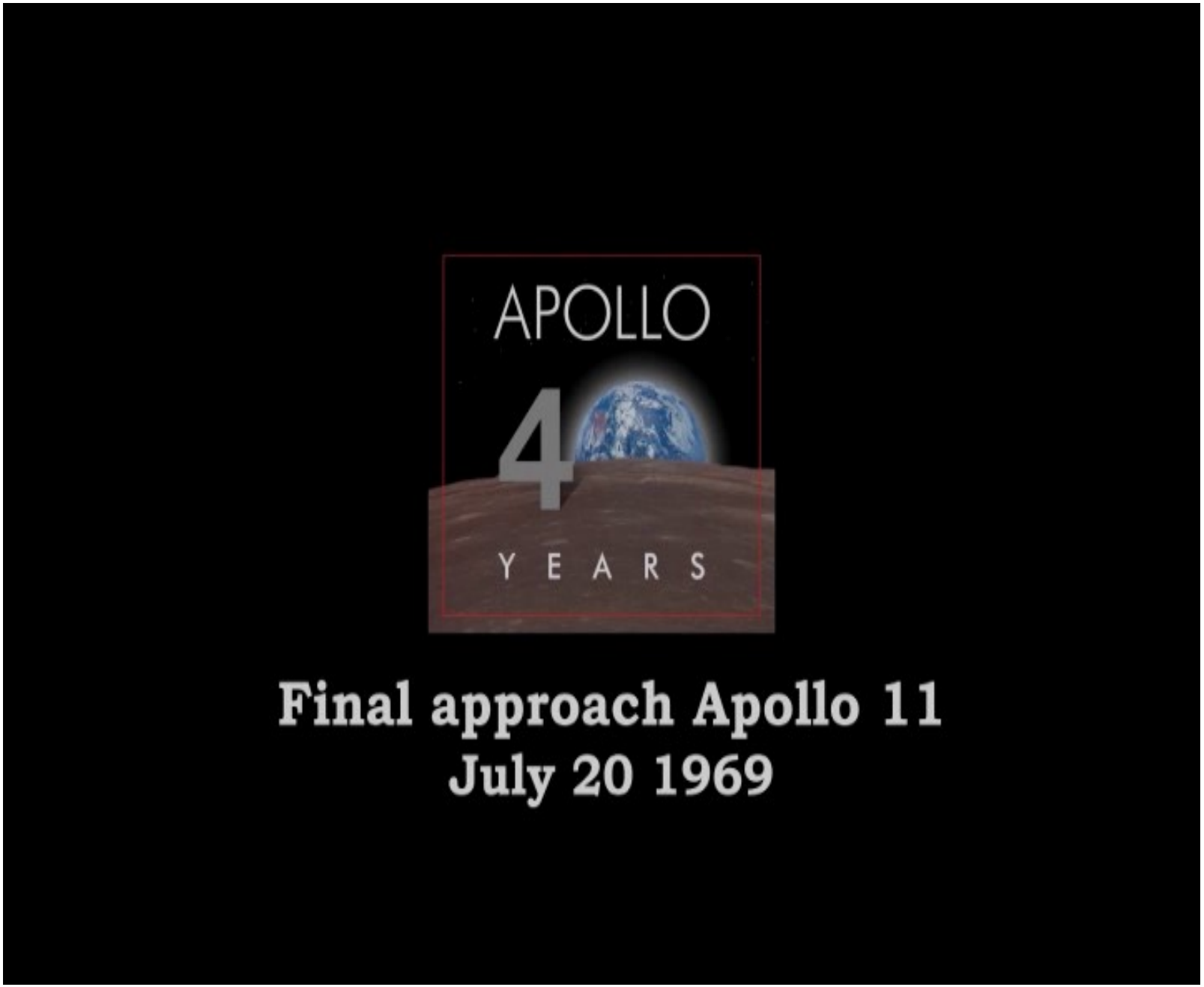

APOLLO
40
YEARS
Final approach Apollo 11
July 20 1969

50 Years After Apollo: Revisiting the Race to the Moon

Jonathan McDowell

Center for Astrophysics

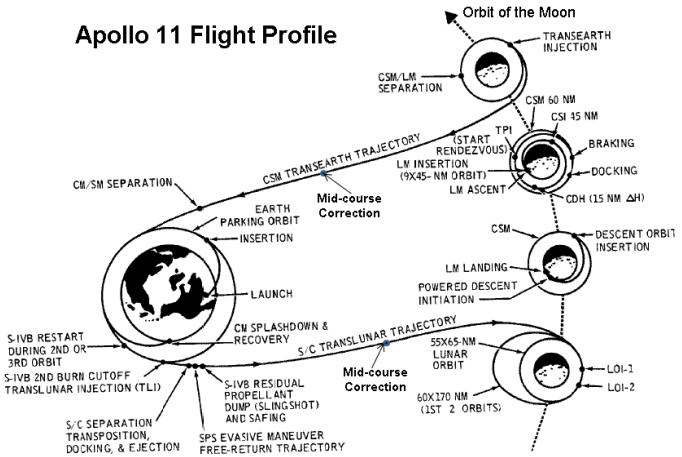
Imagine a stone.

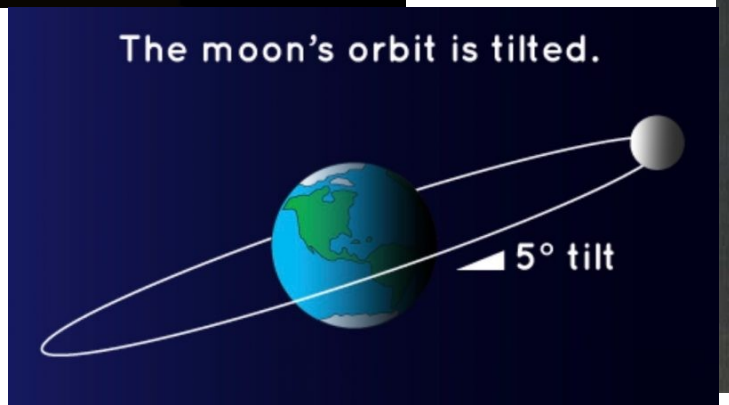
Imagine a stone 2000 miles across.
Hanging over your head.

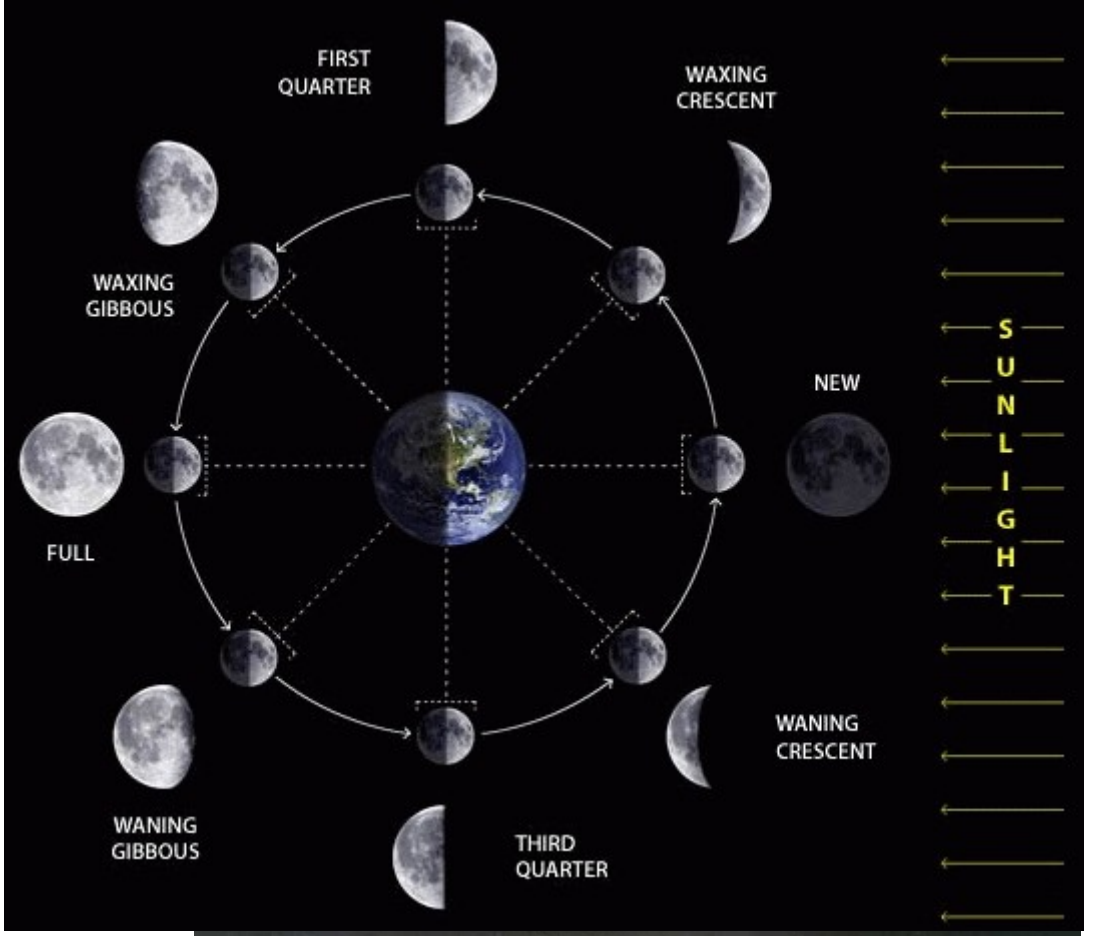
Imagine a stone 2000 miles across.
Hanging over your head.

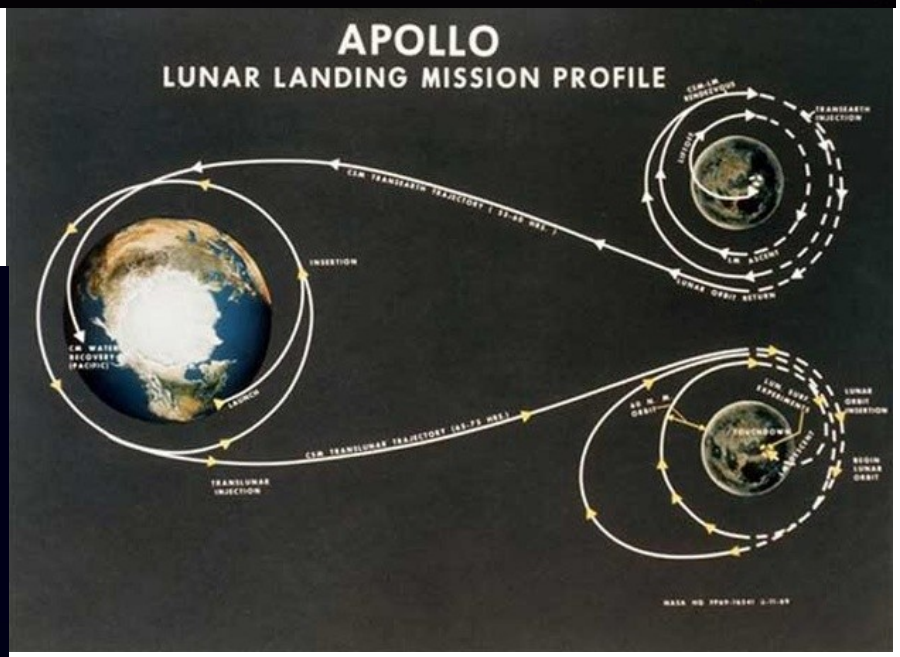
Imagine you hadn’t grown up thinking that was normal!

Don’t be fooled by these diagrams and others like them… the Moon is not **that** close!







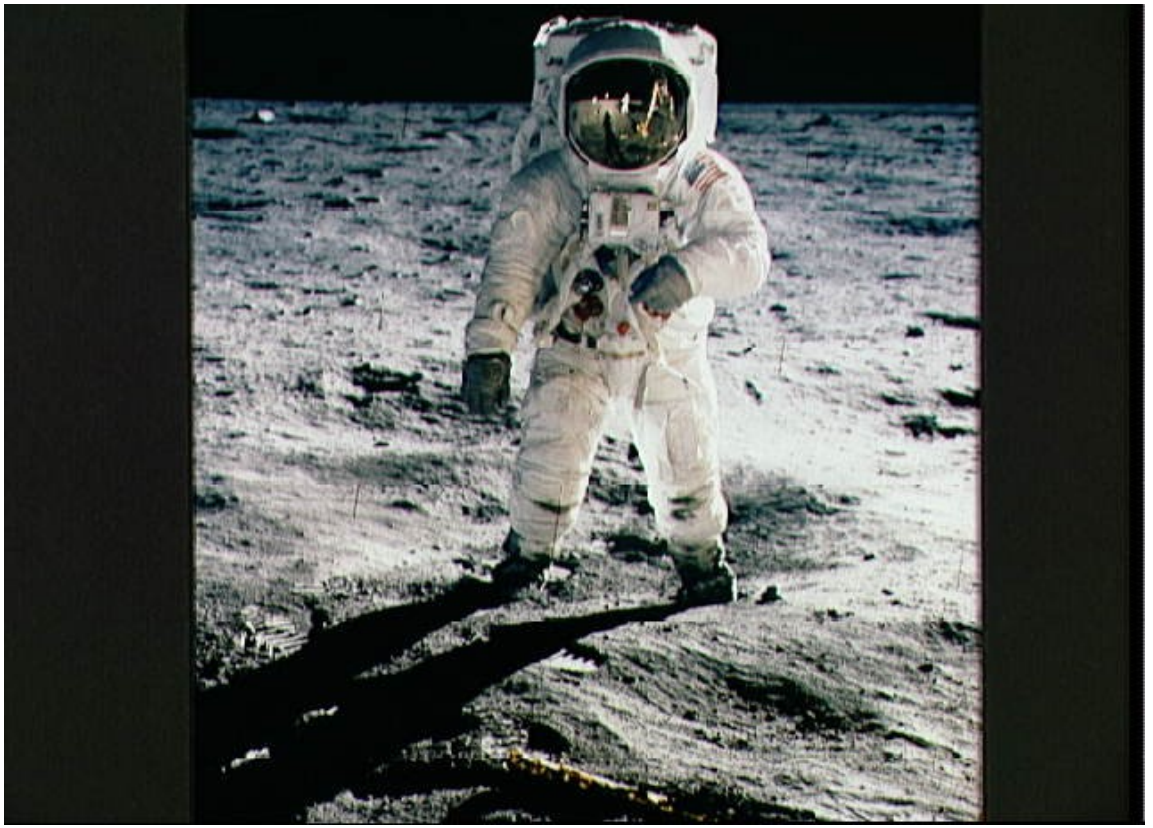


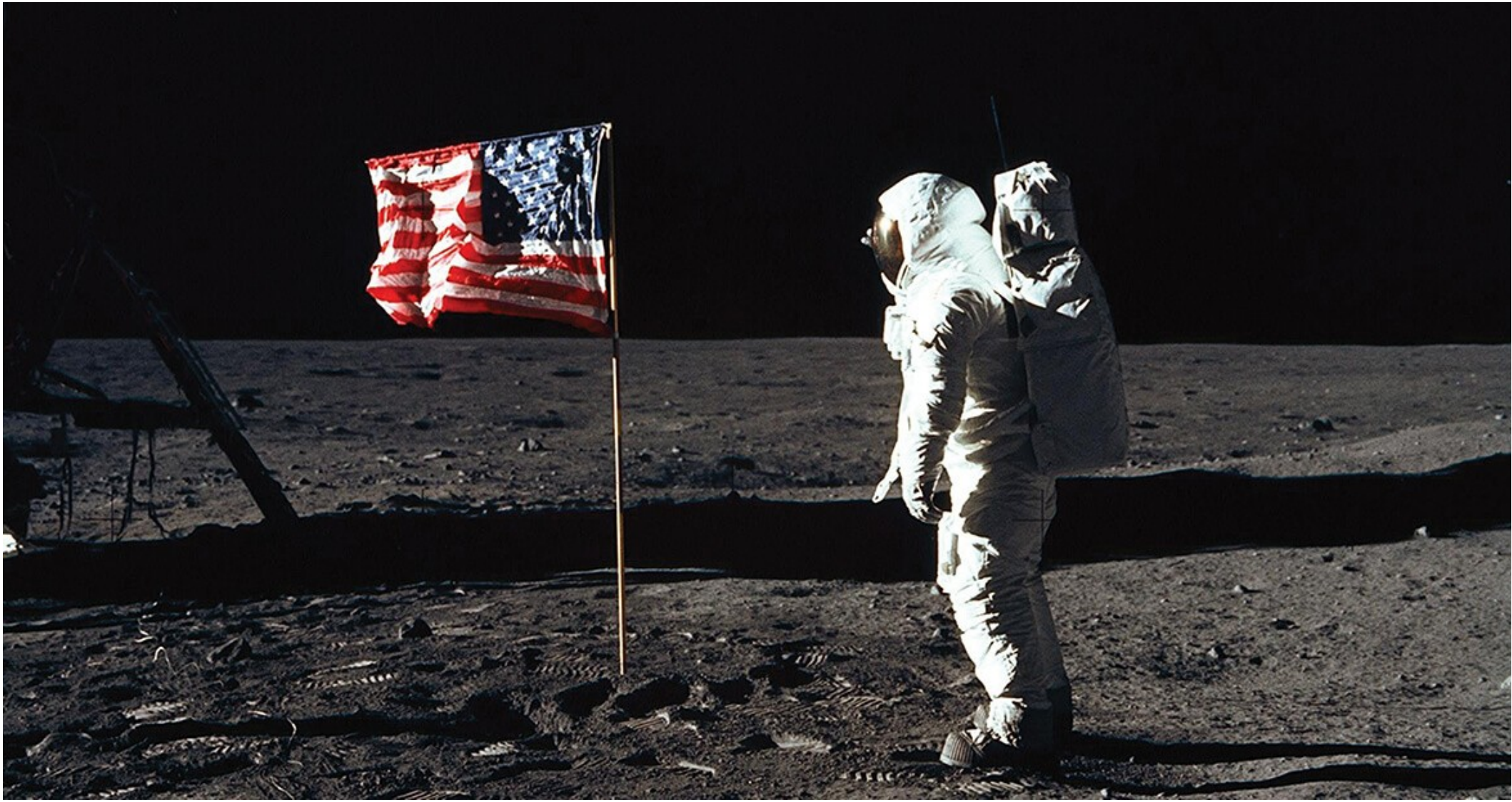
384,400 km
1.3 seconds at lightspeed

24x Boston-Sydney

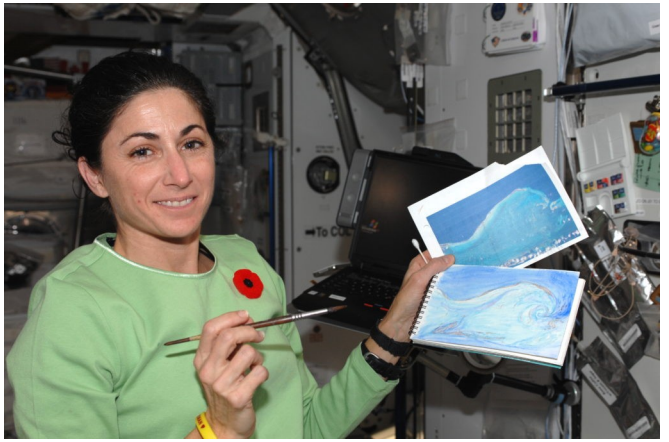
July 1969
Half a century ago

Humans on another world

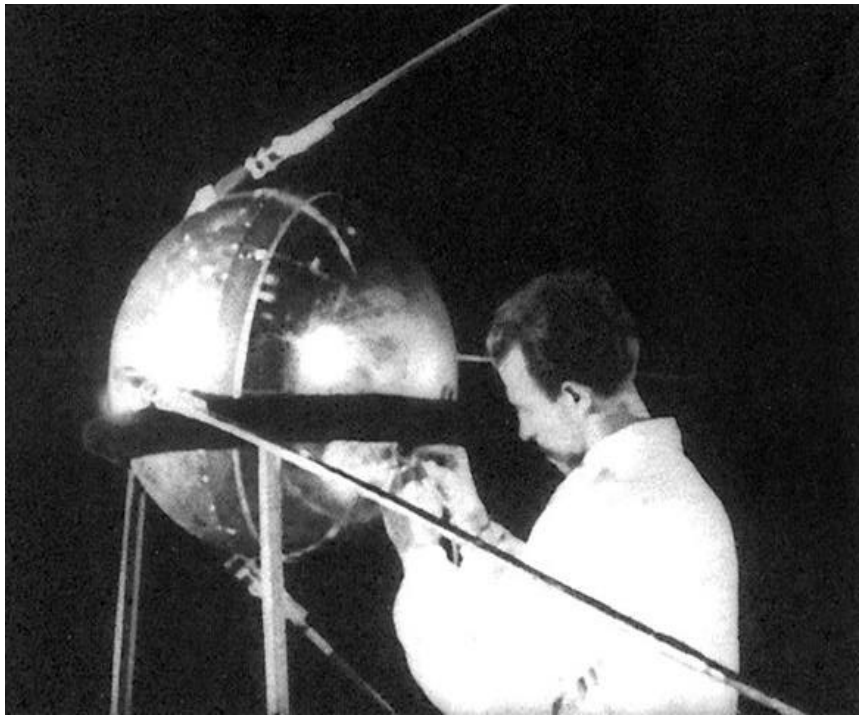


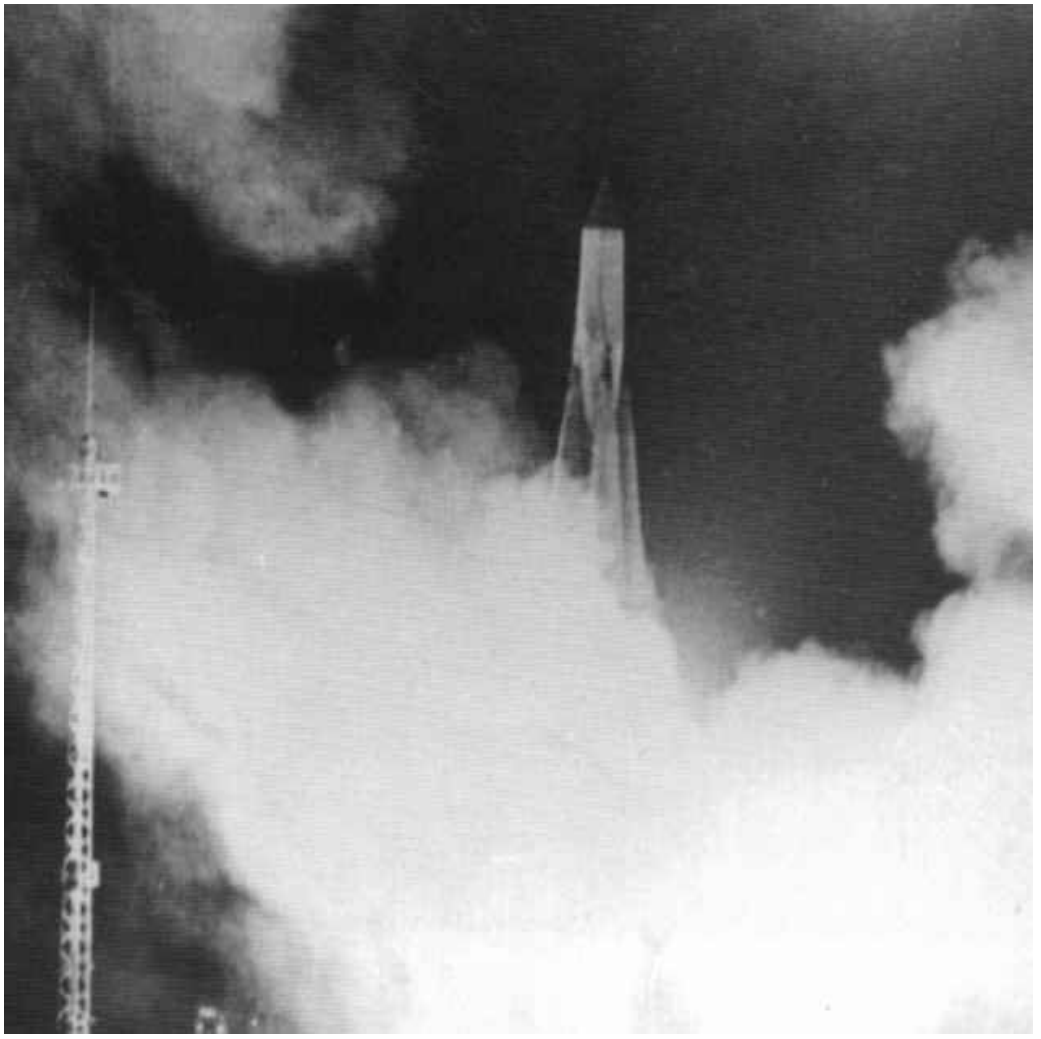


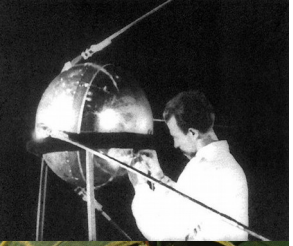
Artists in space...



First Earth Satellite: Sputnik Oct 1957



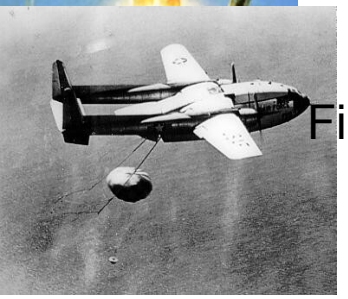




First Earth Satellite: Sputnik Oct 1957

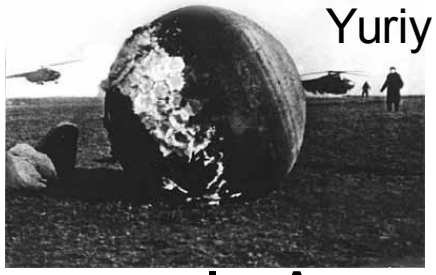
First Living Being in Orbit: Laika, Nov 1957

First Probe to Solar orbit: Luna-1 Jan 1959



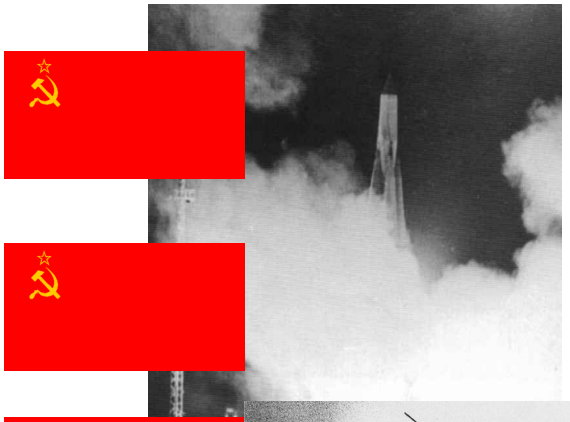
First Probe to hit Moon: Luna-2 Sep 1959

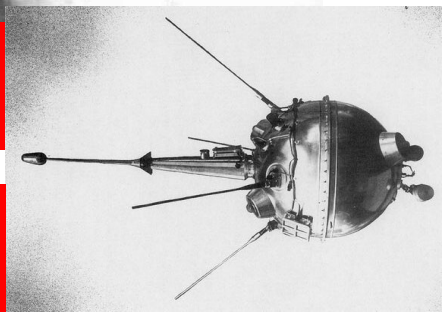
First intact return to Earth from orbit:
Discoverer 13 Aug 1960



First human in space:
Yuriy Gagarin in Vostok-1 Apr 1961

Is America losing the Space Race?
Time to up the stakes dramatically....



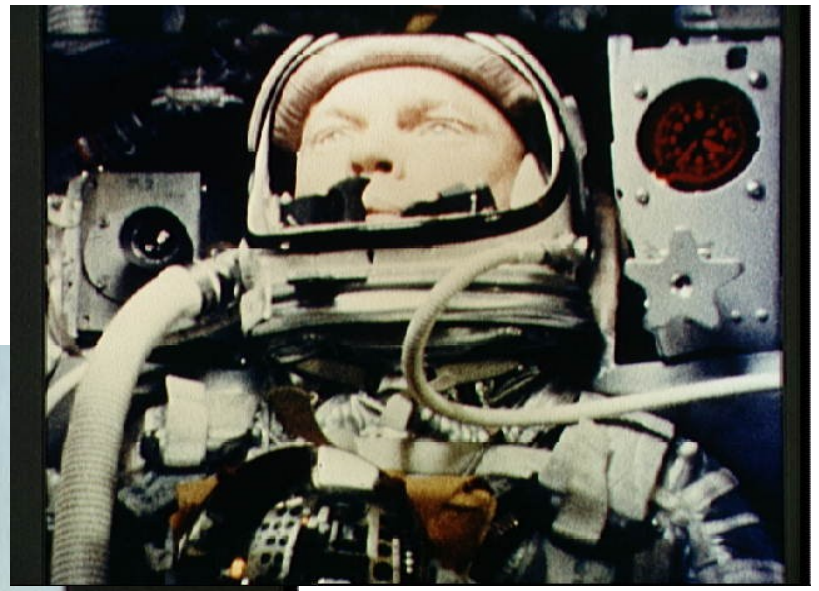


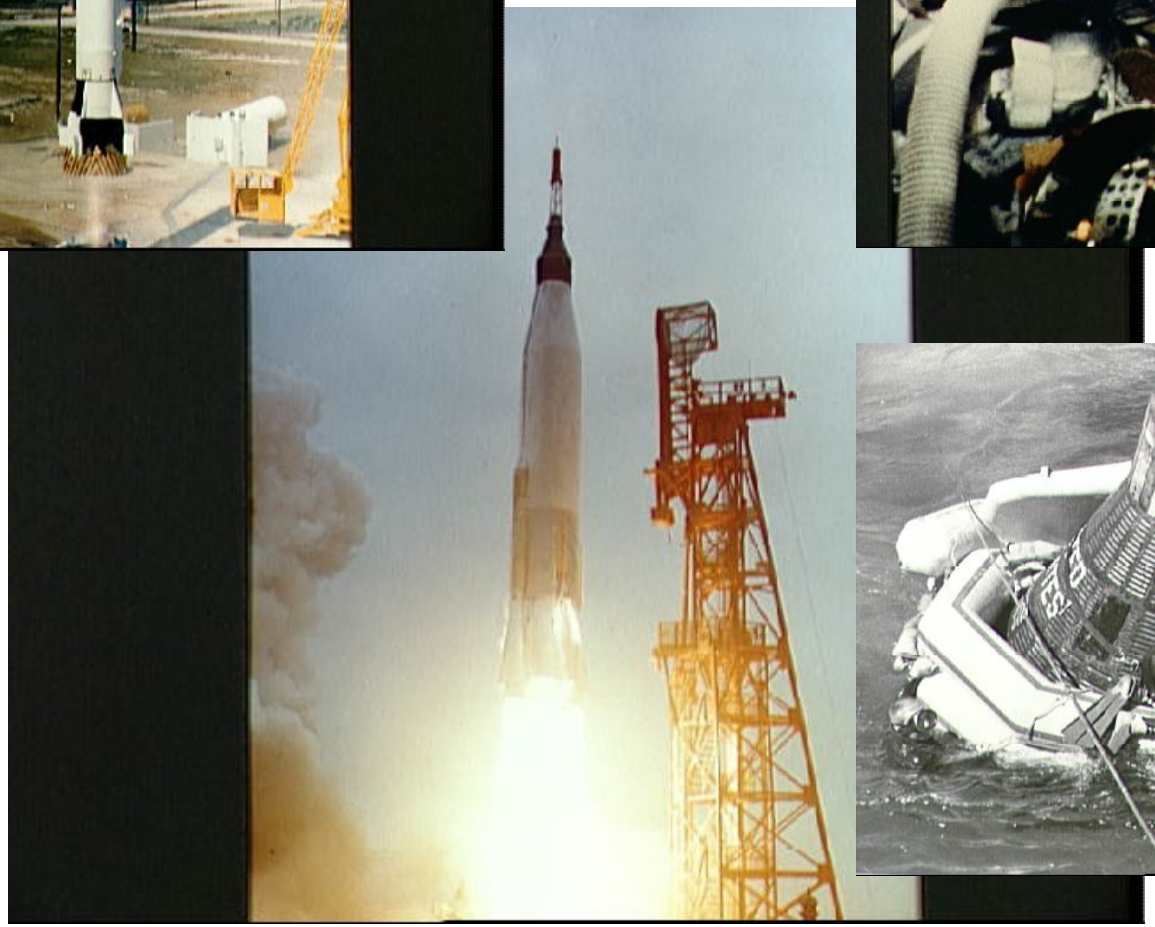
“In this decade...”

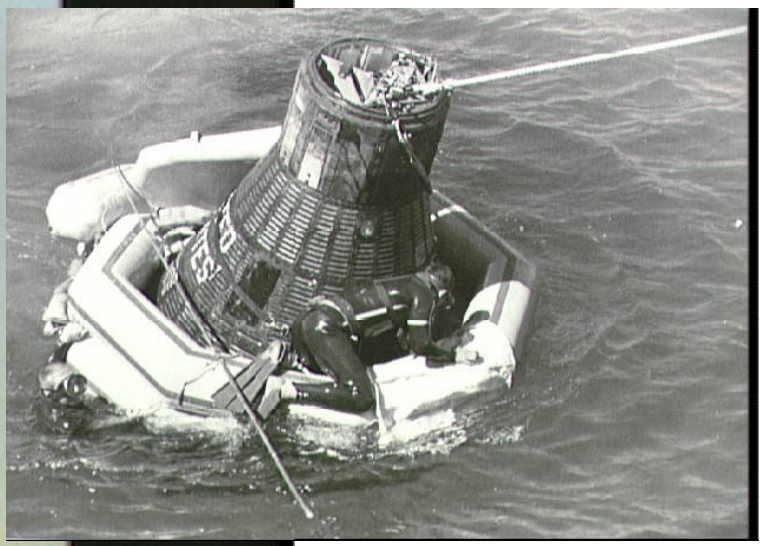
**I believe that this nation should commit itself
to achieving the goal, before this decade is out,
of landing a man on the Moon
and returning him safely to the Earth.**

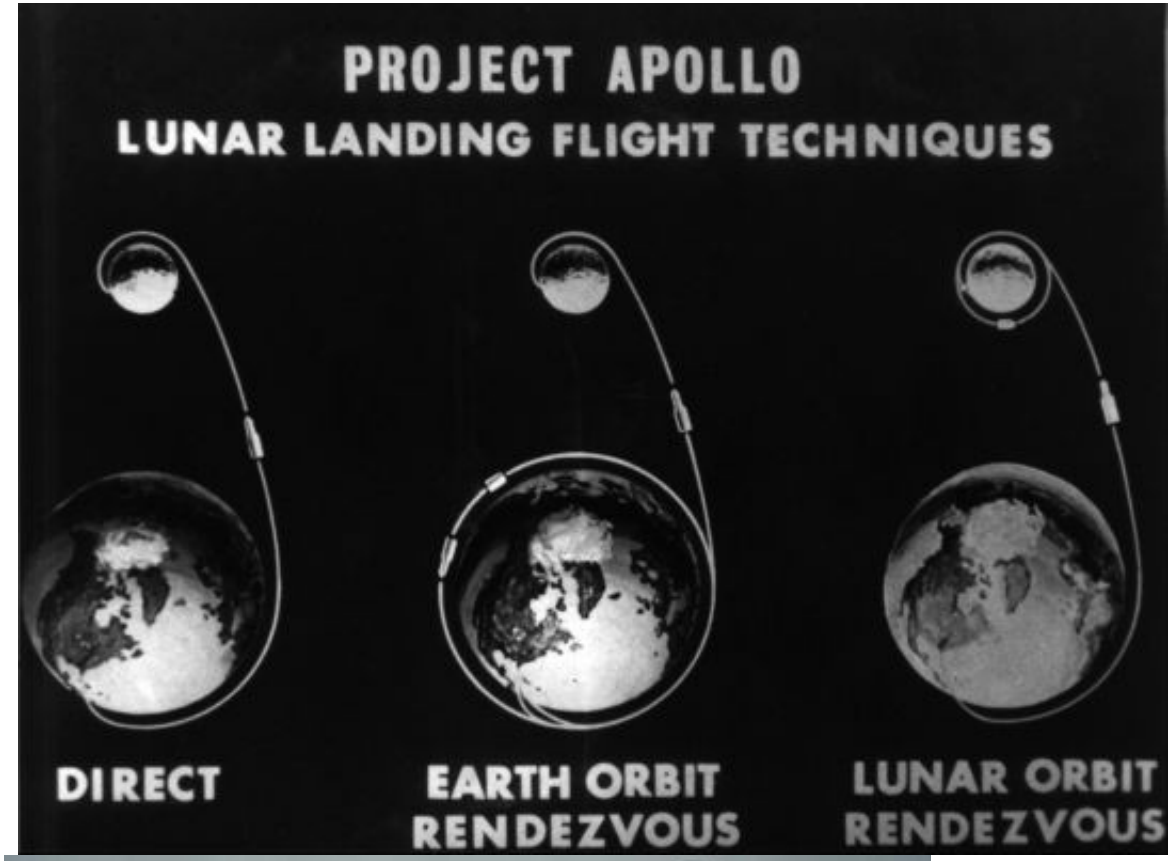
John F Kennedy, address to Congress, May 25, 1961

MERCURY 1961-1963

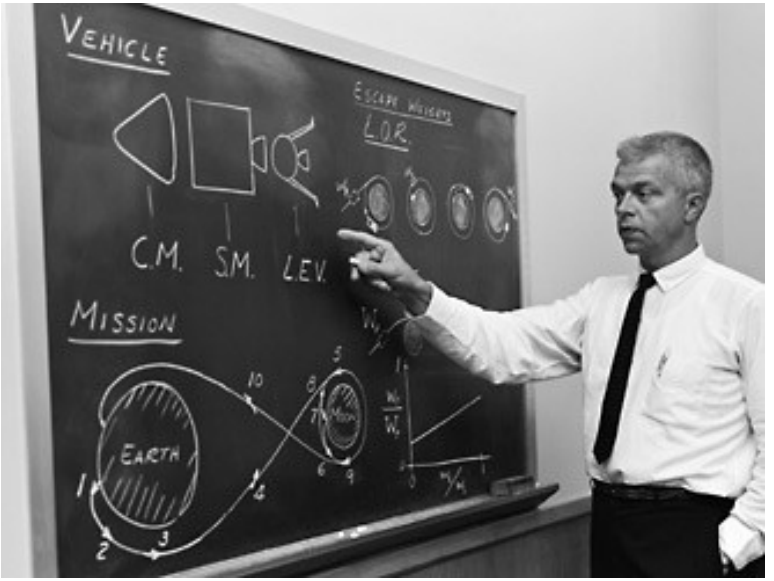


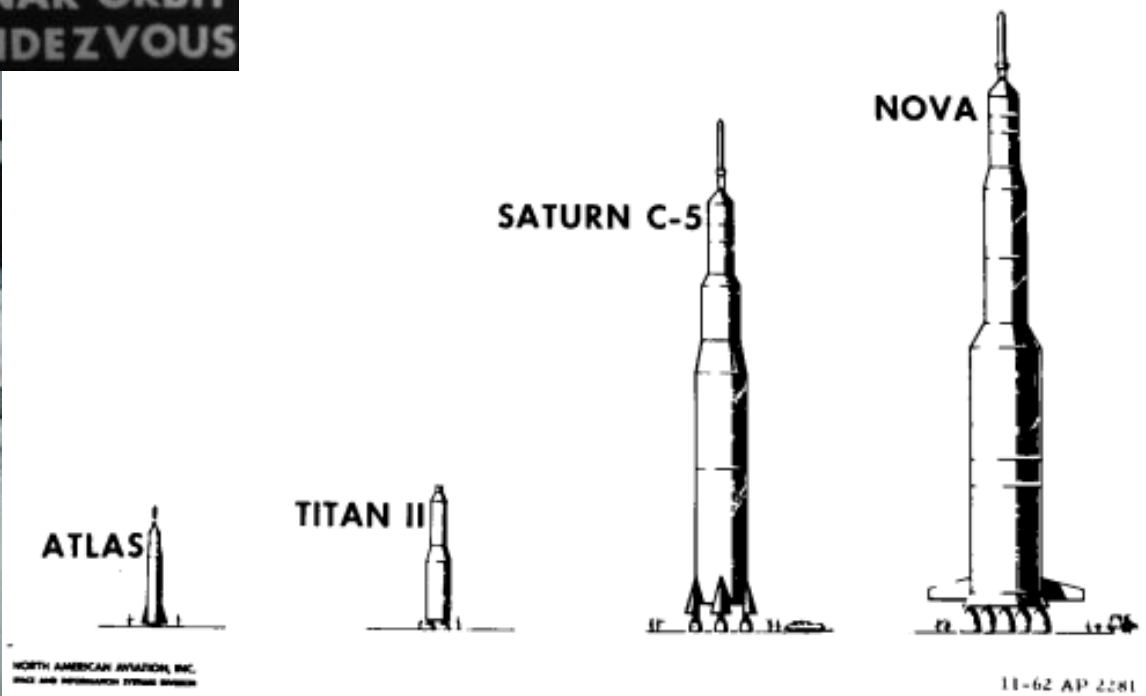




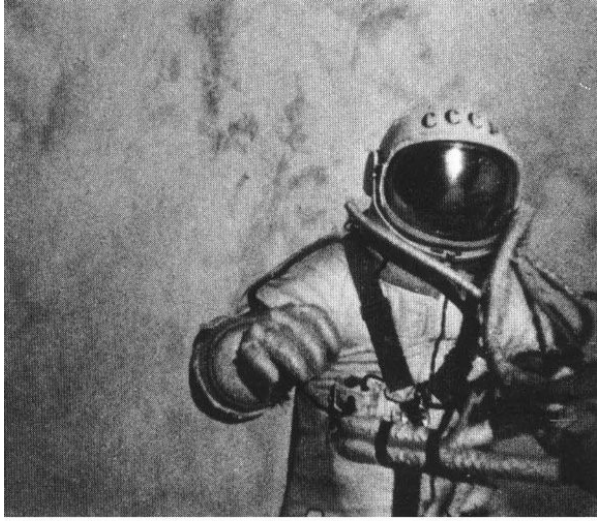


JUNE 1962: Von Braun accepts John Houbolt's scheme for Lunar Orbit Rendezvous, so the enormous Nova rocket is not needed...

