Space Technology Mission Directorate

Game Changing Development Program

National Aeronautics and Space Administration

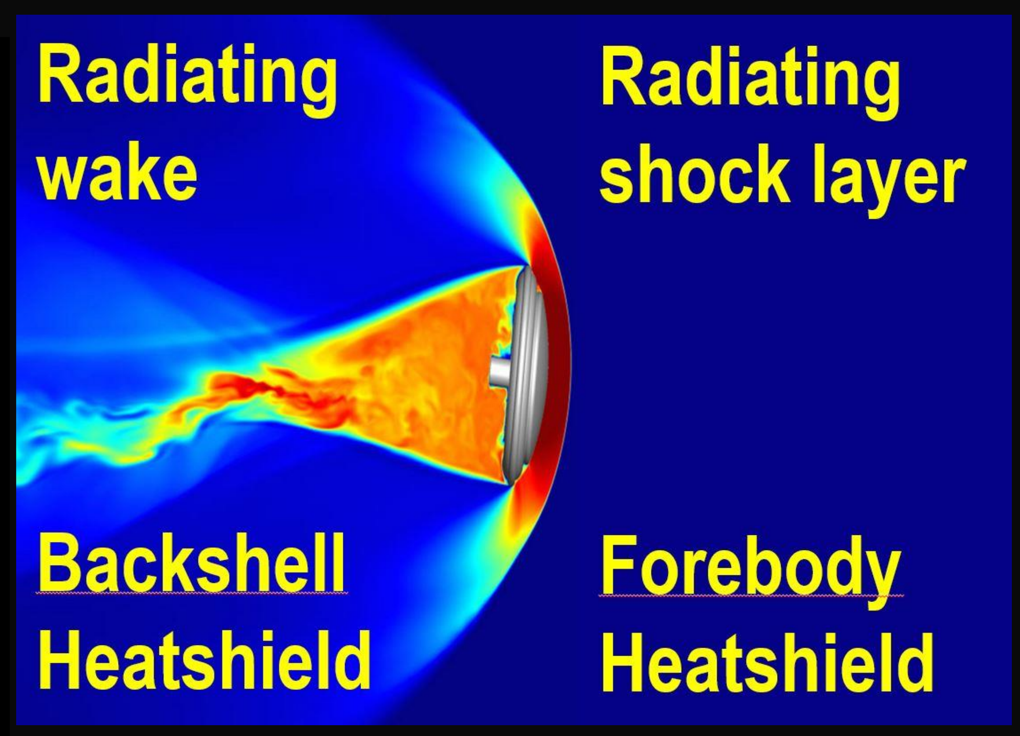
Orion EM-2 TPS Radiometer & Spectrometer

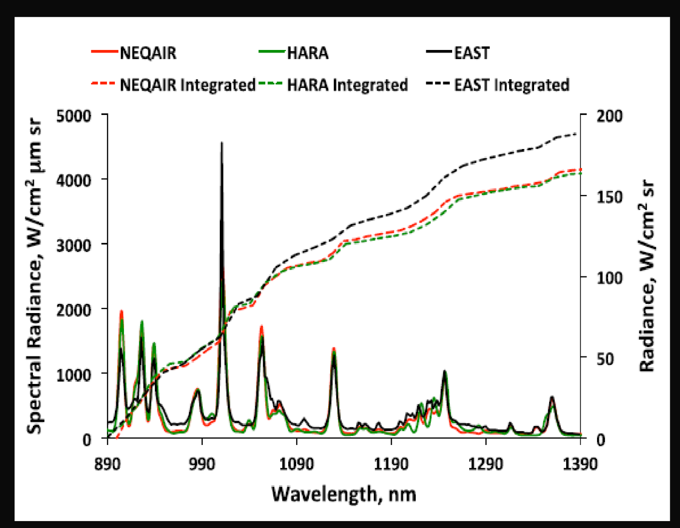
The largest and fastest spacecraft for Mars and Moon missions will see high levels of radiation from the heated shock layer. Flight measurements of radiative heating will validate models, reduce mass and reduce risk – before we have crew on board.

