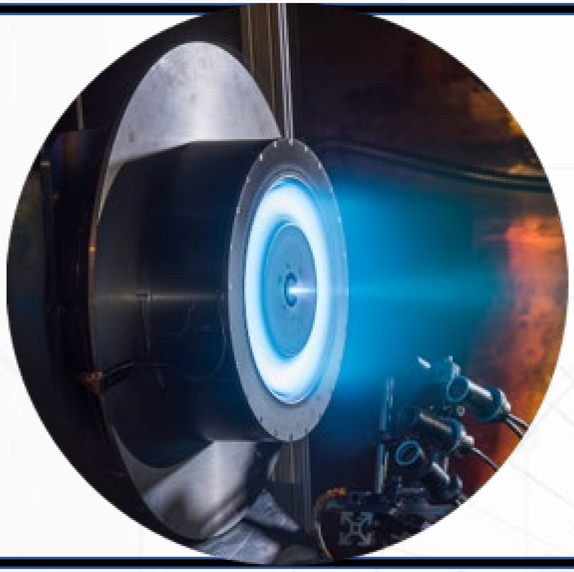
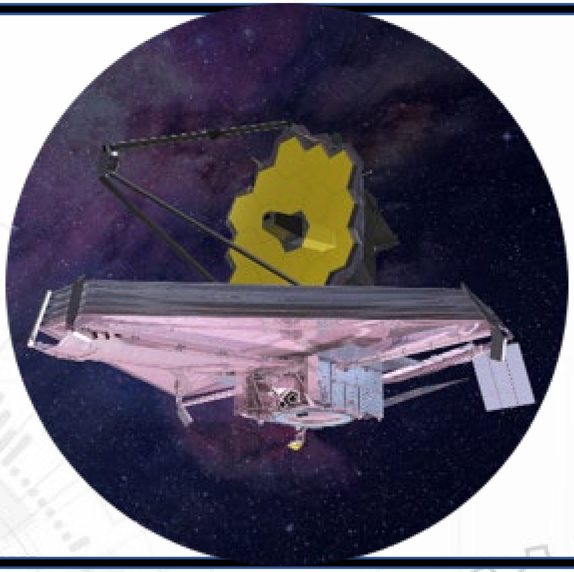
Office of the Chief Technologist

