National Aeronautics and Space Administration

EXPLORESPACE TECH

STMD Advanced Materials, Structures, and Manufacturing Strategic Technology Plan

2020 Innovation & Opportunity Conference (IOC)

Mark W. Hilburger

September 25, 2020

STMD Strategic Framework

LEAD	THRUSTS	CAPABILITIES
Ensuring American global leadership in Space Technology • **Lunar Exploration building to Mars and new discoveries at extreme locations** • **Robust national space technology engine to meet national needs** • **U.S. economic growth for space industry** • **Expanded commercial enterprise in space**	***Go*** ***Rapid, Safe, & Efficient Space Transportation***	• Advanced Propulsion • Cryogenic Fluid Management
	Land ***Expanded Access to Diverse Surface Destinations***	• Human & Robotic Entry, Descent and Landing • Precision Landing
	Live ***Sustainable Living and Working Farther from Earth***	• Advanced human life support and human performance • Advanced Materials, Structures and Manufacturing • Advanced Power Systems • In-situ Propellant and Consumable Production • Autonomous Systems and Robotics
	Explore ***Transformative Missions and Discoveries***	• On-Orbit Servicing, Assembly and Manufacturing • Small Spacecraft Technologies • Advanced Avionics • Advanced Communications and Navigation

Note: Multiple Capabilities are cross cutting and support multiple Thrusts. Primary emphasis is shown

Revision date: May 26, 2020

STMD Strategic Outcomes

LEAD	THRUSTS	OUTCOMES
Ensuring American global leadership in Space Technology • Lunar Exploration building to Mars and new discoveries at extreme locations • Robust national space technology engine to meet national needs • U.S. economic growth for space industry • Expanded commercial enterprise in space	***Go*** ***Rapid, Safe, & Efficient Space Transportation***	• Enable Human Earth-to-Mars Round Trip mission durations less than 750 days. • Enable rapid, low cost delivery of robotic payloads to Moon, Mars and beyond. • Enable reusable, safe launch and in-space propulsion systems that reduce launch and operational costs/complexity and leverage potential destination based ISRU for propellants.
	Land ***Expanded Access to Diverse Surface Destinations***	• Enable Lunar and Mars Global Access with ~20t payloads to support human missions. • Land Payloads within 50 meters accuracy while also avoiding local landing hazards.
	Live ***Sustainable Living and Working Farther from Earth***	• Conduct Human/Robotic Lunar Surface Missions in excess of 28 days without resupply. • Conduct Human Mars Missions in excess of 800 days including transit without resupply. • Provide greater than 75% of propellant and water/air consumables from local resources for Lunar and Mars missions. • Enable Surface habitats that utilize local construction resources. • Enable Intelligent robotic systems augmenting operations during crewed and un-crewed mission segments.
	Explore ***Transformative Missions and Discoveries***	• Enable new discoveries at the Moon, Mars and other extreme locations. • Enable new architectures that are more rapid, affordable, or capable than previously achievable. • Enable new approaches for in-space servicing, assembly and manufacturing. • Enable next generation space data processing with higher performance computing, communications and navigation in harsh deep space environments.

Note: Multiple Capabilities are cross cutting and support multiple Thrusts. Primary emphasis is shown

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AMSM Strategic Technology Plan - Description and Scope

- **The AMSM Strategic Technology Plan (STP) describes the *Advanced Materials, Structures, and Manufacturing* technologies used in the design, development, manufacture, construction, and certification of spaceflight and exploration system hardware elements for NASA missions.**
- **AMSM technologies applications include: crewed and uncrewed - launch vehicles, in-space transportation, landers, surface infrastructure and construction, satellites, science platforms, and commercial space systems.**
- **AMSM applications to subsystems within these larger systems include: advanced propulsion; cryogenic fluid management; entry, decent and landing; in situ resource utilization; life support and habitat systems; and power generation.**
- **Integrated strategic planning across Centers, MD's, OGA's, industry, academia, and international.**
- **AMSM technology advancement is never finished and requires support across the technology pipeline to fully leverage current research and development investments and sustain the innovation ecosystem.**
- **The scope of AMSM technologies is significant and includes 16 different technology categories and 63 sub-categories across the AMSM domain**