Background

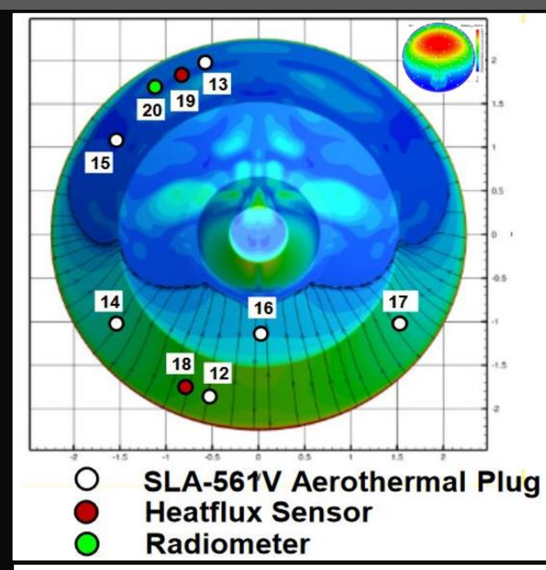
- Why? To validate models, reduce risk, and optimize TPS mass.
- Shock layer radiation has been investigated since the 1960s, using ground tests, flight tests, and theoretical modelling. Radiation was a key component of entry heating to Jupiter's Galileo probe. Heat shield radiometers were on NASA FIRE II & ESA Schiaparelli, are planned for EM-1, possibly EM-2.
- Shock layer radiation in Orion high-speed lunar return missions is predicted to have a major impact on TPS heating.

Mission Infusion: Radiation Measurements during Atmospheric Entry





Representative Earth return radiation (Brandis et al. JTHT 31,1, 2017)

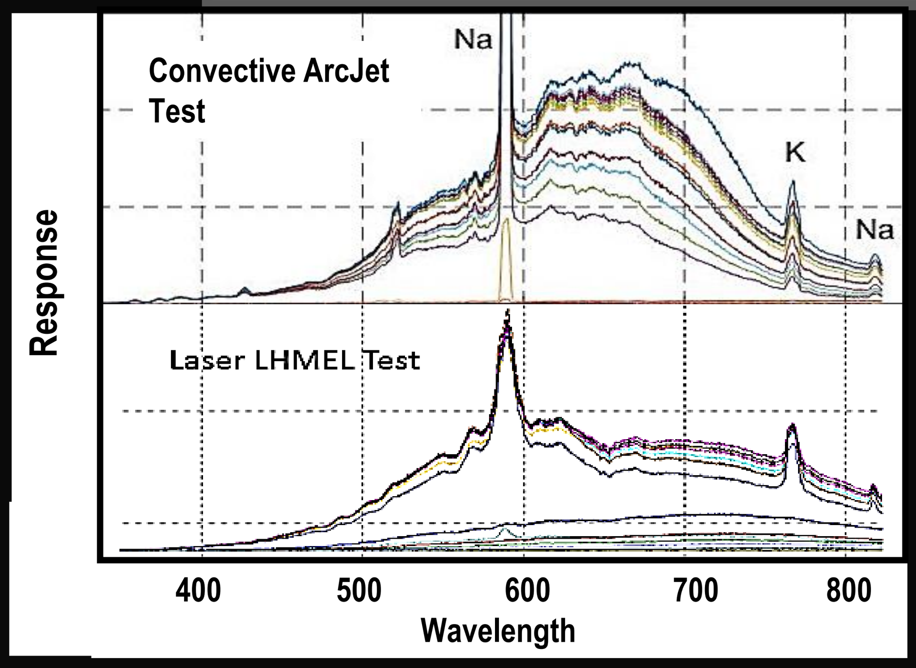


Backshell sensor layout (Brandis, Cruden, White, Saunders & Johnston, AIAA 2015-3111)

Mission or Sensor	Radiometers	Spectrometers	Status
MSL MEDLI-1	0	0	Success Aug 6, 2012 - Improved Entry Descent Landing (EDL) Insight
MEDLI-2	1 Backshell	0	Mars 2020
EFT-1	2 Forebody	0	Success Dec. 5, 2014 - Improved Modelling, Optimization
EM-1	2 Forebody	0	Planned 2019
EM-2	1 Backshell	1 Forebody	Planned
EM-3, -4...	Hopefully	Hopefully	Not Yet Down-Selected