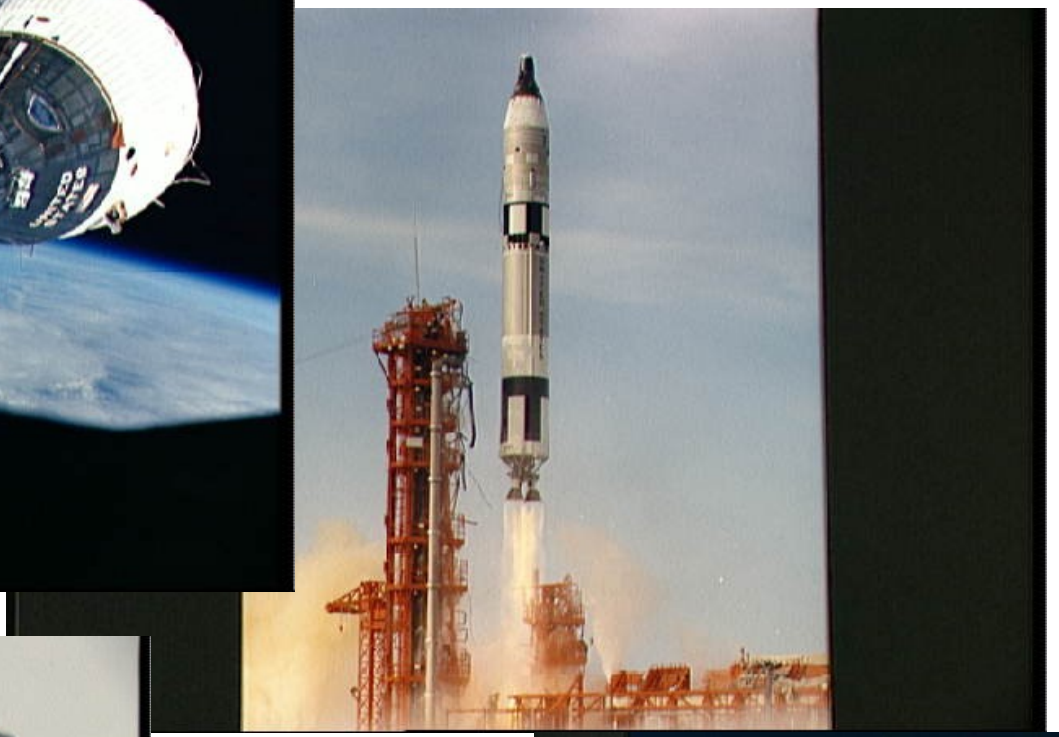




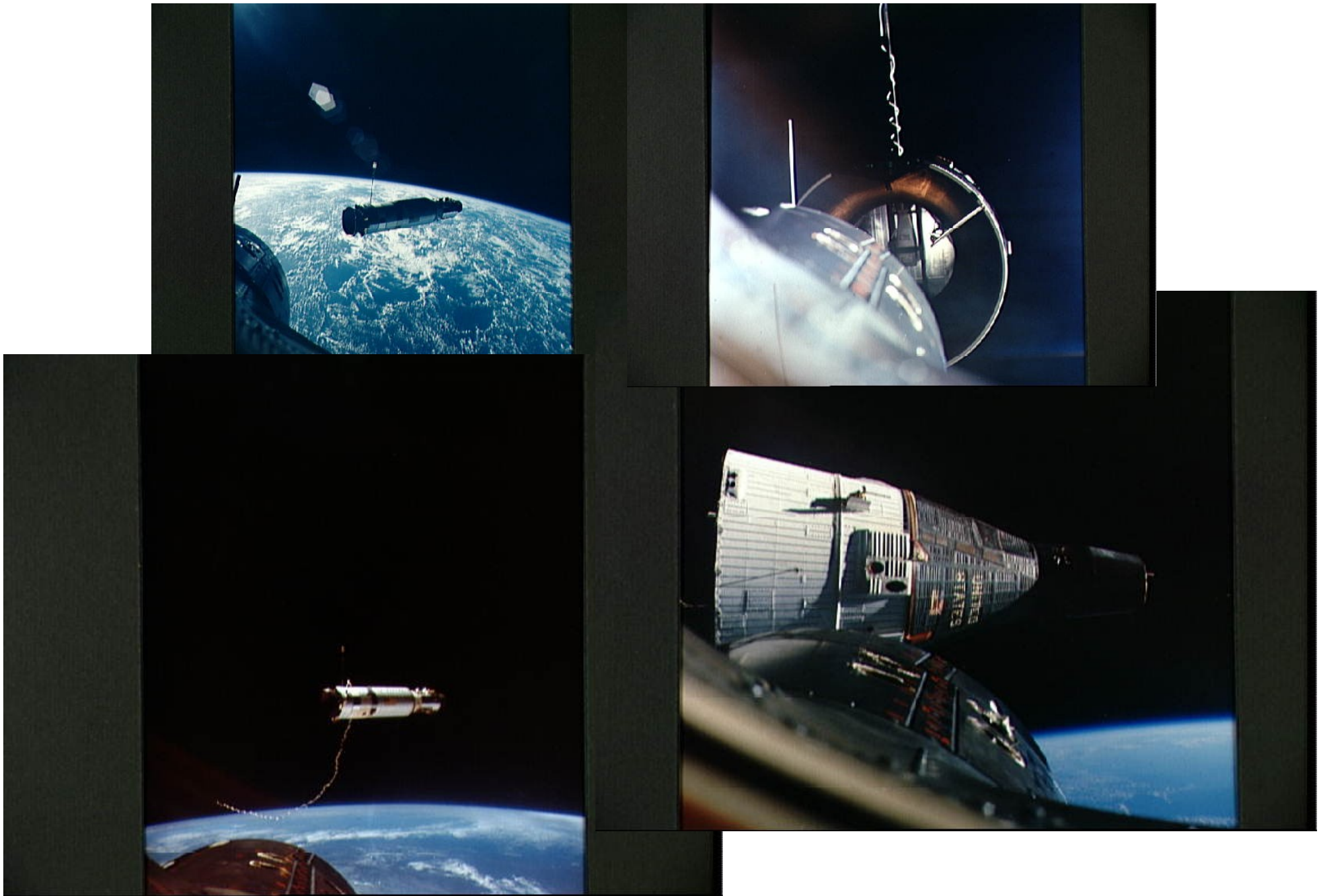
Voskhod 2
First Space Walk
March 1965



GEMINI 1965-1966

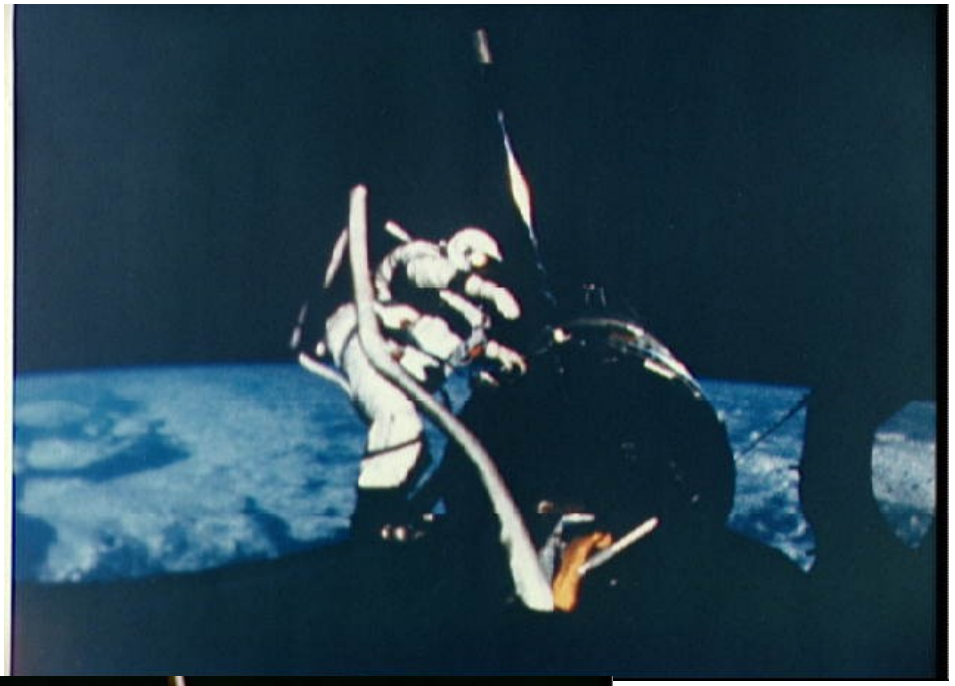


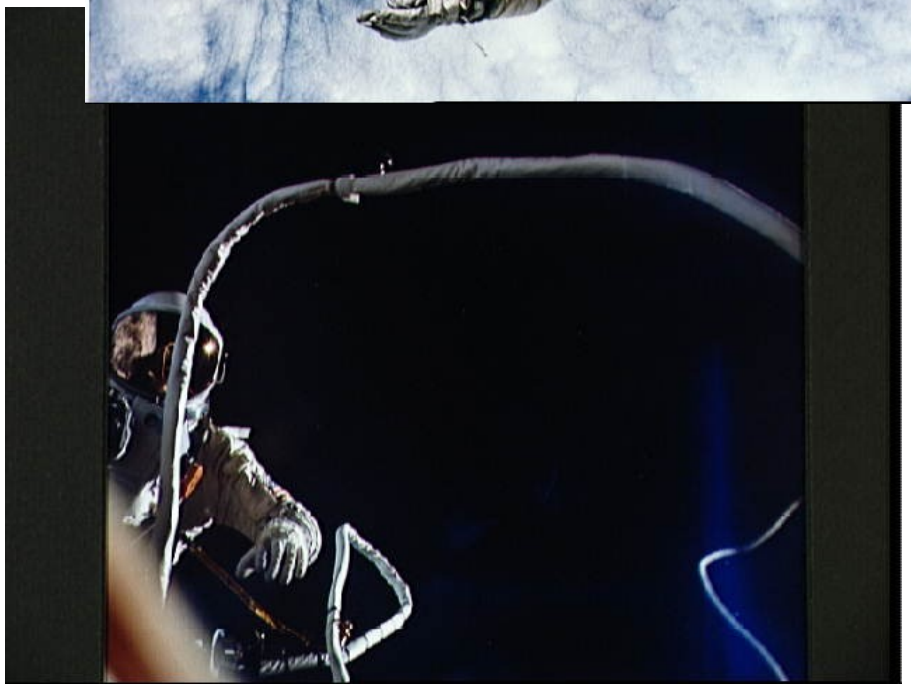
1965-66: Gemini rendezvous and docking

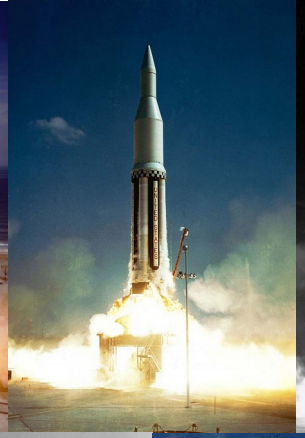
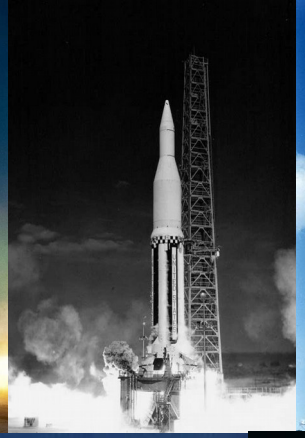
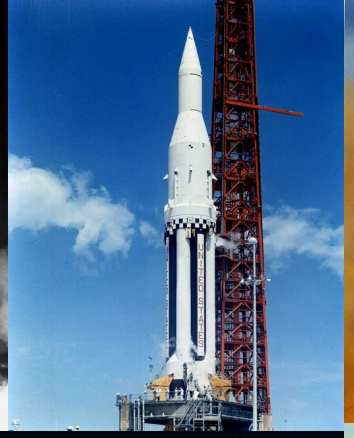


1965-66: Gemini spacewalks

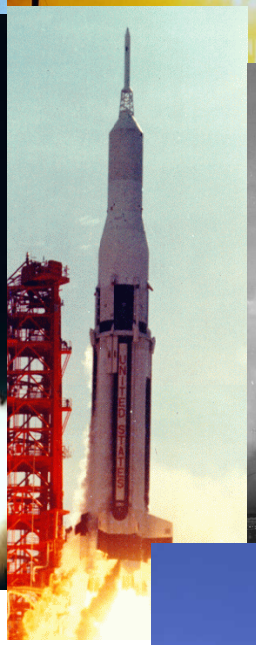
Gemini IV: Ed White **Gemini IX: Gene Cernan** **Gemini X: Mike Collins**
Gemini XI: Dick Gordon **Gemini XII: Buzz Aldrin**







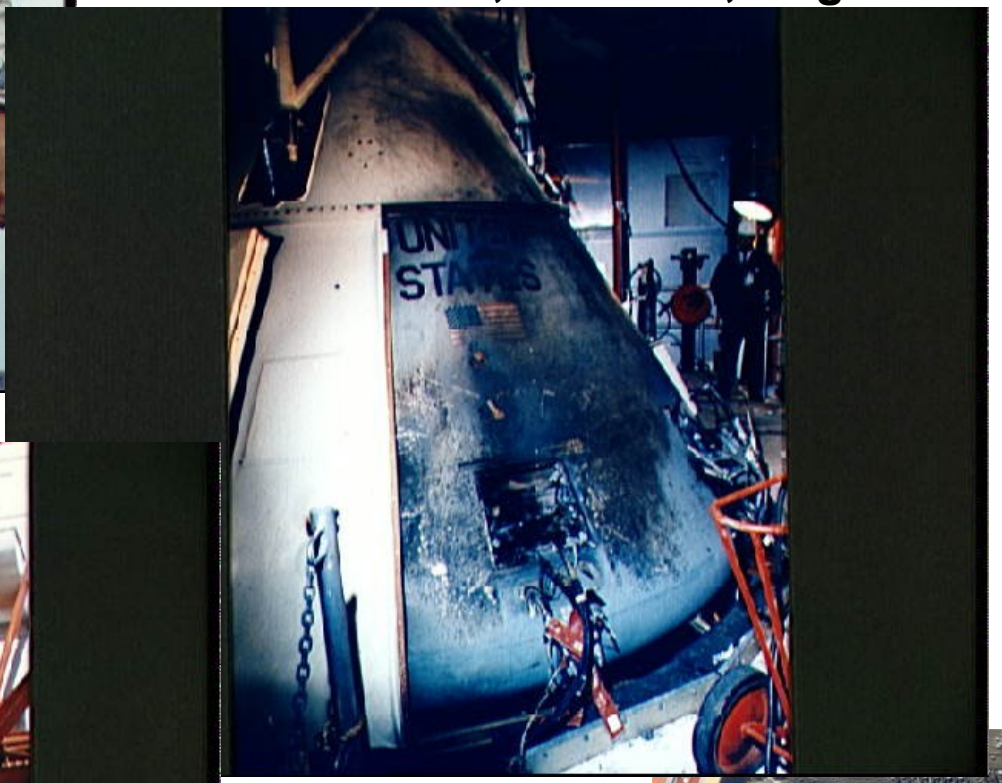


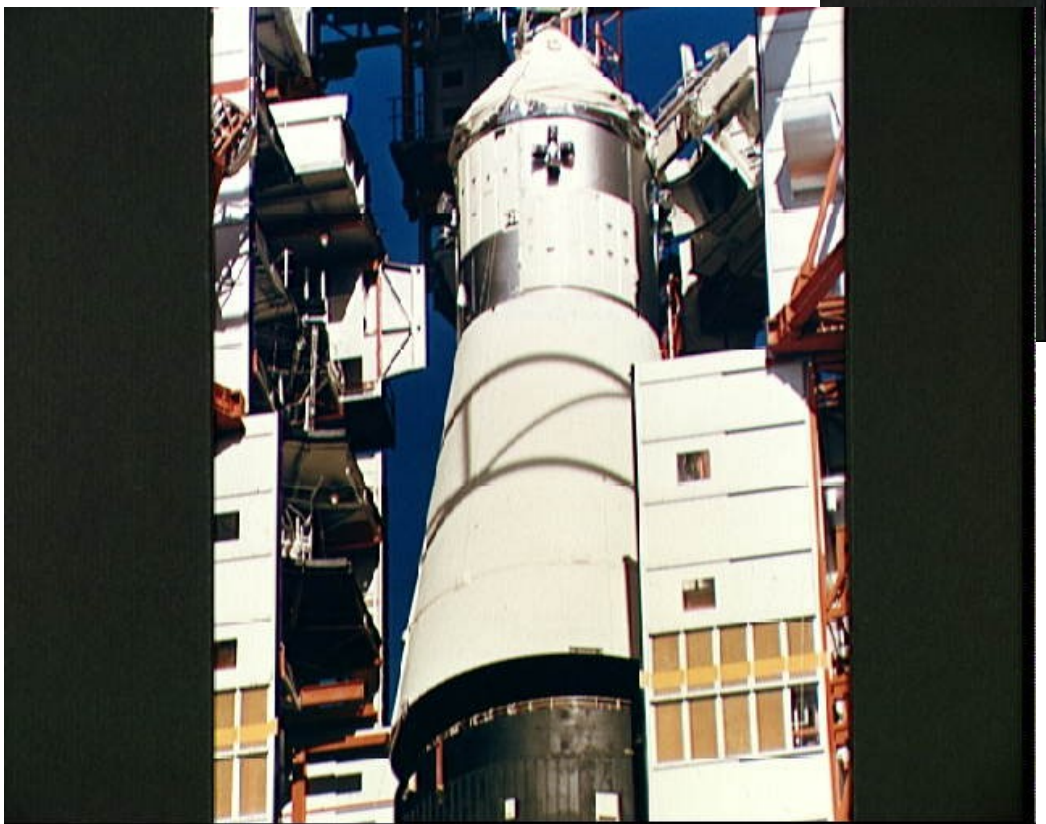



The Apollo AS-204 Fire ("Apollo 1")

January 27, 1967

Gus Grissom, Ed White, Roger Chaffee





November 1967: the first Saturn V, SA-501

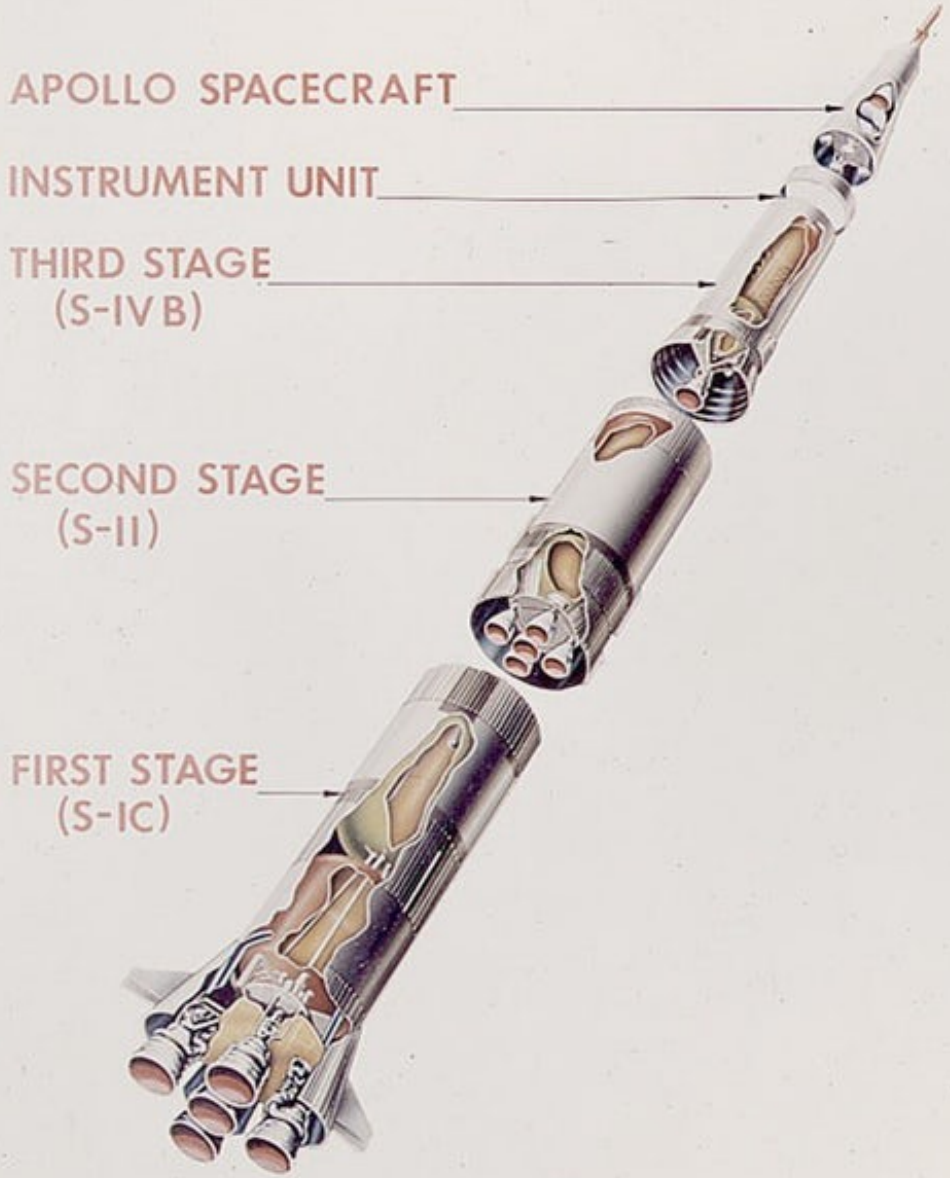
0.11 km high

3000 tonnes

First stage thrust
35 MN

5 F-1 rocket engines – each with as much thrust as a Falcon 9

SATURN V LAUNCH VEHICLE



CHARACTERISTICS

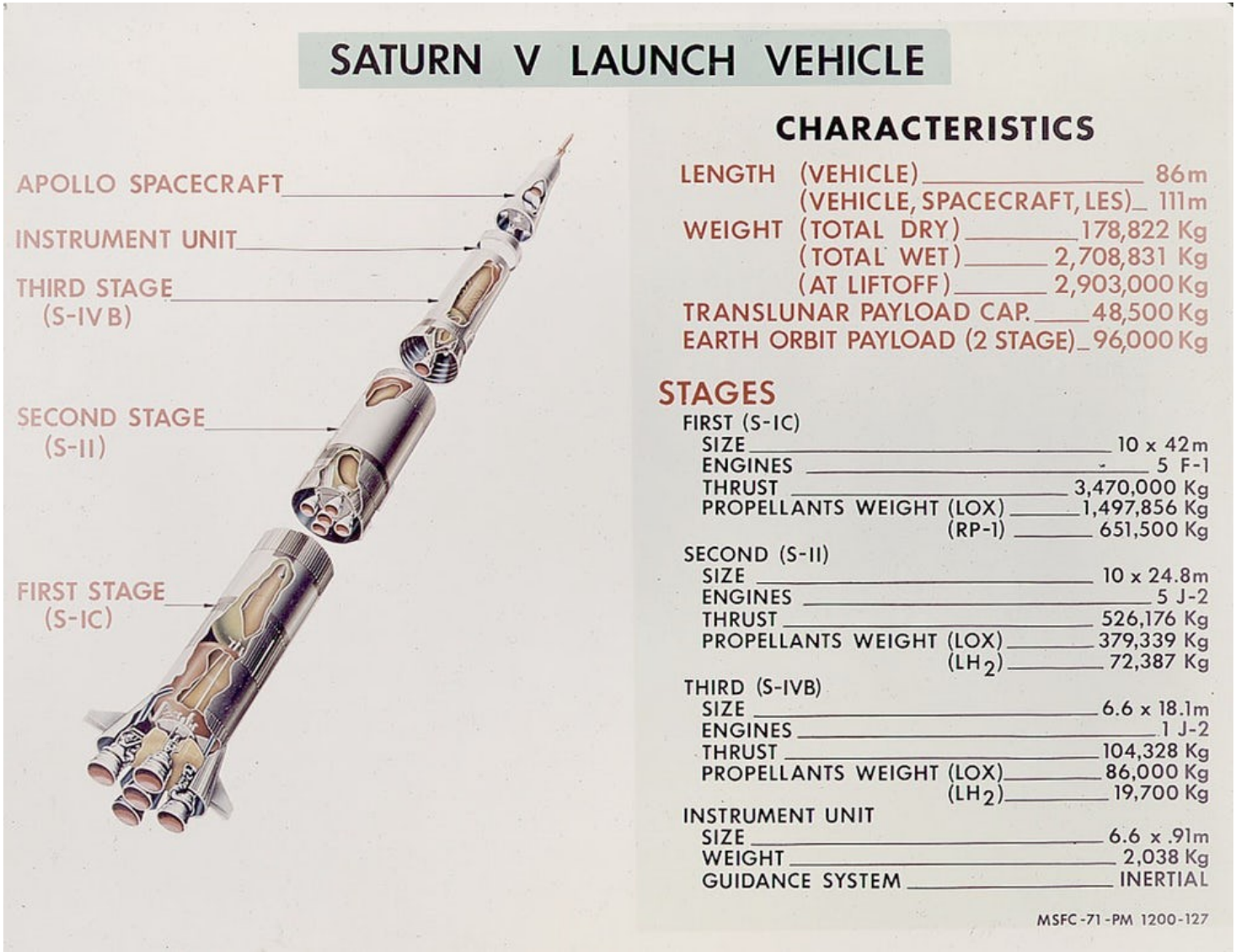
LENGTH	(VEHICLE)	86m
	(VEHICLE, SPACECRAFT, LES)	111m
WEIGHT	(TOTAL DRY)	178,822 Kg
	(TOTAL WET)	2,708,831 Kg
	(AT LIFTOFF)	2,903,000 Kg
TRANSLUNAR PAYLOAD CAP.		48,500 Kg
EARTH ORBIT PAYLOAD (2 STAGE)		96,000 Kg

STAGES

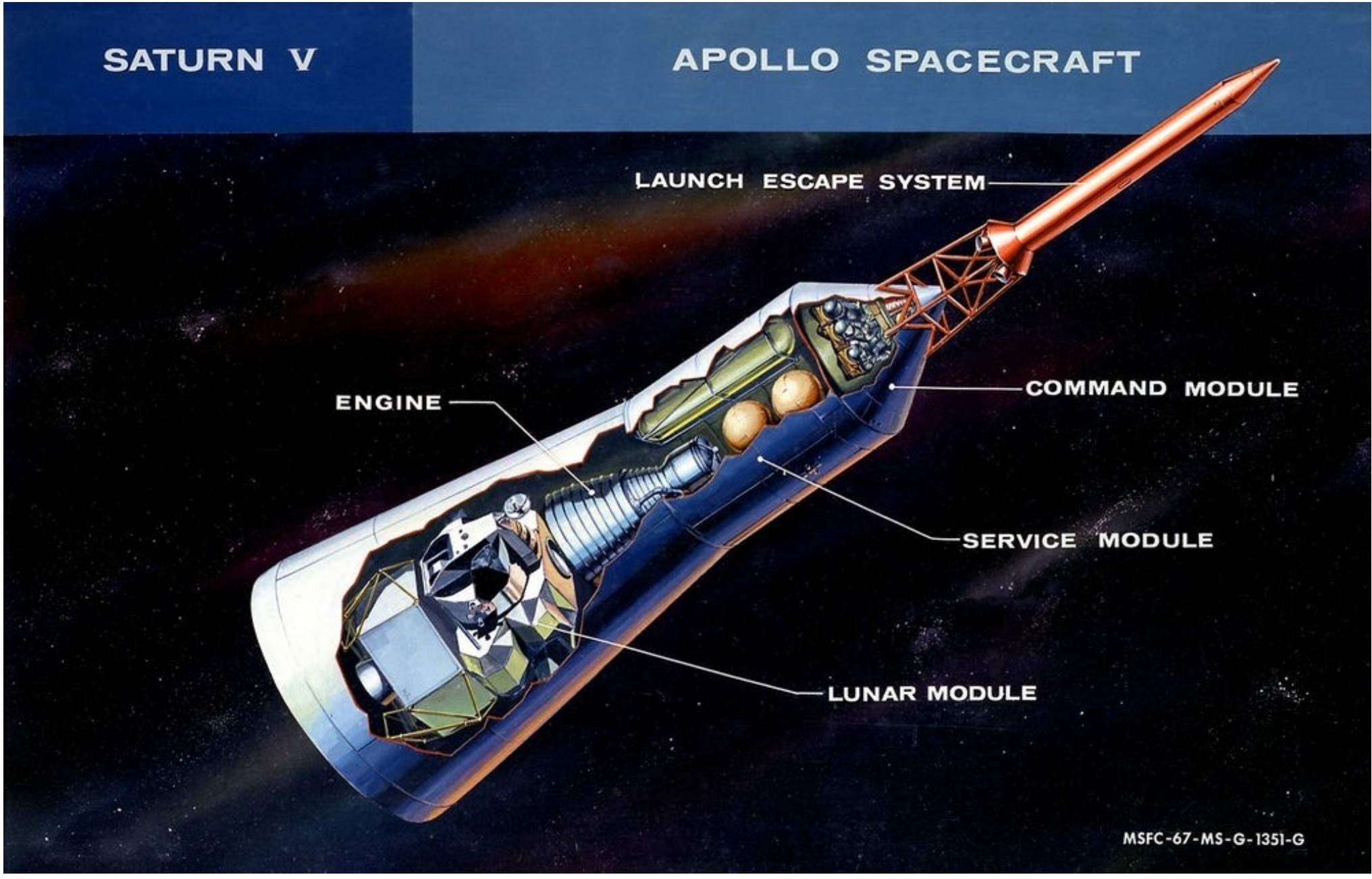
FIRST (S-IC)		
SIZE		10 x 42m
ENGINES		5 F-1
THRUST		3,470,000 Kg
PROPELLANTS WEIGHT	(LOX)	1,497,856 Kg
	(RP-1)	651,500 Kg
SECOND (S-II)		
SIZE		10 x 24.8m
ENGINES		5 J-2
THRUST		526,176 Kg
PROPELLANTS WEIGHT	(LOX)	379,339 Kg
	(LH_2)	72,387 Kg
THIRD (S-IVB)		
SIZE		6.6 x 18.1m
ENGINES		1 J-2
THRUST		104,328 Kg
PROPELLANTS WEIGHT	(LOX)	86,000 Kg
	(LH_2)	19,700 Kg
INSTRUMENT UNIT		
SIZE		6.6 x .91m
WEIGHT		2,038 Kg
GUIDANCE SYSTEM		INERTIAL

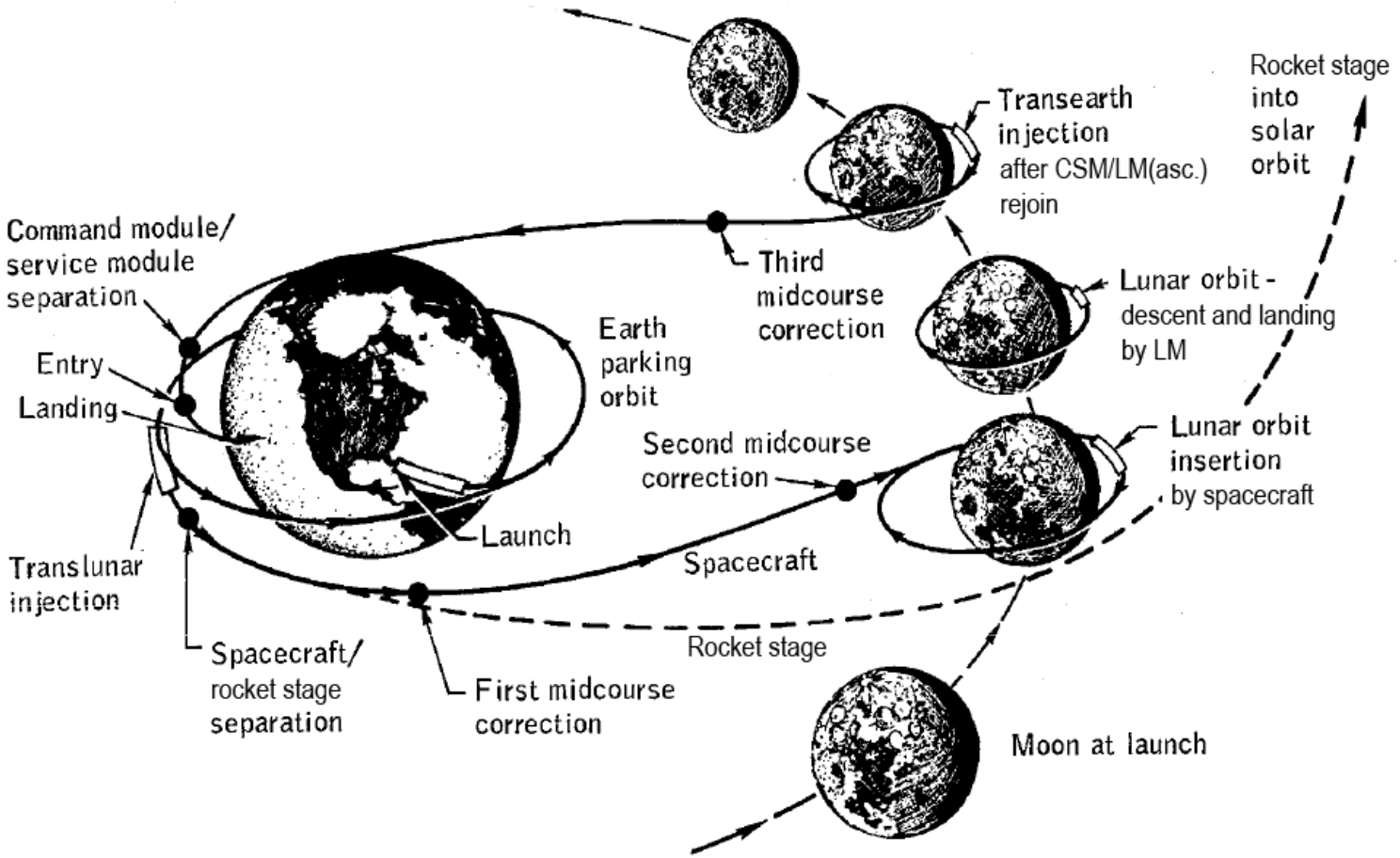
MSFC-71-PM 1200-127

New Orleans: Stage 1
Los Angeles: Stage 2 and 3; F-1 and J-2 rocket engines
Huntsville, Alabama: rocket design, some testing
Mississippi coast: rocket test firings



Los Angeles: Command/Service Module
Bethpage, NY: Lunar Module
White Sands, New Mexico: Escape tower tests
Houston, TX: astronaut training
Sacramento, CA: SM rocket engine
Cambridge, MA: Lunar module computer
Greenbelt, MD: Tracking
Cape Canaveral, FL: launch site





Saturn V three stage rocket places Apollo spacecraft on course for the Moon

Apollo consists of CSM (Command Module, with astronauts, and Service Module, with rocket)
and LM (Lunar Module – consists of Ascent Stage, with astronauts, and
Descent Stage, with rocket)

CSM/LM docked to each other, enter lunar orbit
2 of 3 crew go to LM, undock and land using Descent Stage engine
Walk on Moon, return to LM, Ascent Stage heads back to lunar orbit to rejoin CSM
LM discarded, CSM returns to Earth

Meanwhile, elsewhere...


