49p

N63 17519

Code None

AIAA SPACE FLIGHT TESTING CONFERENCE

COCOA BEACH, FLORIDA MARCH 18-20, 1963

MERCURY SPACECRAFT PRE-LAUNCH PREPARATIONS

PART II - AT THE LAUNCH SITE

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GLOSSARY OF ABBREVIATIONS

1. ASCS - Automatic Stabilization and Control System
2. AMR - Atlantic Missile Range
3. BPMS - Blood Pressure Measuring System
4. CG - Center of Gravity
5. ECS - Environmental Control System
6. FACT - Flight Acceptance Composite Test
7. GSE - Ground Support Equipment
8. HF - High Frequency
9. MSC - Manned Spacecraft Center
10. PDM - Pulse Duration Modulation
11. RCS - Reaction Control System
12. RSCS - Rate Stabilization Control System
13. T - Countdown time; T-0 is Liftoff
14. T-610, etc. - Denotes time before Liftoff in minutes unless otherwise specified
15. TC - Test Conductor
16. TM - Telemetry System
17. UHF - Ultra High Frequency
18. X - Denotes launch day
19. X-1, etc. - Denotes number of days before launch day

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ABSTRACT

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This paper presents the checkout philosophies and procedures employed during the preflight checkout of a Mercury spacecraft at Cape Canaveral. It explains the purpose of the various tests and techniques used in the checkout of the spacecraft at Hangar "S" test complex and at the launch complex. Test flow diagrams are presented to illustrate the building block approach for determining the integrity of Mercury spacecraft prior to launch.

MERCURY SPACECRAFT PRELAUNCH PREPARATIONS

PART II - At the Launch Site

INTRODUCTION:

The Mercury Spacecraft arrives at the Atlantic Missile Range aboard an Air Force C-124 Globe Master which lands at the skid strip on the Cape. The spacecraft is unloaded and transported to the Hangar "S" test complex where it undergoes a series of rigid tests, modifications, and launch preparations. The average time spent at the Hangar "S" complex is approximately four months.

After final preparations in Hangar "S" are complete, the spacecraft is transported to Launch Complex 14 and mated with the Atlas launch vehicle. The spacecraft then undergoes a series of tests with the Atlas launch vehicle and AMR Range to determine system compatibility and flight readiness. This series of tests takes approximately seven test days. The spacecraft then enters a two-day period of final pre-launch servicing. At T-1 day the pre-count is begun. Spacecraft systems undergo final flight confidence checks, pyrotechnics are connected for flight, hydrogen peroxide is loaded and surveilled, and the final countdown begun.

Prelaunch Testing at the Launch Site - History and Test Philosophy

Preflight testing of manned space vehicles combine many of the requirements of research and development testing of missiles and high-speed aircraft. Like the missile, the manned space vehicle has single mission capability. There is no "turn around" after liftoff. Therefore, all testing and preparation must be extensive and thorough enough to provide the highest confidence of mission success.

However, the manned space vehicle, like the high-speed aircraft, must include every possible provision to insure the safety of the pilot. Therefore, inherent reliability of the vehicle must be maximized. An increased reliability is achieved by providing redundancies in critical systems, providing a means of escape for the pilot, and providing increased operational reliability through repeated and thorough developmental preflight testing.

Spacecraft reliability achieved during the Mercury program was attained by a step-by-step developmental flight test program and a repeated detailed examination of the spacecraft and its systems. Because of the urgency of the program, nearly all spacecraft produced were used for flight testing. Few complete spacecraft were available for developmental testing in the laboratories until late in the program. Therefore, the preflight operations conducted at Cape Canaveral on the various spacecraft served not only to prepare that particular craft for flight, but were also part of the design evaluation of the spacecraft.

This examination involved functional testing of the spacecraft systems, and observing in detail the performance of the systems. These tests were repeated often and duplicated as nearly as possible different flight environments and modes. During the tests, all discrepancies, no matter how trivial, were scrutinized for their significance. Design changes indicated by these tests and the flight tests were incorporated as rapidly as possible so that the optimum spacecraft configuration was flown.

The Astronauts participate in all system checkouts at Cape Canaveral and review all design changes. This participation results in intimate familiarization with the spacecraft and a better understanding of its systems.

The Mercury checkout program has evolved through experience gained in the past three and one half years. There were two basic principles followed during its development. The safety of the Astronaut was considered foremost; and secondly, all philosophy and procedure was directed toward a test plan which would guarantee a flight-worthy spacecraft at liftoff. As the program progressed, modifications to test operations were incorporated as required by increased knowledge and experience.

The end result of this evolution has been the development of certain test philosophies which can be considered to reflect best practice as proven by successful application. Testing techniques have evolved around six key points of philosophy. These are:

1. Building block approach to testing.

2. End-to-end testing.

3. Isolation and functional verification of all redundancies.

4. Interface testing and verification.

5. Mission profile simulation.

6. Astronaut participation as an integral part of the system during test.

Building Block Approach to Testing. - This guideline may appear to be an obvious approach to testing. However, time was a limiting factor in the Mercury test program, and the degree to which the building block approach is applied may not be readily apparent. As applied to Mercury preflight checkout, the building block approach means that there is no assumption made as to the operational status of any spacecraft equipment or system on receipt at the Cape. The operational status of each system and each component in the system is functionally verified before that system is operated concurrently or in conjunction with another system with which it might have an interface (Figure 1).

In developing the Cape test program, balance had to be established between a test program which would provide the maximum confidence of mission success and one which would do it in the shortest possible time. Two approaches were studied: (1) To begin Cape system tests on the spacecraft assuming all components and systems completely operational as checked out at the factory, and then repairing component and system malfunctions as they occurred, or (2) To establish a known condition of the spacecraft systems by individual component and systems tests before conducting overall system tests and simulated missions.

Several factors contributed to the necessity of using the component-system test approach as is often used on R & D vehicles. By its very nature an R & D vehicle is constantly changing from moment of inception almost to the moment of launch. The vehicle configuration must be updated continually to reflect the current state-of-the-art if the R & D program is to be successful. This requires that vehicle configuration changes be made at the launch site. Tests then have to be created to adequately verify proper operation of the component or system before flight.

In itself then, this facet of an R & D vehicle requires that a launch site test program be created which can adequately establish in detail the proper operation of a component or system. Overall system tests and simulated flight tests which provide only "landmark, go/no go type" parameters on system performance will not adequately fulfill this requirement. Also, if systems review, flight tests, or preflight tests indicate that a configuration change is required because of flight safety, this change must be incorporated and the systems re-verified before launch.

It was decided that the "prove-it-to-me" approach would be used. The quality of performance of all components and systems would be established by individual tests before testing the total spacecraft system. Practice has shown that this approach has provided the maximum confidence level in flight-worthy system operation.

End-to-End Testing. - Utilize end-to-end testing as much as possible. This concept means that during testing, the initiating function and end function should take place sequentially as they would actually occur in flight. The use of artificial stimuli is kept to a minimum. Implementation of this guideline is most readily apparent in the hangar simulated flight test.

For this test the spacecraft is placed on its adapter with the escape tower installed. Internal spacecraft components and wiring are configured as for actual flight. Test cabling is kept to an absolute minimum and only used where "T" connections to the system can be made. Thus, the process of signal monitoring in no way interrupts the flight wiring which carries the signal. Two-tenth ampere fuses are used as squib simulators. Electrical connections are made at the actual squib location. During the flight simulation, current is delivered to the fuse exactly as it would be to the squib in actual flight. The fuse is sized to experience an actual current slightly in excess of the 3 ampere "sure-fire" requirement on all Mercury pyrotechnics.

In this test, a launch vehicle function simulator provides signals to the spacecraft system in the same manner and at the same place as the launch vehicle would in flight. To illustrate, let us follow a sequence performed during the hangar simulated flight and compare it with what would happen in actual flight. The sequence selected for this illustration will begin with the launch vehicle initiated signal of sustainer engine cutoff (SECO) which occurs just before spacecraft separation from the booster.

The launch vehicle simulator provides a +28 VDC signal to the spacecraft-launch vehicle interface wiring as the launch vehicle would during flight. Using actual flight wiring, this signal through relay action causes a firing voltage to be applied to the main clamp-ring bolts. In actual flight, the bolts would fire and the clamp-ring would mechanically separate; in simulation, the fuses used as squib simulators are blown verifying the validity of the signal path in regard to signal delivery and signal timing. Next, mechanical limit switches provide sensing of in-flight separation of the clamp ring and fire the posigrade rockets when separation is sensed.

During simulation the limit switches are energized mechanically as would be the case in actual flight. These switches provide a firing signal to the posigrade rocket squib simulators.

The test data are monitored by instrumentation pickups, radiated by the spacecraft transmitters, and received and displayed at the ground station in a manner identical to the way it will be done in flight. Warning lights in the spacecraft cabin which monitor the progression of the sequence are observed by the suited Astronaut and transmitted by him to the ground station using his UHF voice link in the same way as would be done during flight.

The example above dealt with simulation of a command signal from its initiating function to end function during a hangar simulated flight. The same basic procedure is followed during pad testing with the booster supplying the initiating signal instead of a booster simulator. RF command, voice, and data reception are also tested on an end-to-end basis in much the same manner as the hardwire initiated signal just discussed.

It is our feeling that end-to-end testing must be performed to maintain the reliability of the total spacecraft, launch vehicle, and range combination at its highest achievable level.

<u>Isolation and Functional Verification of all Redundancies</u>. - All redundant signal paths are isolated and functionally proven by end-to-end tests. This includes redundancies between the spacecraft and launch vehicle, and redundancies within the launch complex.

As applied to redundant hardwire paths, the system is self-explanatory. The concept as implemented in the Mercury checkout program extends to include all pieces of equipment and all signal initiation stations at the Cape. For example, the first orbital Mercury spacecraft contained two command receivers which performed the identical functions of responding to RF command to initiate the following spacecraft signals:

A. Abort

B. Retro sequence start

C. Change orbital clock time

D. R and Z calibration for the flight telemetry system

The RF signal can be generated during an actual operation by either of two low power transmitters or one high power transmitter located at the Cape command building. The RF signal can be initiated from any of four stations on the Cape; three of these stations are located in the Mercury Control Center, and one is located on the Test Conductor's console at Complex 14.

To verify the redundancies in this system, the ability of each command receiver to receive and react properly to the RF signal is tested separately. One receiver is turned off and all commands from all three transmitters are individually functionally tested. Then the first receiver is turned off, the second on, and the process repeated. After this is complete, the whole process is repeated with both receivers on to determine that there is no mutual interference.

Other redundant systems are tested in the same manner. This method contributes significantly to achieving a high confidence level in overall system operational reliability.

Interface Testing and Verification. - There are two basic interfaces in Mercury. The spacecraft/launch vehicle interface, and the total space vehicle/range interface. These interfaces include RF and hardwire. Tests involving these interfaces are consistent with the test philosophy previously discussed, namely, end-to-end testing and testing of all redundancies.

The relatively few problems encountered in the interface areas is basically due to its simplicity. The spacecraft/launch vehicle hardwire interface transfers only 6 flight functions plus several grounds. The RF equipment aboard the spacecraft was chosen in the design state to match the existing capabilities of range equipment.

Mission Profile Simulation. - Simulated mission tests which include the spacecraft, launch vehicle, and range are designed to functionally approach actual mission conditions as much as possible. This includes simulating real-time functions through orbit insertion. The Astronaut is aboard for these simulations and functions as he would during the actual flight.

