ISSRDC

Microgravity Research for Versatile Investigations (MaRVIn): A Modular System for Processing Experiments Aboard ISS

Scott Gilley with Tec-Masters, Inc.

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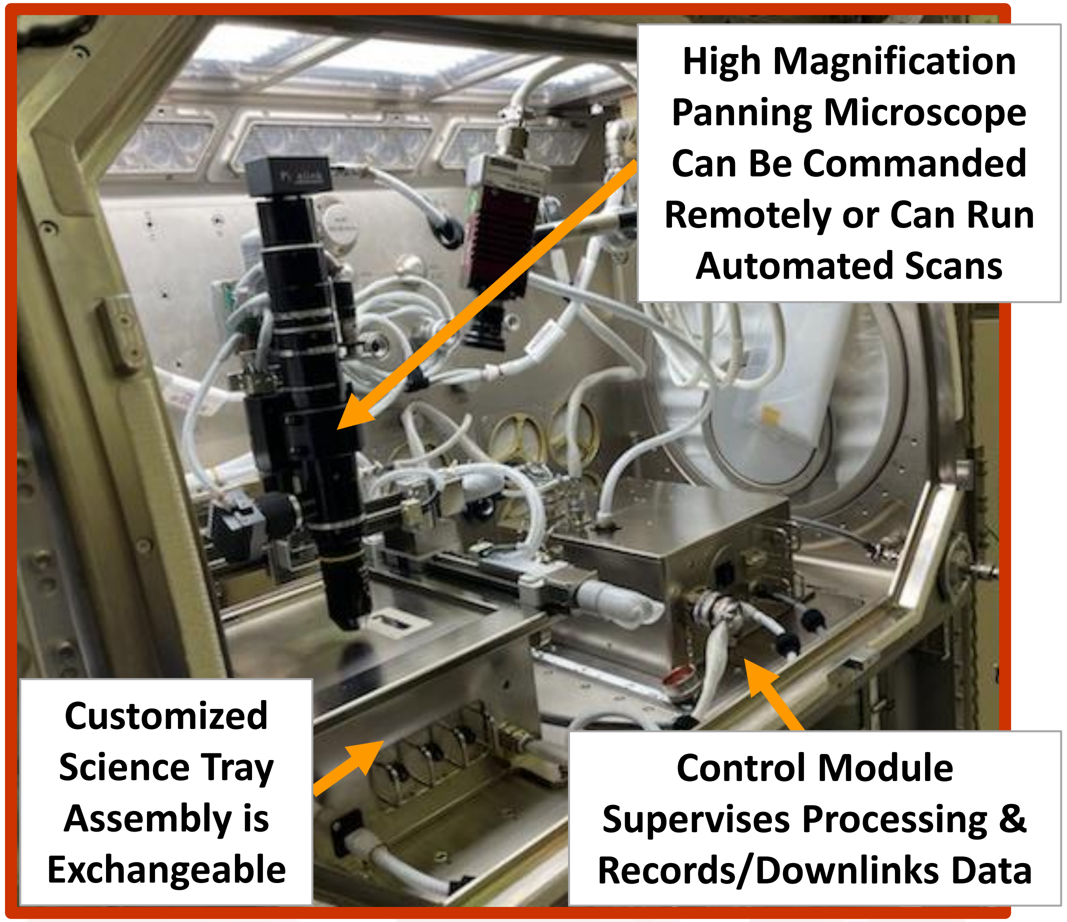
MaRVIn Overview: Developed by Tec-Masters, Inc.

- Operates scientific or commercial investigations aboard ISS in the Microgravity Science Glovebox (MSG) facility with expansion plans for Life Sciences Glovebox (LSG), EXPRESS and Maintenance Work Area.
- Provides a low cost, schedule friendly means to perform a variety of investigations in microgravity such as but not limited to:
  - Particle suspensions behavior experiments with fluorescent imaging and high-speed imaging (< 1 ms shutter speed)
  - Soldering and materials joining investigations
  - Molten materials behavior with solidification characterizations and crystal growth or annealing studies
  - Material properties studies from sub-zero to 1000+ °C
  - Chemical reaction and fluids management studies
- Supports heating, cooling, fluids management, power, data telemetry and video utilities with custom experiment modules.
- Provides imaging with high magnification microscope that has remote commanded or automated lighting, zoom, focus and panning functions along with exchangeable objectives & optical filters.



MaRVIn Installed in Microgravity Science Glovebox (Ground MSG Engineering Unit Shown)

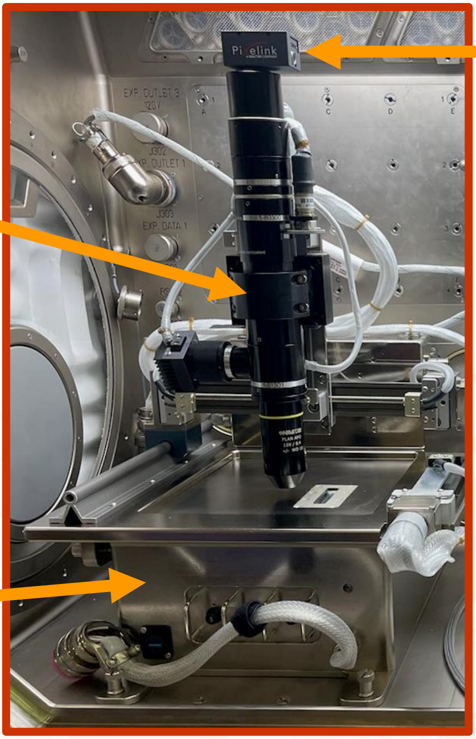
MaRVIn Hardware Overview

- The MaRVIn architecture includes a control system that supervises experiments housed in modular science trays, which contain custom apparatus and support electronics to control actuators or heaters/coolers, gather sensor data & manage imaging hardware.
- The MaRVIn Control Module (MCM) activates and runs experiments in auto-run mode, in remotely commanded mode, or in a hybrid mode that allows remote adjustments to otherwise automated runs.

