56th Session of the Scientific and Technical Subcommittee

11th to 22nd February 2019

Encouraging the Sustainable Exploration of Space by Using ISRU to Mitigate the Plume Effect

For All Moonkind
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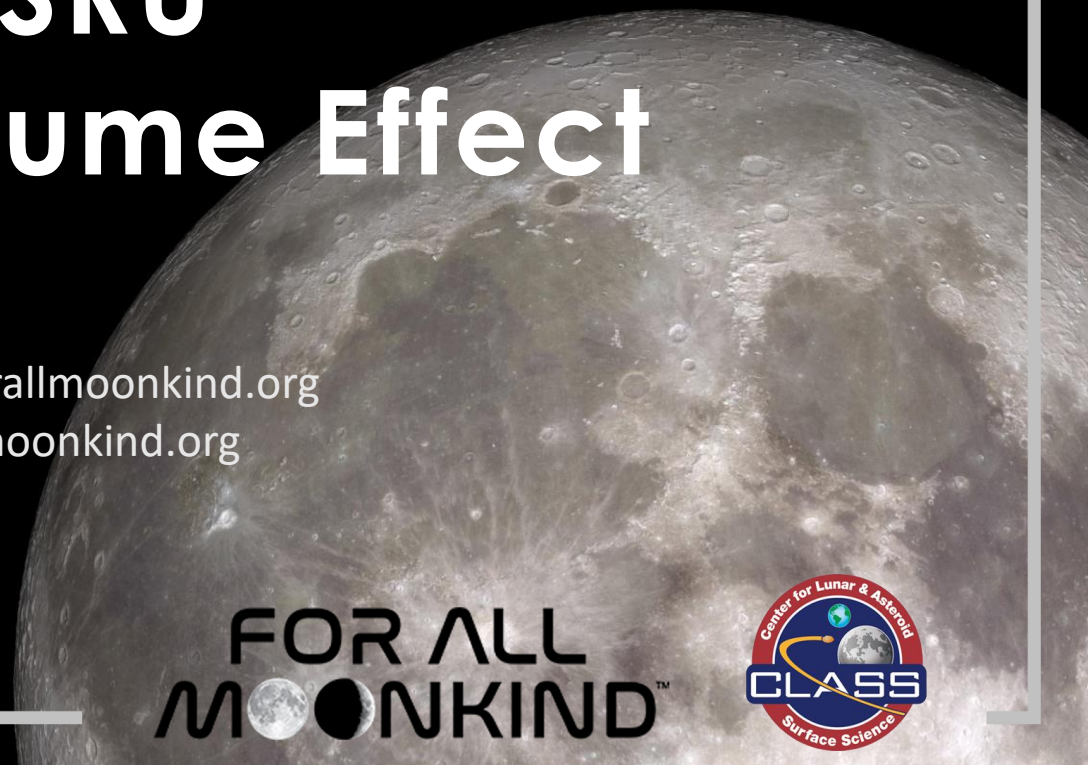
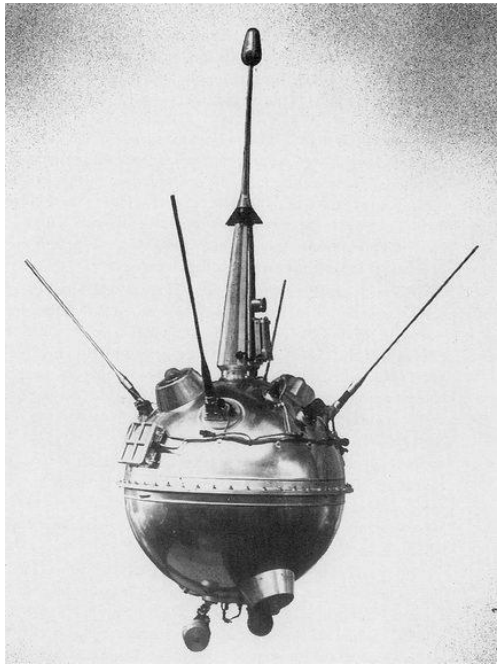
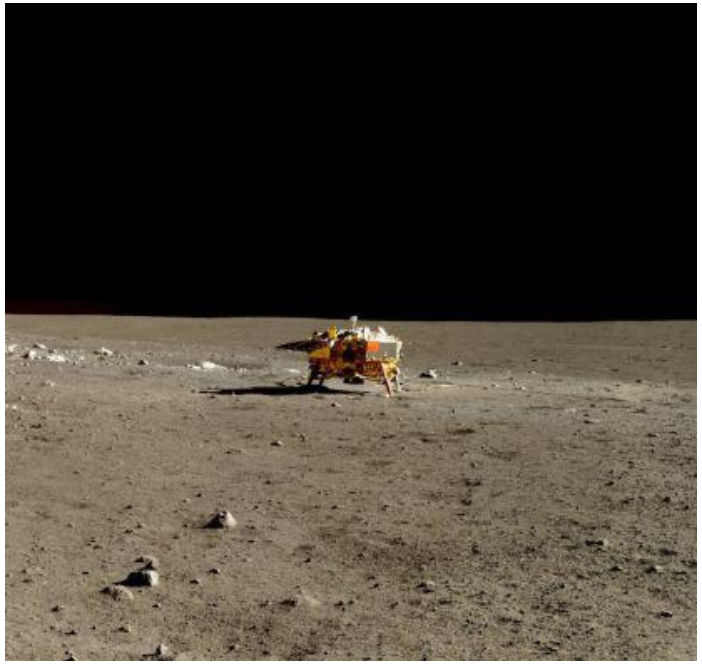


