N65-18128

[redacted]

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE AND NAVIGATION

Approved Milton B. Trageser Date 2/12/62
MILTON B. TRAGESER, DIRECTOR
APOLLO GUIDANCE AND NAVIGATION PROGRAM

Approved Roger B. Woodbury Date 1/3/63
ROGER B. WOODBURY, ASSOCIATE DIRECTOR
INSTRUMENTATION LABORATORY

CLASSIFICATION CHANGE

To UNCLASSIFIED
By authority of GDS - EO 11652
Changed by L. Shirley Date 12/31/72
Classified Document Master Control Station, NASA
Scientific and Technical Information Facility

(Unclassified Title) [redacted]
Report E-1236
Monthly Technical Progress Report
Project Apollo Guidance
and Navigation Program
Period June 11, 1962
through
July 17, 1962

GROUP 4
Downgraded at 3 year intervals; declassified after 12 years

INSTRUMENTATION LABORATORY

CAMBRIDGE 39, MASSACHUSETTS

COPY # 160 OF 325 COPIES
THIS DOCUMENT CONTAINS 83 PAGES

[redacted]

ACKNOWLEDGEMENT

This report was prepared under the auspices of DSR Project 55-191, sponsored by the Space Task Group of the National Aeronautics and Space Administration through Contract NAS9-153.

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U. S. C., Sections 793 and 794, the transmission or the revelation of which in any manner to an unauthorized person is prohibited by law.

PREFACE

This Monthly Technical Progress Report consists of various sections. The section on Management Procedures illustrates the means of supervising the activities of the Participating Contractors. There are several sections containing the progress summaries of the various subsystems of the G & N equipment. There is one technical presentation.

The report concludes with a Bibliography of all Apollo documents published by the Instrumentation Laboratory. The supply of these reports, particularly some of the E-notes, has been exhausted and no copies are available for further distribution.

TABLE OF CONTENTS

SECTION 1
MANAGEMENT PROCEDURES

Col. P. K. Bryant

Many technical directives have been issued as shown in Fig. 1-1 which illustrates the status as of July 16, 1962. Considerable work has been ordered from the participating contractors and more is to come. The total number of resident engineers requested to date is in the order of 60, of which better than half are on-board.

The general story on the Change Control Board (CCB) and Design Review Board (DRB) will be briefly described. Figure 1-2 is the form that releases technical data. It does not constitute authority to do work--only a technical directive does that--but this is the form which transmits the technical data (usually drawings and specifications). There is a signature line for approval by the Design Review Board, Change Control Board, and NASA. In order to release drawings early for hardware, experimental and breadboard, part of the procedure is by-passed and yet control is retained.

Two types of technical document release have been adopted, Type A and Type B. The Type B was adopted because of a critical time situation; it will be discussed first and the differences between it and the Type A will be discussed subsequently. A Class B release is the release of a technical document, whether it is a drawing or a specification, which can be utilized for experimental hardware but cannot be used for flight hardware until the restriction of Class B release has been removed. The procedure works as shown in Fig. 1-3. The orginator submits the document directly to the Change Control Board (CCB). Once approved and signed by the CCB it goes directly to be microfilmed. Copies are made on two reels of film. The original document goes back to the originator's files since it will be subject to many changes. The TDR transmits the information directly into the SIDL (System Indentification List) scheme. One reel of film goes to the master archives to insure that it will not be lost. The second reel is mounted on aperture cards and reproduced. At the moment the intention is to take enough shots so that reproduction will not be necessary. The most important point is that any change to a Class B drawing does not really affect anything; it can be done directly by the originator with agreement of participating contractor's engineer if so desired. If, however, it is a significant change, it should go through the regular CCB operation, but the drawing itself can be changed by simple negotiation between the responsible engineer at MIT and the participating contractor.

This is not the case with a Class A release. The Class A release is for flight hardware. The entire procedure of Fig. 1-4 has to be followed. The original goes directly into a central file for microfilming; one reel of film goes to the archives,

AC SPARK PLUG		KOLLSMAN		RAYTHEON	
TD. NO.	TITLE	TD. NO.	TITLE	TD. NO.	TITLE
A- 1	APOLLO PROJECT OFFICE	K- 1	APOLLO PROJECT OFFICE	R- 1	APOLLO PROJECT OFFICE
- 2	DEVELOPMENT PLAN	- 2	DEVELOPMENT PLAN	- 2	DEVELOPMENT PLAN
- 3	RELIABILITY IMPLEMENTATION PLAN	- 3	RELIABILITY IMPLEMENTATION PLAN	- 3	RELIABILITY IMPLEMENTATION PLAN
- 4	QUALITY ASSURANCE PROGRAM	- 4	QUALITY ASSURANCE PROGRAM	- 4	QUALITY ASSURANCE PROGRAM
- 5	WELDING SPECIFICATIONS	- 5	ENGINEER RESIDENT AT MIT	- 5	WELDING SPECIFICATIONS
- 6	DOCUMENTATION CONTROL PROCEDURE	- 6	DOCUMENTATION CONTROL PROCEDURE	- 6	DOCUMENTATION CONTROL PROCEDURE
- 7	IMU ELECTRONICS FACILITY	- 7	PERT TEAM	- 7	RESIDENT ENGINEERS AT MIT
- 8	IMU ELEC. RESIDENT ENGINEERS	- 8	DESIGN PERSONNEL RES. AT MIT	- 8	CORE ROPE TESTER
- 9	RESIDENT ENGINEERS AT MIT	- 9	DESIGN PERSONNEL RES. AT MIT	- 9	PERT TEAM
- 10	ENGINEER RESIDENT AT MIT	- 10	OPTICAL SUBSYSTEMS FACTORY TEST	- 10	INSULATION EVALUATION - MAGNET WIRE
- 11	ENGINEER RESIDENT AT MIT			- 11	DOCUMENTATION - FACTORY TEST PLANS
- 12	PERT TEAM			- 12	AGC PROGRAM DESIGN
- 13	PIPA DEVELOPMENT GROUP				
- 14	IMU GUIDANCE LABORATORY				
- 15	PIPA DEVELOPMENT GROUP				
- 16	IMU GUIDANCE LABORATORY				
- 17	RELIABILITY				
- 18	RESIDENT TEST EQUIP. ENGINEER				
- 19	PERSONNEL FOR NAV BASE DESIGN				
- 20	PROCURE. LONG LEAD TIME ITEMS				
- 21	EVALUATION-WELDING EQUIPMENT				
- 22	DRAFTING RESIDENCE				
- 23	AGE WORKING MODELS				
- 24	RES. ENG. FOR ERROR ANALYSIS				
- 25	ENG. SUPPORT AT MIT				
- 26	GYRO TEST CONSOLES FOR ACCEPT.				
- 27	FABRICATION FAMILIARIZATION				
- 28	RESIDENT ENGINEERS				
- 29	ENGINEER RESIDENT AT MIT				
- 30	DRAFTING SUPPORT AT MIT				*JULY 16, 1962
- 31	IMU GIMBAL SIMULATOR				

Fig. 1-1 Technical directives issued to date

APOLLO GUIDANCE AND NAVIGATION

TECHNICAL DATA RELEASE OR REVISION

NO.

1. TITLE OF DWG/DOC

DWG. AFFECTED	REV.
	TO

2. DESCRIPTION OF CHANGE:

3. REASON FOR CHANGE:

4. OTHER APPLICABLE DOCUMENTS:

5. NEXT HIGHER ASSEMBLY AFFECTED	7. INTERFACE AFFECTED
6. ACTIVITIES AFFECTED:	8. UNIT OR AGE EFFECTIVITY

9. ______________________________
PREPARED BY DATE

10. ______________________________
ENGINEERING APPROVAL (IL/MIT) DATE

11. ______________________________
DESIGN REVIEW APPROVAL DATE

12. CONTRACTOR ______________________________

13. ______________________________ DATE
CHANGE CONTROL BOARD APPROVAL

14. ______________________________
NASA/MSC APPROVAL DATE

NO.	
DWG. AFFFCTED	REV.
	TO

Fig 1-2 Sample technical data release or revision form

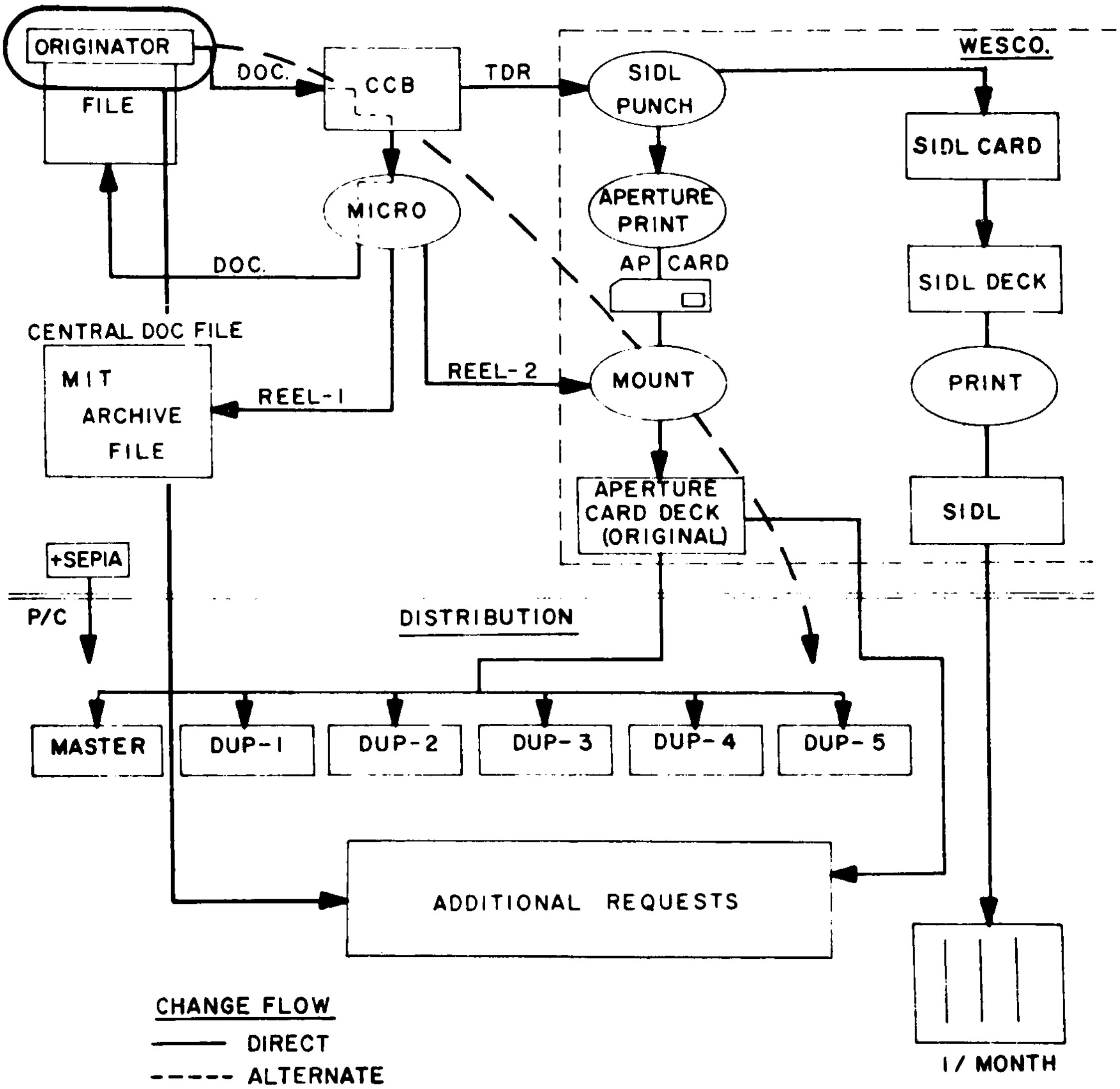


Fig. 1-3 Class B release flow diagram

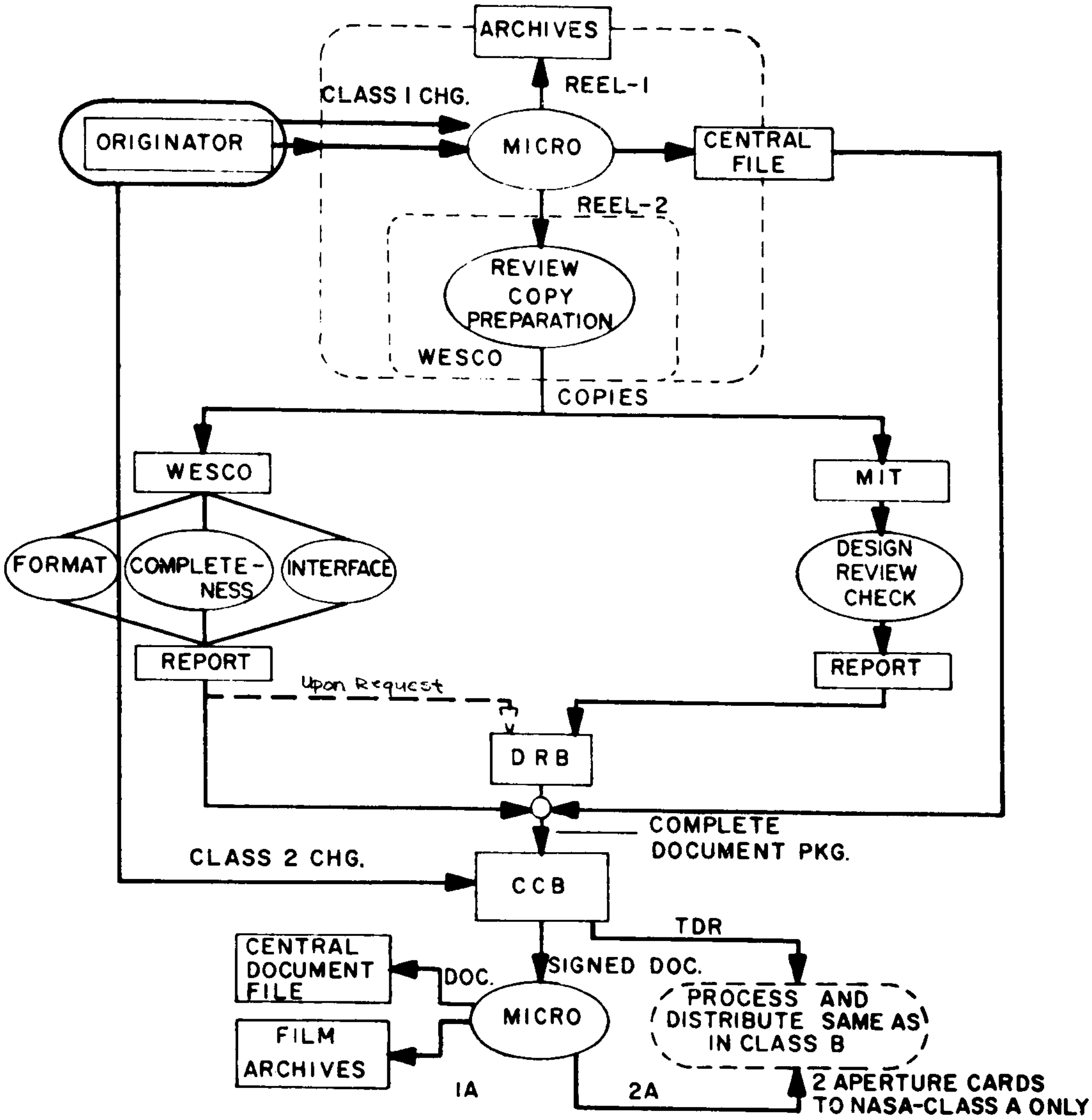


Fig. 1-4 Class A release flow diagram

the document itself to central files, the review copies go out to be checked for format, completeness, and for all interfaces affected. Then a report is prepared by WESCO, and MIT itself makes a design review check. These two reports are submitted simultaneously to the Design Review Board (DRB). The complete package may not be available at the meeting of the DRB; however, it is not absolutely essential, but it is desirable. At any rate, both packages come together into a complete document package before going to the CCB. Once there it is again microfilmed, with a copy to the central document files, a copy to film archives and distribution the same as a Class B release. If a Class A change comes up, there are two possibilites. If it is a Class 1 change - a major change - it must go back through the whole cycle and through the DRB. If it is a minor change (Class 2 change) and does not affect the basic function of the instrument, it can go directly to the CCB.

The first real PERT run, as far as the NASA type run is concerned, showed some 36 weeks negative slack. Like most first PERT runs it is relatively invalid.

The first PERT run has been redone and now shows less than 25 weeks of negative slack. With a few more adjustments and paralleling of some items it is believed that this can be reduced to approximately 4-6 weeks total negative slack. In some of the later sections of this report the basic bar chart schedules will show slippages of the order of 2 to 6 weeks negative slack.

[redacted]

SECTION 2
SPACE GUIDANCE
Dr. J. S. Miller

The MAC system compiler for the H800 computer, as shown in Fig. 2-la, is virtually complete at this time. Close behind it is the YUL assembler, which assembles programs for the AGC. One version of the AGC single-order simulator for the H800 is similarly progressing well, with the exception of some areas in which uncertainties produced by lack of completion in the blocks below cause it to trail off into the future a bit. The last two blocks are considered in parallel; they represent the simulation program for the complete guidance system, in which will be simulated each instruction of the guidance computer program and each of the inputs to the guidance computer from the hardware. This is really just getting underway with the determination of the requirements for the system itself, and very little work has been done in terms of actual program preparation.

In the other areas of Fig. 2-la the items are coming along nicely. Booster monitoring, re-entry guidance, and telemetry are progressing on schedule. Nothing has been done recently on the extra-atmospheric abort for two reasons; first, the problem itself is not urgent, and there are some more pressing things to be worked on. Second, there has been somewhat of a misunderstanding as to what the abort requirements are for the first two unmanned flights. Hopefully, this will be cleared up shortly.

Figure 2-lb shows that orbital navigation is progressing satisfactorily; but orbital abort is in the same catagory as the extra-atmospheric abort: not very urgent and not very well defined at the moment. Rendezvous, lunar landing and AGC communications are progressing as expected.

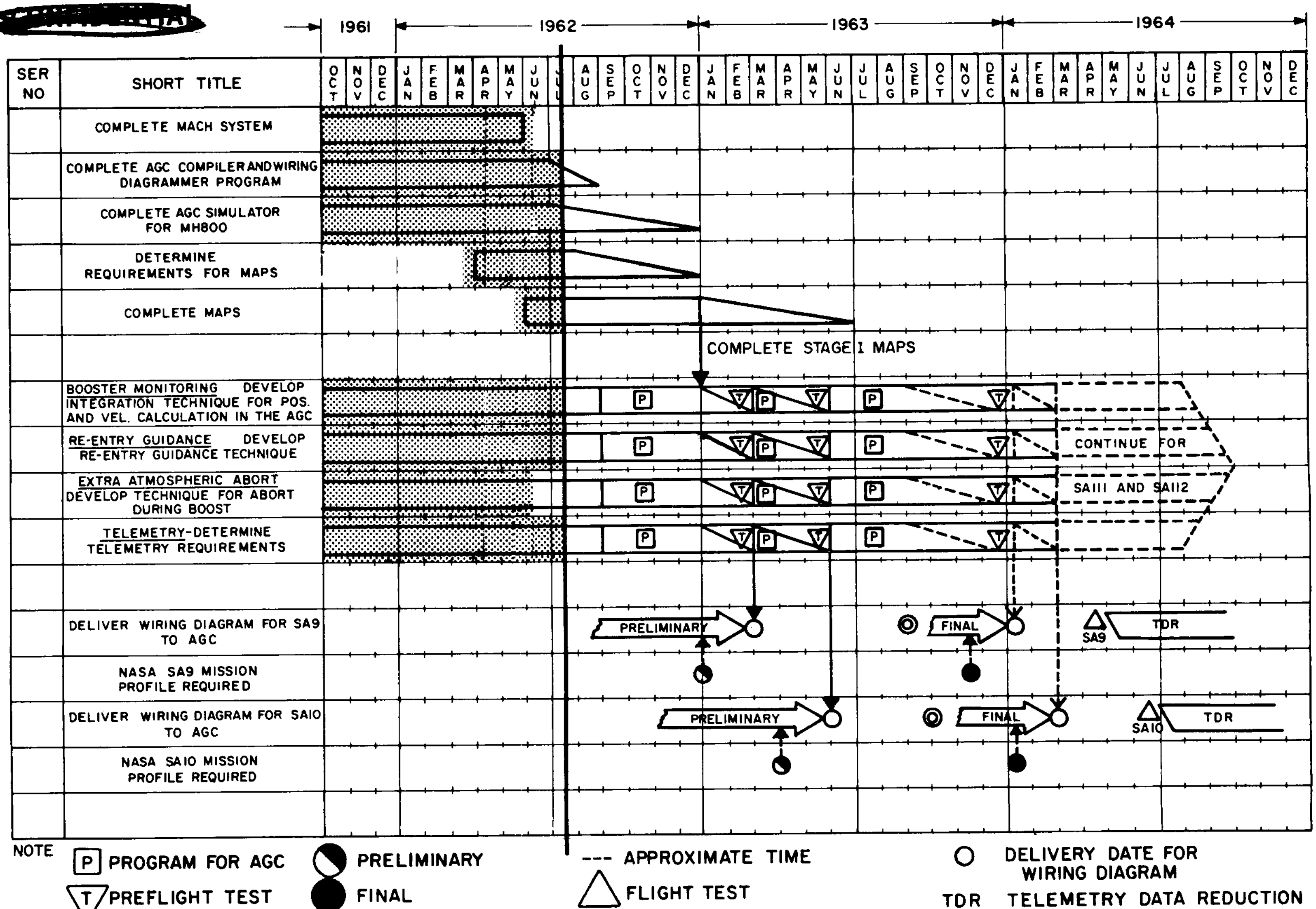
In response to a request by Mr. Gilbert of NASA, the Space Guidance Analysis Division has prepared a list of jobs which now are underway. The list is fairly extensive so only a summary of the major areas is presented in Fig. 2-2. A brief mention will be made of some specific things that are going on under each of these titles. Under AGC Utility Programs and Studies are such things as the interpreter (the program that goes into the AGC to effectively expand its order code), and subroutines for the elementary functions, such as sines, cosines, exponentials, logs, etc.

Distinct from these are the AGC Mission Programs and Studies which are more tailored to the mission itself; for example, the type of trajectory calculation

[redacted]

[redacted]

APOLLO MILESTONE CHART FOR GUIDANCE THEORY & PROGRAMMING (EARTH ORBITAL MISSIONS) (1)



[redacted]

Fig. 2-1a

[redacted]

APOLLO MILESTONE CHART FOR GUIDANCE THEORY AND PROGRAMMING (EARTH ORBITAL MISSIONS), Continued

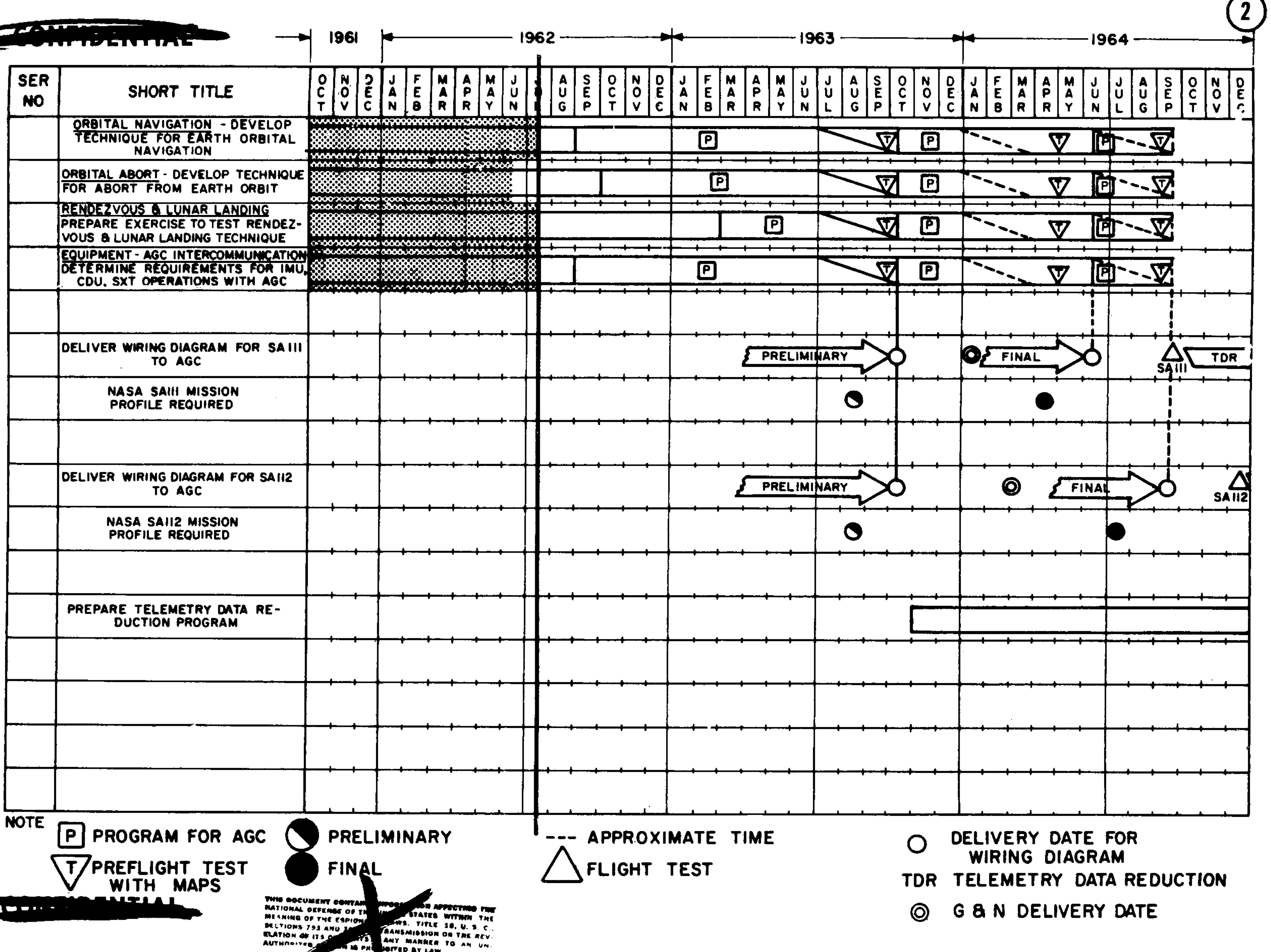


Fig. 2-1b

SPACE GUIDANCE ANALYSIS DIVISION STUDIES UNDERWAY

- AGC UTILITY PROGRAMS AND STUDIES
- AGC MISSION PROGRAMS AND STUDIES
- AGC SIMULATION ON H 800
- TRAJECTORY CALCULATION
- THRUST-GUIDANCE STUDIES
- ATMOSPHERIC ENTRY GUIDANCE STUDIES
- MIDCOURSE NAVIGATION ERROR STUDIES
- LUNAR LANDING AND RENDEZVOUS
- ABORT CONSIDERATIONS

Fig. 2-2 Space guidance analysis division studies underway that is to be used when the spacecraft is in the vicinity of two gravitating bodies.