A total mission simulation is not possible during any one test due to restrictions imposed by environment and space vehicle configuration. However, after the spacecraft has completed all tests, it has completed a series which, taken together, approach almost total simulation. To some extent even the space environment is simulated during the altitude chamber runs. The life support systems including the suited Astronaut undergo a mission simulation which duplicates pressure environment and mission time. The altitude chamber is the only test area adequate for this type of simulation.

Mission simulations conducted at the launch pad with the spacecraft, Astronaut, launch vehicle, and range operating as they would during flight provides assurance that no procedural or functional interference will be encountered on launch day.

Mission simulation as practiced in the Mercury program includes all predictable abnormal flight modes as well as the normal flight modes. These abnormal flight modes include all abort configurations, all manual override modes, partial power loss, chute failure, and others.

The Astronaut as an Integral Part of the System During Tests. - The Astronaut is considered part of the total system and functions during systems tests and mission simulations as he would during the actual mission. This results in a dual advantage. The system tested is closer to flight configuration when the Astronaut is included, and the Astronaut becomes intimately familiar with the unique characteristics of the individual spacecraft to which he is assigned. This contributes to ultimate mission success.

In summary then, the manned spacecraft preflight test operation includes:

1. The building block approach to testing. Component operation is verified, then system operation, and finally full mission simulation with all systems operating.

2. Use end-to-end testing as much as possible. Keep the use of artificial stimuli to a minimum.

3. Isolation and functional verification of all redundancies.

4. Functional verification of interface signal paths. Functional tests across interfaces are consistent with spacecraft test philosophy.

5. Mission profile simulation which includes abnormal modes such as abort, manual override, and others.

6. Using the Astronaut as an integral part of the system during tests.

These philosophies were developed within the guidelines of the two basic principles; pilot safety foremost, and a test plan which guarantees a flight-worthy spacecraft at liftoff. The objectives directed by these two principles, pilot safety and complete system reliance, have been achieved through the Project Mercury Preflight Test Program.

To provide a better understanding of how the test philosophy is implemented, a brief description of launch site operations is presented for each of the following general categories:

1. Hangar component and system tests.

2. Spacecraft modification.

3. Spacecraft repair.

4. Hangar Simulated Flight.

5. Mechanical preparations and servicing for transfer to the launch pad.

6. Complex testing and prelaunch servicing.

Hangar Component and System Tests. - Checkout operations at Hangar "S" include individual component and system tests. These tests are scheduled in such a manner that the final test in each series is performed with the system in flight configuration as nearly as practical. A flow chart of the Hangar tests performed on spacecraft 18 is presented in Figure 2. The major system tests are listed below in the approximate order that they occur for a normal, trouble-free operation.

Electrical Power System Test

The basic test objective is to assure proper operation of on-board and test complex power systems prior to using these systems to support other tests.

The Mercury spacecraft basic DC power requirements are supplied by six batteries. Two main inverters supply the 115 VAC requirements. A third inverter serves as a standby source of AC in case of failure of either one of the main inverters. External DC power is supplied parallel to the main power system through the main spacecraft umbilical connection. All AC is provided by the on-board inverters.

Instrumentation System Test

The spacecraft instrumentation system includes four basic areas: Camera and tape recorders, transmitters, commutators, and internal instrumentation. This test is primarily a system test; however, it does provide for some component testing. The following test objectives are achieved:

(1) Verification of camera lighting and lens setting functions and tape recorder operation.

(2) Transmitter deviation and subcarrier oscillator pre-emphasis adjustment.

(3) Commutator output check through examination of the PAM wave form output from the commutators and a comparison with the discriminator output wave form in the telemetry trailer.

The instrumentation system check is performed in conjunction with the check of the systems supplying signals to instrumentation equipment. Signals are read out through the umbilical via the telemetry link. The spacecraft tape recorder PDM signal is played back as part of the instrumentation system checks to observe the quality of this signal.

Sequence System Test

The sequence system test is a verification of the proper sequence of events for various modes of operation including a normal launch through recovery sequence, the abort modes, and the astronaut emergency manual override modes. This test is performed to assure proper system operation during all predictable flight modes.

The sequential test checks spacecraft operation through the following sequences: Liftoff, Booster Engine Cutoff, Tower Separation; Sustainer Engine Cutoff; Spacecraft Separation and Turn-around; Retrograde Sequence; Drogue and Main Chute Deploy; Landing Bag Extension; and Impact and Recovery Sequence. Test objectives are obtained through a series of tests using a combination of manual and automatic flight simulation. All systems redundancies are tested.

Communication System Test

The spacecraft communication system is composed of two command receivers and associated decoders, two UHF rescue beacons, one HF rescue beacon, one "C" band radar beacon, and one "S" band radar beacon, two UHF voice transmitter-receivers, and two HF voice transmitter receivers. This test is designed to determine proper component and system operation according to specification. The first section of the test is performed on system components prior to actual testing of the complete communication system. The components are not removed from the spacecraft.

Automatic Stabilization Control Systems (ASCS) Test

The ASCS is designed to provide automatic stabilization and orientation of the spacecraft continuously from the time of separation from the booster until the landing parachute is deployed, during either a normal or aborted mission. To accomplish this, the ASCS employs:

(1) Three rate gyros for sensing spacecraft rotational rates in pitch, roll, and yaw.

(2) Two attitude gyros for sensing pitch, roll, and yaw attitudes.

(3) An acceleration switch for sensing 0.05G longitudinal deceleration for initiating the re-entry mode.

(4) A calibrator which contains the necessary switching logic, attitude repeaters, summing and erection circuitry, relays and power supply to effectively tie together all elements of the system.

(5) Horizon scanners to provide attitude reference for the gyros.

The test objective is to verify that the ASCS is capable of providing automatic stabilization and orientation from spacecraft separation to main chute deploy. In order to accomplish the test objective the test is performed in two parts:

(1) Static Tests - Static tests are made with the spacecraft positioned horizontally on the ASCS test fixture or on a standard vertical spacecraft stand. A complete test of the ASCS, with exception of rate gyros, is performed utilizing the prelaunch tester. The horizon simulator is used to test the horizon scanners.

(2) Dynamic Tests - Dynamic tests are made with the

spacecraft installed in a two-axis ASCS test fixture. The spacecraft is sequentially rotated in all three axes at various rates and attitudes. The 24V DC output of the amplifier-calibrator (Amp-Cal) unit to the Reaction Control System thruster solenoids is monitored and recorded together with the actual attitude and rate of the test fixture which are supplied by test fixture attitude and rate transducers. The prelaunch tester is utilized to place the ASCS in various modes of operation. After completion of the tests, the recordings are analyzed to assure that proper ASCS thrust logic has been supplied in accordance with the spacecraft programmed rate and attitude in the various modes. A check of retro and re-entry attitudes is also made at this time while the spacecraft is rotated to the actual angles.

Environmental Control System (ECS) Test

The subsystems and systems which are tested at sea-level conditions while installed in the spacecraft are the Environmental Control System, Suit and Cabin Coolant System (water and freon), and the Blood Pressure Measuring System. Functional checks of these systems are performed, as well as checks of manual controls to verify pull forces and confirm proper rigging of the Snorkel Pull Ring, Decompress "T" Handle, Pressure Gage, and the Emergency O_2 Rate Handle.

All relief valves are checked for relieving excessive positive and/or negative pressures and the following items are checked for leak rate:

(1) Spacecraft Cabin

(2) ECS, High Pressure and Low Pressure Systems

(3) Coolant System: Water, Freon, and Pressurization Systems

(4) Blood Pressure Measuring System, High Pressure and Low Pressure Systems (BPMS)

Flow rate checks are performed for validation of the following:

(1) Emergency O_2 Rate Valve

(2) Suit Circuit Compressors (No. 1 and 2)

(3) Water flow from the three temperature control valves: Suit, Cabin, and Inverter Cold Plates.

A functional checkout of the complete system is performed under simulated malfunctions to check out the backup features of the system.

These tests are performed in conjunction with telemetry to calibrate the transducers in the ECS and the Blood Pressure Measuring System (BPMS) through their full range of normal operation.

Altitude Chamber Test

These tests are made to validate the Environmental Control System (ECS), Blood Pressure Measuring System (BPMS), and coolant systems for proper operation at various altitudes under normal and adverse conditions, both manned and unmanned. The results of this test are monitored by TM for comparison of gage readings and observations made throughout the tests.

There are three separate runs or tests: (1) An unmanned run to calibrate TM pickups and readings to verify accuracy and operation of all monitoring points; (2) An unmanned run to validate the ECS at altitude under normal conditions and simulated adverse conditions; and (3) A manned run simulating normal mission conditions.

Reaction Control System (RCS) Test

The Reaction Control System uses a monopropellant thrust system (90% hydrogen peroxide) to control the attitude of the spacecraft during flight. The system is divided into two independent subsystems, manual and automatic.

The automatic system has twelve thrust chamber assemblies. There are two 24-pound thrusters and two 1-pound thrusters in the pitch and yaw axis. There are two 6-pound and two 1-pound thrusters in the roll axis. These thrusters are electrically operated and are controlled by two completely independent systems: The Automatic Stabilization and Control System (ASCS), and the Fly-by-Wire System. The ASCS system is completely automatic and can be considered the "autopilot" of the spacecraft. The Fly-by-Wire system uses astronaut stick motion to actuate limit switches which energize the thrusters.

The manual system has six thrust chamber assemblies. There are two 6-pound to 24-pound variable thrust assemblies in both the pitch and yaw axis. There are two 1-pound to 6-pound variable thrust assemblies in the roll axis. In addition, the manual system has a rate stabilization control system (RSCS) which can fire the manual thrusters by energizing solenoid valves which are plumbed in parallel with the proportional metering valves. When this method is used, only full thrust of 24-pounds and 6-pounds is available.

In order to verify the proper operation of the RCS thrusters for both manual and automatic systems and to verify the integrity of the fuel and pressurization systems, the following tests are made:

(1) Peroxide system gas leakage test (automatic and manual)

(2) 35% peroxide decomposition surveillance test (automatic and manual)

(3) Hydrostatic leak test (automatic and manual)

(4) Helium source leak test and fuel quantity indicator calibration (automatic and manual)

(5) Hand controller force and deflection test

(6) 90% decomposition surveillance test (automatic and manual)

(7) Static firing test - all thrusters

(8) Drain, purge, and vacuum dry

(9) Proof pressurize test (automatic and manual)

Communications System Radiation Test

The spacecraft is placed atop a 50-foot radiation tower and open loop radiation and HF antenna voltage standing wave ratio (VSWR) checks are made on the communications equipment. These tests verify the absence of interference on RF units by operating the HF and UHF voice transmitter-receivers with all possible noise sources operating and concurrently to check the operational characteristics of the RF systems.

In summation, each of the described system tests are designed to totally verify the operational integrity of the system. This increases confidence in system operational reliability, in support of the MSC policy that states "In manned flight we cannot afford to regard any equipment malfunctions as a random failure. We must regard every malfunction and, in fact, every observed peculiarity in the behavior of a system as an important warning of potential disaster."[1]

Hangar Simulated Flight. - The Hangar Simulated Flight is the final systems test performed on the spacecraft before it is transported to the launch pad. For this reason, all systems are exercised in all predictable operational modes. The test contains two major parts, individual systems tests and simulated flight tests. The primary objectives are:

(1) To verify proper operation of all individual systems (Except RCS).

