Overview of Materials Research at NASA Marshall Space Flight Center

Tracie Prater, Ph.D.
Aerospace Engineer, Materials and Processes Laboratory
NASA Marshall Space Flight Center
Huntsville, AL

Barnard-Seyfert Astronomical Society
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About Me

Originally from Hazard, Kentucky

B.S. Physics from EKU
M.S., Ph.D. Mechanical Engineering from Vanderbilt

Previously worked as a materials engineer at United Launch Alliance (ULA)

currently an aerospace engineer in the Materials and Processes Laboratory at NASA Marshall Spaceflight Center

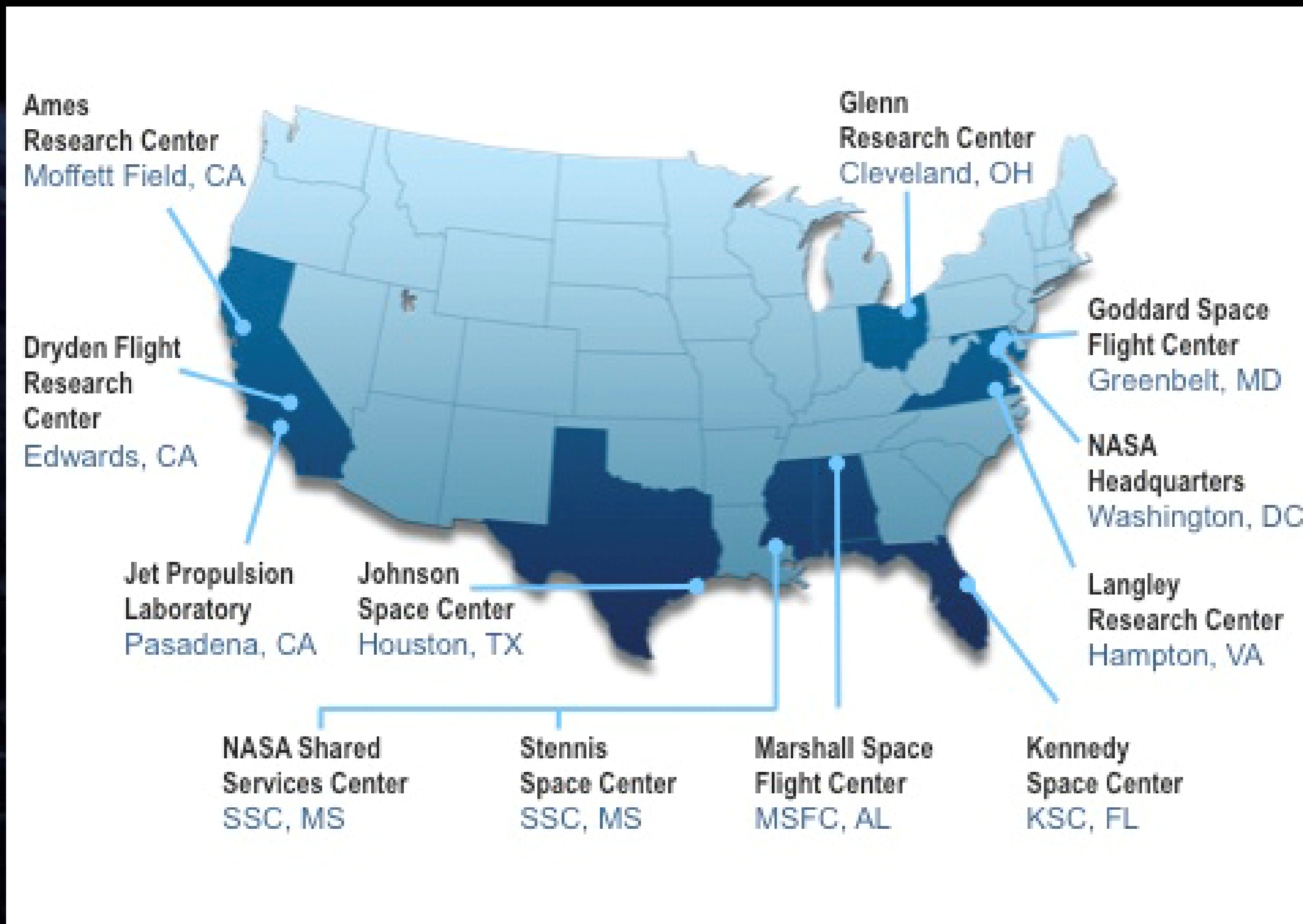
Then…..


