Advanced Electric Propulsion System Integrated Thermal Analysis Summary

Lara Schoeffler, HX5, GEARS Contract

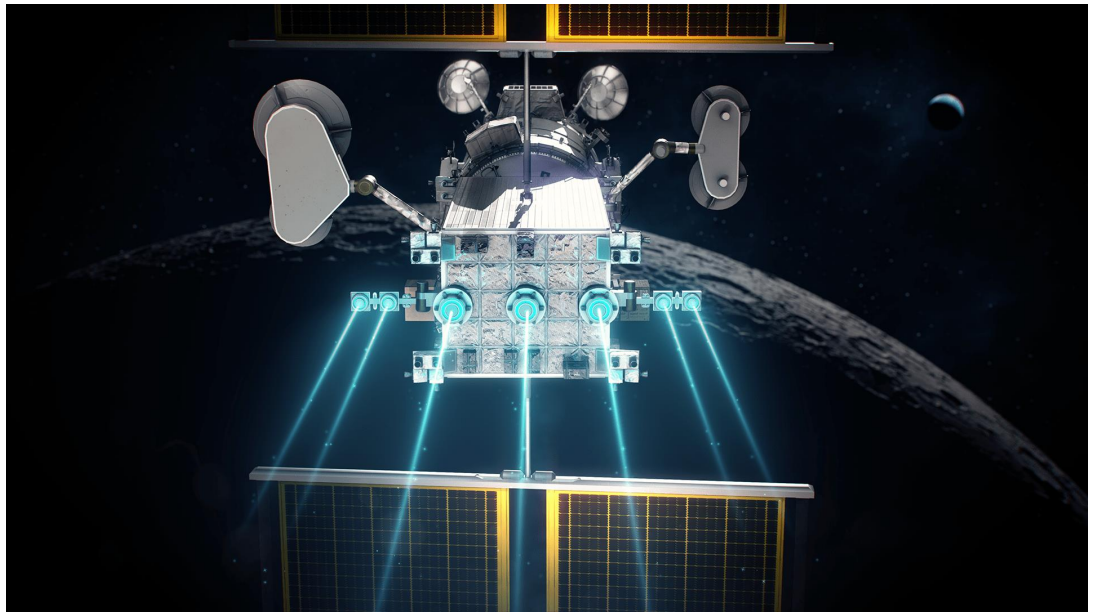
Presented By

Lara Schoeffler

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

