

Mission Constraints for Extreme Terrain Exploration of the Lunar Surface

John Elliot
Andrew Johnson

Jet Propulsion Laboratory
California Institute of Technology

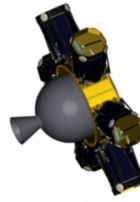
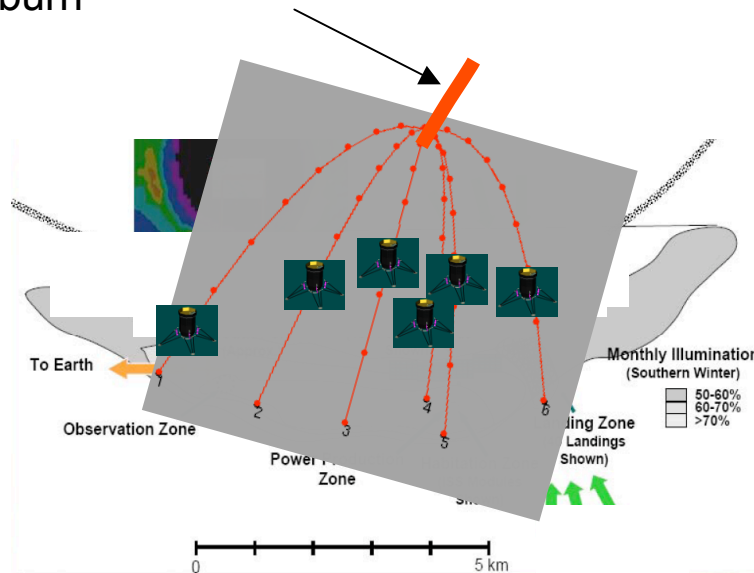


