Update on STMD Strategic Implementation Plan

Presented by:
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www.nasa.gov/spacetech
Primary purpose of this activity was to reframe/repackage the existing strategy so as to focus more on communicating challenges and outcomes, and less on specific technologies & systems.

- STMD Strategic Framework Revision Overview (Slides 3-5)
- Quantifiable Capabilities (Slide 6-9)
- Transformative Themes and Strategic Thrusts (Slides 10-18)
- Next Steps (Slide 19 & 20)
FY16 STMD Strategic Framework

STMD Strategic Alignment Framework
- Core values, guiding principles, implementation goals flowdown

STMD Strategic Themes
- Get There, Land There, Live There, Observe There, Invest There
- Stakeholder input: Space Technology Roadmaps, NRC recommendations, STIP, MD roadmaps, Roundtables, etc.

STMD Thrust Areas
- Focused areas of STMD investments
- Principal Technologists: Technology investment plans

Content Generation
- Crosscutting Investment strategy and content selection

Technology Portfolio Integration
- Implementation instruments

STMD Programs

National Science and Technology Priorities
We will be…

…reframing/repacking the strategy, focusing more on communicating challenges and outcomes, and less on technologies & systems.

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- Principal Technologists: Technology investment plans
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- Implementation instruments

Strategic Guidance
- Content Generation
- Technology Portfolio Integration

National Science and Technology Priorities
STMD Strategic Alignment Framework

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- Stakeholder input: Space Technology Roadmaps, NRC recommendations, STIP, MD roadmaps, Roundtables, etc.
- Focused areas of STMD investments

Strategic Guidance

STMD Thrust Areas
- Principal Technologists: Technology investment plans
- Crosscutting Investment strategy and content selection
- Implementation instruments

Content Generation

Technology Portfolio Integration

STMD Programs

...deriving the framework directly from stakeholders (HEOMD, SMD, other government agencies, & U.S. industry).

...shifting from an internal, discipline-centric focus to a customer-oriented, impact-centric focus, with the intent of more transparently communicating impacts to customers & stakeholders.

...increasing use of quantifiable measures to make the strategy easier to operationalize, increasing traceability of portfolio formulation decisions while providing clearer guidance to and empowering program/project/line management & the technical workforce.
Step 1: Intro of Quantifiable Capabilities

STMD Principle Technologist (PTs) developed quantifiable capabilities:
- Quantified performance metrics
- Investment strategies

Provided a framework for content generation to better inform the formulation of the STMD portfolio and better target & coordinate development of innovative solutions.

In December 2016, 38 QCs had been delivered, reviewed, approved, & grouped in tiers, becoming an integral part of our strategic framework.

By the Numbers
9 Principal Technologists
3 to 7 QCs each
38 total QCs

...increasing use of quantifiable measures to make the strategy easier to operationalize, increasing traceability of portfolio formulation decisions while providing clearer guidance to and empowering program/project/line management & the technical workforce.
Quantifiable Capability:
High Mass to Mars Surface

**Description:**
This capability includes the technologies that, put end-to-end, enable human Mars missions like those defined by the Evolvable Mars Campaign. Hypersonic, supersonic, and subsonic deceleration technologies to accomplish landing on the planet, and how to transition between them, are all part of this area. This is the most challenging mission for EDL and will take a long-term development commitment, including large-scale ground and flight tests at Earth. Multiple solutions exist, but have not been fully vetted against the key characteristics of this long-term capability: efficient performance within the EMC architecture, scalability, flexibility, sustainability, and affordability. Commonality across the architecture is a key desired feature (descent propulsion is same as ascent propulsion, lander structures are common, etc.) Evaluating the systems requires a commitment to a sustained, flexible, modeling and analysis capability at both the technology and the mission levels that will be continually updated as the systems are matured.

