Europa Clipper Thermal Control Design

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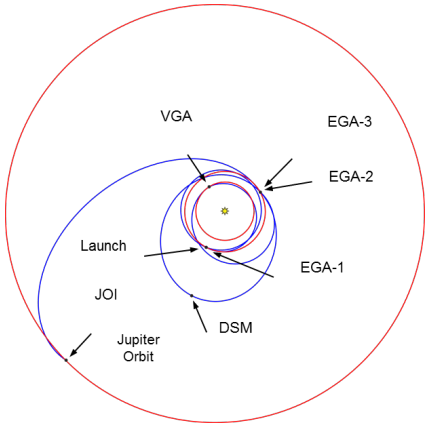
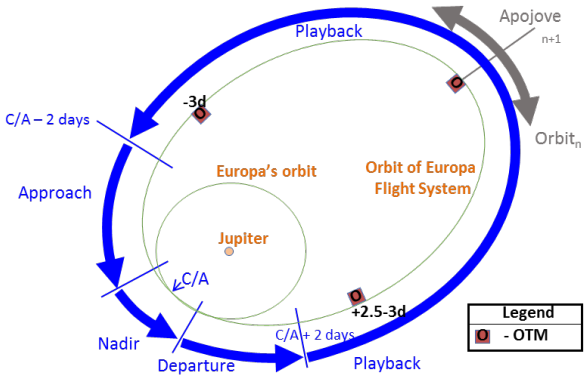
Outline

- Project and Mission Overview
- Flight System Description
- Thermal Subsystem Requirements and Description
- HRS Thermal Control Description
- None-HRS Thermal Control Description
- Text