PODLIPKI
BAYKONUR (NIIP-5)
KURA
PL
KY
R. S. F. S. R.
K A Z A K H S. S. R.
Murmansk
Karel'skaya ASSR
Arkhangel'sk
Nenetskiy NO
Komi ASSR
Taymyrskiy NO
Yakutskaya ASSR
Chukotskiy NO
Koryakskiy NO
Kamchatskaya Oblast'
Magadan
Yamalo-Nenetskiy NO
Evenkiyskiy NO
Khanty-Mansiyskiy NO
Krasnoyarskiy Kray
Sakhalinskaya Oblast'
Khabarovskiy Kray
Amurskaya Oblast'
Primorskiy Kray
Yevreyskaya AO
Buryat-skaya ASSR
Ust'-Ordynskiy Buryatskiy NO
Aginskiy Buryatskiy NO
Chita
Irkutsk
Tuvinskaya ASSR
Altayskiy Kray
Khakas-skaya AO
Gorno-Altayskaya AO
Vostochno-Kazakhstanskaya Oblast'
Novosibirsk
Tomsk
Kemerovo
Omsk
Tyumen'
Sverdlovsk
Chelyabinsk
Kurgan
Severo-Kazakhstanskaya Oblast'
Kustanay
Kokchetav
Tselinograd
Pavlodar
Karaganda
Semipalatinsk
Taldy-Kurgan
Alma-Ata
Dzhambul
Chimkent
Kzyl-Orda
Aktyubinsk
Gur'yev
Ural'sk
Orenburg
Bashkirskaya ASSR
Tatarskaya ASSR
Udmurtskaya ASSR
Komi-Permyatskiy NO
Perm'
Kirov
Mariyskaya ASSR
Chuvashskaya ASSR
Mordov-skaya ASSR
Kuybyshev
Ul'yanovsk
Penza
Saratov
Volgograd
Astrakhan'
Kalmytskaya ASSR
Dagestanskaya ASSR
Stavropol'skiy Kray
Krasnodarskiy Kray
Rostov
MOSCOW
Kalinin
Yaroslavl'
Kostroma
Ivanovo
Vladimir
Gor'kiy
Vologda
Leningrad
Novgorod
Pskov
Smolensk
Kaluga
Tula
Ryazan'
Orël
Kursk
Belgorod
Lipetsk
Voronezh
Tambov
Bryansk
Murmansk
Tallin
Riga
Vil'nyus
Kaliningrad (TO R.S.F.S.R.)
LATVIAN S.S.R.
ESTONIAN S.S.R.
LITHUANIAN S.S.R.
BELORUSSIAN S.S.R.
Minsk
Vitebsk
Mogilëv
Gomel'
Grodno
Brest
UKRAINIAN S.S.R.
Kiyev
Volynskaya Oblast'
Zakarpatskaya Oblast'
L'vov
Ivano-Frankovsk
Rovno
Zhitomir
Chernigov
Khmel'nitskiy
Vinnitsa
Cherkassy
Poltava
Sumy
Khar'kov
Kirovograd
Dnepropetrovsk
Zaporozh'ye
Donetsk
Lugansk
Nikolayev
Kherson
Odessa
Krymskaya Oblast'
MOLDAVIAN S.S.R.
Kishinev
Chernovtsy
Ternopol'
Abkhazskaya ASSR
GEORGIAN S.S.R.
Tbilisi
ARMENIAN S.S.R.
Yerevan
AZERBAIJAN S.S.R.
Baku
Kara-Kalpakskaya ASSR
Khorezmskaya Obl.
TURKMEN S.S.R.
Ashkhabad
UZBEK S.S.R.
Syrdar'inskaya Oblast'
Bukhara
Samarkand
Tashkent
Kashkadar'inskaya Oblast'
Surkhandar'inskaya Oblast'
Dushanbe
TADZHIK S.S.R.
Gorno-Badakhshanskaya AO
KIRGIZ S.S.R.
Frunze
Namangan
Andizhan
Fergana
Osh
AUTONOMOUS REPUBLICS AND OBLASTS IN THE CAUCASUS
1. Adygeyskaya AO
2. Karachayevo-Cherkesskaya AO
3. Kabardino-Balkarskaya ASSR
4. Severo-Osetinskaya ASSR
5. Checheno-Ingushskaya ASSR
6. Yugo-Osetinskaya AO
7. Adzharskaya ASSR
8. Nagorno-Karabakhskaya AO
9. Nakhichevanskaya ASSR (to Azerbaijan S.S.R.)
ADMINISTRATIVE DIVISIONS
BOUNDARY
CENTER
Union Republic (S.S.R.)
Oblast, Kray, or Autonomous Republic (ASSR)
Autonomous Oblast (AO) or National Okrug (NO)
All Union Republic administrative centers are shown. The only other administrative centers shown are for oblasts having the same name as their administrative centers
60
40
80
100
120
140
160

Sergey Korolev's Program

At Podlipki, in the Moscow suburbs, Korolev's factory churns out rockets and satellites

- Sputnik
- Luna moon probes
- Vostok spaceships
- Mars and Venus probes
- Spy satellites


ПОДЛИПКИ-ДАЧНЫЕ
НЕТ ВХОДА
НЕТ ВХОДА
НЕТ ВХОДА
НЕТ ВХОДА
НЕТ ВХОДА
ВЫХОД В ГОРОД
ВЫХОД В ГОРОД
2006.09.22

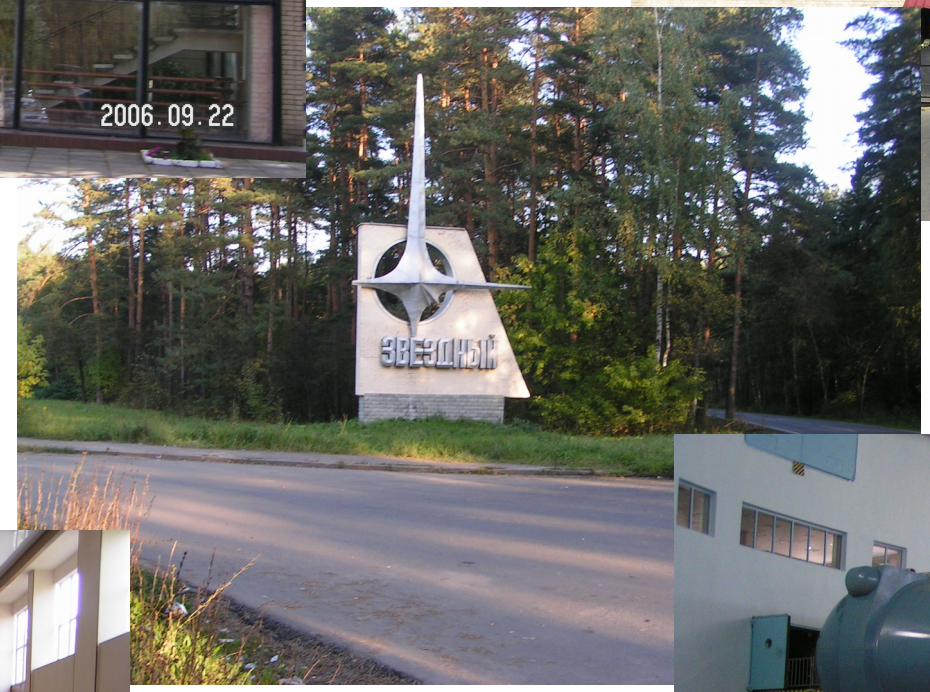

2006.09.22


2006.09.22


2006.09.22

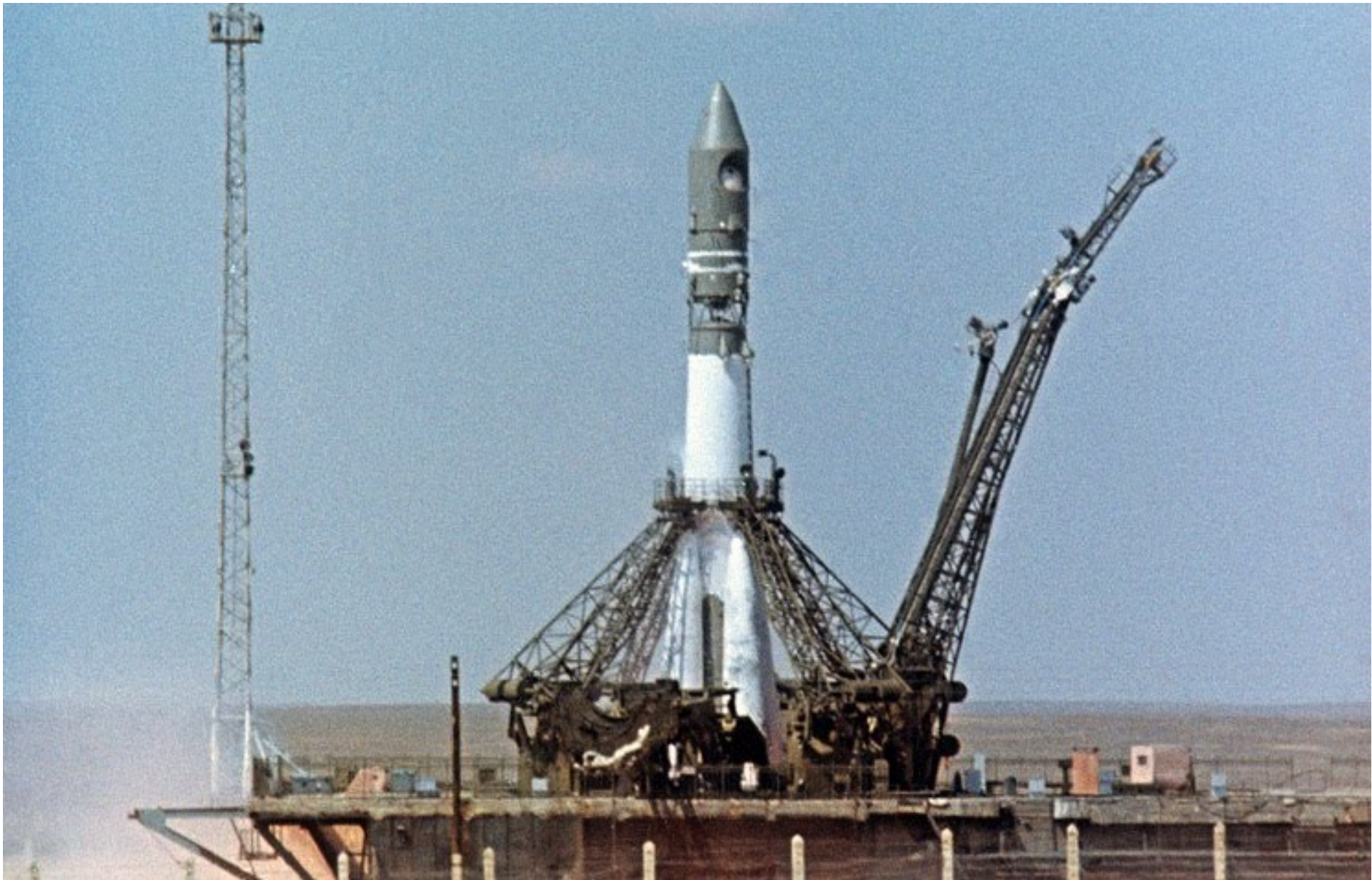
23 km east of
Korolev-Podlipki:

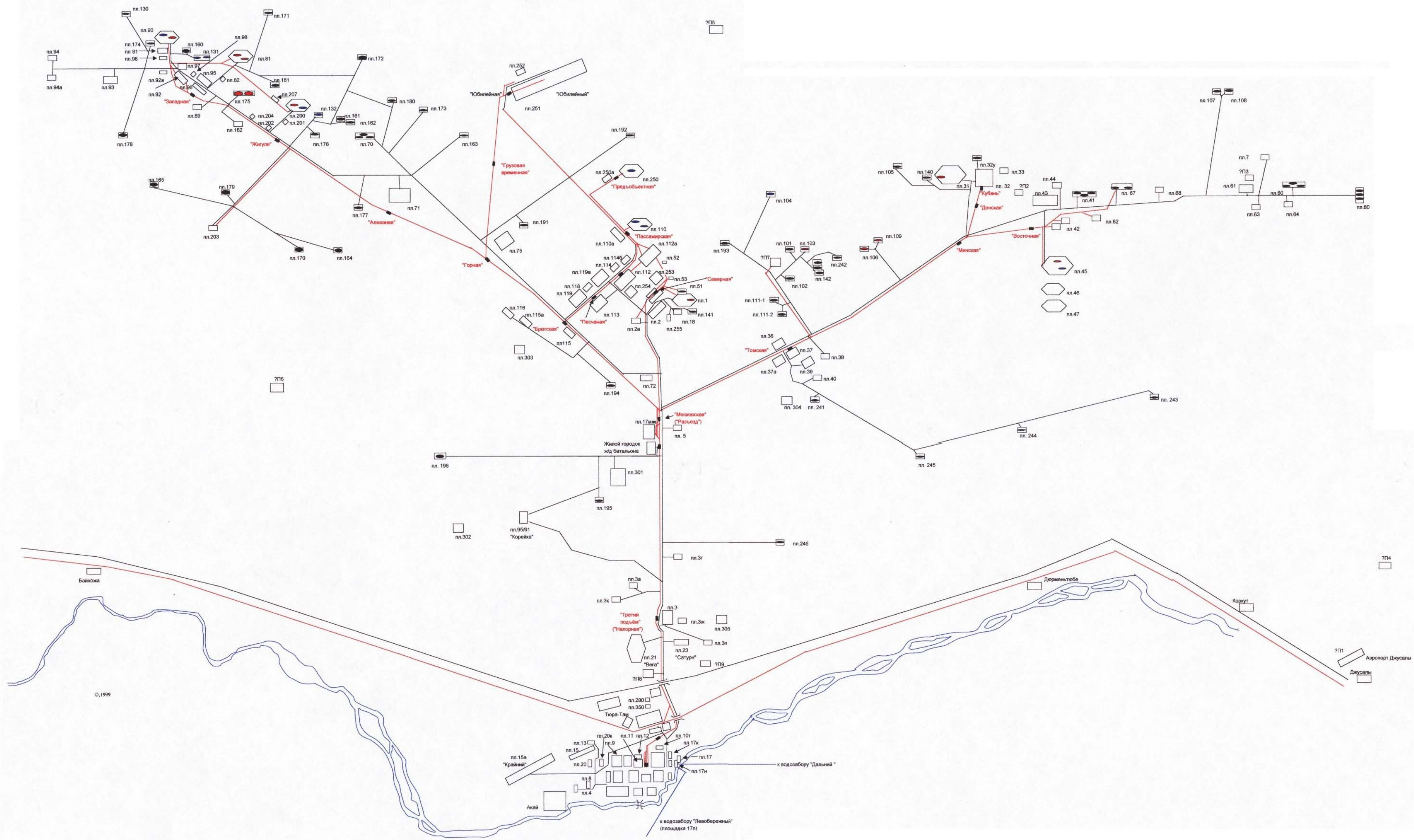
“Zvozydniy Gorodok”
- “Starry Town”



Nauchno-Issledovatelskiy Ispitatel’niy Poligon-5

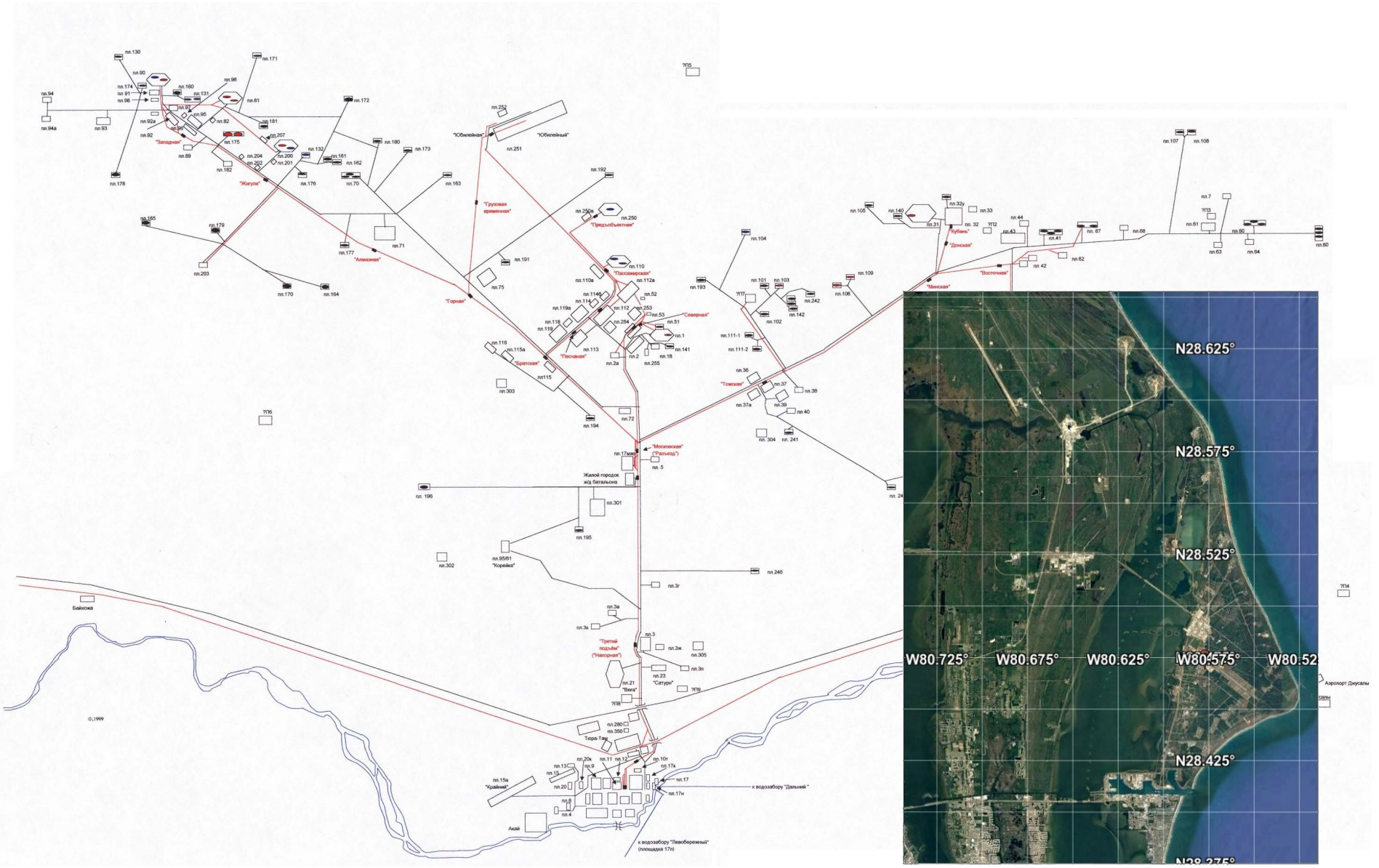
Scientific-Research Test Range No. 5, Kazakhstan
(nowadays “Kosmodrom Baykonur”)

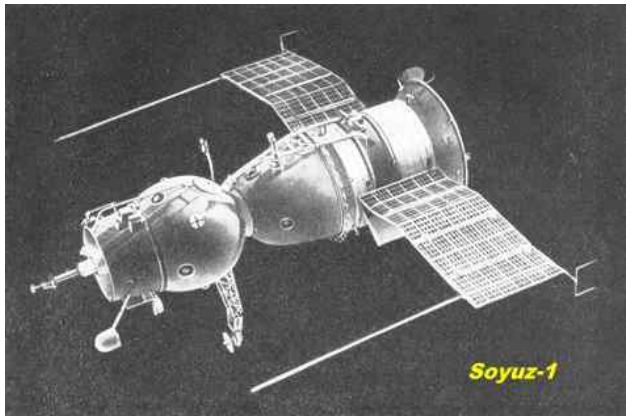




"Западная"
"Жигули"
"Алмазная"
"Горная"
"Юбилейная"
"Юбилейный"
"Грузовая временная"
"Предъобъектная"
"Пассажирская"
"Северная"
"Песчаная"
"Братская"
"Томская"
"Минская"
"Донская"
"Кубань"
"Восточная"
"Московская" ("Разъезд")
Жилой городок ж/д батальона
"Корейка"
"Третий подъём" ("Напорная")
"Вега"
"Сатурн"
Тюра-Там
"Крайний"
Акай
Байхожа
Дюрменьтюбе
Коркут
Аэропорт Джусалы
Джусалы
к водозабору "Дальний"
к водозабору "Левобережный" (площадка 17л)
©,1999

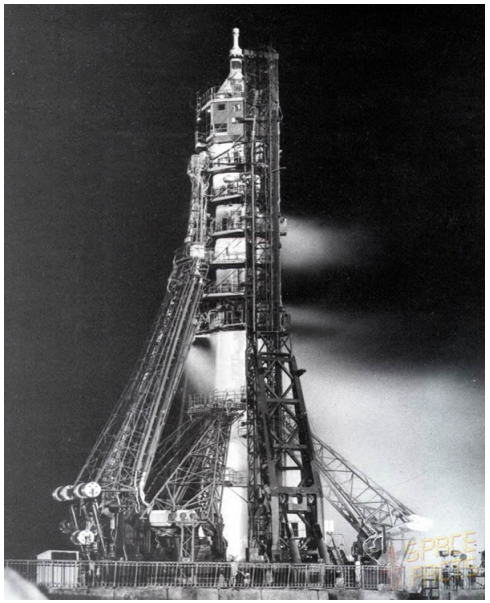
Baykonur is HUGE - 65 km across.
Here it is compared in scale to Cape Canaveral

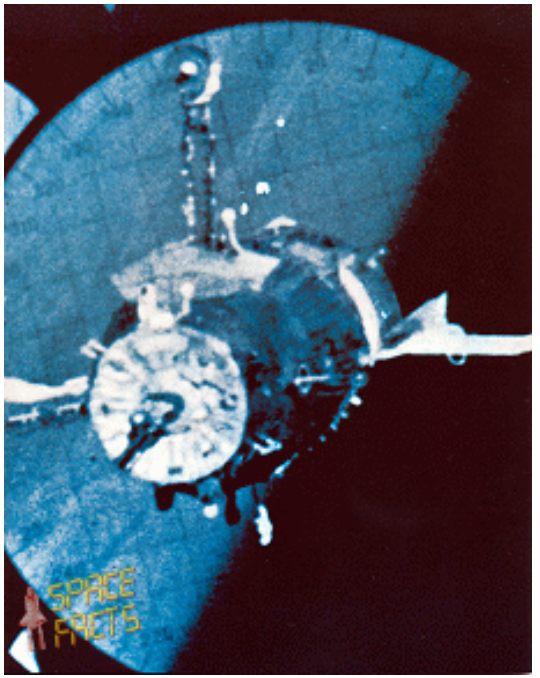




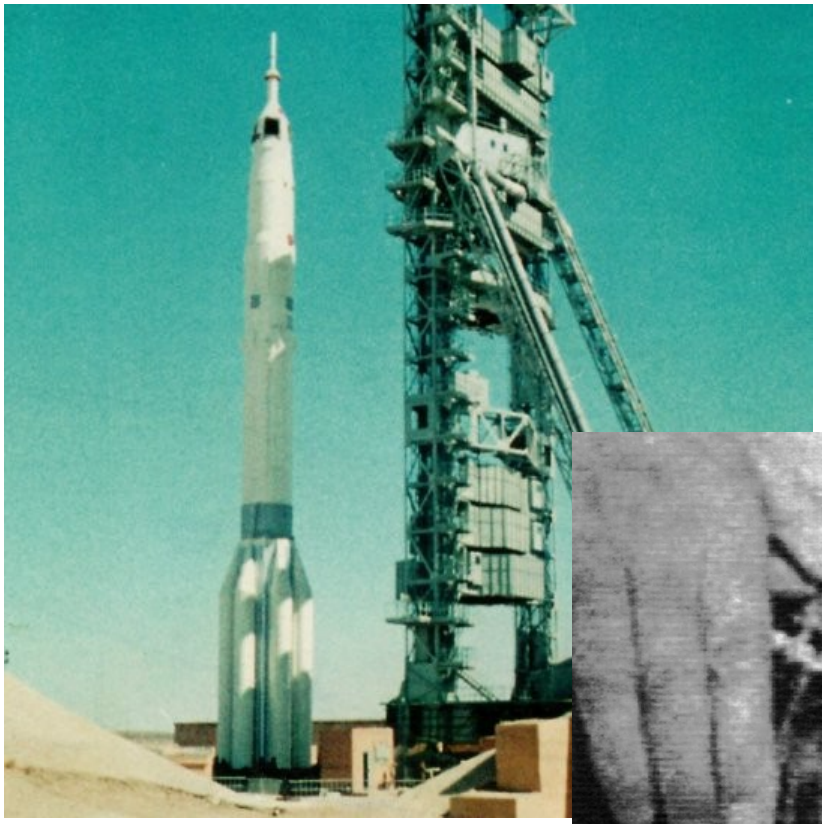
Soyuz-1
Apr 1967

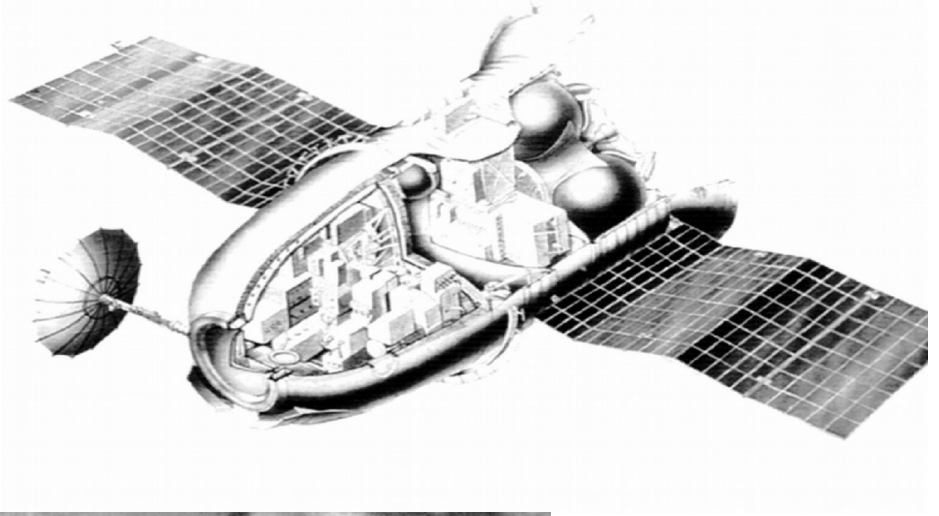
New spaceship design
Designed for lunar flight
Earth orbit test by test pilot Vladimir Komarov
Solar panel failed to open, spacecraft tumbling
Emergency reentry and crash landing
First fatality during a space flight

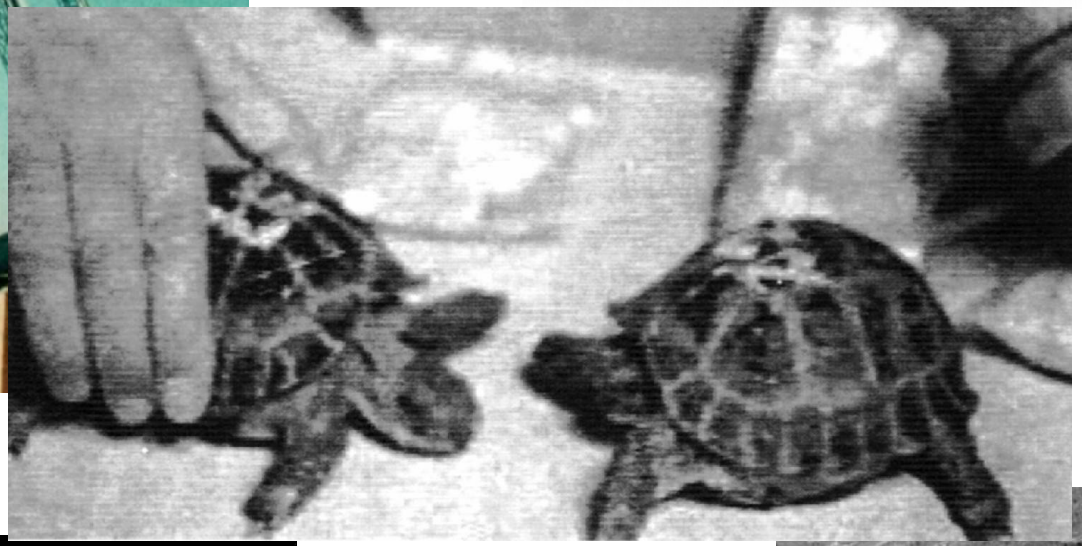


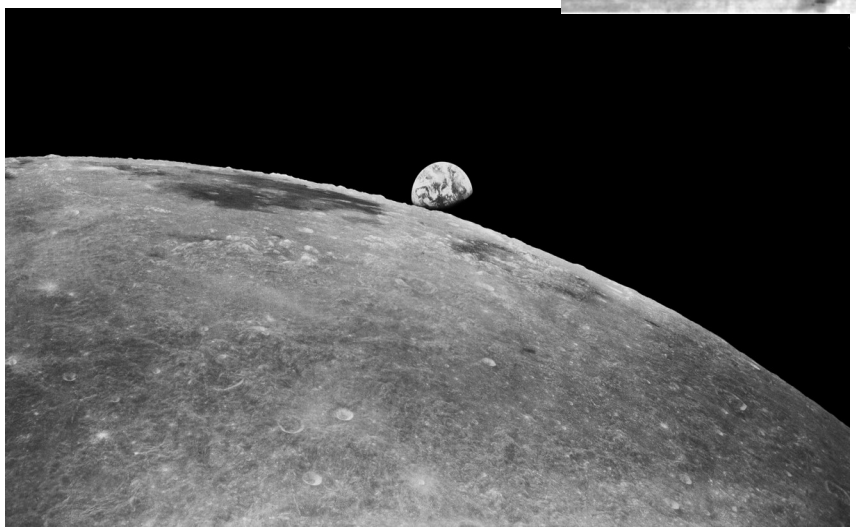


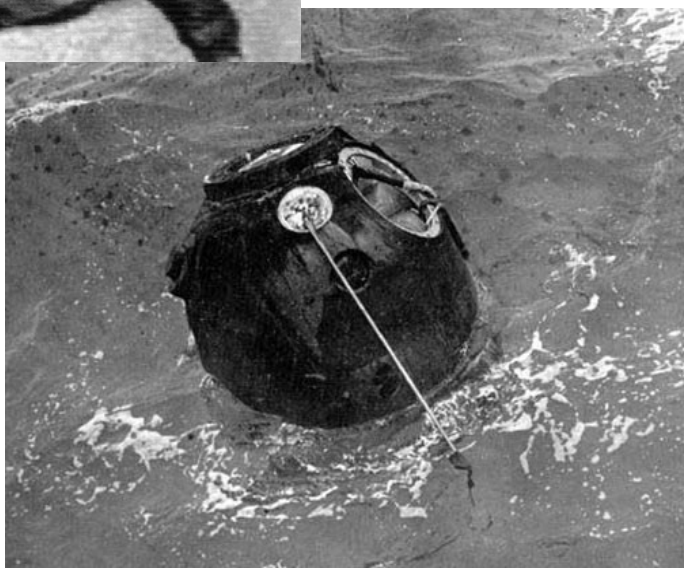
TORTOISES TO THE MOON! (AND BACK)









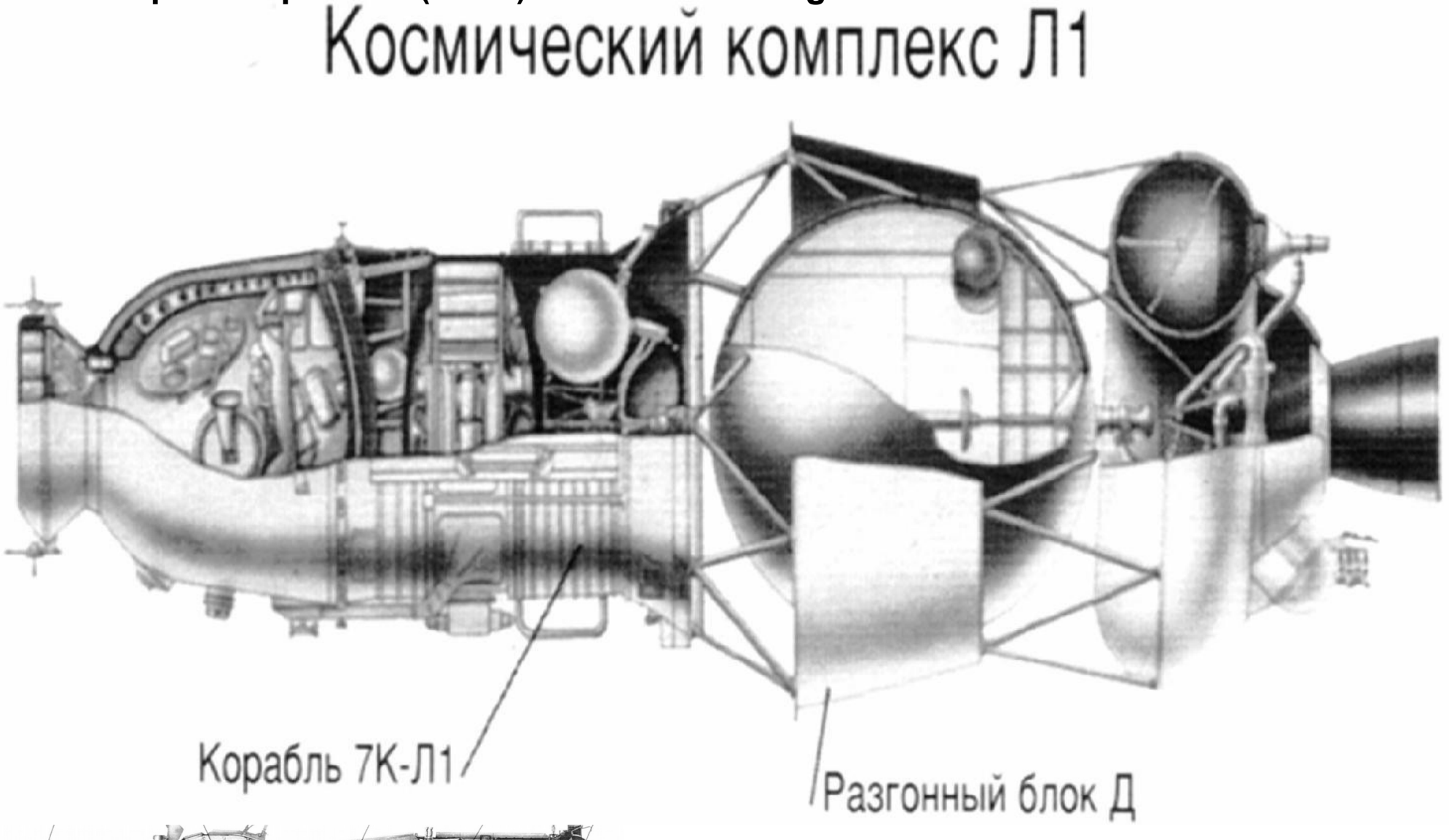


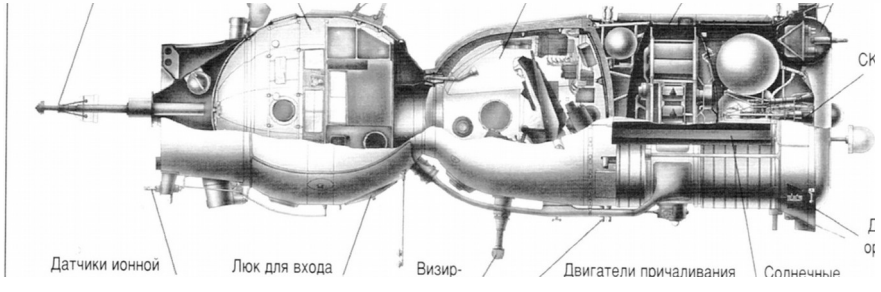
The Flight of Zond-5 Sep 14-21, 1968
First Return To Earth From Lunar Vicinity
First Terrestrial Creatures in Interplanetary Flight

- **Launch into Earth orbit**
- **TLI (Trans Lunar Injection) rocket burn towards the Moon**
- **Fly around lunar farside (but not into a closed lunar orbit)**
- **Pass 1200 mi (1950 km) from lunar surface**
- **Coast back down towards Earth**
- **Reentry at 25000 mph over South Pole**
- **Splashdown in Indian Ocean, recovered by Soviet Navy**

Общее время полета – 7...8 сут.
Направление подхода при возвращении к Земле – со стороны Южного полушария.
Тип спуска – управляемый с качеством.
Приземление на территории СССР.

Space Complex L-1
With Spaceship 7K-L1 (Zond) and Booster Stage “Block D”

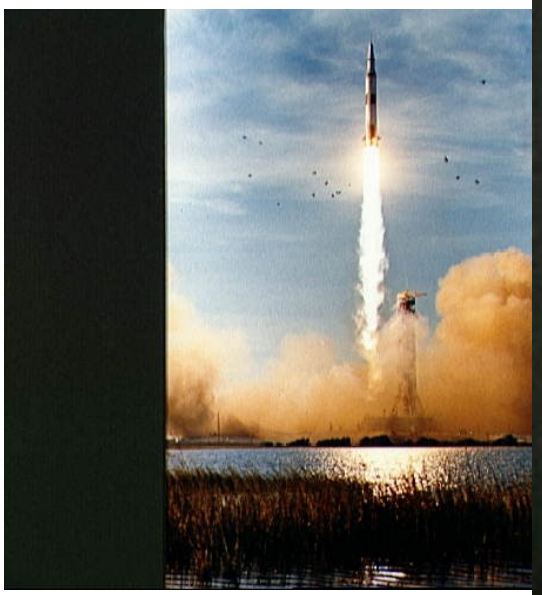


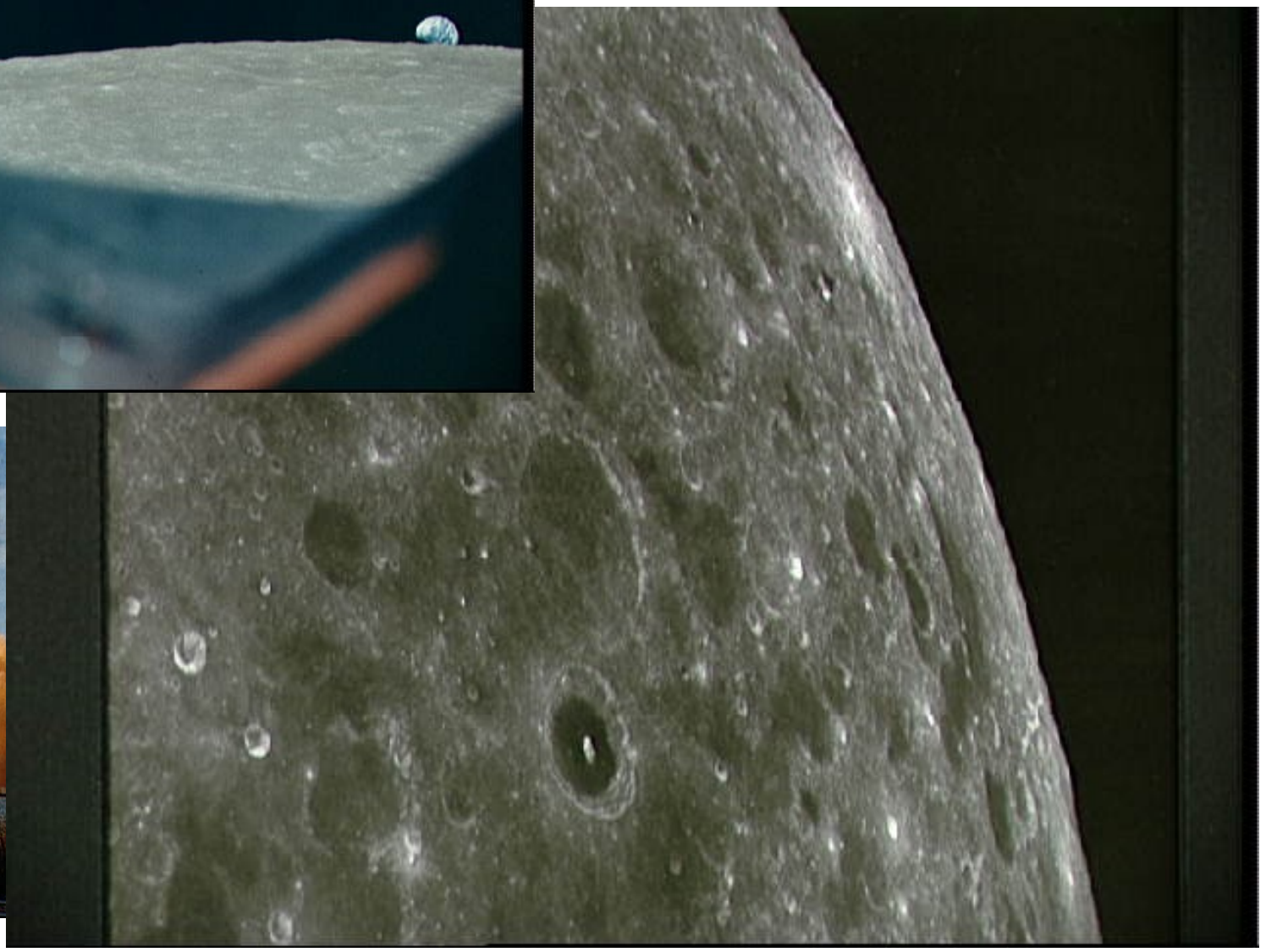


Compare 7K-L1 (above)
with Soyuz (left)

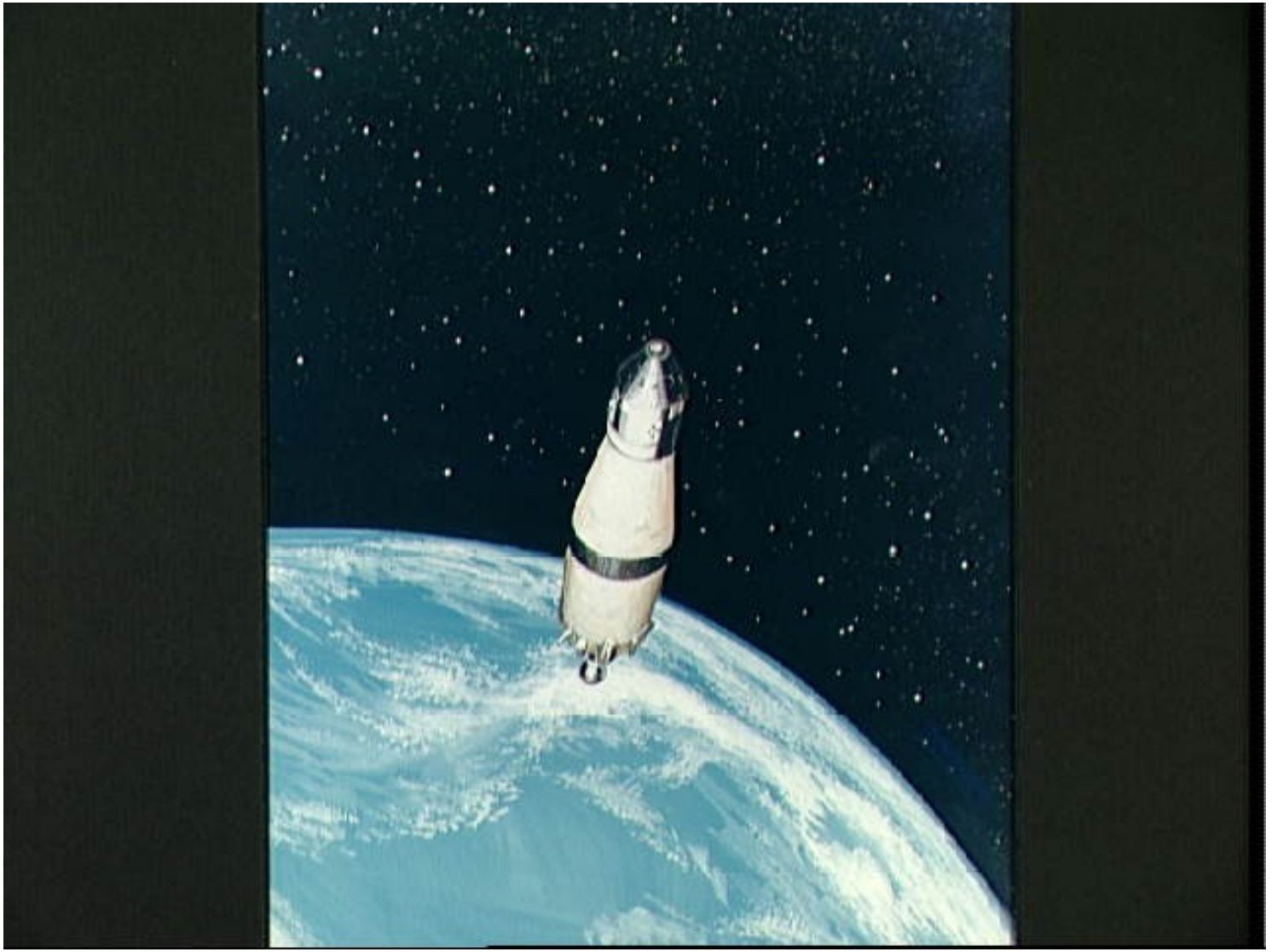
Apollo 8, Dec 1968:
First humans to leave Earth's gravitational sphere of influence

