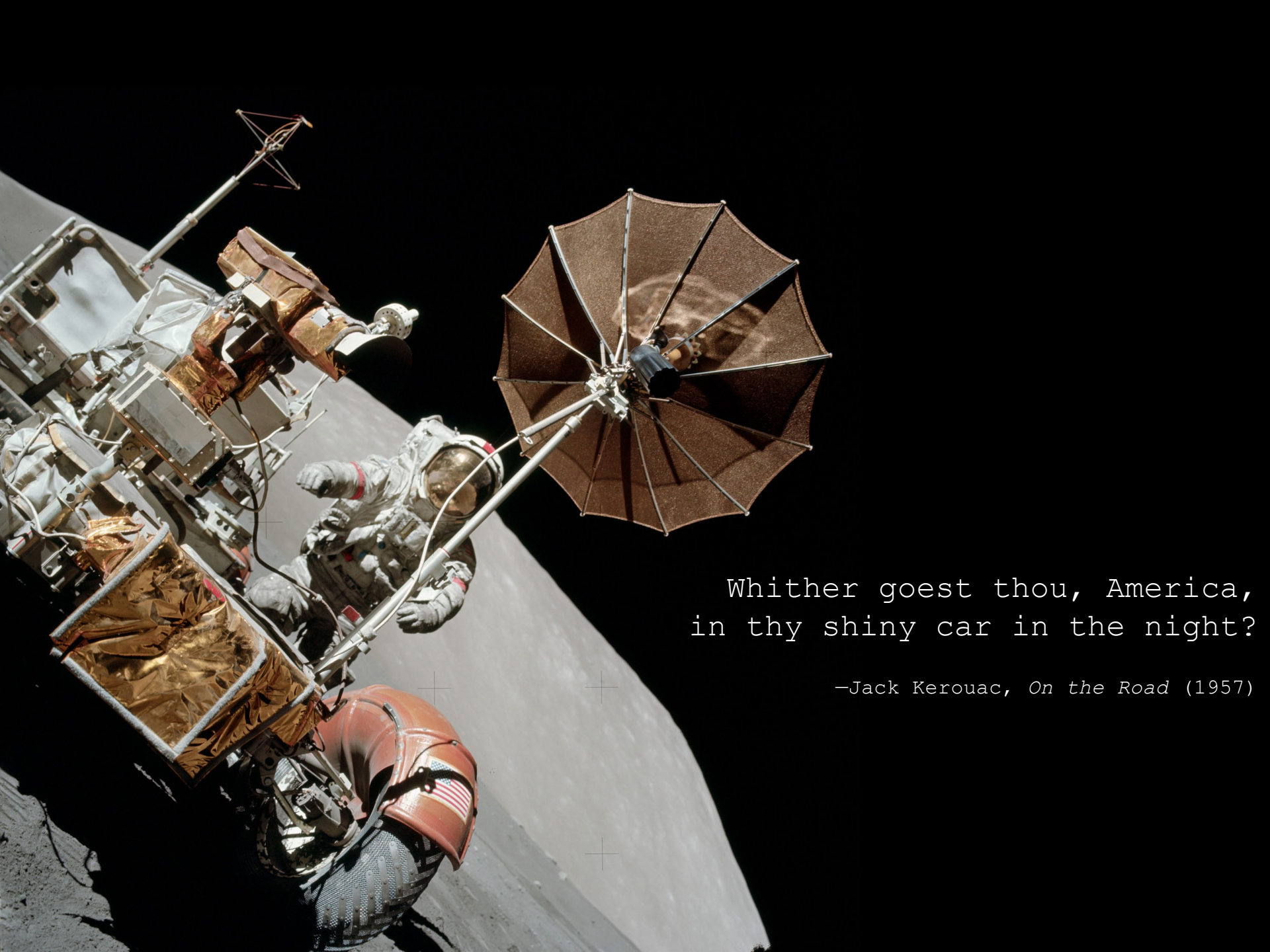


Whither goest thou, America,
in thy shiny car in the night?

—Jack Kerouac, *On the Road* (1957)

The Apollo Lunar Roving Vehicle

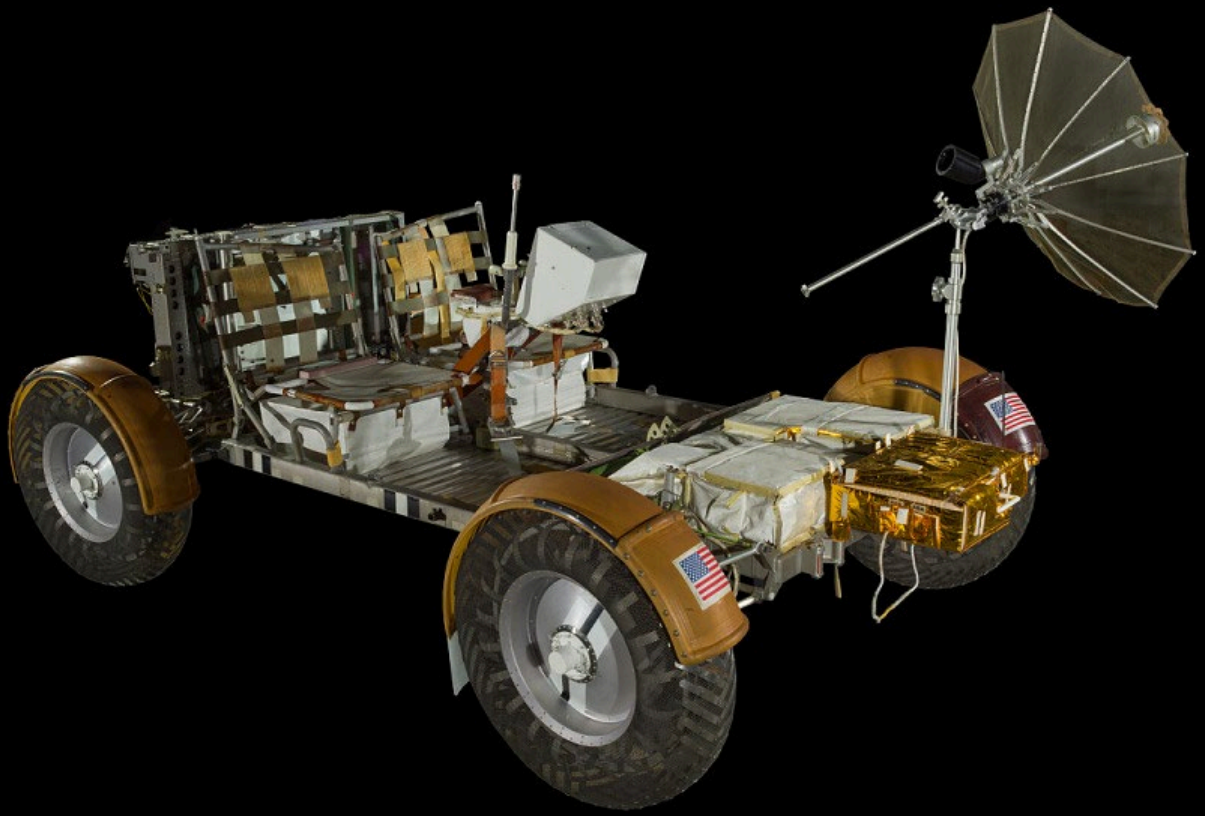
The Apollo Lunar Roving Vehicle

a Boeing joint

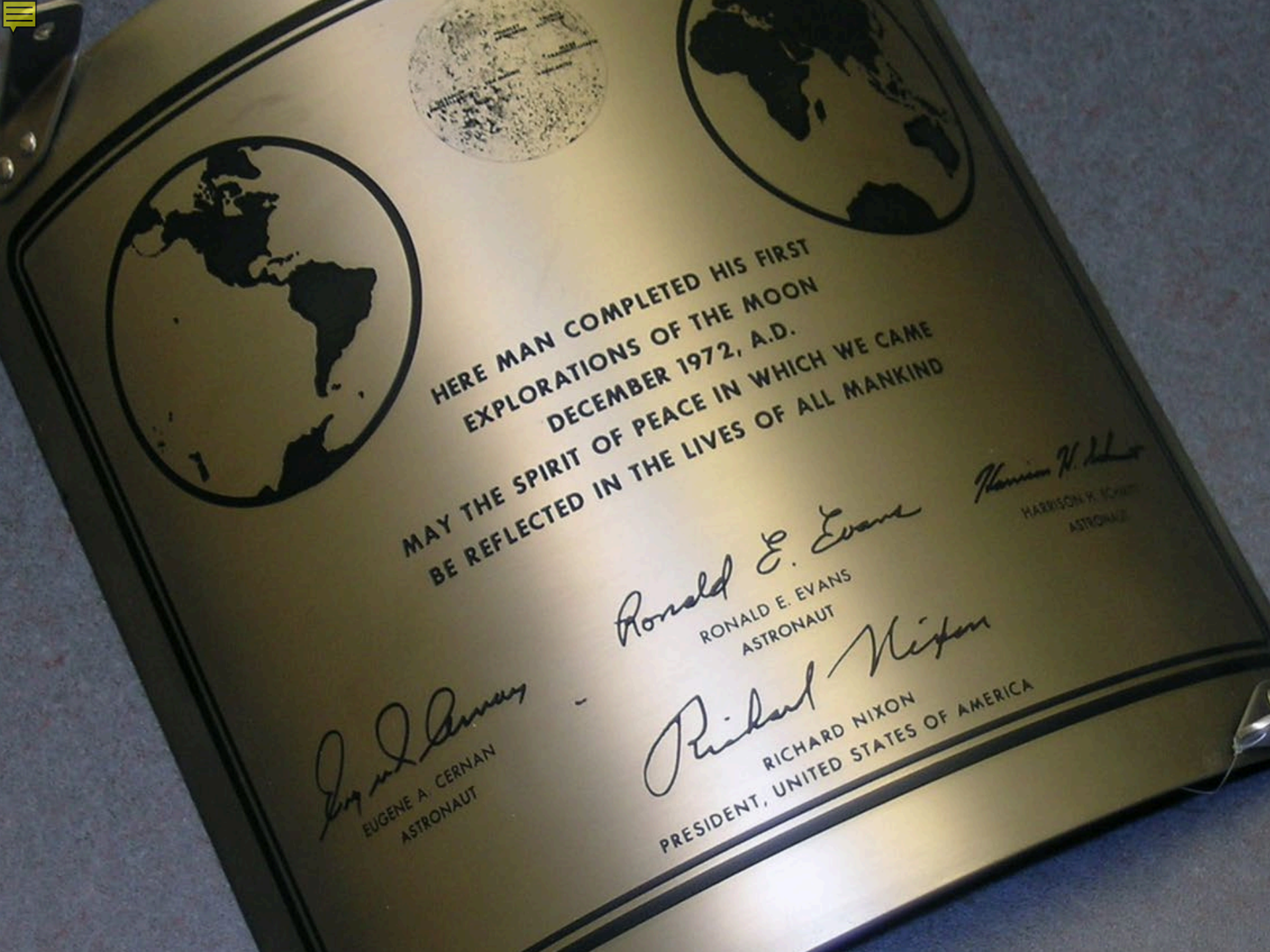
Act I

Act I

Welcome to the moon

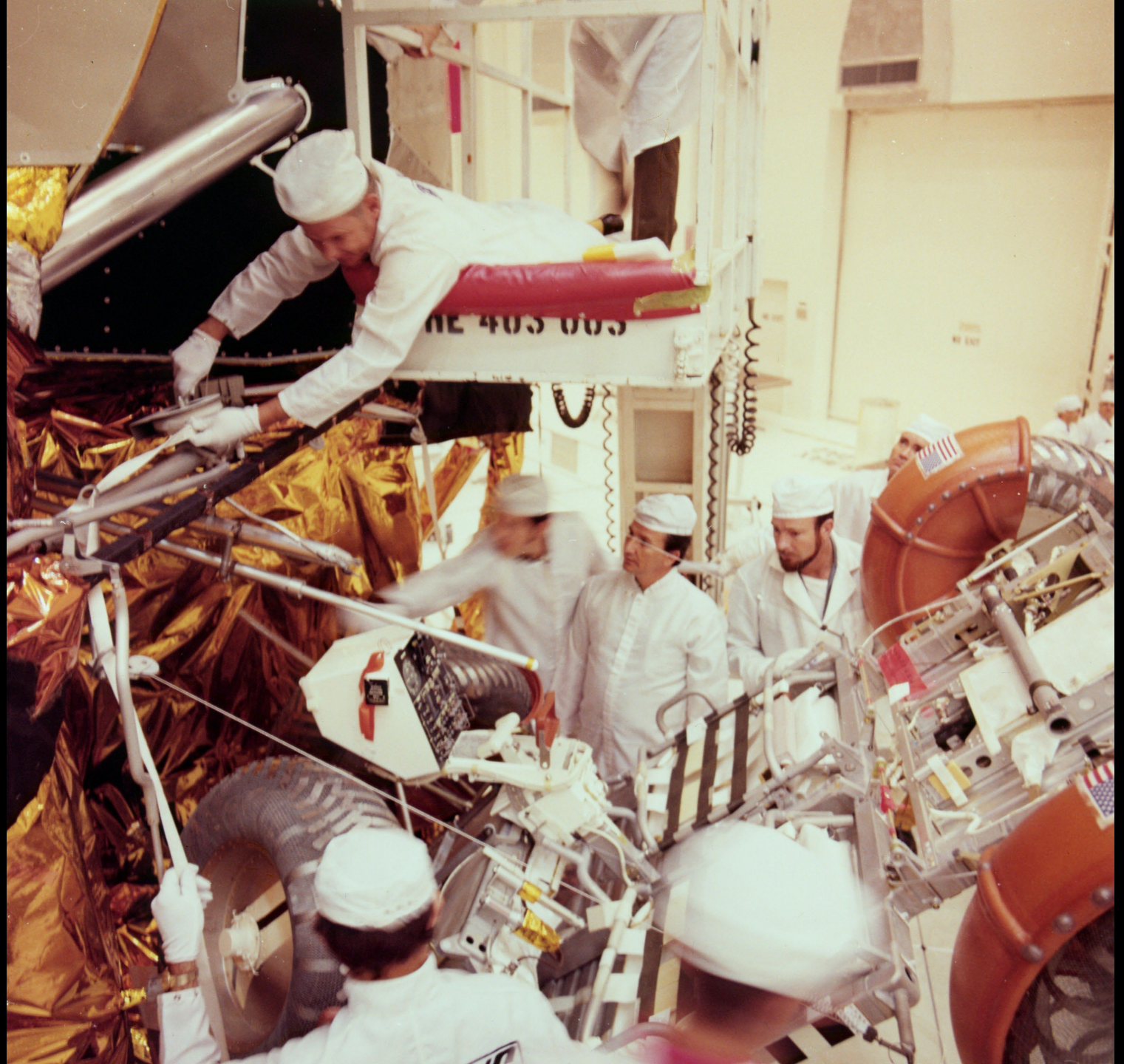



APOLLO XVII
CERNAN EVANS SCHMITT


HERE MAN COMPLETED HIS FIRST
EXPLORATIONS OF THE MOON
DECEMBER 1972, A.D.
MAY THE SPIRIT OF PEACE IN WHICH WE CAME
BE REFLECTED IN THE LIVES OF ALL MANKIND
RONALD E. EVANS
ASTRONAUT
EUGENE A. CERNAN
ASTRONAUT
RICHARD NIXON
PRESIDENT, UNITED STATES OF AMERICA


UNITED
STATES

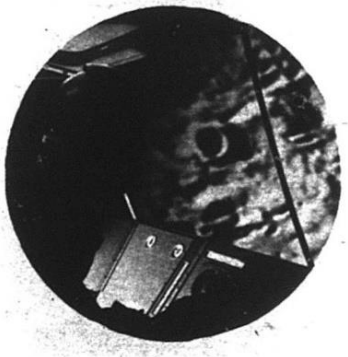

VIP
CAPT E.A. CERNAN
NASA



To help get man to the moon, we're bringing the moon to Kent

When the Boeing space flight laboratory moves into the new Kent research center next year, it will, in effect, bring the moon to Kent.

The space flight facilities, which have already helped train Air Force astronauts, include a simulator which projects television pictures of the moon's surface onto a bowl-shaped screen in front of the pilot's cabin. The pilot, using controls operating through a computer, can direct his craft on a life-like trip through space. The space-flight simulator is used to perform realistic lunar landings, lunar take-offs and re-entry into the earth's atmosphere.



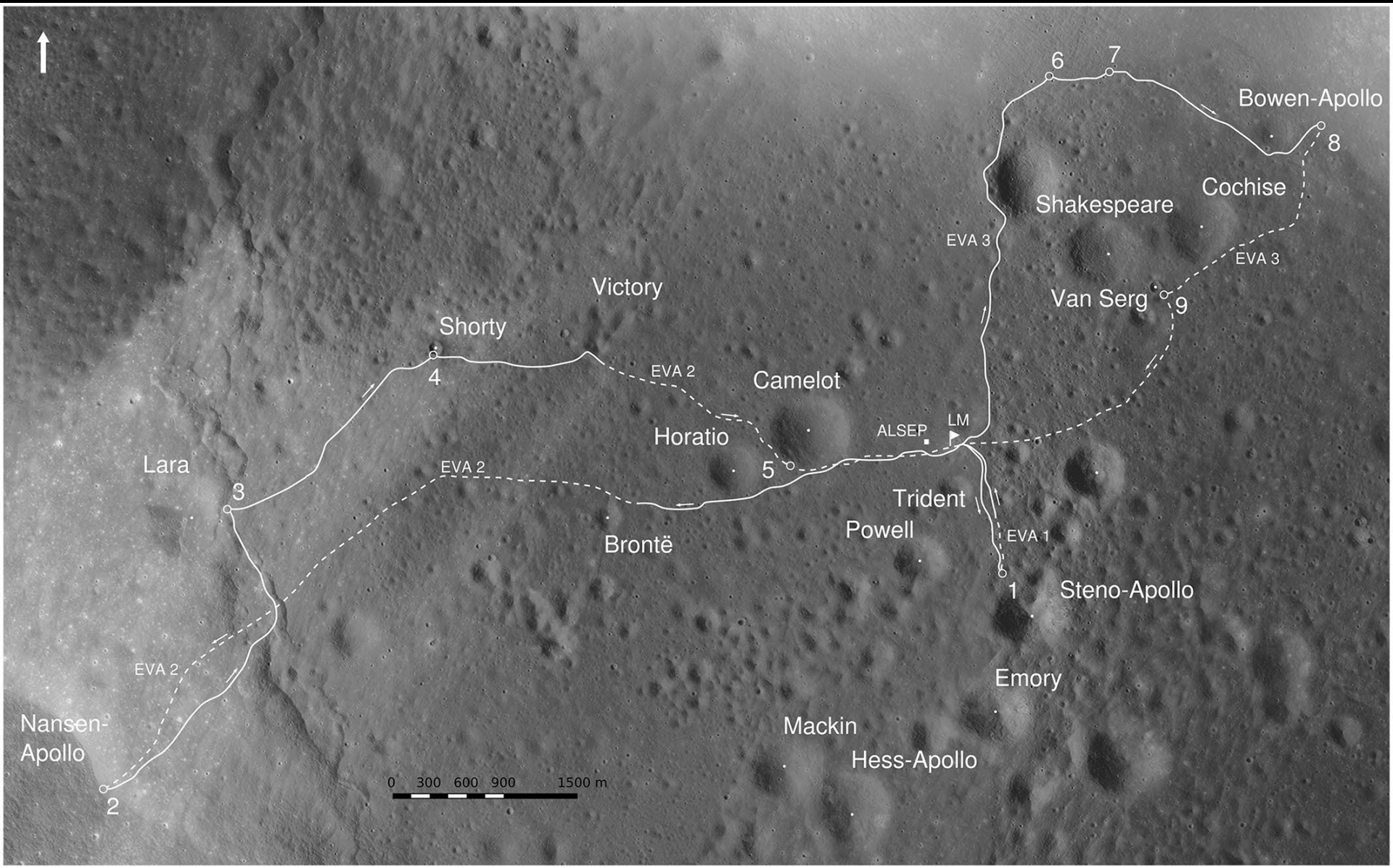
Other Boeing space-research facilities destined for the Kent center include a space docking simulator, in which pilots practice orbital rendezvous techniques. The cabin is mounted on an air bearing which permits angular motion in any direction, making it possible to practice controlling a spacecraft in simulated flight.

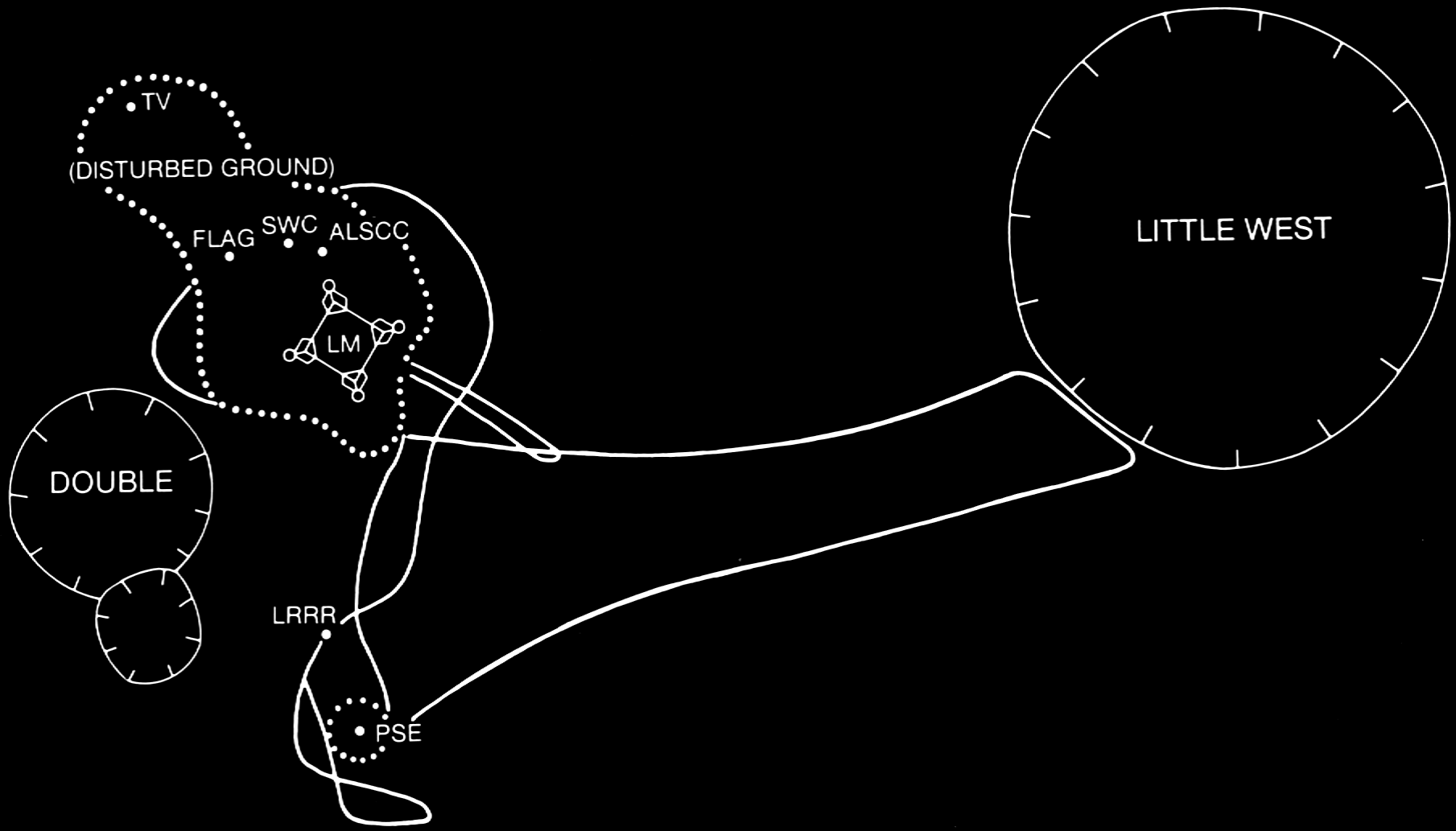
These and other advanced space-oriented research programs will be underway in Kent next year, to help the nation put man on the moon and explore the universe of space.

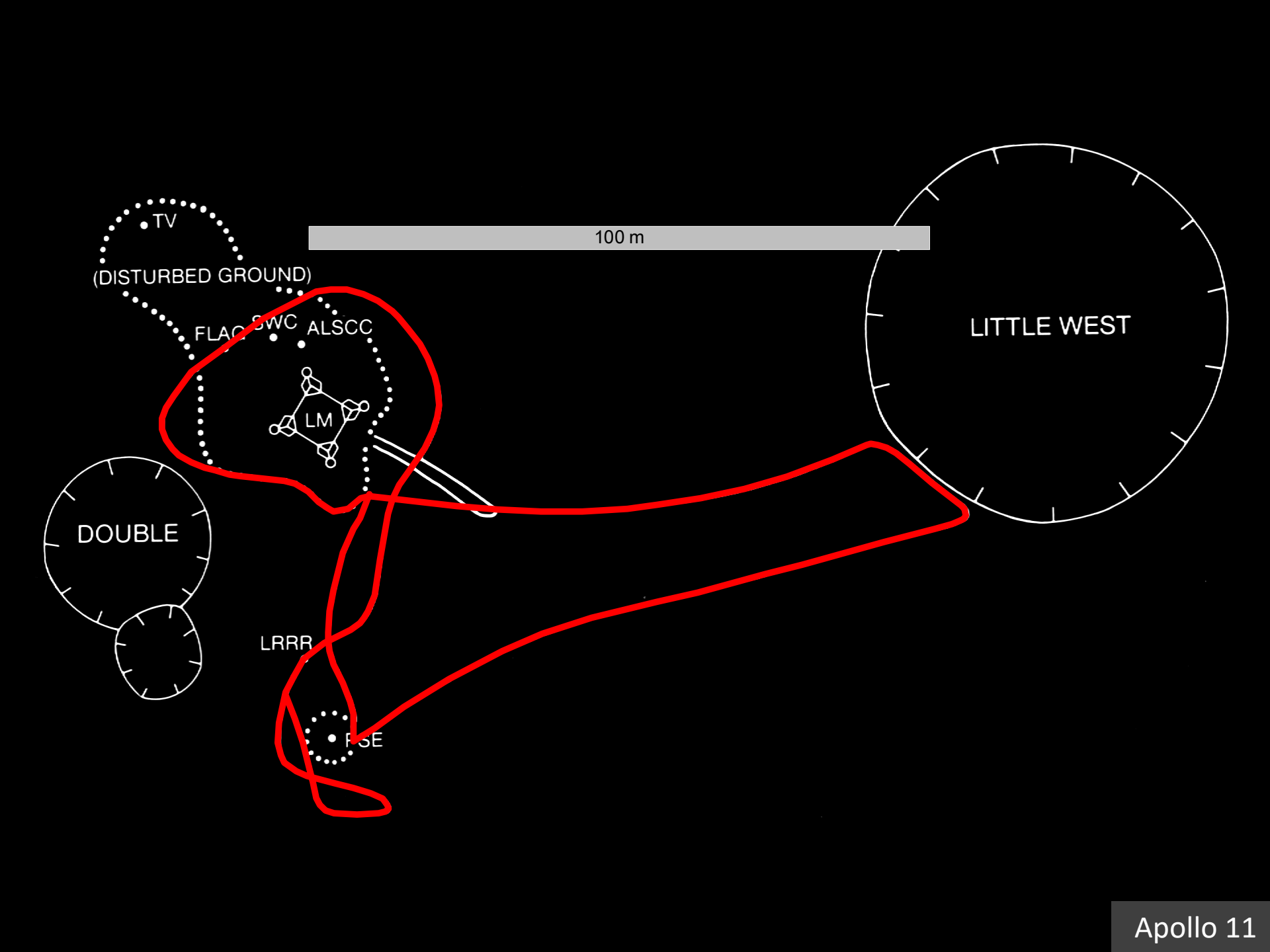
BOEING

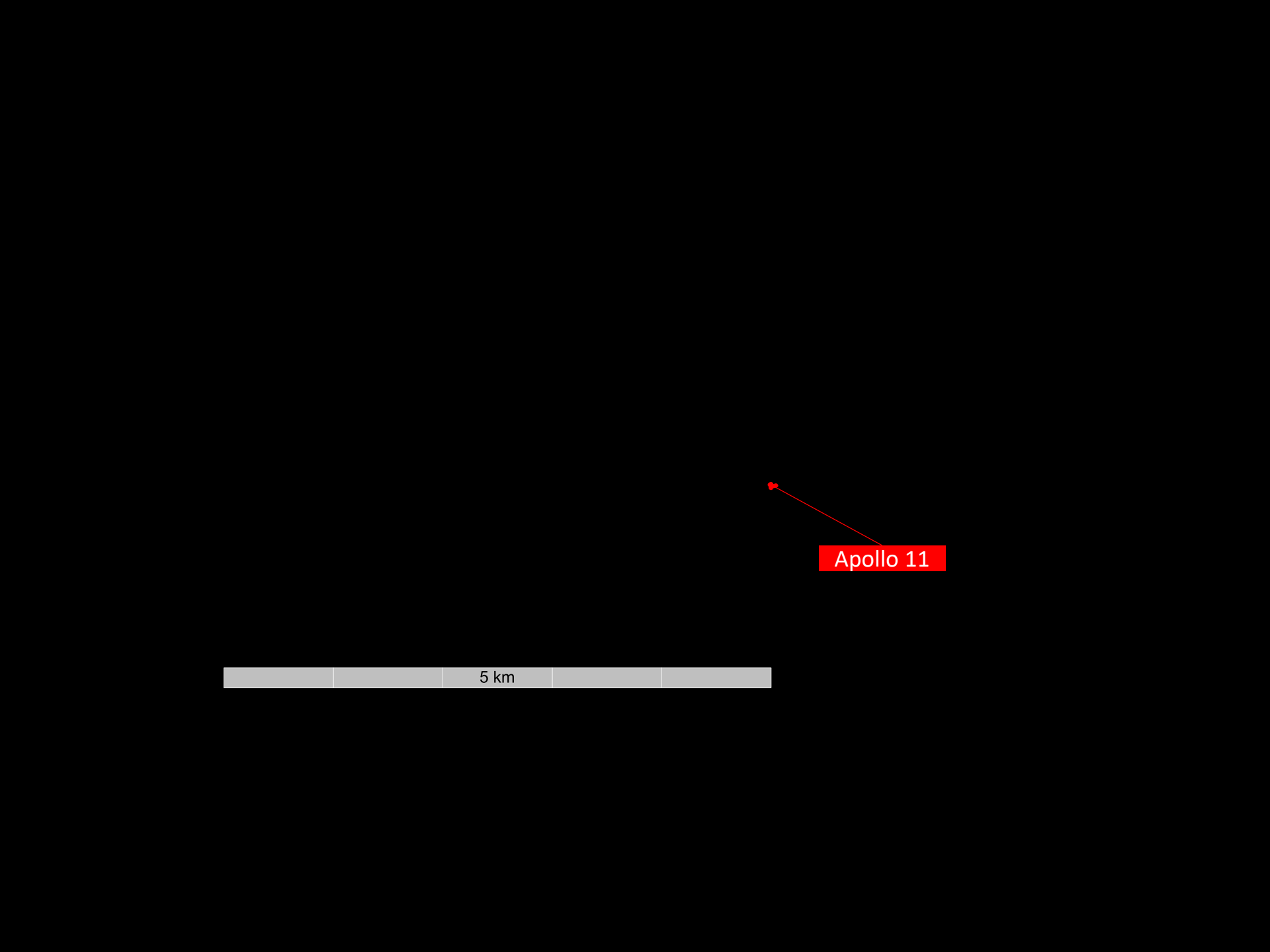
¡DISCLAIMER OF SORTS!