A nearer-term driver is SMD’s Mars Sample Return Lander, expected to be 1.5 t. LDSD technologies (SIAD, parachute, perhaps ballute) should be helpful but it is unclear at this time if these are sufficient and if a larger, more capable parachute is the most robust, affordable option.

**Capability Challenge** (include **Quantifiable Capability objective**, i.e. **98% Water Loop Closure**)
Land 20 t payload on Mars surface in support of the human Evolvable Mars Campaign

**Current State of the Art**
Mars Science Laboratory, 1 t (2012) using rigid 4.5-m 70˚ sphere cone with PICA tiles, supersonic DGB parachute, and skycrane propulsion. Hypersonic guidance based on Apollo, MEDLI forebody instrumentation.

**Where is driving need drawn from** – Stakeholders, Advisory Groups, MD etc.
NASA’s Strategic Goal to land humans on Mars in 2030’s, HEOMD’s Evolvable Mars Campaign, SMD Sample Return Lander at 1.5+ t

**What does the Industry/OGA landscape look like, if one exists** – NASA only; SpaceX has Mars landing goal, in partnership on 2018 robotic mission demonstrating EDL w/SRP (not high-mass capability in the current configuration). ULA interested in HIAD for stage return.

**When Needed**
Flight test or Mars robotic mission to prove end-to-end system at 30-50% scale in late 2020’s; SMD SRL in 2026+

**Why now**
Performing flight tests within funding constraints dictates that the maturation timeline is spread out, requiring commitment to system scale-up and TDM formulation NOW; particularly in support of a Mars EDL Pathfinder mission, but regardless of Mars end-to-end testing.

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**Roadmap: TA09**

**Other Relevant Information**
Current human mission candidates are:
- **Hypersonic decelerators:**
  - Inflatable blunt body (HIAD), at 18-20 m scale
  - Mechanical blunt body (ADEPT), at 18-20 m scale
  - Mid-L/D, at ~20 m long x ~9 m diameter
  - Rigid Capsule, at 9 m diameter (different assumptions)
- **Supersonic decelerators:**
  - Supersonic retropropulsion (LOx/CH₄)
- **Subsonic decelerators:**
  - Propulsion (LOx/CH₄)
## Quantifiable Capabilities

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Precision Landing and Hazard Avoidance  
EDL Data Return and Model Improvement  
High-Speed Planetary Probes / Earth Return Capsules |
| Avionics; Radio Frequency Communications; Electronic Sensors (Stephen Horan) | Flight Computing, Data & Information Systems  
Advances in Packaging and Environment Compatibility  
Sustain High Throughput Communications |
| Optical Communications; Optics & Science Observatories; Radiation Protection (Denise Podolski) | Deep Space Optical Comm  
Near Earth Optical Comm  
Advanced Radiation Protection  
Gravitational Wave Observatory Capabilities (To Be Approved)  
In-Situ Exo-Life Detection Capabilities  
Large UV-Optical-IR / Exoplanet Imaging Space Telescope  
Next Generation Far Infrared (FIR) Space Telescope  
Next Generation X-ray Space Telescope |
| Power and Energy Storage; In-Space Propulsion (Lee Mason) | Power for Human Surface Missions  
Power for Robotic Science Probes  
Power for Electric Propulsion  
Power for Small Spacecraft |
| Launch & Spacecraft Vehicle Systems; Advanced Propulsion Systems (Ron Litchford) | Breakthrough In-Space Propulsion  
EMC LOX/Methane Propulsion Architecture  
EMC Nuclear Thermal Propulsion Architecture  
Enable Small Scale Launch Systems (To Be Approved)  
Mission Enhancing In-Space Green Propulsion  
Mission Enhancing In-Space Storable Propulsion |
| Robotics; Autonomous Systems (Ron Ambrose) | Robotic & System Autonomy  
Surface Mobility  
Human Augmentation  
Robotic Caretakers |
| Lightweight Structures & Materials (Vickers / Belvin) | In-Space Manufacturing and Assembly of Large-scale Precision and Non-Precision Structures  
Human-Rated Composite Structures for Launch, Transit, and Deep Space Vehicles and Habitation  
Materials and Structures for Extreme Environments  
Lightweight, Multifunctional Materials, Manufacturing & Structures for Deep-Space Exploration Systems |
| Thermal Management; Human Health & Life Support; In-Situ Resource Utilization (Molly Anderson) | Cryo-Thermal  
In-Situ Resource Utilization  
Exploration-Class Life Support System Components  
Earth-Independent Life Support Needs  
Advanced Spacesuit Technology |
Tiered Quantifiable Capability

