Europa Mission Status

Curt Niebur
Program Scientist, NASA Headquarters
Planetary Science Subcommittee Meeting
September 29, 2016

Habitability: Ingredients for Life

Water

- Probable saltwater ocean, implied by surface geology and magnetic field
- Possible lakes within the ice shell, produced by local melting

Chemistry

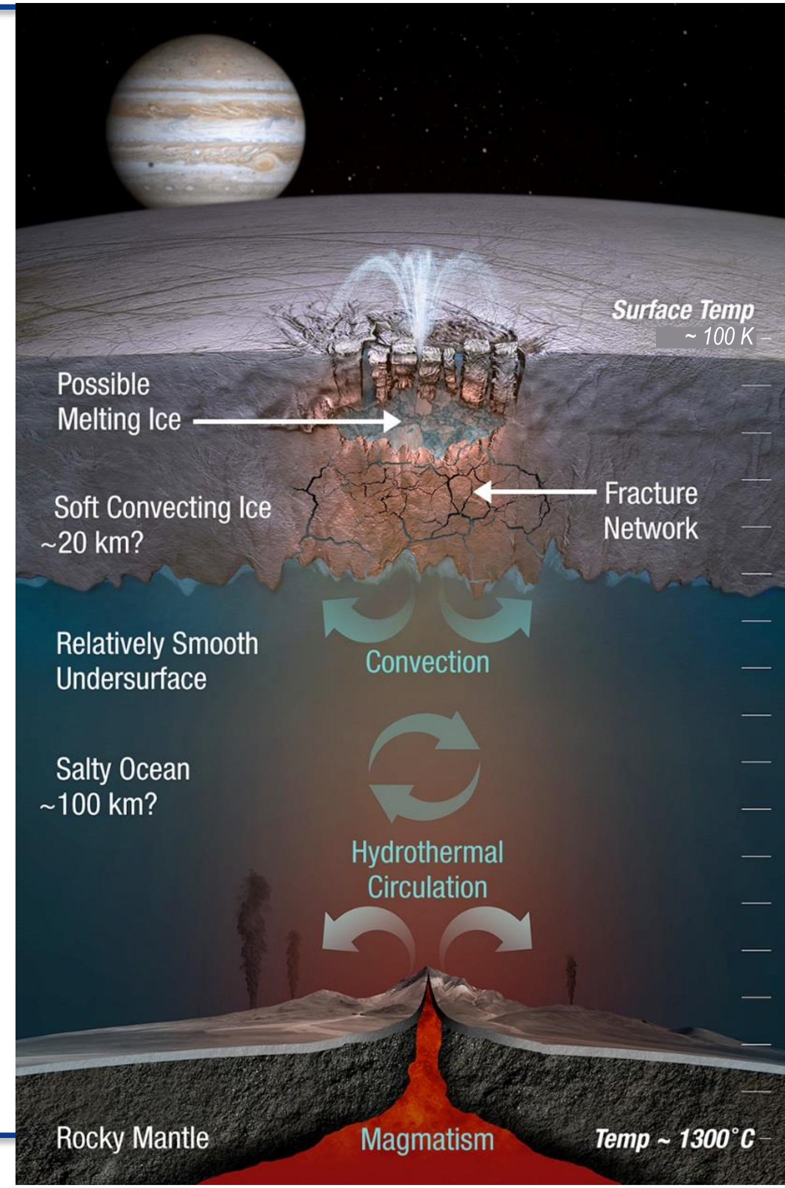
- Ocean in direct contact with mantle rock, promoting chemical leaching
- Dark red surface materials contain salts, probably from the ocean

Energy

- Chemical energy could sustain life
- Surface irradiation creates oxidants
- Mantle rock-water reactions could create reductants (hydrothermal or serpentinization)

Geological activity "stirs the pot"

Europa Flyby Mission will verify key* habitability *hypotheses



Europa Programmatic Highlights

Recent

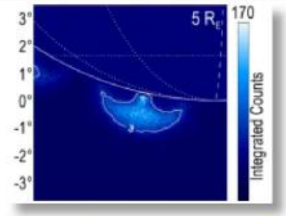
- NASA approved the Project's Acquisition Strategy Plan in June, 2016
  - Project directed to JPL
  - Make/buy decisions at the subsystem level
  - Competitively selected instruments
- Completed assessment of adding a Laser Altimeter to the mission, determined that it did not add enough science value for the added cost and complexity
- Programmatic Analysis (cost and schedule) team kickoff – June
- Completed detailed cost reviews between Project and each instrument, June – July

Upcoming

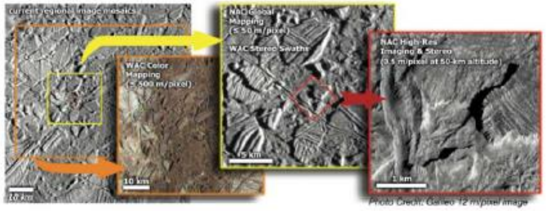
- Mission Design/System Requirements Review - January 2017
- Key Decision Point - B – April 2017

Europa Remote Sensing Instruments

- **Ultraviolet Spectrograph/Europa (Europa-UVS)** – PI Dr. Kurt Retherford, SwRI, San Antonio
  - Detect possible water plumes erupting from Europa's surface and provide data about the composition and dynamics of Europa's rarefied atmosphere.

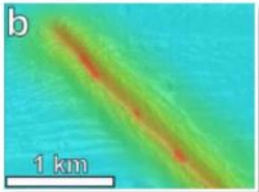


- **Europa Imaging System (EIS)** – PI Dr. Elizabeth Turtle, APL
  - Wide and narrow angle cameras to map most of Europa at better than 100 m resolution, with areas up to 100 times higher resolution.

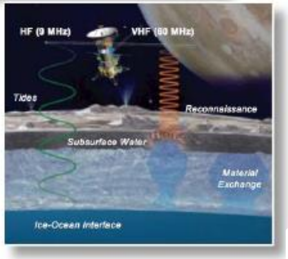


- **Mapping Imaging Spectrometer for Europa (MISE)** – PI Dr. Diana Blaney, JPL
  - Probe Europa's composition, identifying and mapping distributions of organics, salts, acid hydrates, ices, and other materials to determine habitability of Europa's ocean.

- **Europa Thermal Emission Imaging System (E-THEMIS)** – PI Dr. Philip Christensen, Arizona State University, Tempe
  - Provide multi-spectral thermal imaging of Europa to help detect active sites, such as potential vents erupting plumes of water into space.