MaRVIn Control Module (MCM)

High-Speed & High-Resolution Camera

MaRVIn Microscope with XYZ Gantry (Optional: Can be Omitted if Not Needed)



Science Tray Assembly (STA)

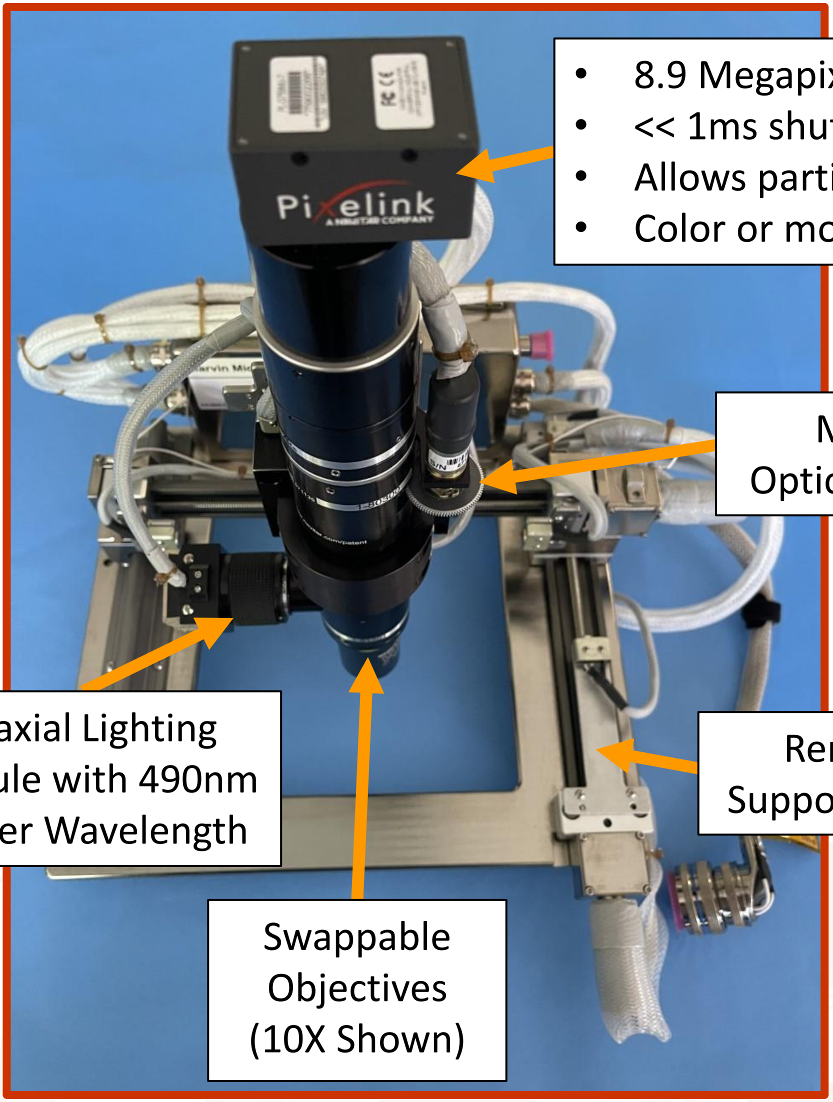
- A typical experiment module, called a Science Tray Assembly (STA), is 9.5 in (W) x 10.5 in (D) x 5.5 in (H).
- Custom sizes and/or multiple STAs can be implemented when additional volume is needed for an investigation’s science test set, such as testing variations of specimen materials and/or geometric configurations.

Hardware Overview: MaRVIn Control Module

- Provides ground operators with an interface to control experiments in real time, initiate automated operation mode upon start-up, or run in a hybrid mode that allows adjustments to automated profiles.
- Manages the Data Acquisition (DAQ) and communication subsystems.
- Reads and records science sensors along with hardware health and status data from the swappable Science Tray Assemblies (STA).
- Controls the microscope and high-definition cameras (either color or monochrome) per remote commands and/or automated scan patterns.
- Provides custom software to supervise the ancillary equipment as well as hardware specific to an experiment, which can be remotely monitored and controlled from telescience center ground workstations.
- Stores data and images locally for downloading to ground workstations in real time (during Acquisition of Signal periods) or manages larger video stream recordings or data sets as post-run data file transfers.

Flight MaRVIn Control Module (MCM)

Hardware Overview: Microscope System Features



- 8.9 Megapixel Camera
- << 1ms shutter speed capable
- Allows particles velocimetry tracking
- Color or monochrome units are available

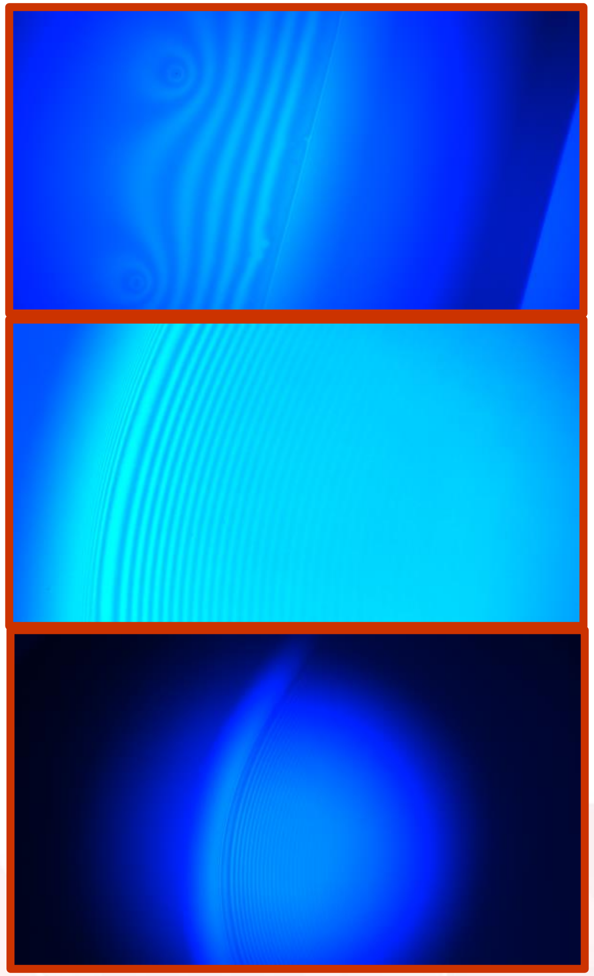
Motorized 7:1
Optical Zoom Module

Coaxial Lighting
Module with 490nm
Center Wavelength

Remote Control XYZ Gantry
Supports High Resolution Panning

Swappable
Objectives
(10X Shown)

