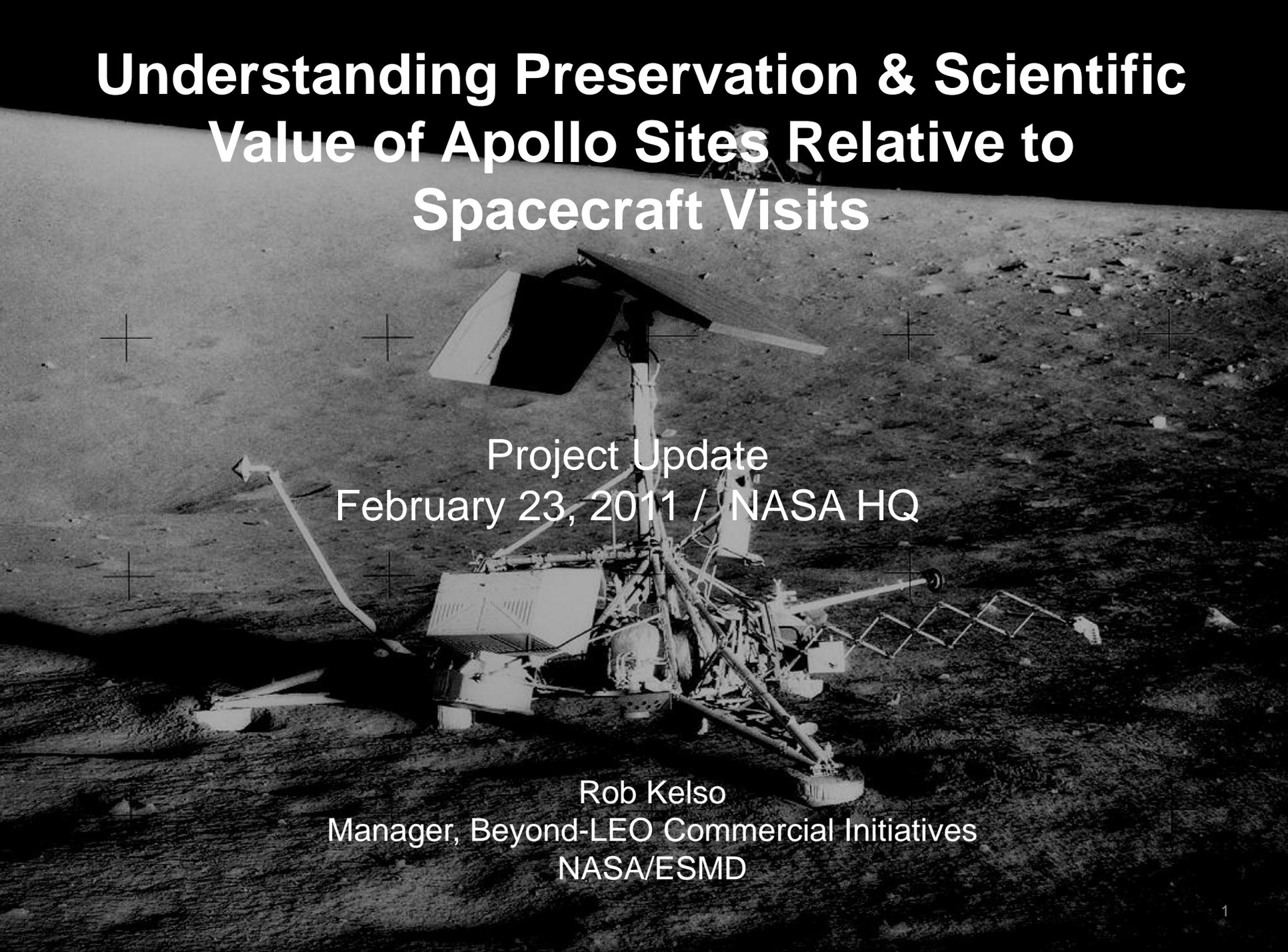


# Understanding Preservation & Scientific Value of Apollo Sites Relative to Spacecraft Visits



Project Update  
February 23, 2011 / NASA HQ

Rob Kelso  
Manager, Beyond-LEO Commercial Initiatives  
NASA/ESMD



# Earth-Moon





# International, NASA and Commercial Landers

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## International

## NASA: LunarQuest, MoonRise

## Private Companies planning lunar visits:

### ◆ **Google Lunar X Prize: \$30M total purse**

- \$20M (1<sup>st</sup> place); \$5M (2<sup>nd</sup> place), \$5M (bonuses)

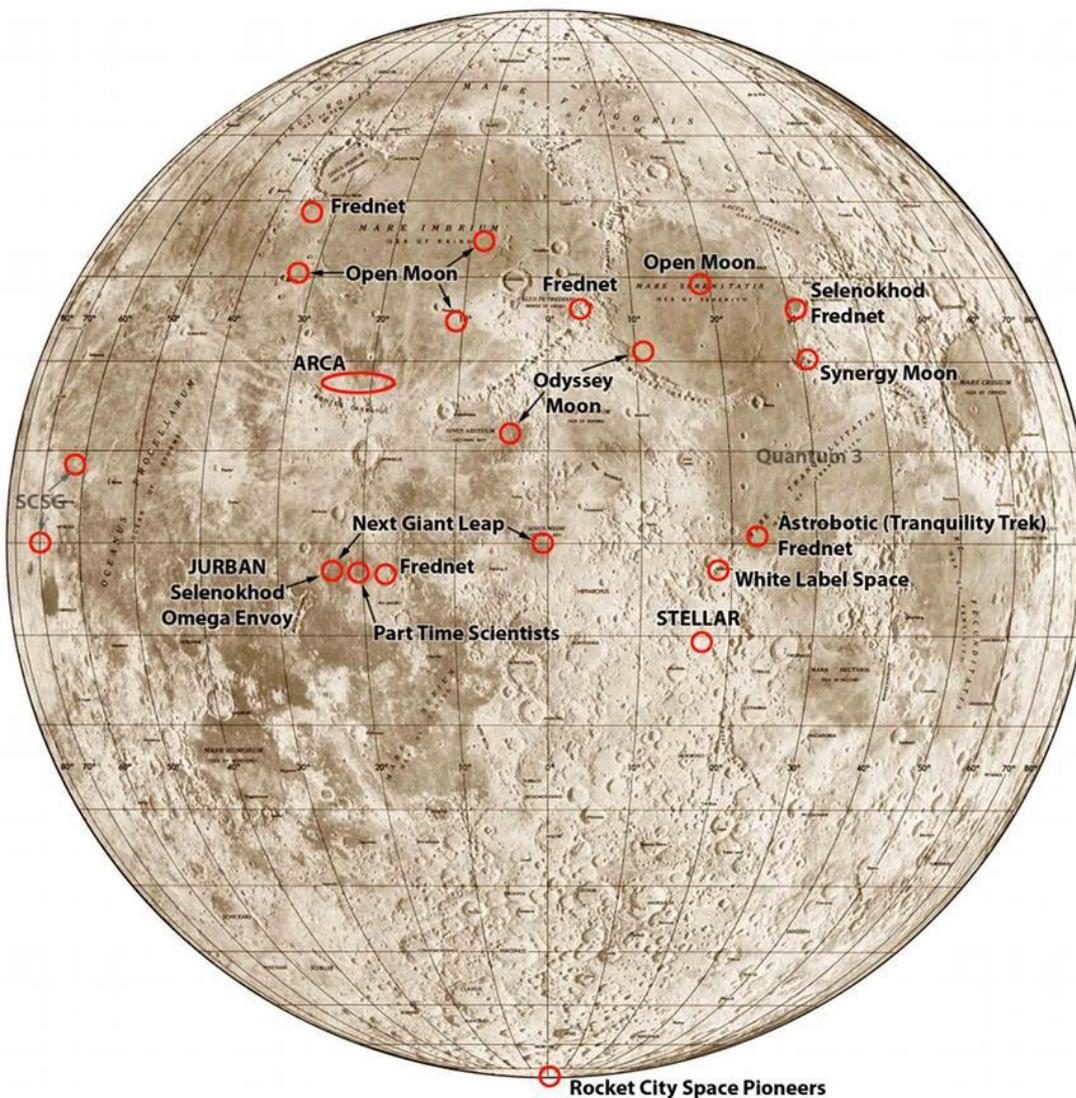
### ◆ **Basic GLXP Rules:**

- Privately funded effort to land, provide photos and video from the landing site and from 500m away“

