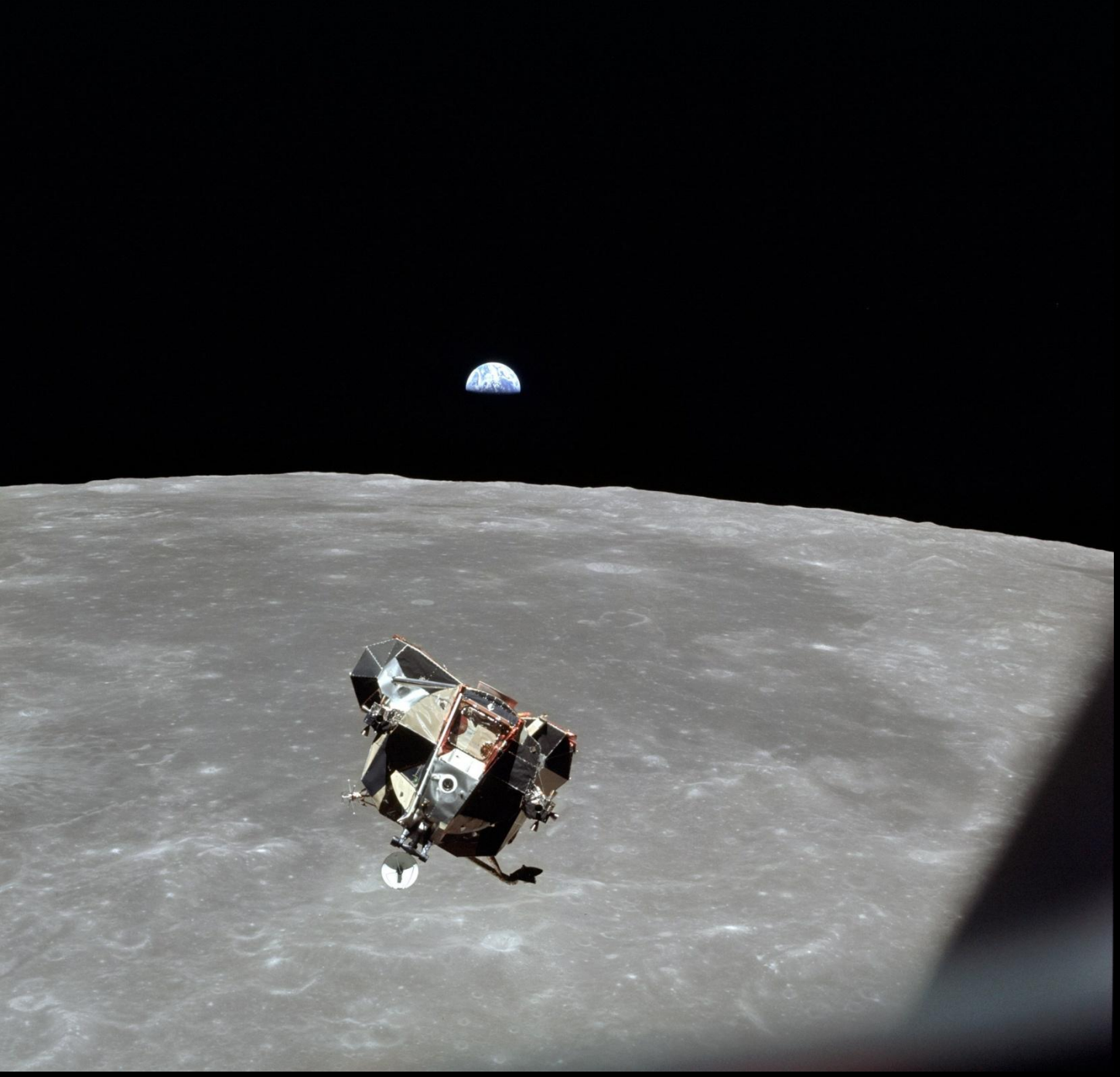
Delivery Systems

Joseph T. Wunderlich, Ph.D.

APOLLO 11 SATURN V ROCKET LUANCH VIDEO :
http://www.youtube.com/watch?v=wvWHnK2FiCk

Apollo 11
first men on the moon
(1969)

No rover on this mission



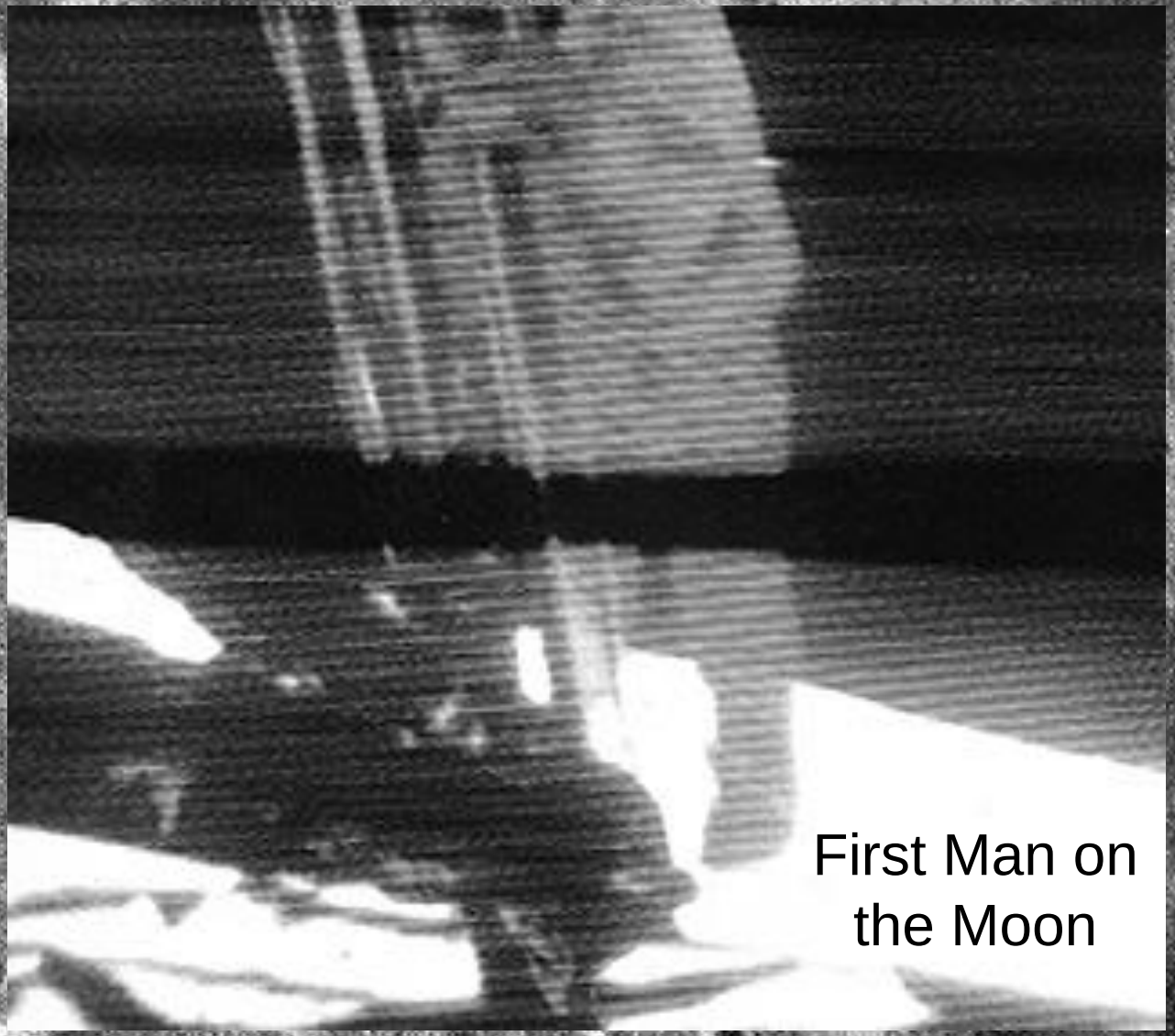
Safely landing is always worth celebrating

Apollo 11 Lunar Module (LM) with first men on the moon (1969)

No rover on this mission

Image from: http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/a11_h_44_6642.html.

LUNAR LANDING SITES



First Man on the Moon

APOLLO 11 VIDEO :
http://www.youtube.com/watch?v=RMINSD7MmT

Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

"Lunar Roving Vehicle" (LRV) *Delivery*

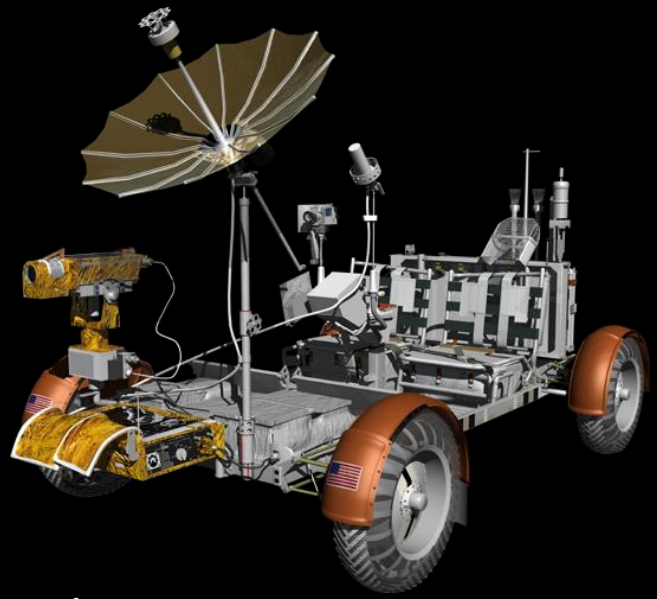
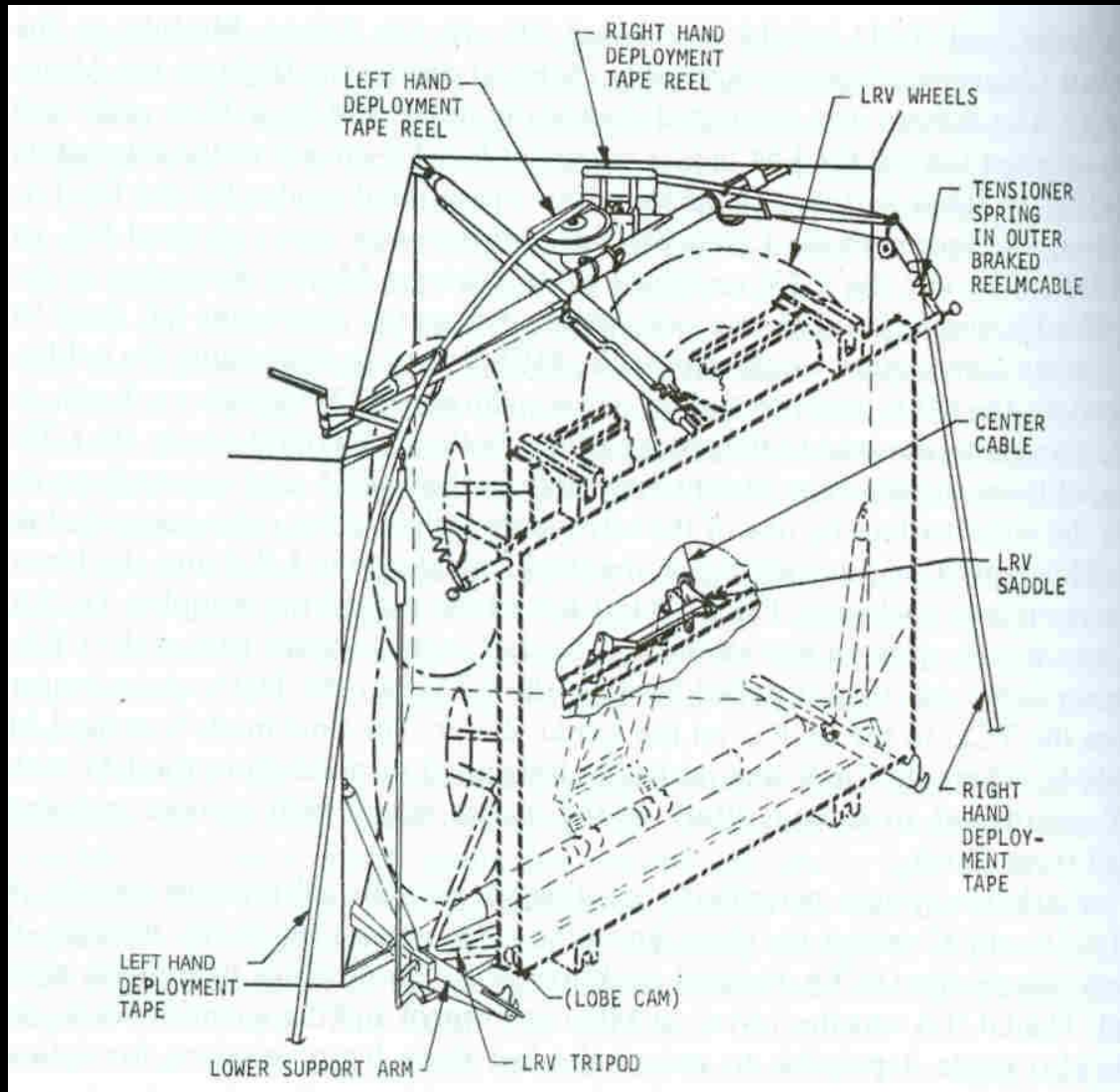


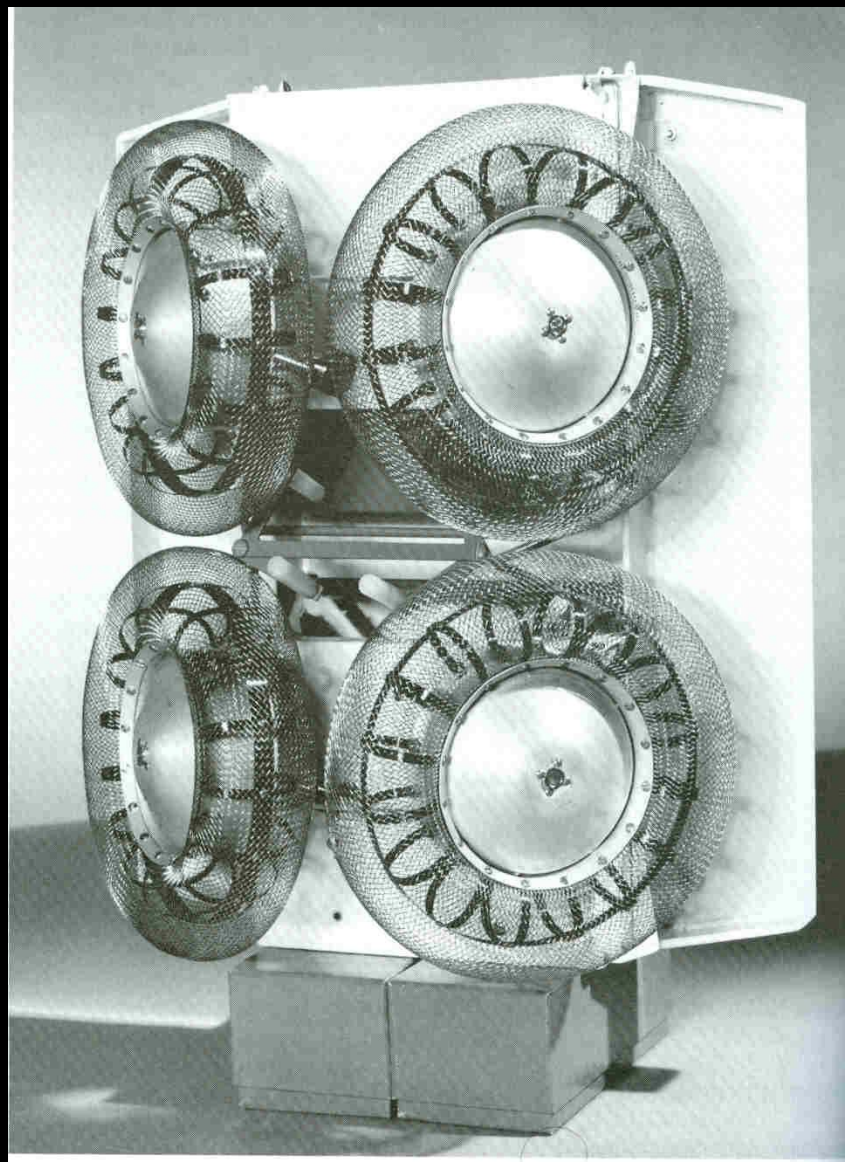
Image from:
http://www.batsinthebelfry.com/rover/index.php



A fully-automatic deployment system was deemed too complex and NASA chose with a semi-automatic deployment system with the involvement of the astron (NASA)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