Human Milestones – Worth preserving!



1959

1969



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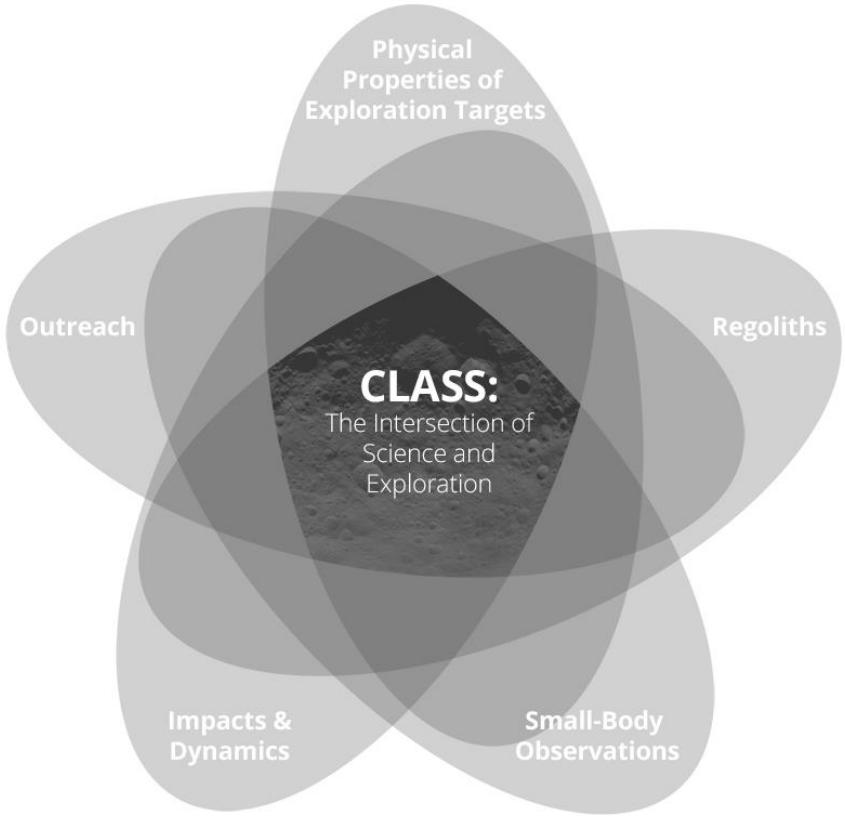

The CLASS Landing Team studies and analyzes the formation and evolution of the surfaces of other celestial bodies, including the Moon, Mars and asteroids, so that future exploration missions, whether human or robotic, will be properly equipped to handle any challenges they face.

