PROSPECT – THERMAL DESIGN CHALLENGES FOR LUNAR VOLATILE EXTRACTION

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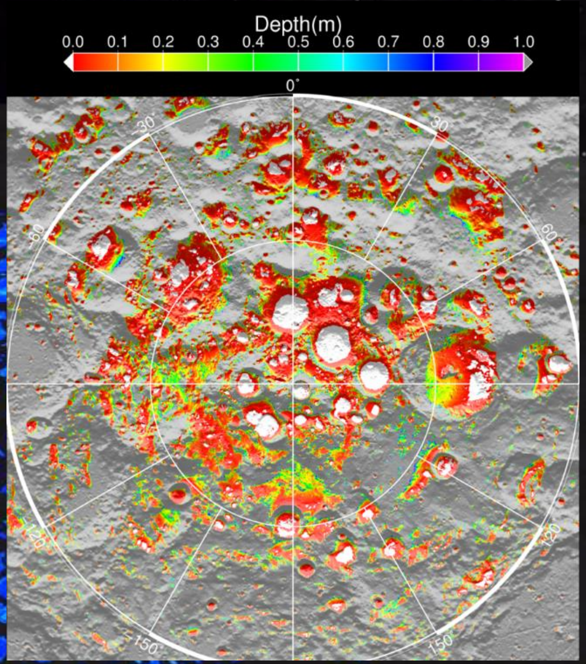
prospect

What is PROSPECT?

PROSPECT - **Pl**atform for **R**esource **O**bservation and in-**S**itu **P**rospecting for **E**xploration, **C**ommercial **E**xploitation and **T**ransportation

- Provide first sub-surface access
  - A depths of at least 1 m
- Acquire samples from potentially volatile rich regions
  - Low-temperatures (~120K), water-ice content, <u>preservation</u>
- Analyse samples for resource potential
  - thermo-chemical extraction and analysis of water, oxygen and other volatiles (identify and quantify)
- Address fundamental scientific questions
  - E.g. Isotopics and organics
- Provide samples to Russian robotic arm, for analysis in Russian instruments
  - Interface with Russian sampling tool



Calculated ice-stability* depth, based on Diviner data
**lost at a rate of <1kgm^{-2} per billion years*

Elements and Interfaces

Objective & Requirements

- **Find and characterize cold-trapped volatiles in lunar sub-surface samples**
- **Acquire, process & analyze** surface and **subsurface** samples during lunar day
- Landing site: 73°S to 85°S
- Operate up to 1 terrestrial year (**Survive lunar night**)
- Operational period is ~7-10 Earth days per terrestrial month
- **Sample temperature < 150 K at moment of oven sealing**
- Oven temperature **up to 1000 ° C**
- Sample transfer and gas exchange with Russian components
- Total PROSPECT **mass < 35 kg**

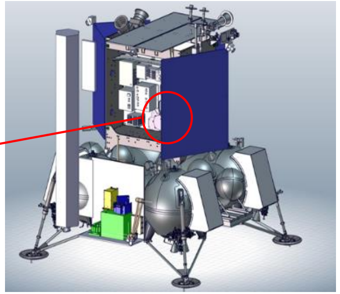
Elements:

- **ProSEED** Drilling and Sampling Element
- **ProSPA** Sample Analysis (including Sample Inlet System - SIS)
- Control Electronics Unit (**CEU**)
- 2 PROSPECT imagers

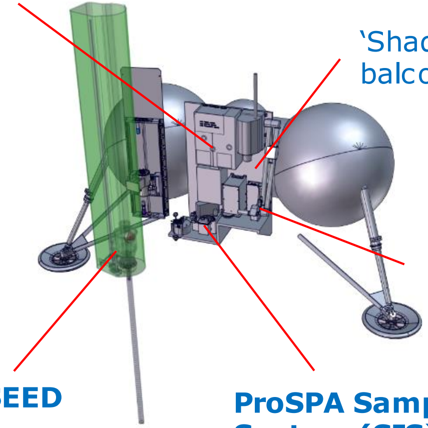
Interfaces:

- Thermo-mechanical interface with Luna-27 platform – *NPO-Lavochkin I/F*
- Electrical & Data interface via Russian BUNI (payload interface unit) – *IKI I/F*

Luna-27



SRR level reduced CAD model



PROSPECT Thermal Requirements

Luna-27

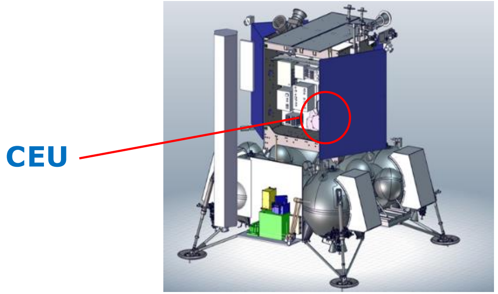
Thermal Requirements:

- (Some) temperature objectives:
  - Cold fingers: approx. **-100 °C**
  - Oven interface: approx. **-130 °C to -100 °C**
  - Mechanisms: approx. **-55 °C to +85 °C**
  - Increase in sample temperature **< 10 K** (Russian sample)
  - Coring, retrieval, delivery: sample temperature **< 150-170 K** (TBD)

- Interface temperatures (to lander)
  - ProSEED drill: **-180°C to +50°C**
  - PorSPA oven & SIS: **-50°C to +50°C**
  - CEU: **-50°C to +50°C**

- Lunar surface hot case:
  - IR flux **707 W/m²**, Solar flux **1425 W/m²**, 73°S plus 15° slope, Albedo moon = 0.07, Emissivity moon = 0.97

- Lunar surface cold case:
  - IR flux **0 W/m²**, Solar flux **0 W/m²**, 86°S, Albedo moon = 0.18, Emissivity moon = 0.97



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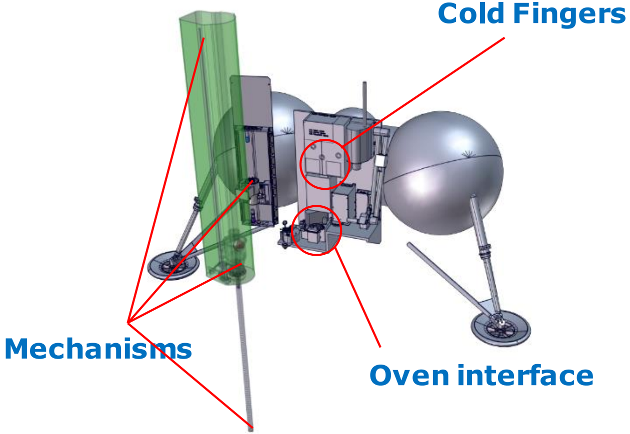
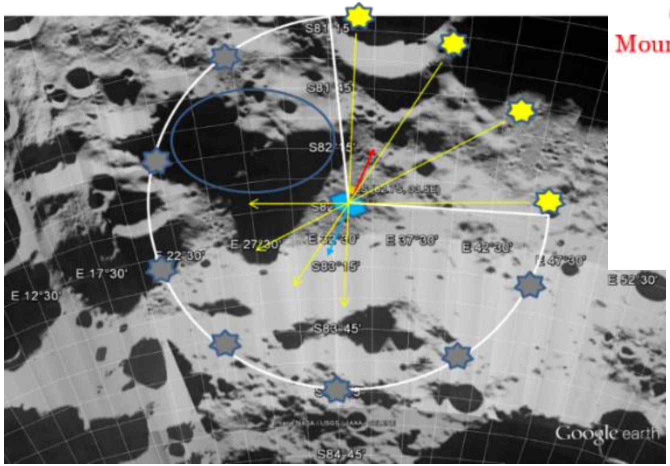
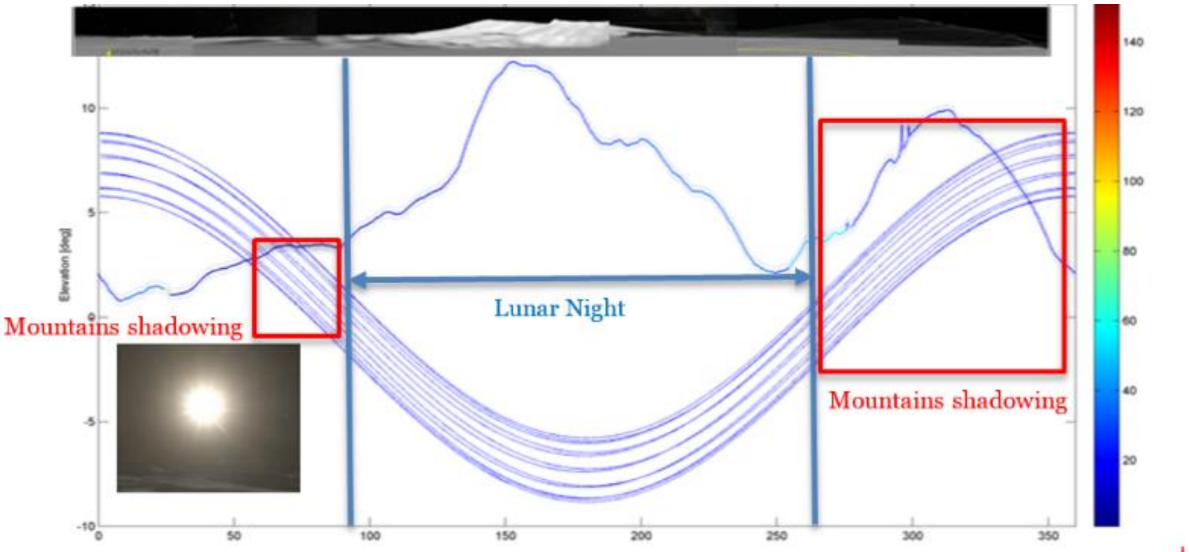


