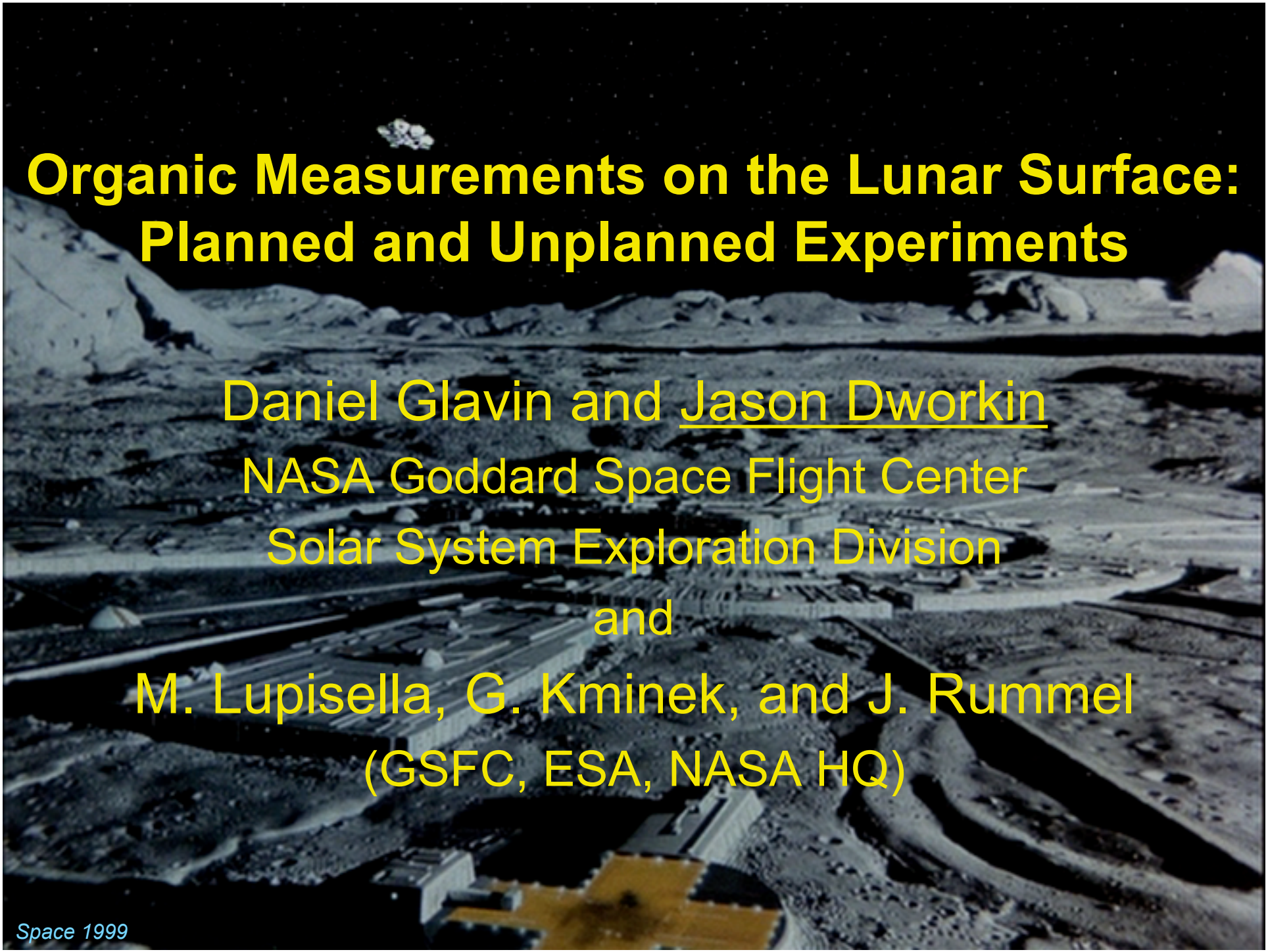
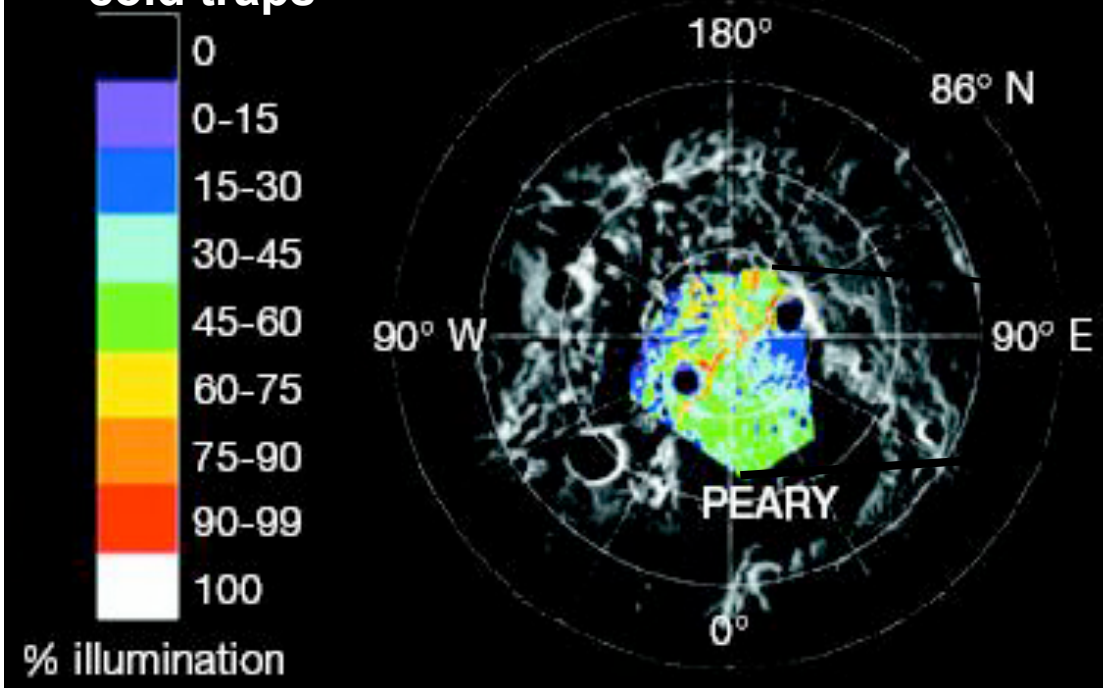


