Appendix D

Thermal Modelling of Luna 27 Landing Site

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Abstract

Luna 27, also known as the Lunar Resource Lander, is the Russian-ESA collaborative mission to the permanently shadowed craters at the south pole of the moon. In this study, the thermal environment of the potential landing site of the lander is assessed with the use of ESATAN-TMS. A series of modelling approaches are explored in order to address the different factors that may impact the thermal environment affecting the lander, namely surface infrared, direct impingent solar flux, the transient cases of sunrise and sunset, and the lunar topography. The effect of the orientation of the lander was further considered with regards to the on-board European units PILOT and PROSPECT. The models were then assessed in light of theoretical flux balances, empirical lunar regolith temperature correlations, and data from NASA's Lunar Reconnaissance Orbiter.

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European Space Agency

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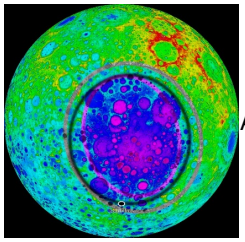
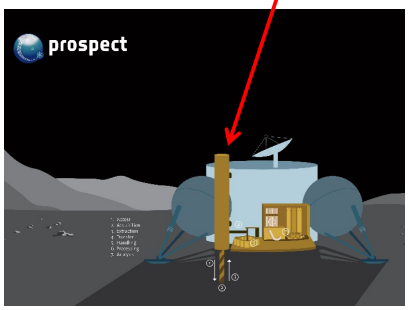
Background

- Luna-27: ESA-Russia collaboration
- Scheduled for flight in 2025
- Landing site: 82.7° S, 33.5° E
- European technology on-board:
  - PILOT (**P**recise **I**ntelligent **L**anding using **O**n board **T**echnology)
  - PROSPECT (**P**latform for **R**esource **O**bservation and in-**S**itu **P**rospecting in support of **E**xploration, **C**ommercial **E**xploitation & **T**ransportation).
- Searching for volatiles (CHON compounds)
  - → access to lunar subsurface & sample capability testing
  - → ensure stringent 120-150K constraint for sample preservation



Aitken basin



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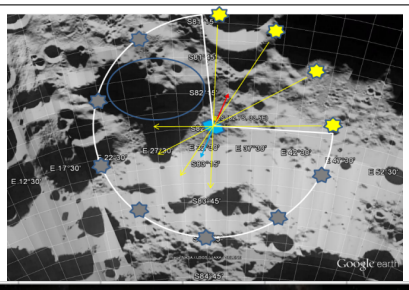
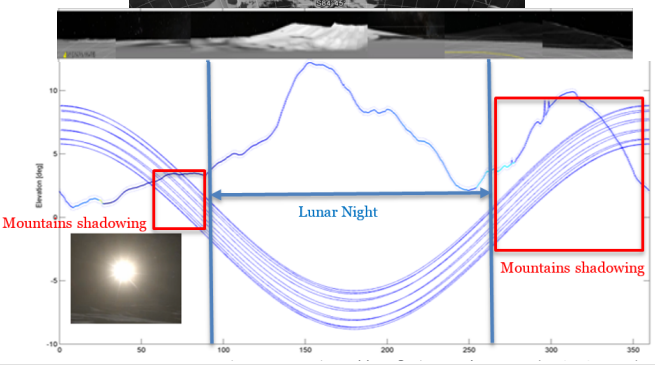
Thermal Modelling Drivers

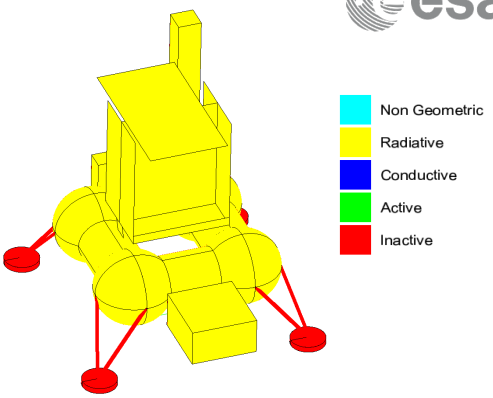
- Light & dark phases
- Sunrise/Sunset cases
- Topographical impact of landing region
- Verify ESATAN-TMS capability for lunar surface model

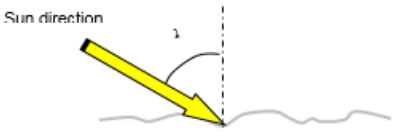




Initial Assessment of Landing Site

- Phase B1 of project
- Thermo-optical properties of lunar surface regolith ε=0.97, α=0.93
- IR steady state flux of 707 W/m^2 for hot case

