Power and Propulsion Element Thermal Summary

Jared Berg, NASA GRC

Presented By

Jared Berg

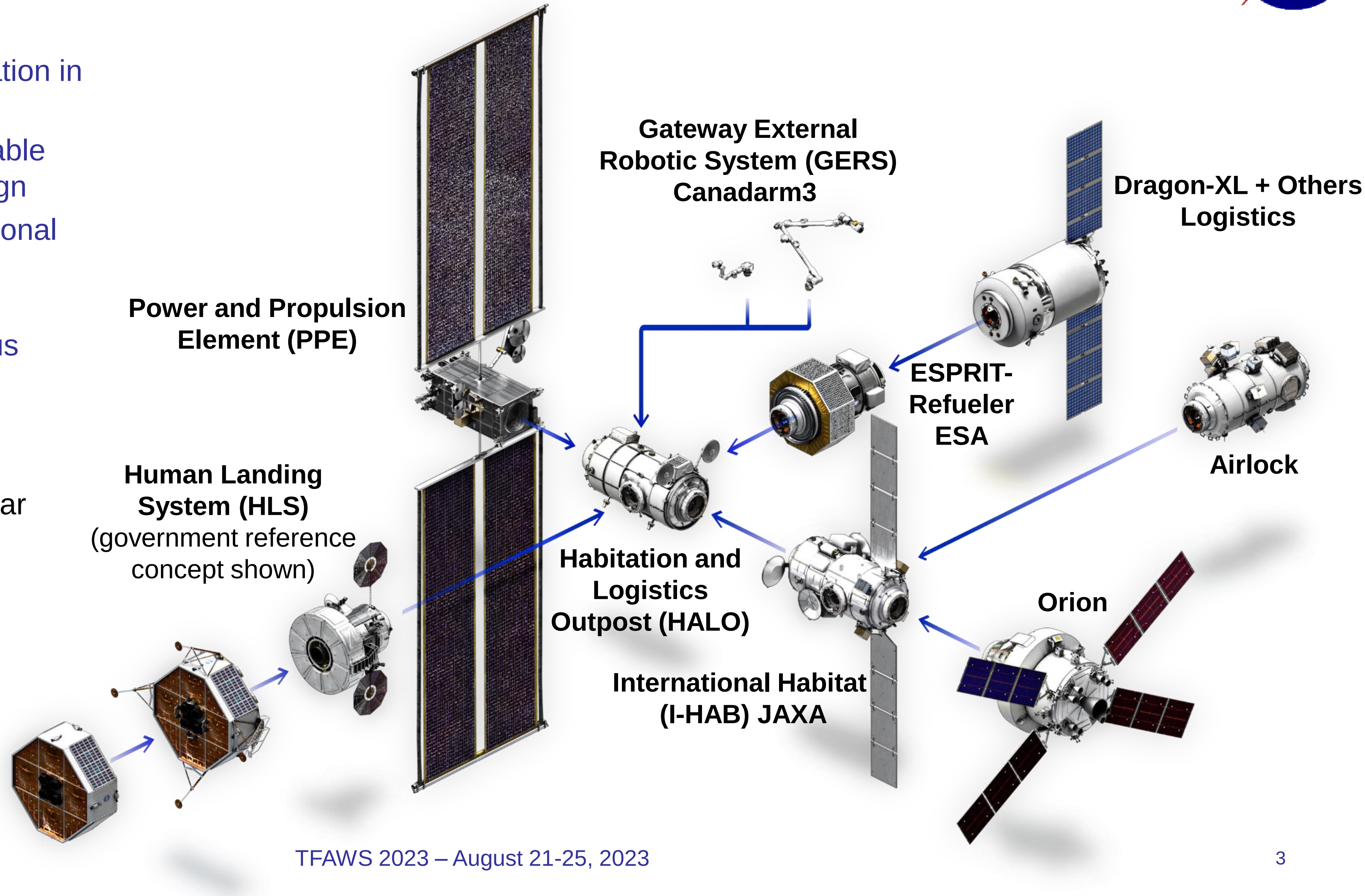
Thermal & Fluids Analysis Workshop
TFAWS 2023
August 21-25, 2023
NASA Goddard Space Flight Center
Greenbelt, MD