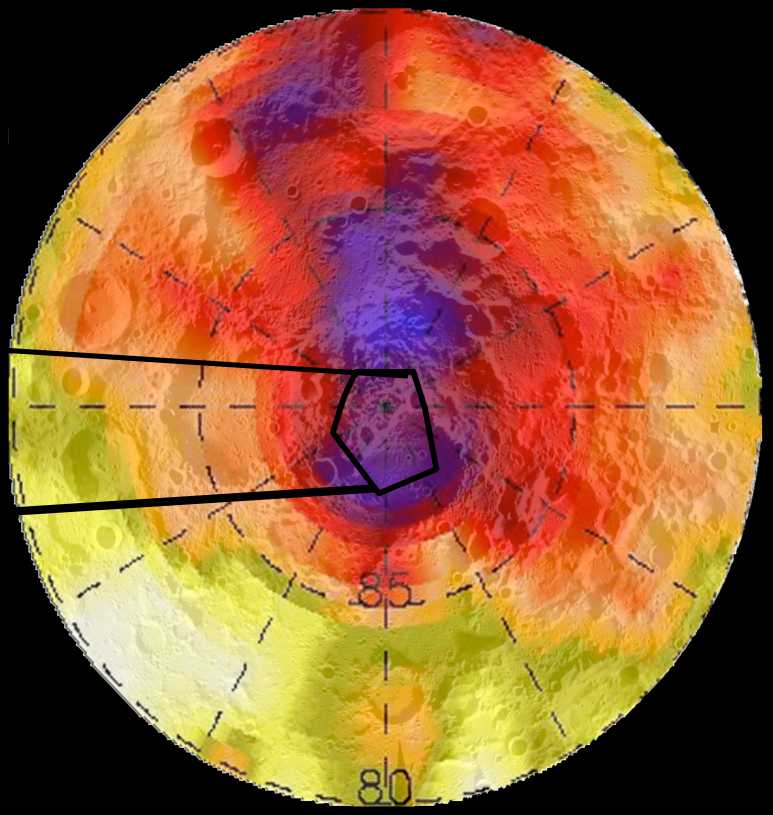

# Organic Measurements on the Lunar Surface: Planned and Unplanned Experiments

Daniel Glavin and Jason Dworkin
NASA Goddard Space Flight Center
Solar System Exploration Division
and
M. Lupisella, G. Kminek, and J. Rummel
(GSFC, ESA, NASA HQ)

# 1. Water-Ice at the Lunar Poles?

**Clementine: Permanently sunlit and shadowed regions consistent with cold traps**




**Earth-Based Radar: High CPR found in both dark and sunlit regions; surface roughness and NO thick ice deposits**

*Campbell et al. 2006*

**Lunar Prospector: Enhanced $H_2$ at poles; ~2% water-ice or solar wind**

*Bussey et al. 2005; Fristad et al. 2004*

# 2. Study the Sources of Lunar Volatiles

Earth
(contamination, possible terrestrial meteorites)

Solar wind
(implanted HCN, He, Ne)


Comets and Asteroids
(water-ice, organics?)

Interplanetary dust particles

# 3. Prepare for Humans on Mars

- Is it possible for humans to visit a body and not hopelessly contaminate it with organic material?
- Can astronauts live and work beyond low Earth orbit for extended periods?
- What infrastructure will function as expected?

*2001: A Space Odyssey*

# Why Study Forward Contamination on the Moon?

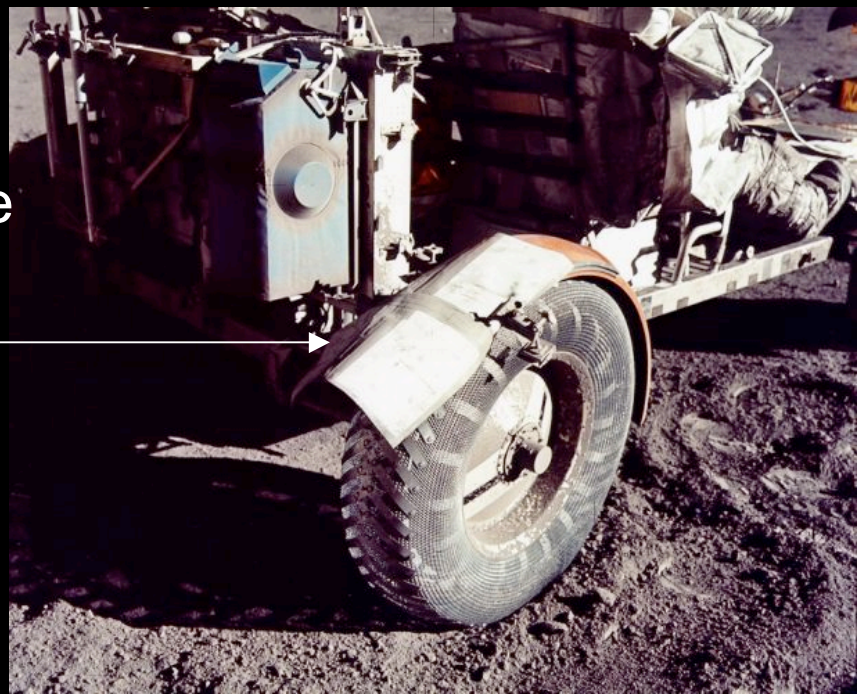


- Hostile surface conditions: ephemeral atmosphere, UV and galactic cosmic radiation, temperature extremes, dry, gardening
  - Growth of bacteria on surface unlikely. But is survival in permanently shadowed regions or below surface possible?
  - Spore forming bacteria can survive harsh conditions of space, e.g. NASA's Long Duration Exposure Facility (LDEF)
- NASA and COSPAR planetary protection policy for the Moon not very stringent since probability of finding life there low, so tests are possible.

