JPL GNC Status Update

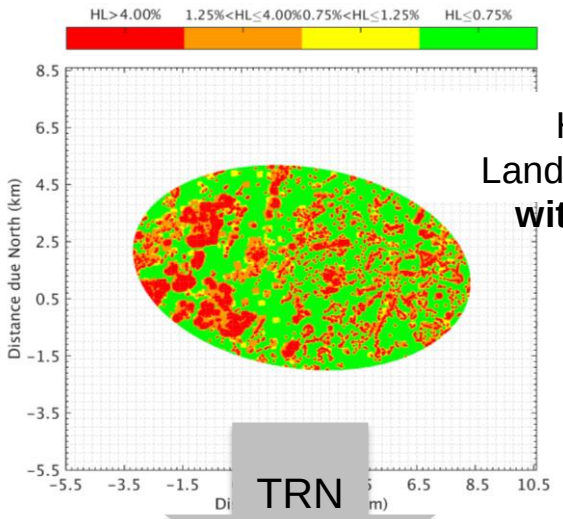
NESC GNC TDT face to face meeting
1/24/17

Aron Wolf, with help from Oscar Alvarez-Salazar, David Skulsky, Andrew Johnson, Ed Wong, and others

Terrain Relative Navigation Baselined for Mars 2020

Jet Propulsion Laboratory
California Institute of Technology

TRN enables access to hazardous landing sites



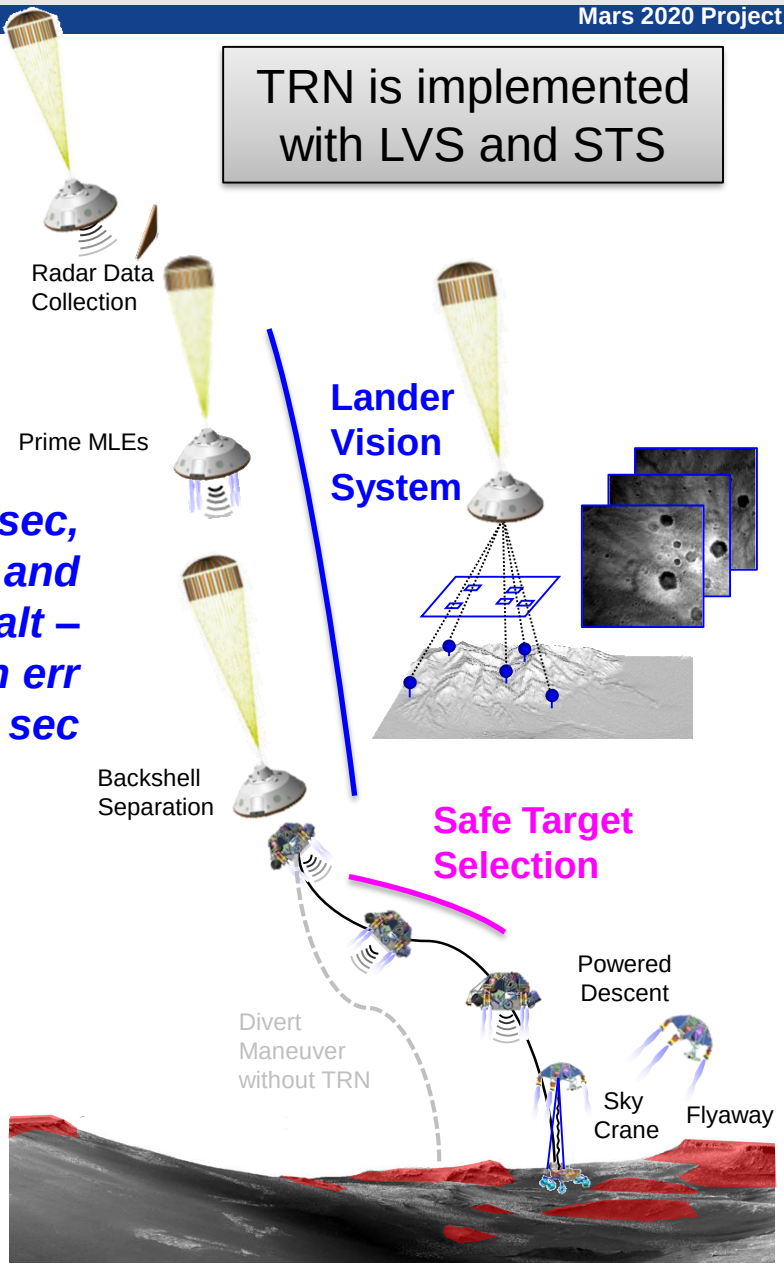
Hazards in Landing Ellipse **without TRN**