(2) To insure proper operation of all systems including the sequential system through all predictable mission profiles.

(3) To demonstrate intra-system compatibility when all systems are operating concurrently.

(4) To verify proper operation of the spacecraft systems when configured as near flight configuration as practical.

In order to accomplish these objectives, the spacecraft is configured as follows:

(1) The spacecraft is installed on the flight adapter and is electrically connected to the adapter through flight wiring.

(2) The escape tower, minus escape rocket, is installed on the spacecraft and electrically connected.

(3) An absolute minimum of test cabling is connected to the spacecraft. The intent is to approach actual flight configuration as nearly as possible.

(4) All squib firing circuit wiring is in flight configuration. Due to limitations imposed by spacecraft configuration, this is the only test where complete flight configuration of squib wiring is possible.

(5) Two-tenth ampere fuses used to simulate squibs are electrically connected at actual squib locations.

(6) The Astronaut is suited and in the spacecraft for the system tests and simulated flight No. 4.

[1]See Reference #2

(7) Event recorders monitor all squib circuits to verify proper firing time and sequence. Recorder inputs are connected directly across the squib simulators so that true end point conditions can be monitored. All systems are operated as they would be in flight and are monitored for any adverse effects from squib firing.

(8) All flight sequences requiring limit switch operation are accomplished by activating the flight limit switch rather than simulating activation using artificial stimuli through test cables.

Mechanical Preparations and Servicing for Transfer to the Launch Pad. - Following the completion of the Hangar Simulated Flight, a final ASCS dynamic test is performed and mechanical buildup and servicing functions are completed before the spacecraft can be moved to the launch pad. These functions are listed below. The order is approximate since some functions are performed concurrently.

(1) Final Automatic Stabilization and Control System (ASCS) Dynamic Test

(2) Environmental Control System (ECS) Oxygen Servicing

(3) Parachute installation and installation of the recovery system pyrotechnics. Pyrotechnics in the Mercury spacecraft include explosive actuators, gas generators, squib cartridges, reefing cutters, and rockets used to initiate or provide various sequential functions during the flight and post-landing phase of a mission. A planned procedure is used for installing such pyrotechnics. It includes the necessary safety measures and provides for an orderly step-by-step installation of pyrotechnics, thereby preventing an already installed item from interfering with the installation of another item.

Torque values, safety wiring, stray voltage checks, and pyrotechnic connections are incorporated in the procedures to eliminate the need for the use of blueprints and schematics for each installation.

As the pyrotechnic devices are installed and connected, shorting plugs are installed, insuring that all pyrotechnics are in a safe condition.

(4) Weighing, Balancing and Rocket Alignment. Prior to mating with the booster, the spacecraft must be weighed and the center of gravity located for various flight configurations. The retrograde rockets and escape rocket must be

properly aligned to insure correct thrust vector alignment. The weighing, balancing, and alignment are performed as follows:

(a) The escape rocket system is weighed and its C. G. is determined.

(b) The spacecraft is put in a flight configuration. The retropack is installed, the Astronaut's couch is installed, and certain systems are serviced. Other known weights and C. G.'s are added as paper corrections. The spacecraft is weighed and the C. G. is located.

(c) The escape rocket and tower are installed on the spacecraft. The spacecraft is weighed again and the C. G. located.

(d) The escape rocket is now aligned otpically. This is necessary to insure that the spacecraft follows a pre-determined trajectory in the event of an abort.

(e) The retrograde rockets are optically aligned so that the thrust vectors pass through the spacecraft's C. G. This minimizes disturbance to spacecraft stability during retro-rocket firing.

(5) Cleanup, inspection, and general preparations required to prepare the spacecraft for transport to the launch pad are performed.

Spacecraft Modification. - Major modifications to the spacecraft are usually accomplished during two separate work periods. The first occurs shortly after the spacecraft arrives at Hangar "S". The second occurs just following the completion of all individual system tests. The modifications made during the first work period are usually retrofit modifications dictated by changes in the mission objectives or changes in design concept resulting from recent ground or flight tests. Following the modifications, additional system tests are performed as required to verify the operational integrity of the affected systems.

Because time was a limiting factor in the Mercury program and the fact that it is MSC policy to fly the optimum spacecraft configuration as dictated by the latest design reviews and flight test results, spacecraft configuration changes incorporated at AMR exceed in magnitude and number field changes normally made on operational aircraft and missile programs. In this sense, we are closer to the X-15 than the B-58.

To achieve maximum confidence in the operational reliability of the spacecraft, its ability to successfully complete its mission, every effort has been made to incorporate design improvement changes before the next spacecraft flies. In this regard, schedule has been considered secondary to flying the optimum spacecraft configuration.

Also, any change indicated which will effect pilot safety is incorporated before flight. These changes have been incorporated and systems re-verified in some cases even after the spacecraft has completed most of its pad tests.

Spacecraft configuration changes at the Cape have been as extensive as re-working a spacecraft from a sub-orbital configuration to an orbital configuration. This involves extensive changes in the Reaction Control System, Environmental Control System, Sequential System, and others. It should be stressed, however, that configuration changes of this magnitude were done at the Cape only because it was more efficient to do so. We do not prefer to have to engineer and incorporate changes of this magnitude since we are primarily an operations organization. Changes which would normally be required to update the spacecraft to an optimum flight configuration are the type we expect to have to make on future spacecraft programs.

We plan to have a spacecraft modification center at the manufacturer's plant accomplish gross modifications to spacecraft configuration. There was no provision for such a modification center during the Mercury program. Production line assembly techniques were used to manufacture the spacecraft, and once manufacturing and acceptance tests were completed, it was delivered to the field. Some configuration changes were reflected in spacecraft on the assembly line but many were accomplished in the field.

Having a modification center located at the factory will allow more efficient and rapid incorporation of changes dictated by current design reviews, ground tests, or flight tests before the spacecraft is delivered to the field. It is felt that gross configuration updating should be handled in this manner.

However, since the Apollo and Gemini programs are, like Mercury, developmental research programs, every spacecraft which flies will be tailored to accomplish a specific mission objective. Each mission with its particular objective is one link in the chain leading to the accomplishment of total program objectives. Therefore, the flight configuration of a particular spacecraft can never be completely defined until the preceding spacecraft completes its mission. If the current spacecraft flies and fails to meet its mission objective, then the failure must be analyzed, proper corrective action must be taken, and the mission must be re-flown. However, if the current spacecraft completes its mission objective, then the following spacecraft will be configured to achieve the next logical mission objective in the chain leading toward achievement of the total program mission objective.

It is currently planned that at least two spacecraft will be undergoing concurrent checkout at the Cape on both the Apollo and Gemini programs. This requires that configuration changes to update the spacecraft to the "best state-of-the-art" as dictated by results of design reviews, ground tests, and flight tests, which may well have taken place since the spacecraft arrived at the Cape, must be incorporated at the Cape.

These requirements were probably best expressed in a speech by Dr. Gilruth in which he states, "Thus we arrive at what is perhaps the most important single requirement in our programs: <u>that designs, procedures, and schedules must have the flexibility to absorb a steady stream of change generated by a continually increasing understanding of space problems</u>."

After the prime mission objectives of Project Mercury had been achieved through the flights of Colonel Glenn and Commander Carpenter, new program objectives evolved. Experiments are required to determine the effects of the space environment in many scientific problem areas; therefore, the scope of the Mercury mission was expanded to encompass these new areas. Increased spacecraft orbital duration, physiological effects of increased mission duration on the Astronaut, and specific scientific experiments, became new mission objectives. The exact scientific experiments to be flown are chosen by a scientific experiment panel.

The increased scope of the mission objective of course requires that many spacecraft modifications be done at the Cape. We expect that once the prime mission objectives of future spacecraft programs are achieved, they too will expand the scope of their mission to encompass the latest "space problems," as indeed they should. Modifications to the spacecraft at the Cape will be required to support the new mission objectives and to assure that the "best state-of-the-art" in spacecraft configuration is being flown on each mission.

In this regard, it is interesting to compare some statistics of Mercury spacecraft preparation and launch (Figure 2). Simple averages for all production spacecraft flown from the Cape, show that of the total average time spent at the Cape, roughly 60% was spacecraft work time in the Hangar (which includes modification, repair, assembly, service, and inspection), 25% for Hangar Test, and 15% time on the pad including all work and test. Of the average total time spent in the Hangar Complex, approximately 70% was work time and 30% active test time.

The average time spent at the Cape for all spacecraft has been five months of which approximately 3 months were spent in Hangar work, 1 1/3 in Hangar test, and 1 on the launch pad.

As an average, the Mercury-Atlas spacecraft have required 43 more total days at the Cape than the Mercury-Redstone spacecraft. They have required 33 more Hangar work days, 6 more Hangar test days, and 4 more days on the pad. It would appear that the increased complexity of the Mercury-Atlas missions over the Mercury-Redstone had little effect on time spent in Hangar test or total time spent on the launch pad.

It also becomes apparent that the greatest portion of the total time the spacecraft spends at the Cape is spent on spacecraft work which includes modification, assembly, repair, servicing, inspection, etc.; that the spacecraft Hangar tests take only 25% of total spacecraft checkout time; and at 15% of the total, time the spacecraft spends on the launch pad is shown to be a small percentage of the total time required to prepare a Mercury spacecraft for flight.

Repairs. - The Mercury spacecraft is literally packed with equipment and internal working space is severely limited. As a result, a certain amount of spacecraft wiring damage and equipment damage occurs during normal work and test operations. Repair is a continuing work item during all phases of spacecraft checkout. Any system affected by these repairs must be re-verified by test.

Careful work methods and rigid inspection procedures have kept spacecraft equipment damage to a minimum. The work area and interior of the spacecraft is maintained in a clean, dust-free environment.

Complex Testing. - The complex operations normally require twelve work days. Ten days are required for testing and two days for servicing (Figure 4). Due to delays caused by system deficiencies uncovered through testing, world wide range conditions, weather, etc., the actual time the spacecraft spends on the pad is usually much longer than twelve days. The launch complex operations are listed below in the order in which they normally occur.

It should be emphasized that the test procedures were developed to be flexible so that if malfunctions are encountered during testing, or if modifications changing the spacecraft configuration are incorporated, the order of testing may be changed as required to verify the affected system. Normally, after the affected system is re-tested, a complete simulated flight is re-run to prove that the spacecraft/launch vehicle system is in a flight-ready condition. The normal order of complex functions are as follows:

Launch Complex Checkout

Electrical verification of the complex which is completed before the spacecraft arrives at the pad.

Interface Inspection

Inspection of the mechanical interface area which is started before the spacecraft arrives at the pad.

Mechanical Mate

All mechanical interface connections to the launch vehicle are connected for flight.

Spacecraft Systems Test (Simulated Flight No. 1)

This test is performed to functionally verify spacecraft systems operation and to verify spacecraft/complex compatibility. The test consists of a series of concurrently run individual system functional validations followed by several integrated system tests functionally simulating mission profiles from liftoff through landing. All launch vehicle functions are provided by a launch vehicle function simulator since the spacecraft is not electrically connected to the launch vehicle during this test day. After successful completion of this test, the spacecraft is considered functionally ready to be electrically mated to the launch vehicle.

Spacecraft/Launch Vehicle Electrical Interface and Abort Tests

All tests after this test are concurrent spacecraft/launch vehicle tests.

