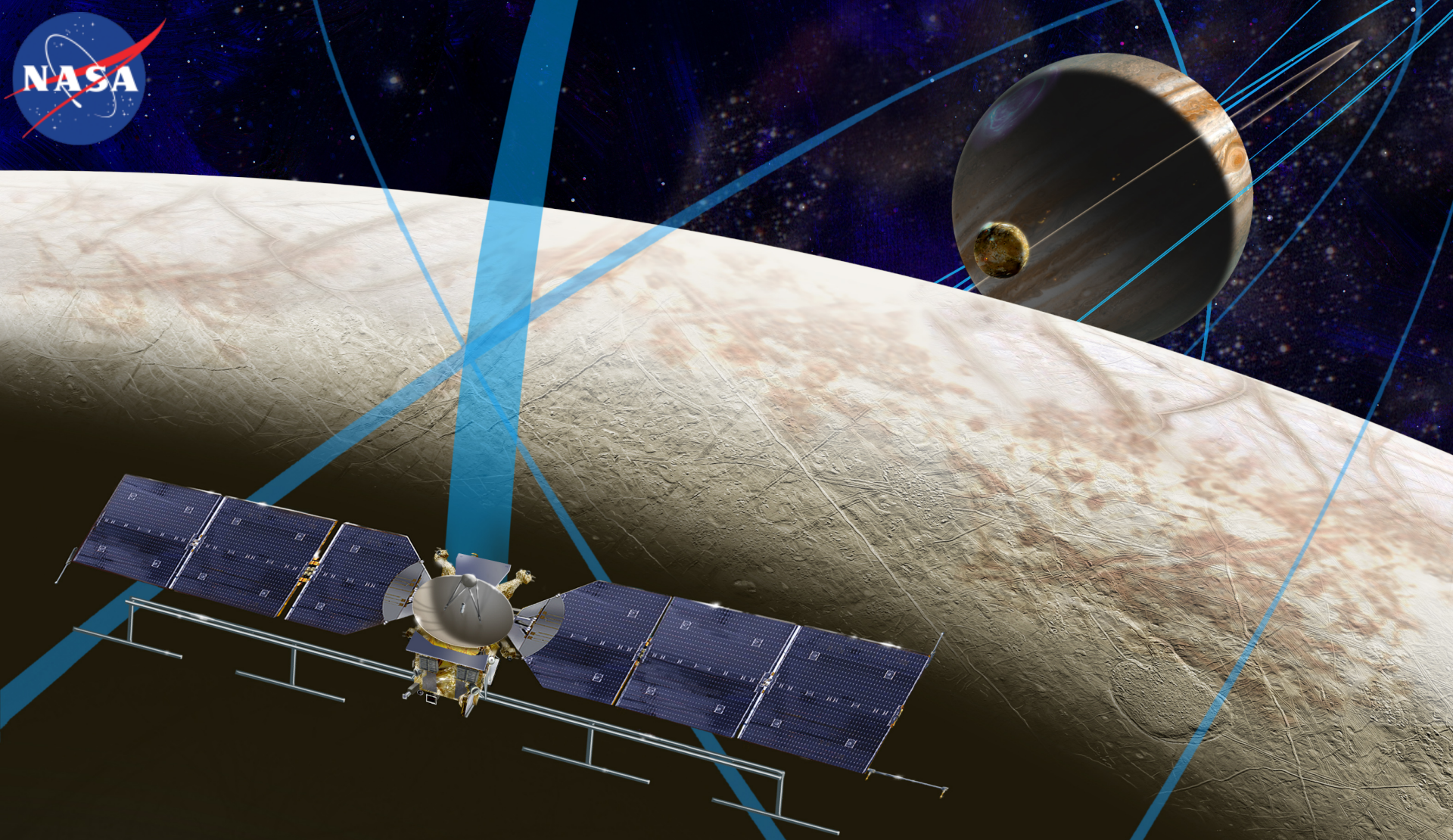

GUIDANCE NAVIGATION AND CONTROL FOR THE EUROPA CLIPPER MISSION CONCEPT

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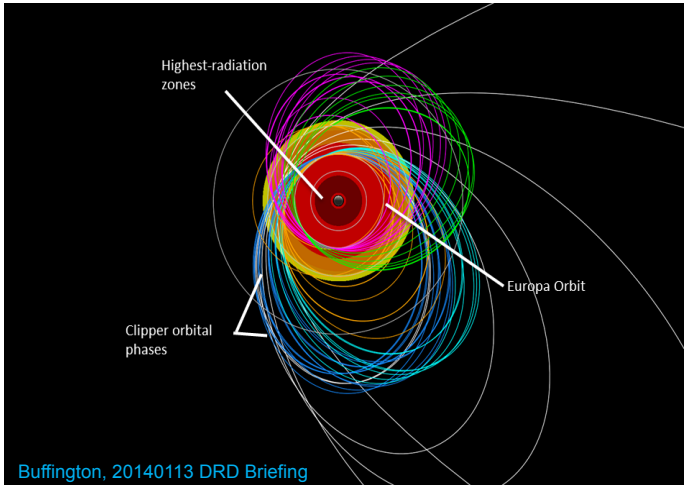
