ELSA

Europa Lidar Sensor Assembly

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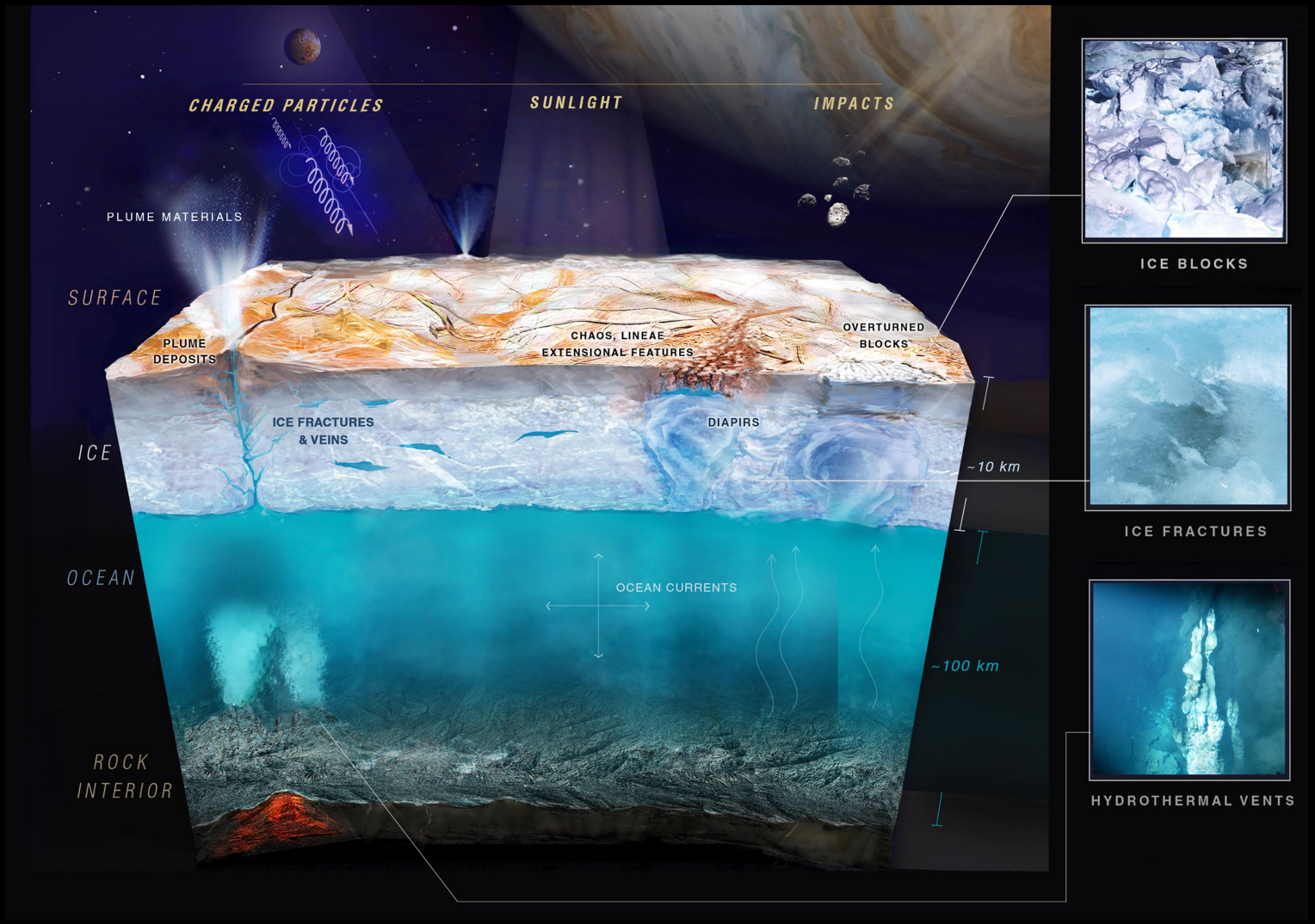
Outline

- Europa lander mission
  - Goals
  - Challenges
  - Concept of Operations
- Lidar system design
  - Challenges
  - Key technologies and approaches
- Brassboard prototype design
- ELSA Elsewhere
- Summary

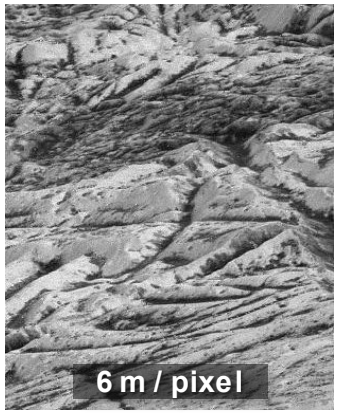
Europa Lander Mission Goals

1. **Life**
   - Search for evidence of life
2. **Habitability**
   - Assess the habitability of Europa via in situ techniques
3. **Context**
   - Reconnaissance for future robotic exploration



