Real-Time Imaging Technology for the Return to the Moon

Dr. Chirold Epp

ALHAT Project Manager

Johnson Space Center

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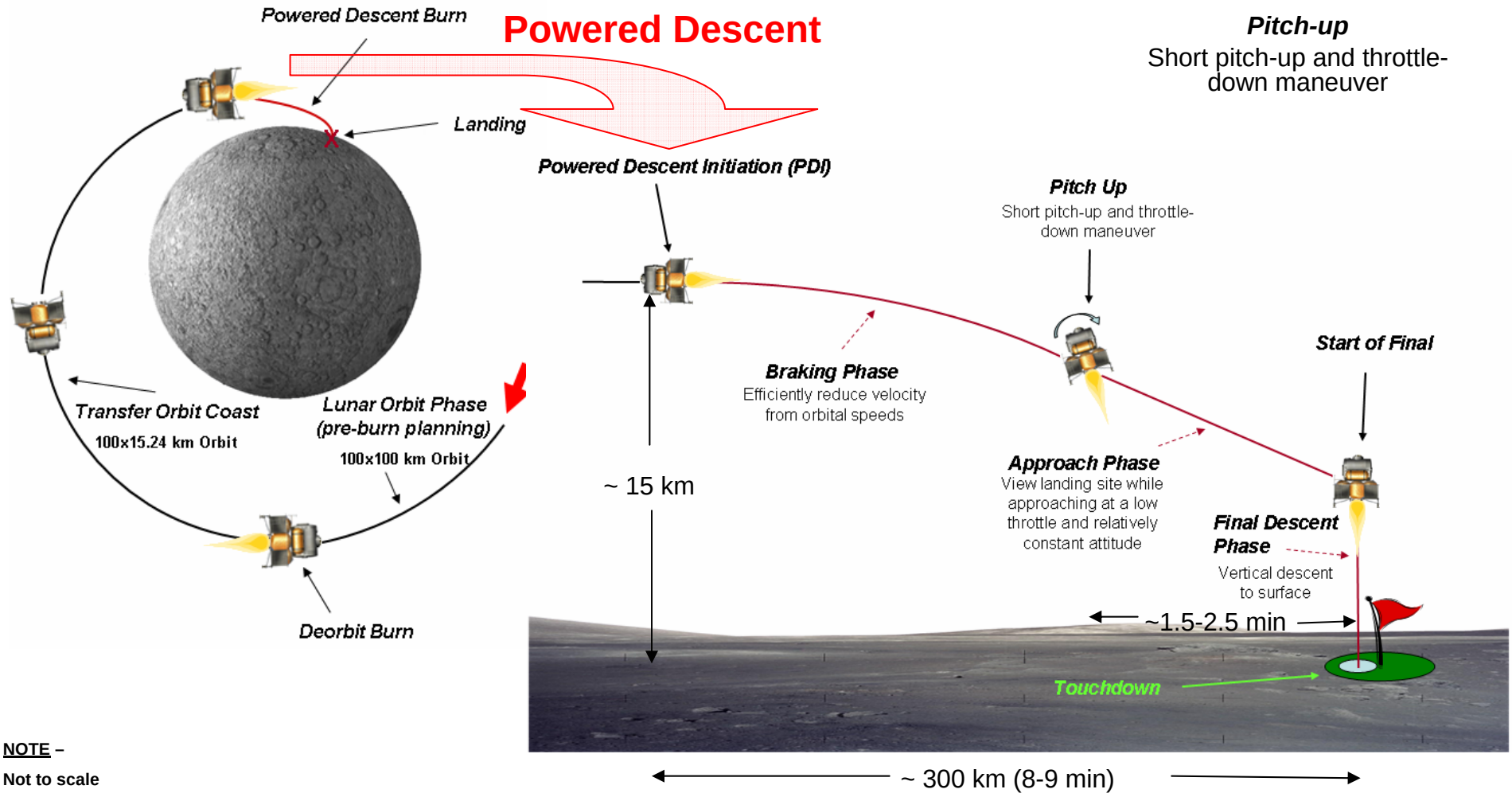
ALHAT BACKGROUND

