NASA Marshall Spaceflight Center: Materials and Manufacturing

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About Me

B.S. Physics
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Materials Engineer at United Launch Alliance (ULA)

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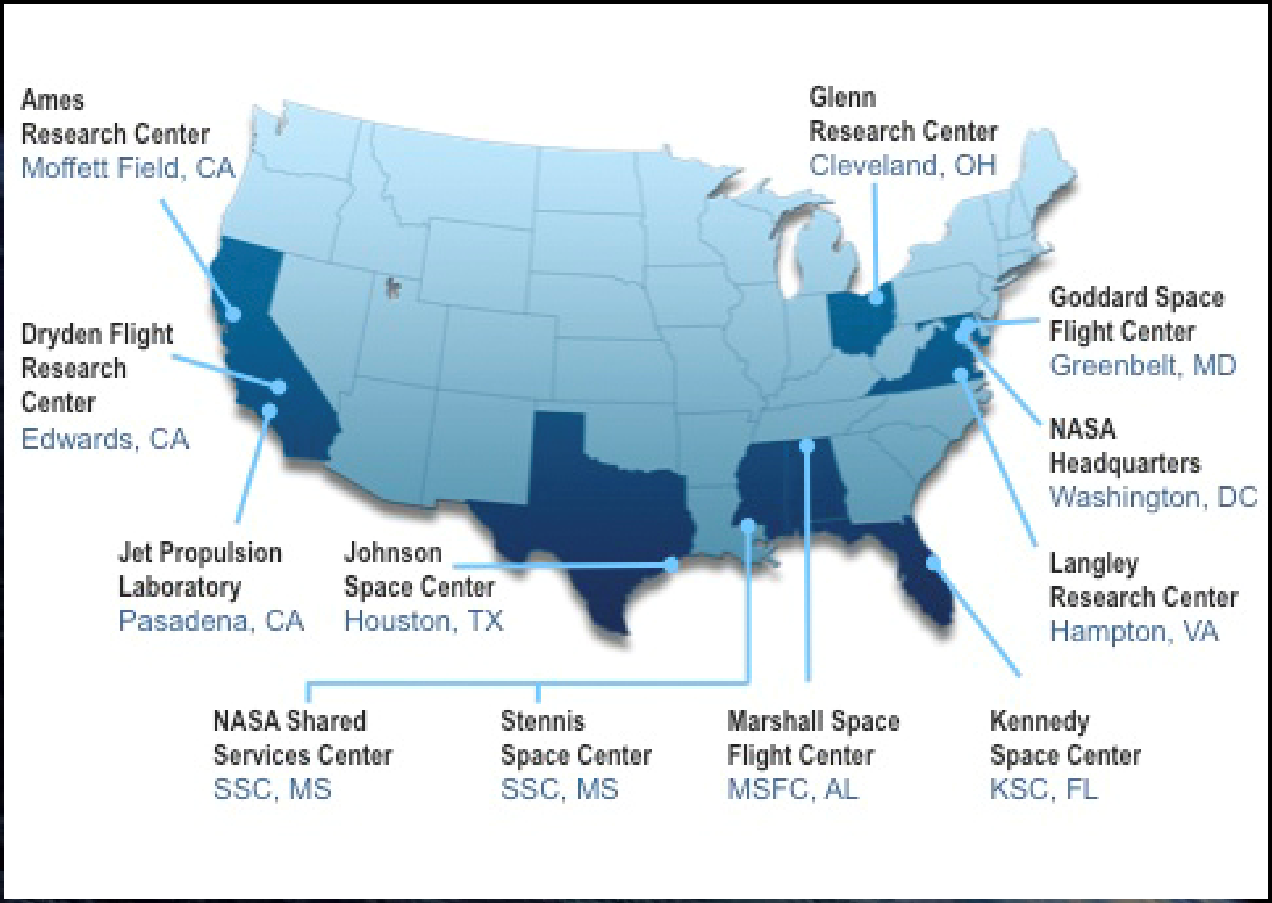
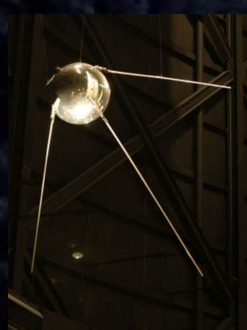
NASA Around the Country



