Dr. William Ballhaus, Chair
Mr. Gordon Eichhorst, Aperios Partners LLC
Mr. Michael Johns, Southern Research Institute
Dr. Matt Mountain, Space Telescope Science Institute
Mr. David Neyland, Draper Laboratory
Mr. Jim Oschmann, Ball Aerospace & Technologies Corp.
Dr. Mary Ellen Weber, STELLAR Strategies, LLC
• Space Technology Mission Directorate Update
  – Dr. James Reuther, Deputy Associate Administrator for Programs, STMD

• Update on NASA’s Future Workforce: Gender and Diversity
  – Ms. Sherri McGee, Deputy Assistant Administrator, Human Capital Management

• NASA Response to TIE Recommendation Discussion
  – Dr. Ryan Stephan, Program Executive, STMD and Mr. Michael Seablom, Chief Technologist, SMD

• Office of the Chief Technologist Update
  – Mr. Jim Adams, NASA Deputy Chief Technologist

• Office of Chief Engineer Update
  – Ms. Dawn Schaible, NASA Deputy Chief Engineer

• Technology Demonstration Missions Program Update
  – Mr. Timothy Chen, Program Executive, STMD

• Advanced Exploration Systems Program Update
  – Mr. Chris Moore, Deputy Director, Advance Exploration Systems, HEO
Agency Capability Leadership Areas

**TECHNICAL CAPABILITY AREAS - DISCIPLINE LEVEL**

1. Aerosciences
2. Avionics
3. Electrical Power
4. Flight Mechanics
5. GN&C
6. Human Factors
7. Life Support/Active Thermal
8. Loads and Dynamics
9. Materials
10. Mechanical Systems
11. NDE
12. Passive Thermal
13. Propulsion
14. Software
15. Structures
16. Systems Engineering
17. Space Environments
18. Cryogenics
19. Instruments and Sensors
20. Others?

**LEADERSHIP:**

- NASA Technical Fellows:
  - Agency resource for providing expertise, guidance and advice
  - Lead Capability Leadership/Technical Discipline Teams with membership from Centers
  - Currently recognized engineering disciplines (bold items on left) plus others as Agency Senior leadership identifies (italics items on left)

**GOVERNANCE:**

- NASA Technical Fellows resident at Centers and managed by NESC
- OCE administers discipline-level Technical Capability Leaders on behalf of Agency
- Capability Leadership plans will document team membership and relationships to other capability areas and Agency-level groups
- EMB (extended if necessary) ensures integration and coordination across all discipline-level Capability Leadership Areas
- Report annually to APMC and as needed for divest/invest decisions
- Issues can be brought to Deputy AA when lower level resolution cannot be reached
Space Technology Strategic Themes

- **Go There**: Improve the Nation’s capabilities for access and travel through space.

- **Land There**: Develop and demonstrate technologies that enable landing more mass, more accurately, in more locations throughout the solar system.

- **Live There**: Develop and demonstrate technologies to live and work in deep space and on planetary bodies.

- **Observe There**: Develop and demonstrate technologies that transform the ability to observe the universe and answer the profound questions in earth and space sciences.
“Developing the capabilities to land humans on Mars will require considerable resources and technological innovation in many disciplines to accommodate the environments to be encountered in space and during surface operations.”

nasa.gov
Space Technology Pipeline

Early Stage – STRG, NIAC, CIF

Phase I and II SBIR

New Technology Partners - FO, CC, SST

GCD
Phase III SBIR

TDM
STMD Successes To Date

Solar Array Development and Testing

Advanced Thrusters and Electronics Development

Composite Cryo Propellant Tank Testing

Utilizing ISS as a Technology Testbed

Entry, Descent and Landing Technology

Creating New Markets and Spurring Innovation while Engaging the Brightest Minds

EVA Suit and ECLS Technologies

JPL H6 with magnetic shielding

GRC 300M with magnetic shielding
Looking Forward to Future Technology Successes

- Flight Demo for Green Propellant Infusion Mission
- Technology Development for Deep Space Optical Communication
- Completion of Entry, Descent and Landing Technology
- Flight Demo for Deep Space Atomic Clock
- Solar Electric Propulsion Testing
- Future Demos on ISS
Recommendation:

The Council recommends that the STMD AA & SMD AA engage with each other and their communities to determine how policies and procedures could be modified to allow the infusion of new mission-enabling and mission-enhancing technologies developed by Principal Investigators, STMD or others in small to medium class missions.

Major Reasons for the Recommendation:

• In highly competitive program solicitations, such as Discovery and Explorer, there is a disincentive to propose new technology because of the perceived risk.