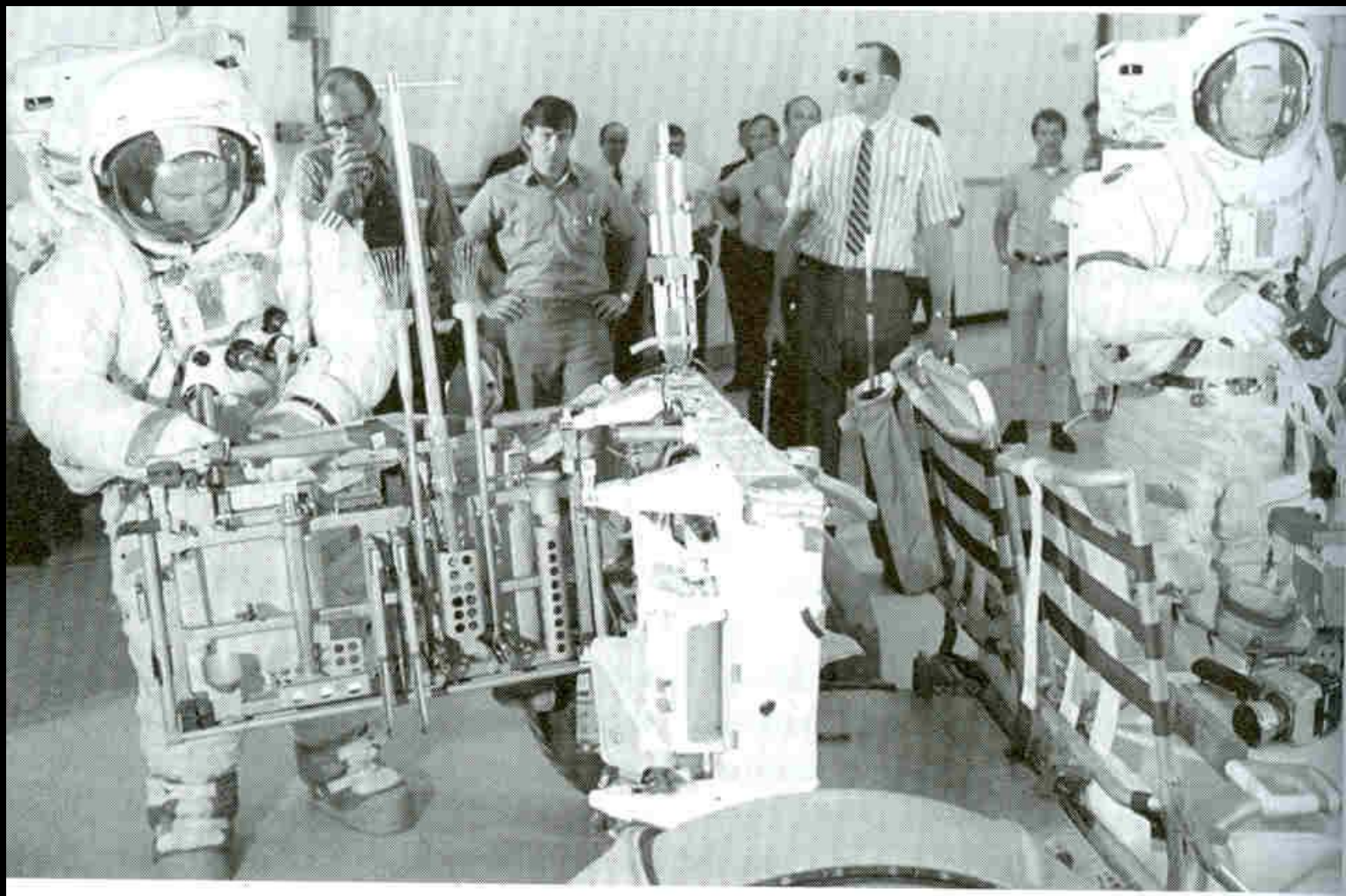
"Lunar Roving Vehicle" (LRV) *Delivery*



GM-DRL built a ⅙ -scale model of a proposed LRV design in 1968 to illustrate the stowage and deployment from the Lunar Module. GM worked closely with Boeing in preparation of the LRV proposal to NASA. (NASA/MSFC)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

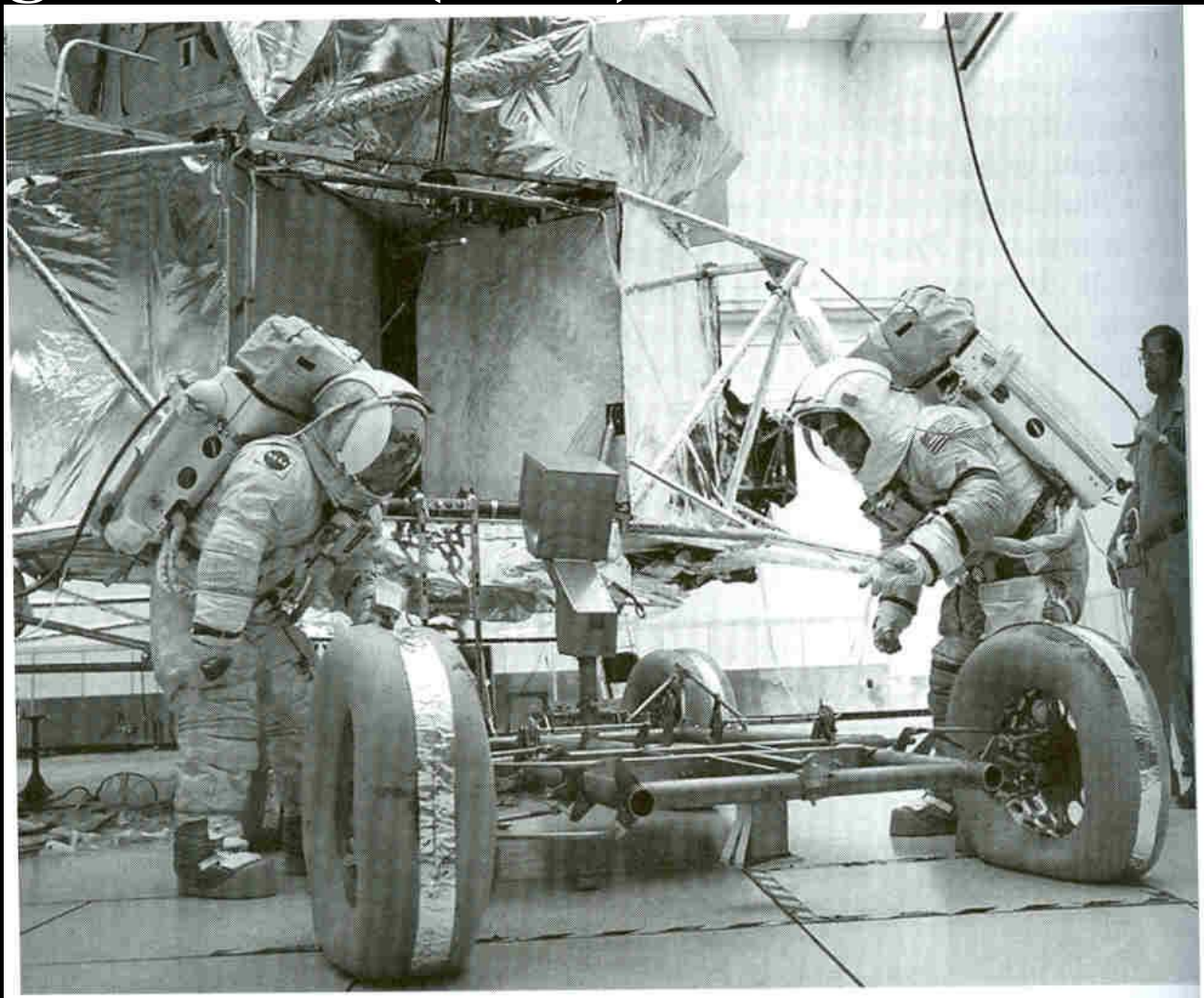
"Lunar Roving Vehicle" (LRV) *Delivery*



The 1-G Trainer was used indoors at KSC for training to configure the LRV after deployment. Jim Irwin (left) is standing behind the Lunar Hand Tool Carrier of the LRV Aft Pallet Assembly. Dave Scott is holding a 70mm film canister for the Hasselblad camera on the right-hand seat. (NASA)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) *Delivery*



J-mission crews practised using the Deployment Trainer in the Flight Crew Training Building at Kennedy Space Center, Florida. Capt. Eugene Cernan (right) and Dr. Harrison Schmitt are shown completing the deployment sequence on 8 June 1972 (Courtesy NASA)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) *Delivery*

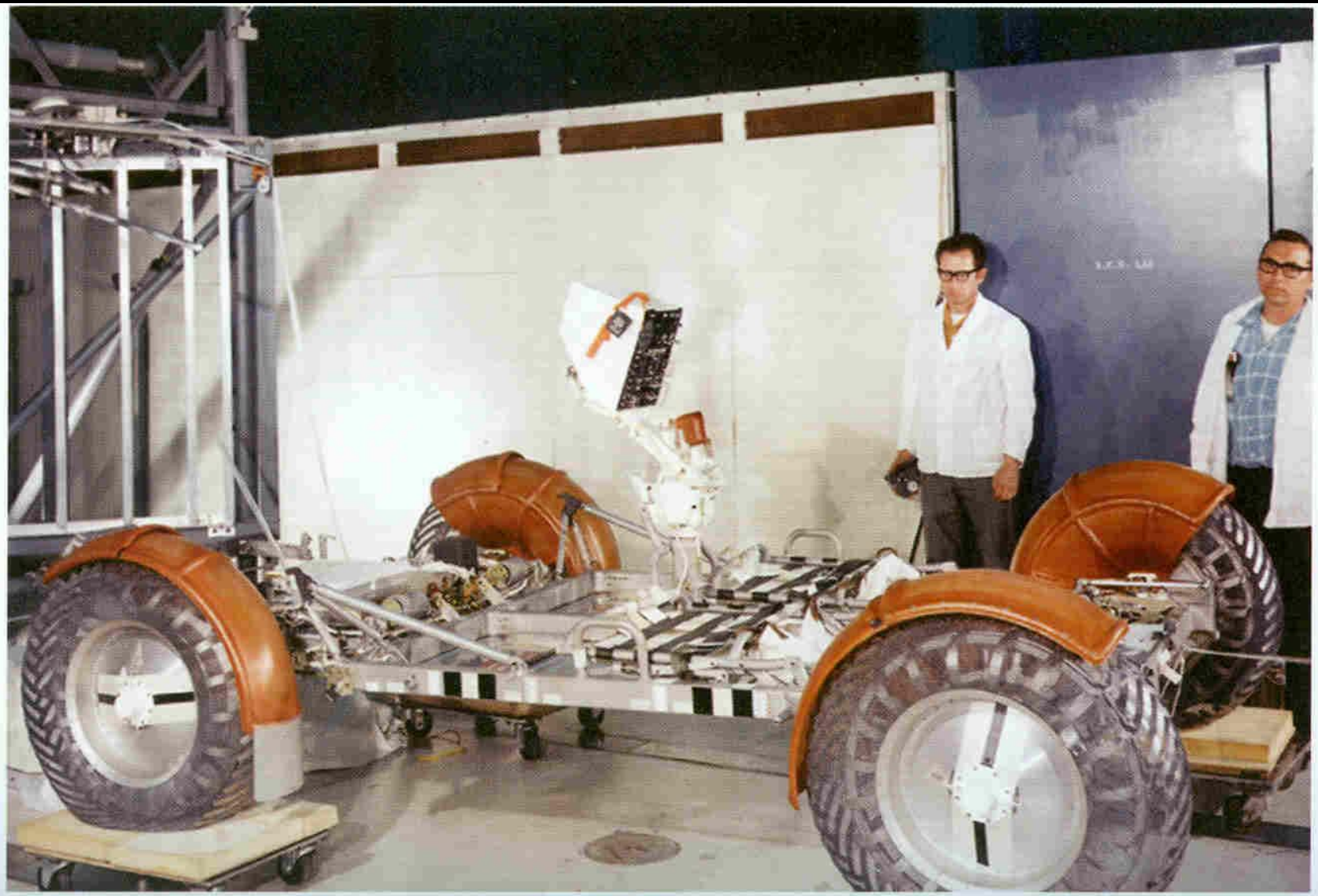


Plate 1–6 Deployment tests of the Lunar Roving Vehicle flight units were conducted at Marshall Space Flight Center (MSFC) in Huntsville, Alabama. (NASA/MSFC)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) *Delivery*

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) *Delivery*

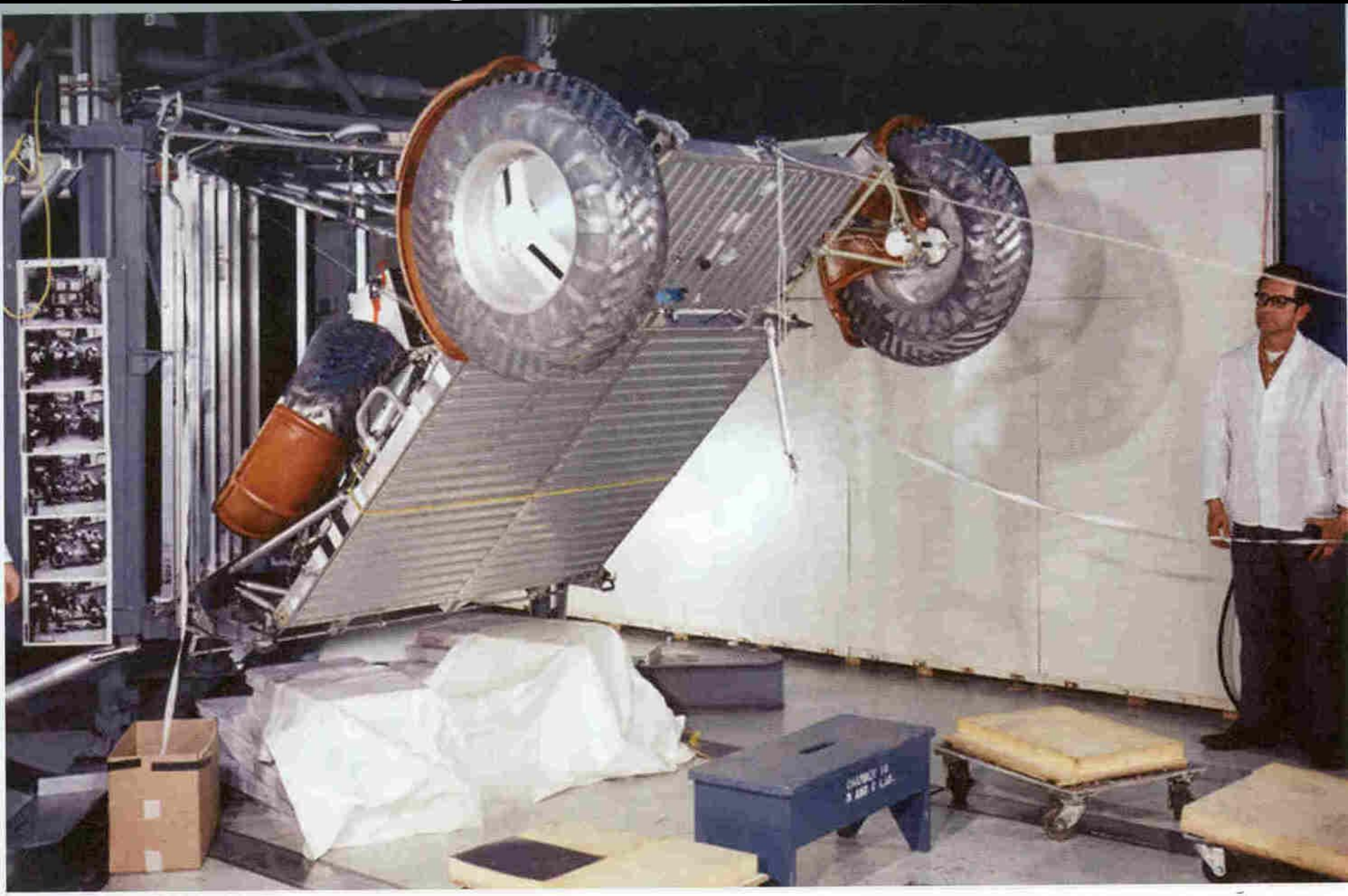


Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) *Delivery*

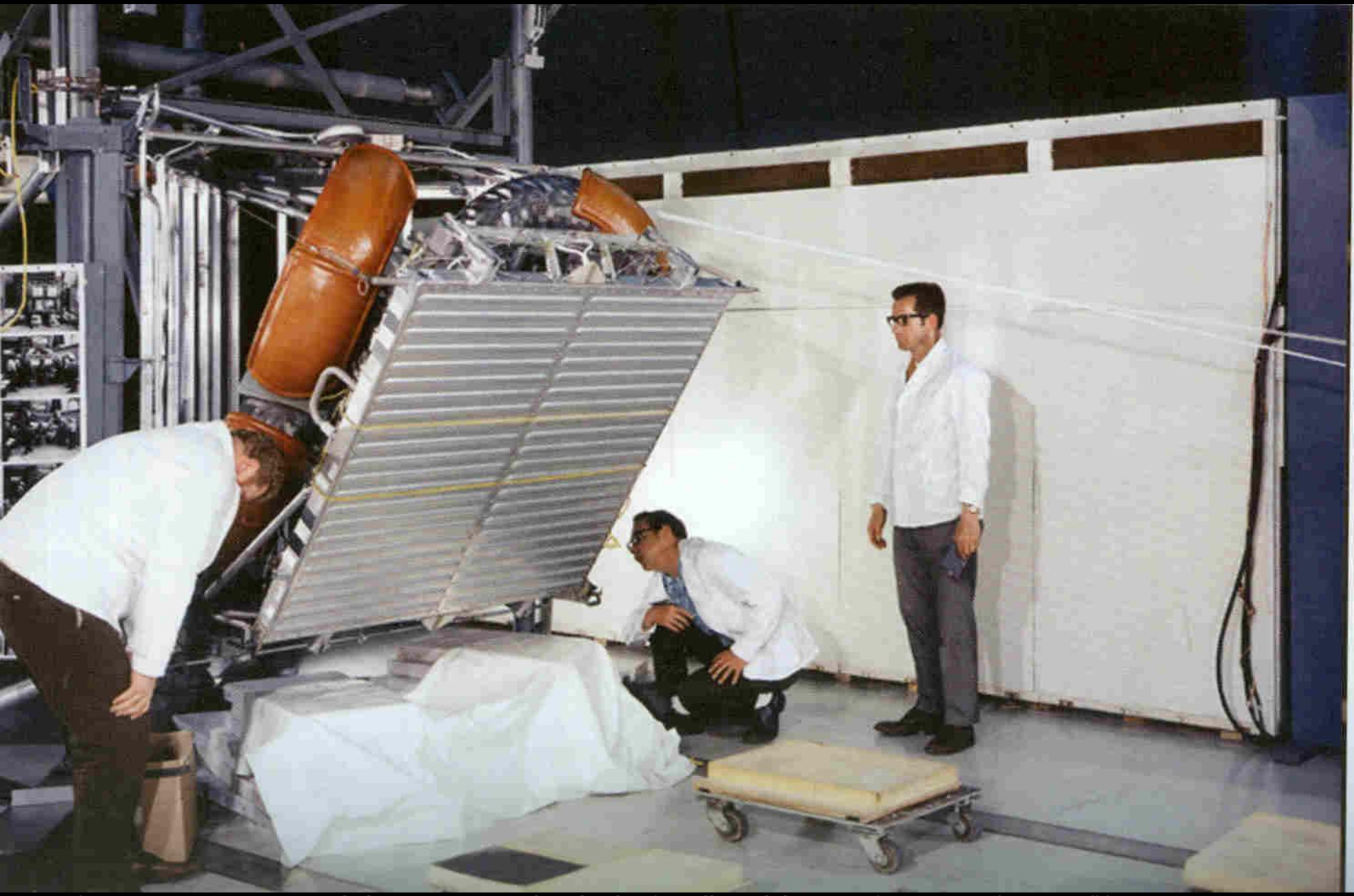


Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) *Delivery*

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV)

