Commercial Space TPS Needs: NASA Assessment

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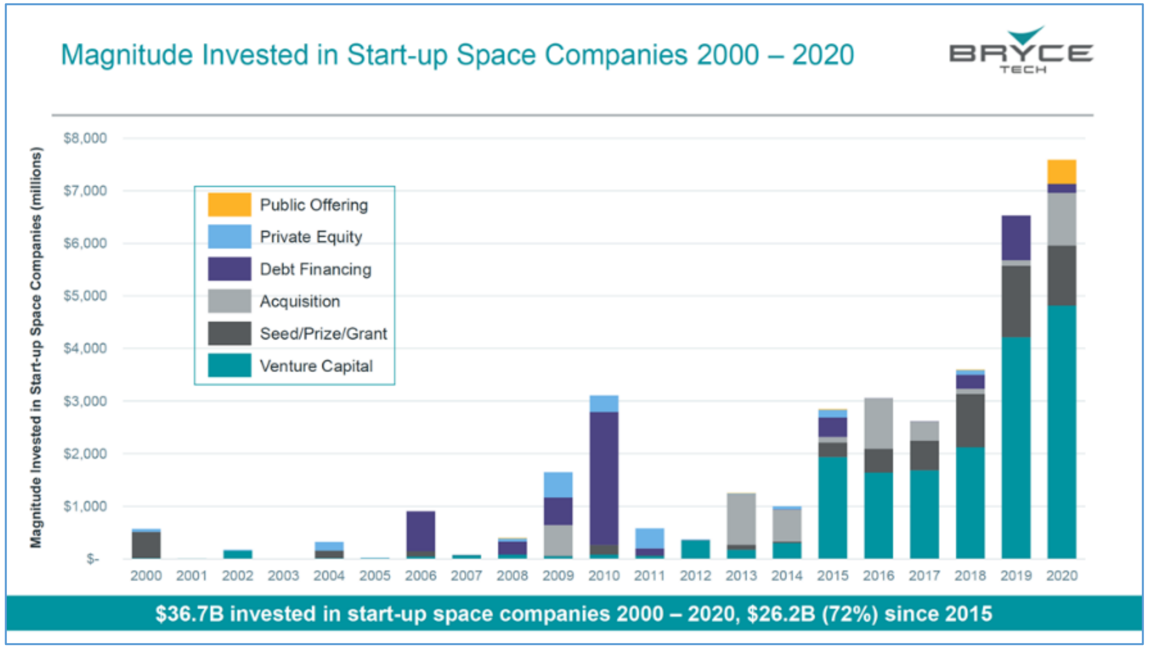
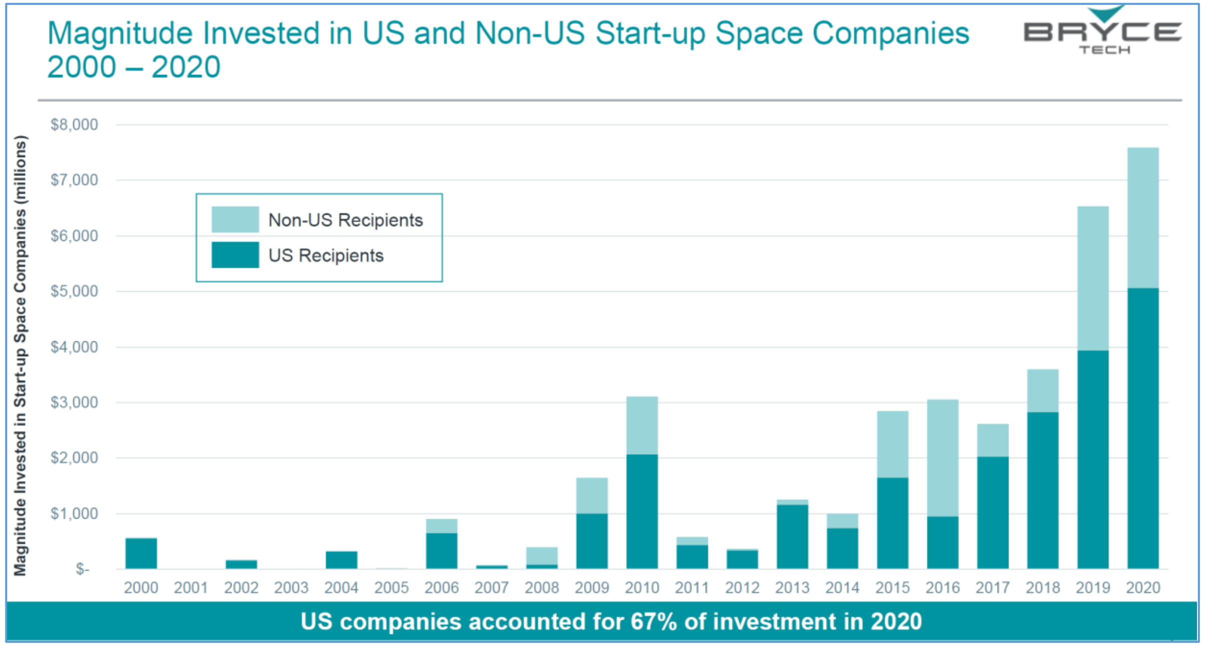
Presentation Overview

