIPTION

The test and checkout tasks associated with experiment integration require a checkout system that is versatile and reliable, and that can exhibit test repeatability at widely separated test locations and times. The ACE-S/C System, which has been used extensively in all phases of manufacture, checkout, and countdown associated with the Apollo CSM and LEM systems, appears to include these general features and many more. As such, the system demands attention as a likely choice to fulfill the needs of ATM testing.

Functionally, this equipment consists of three distinct sections; a command up-link, a data recording and display down-link, and a computer control center. The command system consists basically of test consoles connected through the command computer to the transmitting equipment. This system permits the test operators to conduct a wide variety of tests from the controls on their test consoles.

The test results are monitored by the display system, which consists of data acquisition and recording equipment connected to the display computer. This computer processes the data for presentation on alpha-numeric CRT display units, or for presentation on other analog and digital display devices located in the test consoles.

The testing of each functional experiment and subsystem on the ATM is controlled from the test console through START (Selection To Activate Random Testing)modules. A START module is a plug-in unit that 1) provides manual control of discrete events through relay selection (R STARTS), 2) provides manual selection of computer subroutines and the parameters required by the subroutines through computer communication panels (C STARTS), and 3) provides manual and automatic update of the airborne computer memory through keyboard switches (K STARTS).

4.2 OPERATION REQUIREMENTS

As with a manual checkout system, operational requirements from acquisition of an ACE system through launch of the mission module are a significant factor.

The ACE system at MSC (Thermal Vacuum Testing) and the ACE system at KSC (LEM Testing) are considered to require minimal additional sustaining effort to support ATM, with the exception of spares. GE's budgetary estimate for the relocated unit at MSFC is as follows.

Computer programming, documentation maintenance, hardware maintenance, console operation and system analysis after the ACE station is in operation (GFY '69) 408 man-months, $680,000. As this covers the period during which prototype and flight ATM's will be tested, it can be assumed that the required support level is 34 equivalent men per month. The reasoning behind the dollar requirements cannot be evaluated due to the lack of definition as to its application.

Spares for the ATM ACE-S/C station at MSFC are estimated by GE to cost $100,000. Special spares for the ATM peculiars at KSC and, presumably, at the TV Test Facility would cost $25,000 for each location.

4.3 RELIABILITY

Two distinct and separate aspects of reliability are appropriate when evaluating a ground support system – the reliability of the equipment itself, and the reliability of system performance and the data it produces.

A reliability assessment of the ACE in the NAA Computer Complex, which covers 35,000 hr through December 1965, indicated a MTBF of 187 hr for the computer systems and 1,776 hr for the data-entry equipment. A recent LMSC Trade Study (Ref. 6), using a relative ordering of five candidate systems from the poorest (a "1" rating) to the best (a "5" rating), established the following rating.

Manual	5 rating
ACE-S/C	4 rating
DEE-6	3 rating
RCA-110A	2 rating
Hardcore ACE	1 rating

indicating a comparable reliability between existing ACE-S/C and manual-type systems.

From an aspect of data reliability, it is reasonable to assume that the reduction in operator involvement in test sequencing materially increases the dependability of the operation.

4.4 THERMAL VACUUM TESTING

Three facilities are under review as possible sites for subject testing — Boeing, Seattle; Arnold, Tullahoma; and MSC, Houston. A recent LMSC evaluation of the three candiates has confirmed that all have the overall ATM capability. Considering an all-ACE system for ATM, the facilities can obviously be divided into two categories: those with ACE on site (MSC), and those without (Boeing and Arnold).

MSC. Assuming the availability of an MSC ACE system during the planned period, the second set of ATM-peculiar GSE can be placed at Houston and integrated with the basic station while the prototype ATM is undergoing testing at MSFC. Upon completion of flight ATM TV testing, the ATM peculiars would be relocated to KSC.

Boeing or Arnold. Adherence to the all-ACE concept could be satisfied by two basic approaches: 1) relocate ACE to the TV facility, or 2) control the vehicle by means of a remote station at MSFC.

According to the GE proposal (Ref. 4) the cost of relocation is in excess of $630,000 and 44 manmonths, neglecting the costs of physical transportation to and from the TV facility and the tear-down cost after usage. Additionally, the problems associated with the first-time setup of a system of this complexity at a given facility have not been fully analyzed. The other basic question to this approach is the availability of an ACE system to be placed at the TV facility.

