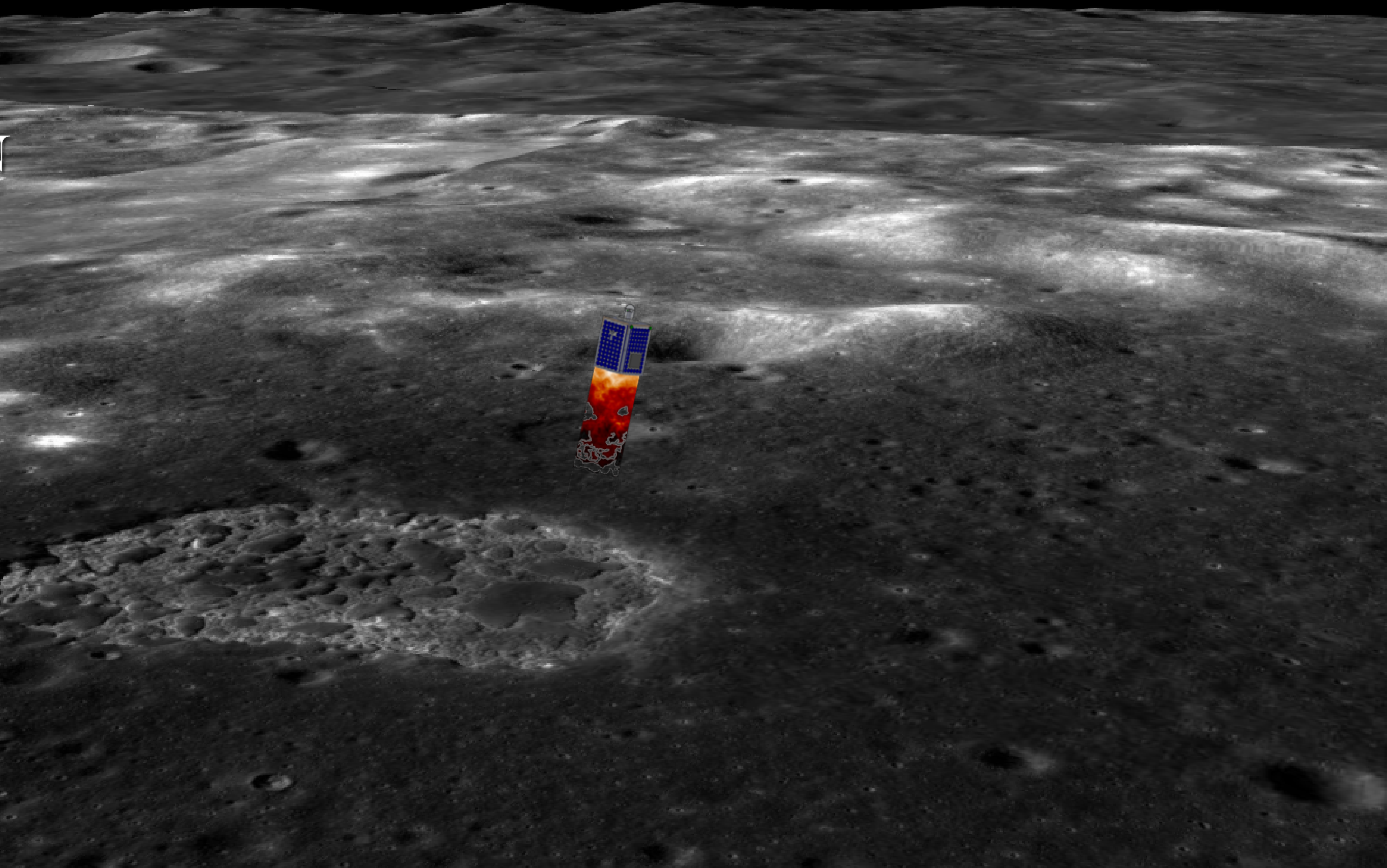
An Innovative Strategy for Exploring the Lunar Surface

