Jet Propulsion Laboratory
California Institute of Technology

Environmental Design Implications for Deep Space SmallSats

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Introduction

- Deep space exploration is a challenging and expensive proposition
- Small satellites (SmallSats) have to be fully capable of completing their mission objectives yet fit within the limited mass and volume allocations
- Space environments pose daunting challenges for using SmallSats to explore deep space
- Two key issues addressed here are:
  1. Radiation induced effects on spacecraft design
  2. Compliance with international planetary protection requirements

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Near Earth Asteroid (NEA) Scout Overview

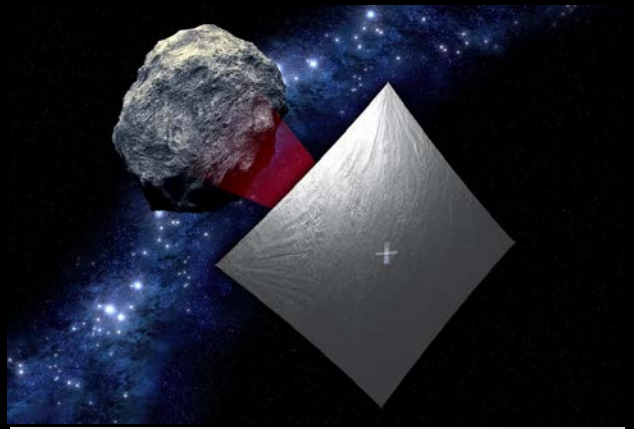
The Near Earth Asteroid Scout Will

- Image/characterize a NEA during a slow flyby
- Demonstrate a low cost asteroid reconnaissance capability

Key Spacecraft & Mission Parameters

- 6U cubesat (20 cm X 10 cm X 30 cm)
- ~86 m^2 solar sail propulsion system
- Manifested for launch on the Space Launch System (EM-1/2018)
- Up to 2.5 year mission duration
- < 1 AU maximum distance from Earth

Leverages: Combined experiences of MSFC (PM, SE, Solar Sail, AMT, G&C, and Mission Operations) and JPL (Flight System Bus, Instrument, Science) with support from GSFC, JSC, and LaRC



Target Reconnaissance with medium field imaging

Shape, spin, and local environment

Close Proximity Imaging

Local scale morphology, terrain properties, landing site survey

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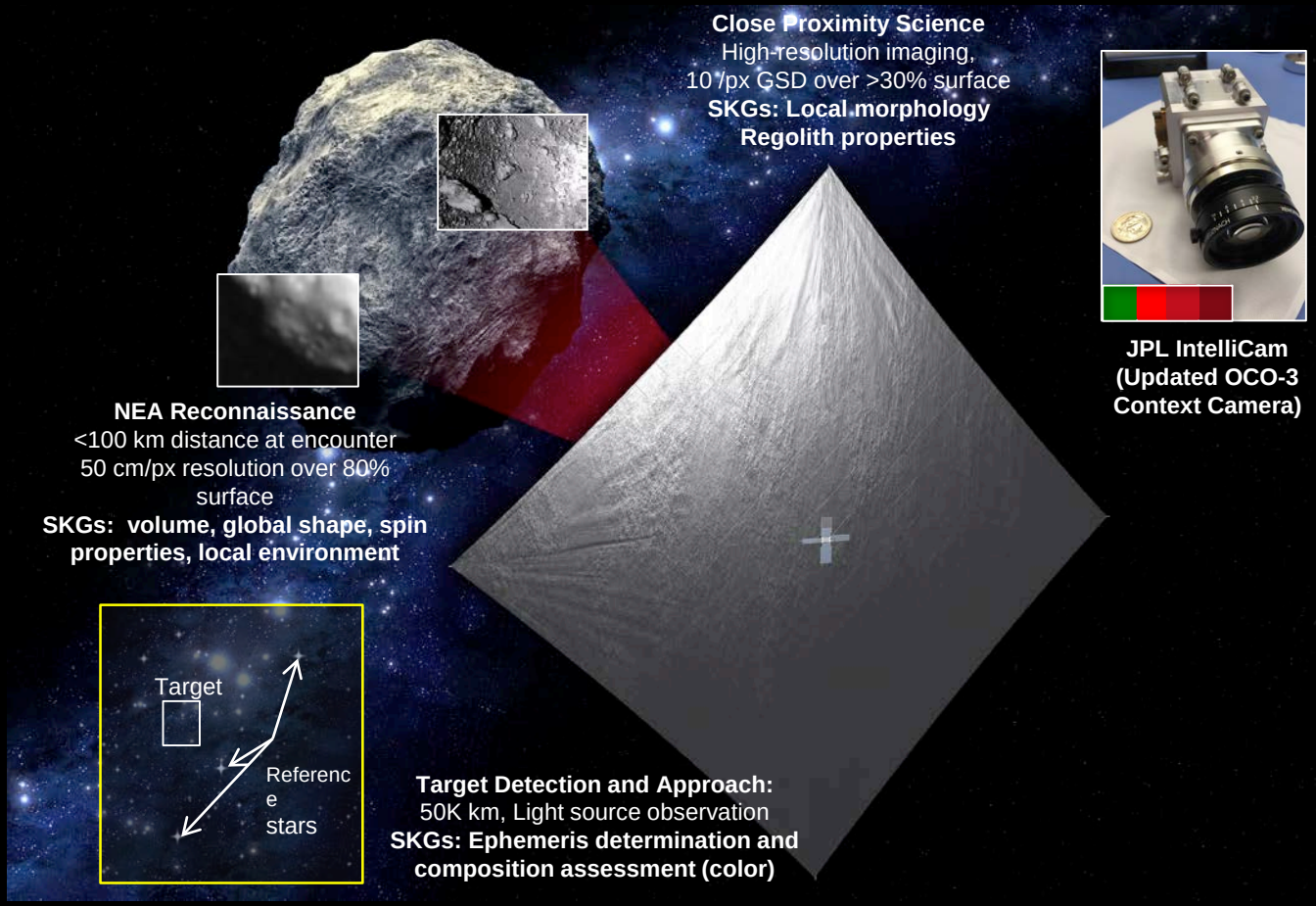
NEA Scout Science