Remote operation from MSFC is also considered in the GE proposal, and any data transmission system considered presents significant problems. Without modification to ACE to match AT&T, the quoted expense is $5.3 million for Seattle and $1.6 million for Tullahoma. By modification of the ACE to provide compatible bit rates with AT&T, the values become $740,000 and $290,000, respectively. The relocation of certain peripheral equipments (PCM Station , DTCS, DTMS, etc.) to the TV facility, and their integration and checkout are additional cost elements. An important factor not considered in the subject proposal is that the delay time introduced into the data system by repeater stations is incompatible with the computer programming, thus resulting in the need for drastic software changes for this application.

The philosophy of employing mission simulation during thermal vacuum testing is regarded as being of questionable value. Worst-cast hot and cold conditions of operation would seem to be more attractive, as performance of the thermal control system and detection of manufacturing inadequacies are the prime reasons for running thermal vacuum tests. Under hot- and cold-testing conditions only, the requirements for ESE can be greatly reduced. Hence, a practical approach to TV testing in an all-ACE system may prove to be the supply of a set of minimal manual ESE to the selected facility.

4.5 FACILITY REQUIREMENTS

The following requirements for ACE facilities consider MSFC only. ACE stations exist at all other testing areas, with the possible exception of thermal vacuum testing. The subject of checkout, should TV testing be done at other than MSC (where ACE is available), is treated elsewhere in this report and will not be discussed here. These facility criteria are derived from General Electric data supplied to MSFC as backup for the GE proposal (Ref. 4).

Item	Requirement
Space	5,000 sq ft
Power	
Single phase	120 v 60 Hz 74,600 w
Three phase	208 v 60 Hz 114,700 w
Environmental Control	406,810 Btu /hr which necessitates approximately 41 tons of refrigerated air conditioning. Equipment mounted on raised floor. Space beneath floor serves as return air plenum.
Lighting	90 ft-candle at 30 in. above floor. Recessed lamp fixtures equipped with cold-cathode florescent lamps with leaded glass shields for RFI suppression.
Floor Loading	0.1 in. max. deflection per concentrated 1,000-lb load per 18-in. by 18-in. panel. Thirty-six-inch elevated floor in control, computer, and terminal facility room (3,800 sq ft). Flooring made up of 18-in. by 18-in. aluminum panels (vinyl covered) and stringers.
Ground	Building, power neutral, static, and signal ground busses

4.6 ACE CAPABILITY COMPARED WITH ATM REQUIREMENTS

4.6.1 Command System

The maximum limitation of the ACE command system is 256 R-START modules or 64 C-START modules, or any combinations of R- and C-START modules in the ratio of one C-START module and four R-START modules (K-START equivalent to one C-START), according to GE and CDC (Ref. 8).

The GE analysis of LM/ATM requirements (Ref. 10) establishes that 176 equivalent R-START modules would be utilized for test of the ATM/LM mission modules, without considering spare module requirements, as follows:

R-START modules for LM	103
R-START modules for ATM	25
Subtotal	128
C-START modules for LM	7
C-START modules for ATM	4
Subtotal	11
K-START module for LM	1
Equivalent R-START modules	$128 + (4 \times 12) = 176$

Although definitive data which would confirm this estimate is not presently available, it is apparent that an adequate reserve capability exists.

4.6.2 Display System

Meters. 216 meters are available, with an additional 76 units possible by substitution of event modules. By switching of functions, the basic 216 meters can be employed to display 180 additional functions on a time-sharing basis. Based on a GE estimate of ATM/LM requirements (186 meters) and available Astrionics data, the ACE meter capability is adequate.

Event Indicators. 1,368 event indicators are available for displaying a maximum of 1,200 different events. GE has assumed that 1,018 event indicators would be required for ATM/LM. Lacking any evidence to the contrary, this appears reasonable.

Event Recorders. 414 event recorder channels are available, with the provision for selection of 60 additional channels on a time-sharing basis. GE's assumption of 390 channels for ATM/LM is the best available estimate.

Analog Recorders. 128 channels are available in the basic system, with the capacity of selecting 168 additional measurements on a time-sharing basis. Sixteen analog recording channels and a 36-channel oscillograph are located in the computer room and could be utilized, if required.

This total capability seems adequate to satisfy the anticipated need for approximately 220 channels of data for ATM/LM.

4.6.3 Software Applicability

The five basic classes of computer programs required for use with the ACE-S/C system are as follows:

- Support programs (compilers, assemblers, etc.)
- Utility programs
- Operating systems
- Self-test/maintenance routines
- Test procedures

The successful application of automation techniques to test and checkout requires that all five of these software packages be combined into a homogeneous entity. Fortunately, the first four groups have been developed for other NASA programs and, except for ATM peculiar revisions, they will suffice to translate the requirements of the test procedures into functional sequences.