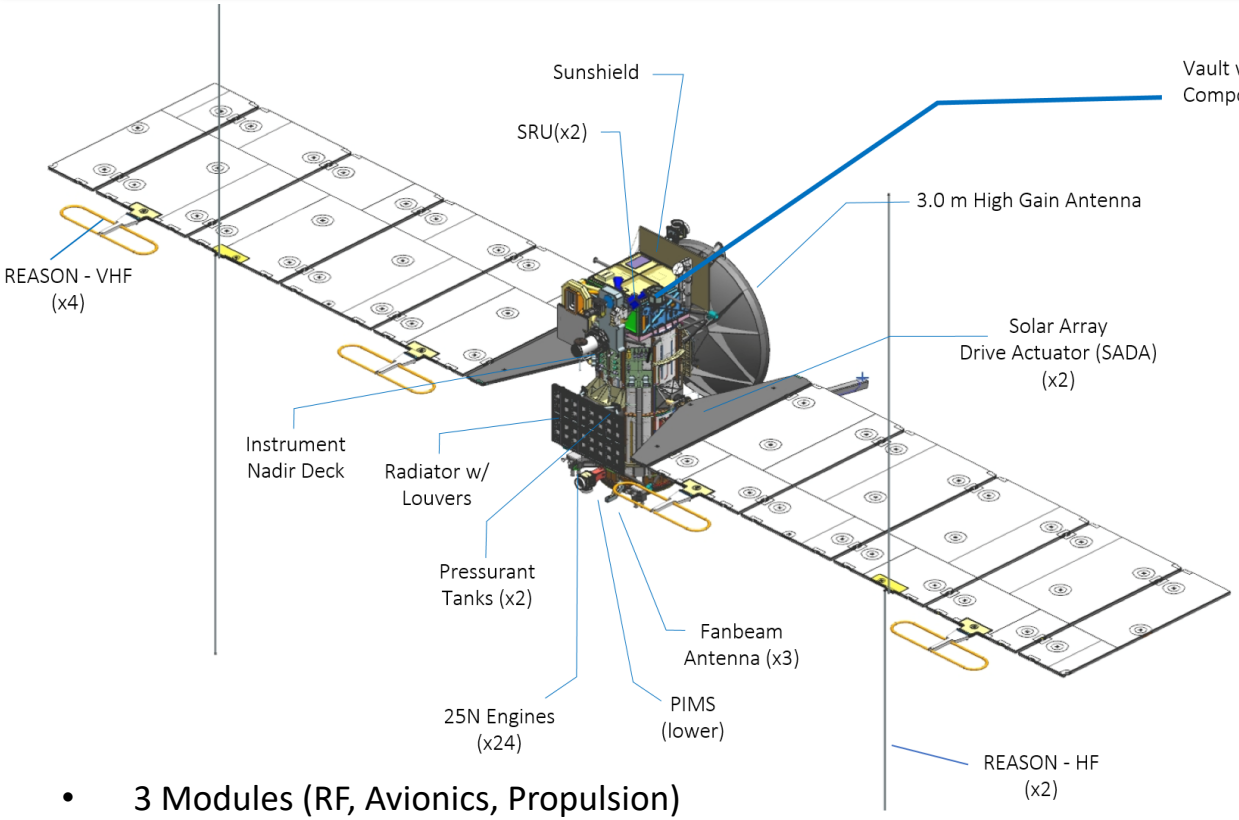
Project and Mission Overview

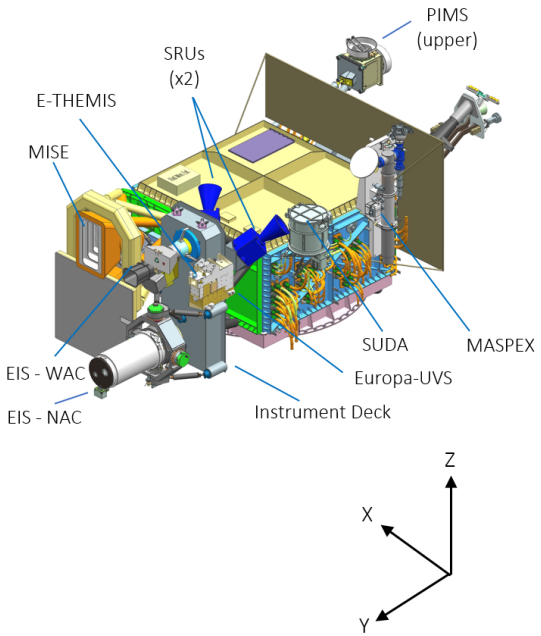
- Europa Clipper will:
  - Characterize ice shell and ocean properties, composition, and exchange.
  - Investigate high science interest locations
  - Search for surface activity
- Planned Launch is 2022
- Flight System is designing for both direct (SLS Block 1) and indirect trajectories (Venus flyby)
- Spacecraft is a flyby observer, (orbits Jupiter but flies by Europa multiple times)
- 8+ year mission timeline





Flight System Overview





- 3 Modules (RF, Avionics, Propulsion)
- 5 panels per solar array wing (90m^2 total)
- Deployed magnetometer boom
- Electronics box vault
- 9 science investigations

Spacecraft Thermal Design

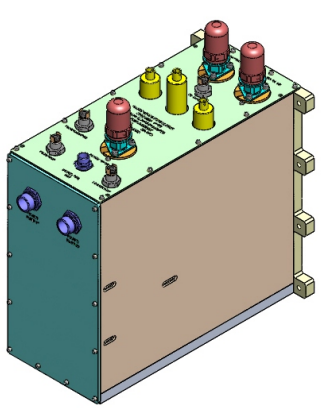
- Primary Requirements:
  - Maintain Hardware Within Allowable Flight Temperatures (AFTs)
  - Stay within allocated resources
- Design Drivers Are:
  - Extreme environments on both ends (0.65 AU and 5.6 AU sun distances, 9 hour eclipse)
  - Narrow Temperature Range or Prop and battery systems
  - Power allocation is low
- Our approach is:
  - Use Heat Redistribution System, (HRS) as primary method to heat components with narrow temperature limits (prop and electronics)
  - Thermally Isolate structures and components that can tolerate wider limits (Solar Arrays, Boom, struts)