These studies must be finished in time to allow thorough simulation, and then sent out to the rope wiring people so that the rope can be delivered in time for the SA-9 flight.

For the so-called MAPS simulation, or the system simulation on the H800, two major items are required; one of which is the simulator for the computer itself and the other is the simulation of the environment. The simulator is written in more or less machine language while the environment is written in symbolic compiler language. One version of the simulator is pretty well along, while the environment is just being started.

The fourth item refers to the calculation of the precise reference trajectories for each mission, as opposed to the calculation of the vehicle actual trajectory in the guidance computer. Included in this area are an improved version of the circumlunar trajectory program that was reported on several months ago, as well as trajectories for achieving specific lunar orbits with the minimum amount of fuel.

The fifth item refers to the guidance studies which deal with the vehicle when the thrust is turned on. This includes such things as compatibility between the Saturn booster and the Apollo vehicle, injection guidance, and, generally speaking, explicit techniques to do any of the boost or powered flight guidance.

The sixth item includes things like trajectory optimization, minimization of the effects of uncertainties in measurements, error studies, and design of control logic.

The seventh item covers the effects of various things on midcourse navigation (position and velocity) errors. Effects of ground data either as back-up or supplementary information, use of star occultations, nonoptimum measurements, and the effect of velocity correction errors on uncertainties in position and velocity are among effects being considered.

For lunar landing and rendezvous there are studies under way of such things as lunar orbit operations, lunar landing rendezvous, and lunar ascent, and finally, under abort considerations, items such as sensitivity at re-entry due to midcourse position and velocity errors, and a study on two-impulse aborts.

SECTION 3
INERTIAL MEASUREMENT UNIT (IMU) and COUPLING AND DISPLAY UNIT (CDU)

John Miller

This section covers only general comments on the Apollo gyro and the Apollo pendulum, since these will be covered in more detail in the later sections. It does cover five other areas briefly; the PIPA electronics, the power and servo assembly, the coupling and display unit, the inertial measurement unit mechanical design, and the effort going on in the IMU system area.

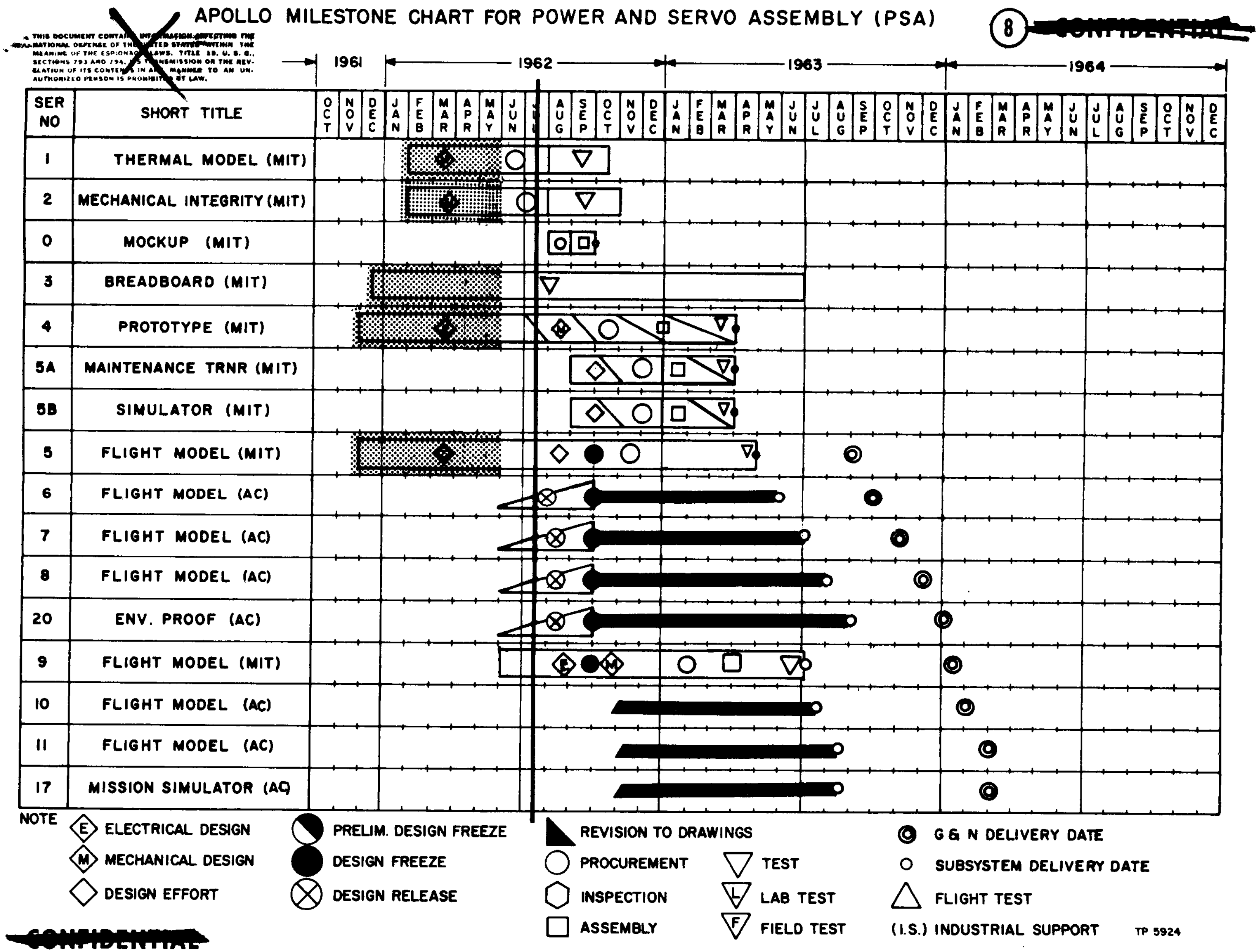
With respect to the PIPA electronics, these items are generally on schedule. The PIPA performance, with pendulums to be described by Mr. Sapuppo, will be reported on at a later meeting. The interrogator for the PIPA electronics has been designed. The gating logic for the precision timing has been completed and work is nearing completion on a high-speed switch to switch the current in the torque motor windings for the accelerometer.

In the power and servo assembly, there are the IMU electronics associated with the gimbal servos and the power conversion electronics. The electronics for the IMU gimbal servos have been about 80% breadboarded. Generally speaking Fig. 3-1 shows the status with respect to the electronics associated with IMU. As can be seen there is roughly about one month delay here. In the area of the power and servo assembly there is a report written on the increased power conversion efficiency in Class B electronic amplifiers by means of power supply switching. A request is in to NASA for disclosure and for patent application in this area.

There should be a word of explanation as to what the systems mean. System No. 3 is the breadboard IMU and power and servo assembly system, where the electronics group in the power and servo assembly area get the systems in order to finalize their design and do any testing that is necessary. System No. 4, which will be talked about a little more in detail, is the system that is used for alignment purposes.

In the area of the coupling and display unit the status is as shown in Fig. 3-2. The resolver-receivers for the CDU have been ordered and delivery expected before October. The first CDU is in the process of assembly. If it had not been for the strike it would be assembled and the servo loop on this unit closed. As of now the encoder has been assembled on the gear train;

[redacted]



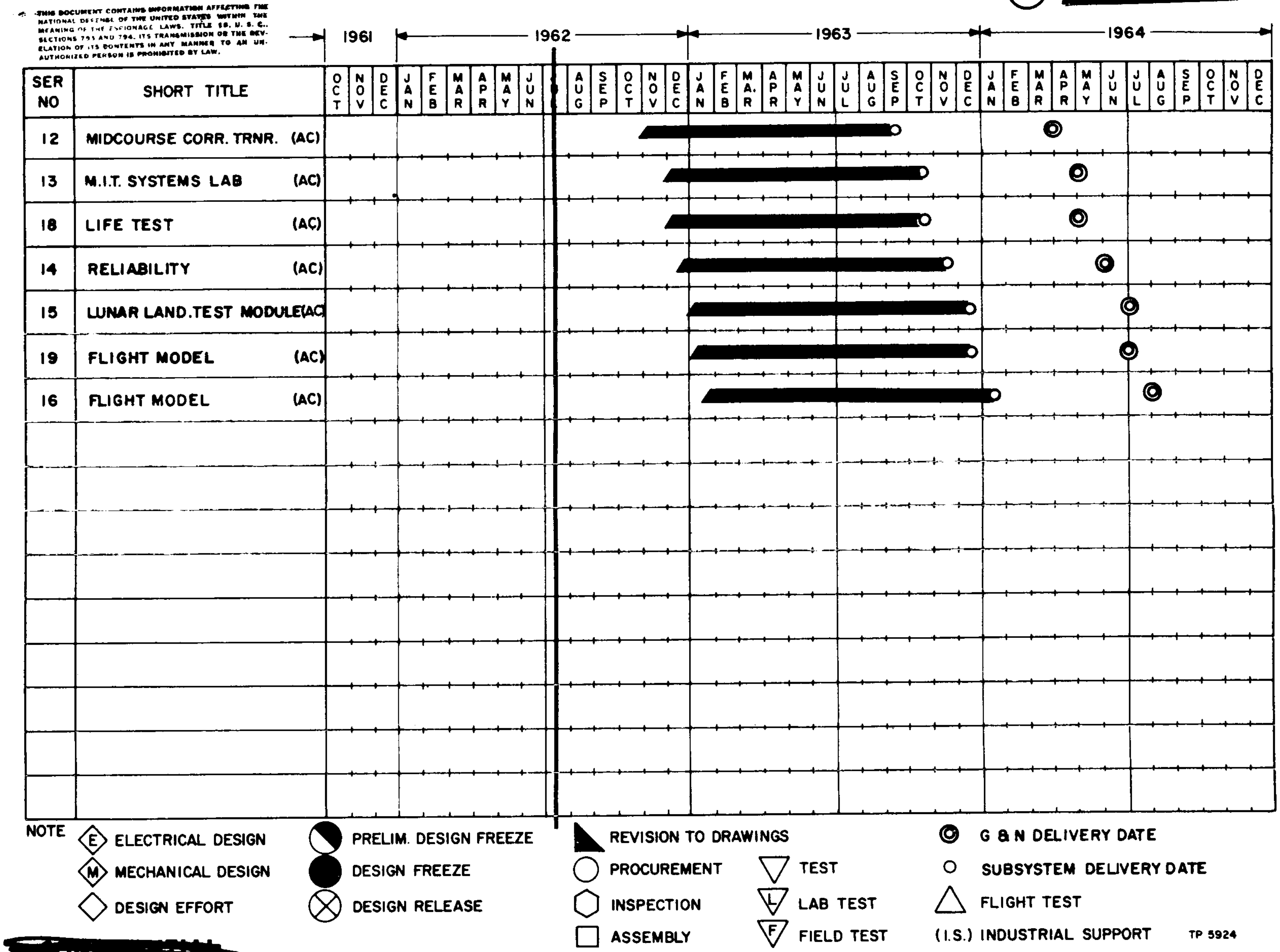
[redacted]

Fig. 3-1a

[redacted]

APOLLO MILESTONE CHART FOR POWER AND SERVO ASSEMBLY (PSA)

(9) [redacted]



[redacted]

Fig. 3-1b

[redacted]

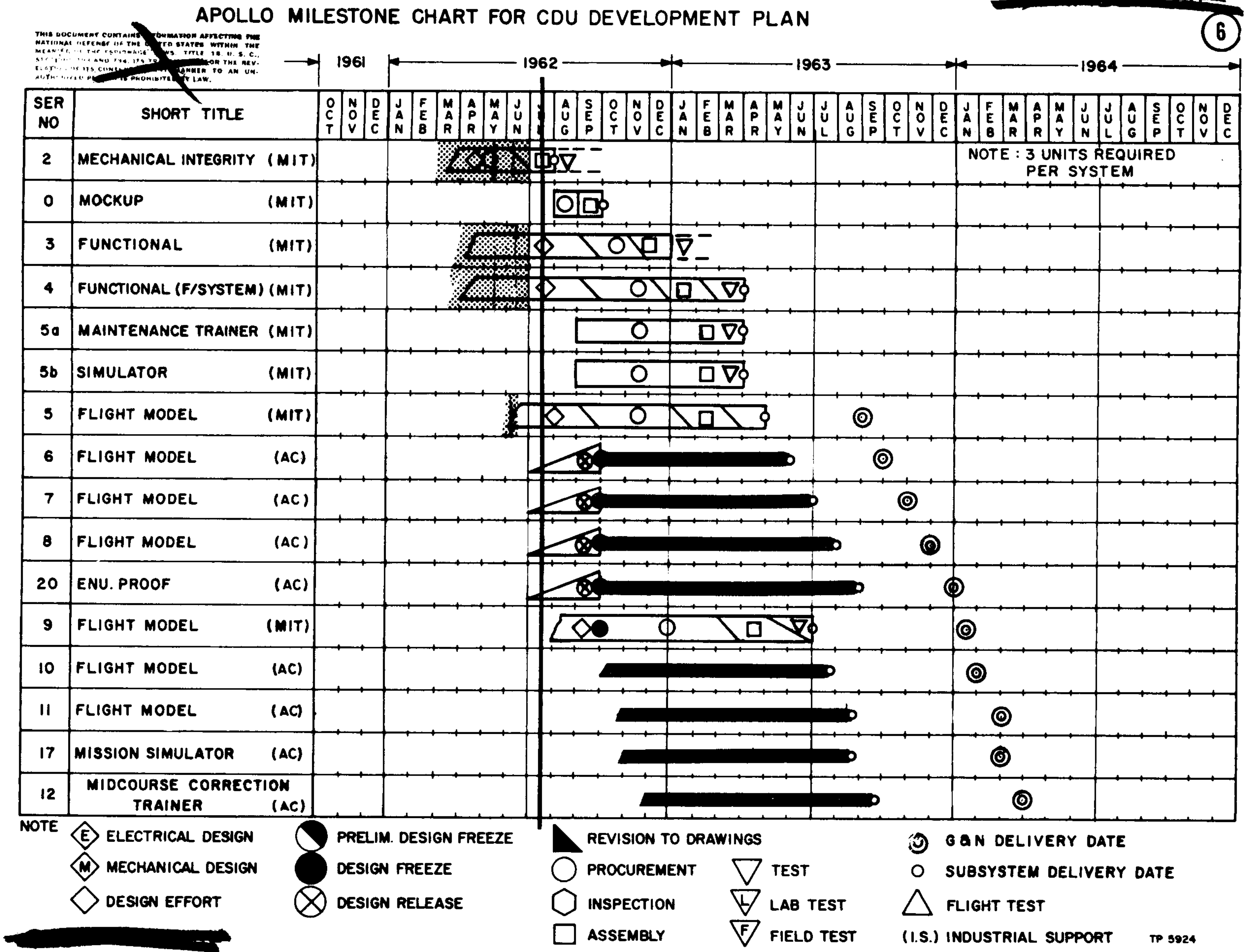
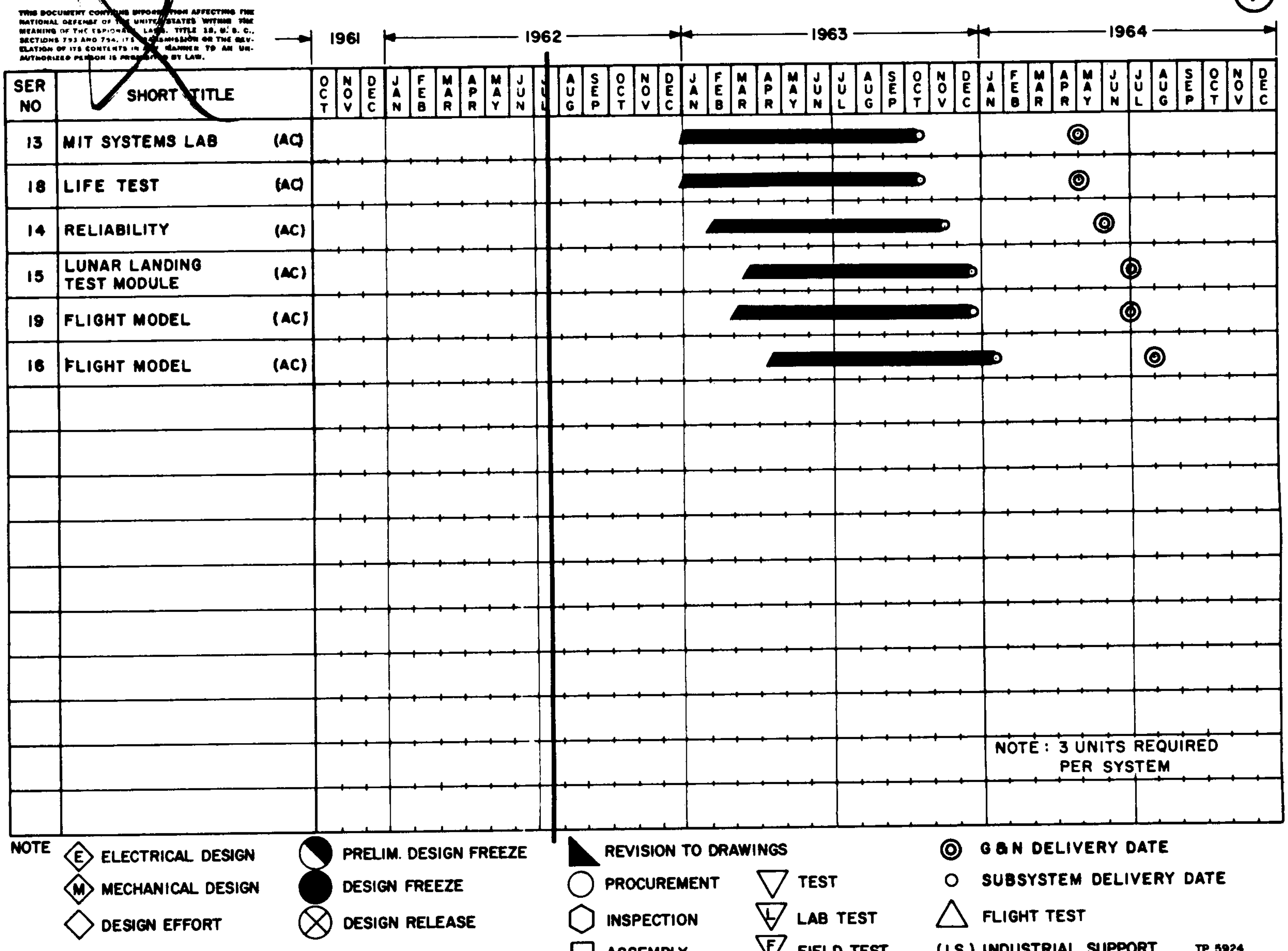

APOLLO MILESTONE CHART FOR CDU DEVELOPMENT PLAN
6
1961
1962
1963
1964
SER NO
SHORT TITLE
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
2 MECHANICAL INTEGRITY (MIT)
0 MOCKUP (MIT)
3 FUNCTIONAL (MIT)
4 FUNCTIONAL (F/SYSTEM) (MIT)
5a MAINTENANCE TRAINER (MIT)
5b SIMULATOR (MIT)
5 FLIGHT MODEL (MIT)
6 FLIGHT MODEL (AC)
7 FLIGHT MODEL (AC)
8 FLIGHT MODEL (AC)
20 ENU. PROOF (AC)
9 FLIGHT MODEL (MIT)
10 FLIGHT MODEL (AC)
11 FLIGHT MODEL (AC)
17 MISSION SIMULATOR (AC)
12 MIDCOURSE CORRECTION TRAINER (AC)
NOTE : 3 UNITS REQUIRED PER SYSTEM
NOTE
ELECTRICAL DESIGN
MECHANICAL DESIGN
DESIGN EFFORT
PRELIM. DESIGN FREEZE
DESIGN FREEZE
DESIGN RELEASE
REVISION TO DRAWINGS
PROCUREMENT
INSPECTION
ASSEMBLY
TEST
LAB TEST
FIELD TEST
G&N DELIVERY DATE
SUBSYSTEM DELIVERY DATE
FLIGHT TEST
(I.S.) INDUSTRIAL SUPPORT
TP 5924

Fig. 3-2a

APOLLO MILESTONE CHART FOR CDU DEVELOPMENT PLAN (CONT.)



CONFIDENTIAL

Fig. 3-2b

the encoder electronics have been designed and now are being optimized. In terms of the digital-to-analog conversion these electronics again have been designed and are awaiting final assembly of the sextant in order to complete loop studies. The relay components associated with the coupling and display unit have been selected. Since the last report the location of the CDU has been moved over onto the left side of the navigation panel. This has allowed more depth in the CDU case and, as a result, a new case is being designed to have integral construction of the CDU. This means that as much as possible of the electronics associated with the CDU will be packed into the case. These all will be interchangeable so that one can be pulled out and another plugged in. A thermal study is under way to get some measure of the temperature problems resulting from the electronics in the CDU case. A CDU and resolver test console is now under design and construction so that the precision resolvers can be listed with the IMU and the CDU performance evaluated. Relative to this chart we have been delayed, as is shown here, about two weeks.

With respect to the IMU, Fig. 3-3 is a chart that was presented before. It is useful to describe the various systems where effort is underway. In the areas of the display models (vibration model, thermal model, and wooden mock-up) these systems are awaiting gimbal assemblies and cases. Those parts are out to the venders now. They should be assembled in August, the first one of which will be the thermal model so that more advanced work can be done in the thermal study area. Figure 3-4 shows six dummy inter-gimbal subassemblies for the display model. These units are cut away to show the relationship of the slip ring bearings, resolvers, and torque motor. Each IMU axis will contain two of these subassemblies, one with one or two 1X resolvers and the other with a 15X resolver.