(1) This test consists of two major parts. Interface circuit and flight circuit checks are performed using launch vehicle simulator initiated signals at the interface to verify proper operation of spacecraft electrical interface. Upon completion of these tests, the interface plugs are mated to the launch vehicle and identical checks are made using launch vehicle initiated signals. A full complement of test cabling is utilized to provide multiple readout and control capability.

(2) The initial tests provide verification of spacecraft interface wiring by using launch vehicle simulator input signals. Each of the two interface connectors are tested separately to verify redundant circuitry. Both interface connectors are then tested simultaneously through eight abort runs. Automatic squib disarm circuitry is activated and its operation verified. An exercise of manual override circuitry (excluding pull rings) completes testing with the launch vehicle simulator.

(3) The launch vehicle support portion is begun with individual interface plug checks. Complex redundant paths for liftoff and abort are verified during the plug checks. Both interface plugs are then connected in flight configuration and the following mode checks are run: Abort off the pad, Abort Sensing Implementation System (ASIS), abort before tower separation, and normal flight through spacecraft separation.

(5) A verification of Mercury Control Center Command functions, and Test Conductor (TC) RF abort capability through Mercury Control Center is performed.

Flight Acceptance Composite Test (FACT)

This test is basically an integrated simulated flight test with the launch vehicle and AMR. The major test objective is to prove combined spacecraft launch vehicle range operational and procedural compatibility, including RF compatibility, during a simulated flight. The following tests are included during the

FACT test:

(1) Range Command Checks

(2) Launch Vehicle Spacecraft RF Compatibility

(3) Simulated Flight through Abort at T plus 200 seconds

(4) Simulated Flight through Recovery (Normal)

After the space vehicle successfully completes this test, the recovery forces are deployed.

Flight Configuration Sequence and Aborts

This test has two primary objectives: To observe any possible electrical interference affecting the launch vehicle autopilot programmer and to exercise abort modes with the spacecraft and launch vehicle in a flight configuration.

There are seven separate tests with the spacecraft and launch vehicle in flight configuration which exercise functionally all predictable abort modes and normal ascent with all complex cabling, including umbilicals, separated from the spacecraft and launch vehicle.

Launch Simulation and RF Compatibility (Launch Countdown Dress Rehearsal)

This test provides as close a simulation of launch day operations as possible in order to verify launch day procedures and to provide training for the launch crew. To accomplish these objectives the following conditions exist:

(1) Hydrogen Peroxide is loaded the night before and the rate of decomposition is monitored for 12 hours as would occur during launch day.

(2) Hydrogen Peroxide launch day systems checks are performed, including thruster firing.

(3) A suited Astronaut is installed in the spacecraft and connected to the life support system.

(4) The hatch is installed and a leak check is made identical to launch day.

(5) The gantry is moved away from the space vehicle.

(6) Launch configuration RF compatibility tests are performed between spacecraft, launch vehicle, and range.

(7) With the gantry removed, emergency egress procedures are performed.

Testing is started at T-390 minutes which represents pickup time for the second half of the actual countdown. The countdown simulation proceeds to T-0. At T-0, all spacecraft and launch vehicle RF is on; spacecraft gyros are exercised and major commands are transmitted from Mercury Control Center to the spacecraft. Both launch vehicle and spacecraft system monitors verify that no RF interference exists before RF shutdown. Final verification that RF outputs did not fire any spacecraft pyrotechnic simulator is performed following emergency egress practice when the gantry is returned to the space vehicle.

Egress practice is conducted after a special hatch crew has been hoisted to the spacecraft and has removed the hatch. With the spacecraft hatch removed, true egress simulation can be performed as directed by the Egress and Rescue Team.

Simulated Flight Test

This procedure, conducted as closely as possible to launch day, contains comprehensive tests of all spacecraft systems to prove the spacecraft flight-worthy. Extensive test cabling is utilized to provide multiple readout and control capability. The test contains the following major parts:

(1) Systems Tests - detailed confidence level tests of all systems except the Reaction Control System (RCS).

(2) Command Checks - all modes of abort and retrofire commands, utilizing range functions.

(3) Abort Sensing and Implementation System (ASIS) - (simulated flight with launch vehicle)

(4) Normal flight, liftoff through recovery (simulated flight with launch vehicle)

(5) Static System Test - Final vacuum test of barostats, altimeter, and rate of descent indicator.

Part 1 of this test includes electrical, environmental, ASCS, telemetry, and communications systems tests. Electrical checks verify lighting, and inverter switching. The environmental checks verify fans control circuitry and oxygen flow rates in the normal and emergency mode. ASCS checks include horizon scanner, amp-cal, and RSCS tests. Telemetry tests verify camera and tape recorder operation, and investigate open loop and hard-wire umbilical signals to prove proper system operation. Communications checks are all open loop.

Part 2 verifies spacecraft command receiver operation, compabibility with the Mercury Control Center Command Console, compatibility with AMR command transmitters, and spacecraft/launch vehicle functional compatibility during simulated flights.

The launch vehicle abort after tower separation run is performed with horizon simulators installed to verify scanner error signals. Retrograde sequence is initiated by RF command. Pre-liftoff and in-flight switching on spacecraft and launch vehicle is performed in accordance with countdown and mission profile control functions. The abort flight is terminated just after retrorocket fire.

A re-cycle to T-10 minutes sets up the spacecraft and booster for the normal flight, liftoff through recovery. The horizon simulators are removed to allow verification of pitch orbital precession rate. Retrograde sequence is initiated by the orbital timing device. All flight functions are recorded to provide permanent data.

Part 5 contains tests of the rate of descent indicator, altimeter, and the barostats. The rate of descent indicator is connected for flight during this test.

Electrical Interface Test

This test provides final flight verification of the electrical interface between spacecraft and launch vehicle and is performed just prior to pre-count servicing after the simulated flight. Spacecraft configuration is the same as it is for simulated flight.

Pyrotechnic Electrical Checks

Following the final simulated flight, bridge wire resistance measurements are performed on all pyrotechnics to assure flightworthy condition. Pyrotechnic fire circuits and shields are tested for continuity. After the pre-count, all pyrotechnics are electrically connected except the escape rocket. The pyrotechnic system is then in flight configuration. An orderly procedure is provided to perform and document these functions. This document provides detailed instructions for resistance checks of each pyrotechnic device, continuity and stray voltage check of associated pyrotechnic wiring in the Mercury spacecraft prior to final connections for flight.

Resistance readings are compared to reference values (values measured before pyrotechnic installation) which are listed in the document, to verify that the pyrotechnic resistance has not changed and that connections and wiring have not opened.

Stray voltage checks are performed with spacecraft power on and off to verify that no voltage is present between pyrotechnic wiring and ground. Continuity is checked on all pyrotechnic wiring through the squib fire relays to verify wiring connections and to make certain that proper ground is provided to pyrotechnics when they are connected.

Final flight electrical connection of each pyrotechnic is made immediately after completion of the power off stray voltage checks during the pre-count.

Reaction Control System - X-5 and X-1 Day Test

As indicated by the title, this test is performed twice while the spacecraft is on the pad. Prior to simulated launch, the spacecraft is serviced with hydrogen peroxide (H_2O_2) and pressurizing gas. Hydrogen peroxide decomposition is monitored over an eight to twelve hour span. The last phase of monitoring and the static firing of the thrusters are integrated with the launch simulation. Following the simulation, the system is drained.

The test is repeated between the pre-count and final countdown. Final static firing is completed during the countdown. The test objectives for the X-1 day test are:

(1) To verify that the peroxide system and pressurizing system do not leak and are ready for flight.

(2) To verify that the decomposition rate of 90% hydrogen peroxide (H_2O_2) in the system is within specified limits with confidence that it will remain within limits during flight.

(3) To verify proper operation by static firing all thrusters.

(4) To allow the alternate Astronaut to evaluate the hand controller characteristics just before flight.

Pre-Count and Launch Countdown

The Pre-Count and Launch Countdown, illustrated in Figure 5, are conducted over a two-day period. The Pre-Count (T-610 to T-390 minutes) is started early X-1 day with a build-in 15-hour hold at T-390 minutes. The Countdown is picked up at T-390 minutes at the end of the hold.

The test objectives of the Pre-Count and Countdown are to determine the launch readiness of all spacecraft systems prior to flight and to perform all preparatory functions required to bring the spacecraft and Astronaut to the proper flight configuration.

Pre-Count (T-610 to T-390):

(1) Environmental control system is tested electrically in a similar manner to previous systems tests.

(2) The TM system is checked both open and closed loop.

(3) The ASCS system is restricted to limited testing due to the necessary spacecraft configuration; however, the system is turned on and gyro precession checks are performed.

(4) The communications system is tested both open and closed loop. Closed loop tests on the auxiliary beacon, HF beacon, and HF recovery transmitter-receiver are necessary due to antenna restrictions caused by the escape tower being installed at the time of testing.

(5) The electrical system performs a momentary power transfer to flight batteries. Performance of all systems on internal power is monitored. All inverters are tested.

(6) Command checks are conducted using the three AMR transmitters. Spacecraft verification of abort, start retrograde sequence, and clock change commands are obtained. As part of the clock changes, a complete clock test is conducted to prove all time change combinations.

(7) A power on stray voltage test is conducted from T-430 to T-390 minutes. At T-390, all power is removed from the spacecraft and spacecraft complex.

(8) Pyrotechnics are then electrically connected for flight.

(9) After the pyrotechnics are connected, 90% hydrogen peroxide is loaded for flight, and a 12-hour surveillance begins.

Decomposition rate is carefully monitored during this period.

Launch Countdown (T-290 to T-0)

After an approximate 15-hour hold, the second half of the count is picked up at T-390 minutes. Mile post functions performed from T-390 minutes to T-0 are:

(1) T-390 Minutes - Mechanical installation and electrical connection of the escape rocket igniter.

(2) T-360 Minutes - The pad area is completely cleared. All launch vehicle and spacecraft electrical power and RF are energized. All range RF is turned on. The abort system is armed. This provides confidence that no pyrotechnic malfunction will occur.

(3) T-290 Minutes - Command checks and final clock changes.

(4) T-270 Minutes - The Reaction Control System (RCS) static firing is begun.

(5) T-135 Minutes - Preparation for and insertion of the Astronaut.

(6) T-90 Minutes - Hatch is installed. Cabin purge and pressure test is performed.

(7) T-55 Minutes - The service structure is cleared and preparations for moving the service structure are completed.

(8) T-50 Minutes - Service structure is moved away from the missile space vehicle.

(9) T-44 Minutes - The abort system is armed.

(10) T-35 Minutes - Spacecraft RF on.

(11) T-10 Minutes - Spacecraft to internal power.

(12) T-5 Minutes - Spacecraft gives - GO - to launch vehicle.

(13) T-35 Seconds - Spacecraft umbilical eject, final Spacecraft GO

(14) T-18 Seconds - Engine sequence started

(15) T-2 Seconds - Engine ignition

(16) T-0 - LIFT-OFF

Conclusion:

The above description of the work performed on the spacecraft from the time it arrives at the Cape until launch shows that the functions performed in each of the categories complements the test philosophy outlined in the first section of this report. For example, the building block approach to testing is exemplified by the test series which begins with Hangar component and systems tests, builds up to the hangar simulated flight, and then proceeds to complex tests.

