

Challenge Accepted
May 25, 1961

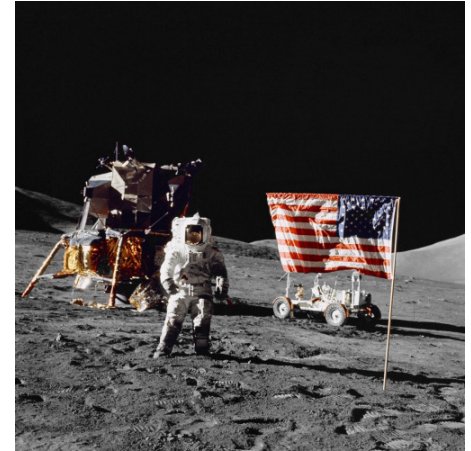


Mission Accomplished
July 20, 1969

In roughly **2950 days**, America transformed from literally tossing a man in a capsule up to high altitudes (60 miles) to building a national-wide aerospace industrial complex in which every method was imagined, invented, engineered and tested, and built for sailing the ocean of space, landing on the distance shore, and returning safely home (feedback!).

In the 1960s, there was no Cape Bajador. There was only a collective goal. Such a monumental challenge and such a redefining moment of accomplishment may never have its parallel in human history.

Project Apollo - to put a man on the moon and return him safely to Earth



On May 25, 1961, twenty days after the first US manned spaceflight Freedom 7, Kennedy proposed the manned Moon landing in a *Special Message to the Congress on Urgent National Needs*:

"Now it is time to take longer strides - time for a great new American enterprise - time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth.

...I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important in the long-range exploration of space; and none will be so difficult or expensive to accomplish."



"But why, some say, the Moon? Why choose this as our goal? And they may well ask, why climb the highest mountain? Why, 35 years ago, fly the Atlantic? ...

We choose to go to the Moon. We choose to go to the Moon in this decade and do the other things, **not because they are easy, but because they are hard**; because that goal will serve to organize and measure the best of our energies and skills; because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win ..."

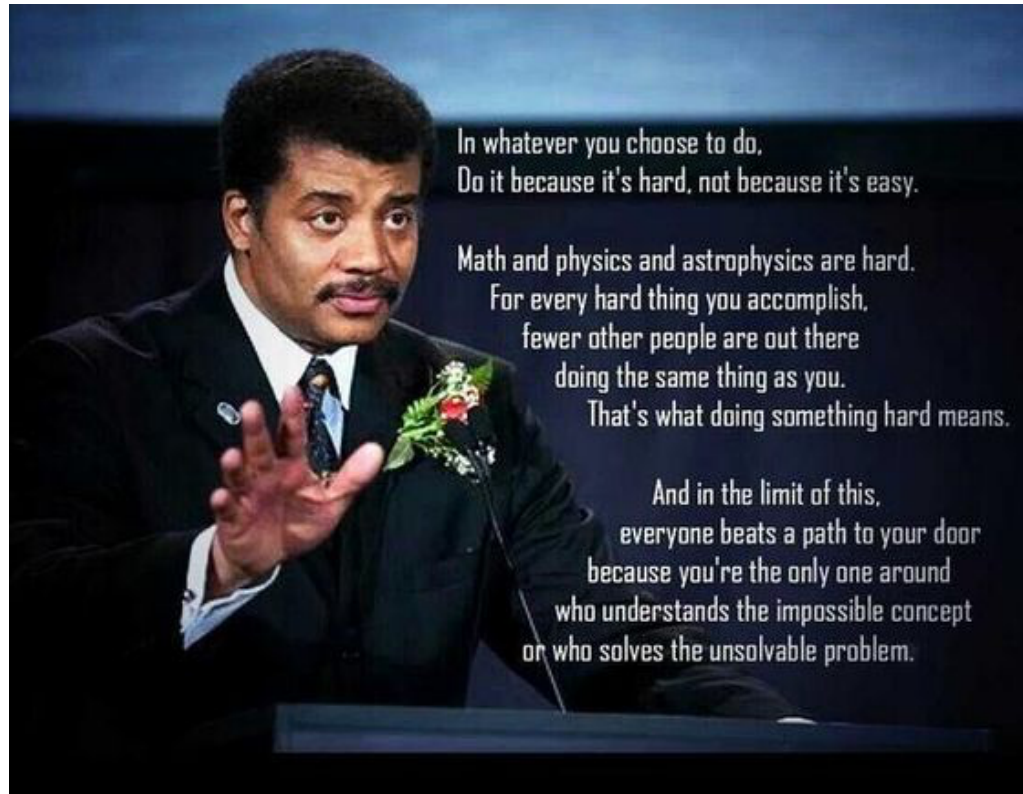


George Hillary on Mt Everest



Charles Lindbergh with *Spirit of St. Louis*

This soap box moment brought to you by Neil DeGrasse Tyson...



People don't decide to be great. They decide to do great things.

Once Kennedy had defined a goal, the Apollo mission **planners were faced with the challenge** of **designing a spacecraft that could meet it while minimizing risk to human life, cost, and demands on technology and astronaut skill**. Four possible mission modes were proposed:

Direct Ascent:

The spacecraft would be launched as a unit and travel directly to the Moon and land. It would return, leaving its landing stage on the Moon. This design would have required development of the extremely powerful **Nova** launch vehicle.

Earth Orbit Rendezvous (EOR):

Multiple rocket launches would carry parts of a Direct Ascent spacecraft and propulsion units for translunar injection (TLI). These would be assembled into a single spacecraft in Earth orbit.

Lunar Orbit Rendezvous (LOR):

A single Saturn V could launch a spacecraft that was composed of a mother ship which would remain in orbit around the Moon, while a smaller, two-stage lander would carry two astronauts to the surface, return to dock with the mother ship, and then be discarded. Landing only a small part of the spacecraft on the Moon and returning an even smaller part to lunar orbit minimized the total mass to be launched from the Earth.

Lunar Surface Rendezvous (LSR):

Two spacecraft would be launched in succession. The first, an automated vehicle carrying propellant for the return to Earth, would land on the Moon, to be followed some time later by the manned vehicle. Propellant would have to be transferred from the automated vehicle to the manned vehicle.

Orbits

LEO – low earth orbit

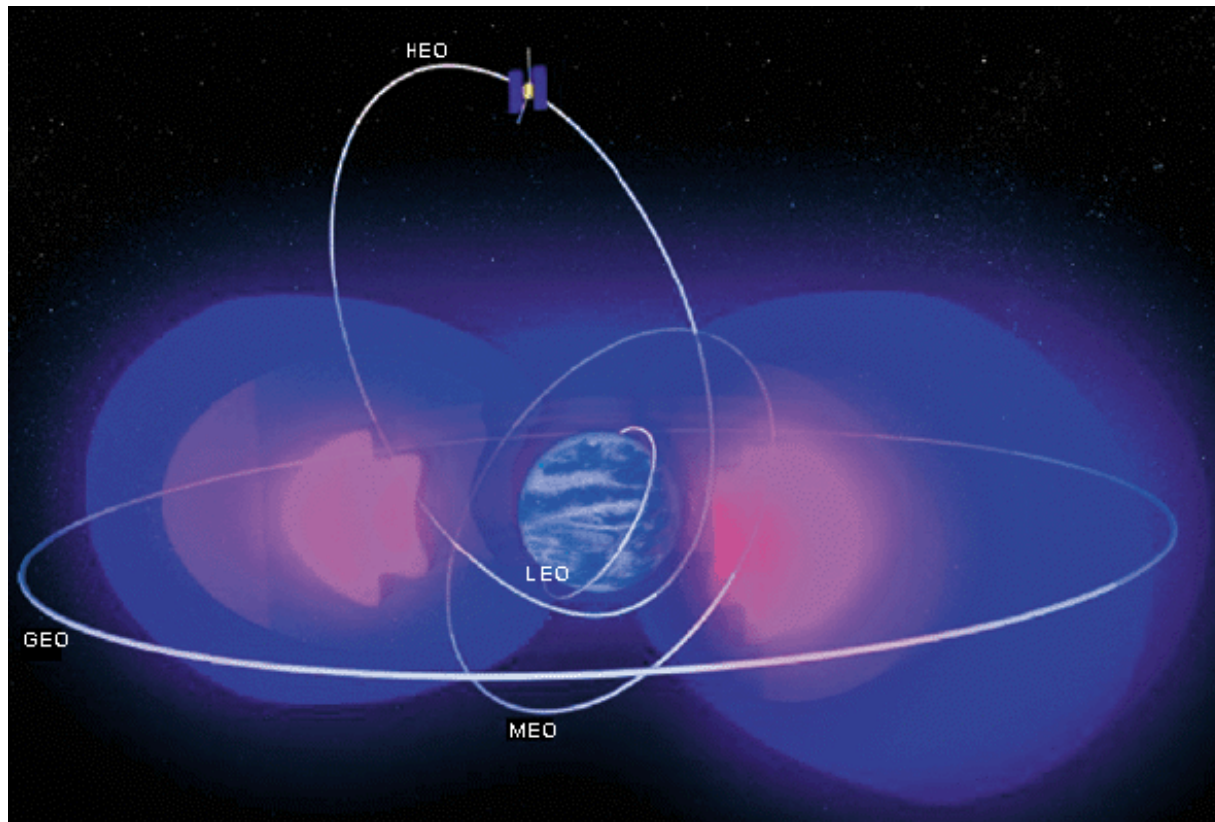
MEO – moderate earth orbit

HEO – high earth orbit

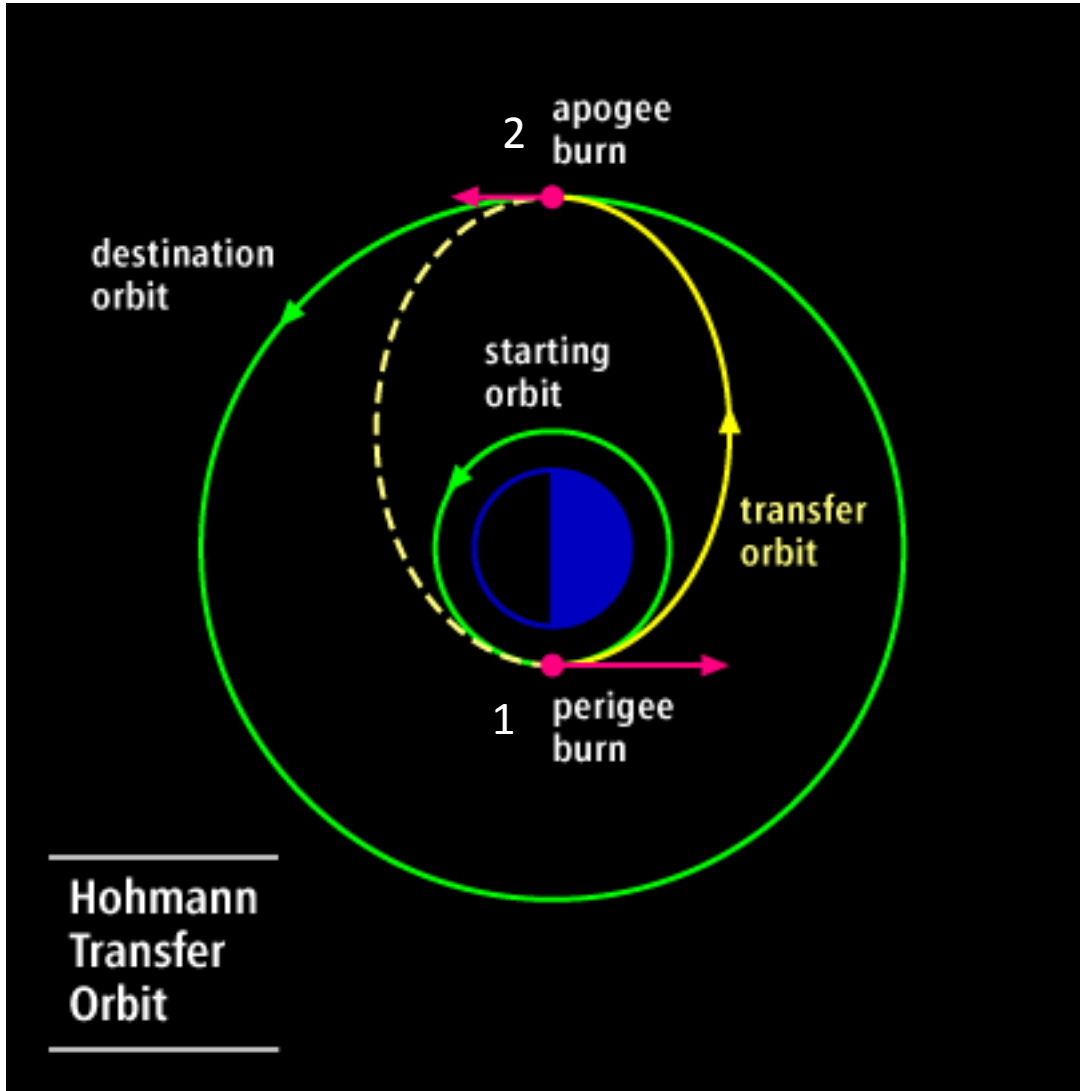
GEO – geosynchronous orbit

But how do you get into these orbits?

