

Luminescence Imager for Exploration

Richard C. Quinn¹, A.J. Ricco¹, N. Bramall², B. Christner³, A. Murray⁴, T. Boone¹,
K. Bywaters⁵, M. Chin¹, W. Czakon¹, A. Gillette¹, B. Harink², A. LoFranco³, N.
Mai¹, B. Meier², K. Palmer³, A. Rademacher¹, J. Shimada¹

¹NASA Ames Research Center, Moffett Field CA ²Leiden Measurement Technology, Sunnyvale CA;
³U. Florida, Gainesville FL; ⁴Desert Research Institute, Reno NV; ⁵Honeybee Robotics, Altadena CA

Richard.C.Quinn@nasa.gov

Science Goals and Objectives

Goals:

- Search for evidence of life
- Assess habitability

Objectives:

1) *Identify and characterize morphological, textural, indicators of 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)*

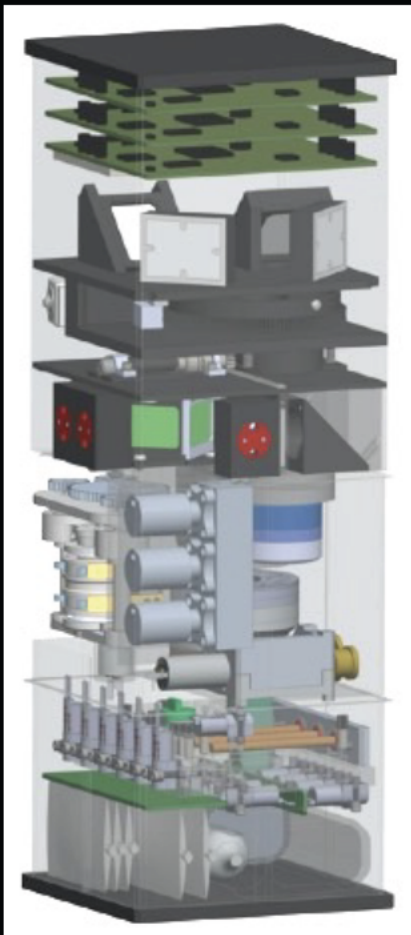
Embedded sensors (pH, Eh, Conductivity)

Luminescence Imager for Exploration

LifE: A Microscope for Life Detection

(Micro)fluidics-based imaging microscope with 3 operational modes:

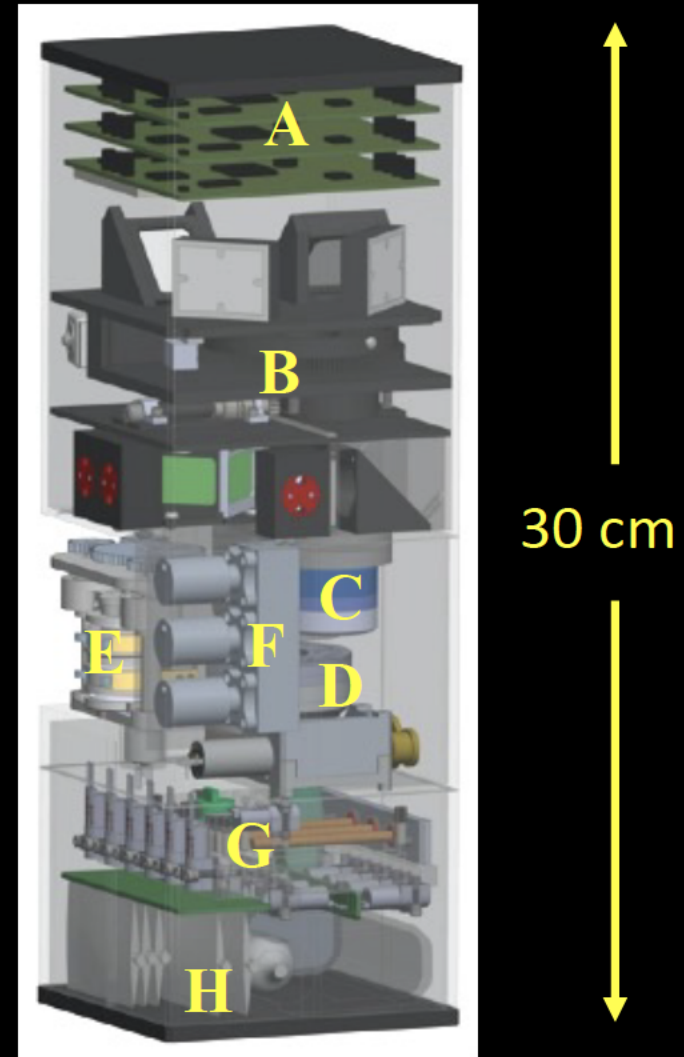
- 1) Bright field imaging for visual characterization and context.
- 2) Using DUV and visible light-emitting diodes (LEDs) for the excitation of native luminescence in the samples; mineralogical and biological.
- 3) Utilizing fluorescence stains specific to key structural biomarkers, i.e., typical membrane constituents such as fatty acids, phospholipid bilayers, and membrane proteins.



Luminescence Imager for Exploration

Subsystems:

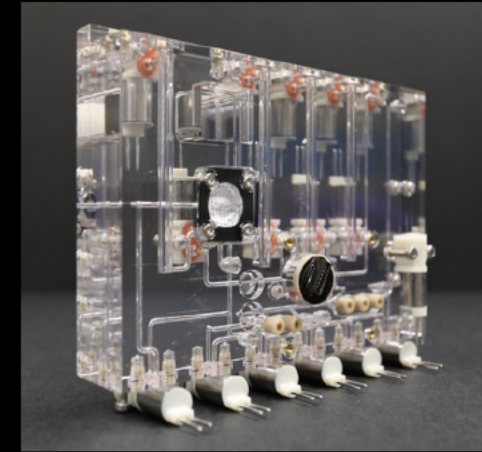
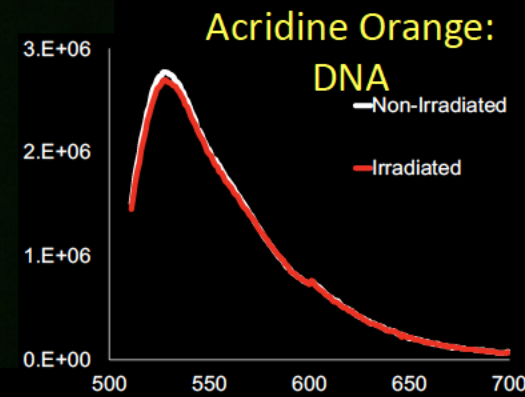
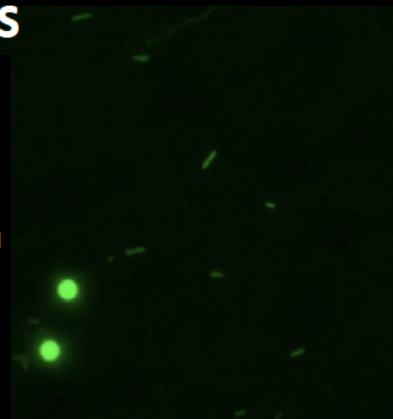
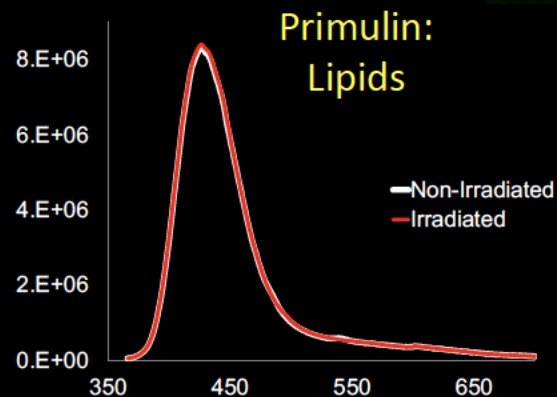
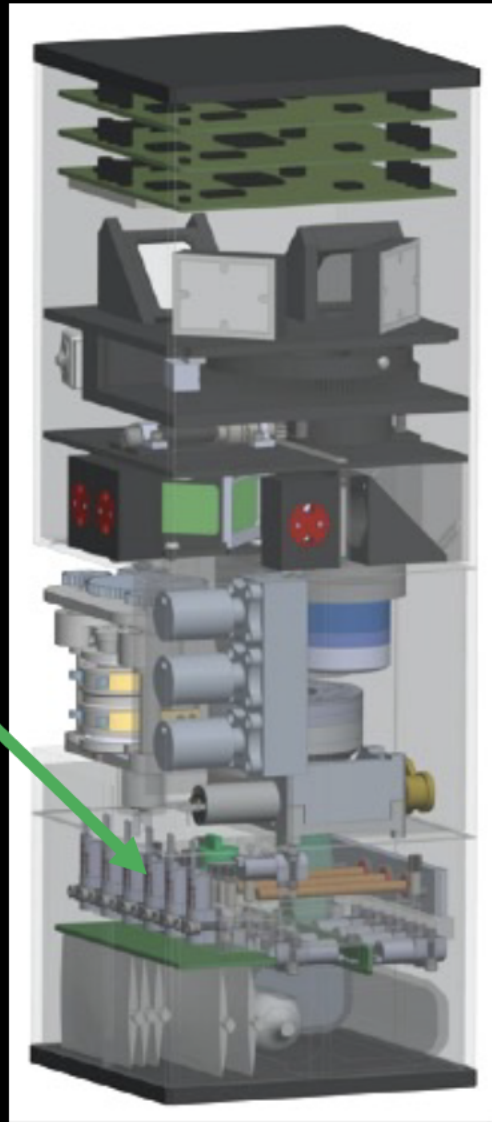
- A) Camera Board/Electronics
- B) Optics (Microscope)
- C) Microscope Objective
- D) Sample Filter Stage
- E) Sample Transfer Dock
- F) Hermetic Valve Block
- G) Fluidics Manifold
- H) Fluid Storage/Waste