Interferometry Images



Hardware Overview: Microscope Imaging Capabilities

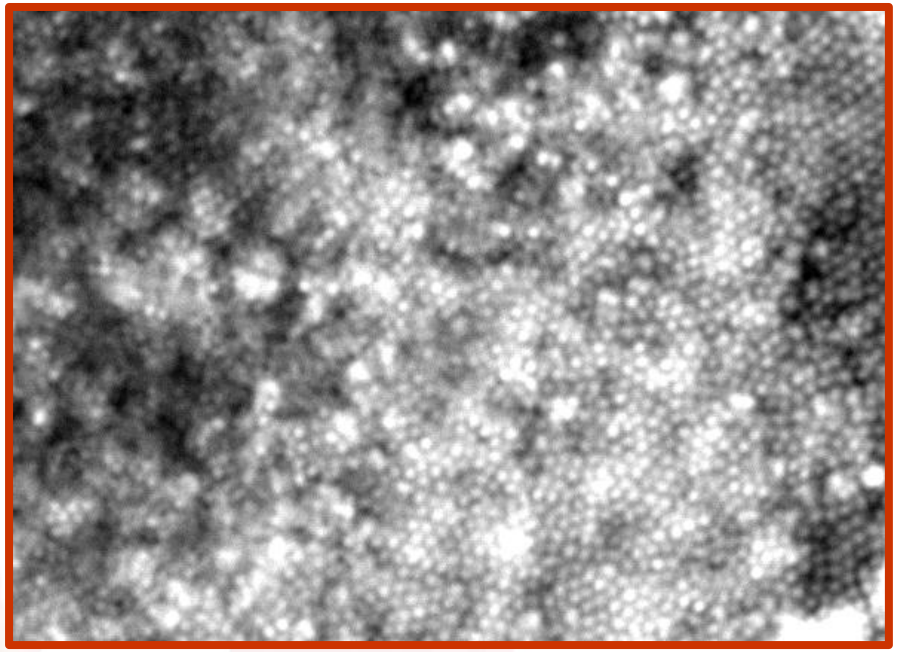
- Navitar Resolv4K with 7X Optical Zoom Module
- Working distance of 10 to 20mm for 10X, 20X or 50X swappable objectives
- LED coaxial lighting module, 490 nm wavelength
- Fluorescent imaging demonstrated for MaRVIn-TABOOS Investigation
- TABOOS will use 530nm long-pass filter inline with color camera sensor

Fluorescent Imaging Capability

TABOOS Flight Cells

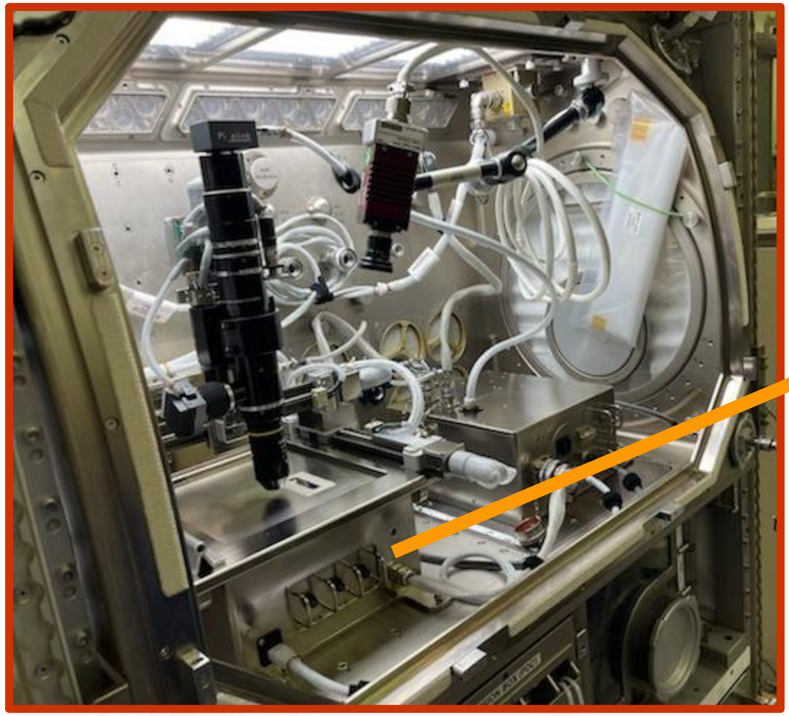
Colloidal Suspensions in Micro-passage Cells

Feature Resolution: 1-micron particles shown using 20X Objective & sub-sensor region of interest



- **Numerical Aperture (NA):** 0.43 for 10X objective
- **Resolution:** 0.67 µm
- **Depth of Field (DOF):** 3.7 µm
- **Field of View (FOV):** 500 x 500 µm

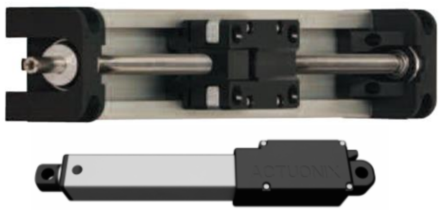
Hardware Overview: Swappable Science Tray Assemblies



- Science Trays are configurable to support each unique investigation.
- Science Trays can be built to provide an extra level of containment for safety purposes.
- Electronics bay provides selectable modules for analog I/O, digital I/O, up to 32 thermocouples, RTDs, thermistors, transducers, heaters control, coolers control, etc.

Hardware Overview: Tailorable Science Tray Components

Linear Actuators



Rotary Motors

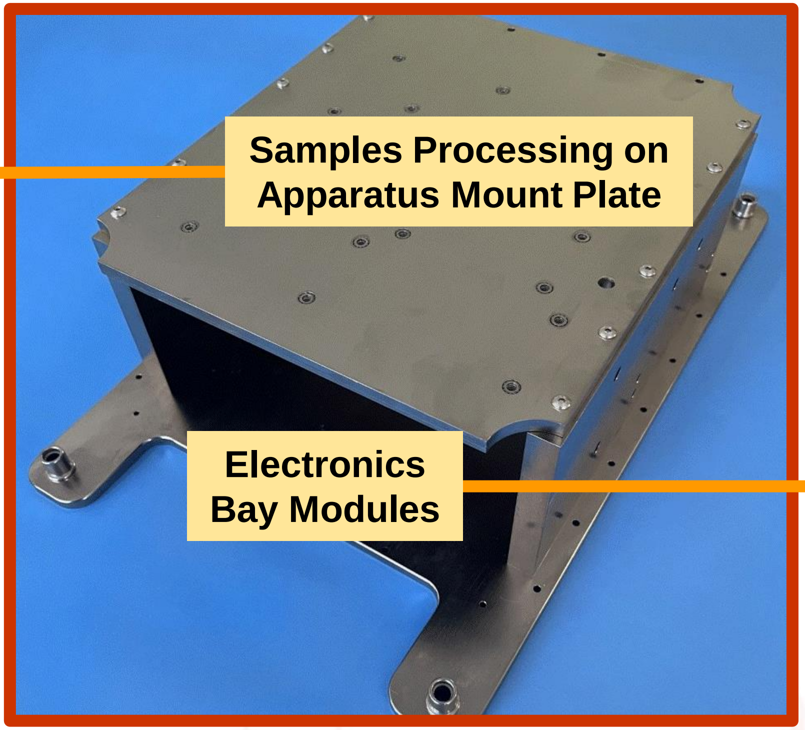
Position Encoders

Sensors

Heaters & Coolers

Up to 1200+°C

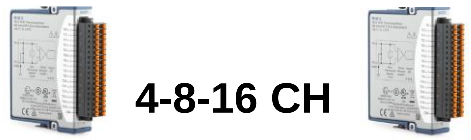
Down to -10°C



- Control & data acquisition modules for digital and analog I/O functions
- 5, 12, 24 and 28 VDC power sources
- Custom tailored PC cards, if needed