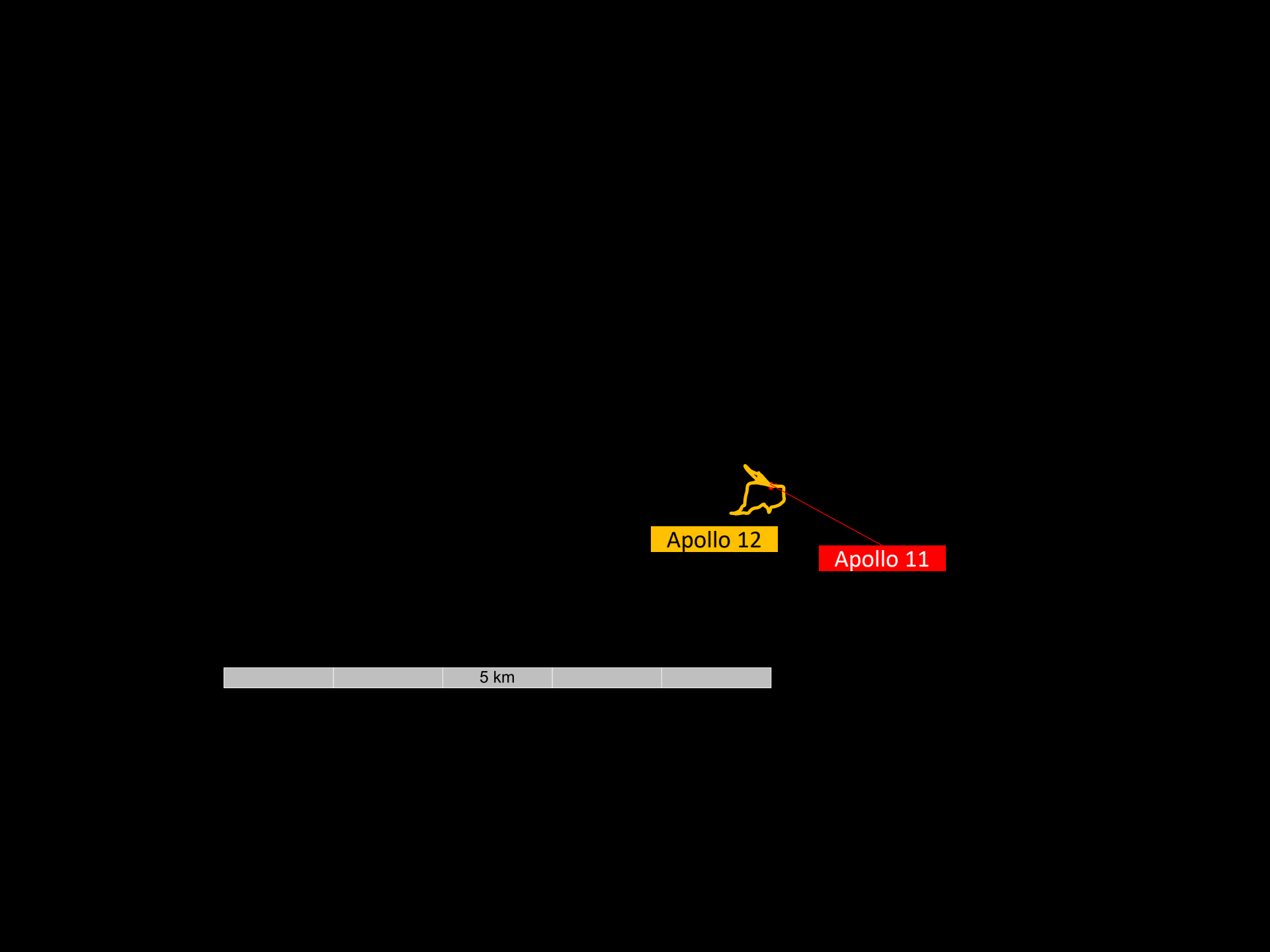
Not a Boeing presentation

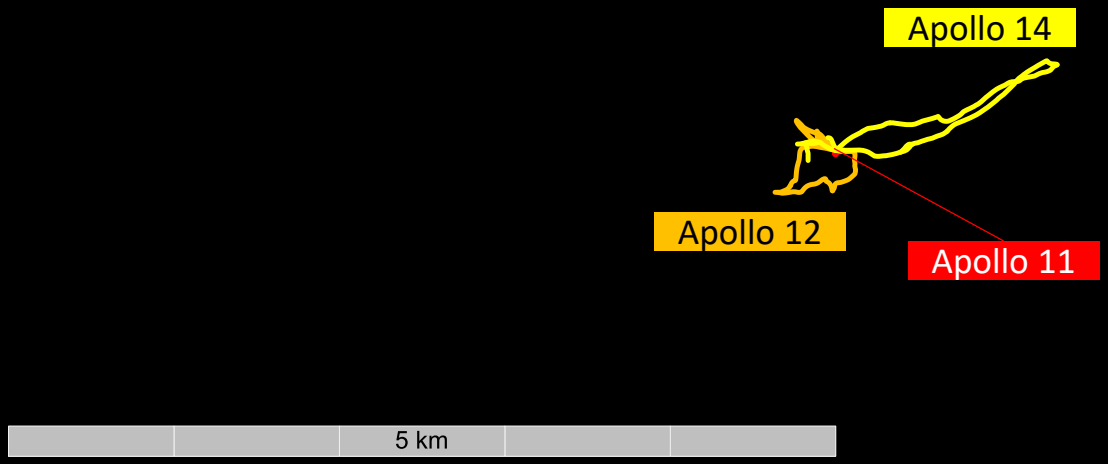

6
7
Bowen-Apollo
8
Cochise
Shakespeare
EVA 3
EVA 3
Victory
Van Serg
9
Shorty
4
EVA 2
Camelot
ALSEP
LM
Horatio
5
Lara
3
EVA 2
Trident
Powell
EVA 1
Brontë
1
Steno-Apollo
EVA 2
Emory
Nansen-
Apollo
Mackin
Hess-Apollo
2
0 300 600 900 1500 m

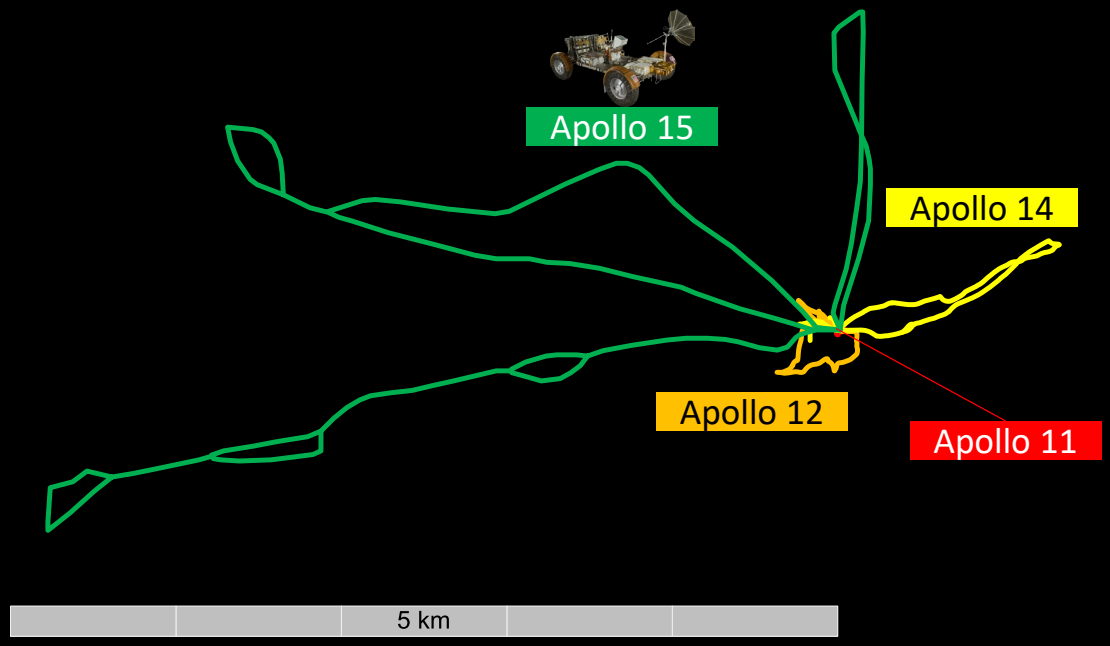

TV
(DISTURBED GROUND)
FLAG
SWC
ALSCC
LM
LITTLE WEST
DOUBLE
LRRR
PSE

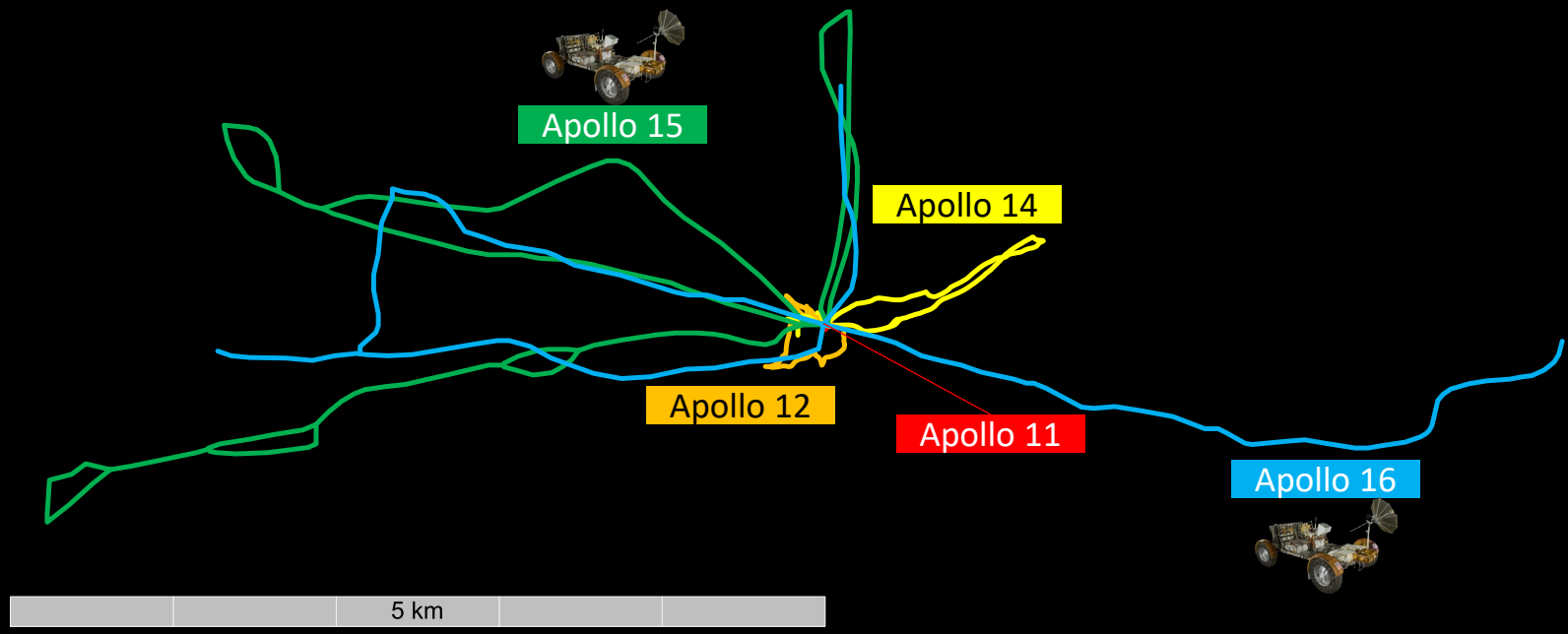

TV
(DISTURBED GROUND)
100 m
LITTLE WEST
ALSCC
LM
DOUBLE
LRRR

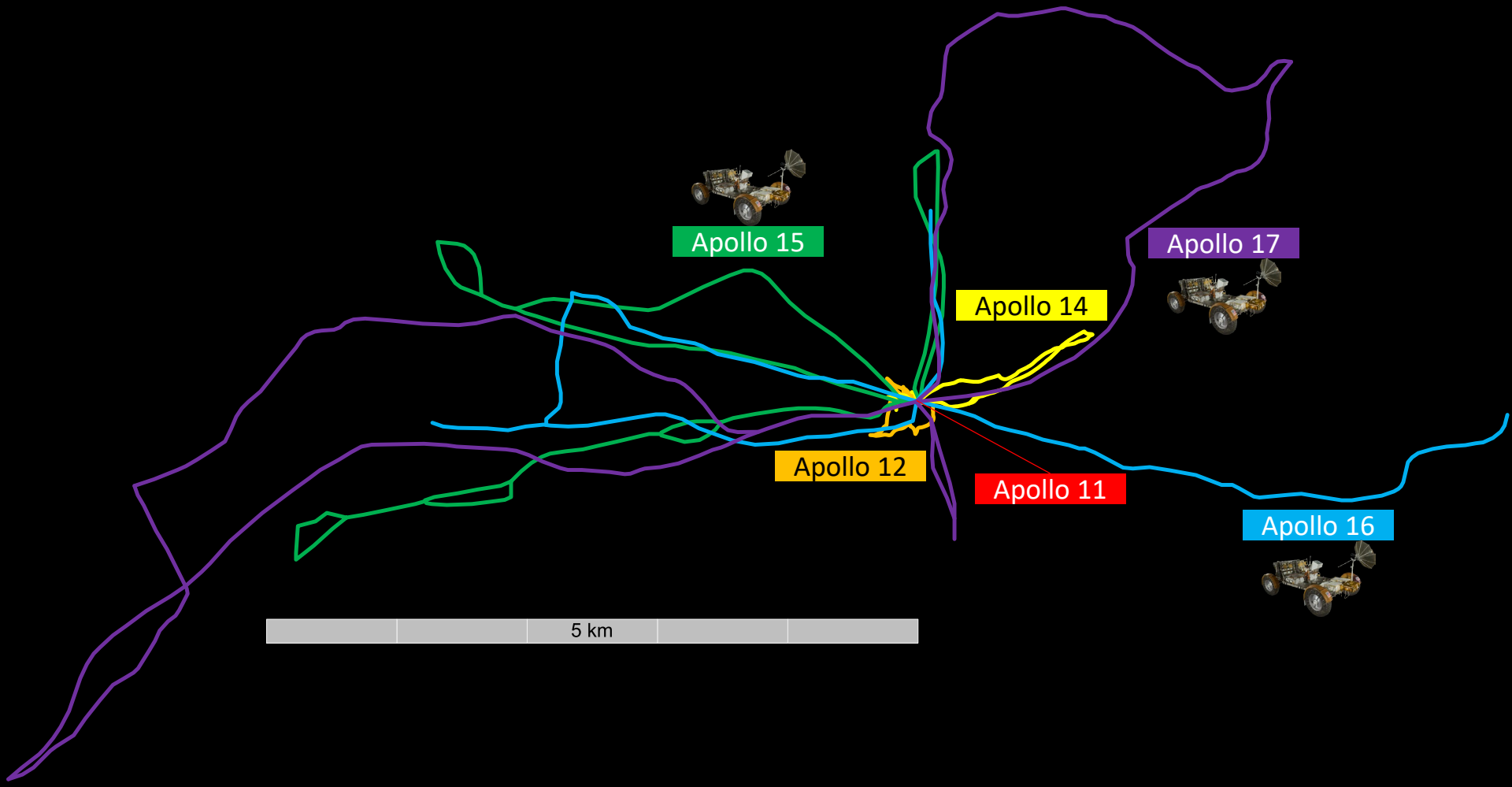

Apollo 11
5 km


Apollo 12
Apollo 11
5 km

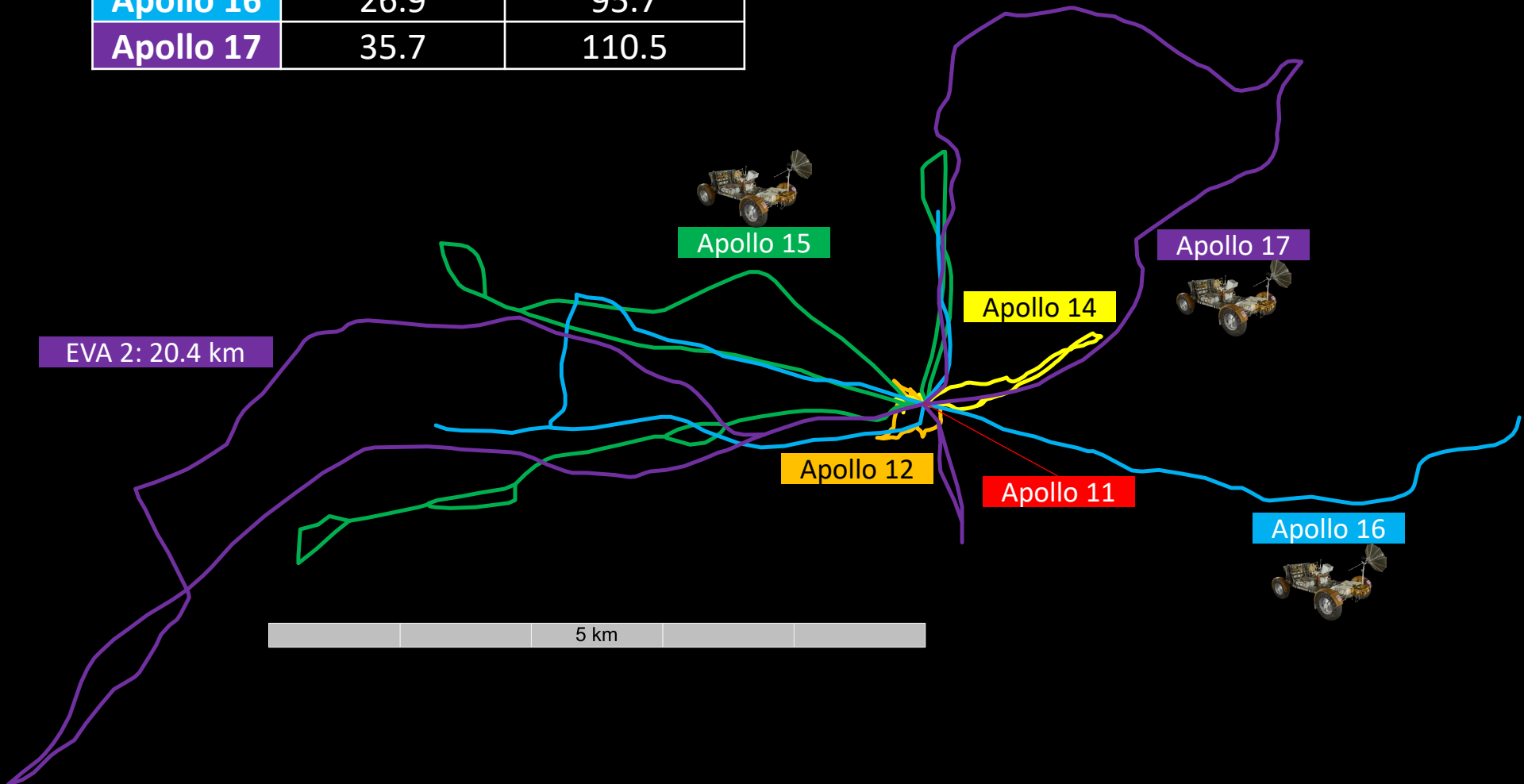

Apollo 14
Apollo 12
Apollo 11
5 km


Apollo 15
Apollo 14
Apollo 12
Apollo 11
5 km


Apollo 15
Apollo 14
Apollo 12
Apollo 11
Apollo 16
5 km


Apollo 15
Apollo 17
Apollo 14
Apollo 12
Apollo 11
Apollo 16
5 km

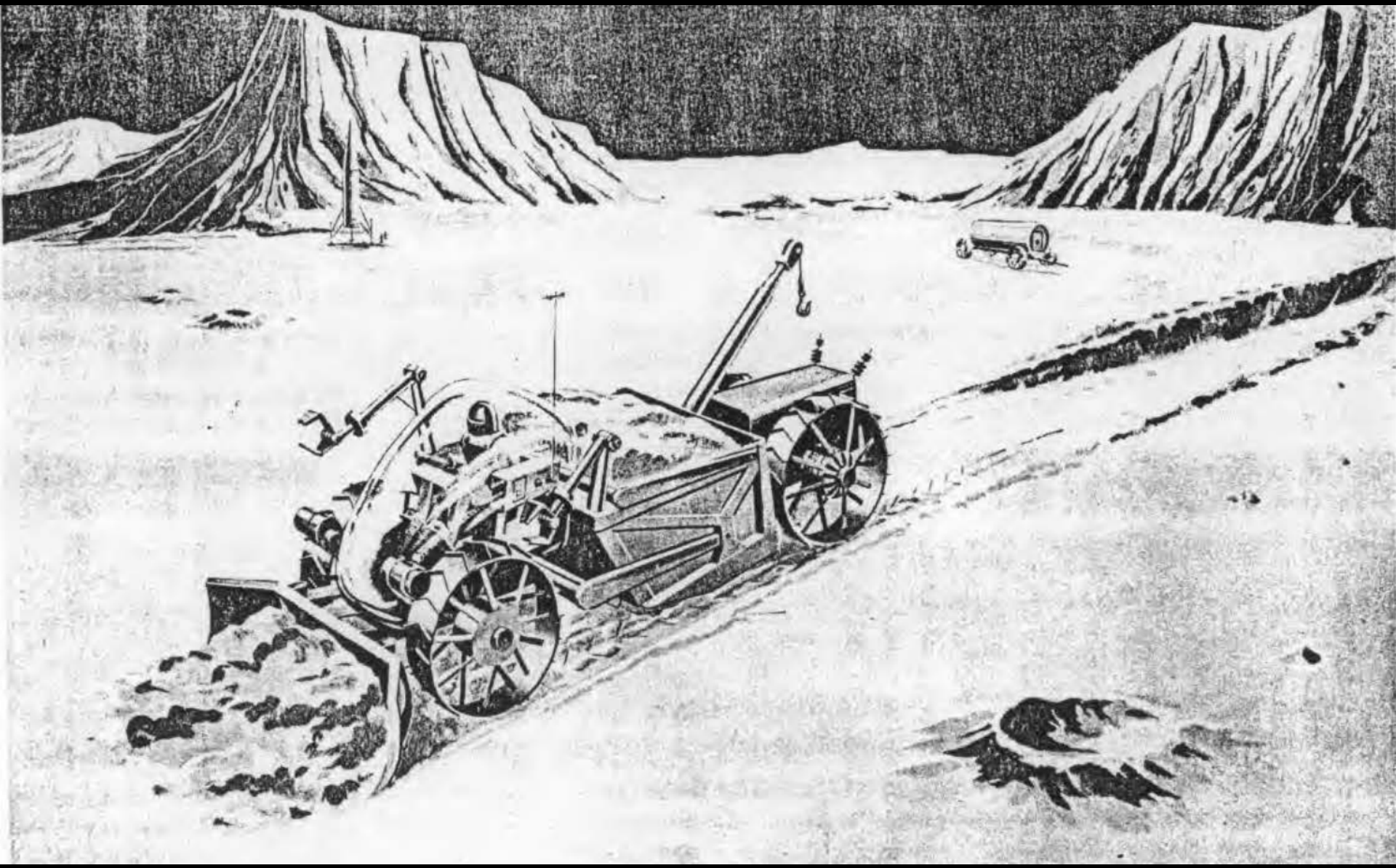
	Distance (km)	Samples (kg)
Apollo 11	0.9	21.6
Apollo 12	2.2	34.4
Apollo 13	0.0	0.0
Apollo 14	4.1	42.3
Apollo 15	28.0	77.3
Apollo 16	26.9	95.7
Apollo 17	35.7	110.5