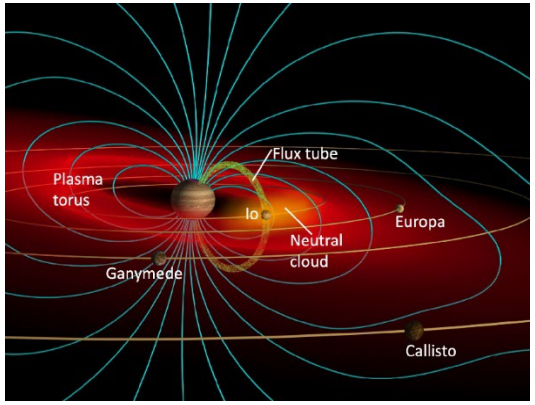
Challenges to Landing on Europa

Unknown Terrain



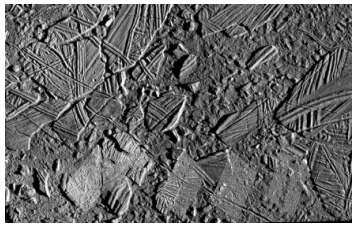
- Current highest resolution image is 6 meters per pixel
- Clipper mission could provide 50 cm imagery over 2 km swaths
- Not enough resolution for lander hazard avoidance

Ultra-high Radiation



- Ionizing radiation of electrons and protons generated by Jupiter's magnetosphere
- 1.5 Mrads with 25 mm Al shielding
- 150 krads in "vault"

Hazardous Terrain

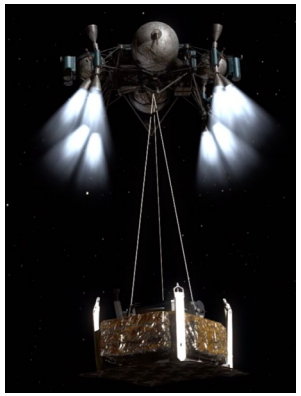


Conamara Chaos, Europa

Atacama Desert, Chile

- Penitents (blades of ice) could be up to 50 meters high

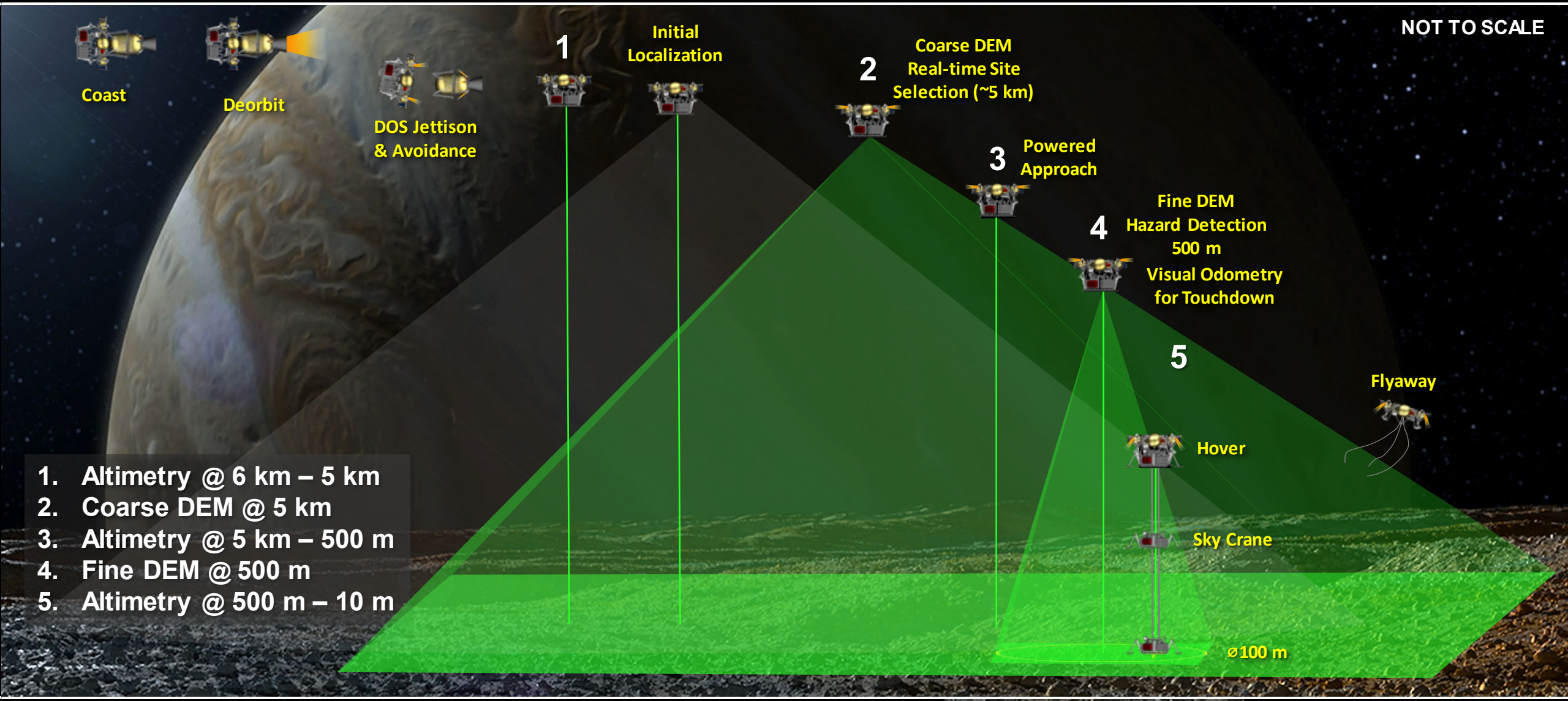
Limited SWaP



- 40+ kg of science equipment
- Sky crane without atmosphere to parachute with
- Limited battery power

