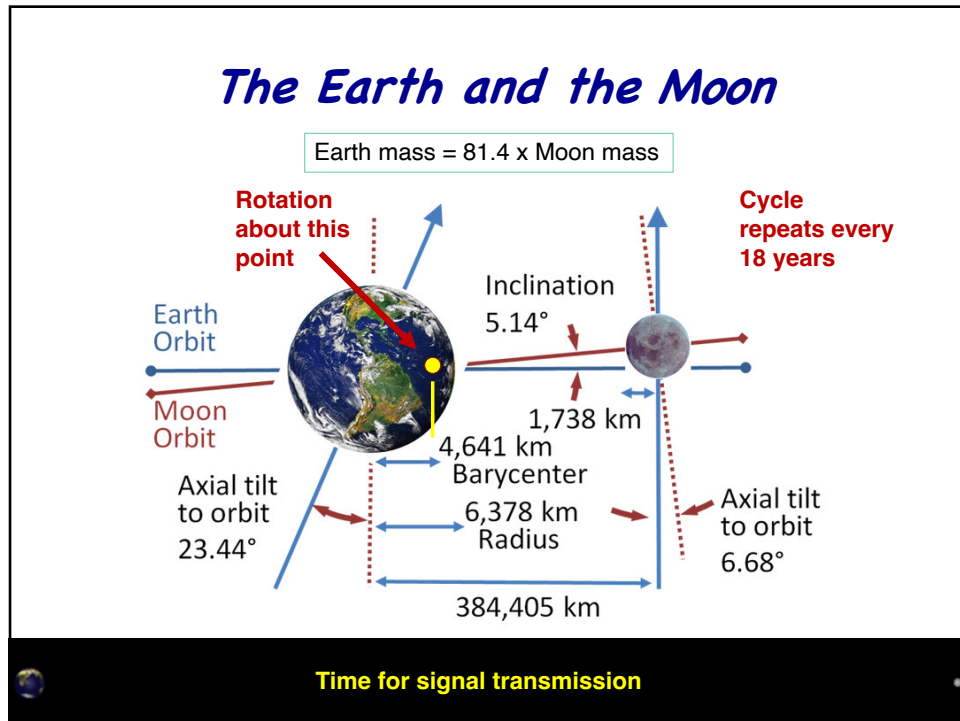




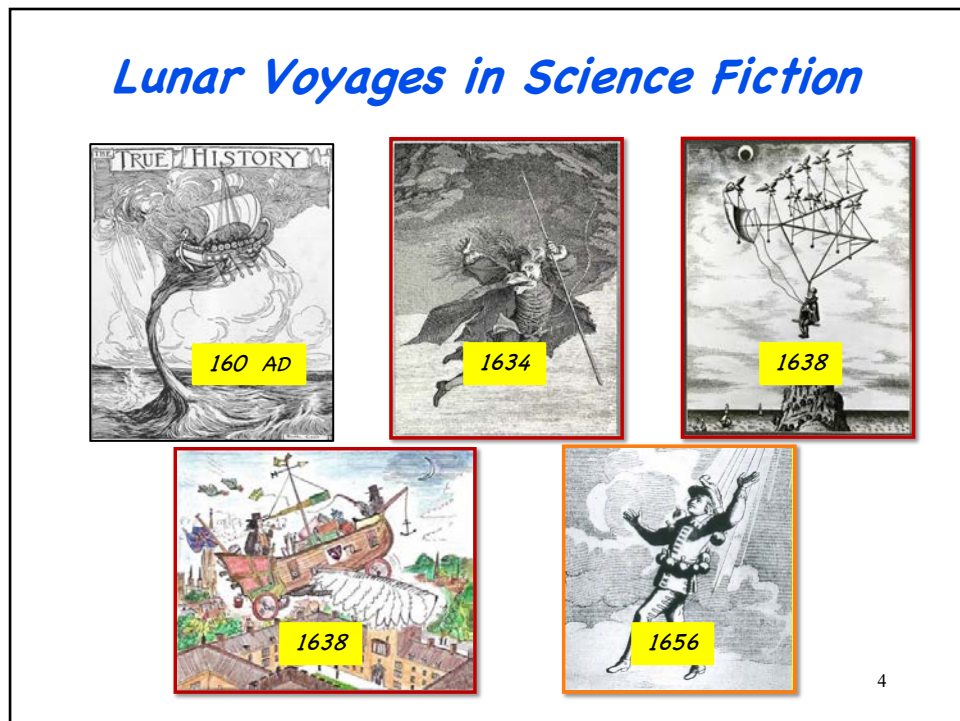
1



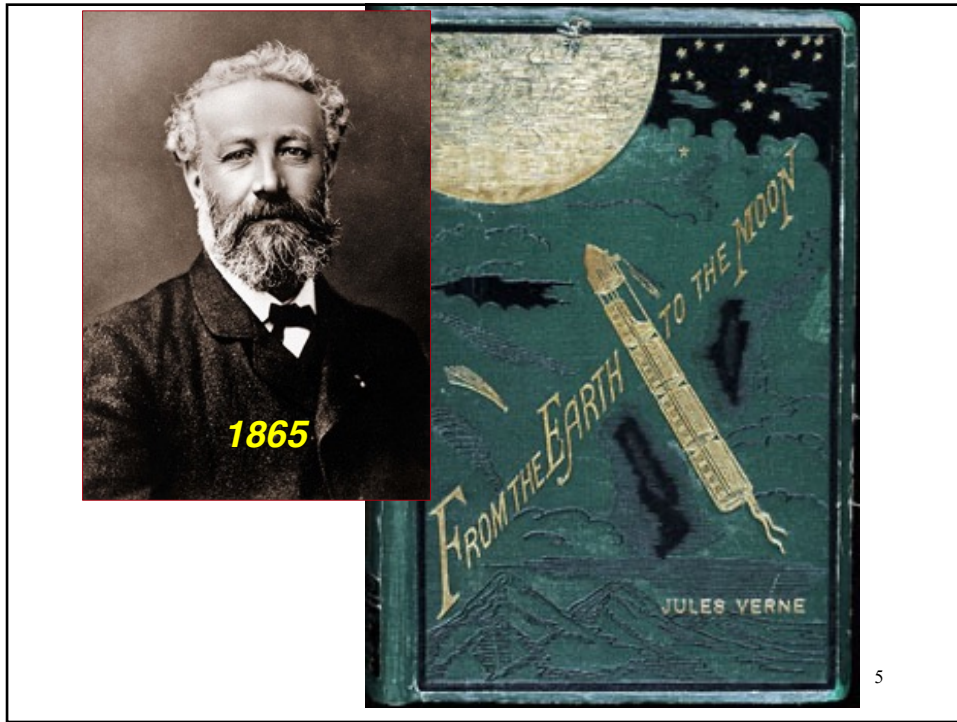
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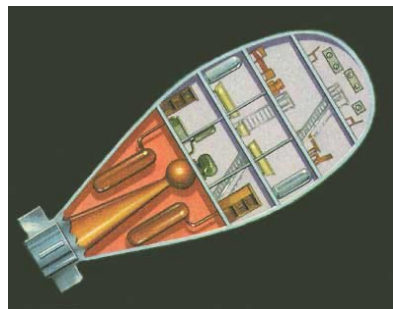
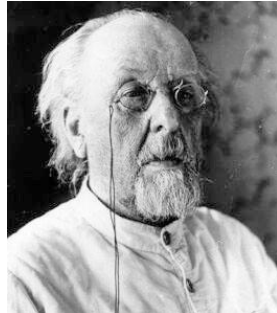


4



5

## Early Russian Rocketry



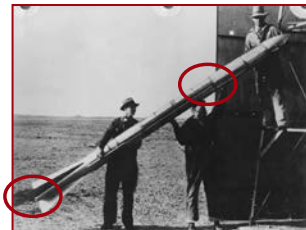
- **Konstantin Tsiolkovsky (1857-1935)** proposed liquid-fuel rockets, spacecraft, and spaceflight (1903)
- **Bolsheviks** established institutes for aerodynamics and rockets (1918)
- **Pre-WWII** development of airplanes and unguided missiles



6

6

## Early American Rocketry



- **Robert Goddard (1882-1945)**
  - Proposed flight to extreme altitude (1917), Built 1<sup>st</sup> liquid-fuel rockets
  - Criticized by New York Times
  - Introduced *gyro steering and control vanes* (~1935)
- **Rocket clubs, US and abroad**
- **Pre-WWII development of airplanes and unguided missiles**