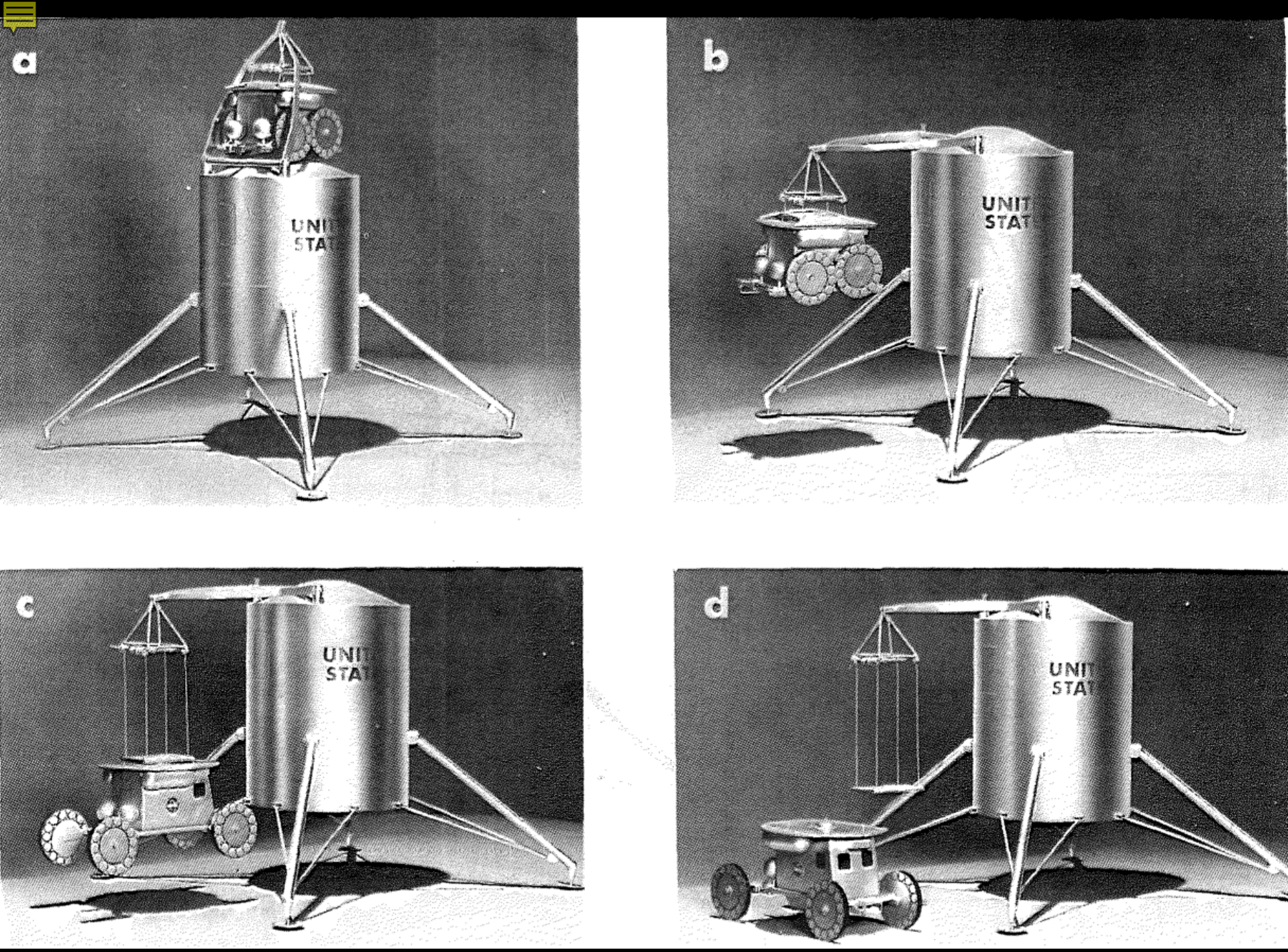
Act II

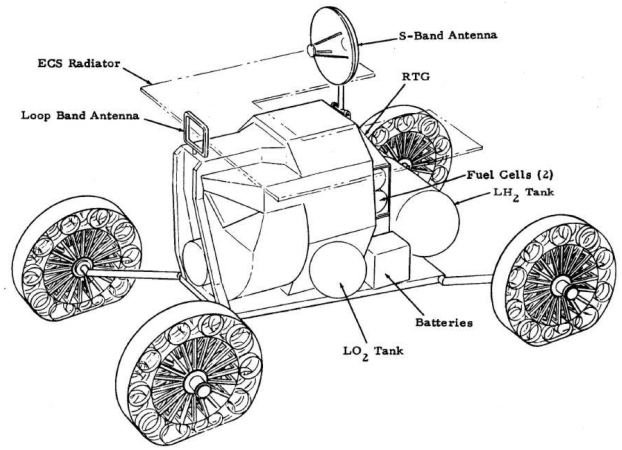
Act II

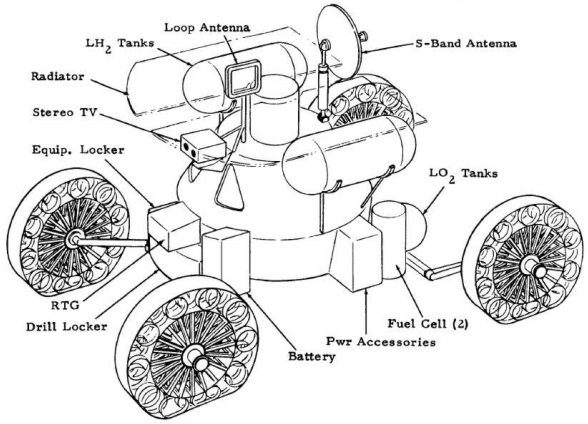
Competitors and precursors

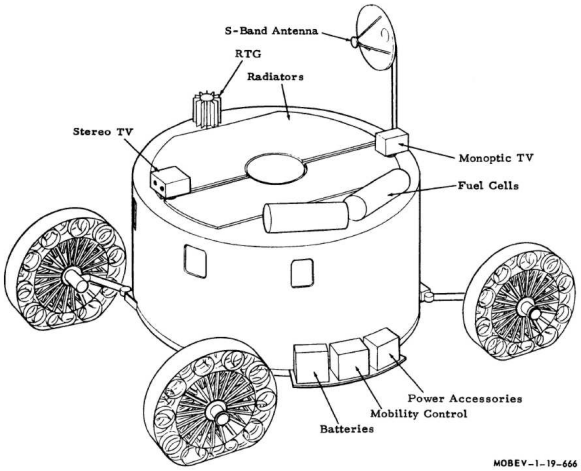



UNITED
STATES

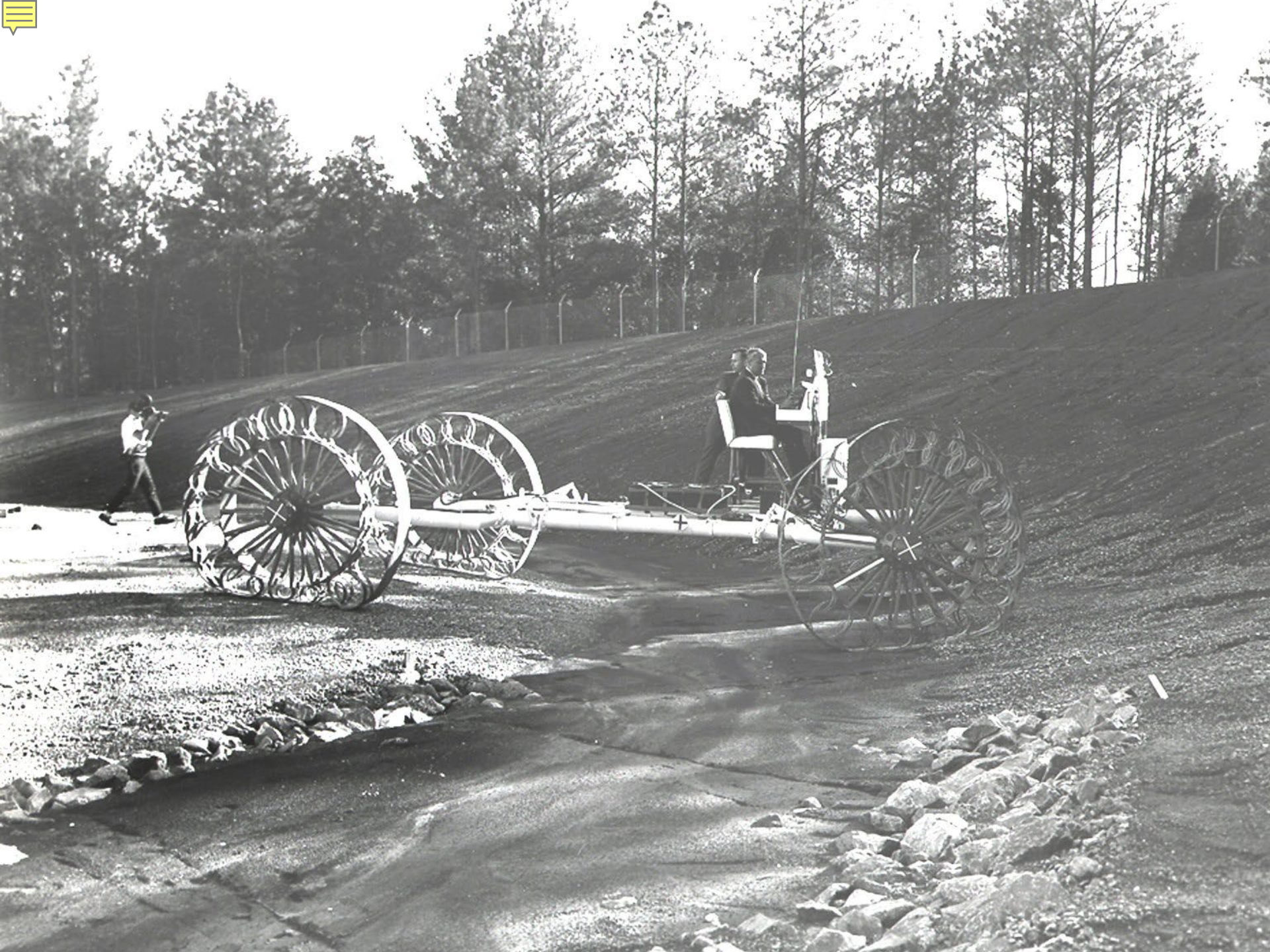

a
b
c
d



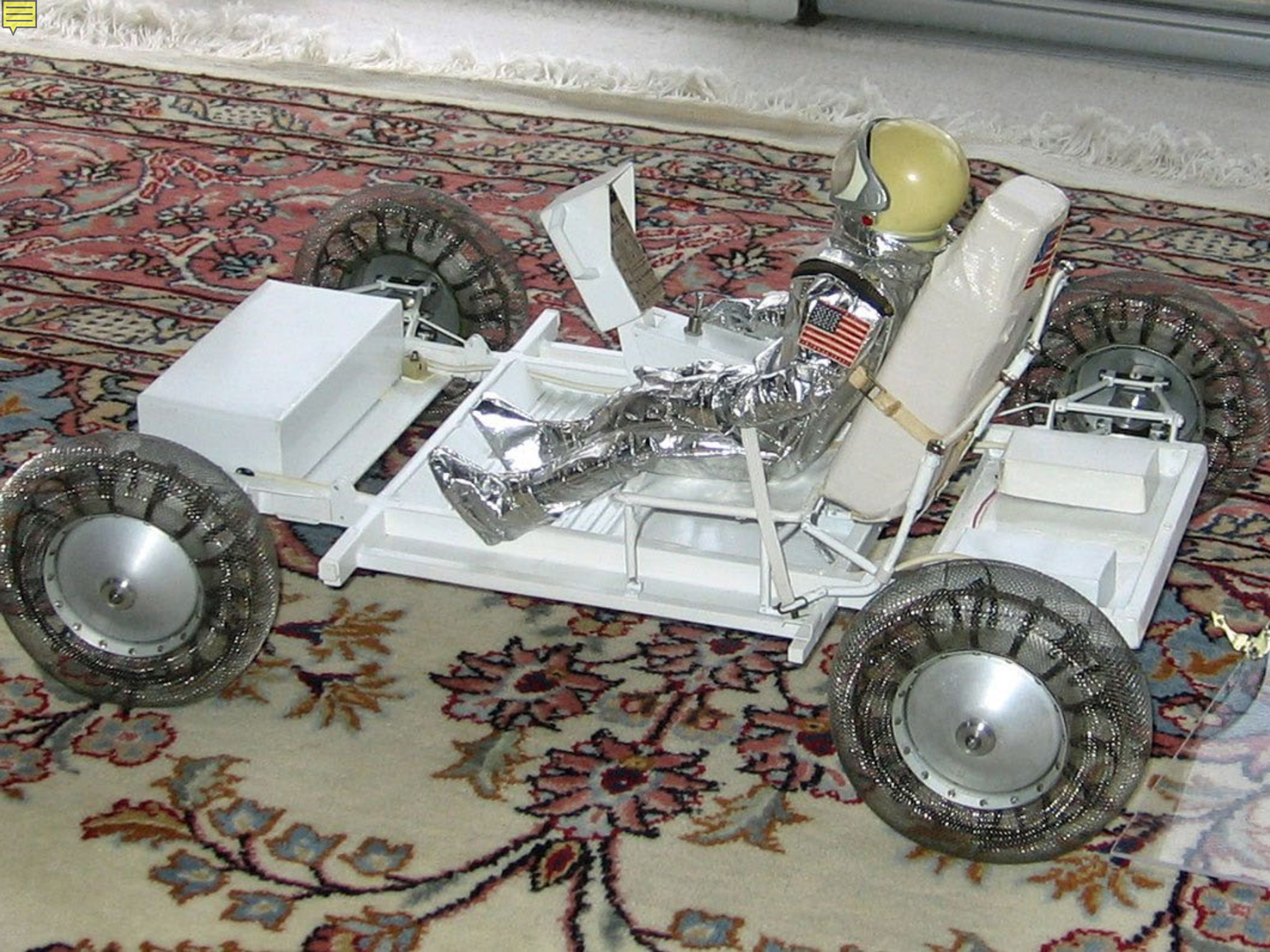


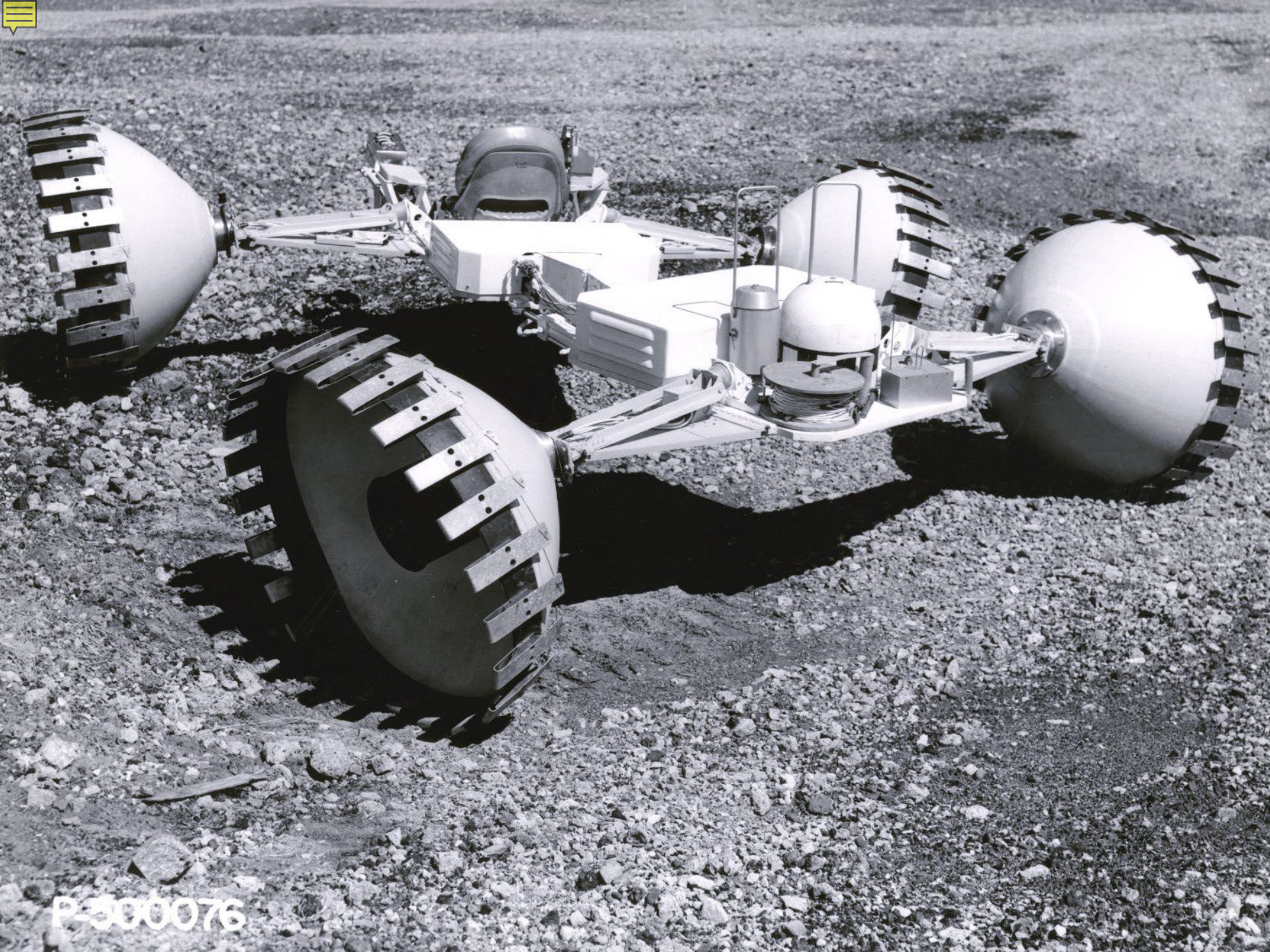


MOBEV-1-19-666




DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
MOBILE GEOLOGICAL LABORATORY
GM

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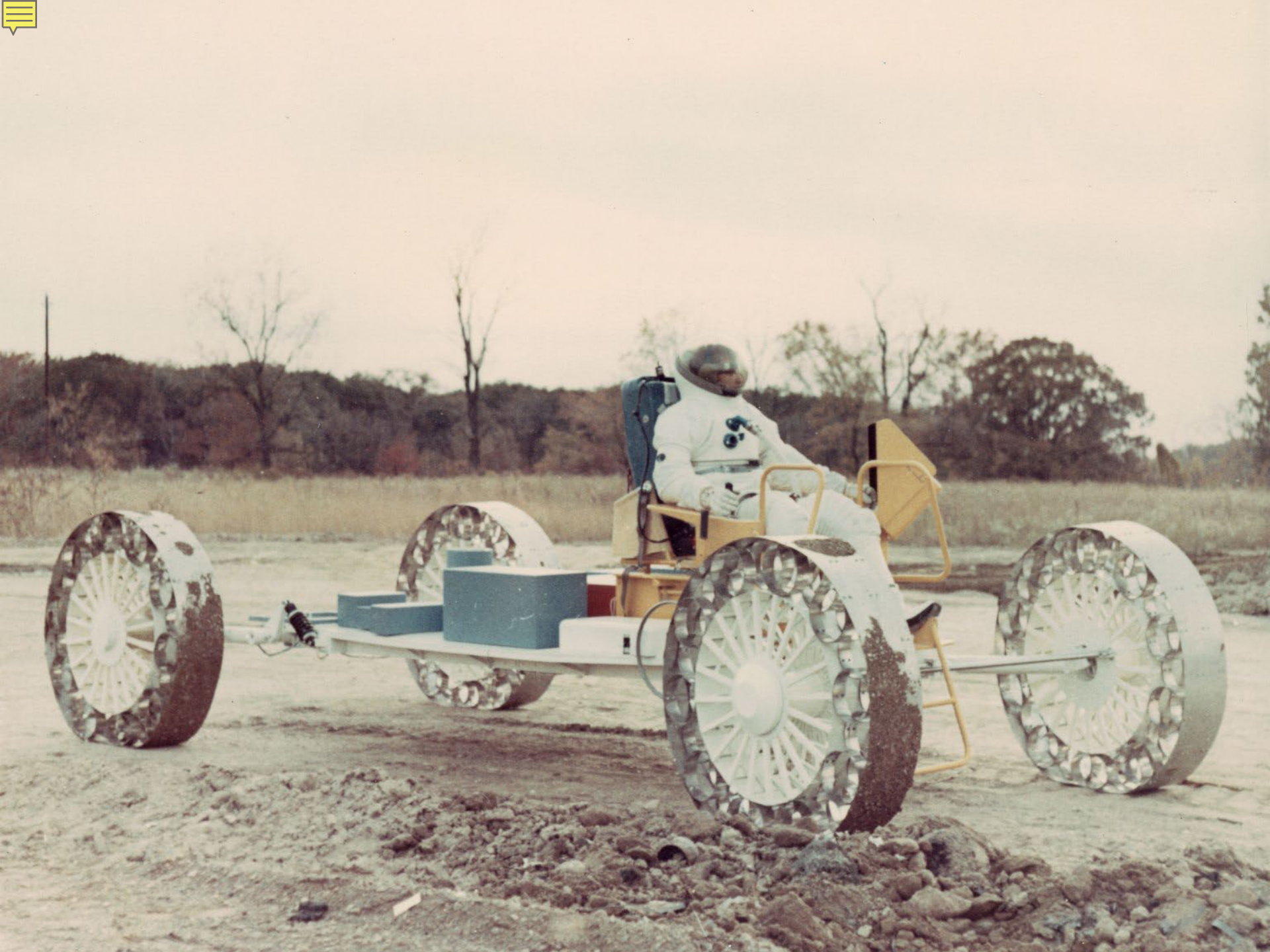
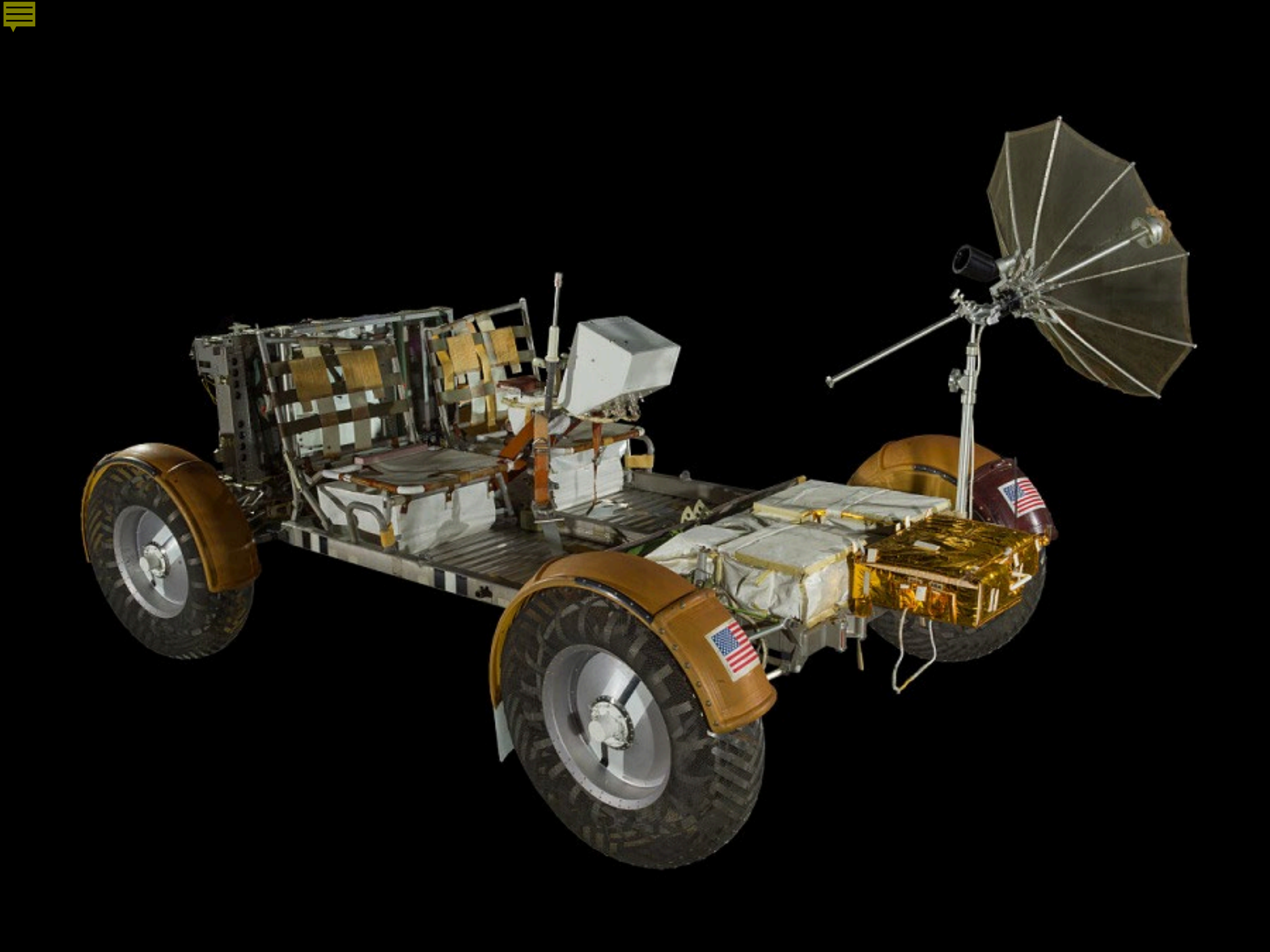



LUNAR ROVING VEHICLE
MANNED MODE
TWO-MAN OPERATION



Congratulations on winning the contract.

You have 17 months to deliver LRV-1 for Apollo 15.

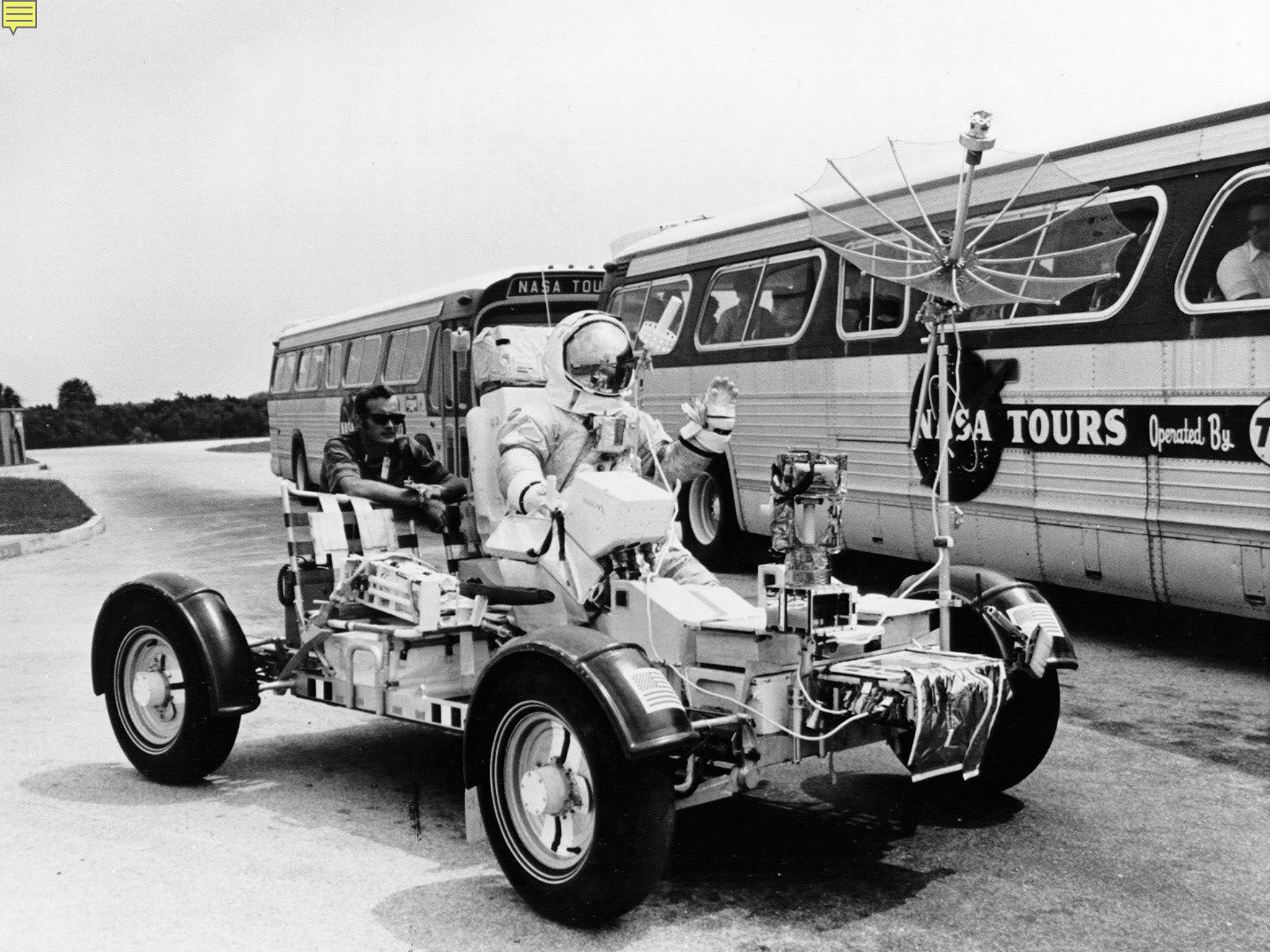
You bid $19M cost-plus.

Good luck.


A FEW
MOMENTS LATER

You are behind schedule and over budget.

¯_(ツ)_/¯


NASA TOU
NASA TOURS Operated By

Act III

Act III

A spacecraft on wheels

Requirements

Configuration: four wheels, batteries, electric motor

Weight: max 400 lbm (including stowage)

Cargo: 100 lbm experiments + two astronauts (370 lbm each)

Range: four 30 km traverses

Life: 78 hours

Stowage: stowed in one LM bay

Speed: max 16 km/hr fully loaded

Deployment: by one astronaut

Requirements

Obstacles: 30 cm high, crevasse 70 cm wide at zero velocity

Slope: climb and descend 25 deg fully loaded

Failures: no single-point failure aborts the mission; no second failure endangers crew

Reverse: yes

Clearance: 35 cm on flat surface

Static stability: 45 deg pitch and roll fully loaded

Turn radius: one vehicle length

Mobility

Electrical power

Thermal control

Control and display

Navigation

Crew station

Payload

Support equipment

Mobility

Electrical power

Thermal control

Control and display

Navigation

Crew station

Payload

Support equipment

Mobility

Electrical power

Thermal control

Control and display

Navigation

Crew station

Payload

Support equipment

Mobility

Electrical power

Thermal control

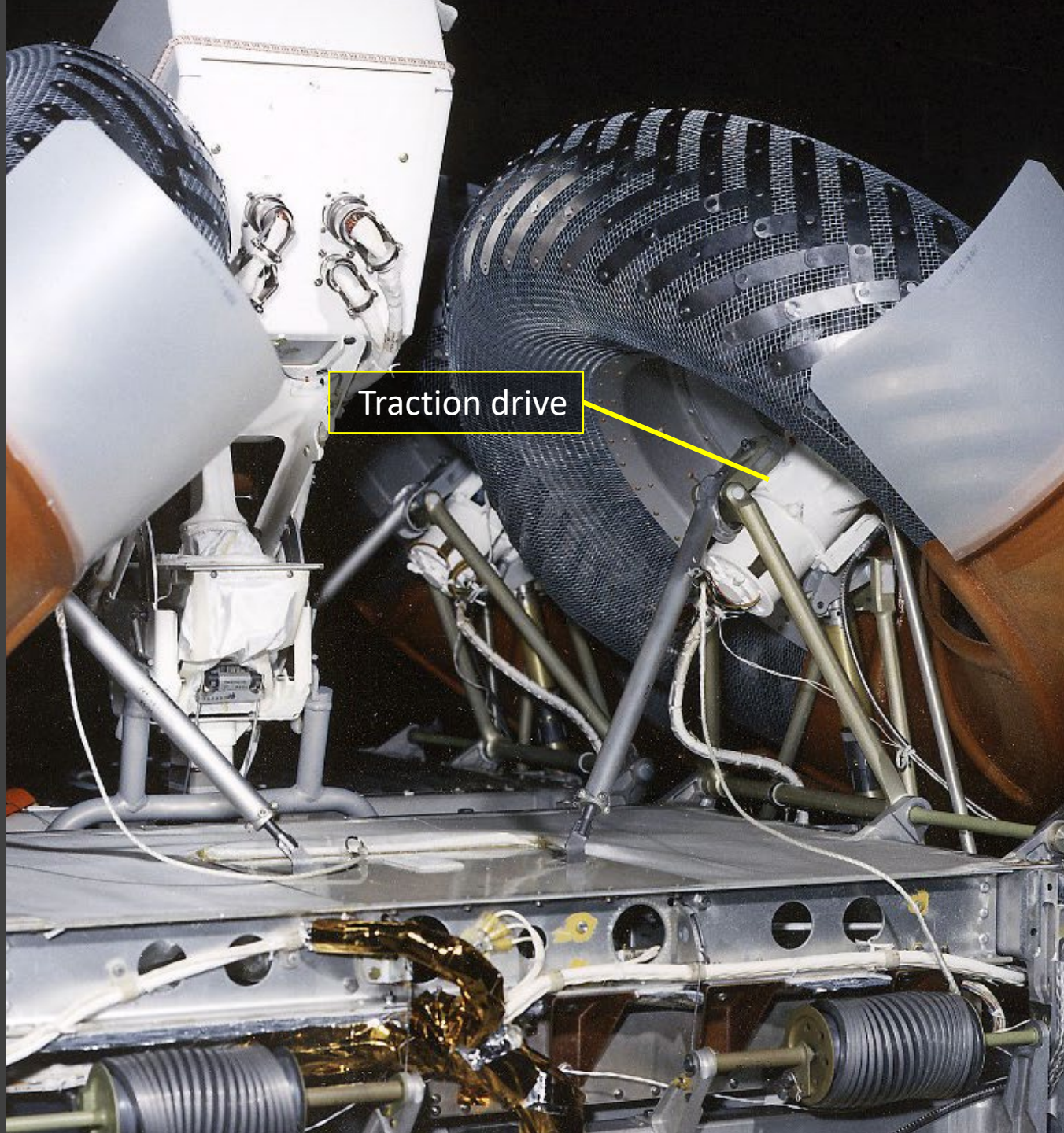
Control and display

Navigation

Crew station

Payload

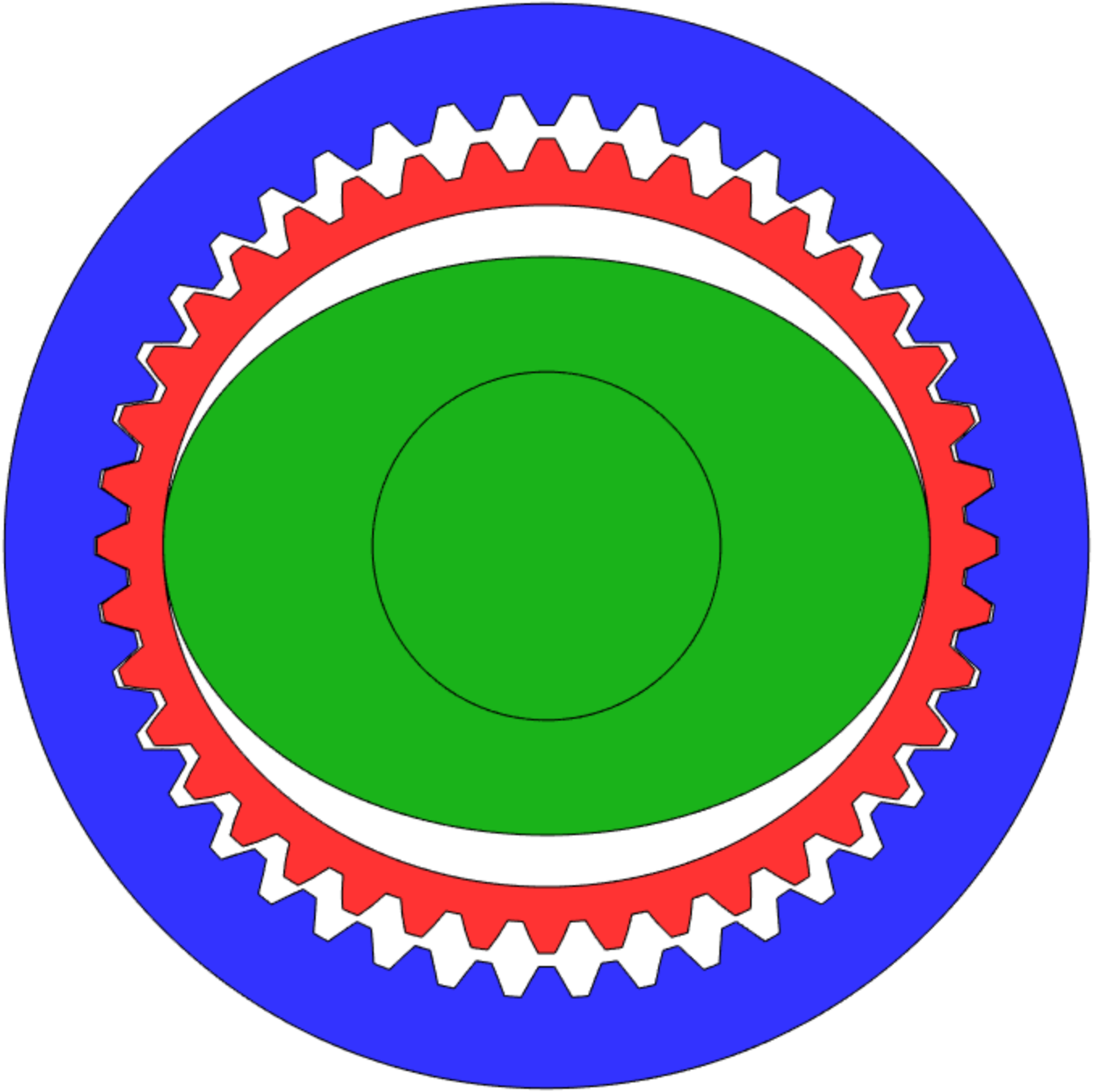
Support equipment




Harmonic Drive
"Used on the Lunar Rover"
Device functioned as a transmission.
One was installed in the hub of each wheel.
They were welded to an electric motors turning
at 10,000 rpms. The gear ratio is 80 to 1 it allowed
the vehicle to travel at a top speed of 15 MPH.
Cost of each device to NASA was approximately


