

Materials Science Research Rack Onboard the International Space Station. S.E. Reagan, Natalie Frazier, John Lehman, NASA Marshall Space Flight Center; Jacobs, Engineering, Teledyne Brown Engineering

The Materials Science Research Rack (MSRR) is a research facility developed under a cooperative research agreement between NASA and ESA for materials science investigations on the International Space Station (ISS). MSRR was launched on STS-128 in August 2009 and currently resides in the U.S. Destiny Laboratory Module. Since that time, MSRR has logged more than 1400 hours of operating time.

The MSRR accommodates advanced investigations in the microgravity environment on the ISS for basic materials science research in areas such as solidification of metals and alloys. The purpose is to advance the scientific understanding of materials processing as affected by microgravity and to gain insight into the physical behavior of materials processing. MSRR allows for the study of a variety of materials, including metals, ceramics, semiconductor crystals, and glasses. Materials science research benefits from the microgravity environment of space, where the researcher can better isolate chemical and thermal properties of materials from the effects of gravity. With this knowledge, reliable predictions can be made about the conditions required on Earth to achieve improved materials.

MSRR is a highly automated facility with a modular design capable of supporting multiple types of investigations. The NASA-provided Rack Support Subsystem provides services (power, thermal control, vacuum access, and command and data handling) to the ESA-developed Materials Science Laboratory (MSL) that accommodates interchangeable Furnace Inserts (FI). Two ESA-developed FIs are presently available on the ISS: the Low Gradient Furnace (LGF) and the Solidification and Quenching Furnace (SQF). Sample Cartridge Assemblies (SCAs), each containing one or more material samples, are installed in the FI by the crew and can be processed at temperatures up to 1400°C.

ESA continues to develop samples with 14 planned for launch and processing in the near future. Additionally NASA has begun developing SCAs to support US PIs and their partners. The first of these Flight SCAs are being developed for investigations to support research in the areas of crystal growth and liquid phase sintering. Subsequent investigations are in various stages of development. US investigations will include a ground test program in order to distinguish the particular effects of the absence of gravity.



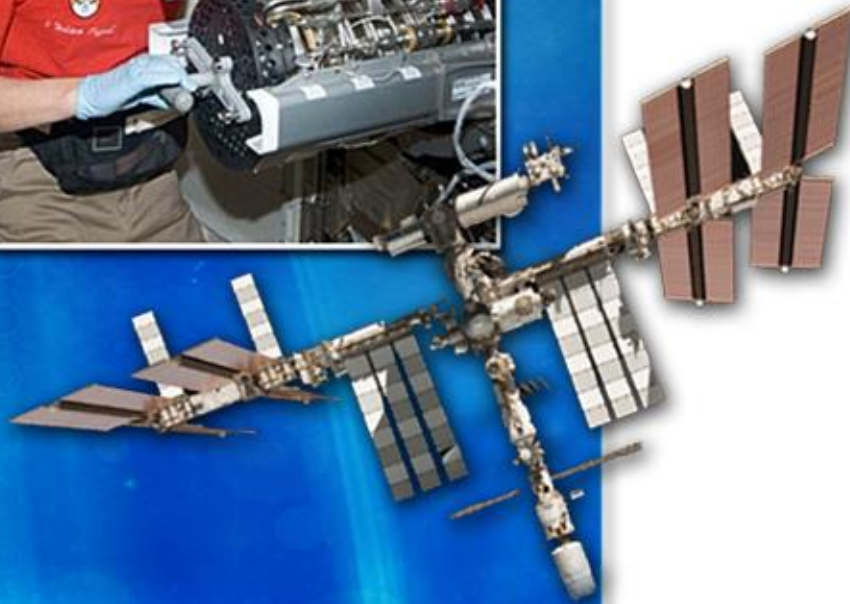
# Materials Science Research Rack Onboard the International Space Station

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# Materials Science Research Rack (MSRR)