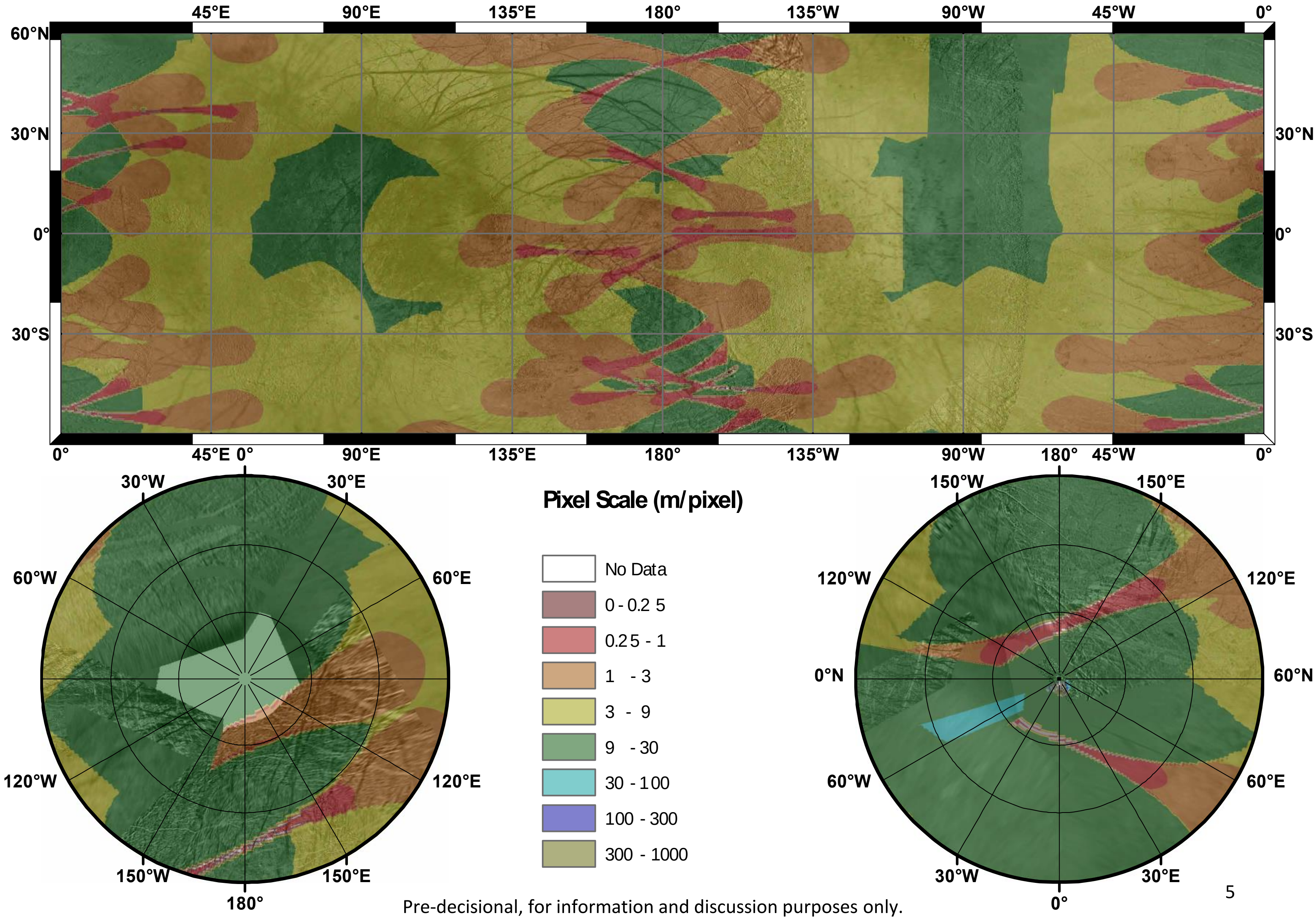


- **Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)** – PI Dr. Donald Blankenship, University of Texas, Austin
  - Characterize and sound Europa's icy crust from the near-surface to the ocean, revealing hidden structures and potential water within.



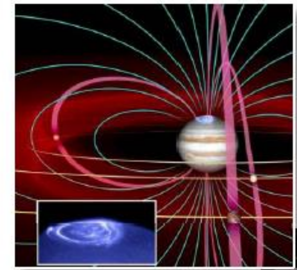
Europa Mission Imaging Potential

Europa Imaging System Narrow Angle Camera (16F11 tour)

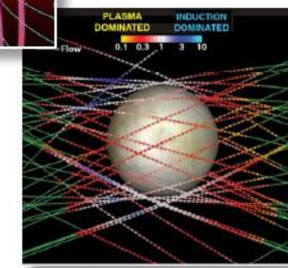


Europa *In Situ* Instruments

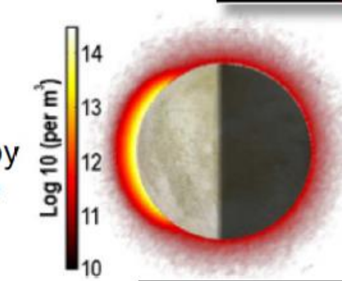
- **Interior Characterization of Europa using Magnetometry (ICEMAG)** – PI Dr. Carol Raymond, JPL
  - Magnetometer to measure the magnetic field near Europa and infer the location, thickness and salinity of Europa's subsurface ocean using multi-frequency electromagnetic sounding.



- **Plasma Instrument for Magnetic Sounding (PIMS)** – PI Dr. Joseph Westlake, APL, Laurel, Maryland
  - In conjunction with a magnetometer, is key to determining Europa's ice shell thickness, ocean depth, and salinity by correcting the magnetic induction signal for plasma currents around Europa.