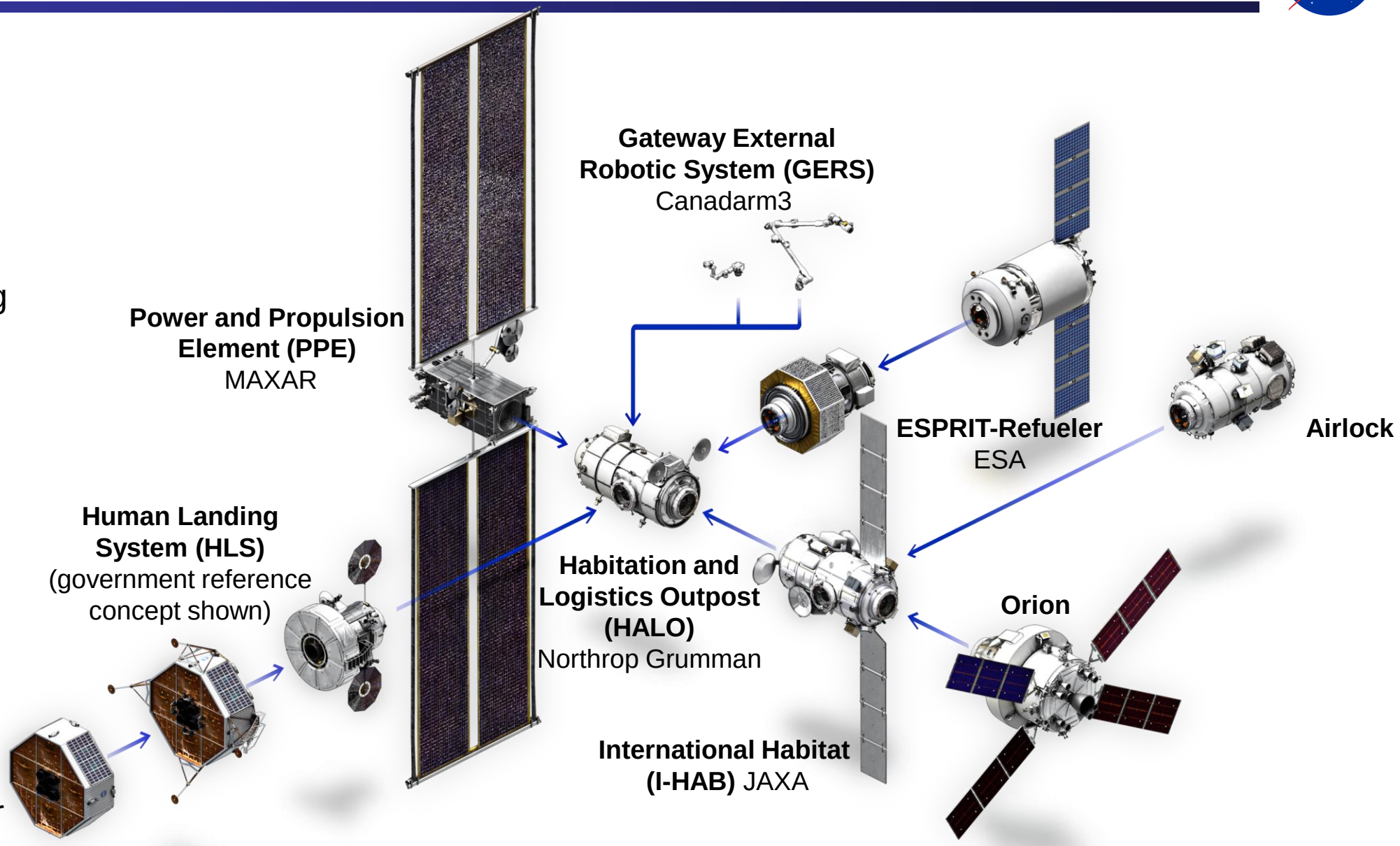
Outline

- Introduction to Gateway
- Power and Propulsion Element (PPE)
- Advanced Electric Propulsion System (AEPS)
  - Overview
  - Thermal Challenges
- Integrated Thermal Analysis



