

## **Materials Science Research Rack Onboard the International Space Station Hardware and Operations**

John R. Lehman  
Teledyne Brown Engineering  
300 Sparkman Drive  
Huntsville, AL 35807  
[john.lehman@nasa.gov](mailto:john.lehman@nasa.gov)

Natalie C. Frazier  
Jacobs, ESTS Group  
1525 Perimeter Parkway, Suite 330  
Huntsville, AL 35806  
[Natalie.c.frazier@nasa.gov](mailto:Natalie.c.frazier@nasa.gov)

Jimmie Johnson  
NASA / Marshall Space Flight Center  
MSFC, AL 35812

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 is currently installed in the U. S. Destiny Laboratory Module. Since that time, MSRR has performed virtually flawlessly, logging more than 620 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. Currently 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) which 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. Once an SCA is installed, the experiment can be run by automatic command or science conducted via telemetry commands from the ground. Initially, 12 SCAs were processed in the first furnace insert for a team of European and US investigators. After these samples were processed the Furnaces Inserts were exchanged and an additional single sample was processed. The processed samples have been returned to Earth for evaluation and comparison of their properties to samples similarly processed on the ground. A preliminary examination of the samples indicates that the majority of the desired science objectives have been successfully met leading to significant improvements in the understanding of alloy solidification processes. Six SCAs were launched on Space Shuttle Mission STS-135 in July 2011 for processing during the Fall of 2011. Additional batches are planned for future processing. This facility is available to support additional materials science investigations through programs such as the US National Laboratory, Technology Development, NASA Research Announcements, and others.



# Materials Science Research Rack Onboard the International Space Station Hardware and Operations



**John Lehman,  
Systems Engineer  
Teledyne Brown Engineering/  
NASA MSFC**

**Natalie Frazier,  
Senior Systems Engineer  
Jacobs ESTS Group/NASA MSFC**

**Jimmie Johnson,  
MSRR Project Manager  
NASA MSFC**



Materials Science Research Rack





# Materials Science Research Rack (MSRR)

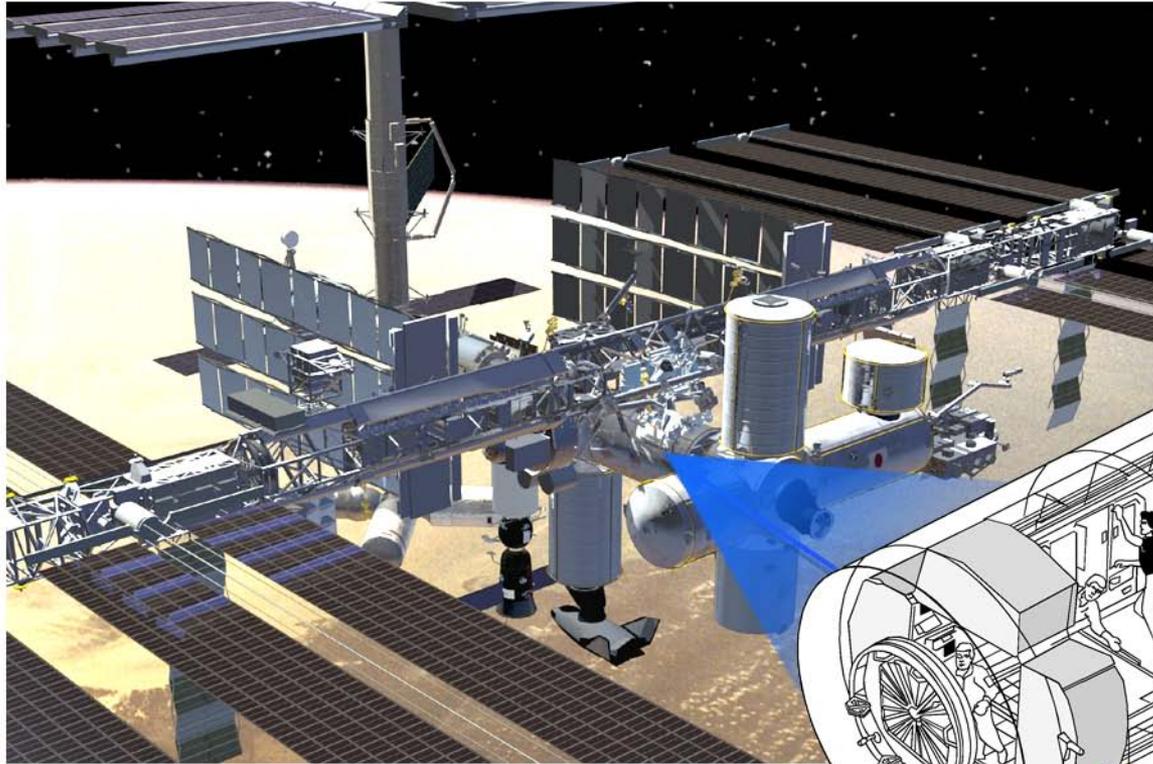


- ◆ **The Materials Science Research Rack (MSRR) is a highly automated facility developed in a joint venture/partnership between NASA and ESA**
  - Allows for the study of a variety of materials including metals, ceramics, semiconductor crystals, and glasses onboard the International Space Station (ISS)
  - 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