- ALHAT is a lunar descent and landing GNC technology development project led by Johnson Space Center (JSC) with team members from Langley Research Center (LaRC), Jet Propulsion Laboratory (JPL), Draper Laboratories (CSDL), Applied Physics Laboratory (APL), University of Texas and Utah State University
- **Vision Statement:** *Develop and mature to TRL 6 an autonomous lunar landing GN&C and sensing system for crewed, cargo, and robotic lunar descent vehicles. The System will be capable of identifying and avoiding surface hazards to enable a safe precision landing to within tens of meters of certified and designated landing sites anywhere on the Moon under any lighting conditions.*

SAFE AND PRECISE LANDING

- The ALHAT project has accepted the challenge of developing an Autonomous GNC system with global access to the moon
  - Global access is interpreted to mean any terrain where there exists an area certified for landing within the tolerance of the lander
  - Implies any lighting conditions because of places like the south pole where the maximum sun elevation angle is 1.5º
- Requires real-time information of the relative elevation of surface features
- Requires real-time surface relative navigation to land relative to a surface feature in a safe, hazard-free area

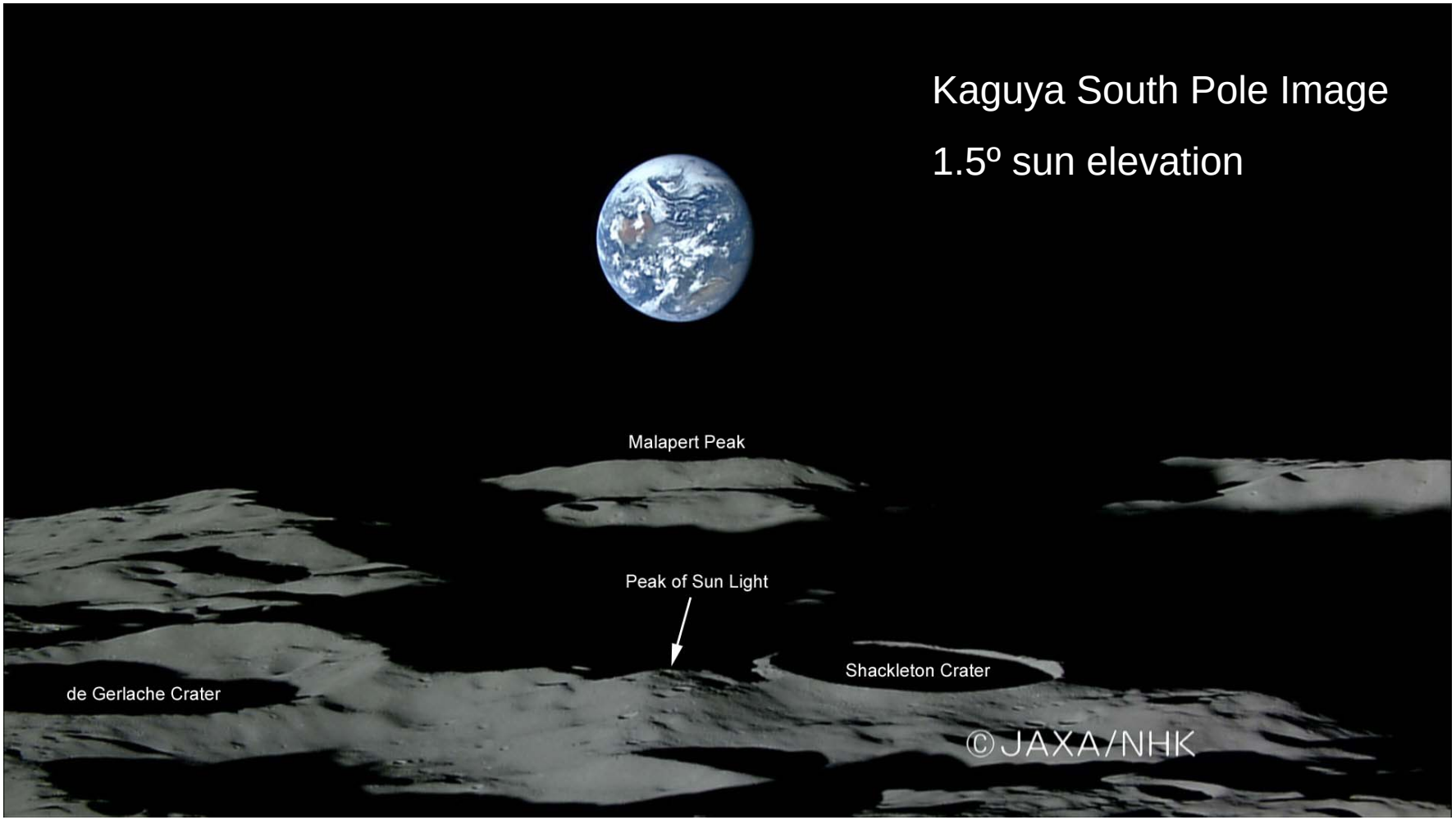
ALHAT MISSION PHASES



NOTE –

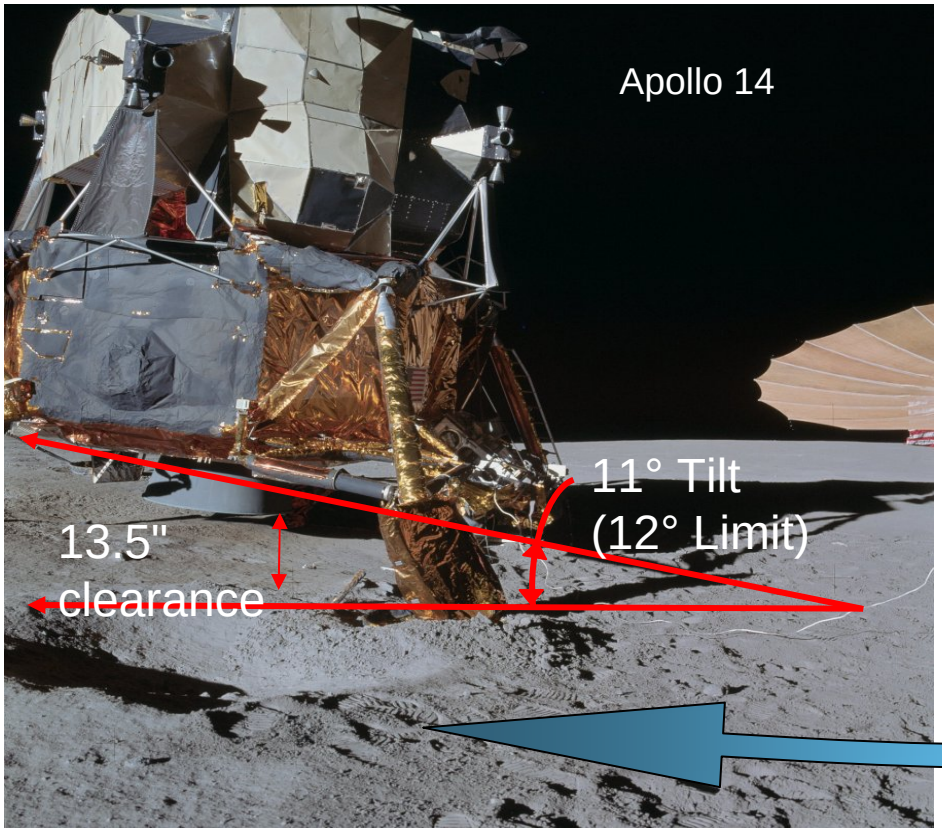
Not to scale

LIGHTING


Kaguya South Pole Image
1.5º sun elevation
Malapert Peak
Peak of Sun Light
Shackleton Crater
de Gerlache Crater
©JAXA/NHK