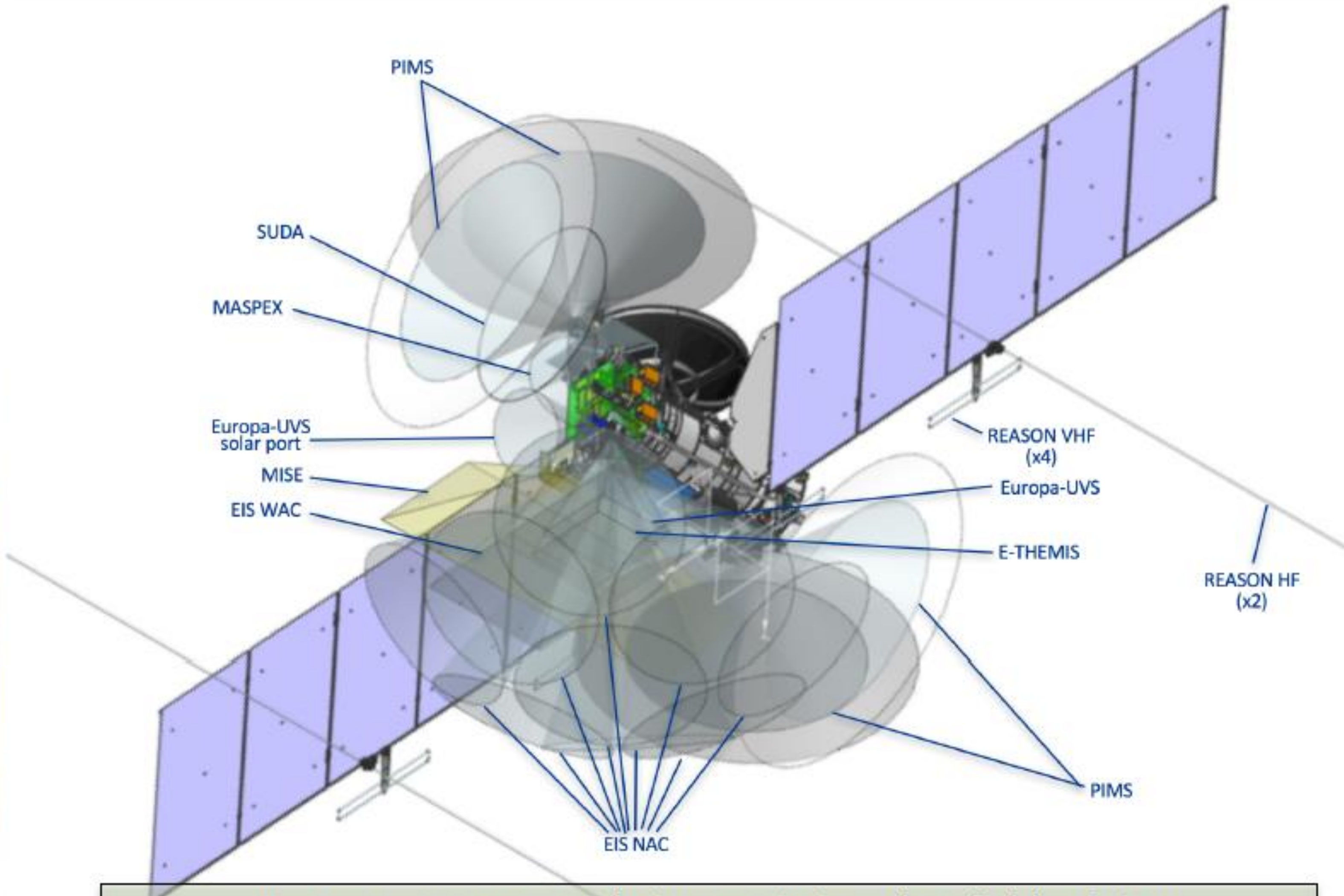


- **MAss SPectrometer for Planetary EXploration/Europa (MASPEX)** – PI Dr. Jack (Hunter) Waite, SwRI, San Antonio
  - To determine the composition of the surface and subsurface ocean by measuring Europa's extremely tenuous atmosphere and any surface material ejected into space.



- **SUrface Dust Mass Analyzer (SUDA)** – PI Dr. Sascha Kempf, University of Colorado, Boulder
  - To measure the composition of small, solid particles ejected from Europa, providing the opportunity to directly sample the surface and potential plumes on low-altitude flybys.

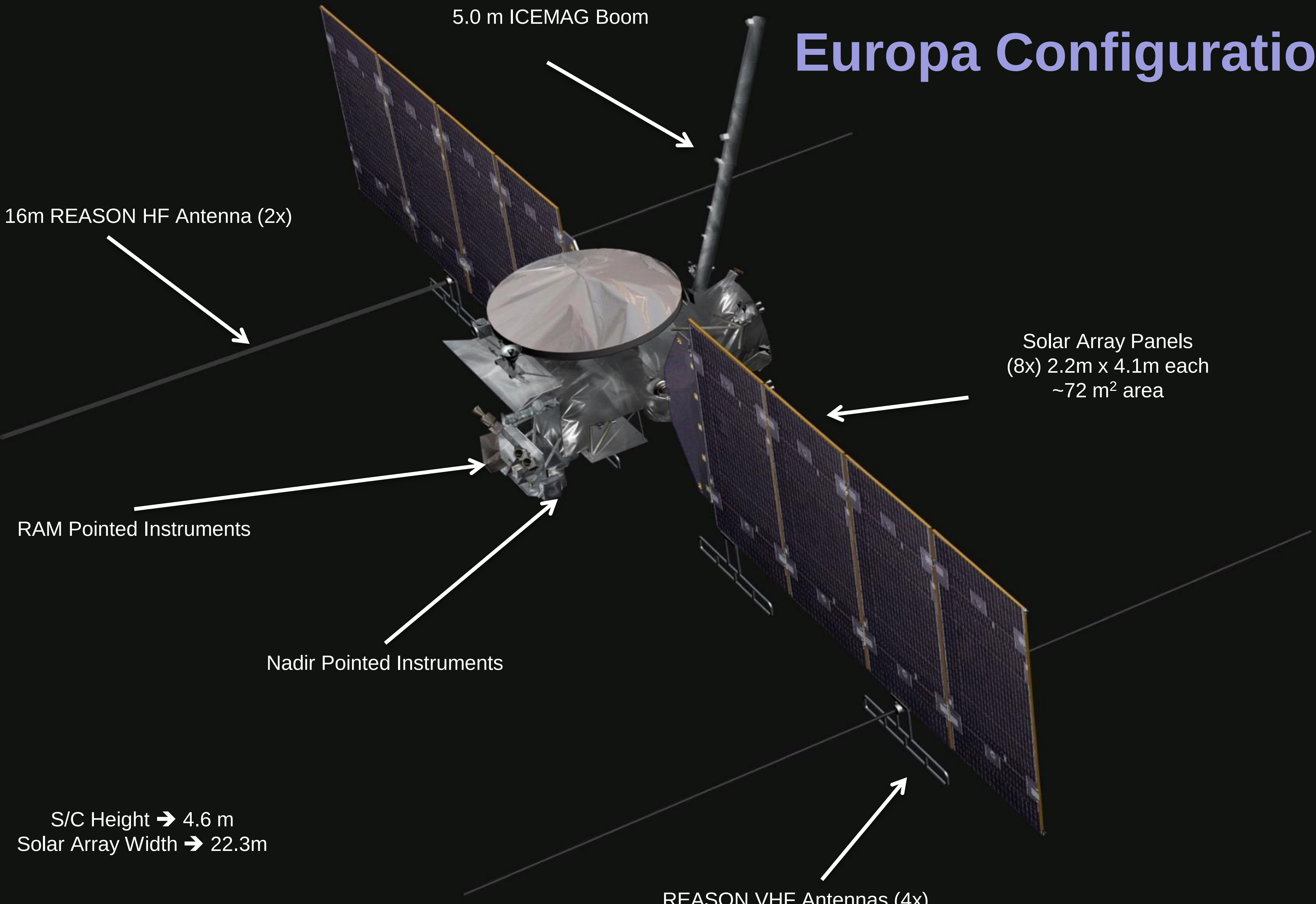
Instrument Accommodation



Instrument accommodation maximizes clear fields of view and permits simultaneity of instrument observations.

Pre-decisional, for information and discussion purposes only.