IMPEL

IRREGULAR
MARE
PATCH
EXPLORATION
LANDER



Astromaterials Research and Exploration Science
Johnson Space Center

Lunar and Planetary Institute

USRA

APL Johns Hopkins Applied Physics Laboratory

Planetary Deep Space SmallSat Mission Concepts Symposium 18 March 2018

The Woodlands, Texas

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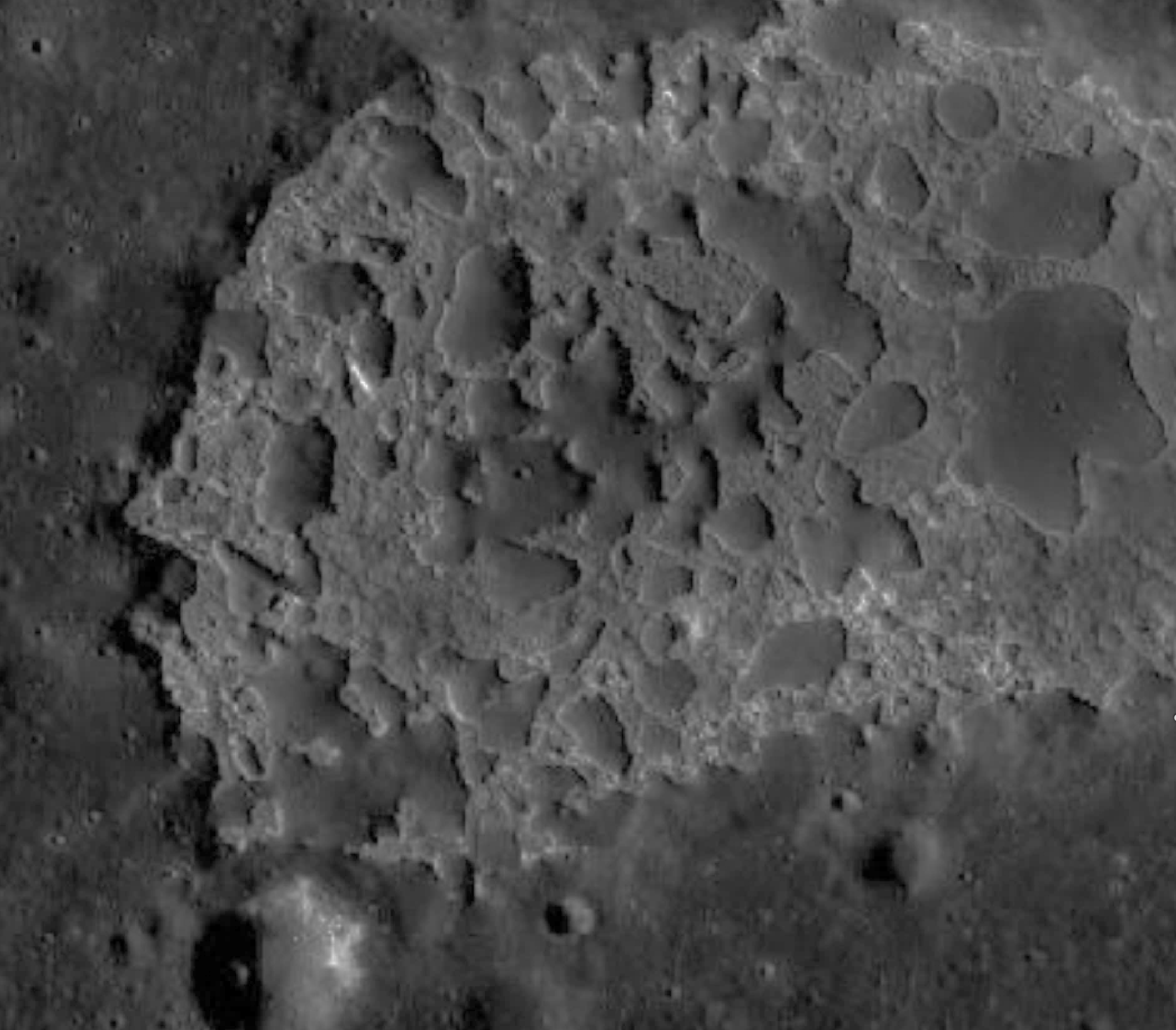
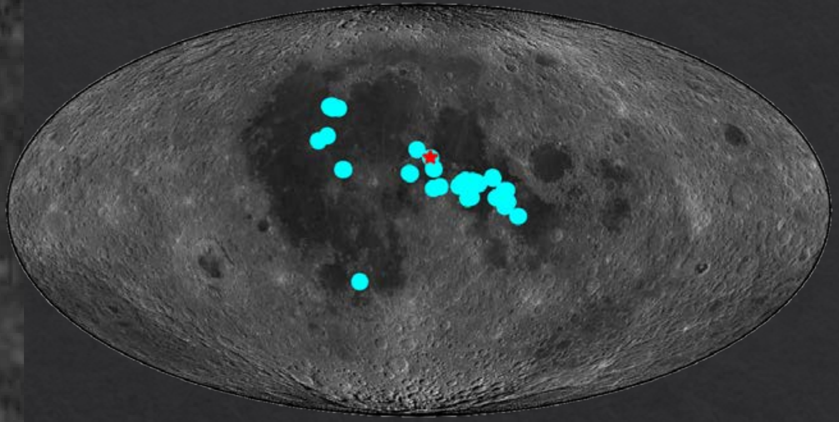
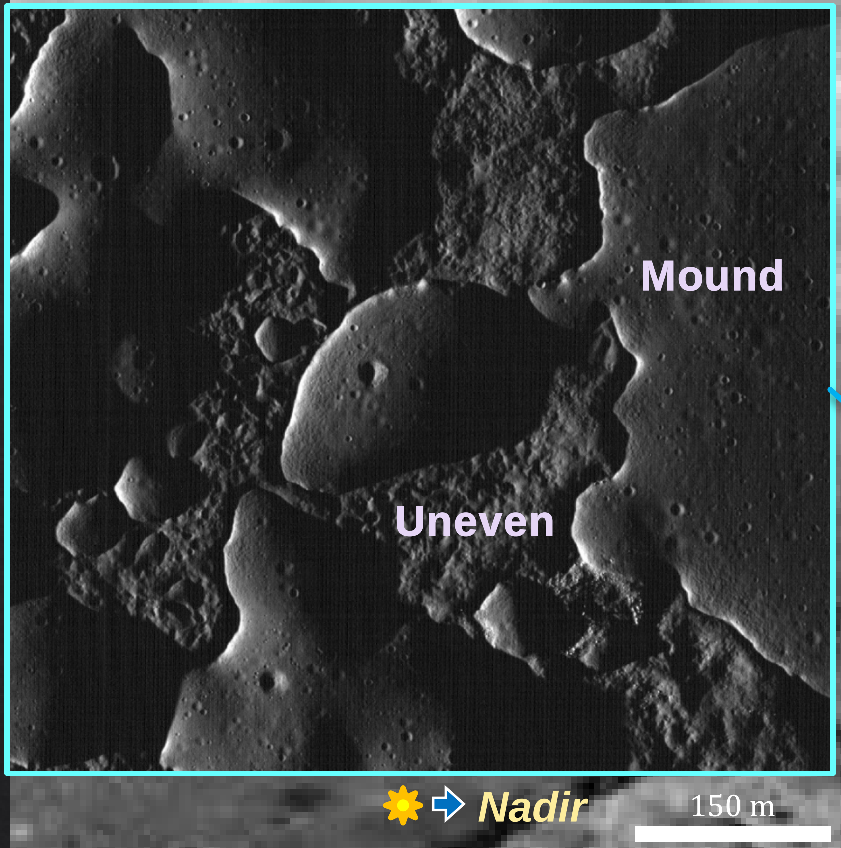
TARGET: INA