A disturbing aspect in the development of the required test procedures is that their effectiveness is just as vital to system performance as the hardware system. For maximum confidence in the results of the test operation, the computer programming must evolve through four distinct phases:

- Analysis of the test problem
- Design of the test sequences
- Coding into a form acceptable to machine manipulation
- Checkout of the resultant automated procedure

Analysis requires detailed specification writing of all test parameters and functions. Design entails translation of the specifications into step-by-step statements of the problem. Coding consists of writing and machine compiling these test instructions and data in a source language (ATOLL, SLAP, etc.) that will precisely control and command the computer to perform all operations. Finally, checkout of the coded subsequences implies a "debugging" process. Documentation of the respective phases consists of detailed test specifications, program flow charts, source program printout and punched cards, and finally the magnetic tape and card-deck machine-language program.

This process has been defined to emphasize the magnitude of the tasks involved in producing an operational checkout program. A realization that the process is essentially sequential adds credance to a predicted lead time of 14 months to produce entirely new test proceduces for ATM. During this period, considerable "machine time" is required by the programmer from approximately mid-way through the coding process until final validation and acceptance of the test procedure. Four to six months of the lead time will encompass heavy scheduling on the system hardware.

GE estimates that 25 ACE/LM programs will require modification for ACE/ATM checkout. They also estimate that these program modifications, including development and debugging, will require 6 to 10 months. LMSC programming experience indicates that this is a low estimate for the time required to develop ATM programs.

4.6.4 Data System

The MSFC ATM Project Development Plan dated April 13, 1967 lists the Model 301 PCM/DDAS Assembly (PCM-301) as a Saturn Program building block to be utilized for ATM. A functional description of this telemetry system is quoted from the ATM Development Plan. "The telemetry subsystem utilizes a pulse code modulation (PCM) technique which provides a variety of sampling rates. All measurements are routed directly or via multiplexer to the Model 301 PCM/DDAS assembly where a 72 k bit per second serial wave train is generated to frequency modulate a 10-w VHF transmitter... Both the Model 301 assembly and the Auxiliary Storage and Playback (ASAP) unit provide a 600-kHz FM carrier, modulated by the 72 k bit per second wavetrains, as the DDAS output for use during testing, checkout, and prelaunch activities."

As the Digital Acquisition and Decommutation Equipment (DADE) of the ACE-S/C System operates at 51.2 k bits per second, an incompatibility exists with the 72 k bit per second rate of the PCM-301. Either the ACE-S/C must be modified to match the ATM, or the ATM must be changed to match the capability of the ground equipment. Subsection 4.6 discusses these two possible approaches.

Whether ACE-S/C is modified to be compatible with the Saturn telemetry system or the ATM is modified to be compatible with ACE-S/C, the following new and modified ACE-S/C hardware is required. (See also Table 5-3.)

<u>New Equipment Required for ACE-S/C</u>

- Digital Test Command System (2 required – MSFC only)
- Digital Test Measurement System (1 required – MSFC only)
- Modified Receiver-Decoder (2 required)
- Signal Conditioners (2 sets required)
- 600 kHz FM demodulator (5 required)
- PCM Receiving Station (2 required)
- Airborne Command Simulator (2 required)
- Microdot Signal Generator (2 required)
- External ATM Power Supplies (2 sets required)
- Hardwire panels and cables as required for safing circuits (2 sets required)
- IU Comparator (Optional. Will be available at Complex 37)

<u>ACE-S/C Equipment Requiring Modifications for ACE/ATM at MSFC, MSC and KSC</u>

- PCM Decommutators
- Multiplexer
- Data Distribution Unit
- Event Storage and Distribution Unit

The application of the new hardware is as outlined below.

Digital Test Command System (DTCS). Two identical DTCS consoles will be required at MSFC because simultaneous testing of two ATM's is required. The DTCS converts hardline digital commands into analog commands and must therefore be located very close to the ATM, otherwise deterioration of the analog commands occurs. Moving one DTCS between test areas is feasible if simultaneous testing is not required, however it is not practical from a system integrity standpoint and when considering the system down time required.

Digital Test Measurement System (DTMS). The basic function of this unit is to multiplex four 51.2 K bps PCM bit streams into one 204.8 K bps PCM bit stream. The unit also contains signal conditioners, power supplies, and other related equipment to monitor discrete events and analog signals. If DADE is modified to be compatible with 72 K bps PCM, the DTMS is not required at MSFC because the 600 kHz subcarriers can be routed directly to the ACE location without being multiplexed. This assumes that LM is not present at MSFC and the LM simulator does not require a remote (remote from ACE) multiplexer. This philosophy should also be applicable to MSOB testing of the ATM; however, the LM would still interface with the DTMS.