Interface Hubs

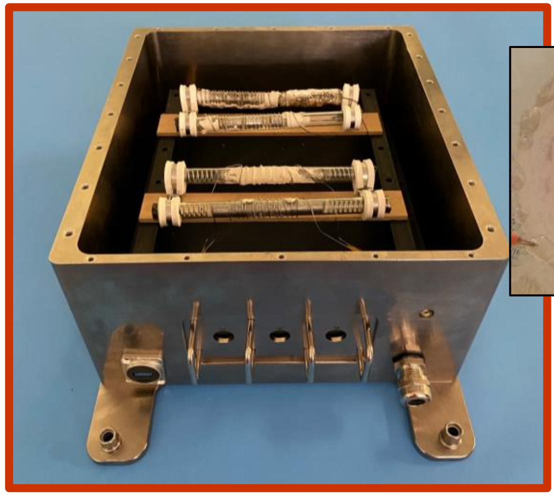
Thermocouple & RTD Readers



Transducers, Counters & I/O Readers

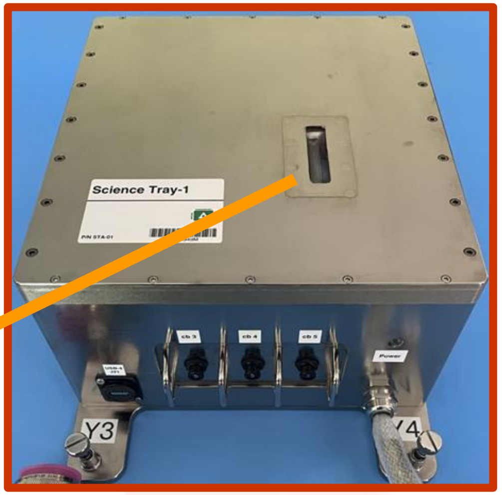
Power: Relays/Sources

Hardware Overview: Science Tray Experiment Apparatus

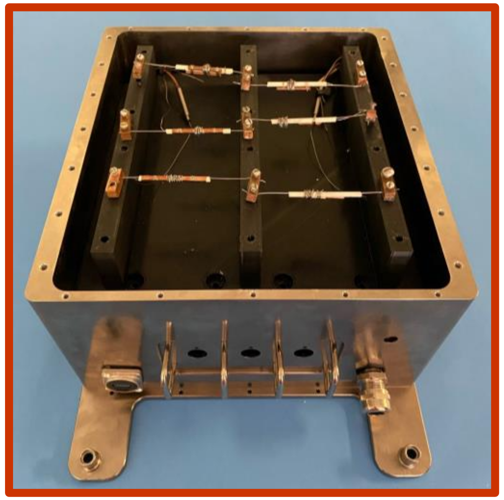


High Temperature Materials Processing

Fluids Investigations



MaRVIn-PCIM: Operated on ISS in 2023 for Four Weeks



Soldering Studies (Nanoracks BlackBox)

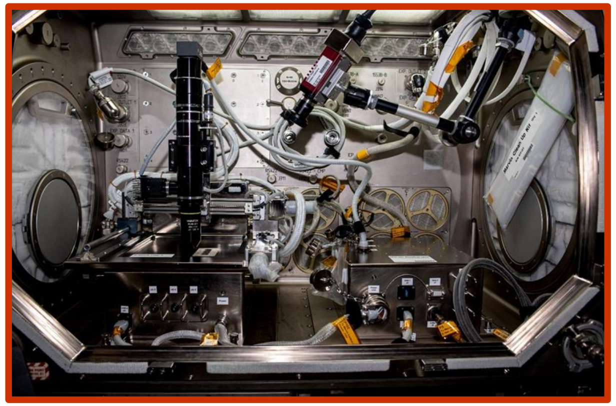
Particle Suspension Studies with High-Speed Velocimetry Imaging

