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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE AND NAVIGATION

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(Unclassified Title)
REPORT E-1474

QUARTERLY TECHNICAL PROGRESS REPORT
PROJECT APOLLO GUIDANCE
AND
NAVIGATION PROGRAM
Period ended September 1963



INSTRUMENTATION LABORATORY

CAMBRIDGE 39, MASSACHUSETTS

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PREFACE

The first section of this Quarterly Progress Report consists of Milestone Charts and progress summaries covering components and assemblies of the Apollo Guidance Equipment.

Section II contains comments and a Milestone Chart on progress of the LEM program.

Also included in this report is a tabulation of meetings attended by MIT/IL Apollo personnel during September 1963.

The report concludes with a bibliography of all reports published by the MIT Instrumentation Library under the Apollo program.

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SECTION I

PROGRESS SUMMARIES

Figure I-1 is the delivery schedule for command module G & N Systems as specified in NASA/MSC letter SGP (RWY:mmm) dated 28 August 1963 from D. Gilbert to M. Trageser.

At the NASA - MIT/IL Quarterly Management Review held on 18 September 1963, the following allocation of systems was proposed by D. Gilbert.

AGE 5	NAA House S/C #1 (BP-14)
AGE 6	AFRM 006 (Vibration and Acoustic Test)
AGE 7	AFRM 008 (Environmental Test)
AGE 8	Downey Spare (006-008-BP14)
AGE 20	MIT House System
AGE 10	AFRM 011 (1st Manned C-1 Flight)
AGE 11	Component Qualification Test
AGE 17	MIT Reliability Test
AGE 12	MSC Research Lab System Test
AGE 9	AMR Spare - AFRM 011
AGE 13	AFRM 012 (2nd Manned Flight)
AGE 18	System Qualification Test at ACSP
AGE 14	Downey Spare (012-014)
AGE 15	AFRM 013

Figure I-1 has not been revised to reflect the changes in allocation, since they were presented as tentative changes only.

Figure I-2 is an MIT/IL proposed G & N System flow plan presented to NASA/MSC in May 1963 (MIT/IL Letter AG-382-63). If MSC approves the flow plan "hanger queen" concept, this chart will be revised to be compatible with the G & N delivery schedule shown in Figure I-1.

Figure I-3 shows the AGE-4 Schedule. System assembly and test of AGE-4 is currently expected to begin approximately 1 November 1963 due to a delay in completion of the AGE-4 harness and PSA end connector assembly. Upon completion of the harness, system assembly and test will begin and continue until approximately mid-January 1964.

APOLLO C/M FLIGHT TEST SCHEDULE

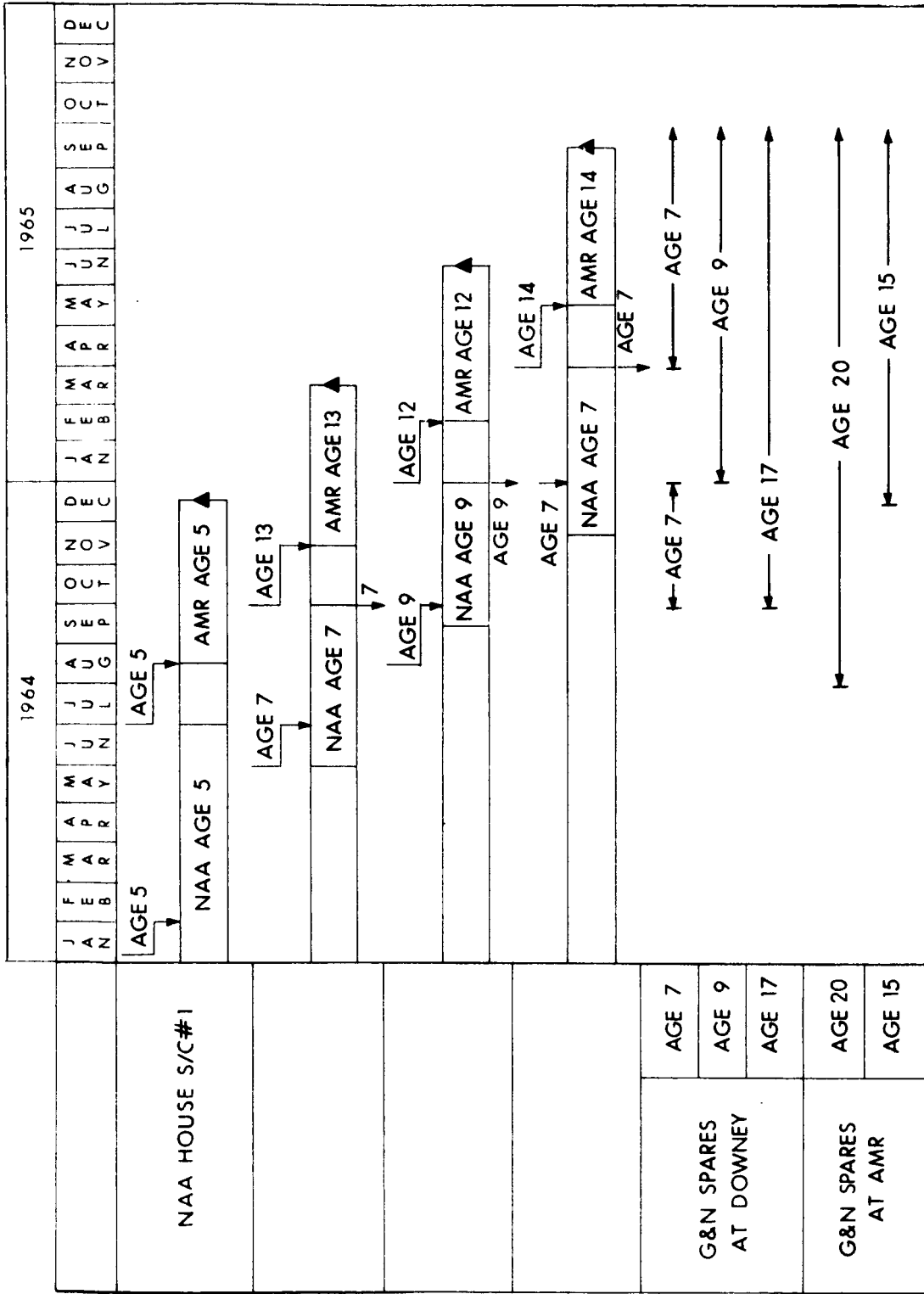


Fig. I - 2

APOLLO MILESTONE CHART FOR AGE 4

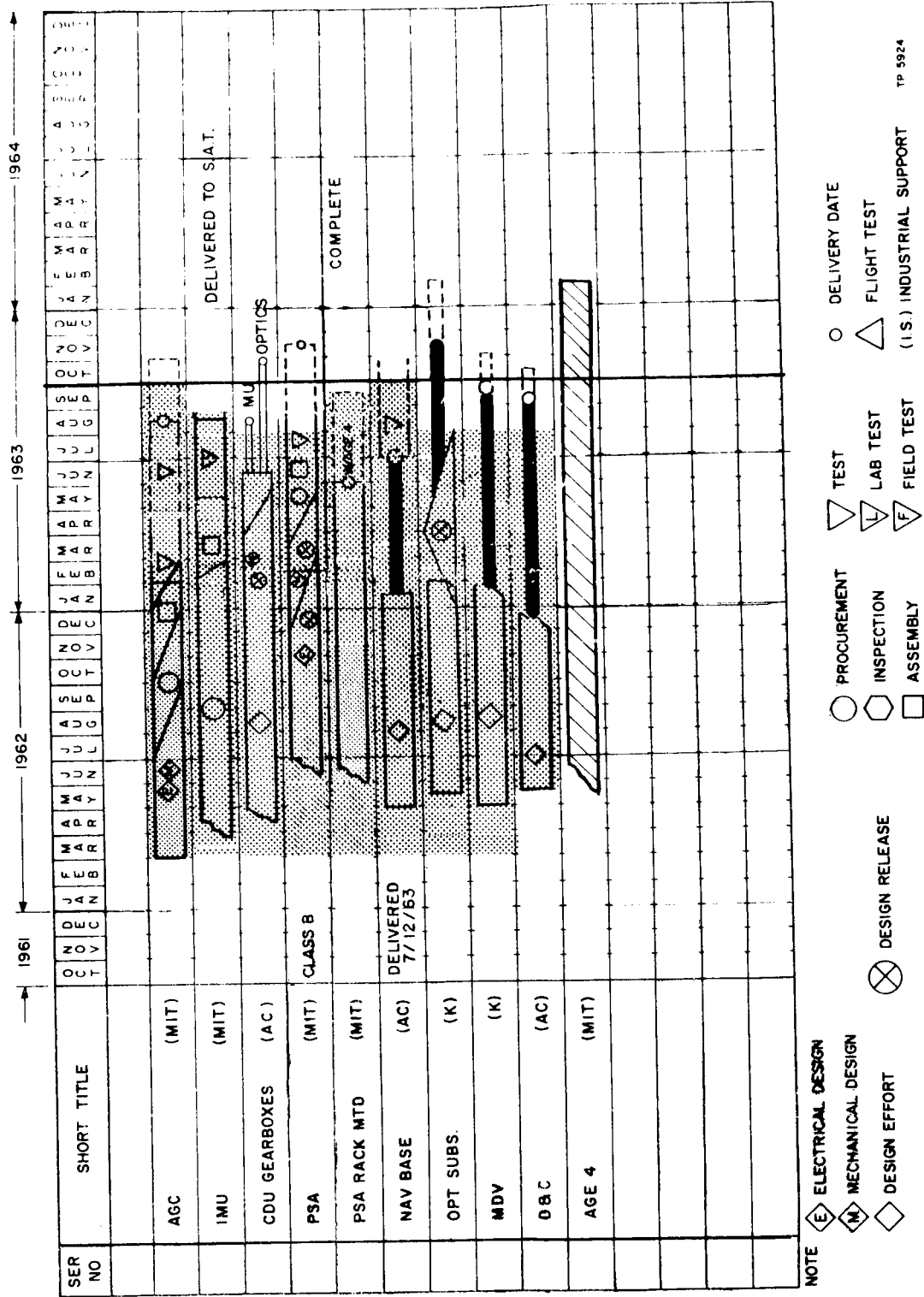


Fig. I - 3

GSE Test Station Breadboard Number 2, originally scheduled for delivery to MIT/IL by AC Spark Plug in August 1963, is now expected to be ready for partial shipment on 15 November 1963. Test Station Breadboard Number 2 will be used during system assembly and test of AGE-4 at the MIT/IL Systems Lab at Cambridge.

Figure I-4 is the AGE-5 Schedule. System assembly and test of AGE-5 is currently predicted to begin approximately 1 January 1964 upon completion of the harness and PSA end connector assembly, and continue through early March 1964.

GSE Test Station Number 1, scheduled for delivery to NAA by AC Spark Plug in December 1963, is now expected to be shipped approximately 31 January 1964. Test Station Number 1 will be required to check out AGE-4 and AGE-5 at the MIT Systems Lab at Downey.

A schedule for Guidance Theory and Programming is shown in Figure I-5. It is planned to replace this chart with a schedule derived from the PERT chart covering this effort.

The AGC delivery schedule is shown in Figure I-6. AGC-4, an MIT/IL breadboard unit, is functioning and will be available for use during system assembly and test of AGE-4 when required. AGC 4-B, the Raytheon Learner Model to be used during system assembly and test of AGE-5, has a predicted delivery date of 3 January 1964. Subassemblies for AGC-5 are expected to be delivered to MIT/IL by Raytheon during the period 25 December 1963 through 17 January 1964. Upon receipt of the subassemblies, AGC-5 will be assembled and checked out at MIT/IL during February and March 1964.

AGC Block I Ropes. On 8 September 1963, MIT/IL issued TD R-132 directing Raytheon to procure parts and materials to construct the required ropes for Block I hardware. Raytheon is to assemble the modules, including all wiring, to Class A documentation up to the operation of threading the sense lines. Specific instructions for sense lines shall be provided by MIT/IL on a usage basis.

AGC Simulation Computers. On 18 September 1963, MIT/IL issued TD R-134 directing Raytheon to design and manufacture three Apollo G & N Simulation Computers. The manufacturing effort shall include the following for each of the three units:

- a) One simulation computer.
- b) Two (2) displays and keyboards.
- c) One computer test set (without operating fixtures).
- d) One connecting cable, thirty feet long, to allow the DSKY's to operate as part of the Simulation Computer while remotely installed in the Spacecraft.