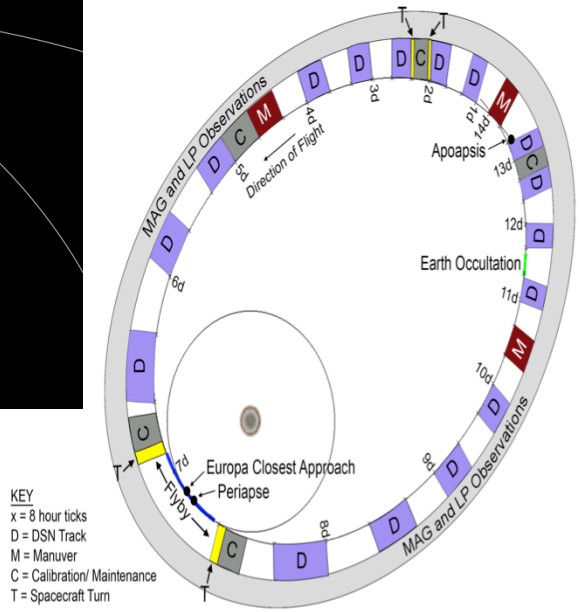
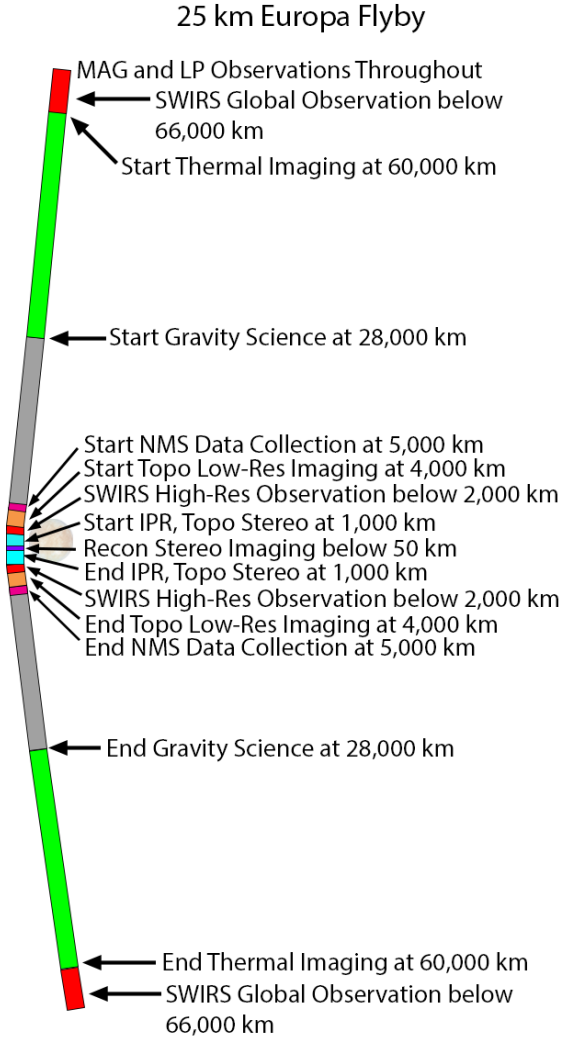
Outline

- Mission concept overview
- GNC Architecture
- GNC Hardware
- GNC Software architecture
- Propulsion
- Pointing assessment