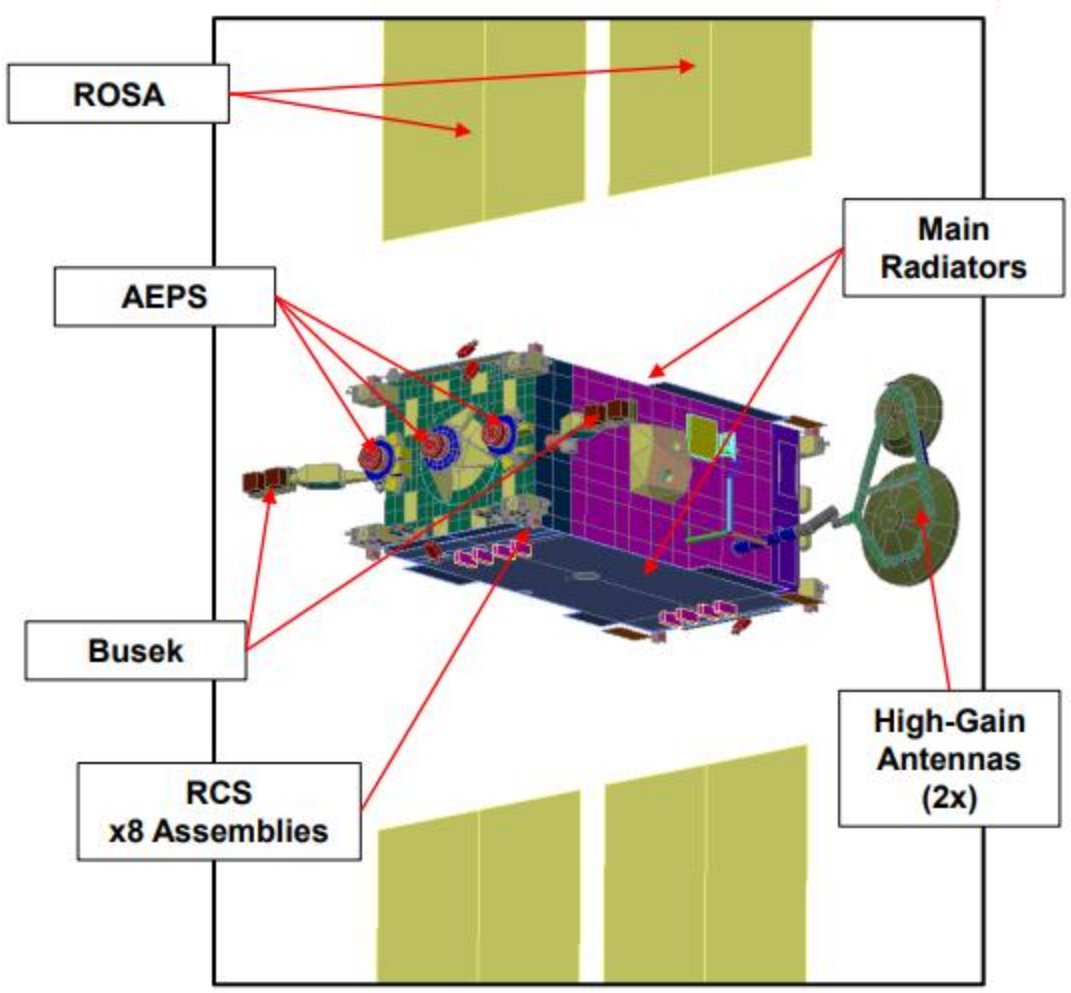
Gateway

- Gateway
  - Space station in near-rectilinear halo orbit (NRHO)
  - Sustainable outpost supporting lunar surface missions
  - Commercial and international partners
  - Opportunities for science in lunar orbit
  - Prepare for human missions to Mars
  - Testing ground for new technologies