- Commercial Space Investments
- NASA Commercial Policy and Strategy
- Space Technology
- Overview of Commercial LEO
- Why Focus on TPS
- NASA Approach to Address the Need
- What We Learned from Industry
- Group Discussions to Focus the Need Discussion
- Concluding Remarks

Background: Commercial Space Investments





Significant Monetary Investment in Space

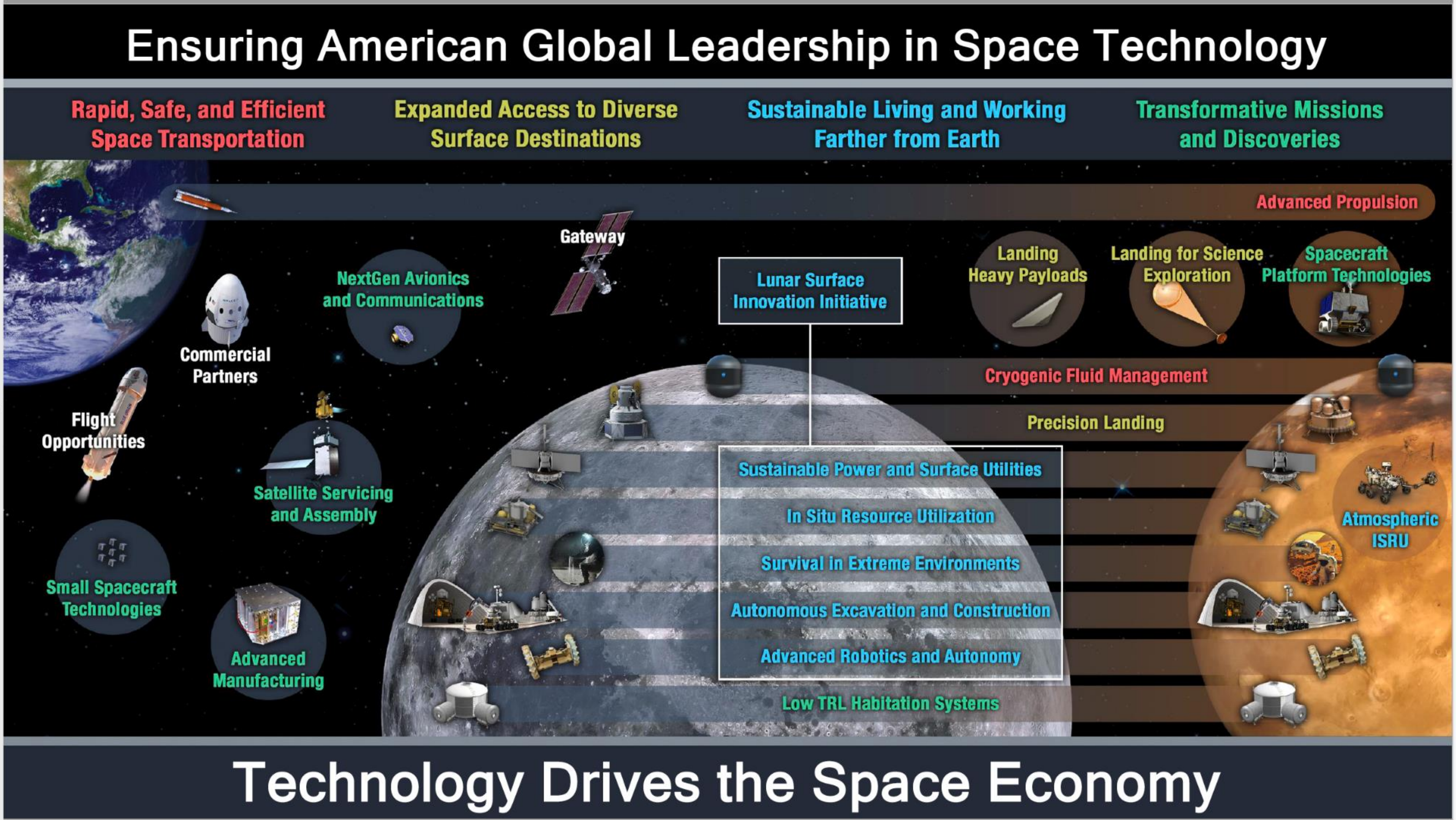
Foreign Competition Increasing

https://brycetech.com/reports/report-documents/Bryce_Start_Up_Space_2021.pdf

Conclusion

The space sector, both domestically and internationally, is rapidly transforming. More nations are engaged in space activities than at any point in history, and private industry is recognizing the economic value of the space domain. Sixty years of NASA's efforts and U.S. government investments have been instrumental in the establishment of the foundational knowledge leveraged by the world.

As NASA looks to the future and moves to expand human knowledge and operational capabilities beyond LEO, *it must recognize and adapt to the new environment and decide strategically how to forge humanity's path outward while managing the risks in an appropriate manner*.


Ensuring American Global Leadership in Space Technology
Rapid, Safe, and Efficient Space Transportation
Expanded Access to Diverse Surface Destinations
Sustainable Living and Working Farther from Earth
Transformative Missions and Discoveries
Advanced Propulsion
Gateway
NextGen Avionics and Communications
Commercial Partners
Flight Opportunities
Satellite Servicing and Assembly
Small Spacecraft Technologies
Advanced Manufacturing
Lunar Surface Innovation Initiative
Landing Heavy Payloads
Landing for Science Exploration
Spacecraft Platform Technologies
Cryogenic Fluid Management
Precision Landing
Sustainable Power and Surface Utilities
In Situ Resource Utilization
Survival in Extreme Environments
Autonomous Excavation and Construction
Advanced Robotics and Autonomy
Low TRL Habitation Systems
Atmospheric ISRU
Technology Drives the Space Economy

