Flight Readiness of Mochii ISS-NL Portable Spectroscopic Electron Microscope

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EM samples analyzed *in-situ* on ISS

Electron microscopy (EM) and energy-dispersive spectroscopy (EDS) are powerful tools for research and engineering. EM offers strong optical scattering, high native resolution, large depth of focus, and multiple available signals including X-rays for chemical ID.

NASA routinely uses ground-based EM's to:

- Understand the origin and evolution of the solar system, especially rocky bodies
- Visualize architecture of tissues and cells
- Characterize particulate debris in air/water, observe catalyst pore sizes, study fibers, and characterize micro-textures
- Guide critical adaptive mission planning via forensic imaging and microanalysis for life support and mechanical systems

Coauthors are working together in partnership with the ISS program and CASIS to bring this powerful capability to ISS as a National Laboratory facility. EM analysis will be available to terrestrial users after its initial demonstration mission. This facility supports in-situ engineering analysis and microgravity science benefiting humankind.

Out of the lab and into the field:

EM is traditionally a high-end large facility lab tool:

- Complex to operate and maintain, needs vacuum and stable environment.
- Training, long queues, and geography limit access, speed to result, and the extent to which many analyses can be executed.
- Field samples must be sent back to a facility, despite potential chemical or morphology changes over time and/or damage in transit.

Mochii™ is the world's first truly field-portable nano-imaging platform bringing EM out of the lab.

Mochii is tiny and versatile and suitable for space use:

- Ultra-portable: 260 mm tall, <12 kg, <80 W
- Low accelerating potential (10 kV) provides capable imaging
- Wireless tablet interface: multi-user collaboration
- Chemical ID via energy-dispersive X-ray spectroscopy (EDS) enabled in Mochii 'S' model
- Easy sample preparation using integrated metal coater
- Low initial procurement, operating, and maintenance costs

Mochii's unique balance of features enables it to perform analyses in extreme field environments, such as outdoors under battery power, on moving vehicles such as ocean vessels, and in the most extreme of environments: space.

Mochii , the first instrument of its kind in this frontie,r has completed preparations for manned space flight and has completed transit to the ISS. We are looking forward now to initial demonstration.

www.projectvoxa.com

mochii

REFERENCES:
[1] Own, et al. LPSC 2019.
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[4] Own, et al, Micros. & Microanal. (2020) (in press).
[5] https://www.nasa.gov/mission_pages/station/research/news/ng-13-research-highlights/
[6] This work was supported by Voxa, NASA, and Jacobs.

Applications

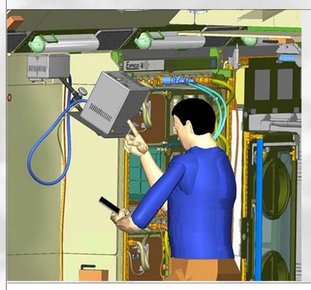
Mochii ISS-NL: Microgravity research facility for the benefit of humankind

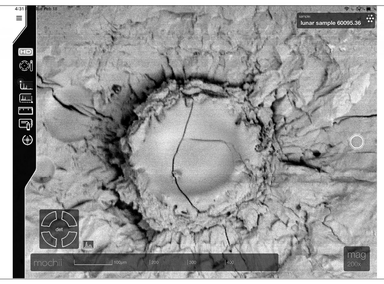
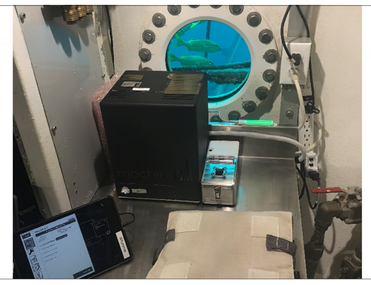
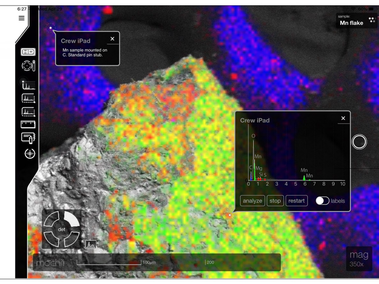
Science: Mochii will enable novel research on board ISS, including EM visualization of samples prepared in microgravity, characterization of new and existing materials, and in the longer term tissue and cell architecture.

Engineering: Mochi will enable mission-critical engineering on board ISS, such as characterizing debris in life support and mechanical systems to reduce crew and vehicle risk.

Future missions: Mochii will serve as a development platform for future missions, including deep space manned and robotic exploration by enabling actionable analysis when sample return to Earth-based labs is not possible.

Voxa will serve as your implementation partner for novel microgravity research on ISS.



Progress Toward Flight

Flight verification testing

Mochii is Class 1-E modified commercial off-the-shelf (COTS) hardware.

To reach technology readiness level (TRL) 9 and achieve flight readiness, Mochii underwent rigorous testing to satisfy ~150 ISS engineering integration, crew/vehicle safety verification requirements, and science verfications.

