human spaceflight and operations

The European Lunar Lander:
Robotics Operations in a Harsh Environment

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Session 3A: Challenges in Planetary Exploration

European Space Agency

Introduction

- Surface environment is a key challenge for robotics in exploration
- Lunar surface, in particular the South Polar Region, is an important environment
  - Potential offered for near term and longer term activities (robotic and human)
  - Particular environmental challenges
- European Lunar Lander mission*
  - Targeting a landing near Lunar South pole in 2018
  - Currently analysing available surface data
  - Ongoing work to assess implications on design
  - Lander mission shall carry out autonomous and robotic operations, as well as making measurements of surface characteristics

**See Keynote speech of Alain Pradier:*

The European Lunar Lander Mission

Mission Objectives

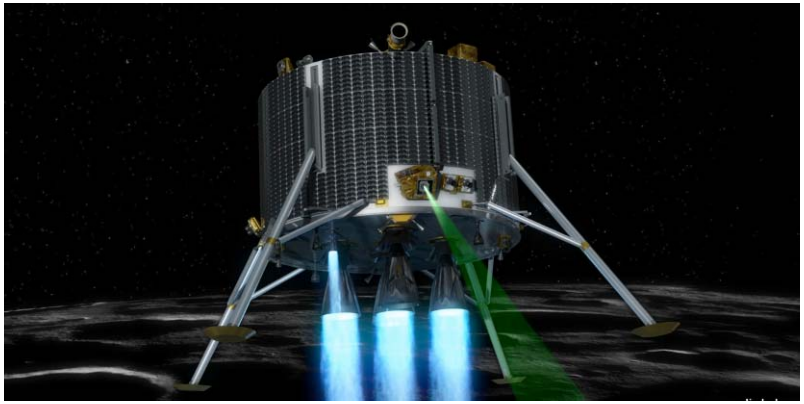
Programme Objective

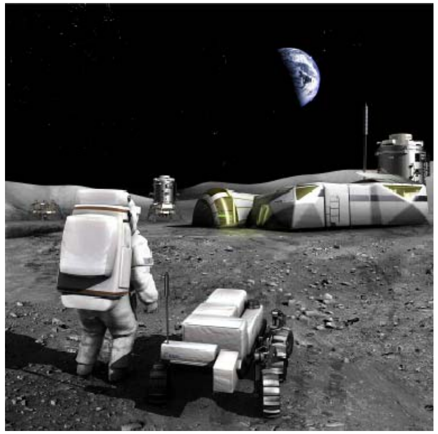
PREPARATION FOR FUTURE HUMAN EXPLORATION

Lunar Lander Mission Objective

ENABLE SUSTAINABLE EXPLORATION

- **Soft Precision Landing with hazard avoidance**





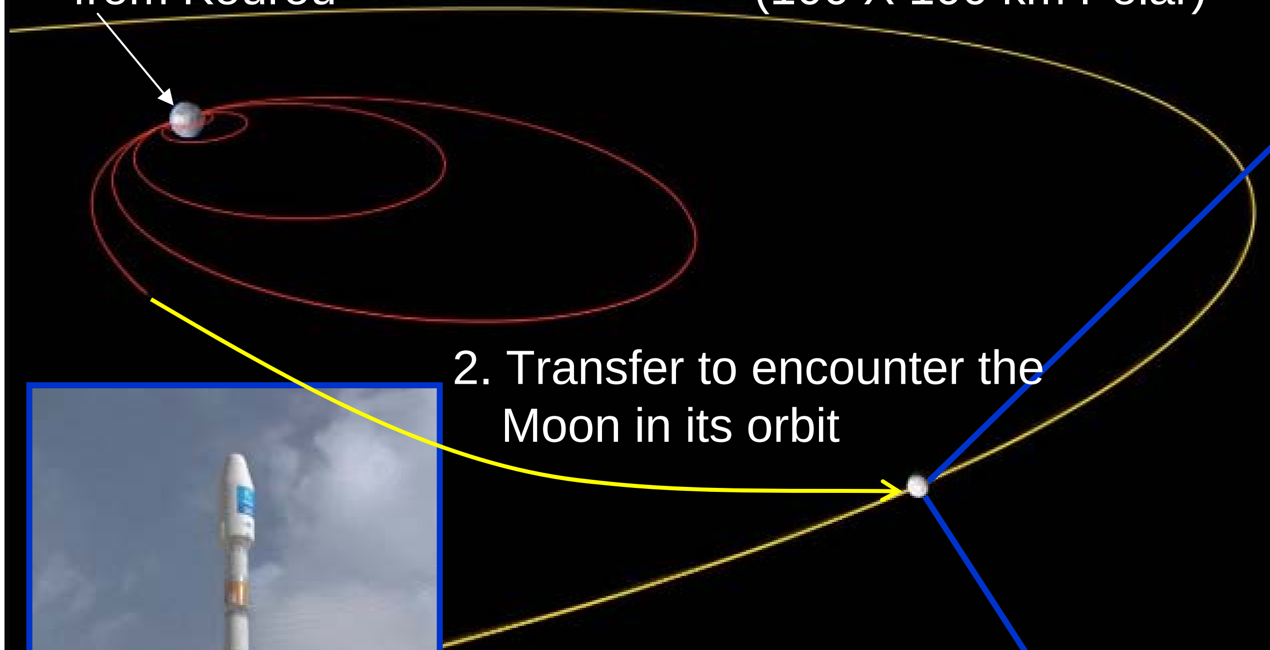
- **Crew health**
- **Habitation**
- **Resources**
- **Preparations for human activities**