How do you change from one orbit to another orbit?



Changing Orbits



To minimize the fuel (i.e., make the weight of the rocket as small as possible), one needs to coast as much as possible.

Hohman Orbit Transfers:

Do two short engine “burns”

1. In some “parking orbit”, increase your velocity to enter a transfer orbit
2. At apogee of the transfer orbit, increase your speed to insert yourself into the desired orbit

Between engine burns, the spacecraft is following

Kepler's Laws of motions.

Moonshot Three Letter Acronyms (TLA) + others

AOS = Acquisition of signal

LOS = Los of Signal

CM = Command Module

SM = Service Module

CSM = Command + Service Module (stack)

LM = Lunar Module

SPS = Service Propulsion System (Engine on CSM)

CMD = Commander (left seat)

CMP = Command Module Pilot (center seat)

LMP = Lunar Module Pilot (right seat)

EOI = Earth Orbit Insertion

LOI = Lunar Orbit Insertion

PDI = Power Descent Insertion

PTC = Passive Thermal Control

TEI = Trans Earth Injection

TLI = Trans Lunar Injection

EVA = Extravehicular Activity

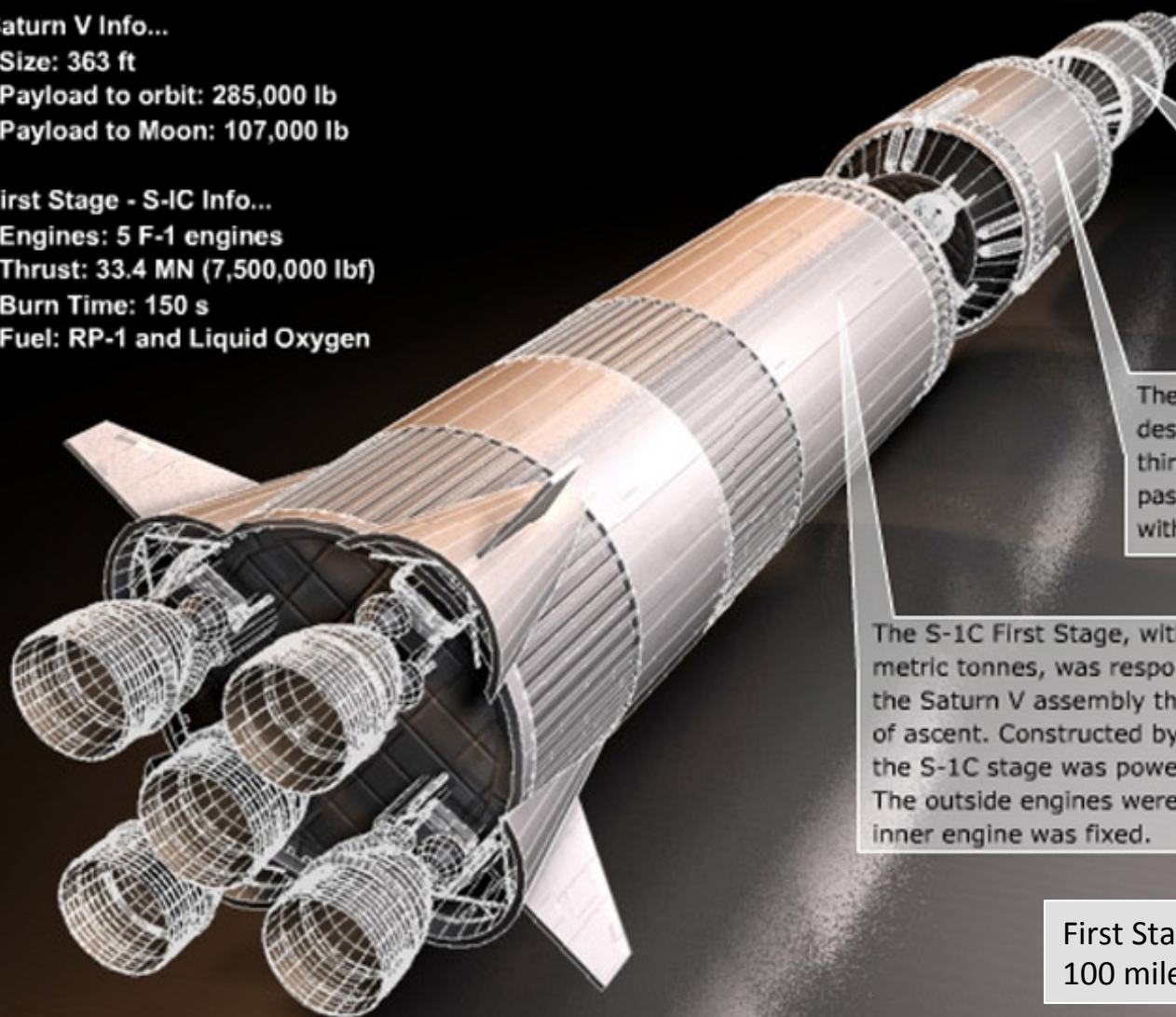
Saturn V Rocket

Saturn V Info...

Size: 363 ft
Payload to orbit: 285,000 lb
Payload to Moon: 107,000 lb

First Stage - S-IC Info...

Engines: 5 F-1 engines
Thrust: 33.4 MN (7,500,000 lbf)
Burn Time: 150 s
Fuel: RP-1 and Liquid Oxygen



The S-IVB 3rd Stage, with the LM and CSM. Powered by 1 J-2 Engine.

The S-II Second Stage was designed to accelerate the third stage and payload past the upper atmosphere with 5 J-2 engines.

The S-IC First Stage, with a mass of over 2000 metric tonnes, was responsible for launching the Saturn V assembly through the 1st 61 km of ascent. Constructed by the Boeing company, the S-IC stage was powered by 5 F-1 engines. The outside engines were steerable and the inner engine was fixed.

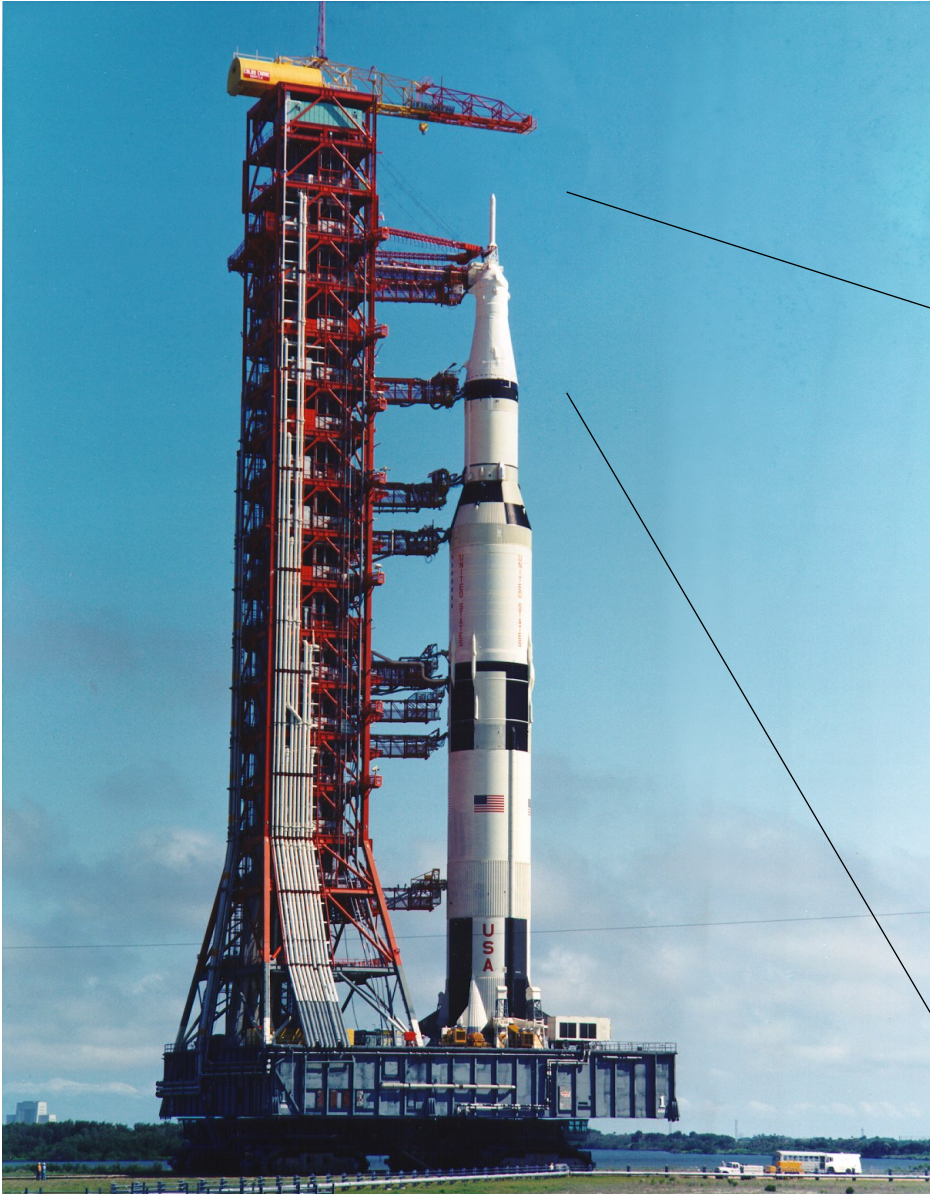
First Stage takes you up 100 miles in 2 and ½ min