S/N


73446



Mobility

Electrical power

Thermal control

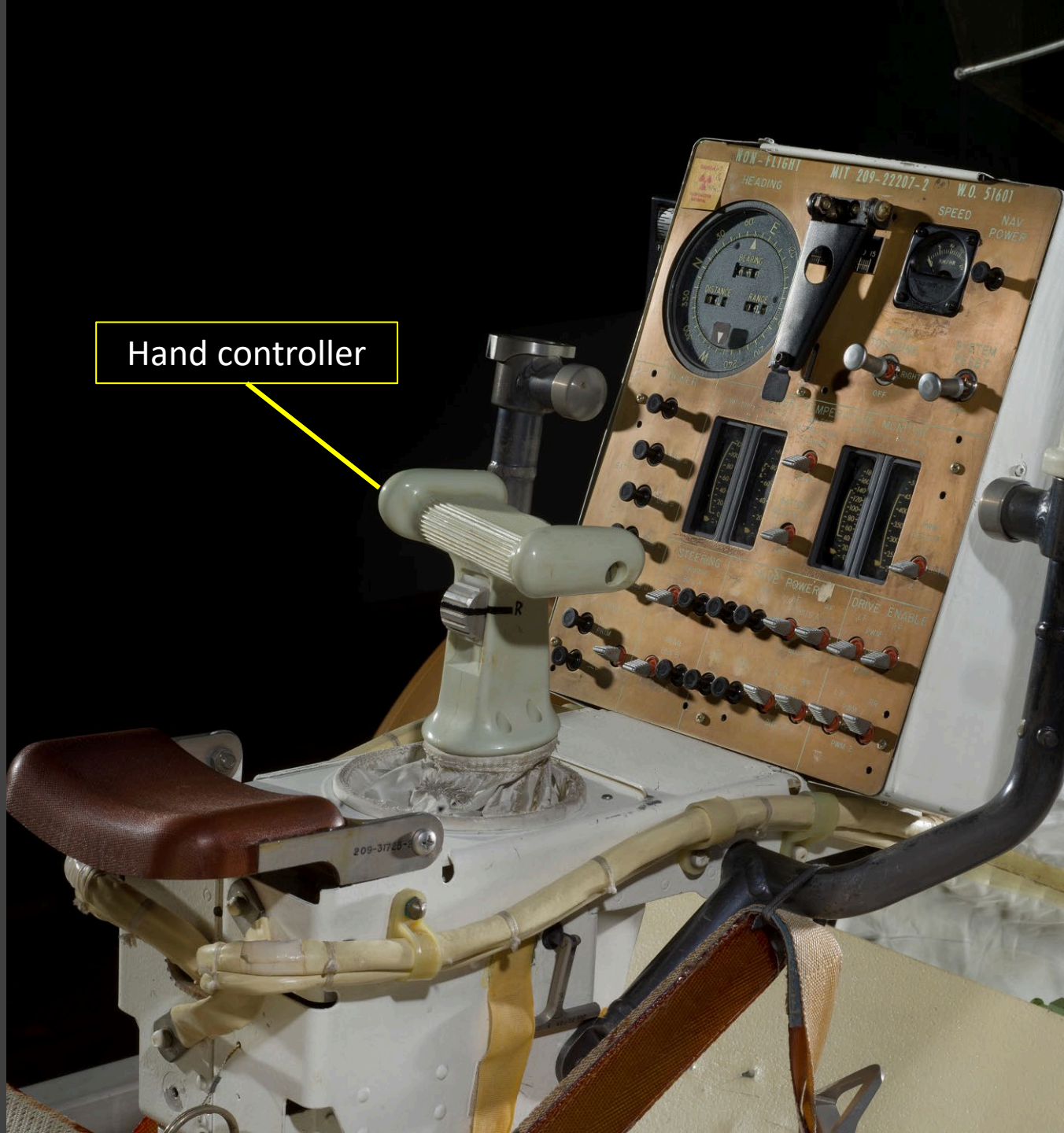
Control and display

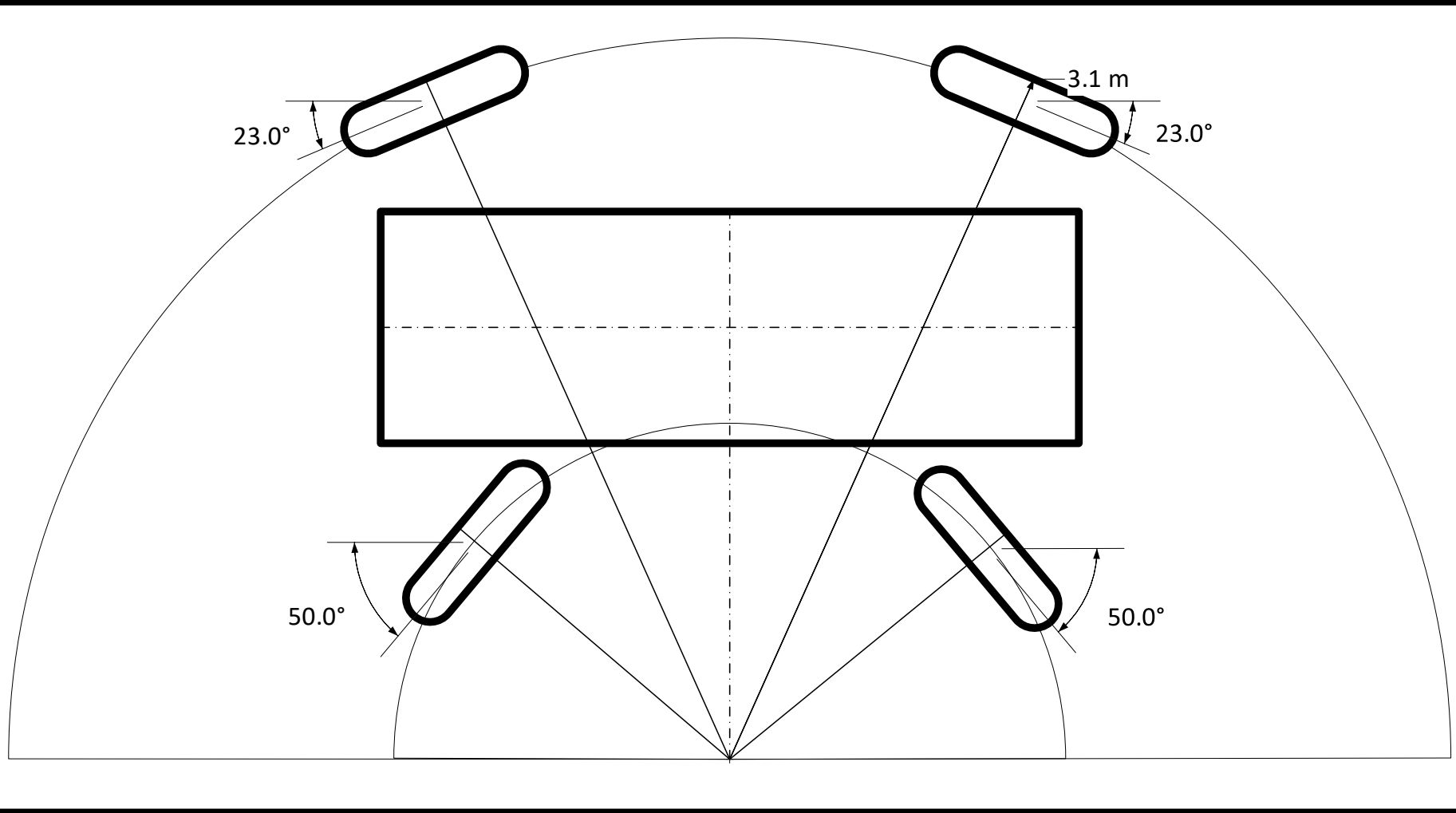
Navigation

Crew station

Payload

Support equipment




3.1 m
23.0°
23.0°
50.0°
50.0°

Mobility

Electrical power

Thermal control

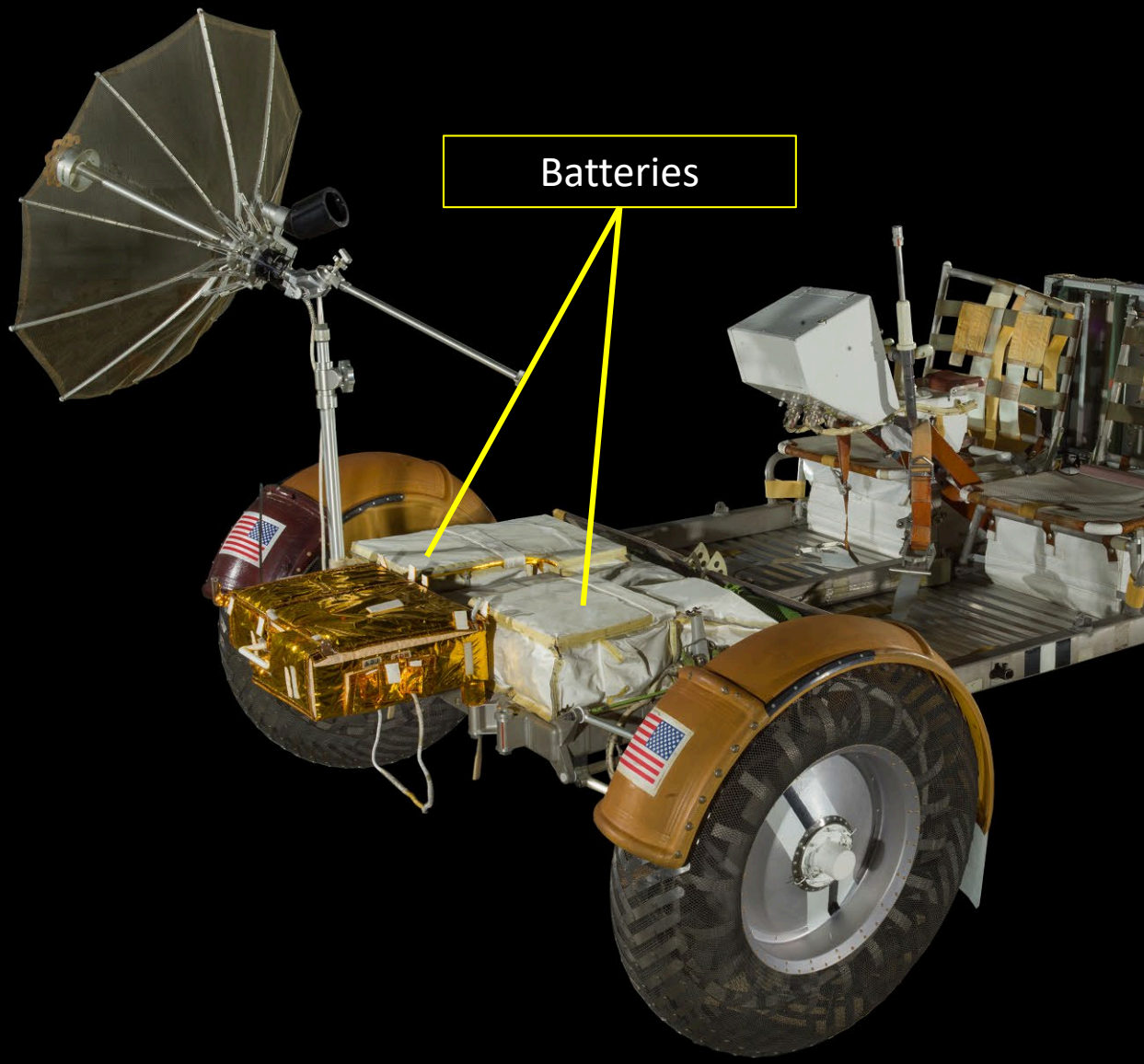
Control and display

Navigation

Crew station

Payload

Support equipment



Mobility

Electrical power

Thermal control

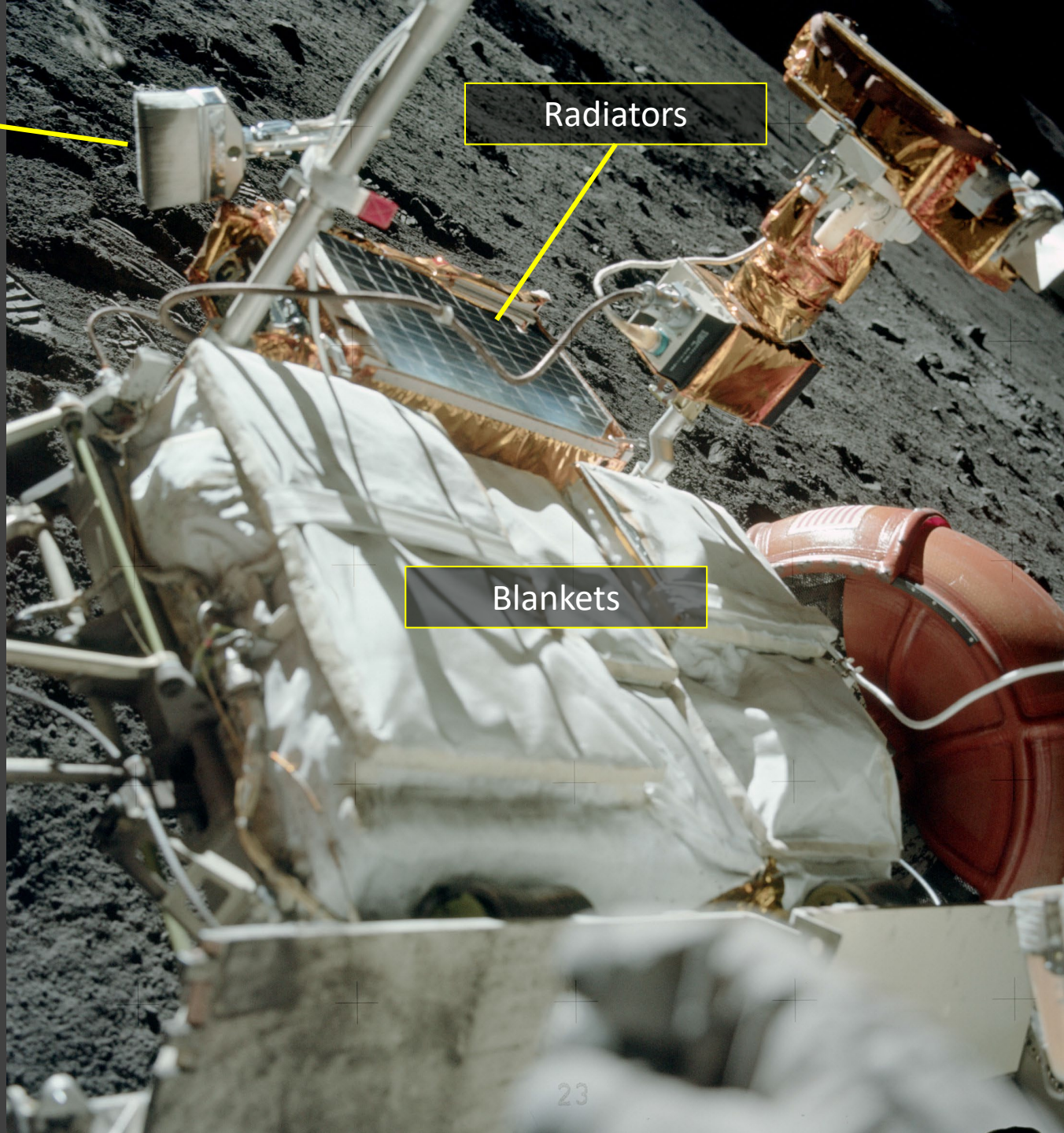
Control and display

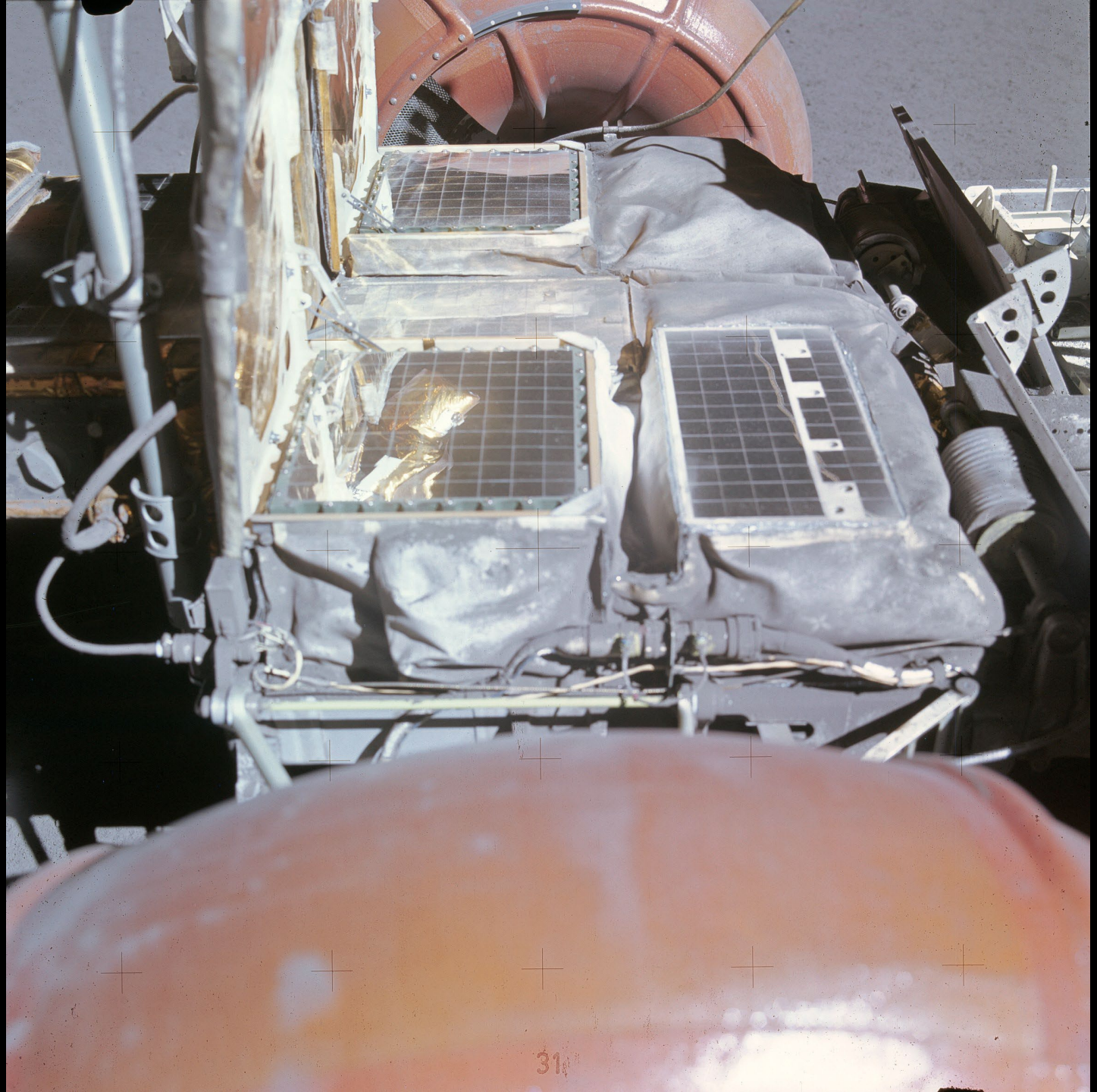
Navigation

Crew station

Payload

Support equipment





Caution and warning flag

Sun shadow device

Mobility

Electrical power

Thermal control

Control and display

Navigation

Crew station

Payload

Support equipment

Mobility

Electrical power

Thermal control

Control and display

Navigation

Crew station

Payload

Support equipment

Mobility

Electrical power

Thermal control

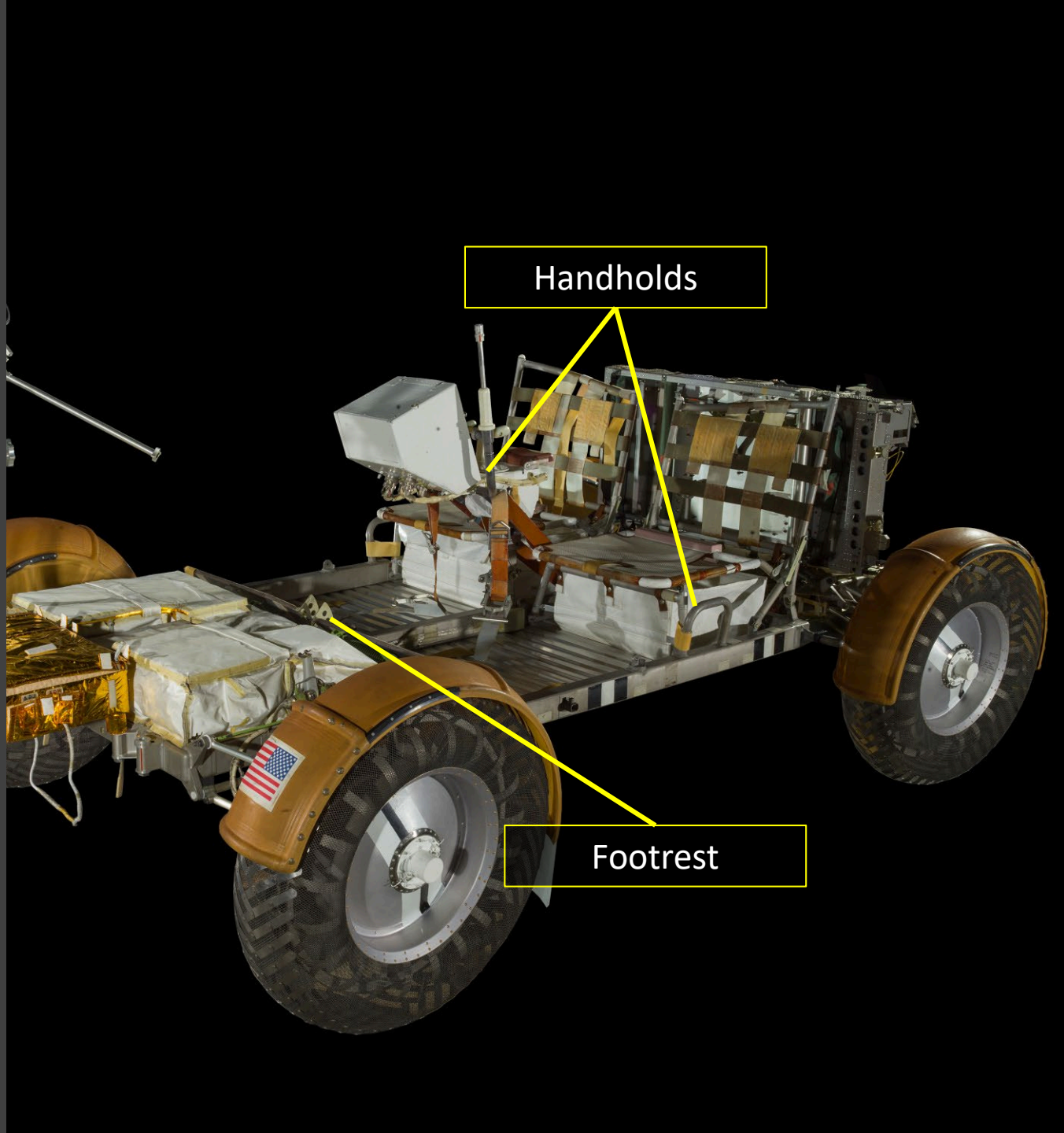
Control and display

Navigation

Crew station

Payload

Support equipment



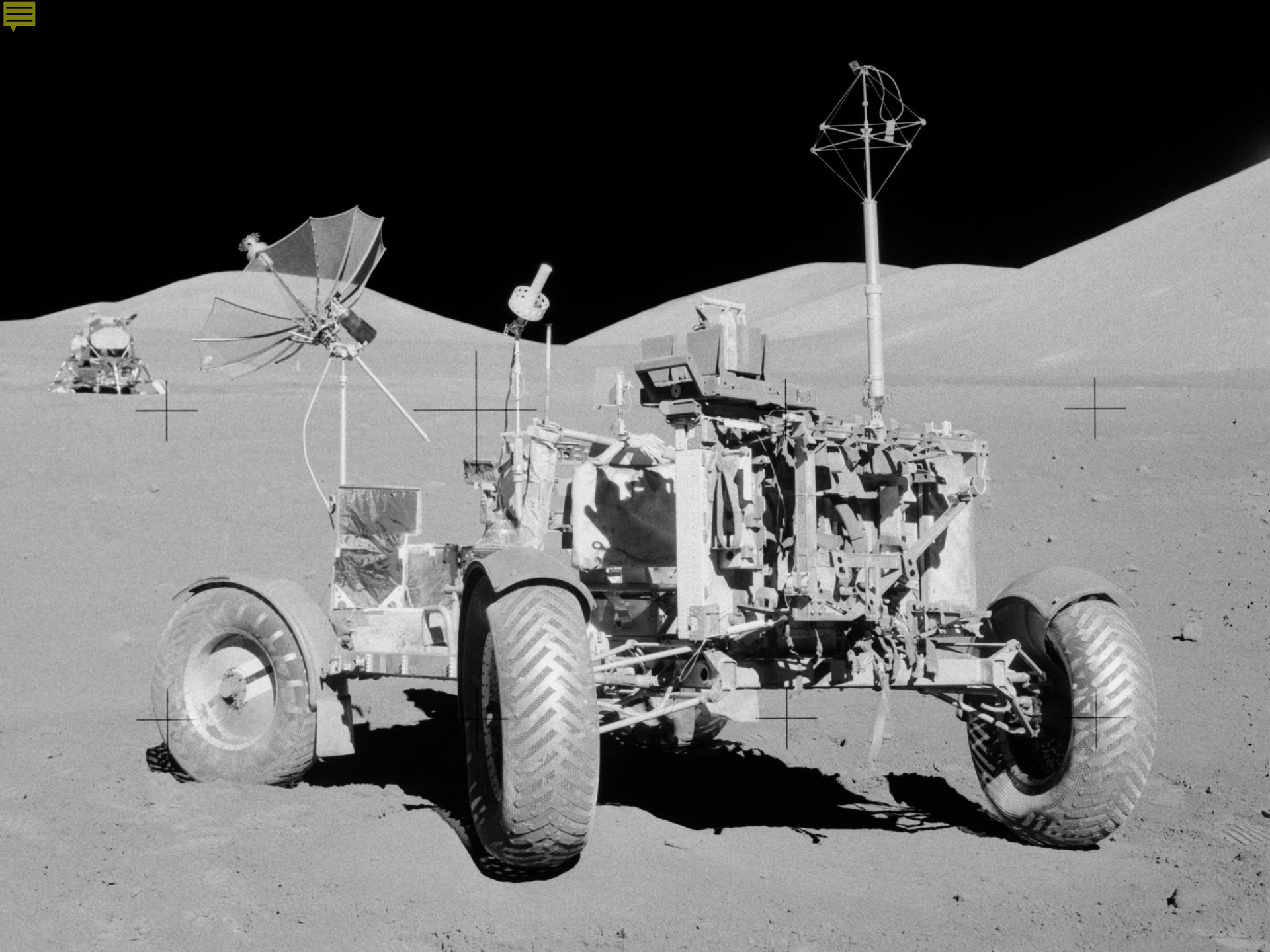

NASA

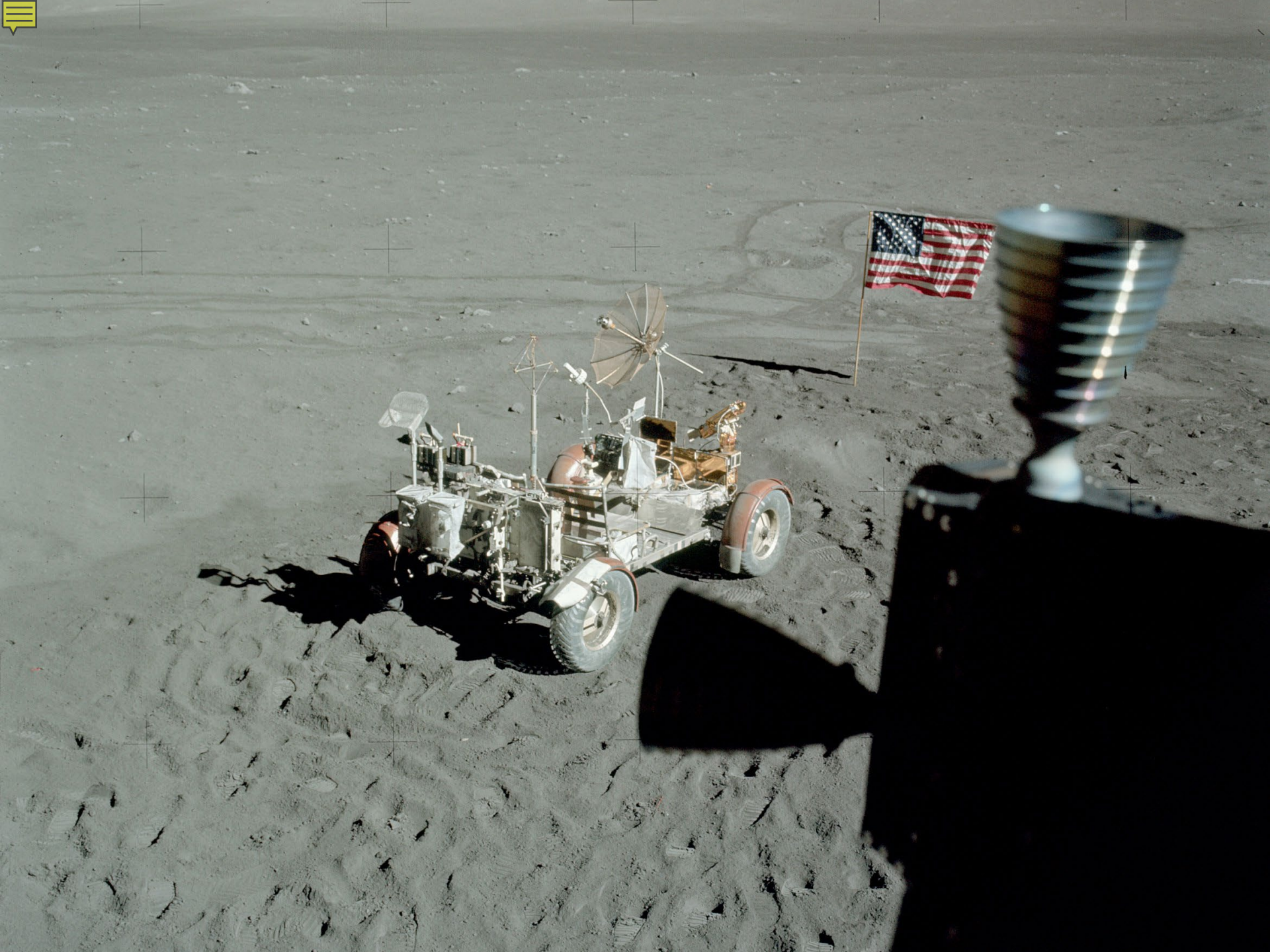
Crew station KC-135

Intermission

Intermission

Rover repair





Mobility

Electrical power

Thermal control

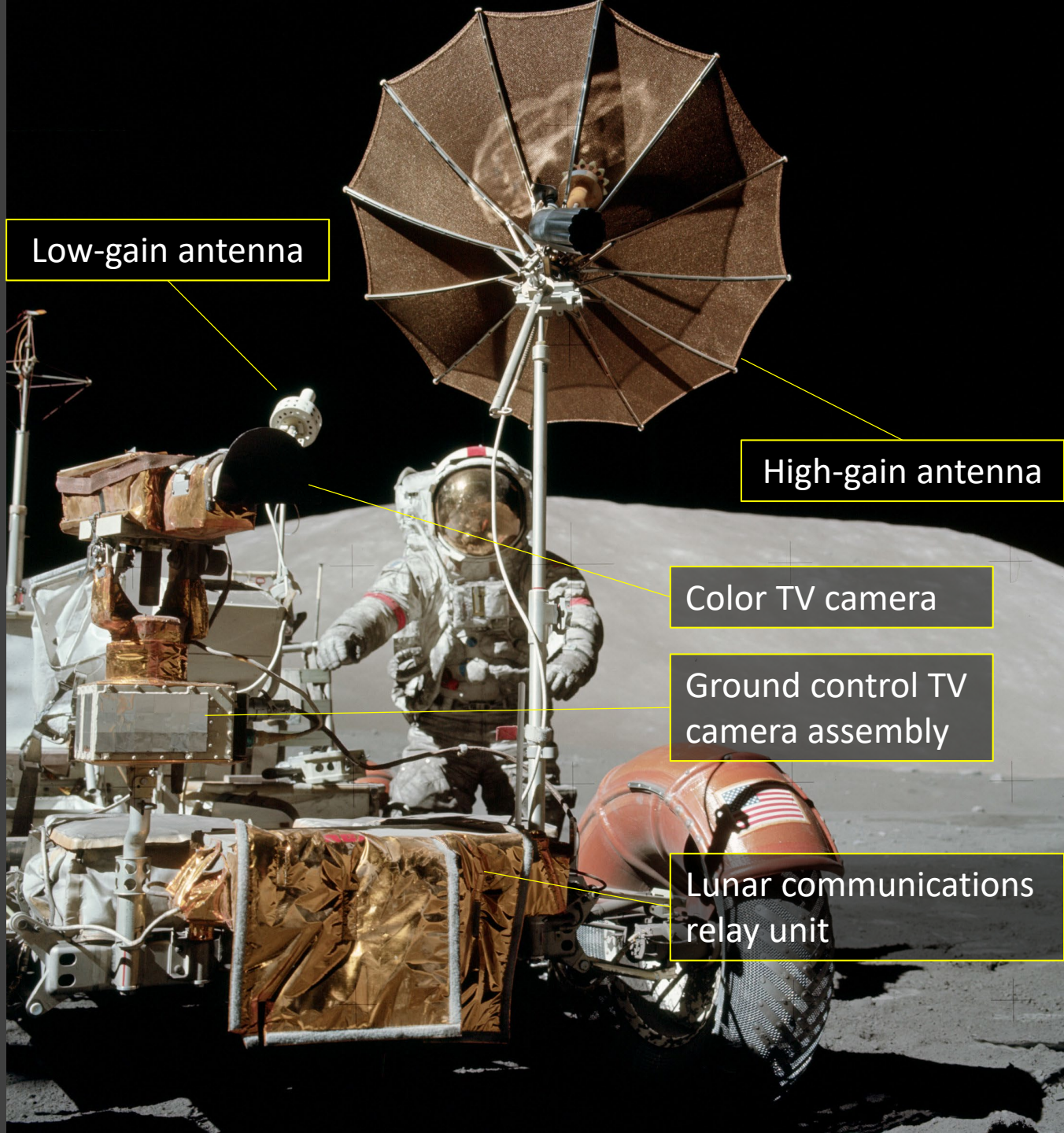
Control and display

Navigation

Crew station

Payload

Support equipment



Mobility

Electrical power

Thermal control

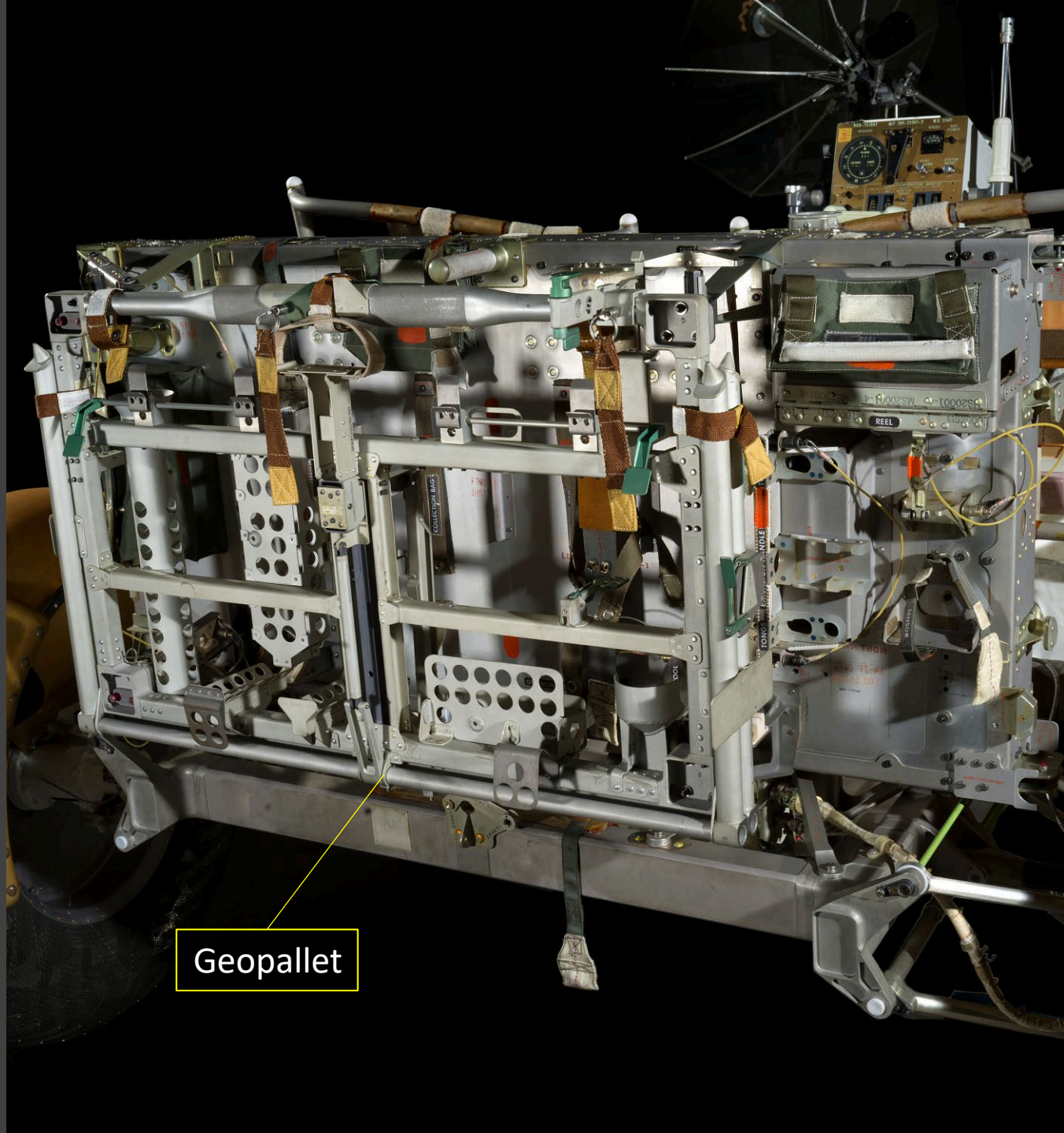
Control and display

Navigation

Crew station

Payload

Support equipment



Mobility

Electrical power

Thermal control

Control and display

Navigation

Crew station

Payload

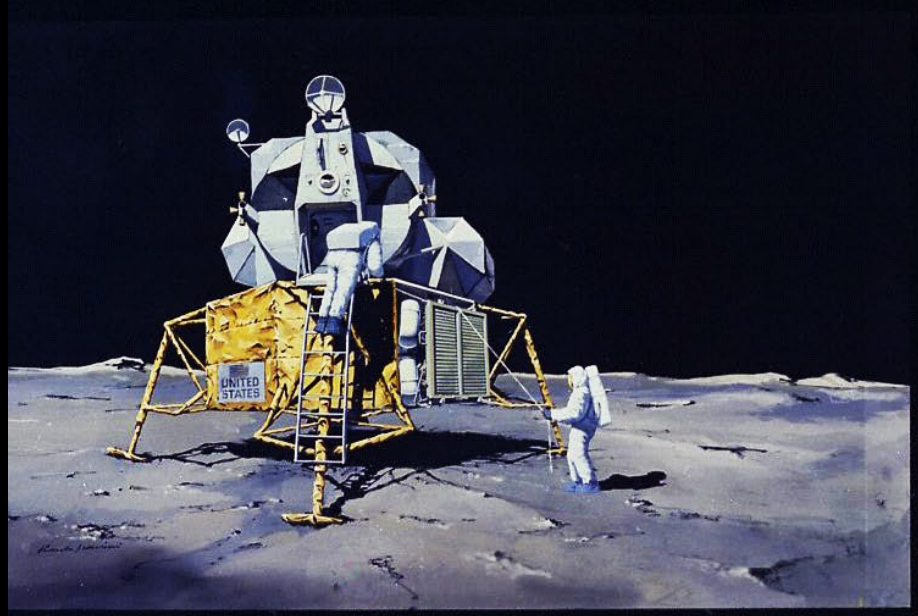
Support equipment

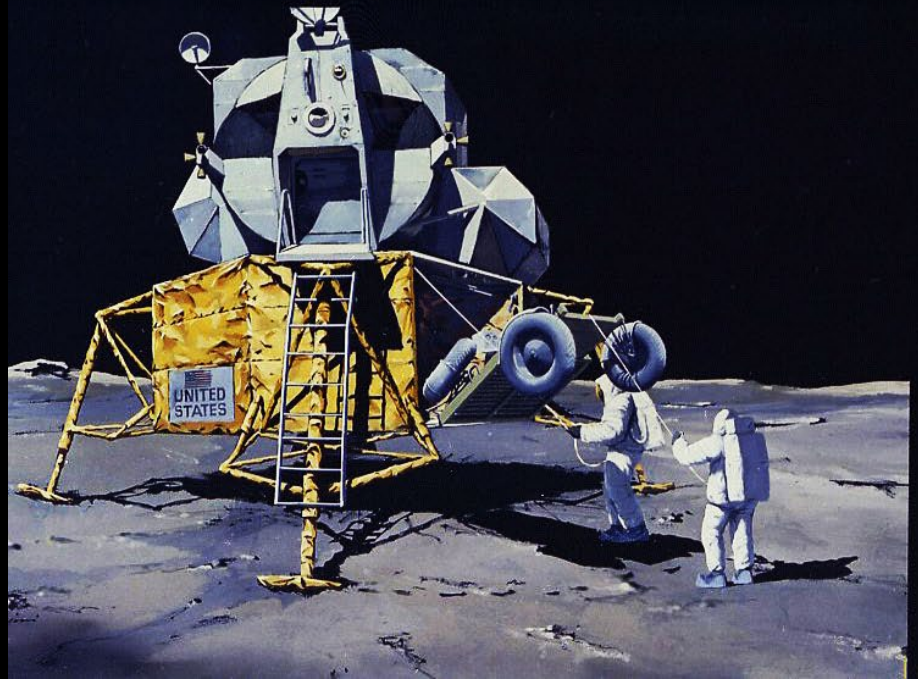
Act IV

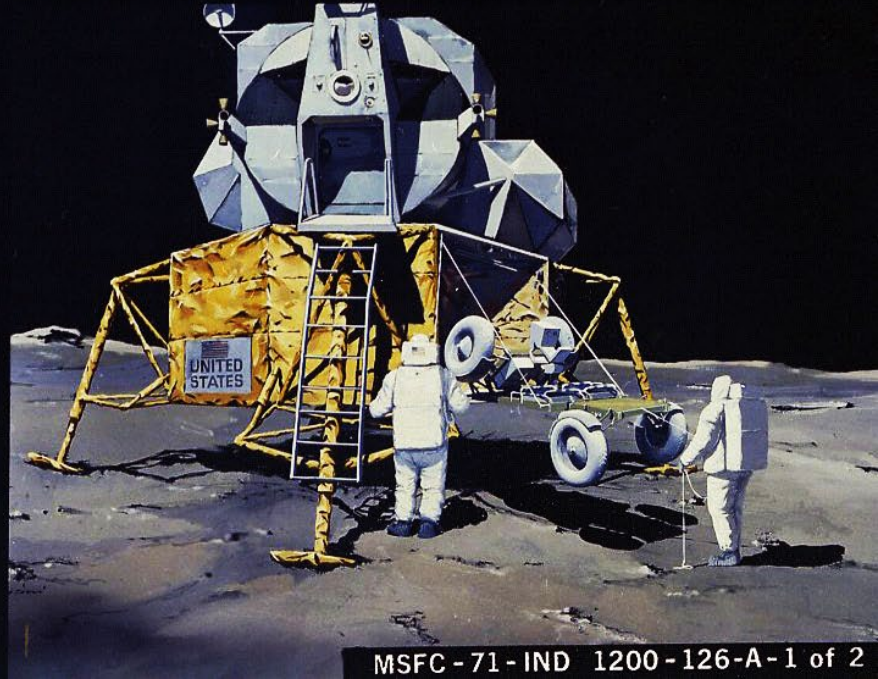
Act IV

Deployment

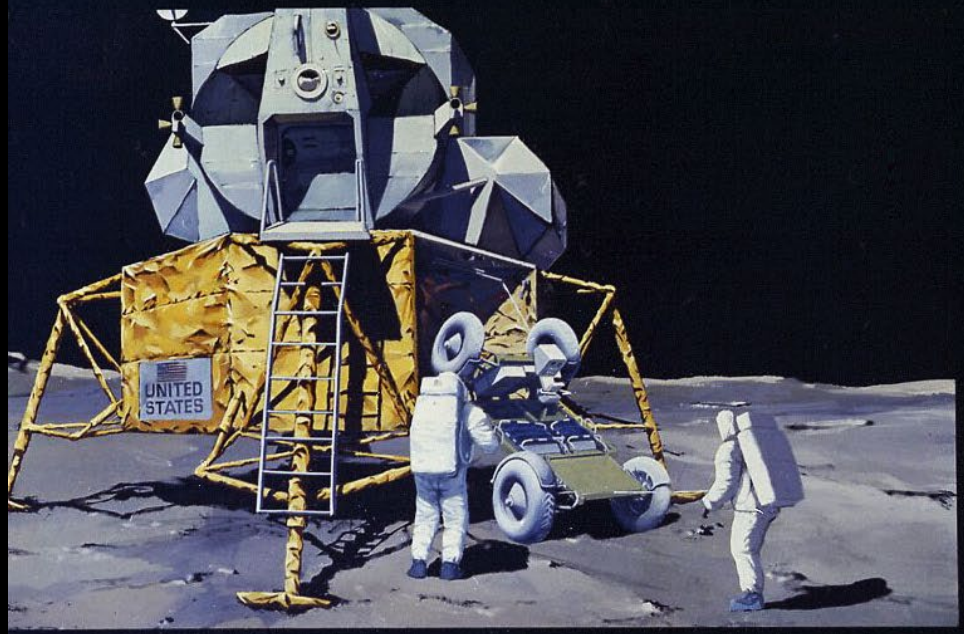
LUNAR ROVING VEHICLE Initial Deployment Sequence

