Presentation Outline

- Space Technology Mission Directorate Overview
- Game Changing Development Program Overview & Introduction to Management Themes
- GCD’s Flagship Project
- STMD’s Technology Pipeline & GCD’s role
- Select GCD Content by Programmatic Alignment
- Recent Program Accomplishments
- Summary
Enables a new class of NASA missions beyond low Earth Orbit.

Delivers innovative solutions that dramatically improve technological capabilities for NASA and the Nation.

Develops technologies & capabilities that make NASA’s missions more affordable and reliable.

Invests in the economy by creating markets and spurring innovation for traditional and emerging aerospace businesses.

Engages the brightest American minds to solve NASA’s toughest technological challenges.
**Space Technology Portfolio**

**Transformative & Crosscutting Technology Breakthroughs**

**Technology Demonstration Missions** bridges the gap between early proof-of-concept tests and the final infusion of cost-effective, revolutionary technologies into successful NASA, government and commercial space missions.

**Small Spacecraft Technology Program** develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration and space operations.

**Game Changing Development** seeks to identify and rapidly mature innovative/high impact capabilities and technologies that may lead to entirely new approaches for the Agency’s broad array of future space missions.

**Pioneering Concepts/Developing Innovation Community**

**NASA Innovative Advanced Concepts (NIAC)** nurtures visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace concepts—while engaging America’s innovators and entrepreneurs as partners in the journey.

**Center Innovation Fund** stimulates and encourages creativity and innovation within the NASA Centers by addressing the technology needs of the Agency and the Nation. Funds are invested to each NASA Center to support emerging technologies and creative initiatives that leverage Center talent and capabilities.

**Creating Markets & Growing Innovation Economy**

**Centennial Challenges** directly engages nontraditional sources advancing technologies of value to NASA’s missions and to the aerospace community. The program offers challenges set up as competitions that award prize money to the individuals or teams that achieve a specified technology challenge.

**Flight Opportunities** facilitates the progress of space technologies toward flight readiness status through testing in space-relevant environments. The program fosters development of the commercial reusable suborbital transportation industry.

**Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)** Programs provide an opportunity for small, high technology companies and research institutions to develop key technologies addressing the Agency’s needs and developing the Nation’s innovation economy.
**GCD Program Vision & Management Themes**

**Game Changing Vision:**
- Enable NASA’s exploration missions by rapidly advancing disruptive mid-TRL technologies from concept to demonstration
  - Technology incubator for STMD & the Agency
- Program organized into five themes

- **Future Propulsion & Energy Systems (FPES)**
- **Affordable Destination Systems & Instruments (ADSI)**
- **Lightweight Materials & Advanced Manufacturing (LMAM)**
- **Advanced Entry, Descent, & Landing (AEDL)**
- **Revolutionary Robotics & Autonomous Systems (RRAS)**
Select GCD Activities By Management Theme

Affordable Destination Systems & Instruments

- Spacecraft oxygen recovery
- In situ production of oxygen
- High performance computing
- Optical communications
- High performance thermal control

Future Propulsion & Energy Systems

- Fission-based power production
- High capacity batteries
- Micro-fluidic electrospray propulsion

Lightweight Materials & Advanced Manufacturing

- Composite cryotank
- Nanotechnology
- Additive manufacturing

Revolutionary Robotics & Autonomous Systems

- Crew-assisting robots
- Habitat automation
- Extreme terrain mobility

Advanced Entry, Descent, & Landing

- Thermal Protection System Materials
- Supersonic retro propulsion
- Inflatable/deployable entry systems

GCD Activities Span 8 STMD Thrust Areas
GCD’s Flagship Project: Composite Cryotank Technologies & Demonstration (CCTD)

• The Problem:
  – NASA requires an affordable, lightweight vehicle to enable future exploration

• The Solution:
  – Design, fabricate, & test an affordable, low mass composite cryotank

• The Accomplishments:
  – Designed & fabricated a 5.5m diameter composite cryotank
    • Developed using automated manufacturing techniques & out-of-autoclave materials/cure
  – Demonstrated 30% (~3,300 lb) mass savings & 25% cost reduction (~$7M)¹

• Development Milestones:
  – Tank delivered from Boeing to MSFC on 26 March 2014
  – 45 psi ambient pressure test was performed on 22 May 2014
    • Analytical models updated/correlated
  – Cryogenic pressure test was performed at ~60 psi on 20 July 2014
  – Will perform 80 cryogenic pressure cycles & mechanical loads/pressure test
Space Technology Pipeline

Mature low TRL technologies from CIF, STRG, & SBIR towards mission infusion
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<tr>
<th>Technology</th>
<th>Maturation Path</th>
<th>Infusion</th>
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| Self Supporting Multi Layer Insulation | • Discovered as Phase I SBIR.  
• Continued technology maturation as Phase II SBIR.  
• Using NASA-owned research hardware, GCD matured the technology to TRL 5 as Phase III SBIR. | • Will be infused into TDM’s Green Propellant Infusion Mission (GPIM) project.  
• Performance will be demonstrated as part of TDM’s eCRYO project.  
• Potential for further infusion into SLS. |
| 20 Watt, 20 Kelvin Cryocooler     | • Component technologies matured as Phase I & Phase II SBIRs.  
• Additional risk mitigation effort performed as Phase II-E & Phase III SBIR.  
• If risk mitigation activity is successfully executed, cryocooler will be developed using a Phase III SBIR. | • Performance will be demonstrated as part of TDM’s eCRYO ground demonstration project.  
• Potential for further infusion into SLS. |
| Deep Space Optical Communication | • Deep-space photon-counting camera matured as Phase II SBIR.  
• Spacecraft disturbance isolation assembly being developed as part of Phase II SBIR activity.  
• Deep-space laser transmitter being developed as part of Phase III SBIR effort. | • STMD will mature & provide deep space optical communication flight hardware as Government Furnished Equipment for potential demonstration on SMD’s Discovery 2014 mission. |