Technology Development Focus – Public-Private Partnership

Topics for Tipping Point/Announcement of Collaboration Opportunity 2022

Topic 1: Cislunar/Lunar Surface Infrastructure & Capabilités

- Technologies that support global lunar utilization leading to commercial commodities and services for a robust lunar economy. Such infrastructure could include examples such as long-distance lunar power distribution; survive and operate during lunar night; in-situ Resource Utilization; lunar communications; autonomous construction. These examples for lunar surface infrastructure are not limiting and other potential examples are invited to create a robust lunar economy.

Topic 2: In-Space Infrastructure & Capabilities

- Low Earth Orbit (LEO) to Geosynchronous Earth Orbit (GEO) technologies that support additional future services for a growing LEO/GEO economy. Such infrastructure could include examples such as climate research or service; assembly and manufacturing technologies; distributed autonomy; measurement/observation capabilities; entry, descent, and landing; advanced propulsion. These examples for LEO/GEO technologies are not limiting and other potential examples are invited to create a robust LEO/GEO economy.

NASA Commercial Policy Established

POLICY AND STRATEGIC DIRECTION

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- It is the sense of Congress that:
  - *"An orderly transition for United States human space flight activities in low-Earth orbit from the current regime, that relies heavily on NASA sponsorship, to a regime where NASA is one of many customers of a low-Earth orbit commercial human space flight enterprise may be necessary."*

-P.L. 115-10, NASA Transition Authorization Act of 2017

"Encourage the growth of United States commercial human space exploration, including [...] the continued commercialization of operations in and beyond low Earth orbit, and the use of microgravity as a domain for research and development"

"[...] maintain continuous human presence in Earth orbit by transitioning from ISS to commercial platforms and services.

