Planning for Validation of Optical Property Degradation Predictions Using On-Orbit Telemetry

Jared Berg, NASA GRC

Presented By
Jared Berg

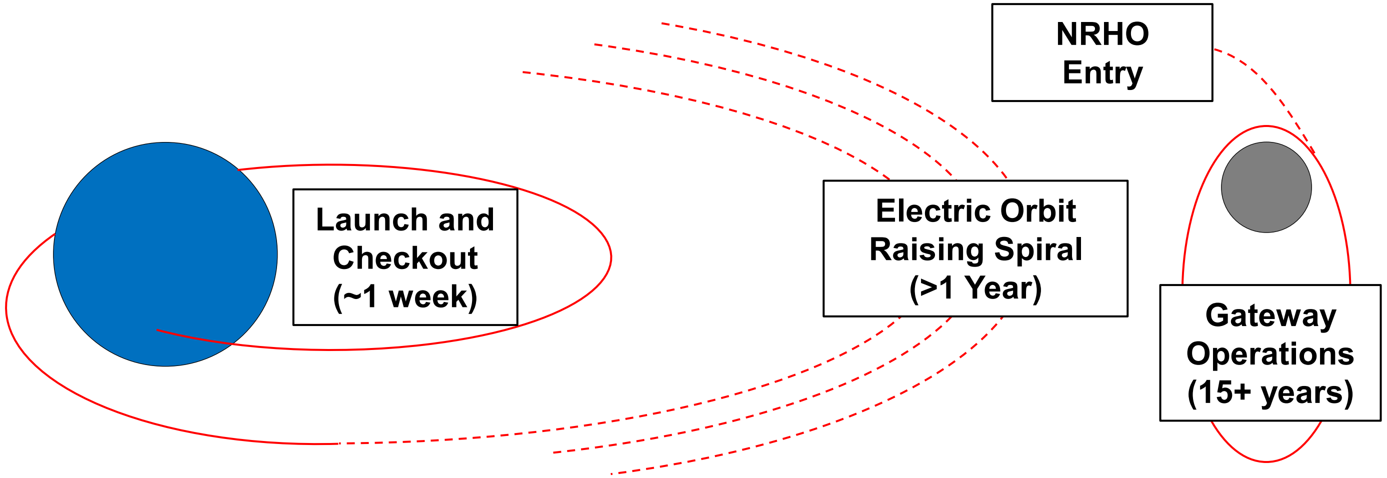
Thermal & Fluids Analysis Workshop
TFAWS 2024
August 26-30, 2024
NASA Glenn Research Center
Cleveland, OH

Outline

- Mission Background
- Problem Description
  - Uncertainty Sources
  - Spacecraft Details
- Proposed Approach
- Forward Work