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

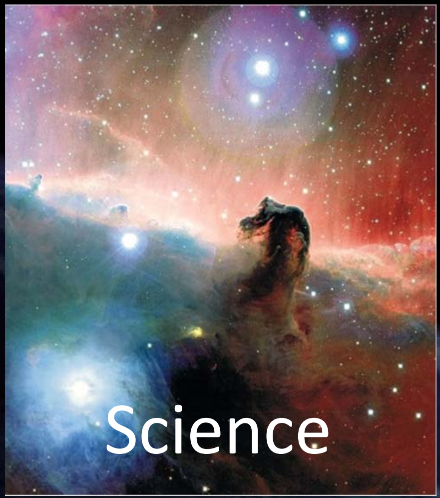
1998-present International Space Station

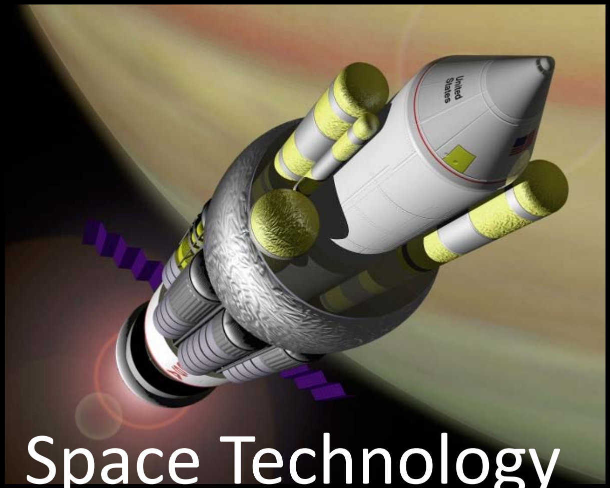
1990-present Hubble Space Telescope

Space Launch System (SLS)

James Webb Space Telescope

NASA's Four Core Mission Areas


Science


Space Technology


Human Exploration and Operations

Aeronautics

Human Spaceflight Architecture

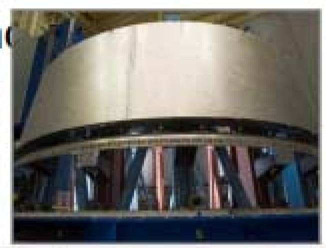
Space Launch System (SLS)