-U.S. National Space Policy (2020)

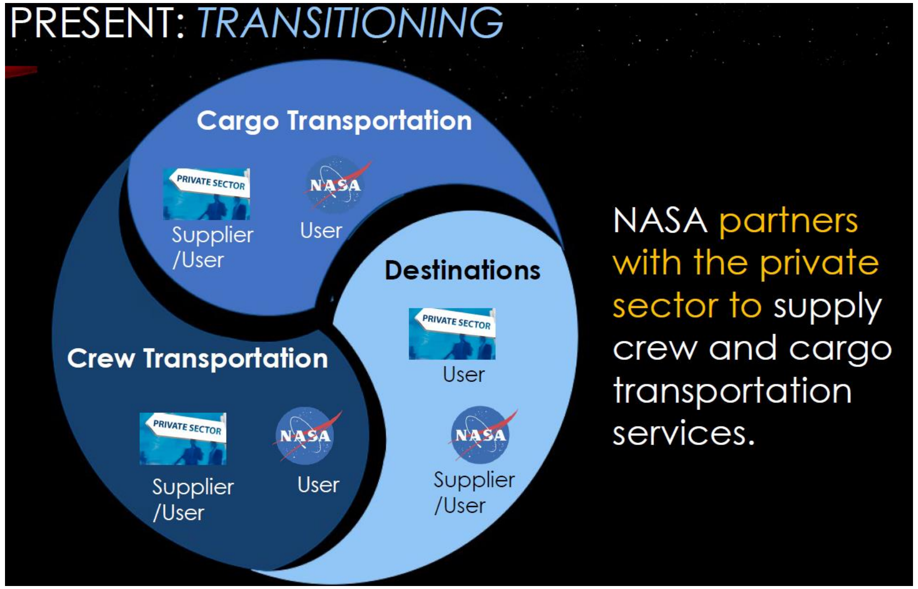
"Lay the Foundation for America to Maintain a Constant Human Presence in Low Earth Orbit"

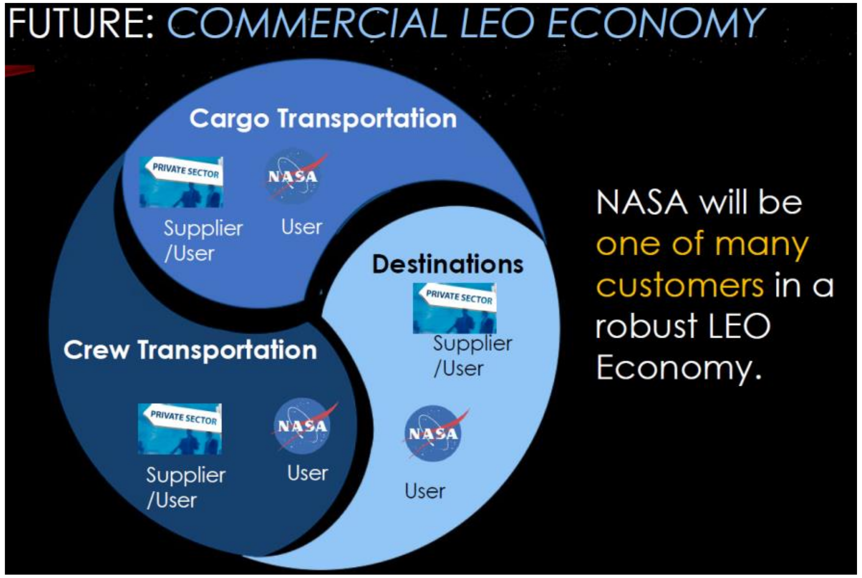
-NASA National Performance Plan, Strategic Objective 2.1

Commercial LEO Destinations (CLD) Industry Briefing, Mar. 23, 2021

Commercial LEO Destinations Program Office

Commercial LEO Destinations (CLD) Industry Briefing, Mar. 23, 2021





Dec. 2, 2021: NASA has signed agreements with three U.S. companies to develop designs of space stations and other commercial destinations in space. The agreements are part of the agency's efforts to enable a robust, American-led commercial economy in low-Earth orbit.

The total estimated award amount for all three funded Space Act Agreements is $415.6 M

Blue Origin and Sierra Space

Nanoracks/Lockheed Martin/Voyager Space

Northrop Grumman

The Situation / The Need

- Key Findings from Industry LEO Commercialization Studies:
  - Crew and cargo **transportation costs were the major barrier to economic development** of LEO and if not reduced, affect both the commercial LEO destination costs and market demand.
  - Commercial LEO human spaceflight destinations are only **viable with significant U.S. government investment and purchase of services**. NASA is expected to be an anchor tenant.
    - https://www.nasa.gov/feature/study-input-informs-nasa-course-for-a-vibrant-future-commercial-space-economy
    - NASA Plan for Commercial LEO Development, June 7, 2019.
- **Every vehicle that transports crew and cargo to and from LEO will need thermal protection systems (TPS).**

Readily Available and Low Cost TPS is Enabler for These Missions.