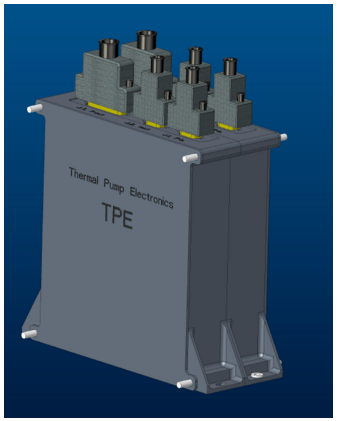
	Allowable Flight Temperatures, °C	
	Operating/Non-operating	
Assembly	Min	Max
Vault	-20	50
Nadir deck	-60	30
Propulsion Module	0	35
Radiator	-95	40
RF Antennas	-135	105
HGA/Boom	-200	100
Solar Arrays	-238	100

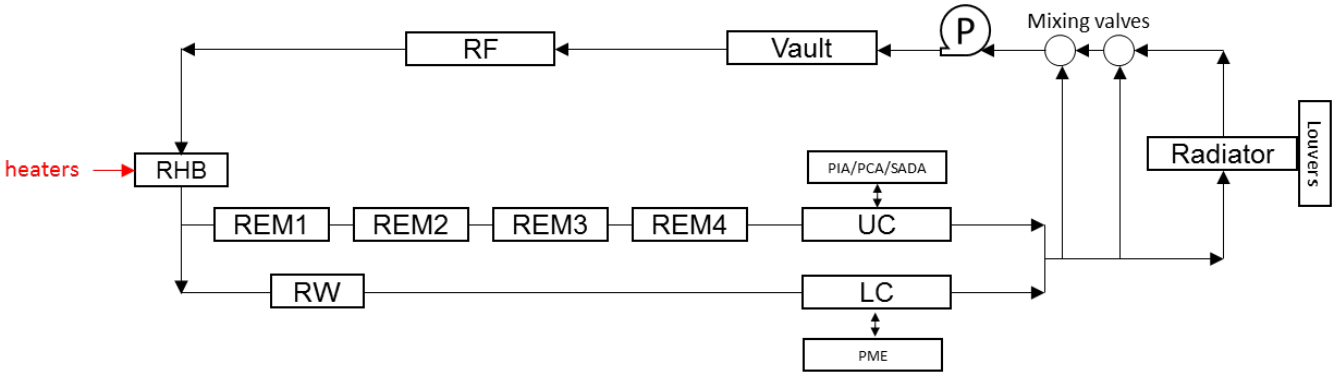
Heat Redistribution System (HRS)

- Mechanically pumped fluid loop system
- Europa Clipper Integrated Pump Assembly (ECIPA) provides 1.5 lpm flow of CFC-11 across the avionics, RF, and propulsion modules
- Harvest waste heat from electronics boxes and redistribute to propulsion subsystem hardware
- Supplemental heat can be provided through the Replacement Heater Block, RHB
- Excess heat is rejected through the HRS radiator
- Amount of heat rejected is modulated via passive valves and radiator louvers

