

Space Life and Physical Sciences Research and Applications Division (SLPSRA)

National Aeronautics and
Space Administration



35th Annual Meeting of the ASGSR

**Programmatics – SLPSRA Physical Sciences:
Materials and Biophysics Status**

**Dr. Louise Strutzenberg – MSFC
Mr. Michael SanSoucie – MSFC**

November 21, 2019



MSRR - SCA
MSRR/SCA - GEDS - German
MSRR/SCA - GTS - Su
MSRR/SCA - FAMIS - Hofmann
MSRR/SCA - TP Properties Diffusion - Ostrogorsky

H/W, Integration and PI Support
SCA Development - Reagan
ESL Ground Test Support - Sansoucie
RSD H/W - Depew
MaterialsLab SUBSA/PFMI SAA Fabrication
MICS - Stephens
MSFC Diagnostic Lab Support

DECLIC
DECLIC/DSI-R - DSI-R SPADES - Trivedi
CETSOL/DECLIC - Karma

Levitation
EML - THERMOLAB/PARSEC/ELFSTONE - Matson
EML - THERMOLAB/ICOPROSOL/QUASI - Kelton
EML - THERMOLAB/ICOPROSOL/PARSEC - Hyers
EML & ELF - ELF2 EML Round Robin - Matson
ELF - ELF1 Interfacial Phenomena - Hyers
ELF - ELF3 Non-Linear Optical Materials - Hyers
ELF - ELF4 Interfacial Tension - Narayanan
ELF - ELF5 Supercooled Molten Oxides - Weber
ELF - ELF6 Titanates and Oxides - Weber

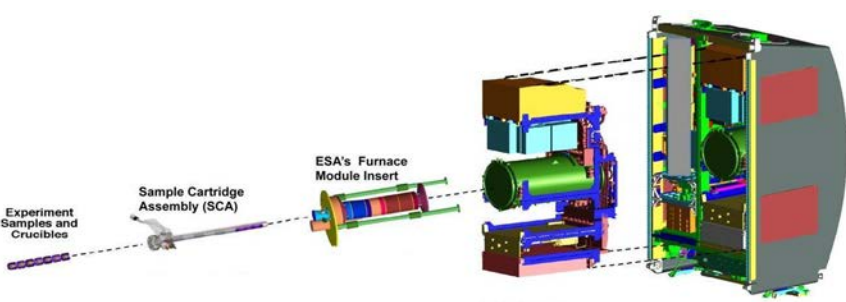
Informatics, PSI
PSI Informatics - Stephens
PSI-B1 Phase Field Modeling (CLSM) - Asadi
PSI-B2 Mushy Zone (PFMI) - Eshraghi
PSI-B3 Phase Coarsening Models (CLSM) - Wang
PSI-C1 Solidification Patterns (IDGE, MICAST/CSS) - Zaeem
PSI - D1 - Adv M&S Growth Dynamics (IDGE) - Ankit
PSI-E1 P-S-P Rel Solders (ISSI) -Pathak
PSI-E2 - Spurious Grain Form (MICAST/CSS, PFMI) - Tewari

Ground-Based Modeling & Development
ICESAGE - Volz
SETA Team - Genau
Varying Crosssections - Poirier/Tewari
ParSiWal - Derby/Volz

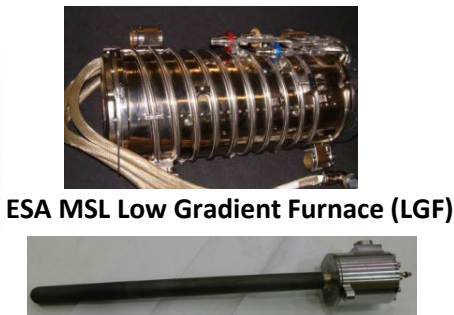
SUBSA
MSG/SUBSA - Brazing of Al Alloys - Sekulic
SUBSA - CETSOL Team - Beckermann
CSLM/SUBSA - SM2 Trans Mstructure - Voorhees

PFMI
MSG/PFMI - FC1 Correlations - Wegst
MSG/PFMI - FC2 Mstructure Evolution - Dunand

Proteins and Biofilms
LMM - MB1 Transport - DeLucas
LMM - MB2 Nucleation - Vekilov
LMM - MB3 Growth Rate Dispersion - Snell
RTPCG - SDT - DeLucas, Carter, Snell, Mueser, Quirk
ESA Protein Team - Vekilov
BioServe - BF1 Biofilm Growth Mechanisms - Zea
BioServe - BF2 Biofilm Growth - McLean
MSG/RSD - Amyloid Fibril Formation - Hirs



Materials Science Research Rack (MSRR)



ESA MSL Low Gradient Furnace (LGF)