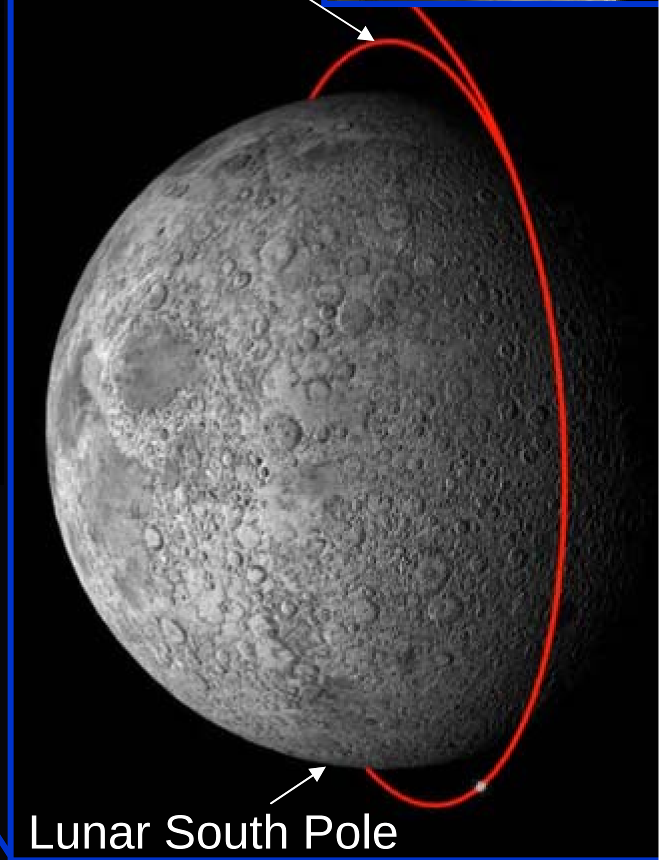
Lunar Lander Operational Constraints (no-RHUs)

Human Exploration Preparatory Objectives

SOUTHERN POLAR LANDING SITE

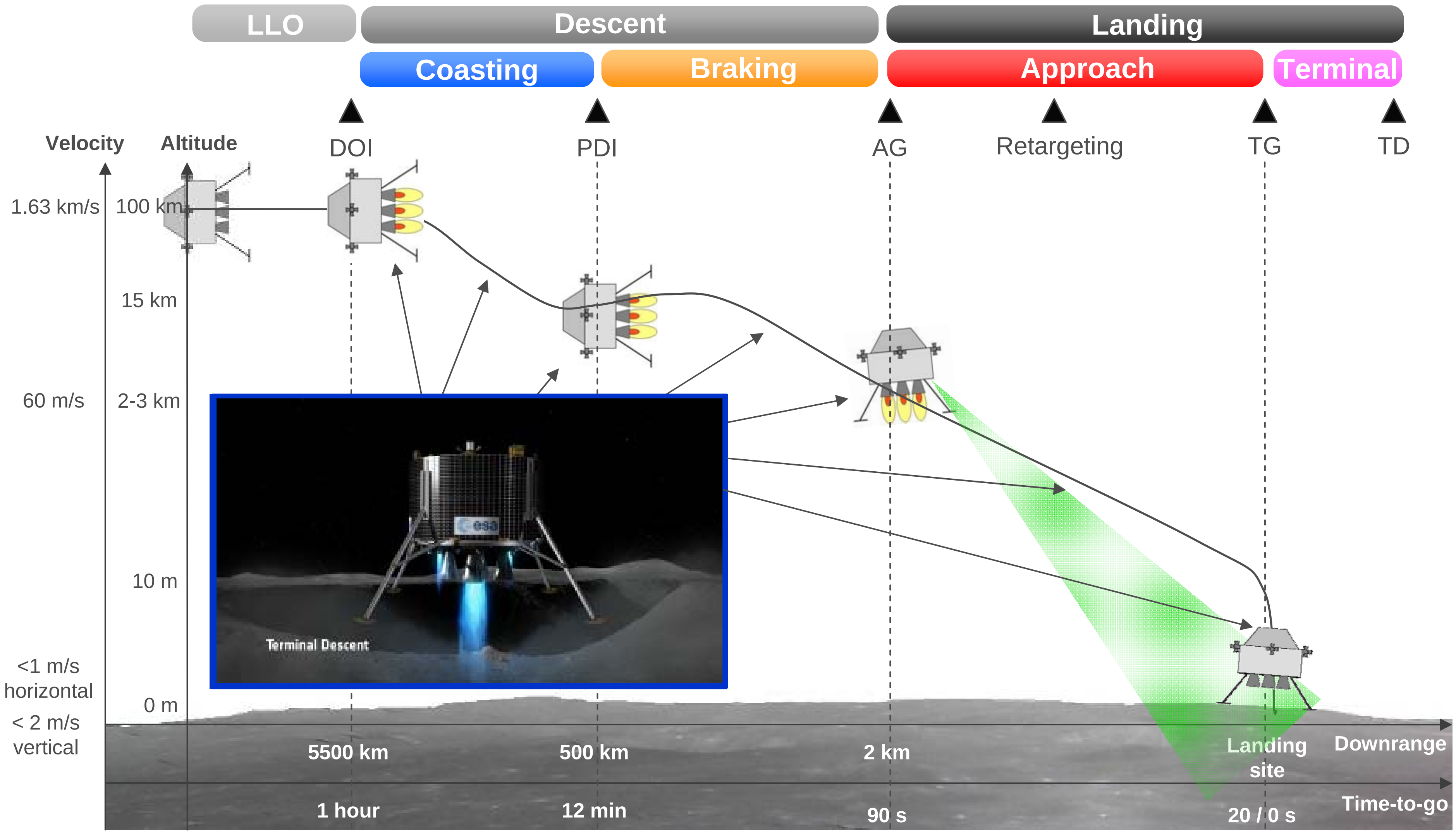
Mission Outline:
Launch to Lunar Capture