- 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

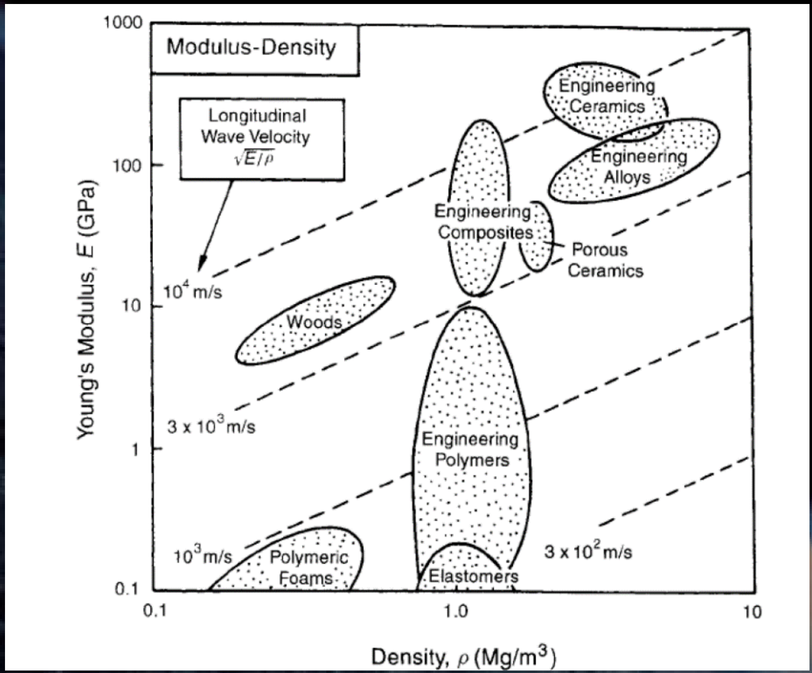
Selective Laser Melting Engine Parts

RS-25 Core Stage Engines in Inventory

EFT1 Adapter

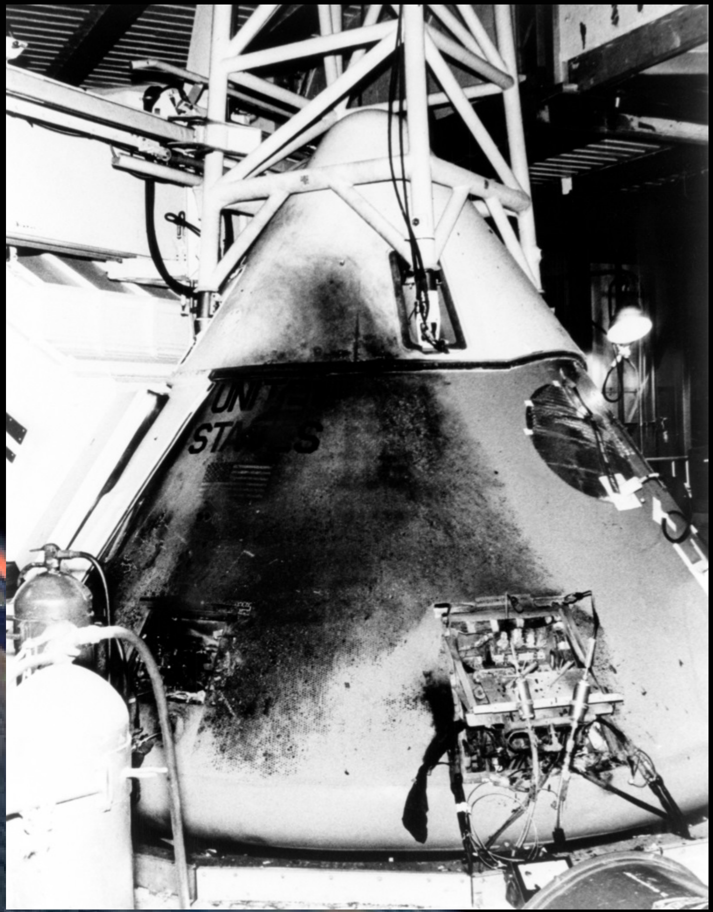
- First test flight of Orion in December 2014 on a Delta IV Heavy
- Re-entry speed of 25,000 MPH
- Adapter designed and manufactured at MSFC mates upper stage of Delta IV Heavy to Orion

Materials Engineering at NASA: An Overview



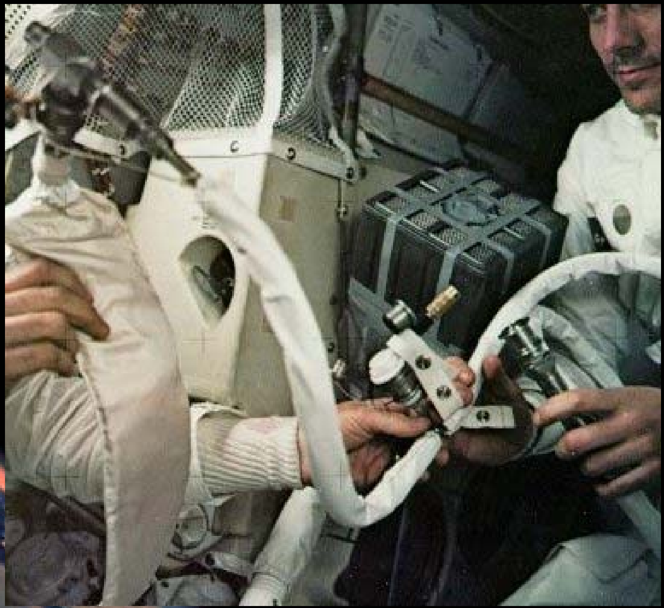
Materials Selection and Control

- Materials selection and control took on greater importance after Apollo 1 accident
- Material technical standards, selection criteria and controls were implemented
- All materials used in NASA spaceflight and ground support hardware must meet acceptance criteria based on intended use environment