Outline

- Intro to Gateway
- Power and Propulsion Element (PPE)
  - Mission Profile
  - Systems Intro
- Thermal Challenges
  - Launch Dissipations (Co-Manifested Vehicle)
  - Electric Orbit Raising (EOR) Impacts
  - Near-Rectilinear Halo Orbit (NRHO) Entry Flyby
  - Gateway Operations and Implications
    - Attitudes
    - Refueling
    - Visiting Vehicle Interactions

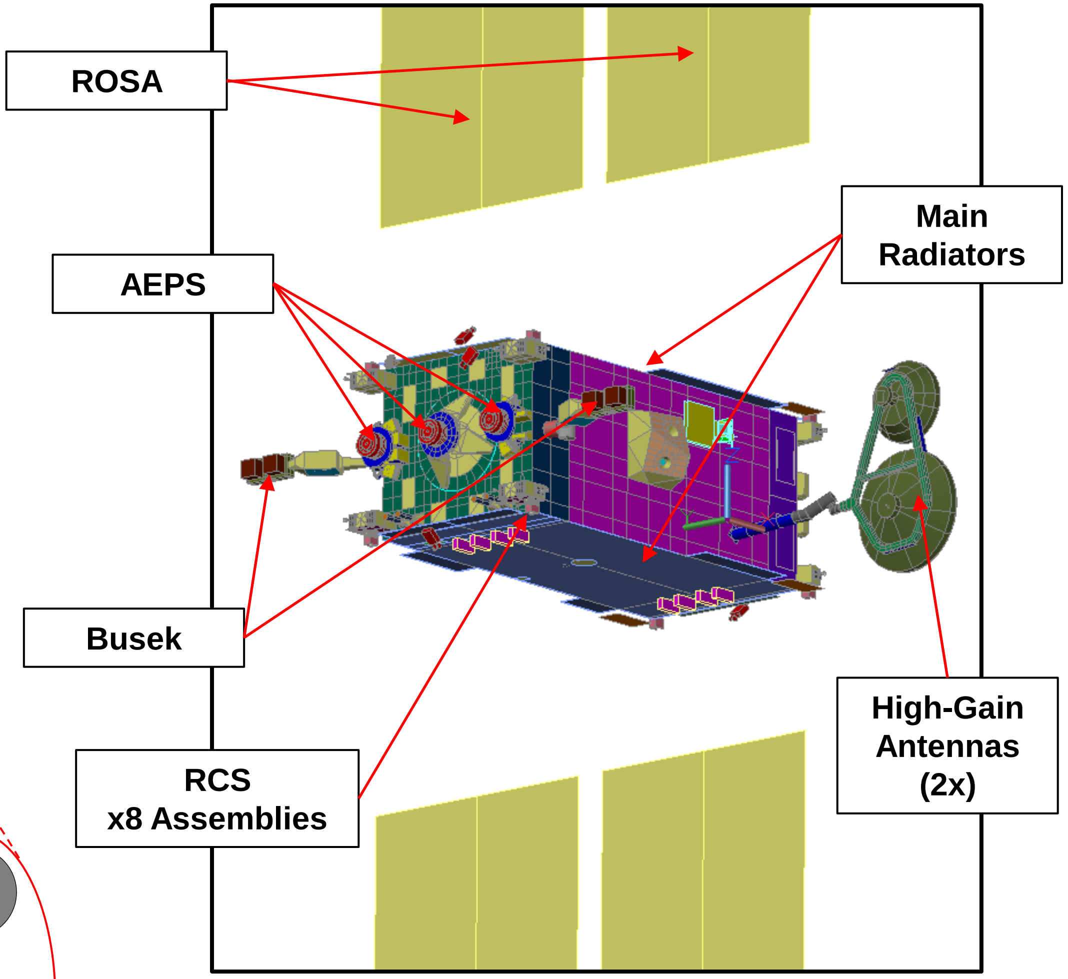
Gateway

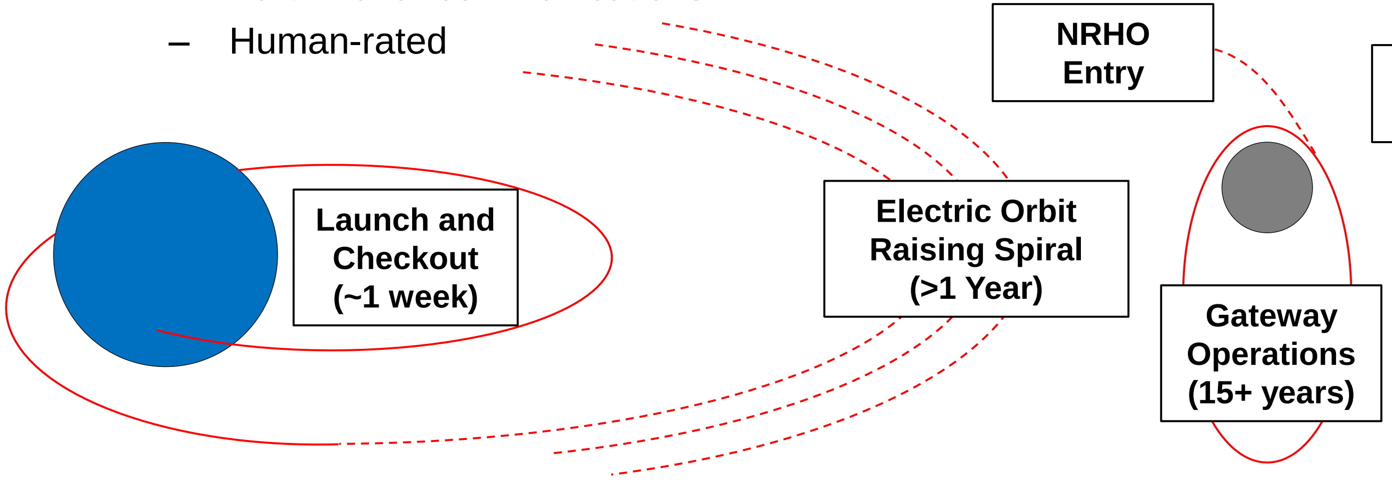
- Small (vs. ISS) space station in NRHO
- Logistics hub for sustainable lunar exploration campaign
- Interactions with International Partners and commercial vehicles
