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GROUND SUPPORT EQUIPMENT AND LAUNCH INSTALLATIONS AT JOHN F. KENNEDY SPACE CENTER, NASA, FOR THE MANNED LUNAR LANDING PROGRAM

by

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ABSTRACT

The magnitude of the Manned Lunar Landing Program has led to the evolution and adoption of a new launch operations concept to cope with the requirements of the program. Major factors contributing to the need for a new approach include the greatly increased size and complexity of the Apollo Saturn V space vehicle, the requirement for unprecedented reliability, and the flexibility of handling varying launch rates. It has been determined that these needs can best be satisfied by the adoption of a "mobile" launch concept.

As compared with the established practice of vehicle assembly, checkout, and launch at a fixed launch site, the "mobile concept" embodies space vehicle transfer in an assembled and checked out condition to the actual launch pad. Advantages of this new concept are assembly and checkout in a protected environment, reduction of actual "pad time" with a consequent increase in launch rate capability, and the ability to adapt to expanding program requirements.

Major facilities at Launch Complex 39, where the "mobile concept" is being implemented, include: (1) a vertical assembly building, for assembly and checkout of the space vehicle; (2) a launcher-umbilical tower, upon which the vehicle is erected vertically for checkout, transfer, and launch; (3) a crawler-transporter, to move the space vehicle and launcher-umbilical tower to the launch pad; (4) an arming tower, to provide space vehicle access at the launch pad; and (5) the launch pad area.

Necessary equipment to assemble the space vehicle stages and payload is provided in the 525-foot high vertical assembly building. The building will consist of a low bay area and a high bay area. The low bay area contains eight stage preparation and checkout bays. Erection of the vehicle begins when the S-IC stage is positioned on the launcher-umbilical tower within the high bay area. After initial preparation in the low bay area, the S-II and S-IVB stages are transferred to the high bay area and erected. Erection is completed when the Instrument Unit and the Apollo Spacecraft are positioned atop the launch vehicle.

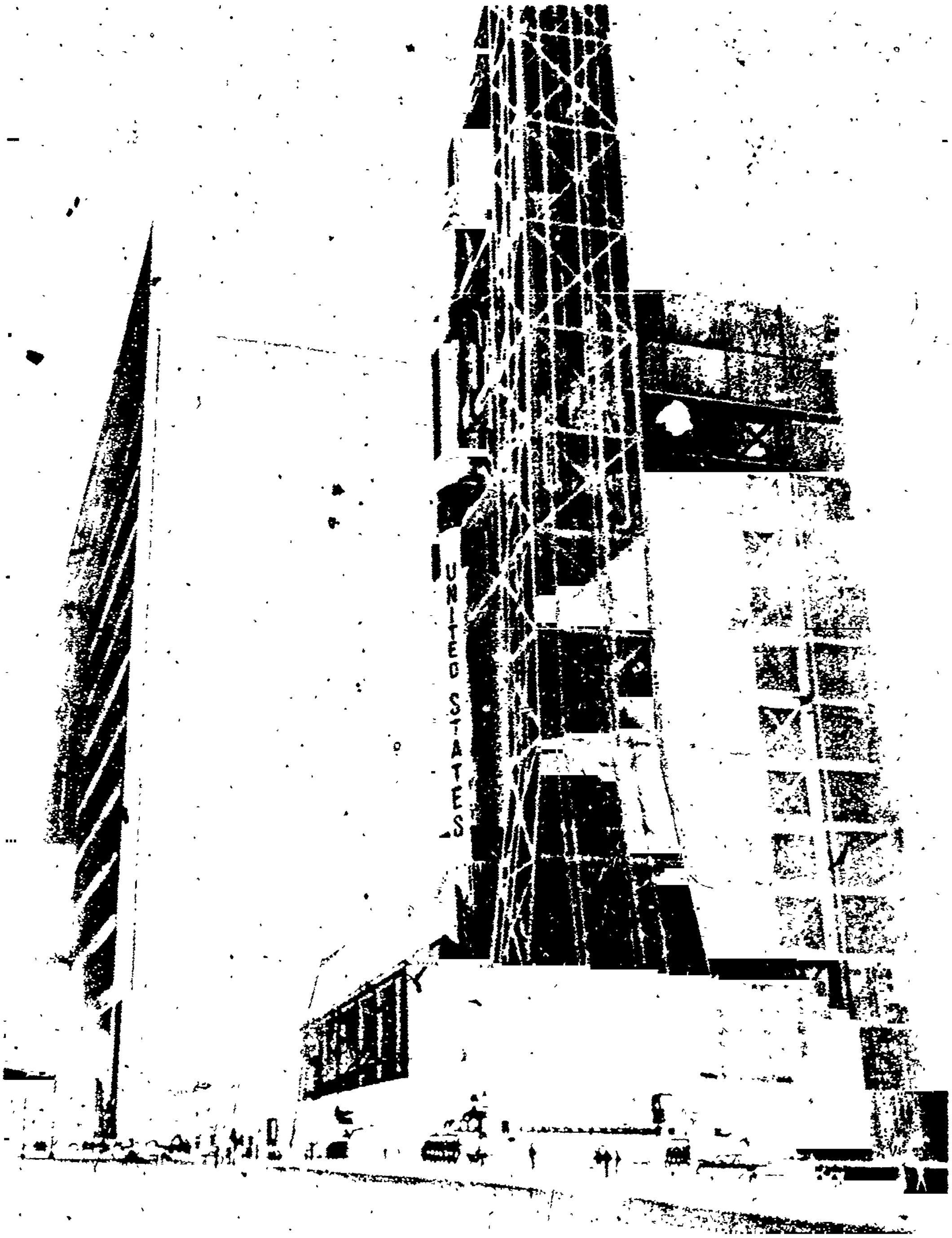
Systems checkout is performed concurrently in the high bay and, following validation of all stages, a combined-systems test and a simulated-flight test are performed. After all tests have been performed satisfactorily in the high bay, the vehicle is ready for transfer to the launch pad.

Vertical transfer of the space vehicle to the launch pad is provided by the 5.5-million-pound crawler-transporter capable of carrying a load of 12-million pounds. In addition, it is used to transfer the arming tower between a parking area and the launch pad.

Remote control of launch operations, using automatic checkout techniques is performed from a launch control center which is located adjacent to the vertical assembly building. Data is transferred between the launch control center, the vertical assembly building, and the launch pads by digital data transmission networks. Automatic checkout will increase reliability, decrease pad time, and provide rapid troubleshooting of the space vehicle on the pad.

At the pad, prior to countdown, all systems are verified and a second simulated-flight test is performed. Countdown is then initiated, propellant loading accomplished, and astronaut embarkation takes place. Final systems checks are conducted and the vehicle is launched.

The provision of these launch facilities at Launch Complex 39 has progressed through the programming, planning, criteria development, and design stages and is now under construction. Construction is well underway at the vertical assembly building area. An extensive pile driving operation has been completed, foundations have been poured, and steel erection has begun. It is expected that vertical assembly building construction will be completed in early 1966. Launcher-umbilical tower erection is now in progress and crawler-transporter fabrication is underway. Three launcher-umbilical towers will be operational by mid-1966, and two crawler-transporters will be operational in early 1965. At present, one of the two planned launch pads is under construction, and a massive surcharge operation is underway for the second.



APOLLO/SATURN V

INTRODUCTION

One day within this decade an American will land on the Moon.

The program to achieve this goal will require the most extensive concentration of scientific and technical talent ever devoted to a single undertaking. It is a blending into which the efforts of many organizations, activities, and individual identities will be dissolved to accomplish what has been established as a major national goal of the United States - landing an American crew on the moon and returning them safely to earth.

Development of the Apollo/Saturn V Space Vehicle and the launch facilities required to pursue this goal is an extremely challenging technical program compressed into a specified time limit. The successful execution of this program will demand a higher degree of skillful direction and coordination than heretofore given to any technical program carried out by this country.

The National Aeronautics and Space Administration's Office of Manned Space Flight, headed by Dr. George E. Mueller, is directing the Manned Lunar Landing Program, and coordinating the programs of three NASA Centers in the development of launch vehicles, spacecraft and facilities.

Marshall Space Flight Center (MSFC), in Huntsville, Alabama, headed by Dr. Wernher von Braun, is developing the launch vehicle, designated Saturn V, that will place the manned spacecraft in Earth orbit, then inject it into a translunar trajectory.

Manned Spacecraft Center (MSC) in Houston, Texas, driected by Dr Robert C. Gilruth, is developing the spacecraft, designated Apollo, that will carry the astronauts on the lunar landing mission. MSC has responsibility for flight mission control of the lunar landing program, and selects and trains the astronauts who will participate.

The John F. Kennedy Space Center, NASA, (KSC) directed by Dr. Kurt H. Debus, is developing the facilities on the new Merritt Island Launch Area (MILA), figure 1, from which the Apollo/Saturn V will be launched and has operational responsibility for launch operations.

The launch of the Apollo/Saturn V on its journey to the moon will be the culmination of the dedicated efforts of many thousands of individuals in government and industry whose combined endeavors began many years before actual liftoff. This presentation is intended to portray the scope and magnitude of these endeavors as related to ground support equipment and launch installations.