# Lunar Organic Contamination

- Apollo soil samples were analyzed for terrestrial contaminants
  - $\delta D$ and $\delta^{18}O$ of water in lunar soils show terrestrial origin
  - The amino acids detected (>ppb) are terrestrial
- No viable organisms detected in Apollo 11 and 12 samples and Surveyor 3 bacteria survival questioned
- Introduction of organic contamination
  - Lunar surface (tools, exhaust, outgassing, leakage, venting, waste systems, improvisations, etc.)
  - Earth (handling operations, monitored using witness plates)

see Allen & Lindsay for more



AS17-137-20979

# Thrusters

- Thrusters use(d) any of a mixture of hydrazine $N_2H_4$, methyl-hydrazine $(CH_3)_nN_2H_2$, and nitrogen tetroxide ($N_2O_4$).

- Spacecraft exhaust will complicate the identification of native volatiles on the lunar pole. Mobility desired to move away from plume (hoppers don't count).

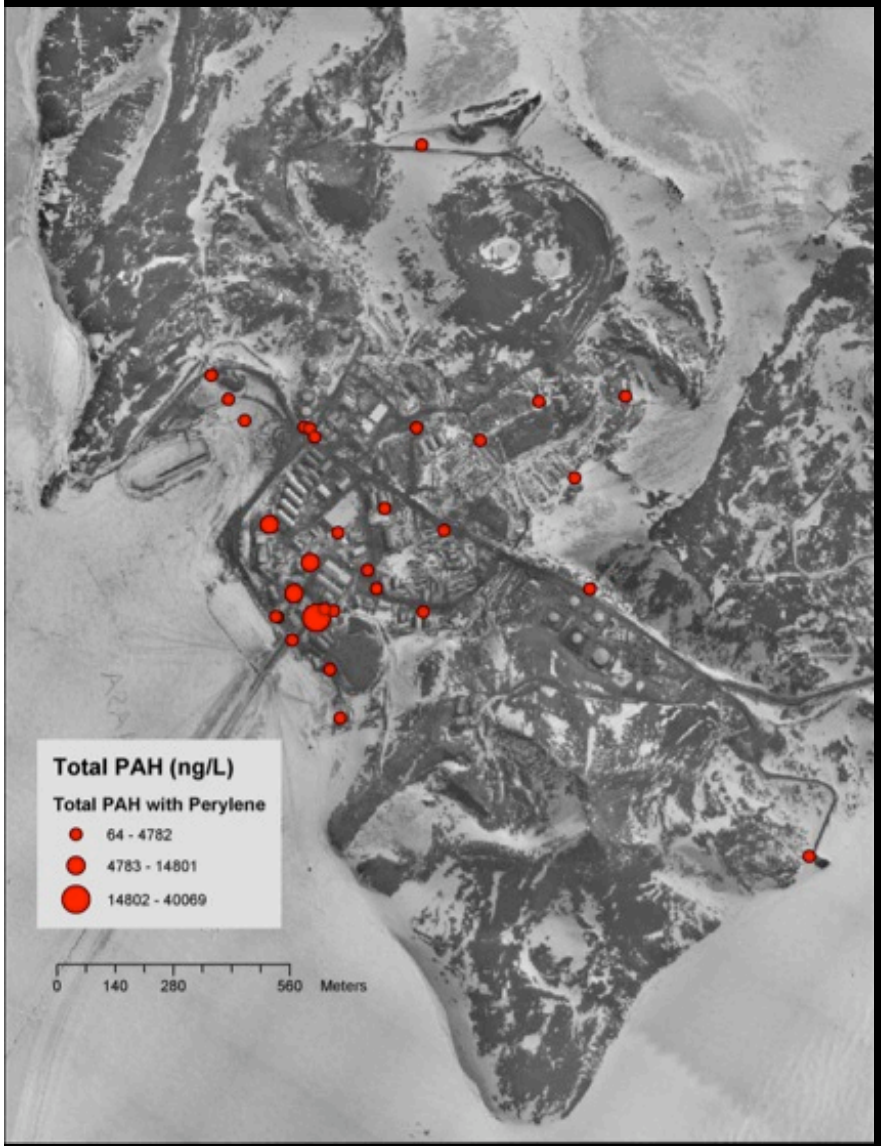
Bi-propellant Thruster
http://www.space1.com/

- Apollo lunar module exhaust products include compounds of interest: $NH_3$, $H_2O$, CO, NO, $O_2$, $CO_2$, $NO_2$, trace organics.

- Modern thrusters are better, however:

We need to understand how far these plumes extend and how long the compounds persist and how they react.