Why Focus on TPS?
Reduce Space Transportation Costs

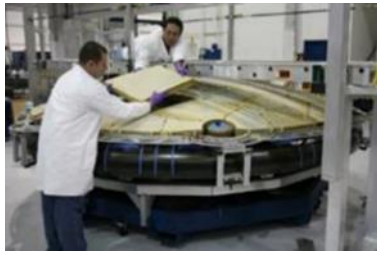
- Current and future Space transportation vehicles will need TPS (and hot structures)
  - *Launch vehicles, hypersonic planes, capsules, lifting vehicles, landers.*
- Manufacturing processes and vehicle integration often drive costs
  - Options available today are limited
  - Design/integration challenges – tiles/blocks bonded to structure & filled gaps
  - Labor intensive and costly; long manufacturing and integration times

Can Automation / Additive Manufacturing help Address the Challenges?

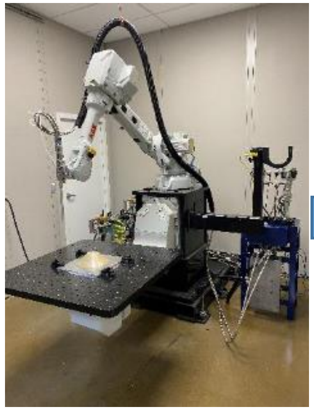
Manual Cell Filling

Can Automate Cell Filling

Hand-packed Heat Shields

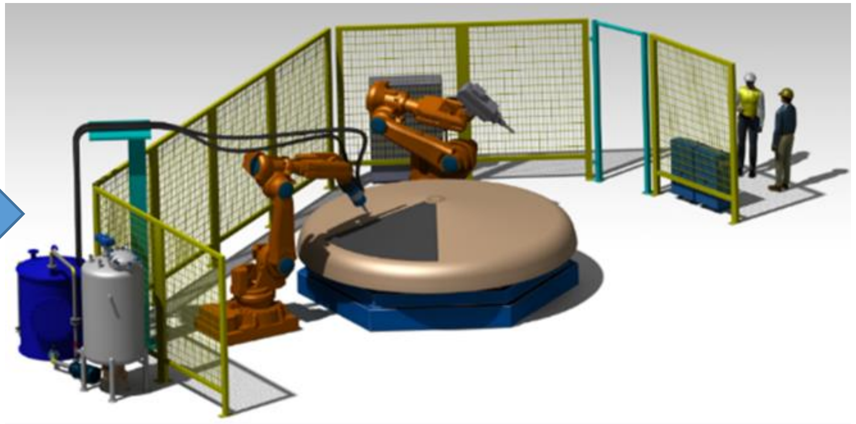


Manual Block Install



Prototype Robotic Cell (ORNL)

Future Heat Shield Manufacturing



NASA's Approach
Assess AM-TPS Feasibility and Assess Future TPS Needs

- In-house Additively-Manufactured TPS Research & Development
  - Early Carrier Innovation (ECI) Funded Effort (Adam Sidor)
    - Start with ablators and expand to other types of TPS
    - Partner with Oak Ridge National Lab (ORNL) Manufacturing Demonstration Facility
  - IRAD for Sharp Leading Edge using AM Manufactured Heat-Pipe (Keith Peterson)
- Fund several NASA SBIR and STTR projects
- Engage the Larger Community via Additively-Manufactured TPS Workshop
  - Involve DoD, NASA Centers, National Labs, Commercial and Space Industry, Small Business and Universities
  - Phase 1 of Workshop (complete) - Reach out to Industry
  - Phase 2 of Workshop - Conduct In-Person, Invitation-Only Workshop
    - DoD, Commercial and Space Industry, National Labs and Small businesses

AM-TPS Workshop
Phase 1: Industry Inputs

Presentations given by

- Lockheed Martin
- Siemens Energy
- Northrop Grumman
- Rocket Lab
- Sierra Nevada
- Boeing
- Blue Origin
- General Electric
- Relativity Space
- Firefly
- Varda Space Industries
- General Atomics
- GE – Additive
- Inversion Space