KENNEDY SPACE CENTER
TRACIE


Living and working
on the new frontier of space

Now

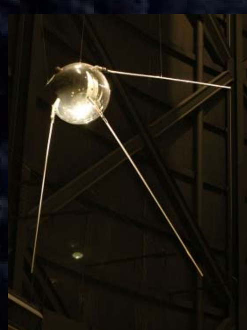
NASA Around the Country



A Brief History of NASA MSFC

1945 Project Paperclip

1950 German team moves to Redstone Arsenal to work for ABMA on development of Redstone Rocket



October 4, 1957
Sputnik launch

December 6, 1957
Vanguard explosion

January 31, 1958
Redstone Rocket puts Explorer I in orbit

A Brief History of NASA MSFC

1960 Eisenhower signs act creating civilian space agency

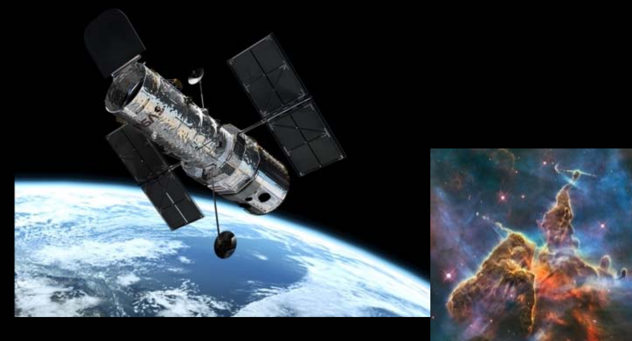
1960-1972 MSFC develops Saturn V

1973-1979 Skylab

1981-2011 Space Shuttle

A Brief History of NASA MSFC

1998-present International Space Station



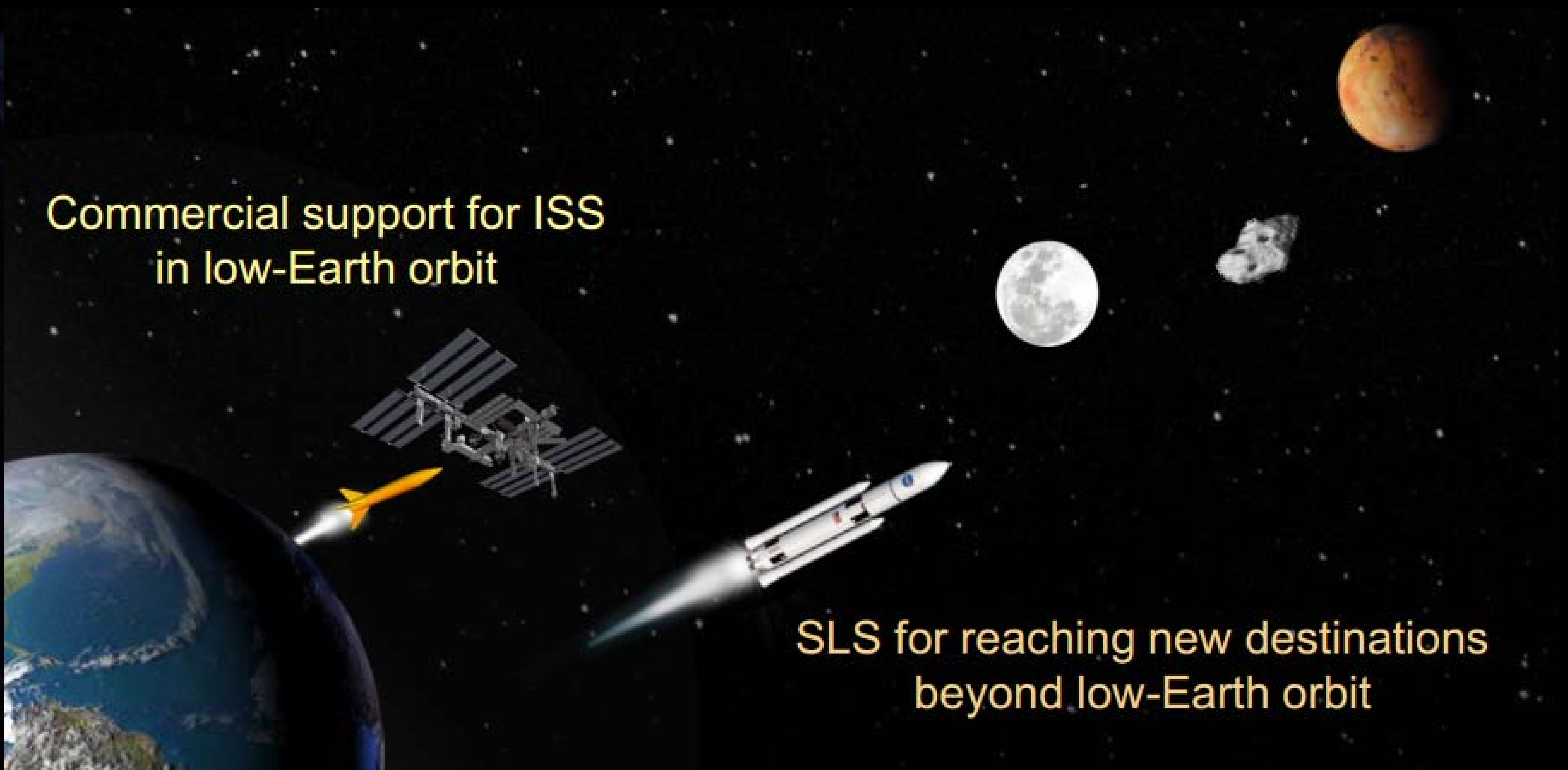
1990-present Hubble Space Telescope

Space Launch System (SLS)

James Webb Space Telescope

NASA's Four Core Mission Areas

Human Spaceflight Architecture



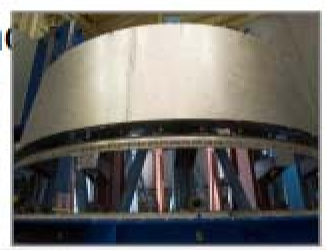
Space Launch System (SLS)

- Initial lift capacity of 70 MT, evolvable to 130 MT
- Carries the Orion Multipurpose Crew Vehicle (MPCV)
- First flight of SLS in 2017

Solid Rocket Booster Test

Friction Stir Welding for Core Stage

Shell Buckling Structural Test



MPCV Stage Adapter Assembly

Selective Laser Melting Engine Parts