### ◆ **Currently 29 Entrants**



# Multiple Commercial Landing Sites Targeted

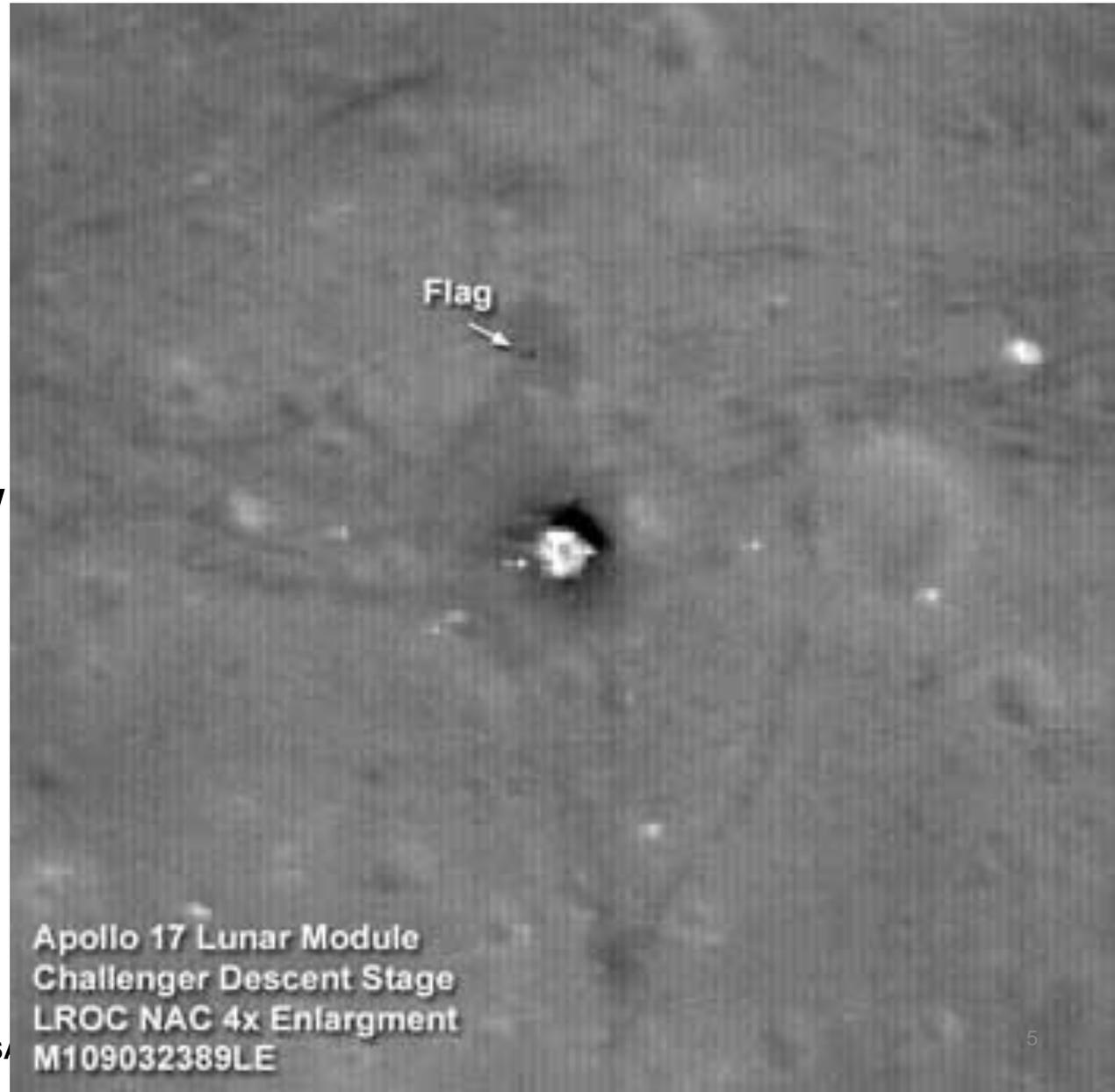




# LUNAR HERITAGE SITES

◆ *Historic* value /  
interest

◆ *Scientific* value /  
interest





# Apollo LM Descent Stage

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Apollo 16 from LRV camera

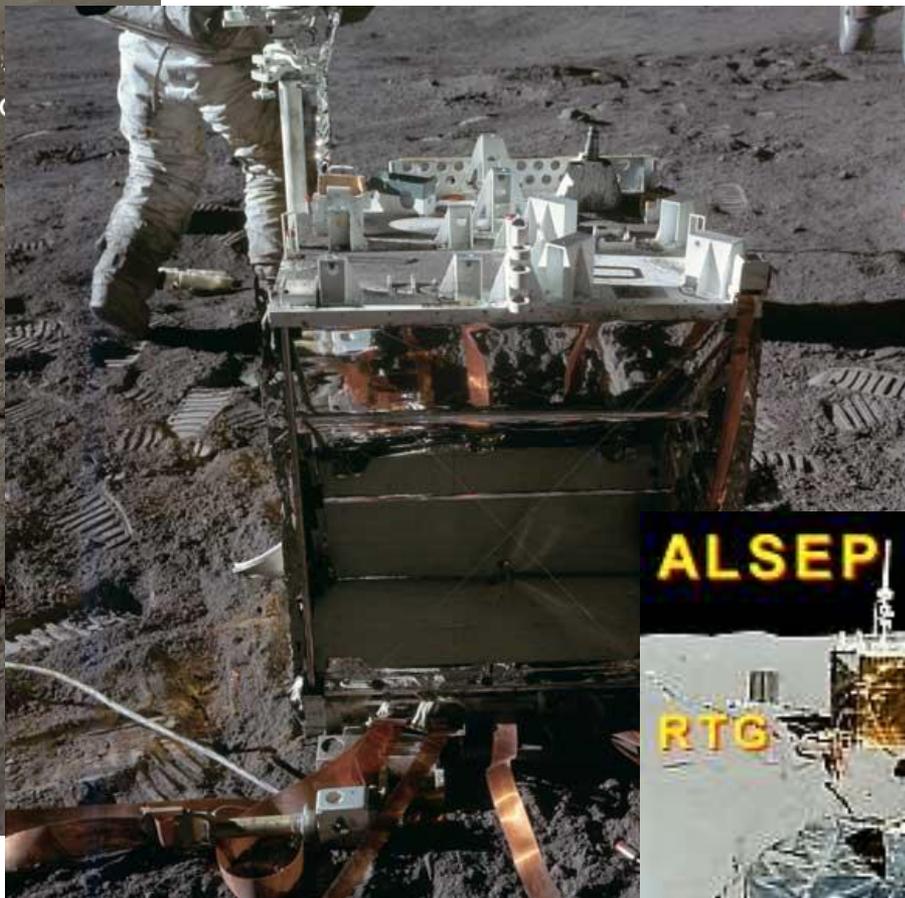
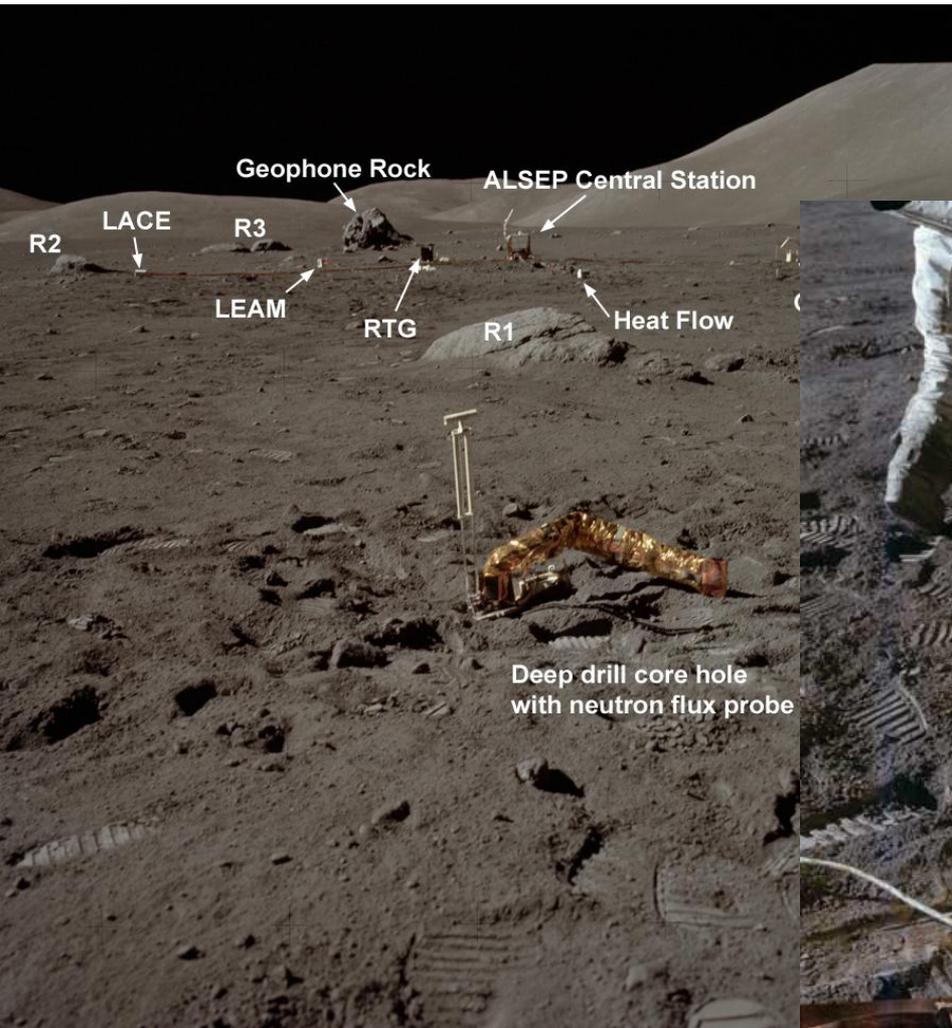