AMSM Taxonomy

Materials

- Lightweight Structural Materials
  - Advanced Alloys
  - Advanced Composites
- Computational Materials
  - Multiscale Modeling
  - Multiphysics Modeling
- Flexible Materials
  - Flexible Structural Materials
  - Fabrics
- Materials for Extreme Environments
  - High-Temperature
  - Low-Temperature
- Materials with Specialized Functions
  - Multifunctional Materials
  - Adhesives
- Materials for Advanced Manufacturing and Construction
  - Materials for Additive Manufacturing

26 sub-cat.

Structures

- Lightweight Concepts
  - Tailored Structures
  - Deployable & Inflatable Struc.
- Design, Analysis, and Certification Methods
  - Analysis-Based Design & Cert.
  - Uncertainty-Based Methods
- Reliability and Sustainment
  - Durability, Damage Tolerance, & Life Assessment
  - Health Monitoring
- Innovative, Multifunctional Concepts
  - Integrated Systems
  - Modular & Reconfigurable
- Mechanical Systems
  - Surface System Docking and Interfaces
  - Elec-mech, Mech,

20 sub-cat.

Manufacturing

- Advanced Manufacturing Processes
  - Advanced Composites
  - Additive Manufacturing
- Digital Model-Based Manufacturing
  - Analysis-Based Manufacturing
  - In-Situ Process Monitoring and Control
- Nondestructive Evaluation
  - Sensors and Systems for 3D Inspection
  - Autonomous Inspection Systems
- Sustainable Manufacturing
  - Design for Reuse
  - Recycle of Metals and Composites for AM Feedstock
- Excavation and Surface Construction
  - Site Planning & Design
  - Site Prep

17 sub-cat.

AMSM STP Table of Contents

- **Section 1: Capability Area**
  - **1.1 Description and Scope**
  - **1.2 Architecture Applicability & Capability-Specific Outcomes**

- **Section 2: Technology & High-Risk Development Gaps**
  - **2.1 Overview**
  - **2.2 Technology & High-Risk Development Gaps (32 top priority gaps identified)**

    Gap Title & Description

    Current State of the Art Metrics

    Minimum Acceptable Performance Metrics for Exploration Missions

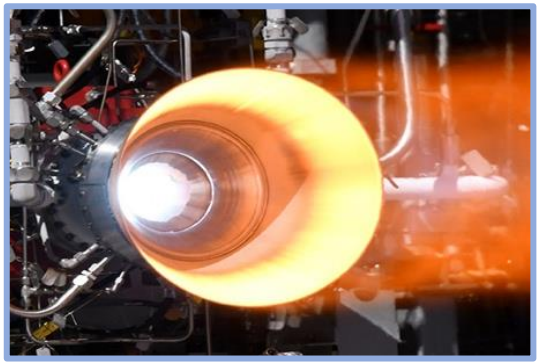
    Gap Closure Plan

    Platforms/Elements Enhanced or Enabled

- **Section 3: Push Technology & Transformative Approaches**
  - **3.1 Strategy**
  - **3.2 Push Technology & transformative Approaches Concepts**