Spacecraft modification incorporated at the launch site implements the MSC policy that the spacecraft configuration shall be updated as required by ground test and flight test results so that the optimum configuration is flown. This policy is emphasized emphatically by Dr. Gilruth's statement, "In manned flight we cannot afford to regard any equipment malfunctions as a random failure. We must regard every malfunction and, in fact, every observed peculiarity in the behavior of a system as an important warning of potential disaster. Only when the cause is understood and eliminated, can we proceed with the flight program. If the space program is to meet schedules with hardware that is fit to fly, rapid corrective response to malfunctions throughout system development and preflight preparations is a critically important requirement."

Admittedly, the rigorous prelaunch test and inspection program performed on the Mercury spacecraft at Cape Canaveral has resulted in a long checkout period; however, a single mission failure would undoubtedly have resulted in an even greater delay.

In summary, the Mercury Test Program has been a successful one. It is felt that the use of thorough prelaunch testing and inspection techniques have contributed significantly to the success of the program. Extensive spacecraft checkout and inspection have helped provide the confidence in mission reliability necessary for a Manned Spacecraft Program.

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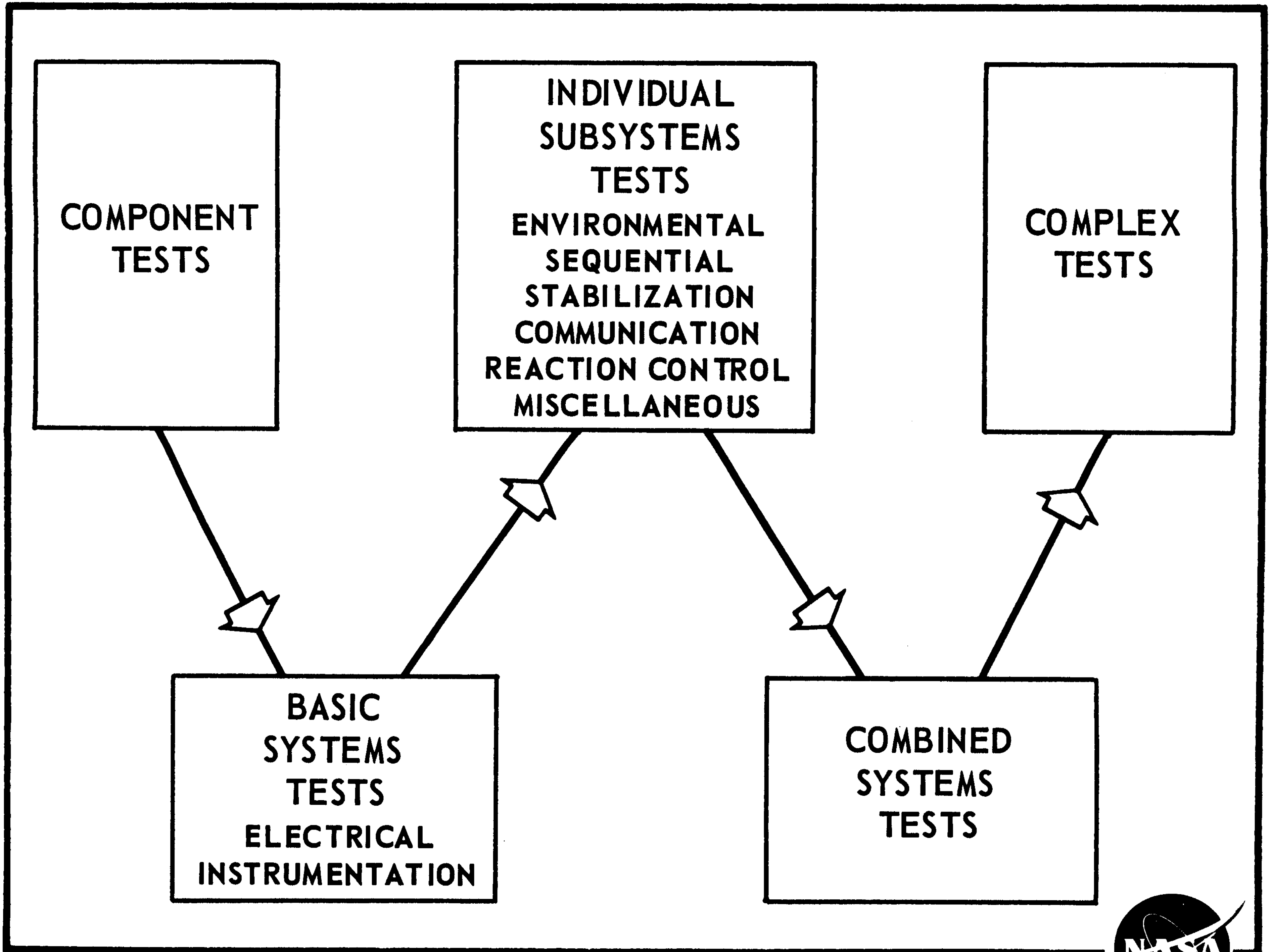
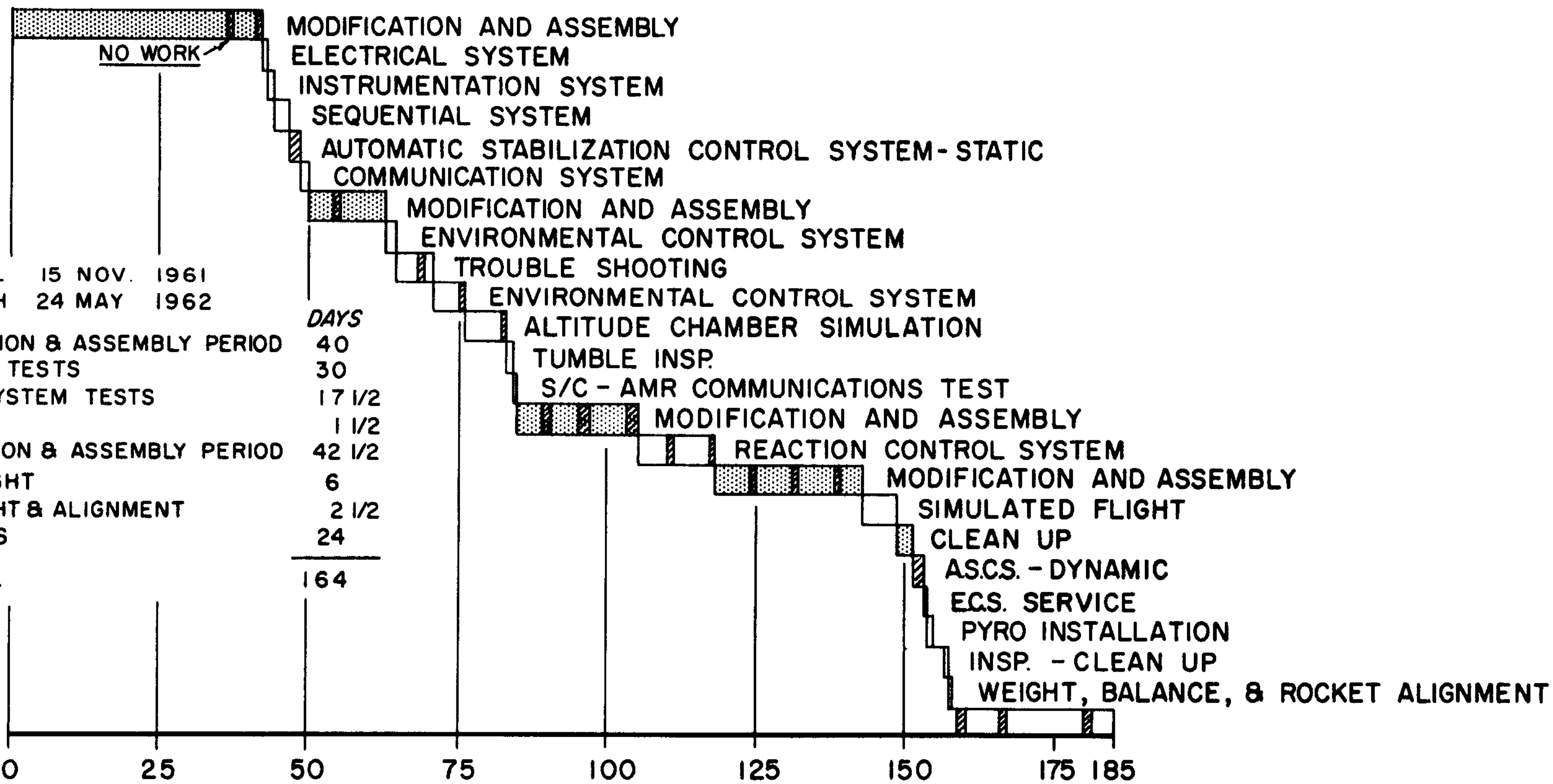
1. Corcoran, Donald M. "Preflight Crew Operations," Astronautics and Aerospace Engineering, February, 1963, pp. 68-70.

2. Gilruth, Dr. Robert R. "Manned Spacecraft Center Viewpoints on Reliability and Quality Control," before the American Institute of Architects, Houston, Texas, February 18, 1963.


COMPONENT TESTS
INDIVIDUAL SUBSYSTEMS TESTS
ENVIRONMENTAL
SEQUENTIAL
STABILIZATION
COMMUNICATION
REACTION CONTROL
MISCELLANEOUS
COMPLEX TESTS
BASIC SYSTEMS TESTS
ELECTRICAL
INSTRUMENTATION
COMBINED SYSTEMS TESTS

HISTORY OF SPACECRAFT NO 18 - MA-7



DATE OF ARRIVAL 15 NOV. 1961
DATE OF LAUNCH 24 MAY 1962

	DAYS
FIRST MODIFICATION & ASSEMBLY PERIOD	40
INITIAL SYSTEM TESTS	30
WORK DURING SYSTEM TESTS	17 1/2
RETESTS	1 1/2
LAST MODIFICATION & ASSEMBLY PERIOD	42 1/2
SIMULATED FLIGHT	6
SERVICE - WEIGHT & ALIGNMENT	2 1/2
PAD OPERATIONS	24
TOTAL	164

MERCURY SPACECRAFT
CAPE TIME LOG
SUMMATION

MISSION	SPACECRAFT NO.	HANGAR TIME (Days)			PAD TIME (Days)	TOTAL CAPE TIME (Days)
		WORK	TEST	TOTAL		
Σ M AVERAGE TIME		91	40	131	25	156
Σ M % HANGAR TIME		70 %	30 %			
Σ M % TOTAL CAPE TIME		58 %	26 %	84 %	16 %	

LEGEND

- (M) MANNED
- (UM) UN-MANNED
- MA MERCURY ATLAS
- MR MERCURY REDSTONE
- Σ MA SUMMATION MERCURY ATLAS
- Σ MR SUMMATION MERCURY REDSTONE
- Σ M SUMMATION Σ MA + Σ MR