# A Future Lunar Colony




- Ground-truth data to define planetary protection requirements for future life detection missions on Mars (or elsewhere) and
- Likely generate a wide region of contamination since
- Anytime many people are working and living, contamination should be expected,
- Especially under difficult conditions

Polycyclic aromatic hydrocarbons in 17 runoff sites at McMurdo Station

*Spatial and Temporal Scales of Human Disturbance McMurdo Station, Antarctica* (2003)

# Planned Experiments

- Examine the survivability rate of microbes and spores
- Measure the rate of destruction of various organic compounds
- Gain understanding of effect of different levels of cleaning in different environments on organic abundances.
- Understand the extent and persistence of thruster exhaust
- Determine the integrity of construction materials
- Do all of these with and without UV

*In situ*: can limit contamination, more sites

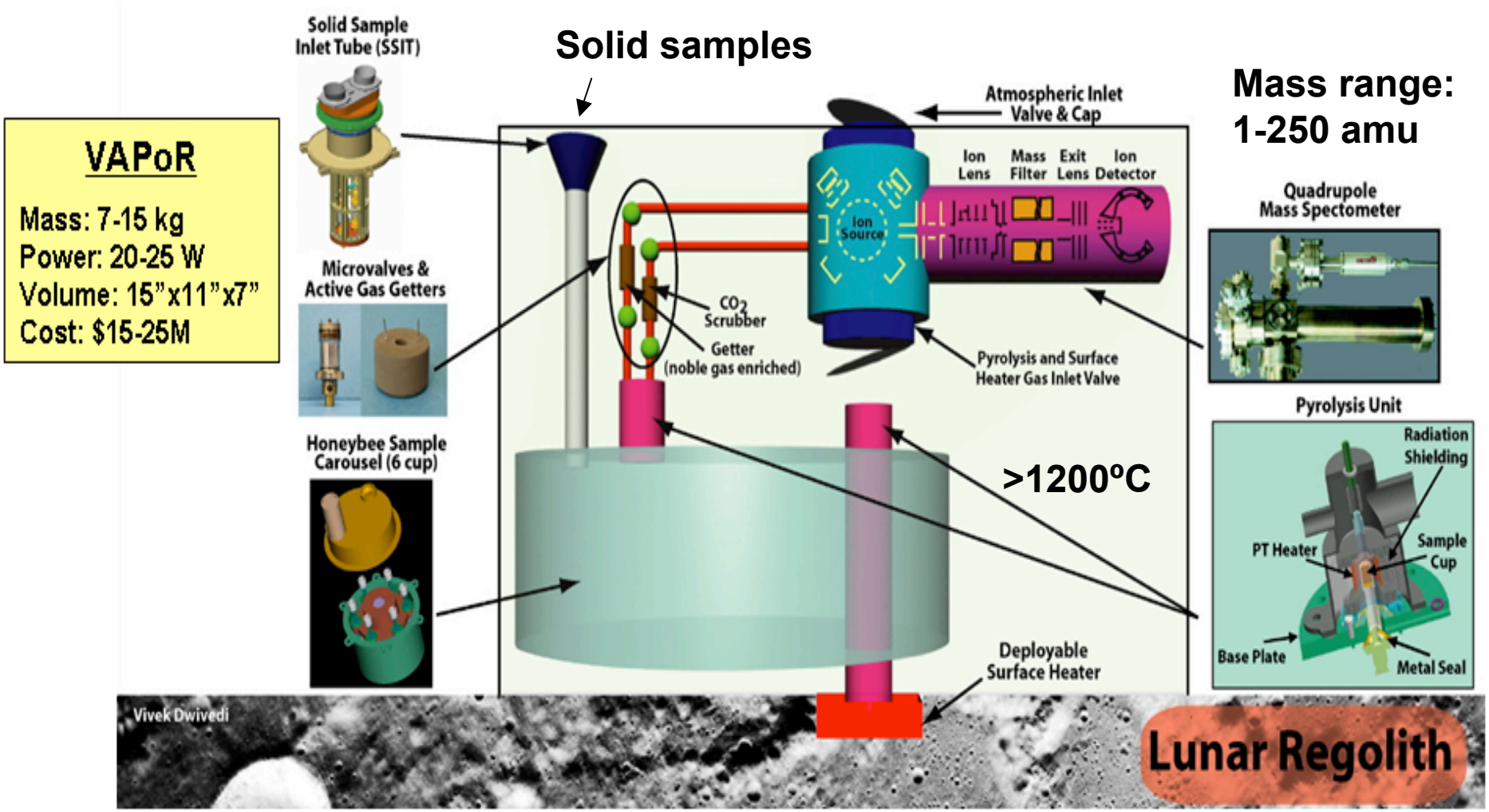
Terrestrial: more diverse and sensitive

Alan Bean with Surveyor 3 and LM Intrepid

# Shameless Advertisement

## See K. Fristad's Poster Tomorrow

"In Situ Volatile Analysis by Pyrolysis of Regolith (VAPoR) on the Moon using Mass Spectrometry"



