Materials Science Research Rack Onboard the International Space Station

Natalie C. Frazier
Jacobs, ESTS Group
1525 Perimeter Parkway, Suite 330
Huntsville, AL 35806
Natalie.c.frazier@nasa.gov

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

Winfried Aicher
Astrium GmbH – Space Transportation
88039 Friedrichshafen, Germany

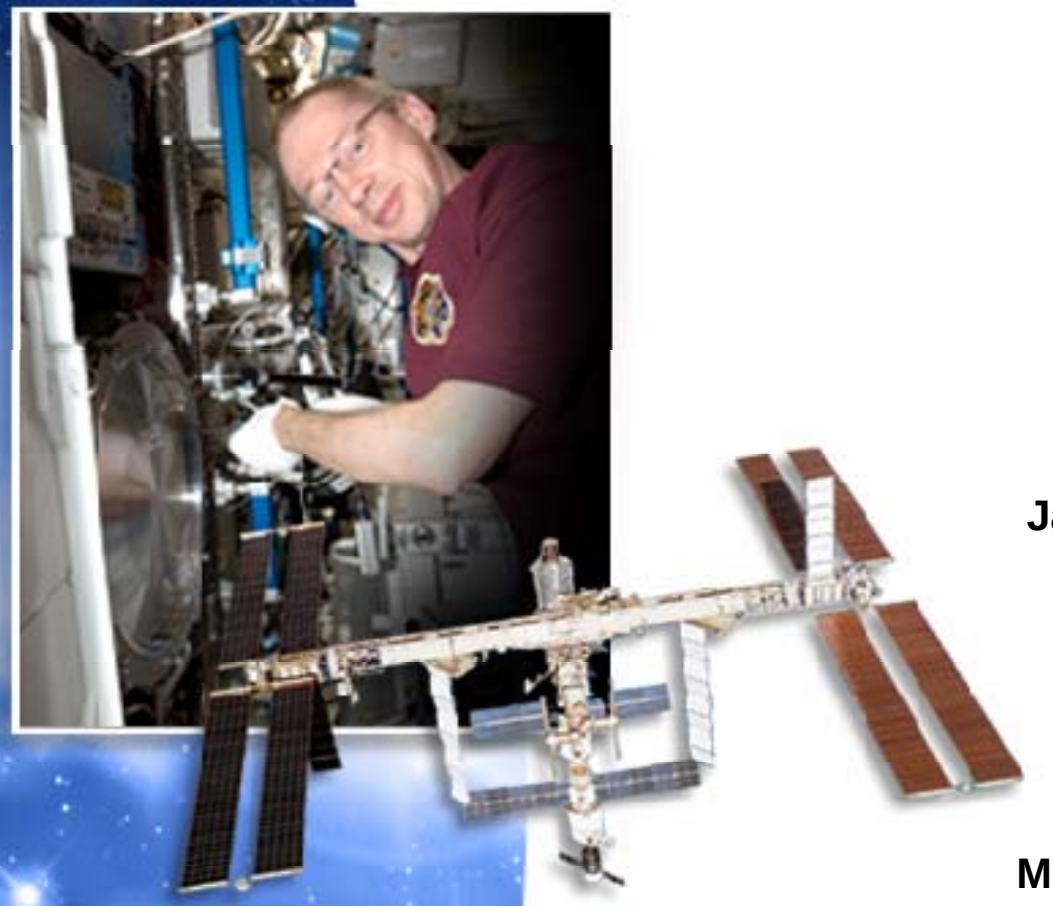
The Materials Science Research Rack (MSRR) allows for the study of a variety of materials including metals, ceramics, semiconductor crystals, and glasses onboard the International Space Station (ISS). MSRR was launched on STS-128 in August 2009, and is currently installed in the U. S. Destiny Laboratory Module. Since that time, MSRR has performed virtually flawlessly logging more than 550 hours of operating time.

Materials science is an integral part of development of new materials for everyday life here on Earth. The goal of studying materials processing in space is to develop a better understanding of the chemical and physical mechanisms involved. 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 containing two furnace inserts in which Sample Cartridge Assemblies (SCAs), each containing one material sample, can be processed up to temperatures of 1400°C. Once an SCA is installed by a Crew Member, 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. 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. The second furnace insert will be installed in the facility in January 2011 for processing the remaining SCA currently on-orbit. Six SCAs are planned for launch summer 2011, and 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, ESA application-oriented research programs, and others.

The development of the research rack was a cooperative effort between NASA's Marshall Space Flight Center and the European Space Agency (ESA).

