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SATURN V/APOLLO LAUNCH OPERATIONS PLAN

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ABSTRACT

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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: (1) the greatly increased size and complexity of the SATURN V/APOLLO space vehicle, (2) a requirement for unprecedented reliability, (3) the flexibility of handling varying launch rates and having a fast re-cycle time. It has been determined that these needs can best be satisfied by the adoption of a mobile launch concept.

The facilities required to implement the mobile concept include: (1) a vertical assembly building where space vehicles undergo detailed stage preparation, assembly and checkout operations on a launcher-umbilical tower platform, (2) a crawler-transporter to move the vertically assembled and checked-out vehicle on the launcher-umbilical tower to the launch pad, (3) automated checkout facilities incorporated into the space vehicle and the ground support equipment, (4) a digital data system permitting checkout and launch of the space vehicle on the pad from a location remote from the pad.

The translation of the mobile concept into operating facilities presents great challenges. Basic design criteria have been established and detailed design is underway on various portions of this launch complex, now designated SATURN Complex 39.

This paper describes these facilities from an operational viewpoint.

SATURN V/APOLLO

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 the nation's 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 - landing an American crew on the moon and returning them safely to earth.

The development of the Saturn V/Apollo and its 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 (OMSF), headed by D. Brainerd Holmes, is directing the Manned Lunar Landing Program (MLLP), and coordinating the programs of three NASA Centers in the development of launch vehicles, spacecraft and facilities.

The 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.

The Manned Spacecraft Center (MSC) in Houston, Texas, directed 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 Launch Operations Center (LOC), directed by Dr. Kurt H. Debus, is developing the facilities on the new Merritt Island Launch Area (MILA) (Figure 1) from which the Saturn V/Apollo will be launched and has operational responsibility for launch operations.

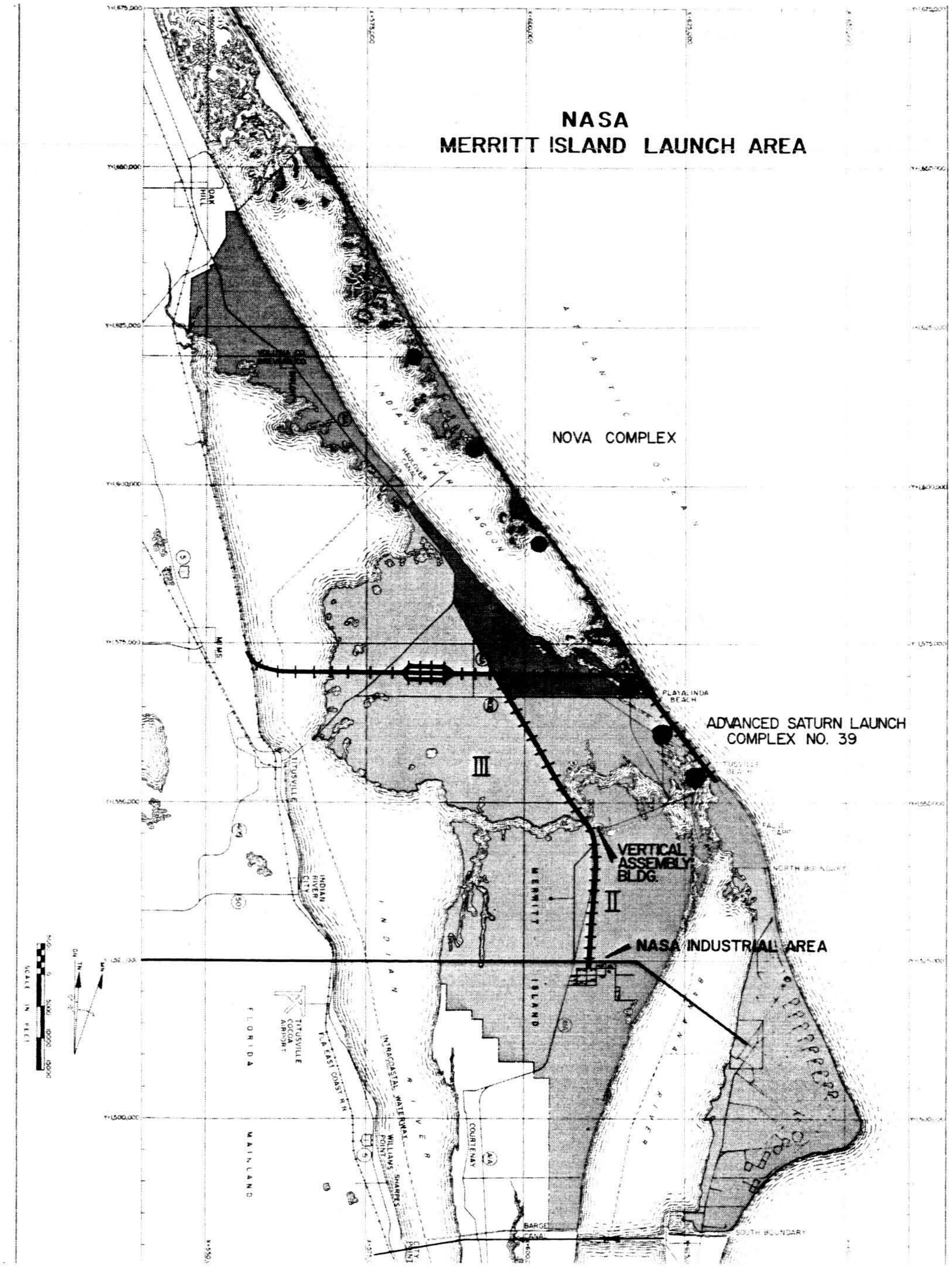

FIGURE 1. MERRITT ISLAND LAUNCH AREA (MILA)

The launch of the Saturn V/Apollo 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 the launch operations.

SATURN V/APOLLO DESCRIPTION

Development of the Saturn V/Apollo (Figure 2) 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.

S-IC Stage

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

The S-IC stage is 140 feet long, with a diameter of 33 feet. Its dry weight is 144 tons, and it has propellant capacity of 2,200 tons of liquid oxygen (LOX) and kerosene (RP-1) loaded in its two tanks with an oxidizer to fuel ratio of 2.36:1.