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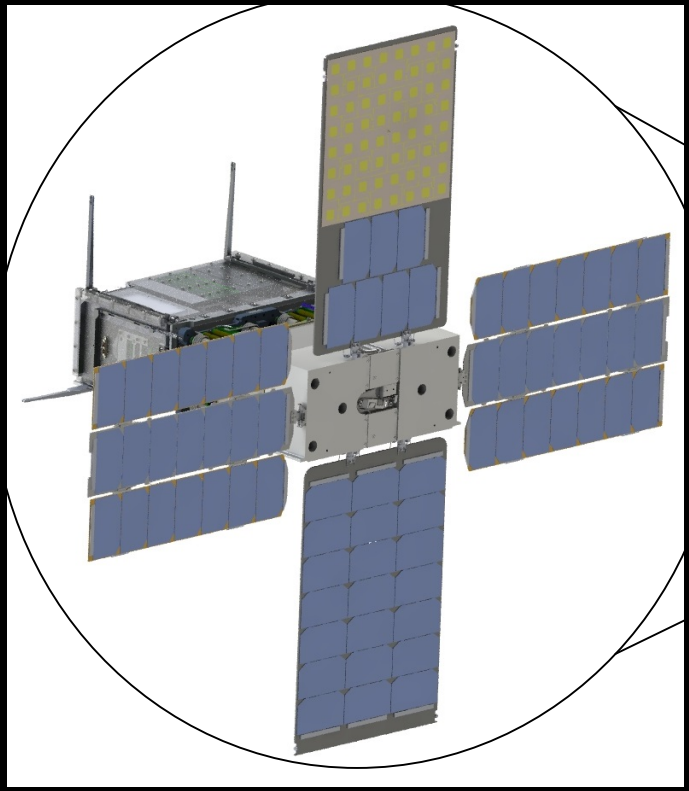
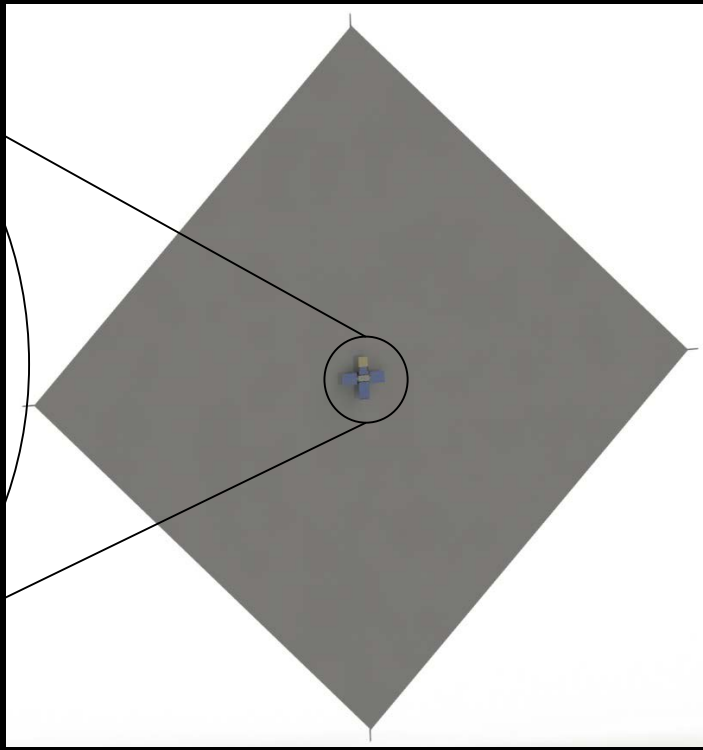
Flight System Configuration – Deployed