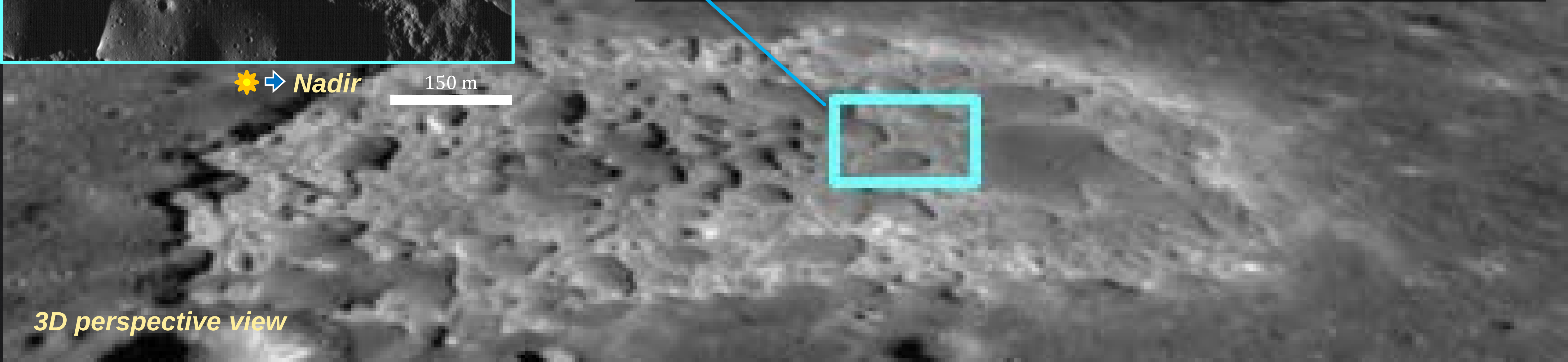
- 70+ Irregular Mare Patches (IMPs) on Moon
- Ina Formation discovered in Apollo photography, others in LRO imagery (Braden et al., 2014)
- Constellation Region of Interest – complete set of data necessary for site certification available
- Volcanic emplacement for mounds and uneven materials
    - Mounds and uneven materials have not undergone heavy or even moderate degradation
    - There is a >5cm coating of fine particulate materials or regolith (Elder et al. 2017)

EXPLORING AN ENIGMA

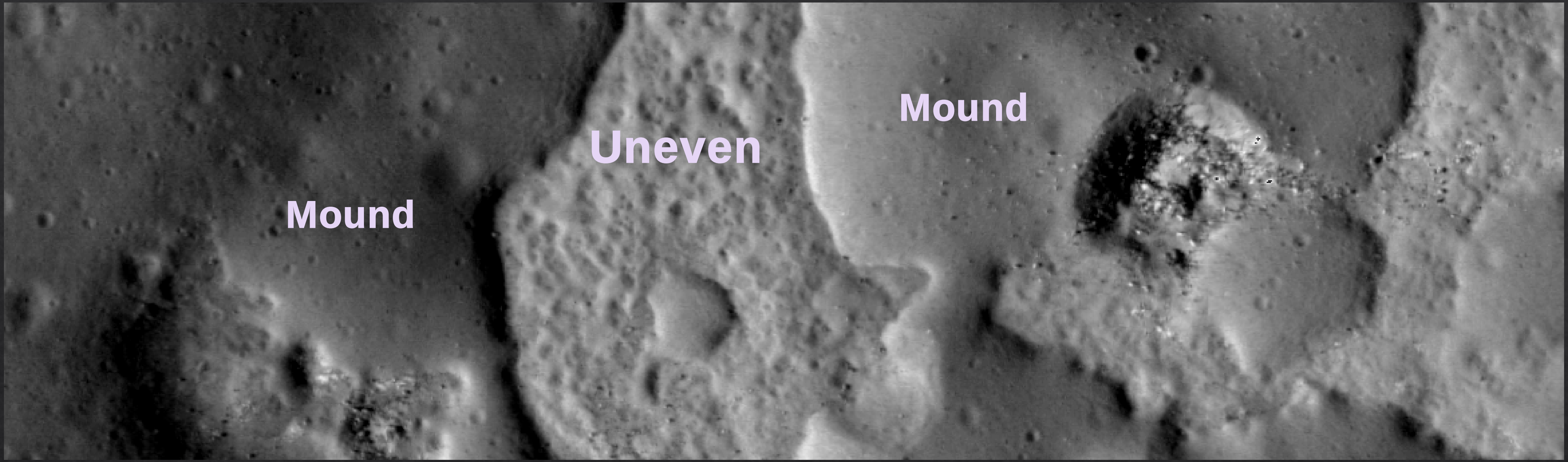


Open Questions:

- What came first – mounds or uneven deposits?
- What are they made of –residual vent materials? Highly vesiculated basalts in a lava pond/lake setting, or something else?
- When were they deposited – are they ancient (3.5 Ga) or relatively young (100 Ma or even more recent)?
- Understanding the origin and evolution of lunar volcanism is a key goal of the 2014 NASA Science Plan, the Decadal Survey, and the 2007 NRC Report



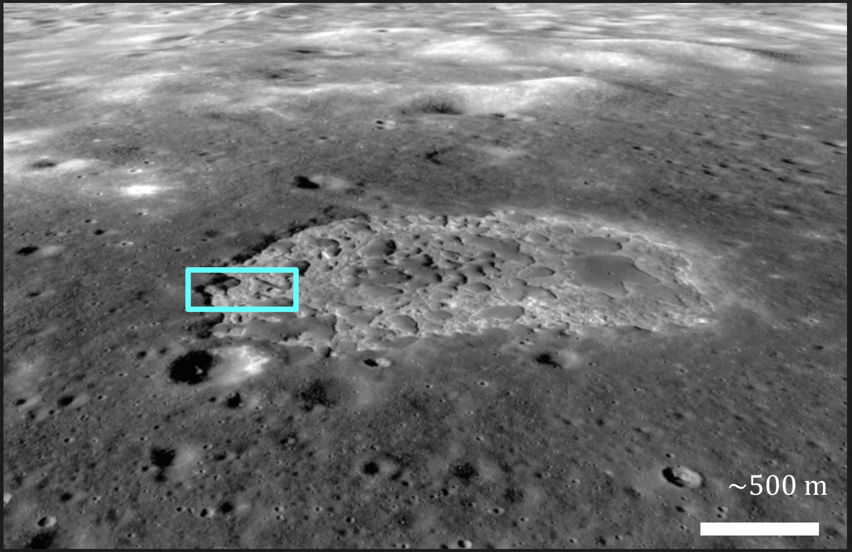
THE CASE FOR A LANDER



W interior of Ina

Nadir

75 m

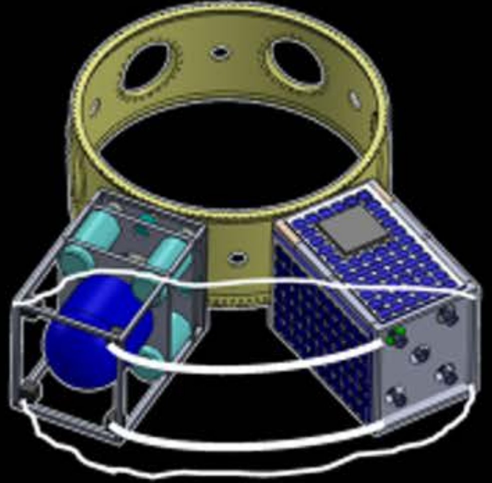


- The small area (~7 km^2) and small scale of the surface deposits require surface access and in situ investigations
- For example, sharp contacts between deposits are less than a few to 10 m across, and many details exceed the currently available best resolution of 0.4 m/pix
- A focused, surface investigation using a lander will address many specific science objectives

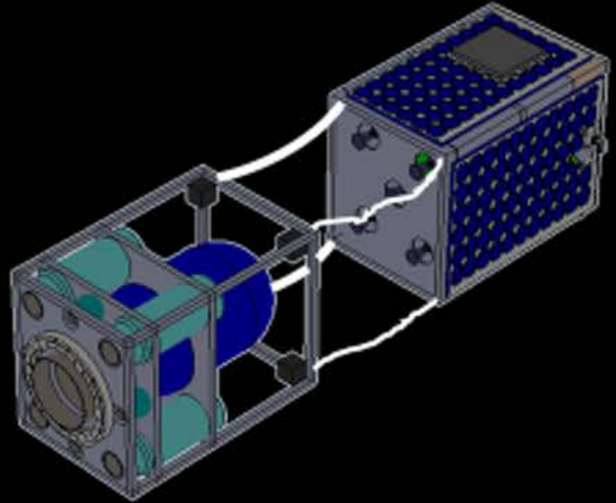
IMPEL SCIENCE OBJECTIVES

IMPEL Mission Science Objectives			Rationale
Primary objective	Determine the geomorphology of an IMP at the sub-meter-scale, improving on the best-available imaging (currently a scale of roughly 40-cm from select LROC observations)	P1: determine the presence and abundance of any sub-meter-scale fractures in Ina's deposits	Test young volcanic origin theory (improving on currently available data sets)
		P2: determine the presence and abundance of any sub-meter-scale pitting or collapse features in Ina	Test erosion origin theory (improving on currently available data sets)
Secondary objectives	Determine the composition and physical properties of an IMP	S1. Determine grain size and cohesiveness of the IMP mounds and associated deposits	Distinguish between volcanic and other regolith deposits
		S2. Determine abundances of regolith constituents present on the surface of the IMP	Distinguish between volcanic and other regolith materials, and constrain age by directly determining maturity of regolith

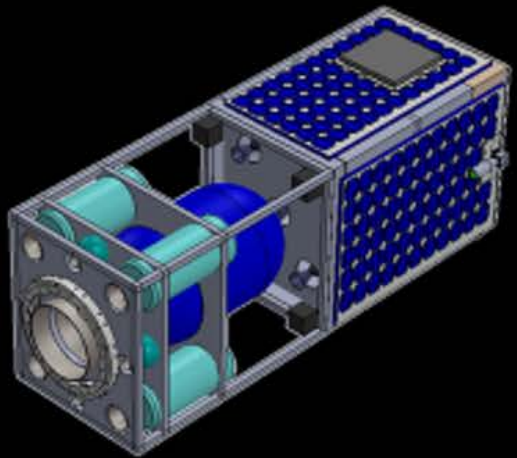
IMPEL:
A DUAL ESPA MODULE PLANETARY LANDER