Apollo 13 LM Descent Stage





# ALSEP Sites





# American Flag from Apollo

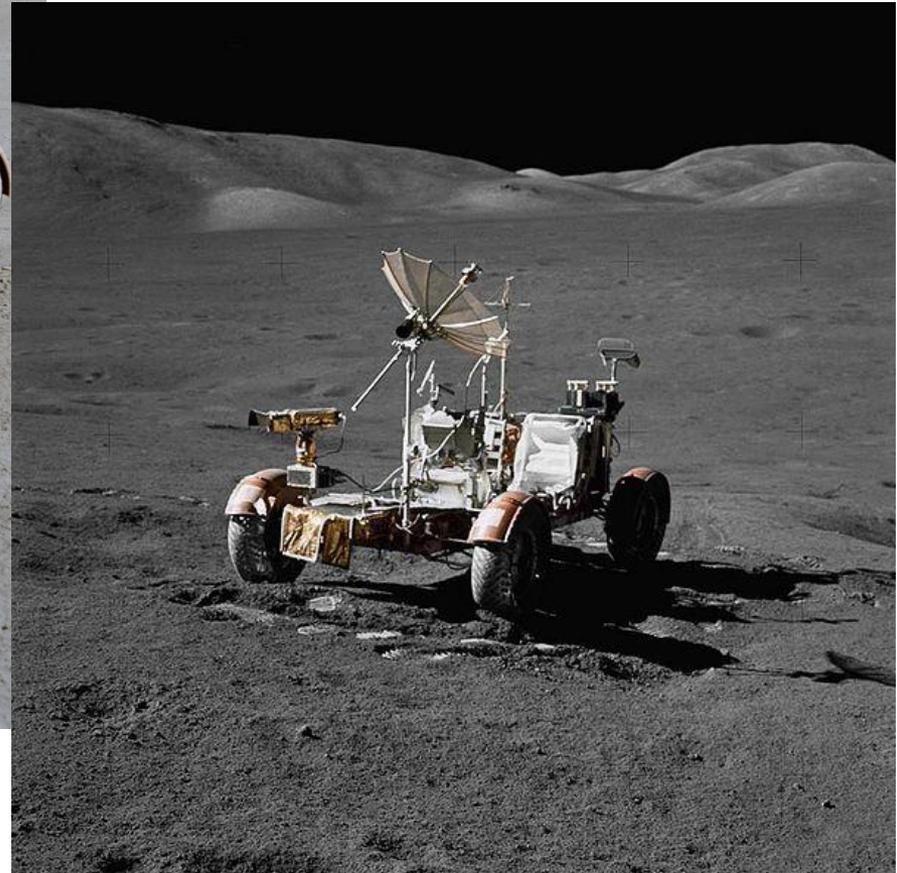
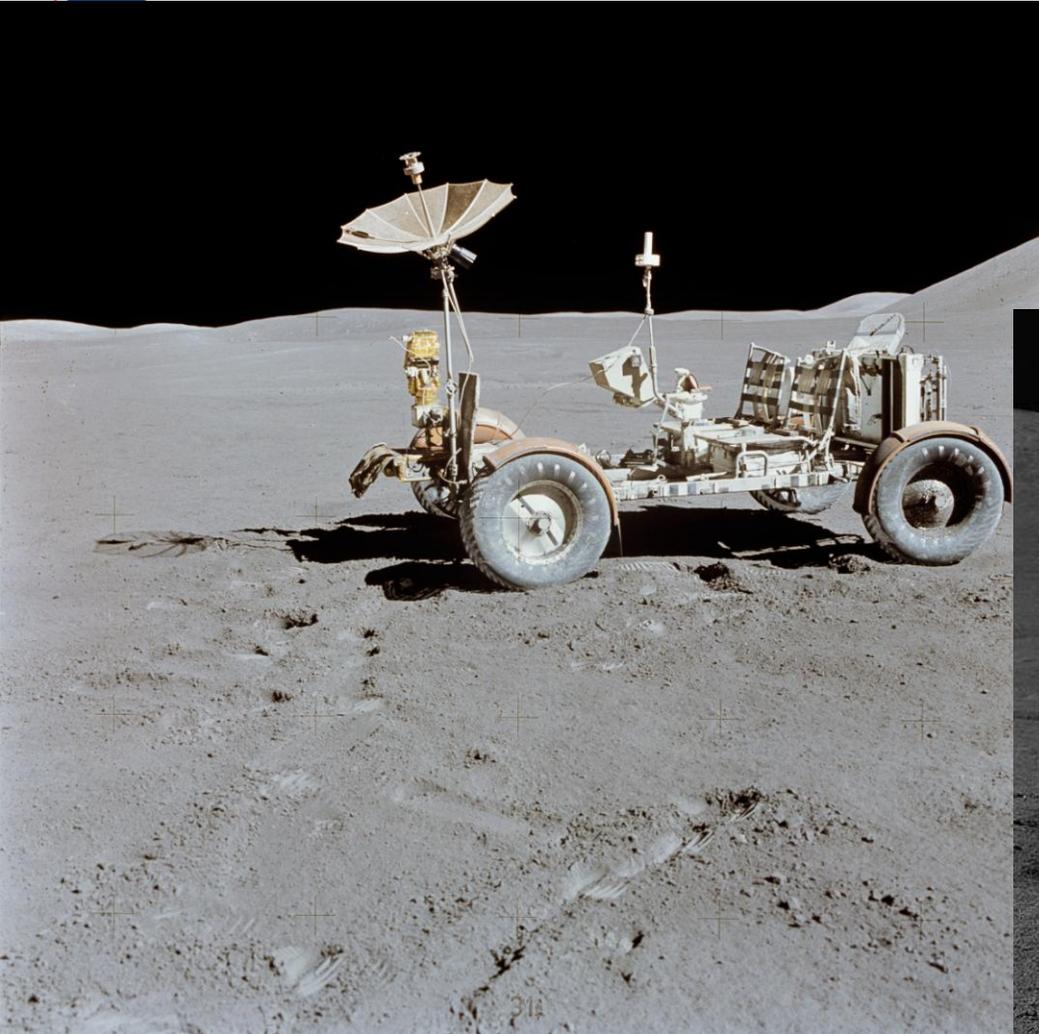
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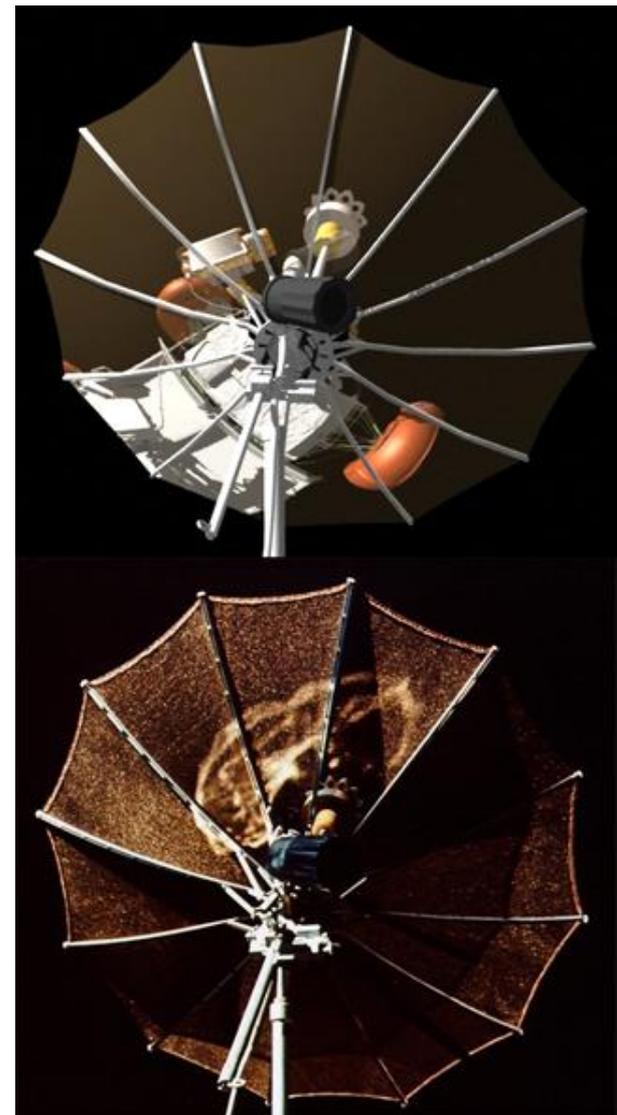
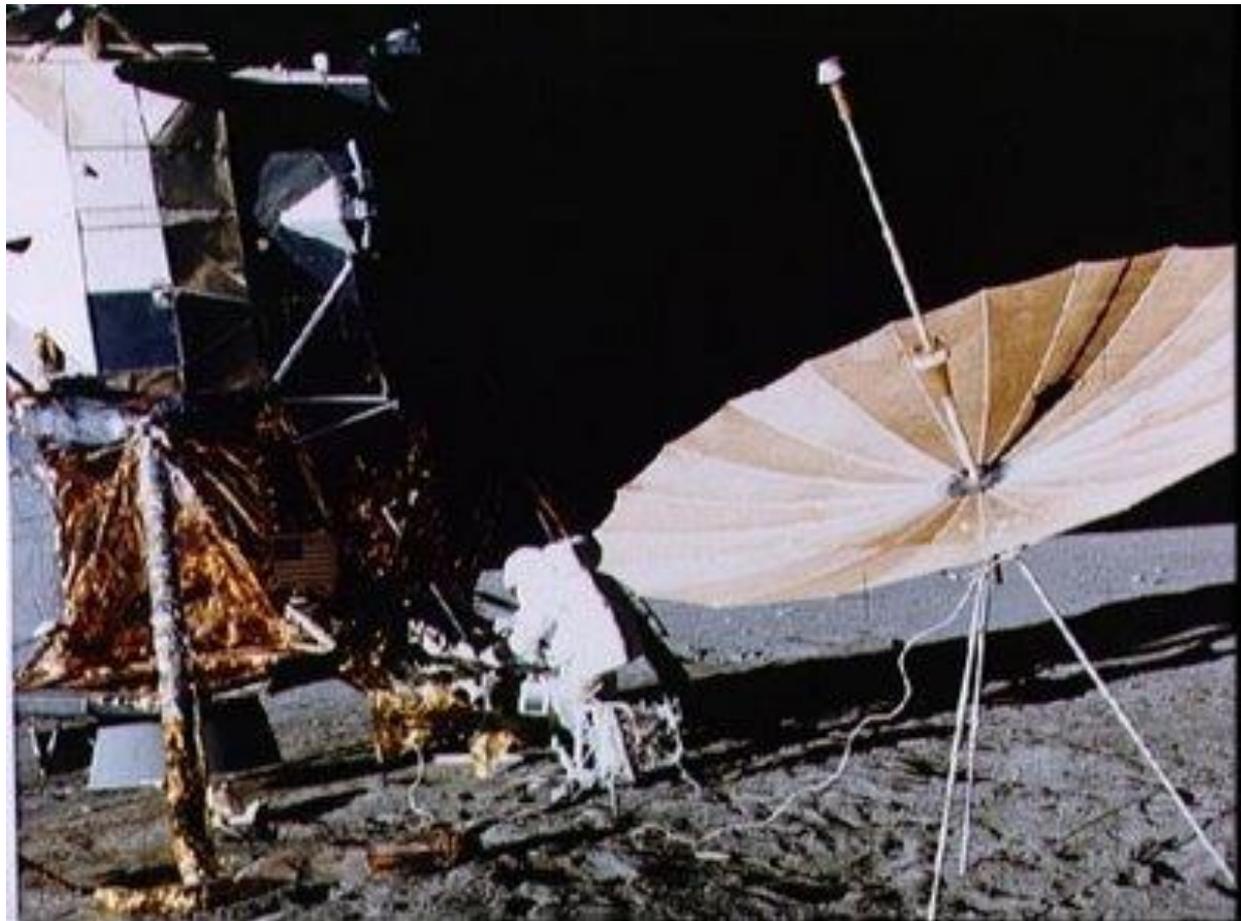
# Lunar Rover

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# Communication Antenna





# “THE” Footprint...the First Step

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# LUNAR HERITAGE SITES: RELEVANT SCIENCE

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***“Sites of U.S. hardware on the lunar surface may be viewed as unique ongoing experiments in **biology, planetary science, space weathering,** and other fields with direct relevance to NASA’s long-term plans for exploration, lunar development and scientific study.”***



# Scientific interest at lunar heritage sites

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## ◆ Dust Transport

- To confirm the absence or presence of electro-statically lofted dust

## ◆ Micrometeorite Bombardment Rate

- To assess recent micrometeorite impact flux

## ◆ Sandblasting Effect

- To characterize the effect of nearby lift-offs and/or landings on surface and orbital hardware, considering thrust levels and proximity as parameters.