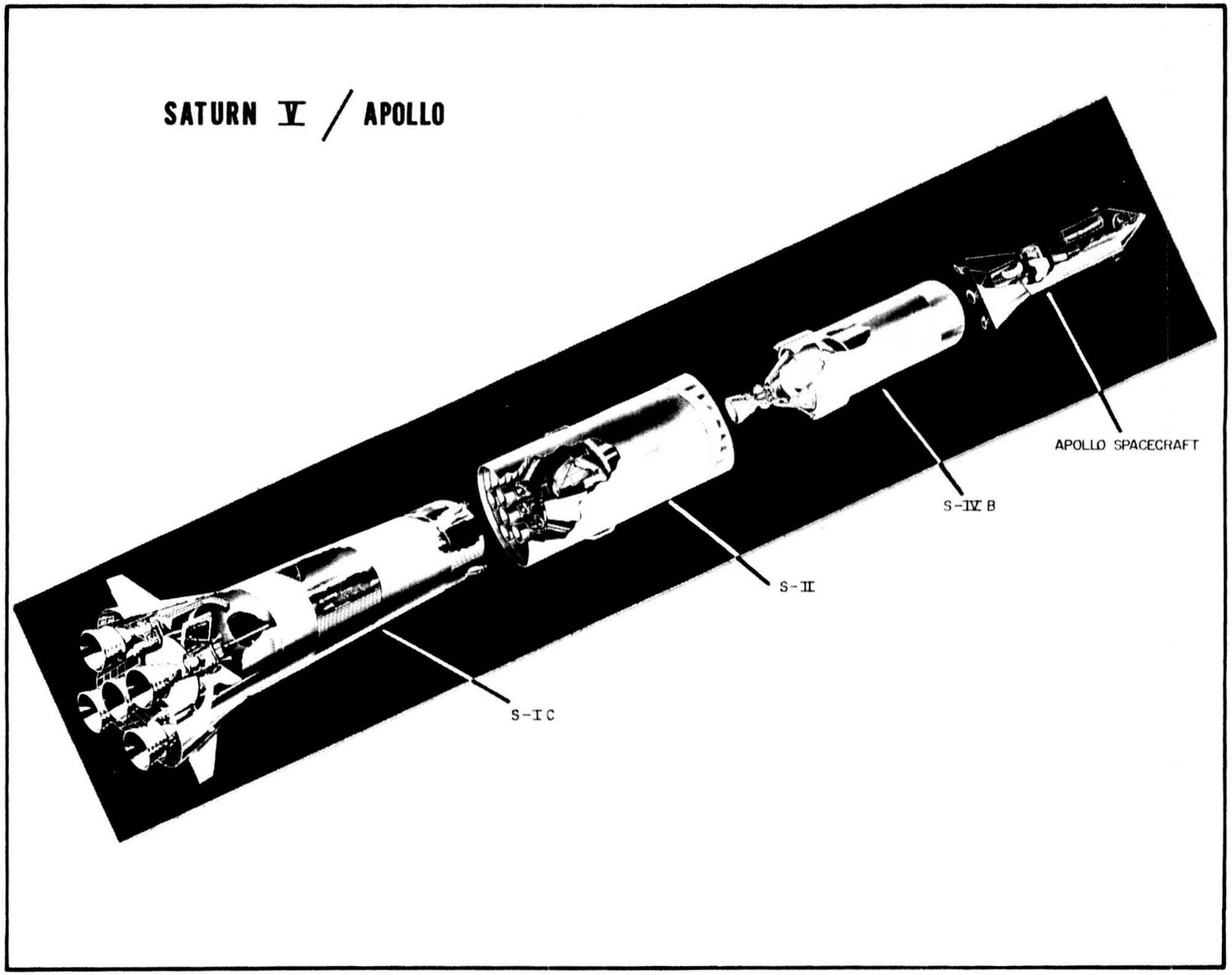

FIGURE 2. SATURN V/APOLLO

Its 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 capability, 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.

Its cluster of five J-2 engines develops a total of 1 million pounds of thrust. The engine array is similar to that of the S-IC stage, with the four outboard engines gimballed and the center engine fixed.

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 in test facilities near Sacramento, California.

Smaller than the first two stages of the launch vehicle, it is 59 feet long and has a diameter of 21 feet 8 inches. Its dry weight is approximately 14 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 Saturn V/Apollo through burnout of the S-IVB stage. Under development by MSFC at Huntsville, Alabama, it will be shipped to the MILA 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), Command Module (CM), and Launch Escape System (LES). The Apollo will be approximately 51 feet high and a maximum of 12 feet 10 inches in diameter. With the LES in place, it will be 79 feet high. The spacecraft will weigh 45 tons, with full propellant loading.

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 12 1/4 tons, including all propellants. The LEM 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 26 tons, including propellants.

The propulsion system, fueled by Aerozine 50 and nitrogen tetroxide, nominally provides 21,900 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 12 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 weigh 4 1/2 tons.

Launch Escape System

The LES is 28 feet long and equipped with a solid rocket engine. The engine will provide 150,000 pounds of thrust for six seconds to separate, in the event of an emergency, the CM from the launch vehicle in a longitudinal direction 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.

Saturn V/Apollo 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 of 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), in 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 VAB (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 High Bay and Low Bay Area is shown in Figure 5.

The Low Bay Area is 256 feet long and 437 feet wide, and has a center section 209 feet high. The Low Bay Area has eight stage preparation and checkout cells, equipped with systems to simulate stage interface and operation with other stages and the IU. Upon their arrival at the Merritt Island Launch Area (MILA) the S-II and S-IVB stages will be moved to the Low Bay Area for checkout.

The High Bay Area is 524 feet high by 513 feet wide and 432 feet long. It contains four checkout bays arranged as shown in Figure 5. Each pair of bays is served by a 250-ton bridge crane, with a hook height of 456 feet (Figure 6). A 175-ton overhead bridge crane serves the transfer aisle between the two pairs of bays, and the Low Bay Area. Each bay 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. 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