LANDER TOLERANCE

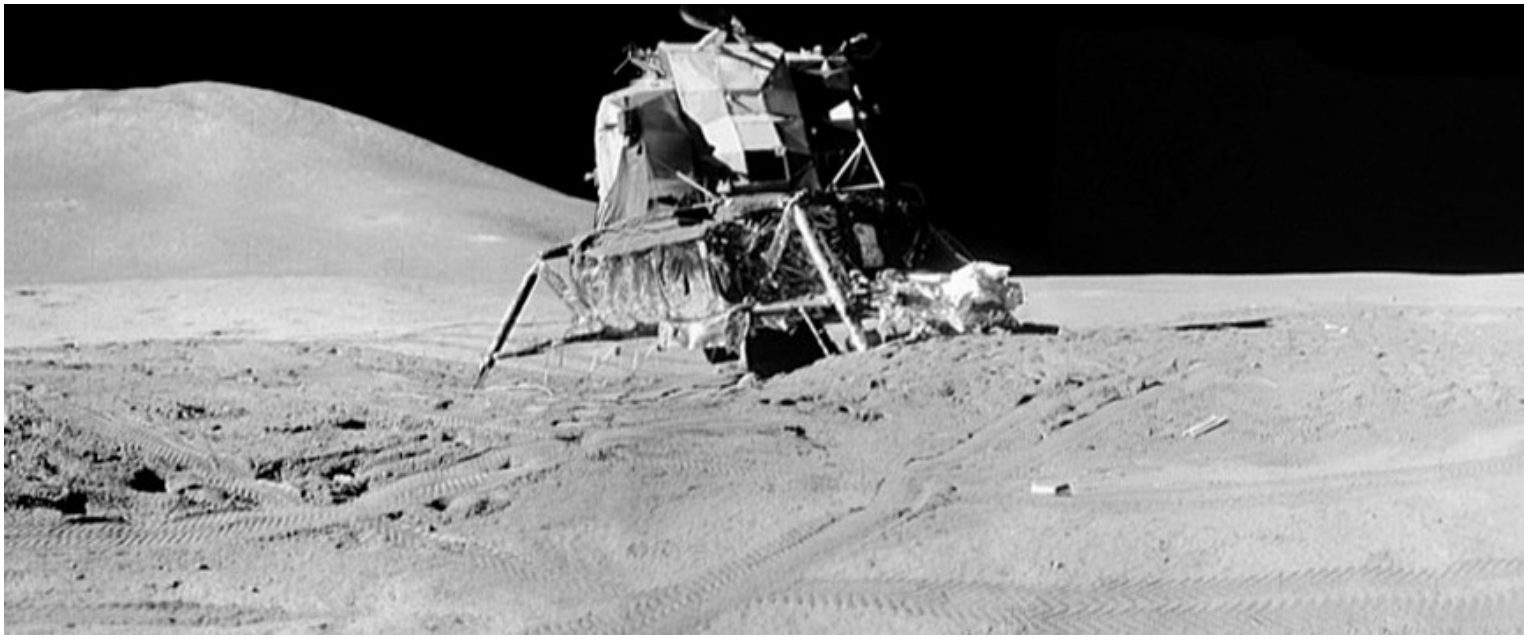
Some hazards recognizable during pre-flight planning….



However….

….some are not.

LANDER TOLERANCE



Apollo 15 set down on the rim of a small crater,
damaging the engine bell and tilting at ~10º

HDA SENSOR PERFORMANCE

- Must support landing without surface or orbiting navigation aids (supports sortie and first down missions)
- Sensors required to provide real-time surface hazard elevation information
- Factors effecting sensor performance
  - Range and angle at which sensor capability provides required hazard resolution
    - High flight path angles increases the ability of sensors to resolve hazards
    - Higher range allows time to analyze, divert and fly efficiently to safe site
  - Time required to obtain hazard information and define safe landing site
    - Depends on range from target site data and deceleration rate
    - Approximately 1.0 to 1.5 minutes to collect the data, process it, do analysis to pick safe site and divert to the safe site
- Based on the ALHAT Team current research and analysis knowledge, we believe a LIDAR provides the best option to meet safe landing requirements
  - Considered to be a good sensor for determining real-time elevation information
  - Additional development required to improve capability and resolution at higher altitudes and improve efficiency, robustness, reliability and space qualification
  - Real-time LIDAR data requires high volume and high speed processing