Edge-On View of Self Supporting MLI

Cryocooler Recuperative Heat Exchanger

DSOC Optical Transceiver Assembly
## Examples of SBIR Success Stories Continued

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| 3D Print            | • Phase I SBIR was used to complete a feasibility & trade study for a microgravity 3D Printer.  
                     | • Phase III SBIR was used to design, fabricate, & test a 3D Printer for demonstration on ISS. | • Flight hardware will be delivered on SpaceX-4 & demonstrated on ISS. |
| Phase Change Material Heat Exchanger | • Proof-of-concept heat exchanger developed as part of Phase I SBIR.  
                                 | • Proof-of-concept heat exchanger performance subsequently verified at JSC.  
                                 | • Phase III SBIR awarded to develop prototype heat exchanger. | • If successfully demonstrated on ISS, heat exchanger will be infused into Orion’s thermal control system for Lunar missions. |

3D Printer Flight Hardware

Water-Based Phase Change Material Heat Exchanger
STMD Will Develop Two Payloads for Infusion into the Mars 2020 Mission:

1. In Situ Resource Utilization (ISRU) Demonstration
   - Competitively selected technology demonstration to convert Mars’ atmosphere into valuable oxygen (fuel & life support)
   - Benefits both robotic & human exploration:
     - Reduced Earth-launch mass & mission cryogenic storage burden
     - Reduced burden on EDL systems

2. Mars Entry, Descent, and Landing (EDL) Instrument (MEDLI-2)
   - Developing sophisticated instrumentation suite to acquire critical EDL data benefiting future exploration missions
   - Instrument both heat shield AND backshell
   - Benefits Include:
     - Valuable flight data to validate analytical models (Reduced TPS design margins)
     - Data necessary to reconstruct planetary entry
STMD Leverages, and Partners With, the Valuable On-Orbit National Asset:

1. SPHERES SLOSH Experiment
   - KSC, FIT, & MIT partnered to develop demonstration hardware for ISS
   - Hardware delivered to ISS in January 2014
   - Three experimental sessions completed subsequent to hardware delivery
   - Performed microgravity experiments to obtain slosh data for model correlation/validation

2. Phase Change Material (PCM) Heat Exchanger
   - Develop & demonstrate 2 PCM heat exchangers
   - Will retire risks associated with microgravity operation of large-scale PCM heat exchanger for infusion into Orion TCS

3. Station Explorer for X-Ray Timing & Navigation Technology (SEXTANT)
   - Partnering with NICER project (SMD) to demonstrate advanced, autonomous navigation technology using Pulsars as beacons

¹List does NOT include all planned ISS demos
STMD is Developing Critical Technologies to Enable Orion & SLS Exploration:

1. **3D Multifunctional Ablative TPS (3D MAT)**
   - Maturing woven TPS for infusion into Orion
   - Compression pad is required to meet severe structural and thermal loading

2. **Composite Cryotank**
   - Fabricated & currently testing 5.5m diameter composite cryotank

3. **20 Watt, 20 Kelvin Cryocooler**
   - Develop high capacity cryocooler to enable zero boil-off of liquid hydrogen
STMD is Maturing Revolutionary Technologies for Discovery 2014¹:

- Technologies were highlighted during April Technology Workshop
- Technologies included in July’s draft AO
- MOU signed to mature two technologies to TRL 6 by the end of FY 2017

1. Heat Shield for Extreme Entry Environment Technology (HEEET)
   - Low mass (40%), high performance TPS material for planetary entry missions
   - SMD will provide $10M incentive

2. Deep Space Optical Communication
   - Communication technology providing order of magnitude higher data rates for deep space exploration
   - STMD will GFE flight hardware
   - SMD will provide $30M incentive

¹List does not include additional technologies being matured by TDM (ASA, GPIM, & DSAC)
Recent Program Accomplishments

- Delivered two RPM prototype instruments to AES
- Delivered & integrated two EVA components into AES’s PLSS 2.0 testbed
- Delivered nuclear reactor simulator
- Completed fabrication & integration of two Stirling power conversion units
- Selected 4 performers for energy storage
- Completed HEEET Arc Jet testing
- Completed long-term creep test with Vectran (webbing material for inflatable structure) and delivered results to AES/BEAM
- Completed continuation review for 10 on-going National Robotics Initiative grants
- Delivered R2 legs to ISS on SpaceX-3
Summary

- GCD is rapidly maturing critical technologies to enable future exploration missions
- GCD’s investments span all eight STMD thrust areas
- GCD enables the space technology pipeline
- GCD’s technology investments are well-aligned with top agency priorities