TRW

APOLLO 11

TRW


TRW
SYSTEMS GROUP

APOLLO 11

TRW NEWS

TRW INC. · ONE SPACE PARK · REDONDO BEACH, CALIFORNIA 90278 · TELEPHONE 213/679-8711

CONTACT: (Cape) Tom Branigan, Bob Lander,
Mike Steinman (305) 783-9441
(Houston) Ben Gillespie, Bob Lander,
Hank Litten (713) 591-3133, ext. 2611
or JIPC (713) 488-5472
(Los Angeles) Hank Litten, Mike Steinman
(213) 679-8711, ext. 65647

FOR RELEASE: July 1, 1969

ONCE UPON A TIME THERE WAS THIS MILKWAGON
THAT THOUGHT IT WAS A LUNAR MODULE ......

HOUSTON, Texas -- Somewhere at the Manned Spacecraft Center there is a group of NASA test engineers sure to win an "excellent" on their cost effectiveness rating for using an old walk-in panel truck as a substitute for a new lunar module.

The requirement was for a dynamic platform -- that's something moveable -- for the testing of the Lunar Module's Abort Guidance System (AGS). (The AGS is the backup guidance system which permits the LM astronauts to take over control of the vehicle, abort the mission, and rendezvous with the Command Service Module. Only, of course, if the primary guidance system should develop a malfunction.)

AGS was designed and built by TRW's Systems Group for Grumman Aircraft Engineering Corporation, Lunar Module prime contractor.

Naturally the ultimate test is in space, but for the AGS then it was a case of riding before it flew. And AGS needed a vehicle which could house several racks of test equipment, although it occupies 3 cubic feet in the real lunar module.

Test engineers combed the NASA motor pool for an answer. The milk-wagon-like walk-in van fulfilled the specifications except that it couldn't fly. But it could walk forward and backwards, right and left, and that was sufficient for the tests required.

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TRW, which designed and built the AGS for the Apollo program, helped even further by supplying a refurbished quality test model of the AGS for the low budget test program and the software.

Numerous tests were conducted, and computer programming and targeting were checked out on Houston's streets before similar programs were designed for the lunar landing.

Thus was born what NASA acronamed the MISER program for Mobile Inertial Sensor Evaluation Rogatory.

Rogatory? Look that one up in your Funk and Wagnalls. It means information seeking. And that MISER did on a bare bones budget.

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(Cape) Tom Branigan, Bob Lander, Mike Steinman - (305) 783-9441
(Houston) Ben Gillespie, Hank Litten, Tom Branigan, Bob Lander - (713) 591-3133, ext. 2611, or JIPC (713) 488-5472

FOR RELEASE: July 1, 1969

LUNAR LANDING ALREADY ACCOMPLISHED
--VIA COMPLEX COMPUTER SIMULATIONS

HOUSTON, Texas -- Apollo already has landed on the Moon--at least in computer simulations.

It has been there hundreds of times via "Flights" on high-speed computers conducted and developed in cooperation with the NASA Manned Spacecraft Center by TRW Inc., at the Redondo Beach, California, headquarters and Houston Operations of TRW's Systems Group.

One of its major tasks for the Apollo program has been assisting NASA in the design and development of spacecraft trajectories, simulating and evaluating these trajectories to come up with the best route to the lunar surface and back within the many limitations imposed by launch windows, launch vehicle, spacecraft, communications, and tracking systems capabilities.

One computer simulation TRW developed for the Apollo program incorporates mathematical models of all the subsystems of the Apollo spacecraft, together with elements to compute their significant interactions (such as when the fuel cells generate power they also produce water which goes into the water management system).

The functioning of spacecraft's environmental control system, for example, is affected by the position of the sun relative to the spacecraft radiators; this means that the program must provide the attitude of the spacecraft in relation to the sun and, from that, the solar heat changes on the radiators are computed. Communications capabilities for the several communication links with earth are also calculated at each point in time.

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The purpose of this TRW program is primarily to monitor the state of critical values and operations during the mission. These include fuel and oxygen remaining in the tanks, cabin and suit temperature, electrical power available, and others, in addition to the communication requirements mentioned earlier.

By running the program through an Apollo lunar landing mission, it is possible to determine whether the spacecraft and its subsystems are, in fact, capable of performing the mission without exceeding allowable limits or running out of some consumables, such as oxygen, electrical power or propellants.

The advantage of such a simulation is that many different kinds of missions can be evaluated, including off-nominal and abort cases. The program can also be used in designing missions that will stay within prescribed limits, or even in analyzing spacecraft and subsystem design to determine if some relatively small change might extend significantly the mission capabilities of the spacecraft.

Because of the size and complexity of this computer program, a single Apollo mission simulation may require upwards of 20 minutes on a computer performing half a million operations per second. (Thus, one simulation may require 600 million computer operations.)

Even at that rate, however, it is a very inexpensive way to check on whether or not a given mission can be performed successfully.

The other way to check would be to launch the spacecraft and see what happened.

TRW is one of the nation's pioneers in space flight, having been the first industrial company to build a spacecraft and a contributor to nine out of every 10 U. S. space launches.

TRW's Mission Trajectory Control Program has aided the engineers, scientists and Astronauts at NASA's Manned Spacecraft Center in the Mercury, Gemini and Apollo programs.

TRW NEWS **APOLLO II**

TRW INC. · ONE SPACE PARK · REDONDO BEACH, CALIFORNIA 90278 · TELEPHONE 213/679-8711

CONTACT: (Los Angeles) Mike Mathews
(213) 679-8711 Ext. 65647
(Cocoa Beach) Mike Steinman
(305) 783-9441
(Houston) Bob Lander
(713) 591-3133, Ext. 2611 or
JIPC (713) 488-5472

FOR RELEASE: Immediate

FIRST MOON LANDING REQUIRES

SOLAR FLARE WARNINGS

CAPE KENNEDY, Fla. -- The first manned lunar landing will take place at the time when the possibility of encountering dangerous radiation from the sun is at its highest.

The sun is at the peak of its eleven year cycle of activity. Larger and more frequent solar flares streak across the universe. Some of these are powerful enough to harm an astronaut on the moon or in the Lunar Module.

Monitoring the sun for advance signs of these dangerous eruptions are four sun-orbiting Pioneer spacecraft and ten earth-orbiting Vela nuclear test detection satellites, all built by TRW Inc. in Redondo Beach, Calif.

Information about the sun from the Pioneers and Velas is transmitted to the Environmental Sciences Services Administration (ESSA) forecast center in Boulder, Colo. It is correlated with information received from earth-based observatories.

From this data, ESSA is able to provide sufficient warnings of major solar eruptions to delay a launch or alter an orbit if necessary.

"While it is quite improbable that a dangerous solar flare would occur during any given Apollo mission," according to Dr. A. K. (Dolf) Thiel, vice president and general manager of TRW's Space Vehicles Division, "it is a definite possibility. The ESSA predictions, aided by Pioneer and Vela, are keeping NASA alerted for action if such a flare occurs."

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Pioneer is a program of NASA's Ames Research Center, Mountain Vies, Calif. Vela is a program of the Advanced Research Projects Agency and is managed by the USAF Space and Missile Systems Organization, El Segundo, Calif.

The first attempt to reach a moon was by a Pioneer spacecraft. TRW's Pioneer I, the first spacecraft built by an industrial contractor and NASA's first spacecraft, was launched on October 11, 1958. It reached an altitude of 70,717 miles, 29 times as far as any previous spacecraft had traveled from the earth.

TRW Inc. has more than 75,000 people at over 250 locations around the world applying advanced technology to electronics, space, defense, aircraft, automotive, and related industrial and commercial markets.

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FOR RELEASE: July 1, 1969

APOLLO IS A FAMILY AFFAIR
FOR YOUNG TRW COUPLE

HOUSTON, Texas -- For the Leon M. Vick, Jr., family, going to the Moon is really a family affair.

Leon, a 31-year-old engineer, and his wife, Mary, a mathematician, are both members of the professional staff at the Houston Operations of TRW's Systems Group and both are deeply involved in NASA's program to land U.S. astronauts on the Moon.

Leon is a member of the TRW team which assists the Flight Crew Support Division at the NASA Manned Spacecraft Center in preparing flight plans for Apollo missions, while Mary has the task of positioning the tracking ships to cover reentry into the earth's atmosphere and the splashdown.

Mary, in fact, was once thought by U. S. Navy representatives to be a computer.

Often when the Navy came to NASA with a question concerning tracking ship placement or movement, NASA officials would reply, "Let us check it with Mary." Thus the Navy men assumed "Mary" was an acronym for a computer or computer program.

One day, Mary walked into a NASA-Navy meeting and the naval officers were most pleasantly surprised to learn Mary was really a very attractive brunette, who has been described as looking "more like a chorus girl than a mathematician."

Mary's introduction to the space program came in April of 1968 when she and Leon joined the TRW staff in Houston. At that time, she made the seemingly improbable transition from cows to spaceflight. Prior to joining TRW she headed the Data Processing Department of the Texas and Southwestern Cattle Raisers Association in Ft. Worth, Texas.

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A native of Sylacauga, Alabama, Mary received her degree in mathematics -- along with a host of academic honors -- from Birmingham-Southern College in 1966.

While Mary's job requires coordination with Mission Planning and Analysis Division officials at the Manned Spacecraft Center and with Navy representatives, Leon's responsibilities in flight planning bring him into contact with the astronaut crews themselves.

"We must review everything with the crew," he points out, "and integrate the various activities into a timeline--or schedule--that is workable and will allow the achievement of mission objectives."

The team--usually composed of two TRW engineers and two or more NASA planners--also sits in on mission simulations to monitor how well the flight plan can be followed by the crew.

Leon is the space "veteran" of the family, having become associated with the program following graduation from the University of Alabama in 1963.

During missions Leon works in the Flight Director's Staff Support Room in the Mission Control Center, monitoring the progress of the flight and assisting in rescheduling crew activities, should such be required.

So, while Leon is at work in flight planning, Mary is determining the best positioning and movement of tracking ships in the South Pacific. Ship positioning is not as simple as it may first appear. Because NASA's requirements call for tracking, telemetry and communications between the spacecraft and Mission Control from two minutes prior to the translunar injection maneuver--or launch out of earth orbit toward the Moon--to the completion of the maneuver.

Because the ships' tracking capability extends only so far, and the ground track of the spacecraft changes with the passage of time, position of the ships to obtain maximum coverage during a specified time period must be determined.

A launch delay of a day or more would, also, change the ground track even more and require movement of the ships.

Considering rate of change of the spacecraft ground track, the speed at which the ships can move, islands, reefs, atolls, and--in some instances--relatively uncharted waters, the complexity of the task becomes apparent.

Surprisingly, perhaps, Mary and Leon find that the periods during missions are not their busiest. The largest part of their work has been completed by the time the spacecraft leaves the launch pad.

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"Pre-mission periods are the most hectic," Leon observes. Changes are made frequently to trajectories, procedures and other elements of the flight, sometimes up until 24 hours before launch.

Mary and Leon are parents of a two-year-old daughter, Lara Ann, and live in nearby Clear Lake City, a few minutes from their TRW offices and the adjacent Manned Spacecraft Center.

Boating and tennis are favorite recreations, and both are active in the Clear Lake Civic League. Mary has also served as a block chairman for her political party.

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(Houston) Ben Gillespie, Hank Litten 713-591-3133 ext. 2611
or JIPC 713-488-5472
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FOR RELEASE: July 1, 1969

BACKGROUNDER: TRW'S LUNAR MODULE DESCENT ENGINE

Project History

The history of the Apollo spacecraft's Lunar Module Descent Engine (LMDE) can be traced to a handful of engineers who, in 1960, initiated research at TRW Inc. on a stable, throttleable rocket engine for varied space applications.

In the next two years their efforts resulted in the demonstration of a 500-pound-thrust engine. Successful tests of this engine attracted the interest of NASA and Grumman Aerospace Corp., the Lunar Module prime contractor. In July 1963, TRW's Systems Group was awarded a preliminary development contract by Grumman. In January 1965, TRW was declared the winner of an intense 18-month competition with a parallel subcontractor and was awarded the contract to build 15 LMDE flight model engines.