APOLLO MILESTONE CHART FOR AGE 5

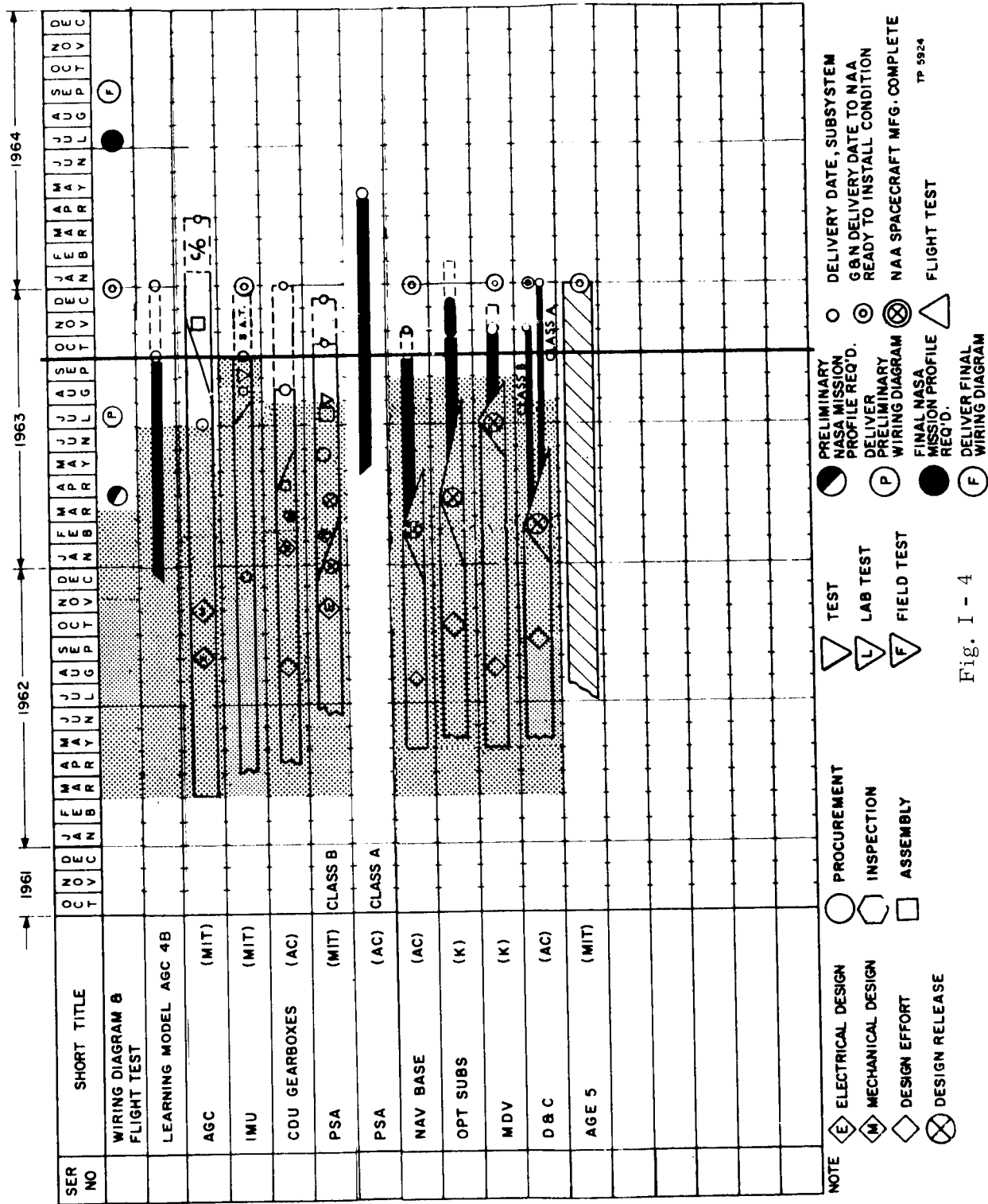
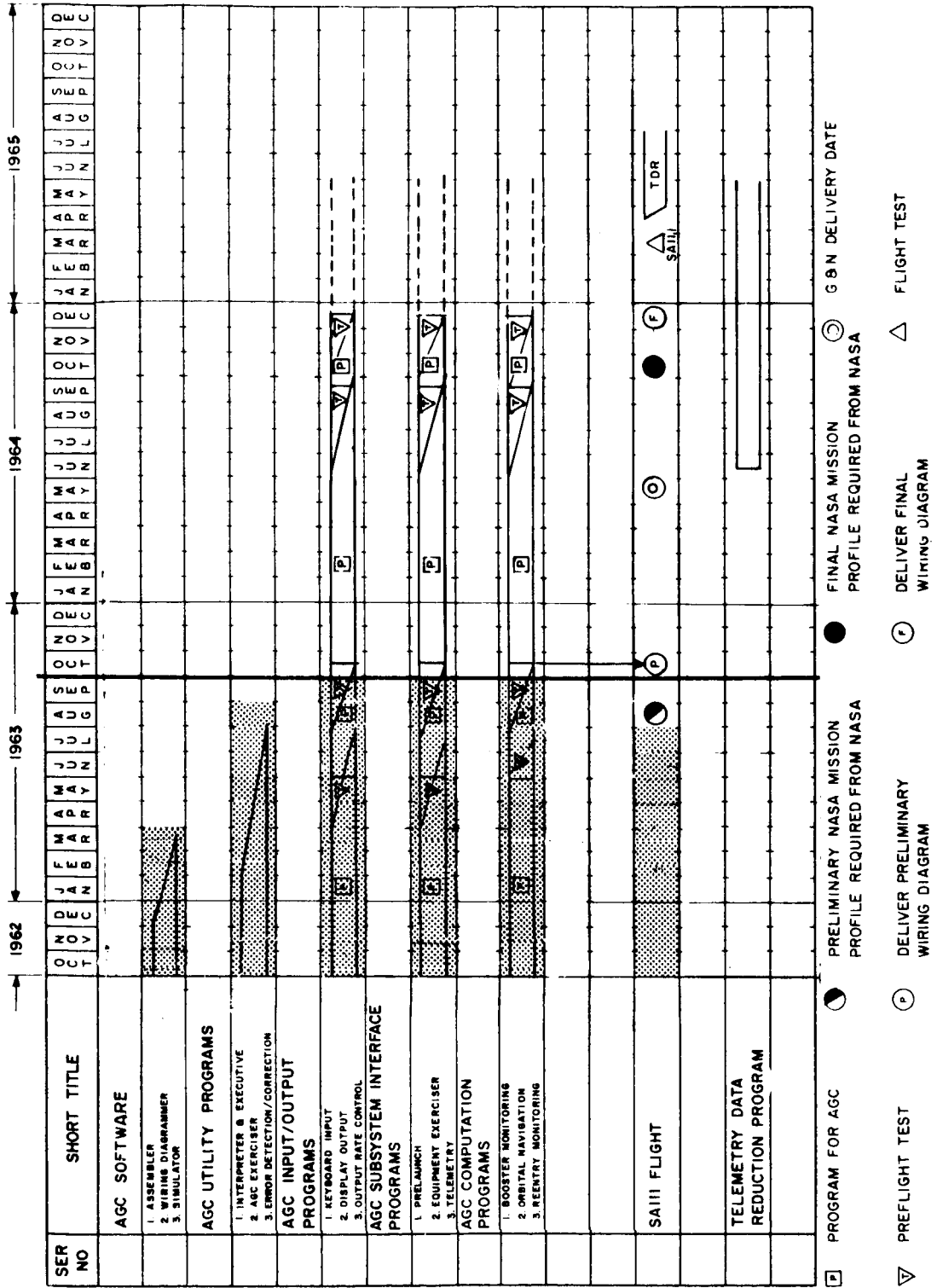


Fig. I - 4

TP 5924

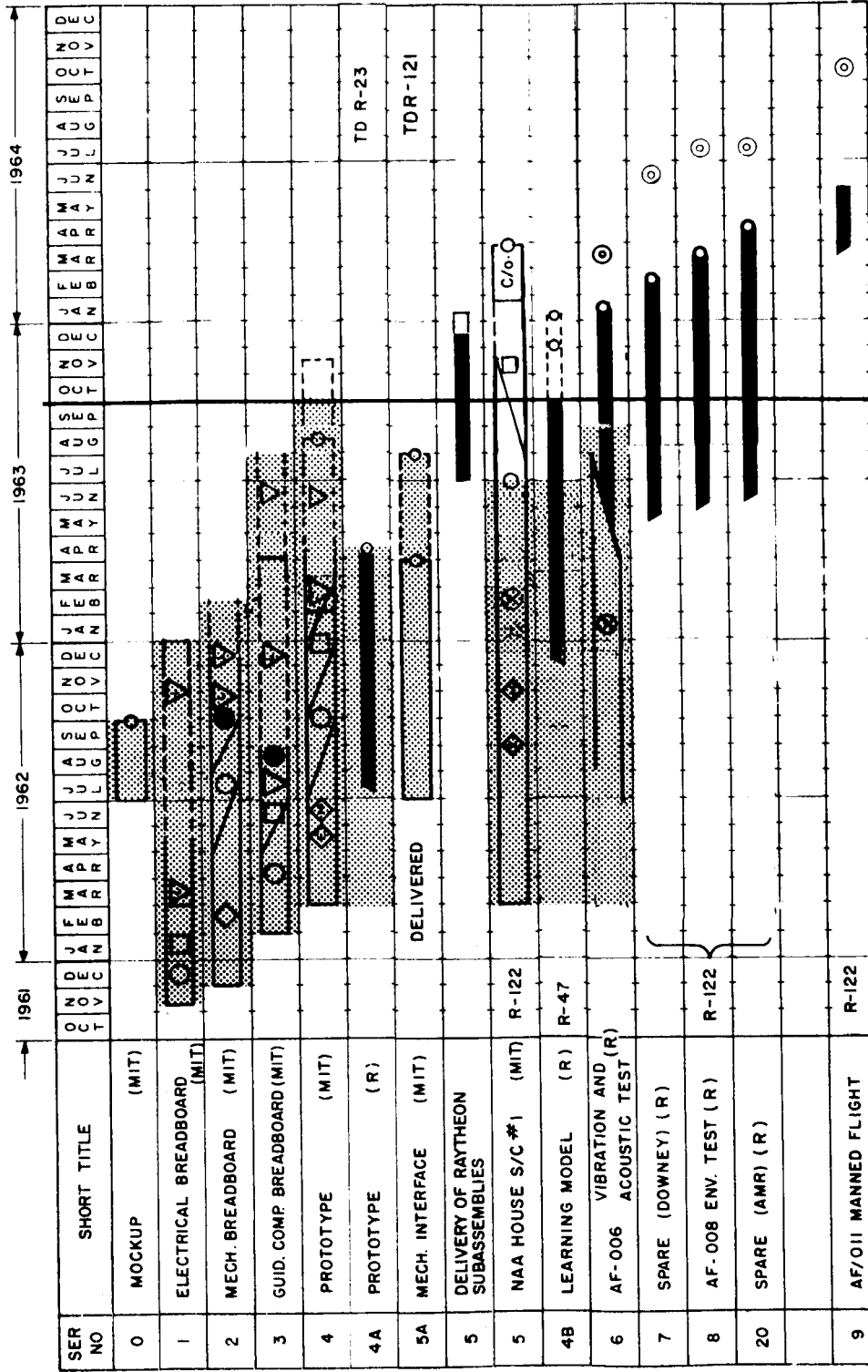
APOLLO MILESTONE CHART FOR GUIDANCE THEORY & PROGRAMMING (EARTH ORBITAL MISSION)