TRN

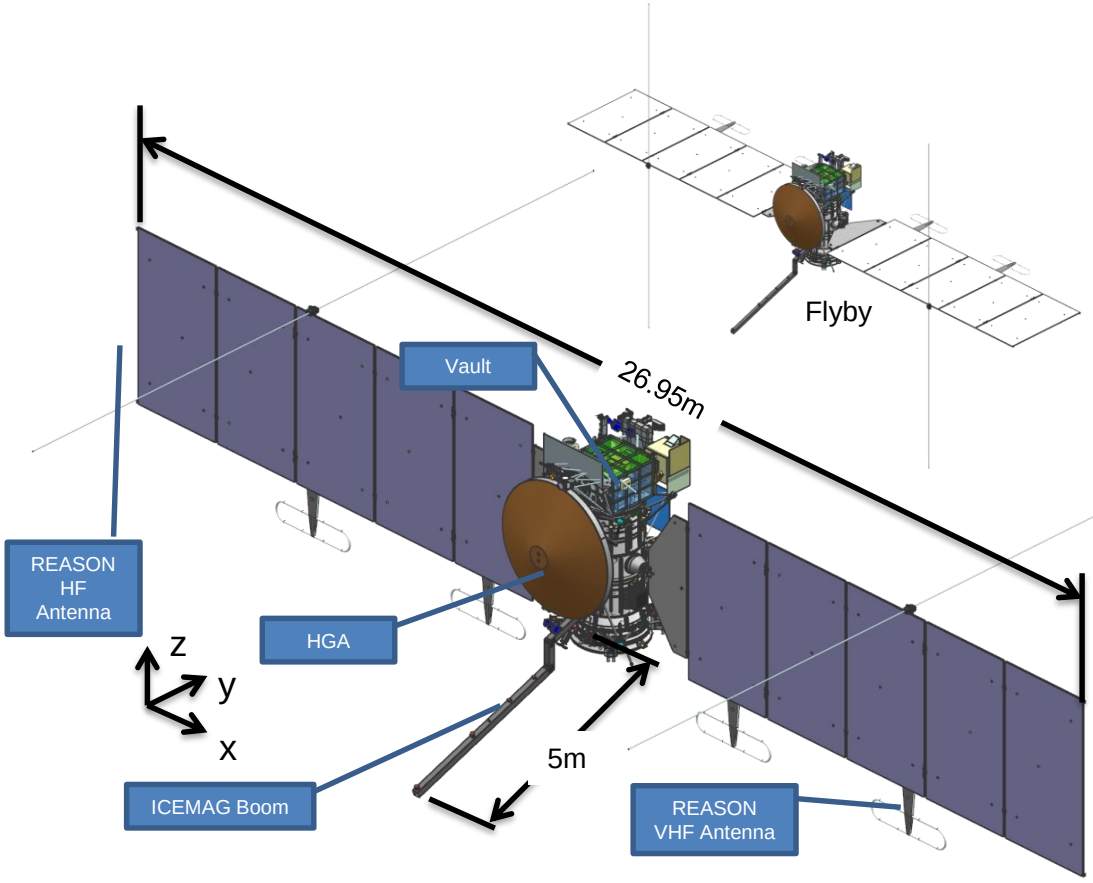
Hazards in Landing Ellipse **with TRN**

6 images in 10 sec, between ~4200 and 2000m alt – nominal position err 40m 99%ile at 10 sec