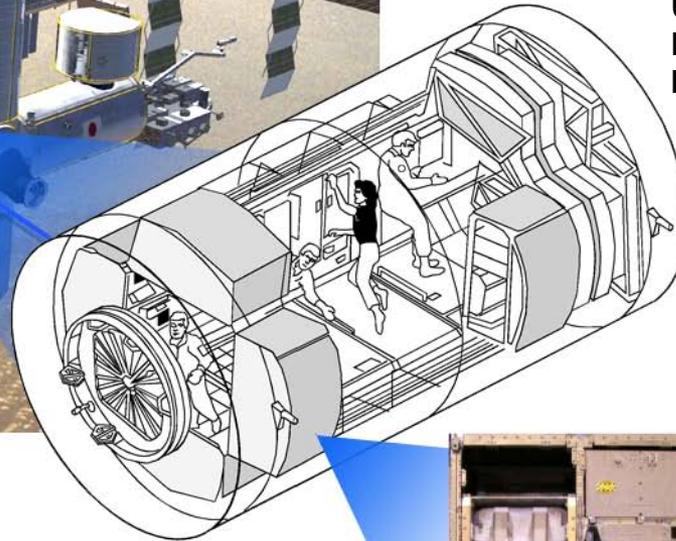




# MSRR Location



**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**



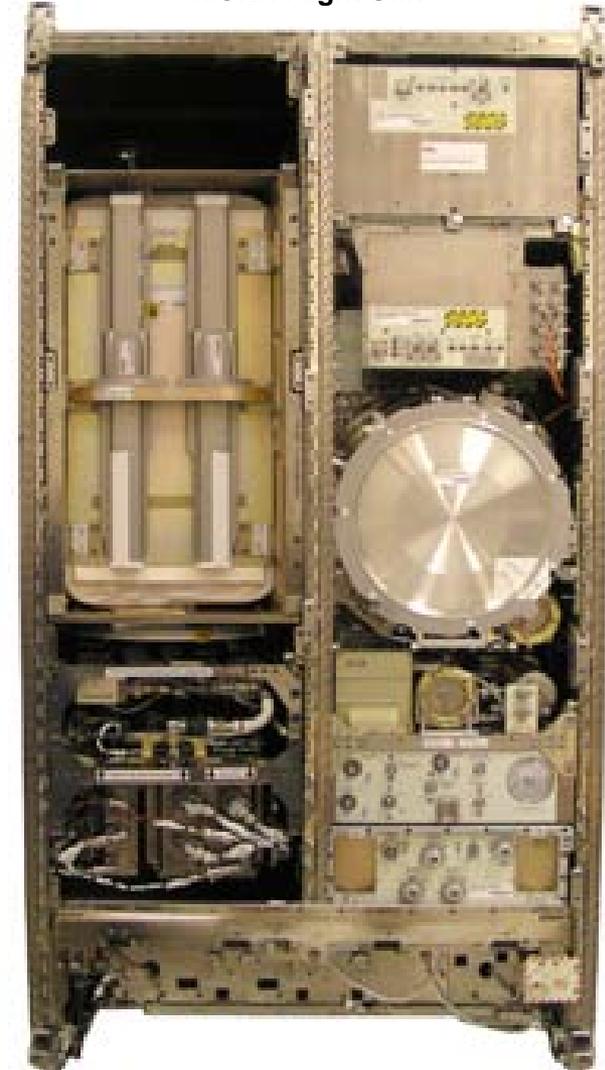
# Integrated Facility Overview



## ◆ 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 additional an Experiment Module for future use

MSRR Flight Unit



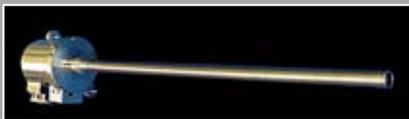


# Integrated Facility Overview (continued)



## ◆ 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 1065 °C, respectively



LGF-Type SCA



LGF Flight Model



MSL Flight Model



SQF Flight Model



SQF-Type SCA



# 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) present in HOSC and MUSC control rooms during sample processing; PIs also receive near real-time data at the PI facilities
  - Ground labs available at MUSC and MSFC