Europa Configuration



Europa Project Science Group Meeting #4
Ann Arbor, MI, July 19–21, 2016

- Project Presentation and Discussion topics:
  - Planetary Protection approach
  - Science Requirements status
  - Observation Timeline development
  - Introduction of new trajectory (16F11)
  - PSG “Rules of the Road” development
- Science “workshop mode” discussions:
  - Considerations of how multiple flyby investigations address NASA’s “Ladder of Life”
  - Interior, Composition, and Geology Working Group topical science discussions (including community members by invitation)

Addressing the Ladder of Life: A Rough Cut

First-order assessment by Europa Science Team, led by Habitability Working Group (Lunine, Hand co-chairs)

Colors refer to ability of Europa payload to address properties or materials cited in "Feature" column:

Blue: Payload provides a comprehensive investigation that fully addresses

Green: Two or more instruments can address

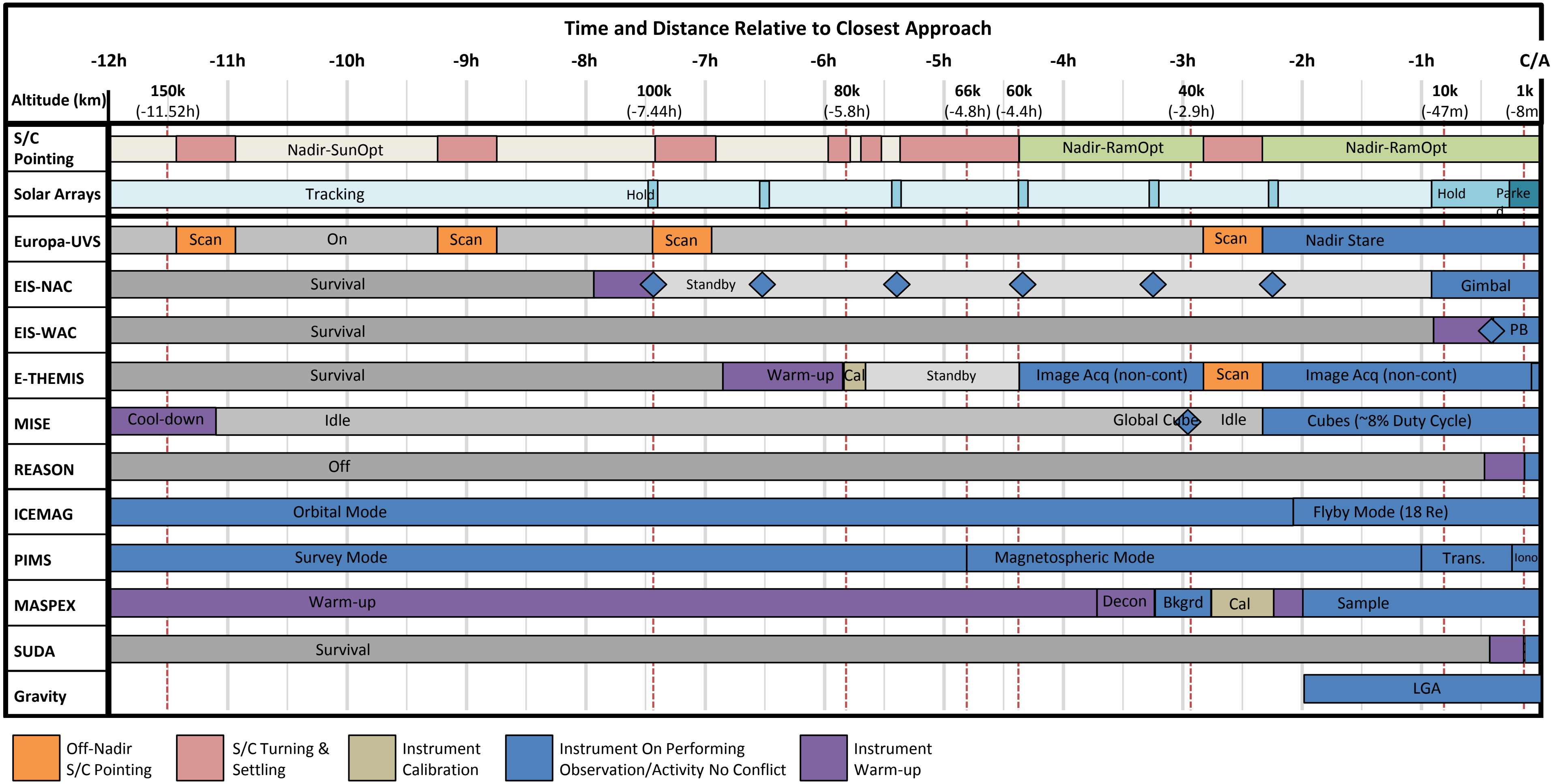
Yellow: Two or more instruments can probably address (more work required to confirm)

Red: cannot address or only one instrument can possibly address (more work required to confirm)

Ladder Rung	Feature	Clipper	Target
Life (metabolism, growth, reproduction)			
Darwinian Evolution	changes in heritable traits in response to selective pressures		
Growth and Reproduction	concurrent life stages or identifiable reproductive form [growth and reproduction]	EIS?	
Metabolism	isotopes	MISE?, SUDA?, MASPEX	Plumes, Patches [caveat on sensitivity needed to conclude metabolic effect]
	co-located reductant and oxidant (e.g. persistant H2 +/- CH4 v. O2, nitrate, Fe3+, CO2) [Inferred Persistence]	UVS, MISE, SUDA, MASPEX [split into yellow and green based on plume]	Plumes, Patches, Surface [Green only with Plume!]
Suspicious biomaterials [not necessarily biogenic]			
Functional Molecules	DNA		
	RNA		
	pigments	EIS?	Patches,
	structural preferences in organic molecules [non random and enhancing function)	MASPEX, SUDA, MISE	Plumes, Patches
Potential Biomolecule Components	complex organics (peptides, PAH, nucleic acids, hopanes)	MASPEX, SUDA, MISE	Plumes, Patches
	amino acids (e.g. glycine, alanine)	MISE, SUDA, MASPEX	Patches, Plumes,
	lipids (fatty acids, esters, carboxylic acids)	MASPEX, SUDA, MISE	Plumes, Patches
General indicators	distribution of metals [e.g. vanadium in oil reserves or others like Fe, Ni, Mo/W, Co, S, Se, P]	MISE, UVS, SUDA, MASPEX	Patches, Plumes,
	patterns of complexity (organics)	MISE, SUDA, MASPEX	Patches, Plumes,
	chirality	MISE?	Patches,
Habitability			
	water, presence of building blocks for use, energy source, gradients	MASPEX, SUDA, PIMS, ICEMAG, UVS, EIS, MISE, E-THEMIS, REASON, Gravity,	Plumes desirable, Surface, Patches, Sub-surface