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Lunette Mission Overview

3. Carrier stage performs braking burn

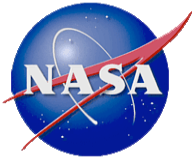


2. Multiple landers with carrier stage cruise to moon



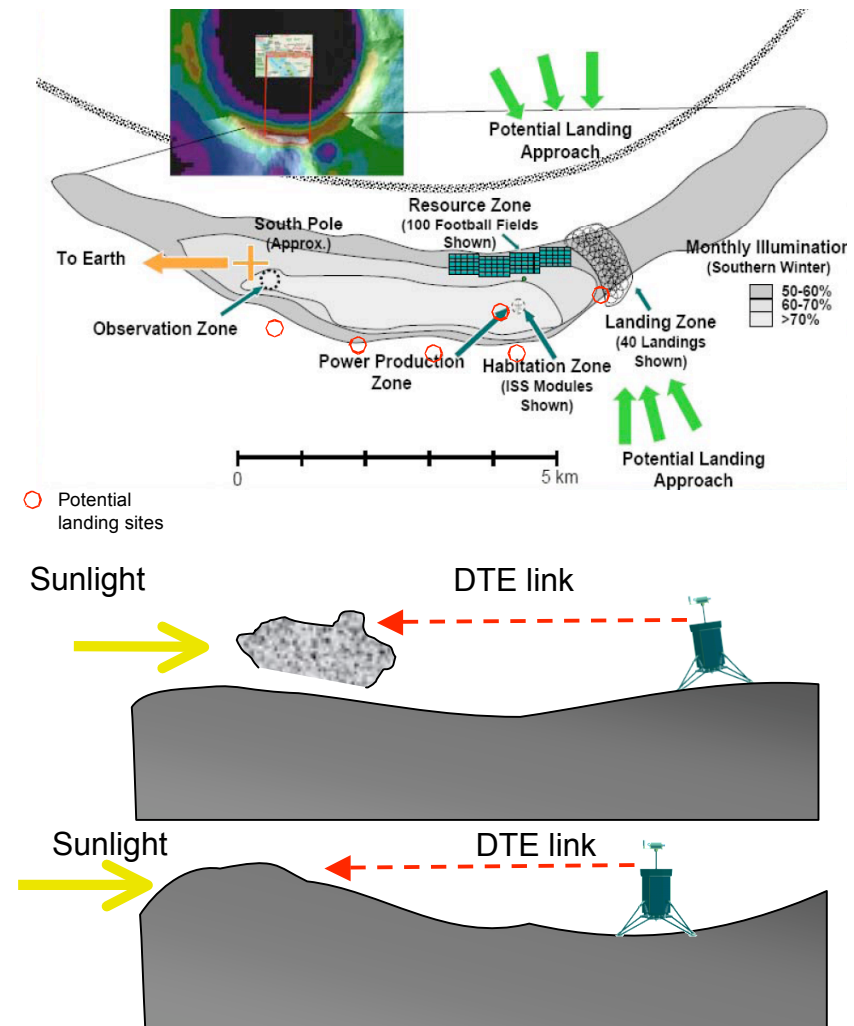
1. Launch as secondary payload on EELV

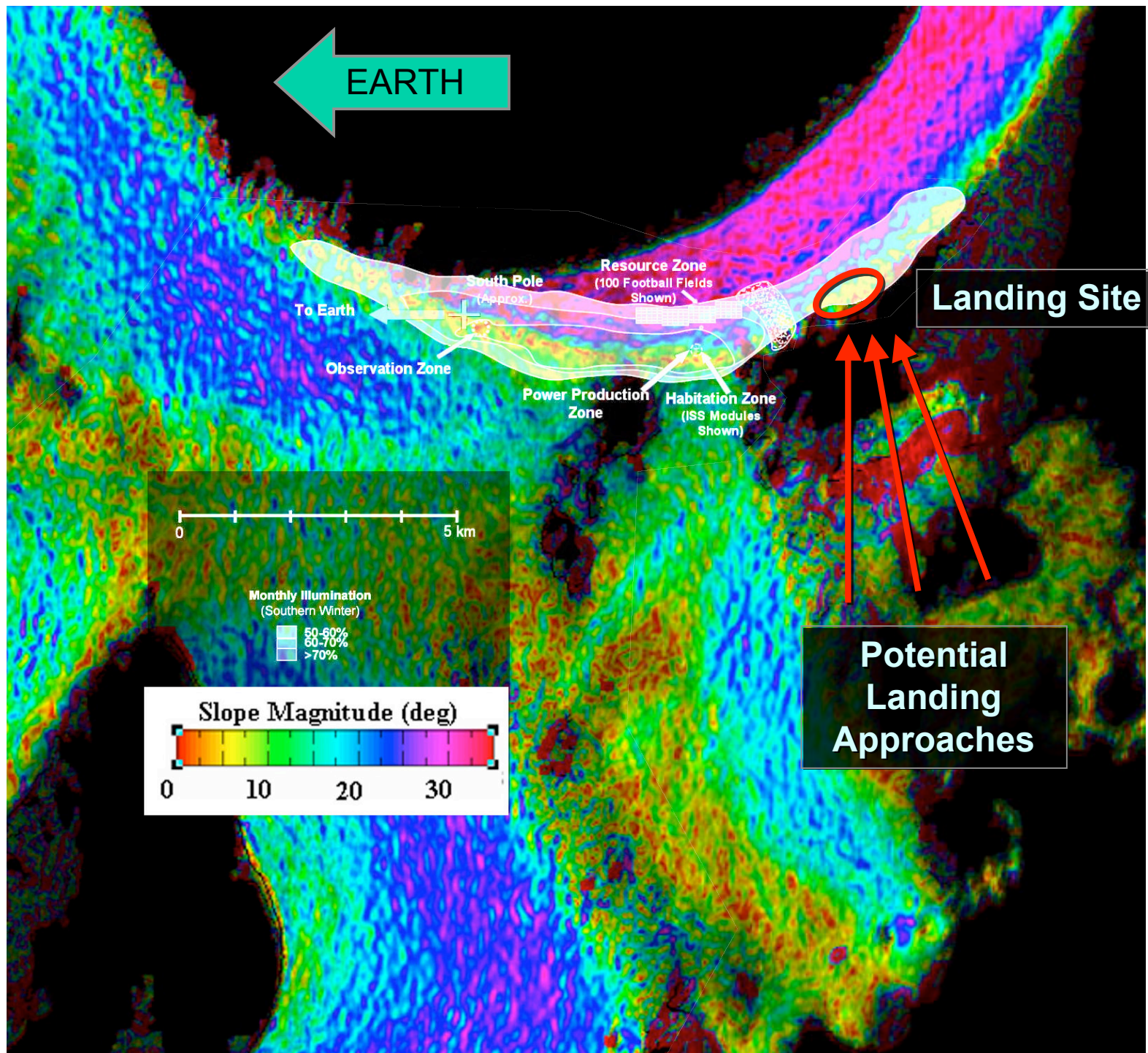
4. Landers separate at termination of burn (~4 km alt.), perform final descent and landing