MaRVIn-TABOOS: To Launch Sep 2024 on SpX-31

Quartz Cuvette acts as Transparent Heat Pipe

32 Thermocouples Measure Detailed Thermal Profile at 1 Hz Sample Rate

MaRVIn: Flight Proven Status Aboard ISS in August 2023

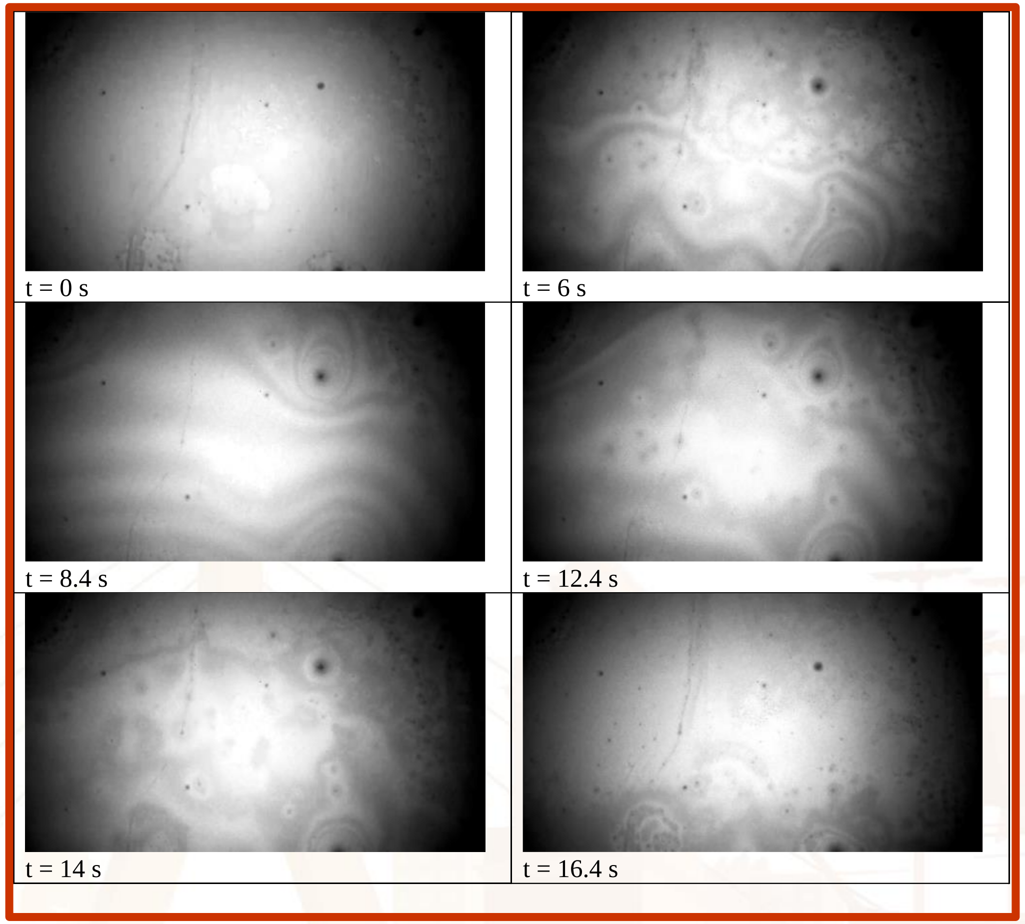


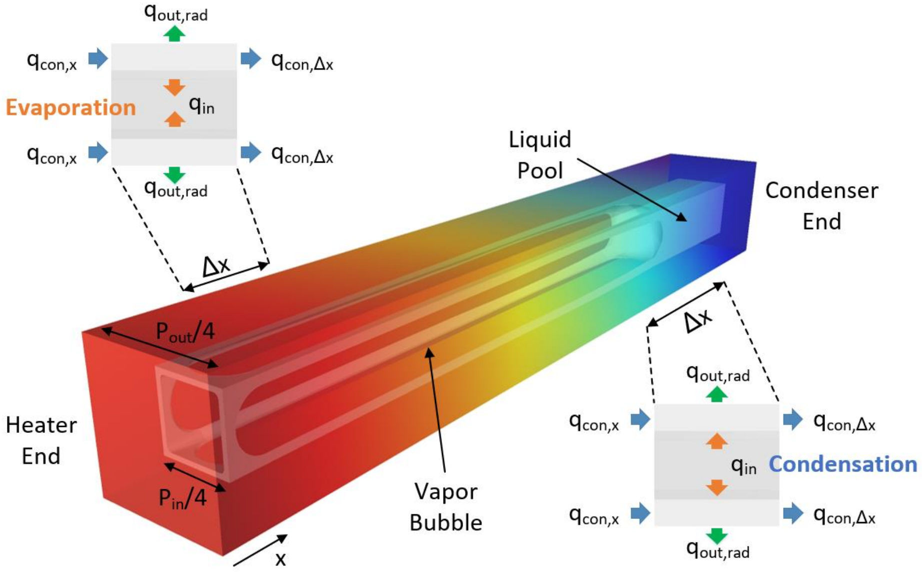
- Operated for 4 weeks with successful completion in Sep. 2023
  - **PCIM**: Phase Change in Controlled Mixtures
  - Principal Investigator: Dr. Joel Plawsky, Rensselaer Polytechnic Institute
  - Transparent heat pipe investigation with Pentane/Isohexane working fluid
- Three Current MaRVIn Investigations
  - **TABOOS**: Thermophoretic and Brownian Optical Observation System for Sep 2024 Launch on SpX-31
    - ✓ Principal Investigator: Dr. James Gilchrist, Lehigh University
    - ✓ High-speed particles velocimetry studies at < 1 ms shutter speed using fluorescent imagery
  - **Wafer Annealing**
    - ✓ Principle Investigator: Dr. Debbie Senesky, Stanford University
    - ✓ Wide bandgap semiconductor wafer annealing at up to 1,000°C processing temperature
  - **Proprietary Commercial Investigation**
    - ✓ Principle Investigator: To be announced

MaRVIn-PCIM Transparent Heat Pipe Results

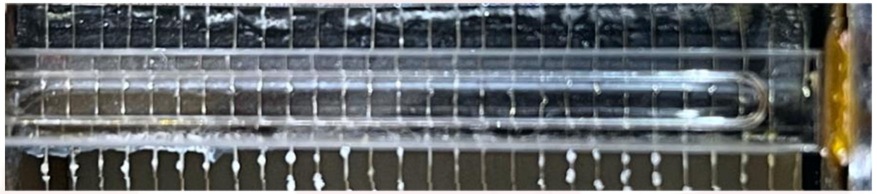
Data from: Plawsky, Joel
Rensselaer Polytechnic Institute

- Coherent, cavity oscillator using binary liquid
- Images show cavity oscillations w/interference rings
- Heater: 75˚C; Condenser: -5 ˚C