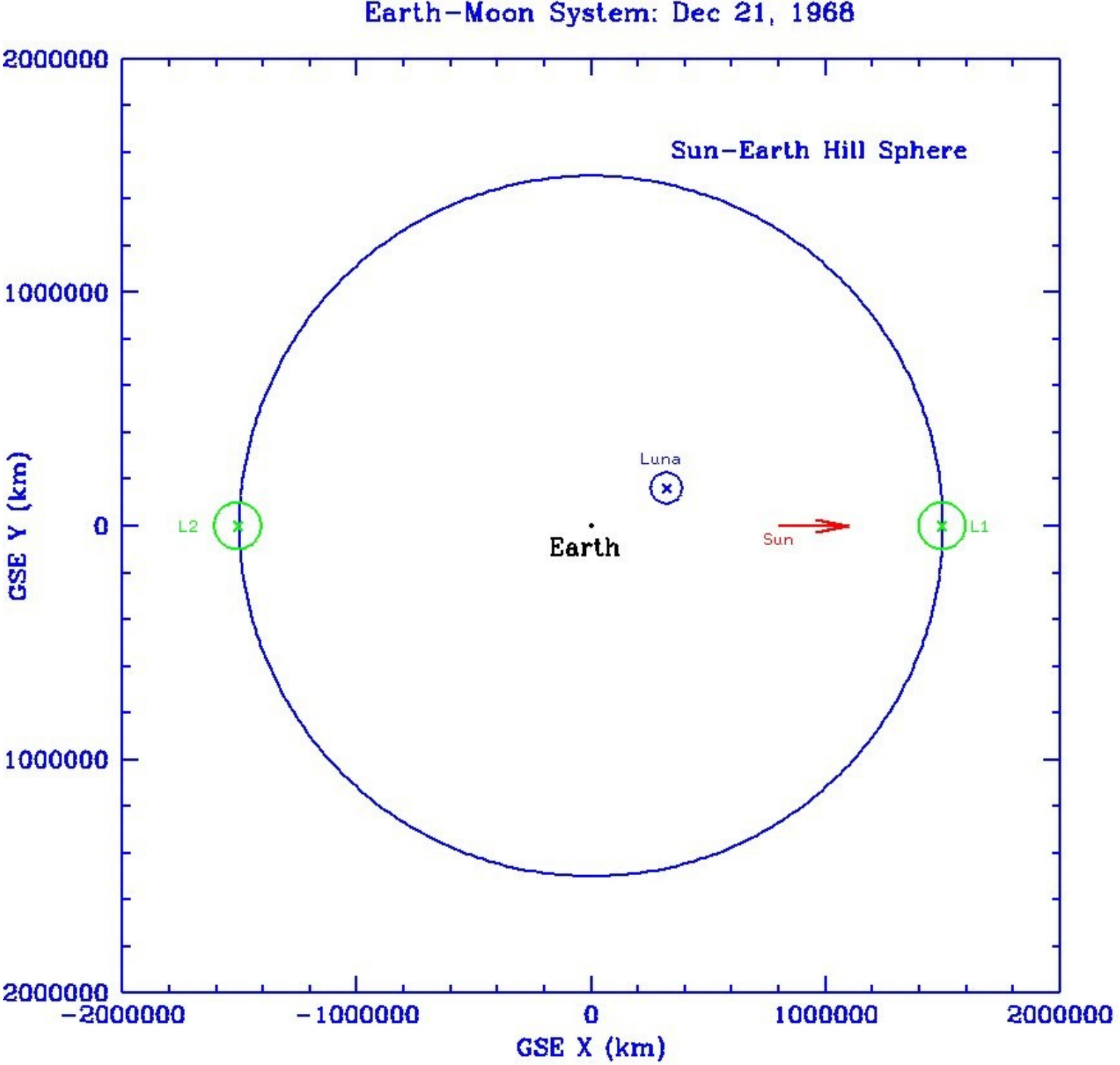
First humans to orbit the Moon:
F. Borman J. Lovell W. Anders

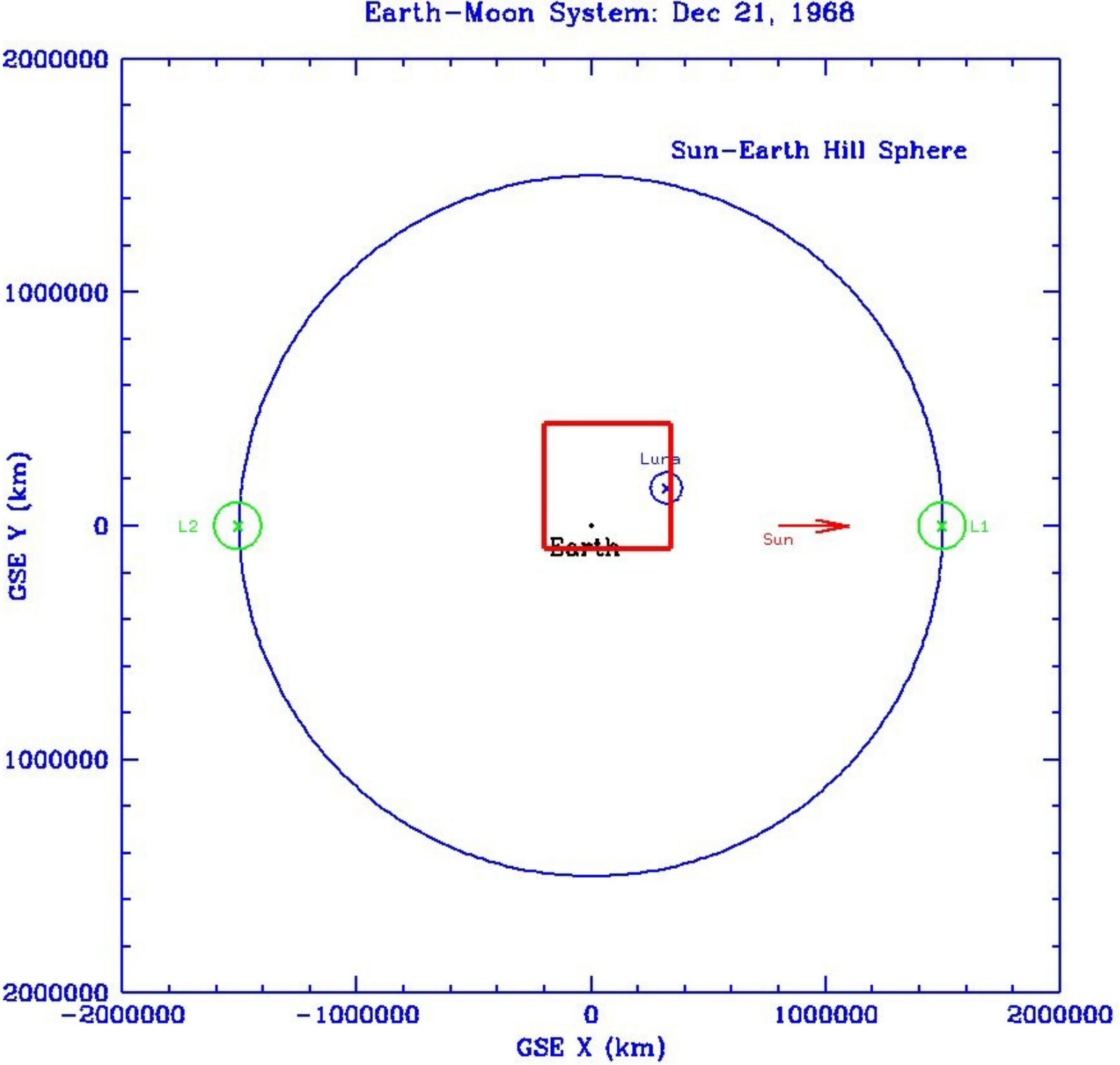


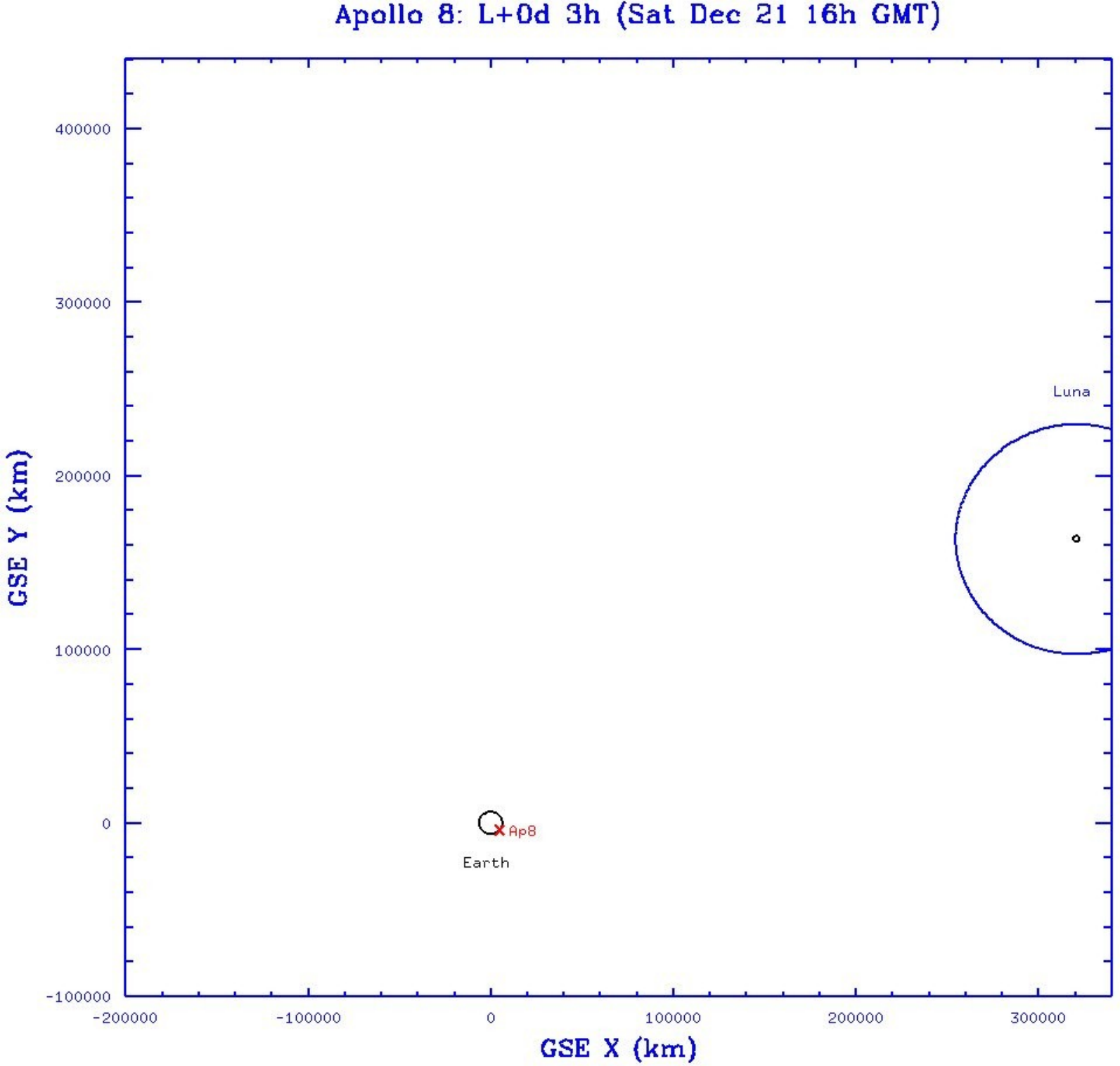


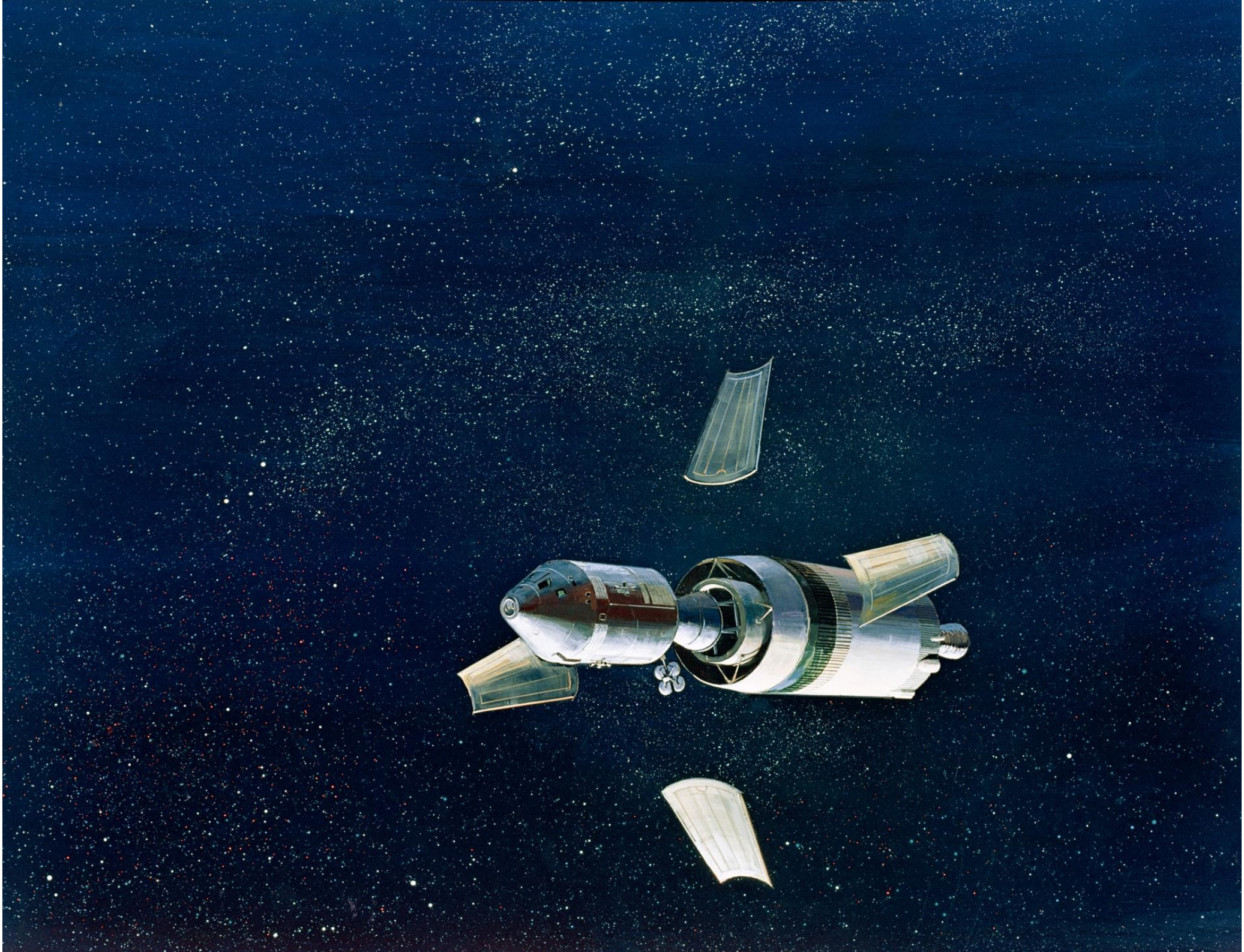
Apollo/Saturn 3rd stage in Earth orbit 128 tonnes
Apollo/Saturn 3rd stage departing Earth orbit 59 tonnes
Apollo 8 spaceship is 10 tonnes dry plus 14 tonnes propellant

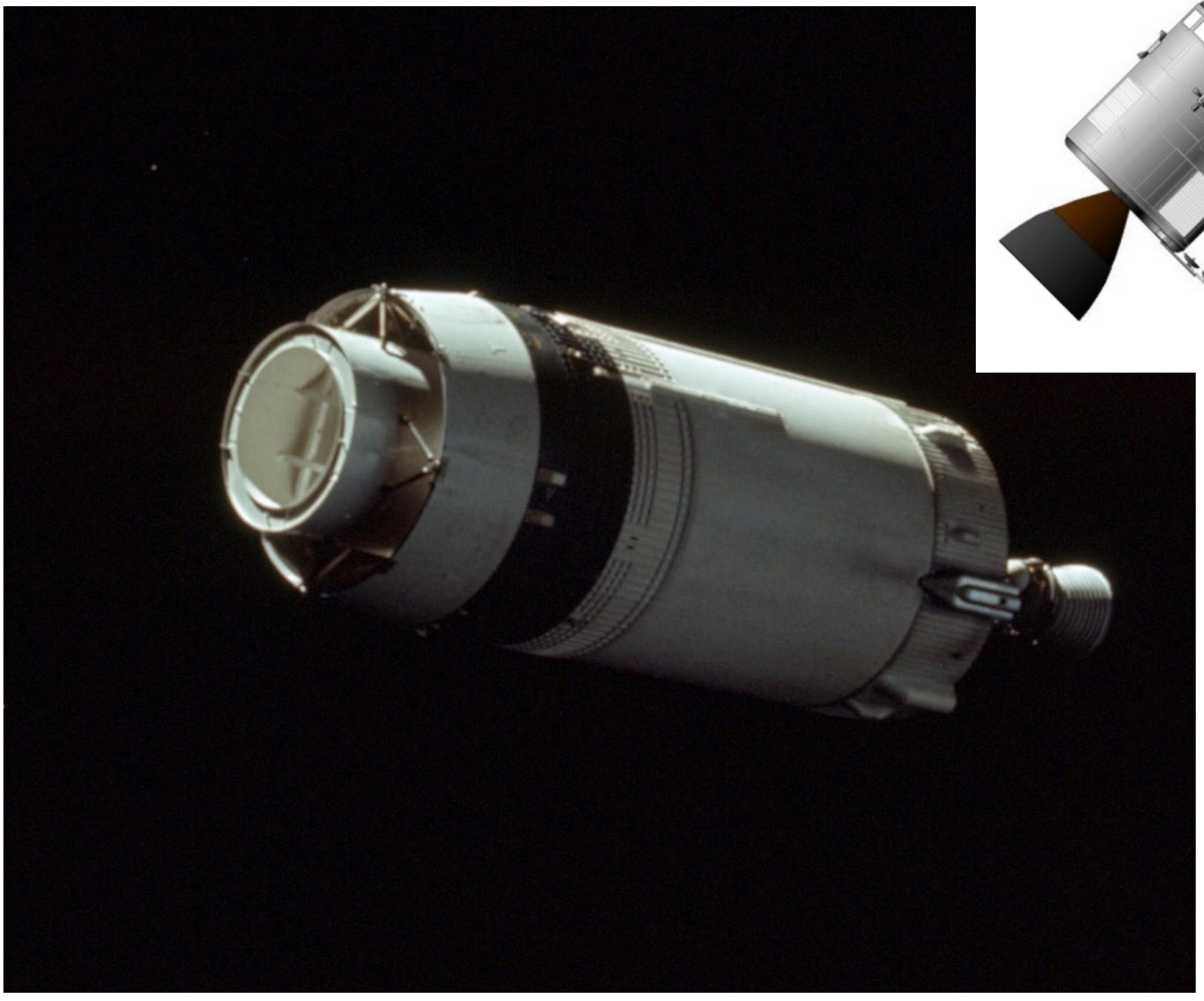


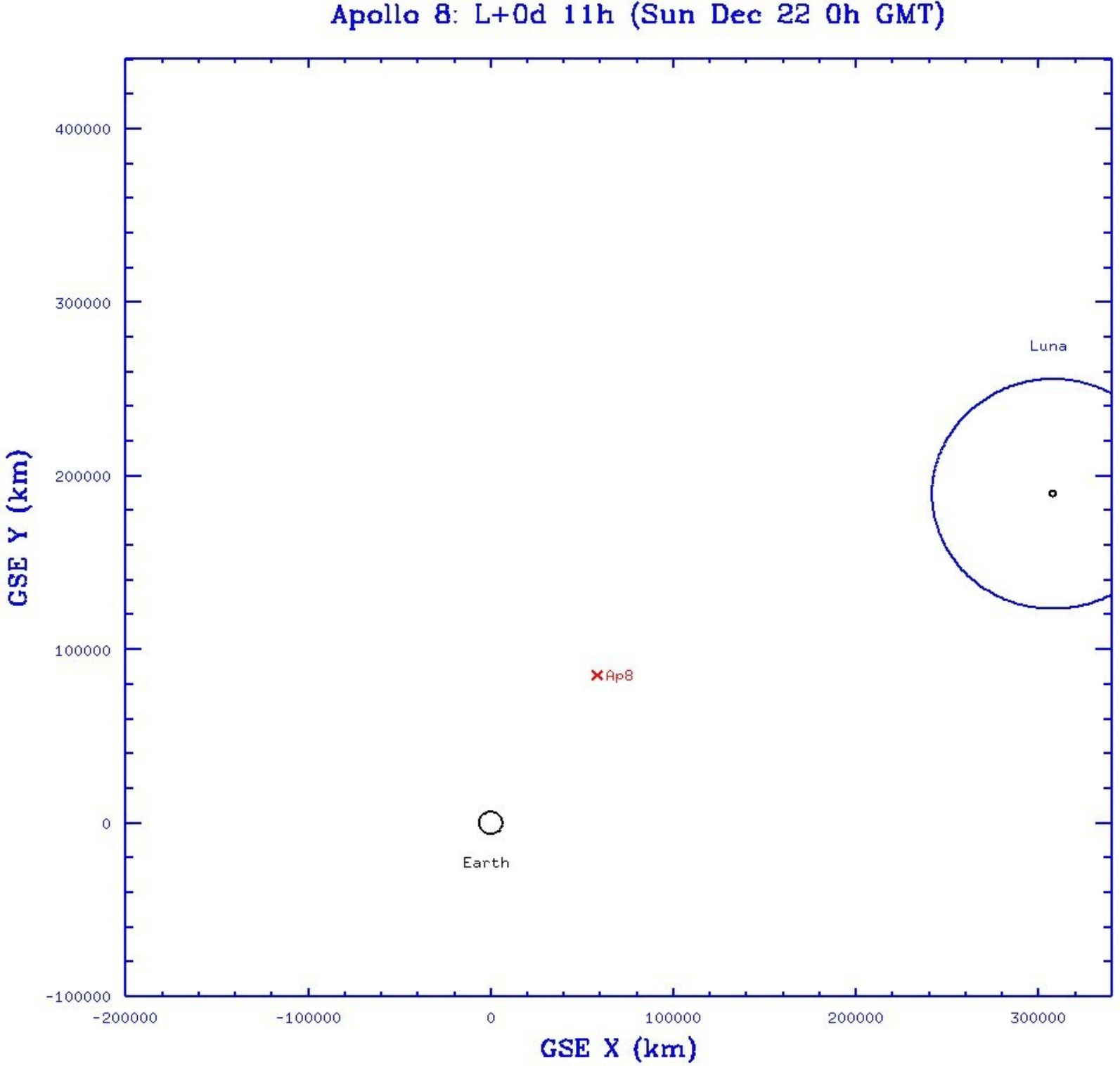

Earth-Moon System: Dec 21, 1968
Sun-Earth Hill Sphere
Luna
L2
L1
Earth
Sun
2000000
1000000
0
1000000
2000000
GSE Y (km)
−2000000
−1000000
0
1000000
2000000
GSE X (km)

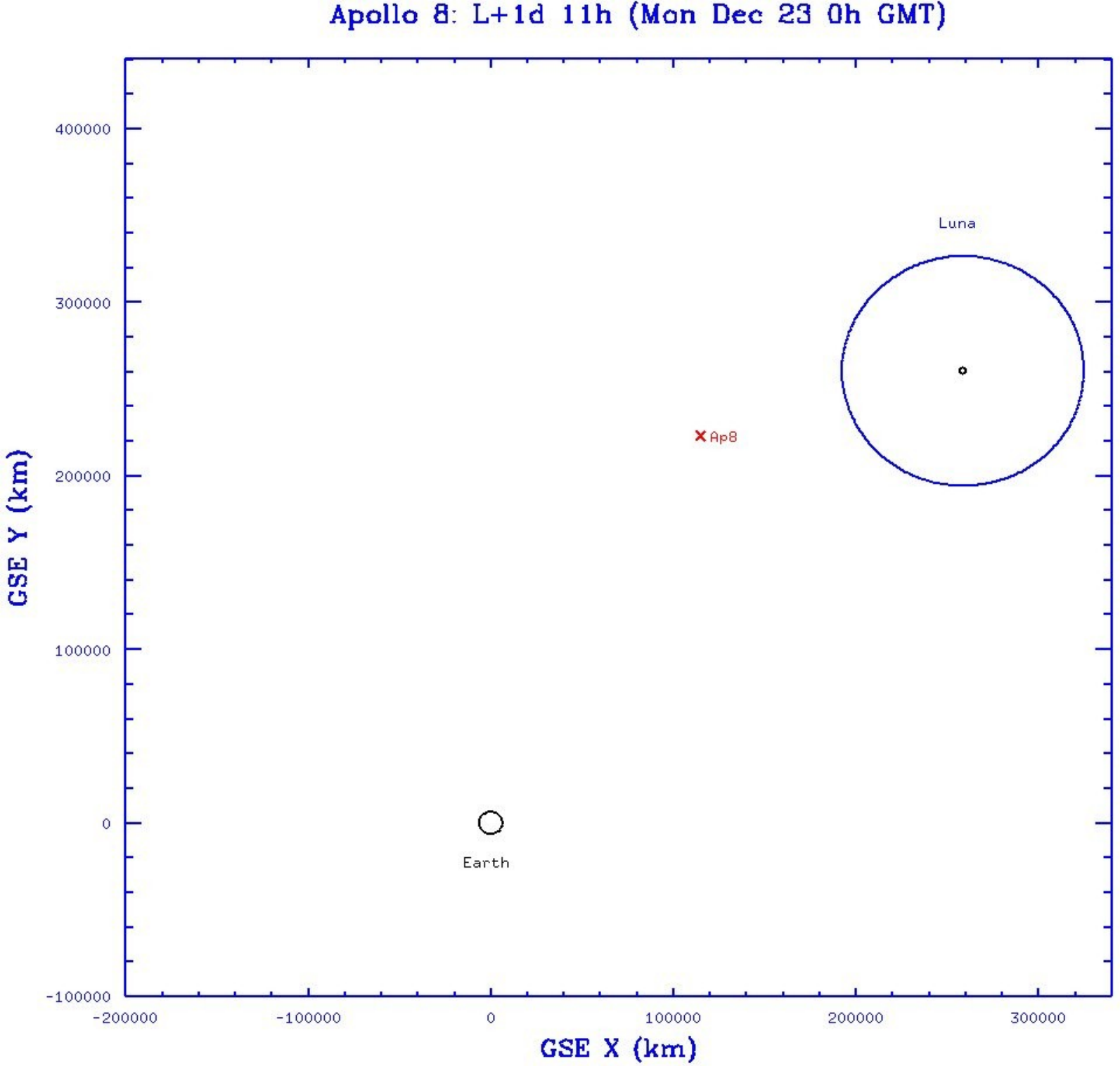

Earth-Moon System: Dec 21, 1968
Sun-Earth Hill Sphere
Luna
L2
L1
Sun
Earth
2000000
1000000
0
1000000
2000000
GSE Y (km)
−2000000
−1000000
0
1000000
2000000
GSE X (km)

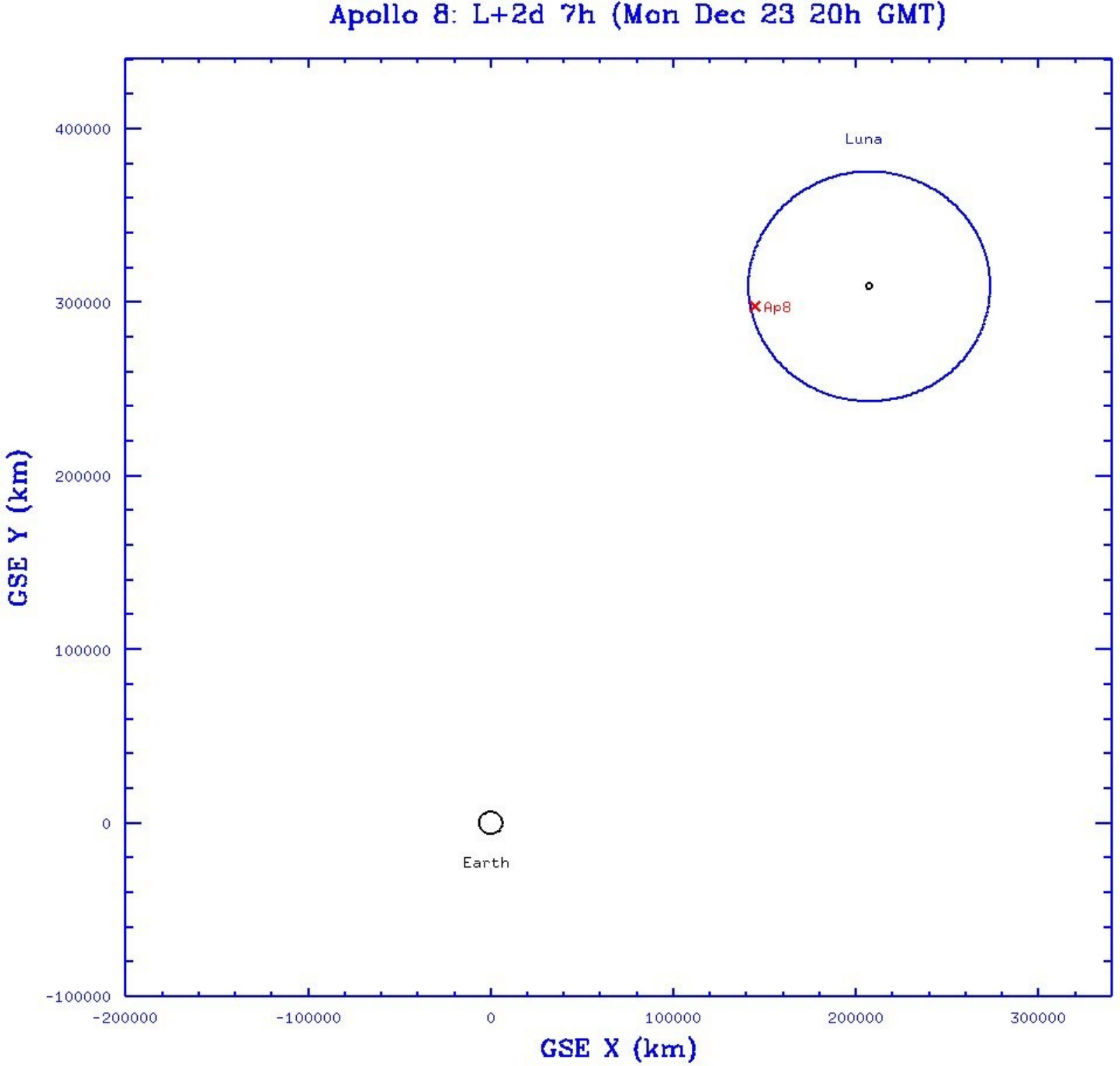

Apollo 8: L+0d 3h (Sat Dec 21 16h GMT)
GSE Y (km)
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000
GSE X (km)
Luna
Ap8
Earth

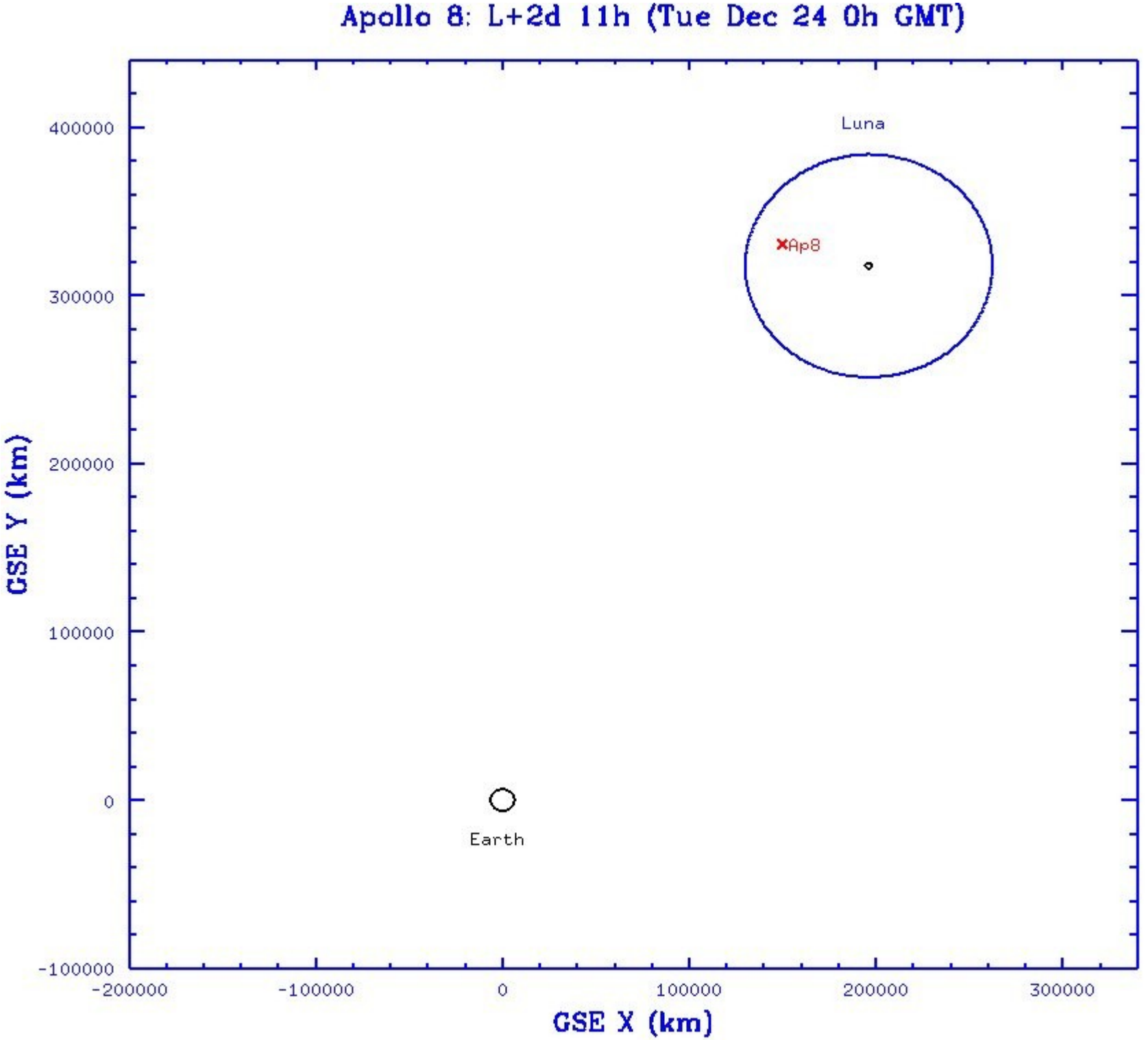


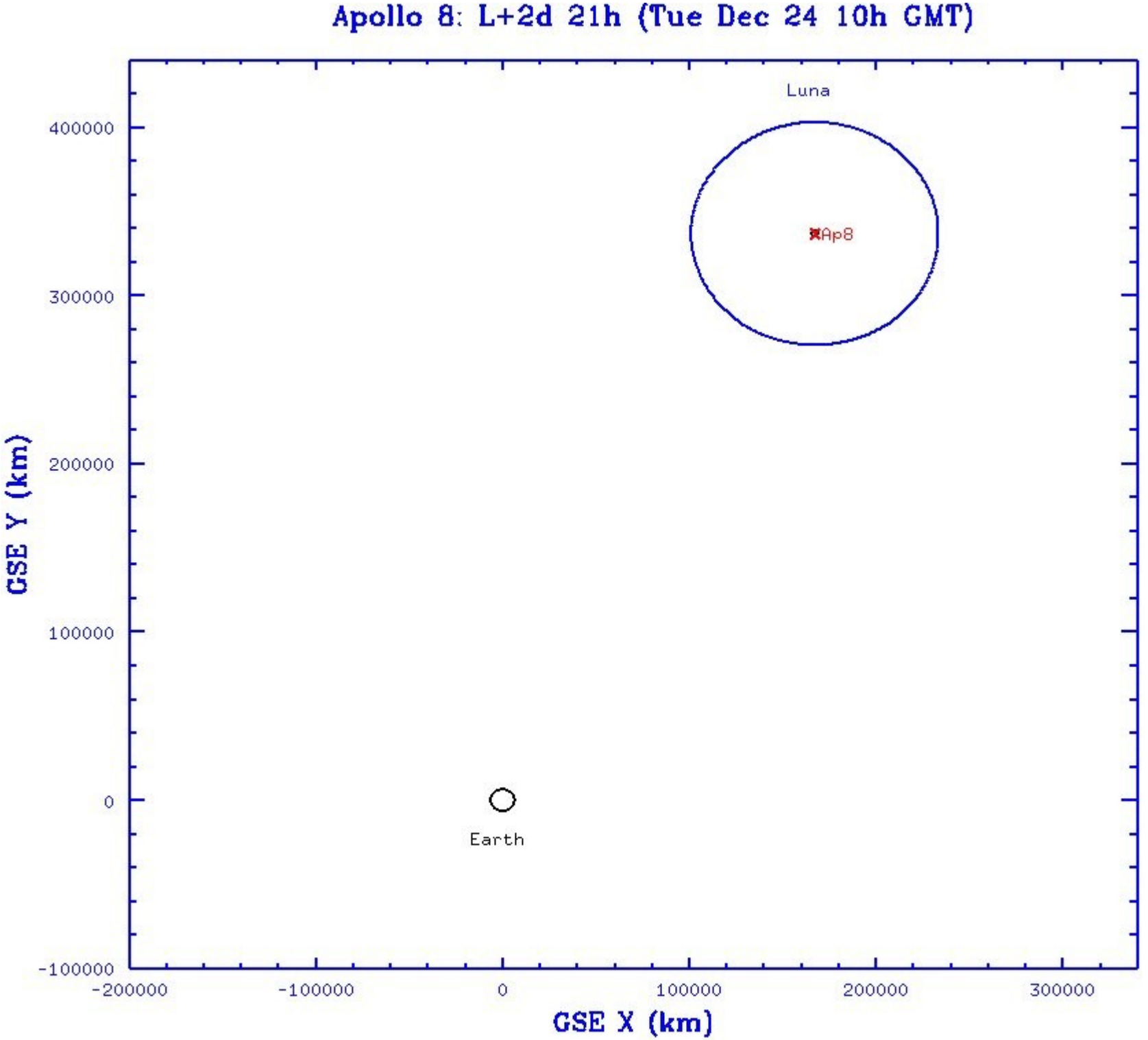


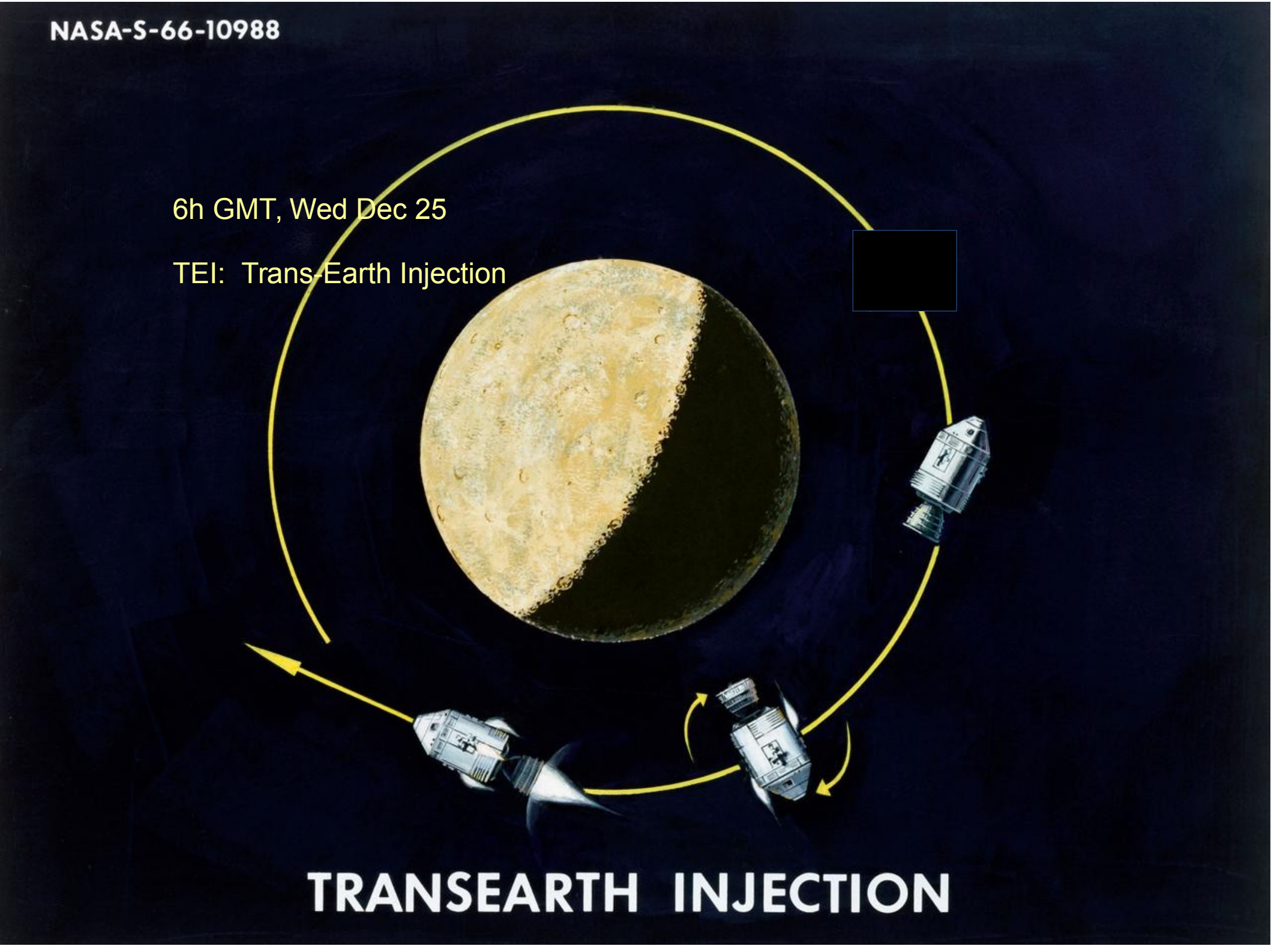

Apollo 8: L+0d 11h (Sun Dec 22 0h GMT)
400000
300000
200000
100000
0
-100000
GSE Y (km)
Luna
Ap8
Earth
-200000
-100000
0
100000
200000
300000
GSE X (km)