With respect to systems 1 through 9, the 15-speed stub shafts and bearing assemblies are nearing completion. The resolvers for the IMU have been ordered and delivery expected about the first of October. With respect to the two venders for these resolvers, both of them feel that they are about on time. In the roll-bond pattern being used for the gimbals, the inflation has been presenting some problems. In order to illustrate what is meant, Fig. 3-5 shows the type of gimbals on which some study work has been done on the roll-bonding and inflation. One of the areas of difficulty has been in locating the hole in order to do the expansion and another has been some kinking. Now it has only been very recently that any real progress has been made in this area, but as a back-up some 0.040 thick aluminum gimbal hemispheres have been ordered. If these must be used, roll-bonding will be made available when it is possible to use it. The one-speed resolver mounting rings are nearing completion. A sintered powder beryllium stable member has been received, but is both undersized and defective in some areas. However, Brush Beryllium wanted to try out some of their techniques on this unit so it is not unusual for a first cut to be this way. Cold pressed units of the stable member are due in a couple of weeks. As

WEIGHT	POWER	THERMAL CONTROL	SERIAL NUMBER	NAME (IMU ASSEMBLY)	CASE	GIMBALS	STABILIZED MEMBER	RESOLVERS	TORQUERS	SLIP RINGS	IRIGS	PIPS	ADAS	GME	THERMAL SYSTEM	CASE COOLING	
D	N	N	-DM	DISPLAY MODEL	S	S	S	D	D	D	D	D	D	N	N	N	IN HOUSE
	N	N	-VM	VIBRATION MODEL				N	N	N	N	N	N	N	N	N	IN HOUSE
D			-TM	THERMAL MODEL	S	S	S		S	N			D	N	R	S	IN HOUSE
D	N	N	-0	MOCK-UP	WOODEN MOCKUP												TO S & ID
R		R	-1	THERMAL	R	R	R		R	R			D	D	R	R	IN HOUSE
S		N	-2	MECHANICAL INTEGRITY	R	R	R	R	R	R					N	N	IN HOUSE
R	R	R	-3	FUNCTIONAL	R	R	R	R	R	R	R	R	R	R	R	R	IN HOUSE
R	R	R	-4	FUNCTIONAL	R	R	R	R	R	R	R	R	R	R	R	R	IN HOUSE
	N	N	-5A	MAINTENANCE TRAINER	R	N	N	N	N	N	N	N	N	N	N	R	TO S & ID
			-5B	SIMULATED	R	N	N	N	N	N	N	N	N		S	R	TO S & ID
R	R	R	-5	FLIGHT MODEL	R	R	R	R	R	R	R	R	R	R	R	R	TO S & ID
R	R	R	-9	FLIGHT MODEL	R	R	R	R	R	R	R	R	R	R	R	R	TO S & ID

R - REAL D - DUMMY
S - SIMULATED N - NO

Fig. 3-3 Physical descriptions of IMU assemblies

Fig. 3-4 Inter-gimbal subassemblies for IMU-DM #1

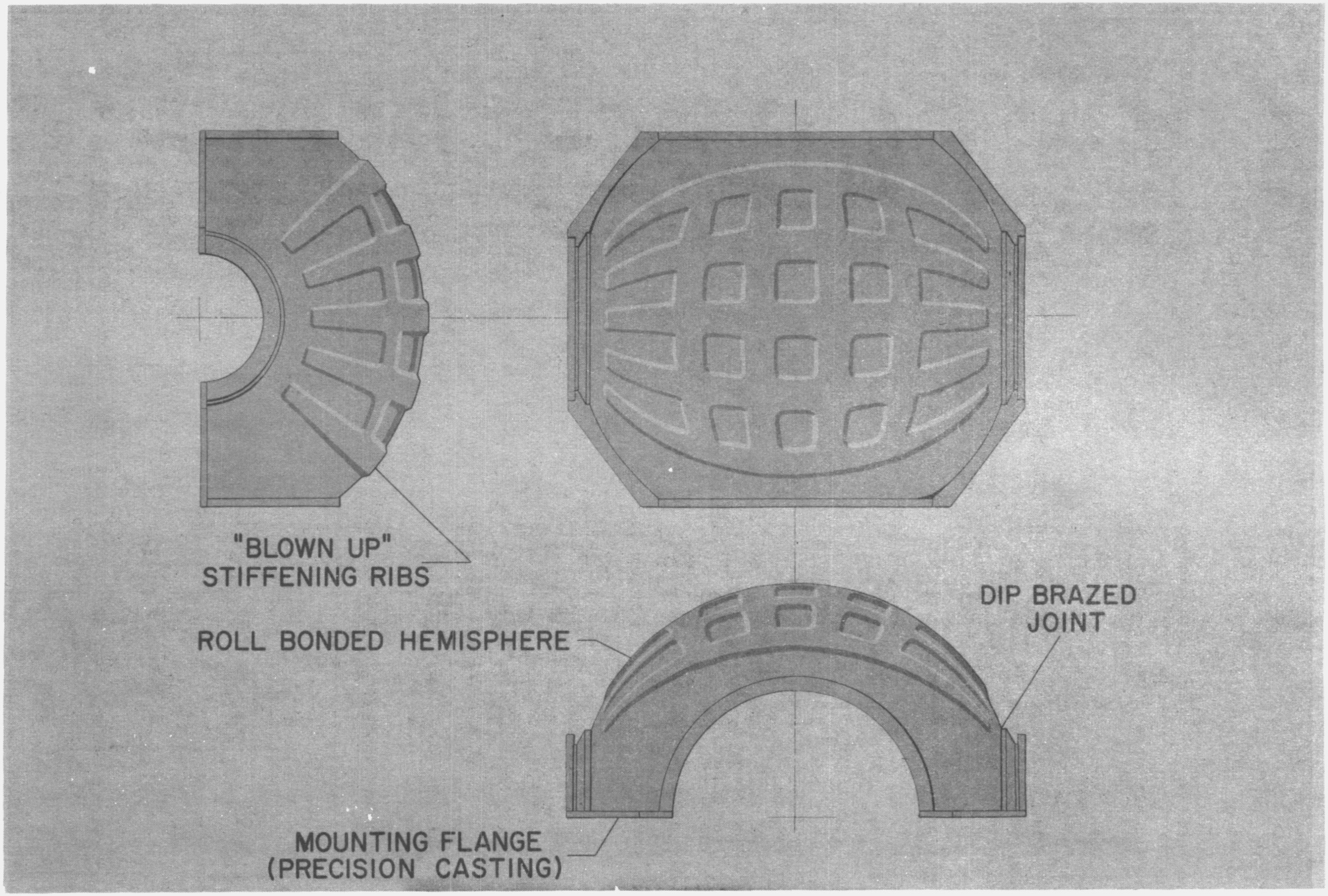


Fig. 3-5 Typical gimbal hemisphere for Apollo IMU

an alternate some cast aluminum blocks and some hot-pressed beryllium stable members have been ordered. Miscellaneous hardware has been detailed and will be ordered soon. The gimbal assemblies have not yet been completely detailed. The gimbal torque motors will be delivered about the end of August, which is about on schedule and this will give sufficient amount of time to do the testing before they have to be installed in the first systems. The studies now in progress are on techniques for this roll-bonding and alternate methods of achieving case-cooling passages.

To refresh your memory, the systems 1 through 5 have the following uses. System 1 is a thermal system for thermal design studies. The second one is a mechanical integrity system. The third one is a fuctional system which will be used for electronic studies. The fourth system is a functional system which will be used for alignment studies. The fifth system is the system that will fly in the first flight.

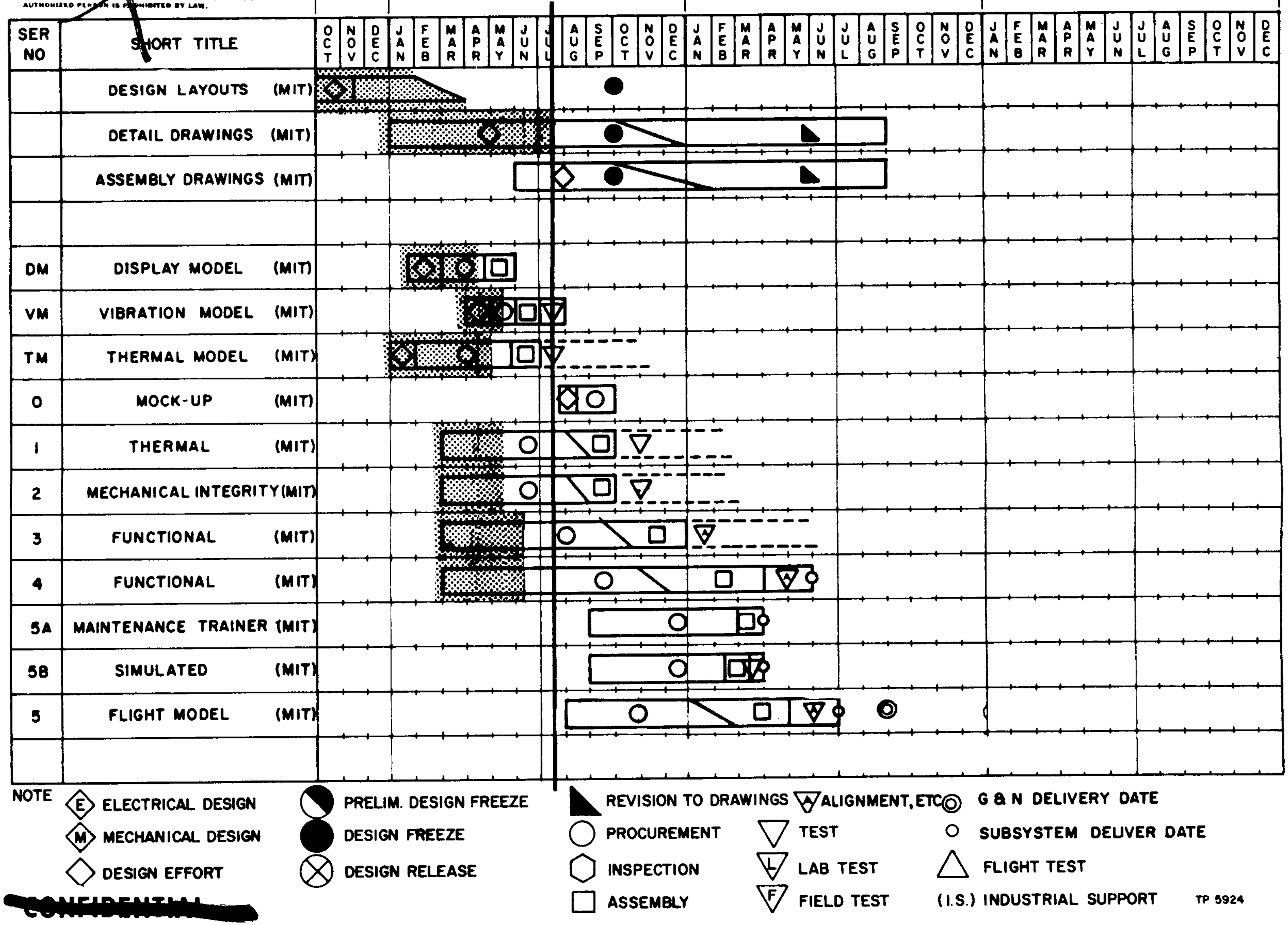
Relative to the schedule of Fig. 3-6, it looks presently that these display models, vibration models, and thermal models, which should be completed now, will be completed in August. The shaded area shows the relative position of systems 1 through 5. In the IMU system area, alignment procedures are being detailed. A two-axis alignment table has been ordered and has been scheduled for delivery in August which is sufficiently in advance of the time when it will be needed to allow a calibration of it. In one other area an inertial component performance reporting program is now being prepared. The purpose of this program is to tabulate and keep on record the performance of inertial components from the day they are accepted until their useful life is over. Each time these components are checked a measure of their performance will be obtained, which will be very useful in areas of reliability. This sort of program was carried out under Polaris, and will also be done on the Apollo project.

CONFIDENTIAL

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U. S. C., SECTIONS 793 AND 794, ITS TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

APOLLO MILESTONE CHART FOR IMU DEVELOPMENT PLAN

(5)



CONFIDENTIAL

Fig. 3-6a

CONFIDENTIAL

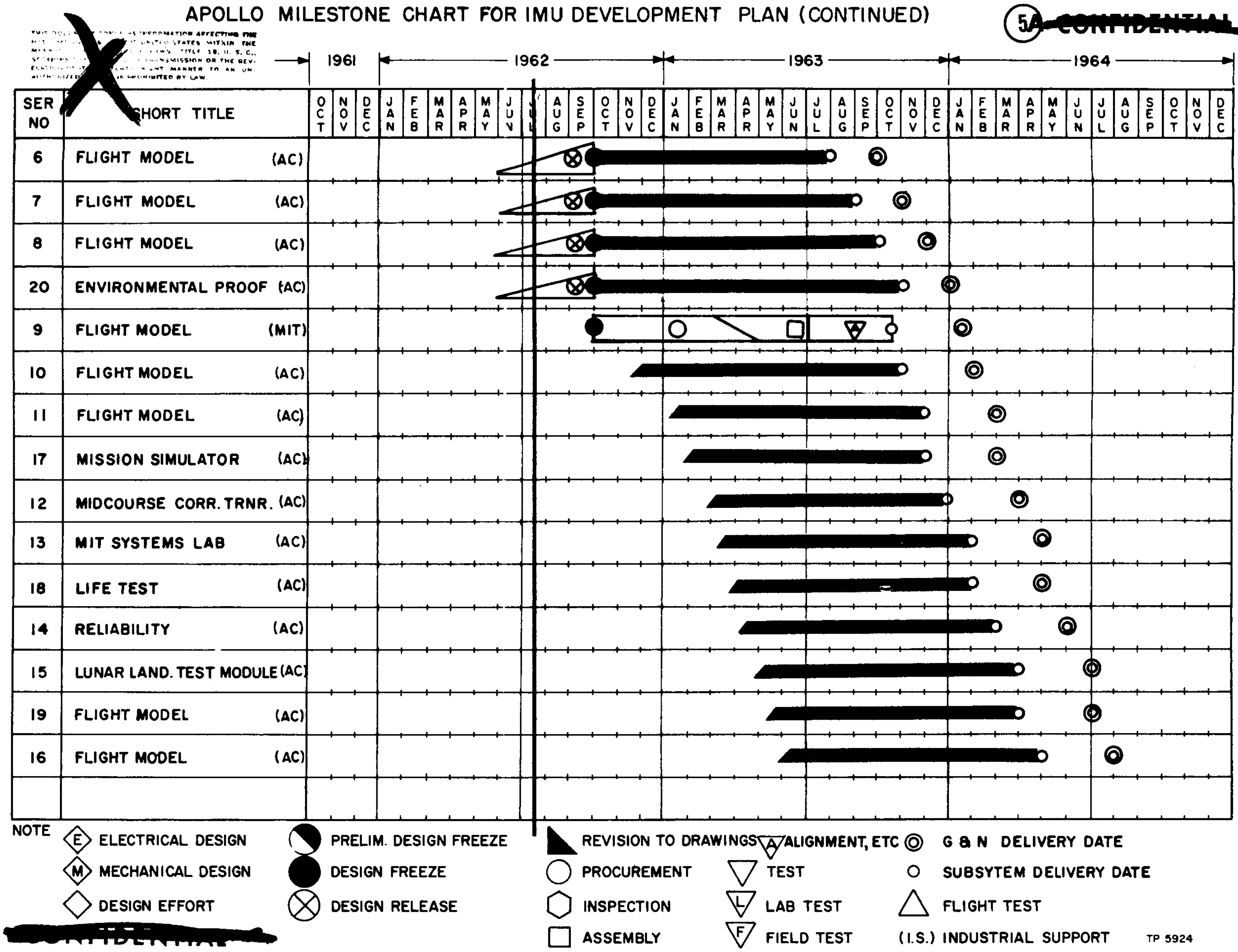

APOLLO MILESTONE CHART FOR IMU DEVELOPMENT PLAN (CONTINUED)
5A
1961
1962
1963
1964
SER NO
SHORT TITLE
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
6 FLIGHT MODEL (AC)
7 FLIGHT MODEL (AC)
8 FLIGHT MODEL (AC)
20 ENVIRONMENTAL PROOF (AC)
9 FLIGHT MODEL (MIT)
10 FLIGHT MODEL (AC)
11 FLIGHT MODEL (AC)
17 MISSION SIMULATOR (AC)
12 MIDCOURSE CORR. TRNR. (AC)
13 MIT SYSTEMS LAB (AC)
18 LIFE TEST (AC)
14 RELIABILITY (AC)
15 LUNAR LAND. TEST MODULE (AC)
19 FLIGHT MODEL (AC)
16 FLIGHT MODEL (AC)
NOTE
E ELECTRICAL DESIGN
M MECHANICAL DESIGN
DESIGN EFFORT
PRELIM. DESIGN FREEZE
DESIGN FREEZE
DESIGN RELEASE
REVISION TO DRAWINGS
PROCUREMENT
INSPECTION
ASSEMBLY
A ALIGNMENT, ETC
TEST
L LAB TEST
F FIELD TEST
G & N DELIVERY DATE
SUBSYTEM DELIVERY DATE
FLIGHT TEST
(I.S.) INDUSTRIAL SUPPORT
TP 5924

Fig. 3-6b

SECTION 4
PIP DEVELOPMENT AND MANUFACTURE

M. Sapuppo

The Miniature Components Group of the Instrumentation Laboratory is responsible for the design and the development of 16 size pendulum. In addition, the Group is responsible for the technical direction of the Sperry Gyroscope Company who is manufacturing these components. Together, the objective is to deliver acceptable pendulums to the systems users on schedule.

Figure 4-1 shows a view of the Apollo pendulum. The total unit weighs about 5 ounces, is about 1. 9 inches in length, and about 1. 6 inches in diameter, and has a pendulosity of a quarter of a gram-centimeter. The float is cylindrical in shape and made of beryllium with tapered ferrite rotors on either end. This unit discerns local gravity to better than two seconds of arc which is equivalent to an uncertainty for the pendulum in the order of 2000th of a dyne-centimeter. The ball pivot arrangement acts as a stop, both in the radial direction and axially, since the floated element is magnetic suspended during operation at temperature. Even under twenty gravities along the output axis there is sufficient stiffness in the suspension system to keep the float, the ball pivots in particular, from touching either the endplates or the jewels.

The contact area indicated on the figure encompasses the three-ring system for alignment of the PIP about three axes. There is a spherical surface between the two bushings which allows the unit to rotate in two planes as well as about the output axis. The external housing arrangement essentially consists of a magnetic shield of Mu-material, which can attenuate an external 5-gauss field to a 0.05-gauss field internally. Seven units have been delivered to Systems people since the latter part of January. These have been development units and are not totally of this configuration, since they have been assembled principally to verify and explore some of the design features shown here. For example, it has been verified that a quarter-gram centimeter pendulum is adequate, and gives acceptable performance for the Apollo application. Prior to this one-gram centimeter pendulums and half-gram centimeter pendulums were tested.

The ducosyn tapered system has been tested. Assembly techniques and procedures involved in locating the tapered float in the proper location have been resolved. Alignment stability has been verified as well as the adjustment technique to achieve the alignment specifications. The merits of the three-piece

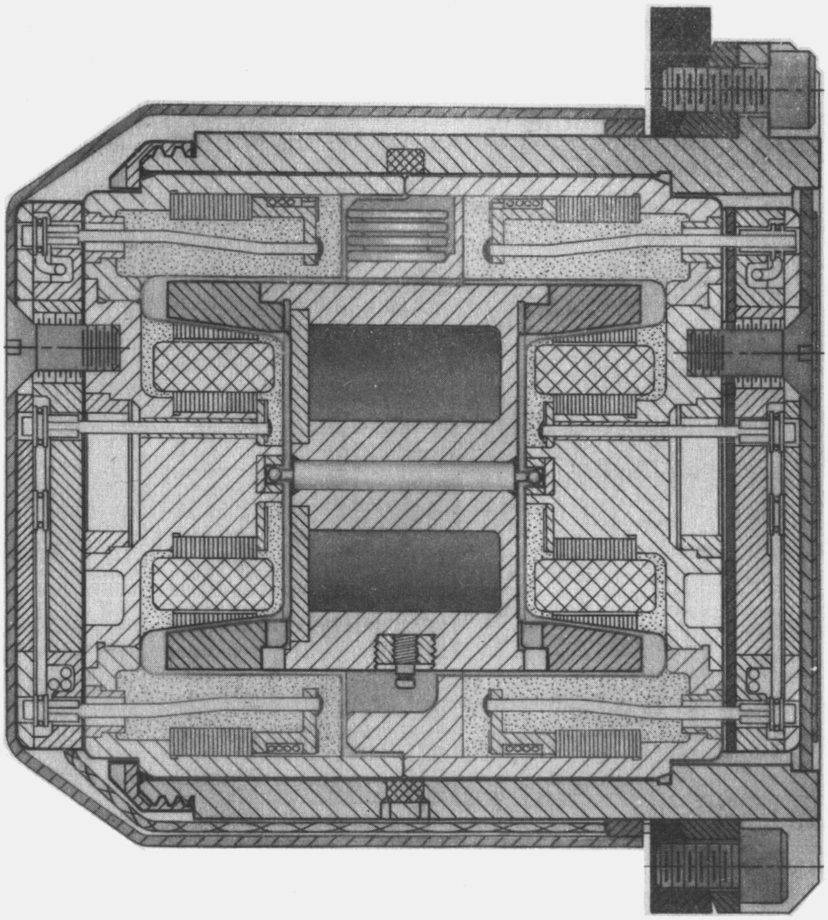


Fig. 4-1 16 PIP

rotor have been compared to the single-ferrite rotor shown in the figure and it has been determined that the single-piece ferrite for this application is the better of the two. Also, the merits of a new torquer construction have been investigated and will be shown in a later figure.

Figure 4-2 is a program plan for the Apollo 16 PIP. It ties system needs to Sperry milestones and MIT milestones. These system milestones are taken directly from AGANI pages and do not indicate the lead time that will be required for the delivery of the accelerometers. It is not known exactly how much lead time will be necessary for delivery, but as long as it doesn't approach 6 months no problem in delivery of PIP's to System's people is foreseen. Sperry production of the block zero PIP's has been projected on the figure. The 8-unit block is designated Block 0, 19-unit block as Block 1 and the remainder of the 45 units as Block 2. The circle under documentation represents the April 15th date when the original Block 0 design was released to Sperry. At that time the tapered suspension configuration with the tapered rotors and the alignment rings were released. Of course, the connector and the magnetic shroud and mircrosyn assembly were included, making up a complete documentation package which ties in with the requirements. It is expected that units will continually be produced in-house for the earlier systems, and additionally MIT expects to be building to support the manufacturing line at Sperry throughout the program. With regard to the general block under "PIP Assembly Facility", it is mentioned because the work statement with Sperry asked for a completely centralized and independent facility. In about two months hence there will be an independent facility exclusively for Apollo; at the present time it is being shared with Polaris.

There is only one item which concerns the Block 0 release that has been delayed until August 1 which is the latest date that a change can be received without schedule impact. It concerns the heater-sensor combination. Several units are being tested right now. The results of these tests will enable us to meet the August 1st release. The reset coil, the changes in the connector, the magnetic shroud, and the microsyn assembly will be documented for the August 15 release which defines the configuration Sperry will produce between January 1 and April of 1963 (Block 1).