Investigation of environmental heat flux modelling

- Characterize environmental heat fluxes
  - Local topography
  - Sunrise & sunset
  - Surface temperature

- landing site at 82.7° S, 33.5° E





Models of the landing site

Disc Model:

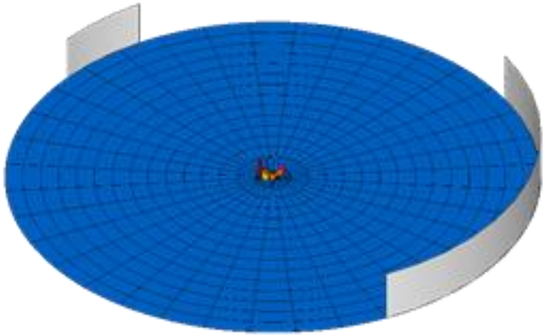
- 30m radius disc with simplified horizon
- Simplified lander model
- PROSPECT components assumed to be black bodies
- Modeled in ESATAN-TMS
    - Solar Absorptivity lander = 0.6,
    - IR Emissivity lander = 0.4,

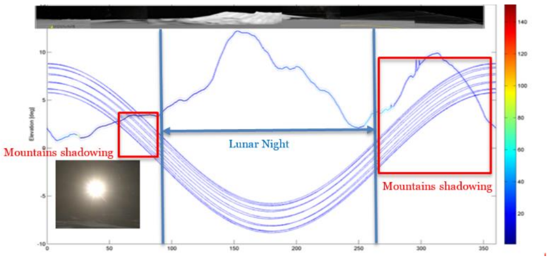
Topography Models:

- LRO LOLA data set
- 30 km x 30 km
- 1 km x 1 km
- black body cube (T = -20°C)

Common assumptions:

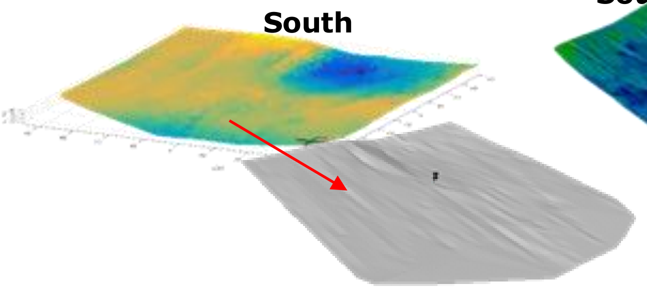
- Thermal capacity of soil neglected
- Thermal conductivity of soil neglected
- Optical surf. prop. regolith based on literature
    - Solar Absorptivity moon = 0.93
    - IR Emissivity moon = 0.97

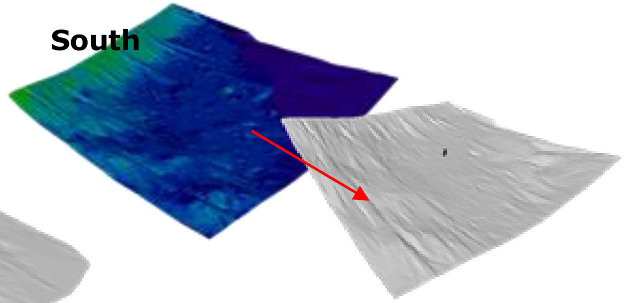




1 km x 1 km topography model

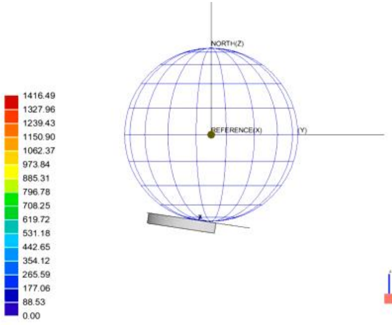
30 km x 30 km topography model



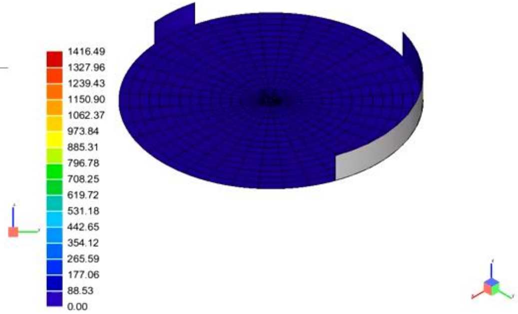


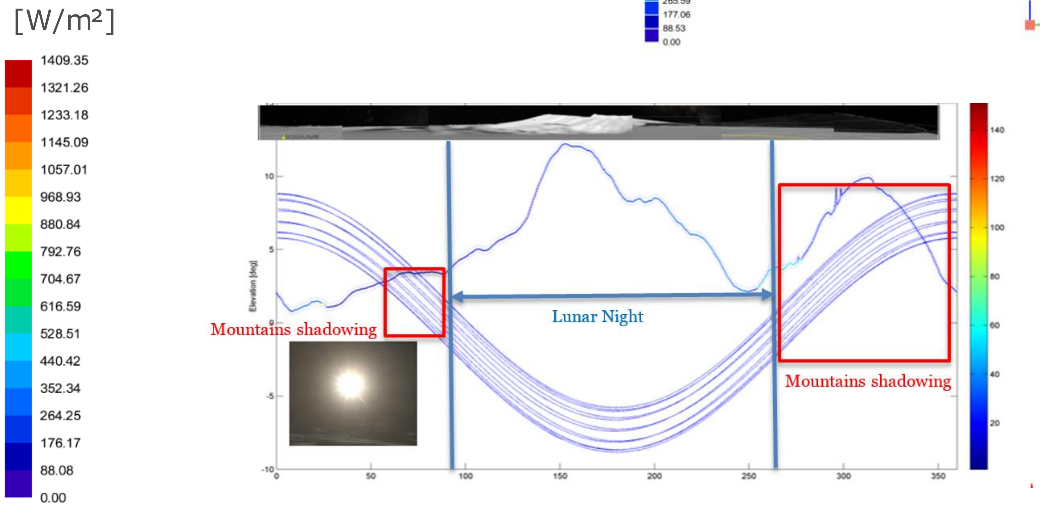
30 m Disc Model – Results

Heat flux [W/m²]