**Tier 1**
- Flight Computing, Data, & Information Systems (Avionics)
- Deep Space Optical Comm (Comm)
- Near Earth Optical Comm (Comm)
- High Mass to Planetary Surface (EDL)
- Precision Landing and Hazard Avoidance (EDL)
- Cryo-Thermal (Thermal Management)
- Power for Human Surface Missions (Power)
- Power for Robotic Science Probes (Power)
- Robotic & System Autonomy (Robotics)
- In-Space Manufacturing and Assembly of Large-scale Precision and Non-Precision Structures (Structures)

**Tier 2**
- Large UV-Optical-IR / Exoplanet Imaging Space Telescope (Observatory)
- Power for Electric Propulsion (Power)
- EMC Nuclear Thermal Propulsion Architecture (Propulsion)
- Materials and Structures for Extreme Environments (Structures)
- EDL Data Return and Model Improvement (EDL)
- In-Situ Resource Utilization (Life Support)
- Surface Mobility (Robotics)
- Human-Rated Composite Structures for Launch, Transit, and Deep Space Vehicles and Habitation (Structures)

**Tier 3**
All other QCs.

**Purpose of prioritization** is to allow communication of strategic priorities internally & externally, and to focus limited resources more efficiently, particularly within the Game-Changing Development Program and Technology Demonstration Missions Program.
Step 2: Transformative Themes

By shifting from an internal, discipline-centric focus to a customer-oriented, impact-centric focus, with the intent of more transparently communicating impacts to customers & stakeholders.
Step 3: Strategic Thrusts

STMD Thrust Areas provide the bridge between the Transformative Themes and the Quantifiable Capabilities

By shifting from an internal, discipline-centric focus to a customer-oriented, impact-centric focus, with the intent of more transparently communicating impacts to customers & stakeholders.

- Core values, guiding principles, implementation goals flowdown
- Get There, Land There, Live There, Observe There, Invest There
- Major, community-level outcomes STMD will achieve
- Focused areas of STMD investments
- Key, quantified, & prioritized challenges that must be addressed to advance trusts & themes
- Crosscutting Investment strategy and content selection
- Implementation instruments

STMD Strategic Alignment Framework

STMD Strategic Themes

Transformative Themes (6)

STMD Thrusts (19)

Quantifiable Capabilities (38)

Technology Portfolio Integration

STMD Programs
Transformative Themes and Associated Thrusts

Expand Utilization of Near-Earth Space
- Provide safe and affordable routine access to space
- Enable extension, reuse, and repair of near-Earth assets
- Expand near-Earth infrastructure and services to support human and science exploration beyond low Earth Orbit

Develop Efficient & Safe Transportation Through Space
- Provide cost-efficient, reliable propulsion for long duration missions
- Increase effectiveness and applicability of current propulsion options
- Enable significantly faster, more efficient deep space missions
- Provide efficient and safe in-space habitation

Increase Access to Planetary Surfaces
- Safely and precisely deliver humans & payloads to planetary surfaces
- Increase access to high-value science sites across the solar system
- Provide efficient, highly-reliable Earth sample return reentry capability

Enable Humans to Live and Explore on Planetary Surfaces
- Enable humans to survive
- Provide efficient/scalable infrastructure to support exploration at scale
- Increase crew effectiveness and access to diverse, high-value sites