TRN is implemented with LVS and STS



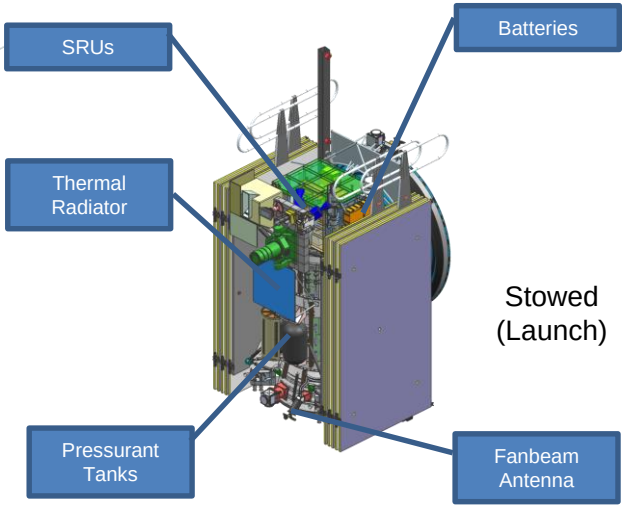
Planned Europa Mission



Baseline configuration

INSTRUMENT PAYLOAD

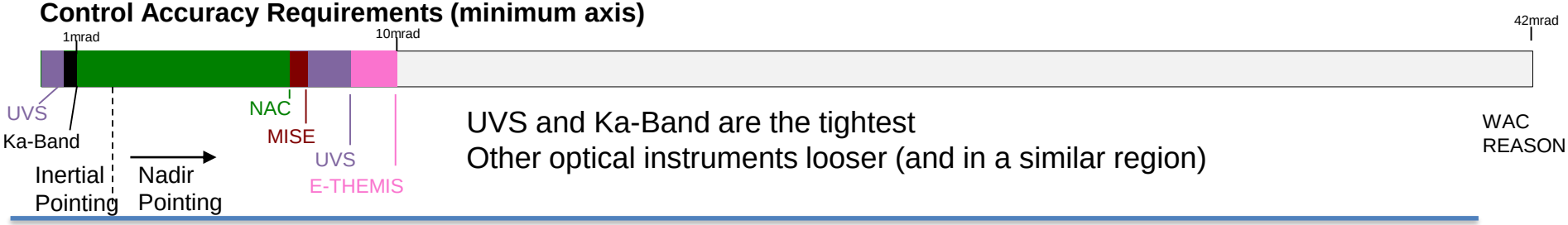
- Plasma Instrument for Magnetic Sounding (PIMS)
- Interior Characterization of Europa using Magnetometry (ICEMAG) magnetometer
- Mapping Imaging Spectrometer for Europa (MISE)
- Europa Imaging System (EIS) – wide and narrow angle cameras
- Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) – ice-penetrating radar
- Europa Thermal Emission Imaging System (E-THEMIS)
- MAss SPectrometer for Planetary EXploration/Europa (MASPEX)
- Ultraviolet Spectrograph/Europa (UVS)
- SUrface Dust Mass Analyzer (SUDA)



Stowed (Launch)

Instrument Pointing Requirements

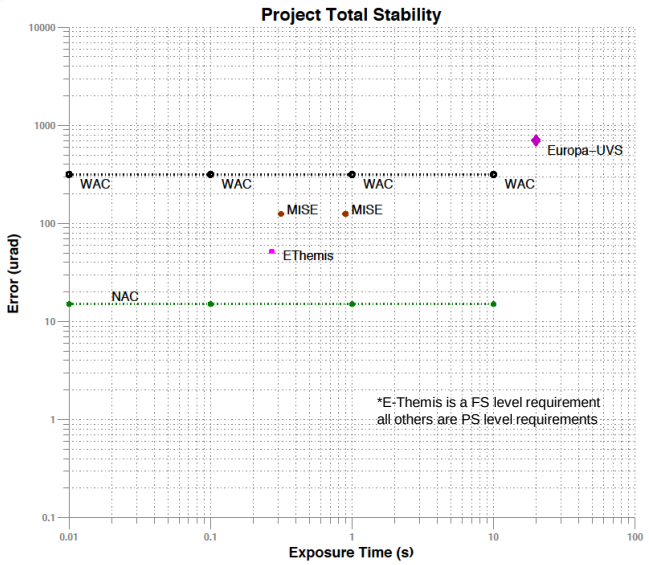
Control Accuracy Requirements (minimum axis)