- Proving ground for various technologies
  - High-power electric propulsion
  - Large, low mass solar arrays
  - Refueling
  - Deep space communications
  - Autonomy



PPE Mission

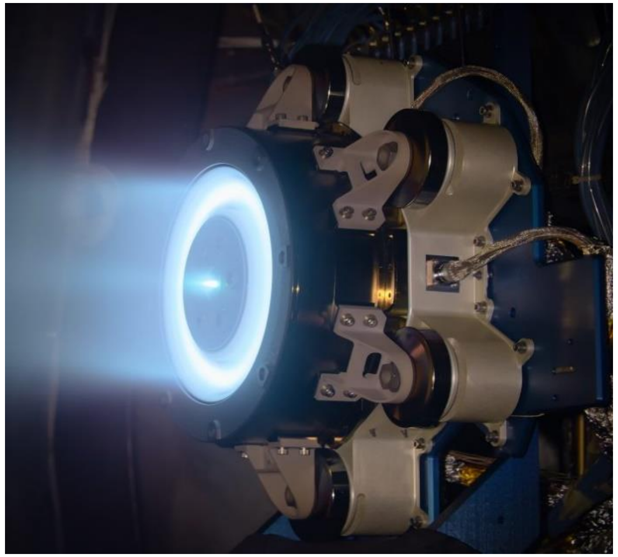
- **Power**
  - 60 kW ROSAs
  - Power Processing Units
- **Propulsion**
  - 3x 12 kW AEPS (Advanced Electric Propulsion System)
  - 4x 6kW Busek
  - Bi-prop reaction control thrusters
- **Element**
  - 15+ year lifetime
    - Refuellable
    - Redundancy and design margin
    - Flexibility
  - Earth-Lunar communications
  - Human-rated