Delivery

Plate 19 LRV-1 undergoing fit checks with the Lunar Module *Falcon*. Lunar Module Pilot Jim Irwin is standing closest to the LRV with his hand on the Handling and Installation Tool fixture. (NASA/KSC)

Verifying that everything fits

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

LUNAR LANDING SITES

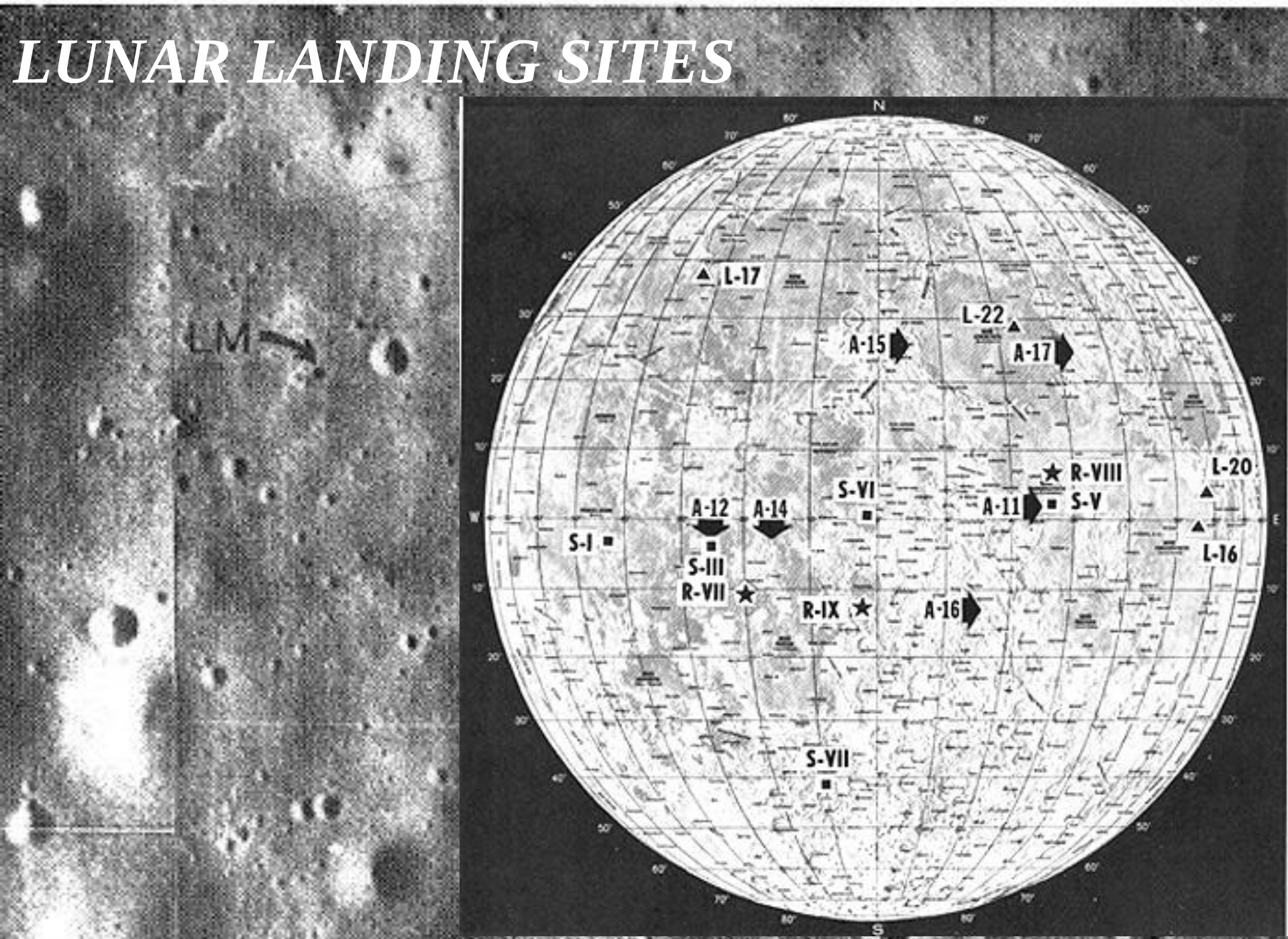


Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

LUNAR LANDING SITES

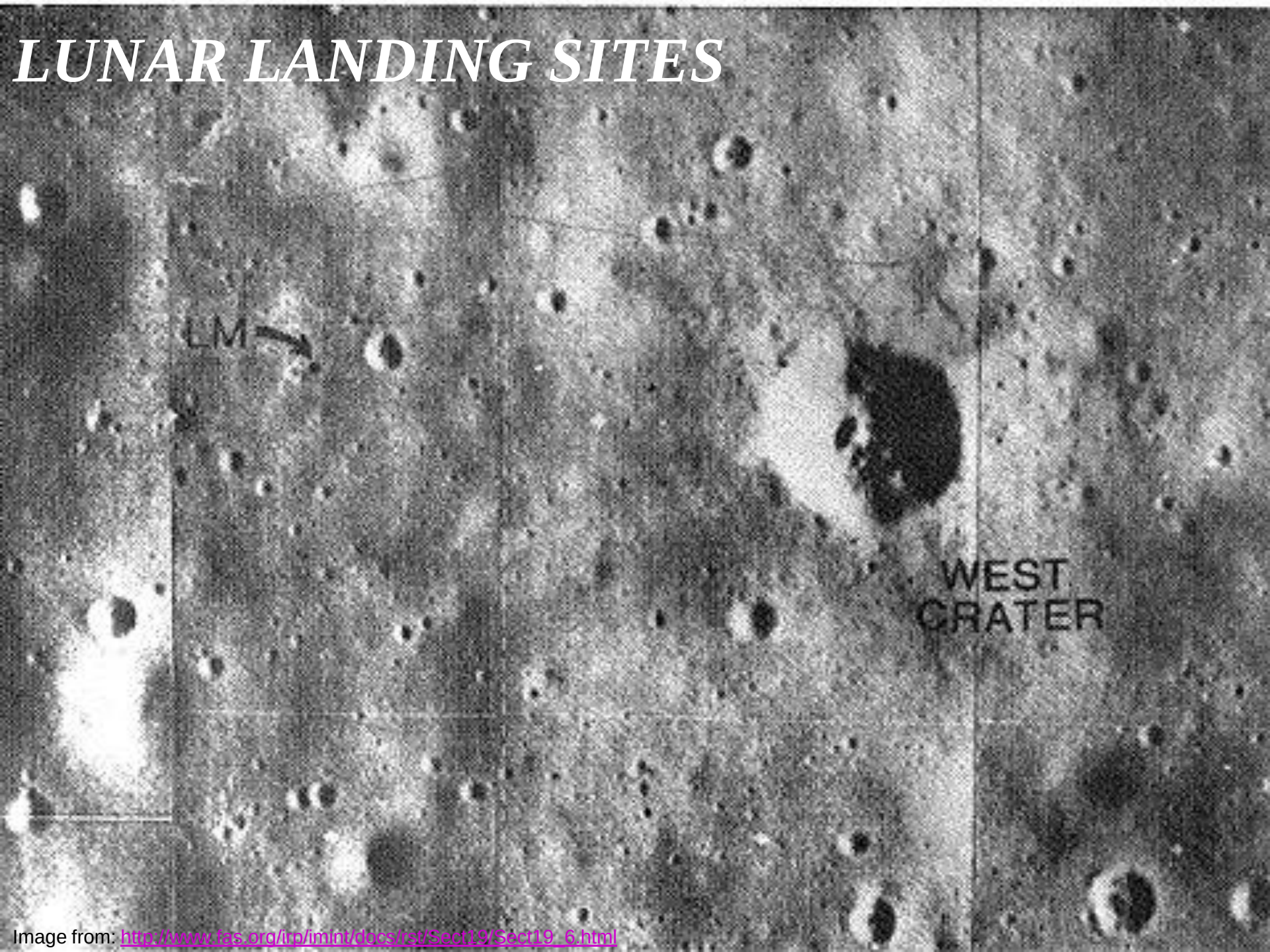


Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

LUNAR LANDING SITES

1960's and 1970's

1969 First Man on Moon

1971 Lunar Rover

Site Science Rationale

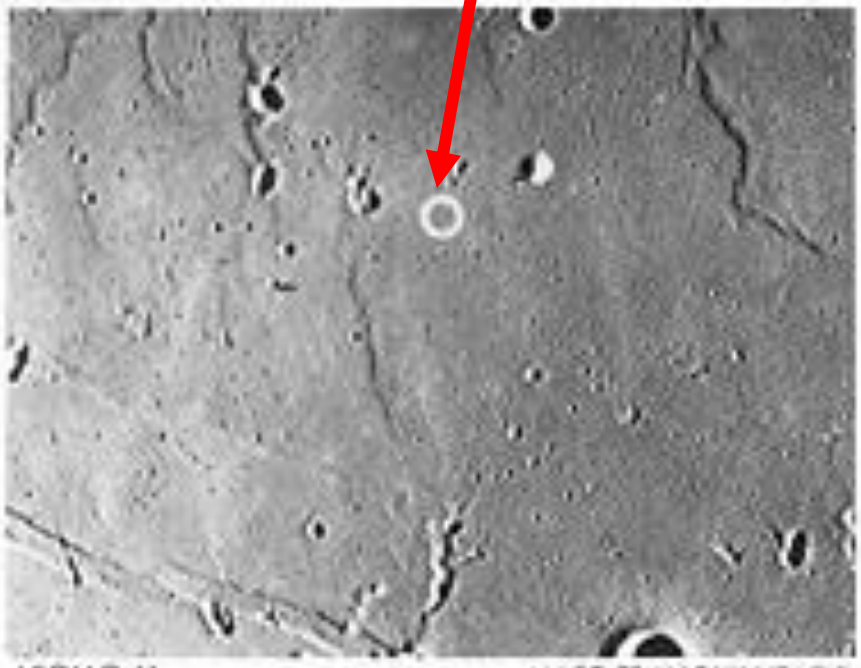
	Apollo 11	*Apollo 12*	*Apollo 14*	*Apollo 15*	*Apollo 16*	*Apollo 17*
Type	Mare	Mare	Hilly upland	Mountain front/ rille/mare	Highland hills and plains	Highland massifs and dark mantle
Process	Basin filling	Basin filling	Ejecta blanket formation	• Mountain scarp • Basin filling • Rille formation	• Volcanic construction • Highland basin filling	• Massif uplift • Lowland filling • Volcanic mantle
Material	Basaltic lava	Basaltic lava	Deep-seated crustal material	• Deeper-seated crustal material • Basaltic lava	Volcanic highland materials	• Crustal material • Volcanic deposits
Age	Older mare filling	Younger mare filling	• Early history of moon • Premare material • Imbrium Basin Formation	• Composition and age of Apennine Front material • Rille origin and age • Age of Imbrium Mare fill	• Composition and age of highland construction and modification • Composition and age of Cayley Formation	• Composition and age of highland massifs and possibly of lowland filling • Composition and age of dark mantle • Nature of a rock landslide

Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

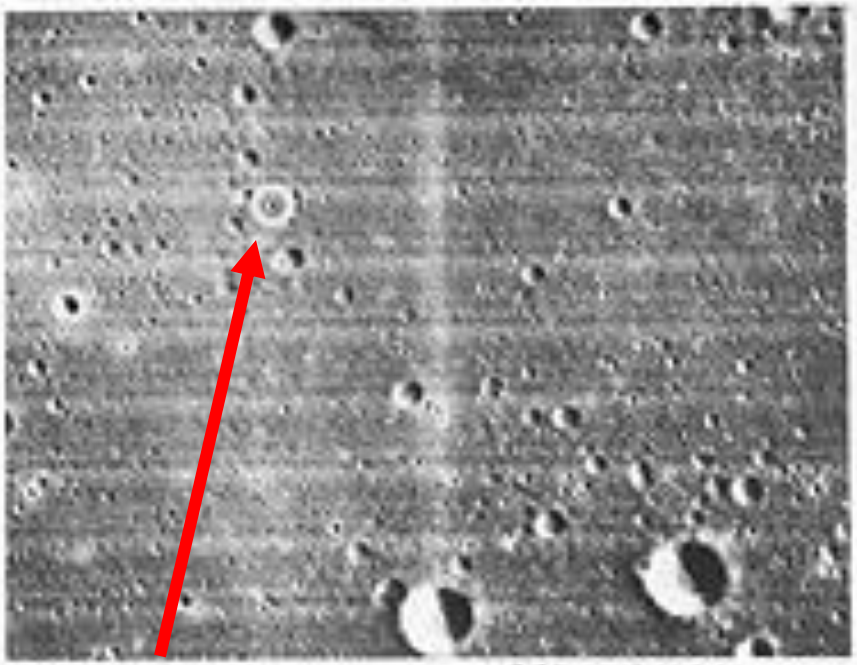
LUNAR LANDING SITES

1969
First Man
on Moon

LM



APOLLO 11 MARE TRANQUILLITATIS

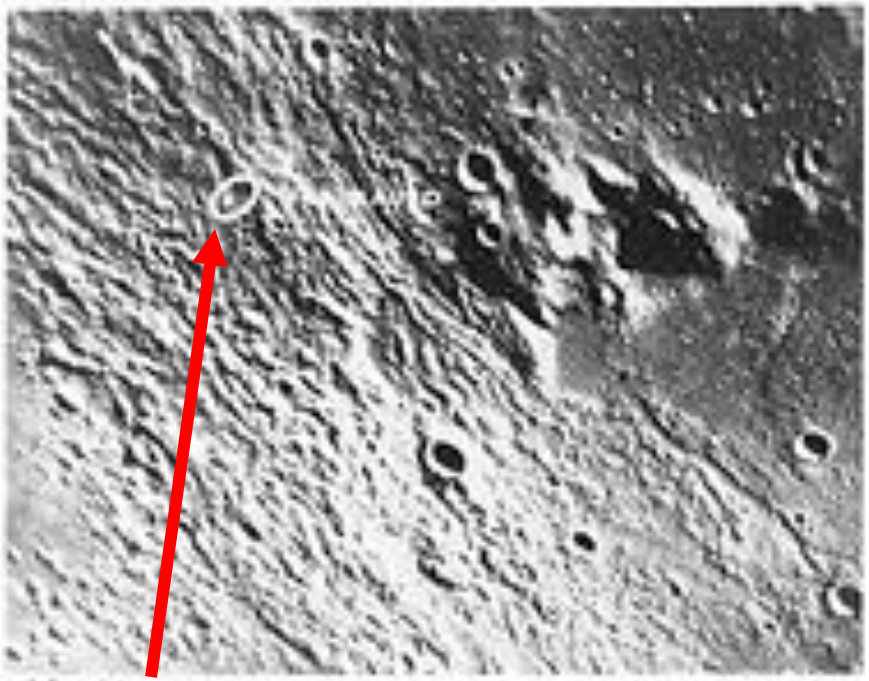


APOLLO 12 OCEANUS PROCELLARUM

Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

LUNAR LANDING SITES

1971 Lunar Rover



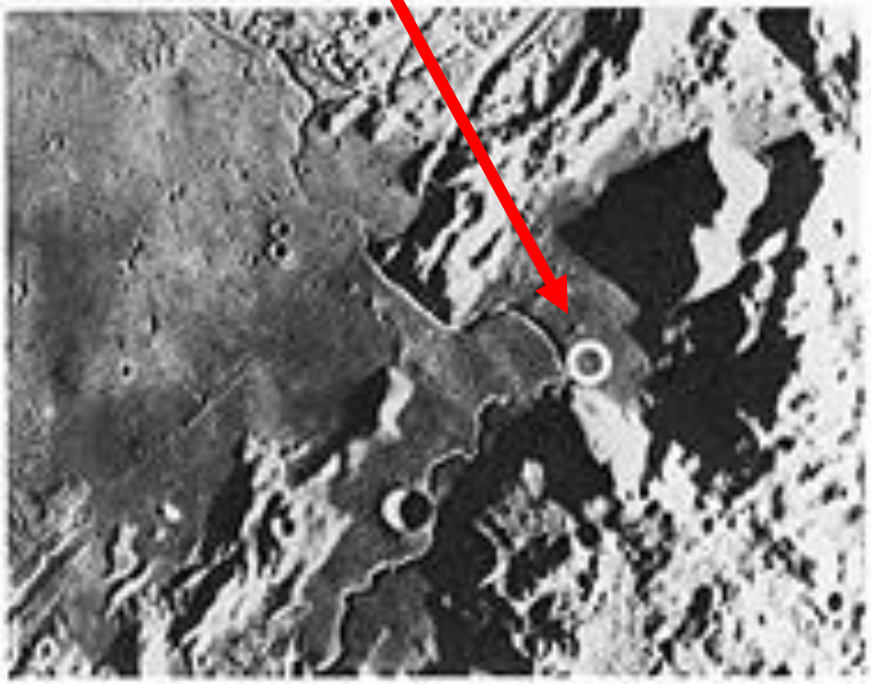
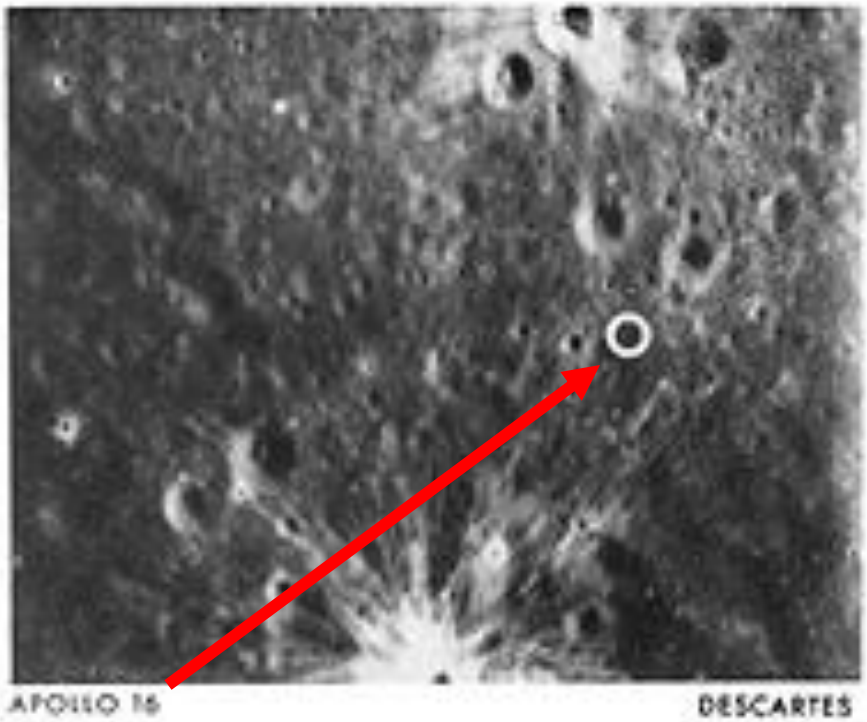


Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

LUNAR LANDING SITES



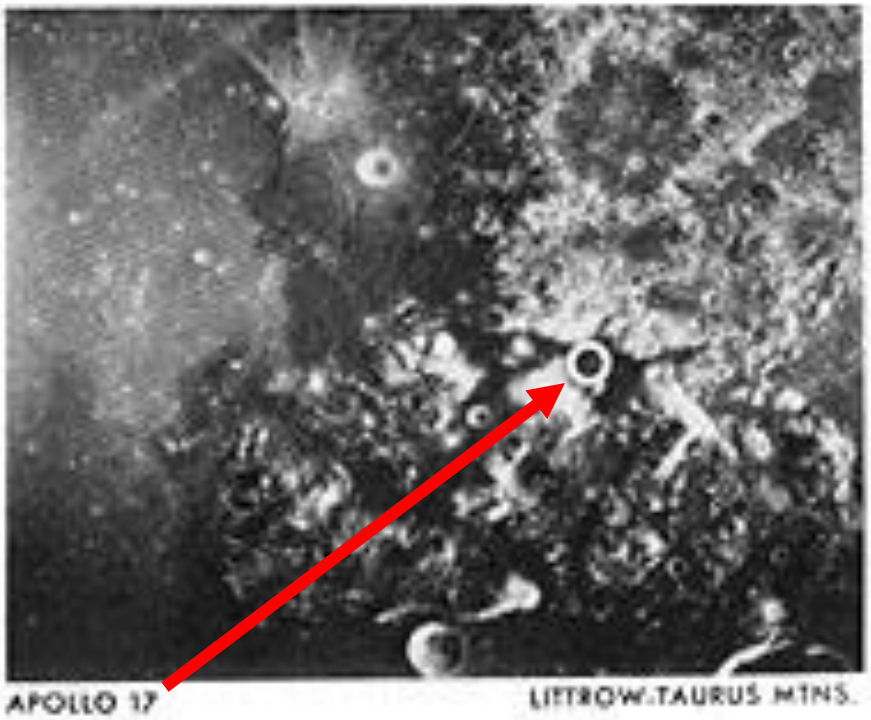


Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

"Lunar Roving Vehicle" (LRV)

Delivery
1971

Need to prevent all equipment from damage due to mechanical vibration and solar radiation

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV)

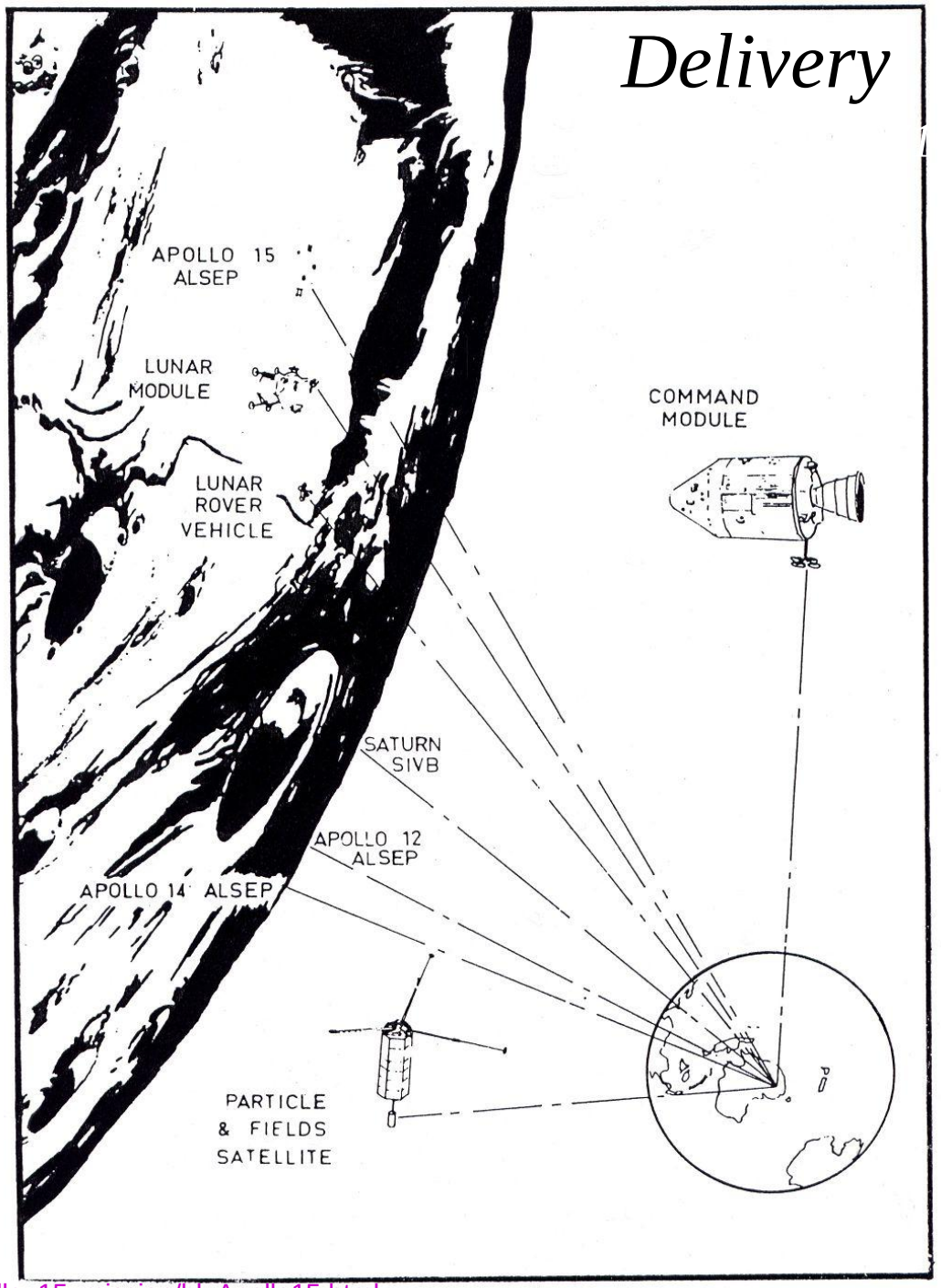


Image from: http://www.honeysucklecreek.net/msfn_missions/Apollo_15_mission/hl_Apollo15.html

"Lunar Roving Vehicle" (LRV) *Delivery*

Command/Service Module (CSM) and Lunar Module (LM) – LRV folds into side of LM

Image from:http://www.celestialmatters.org/?q=node/20.

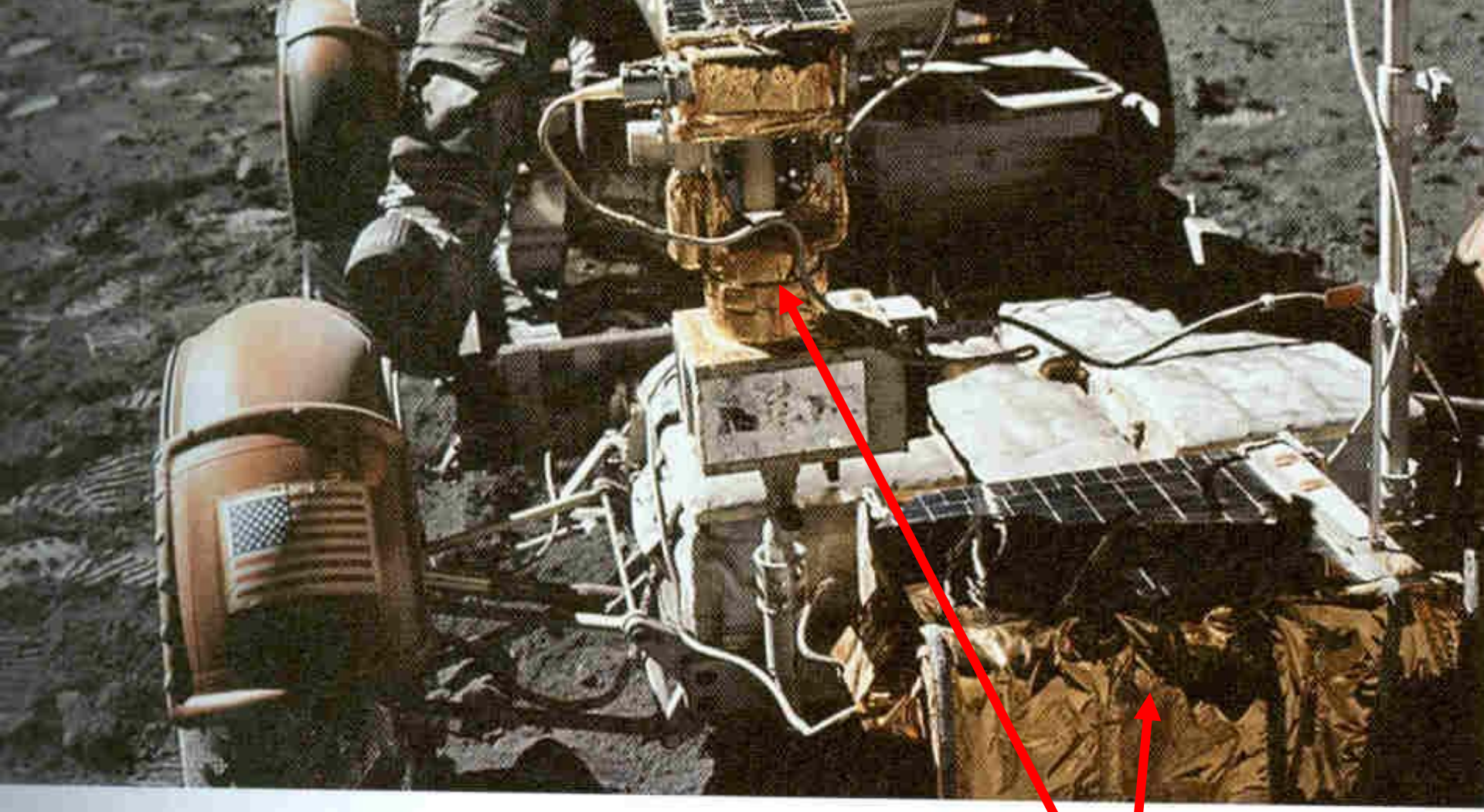
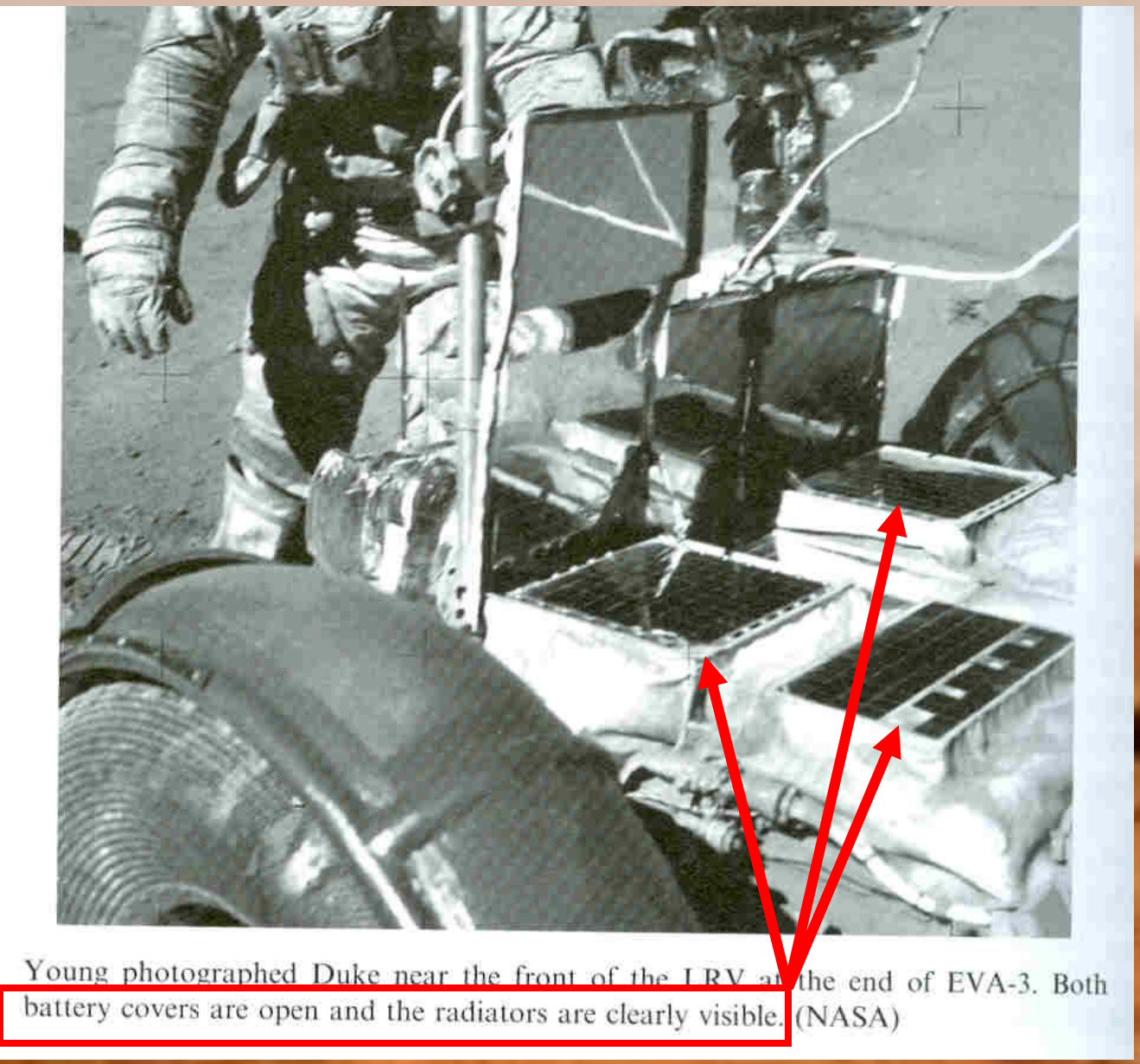


Plate 45 The pressurized EVA suit made it difficult to bend at the waist while trying to get into the LRV, as shown here with Harrison Schmitt at the Station 9 stop. He is holding the LRV Sampler in his right hand. Good photo showing the radiating surfaces of the TV camera and the Lunar Communications Relay Unit (LCRU). (NASA)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) - *HARDENING FOR SPACE*