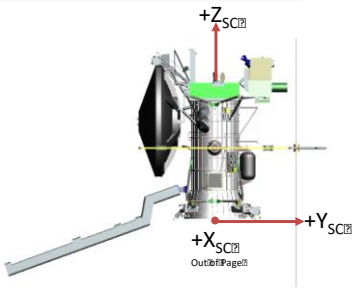


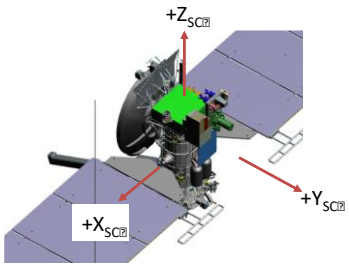
UVS and Ka-Band are the tightest
Other optical instruments looser (and in a similar region)

Image Smear / Stability Requirements

- NAC requirements are significantly tighter than other instruments
  - Requirement is met by holding the SA for NAC observations
- MISE & E-THEMIS requirements are more easily met by holding the SA, and that is in the baselined observation profile
- Possible disturbances from microphonics are being worked

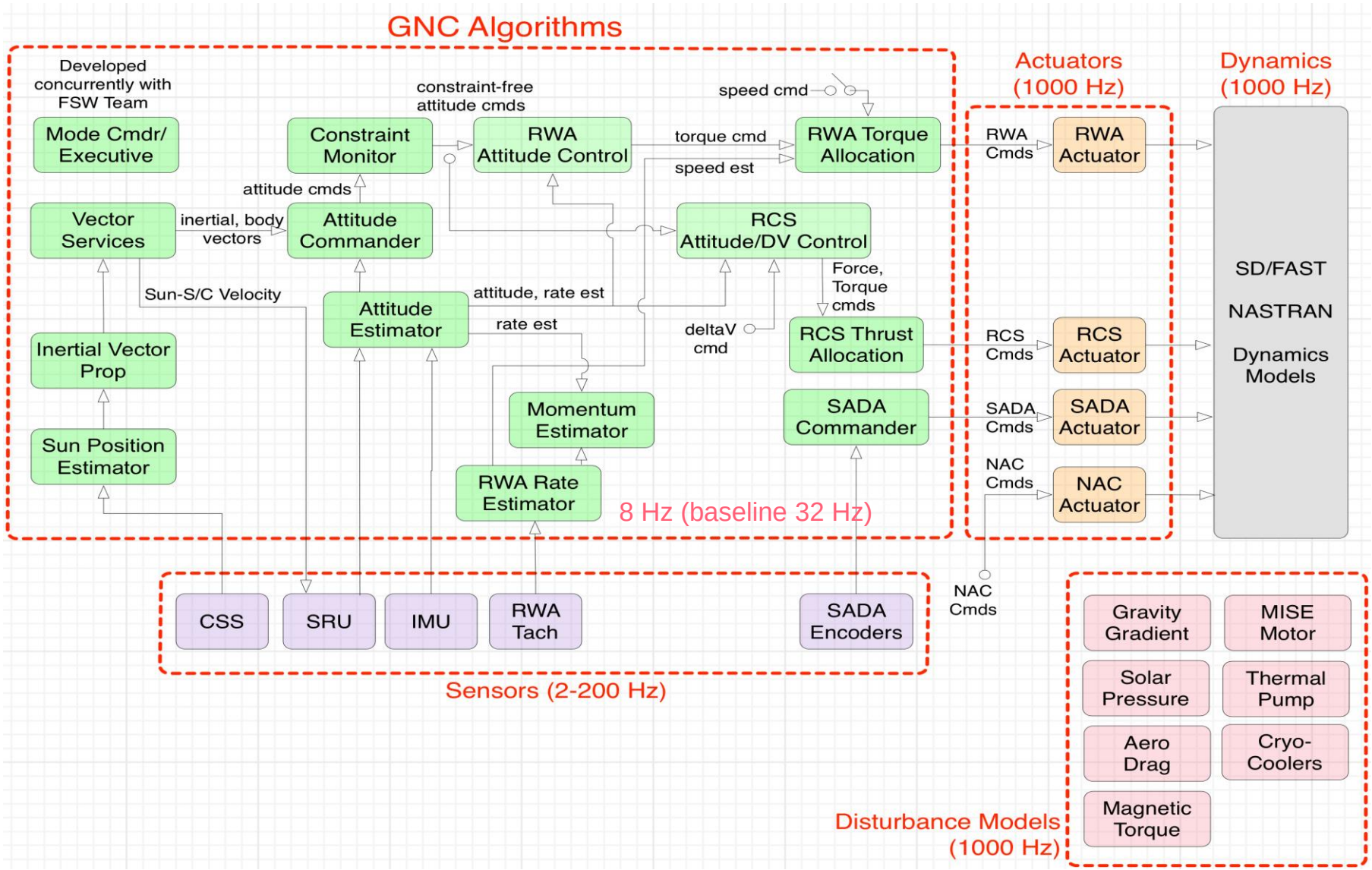






The spacecraft meets the instrument pointing requirements

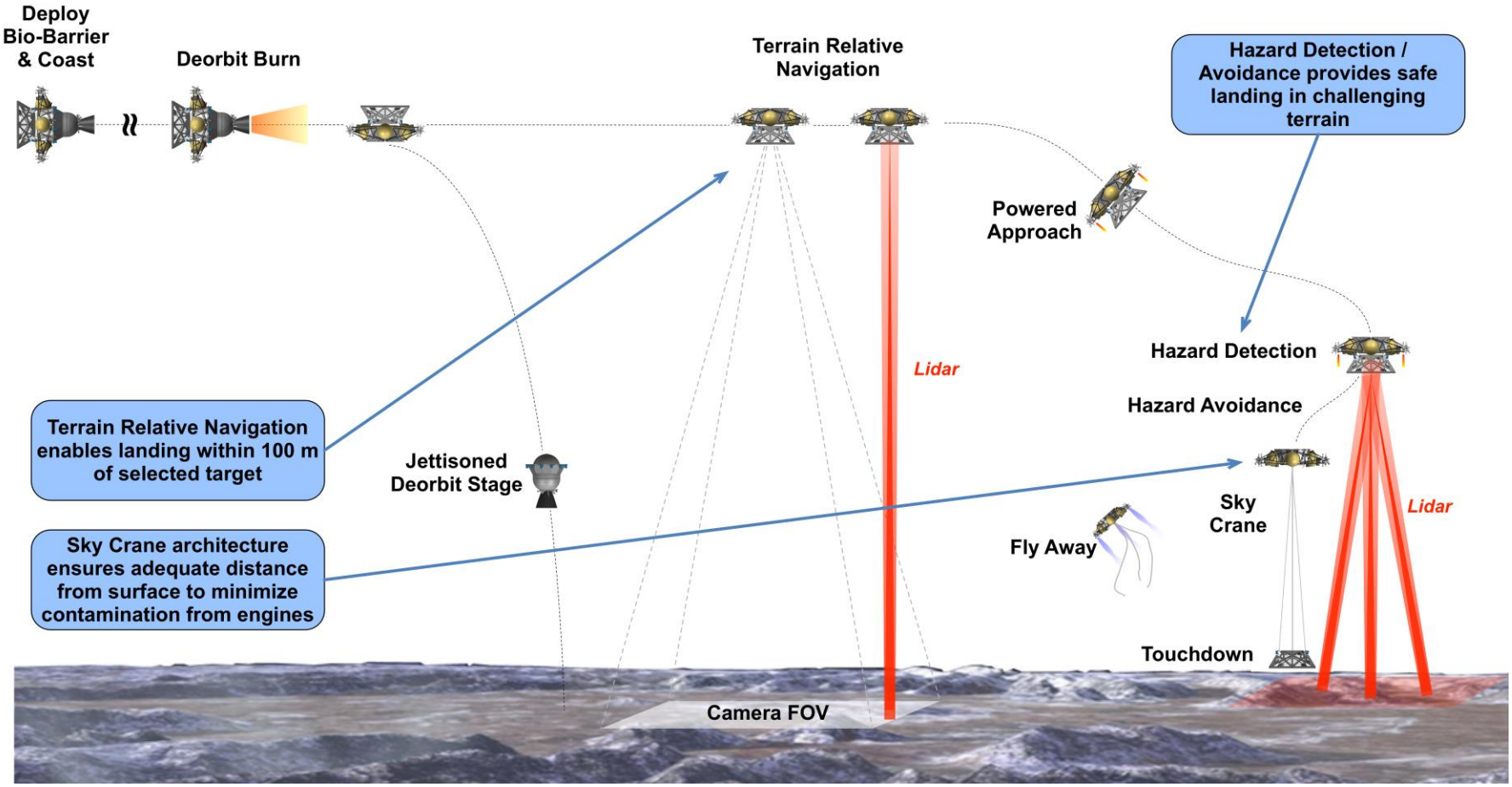
GN&C Control Block Diagram



Europa Lander Concept GN&C

- Lander activity is in Pre-Phase A
- GN&C emphasis to date on