TDR - PERFORM TELEMETRY DATA REDUCTION

Fig. I - 5

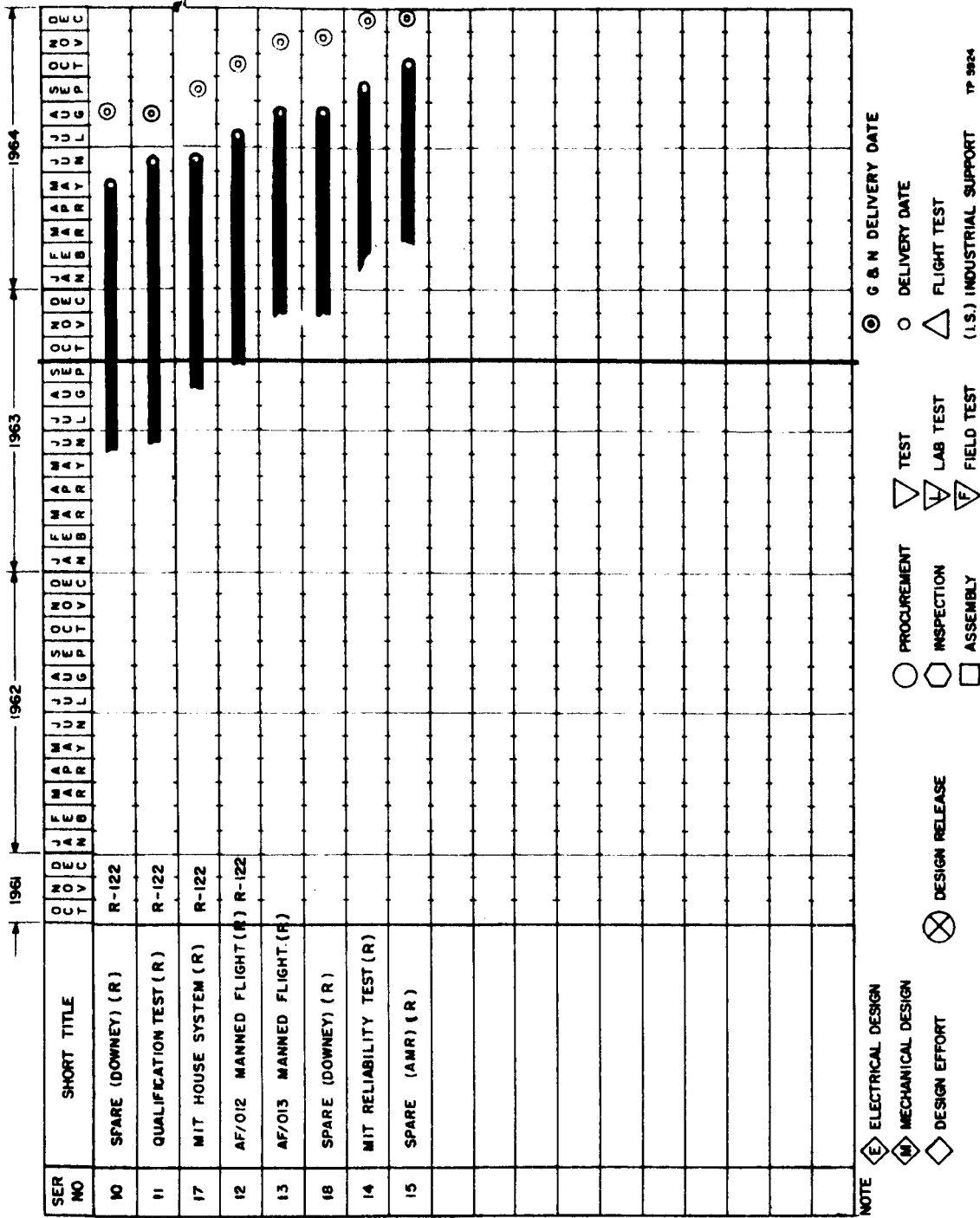
APOLLO MILESTONE CHART FOR APOLLO GUIDANCE COMPUTER (AGC)



- NOTE
- ELECTRICAL DESIGN
 - MECHANICAL DESIGN
 - DESIGN EFFORT
 - DESIGN RELEASE
 - PROCUREMENT
 - INSPECTION
 - ASSEMBLY
 - TEST
 - LAB TEST
 - FIELD TEST
 - G & N DELIVERY DATE
 - DELIVERY DATE
 - FLIGHT TEST
 - (I.S.) INDUSTRIAL SUPPORT

Fig. I-6

APOLLO MILESTONE CHART FOR APOLLO GUIDANCE COMPUTER (cont.)



- NOTE
- ⬠ ELECTRICAL DESIGN
 - ⬠ MECHANICAL DESIGN
 - ⬠ DESIGN EFFORT
 - ⊗ DESIGN RELEASE
 - PROCUREMENT
 - ⬠ INSPECTION
 - ⬠ ASSEMBLY
 - ▽ TEST
 - ⬠ LAB TEST
 - ⬠ FIELD TEST
 - ⊙ G & N DELIVERY DATE
 - DELIVERY DATE
 - ⬠ FLIGHT TEST
 - (I.S.) INDUSTRIAL SUPPORT TP 9824

Fig. I-6 (cont)

The IMU delivery schedule is shown in Figure I-7. Thermal testing is continuing on IMU-1. IMU-2 is being rebuilt with new stub shafts and vibration tests will be re-run on November 14th and 15th. IMU-4 is continuing to undergo functional checkout and alignment tests as part of AGE-4 inertial subsystem marriage and checkout.

IMU-5 was assembled, balanced, and open-loop checked and is now ready for functional checkout and alignment tests as part of AGE-5.

The PSA delivery schedule is shown in Figure I-8. PSA-2 is a development model under construction at MIT/IL, and work will continue for several months. Completion of PSA-4 has slipped to 15 November 1963. PSA-5 completion has slipped to approximately 15 December 1963. PSA-5A was completed in September and shipped with AGE-5 to NAA.

AGE Harness and PSA Connector Assembly. On 11 September 1963, MIT/IL issued TD A-175 which redefined the PSA Junction Box and AGE Harness. These items had previously been referred to as separate pieces of hardware, but are now incorporated as one integral assembly called the "AGE Harness and PSA End Connector Assembly". AC Spark Plug is to fabricate and deliver the AGE Harness and PSA End Connector Assemblies for AGE 6, 7, 8, 9, 10, 11, 12, 17, and 20 to Class A drawings; for AGE-5, AC Spark Plug is to fabricate the AGE Harness only; MIT/IL will continue to fabricate the AGE-5 PSA Junction box, and will marry the junction box and harness. Deliveries will be commensurate with the AGE system deliveries.

The CDU delivery schedule is shown in Figure I-9. AC Spark Plug's expected delivery date for CDU's for AGE-5 is 1 January 1964. CDU's for systems prior to AGE-5 are covered by TD A-147 which authorized AC Spark Plug to deliver 15 CDU's to the schedule shown below.

<u>Quantity</u>	<u>Scheduled Delivery</u>	<u>Expected Delivery</u>	<u>Documentation</u>
2	8/ 1/63	9/23/63	Less than Class A
3	9/15/63	11/ 3/63	Less than Class A
3	10/15/63	11/ 8/63	Less than Class A
2	10/15/63	11/22/63	Less than Class A
2	11/ 1/63	11/22/63	Less than Class A
2	11/ 1/63	11/22/63	Less than Class A
1	11/ 1/63	1/10/64	Less than Class A

The Navigation Base delivery schedule is shown in Figure I-10. Navigation Base for AGE-2, scheduled for delivery 30 June 1963, is now expected on 4 October 1963 due to the brazing problem. Navigation Base for AGE-5, scheduled for delivery 1 October 1963, is expected 12 November 1963 due to vendor machining delays.

APOLLO MILESTONE CHART FOR IMU DEVELOPMENT PLAN

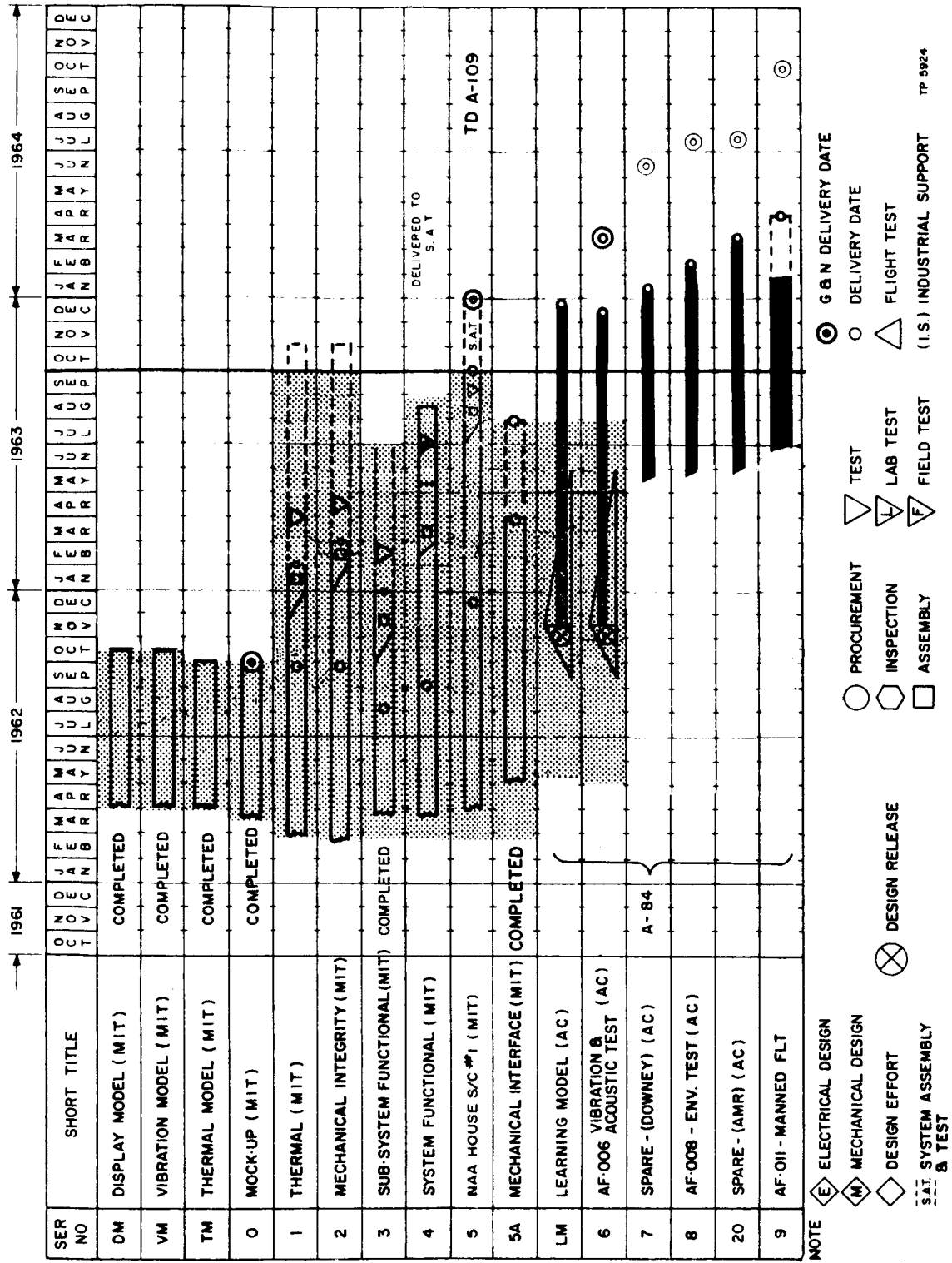
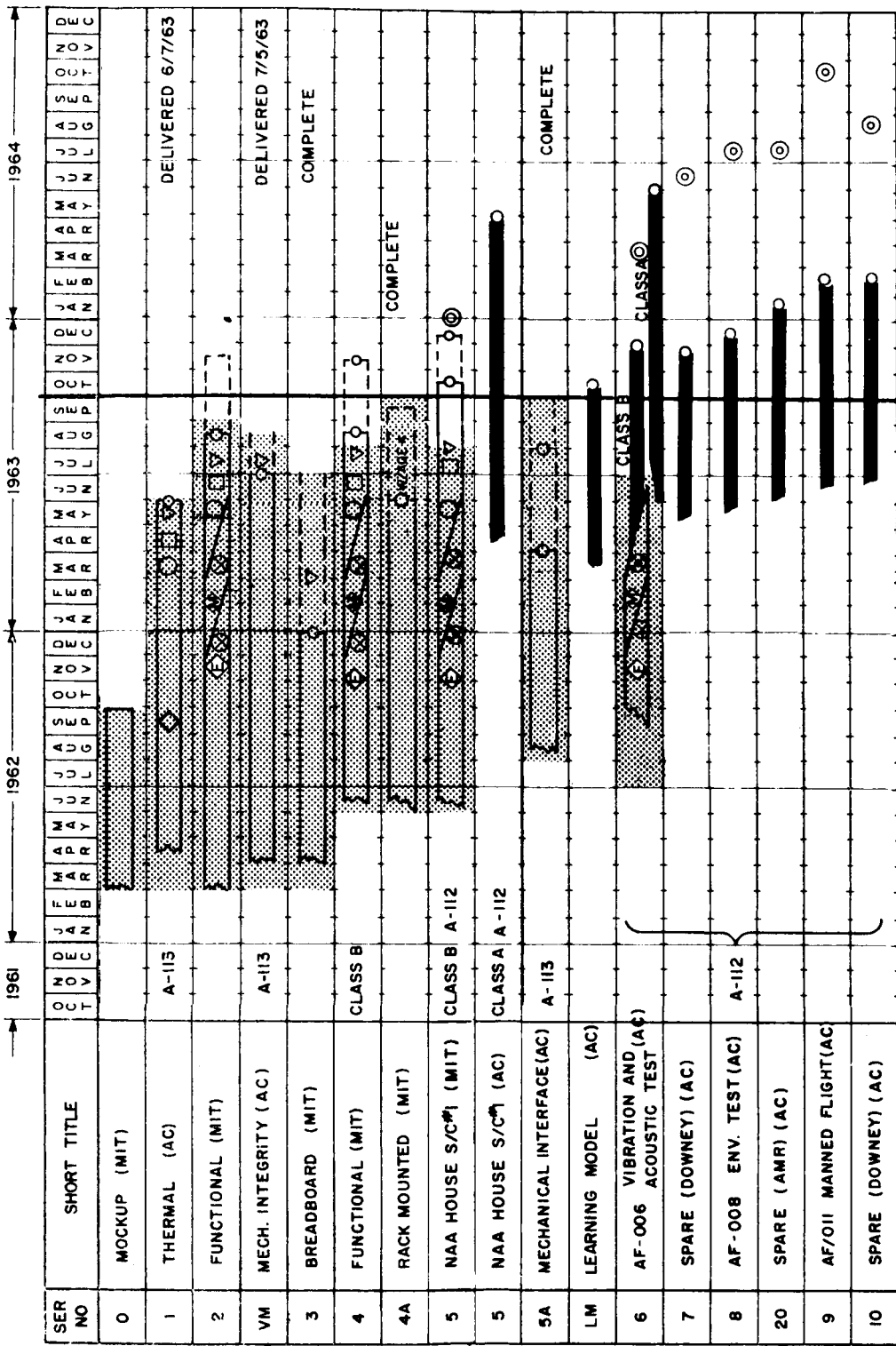