RS-25 Core Stage Engines in Inventory

Materials Research at NASA MSFC

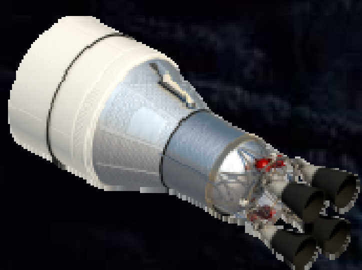
What materials are used for aerospace structures?

- Metals
  -Aluminum
  -Steel/stainless steel
  -Titanium
  -Magnesium
  -Superalloys
- Ceramics
- Plastics/Elastomers
- Composites

Composite Cryotank

NASA needs an affordable, lightweight vehicle for greater payload capability to enable future exploration missions.

- Composite cryotanks could lead to rocket propellant tanks that achieve greater than 30% weight savings and 25% cost savings compared to the state-of-the-art metal tanks.
- Revolutionary manufacturing capabilities (automated fiber placement, out of autoclave cure) with innovative composite materials enable low cost, higher performance cryogenic tankage.



Friction Stir Welding

- Friction stir welding

-welding process that does not melt the material

-produces high-strength, defect-free joints

-completely robotic process

-used for almost all launch vehicle primary structures and habitable modules

-largest vertical weld tool ever constructed for SLS barrel panel welds at MAF

Friction Stir Welding at Michoud Assembly Facility for SLS

Additive Manufacturing

For Space

Near-Term

Long-Term

In-Space

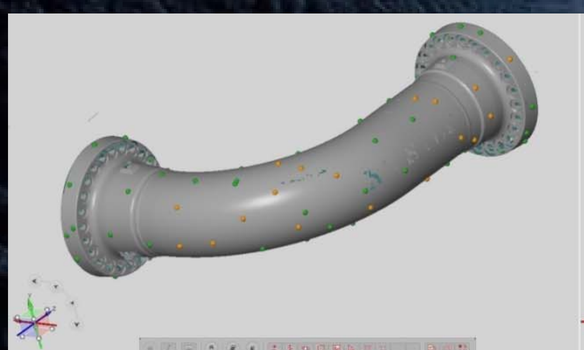
Why Additive Manufacturing?