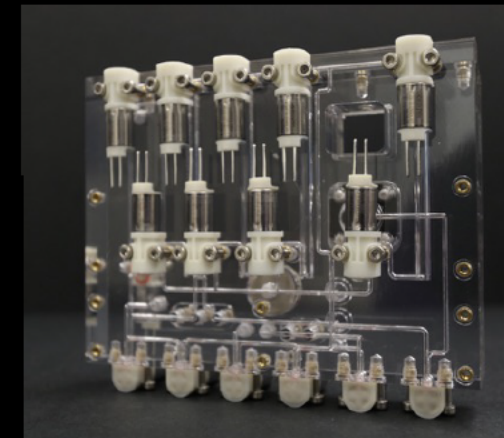
Fluidics Subsystem (Sample Processor)

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
- System control valves
- Fluorescent Stains: Porous Polymer Stabilization and Storage
- Radiation Tested to > 300 krad; including fluorescent stains



"Top"

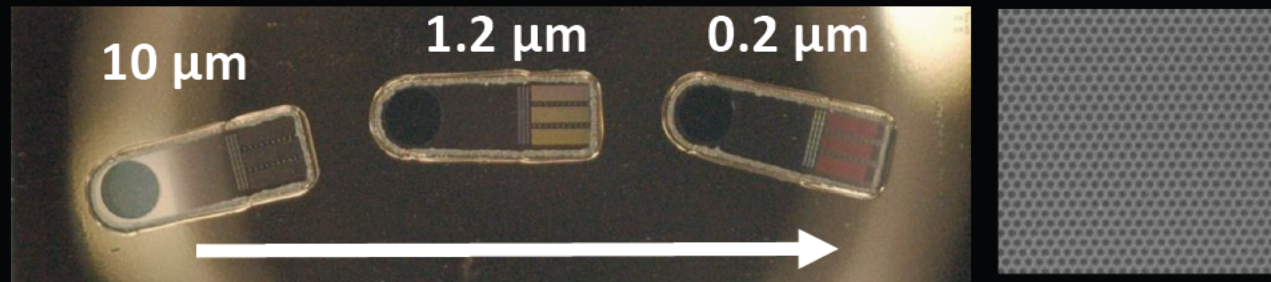
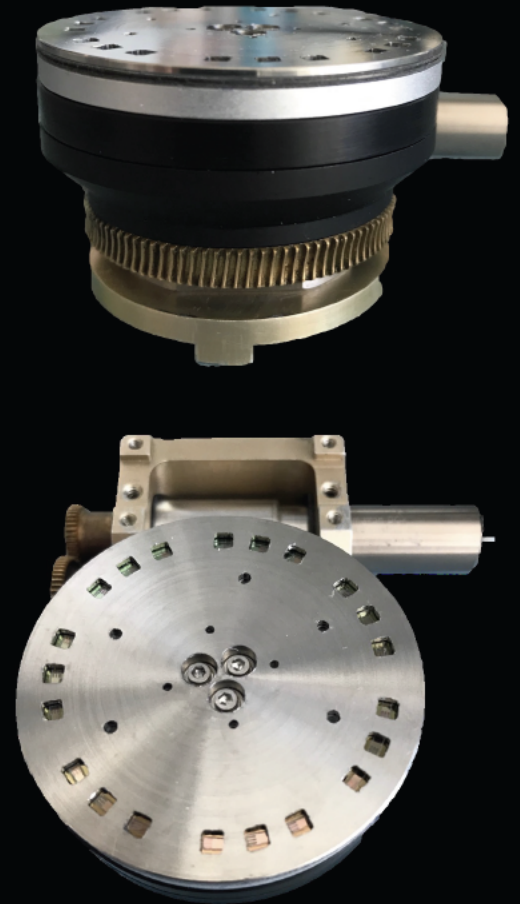
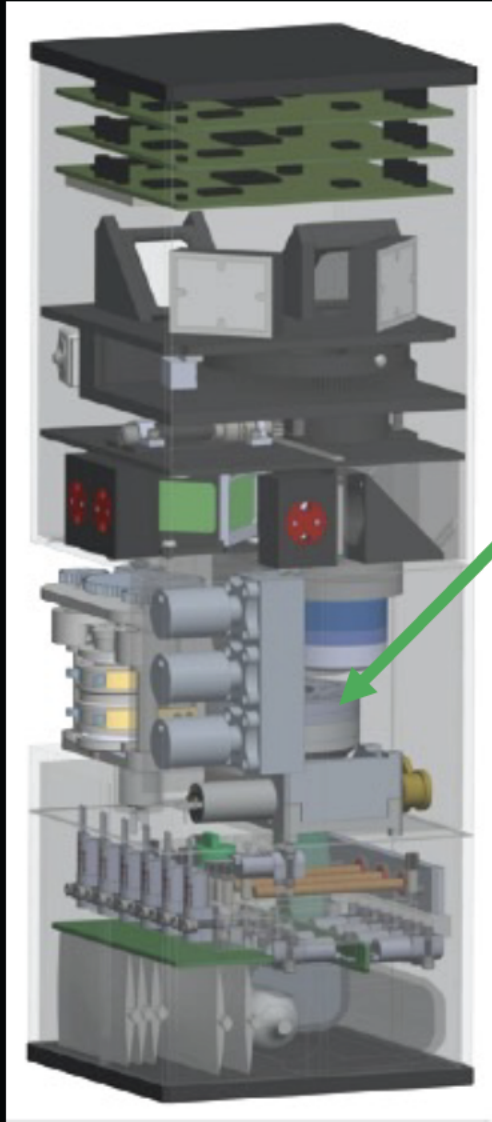