Europa Clipper Mission Concept

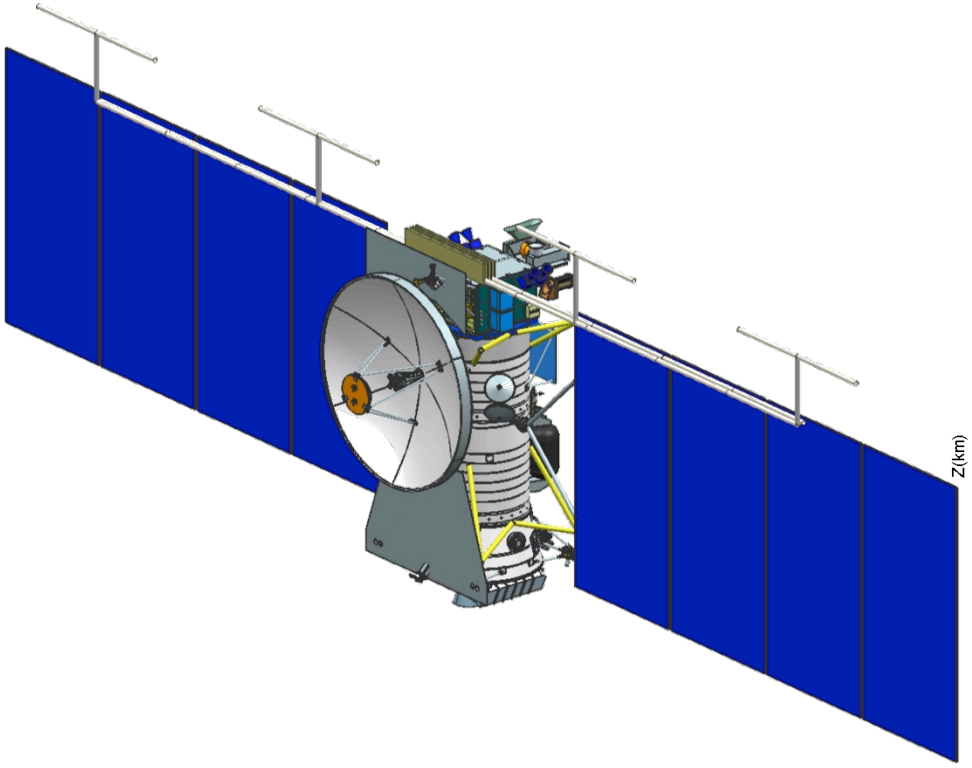


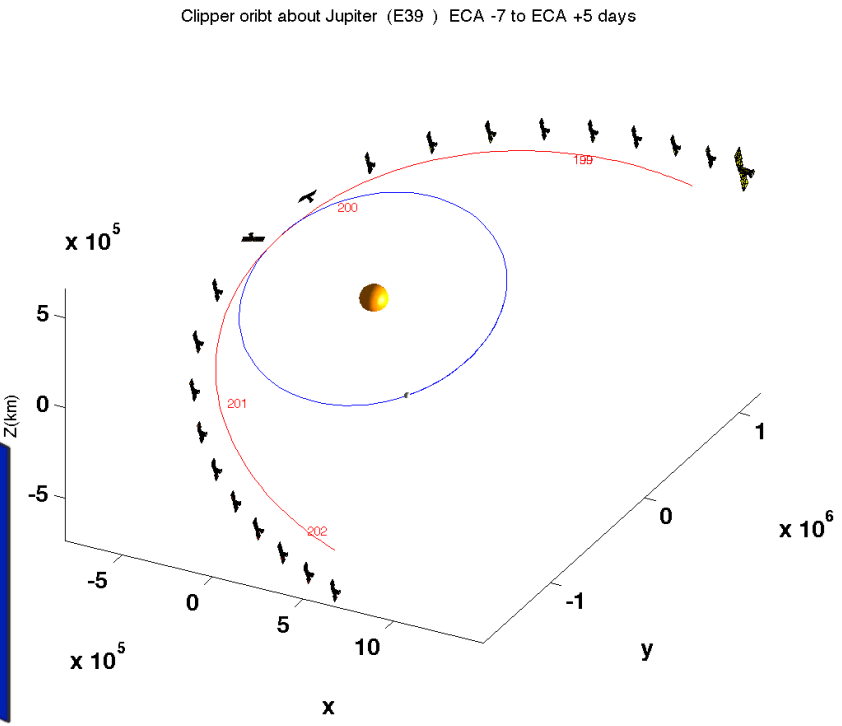




- Flyby mission (primary mission: 45 flybys)
- Key challenges:
  - Radiation environment
  - Planetary protection
    - Flyby design puts vehicle in Europa impact trajectories

Baseline GNC Architecture





- 3 axis stabilized spacecraft (Cruise on RCS, Science on Reaction Wheels)
- Attitude determination:
  - Star Tracker and IRU (nominal modes)
  - Sun Sensors (safe mode)
- Trajectory Maneuver Burns completed by accelerometer

