Europa Luminescence Microscope

Richard C. Quinn[1], Antonio J. Ricco[1], Nathan Bramall[2], Joshua Forgione[1], Travis Boone[1], Kathryn Bywaters[3], Matthew Chin[1], Jonathan Diver[4], Arturo Escajeda[4], Christian Espinoza[1], Alden Falcon[2], Amanda Giacobbe[4], Björn Harink[2], Trinh Hoac[1], Isabel King[3], Sarah MacGregor[3], Brian Meier[2], Connor Nelson[1], Abraham Rademacher[1], Leslie Ann Radosevich[1], Jared Shimada[1], Justin Spring[3], Ming Tan[4], Linda Timucin[1], Huyen Tran[4], Jonathan Lu Wang[1], Kris Zacny[3]

[1]NASA Ames Research Center, Moffett Field CA
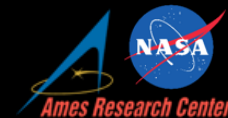[2]Leiden Measurement Technology LLC, Sunnyvale CA
[3]Honeybee Robotics, Altadena, CA
[4]Wainamics Inc, Pleasanton CA

Richard.C.Quinn@nasa.gov

Science Goals and Objectives

Goals:

➤ Search for evidence of life

➤ Assess the habitability

Objectives:

1) *Identify and characterize morphological, textural, indicators or life*

   Sub-micron bright field imaging; Spatial Fluorescence

2) *Detect and characterize inorganic indicators of life*

   Native Fluorescence - mineralogy

3) *Detect and characterize any organic indicators of life*

   Proteins, polypeptides (i.e. amine-containing compounds), Lipids in organized structures (e.g. membranes), Nucleic Acids

4) *Determine the presence of environmental factors essential for life (habitability)*

   Embedded sensors (pH, Eh, Conductivity)

Europa Luminescence Microscope

ELM: Europa Luminescence Microscope

(Micro)fluidics-based fluorescence and bright field imaging microscope with sub-micron resolution
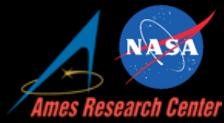
3 Operational Modes:

1) Bright field imaging for visual characterization and context.

2) Using DUV and visible light-emitting diodes (LEDs) for the excitation of native luminescence in the samples; mineralogical and biological.

3) Utilizing fluorescence stains specific to key structural biomarkers, i.e., typical membrane constituents such as fatty acids, phospholipid bilayers, and membrane proteins.
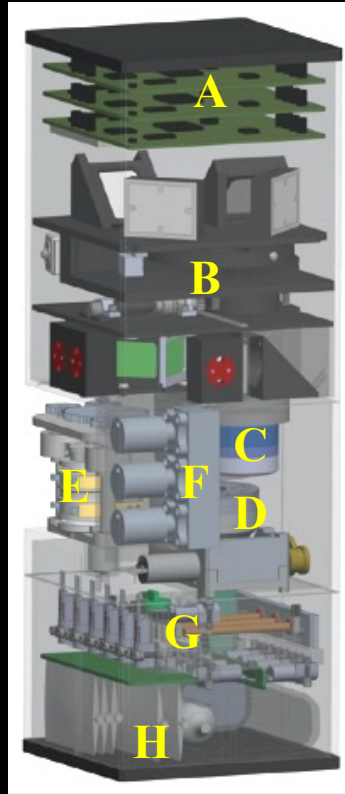
Europa Luminescence Microscope
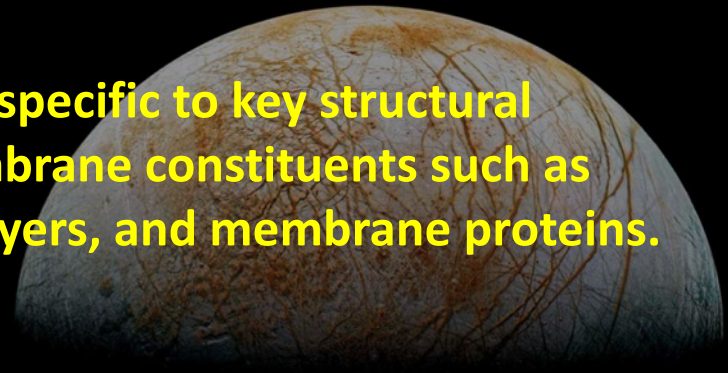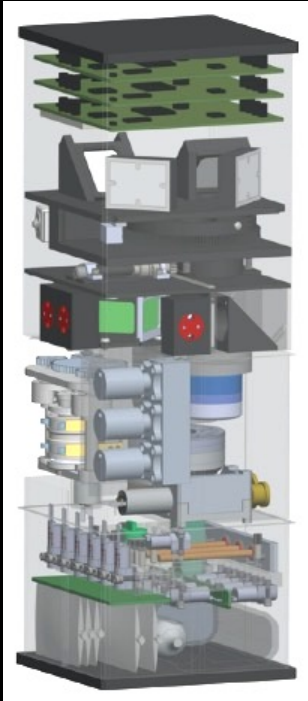
ELM Subsystems and ICEE-2 Development
Lineage: FLAIR Prototype (CubeSat) & LIfE Prototype (COLDTech)