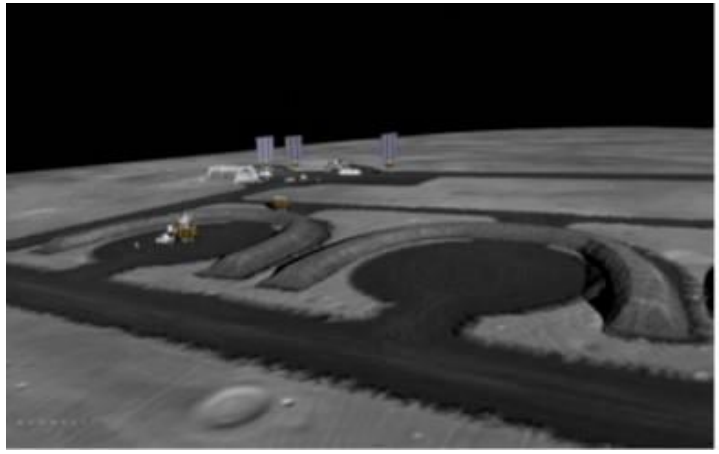
AMSM STP – Example Gaps

- **Gap ID:** STMD-AMSM-002
- **Gap Title:** High-temperature composites with reduced property variability and increased strength
- **Gap Description:** A newer version of C/C, called Advanced Carbon/Carbon (ACC), is one of the current high-temperature materials of choice in the US, and is used for the X-37 control surfaces, the Solar Probe heatshield, and by DoD. ACC was evaluated for the ablative heatshield for Earth reentry of the Mars Sample Return (MSR) capsule, but was rejected primarily due to the low interlaminar properties of the ACC.
- ACC currently has very large scatter in the properties, and cannot meet the reliability requirements. A high temperature composite material with increased interlaminar properties and lower material property scatter is required to enable high reliability hot structures to realize the benefits.
- In addition, we cannot model accurately compressive thermal stress failure or failure modes with combined thermal and mechanical stress.
- In order to accelerate the development of these process dependent extreme temperature composites, a process modeling capability is needed to provide an understanding of the relationship between chemistry during the mfg process and final material performance.



AMSM STP – Example Gaps

- **Gap ID:** STMD-AMSM-026
- **Gap Title:** Construction of landing pads, habitats, shelters, roadways, berms and blast shields using lunar regolith-based materials.
- **Gap Description:** Surface construction technology is needed to stabilize regolith, using locally derived and possibly Earth feedstock to construct horizontal capabilities for berms and landing/launch pads. Vertical construction applications include dust mitigation, foundations, blast protection, radiation shielding, shade structures, unpressurized shelters, and pressurized habitats.
- Evaluation of multiple construction and regolith stabilization technologies, materials, and construction element forms are needed.
- Performance metrics are related to landing and launch pad capability to support HLS landers in the 15-20 ton range for a sustainable lunar base scenario where landings and launches occur routinely from the same site.
- Technology demonstration should be conducted in simulated lunar environmental conditions including thermal, vacuum, radiation, EMI/ECI, and dust.



AMSM STP – Example Gaps

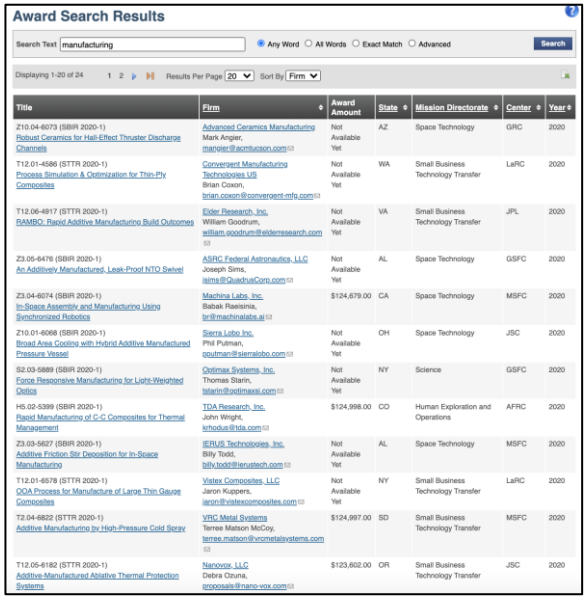
- **Gap ID:** STMD-AMSM-029
- **Gap Title:** Additive manufacturing of large-scale propulsion system components.
- **Gap Description:** Technology developments and advancing large-scale light-weight multi-metallic freeform manufacturing and composite overwrap techniques and analysis capabilities are required to implement them to reduce design and fabrication cycles for regeneratively-cooled liquid rocket engine thrust chambers.
- While AM technologies developed under previous work are transforming component fabrication, there remain some challenges to allow for optimized performance and to further mature and adopt the technologies for ascent/descent landers and industry applications. For example, long duration builds such as large scale DED components may take multiple months and build failures from distortion or residual stresses are a significant concern.