Receiver - Decoder. This unit receives computer commands from the ACE up-link computer and decodes the digital words for subsequent signal conditioning before being converted to ATM FM commands.

Signal Conditioner. The decoded up-link ACE commands must be signal conditioned before interfacing with the airborne command simulator; this unit performs that function.

Airborne Command Simulator. This unit simulates the commands sent from the ground during ATM orbit.

Microdot Signal Generator. This unit generates the RF carrier which carries (to the ATM) the commands generated by the Airborne Command Simulator.

600 kHz FM Demodulator. The two 600 kHz FM demodulators strip the 72 K bps PCM bit stream from two 600 kHz subcarriers originating in the ATM DDAS and the ASAP.

PCM Receiving Station. Information indicates that the primary function of the PCM Receiving Station is to receive and decommutate the PCM originating from the ATM ASAP. It also serves as a supplement to ACE DADE for the PCM originating in the ATM DDAS. It appears possible that the ACE-S/C could be utilized to fully support ATM PCM processing and delete the requirement for a separate ATM PCM decommutator station (PCM Receiving Station).

External ATM Power Supplies. These power supplies provide the ground power for ATM and partial LM operation during prelaunch tests.

Safing Panels. These panels provide the ground circuits that interface with ATM safing circuits.

IU Comparator. Compares commands generated by the Airborne Command Simulator. This unit is optional.

4.7 ACE COMPATIBILITY WITH ATM REQUIREMENTS

4.7.1 Modification of ACE to Match ATM

Several choices in merging the Apollo 51.2 kilobits/sec PCM with the Saturn 72 kilobits/sec PCM are possible and present varying degrees of hardware vs. software complexity for consideration. Figure 4-1 illustrates one technique which requires what appears to be a minimum of hardware change. Telemetry receiving equipment for the 72 kilobits/sec PCM link is added to the existing ACE-S/C Digital Acquisition and Decommutation

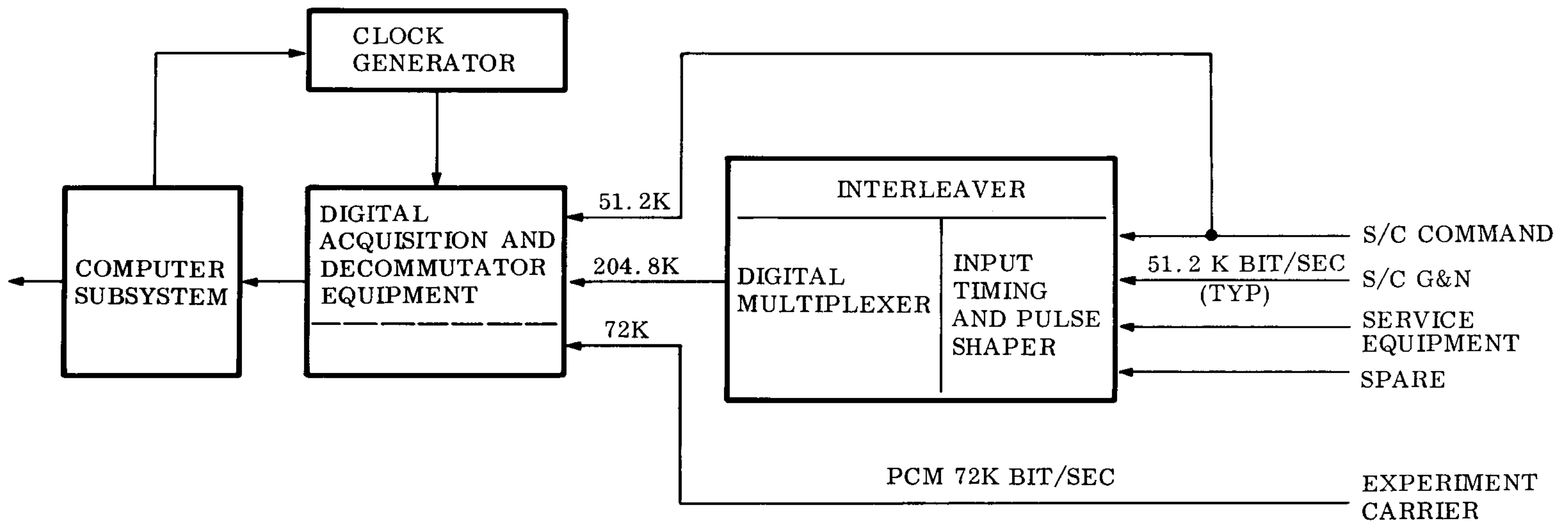

Fig. 4-1 Technique for Merging Apollo and Saturn PCM Rates – Minimum Hardware Change

Equipment (DADE) and a separate data channel is added to the computer input system. Software changes are then incorporated to accept data on the new channel and to time share the processing functions between the two inputs.