Affordability
-reduced part count
-fewer critical welds and brazes
-reduced tooling
-schedule and cost savings

Performance
-Optimized internal flow passages
-Minimized leak paths
-Lower mass

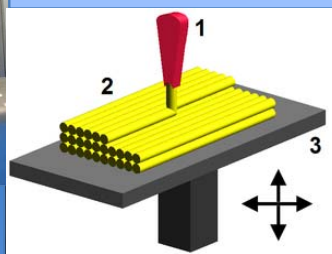
Additive Manufacturing: Metals

- Propulsion components manufactured using Selective Laser Machining (SLM)
  atomized metal powder fused by laser
  -Inconel, Titanium
- Hot fire testing and burst testing for validation
- Immense potential to reduce cost and development life cycle for propulsion systems
- Uncertainty in how additively manufactured parts compare to conventionally manufactured counterparts
- MSFC's role is primarily development of certification path and standards



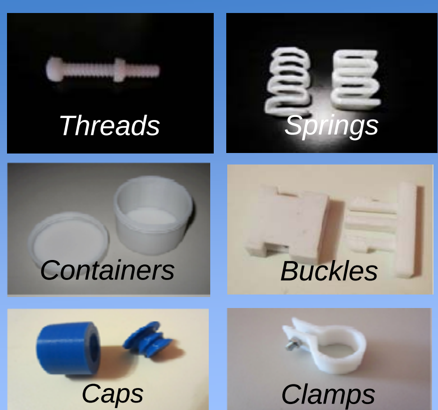
3D Printing in Space

The 3D Print project will deliver the first 3D printer on the ISS and will investigate the effects of consistent microgravity on melt deposition additive manufacturing by printing parts in space.



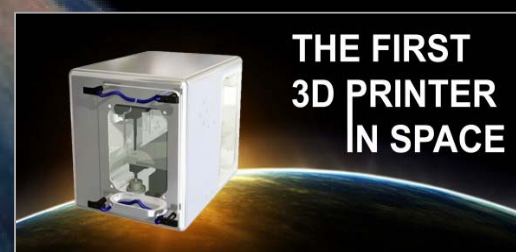
Melt deposition modeling:
1) nozzle ejecting molten plastic,
2) deposited material (modeled part),
3) controlled movable table

Potential Mission Accessories



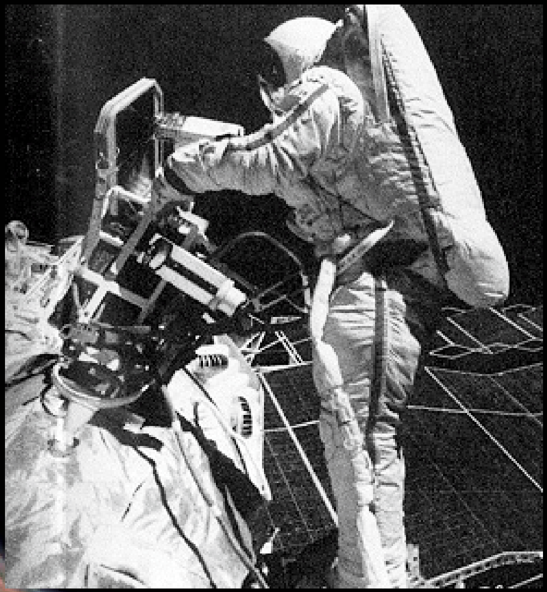
3D Print Specifications

Dimensions	33 cm x 30 cm x 36 cm
Print Volume	6 cm x 12 cm x 6 cm
Mass	20 kg (w/out packing material or spares)
Est. Accuracy	95 %
Resolution	.35 mm
Maximum Power	176W (draw from MSG)
Software	MIS SliceR
Traverse	Linear Guide Rail
Feedstock	ABS Plastic