Fig. I-7

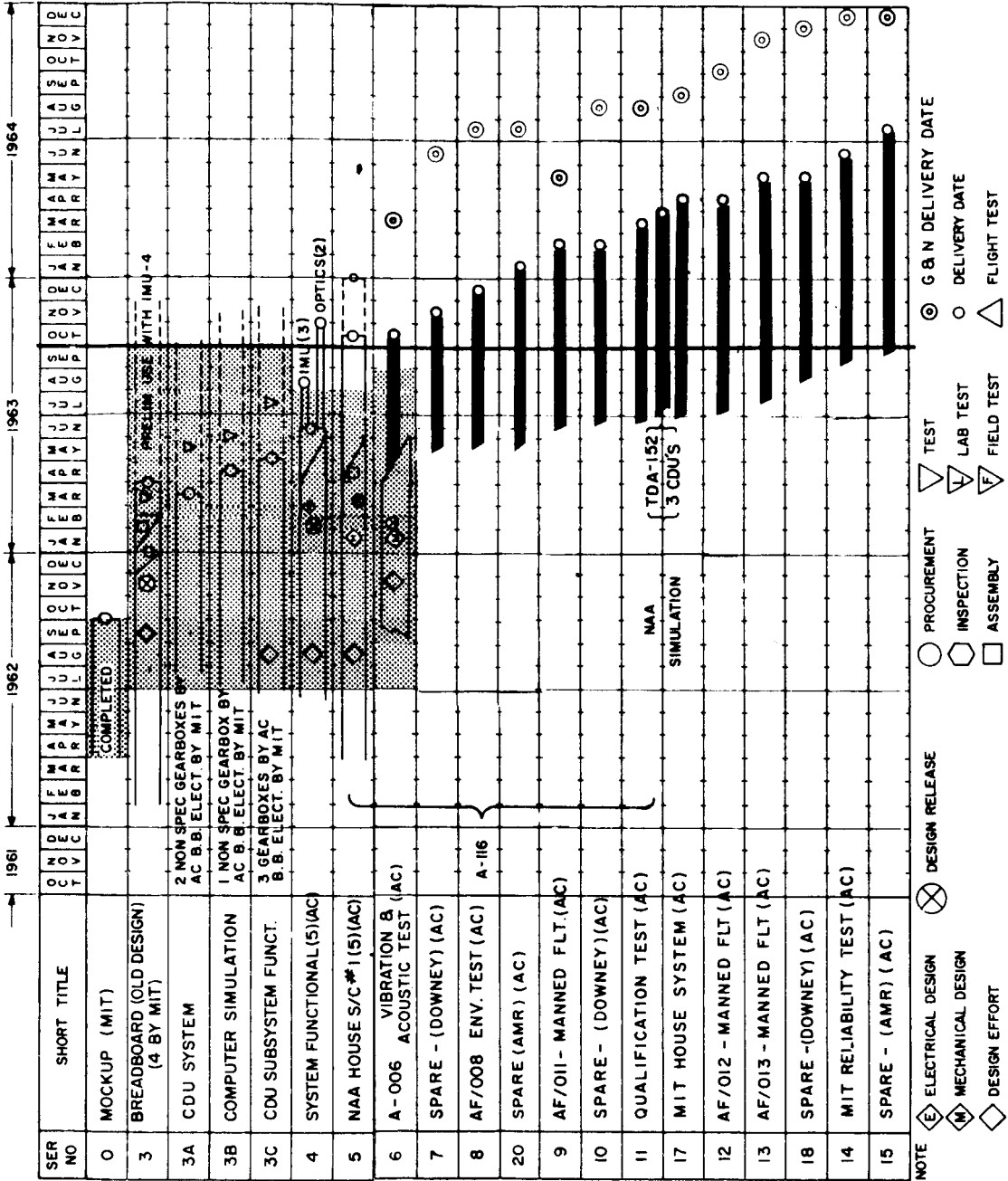
APOLLO MILESTONE CHART FOR POWER AND SERVO ASSEMBLY (PSA)



- NOTE
- ⊠ ELECTRICAL DESIGN
 - ⊠ MECHANICAL DESIGN
 - ⊠ DESIGN EFFORT
 - ⊠ DESIGN RELEASE
 - PROCUREMENT
 - ⊠ INSPECTION
 - ⊠ ASSEMBLY
 - ⊠ TEST
 - ⊠ LAB TEST
 - ⊠ FIELD TEST
 - ⊠ G. S. N. DELIVERY DATE
 - DELIVERY DATE
 - ⊠ FLIGHT TEST
 - (I.S.) INDUSTRIAL SUPPORT TP 5924

Fig. I-8

APOLLO MILESTONE CHART FOR CDU GEARBOXES



(U.S.) INDUSTRIAL SUPPORT TP 5924

Fig. I-9

APOLLO MILESTONE CHART FOR NAVIGATION BASE SUB-SYSTEM

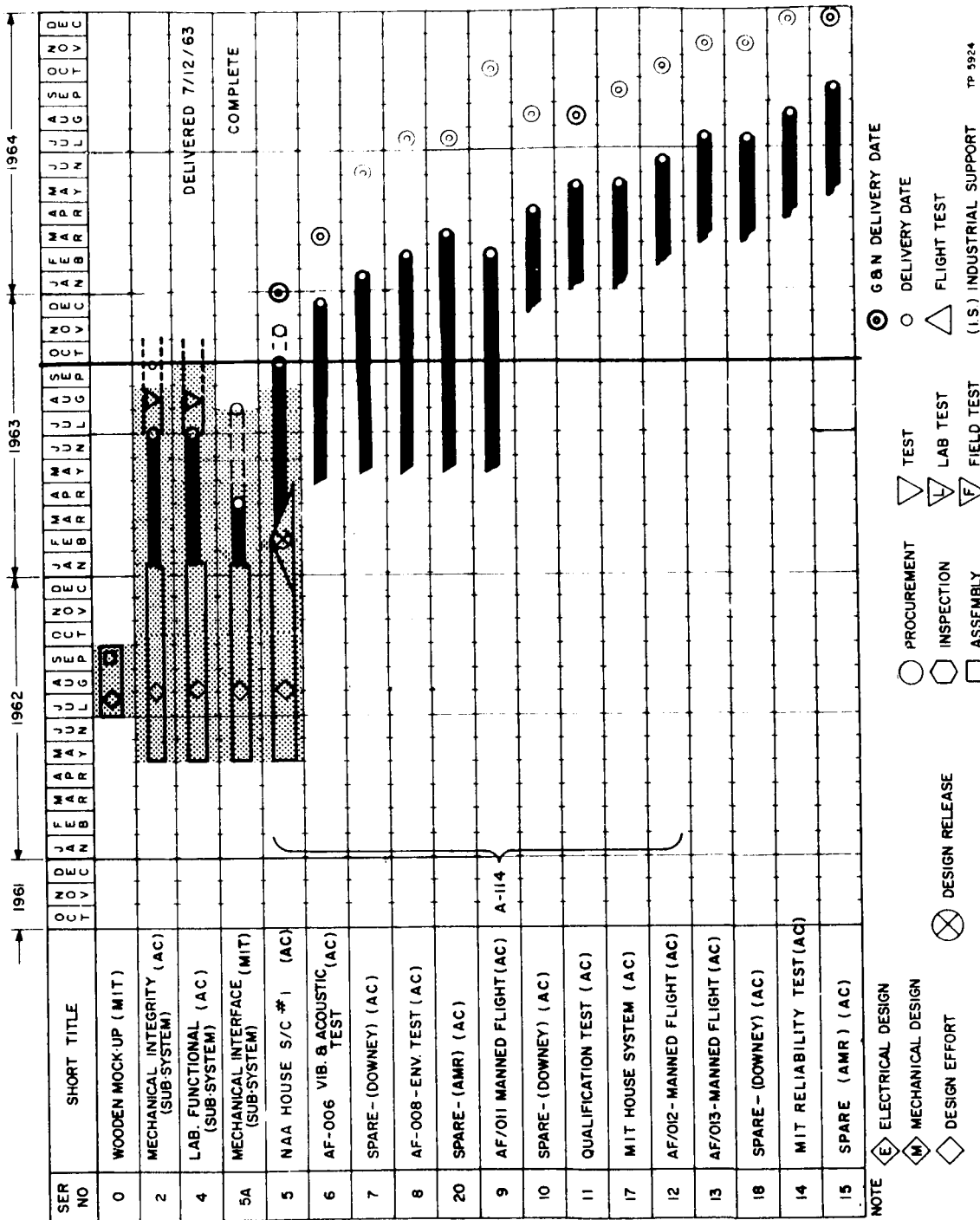


Fig. I-10

The D & C schedule is shown in Figure I-11. The breadboard D & C Panels (G & N Indicator Panel, and Optical Shroud) schedule for delivery for AC Spark Plug are expected early in October.

D & C Panels for AGE 1. The panels scheduled for delivery 1 August 1963 are now expected in October due to delayed honeycomb panel delivery. The Optical Shroud is expected 27 October; the G & N Indicator Panel is expected 10 October; and the IMU Control Panel is expected 1 October.

D & C Panels for AGE 2. The panels scheduled for delivery 1 August 1963 are now expected in October due to delayed honeycomb panel delivery. The Optical Shroud is expected on 27 October; the G & N Indicator Panel is expected 17 October; and the D & C electronics are expected 27 September.

D & C Panels for AGE 4. These panels were scheduled for delivery 1 September 1963, and are now expected on 18 October due to delayed honeycomb panel deliveries.

D & C Panels for AGE 5. These panels were scheduled for delivery 1 November 1963, and are now expected on 27 December 1963 due to procurement of long-lead parts.

The optical subsystem delivery schedule is shown in Figure I-12. Kollsman has reported an anticipated slippage in delivery of optical subsystems, as shown in I-12, due to problems associated with the optical base. When this item was purchased by Kollsman, it was anticipated that problems would arise due to the complexity of the beryllium structure. To reduce some of the obvious risks, the award was given to two vendors, but unfortunately both vendors are experiencing difficulty and are late in their delivery to Kollsman.