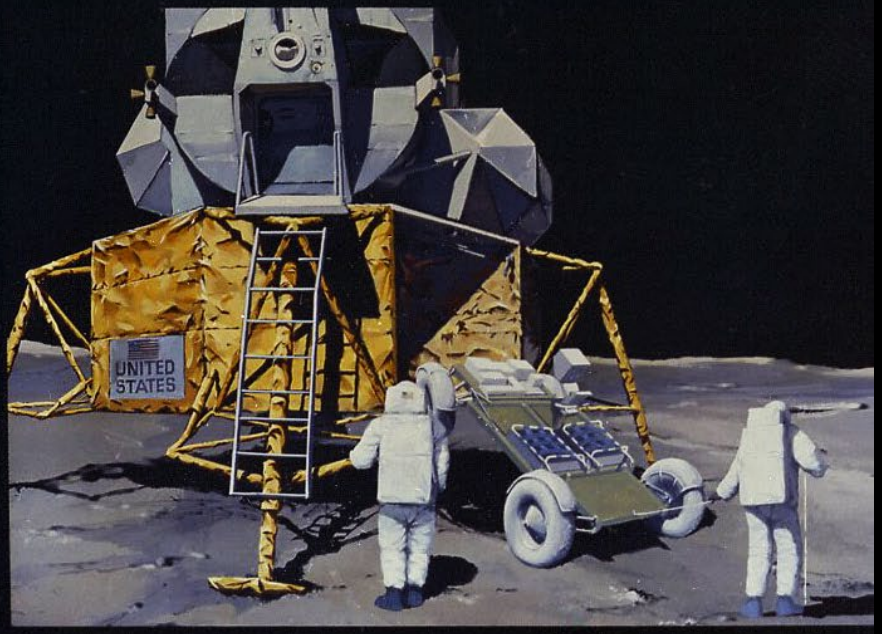


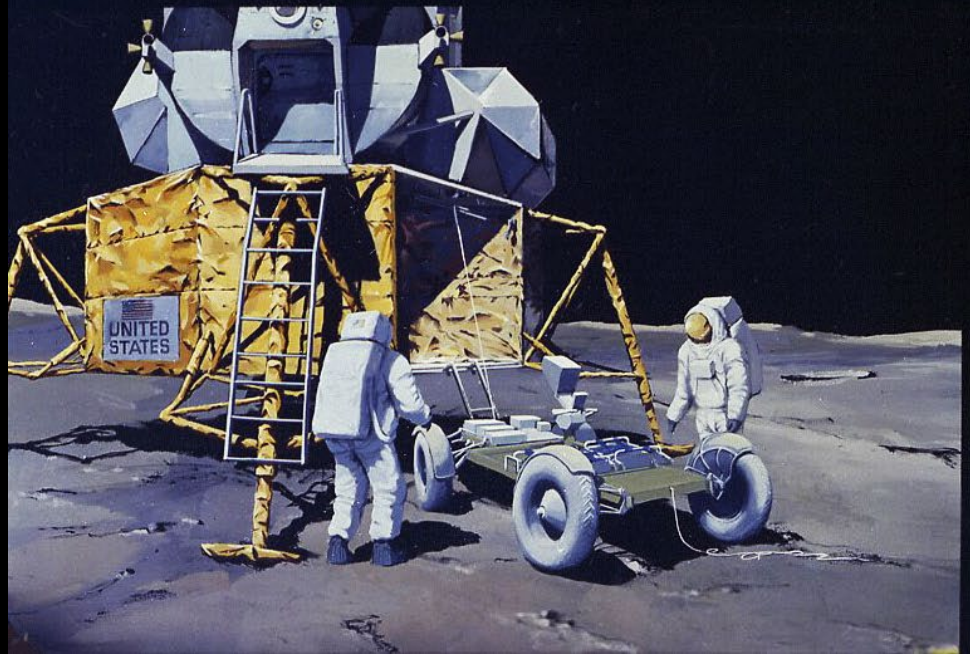


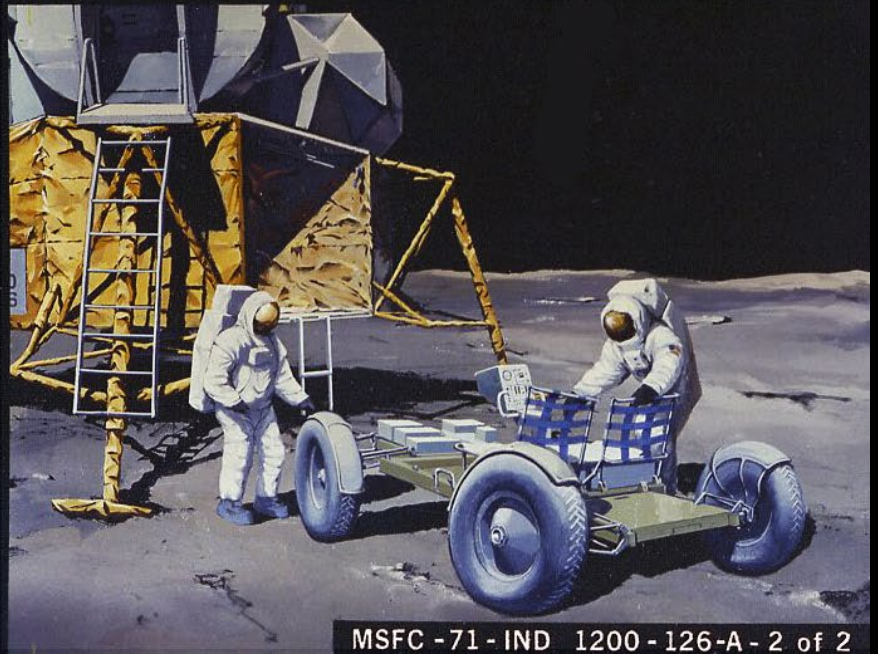


LUNAR ROVING VEHICLE Final Deployment Sequence

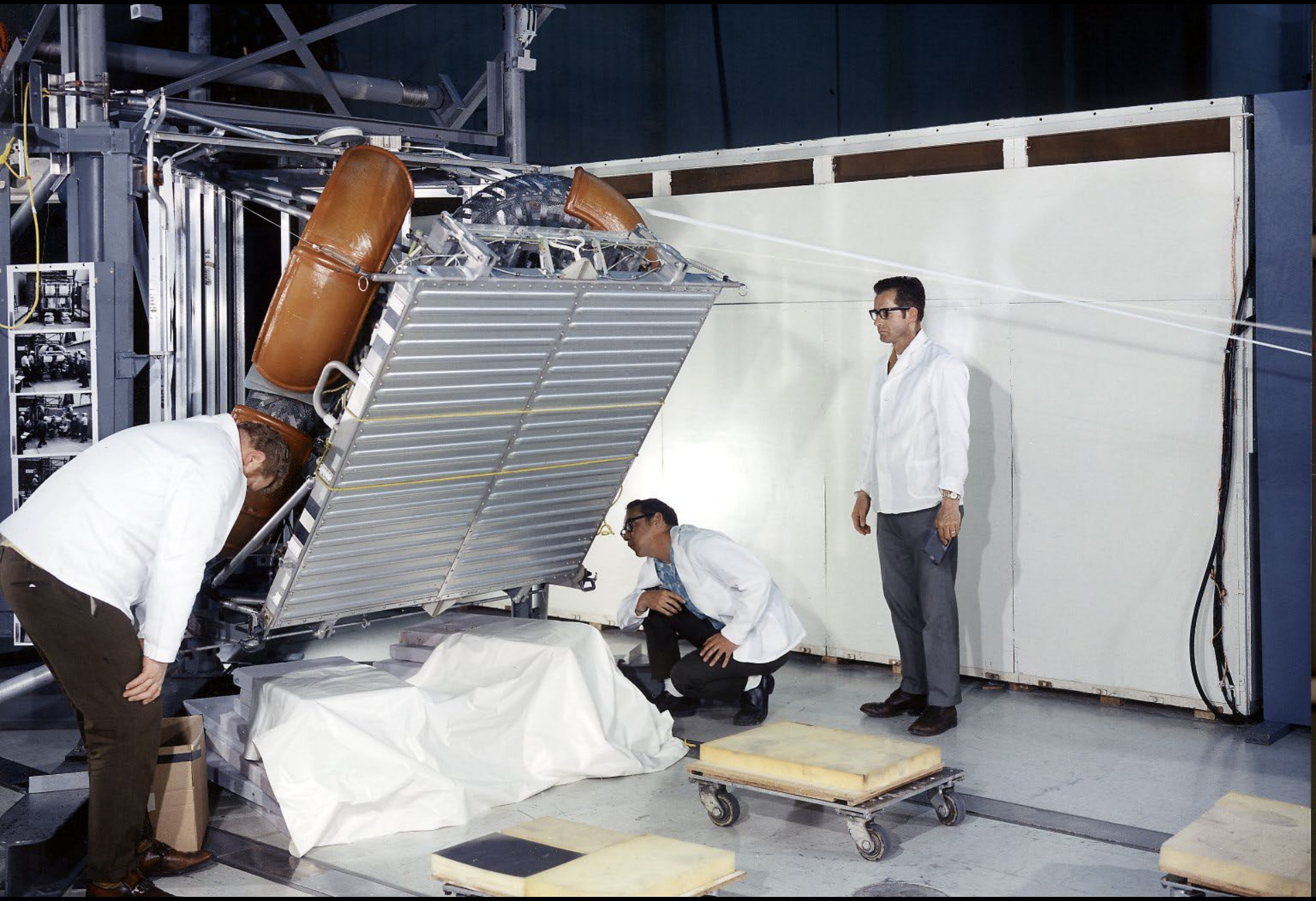


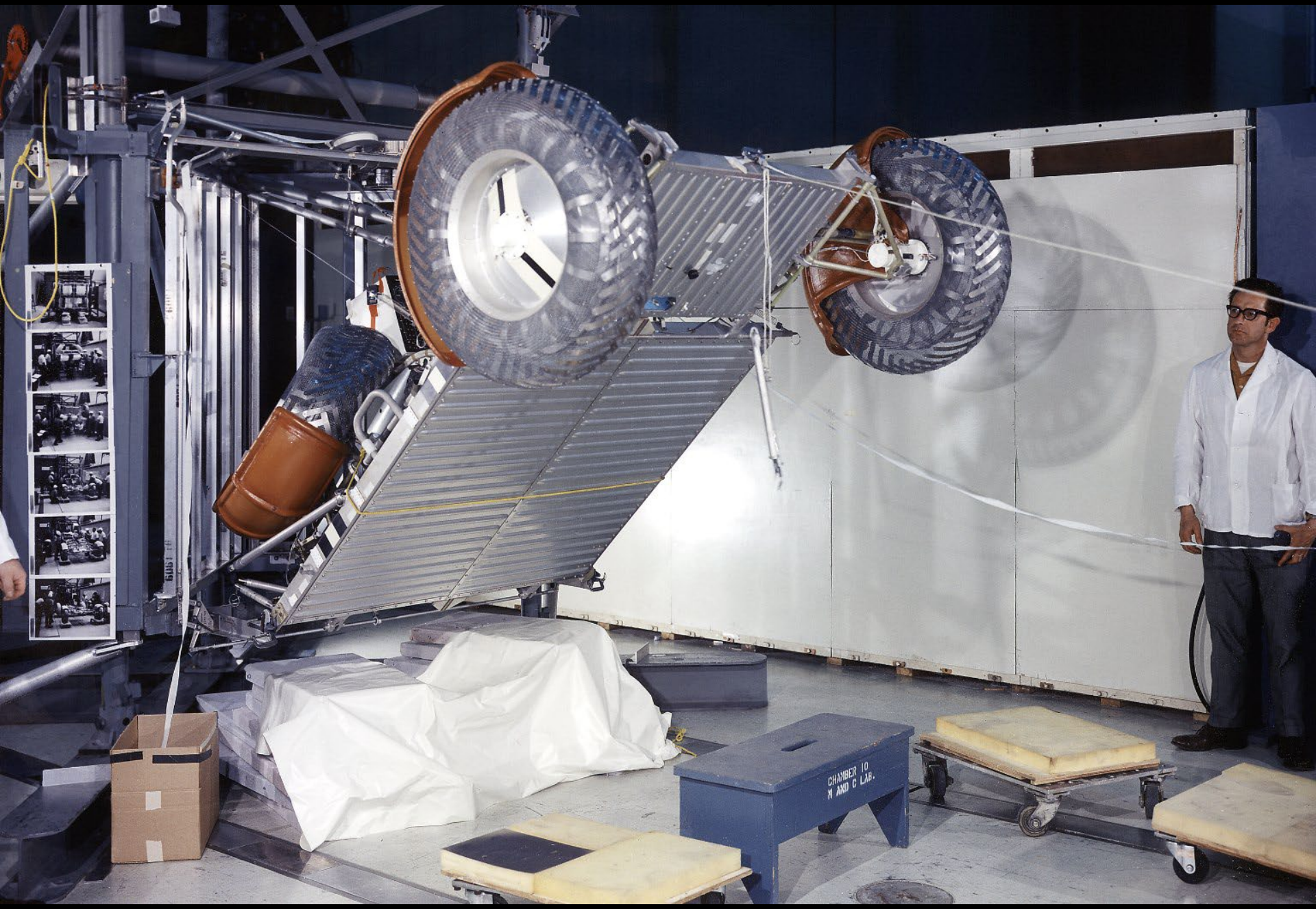


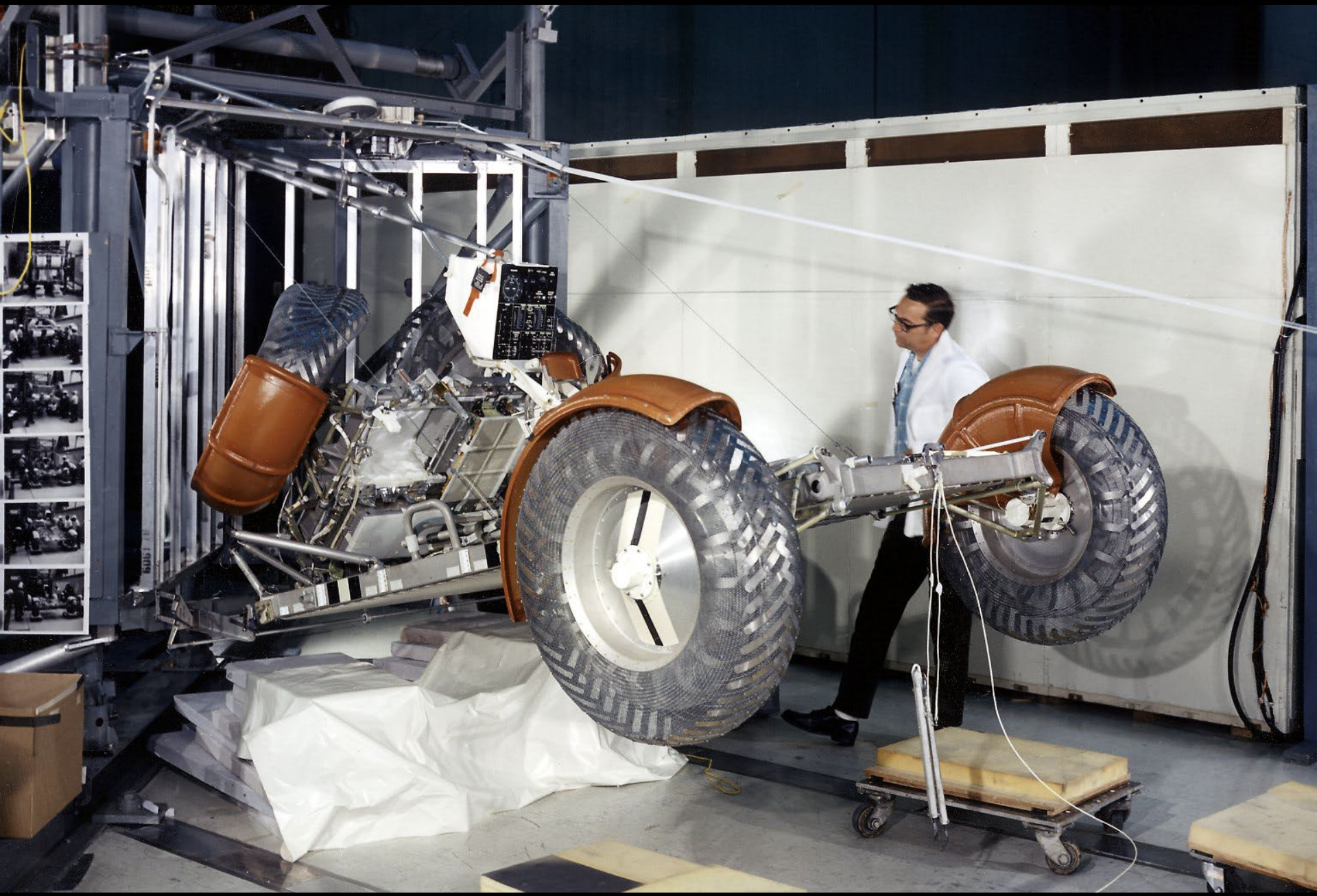


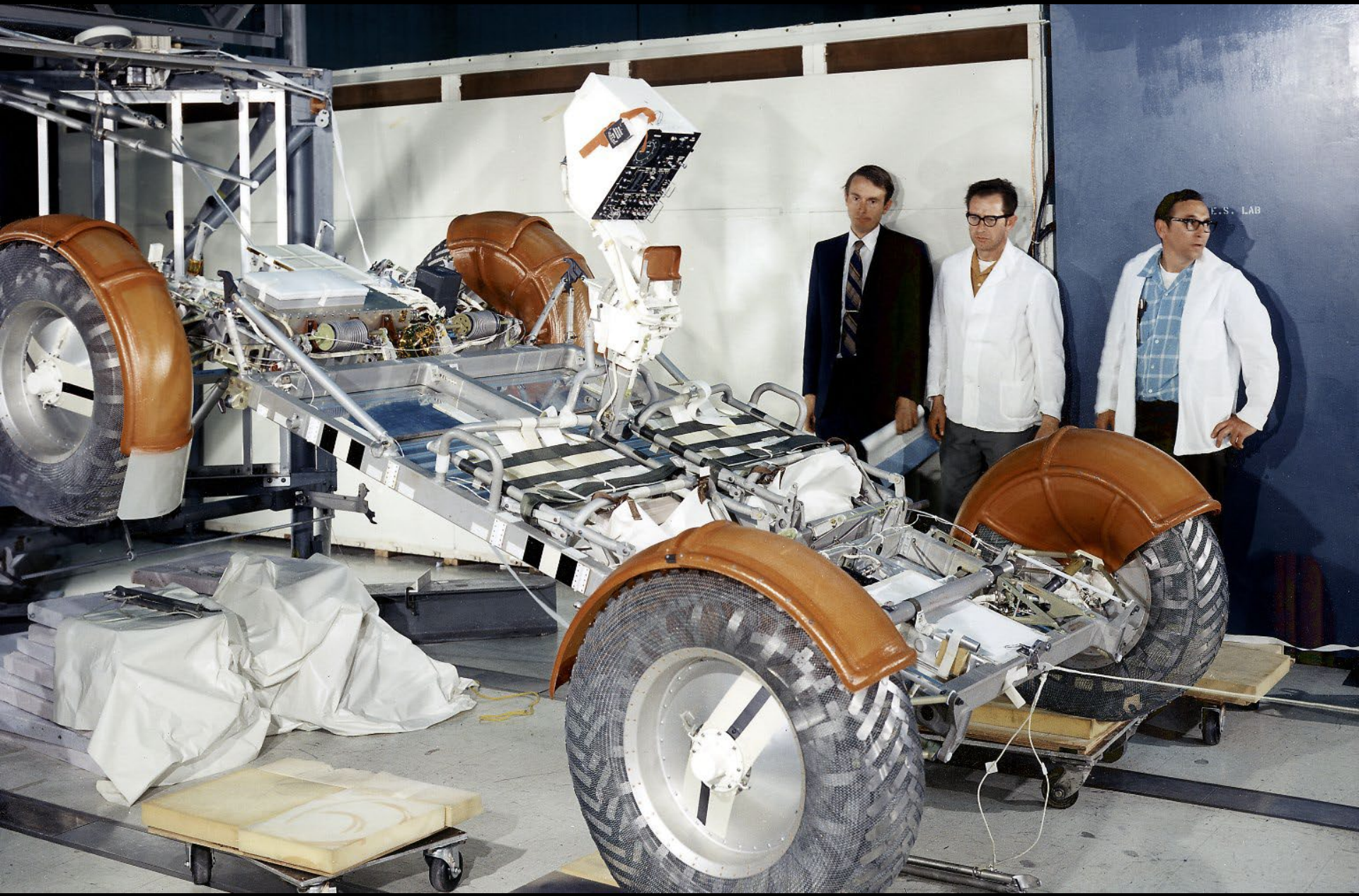


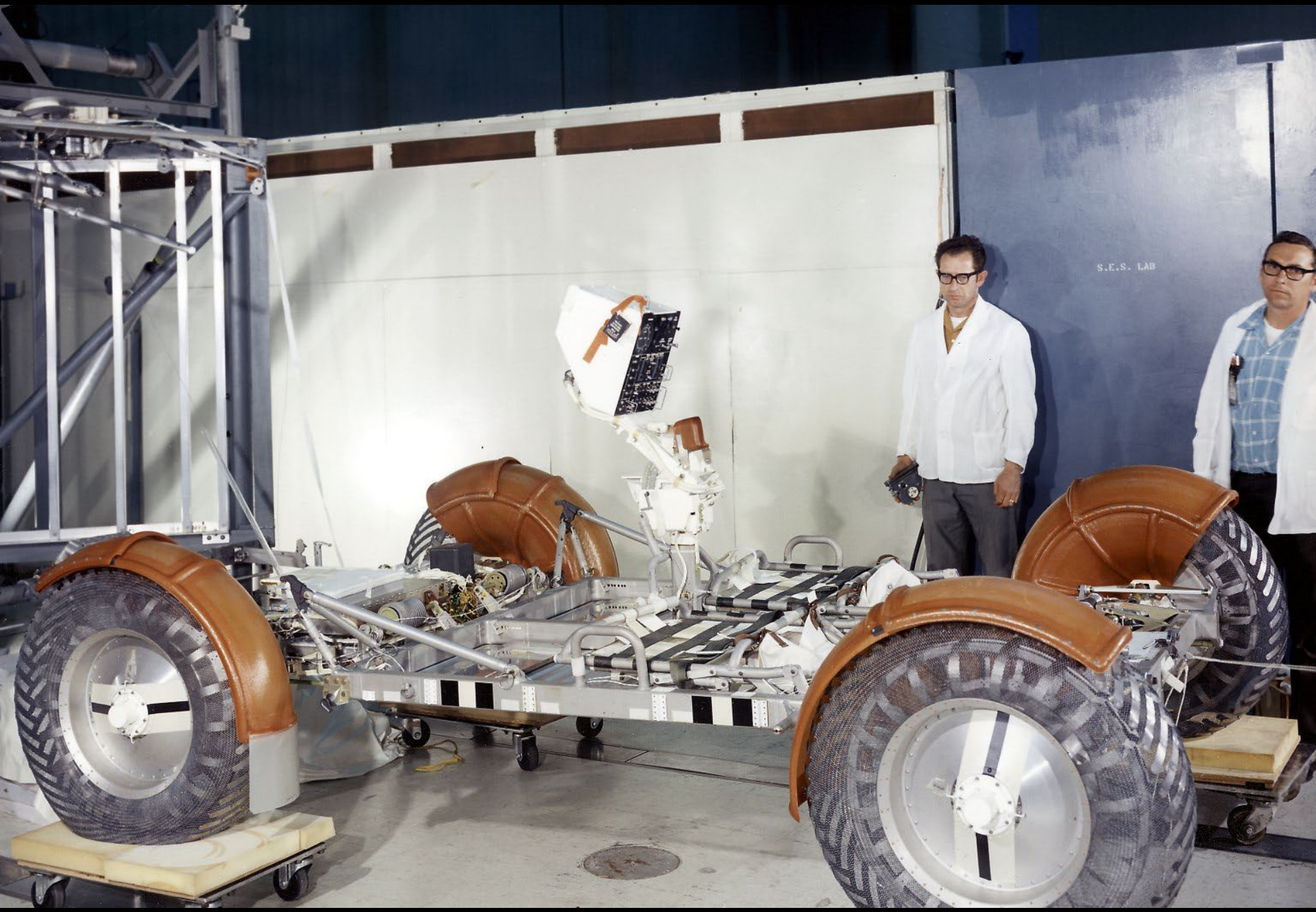
MSFC - 71 - IND 1200 - 126-A - 2 of 2

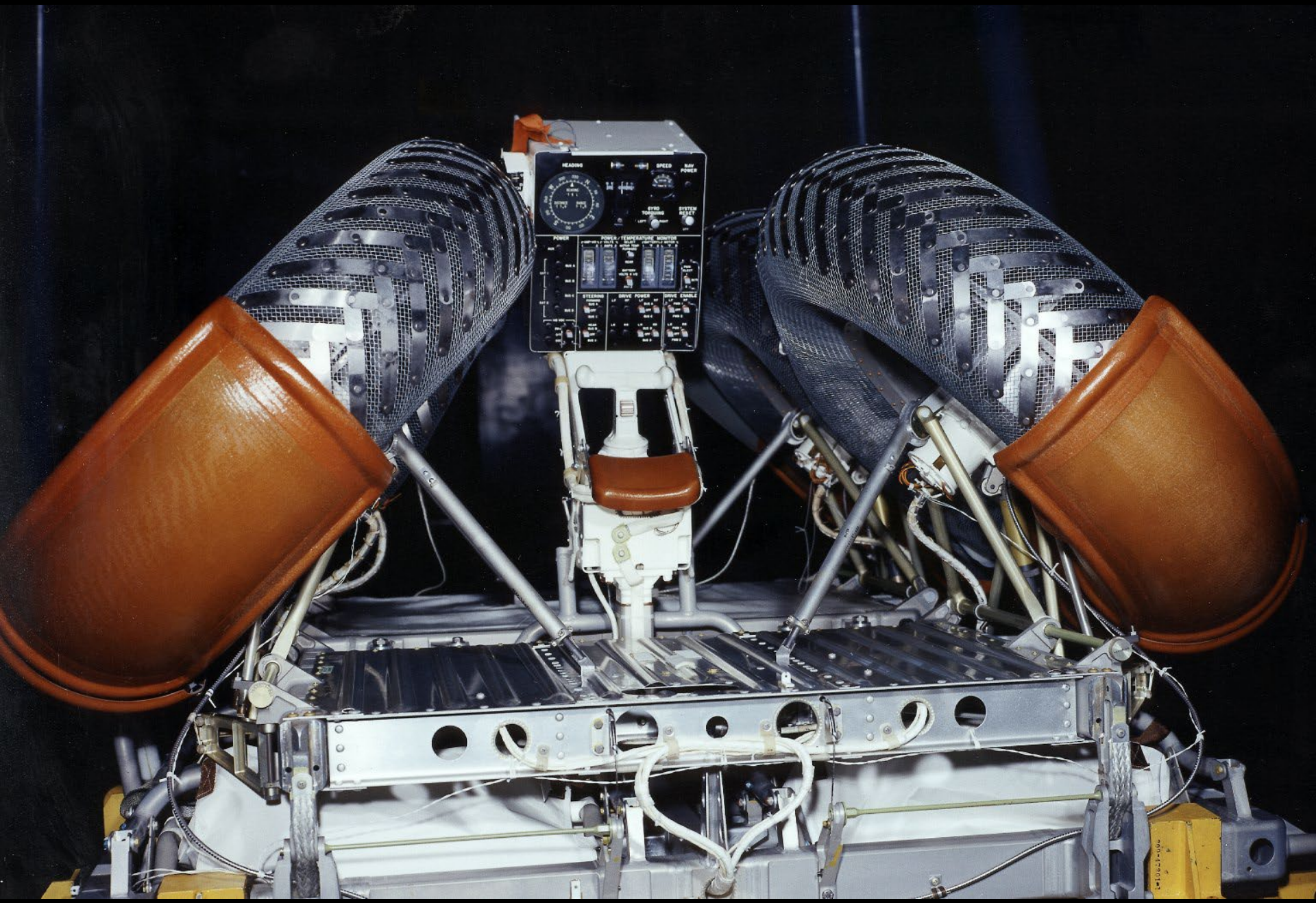


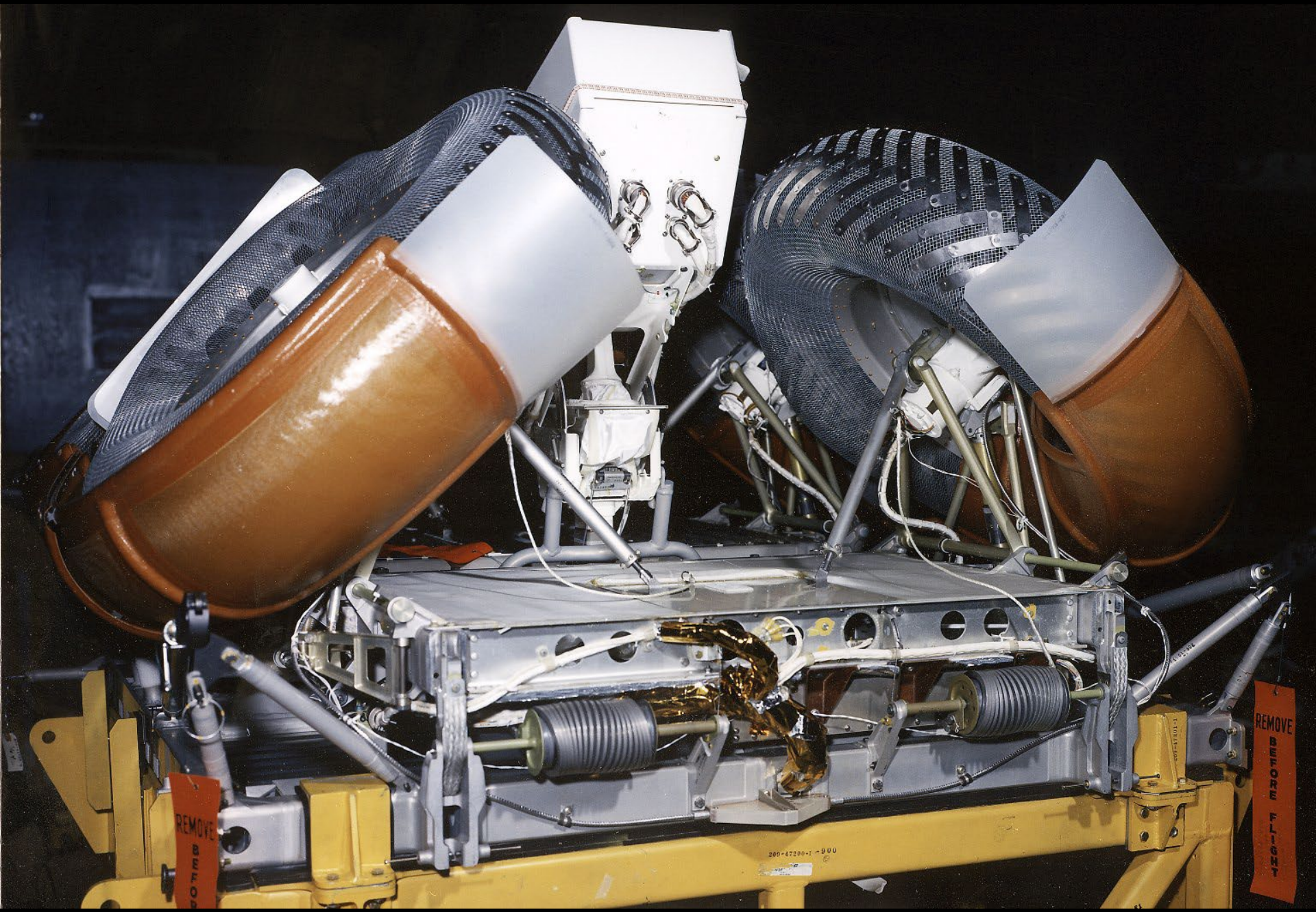

CHAMBER 10
M AND C LAB.



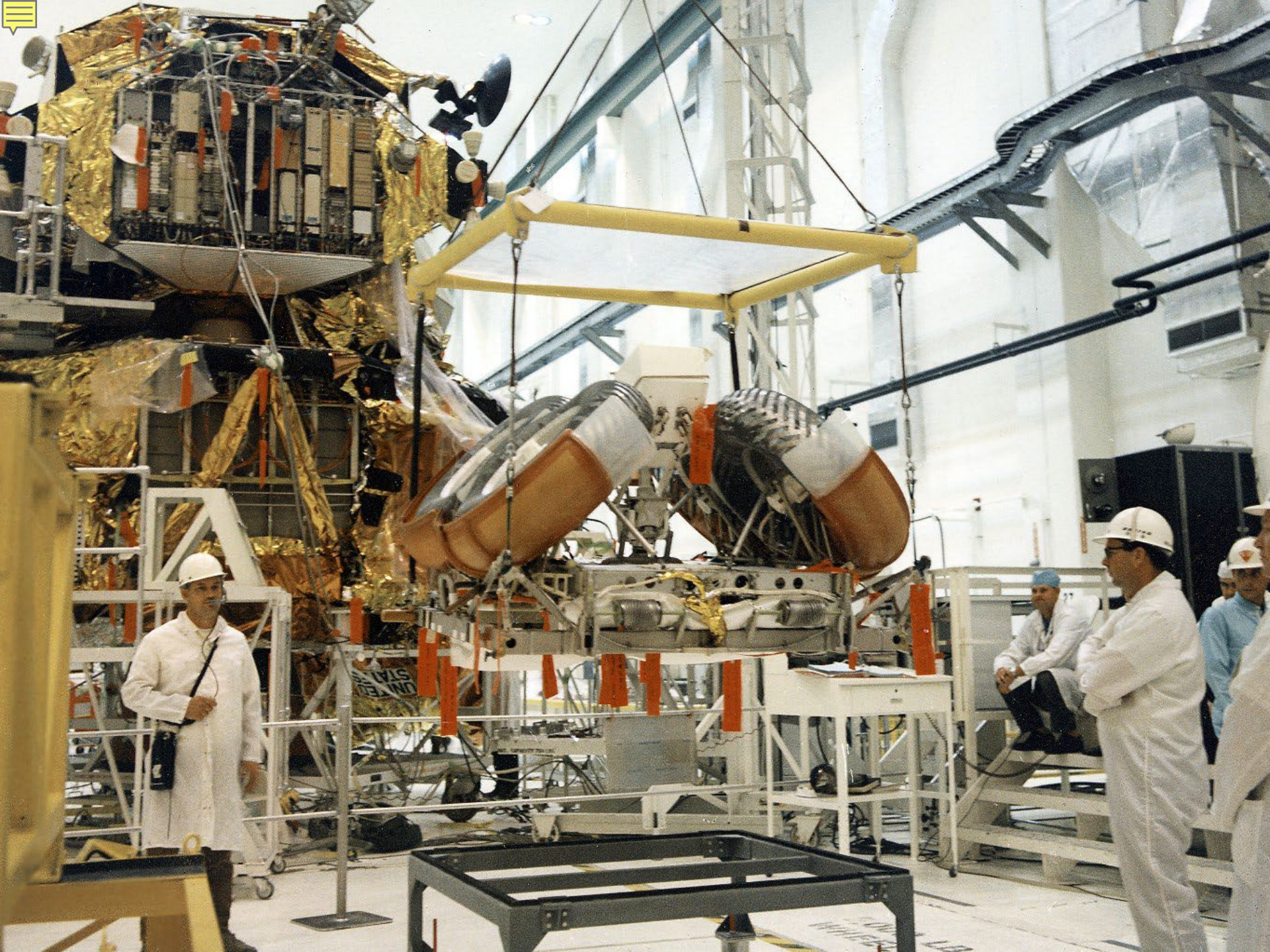

E.S. LAB

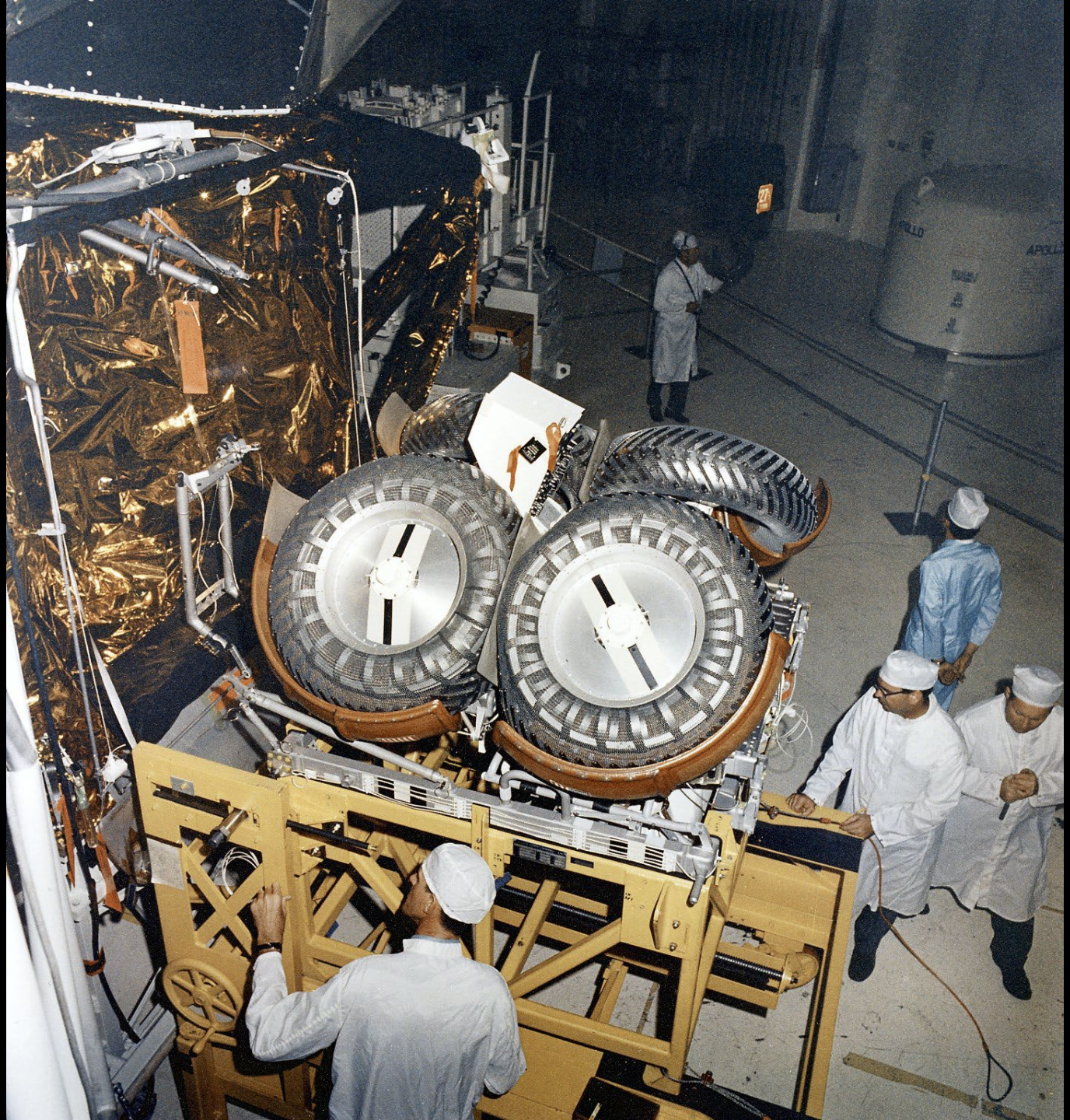

S.E.S. LAB

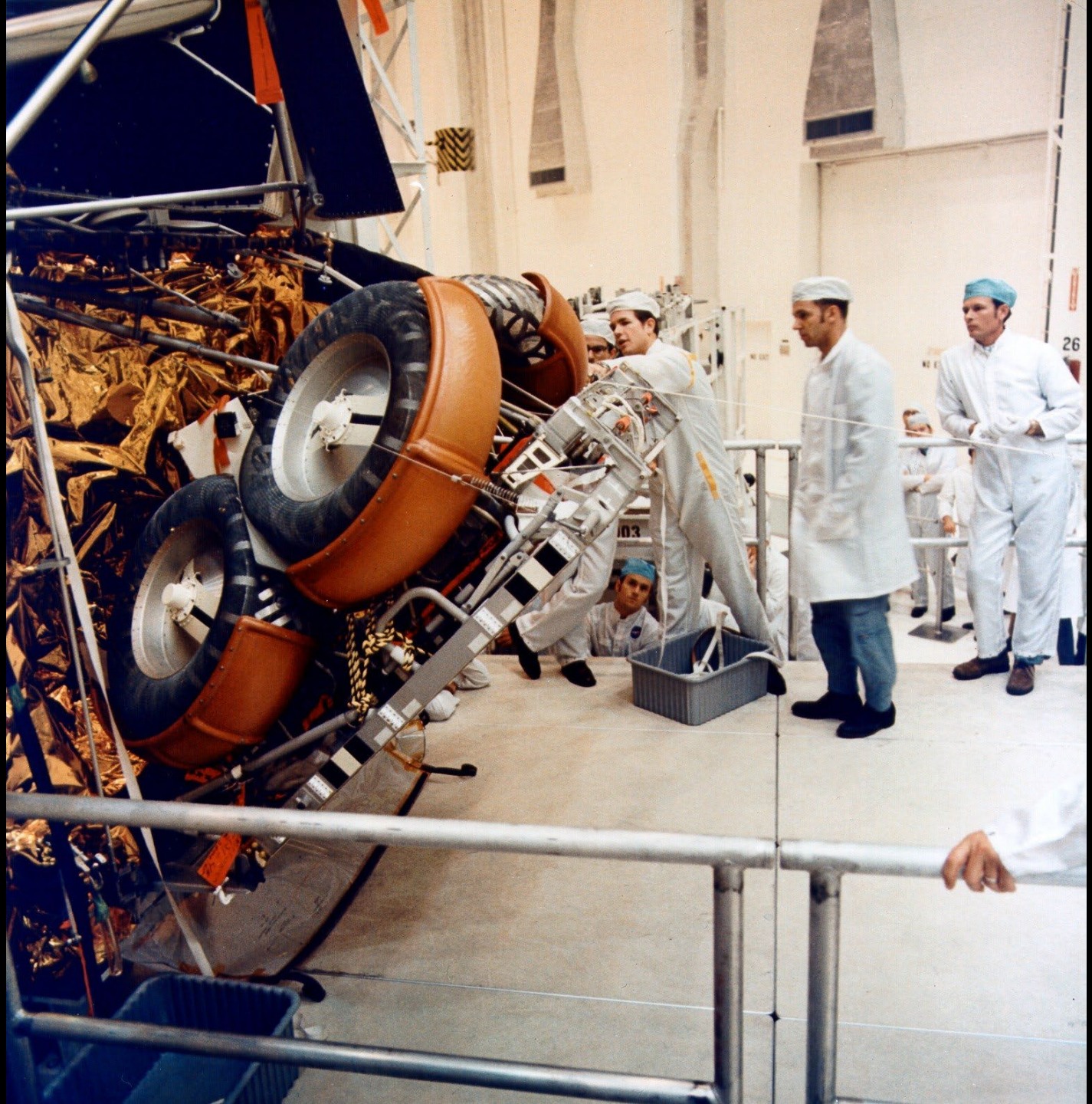

HEADING
SPEED
NAV POWER
GYRO TORQUING
SYSTEM RESET
POWER
POWER / TEMPERATURE MONITOR
STEERING
DRIVE POWER
DRIVE ENABLE

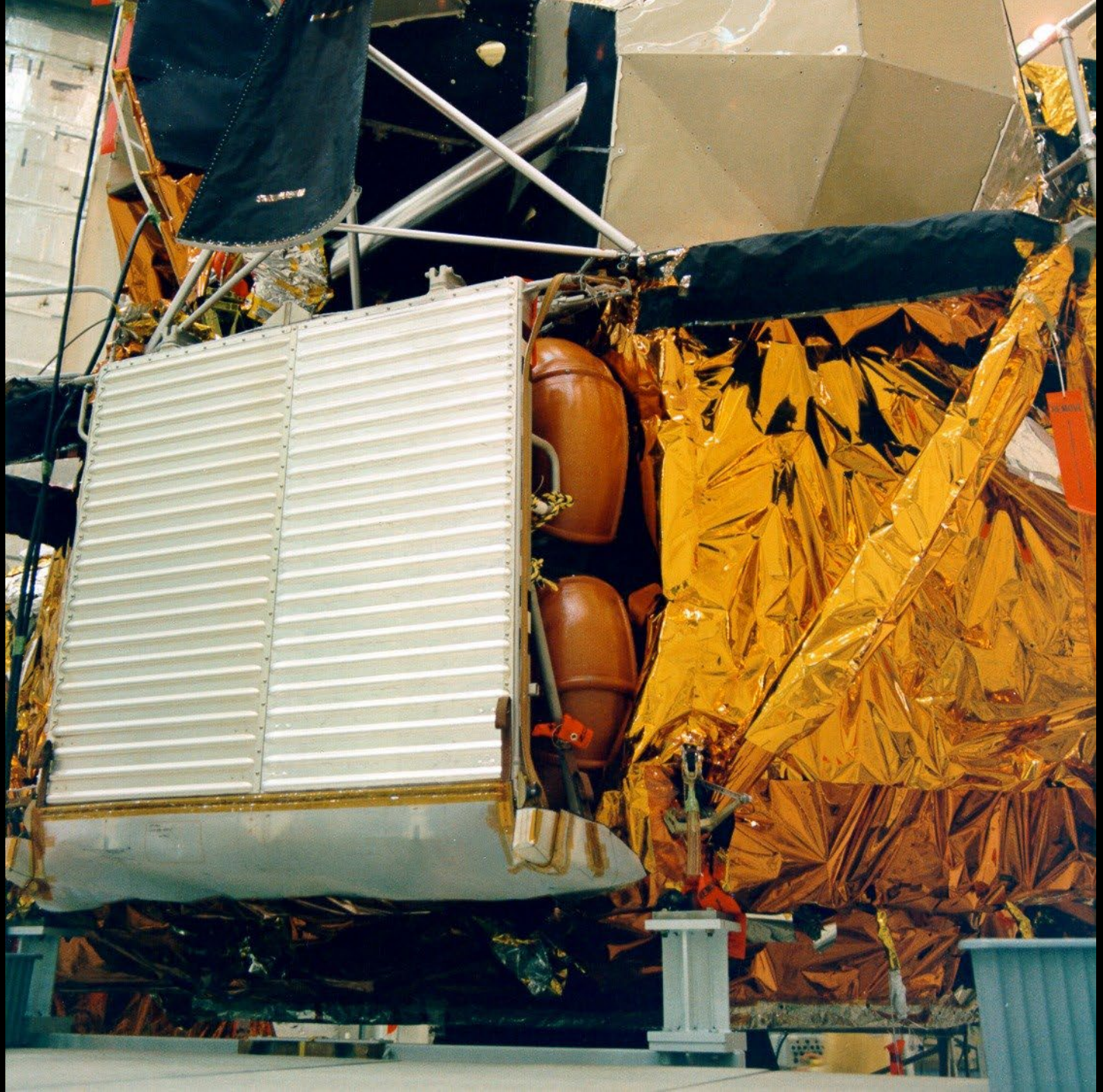

REMOVE BEFORE FLIGHT
REMOVE BEFORE FLIGHT


26
BOEING









Act V

Act V

On your mark


GEO PREP GRESS 1 AREA
SEP TRAV UIP PREP MAP
0+25 GEO PREP
Stow LMP PLSS
• Cap disp (SCB 7)
• Rammer
• Hammer
• SCB 8
LMP to secure SCB 7
TGE - READ -
TGE to LRV
LRV EQUIP CHECK:
• EP Xptr (2,3)
• LCRU blnkts 100% open
• LRV batt covers closed
• Dust brush on LCRU
• TGE
• Mags & polar filter
GEO PREP
NAV: RESET then OFF

LRV SET-UP
TEST DRIVE

Pull down on RH reel tape until outrigger cables slack — [PULL ON DEPLOY CABLE]

Pull RH pin, outrigger cable — [PULL LH PIN, LOWER]

When fwd wheels on surface:

- Pull pins on deploy cable & fittings — [RELEASE SADDLE]

Move LRV from LM

0+32 SET UP LRV

Do RH side-aft 1st — [LMP DOES LH SIDE]

Erect geo post

Extend rear fender

VERIFY rear hinge pins & seal

Erect seat & unstow seatbelt

CDR-8
EVA1
11-1-72

CDR-9
EVA1
11-1-72

Lower armrest