EOI
TLI

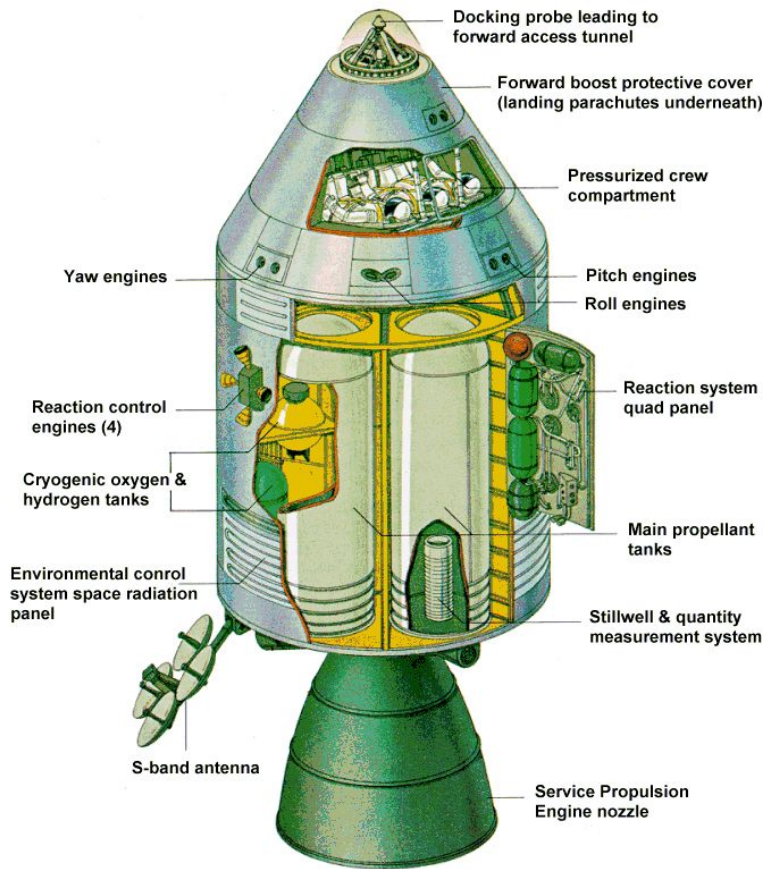


The Saturn V Moon Rocket

Mode: Lunar Orbit Rendezvous (LOI)

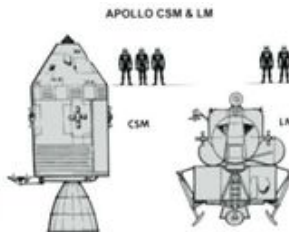


Apollo Command and Service Modules

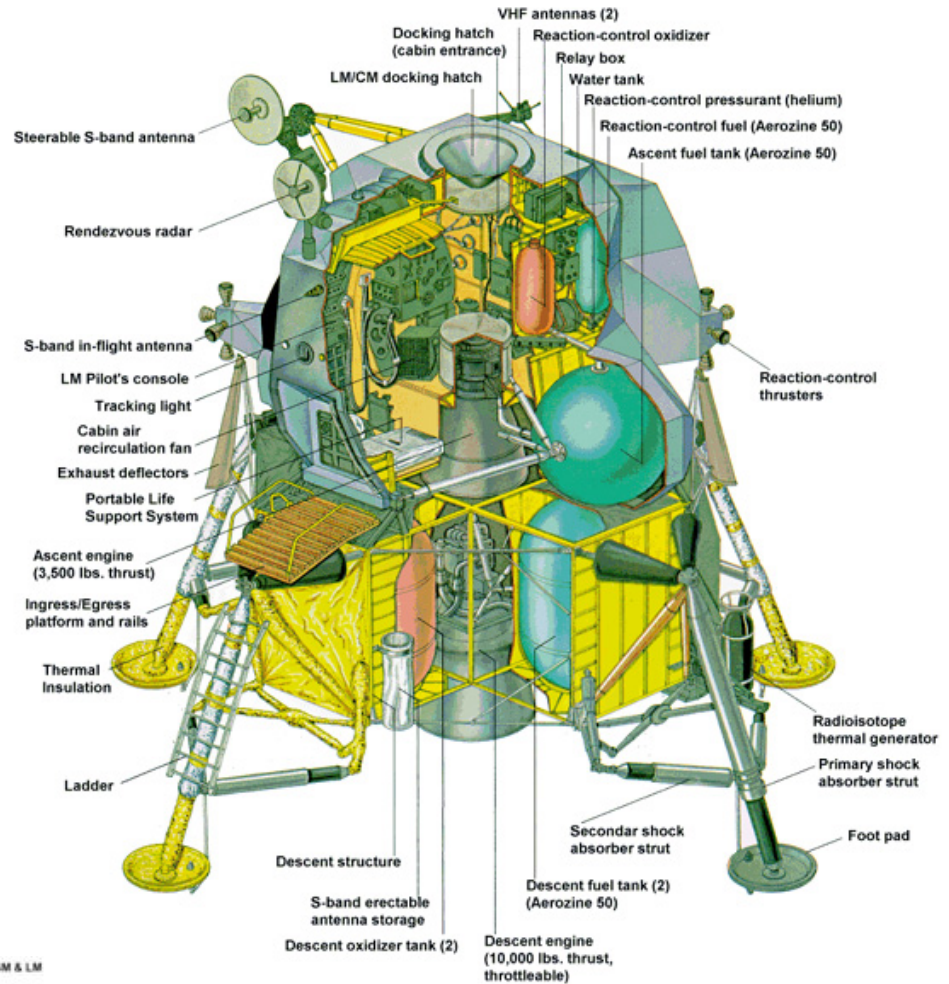


Apollo CSM Facts

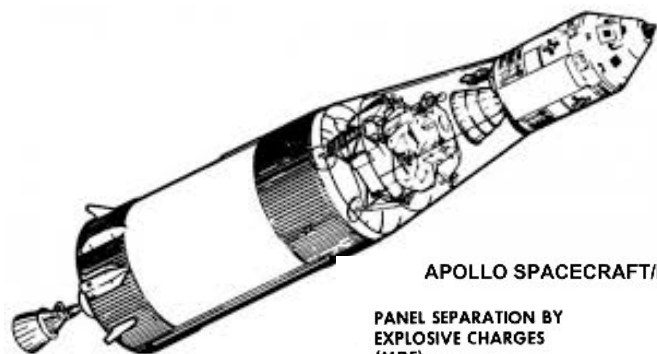
The Apollo Command Module was 10.6 ft. tall and 12.8 ft. at its maximum diameter, and typically weighed 13,090 lbs. with astronauts. The Service Module was 24.3 ft. tall and 12.8 ft. in diameter and weighed 54,074 lbs.. The Service Propulsion System engine delivered a thrust of 20,500 lbs..



Apollo Lunar Module

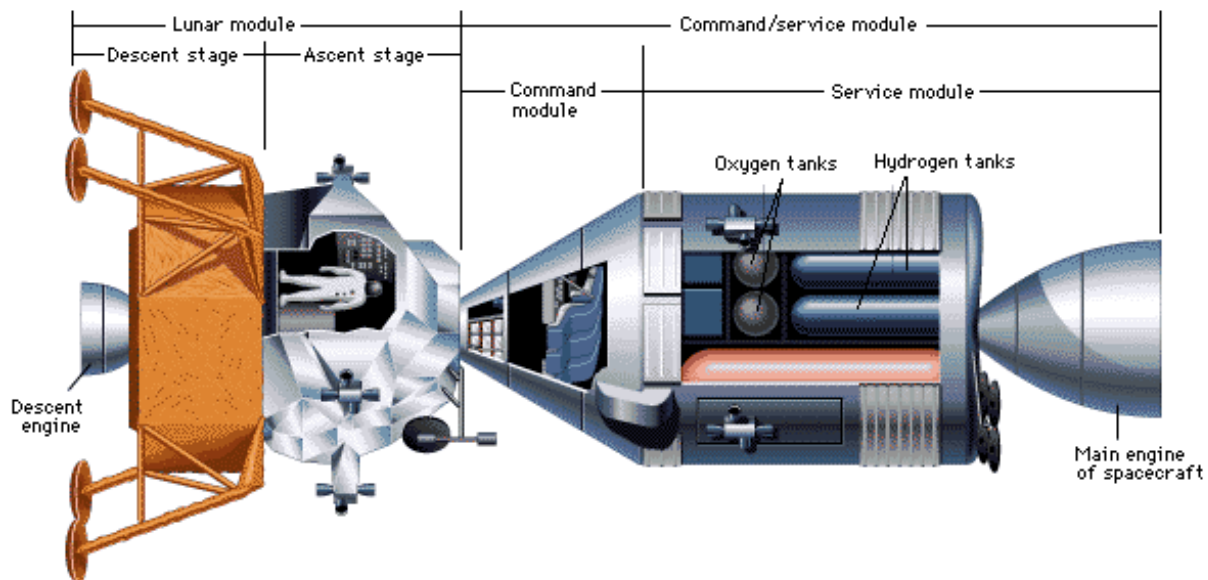
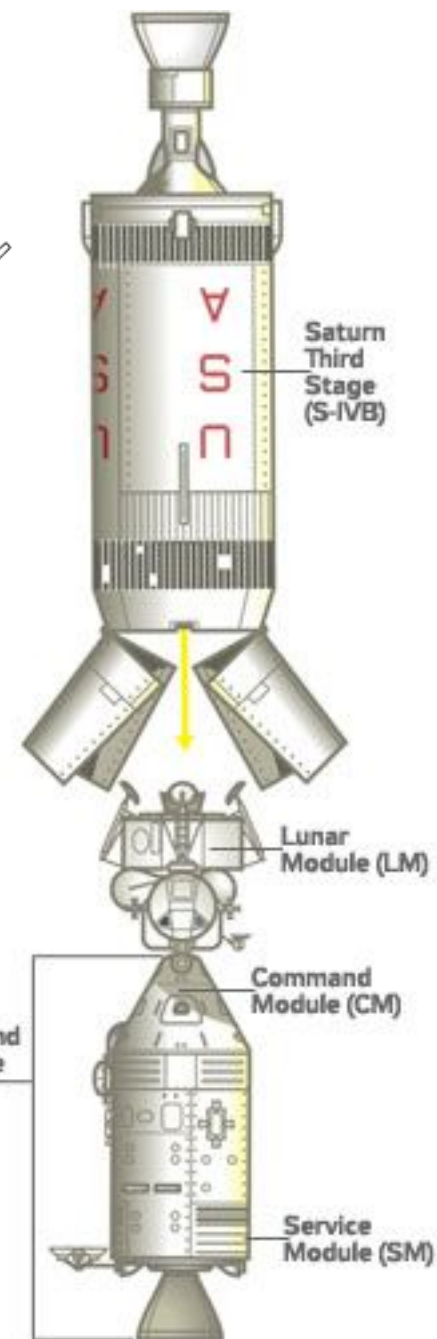
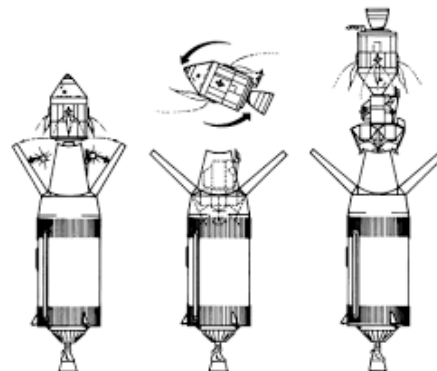
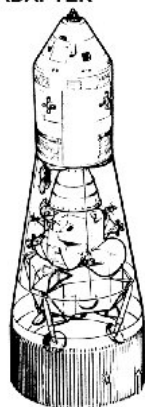


The lunar module was 23 ft. tall and had a launch weight of 33,205 lbs. (The Apollo 17 J-Series lunar module weighed 36,244 lbs.)