The documentation that will be released as of August 15 will consist of a documentation control list that defines every piece of paper which has been released to them as of that date. In addition, it records the latest revision letter as of August 15. The actual revisions and reproducible drawings will also be included in the release. In spite of the block system there is no intent to let these changes pile up. The intent is to maintain a smooth flow of changes as they occur. The dates primarily represent definition dates for the Blocks. Test equipment will

[redacted]

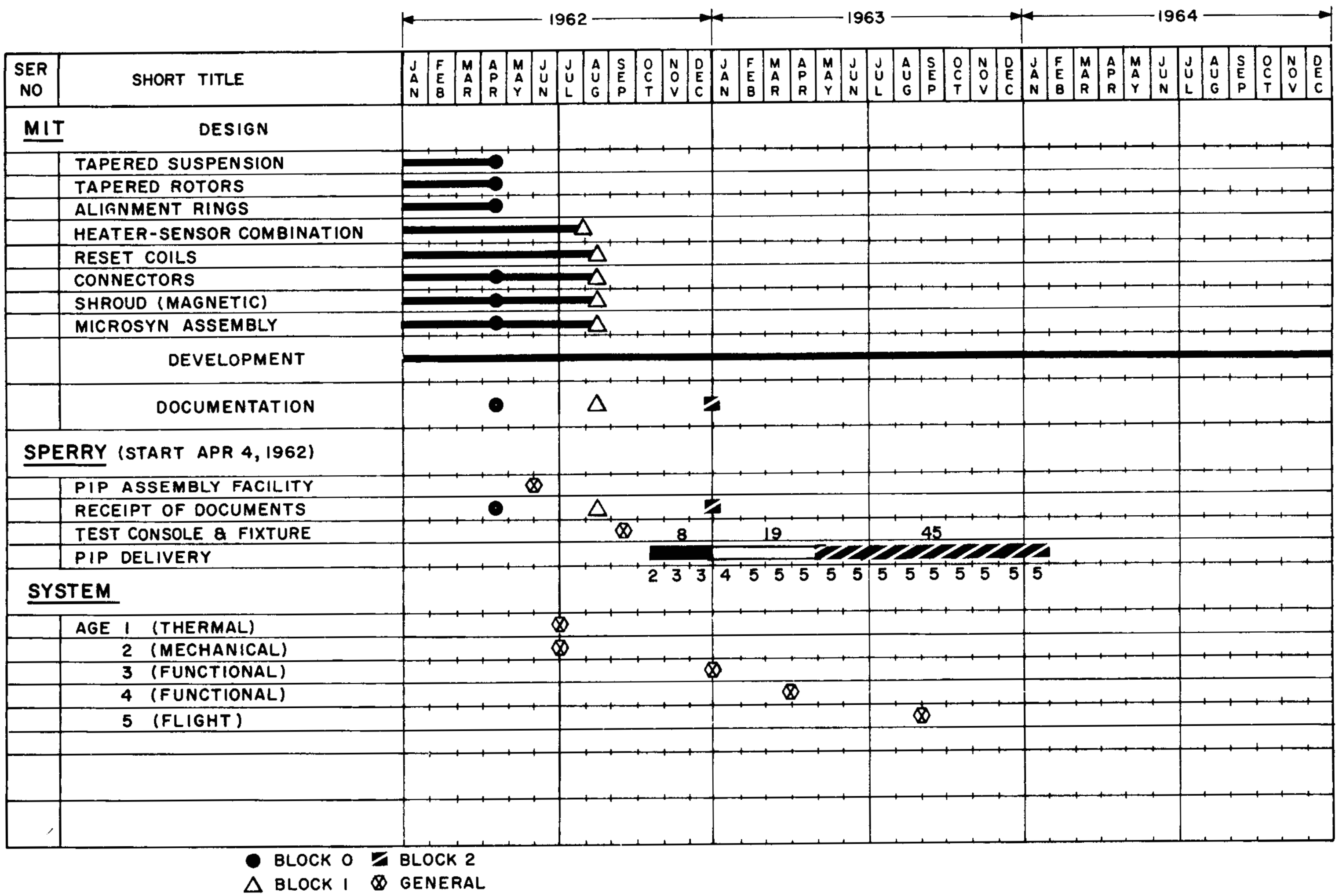


Fig. 4-2 Apollo milestone chart for 16 PIP Mod D

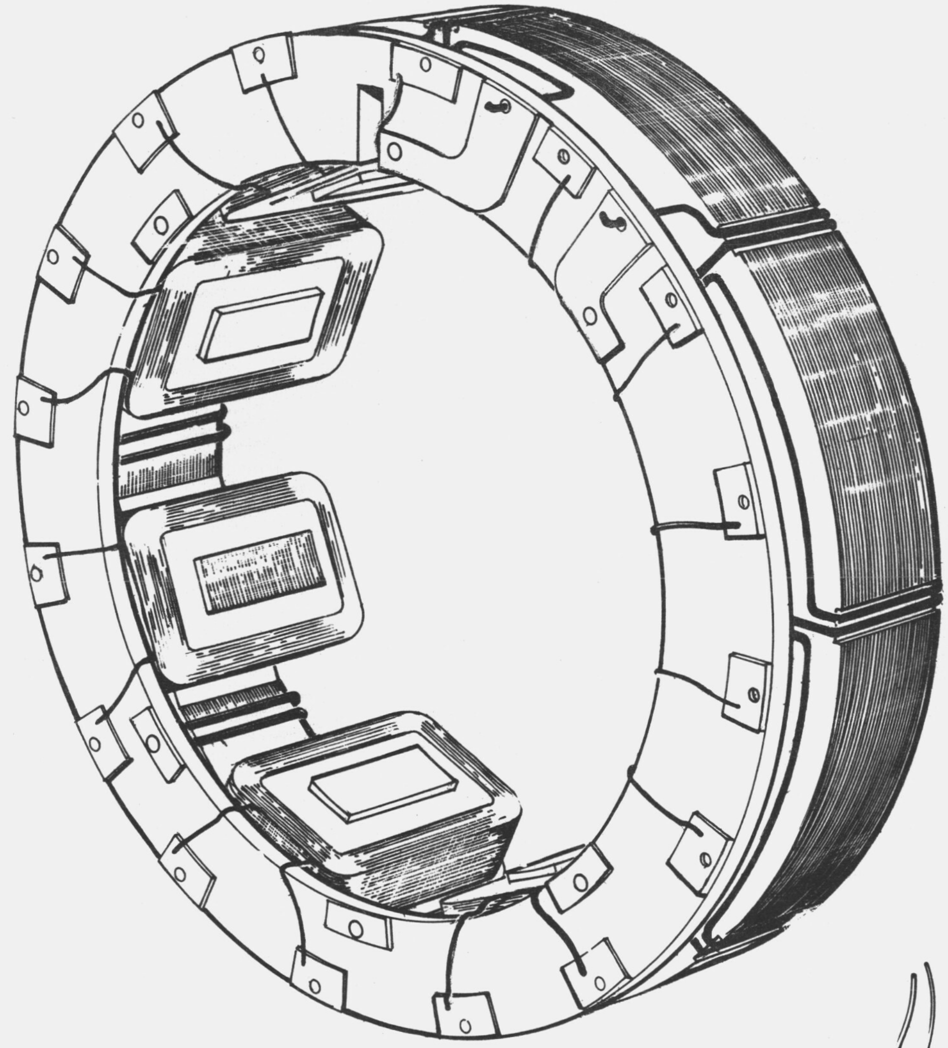
[redacted]

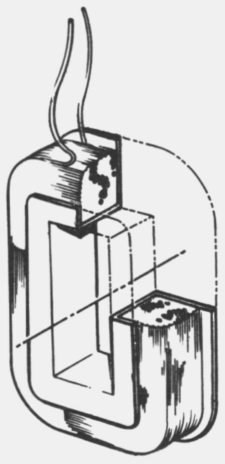
have been required as of September 15 for this item in order to meet the October 15 delivery date of the first unit. Apparently there is some problem there. Sperry has a contract to build the test equipment and does not expect to have the equipment ready before the first of November. They have a letter of intent for $100, 000 but they feel this is insufficient to place all the equipments and piece parts on order. This is pointed out as the primary reason for the delay. It has been made clear to Sperry that the instruments are needed in October and, if no test equipment exists at their plant,MIT will accept the units from Sperry and test them at MIT.

The change procedure being used is a very simple one and one that is approved by NASA. It is common to both the IRIG and PIP; the same forms are used and, although the flow is slightly different, both are completely compatible.

Figure 4-3 shows one area of the design that really is a primary area of change between the Block 0 and the Block 1 unit. Eight coils have been wound around the stator core of the torque generator microsyn assembly, two turns each, between the poles. It was determined in the earlier laboratory PIP's that the pulse-torquing technique deposited some residual magnetism around the stator core which confused the acceleration indication. There were two solutions available: one resulted in the formulation of an additional externally-mounted black box which could reset the pulse; the other was to wind these coils around the stator and excite them in series with the magnetic suspension whereby no additional equipment would then be required. These coils automatically reset the magnetic condition of that stator, hence the term "reset coil". This will be available for release to Sperry on 15 August. In addition, the figure shows two other design features that are actually Sperry recommendations which MIT has approved. One was the coil bobbin assembly which is a nylon bobbin about 8-mils thick. By careful selection of the wire size in the half-tolerance range Sperry was able to pack enough wire to make up for that 8-mil thickness of the bobbin. It is a very clean design and provides a resting place for the terminal ring which is their second recommendation. The new terminal ring is an improvement over the earlier terminal ring in that it is a laminated printed circuit. There are actually five substrates involved in this circuitry with deposited copper which provides the inter-winding interconnection of the terminal points. Also, the earlier ring had a section between the stator core and the top ring which did not allow the capsulating compound to flow uniformly within this area. It was necessary, since the potting compound was injected in the center, for it to flow around and over the terminal board to get in behind the top ring. With this new terminal assembly there are open spaces between the coils and terminal board for a smoother flow of potting material.

Sperry was asked recently to submit a proposal on a reliability program.





COIL BOBBIN
ASSEMBLY

Fig. 4-3 16 PIP microsyn assembly

Their reliability program recommendation consists of five phases:

Phase I - a reliability evaluation test, primarily to determine that the instrument has the 20,000-hour (MTBF) mean-time before failure.

Phase II - a subassembly and detail parts evaluation test program.

Phase III - unit sensitivity to environments and electrical excitation.

Phase IV - freak environments.

Phase V - materials compatibility program. This is going to be a subject of a meeting soon between MIT and Sperry.

[redacted]

SECTION 5

GYRO DEVELOPMENT & MANUFACTURE

Robert Booth

The Milestone Chart for the Apollo 25 IRIG (Fig. 5-1) shows the gyro delivery schedule that MIT and the gyro vender, AC Spark Plug, expect to meet. The MIT delivery is geared to meet the early system requirements; systems 3, 4, and 5 will use MIT gyros. Two gyros a month have been scheduled, with the exception of July, when only one is scheduled. This will fill the requirements, with spares as necessary. AC Spark Plug's delivery schedule is set at 2, 2, 3, 3 and 6 a month thereon for the rest of the 70 units. AC Spark Plug's delivery has been broken up into blocks one, two, and three. Block one is in the procurement stage now. AC Spark Plug has ordered, or has on order about 90% of the parts, some of which are in-house now. Block deliveries are scheduled so that design changes can be introduced where necessary. At this time there are no major changes contemplated. The Apollo gyro is essentially a fixed-design right now. The design changes that will be made are generally minor and should not affect the systems interface.

The following is a run-down of the advanced work that is underway in the IRIG group. There are a number of projects which because of their nature, may or may not be included in the Apollo gyro. Figure 5-2 shows the Apollo IRIG Motor Design that may be included. One of the main reasons for its inclusion is that it can save approximately one watt of power. A solid graphmo hystersis ring is presently being used in the Apollo gyro but now a laminated Simonds 73 hysteresis ring is proposed. In conjunction with this material change the 7-mil air gap will be reduced to a 4-mil air gap. This change would have no affect on the system interface, but it would hopefully save power and, by reducing the power consumption within the gyro, produce better stability characteristics. Several tests have been run with different power supplies. As an example of the savings, on the standard two-phase sine-wave supply the Simonds 73 motor required 7.8 watts starting, while the Graphmo required 8.8 watts starting, a saving of 1 watt. In sync it was 3 watts vs 4-1/2 or a saving of 1-1/2 watts or 33%. This saving is repeated all the way down the line, with another two-phase square wave supply and several single-phase supplies.

Another item that is being developed and could possibly be used is a ceramic potted motor stator. This should result in increased float stability because of the use of ceramic encapsulating materials. With improved float stability we expect increased stability in the gyro drift due to float unbalance.

[redacted]

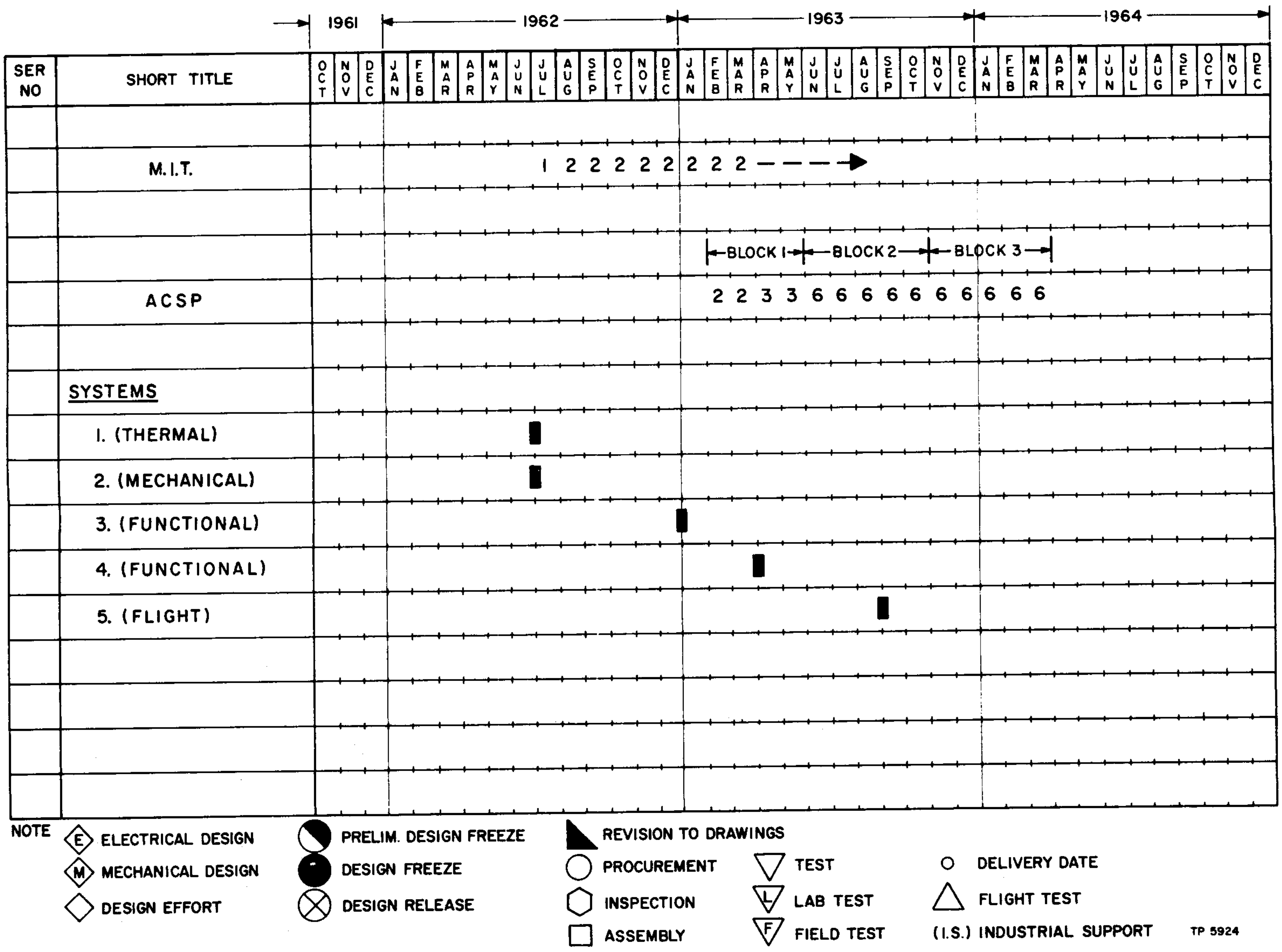
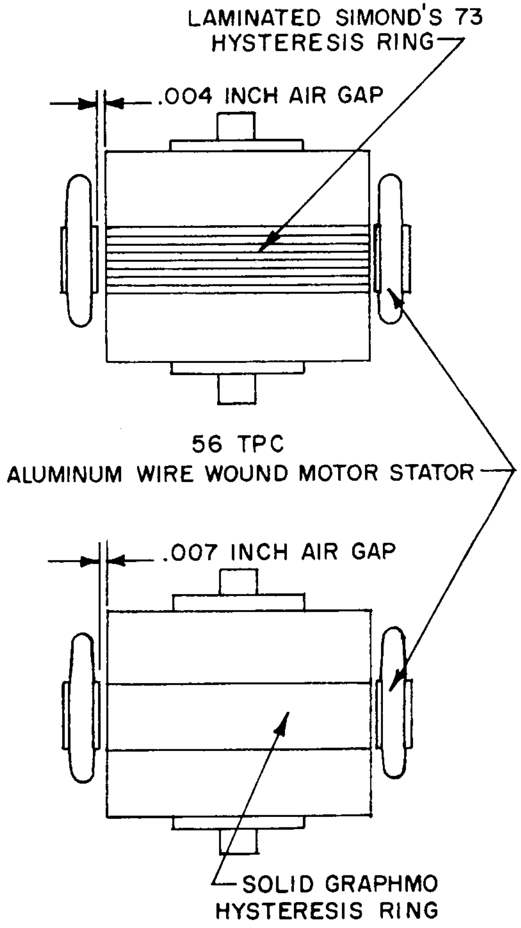


Fig 5-1 Apollo milestone chart for 25 IRIG



POWER SUPPLY / MOTOR DESIGN	UNIT #59 FLOAT SIMOND'S 73 WHEEL	UNIT #61 FLOAT GRAPHMO WHEEL
2 PHASE		
POWER TO START	7.8 WATTS	8.8 WATTS
RUN UP TIME	82 SECONDS	84 SECONDS
POWER IN SYNC	4.25 WATTS	5.7 WATTS
POWER IN SYNC (AFTER 40 V EXCIT.)	3.0 WATTS	4.5 WATTS
POLARIS (SINGLE PHASE)		
POWER TO START	6.35 WATTS	7.1 WATTS
RUN UP TIME	78 SECONDS	140 SECONDS
POWER IN SYNC	4.6 WATTS	5.3 WATTS
SINGLE PHASE (SERIES CAPACITOR)	(.7 μfd)	(.6 μfd)
POWER TO START	5.7 WATTS	7.2 WATTS
RUN UP TIME	113 SECONDS	107 SECONDS
POWER IN SYNC	4.1 WATTS	5.3 WATTS
2 PHASE (SQUARE WAVE)		
POWER TO START	6.75 WATTS	6.0 WATTS
RUN UP TIME	117 SECONDS	125 SECONDS
POWER IN SYNC	4.2 WATTS	4.45 WATTS

Fig. 5-2 Apollo IRIG motor design

There is a thermal study underway on the high-precision elastic-limit beryllium float. A mock-up will be built and instrumented to try to obtain a complete thermal picture of the inside of the gyro.

A program is underway with the Beryllium Corporation of America to develop a high-precision elastic-limit beryllium of 20,000 psi or better, for use in floats in order to increase mechanical stability.

An air bearing wheel design is also underway.

A tapered suspension gyro will be built, from which is expected better stability in the drift terms, if the float can be held centered better.

AC Spark Plug is preparing a reliability program and will present a proposal to MIT for study.

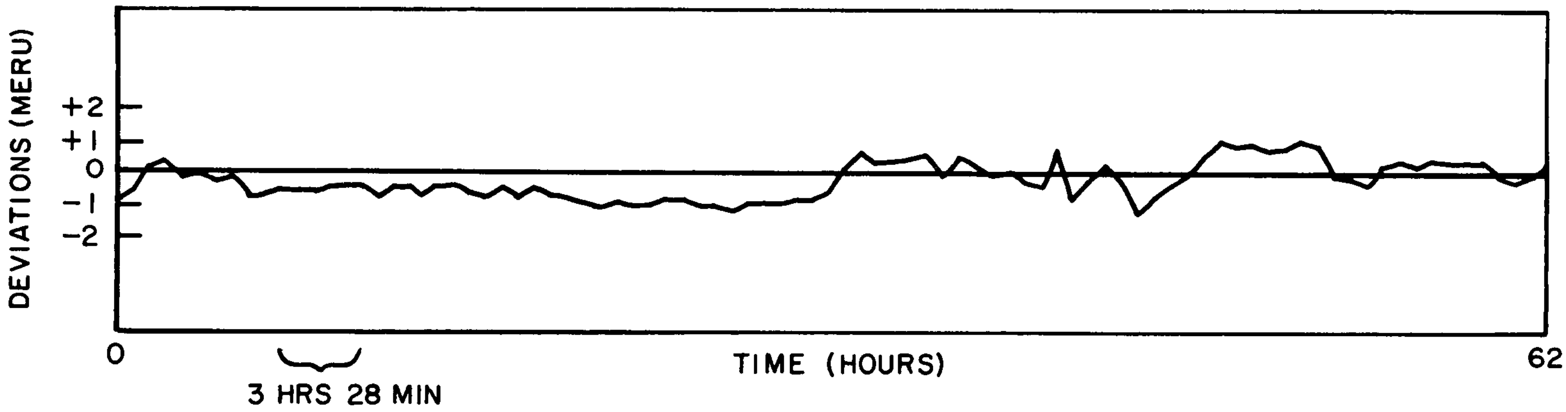
There is a cylindrical float design under study; beryllium oxide is proposed as the structural material.

Figure 5-3 shows how a gyro change order is handled. The details of the change are first discussed with the vender, then with Mr. Ralph Ragan and Mr. John Miller to protect the systems interest, and with Mr. Jack Barnard to represent NASA. After the change has been approved a copy of it plus drawings would be sent to the interested parties as shown on the figure. AC Spark Plug determines whether or not this will have a cost impact on the program. Any cost change must be justified before the change is made.

One Apollo gyro has been built and delivered to the Systems people for test. It is in Mr, McNeil's lab now. One of the tests performed on this unit was a 62-hour pulse-torque stability run. The test was started late on a Friday afternoon and run until Monday morning in a torque-to-balance loop with pulse torquing similar, but not identical, to what would be used in the Apollo system. It speaks fairly well for the gyro and the electronics since the curve of Fig. 5-4, which has a deviation plus or minus 1-1/2 meru at the most, represents the total instability in the gyro and the electronics for a period of several days.

[redacted]

UNIT 52 IA//EA NORTH



SCALE FACTOR = 3.35 μrad/pulse

Fig. 5-4 Pulse torqued stability run

[redacted]

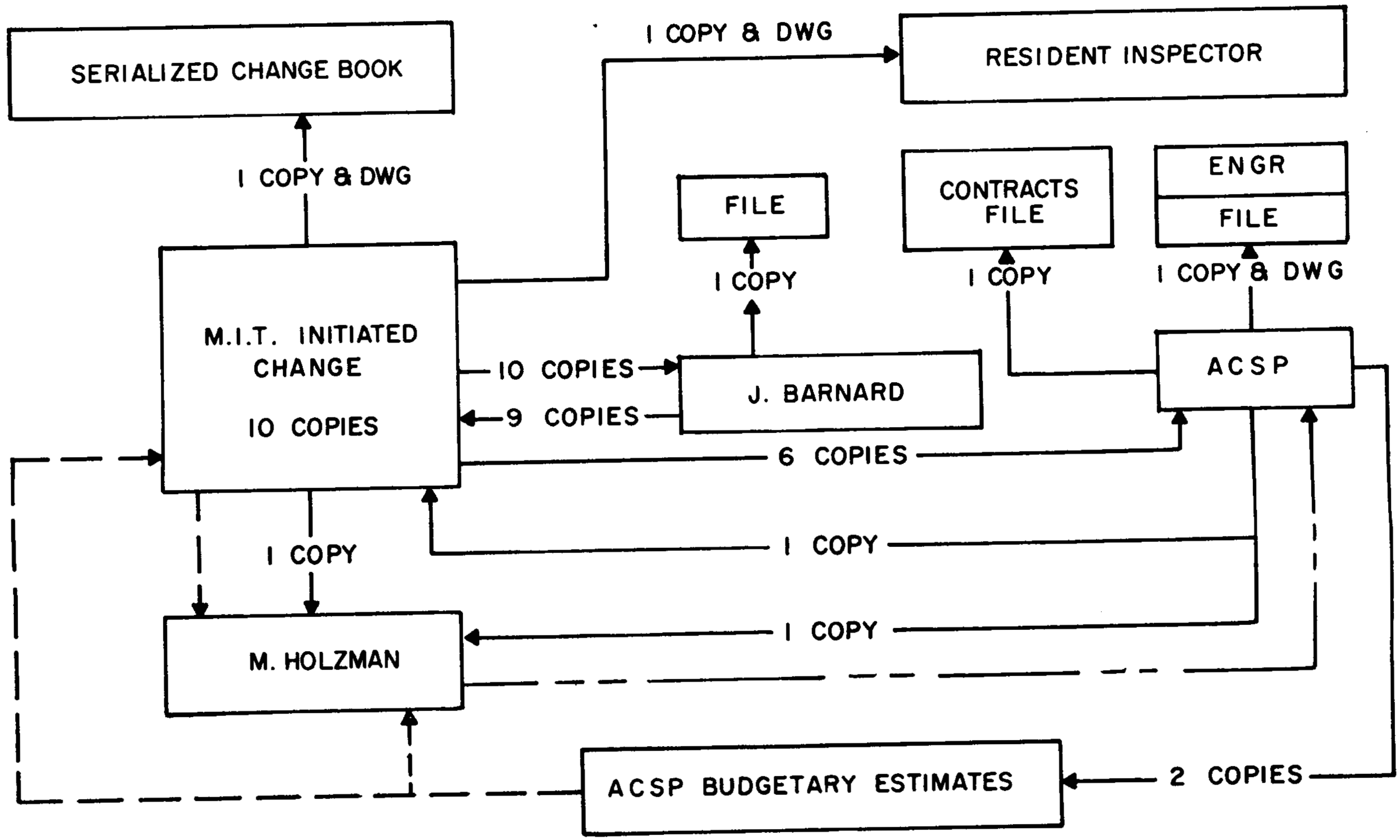


Fig. 5-3 Change order flow

[redacted]

SECTION 6

COMPUTER

Eldon Hall

The AGC (Apollo Guidance Computer) design effort includes the electrical and mechanical design of the computer. The electrical design effort, which has been going on for a considerable period of time, has been delayed by many unresolved details of the computer interface and slightly by the strike, but is very close to schedule. The mechanical design of the computer has been delayed by the changing form factor of the computer to accommodate different locations in the spacecraft. On May 7th an agreement was reached with North American Aviation to locate the computer in the lower equipment bay below the IMU (Inertial Measurement Unit).

Since the allocation of space, and since the last monthly progress report, a concept of the computer packaging has been presented which incorporates a form factor compatible with the space made available in the command capsule. A wooden mock-up, incorporating the packaging concept, can be been in Fig. 6-1. The computer will have twenty-two subassemblies, called blocks, which will plug into the computer end connector. Each computer block can be further subdivided into components or sticks.

The AGC progress, which will presently be described, is based to a large extent on the validity of this concept. Also, as a result of this clearer definition of the scope of the computer development program, the definition of AGC 2 and AGC 4 is being changed. It is felt these changes will decrease the design time required to complete the design of AGC 5 and AGC 9 which are the first flyable models.