  - Deorbit, Descent, and Landing phase architecture
    - Timeline, activities, performance analysis
  - Addressing significant challenges associated with landing on Europa (radiation, terrain uncertainty, planetary protection)
  - Lidar detector studies for *Hazard Detection* sensor
  - Performance analysis, camera specification, estimator design, and simulation of *Terrain Relative Navigation* for Europa landing application
  - Hardware configuration (propulsion, sensing, landing strategy)
  - High-fidelity simulation development

Europa Lander Concept: Deorbit, Descent and Landing Architecture



NISAR Dynamics & Controls: Technical Architecture: Pointing Vs. Frequency

Gimbaled Appendages: High Gain Antenna & Solar Arrays

ACS compensated Low Frequency Rigid Body Response to Gimbal Commands (<0.003 Hz)	Uncompensated Low Freq. Rigid Body Response to Gimbal Commands (0.003 → 0.2 Hz)	Uncompensated Jitter Response to Gimbal Commands (> 0.2 Hz) Rigid & Flex dynamics

→ ***Increase ACS BW & Reduce gimbal disturbance***

- *Misalignments → Pointing accuracy & knowledge error*
- *Quasi-static drift → Pointing accuracy & knowledge errors*
- *Closed Loop ACS error → Pointing accuracy & knowledge errors*
- *First mode (SA) ~ 0.3 Hz*
- *RWA induced jitter (> 5 Hz)*
- *→ Pointing Accuracy, Knowledge, & stability errors*

ACS BW = 0.003 Hz →

← $< 10^{-4}$ | 10^{-3} | 10^{-2} | 10^{-1} | 1 | >10 → ***Frequency (Hz)***

1. *Gravity Gradients*
2. *Solar Pressure*
3. *Aero Drag,*
4. *Hysteresis (180° flips)*

1. *Fuel Slosh*
2. *Momentum dumping*
3. *Zero-Doppler steering*

Quasi-static drift (thermal)