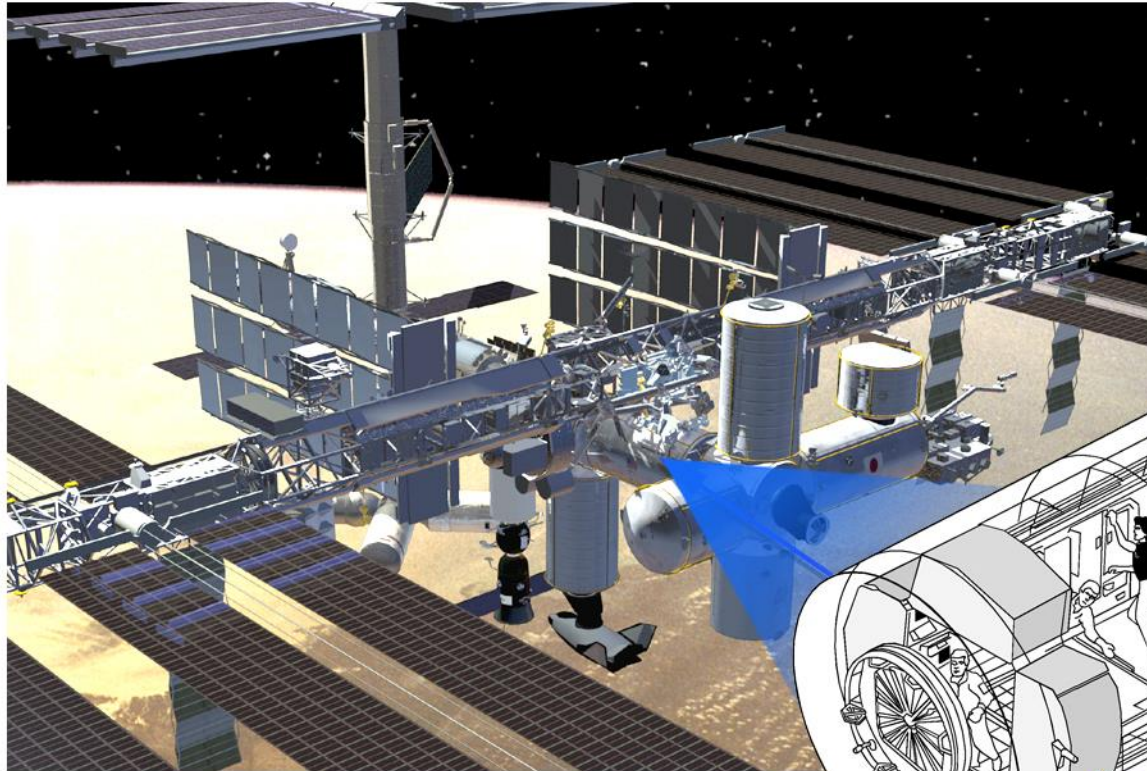
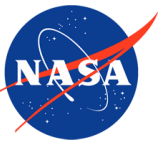


- ◆ **The Materials Science Research Rack (MSRR) is a highly automated facility developed in a joint venture/partnership between NASA and ESA**
  - Allows for the study of a variety of materials including metals, ceramics, semiconductor crystals, and glasses onboard the International Space Station (ISS)
  - Multi-user facility for high temperature materials science research
  - Launched on STS-128 in August 2009, and is currently installed in the U.S. Destiny Laboratory Module
- ◆ **Research goals**
  - Provide means of studying materials processing in space to develop a better understanding of the chemical and physical mechanisms involved
  - Benefit materials science research via the microgravity environment of space where the researcher can better isolate the effects of gravity during solidification on the properties of materials
  - Use the knowledge gained from experiments to make reliable predictions about conditions required on Earth to achieve improved materials