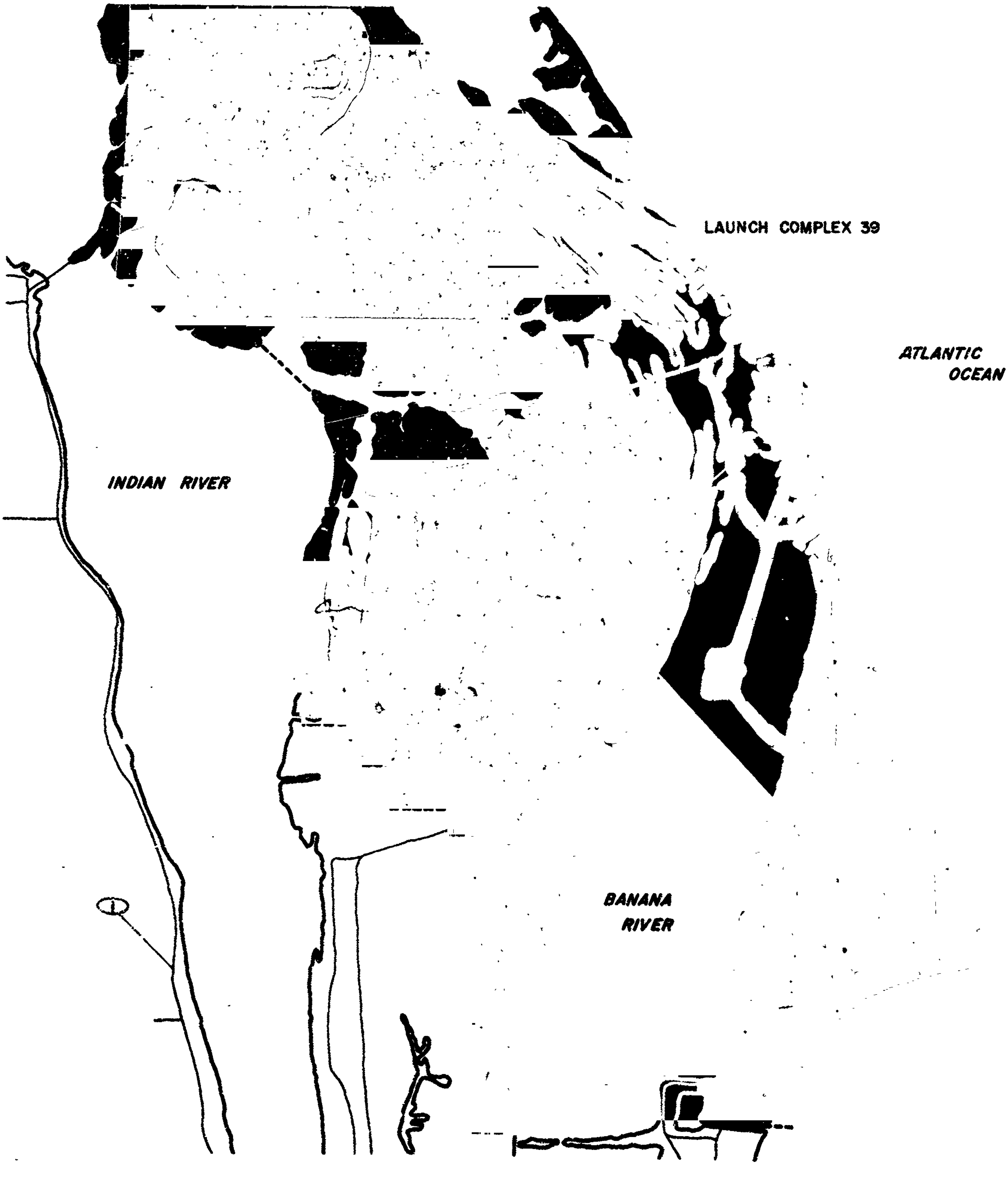


FIGURE 1. MERRITT ISLAND LAUNCH AREA (MILA)

APOLLO/SATURN V DESCRIPTION

Development of the Apollo/Saturn V is an extensive undertaking, certainly too broad to be accomplished by any one industrial organization. NASA has contracted with several industrial concerns for the development and production of launch vehicle stages and the spacecraft. These companies have in turn contracted with many other firms throughout the United States for the building of components and subsystems for the stages and the manned spacecraft. It is truly a national effort, with important operations centered in every region of the United States.

Saturn V

The Saturn V launch vehicle consists of three stages, the S-IC, S-II, and S-IVB, and the Instrument Unit as shown in figure 2.

S-IC Stage

The first of the Saturn V stages, the S-IC, is under development by MSFC and the Boeing Company at MSFC, Huntsville, Alabama. Static testing of these early developmental models will be conducted in Huntsville by MSFC. The production models of this stage will be manufactured by Boeing at the Michoud Plant in New Orleans, Louisiana, and will be static tested at the Mississippi Test Facility under the direction of MSFC.

The S-IC stage is 138 feet long, with a diameter of 33 feet. Its dry weight is 144 tons, and its propellant capacity is 2,200 tons of liquid oxygen (LOX) and kerosene (RP-1). The oxidizer to fuel ratio is 2.25:1.

The S-IC's cluster of five F-1 engines develops a total of 7.5 million pounds of thrust. The four outboard engines are gimballed to provide attitude control, and the center engine is mounted in a fixed position.

S-II Stage

The second stage of the Saturn V launch vehicle, designated S-II is being developed by North American Aviation, Inc., under the direction of MSFC. It will be static tested at the Mississippi Test Facility.

The S-II stage is 82 feet long and, like the S-IC stage, has a diameter of 33 feet. Its dry weight is 37.5 tons, and its propellant tanks have a capacity of 465 tons of LOX and liquid hydrogen (LH_2) with an oxidizer to fuel ratio of 5:1.

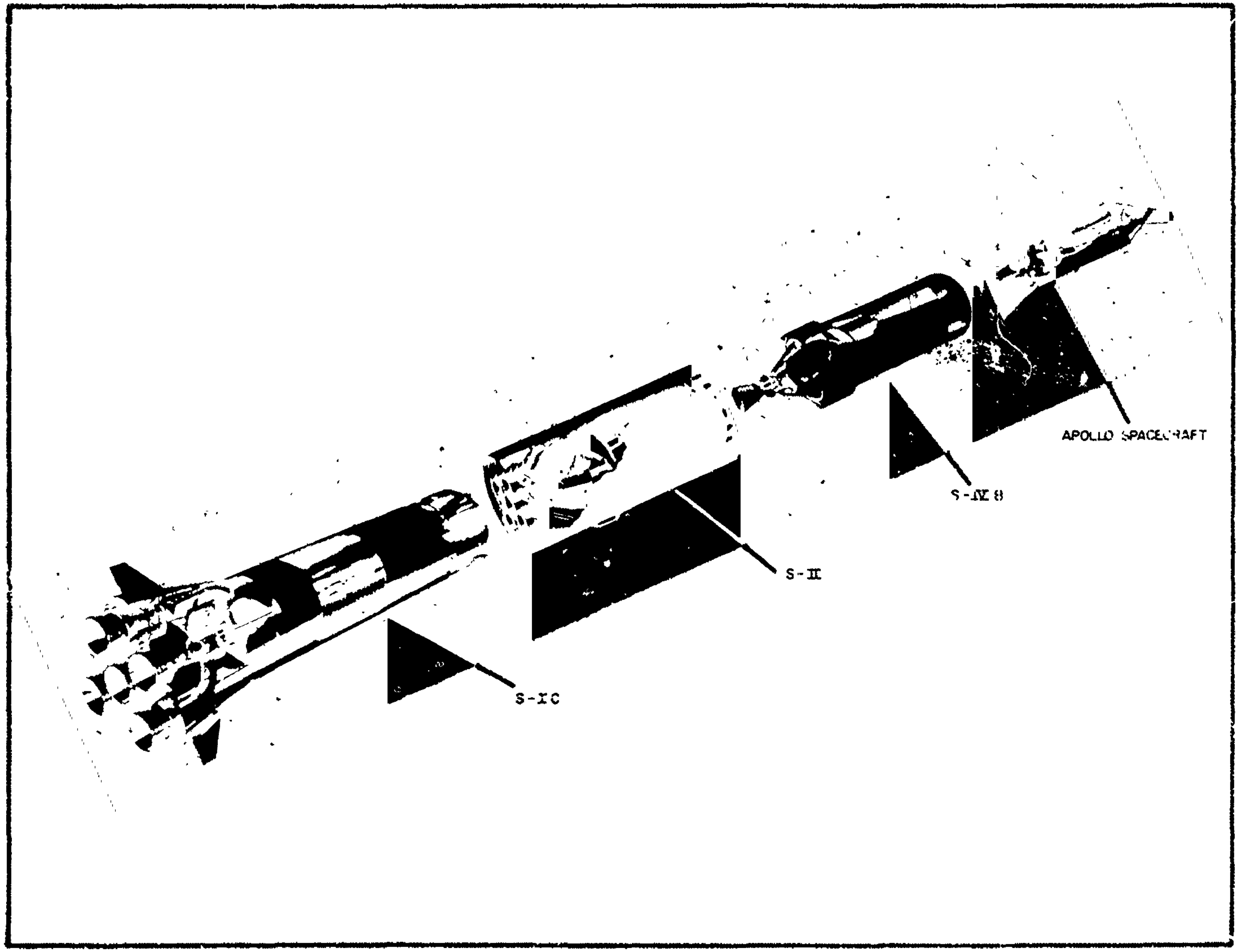


FIGURE 2. APOLLO/SATURN V

S-IVB Stage

The third stage of the Saturn V, designated S-IVB, is being developed by the Douglas Aircraft Company, Inc., under the direction of MSFC. It is scheduled for static testing at facilities near Sacramento, California.

Smaller than the first two stages of the launch vehicle, the S-IVB is 59 feet long and has a diameter of 21 feet 8 inches. Its dry weight is approximately 10 tons, and its propellant tanks have a capacity of 115 tons of LOX and LH_2 with an oxidizer to fuel ratio of 5:1.

The S-IVB stage's single J-2 re-startable engine develops 200,000 pounds of thrust.

Instrument Unit

An Instrument Unit (IU), assembled between the S-IVB stage and the spacecraft, will provide guidance and control instrumentation for the Apollo/Saturn V through burn-out of the S-IVB stage. Under development by MSFC at Huntsville, Alabama, it will be shipped to the launch area in three 120-degree segments.

Its length is 3 feet, its diameter, 21 feet 8 inches, and it weighs approximately 2 tons. The IU contains a gyro-stabilized platform, guidance and control computers, flight sequencer, command receiver and decoder, measuring system equipment, telemetry package, tracking transponders, and electrical distributors.

Apollo Spacecraft

In its launch configuration the Apollo spacecraft will consist of a Lunar Excursion Module (LEM), Service Module (SM), and Command Module (CM), and Launch Escape System (LES). The spacecraft will be approximately 52 feet high and tapers from 21 feet 8 inches diameter at the bottom to 12 feet 10 inches diameter at the Service Module. With the LES in place, it will be 82 feet high. The spacecraft will weigh 48 tons (including the 3-ton Launch Escape System) when fully loaded with propellants.

Lunar Excursion Module

The LEM will be designed to descend from lunar orbit, land two astronauts on the moon, return them to lunar orbit, and rendezvous and dock with the Apollo spacecraft in lunar orbit. The lunar landing stage will have a throttleable engine powered by hypergolic propellants. Its landing gear will serve as a launch pedestal in the lunar launch operation. The lunar launch stage is also powered by hypergolic propellants, as are the reaction and attitude control system. The LEM will weigh 13 tons, including all propellants. It is being developed by the Grumman Aircraft Engineering Corporation under the direction of MSC.

Service Module

The SM will provide an abort capability following jettison of the LES, propulsion and reaction control for midcourse corrections after separation of the S-IVB stage, braking for entry into lunar orbit, escape from lunar orbit, and midcourse corrections for the return to earth. It will be 23 feet long, 12 feet 10 inches in diameter, and weigh 25 tons, including propellants.

The propulsion system, fueled by Aerozine 50 and nitrogen tetroxide, nominally provides 22,000 pounds of thrust and utilizes a re-startable gimballed engine.

Command Module

The CM will be equipped to sustain three astronauts during the lunar mission. It will be 11 feet long, 12 feet 10 inches in diameter, and have a hypergolic propellant reaction control system. The CM will have an ablative heat shield and protected outer surfaces for re-entry, and will weigh 5 tons.

Launch Escape System

The LES is 29 feet long and equipped with a solid rocket engine. The engine will provide 150,000 pounds of thrust for six seconds to separate the CM from the launch vehicle in the event of an emergency. It provides crew protection during the period from crew embarkation, while the space vehicle is on the launch pad, to a few seconds after ignition of the S-II stage. The LES will be jettisoned at this time.

Apollo/Saturn V Statistics

The space vehicle will have an assembled length of 360 feet and a total dry weight of 250 tons. Liftoff weight will be approximately 3,000 tons.