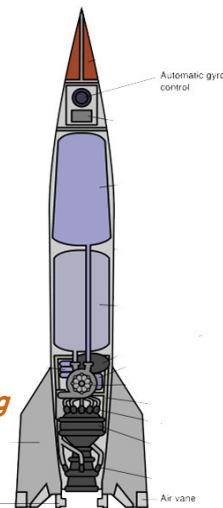
7

7

## German Army Rocket Team



- **Wernher von Braun (1912-1977),**
  - German Rocket Society -> Army Lab
- **V-2 Rocket, guided missile (1942)**
  - von Braun directed development
  - Pre-programmed trajectory, Gyro steering and control vanes [after Goddard]
  - Psychological impact but inaccurate
- **Foundational for post-WW II rocket development in USA and USSR**



8

8

## Post-World War II US Rocketry

US and USSR built on V-2 technology

- Nuclear weapons changed the world of defense
- 1945-54: Beginning of COLD WAR
  - Guided ballistic missiles: IRBMs, ICBMs
  - Von Braun team to USA
  - Gröttrup team to USSR
- Redstone missile based on V-2
- 1954: Russia's closed society:
  - Need for military surveillance satellites
- Ballistic missiles were enabling technology for spaceflight



9

9

## Post-WW II Science Fact and Fiction Catalyzed human imagination

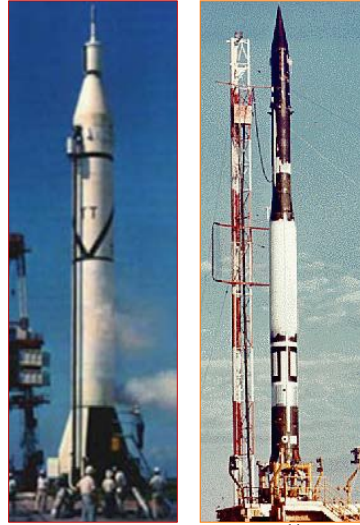


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## US Cautious About Satellite Launch

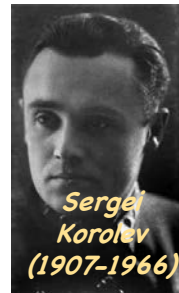
- **International Geophysical Year, '57-'58**
  - Scientific "artificial" satellite
- **Distinct military and civilian programs**
  - Secrecy vs. public information
- **Contenders for satellite launch**
  - **Project Orbiter based on Redstone**  
[Army Ballistic Missile Agency]
  - **Project Vanguard based on Viking**  
[Martin Co., Naval Research Lab]
- **Eisenhower's reluctance**
  - Political implications of OVERFLIGHT
  - Evolution of Missile or Sounding Rocket for IGY satellite launcher?



11

## R-7: First ICBM Tested (August 21, 1957)

- **Oct 4, 1957: USSR launches 1<sup>st</sup> satellite for IGY with R-7**
- **Solved the US overflight quandary**
- **The SPACE RACE had begun**
- **CCCP won the 1<sup>st</sup> round with MISSILE**
- **AND it unsettled the American public**



12

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**NEW YORK**  
**Herald Tribune**

this day in history:

My God in Heaven!  
It's...it's...

COMMUNISM!

October 4, 1957

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Established in New York 1848

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## Vanguard and Explorer

Vanguard TV3,  
December 1957

Explorer I success,  
January 1958\*

\* von Braun's Project Orbiter

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**NASA**  
SPACE TASK GROUP

December 17, 1958

**PROJECT MERCURY  
BALLISTIC CAPSULE**

**PUBLIC**  
Mercury 7, 1959

**SECRET**  
1st Cosmonaut Class, 1959

15

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April 12, 1961

**Feature Index**

Star	11	Editorial	4
Announcements	4	Sports	21
Arts	21	Service	3
Classified	28	Special Ads	26
Jobs	11	Radio-TV	28

25 PAGES TODAY

**The Huntsville Times**

HUNTSVILLE, ALABAMA, WEDNESDAY, APR. 12, 1961

Where Progress...

Covers The Valley!

**Man Enters Space**

**'So Close, Yet So Far,' Sighs Cape U.S. Had Hoped For Own Launch**

CAPE CANAVERAL, Fla. (AP) — The Redstone rocket which the United States had hoped would boost the first man into space stands on a launching pad here. The Soviet Union beat its firing date by at least two weeks.

**Vostok 1**

**CCCP wins 2nd round of SPACE RACE**

**Soviet Officer Orbits Globe In 5-Ton Ship Maximum Height Reached Reported As 188 Miles**

MOSCOW (AP)—A Soviet astronaut has orbited the globe for more than an hour and returned safely to receive the plaudits of scientists and political leaders alike. Soviet announcement of the feat brought praise from President Kennedy and U.S. space experts left behind in the contest to put the first man into successful space flight.

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16



**April 20, 1961**

**JFK to LBJ**

- *What can the US do to show technical supremacy?*
- "Do we have a chance of beating the Soviets ... to the moon and back with a man?"

**April 28, 1961**

**LBJ to JFK**

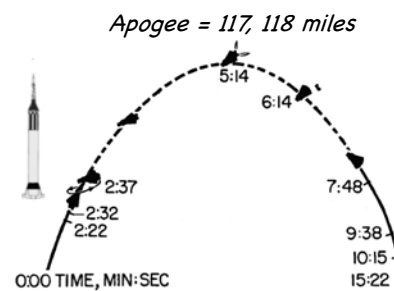
- "Neither the US nor the USSR has such capability... However, with a strong effort, the US could conceivably be first ... by 1966 or 1967."

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## **Mercury-Redstone Sub-Orbital Flights** **May 5 & July 21, 1961**

**Alan Shepard**  
**Gus Grissom**



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# Project Mercury Orbital Flights February 20, 1962 - May 15, 1963



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# Project Gemini [1965-66]



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# Lunar Missions

*Command-Service  
Module*



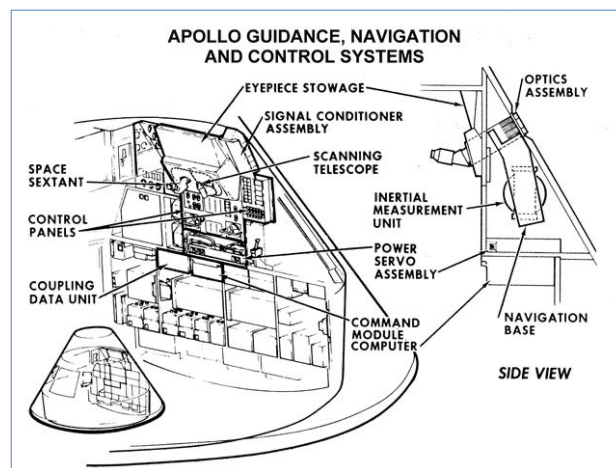
*June 1961*

- *NASA indecision about contractors for the spacecraft and launch rockets*
- *No indecision about design of guidance, navigation, and control system*

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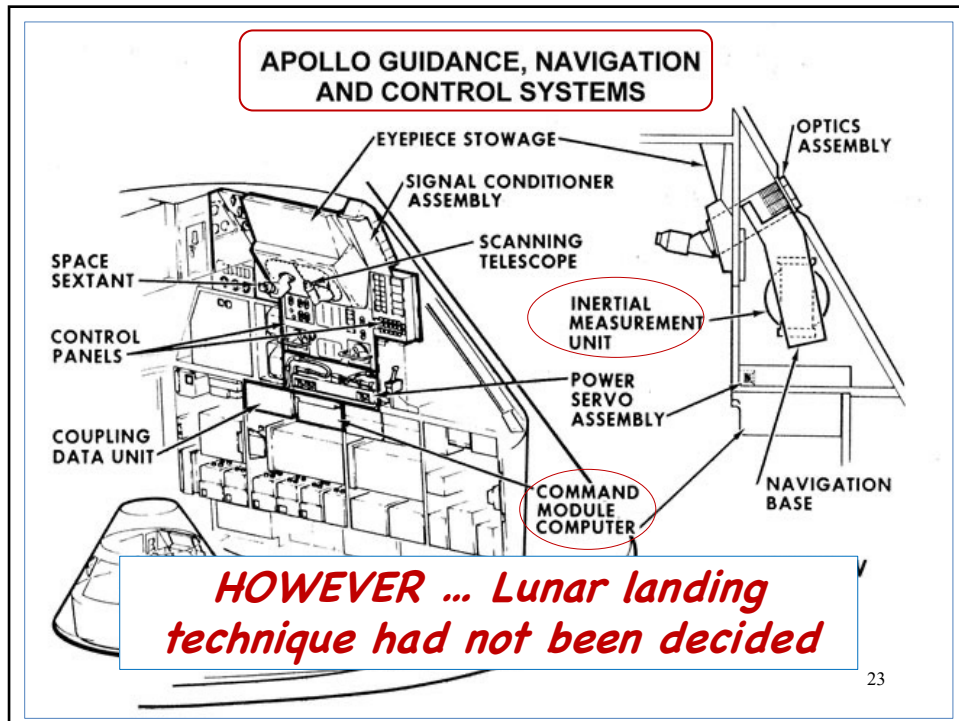
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## *First Apollo Program Contract MIT Instrumentation Laboratory August 9, 1961*