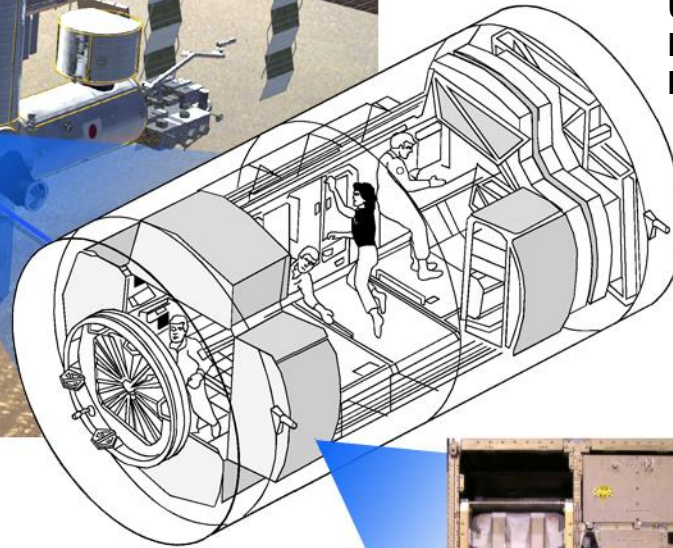




# MSRR Location



**International  
Space Station**



**U.S.  
Laboratory  
Module**



**Materials  
Science  
Research Rack**

- ◆ **MSRR is resident onboard ISS in the U.S. Destiny Laboratory Module in the Lab Overhead 3 position**



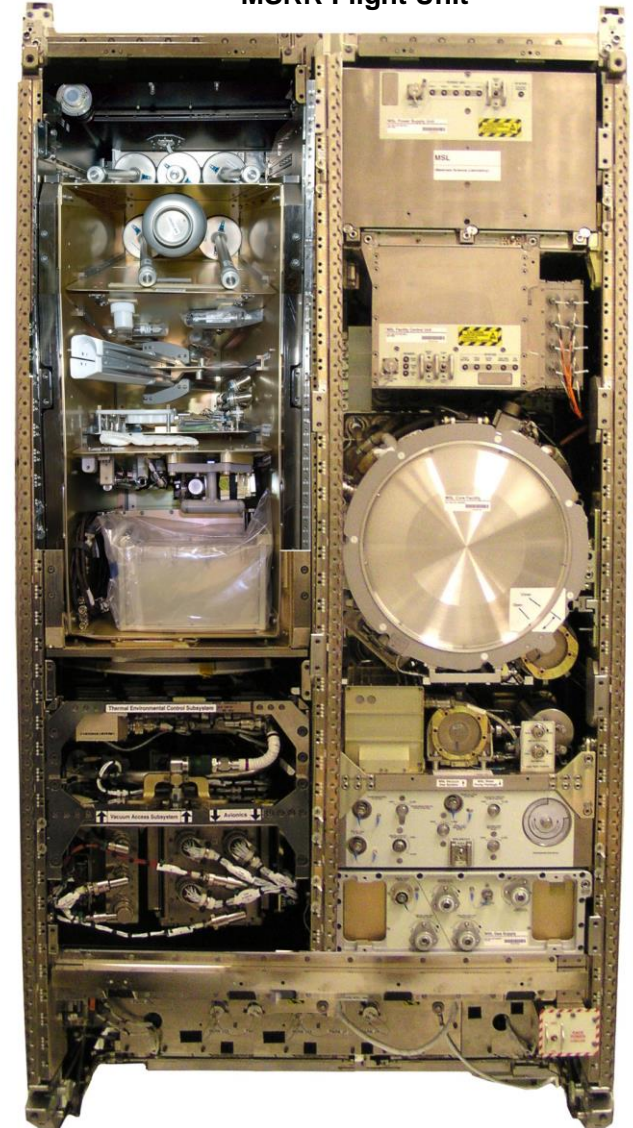
# Integrated Facility Overview



## ◆ NASA

- MSRR Experiment Carrier (EC)
  - Boeing International Standard Payload Rack (ISPR) with Active Rack Isolation System (ARIS) capability
  - Rack Support System (RSS) – provides resource allocation to 2 Experiment Modules (Alpha and Beta sides of the rack) and provides access for the EMs to the ISS systems
    - Power
    - Data – 1553 BUS, Payload MDM
    - Video – provides signal and downlinks to ISS internal video system
    - Vacuum access – Vacuum Exhaust System and Vacuum Resource System
    - Thermal environment control - Moderate temperature cooling loop
    - MSRR Payload Laptop Computer
- Stowage – Experiment Module (EM) Alpha
  - On-orbit stowage for MSFC/ESA-provided tools, spares, Orbital Support Equipment, and Sample Cartridge Assemblies (SCAs)
  - Scarred with resources/services for an additional Experiment Module for future use