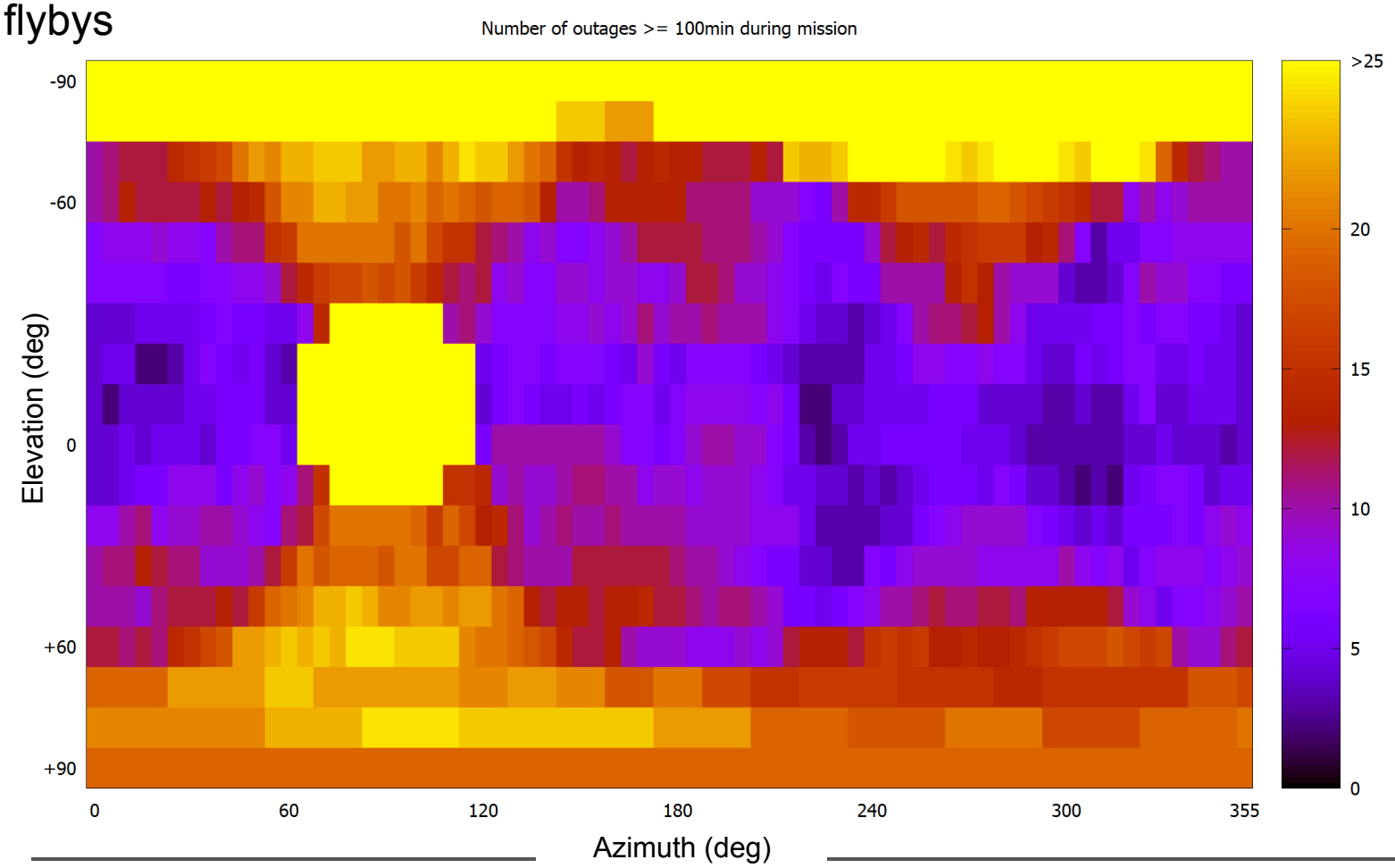
Baseline GNC Hardware

- Star Trackers (2, 1 prime, 1 backup)
  - Ongoing study to evaluate if we need more heads due to FOV occultations (Sun, Jupiter, Galilean moons) during science tour.
- IMUs (2, 1 prime, 1 backup)
- Reaction Wheels (4, 3 prime, 1 backup)
  - Ongoing study to assess pointing performance impacts of Reaction Wheel zero crossings.
- Sun Sensors (6, block redundant)
- Phase A study contracts with potential GNC hardware vendors to reduce risk associated with the Europa environment and assess the planetary protection requirements.
  - Jupiter radiation environment: Peak Flux (~ same JUNO); and TID (RDF = 2): Externally mounted hardware: ~6.4 Mrad (~20x JUNO); Inside avionics vault: 300krad (~6x JUNO)
  - Planetary protection: Dry Heat Microbial Reduction (DHMR) Approach