Subsystems:
A) Camera Board/Electronics
B) Optics (Microscope)
C) Microscope Objective
D) Sample Filter Stage
E) Sample Transfer Dock
F) Hermetic Valve Block
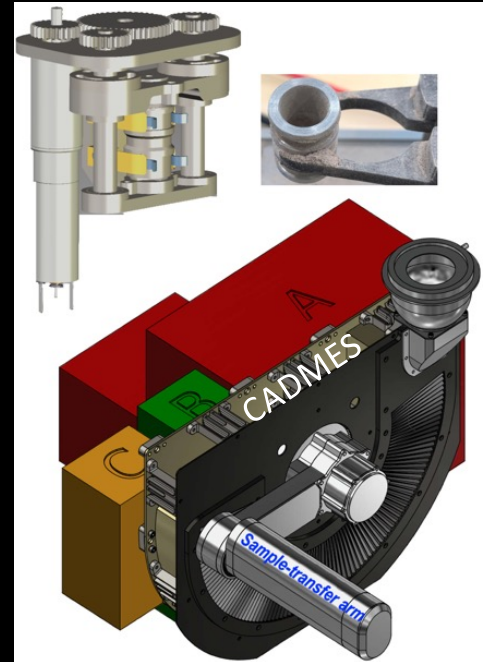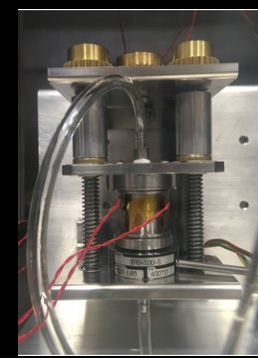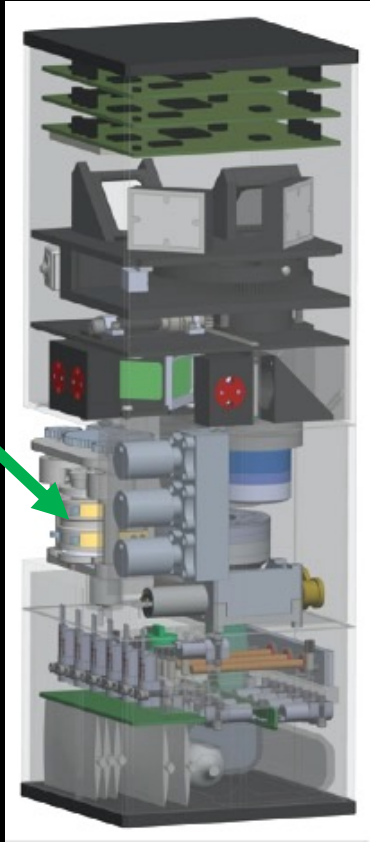G) Fluidics Manifold
H) Fluid Storage/Waste

ICEE-2 Focus:
➤ Environmental
➤ Packaging
➤ Performance
➤ COTS ⟶ Custom

1) Sample Transfer
2) Sample Filter Stage
3) Objective and Piezo Stage
4) Rad-Tolerant Camera
5) ConOps & Data Processing

Europa Luminescence Microscope
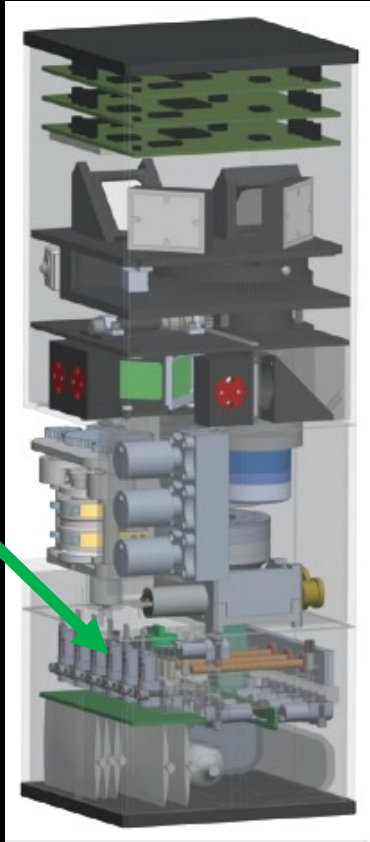
Sample Transfer Subsystem