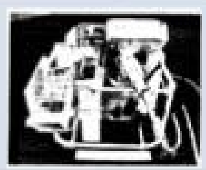


Materials Joining in Space

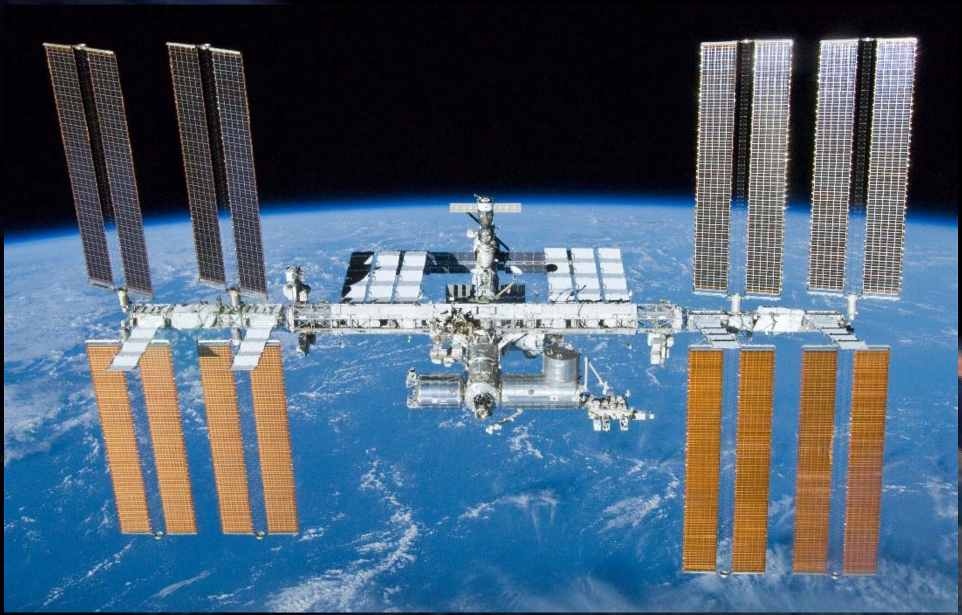
- Space structures are increasingly susceptible to MMOD and collisions with other hardware – current risk is low, but could be catastrophic
- Welding would enable a rapid repair capability and versatile means of on-orbit assembly
- Offers advantages over mechanical fasteners and adhesives:
  -reduced weight
  -improved mechanical properties
  -reduced stress concentrations
  -increased rigidity



A Brief History of In-Space Welding

Year	Activity	Country	Process	Vehicle	Images	Outcome
1969	Vulcan, Self-contained experiment	Russia	EB, Arc	Soyuz 6		First demonstration of on-orbit welding.
1973	M551 Materials Melting, Self-contained experiment	US/MSFC	EB	Skylab I		Demonstrated metallurgy of 2219-T87 welds in microgravity.
1984	First Manual Electron On-orbit Manual Weld	Russia/ Ukraine	EB	Salyut 7		Demonstrated concept and challenges of maintaining control during welding in a space suit.
1989	On-orbit Electron Beam Welding Experiment Definition	US (MSFC/ Martin Marietta)	EB	Ground Demo only		Demonstrated on-orbit repair concept, weld schedule, and 2219-T87 metallurgy utilizing beam deflection.
1990s	International Space Welding Experiment	US (MSFC)/ Ukraine (Paton Weld Institute)	EB	Space Shuttle (Not Flown)		Demonstrated safety challenges associated with manual EVA welding.
1995	Versatile Space Welding System Phase II SBIR	US (MSFC/ Electric Propulsion Lab)	Arc	Ground Demo Only		Developed Hollow Cathode Arc Weld System

