

National Aeronautics and Space Administration

Research Infrastructure for Decadal Science Campaigns: MATRICES

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Component goals of MATRICES

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Translating Earth to space, and back again



Recycling and reprocessing



Fundamental understanding of materials phenomena and interactions as a system

Inspired by: NASEM, 2023. Thriving in Space: Ensuring the Future of Biological and Physical Sciences Research: A Decadal Survey for 2023-2032. doi: 10.17226/26750

Driving influences on materials in space

Example of melt pool during laser beam welding

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Gravity (reduced)

- Reduces buoyancy
- Suppresses convection
- Quiescence

Pressure (reduced)

- Increases
 vaporization
- Reduces convective heat transfer
- Alters fluid behavior (pressure balance)

Temperature

- Affects thermophysical properties (*e.g.* thermal conductivity)
- Alters energy balance (*e.g.* inducing more/less melting)

Broad-based community enables discovery

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Academia highlight: Collaboration with the Ohio State University on in-space welding

- Unique facility (electron beam vacuum chamber originally developed by NASA Langley) refitted for laser beam welding by the Ohio State University in collaboration with NASA Marshall
- Investigate combined effects of reduced gravity and pressure (vacuum) on metal solidification
- Many benefits:

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- Enhanced fundamental understanding of rapid solidification under reduced gravity, of reduced pressure on thermofluids & vaporization, of detachment & trajectory of spatter from melt pool, etc.
- New benchmark datasets for modeling
- Workforce development (students)



Government highlight: Partnership with DARPA NOM4D program on in-space forming of sheet metal

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Thermal Gradient Mechanism (TGM) enables bending towards laser beam



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Sheet metal specimens observed with thermography and spectroscopy within



- Unique facility (thermal vacuum) at NASA Marshall extending work of another performer (Univ. of Fla.)
- Investigate combined effects of reduced pressure (vacuum) and extreme temperatures on thermomechanical responses of metal sheets
 - Recently advanced to complex geometries
 - Thermal modeling by BPS post-doc
- Many benefits:
 - Enhanced fundamental understanding of laser-metal interactions, thermophysical properties under intense thermal gradients, etc.
 - New benchmark datasets for modeling
 - Workforce development (interns)

Industry highlight: Reduced gravity ICME study group including CFDRC

Integrated Computational Materials
 Engineering (ICME) leverages experimental
 datasets with computational modeling to
 stimulate a virtuous cycle of experiment model-experiment that accelerates materials
 design & development

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- CFD Research Corporation (CFDRC) employed advanced computational fluid dynamics techniques to extend previous work on modeling of directional solidification in the presence of bubbles performed on ISS
- Experiment performed by academiagovernment collaboration and modeled by industry



MICAST2-12: directional solidification of AI-7wt%Si in microgravity

Setup and temperature distribution with stream traces for MICAST2-12; bubble allowed to move at 0.1 s (left) and 5 s (right)





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Taken from O'Connor et al., 2025, NASA/TM-2025-0000717 (pending).

Pending publication: ICME study group report

NASA/TM-20250000717



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Academia, government, and industry team

Reduced gravity and microgravity Integrated Computational Materials Engineering (ICME)

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Will be available at https://ntrs.nasa.gov/citations/20250000717 when published



Engaged with PRISMS-PF developers to compare 3-dimensional version with GPU-PF code using parameters relevant to DECLIC-DSI-R flight data

NASA supercomputer accelerates modeling



Predictions of thermophysical & interfacial properties via physically informed neural networks, anchored by levitatorderived datasets



How to nurture these relationships?

- Literature Open science
 - Physical Sciences Informatics
- Discussions in person, virtual
- Public awareness

Physical Sciences

- NASA to Transform In-Space
 Manufacturing with Laser Beam
 Welding Collaboration
- Posted on nasa.gov then spread to social media sites, link aggregators, tech news sites, etc.

- Vehicles for partnerships
 - Collaborative agreements
 - Academia & non-profits
 - Industry
 - Contracts
 - Grants
 - BPS ROSES, especially the New NASA Investigator category
 - Awards & Challenges
 - *Not an exhaustive list

NASA SMD Strategy §3

MATRICES entails a matrix of academia, government, and industry working together



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- Complex and demanding influences of the space environment require BPS science to leverage the unique and irreplaceable contributions from each sector
- Maintain awareness of and interact with scientific community and technical field
- Explore partnership vehicles

BPS Science: The Weightless Fronter

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- Thanks to CBPSS for their kind invitation to share about paths to implement MATRICES via collaborations & partnerships across academia, government, and industry.
- Thanks to Michael SanSoucie, also of NASA Marshall.