# Lunar Artifacts to Study Planetary Protection: Unplanned Experiments

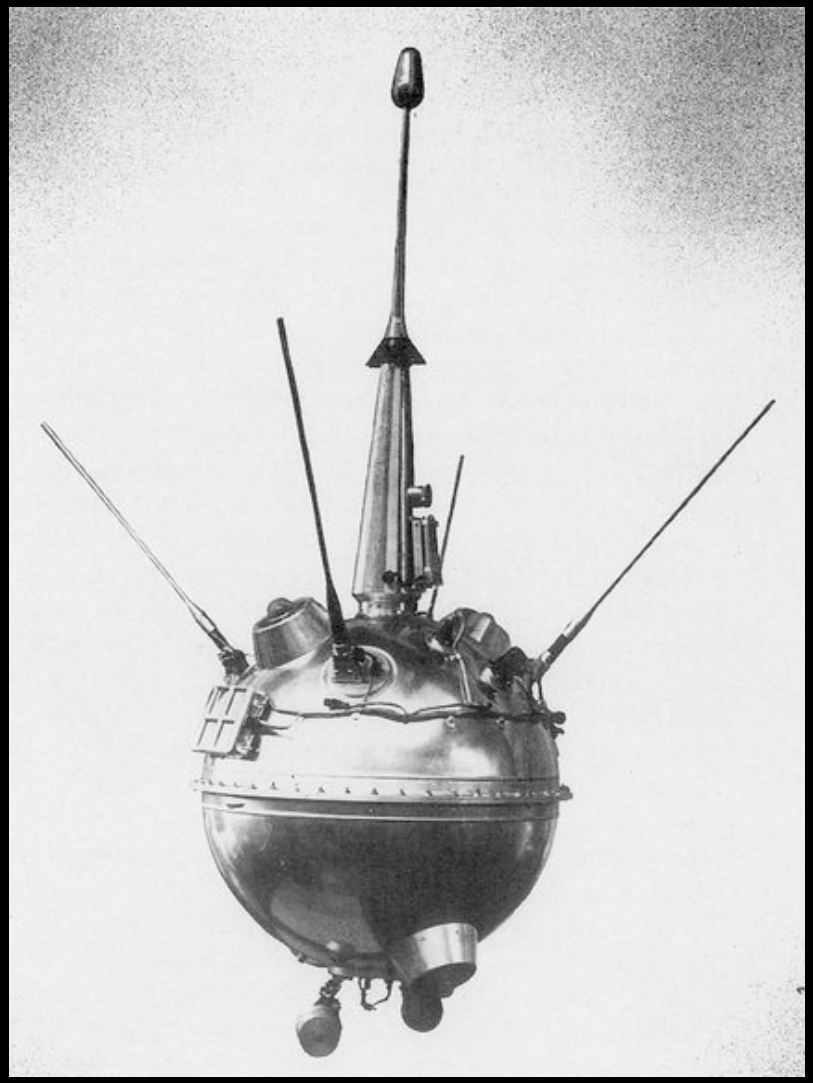
How can you do long term studies?

…start early.

*2001: A Space Odyssey*

# Luna 2: A Half Century of Exposure

Luna 2 has been sitting on the lunar surface almost 50 years. What is the condition of the biology, organics, and materials?



Long Duration Exposure Facility (LDEF) was “merely” exposed to low Earth orbit for 5.7 years, and UV protected spore-forming bacteria survived

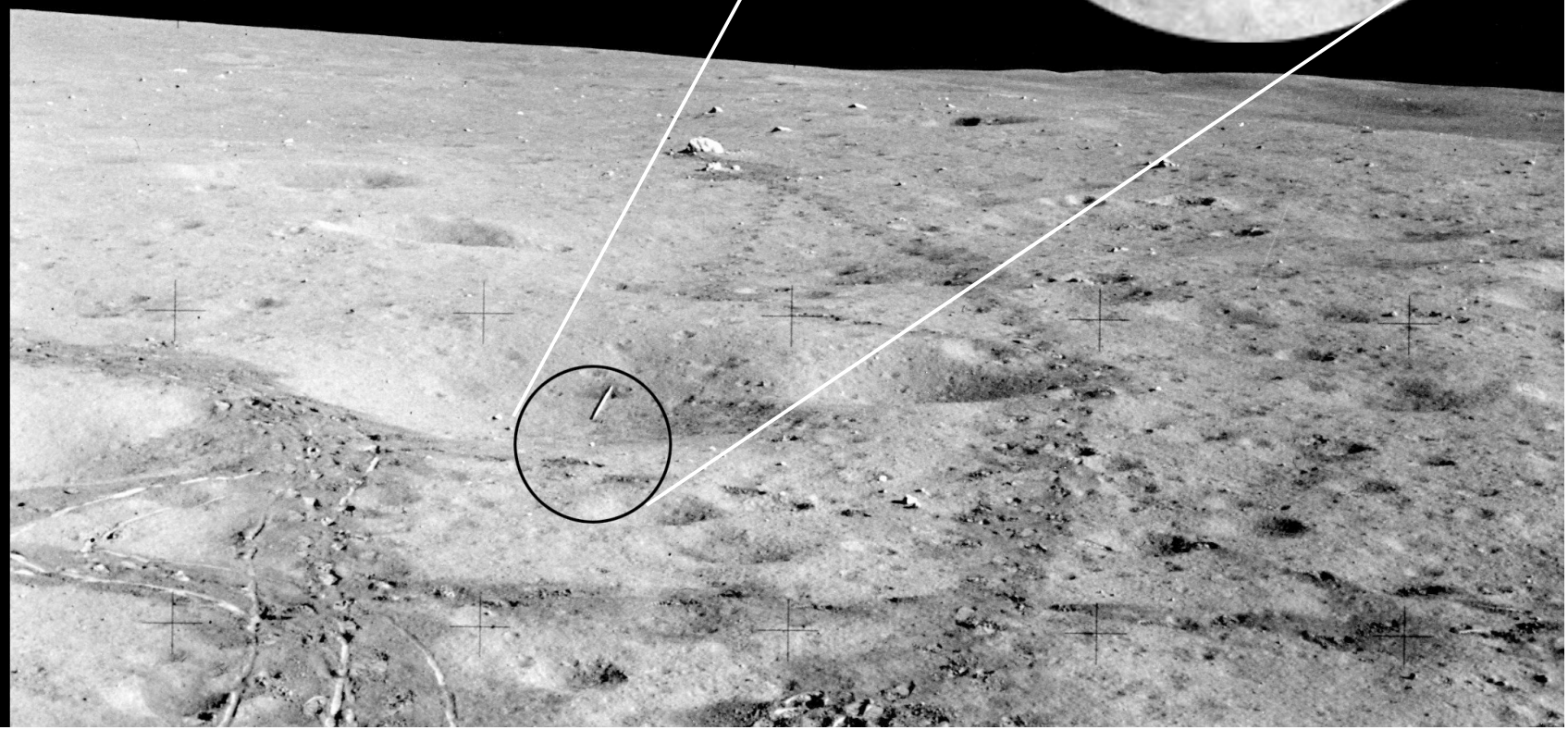
http://nssdc.gsfc.nasa.gov/

/http://setas-www.larc.nasa.gov/LDEF/

# Apollo 14: "Deliberate" Contamination

Figure shows one of two lunar golf balls and a "javelin"