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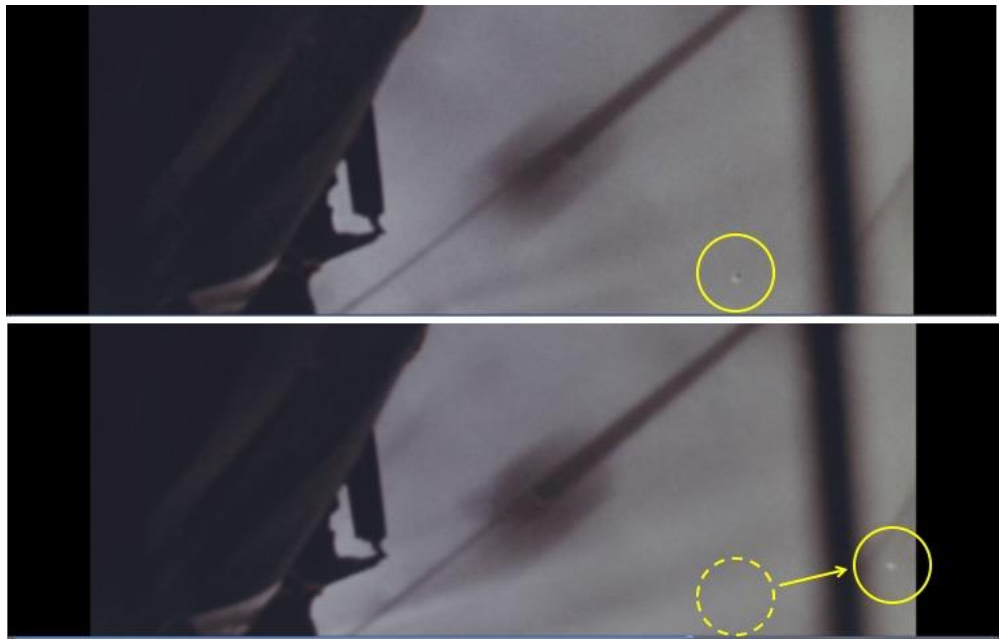
The Science of Plume Effects



Images of a rock blowing at high speed during an Apollo landing

When rockets land on planets, the rocket exhaust will produce dramatically different effects depending on the gravity and size
of the spacecraft, the mechanical strength and porosity of the soil, and the density of the atmosphere.

In lunar landings, for example, a spacecraft the size of the Apollo Lunar Module will blow away more than a ton of soil, dust, and rocks at high velocity.

For human-class landers on Mars, the supersonic jet will dig a deep, narrow crater that redirects a jet of gas carrying rocks and sand back up at the landing spacecraft.

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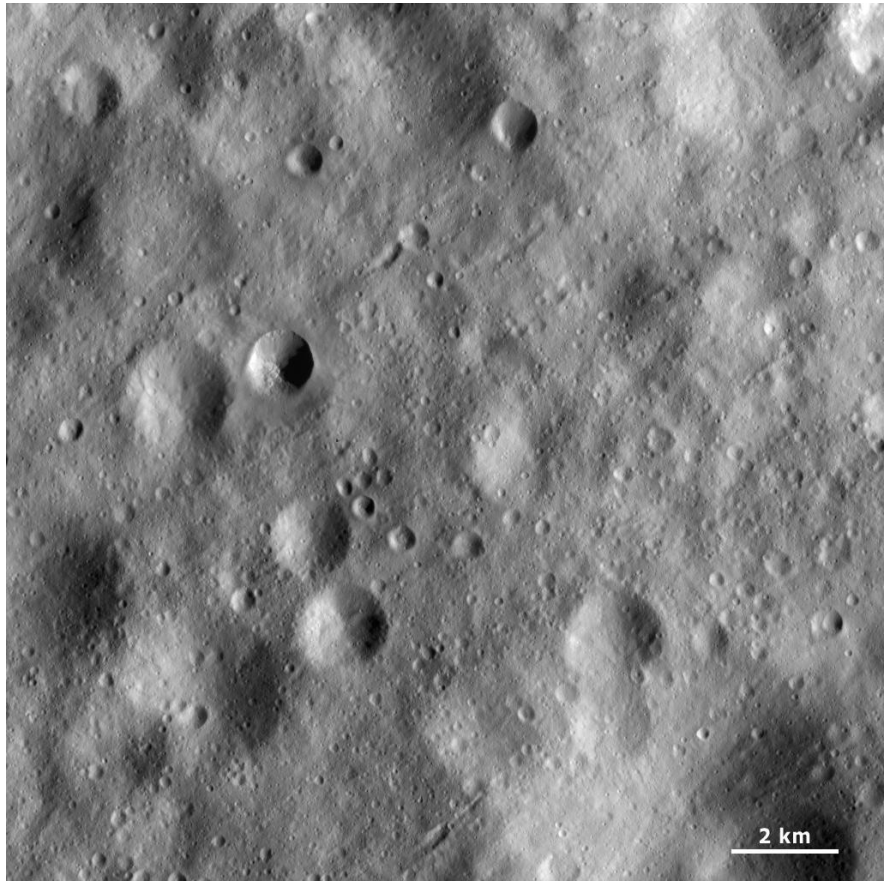
Lunar Regolith – Resistance to Deep Cratering



- The Moon's unique regolith was formed by billions of years of impacts
- The regolith is very loose in the top few centimeters, generally becomes more compacted over the next few tens of centimeters
- It is very fine – relatively impermeable and very cohesive
- Rocket exhaust can easily scour away loose surface material

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Hazard to Landers

"…at 300 feet, we picked up a tremendous amount of dust;
much more so than I expected…the dust went as far as I could see in any direction
and completely obliterated craters and anything else.
All I knew was there was ground underneath that dust…
I couldn't tell what was underneath me…
I was just going to have to bite the bullet and land,
because I couldn't tell whether there was a crater down there or not."