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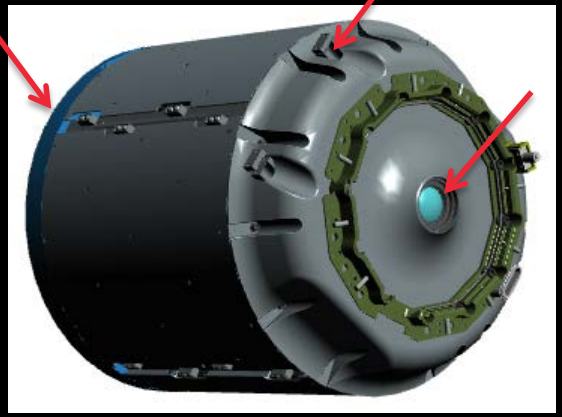
Sylph Probe Concept

Sylph is a single-task probe that would fly as a daughter spacecraft on the planned Europa Mission

~ 40 kg Probe

One of the most unique and capable small spacecraft ever studied by JPL for such a harsh environment designed to be sterilized

Deployed from a shielded, biobarrier hangar



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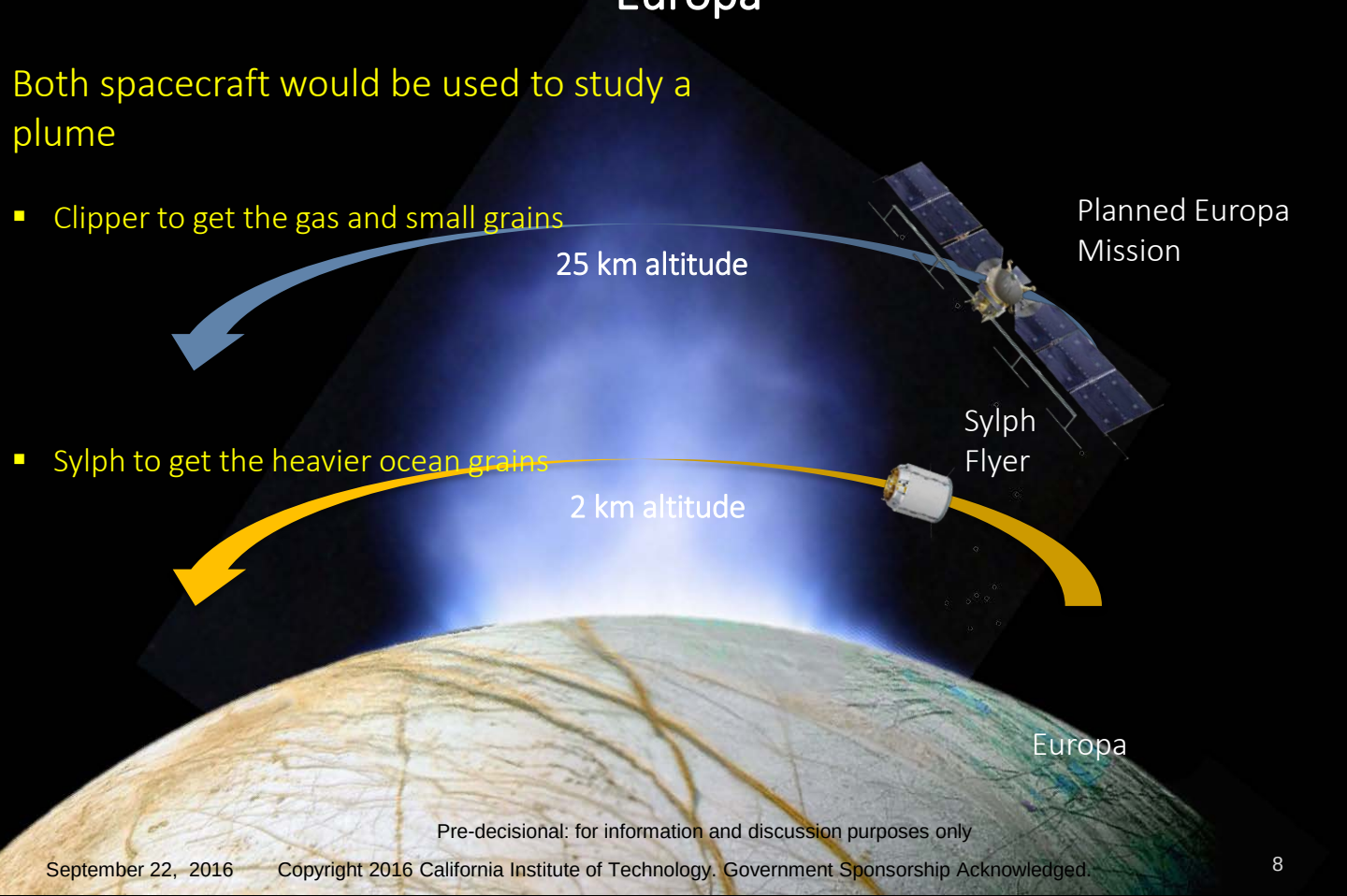
A concept of a tandem set of science measurements at Europa