HDA TERRAIN SENSORS

- Flash LIDAR
  - Digital camera which carries its own light source and is able to measure time of flight for light striking each pixel (thus elevation data)
  - Data independent of surface lighting conditions
  - Provides Digital Elevation Map of the surface thus identifying rocks, holes and slopes
  - Data utilized for hazard relative navigation to safe landing site
  - Requires significant data processing
  - Data available in near real-time (few seconds)
- Scanning LIDAR
  - Similar to flash LIDAR except uses scanning beam
  - Technology more mature than flash
  - Time required for data collection is higher than for flash
  - More moving parts than flash

HDA TERRAIN SENSORS

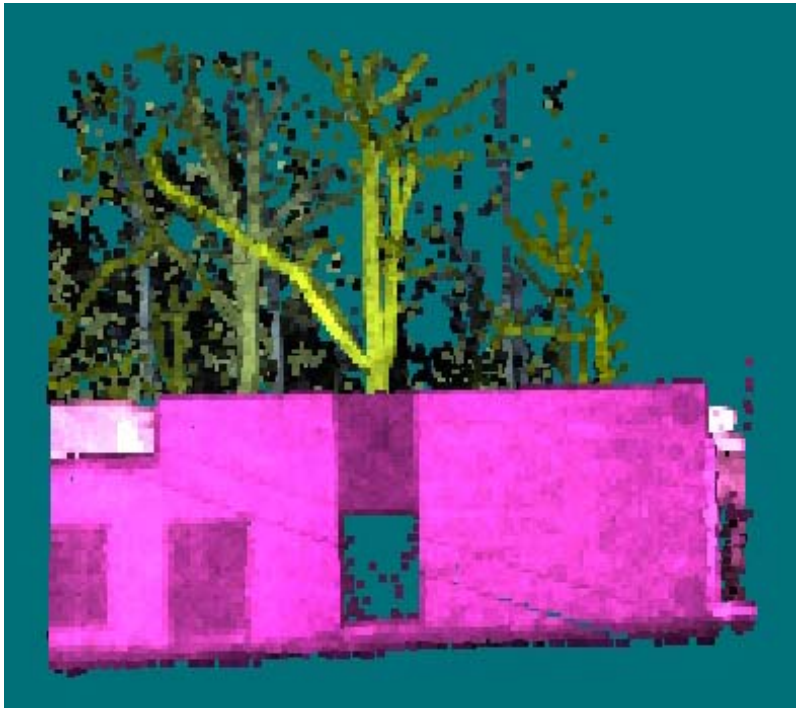
- Human eye
  - Unclear about the ability to define hazards and hazard elevations, particularly holes and slopes, with significant shadows and contrast problems like expected at Shackleton Crater during real-time descent operations
- Optical or infrared cameras
  - Provides 2-D image with adequate light
  - Limited ability to define hazard elevations
- Stereo cameras and Radar
  - Evaluated but not currently being considered for real-time imaging for altitudes between 500m and 1000m

SUMMARY

- The biggest GNC challenge for safe landing is having a real-time system that can detect hazards, identify safe landing areas and perform Hazard Relative Navigation (HRN) to support precision landing
- The relative elevation data of surface features is the most important information needed from imaging
- ALHAT believes that a LIDAR sensor is the best candidate for acquiring the needed real-time hazard information
- Important to continue to develop promising low TRL technologies that assure safe landing for crewed and autonomous vehicles for outpost and sortie missions

BACK UP

LIDAR Image from LaRC STR



LIDAR Image from LaRC STR