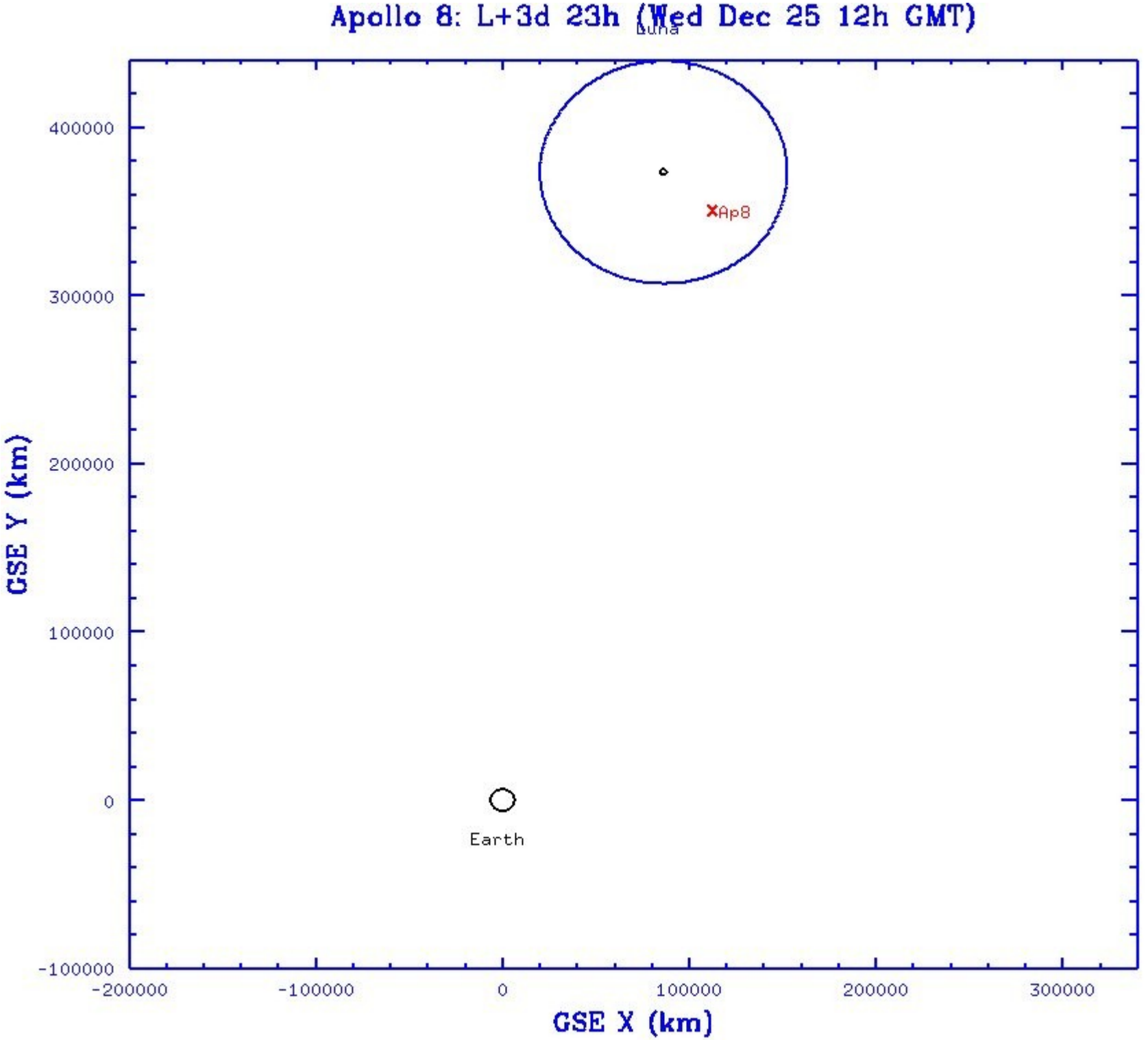

Apollo 8: L+1d 11h (Mon Dec 23 0h GMT)
Luna
Ap8
Earth
GSE Y (km)
GSE X (km)
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000

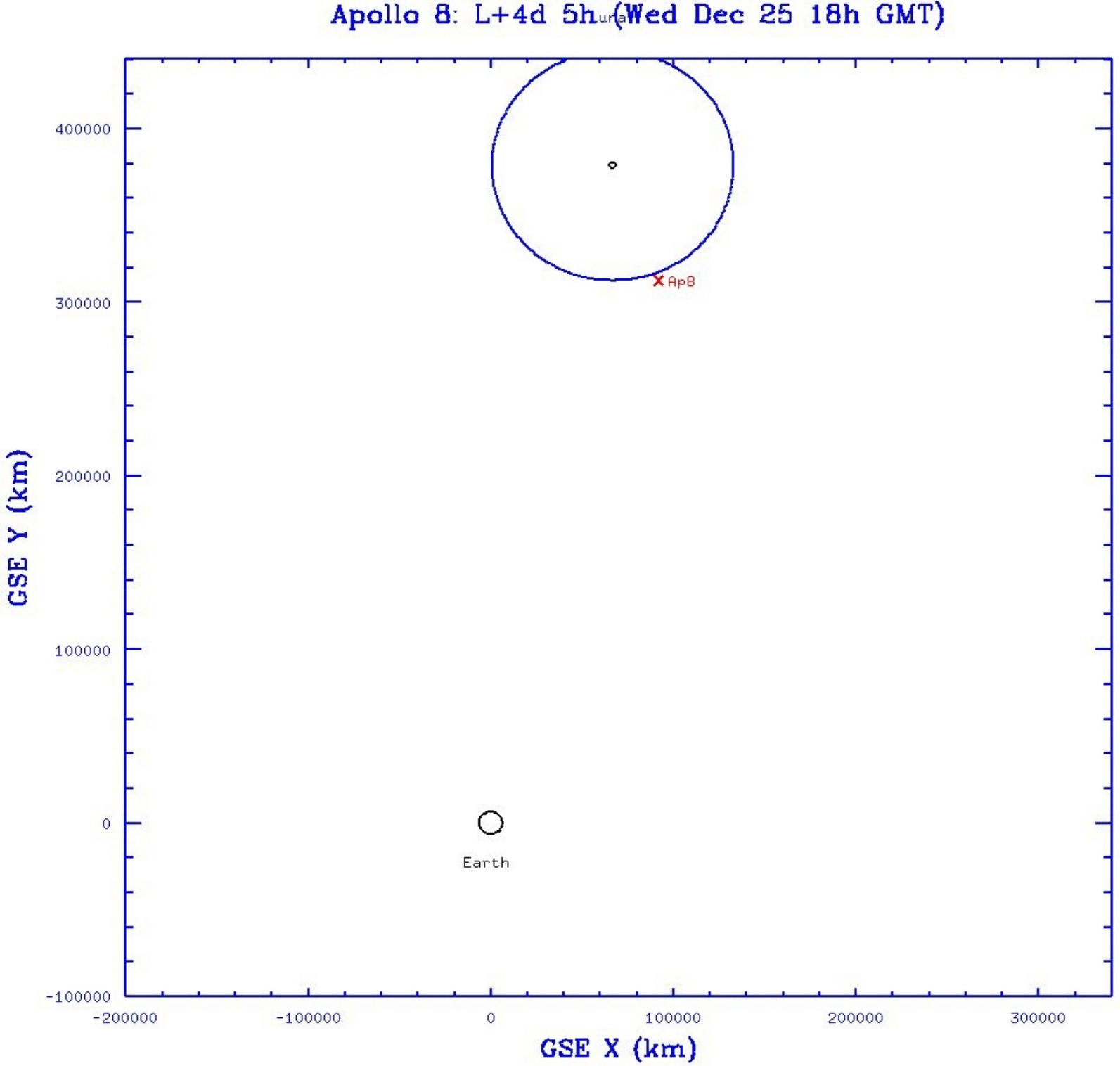

Apollo 8: L+2d 7h (Mon Dec 23 20h GMT)
Luna
Ap8
Earth
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000
GSE Y (km)
GSE X (km)

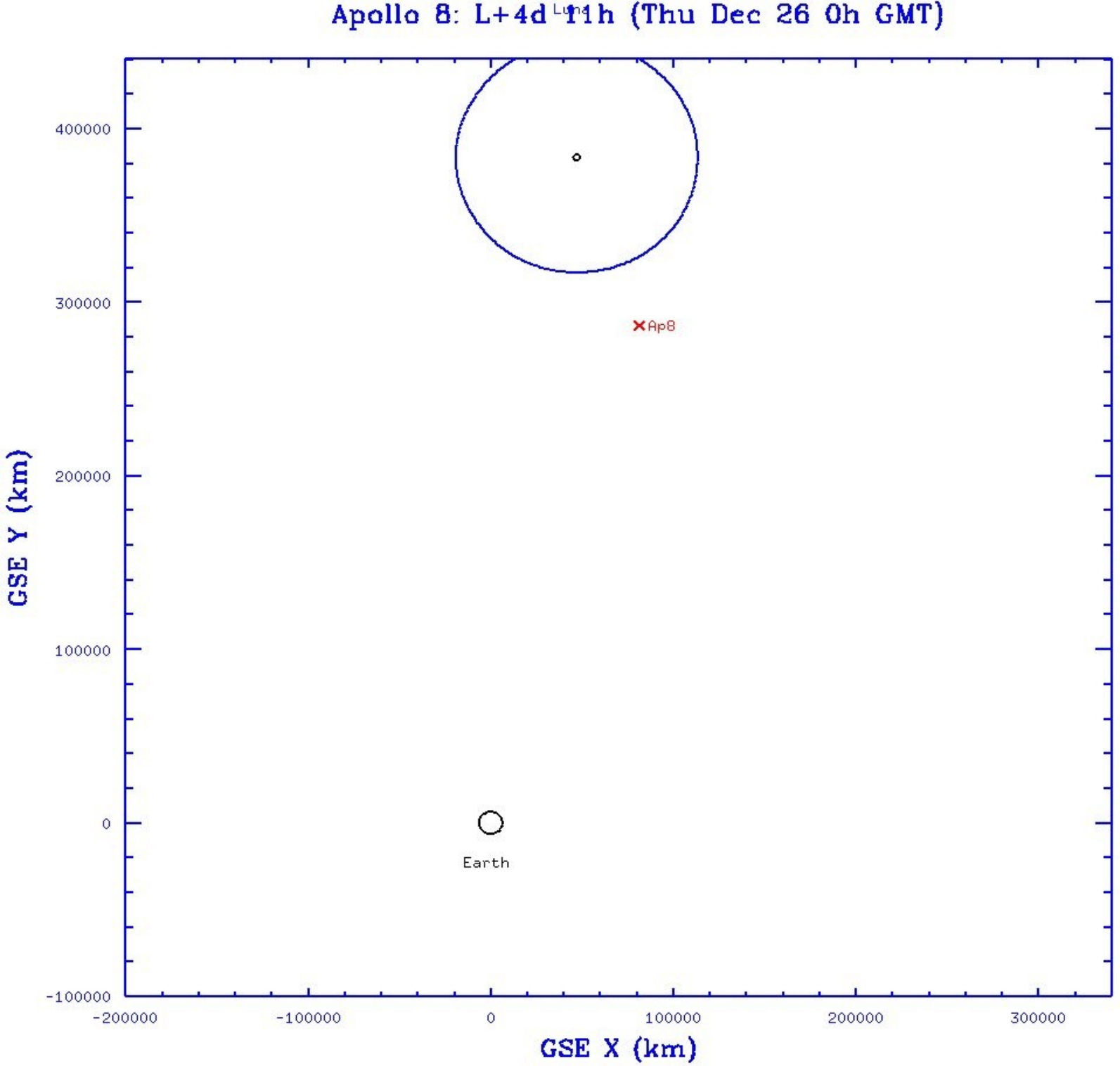

Apollo 8: L+2d 11h (Tue Dec 24 0h GMT)
Luna
Ap8
Earth
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000
GSE Y (km)
GSE X (km)

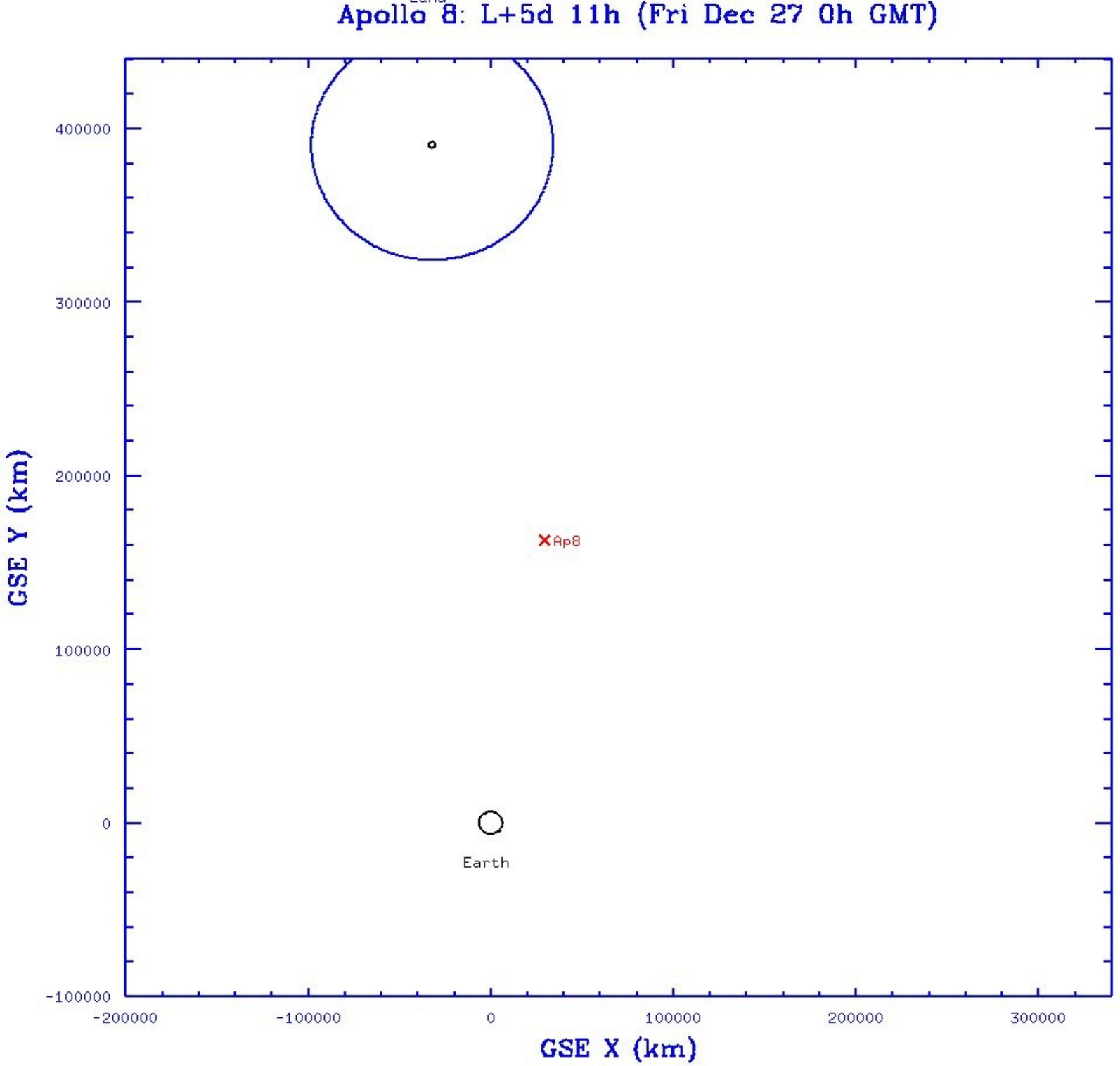

Apollo 8: L+2d 21h (Tue Dec 24 10h GMT)
Luna
Ap8
Earth
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000
GSE Y (km)
GSE X (km)

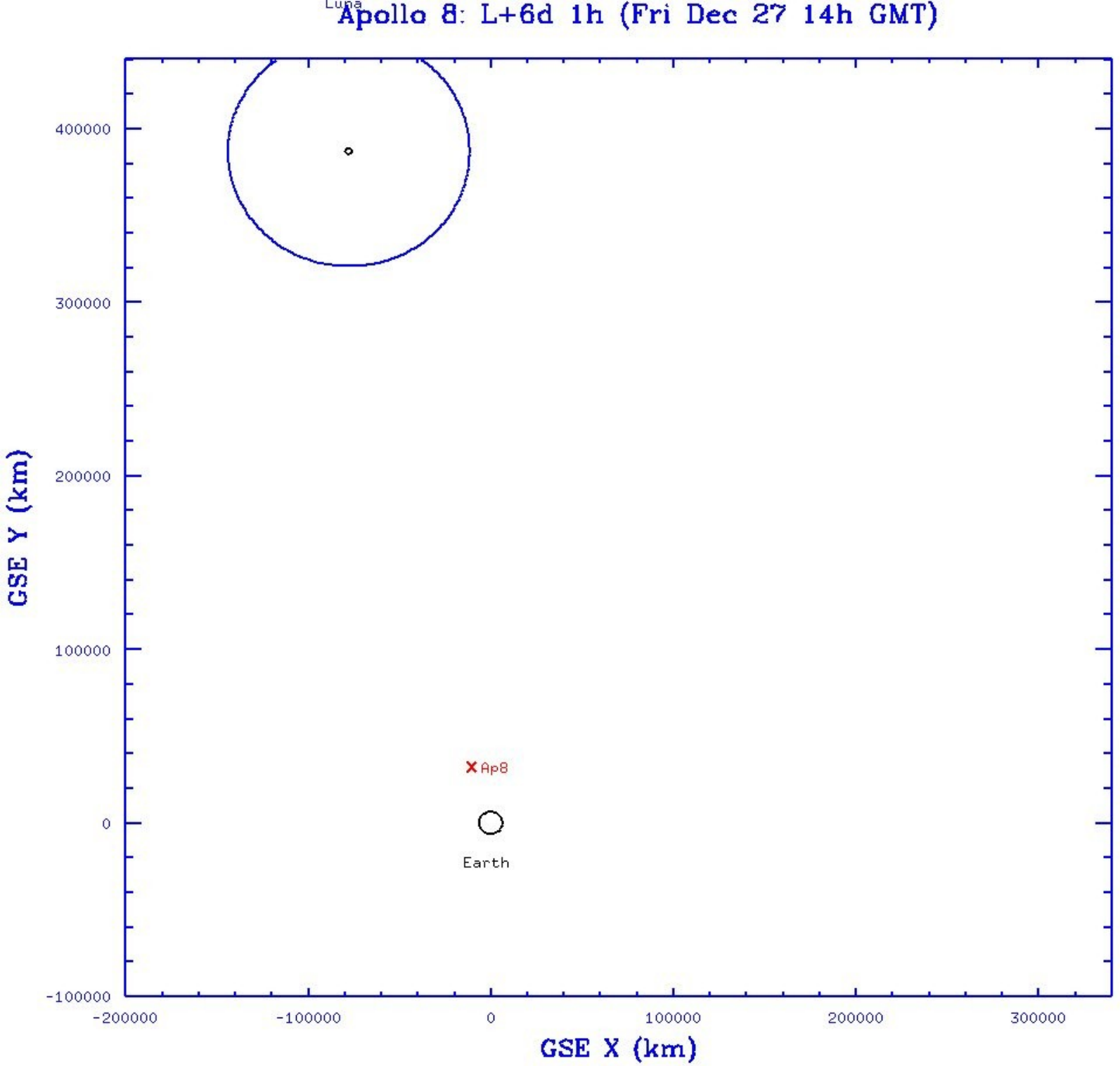

NASA-S-66-10988
6h GMT, Wed Dec 25
TEI: Trans-Earth Injection
TRANSEARTH INJECTION

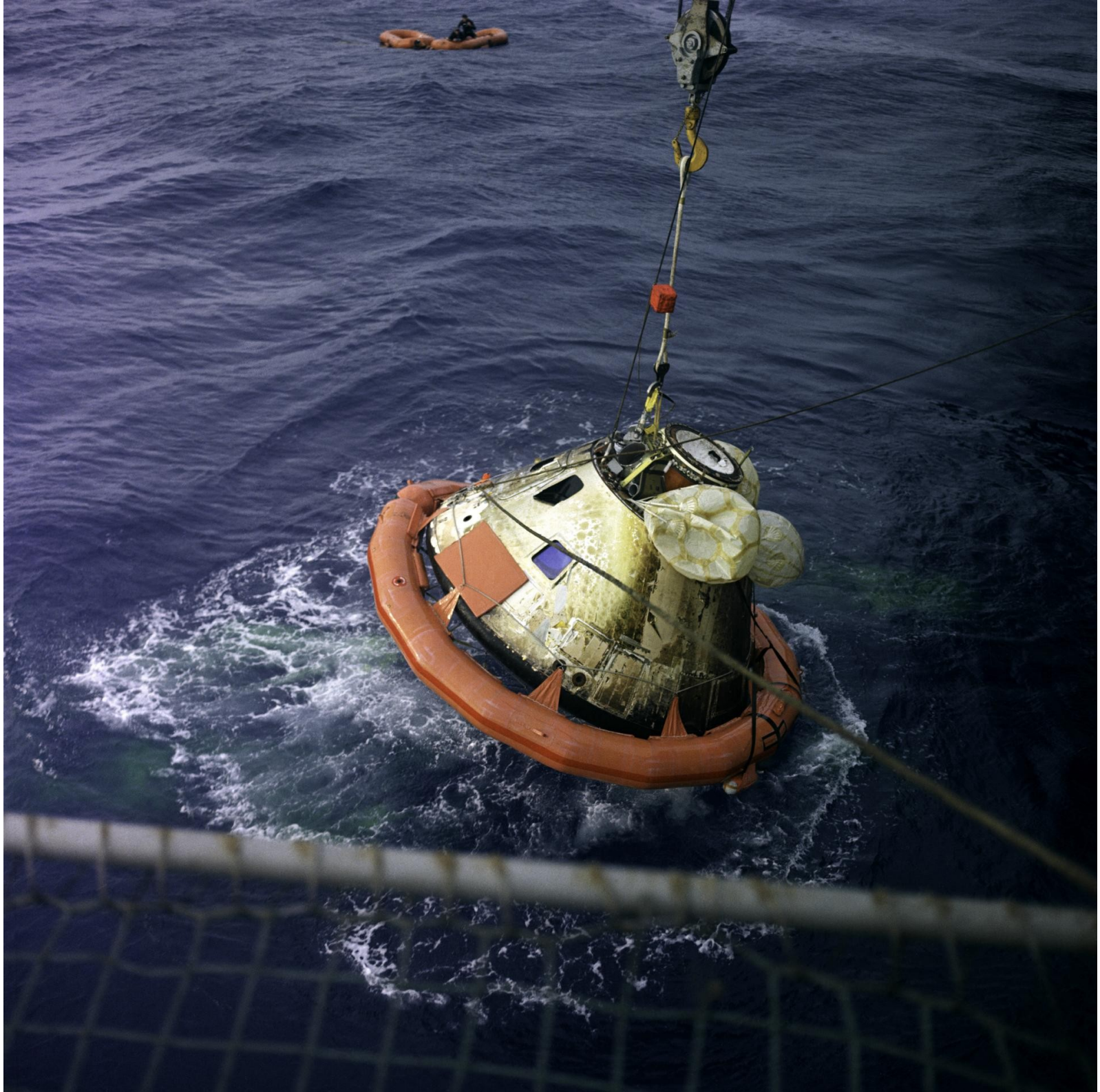

Apollo 8: L+3d 23h (Wed Dec 25 12h GMT)
Luna
Ap8
Earth
GSE Y (km)
GSE X (km)
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000


Apollo 8: L+4d 5h (Wed Dec 25 18h GMT)
Ap8
Earth
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000
GSE Y (km)
GSE X (km)

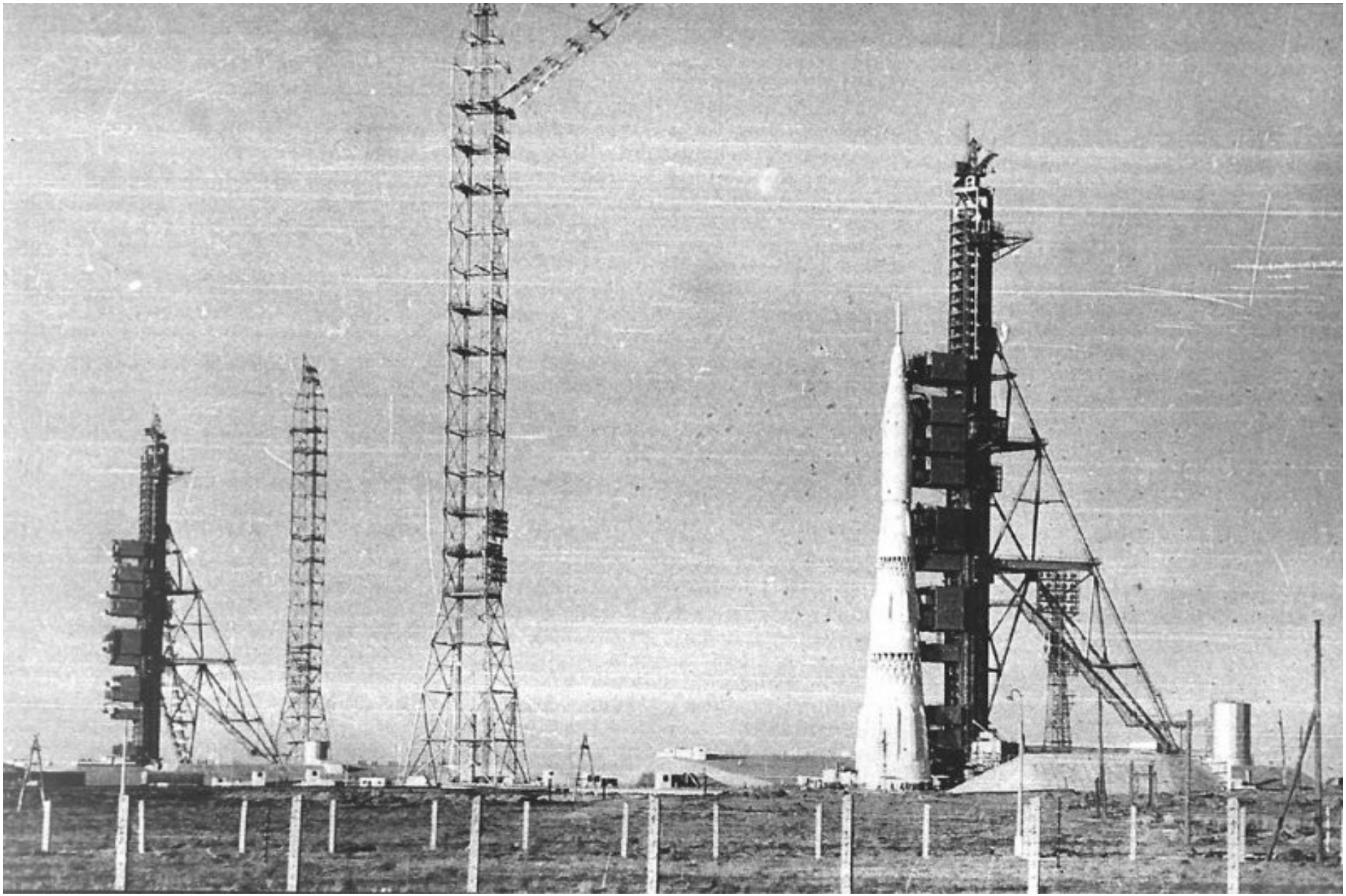

Apollo 8: L+4d 11h (Thu Dec 26 0h GMT)
400000
300000
200000
100000
0
-100000
Ap8
Earth
-200000
-100000
0
100000
200000
300000
GSE Y (km)
GSE X (km)


Apollo 8: L+5d 11h (Fri Dec 27 0h GMT)
400000
300000
200000
100000
0
-100000
GSE Y (km)
Ap8
Earth
-200000
-100000
0
100000
200000
300000
GSE X (km)


Apollo 8: L+6d 1h (Fri Dec 27 14h GMT)
Luna
Ap8
Earth
400000
300000
200000
100000
0
-100000
-200000
-100000
0
100000
200000
300000
GSE Y (km)
GSE X (km)

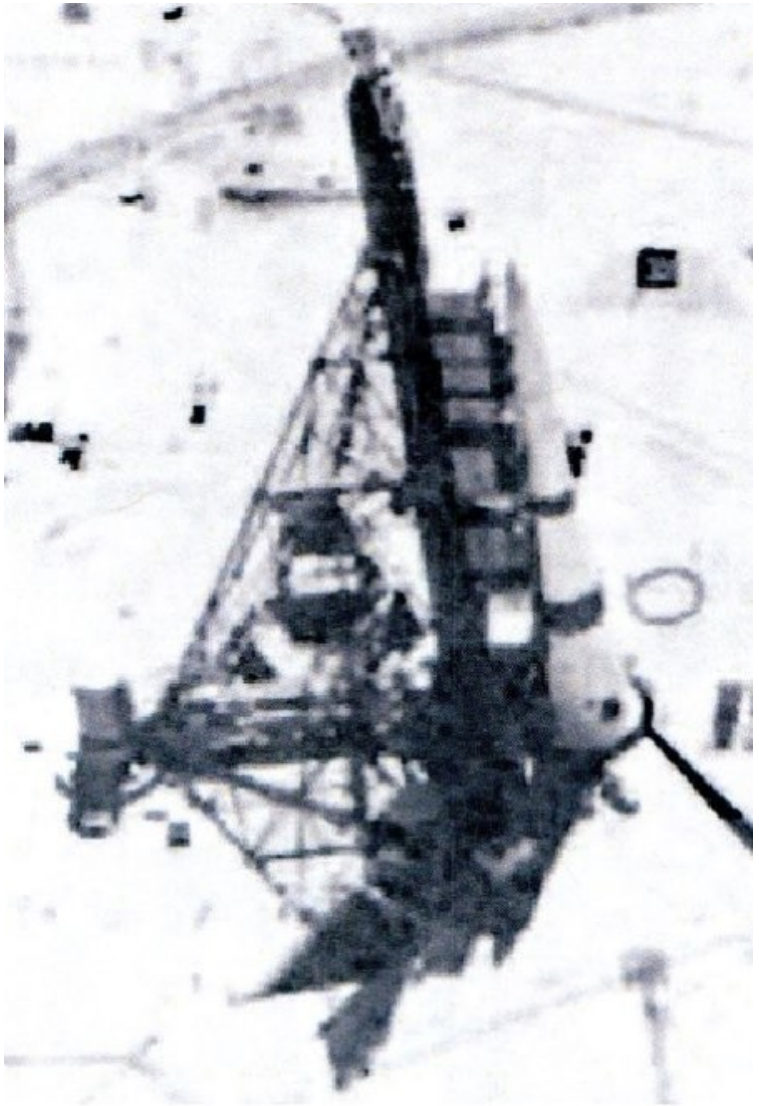


1969 – Soviet N-1 Moon Rocket

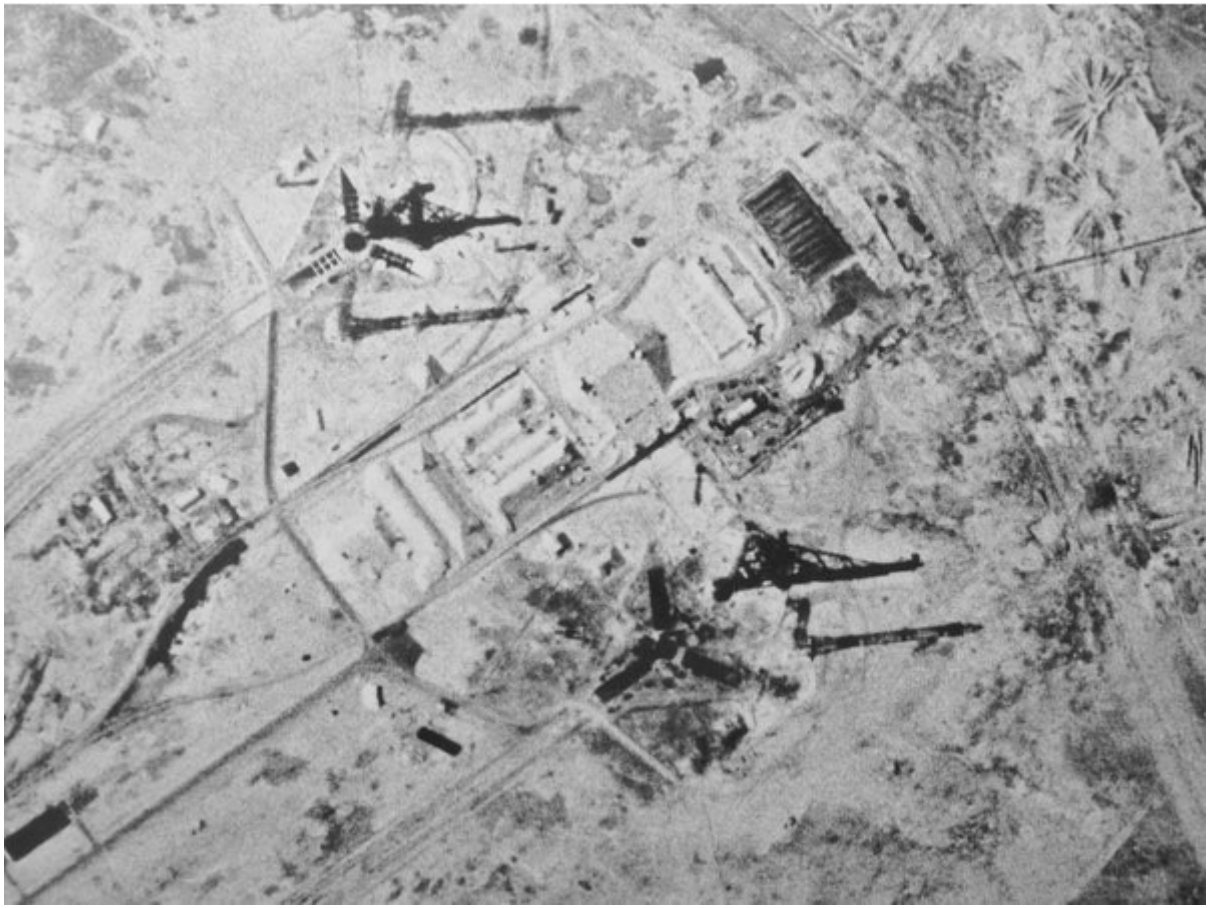


Jun 14, 1969

After an 11 day mission, a film capsule is ejected from the US NRO's GAMBIT-3 Mission 4322. A rocket motor fires to drop it out of orbit; it is recovered in mid-air over the Pacific and flown via Hawaii to Washington. D.C.
It contains this picture: the N-1 moon rocket is on pad 110 at Baykonur ready for launch



CORONA satellite photo of the same launch pad in August 1969: note blast damage



July 3, 1969
One engine catches fire at launch
14 seconds in, the first stage fails and falls back to the pad from a height of one hundred metres
Launch escape tower fires to pull the uncrewed Soyuz L1-S spaceship to safety
Rocket hits pad.
Boom
Estimated explosive force 7 kiloton (1/3 Hiroshima)

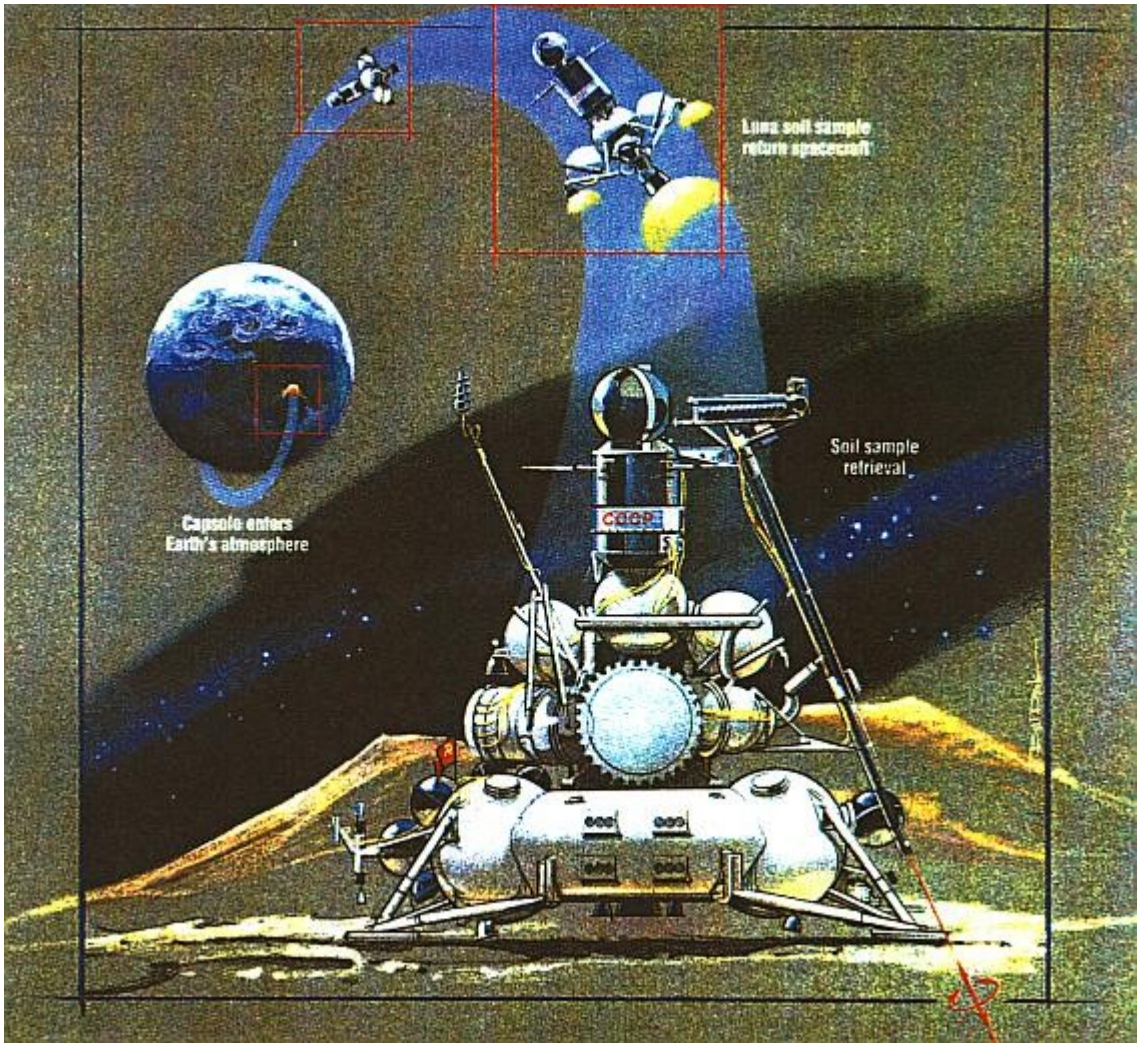
SUNDAY JULY 13, 1969

STATE TEST RANGE No. 5
KAZAKH SOVIET
SOCIALIST REPUBLIC

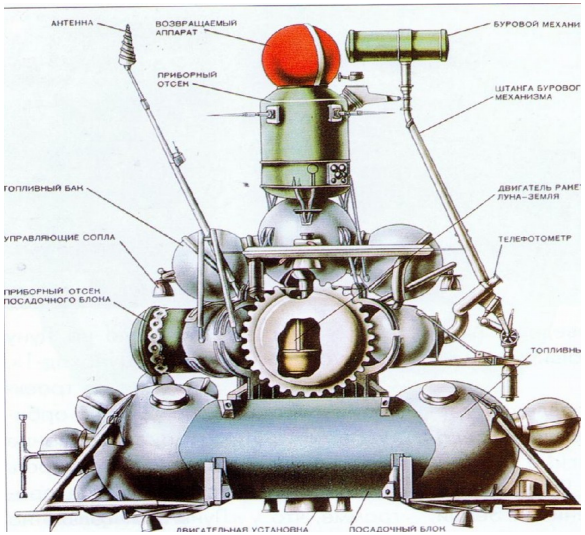
LAUNCH OF ROCKET
8K82K No. 242-01

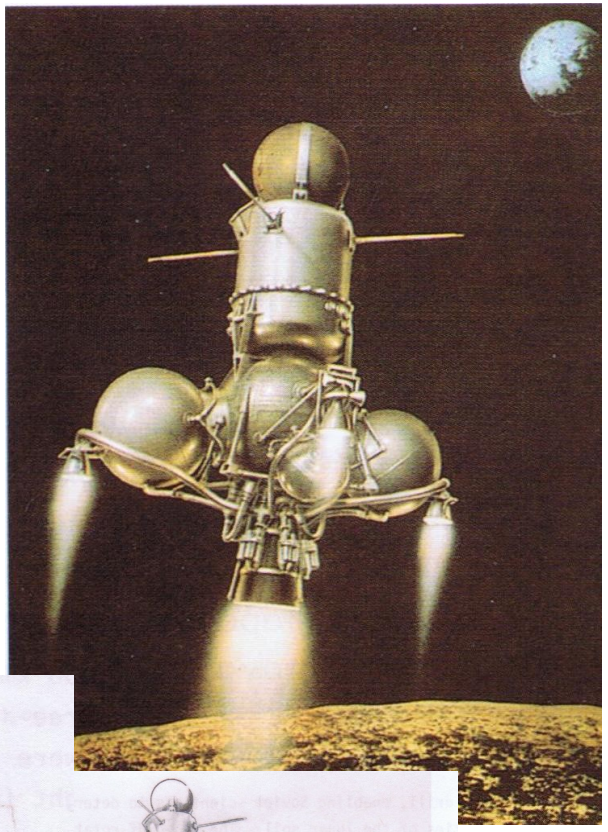
SPACE PROBE E-8-5 No.
401 ON TRANSLUNAR
TRAJECTORY