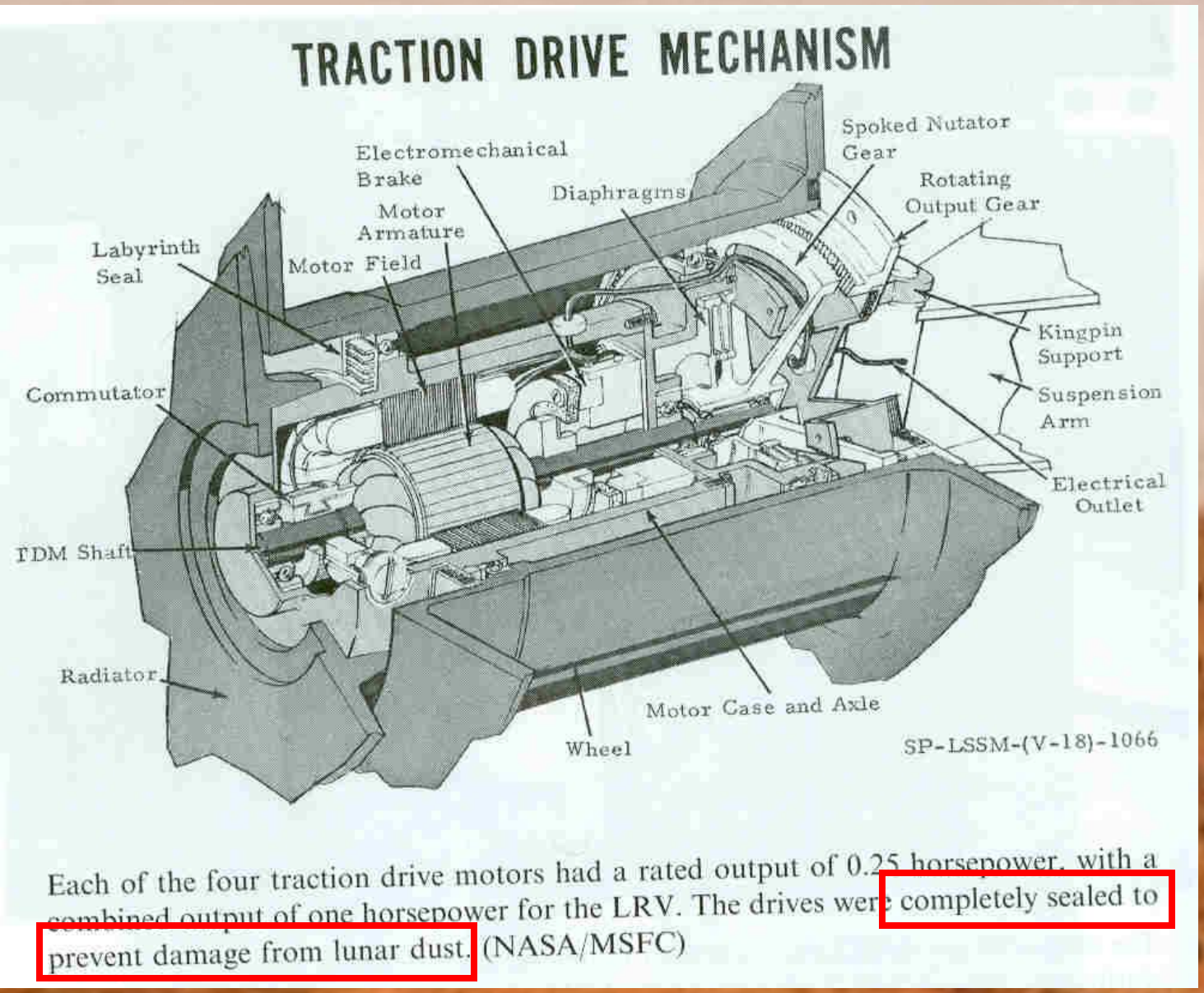


Young photographed Duke near the front of the LRV at the end of EVA-3. Both battery covers are open and the radiators are clearly visible. (NASA)

"Waste Heat" from all devices needs to be dissipated to prevent overheating

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

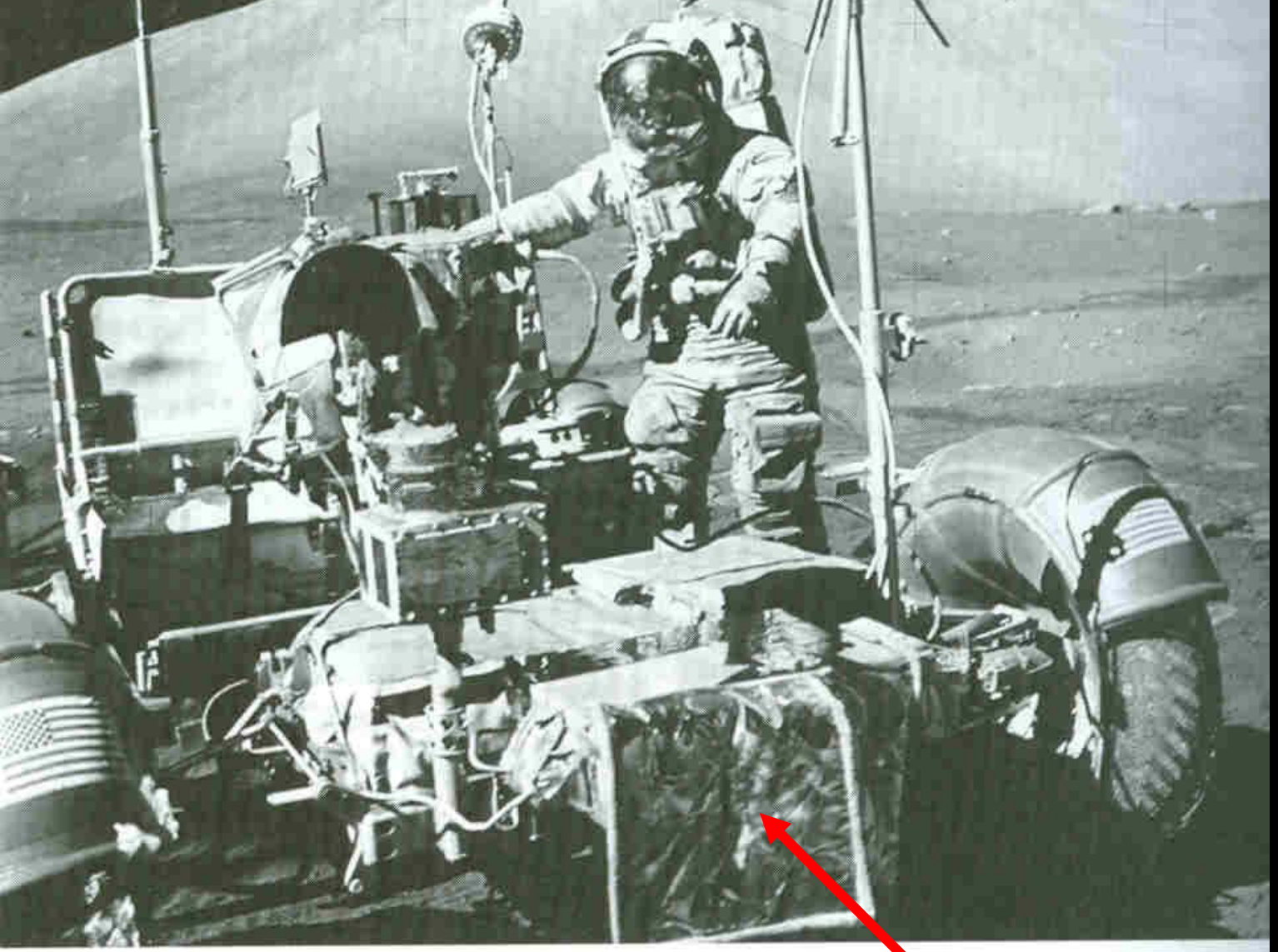
"Lunar Roving Vehicle" (LRV) - *HARDENING FOR SPACE*



Each of the four traction drive motors had a rated output of 0.25 horsepower, with a combined output of one horsepower for the LRV. The drives were completely sealed to prevent damage from lunar dust. (NASA/MSFC)

Motors

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.



Harrison Schmitt photographed Eugene Cernan next to the LRV at the end of the third EVA, with the South Massif prominently in the background. Note the reflection on the gold mesh of the high-gain antenna from the radiator surface of the TV camera. The thermal blankets of the LCRU are pulled back to help dissipate heat. (NASA)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

"Lunar Roving Vehicle" (LRV) *1971*

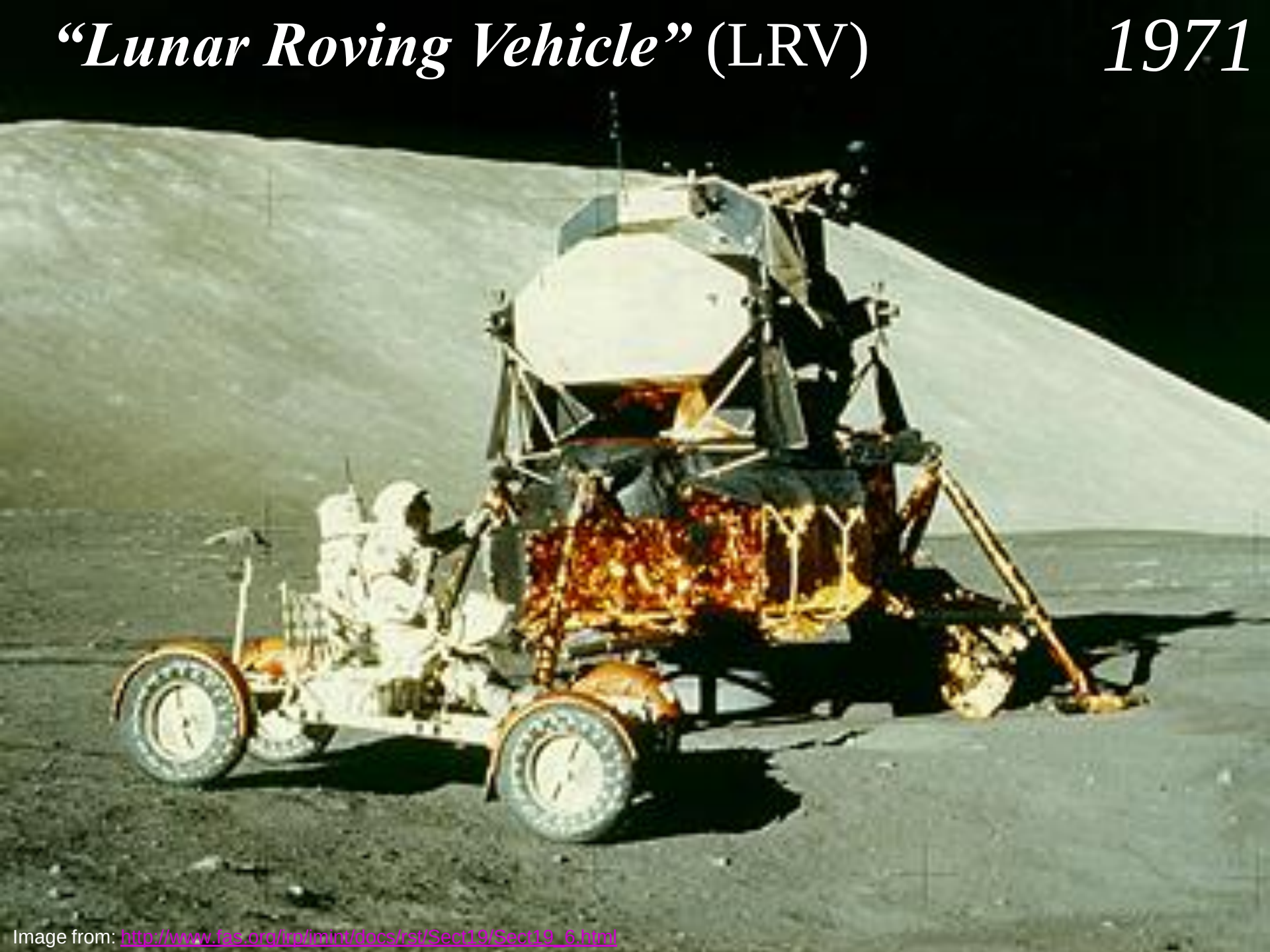


Image from: http://www.fas.org/irp/imint/docs/rst/Sect19/Sect19_6.html

Mars

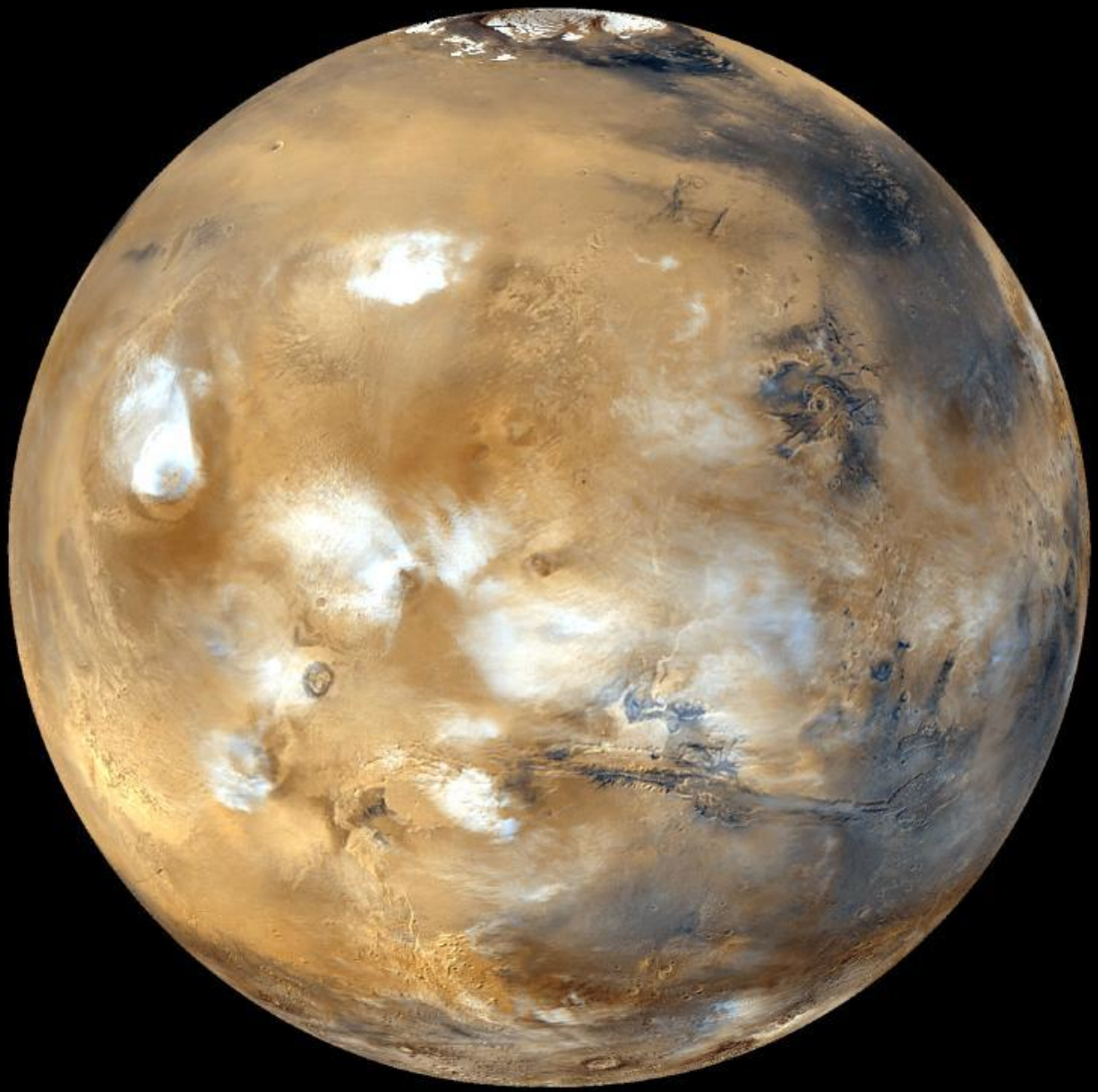


Image from: http://photojournal.jpl.nasa.gov/catalog/PIA02570

Mars Rovers

Delivery

Mars Pathfinder “Sojourner”