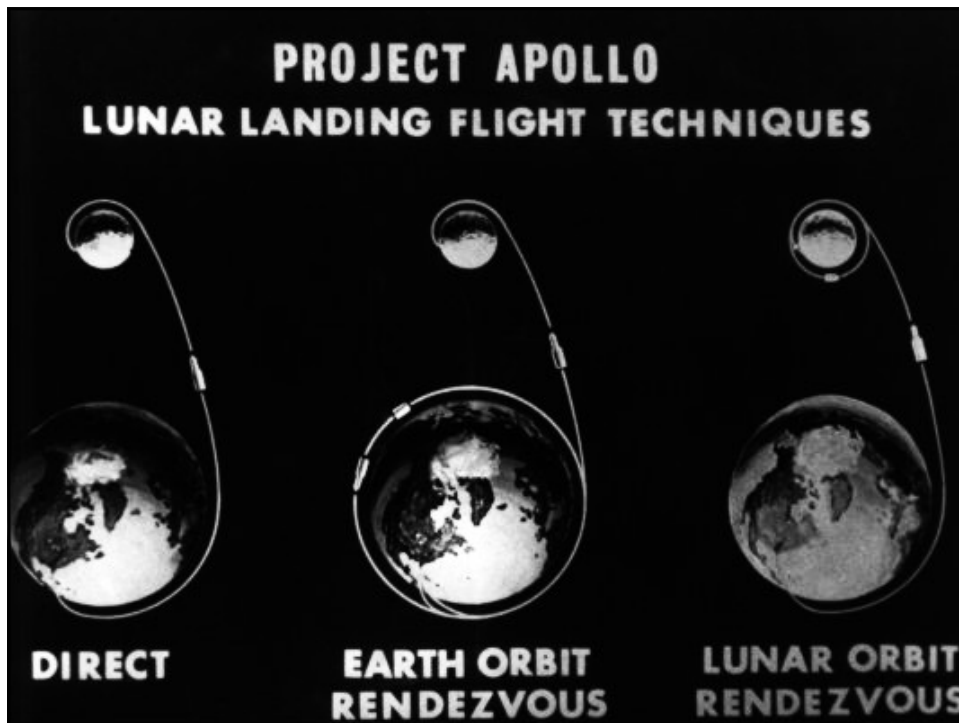


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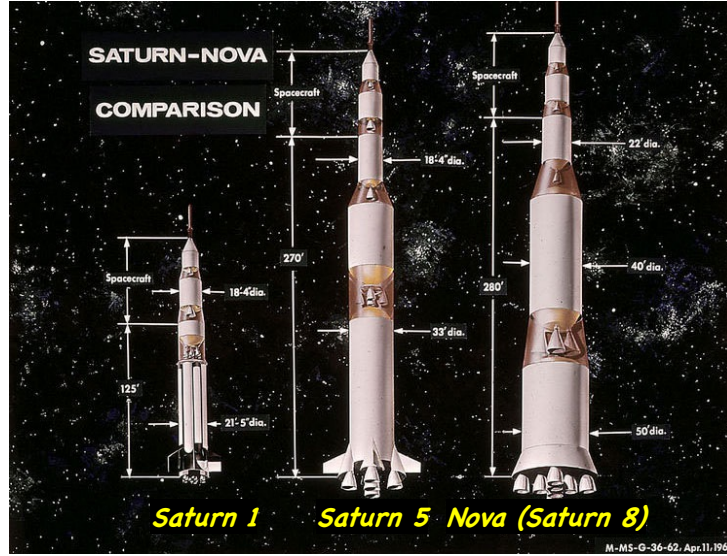


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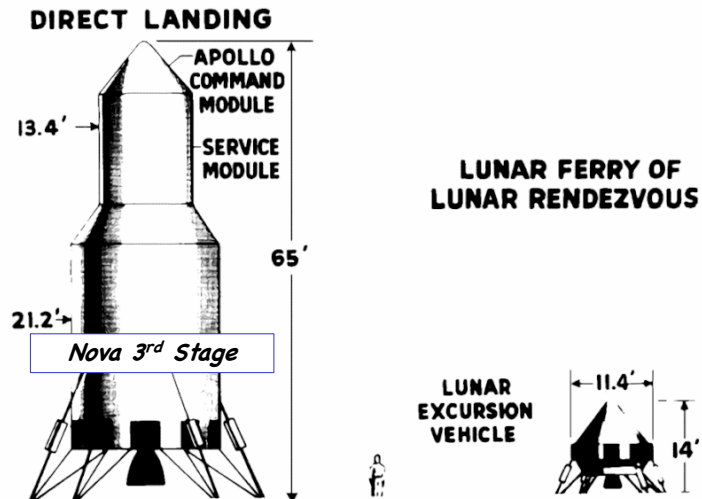
## Proposed Saturn Launch Vehicles



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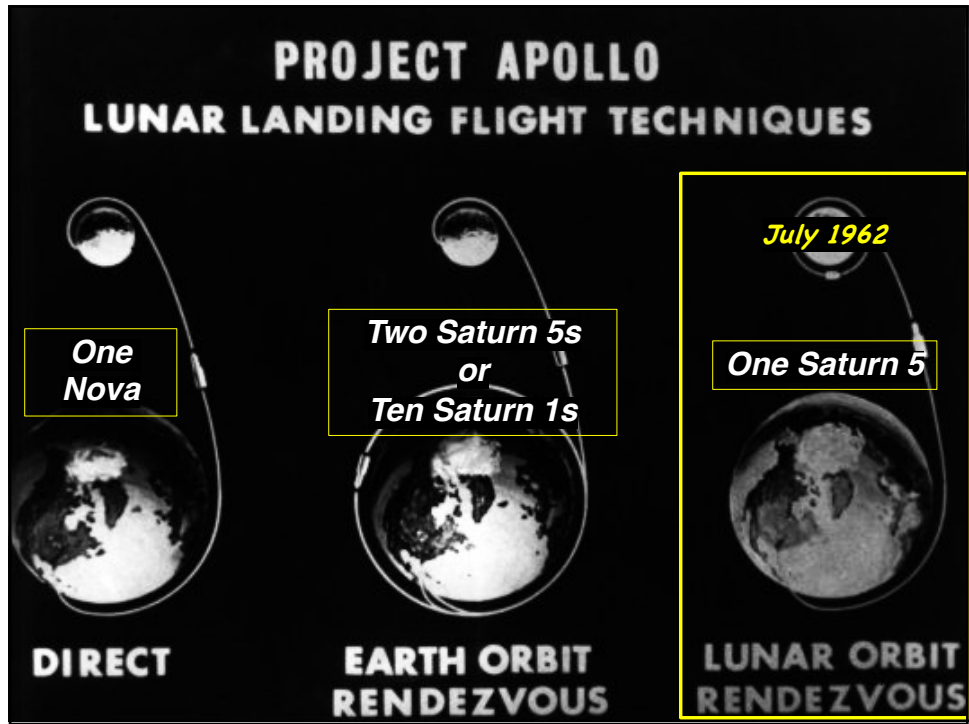
## Alternative Landers