Key Features

➢ **Designed for compatibility with the CADMES (Collaborative Acceptance and Distribution for Measuring Europan Samples) system (C. Malespin, PI GSFC)**

➢ **5 cc sample cup w/mesh bottom; sealing mechanism for reversible docking and undocking; thermal control to melt ice sample; piezo-agitator for particle transfer, coupled with fluidic manifold transfer line**

➢ **Honeybee Robotics breadboard complete.**

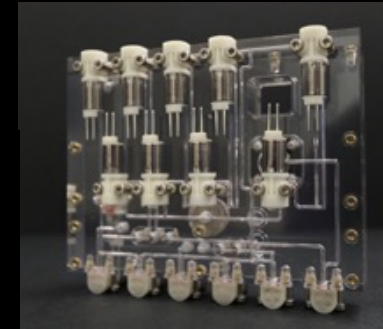➢ **Brassboard including environmental testing in progress.**

Europa Luminescence Microscope

CADMES

Sample-transfer arm

Fluidics Subsystem (Sample Processor)
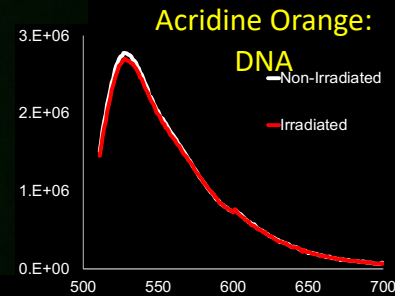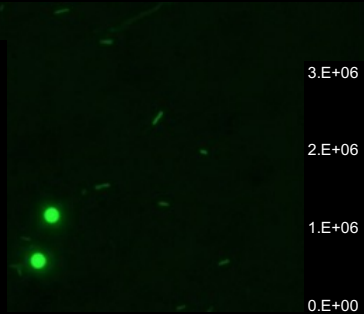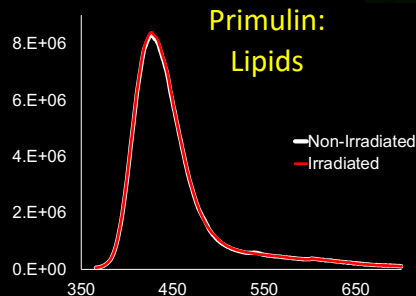
Key Features

➢ **8 cm x 9 cm Monolithic Fluidic Manifold**

➢ **Space Biology Lineage:**

   Requirement for Perfect Sterility

➢ **pH, ORP and Pressure Measurements for feedback control**

➢ **Fluorescent Stains: Porous Polymer Stabilization and Storage**

➢ **Radiation Tested to > 300 krad; including fluorescent stains**

Europa Luminescence Microscope

"Top"

"Bottom"