Photo: Relativity Space

AMSM Activities

FY20 SBIR/STTR AMSM subtopics:

Topic Area	Awards
H5.01 – Lunar Surface Solar Array Structures	6
T12.01 – Thin-Ply Composite Technology and Applications (STTR)	4
T12.05 – Deposition and Curing of Thermoset Resin Mixtures for Thermal Protection (STTR)	4
Z4.04 – Real Time Defect Detection, Identification and Correction in Wire-Feed Additive Manufacturing Processes	4
Z4.05 – Nondestructive Evaluation (NDE) Sensors, Modeling, and Analysis	6
20 Total subtopic areas represented	40+ total



Award Search Results

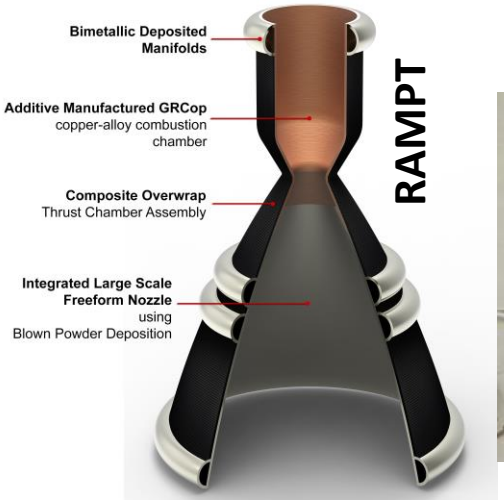
Search Text manufacturing — Any Word / All Words / Exact Match / Advanced — Search