Launch constraints:
- Sun-Moon constellation
- Earth-Moon constellation
- Contingency

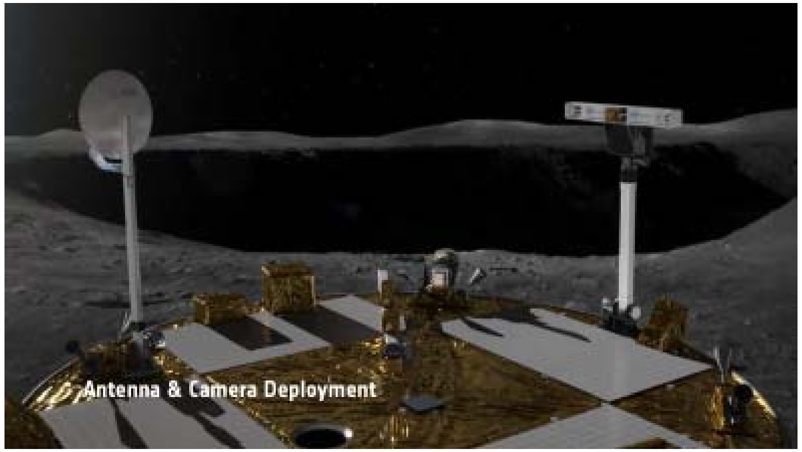
Mission Outline:
Descent and Landing

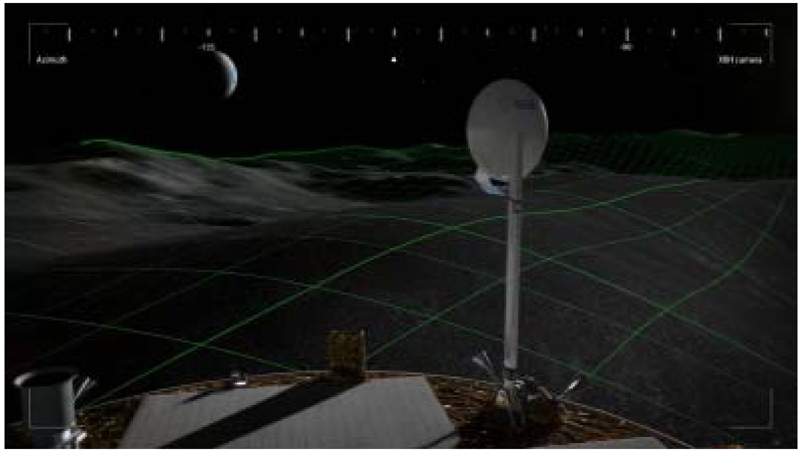


Note: the velocity, altitude, downrange, delta-V and time values are provided to give an order of magnitude

Mission Outline:
Surface Operations

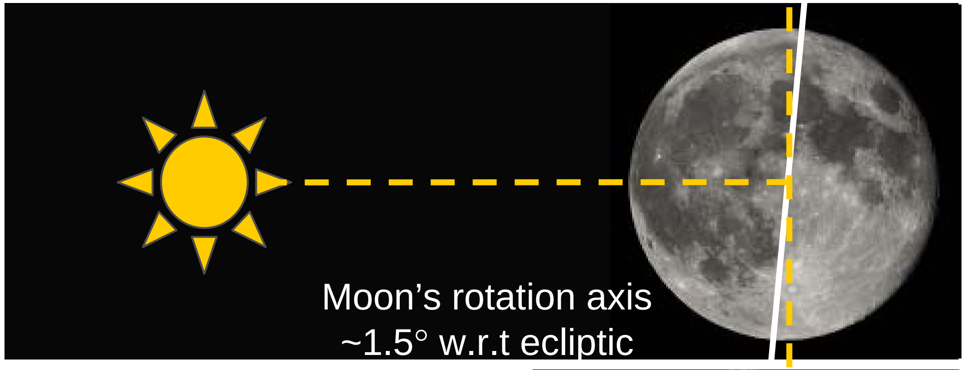
- Critical deployments:
  - *High gain antenna*
  - *Camera mast*
- Transmit descent & landing dataset
- Conduct site reconnaissance and horizon evaluation
- Commence payload deployments
- Initiate nominal surface operations (measurements, sampling etc.)
- Implement survival operations in case of short (10s hours) darkness periods