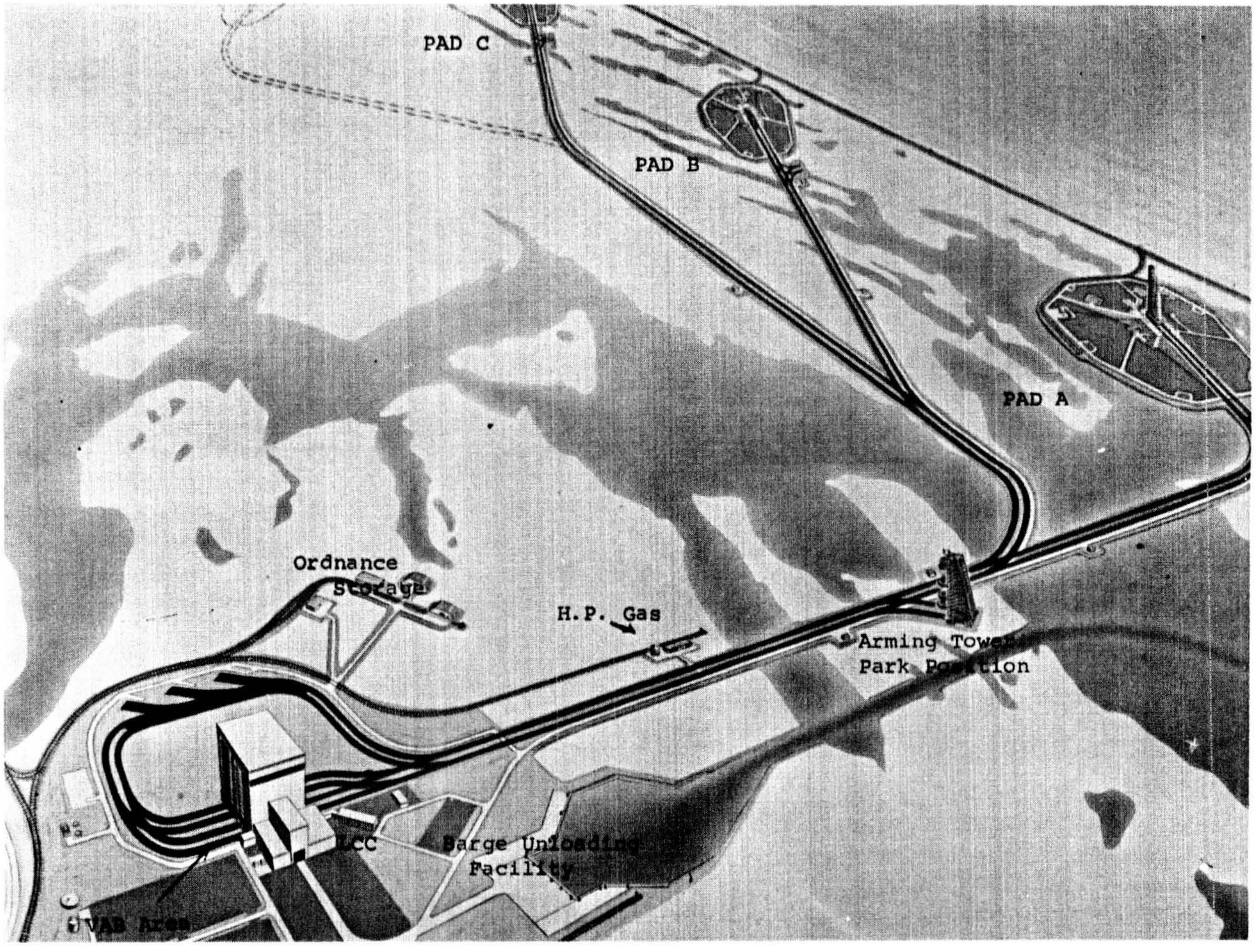

FIGURE 3. LAUNCH COMPLEX 39

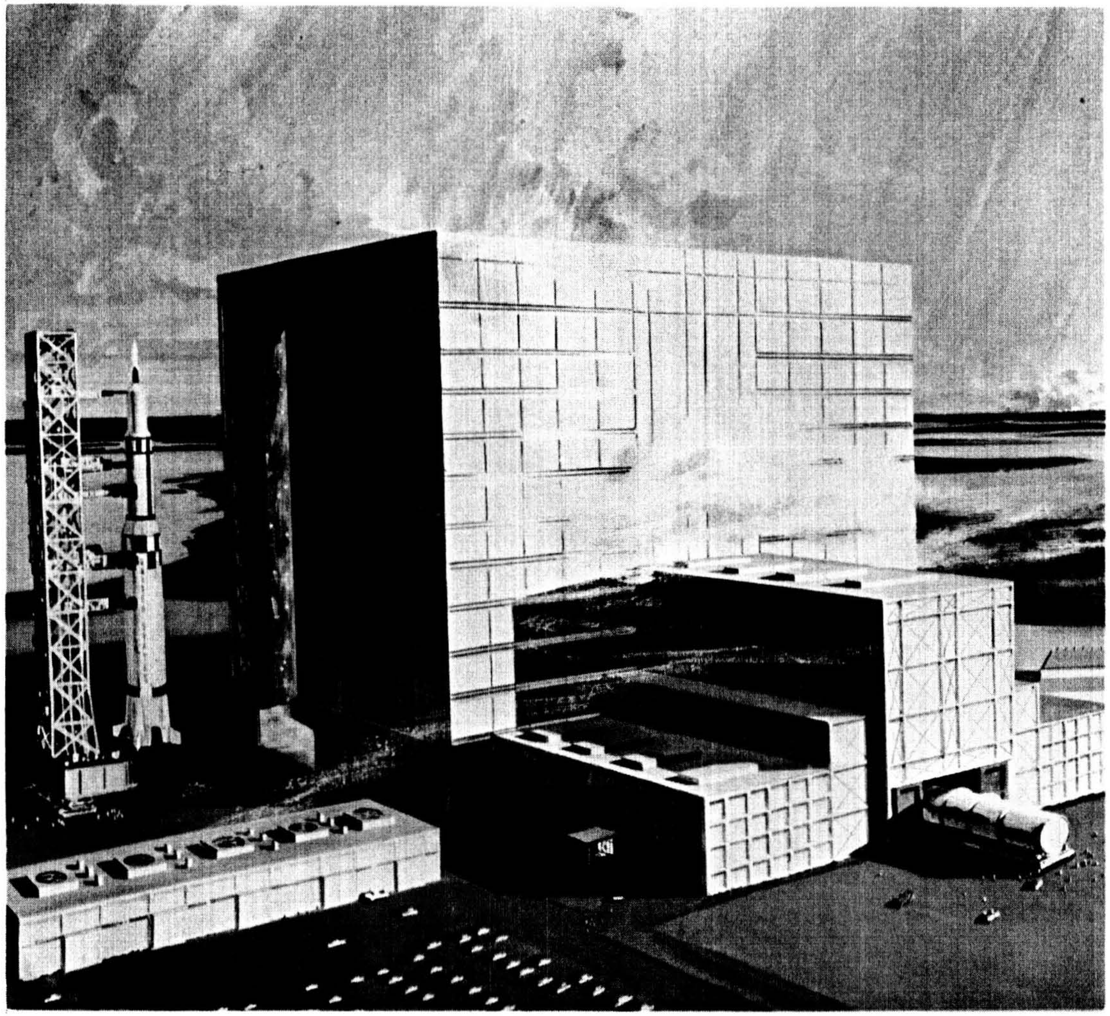

FIGURE 4. VERTICAL ASSEMBLY BUILDING (VAB)