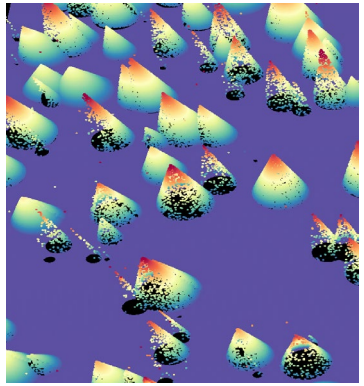
Lidar is the best technology for rapid high-resolution imaging in ultra-high radiation environment

Europa Lander OV-1



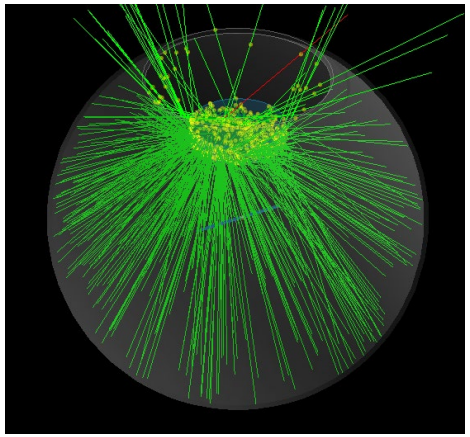
Challenges to ELSA Design

Performance Requirements



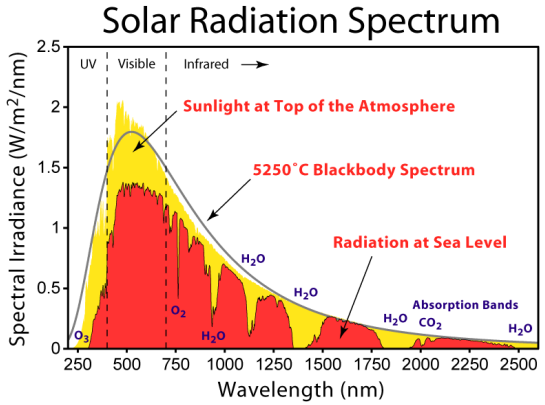
- Dynamic range:
  - Altimetry: 10 m to 10,000 m
  - Mapping: 500 m to 5,000 m
- Fine mapping:
  - Precision: 5 cm xyz
  - Accuracy: 100 cm
- ± 6 degree field-of-view

Ultra-high Radiation



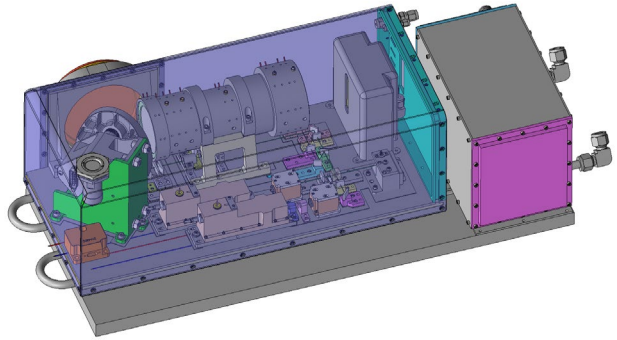
- Optical system must have line-of-sight to surface
  - Optical head must be outside vault
- Radiation damage concerns to laser, optics, and detector
- Potential radioluminescence and Cherenkov radiation

Solar Background Noise



- Radiation hardness pushes us to wavelengths of peak levels
- Competitive with signal link
- Narrowband filter design limited by wide field-of-view