A more complex hardware interface will permit alternate software solutions. Figure 4-2 defines hardware additions which will convert the 72 kilobits/sec PCM in the Bit Rate Multiplier into a 102.4 kilobits/sec pulse train. This pulse train is then divided by the Alternator into two 51.2 kilobits/sec serial pulse trains suitable for injection into the Interleaver. Expansion of the Interleaver capacity to accommodate the two additional inputs will require a half-rack of equipment which also includes additional timing circuitry.

The additional data will be interwoven into the ACE-S/C Data Acquisition subsystem by the clock signal. A 50-percent higher clock rate would permit the retention of a Master frame duration of one second. Each Major frame within the Master frame will still contain approximately 400 8-bit words, but the number of Major frames will increase by 50 percent. Modified DADE hardware will interface with the computer subsystem whose software will require extensive revision to accommodate the higher input data rate of 307.2 kilobits/sec from the Interleaver.

An alternate approach accepts the existing input data rate but because the quantity of data has been increased by 102.4 kilobits/sec, the Master frame time will require 1.5 sec instead of 1.0 sec. Each Major frame within the Master frame will still contain 400 8-bit words, but there will be 50 percent more Major frames. The computer software modification would accomplish the task of separating and processing the individual input links.

In summary, the technical feasibility of merging the two different PCM rates for processing by ACE-S/C hardware is evident.

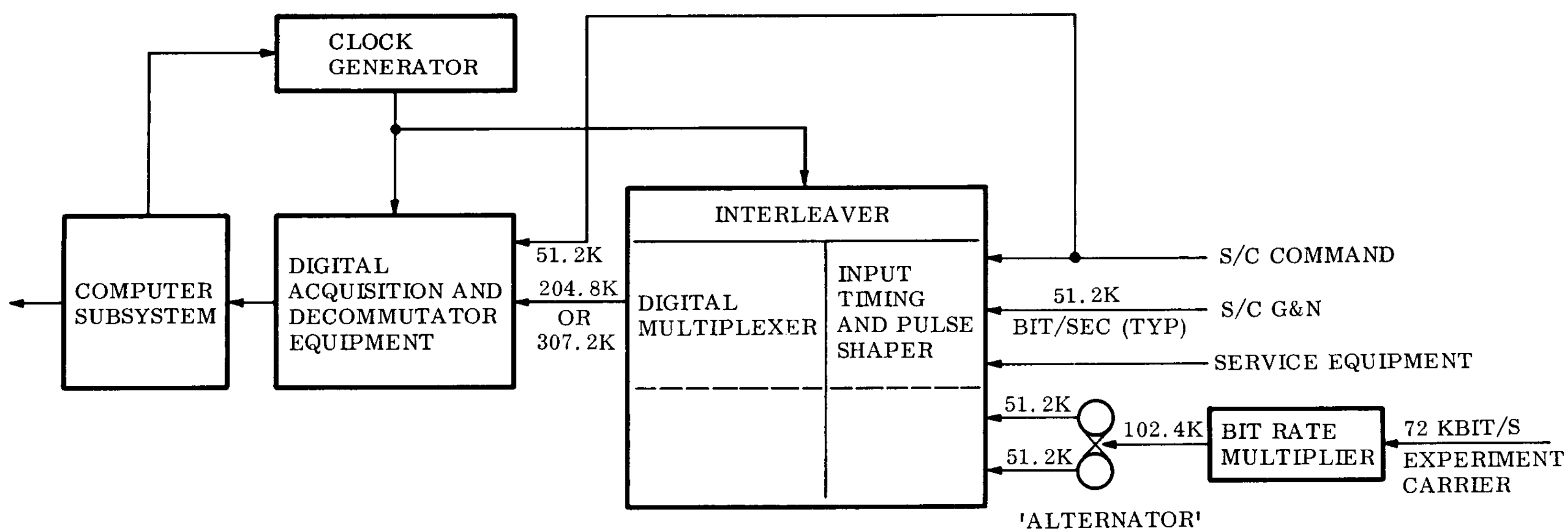

Fig. 4-2 Technique for Merging Apollo and Saturn PCM Rates
– Complex Hardware Interface

4.7.2 Modification of ATM to Match ACE

Another approach to utilizing ACE-S/C system for ATM checkout would be to modify the ATM telemetry system to be compatible with existing ACE-S/C design. Substitution of the ATM Saturn telemetry system with an Apollo System is one method.