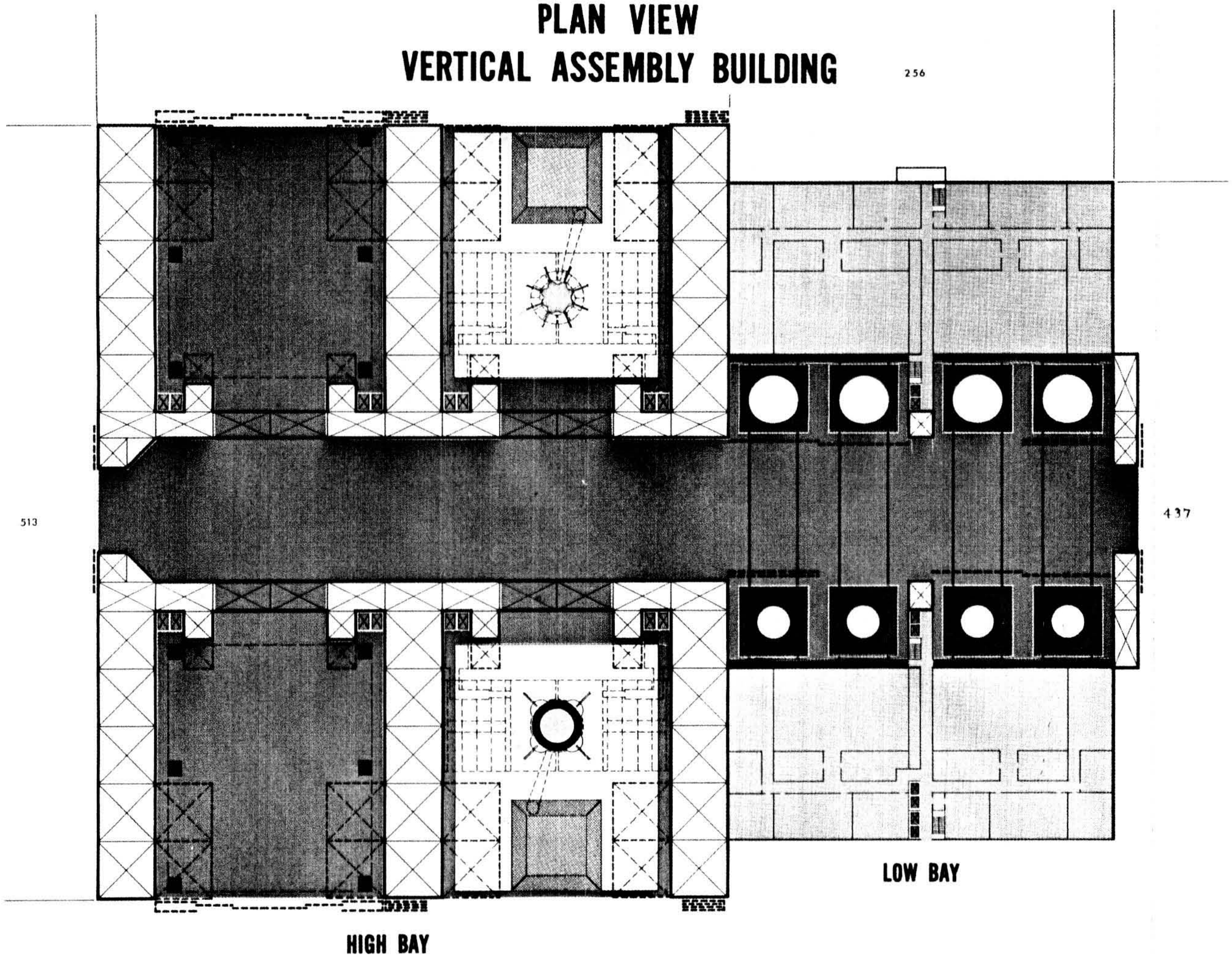

FIGURE 5. FLOOR PLAN OF VAB

CROSS SECTION
VERTICAL ASSEMBLY BUILDING

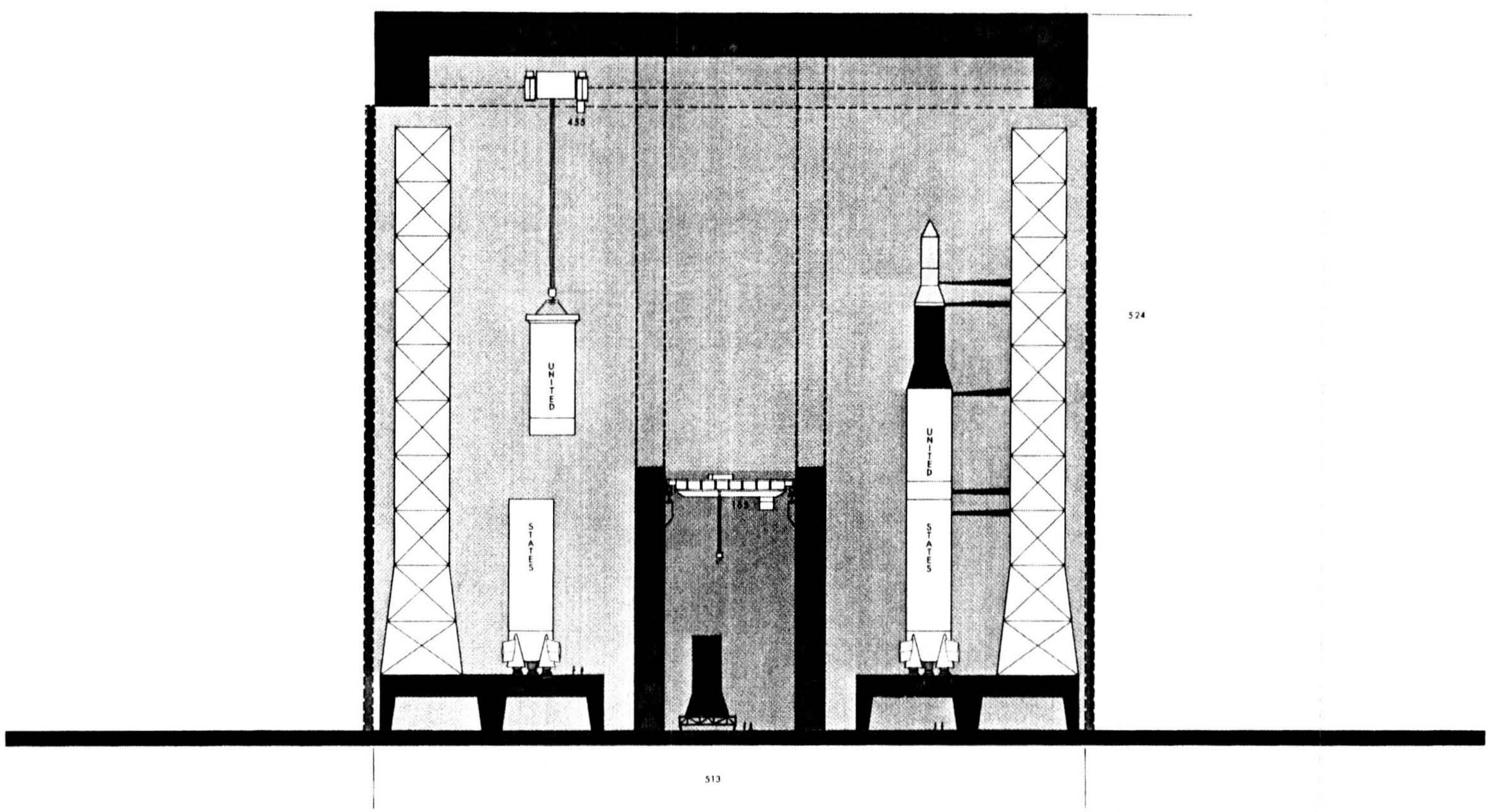

FIGURE 6. CROSS SECTION HIGH BAY AREA OF VAB

stage will undergo stage checkout, utilizing LUT and LCC instrumentation.

The LCC provides display, monitoring, and control equipment used for both checkout and launch operations. The three-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.

Data Acquisition, Transmission and Display Systems

A high speed data link 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 speed data link from the LCC to the Pad Terminal Connection Room (PTCR) provides for checkout of the GSE in the pad area, such as the 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 systems 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, 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 (Figure 7).

Its launch platform is a two-story steel structure, 25 feet high, 160 feet long, and 135 feet wide, which is positioned on six steel pedestals 21 feet high when in the VAB or at the LUT maintenance area near the VAB. At the launch pad, in addition to the