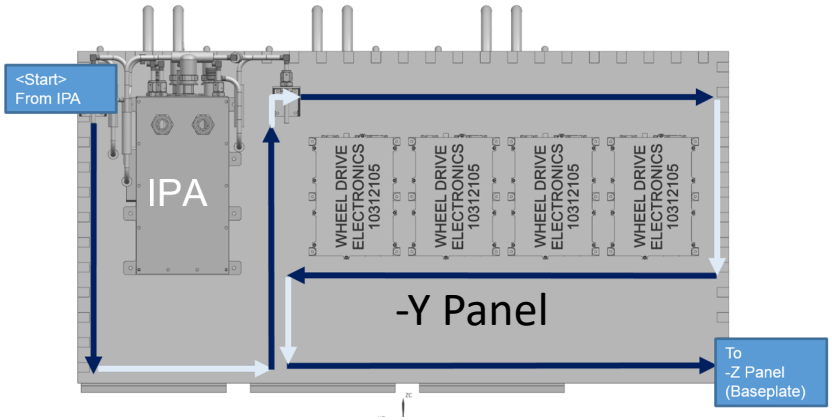
ECIPA & Thermal Pump Electronics

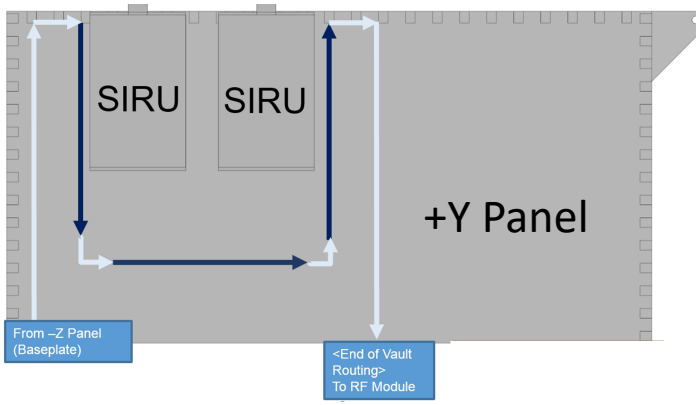




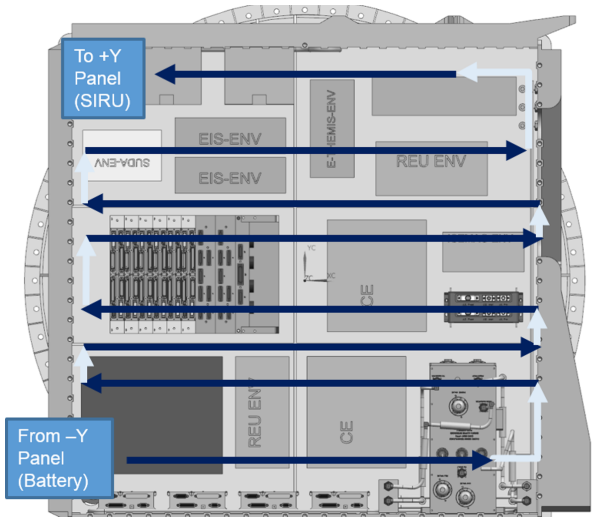


Vault HRS



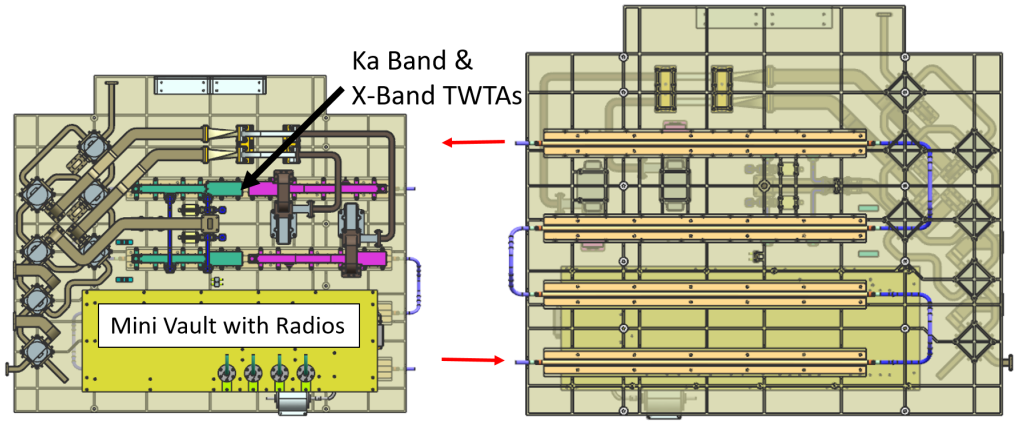


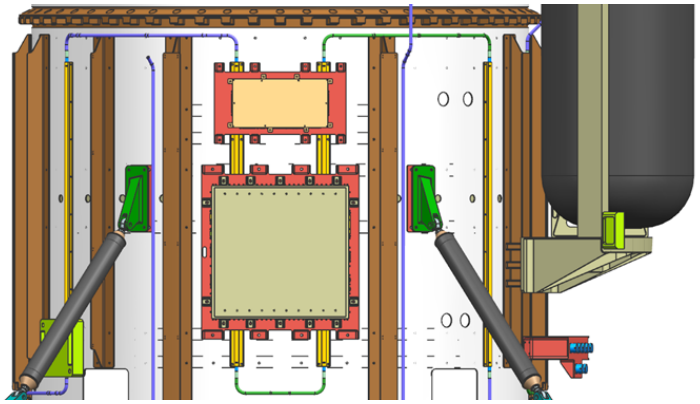
- Three vault panels have HRS
- Fluid routed to Batteries first due to battery AFTs
- Thick panels allow fluid passes to remain simple



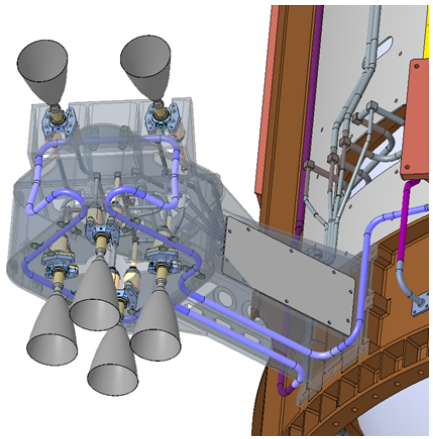
-Z Panel

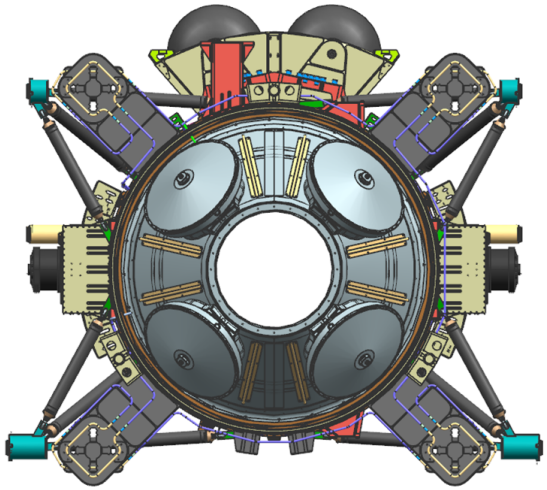
RF Module and Prop Module HRS





- Fluid loop routed components with lower max AFTs first (Radios)
