Meidinger, Jolene A. (HQ-LP020)

From: Meidinger, Jolene A. (HQ-LP020)
Sent: Tuesday, January 10, 2017 1:20 PM
To: 'Jeff Waksman'; christopher.m.shank@ptt.gov; Rodney Liesveld
Subject: FW: Road Closures and Vehicle Restricted Areas for the Inauguration

Just FYI. Best regards/Jolene

From: HQ-NASA-INC
Sent: Tuesday, January 10, 2017 1:08 PM
Subject: Road Closures and Vehicle Restricted Areas for the Inauguration

MESSAGE TO ALL NASA HEADQUARTERS EMPLOYEES

Point of Contact: Nichole Pinkney, Office of Headquarters Operations, 202-358-3768
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Road Closures and Vehicle Restricted Areas for the Inauguration

The 2017 Inauguration street closures have been posted at: http://inauguration.dc.gov/page/2017-inauguration-street-closures. NASA Headquarters falls within the Green Zone, in which vehicle traffic will be restricted to residents and businesses located within the restricted area. National Guard personnel will be present to assist with verifying traffic entering the Green Zone. **Parking restrictions (posted as Emergency No Parking with ticketing and towing enforcement) within the Green Zone will begin at 7 a.m. Thursday, Jan. 19, and end at 1 a.m. Saturday, Jan. 21.**

For NASA civil service employees: Supervisors are encouraged to take full advantage of telework and other schedule flexibilities to the maximum extent possible (subject to work requirements) on **Tuesday, Jan. 17, Wednesday, Jan. 18 and Thursday, Jan. 19**, the days between the federal holiday Birthday of Martin Luther King, Jr. on Monday, Jan. 16 and the federal holiday for federal employees on Inauguration Day, Friday, Jan. 20.

Please note: Inauguration Day falls on Friday, Jan. 20, 2017, and is a legal public holiday **only** for federal employees who work in the "Inauguration Day area" (defined in law as the District of Columbia, Montgomery and Prince George's Counties in Maryland, Arlington and Fairfax Counties in Virginia, and the cities of Alexandria and Falls Church in Virginia). (See 5 U.S.C. 6103(c).) The City of Fairfax is considered to be part of Fairfax County for this purpose.

Contractors should work with their senior management and their NASA Contracting Officer to determine how this guidance applies to their specific contract.

Additional information about the Inauguration holiday impacts to Headquarters as well as OPM guidance on holiday leave and pay can be found at: http://fasd.hq.nasa.gov and https://www.chcoc.gov/content/federal-holidays-and-human-resources-flexibilities-employees-located-washington-dc-area.

Jay M. Henn
Executive Director
Office of Headquarters Operations

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National Aeronautics and Space Administration

Transition Requested Information from HEO/AES

January 6, 2017

AES Updates

1. Plans to do Science on Orion

2. Status of Resource Prospector

3. Potential synergy with Exploration for a possible South Pole Aitken Basin sample return mission

AES Updates - Topic 1

1. Plans to do Science on Orion

Science Enabled by Orion EM Missions

- **Exploration missions in cislunar space provide valuable scientific opportunities in the lunar environment in addition to demonstrating Orion systems and human microgravity research**

- **Human exploration systems permit the selection and employment of scientific instruments on a scale different from what scientists/engineers typically consider:**
  - More mass/power/volume available for instruments greatly expanding suite of possible instruments and types of instruments
  - Deployment of cubesats beyond LEO; to cislunar space and beyond
  - Optical communication could relieve communication pressure for other orbital and surface assets

- **Science opportunities enabled by human missions to cislunar space have been studied by NASA and international space agencies**
  - A large number of studies on this topic have been completed in the past several decades by NASA.
  - NASA-led updates to international studies have been recently initiated to identify science that could be achieved in the cislunar environment
  - Leverages Science White Paper being produced by International Space Exploration Coordination Group (ISECG)

ISECG Science White Paper (late spring 2017 release)

- **Background: ISECG is a non-political forum of 15 space agencies seeking to collaborate on human and robotic space exploration**

- **ISECG agencies acknowledge science communities as major stakeholders and the pursuit of scientific knowledge gain as important benefit of exploration activities**

- **Science White Paper (SWP) developed by ISECG science community**
  - *"Describe the international view of the science enabled by human exploration after ISS, as outlined in the GER"*
  - *Encompassed short and long term stays in cislunar environment (Orion and DSH)*
  - Engaged the scientific communities in identifying these opportunities
  - Additional community interaction and feedback provided by presenting initial science ideas at multiple major meetings

- **Ensure that SWP incorporated interdisciplinary scientific topics:**
  - Encompassed all relevant science communities and disciplines: planetary science, space science, life sciences, astrobiology, astronomy, physical sciences, etc.

Science Enabled by Orion in the Lunar Vicinity

- **Lunar surface science using telerobotics**
  - Facilitate access to challenging regions by low-latency telerobotics
    - e.g. looking for volatiles in permanently shadowed crater floors
  - Test/improve telerobotic efficiency
    - Control Robotic Elements on the surface of the moon
    - Permits farside exploration without a communication relay
  - Set up surface science instruments
    - e.g. set up large scale surface antennae, geophysical network
  - Potentially support a sample return mission – surface samples sent to lunar orbit while Orion collects and returns samples to Earth

- **Lunar science from instruments on Orion or deployed from Orion/SLS**
  - Apollo J CSMs had SIM bay for flying remote sensing instruments – these included:
    - Gamma ray, X-ray and UV spectrometers
    - Particle & fields subsatellite
    - Lunar sounder
  - Orion program evaluating a similar capability

- **Orion provides for a 1-2 week stay in cislunar space**
  - Longer durations greatly expand possible science
  - Longer durations possible through the use of a cislunar deep space habitat

Science Enabled with Deep Space Hab

- **Lunar surface science using telerobotics**
  - Provides same telerobotic advantages of Orion missions over much longer periods and more complex surface operations
- **Human-assisted lunar sample return – same as Orion missions with:**
  - Increased return through more and improved selection of lunar samples
  - Only need to get samples to the deep space habitat for capture and retention, not all the way to Earth. Returned with the crew in Orion
- **Staging post for human/robotic missions**
  - Could provide global lunar access with a reusable lander
  - Can act as a fuel/maintenance depot or lunar communications relay point for farside satellites
- **Understand combined effects of radiation/fractional-gravity on humans**
- **Additional science opportunities**
  - Astronomical Observations, Fundamental Physics, Collecting Interplanetary Material, Heliophysics, Monitoring Earth's Climate
- **NASA is currently working with industry to develop innovative Cislunar Habitation Concepts that leverage existing commercialization plans for LEO**
  - Working with 6 contractor teams to refine habitation concepts, develop ground prototypes and develop interfaces and human rating certification plans over the next two years
  - Working with 3 contractors to develop Environmental Control and Life Support Systems for deep space
  - Positions NASA to be able to develop Deep Space Habitat spacecraft for flight in the early 2020s
- The lunar vicinity may not be the "ideal" location for all types of science instruments, yet the presence of humans and their associated infrastructure provides opportunities that can yield Decadal relevant science

AES Updates – Topic 2

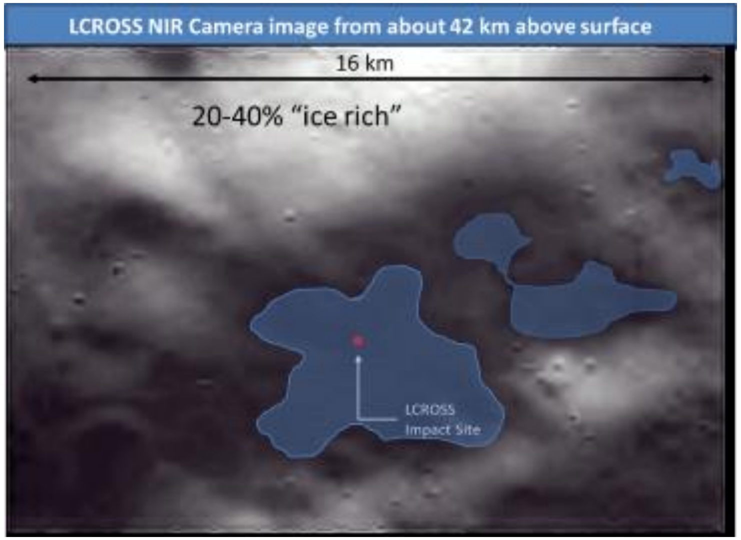
2. Status of Resource Prospector

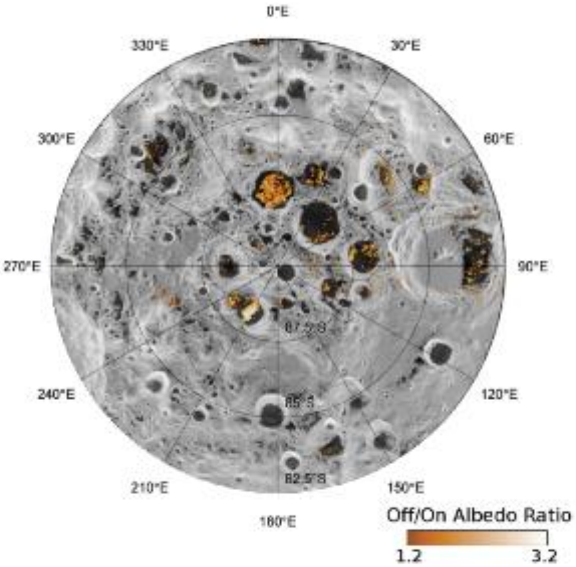
Resource Prospector - Background

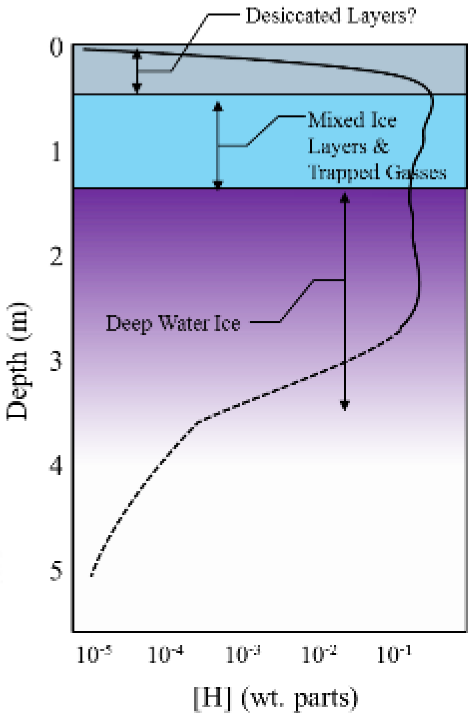
Moon: We know that water and other H-bearing compounds are there…

- Data from multiple missions suggest patchy and/or buried distributions of hydrogen
- 'Impact gardening' will create heterogeneity at lengths scale of ~10-100m
- Several data sets suggest time-dependent surface component
- Near sub-surface temperatures are cold enough to retain water, even in locations that are illuminated

Water and other hydrogen bearing compounds are key resources for human exploration





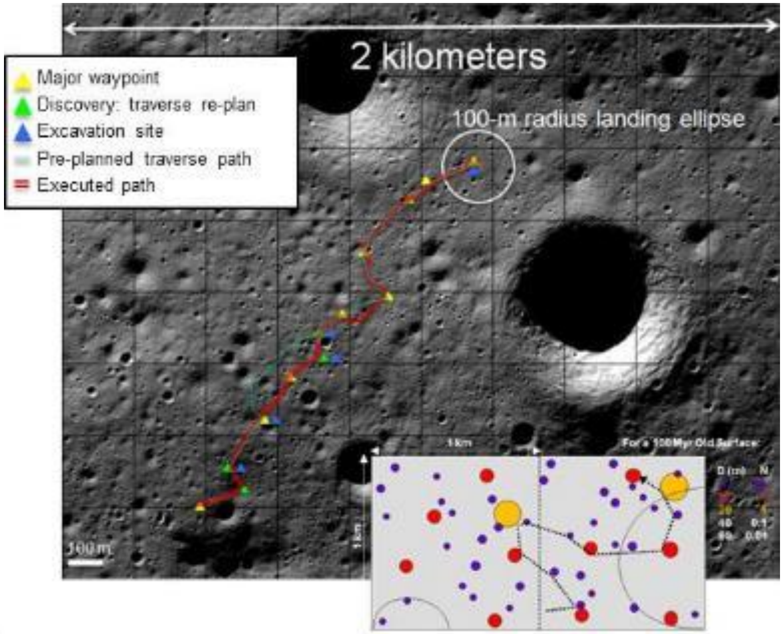


…but are they adequate and accessible for human use?

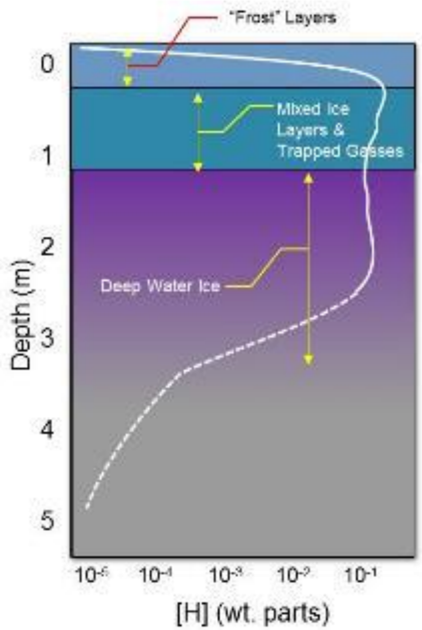
Determining ‘Operationally Useful’ Deposits

Need to assess the extent of the resource ‘ore body’

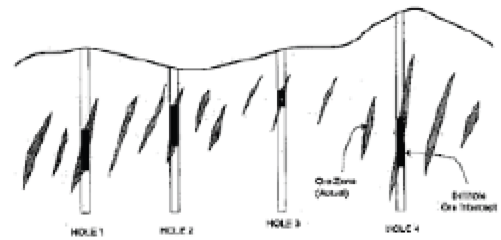
Need to Evaluate Local Region (1 to 3 km)



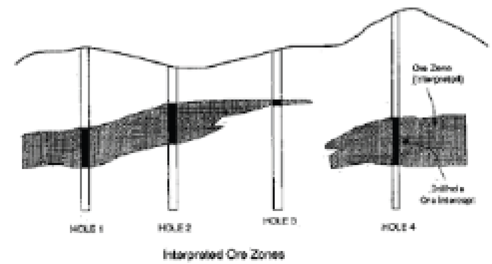
Need to Determine Vertical Profile



Need to Determine Distribution



OR



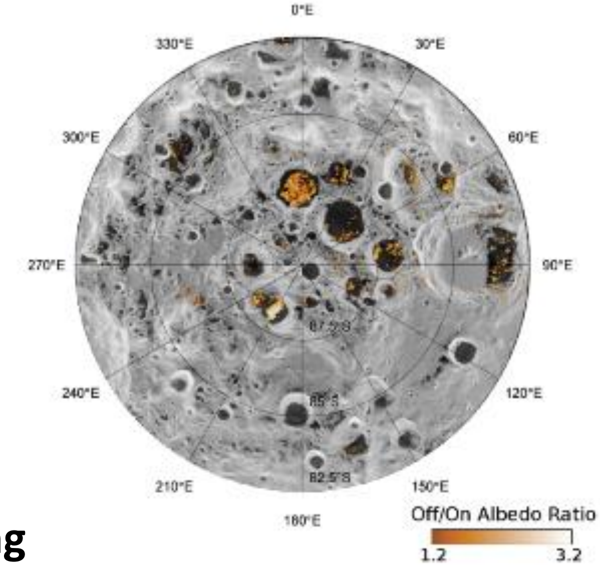
An ‘Operationally Useful’ Resource Depends on What is needed, How much is needed, and How often it is needed

Potential Lunar Resource Needs*

- 1,000 kg oxygen (O_2) per year for life support backup (crew of 4)
- 3,000 kg of O_2 per lunar ascent module launch from surface to L_1/L_2
- 16,000 kg of O_2 per reusable lunar lander ascent/descent vehicle to L_1/L_2 (fuel from Earth)
- 30,000 kg of O_2/Hydrogen (H_2) per reusable lunar lander to L_1/L_2 (no Earth fuel needed)

*Note: ISRU production numbers are only 1st order estimates for 4000 kg payload to/from lunar surface

Searching for Lunar Resources



Mission Goals and Relevance

- Determine location, depth and extent of 'Operationally Useful' deposits
  - Observations from lunar orbit limited in scope
  - Surface instruments necessary to determine types of hydrogen compounds, expanse and depth of deposits, and sub-surface composition

From *LEAG Robotic Campaign Analysis (2011):*

Phase I: Lunar Resource Prospecting

- Defining the composition, form, and extent of the resource;
- Characterizing the environment in which the resources are found;
- Defining the accessibility/extractability of the resources;
- Quantifying the geotechnical properties of the lunar regolith in the areas where resources are found;
- Being able to traverse several kilometers and sample and determine lateral and vertical distribution on meter scales;
- Identifying resource-rich sites for targeting future missions

Resource Prospector is aligned with the community vision for the next lunar resource mission – RP continues to work with LEAG

RP Mobile Instrument System

Find & excavate lunar volatiles…

- Surface mobility: Rover system (add KG and approx size)
- Surface mapping: Neutron Spectrometer & Near-IR Spectrometer to look for hydrogen-rich materials
- Regolith drilling: Drill Subsystem to bring material from up to 1 [m] depth to examine with Near-IR Spec

Collect and process the volatiles…

- Capture regolith: Use the Drill Subsystem to capture samples from up to 1 [m] depth
  - Heat samples (150-450 degC) in the OVEN Subsystem
  - Identify type and quantity of volatiles in the LAVA Subsystem, (H2, He, CO, CO2, CH4, H2O, N2, NH3, H2S, SO2)
- Image and quantify the water created using the LAVA Subsystem

Launch Options

- SLS Co-Manifested Payload Analysis:
  - Discussions ongoing but no issues to date
  - Held RP/SLS-SPIE TIM#1 on 8/30/2016.
- Commercial Launch Options:
  - Original concept was for RP to launch on an early Falcon 9 Heavy. RP Flight System will fit within Falcon 9 mass constraints.

RP Technical Status

2015-16 Accomplishments:

- Completed integrated test of an engineering test unit rover in 2015 with the RESOLVE payload. This distributed operations test involved NASA-ARC, NASA-KSC and NASA-JSC, driving remotely as will be done on the actual mission (RP15 activity).
- Completed rover traction testing at 1/6-g (lunar gravity) in the Active Response Gravity Offload System (ARGOS) at JSC.
- Conducted thermal vacuum and vibration tests of rover and payload subsystems.
- Completed a 3-month Analysis of Alternatives for the rover to reduce its complexity, risk, and cost, followed by a Tiger Team Review.
- Completed night-driving simulation to test navigation approaches in poor lighting with long shadows.
- Completed feasibility study of co-manifesting the lander on SLS EM-2.
- Completed detailed digital elevation models of potential landing zones.

RP FY17 Milestones:

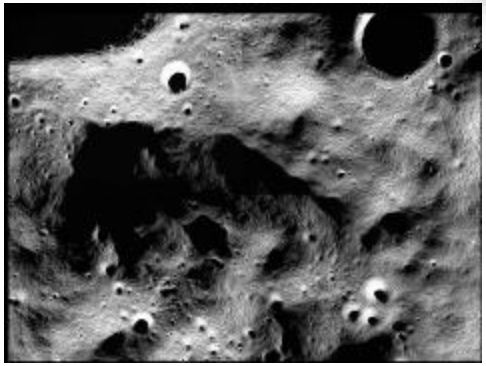
- **Jan 2017: Complete baselined rover flight design concept, following AoA2 (Analysis of Alternatives #2)**
- **April 2017: Build and commence testing an updated RP ETU drill, to raise the TRL from 4 to 5**
- **Sep 2017: Convene RP SRR/MDR, *pending Taiwan flight partnership***

RP rover in JSC rock yard

1/6g testing of rover in ARGOS facility

Thermal vacuum testing of RP subsystems

Night driving test in the Mojave desert.