Optical Component Testing: Performance, Transmission & Effect of Contamination

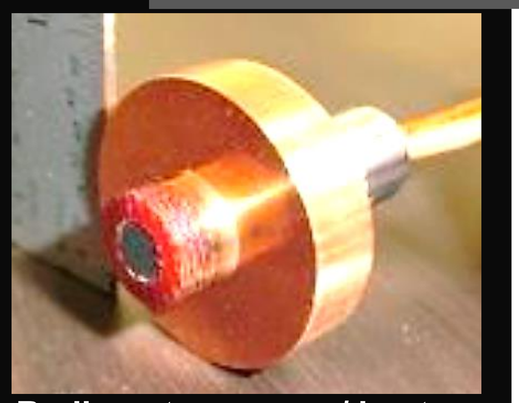
Spectrometer



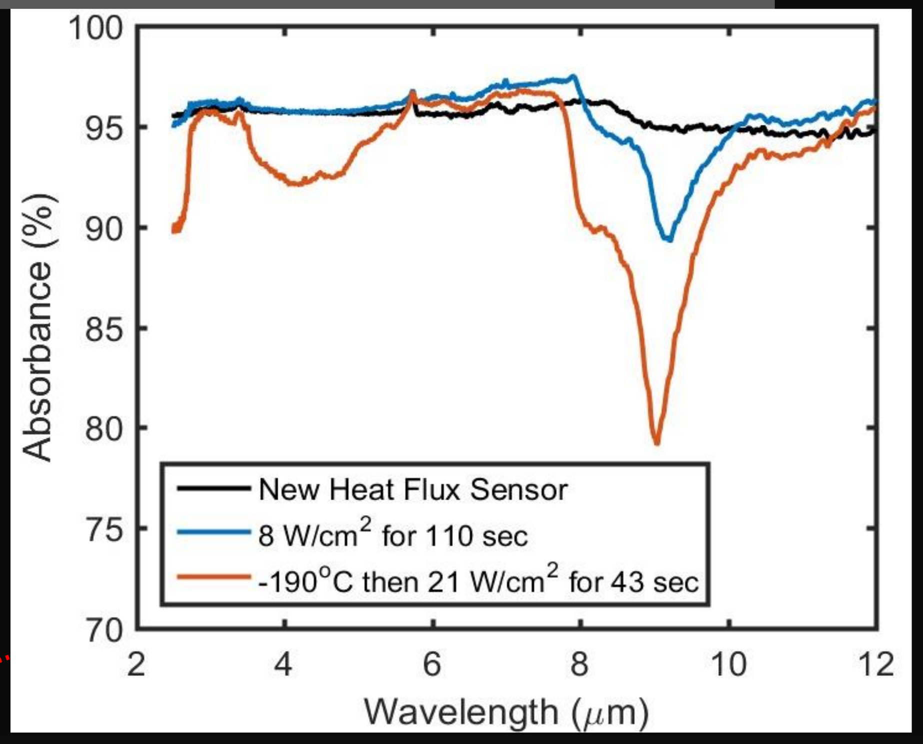
Commercial palm-sized mini-spectrometers R&D: quantum dots / spectro-on-a-chip

Resolution: Ocean Optics mini-spectrometers detected the strongest Na and K spectral lines in both Arcjet test and Laser tests above the blackbody thermal radiation background. Multiple scans from time steps shown on each plot show consistent emission over increased thermal radiation from heated surfaces. (MacDonald & White. See also Winter and Prabhu AIAA 2012-0215 for shock layer emission spectra w/o thermal background)