### COMPARISON OF LANDER SIZES

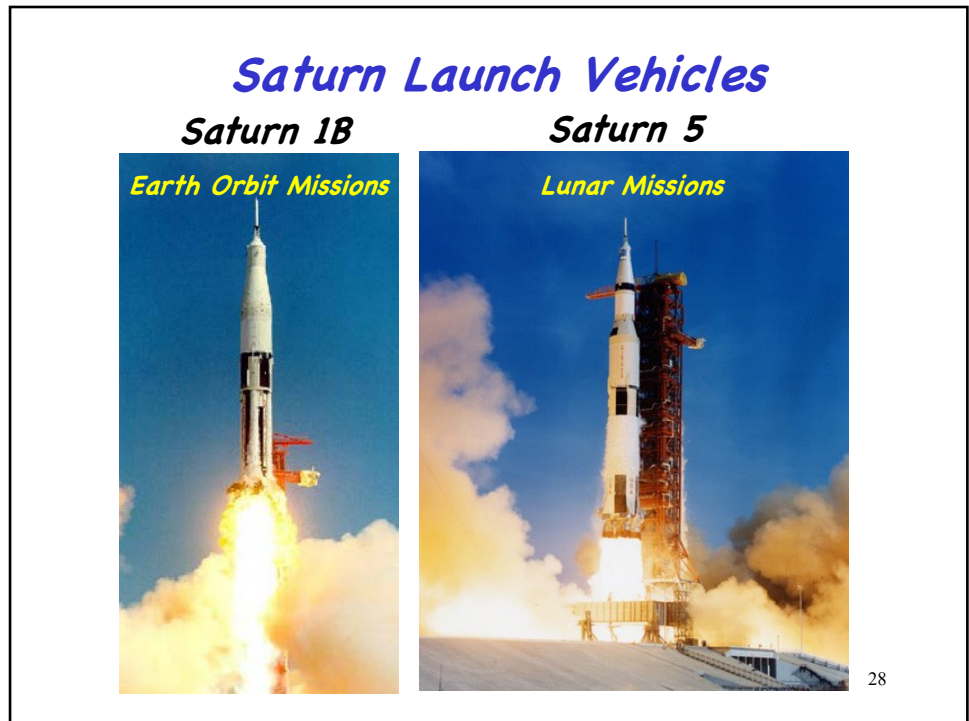


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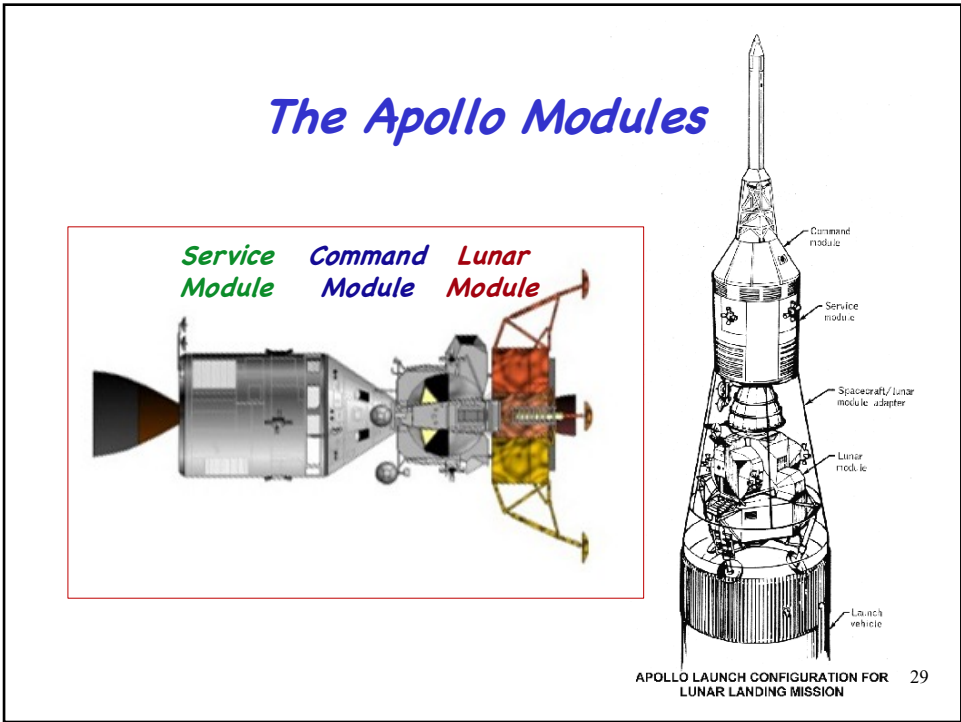
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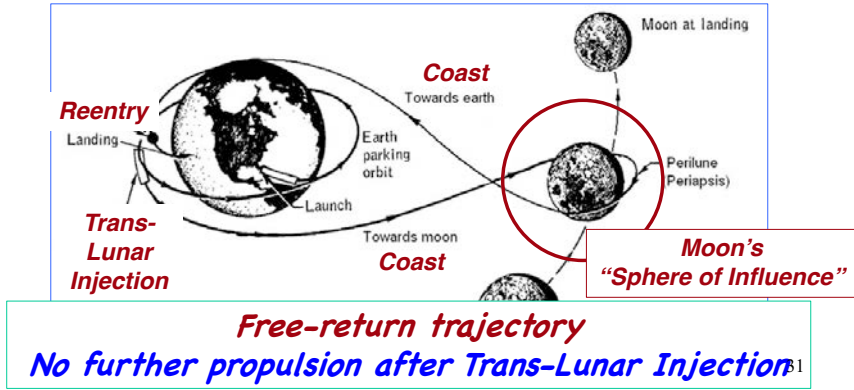
29



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## Apollo 8, December 21-27, 1968

- **Earth-orbit** mission to test LM planned
- Repurposed to **1<sup>st</sup> manned flight to the Moon**
- **6-day mission, no Lunar Module**
- **WHY?**



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## August 1968, CIA KH-8 GAMBIT Reconnaissance Satellite

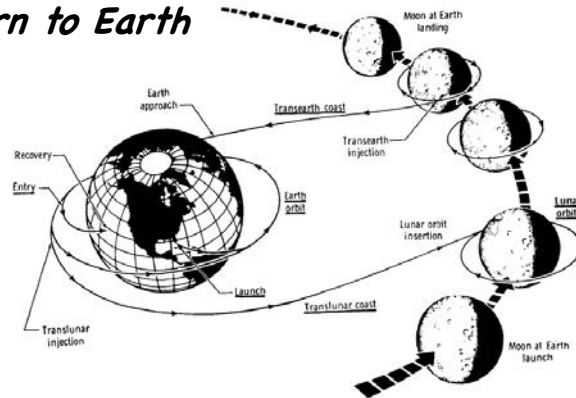
**N-1 Rocket: Russia was indeed racing for the Moon**

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## *Apollo 8 Entered Lunar Orbit*

- *More daring alternative*
- *Rocket fired on far side for **Lunar-Orbit Insertion; no free return***
- *Rocket had to **fire again on far side to return to Earth***



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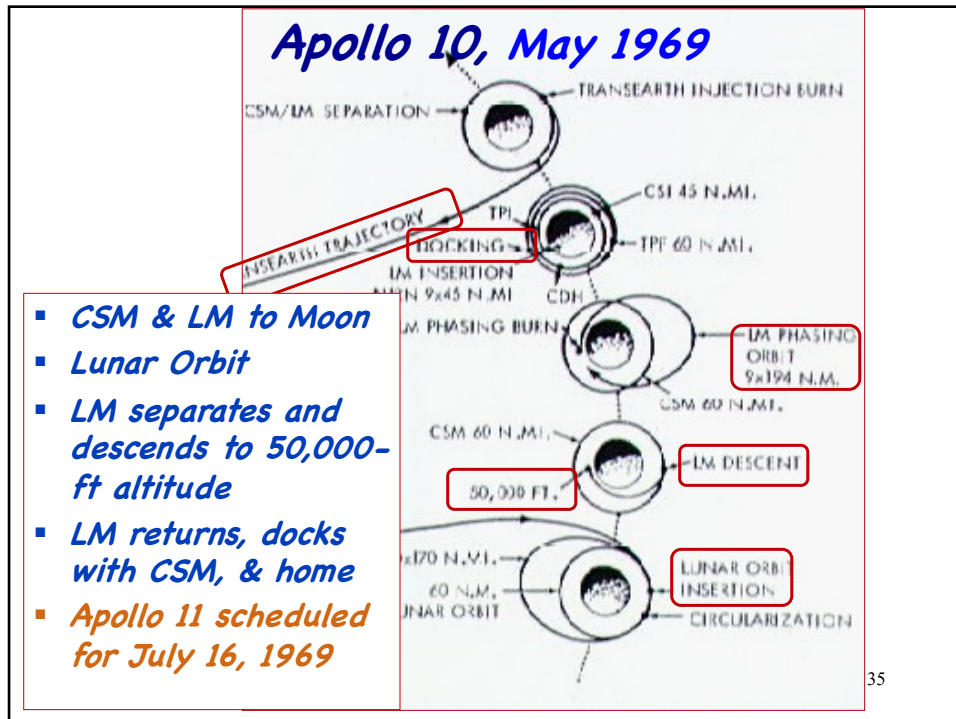
## *Apollo 9 March 1969*