On August 11, 1967--49 months after the initiation of TRW's development program, an unusually short time for the development of a new rocket engine to perform such a complex task--the LMDE completed its qualification testing.

The LMDE was first tested in orbit on Apollo 5 in January 1968. After being prematurely shut down during its initial ignition due to an error in the guidance computer programming, the engine was successfully fired two additional times--for 33 and 28 seconds. LMDE performance on Apollo 5 was rated normal and the engine subsequently was given a "man-rated" designation.

The Apollo 9 mission in March 1969 included the second orbital test of the LMDE. On Apollo 9's third day in orbit the descent engine was fired for 370 seconds--the first manual throttling of a rocket engine in space, as astronaut

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Jim Mc Divitt varied the engine's thrust between 40 to 10% for the last 56 seconds of the burn. This firing, conducted with the LM and CSM docked, simulated both the use of the LMDE to return the Apollo spacecraft to earth (in the event of a SPS malfunction) and the Apollo 11 lunar landing throttling profile. The LMDE's second and third burns, for 21 seconds each, were phasing and insertion burns during the LM's rendezvous maneuvers. All three burns were executed as planned.

Apollo 10's flight in May 1969 represented the final in-orbit test of LMDE prior to the Apollo 11 lunar landing mission. Apollo 10 was placed in lunar orbit, the LM and CSM separated and the LMDE fired for 27 seconds in a DOI (descent orbit insertion) burn identical to that required on Apollo 11. The burn caused "Snoopy" to drop, 57 minutes later, to a pericythion (low point) of nine miles, some 300 miles east of landing site #2. One hour and 12 minutes later the LMDE was restarted and burned for 40 seconds, to modify the LM's orbit for rendezvous and docking maneuvers. Both burns were normal.

Design of the Descent Engine

The LMDE is a pressure-fed, liquid bipropellant, variable-thrust, gimballing rocket engine employed in the Apollo Lunar Module's descent propulsion system (DPS). The LMDE produces a maximum thrust of about 9,850 pounds and is throttleable down to 1,050 pounds. The propellants are nitrogen tetroxide (N_2O_4) and a 50-50 blend of hydrazine and unsymmetrical dimethyl hydrazine (N_2H_4/UDMH). Ignition is hypergolic. The engine has an ablative combustion chamber and nozzle throat, with a crushable, radiation-cooled nozzle extension. The total dry engine weight is about 383 pounds.

The key to the LMDE design is the single-element coaxial injector that distributes propellants into the combustion chamber. The LMDE injector meets the stringent Apollo requirement to insure a soft landing: throttling range of 10:1, high combustion efficiency, dynamic stability, and high reliability.

Other major elements of TRW's design include dual flow control valves and an ablative combustion chamber. The LMDE utilizes variable-area, cavitating venturi flow control valves. In operation, the flow control valves isolate the propellant feed system from the combustion chamber, accurately maintaining propellant delivery regardless of chamber pressure fluctuations or changes in injector or manifold pressures. The titanium-encased ablative combustion chamber is designed for an operating lifetime of 1,000 seconds. The chamber is surrounded by a heat shield to keep external temperatures within the LM below 400°F. A crushable, radiation-cooled, columbium nozzle skirt extends below the chamber to provide complete flow expansion with minimal additional weight. The combustion chamber is mounted in a lightweight box-beam gimbal assembly which can be swivelled ± 6° in two planes to provide directional control.

Descent Engine Test Program

Testing the LMDE is an extensive task. As of July 1969, the test record showed:

Injector test firings	1862
Head end assembly test firings	1346
Ablative engine test firings	573
Total ground test firings	3781
Total ground test firing time	207,213
Total in-orbit test firings	8
Total in-orbit test firing time	544

The engine to be employed on Apollo 11 (serial number 1043) has been test fired for 147 seconds at TRW's Capistrano Test Site near San Juan Capistrano, Calif.

Descent Engine Program Management at TRW

Robert Bromberg, V.P. and General Manager, Science & Technology Div. (STD)
Arthur F. Grant, Jr., Assistant General Manager, STD
Gerard W. Elverum, Jr., Manager-Energy Systems Operations, STD
Robert C. Anderson, Manager - Project Operations, STD
Robert L. Larson, Manager - LMDE Project Office, STD

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Descent Engine Fact Sheet

Engine specs:	Thrusts: 9,850 to 1,050 lbs
	Oxidizer/fuel ratio: 1.6 to 1
	Flow rate: oxidizer - 20 lbs/sec, fuel - 12.5 lbs/sec (max.)
	Chamber pressure: 104 psi (max.)
	Expansion area ratio: 47 to 1
	Restart capability: 20 times
	Engine life: 1,000 seconds
	Gimbal: $\pm$ 6 degrees, x and y axes
	Weight: 383 pounds
Dimensions:	Overall length: 90.5 inches
	Skirt diameter (at base): 59 inches
Materials:	Thrust chamber shell: titanium
	Thrust chamber ablator: silica phenolic
	Thermal blanket: stainless steel foil & glass wool
	Nozzle extension: columbium alloy
	Gimbal assembly: aluminum alloy
	Gimbal bearings: Fabroid
Contractor:	TRW Systems Group (under subcontract to Grumman)
Major subcontractors:	Bendix Corp. (throttle actuator)
	Ryan Aeronautical Co. (combustion chamber case)
	TRW Equipment Group (combustion chamber liner)
	Transport Dynamics (gimbal bearings)
	Whittaker Corp. (bipropellant shutoff valve)

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FOR RELEASE: July 1, 1969

DOWN TO THE SEA IN LM --
COURTESY TRW'S DESCENT ENGINE

REDONDO BEACH, Calif. -- Only 10 untried miles now separate man from the moon.

With Apollo 10 successfully behind us, the U.S. will bridge that final gap on July 20 with the soft landing of NASA astronauts Neil Armstrong and Edwin Aldrin in the lunar Sea of Tranquility.

To do so, NASA and the Apollo 11 crew will depend on a rocket engine designed to throttle--like an automobile engine--so that the LM can cover those last 10 miles slowly, safely and successfully.

This unique rocket engine was built by TRW Inc. for the LM prime contractor, Grumman Aerospace Corp. It has been designed and fabricated at TRW's Systems Group in Redondo Beach, California.

Its Role on Apollo 11

The LM descent engine will be fired twice during Apollo 11. First, as on Apollo 10, to bring the LM from its 69 statute mile orbit down to an altitude of 50,000 feet, 300 miles east of the landing site.

Then the descent engine will be put through the longest and most complex firing in space for a U.S. rocket engine. The 12-minute firing will brake the LM's fall toward the moon, will permit the crew to hover above their landing site if necessary and will finally lower the LM onto the moon at 2 mph (vs. Apollo 11's top speed of almost 25,000 mph achieved in leaving earth orbit enroute to the moon).

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Its Background

Work on the LM descent engine began nine years ago at TRW. By 1962, a small group of engineers had demonstrated a 5000-pound-thrust throttleable engine, and the following year Grumman awarded TRW a preliminary development contract for the LM descent engine. In January 1965, the company was awarded the contract to build 15 flight model engines.

It's Throttleable

The LM descent engine is the first large throttleable rocket engine in the U.S. space program. Its thrust can be varied--automatically by the LM primary guidance system or manually by either member of the LM crew.

Maximum thrust of the engine is 9,850 pounds. It can be throttled down to as low as 1,050 pounds for the delicate task of lunar soft landing.

It's Durable

The LM descent engine can be fired in space for up to 1,000 seconds. On Apollo 11, it is expected to be fired for 28 seconds on its first or "DOI" (descent orbit insertion) burn and for more than 700 seconds on its second or "powered descent" burn. This is longer than any other large U.S. rocket engine.

To provide this long-duration burn capability, more than one-half of the LM's total weight is in propellants for the descent engine--about 18,180 pounds out of a LM total of 33,742 pounds.

The engine itself weighs only 383 pounds (13 pounds under the design specifications--a feat that earned TRW an $162,000 incentive bonus).

It's Crushable

The LM descent engine also features the first crushable nozzle extension or "skirt." The skirt, intended to improve the engine's efficiency by providing more complete flow expansion of exhaust gases, extends below the bottom of the LM to within 18 inches of the landing pads.

Should the skirt strike a rock or small boulder during the LM's landing, it must crush up to a maximum of 28 inches to avoid tipping over the LM. To accomplish this, TRW engineers selected a columbium alloy for the skirt that will both crush and withstand the temperatures predicted--2,400°F at the top of the skirt.

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<u>It's Ready</u>

The descent engine has been test fired almost 4,000 times on the ground (at TRW's propulsion test site near President Nixon's summer residence at San Clemente, Calif.) and eight times in space--thrice on Apollo's 5 and 9 and twice on Apollo 10.

This unique engine is now ready to carry out its intended function--to land man on the moon.

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FOR RELEASE: July 11, 1969

BACKGROUNDER: HOW MAN WILL LAND ON THE MOON

Apollo 11 Spacecraft Commander Neil Armstrong and LM Pilot Edwin Aldrin will begin their historic descent to the lunar surface with a 28-second "descent orbit insertion (DOI)" burn of their TRW-built LM descent engine.

After a coast period of 57 minutes, the LM will reach an altitude of 50,000 feet and the descent engine will be restarted for "powered descent" lasting about 12 minutes--until the LM is settling onto the lunar Sea of Tranquility.

The powered descent burn will be the longest and most complex firing of a U.S. rocket engine in space.

The Lunar Module descent engine is built by TRW's Systems Group in Redondo Beach, California for the LM prime contractor, Grumman Aerospace Corp.

The unique engine is the first large throttleable rocket engine in the U.S. space program. Its thrust can be varied in direction and magnitude--from 9,850 pounds down to 1,050 pounds--automatically by the LM's guidance system or manually by either member of the LM crew.

Descent Orbit Insertion (DOI)

Apollo 11's initial burn essentially will duplicate Apollo 10's DOI burn. The descent engine will be fired for 15 seconds at 10% thrust (1,050 pounds), then the crew will throttle up to 40% thrust (4,200 pounds) for about 13 seconds. When the LM has been slowed 47 mph (70 fps ΔV), to a speed of 3,600 mph, the engine's firing will be terminated by the primary guidance & navigation system (PGNS).

As on Apollo 10, the DOI burn will take place behind the moon. About 40 minutes later, as the LM and its crew are "falling" toward the moon, communications will be re-established and a good burn confirmed.

Powered Descent: Braking Phase

When the LM reaches the pericynthion (low point) in its orbit of about 50,000

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feet, 300 statute miles east of landing site #2, the descent engine will be restarted to begin powered descent.

This final descent is divided into three phases: braking, approach and landing. The braking phase is designed for efficient reduction of the LM's orbital velocity, the approach phase is intended to permit the crew to visibly assess their landing site and the landing phase will permit manual control for lunar touchdown.

The braking phase will begin at the 10% thrust level for 26 seconds, then automatically will throttle to full thrust (9, 850 pounds) for about 358 seconds, and finally will be throttled in the range of 55% thrust (5, 775 pounds) to 59% thrust (6, 150 pounds) for two minutes. This portion of the burn is intended to place the LM on a trajectory that passes through a "high gate" target--an altitude of 7, 500 feet where the vehicle should be traveling about 340 mph.

The LM will be in a windows-down attitude until it reaches an altitude of 45, 000 feet, when it will be rotated 180^{o} to a windows-up attitude so that the landing radar can be used beginning at an altitude of about 40, 000 feet. The LM will be in PGNS control throughout the braking phase.

Powered Descent: Approach Phase

The approach phase begins "high gate," when the guidance system switches to its "low gate" target--an altitude of 500 feet where the LM should be slowed to a speed of about 40 mph. The landing site will come into view for the crew during the approach phase, at about 8 1/2 minutes into the powered descent.

During the approach phase the engine will be throttled in the range of 59% thrust to 26% thrust (2, 725 pounds).