Pull T-handle — [BOTH CDR & LMP]

Lower console, raise handhold, lock T-handle — [BOTH CDR & LMP]

Remove tripod apex

Tool behind footrest

VERIFY front hinge pins

Erect footrest

Extend front fender

VERIFY bat covers CLOSED

0+40 LRV CHECKOUT

POWER UP — [LM AREA DESCRIP]

Drive to MESA

+15 VDC sw - OFF -

TEST DRIVE
LRV SET-UP

0+46 LRV FRONT CONFIGURE

Lift LCRU post locks
Release Y-cable
Install LCRU, lock posts & conn. pwr conn. [GEO PALLET SET-UP]
Install TCU(conn. inboard)
Conn. pwr cable to TCU

Unstow Rake

Install LGA, CDR side, tilt to 45°, align
Conn LGA to LCRU [CDR CAM, ETB]

Install, raise HGA mast
Conn HGA to LCRU
Velcro cable to staff

LRV FRONT CONFIG

EVA1

CDR-10

11-1-72

1+08 Unstow TV cam (MESA LH)
TV to TCU
TV sunshade to TV cam
TV cable (TCU) to TV cam

Deploy HGA/Align
Check LCRU:
- Deploy LCRU whip ant
- LCRU Blkts - 100% open
- Cb - Closed
- Pwr sw - INT -
- Report - AGC, TEMP, PWR
- Pwr sw - EXT -
- Mode sw - 2 -(FM/TV)
- TCU pwr sw - ON -(mom.)
- VERIFY - AGC & PWR ~2

CDR-11

EVA1

11-1-72

LRV FRONT CONFIG

CDR-15

EVA1

11-1-72

Remove MESA brkts, L. side
LiOH Cann. to middle of MESA
Tidy MESA Blankets

1+35 LRV Equip Ck

- LCRU - blnkts 100% open
- TV/Sunshade
- SEP RCVR/ant - nav cable
- EP Xptr (4,5,6,7) on LRV
- TGE (3 meas. complete)
- Drill, bag, N. Flux

1+37 ALSEP TRAV

TV cam; Mode sw -1-(PM1/WB)
Drive to ALSEP site, 300 ft W
Park 60 ft NE of C/S, H = 180
+15 vdc sw - OFF -
Mode sw - 3 - (TV RMT)
Dust TV, TCU & LCRU
HGA
TGE - GRAV -

ALSEP TRAV

CDR-25

EVA1

11-1-72

3+52 LRV NAV INIT

Mode sw - 1 - (PM1/WB)
TV cam
+15 vdc sw - PRIM -

NAV INITIALIZE

WALK LM

3+57 ALSEP TO SEP SITE VIA LM

Drive to LM - Rpt:

- Bearing, Dist., Range

Drive to SEP site

- (>100m E)