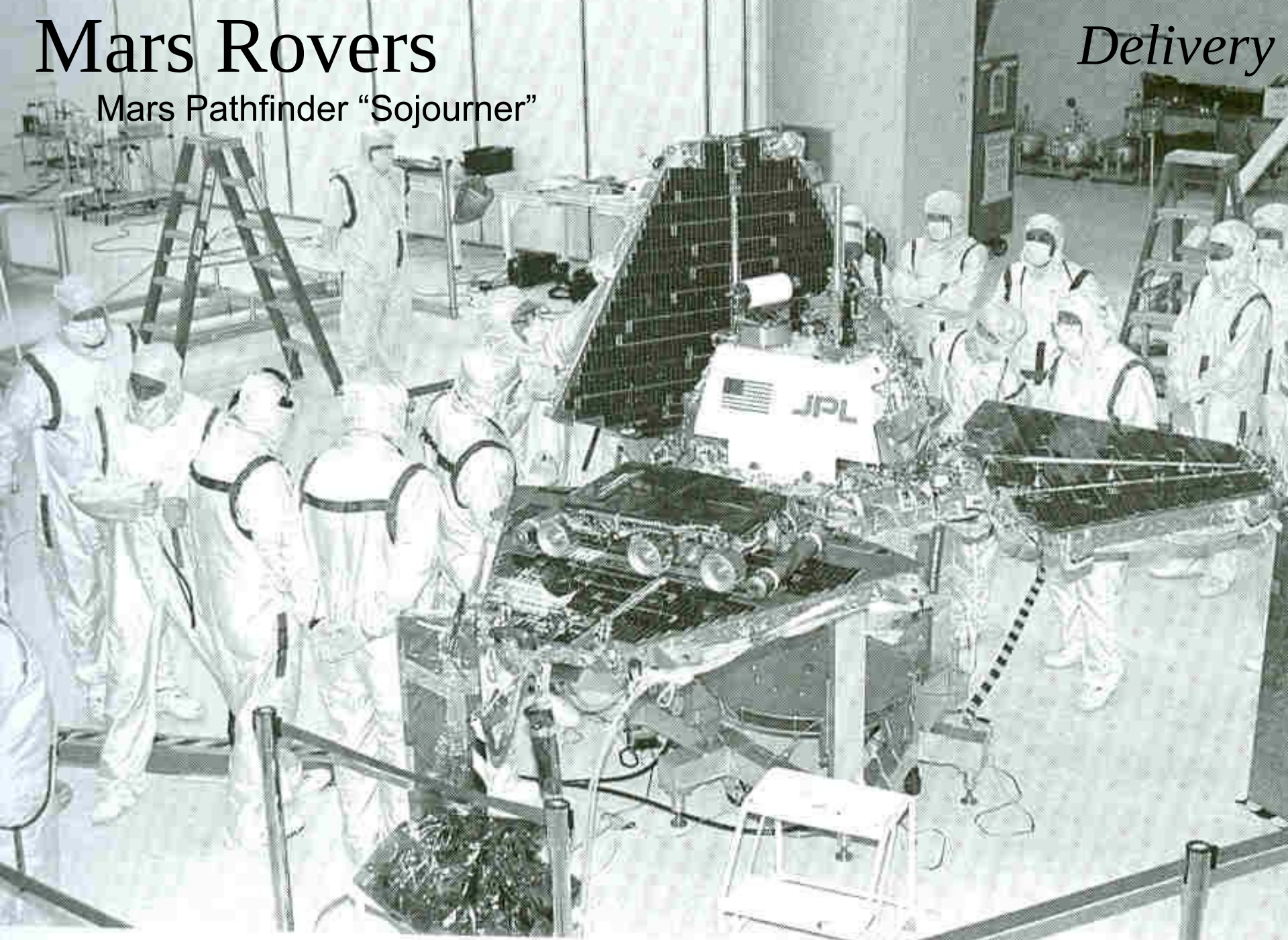
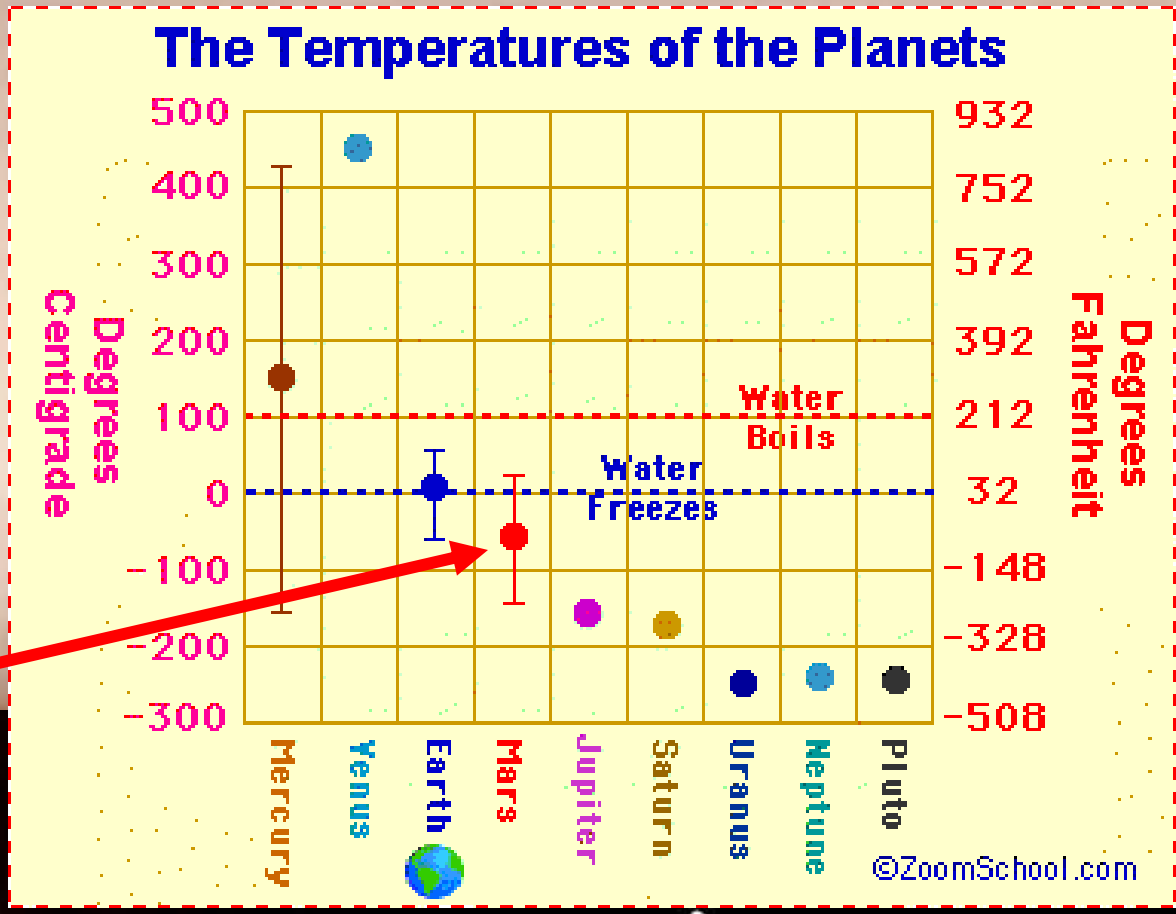


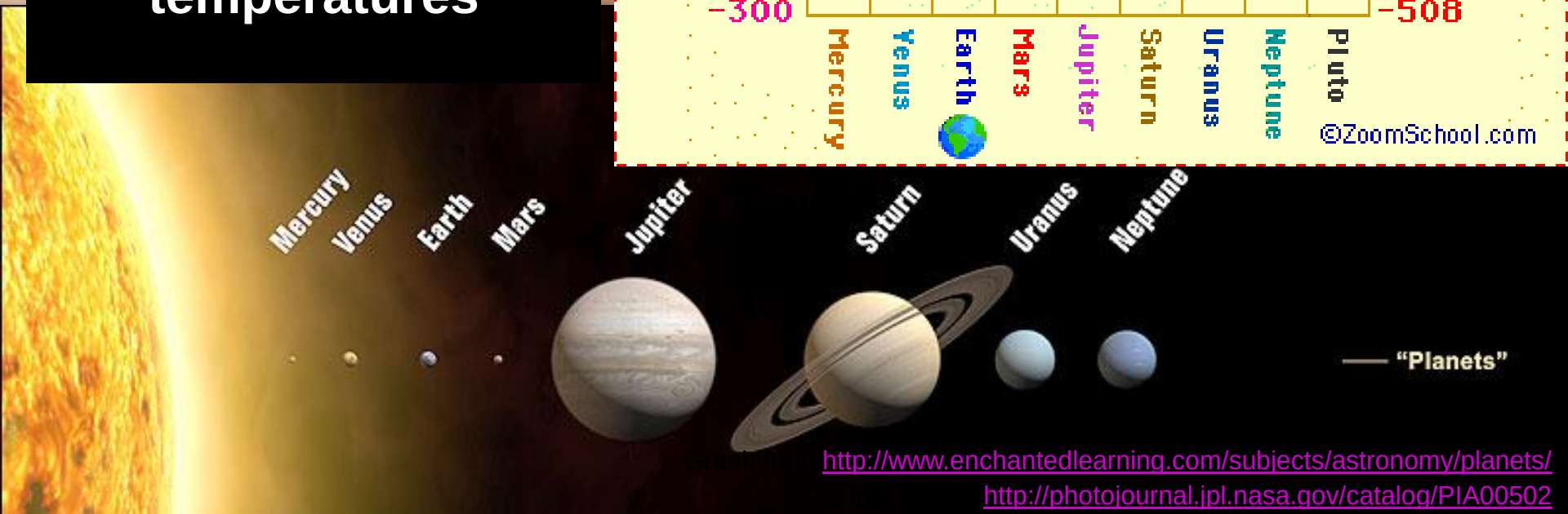
Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition,

HARDENING FOR SPACE

PLANET TEMPERATURES

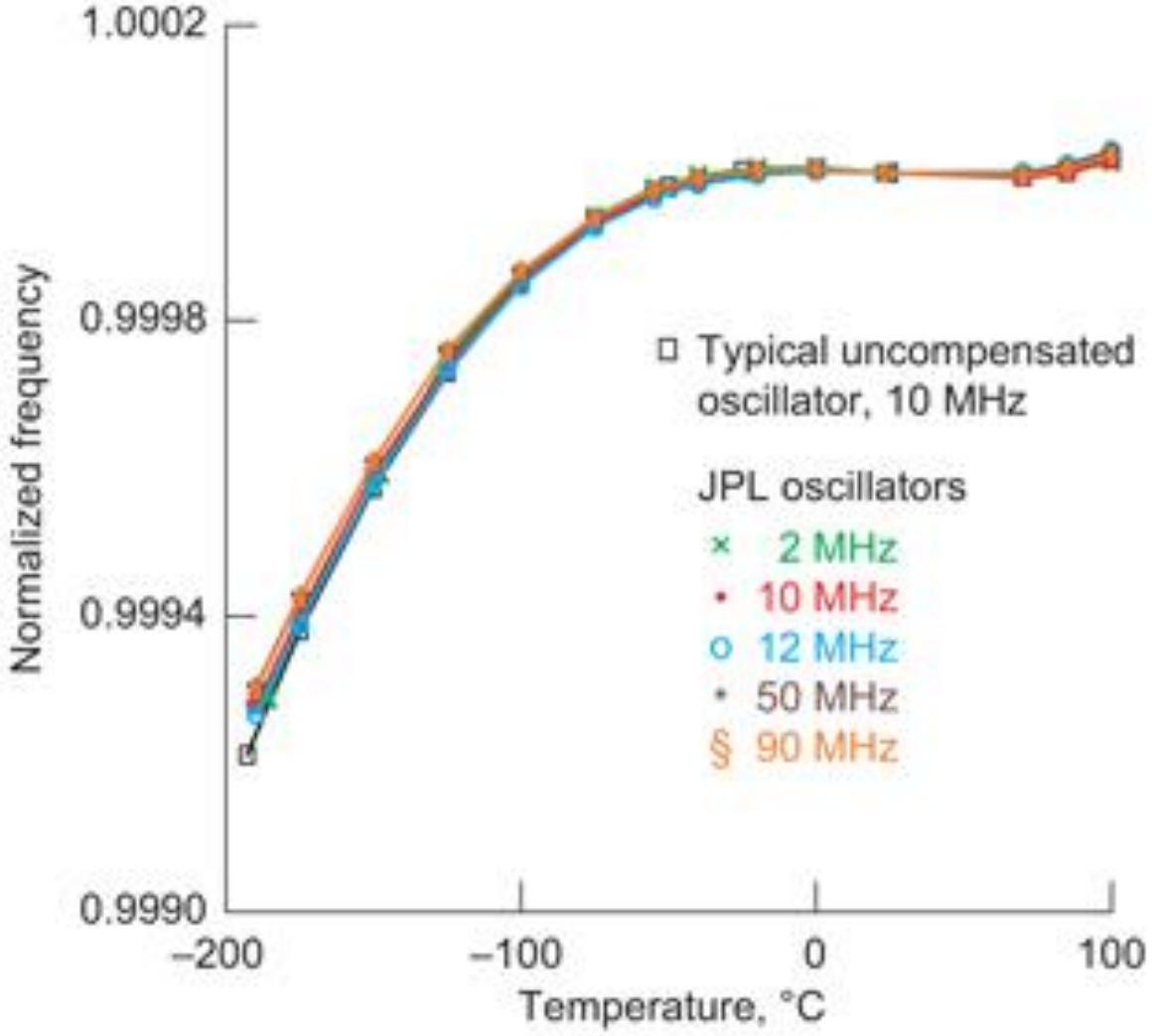
Circuit functionality (including computing) diminished at lower temperatures





Graphics: http://www.enchantedlearning.com/subjects/astronomy/planets/
http://photojournal.jpl.nasa.gov/catalog/PIA00502

HARDENING FOR SPACE



SOURCE: http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20050217239_2005219510.pdf

HARDENING FOR SPACE

See more on hardening for space at:

Patterson, R.L.. and Hammoud, Ahmad. (2004) Reliability of Electronics for Cryogenic Space Applications Being Assessed. NASA Research and Technology 2004.

and at:

NASA Glenn Research Center Space Environment and Experiments Branch

Mars Rovers

Mars Pathfinder “Sojourner”

Delivery

1996

Also need to prevent all equipment from damage due to mechanical vibration and unshielded solar radiation

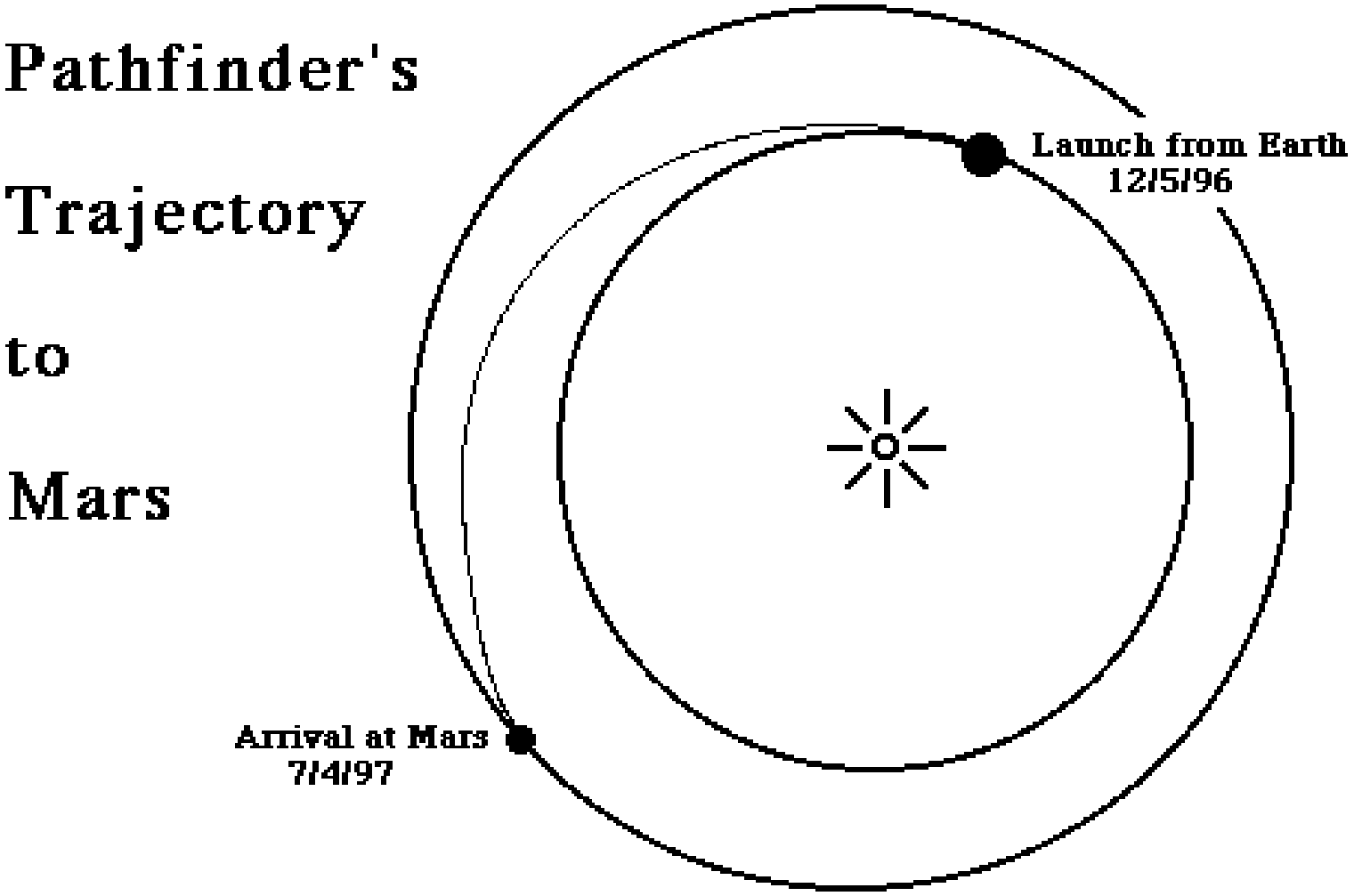
Image from: http://science.ksc.nasa.gov/mars/rovercom/rovintrot.html

Mars Rovers

Mars Pathfinder “Sojourner”

Delivery

1996



http://tes.asu.edu/EDUCATION/activities/95_96guide/mpf_diagrams.html

Mars Rovers

HARDENING FOR SPACE

1996

Mars Pathfinder “Sojourner”

A sophisticated airbag deployment system was developed by JPL to cushion the landing of Pathfinder and protect the spacecraft from boulders and rocks by bouncing and rolling across the surface of Mars until coming to a stop. The airbags were then deflated and retracted underneath the lander. (NASA/JPL-Caltech)

Need to prevent all equipment from damage due to mechanical vibration

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

HARDENING FOR SPACE

1996

Mars Rovers

Mars Pathfinder “Sojourner”