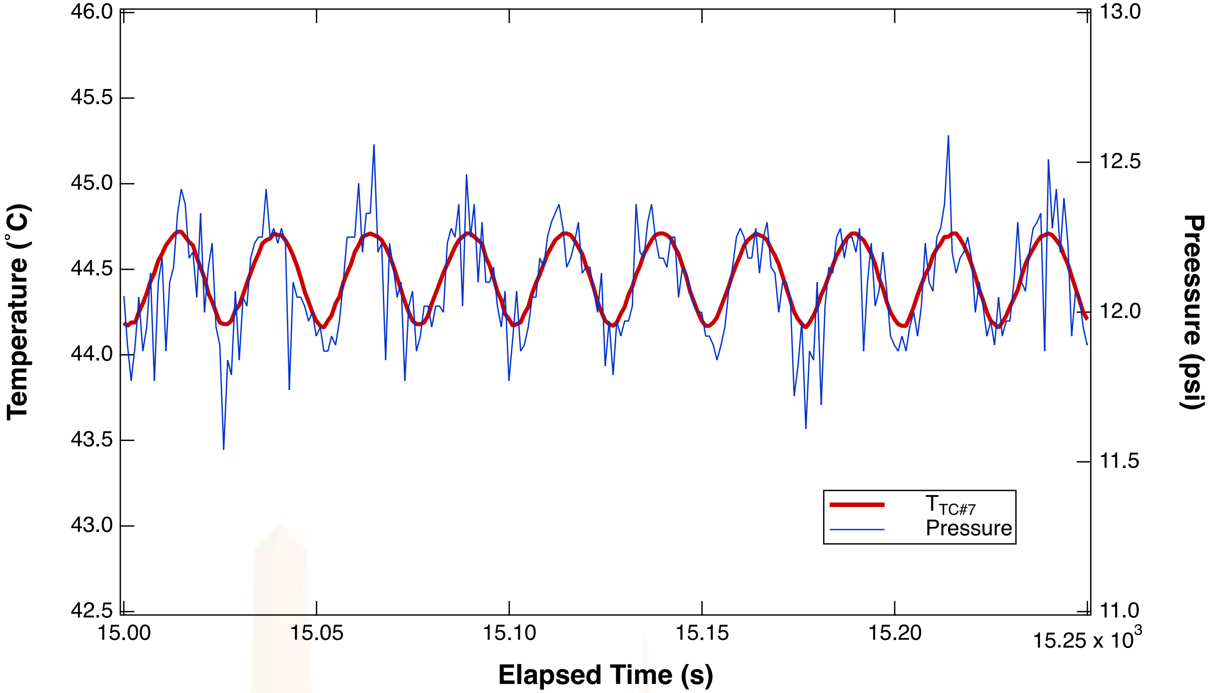
Wickless Heat Pipe Theoretical Model



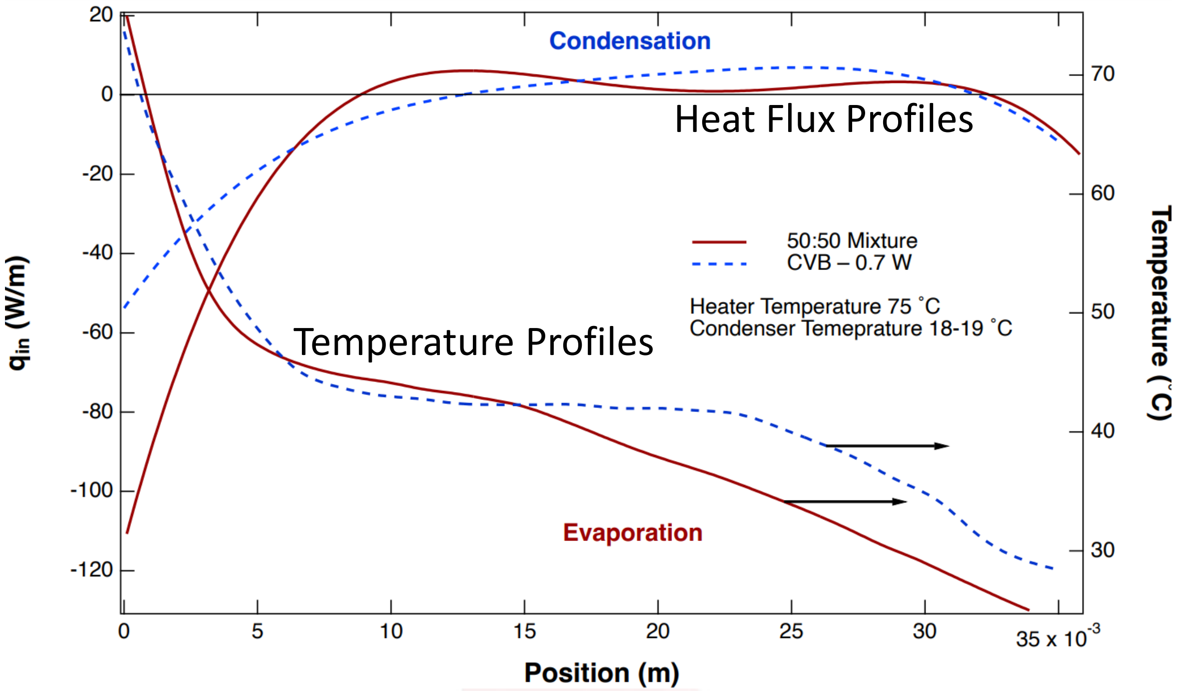
Flight Cuvette: 3 x 3 x 50mm Passage
28 Fine-wire Sensors On Underside
50/50 vol% Pentane/Isohexane

MaRVIn-PCIM Transparent Heat Pipe Results

Data from: Plawsky, Joel
Rensselaer Polytechnic Institute



Temperature & Pressure Oscillations



Axial Temperature & Heat Flux Profiles

Oscillations in pressure occur at same frequency as those in temperature, are set up over a narrow temperature range, and begin as a temperature threshold is crossed.

Oscillations are generated by a form of evaporative distillation: vapor pressures of binary mixture result in differential condensation areas along the main axis thermal profile. Restoring force is not large, and the pumping action cannot overcome gravity with evaporator end situated at the top of a vertically oriented heat pipe on Earth.

One conclusion is that previous studies had too little Isohexane for oscillations to occur.

Gilchrist, Cheng, Schultz
Lehigh University
CASIS: 2126481

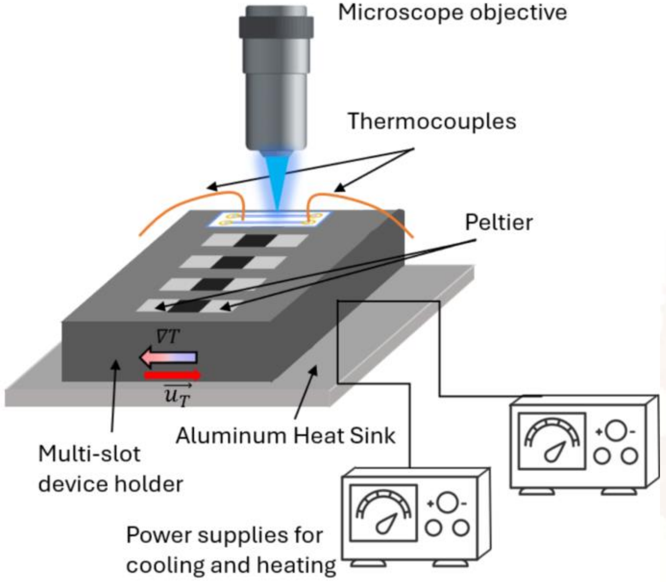
MaRVIn-TABOOS

Data from N. Hasanova

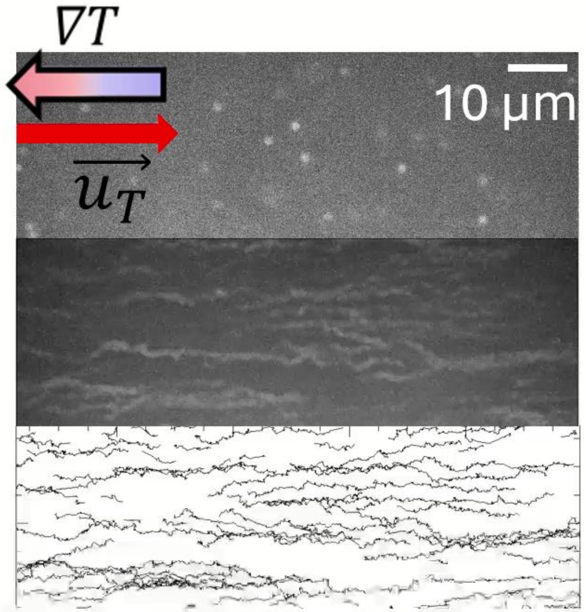
- Observing motion of nanoparticles in non-Newtonian fluids in temperature gradients
- Microgravity reduces impact of buoyancy-induced recirculation
- Imaging particle motion allows both measurement of thermophoresis and local rheology using Brownian motion