LAUNCH FACILITIES

The "Mobile" Concept

The Manned Lunar Landing Program, because of the very large space vehicle to be used, the increase in launch rate expected to evolve as our space exploration program develops, and the obvious need to achieve the highest standard of launch reliability, compelled the development of a new and improved concept for launch operations. In evolving this new concept, facilities were established to meet expected operational requirements as well as research and development testing.

A number of feasibility studies were made to guide the selection of the facilities required to implement the basic concept. It was decided, first, to provide for assembly and checkout of the space vehicle on a mobile launcher-umbilical tower (LUT) within a vertical assembly building; second, transfer of the assembled and checked out space vehicle to the launch pad with all connections between the vehicle and the LUT intact; third, through the use of digital data transmission techniques, control and conduct launch operations from a launch control center located more than three miles from the launch site.

The launch facilities which are planned to incorporate the features of the "mobile" concept, have been designated Launch Complex 39, figure 3, and are now in various stages of design and construction.

Major Elements of Launch Complex 39

Vertical Assembly Building

One of the important facilities of Launch Complex 39 is the Vertical Assembly Building, figure 4. Its three operational elements are a Low Bay Area, High Bay Area, and Launch Control Center, which is adjacent to, and connected with, the High Bay Area. The floor plan of the VAB is shown in figure 5.

The Low Bay Area is 274 feet long and 442 feet wide, and has a center section 210 feet high. The Low Bay Area has eight stage preparation and checkout cells equipped for stage pre-mating operations. Upon their arrival at the Merritt Island Launch Area, the S-II and S-IVB stages will be moved to the Low Bay Area prior to erection within the High Bay Area.

The High Bay Area is 525 feet high by 518 feet wide and 442 feet long and contains four checkout bays. Each pair of bays is served by a 250-ton bridge crane, with a hook height of 462 feet, figure 6. A 175-ton overhead bridge crane serves the transfer aisle extending through both the High and Low Bay Areas. Each of the high bays has four elevators to provide personnel access to the High Bay Area's many levels.

Prior to arrival of the S-IC stage, a LUT will be positioned in one of the high bays by the Crawler-Transporter, figure 7. The S-IC stage will be moved into the High Bay Area transfer aisle on its transporter, hooked to the 250- and 175-ton bridge cranes and hoisted to a vertical position. The 250-ton crane will move the stage to the LUT and lower it onto the LUT support-holddown arms. Then the S-IC stage will undergo stage checkout, utilizing LUT and LCC instrumentation.

The LCC provides display, monitoring, and control equipment for both checkout and launch operations. The four-story building has telemeter checkout stations on its second floor, and four firing rooms, one for each bay of the VAB, on its third floor. Each firing room contains an identical set of control and monitoring equipment, so that launch of a vehicle and checkout of others may take place simultaneously.

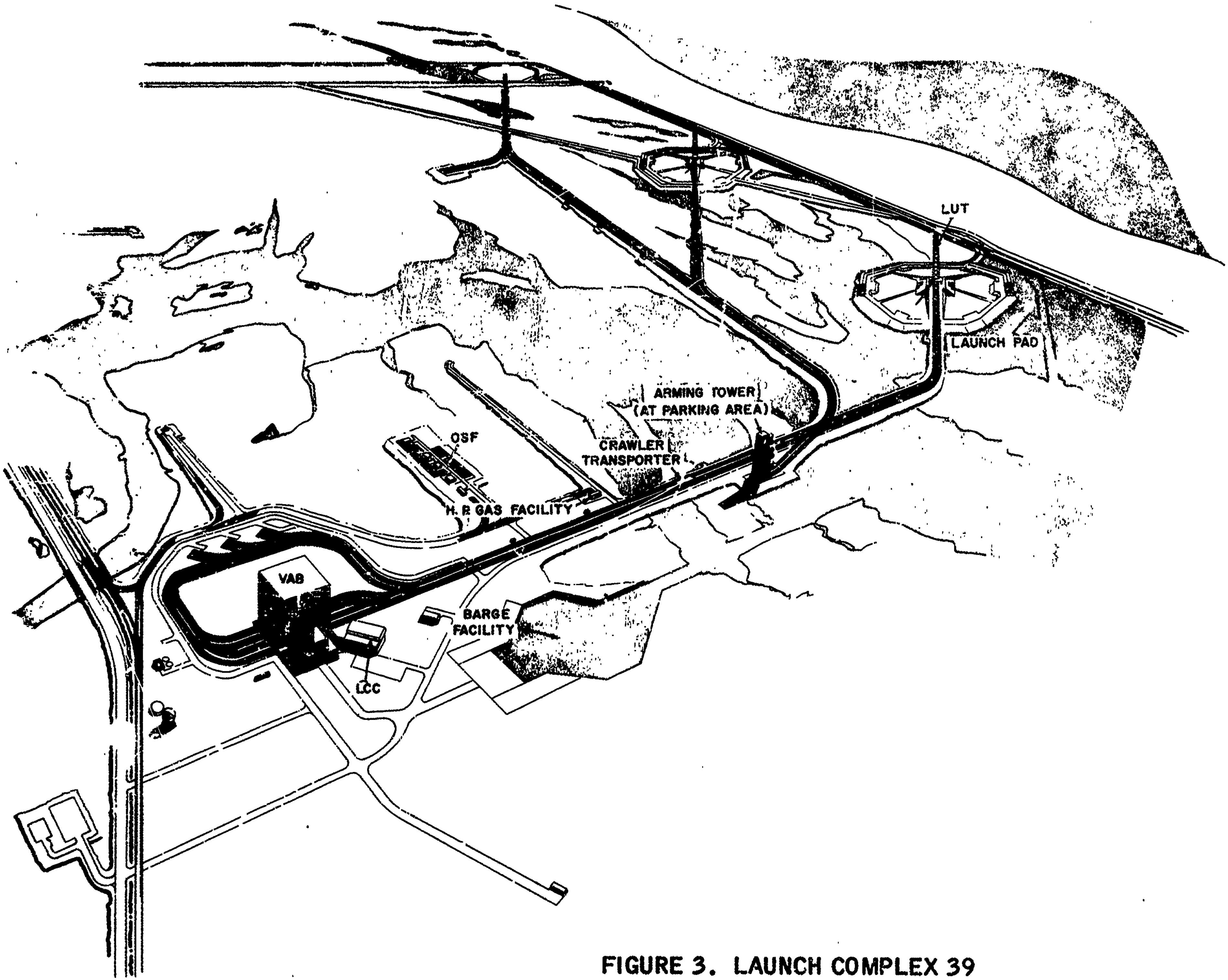


FIGURE 3. LAUNCH COMPLEX 39

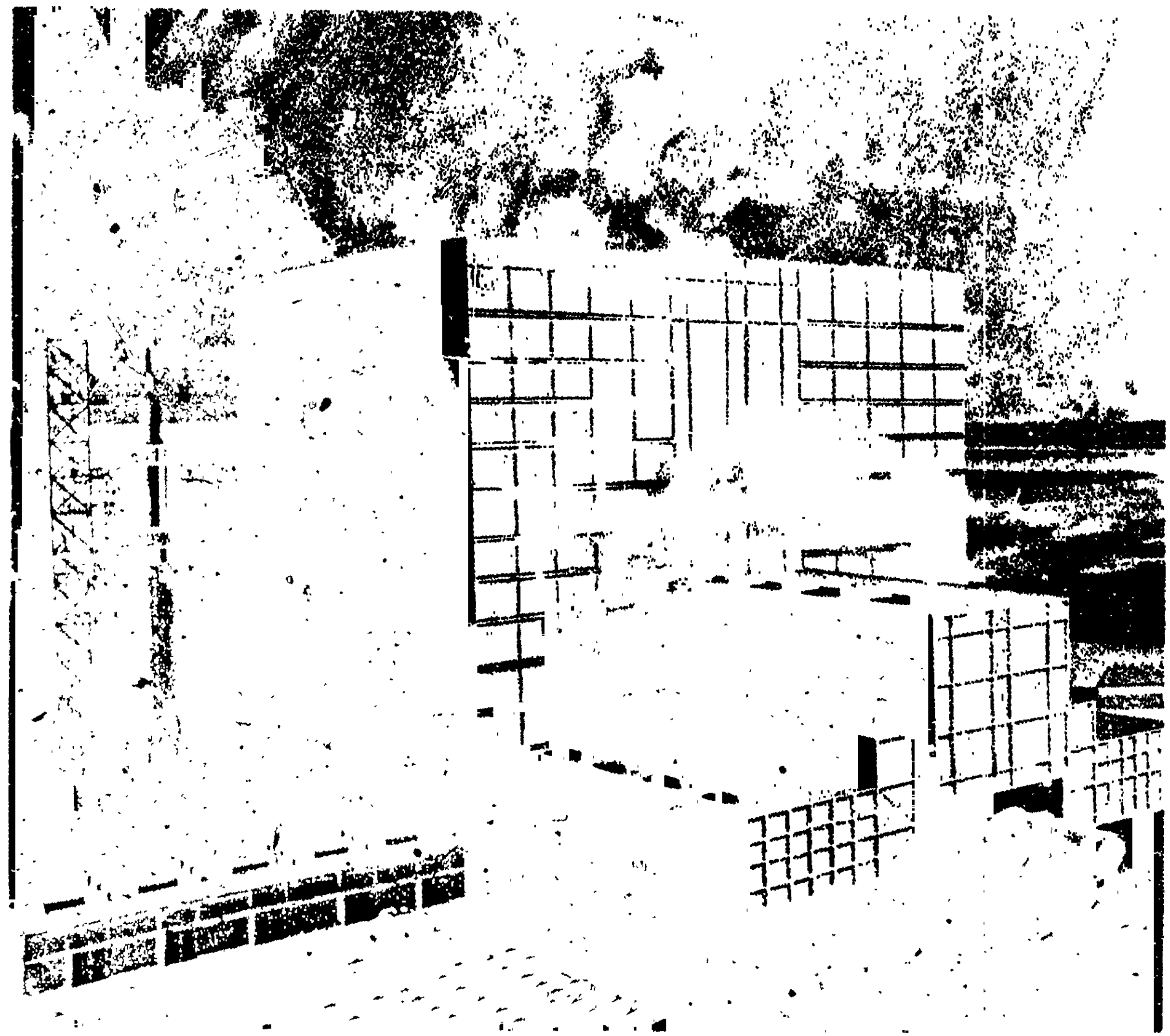


FIGURE 4. VERTICAL ASSEMBLY BUILDING (VAB)