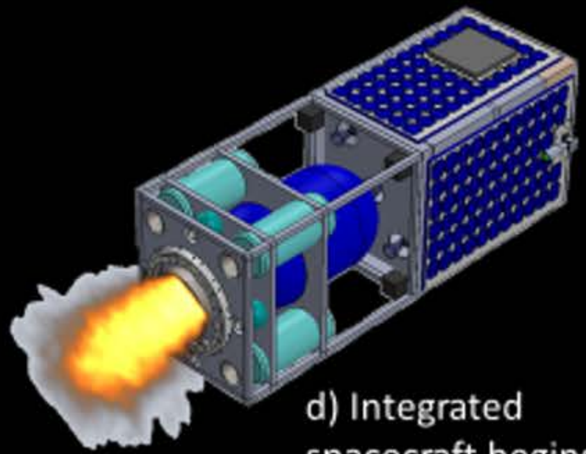
a) Two 180 kg, tethered spacecraft attached to ESPA ring.



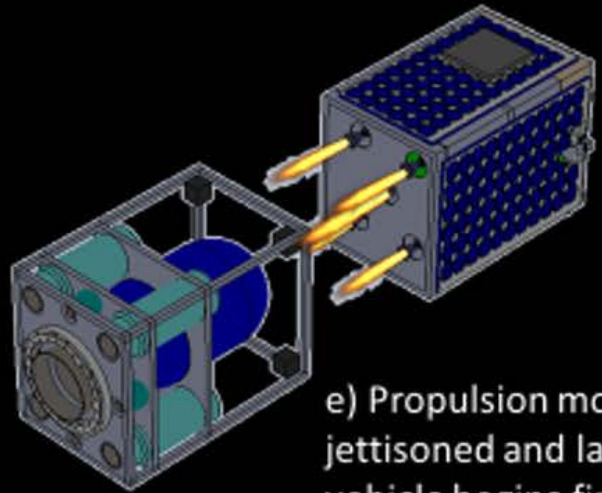
b) Spacecraft configuration after deployment. Tether-reel system retracts tether.



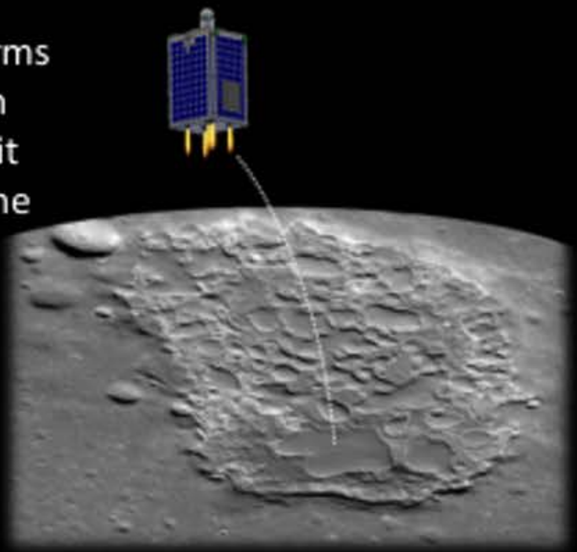
c) Spacecraft are pulled together and held together by tether tension.



d) Integrated spacecraft begins terminal descent burn.