MERCURY SPACECRAFT
CAPE TIME LOG
MERCURY/ATLAS

MISSION	SPACECRAFT NO.	HANGAR TIME (Days)			PAD TIME (Days)	TOTAL CAPE TIME (Days)
		WORK	TEST	TOTAL		
MA 8 (M)	16	142	40	182	17	199
MA 7 (M)	18	102 1/2	37 1/2	140	24	164
MA 6 (M)	13	71 1/2	49 1/2	121	45	166
AVERAGE TIME (M)		105	42	148	29	176
% HANGAR TIME		71%	29%			
% TOTAL CAPE TIME		60%	24%	84%	16%	
MA 5 (UM)	9	191 1/2	60	251 1/2	18 1/2	270
MA 4 (UM)	8A	59 1/2	24 1/2	84	33	117
MA 3 (UM)	8	80 1/2	46	126 1/2	16 1/2	143
MA 2 (UM)	6	75	39	114	30	144
AVERAGE TIME (UM)		102	42	144	25	169
% HANGAR TIME		71%	29%		15%	
% TOTAL CAPE TIME		60%	25%	85%	15%	
Σ MA AVERAGE TIME		103	43	146		172
Σ MA % HANGAR TIME		71%	29%			
Σ MA % TOTAL CAPE TIME		60%	25%	85%	15%	

MERCURY SPACECRAFT
CAPE TIME LOG
MERCURY/REDSTONE

MISSION	SPACECRAFT NO.	HANGAR TIME (Days)			PAD TIME (Days)	TOTAL CAPE TIME (Days)
		WORK	TEST	TOTAL		
MR 4 (M)	11	78 1/2	32 1/2	111	17	128
MR 3 (M)	7	80 1/2	46	126 1/2	16 1/2	143
AVERAGE TIME (M)		80	39	119	17	136
% HANGAR TIME		67 %	33 %			
% TOTAL CAPE TIME		59 %	29 %	88 %	12 %	
MR 2 (UM)	5	57	38 1/2	95 1/2	12 1/2	108
MR 1 (UM)	2	65 1/2	29	94 1/2	40 1/2	135
AVERAGE TIME (UM)		61	34	95	27	122
% HANGAR TIME		64 %	36 %			
% TOTAL CAPE TIME		50 %	28 %	78 %	22 %	
Σ MR AVERAGE TIME		70	37	107	22	129
Σ MR % HANGAR TIME		65 %	35 %			
Σ MR % TOTAL CAPE TIME		54 %	29 %	83 %	17 %	

LAUNCH COMPLEX INTEGRATED TESTS

TEST	TEST OBJECTIVE
MECHANICAL MATE	FLIGHT ASSEMBLY
SIMULATED FLIGHT #1	S/C - SYSTEMS VERIFICATION S/C - COMPLEX COMPATIBILITY
ELECTRICAL MATE & ABORT	S/C-LAUNCH VEH. ELECTRICAL COMPATIBILITY S/C-LAUNCH VEH.-RANGE ABORT COMPATIBILITY
SIMULATED FLIGHT #2 (FLIGHT ACCEPTANCE COMPOSITE TEST)	S/C - LAUNCH VEH. - RANGE COMPATIBILITY MISSION SIMULATION COMMIT SPACE VEH. FOR LAUNCH
FLIGHT CONFIGURATION SEQUENCE & ABORTS	S/C - LAUNCH VEH. COMPATIBILITY ALL UMBILICALS OUT
LAUNCH SIMULATION & RF COMPATIBILITY	COUNTDOWN DRESS REHEARSAL LAUNCH CONFIGURATION RF COMPATIBILITY EMERGENCY EGRESS PRACTICE
SIMULATED FLIGHT #3	S/C FINAL SYSTEMS VERIFICATION MISSION SIMULATION FLIGHT ACCEPTANCE

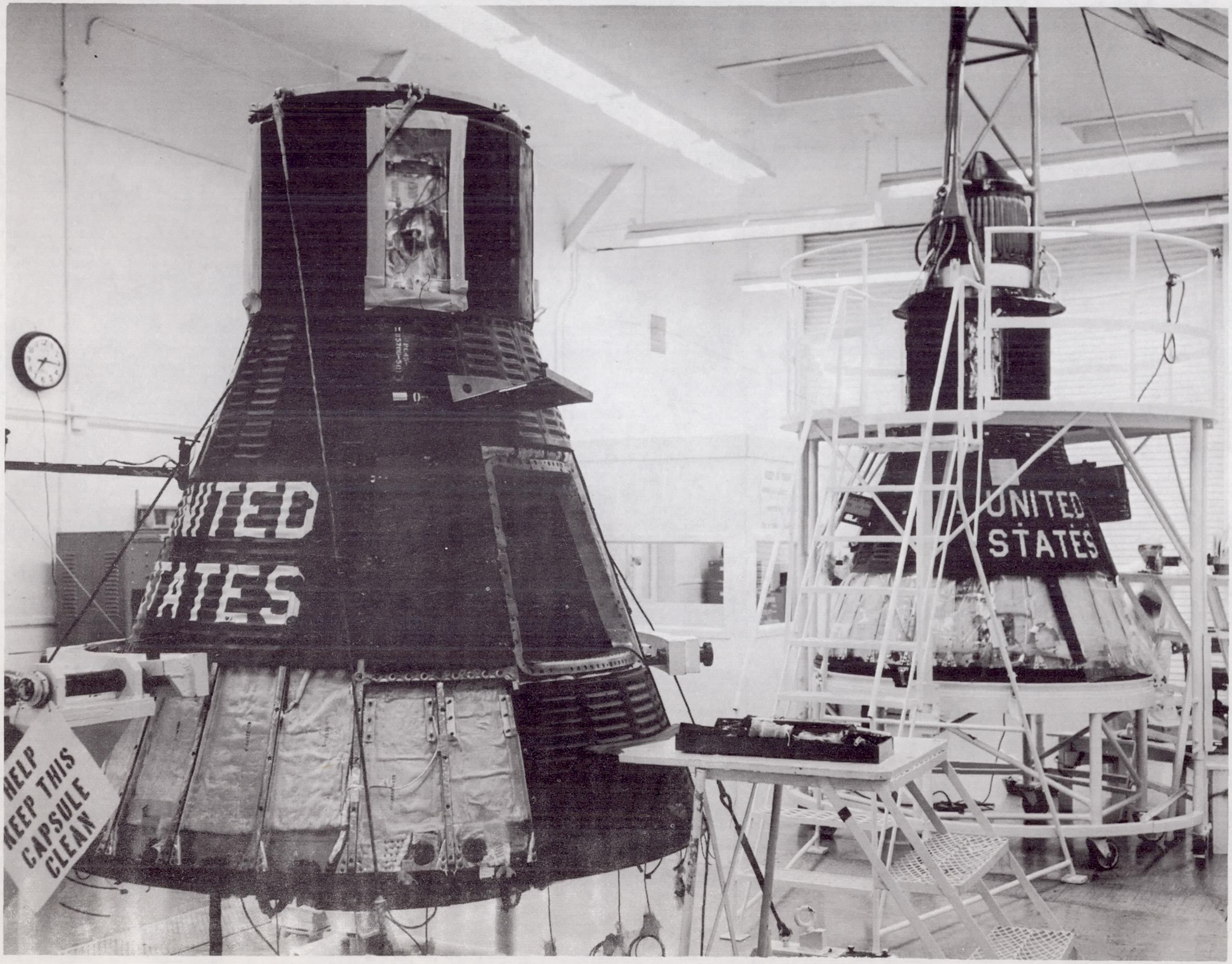


Figure 7 - Spacecraft White Room

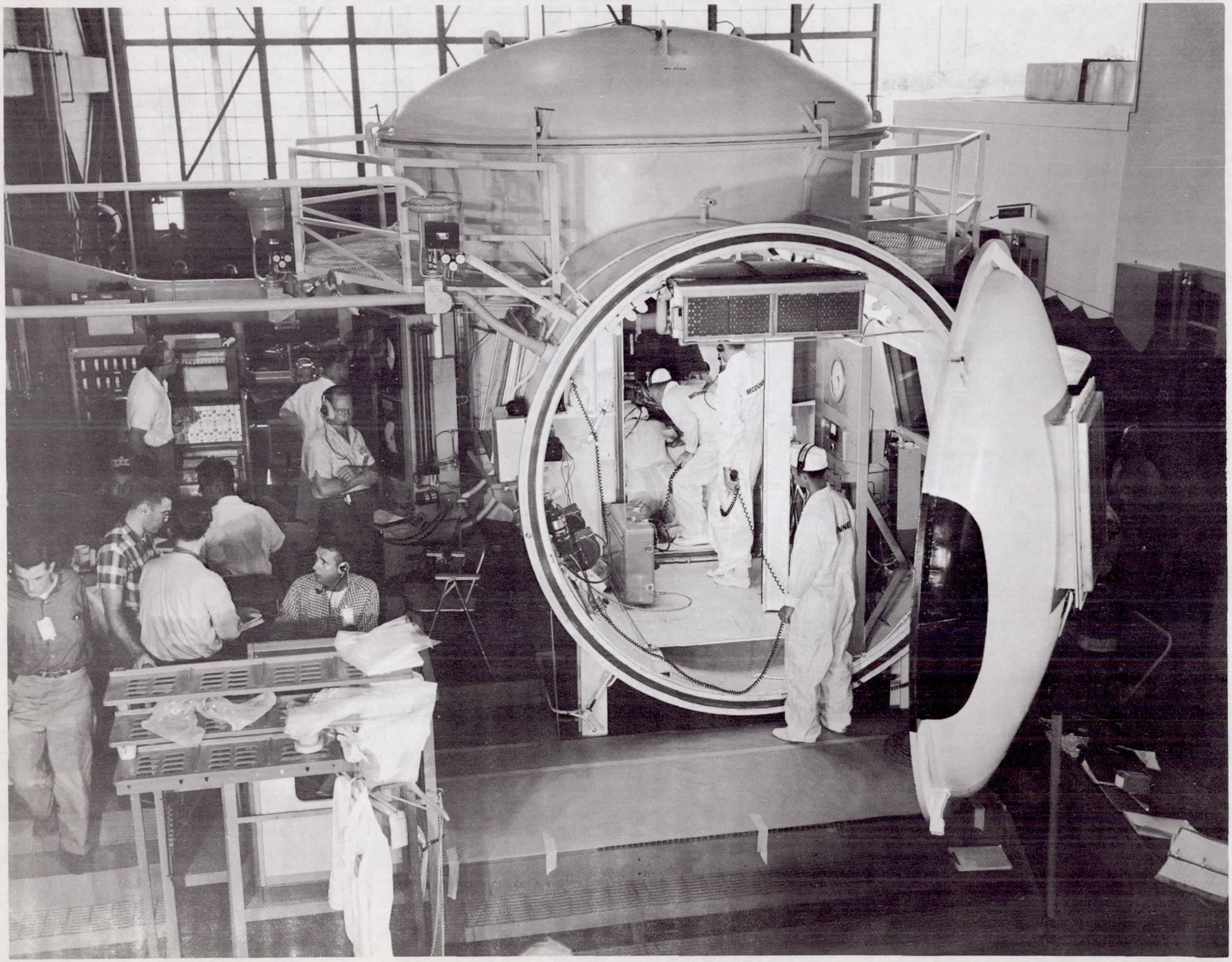


Figure 8 - Altitude Chamber Located in Hangar "S"