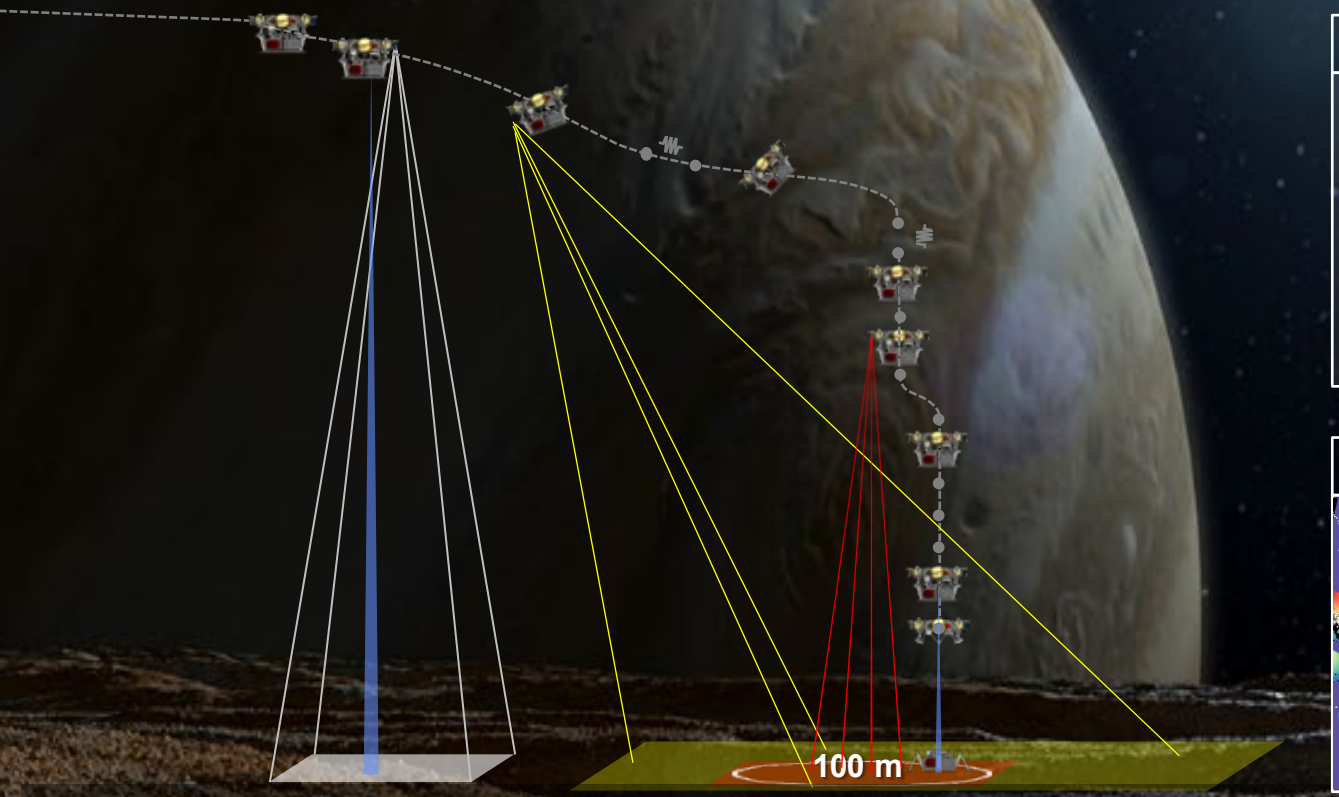
Limited SWaP



- Weight: 7 kg
- Size: 15,625 cm^3 = $(25\ cm)^3$
- Compact optics
- Limited power:
  - Laser
  - Data processing

ELSA Overview

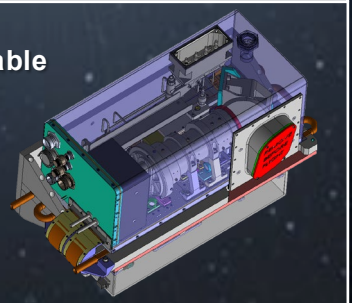
Real-time 3D Mapping & Hazard Avoidance



Key Technologies & Approaches

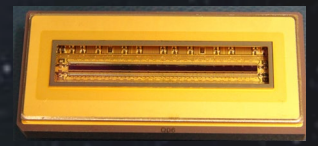
Low-SWaP Ladar System

Flight-traceable design



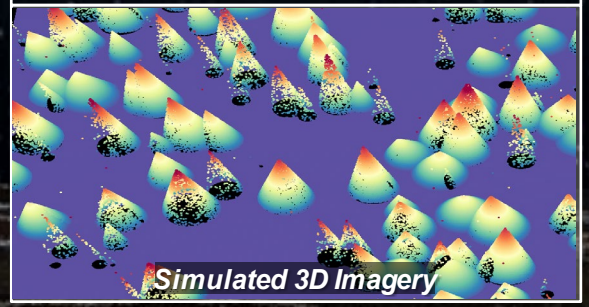
Novel FPA Technology

32 x 2048 Si APDs

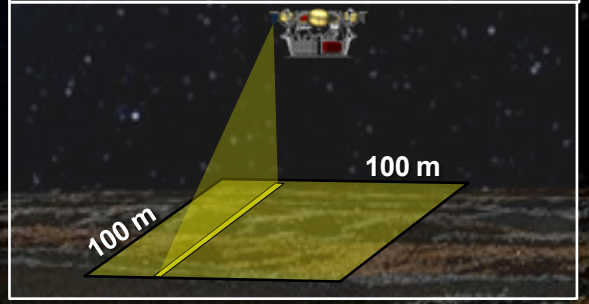


Rad-hard

Embedded Real-time Processing



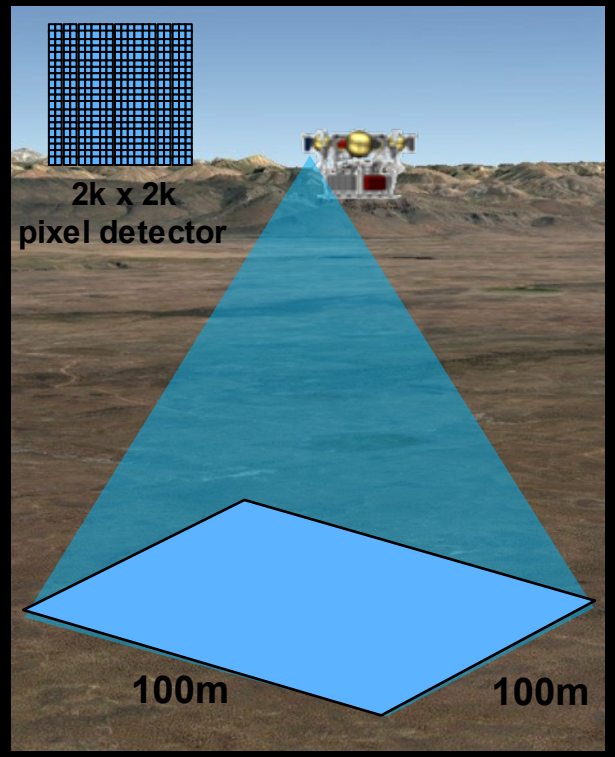
Simplified Scan Architecture



- Goal: Land 1-m² lander on unknown rough terrain in extreme radiation environment
- Multi-function ladar: Altimetry, course & fine 3D mapping
- *Real-time mapping 100 m x 100 m at 5-cm resolution in 1 second and image processing in 1 second*
- Current phase of program is to develop, build, and test a brassboard prototype