Criticality of Materials Selection and Control

- *Apollo 1*: ignition source (uninsulated Ag-plated copper wire) + flammable materials (Velcro) + pure oxygen environment (16.7 psi)
- *Apollo 13*: oxygen tank 2 damaged by mishandling at NAA; during countdown demonstration test, technicians heat tank to drain it; thermostat welds shut and wiring is damaged; on-orbit damaged wiring starts a fire inside tank
- *Challenger:* failure to consider effects of temperature on O-ring/rubber elastomeric materials
- *Columbia:* foam on left bipod ramp detaches during launch and impacts TPS on left wing (RCC panel 8); during re-entry superheated air penetrates insulation and melts Al structure of left wing



Challenges of Materials Selection for Aerospace

- Materials must function in the extreme environments (natural or induced)
  -often necessitates development of new materials

-plastic deformation/yielding
-fatigue
-abrasion/wear
-corrosion
-thermal shock
-fracture
-melting
-impact
-buckling
-creep
-fluid compatibility
-space environmental effects

What materials are used for aerospace structures?

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

Example: Solar Sails

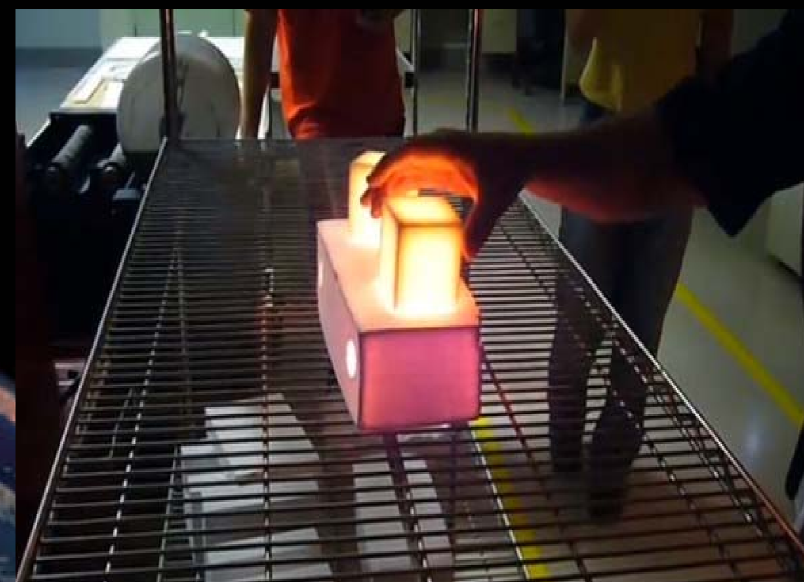
-solar sails exploit solar pressure to provide a means of propulsive energy
-sail material is typically a very thin (~micrometers) aluminum (or aluminized) film
-Kapton, Mylar, Alumina
-sample material is CP1 polyimide
-material selection drivers for solar sails: degradation in space environment, weight, operating temperature range, fabrication (manufacturing), reflection and emissivity
-solar sail missions: IKAROS (JAXA, 2010)Sunjammer (January 2015), NEOScout, Lunar Flashlight

Example: Space Shuttle Tile

- Requirements:

-Reusable thermal protection system

-Ability to dissipate heat at 2200 F



- LI-900, low-density surface insulation with silica glass fibers
- 94% air by volume
- Adhere to orbiter structure

Materials Selection Tools

- MAPTIS (Materials and Processes Technical Information System)

-curated and maintained by NASA

-provides materials design data, reference data, and requirements to NASA and NASA support contractors and partners

- Contains information on:

-physical and structural properties

-chemical compatibility

-flammability

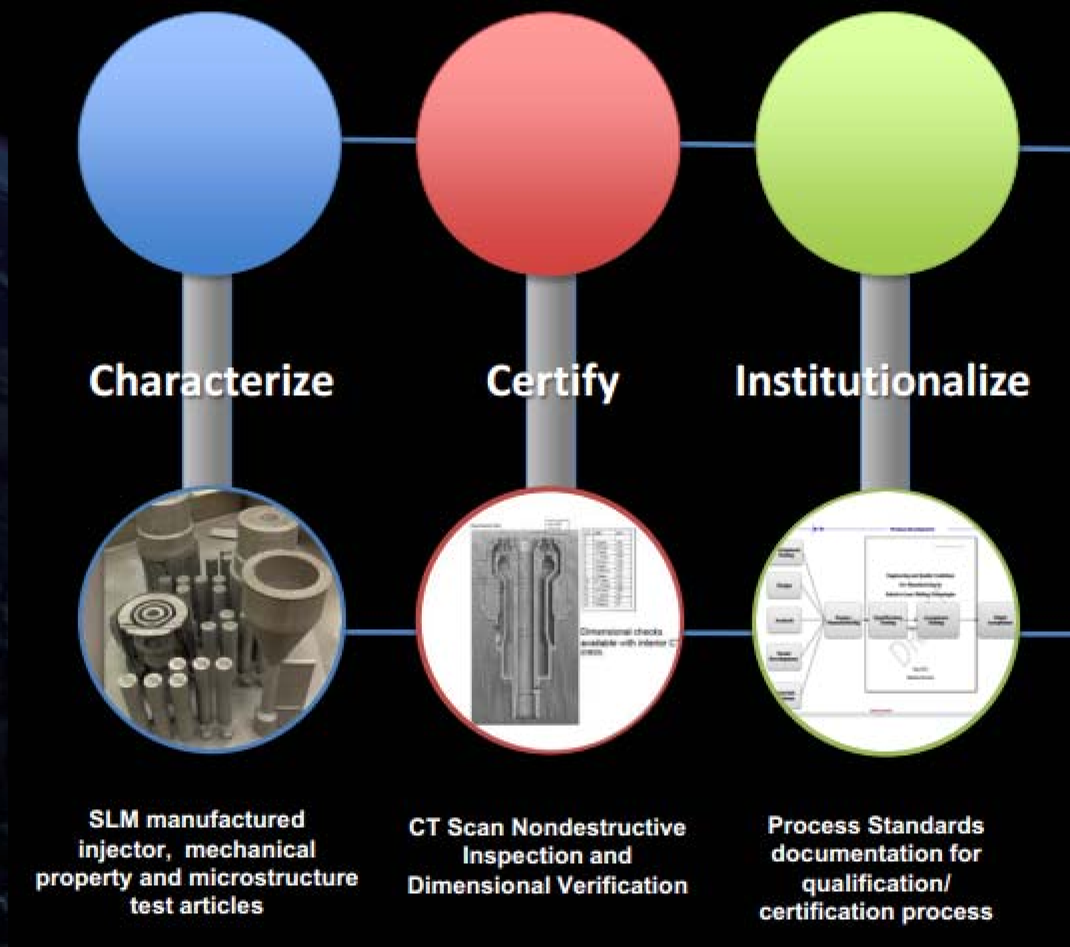
-development data

-thermal protection systems

-space environmental effects

-thermophysical and thermal data

Path to Process Certification



Path to Hardware Certification

System Definition and Requirements → Design → Verification Events → Acceptance of Verification = **Certification**

- Definition document
- Program requirements
- NASA standards
- Vendor tailored standards
- Component specs
- Vendor specs