"Bottom"

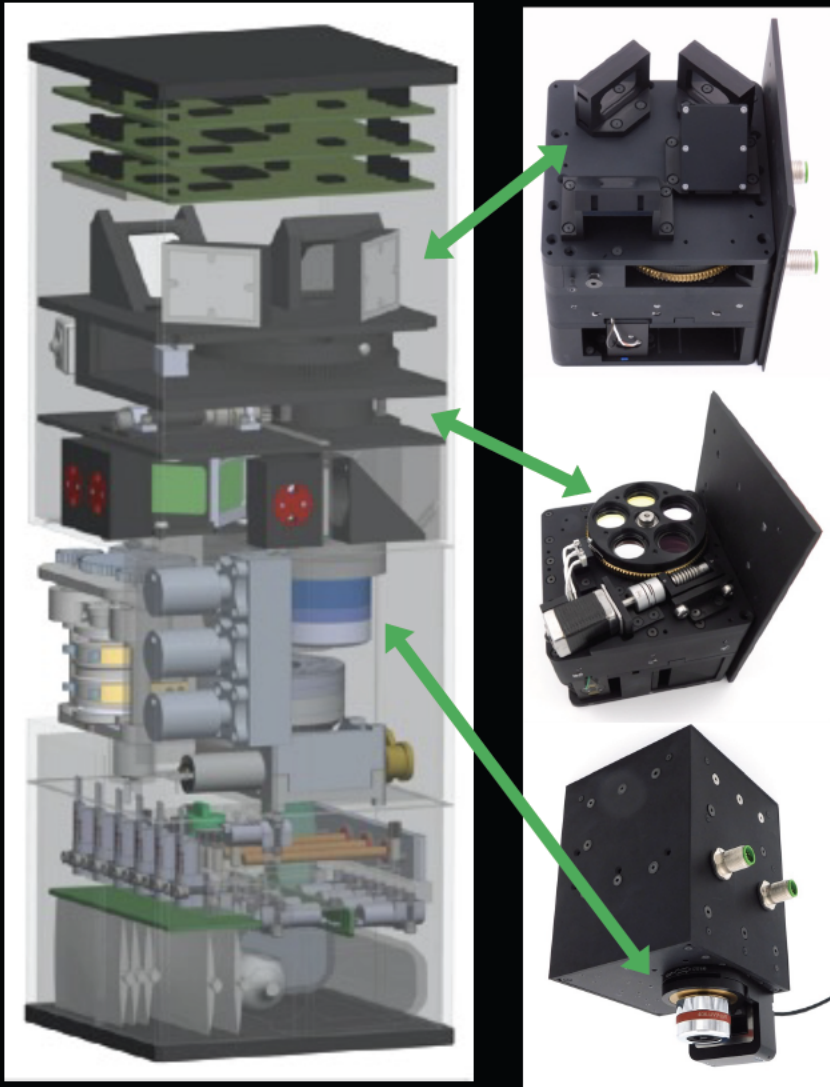
Fluidics Subsystem (Particle Filter Stage)

Key Features

- Custom silicon nitride membrane particle filters on Si wafer
- 7-sets of three inline filters
- Three stage filtering $10\ \mu\text{m}$; $1\ \mu\text{m}$; $0.2\ \mu\text{m}$
- Etched calibration targets on Si wafer
- Filter geometry optimized for microscope field of view
- Optical positioning sensor on rotary stage



Optics Subsystem (Microscope)



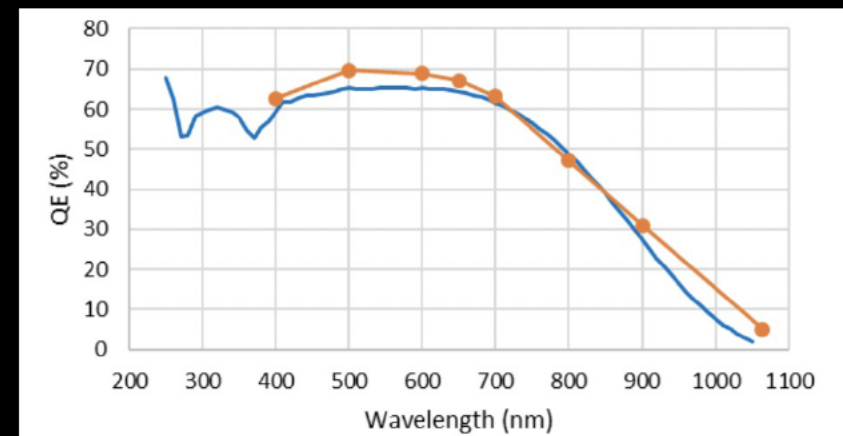
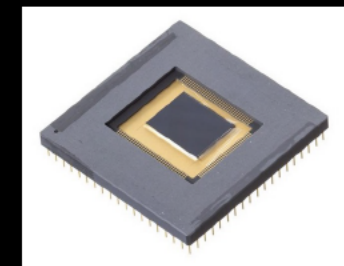
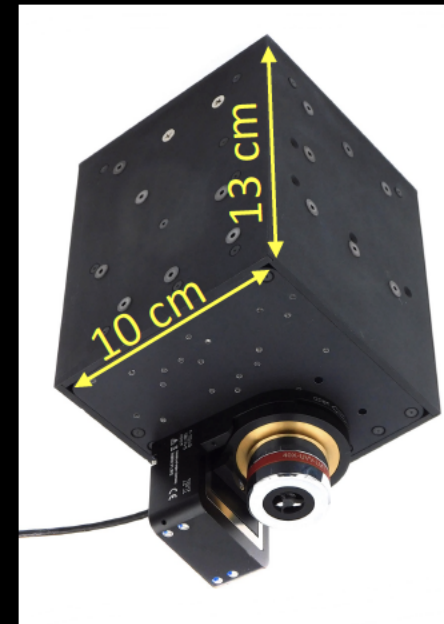
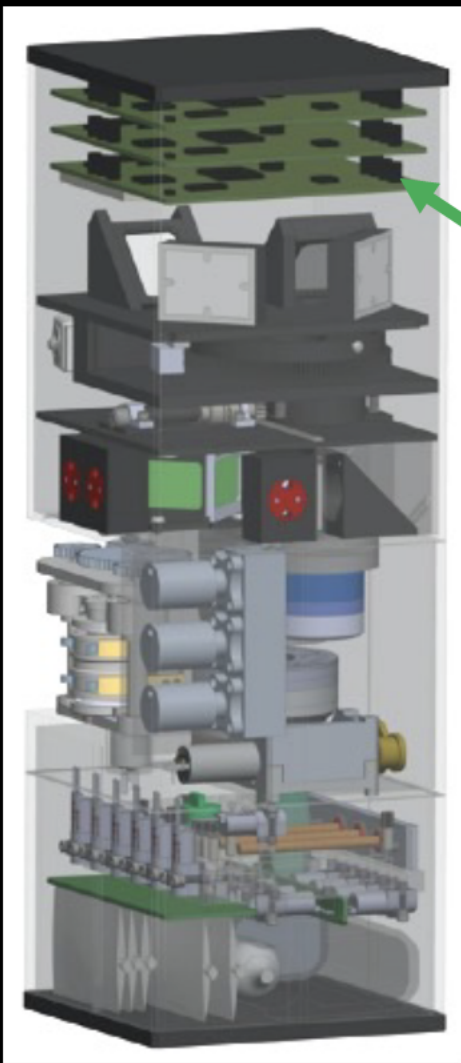
Key Features:

- Custom folded optics
- 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 nm
- 300 krad tested including:
Bandpass filters (single- and multi-band); Lenses and Lens Materials.
- General Environmental Verification Standard vibration and shock testing (GSFC-STD-7000).