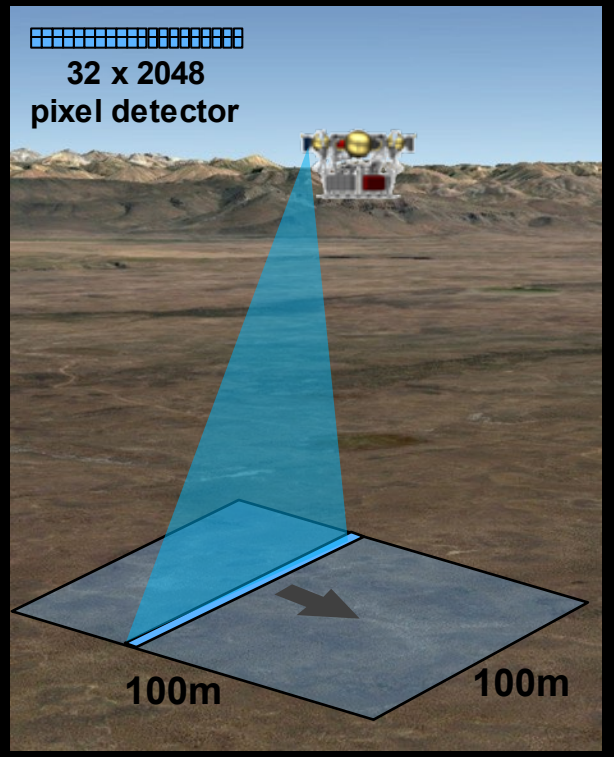
Lidar Scan and Array Format

Flood Illumination



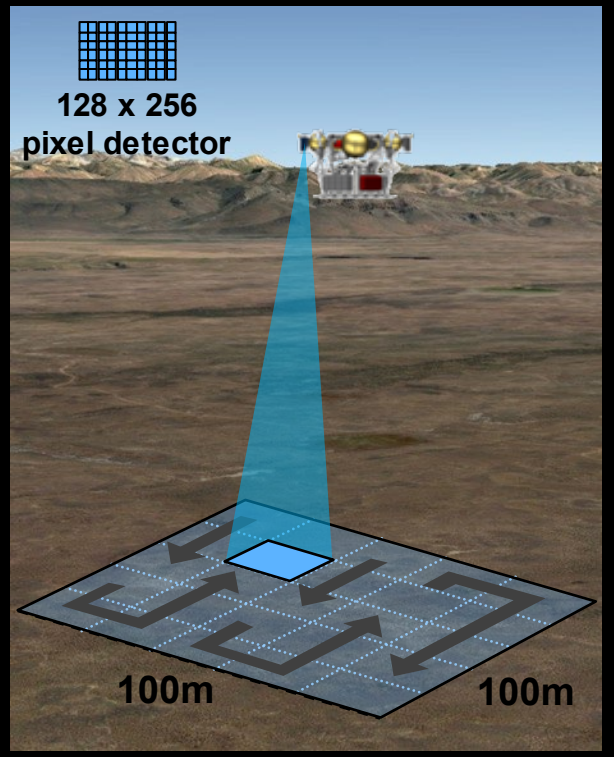
- Simple optics, scan mirrors & data processing
- Very challenging array design
- Link challenges

Line Scan



- Fairly simple optics, 1 D scan mirrors
- Limited tolerance to pixel loss
- Improved link

2D Scan

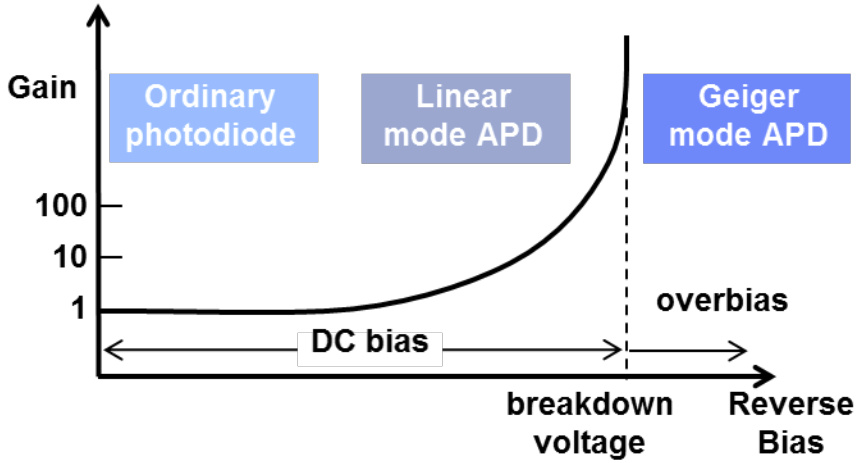


- Array similar to already fielded ladar systems
- More complex scanning and data processing
- Best link