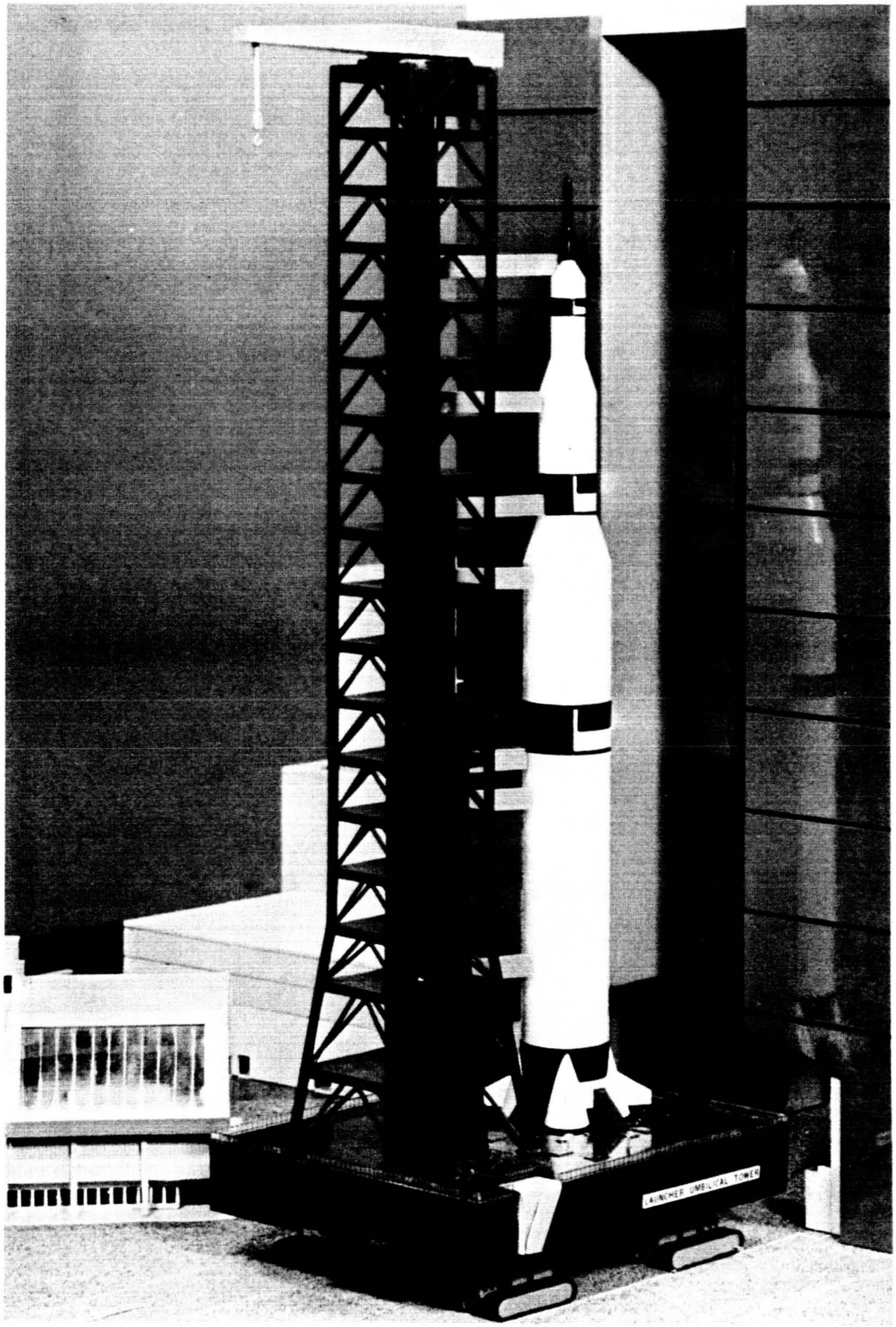

FIGURE 7. LAUNCHER UMBILICAL TOWER (LUT)

six steel pedestals, four extendable columns are also used to stiffen the LUT against rebound loads, should engine cutoff occur.

Four launcher arms are mounted on the top deck of the launch platform. Each arm is approximately 11 feet high by 9 feet by 6 feet at the base, and weighs 20,000 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.

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.

The Crawler-Transporter

The Crawler-Transporter 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 (Figure 8).

The Crawler-Transporter unit is 131 feet long and 114 feet wide, and is powered by two diesel generators that provide 5,600 horsepower for a main drive system powered by electrical drive motors. It moves on four double-tracked crawlers, with hydraulic jacking pads on 90-foot centers. 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 $\pm$ 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 $\pm$10 minutes of arc, when used with its level sensing system. Its speed while carrying the LUT-space vehicle configuration on a level crawler-way is one mile per hour. While carrying this load, the

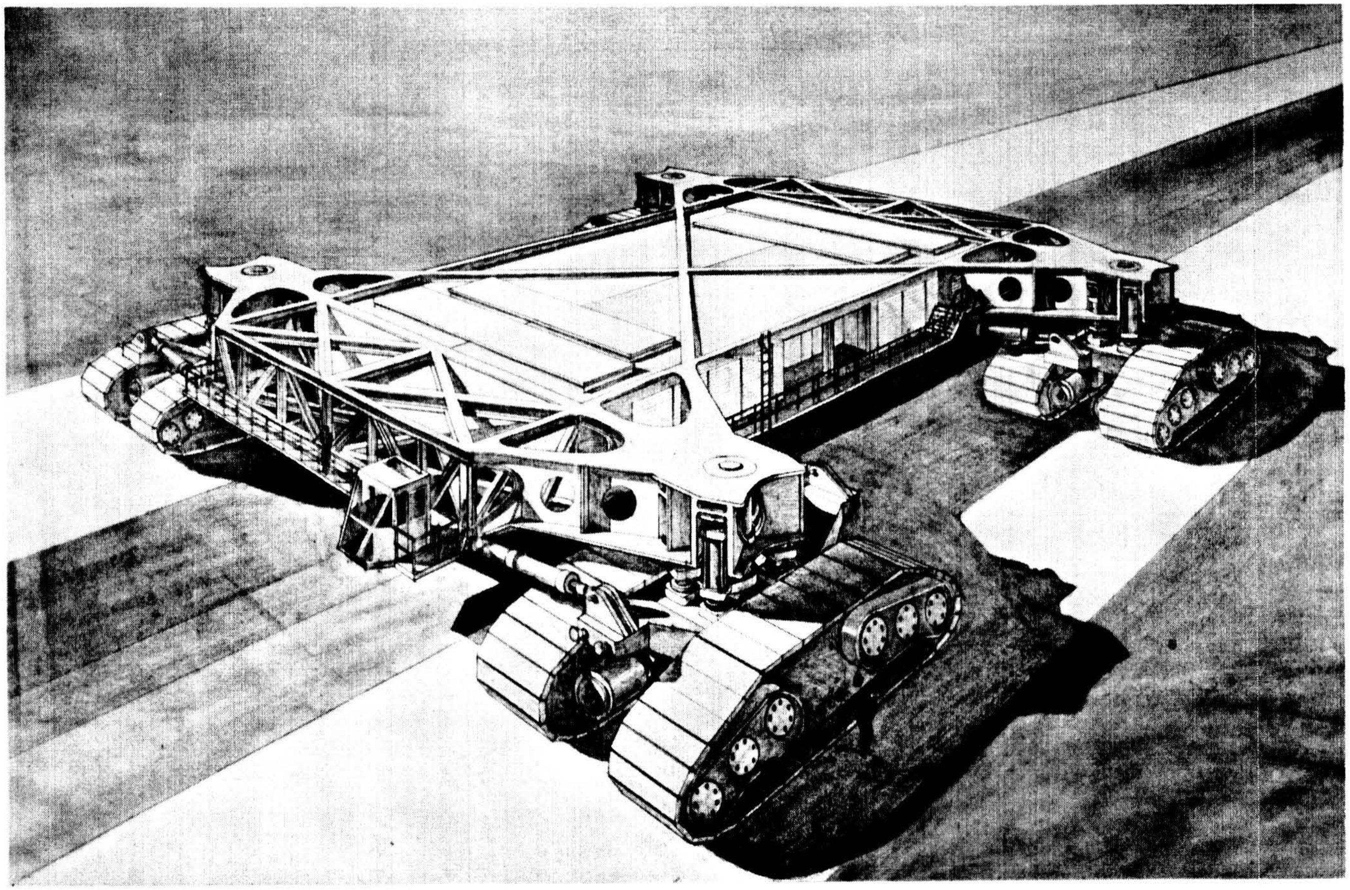

FIGURE 8. CRAWLER-TRANSPORTER

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.

Arming Tower

The Arming Tower provides 360-degree access to the space vehicle by means of platforms for ordnance installation and for service access to the vehicle (Figure 9). It is moved to the launch pad and positioned by the Crawler-Transporter (Figure 10). The 415-foot high structure measures 150 feet by 125 feet at the base, and is 80 feet square at the top. It remains in position at the pad until about T-7 hours before being transported back to its launch park area, which is 7,000 feet from the nearest launch pad.

Launch Pad Area

The Launch Pad Area is designed for final preparation of the space vehicle for launching, including propellant and ordnance loading, final checkout, and countdown (Figure 11).

Three 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 determine 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 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 with 35 feet from the exhaust plane of the F-1 engines to the deflector ridge. This ridge will be made of removable refractory material.