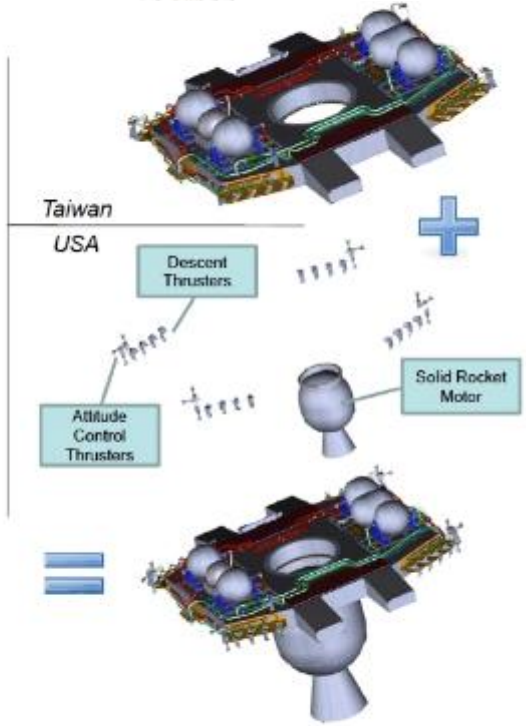


Hi-res DEM of Hermite-A

Taiwan Partnership- Overview

- NASA and Taiwan signed a study agreement on January 15, 2016 to develop design concepts for the RP lander.
- **Taiwan completed the preliminary implementation plan; a 1-year extension to the current study agreement is underway to write the flight agreement.**
- State Department export control regulations require that NASA provide all lander thrusters, but the rest of the propulsion system can be provided by Taiwan. NASA will perform the final propulsion system integration in the US.
- Taiwan will also provide all other lander hardware, including structure, avionics, power, and communications systems.
- The RP team has had **five** face-to-face meetings (with a sixth scheduled for Feb 2017) with Taiwan to discuss the implementation plan, work breakdown structure, and the follow-on agreement for development of the flight system.

Pallet lander



LUNAR**CATALYST**

Lunar CArgo Transportation And Landing bY Soft Touchdown

- **Private investment in space transportation systems is increasing**
- **Commercial lunar cargo transportation is a potential new area of opportunity that could provide services to both public and private customers and enable science and exploration missions**
- **Per National Space Transportation Policy, NASA is "committed to encouraging and facilitating a viable, healthy, and competitive U.S. commercial Space Transportation Industry."**
- **NASA has accumulated decades of technical experience relevant to lunar cargo transportation**

Moon Express

Astrobotic Technologies

Masten Space Systems

AES Updates - Topic 3

3. Potential synergy with Exploration for a possible South Pole Aitken Basin sample return mission

South Pole Aitken Sample Return

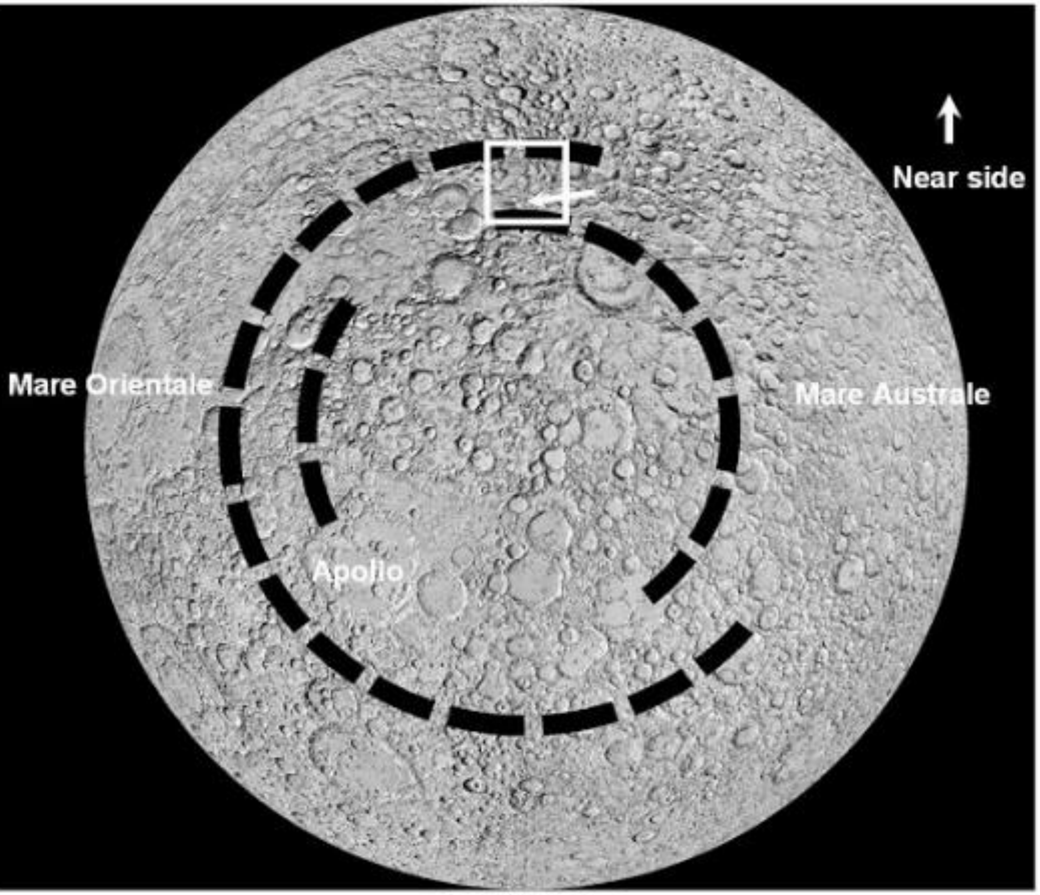
- **Returning a sample from the Moon's South Pole-Aitken (SPA) impact basin is a high scientific priority in the last Decadal Survey (SMD New Frontiers program candidate).**
  - Focus is on solar system history/planetary body formation, not presence of volatiles
  - SPA is oldest basin on the Moon and dating it (which requires a sample) provides new information on the early impact rate of the Earth-Moon system
  - Largest basin on the Moon may have exposed upper mantle for examination and sampling

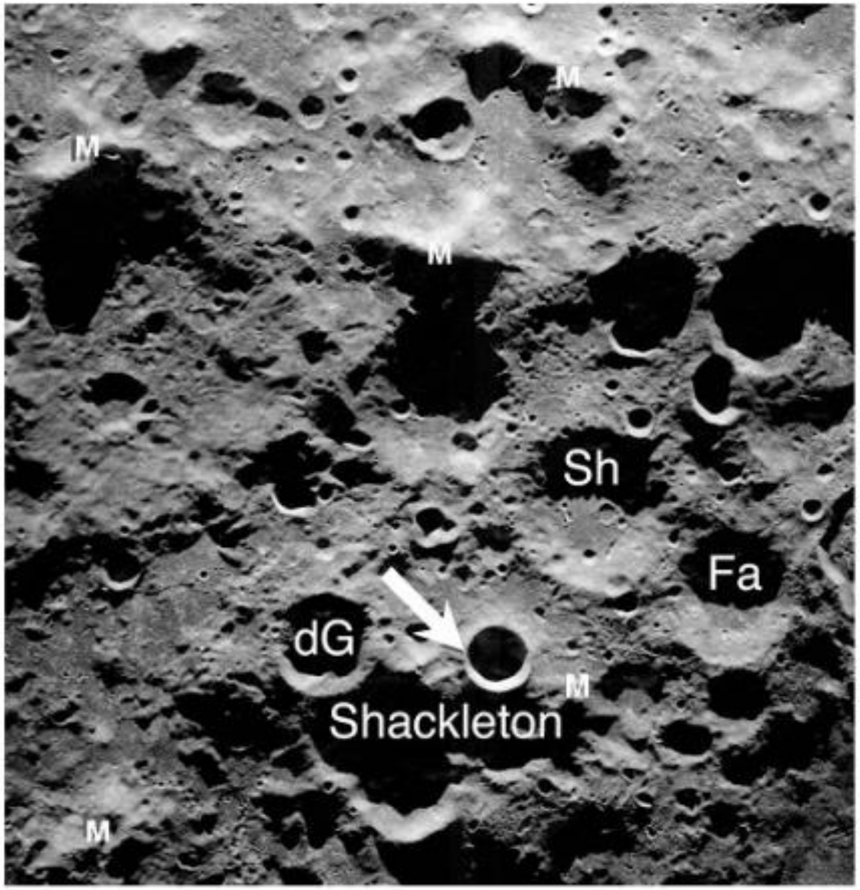
- **Typical proposals have focused on returning a sample from the floor of the basin on the central far side (~55° S, 180°), distant from the pole.**
  - However, basin is so large that portions of it extend over the near side, close to the south pole
  - Geological studies indicate that Shackleton crater (near S pole) formed on an SPA basin massif; these features yielded samples of basin impact melt during the Apollo missions
  - Desired SPA basin melt sample can be obtained from ejecta blanket of Shackleton crater

- **SPA basin sample return from the South Pole could also acquire strategic data on the location and form of polar volatiles, a critical long-term resource**

- **Polar sample return mission also provides useful operational experience for future human missions, including navigation, precision landing and hazard avoidance, and surface operations under highly oblique illumination polar lighting.**

South Pole Aitken Sample Return



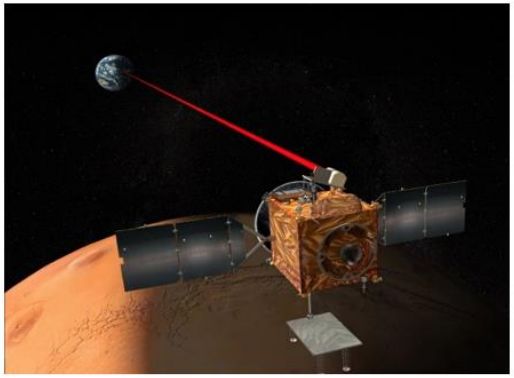


Space Communications and Navigation (SCaN) Agency Review Team for POTUS 45 Transition

National Aeronautics and Space Administration

Badri Younes, Deputy Associate Administrator
January 5, 2017

SCaN is a HQ Program Office



- Operate, manage, and develop all NASA space communications capabilities and enabling technologies.
- Expand SCaN capabilities to enable and enhance robotic and human exploration.
- Manage spectrum and represent NASA on national and international spectrum management.
- Lead space communication Standards and advocate Positioning, Navigation, and Timing policy.
- Represent and negotiate on behalf of NASA on all matters related to space telecommunications in coordination with the appropriate offices and flight mission directorates.

SCaN Networks

Deep Space Network

- Three global ground stations providing services to missions for deep space exploration
- Focused on detecting and differentiating faint signals from stellar noise
- Provided over **89,967** hours of service in FY 2016
- *Missions include: New Horizons, Juno, Kepler, Cassini, Mars Rovers and Orbiters, Mars Science Laboratory, Voyager 1/2, Spitzer Space Telescope*

Near Earth Network

- Set of world-wide NASA and commercial ground stations
- Provides services to near earth missions from Low Earth Orbit (LEO) to Lagrange points
- Optimized for cost-effective, high data rate services
- Provided over **45,713** hours of service in FY 2016
- *Missions include: Aqua, Aura, Lunar Reconnaissance Orbiter, Landsat, Radiation Belt Storm Probes*

Space Network

- Fleet of TDRS and their ground stations providing services to suborbital and LEO missions including launch vehicles
- Optimized for continuous, high data rate comm.
- Critical for human spaceflight safety, critical event coverage
- Provided over **190,305** hours of service in FY 2016
- *Missions include: International Space Station, ISS Resupply, Hubble Space Telescope, Terra, Fermi Gamma-Ray Space Telescope*

Network Assets

Spanning the Globe – Covering the Solar System

Deep Space Network | Near Earth Network | Space Network

User Mission Set

Planetary Science
Astrophysics
Heliophysics
(F) = Future Mission

HEO, LEO, Lunar, L1, L2

- CHANDRA
- Fermi GST
- HST
- JWST (F)
- NEOWISE
- NuSTAR
- RHESSI
- TESS (F)
- GEOTAIL
- WIND
- SOHO
- ACE
- IBEX
- ICON (F)
- IRIS
- THEMIS A, D, E
- Van Allen Probes A&B
- SDO
- CLUSTER II-1,2,3,4
- MMS-1,2,3,4
- ARTEMIS B & C
- DSCOVR
- LRO
- RPM (F)
- TDRS
- ELVs

Space Technology

- CryoCube-1 (F)
- PONSFD (F)

Human Space Flight

- EFT-1
- Exploration Mission – 1 (F)
- Exploration Mission-2 (F)
- SOYUZ
- AA2 (F)
- ISS
- Commercial Crew
- Commercial Cargo

Deep Space

- ARRM
- BepiColombo
- Cassini
- Dawn
- ExoMars 2016 (F)
- ExoMars 2018 (F)
- Hayabusa-2
- InSight(F)
- INSPIRE (F)
- ISIS (F)
- Juno
- Mars Express
- Mars Odyssey 01
- MER Opportunity
- Mars Orbiter Mission
- Mars Recon Orbiter
- Mars Rover 2020 (F)
- MAVEN
- MSL CURIOSITY
- OSIRIS-REx (F)
- ROSETTA
- MESSENGER
- NEW HORIZONS
- PLANET-C
- VENUS EXPRESS
- Spitzer Space Telescope
- Kepler
- LISA Pathfinder (ST-7)
- VOYAGERS 1 & 2
- STEREO A & B
- Solar Orbiter Collaboration (F)
- Solar Probe Plus (F)

DSN Science:

- EGS
- GAVRT
- GBRA
- GSSR
- HCRA
- SGP

Ground Observations:

- ATOT
- REF FRAME CAL

Earth Science

- GRACE-1&2
- GRACE FO
- Landsat-7, 8, 9
- MetOp-A, B, C
- OCO-2, 3
- Polar Free Flyer-1
- QuikSCAT
- SAC-D/Aquarius
- SciSat-1
- ACRIMSAT
- AIM
- Aqua
- Aura
- C/NOFS (CINDI)
- COSMIC 3A, 3B, 3D, 3E, 3F
- CYGNSS
- EO-1
- GOES
- GPM Core
- SMAP
- Suomi NPP
- Terra
- TIMED
- TRMM

Guiding Principles for Sustainable Space Communications and Navigation Capabilities

- **GLOBAL STRATEGY**:
  - Lead development of space communications and navigation technology and capabilities where NASA has unique requirements and expertise,
  - Leverage investments made by the commercial sector and other government agencies,
  - Collaborate on interoperable and compatible architecture, technologies, spectrum and standards through interagency, international, and commercial partnerships
- **SCIENTIFIC EXPLORATION**: Develop leading edge space communication capabilities and services to further scientific exploration while reducing the burden on all science missions.
- **HUMAN EXPLORATION**: Enhance capabilities to enable the evolving Human Spaceflight Program.
- **TECHNOLOGY PULL AND PUSH**: Develop, demonstrate, and infuse flexible and robust space communications and navigation technologies.
- **GRADUAL BUILD UP OF CAPABILITY**: Define a scalable architecture in coordination with customers and stakeholders (development of requirements; collaboration on payloads, where possible).
- **ECONOMIC OPPORTUNITY**: Develop communications capabilities and transformational technologies that can be leveraged to meet NASA's need; while advancing U.S. commercial interests.
- **ARCHITECTURE OPENNESS AND RESILENCE**: Develop an open and resilient space communication architecture and capabilities for Earth and beyond as NASA mission requirements are evolving.
- **FISCAL REALISM**: Manage network and technology resources within the bounds of budgeting realities to fully develop new capabilities while meeting all current commitments at required proficiency level or higher.

Next Generation: Paradigm Shift

- Transformational technology (Optical, Cognitive and Robust Networking)
- Adaptive multiple access
- Robust and secure access on demand
- Networked services
- Flexible and robust connectivity between space missions and their ground operation centers
- Integrated Services and harmonized architecture
  - Maximized commonality between near Earth and deep space capabilities

Enabling new mission concepts and increasing networks effectiveness

Top Strategic Goals and Priorities (next 4 years)

- Meet mission requirements
- Maintain, sustain, and improve the networks
  - Launch Tracking and Data Relay Satellite (TDRS) – M August 2017
  - Complete Space Network Ground Segment Sustainment (SGSS) FY19
  - Continue Deep Space Network (DSN) Aperture Enhancement Project (DAEP) Implementation
- Demonstrate Optical communication on space platforms (ISS, other free-flyers)
  - Begin infusion of direct-to-earth optical technology into operations
- Complete studies to define the architecture and begin implementation of the next generation data relaying capabilities
- Continue to build new and strengthen existing partnerships
  - Continue technology development and partnerships to evolve critical future capabilities (e.g. optical communications etc.)
- Develop creative solutions for the next generation architecture and future capabilities.

Next Generation Architecture and Acquisition Options

- SCaN is studying options for implementing the Next Gen Architecture
  - Future options include retaining government ownership, fully commercial services, Space Act Agreements, public-private partnerships or combination of these options. Commercial options would require a transition phase.
    - SCaN released an Announcement for Commercial Partnership (2015) as part of Laser Comm Relay Demo mission launching in 2019
    - SCaN released an RFP for industry studies (2016): Industry recommendations included commercial alternatives that are being evaluated
    - SCaN is studying alternatives including working with the HEOMD Commercial Space Division to assess an approach similar to the Commercial Cargo & Crew Programs
- Commercial SATCOM industry generates global revenue >$127 B/yr. but does not provide space-to-space services equivalent to TDRSS
  - NASA evaluating potential to create a new commercial sub-market to meet Government needs
  - Industry members have expressed willingness to move towards open architecture in order to create a new sub-market

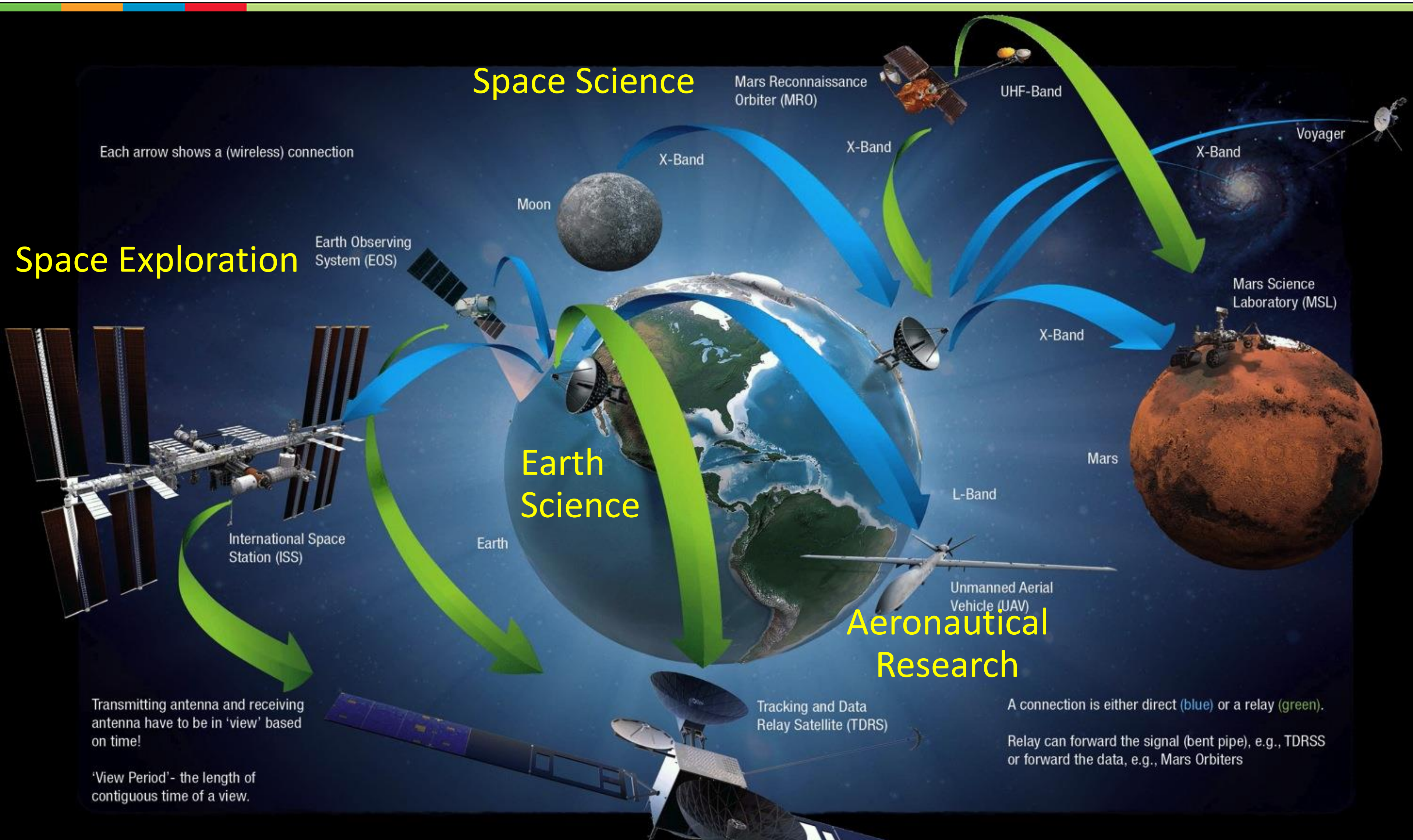
Optical and Cognitive Priorities for next 4 years

Data Standards Project
(Enabling National & International Interoperability)

- NASA Data Standard Project develops space communication standards to enable international interoperability of space systems and to lower operating costs and risks, and to provide innovative capabilities for current and future NASA missions.
  - Space communications data standards enable the world space agencies to provide cross support to each other and hence minimize the need to build additional capabilities.
- NASA leads a global organization of 26 spacefaring nations, known as the Consultative Committee for Space Data Systems (CCSDS), to develop these standards on a consensus basis through collaboration leveraging space communication expertise from across the world.