Facilities for mechanical integrity testing of AGE-2 Optics have been completed and certified at Kollsman. The facilities for vacuum and thermal testing should be complete and certified about the middle of December. Tenny Engineering has completed a dual chamber, but a faulty header assembly has caused them to delay shipment to Kollsman until 15 November. A month will be required after acceptance to assemble the instrumentation to the chamber and certify it.

On 13 September 1963, MIT/IL issued TD K-100 authorizing Kollsman to fabricate long eye relief eyepieces for breadboard and Block I sextants and scanning telescopes.

The MDV delivery schedule is shown in Figure I-13. MDV 1 and 2, scheduled for delivery by Kollsman 30 August 1963, are now expected on 29 October due to procurement problems associated with the MDV access door assembly. Purchase orders have been placed by Kollsman for several long lead parts (access door, lens

APOLLO MILESTONE CHART FOR DISPLAY & CONTROL SUBSYSTEMS

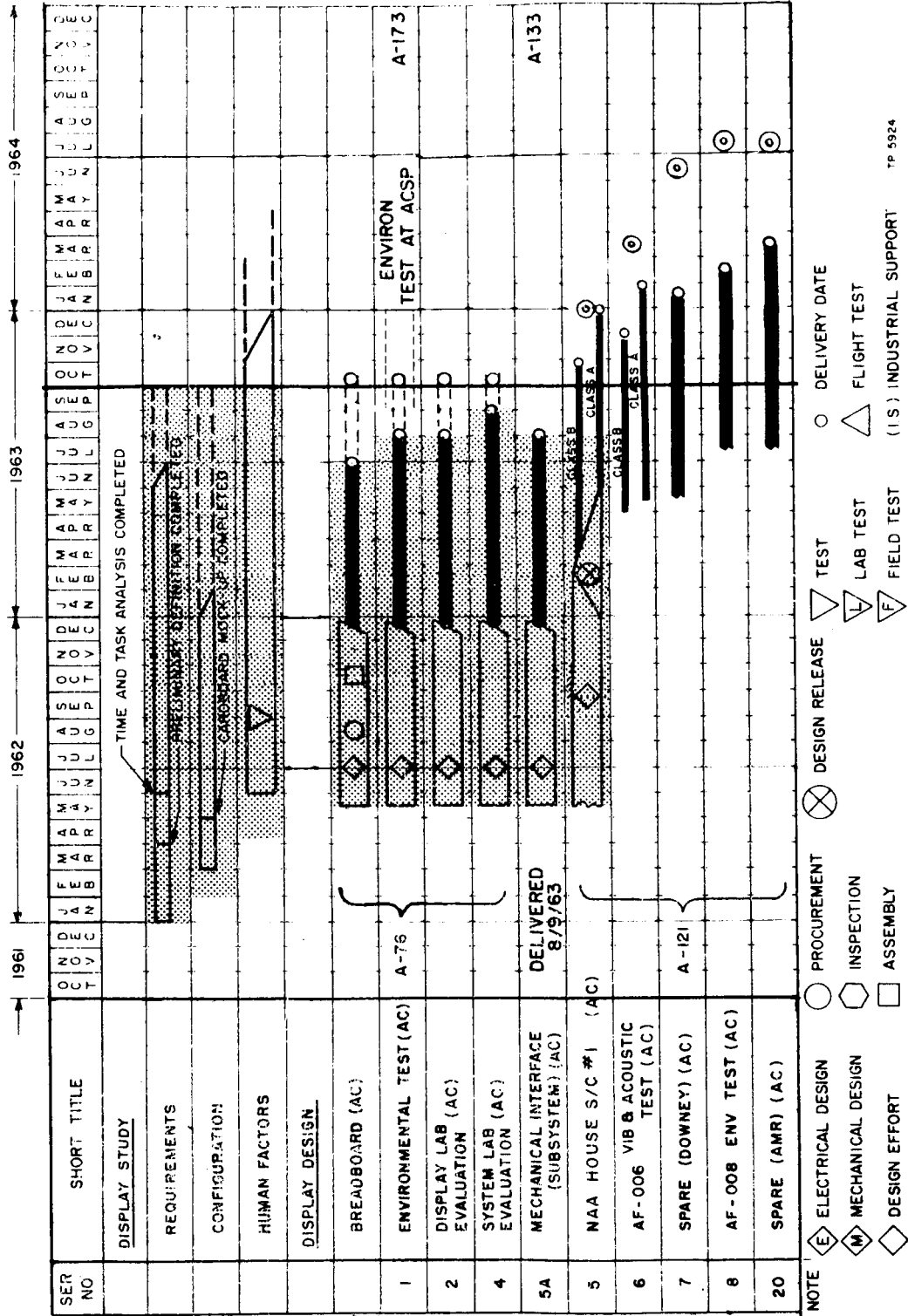


Fig. I-11

APOLLO MILESTONE CHART FOR OPTICAL SUBASSEMBLY

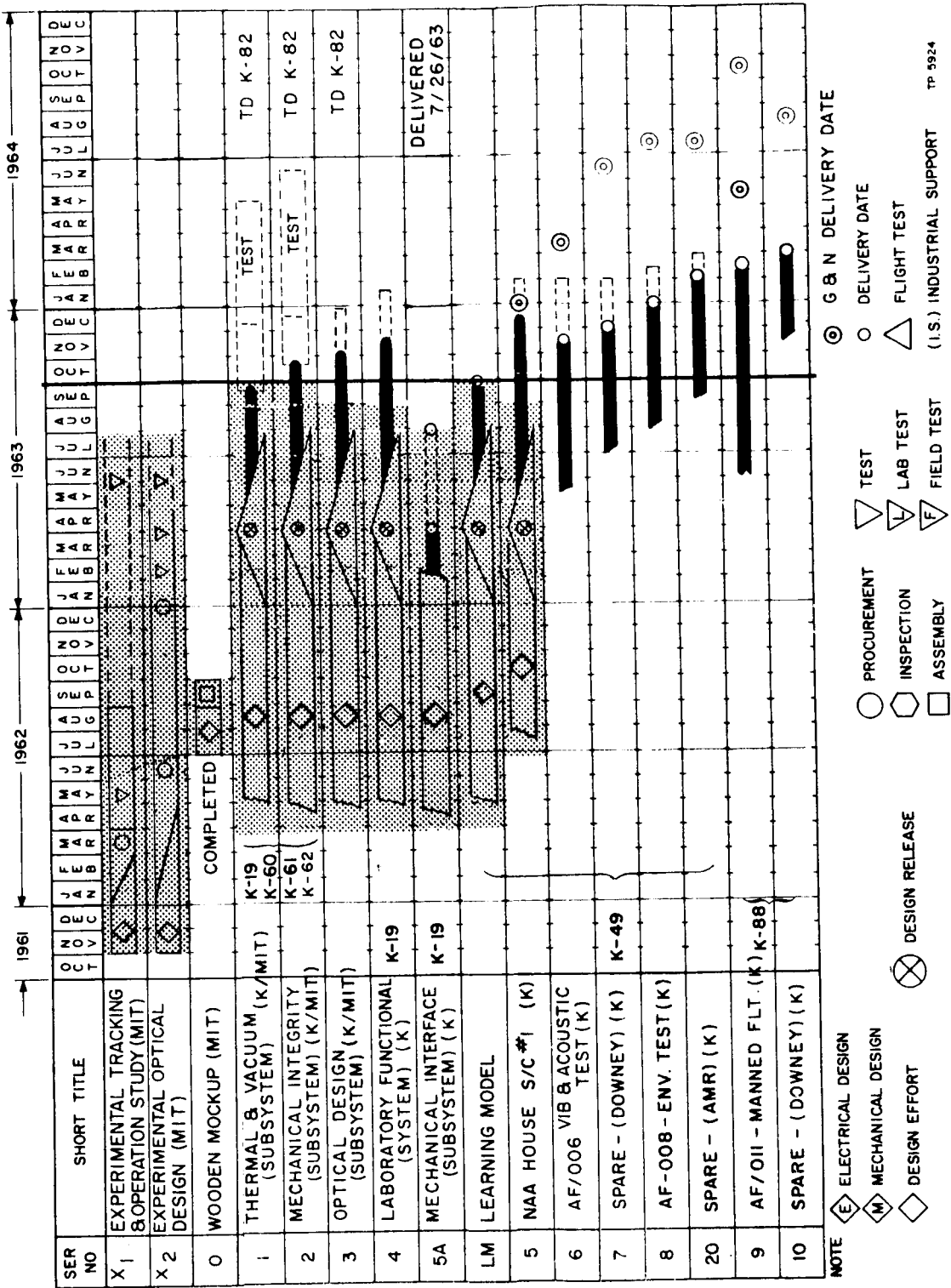
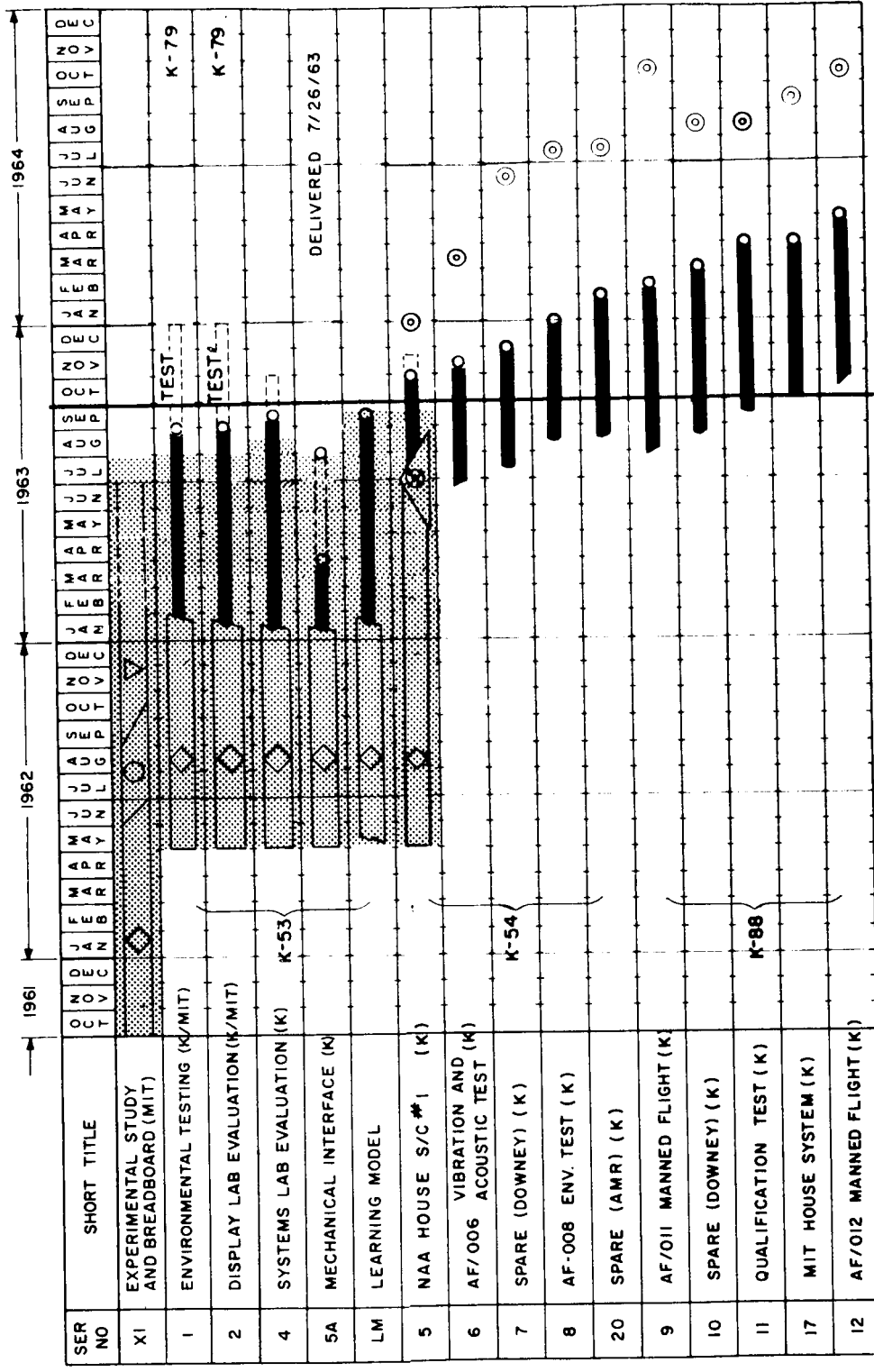


Fig. I-12

APOLLO MILESTONE CHART FOR MAP AND DATA VIEWER SYSTEM



- NOTE
- ◊ ELECTRICAL DESIGN
 - ◊ MECHANICAL DESIGN
 - ◊ DESIGN EFFORT
 - ⊗ DESIGN RELEASE
 - PROCUREMENT
 - ◊ INSPECTION
 - ◻ ASSEMBLY
 - ▽ TEST
 - ▽ LAB TEST
 - ▽ FIELD TEST
 - ⊙ G & N DELIVERY DATE
 - DELIVERY DATE
 - △ FLIGHT TEST
 - ⊙ (I.S.) INDUSTRIAL SUPPORT

Fig. I-13

TP 5924

housing, and projection screen) with delivery expected in October. Following assembly of MDV 1 and 2, Kollsman will conduct thermal structural integrity tests through 1 February 1964.