MSRR Flight Unit



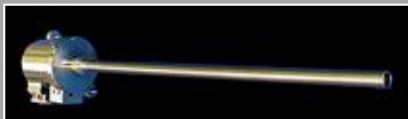


# Integrated Facility Overview (continued)



## ◆ ESA

- Materials Science Laboratory (MSL) – Experiment Module Beta
  - Main mode of operation is directional solidification of alloys and semiconductors
  - Supports crystal growth by zone melting or measurement of diffusion coefficients (stationary temperature profiles)
  - Operation of resistance heated Furnace Inserts with up to 8 individually controlled heaters qualified for maximum temperatures of 1400 °C
  - Precise experiment control (temperature profiles and growth speed) with various experiment diagnostics and stimuli (e.g., rotating magnetic field to stir the liquid metal)
- Low Gradient Furnace (LGF)
  - Designed to achieve a well-controlled low or medium thermal gradient inside the sample between one high- and one low-temperature heater zones with an adiabatic zone in-between these 2 heater zones
- Solidification and Quenching Furnace (SQF)
  - Bridgman furnace designed to provide for high gradients typically in the range of 50 - 150 K/cm in the cartridge, consisting of one hot cavity, an exchangeable adiabatic zone, and a water cooled chill block (cooling zone) acting as heat sink
  - Quench capability provided by a rapid displacement of the furnace insert, typically 50 to 100 mm within about 1 second
- Sample Cartridge Assemblies (SCAs)
  - Leak-tight containers for materials samples, sensors for process control & safety, and stimuli
  - LGF-type SCAs and SQF-type SCA qualified for maximum temperatures of 940 °C and 1380 °C, respectively



LGF-Type SCA



LGF Flight Model



MSL Flight Model



SQF Flight Model



SQF-Type SCA



# Integrated Facility Overview (continued)



## ◆ MSRR-1 Rack Level Accommodations

- Power – 6000W rack location with 5000W of 120/28 Vdc power supplied to EMs
- Data – 2 Ethernet and 2 MIL-STD-1553B
- Vacuum – 1 connection each to the Vacuum Exhaust System and the Vacuum Resource System
- Thermal – Connected to ISS Moderate Temperature Loop (MTL)

## ◆ MSL Low Gradient Furnace (LGF) Capabilities

- Supports directional solidification at gradients up to  $\sim 40\text{K/cm}$  (isothermal profiles can be supported also)
- Furnace bore: 30mm
- Furnace temp control range: 500 - 1400°C
- Maximum heatup rate: 10 K/min

## ◆ MSL Solidification and Quenching Furnace (SQF) Capabilities

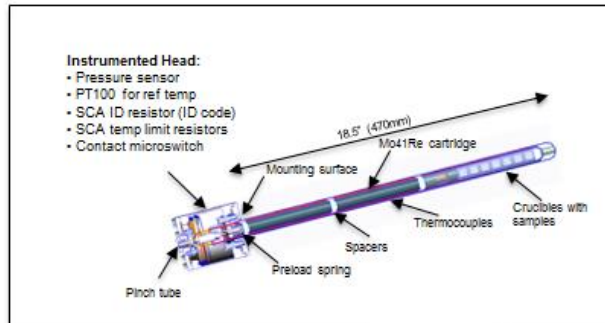
- Bridgman furnace consisting of a hot cavity, a water cooled chill block, and an adiabatic zone
- Heat transfer between cooling zone and SCA can be by radiation or liquid metal ring (LMR)
- Support directional solidification at gradients in a range of 50-150 K/cm with LMR or 20-30 K/cm without LMR
- Furnace bore: 20mm
- Maximum temperature: 1400°C

## ◆ Sample Cartridge Assembly (SCA)

- Provides containment of samples
- Temperature monitoring for up to 12 thermocouples
- SCA internal pressure sensor