- Passes directly underneath the TWTAs and isolators
- RHB is immediately upstream of propulsion module (next page)
- Rocket engine modules (REMs) immediately after RHB
- Fluid loop passes on the prop cylinder and WU cone structures

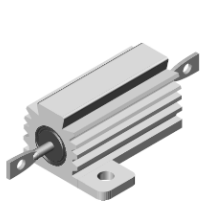


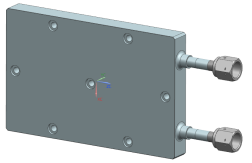


RHB and Radiator/Louver

RHB

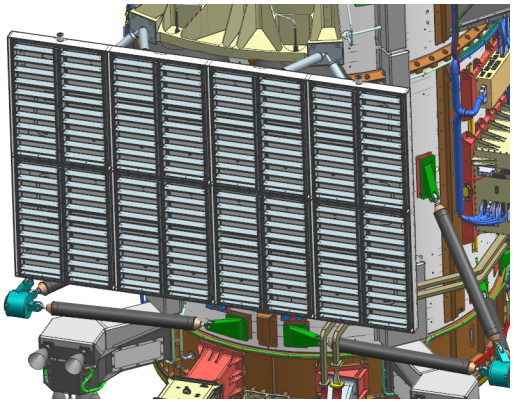
- immediately upstream of propulsion module, (downstream of RF panel)
- Mounted on the Prop Module cylinder, (thermally isolated)
- Heat exchanger with multiple dale ohm heaters