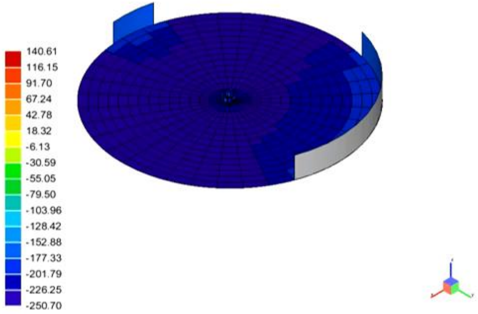


Heat flux [W/m²]





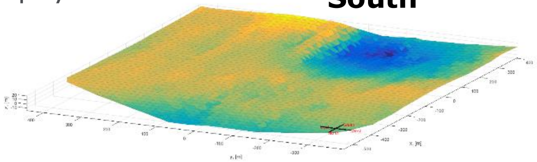
Temperature [°C]



Topography Model 1 km x 1 km - Results

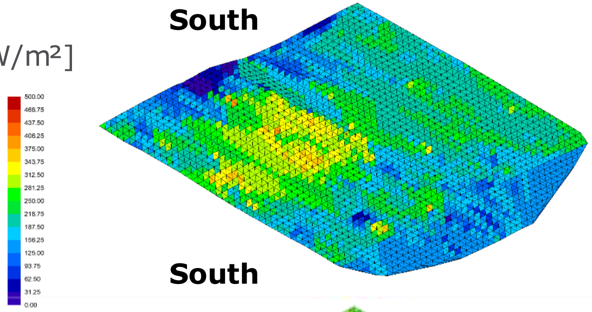
Topography

South



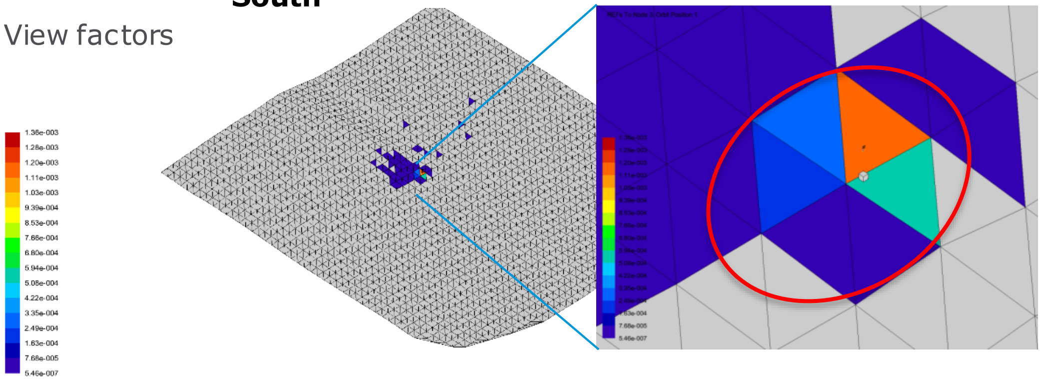
[W/m²]