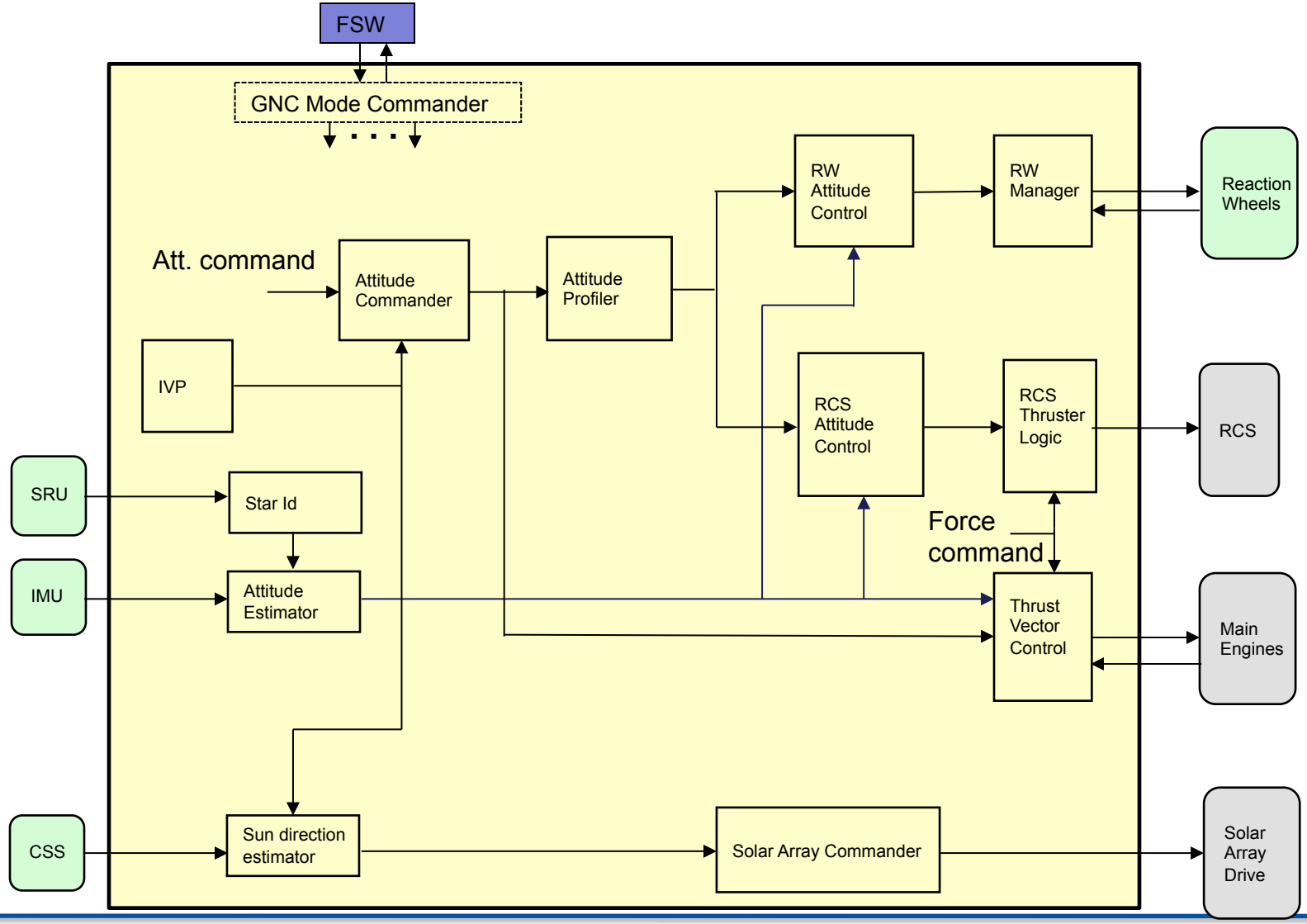
204.75hr @111C	131.75hr @125C
180.4hr @115C	114.75hr@130C
154.5hr @120C	64.2hr@135C