The crawler-way is a specially prepared road bed which will take the total load of 17.5 million pounds, with an average ground

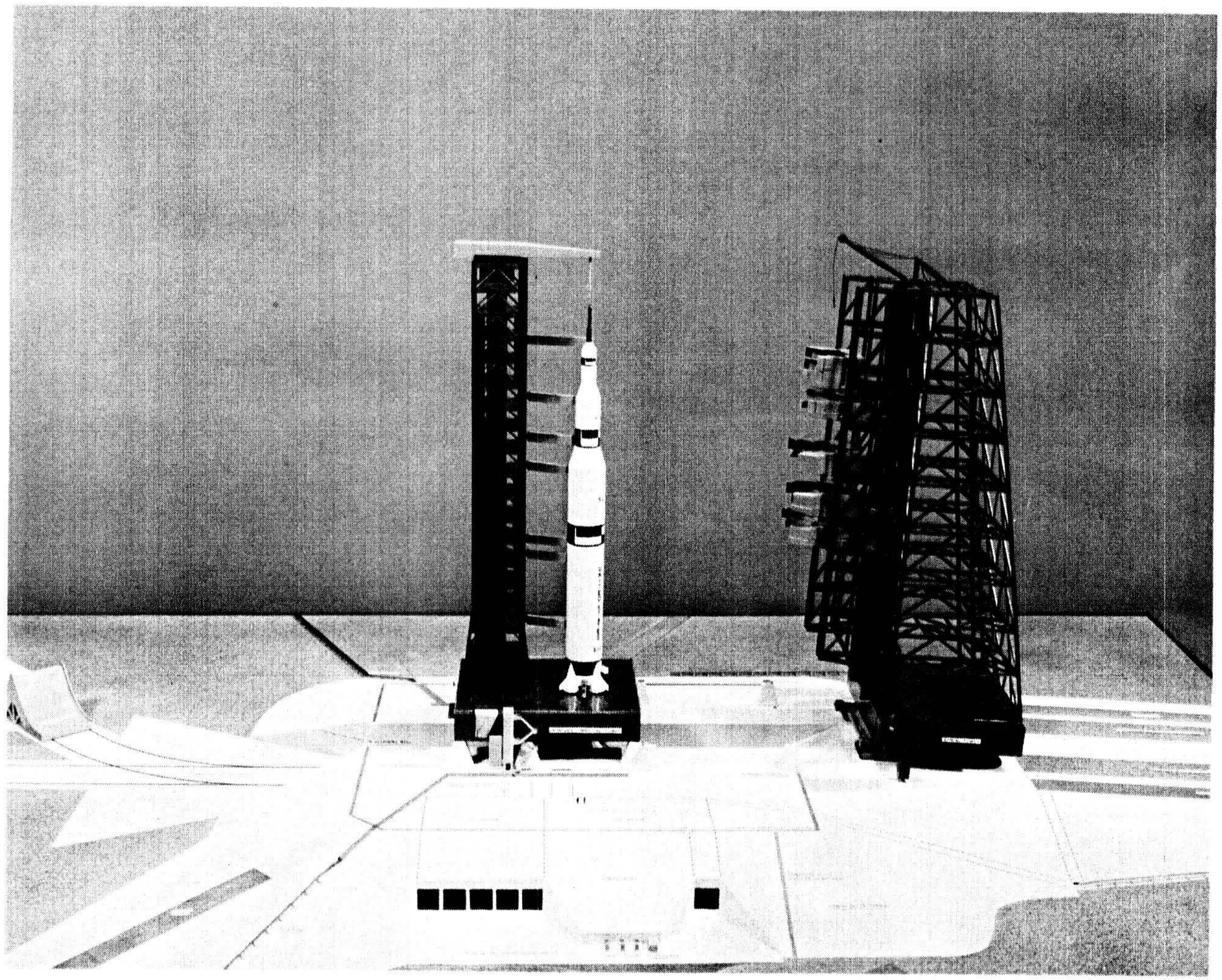

FIGURE 9. ARMING TOWER

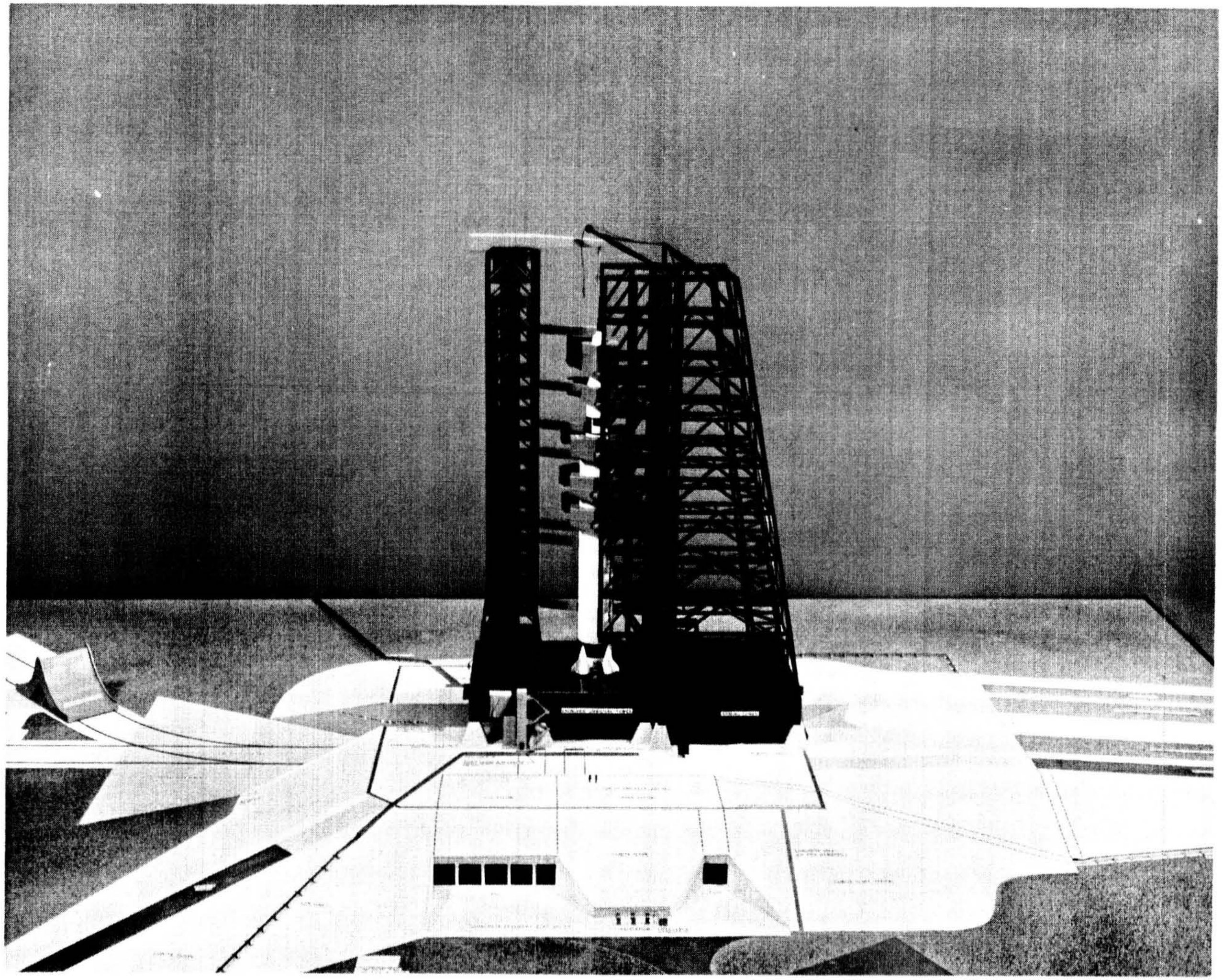

FIGURE 10. ARMING TOWER IN PLACE

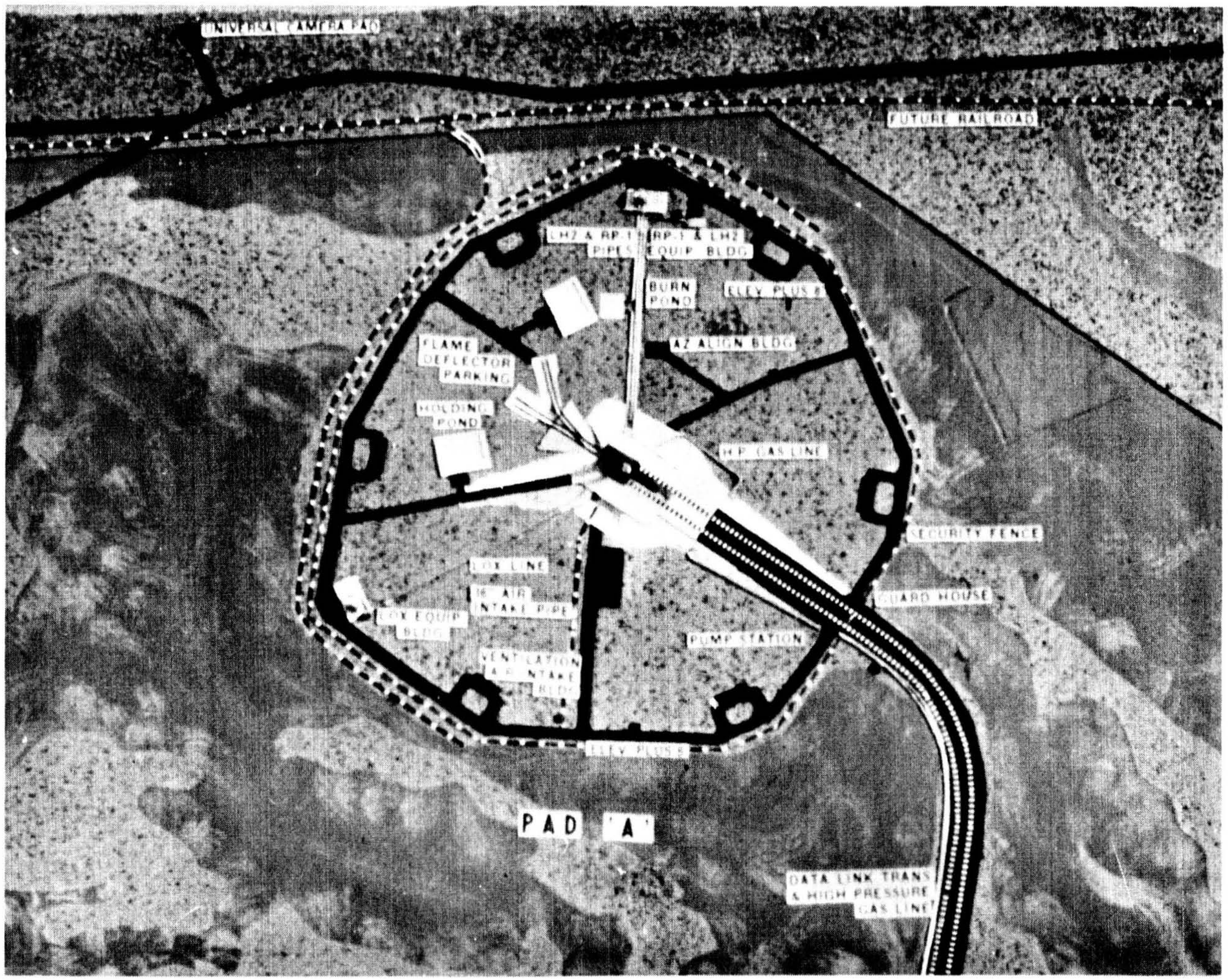

FIGURE 11. LAUNCH PAD AREA

pressure under crawler tracks of 65 psi. The crawler-way 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 880,000-gallon tank some 1,450 feet from each launch pad.