- Ball was carried in Alan Shepard's pocket
- Location is precisely known

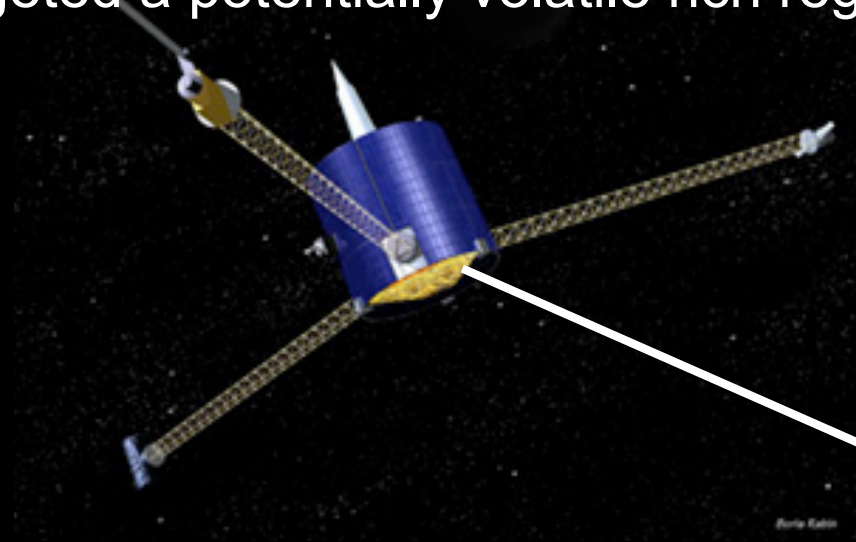


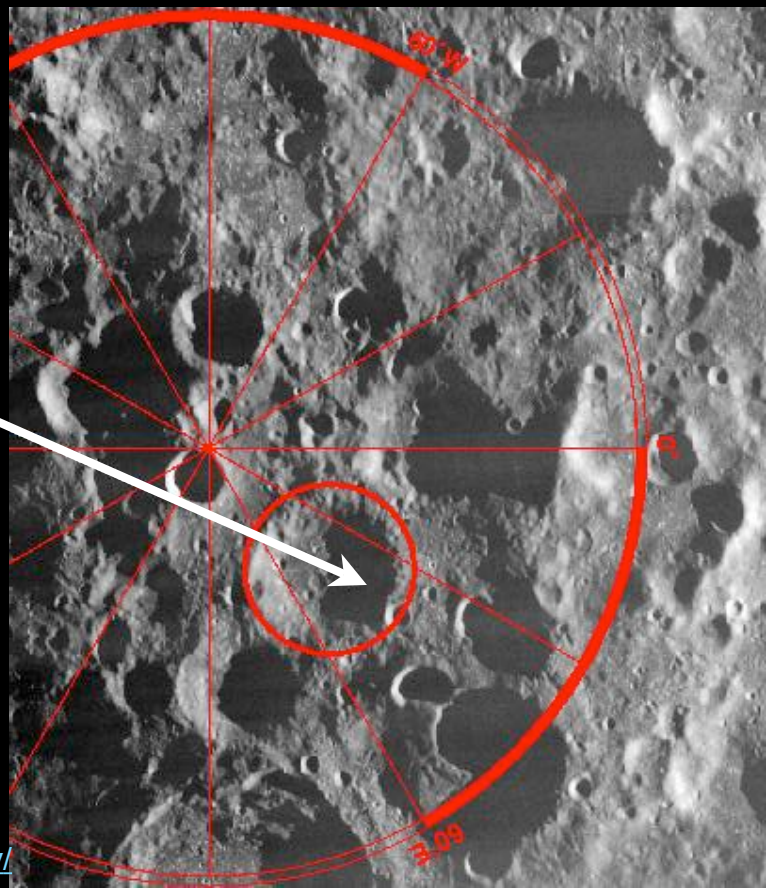
AS14-66-9337


Apollo 14: An experiment in progress
Bacteria, skin cells, plastic has been exposed to UV light, gardening, etc. since 1971.
Bacteria, skin cells, plastic have been exposed to regolith and vacuum, but shielded from space since 1971.

# Lunar Prospector: Impacted an Unusual Region of the Moon

- Spacecraft was not sterilized*
- Targeted a potentially volatile rich region shielded from UV damage