Both spacecraft would be used to study a plume

- Clipper to get the gas and small grains
- Sylph to get the heavier ocean grains



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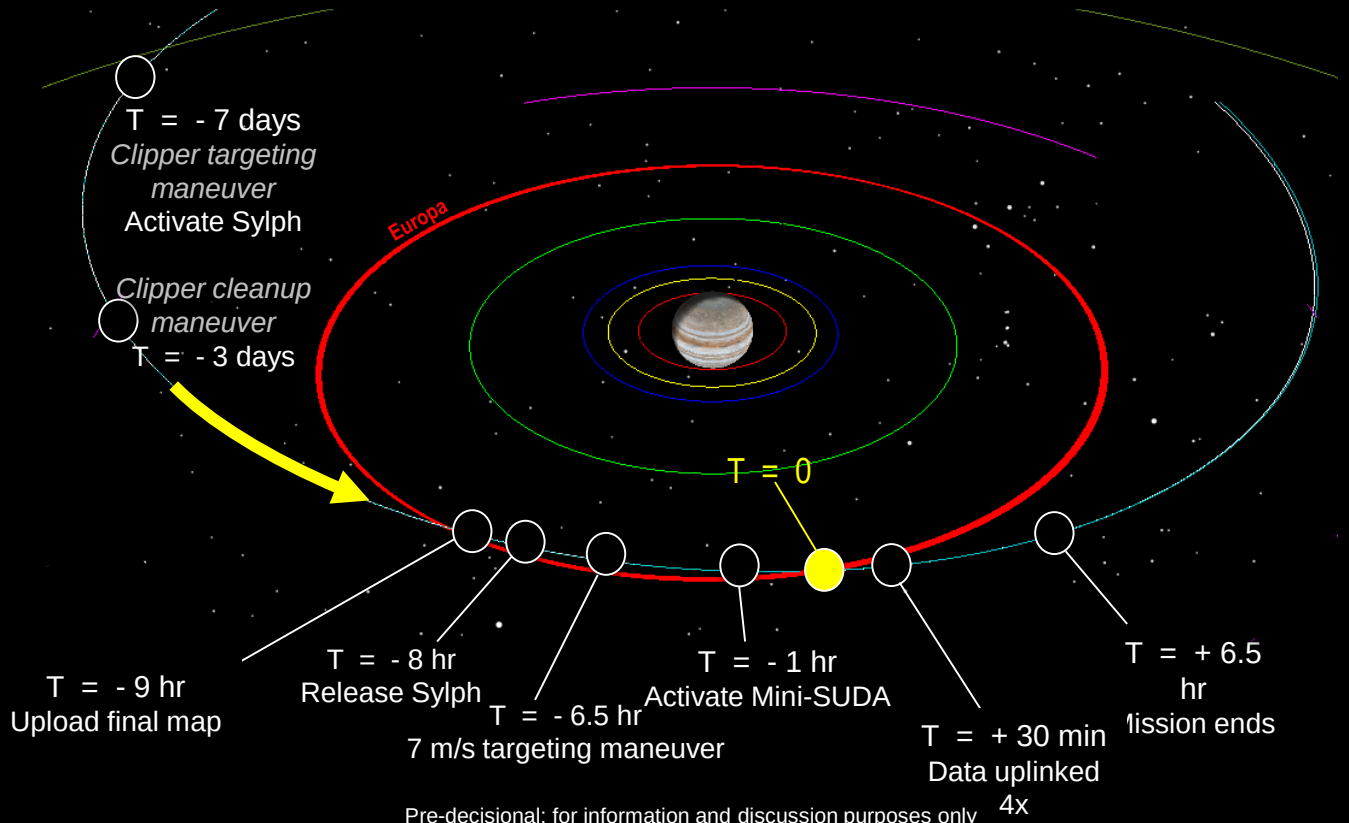
From deployment to final data retrieval, Sylph's mission concept would take less than 15 hours



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Space Radiation Drivers on the Design

- The lack of available technologies or low Technology Readiness Levels for deep space Smallsats require unique mitigations and solutions that include:
  - Requiring the use of of “large” flight-mature spacecraft components (e.g. IMU)
    - However, this can highly impact mass and volume constraints
  - Adding additional shielding if applicable and within mass or volume constraints
    - 6U Smallsats are often limited to 12 kg
  - Carefully selecting parts to meet environments, if options exist
    - Processor choice and computer board design
    - SRAMs vs DRAMs depending on the data storage requirements
  - Assessing the acceptable sensor noise and the potential impacts on imaging quality or pointing control and knowledge
  - Designing a more robust operational response that re-boots the system to clear out SEE unintended effects.