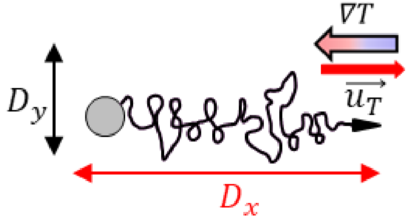
Physics of combined **Thermophoresis** and **non-Newtonian Rheology**

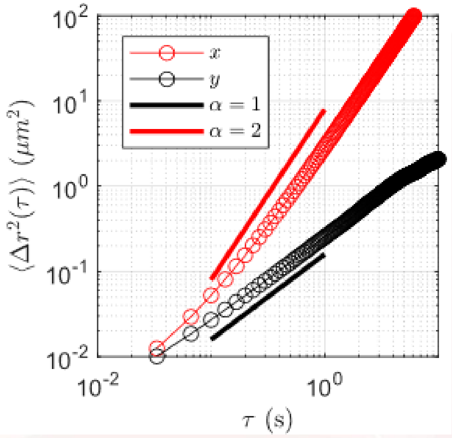
MaRVIn Data Collection

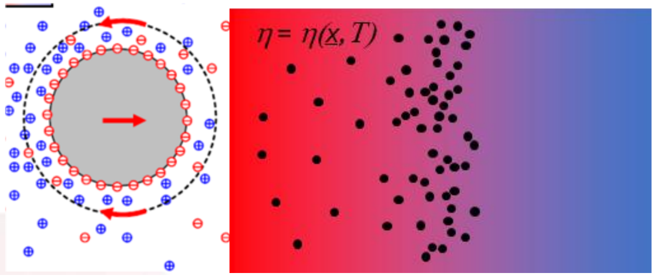


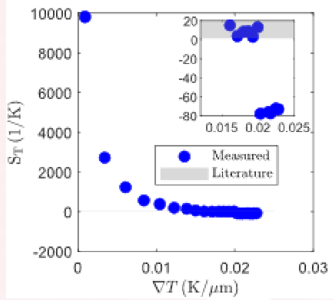
Data Analysis

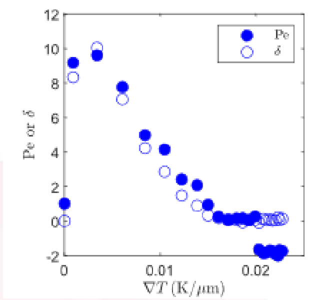




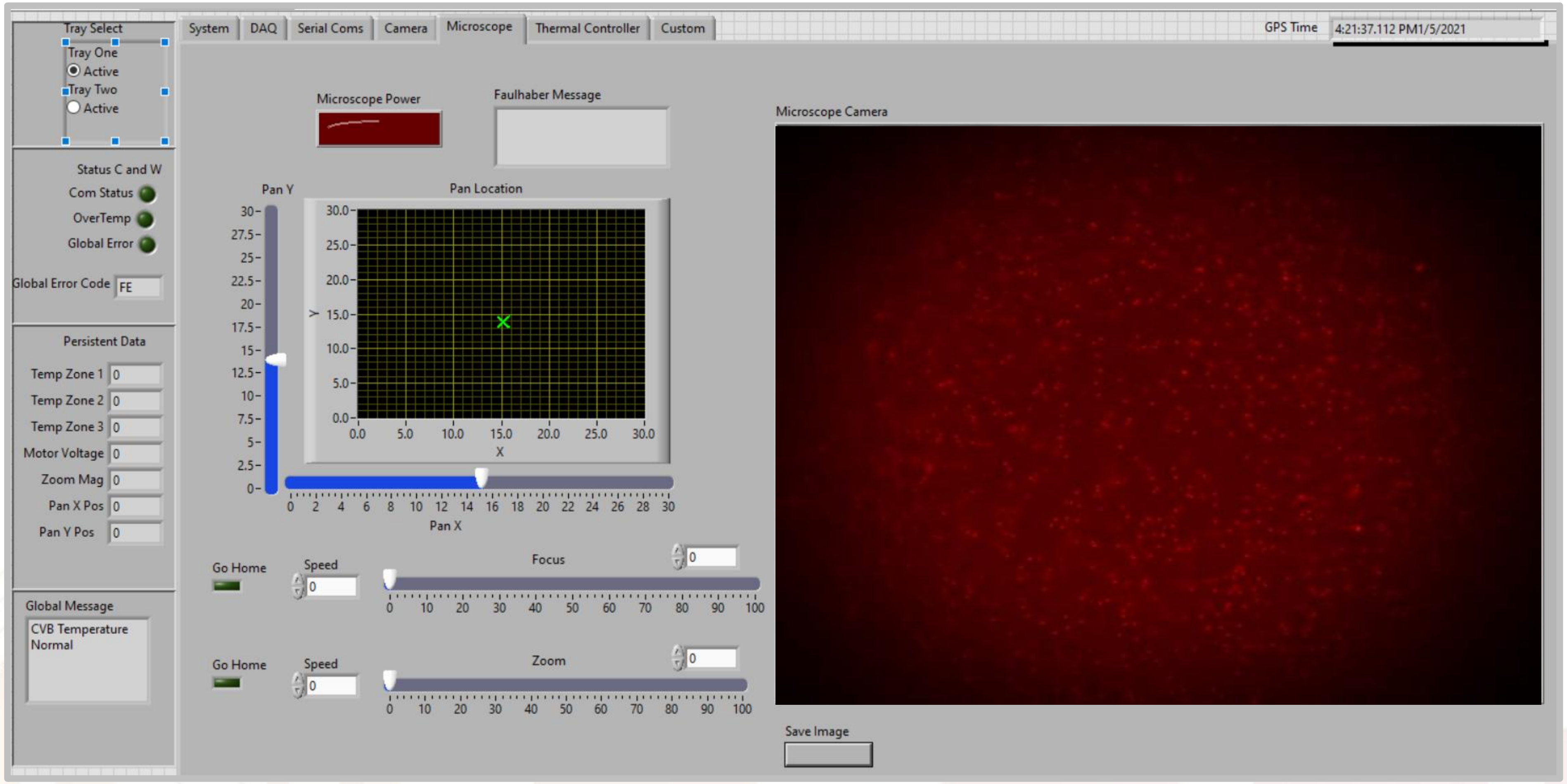








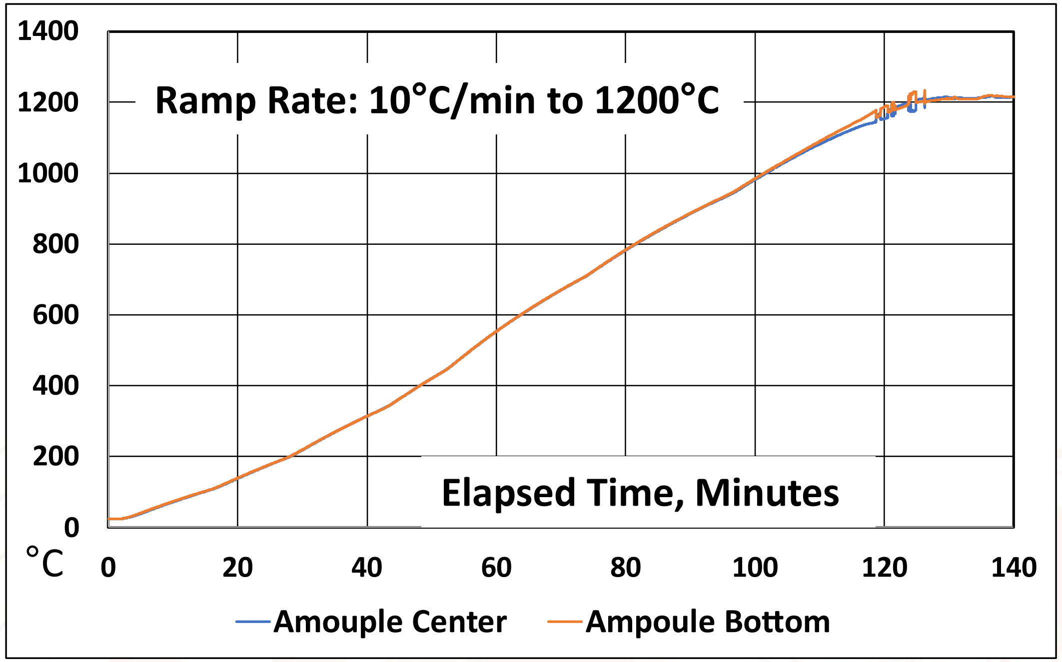
Software Overview: Microscope Remote Control Panel



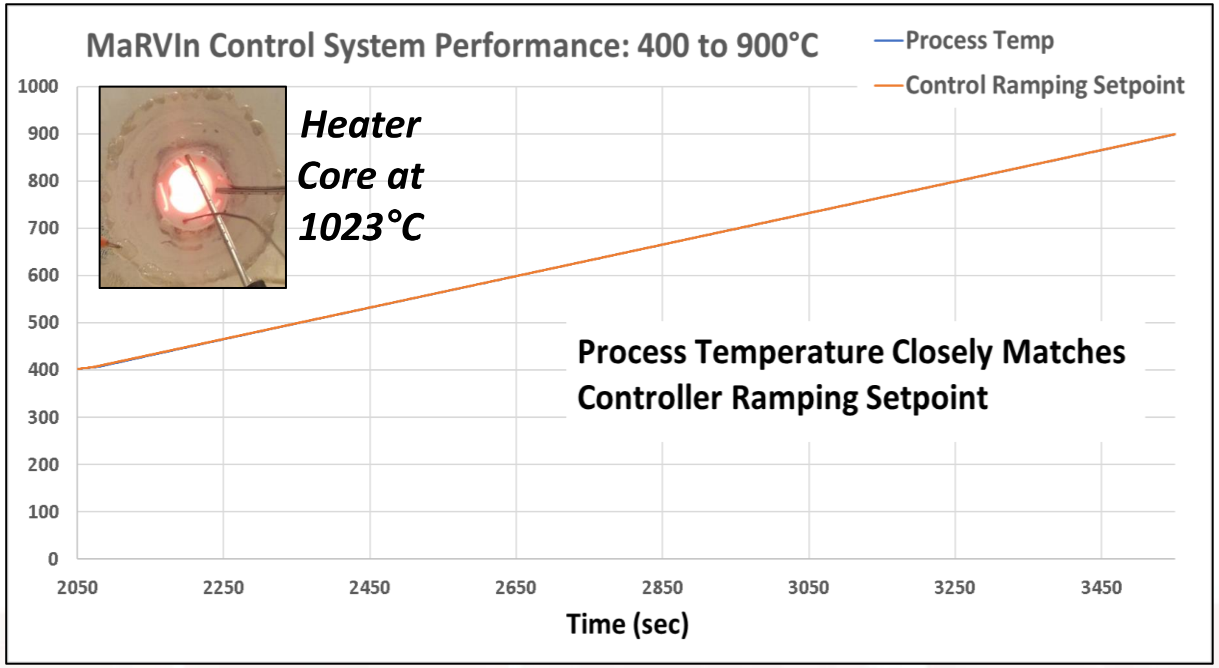
Ground Operator Workstation Interface: Remote X-Y Panning, 7:1 Zoom, Fine Focus & Lighting

Materials Processing at Elevated Temperatures

- MaRVIn control system can maintain temperatures within 0.1°C of setpoint, with similar accuracy for ramping rates. This supports precision ramp & hold thermal profiles for solders, brazing, crystal growth or annealing studies.
- Prototype heater modules can reach 1215°C with bore passage = 150mm length x 10mm inner diameter. An 8mm OD x 100mm length ampoule's isothermality from midline to end = 2°C at 1216.2°C and 1214.2°C, respectively.
- Current design could potentially reach up to 1350°C. Going above 1350°C will require upgraded materials.



Power = 80 W during ramp up, 69 W holding at 1200°C, 40 W holding at 1000°C on 28 VDC power supply



MaRVIn Is Developed & Operated by Tec-Masters, Inc. (TMI)