WALK TO DEPLOY SITE

+15 vdc sw - OFF -

Rpt: Bearing, Dist., Range, Amp Hrs & Temps

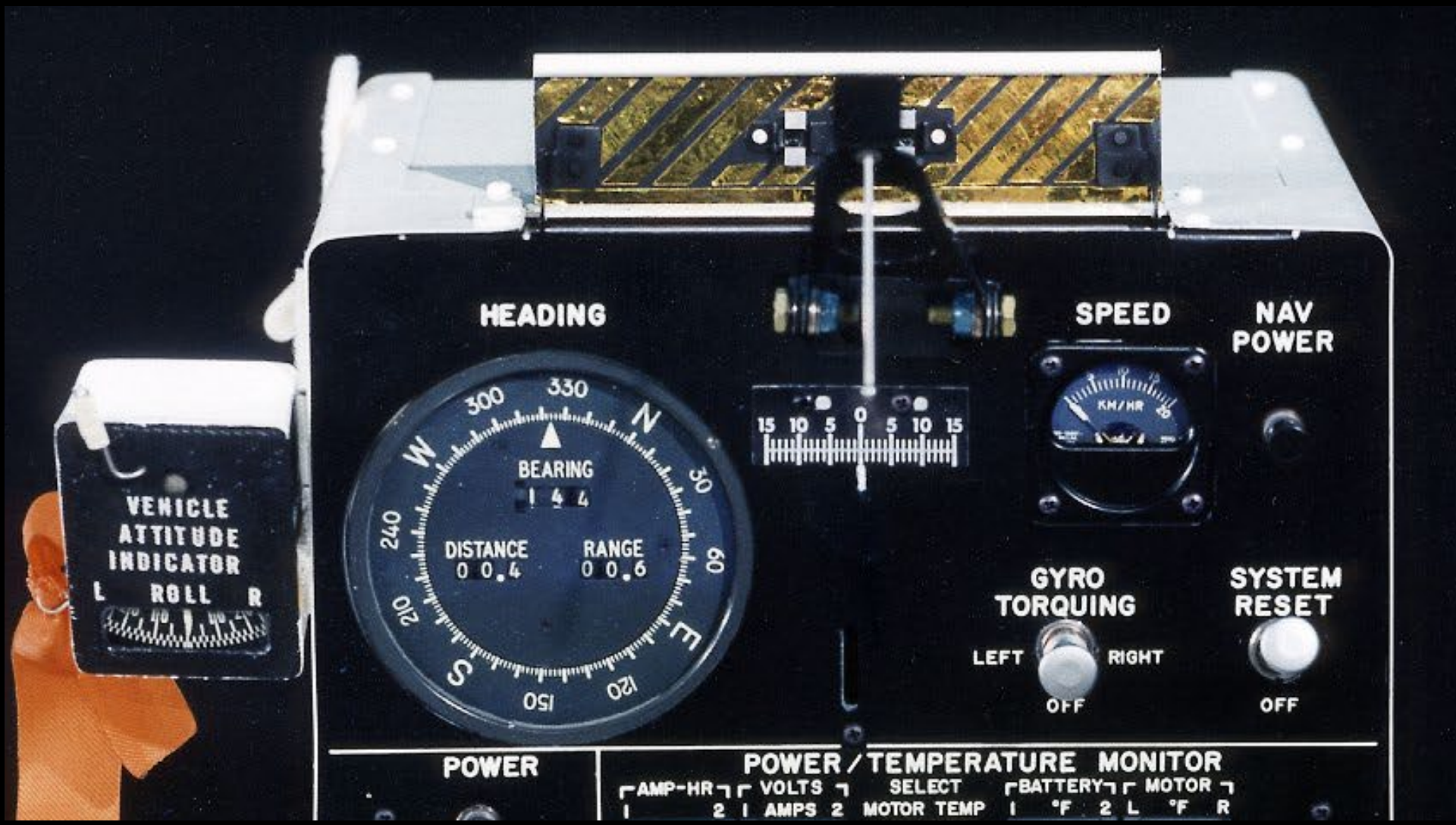
NAV: RESET then OFF

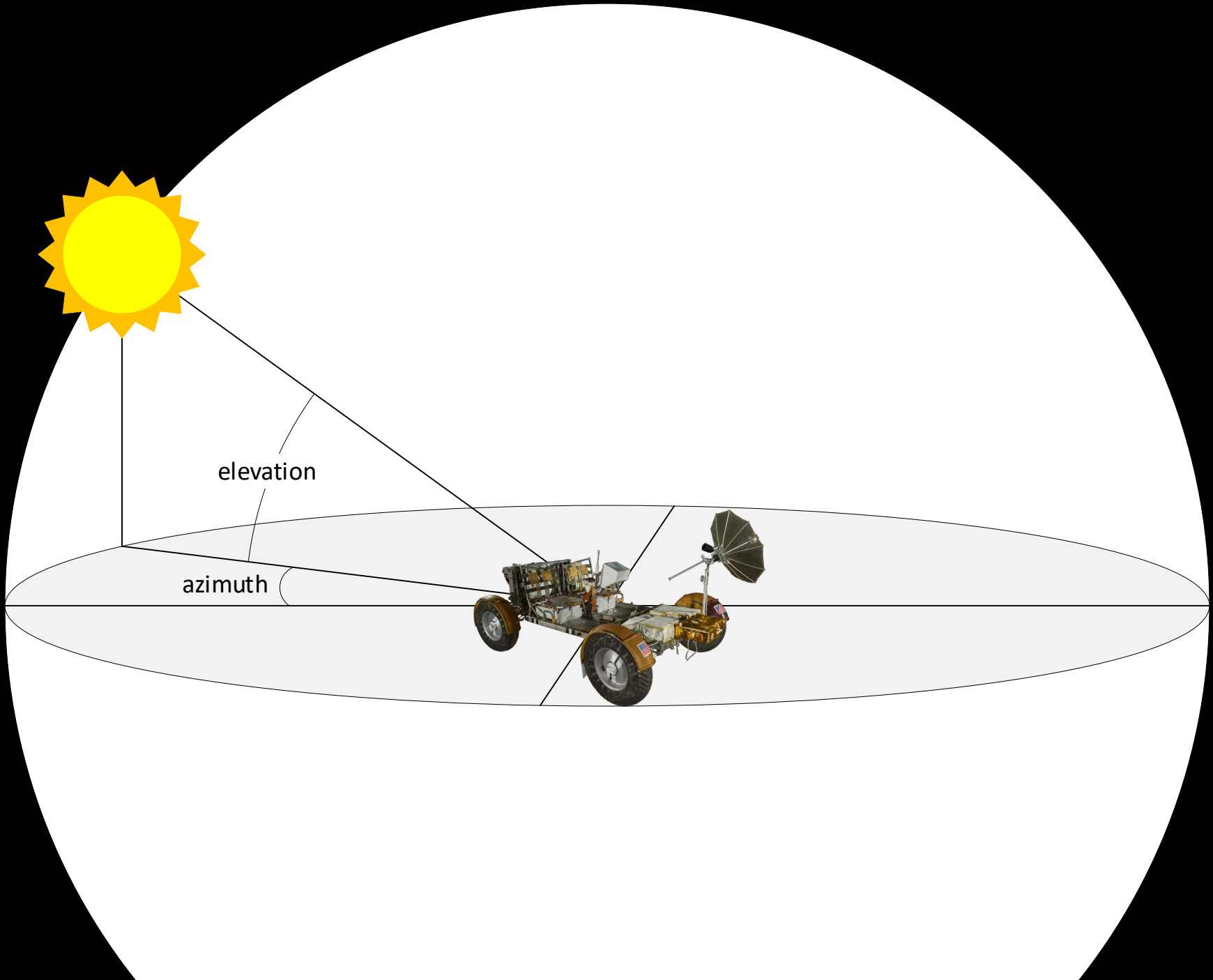
GET EP 6

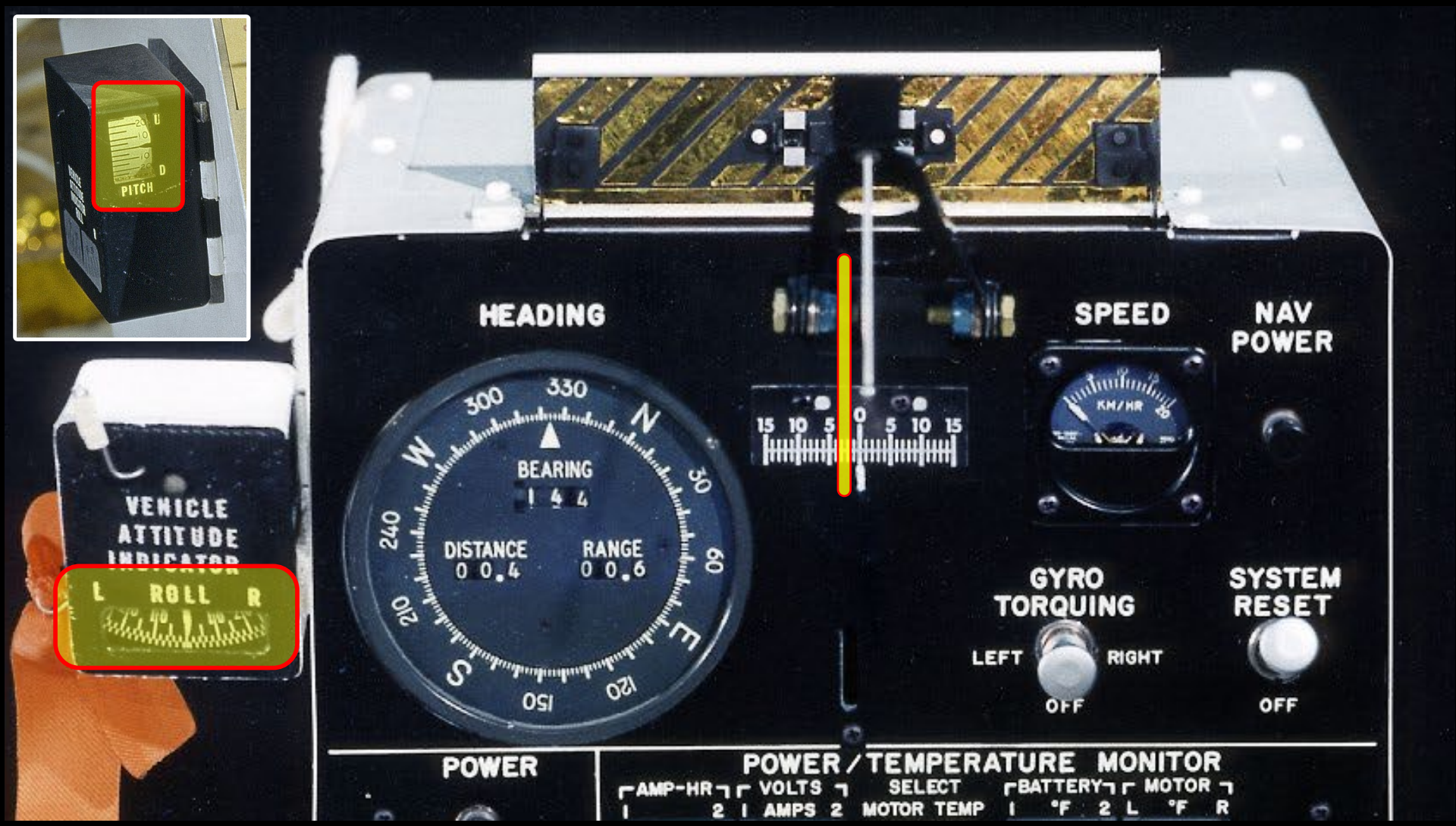
LGA = 150

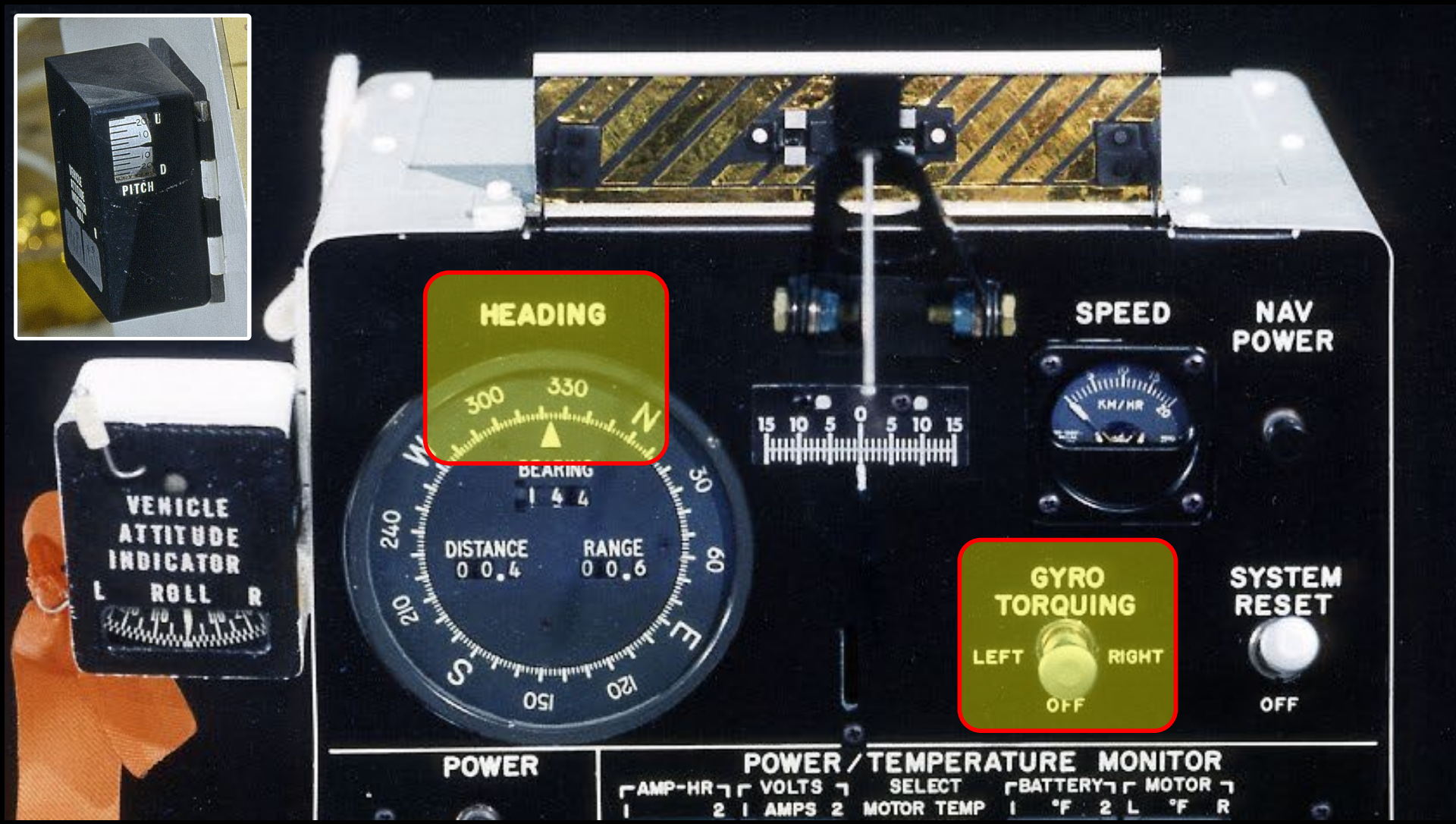
SEP PREP

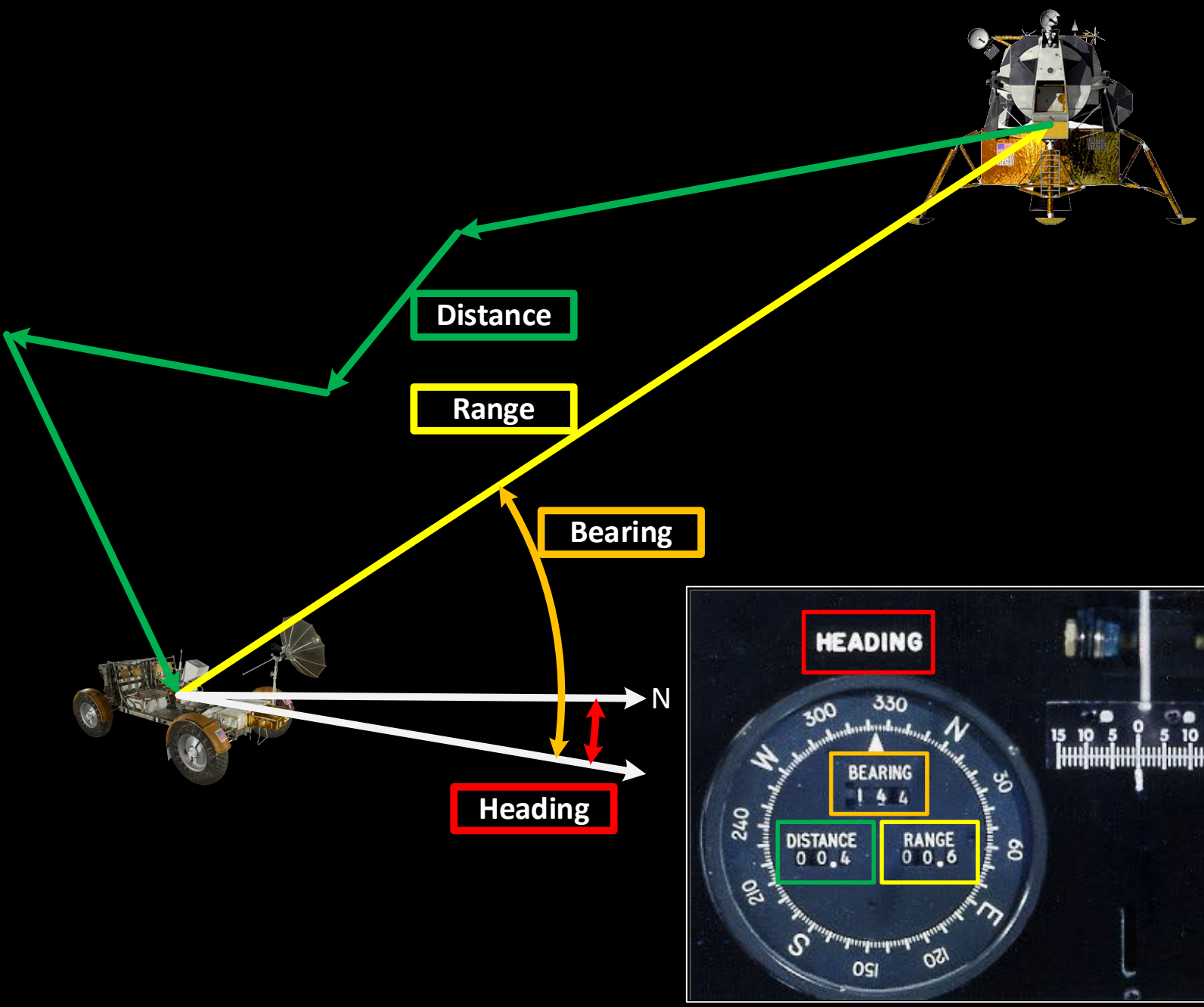
GEO PREP


VENICLE
ATTITUDE
INDICATOR
L ROLL R
HEADING
300
330
N
30
W
240
60
210
S
150
120
E
BEARING
144
DISTANCE
00.4
RANGE
00.6
15 10 5 0 5 10 15
SPEED
KM/HR
NAV
POWER
GYRO
TORQUING
LEFT
RIGHT
OFF
SYSTEM
RESET
OFF
POWER
POWER/TEMPERATURE MONITOR
AMP-HR 1 2
VOLTS 1 AMPS 2
SELECT
MOTOR TEMP
BATTERY 1 °F 2 °F
MOTOR L R


elevation
azimuth


U
D
PITCH
VENICLE
ATTITUDE
L ROLL R
HEADING
SPEED
NAV
POWER
KM/HR
15 10 5 0 5 10 15
300 330 N 30 60 E 120 150 S 210 240 W
BEARING
144
DISTANCE
00.4
RANGE
00.6
GYRO
TORQUING
LEFT
RIGHT
OFF
SYSTEM
RESET
OFF
POWER
POWER / TEMPERATURE MONITOR
AMP-HR 1 2
VOLTS 1 AMPS 2
SELECT
MOTOR TEMP
BATTERY 1 °F 2 °F
MOTOR L R


PITCH
HEADING
300
330
N
VENICLE
ATTITUDE
INDICATOR
L ROLL R
BEARING
144
DISTANCE
00.4
RANGE
00.6
W
30
240
60
210
S
E
150
120
15 10 5 0 5 10 15
SPEED
KM/HR
NAV
POWER
GYRO
TORQUING
LEFT
RIGHT
OFF
SYSTEM
RESET
OFF
POWER
POWER / TEMPERATURE MONITOR
AMP-HR 1 2
VOLTS 1 AMPS 2
SELECT
MOTOR TEMP
BATTERY 1 °F 2 °F
MOTOR L R


Distance
Range
Bearing
N
Heading
HEADING
SPEED
BEARING
1 4 4
DISTANCE
0 0.4
RANGE
0 0.6
GYRO
TORQUING
LEFT
RIGHT
OFF

Act VI

Act VI

Hit it


SCOTT


J. YOUNG


E. CERNAN


J. IRWIN

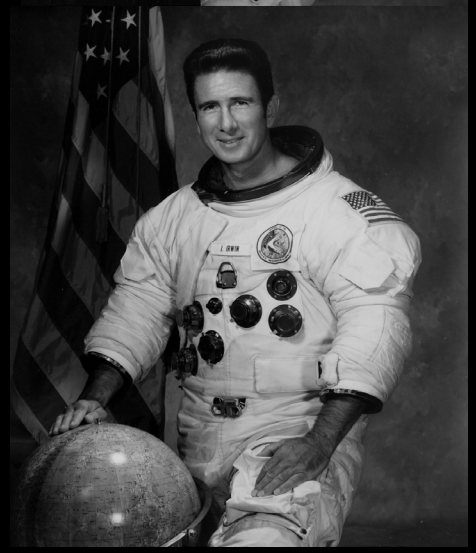

C. DUKE


SCHMITT


SCOTT

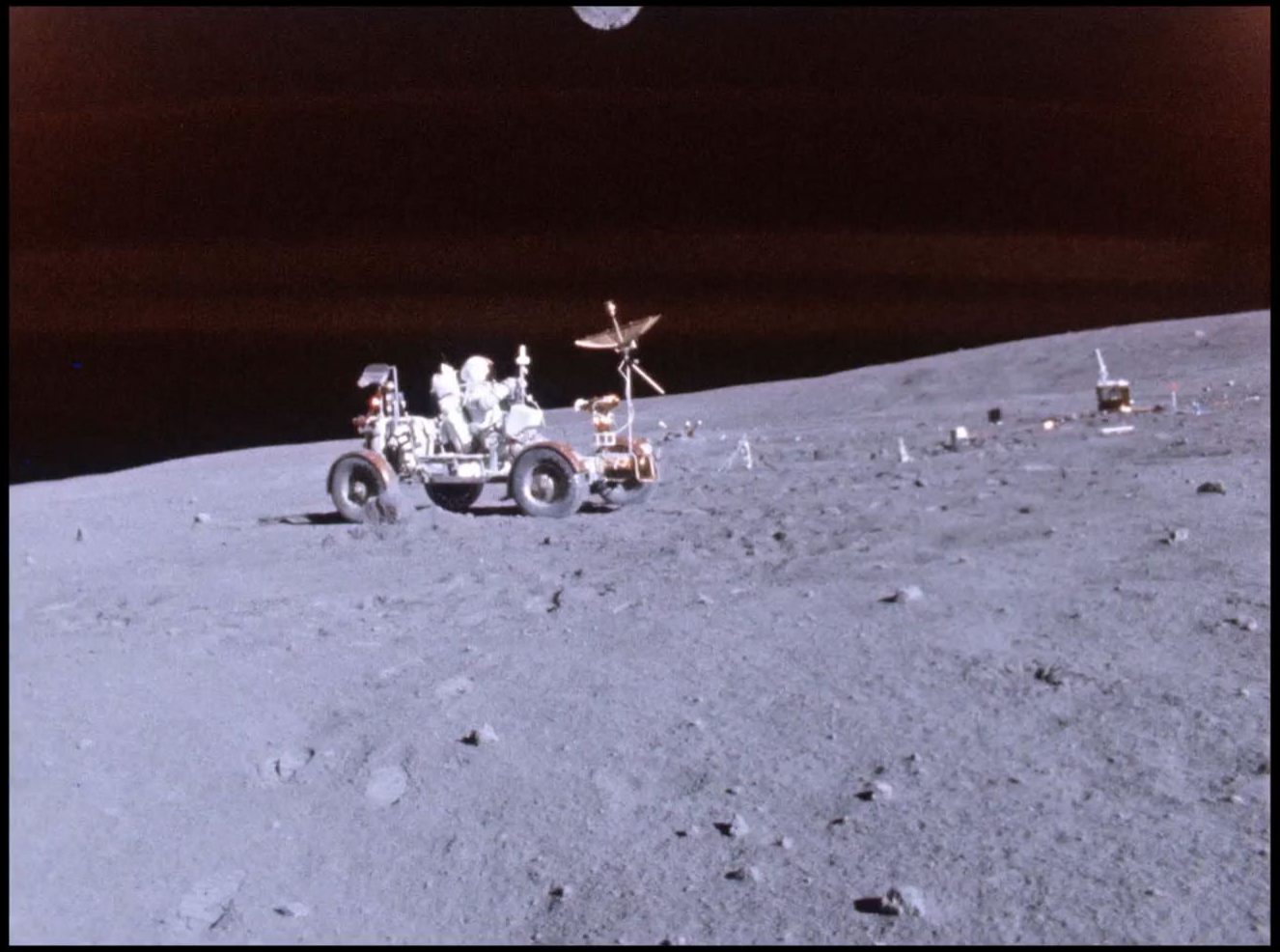

J. YOUNG


E. CERNAN


J. IRWIN

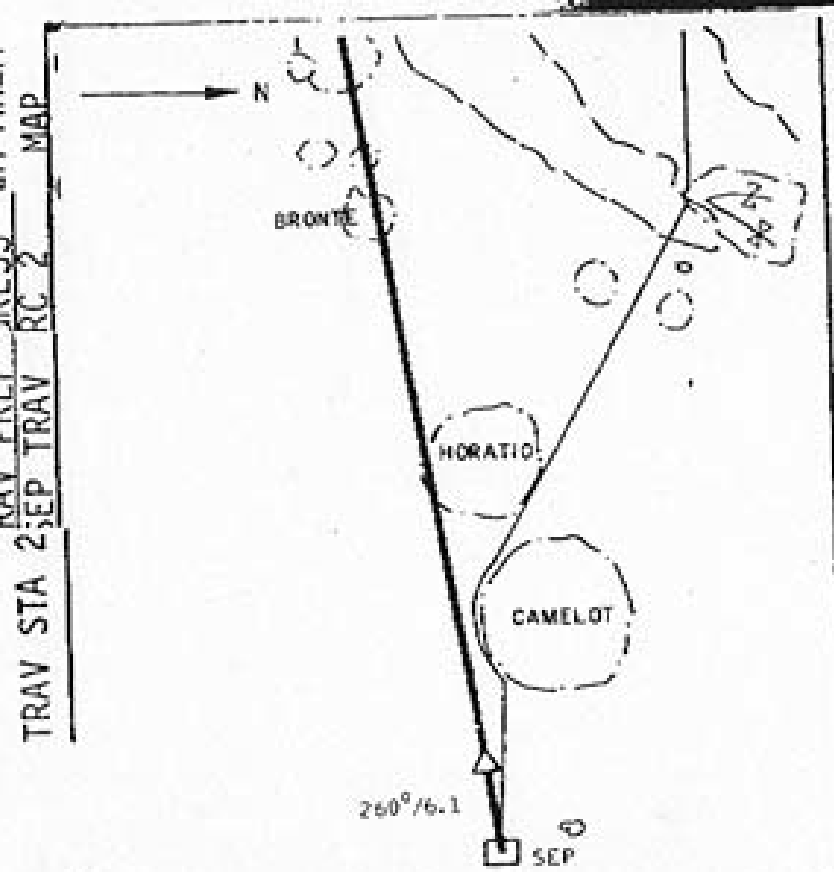

C. DUKE


SCHMITT



TRAV PREP PROGRESS LM AREA

TRAV STA 2 SEP TRAV RC 2 MAP



EMU MALF

NAV INITIALIZE

LGA = 240

0+52 TRAV TO STA 2-70min (260/8.4)

Δ 080/0.4 EP 4 - part pan
(0.2 W ALSEP)

- Mtl - variatn,dynam,pat gnd
- Cra - strat, sources

080/1.1 View Sta 5

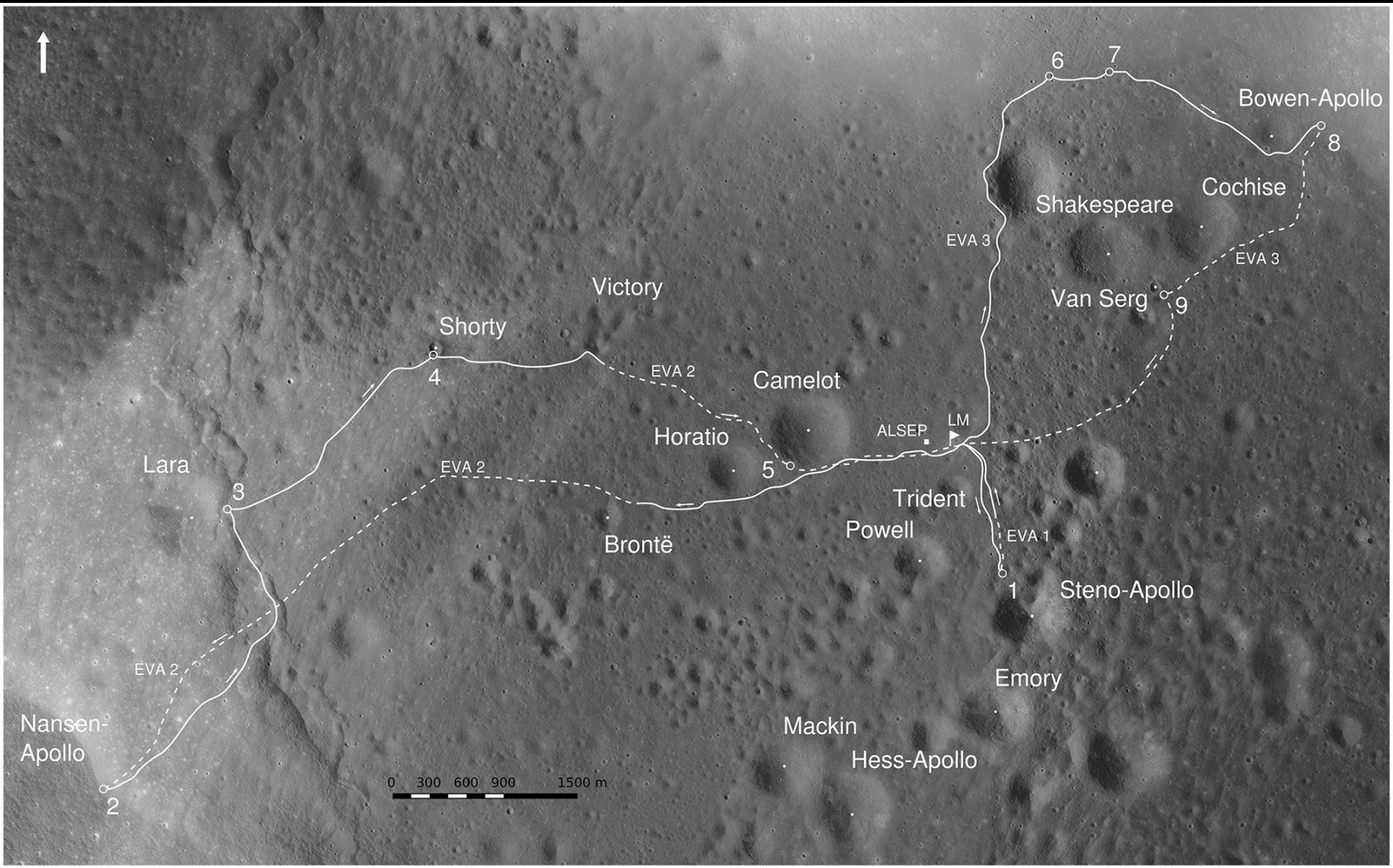
080/1.5 HORATIO - subflr

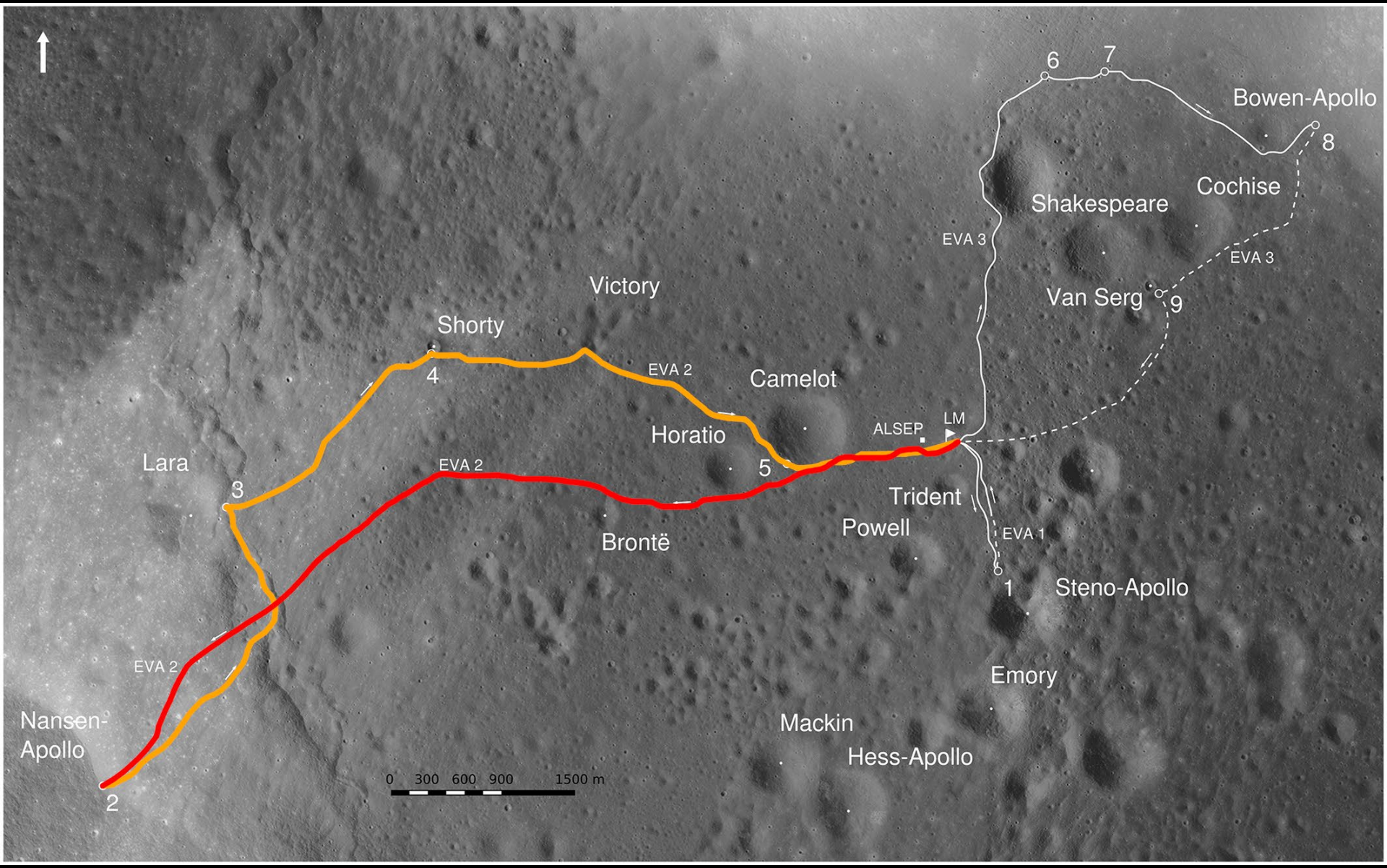
080/3.9 LRV spl - lst lt mtl

080/4.0 Contact - age
- Cra - strat, thick, reg
- TORTILLA FLAT

080/4.2 LRV spl - dk mtl

TRAV STA 2 STA 2 STA 3 STA 3 TRAV STA 2


6
7
Bowen-Apollo
8
Cochise
Shakespeare
EVA 3
EVA 3
Victory
Van Serg
9
Shorty
4
EVA 2
Camelot
ALSEP
LM
Horatio
5
Lara
3
EVA 2
Trident
Powell
EVA 1
Brontë
1
Steno-Apollo
EVA 2
Emory
Nansen-
Apollo
Mackin
Hess-Apollo
2
0 300 600 900 1500 m


6
7
Bowen-Apollo
8
Cochise
Shakespeare
EVA 3
EVA 3
Victory
Van Serg
9
Shorty
4
EVA 2
Camelot
Horatio
ALSEP
LM
Lara
3
EVA 2
5
Trident
Powell
Brontë
EVA 1
1
Steno-Apollo
EVA 2
Emory
Nansen-
Apollo
Mackin
Hess-Apollo
2
0 300 600 900 1500 m