PPE Systems

- Maxar 1300 Bus
  - Many components shared with commercial applications or derived from them
  - Thermal control system (TCS)
    - Embedded heat pipe radiators with Optical Solar Reflectors (OSR)
    - Crossing heat pipes to balance load
    - MLI blankets
- Redwire ROSAs
  - Similar design to ISS array replacement units
- Large Xenon and bi-propellant storage tanks
- NASA / Aerojet AEPS
  - Will be largest Hall thruster flown

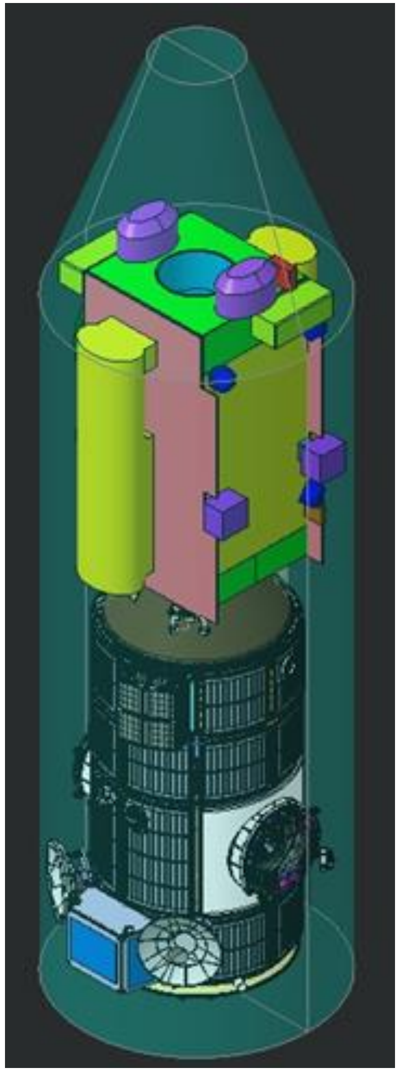


AEPS 12 kW Thruster

Roll Out Solar Array (ROSA)