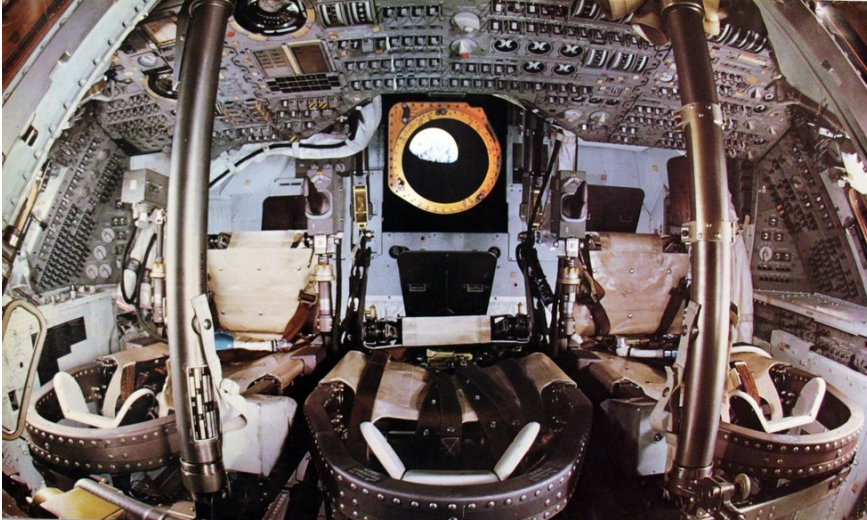


APOLLO SPACECRAFT/LM ADAPTER

PANEL SEPARATION BY
EXPLOSIVE CHARGES
(MDF)



INSIDE THE COMMAND MODULE



INSIDE THE LUNER MODULE



Notable: pure oxygen at 16 PSI, electrical spark starts fire, astronauts die

APOLLO 1- The Fire (mission aborted)

January 1967

Gus Grissom CMD
Ed White CMP
Roger Chaffee LMP



Before



After



Notable: the first mutiny in space

Wally Schirra CMD
Walt Cunningham CMP
Don Eisele LMP



APOLLO 7- The “Shakedown” Test the Block II CM in Earth Orbit



October 1968

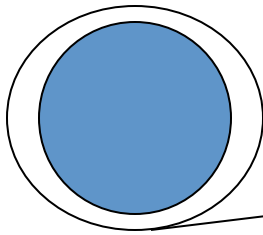


It takes 3 days for translunar flight, so you “shoot” for where the moon is GOING to be....

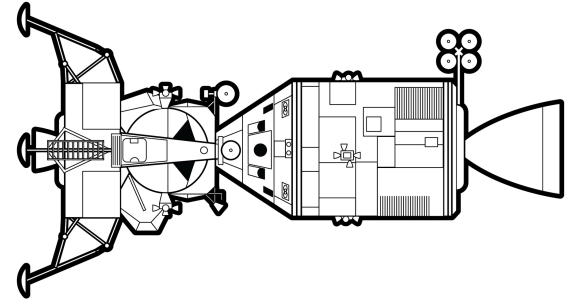
Spacecraft arrives going 5000 mph

Moon is traveling 2300 mph

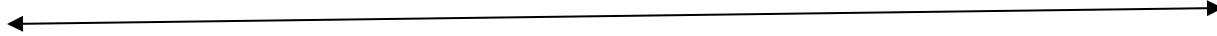
You arrive 120 miles in front of the moon



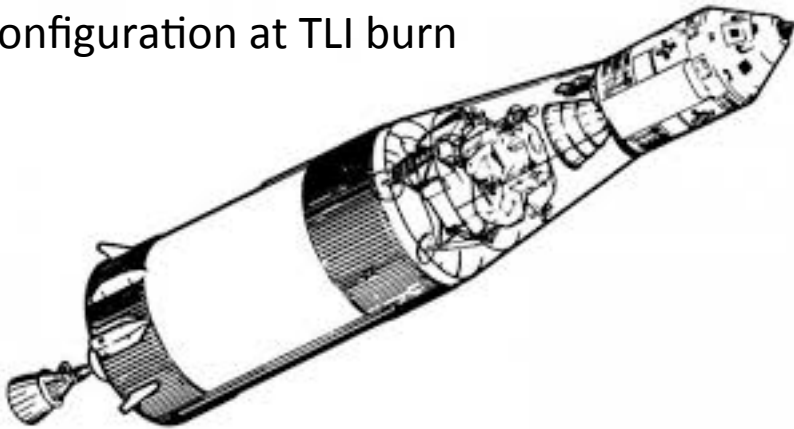
Configuration at LOI burn



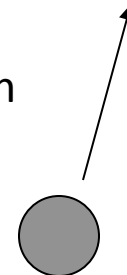
248,000 miles



Configuration at TLI burn



Location of moon
at TLI burn



From the Apollo 8 Press Release Package

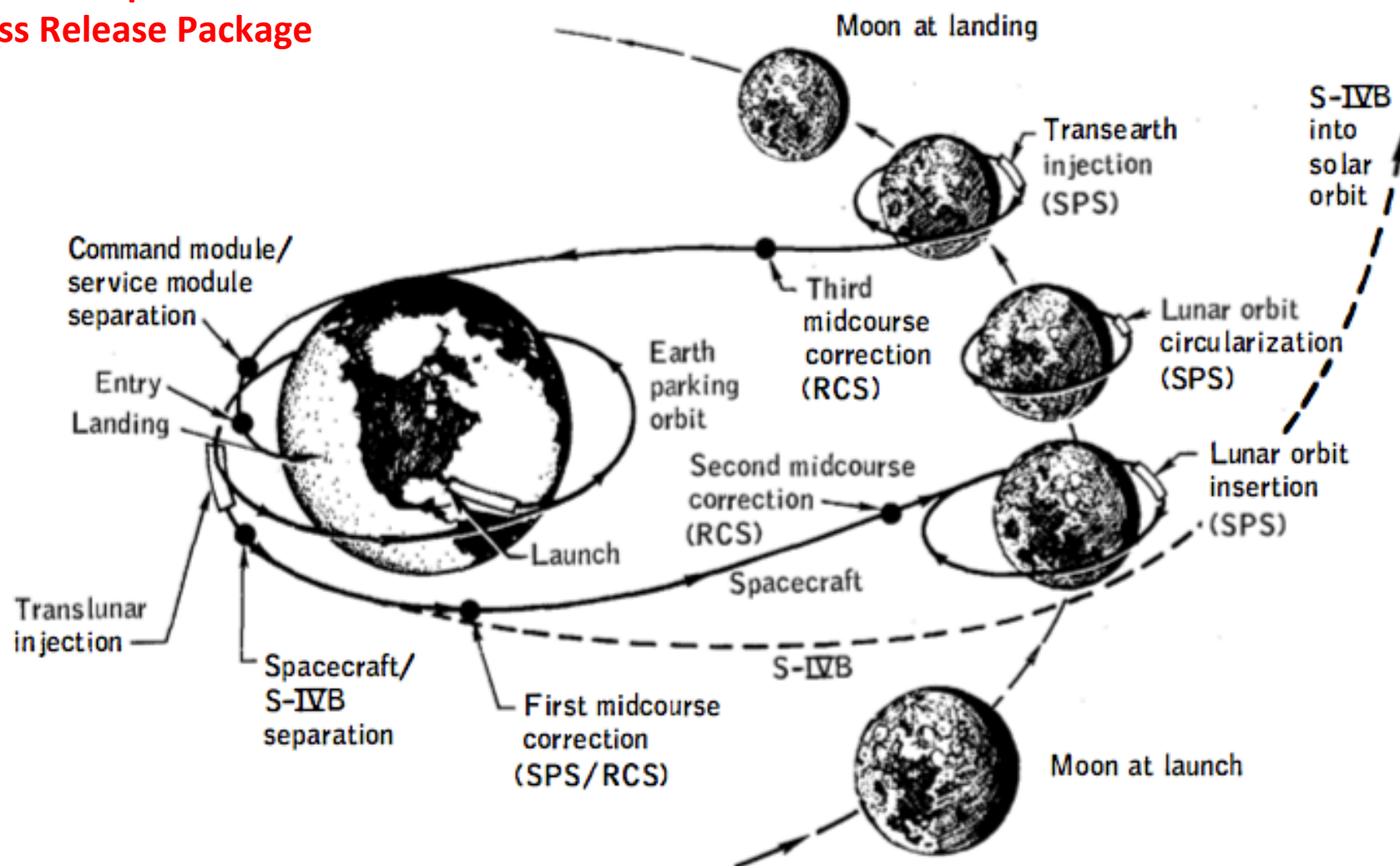


Figure 3-1.- Apollo 8 mission profile .

Notable: a mission with a destination; the moonrise photo; Genesis on Christmas 1968

APOLLO 8- The First to Leave 10 orbits around the Moon

Frank Borman CMD
James Lovell CMF
Bill Anders LMP



December 1968



Re-entry 34,000 mph

Notable: first LM flight; first Apollo EVA; first full integrated systems test

APOLLO 9- THE LM shakedown (Earth orbit test flight par none)