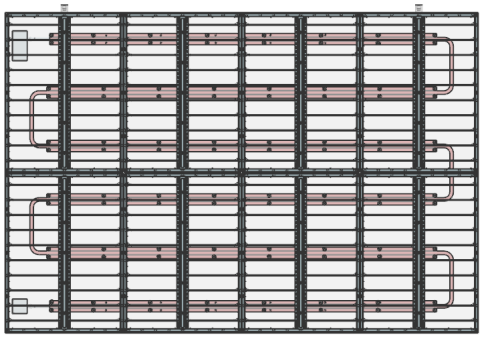




Radiators/Louvers

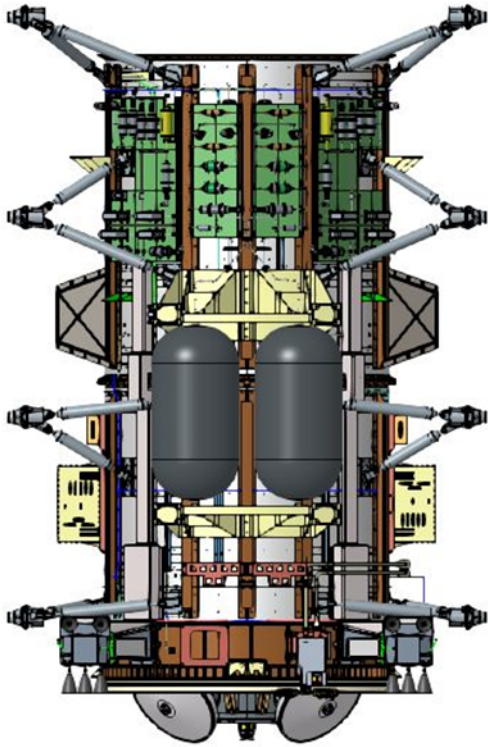
- Downstream of propulsion module
- Flow to Radiator modulated via passive oil actuated valves
- 1 mm thick radiator
- Heaters to maintain CFC-11 above freezing
- 8 full louver set to decrease heat loss during low power states





Non-HRS Control

- Thermally Isolate hardware that can survive much wider temperature limits
- Ensure hardware can be maintained within temperature requirements via passive designs (MLI, surface finishes, sunshades, spacecraft attitude constraints, operations constraints)
- Strive for high blanket performance to ensure heat loss across all spacecraft surfaces is limited (Schmidt, T. et al.)