DAC

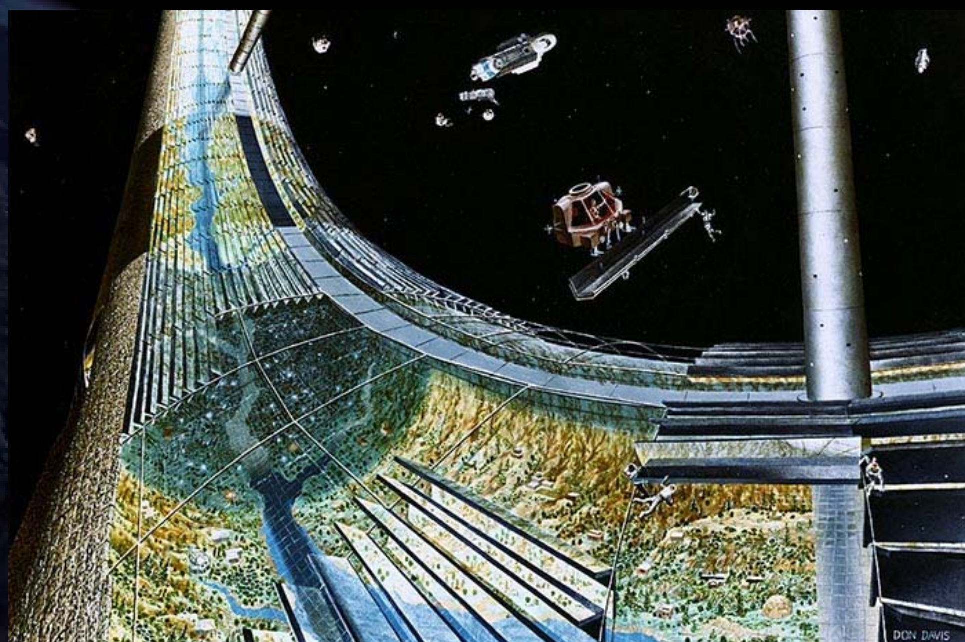
Validation

Does part meet customer intent?

Design
- Test
- Analysis
- Review process
  - RIDs, etc.

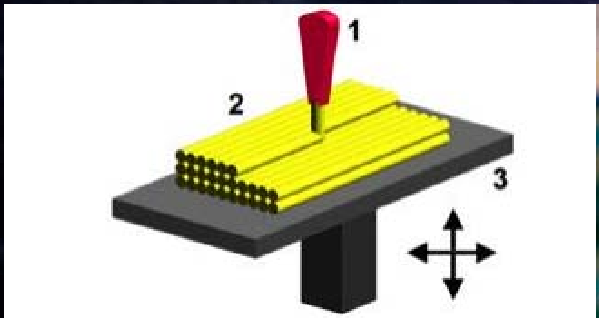
As-Built
- Inspection
- Acceptance Test
- MRB

Advanced Manufacturing

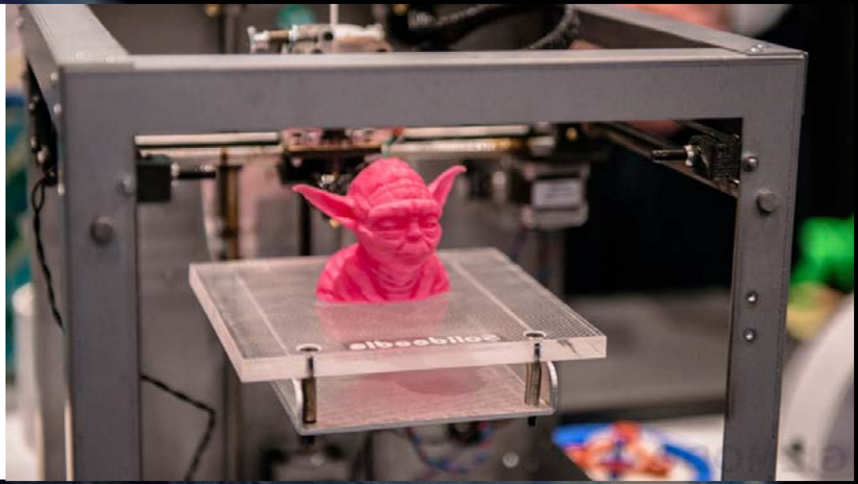


Additive Manufacturing: Plastics

Additive manufacturing (AM) or 3D Printing (3DP) is the method of building parts layer by layer. Melt deposition fabrication builds the object out of plastic deposited by a wire-feed via the extruder head. The parts are 'printed' from 3-D CAD drawings loaded on the printer.