Invited Attendees (Govt. Only)

- NASA ARC, JSC, LaRC, AFRC, MSFC
- NESC
- STMD
- FFRDCs: ORNL, JPL, APL
- Missile Defense Agency
- US Army
  - DEVCOM Armaments Center
  - Army Research Lab
  - Advanced Manufacturing, Rock Island Center
- US Navy
  - Naval Surface Warfare Center
  - Naval Air Systems
- AFRL
- NRO

What We Learned from Industry: Common Feedback

- **NASA should be investing in new TPS materials and make them production ready**
  - Need TRL 6/MRL 6 materials/processes for programs to consider for evaluation/insertion; off-the shelf availability
  - **Collaborate with industry** to advance TRL/MRL of these materials
    - Some industries have specific needs
    - Fundamental Material & Process development in partnership with industry
      - Raw material supply chain issues
  - **Commercialization** should be core of NASA tech program
    - Streamline Licensing agreements and/or technology transfers
- **Collaborate with DoD to leverage overlap between needs**
- **Reduce costs of fabrication, assembly and integration**
- **Types of TPS/Hot Structures to Pursue**
  - AM of high temperature composites
  - Increase domestic supply of C/C and C/SiC manufacturers
  - Reusable heat shield materials
  - Need large scale solutions with simple/robust attachment and minimized part count
  - Need high-temperature, durable and lower-cost TPS
  - Need integrated TPS/structure solutions
- **Reduce barriers to development/insertion into programs**
  - Reduce cost and increase availability of material high-temperature testing
    - Arc-jet testing cost prohibitive
  - Need microstructure characterization
  - Need in-process instrumentation

What We Learned from Industry: By Category

- Suppliers
  - Already developing AM processes in specialized areas such as high-temperature metals, some ceramics and Ceramic Matrix Composites
  - Demonstrating reduction in manufacturing schedule and potential cost savings
- Large Established Aerospace Industry
  - Continue to leverage existing TPS with efforts to assess AM potential
  - Some companies developing in-house AM capability for hot structure pre-forms and reusable TPS
  - Responsive to NASA and DoD’s needs
- Commercial Space
  - Reusable launch vehicles are key to cost reduction. Reusable TPS needed.
  - Re-entry vehicles need reusable TPS or very inexpensive ablators (and manufacturing/installation processes) to be cost effective.
  - Some companies are already utilizing AM in many areas and open to adapting it for TPS.

Group Discussions Planned for Day 3


SLS base during a test firing


NASA Space Plane


Large Aeroshells for Mars Lander Missions
(MSL, Mars 2020 and MSR SRL)

- TPS/Hot Structure Design is specific to the Application/Mission.
- Group Discussions will allow us to focus on the TPS needs in four different categories of vehicles/missions.

TPS Application Focus Areas

1: Launch Vehicles & Landers
- Plume heating and aerodynamic heating
- Acreage, Nose Cone, Fins, Legs, Base, Joints/Seals

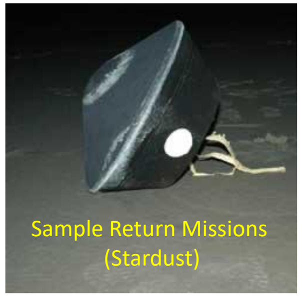
2: Hypersonic Vehicles – Military and Commercial
- Long-duration aerodynamic heating
- Acreage, Leading-Edge, Control Surfaces, Joints/Seals

3: Low-Earth Orbit Entry Vehicles
- Aerodynamic heating
- Acreage, Leading-Edge, Control Surfaces, Joints/Seals

4: Cislunar Return & Inter-planetary Entry Capsules / Re-Entry Vehicles
- Aerodynamic heating plus shock radiation
- Heat Shield, back shell, other

- Discussions to identify overlapping needs and common solutions.
- Results of discussions will be used to set priorities for future NASA research and collaborations.


Orion EFT-1 Post-Flight


Sample Return Missions
(Stardust)


Galileo Probe entry - Jupiter

Concluding Remarks

- Entering a new era of space exploration and a rapidly developing space economy demands:
  - Lowering the cost of and rapid manufacturing/integration of reusable TPS including hot structures will be enablers.
- Government resources and development need to focus on enabling these developments.
- Additively-Manufactured TPS Workshop aims to get a community consensus on technology development focus and strategy.