# Scientific interest at lunar heritage sites

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## ◆ Lunar Weathering

- To characterize the effects on engineered materials following four decades of exposure to the lunar environment.
  - “scientific witness plates”

## ◆ Survival of Microbes

- To investigate residual forward contamination.
  - refining planetary protection policies as human exploration of the Moon advances.
  - address important astrobiological questions

## ◆ Seismology, environmental baselines

- Laser retro reflectors still in use; lunar environment characterization



# Possible Mechanisms of Damage to Scientifically Interesting Data

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## ◆ Proximity Landing/Lift-off/Flyover:

- Rocket thrust may erase footprints and treads, sandblast nearby hardware, and cause deposition of chemicals/dust

## ◆ Proximity Surface Travel:

- Rover wheels may run over footprints and treadmarks, and kick up dust

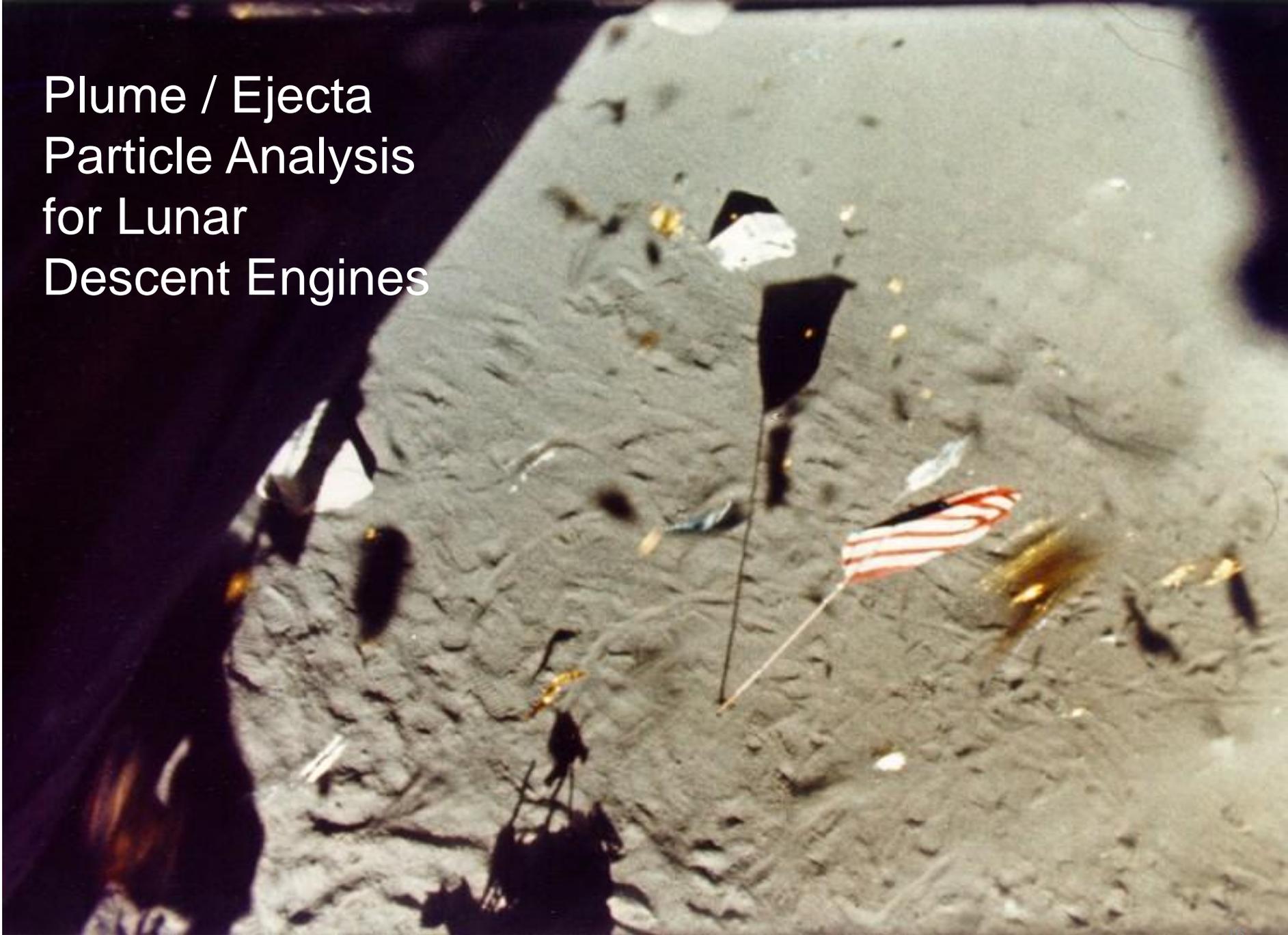
## ◆ Biological contamination:

- Unsterilized rovers may contaminate a site by coming in physical contact with heritage hardware

## ◆ Entry, Descent, and Landing (EDL) Errors:

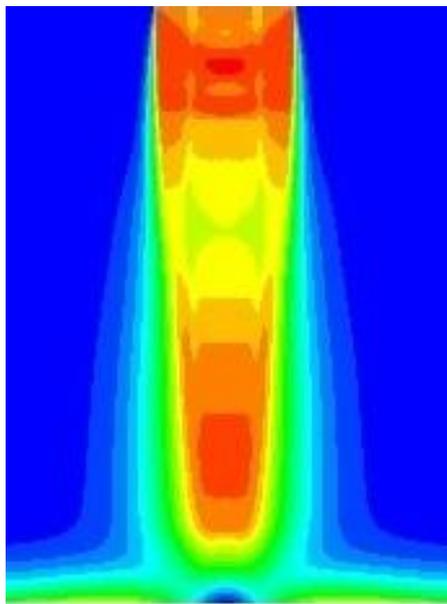
- A crash or off-nominal landing near a heritage site may produce enormous amounts of debris, dust, chemical contamination, and possible biological contamination.

Plume / Ejecta  
Particle Analysis  
for Lunar  
Descent Engines

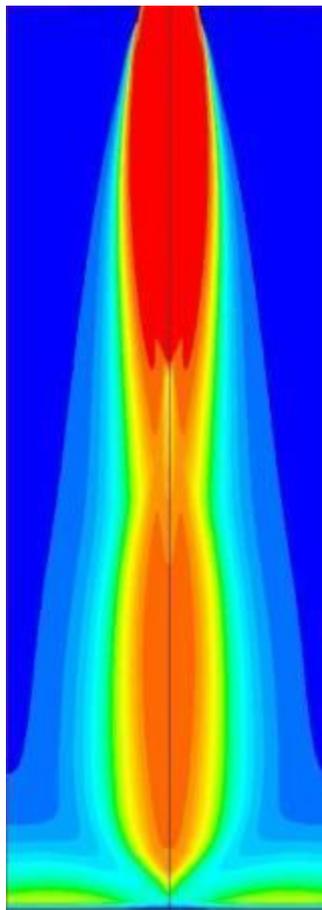




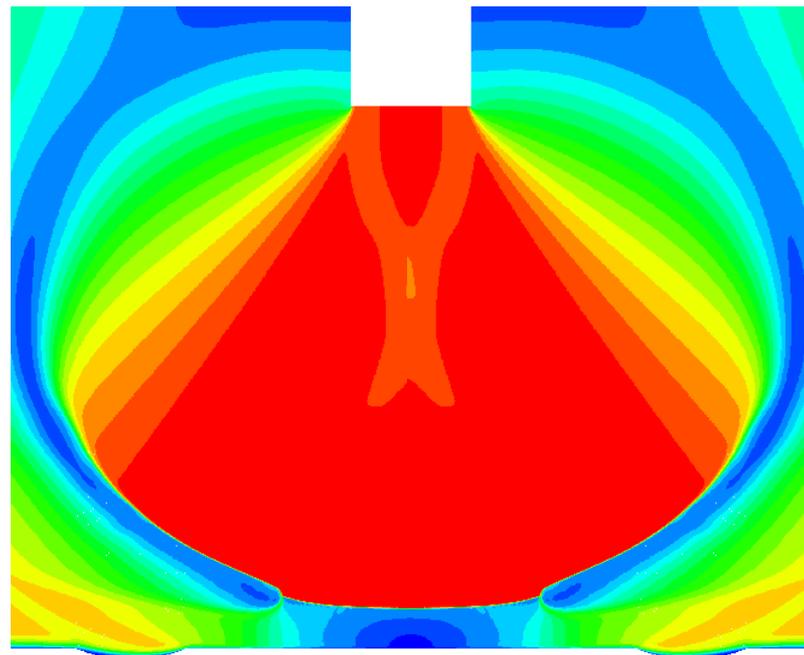
# Different Effects in Different Environments