• As a result, NASA may be missing an opportunity to leverage scientifically beneficial technology through small and medium science missions. In the long-term, this could erode NASA’s scientific and technical capabilities.

• If the Agency wants to encourage and infuse appropriate new technologies in its small and medium class missions, it must develop a policy that provides a pathway to the inclusion of these technologies in the solicitation release.

Consequences of No Action on the Recommendation:

Erosion of NASA’s science and technical capabilities
NASA Evolutionary Xenon Thruster (NEXT)
• 2 thrusters, 2 PPUs are GFE
• Risk of thruster, PPU readiness will not impact proposal evaluation

Deep Space Optical Communications (DSOC)
• DSOC Hardware is GFE
• Risk of DSOC readiness will not impact proposal evaluation
• $30M incentive for use

Heatshield for Extreme Entry Environment Technology (HEEET)
• HEEET team, consulting, tech transfer provided
• Cost of 3D Woven TPS material covered to $10M

Deep Space Atomic Clock (DSAC)
• Risk of DSAC readiness will not impact proposal evaluation
• $5M incentive for use

… and others!

Green Propellant, Lightweight Radio-isotope Heater Units,
Autonomous Landing and Hazard Avoidance Technology

Tech Infusion for Discovery ‘14 is a partnership between SMD and the Game-Changing and Technology Demonstration Programs of STMD
Proposers may also include their own demonstrations without additional penalties for inherent technical risks
STMD & HEOMD Will Develop Instrument Payloads for Infusion into the Mars 2020 Mission:

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

**Mars Entry, Descent, and Landing 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

**Weather Instrument Suite**
- Instrument suite contributed by Spain to measure temperature, wind speed and direction, pressure, relative humidity, and dust size/shape
Technology Portfolio Supports Missions

National Science and Technology Priorities

NASA Mission Requirements Driven

External Technology Priorities & Partnerships

Top Down Driven Strategic Guidance

Technology Portfolio

Aeronautics ARMD
Human Exploration HEOMD
Cross Cutting STMD
Science SMD
Information Technology
What Does Update Mean? Scope Expanded – All NASA

Technology Roadmap Update

Will Consider:
• Updates in Science Decadal surveys
• Human Exploration capability work
• Advancements in technology

Will Include:
• State-of-art
• Capability needs
• Performance goals

Expanded Scope:
✓ Aeronautics technology
✓ Autonomous systems
✓ Avionics
✓ Information technology
✓ Orbital debris
✓ Radiation
✓ Space weather

Strategic Technology Investment Plan Update

Will Consider:
• New priorities
• Current investments
• Unmet needs
• Partnerships & more

Expanded Scope:
✓ Aeronautics technology
✓ Information technology
✓ Other technologies as influenced by other roadmap updates
Roadmap Update Overview

- NTEC* Initiated Radiation Technology Study
- NTEC Decision IT Scope
- NTEC Decision Aero Scope
- NTEC Review Roadmap Process
- NTEC Decision Independent Assessment Scope
- Center Technology Council (CTC) Provide Input to Roadmap Process
- Roadmap Candidates Selected
- Roadmap Team Kick Off

- External Input
  - Other Government Agency (OGA), Academia & Commercial Technical Interchange Meeting
  - OGA TIM SOA Plus - Review
  - OGA Review
  - Independent Review

- Input & Decisions
- Input & Reviews

*NTEC - NASA Technology Executive Council
SOA – State of Art
LDSD’s SFDT-1 shake-out flight was successful; several accomplishments and notable firsts:

- **Largest blunt body aeroshell ever flown supersonically**
- **SIAD-R was a phenomenal success**
  - Largest Inflatable Aerodynamic Decelerator (IAD) ever deployed and tested at supersonic conditions
  - Minimum vehicle disturbances: SIAD inflated to rigid in <1/3 sec using off-the-shelf auto gas generators
  - Extremely rigid geometry: Max measured aeroelastic deflection of <4 mm during operation, <12 mm during parachute deploy at an internal pressure of <3 psi
  - No observed aerothermal damage or degradation
- **Largest ballute (PDD) ever successfully flown at supersonic conditions**
- **First ever supersonic pilot deployment** of the largest supersonic parachute ever deployed
- **Unprecedented quantity and quality of data collected**
  - Several orders of magnitude increase in the amount of data available on supersonic aerodynamic decelerators
  - Most detailed set of data ever collected on any of the three decelerators flown
  - Parachute experts now have new known unknowns about initial inflation of the chute at supersonic speeds
LDSD Built its *Own* Ride