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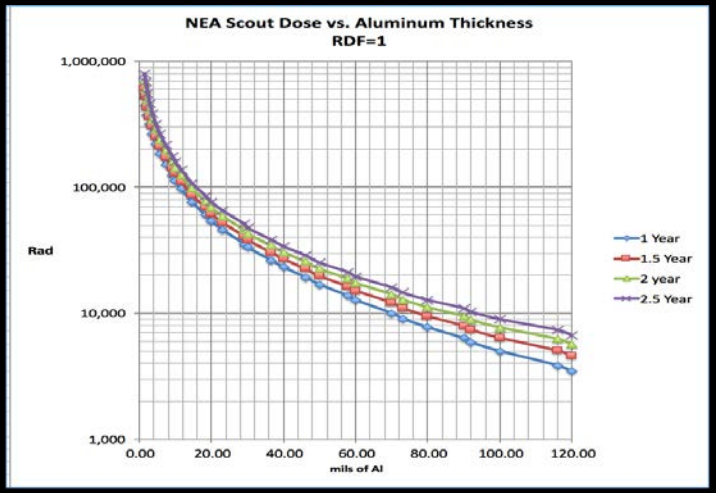
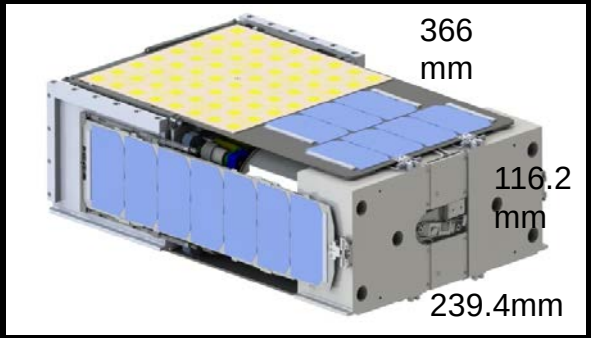
Implementation Constraints on Environmental Mitigations for NEAScout

- Limited mechanical and volume resources to deal with radiation effects & margin options
  - Detrimental to COTS electronic parts
- > 2 year mission drives need for shielding
  - Within a ~14 kg total mass allocation (6U)
- Single-string Mission
- Radiation tolerant design to both TID as well as SEE
- A Radiation Design Factor (RDF) of 1 implies there is no additional margin added on to radiation requirements.





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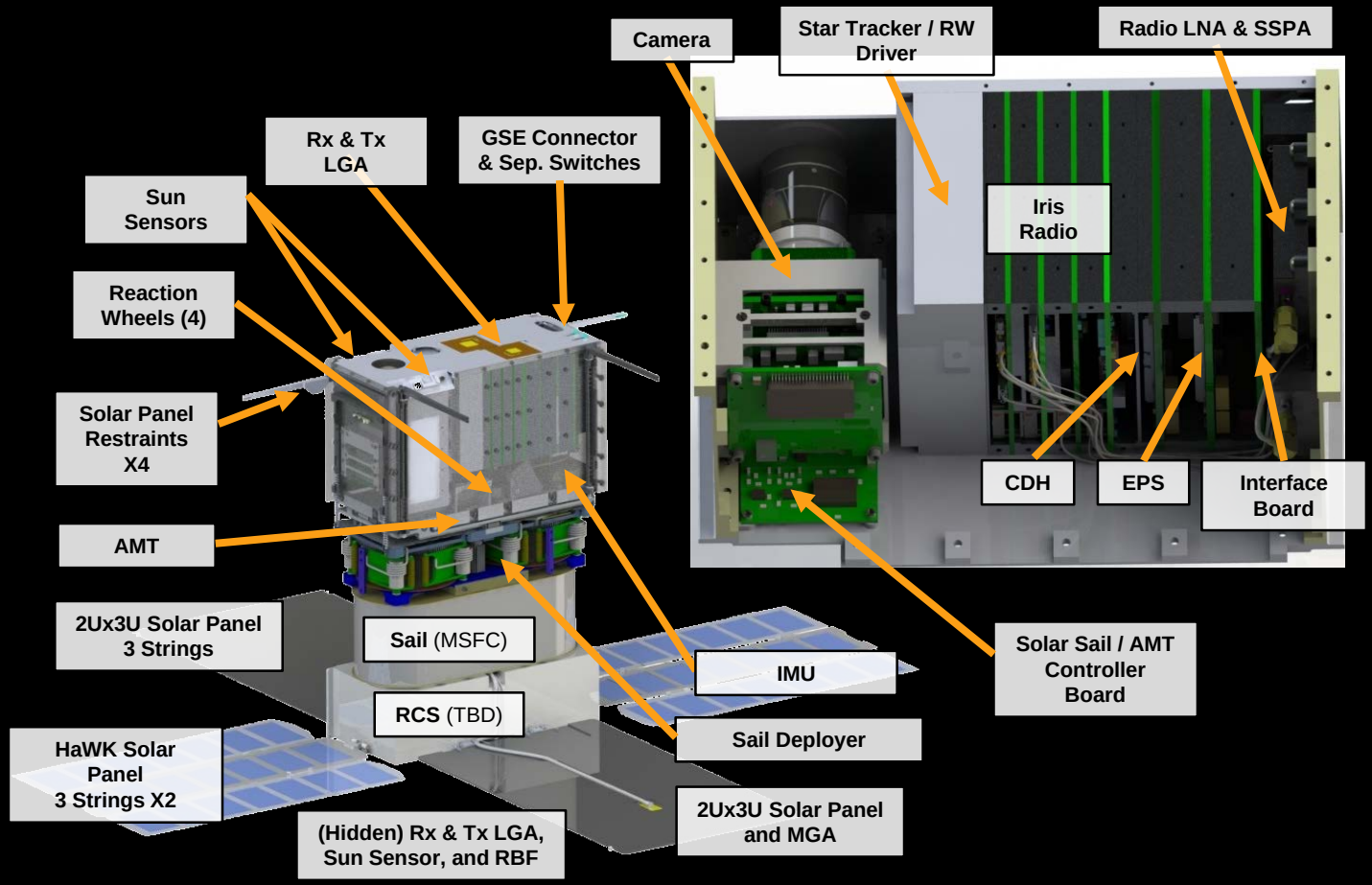
NEAScout Flight System Overview