SRU outages

- Parameterized study to evaluate outages associated with extended bodies (Sun, Jupiter, Galilean moons) on SRU FOV during +/- 5 hours for 45 science flybys



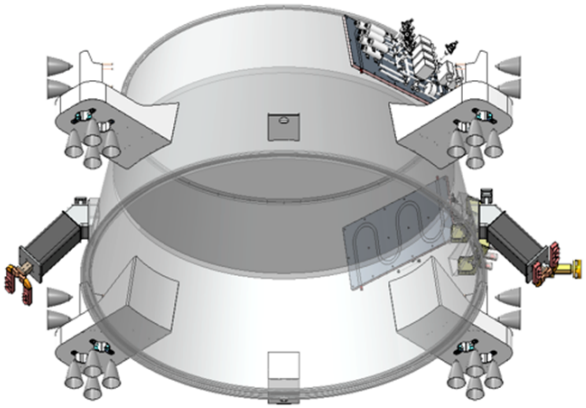
Notional GNC Software Diagram



Propulsion Trade

- Current baseline: Biprop (MMH, NTO)
  - Main Engines: 445 N (2, 1 prime, 1 backup)
  - RCS Thrusters: 9N (16, 8 prime, 8 backup)

- Main Engine Trade:
  - Down-selected a new configuration with 24x22N* (12 prime, 12 backup) engines to be used for both TCM burns and RCS attitude control.
    - ISP ~300 sec
    - Min I-bit ~0.01 sec
    - RCS attitude control (8x22N, 4 z-facing, 4 y-facing)
    - DV burns (turn and burn approach).
      - 8x22N, 4x22N or 2x22N z-facing thrusters for DV.
      - 4x y-facing thrusters for roll control.

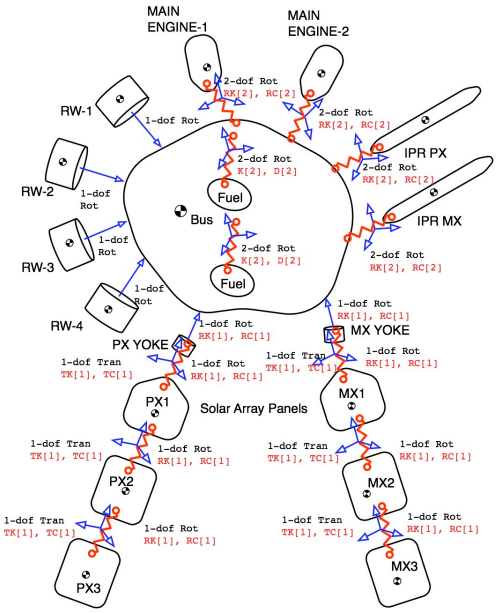


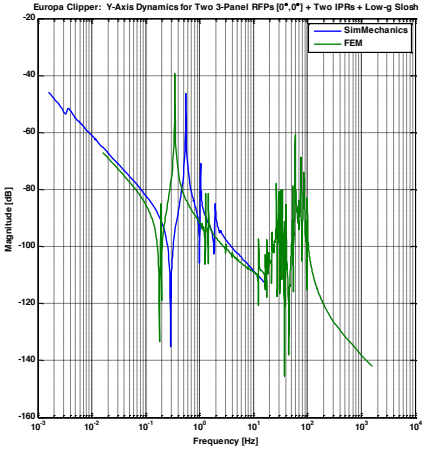
(*) Driscoll, R. J., Yager, J., Roy, M. J., and Kammerer, H. G., Development Tests on a 5-lbf Bipropellant Thruster Using a Platinum/ Rhodium Thrust Chamber, 34th AIAA/ASMW/SEA Joint Propulsion Conference & Exhibit, Cleveland, Ohio, July 1998.

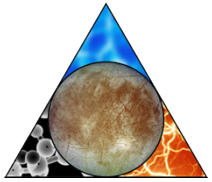
Pointing Capability Assessment

- Pointing accuracy: ~ 1-2 mrad (3 sigma)
- Pointing stability (3 sigma)
  - Multi-body simulation assessment of pointing stability during Europa flyby for two cases (Articulating and non-articulating solar arrays)

Pointing Stability (3 σ)	Stability window (s)	X (urad)	Y (urad)	Z (urad)
Articulating SA	1	45.5	5.4	10.9
	3	47.2	8.1	11.7
	10	52.3	19.1	15.6
Non Articulating SA	1	1.9	1.9	1.1
	3	5.6	5.6	2.9
	10	17.3	18	9.1







Thank you!