- TMI is a flight-proven Implementation Partner with 25+ years experience designing and developing flight hardware for NASA.
- TMI personnel have developed multiple MSG payloads for ISS:
  - SUBSA: Solidification Using a Baffle in Sealed Ampoules
  - PFMI: Pore Formation and Mobility Investigation
  - RSD: Ring Sheared Drop (TMI supported Teledyne Brown)

- Designed, developed, integrated and/or operated 60+ payloads on ISS.
- Provided mission integration & operation services for over 66,500 hours of operation for the MSG, LSG, MaRVIn, RSD, SUBSA, and PFMI flight and ground unit payloads.
- Supports ongoing flight operations for the MSG facility including systems engineering, payload integration/verification, testing, thermal and structural analyses for over 25 years.

For more information: Please visit our Tec-Masters booth in the ISS R&D Marketplace

Points of Contact: Scott Gilley (256-426-7694) or Mala Thompson (256-721-6672)

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Appreciation is extended to NASA Marshall Space Flight Center (MSFC) Materials and Processes scientists as well as the MMaJIC Project interns, from whose efforts the MaRVIn architecture was derived.

Appreciation is also extended to the MSFC Microgravity Science Glovebox Project for their expertise in supporting ISS experiments, and to Dr. Sid Pathak at Iowa State University for the opportunity to support ISS Soldering Studies.

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