MDV 4, scheduled for delivery to MIT on 15 September 1963, is now expected on 1 November 1963, a slippage caused by the same problem as noted above. MDV 5, scheduled for delivery to MIT on 30 October 1963, is now expected on 14 November 1963.

MIT issued TD K-87 authorizing Kollsman to fabricate and assemble one additional Block I MDV to be delivered to NAA at Downey by 1 March 1964. This MDV will be used for a guidance and control simulation program to be conducted by NAA.

Figure I-14, covering midcourse Guidance Studies is included only to avoid discontinuity in reporting. In future reports this figure will be replaced by a schedule of guidance studies that will be derived from the PERT printout of this program.

Raytheon's GSE delivery schedule is shown in Figure I-15.

Computer Test Sets: Breadboard Test Set Number 2, originally scheduled for completion in June 1963, was completed 27 September. Test Set Number 3 scheduled for delivery to MIT/IL on 15 September, is now expected on 6 December 1963.

Computer Simulators: Simulator Number 4, originally scheduled for delivery to AC Spark Plug by Raytheon in July, was delivered on 17 September 1963. Computer Simulator Number 5 scheduled for delivery to AC Spark Plug on 15 August 1963, is now expected on 11 October.

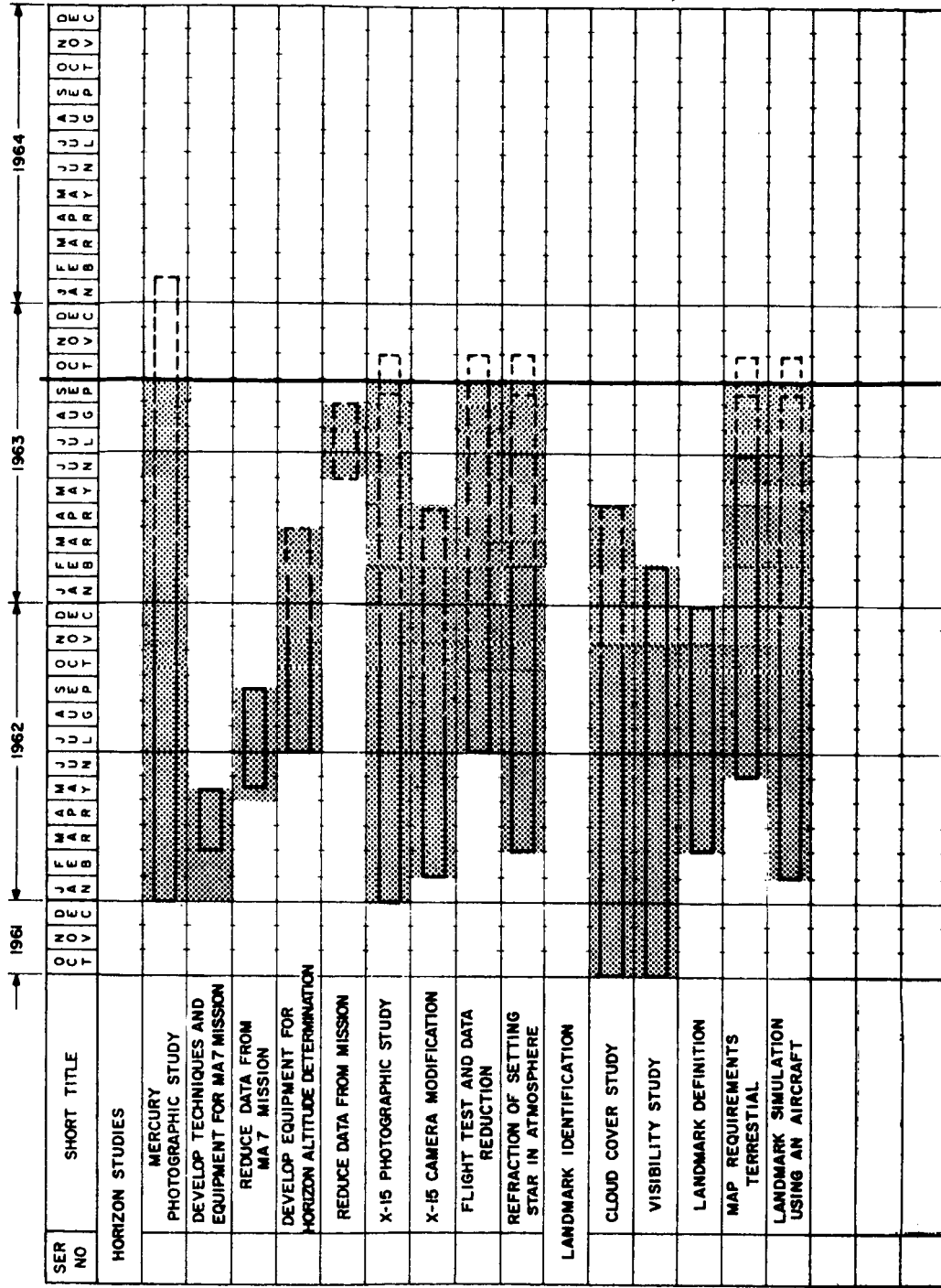
Computer Calibration Unit: Calibration Unit Number 2, scheduled for delivery to MIT/IL in August, is now expected on 1 November.

AC Spark Plug's GSE delivery schedule is shown in Figure I-16.

Test Stations. ACSP reports that the partial pre-production test set scheduled for delivery to MIT/IL on August 1963 is now expected on 15 November due to late definition and procurement problems associated with the coolant supply. Expected delivery dates for the remainder of test set components is as follows: AGE Fixture, 23 November; Temperature Monitor and Control, 1 November; Monitor Panel, 1 November; Gimbal Position Control, 11 October; Optics-NB Mounting Fixture 10 December; and PSA Fixture, 18 October. Test set Number 1 scheduled for delivery by ACSP to NAA on 1 December 1963 is now expected on 31 January 1964.

Kollsman's GSE delivery schedule is shown in Figure I-17. This schedule has been revised in accordance with a recent redefinition of optical GSE items to be supplied by Kollsman. At this writing, it is MIT/IL's understanding that all the GSE items listed have been authorized by NASA. Kollsman's expected delivery dates as shown in Figure I-17 are contingent upon such approval.

APOLLO MILESTONE CHART FOR MIDCOURSE GUIDANCE STUDIES



NOTE

- ◇ ELECTRICAL DESIGN
- ◇ MECHANICAL DESIGN
- ◇ DESIGN EFFORT
- ⊗ DESIGN RELEASE
- PROCUREMENT
- INSPECTION
- ASSEMBLY
- ▽ TEST
- ▽ LAB TEST
- ▽ FIELD TEST
- ⊙ G & N DELIVERY
- DELIVERY DATE
- △ FLIGHT TEST
- (I.S.) INDUSTRIAL SUPPORT

Fig. I-14

APOLLO - AC SPARK PLUG GSE SCHEDULE

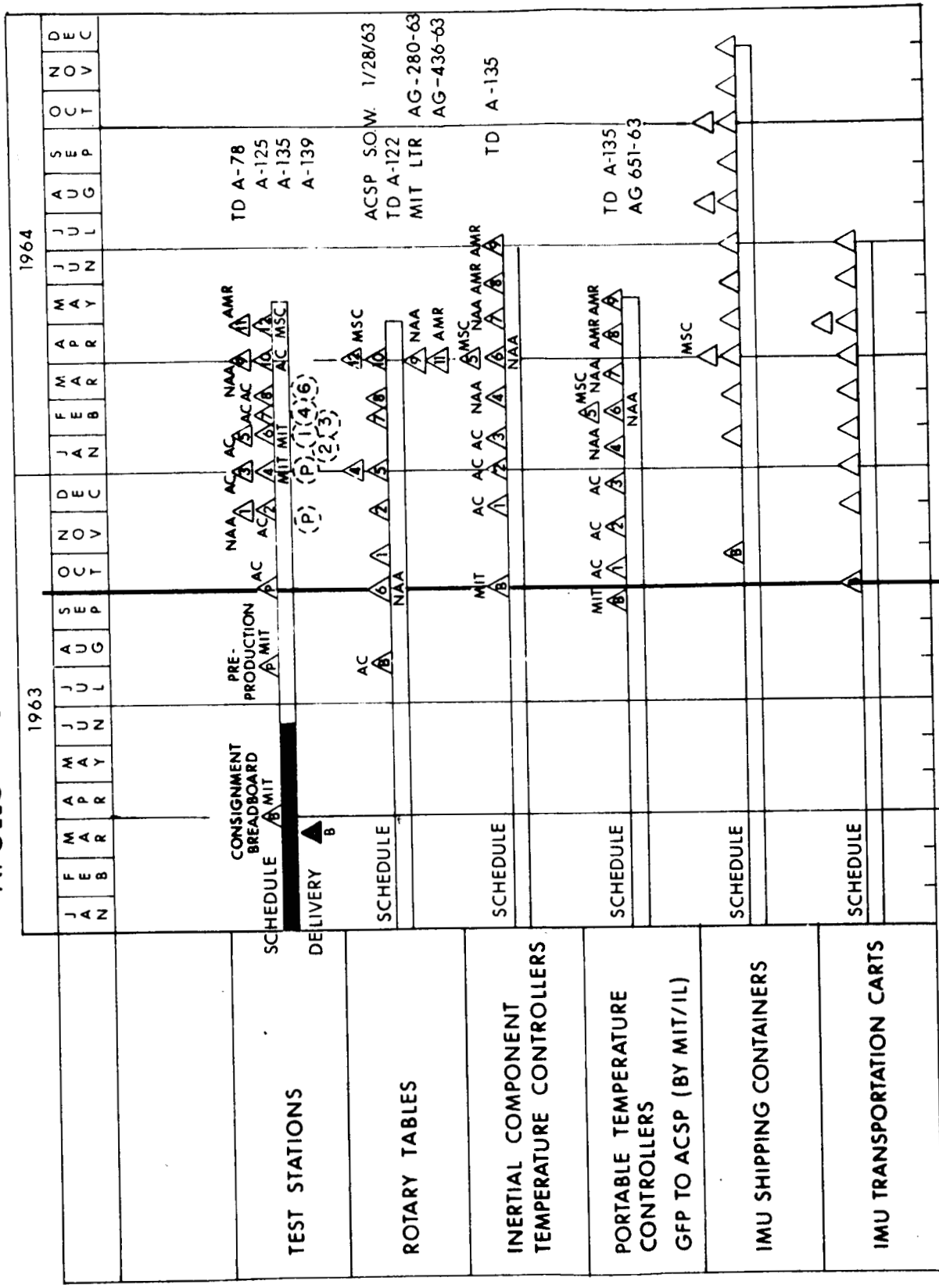
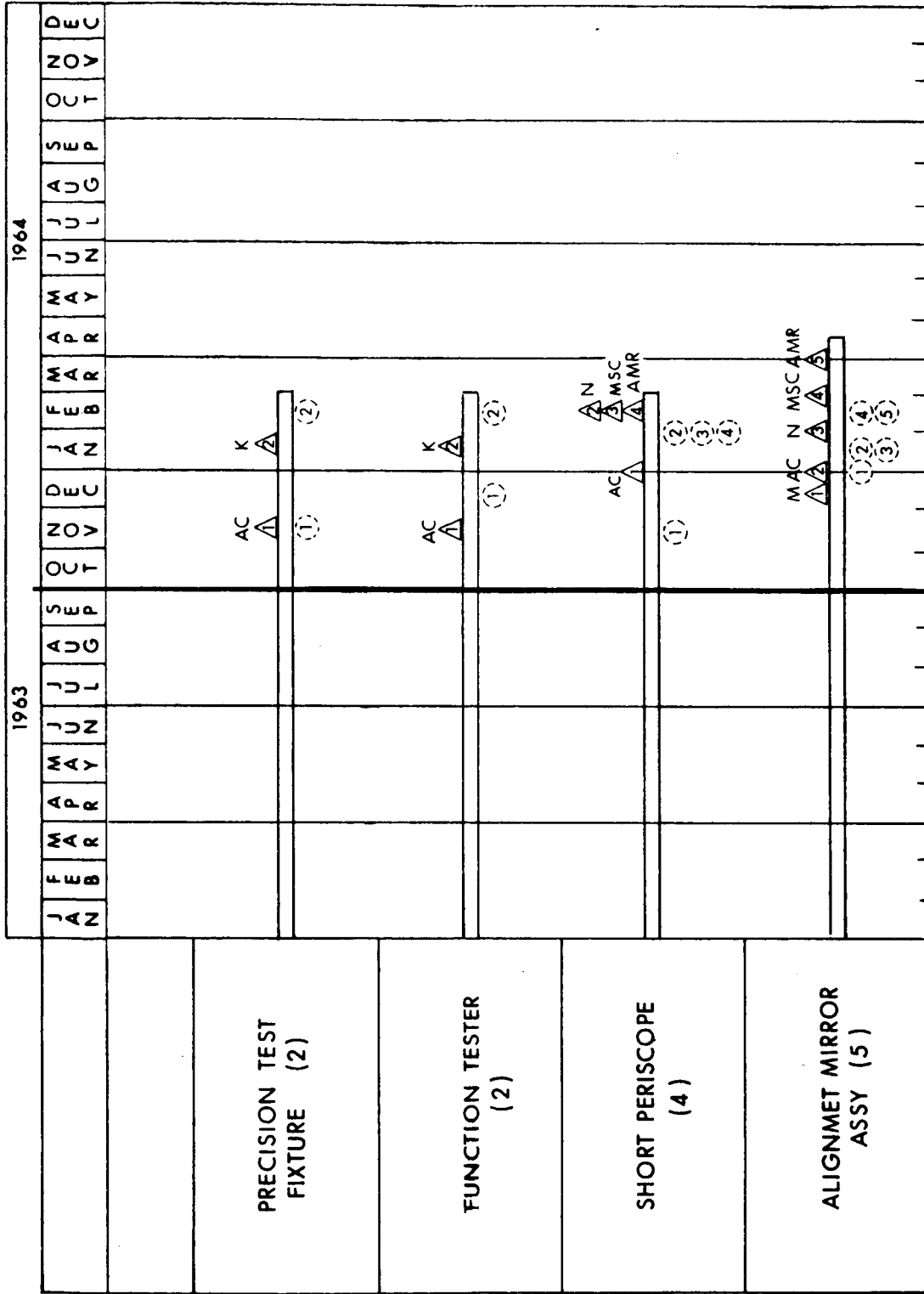