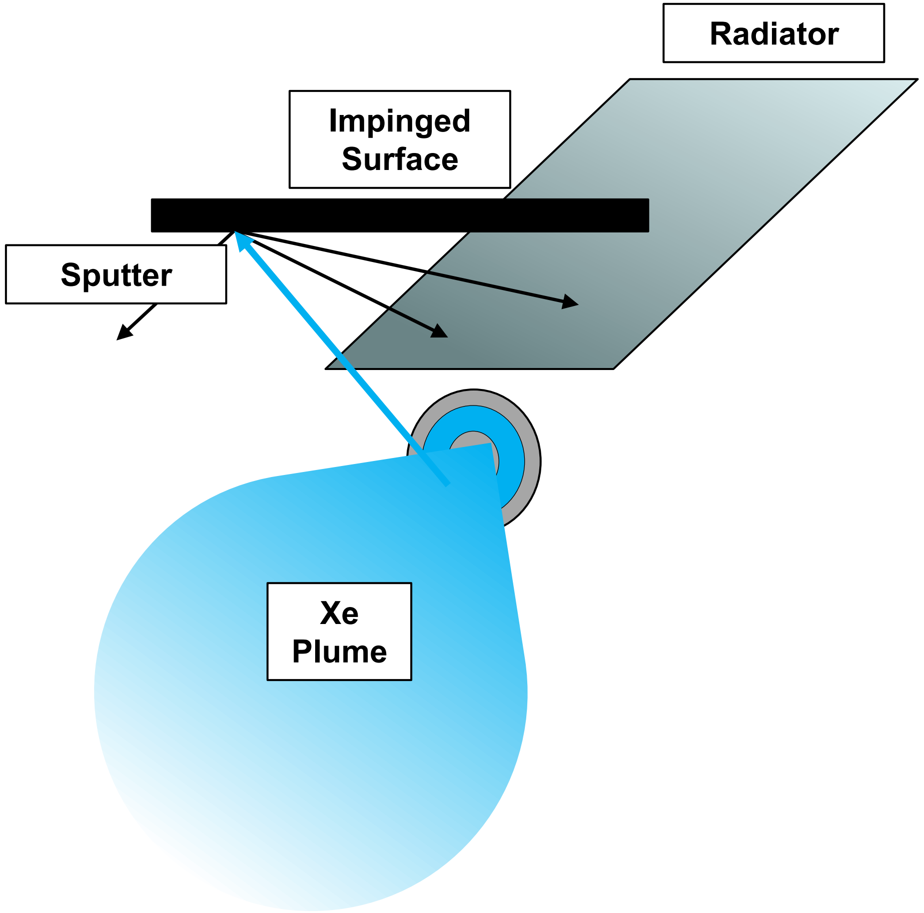
Mission Background

- Power and Propulsion Element (PPE) will be launched with the Habitation and Logistics Outpost (HALO) as the first two Elements of Lunar Gateway
- Gateway designed for 15+ year life
- PPE will utilize Hall thrusters to perform Lunar transfer via an Electric Orbit Raising (EOR) spiral trajectory
  - EOR lasts more than a year, with high duty cycle and significant Xenon propellant throughput
- PPE will provide attitude control and station keeping thrust for Gateway, including via electric propulsion



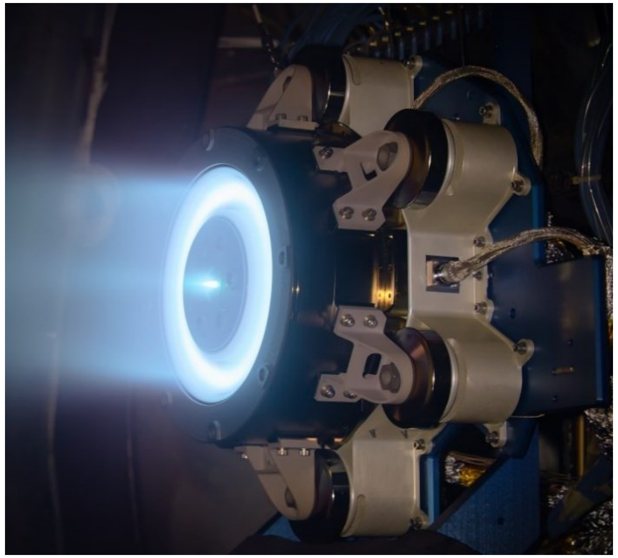
Problem Description - Ion Sputter Redeposition

- High-energy ions from the electric propulsion plumes can impinge on spacecraft deployed geometry
- Material from exposed surfaces will be sputtered and redeposit on spacecraft surfaces with a view to the impinged surface
- Deposited material will alter the optical properties of the main body radiators
- Common practice to size radiators based on End Of Life (EOL) values, but:
  - Significant uncertainty in redeposition severity