The principal differences between the Saturn and Apollo PCM telemeter formats are:

Apollo	Saturn
51.2 kilobits/sec	72 kilobits/sec
8 bits/word	10 bits/word
1 subframe/sec	4 subframes/sec
one component	modular (i.e., several components comprise one telemeter system)

The differences between the two telemeters present difficulties when one set of equipment is to be substituted for another. For instance, many of the ATM experiments output their data in a 10-bit per word digital format. If Apollo equipment is substituted, the experimenters will be required to modify their counters to provide an 8-bit output format. Also the experiments are located on a moving platform and a flexible cable carries the electrical signals between the platform and the ATM. Because the spring constant of the flexible cable imposes a problem on the motors which position the movable platform, it is essential that the number of interface lines be kept to a minimum. Since the vehicle subsystem data originates on the nonmovable portion of the vehicle, no economy of interface in the Saturn system lines can be brought about by placing the entire telemeter on the movable platform.

Remote multiplexers are placed on the movable platform to reduce the number of interface lines. With the Apollo system, the number of interface lines in the flexible cable will be increased whether the Apollo telemeter is placed on the movable platform or not.

Procurement lead time for the Apollo telemetry system is approximately 13-17 months, at a cost of approximately $225,000. The units for the first ATM flight have been ordered and orders have been placed for the long lead time items in the Saturn telemetry units.

Another approach to making the ATM telemeter compatible with ACE is to modify the Saturn telemetry units. This could be done by changing the word structure from 10 bits/word to 8 bits/word, and by changing the output bit rate from 72 kilobits/sec to 51.2 kilobits/sec.

The most affected units in the Saturn telemetry system would be the Type 301 programmer-encoder. Chagning the word structure would require only moderate redesign, whereas the reduced bit rate would require a major modification because transformer coupled gates are used. The gates are optimized for a certain rate and performance degradation can be expected at bit rates differing from 72 kilobits/sec. Therefore, not only would the programmer and clock require modification but the multiplexer gates would require redesign for operation at the new bit rate.

Either replacing the ATM telemeter unit with an Apollo type unit or modifying the present telemeter unit presents significant problems.

4.7.3 Schedule to Implement

Modified ACE-S/C. The present ATM Project Master Schedule (ATM-1, June 1, 1967) establishes a Ready for Use date of August 1968 for the ACE-S/C in MSFC. An analysis of the steps to be undertaken to RFU indicates a time span of approximately 14 months elapsed time after a decision to implement. The two critical paths of almost identical length are the facility readiness activity and the software development program (Fig. 4-3). The latter is considered more critical, particularly when it is realized how much the detail program test requirements will constrain its preparation. Changes to these requirements were not a factor in the establishment of the 14-month lead time and would probably offset any appreciable schedule compression which might otherwise be realized.