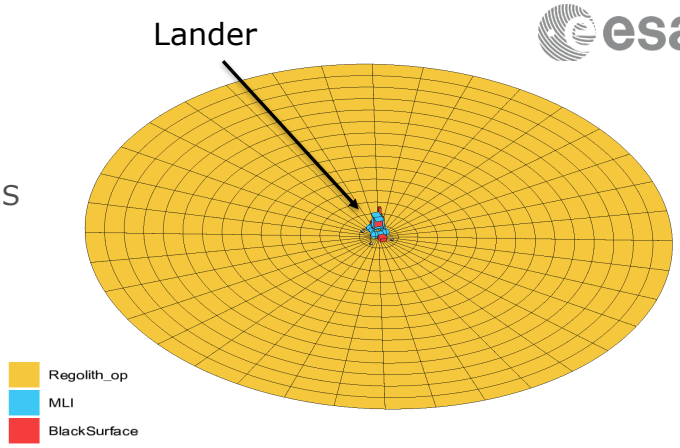




- Illuminated: $T_{moon} = ((1-a).\ Cs.\ \cos(\lambda)/(\varepsilon.\sigma) + (2.3+3.1*\cos(lat)^{1/4})/(\varepsilon.\sigma))^{(1/4)}$
- Non illuminated: $T_{moon} = ((2.3+3.1*\cos(lat)^{1/4})/(\varepsilon.\sigma))^{(1/4)}$

Disc Model

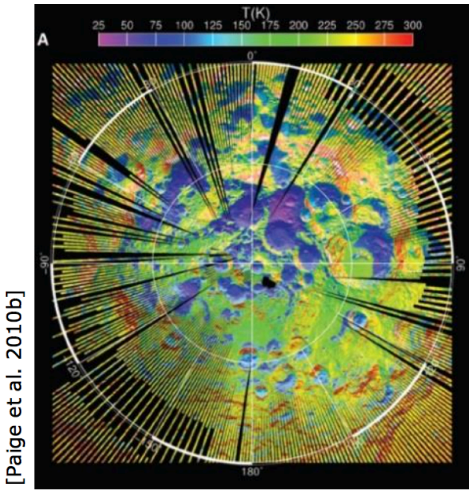
- Multi-node 30m radius disc
- Scaled down horizon
- 'Planet Surface' in ESATAN-TMS
- Defining moon as planetary body
- Surface without capacity; only positioning in space



Optical Finish	IR Emissivity	Solar Absorptivity
Lunar Regolith	0.97	0.93
MLI	0.6	0.4
Black Surface	1.0	1.0

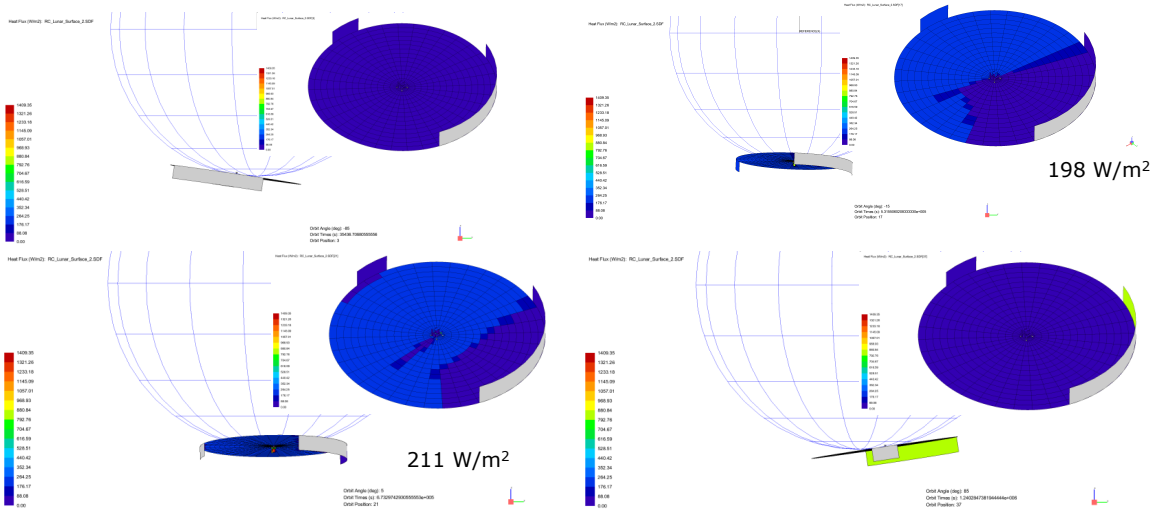
Lunar Topography

- Several mountains in region; might radiate heat to lander
- Lunar surface close to black body
- 90° incident angle of sun; surface heating to 300-400K (right)
- Southern pole slopes
- Mountains 20-100km may be significant
- Concerned with temperature development of samples being drilled



[Paige et al. 2010b]