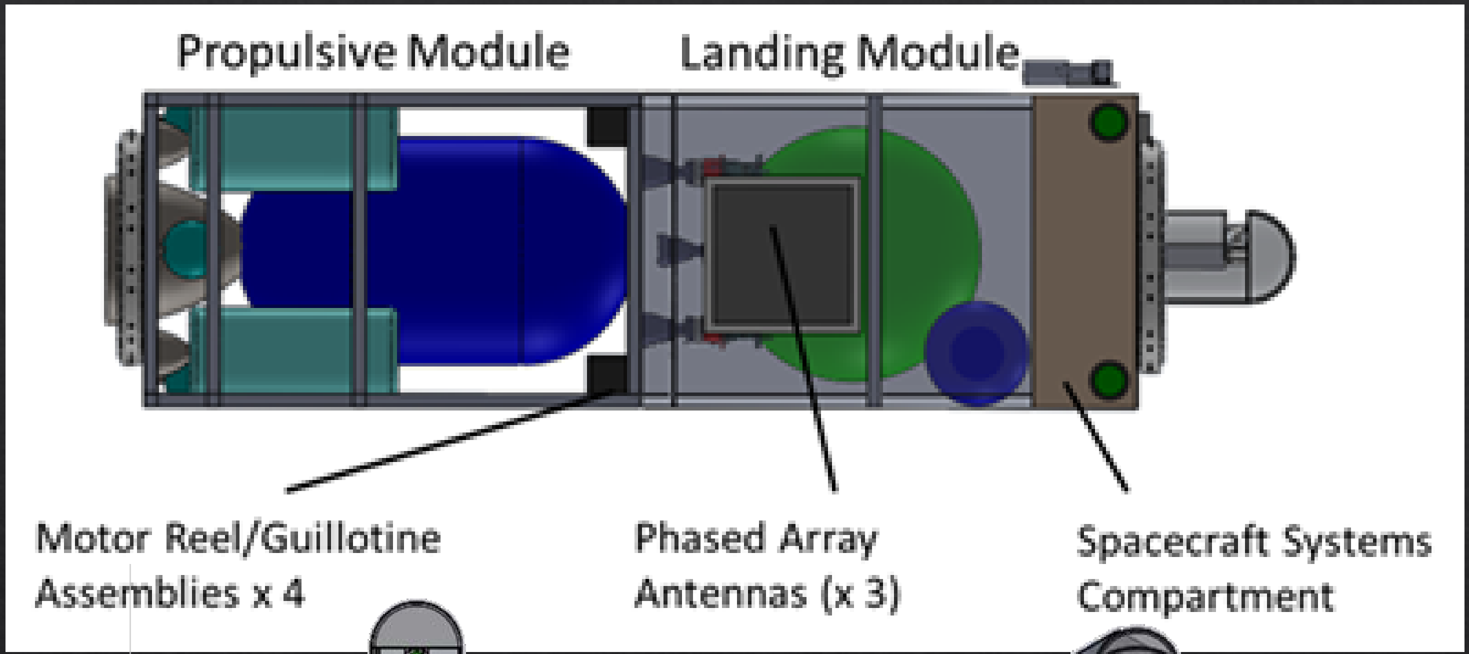


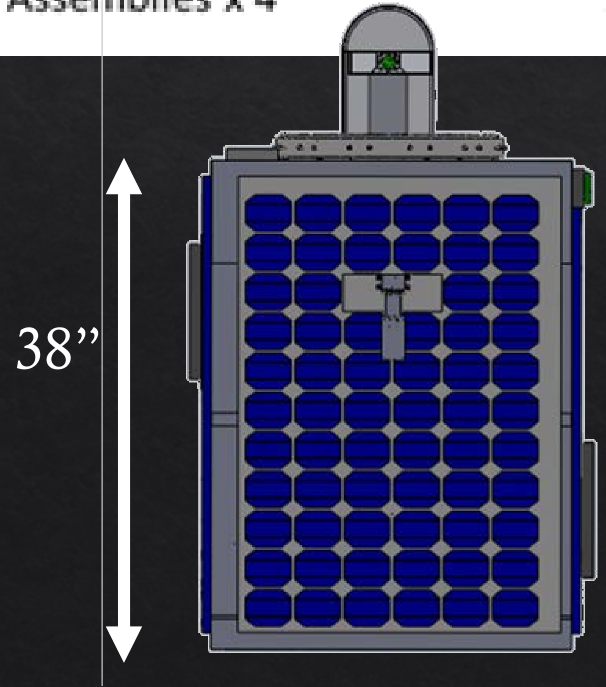
e) Propulsion module is jettisoned and landing vehicle begins final descent thrust.

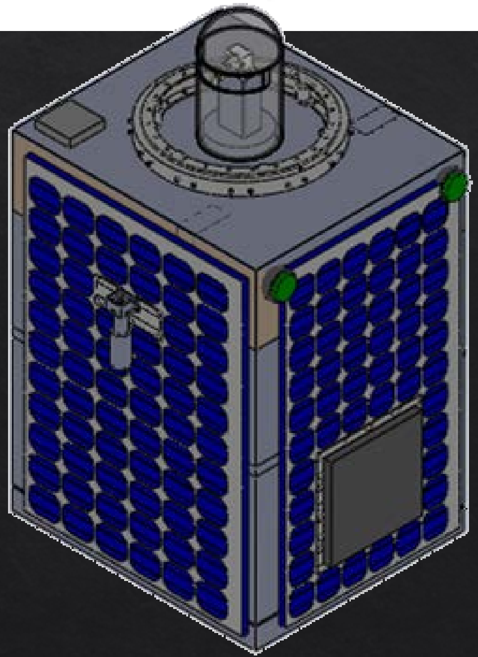


f) Landing vehicle performs throttle-down maneuver as it approaches the lunar surface.