Electronics Subsystem (& Microscope Camera)

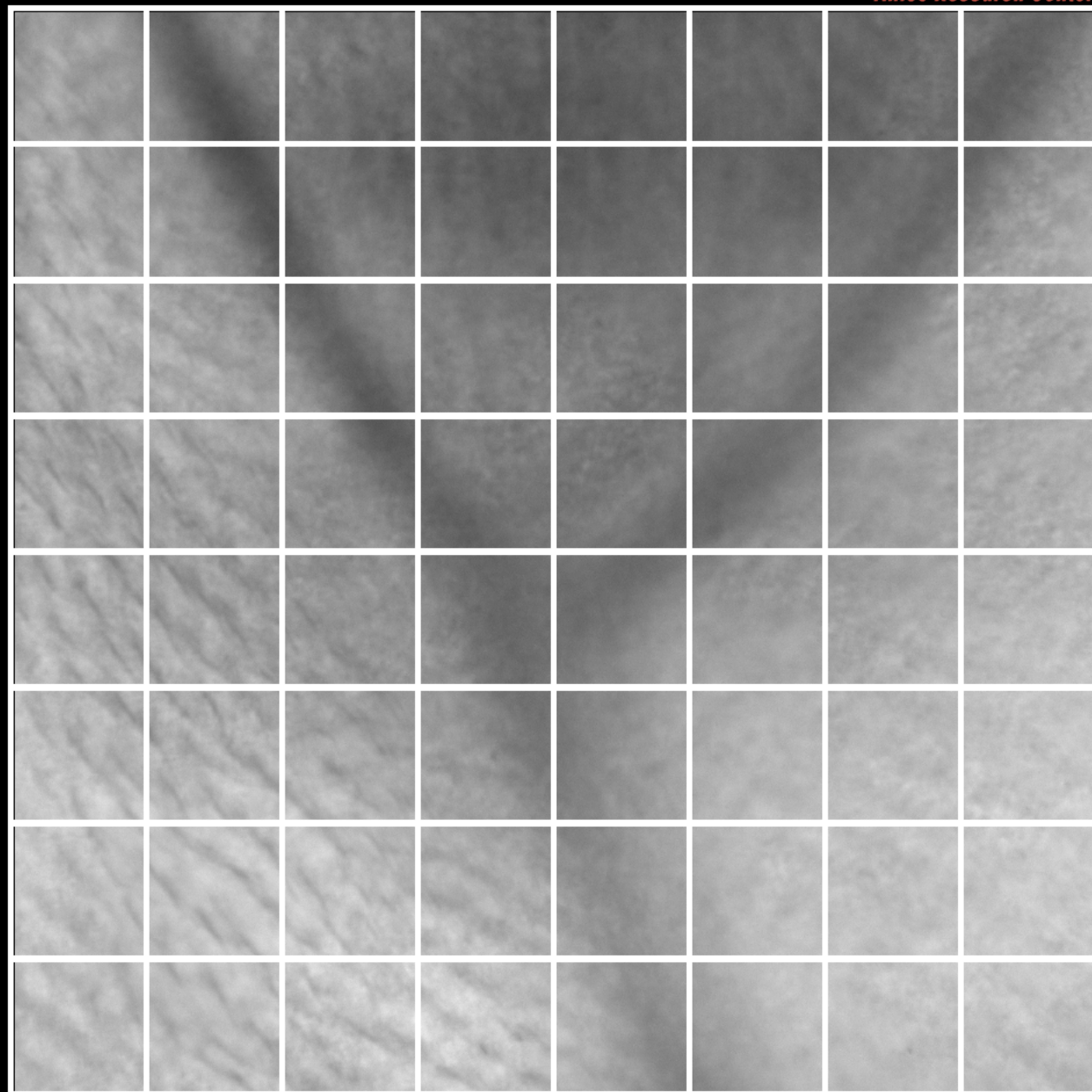
Key Features:

- COTS camera replaced with custom rad-tolerant board using e2V CIS115 image sensor (JUICE mission heritage)
- Back thinned - UV sensitive
- Sample maps to $0.18 \mu\text{m}/\text{pixel}$
- Image processing software ported to rad-hard microcontroller
- Autonomous Image Processing: incorporates z-stacking, data interpretation, data compression and decisional data generation



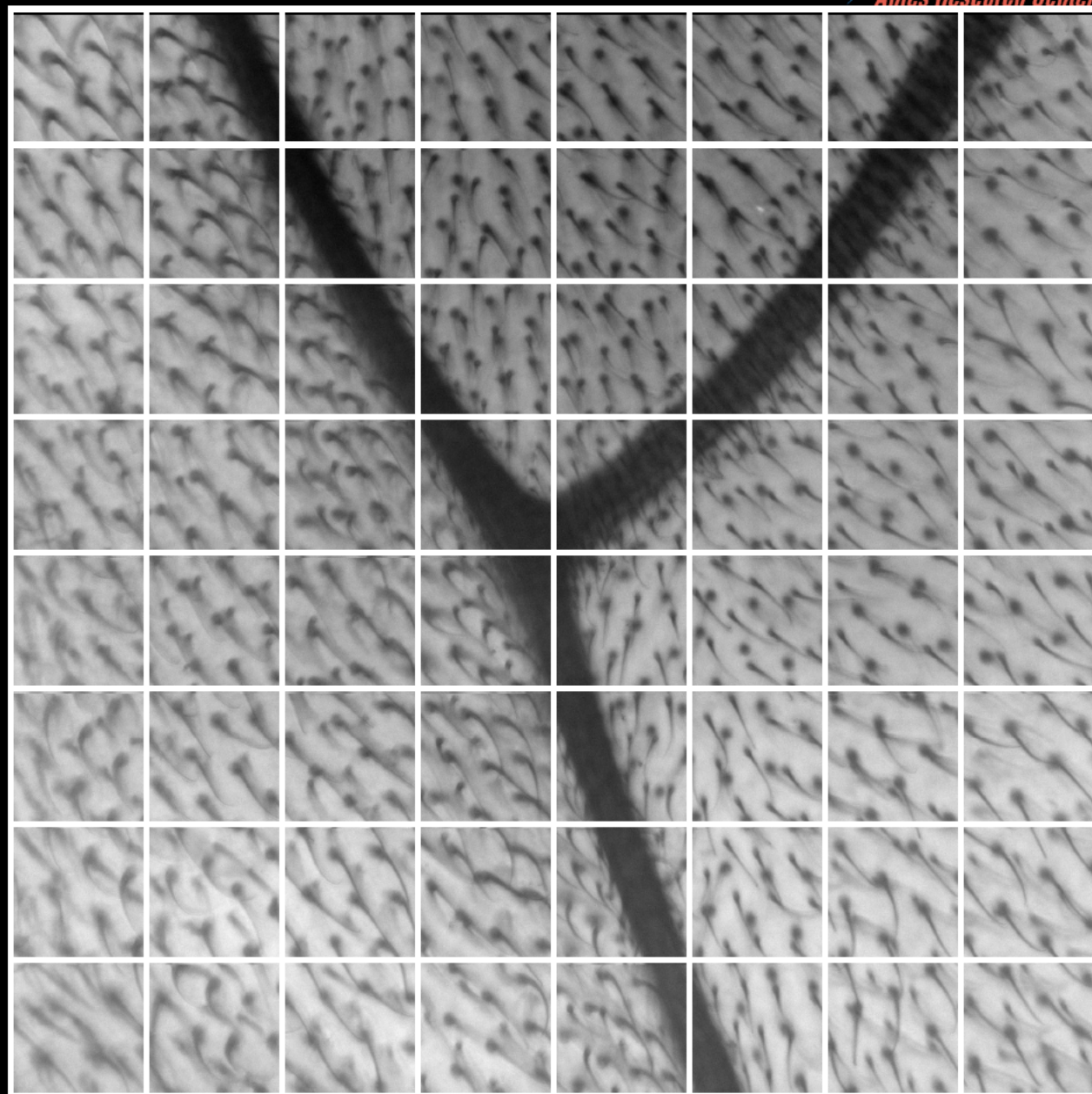
LfE Bright-Field Imaging

- 275, 375, 470, and 525 nm LED illumination
- Autonomous Z-stack focusing
- 50 images collected along z-axis
- 1 μm increments using piezo stage
- Images are divided into tiles
- In-focused tile from each stack selected
- Single in-focus image is stitched together