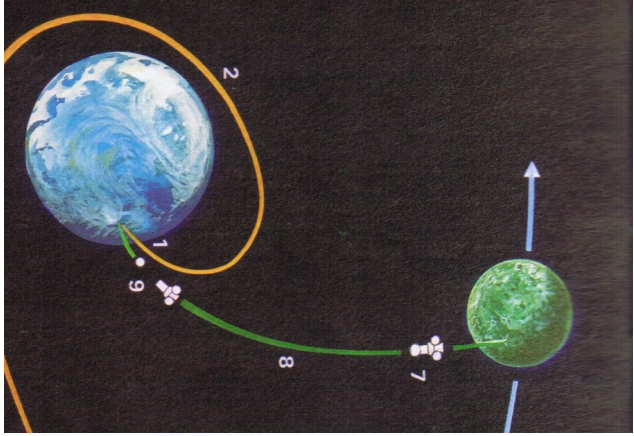
TASS ANNOUNCES
LAUNCH OF “LUNA-15”

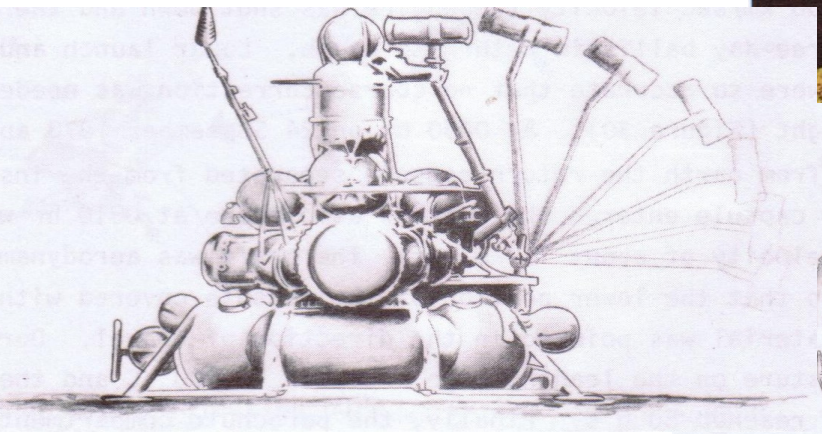

Luna soil sample
return spacecraft
Soil sample
retrieval
Capsule enters
Earth's atmosphere
CCCP

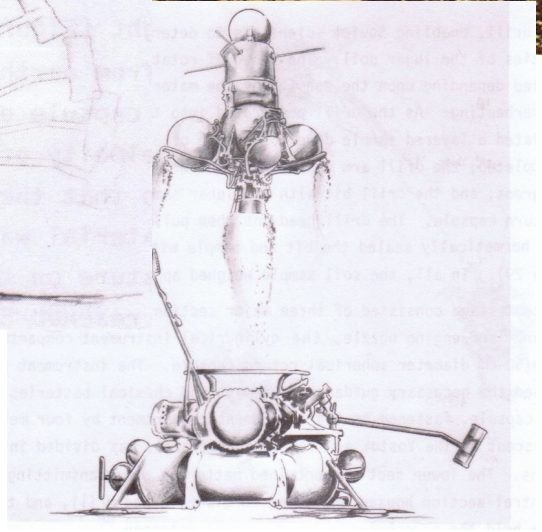
WHAT NEARLY HAPPENED: LUNA-16, SEPTEMBER 1970

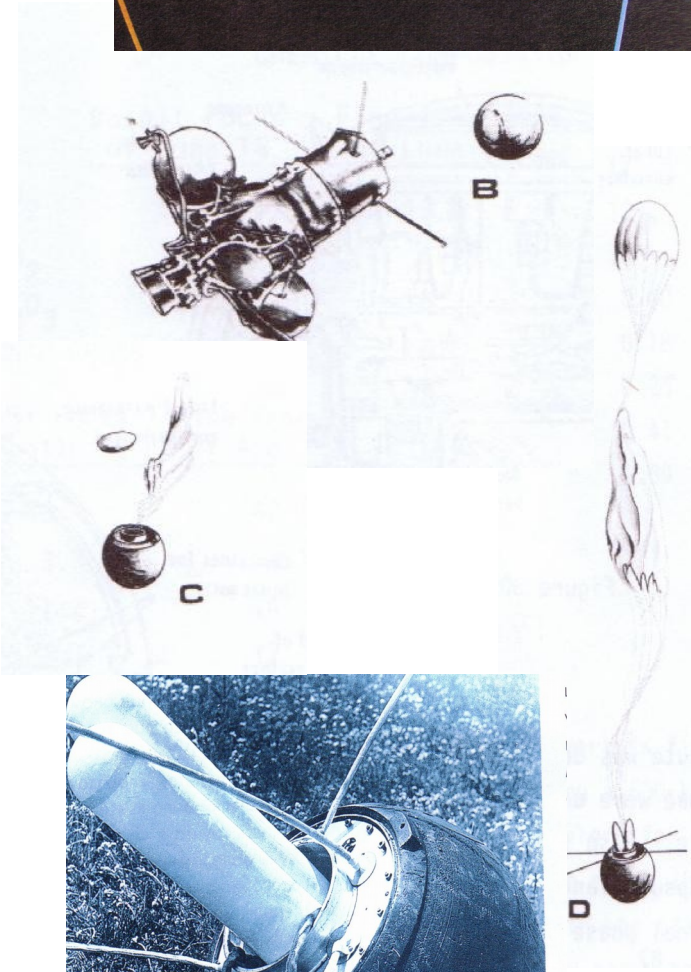


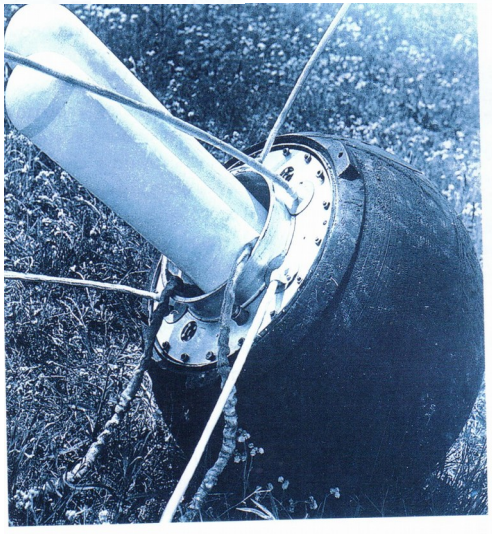






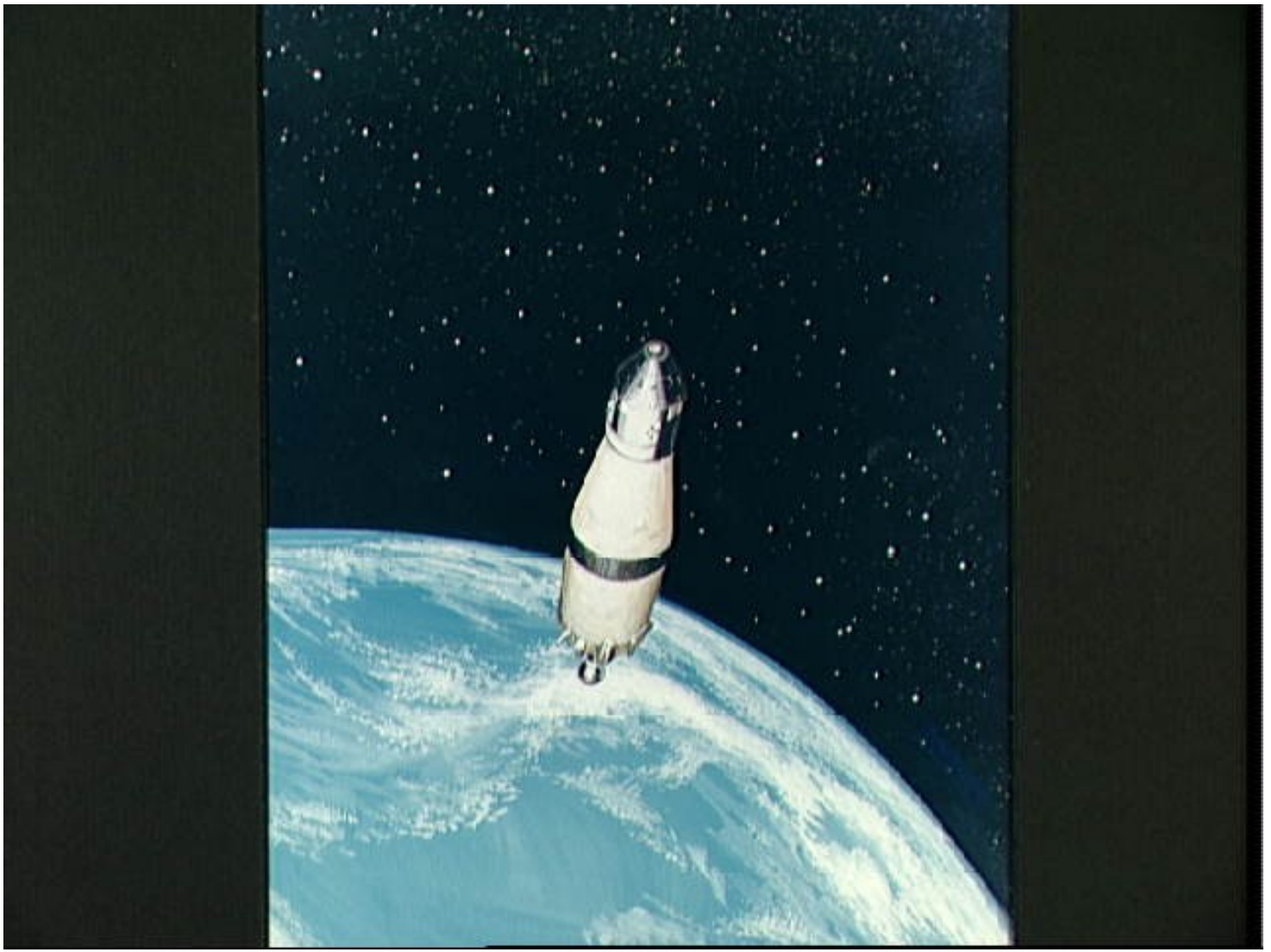




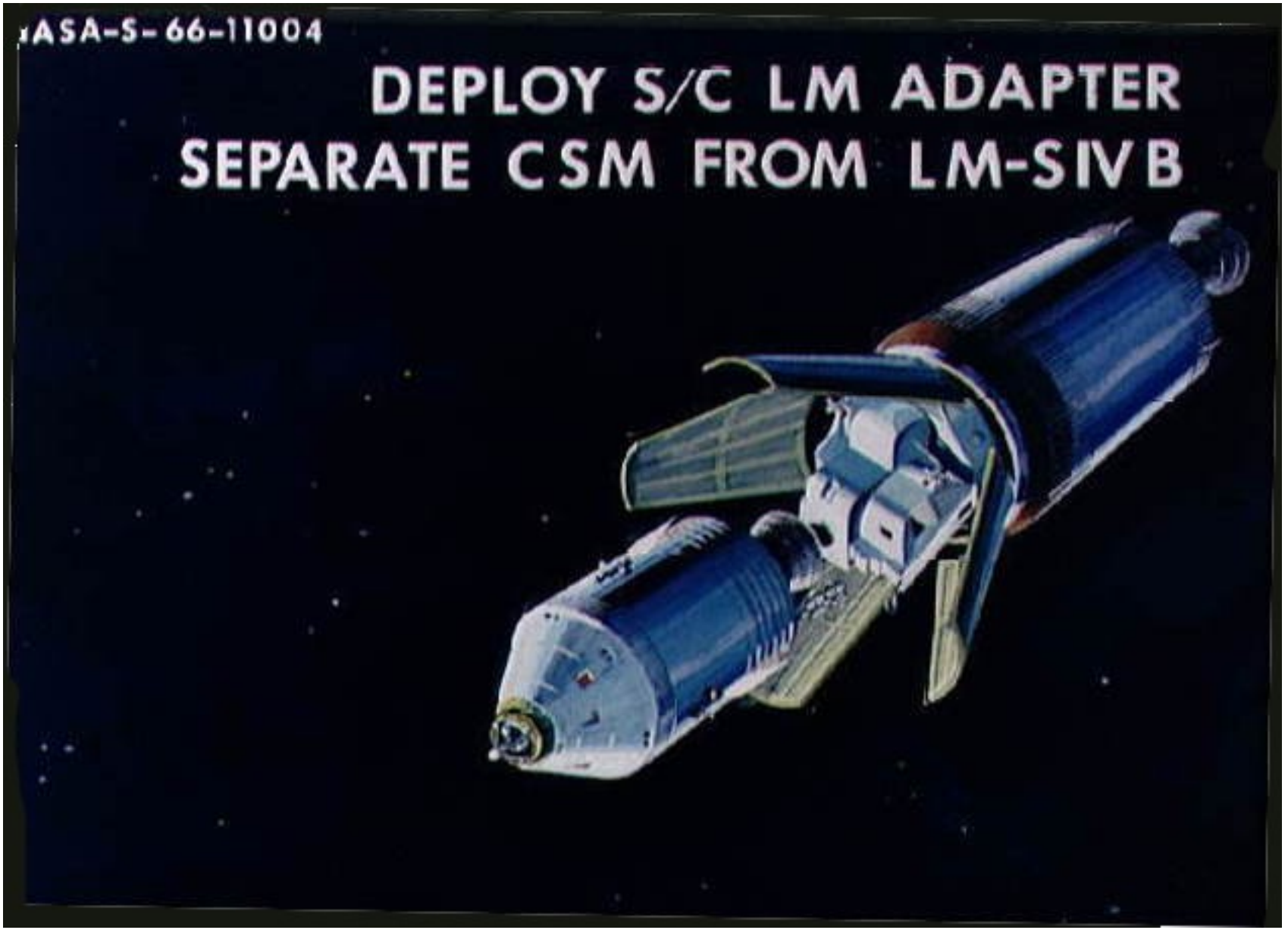


WED, JUL 16, 1969, 1:32pm GMT: APOLLO 11 LAUNCHES FROM KENNEDY SPACE CENTER, FLORIDA

Wed. July 16, 4:22pm GMT TLI: Translunar Injection
Apollo spacecraft and Saturn S-IVB third stage reach near-escape velocity
Orbit 262 x 565954 km



Wed, Jul 16, 1969, 4:47pm GMT – Transposition and Docking
Columbia separates from rocket, turns around, docks with Eagle

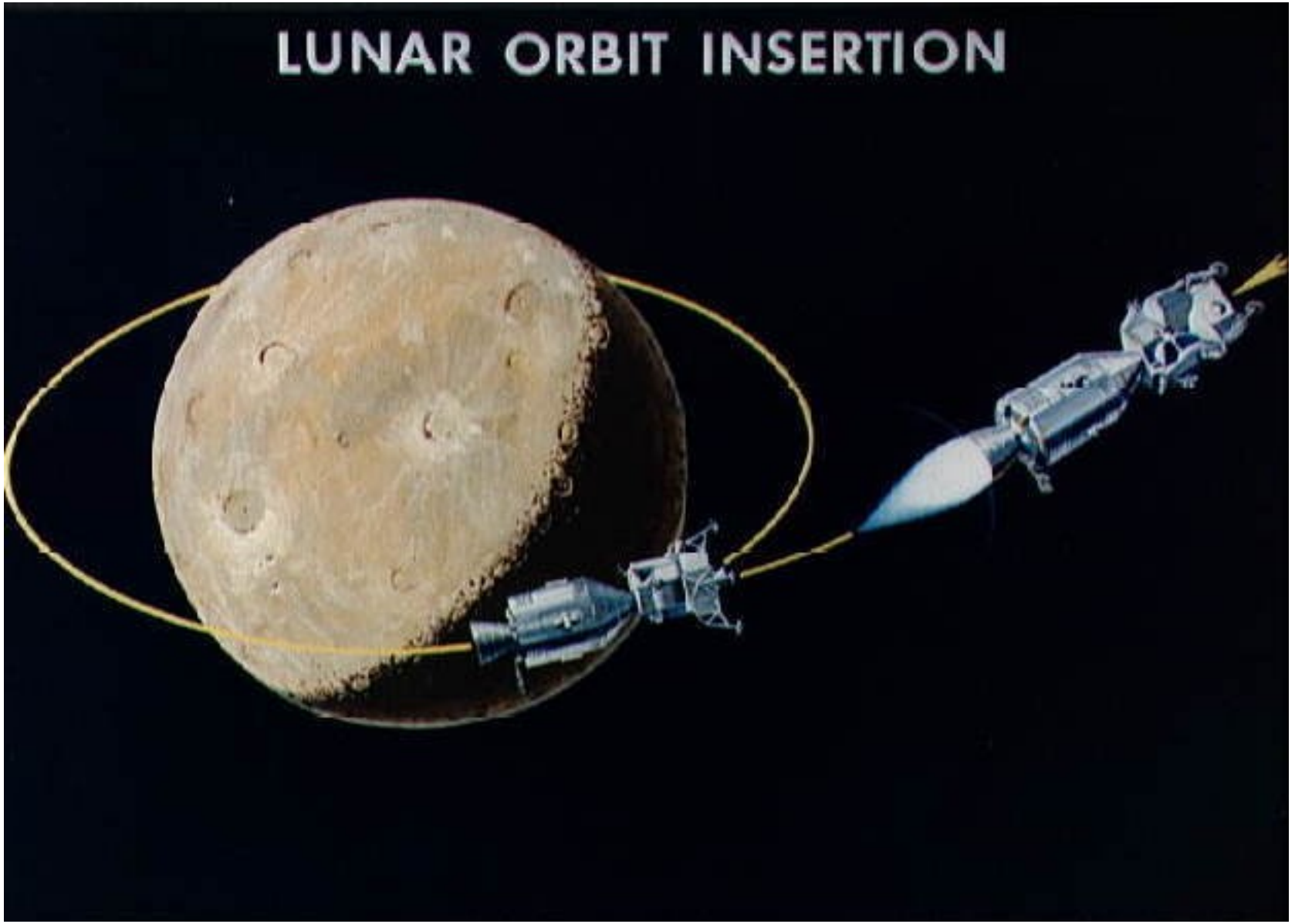


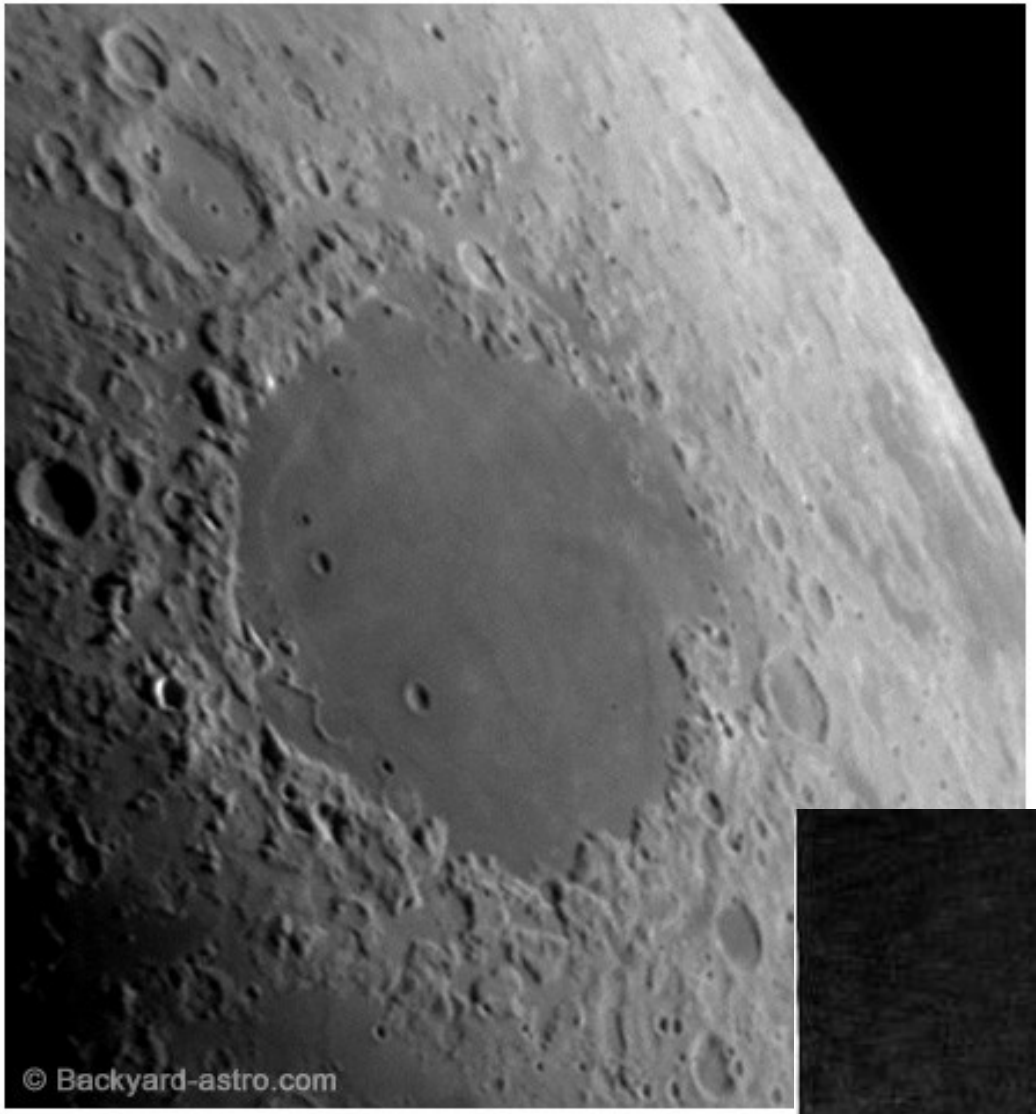
Lunar module still attached to Saturn rocket stage
Seen from approaching command module

Apollo 12 Nov 1969

Wed, Jul 16, 1969, 5:49pm GMT: Columbia and Eagle docked, Apollo 11 spaceship backs out from the Saturn S-IVB stage

Sat. Jul 19, 1969, 5:27pm: Apollo 11 in orbit around the Moon
111 x 311 km elliptical path adjusted at 9:43pm to 100 x 122 km

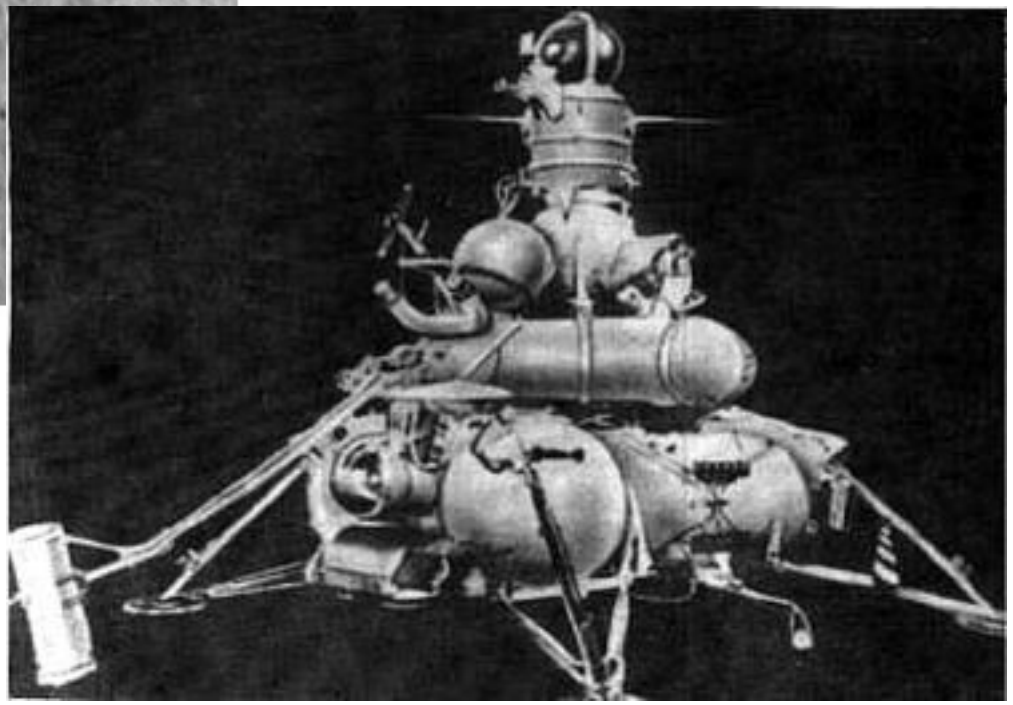


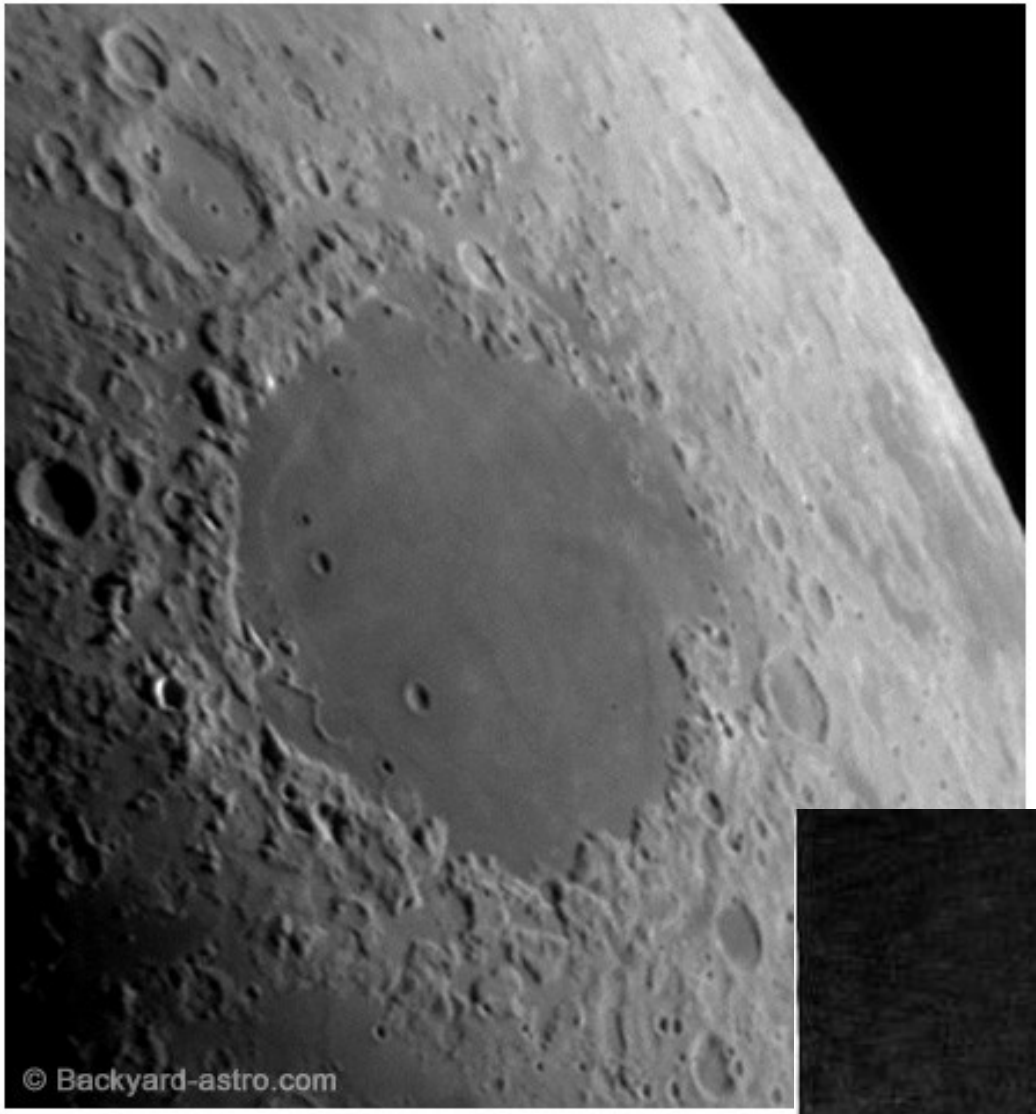


Luna-15

Sun July 20, 2:16 pm

Luna-15 lowers orbit to ony 16 km from the surface





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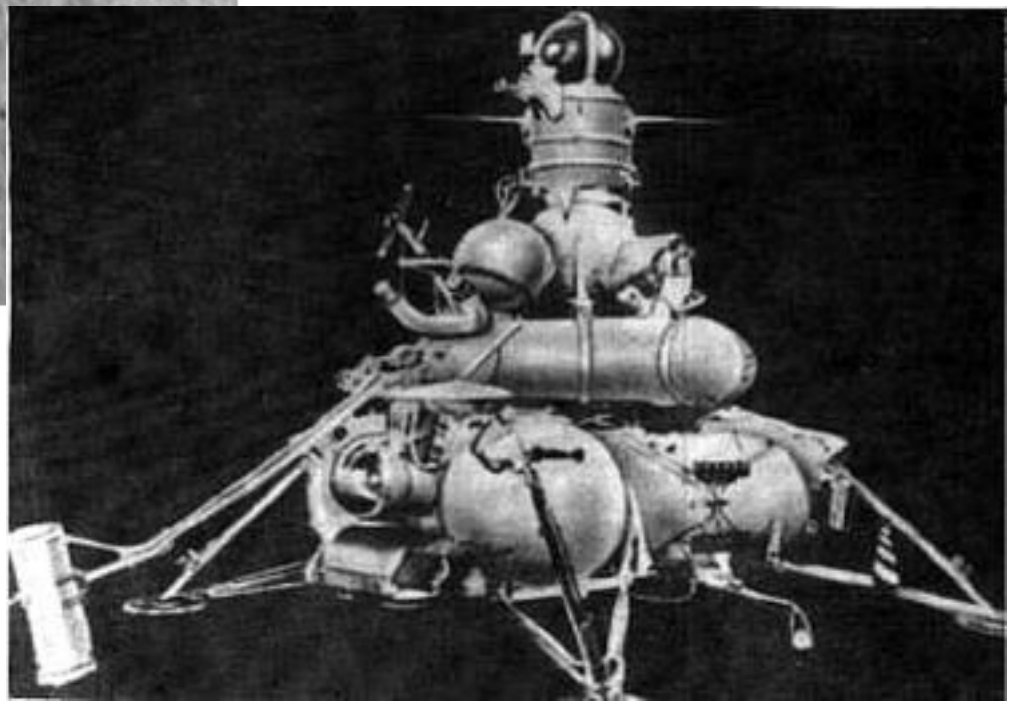
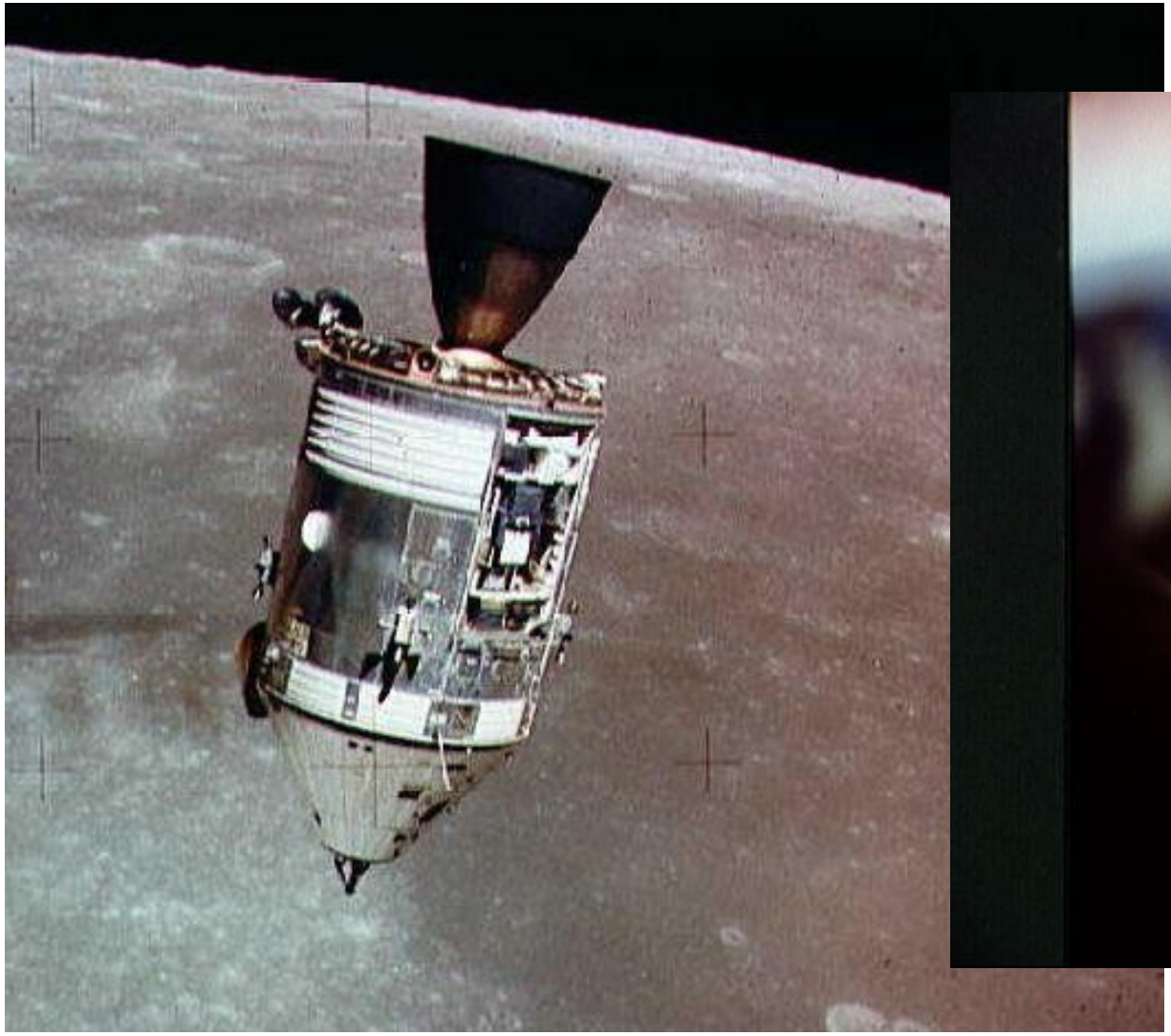
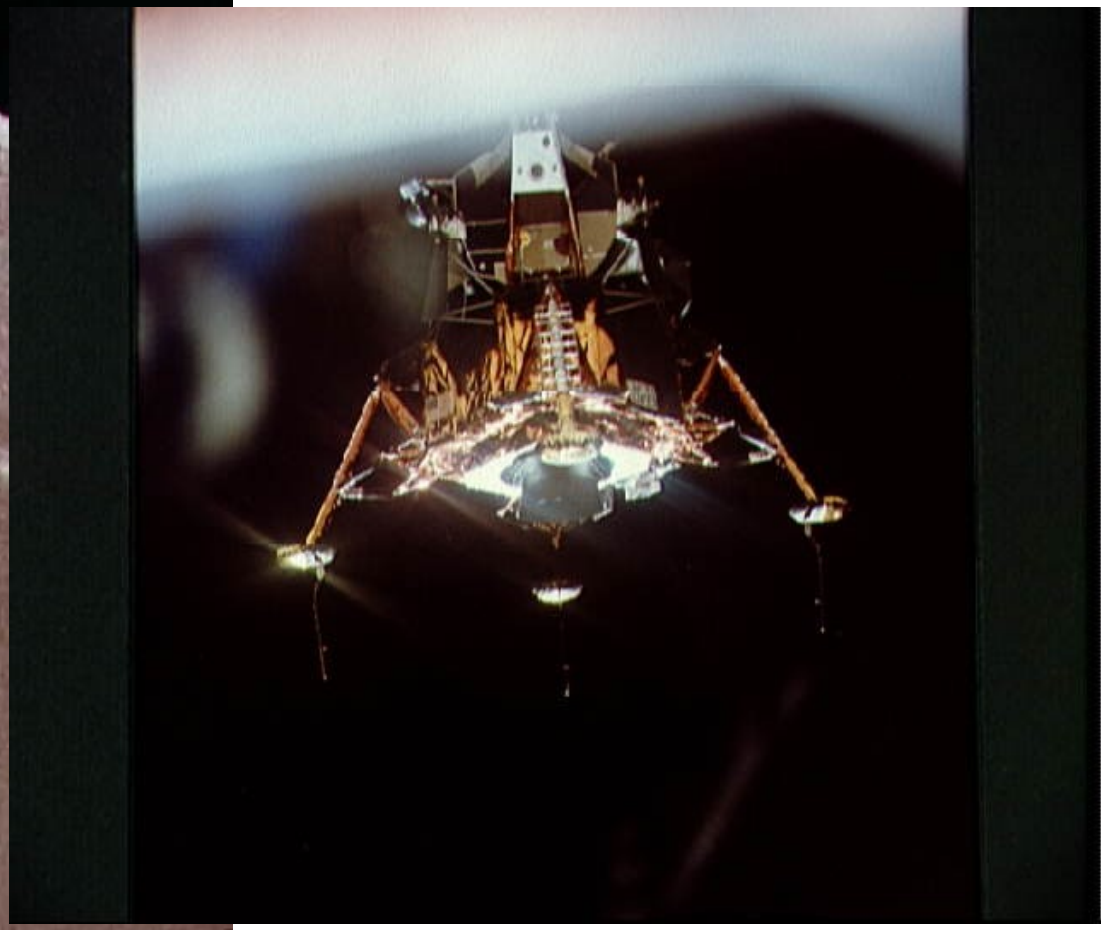


Sun. Jul 20, 5:45pm: Columbia undocks from Eagle
Command and Service Module (CSM) and Lunar Module (LM)
in separate lunar orbit



Command and Service Module CSM-107 "Columbia"
(This image: Apollo 16 CSM-113 "Casper", May 1972)



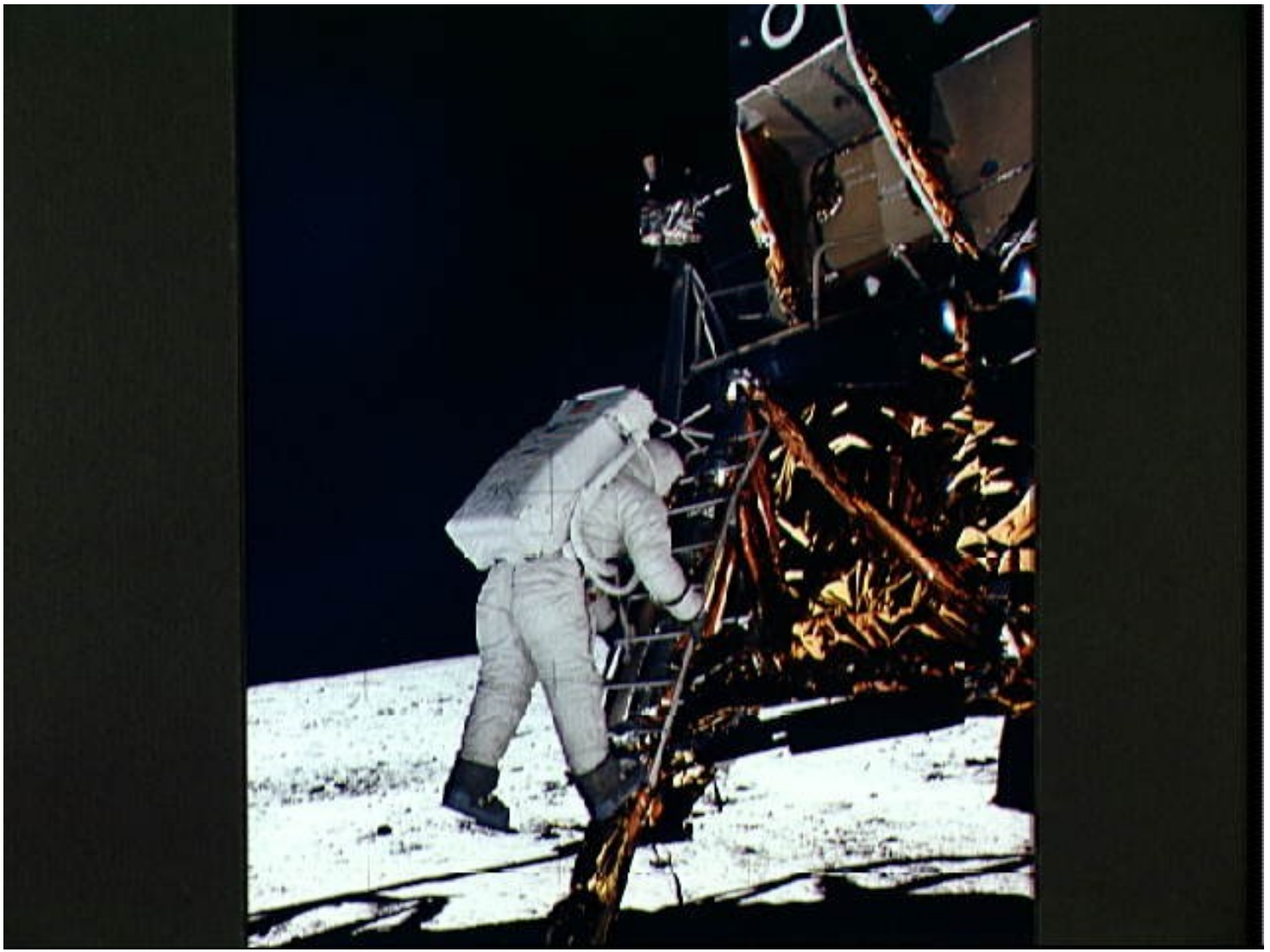
"Eagle"
Lunar Module 5

Sun Jul 20, 1969: 8:05 pm: Powered Descent
15 km above the Moon

Sun Jul 20 1969, 8:17pm GMT: TOUCHDOWN

Houston: “30 seconds” [of fuel left]
Eagle: “Contact light.. OK, engine stop.....”
Houston: “We copy you down, Eagle”.
Eagle: “Houston, Tranquility Base here... the Eagle has landed.”