Sunrise to Sunset



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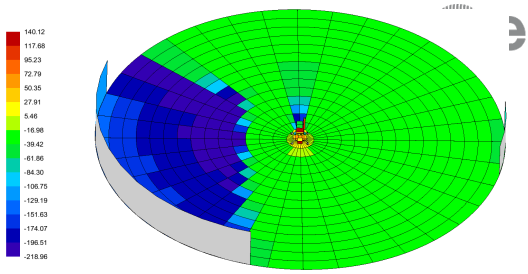
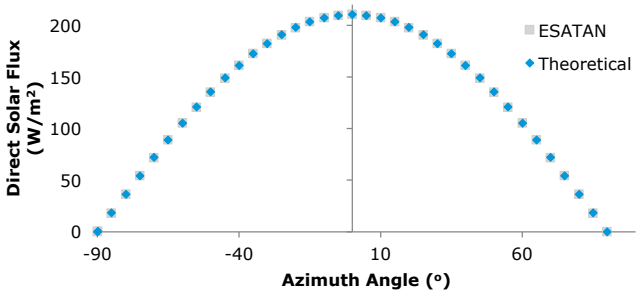
Model Validation

- Control method: FIXED RAYS
- Surface criticality: NORMAL
- Number of rays for REF and HF: 10,000



- Theoretical vs computed: 0.37% maximum difference
- Maximum sun elevation (245.6K; 27.6 °C)



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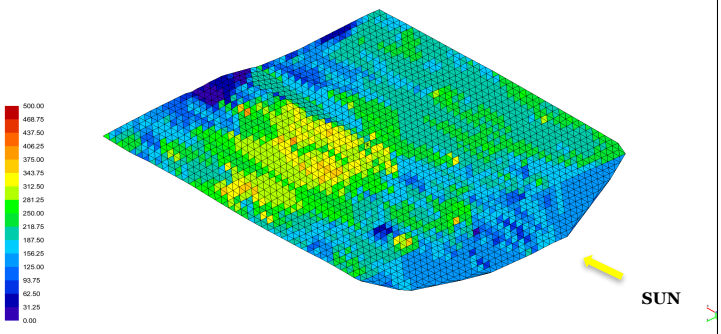
Topography Model – 1km x 1km

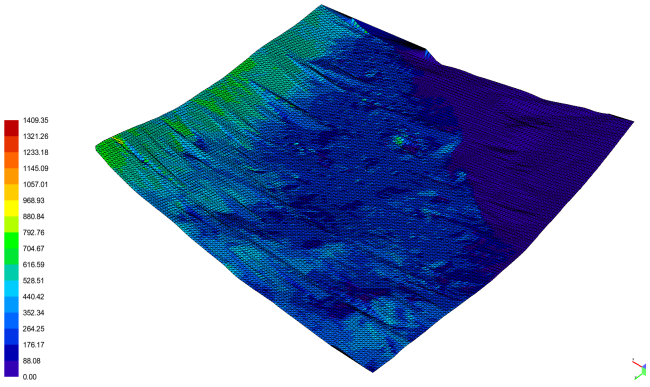
- 1 km x 1 km from LRO (maximum sun elevation)
- Lander modelled as black cube
- PROSPECT Node (facing away from sun) considered
- Comparable results to disc model - Q_S and Q_{IR} impingent on lander



Heat Load	Surface - Disc	Surface - Topography
Q_S	6.38 W	10.47 W
Q_{IR}	45.66 W	60.28 W

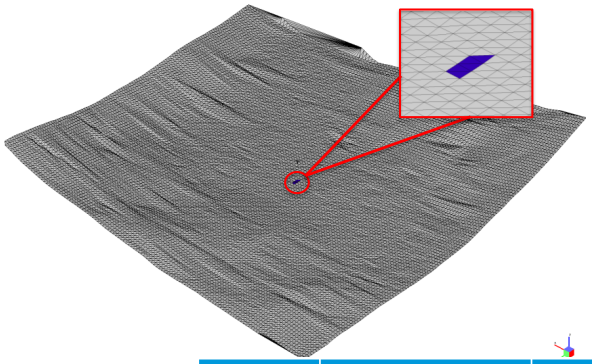
Topography Model – 30km x 30km

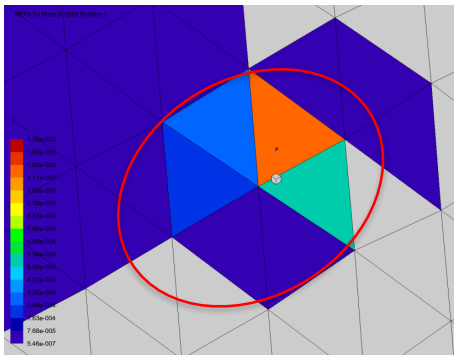
- Limited number of surface nodes with view factor to cube node
- Small dimensions of cube vs scale of topography



Topography Model – 30km x 30km

- 30m radius – comparable to disc model





Heat Load	Surface – Disc (30m radius)	Surface – Topography (1 km x 1 km)	Surface – Topography (30 km x 30 km)
Q_S	6.38 W	10.47 W	4.94 W
Q_{IR}	45.66 W	60.28 W	48.75 W

Discussion

- Demonstrated feasibility of ESATAN-TMS for modelling lunar surface environment.
- Effect of mountains located 20-30km away negligible.
- 1km x 1km heat load presents highest heat loads; useful for specifying worst hot case conditions.
- All results specific for 82.7° S and 33.5° E.

Thank you for your attention!

Thanks to **Vito Laneve** & **Philipp Hager**

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