HOSC Ground Control Room

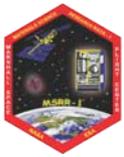


MUSC Ground Control Room

MUSC Ground Lab



MSFC Ground Lab including PRCU



# Materials Science Research with MSRR/MSL

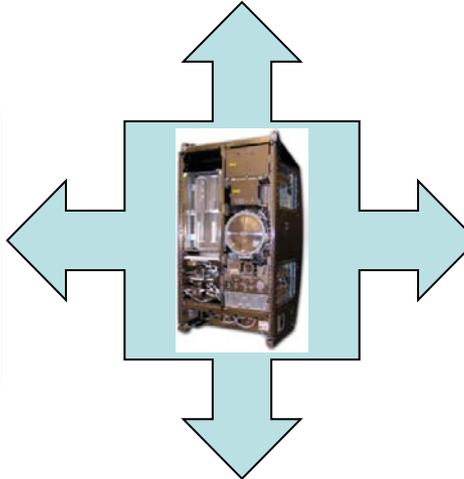


**SETA**  
*Solidification along an Eutectic Path  
in Ternary Alloys*  
(ESA-MAP AO-99-046)

Team composed of  
Academic Partners from **D, F, B, US**

**MICAST**  
*Microstructure Formation in  
Casting of Technical Alloys  
under Diffusive and Magnetically  
Controlled Convective Conditions*  
(ESA-MAP AO-99-031)

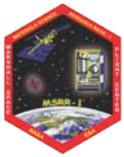
Team composed of  
Academic Partners from **D, F, H, CDN, US**  
and Industrial Partners



**CETSOL**  
*Columnar-to-Equiaxed Transition  
in Solidification processing*  
(ESA-MAP AO-99-117)

Team composed of  
Academic Partners from **D, F, IRL, US**  
and Industrial Partners

**Other Researchers**  
Principal Investigators from **US**

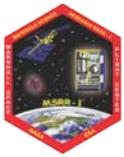


# MSRR/MSL Operations



- ◆ **MSRR/MSL have performed as designed, successfully completing over 650 hours of operational time**
- ◆ **On-orbit commissioning was completed Nov 6, 2009**
- ◆ **12 SCAs have been successfully processed in the LGF and downloaded on various Shuttle flights**
  - Preliminary science results from the first 12 SCAs were presented by researchers at the June 2010 MSRR/MSL Operations Technical Interface Meeting at DLR in Cologne, Germany
  - Preliminary examination of samples indicate that the majority of the desired science objectives have been successfully met
- ◆ **4 SCAs have been processed in the SQF; one has been downloaded and three more are scheduled for download on SpaceX Demo in March 2012**





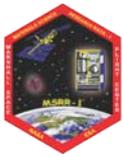
# Future Plans

---



- ◆ **Three SCAs are on orbit awaiting processing in SQF**
  
- ◆ **Future SCAs provided by ESA**
  - Batch 2a Set 2 consisting of 11 SCAs will be available for flight July 2012
  - Batch 2b SCAs planned for NET 2013
  - Batch 3 SCAs planned NET 2013
  
- ◆ **Future SCAs provided by NASA**
  - First MSFC experiment development SCAs planned for Fall 2012
  - First MSFC Flight SCAs planned for June 2014, total of approximately 50 units by end of 2016





# Future Plans



## ◆ NASA Developed Cartridge

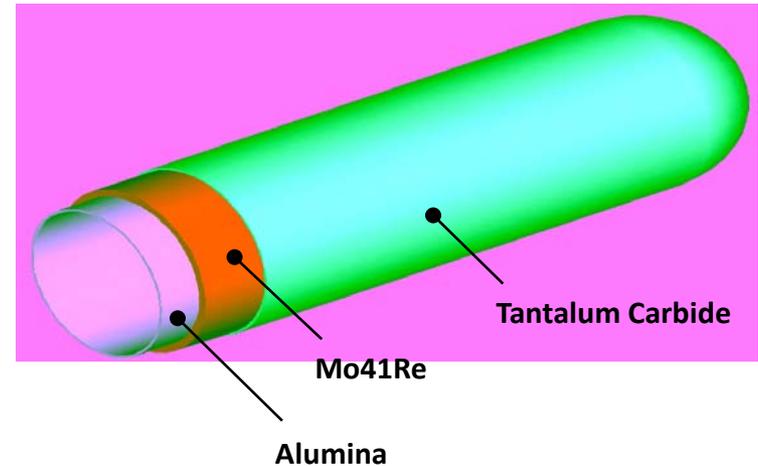
### ◆ Materials (Plasma Sprayed):

- Base Metal: Molybdenum-Rhenium
- Interior: Alumina Liner
- Exterior: Tantalum Carbide Coating

### ◆ Two Diameters

- ~15 mm for use in SQF or LGF
- ~25 mm for use in LGF

### ◆ Testing is being conducted in order to qualify the cartridge as a level of containment for a wide range of sample materials



*MSRR 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.*