Working with US industry to incorporate space data standards into products and to ensure US leadership in space

Why Is Spectrum Important to NASA?



Virtually every NASA mission requires radio spectrum

Agency Spectrum Management

- Enabling space exploration and scientific discoveries
  - Providing the overall planning, policy, coordination and implementation necessary to ensure adequate access to and protection of electromagnetic (EM) spectrum in support of NASA's present and future programmatic goals.
  - Ensuring spectrum access for NASA systems and that operations are compliant with Federal regulatory policies
  - Advancing NASA's strategic spectrum requirements and policies in collaboration with national and international regulatory and technical coordination bodies
  - Leveraging partnerships with other space agencies, promotes spectrum related technology developments and educates NASA community
  - Working within the Plans Policy Steering Group (PPSG) providing effective leadership to enable commercial opportunities and to meet evolving commercial requirements

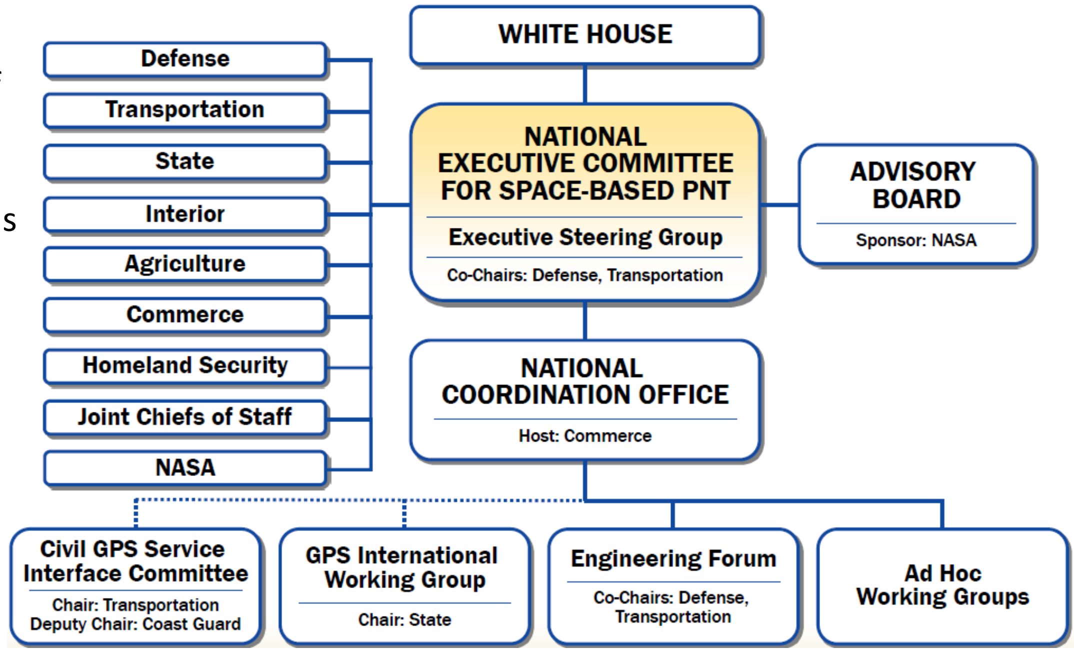
Working with US industry and other civil space agencies around the globe to maintain US leadership in space communications

NASA Spectrum Use

- **NASA uses frequency bands from 50 MHz to 275 GHz**
  - Science (both passive and active sensors)
  - Space communications (both near-Earth and deep space)
  - Airborne and terrestrial sensors (e.g., meteorological radars)
- **All communication and active sensing bands are shared with others**
- **Several national/international regulatory activities have made allocation changes or are considering changes in many bands > 20 GHz**
  - FCC Proceedings - "Spectrum Frontiers"
  - ITU WRC-19 - several agenda items
  - Mobile Now Act
- **<u>NASA is fully engaged in these activities</u>**
  - NASA works with NTIA through the PPSG and IRAC processes
  - At this time, NASA believes that the existing allocations > 20 GHz are sufficient for future NASA needs - however, significant changes may alter that assessment and affect NASA's mission
  - Introduction of new services in bands > 20 GHz can be accommodated as long as appropriate protection and feasible sharing methods are specified

NASA's Role in U.S. PNT and Space Policy: PNT EXCOM Organization Structure

- The National Space-Based Positioning, Navigation, and Timing (PNT) Policy tasks the NASA Administrator, in coordination with the Secretary of Commerce, to develop and provide requirements for the use of the Global Positioning System (GPS) and its augmentations to support civil space systems
- PNT Policy goals are for the U.S. to maintain space-based PNT services that:
  - Meet growing national, homeland, economic security, civil requirements, and scientific and commercial demands
  - Continue to provide civil services that exceed or are competitive with foreign civil space-based PNT services
  - Remain essential components of internationally accepted PNT services
  - Promote U.S. technological leadership in applications involving space-based PNT service



- The 2010 National Space Policy reaffirms PNT Policy commitments to GPS service provisions, international cooperation, and interference mitigation
  - Foreign PNT services may be used to augment and strengthen the resiliency of GPS
- NASA seeks to contribute fulfilling governmental policy goals through technology development and/or application.

Summary

- SCaN continues to exceed its operational commitments to all customers
  - NASA, other Government agencies (OGA)s, and international space partners
- Risks to operations of three networks remains manageable
- SCaN continues to evolve NASA's Space Communications architecture through a dynamic approach to meet Agency and partners' requirements
- Optical communication, as an enabling technology, is moving to initial operations faster than expected (by 2021).
- SCaN actively coordinates with national and international organizations
  - Radiofrequency spectrum allocation (achieved all WRC-15 objectives)
  - Space operations, architectures and space data systems standards development
    - Strategic interface and communication standards coordination with international partners (Interoperability plenary (IOP), Interagency Operations Advisory Group (IOAG), and CCSDS.)
    - Cross Support
  - Global Navigation Satellite Systems (GNSS), protecting NASA's interests in Positioning, Navigation and Timing (PNT)

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Agency Review Team Actions -

The ART has requested the following information:

Provide data and examples of how NASA does technology development (perhaps even in the form of products) when working with industry - for example, types of contracts/partnerships and IP arrangements. The interest is in how the results of government-funded development get disseminated (or not).

NASA pursues technology development to support both the national innovation system (industry, academia, other government agencies, and the general public) and specific NASA mission requirements. The Space Technology Mission Directorate (STMD) is NASA's independent technology mission directorate with the objectives to develop from early stage to advanced cross-cutting technologies necessary to accomplish NASA's future human and robotic space exploration missions; stimulate growth in the domestic aerospace industry through new revolutionary technological capabilities that create or expand markets, products, and services; and harness innovation and entrepreneurship through partnerships with universities, small businesses, emerging commercial entities, and other industries and government agencies.

STMD routinely competes nearly all of its technical needs and objectives either externally or internally. STMD develops partnerships to leverage innovation and resources of other government agencies (OGAs) and industry, while utilizing merit-based competition to achieve most of its technology goals.

As STMD research and technology (R&T) efforts mature, appropriate technologies are transferred to industry and commercialized through multiple programs and approaches to benefit a wide range of users ensuring the nation realizes the full economic value and societal benefit of these innovations.

STMD utilizes three types of procurement approaches with the commercial sector (in addition to the SBIR/STTR program) to meet its technology goals and needs:

- Broad Area Announcements (BAA) or NASA Research Announcements (NRA), which results in a traditional government contract with a commercial company for a specific technology or mission need, with intellectual property rights owned by the government.
- STMD's Tipping Point Technologies Public-Private Partnerships, seeking industry-developed space technologies that can foster the development of commercial space capabilities and benefit future NASA missions. A technology is considered at a 'tipping point' if an investment in a demonstration of its capabilities will result in a significant advancement of the technology's maturation, high likelihood of infusion into a commercial space application, and significant improvement in the ability to successfully bring the technology to market. A Tipping Point partnership:

    - Increases the focus on collaboration with the commercial space sector
    - Requires a minimum 25 percent contribution from corporation or customer
    - Leverages emerging markets and capabilities to meet NASA's strategic goals AND focus on industry needs
    - Increases likelihood of infusion into a commercial space application
    - Results in substantial benefits to both commercial and government sectors.

- STMD's Announcement for Collaborative Opportunities, utilizing non-reimbursable Space Act Agreements (SAA) to collaborate for the accelerated development and testing of critical technologies for emerging space system capabilities.

    - Partnerships are focused on industry-developed space technologies that can advance the commercial space sector and benefit future NASA missions
    - Can accelerate the availability of, and reduce costs for the development and infusion of these emerging space system capabilities
    - NASA will provide technical expertise and test facilities, as well as hardware and software to aid industry partners in maturing technologies that can enable or enhance space vehicle systems or other closely related subsystems

For all three approaches, STMD requires prompt public disclosure of the results of its sponsored research to generate knowledge that benefits the Nation. Thus, it is STMD's intent that all knowledge developed under awards resulting from solicitation be shared broadly as appropriate. Award recipients are generally expected to publish their work in peer-reviewed, open literature publications to the greatest extent practical.

STMD recognizes that there are cases when data cannot be disclosed to the public (e.g., export controlled data). Even in these cases, offerors are expected to publish data to the greatest extent possible (e.g., use normalized data or at least discuss new methodologies used with clean "test cases"). STMD also understands that offerors may have legitimate proprietary interests in the technology or data they have produced at their own expense. With each solicitation award, STMD negotiates intellectual property and data rights as appropriate on a case-by-case basis while maintaining our goal for broad public disclosure of knowledge. STMD also negotiates for NASA's rights to use these technologies, data, and/or capabilities for mutually agreed upon timeframe.

Over the past five years, STMD has utilized several mechanisms to disseminate R&T knowledge and data to the broader aerospace community, while protecting our industry partners' proprietary interests. For example, after the completion of the Game Changing Development 5.5M Composite Cryogenic Tank Development project, STMD worked with Boeing (the prime contractor for the effort) to hold industry workshops to disseminate the test data and knowledge to the broader community. Additionally, the evolvable Cryogenics Technology Demonstration Mission project holds periodic industry day workshops to discuss and disseminate the latest in advancements in cryogenic fluid management technology development efforts.

The project team members authored more than two dozen technical conference papers and presentations and initiated more than a dozen public engagements with television, magazine, and social media. A few recent examples are listed below:

- http://www.compositesworld.com/articles/nasaboeing-composite-launch-vehicle-fuel-tank-scores-firsts
- John Fikes, "NASA Composite Cryotank Technology Project Game Changing Program," Defense Manufacturing Confernce (DMC) 2015
- Justin Jackson, John Vickers, John Fikes, "Composite Cryotank Technologies and Development 2.4 and 5.5 meter Out of Autoclave Tank Test Results, Composites and Advanced Materials Expo (CAMX) 2015
- Proceedings of a NASA-sponsored Technical Interchange Conference held in New Orleans, Louisiana, May 6–7, 2015.

Another STMD investment, 3D-Woven material, began as a Game Changing development project. NASA issued a sources sought announcement seeking carbon fabric weavers for entry descent and landing technologies. Bally Ribbon Mills (a small business) responded and were interested in a partnership. NASA has funded the Bally Ribbon Mills work via phase III SBIRs and contracts. The 3D Woven project team submitted a patent application on 3-D Weaving for multi-functional application which includes inventors from NASA and Bally Ribbon Mills. In addition, NASA has submitted multiple patent applications related to 3-D Woven TPS. NASA does hold the primary rights for the technology and different applications, but has shared all non – ITAR restricted results with Bally Ribbon Mills as well as disseminated data to the public at large and presentations.

- Feldman, J. D.; Stackpoole, M. M.; Ellerby, D. T.; Venkatapathy, E. "Performance of High-Density Woven TPS Ablative Materials." 6th Spacecraft Propulsion Joint Subcommittee Meeting paper 2013-0002FK, May 2013. JSC CD-72.
- Stackpoole, M. M.; Feldman, J. D.; Ellerby, D. T.; Venkatapathy, E. "Performance of Mid-Density Woven TPS Ablative Materials." 6th Spacecraft Propulsion Joint Subcommittee Meeting paper 2013-0002GE, May 2013. JSC CD-72.
- Stackpoole, M.; Feldman, J.; Venkatapathy, E. "Woven Thermal Protection System Final Report." NASA Ames Research Center. May 30, 2013.
- Venkatapathy, E., Ellerby, D., Gage, P., Stackpoole, M., Peterson, K., Chinnapongse, R., and Shelly, M., "NASA ARC Workshop: Defining Heatshield Capability Needs for Extreme Entry Environment, April 30, 2013, NASA Ames Research Center, Moffett Field, CA.

The technology has also been incorporated into many NASA development activities and industry uses. Examples are listed below:

- NASA STMD's Adaptable, Deployable Entry Placement Technology (ADEPT) project is using the 3-D weaving.
- Department of Defense (ARMDEC), based on NASA's work, is working with BRM on weaving carbon 3-D preforms.
- Johns Hopkins Applied Physics Lab, in support of Solar Probe+, is evaluating a 3-D polar Weave for their application.
- Orion program has expanded the application of 3-D MAT from the compression pad to other locations where they were using carbon phenolic.

With the Green Propellant Infusion Mission (GPIM), STMD worked with the two prime awardees: Ball Aerospace (providing the spacecraft and performing all integration functions) and Aerojet Rocketdyne (providing, and retaining the data rights to, the propulsion subsystem) to develop a knowledge dissemination plan. GPIM's objective is to advance the technology readiness level of a non-toxic or "green" propulsion system, specifically by demonstrating its capability on-orbit. The propulsion system is referred to as green because it uses fuel with substantially reduced toxicity hazards and improve ground based worker safety compared to traditional hydrazine systems. The propellant for this mission is AF-M315E, a blend of hydroxylammonium nitrate and other ingredients. Developed by the Air Force Research Laboratory (AFRL), it offers nearly 50 percent higher performance for a given propellant tank volume compared to a standard hydrazine propellant system. This technology promises higher performance for future satellites by providing options for longer mission durations, additional maneuverability, increased payload, and simplified launch processing. At the completion of an on-orbit demonstration, sufficient data will be developed to allow for infusion of AF-M315E as a hydrazine replacement for spacecraft attitude control and primary propulsion. The targeted infusion community for the results of the GPIM mission is the marketplace for small and medium size spacecraft producers and customers. A final report including lessons learned and all data acquired during mission operations will be produced and disseminated to interested stakeholders. Additionally, two recent examples of publications are listed below:

- Christopher H. McLean, “Green Propellant Infusion Mission (GPIM), Advancing the State of Propulsion System Safety and Performance”, 54th AIAA Aerospace Sciences Meeting, (AIAA 2016-0183)
- Ronald A. Spores. "GPIM AF-M315E Propulsion System", 51st AIAA/SAE/ASEE Joint Propulsion Conference, AIAA Propulsion and Energy Forum, (AIAA 2015-3753)

Currently, three Tipping Point projects awarded under the In-Space Robotic Manufacturing and Assembly (IRMA) activities will ground demonstrate enabling technologies that not only leverage capabilities to meet NASA’s strategic goals, but also focus on U.S. industry markets that are at a tipping point for commercialization and infusion:

- Dragonfly (Space Systems Loral) - On-orbit Robotic Installation and Reconfiguration of Large Solid RF Reflectors: Will perform a high fidelity antenna assembly ground demonstration using existing antenna/robotic equipment to provide next generation of performance advancements in GEO ComSats. Satellites assembled on-orbit using integrated robotics capability will be capable of higher performance than satellites that can be launched today. An added benefit will be antennas that can be moved and changed during a satellite’s mission life for flexibility and to accommodate changing market requirements.
- Commercial Infrastructure for Robotic Assembly and Services (CIRAS) (Orbital ATK): The CIRAS mission capabilities will include methods of connecting or disconnecting joints on a structure and performing precision measuring and alignment with a 15-meter robotic arm and a precision robot. The team will also develop technologies needed to conduct on-orbit modular assembly of structures, allowing parts to be brought to space as needed via multiple launches. This approach to space logistics is designed to simplify the design of spacecraft and reduce cost.
- Versatile In-Space Robotic Precision Manufacturing and Assembly System - “Archinaut” (Made in Space, Inc., teaming with Northrop Grumman and Oceaneering Space Systems): Will develop the necessary technologies and subsystems which will enable the first additive manufacturing, aggregation, and assembly of large and complex systems in space without astronaut extravehicular activity. The full vision of Archinaut will enable on-orbit manufacture and assembly of unlaunchable structures, enabling new mission capabilities such as large antennas and base stations. The initial Archinaut Phase I program will perform a series of technology demonstrations in order to bring the final technical hurdles beyond the tipping point for commercial feasibility.

These Tipping Point awards were designed to advance/enable a business case for the selected companies while relying heavily on company in-kind contributions. Therefore, the technologies developed through these partnerships and thus identified, are protected under limited data rights clauses and cannot be shared publically without consent of the company partner.

Restore-L is a STMD satellite-servicing mission designed to robotically demonstrate the tools, technologies and techniques needed to extend satellites' lifespans. During its mission, the Restore-L servicer will rendezvous with, grasp, refuel and relocate a government-owned satellite to extend its life. Successful completion of this mission will demonstrate that servicing technologies are ready for incorporation into other NASA missions, including exploration and science ventures, and will also enable the transfer Restore-L's technologies to commercial entities. Restore-L technologies include an autonomous relative navigation system with supporting avionics, and dexterous robotic arms and software. The suite is completed by a tool drive that supports a collection of sophisticated robotic tools for robotic spacecraft refueling, and a propellant transfer system that delivers measured amounts of fuel at the proper temperature, rate, and pressure. The Restore–L project is utilizing workshops with commercial industry following key development milestones to directly transfer the government -derived knowledge to the broader aerospace community. In addition, DARPA and NASA recently announced co-sponsorship of an industry-led effort to leverage emerging government-developed best practices to develop non-binding industry consensus standards for safe robotic servicing by commercial servicers. While DARPA and NASA are serving as the impetus for this consortium with DARPA providing initial funding, it is envisioned that industry will eventually take full responsibility for this effort as it has done with standards-setting in other domains.