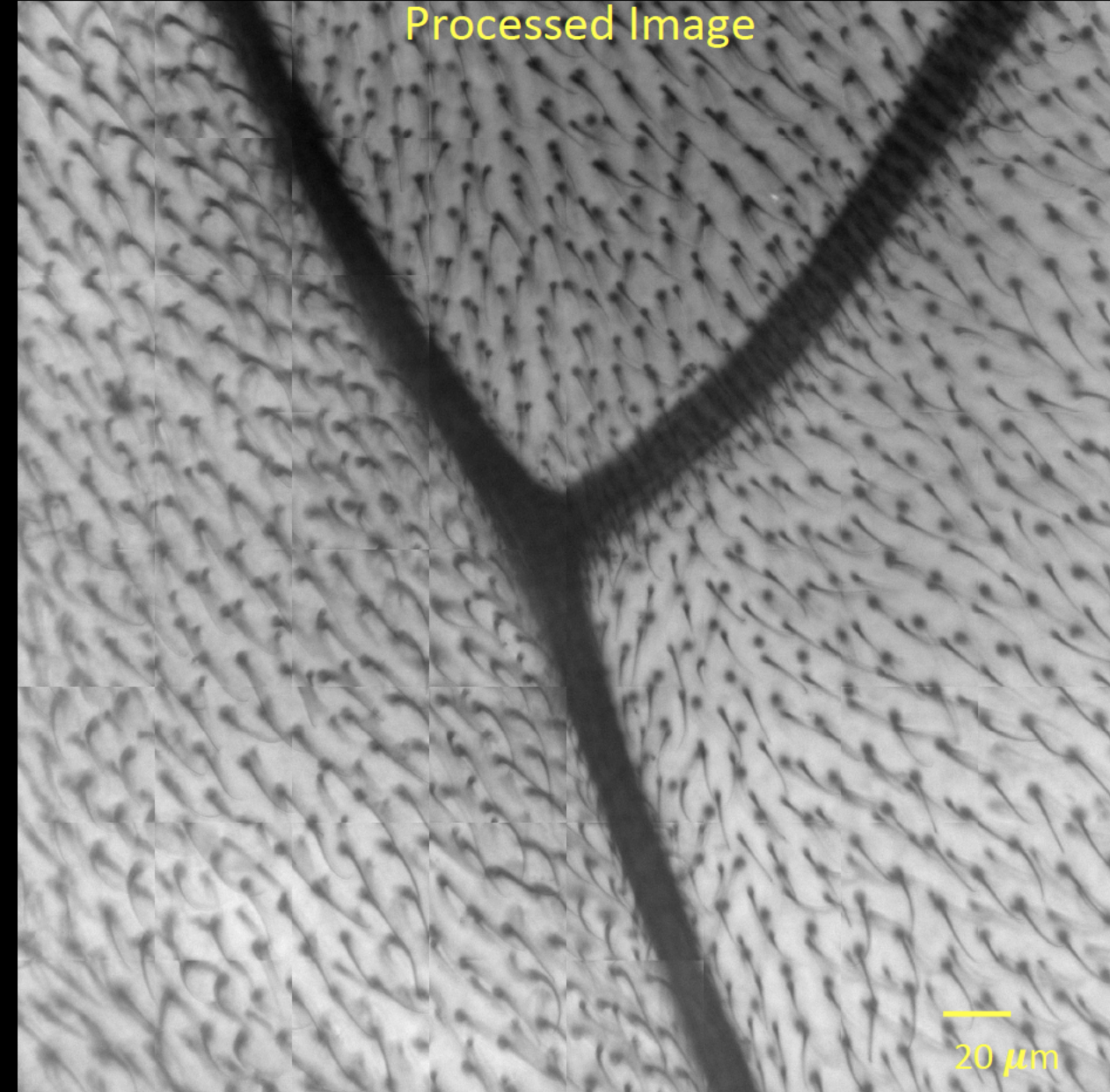
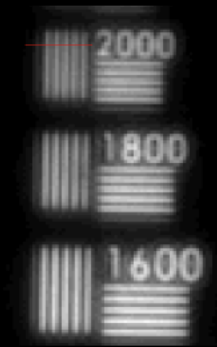
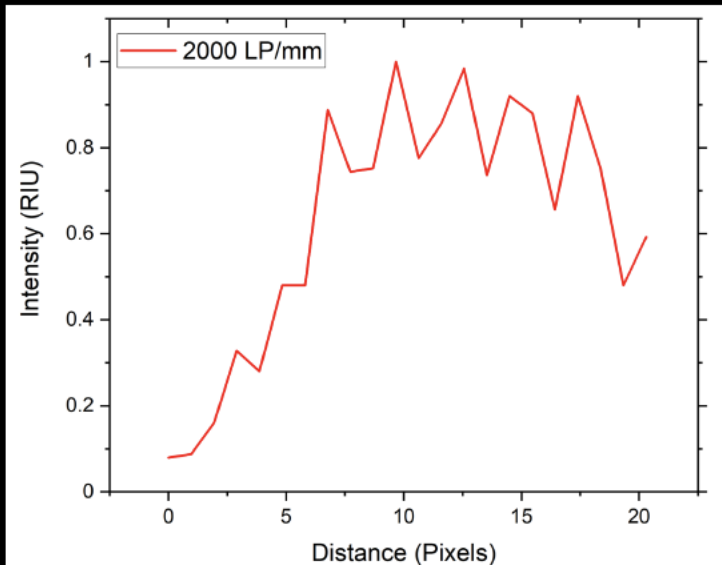
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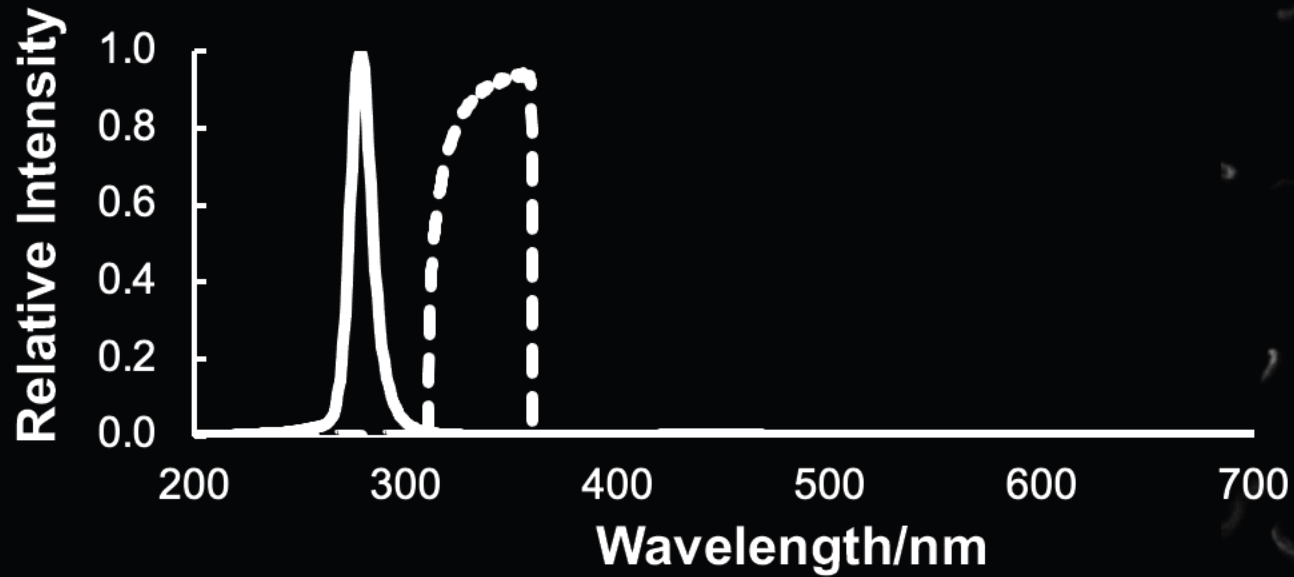
LfE Bright-Field Imaging