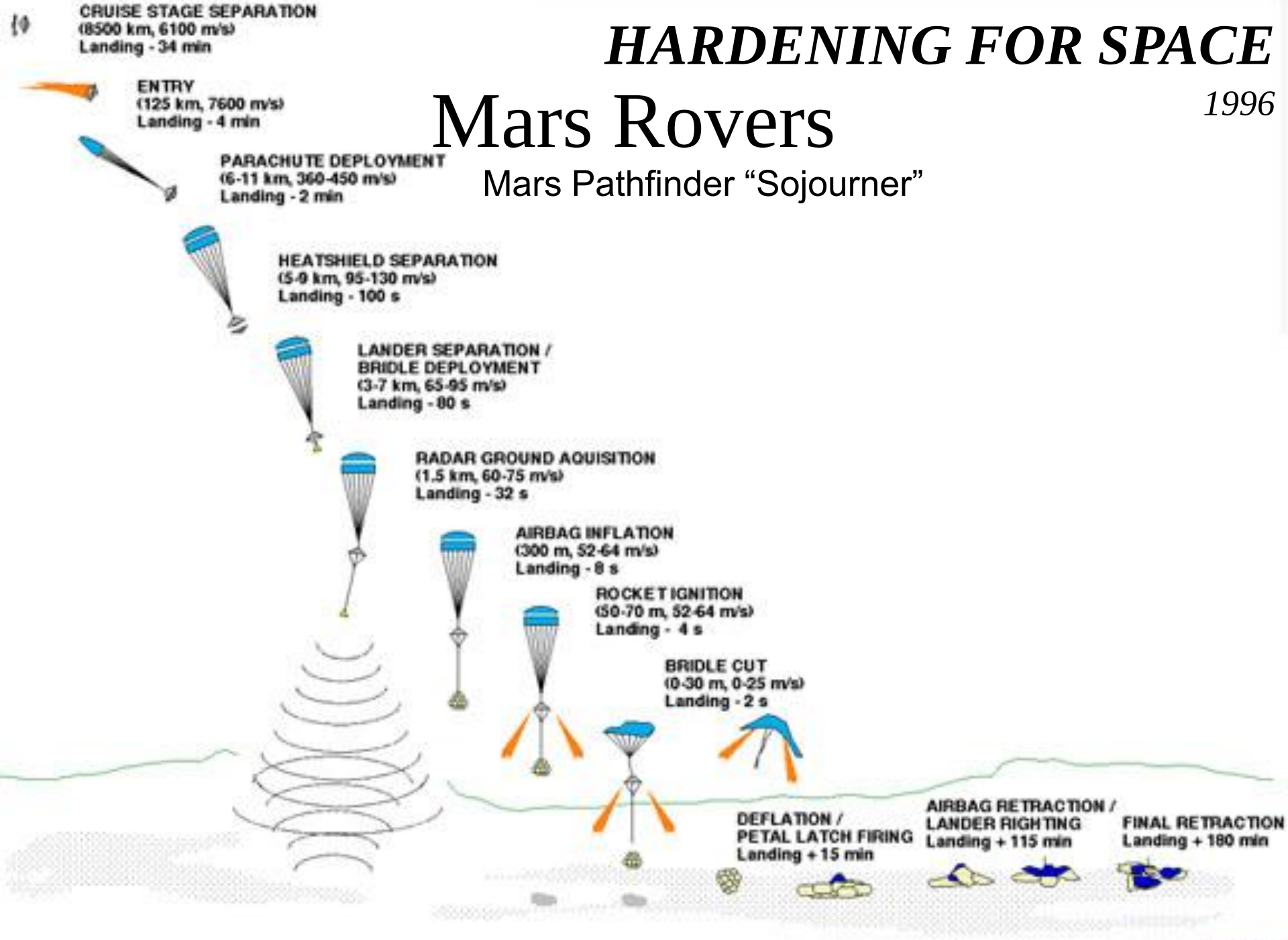


Image from: http://marsprogram.jpl.nasa.gov/MPF/mpf/edl/edl1.html

Mars Rovers

Delivery (Deployment)

1996

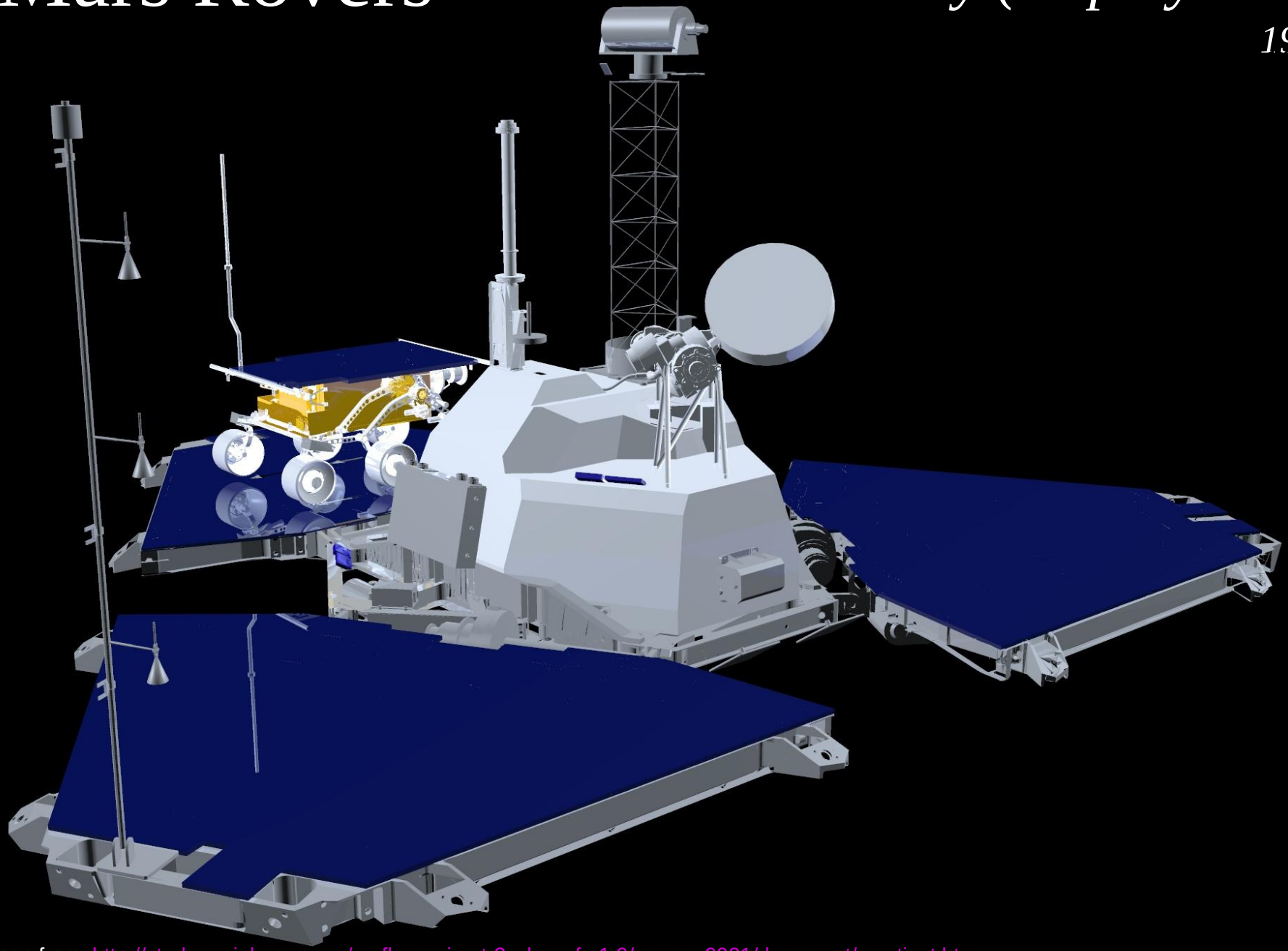


Image from: http://starbase.jpl.nasa.gov/mpfl-m-asimet-3-rdr-surf-v1.0/mpam_0001/document/asmtinst.htm

Mars Rovers

Mars Pathfinder “Sojourner”

Delivery (Deployment)

1996

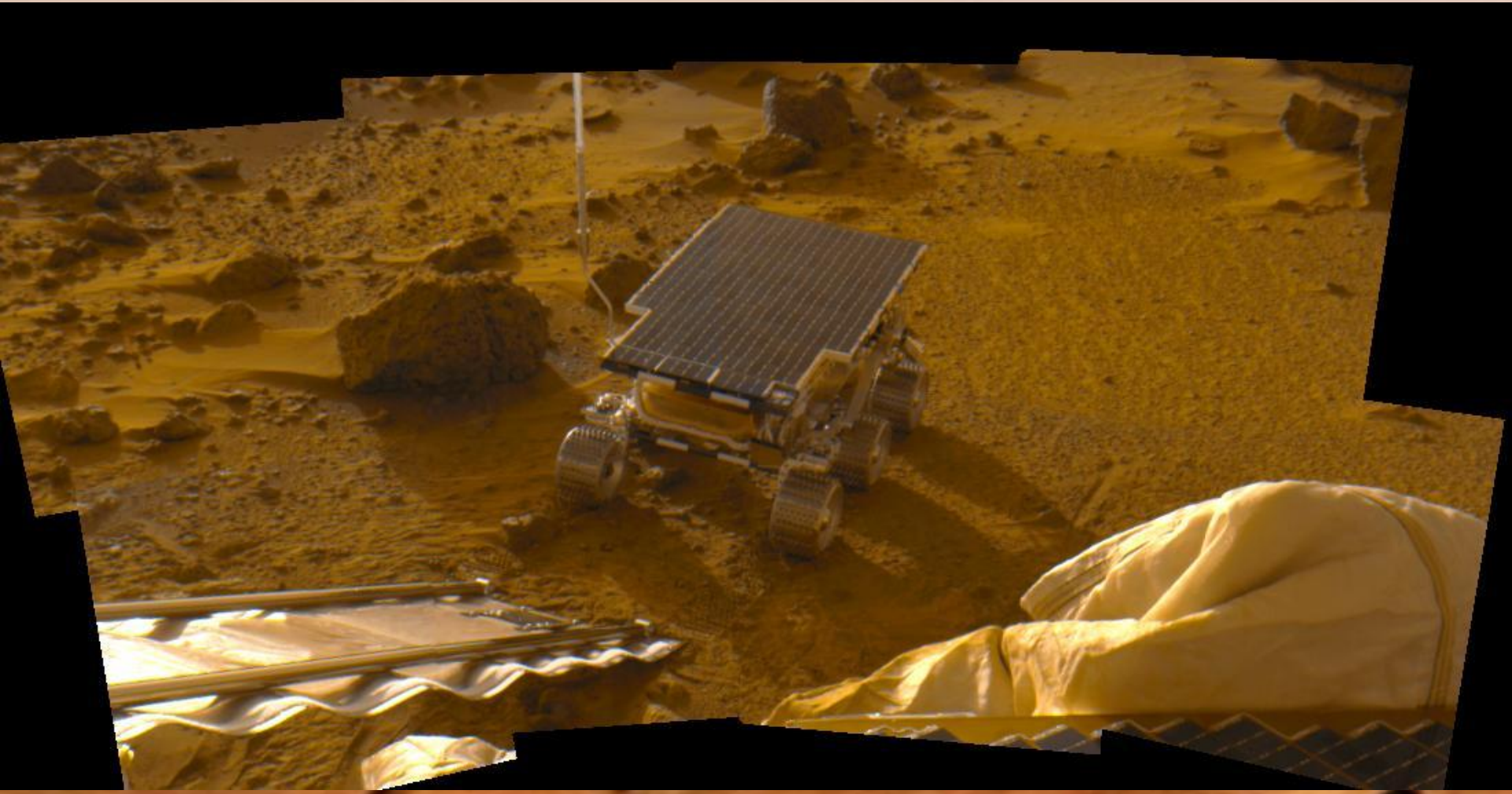


Image from: http://photojournal.jpl.nasa.gov/index.html

Mars Rovers

"Spirit" & "Opportunity"

Delivery

Plate 51 Technicians at the Kennedy Space Center close the solar panels on MER-2 in preparation for mounting in the lander. Mars Exploration Rover *Spirit* was launched toward Mars on 10 June 2003, and *Opportunity* followed on 7 July 2003. They landed successfully on 4 and 24 January 2004 (Universal Time). (NASA/KSC)

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

Mars Rovers

“Spirit” & “Opportunity”

Delivery

2004

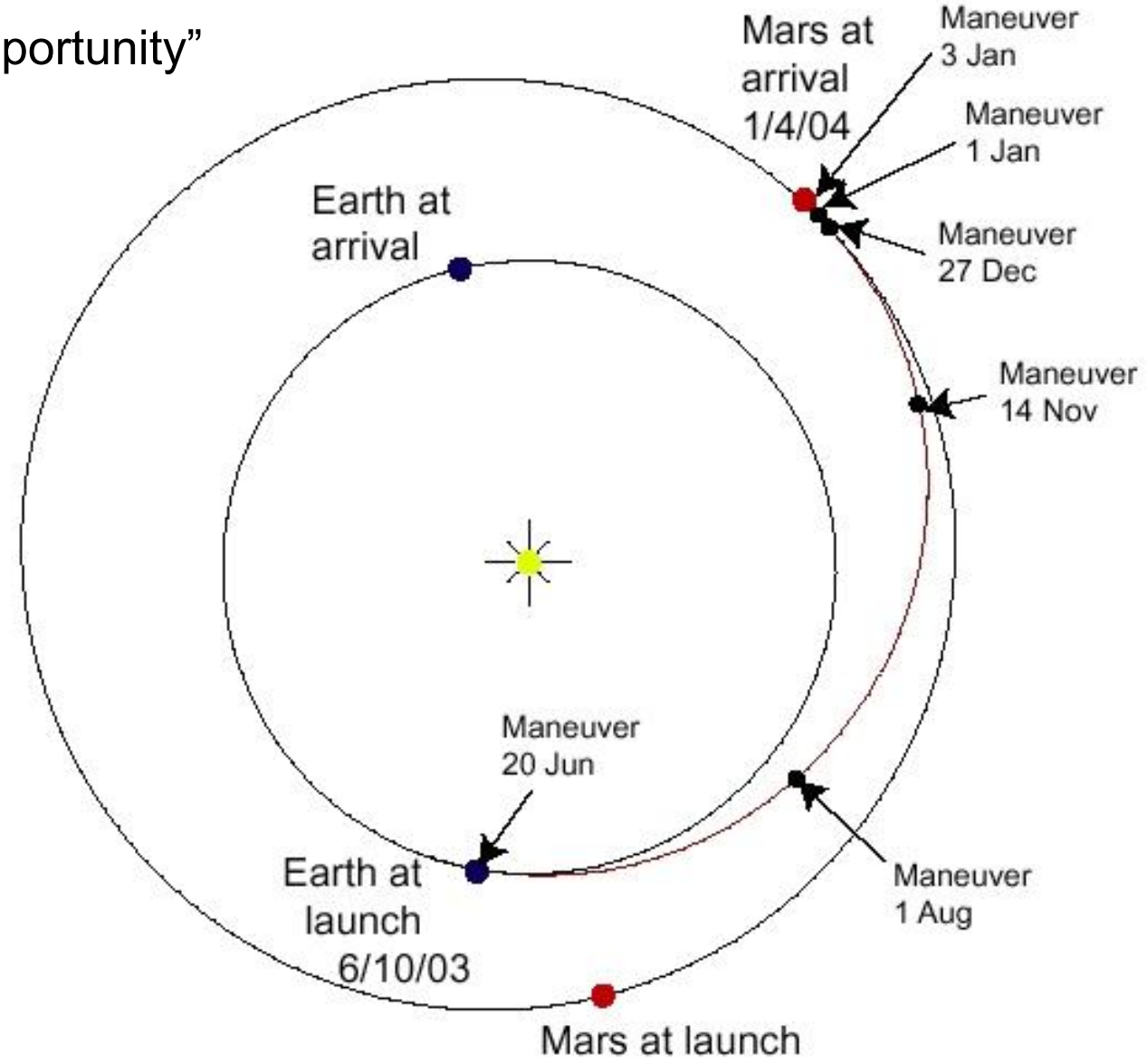
Image from: http://www.talkingproud.us/ScienceMarsUpdate.html

Mars Rovers

Delivery

2004

"Spirit" & "Opportunity"



Spirit trajectory

Image from: http://www.mars.tv/mer/overview.html

Mars Rovers

Delivery
2004

"Spirit" & "Opportunity"

NOTE: Diagram from 1996 Pathfinder mission

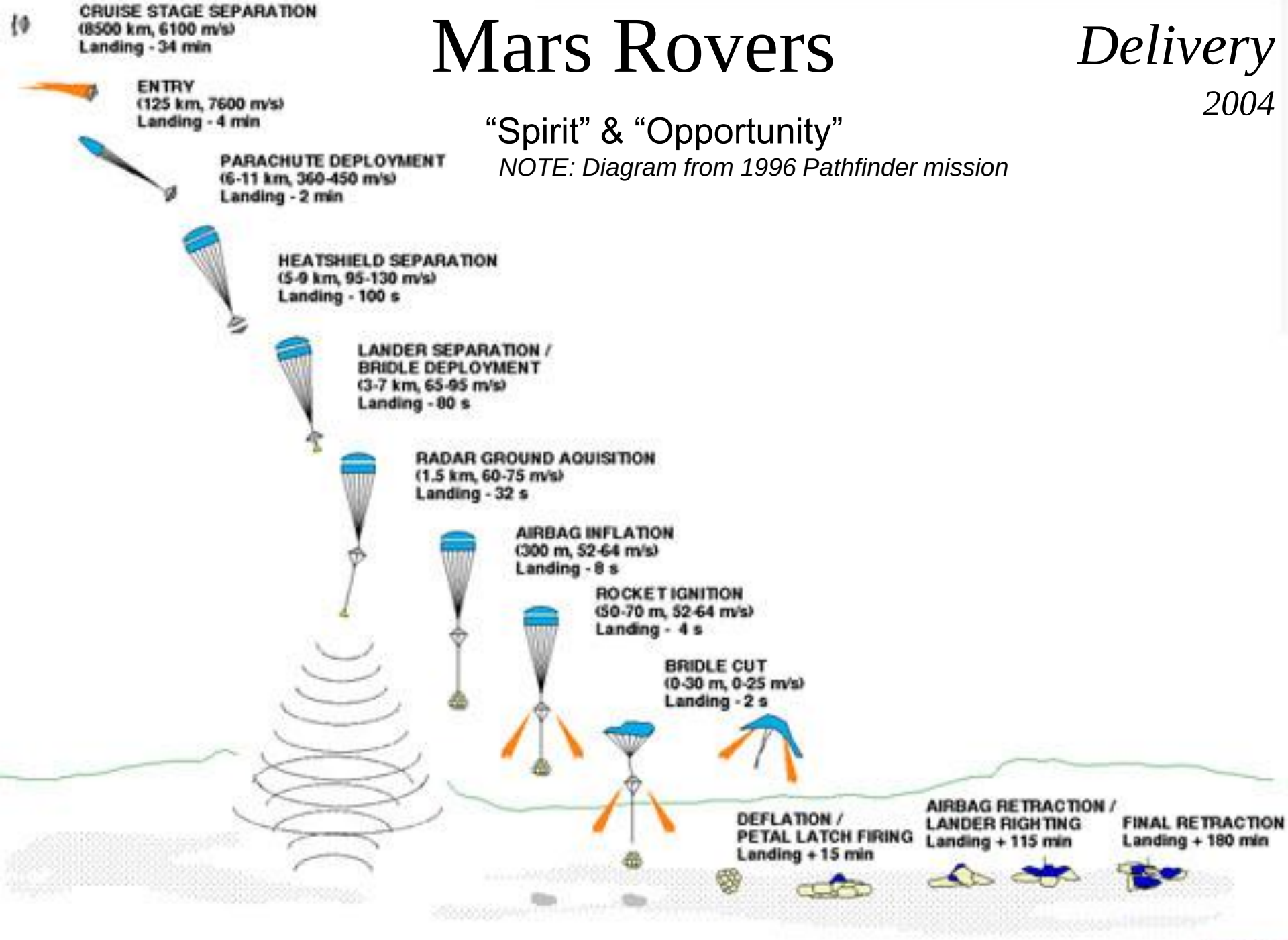


Image from: http://marsprogram.jpl.nasa.gov/MPF/mpf/edl/edl1.html

Mars Rovers

"Spirit" & "Opportunity"