A Vision of In-Space Manufacturing



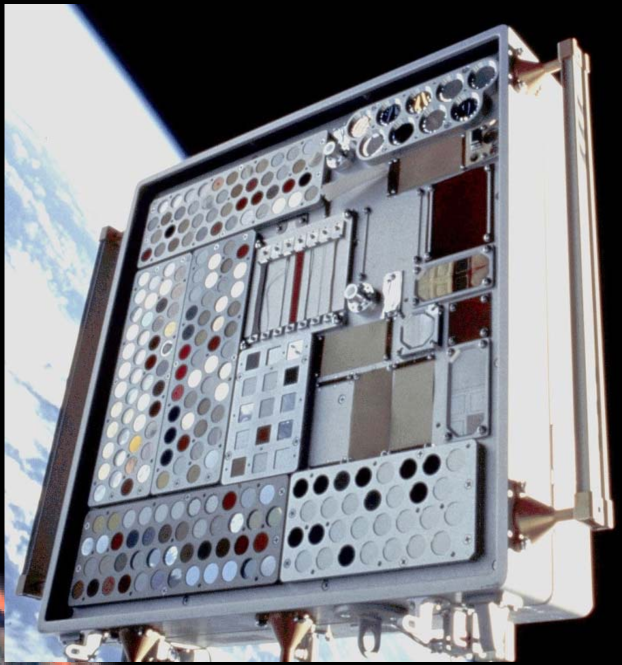
-In-space fabrication and repair of plastics using 3D printing
-Qualification/inspection of on-orbit parts using structured light scanning
-Printable small satellite technologies
-On-orbit plastic feedstock recycling
-In-space metals manufacturing process demonstration
-Welding in space
-Additive construction using regolith

Materials in the Space Environment: MISSE

- MISSE: Materials International Space Station Experiment
- Material samples mounted externally on the Kibo module (JAXA) of the ISS
- Samples are exposed to the space environment for up to two years, then downmassed for testing and analysis
- Experiments evaluate material degradation in the space environment

  -atomic O_2

  -UV radiation



Nuclear Propulsion Fuel Development

-NASA’s Nuclear Cryogenic Propulsion Stage Project was started in to assess the affordability of Nuclear Thermal Propulsion

-NTP is a game changing technology for space exploration

Fewer launches, reduced trip times, increased payloads

-Goal of overall NTP tasks

Fuel fabrication and testing

Design and architecture integration

Affordable engine qualification

-Critical need for nuclear fuels development

Lack of qualified fuel material is a key risk

-MSFC currently developing critical fuel fabrication capabilities using full scale fabrication and testing

Enable future fuel optimization

Buy down risk for future engine ground testing

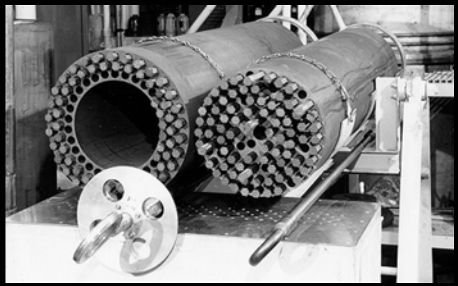
-Highly integrated NASA and DOE team

Nuclear Propulsion Fuel Development

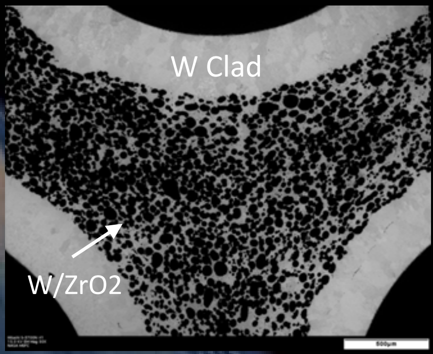
-Graphite based fuel materials
- Full scale engines demonstrated during ROVER/NERVA program in 1960's
- Previous M&P capabilities do not exist

-CERMET fuel materials
- Investigated in 1960-70's to provide improved performance over graphite materials, but not proven
- No "qualified" materials or fabrication processes
- Critical materials and process capabilities do not exist

-Objectives
- Recapture graphite fuels and fabrication capability
- Develop W-UO2 CERMET fuels fabrication capability
- Characterize microstructure, properties, and performance
- Perform subscale and full scale fuel element testing



Rover/NERVA Graphite



W/ZrO2 CERMET
(MSFC HIP fabrication)

Solar Sails

-solar sails exploit solar pressure to provide a means of propulsive energy
-sail material is typically a very thin (~micrometers) aluminum (or aluminized) film: Kapton, Mylar, Alumina
-material selection drivers for solar sails: degradation in space environment, weight, operating temperature range, fabrication (manufacturing), reflection and emissivity
-solar sail missions: IKAROS (JAXA, 2010), NEAScout, Lunar Flashlight

Questions

Tracie Prater, Ph.D.
Aerospace Engineer, Materials and Processes Laboratory
NASA Marshall Space Flight Center
tracie.j.prater@nasa.gov