National Aeronautics and Space Administration



www.nasa.gov

Materials Science Research Rack Onboard the International Space Station

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

Jimmie Johnson,
MSRR Project Manager
NASA MSFC

Winfried Aicher,
MSL Payload Integration Manager
Astrium GmbH/ESA

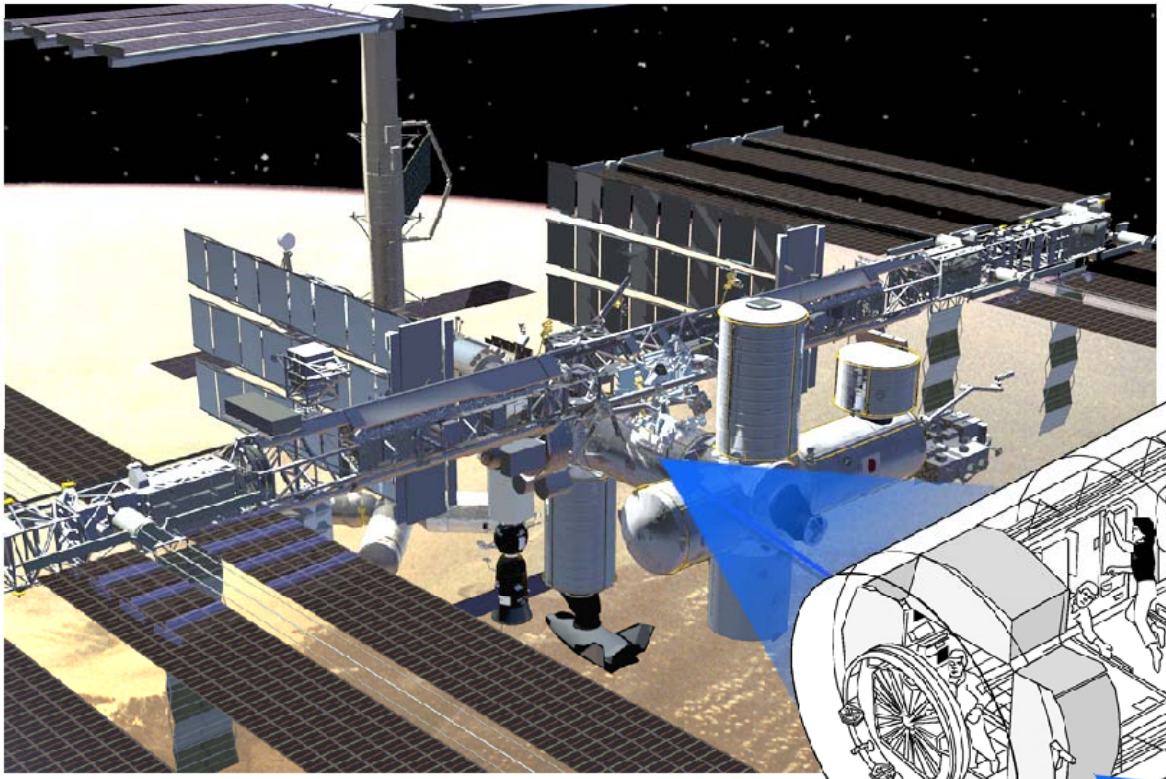
Materials Science Research Rack

Materials Science Research Rack (MSRR)

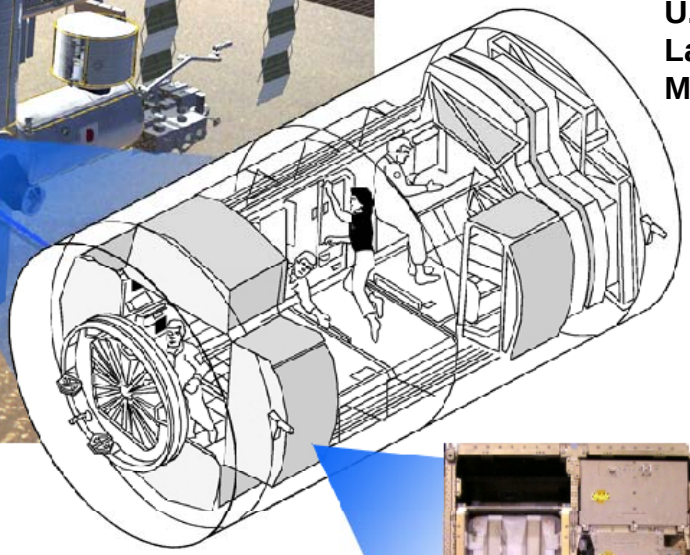
- **The Materials Science Research Rack (MSRR) is a highly automated facility developed in a joint venture/partnership between NASA and ESA**
  - Allows for the study of a variety of materials including metals, ceramics, semiconductor crystals, and glasses onboard the International Space Station (ISS)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

MUSC Ground Control Room

HOSC Ground Control Room

MSFC Ground Lab including PRCU

MUSC Ground Lab

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 – Success Story

- **MSRR/MSL have performed virtually flawlessly, successfully completing over 620 hours of operational time (as of 1/20/11)**
- **On-orbit commissioning was completed Nov 6, 2009**
- **12 SCAs have been successfully processed November 2009 – April 2010 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
- **1 SCA was successfully processed January 19 – 20, 2011 in the SQF and is planned for download on Flight ULF6 in April 2011**

Future Plans

- **Future SCAs provided by ESA**
  - Batch 2a Set 1 experiments consisting of 6 SCAs is planned for launch on Flight ULF7 June 2011 (if this Flight is approved) or Flight 44P in Sept 2011
  - Batch 2a Set 2 consisting of 11 SCAs will be available for flight June 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 Feb 2012
  - First MSFC Flight SCAs planned for Aug 2013, total of approximately 50 units by end of 2016; pending NASA Budget approval

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.