In August, 2016, Restore-L released a "Plan to Facilitate Commercial On-Orbit Robotic Servicing" via FedBizOpps (https://www.fbo.gov/notices/e7beb15477e9a478c922a274bf52ad98) and includes extensive activities to transfer robotic on-orbit servicing technologies to domestic industry entities, listed below:

- The direct transfer of a rolling portfolio of technologies and software through patent licenses and other agreements;

- Access to NASA's programmatic, technical and operational expertise in satellite servicing through reasonable contact/engagement with the NASA satellite servicing team during the development and execution of the Restore-L mission and after its conclusion;

- Invitations to attend industry days, which provide data from major Restore-L reviews;

- Access to major Restore-L review packages post-review (note that packages will be redacted to remove some programmatic information and all third-party intellectual property);

- Access to Restore-L Mission Operation Control rooms and other facilities at established intervals during mission development and rehearsals for on-orbit operations;

- Opportunity after mission completion to review additional data not available real-time during the mission;

- The benefit of NASA's mature, vetted technology transfer processes already in place;

- An open and level playing field for all domestic entities

The Laser Communication Relay Demonstration (LCRD) project, co-funded by STMD and HEOMD/SCaN (Space Communications and Navigation), is NASA's pathfinder mission towards demonstrating an optical relay capability for Near Earth applications. LCRD will use lasers capable of encoding and transmitting data at rates 10 to 100 times faster than radio, or at the same data rate as today's fastest RF radios, but using significantly less mass and power. The mission goal is to provide two years of continuous high data rate optical communications in an operational environment from GEO, demonstrating how optical communications can meet the growing need for higher data rates, or for the same data rate provided by a comparable RF system. Its purpose is to prove the technology is ready for the next generation space relay systems to provide mission critical communications for users. A partnership with another government agency is in place to add encryption capability. Anticipated mission use is in next-generation TDRS and infusion into industry for future missions. The two-year plan includes a guest user program for demonstrating viability of the optical communication for commercial needs.

As part of the effort to disseminate laser communication technology to interested parties, STMD released an "RFI for Guest Investigators" in 2014, which was well-received:

- https://prod.nais.nasa.gov/eps/eps_data/162705-OTHER-001-001.pdf

Additionally, SCaN/GSFC released an Announcement for Commercial Partnership in Dec. 2015:

- http://partnerships.gsfc.nasa.gov/pcocs/NASA-PCOCS-Announcement_12-18-15.pdf
- or http://www.spaceref.com/news/viewsr.html?pid=48259

The forward plan is to release similar, updated announcements in 2017 to identify and eventually select guest investigators for LCRD (who will then have a front-row seat on how these systems will work operationally) and also to identify partners to commercially develop the next-generation hardware which can be purchased by either the government or commercial service providers. One item of note is that the intellectual property for the current LCRD design is owned by MIT Lincoln Laboratory so future licensing will be via MIT-LL.

STMD also conducts several major in-house technology development projects in the Game Changing Development program and the Technology Demonstration Missions program. For example, the Solar Electric Propulsion (SEP) program recently made all of its in-house technology data and knowledge available to the broad aerospace community in preparation for the recent Advanced Electric Propulsion System contract. Both conferences/workshops were utilized and a "bidder library" was created to facilitate the transfer of the government developed R&T. The SEP technology is advancing in-space transportation capability for a variety of NASA deep space human and robotic exploration missions, as well as having direct applicability to enhancing Other Government Agency uses and the commercial spacecraft market. These Hall thruster electric propulsion systems have a four to six times higher specific impulse, requiring five to ten times less propellant for the same mission. The thrusters will operate at ~2.5 times the power level of the highest powered electric thrusters now in use. This work directly complements recently completed STMD advanced solar array systems work. Two advanced solar array concepts (Roll Out Solar Array (ROSA) by Deployable Space Systems (DSS), and UltraFlex Solar Array by Orbital ATK) were developed to TRL6, and are now being infused into commercial spacecraft. These advanced solar arrays are 2 times lighter and use 4 times less stowed volume for the amount of electricity produced than commercially available arrays, with an ability to withstand 4 times more radiation exposure.

QRB MORATORIUM GUIDANCE

This guidance is issued to agencies on the process and appropriate instances to request any exception to the December 7, 2016 Governmentwide QRB moratorium.

Background

In accordance with OPM's authority under 5 CFR 317.502(d), and consistent with past practice, OPM stops accepting and processing new agency Senior Executive Service (SES) Qualifications Review Board (QRB) cases, effective when an agency head departs, announces his or her departure, or upon the nomination of a new agency head. Such QRB moratoriums are imposed to ensure the incoming head of the agency will have the full opportunity to exercise his or her prerogative to make or approve executive resource decisions that will impact the agency's performance during his or her tenure.

During Presidential election years, OPM has followed an established practice to impose a Governmentwide QRB moratorium in situations where the President requests letters of resignation from all non-termed presidential appointees to provide the President-elect with maximum flexibility to assemble the new leaders of a new upcoming administration. On November 7, 2016, the President requested letters of resignation – due on December 7, 2016 – from all Presidential Appointees with the exception of the following: U.S. Marshals; U.S. Attorneys; Inspectors General; Appointees serving in termed appointments; Appointees of independent and regulatory agencies headed by termed appointees; and Appointees serving on part-time boards and commissions. Consequently, OPM is implementing a Governmentwide QRB moratorium effective December 7, 2016.

Suspension of QRB Case Processing

Under a Governmentwide QRB moratorium, OPM suspends QRB case processing for career SES appointments. During the period of the QRB moratorium:

- OPM will not accept the agency submission of any new QRB cases;
- OPM will suspend the usual 90-day deadline for agency submissions of QRB cases; and
- OPM will continue to process QRB cases submitted by agencies prior to the effective date of the QRB moratorium.

Agencies are permitted to continue conducting SES merit staffing actions in the absence of an agency head or designated official, up to the point of submission of the selected candidate for QRB review and certification for initial appointment to the SES. Additionally, each agency is strongly encouraged to closely track QRB cases held during the moratorium so the agency may immediately submit the cases to OPM once a new agency head is appointed, resulting in the end of the moratorium for the agency.

Exceptions to the Governmentwide QRB Moratorium

A number of exceptions exist to the Governmentwide QRB moratorium. First, the Governmentwide QRB moratorium does not apply to agencies whose agency head's resignation was not required by the President. Second, the moratorium does not apply to agency submissions of "Criterion B" cases – these involve individuals who have successfully completed an OPM-approved SES Candidate Development Program (CDP) and whose executive qualifications are then submitted to OPM for QRB review and certification for general non-competitive SES appointment eligibility; these candidates are not submitted for certification for appointment to a specific SES position for which they were competitively selected. Third, an exception may be requested by an agency for a specific position based upon critical need.

1. <u>Agencies with Agency Heads whose Resignations were not Required by the President</u>

The Governmentwide QRB moratorium does not apply to any agency with an agency head whose resignation was not specifically required by the President. As mentioned above, a number of categories of appointees were not required to submit letters of resignation; consequently, any agency head not required to submit a letter of resignation remains in place, and their agency therefore is not subjected to the moratorium.

2. <u>Graduates of OPM-Approved SES CDPs (Criterion B Submissions to the QRB)</u>

The Governmentwide QRB moratorium does not apply to agency Criterion B submissions. Criterion B cases involve the agency submission to the QRB of the executive qualifications of individuals who have successfully completed an OPM-approved SES CDP. Following the completion of the SES CDP, a graduate's executive qualifications may be reviewed and certified by the QRB – this QRB certification gives the SES CDP graduate eligibility for non-competitive appointment to the SES. Because such submissions do not involve a selection and appointment to a specific SES position following a competitive process, any QRB certification of a SES CDP graduate will not significantly impinge upon the prerogative of a new agency head to select his/her senior executives.

3. <u>Agency Requests for Specific Exceptions to the Governmentwide QRB Moratorium</u>

In other circumstances, an agency may submit a request to OPM for an exception to the Governmentwide QRB moratorium, for a specific position, based upon critical need. OPM considers such requests on a case-by-case basis to balance the important prerogative of a new agency head to select his/her senior executives against the agency's critical operational needs.

Requests for exception should be signed by the agency head or the official who is designated to act in the agency head's absence. Agencies must address the following factors in agency requests:

- the impact on the agency should the position not be filled during the moratorium; specifically addressing why it is critically important that an exception be granted given the potential for adverse impact on national security, homeland security, or a critical agency mission, program, or function;

  - the likelihood the new agency head will have specific interest in the position or the individual appointed to the position;
  - the organizational level of the position (provide organization chart) including to whom the position reports;
  - the degree to which the candidate would be involved in policy matters;
  - any special or unique qualifications of the candidate (a resume should be included);
  - whether the candidate is currently on a Schedule C or noncareer SES appointment, or has been within the most recent 5 years;
  - whether the candidate is currently performing the duties of the position via detail or "acting" designation and the length of time for the detail or "acting" designation (e.g., 30 days);
  - how long the position has been vacant; and
  - when the Agency Head has not yet departed, whether he or she has certified that the action is necessary to ensure continuity of critical agency operations.

What is Considered Mission Critical?

Mission critical positions are directly related to national security, homeland security, or an agency mission, program, or function critically important to the operation of the agency. For any of these positions, the agency's justification must identify the impact to the agency's mission or the public if the agency's candidate for initial appointment to the SES is not certified by the QRB.

What is Considered When Evaluating Organizational Level?

The purpose of the QRB Moratorium is to ensure the incoming agency head, or new Administration's ability to determine who will have the full opportunity to exercise his or her prerogative to make or approve executive resource decisions that will impact the agency's performance during his or her tenure. Therefore, requests for moratorium exceptions for positions reporting directly to the agency head should be extremely rare, and may not be granted.

Resumption of QRB Case Processing

After a new agency head has been appointed, agencies may request OPM to resume the processing of their agency QRB cases and should specifically indicate the new agency head's intention to resume processing of its QRB cases, as follows:

- The QRB cases held by the agency due to the Governmentwide QRB moratorium must be sent to OPM within 120 calendar days of the appointment of the new agency head.

- Once a new agency head has been appointed, the 90-day timeline for submitting new QRB cases (i.e., cases other than ones an agency has been holding due to the moratorium) is reinstated.

- The request to resume QRB case processing should include the title and name of the new agency head and the date he/she was sworn in.

- The request must be sent from the senior Executive Resources Office official, or a higher level official, and OPM will respond via email.

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The Innovation Landscape within a Large Government Agency: Promising Practices from the US National Aeronautics and Space Administration

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ABSTRACT

The NASA Mission is to "drive advances in science, technology, aeronautics and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth. NASA's complementary Vision is to "reach for new heights and reveal the unknown for the benefit of humankind" (NASA Strategic Plan).[i] NASA's future success will be determined largely by the investment and innovations made today in scientific research, technology and our workforce. To achieve mission success through the highest standards in engineering, research, operations and management, NASA is committed to nurturing an organizational culture of innovation within our workforce. Innovation is the application of a novel approach that provides improved outcomes or enables new outcomes to create value for people. Innovation as defined here, is broadly applied to technological, scientific, engineering, educational, outreach and organizational activities across NASA.

This paper presents a NASA Innovation Landscape that builds on a framework proposed by Pisano (2015) and other researchers. The framework maps the Innovation landscape into four quadrants, depending on whether the innovation pursues new approaches in the area of technology or organizational processes. This paper adapts the framework to a large, public sector agency and explores Continuous, Disruptive, Revolutionary and Transformative innovations. Continuous innovation builds on existing technological capabilities and fits within the existing organizational model. Disruptive innovation requires organizational change rather than a breakthrough in technology, as proposed by Christensen. Revolutionary innovation is the counterpoint to disruptive innovation, requiring a technological breakthrough within the existing organization. Transformative innovation combines technological and organizational disruptions. The discussion provides examples of innovative activities from NASA that represent the four quadrants of the Innovation Landscape. The closing explores how leaders can use the concepts from the Innovation Landscape as a communication tool to foster an innovation culture within the workforce of a large government agency.

I. NASA'S INNOVATION LANDSCAPE

Innovation is vital to achieving the ambitious objectives of the US National Aeronautics and Space Administration (NASA), from peering into the universe with the James Webb Space Telescope to conceiving revolutionary new designs for future airplanes to sending humans to explore Mars. This paper presents an Innovation Landscape that provides both a description of innovation within NASA and a communication tool that expresses a vision for the agency's innovation culture. The paper builds on a series of formal and informal discussions on innovation that were held by senior leaders within NASA during the 2015 and 2016 calendar years.

For this discussion, we define innovation as the application of a novel approach that provides improved outcomes or enables new outcomes to create value for people. As captured in the NASA Culture Strategy released by the Office of Human Capital Management in 2013, innovation includes the constant search for ways to improve within one's job responsibilities; it includes ideas that are likely to support NASA programs in the long term; and it includes the application of novel ideas that enable new technologies, services, policies and processes[ii]. Innovation as defined here, is broadly applied to technological, scientific, engineering, educational, outreach, security, financial and organizational activities across the agency. Innovation is essential to enable NASA to achieve all three Strategic Goals outlined in the NASA Strategic Plan.[iii] The first strategic goal focuses on expanding the frontiers of knowledge, capability, and opportunity in space. The second strategic goal focuses on our work to improve the understanding of life on Earth. Finally, the third strategic goal focuses on major management priorities and challenges.

This discussion on innovation within NASA is guided by the visual map of an Innovation Landscape that groups activities into four areas based on the type of contribution each innovation brings. At a high level, the Innovation Landscape maps specific activities by asking two questions: 1) What type of novel approach does the innovation apply? and 2) How novel is the innovation?

To address the first question, the Innovation Landscape highlights whether the innovative activity improves outcomes by leveraging new technological approaches, new organizational approaches or a combination of both. Technology in this case includes approaches grounded in engineering, science, technology or medicine; similarly, the concept of organizational approaches serves as short hand for the wide range of business, human capital, contracting, procurement, finance, safety, management, education and communication approaches. To address the second question about novelty, the Innovation Landscape also maps new approaches as either minor changes that harness existing technology and organizational approaches or as major changes to the state of the art.

To operationalize these two questions about the type and extent of novelty, the Innovation Landscape map includes four quadrants labeled Continuous, Disruptive, Revolutionary and Transformative.[iv] Continuous innovation brings evolutionary changes to existing technology and organizational approaches. The majority of innovation is categorized as continuous. It is the constant search for ways to improve outcomes while harnessing the existing infrastructure, team structure and organizational models. Disruptive innovation brings a highly novel organizational approach, while maintaining the existing technology.[v] Revolutionary innovation is the counterpoint to disruptive innovation, implementing a highly novel technology or scientific breakthrough within the existing organization.

Transformative innovation implies an approach that is highly novel in both the organizational and technological dimensions.

Figure 1 presents the Innovation Landscape as a visual mapping of the four types of innovation. A particular innovative activity can be mapped to one of the four quadrants based on the extent and type of novelty. A particular innovative activity is defined as Continuous, Disruptive, Revolutionary or Transformative at a given point in time. An innovative idea may be transformative when it is first introduced to a firm, government agency or community; that same idea may be categorized as Continuous later in its lifecycle as users adopt the idea and the overall state of the art evolves. Similarly, we can view the Innovation Landscape in terms of the efforts of an Innovator to solve a problem. The Innovator may first apply methods using Continuous Innovation because these potential solutions are accessible. Additional effort may generate Disruptive or Revolutionary solutions. If these do not fully solve the problem, a Transformative solution may need needed. Disruptive and Revolutionary solutions require great creativity to generate because they depart from existing technology and organizational models. Transformative solutions often require great effort to implement because they require overcoming the inertia of both existing technology investments and established organizational norms.

Across NASA, in order to concurrently pursue all four types of innovation, the agency displays the characteristic of ambidexterity, defined as the simultaneous pursuit of seemingly competing requirements.[vi] For example, NASA demonstrates ambidexterity by leveraging both operational space flight centers and research centers. Another form of ambidexterity is to emphasize both integration and differentiation. Integration refers to organizational practices and processes that seek to unify efforts across the agency. Differentiation refers to organizational practices that allow organizational units to operate with unique organizational structures, culture, capabilities, policies and communication approaches.[vii] Integration within NASA is seen when we establish strategic objectives, core values, and implement innovation across the agency. Differentiation within NASA is seen in the unique processes and structures across centers and Mission Directorates. Seemingly paradoxical, innovation capability depends on integration that sets a vision for the challenges NASA pursues and allows diverse groups to come together to solve problems; it also depends on differentiation that allows groups to divide into communities of practice to solve specialized challenges.[viii]

Figure 1 provides an initial attempt to visualize NASA's distribution of innovation across the four quadrants of Continuous, Disruptive, Revolutionary and Transformative. The extent of the shading in each quadrant represents the relative frequency of each type of innovation according to preliminary data collection. This summary is based on a data call with NASA senior leaders that represent all the major organizational units across the agency. Specifically, these leaders are heads of the NASA Field Centers, four NASA Mission Directorates and agency-level offices (such as human capital, education and communication, etc). As part of a senior meeting on innovation, NASA leadership asked each of the heads of centers, mission directorates and offices to submit one or two example of activities they consider to be Promising Innovation Practices within their area of responsibility. The submitted activities were categorized into the four quadrants by the authors of this paper; the number of examples is reflected by the extent of shading in Figure 1.

This informal call for example of Innovation Promising Practices provides preliminary insight showing how common the four types of innovation are within NASA. As is expected based on literature, Continuous Innovation is the most common, while Transformative is the least. It may appear surprising that there are apparently more examples of Disruptive Innovation that bring new organizational models rather than Revolutionary new technologies. NASA has a reputation for being an agency that regularly develops new technology; technology development is the primary goal of several organizations within NASA, including the Space Technology Mission Directorate and the Advanced Exploration Systems division within the Human Exploration and Operations Mission Directorate.

What explains the fact that more Innovation Promising Practices were submitted in the Disruptive quadrant than the Revolutionary quadrant? The authors propose two explanations. First, the data underlying this graphic is drawn from senior leaders who serve as managers over large offices or organizations. The perspective of these managers is focused highly on the Disruptive approaches they use to bring innovative new organizational models because this is a key aspect of their responsibilities. NASA uses many types of partnership mechanisms to collaborate with other government agencies, firms, universities and non-profits to meet both technical and organizational goals. Identifying a new approach to partner with an external entity to solve a problem for NASA is a form of Disruptive innovation. Meanwhile, NASA develops Revolutionary technologies to support the agency missions both within the government field centers and by funding technology development at universities and companies. This data collection process did not delve deeply into examples of specific new technologies. Rather, the examples provide broad themes of technology development, which will be discussed further below. Further data collection will be required to identify the full range of Revolutionary technology inventions enabled by NASA.