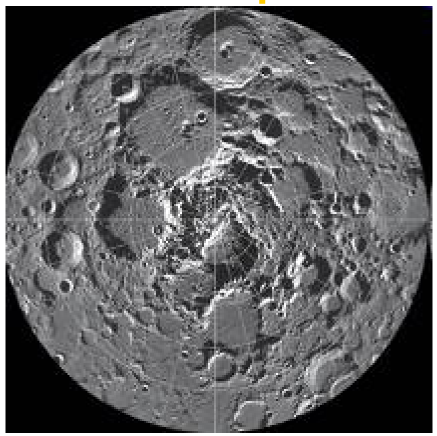


Lunar Orbit & Surface Characteristics

- Rotation axis ~1.5° w.r.t ecliptic → polar regions can experience long durations of illumination
- Major effect of lunar topography
- Surface conditions (illumination/comms) location specific
- South Polar region differs at large scales from flat mare regions → potential for hazards
- Orbit plane axis ~5.1° → Periodic Earth visibility at poles



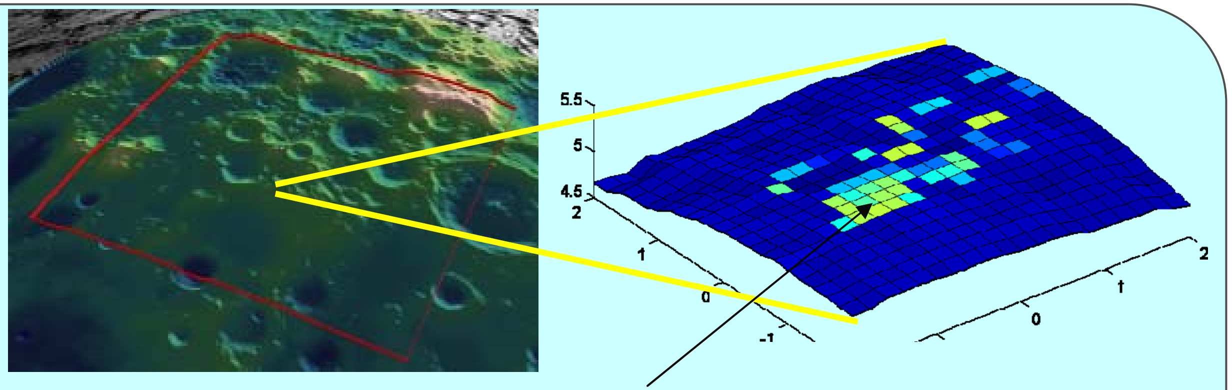
South Pole Image: Clementine (NASA)



Illumination: Data

Lunar Lander Questions

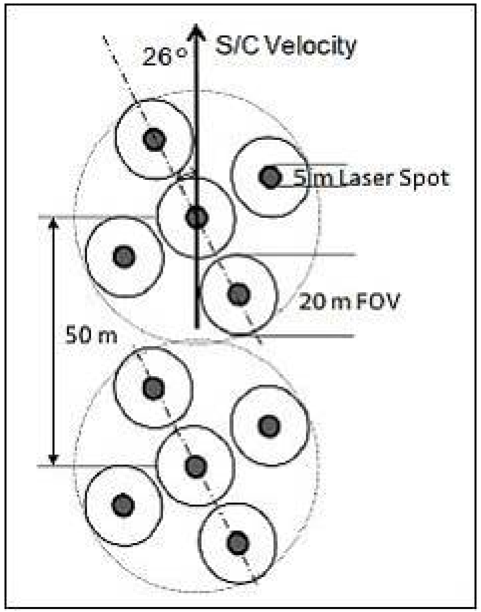
- Where
- How large
- Light/dark pattern



Example illumination pattern at a lunar polar landing site

1 year

Topographic data from south polar region
- Kaguya (LALT) & LRO (LOLA)



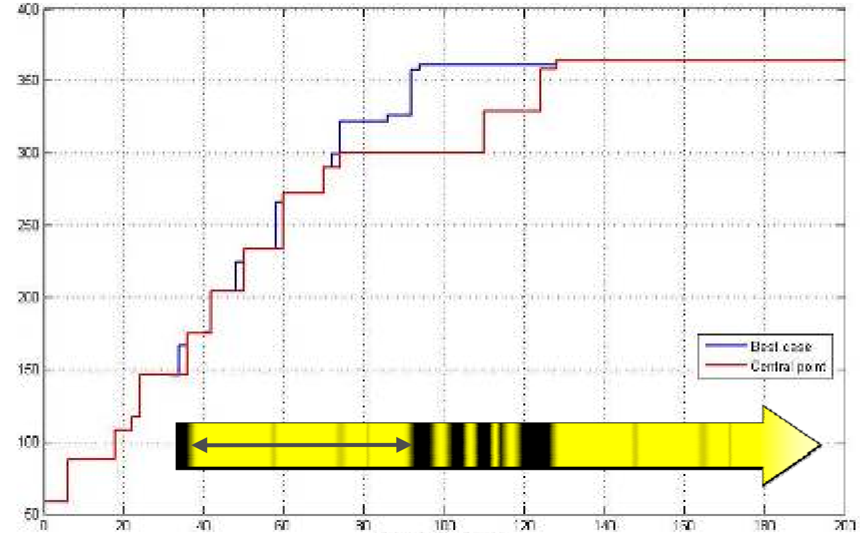
Topographic data analysis
- ESA-internal
- Astrium Bremen (LLB1)
- Consultancies:
  - Birkbeck College
  - Freie Uni. Berlin