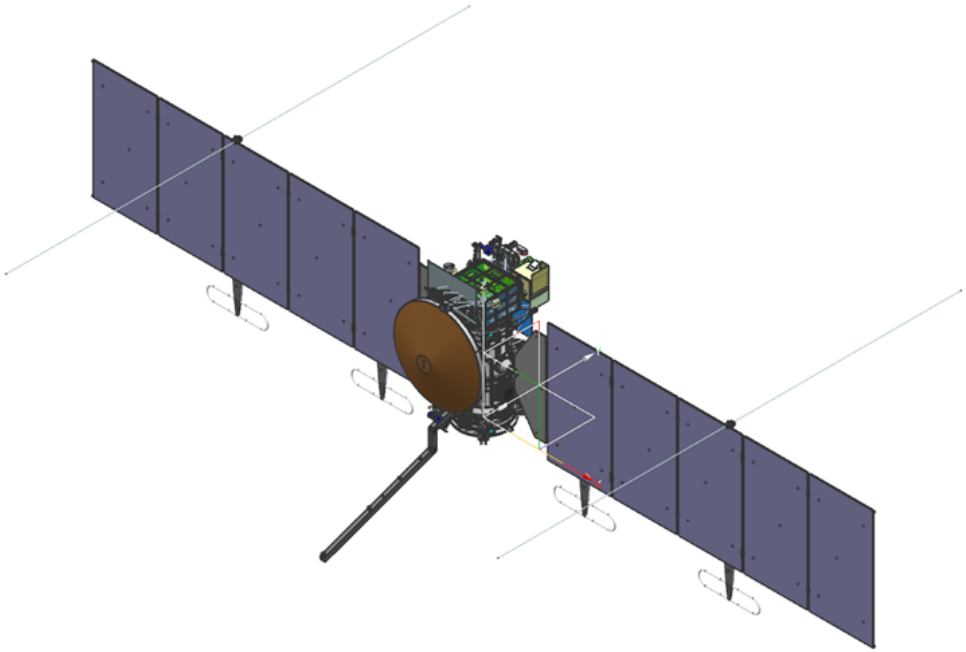
Solar Array and Magnetometer Boom

Solar Array

- Spacecraft attitude constraints maintain solar array safety during launch and inner cruise
- Hardware must be designed to withstand cold predicted temperatures at Jupiter

Magnetometer Boom

- Flight software controlled heaters for deployment hardware are turned off post deployment
- Hardware must be designed to withstand cold predicted temperatures at Jupiter



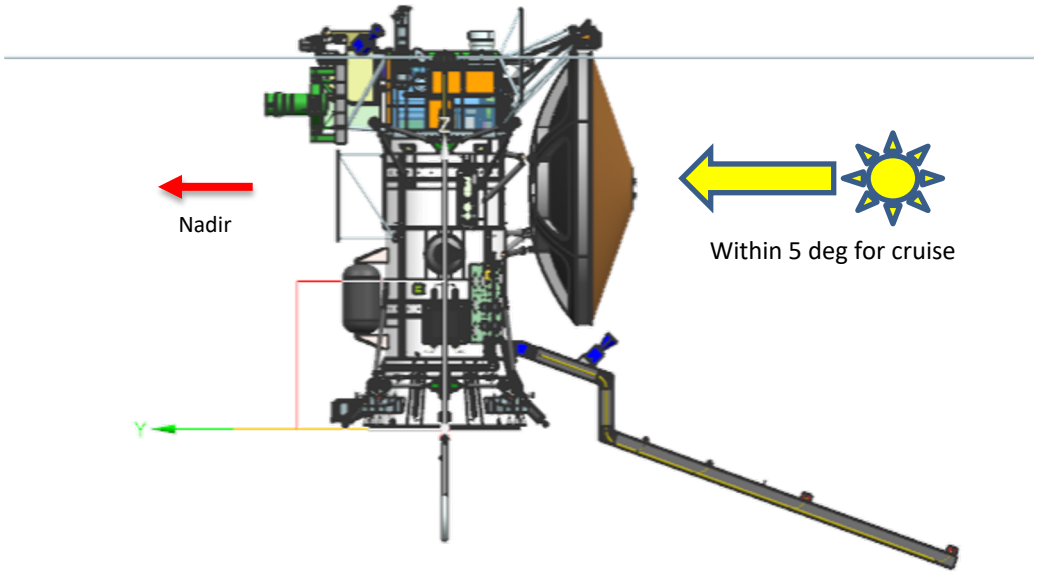
RF Antennas and Secondary Structures

RF Antennas

- High Gain Antenna provides thermal shielding for most of the spacecraft during inner cruise
- Radome (stamet layer) used to modulate high temperatures of HGA
- Thermally isolate from Avionics and Propulsion module
- Hardware must be tested to worst case predicted temperatures (plus margin)