Primulin: Lipids

- Non-Irradiated
- Irradiated

Acridine Orange: DNA

- Non-Irradiated
- Irradiated

# Fluidics Subsystem (Particle Filter Stage)

Key Features

➢ **Custom silicon nitride membrane particle filters on Si wafer**

➢ **7-sets of three inline filters**

➢ **Three stage filtering 10 μm; 1 μm; 0.22 μm**

➢ **Etched calibration targets on Si wafer**

➢ **Filter geometry optimized for microscope field of view**

➢ **Optical positioning sensor on rotary stage**

Europa Luminescence Microscope
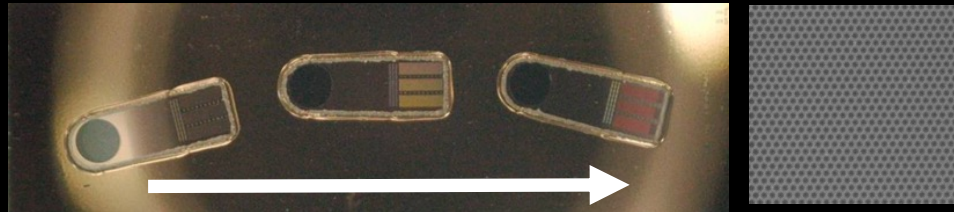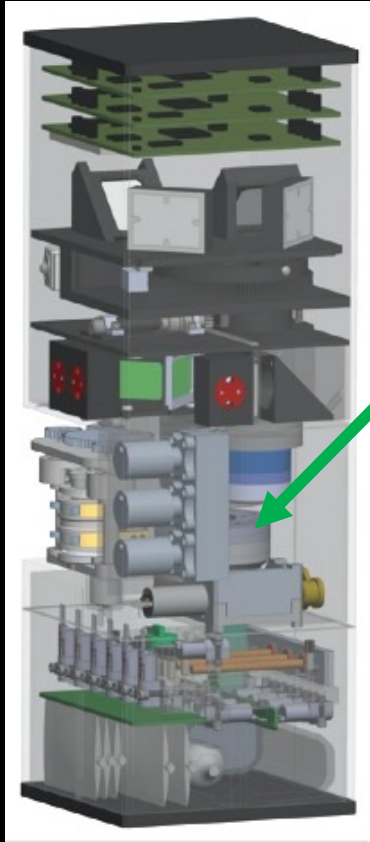
Optics Subsystem (Microscope)

Key Features:

- ➤ **Custom 40x objective**
- ➤ **Field-of-View - 300x263 μm**
- ➤ **Spatial Resolution < 0.5 μm**
- ➤ **Depth-of-Field - 2 μm**
- ➤ **Custom piezo focusing stage**
- ➤ **Z-motion up to 400 μm**
- ➤ **Z-positioning accuracy 1 nm**
- ➤ **LED Excitation Wavelengths (4):**

  275, 375, 470, & 525 nm

- ➤ **Emission Filters (4):**

  334, 470, 529, & 579
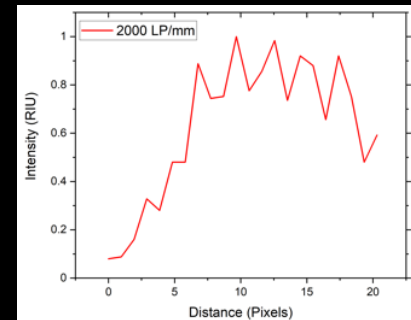
Optical components have passed radiation testing to 300 krad, including:
Bandpass filters (single- and multi-band); LED modules; Lenses and Lens Materials.

Europa Luminescence Microscope

Electronics Subsystem (& Microscope Camera)

Key Features:

- ➢ **COTS Camera replaced with custom board using e2V CIS115 image sensor (JUICE mission heritage)**

- ➢ **Back thinned - UV sensitive**

- ➢ **Sample maps to 0.18 µm/pixel**

- ➢ **Image processing software ported to rad-hard microcontroller**

- ➢ **Autonomous Image Processing: incorporates z-stacking, data interpretation, data compression and decisional data generation**

Europa Luminescence Microscope
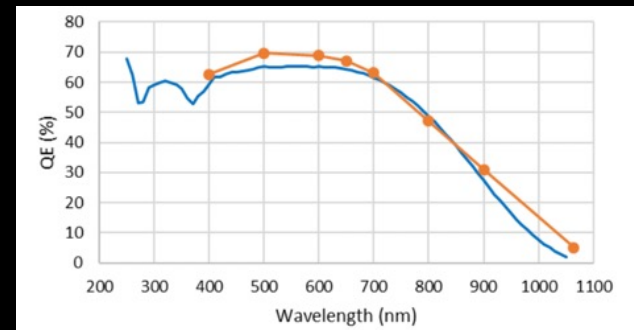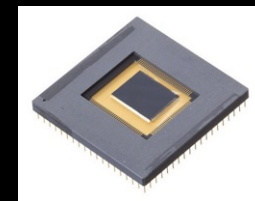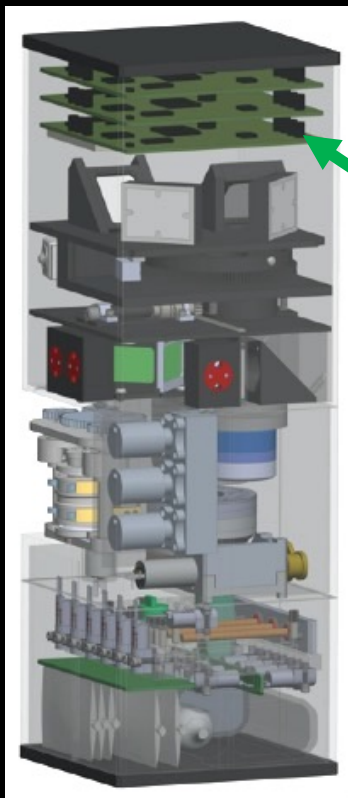
Acknowledgements

NASA Instrument Concepts for Europa Exploration