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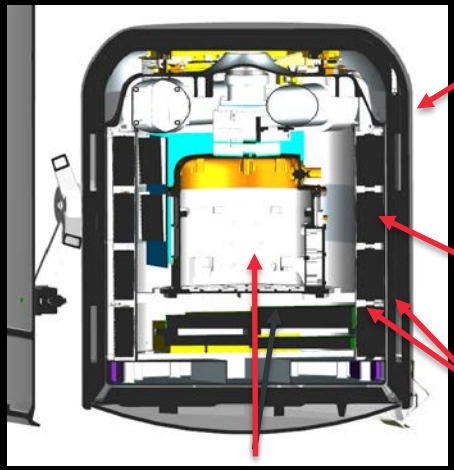
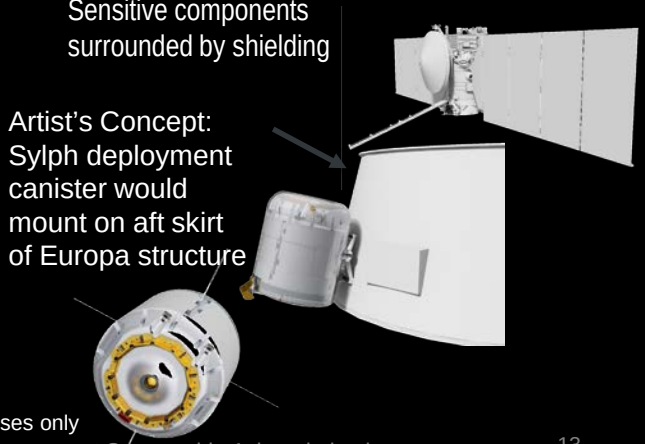
Implementation Constraints on Environmental Mitigations for the Sylph Concept

- Decade of survival in storage on-board the Europa spacecraft
- Designed to handle the highest expected radiation environment
  - TID < 150 krad to internal components over mission lifetime
    - 91 krad pre-deployment
    - 13 krad post-deployment
    - Total mission dose: 104 krad (2.9 eff. RDF)
    - Total effective shielding thickness of 29 mm
- Small size and short mission operations (24 h) allow an efficient approach to radiation mitigation that minimizes excess "dumb mass"
  - Shielding requirement is suballocated between the probe and its biobarrier deployer





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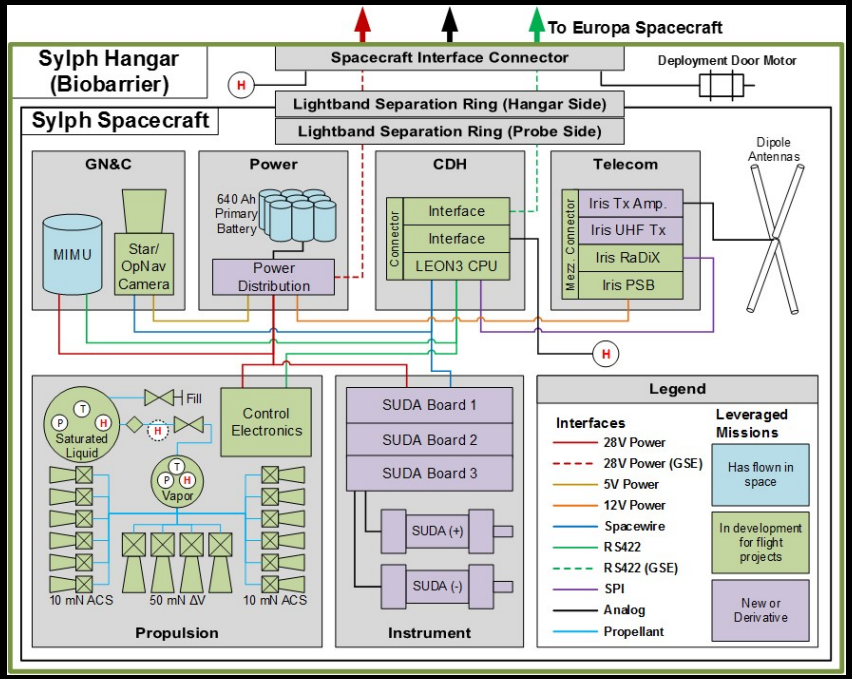
Sylph Concept