Fig. I-16

APOLLO MILESTONE CHART FOR KOLLSMAN GSE SCHEDULE



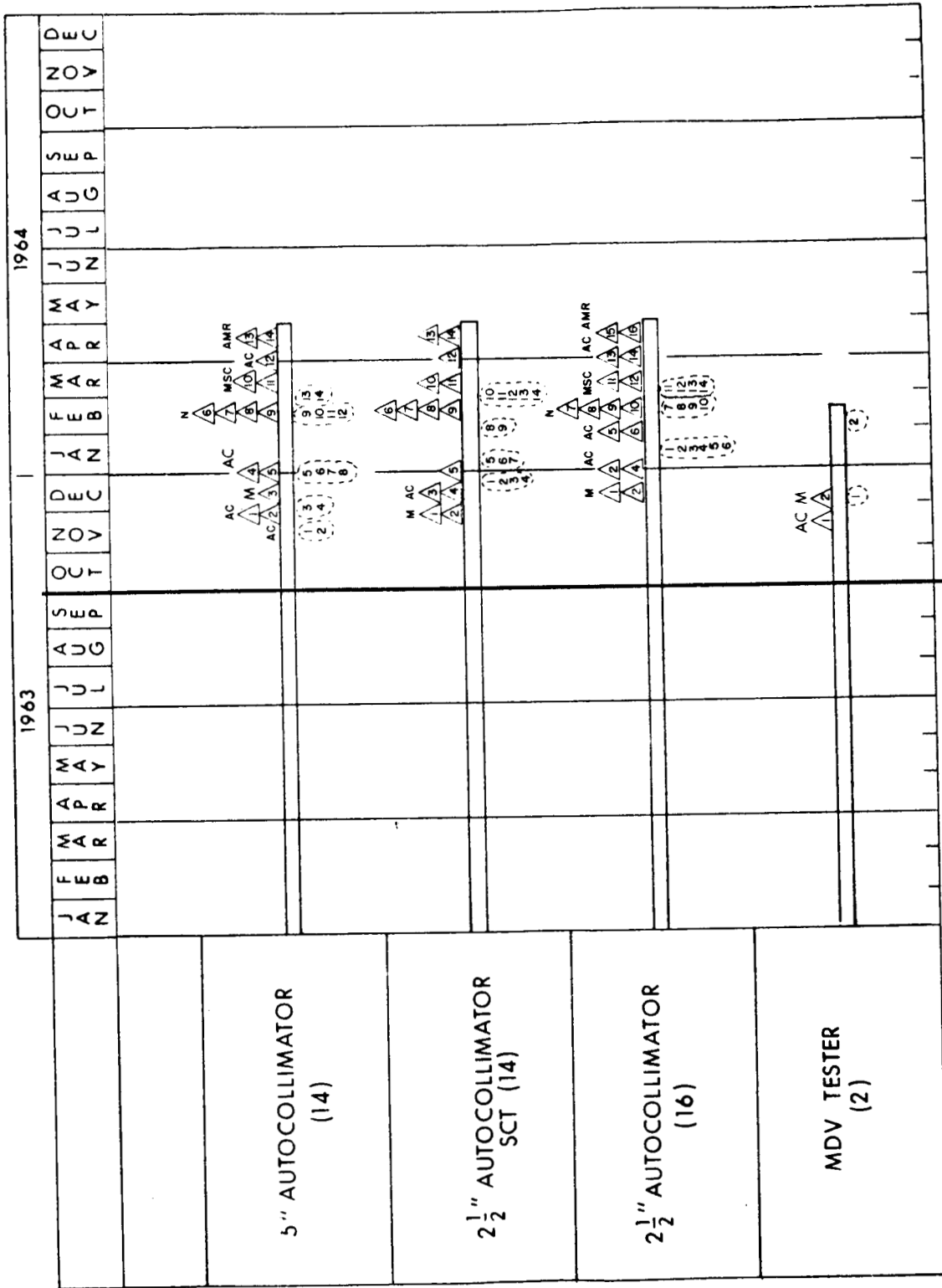
AC - A. C. SPARK PLUG
K - KOLLSMAN

M - M. I. T.
N - NAA

Δ - SCHEDULE
 \circ - EXPECTED

Fig. I-17

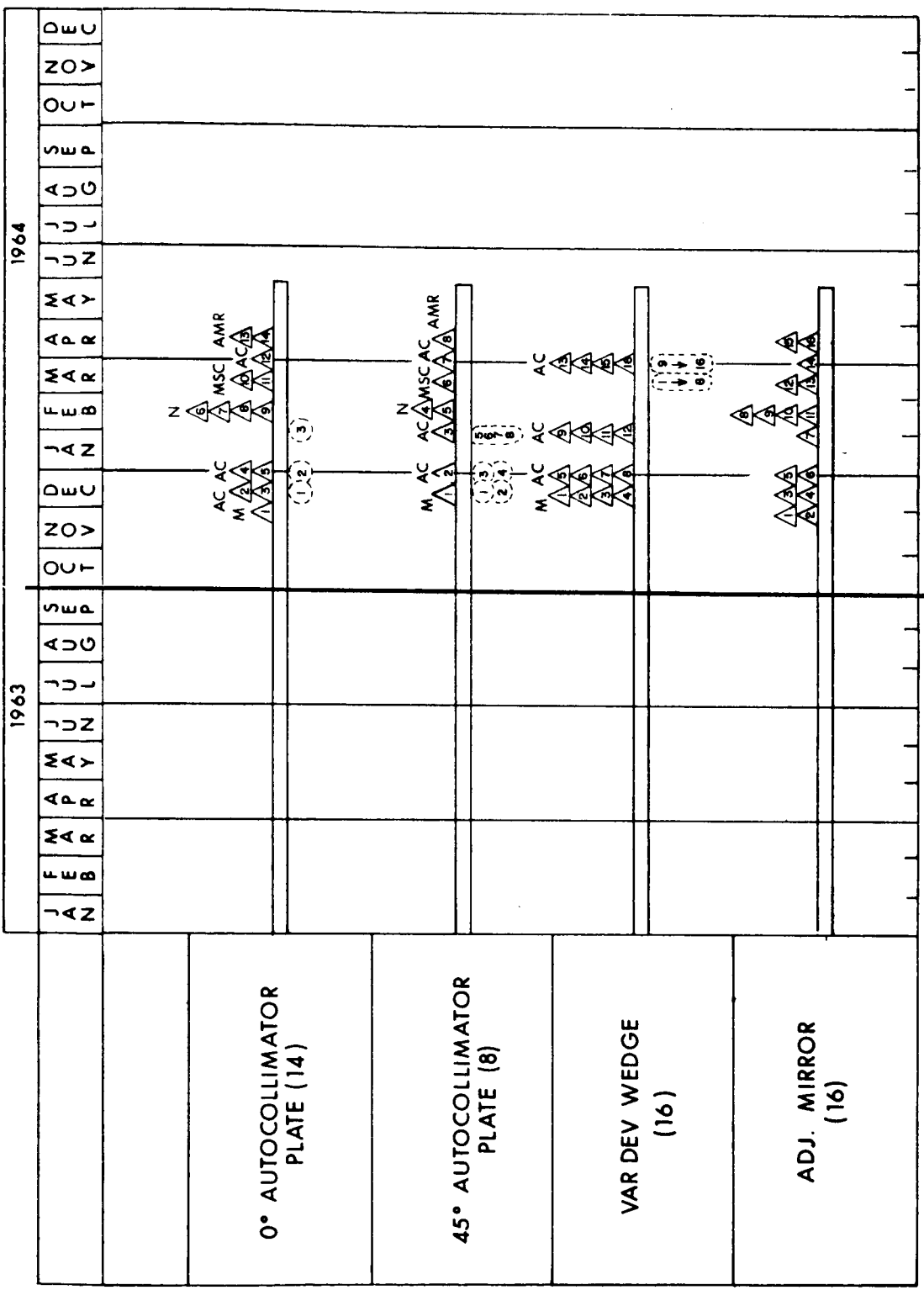
APOLLO MILESTONE CHART FOR KOLLSMAN GSE SCHEDULE (cont.)



AC - A.C. SPARK PLUG
 K - KOLLSMAN
 M - M.I.T.
 N - NAA
 Δ - SCHEDULE
 ○ - EXPECTED

Fig. I-17 (cont)

APOLLO MILESTONE CHART FOR KOLLSMAN GSE SCHEDULE (cont.)