James McDivett CMD
David Scott CMP
Rusty Schweickart LMP

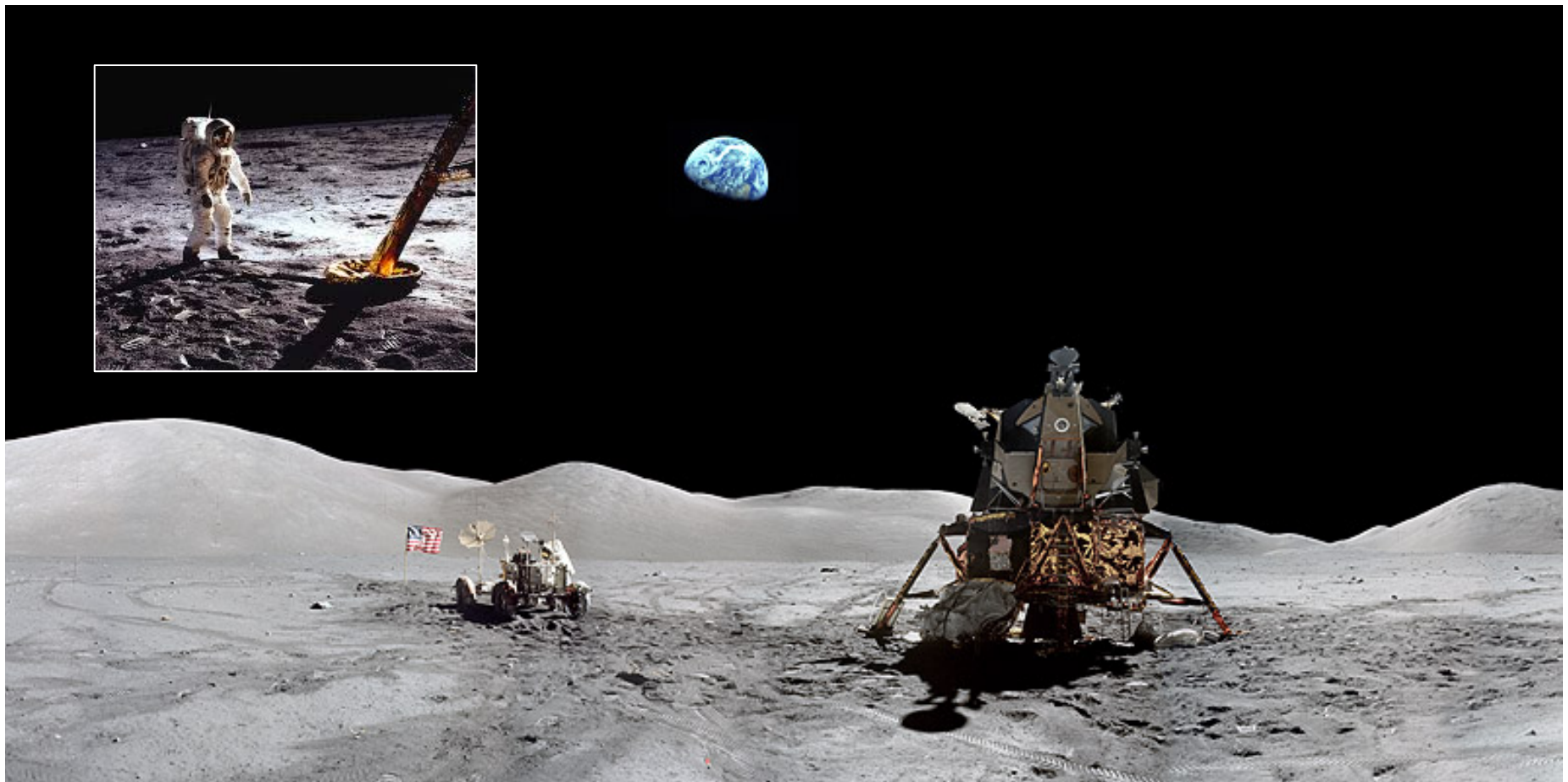
March 1969



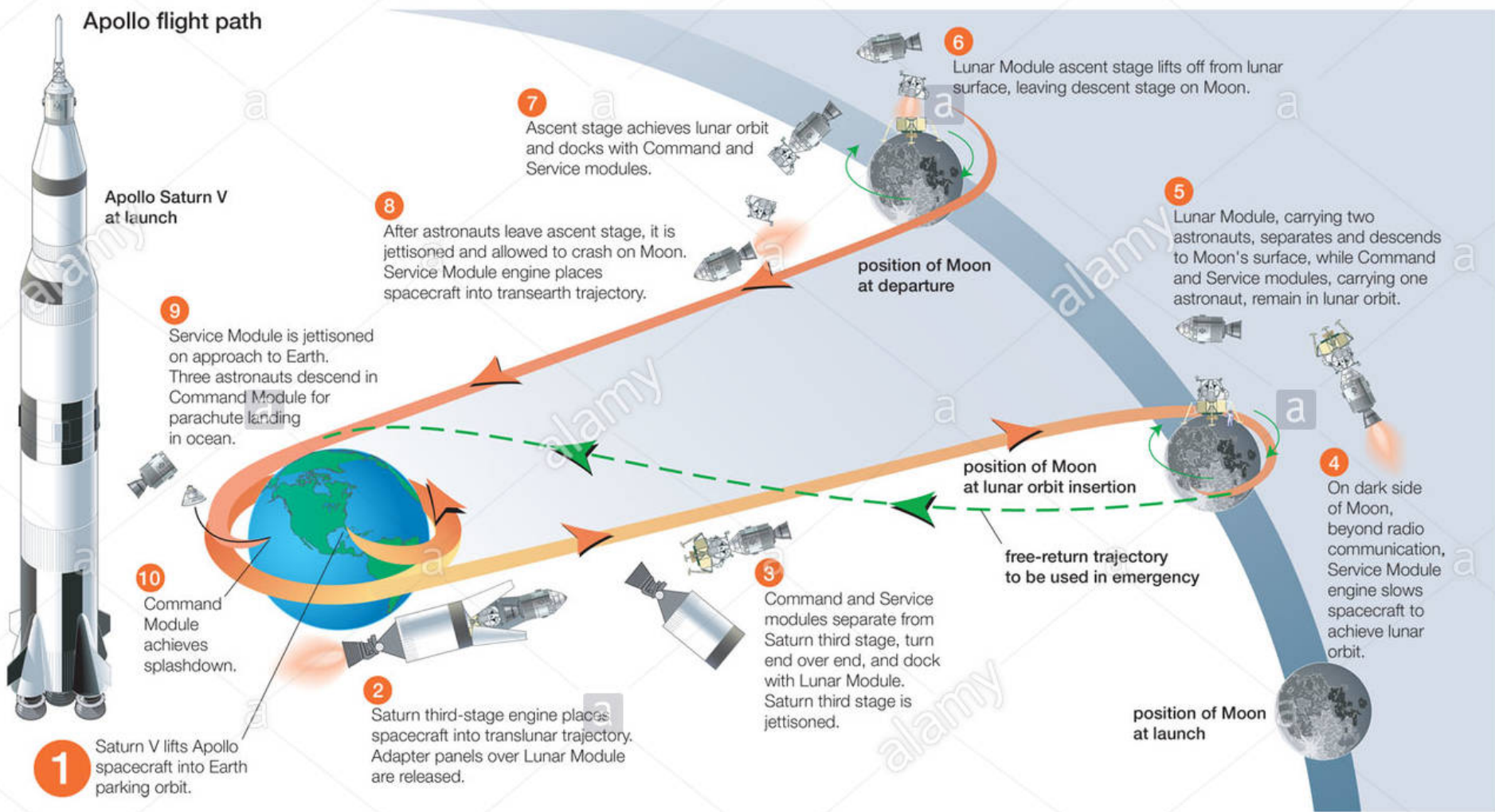
April 1969 onward - The Final Stretch:

- (1) go back to the Moon and test all methods in Lunar Orbit (repeat Apollo 8 and 9)
- (2) Once all tests are successful and methods mastered, attempt the landing

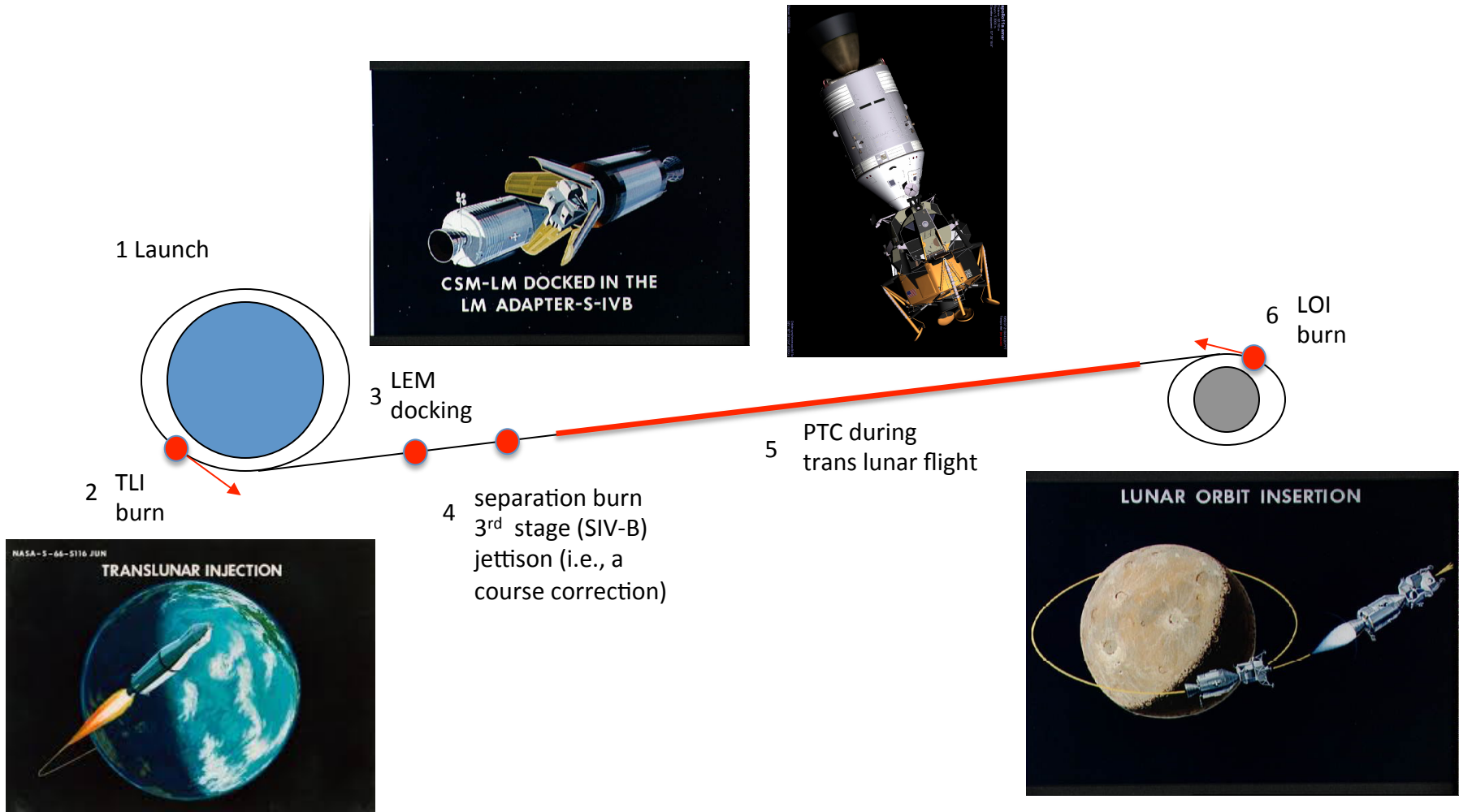
11 more Saturn V missions were funded for the attempt; we did it in the next 2 missions!



How You Go To The Moon And Do The Other Things...



Milestones to the Moon...



Powered Descent and Landing

(Step 7)

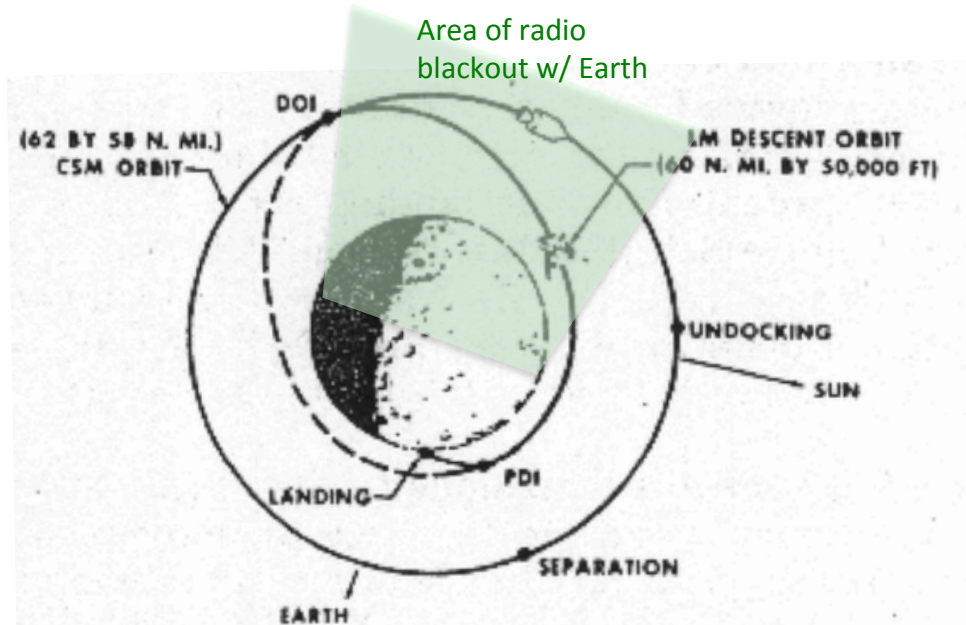
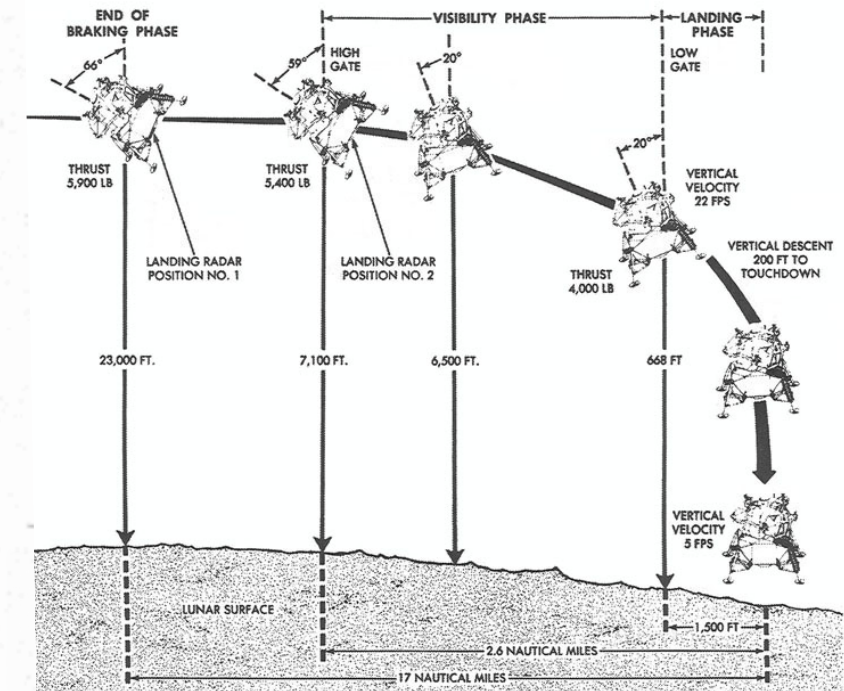