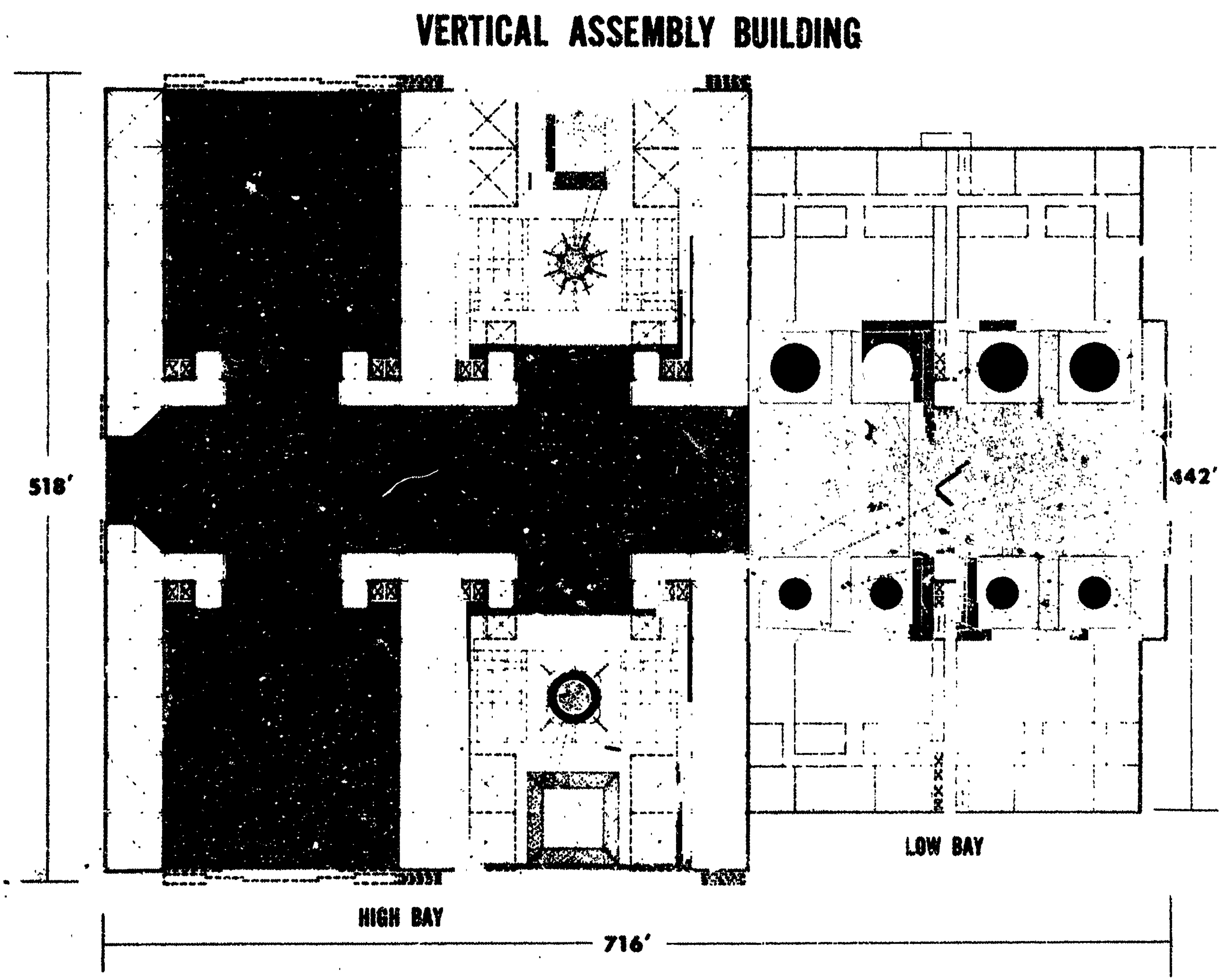


FIGURE 5. FLOOR PLAN OF VAB

VERTICAL ASSEMBLY BUILDING

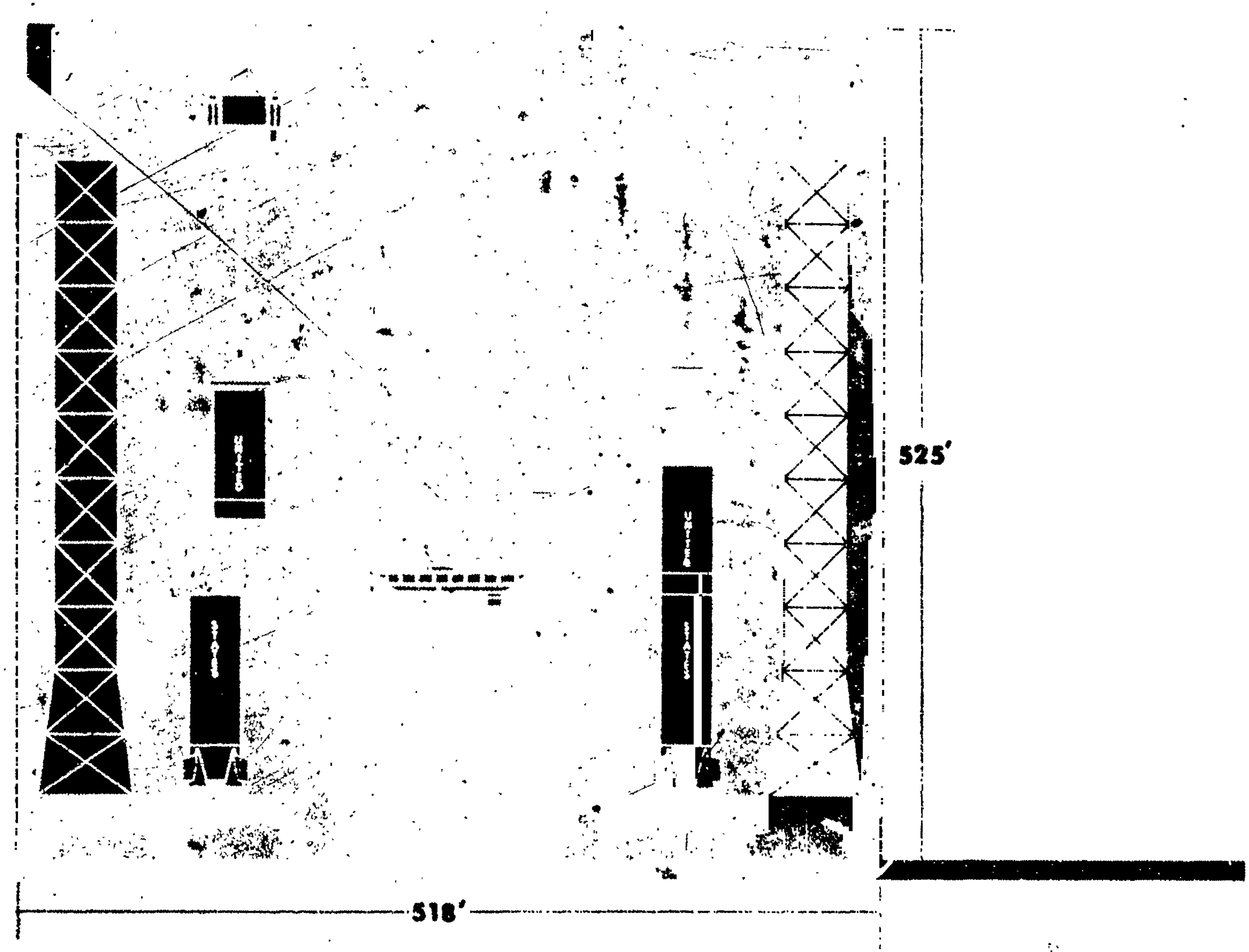
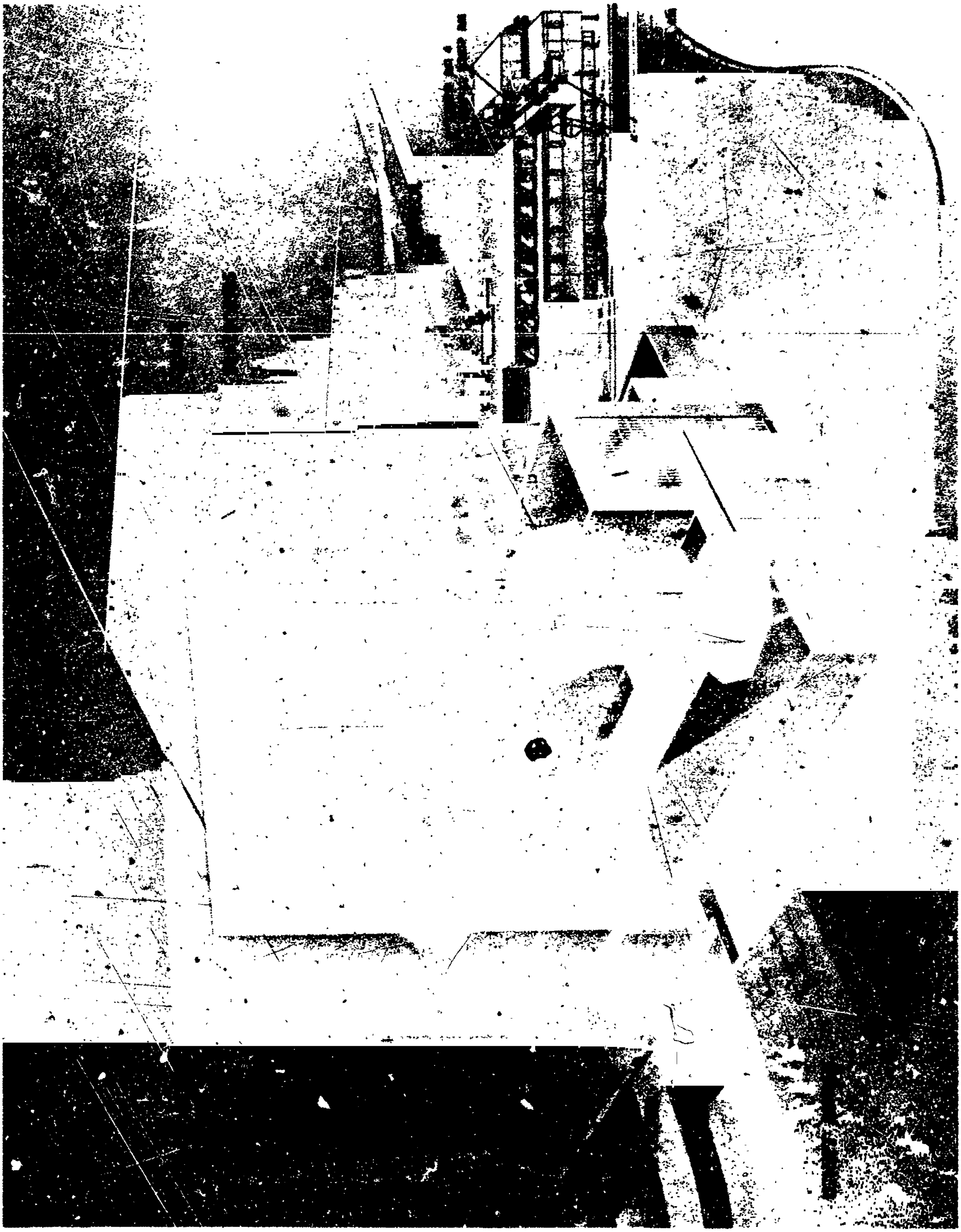


FIGURE 6. CROSS SECTION OF HIGH BAY AREA OF VAB



Construction is well underway at the VAB area. An extensive pile driving operation has been completed, foundations have been poured, and steel erection has begun. It is expected that VAB construction will be completed in early 1966.