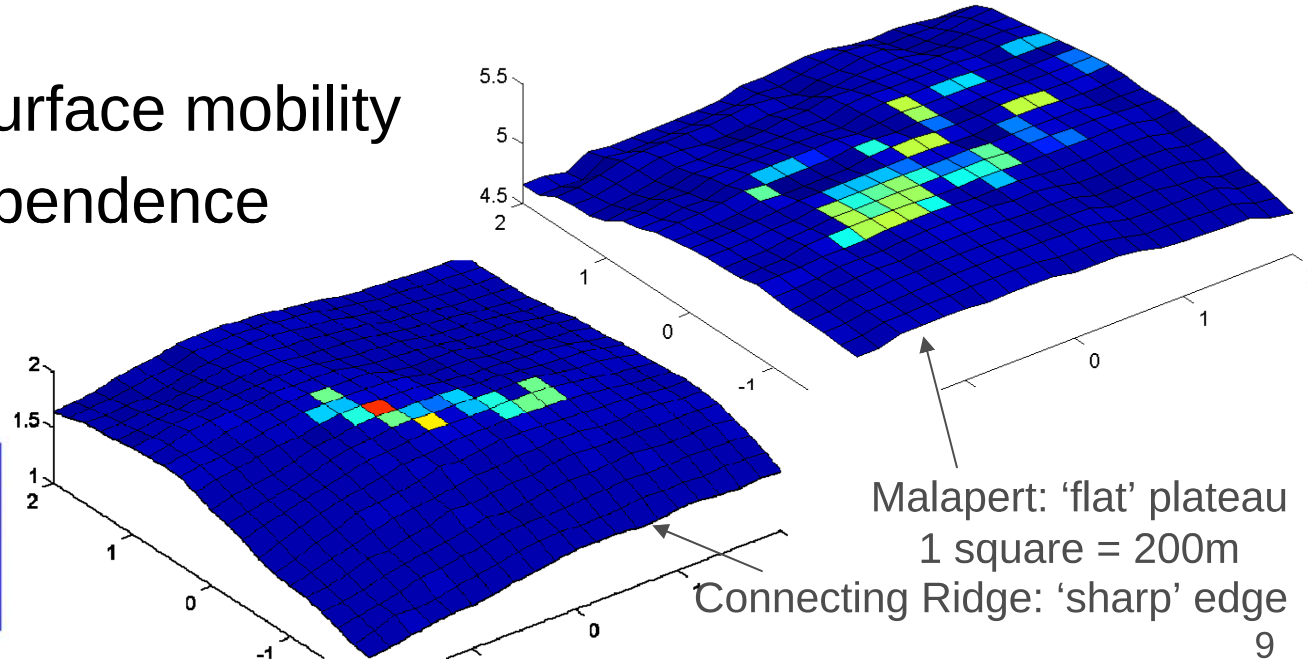
Illumination: Ongoing Analysis

- Analysis ongoing

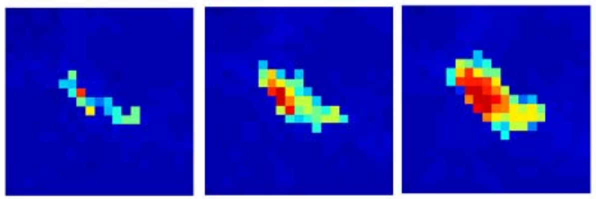
1. Size of well illuminated sites ~ several 100's of metres

- 'Good' locations represent local maxima
- Strong driver of landing precision
- Limits range of surface mobility
- Strong height dependence





2 metres 10 metres 20 metres



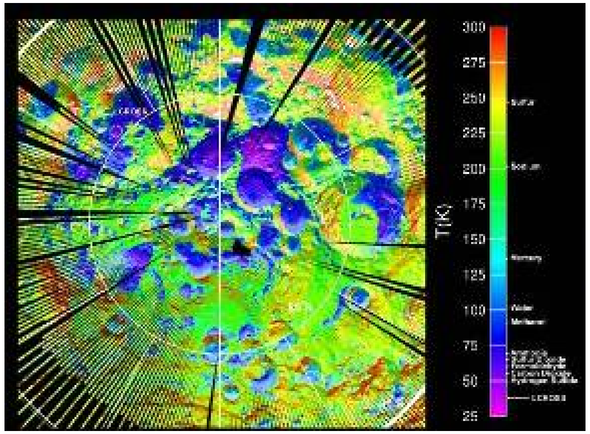
Illumination: Ongoing Analysis

2. Presence of shadow & temperature

- No locations present year-round illumination
- Short duration's of darkness by:
  - Close range obstacles
  - Terrain features on horizon
- Large shadows due to boulders & local slopes
- Temperature range:
  - (<100K to ~300K)
  - Spatially and temporally sensitive

3. Illumination 'quality'

- Sun never more than few degrees above horizon
- Long shadows, high contrast, specific reflective properties



LRO – Diviner Temperature map (NASA)