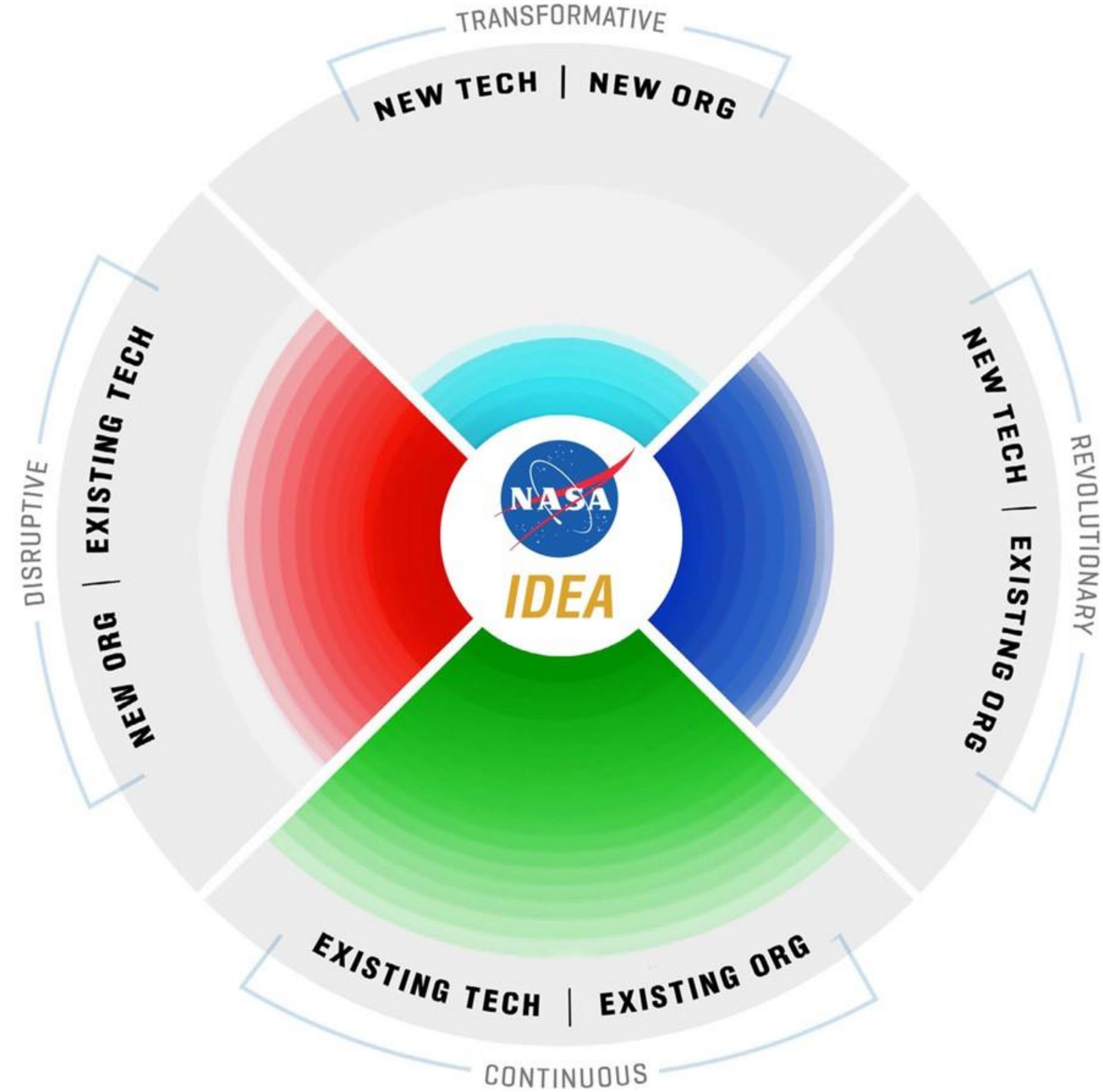

Figure 1: NASA Innovation Landscape (Image Credit: JPL Studio)

II. EXAMPLES OF NASA INNOVATION ACTIVITIES

The discussion above provides a theoretical summary of the NASA Innovation Landscape. In order to gain a more empirical understanding of NASA Innovation Promising Practices, this section presents short case studies of activities provided by senior NASA leaders from across the agency. The examples provide more detailed descriptions of Continuous, Disruptive, Revolutionary and Transformative projects or programs within the Innovation Landscape.

Although the section that follows categorizes examples of innovation activities into one of the four quadrants, the authors acknowledge that the mapping is not absolute. A particular example may fit in several quadrants, depending on the aspect of the activity that is emphasized. The goal of the discussion below is not argue that these NASA activities can only be categorized in specific areas; rather the goal is to illustrate how Continuous, Disruptive, Revolutionary and Transformative activities appear in practice. Another is that the examples include a variety of scales in terms of resources and time. Some of the examples below, such as Commercial Crew and Cargo, are large scale programs leveraging major financial resources. Other examples, such as the Solution Mechanism Guide and the Diversity "All in" Training, are small scale internal NASA projects that contribute to professional development for NASA employees. A large scale, long term program is more complex than a small scale training tool, but such differences in complexity are not yet accounted for in the visual presentation of the Innovation Landscape.

A. Continuous Innovation Examples

Figure 2: Continuous Innovation Promising Practices (Image Credit: JPL Studio)

Figure 2 introduces the Continuous Innovation Promising Practices, which bring improved outcomes by harnessing existing technology and existing organizational models. The list on the right in Figure 2 shows some of the Continuous Innovation examples submitted by

NASA senior leaders, however, there are more that are not shown in this graphic due to space limitations. Several case studies are selected that illustrate the benefits of employees and team leaders viewing their role as the continuous search for opportunities to improve the quality, efficiency or scope of their outcomes.

Digital Learning Network: The Digital Learning Network (DLN) is an example of continuous innovation as the NASA Office of Education uses this communication platform to expand the impact of their programs[ix]. The DLN enhances delivery of content harnessing Science, Technology, Engineering and Mathematics by linking customers with one or more of the NASA Centers (or other federal agencies) and allowing them to participate in interactive virtual presentations and discussions, both domestically and internationally. Since 2003, the DLN has reached over one million students. The DLN leverages commercially available technology in a unique way across NASA to blend high quality videoconferences with pedagogical best practices. The NASA Office of Education employs the Digital Learning Network as part of their broader effort to expand the participation of communities that benefit from NASA resources (people and facilities). NASA seeks to enable underrepresented and underserved populations to have access to NASA educational programming. Examples of underserved population may be students of military parents who live abroad or communities in remote locations in Alaska and rural areas of the Midwest. There remain future opportunities to expand both the technological capabilities and user experiences with the DLN. For example, planned use of Virtual and Augmented reality systems will make user experiences much more immersive in the future.

Diversity and Inclusion "All In" Training: The "All In" training is an internal classes offered by the NASA Office of Diversity and Equal Opportunity for NASA employees. The training is designed to provide the NASA workforce with education and awareness on the value and utility of diversity and inclusion in our community, with a special emphasis on addressing the impact of implicit bias in the employment setting. Implicit bias in this context refers to the unconscious actions by individuals and institutions negatively impact efforts to foster a diverse and inclusive workforce. The "All In" training has customized modules for different elements of the workforce, including senior leaders, mid-level managers, non-supervisory employees. The All In training is a continuous innovation because it addresses the topic of implicit bias with more depth than other similar training and provides useful examples and actions for mitigating implicit in the workplace setting.

Early Career Initiatives: NASA's Space Technology Mission Directorate leads a number of programs to develop and demonstrate new technologies that are used by our aeronautics, science and exploration missions. As part of its portfolio, STMD has sponsored several Early Career Initiative (ECI) projects. An explicit goal of the ECI projects was for the team to benchmark, adopt and apply innovative technical and project management solutions and approaches. The ECI project teams were explicitly directed to consider project management and system engineering methods that are outside the scope of the standard policy documents to which NASA projects comply. The ECI teams sought to use NASA processes when appropriate and also adopt best practices from systems engineering methods used outside the agency. The ECI teams were empowered to develop plans and execute them with limited guidance or constraints from Mission Directorate or Center management. In some cases, ECI team attempted methods that they found to be unsuccessful, but they had the flexibility to learn from this and develop another path. ECI teams were able to define requirements, build hardware and software prototypes rapidly, test them with the end-users, obtain performance data and user feedback, and repeat this process in the next iteration. This cycle was repeated over several weeks rather than several months or years. The ECI teams contributed to training others to apply the non-traditional practices they chose to adopt. They were also required to partner with one or more organization external to NASA with whom they exchanged ideas and practices regarding technical and programmatic innovation.

MissionSTEM: The MissionSTEM initiative is an outreach effort of the NASA Office of Diversity and Equal Opportunity in the area of compliance with federal civil rights legislation. The relevant civil rights legislation includes Title IX of the Education Amendments of 1972, which requires that any education program or activity receiving federal funding ensures that no one is excluded from participation or denied equal opportunity on the basis of sex.[i] Similarly, Title VI of the Civil Rights Act of 1964 requires that no one can be excluded from or denied equal opportunity in federally funded programs on the basis of race, color or national origin.[ii] The Office of Diversity and Equal Opportunity uses several mechanisms to support NASA grantee institutions, including universities, museums and youth serving organizations, in their efforts to comply with civil rights legislation. One tool is the MissionSTEM website (http://missionstem.nasa.gov/), a comprehensive resource for NASA grantees on civil rights compliance, equal opportunity, and diversity and inclusion (D&I) for STEM environments. The website provides a host of materials, both written and visual, on compliance requirements as well as promising practices for advancing D&I in the STEM context. It is intended to touch all members of NASA grant recipient institution communities (~750 in FY 16), including administrators, compliance officials, faculty, staff and students. In this regard, it serves as a focal point and clearinghouse for grantees on civil rights and related matters in STEM. The MissionSTEM site is unique because it provides valuable information about civil rights for the NASA grantee STEM community that is not easily accessible from other sources. The website highlights the diverse perspectives of different disciplines, different kinds of grantees, as well as different individuals at the grantee institutions, such as faculty, staff and students. To augment the outreach of the website, on August 8-9, 2016, NASA hosted a MissionSTEM Summit for key stakeholders. The Summit brought together a variety of perspectives from different institutions and individuals seeking to increase diversity in STEM, including governmental and non-governmental actors, scientists and engineers, university presidents, deans, compliance officers and students. The overall intent of the Summit was to identify and develop more effective practices that enable universities and science museums to comply with civil rights legislation and ensure equal access to STEM research and education.

Solution Mechanisms Guide: The SMG is a web-based, knowledge management platform that teaches NASA employees about problem solving tools available to address a problem, question or research objective. The SMG was originally developed by the Health and Human Performance Directorate at NASA Johnson Space Center as part of a strategy to foster collaborative innovation in pursuit of their work on astronaut health.[x] NASA is currently pursuing options to adapt the Solution Mechanisms guide as a tool with agency-wide relevance to facilitate the formulation of NASA partnerships with external entities. NASA has many tools available to enable collaboration with external entities for problem solving, however, the disparate and complex suite of legal mechanisms available is not easily understood by employees who do not work full time on partnership development. By asking objectives-based questions related to project maturity, available resources, schedule and other details, the SMG identifies the options of suitable legal mechanisms available for solving the user's particular objective and provides information on how to implement them. The options include more traditional mechanisms like grants, contracts, cooperative agreements, and leases, as well as a variety of partnership instruments such as Space Act Agreements and open innovation approaches. Through the open innovation tools, NASA teams are able to invite the public to suggest ideas or solutions in response to problem statements.

B. <u>Disruptive Examples</u>

Figure 3: Disruptive Innovation Promising Practices (Image Credit: JPL Studio)

Figure 3 introduces the Disruptive Innovation Promising Practices, which bring improved outcomes by harnessing existing technology and novel organizational models. The list on the right in Figure 3 shows Disruptive Innovation examples submitted by NASA senior leaders. The case studies below illustrate how disruptive innovation practices have updated the approaches NASA uses for problem solving and partnering.

Centennial Challenges: The Centennial Challenges program within the Space Technology Mission Directorate uses crowd-based competitions to engage the public as part of NASA's portfolio of technology development approaches.[i] Each challenge addresses a technology area that NASA needs to advance in order to achieve long term science and exploration goals such as human exploration of Mars. STMD provides prize funding for the challenges and works with non-profit organizations that administer the competition. Other groups interested in the potential technology solutions also partner with NASA or the allied organizations for the competition. STMD selects challenges by identifying and prioritizing topic areas related to NASA missions in aeronautics, human exploration and science. Examples of targeted technologies include: 1) autonomous identification and collection of samples from the surface of Mars without the use of terrestrial navigation aids; and 2) advancement of Cube Sat communication and propulsion technologies for deep space. Teams must meet challenge requirements to win the pool of prize money. Recent prize pools range from $500,000 to $5 million US dollars. The Centennial Challenge program actively invites non-traditional participants, including individuals, families and universities with limited NASA experience, to work on problems that are important to NASA, learn about our missions and share their creative ideas.

Center of Excellence for Collaborative Innovation: The NASA Center of Excellence for Collaborative Innovation is a virtual center designed to advance the use of open and distributed innovation methodologies to improve government missions.[xi] Established in November 2011, with support from the White House Office of Science and Technology Policy (OSTP), the CoECI is actively leveraging NASA's success with these methodologies to harness and redistribute the collective experience and best practices in collaborative and distributed innovation in the government. Collaborative, open and distributive innovation practices use a variety of platforms such as websites, hackathons and ideation events to invite broad communities to contribute to proposed solutions to problem statements. As discussed by von Hippel[xii] the process of participating in innovation has been found to bring inherent satisfaction, in addition to the satisfaction of using the results of innovation. That is why people choose to respond to challenges posted on crowdsourcing platforms such as NASA@Work or participate in Hack-a-thons. Meanwhile, harnessing a competition or crowdsourcing model (either within NASA or externally) expands the range ideas that can be applied to the problem[xiii]. The CoECI provides guidance to other agencies on implementing open innovation initiatives from problem definition, to incentive design, to post-submission evaluation of solutions. CoECI has launched more than 200 challenges in the realms of idea generation, hardware/prototype development, software and applications development, analytics and data visualization, science investigations, and film creation. This includes 115 NASA internal challenges (using the platform of NASA@work) and 16 challenges in partnership with other federal agencies (USTPO, USAID, EPA, CMS, OPM, DoE, DOD, DHS and VA). CoECI's academic partner, the Harvard Crowd Innovation Lab, since establishing a formal relationship with NASA, has published over 15 peer-reviewed papers seeking strategies for repeatable practice by examining such topics as motivation, incentives, team formation, and user-focused metrics.

Citizen Science: Citizen Science is the practice by which scientists invite members of the public to participate in the scientific process to address real-world problems in ways that include identifying research questions, designing/conducting investigations, collecting and analyzing data, developing data applications, developing technologies to advance science, and solving complex problems. Projects within the NASA science portfolio that invite participation from citizen scientists include, for example, Disk Detective, through which participants look at images from the NASA WISE satellite-based telescope and help look for debris disks that signal possible areas in which new planetary systems are forming.[xiv] Another project, GLOBE Observer**,** invites people to take environmental measurements that complement NASA satellite observations to improve scientific studies of Earth.[xv]

Commercial Crew and Cargo Program: The Commercial Crew and Cargo Program within the NASA Human Exploration and Operations Mission Directorate is a platform that NASA is using to spur capability within the private industry to provide services to the U.S. government to deliver cargo and government astronauts to the International Space Station. NASA used the Commercial Orbital Transportation Services program to apply public-private partnerships with several companies as they developed new rocket and spacecraft. For the first round of the Commercial Cargo Program, NASA currently manages Commercial Resupply Services contracts with Orbital-ATK and Space Exploration Technologies to provide cargo delivery services to ISS.[xvi] For the second round of Commercial Resupply Services, from 2019 to 2024, NASA selected Orbital-ATK, Sierra Nevada and Space Exploration Technologies.[xvii] Similarly, NASA used several rounds of Space Act Agreements to partner with companies that proposed to build rockets and spacecraft to transport crew to the ISS.[xviii] Currently, NASA has awarded contracts to the Boeing Company and Space Exploration Technologies for future crewed flights and is progressing through on a certification process for the vehicles of each company.[xix] The Commercial Crew and Cargo programs represent a new approach for NASA to work with companies for spaceflight hardware development. In the traditional approach, NASA developed detailed requirements for spacecraft and launch vehicles for human space flight, contracted with a company to build the vehicles, took ownership of the vehicles and worked closely with the contractors on the operations. In this new approach, the Commercial Crew and Cargo programs allows companies to provide the service of crew and cargo delivery using vehicles that do not belong to the government, while meeting a set of government performance and safety requirements. In order to prepare for this new capability, NASA engineers worked with companies during the development phases of their vehicles.

Partnerships Supporting Commercial Space Activity: NASA has substantial interest in supporting the expansion of commercial space activity beyond Commercial Cargo and Crew. NASA envisions a future in which low Earth orbit is largely the domain of commercial activity while NASA leads its international and commercial partners in the human exploration of deep space. In order to implement national space policy goals and meet both commercial and NASA objectives, NASA's Human Exploration and Operations Mission Directorate (HEOMD) is very actively engaged in a strategy to enable industry partnership opportunities. NASA HEOMD has the mission to "extend and sustain human activities across the solar system." HEOMD has many programs, projects, and initiatives to accomplish this overall mission. Examples include the role of the Center for the Advancement of Science in Space (CASIS) to facilitate non-NASA use of the International Space Station; NextSTEP awards in Habitation, Advanced Propulsion, and Small Satellites where there was a requirement of 50% corporate resource contribution; and the Collaborations for Commercial Space Capabilities announcement, which allows NASA to formally interact with entrepreneurial space efforts. Meanwhile, Kennedy Space Center is driving innovation in enabling commercial operations by promoting the sharing of NASA assets in the launch infrastructure and maximizing the use of surplus capability, which will reduce NASA costs.

C. <u>Revolutionary Examples</u>

Figure 4: Revolutionary (Image Credit: JPL Studio)

Figure 4 presents the Revolutionary Innovation Promising Practices, which bring improved outcomes by harnessing novel technology and existing organizational models. The list on the right in Figure 4 shows Revolutionary Innovation examples submitted by NASA senior leaders. This section discusses one program within NASA that fosters the development of Revolutionary technologies as well as an example of a specific technology.

NASA's Transformative Aeronautics Concepts Program: The Transformative Aeronautics Concepts Program provides funding for researchers to experiment with new ideas and to perform ground and small-scale flight tests. Through these tests researchers learn from failure and quickly update their concepts. The program seeks to support the development of aeronautics systems that can transform commercial aviation and unmanned aircraft systems.

Ultra-Long Duration Balloon Capability: NASA's scientific balloons provide a low-cost, near space platform for cutting edge science and technology investigations. For decades, the Balloon Program has provided fundamental discoveries of our Earth, the Sun, the solar system, and the universe, in addition to playing an important role in developing and validating space technologies. Many precursor instruments that were initially proven on balloons have been implemented on spacecraft missions. NASA's balloons also serve as a training ground for young scientists and engineers. Through development of the new super-pressure balloon (SPB) vehicle, NASA is opening a new era of scientific observations. NASA continues a broad range of balloon and flight support systems development activities in order to advance the state-of-the-art of scientific ballooning. While long-duration ballooning using traditional 'vented' balloons has a proven history of scientific discovery, flights are limited to the Polar Regions in local summertime, and without nighttime viewing critical for astronomy. NASA's vision for the SPB centered on developing a completely new balloon design incorporating a closed, unvented envelope that can carry an observatory-class scientific experiment to the edge of space, and fly for 60-100 days at any latitude. NASA has overcome many engineering challenges in developing the SPB to include advanced thin-film materials, balloon structural design, and load tendons needed to safely withstand the stresses the SPB will see in flight. The Balloon Program has completed SPB development and is conducting operational flight tests. Through integration of the SPB with advanced power, pointing, communication systems and trajectory control, NASA is creating an Ultra-Long Duration Balloon (ULDB) system, capable of addressing key scientific questions in Astrophysics, Earth Science, Heliophysics, and Planetary Science. ULDB flights can circumnavigate the globe at any latitude, for durations upward of a hundred days to serve as "observatories floating on the edge of space." ULDB will serve as a test-bed for spacecraft instruments, with rapid testing of new technology for the Physical and Space Sciences with extended time near the edge of space.

D. Transformative Examples

Figure 5: Transformative Innovation (Image Credit: JPL Studio)

Figure 5 presents the Transformative Innovation Promising Practices, which bring improved outcomes by harnessing novel technology and novel organizational models. The list on the right in Figure 5 shows Transformative Innovation examples based on NASA's agency level strategic objectives, as outlined in the NASA Strategic Plan.