Redeposition Uncertainty

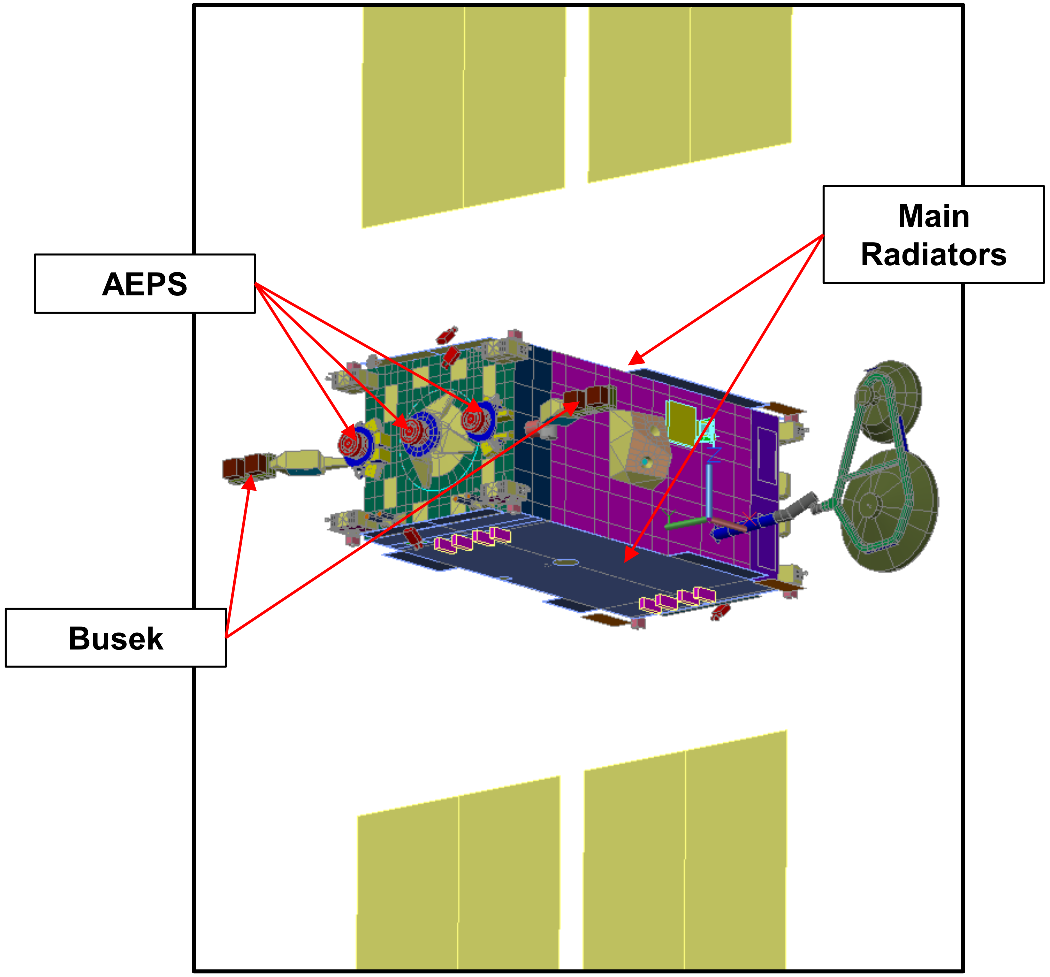
- Difficult to determine what EOL assumption should be
  - Plume characteristics [1] are not perfectly constrained
    - Ground testing is insufficient
  - Geometry / view factor over mission
    - Impinging on moving surfaces
  - Complex composition of impinged surfaces
    - Different materials
  - Redeposition distribution will vary in thickness and composition over the radiators
  - These are the largest Hall thrusters flown
- Unknown interaction between different types of contamination
  - Regular outgassing of volatiles
  - UV / radiation impacts on deposited layers
  - Mixtures of various contaminants
  - Self / visiting vehicle hypergolic plume contamination
  - Dust, crew waste dumps, etc.
- Degradation expected to be front-loaded due to EOR
- Spacecraft is mass / volume constrained
  - Not able to just radically oversize radiators



AEPS 12 kW Thruster

Spacecraft Considerations

- PPE is a modified Maxar 1300-class bus
- Main radiators are Optical Solar Reflectors on top / bottom faces
  - Radiator has embedded heat pipes
- Typical attitude restricts the amount of sun on radiators
  - Nominal EOR and Gateway mission features periods of transient high sun angle
- Critical components are instrumented, and telemetry sent to the ground

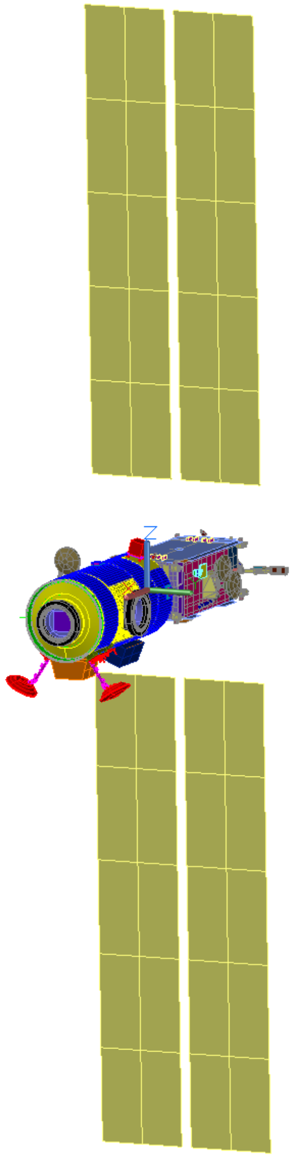


Analytical Challenges

- Radiators are large and predicted redeposition distribution varies greatly over this area
  - Heat pipes minimize the temperature variation due to localized heating
- Few ways to cross-validate redeposition distribution
  - May get external camera views at some point during mission
  - Difficult to characterize absorptivity only with visual data
- Periods of sun angle are not long enough to reach steady-state (likely)
  - Transient correlation significantly more difficult
- Many other sources of uncertainty
  - Attitude error
  - Thermistor locations
  - IR backload from deployed items and other spacecraft
  - Dissipation state of items on main radiator
  - Solar intensity