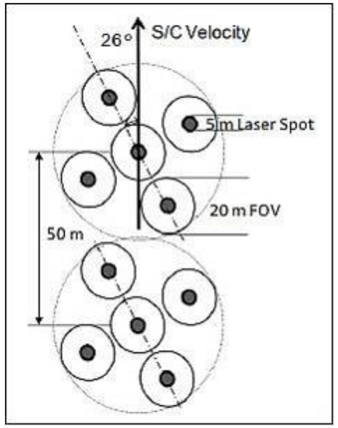
ESA Lunar Robotics Challenge - Tenerife

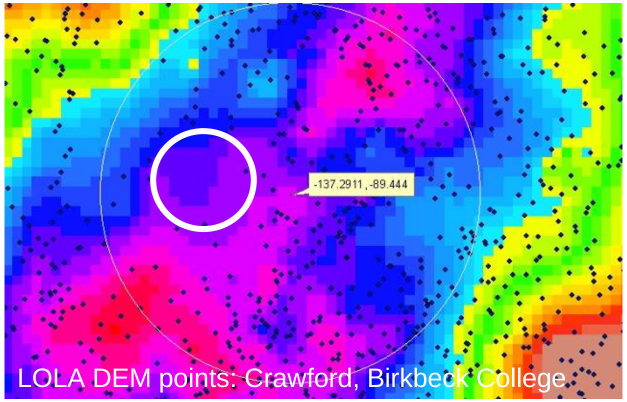
Surface Hazards: Data

- Slopes
- Boulders
- Shadows

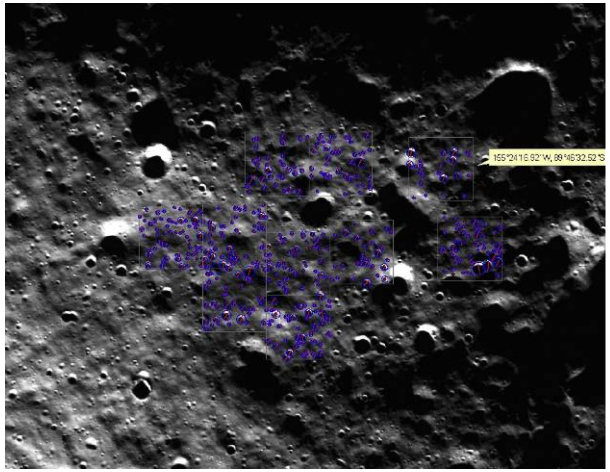
LOLA

- Laser altimeter: ~1.8m vertical ranging accuracy (0.1m rms for individual shots)
- Along/cross track accuracy: ~10m
- Slopes determined from DEMs:
  - Not all points in DEM derived from actual data point
  - Slope determination below baseline of ~10-20m not reliable





LOLA DEM points: Crawford, Birkbeck College


LROC image of Southern Polar site: Crawford, Birkbeck

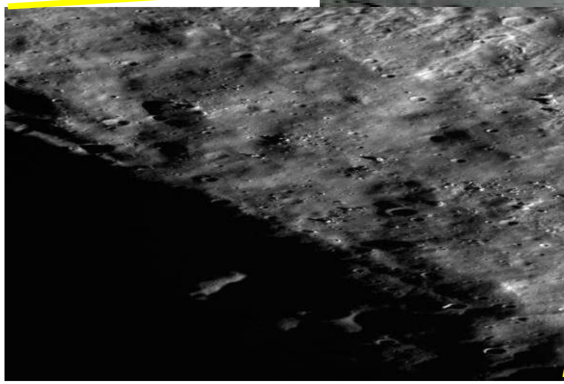
LROC

- 0.5m/pixel → Nyquist ~1m
- Low inclination of illumination
- Image cross-correlation still presents errors of ~100m

Surface Hazards:
Preliminary Results

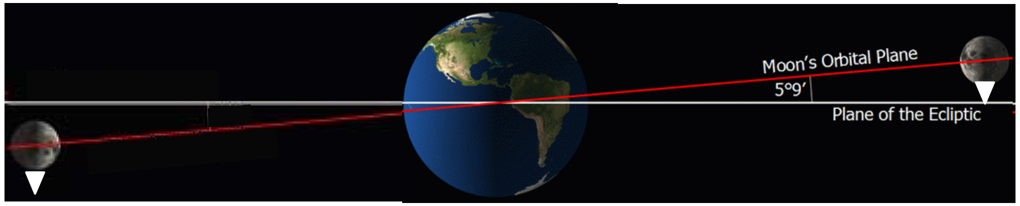
- Current data indicates that slopes in the regions-of-interest[*] are largely compatible with the lunar lander (<15 degrees) over the baselines which the data can represent
- Below the resolution of the data, knowledge of crater statistics and crater maturation process indicates more severe slopes are unlikely to be present at smaller scales
- Boulders appear rare within the regions of interest, at the sizes which can be detected (2-3m)
- Boulder detection via images remains strongly illumination (direction) dependent – further image analysis required

* Outside of the regions-of-interest (landing zones), high slopes (up to 35 degrees) and significant boulder fields do exist