Data Acquisition, Transmission and Display Systems

A high speed data link system is provided between the LCC and the LUT for checkout of the launch vehicle. This link can connect to the LUT at either location, in the VAB or at the pad.

A separate lower capacity data link from the LCC to the Pad Terminal Connection Room (PTCR) provides for checkout of pad area GSE, such as propellant systems, high pressure gas system, and environmental control system. When the vehicle is not at the pad, a LUT simulator in the PTCR is used to permit checkout of the pad GSE system independent of vehicle checkout.

A hard wire system using battery powered independent circuitry provides a back-up link between the LCC and pad for safing and monitoring of the Launch Vehicle at the pad in the event of data link failure.

Additional data links provide connections from the spacecraft (when assembled on the LUT) to the Spacecraft Operations and Checkout Building, and to the LCC.

Launcher-Umbilical Tower

The LUT, figure 8, upon which the space vehicle will be assembled, provides the base for actual launch, and is designed for the temperatures, stresses, and vibrations of holddown and launch.

Its launch platform is a two-level steel structure, 25 feet high, 160 feet long, and 135 feet wide, which is positioned on six 22-feet high steel pedestals when in the VAB or at the LUT maintenance area near the VAB. At the launch pad, in addition to the six steel pedestals, four extendable columns are also used to stiffen the LUT against rebound loads, should it be necessary to cut off the engines after ignition.

Four launcher arms are mounted on the top deck of the launch platform. Each arm is approximately 10 feet high and 9 feet by 6 feet at the base, and weighs 37,000 pounds. Holddown is accomplished by a preloaded toggle linkage that is released on receipt of launch commit signal.

An umbilical tower extending 380 feet above the deck is mounted on one end of the launch platform. A hammer-head crane at the top has a hook height of 376 feet above the deck with a traverse radius of 85 feet from the center of the tower.

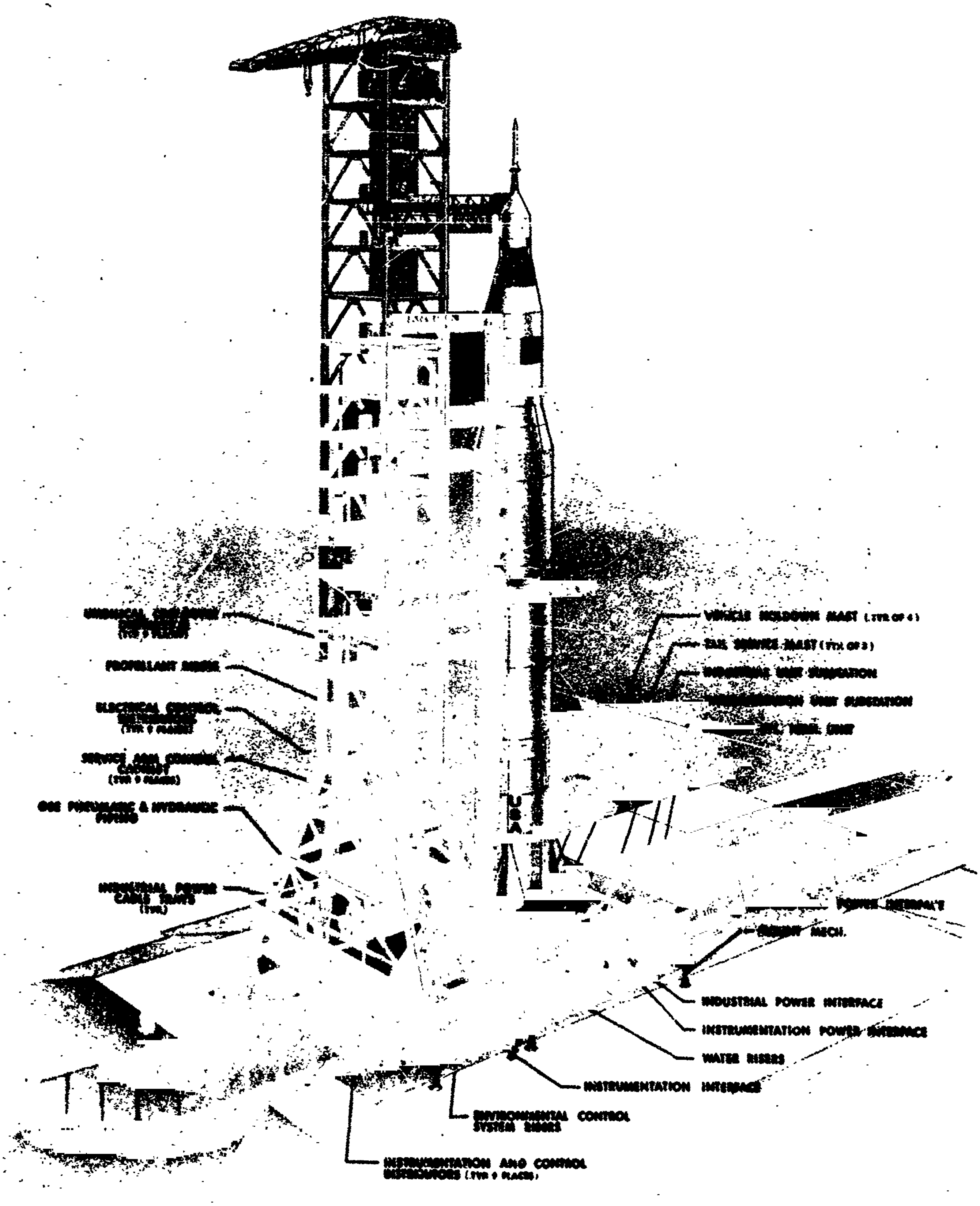


FIGURE 8. LAUNCHER-UMBILICAL TOWER (LUT)

Eight umbilical swing arms, varying in length from 35 to 45 feet, carry electrical, pneumatic, and propellant lines to the space vehicle. They also provide walkways for checkout personnel to use to enter the interstage areas.

The astronauts will board the spacecraft over a 68-foot loading walkway, which will be swung away shortly before ignition of the S-IC stage.

LUT erection is now in progress. Two are scheduled for completion in January and August 1966, respectively. A third LUT, to be used initially as a checkout unit, will be ready for facility tests in March 1965.

The Crawler-Transporter

The Crawler-Transporter, figure 9, is used to position the LUT in the VAB, move the LUT-space vehicle configuration from the VAB to the launch pad, and the Arming Tower from its park position to the pad.

The Crawler-Transporter unit is 131 feet long and 114 feet wide, and is powered by two 2750-horsepower diesel generators that provide 4,000 kw for a main drive system powered by electrical drive motors. It moves on four double-tracked crawlers, which are equipped with hydraulic jacking pads spaced 90 feet apart. The four crawler trucks may be centrally steered, or the front or rear trucks may be steered as pairs. The Crawler-Transporter will be capable of positioning the LUT on the steel pedestals within ± 2 inches. Its hydraulic jacks, used to lift and lower the crawlers' loads, have a 72-inch maximum stroke and also maintain the loaded LUT in a level position within ± 10 minutes of arc, when used with its level sensing system. Its speed while carrying the LUT-space vehicle configuration on a level crawlerway is one mile per hour. While carrying this load, the Crawler-Transporter can move against winds up to 40 knots steady state. Unloaded, its maximum speed is two miles per hour. The Crawler-Transporter can negotiate turns of 500 feet mean radius.

The Crawler-Transporter weighs 5.5 million pounds and can transport a load of 12 million pounds.

Crawler-Transporter fabrication is underway and nearing completion for one of the two being constructed. Fabrication of the second unit will be completed in late 1964. It is expected both units will be assembled and operational by early 1965.

Arming Tower

The Arming Tower, figure 10, provides 360-degree access to the space vehicle by means of platforms for service access to the vehicle. It is moved to the launch pad and positioned by the Crawler-Transporter. The 402-foot high structure measures 135 feet at the base, and is 113 feet square at the top. It remains in position at the pad, as shown in figure 11, until about T-7 hours before being transported back to its launch park area, which is 7,000 feet from the nearest launch pad.