- n-focused tile from each stack selected
- Single in-focus image is stitched together
- Focused resolution better than $0.5\ \mu\text{m}$
- 2000 line pairs per mm
- Line width $0.25\ \mu\text{m}$

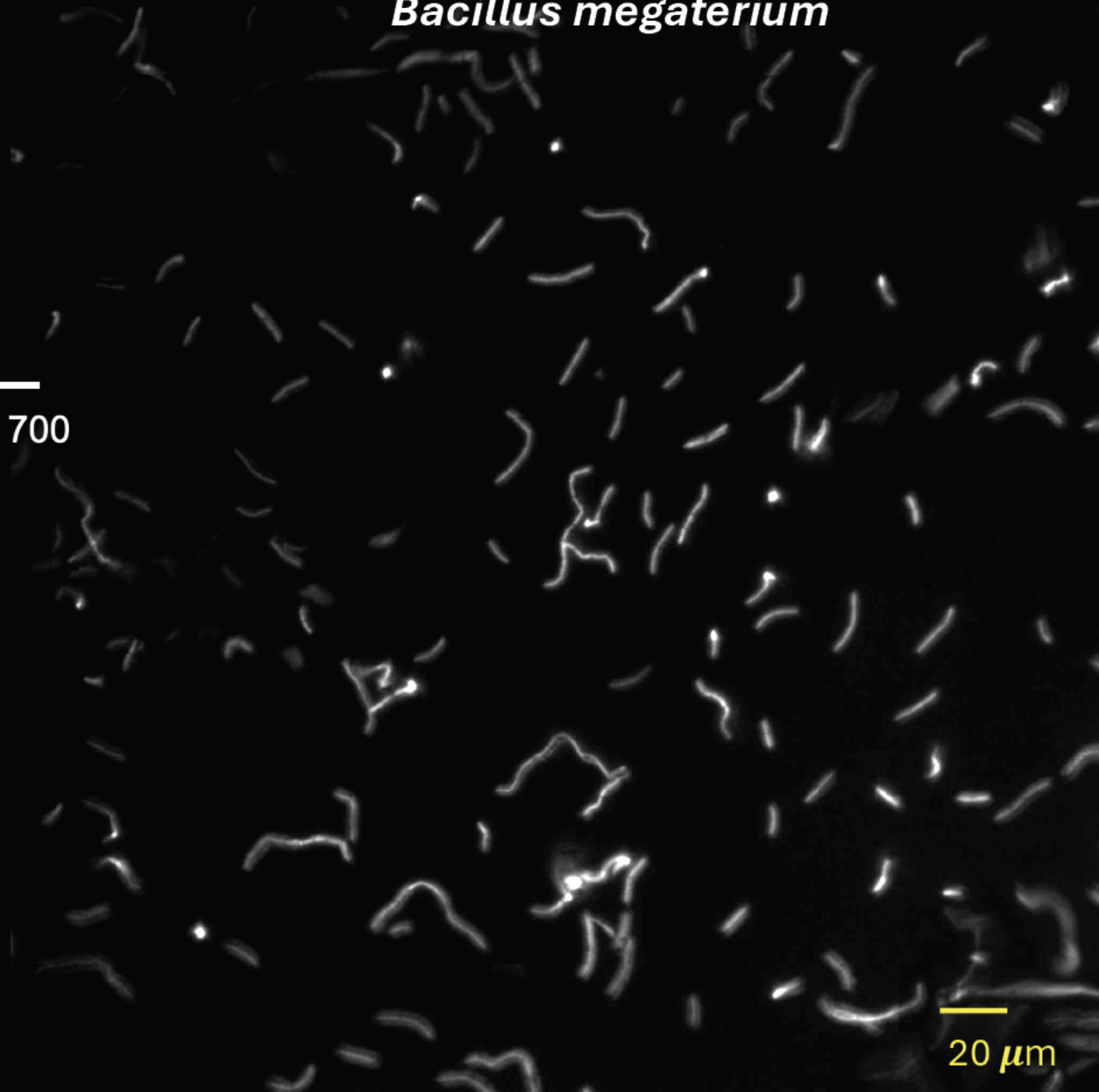


Native UV Fluorescence Imaging