Kerosene (RP-1), the S-IC stage fuel, is stored in three tanks of 235,000-gallon total capacity, located on the opposite side of the launch pad from LOX tanks.

A 650,000-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 tothe 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 10,000 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.

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 12).

SATURN V/APOLLO LAUNCH OPERATIONS

Saturn V Stage Transport

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

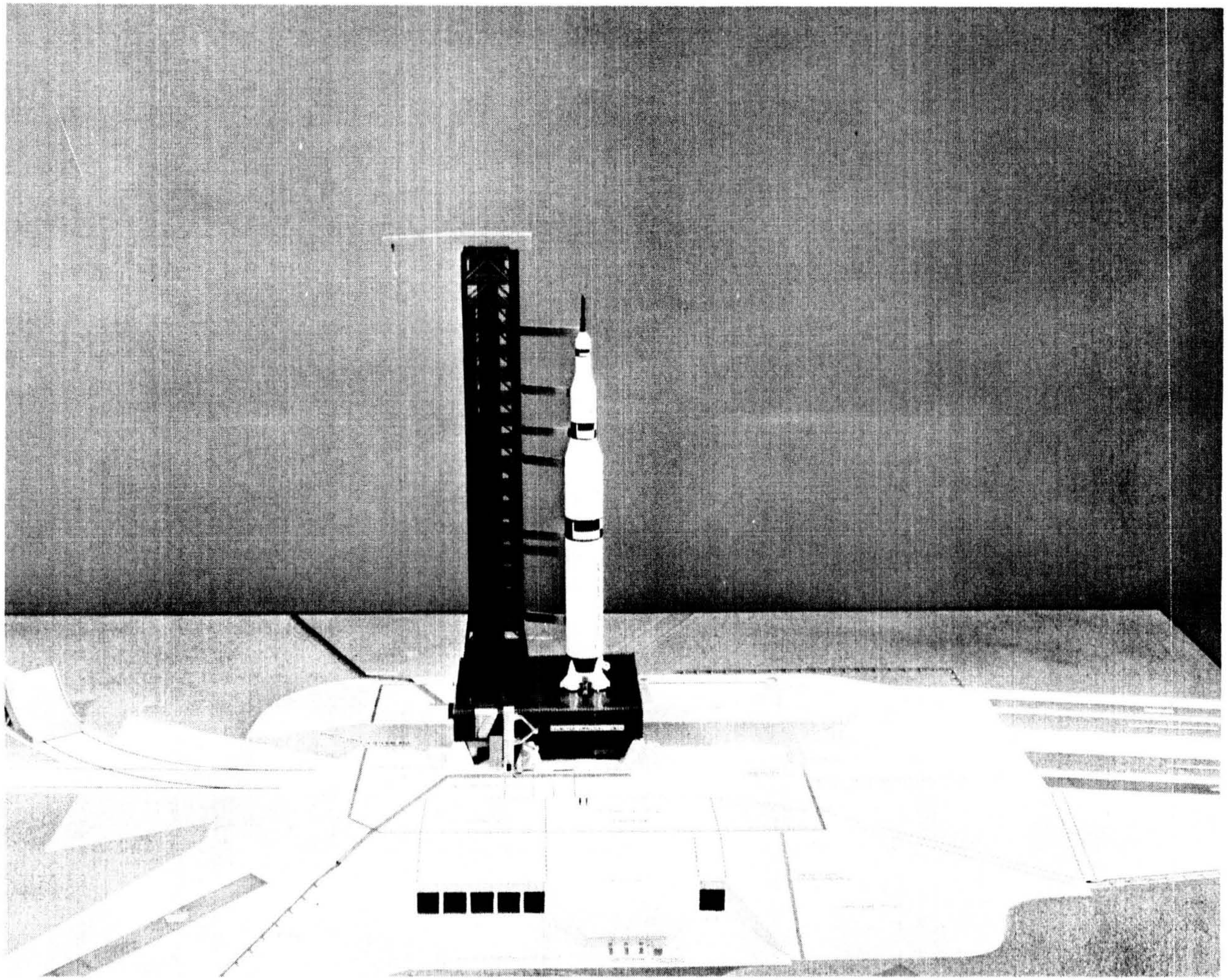

FIGURE 12. LAUNCH READY CONDITION

the VAB.