The AGC 0 is a mechanical gauge to be used by North American to test the mechanical interface between the AGC and the command capsule. This model may also be used by MIT for mechanical tests. No work has been done on this model yet. Little fabrication will be necessary so that a delay now does not indicate that the model will not be delivered by 1 October 1962.

AGC 1, as described in the last monthly progress report, is completed and is being used as a test-bed to test components and techniques which can be incorporated in the AGC flight model computers; in this capacity the AGC 1 is on schedule.

The role and design of the AGC 2 has been modified to be compatible with the new packaging concept. The AGC 2 will be a rack mounted computer electrically similar to AGC 3, but will be wired to be able to accept welded sticks or complete computer blocks. AGC 2, with this arrangment, can be used to evaluate the pack-

[redacted]

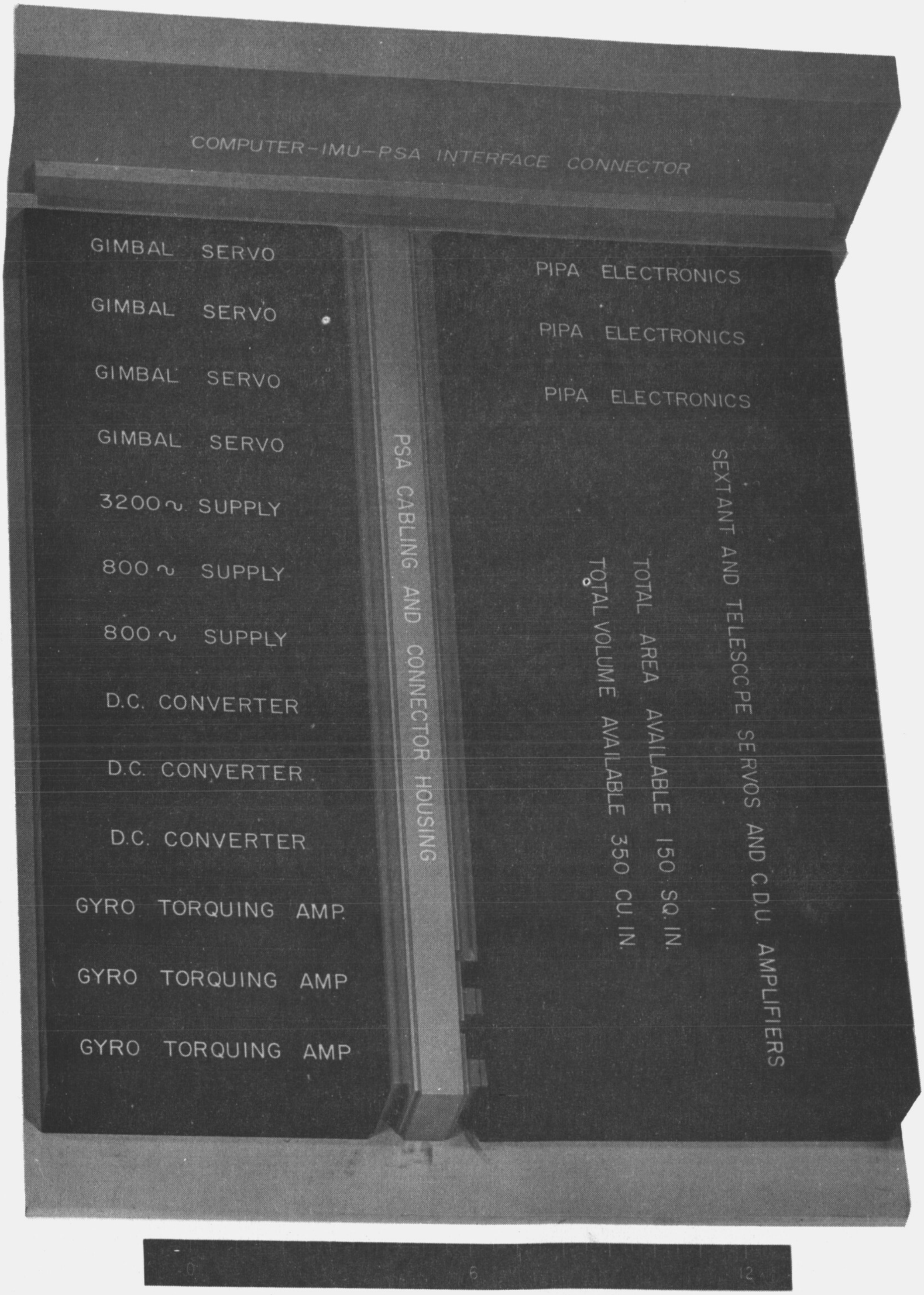


Fig. 6-1 Mock-up

aging concept and to establish in detail the functional break-down in each block, and determine the limitations due to connector pin saturation. This computer when finished can be used as a test set for the succeeding computer subassemblies. The progress of the AGC 2 has fallen behind schedule as illustrated by Fig. 6-2a. This is due in part to its change in role and in part to the delay in formulating a packaging concept.

The assembly of AGC 3 is to a large extent completed and many sections of it are now being tested. The principal deficiency of AGC 3 is the interface circuitry which is now only partially defined. The lack of clearly defined system functions which will define the role of the computer at the interface in regard to telemetry, booster control, lunar landing module, and other guidance and navigation subsystems, prevent a clear cut definition of the interface problem. Even though AGC 3 at present is very close to its schedule, it is felt that the schedule may tend to slip due to many of the uncertainties related to the computer interface.

AGC 4 is a complete prototype of AGC 5, therefore is being gated by the schedule of AGC 2. The progress line for AGC 4 is at the same level as AGC 2, to reflect the delay in the mechanical design.

The progress that has been indicated on AGC 5 and AGC 9 reflect the electrical design of the computer. It is difficult to indicate where the computer presently stands when part of the design is up to schedule and part is behind schedule. To be safe, the progress of AGC 5 and AGC 9 has been left at the same point as AGC 2, to reflect the delay in the mechanical design.

In general, the design of these computers is far enough along to permit the release of many of the circuits. The first release was made during the week of 9 July and releases will continue as rapidly as the drawings can be prepared.

Among other activities is some test equipment design, one of which is a core rope tester (Report E-1179-to be published). This design has been released to Raytheon for their consideration as a production test set.

Studies that are being undertaken at the present time are shown in Fig. 6-3. In general it is difficult to segregate studies from design effort in the computer activity but some items are closer to pure study than they are design. In this category are the component reliability type of study such as transistor step stress level testing. These tests detect failure modes in the components. The knowledge of how a component fails can be used to establish component qualification test, and can also be used to help the vender redesign the component for greater life expectancy. As an example, on the relays, one manufacturer has discussed some proposed changes with George Mayo which should improve their life capabilities. However, tests of these relays both in shock and life testing indicate higher reliability than the manufacturer is willing to guarantee.

APOLLO MILESTONE CHART FOR APOLLO GUIDANCE COMPUTER

CONFIDENTIAL (3)

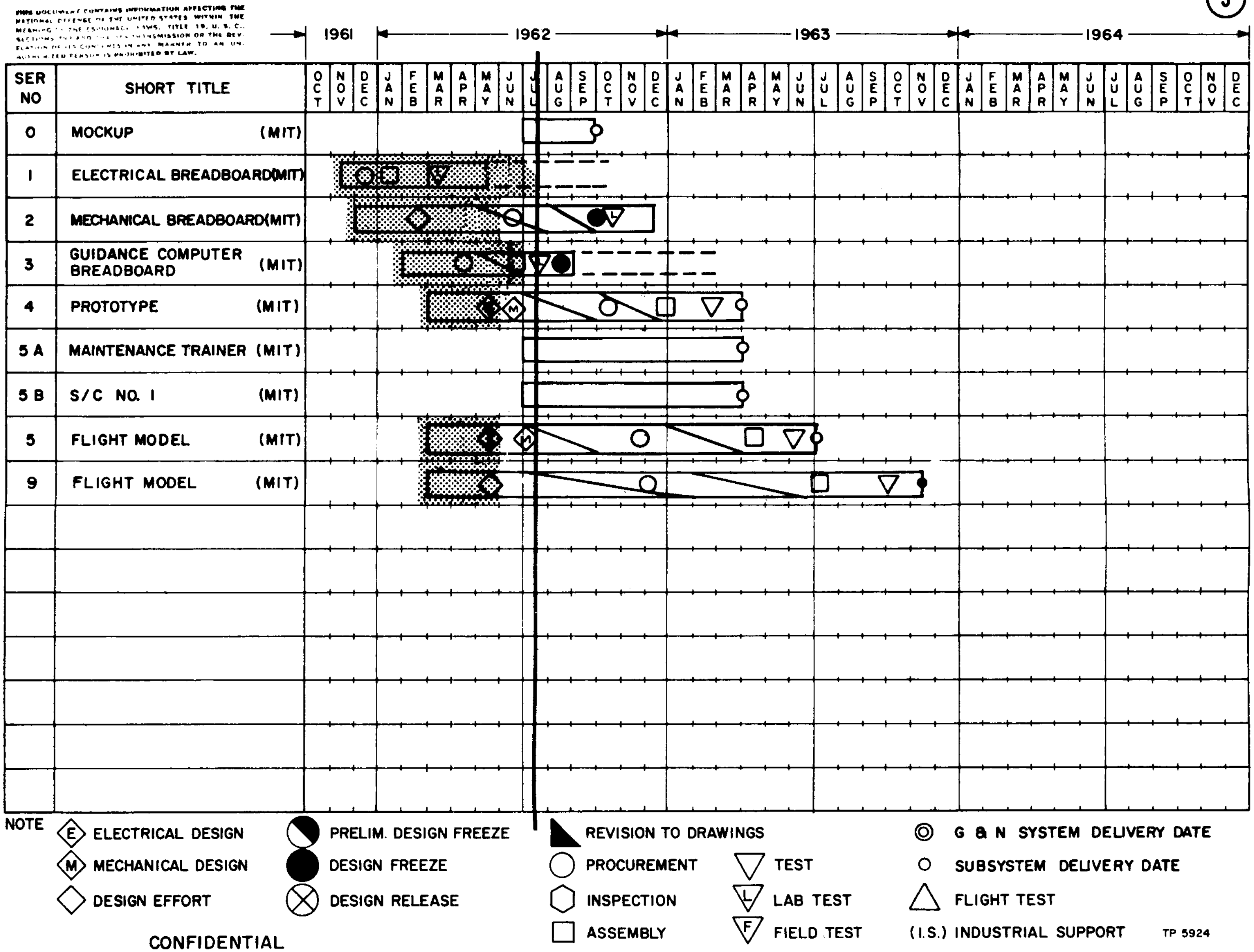
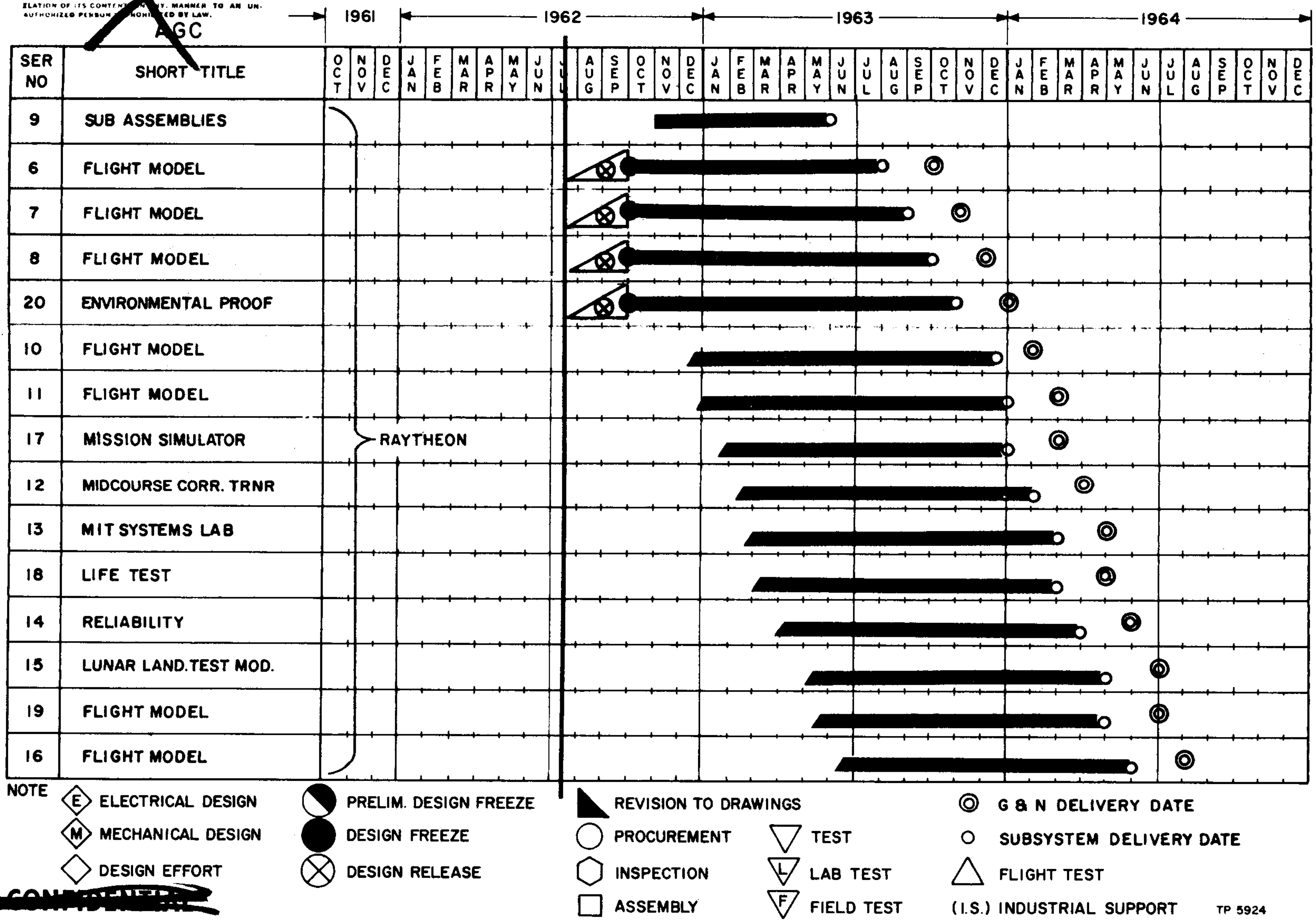


Fig. 6-2a

[redacted]

APOLLO MILESTONE CHART FOR GUIDANCE COMPUTER

[redacted]



[redacted]

Fig. 6-2b

[redacted]

1. COMPONENT RELIABILITY

- a. TRANSISTOR STEP STRESS LEVEL TESTING
- b. DIODE TESTS
- c. RELAY SHOCK AND LIFE TESTING

2. COMPUTER FAILURE DETECTION AND CORRECTION

3. TELEMETRY REQUIREMENTS

- a. SA 9 AND SA 10
- b. MANNED FLIGHTS
- c. GROUND DATA PROCESSING EQUIPMENT

4. AGCI AND IB

REPORT R-358

5. INTEGRATED CIRCUITRY

- a. CIRCUIT PARAMETERS
- b. PACKAGING CONFIGURATIONS
- c. THERMAL STUDIES

Fig. 6-3 Studies

[redacted]

There is some activity in the nature of methods of detecting computer failures and their correction primarily in the line of what the pilot would do in flight; that is, the programs necessary to detect these errors and isolate them down to one replaceable block, so that the pilot by interchanging blocks could repair the computer and put it back into working condition.

The telemetry requirements for SA-9 and SA-10, the two unmanned flights, are under consideration. For the unmanned flights additional telemetry will be needed to indicate (or in the guidance system of the vehicle, if recovered) what types of failures or problems have occurred in flight. The telemetry is somewhat simpler on the manned flights. The study on telemetry will try to work out the details of both the unmanned and manned flight. The ground data processing equipment is being studied to determine how to reduce the data and present it for quick-look summary.

AGC 1 is being used primarily for test now and computer 1B has been under test for a considerable time. The activity associated with 1B is covered in Report R-358 which is ready for distribution now.

Another group of activities is associated with integrated circuitry. With integrated circuitry the components, such as resistors, condensers, diodes, transistors, etc., are all built on one piece of silicon semiconductor material and put in one can which looks similar to a transistor can. There are various types of activities in the area of logic itself, particularly the circuit parameters of devices which are now in production. In the area of devices like sense amplifiers and core drivers and more specialized circuits, MIT and venders are working together to determine the advantages or disadvantages of using these devices for that type of circuit. In addition, package configurations are being investigated for reducing the computer size and weight. Then also, coupled with this, the thermal characteristics of the computer are being studied since the packages will be denser and there will be more problems with removing the heat.

[redacted]

SECTION 7
OPTICAL MEASUREMENT EQUIPMENT & DISPLAYS

John W. Hursh

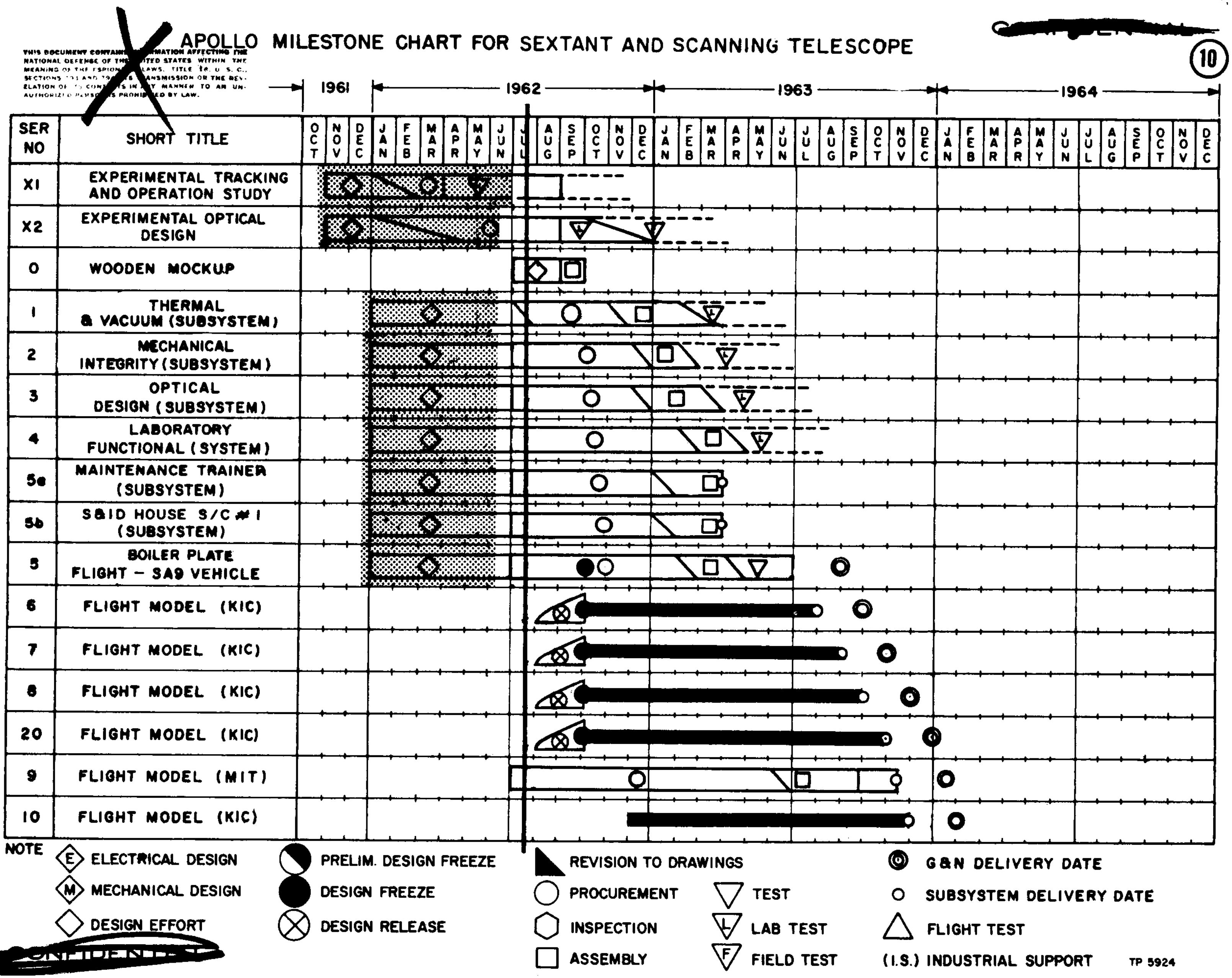
The following instruments are under development for the guidance system:

The space sextant, a dual line-of-sight instrument, is used to measure the angle between the line-of-sight to a star and the line-of-sight to a landmark on the earth or moon. It is also used to measure the elevation of a line-of-sight to a star above the horizon of the earth or moon; to detect occultation of the star by earth or moon; and to provide erection signals to the IMU. The scanning telescope .is a single line-of-sight instrument used as a finder for the sextant and for tracking landmarks during orbital phases of the mission. The navigation base, which is the common mount for the two optical instruments and the inertial measurement unit, is also under design in the division. Servo drives, hand controller, and digital readout electronics are being developed concurrently with the optical instruments. The design of the optical instruments and the controller electronics was described briefly in a previous report.

Figure 7-la is the sextant and scanning telescope milestone chart. Some of the features and studies in progress in support of the design should be mentioned. The experimental tracking and operations study making use of a pair of articulating mirrors with drives similar to those being used on the sextant is about completed. These mirrors, lent to MIT by the Nortronics people, have sextant drives very similar in design to those of the breadboard sextant. These have been connected to a Verdan computer to simulate the motion of the lines of sight and to observe images while the mirrors are moving. This might be called a breadboard of a breadboard. The X2 design (breadboard sextant) is under construction and has been described in previous reports, one of which is the request for a proposal that was sent out to the prospective participating contractors. The precision gears are expected to be received about the first of August. The wooden mock-up has not yet been started.

A thermal lab has been set up for study of thermal control of instrumentation in vacuum environment. This consists of a vacuum chamber and a solar source that will be capable of testing a sextant and scanning telescope as a unit. Some tests on motors and on representative blocks of material, separated by substances which might be used in the design, have been made using this setup. The results to date have shown that Indium foil between surfaces improves heat flow under vacuum conditions by about two orders of magnitude. These experiments are being conducted primarily at Ilikon, a subcontractor, and chambers are being constructed at MIT for evaluation of assemblies.

[redacted]



[redacted]

Fig. 7-1a

[redacted]

A series of ball bearings of different materials have been tested, among which have been tungsten carbide and sapphire. These have been found to be superior to ordinary or plated balls, such as gold-plated balls. It has also been found that oil in Synthane retainers may do a more adequate job of lubricating than a solid lubricant. Gearing materials will be tested shortly using a solid lubricant. At present, a nickel-molybdenum disulphide matrix looks promising for the worm material.

In the area of mechanical integrity and testing gearing accuracy there is now available in the Laboratory a setup using Ultradex and Mydarm instruments with electronic counters capable of measuring to 0.5 seconds of arc for use in checking gears. When the breadboard sextant gears arrive (these are useable for either the breadboard sextant or the operational sextant design) they will be tested on this setup. There is a parallel program of gear development for high-accuracy gears. A gear is being cut at Riley in Tonawanda, while Bellock will start cutting the worm soon; these will be compared with the gears that are being procured from Nortronics.

Vibration and structural rigidity design studies are being conducted by MIT, and by AC Spark Plug as participating contractor, for the navigation base.

The electronics for various sextant drives and controllers are under development. The geometry of the line-of-sight control has been mechanized in a command gear box assembly. Modes of operation using the hand controller, the Apollo guidance computer, and spacecraft stabilization and control system, are being worked out in detail. The breadboard work of the servo drive amplifiers for the command gear box, used to produce precision rates of the line-of-sight, is complete and the design is about ready for release. The sextant drive servo amplifiers have been breadboarded and work is in progress. Breadboard work is nearly complete on the computing resolver drive amplifier for use in the sextant control and resolution system. Breadboard work for the two-speed servo system which links the command gear box to the sextant and scanning telescope is progressing. A 256-speed fine course switch has been designed for use in the servo and work is proceeding on the digital readout circuitry for the incremental encoders, as well as the zero reference on the sextant. The design release is scheduled to start about August 1st. The Kollsman people are participating and we have requested all their resident people to work in the development of the controller electronics in order that they can design and build the test equipment for the sextant in their plant. These people will be in residence at the Laboratory soon.

The area of optical design and feasibility studies and experiments, in support of the sextant work in general, includes a ray trace analysis program. The object of this is to determine image quality and feasibility of proposed lens systems and system tolerances by means of a digital computer program. Several ray traces of optical trains pertinent to the scanning telescope have been made. In addition, Kollsman is conducting an optimization study on the lens design for the scanning telescope. The sextant train will be analyzed when the radii of curvatures and indices of refraction are available for all the elements. The existing ray trace computer program is being modified to become capable of redesigning an optical train to remedy aberrations caused by introduction of plates and prisms into the optical train. This program is in the process of being debugged. Experiments are being carried out on measurements of scattered sunlight from optical elements and surfaces. Experimental test equipment is being assembled, with plans to use the results in the optical instrument designs.