Displaying 1-20 of 24 — 1 2 — Results Per Page 20 — Sort By Firm

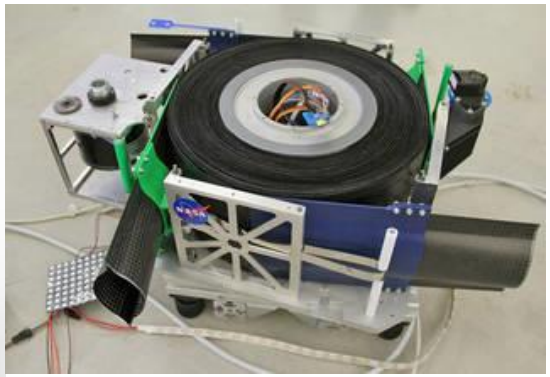
Title	Firm	Award Amount	State	Mission Directorate	Center	Year
Z10.04-6073 (SBIR 2020-1) Robust Ceramics for Hall-Effect Thruster Discharge Channels	Advanced Ceramics Manufacturing Mark Angier, mangier@acmtucson.com	Not Available Yet	AZ	Space Technology	GRC	2020
T12.01-4586 (STTR 2020-1) Process Simulation & Optimization for Thin-Ply Composites	Convergent Manufacturing Technologies US Brian Coxon, brian.coxon@convergent-mfg.com	Not Available Yet	WA	Small Business Technology Transfer	LaRC	2020
T12.06-4917 (STTR 2020-1) RAMRO: Rapid Additive Manufacturing Build Outcomes	Elder Research, Inc. William Goodrum, william.goodrum@elderresearch.com	Not Available Yet	VA	Small Business Technology Transfer	JPL	2020
Z3.05-6476 (SBIR 2020-1) An Additively Manufactured, Leak-Proof NTO Swivel	ASRC Federal Astronautics, LLC Joseph Sims, jsims@QuadrusCorp.com	Not Available Yet	AL	Space Technology	GSFC	2020
Z3.04-6074 (SBIR 2020-1) In-Space Assembly and Manufacturing Using Synchronized Robotics	Machina Labs, Inc. Babak Raeisinia, br@machinalabs.ai	$124,679.00	CA	Space Technology	MSFC	2020
Z10.01-6068 (SBIR 2020-1) Broad Area Cooling with Hybrid Additive Manufactured Pressure Vessel	Sierra Lobo Inc. Phil Putman, pputman@sierralobo.com	Not Available Yet	OH	Space Technology	JSC	2020
S2.03-5889 (SBIR 2020-1) Force Responsive Manufacturing for Light-Weighted Optics	Optimax Systems, Inc. Thomas Starin, tstarin@optimaxsi.com	Not Available Yet	NY	Science	GSFC	2020
H5.02-5399 (SBIR 2020-1) Rapid Manufacturing of C-C Composites for Thermal Management	TDA Research, Inc. John Wright, jshodus@tda.com	$124,998.00	CO	Human Exploration and Operations	AFRC	2020
Z3.03-5627 (SBIR 2020-1) Additive Friction Stir Deposition for In-Space Manufacturing	IERUS Technologies, Inc. Billy Todd, billy.todd@ierustech.com	Not Available Yet	AL	Space Technology	MSFC	2020
T12.01-6578 (STTR 2020-1) OOA Process for Manufacture of Large Thin Gauge Composites	Vistex Composites, LLC Jaron Kuppers, jaron@vistexcomposites.com	Not Available Yet	NY	Small Business Technology Transfer	LaRC	2020
T2.04-6822 (STTR 2020-1) Additive Manufacturing by High-Pressure Cold Spray	VRC Metal Systems Terree Matson McCoy, terree.matson@vrcmetalsystems.com	$124,997.00	SD	Small Business Technology Transfer	MSFC	2020
T12.05-6182 (STTR 2020-1) Additive-Manufactured Ablative Thermal Protection Systems	Nanovox, LLC Debra Ozuna, proposals@nano-vox.com	$123,602.00	OR	Small Business Technology Transfer	JSC	2020

Other NASA Activities:

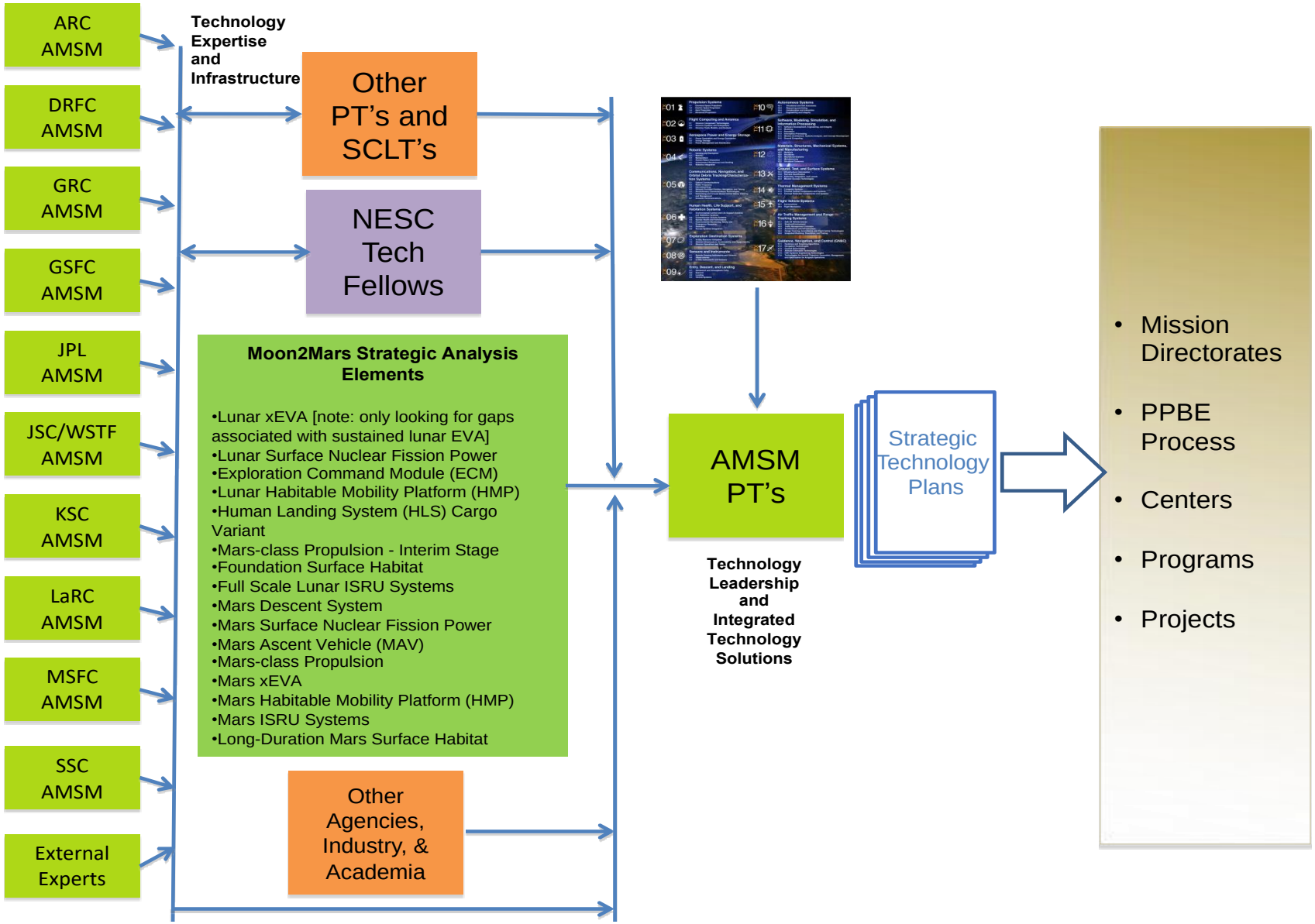
Name	Activity Title	Prog.
	Next Generation Durability and Damage Tolerance Methodologies	ESI
	Lightweight Multifunctional Lattice Materials for Space Applications	ESI
	Robotic Deposition Technology - Aerojet Rocketdyne	ACO
ARMADAS	Automated Reconfigurable Mission Adaptive Digital Assembly Systems	GCD
RAMPT	Rapid Analysis and Manufacturing Propulsion Tech.	GCD
BMG	Bulk Metallic Glass	GCD
DCB	Deployable Composite Boom	GCD
CTE	Composite Technology for Exploration	GCD
SAC	Superlightweight Aerospace Composites	GCD

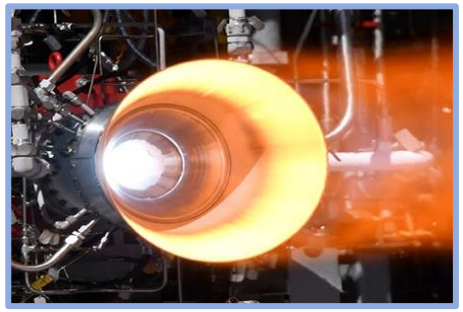


DCB



Integrated AMSM Strategy



AMSM Strategic Technology Plan - Description and Scope (cont.)

- **The scope of AMSM technologies is significant and includes sixteen different technology categories and 63 sub-categories across the AMSM domain**
- **AMSM applications and technology areas are diverse, several overarching themes are present and include:**
  - **Lightweight Materials and Structures**
  - **Materials and Structures for Extreme Environments**
  - **Multifunctional and Specialized Materials and Structures**
  - **Advanced Manufacturing Processes**
  - **Model-based Technologies for Materials, Structures, and Manufacturing**
  - **Lunar Surface Excavation, Manufacturing and Construction**
  - **Materials and Manufacturing Research and Technology for the Commercialization of Space**