Landing Considerations

- Nature of landing site demands special consideration
 - ◆ Narrow strip (~ 5 km x 1 km) for landing in “permanently lit” area
 - ◆ Hazardous drop-off if landing approaches crater rim
 - ◆ Landing site on crater rim likely to have abundance of rocks and other hazards
- Surface hazards also affect operational risks
 - ◆ Earth and Sun are at horizon
 - Relatively small surface features/boulders can shadow solar arrays or block view of Earth for communications





Terrain Sensing and Recognition Functions

**PRECISION
LANDING
FUNCTIONS**

**SAFE LANDING
FUNCTIONS**

**De-Orbit
Coast**

Terrain Relative Navigation (TRN)
Reduce Navigation Dispersions During
Breaking Burn and Eliminate Map Tie Error

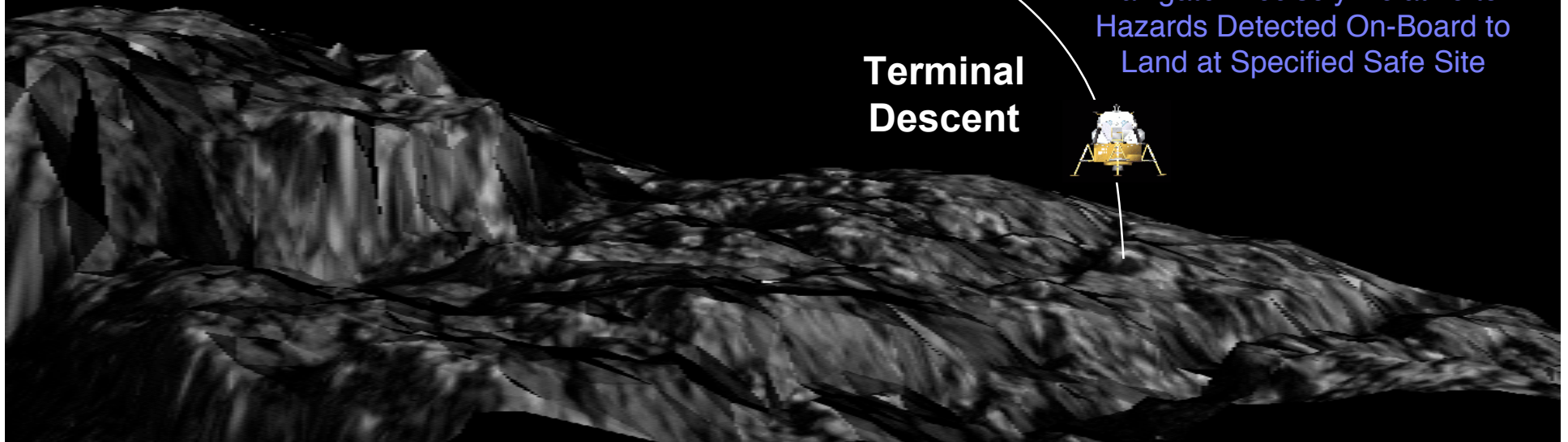
**Braking
Burn**

Hazard Detection and Avoidance (HDA)
Detect Crater, Rock and Slope Hazards
and Select a Reachable Safe Site