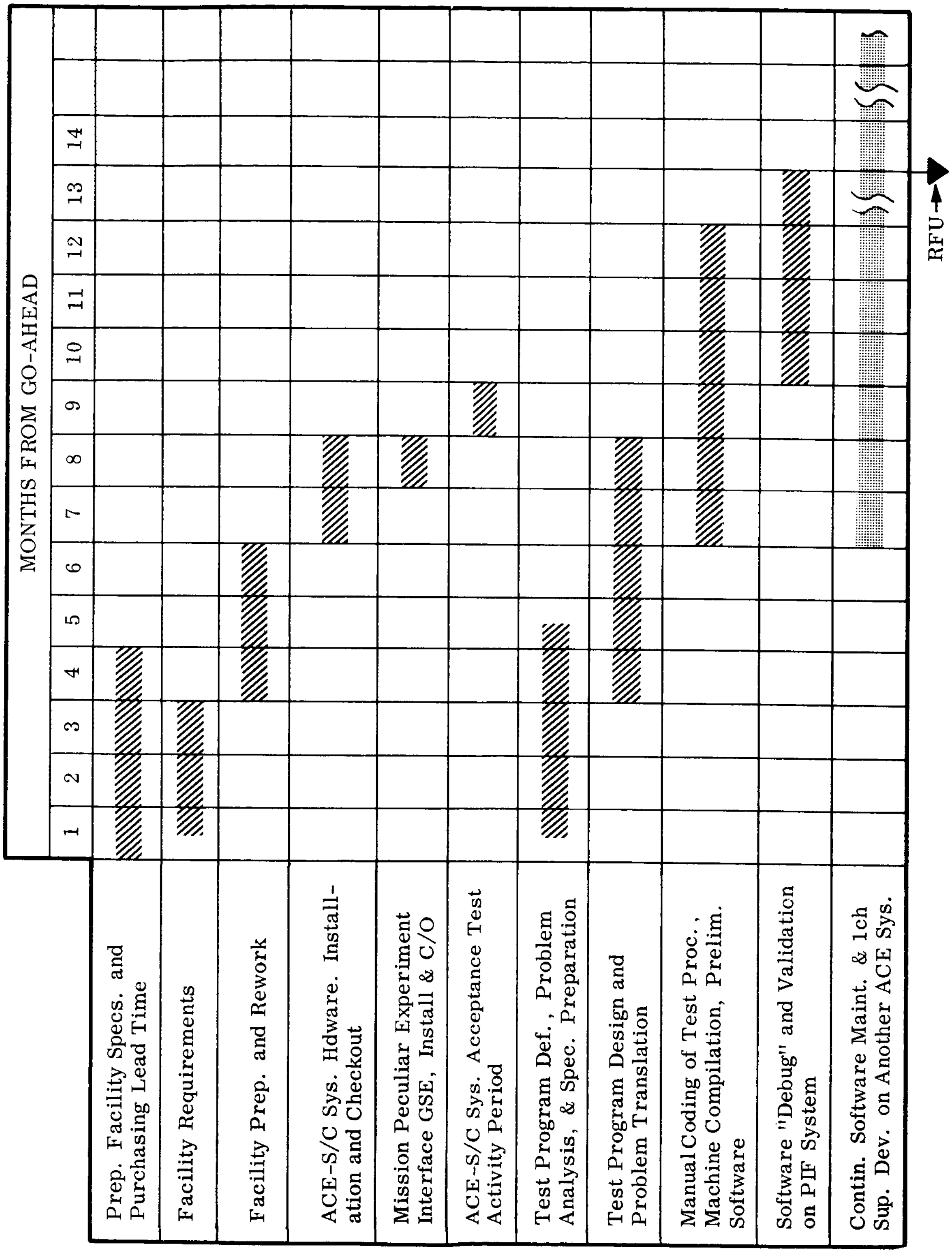

Fig. 4-3 ACE-S/C Implementation Schedule

Modified Flight Item. All comments in the preceding paragraph apply equally to this approach. In addition, the schedule for flight hardware modification could prove to require even more lead time.

Section 5
COMPARATIVE DATA

When characteristics of two systems are being compared, the relative weights assigned to significant parameters can vary with the intended usage of the systems. Therefore, this section is divided into two subsections:

- Ground system to support ATM only
- Ground system to support all AAP missions subsequent to ATM

5.1 SUPPORT OF ATM ONLY

A recent trade study conducted by LMSC explored the relative merits of 15 combinations of candidate GSE systems for support of AAP. One of these was the all-manual system, which was rated seventh in order of preference. Another was the all-ACE system, which was rated fourth. When the single ATM mission is the basis for comparison, however, the relative merits of the two systems tend to be reversed. Parameters such as Flexibility, Technical Risk, and Software Development Cost cease to favor the ACE approach on a one-shot basis, and Test Repeatability, Maintainability, and Adaptability to On-Board Checkout can be relaxed as specific requirements. Table 5-1 reflects this revised analysis.

5.2 SUPPORT OF AAP MISSIONS SUBSEQUENT TO ATM

The findings of the Trade Study referenced above, and a subsequent expansion of that study, established the superiority of ACE over any system employing manual checkout. Continuing analysis has not significantly changed that conclusion, as can be seen from Table 5-2.

Table 5-1

COMPARISON MATRIX – ATM MISSION ONLY

Item	Manual	ACE	
		ACE Mod	Veh Mod
Initial Hardware Cost	Least	More	Most
Software Dev. Cost	Minor*	Significant	Significant
Schedule Compatibility	OK	Marginal	Unlikely
Thermal Vacuum Support Practicality			
MSC, Houston	OK	OK	OK
Seattle or Tullahoma	OK	NO	NO
Technical Risk	Minimal	Minor	Medium
Reliability			
Data	Adequate	Good	Good
Equipment	Best	Good	Good
Flexibility (changes to ATM)	Good	Fair	Fair
Schedule Risk	None	Appreciable	Appreciable
Facility Requirements (MSFC)	2 systems	1 system	1 system
Space (sq ft)	1400-2000	5000	5000
Air Cond. (tons)	7	41	41
Power (kw)	30	190	190
Cost	Minimal	Significant	Significant