IMPEL CONFIGURATION



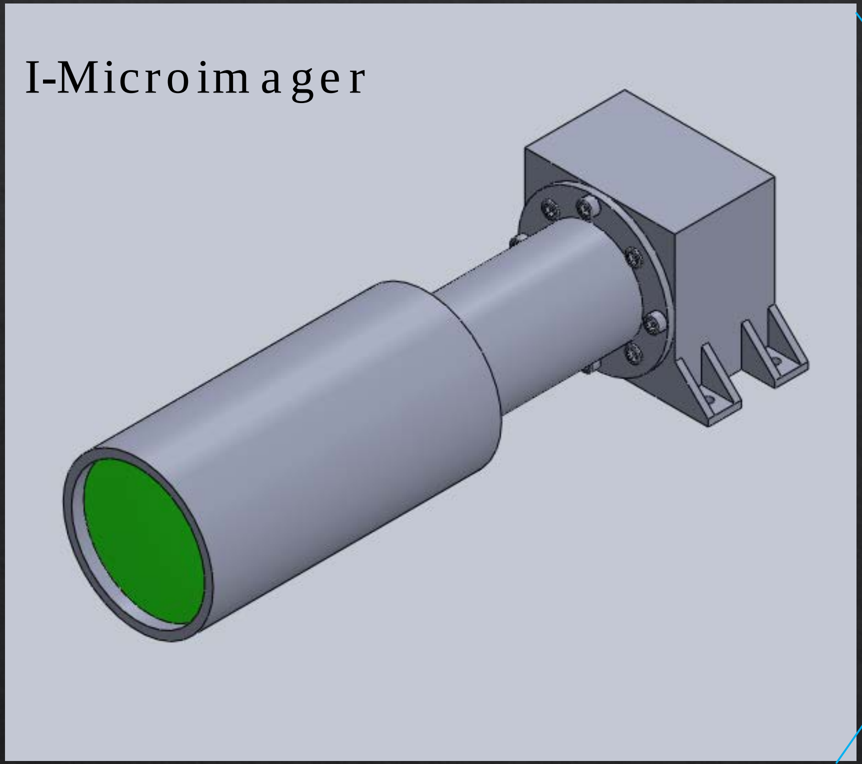


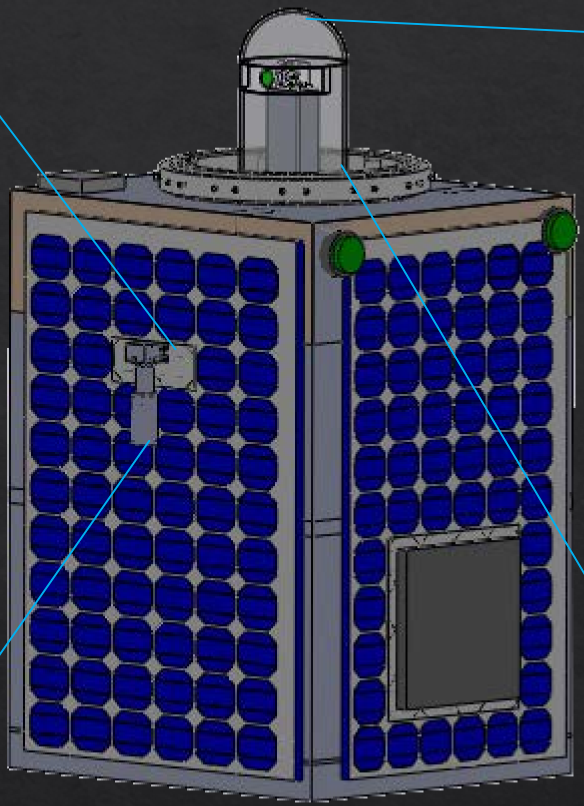


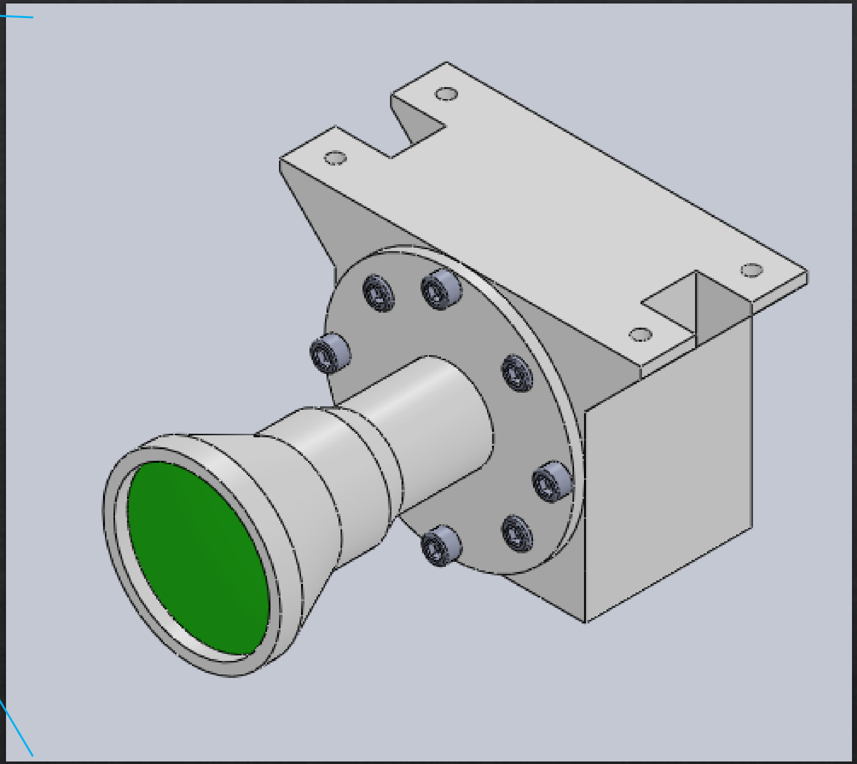
Configuration Highlights

- Each Spacecraft: 180 kg
- Nano-star trackers for navigation
- Launch vehicle provides trans lunar injection for direct landing
- Two small navigational cameras enable Terrain-Relative navigation
- Primary science payload
- Descent Module Propulsion: STAR17A Solid Rocket Motor
- Landing Module Propulsion: 5 Aerojet GR-22 hydrazine engines
- Body mounted solar arrays for power recharge the 204 W-hr lithium-ion battery
- Ka-band communications (10 Mbits/second)

IMPEL INSTRUMENT SUITE







A side-mounted near-field RGB microimaging camera

Acquire up to 10-micron pixel scale images near the lander (S1 & S2)

-Observe regolith agglutinates

-Characterization of surface grain morphologies;

DETPL architecture enables 9 kg science payload to the surface!