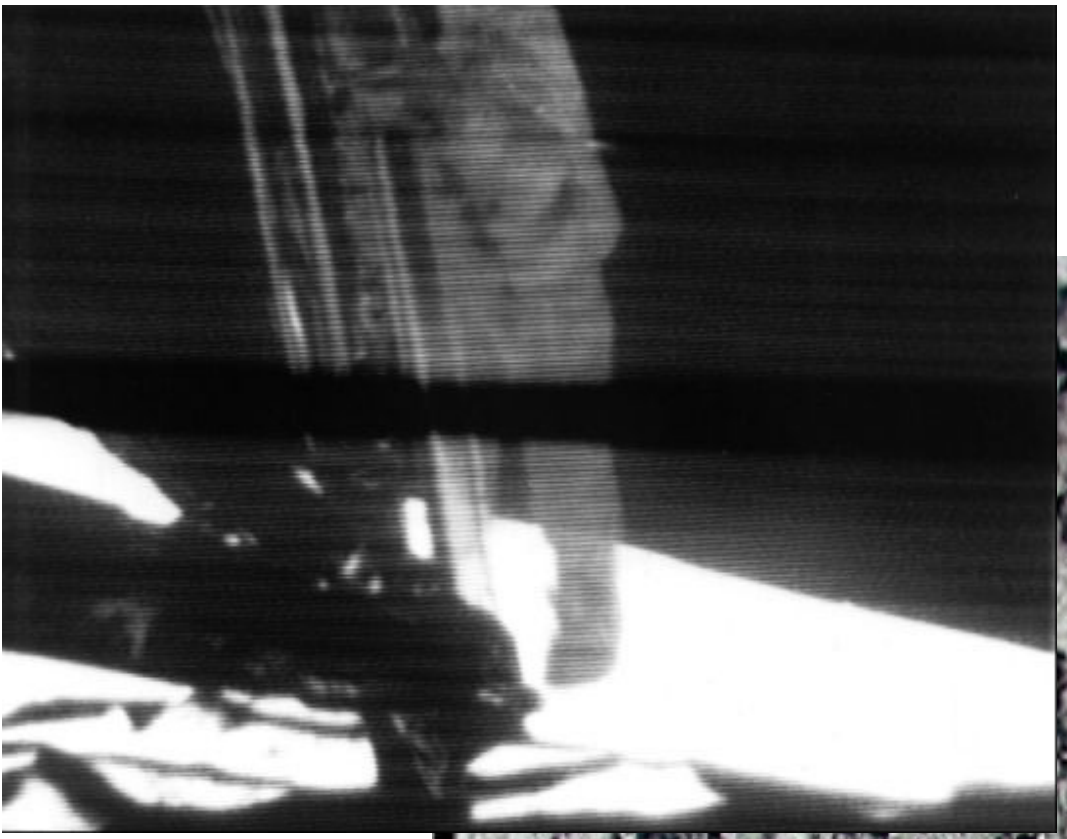
Monday July 21, 2:50am Armstrong out the hatch and on the ladder

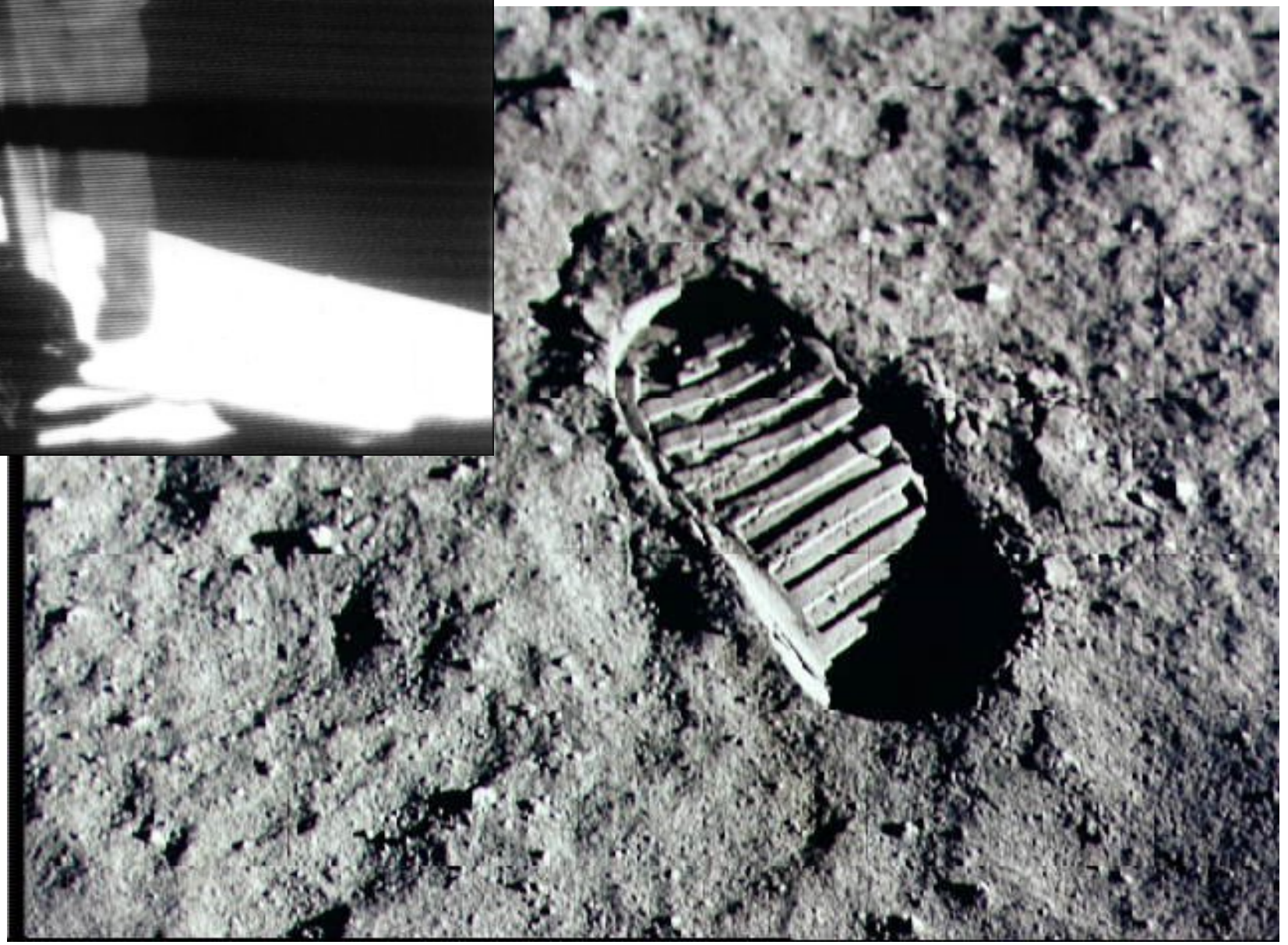


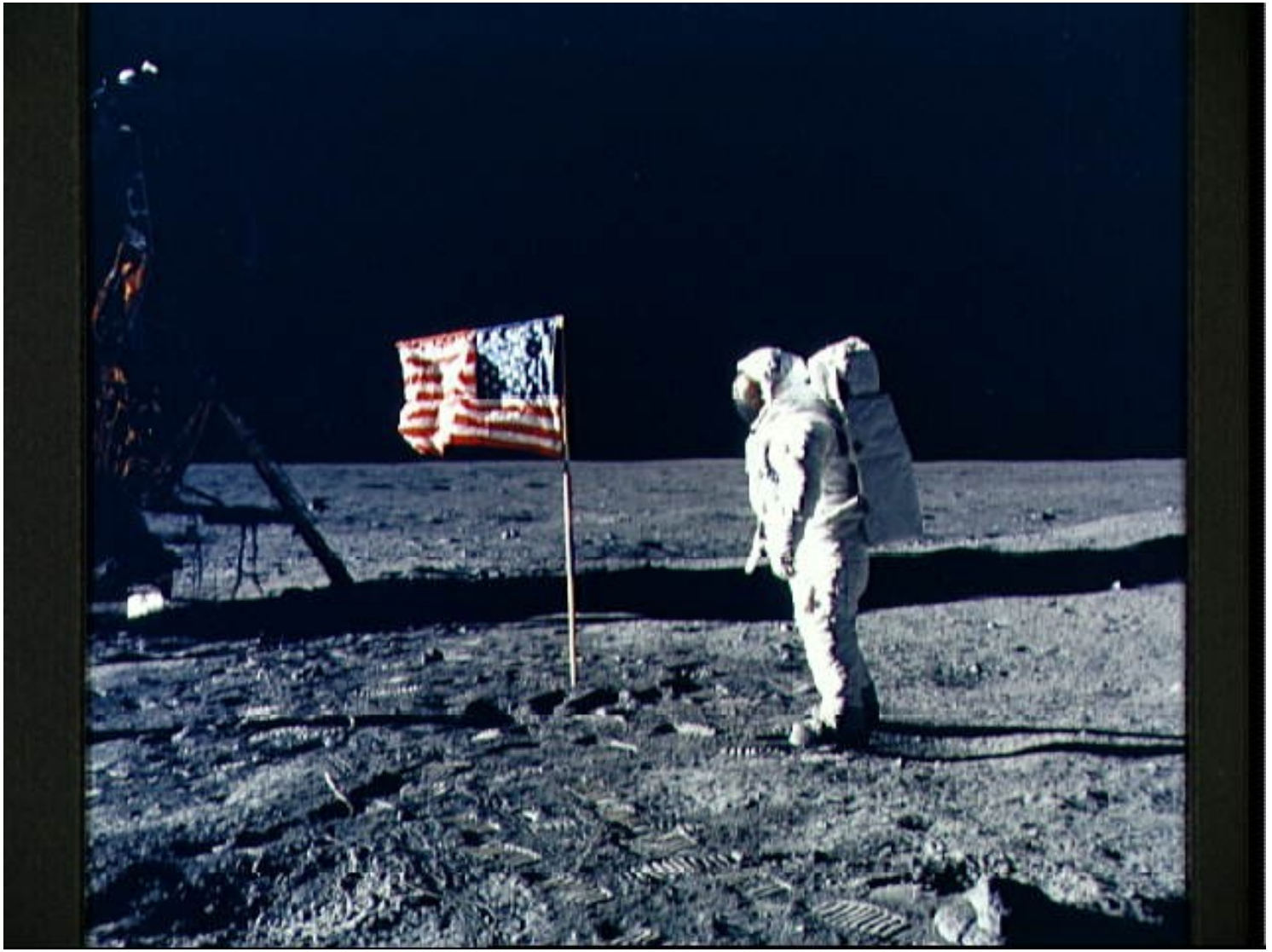
This photo actually from 3:12am, showing Aldrin coming down the ladder

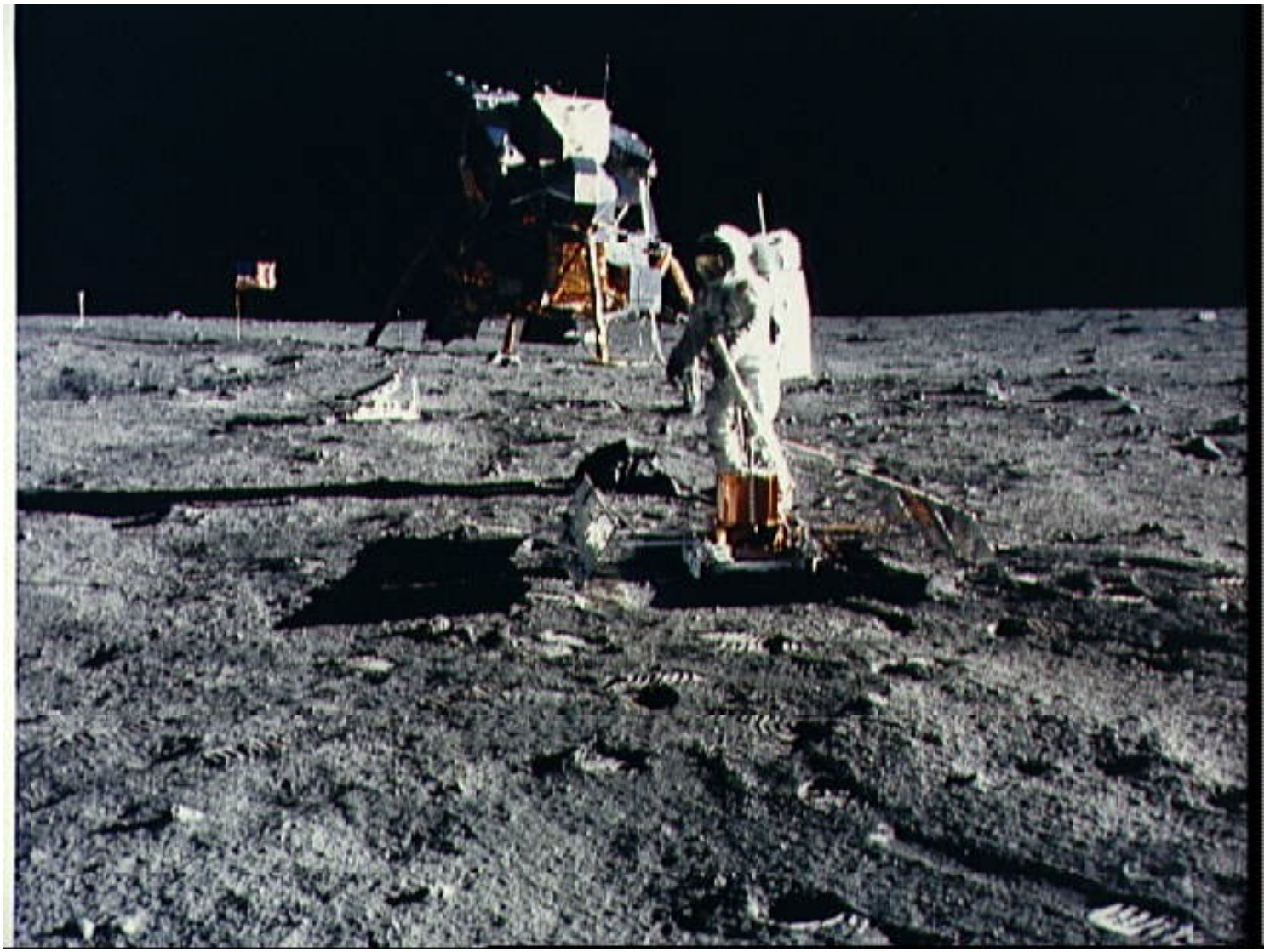
Monday Jul 21, 2:56am GMT

“That's one small step for (a) man,
One giant leap for mankind”



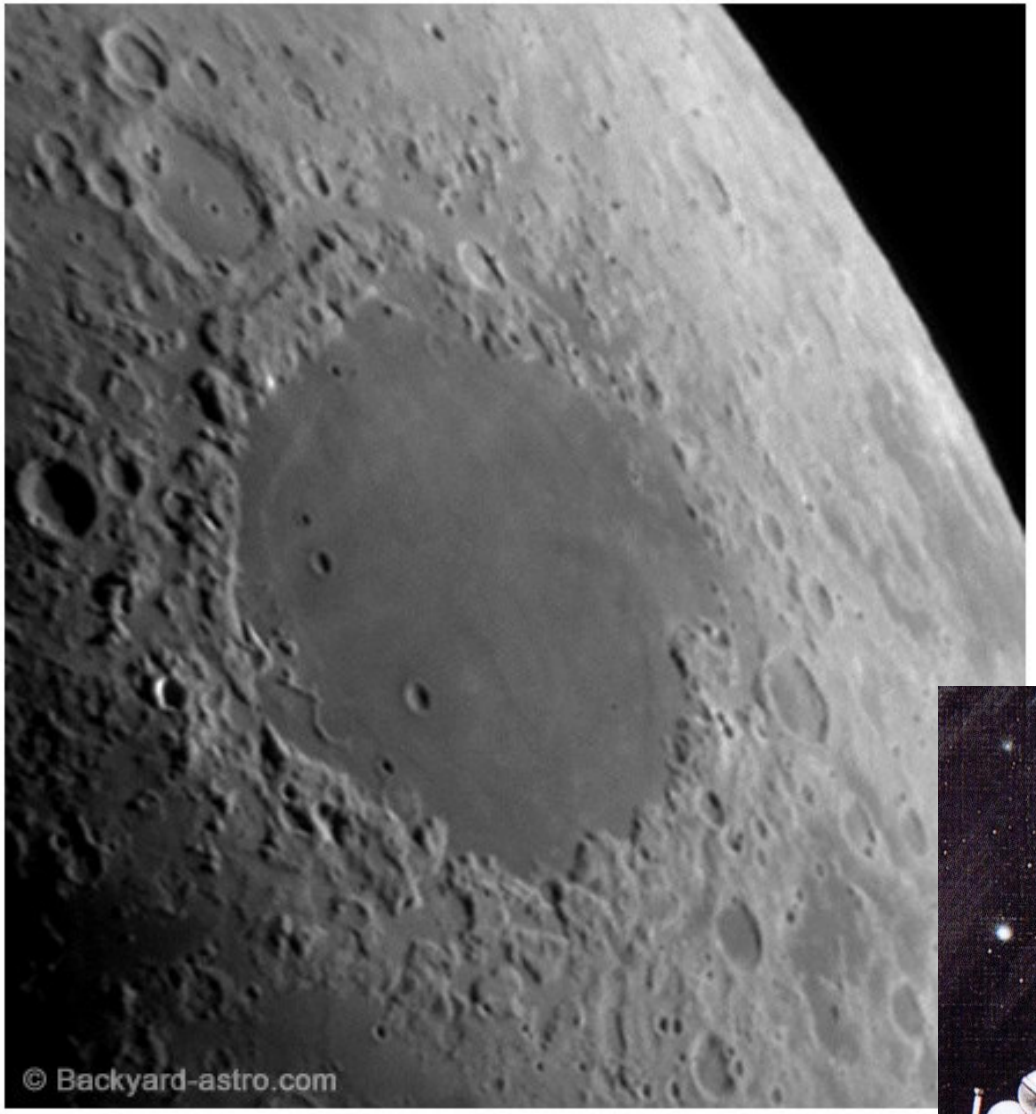






Neil Armstrong aboard Eagle after the moonwalk
Mon Jul 21, 0800 GMT

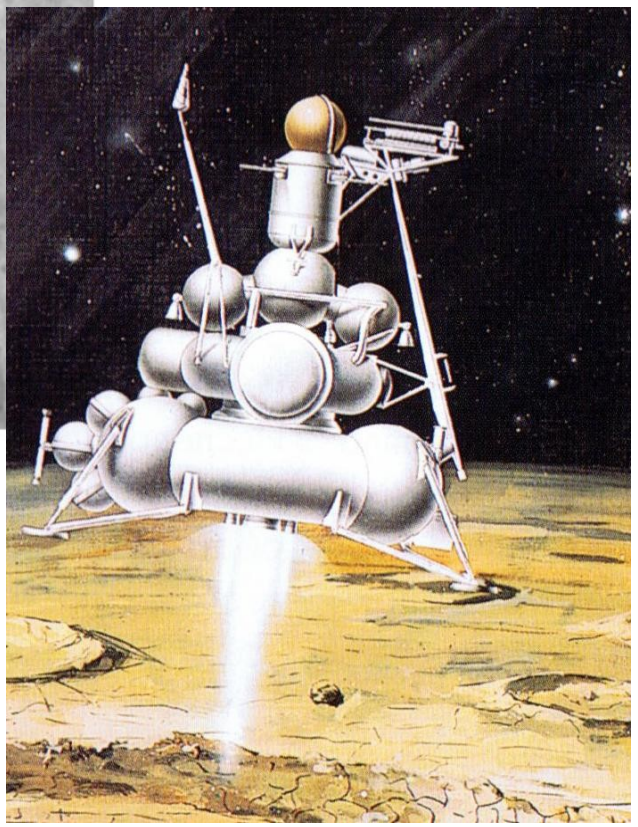
Buzz Aldrin aboard Eagle after the moonwalk

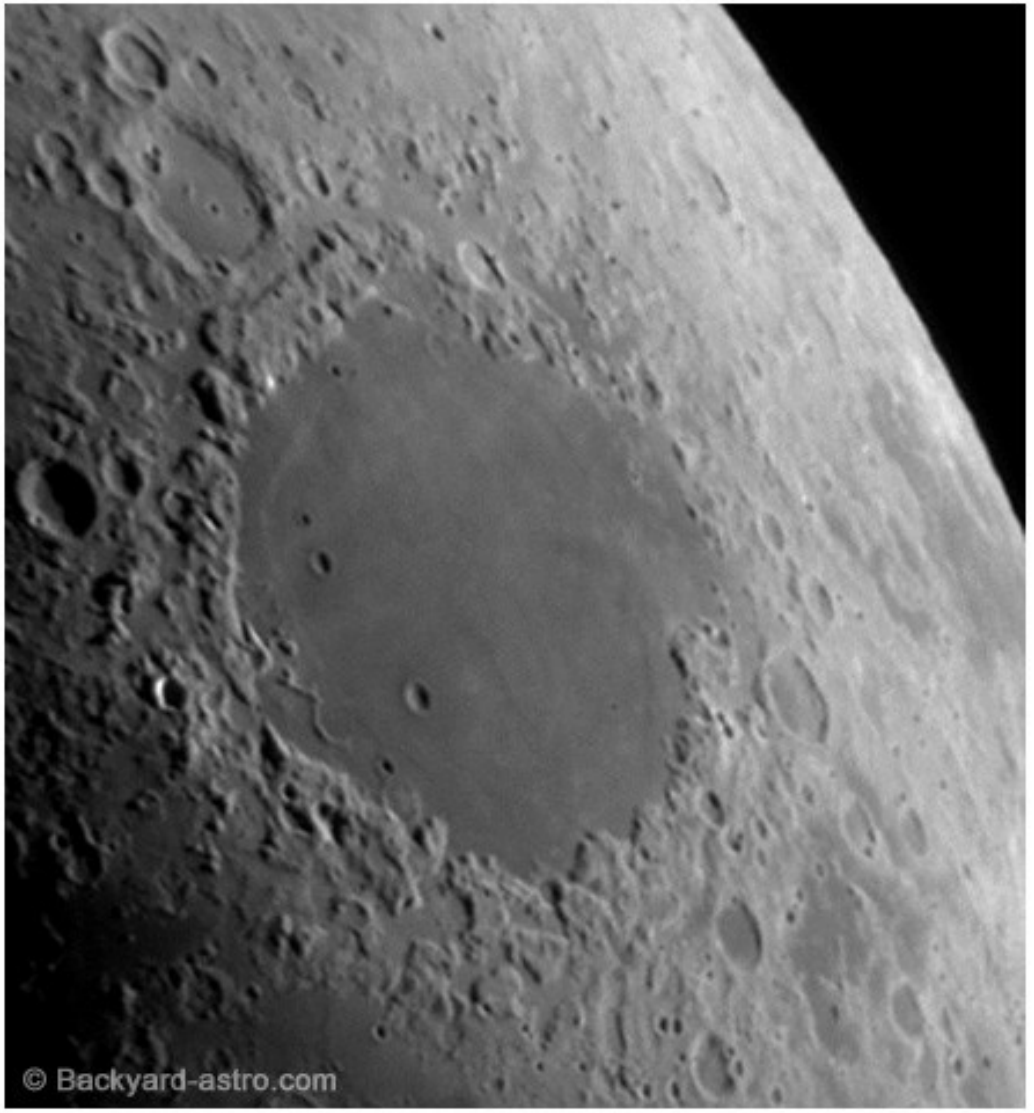


Luna-15

July 21, 3:47 pm

Luna-15 begins descent to lunar surface towards Mare Crisium (“the Sea of Crises”)





Luna-15

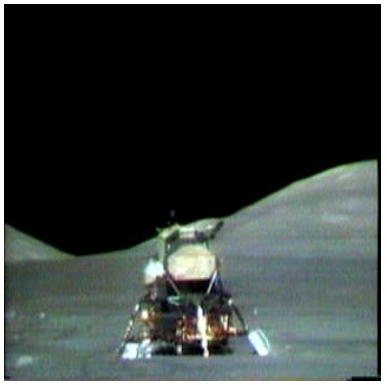
July 21, 3:51 pm

TASS ANNOUNCEMENT: AUTOMATED PROBE LUNA-15 COMPLETES FLIGHT

“THE PROBE LEFT THE ORBIT AND REACHED THE LUNAR SURFACE AT A PREDETERMINED PLACE. THE WORK OF THE PROBE WAS OVER AT 1851 HOURS MOSCOW TIME.”

In England, Jodrell Bank radio observatory tracks the probe's signals,
and deduces that Luna-15 landed on the Moon at a speed of 300 mph.
The braking engines failed to operate...

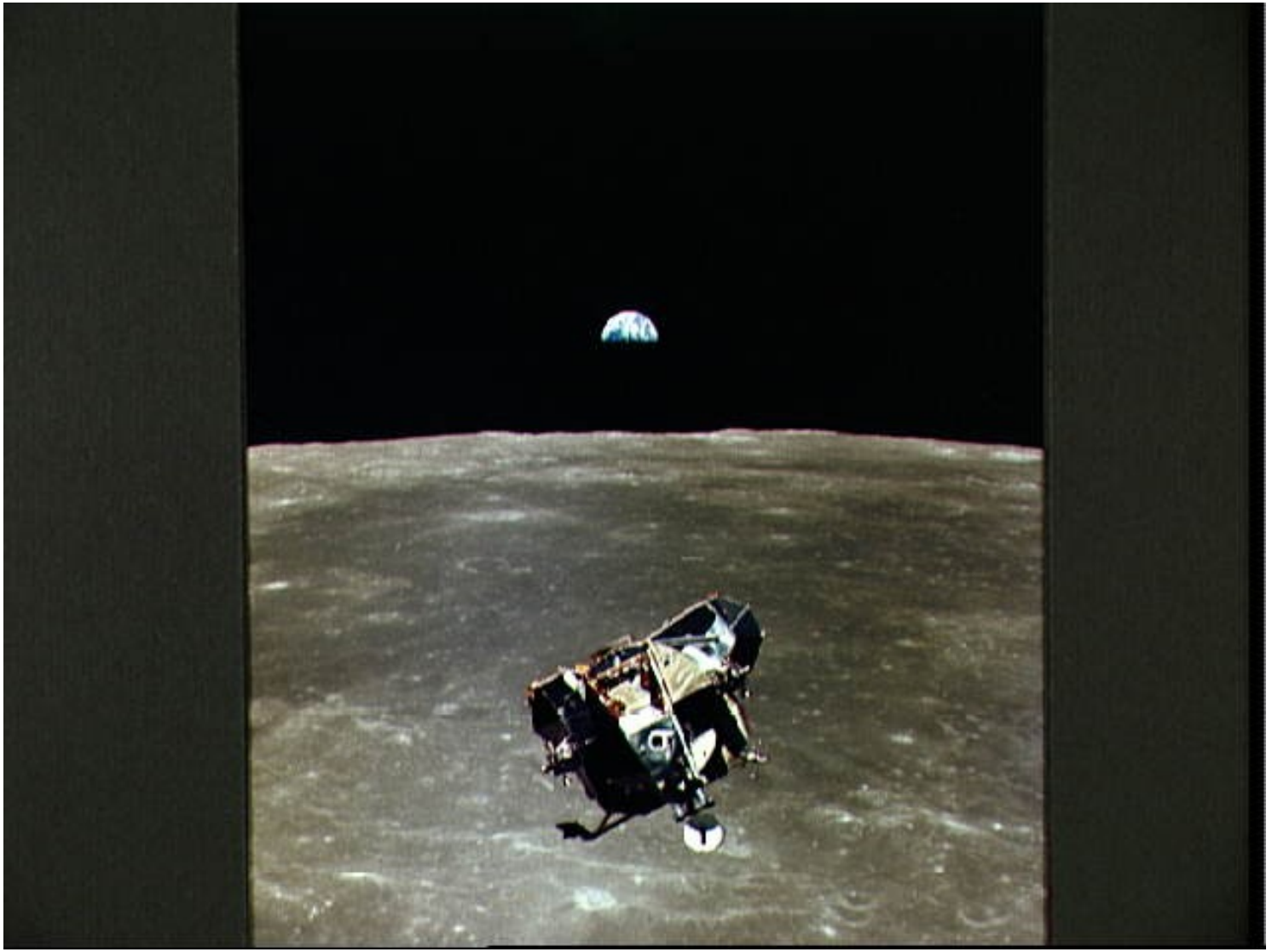
The last-minute challenge to Apollo 11 is over!



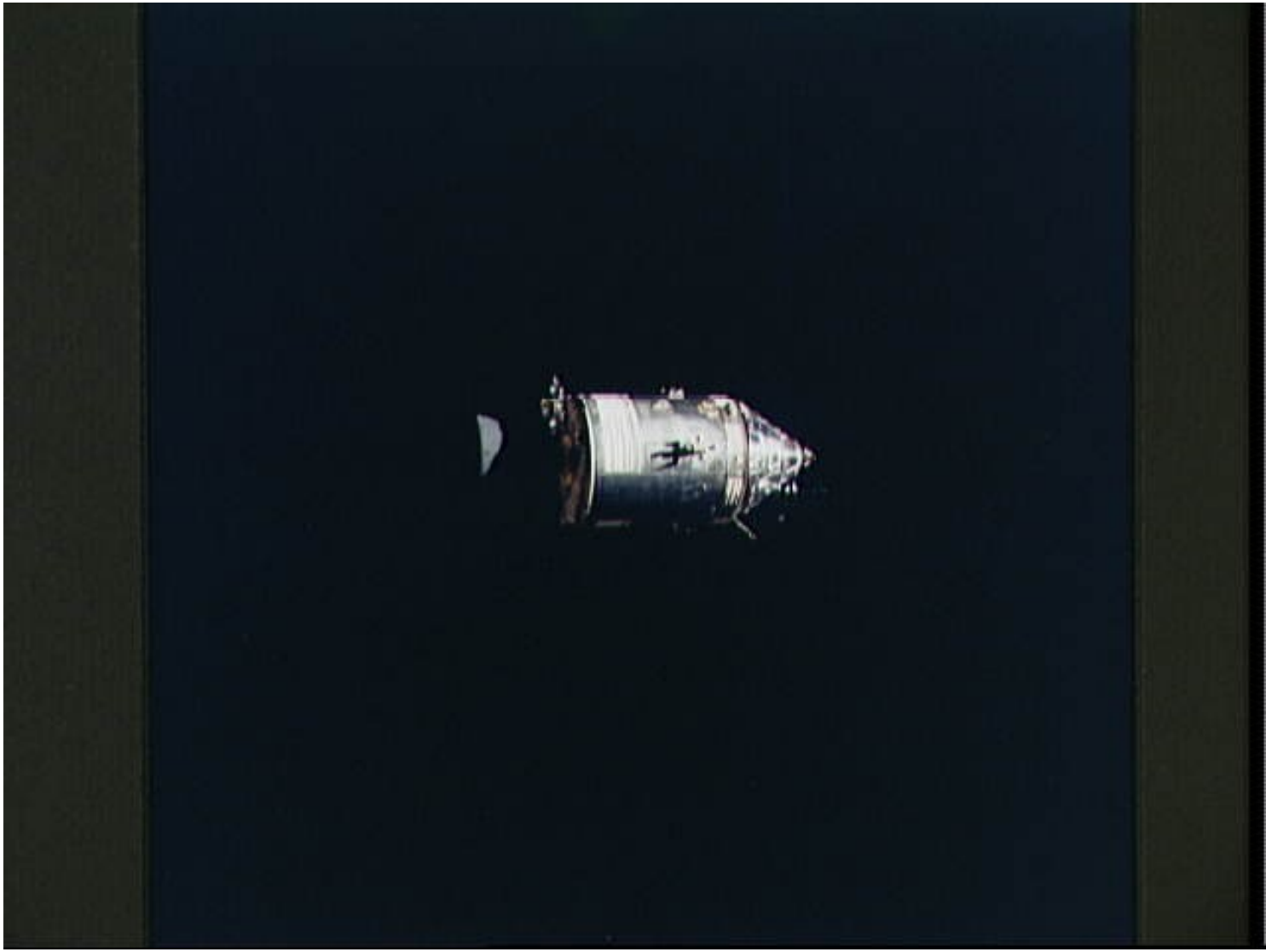
Mon Jul 21, 5:54pm: Eagle's Ascent Stage lifts off, using Descent Stage as launch pad.

Apollo 17 - Dec 1972

Mon Jul 21, 9:17pm:
Rendezvous with Mike Collins in Columbia



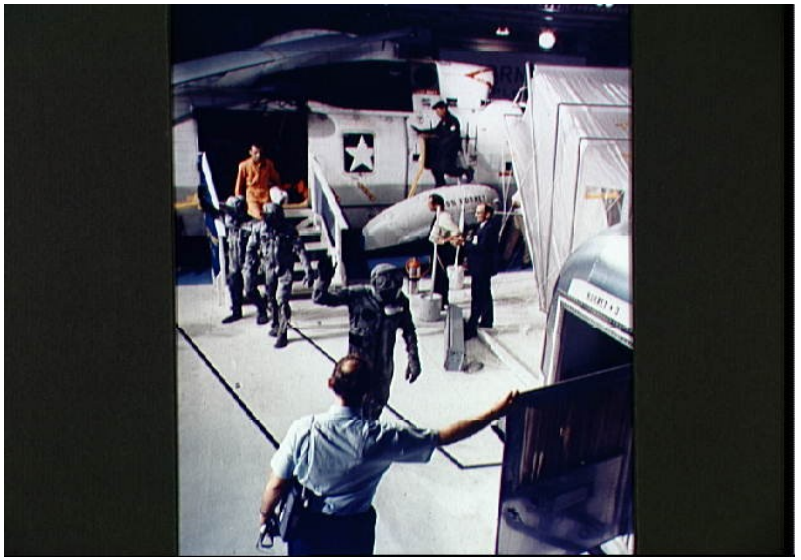
Tue Jul 22, 04:58 am
En route to Earth

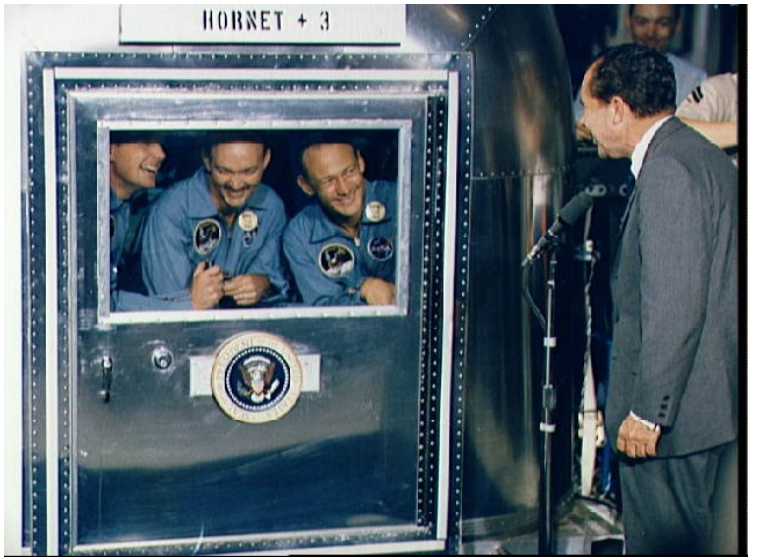


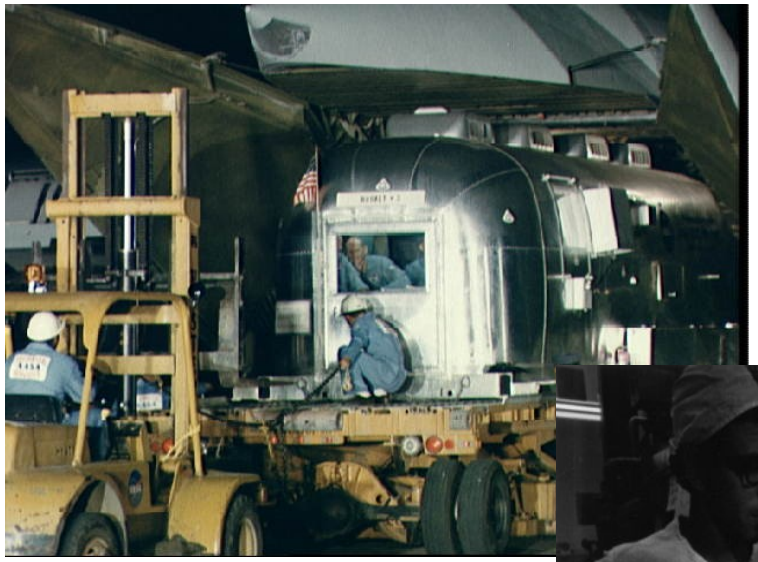
Thurs Jul 24, 4:50pm
Splashdown in the Pacific

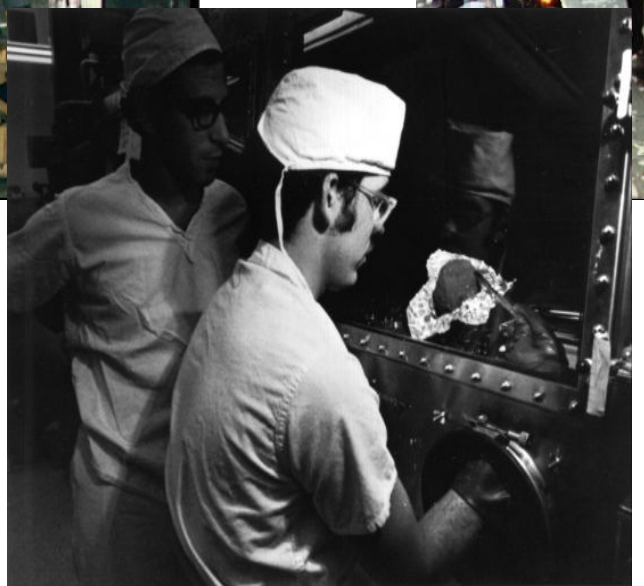
Apollo 17 – Dec 1972

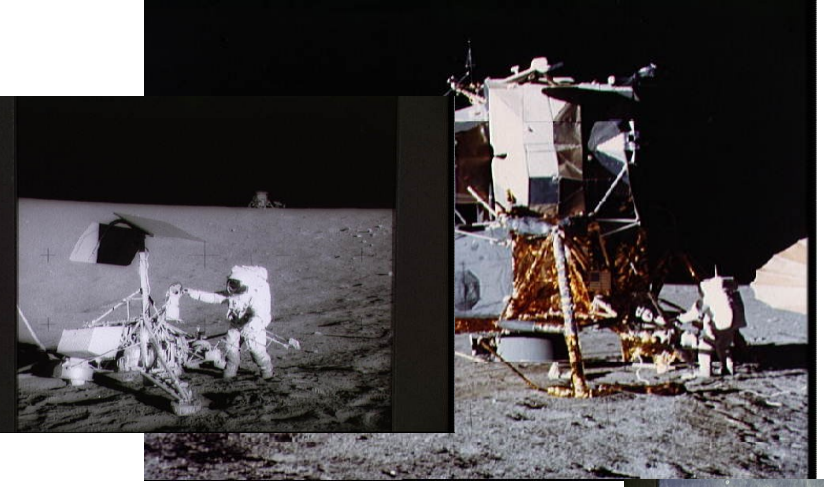
Command Module “Columbia”
Pacific Ocean, 13 N 169 W
July 24, 1969: “... and returning him safely to the Earth”.