Figure 1. - Lunar module descent.



Nominal Descent Trajectory from High Gate to Touchdown

After CSM-LEM undocking/inspection, there is a separation burn. Half an orbit later, the LEM performs a Descent Orbit Insertion (DOI) burn. If all goes well, the LEM does a Powered Descent Insertion (PDI) burn. The checklist for powered descent is refined to the tenth of a second...

Note Sun and Earth direction – Sun for illumination; Earth for communication

Powered Descent

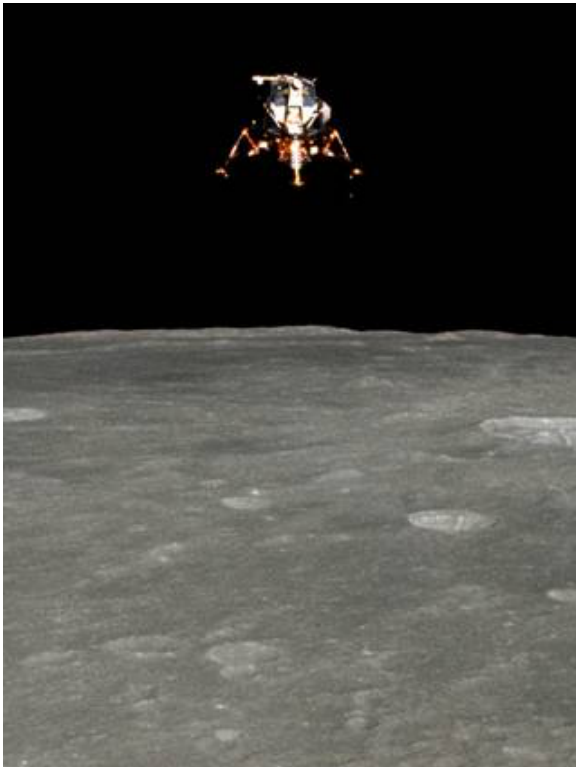
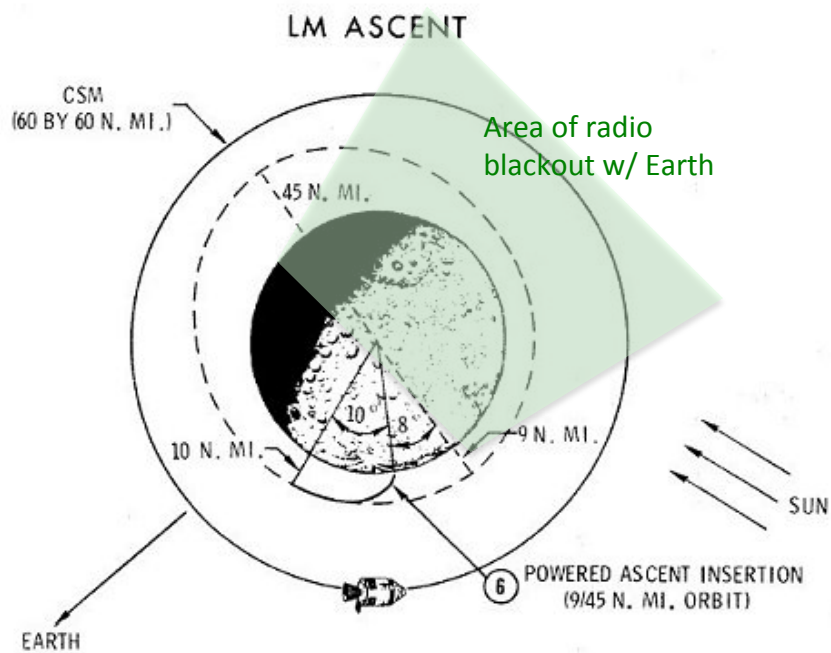


TABLE 7-IV.- SEQUENCE OF EVENTS DURING POWERED DESCENT

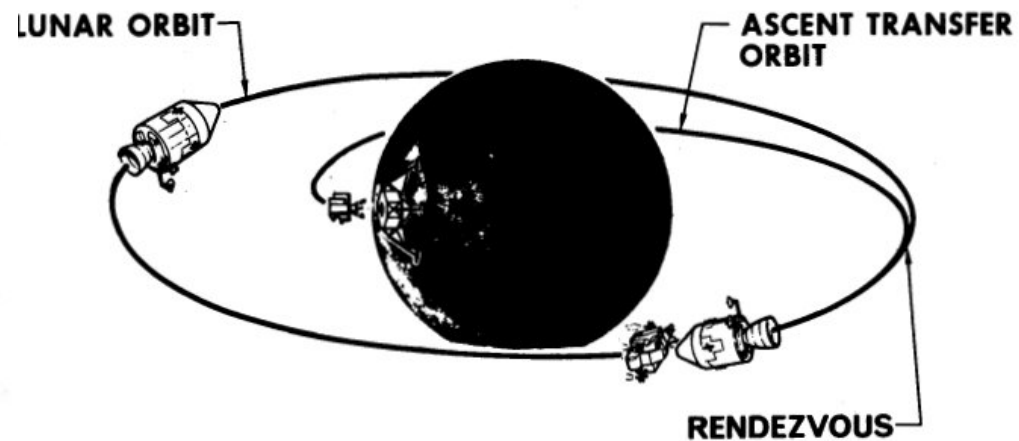
Elapsed time from lift-off, hr:min:sec	Time from ignition, min:sec	Event
104:25:13.0	-04:56.4	Landing radar on
104:30:02.0	-00:07.4	Ullage on
104:30:09.4	00:00.0	Ignition
104:30:35.9	00:26.5	Throttle to full throttle position
104:31:44.2	01:34.8	Manual target update (N69)
104:33:10.4	03:01.0	Yaw to face up
104:33:26.2	03:16.8	Landing radar range data good
104:33:38.2	03:28.8	Landing radar altitude data good
104:33:50.2	03:40.8	Enable landing radar updates (V57)
104:37:31.1	07:21.7	Throttle down
104:39:32.2	09:22.8	Approach phase program selected (P64)
104:39:39.0	09:29.6	Landing radar antenna to position 2
104:39:40.0	09:30.6	First landing point redesignation
104:40:13.0	10:03.6	Landing radar to low scale
104:41:08.7	10:59.3	Select attitude hold mode
104:41:10.2	11:00.8	Select landing phase program (P66)
104:42:28.6	12:18.2	Engine shutdown
104:42:29.3	12:19.9	Right side and forward foot pad contact
104:42:31.1	12:21.7	Final spacecraft settling

Ascent and LOR

(Step 8)



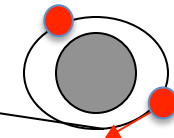
LEM ASCENT & LUNAR ORBITAL RENDEZVOUS



Milestones back to Earth...

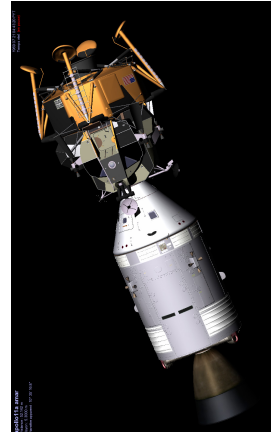


9 LEM jettison

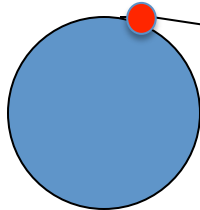


TEI burn 10

11 PTC during translunar flight



13 Rentry/Splashdown



12 Jettison CM

(34,000 mph)



Notable: The LM spinning out of control while 50,000 ft above the moon

APOLLO 10- The Dress Rehearsal

All but the landing; prove LOR

May 1969

Tom Stafford CMD
John Young CMP
Gene Cernan LMP



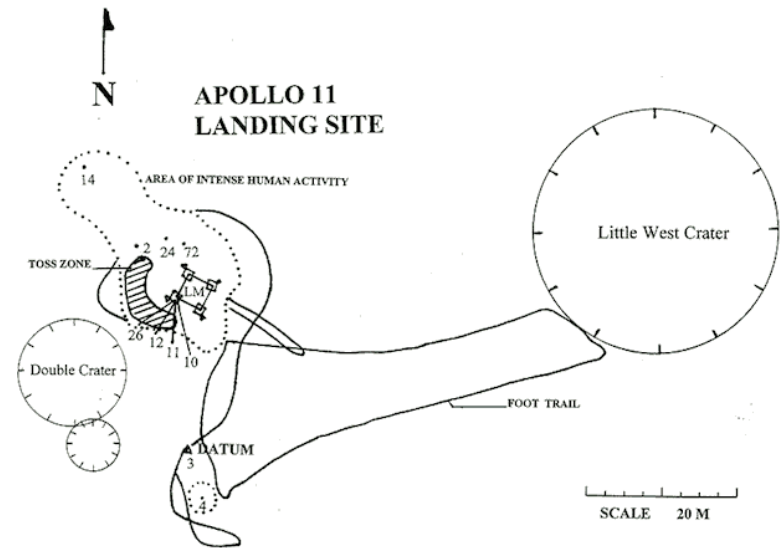
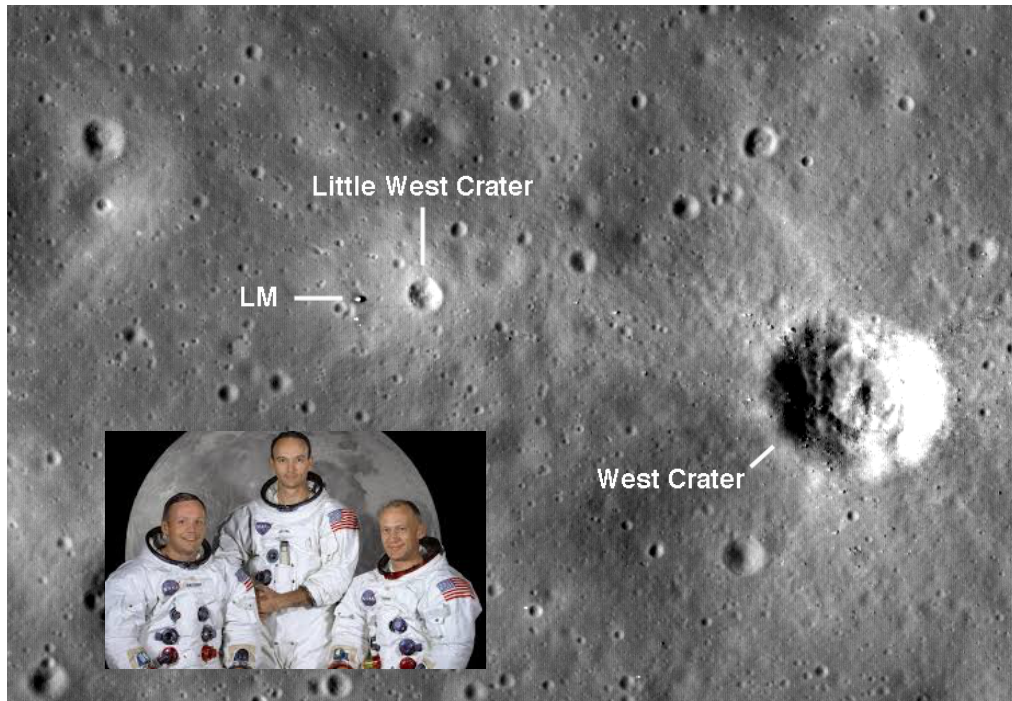
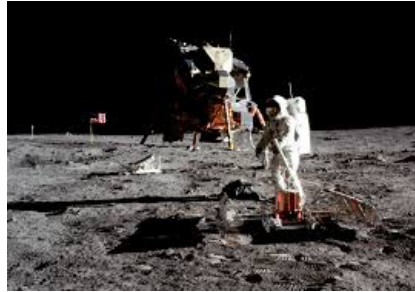
Notable: Yes