# Integrated Facility Overview (continued)



**Experiment Samples and Crucibles**

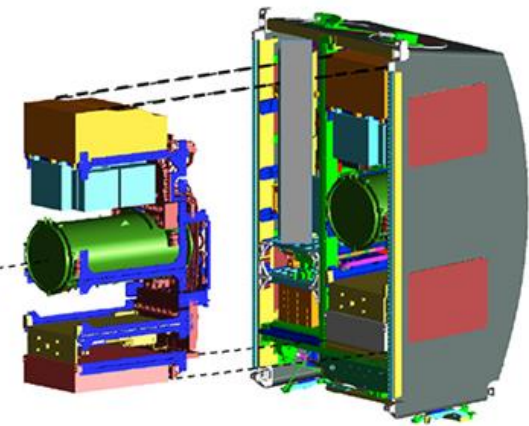
- PI provided
- Samples and crucible for processing

**Sample Cartridge Assembly (SCA)**

- Houses and provides containment for sample and crucible set
- Instrumentation sensors for monitoring temperature and cartridge integrity
- Loaded into the insert by flight crew
- Sealed to provide one level of containment

**ESA's Furnace Module Insert**

- Insert designed to accommodate investigation-unique processing requirements
- Replaceable on-orbit
- Provides for "Automatic" processing
- Vacuum operations

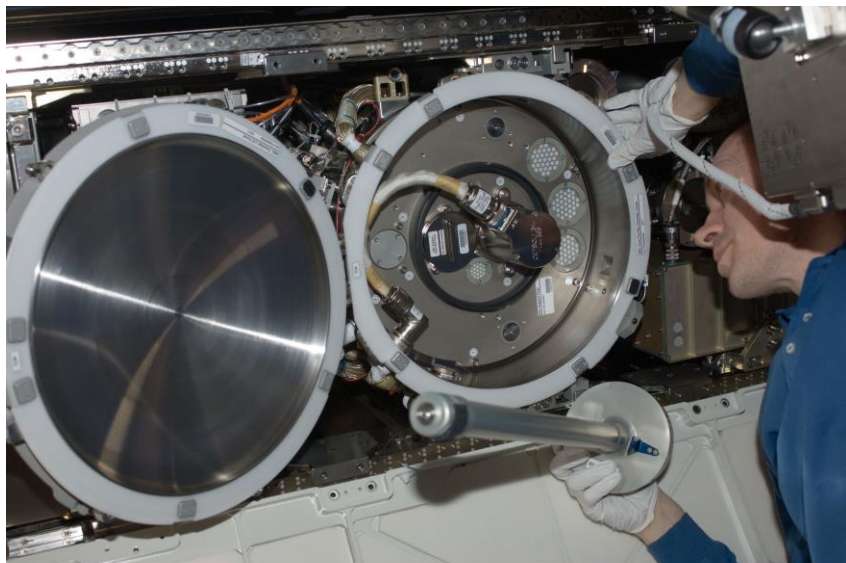


**Materials Science Laboratory Experiment Module Accommodates ESA Module Insert**

- ESA Provides:
- Core Facility
  - Power Supply
  - Avionics/Control System
  - Gas/Vacuum Distribution
  - Sub-system
  - Data Electronics
  - Water Pump Package
  - Gas Supply

**MSRR-1**

- NASA provides Rack and Subsystems
- NASA integrates the Rack with Payload Experiment Hardware







# Basic Operational Concept



- ◆ Furnace Inserts are exchangeable on-orbit
- ◆ SCAs are installed, one at a time, into the Furnace Insert by a Crew Member
- ◆ Experiments can be run by automated command via Sample Processing Programs (SPPs), telemetry commands from the ground, or by Crew Member commanding via the MSRR Laptop Computer
- ◆ Joint MSRR/MSL operations are performed via integrated team approach
  - MSRR operations team at the Huntsville Operations Support Center (HOSC) in Huntsville, AL
  - MSL operations team at the Microgravity User Support Center (MUSC) at DLR in Cologne, Germany
  - Principal Investigators (PIs) may be present in HOSC and/or MUSC control rooms during sample processing; PIs can also receive near real-time data at the PI facilities
  - Ground labs available at MUSC and MSFC