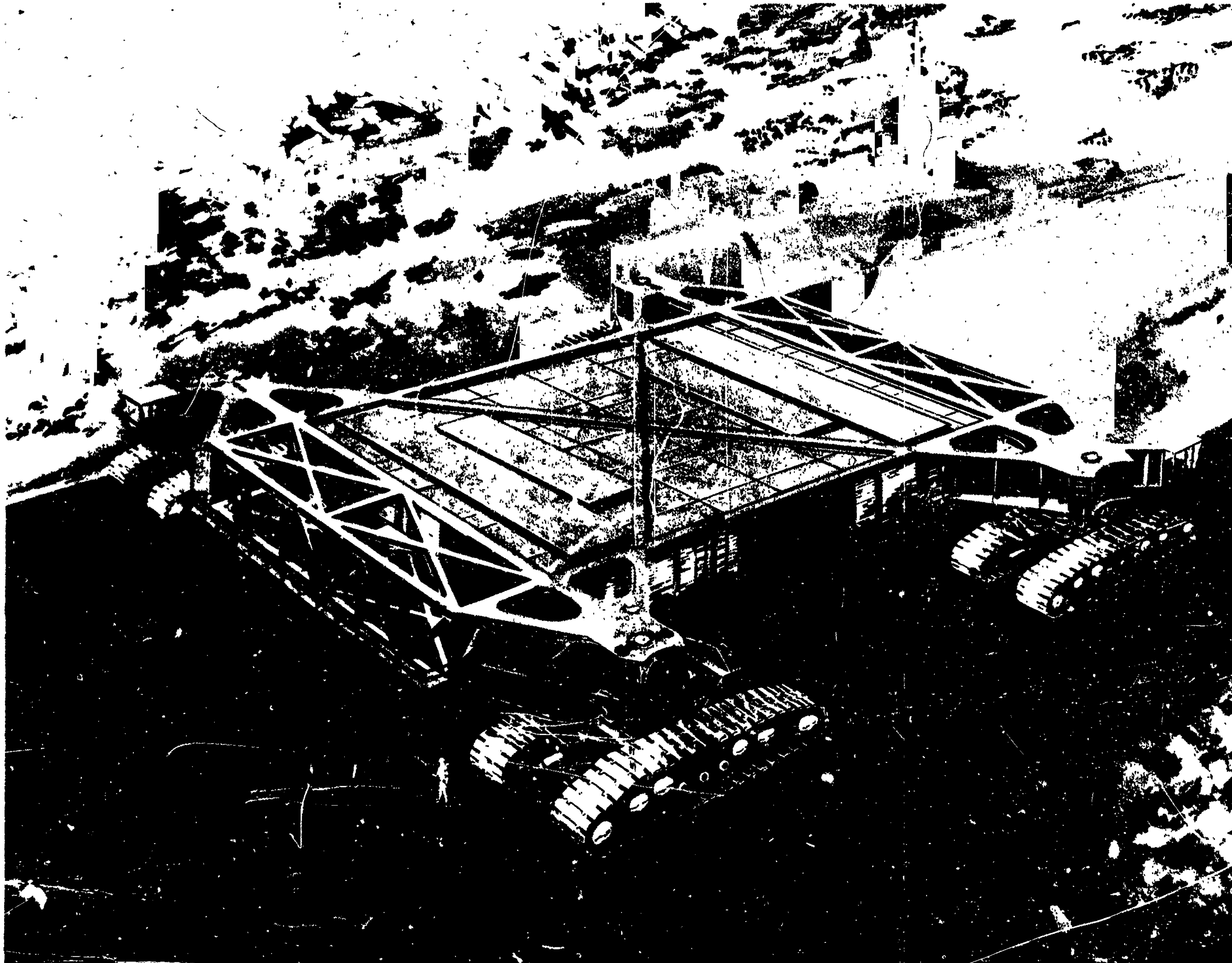


FIGURE 2 CRAWLER TRANSPORTER

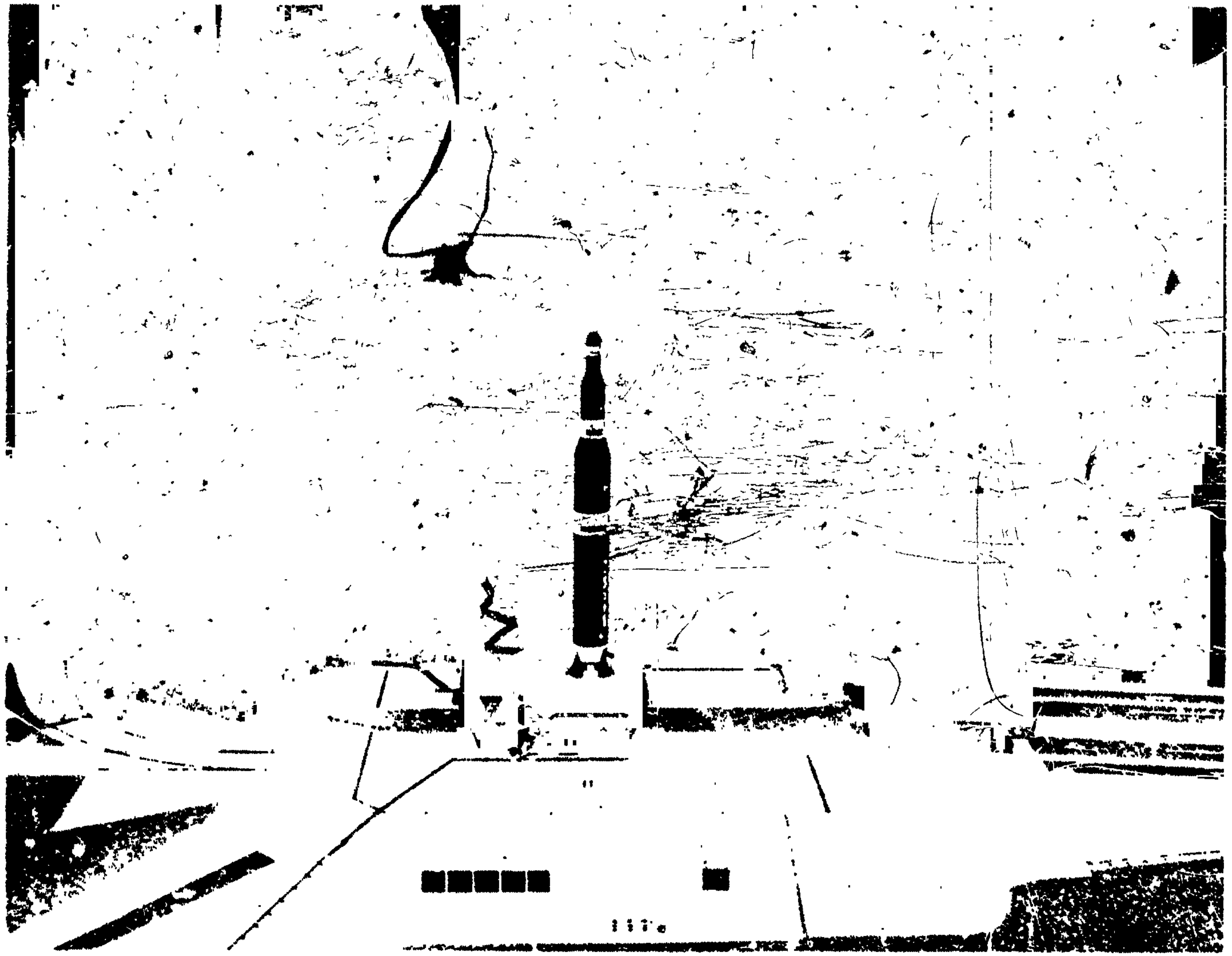


FIGURE 10. ARMING TOWER

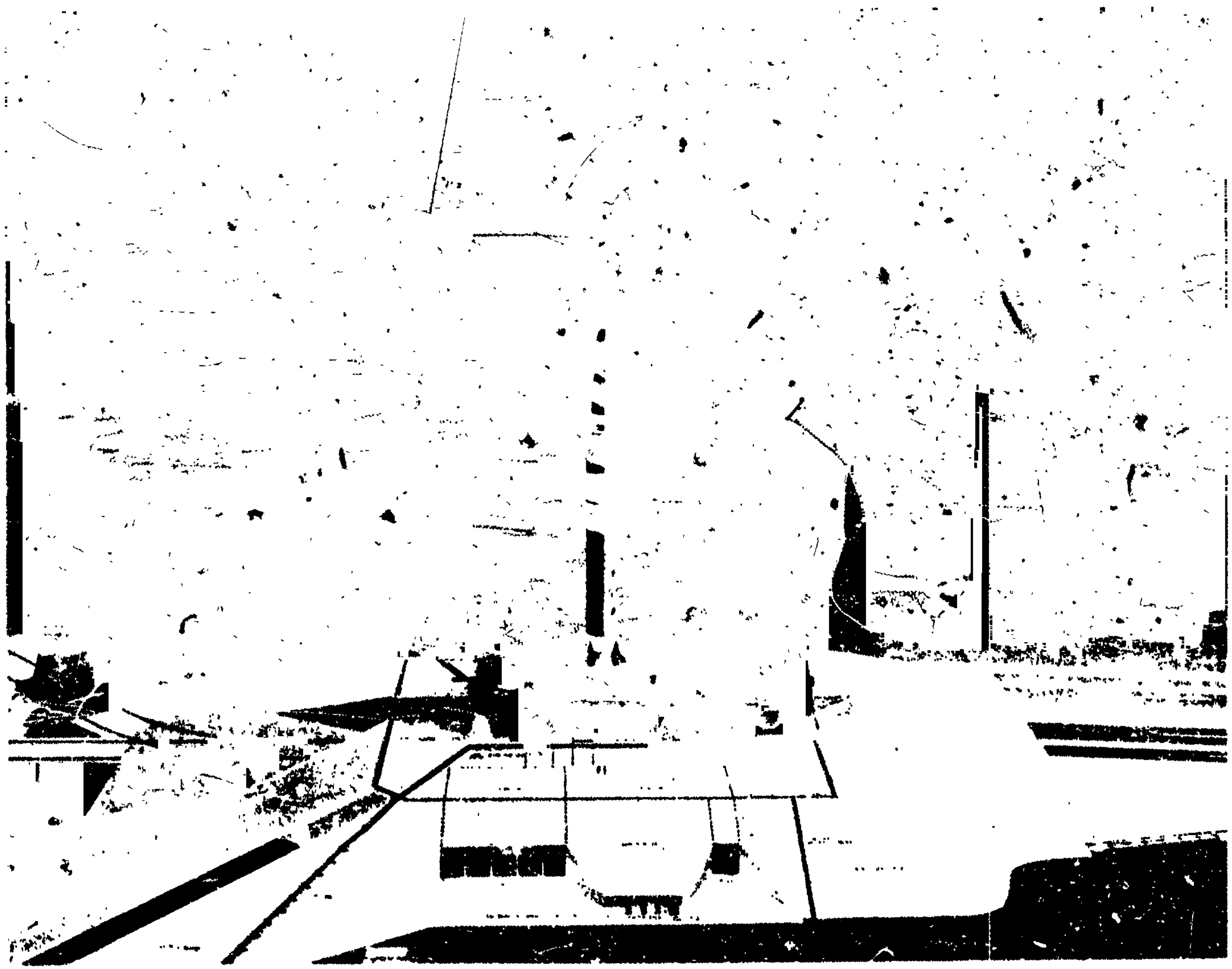


FIGURE 11. ARMING TOWER IN PLACE

Launch Pad Area

The Launch Pad Area, figure 12, is designed for final preparation of the space vehicle for launching, including propellant and ordnance loading, final checkout, and countdown.

Two launch pads and associated facilities are presently planned for construction at Launch Complex 39. The launch pad areas are located approximately one-half mile from the shore of the Atlantic Ocean, and are separated by 8,730 feet. Based on studies to determined maximum expected yield in the event of explosion on the pad, it has been determined that this pad separation distance will allow operations on these pads to be independent of each other. However, it will be necessary to clear the adjacent pads of launch personnel during actual launch.

The center portion of each pad, figure 13, is elevated 42 feet above the grade which is 6 feet above sea level. There will be a mobile, two-way, steel flame deflector positioned under the center-line of the vehicle. A removable refractory material will protect the flame deflector ridge which will be 37 feet from the exhaust plane of the F-1 engines.

The Crawlerway is a specially prepared roadbed which will take the total load of 17.5 million pounds, with an average ground pressure under crawlertracks of 65 psi. The Crawlerway is 150 feet wide, and has a grade of 5 percent approaching the pad.

Liquid oxygen (LOX), used in all Saturn V stages, is stored in an 900,000-gallon tank some 1,450 feet from each launch pad.

Kerosene (RP-1), the S-IC stage fuel, is stored in three 86,000-gallon tanks for a total capacity of 258,000 gallons. The tanks are located on the opposite side of the launch pad from LOX tanks.

An 850,000-gallon liquid hydrogen (LH_2) tank is located in the same general area as the RP-1 tanks. Pressure of 75 psig is maintained in the vacuum-jacketed tank during fueling operations to accomplish transfer of LH_2 to the S-II and S-IVB stages.

Gaseous nitrogen (GN_2) and helium (He) are stored underground in vessels near the launch pad at pressures of 6000 psi. A converter-compressor facility, located in the vicinity of the VAB, distributes the gas through transfer lines to the storage battery at each pad.

The Pad Terminal Connection Room is located underground adjacent to the pad. It will house electronic equipment which will provide a connecting link for communication and digital data link transmission lines from the LCC to the LUT. It will also serve as a distribution point for high pressure gas and electrical systems. Equipment for simulation of space vehicle and LUT functions is mounted there for use in the checkout of facilities when the LUT is not present.