Earth



Mars

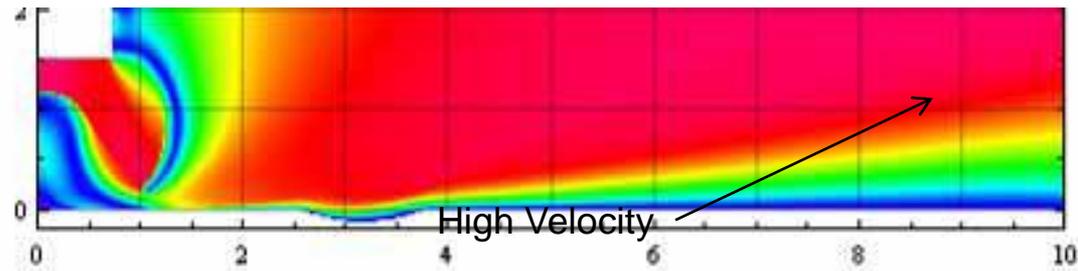


Moon



# Summary of Current Assessments

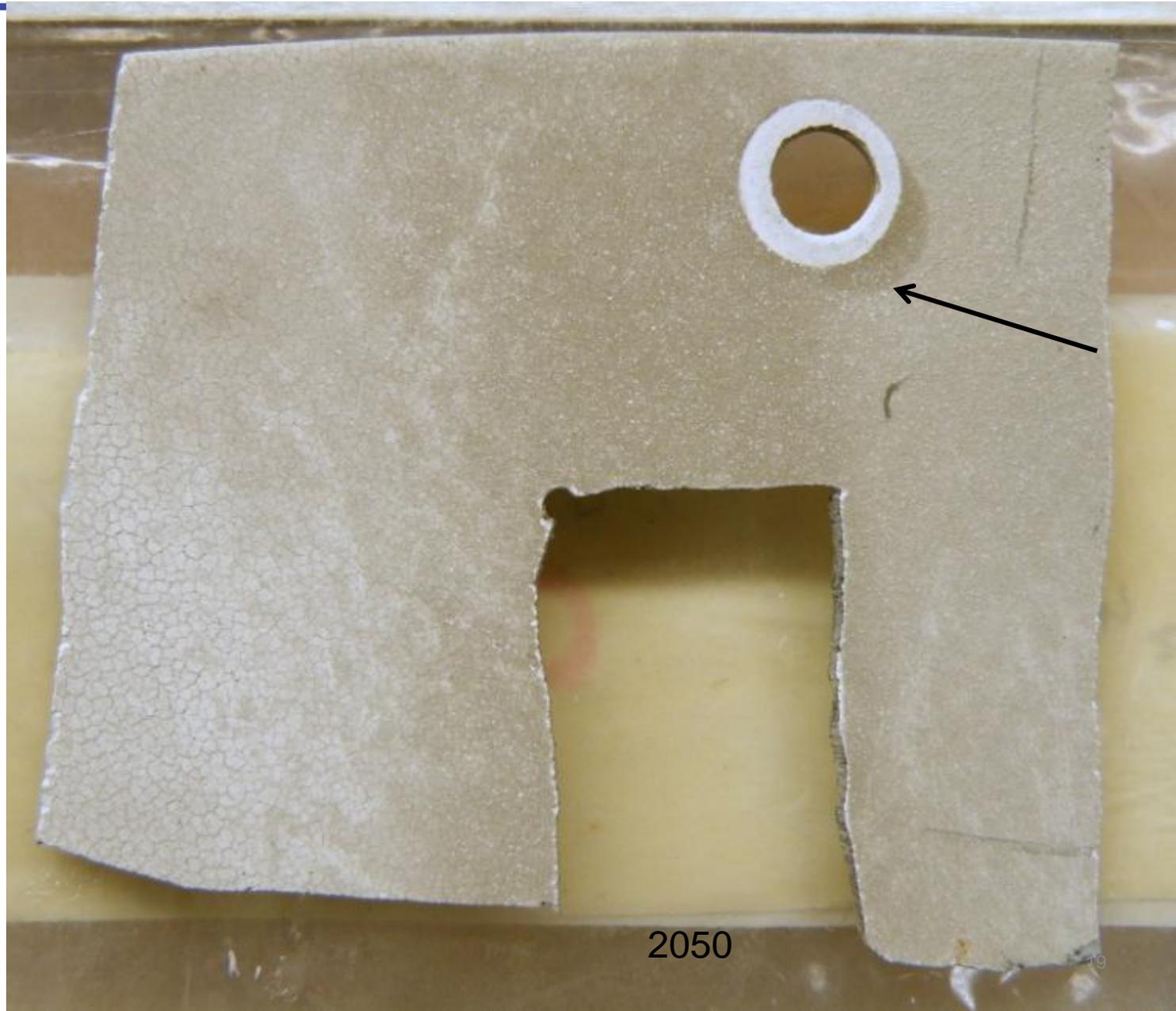
- ◆ **Primary hardware/science damage caused by ejecta impingement**
- ◆ **Lander descent engines create high velocity / horizontal flow across surface**
- ◆ **Relatively flat sheet of dust (1-3 deg to surface)**
  - Particles lifted by aero forces
- ◆ **Total eroded and scouring volume: ~2MT**
- ◆ **Dust velocities can reach as high as 2000 m/sec**
  - Sand / dust travel out over horizon
  - Horizon ~2km away
- ◆ **Pulse / multi-engines worse**
  - shock-wave effect
  - Rooster tails
- ◆ **Follow-on assessment: multi-engines vs single, continuous engines configurations**





# Scouring of Surveyor III

- ◆ Bolt hole with shadow. White paint was underneath the bolt head.



2050

# Current Recommendations





# Categories of the Landing/Impact Sites

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- ◆ **3 categories of the sites**
  - 6 Apollo sites
    - Apollo 11\*
  - Unmanned soft-landing sites
    - Surveyor, Luna, etc
  - Impact\crash sites
    - Ranger, S-IVB, etc



# KEEPOUT ZONE – APOLLO 11 & 17 SITES

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## ◆ A3-1

### GENERAL OVERVIEW – HISTORICAL PERSPECTIVE PER APOLLO SITE

- While all the Apollo sites represent significant historical/heritage value in material culture, the Apollo 11 and 17 landing sites carry special significance. It is recommended that the site for Apollo 11 and 17 be treated as unique by prohibiting visits to any part of the site and that all vehicles remain beyond the boundaries of the entire site.

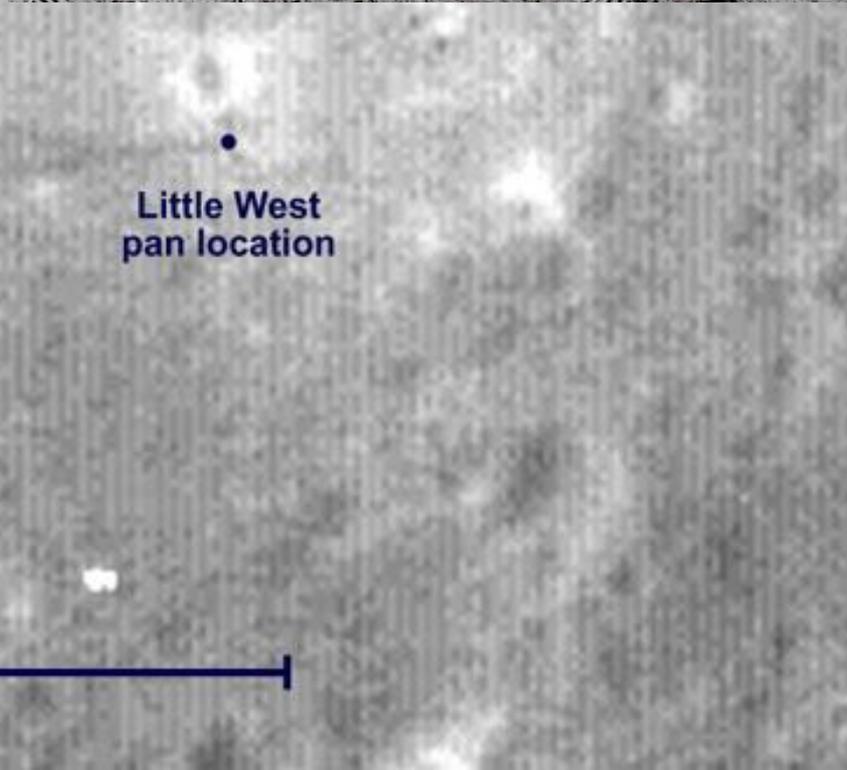
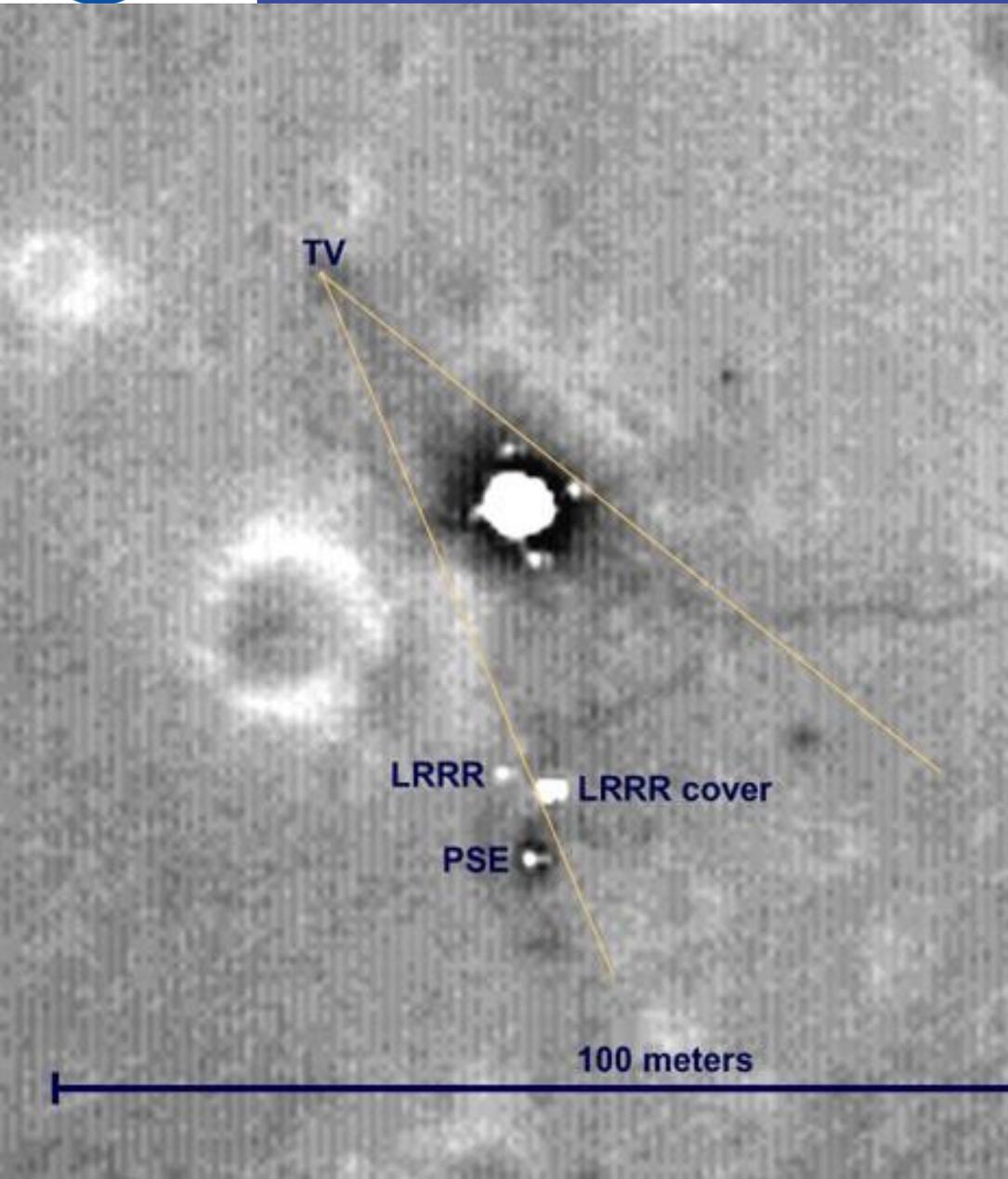
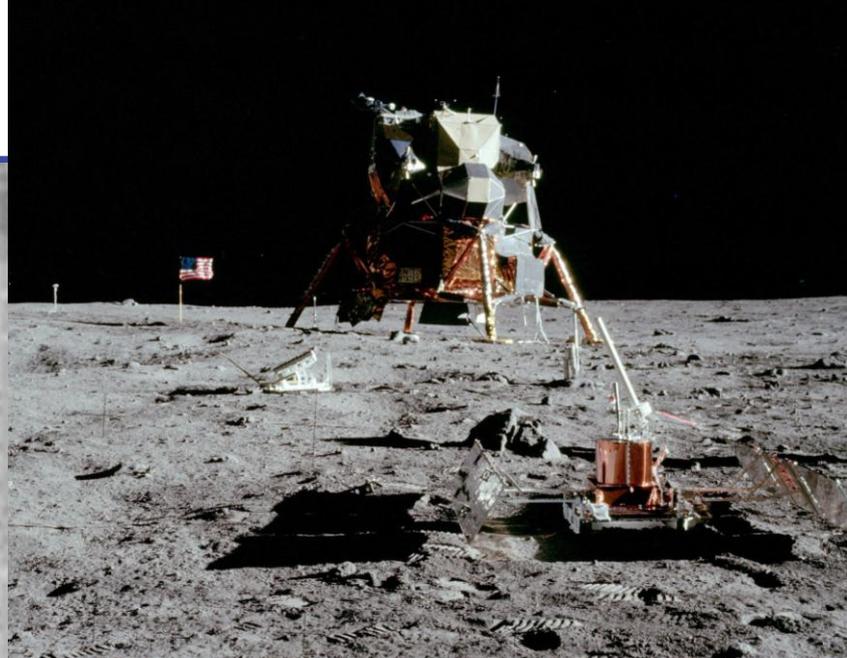
## ◆ A3-2