Enable Next Generation of Science Beyond Decadal
- Expand access to new environments and measurement platforms to enable high-value science
- Enable substantial increases in the quantity and quality of science data returned
- Enable high-power measurements for long duration science missions

Grow & Utilize the U.S. Industrial and Academic Base
- Provide NASA technology to grow the U.S. industrial & technology base
- Open and foster new space markets for U.S. commerce
- Drive U.S. innovation & expand opportunities to achieve the NASA dream
Expand Utilization of Near-Earth Space

Provide safe and affordable routine access to space

**Impact:**
- Enable more affordable and reliable access to space.
- reductions lower barriers to market entry, enable new markets, lower risk reduction costs, and allow increased investment in payload capabilities, additional payloads, and/or R&D

**Challenges:**
- Innovation and technology development required to further reduce launch costs
- Increase launch system availability & robustness through a combination of system reliability growth, higher capacity ground infrastructure, and alternative launch sources

Enable extension, reuse, and repair of near-Earth assets

**Impact:** The ability to inspect, service, repair, upgrade, and transfer near-Earth systems will
- Lower system life-cycle costs
- Make systems more robust to unwanted/unforeseen events
- Expand system lifetimes
- Allow reuse of systems for new missions

**Challenges:** Requires investment in
- Replacement of expendable resources (e.g. storable, non-storable propellants)
- Adaptable/reliable autonomous robotic systems
- Serviceable components/subsystems on client spacecraft
- Ability to manufacture components in space

Expand near-Earth infrastructure and services to support human and science exploration beyond low Earth orbit

**Impact:**
- Multiple launches and element refurbishment required
- Near-Earth space-based infrastructure will facilitate these operations
- Will also enable cost effective construction of the next generation of astrophysics telescopes

**Challenges:**
- Establish space-based refueling and long-term storage capabilities for propellants
- Develop autonomous robotic servicing and repair capabilities
- Establish an in-space manufacturing and repair capability

Customers & Partners

(examples, not inclusive)
Provide cost-efficient, reliable propulsion for long duration missions

**Impact:**
- Storable propulsion systems derived from 1960’s heritage technology and need to be upgraded
- Human exploration of the solar system will require propulsion systems that can reliably perform multiple restarts with long periods of dormancy between uses
- Highly efficient propulsion for cargo transport.

**Challenges:** Will require investments in
- Advanced engine materials and manufacturing techniques
- Higher thrust storable engines, and low-freezing point monopropellants & oxidizers

Increase effectiveness and applicability of current propulsion options

**Impact:**
- Need to improve storability of cryogenic propellants to allow use on multi-month missions, reducing the propellant mass required to deliver payloads to destinations
- Develop ability to increase scale and improve efficiency of electric propulsion

**Challenges:** Will require investments in
- Human-class Oxygen/Methane propellant & engine, & low mass near-zero-boil-off cryo systems
- Improved performance of solar electric transportation

Enable significantly faster, more efficient deep space missions

**Impact:**
- Current deep-space transportation limited by propulsion technologies (chemical & solar electric)
- Improvements can enable faster trip times, reduce mass, and expand reach into the solar system

**Challenges:** Will require investments in
- High-power nuclear electric propulsion, advanced thermal management, & advanced solar sails
- In-space refueling and aggregation

Provide efficient and safe in-space habitation

**Impact:**
- Ensure availability of long-duration habitation systems capable of operating in the deep space environment (e.g., microgravity, radiation, orbital debris, thermal)

**Challenges:** Will require investments in
- Radiation protection from solar particle events and galactic cosmic radiation
- Life support systems with >1000 day availability
Safely and precisely deliver humans & payloads to planetary surfaces

Impact: Landing humans on Mars will be enabled by
- Delivery of payloads in the 18t-27t range
- Precise landing of payloads within 50m to allow base aggregation
Aero-entry technologies will reduce total entry system mass by >75% over propulsive approach.