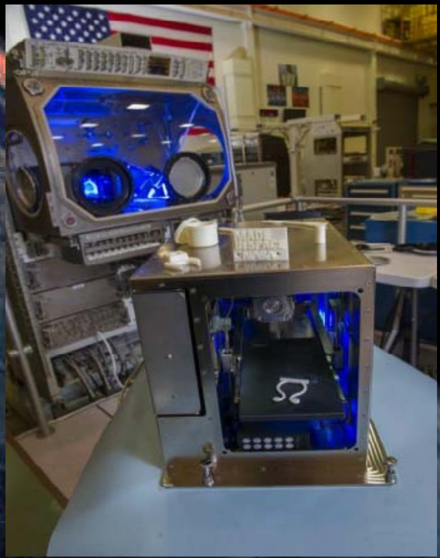
Melt deposition modeling:
1 - nozzle ejecting molten plastic
2 - deposited material (modeled part)
3 - controlled movable table



"3D print, you will."

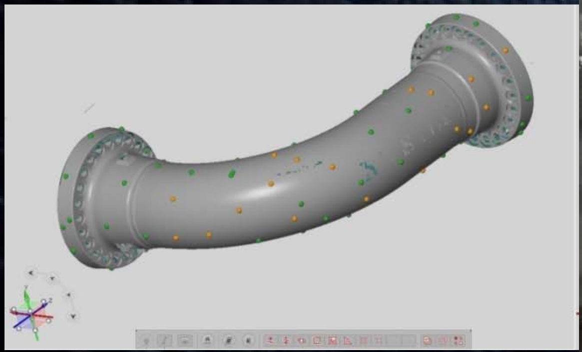
3DP in Zero G

- When a tool on the space station breaks, astronauts must often wait months for a replacement
- 3-D printer on board the space station would enable astronauts to print replacement parts within hours; enhanced safety for crewed operations
- Could also enable the manufacturing of small satellites (nanosats) on orbit
- NASA is partnering with Made in Space, Inc. to develop and fly a 3-D printer to the space station in fall 2014



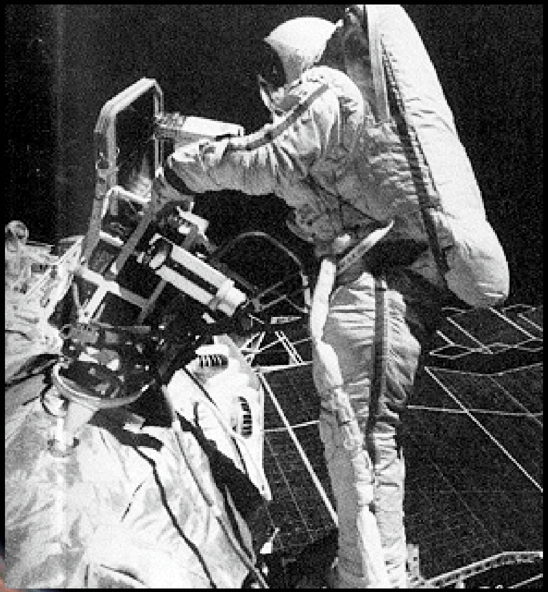
Additive Manufacturing: Metals

- 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
- Development of certification path and standards

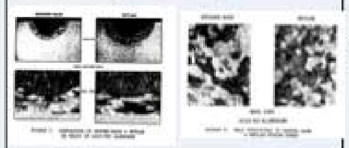
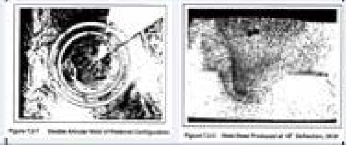
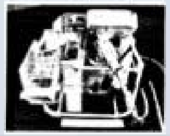