The crew can assume manual control of their attitude and/or semi-manual or manual throttling of their descent engine, or can let the PGNS continue to control the descent during this phase.

Attitude control is maintained by gimballing the descent engine and/or by firing the reaction control system (RCS) engines. In the semi-manual throttling mode, the crew can select their rate of descent and have it carried out by the guidance system. In the manual throttling mode, the rate of descent is directly controlled by the crew, using a hand control.

The approach phase will be completed when the LM reaches its "low gate."

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Powered Descent: Landing Phase

The crew probably will have assumed semi-manual throttling by the time they reach "low gate," and will be steadily throttling back as they near the moon.

If they want to take one last good look at their landing site, they can hover for up to about two minutes (a longer hover period could cause them to run out of propellants). Here they can select their precise landing site and can make final adjustments, translating horizontally if necessary with their RCS engines.

From an altitude of 150 feet on, their descent will be straight down. Final descent will be at 3 fps (2.0 mph), with about 25% thrust (2,625 pounds) throttle setting. The LM's landing probes will make contact with the surface at an altitude of 5 feet, turning on a warning light in the cabin.

Astronaut Armstrong will shut off the descent engine as Apollo 11's LM is settling onto the surface of the moon.

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BACKGROUND INFORMATION APOLLO 11

LUNAR MODULE ABORT GUIDANCE SYSTEM (AGS)

The LM AGS (called ags, rhymes with tags, by the astronauts) was named for its ability to allow astronauts to take over control of the LM vehicle safely, to abort the mission, and rendezvous with the CSM orbiting above them. The astronauts do not plan to use the abort guidance capability of AGS unless a malfunction develops in the primary guidance system (PGNCS). Under normal circumstances, the AGS functions in an "open-loop" fashion, navigating in parallel with the LM primary guidance system and supplying the astronauts with an independent source of position, velocity, attitude, and steering information which they can compare with the primary system to help evaluate its performance. At any point in the normal descent to the lunar surface, on the lunar surface, or ascent and rendezvous with the CSM, the AGS is immediately available to take over control to effect a safe return to the CSM.

The AGS, developed and produced by TRW's Systems Group under subcontract to Grumman Aircraft Engineering Corporation (GAEC), consists of three assemblies: Abort Electronics Assembly (AEA) -- the guidance computer; Abort Sensor Assembly (ASA) -- the inertial sensor package; and the Data Entry and Display Assembly (DEDA, pronounced deeda) -- a keyboard device for astronaut interface with the guidance computer. The ASA is provided by Hamilton Standard Systems Center (HSSC) under subcontract to TRW.

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The key functions performed by the AGS are as follows:

* Maintains attitude reference
* Performs navigation (LM and CSMO)
* Solves explicit guidance problems
* Drives attitude and navigation displays
* Provides steering and engine commands
* Provides for navigation updating using the on-board radar
* Provides automatic alignment and sensor calibration

The AGS is the first complete strapdown guidance system to be employed in space and the first such system to be used in a manned space program. In this system, additional mathematical computations are substituted for considerable electromechanical gear (gimbals, torque motors, slip rings, etc.) found in conventional inertial guidance systems. This technique results in a smaller, lighter, and more reliable unit than the typical gimbaled systems.

Guidance equations and software for the AGS are provided by TRW's Systems Group under a contract to NASA/MSC.

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FOR RELEASE:
July 1, 1969

TRW'S ELECTRONIC "GOLD" BOXES
HELP ASSURE SAFE LUNAR VOYAGE

HOUSTON, Texas--Two gleaming gold-plated boxes and a grey and black panel assembly house the backup guidance system that will help assure a safe voyage by the Apollo 11 astronauts to and from the moon's surface in the lunar module.

The gold-plated boxes and panel assembly physically represent the vital components of the Lunar Module Abort Guidance System or AGS (rhymes with tags) as it is called by NASA's astronauts. Built for Grumman Aircraft Engineering Corp., LM prime contractor, by TRW's Systems Group, the AGS is named for its ability to allow astronauts to safely take over control of the LM vehicle in the event the mission is aborted, and rendezvous with the Command Service Module orbiting above them.

Should trouble develop in the Primary Guidance Navigation Control Systems (PGNCS) of the LM, the astronauts may take over control with AGS at any point in the normal descent to the moon's surface, on the surface, or during ascent and rendezvous with the CSM with the AGS.

During the periods of communications blackouts when the LM is behind the moon, the AGS takes on an additionally important role because the astronauts must depend on the system for verification of navigational data. This is normally done with Mission Control Center here with AGS serving as an auxiliary source.

The AGS was first tested successfully in space during the Apollo 9 mission and then in lunar orbit during the Apollo 10 mission. The system was "exercised" by putting it through a number of operations such as controlling staging, descent and ascent engine firing, and other navigational maneuvers.

-more-

Astronaut control with the AGS is achieved by actuating switches located on the main control panel which technically are not part of the AGS itself.

Tucked strategically into the LM are the gold boxes and the grey control panel of the AGS. One gold box, measuring 5 inches by 8 inches by 23.75 inches, "the brain" of the AGS, is a digital computer with 4096 word memory located in the aft equipment bay of the lunar module. Technically its the Abort Electronics Assembly (AEA).

The other gold box, the Abort Sensor Assembly, is the "nerve" center of the AGS and contains the motion detection devices -- the gyroscopes and accelerometers -- for sensing the attitude and velocity of the LM. Weighing 20.7 pounds this assembly is 9 inches by 13.5 inches by 9 inches and is mounted on the LM navigation base. The ASA was designed and built for TRW by Hamilton Standard Systems Center of United Aircraft Corporation.

Gold plating serves to control thermal radiation and to provide the ultimate anti-corrosion protection afforded by a noble metal.

Astronauts can put data into the computer and read it out on the grey panel with the pushbuttons and luminescent numbers. This panel is 5.5 inches by 6 inches by 5.19 inches and is located on the right side of the LM control panel at waist level. Because it contains additional electronics besides lights and pushbuttons, this Data Entry and Display Assembly (DEDA) tips the scales at 8.4 pounds.

Under normal circumstances the AGS operates in parallel with the PGNCS. It supplies the astronauts with an independent source of position, velocity, attitude and steering information which they compare with the primary system to evaluate performance.

Astronauts may call up data from the AGS by operating the DEDA, or may enter data into the AGS via the same grey-panelled set of pushbuttons and lights.

TRW NEWS APOLLO 11

TRW INC. · ONE SPACE PARK · REDONDO BEACH, CALIFORNIA 90278 · TELEPHONE 213/679-8711

CONTACT: (Los Angeles) Hank Litten, Mike Steinman, (213) 679-8711, ext. 65647
(Cape) Tom Branigan, Bob Lander, Mike Steinman - (305) 783-9441
(Houston) Ben Gillespie, Hank Litten, Tom Branigan, Bob Lander - (713) 591-3133, ext. 2611, or JIPC (713) 488-5472

FOR RELEASE: July 1, 1969

TRW ROLES IN THE APOLLO PROGRAM

REDONDO BEACH, California -- TRW Inc., the first industrial firm to build a spacecraft and a participant in 9 out of 10 space projects, is performing eight major roles in the Apollo lunar landing program. They are:

LUNAR MODULE DESCENT ENGINE (LMDE)

TRW Systems Group's Science & Technology Division, under subcontract to Grumman Aircraft Engineering Corp., supplies the rocket engine that will soft-land the Lunar Module on the moon. A throttleable, gimballed, liquid bi-propellant engine, LMDE will be varied in thrust from 1,050 to 9,850 pounds during the lunar landing. LMDE, as the key element of the LM's descent propulsion system (DPS), will be fired twice during Apollo 11. The first burn, behind the moon, will initiate LM's descent to a lunar altitude of 10 miles. The second burn will last some 12 minutes and will slowly lower the LM to the lunar surface.

MISSION TRAJECTORY CONTROL PROGRAM (MTCP)

At its Houston Operations adjacent to the NASA Manned Spacecraft Center, TRW's Systems Group is providing major assistance to the MSC Mission Planning and Analysis Division in the areas of trajectory design and analysis, orbital maneuvers, flight control computer program development, range safety analysis, operational software, and mission error analysis.

SPACECRAFT SYSTEMS ANALYSIS PROGRAM (SSAP)

Also at its Houston Operations, TRW is performing analytical and experimental studies, technical fact-finding and evaluation, technical systems analysis, and investigations of spacecraft systems and associated equipment to provide a basis for technical decision-making by NASA MSC personnel.

-more-

LUNAR MODULE ABORT GUIDANCE SYSTEM (LM/AGS)

The LM/AGS, designed and built by the TRW Systems Group's Electronic Systems Division for Grumman, understudies the primary guidance and navigation system (PGNS) and provides a backup should PGNS develop a malfunction. The AGS also provides reference data for comparison with other systems during normal LM operations.

SIGNAL DATA DEMODULATOR SYSTEM (SDDS)

Built by the TRW Systems Group's Electronic Systems Division for Collins Radio Co., the SDDS equipment, which enhances clear voice communications through advanced techniques during the Apollo missions, is installed at 18 worldwide locations and on board Apollo ships as part of the Apollo S-band communications network. The SDDS handles nearly all forms of information from the spacecraft including telemetry data, in addition to voice communications. Should an emergency occur, SDDS will provide communications via a simple telegraph key.

SATURN V THIRD STAGE ATTITUDE CONTROL ENGINES (ACE)

TRW's Equipment Group, under subcontract to McDonnell Douglas Corp., provides six 150-pound-thrust attitude control engines for the Saturn V's S-4B third stage. The rockets, a part of the S-4B auxiliary propulsion system (APS), are mounted in two clusters of three each and may be fired singly or in groups. On the Apollo 11 mission, the engines will maintain roll control during the first J-2 engine burn, provide roll, pitch and yaw control in earth orbit and align the S-4B stage in earth orbit prior to J-2 restart to inject Apollo 11 into translunar trajectory.