Astronaut Pete Conrad - Apollo 12 Commander

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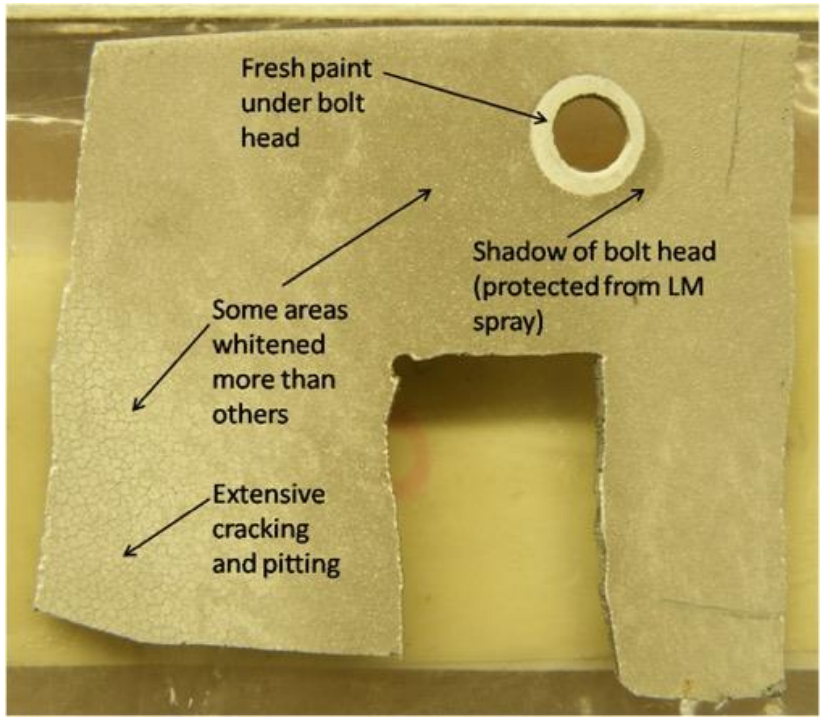
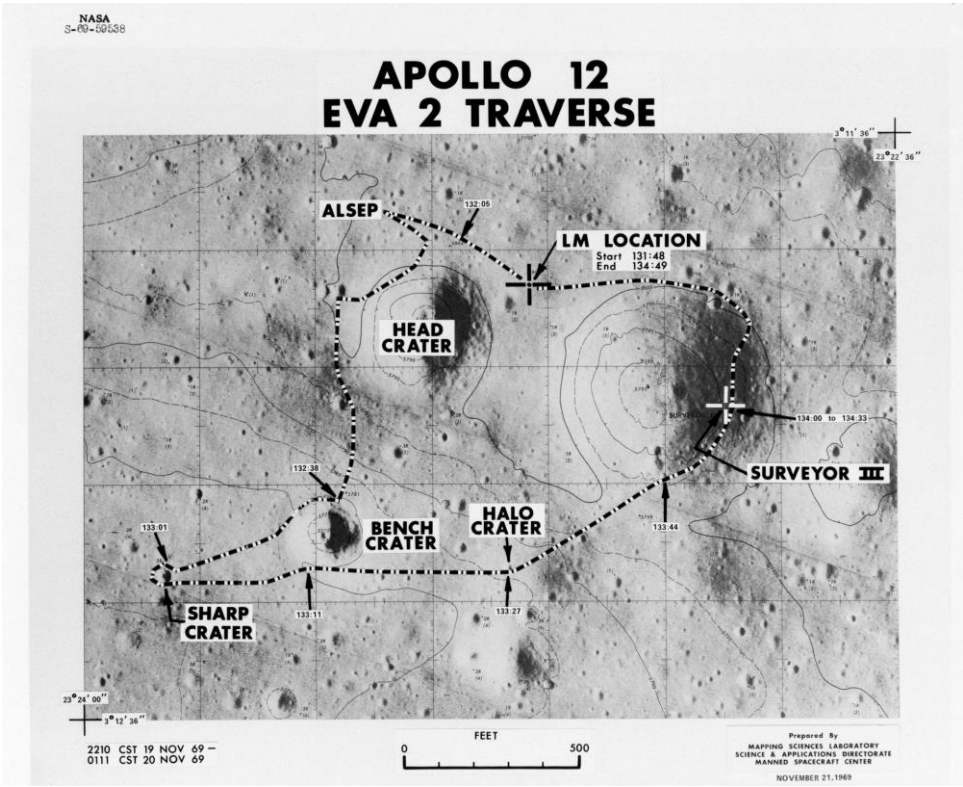
Plume Effects on the Moon