Spacecraft Transport

Apollo spacecraft modules will be transported to the MILA by air.

The CM, SM, and LEM will be delivered to the Manned Spacecraft Center 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 to the VAB, stage preparation and checkout will be performed. The S-IC stage test sequence on the LUT in the VAB will require approximately eight weeks. The S-II and S-IVB stage checkout in the Low Bay Area will require approximately four weeks prior to assembly on the checked-out S-IC stage. Apollo spacecraft preparation and checkout will require approximately 14 weeks, including spacecraft static tests which will be conducted at MILA. Upon completion of these tests, the spacecraft will be ready for assembly to the Saturn V launch vehicle.

S-IC Stage

Since many of the tests conducted for verification of the readiness of the S-II and S-IVB stages are similar to those used in S-IC stage preparation, a complete sequential operational plan will be presented here on the S-IC stage only. While the sequence of tests is presented in the order of intended application, it should be realized that many checks will be performed simultaneously.

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 support/holddown 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.

The 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 1/2 ft. and a surface area of 75 square feet.

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

The 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 the 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.

The IU, previously assembled in the Low Bay Area, will then be positioned on a special platform, above the S-IC stage, at approximately the 314' level. This will allow the IU to be cabled directly to the LUT GSE, through the same umbilical arm utilized for launch. This connection makes the IU accessible to the LCC via the same high speed data link used by the S-IC stage. The S-IC and IU will be electrically coupled through S-II and S-IVB stage simulators for interface checks. The stage simulators, as well as other special test equipment, will be located in test station rooms at various elevations in the high bay towers.

After completion of subsystems testing, an all-systems test will be performed on the S-IC stage and IU with S-II and S-IVB stage simulators connected. This completes the checkout of the S-IC as a stage.

S-II Stage

Upon its arrival in the Low Bay Area of the VAB, the S-II stage will be positioned vertically in a test cell for a checkout prior to mating with the S-IC stage.

The electrical GSE used to checkout the S-II stage in this area is essentially the same type equipment used in stage checkout at the factory and static test stand.

The electrical GSE for stage checkout is located in a control room adjacent to the stage checkout cell, and like the LCC checkout equipment is capable of fully automatic operation.

After the completion of the test program, the S-II stage will be positioned in the center aisle for mating the stage to the S-IC interstage adapter. After mating, the S-II will be moved to the High Bay Area, and erected on the S-IC stage (Figure 6). Prior to erecting the S-II stage, the IU will be temporarily disconnected from the umbilical and repositioned on the platform to allow the S-II and S-IVB assembly operation.

S-IVB Stage

Similar checkout operations for the S-IVB will be conducted in the Low Bay Area, followed by assembly atop the S-II stage in the High Bay Area.

Instrument Unit

After the S-IVB has been mated to the S-II stage, the IU will be assembled to the S-IVB.

Saturn V Launch Vehicle

The ordnance items to be installed on the launch vehicle in the VAB will be determined by safety considerations in the VAB and by restrictions due to limited accessibility at the pad.

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

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 individually and as part of the Apollo spacecraft system.

Saturn V/Apollo

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.

Upon assembly of the Saturn V/Apollo space vehicle, alignment of the complete space vehicle will be accomplished through adjustment of the support holddown arms.

A number of interface and compatibility checks will be required prior to a combined spacecraft-launch vehicle systems test. Tests in this category would be Electrical Ground Support Equipment (EGSE) interface, airborne interface, abort and emergency detection systems, RF systems and computer interface.

A combined spacecraft and launch vehicle systems test would include:

(1) Umbilical eject and retract
(2) Fire live ordnance in test chambers
(3) Internal power on batteries (flight type)
(4) Electrical disconnect of stages during sequence run
(5) All flight systems possible active

The final step in the test program before preparing the vehicle for movement tothe launch pad will be a Simulated Flight Test. This test includes all systems and essentially should approximate the countdown and simulated normal flight functions.

When the complete space vehicle is verified as in a ready condition, final preparations will be made for transporting the vehicle from the VAB to the launch 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 jack it up approximately three feet so that it will clear the VAB support pedestals. Then, the Crawler-Transporter will move out of the VAB, over the crawler-way, to the launch pad.

Arriving at the launch pad, the Crawler-Transporter will move the LUT into position and lower the LUT on to the steel pedestals The LUT will be locked to these pedestals. Then, the Crawler-Transporter will move the Arming Tower into position alongside the space vehicle, where it will provide 360 degree access to the vehicle for ordnance installation and servicing.

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; the vehicle vertically aligned and ordnance installed. Ordnance installation will be accomplished concurrently with other pad preparations. This ordnance consists of that which could not be installed in the VAB due to safety considerations.

Launch Pad Program

The launch pad program will consist of the following:
(1) Limited sub-systems verification checks from LCC
(2) Checkout of hardwire backup circuits to LCC
(3) Tank pressurization test (Flight pressure)
(4) Propellant loading tests
(5) RF systems tests
(6) Abort system test
(7) Simulated flight test

The simulated flight test involves a complete launch day simulated countdown, launch, and flight operations. Compatibility with all range and the Integrated Mission Control Center (IMCC) is verified at this time.

The Integrated Mission Control Center

The IMCC, located at MSC in Houston, will execute overall mission control, whereas the LCC at Launch Complex 39 will be responsible for flight readiness of the space vehicle and the launch. The IMCC will be the focal point for coordinating a Ground Operational Support System (GOSS); a worldwide network of ground stations for tracking, ground communications and command, and telemetry. The LCC must operate in conjunction with the IMCC in order to assure that the GOSS is in flight ready condition at launch time.

Launch Countdown

Upon the completion of the Simulated Flight Test, the space vehicle is ready to enter the countdown phase of launch operations.

The ordnance will be connected.

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, the hypergolics for the S-IVB reaction control system will be loaded.

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 is initiated next and will require 30 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 to launch.

Astronaut Embarkation

At approximately T-4 hours, after propellants are loaded, the astronauts will enter the spacecraft from the umbilical tower over the swing arm walkway. The 135 minutes required for that operation will bring the time to approximately T-105 minutes.

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.

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 15,000 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 17,500 miles per hour.

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.

After injection of the third stage and Apollo spacecraft into a parking orbit, the IMCC must compute the trajectory and establish the point and time of departure from parking orbit into the translunar trajectory.

At the pre-calculated point and time, the S-IVB engine is again ignited to provide an orbital plane adjustment and to accelerate the spacecraft for injection into a translunar trajectory, with a velocity of 25,600 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.

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 mankind strives for these new goals, the effort required to meet these challenges can only result in an improvement of our abilities to meet the increasing needs of future generations.