Concept of Operations: Simple & Repeatable

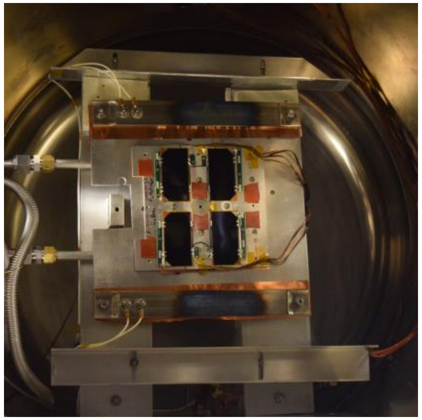
- Occasional spacecraft scanning for distant observations and calibrations (>34,000 km)
- Nadir-pointed orientation during flyby period (within ±34,000 km)
- Solar panels parked for up to an hour bracketing closest approach (REASON, NAC)

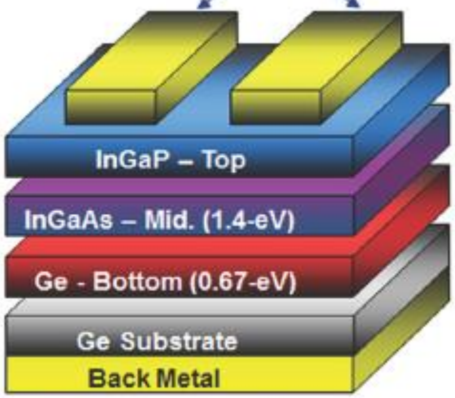


Pre-decisional, for information and discussion purposes only.

Europa – Recent Accomplishments
Solar Cell testing and selection

- Low Intensity - Low Temperature (LILT) and radiation testing on candidate solar cells completed
  - ZTJ cells (SolAero's version of triple junction cells) showed the best performance, with approximately 5% better performance than the other cells
  - Selection made and procurement awarded
    - Vendor will provide cells, cover glass, interconnects and will lay down the cells on the solar panels





ZTJ Solar Cell Structure

Europa Lander Concept Studies

Europa Lander Science Definition Team

- Science Definition Team (SDT) was formed to craft the science priorities of a Europa lander mission
- SDT Charter includes science goals prioritized as:
  1. Search for evidence of biomarkers and/or signs of extant life.
  2. Assess the habitability (particularly through quantitative compositional measurements) of Europa via in situ techniques uniquely available by means of a landed mission.
  3. Characterize surface properties at the scale of the lander to support future exploration.
- SDT output:
  – Science-enabling mission requirements delivered Aug. 19
  – Interim report due Sept. 30
  – Final report due Nov. 30*
- SDT progress is being regularly reported to the broad scientific community via meetings of OPAG, CAPS, etc.

Science Definition Team

<u>Co-Chairs</u>: Alison Murray, DRI/Univ. NV Reno, Jim Garvin, GSFC; Kevin Hand, JPL

- Ken Edgett, MSSS
- Bethany Ehlmann, Caltech
- Jonathan Lunine, Cornell
- Alyssa Rhoden, ASU
- Will Brinkerhoff, GSFC
- Alexis Templeton, CU Boulder
- Michael Russell, JPL
- Tori Hoehler, NASA Ames
- Ken Nealson, USC
- Sarah Horst, JHU
- Peter Willis, JPL
- Alex Hayes, Cornell
- Brent Christner, Univ FL
- Chris German, WHOI
- Aileen Yingst, PSI
- David Smith, MIT
- Chris Paranicas, APL
- Britney Schmidt, GA Tech

Planetary Scientists, Microbiologists, Geochemists from across the scientific community

Goal 1: Search for Evidence of Biosignatures and Signs of Life on Europa

- Obj. 1: organic indicators of life
  - abundances and patterns of potentially biogenic molecules
  - enantiomeric ratios of chiral organics
  - carbon isotopic distribution among organic and inorganic carbon *
- Obj. 2: morphological and textural indicators of life
  - resolve and characterize microscale evidence for life in samples
  - resolve and characterize the landing site for any macroscale morphological evidence for life *
- Obj. 3: inorganic indicators of life
  - Detect and characterize potential biominerals
- Obj. 4: provenance of sample
  - Determine the geological context from which samples are collected
  - Determine endogenous versus exogenous origin (chemistry), surface processing of potential biosignatures
- Obj. 5: persistence of life in sample
  - Detect activity indicative of biological processes such as motion, change, metabolism*

Life Detection

- Credibly achieving the primary goal (search for evidence of biomarkers and/or signs of extant life) requires broad consensus on the definition of:
  - The type of evidence that would be indicative of life;
  - The appropriate measurement and sampling techniques used to look for that evidence; and
  - The instruments used to take those measurements and samples.
- The Astrobiology community has been discussing these topics and NASA has been investing in technology development for over a decade.
- NASA has accelerated discourse and investment in this area, including:
  - COLDTech program and refocusing of Picasso and Matisse programs;
  - Discussions with STMD on Centennial Challenge focused on life detectors;
  - Series of workshops:
    - Technical Workshop on the Potential for Finding Life in a Europa Plume (NASA, 2015)
    - Biosignature Preservation and Detection in Mars Analog Environments (NASA, May 2016)
    - Probabilistic frameworks for recognizing complex molecules as biosignatures (NASA, September 2016)
    - Biosignatures of Extant Life on Ocean Worlds Workshop (NASA, September 2016)
    - A Workshop on Searching for Life Across Space and Time (NRC SSB, December 2016)
- It is important to establish a broad community consensus on a practical framework to guide mission and payload design.