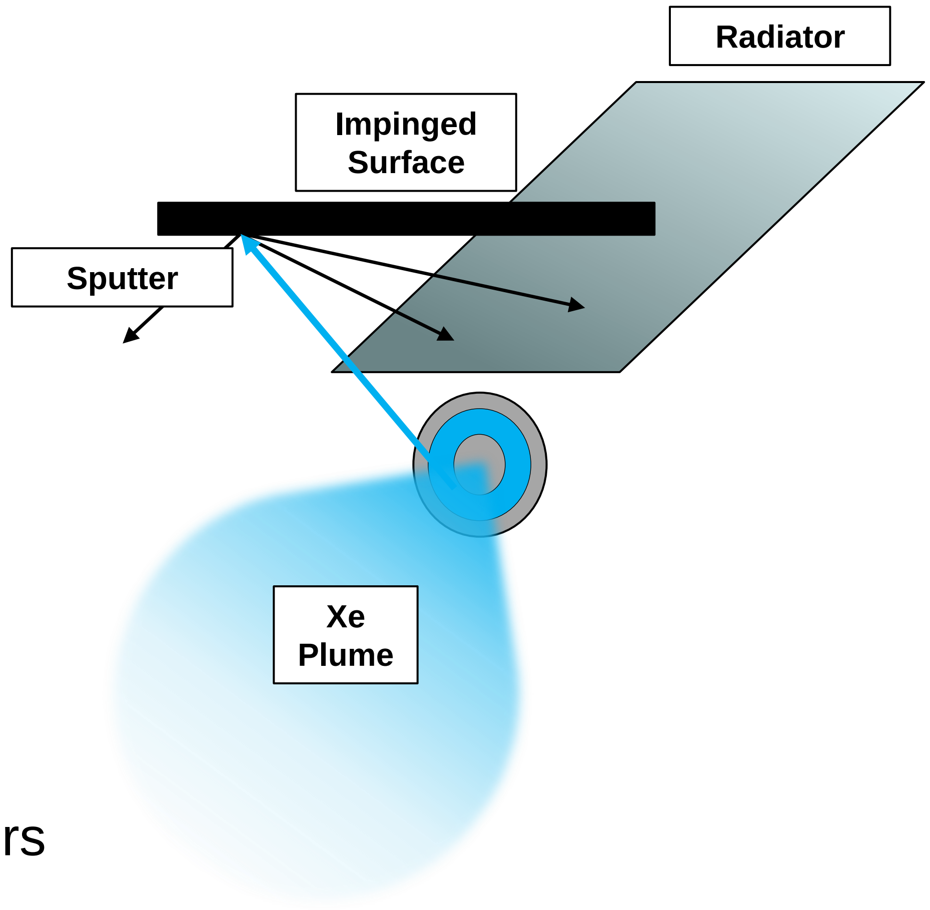
Launch Dissipation

- Co-Manifested Vehicle (CMV)
  - PPE launched with hard interface to HALO (PPE+HALO=CMV)
- Approximately twice the encapsulated heat dissipation of a typical vehicle
  - Both spacecraft have independent thermal control systems, vehicle computers, guidance, etc.
  - Many systems are launched in powered-on state for reliability / contingency
- Must design for worst case Florida summer natural environments
- MLI blankets have limits on air impingement velocity