Challenges: Requires investments in
- Deceleration capabilities at least 18x current non-human-rated SOA
- Precision landing, navigation & control algorithms, and high-performance, real-time computational hardware and software

Increase access to high-value science sites across the solar system.

Impact: To enable access to more challenging surface sites, NASA increasingly requires
- Improved aero-entry capabilities to reduce entry mass
- Ability to precisely land and avoid hazardous terrain (e.g. Europa)

Challenges: Requires investment in
- New materials to reduce entry system mass
- Precision landing (10-100m footprint) and hazard avoidance technology

Provide efficient, highly-reliable Earth sample return reentry capability.

Impact:
- Returning samples allows for higher fidelity measurements
- Currently prioritized sample return from comet surfaces, the Moon’s permanently shadowed craters, and the Mars surface
- Expect further demand for sample return missions

Challenges:
- Introduce new materials and apply systems analysis to reduce aero-shell mass
- Develop highly reliable entry systems (one in a million chance of failure) to allow return of potentially biologically-hazardous samples from destination like Mars, Enceladus, or Europa
Enable humans to survive

**Impact:** Human exploration of the solar system will be enabled by

- Highly reliable systems to provide life support
- Habitats and life support systems that can survive pre-deployment, then operate for hundreds of days
- Systems to minimize the crews’ exposure to the surface environment

**Reuse of hardware for multiple missions will require lifetimes of thousands of days**

**Challenges:**

- Operate reliably for 1000-day class missions, with minimal maintenance and spares
- Increase ability to recover and process local resources
- Increase oxygen recovery from crew
- Increase level of recovery from water

Provide efficient/scalable infrastructure to support exploration at scale

**Impact:** Sustaining surface systems will require

- Reliable high-power infrastructure (i.e. production, management, & distribution)
- Capability to link power sources to power sinks across multiple landed payloads
- Assembly & aggregation of large payloads
- Large bandwidth communications

**Challenges:**

- Produce 40 kW continuous power with long lifetime (>10 years)
- Autonomously deploy, assemble, and inspect base infrastructure prior to crew arrival
- Develop optical comm for deep space (100x increase in capacity)

Increase crew effectiveness and access to diverse, high-value sites

**Impact:** Enable effective exploration by

- Increase time available for utilization by crew
- Reducing EVA suits mass and maintenance requirements
- Allowing crew to range farther from the habitat and traverse rough terrain (e.g. craters)

**Challenges:**

- Reduce crew time spent on overhead through automation of systems and human augmentation devices
- Reduce EVA capability mass requirements and decrease maintenance frequency
- Develop mobility capability to allow crew to explore up to 100s of kms, at least a speed of 5 m/s, with a payload capacity of 2000 kg, and navigate slopes up to 30 deg

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**Customers & Partners**

(Examples, not inclusive)
Expand access to new environments and measurement platforms to enable high-value science

**Impact:**
- Planetary science increasingly requires operation in hostile environments (e.g., Jupiter’s radiation environment, surface of Venus), requiring new platforms and more capable components
- Astrophysics increasingly requires access to larger measurement platforms to conduct the next generation of cosmological science

**Challenges:** Requires investment in
- New observation platforms
- Radiation protection for avionics
- Subsystems and components that operate in extreme temperature environments

Enable substantial increases in the quantity and quality of science data returned

**Impact:**
- Demand for science data expected to increase at least 10x over the next 10 years
- Some planned missions capable of producing as much as a TB of useful data every 90 minutes
- Rapid increase threatens to overwhelm NASA’s comm infrastructure

**Challenges:**
- Develop optical comm for near Earth and deep space (10x to 100x increase in capacity)
- Increase throughput by a factor of 10 through improved modulation, coding, and signal processing

Enable high-power measurements for long duration science missions

**Impact:**
- Active remote sensing instruments need increase power to increase fidelity and range
- Outer-planet-class missions require long life, solar independent power sources