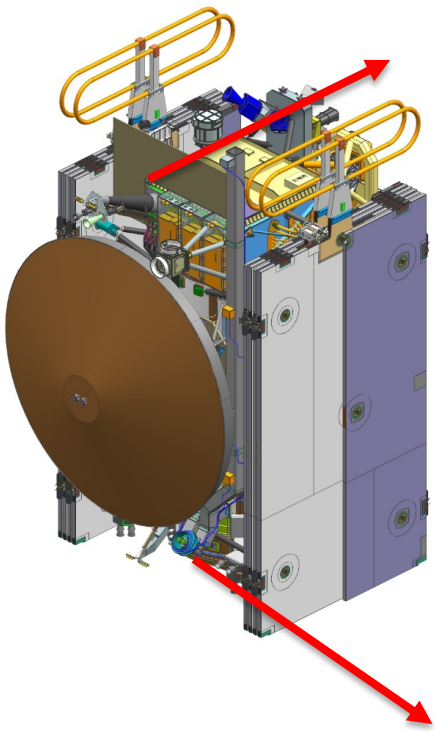
Secondary Structures

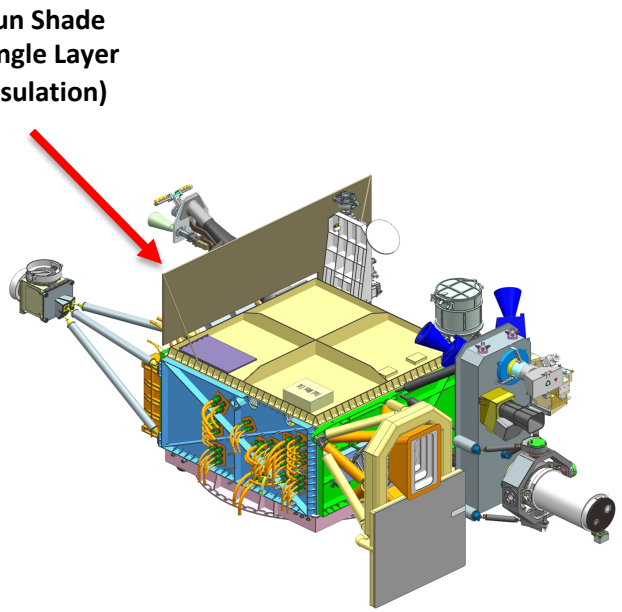
- Struts, instrument decks and brackets are thermally isolated from avionics and propulsion module

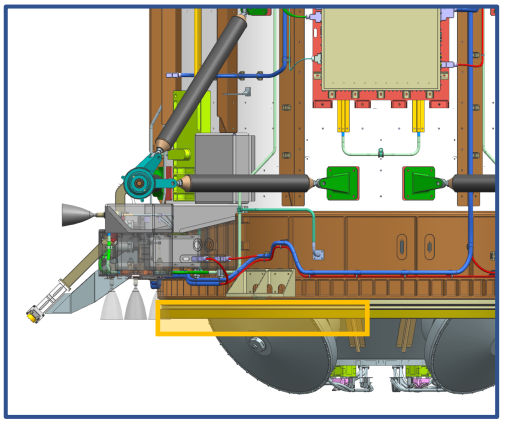


Sunshades

- Sunshades used to decrease solar load onto hardware during cruise: Nadir Deck, vault, propulsion cylinder, and Launch Separation Adapter
- Single Layer Stamet Coated Black Kapton surfaces
- Spacecraft attitude constraints in place







Conclusion

- Europa Clipper spacecraft thermal design is driven by
  - Extreme Environments
  - Limited hardware temperature ranges
  - Limited flight system power resources
- Thermal Subsystem employs:
  - Heat Redistribution System (HRS) as the primary control method of the spacecraft
  - Thermal Isolation and passive thermal control schemes for secondary structures and hardware with wide AFTs

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