Launch Tower

Composite Core Structure

Star-48B Motor

Spin Motors

Video Recorders

Parachute Cameras

Test Vehicle Electrical Pallet

Parachute

Test Vehicle Electrical Pallet

Video Recorders

Parachute Cameras

Star-48B Motor
2014 Accomplishments & Status

• **Supersonic Flight Dynamics Test (SFDT) #1 in 6/28/2014**
  – Met all success criteria for this first shakeout flight
  – Met all four bonus goals for the first flight
  – Parachute failed structurally
    • But it was not part of success criteria

• **Parachute Development Test (PDV) -1b – 10/9/2014**
  – Deliberately tested it to failure to understand design margin and workmanship issues
    • Post test analysis showed workmanship issue

• **Issued contracts to 2 parachute suppliers for FY15**
  – Changed from Disksail to Ringsail design
  – Pursuing parallel path with both vendors
  – Planned PDV test in Spring 2015

• **STMD is pursuing different SFDT flight options in FY15 & 16**
  – Potentially 1 flight in FY15 and 1 flight in FY16 pending the parachute development verification (PDV) test result in Spring 2015.
• ROSA Solar Array Brought to TRL 5
  – The final review for the DSS Mega-ROSA contract was held on June 25. Additional tasks were subsequently added. The review included:
    • Vacuum deployment demonstration results at ambient, -65°C, and +65°C temperatures
    • Test results for deployed and stowed dynamics, and deployed strength and stiffness
    • Developed better predictive tools to match test data
    • Electrical power and performance analysis (W/kg and W/m3)
    • Extensibility concept to >250 kW system power
  – Great advances compared to the current design state of arts
    • 20X greater deployed strength,
    • 4X greater specific volume,
    • 3X higher operating voltage,
    • 1.7X greater specific mass,
    • 1.5X more power per wing

• Next steps: issued Request for Information (RFI) for Advanced Solar Array for Flight Demonstrations December 2014
Mega Flex Solar Array Brought to TRL 5

- The final review for the ATK Mega Flex development contract was held on April 29. Additional tasks were subsequently added. The review included:
  - Vacuum deployment demonstration results at ambient, -65°C, and +65°C temperatures
  - Test results for deployed and stowed dynamics, and deployed strength and stiffness
  - Developed better predictive tools to match test data
  - Electrical power and performance analysis (W/kg and W/m3)
  - Extensibility to >250 kW system power

Next steps: issued Request for Information (RFI) for Advanced Solar Array for Flight Demonstrations December 2014
12.5 kw EP Thruster Testing
- Achieved ~60% efficiency at Isp >3,000 sec at 12.5kw and 800V.

Procurement Authorization
- Released Solar Array RFI 12/23/14
- Expected RFP release in Spring 2015

STATUS
- Extended Solar Array System contracts with DSS and ATK for additional analysis, expected to be completed by December 2014
- Performing detailed performance and thermal characterization testing on electric thruster in vacuum test facility (operation up to 12.5kW performed)
- Completing second electric thruster assembly for vacuum testing at JPL
- Finishing 120 V_{in}/800 V_{out} Power Processing Unit testing
- Monitoring Solar Array study contracts
  - Boeing, ExoTerra, SSL, LM
  - Results will inform procurement strategy
- NASA assessing ability to launch, install and operate a 25 kW class wing
EFT-1 FLIGHT EXPERIMENTS

Radiation Environment Monitors measured radiation inside Orion when it passes through Van Allen belts.

Advanced Caution & Warning System operated in shadow mode during flight to detect faults in Orion power system.
• A mockup of the Bigelow Expandable Activity Module (BEAM) was delivered to JSC for integrated sensor testing and crew training.
• Completed critical design reviews on the primary integrated structure and flight support equipment.
• Completed all structural tests including pressurization, rapid depressurization, random vibration, and modal survey.
• Passive Common Berthing Mechanism will be integrated with BEAM in December.
• Project is on schedule to launch BEAM in September 2015 on SpaceX-8 mission.
Committee believes it is important for NASA and the Nation to develop a new domestic alternative to the current suite of foreign hydrocarbon rocket main engines.

Committee also believes NASA plays a key role in this activity especially in the development and understanding of advanced materials and metallurgy technologies for a future domestic hydrocarbon rocket main engine.
BACK-UP
STMD Successes to Date: Slide 8

- **Advanced Solar Arrays**: STMD competitively selected two advanced solar arrays (DSS ROSA and ATK Megaflex) and designed, fabricated and tested EDU hardware for these arrays. The arrays have \(\frac{1}{2}\) the mass, \(\frac{1}{3}\) the packaging volume and a \(\frac{1}{3}\) reduction in manufacturing costs relative to state of the art arrays used for commercial satellites.