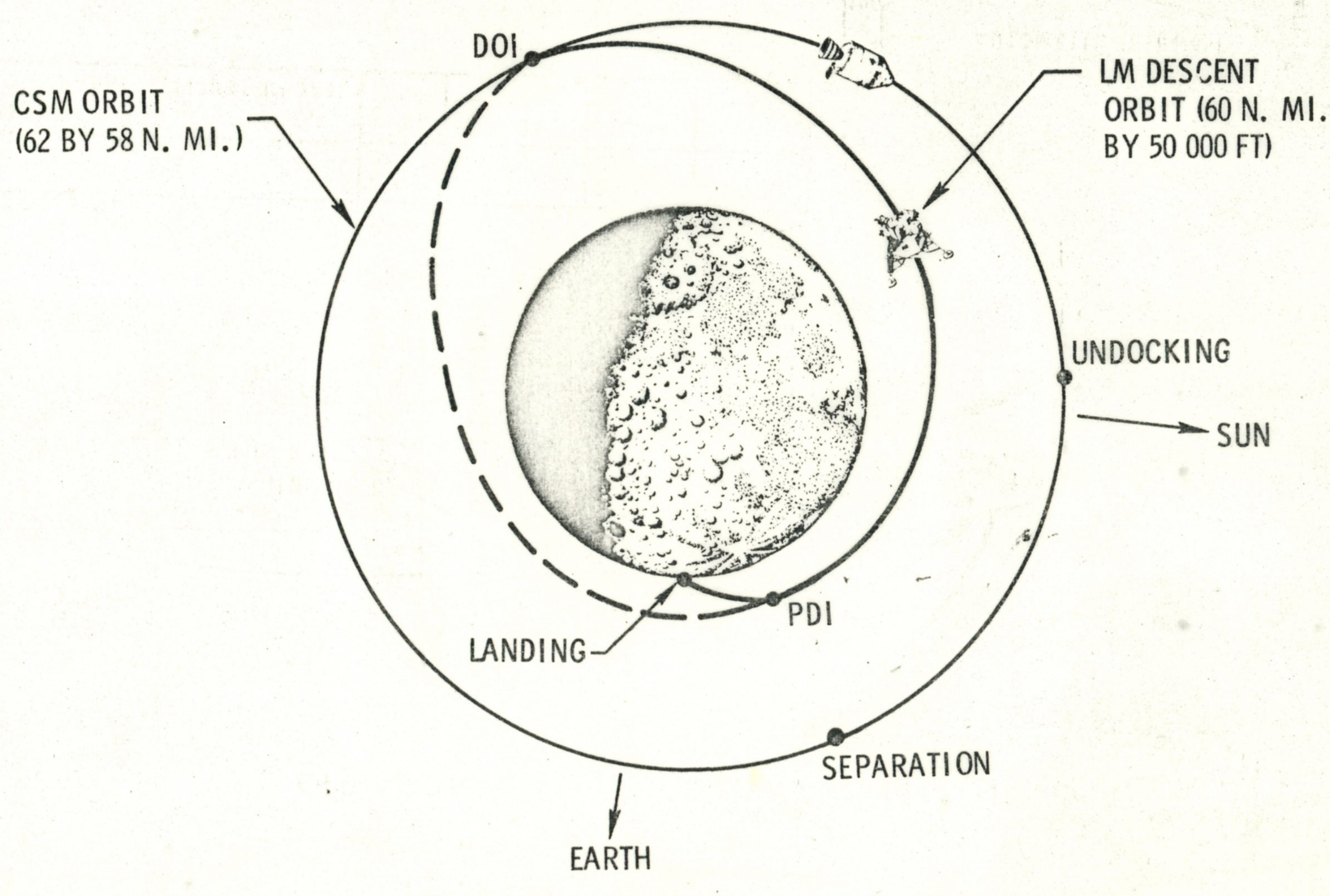
TEST & TRAINING (TETR) SATELLITES

TRW Systems Group's Space Vehicles Division, under contract to NASA's Goddard Space Flight Center, has produced two Test & Training Satellites placed in low earth orbit to check out the Apollo's worldwide Manned Space Flight Network and train the network's operators. The 44-pound octahedral satellites are members of TRW's Environmental Research Satellite (ERS) series. TETR 1 was launched December 13, 1967, and simulated Apollo spacecraft communications during its 4 1/2-month lifetime. The second TETR was orbited November 8, 1968 and has been used to ready the Apollo network for the Apollo 11 mission.

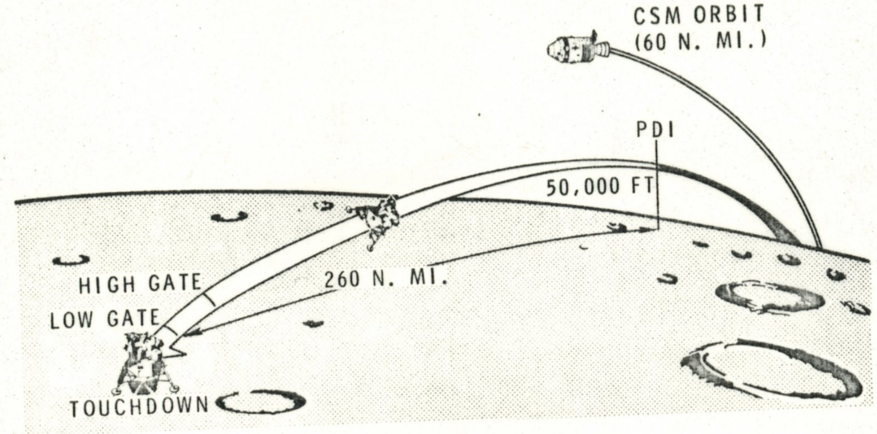
SOLAR FLARE WARNING (PIONEER AND VELA)

Four Pioneer spacecraft in orbit around the sun and 10 Vela satellites orbiting the earth are monitoring the sun for signs of major solar flares and other radiation powerful enough to harm an astronaut in space or on the moon. Built by TRW Systems Group's Space Vehicles Division, they are providing NASA with sufficient advance warning to delay a launch or alter an orbit, if necessary.

LM DESCENT

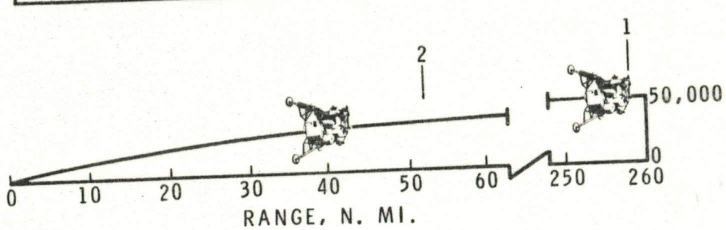

DOI
CSM ORBIT
(62 BY 58 N. MI.)
LM DESCENT
ORBIT (60 N. MI.
BY 50 000 FT)
UNDOCKING
SUN
LANDING
PDI
SEPARATION
EARTH

OPERATIONAL PHASES OF POWERED DESCENT

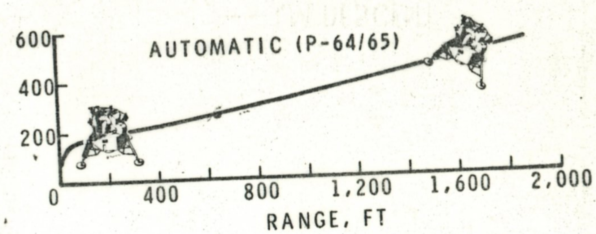


(LANDING PHASE)