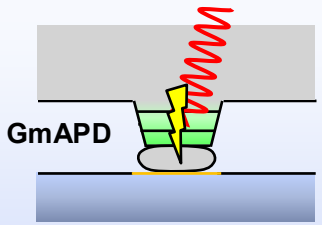
Line scanner selected as best balance between array design, link, and processing complexity

Geiger-Mode Avalanche Photodiode (GmAPD) Detector Technology

Photodiode Modes of Operation for MIT/LL Digital Pixel FPAs



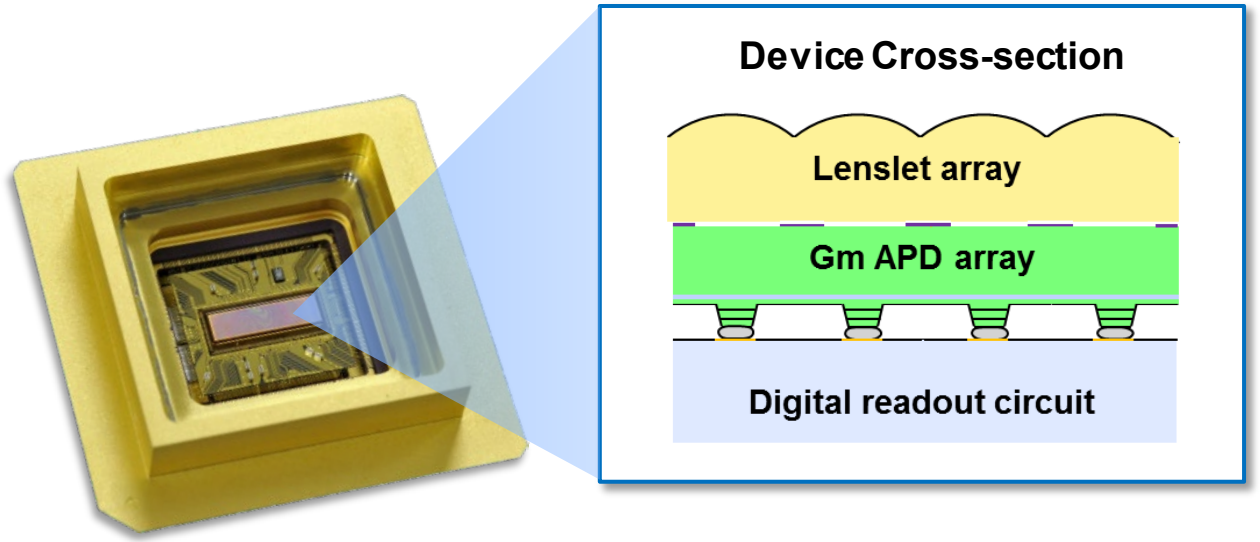
A single photon absorbed by the overbiased APD generates a fast rush of current



Single APD Cross section

Geiger-mode APDs provide:

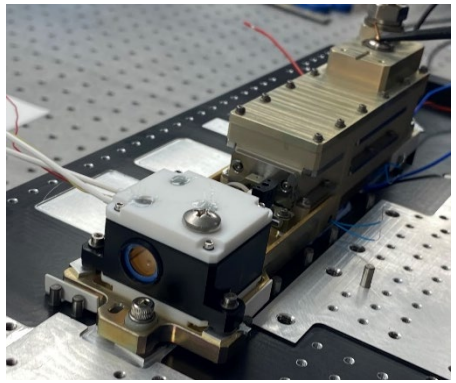
- Single-photon sensitivity
- Lots of current → easy digitization
- Fast breakdown → excellent (sub-ns) time resolution
- TEC accessible temperatures → low SWAP
- Large format arrays
- Stable operation compared to linear mode APD