*Considers preparation of test procedures

Table 5-2

COMPARISON MATRIX – AAP MISSIONS SUBSEQUENT TO ATM

Item	Manual	ACE	
		ACE Mod	Veh Mod
Hardware Cost	Continuous	Decreasing	Decreasing
Software Cost	TP/Flight	Initial & TP	Initial & TP
Schedule Compatibility	OK	Practical	Possible
Thermal Vacuum Support Practicality			
MSC, Houston	OK	OK	OK
Seattle or Tullahoma	OK	NO	NO
Reliability			
Data	Fair	Good	Good
Equipment	Best	Good	Good
Flexibility	Poor	Good	Good
Schedule Risk	None	Appreciable	Appreciable
Facility Requirements (MSFC)	2 systems	1 system	1 system
Space (sq ft)	1400-2000	5000	5000
Air Conditioning (tons)	7	41	41
Power (kw)	30	190	190
Cost	Minimal	Significant	Significant

Should the final decision be that the manual approach be pursued for ATM with development of ACE for subsequent MSFC operations, complete redundancy is not necessarily the result. Certain peripheral equipments are common to both systems (Table 5-3) and a potential use of the obsolete manual station might be thermal vacuum test support at Seattle or Tullahoma, thus obviating complete reliance on MSC chambers.

Table 5-3

HARDWARE REQUIREMENTS – CANDIDATE SYSTEMS

	Manual	ACE Mod to Accept 72 k bits/sec	ACE Mod to Convert 72 k bits/sec to 51.2 k bits/sec	ATM Mod to Convert 72 k bits/sec to 51.2 k bits/sec	ATM Mod to Replace TLM With Apollo TLM
New Equip.	(2) PCM Stations (2) Airborne Command Simulator (2) Microdot Sig. Gen. (2 sets) ATM Extn. Pwr Supplies (2 sets) Safing Pnls (1) IU Comparator (Optional) (4) 600 kHz FM Demod.	Common Equipment (4) 600 kHz FM Demod (2) DTCS - MSFC (2) Receiver/Decoder (2) Signal Conditioner	(1) DTMS - MSFC (2) DTCS - MFSC (2) Receiver/Decoder (2) Signal Conditioner (2) Bit Rate Multiplier (2) Alternator	(1) DTMS - MSFC (2) DTCS - MSFC (2) Receiver/Decoder (2) Signal Conditioner	(1) DTMS - MSFC (2) DTCS - MSFC (2) Receiver/Decoder (2) Signal Conditioner ATM - Apollo TLM System
Modified Equip.	(2) Sets of 500FS Equipment	(2) PCM Decommutator (2) Multiplexer (2) Data Distribution Unit (2) Event Storage and Distribution Unit	(1) DTMS - KSC	(1) DTMS - KSC ATM Type-301 Programmer-Encoder ATM Clock ATM Multiplexer Gates	(1) DTMS - KSC ATM Experiments to Output 8-Bit Words

Section 6
REFERENCES

1. "ATM Checkout Concepts and ESE Requirements" dated 9 August 1966 by R-ASTR-ESA

2. "ATM ESE Design Concepts, Checkout and Schedule" dated (no date) by R-ASTR-ESA

3. Study of the ATM/LM Checkout Using ACE-S/C Dated (no date) by GE

4. "MSFC/Acceptance Checkout Equipment - S/C For ATM and Future Missions" dated 13 June 1967, by GE Apollo Support Department ASD Ref. 2-291-6

5. MSFC Apollo Applications Program Manager to NASA Headquarters letter dated 23 May 1967, Subject; "Utilization of ACE versus a Hybrid Manual/ACE System for Checkout of LM/ATM at Kennedy Space Center"

6. "S/AA GSE Checkout Systems Trade Study" dated 30 December 1966 by LMSC Doc. No. 4,900,218

7. "Apollo Telescope Mount Electrical Support Equipment System Specification " dated 5 June, 1967 MSFC 40M51002

8. "ACE-S/C System" dated 31 December 1965 by Control Data Corporation, Document No. 14292400C

9. "Analysis fo the ACE-S/C System for S/AA" dated 6 December 1966 by LMSC, Doc. No. 4,900,215A

10. "LM Configured ACE-S/C Display and Command Capabilities in Control Room With LM and ATM Requirements Estimated," dated 23 June 1967, by GE

11. "Technical Review of Acceptance Checkout Equipment – Apollo Telescope Mount Proposal," dated 12 June 1967, by Sperry Rand Corporation.