Bacillus megaterium



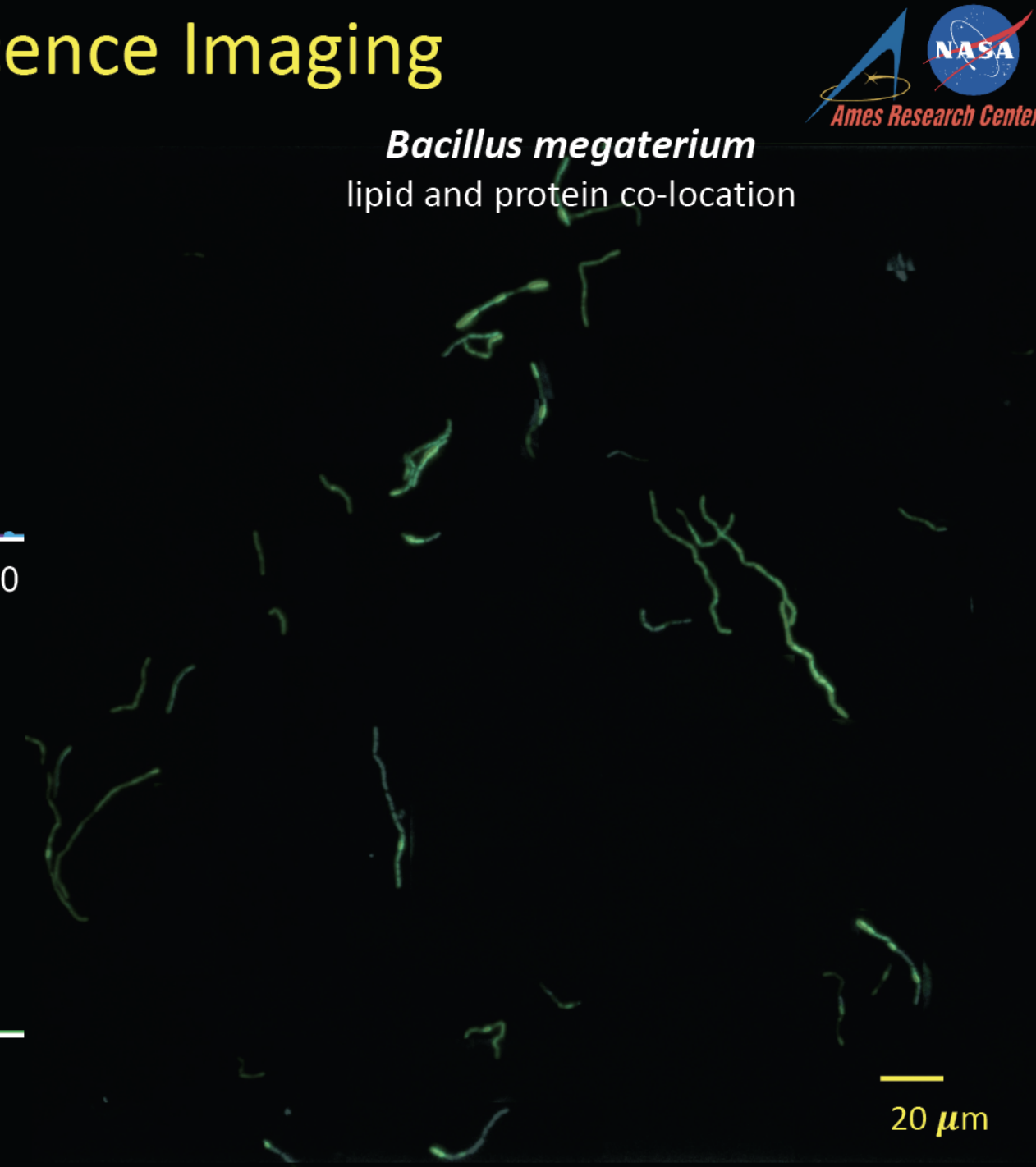
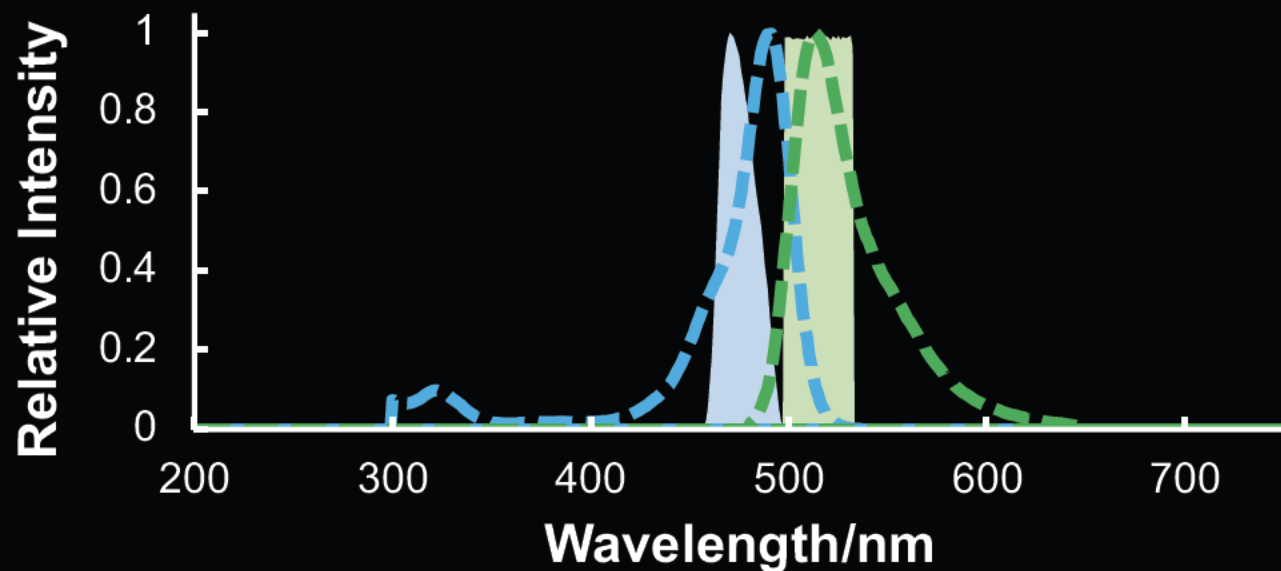
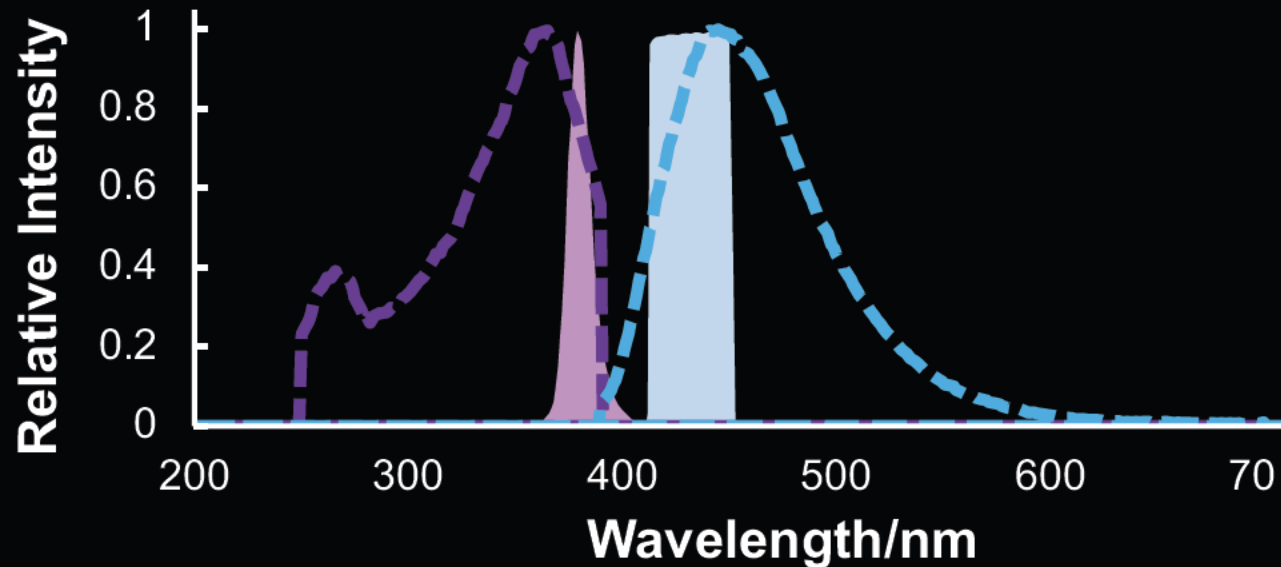
- 275 nm LED Excitation
- 334/40 nm Bandpass Emission Filter
- Intrinsic protein fluorescence