HOSC Ground Control Room



MUSC Ground Control Room

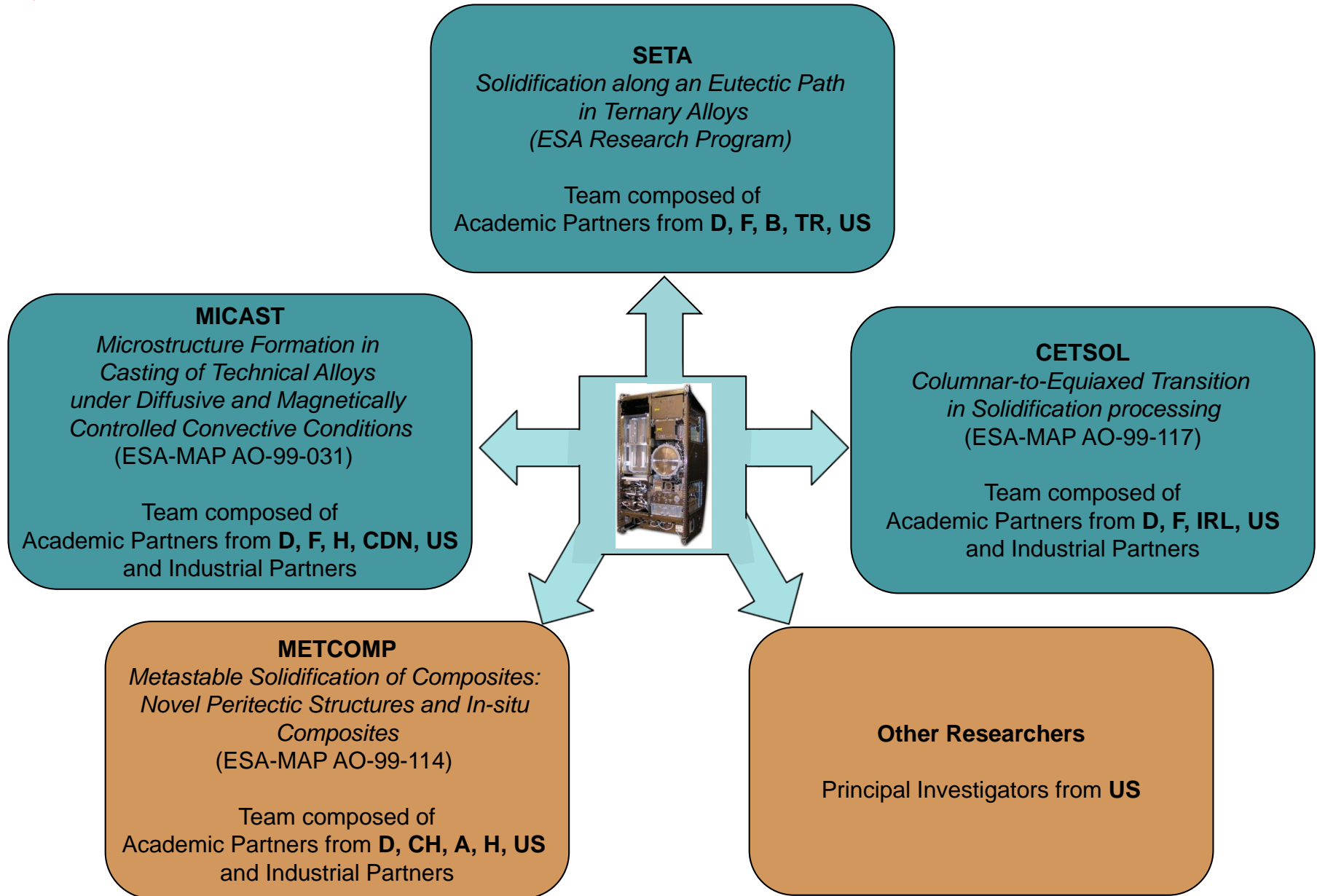
MUSC Ground Lab



MSFC Ground Lab including PRCU



# Materials Science Research with MSRR/MSL





# MSRR/MSL Operations – Success Story



- ◆ MSRR/MSL have successfully completed approximately 1750 hours of operational time (as of September 2016)
- ◆ On-orbit commissioning was completed Nov 6, 2009
- ◆ 12 SCAs were successfully processed November 2009 – April 2010 in the LGF and downloaded on various Shuttle flights
- ◆ 21 SCAs were successfully processed January 2011 – September 2016 in the SQF and downloaded on various SpaceX flights
- ◆ Preliminary examination of samples indicate that the majority of the desired science objectives have been successfully met
- ◆ ESA's batch 2b set of SCAs are currently on orbit and are being processed





# Future Plans

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## ◆ Future SCAs provided by ESA