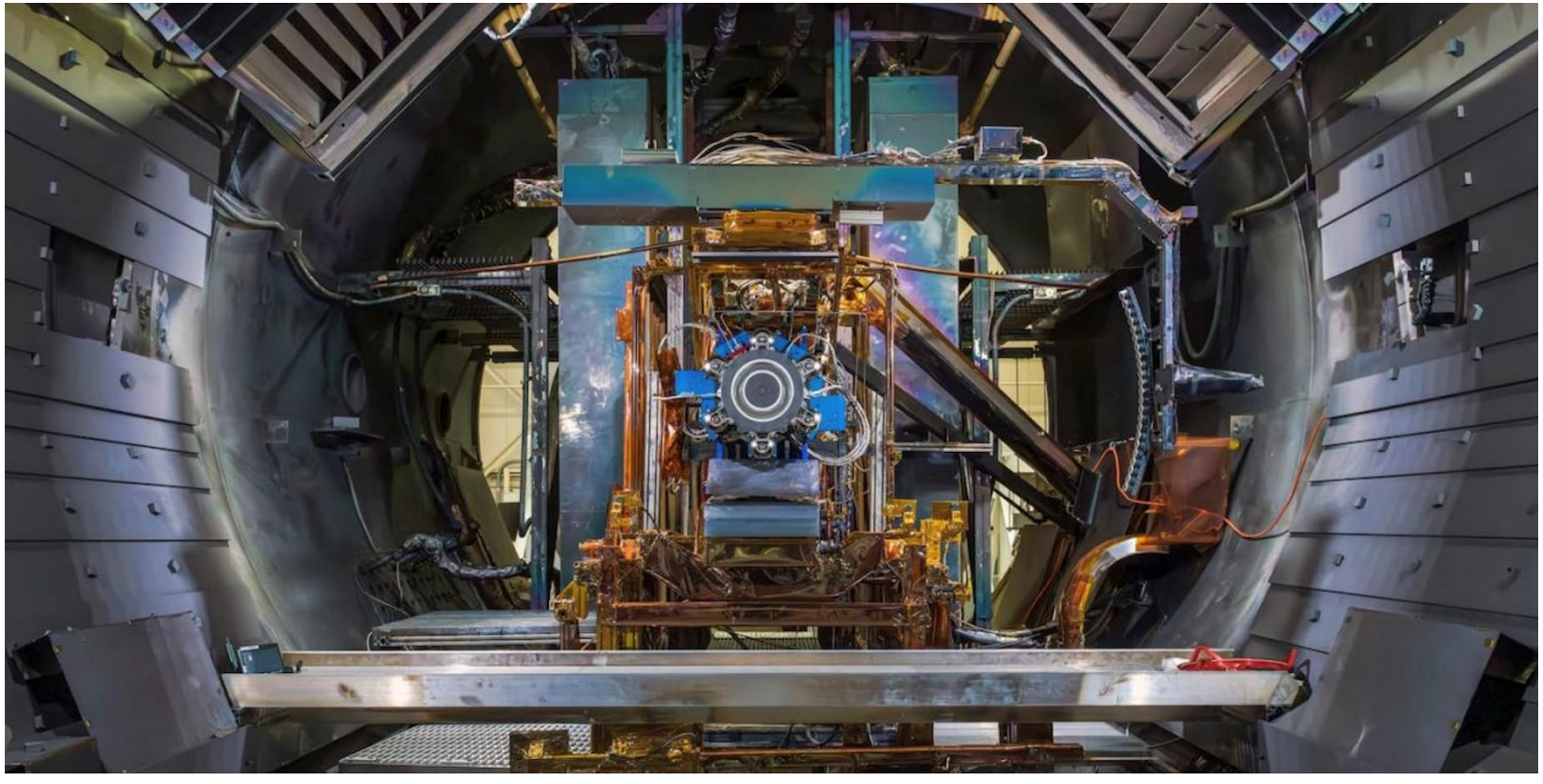
PPE

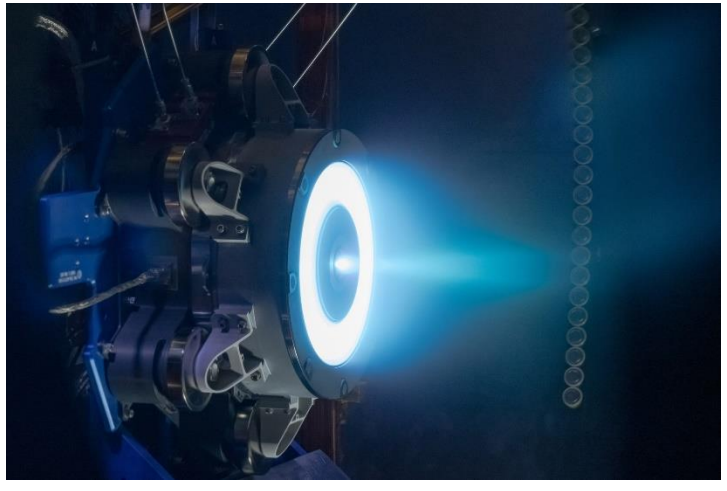
- PPE
  - Power and propulsion foundation of Gateway
  - 15+ year lifetime
  - Solar Electric Propulsion (SEP) System
    - Roll out solar arrays (ROSAs)
    - Three 12kW AEPS Thrusters
      - Will be the largest Hall thrusters flown
      - Two on gimbals, one is hard-mounted
    - Four 6kW Busek Thrusters
    - High power, low thrust, high ISP
    - Facilitates electric orbit raising (EOR) spiral flight (1+ year duration) from Earth to NRHO



AEPS Overview

- NASA developed the 12kW-class Hall Effect Rocket with Magnetic Shielding (HERMeS) before transitioning flight hardware (AEPS) development to Aerojet Rocketdyne.
- Two AEPS Engineering Test Units (ETU) thrusters completed environmental, functional, and long duration wear tests
- Thruster qualification testing is ongoing