EVENT	TIME, MIN	ALTITUDE, FT	RANGE, N. MI.	PITCH, DEG
1 IGNITION	0	50,000	258	92
2 RADAR ALTITUDE UPDATE	5	36,000	52	74



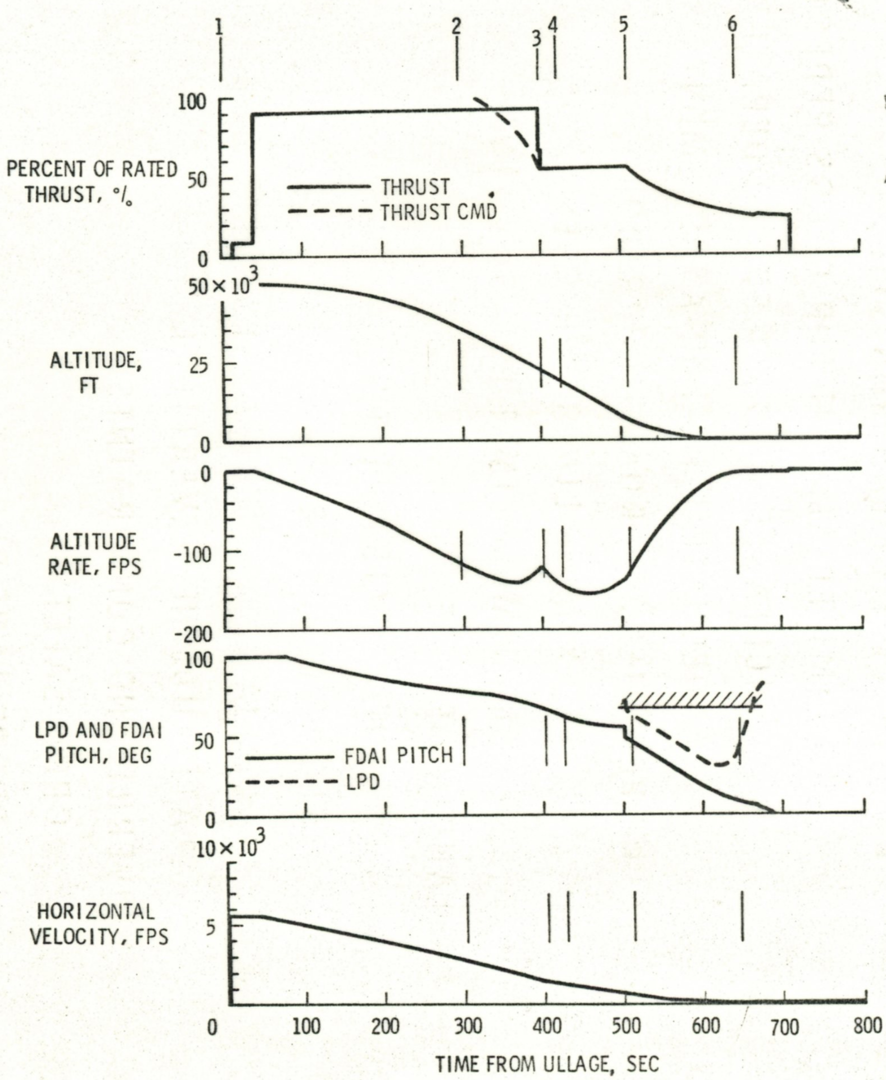
ALTITUDE, FT



TIME HISTORIES OF DESCENT TRAJECTORY AND GUIDANCE PARAMETERS

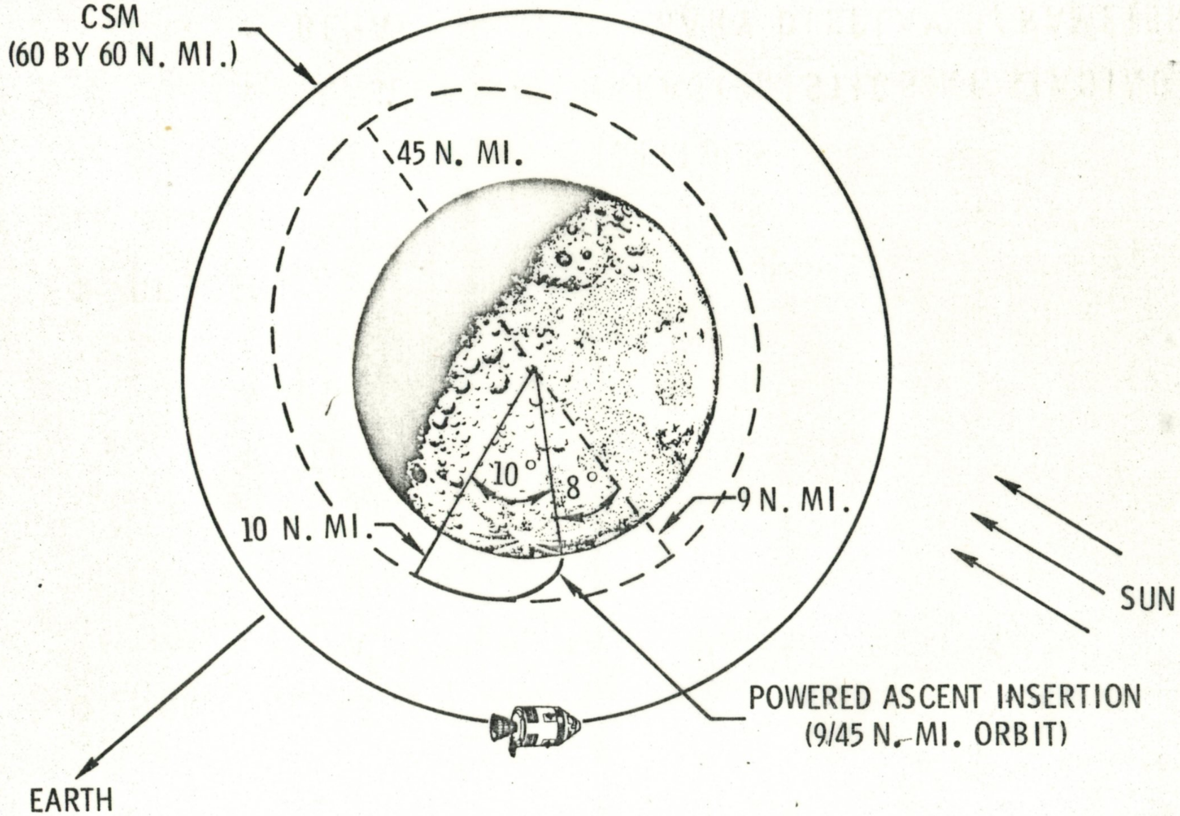
SEQUENCE OF EVENTS

1 PDI
2 LR ALT UPDATE
3 THROTTLE RECOVERY
4 LR VEL UPDATE AND HORIZ VISIBILITY
5 HIGH GATE
6 INITIATE VERTICAL DESCENT

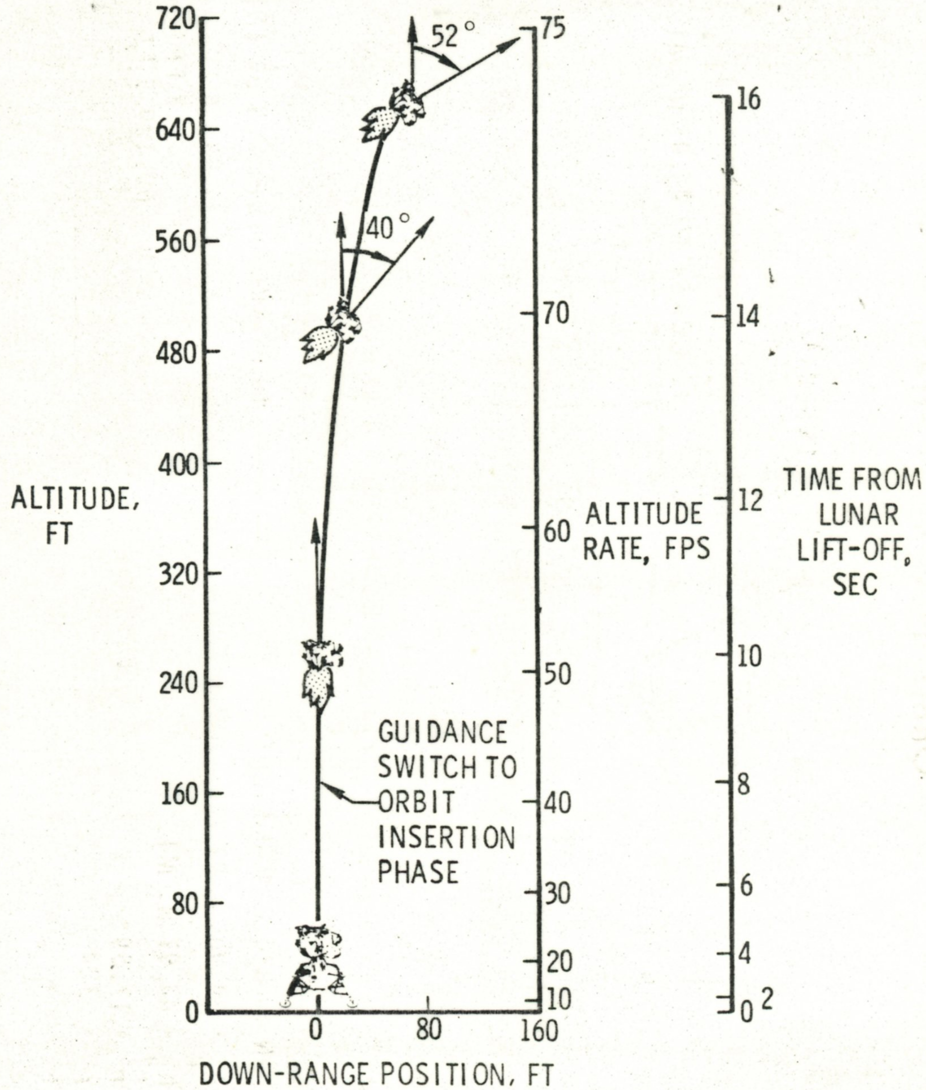


MPAD 4846 S

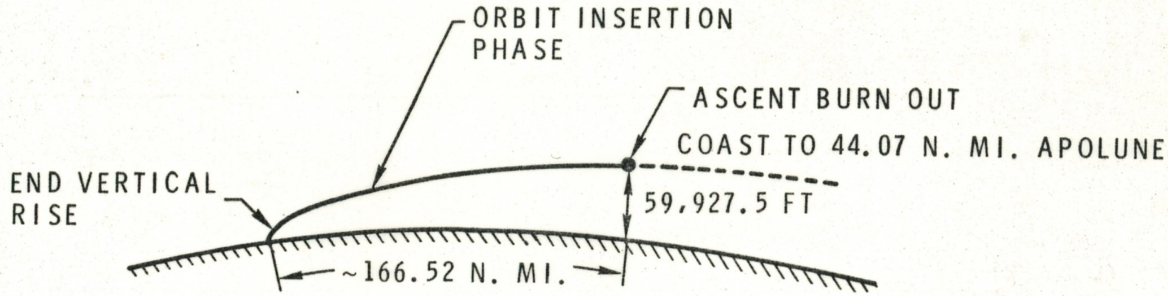
LM ASCENT



VERTICAL RISE PHASE



ORBIT INSERTION PHASE



TOTAL ASCENT:
BURN TIME = 7:14.65 MIN:SEC
ΔV REQUIRED = 6,055.39 FPS
PROPELLANT REQUIRED = 4,989.86 LB

INSERTION ORBIT PARAMETERS

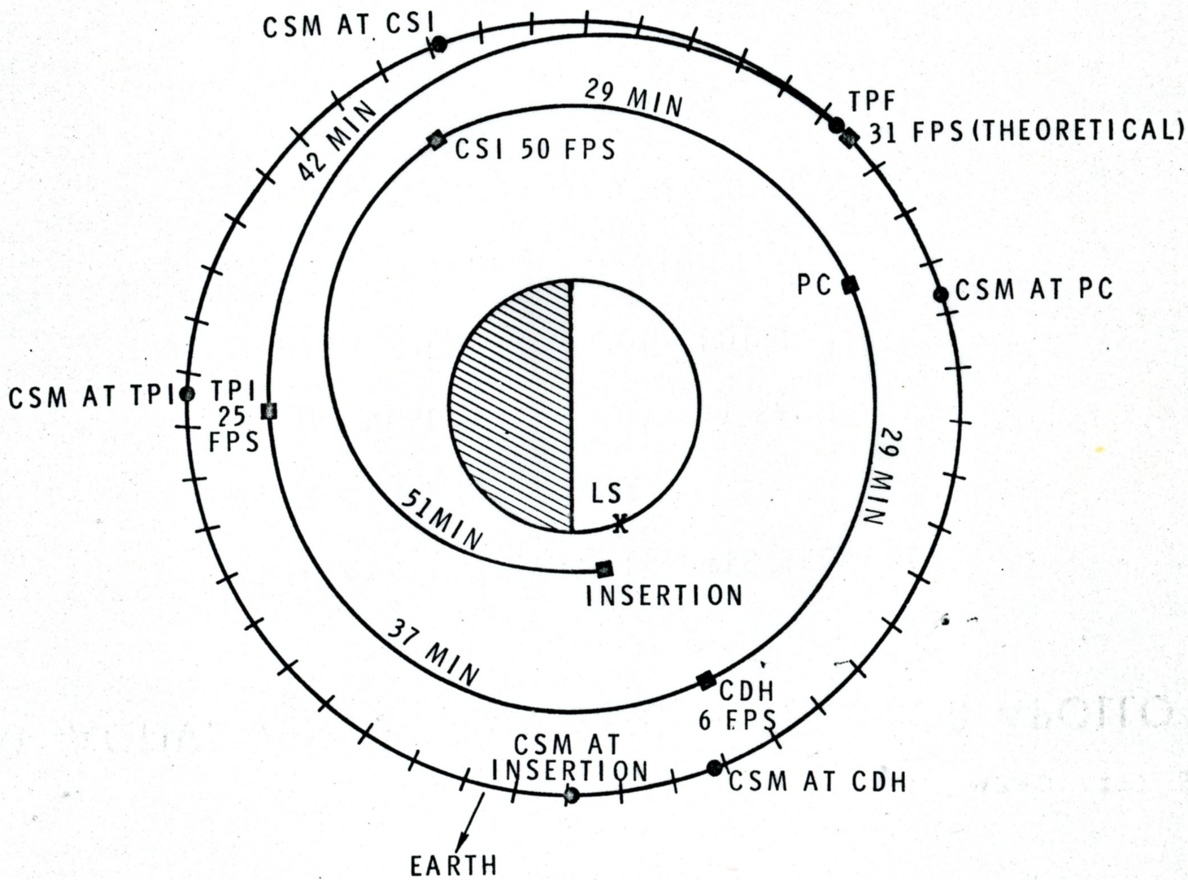
h_p = 54,905.4 FT
h_a = 44.07 N. MI.
η = 17.59°
γ = .324°

ONBOARD DISPLAYS AT INSERTION

V = 5,535.9 FPS
$\dot{h}$ = 32.2 FPS
h = 60,129.5 FT

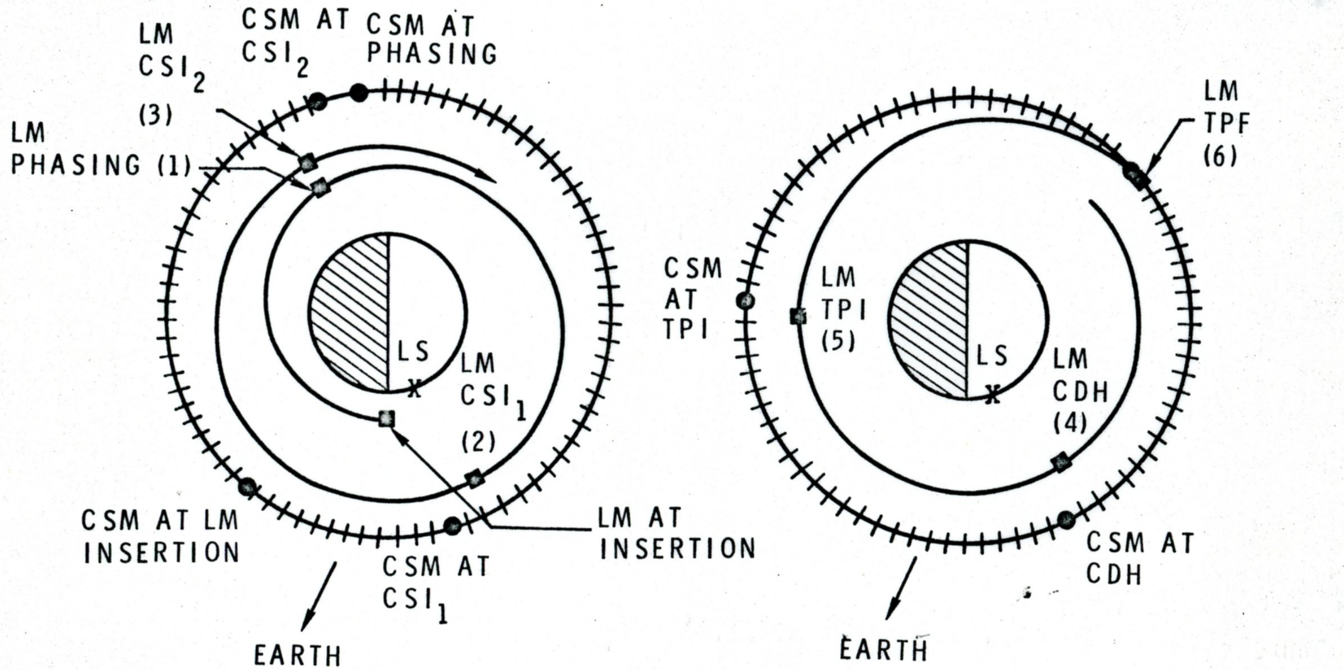
MPAD 5470 S(IU)