Selected Science-Enabling Mission Requirements from SDT

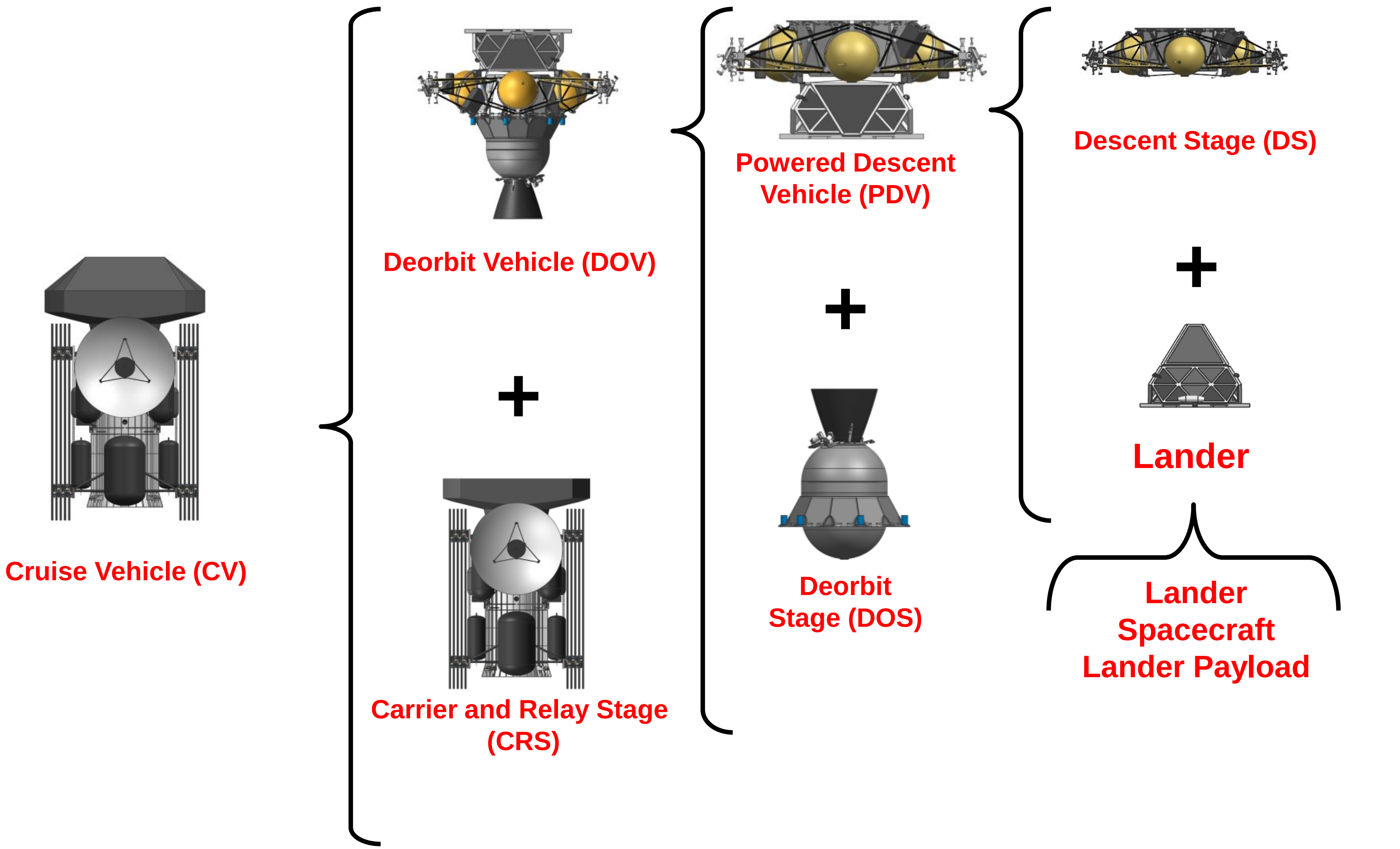
- Sampling: 5 samples, 5 grams/5 mL each from a depth of at least 10 cm (3 samples for threshold mission)
- Delivery: samples delivered to payload kept at Europa surface temperature prior to destructive sampling (i.e., heating) for certain instruments
- Imaging: panoramic imaging of landing site and detailed imaging of sampling area
- Model Payload: Gas chromatograph mass spectrometer, microscope with 0.2 µm per pixel resolution, Raman spectrometer, seismometer, cameras on mast at least 1 m above the surface
  - Assumed payload allocation is limited to 35 kg filling less space than a milk crate (~1 ft^3)

Engineering team currently working to determine feasibility of SDT mission requirements and model payload

Europa Lander Programmatic Highlights

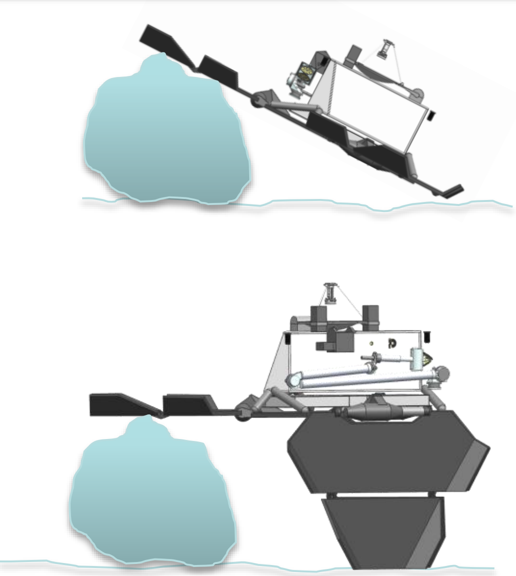
- Pre-Phase A study team briefed HQ in June:
  - Reasonable lander (350 kg) cannot be co-manifested with Multiple Flyby mission
  - Payload mass capability can be increased from 25 to 35 kg
  - Lifetime using batteries can achieve approx. 20 days
- Mission Concept Review targeted for April 2017

Flight System

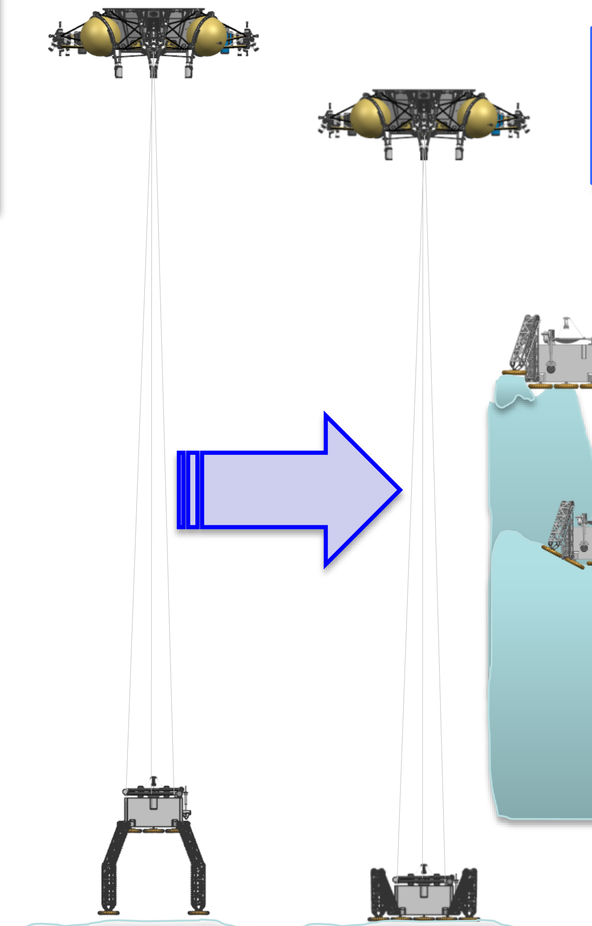


Landing Design for Undefined Terrain: Trade Study of Petals vs Legs

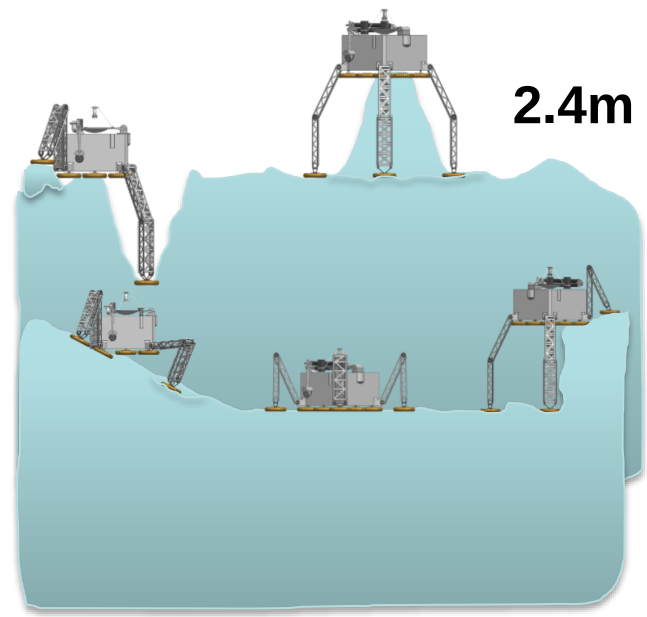
Motivation for Change:
- Better accommodation of irregular terrain
- Volumetric packaging efficiency (e.g., rectangular vault)
- Lower system mass