South



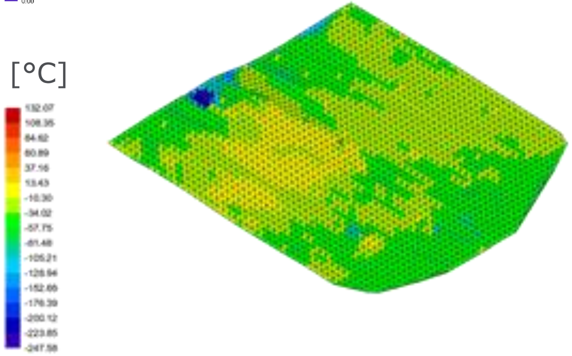
View factors

South



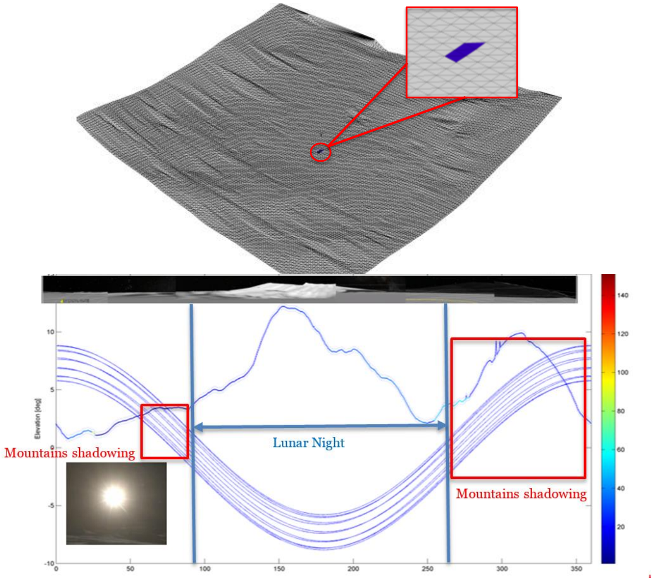
South

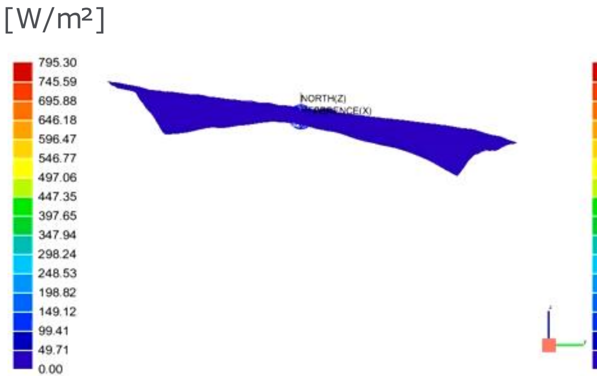
[°C]

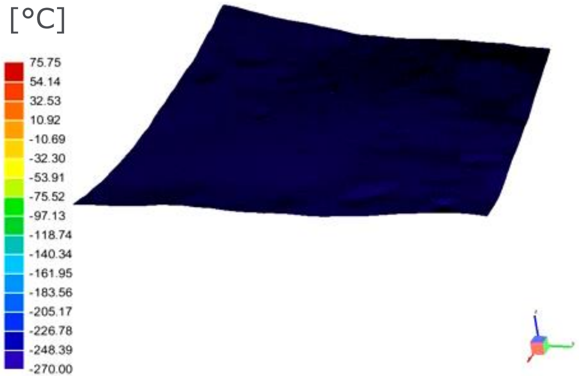


- Optical surface properties, slope angle and local shadowing effects govern surface temperature and hence environment heat fluxes
- Influencing surface elements within a 30m radius – comparable to disc model

Topography Model 30km x 30km - Results







Summary & Conclusions

Summary table:

Heat Load		Surface - Disc	Surface – Topography (1 km x 1 km)	Surface – Topography (30 km x 30 km)
Solar heat load	Q_S	6.38 W	10.47 W	4.94 W
Infrared heat load	Q_{IR}	45.66 W	60.28 W	48.75 W

Note1: Heat load for 1m² area on the South facing side; no direct Sun illumination; location of PROSPECT on Luna 27

Note2: Results are specific for a lunar south pole landing site with coordinates 82.7° S, 33.5° E. Other locations will yield different results.

Conclusions:

- Feasibility of modelling the lunar surface environment with standard thermal analysis software for space applications was demonstrated
- Local / near field topography has an impact on the overall IR and solar albedo heat fluxes
- The effect of mountains located 20-30 km away from the test cube is negligible.
- 30 m disc & simplified mountains model is now used by PROSPECT industry team

Outlook (Optional):

- Re-iterate with higher resolution topographic map
- Investigate different possible landing sites
- Investigate the impact of local boulders based on to be expected size and distribution

THANK YOU

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