APOLLO 11- First on the Moon

Sea of Tranquility

July 1969

Neil Armstrong CMD
Mike Collins CMP
Buzz Aldrin LMP

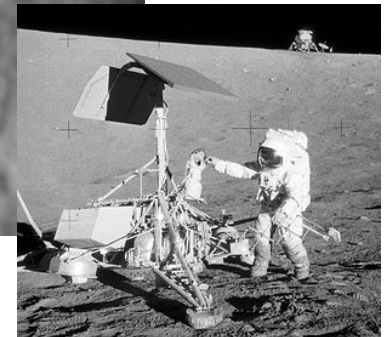
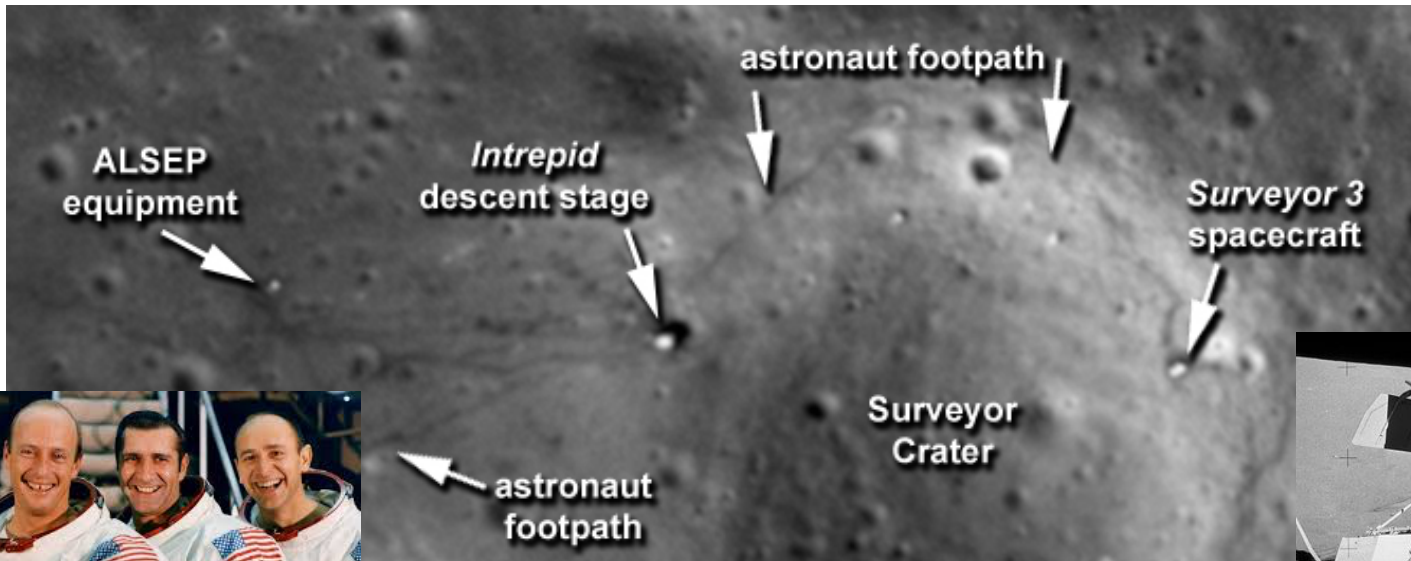
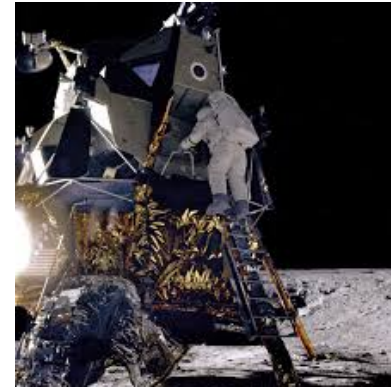
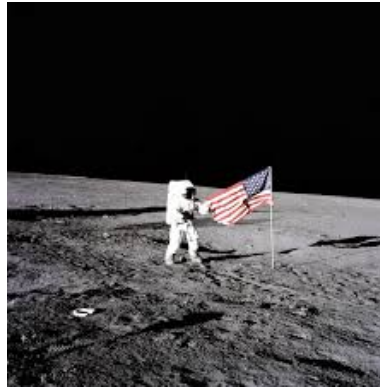


Notable: hit by lightning 2x during launch, lost CSM navigation platform
landed 300 yards from the target

APOLLO 12- First Precision Landing Ocean of Storms

November 1969

Pete Conrad CMD
Dick Gordon CMP
Allen Bean LMP

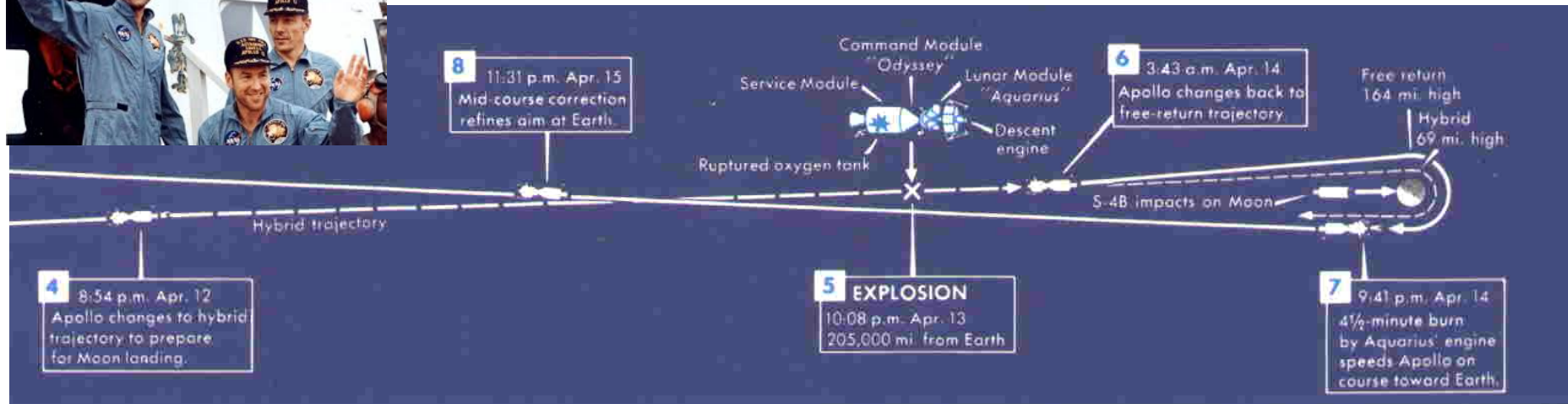


Notable: oxygen tank 2 exploded about 2/3rd on the way out to the moon

APOLLO 13- The Successful Failure (Fra Mauro – mission aborted)

April 1970

James Lovell CMD
Jack Swigert CMP
Fred Haise LMP

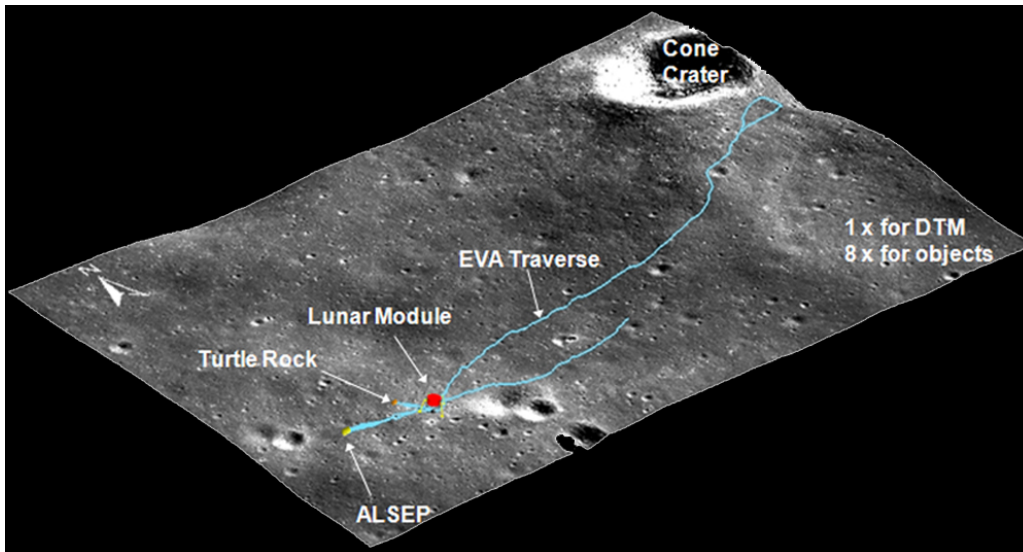
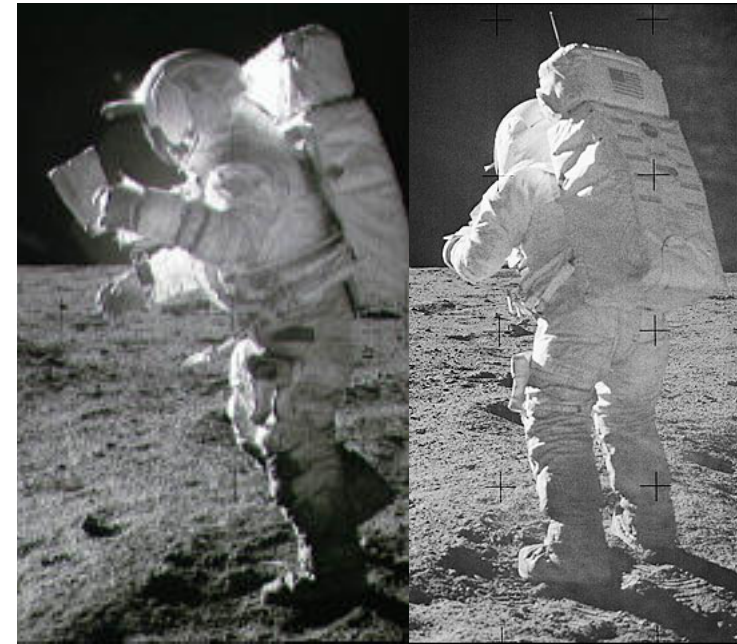


Notables: almost couldn't dock with the LEM on the way to the moon
landing radar would not acquire ranging data; 1st golf on moon

APOLLO 14- The Retread + Two Rookies

Fau Mauro Highlands February 1971

Alan Shepard CMD
Stu Roosa CMP
Edgar Mitchell LMP



Rock n Roll



Zep sports the Apollo 14 mission patch;
Note the “bullet” space craft from Jules
Verne’s *From the Earth to the Moon*



Zep airbrushes in Apollo 8 CMD Frank Borman
on the cover of their second album; they
mistakenly thought it was Neil Armstrong!