### KEEPOUT ZONE – APOLLO 11 & 17 SITES

- It is recommended that the entire site at Apollo 11 and 17 be restricted from close inspection by visiting robotic systems. The visiting vehicle mobility exclusion boundary will encompass all artifacts (hardware, footprints, etc) for this site.
  - For the **Apollo 11 site**, the keep-out zone extends 75 meters from the lunar module descent stage.
  - For the **Apollo 17 site**, the keep-out zone extends 200 meters from the lunar module descent stage.



# APOLLO 11 SITE

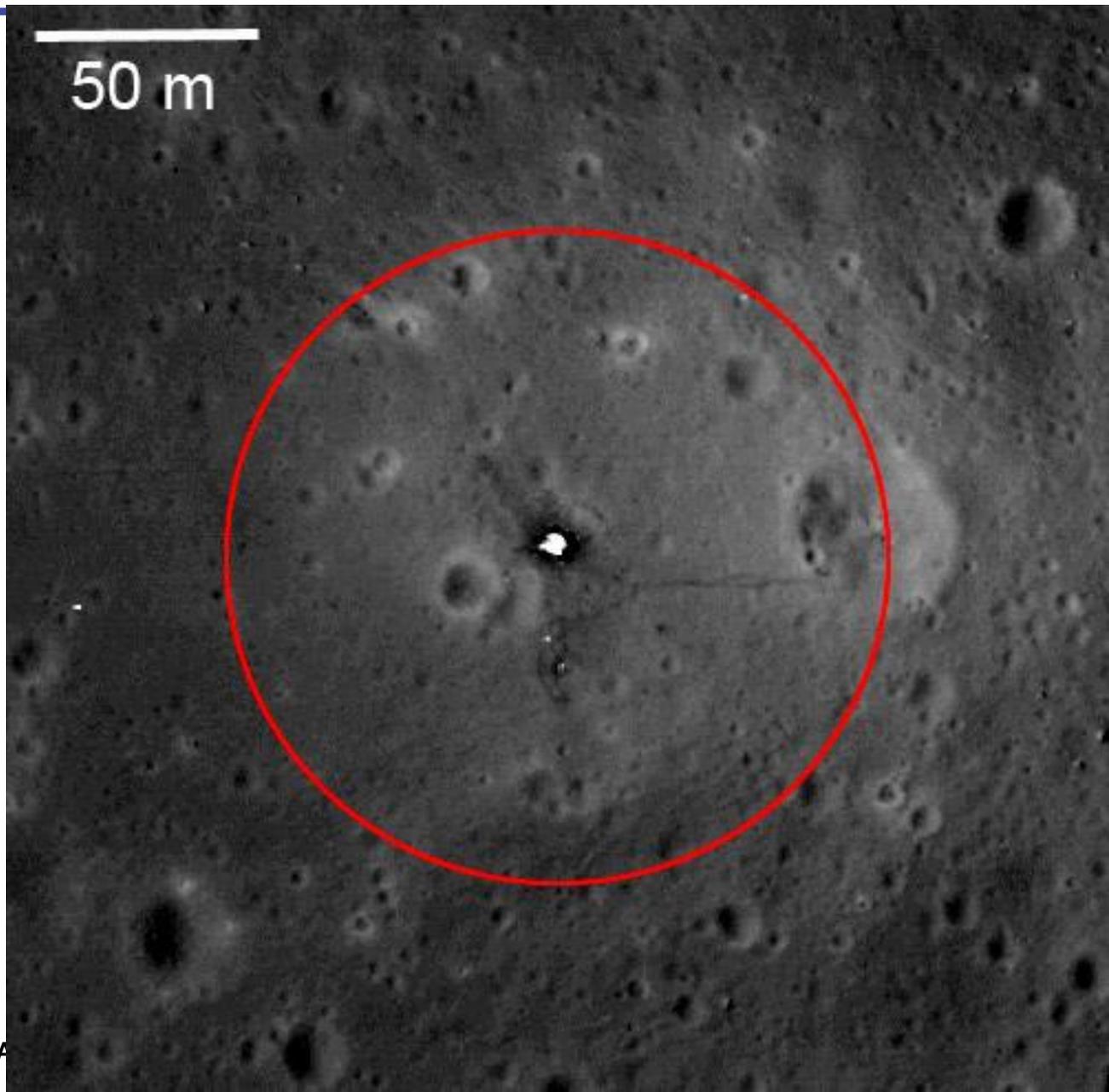




# Recommendation for Site of Apollo 11

Exclusion zones extends 75 m from the LM descent stage.