Hazard Relative Navigation (HRN)
Navigate Precisely Relative to
Hazards Detected On-Board to
Land at Specified Safe Site

**Terminal
Descent**

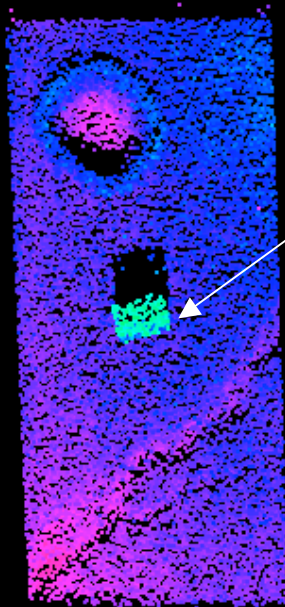
not to scale



ALHAT

Flash Lidar Images For Hazard Detection

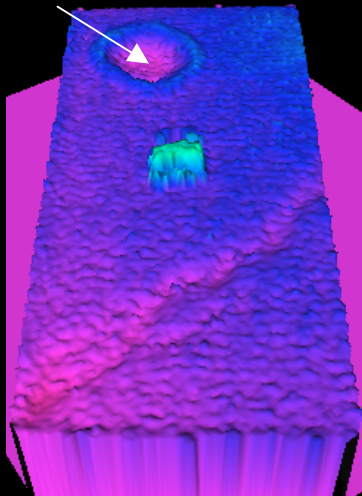
ALHAT HDA requirement is to detect 0.3m high rocks



box

63° Off Nadir

crater

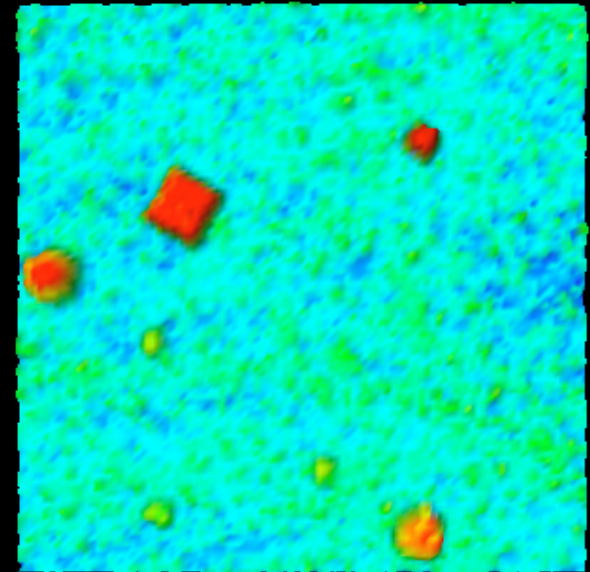
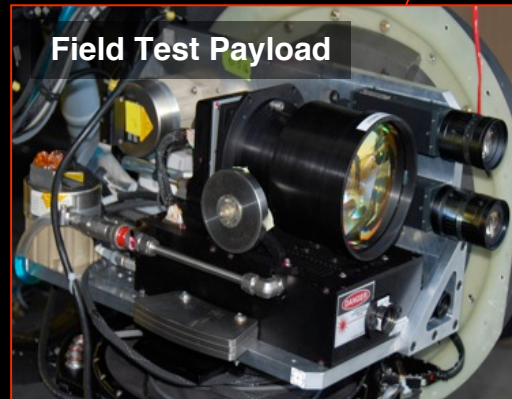