32
32

Feature

Feature

The crest of a high and beautiful wave

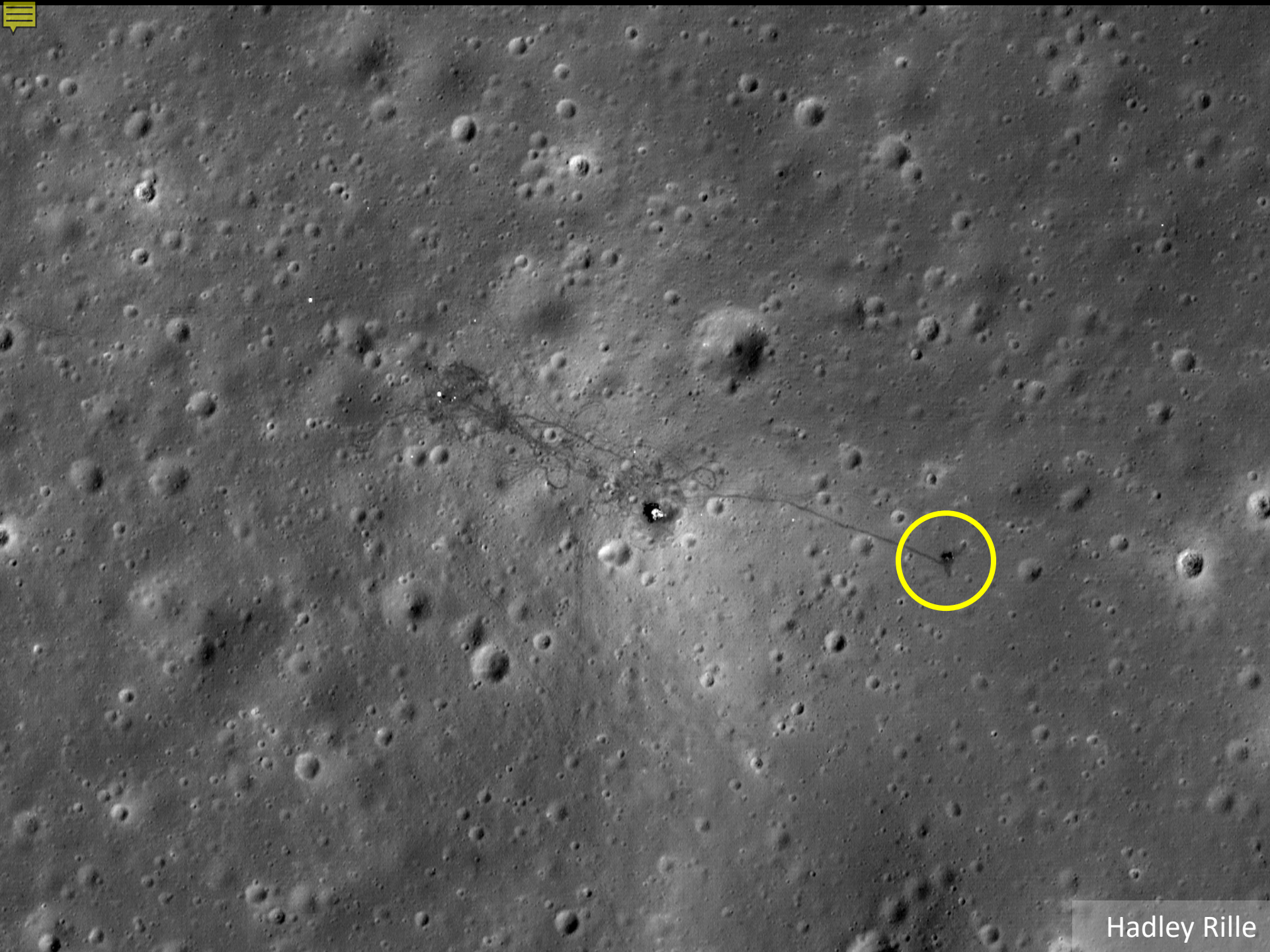
Feature

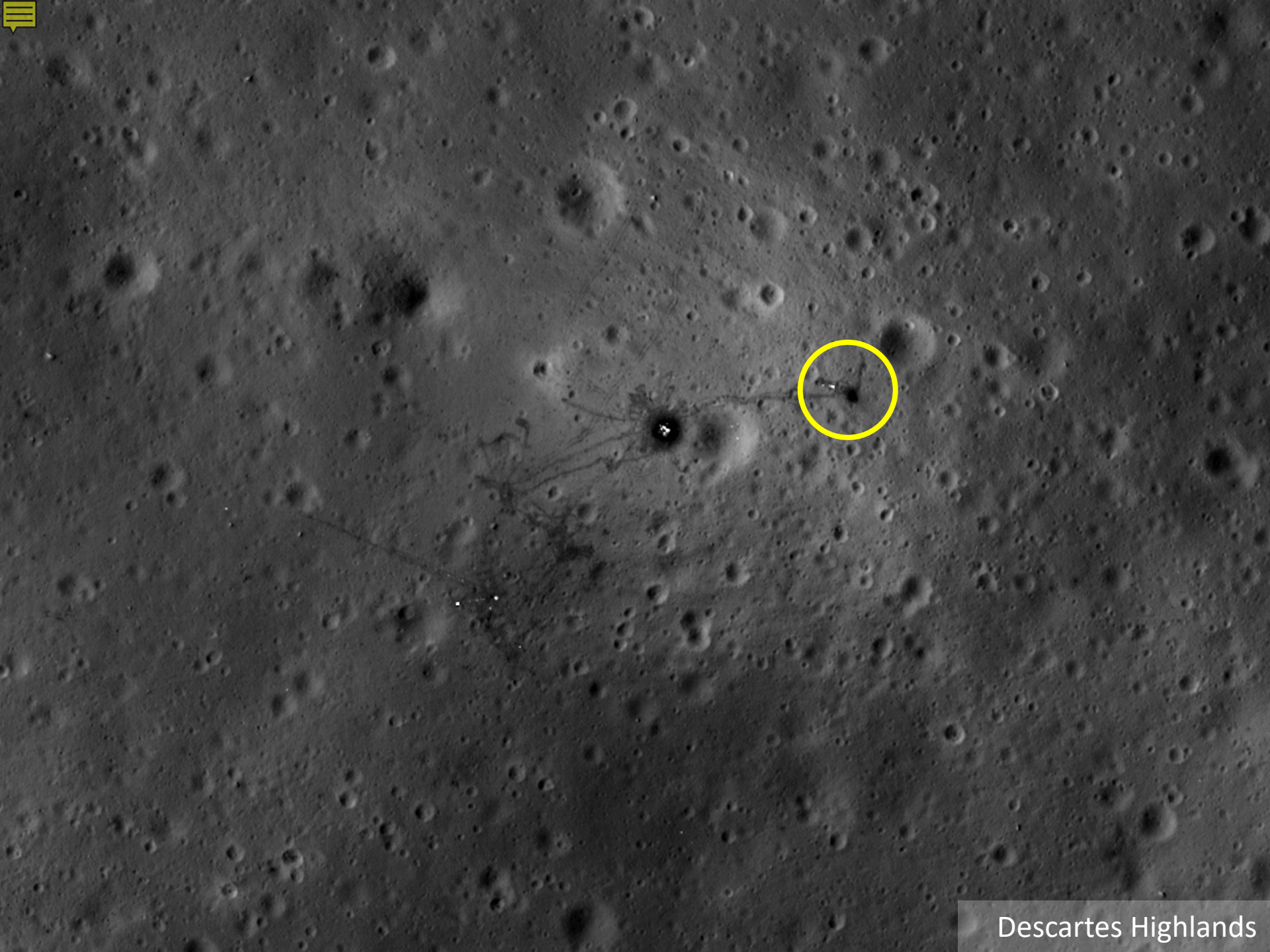
The crest of a high and beautiful wave

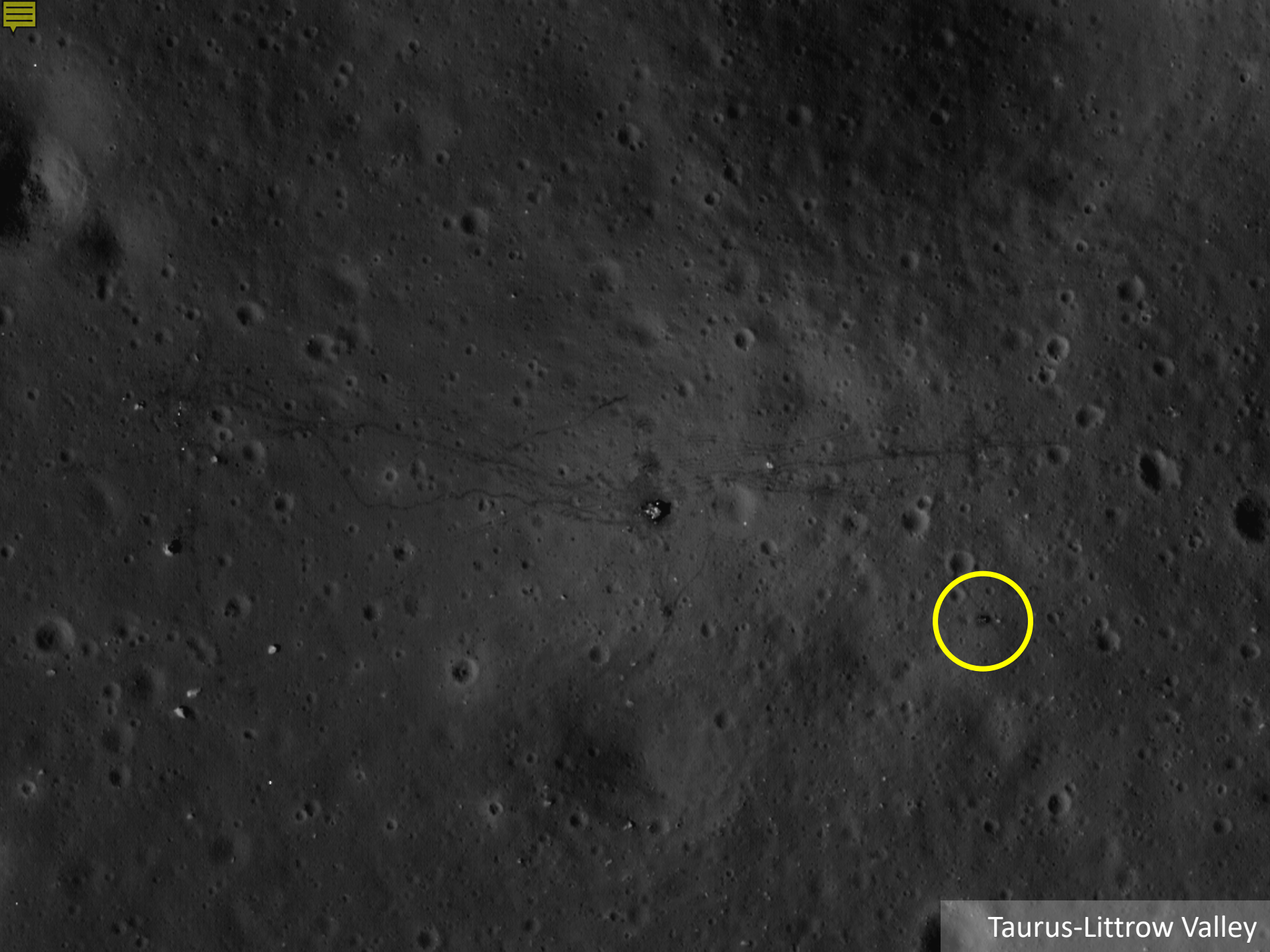
Act VII

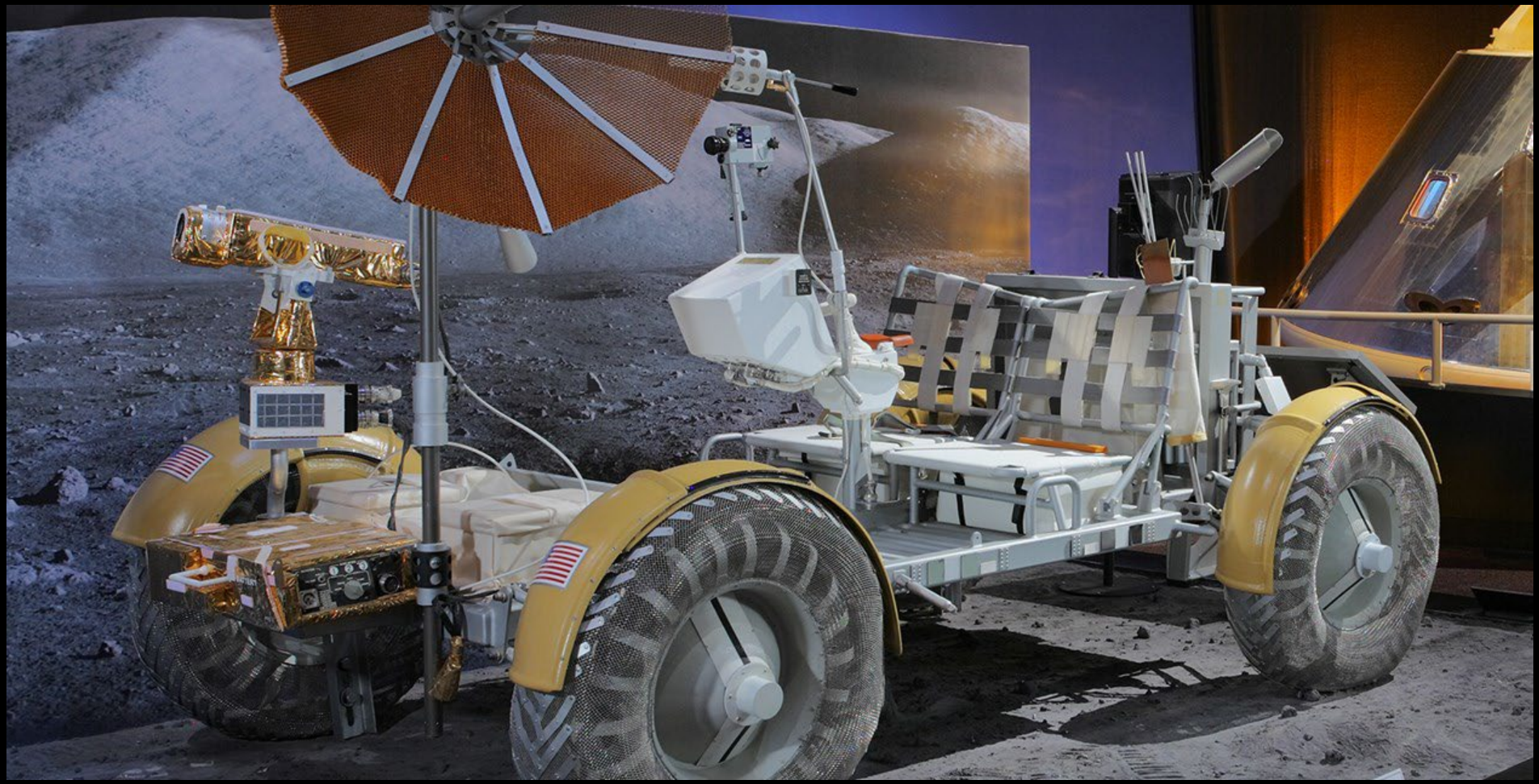
Act VII

Where are they now


Hadley Rille


Descartes Highlands

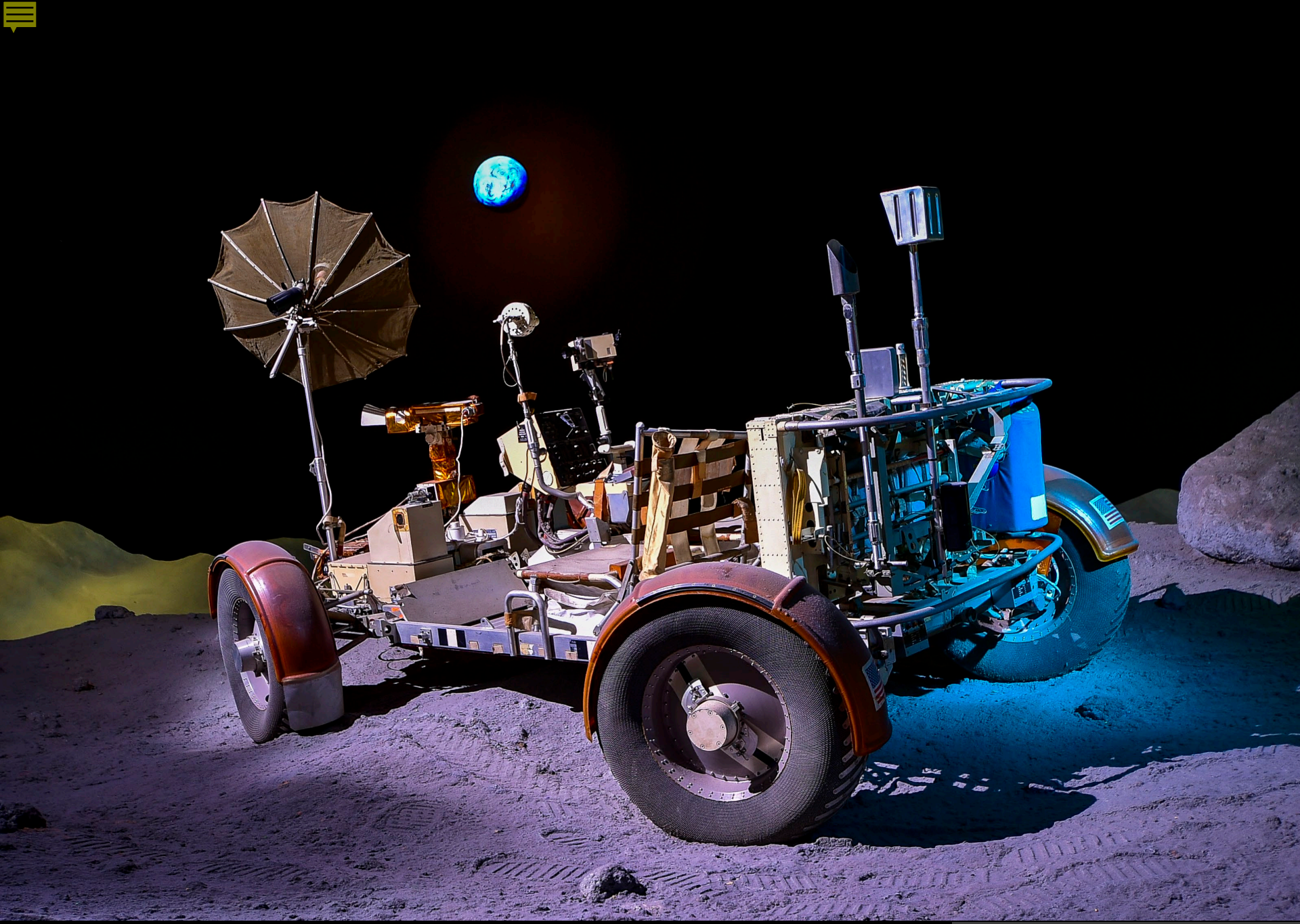

Taurus-Littrow Valley



Museum of Flight, Seattle

Smithsonian Institution

Smithsonian Institution



Space Center Houston

Cradle of Aviation Museum, New York

U.S. Space & Rocket Center, Alabama


IT'S NOT ROCKET SCIENCE
POLARIS
030564

Power Steering

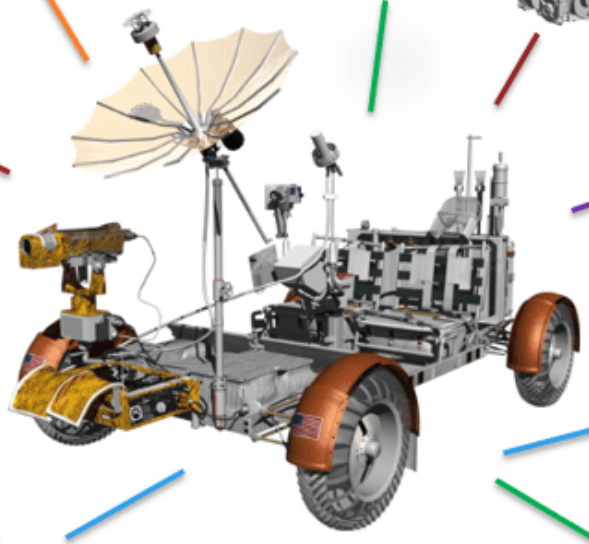
Fabricated Chassis

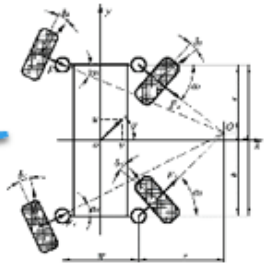
Lights

Electronic Brakes

Driveline
Motor Controller

Li-Ion Battery





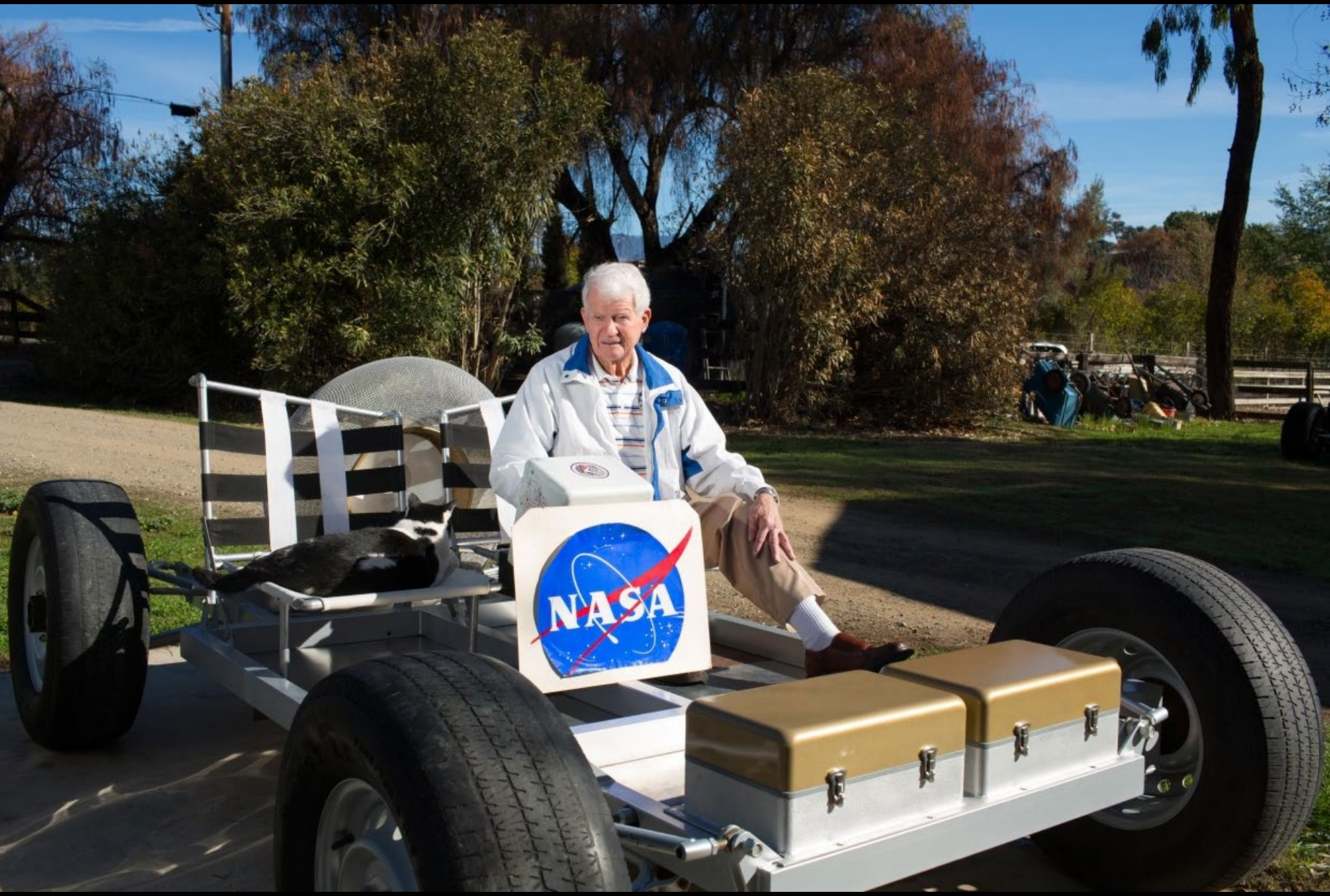
4-wheel Ackermann Steering

Arms

Steering Rack

Exhaust Valve
Actuator

Half Shafts


NASA

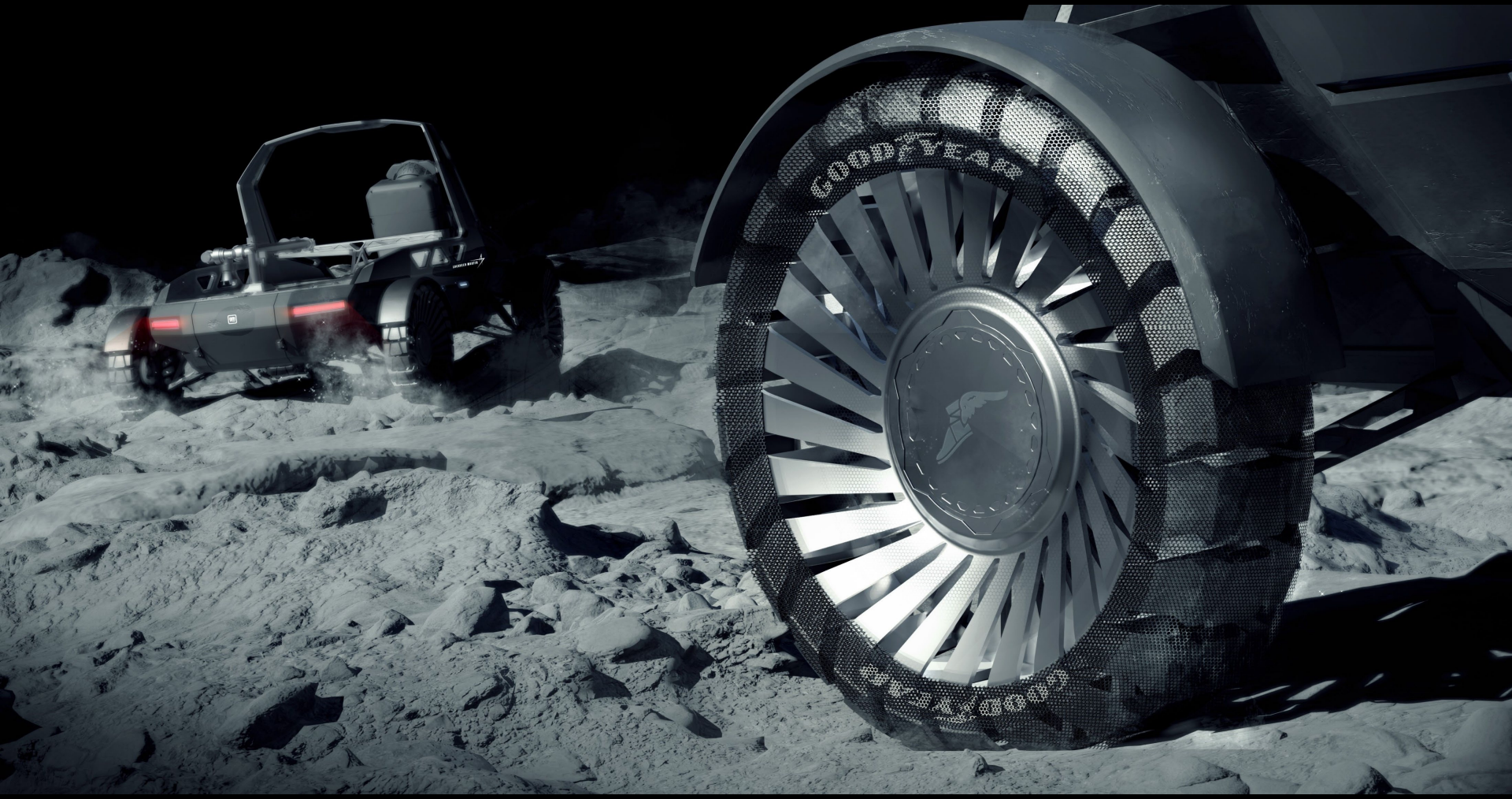
Onward

Onward

The age of Artemis

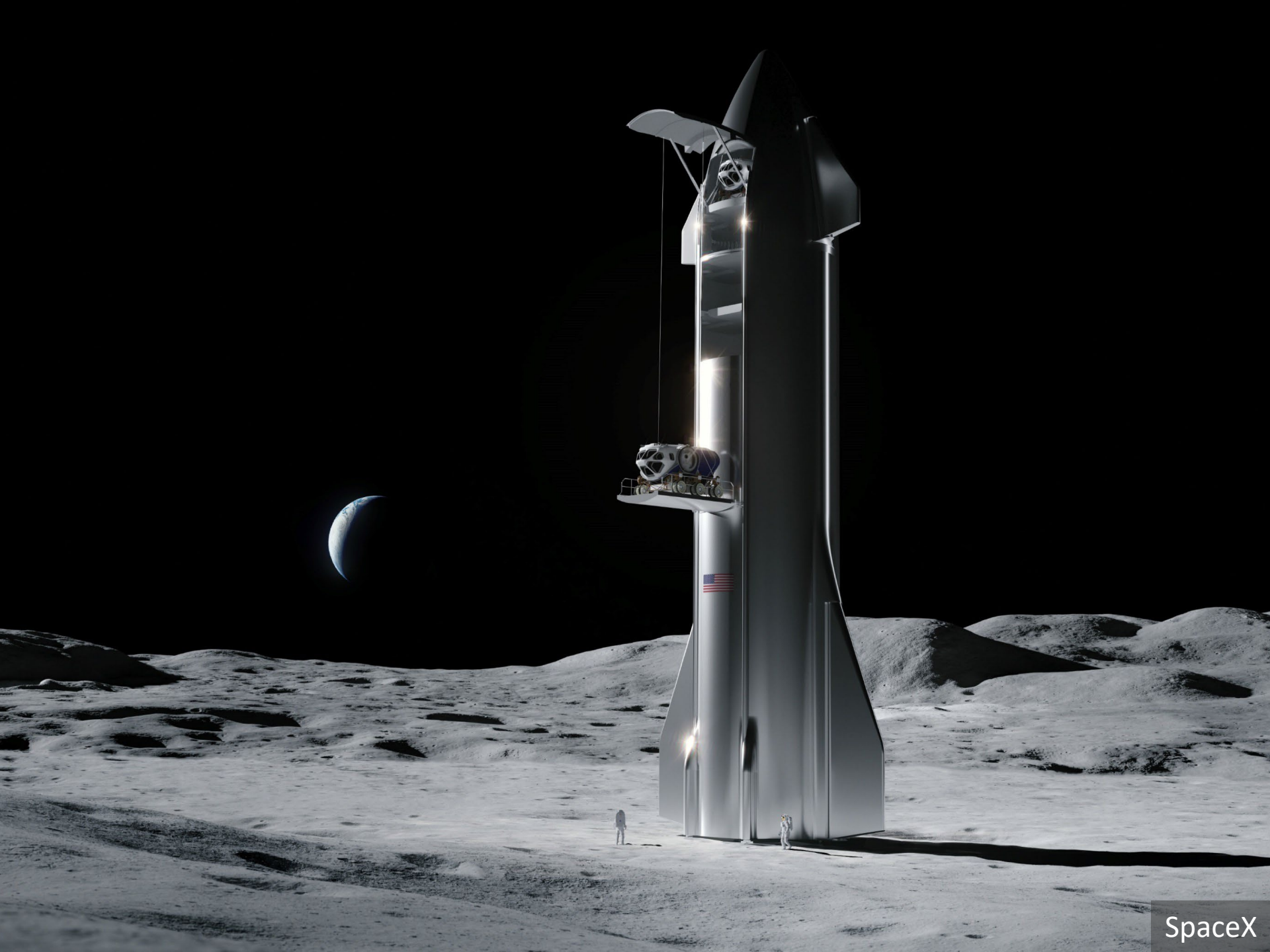

Next launch attempt: Nov 13 23:07 CT
https://www.nasa.gov/specials/artemis-i

Lockheed Martin and General Motors


GOODYEAR


Northrop Grumman


Astrolab


SpaceX

Desert Research and Technology Studies (Desert RATS)

Resources

General

Apollo 17 In Real Time

Apollo 17 Lunar Surface Journal

Apollo 17 Analyst's Notebook

Lunar Reconnaissance Orbiter Camera, Apollo 17

Books

- Earl Swift, *Across the Airless Wilds: The Lunar Rover and the Triumph of the Final Moon Landings* (2021)
- Anthony Young, *Lunar and Planetary Rovers: The Wheels of Apollo and the Quest for Mars* (2006)
- Christopher Riley, David Woods, and Philip Dolling, *Lunar Rover: 1971-1972 [Hayne's Owners' Workshop Manual]* (2012)

Videos

- Apollo 16 - Apollo Flight Journal, The Apollo 16 LRV Grand Prix
- Apollo 15 Rover Deployment
- Smithsonian Channel, The Design of the Lunar Rover Was Mostly Guesswork
- NASA Marshall Space Flight Center, Spacecraft with Wheels: The Lunar Roving Vehicle
- Computer History Archives Project, NASA 1966 Near Zero Gravity Tests in the KC-135 Vomit Comet
- USGS, Grover Geologic Rover

LRV overviews

- Lunar Rover Operations Handbook (1971)
- Lunar Roving Vehicles, Washington Heritage Register
- ADAMS, W., and C. ARNETT. "America's Lunar Roving Vehicle." Weightlessness and Artificial Gravity Meeting. 1971.
- Clow, David, and Roving Vehicles LRV. "Ferenc Pavlics and the Lunar Rover." QUEST 18.1 (2011): 7.
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More technical

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- Lunar Roving Vehicle, Smithsonian National Air & Space Museum
- David Clow, The Difference It Made: Building a Car for the Moon, RocketSTEM (2015-07-06)
- Rebecca Boyle, 50 Years Ago, NASA Put a Car on the Moon, The New York Times (2021-07-27)
- Anthony Young, Lunar rovers past and future, The Space Review (2004-04-05)
- Ryan Cruz, The Lunar Rover's 50th Anniversary and Its Goleta Roots, Santa Barbara Independent (2021-08-05)
- Bob Barrett, Apollo 15: 'The Lunar Rover Changed Everything', WUMF (2021-07-31)
- Kristin Shaw, Unsung Heroes of Apollo-Era Moon Missions: the GM-Designed Lunar Rovers, The Drive (2021-08-01)

Music

- Section transitions: The Presidents of the United States of America, "Dune Buggy", *The Presidents of the United States of America* (1995)
- 4x Grand Prix: Minutemen, "Corona", *Double Nickels on the Dime* (1984)
- EVA 2: Nick Cave and Warren Ellis, "Another Rather Lovely Thing", *The Assassination of Jesse James by the Coward Robert Ford soundtrack* (2007)