Flight system comprises components and subsystems that leverage mission hardware currently in flight or in development



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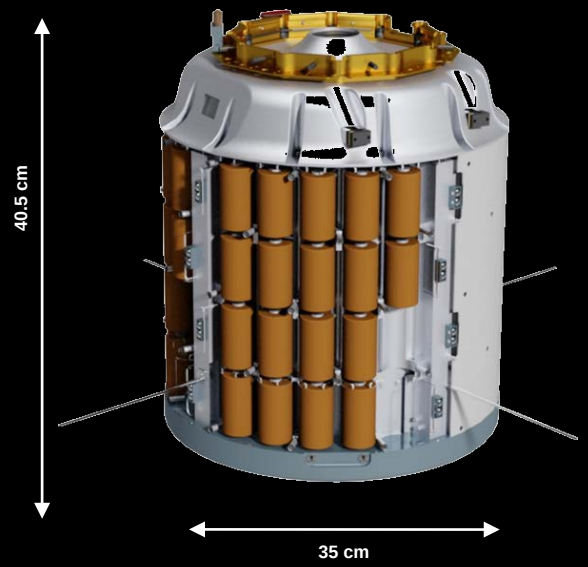
Batteries are purposely used as a part of the self-shielding layout for radiation protection

The Probe would be the size of a home propane tank

Standard interface, self-shielding layout includes batteries

Li-$SOCl_2$ Primary Batteries (72) used



Artist's Concept

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Designing the Sylph Concept for Planetary Protection Considerations for Ocean Worlds

- Driving Planetary Protection Requirement:
  - The probability of inadvertent contamination of a liquid water body by a single viable terrestrial microorganism shall be less than 1×10^{-4}
- Driving Compliance Consideration:
  - Given Sylph's limited propulsive capability and very close flyby of a presumed geologically active region of Europa, probability of impact of the flight system on a subsequent orbit would be near one
- Approach to Compliance:
  - Sterilize the flight system prior to integration with the primary Europa spacecraft to eliminate any viable microorganisms via:
    1. Heat Microbial Reduction (HMR – 128 for 12 weeks)
    2. Irradiation (Batteries – 10 Mrad))
    3. Vapor Phase Hydrogen Peroxide (VHP)
  - Take no microbial reduction credit for radiation exposure after launch, spacecraft reliability, or assumptions about Europan geological processes
- Recontamination Prevention: Dispenser would act as bio-barrier to protect spacecraft from recontamination during processing, or by primary spacecraft or launch vehicle

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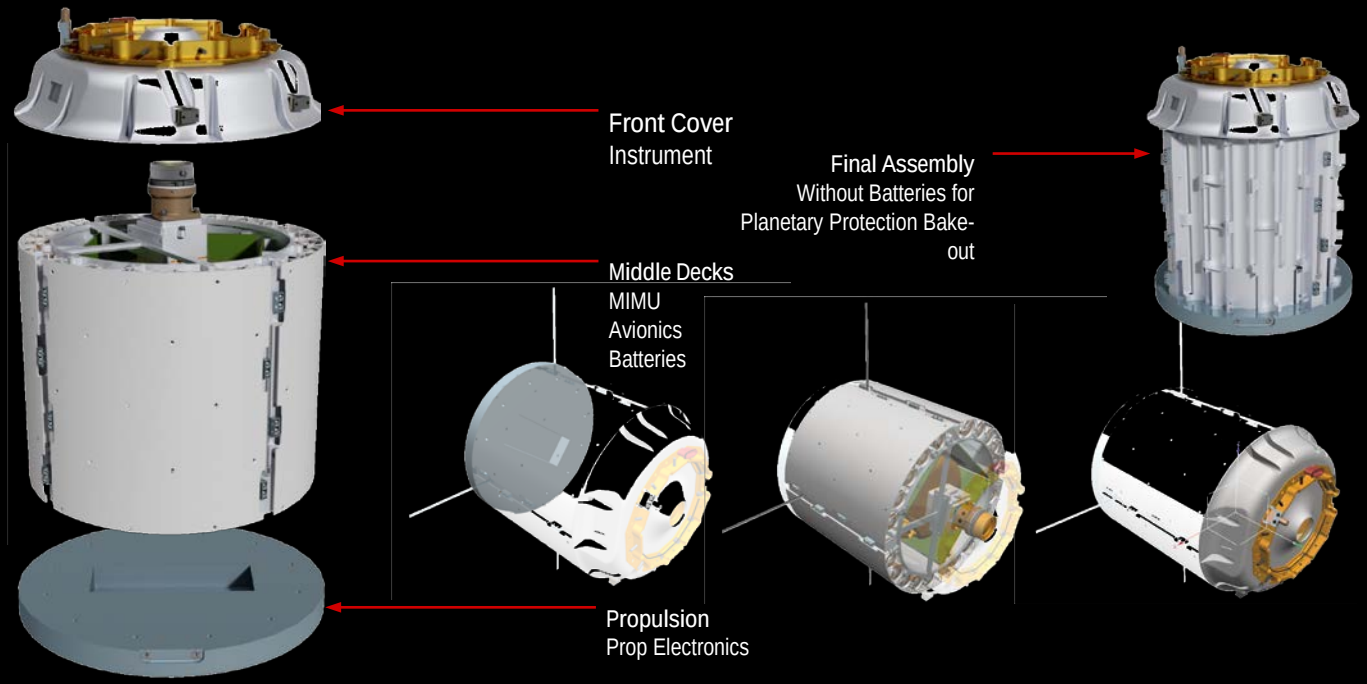
The Sylph Concept core is baked for planetary protection following HMR protocols