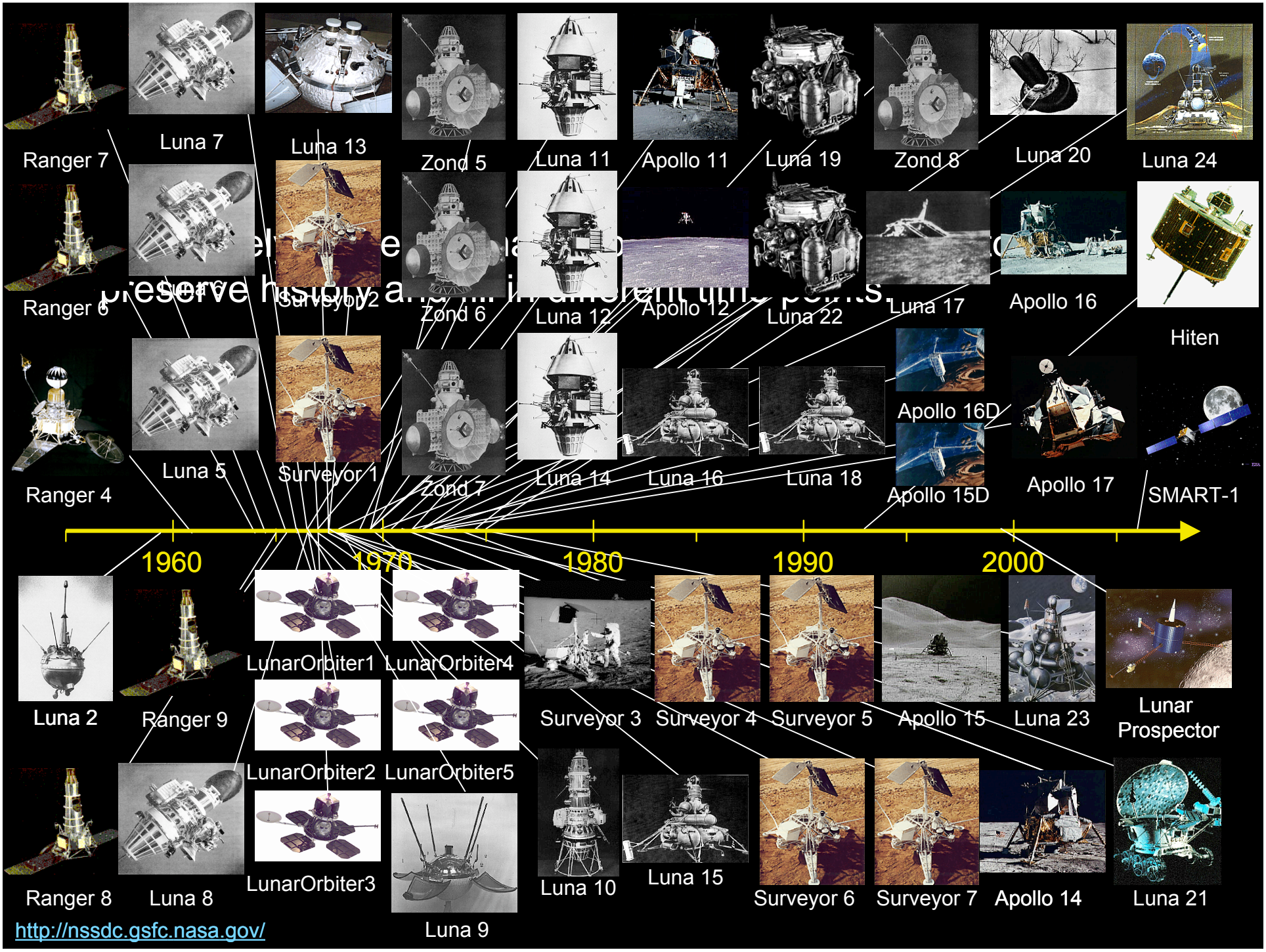
- Did any organisms survive the impact?
- Are they still viable? growing?

*The ashes of Gene Shoemaker were pyrolyzed of organics

http://lunar.arc.nasa.gov/

# Some Sites Should Be Preserved for Future Astroarchaeologists


Apologies to *Raiders of the Lost Ark*



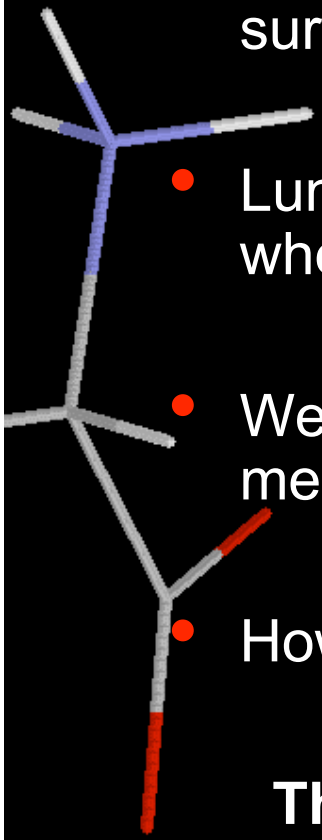

http://nssdc.gsfc.nasa.gov/

# Contamination Studies on the Moon

- Sterilized bacteria is still rich organics. Processing on lunar surface may mask their origin
- Lunar exploration is a test-bed for future Mars exploration where life detection is a primary objective
- We need to know, first hand, if past planetary protection measures were insufficient or excessive
- How much contamination is spread when working in space

