Lunar Surface Innovation
CONSORTIUM

EE: Thermal systems and illumination subgroup

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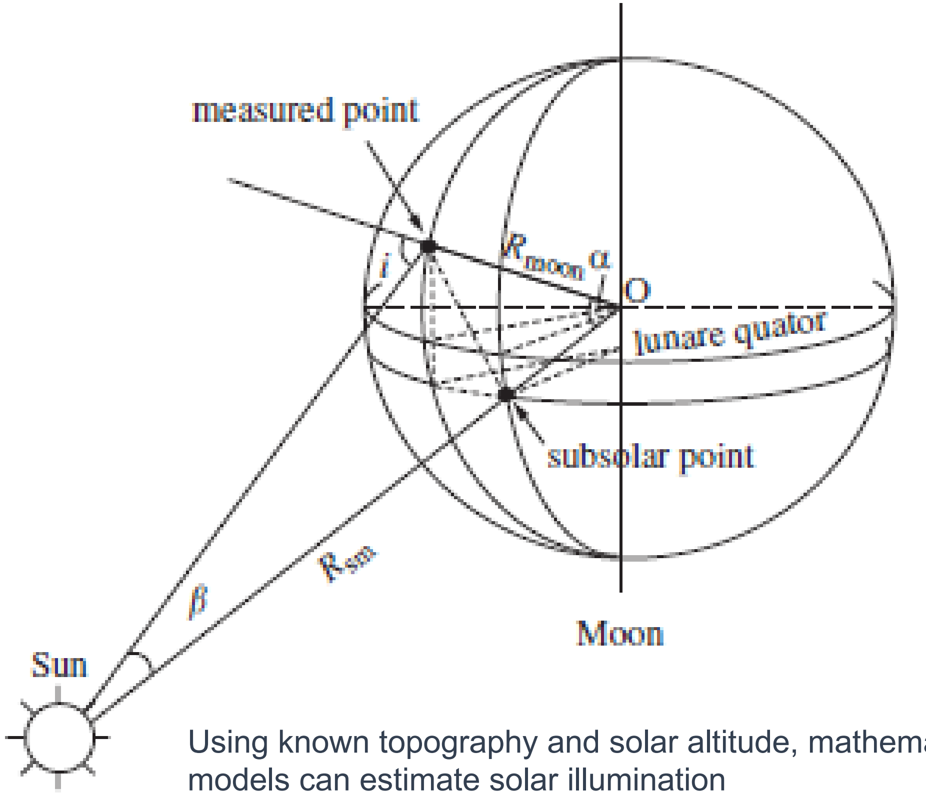
Thermal considerations in a lunar environment