Component error analyses are proceeding and some of the tolerances have been established. Presently, the pyramidal error tolerances of the articulating dove prisms of the sextant and scanning telescope are being developed.

The studies on image motion and modulation, as well as appearance of the objects as viewed through the sextant, are progressing. The object is to measure the usefulness of this sort of device, referring to modulation in particular in aiding detection of a star against a landmark or lunar feature. An experimental setup has been made using the unaided eye in viewing an artificial star against a bright field background. The field is variable. Artificial stars then blink at various frequencies and on-off ratios, and results so far indicate that blinking or modulating the star is a disadvantage when the star is near the threshhold of visibility. There may be some merit in modulating the landmark, however, and this is being investigated.

Graphs have been made for general use showing up the spectral envelope of five different color temperature stars throughout the range from red to blue. These have been multiplied point by point with the spectral sensitivity of the eye to show the actual color appearance of the star to the observer.

In the area of automatic eyepieces, two non-visual eyepieces are being investigated and designed. The first, of relatively low sensitivity, will be used during system erection at the launch site. The second will be used to automatically find the angle between a navigational star at a particular altitude above the horizon. The design of a suitable motor for the latter non-visual eyepiece has been started.

Figure 7-1b shows the remainder of the systems to be furnished by Kollsman, the participating contractor in the optical area.

Midcourse Guidance studies are proceeding as show in Figure 7-2a and 7-2b. The Mercury MA-7 mission data has been received and measurements have been made on 26 frames of blue and red earth horizons using the microdensitometer in the Harvard Physics Department. The experiments were set up so each frame was exposed with a double filter, a red and a blue, with a line separating the two down the center of the frame perpendicular to the horizon. Measurements have been made at two zones close to the boundary between the two filters against the reference line. The results from

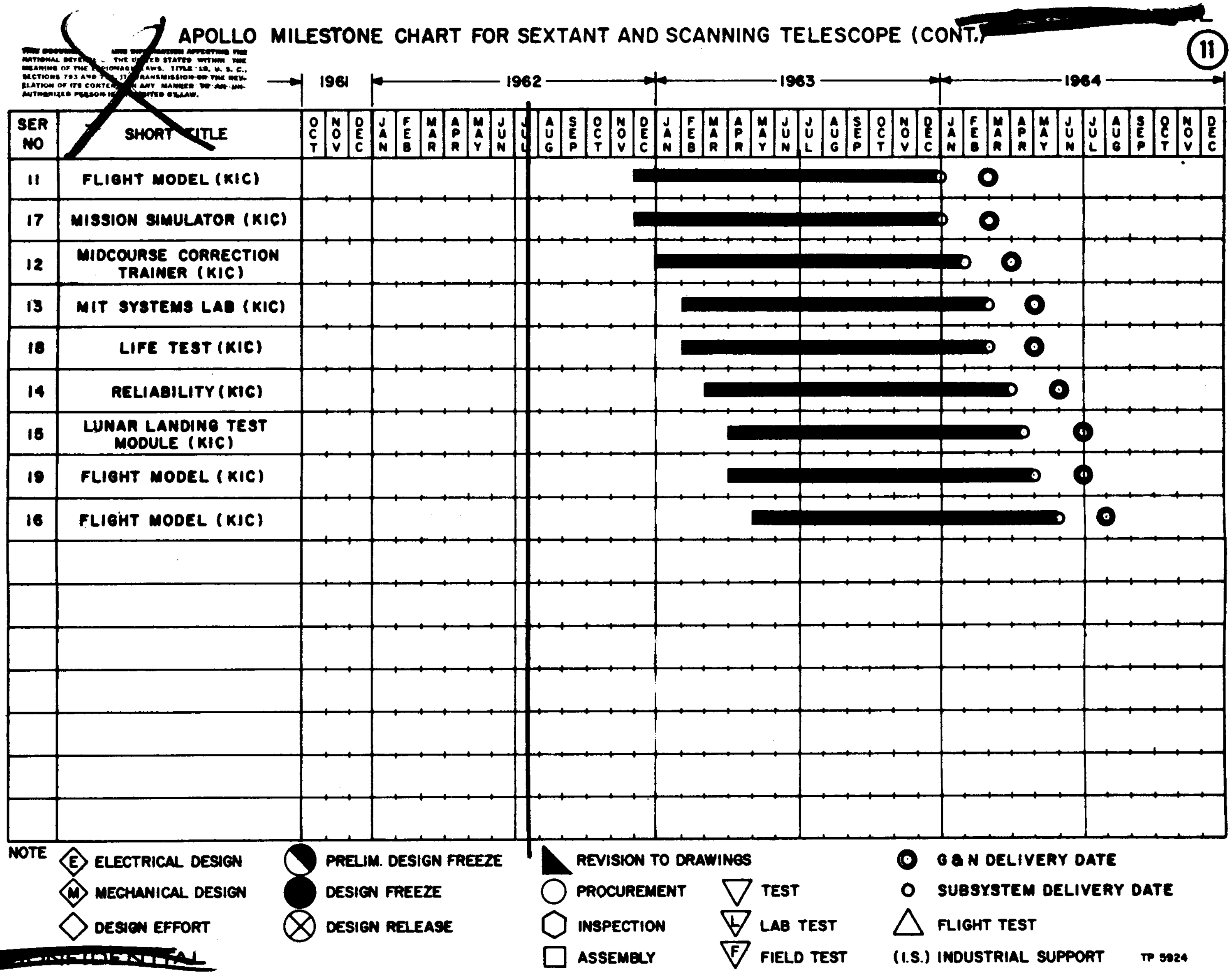
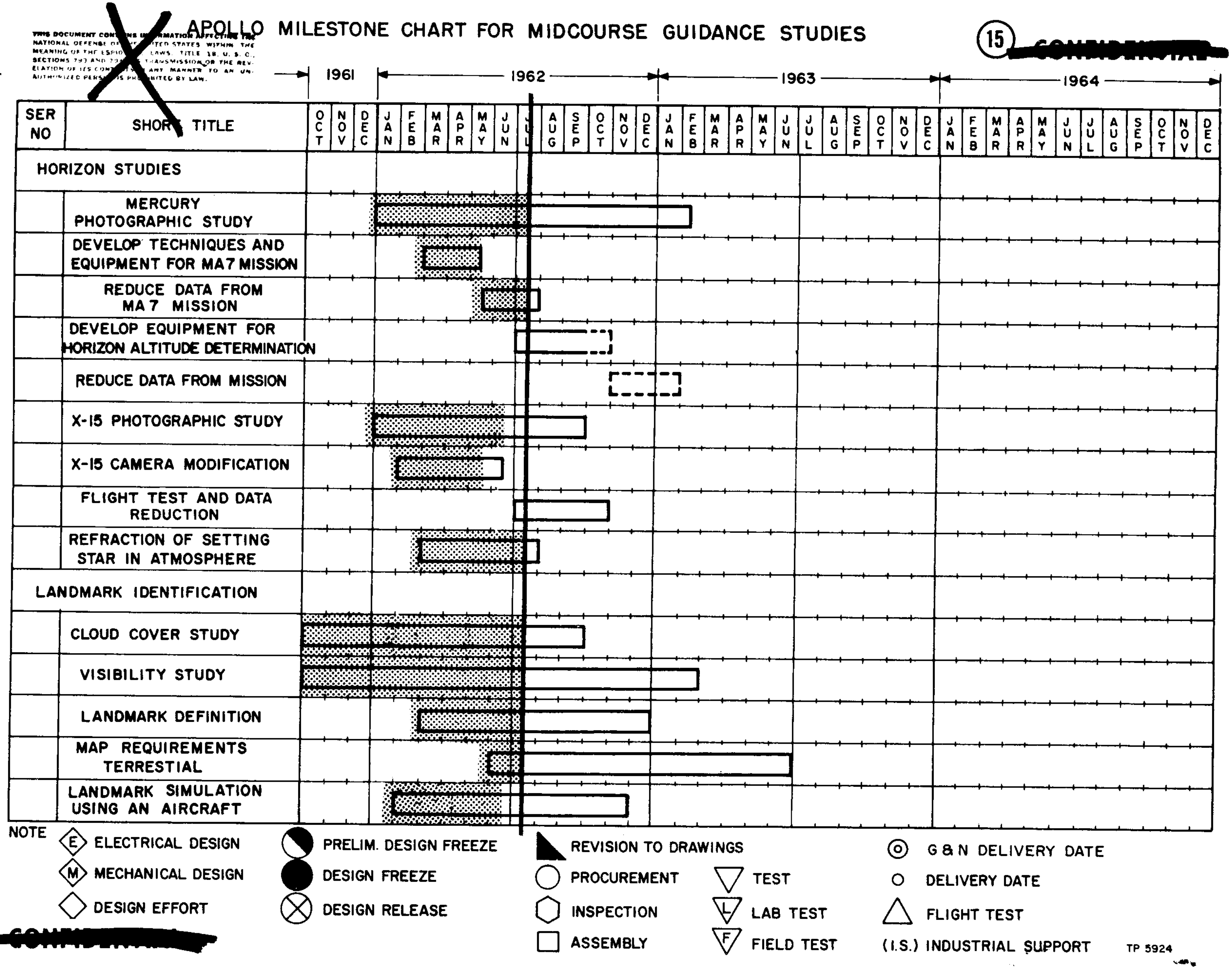

APOLLO MILESTONE CHART FOR SEXTANT AND SCANNING TELESCOPE (CONT.) [redacted]
11
1961
1962
1963
1964
SER NO
SHORT TITLE
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
11 FLIGHT MODEL (KIC)
17 MISSION SIMULATOR (KIC)
12 MIDCOURSE CORRECTION TRAINER (KIC)
13 MIT SYSTEMS LAB (KIC)
18 LIFE TEST (KIC)
14 RELIABILITY (KIC)
15 LUNAR LANDING TEST MODULE (KIC)
19 FLIGHT MODEL (KIC)
16 FLIGHT MODEL (KIC)
NOTE
ELECTRICAL DESIGN
MECHANICAL DESIGN
DESIGN EFFORT
PRELIM. DESIGN FREEZE
DESIGN FREEZE
DESIGN RELEASE
REVISION TO DRAWINGS
PROCUREMENT
INSPECTION
ASSEMBLY
TEST
LAB TEST
FIELD TEST
G & N DELIVERY DATE
SUBSYSTEM DELIVERY DATE
FLIGHT TEST
(I.S.) INDUSTRIAL SUPPORT
TP 5924
[redacted]

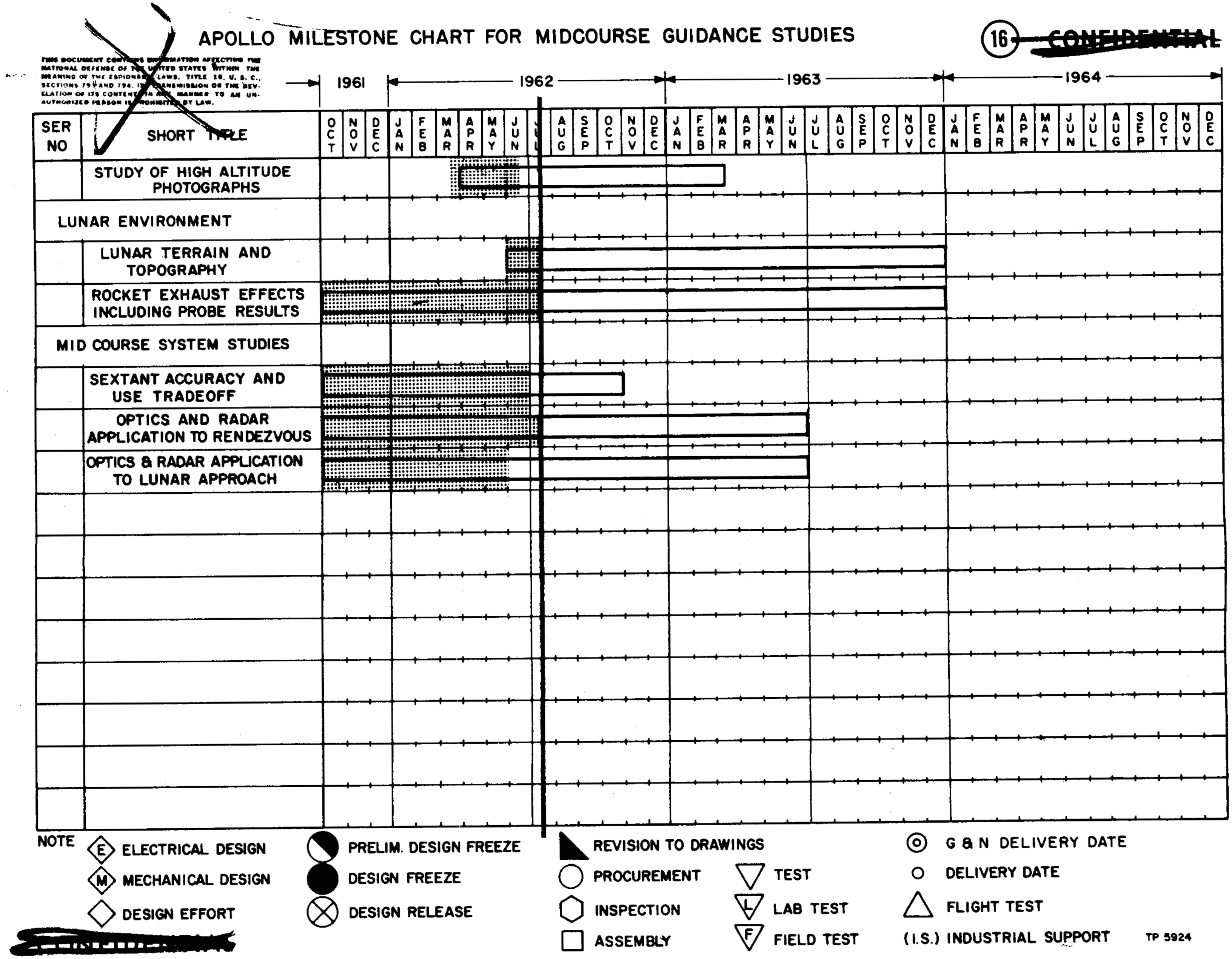
Fig. 7-1b

[redacted]



[redacted]

Fig. 7-2a



APOLLO MILESTONE CHART FOR MIDCOURSE GUIDANCE STUDIES
16
CONFIDENTIAL
THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U. S. C., SECTIONS 793 AND 794. ITS TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.
1961
1962
1963
1964
SER NO
SHORT TITLE
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
STUDY OF HIGH ALTITUDE PHOTOGRAPHS
LUNAR ENVIRONMENT
LUNAR TERRAIN AND TOPOGRAPHY
ROCKET EXHAUST EFFECTS INCLUDING PROBE RESULTS
MID COURSE SYSTEM STUDIES
SEXTANT ACCURACY AND USE TRADEOFF
OPTICS AND RADAR APPLICATION TO RENDEZVOUS
OPTICS & RADAR APPLICATION TO LUNAR APPROACH
NOTE
ELECTRICAL DESIGN
MECHANICAL DESIGN
DESIGN EFFORT
PRELIM. DESIGN FREEZE
DESIGN FREEZE
DESIGN RELEASE
REVISION TO DRAWINGS
PROCUREMENT
INSPECTION
ASSEMBLY
TEST
LAB TEST
FIELD TEST
G & N DELIVERY DATE
DELIVERY DATE
FLIGHT TEST
(I.S.) INDUSTRIAL SUPPORT
TP 5924

Fig. 7-2b

the densitometer measurements are the transmission factors of the film and these must now be converted to relative brightness values (gradient) using density exposure characteristics of the emulsion. These can be obtained from the pre-exposed portions of film that were carefully calibrated prior to loading the magazine for Commander Carpenter's use. This work is progressing with some preliminary results.

It has been found that in all cases the blue horizon is farther from the earth than the red. Because the latter is lower it shows many clearly discernible cloud images. The difference in radial scale will be evaluated on completion of applying the density exposure characteristics of the emulsion to the transmission characteristics already measured. A preliminary conclusion will probably be that the red area cannot be used. The data from the Mercury flight, as obtained, will not allow measurement of the height of the horizon above the earth's surface. A possibility of obtaining this data was discussed briefly in the previous meeting and would involve more elaborate instrumentation aboard the Mercury capsule. This is not feasible unless some other piece of equipment is removed; for, particularly where the Mercury people are trying to obtain longer times of flight, weight is at a tremendous premium. A study is under way of some means to do this with equipment similar to what was used on the first flight, particularly the possibibility of using a bright planet image that is visible in a frame, knowing the position of the capsule, to get some idea of the height of the horizon. The question is, how can the time of exposure be determined if a clock is not visible in the frame of the film?

The X-15 instrumentation is proceeding but has been held up somewhat since more effort has been concentrated on the Mercury work and evaluation of data. There is now a man aboard who will spend full time on it and complete the modification on the 16-mm automatic camera that has been obtained for use in one of the bugeye positions in the X-15. The filter is being installed in the camera which hopefully should be at Edwards Air Force Base shortly. The people at Edwards AFB have offered to load the camera with precalibrated film, run the tests, and send the film back either developed or undeveloped as requested. One advantage of using the X-15 is that the timing of the camera exposure can be tied to the central data recording system onboard the aircraft, which will permit accurate determination of the attitude and position of the ship, and the time that the exposure was taken. Data on horizon height not obtainable from the Mercury flights might be obtained from the X-15. Also, when the equipment has been checked out it may be that MIT can have an input to the flight plan on certain missions; but this has not yet been requested.

In the areas of landmark identification, cloud coverage studies, visibility studies, and landmark definition, data from high altitude pictures at Air Force Cambridge Research Center will be used in studies to locate suitable landmarks. The

Air Force Chart Information Center was visited to talk over the types of maps that are available, both terrestial and lunar. Visits on this are also planned with Dr. Dornbach in the Manned Spacecraft Center; the U. S. Geological Survey; and the Army Map Service. The work is essentially complete on modifying a twin engine Beechcraft by installing a surplus drift sight which will be used on simulated landmark flights in the local area, using small islands and coastlines that are appropriately scaled. There has been a delay because this installation must be certified by the FAA. The problem is to choose world-wide landmarks and then gather statistical data on the probability that these landmarks may be covered by clouds. Results from Tiros may be used, but would have to be tied to other higher definition photographs in order to select a particular landmark.

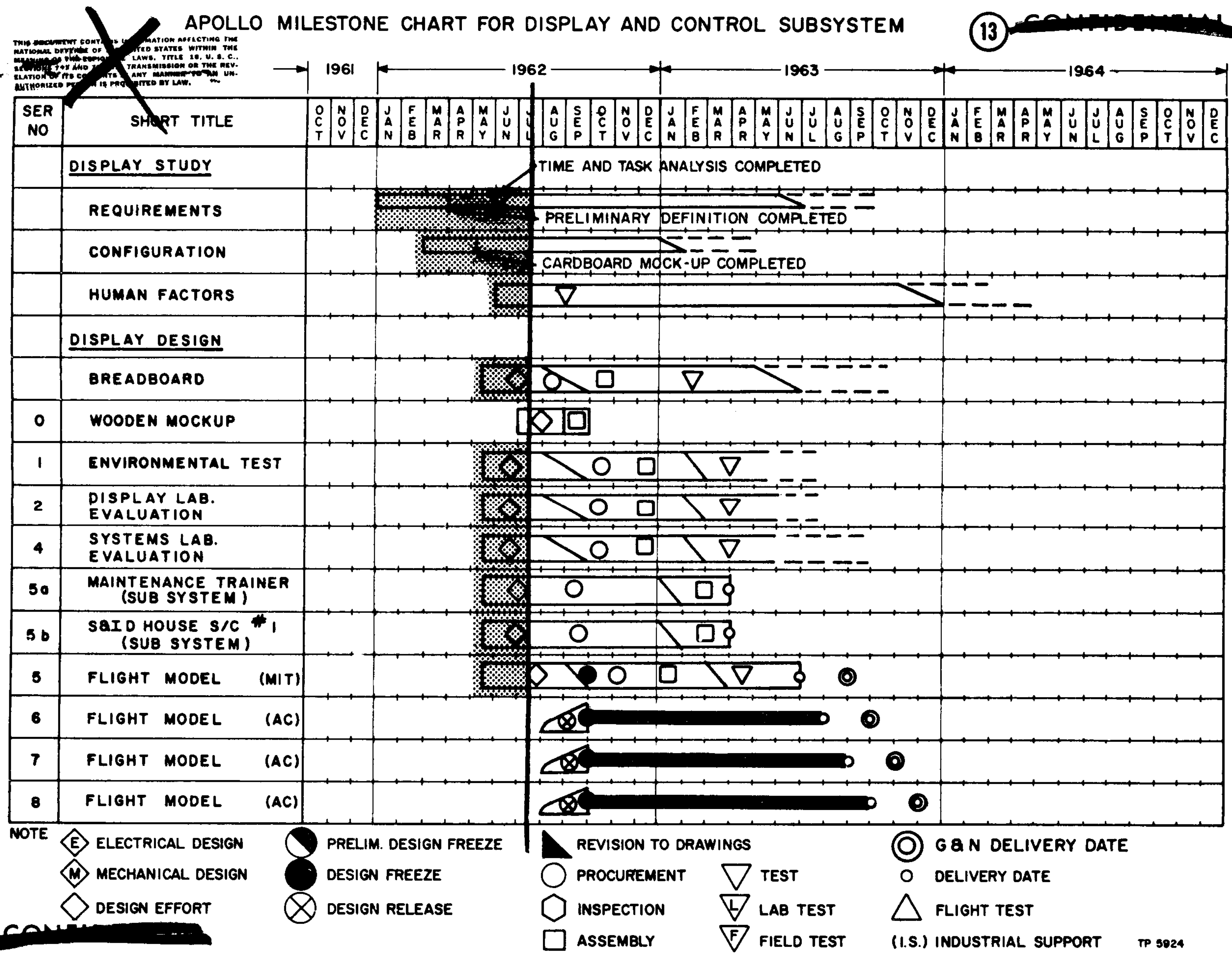
Information on lunar terrain studies, topography, and the area of exhaust effects is becoming available. Dudley Shepard, in a previous meeting, presented the analytical studies that he carried out and has submitted a report in a letter to NASA listing the findings of these studies and making recommendations. Those particular studies have been terminated here at MIT, but NASA is continuing the studies and experiments at Langley and will of course advise MIT of the results.

Midcourse guidance system studies are being influenced a great deal by the reduced requirement for maintaining orientation of the spacecraft with respect to the sunline. North American advises that the study of spacecraft orientation made at MIT's request is nearing completion. It appears that roll axis orientations away from the sunline may be in the order of hours rather than minutes, as was first assumed. The effect of this result on the use of maneuvering fuel prior to taking the midcourse measurements using the sextant is being investigated.

The studies of optics and radar application to rendezvous and lunar approach are proceeding but have been held up somewhat because of the unknown impact of the decision to go to the LEM (lunar excursion module) concept.