NOMINAL LM RENDEZVOUS FOR APOLLO 11



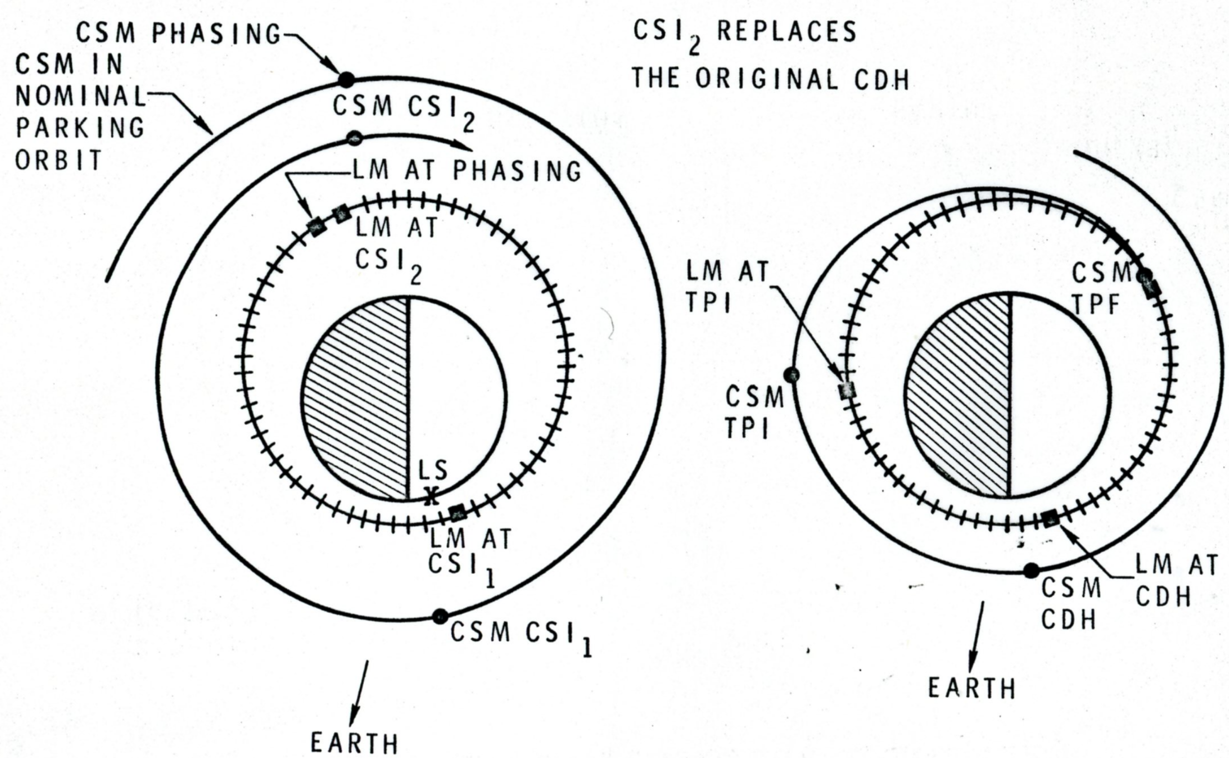
PHASING/CSI-FOR-CDH LM-ACTIVE SEQUENCE

NOTE: CSI_2 REPLACES THE ORIGINAL CDH



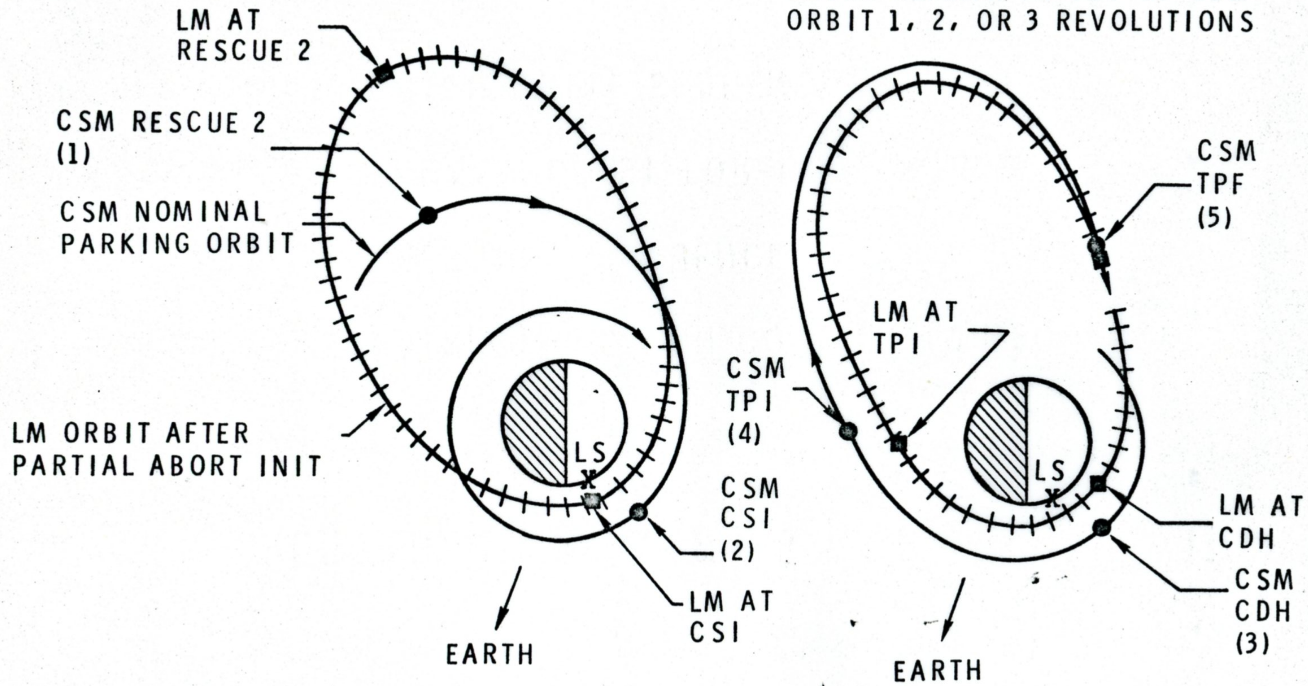
MPAD 5471 S (IU)

PHASING/CSI-FOR-CDH RESCUE SEQUENCE



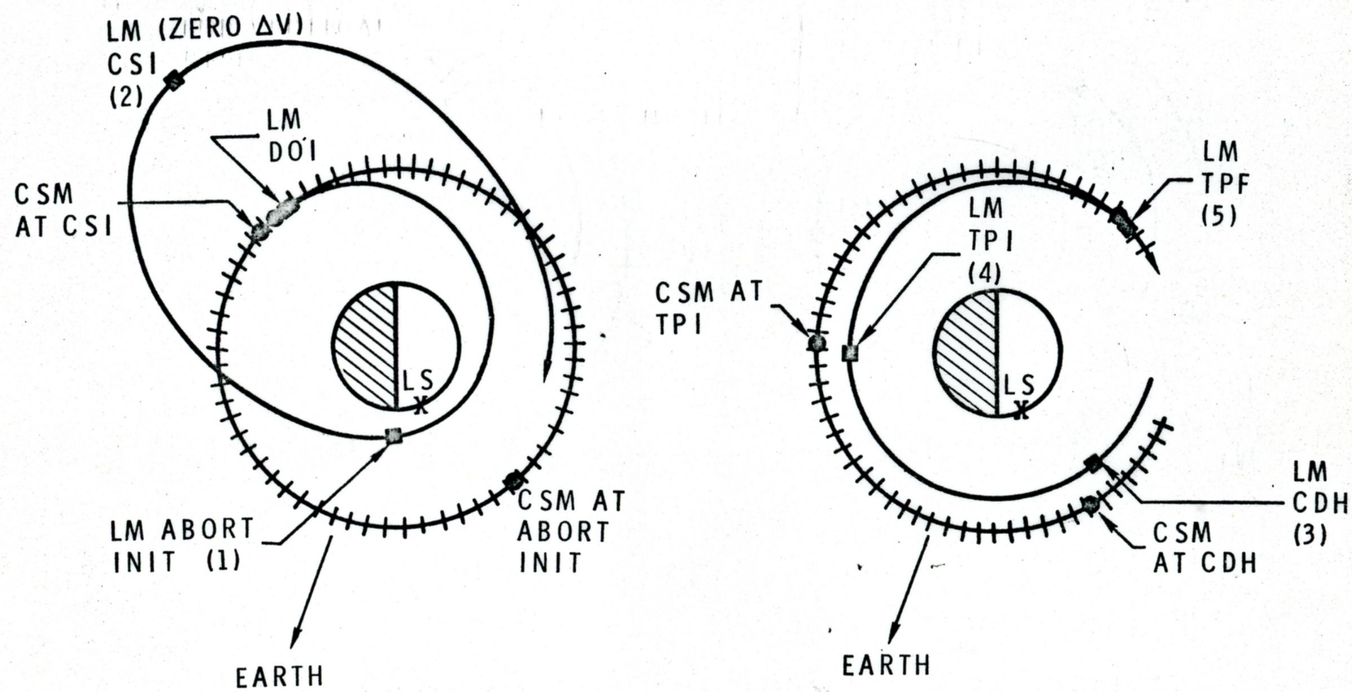
RESCUE 2 SEQUENCE

NOTE: DEPENDING ON SITUATION, CSM COULD REMAIN IN CSI-TO-CDH ORBIT 1, 2, OR 3 REVOLUTIONS

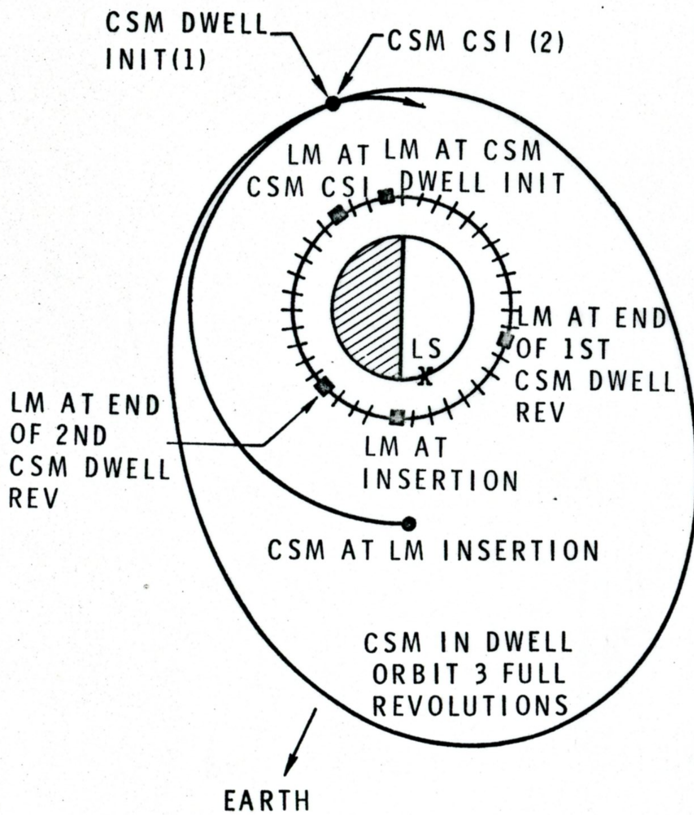


NO-PDI ABORT LM-ACTIVE SEQUENCE

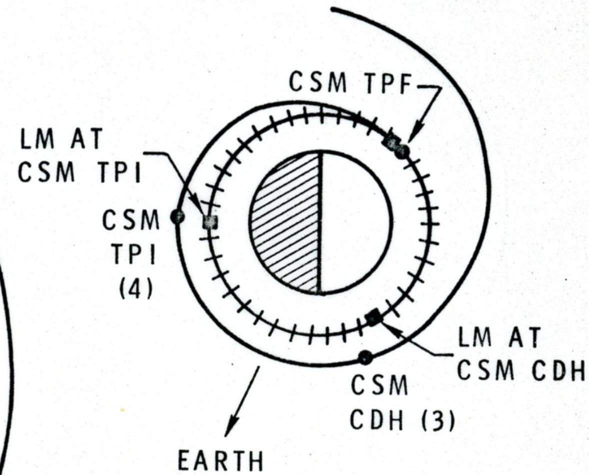
(2 IMPULSE TO CDH-OFFSET)