Vehicle integration and safety:

- Command & Data Handling / IT security
- Flight vibe
- Power quality
- EMI/EMC
- Radiation safety
- Thermal

Science verifications:

- Imaging resolution
- Spectrometer resolution and sensitivity
- Semi-quantitative spectroscopy calibration
- Magnetic field susceptibility

Procedures verifications:

- Procedures testing (analog mission)
- On-board training (pre-mission)
- Procedures security

NEEMO XXIII Mochii undersea flight analog testing



Top: Aquarius Reef Base, Islamorada Fl.
Middle: NEEMO XXIII crew (clockwise from top-left): S. Pomponi, S. Christoforetti, C. Ari D'agostino, J. Watkins
Bottom: NEEMO XXIII Mission Control Center

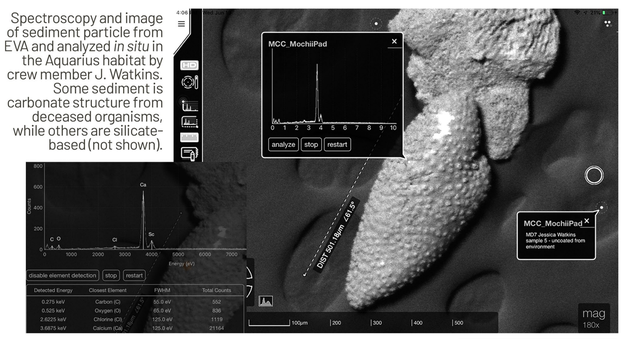
NASA's Extreme Environment Mission Operations (NEEMO) is a unique analog test program for space mission operations and equipment testing. It provides a rigorous flight-like mission environment 63 ft. underwater at the Aquarius Reef Base (ARB) in the Florida Keys.

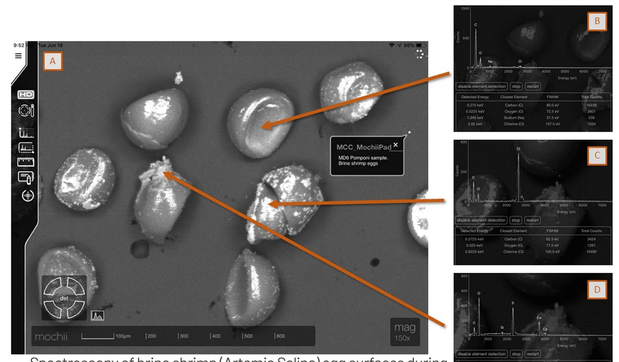
Mochii participated in the 23rd NEEMO in June 11-21, 2019, completing successful mission science in the 2.6 atm hyperbaric setting, vetting ISS prototype procedures and practicing engineering support to be provided to NASA and the public as an ISSNL facility. We remotely controlled wireless Mochii and supported the crew from mission control center on shore, and potential ISS-NL customers were able to operate Mochii from across the continent while in-mission, similar to planned utilization on ISS.

Crew members Drs. Ari, Pomponi, Watkins, and Cmdr. Cristoforetti each conducted in-situ analyses on samples acquired from the marine environment on-board and during EVA, using model crew procedures under test for use on ISS. These analyses – of cnidaria skeleton, brine shrimp eggs, sediment, and marine sponge as well as pre-prepared samples – additionally model activities at the forefront of exploration on other worlds, for example for future crewed missions to the Moon and Mars.

The Mochii team was fortunate to achieve all target mission objectives, ranging from end-to-end crew operations testing for ISS (including experience handling remote telemetry outages and planned lossof-signal), to crew-driven in-situ exploration of the environment at the microscopic scale.

Spectroscopy and image of sediment particle from EVA and analyzed *in situ* in the Aquarius habitat by crew member J. Watkins. Some sediment is carbonate structure from deceased organisms, while others are silicate-based (not shown).





Spectroscopy of brine shrimp (Artemia Salina) egg surfaces during NEEMO XXIII mission. a) Quadrant backscatter electron image showing morphology of ~200 um particles. Spectra from b) organic egg body, c) stony inclusion adhered to surface, d) brine deposits on egg surface.

Mochii ISS-NL On-Orbit

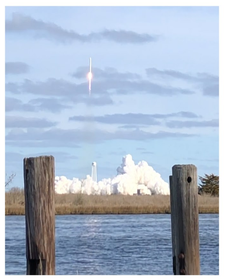
Launch to ISS

The Mochii payload was handed over to the ISS payload processing center in Houston TX Dec 17, 2020 for launch processing. Originally scheduled for SpaceX-20 in Mar 2020, the payload was moved up to the earlier NG-13 flight.

Mochii arrived at Wallops Flight Center in the first week of Feb 2020 and was loaded into the Cygnus spacecraft. After multiple launch attempts, NG-13 departed Feb 15, 2020 at 3:21P ET.

Two days later, crewmember Andrew Morgan captured Cygnus by robotic arm, docking with the ISS Feb 17, 2020 at 4:05A ET. Mochii is now on orbit awaiting crew operational time to install and perform initial checkouts and demonstration. Mochii will be installed in the Japanese Experiment Module (JEM) where ISS crew will access Mochii wirelessly. Payload operators and ISS-NL customers will collaboratively operate Mochii from the ground using iPads connecting to ISS through JSL uplink routed through Voxa servers.

Mochii hardware packed in flight foam at payload handover at the Cargo Mission Contract processing facility in Houston, TX.


a) NG-13 mission craft awaiting launch of Wallops Flight Facility in VA. The Cygnus spacecraft containing Mochii is mounted to Antares launch vehicle and ready for first launch attempt Feb 09, 2020. The launch was scrubbed and rescheduled multiple times, successfully taking off (b) on Feb 15 at 3:21P ET. c) The Cygnus spacecraft was captured by robotic arm at the ISS at 3:05A CT.