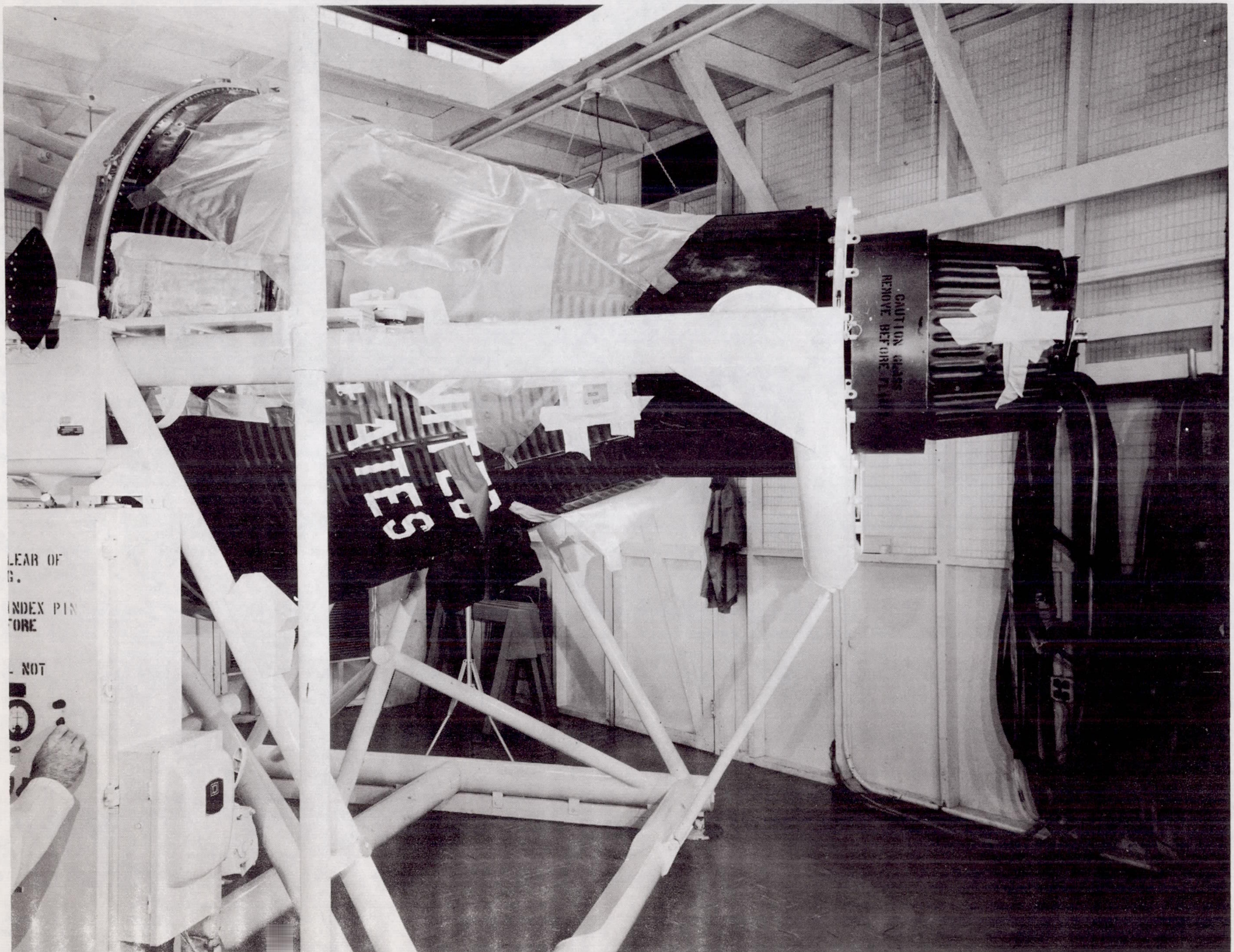


Figure 9 - ASCS Fixture Room in Hangar "S"

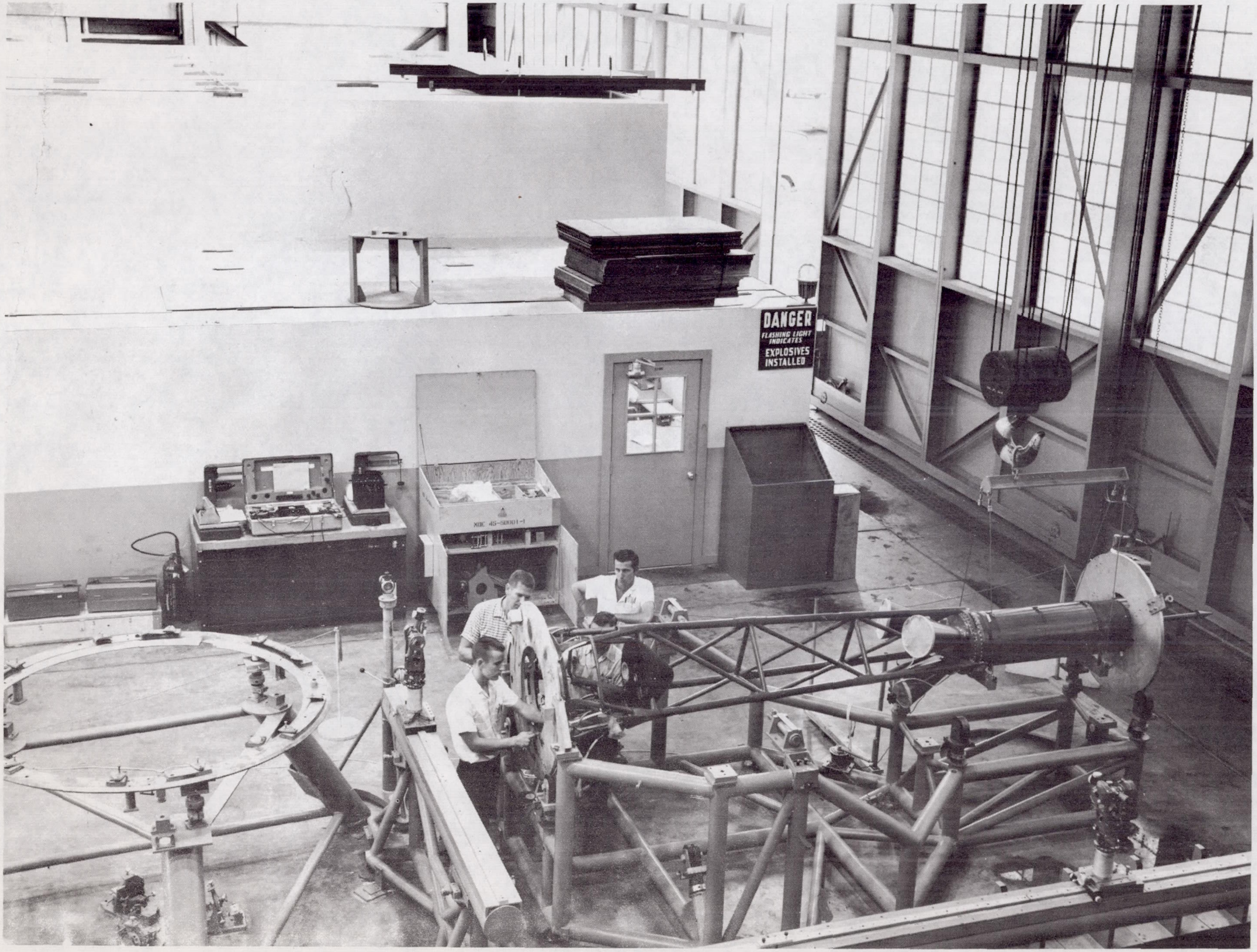


Figure 10 - View Showing Weight and Balance Fixtures

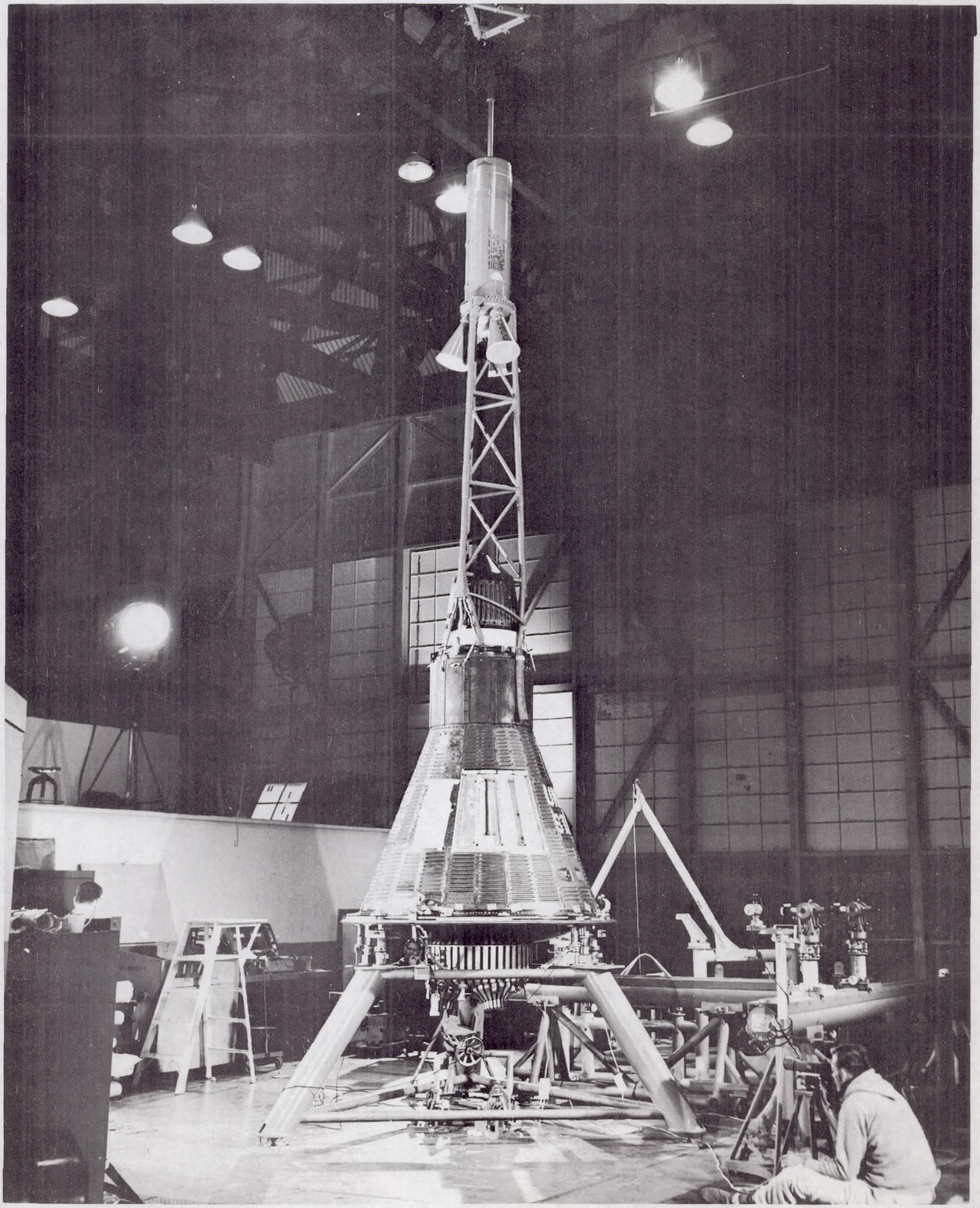


Figure 11 - Weight and Balance Area in Hangar "S"