Life Fluorescence Imaging

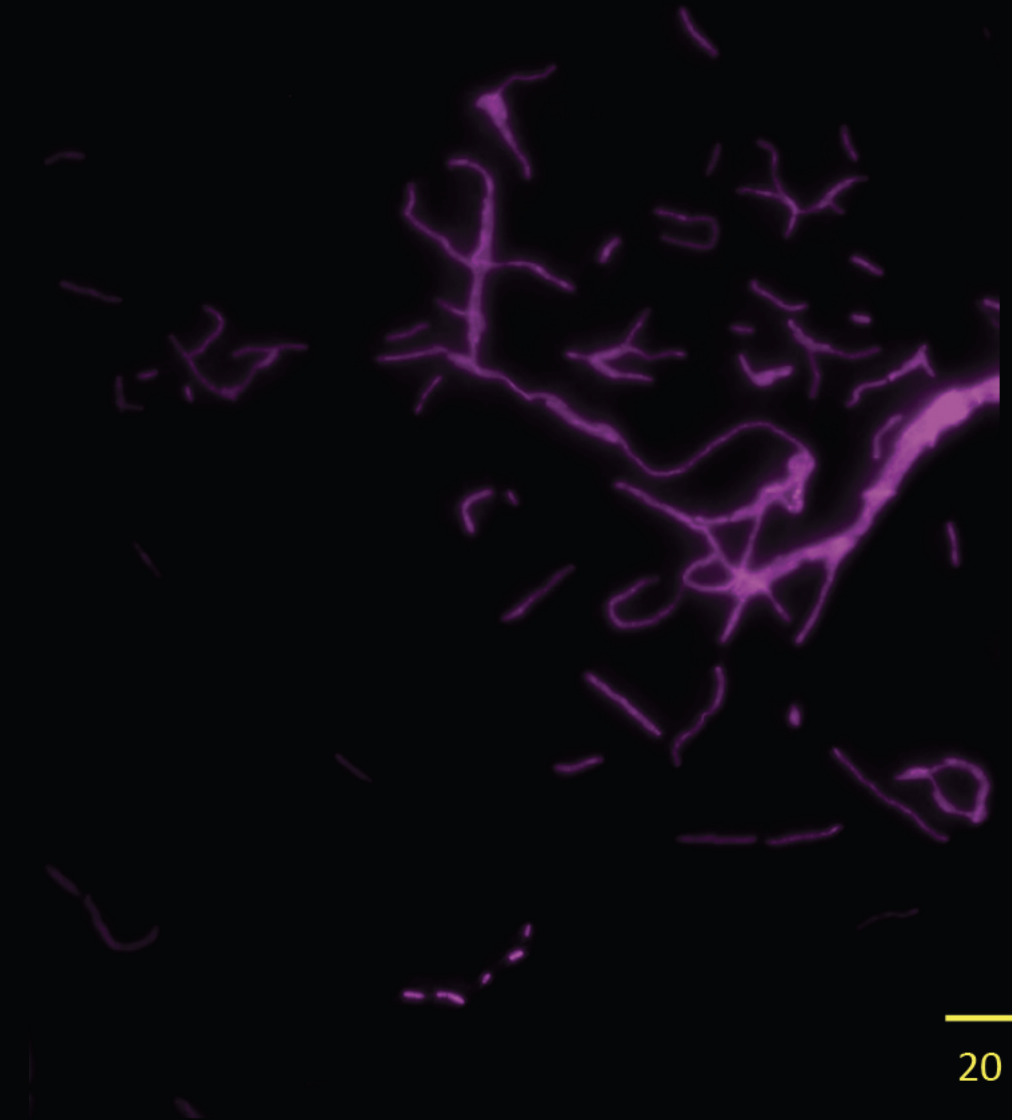
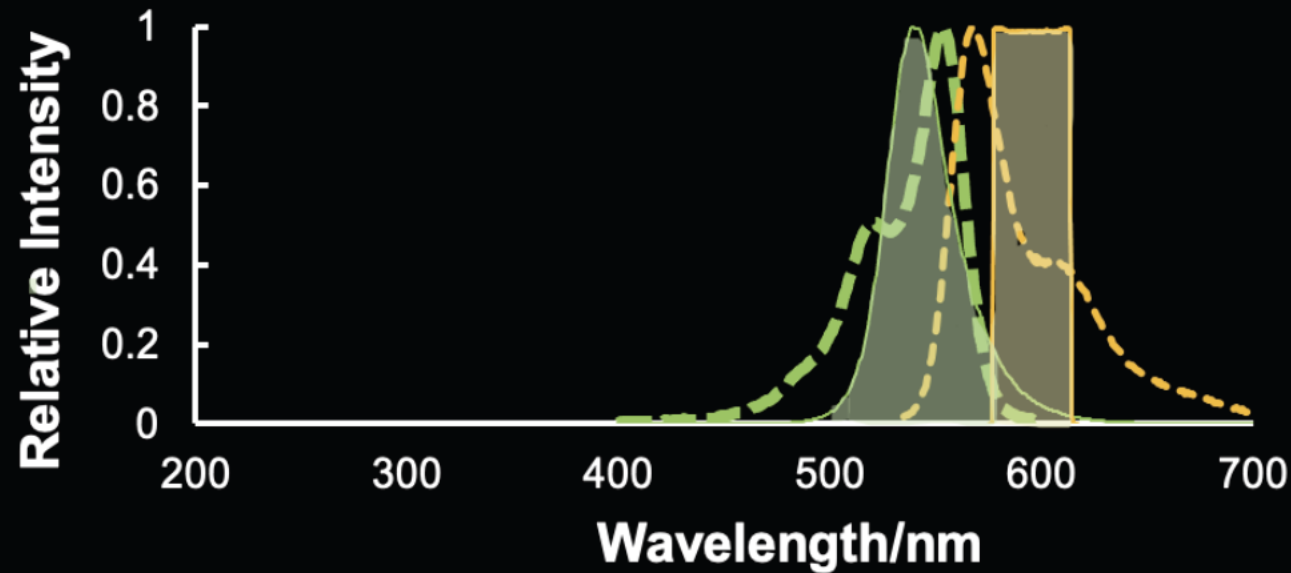
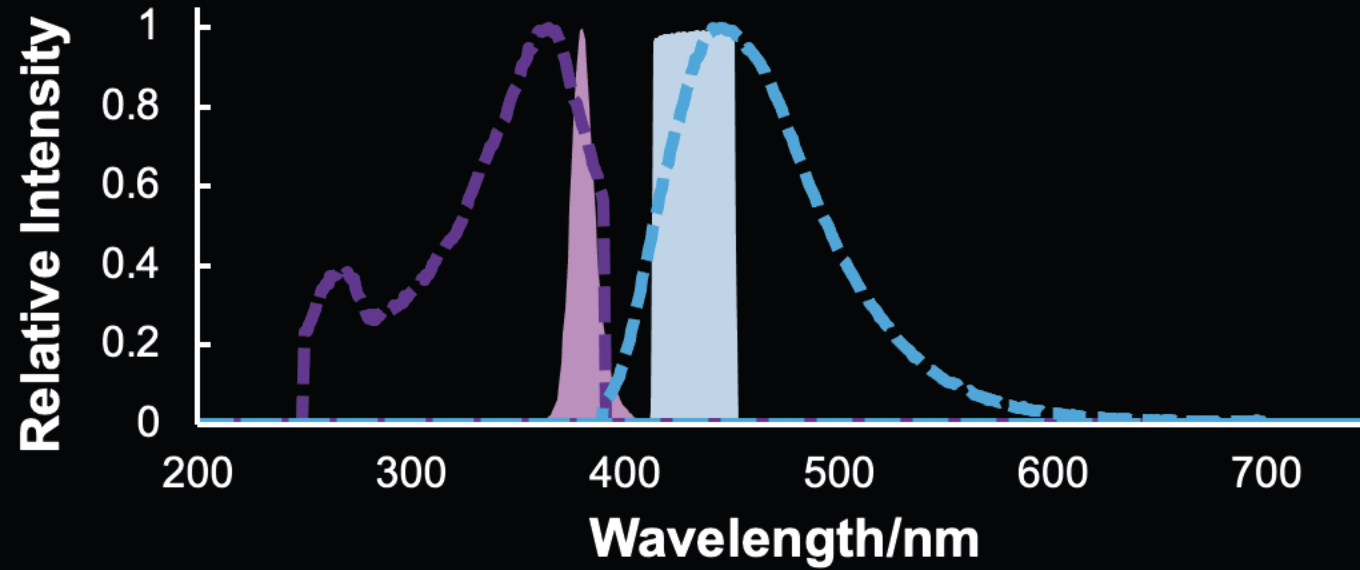
Bacillus megaterium

lipid and protein co-location



Life Combined Imaging

Bacillus megaterium
Protein Stain – Alexa 555



Life Technical Summary (CBE)	
Field-of-View	280 x 211 μm
Objective	50x flat field
Spatial Resolution	< 0.5 μm
LED Excitation	275, 375, 470, 515 nm
Emission Filters	334, 432, 527, 595 nm
Piezo Z-motion	up to 400 μm
Piezo Positioning	1 nm accuracy
Inline Particle Filters	10 - 1.2 - 0.2 μm
Environmental Sensors	pH, Eh, Conductivity

Acknowledgements

NASA Maturation of Instruments for Solar System Exploration (MatISSE) Program