HIGH-DWELL RESCUE SEQUENCE



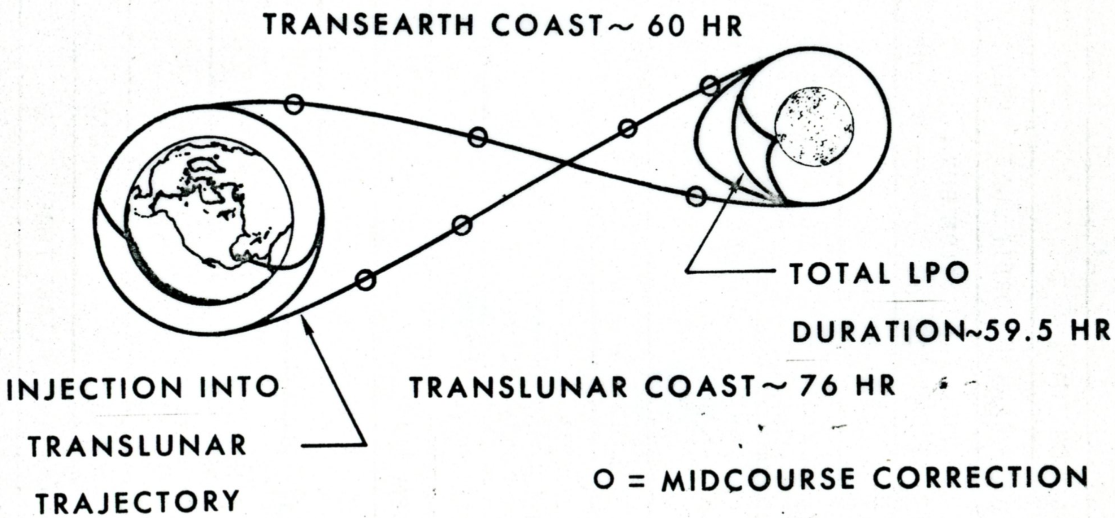
NOTE: CSI 3 REVS AFTER DWELL INITIATION



MPAD 5422 S

MISSION PROFILE

LOI-1 60 BY 170 N. MI.
LOI-2 65 BY 55 N. MI.
LUNAR SURFACE STAY TIME 21.5 HR



3.4 NOMINAL TIMELINE
LUNAR SURFACE EVA

CDR / LMP (0+00 to 0+10)

SEQUENCE CAMERA DOCUMENTATION-
SEE LEGEND ON SUMMARY TIMELINE

DEPRESS CABIN FROM 3.5 PSI
OPEN HATCH
INSURE SUBLIMATOR ICED
PERFORM FINAL SYSTEMS CHECKS
CONFIRM "GO" FOR EVA

NOTE: DETAILED PROCEDURES
ARE PRESENTED IN "FINAL
EVA PROCEDURES APOLLO 11"
SUBMITTED BY EVA BRANCH, FCSD

CDR: MOVE THROUGH HATCH
CHECK INGRESS PROCEDURE

LMP: ASSIST CDR
PLAY OUT LEC

CDR / LMP (continued)

PERFORM COMM CHECK

10 52

CDR	LMP
MOVE TO POSITION AND RELEASE MESA	MONITOR CDR ACTIVITY PLAY OUT LEC
	TURN TV ON START SEQUENCE CAMERA (SC)
DESCEND TO FOOTPAD CHECK ASCENT PROCEDURES	PLAY OUT LEC
STEP TO SURFACE REST/CHECK EMU	CHANGE SC FR TO 24/SEC
	CHANGE SC FR TO 12/SEC
STOW LEC (0+20)	
	VISUALLY MONITOR CDR ACTIVITY PROVIDE CHECKLIST ASSISTANCE
CHECK AND DISCUSS BALANCE/STABILITY	
	CHANGE SC FILM MAG CHANGE FR TO 6/SEC

NOMINAL TIMELINE

CDR

- REST/CHECK EMU
- UNSTOW CSC AND DEPLOY HANDLE
- EXTEND BAG COLLECT SAMPLE
- DETACH BAG AND DISCARD HANDLE
- STOW SAMPLE
- TRANSFER STILL CAMERA TO SURFACE
- TETHER CAMERA
- REST/CHECK EMU
- CHECK AND REPORT LM STATUS
- CHECK TERRAIN AND LIGHTING

LMP

- CHECK LM AND EMU
- START SC
- MONITOR CDR ACTIVITY
- PREPARE FOR CAMERA TRANSFER ASSIST CDR
- CHANGE SC FR TO 1/SEC
- PERFORM FINAL LM AND EMU CHECK CONFIRM "GO" FOR EVA PLACE SPARE CAMERA ON LM FLOOR
- REORIENT SC

30

CDR

- MONITOR AND PHOTO EGRESS
- MONITOR AND PHOTO LMP
- PREPARE MESA FOR TV DEPLOYMENT
- REMOVE TRIPOD
- CHANGE FROM WA TO LD LENS
- REMOVE TV CABLE
- REMOVE CAMERA CARRY TV TO DEPLOY SITE

LMP

- MOVE THRU HATCH CHECK INGRESS PROCEDURE
- PERFORM COMM CHECK
- DESCEND TO PAD CHECK ASCENT PROCEDURE
- STEP TO SURFACE REST/CHECK EMU
- CHECK BALANCE/STABILITY REACH CAPABILITY
- DETERMINE WALKING CAPABILITY

0+40

MISSION	EDITION	DATE	MISSION TIME	DAY/REV	PAGE
APOLLO 11	FINAL	JUNE 27, 1969	112+54 - 113+18	5/20	2 of 7

NOMINAL TIMELINE

CDR

+50 / +00

- CARRY TV TO DEPLOY SITE
- TAKE FAST-SCAN PANORAMA OR SEVERAL POINTS OF INTEREST
- PLACE TV FOR SUB. EVA
- MOVE NEAR LMP REST/CHECK EMU
- PHOTO SWC
- PLACE CAMERA ON MESA
- PREPARE MESA FOR BULK SAMPLE COLLECTION
- PREPARE ALHT AND SRC
- COLLECT ROCKS AND LOOSE MATERIAL

LMP

- REST/CHECK EMU PULL TV CABLE FROM MESA
- ERECT SRC TABLE
- REMOVE SWC FROM MESA-DEPLOY IN SUNLIGHT
- EVALUATE AND REPORT EVA CAPABILITY AND EFFECTS ON SURFACE (TETHER CAMERA WHEN REQUIRED)
- EVALUATE AND REPORT LIGHTING/VISIBILITY

CDR

1+10

- REST/CHECK EMU
- PACK SRC
- CLOSE AND SEAL SRC CONNECT LEC

LMP

- AND TERRAIN IN SUNLIGHT
- EVALUATE AND REPORT LIGHTING/VISIBILITY AND TERRAIN AT SHADOW EDGE
- TAKE PHOTO PANORAMA
- EVALUATE AND REPORT LIGHTING/VISIBILITY AND TERRAIN IN SHADOW
- REPORT STATUS AND PHOTO QUAD I
- REPORT STATUS AND PHOTO +Z GEAR PHOTO BULK SAMPLE AREA

NOMINAL TIMELINE

CDR

CARRY ALSCC
REPORT STATUS QUAD IV

REPORT STATUS +Y GEAR

EVALUATE TERRAIN/VISIBILITY
TAKE CLOSE-UP PHOTOS

REPORT STATUS QUAD III

REPORT STATUS -Z GEAR

TETHER STILL CAMERA

REPORT STATUS AND PHOTO QUAD II

PHOTO EASEP OFF LOAD

LMP

REMOVE ALSCC FROM MESA AND DEPLOY

PHOTO QUAD IV

PHOTO +Y GEAR

TAKE PHOTO PANORAMA

PHOTO QUAD III

PHOTO -Z GEAR

TRANSFER CAMERA TO CDR

OPEN SEQ BAY DOOR

1+30

CDR

REPORT STATUS AND PHOTO -Y GEAR

TAKE PHOTO PANORAMA

PHOTO EASEP OFFLOAD
TAKE CLOSE-UP PHOTOS

REST/SELECT DEPLOY SITE

CARRY CAMERAS TO DEPLOY SITE
REPORT POSITION FROM LM

DEPLOY LR^3

PHOTO LR^3

MOVE TO PSE

LMP

REMOVE PACKAGE 1 (PSE)

REMOVE PACKAGE 2 (LR^3)

CLOSE SEQ BAY DOOR

CARRY EASEP PACKAGES TO DEPLOY SITE

REST/CHECK EMU

DEPLOY PSE

TAKE CLOSE-UP PHOTOS

NOMINAL TIMELINE

CDR	LMP	CDR	LMP
PHOTO PSE	MOVE TO MESA REST/CHECK EMU	PHOTO SAMPLES AND SAMPLE AREA ASSIST LMP	DESCRIBE SAMPLES AND SAMPLE AREA COLLECT SAMPLES
MOVE TO QUAD IV	MOVE BULK SRC TO STRUTS OR FOOTPAD		
REST/PHOTO LMP TAKE CLOSE-UP PHOTOS	PREPARE DS SRC AND SAMPLING EQUIPMENT		
PHOTO SAMPLING	COLLECT CORE TUBE SAMPLE		
TETHER SAMPLE BAG TO LMP			
UNSTOW GNOMON			
SELECT DS AREA MOVE TO DS AREA			
PHOTO DS AREA			

NOMINAL TIMELINE

CDR

- STOW ALSCC FILM
- MOVE TO MESA PLACE SAMPLE BAG ON SCALE
- HOLD CONTAINER SEAL AND STOW
- HOLD CONTAINER SEAL AND STOW
- RETRIEVE SWC PUSH STAFF INTO SURFACE. ASSESS FORCE. PHOTO
- PLACE SWC IN BAG
- PACK SRC
- CLOSE AND SEAL SRC

LMP

- REMOVE ALSCC FILM STOW IN CSC POCKET
- MOVE TO MESA PLACE SCOOP BY MESA
- OPEN LARGE ENVIR. SAMPLE CONTAINER. COLLECT LOOSE MATERIAL
- OPEN SMALL CONTAINER COLLECT ROCK SAMPLE
- SCOOP LOOSE MATERIAL INTO SAMPLE BAG
- HOLD SWC BAG
- IF TIME AVAILABLE COLLECT CORE SAMPLE
- MOVE TO LADDER CLEAN EMU