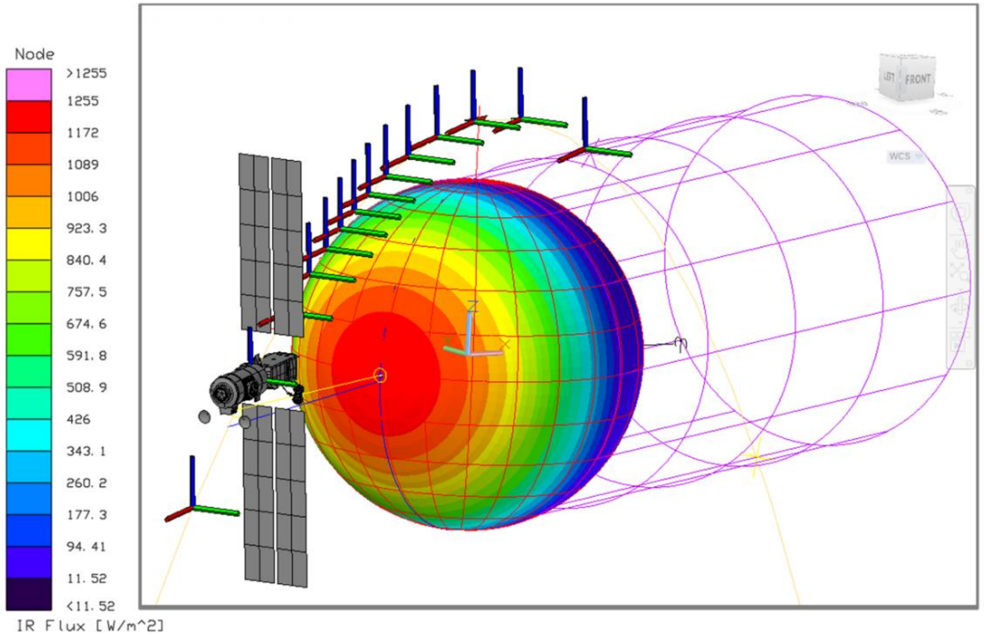
Electric Orbit Raising

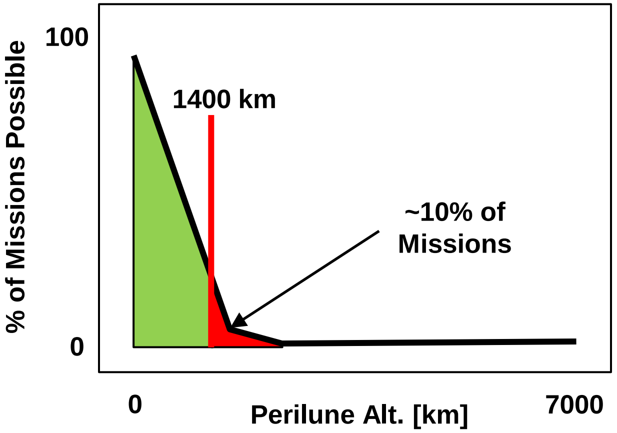
- Transit via electric propulsion (EP) system
- Low-thrust spiral orbit raising and transfer trajectory with 400+ day duration
  - Very high propellant throughput
- Early orbit period close to earth with high IR / albedo loads and residual atmosphere
- Long flight through radiation belts
  - Degradation of thermal coatings
- Sputter and redeposition of materials due to high-energy ions from EP system
  - Damages thermal coatings
  - Deposits high solar absorptivity materials on radiators leading to early “end of life” optical properties
  - Addressed via shields and modeling

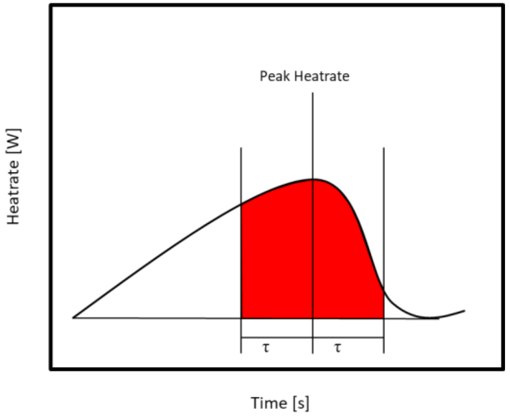


NRHO Entry Flyby

- Flyby below standard Gateway altitude required to enter NRHO
- Lunar IR / albedo environment is demanding to TCS
- Designing just for this case would have negative mass impacts
- Flyby is transient event, so thermal mass of systems is important
- Solved with integrated heat rate approach
  - See 2021 TFAWS presentation for details