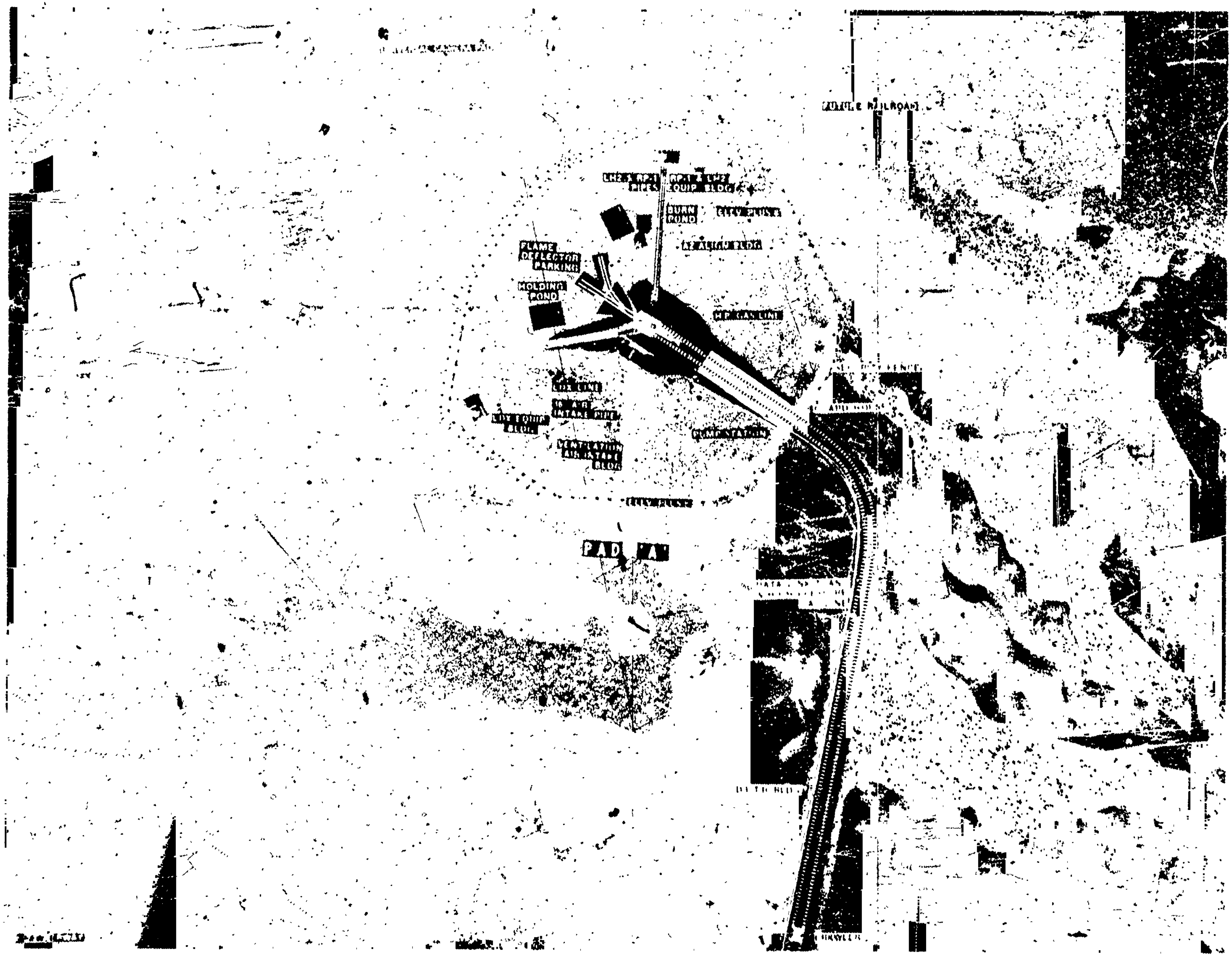


FIGURE 12 LAUNCH PAD AREA

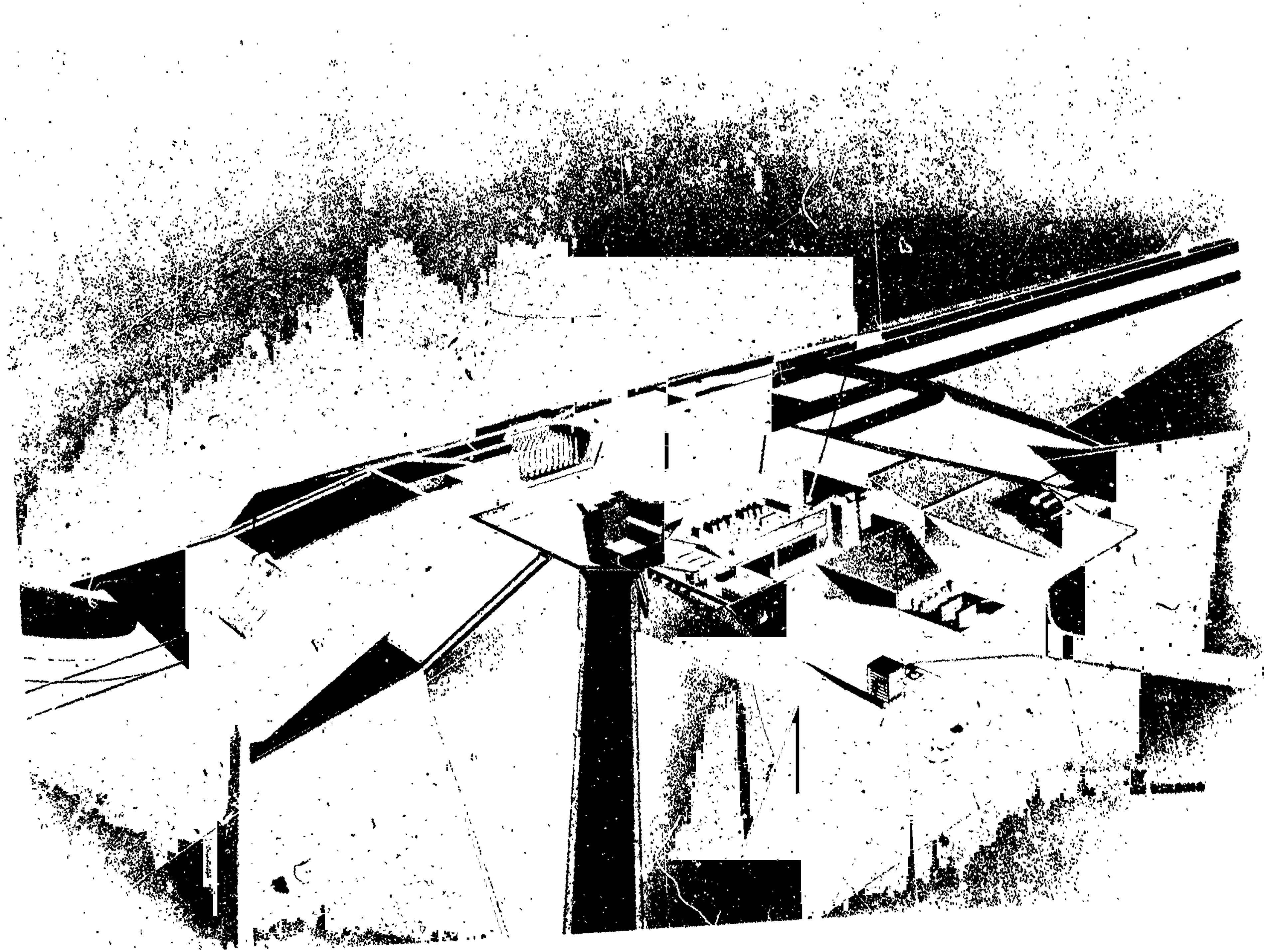


FIGURE 13 LAUNCH PAD HARDSTAND

Propellant loading will be remotely controlled from the LCC. The Arming Tower will have been moved from the pad, and the pad placed in launch ready condition, figure 14.

At present, two pads are under construction with scheduled completion dates of mid-1965 and early 1966, respectively.

APOLLO/SATURN V LAUNCH OPERATIONS

Saturn V Stage Transport

Saturn V stages will be shipped to MILA by ocean-going vessels or by specially designed aircraft. Arriving at a terminus near the VAB, a stage will be rolled-off on its specially constructed transporter and towed into the VAB.

Spacecraft Transport

Apollo spacecraft modules will be transported to MILA by air.

The CM, SM, and LEM will be delivered to the Manned Spacecraft Operations and Checkout Building in the Merritt Island Industrial Area for servicing and checkout.

Inspection and Checkout

After removal of each of the stages from the barge, they will be transported to the VAB where stage preparation and checkout will commence. Receiving inspection will first be performed on the stages, and then they will be erected beginning with the S-IC stage within the High Bay. Separately packaged items such as fins and interstage skirts will be installed and mandatory modifications will be performed. Any components requiring scheduled laboratory checkout will be shipped separately and sent to the labs prior to installation. Certain tests which cannot be performed after stage mating in the High Bay will be performed on the S-II and S-IVB stages in the low bay prior to stage mating.

Erection and checkout of the space vehicle on the LUT within the High Bay will require approximately nine weeks. Apollo spacecraft preparation and checkout will require approximately 22 weeks prior to mating with the Saturn V launch vehicle.