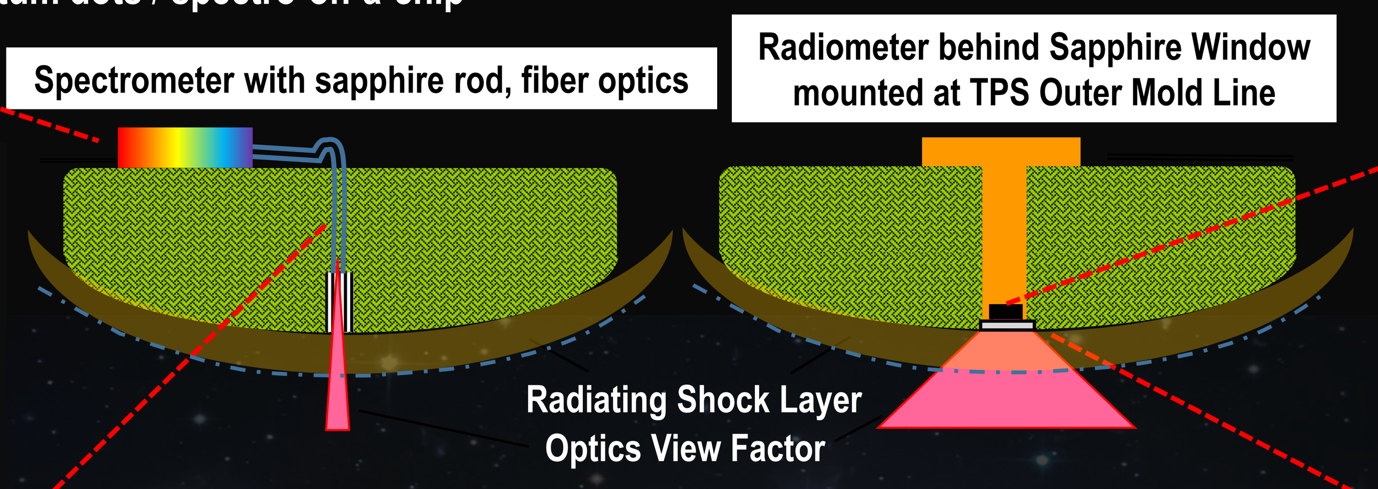
Radiometer

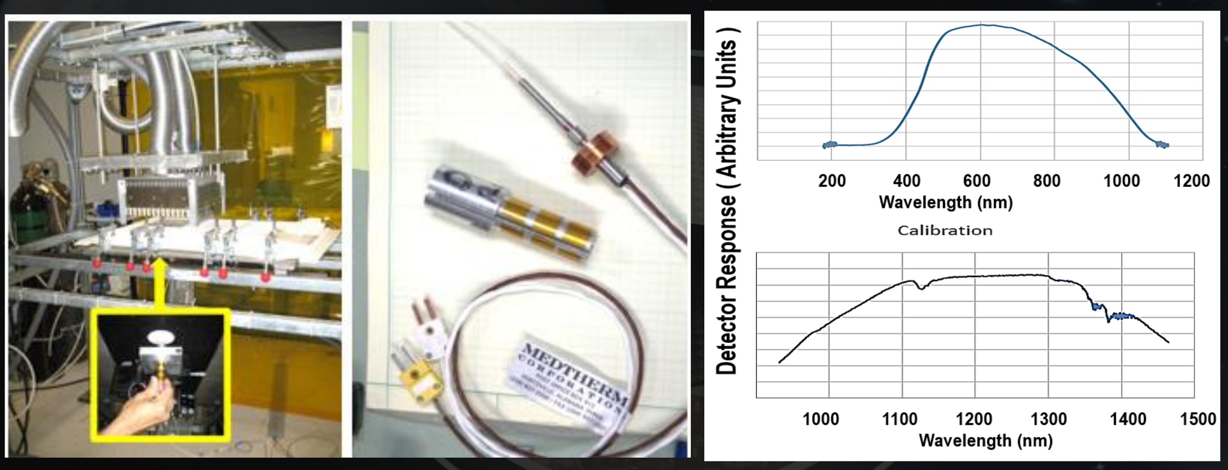


Radiometer sensor / heat flux gage



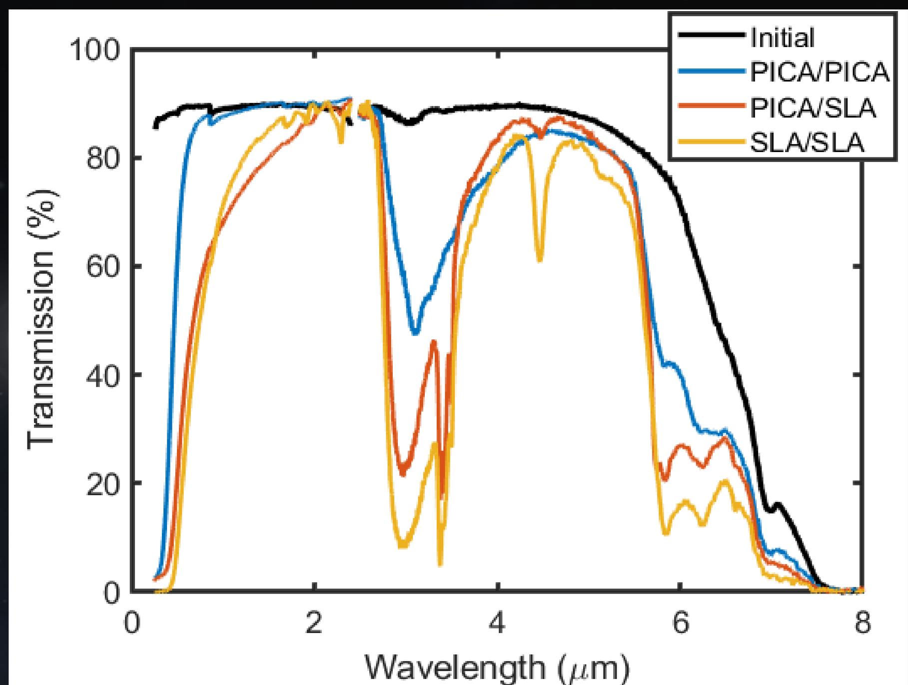
Coating degradation after aggressive thermal cycling / thermal shock but not from nominal test(Miller & White)