Use on-orbit calibration

SC to Payload misalignment

Use on-orbit calibration

Low CTE & gradient structural design

Boom isolates reflector from SC jitter →

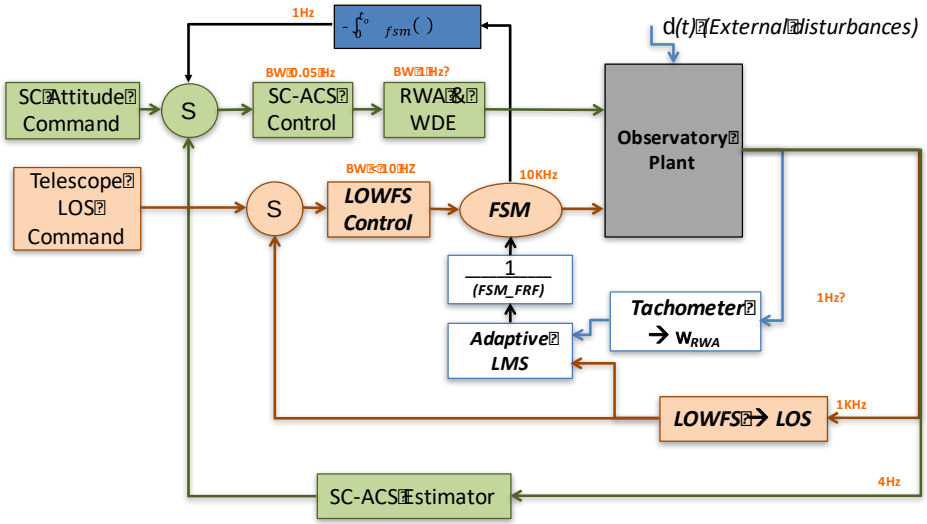
Jitter (gimbals, & RWAs) > 0.2 Hz

Control Structure Interactions (CSI) Generate Jitter Up to ~0.5 Hz

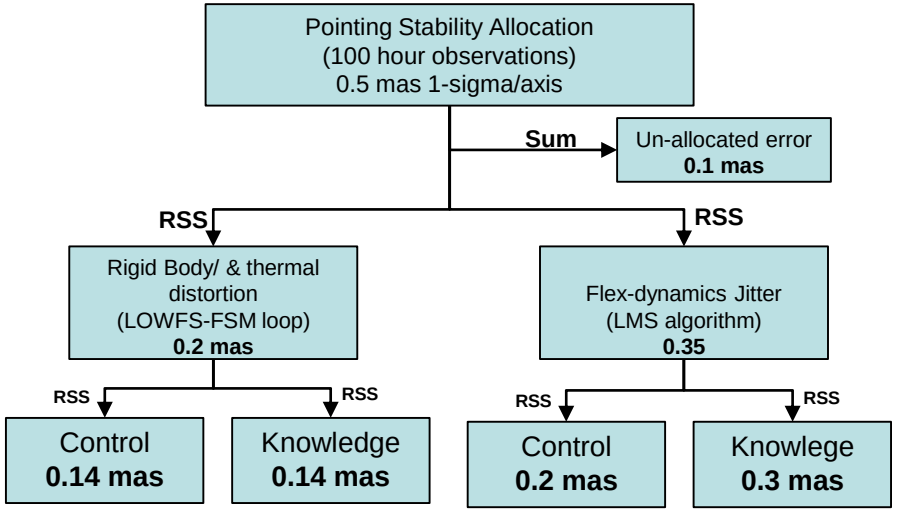
Minimized through ACS Loop Shaping

WFIRST Pointing System

MCR CGI-Pointing Control Flow Diagram

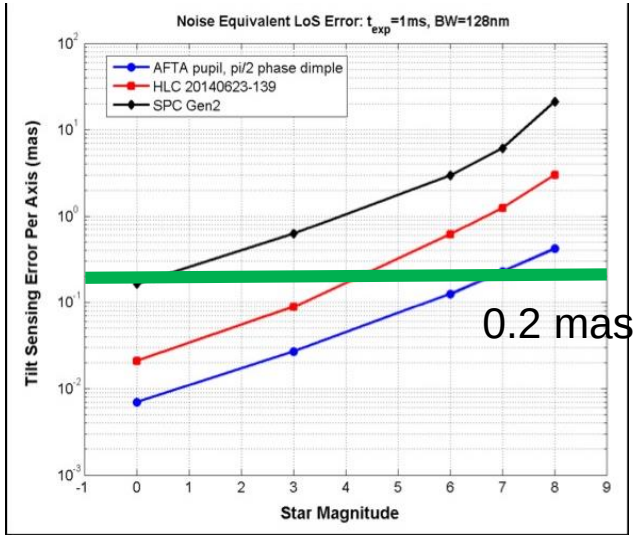


High Level Pointing Error Budget



Key assumptions & assessments

i. **<u>LOWFS-FSM Feedback Loop Bandwidth is limited to 10 Hz because LOWFS is photon limited</u>**
   i. Increasing Bandwidth to higher than 100 Hz would require exposure times shorter than 0.1 milli-seconds
   ii. Figure to the right show that the LOWFS exposure time needs to be longer at higher star magnitudes just to reject ACS residuals at 0.05 Hz



Backup

TRN Flight Interfaces