International Space Station: The International Space Station program is a current example of Transformative Innovation. The new technology and scientific achievements include on orbit integration of hardware segments that were built in multiple nations; repeated proximity operations with a variety of vehicles; logistical management of a supply chain that enables crew wellbeing and hardware maintenance; multiple long duration human space flight records;[xx] and hundreds of scientific experiences in the microgravity environment. The ISS program also includes many innovations in the organizational models. The international agreement that allows fives space agencies representing 15 nations to collaborate on the ISS program is a major non-technical innovation that justifies including ISS in the Transformative quadrant. The Intergovernmental Agreement on Space Station Cooperation was signed in 1998 and allows the partners to cooperate on human space flight missions with international crews.[xxi] Beyond the initial agreement, another non-technical innovation is the designation of the US segments on the ISS as a National Laboratory that is accessible for guest researchers. The Center for the Advancement of Science in Space serves as the manager that helps firms, government agencies and academic institutions in the US access opportunities to put experiments in the space environment via the ISS.

NASA expects to achieve new Transformative Innovation in the following areas, as we work to achieve current strategic objectives in science and exploration

Continuing to Pursue Fundamental Science Questions: The NASA Science Mission Directorate works to answer fundamental questions about the earth, our solar system and the universe. Here on earth, NASA uses sensors on land, in air and in space to study the dynamics of the earth system and try to understand how the earth is changing and how we expect it might change going forward.[xxii] As NASA studies the solar system, fundamental questions include, "How did our solar system originate and change over time?" and "What drives variations in the Sun, and how do these changes impact the solar system and drive space weather?"[xxiii] Looking further out to the university, we wonder "How did the universe begin and evolve; what is its destiny? How did life originate, and are we alone?" Part of answering these questions involves learning how to better observe and characterize planets around other stars, known exoplanets to see if they can harbor life. Answering these questions will have transformative impacts on our scientific understanding and on our human culture. We expect that in order to answer these questions, NASA will need to continue to adopt innovations that bring both novel technology and novel organizational models.

NASA's Journey to Mars: The current horizon goal for the human space flight is the Journey to Mars.[xxiv] NASA is developing the capability to explore Mars with humans, which will augment our current robotic exploration program that uses orbiters, landers and rovers to study Mars. In order to achieve the capability to send humans to live and work on Mars for months at time, NASA is developing new technologies and organizational approaches in heavy lift launch, habitation systems, environmental control and life support, human health and performance, interplanetary logistics, radiation protection, fire safety, autonomy, communication and in-space propulsion. The needs are described as technology goals, but implementing so many new technology capabilities successfully calls for organizational innovation as well.

III. THE INNOVATION LANDSCAPE AS A LEADERSHIP TOOL

The previous sections used the Innovation Landscape as a descriptive tool to identify similarities within Innovation Promising Practices based on whether they brought novel technology, organizational models or both. This section proposes that the Innovation Landscape can also be used as a leadership tool that helps define a thriving innovation culture. To provide additional context for the role of leaders to foster innovation culture, this section first presents recent milestones regarding the dynamics of NASA's internal culture of innovation. The focus here is not on NASA's role to spur innovation in the broader aerospace community; rather the focus is on the attitudes and behaviors of NASA employees as they pursue innovation in their daily work.

One key milestone in NASA's innovation history was an internal assessment completed in 2013 that explored concerns from employees about factors that could be barriers to an internal innovation culture. A team from the Office of the Chief technologist and the Chief Technologist Council used surveys, focus groups and interviews to collect employee perspectives on NASA's innovation culture. The assessment identified themes such as risk aversion and communication challenges as employee concerns about opportunities to pursue innovative ideas in their daily work. The assessment results also recommended practical approaches to reduce barriers to NASA employees practicing innovation, such as identifying physical workspace that fosters collaboration and looking for opportunities to streamline program and project management processes.

Since the 2013 assessment on employee concerns about innovation, a number of leadership initiatives have contributed to addressing the recommendations. One example is the Agency Culture Strategy prepared by NASA's Office of Human Capital Management in 2013.[xxv] The Agency Culture Strategy recommended fostering a culture of innovation by "recognizing and rewarding innovative performance, engaging and connecting the workforce and building model supervisors and leaders." One of the programs to reward innovative performance is the "Lean Forward/Fail Smart" award given by the Office of Human Capital Management.[xxvi] This award recognizes teams within NASA that pursue a risky project, manage the risk appropriately, fail during their early attempts and demonstrate learning from the failure. Applicants submit videos describing the project or activity in which they failed while taking a risk to implement an innovation.[xxvii] The Office of Human Capital Management also has several programs to emphasize training supervisors and leaders within the NASA workforce. The training helps leaders enable their employees and colleagues to pursue innovative ideas as part of their daily work. The training programs target employees at specific stages in their career development, for example, the FIRST (Foundations of Influence, Relationships, Success and Teamwork) training program for early career employees; Mid-Level Leader Program; LASER (Leveraging Agency Supervisory Excellence and Resilience) training for supervisors; and the Senior Executive Service Candidate Development Program. The Office of Human Capital Management uses all of these venues to help foster an innovative culture and organization that pursues Continuous, Disruptive, Revolutionary and Transformative innovation.

In reflecting on the dynamics described above, the Innovation Landscape provides an opportunity for NASA employees and leaders to help foster a strong innovation culture within the NASA workforce. Here are some examples of themes that the Innovation Landscape helps to reinforce.

Celebrate existing innovation. Innovation Landscape highlights the many innovative achievements of the NASA workforce and acknowledges the existing culture of innovation. One of the findings from innovation workshops with NASA senior leaders emphasized the value of communicating to the workforce that they are already innovating and asking how leaders can continue to equip employees to innovate.

Define innovation inclusively. The NASA Innovation Landscape presents a broader definition of innovation than that which is often used within NASA. The concept of innovation is often applied only to the examples in the Revolutionary quadrant, those that bring novel technology or apply new scientific discoveries. The Innovation Landscape contributes to an inclusive culture of innovation by inviting employees that work outside science and engineering fields to view themselves as innovative. NASA's Mission Support teams enable the agency's mission indirectly in areas such as finance, health & medical, safety, diversity & equal opportunity, education, international relations, legal, legislative affairs, communications, procurement, human capital, infrastructure, operations, and security. The NASA Innovation Landscape sends a message to the full workforce that creative ideas and improvements in these mission support offices are consider part of what makes NASA innovative. Many of the Disruptive Innovation Promising Practices described above come from these offices.

Allowing Appropriate Risk and Learning from Failure. The NASA Innovation Landscape is part of the discussion that allows leadership to consider how the agency's posture toward risk and failure impact our culture of innovation. Each quadrant of the Innovation Landscape invites a potentially different posture toward risk and failure. Continuous innovation allows experimentation with minor updates to existing methods. In the Continuous quadrant, there is little risk in trying a small variation that may bring improved outcomes. In the Disruptive, Revolutionary and Transformative quadrants, the risk of failure can be greater because the change from the old methods to the new is greater. At the same time, the potential reward from the innovation is also greater. NASA culture sometimes includes am emphasis on the traditional mentality from human spaceflight that "Failure is not an option." There are times when this is appropriate, as we emphasize the safely of human life during dangerous missions. The Innovation Landscape is a reminder that this mantra should not be universally applied to all innovation suggestions. As mentioned above, NASA's Office of Human Capital Management instituted an internal award to encourage employees to demonstrate what it means to accept risk appropriately and to learn from failure.

Connect top down agency vision with bottom up innovation progress: A closing observation is that agency leadership can facilitate local innovation within field center and offices in several ways. First, agency leadership can communicate about how local innovation activities foster the broad agency vision. Second, agency leadership can make it easier to share information about local innovation practices with the broader workforce. Not every local innovation is appropriate to scale broadly, but many ideas developed at one field center or in one office can be adapted both others. Discussions among directors of field centers and agency-level offices revealed that many employees are unaware of the innovative practices used at different NASA locations. NASA's field centers and other installations are scattered geographically across the United States. The NASA leadership team is putting in place several mechanisms to improve coordination and information sharing across the centers. One of these is to identify Capability Leaders that represent specific technical or scientific disciplines. These Capability Leaders will physical work at one NASA location, but they will coordinate a virtual community of practice across the agency and ensure communication among those interested in their topic.[xxviii]

This paper has introduced an Innovation Landscape that provides a platform for description, celebration and communication by leadership. The long term science and exploration objectives for NASA will require innovation across the landscape, including Transformative. NASA has many examples of Innovative Promising Practices, and we continue to look for opportunities to strengthen our culture of innovation to ensure that we achieve fundamental objectives such as the Journey to Mars and the search for life beyond earth.

IV. ACKNOWLEDGEMENTS

The authors acknowledge the valuable contributions of several team members that helped to make this paper possible. Kira Blackwell and Catherine Coleman of the NASA Headquarters Office of the Chief Technologist collaborated closely in Innovation Initiatives and data collection. The JPL Studio team, including Dan Goods, Joseph Harris, Lizbeth Barrios de la Torre created the visualization of the Innovation Landscape. The members of the NASA Senior Management Council and the Office of the Administrator provided valuable input regarding the Promising Innovation Practices. Also, several subject matter experts provided review of the text about their specific office activities in Section II.

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Mission/Theme	FY 2016 Enacted	FY 2017 PBR	FY 2017 House Markup	FY 2017 Senate Markup	FY 2017 CR 1 with .496% Rescission (P.L. 114-223) Oct. 1 - Dec. 09	FY 2017 CR 2 with .1901% Rescission (P.L. 114-254) Dec. 10 - Apr. 28	Total thru April 28, 2017
Science	**$5,589.4**	**$5,600.5**	**$5,597.0**	**$5,395.0**	**$1,066.7**	**$2,140.0**	**$3,206.7**
Earth Science	$1,921.0	$2,032.2	$1,690.0	$1,984.0	$350.8	$750.8	$1,101.6
Planetary Science	$1,631.0	$1,518.7	$1,846.0	$1,355.9	$266.1	$568.5	$834.6
Jupiter Europa	*$175.0*	*$49.6*	*$260.0*		*$33.4*	*$67.0*	*$100.4*
Astrophysics	$767.6	$781.5	$792.9	$807.0	$150.6	$329.8	$480.4
Heliophysics	$649.8	$698.7	$698.7	$678.7	$130.6	$214.9	$345.5
James Webb Space Telescope	$620.0	$569.4	$569.4	$569.4	$168.7	$276.0	$444.7
Aeronautics	**$640.0**	**$790.4**	**$712.0**	**$601.0**	**$122.1**	**$245.0**	**$367.2**
Space Technology	**$686.5**	**$826.7**	**$739.2**	**$686.5**	**$131.0**	**$262.8**	**$393.9**
Restore-L	*$133.0*	*$130.0*		*$130.0*	*$25.4*	*$50.9*	*$76.3*
Exploration[1/]	**$4,030.0**	**$3,336.9**	**$4,183.0**	**$4,330.0**	**$769.1**	**$1,761.0**	**$2,530.3**
Exploration Research and Development	$350.0	$477.3	$404.0	$396.0	$66.8	$134.0	$200.8
Exploration Systems Development	$3,680.0	$2,859.5	$3,779.0	$3,934.0	$702.3	$1,627.2	$2,329.5
Orion	*$1,270.0*	*$1,119.8*	*$1,350.0*	*$1,300.0*	*$242.4*	*$589.4*	*$831.8*
SLS - Launch Vehicle Development	*$2,000.0*	*$1,310.3*	*$2,000.0*	*$2,150.0*	*$381.7*	*$845.7*	*$1,227.4*
SLS/EUS	*$85.0*		*$250.0*	*$300.0*	*$16.2*	*$103.7*	*$120.0*
SLS - Exploration Ground Systems	*$410.0*	*$429.4*	*$429.0*	*$484.0*	*$78.2*	*$192.0*	*$270.2*
Space Operations	**$5,029.2**	**$5,075.8**	**$4,890.3**	**$4,950.7**	**$959.8**	**$1,925.5**	**$2,885.3**
Education	**$115.0**	**$100.1**	**$115.0**	**$108.0**	**$21.9**	**$44.0**	**$66.0**
EPSCOR	*$18.0*	*$9.0*	*$18.0*	*$18.0*	*$3.4*	*$6.9*	*$10.3*
National Space Grant	*$40.0*	*$24.0*	*$40.0*	*$40.0*	*$7.6*	*$15.3*	*$22.9*
Safety, Security, and Mission Services	**$2,768.6**	**$2,836.8**	**$2,835.4**	**$2,796.7**	**$528.4**	**$1,060.0**	**$1,588.4**
Construction & Envrmtl Compl Restoration[2/]	**$388.9**	**$419.8**	**$398.0**	**$400.0**	**$74.2**	**$223.6**	**$297.8**
Hurricane Matthew Supplemental						*$74.7*	*$74.7*
Inspector General	**$37.4**	**$38.1**	**$38.1**	**$38.1**	**$7.1**	**$14.3**	**$21.5**
NASA FY 2017	**$19,285.0**	**$19,025.1**	**$19,508.0**	**$19,306.0**	**$3,680.5**	**$7,676.4**	**$11,357.1**

1/ NASA has requested the following anomaly adjustments that exceed the FY 2017 continuing resolution rate of operations (but do not represent an increase in annual budget) per Section 153 of P.L. 114-254: Orion +103.2M, SLS +80.0M, and EGS +35.0M.

2/ Additional emergency no-year funding of $74.7M to cover a portion of NASA's estimated requirements related to Hurricane Matthew repairs per P.L. 114-254.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHARTER OF THE

INTERNATIONAL SPACE STATION ADVISORY COMMITTEE

1. Official Designation: The International Space Station (ISS) Advisory Committee (the "Committee").

2. Authority: Having determined that it is in the public interest in connection with the performance of the National Aeronautics and Space Administration (NASA) duties under law, and with the concurrence of the General Services Administration, the NASA Administrator hereby renews and amends the Committee's charter, pursuant to the Federal Advisory Committee Act (FACA), as amended, 5 U.S.C. App.

3. Scope and Objectives: The Committee shall draw on the expertise of its members and other sources to provide advice and recommendations to NASA on all ISS aspects related to safety and operational readiness, utilization, and exploration.

4. Description of Duties: Specific areas for review and/or assessment by the Committee may include spaceflight operations, including rendezvous, proximity operations, and docking procedures; crew, controller, and support training; aerospace systems test and verification procedures; aerospace structures, loads, and materials; aerospace medicine, including crew health; program and project management, including spaceflight safety and mission assurance strategies; the readiness of significant ISS missions; and the ability of Soyuz to support ISS operations. The Committee has also been tasked with assessing the options for using the ISS for future exploration. In addition, the Committee shall address additional issues and/or areas of interest identified to it by the NASA Associate Administrator (AA) for the Human Exploration and Operations Mission Directorate (HEOMD).

The Committee shall reassess its current makeup, operations, and approach to providing advice and recommendations to NASA in order to remain effective and to respond to shifting program needs in this new era of ISS operations, utilization, and exploration and shall submit a report to the NASA AA for HEOMD within the timeline specified by the NASA AA for HEOMD.

The Committee shall conduct independent or joint fact-finding meetings with counterpart international advisory review groups, including the State Space Corporation Roscosmos Advisory Expert Council. These fact-finding meetings may result in signed minutes ("summaries of discussion") or other joint documents.

The Committee shall function solely as an advisory body and will comply fully with the provisions of FACA.

5. Official to Whom the Committee Reports: NASA AA for HEOMD.

6. Support: Travel funds for the Committee non-Federal members shall be provided by the NASA Office of International and Interagency Relations (OIIR). Travel funds for Committee Federal members shall be provided by their own respective NASA organizations. Operating funds for technical and administrative support, nonmember consultants, subject-matter experts, and their respective travel shall be borne by the NASA HEOMD, as required. Operating funds for Federal staff support, including travel, shall be provided by OIIR.

7. Estimated Annual Operating Costs and Staff Years: The estimated annual operating costs total approximately $800,000, including staff and contractor support. The estimated staff support is 0.3 Full-Time Equivalent (FTE).

8. Designated Federal Official (DFO): The Executive Director of the Committee shall be a NASA Federal employee appointed by the NASA AA for HEOMD, in consultation with the NASA AA for OIIR, and shall serve as the DFO. The DFO will approve or call all of the advisory committee's meetings, prepare and approve all meeting agendas, attend all committee meetings, adjourn any meeting when the DFO determines adjournment to be in the public interest, and chair meetings when directed to do so by the official to whom the advisory committee reports. The DFO shall also work closely with the NASA Office of General Counsel (OGC) to ensure that all potential members (i.e., nominees) for the Committee, subcommittees, and task forces complete the mandatory Office of Government Ethics financial disclosure reports and receive full ethics vetting and clearance by OGC prior to formal appointment by NASA. In addition, the DFO shall ensure that all appointed members of the Committee, subcommittees, and task forces shall file the mandatory financial disclosure reports (annual and otherwise) and shall receive the mandatory annual ethics training by OGC. The DFO shall refer any issues that may arise relating to potential conflicts of interest to OGC for resolution.

9. Estimated Number and Frequency of Meetings: The Committee shall meet approximately two times a year or as required by the NASA AA for HEOMD to fulfill its responsibilities. Meetings shall be open to the public unless it is determined that the meeting, or a portion of the meeting, will be closed in accordance with the Government in the Sunshine Act or that the meeting is not covered by FACA.

10. Duration: This charter shall be effective for a one-year period.

11. Termination: This charter shall terminate on September 30, 2017, unless renewed or terminated earlier by the NASA Administrator.

12. Membership and Designation: The chair, deputy chair, and members of the Committee shall be appointed by the NASA AA for HEOMD. The Committee shall consist of 6 to 12 full voting members. Membership shall be comprised of experts in disciplines that permit the assessment of any aspect of the ISS program. These experts are Special Government Employees (SGEs) and Regular Government Employees. In addition, consultants or subject-matter experts may be called in on a temporary basis to assist the Committee when unique or additional expertise is required. The term of membership shall be for the duration of this charter. The

NASA AA for HEOMD shall ensure a balanced representation in terms of the points of view represented and the functions to be performed.

Voting members include SGEs, as well as NASA civil servants, including the NASA Deputy Chief for Safety and Mission Assurance and a representative from the NASA Astronaut Office. The SGEs are not compensated, but are reimbursed for their travel and per diem expenses. Nonmember personnel, such as other NASA employees and contractor personnel, may provide technical expertise and other support to assist the Committee, as needed, in a non-voting capacity.

13. Subcommittees: Subcommittees, task forces, and/or working groups (WGs) may be established by NASA to conduct studies and/or fact-finding requiring an effort of limited duration. Such subcommittees, task forces, and WGs will report their findings and recommendations to the Committee. However, if the Committee is terminated, all subcommittees, task forces, and WGs will terminate.

14. Recordkeeping: Records of the Committee, formally and informally, shall be handled in accordance with General Records Schedule 6.2 or other approved Agency records disposition schedule. These records shall be available for public inspection and copying, subject to the Freedom of Information Act, 5 U.S.C. 552.

15. Filing Date: This charter shall become effective upon the filing of this charter with the appropriate U.S. Senate and House of Representatives oversight committees.

Charles F. Bolden, Jr.
NASA Administrator

SEP 28 2016
Filing Date

NASA International Space Station Advisory Committee (NISSAC)

On May 2, 1994, NASA established the Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions. The purpose of the Task Force (also referred to as the Stafford Task Force after its Chair, Lt. General Tom Stafford) was to review the safety, planning, training, rendezvous/docking, operations, and management of the Shuttle-Mir Program and report back to the NASA Administrator, Dan Goldin and the NASA Advisory Council (NAC). Following the Gore-Chernomyrdin Commission that was held later that year, the Stafford Task Force collaborated with an advisory committee of the Russian Space Agency led by Vladimir Utkin to conduct a joint review on issues of safety and reliability. In 1998 the Stafford-Utkin Joint Commission turned its attention to safety and operational readiness of the ISS. In 1999 the name of the Stafford Task Force was changed to the NASA Advisory Council Task Force on ISS Operational Readiness and continued to report to the NAC, Administrator Goldin and later Administrator Sean O'Keefe. Under NASA Administrator Mike Griffin, the Task Force was enhanced and chartered as a Federal Advisory Committee which is renewed annually. The name was changed to the NASA ISS Advisory Committee and the reporting structure placed it under the direction of the Associate Administrator (AA) for the Human Exploration and Operations Mission Directorate (HEOMD). General Stafford remains the chairman.