*Earth-orbit test of Lunar Module, rendezvous, and docking*



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### 2<sup>nd</sup> N-1 Launch Attempt, Unmanned Lunar Fly-By, July 3, 1969

*Saturn 5    N-1*

- *Oxygen pump explosion*
- *Launch site demolished*

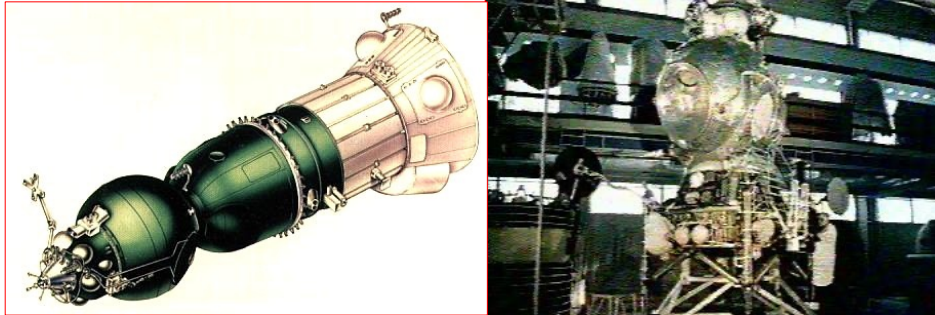
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## *Soviet Manned Lunar Spacecraft, revealed in 1989*

*Soyuz 7K-LOK,  
2-man CSM*

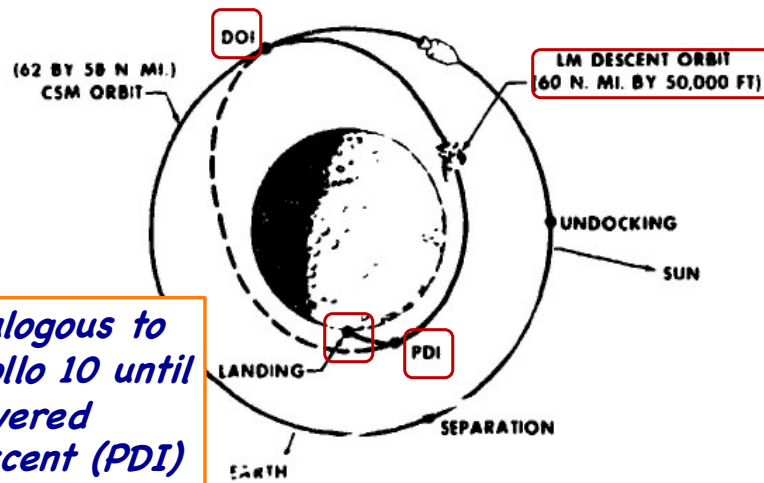
*LK, 1-man  
Lunar Lander*



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## *Lunar Module Transfer Ellipse to Powered Descent Initiation*

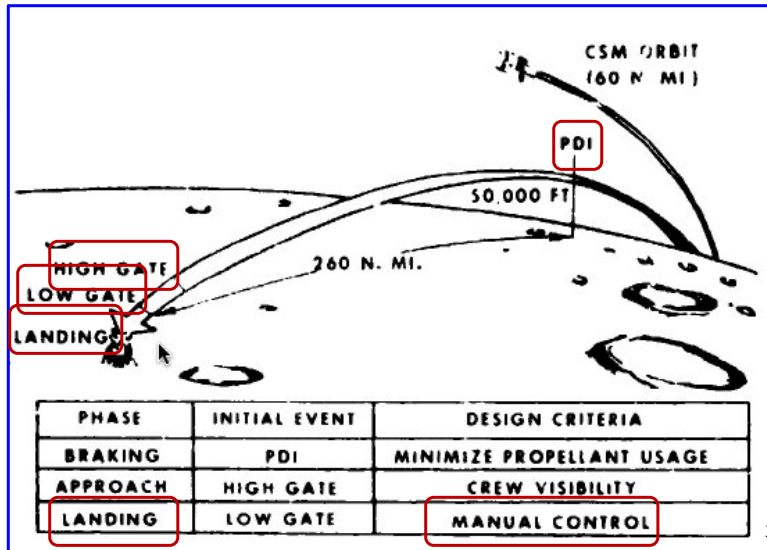


▪ *Analogous to Apollo 10 until Powered Descent (PDI)*

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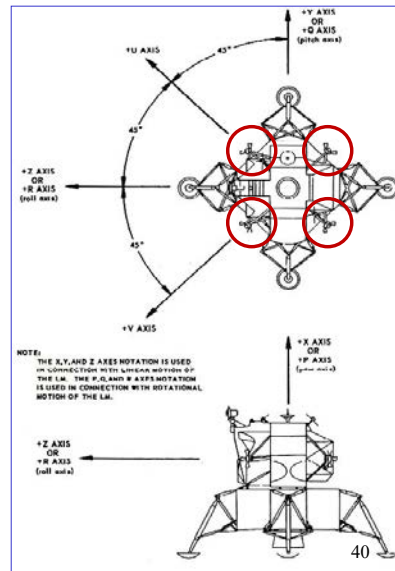
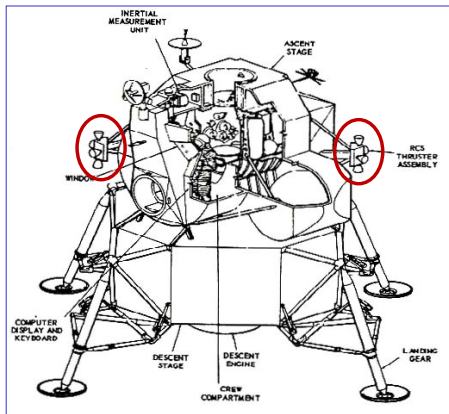
## Landing on the Moon July 20, 1969



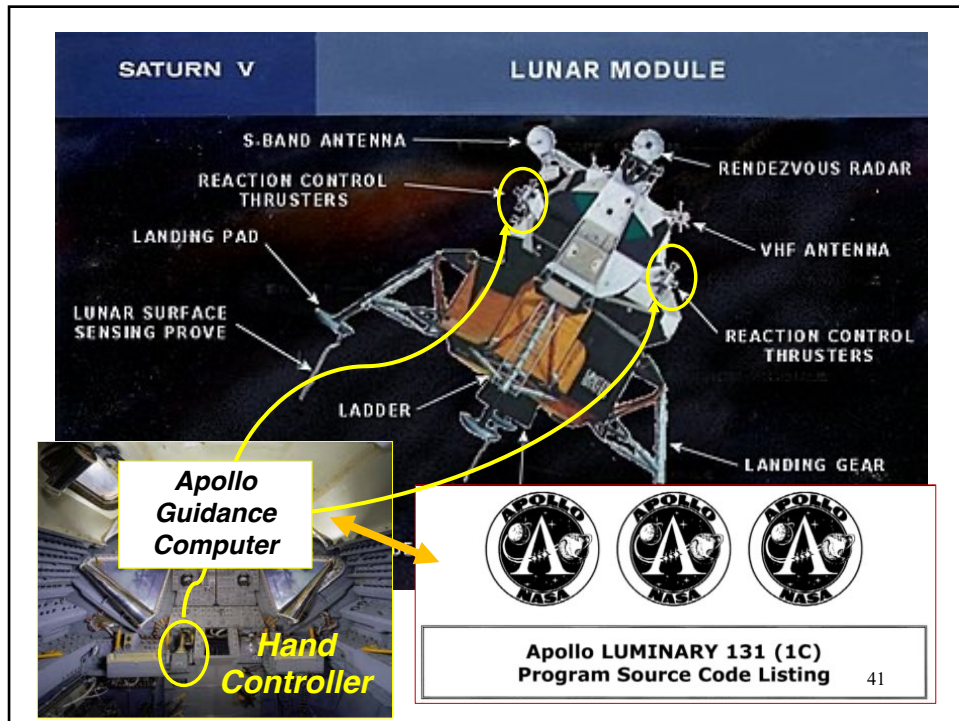
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## Lunar Module Attitude Control