**Challenges:**
- Develop high-performance RPS/fission power sources
- Increase photovoltaic efficiencies in low intensity/low temperature environments
- Increase energy density of batteries to >300 Wh/kg

All advancements need to be able to operate for >10 years with high reliability.
**Provide NASA technology to grow the U.S. industrial & technology base**

**Impact:**
- NASA-developed technologies increase U.S. aerospace and non-aerospace competitiveness, directly benefit other government agencies, and promote growth of U.S. industry
- Active transfer of technology solutions to U.S. industry and other governmental agencies maximizes benefit to the public and the Nation

**Challenges:** Will require investments in:
- Communication of NASA technology solutions to U.S. industry and the public
- Engagement with U.S. industry and the public to identify new applications for NASA-developed technology solutions beyond the aerospace community
- Facilitation of transfer of technology solutions

**Open and foster new space markets for U.S. commerce**

**Impact:**
- Opportunities exist to increase commercial use of space through opening of new markets and engagement with new customers enabling introduction by U.S. industry of new products and services (e.g. space manufacturing, spacecraft servicing, crew launch)
- Development, demonstration, and dissemination of key technologies by NASA lowers barriers of entry to new commercial opportunities, allowing U.S. entrepreneurs and companies to open and dominate these markets and fueling further sustainable growth of the U.S. space sector

**Challenges:** Will require investments in:
- Identification of key technology barriers for new space markets
- Technology demonstrations to reduce development & operations risks for U.S. industry & entrepreneurs.
- Responsive partnerships that address partner critical needs and schedules

**Drive U.S. innovation & expand opportunities to achieve the NASA dream**

**Impact:**
- Harness and encourage entrepreneurship and academia to develop and implement innovative ideas to enable and enhance NASA missions
- Increase the competitiveness, experience, and technical skills of the American aerospace workforce to support future U.S. industry and NASA missions

**Challenges:** Will require investments in:
- Identification, development, and implementation of innovative ideas and concepts by agency personnel, academia, small businesses, and companies to support NASA missions
- Recruitment, development, and retention of American technicians, scientists, and engineers

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**Customers & Partners**

(Examples, not inclusive)
Step 4: Mega-Drivers – Needed Final Step

Mega-Drivers are identified through discussions with customers and market research & analysis. Transformative Themes and Thrust Areas may be modified to better align with Mega-Drivers.

Derive the framework directly from stakeholders (HEOMD, SMD, other government agencies, & U.S. industry).

Mega-Drivers (TBD)
- Major trends that will shape the space industry over many years

Transformative Themes (6)
- Major, community-level outcomes STMD will achieve

STMD Thrusts (19)
- Focused areas of STMD investments

Quantifiable Capabilities (38)
- Key, quantified, & prioritized challenges that must be addressed to advance trusts & themes

Technology Portfolio Integration
- Crosscutting Investment strategy and content selection

STMD Programs
- Implementation instruments
Next Steps

• Continued dialogue to evolve the STMD Strategy
  • Feedback Sessions
  • Review processes

• Begin to develop Mega-Drivers through discussions with customers and market research.

• Find pathways to infuse the strategy into the STMD operating model as we engage in solicitations, new start discussions, portfolio formulation activities, and partnerships / collaborations

The STMD strategy and strategic framework will continue to evolve as we learn and our customers change. This is a first step in a living process.
Back-up
# Quantifiable Capabilities

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Definitions

- Mega-Driver: A major trend that will shape the space industry (government & commercial) over many years. Mega-drivers are a product of conversations with customers (e.g. HEOMD, SMD, other governmental agencies, & industry) and analysis of space industry trends.

- Transformative Theme: Major community-level outcomes that STMD plans to achieve in response to the Mega-Driver.

- Strategic Thrust: Focused areas of STMD investments in order to achieve the Transformative Themes.

- Quantifiable Capability: Key quantified and prioritized challenges that STMD plans to address in order to advance the Transformative Themes and Strategic Thrusts.