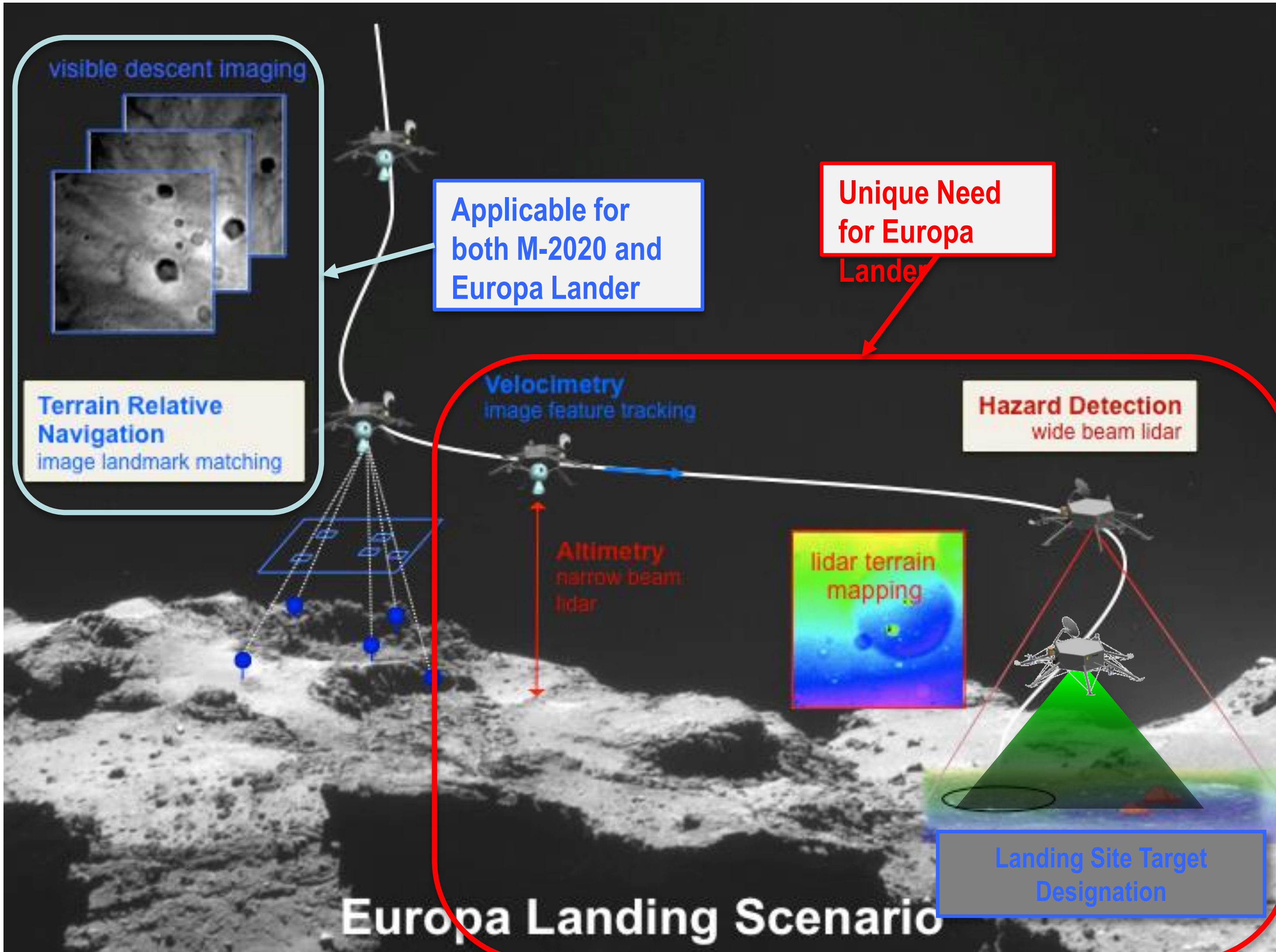
Tetrahedral Lander (Design 3.0) with "Petal" Landing Gear



"Cricket" Concept with Adaptable Landing Gear (designed to lock once base contact established)



Intelligent Landing System being Developed in Collaboration with Mars-2020 Mission



Intelligent Landing System for Europa: Terrain-Relative Navigation

Terrain-Relative Navigation

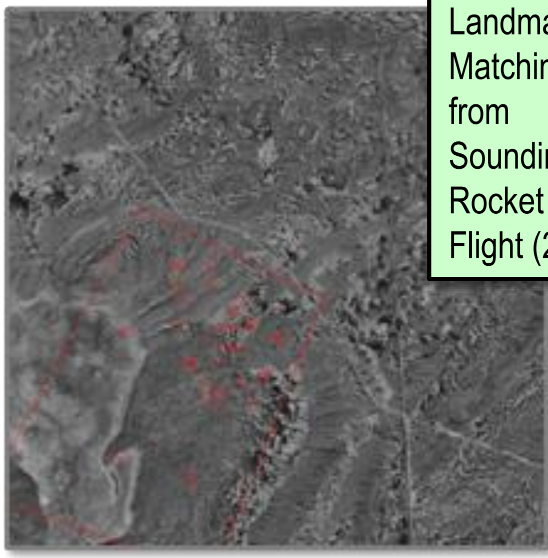
- Enables accurate landing (± 25-50 m) near desired landing sites identified from orbit

Approach:

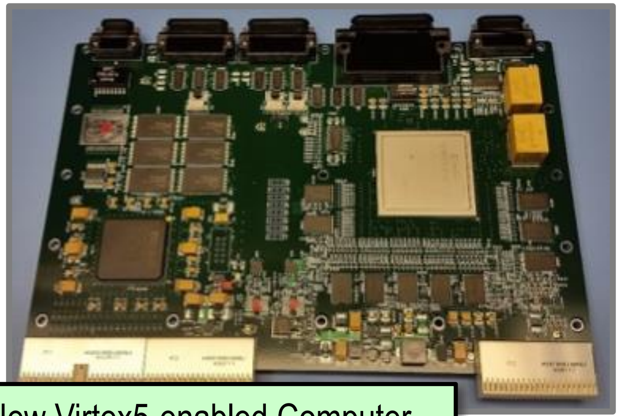
- Develop prototype TRN system with Mars-2020
- Mars-2020 Project will develop flight version for Mars landing application
- Extend TRN prototype for Europa application
  - Utilize horizontal velocity and altitude estimation
  - Accommodate Europa lighting and terrain characteristics