- 16 reaction control thrusters
  - Control about 3 axes
  - Redundancy of thrusters
- LM Digital Autopilot





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## Apollo Guidance Computer (AGC) vs. 2024 USB-C Charger

<ul style="list-style-type: none"> <li>▪ 16-bit computer, \$1.5M today</li> <li>▪ Storage: 38,332 words</li> <li>▪ Speed: 1 million "ticks" per sec</li> <li>▪ Weight: 70 lb</li> <li>▪ 1<sup>st</sup> integrated-circuit computer</li> <li>▪ <u>Plus</u> Inertial Measurement Unit</li> <li>▪ <u>TWO</u> per mission (CSM and LM)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Anker Charger, \$20</li> <li>▪ 16-bit computer</li> <li>▪ 2 x RAM Storage</li> <li>▪ 4 x ROM Storage</li> <li>▪ 563 times faster</li> <li>▪ 6.7 ounces</li> </ul>
---	--

<https://forrestheller.com/Apollo-11-Computer-vs-USB-C-chargers.html#:~:text=The%20Anker%20PowerPort%20Atom%20PD2%20has%20a%20little%20over%20twice,done%20in%2016%2Dbit%20words.>

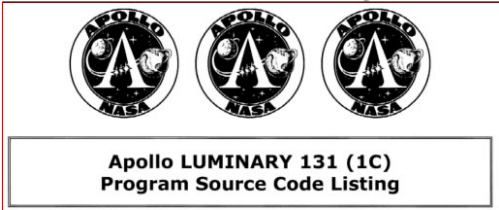
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## A Little AGC Digital Autopilot Code

```

CA 40CYC
TS TCP
TC PEGI
CA RCSFLAGS CHECK FOR DIRECT RATE COMMAND LAST TIME.
MASK PBIT
EXTEND
BZF +2
TC PEGI
CA DXERROR TO PURE RATE COMMAND
TS E PSEUDO-AUTO CONTROL.
TS PERROR X-ATTITUDE ERROR (SP)
TC PURGENCY +4 LOAD P-AXIS ERROR FOR MODEL F0A1 DISPLAY
DIRECT RATE CONTROL.
CA CDUX
TS CDUXD
CA ZERC
TS DXERROR
TS DXERROR +1 ZERC P-AXIS ERROR FOR MODEL F0A1 DISPLAY
TS PERROR
CCS EDDTP
TC +3
TC +2
TC +1
TS ABSEDDTP
AD TARGETDB
EXTEND
BZMF LAST
CA TCP
EXTEND
BZMF LAST
CS RCSFLAGS
    
```



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## Low Gate to Touchdown

[HBO dramatization, "From the Earth to the Moon"]



Armstrong's comment on manual control:  
"As anticipated, quick and responsive."

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## Apollo Landing Missions ('69-'72)



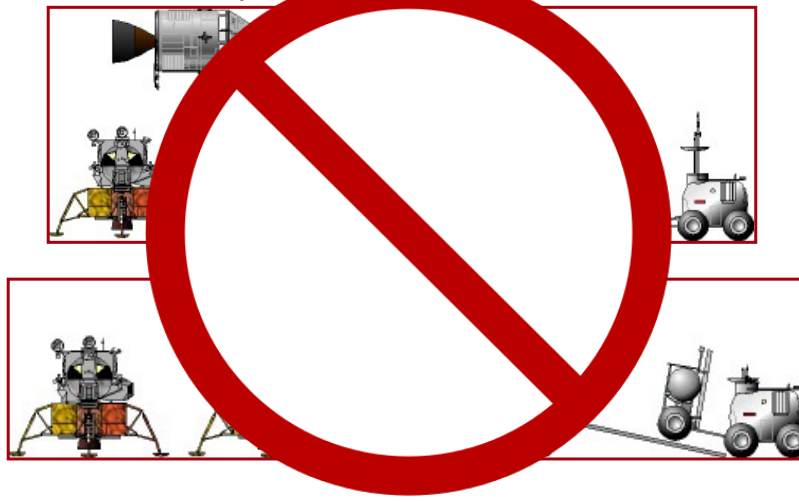
45

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## Proposed Apollo Applications Program Flights

Saturn 5 payload to lunar orbit: 50 tons

Apollo Earth Return Vehicle Lunar Base



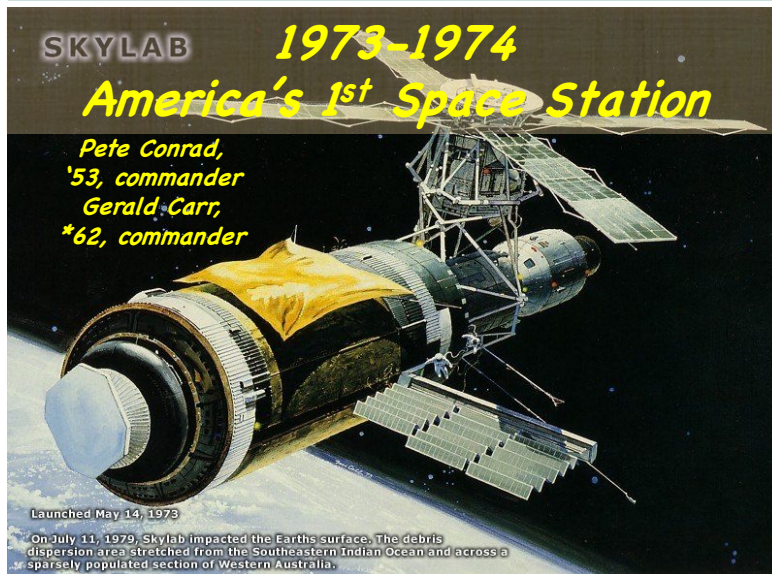
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## Proposed Apollo-Derived Venus Flyby



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### *SKYLAB based on Venus Flyby Workshop Module*



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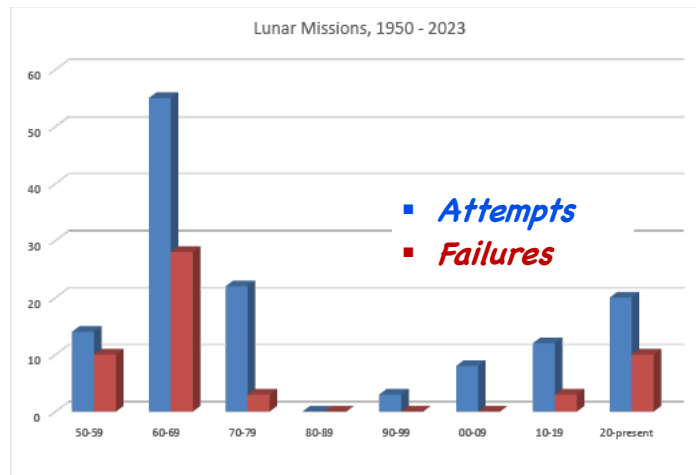


# *The Legacy*

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## *134 Lunar Missions, 1958-2023*



*Resurgent interest in lunar missions*

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## *Why Return to the Moon?*

- ***Science: lunar geology and astronomy***
    - *Technological Development*
    - *Educational Benefit*
    - *Economic Stimulus*
  - ***International Competition & Leadership***
- 
- ***Robots?***
    - *Preliminary exploration*
    - *Search for WATER and raw materials*
  - ***Humans?***
    - *Long-term utilization of lunar resources*
    - *Dealing with uncertainty*

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## *Where is the Water?*



*Valleys and craters near the North/South Pole*

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## Recent Robotic Lunar Landers



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## NASA Artemis Program



- 30-year delay
- Constellation Program, 2005-2009
- Inadequate funding, 45-year delay
- Reborn as Artemis Program, 2017

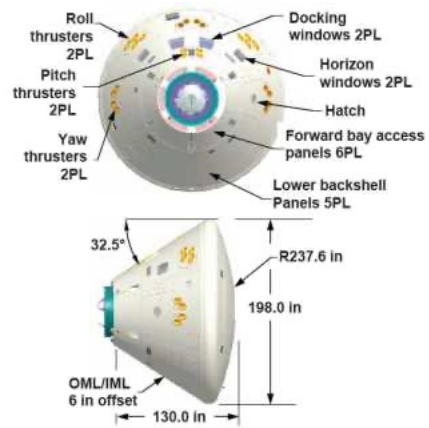
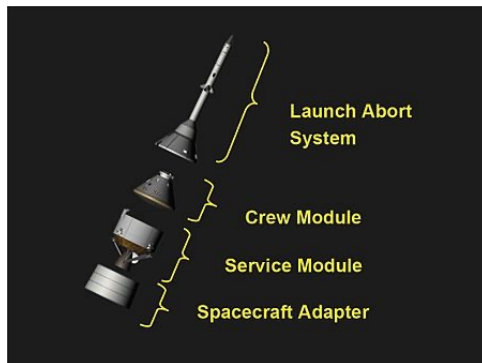