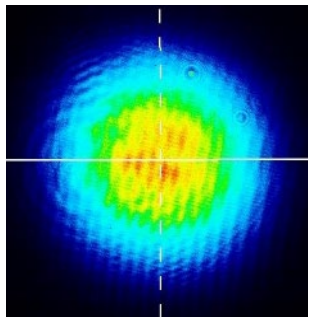


Ongoing ELSA Assembly and Integration

Lasers

- 532 nm, 10 kHz, 250 mW, 490 ps
- Space-traceable
- Completed



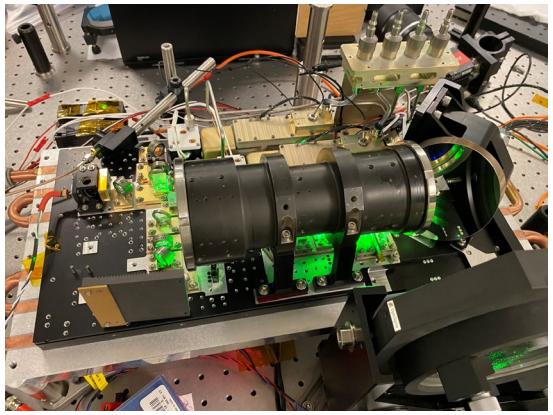


Detector

- 32 x 2048 pix
- 500ps timing
- Rad-hard design
- Completed

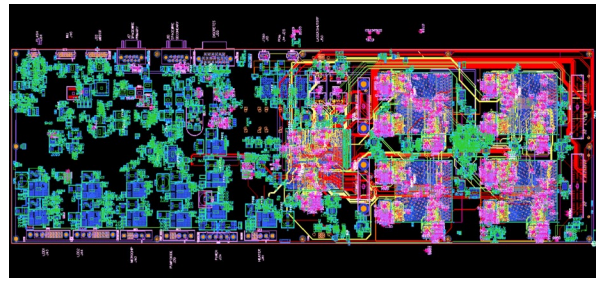
Opto-mechanical

- Integrated w/ lasers
- Tx & Rx assembled and aligned
- Next: integrate camera



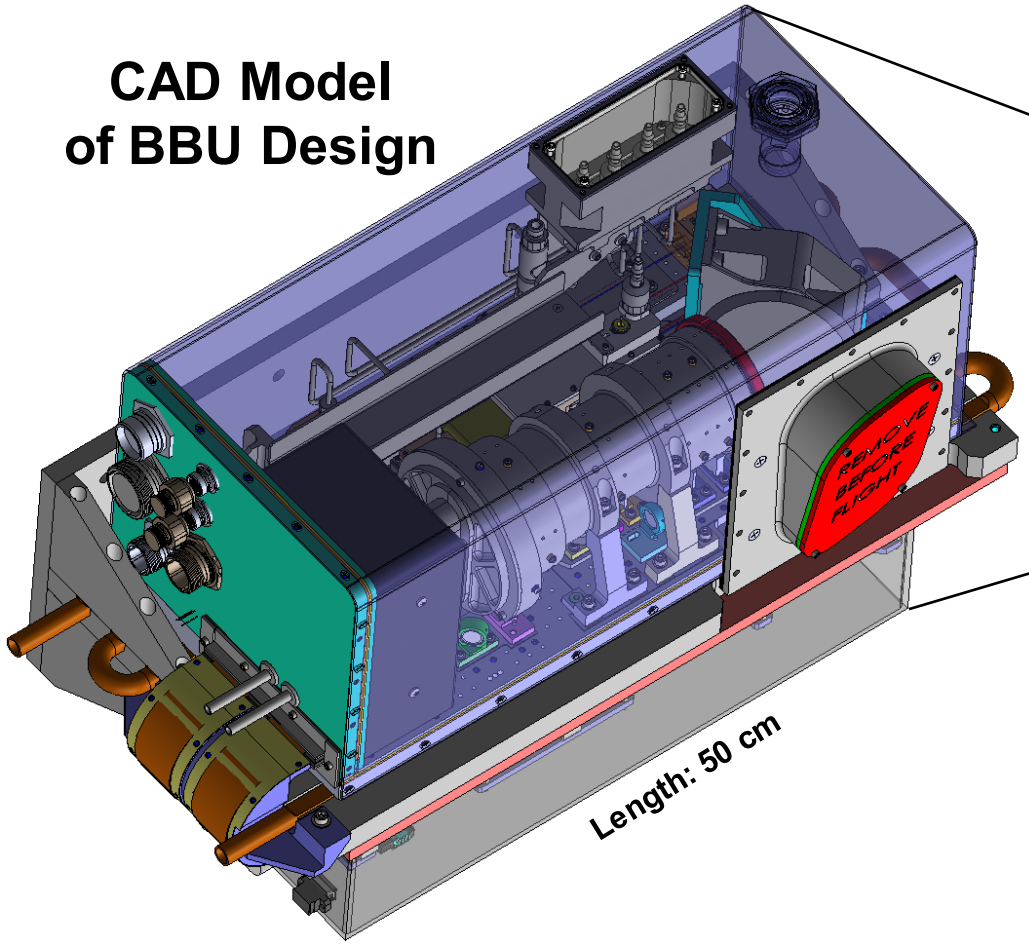
Electronics & Firmware

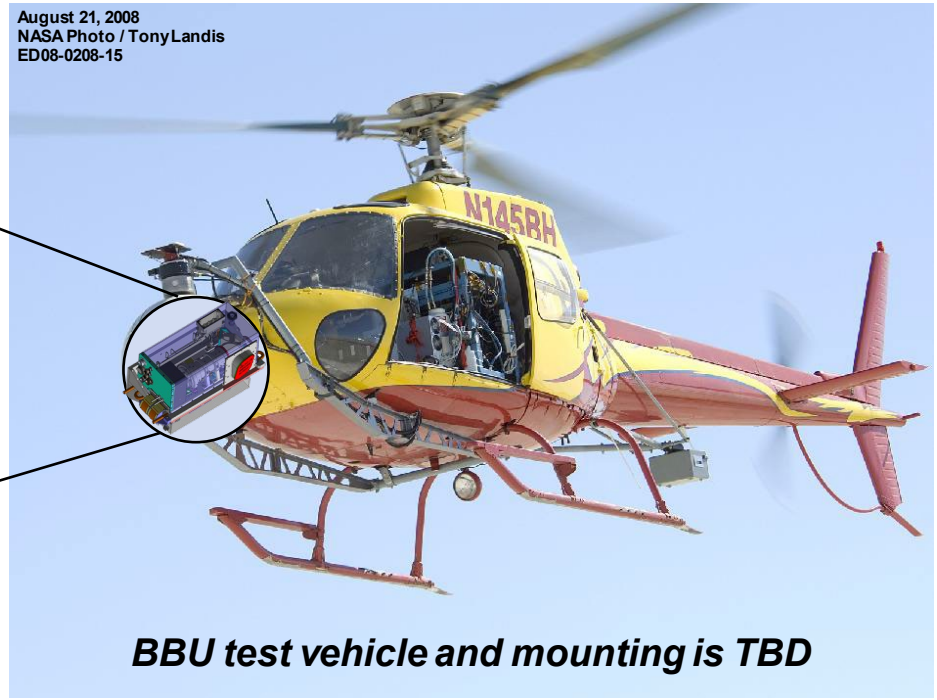
- Real-time mapping on 4x rad-tolerant FPGAs
- PCBs in fabrication
- FPGA processing implemented