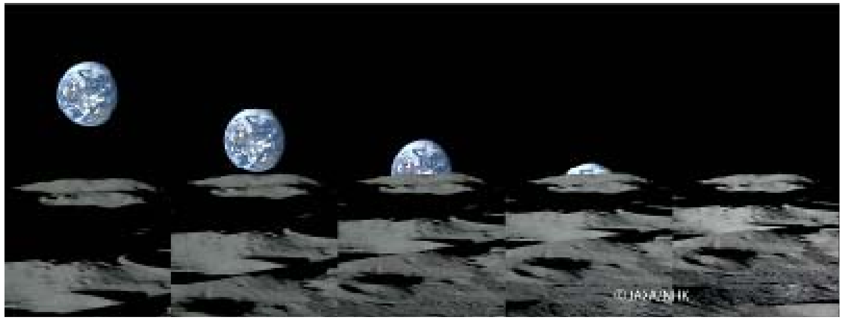


Boulder fields are present in vicinity of Shackleton rim: Crawford, Birkbeck

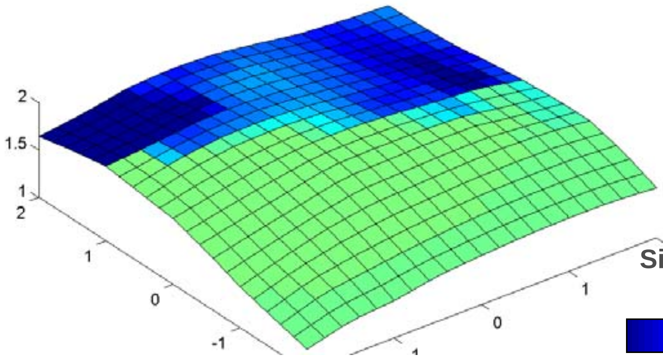
Communication



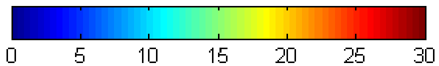
- Pole neither near nor far side
- Earth visibility influenced by Moon's orbit plane inclination

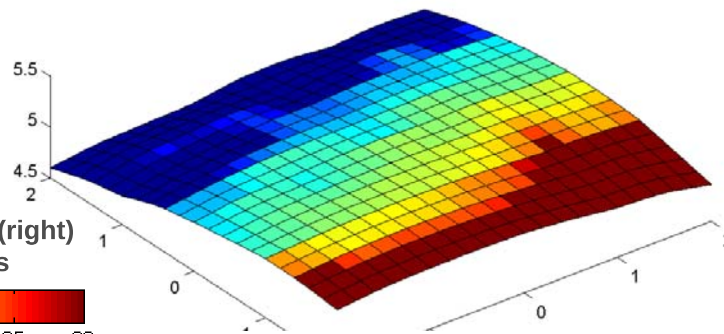


- Comparing to 14days-on/14-days off, Earth visibility dependent on:
  - Landing site location
  - Local topography
- Patterns of illumination and communications can be determined in advance by analysis of surface data, however they are not connected → Should be carefully considered for scheduling of (teleoperations)