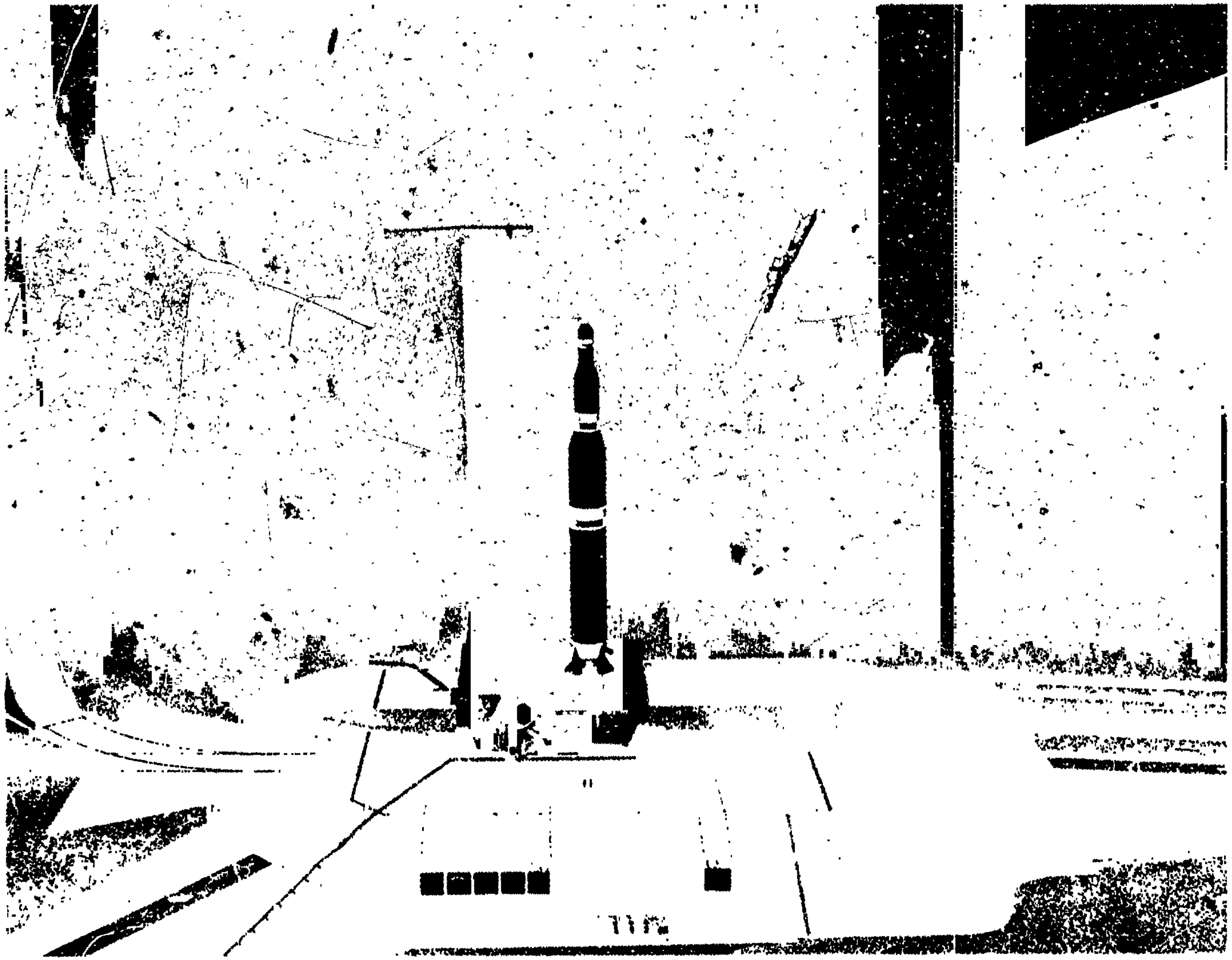


FIGURE 14. LAUNCH READY CONDITION

S-IC Stage

After being towed into the High Bay Area of the VAB and positioned under the 250-ton overhead bridge crane, the S-IC stage will have slings attached to it and hooked to the crane. This crane, together with the 175-ton crane, will lift the stage and tip it to vertical position. It will then position the S-IC above the launch platform of the LUT, and lower it into place. After it is positioned, it will be secured to the four hold-down/support arms that will support the entire space vehicle during launch preparation and provide holddown during thrust buildup prior to launch. The arms are located between the outboard engines.

Work stands will be positioned about the stage, inspection and engine covers will be removed, and all accessible components and systems will be inspected for possible handling damage.

Engine shrouds will be installed on the stage. The fins will be similarly moved into position and installed on the planes of the four outboard engines. Each fin has a span of $11\frac{1}{2}$ feet and a surface area of 75 square feet.

The stage will be vertically aligned, mated to the GSE, and connected to necessary simulators.

LUT electrical GSE will be connected to the Launch Control Center (LCC) via the high speed data link, and the S-IC test program will be performed utilizing the actual launch control equipment.

The test program will essentially follow the building block pattern with some initial checks at the component level and progressively expanding into subsystem/systems and composite system tests. These checks are conducted with VAB work platforms in place, and with LUT umbilical arms connected.

S-II Stage, S-IVB Stage, and Instrument Unit

During this time all low-bay testing will have been completed and the upper stages prepared for mating.

Following mating preparations, the upper stages are moved to the high bay and mated with the S-IC. The mating operation will consist of mating each stage as soon as the previous stage has been prepared. Umbilical connection will begin immediately and continue during the mating operation on a non-interference basis. After the S-IVB has been mated to the S-II stage, the IU will be assembled to the S-IVB. The vertical alignment of the vehicle will be performed after each stage has been mated.

Saturn V Launch Vehicle

After the mechanical mating and alignment of the stages and IU, the S-II and S-IVB are electrically mated to the LUT GSE and limited stage-GSE checks performed prior to electrically mating the stages with each other. Following the completion of the stage-GSE compatibility tests, the stages will be electrically mated and launch vehicle systems tests will be performed. Examples of tests in this category which involve the IU and the stages are: Control Systems Test, Ordnance Systems Test, and RF Systems Test.

After completion of launch vehicle systems tests, an overall launch vehicle systems test will be performed.

Apollo Spacecraft

Concurrent with stage mating operations, component and systems tests of the Apollo spacecraft will be run in the Operations and Checkout Building. Included in the testing to be performed at MILA will be a sequence of static tests, the only ones conducted on the modules after their manufacture.

The CM and the SM will be assembled and verified as a combined unit, and will remain assembled for transport to the VAB. The LEM will be checked out both individually and as a part of the Apollo spacecraft system.

Apollo/Saturn V

After the launch vehicle is ready to receive the Apollo spacecraft, the spacecraft will be brought to the VAB and assembled into a complete space vehicle on the LUT in the High Bay Area.

Systems checkout will be performed concurrently in the high bay. Certain tests will begin on previously installed stages prior to the completion of the mating operation on a non-interference basis. The first tests will provide power and cooling capability to the vehicle, validate the connections and set up the instrumentation. When this has been completed, systems testing can begin. The systems tests will be controlled and monitored by the LCC wherever practical and "break-in" tests will be held to a minimum. Ordnance installation will begin. Following the validation of each stage, a data review will be held and the vehicle will be prepared for combined systems tests.

The combined systems tests will verify the flight-readiness of the overall vehicle. These tests will include a malfunction sequence test, an overall test of the launch vehicle, an overall test of the spacecraft, an overall test of the space vehicle and a simulated flight test. Prior to the simulated flight test the final ordnance installation will be completed. After the simulated flight test, the vertical alignment will be checked, a data review will be held and the vehicle will be prepared for transfer to the pad. These preparations will include disconnecting of pneumatics, hydraulics, and electrical lines from the LUT to the VAB.

Transfer from VAB to Launch Site

The Crawler-Transporter will be moved into position beneath the LUT. Its hydraulic jacks will engage the fittings on the LUT and raise it approximately three feet so that it will clear the VAB support pedestals. Then, the Crawler-Transporter will move out of the VAB, over the crawlerway, to the launch pad.

Arriving at the launch pad, the Crawler-Transporter will move the LUT into position and lower and lock the LUT onto the steel pedestals. Then, the Crawler-Transporter will move the Arming Tower into position alongside the space vehicle, where it will provide access to the vehicle for pad operations.

LAUNCH PREPARATIONS

Pad Preparation

Prior to the transfer of the space vehicle to the pad, the permanent-type pad GSE will be checked out. The initial interface checks of the pad GSE and the LUT will be performed from a local checkout station. Upon completion of these checks, the data link will be connected to the LCC and a remote checkout of the pad GSE performed.

LUT Connections to Pad

Upon arrival at the pad, the LUT and space vehicle services such as digital data link, communications circuitry, pneumatics supply lines, propellant lines, environmental controls, and electrical power supply lines will be connected.

After all connections have been made, power will again be applied to the vehicle and the control and monitor links will be verified. Pad testing will be held to a minimum. The applicable high bay will remain empty during pad operations. RF systems will be checked out with their associated ground station, the Digital Data Acquisition System will be validated and the guidance platform will be aligned. A simulated tank pressurization and a simulated propellant tanking test will be performed. Next, a complete propellant tanking test will be performed, and RFI checks will be made. An Environmental Control System functional test and a simulated flight test will also be performed.

The simulated flight test involves a complete launch day: simulated countdown, launch, and flight operations. Compatibility with tracking range and mission control operations is verified at this time.

Launch Countdown

Upon completion of the simulated flight test, pre-launch preparations such as hypergolic loading, platform removal, etc., will be performed, and the space vehicle will then be ready to enter the countdown phase of launch operations.

Propellant Loading

Propellant loading of the Apollo spacecraft will be performed prior to T-7 hours on launch day. Aerozine 50 will be the fuel and nitrogen tetroxide the oxidizer. Prior to T-7 hours, hypergolics for the S-IVB reaction control system will be loaded and ordnance will be connected.

Loading of the cryogenic propellants for the launch vehicle begins on launch day at approximately T-7 hours. (The RP-1 will have been loaded on L-1 day.)

LOX loading is first. The tanks are pre-cooled before filling. Pre-cool of one tank can be accomplished concurrently with the fill of another. Loading is started with the S-IVB stage, followed by the S-II, and then the S-IC. LOX is pumped at a flow rate of 1,000 gpm for the S-IVB; loading will require 32 minutes, including 12 minutes for pre-cool.

For the S-II, the tank flow rate is 5,000 gpm and fill time is 25 minutes including 6 minutes pre-cool. The S-IC tank flow rate is 10,000 gpm and requires 40 minutes including 11 minutes pre-cool.

LH_2 fill in initiated next and will require 35 minutes, including 10 minutes pre-cool, to fill the S-IVB tank at a 3,000 gpm flow rate; the S-II tank will require 35 minutes including 10 minutes pre-cool, to fill at a flow rate of 10,000 gpm.

Topping of cryogenic tanks of the launch vehicle will continue until launch.

Astronaut Embarkation

At approximately T-45 minutes, after propellants are loaded, the astronauts will enter the spacecraft from the umbilical tower over the swing arm walkway.

Launch

During the remainder of the countdown, the final systems checks will be conducted.

Launch vehicle propellant tanks will be pressurized, and the S-IC engines will be ignited. During the thrust buildup of the F-1 engines, the operation of each of these engines will be automatically checked. Upon confirmation of thrust "O.K." condition, the launch commit signal will be given to the holddown arms and liftoff occurs, figure 15.

FLIGHT

The trajectory of the basic mission calls for the S-IC to burn about 150 seconds to reach an approximate altitude of 40 miles and velocity of 5200 miles per hour at burnout. Separation of the S-IC stage then occurs and the five J-2 engines of the S-II stage are ignited.

Shortly after ignition of the S-II stage the escape tower is jettisoned. The burn of the S-II second stage will boost the space vehicle to an approximate altitude of 115 miles and a velocity of about 14,500 miles per hour. Second stage burnout occurs about nine minutes after liftoff. The stage is separated and the single J-2 engine of the S-IVB third stage is ignited.

A partial burn of the S-IVB stage occurs to put the S-IVB/Apollo spacecraft into an earth orbit. Engine cutoff occurs at an altitude of 115 miles and velocity of 16,500 miles per hour.

After injection of the third stage and Apollo spacecraft into a parking orbit, the trajectory must be computed and the point and time of departure from parking orbit into the translunar trajectory established.

This configuration will continue in earth orbit for at least a half revolution while checkouts are being made (from the ground) of the S-IVB and Apollo spacecraft to assure that both are ready for the lunar flight.

At the pre-calculated point and time, the S-IVB engine is again ignited to accelerate the spacecraft for injection into a translunar trajectory, at a velocity of 25,000 miles per hour.

Upon injection of the spacecraft into the translunar trajectory and separation of the S-IVB and IU from the Apollo spacecraft, the launch operation is completed.

FIGURE 15. APOLLO/SATURN V LIFTOFF

CONCLUSION

The successful achievement of the manned lunar landing will mark a significant milestone along the path now being taken to develop our manned space flight capability. Other milestones will follow as man learns to live and operate in space and sets new goals that only a few years ago were merely dreams. As man strives for these goals, his efforts must surely result in an improved ability to meet the increasing demands of future generations.