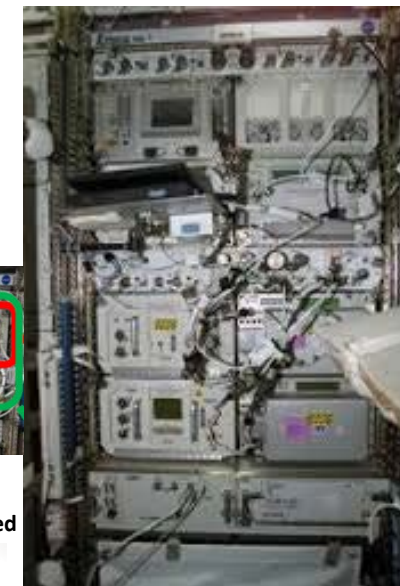
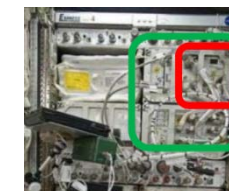
MSL/LGF Sample Cartridge Assembly (SCA)



MWA – Portable Glovebag



ESA STES - PCAM



EXPRESS Rack

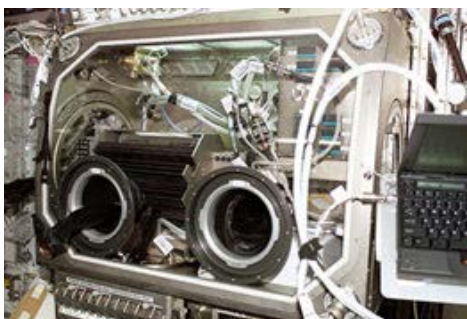
CNES DECLIC Facility – green
Directional Solidification Insert (DSI) - red



Techshot
Multi-Use Variable Gravity Platform (MVP)



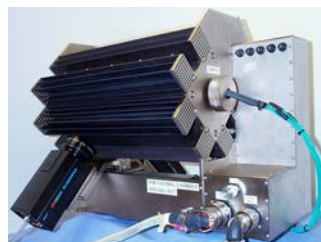
Bioserve Incubator Well Plates,
Group Activation Pack (GAP)
Plate Habitat (PHAB)



Microgravity Science Glovebox (MSG)



SUBSA Thermal Chamber

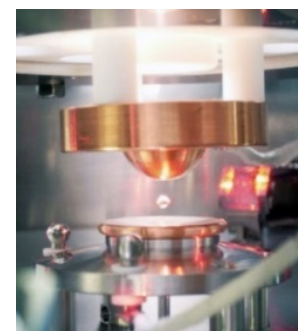


PFMI Directional Solidification Unit

ZIN



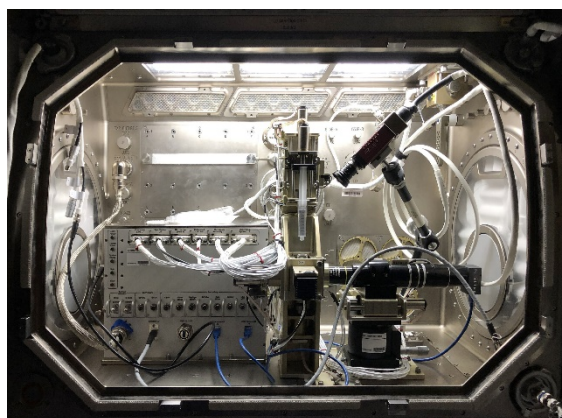
Burst Seal Sample Pouch



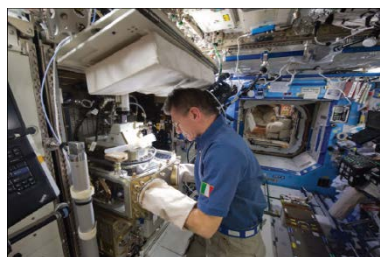
JAXA Electrostatic
Levitation Furnace (ELF)



ISS - ElectroMagnetic Levitator (EML)



Ring-Shear Drop (RSD) Hardware in MSG



Light Microscopy Module (LMM)

- **Materials Science Research on ISS continues to provide insight into dynamics that may significantly affect viability and performance characteristics of advanced manufacturing processes in either microgravity or reduced gravity environments.**

- Pore Formation and Mobility Investigation (PFMI)
 - Dynamics of mushy zone porosity in a thermal gradient
 - Marangoni convection in the region of pores

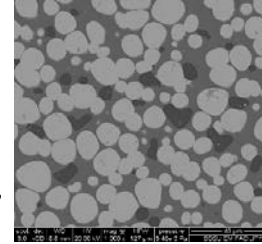
- Gravitational Effects on Distortion in Sintering ([GEDS](#))