Microgravity Materials Science: Materials Joining

- 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

Friction Stir Welding

- Friction stir welding

-new 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

ULA, SpaceX, Orbital

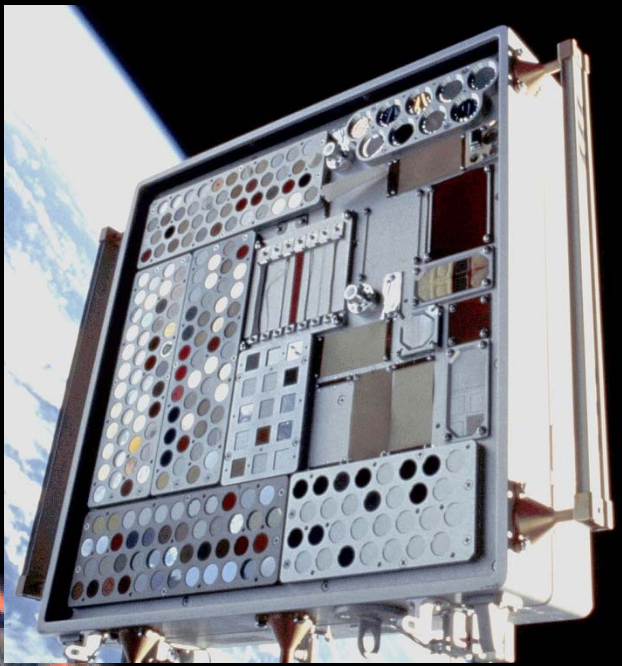
-largest vertical weld tool ever constructed for SLS barrel panel welds at MAF

Microgravity Materials Science: MISSE

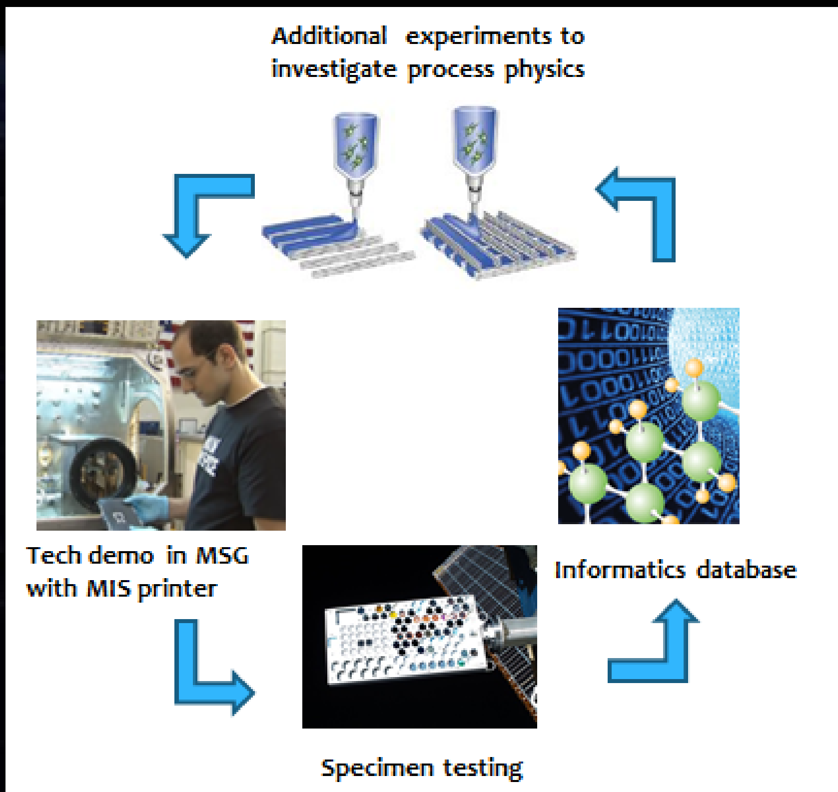
- Material samples mounted externally on the Kibo module (JAXA) of the ISS
- Samples are exposed to the space environment for up to two years, then downmassed for testing and analysis
- Experiments evaluate material degradation in the space environment

  -atomic O_2

  -UV radiation



ISS Open Data Portal



-current initiative in compliance with presidential directive to make science data from International Space Station open-source
-global access to cutting edge research data
-increased products, patents, and publications
-accelerate path from idea to research to products

Advanced Manufacturing Roadmap