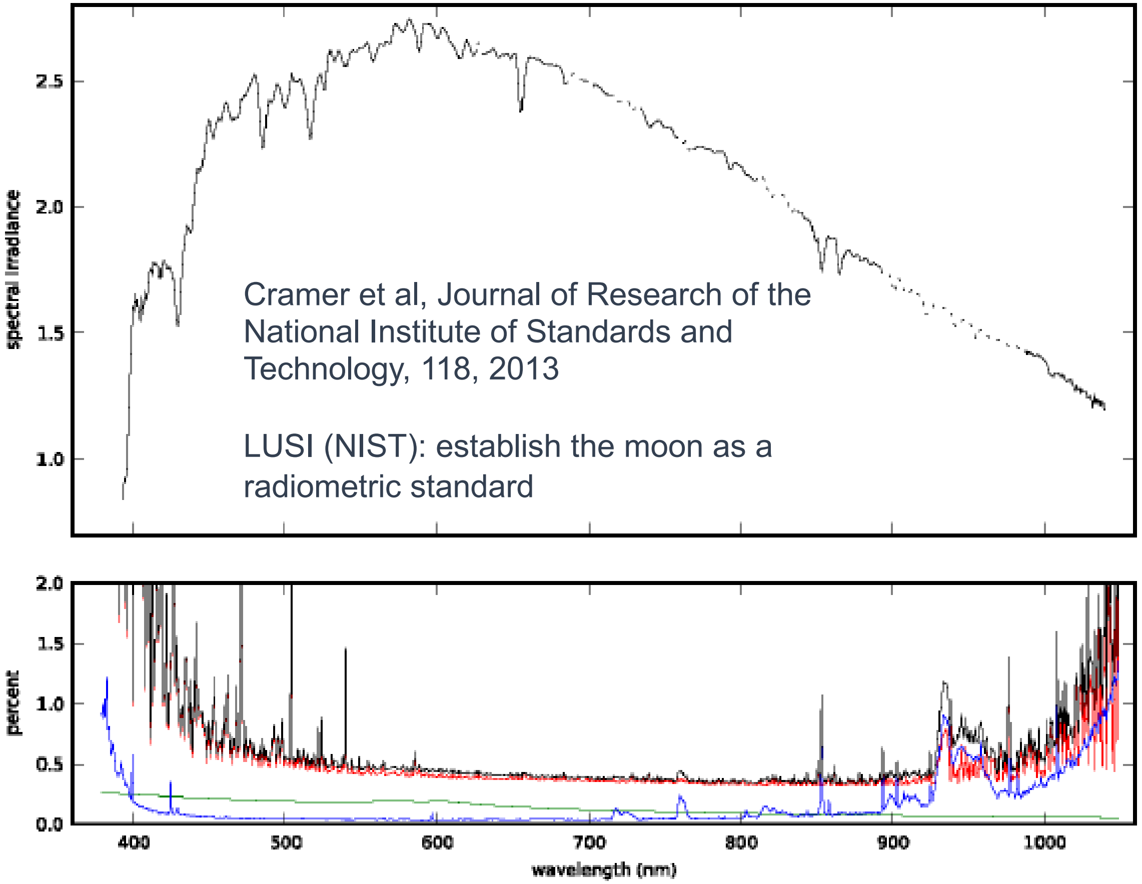
- Extreme thermal environment of the moon makes any exploration mission challenging
  - Important daily surface temperature differences (120^{o}C at the equator, -253^{o}C near poles)
  - High intensity electromagnetic radiation with associated thermal effects
  - Permanently shadowed regions
  - Unique properties of regolith (low Cp, high emissivity, etc)
- Extreme exposure to solar radiation (illumination)
  - Affects all surfaces exposed (thermal viewpoint)
    - Daytime affected by solar wind
    - Nighttime from plasma in lunar wake
- System with Thermal Considerations for Artemis Base Camp (tentatively in or near Shackleton Crater)
  - Power infrastructure (generation and storage)
  - Habitats (climate control for T and rh, waste disposal
  - Local mobility system (EVA)
  - Robust mobility platform for exploration (up to 45 days)
  - Materials processing equipment
- Equipment viewpoint
  - radiators, heat pipes, thermal control equipment, heat pumps, and thermal storage c
  - Multiphase flow loops in 1/6 g, separators (hydrocyclones)
  - Design of evaporators, condensers in 1/6 gravity
  - Computers, power electronics
  - Manufacturing equipment

Solar irradiance on the moon / illumination



Using known topography and solar altitude, mathematical models can estimate solar illumination

Li, X. et al.,
"Estimation of solar illumination on the Moon: a theoretical model",
Planetary and Space Science, 56, 2008



Cramer et al, Journal of Research of the National Institute of Standards and Technology, 118, 2013

LUSI (NIST): establish the moon as a radiometric standard

Fig. 1. Spectral irradiance of the Moon in units of $\mu W\ m^{-2}\ nm^{-1}$ at 11:40:43 on 30 November, 2012 UT (top panel). The associated uncertainty in the linear fit (blue), combined uncertainty in the corrections for ozone and stratospheric aerosols (green), uncertainty in the calibration (red), and total combined uncertainty (black) are shown in the lower panel. Our measurement is valid with the uncertainty shown here in the regions of the spectrum not affected by strong molecular absorption. At wavelengths where the discrepancy between our measured Rayleigh transmission and the expected Rayleigh transmission is greater than 1 % (see Fig. 2), we scale the USGS model prediction to produce the dotted line in the upper panel.

What have we done

- Started in Spring 2022 as thermal subgroup lead
    - Provided feedback on RFI
    - Recently started presentations on thermal systems (Josh Anibal/Prof Martins)
    - Next speaker from FRIB at MSU on cryogenic systems (10/21)
    - Follow on speaker from LBNL on topology optimization for design of thermal systems

    - Need help to identify speakers

Next steps

- Need help identifying speakers for a range of topics
  - Equipment aspects (heat pipes, flow loops, heat exchangers, pumps, evaporation/condensation)
  - Habitat design and climate control (temperature and humidity)
  - Local mobility system designs, EVAs
  - Robust mobility platform for exploration (up to 45 days)

- Clear need for compiling NASA/AIAA reports / have a repository / review papers

- Thank you!!

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