50 m





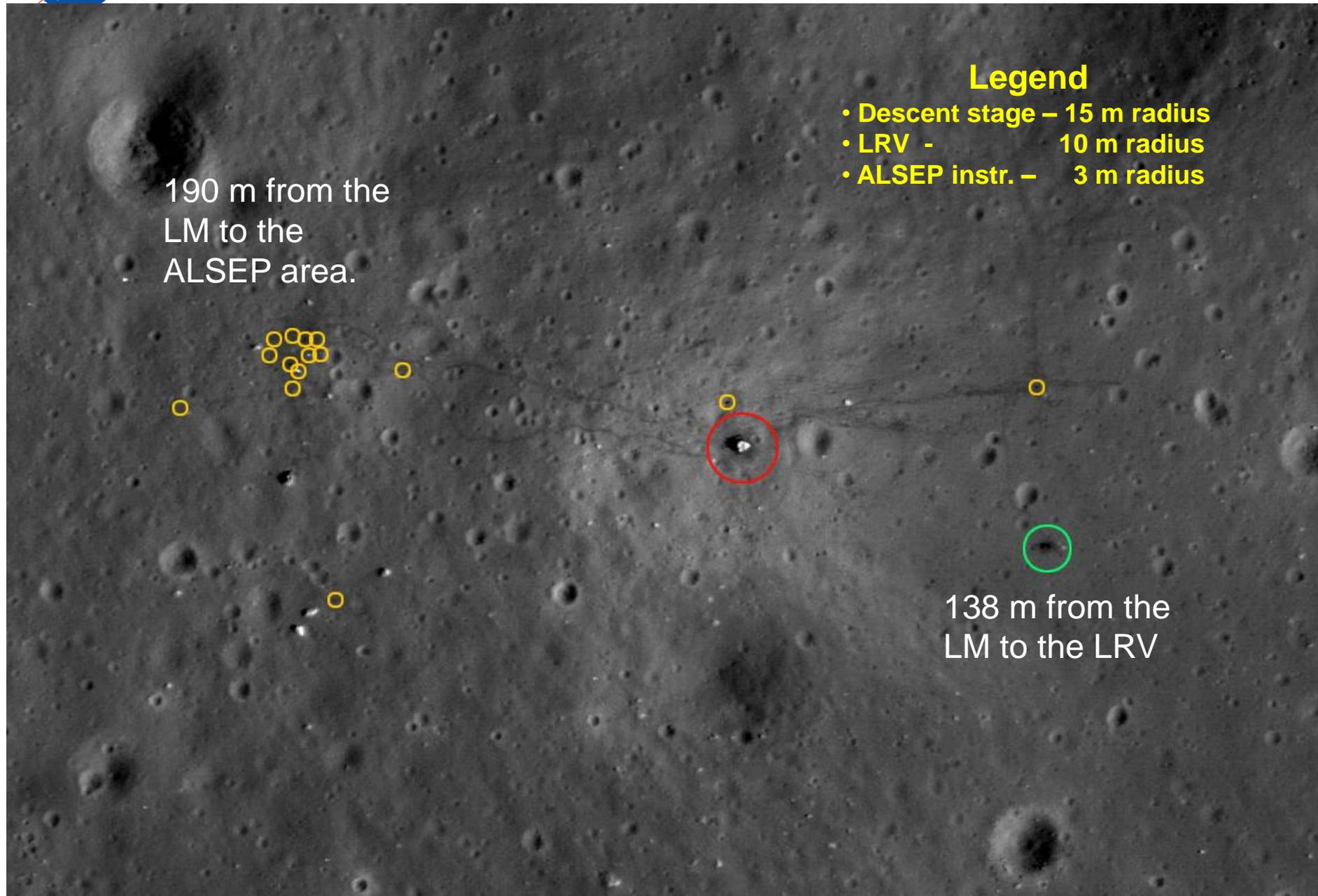
# Apollo 17 site – boundary zones

## Legend

- Descent stage – 15 m radius
- LRV - 10 m radius
- ALSEP instr. – 3 m radius

190 m from the  
LM to the  
ALSEP area.

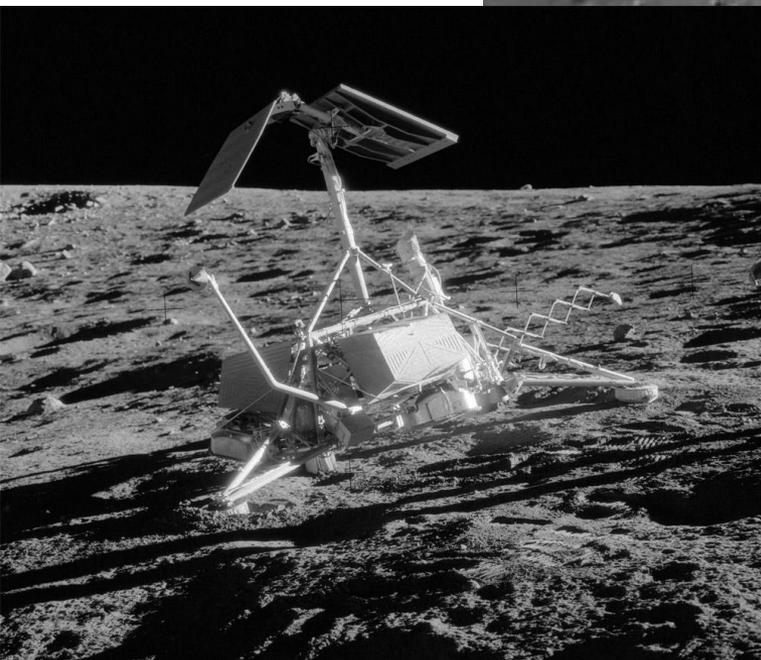
138 m from the  
LM to the LRV





50 m

# Surveyor 7 Exclusion Zone



20 m radius

Launch: 7 January 1968

Landed: 10 January 1968

Site:

$-40.980138^{\circ}$  S /  $348.484211^{\circ}$  E

Tycho Crater ejecta



# Apollo 14 SIVB

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**Launch: 31 January 1971**

**Landed: 4 February 1971**

**Impact Velocity: 2.54 km s<sup>-1</sup>**

**Mass: 14016 kg**

**Location:**

**Mare Cognitum (near Euclides  
D)**

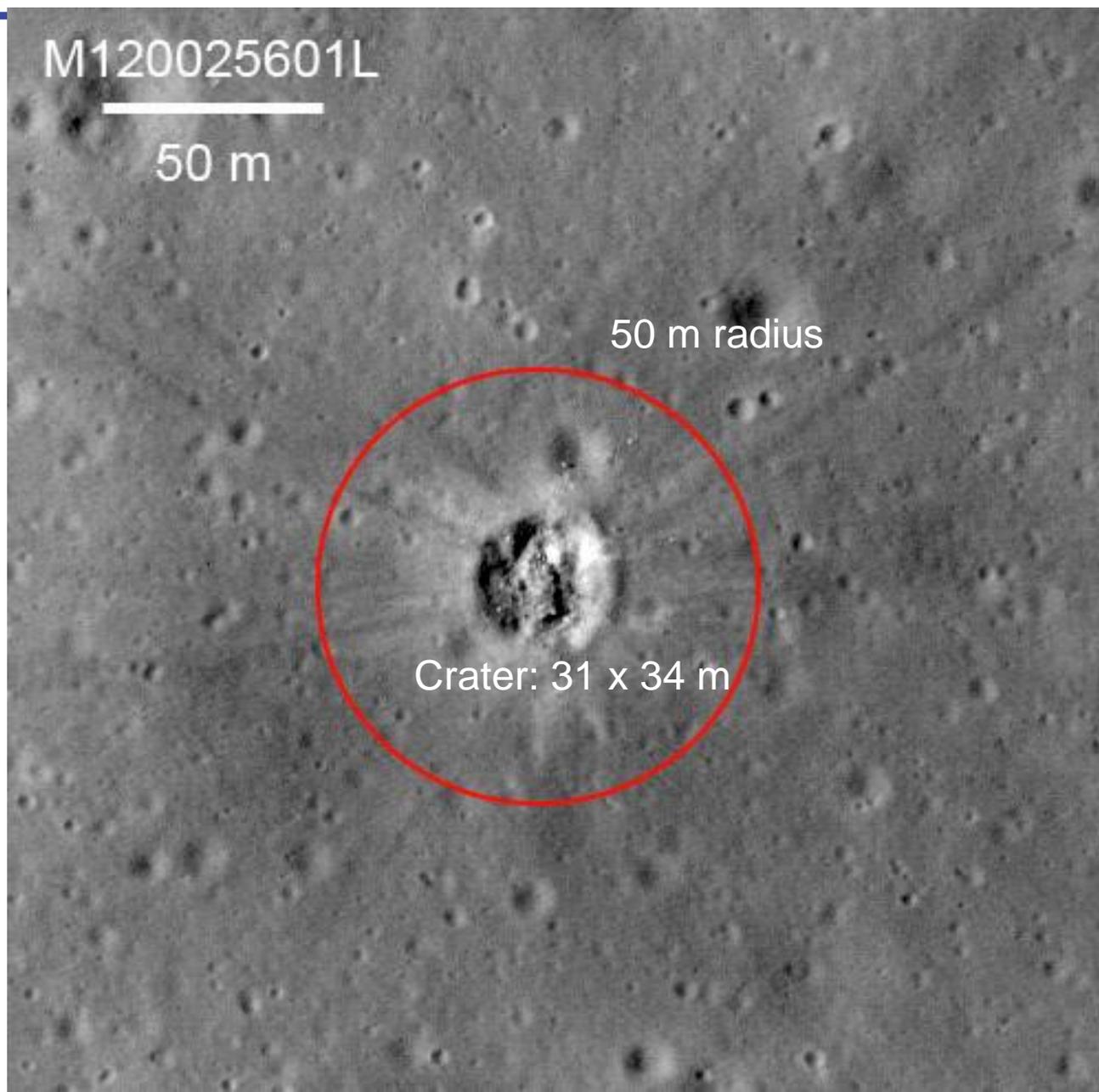
**-8.179415° S; 333.969547° E**

**Crater: 31 x 34 m**



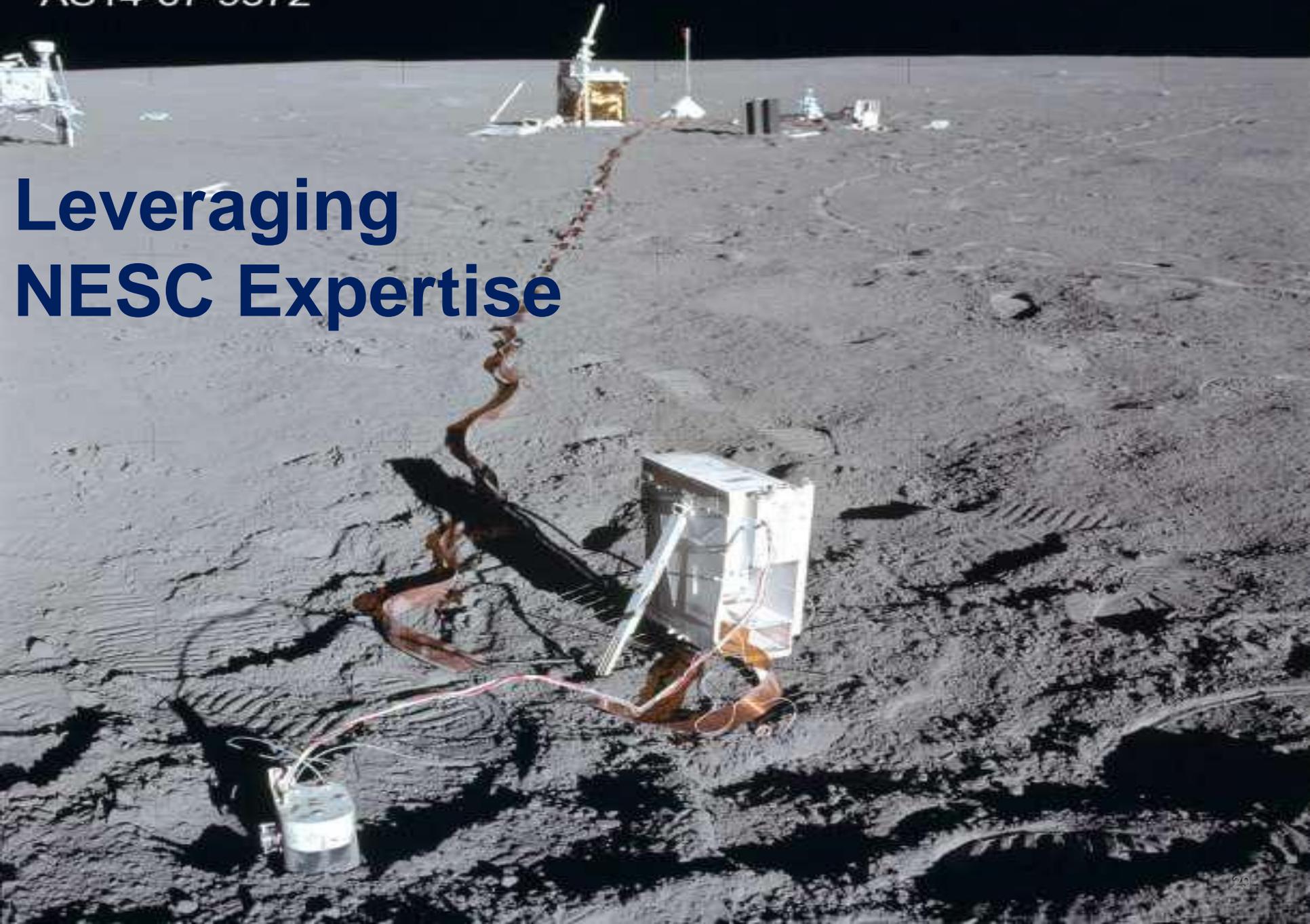


# Apollo 14 SIVB Impact Site Exclusion Zone



AS14-67-9372

# Leveraging NESC Expertise





# Priorities for Assessing the Apollo Sites as “Witness Plates”

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## ◆ LRV

- Wide variety of materials
- Away from ascent blast zone
- No cables to “trip” on
- Flat components for dust deposition

## ◆ Micrometeoroid Impacts

- Probably need ~0.1 cm resolution

## ◆ Rocket Blast Effects

- Blast effects as a function of distance with different artifacts located varying distances from descent stage

## ◆ Material Degradation

- Color/appearance changes from original photographs or baseline material
- Thermal effects
  - Fatigue failure
  - Warping



# Priorities (Cont'd)

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## ◆ Dust Deposition

- Find artifacts away from ascent blast with flat surfaces (and pristine at start)
  - Passive Seismic Experiment Thermal Shroud
  - Lunar Surface Magnetometer sun shield
  - Laser Range Reflectometer Experiment

## ◆ Thermal Paint Delamination

- Central Station
- Solar-wind Spectrometer
- Suprathermal Ion Detector Experiment (SIDE)
- Heat Flow Experiment (HFE)

# Our Lunar Legacy: One Giant Leap for Historic Preservation

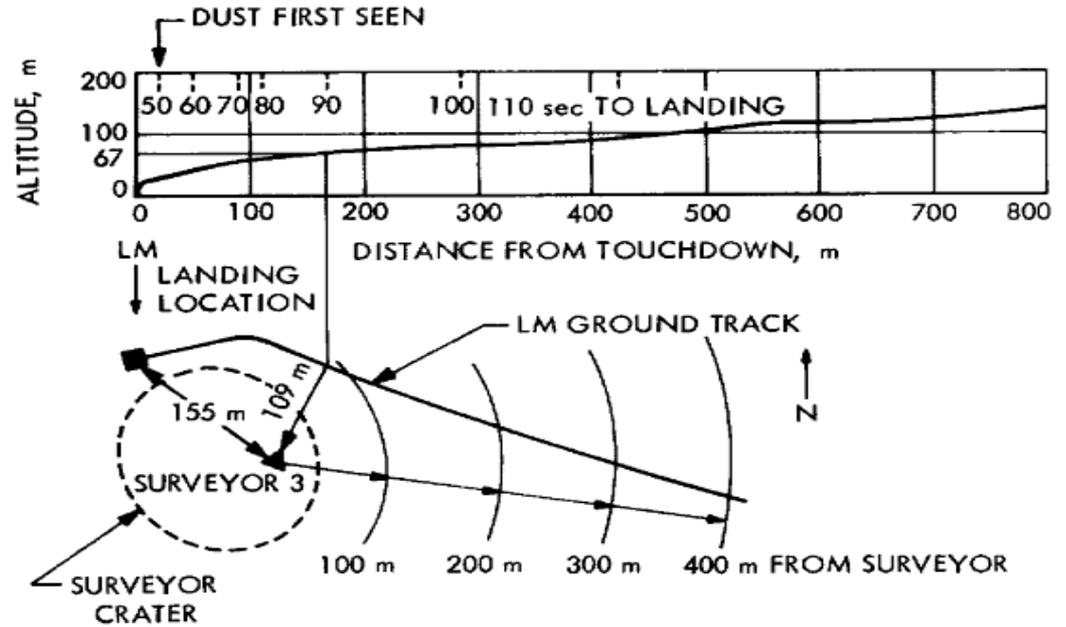
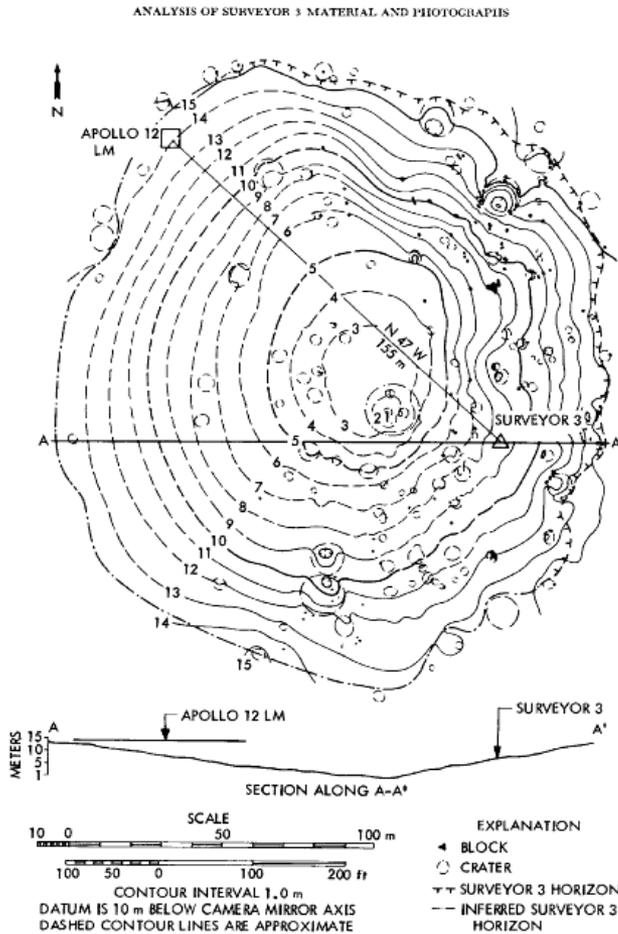




# BACKUP



# APOLLO 12 LM Landing



- ◆ LM landed 155 m away
- ◆ Closest approach was 109 m
- ◆ LM landed on a higher point than Surveyor

FIGURE 1.—“Surveyor Crater” showing the relative position of Surveyor 3 and Apollo 12 in plan and cross-section view. The LM was situated 155 m away from, N 47° W of, and at a ground level of 4.3 m higher than the television camera on Surveyor 3 (see ref. 7). Base map from Baton (see ref. 8).



# Tranquility Base Archaeological Inventory

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1. Apollo 11 Lunar Module Descent Stage(1)
2. US 3' x 5' Flag(1)
3. Laser Ranging Reflector (LRRR)(1)
4. Passive Seismic Experiment (PSE)(1)
5. Neil Armstrong's Apollo Space Boot, Model A7L (1)
6. Neil Armstrong's Apollo Space Boot, Model A7L (1)
7. Edwin (Buzz) Aldrin Jr's Apollo Space Boot A7L (1)
8. Edwin (Buzz) Aldrin Jr.'s Apollo Space Boots Model A7L (1)
9. Empty Food Bags (2+)
- 10 A Silicon Disc Carrying Statements from Presidents Nixon, Johnson, Kennedy, Eisenhower and from the leaders of 73 Other Nations(1)
11. A gold replica of an olive branch, the traditional symbol of peace
12. Mission patch from Apollo 1, commemorating Astronauts Gus Grissom, Ed White and Roger Chaffee (1)
13. Commemorative plaque attached to the Lunar Module Descent Leg. "Here men from the planet Earth first set foot upon the Moon. July 1969, A.D. We came in peace for all mankind." Signed by Astronauts and President Nixon
14. TV Camera
- 15 Spring scales(2)
16. Tongs (1)
17. Small scoop (1)
- 18 Scong
- 19 Bulk sample scoop
20. Trenching tool.
21. Camera (Hasselblad E1 Data)(1)
22. Armrests (4)
23. Mesa Bracket
24. Solar Wind Composition Staff
- 25 Handle of contingency lunar sample return container (1)
26. Medals Commemorating Two Dead Cosmonauts (2)
27. Document Sample Box Seal (1)
28. Storage container (empty) (1)
29. Hasselblad pack (1)
30. Film Magazines (2+)
31. Filter, Polarizing (1 )
32. Remote Control Unit (PLSS) (2)
33. Defecation Collection Device (4)
34. Overshoes, Lunar (2)
35. Covers, Pga Gas Connector (2)
36. Kit, Electric waist, Tether (1)
37. Bag Assy Lunar Equip. Conveyor & Waist Tether (1)
38. Conveyor Assy, Lunar Equip (1)
39. Bag, Deployment, Life line (1)
40. Bag, Deployment, Lunar Equip. Conveyor (1)
41. Life line, Lt. wt. (1)
42. Tether, Waist, EVA (4)
43. Food Assembly, LM (4 man days) (1)
44. TV subsystem, Lunar (1)
45. Lens, TV wide angle (1)
46. Lens, TV lunar day (1)
47. Cable assembly, TV (100') (1)
48. Adapter, SRC/OPS (2)
49. Cannister, ECS LIOH (2)
50. Urine collection assembly, small (2)