Figures 7-3a and 7-3b summarize the work in the display and control area. The display work covers the development of general instrumentation for guidance and navigation systems display and control together with an optical device for storing and presenting visual information. The studies leading to the definition of arrangements, modes, and methods of operations are included. The study is proceeding using a cardboard mock-up for the design configuration, layouts, etc. After several meetings with S&ID of North American, one in the middle of June and one just concluded, decisions were reached regarding the location of the guidance and navigation system in the lower equipment bay. This permits detailing the design of the instruments and their size, location, and capability with respect to the guidance system and general spacecraft mission. All efforts are concentrated right now on the lower equipment bay area, including specification of the instruments and controls, and

[redacted]

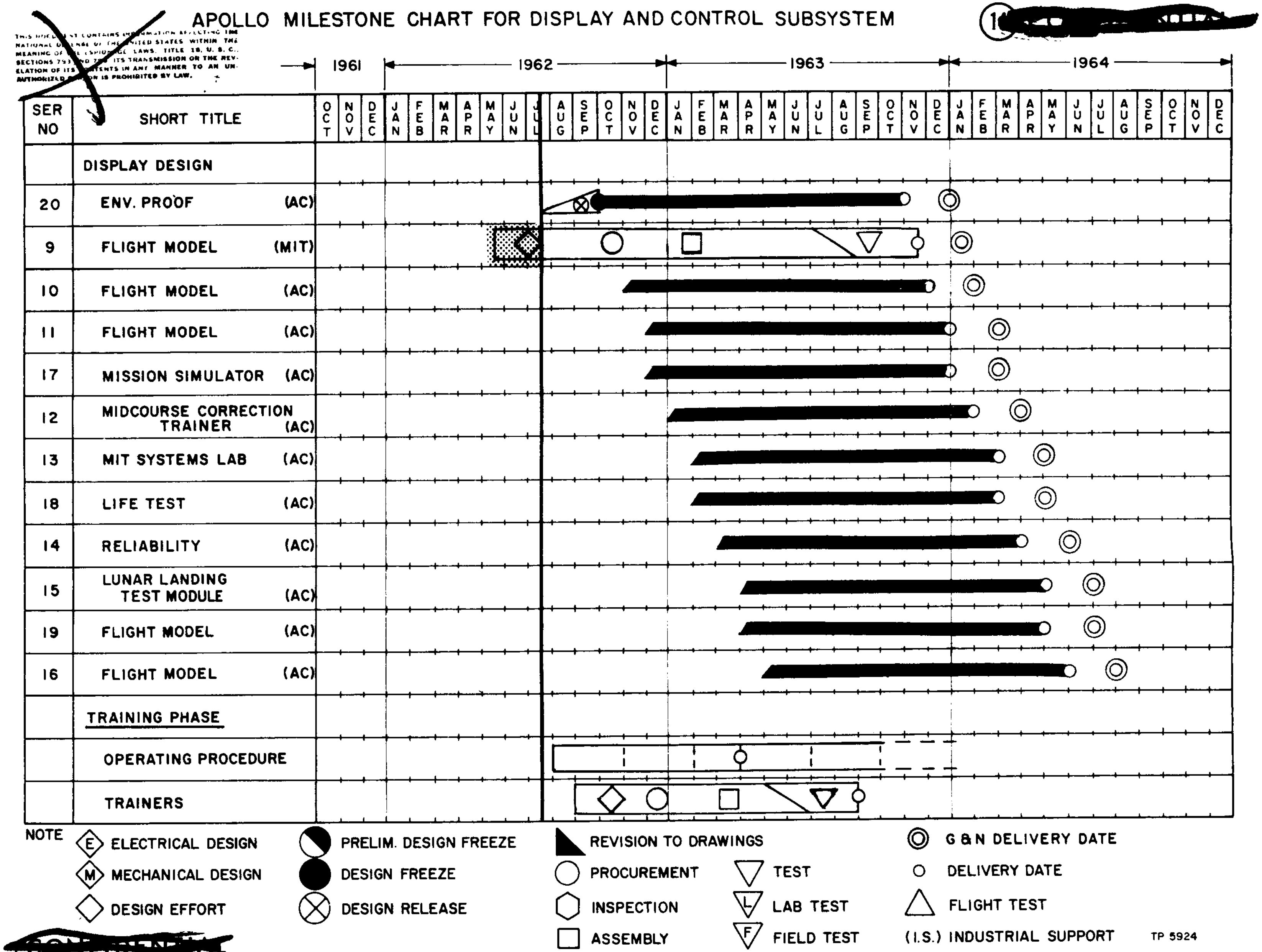


[redacted]

Fig. 7-3a

[redacted]

[redacted]



[redacted]

[redacted]

Fig. 7-3b

[redacted]

design of the mounting means. AC Spark Plug engineers and designers are participating particularly in the area of design of the display panel and mounting for the instruments, stress analysis, etc. The displays to go on the main panel will be supplied to S&ID with the information needed in order to integrate the instruments into the central display.

The services of a human factors consultant have been retained. Experiments are being designed to simulate the operations of using the optical instruments. A breadboard display under design will be an operating display and will include a Verdan digital computer making the displays function as they will when the operational display is combined with the rest of the system. Most of the display and control instrumentation will be produced by AC Spark Plug. The delivery schedules in Figure 7-3 are keyed to the main delivery schedules for the G & N systems.

The map and data viewer of Figure 7-4 is an optical instrument being designed in the MIT Laboratory with the assistance of the Kollsman people and will be produced by the latter. It will have a 5 x 8 inch screen and will make use of dual 16-mm magazines designed for manual operation with a changeover arrangement so that either magazine can be viewed. One would be used primarily for maps and the other for checklist and numerical data. Delivery of the map and data viewer is keyed to the first manned flight. Two instruments will be required per system; one in the lower equipment bay and one in the main panel.

APOLLO MILESTONE CHART FOR MAP AND DATA VIEWER

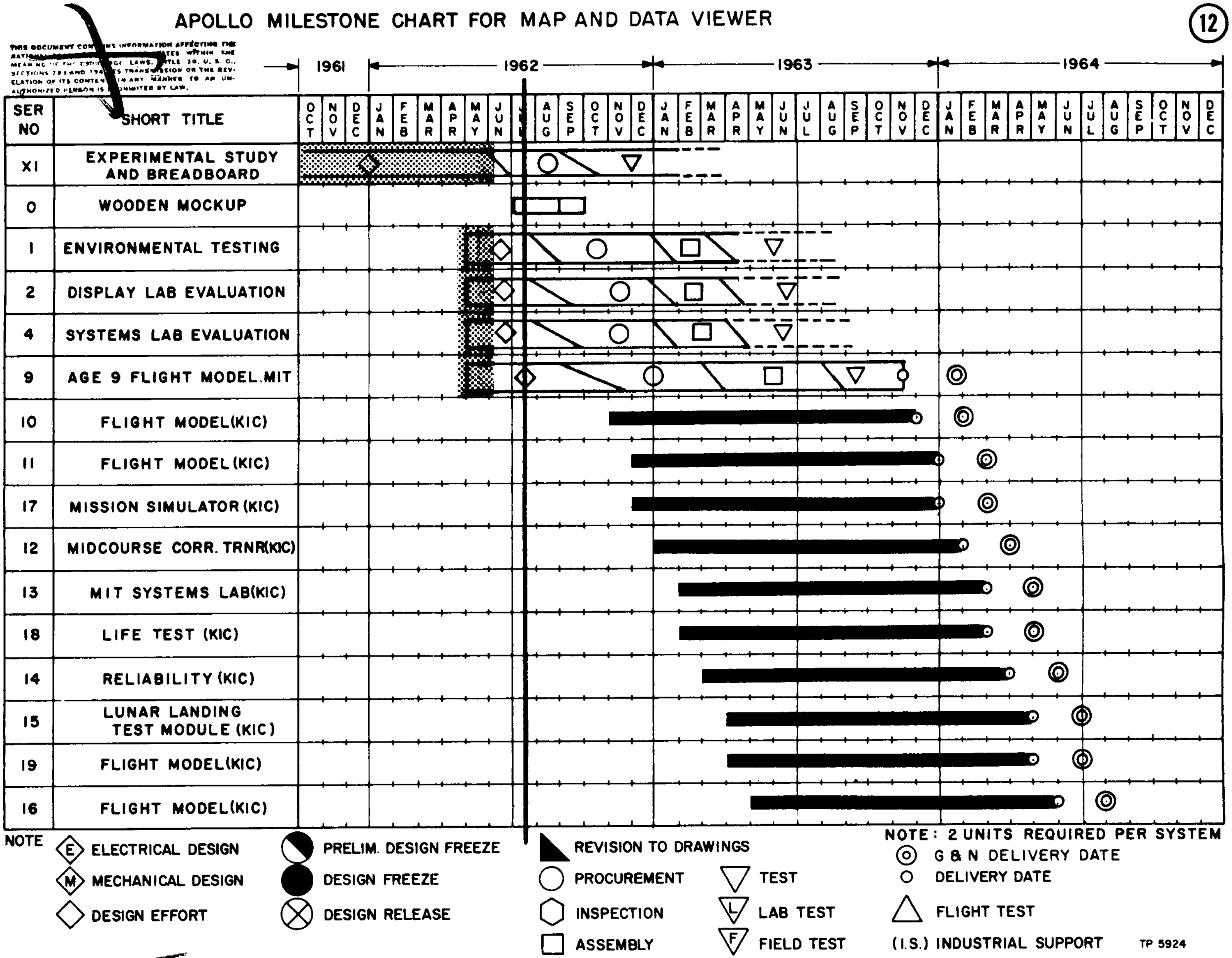


Fig. 7-4

SECTION 8
GROUND SUPPORT EQUIPMENT

E. A. Olsson

The detailed design, manufacture, and assembly for the ground support equipment is being performed entirely by our participating contractors, Raytheon and AC Spark Plug. Consequently, the important items on the milestone chart of Fig. 8-1 are somewhat different from other milestone charts.

The important items of principal interest are the delivery dates of design specifications and of complete systems. Freeze date for the electrical design is 1 September and for mechanical design 1 October, at which time the problems to a great extent become the responsibility of AC Spark Plug and Raytheon. Included in this milestone chart is the method by which AC Spark Plug decided they could live within these design specifications and this delivery schedule. Their conclusion, as stated during the negotiating sessions, was that they would be able to meet these schedules, even though the first two would be rather difficult. In order to meet this early schedule, the first two would be model shop units rather than production units.

As of this time, the participating contractors have been on-board for six weeks. A good deal of progress toward evolving these specifications has been accomplished. Raytheon has been on vacation for the last two weeks; however they generated a very good first cut at the design of the computer GSE before they left. Basically the GSE is about on schedule toward the release of TD's completely by 1 September, or 1 October.

The major accomplishments during these last two months have been the evolution of a reasonable concept of the ground support equipment for the guidance and navigation system. A principal objective has been to build into the design sufficient flexibility to accommodate the various system changes that can be expected over the first several systems without major GSE modifications and yet to be simple enough in design to meet the early delivery schedule.

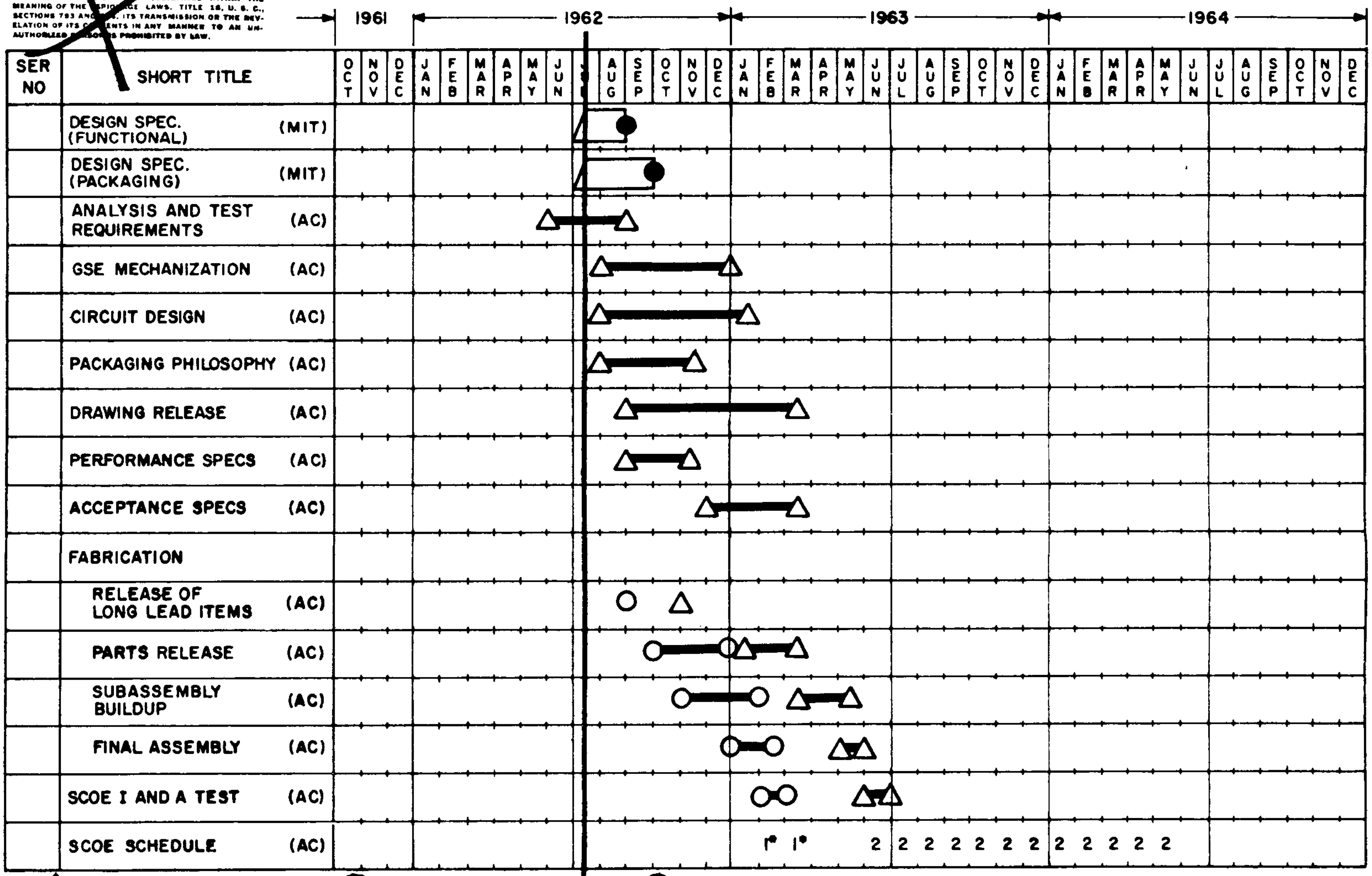
The concept that has evolved is reflected in Fig. 8-2. This consists of post-installation equipment, launch site equipment, as well as equipment for the spacecraft assembly area, the vertical assembly area, and the launch pad. It is built around a requirement of as much as twenty miles between the control area and the spacecraft. Basically, it is a two-operation ground support equipment concept which is run concurrently via the computer GSE, via telemetry, and via hard lines. The normal operation of the guidance and navigation equipment can be run through. It can be either commanded or monitored. The intention is to run through the turn-on procedure which

[redacted]

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS. TITLE 18, U. S. C., SECTIONS 793 AND 794. ITS TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

APOLLO MILESTONE CHART FOR PARTICIPATING CONTRACTOR GSE

(17)



△ DELIVERABLE UNITS ● DESIGN FREEZE * ○ PROTOTYPE (I.S.) INDUSTRIAL SUPPORT

NOTE: ADAPTED FROM ACSP SYSTEM CHECKOUT EQUIPMENT (SCOE) DEVELOPMENT AND FABRICATION MILESTONE CHART, P. 4-17, ACSP PROGRAM PLAN DATED 29 JUNE 1962

[redacted]

Fig 8-1

[redacted]

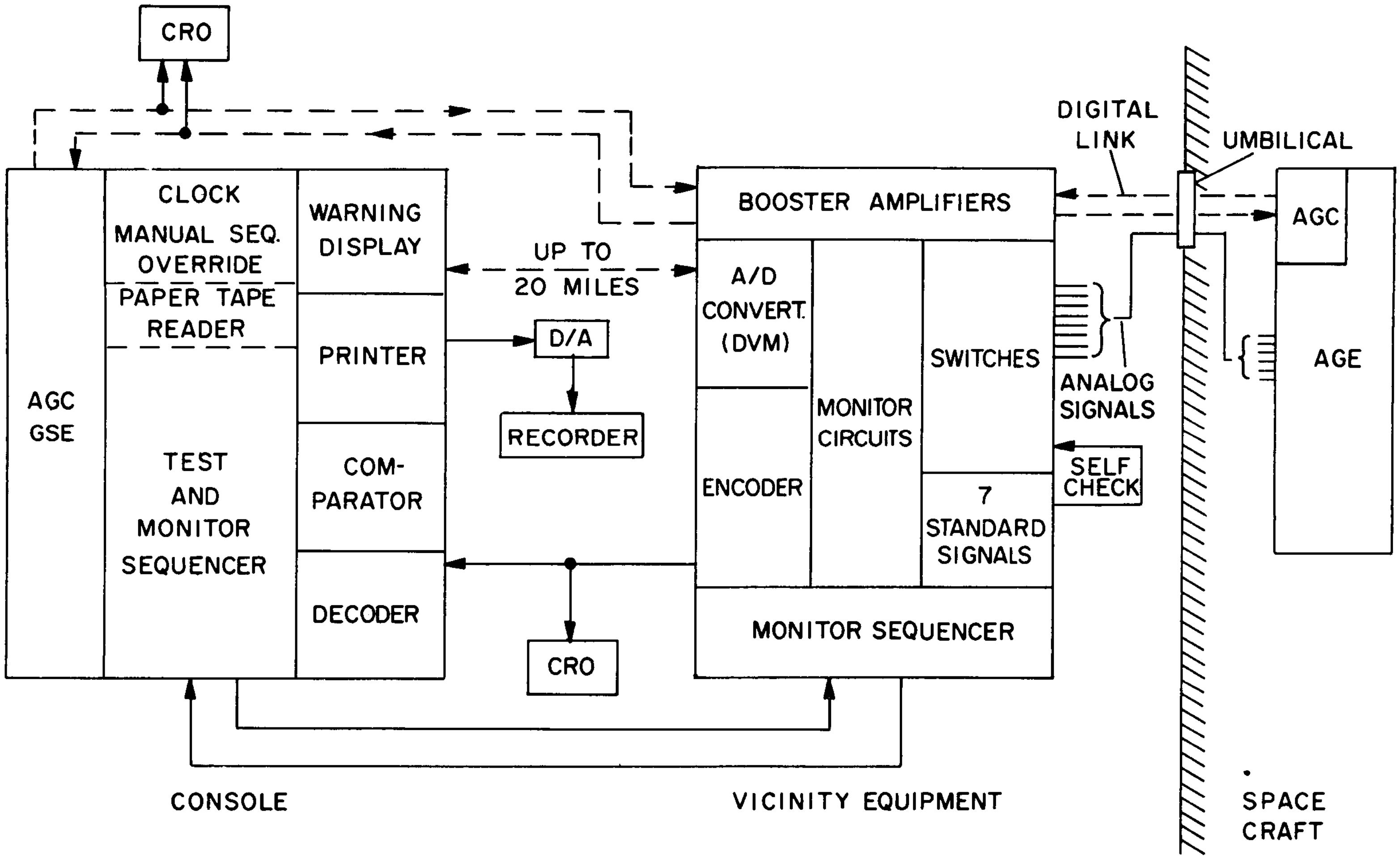


Fig. 8-2 Post installation Ground Support Equipment

[redacted]

is pretty well specified in some of Mr. Miller's AGANI pages; turn on, turn on the computer, get clock power, get the various power drive units operating right through coarse and fine erect. The only difference is that, where appropriate through the normal turn-on procedure, a check would be made of the computer memory at the time that it is turned on: a check of the constants, and a PIPA calibration test checking the scale factors and the biases to make sure that they are the same as already listed in the computer. Likewise, running through a sextant precision measurement and, in the process, checking that all the various warning lights are operable. In addition, one would exercise the sextant and scanning telescope to demonstrate that it will slew, can be slaved, and that the slewing capabilities appear to be within specifications. This is a fairly coarse type of operation, but does demonstrate all the various requirements of the system.

These operation can be performed automatically, via the AGC as indeed they must be for flights SA-9 and SA-10. However, in a manned flight or in the spacecraft assembly area where post-installation checkout is performed, it is planned to have this work done by an astronaut or by a simulated astronaut and have the results monitored via the computer GSE which will include, among other things, a complete replica of the computer display that is available to the astronauts and will also include a number of other words of display such as ΔV's and CDU angles and the sextant azimuth angle. At this point of the procedure, which might be two or three hours before the time of launch, the services of the astronaut are no longer required.

At this same time the automatic eyepiece would be used to lock the sextant on the target. The IMU is already locked to vertical. The GSE is then switched over to an inertial mode of operation with a computer program providing correction for earth rate and predictable drift, and, if the system is operating properly, the drifting of the inertial reference will be within the compensated one meru specification.

The degree to which the system is conforming to the specifications can be noted by measuring continually ΔV's on the stable member and measuring continually the sextant reading. The sextant reading should remain constant except for major deformation of the spacecraft and on the average the ΔV's should remain zero in the horizontal plane. This gives a "hold" right up through launch and indicates that the entire system is operating; the computer, the sextant, the IMU, and the power assemblies, everything is involved in this particular loop.

Simultaneously, but independently, a vicinity equipment is monitoring various key analog signals. For example, a continuous read-out via telemetry shows the status of all the condition lights and the warning lights which will be displayed in a duplicate warning display back at the control console. In a similar manner the voltage, power input, and various power outputs in the power and servo assembly will be monitored for such measurements as noise level, and distortion if it is significant. A series of approximately one hundred measurements sequentially performed is envisioned on a total of about 33 signals which will include most of the key points to diagnose trouble in the system; the IRIG and PIPA signal generator output voltages, the automatic eyepiece output voltages, and the various voltage levels. This information, via sequencing, is switched through various monitoring circuits (one giving RMS outputs, dc outputs, noise power level) in which the output in each case is a dc voltage passing through the A/D converter. The encoded signal is sent back through the 20 miles of hard line. The two cathode ray oscilloscopes indicate that transmission is being maintained along the two paths.

The various operations, the measurement operations, are sequenced from the console equipment. The master sequencer knows what is being measured and includes appropriate comparator values on punched tape. What the various "go", "no-go" limits should be for the particular signal are fed to a comparator; if it is "go" it would just continually sequence through. At the same time the various data coming back will be printed out and, in instances where desirable, such as watching the ΔV signals coming back from the computer, would be D/A converted and recorded. The intention is, with this dual operation concept, that the system will be exercised through its normal operating procedure while marginal checks will be made on the various key signals. Even in instances where something is "go", a sequence of longer than three hours may indicate that one of the signals is probably drifting toward being out of spec. and this system provides an opportunity to pick up this information.

The total umbilical requirements are something like 40, reasonably moderate requirements.

The sequencing is planned so that the operation can be performed automatically by its tape, automatic sequence, with capabilities for a manual over-ride such that if some particular signal, in the process of sequencing, does not look good one can command the sequence to stop, sit on that particular signal and watch it for as long as seems reasonable. It has been established that the bandwidth of the system is such that a data rate of the order of ten words per second would give as much information as would be required to analyze the activities of any particular signal.

The preceding launch pad philosophy is quite similar to that back at the spacecraft assembly area. There are a number of additional measurements that will be made. For the last time an end-to-end polarity check will be made at the vertical assembly building. Incidentally, all of the connections are either telemetry or via the umbilical at the pad. The last time that a cable is allowed to go through the hatch stimuli measurements will be made by varying the several voltages thus artificially generating signals to demonstrate that the criteria on the warning lights are working. The philosophy has been that, once erected out on the pad, nothing should go through the hatch nor should any artificial requirements be imposed on the system at this point.

In the area of preinstallation checkout, basically the same procedure is used except that more measurements are available: checking the bias and scale factors of the accelerometers as well as checking the error matrix, the misalignment matrix, gyro drift, and the precision of the sextant. Certain additional equipment will also be provided, such as a resolver checker and a checker for measuring the PIP electronics, strictly for diagnositic or trouble-shooting purposes if anything is discovered to be somewhat out of spec. during system operation in the preassembly area.

This concept has been the result of the principal study that has been continuing over the last six-to-eight-week period. There are, however, other studies that are going on. Briefly, these are:

1. Minimum signal requirements for operating the sequence. A literature search and a design study are in process.

2. A good reliable A/D converter that will withstand the environment at the umbilical tower. The environmental requirements vary considerably throughout the GSE equipment. The environment is quite benign back in the spacecraft assembly area and the control area. It perhaps gets a little more bumpy down in the equipment room under the umbilical tower but whatever vicinity equipment is required to be on the tower may expect a rough environment.

3. Independent consideration of the problem of vignetting for considerable spacecraft displacement and a narrow-beam collimated source.

4. Integration of guidance and control checkout procedures. Several discussions have been held with North American Aviation.

5. Standardization of measurement techniques throughout the testing cycle for the purpose of reliability and for quality control implementation for George Mayo.

6. Study of the telemetry requirements, not only for the ultimate manned flights, but also for SA-9 and SA-10.

The GSE post-installation facility will be physically situated in the same room and integrated with North American equipment. A single control room will control a single spacecraft all the way down the line.

SECTION 9
AC SPARK PLUG PROGRESS
Dr. Robert Sparacino

The first chart Fig. 9-1 may seem somewhat superfluous, but there does seem to be a communication problem. AC Spark Plug in general, has the responsibility for the production of inertial measurement units, power and servo assemblies, the navigation base, display and control panels, ground support equipment and finally, system integration. Items to be GFE to AC Spark Plug are the 25 IRIG (which AC has a separate contract for), the 16 PIP by Sperry, the computer by Raytheon, and the sextant by Kollsman. Throughout our own program these are the basic terminologies that will be used and referred to.

Figure 9-2 is an AC Spark Plug organization chart. Mr. Anderson, Vice President and General Manager of AC Spark Plug directs the entire AC Spark Plug operation. Dr. Blasingame is in charge of the Milwaukee division, of which we are a part, and the following directors report to him: Mr. Hal Yost, Director of Reliability; Mr. Don Atwood, Director of Engineering; Mr. Howard Roat, the Works Manager. Finally, all projects, of which Apollo is one, report through the Director of Engineering. The other projects currently are Titan, ACRD, etc.

The Apollo organization chart of Figure 9-3 is familiar to most of you. Some growth is indicated in the Manufacturing and Reliability Sections. Fundamentally there are five groups reporting to the Program Director: Engineering, the Project Office (which is concerned with the business management of the contract), Contracts Administration, Manufacturing, and Reliability.

Most of the work to date has been done in the engineering group. Primarily it has been a matter of education, i.e. finding out what has been done and what is new. The defining areas are the Systems Assembly and Test area which is a system integration, the Ground Support System, and the Airborne Equipment. The Airborne Equipment Section includes the power and servos assemblies, the inertial measurement unit, the navigation base, and the display and control panels.