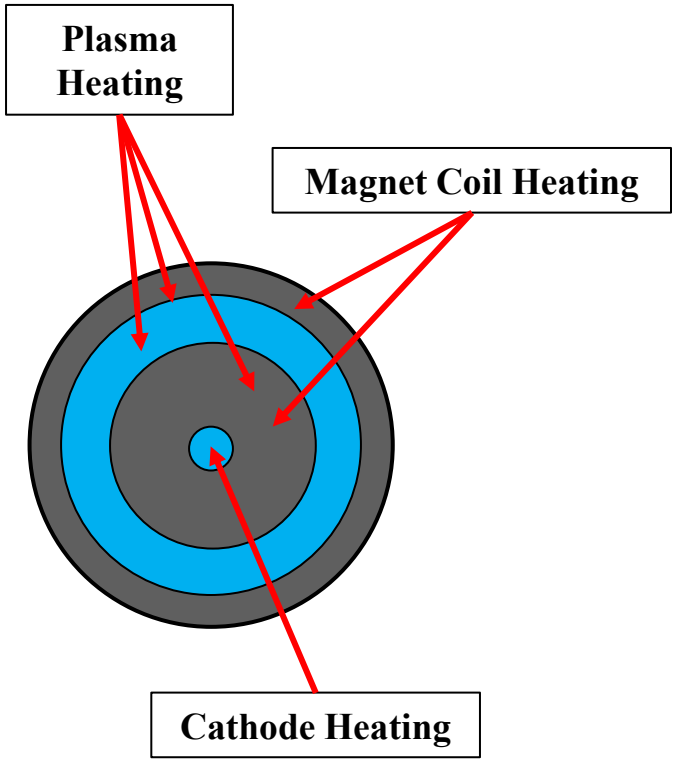




AEPS ETU thruster in NASA GRC vacuum chamber

AEPS Thermal Challenges

- AEPS Heat Sources
  - Internal thruster temperatures can exceed 500 degrees C during steady state operation
  - Thruster self-heating comes from three sources:
    - Ionized plasma heating
      - » Deposits heat via particle bombardment on the surface of various components (anode, discharge channel, inner front pole). Heat loads are associated with the ionization, containment, and acceleration of the propellant.
    - Ohmic heating in the magnet coils
    - Cathode heating (high transient temperatures during thruster start up)
      - » Ohmic heating raises cathode temperatures, which heats the emitter to high enough temperature to ionize the xenon



AEPS Thermal Challenges

- Thruster Thermal Challenges
  - High operating temperatures
    - Complex geometry limits heat rejection methods
  - Natural thermal environment
    - Solar radiation
    - Eclipse

- Passive Thermal Control
  - Heat generated by internal components must be conducted to external surfaces for rejection via radiation to space
    - Coatings/surface treatments
    - Material choices – survive high temperatures and minimize thermal expansion
  - Minimal conduction to spacecraft
  - Heaters

AEPS + PPE Integrated Thermal Analysis

- Integrated thermal analysis characterizes the thermal relationship between AEPS and PPE
  - AEPS rejects most heat to space, but inevitably some is conducted or radiated to the spacecraft
  - Standalone AEPS analysis uses conductive boundary assumptions
  - Understand temperatures and heat transfer at interfaces between AEPS and PPE
  - Incorporates:
    - Effects of natural environment, as well as induced environment caused by PPE and the AEPS thrusters
    - Effects of other Gateway modules
    - Degraded optical properties (erosion/deposition from EP plume effects damages thermal coatings)

AEPS + PPE Integrated Thermal Analysis

- Integrated Thermal Analysis Results
  - Predict temperatures of interfaces between PPE and AEPS hardware
    - Gimbal mounting surfaces, xenon propellant lines and fittings, harnesses
  - Design gimbal actuator heater power and duty cycle
  - Impact of PPE on AEPS heater duty cycle
  - Transient behavior during EOR
- Determine system-level thermal behavior
- Support other subsystem analysis
- System-level analysis is ongoing as PPE moves closer to qualification and launch