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## NASA Orion Spacecraft

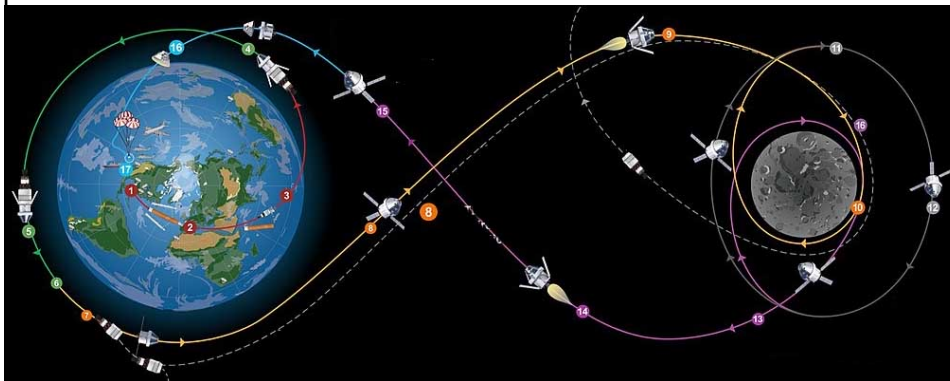
- Larger equivalent of Apollo CSM



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## NASA Artemis 1, 2022 Uncrewed ORION to Lunar Orbit

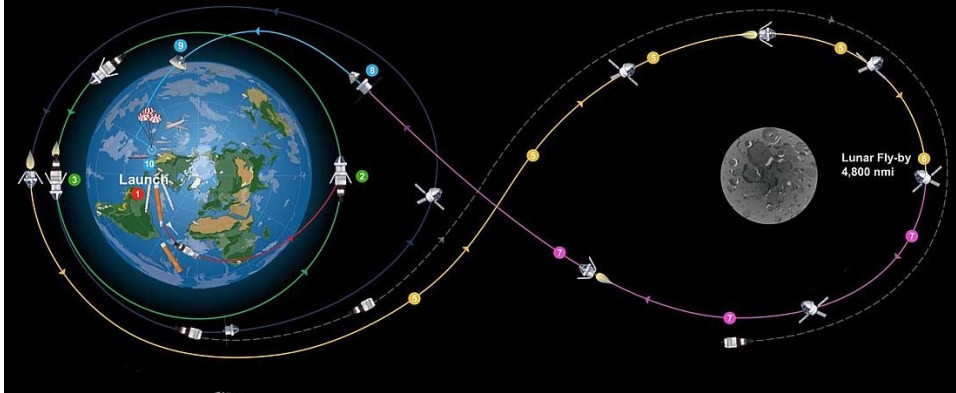


- 5-year delay (from 2017)
- Lunar orbit (~Apollo 8) and return
- 13 CubeSats deployed

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## NASA Artemis 2, 2025 ORION with 4-person crew



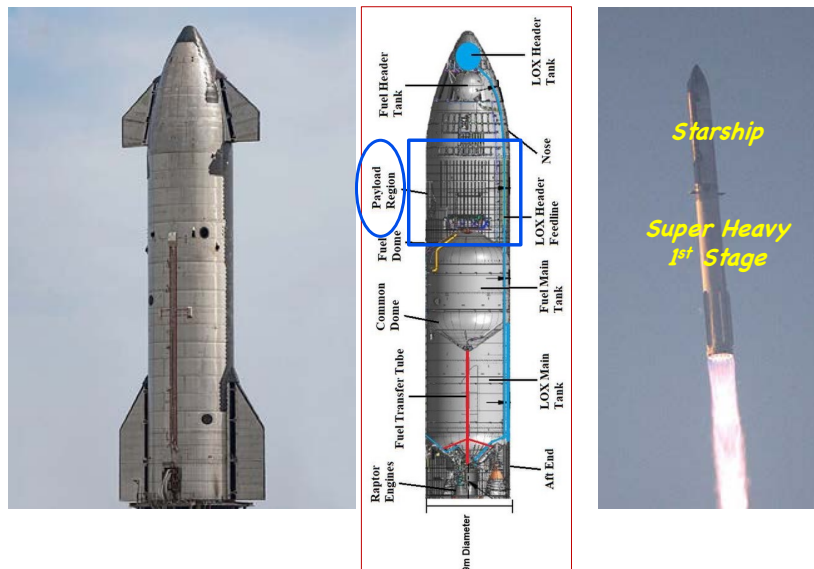
- 3-year delay
- Two ICPS burns to raise orbit
- One ORION rocket burn to circle the Moon
- Free return

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## SpaceX Starship, Super Heavy Rocket

*Proposed Lunar Lander and Propellant Carrier for Artemis 3 & 4 Missions*



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## NASA Artemis 3, 2027 (?) Orion/Starship, 4-person crew

**Artemis III Concept of Operations**

- NASA and SpaceX have not revealed details
- Earth-Orbit and Lunar-Orbit Rendezvous
- 2 astronauts land on the Moon
- One week stay
- Starship payload to lunar landing: 100 tons
- Empty mass: 100 tons, returned to orbit
- Fully reusable
- SLS payload to lunar orbit: 42 tons
- Only Orion is reusable

Propellant aggregation    HLS Starship launches    Extended loiter if needed    Orion launch    Variable Stay on the Moon    Crew returns to Orion

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## Artemis Program LUNAR LANDING FLIGHT TECHNIQUES

*One Nova*

**DIRECT**

*Artemis*

**One SLS,  
One Starship,  
AND  
? Cargo  
Starships**

**EARTH ORBIT  
RENDEZVOUS**

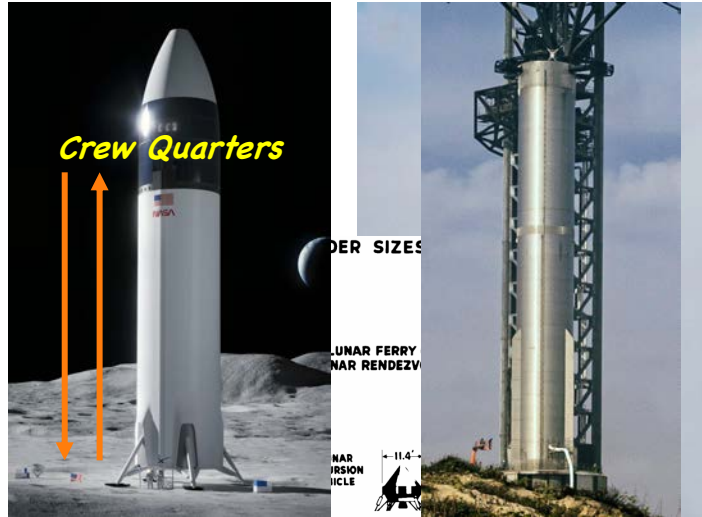
*July 1962*

**One Saturn 5**

**LUNAR ORBIT  
RENDEZVOUS**

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*Comparison of pre-Apollo Lander, Artemis Starship Lander, and Super Heavy*



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**Michael Griffin**  
**Congressional Testimony**  
 January 17, 2024