Piece of Surveyor 3, cut from the spacecraft by the Apollo 12 Astronauts



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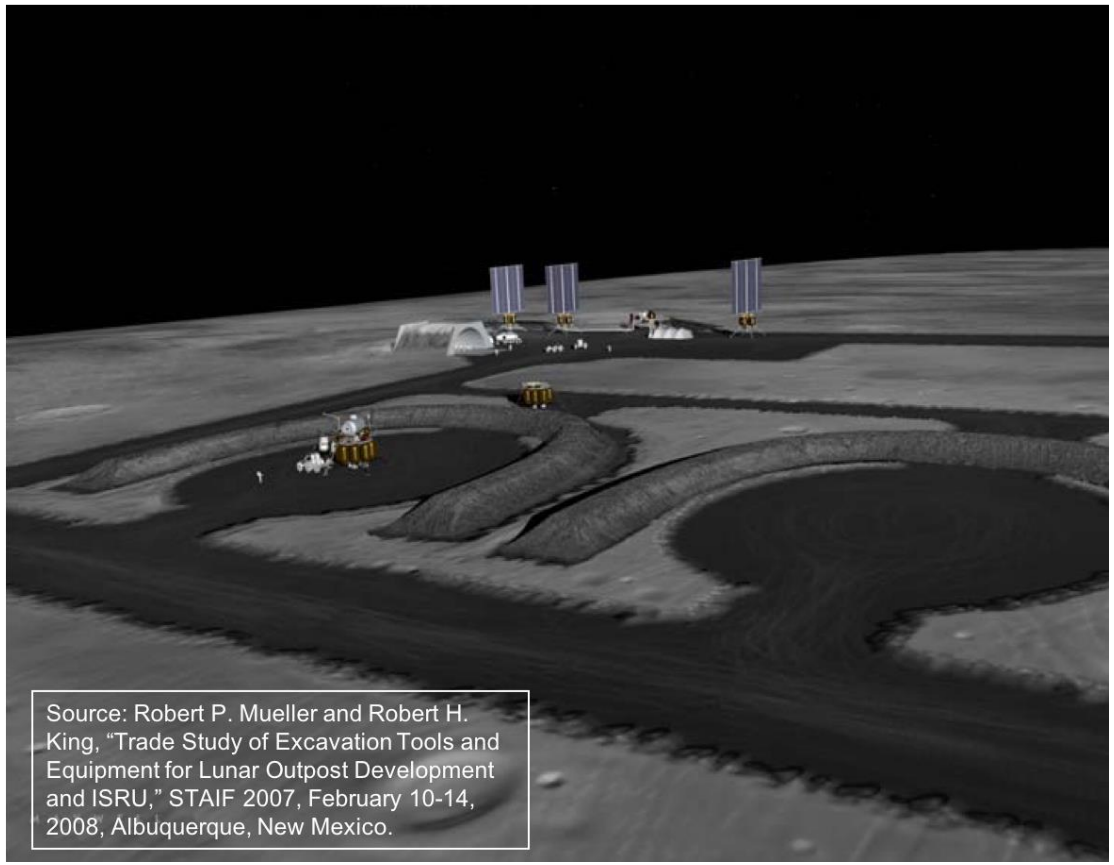
Landing Pads



Source: Robert P. Mueller and Robert H. King, "Trade Study of Excavation Tools and Equipment for Lunar Outpost Development and ISRU," STAIF 2007, February 10-14, 2008, Albuquerque, New Mexico.

The concept of landing pads can be interpreted broadly to mean any or all of the following:

- A concrete-like, impermeable surface that can handle high temperature and will not erode
- Gravel or polymer applied to the region surrounding this hard surface, to extend the region where soil does not erode
- Berms or fences surrounding the landing zone to block ejecta
- Blast barriers erected locally in front of critical hardware to protect them from the blast

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The three steps of developing ISRU

1) Understand the physics and develop adequate computer modeling

2) Use computer models, coupled with experiments and experience,
to determine what mitigation is actually required to control blast effects

3) Develop the technologies

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THANK YOU!

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