2+20

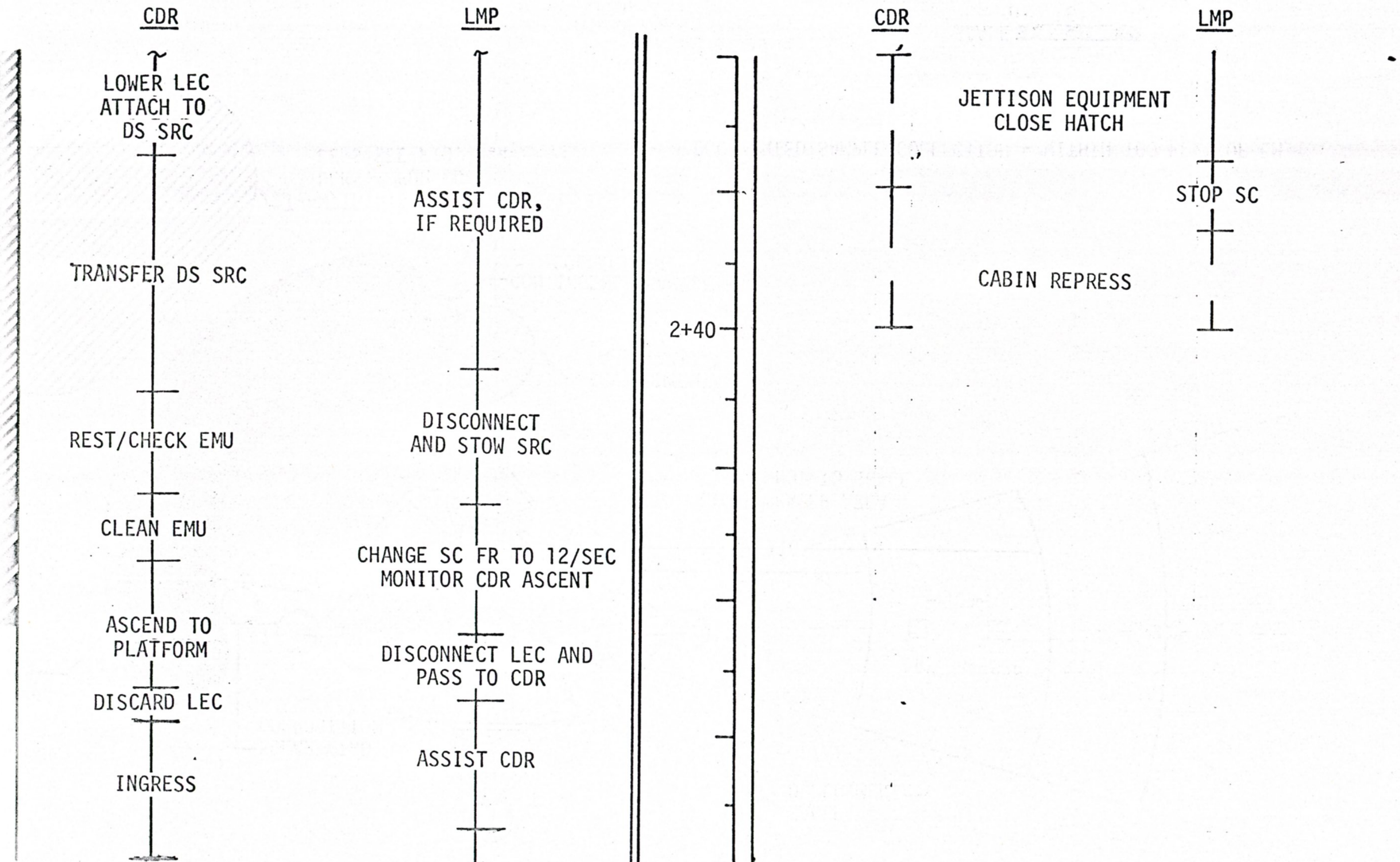
CDR

- REST/PHOTO LMP
- REMOVE CAMERA MAGAZINE AND CONNECT TO LEC
- TRANSFER BULK SAMPLE SRC AND CAMERA MAG.
- REST/CHECK EMU

LMP

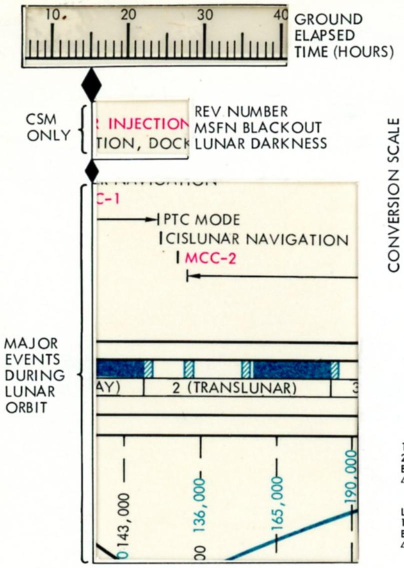
- ASCEND TO PLATFORM
- INGRESS
- CHECK LM AND EMU
- CHANGE SC FILM REORIENT CAMERA CHANGE FR TO 6/SEC
- ASSIST CDR, IF REQUIRED
- DISCONNECT AND STOW SRC AND CAMERA MAG.

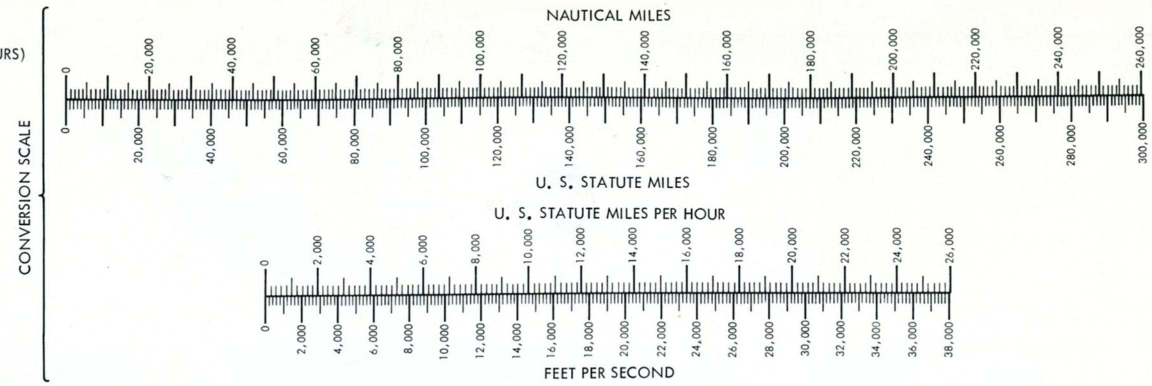
NOMINAL TIMELINE



MISSION	EDITION	DATE	MISSION TIME	DAY/REV	PAGE
APOLLO 11	FINAL	JUNE 27, 1969	114+54 - 115+18	5/21	7 of 7

TRW
SYSTEMS GROUP





— NOMINAL MANEUVER DATA —

TLI - S-IVB
2:44
BT: 5 MIN 20 SEC
ΔV: 7,126 MPH

EVASIVE MANEUVER
(CSM/LM FROM S-IVB
4:40
BT: 2.8 SEC
ΔV: 13 MPH

CSM MCC-1 11:44
MCC-2 26:44
MCC-3 53:54
MCC-4 70:54
ΔV: NOMINALLY ZERO

LOI-1-SPS
75:54
BT: 5 MIN 59.9 SEC
ΔV: 1,994 MPH

LOI-2-SPS
80:10
BT: 16.4 SEC
ΔV: 108 MPH

CSM/LM SEP RCS
100:40
BT: 8.0 SEC
ΔV: 1.7 MPH

LM DOI-DPS
101:39
BT: 28.5 SEC
ΔV: 48 MPH

LM PDI-DPS
102:35
BT: 11 MIN 58 SEC
ΔV: 4,613 MPH

CSM PLANE CHANGE
107:06
ΔV: NOMINALLY ZERO

LM LIFT-OFF - APS
124:23
BT: 7 MIN 18 SEC
ΔV: 4,132 MPH

LM CSI
125:21
BT: 45 SEC
ΔV: 34 MPH

LM PLANE CHANGE
125:50
ΔV: NOMINALLY ZERO

LM CDH-RCS
126:20
BT: 1.9 SEC
ΔV: 3 MPH

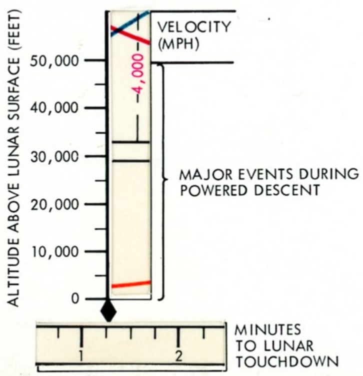
LM TPI-RCS
126:58
BT: 22.4 SEC
ΔV: 17 MPH

LM RENDEZVOUS
MCC-1 127:13
MCC-2 127:28

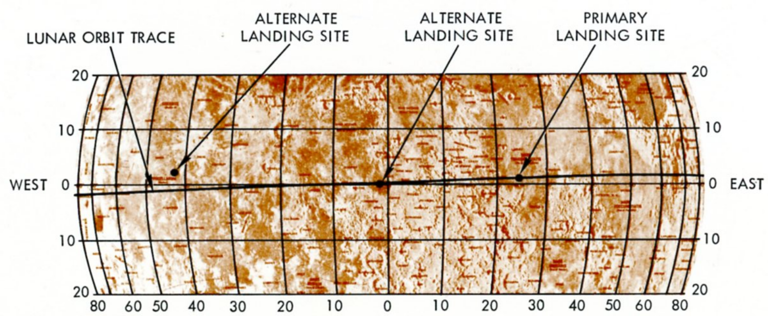
LM JETTISON
131:53
BT: 3.1 SEC
ΔV: 0.5 MPH

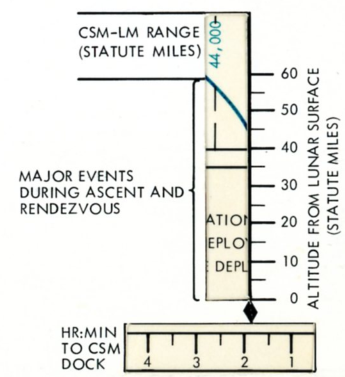
CSM TEI - SPS
135:25
BT: 2 MIN 29 SEC
ΔV: 2,245 MPH

CSM MCC-5 150:25
MCC-6 172:03
MCC-7 192:03
ΔV: NOMINALLY ZERO



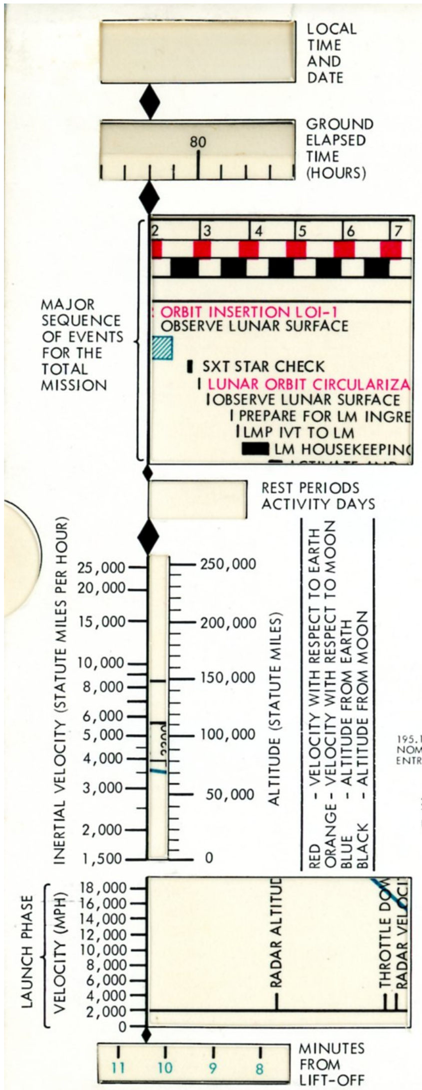
— LUNAR SURFACE MAP —





NASA APOLLO 11 — FIRST MANNED LUNAR LANDING
MISSION INFORMATION DISPLAY

TRW
SYSTEMS GROUP



HOW TO USE THIS MISSION INFORMATION DISPLAY

This Mission Information Display is a quick reference for information on the nominal Apollo 11 mission launched July 16, 1969. It is keyed to local time and date and to ground elapsed time (GET). The Display is set by removing the large inner slide and setting the small slide for local time and date so that zero on the GET scale is opposite the local time and date of lift-off. For convenience, the local time and date scale may be permanently set after lift-off by stapling or using transparent tape. After inserting the large slide back into the outer jacket, the major events, activity days, and rest periods for the nominal mission may be read in terms of calendar date and time or GET. The velocity and distance with respect to the earth and moon are also presented and may be read where the line crosses the left side of the window. Major event data for the launch phase and entry phase are also presented with an expanded scale. On the reverse side, major events during lunar orbit and lunar surface activities, powered descent and ascent, and rendezvous are presented in greater detail. Conversion scales, nominal maneuver data, and other mission information are found on the jacket.

TRW Inc., one of the nation's pioneer space companies, is proud to be a member of the vast governmental-industrial team which has brought Project Apollo to this major milestone in the history of mankind--man's first landing on the moon. TRW's contributions to this historic event include

- Trajectory Design and Analysis
- Spacecraft Systems Analysis
- Flight Planning Support
- Lunar Module Abort Guidance System
- Attitude Control Thrusters for the Saturn V S-IVB Stage
- Lunar Module Descent Engine
- Solar Radiation Data Provided by TRW-Built Pioneer and Vela Satellites
- Apollo Communications Equipment
- Test and Training Satellites for the Manned Spaceflight Network

APOLLO 11 TRAJECTORY

(EARTH - MOON PLANE)