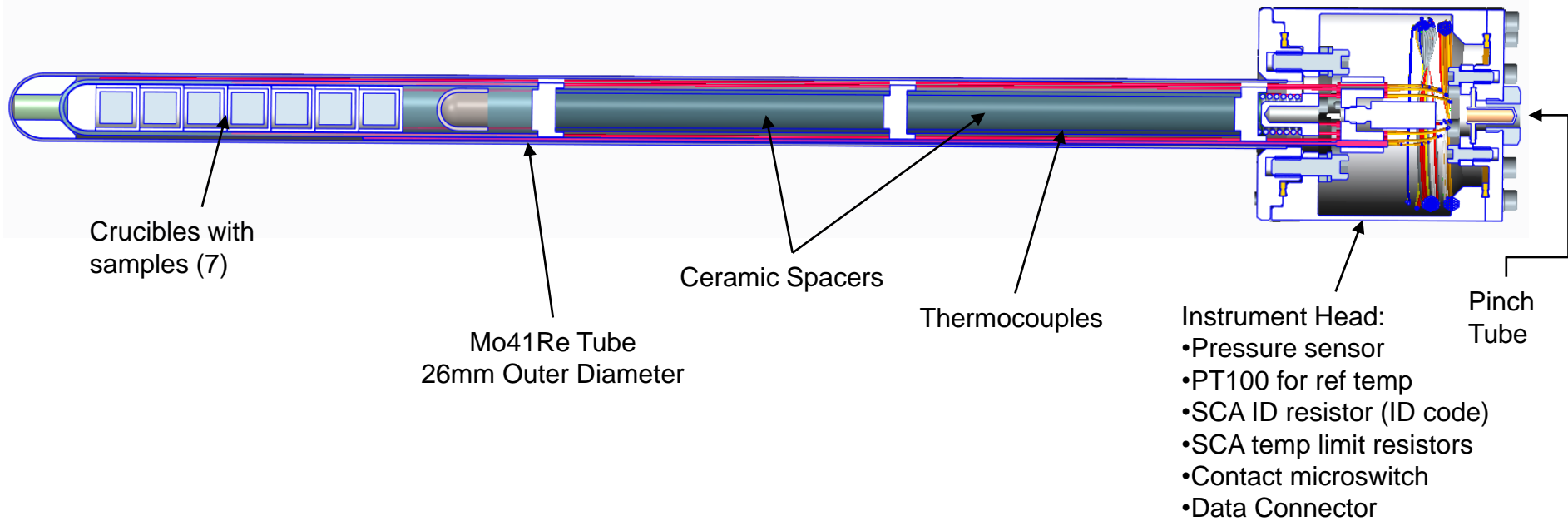
- Batch 3 SCAs planned for 2020 timeframe

## ◆ Future SCAs provided by NASA

- NASA SCA development supports US PIs and their partners
- The first of these Flight SCAs are being developed for investigations to support research in the areas of crystal growth and liquid phase sintering
- Subsequent investigations are in various stages of development
- NASA SCAs will be qualified for use in the LGF at maximum temperatures of 1250 °C
- US investigations will include a ground test program in order to distinguish the particular effects of the absence of gravity.



# NASA SCAs





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*This facility is available to support additional programs such as the US National Laboratory, Technology Development, NASA and International Research Announcements, ESA application-oriented research programs, and others.*