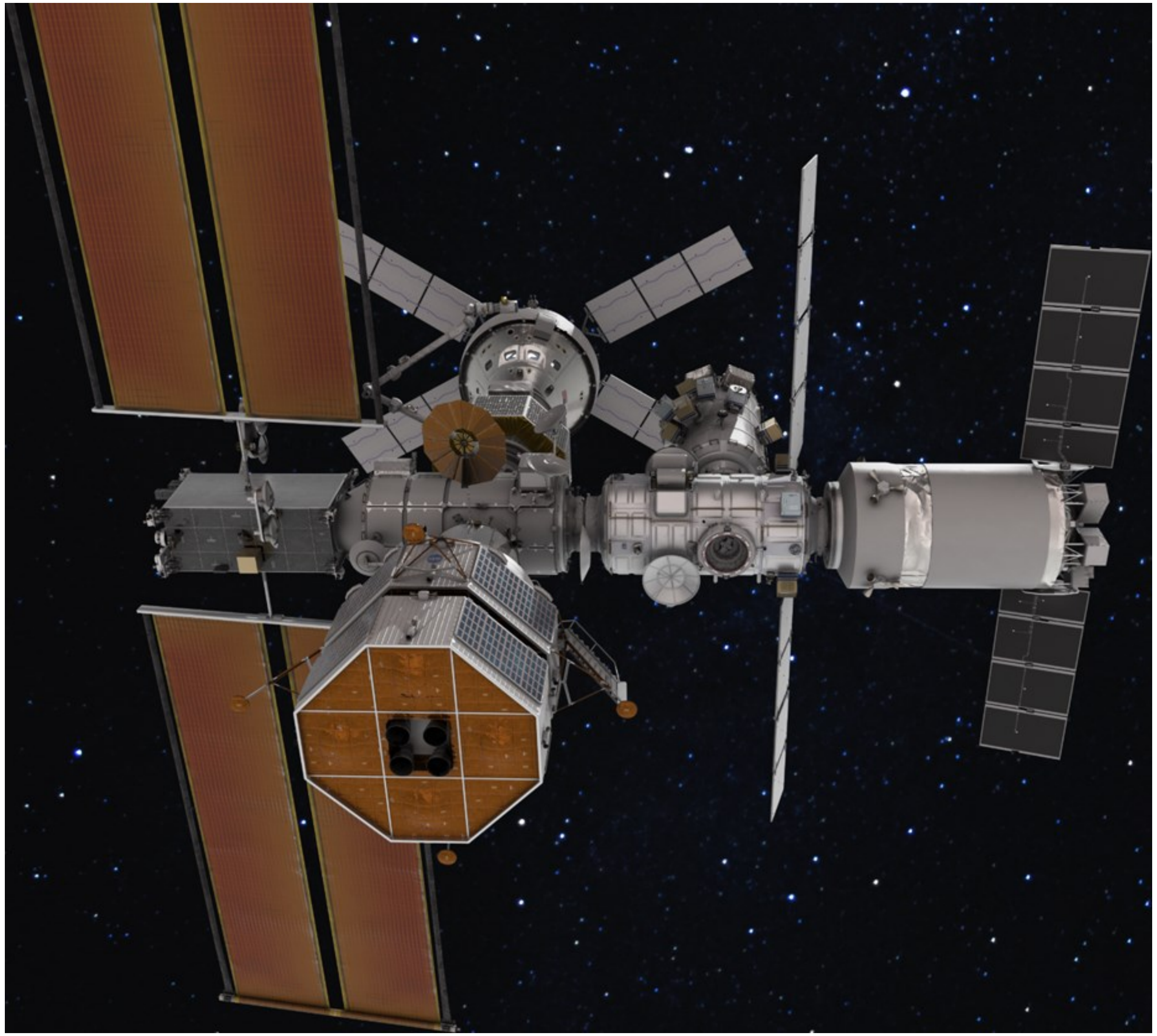
Proposed Approach

- Compare transient response of radiator temperature with range of area-averaged solar absorptivity
  - Determine sensitivity of peak temperature with varied:
    - Max sun angle
    - Duration of sun angle excursion
    - Solar array temperature
- Determine sensitivity in steady state to:
  - Radiator dissipation
  - Predicted redeposition distributions (non-averaged absorptivity)
    - Based on modeling and experimental absorptivity data
  - Sun angle (pointing error)
- Combine above data with experimental sweep of variables and actual planned mission attitude profiles
  - Iterative process



Forward Work

- Looking for guidance / references for design of experiments (DOE) approach to quantifying uncertainty contribution of various factors
- Increase model fidelity with test data
- Coordinate with mission design on attitude profiles best suited to the measurement
- Coordinate with Gateway operations on possible external validation opportunities



References

[1] Yim, J. T., "Differential yields and uncertainty assessments for electric propulsion plume impingement sputter redeposition contamination," 37th International Electric Propulsion Conference Massachusetts Institute of Technology, Cambridge, MA USA, June 19-23, 2022.