Current Status:

- Breadboard hardware assembly is in progress
- Prototype TRN flight S/W coded and in test
- TRN real-time simulation is in progress



Landmark Matching from Sounding Rocket Test Flight (2006)



New Virtex5-enabled Computer Vision Accelerator Card (CVAC)

Intelligent Landing System for Europa: Hazard Detection and Avoidance

Hazard Detection & Avoidance

- Detect small-scale terrain features (0.5 m height)
- Choose safe landing site

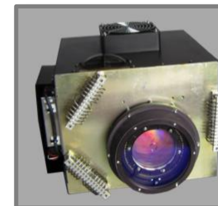
Approach:

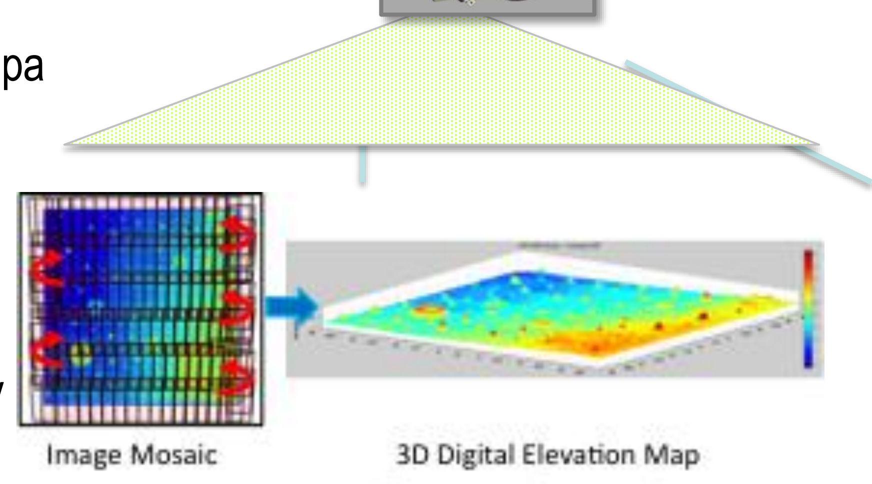
- Sensor adaptation/development for Europa environment
- Build and test prototype

Current Status:

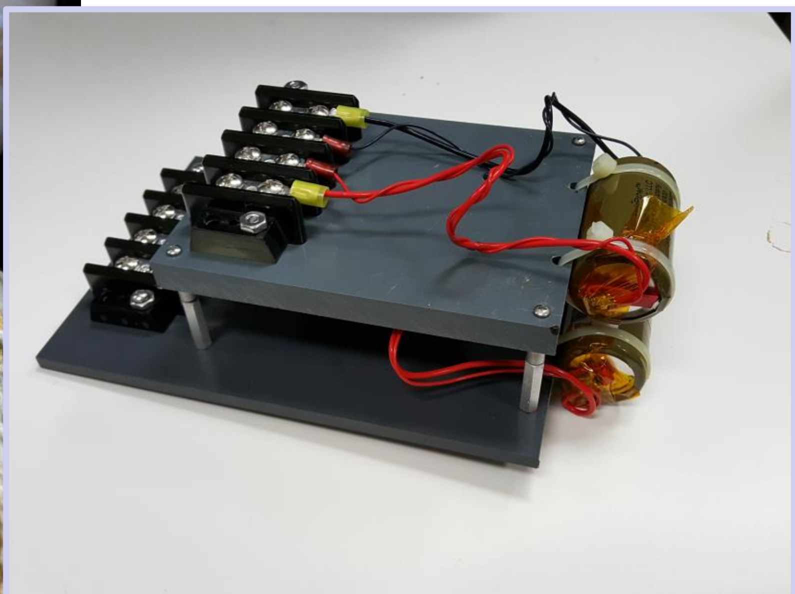
- Five study contracts started with industry
- Preparing RFP for prototype

Example Imaging Lidar

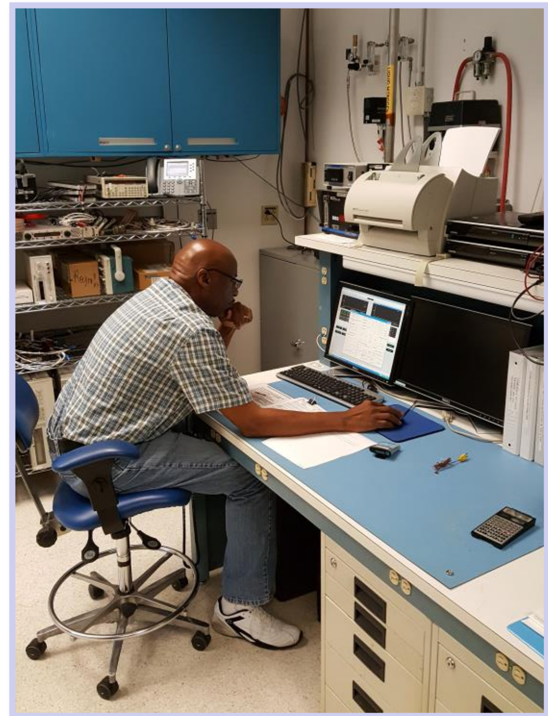




Radiation Testing And Evaluation of Potential Lander Battery Cells



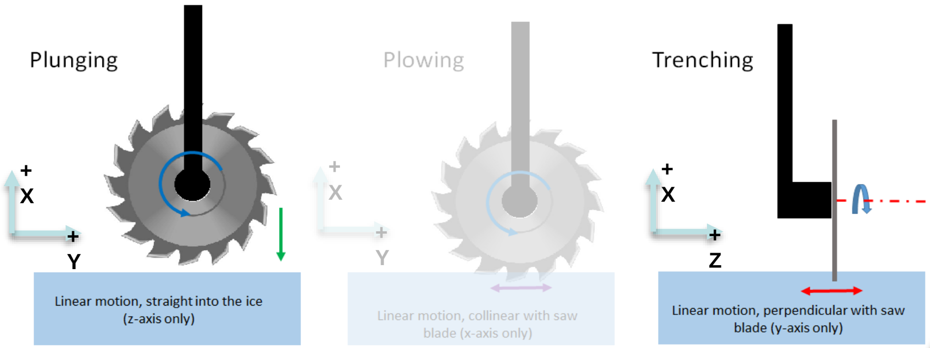
Test fixture used during irradiation of primary battery cells



Radiation test engineer, monitoring exposure of primary cells to 1 MRad TID using JPL Co-60 source

- Completed safety reviews and facilities modifications
- Initiated radiation testing; no significant change (voltage, temp.) detected thus far
- Initial results up to 2 MRad indicate no change in impedance of cells
- Full capacity check in progress, followed by further irradiation exposure

Potential Sampling End-Effector Testing



Linear test apparatus for controlled force/moment measurements