High-temperature sapphire rod coupled to mini-spectrometer configuration was tested using NASA Quartz Lamp source. Plots shown give effect of sapphire rod on system response and a representative calibration using integrating sphere. (Cruden & White)

Sapphire window contaminated by charring ablators' deposits



Window Contamination after mini-ARC tests causes transmission data loss at characteristic wavelengths. (Miller & White, see "Characterization of a Radiometer Window", R. Miller et al., AIAA2018-3590)

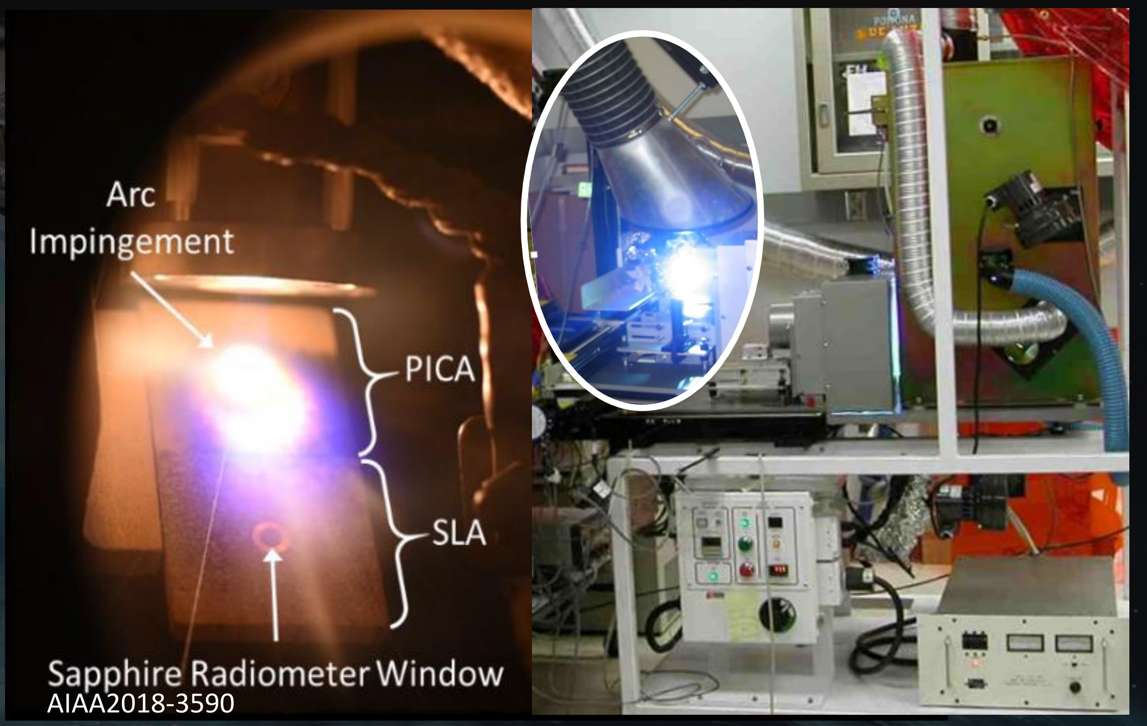
Window Contamination Control – open ports or sacrificial "blowing" coatings to reduce char deposition.

Evaluating space-qualified coatings (low-char Silicone, NuSil CV-144, Teflon, etc.) for window contamination control.
First tests run: demonstrated concept in lab when low-char RTV protected glass from contaminating deposits.
Characterized reflectance/ emittance effect of NuSil–coatings on PICA

Summary: Characterizing the optical performance of system components enables robust and accurate measurement of shock layer radiation. Sacrificial coatings are under investigation to prevent blockage of open ports and/or increase signal and reduce post-processing in contaminants' absorption bands.

Challenges: Sacrificial coating material selection is limited by narrow operating window (must pyrolyze or sublime at high shear but mild backshell heating conditions).

Requesting Follow-on FY19: Screen-testing blowing coatings is proposed in more relevant environments under controlled cross-flow, potentially in both mini-ARC and 8 kW UV arc-lamp.



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