ELSA Brassboard Validation Testing

CAD Model of BBU Design





BBU test vehicle and mounting is TBD

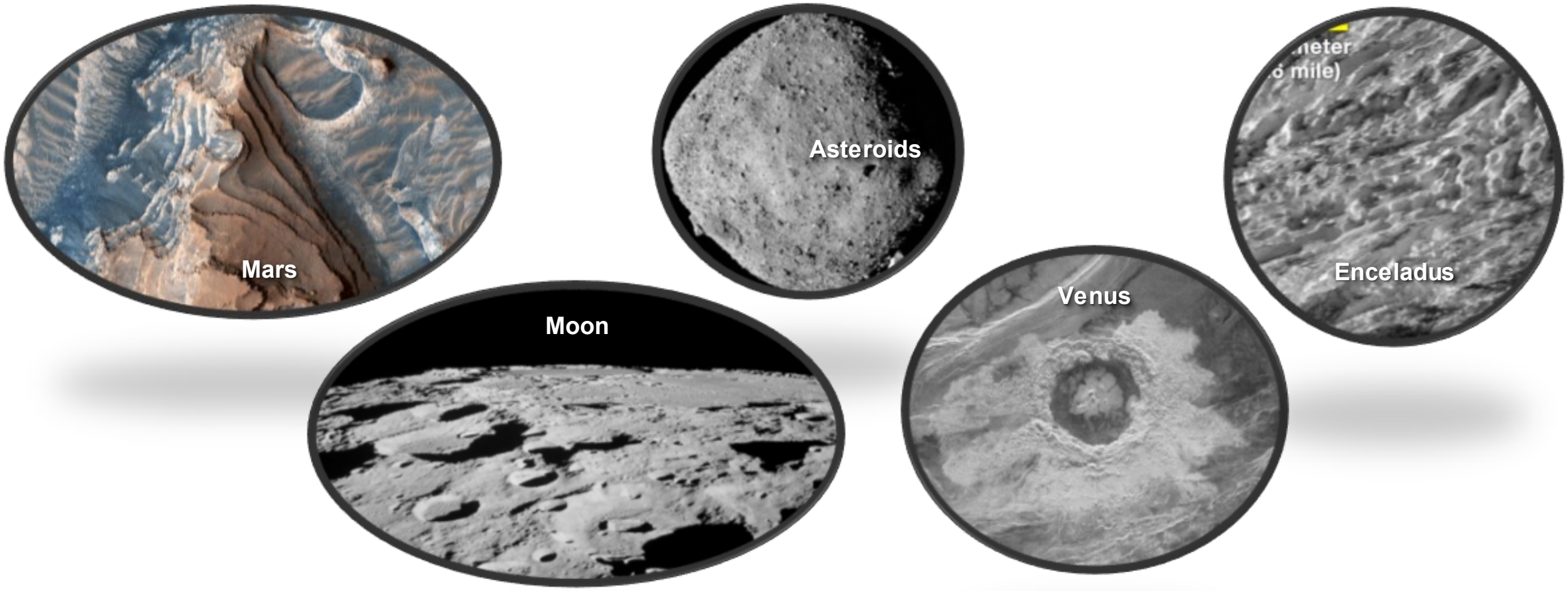
- Final BBU testing to cover all modes of operation, as test vehicle permits
- Daylight testing limited from significantly more solar background than Europa
- Radiation testing to be done on specific components

ELSA brassboard will demonstrate flight-traceable design with real-time FPGA processing and rad hard GmAPD camera

BBU: Brass Board Unit
SWaP: Size, Weight, and Power

GmAPD: Geiger-mode Avalanche Photodiode

ELSA Elsewhere



Optimized for a Europa mission, ELSA design could be utilized for other space missions

Summary

- NASA has a strong interest to explore Europa for signs of life
- Existing imagery of Europa lacking enough detail for site selection and hazard avoidance
- ELSA's high resolution imagery and altimetry enables autonomous hazard avoidance and safe landing on Europa
- The ELSA design brings significant technical challenges
- MIT Lincoln Laboratory has pushed technology and engineering to meet these challenges
- ELSA brassboard prototype is scheduled to be tested in 2023
- ELSA design general enough to be used for other missions (Enceladus, Moon, etc.)

Contact Information

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