- **Composite Cryogenic Propellant Tanks**: Demonstrated the first successful large scale (5.5-meter diameter) composite cryogenic propellant tank. The completed pressurized load tests with liquid hydrogen simulated launch vehicle flight conditions and proved that by using out-of-autoclave technologies, it is possible to create very large composite tanks that can reduce the mass by 30 percent and fabrication costs by 25 percent relative to conventional metallic cryogenic launch vehicle tanks.

- **EVA suit and ECLS technologies**: Completed development and fabrication of component technologies for next generation space suits, Personal Life Support System (PLSS), including a variable oxygen regulator and a rapid cycle amine integrated CO\(_2\) and control system. Also completed development of an Alternate Water Recovery system for habitat ECLS systems.

- **Entry, Descent and Landing Technologies**: Completed a series of sounding rocket tests of a hypersonic inflatable aerodynamic decelerator (HIAD) proving that the concept for larger entry masses at Mars is viable. Completed the development and testing of a supersonic inflatable aerodynamic decelerator (SIAD) and a new supersonic parachute leading to the first successful, rocket-powered, high-altitude, supersonic test vehicle demonstration.

- **Using ISS as a Technology Testbed**: Completed the Smart SPHERES navigation demonstration, illustrating fully automated navigation capability onboard the ISS using consumer smart phone technology. Completed a series of tele-robotics demonstration tests showing the practical realistic remote operation of robots (on Earth) controlled from ISS. Delivered and demonstrated the complete Robonaut 2 including legs designed to give the robot mobility in zero gravity. Demonstrated a zero-g fluids experiment on ISS (SLOSH) using SPHERES to learn more about propellant behavior. In partnership with HEO, demonstrated the first in-space 3D printing capability on ISS to allow astronauts to fabricate their own parts and tools.

- **Space Technology Research Grants**: Created and implemented a new NASA university grants and fellowships program to leverage the innovative capabilities from U.S. universities to provide solutions to address difficult challenges facing the aerospace sector.

- Restarted the NIAC program, started the Small Spacecraft Technology program, and restructured the commercial reusable sub-orbital flight demonstration program, Flight Opportunities. Continued and more tightly integrated the SBIR/STRR program and the Centennial Challenges program.
Looking Forward to Future Technology Successes: Slide 9

- **Green Propellant Infusion Mission:** Will complete a flight demonstration of AF-M315E propellant and integrated propulsion system, clearing the way to replace hydrazine as the go-to storable mono-propellant with a safer, non-toxic, and high performance alternative.

- **Deep Space Atomic Clock:** Will complete a flight demonstration of a Deep Space Atomic Clock that is two orders of magnitude better in time-keeping relative to the best current space clocks.

- **Entry, Descent and Landing Technologies:** We will complete the last two LDSD flights to certify the SIAD-R and a new more capable supersonic parachute. We will complete the development of 3D-woven TPS as applicable to future Venus and outer planetary entry systems—replacing carbon phenolic for these applications which is no longer available and shows poor performance.

- **Optical Communications:** Will complete initial development of deep space optical communications technologies. The technology will fly as a demonstration on either a Discover mission or the next Mars orbiter.

- **Solar Electric Propulsion:** Will complete flight hardware fabrication of an advanced solar array for either an ISS demonstration and/or a SEP demo. Will also complete fabrication and testing of a high powered (~12.5 kW) magnetically shielded Hall thruster for an SEP demo.

- **ECLS technologies:** Will complete Phase I development of a closed loop Oxygen Recovery system for habitats. Will complete initial development and testing of a soft hatch for an inflatable airlock. Will complete initial development of new power storage devices raising the specific energy from 2 to 3, versus the best lithium ion batteries in use today.

- **Using ISS as a technology testbed:** Will demonstrate the SEXTANT instrument that will use known regular pulsars like a intergalactic GPS system to improve interplanetary navigation. Will demonstrate two (wax based and water based) phase change material heat exchangers needed for Orion to perform lunar orbit missions.

- **High Performance Space Flight Computing:** Will complete initial development of a replacement of the RAD 750, with a goal of 100x performance improvement at the same radiation tolerance levels and same power consumption 5-7W.

- **AFTA/WFIRST coronagraph:** Will complete prototype development of a coronagraph for the AFTA/WFIRST mission demonstrating that coronagraph technology can be used on large space based observatories to determine the atmospheric composition of eco-planets.

- **Small nuclear fission / Stirling cycle:** Will complete initial development of a small fission (1 to 10 kW) coupled with a solid state heat pipe and a Stirling cycle to production abundant reliable power for future outer planetary science missions as well as human surface missions to Mars.

- **Small Spacecraft:** Will complete and fly approximately 20 cubesats demonstrating various technologies that either enable cubesats to perform more demanding missions or will serve as an affordable testbed to demonstrate the technology for a wide range of missions.