Figure 12.- Spacecraft Checkout Racks in Mercury-Atlas Blockhouse

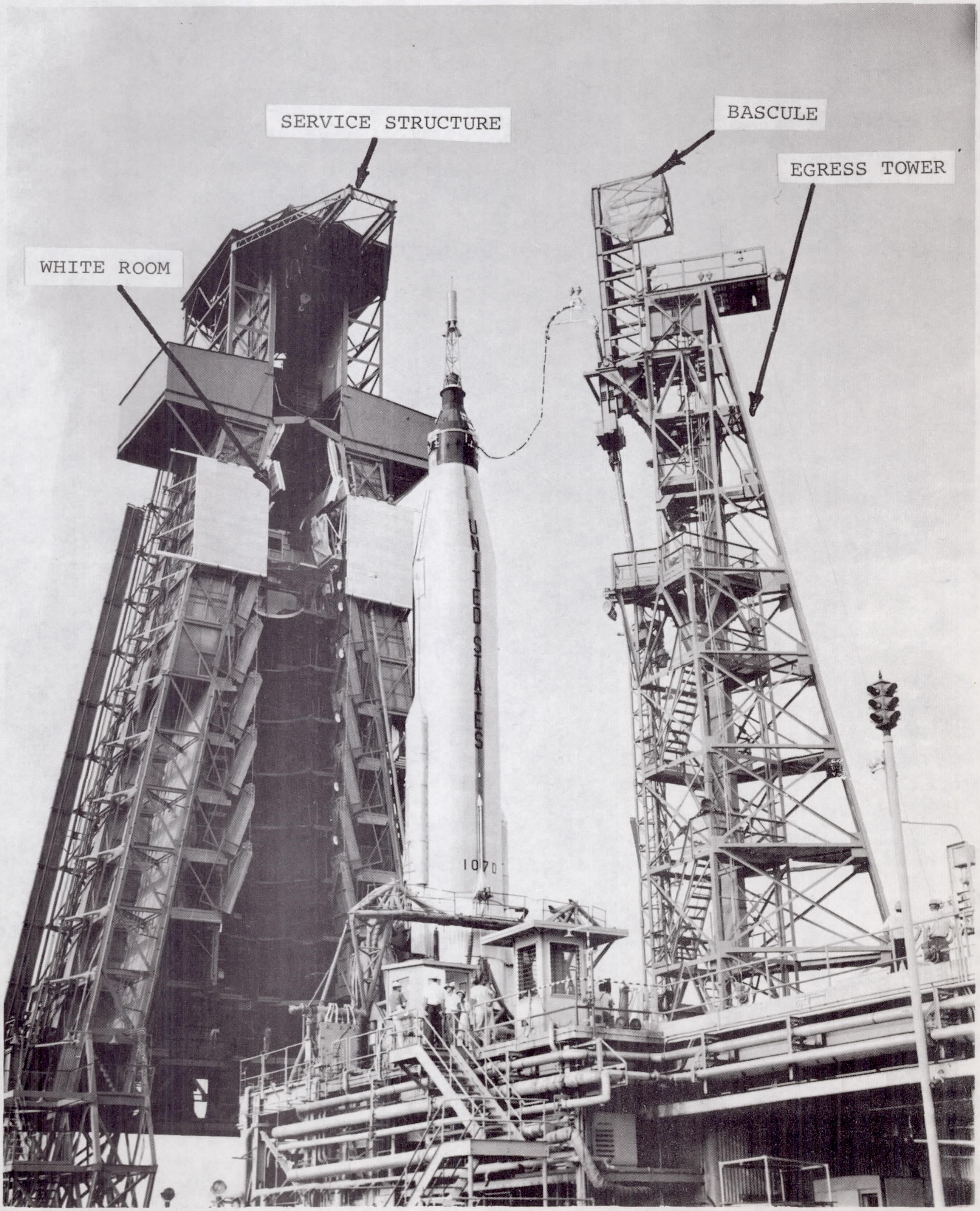
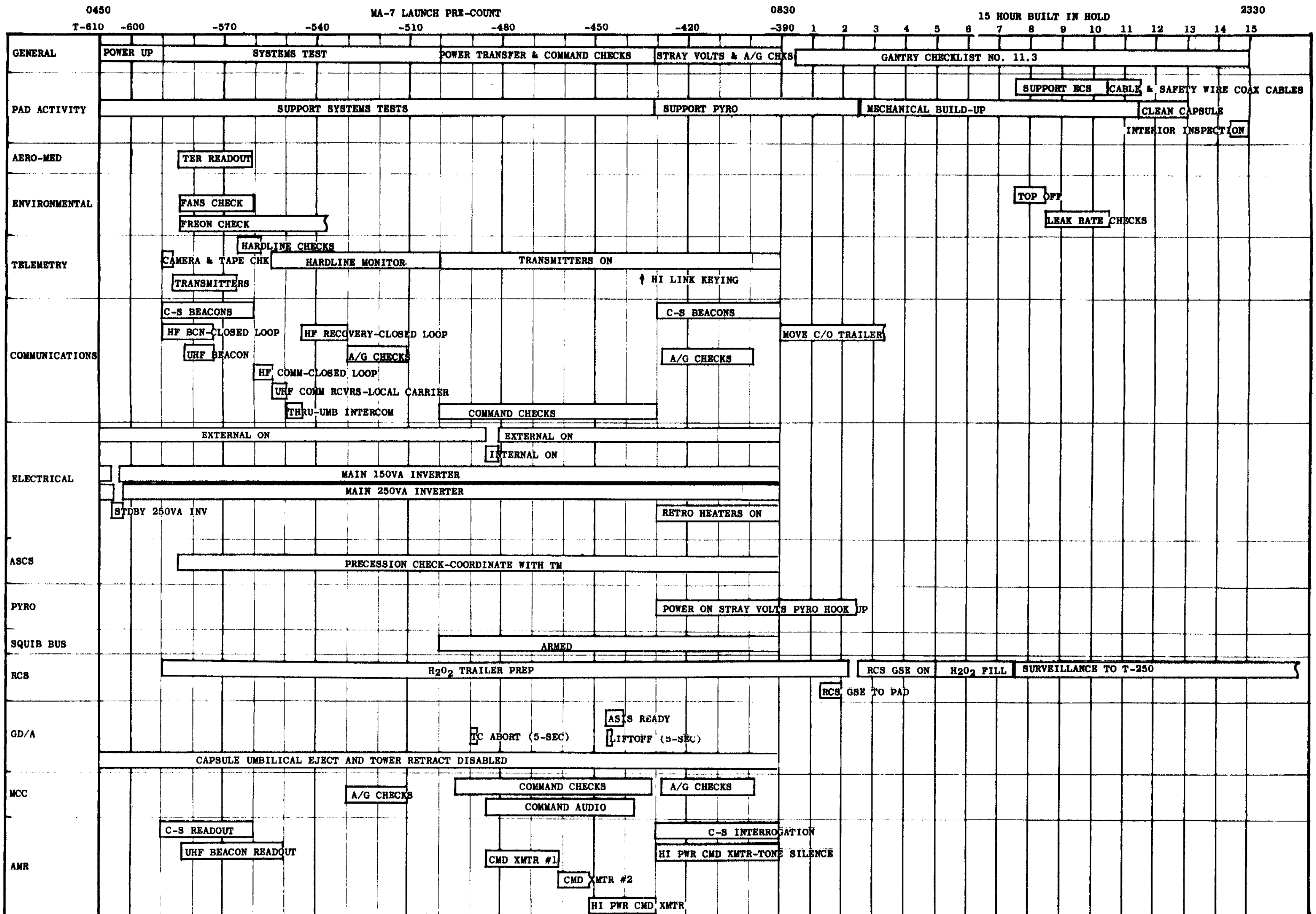


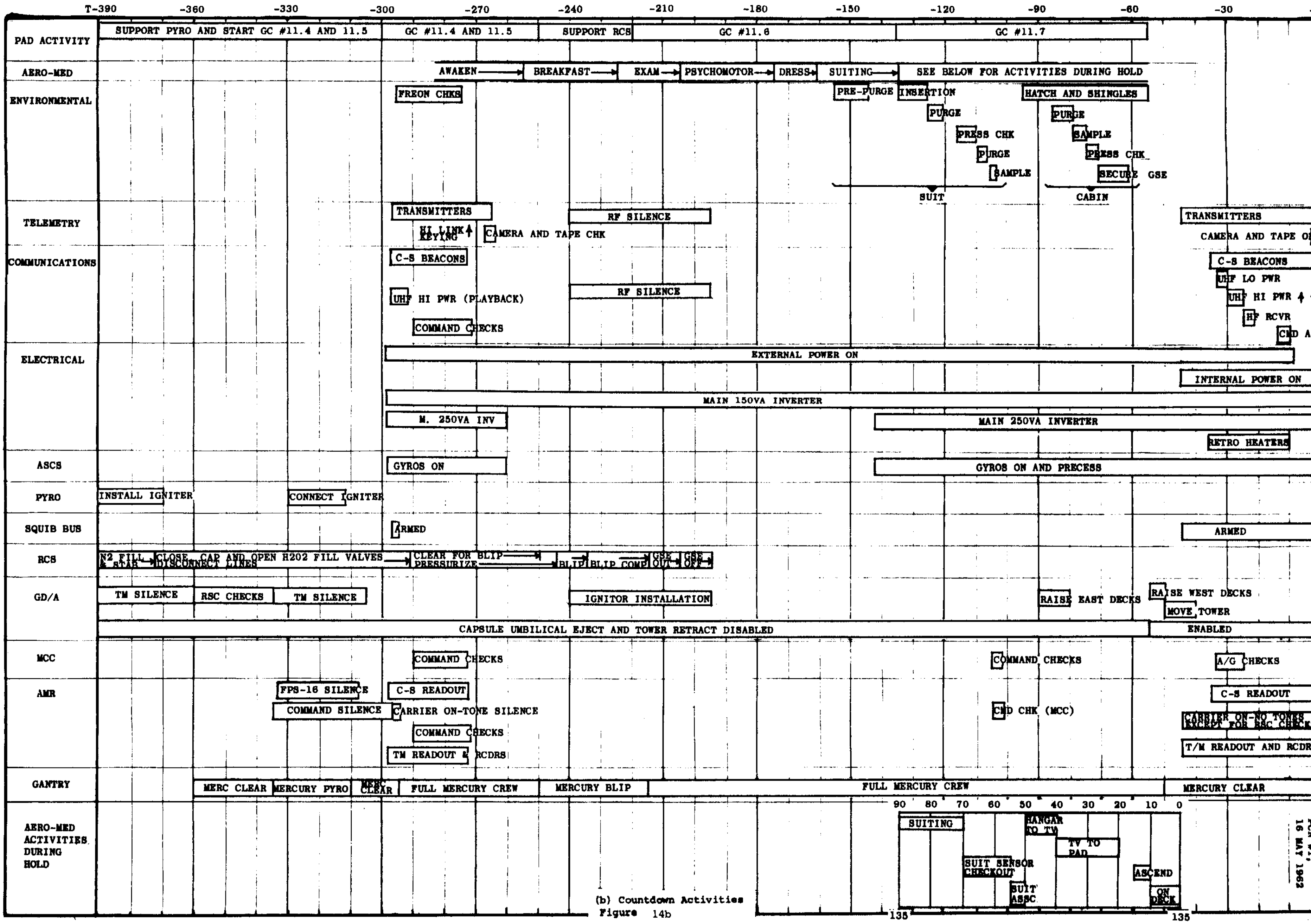
Figure 13 - View Showing Service Structure and Egress Tower for Mercury-Atlas Launch Pad Facilities



(a) Pre-count Activities

Figure 14a Barcharts Showing Schedule of Pad Activities During Launch

MA-7 LAUNCH



(b) Countdown Activities
Figure 14b