Google it if you don’t believe me.

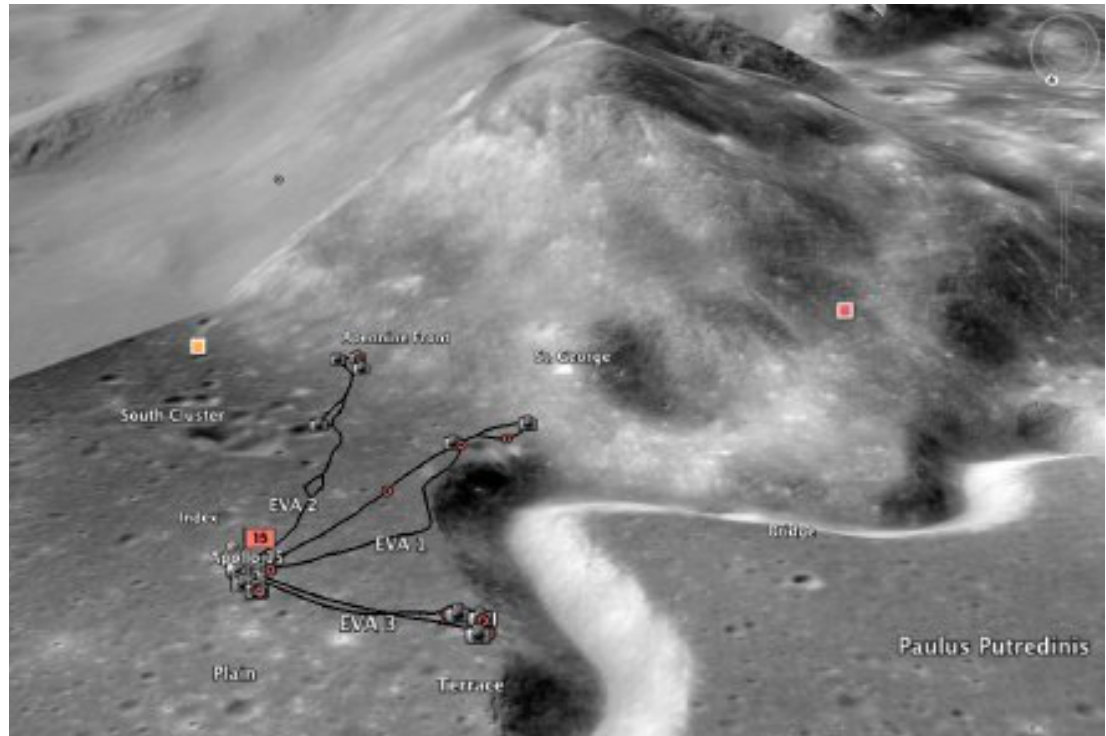
Notables: First Lunar Rover; Found the “Genesis Rock”

APOLLO 15- First Science Mission! Apennine Mountains / Hadley Rill

Dave Scott CMD
Al Worden CMP
James Irwin LMP



July/August 1971

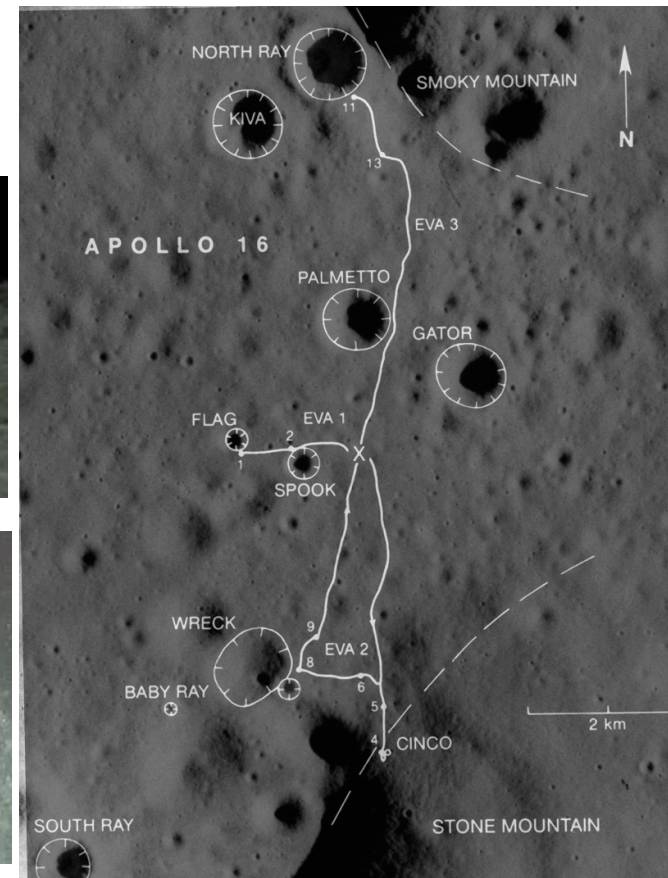


Notables: The John and Charlie Show. Ruled out volcanism.

APOLLO 16- Find Those Volcanoes Descartes Plains

John Young CMD
Ken Mattingly CMP
Charlie Duke LMP

April 1972

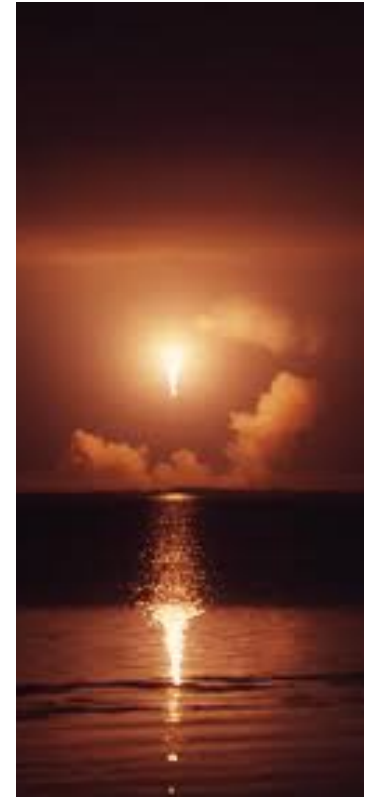
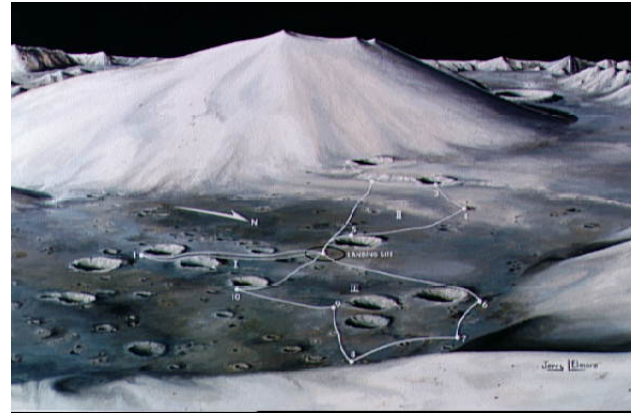
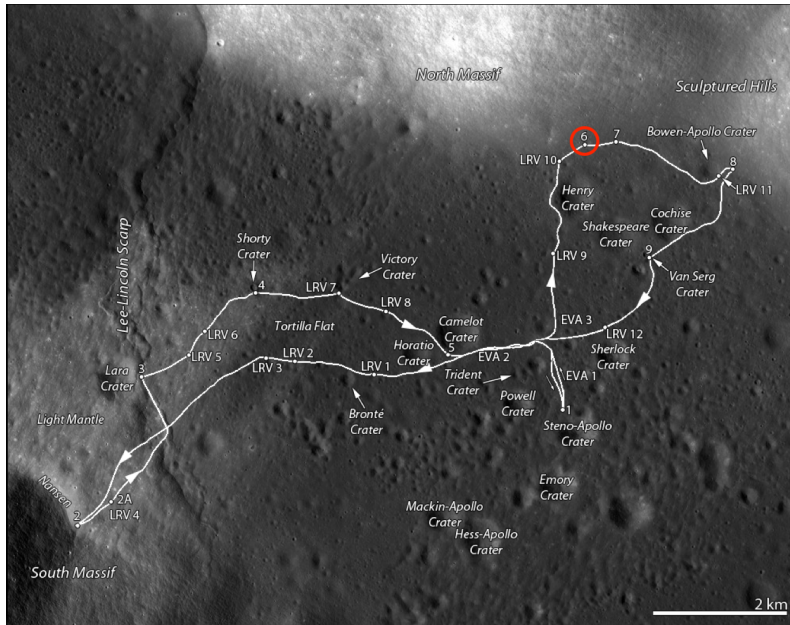


Notables: only night launch; first scientists/geologist on the moon

APOLLO 17- Geology on the Moon

Taurus-Littrow Highlands

Gene Cernan CMD
Rod Evans CMP
Jack Schmidt LMP
December 1972



When Apollo 11 made the successful landing, the funding and plan allowed for 9 more missions of greater and great complexity and longer stays. They were divided into H missions and J missions. Then the funding was cut for Apollo 18, 19, and 20, so NASA re-adjusted the schedule.

BEFORE THE BUDGET CUTS

Apollo 11 (G1) Mare Tranquilitatus

Apollo 12 (H1) Ocean of Storms

Apollo 13 (H2) Fra Mauro Highlands

Apollo 14 (H3) Littrow crater

Apollo 15 (H4) Censorinus Crater

Apollo 16 (J1) Descartes Highlands

Apollo 17 (J2) Marius Hills

Apollo 18 (J3) Copernicus Crater

Apollo 19 (J4) Hadley Rille

Apollo 20 (J5) Tycho Crater

AFTER THE BUDGET CUTS

Apollo 11 (G1) Mare Tranquilitatus

Apollo 12 (H1) Ocean of Storms

Apollo 13 (H2) Aborted

Apollo 14 (H3) Fra Mauro Highlands

Apollo 15 (J1) Apennines/Hadley Rille

Apollo 16 (J2) Descartes Highlands

Apollo 17 (J3) Taurus-Littrow Valley

In 1975, Apollo had one last mission- to conduct a docking with a Russian Soyuz spacecraft. The mission was called **Apollo-Soyuz**.

Alexi Leonov, the first man to walk in space, and **Deke Slayton**, the Mercury astronaut that was grounded with Afib, flew on this mission.

The first international handshake in space was between Tom Stafford and Alexi Leonov.