Specific areas for review and/or assessment by the Committee include space flight operations, rendezvous, proximity operations, and docking procedures; crew, controller and support training; aerospace systems test and verification procedures; aerospace structures, loads, and materials; aerospace medicine, including crew health; program and project management; including space flight safety and mission assurance strategies; the readiness of significant ISS missions; and ISS visiting vehicles and crew.

The Committee conducts independent or joint meetings with counterpart international advisory review groups, including the Russian Federal Space Agency's Advisory Expert Council. The meetings result in signed summaries of discussion or other joint documents. The Committee does not represent NASA or the US Government, and does not conduct foreign relations during any joint meetings with international advisory review groups.

The Committee meets approximately two times a year or as required by the NASA AA for HEOMD. Meetings include both open and closed sessions. The Committee reports directly to the NASA AA for HEOMD, while administrative support including an Executive Director, is provided through the Office of External Relations (OER).

Non-Federal Committee members travel on Invitational Orders. HEOMD provides operating funds for technical and administrative support, nonmember consultants, subject-matter experts, and their respective travel. Operating funds for Federal staff support, including travel is provided by OER.

Major Accomplishments

- Developed a solid and cordial working relationship with counterparts at the Russian Federal Space Agency during Phase I-Shuttle-Mir Program.
    - Investigated the collision of Progress M-34 with Mir Spektr Module.
    - Investigated the Solid Fuel Oxygen Generator Fire on Mir.
    - Reviewed and assessed planning and management of Medical Support, Crew Health Status Evaluation and Preventive and Rehabilitative Measures.
    - Reviewed and assessed Habitation Environment Monitoring.
    - Reviewed and assessed Joint Training Issues.
    - Reviewed and assessed MCC-H/MCC-M Interaction.
    - Reviewed and assessed Joint EVA's by Astronauts and Cosmonauts.

- Reorganized into the NASA Advisory Council (Stafford) Task Force (TF) – Rosaviakosmos (Anfimov) Advisory Expert Council (AEC) Joint Commission from April 1998 through the Phase II program to ensure that the ISS remains safe and operationally ready to support its crews.
    - Proton Launch Vehicle Assessment- the TF-AEC Joint Commission engaged in a detailed review and discussion of the actual Utkin Russian Proton Failure Investigative Committee Report.
    - TF-AEC Joint Commission's assessment of the safety and operational readiness issues of flying a non-professional cosmonaut to the ISS during the Soyuz 2 taxi flight (Tito flight).
    - Conducted reviews of each Expedition Crew's training and reported on the readiness of the new crew prior to launch to ISS.
    - The Joint Commission reviewed and assessed numerous areas:
        - Crew Exercise Devices (TVIS/TVIS 2).
        - Lead Center between MCC-H and MCC-M.
        - Operations (Flight) Planning.
        - ISS Systems Anomalies.
        - Environmental Control and Life Support System (ECLSS).
        - Batteries.
        - Caution and Warning (C/W) Systems.
        - Guidance, Navigation, and Control (GNC).
        - Onboard Computers.
        - Software (maturity).
        - Crew Training.
        - Trainer Equipment-hardware & software.
        - Common Language.
        - Testing philosophy.
    - Conducted reviews of the plan to bring the ISS to a 6 Person Crew.
    - Conducted reviews of the ISS program's plan to integrate Commercial Cargo Vehicles to support ISS.
    - Conducted reviews of the ISS program's plan to integrate Commercial Crew Vehicles into the support of the ISS.
    - Identified areas of concern for the Commercial Crew vendors to re-

evaluate and investigate prior to launching the first crewed vehicles.

Membership Status

The AA for HEOMD appoints the Chair and members of the Committee. The current Committee has 11 full-voting members who serve as Special Government Employees (SGE). Voting members include persons not employed by NASA, as well as three Agency employees -- the NASA Deputy Chief for Safety and Mission Assurance, a representative from the Astronaut Office and a representative from the Human Health and Performance. Non-voting members include other NASA employees who may support the Committee. Members not employed by NASA are unpaid volunteers, but are reimbursed for their travel and per diem expenses.

Meidinger, Jolene A. (HQ-LP020)

From: Meidinger, Jolene A. (HQ-LP020)
Sent: Tuesday, December 20, 2016 8:48 PM
To: Chris Shank; Jeff Waksman
Subject: FW: request for NASA badging (Transition Team)

FYI. I will share the same pre-coordination information as I did with other team members, but must wait for WH notification before we can execute. /Jolene

Sent from my Windows 10 phone

From: Charles Miller
Sent: Tuesday, December 20, 2016 6:30 PM
To: Meidinger, Jolene A. (HQ-LP020)
Subject: request for NASA badging (Transition Team)

Jolene,

As you may know, I have been recently added to the NASA Landing Team.

I know that you can not begin the process until you receive the green light from the White House.

I would like to set up a phone call on the morning to discuss the process for after that happens.

Are you available between 9 am and 10 am to talk by phone?

Best,

- Charles

Charles Miller
President
NexGen Space LLC

Pursuit of Scientific Knowledge and Discovery

Discover

Background:

Since NASA's inception, scientific discovery about our Earth, the Sun, the solar system and the universe beyond has been an enduring purpose of the Agency. Through its missions and sponsored research, NASA provides access to the farthest reaches of space and time and essential information about our home planet. We seek to solve the mysteries of the Universe and to better prepare for continued journeys beyond Earth. Our integrated programs, satellites, technology development and research spearhead humanity's advances toward three overarching objectives.

Safeguarding and improving life on Earth. The Earth - the only planet known to harbor life - is an immensely complex system. Understanding the Earth and its environment requires knowledge not only of individual physical, chemical, biological and thermal processes on the land and within the ocean and atmosphere, but also insight into the connections between processes. Only from the vantage point of space can we make the necessary simultaneous measurements of many different quantities - all with high accuracy, global coverage, high resolution and frequent sampling over long periods of time. NASA satellites drive research by measuring and monitoring nearly every important aspect of atmospheric motion and composition; land cover, land use and vegetation; ocean currents, temperatures and upper-ocean life; and ice on land and sea. Combining the measurements through interdisciplinary research, SMD funded scientists quantify the global and regional exchanges between air, land and sea, and provide the objective foundations for, and track the impacts of, policy decisions. Just as NASA's technology developments and satellites have revolutionized our knowledge of the Earth, our Earth research and applications programs transform the measurements and the knowledge into focused, efficient information that can be used by non-scientists and scientists alike to improve the lives of every human being. In addition, NASA's suite of missions provides key situational awareness to address the triggers and impacts of environmental change and natural hazards across the globe.

The Sun is the source of energy allowing life to thrive on Earth. But there is still much we don't understand about our star, including the internal processes of heating and the build-up and eventual eruptions of high-energy particles that sometimes impact our lives on Earth in the form of solar storms. These storms can disrupt our communications and navigation capabilities, disable satellites, cause power outages and pose a challenge for human space exploration. NASA is at the forefront of space weather research. In partnership with NOAA and the Air Force, we work to better prepare for the impacts that solar storms can have on our daily lives.

NASA is also a leader in the global effort to identify, track, and characterize near Earth objects and to avoid or mitigate threats from potentially hazardous bodies. Part of this effort is developing a joint mission with the European Space Agency to demonstrate the technology needed to deflect hazardous asteroids while continuing to collaborate with other agencies to explore alternative responses to all possible asteroid threats.

The search for extraterrestrial life. The discovery of life that has independently arisen somewhere in the universe outside of Earth would be among the most profound scientific findings of all time, and NASA is closing in on this discovery. SMD missions have demonstrated that Mars was once habitable and that large, salt-water oceans exist today under multiple ice-covered moons in the outer solar system, such as Europa. Mars and Europa are two of the most likely places in the solar system to find life, so NASA will look for possible signatures of past life and collect samples at Mars, as well as build a mission to assess Europa's habitability.

Yet, one of the most overwhelming space discoveries in recent decades has been the detection of thousands of planets orbiting stars other than the Sun - called exoplanets. Exoplanet observations to date have focused on measuring size, mass, and orbital properties. NASA missions have shown that an estimated 1/5 of all Sun-like stars have a habitable planet in orbit (described as rocky, not too hot, not too cold). Of the billions of habitable planets in our Galaxy, is there even one similar to Earth, an "Earth 2.0," and where is the nearest one? Within a few years, NASA missions are poised to find the nearest habitable exoplanets. The next step is to characterize the atmospheres of such planets, just as we do with the Earth, allowing us to assess their habitability and search for telltale chemical signs of life. The James Webb Space Telescope and the next generation of our space telescopes will be able to do this for the closest and brightest exoplanets. We cannot yet image Earth-like exoplanets, but NASA is working on the technology to make this possible.

Fundamentals of the Universe. How does the universe work? How did the familiar night sky of galaxies, stars and planets come to be? These are the questions that NASA missions are answering. NASA missions can detect the first galaxies and first stars after the Big Bang, show how galaxies evolved through time, and track how the elemental constituents of life were created in stars and distributed by supernova explosions to form new stars and planets (and us). NASA spacecraft also discover and help explain physical phenomena, including fundamental processes like the effect of the Earth's rotation on space and time, as well as more localized processes such as cloud formation and dynamics, atmospheric escape and magnetic reconnection at Earth and other planets. In addition, NASA missions have shown that only five percent of the universe is made of normal matter; the rest is dark energy, which drives the accelerating expansion of the universe, and dark matter, which provides the gravity that holds galaxies together. The recent detection of gravitational waves opens a new window on the universe; and NASA is working to understand how these waves are created as well as develop a space observatory to detect merging black holes across the universe.

NASA explores the most extreme environments of Earth and space and as such is an engine of innovation, leveraging technologies to solve scientific problems. Our sounding rockets, balloons, aircraft and small satellite initiatives, provide low-cost opportunities for innovative technology demonstration and complementary observations.

Challenges/Risks:

Maintaining a balanced program amongst competing disciplines, mission sizes and participating stakeholders is a challenge. With the broad and important range of science activities and areas, along with stakeholders in each, tensions arise over priorities and the emphasis NASA places in these areas at times. For example, currently, there is Congressional interest in flying a Europa orbiter and lander in close succession, while NASA and the scientific community feel greater space between these missions would be more appropriate. There is also a divergence by stakeholders over the importance of Earth Sciences within NASA versus the priority that should be place on other parts of the science portfolio. Integrating the search for extraterrestrial life and Mars robotic exploration into the agency's overall plan, particularly with regards to human exploration and technology investments is another challenge and risk. For example, there is no identified Mars robotic mission after 2020, despite U.S. historical leadership and presence at Mars, and the increasing signs that life may have been present there. Another challenge and risk has been preserving mission cadence while a dynamic, costly launch vehicle industry creates uncertainty.

Mitigations/Actions:

- Over the past year, working within the Agency Integration framework, SMD has been working, with HEOMD and STMD, on the integration of human exploration and scientific objectives as part of NASA's LEO-Mars Strategy. This effort is helping to align and coordinate plans, investments, and aids in external stakeholder engagement.
- NASA's Launch Services Program is creating more opportunities to on-ramp commercial launch providers, and with the advent of SLS and the new Venture Class Launch Services initiative jointly developed by HEOMD and SMD, other opportunities are emerging that may allow a greater launch cadence and mission opportunities.
- NASA's approach to Earth system science incorporates global and regional scale inputs, multi-decade data continuity plans, and data from interagency, international, industry/commercial and academic partners, allowing us to safeguard and improve life on Earth

National Aeronautics and Space Administration

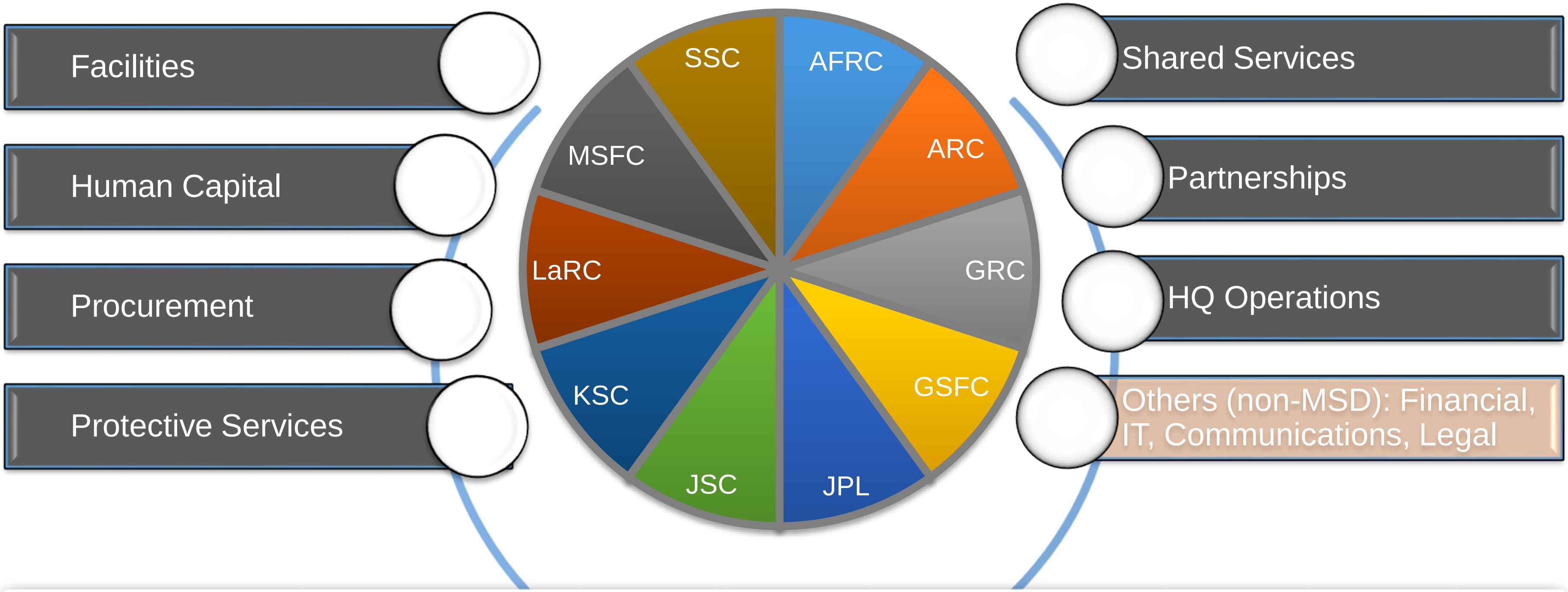
Mission Support Overview for the ART

December 21, 2016

"Enabling Mission Success"

Mission Support Directorate Introduction

Mission Support Directorate (MSD) enables mission success for NASA



MSD strategy is to provide effective:

- ***Stewardship of resources by reducing costs and revitalizing capabilities***
- ***Integration of capabilities across NASA Centers & mission support areas***
- ***Optimization of operations by moving toward a model of interdependence***

Major Changes Over the Past 8 years

PEOPLE

- 5 consecutive years "best place to work"
- +4% increase in proportion of scientists/engineers
- +7% increase in number of early career hires
- 90% of student/intern converted
- 16% (-1,215) reduction to civil service (post shuttle)
- 30% (-15,000) reduction to contractors (post shuttle)

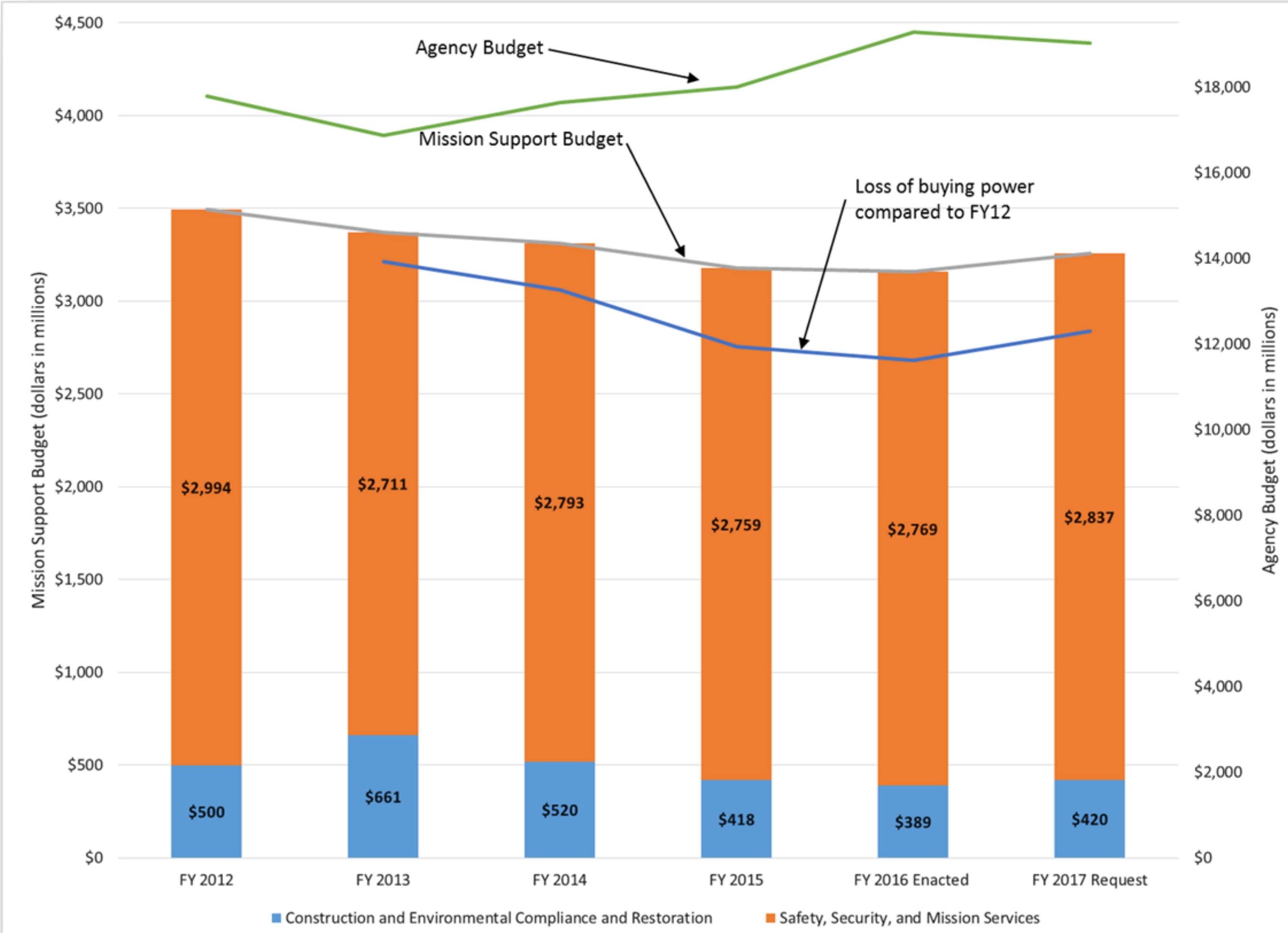
FACILITIES

- 577 buildings disposed
- 3.6M square feet disposed
- 5 property sites disposed
- 2M sf of sustainable office, lab, and other added
- 790K renovated sq. feet of sustainable office space
- $150M reduction in deferred maintenance

Producing results towards a more efficient operating model that maintains a minimum set of capabilities to meet mission objectives

Mission Support Budget Trends

Mission Support Directorate



Mission Support budget buying power has decreased more than 10% since FY12 in an environment of increasing mission requirements

Mission Support Budget Elements

FY17 Total Mission Support Budget Request ($3,257M)

Facilities $847M

- Construction & repair of institutional facilities
- Facility, roads, and grounds maintenance
- Facility management & operations
- Utilities
- Custodial support