AC - A.C. SPARK PLUG
 K - KOLLSMAN
 M - M. I. T.
 N - NAA
 Δ - SCHEDULE
 ○ - EXPECTED

Fig. I-17 (cont)

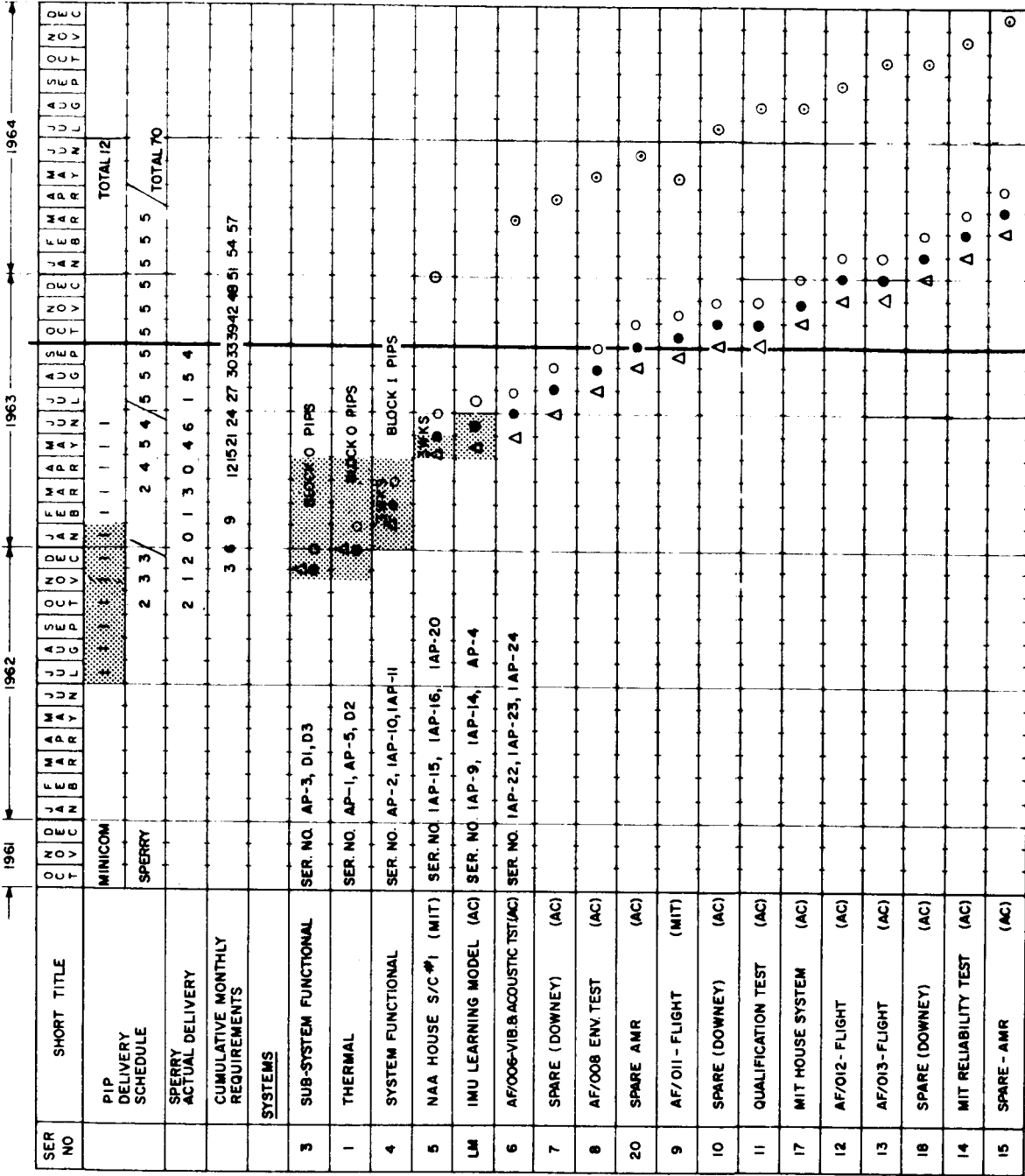
The PIP delivery schedule is shown in Figure I-18. During September, four PIPs were received as follows:

<u>Number</u>	<u>Date</u>
2 AP 28	5 September
2 AP 29	17 September
2 AP 30	23 September
2 AP 31	30 September

The 25 IRIG delivery schedule is shown in Figure I-19. During September, eight IRIG's were received as follows:

<u>Number</u>	<u>Date</u>
2 A 6	12 September
2 A 7	11 September
2 A 8	23 September
2 A 9	25 September
2 A 10	30 September
2 A 11	30 September
2 A 12	30 September
2 A 13	30 September

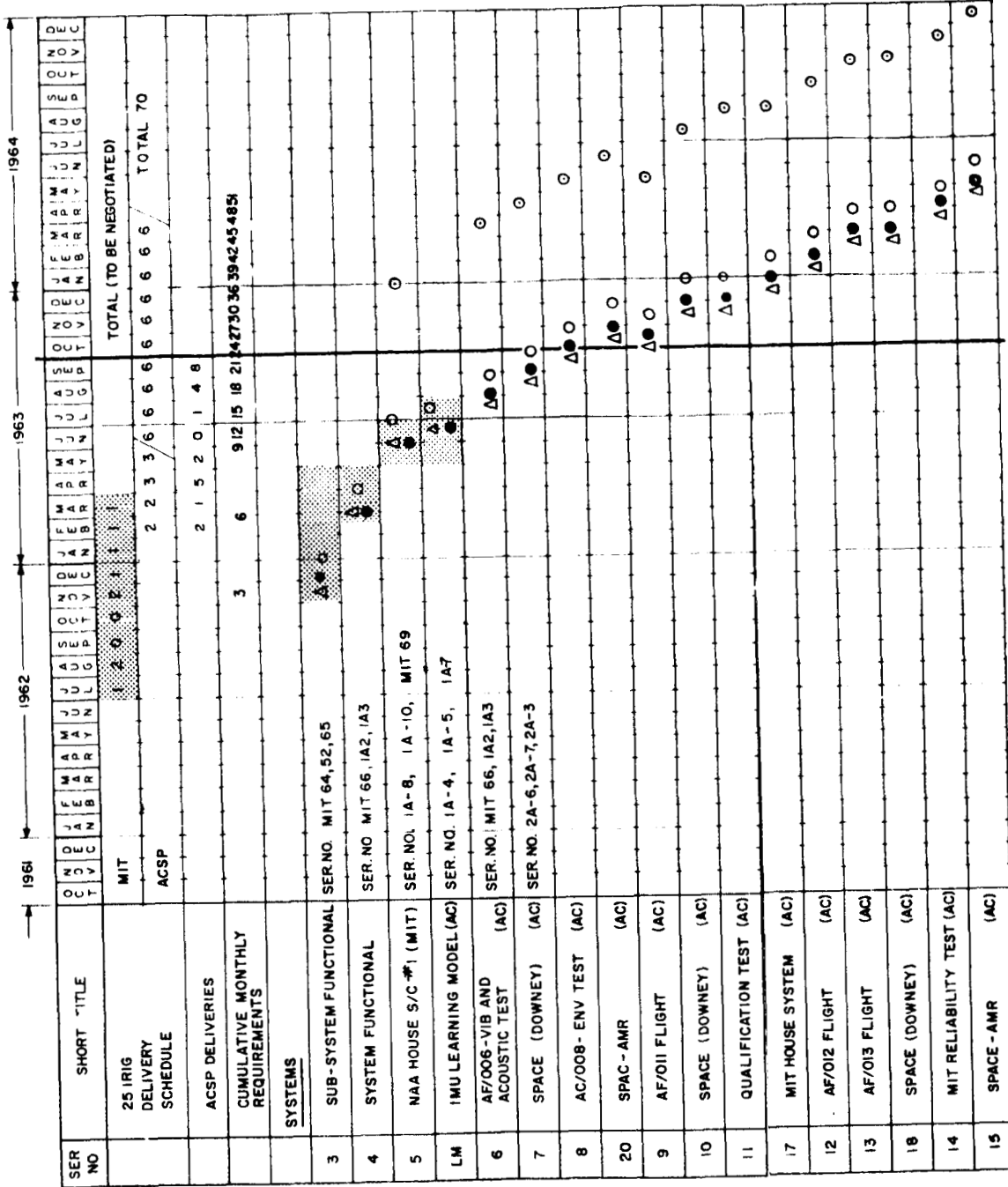
APOLLO MILESTONE CHART FOR PIP REQUIREMENTS & DELIVERY SCHEDULES



NOTE: Δ DELIVERY OF PIPS FOR CALIBRATION
 ● DELIVERY OF PIPS FOR INSTALLATION ASSY.
 ○ IMU SUBSYSTEM DELIVERY DATE
 ○ G & M DELIVERY DATE (READY TO INSTALL INS/C)

Fig. I-18

APOLLO MILESTONE CHART FOR IRIG REQUIREMENTS AND DELIVERY SCHEDULES



NOTE Δ DELIVERY OF IRIGS FROM SUPPLIER TO USER
 ● READY FOR INSTALLATION IN IMU
 ○ IMU SUBASSEMBLY DELIVERY DATE
 ⊙ GAND N DELIVERY DATE

Fig. I-19

SECTION II

LUNAR EXCURSION MODULE (LEM)

Several meetings were held in September 1963 between MIT/IL and GAEC to discuss questions concerning weight, Flight Test Plans, LEM concept and certain action items. Another meeting at GAEC was concerned with inspection and discussion of areas available for the MIT/IL facility at GAEC. These meetings under their respective dates are included in the tabulation of meetings attended by MIT/IL Apollo personnel.

Figure II-1 is a proposed LEM G & N System flow plan showing the allocation of G & N Systems to LEM vehicles. This proposal was presented to NASA/MSC in May 1963 (MIT/IL letter AG-382-63) but has not been approved by NASA.

TABLE I-1
MEETINGS ATTENDED BY MIT/IL APOLLO PERSONNEL
Period 1 September through 30 September 1963

<u>Date</u>	<u>Location</u>	<u>Subject</u>
3 Sept	MIT	AGC/LEM-CM Timing #L17B
4 Sept	MSC	AGC Briefing
9 Sept	MIT	Documentation Mtg #2
9-10 Sept	S&ID	GSE STU ICD's #65B
10 Sept	MSC	LEM Weight Mtg
10-11 Sept	MSC	Apollo Spacecraft Mission Trajectory Subpanel
10-11 Sept	MIT	Astronaut Training Equipment
10-12 Sept	Los Angeles	Symposium by the American Astronautical Society
11 Sept	MIT	Maintenance Repair Concepts
11-12 Sept	S&ID	Design Review
12 Sept	MIT	Documentation Control System
12-13 Sept	MSC	G&N System Mtg
16-17 Sept	MIT	NASA Coordination Mtg #L3A LEM ICD Review
16-17 Sept	Downey	CM/SM Stabilization & Control System #66B
16-17 Sept	MIT	LEM G&N Coordination Mtg #3A
17-18 Sept	Downey	Facilities Mtg #67B
17-18 Sept	MIT	Failure Effects Analysis Review #68B
18-19 Sept	MIT	Quarterly Program Management Review
20 Sept	MIT	LEM Concepts Design Program Review
23 Sept	GAEC	Installation of Computer
23 Sept	MIT	LEM - 3 Flt. Test Plan
24 Sept	MIT	LEM - 5 Flt. Test Plan
24 Sept	Raytheon	Raytheon Monthly Status Mtg
24 Sept	MIT	G&N Requirement on C-1 & C-2 Flts.
24 Sept	MIT	Landmark Accuracy Requirements
24 Sept	MIT	NASA/Contractor G&N Press Conference
24-25 Sept	S&ID	S&ID/MIT Mtg #69B Material Disc.
25 Sept	GAEC	ICD Review #L19B
25 Sept	MIT	AGE 5A Install and Assy. Review
25 Sept	KIC	Monthly Status Mtg

<u>Date</u>	<u>Location</u>	<u>Subject</u>
25-26 Sept	MIT	G&N Systems Mtg #7 on Entry Guidance
26 Sept	Sperry	Monthly Status Mtg
26 Sept	GAEC	Facilities Inspection
26-27 Sept	MSC	Quarterly Reliability and Quality Assurance Panel #1
26-27 Sept	ACSP	Monthly Management Review
30 Sept, 1 Oct	MIT	Review of LEM Concept Program
30 Sept, 1 Oct	MIT	Review of C/M Field Operations

BIBLIOGRAPHY
TECHNICAL PROGRESS REPORTS

<u>No.</u>	<u>Type</u>	<u>Period Ended</u>
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)
E-1237	Monthly	July 17 through August 21, 1962 (C)
E-1238	Quarterly	Period ended September 11, 1962 (C)
E-1302	Monthly	September 11 through October 11, 1962 (C)
E-1303	Monthly	October 11 through November 13, 1962 (C)
E-1304	Quarterly	Period ended December 11, 1962 (C)
E-1305	Monthly	December 11, 1962 through January 11, 1963 (C)
E-1306	Monthly	January 11 through February 11, 1963 (C)
E-1307	Quarterly	Period ended March 1963 (C)
E-1308	Monthly	April 1963 (C)
E-1378	Monthly	May 1963 (C)
E-1389	Quarterly	Period ended June 1963 (C)
E-1410	Monthly	July 1963 (C)
E-1445	Monthly	August 1963 (C)
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