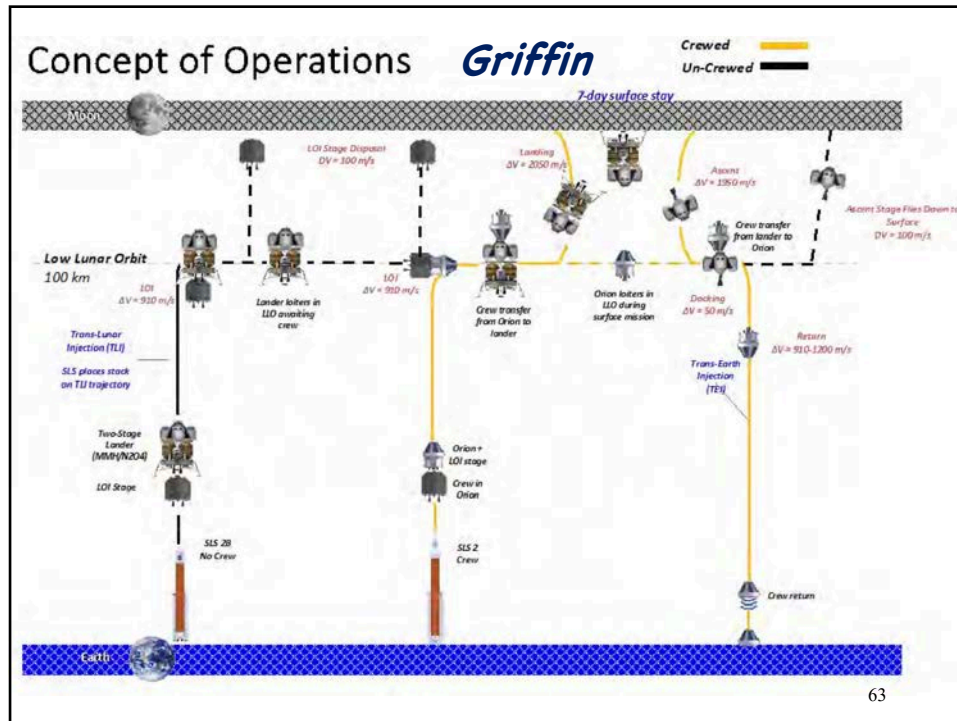
- *Former NASA Administrator, 2005-2009*
- *Artemis Program is severely under-budgeted (about 1.5% of Apollo's cost in current \$)*
- *"impractically large number of orbital refueling operations for even a single lunar mission"*

**Artemis Reliability of n Operations**

Reliability of One Operation	Number of Operations			
	5	10	15	20
99%	0.95	0.90	0.86	0.82
98%	0.90	0.82	0.74	0.67
97%	0.86	0.74	0.63	0.54
96%	0.82	0.67	0.54	0.44
95%	0.77	0.60	0.46	0.36

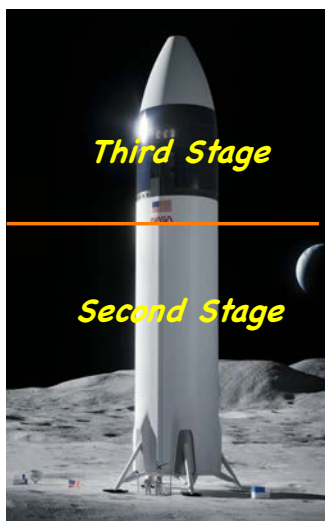
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## *Starship II, A 2-Stage Alternative*



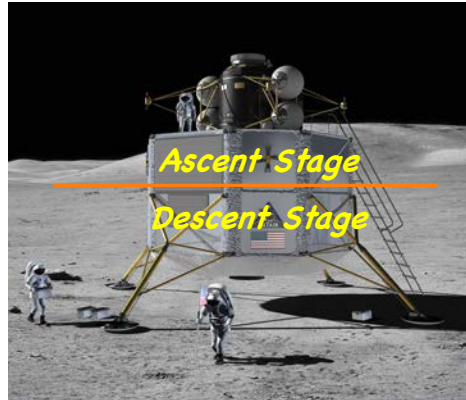
- **Novel concept**
- **Same net weight as Starship**
- **Launched by Super Heavy**
- **Payload ratio increased by 100%**
- **Final stage contains conventionally configured Lunar Module (i.e. Altair)**
  - **Ascent Stage**
  - **Descent Stage**

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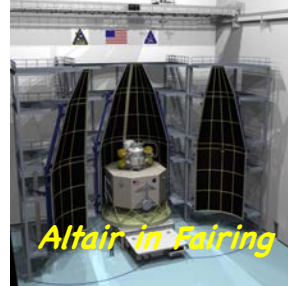
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## Altair Lunar Module, from Constellation Program, 2011



- Lunar orbit rendezvous with Orion
- Four astronauts to lunar surface
- Realistic ingress/egress
- Storable propellants

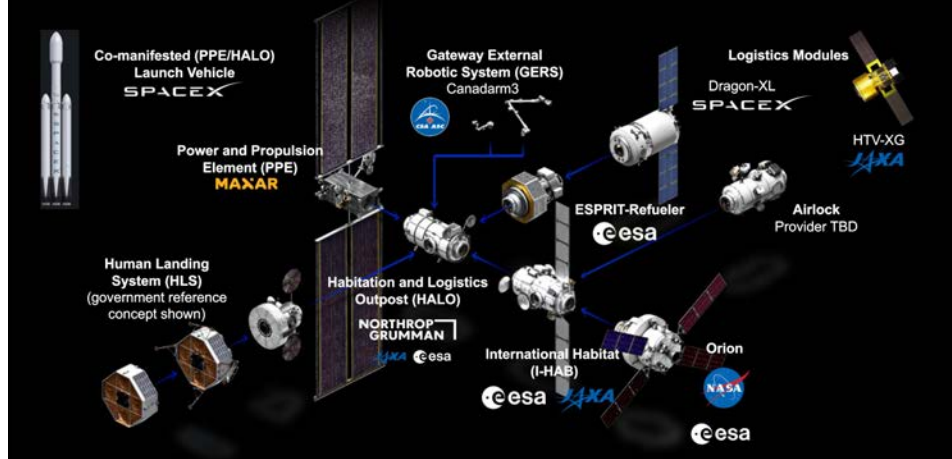


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## NASA Lunar Orbital Platform-Gateway

### GATEWAY INTEGRATED SPACECRAFT CONFIGURATION

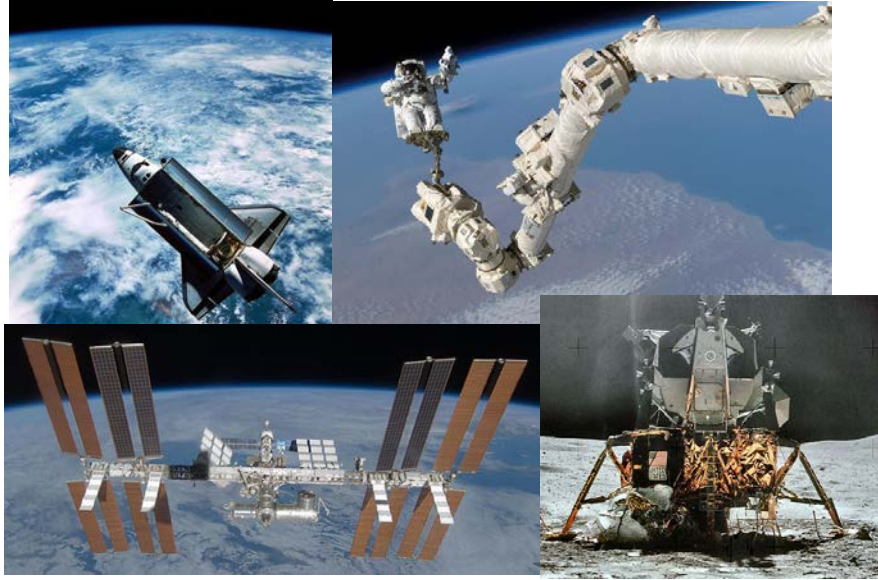


- **LUNAR SPACE STATION**
- Near-Rectilinear Halo Orbit, Period = 6.5 days
- Not required for Artemis 3 and 4

66

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## *Science Fiction becomes Science Fact*



67

## *Beyond Science Fiction?*



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## ***Sources and Acknowledgements***

- *Andrew Chaikin, A Man on the Moon*
- *William Compton, Where No Man Has Gone Before*
- *Donald Eyles, Sunburst and Luminary*
- *Eldon Hall, Journey to the Moon*
- *James Harford, Korolev*
- *Roger Launius, Apollo: A Retrospective Analysis*
- *Willy Ley, Rockets, Missiles, and Men in Space*
- *Walter MacDougall, ...The Heavens and the Earth*
- *Howard McCurdy, Space and the American Imagination*
- *Bernard Miller, Ranger Missions*
- *David Mindell, Digital Apollo*
- *Jules Verne, From the Earth to the Moon and Around the Moon*
- *Colleagues at*
  - *MIT Instrumentation Laboratory (Charles Stark Draper Laboratory)*
  - *NASA Wallops Flight Facility, Wallops Island, VA*

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