- Liquid phase sintering, start of ISS operations 11/5/19

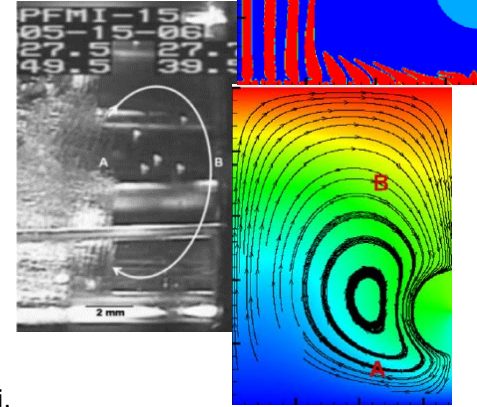
- Coarsening in Solid-Liquid Mixtures (CSLM)

- *Dendrite Fragmentation and Morphology during Melting and Solidification – development (SUBSA)*

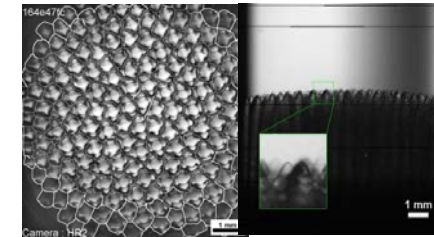
GEDS W-heavy alloy,
Earth sintered
(www.nasa.gov: ISS mission pages GEDS)



Effect of Bubble-Induced Convection on Solidification
Nabavizadeh, Eshraghi, Felicelli,
Tewari & Grugel, Int. J.
Multiphase Flow 116 (2019) 137



- **Multiple ISS-based benchmark solidification experiments are being used to anchor multi-scale models of microstructure evolution (e.g. phase field, cellular automata-finite element, dendritic-needle-network) relevant to process-structure-property-performance (PSP) linkages at the microscale and above**

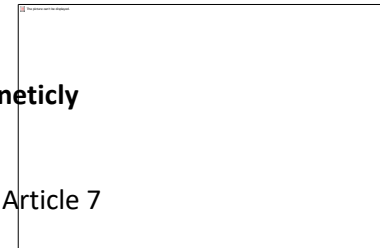


Axial and transverse views of dendritic interface in DECLIC-DSIR (2018)
IAC-19-A2.6.2 Mota, Ji, Lyons, Strutzenberg, Trivedi,
Karma & Bergeon (October 2019)

- **ISS-based thermophysical properties measurements (e.g. density, specific heat, surface tension and viscosity) of metals, semiconductors, oxides and glasses are also providing key inputs to multiscale modeling of manufacturing processes.**

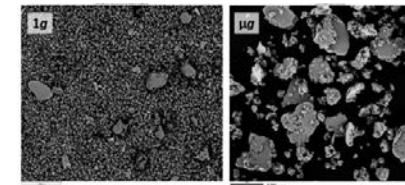
- ISS-EML can provide accurate thermophysical properties that are used in models of casting, welding, and metal additive manufacturing.
- JAXA ELF can be used to study metal oxides, which are precursors to high value-added glass materials that are used in photonics, lasers, optical communications, and imaging applications.

MHD model of electromagnetically levitated droplet
Xiao, Lee, Hyers, & Matson
Nature Microgravity, Vol 5, Article 7
(2019)

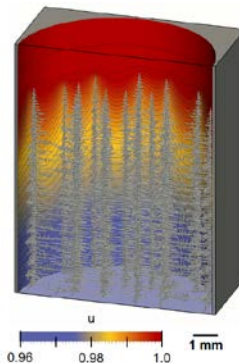


- **The ISS can also be used as a platform to conduct targeted experiments to better understand the observed or predicted effects of microgravity or reduced gravity on materials production and repair processes needed to sustain extended duration Gateway or lunar surface operations.**

- Microgravity Investigation of Cement Solidification (MICS) – MWA and MVP
- *BRAZing of Aluminum alloys IN Space (BRAINS) – development (SUBSA)*



MICS: Diffusion-dominated growth in C3S (2018)
15th ICC, Neves, Grugel, Scheetz & Radlinska (September 2019)



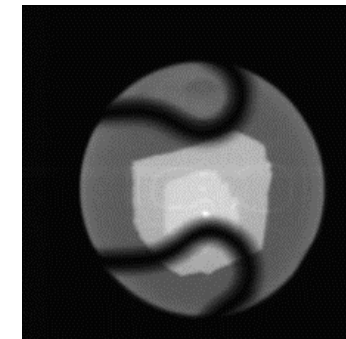
3D dendritic needle network model
D. Tourret & A. Karma, Acta Mater. 120
(2016) 240

International Space Station Electromagnetic Levitator (ISS-EML)

- Since operations began in early 2015, the ISS-EML has consistently provided materials science data
- ISS-EML is currently processing Batch 2.4
- Batch 3 is planned to be launched late next year
- There are over 10 project teams with experiments on ISS-EML
 - Each with from a few to over 30 Investigators
- There are 3 US Co-Investigators, each of which is on at least 2 project teams



ISS-EML after being loaded with a Batch of samples.