Information Technology $506M*

- Cyber security
- Network services
- E-mail, calendaring, & software management
- Business & management systems
- IT investments

Technical Capabilities $656M

- Independent technical authority
- Independent verification & validation of mission software
- Management of strategic capabilities
- Scientific and engineering tools, laboratories, & support
- Construction of specialized facilities

Workforce and Mission Services $964M

- Recruitment & hiring
- Workforce planning, training & development
- Agency/Center leadership, EO/Diversity, legal
- Acquisition and contract management
- Financial management
- Logistics and Center operations

Safety, Security, Environment $284M

- Institutional safety
- Aviation safety
- Emergency management
- Security & fire protection
- Environmental management

** Does not include Mission IT*

Mission Support Risks and Challenges

Mission Support Directorate

People

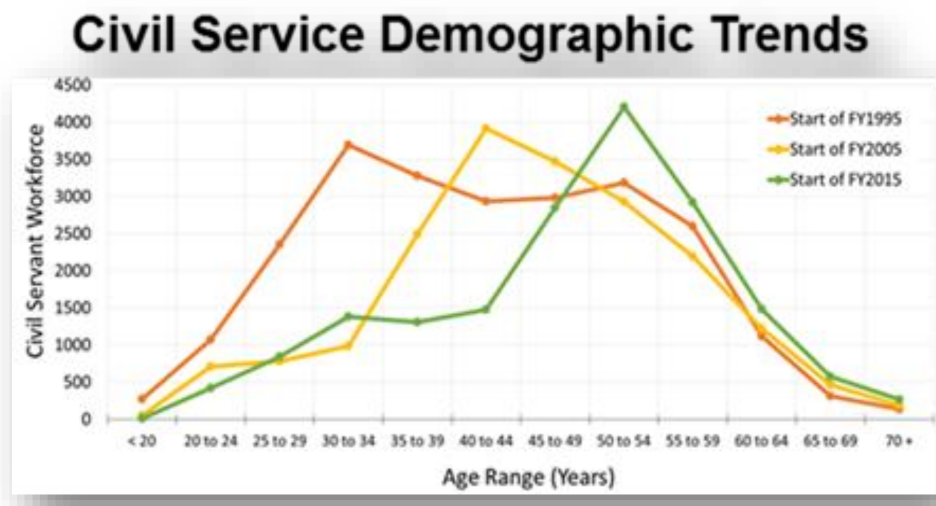
- *Constrained hiring limits ability to recruit, promote, and retain engineers and scientists, especially female and minorities*
- *NASA has thousands of employees housed in degraded facilities*

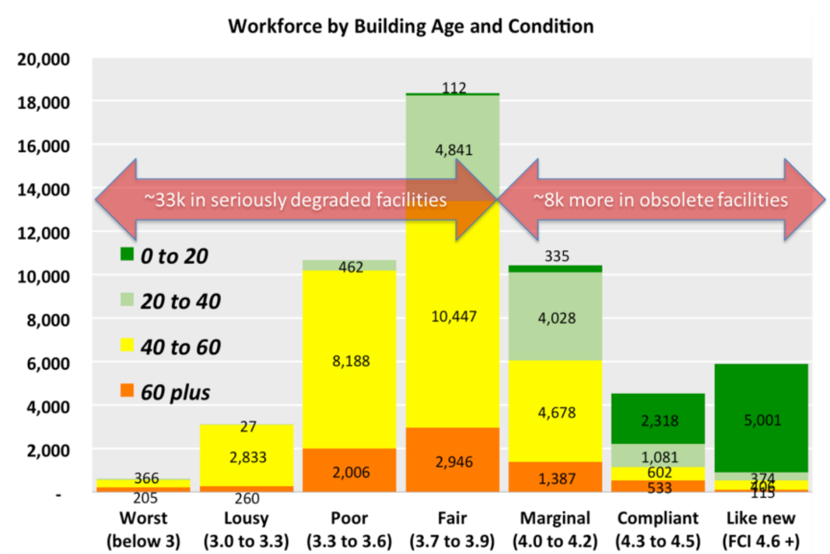
Infrastructure

- *Assets are aging, obsolete and degraded*
- *Maintenance underfunding increases reactive repairs*

Technical Capabilities

- *Deferred maintenance and lack of funds for ongoing investment in critical agency facilities & laboratories increases likelihood of test failures that negatively impact mission objectives*





Strategic Initiatives for the next 4 years

Revitalizing Facilities

- Operate in fewer more efficient facilities
- Reduce the footprint by demolishing unneeded older/costly facilities
- Invest in energy savings & renewable energy projects to offset cost of operations

Business Services Assessment

- Evaluate the health of associated capabilities
- Review existing mission support practices
- Identify opportunities to optimize performance

Strategic Workforce Management

- Define near and long term Center work assignments
- Integrate across Centers and Mission Directorates
- Serve as basis for hiring and reshaping the workforce

Evolving Capability Leadership

- Shape capabilities needed for future missions objectives
- Enable new capability management model
- Revitalize key infrastructure capabilities

Shared Services

- Expand Centralization of business services at the NSSC
- Enable more standard services across Centers
- Transition to Federal Shared Services provider

MSD leadership of an integrated and focused strategy to ensure mission support effectively enables NASA mission objectives

Strategic Initiative: Business Services Assessment Optimizing for Success

Stronger Information Technology

- Advancing Technology – consolidate management of network transformation
- Saving Resources – enable a federated/virtual approach for data centers
- Standardization – establish a suite of common collaboration tools for employees

More Efficient Procurements

- Reducing Redundancy – expand use of strategic sourcing contracts across NASA
- Strategic Assignments – leverage centers for admin of multi-center contracts
- Reducing Time – streamline and reduce lead-times for contract selection practices

Advanced Human Capital

- Strategic Planning – develop long-term workforce plans/strategy for NASA
- Modernize Recruiting – leverage NASA brand and modernize recruiting
- Saving Resources – consolidate staffing and classification roles at NSSC

Leveraged Facility Operations

- Strategic Planning – develop an integrated Agency master plan
- Enable Divestments – incentivize divestments through demolition and leasing
- Leverage Others – fully consider use of other agencies for construction management

More Efficient and Effective Budget Processes

- Budget formulation– streamline budget formulation to balance benefit/risks
- Resources management– enable efficiencies through consolidation of under CFOs
- Integration– leverage Program Planning and Control (PP&C) capabilities across Centers

Strategic Initiatives: Improving and Optimizing Administrative Functions Through Shared Services

Background

- Services are provided in the areas of Financial Management, Human Resources, Procurement, and Enterprise IT Contract Administration.
- NSSC is a Working Capital Fund fee-for-service
- Operational March 1, 2006
- $33M LEED Silver Office Building funded/owned by State of Mississippi, located on site at the Stennis Space Center

Progress

- Agency investment paid back in 4.2 years
- Customer Service Ratings in excess of 95% annually
- The NSSC is held up as a model within the community
- National Center for Critical Information Processing and Storage (NCCIPS) (Tier 3 Compliant Data Center) transitioned to NSSC April 2015, which is utilized by other Federal Agencies
- More than 60 activities have transitioned to date
- Recent additions to the NSSC portfolio include: Suitability and Reinvestigations; Workers/Unemployment Compensation; and Simplified Acquisition Threshold purchases
- Upcoming service transitions include: HR Classification, Staffing and Extended TDY support

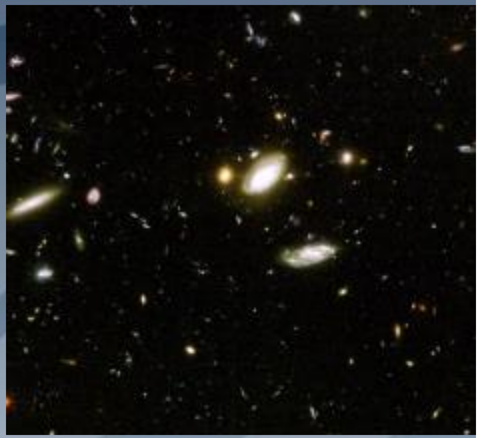
Tactical Topics of Interest in FY 2017

- Formalize implementation planning for transition of NSSC to Federal Shared Services
- Begin consolidation of staffing and classification support at the NSSC
- Initiate BSA deep dives for Technical Authority and Protective Services
- Develop mission support operating model decision framework

National Aeronautics and Space Administration

Astrophysics

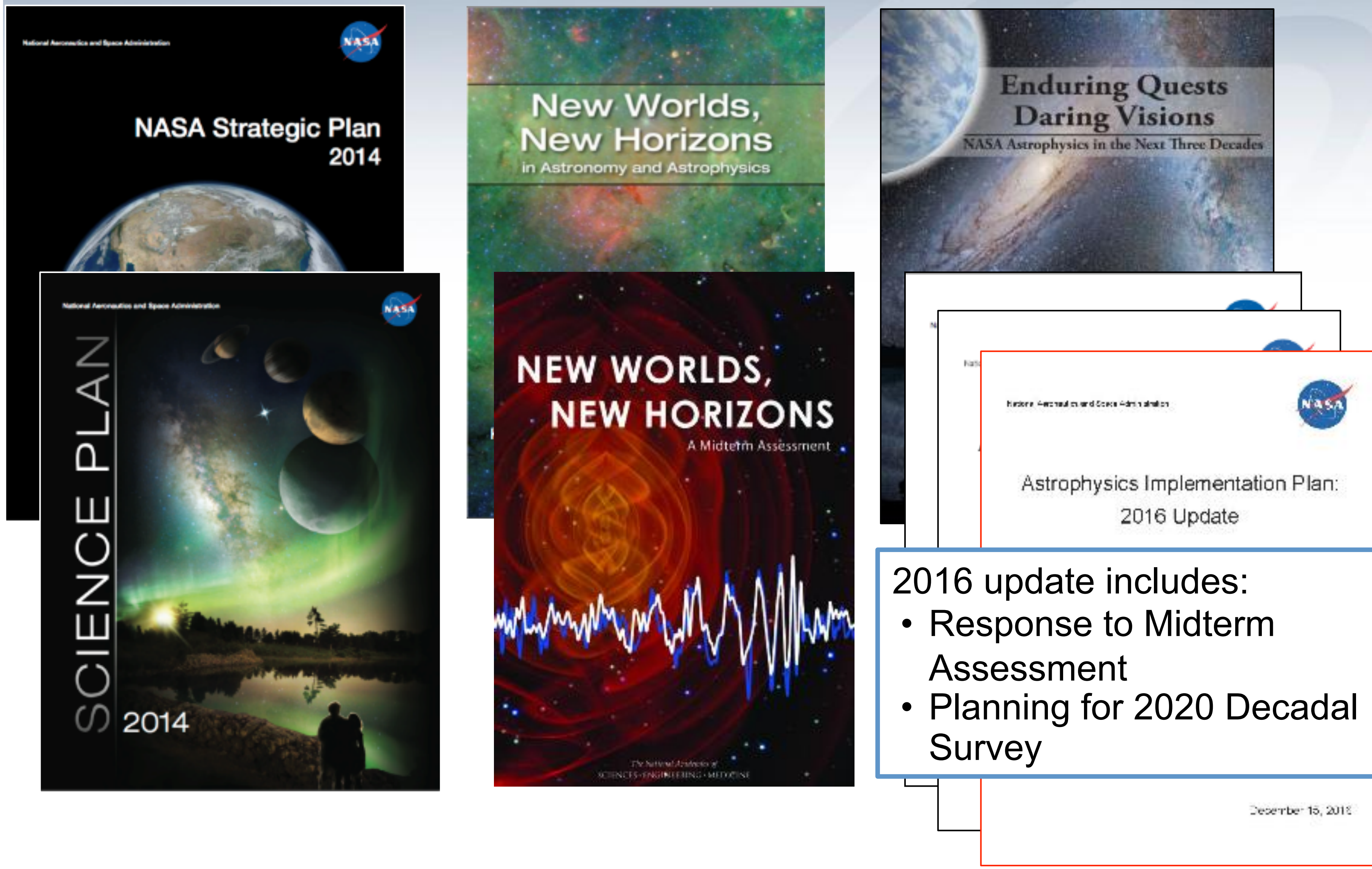


Overview for NASA Agency Review Team
December 20, 2016

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

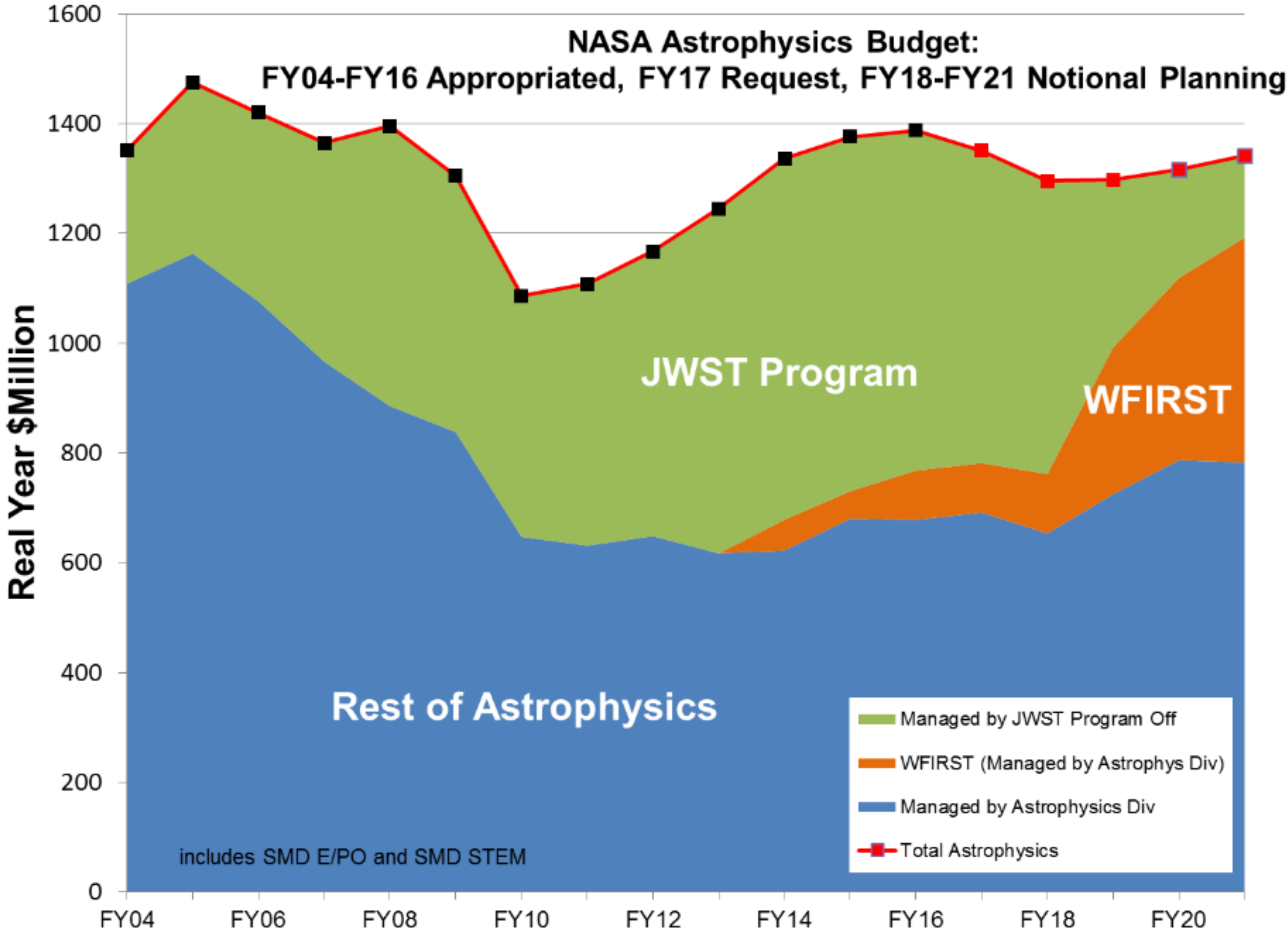
Astrophysics Driving Documents



2016 update includes:

- Response to Midterm Assessment
- Planning for 2020 Decadal Survey

http://science.nasa.gov/astrophysics/documents

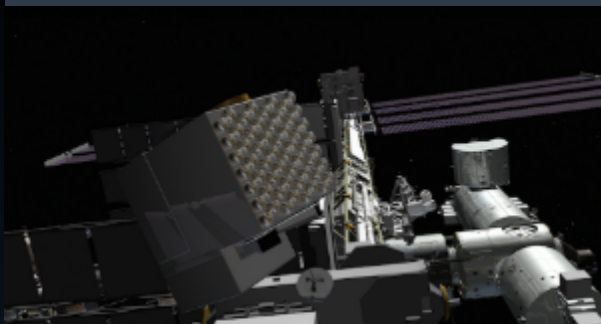


Unchanged since February 2016

Astrophysics Missions in Development

ISS-NICER
4/2017

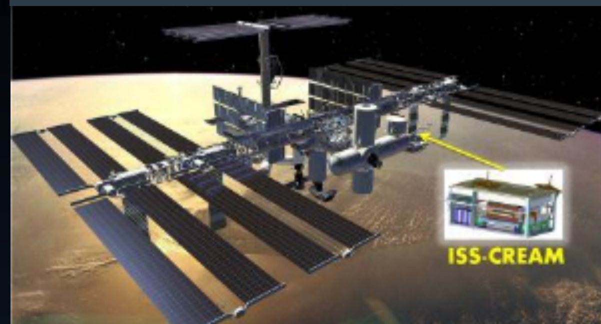
NASA Mission



Neutron Star Interior
Composition Explorer

ISS-CREAM
6/2017

NASA Mission



Cosmic Ray Energetics
And Mass

TESS
12/2017

NASA Mission

Transiting Exoplanet
Survey Satellite

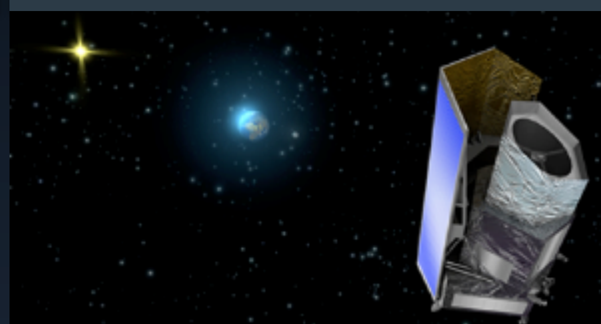
Webb
10/2018

NASA Mission

James Webb
Space Telescope

Euclid
2020

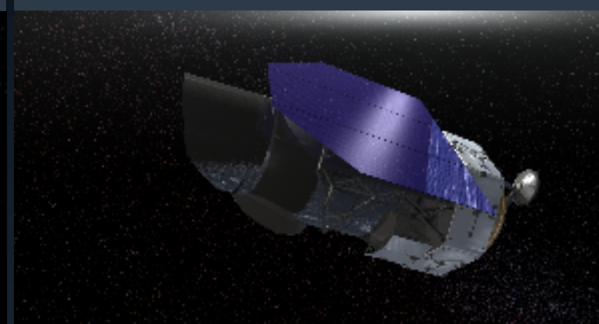
ESA-led Mission



NASA is supplying the NISP
Sensor Chip System (SCS)

WFIRST
Mid 2020s

NASA Mission



Wide-Field Infrared
Survey Telescope


Spitzer
8/25/2003
Kepler
3/7/2009
Formulation
Implementation
Primary Ops
Extended Ops
LISA Pathfinder (ESA)
12/3/2015
Webb
2018
WFIRST
Mid 2020s
Euclid (ESA)
2020
XMM-Newton (ESA)
12/10/1999
TESS
2017
Chandra
7/23/1999
NuSTAR
6/13/2012
SMEX
(Jan 2017)
Swift
11/20/2004
Fermi
6/11/2008
Hubble
4/24/1990
ISS-NICER
2017
ISS-CREAM
2017
SOFIA
Full Ops 5/2014
Revised
December 17, 2016