The PERT network has been set up and a preliminary chart has been submitted by B. Lynn. A small preliminary group has been established in Manufacturing to look ahead and see what the problems are going to be.

IMU	Inertial Measurement Unit	ACSP
PSA	Power and Servo Assemblies	ACSP
NB	Navigation Base	ACSP
D&C	Display and Control Panels	ACSP
GSE	Ground Support Equipment	ACSP
SAT	System Assembly and Test	ACSP
Inertial Components		
25	IRIG	ACSP
16	PIP	Sperry-Rand
AGC	Apollo Guidance Computer	Raytheon
SXT	Sextant	Kollsman

Fig. 9-1 AGE Apollo G & N System

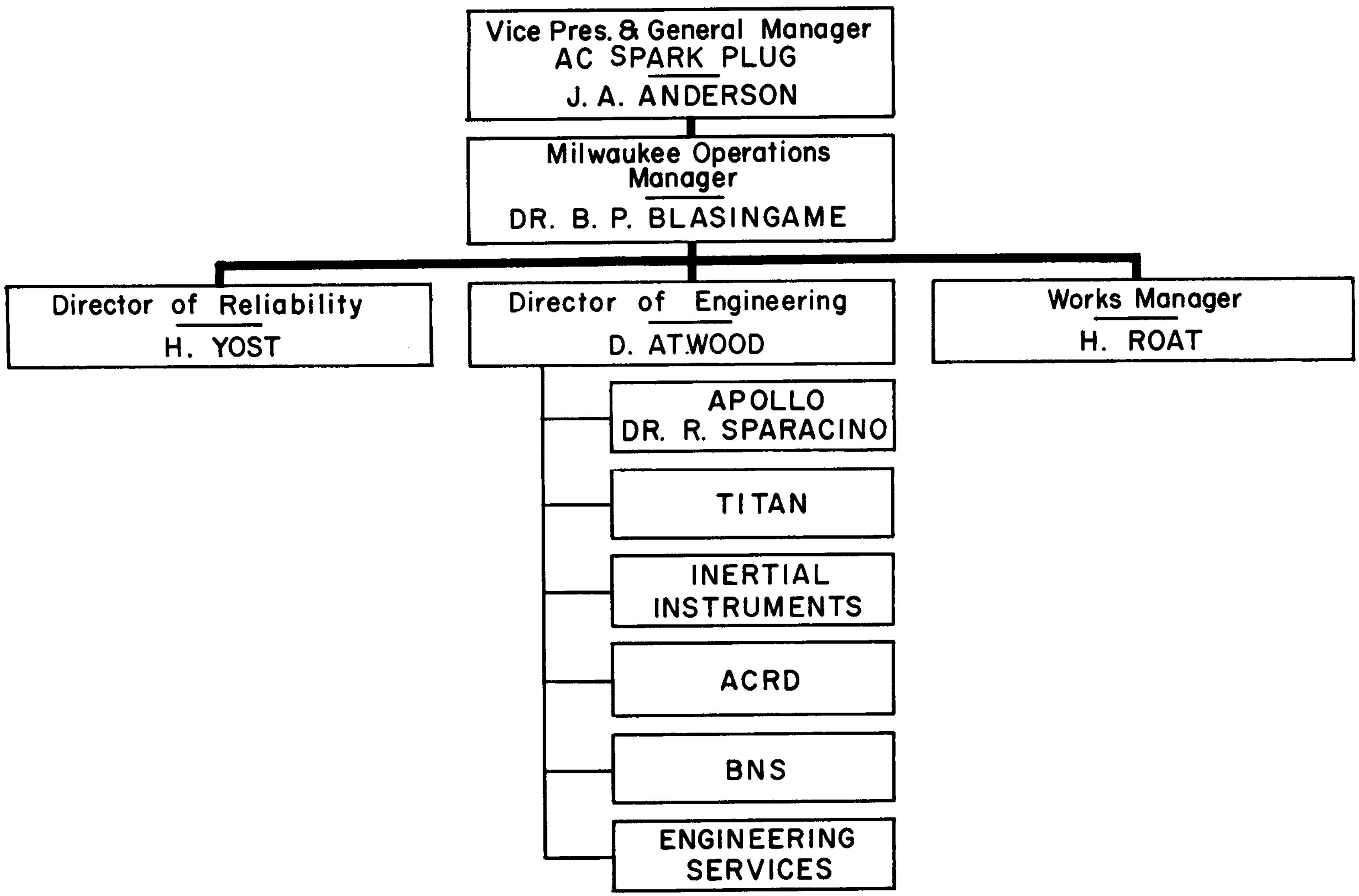


Fig. 9-2 ACSP Organization

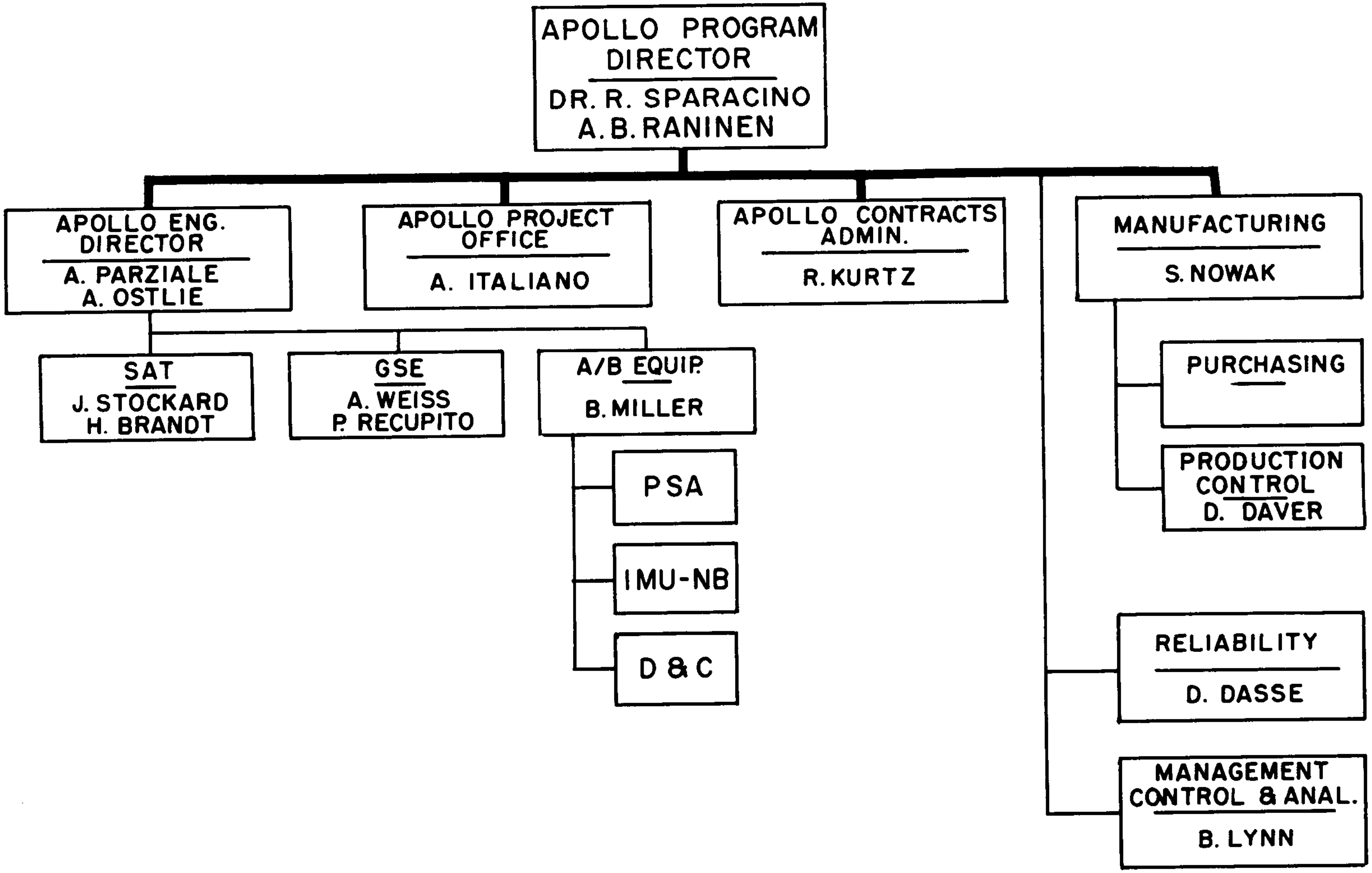


Fig. 9-3 Apollo Organization

Primary effort almost from the beginning was with the GSE where AC Spark Plug worked with Mr. Olsson on the conceptual details. GSE effort has occupied a considerable amount of time, but work has also been going on in the IMU and power and servo assembly areas.

Figure 9-4 shows what has been accomplished since the beginning of the program six weeks ago. First, the establishment of an organization. Second, the level-of-effort assignments. There is a requirement for 24 level-of-effort assignments and at the present time 20 have been filled. The delinquency can be explained as follows. Originally it was anticipated that 15 would be the maximum needed during the life of the program. Since these are principally key people the increased requirement has resulted in some lag. The level-of-effort assignments are extremely useful and it has been found that the learning curve is directly proportional to the LOE assignments.

A preliminary program plan was prepared and submitted on June 30. This effectively established major and minor milestones, indicated how the job would be performed, and indicated the time schedule. In addition, due to the increased scope, a scope definition phase was gone through and on July 14 the new cost proposal was submitted.

First, what is our operational philosophy? Technical Directives will cover level-of-effort assignments here in-house and/or assignments within the AC Spark Plug organization. Second, the requirement is to investigate reliability and producibility on the program. Third, and this is quite important, we have been given to understand that part of our responsibility is to offer to you our professional advice on things that we are told to do.

What is on the fire for the future? The level-of-effort assignments will be completed in the relatively near future. We anticipate other level-of-effort assignments that have been asked for, but where starting dates are perhaps two to six weeks away from now. We are also anticipating a considerable increase in our own in-house activities. It is very important for us to participate as closely as possible in the MIT internal coordination meetings. Let me recommend that wherever possilble if you have having a meeting and feel that the transfer of information can be most efficiently performed by having an AC Spark Plug representative attend the meeting, please do so.

There will not be any deliverable hardware manufactured in Wakefield. There will be some hardware work associated with the mechanization problems, but the model shop facility in Milwaukee will be used to build the GSE prototypes and the production facility in Milwaukee will be used to produce the balance.

1. ESTABLISHMENT OF ORGANIZATION
2. LOE ASSIGNMENTS
3. PRELIMINARY PROGRAM PLAN
4. SCOPE DEFINITION

Fig. 9-4 Accomplishments

SECTION 10
RAYTHEON PROGRESS
Thomas P. Cutler

The Division of Raytheon engaged in work on the Guidance Computer is the Missile and Space Division with headquarters in Bedford, Massachusetts. The Apollo work is done in the Sudbury plant and it shares this plant with the Polaris project. Since the work and techniques are very similar, this is an optimum arrangement. The exception to this location of Apollo personnel is that our System Analysis people working for Dr. Battin will operate out of our Bedford plant.

The first two weeks were spent establishing a Project Office. Our first TD was for this organization. The chart of Fig. 10-1 indicates how we have set up to manage the program. I report directly to the Vice President and General Manager of the Missile and Space Division. There are two technical directors. Dr. Nesline is Technical Director of our Systems Analysis Group and has several people assigned to him who are at present resident at MIT. He will have more people assigned for programming as time goes on. Mr. Jack Poundstone is Technical Director of the Computer and GSE equipment. The Program Management Director, Mr. Bob Froncillo, has Administration, Purchasing, Documentation, PERT and Planning, and Program Coordination. This is the administration and management office for our project.

Under the Technical Director for the AGC and GSE we have Production Development as well as Reliability and Quality Control. There is a Reliability manager higher than this but not shown on the chart. GSE design, Field Operations, Systems Integration and Diagnostic Programming, and Computer Design and Evaluation are parts of this technical organization. We also have a Manufacturing Director who will be in charge of the production when the equipment gets to that point.

There is shown an interesting organizational switch here in our Production Development Group which is something that developed from our work with MIT on Polaris. We think that this organization will be effective and will work better than it did on Polaris. The reason for not having Production Development directly under, but tied indirectly to the Production Director, is that, in this type of program, production engineering work such as methods, processes and controls, are tied very closely in with the requirements of the customers, both NASA and MIT. Normally when you are designing something yourself, you are left to do methods, processes and production engineering items on your own; it is something the customer does not usually get into. But in this case it is quite different because of the peculiar demands of

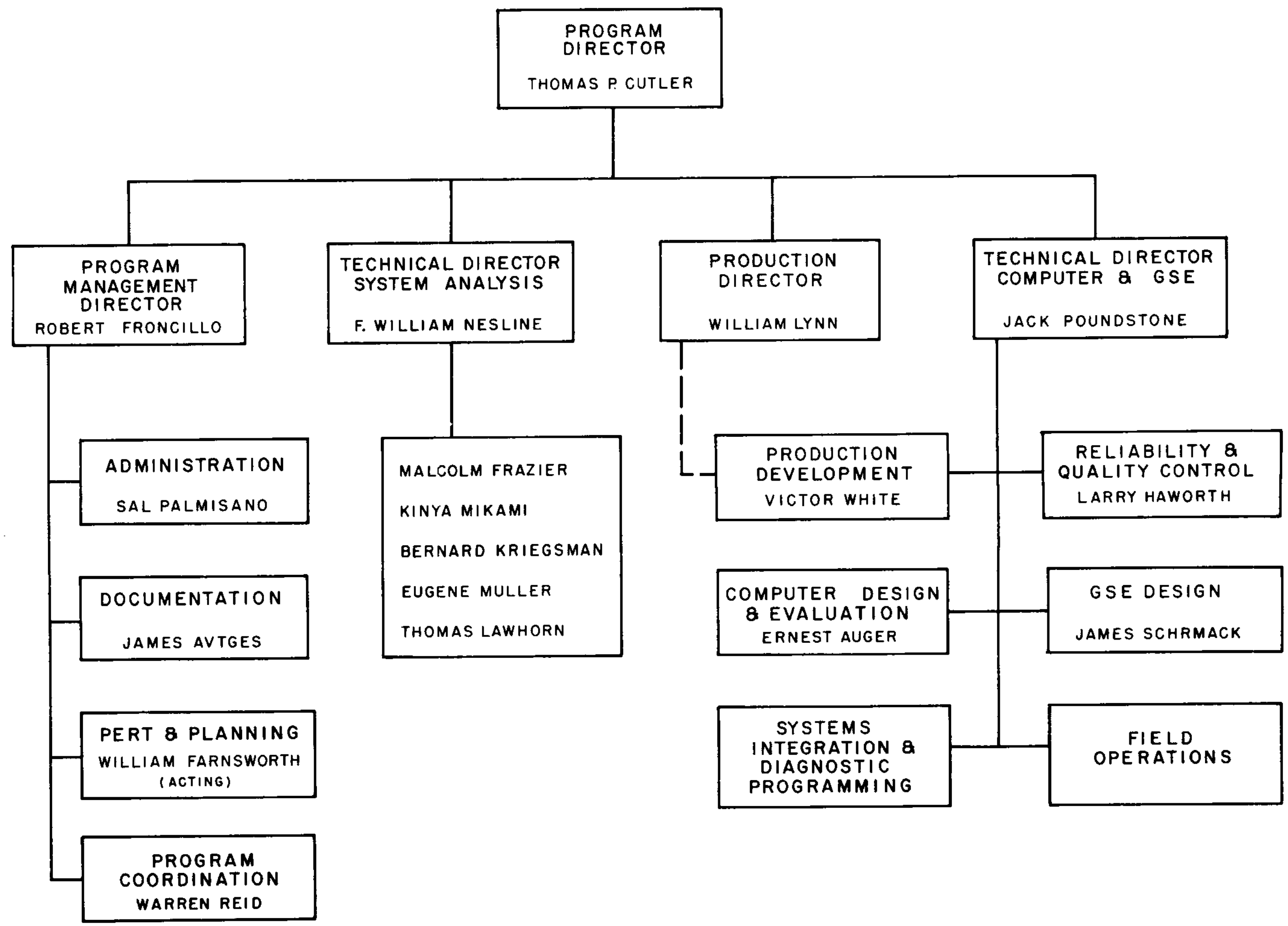


Fig. 10-1 Raytheon Apollo Organization

industrial support. In time the close technical liaison required will decrease and these people, who have worked before in the production group in the plant, will shift over to the Production Director's staff and he will have a complete organization.

Eleven TD's have been received so far. The first TD was to establish a Project Office, which was done. Under TD 2 we were required to furnish a Development Plan, which was submitted before the end of June. We were also requested to develop a Facilities Rearrangement Plan, but until the extent of our work has been established, due to the submission of our change in scope, the Plan will not be finalized. A facilities plan, however is expected to be submitted the first week of August. TD's 3 and 4 were the Reliability and Quality Control Plans which were submitted on June 30. MIT will review these and send them back to be corrected and modified as required. TD 5 created a Committee on Welding Techniques which was established and the first meeting was on the 12th of June. The function of this committee, which as you know, consists of AC Spark Plug, MIT and others who will do welding, is to insure that we are using the same techniques. TD 6 is the Documentation Plan which was submitted. TD 7 was assignment of four residents under the engineering group. The analysis people might be called residents too, since they will be largely resident over here until they get jobs to go back to the plant. TD 8 was to design and fabricate a core rope tester. We received the initial design from MIT and have started on the core rope tester. This will take a little while and will not be completed by the end of our present contractural limitations of August 31. It will continue beyond that date but we will be quite a long way towards completing it by then. TD 9 was a PERT team and a preliminary network. A preliminary PERT network was submitted prior to our vacation period. TD 10 related to an evaluation of magnet wire, which is going on. A preliminary test plan will be submitted within this week. TD 11 is the Factory Test Plan for each assembly. The Factory Test Plan will have to wait until we get the TD's on the assembly itself, on which the Test Plan will be based, so we are just doing preliminary work examining what these plans would be.

Through the effort we have made in working with MIT, new scope was added in certain items, such as the GSE requirements for the computer and the SIRE equipment which is a part of the GSE. In the last two weeks we have learned more of the scope of the GSE. We now have a much better insight into the program than we had before our first proposal.

By the first of next year we expect to have between 160 and 180 technical personnel directly engaged on this program.

SECTION 11
KOLLSMAN INSTRUMENT CORPORATION PROGRESS
A. Ferraro

First I would like to spend a few minutes on our organization. There are three space projects at Kollsman and all three are directly attached to the president's office. The two other projects are part of the OAO. We have technical help and assistance in manning from the Advance Development Staff, headed by Dr. J. R. Downing and Mr. L. Sharpe. Also, in Research Staff we are aided by Dr. Robinson, and contractually we are aided by Contract Administration Group or Mr. McGowan. We have broken up our organization into five areas; Documentation, Reliability, Project Group, Quality Assurance, and the Chief Scientists who are assigned to Analysis and Level of Effort Endeavor. Mr. R. Hiebert is in charge of our Documentation Group. Mr. L. DeBonis heads our Reliability Engineering Group. Our Project Engineering Group is headed by Mr. J. Connors. Associate to him is Mr. T. Stearns who is assigned here at MIT and in charge of the External effort. The Chief Quality Assurance Engineer is Mr. M. Shear. We have not as yet selected a supervisor for our Level of Effort Group. It is temporarily being supervised by Dr. Robinson who has been dealing with Dr. Battin during the last two or three weeks. The Project Engineering Group as shown is further broken down into External Project Engineering, Internal Project Engineering and Production Support.

We agree with what Mr. Cutler from Raytheon has presented; the close contact shown between the hardware and the customer is different from our ordinary trend of organizational charts. We thought it important that it be very closely associated through the Project Engineering group and directly supervised by Mr. Connors and also some liaison effort would be from myself to this group. The Internal Project Engineering group, headed by Mr. S. Millman covers all of Kollsman engineering per se. It does not cover the participation with Mr. Hursh and Mr. Bowditch at MIT. That portion is supervised by Mr. Stearns.

Briefly, the quickest way to present our progress is to go through the group of technical directives and show our effort in each one. It will succinctly show what we have done.

The first TD was to set up a project office and start our facility studies; this is on schedule. You have a layout of the project office, the engineering section, on page 5 of our 17 July Progress Report. There are two extra bays about the same size as the office, which is about 2000 sq. ft. As additional endeavor is requested we will expand in to these other areas.

The second TD covers the formulation of a Development Plan and the formulation of the Internal Project Engineering Group for the internal support. We have turned in our plan, and again we are on schedule. The Internal group is thoroughly staffed and awaiting more assignments.

The third TD authorized us to formulate a Reliability Plan and a Reliability Group. Here we are on schedule, mainly in manpower, for the expected releases in that area.

The fourth TD covers the Quality Assurance group. We did complete a Quality Assurance Plan and we have a group staffed and awaiting effort.

The fifth TD authorizes our sending the external support to MIT. There is a manpower schedule on page 10 of the referred report which shows how we have supplied this. We have transferred all people who will be on call in this effort to smaller projects so that it will be easier to break off and send them to MIT upon request.

The sixth TD covers the Documentation Plan and the Documentation Group. The plan is complete; it is awaiting approval from our group and will be here tomorrow.

The External Support, mainly in design and drafting, covers the seventh TD. Here again, we are on schedule. We have the participants up here.

The eigth TD covers a certain breed of design specialists as specified by Mr. Hursh and Mr. Bowditch and here again we are on schedule. People required have come up here and participated.

The ninth TD came to us Friday and we have not had a chance to process it. It covers the design and manufacture of factory test equipment plus a certain portion of Level of Effort engineering which should be supplied to Mr. Hursh. This is in work and on schedule. The concept of the factory test equipment has been approved by MIT and we are now actually starting the design in the areas that we can go into. There are certain areas that have not been firmed up and will require more coordination with John Hursh. The design has started and I believe we are on schedule in that area.

The foregoing briefly tells our progress to date. Outside of what Mr. Hursh mentioned before our progress has been more or less of an organizational and a planning type of progress, setting up various areas, having Kollsman think the Apollo way in formulating our present systems to agree with the NASA and MIT method of doing things. We find the TD's very helpful in that they do not vary too much from our system. It does add quite a bit of effort in the over-all picture.

We have a Manpower Allocation Chart that we have just derived, which builds up to 200 people about the middle of January 1962. January 15 is the target date where we would have to be going at our conventional rate and out of 200 people, 110 are of engineering caliber. We are constantly taking people off larger projects, so they can be called as we receive authorization to apply time to them.

One thing that I did forget to mention in the Quality Assurance Plan, there is effort assigned to zero hours. Most of the work has been done by the management group in Quality Assurance and they do not carry a direct charge.

SECTION 12
VELOCITY STEERING LOOP

D. G. Hoag

This is the only technical presentation on the formal agenda. The guidance and navigation equipment is involved in two of the control loops during the major thrusting phases of the Apollo mission; one loop being the attitude feedback, in the stabilization loop through the IMU, and the other being the steering based on acceleration signals through the computer. Now it will take concentrated effort between MIT and North American Aviation and their subcontractor, Minneapolis-Honeywell, coordinating the activities in these control loops to get a satisfactory operation.

There is one area of steering control where a number of decisions have to be made now that can reflect grossly on the over-all control performance. This has to do with the quantization and iteration periods in the computer. In particular, the quantization of the input size of velocity pulses of the accelerometers, the output size of the angular velocity step commands to the CDU, and the updating frequency of steering commands are basic nonlinearities which can affect the outside control loop. The decision has already been made on the sizes of these quantizations.

Mr. J. Flanders had made a study showing the consequences of these nonlinearities on an otherwise ideal linear steering control system.

This information is contained in Report R-372, Velocity Steering Studies for the Apollo Mission, by J. H. Flanders now being published and is available through normal channels. The abstract of this report follows.

ABSTRACT

This report presents a preliminary analysis of a velocity steering loop in the MIT Apollo Guidance Equipment for use when vector velocity changes are being commanded during the Apollo Mission. The purpose of the study is to provide preliminary verification of proposed signal quantization levels and computer sampling intervals. Based on ideal spacecraft attitude loop dynamics and planar maneuvers only, the study results indicate that transient response times of transverse velocity errors will be about seven seconds. The steady state limit cycle involves velocity excursions that do not exceed one velocity quantum (5.22 cm/sec).

BIBLIOGRAPHY

TECHNICAL PROGRESS REPORTS

E-1067	Monthly	August 11 through September 13, 1961 (C)
E-1068	Monthly	September 13 through October 4, 1961 (C)
E-1099	Monthly	October 4 through November 9, 1961 (C)
E-1116	Quarterly	Period ended December.11, 1961 (C)
E-1117	Monthly	December 11, 1961 through January 16, 1962 (C)
E-1139	Monthly	January 16 through February 1962 (C)
E-1140	Quarterly	Period ended March 11, 1962 (C)
E-1157	Monthly	March 11 through April 11, 1962 (C)
E-1177	Monthly	April 11 through May 1, 1962 (C)
E-1199	Quarterly	Period ended June 11, 1962 (C)
E-1236	Monthly	June 11 through July 17, 1962 (C)