**This can be via new experiments and old spacecraft**

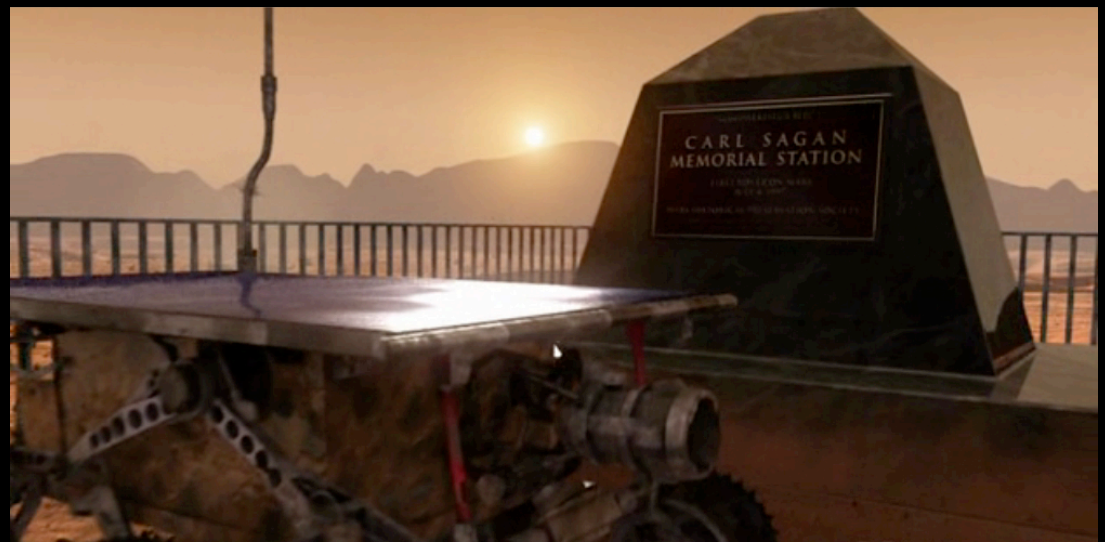
**See Glavin, Dworkin, Lupisella, Kminek, & Rummel**
***Int. J. Astrobiology*** 3**: 265–271(2004)**


glycine


*Streptococcus*

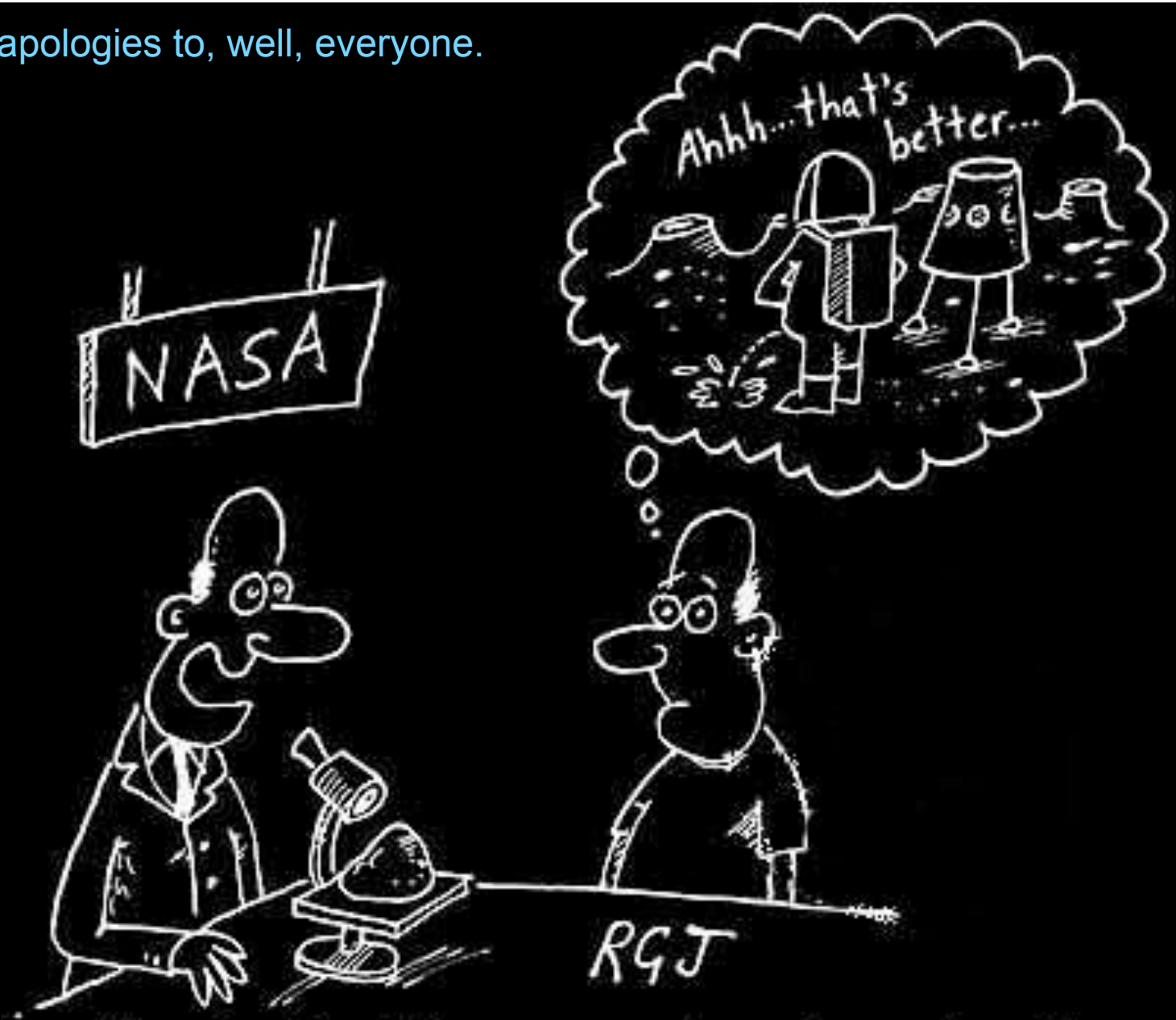
# A Small Dose of Reality

- When can we expect a lunar planetary protection experiment?
  - Perhaps when lunar missions are fairly common.
- When can we expect *in situ* organic analyses of exposed hardware?
  - Hopefully before construction of a lunar or martian colony.
- When can we expect a golf ball sample return mission?
  - Perhaps when Titleist$^{tm}$ pays for it.




*Star Trek: Voyager*

With my apologies to, well, everyone.




"Amazing Buzz! These moon rock samples you brought back in '69 contain evidence of water on the moon."

http://cartoonstock.com/lowres/rjo0120l.jpg