Artist's Concept

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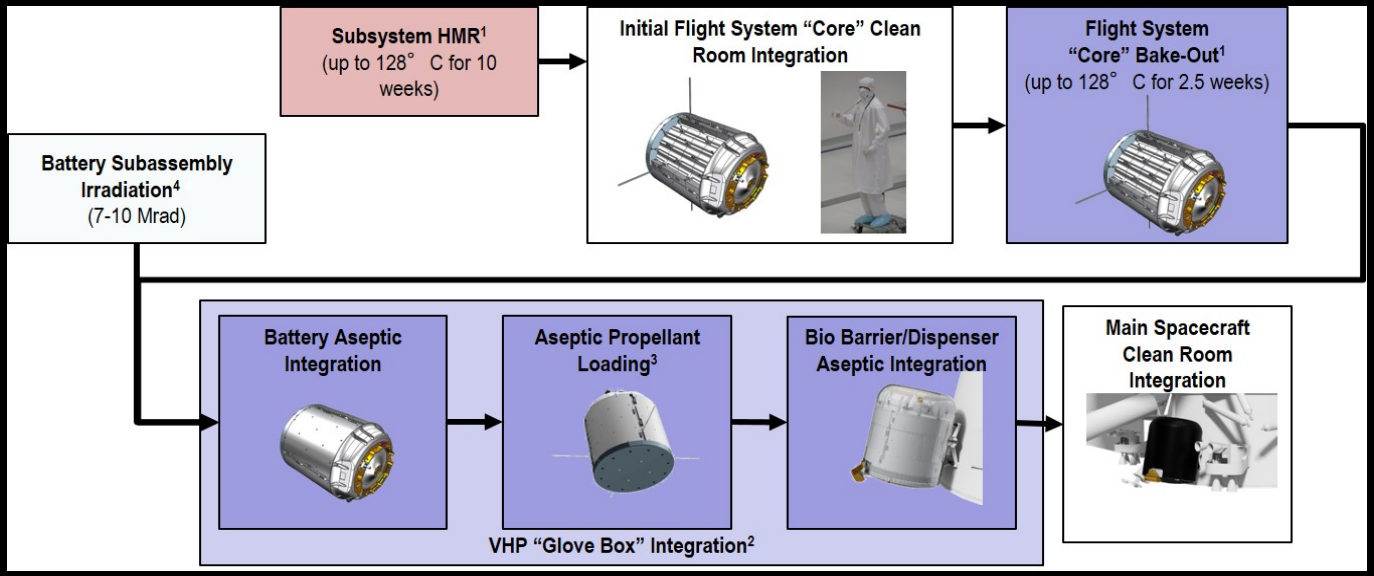
PP implementation approach is integral to design and assembly processes



[1] Requires HMR-compatible components in the "core" assembly. 12.5 weeks provides 6-order-of-magnitude reduction in encapsulated spore population

[2] VHP sterilizes surfaces during integration

[3] Propellant is filtered through 0.2 µm filter to remove micro-organisms

[4] Not all battery chemistries can withstand high temperatures and maintain charge after being baked

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Conclusion

- New deep space mission concepts and technologies to enable the exploration of deep space using SmallSats face unique space environmental challenges such as radiation induced effects and mitigation of bioburden contamination
- The NEAScout and Sylph mission concepts have explored and architected design options within the tight constraints of mass, power and volume as well as SmallSat limitations on physical and financial resources.
- These missions are establishing an approach to enable new frontiers of exploration and space science to be conducted at a fraction of the cost.

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