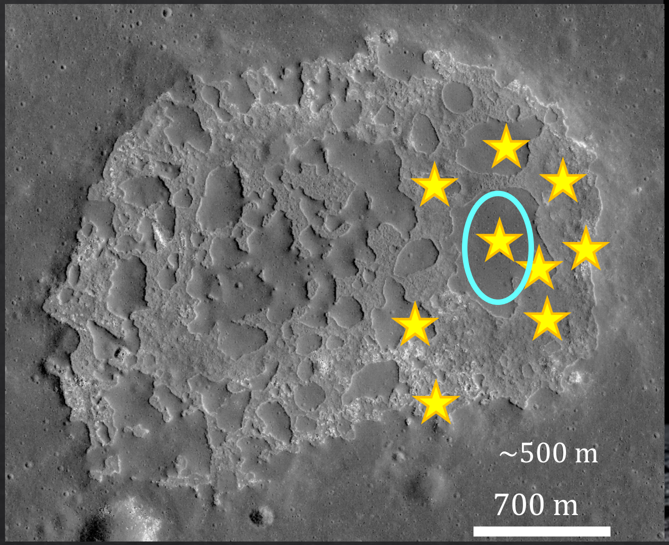
Top-Mounted RGB (Bayer pattern) Imaging System

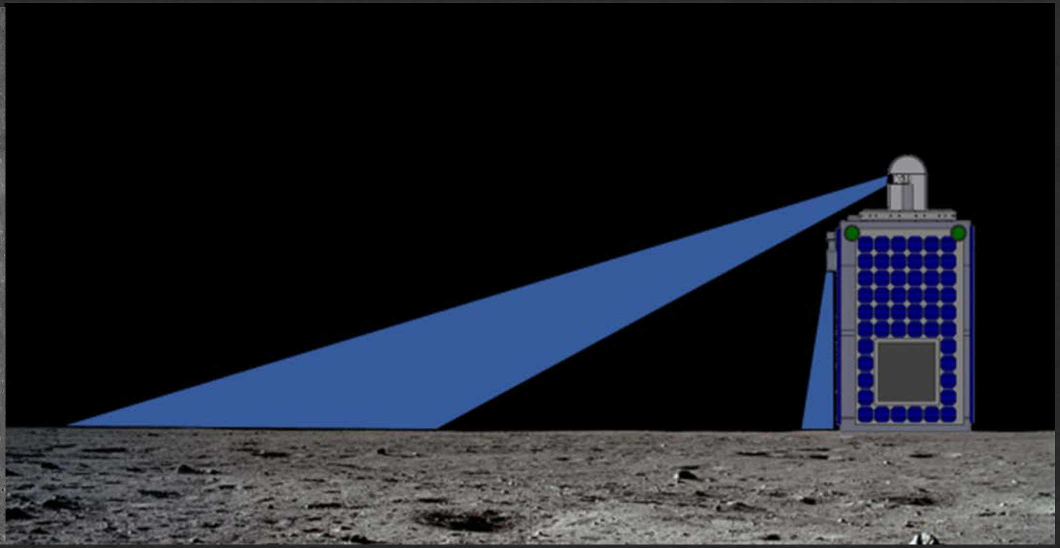
Panoramas (P1 & P2)

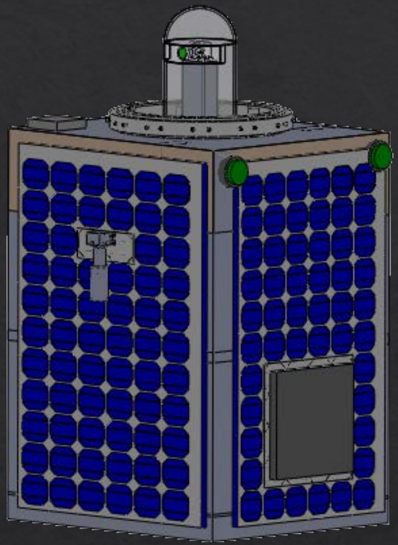
-Observe fractures and pits

-Observe deposits and outcrops.

IMPEL CONCEPT OF OPERATIONS





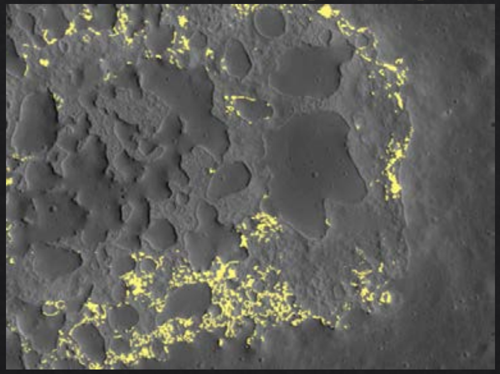


Nadir

Targeted landing site

High-priority visible targets for observations

Blocks & Outcrops Map in Yellow



- Upon landing, *IMPEL* would collect panoramas and targeted images of mounds, uneven materials, and outcrops
  - Examples of these materials are expected (using line-of-sight analyses) to be visible within 650 m distance, primarily located upslope, from any landing point on the east mound
- Primary science objectives accomplished within 8 hours after landing
- Highest priority observations collected between lunar dawn and noon
  - Primary science camera will be stowed in a thermal shelter during lunar noon until the temperature decreases back to normal operating range

NEEDED TECHNOLOGIES AND FUTURE WORK

- Demonstration of the spring/tether mating technique
- Additional Instruments: Our emphasis was on imaging suite for high-value science observations, but other instruments (penetrometers, spectrometers) are also viable and would enhance science return
- Commercial opportunities: New Lunar Discovery and Exploration Program

An Innovative Strategy for Surface Exploration

- The IMPEL mission to Ina using a small, focused instrument suite can address numerous Decadal, 2007 NRC Report, and 2018 LEAG ASM-SAT objectives
- Dual ESPA Module Planetary Landers enable lunar landings with meaningful science payloads using a SmallSat
  - Lunar surface missions are critical for making advances in lunar and planetary science
  - DEMPL architecture can be adapted for other payloads to accomplish different surface missions