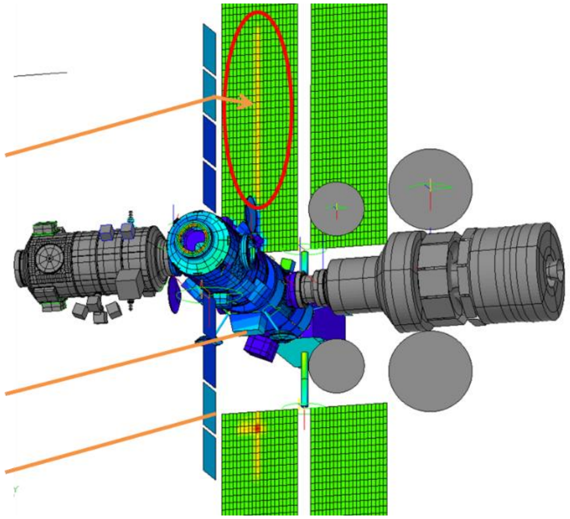




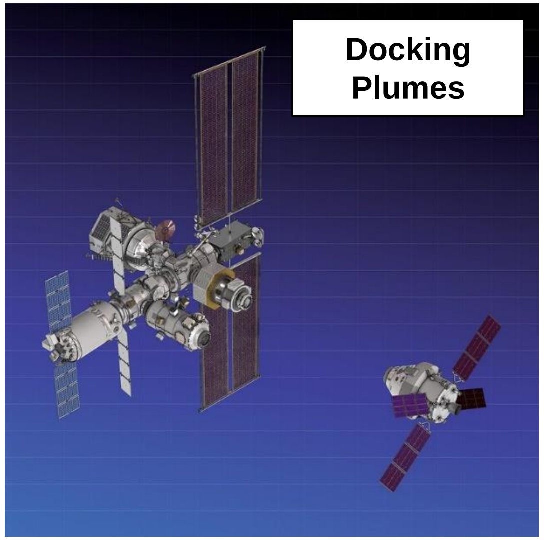


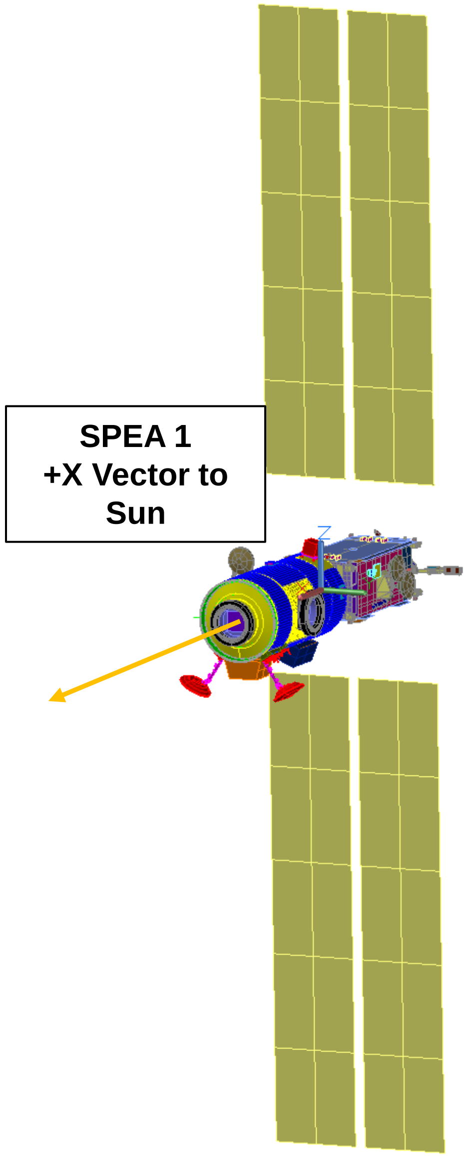
Gateway Operations

- “Attitude Independence” Requirement
  - Majority of time in Solar Pressure Equilibrium Attitude
    - Imagine Gateway “weathervaning” in solar flux
    - SPEA attitude changes for each Gateway configuration
  - Some operations require different attitudes for various durations
    - Orbital maintenance maneuvers (OMM)
    - Docking (Orion, HLS, assembly, refueling)
- Glint / Shadowing
  - Specular reflections from Gateway elements
  - Radiators / solar arrays blocking other elements
- Refueling
  - Both Xenon and bi-propellant
  - Thermal conditioning of lines and propellant
- Visiting Vehicle Plumes
  - Smaller than ISS -> RCS plumes closer to sensitive surfaces
  - Erosion and heating
  - Modeling and testing approach to mitigate



Glint heating on PPE Solar Array





Conclusion

- Gateway environment is challenging
  - Natural
    - Lunar IR / albedo
    - Radiation
    - Eclipse
  - Induced
    - Glint / Shadow
    - Contamination
    - Visiting vehicle plumes
- Requires flexibility
  - Long mission life, high reliability
  - Use will change beyond original requirements
- Evolving modeling and analysis needs
- PPE TCS is robust