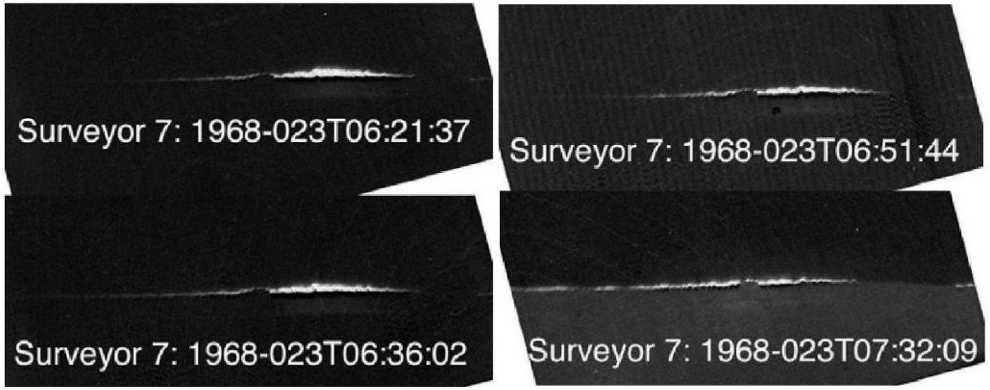


Sites CR1 (left) and MP2 (right)
Colour scale in Days





Surface Characteristics

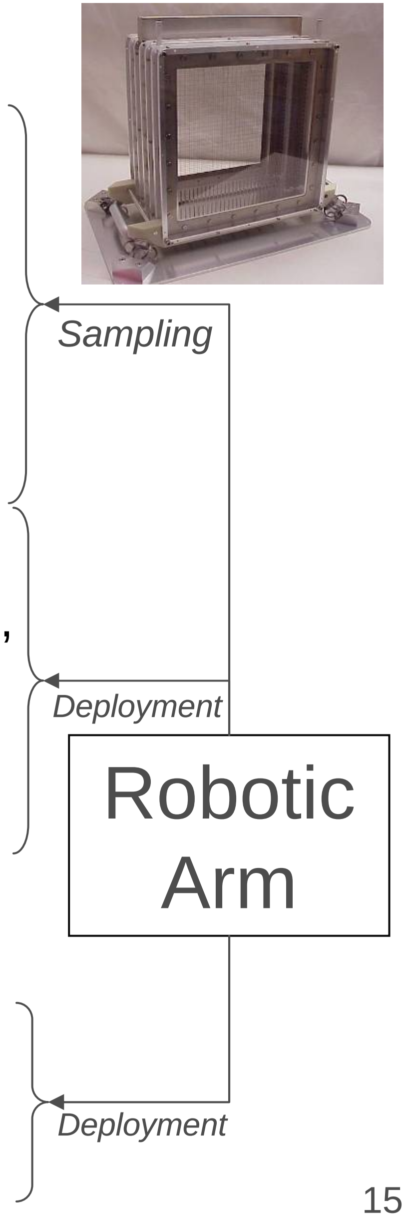


- Dust
  - Shape and size of dust particles → abrasion
  - Charge of dust particles → adhesion
- Electric fields
  - Key role in dust levitation, transportation and deposition
  - Can accelerate dust particles to velocities which may cause impact damage
  - Electric potential environment in areas of light & shadow can lead to powerful electrical discharge and possible disruption to electrical and communications systems
- Radiation

Payload

Model payload:

- Dust microscopy and chemistry package (L-DAP)
  - Investigate morphology, incl size dist., of dust grains, as well as composition, and permittivity/magnetic properties
- Volatiles analysis package (L-VRAP)
  - Investigate the type and abundance of volatiles present in the surface layers
- Dust, plasma, waves and fields package (L-DEPP)
  - Investigate charge properties of levitated lunar dust particles, their sizes, velocities and trajectories
  - Investigate the temperature and density of the local plasma, and measure electric surface potential
- Camera package for surface imaging
- Radiation monitor, radiation biology experiment (AMERE)
- Mobile Payload Element (MPE; DLR contribution in-kind)
  - Demonstrate robotics and mobility capabilities
  - Return data to support the design of future robotic elements



Operations

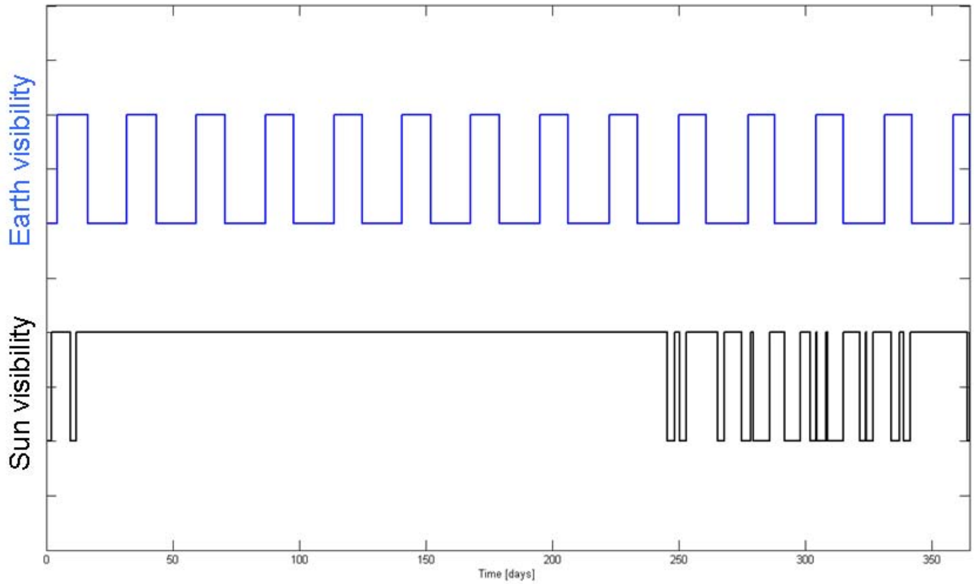
- Landing date selected to maximise illumination ‘window’
- Post-landing, and surface commissioning operations
- Deployment of surface payload elements via robotic arm
- Sampling of surface material for dust analysis and volatiles detection
- Autonomous operations while Earth is below horizon
- Management of onboard systems during short darkness periods

Balance of autonomy and teleoperation

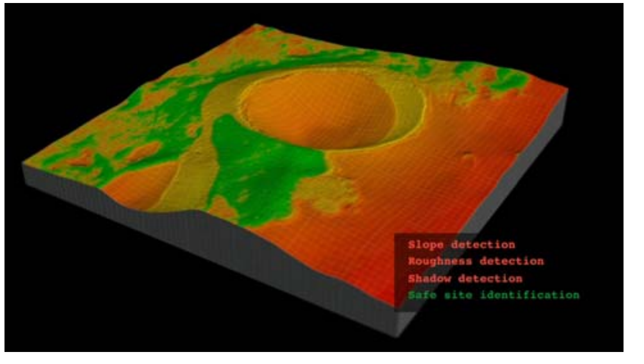
Distribution of critical functions during night survival

Operation in severe illumination condiitons

Characterisation of components to enable survival (low-T)



Conclusion



- Lunar South Pole is an interesting and attractive, but challenging environment
- Lunar Lander mission definition must address these challenges, particularly through the ongoing analysis of available data
- Outputs, methods and products can be of use for future exploration mission and capability development
- Lander mission shall make measurements of relevance for the development of future robotics
- Lander mission itself shall implement autonomous & robotic capabilities, in the D&L phase and during surface operations
- Lander mission is a concrete first step on a path of exploration which utilises the best of robotic and human capabilities

Surface Characterisation References – in the near future

- Crawford et.al.: Birkbeck College, University of London, UK
- Neukum et.al.: Freie Universitat, Berlin, Germany


THANK YOU
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