ALHAT

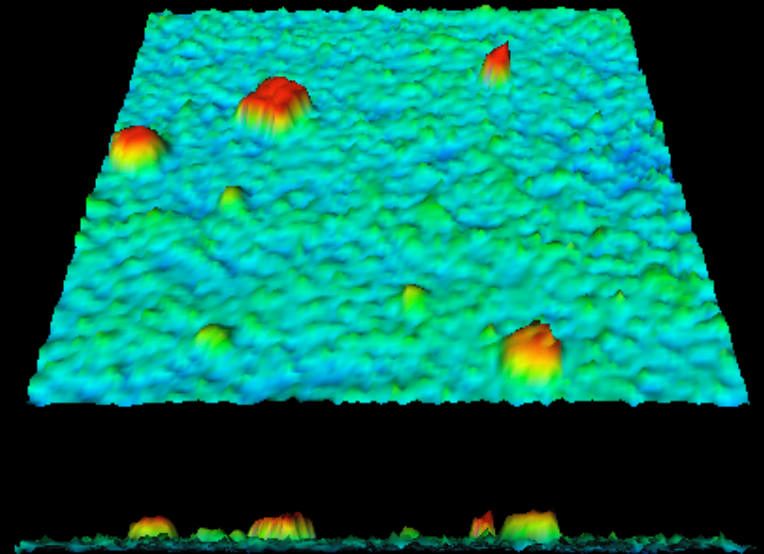
Field Test Platform



Field Test Payload

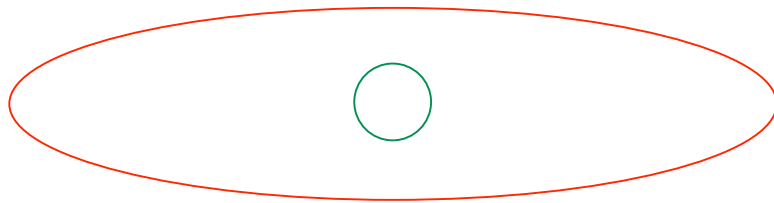


7° Off Nadir



Terrain Relative Navigation

Lunar Landing Error Ellipse without TRN
 $\sim 1\text{km} \times 0.250\text{km } 3\sigma$



Lunar Landing Error Ellipse With TRN
 $90\text{m} \times 90\text{m } 3\sigma$

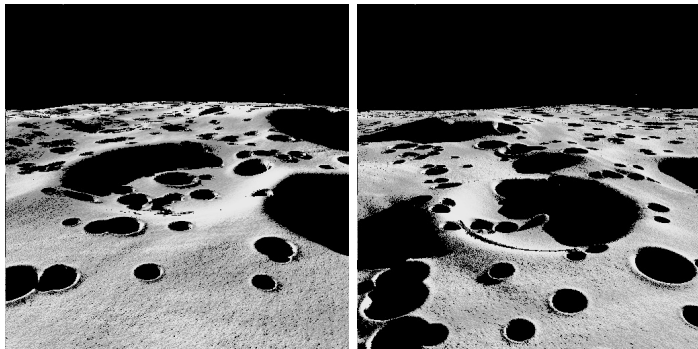
Purpose of TRN enables pin-point landing

There are multiple TRN approaches

ALHAT TRN requirement is $30\text{m } 1\sigma$ under any lighting conditions

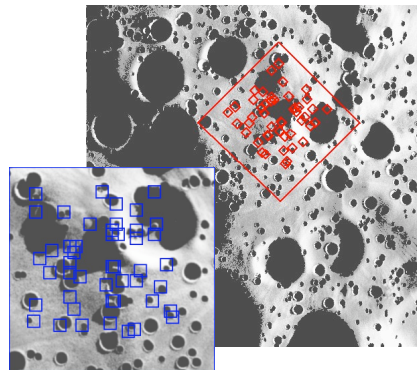
1-10m precisions are possible with passive optical approaches

Passive Optical TRN:
APLNav Images



ALHAT

Passive Optical TRN:
MAIA Landmark Matches



Lidar TRN:
Area Correlation