FeCrNi austenitic steel casting alloy being processed in ISS-EML.

Japan Aerospace Exploration Agency (JAXA) Electrostatic Levitation Furnace (ELF)

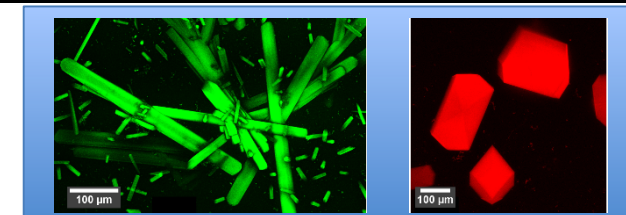
- JAXA-ELF launched to ISS in 2016
- 4 US ELF projects (first scheduled to launch Spring 2020)
- 2 JAXA ELF projects with US Co-Investigators
 - ELF1 Interfacial Phenomena (molten steel and oxide melt) – Hyers
 - ELF6 Properties of Non-equilibrium Titanates and Oxides – Weber



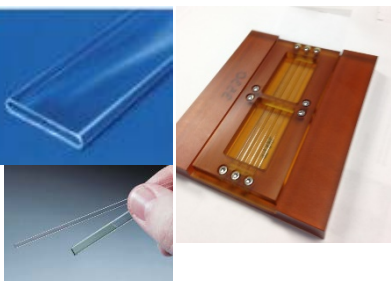
ELF electrode assembly.

Protein Crystal Growth

- Microgravity missions have shown that crystals of some proteins (and other complex biological molecules such as viruses) grown on orbit are larger and have fewer defects than those grown on Earth.
- Real-time protein crystal growth (RTPCG) experiments are planned to evaluate the success of an iterative protein crystallization process on-orbit, using ISS crew in coordination with ground principal investigators to provide a better mechanism for screening crystallization conditions in microgravity.



ISS-grown crystals of fluorescently-labeled PfGST and lysozyme



PCG hardware used in space.

LMM - MB1, LMM - MB4 Transport – DeLucas

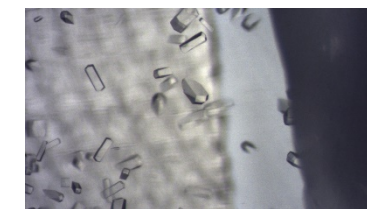
Validate the hypothesis that the improved quality of microgravity-grown biological crystals is the result of slower protein transport and predilection for incorporation of protein monomers higher protein aggregates

LMM MB3, MB6: Growth Rate Dispersion– Snell

Validate the hypothesis that growth rate dispersion could be an indicator of crystals whose quality could be improved in microgravity

LMM MB2, MB5: Solution Convection and Nucleation Precursors – Vekilov

To test if the absence of shear flow affects the concentration and properties of the nucleation precursors and establish the mechanisms of these effects



Lysozyme crystals grown on ISS during ops in July 2018. Returned on SpaceX-15.

RSD-Amyloid Fibril Formation – Hirs

Investigate amyloid fibril formation nucleation and growth upon perturbing the native structure of a protein by hydrodynamic shear forces, using a containerless bioprocessing facility and optical imaging techniques.

Biofilms

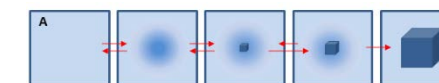
Elucidate mechanisms of gravity-sensing in bacteria by comparing the structure and composition of biofilms generated in microgravity to those grown on earth. Develop knowledge of biophysical mechanisms of material/microorganisms interactions that can influence/inhibit the formation of biofilms on substrates. Characterize biofilm mass, thickness, morphology and the associated gene expression of microbial species growing on different substrate materials.

BF1: Biofilm Growth Mechanisms “SPACE BIOFILMS” – Zea

The Space Biofilms project aims to characterize biofilm inside the International Space Station in a controlled fashion, assessing changes in mass, thickness, and morphology. The space-based experiment also aims at elucidating the biomechanical and transcriptomic mechanisms involved in biofilm formation in space. To search for potential solutions, different materials and surface topologies will be used as the substrata for microbial growth.

Fungal biofilms (mold) will be grown in 24-Well Plates.

Bacterial biofilms will be grown in BioServe's Fluid Processing Apparatus (FPA) contained in Group Activation Packs (GAP).



Proposed Two-Step Model for Nucleation: “dense cluster” formation followed by subsequent crystal nucleation and growth