HORNET + 3



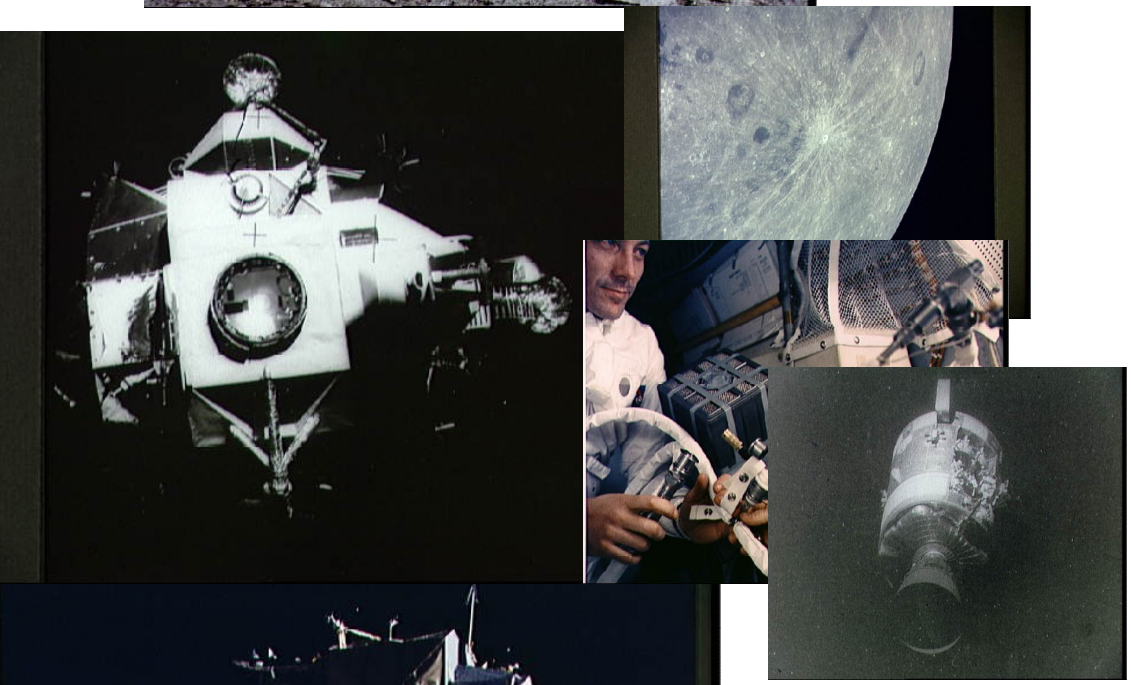


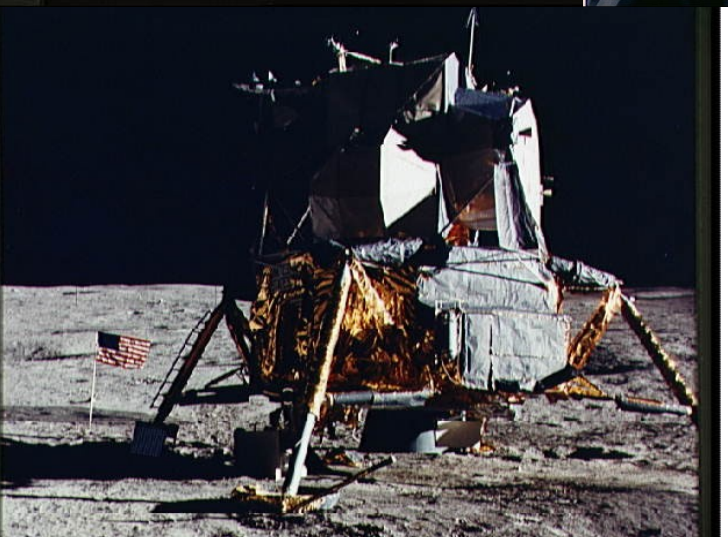


APOLLO 12 AT SURVEYOR 3 – NOV 1969

APOLLO 13 – APR 1970

APOLLO 14 AT FRA MAURO – FEB 1971

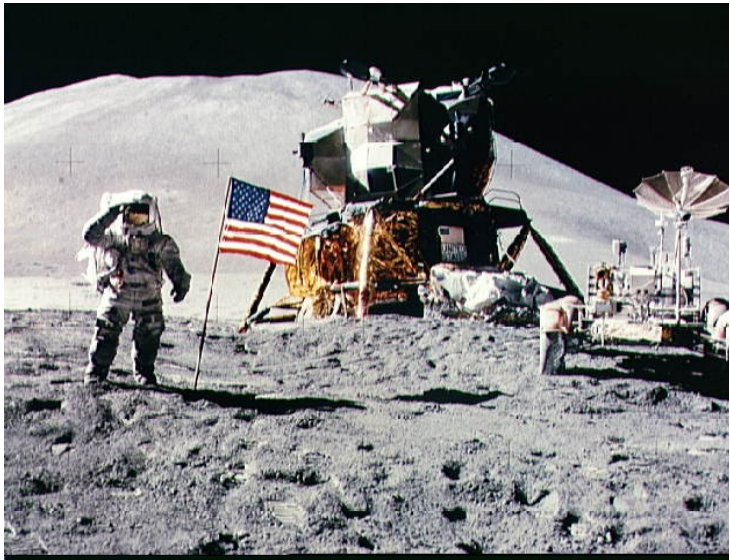


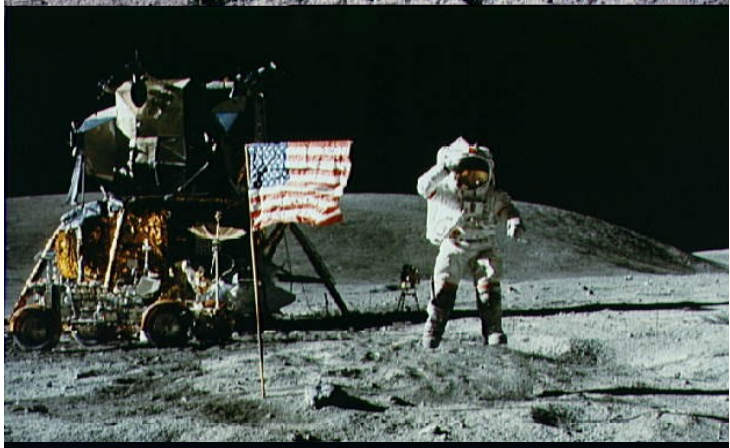


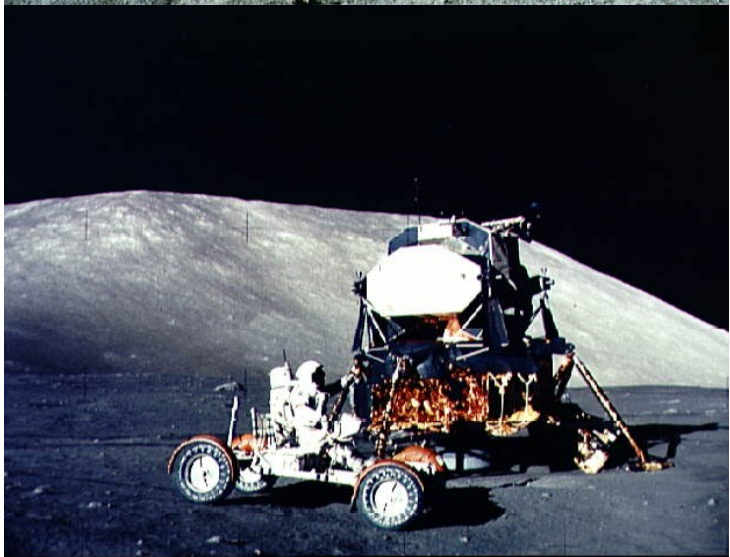
APOLLO 15 AT HADLEY – JUL 1971

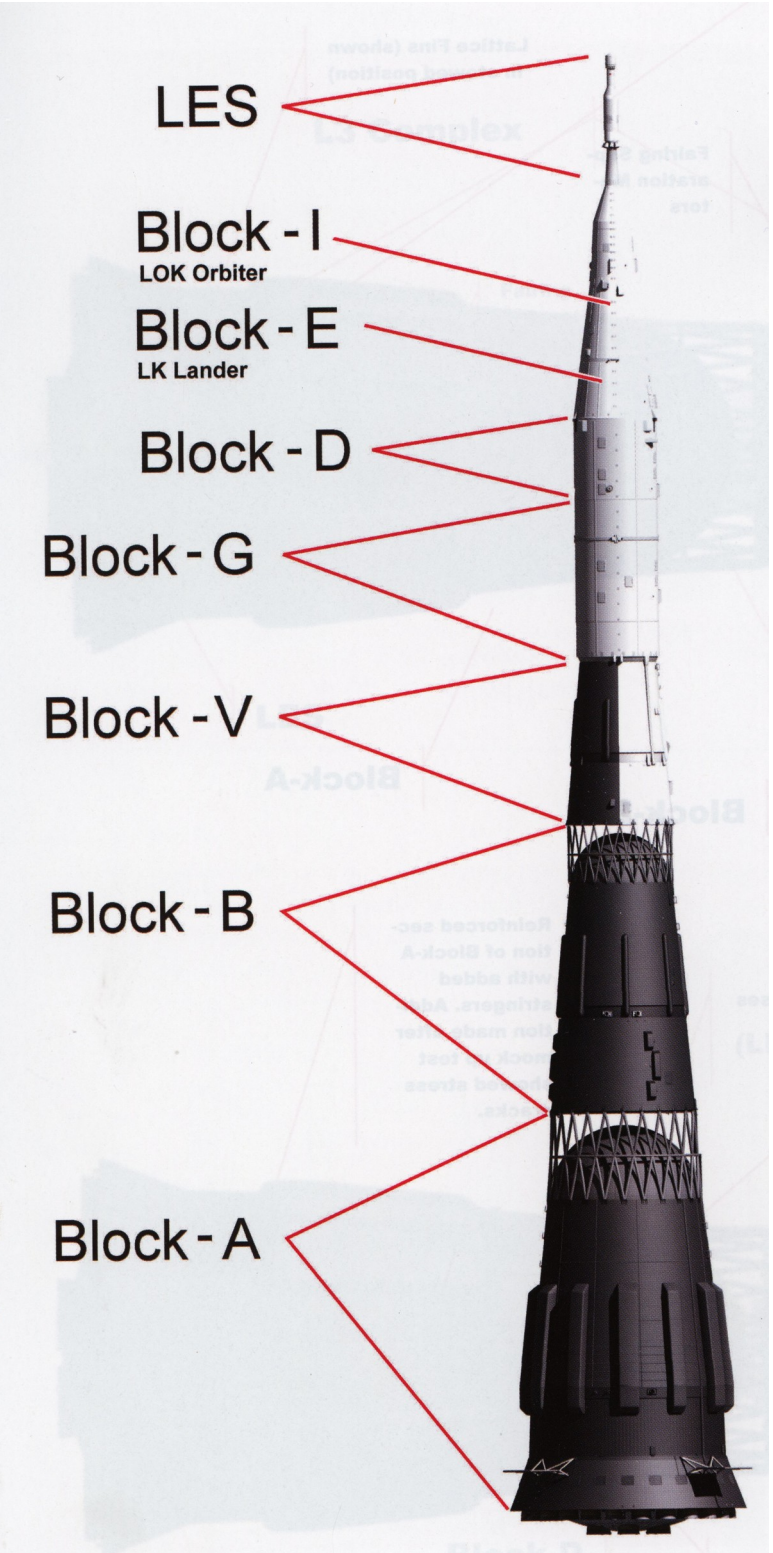
APOLLO 16 AT DESCARTES – MAY 1972

APOLLO 17 AT TAURUS-LITTROW – DEC 1972









1969 – Soviet N-1 Moon Rocket

N-1 is a three stage rocket

Blok A, Blok B suborbital
Blok V puts the stack in Earth parking orbit and separates from the rest of the vehicle: the L-3 spaceship complex

L-3 consists of:
- LOK (Soyuz) lunar orbiter and Earth return ship
- LK lunar lander
- Blok-G Earth escape stage
- Blok-D lunar orbit insertion stage

2 crew members – one would descend to the lunar surface

Alexei Leonov was in training for the job..

L-3 spaceship

More complicated than Apollo/Saturn V – the deep space part plays out a bit differently

	N-1/L-3	Apollo/Saturn V
Total crew	2 people	3 people
Earth orbit insertion	N-1 stage V	Saturn V stage 3
Translunar insertion	L-3 stage G	Saturn V stage 3
Lunar orbit insertion	L-3 stage D	Apollo service module
Descent and landing	Stage D + LK	Lunar Module Descent S
Crew on moon	1 person	2 people
Crew transfer	External spacewalk	Internal tunnel
Lunar takeoff	LK (same engine)	Lunar Module Ascent S.
Lunar orbit rendezvous	LK/LOK	LM/CSM
TransEarth insertion	LOK service module	Apollo service module

Fig. 1: Cosmonaut transfers from LOK to LK

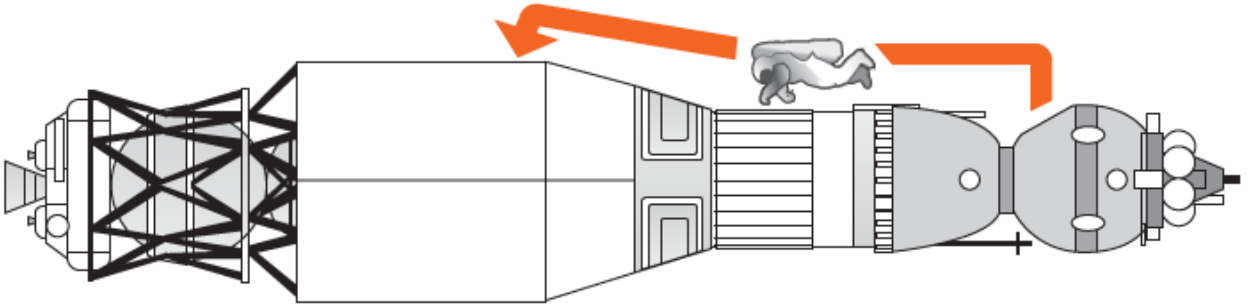
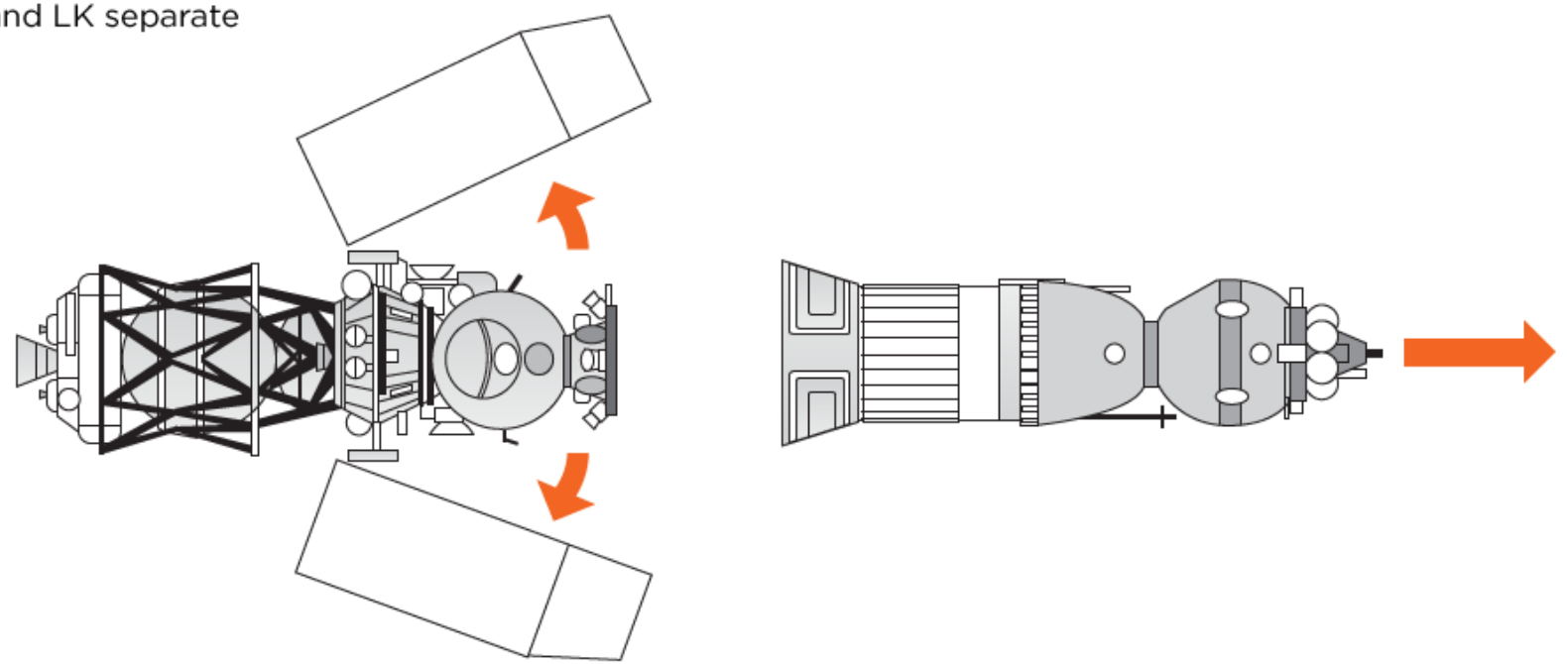
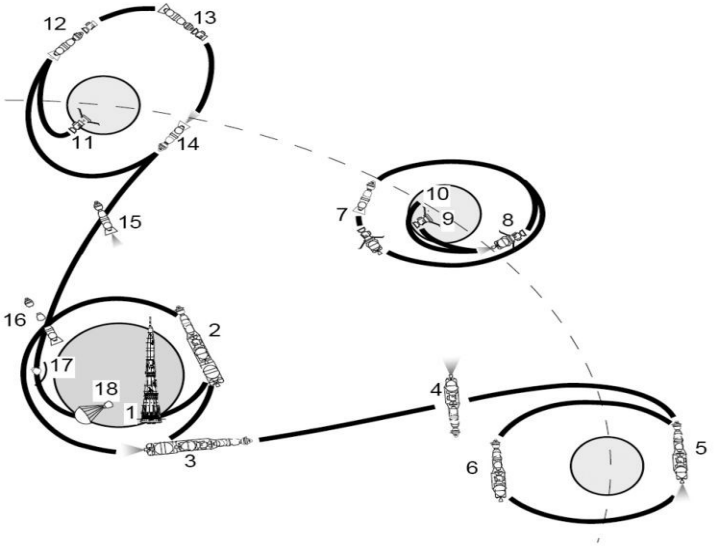


Fig. 2: LOK and LK separate

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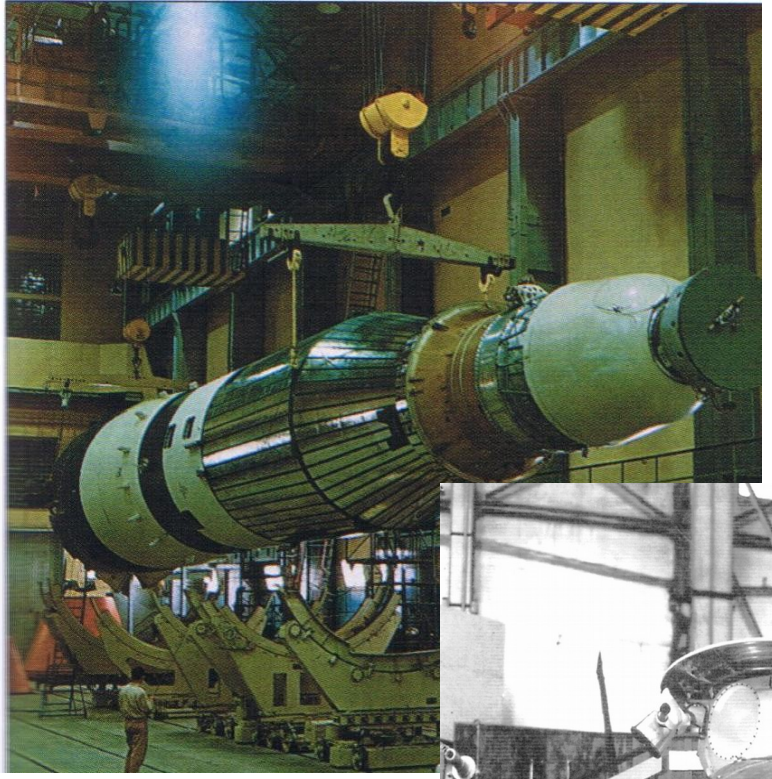
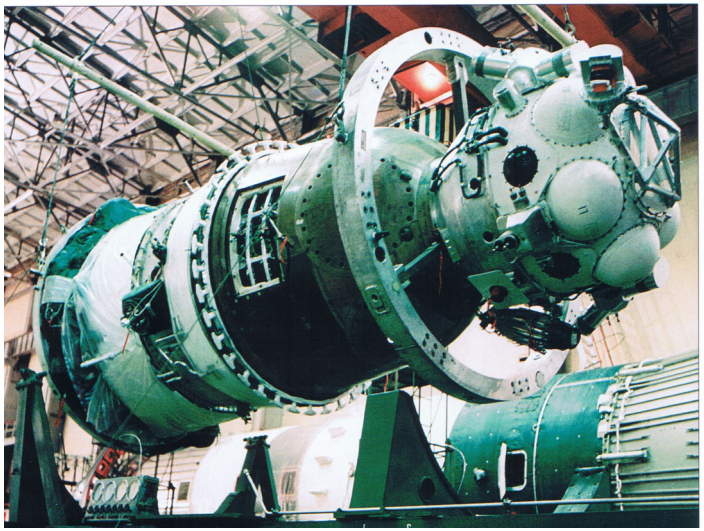
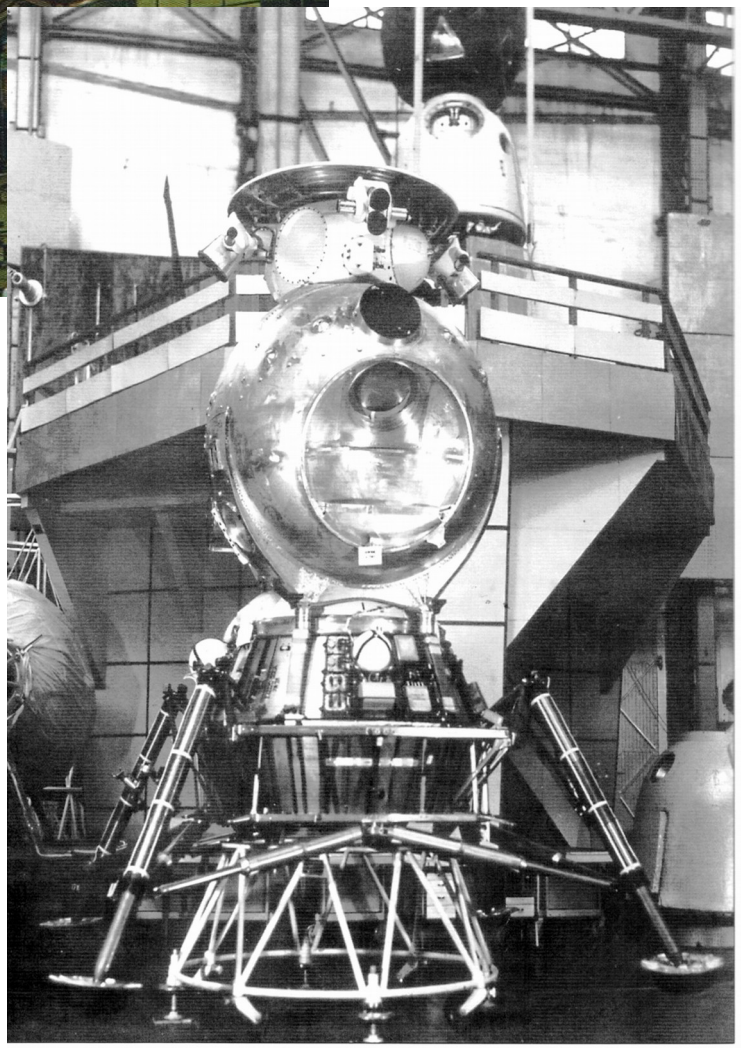
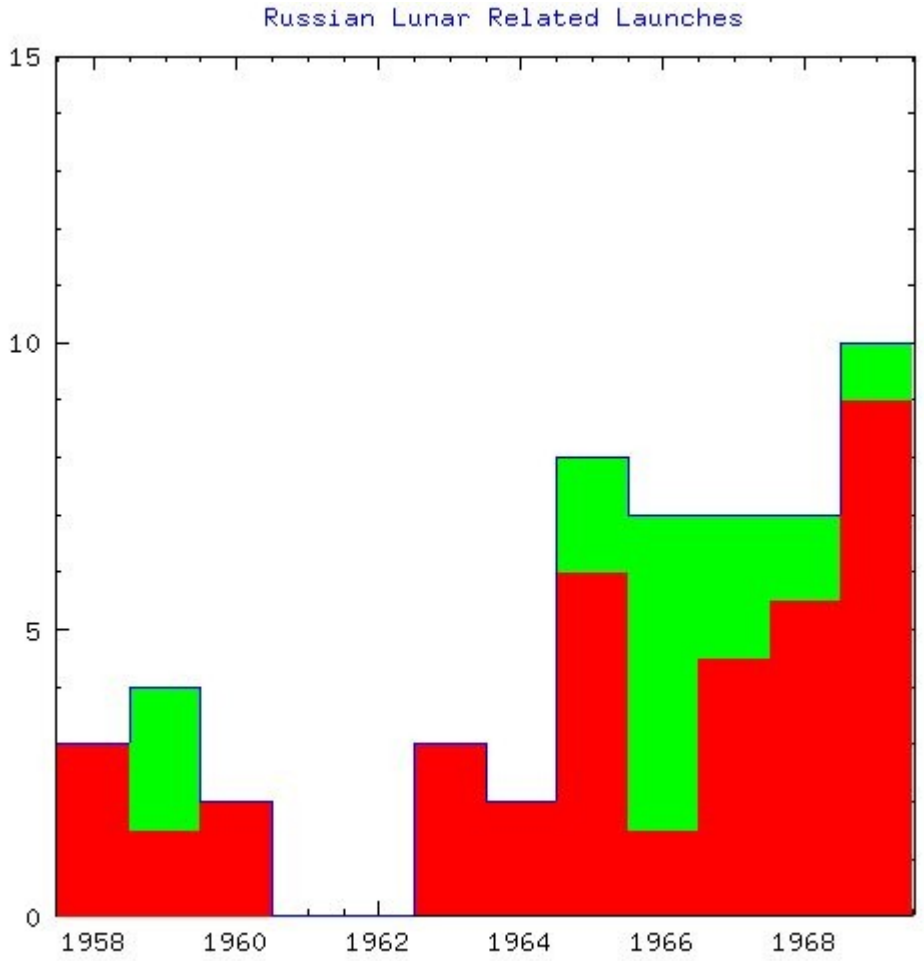


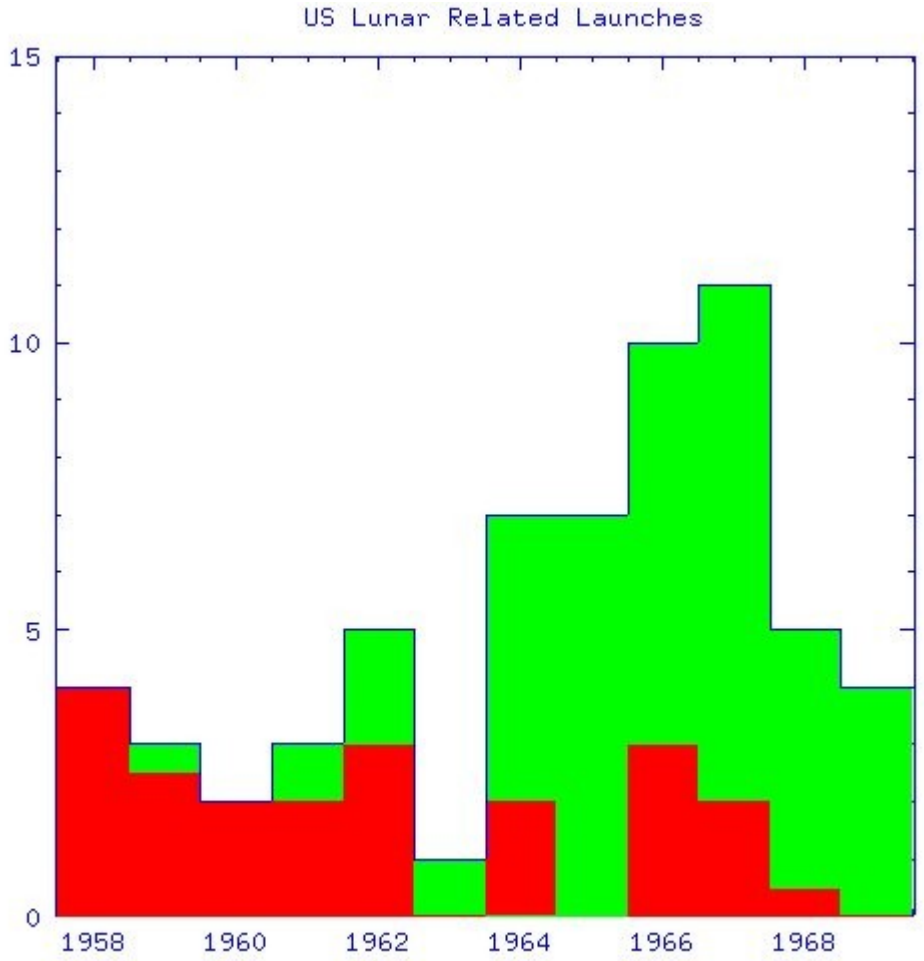




Nov 1972
Final launch of N-1/L-3 Blew up 40 km above Kazakhstan

Dec 19, 1972: Apollo 17 splashdown
End of human exploration of the Moon – for now


Russian Lunar Related Launches
15
10
5
0
1958
1960
1962
1964
1966
1968


US Lunar Related Launches
15
10
5
0
1958
1960
1962
1964
1966
1968

Apollo Science Discoveries:

The moon has internal structure
- Small iron core? 100 km/ 60mi?
- soft asthenosphere (mantle) 700 km / 450 mi
- Lithosphere 1000 km/ 600 mi
- Crust 60 km / 40 mi
- Regolith (`soil') 10 m/ 3 feet

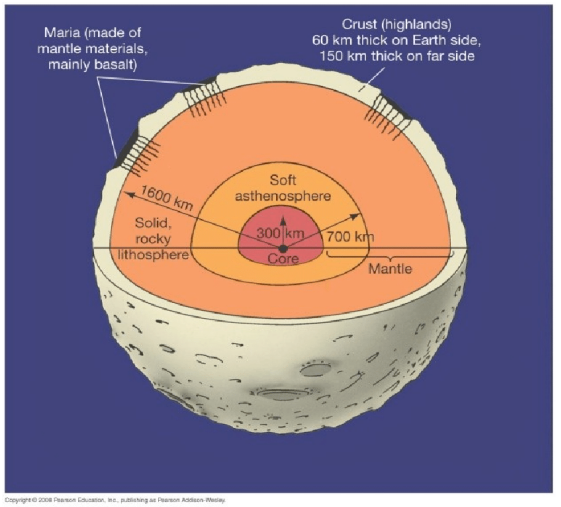


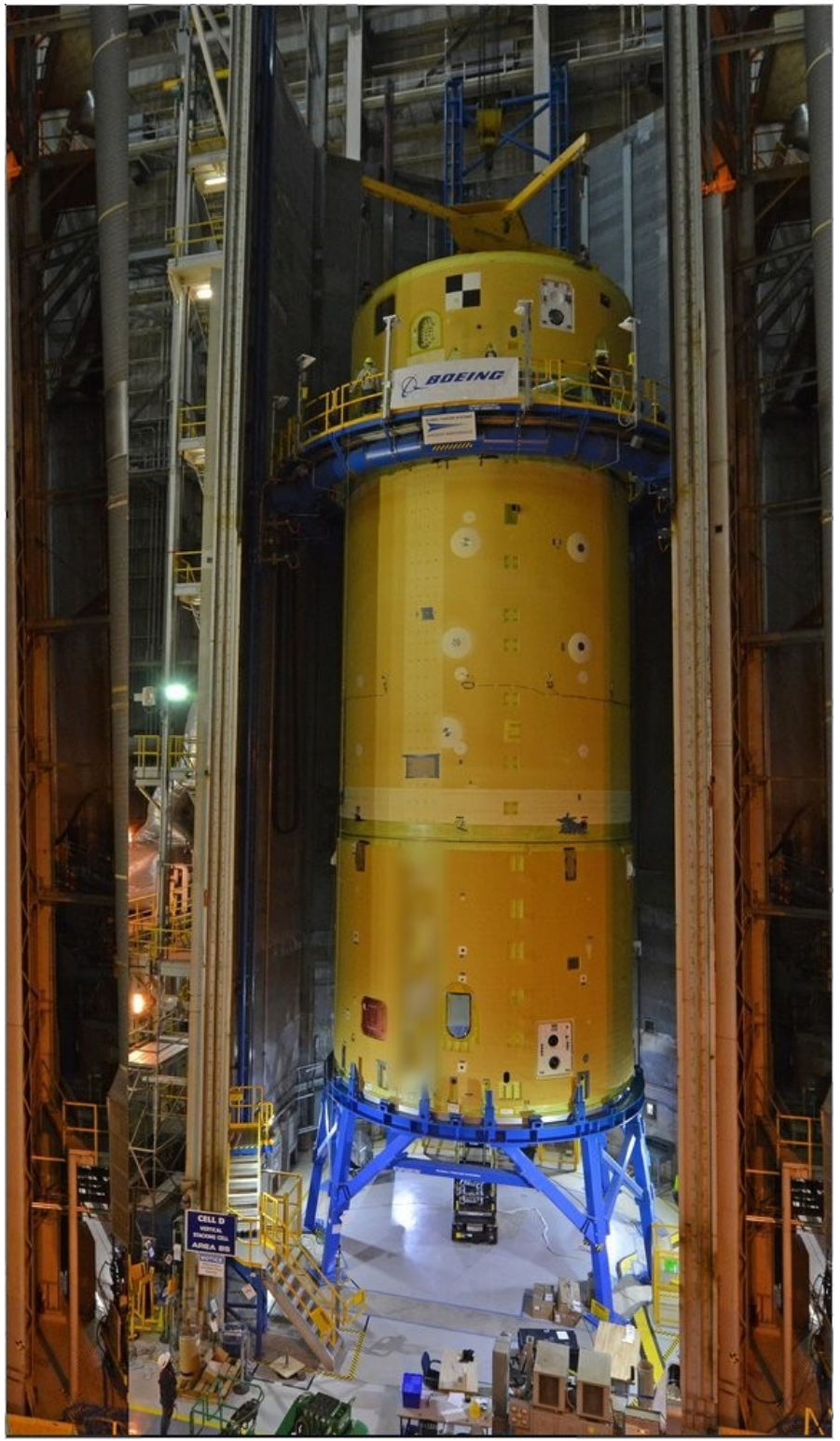
Image: Pearson Ed.Inc.

Craters are due to impacts

Moon rocks are old; 3.2 to 4.6 billion years
- preserves early history of solar system lost on Earth due to geological processes
- No organic molecules
- Mare areas are lava (basalts)

About 4.5 billion years ago, the Moon was molten; lunar highlands have some of the rocks that cooled on its surface then
Afterwards (3-4 billion years ago) big asteroids hit the moon and made the basins (maria)
Later (about 3 billion years ago), lava filled the basins

Moon is lumpy - `mascons' (mass concentrations) under large impact basins affect path of spacecraft in low orbit



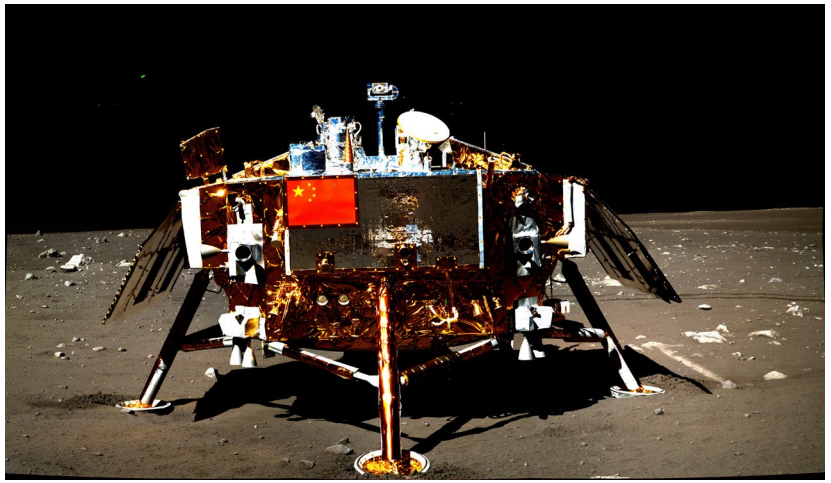
50 years later:

ARTEMIS

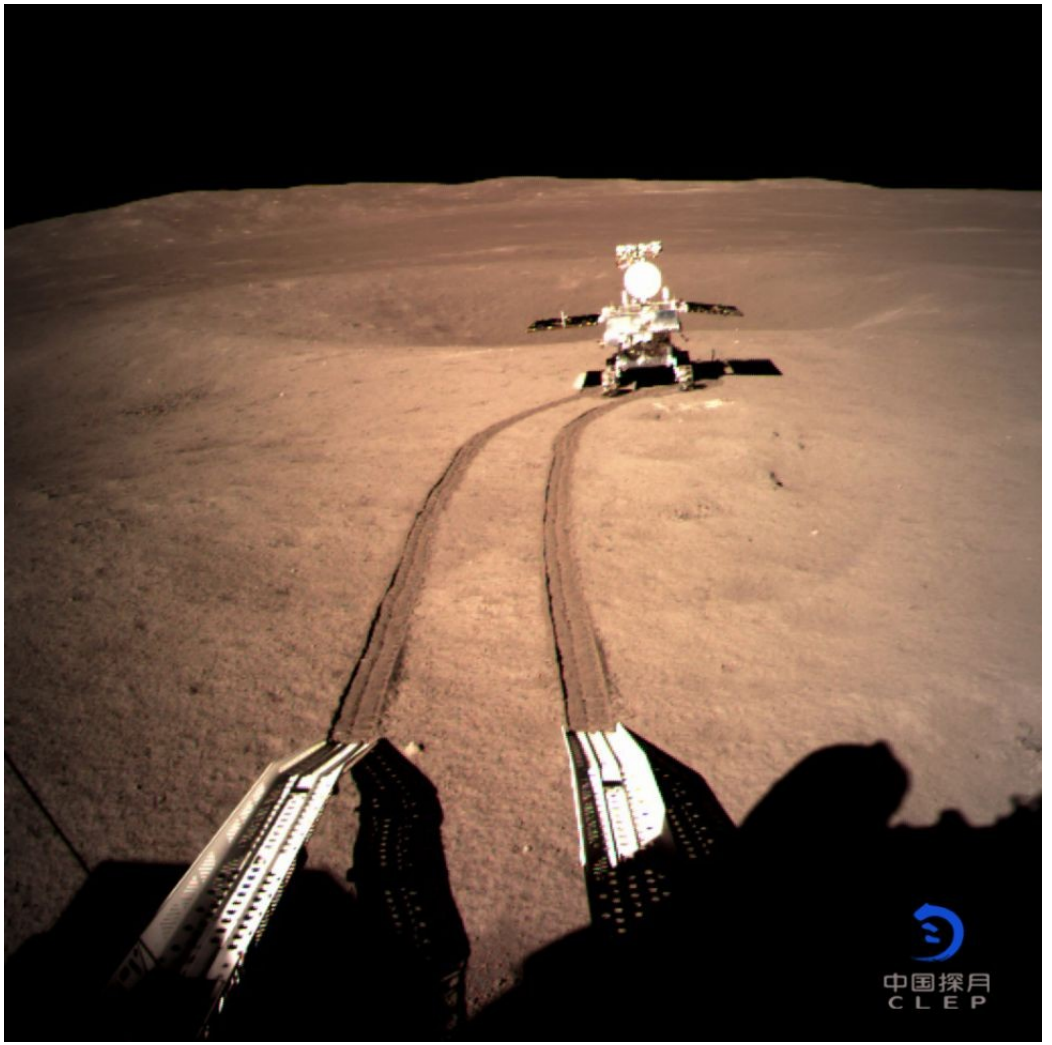
NASA and Boeing build the core stage for the first SLS rocket

Plans still in flux for returning US astronauts to the Moon

Meanwhile, on the lunar farside:



嫦娥四号



玉兔二号