Delivery

2004

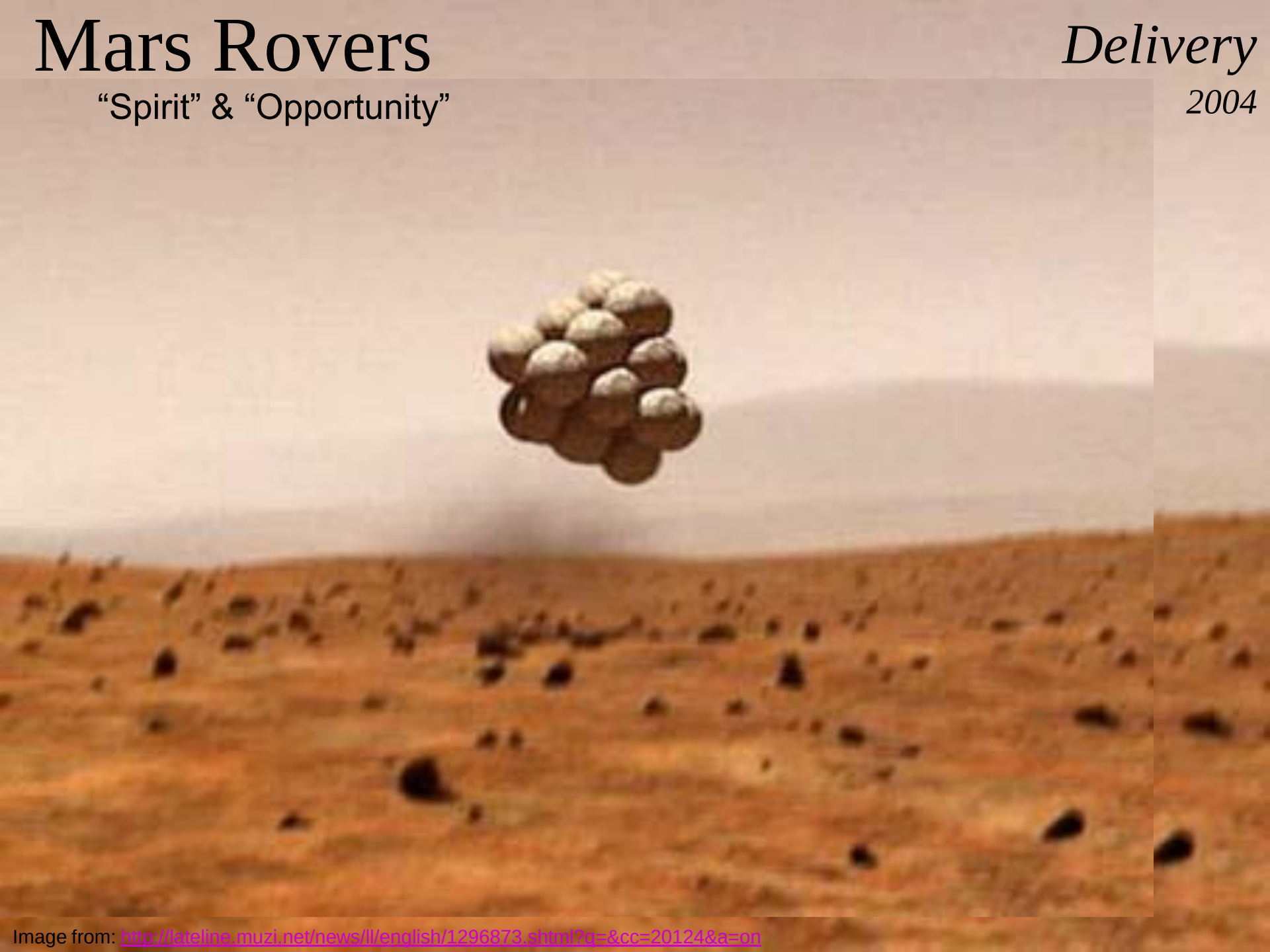


Image from: http://lateline.muzi.net/news/ll/english/1296873.shtml?q=&cc=20124&a=on

Mars Rovers

"Spirit" & "Opportunity"

Delivery (Deployment)

2004

Image from: Young, A.H. ***Lunar and planetary rovers: the wheels of Apollo and the quest for mars***, Springer; 1 edition, August 1, 2006.

Mars Rovers

Mars Science Lab Curiosity

Delivery

Image from: http://www.nasa.gov/mission_pages/mars/images/20081204-b.html

Mars Rovers

Mars Science Lab

Delivery

Image from: http://marsprogram.jpl.nasa.gov/msl/news/whatsnew/index.cfm?FuseAction=ShowNews&NewsID=86

Mars Rovers

2011

Mars Science Lab “CURIOSITY”

Image from: https://www.youtube.com/watch?v=7zpojhD4hpI

Europa Rover ?

TRAVEL DISTANCES FROM EARTH:

```
To Moon    =      384,403 km
To Mars    =   54,600,000 km (closest)
To Europa  = 590,629,248 km (closest)
```

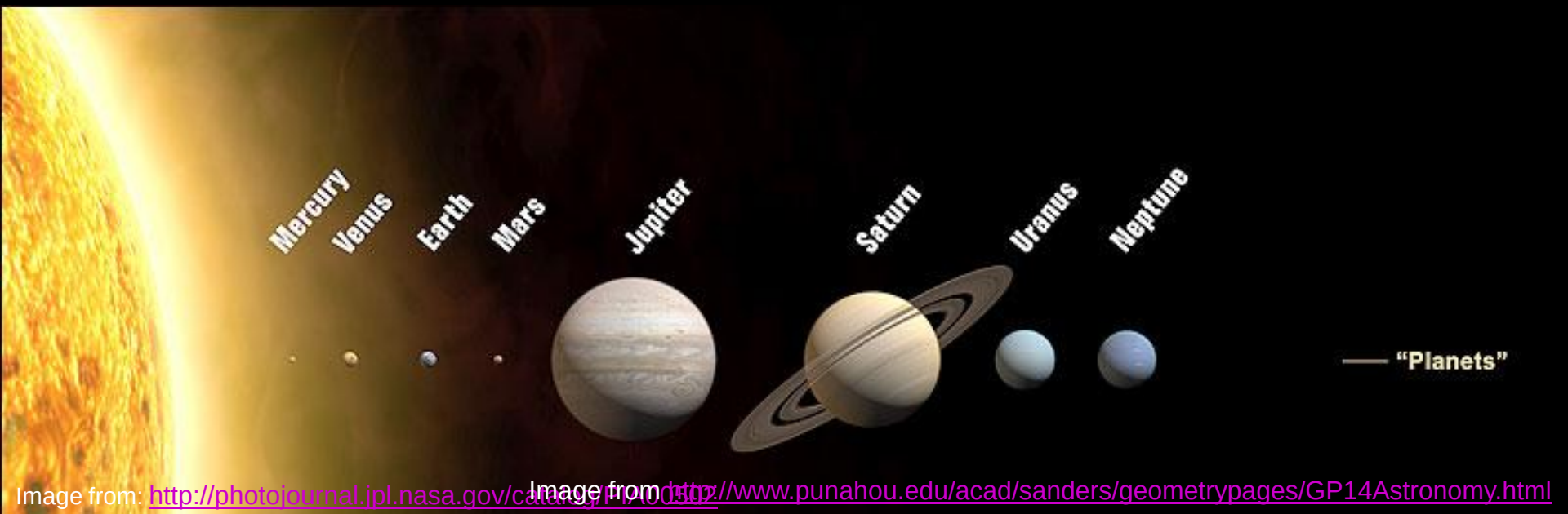
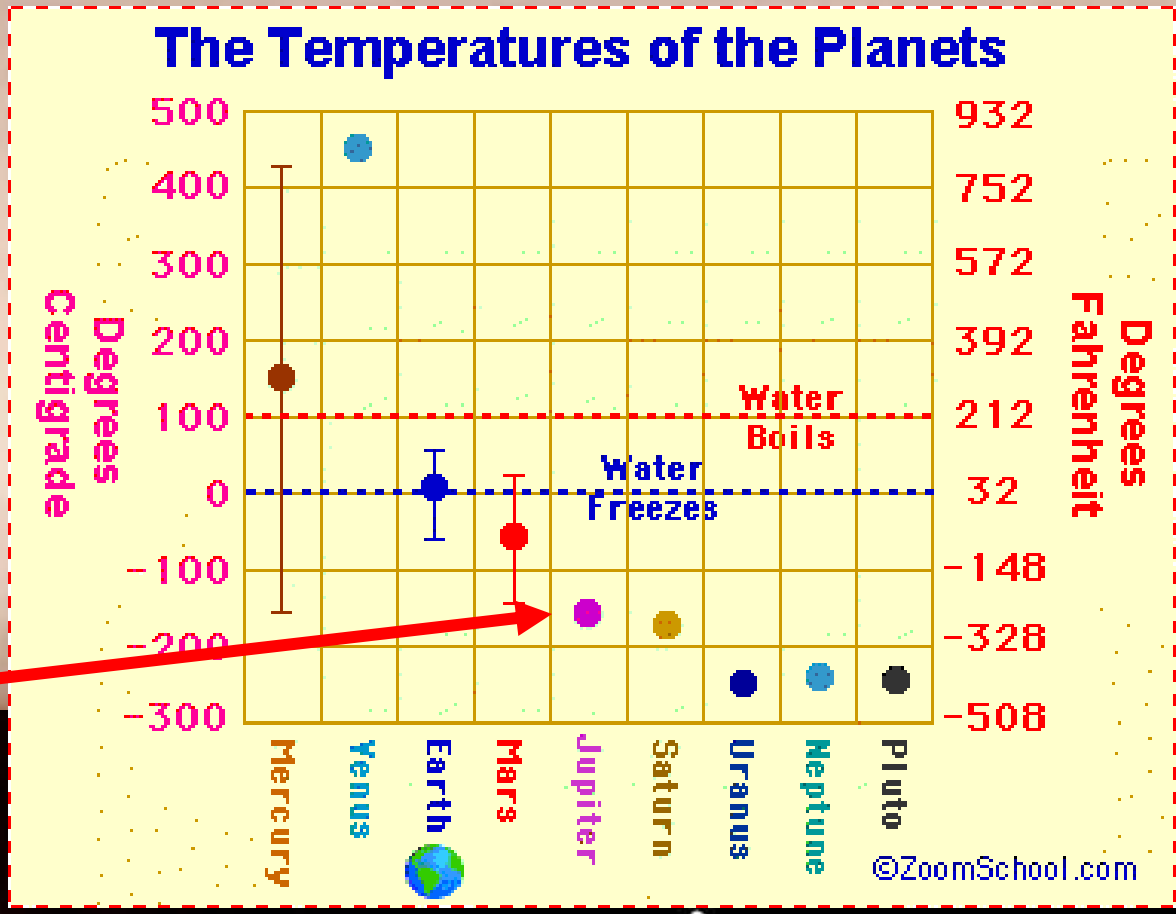


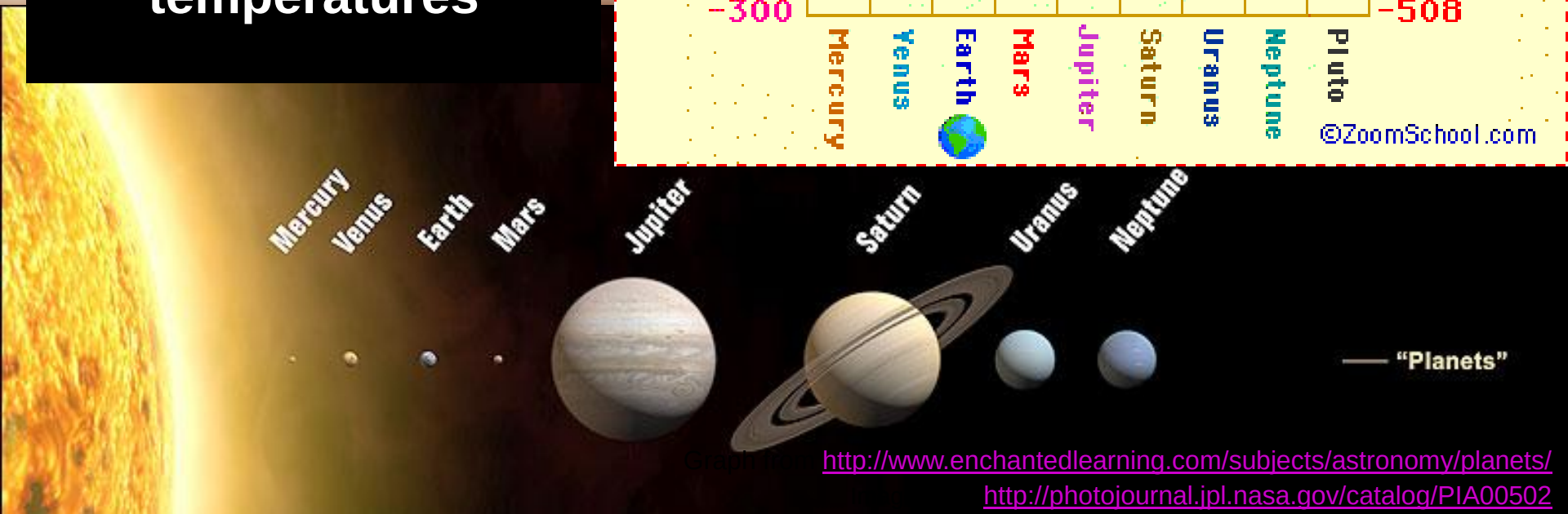
Image from: http://www.punahou.edu/acad/sanders/geometrypages/GP14Astronomy.html

HARDENING FOR SPACE

PLANET TEMPERATURES

Circuit functionality (including computing) diminished at lower temperatures





Graphic from http://www.enchantedlearning.com/subjects/astronomy/planets/

http://photojournal.jpl.nasa.gov/catalog/PIA00502

SOLAR POWER GENERATION

DISTANCES FROM SUN:

To Moon = ~1 AU (Astronomical Unit)
To Mars = 1.524 AU
To Europa = ~5.203 AU

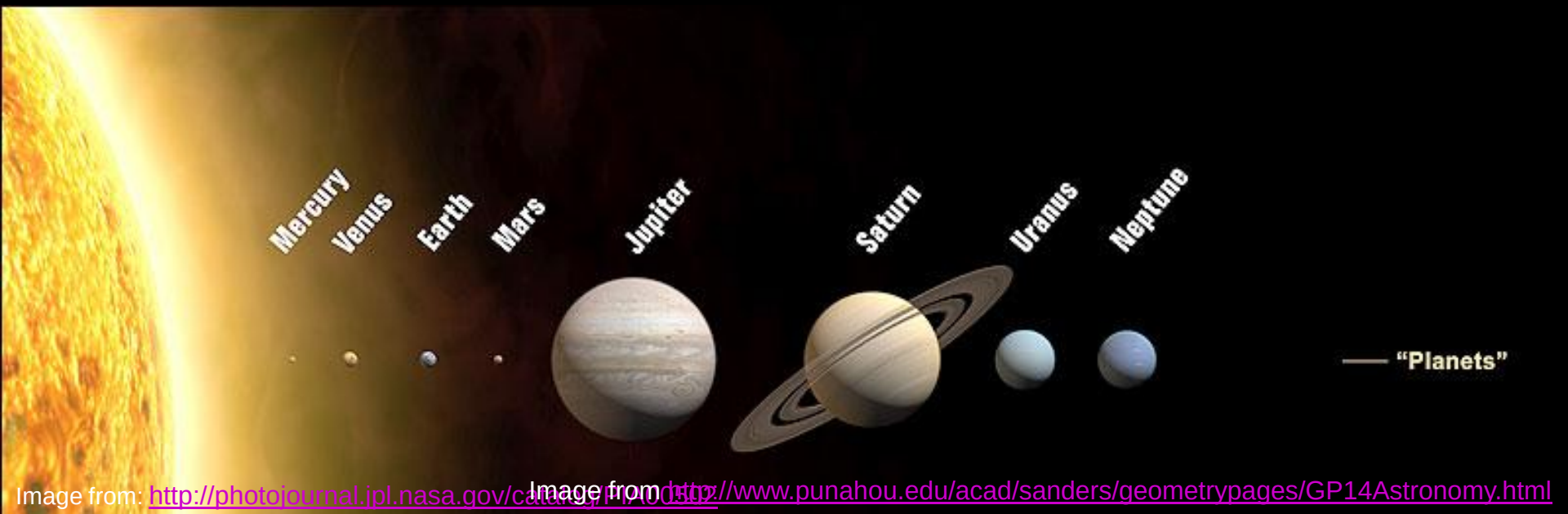


Image from: http://photojournal.jpl.nasa.gov/catalog/PIA00302

Image from: http://www.punahou.edu/acad/sanders/geometrypages/GP14Astronomy.html