National Aeronautics and Space Administration





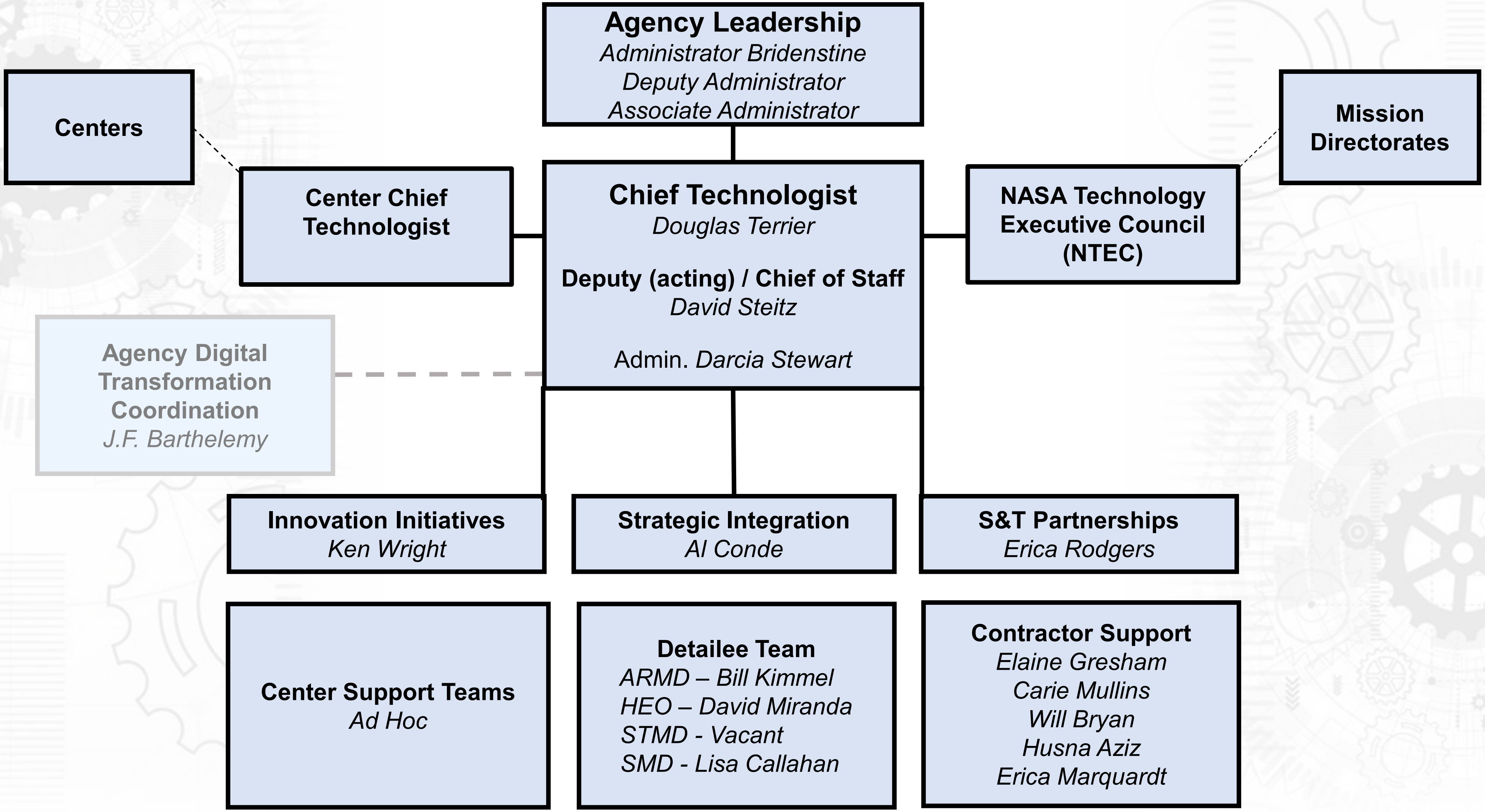
An Update to the NASA Advisory Council

Technology Innovation and Engineering Subcommittee

30 April 2019

Our Office

National Aeronautics and
Space Administration



DRAFT

NASA Technology Portfolio

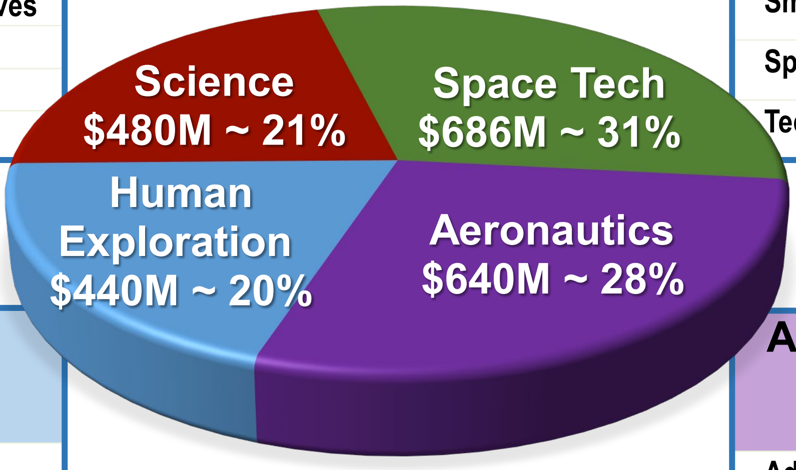
National Aeronautics and Space Administration

Science Mission Directorate ~ $480M

- Advanced Component Technology
- Advanced Information Systems Technology
- Astrophysics Research and Analysis
- Europa Technology
- Heliophysics - Tech and Instrument Development for Science
- In-Space Validation of Earth Science Technologies
- Instrument Incubator
- Maturation of Instruments for Solar System Exploration
- Nancy Grace Roman Technology Fellowships
- Planetary Instrument Concepts for Adv of Solar Sys Objectives
- Planetary Science and Tech Through Analog Research
- Strategic Astrophysics Technology
- + Mission-Directed Technology

Space Technology ~ $686M

- Centennial Challenges
- Center Innovation Fund
- Flight Opportunities
- Game Changing Development
- NASA Innovative Advanced Concepts
- SBIR/STTR
- Small Spacecraft Technology
- Space Tech Research Grants
- Technology Demonstration Missions



Human Exploration and Operations Mission Directorate ~ $440M

- Advanced Exploration Systems
- Space Life and Physical Sciences Research
  - Human Research Program
  - Life and Physical Sciences
- Space Communications and Navigation

Aeronautics Research Mission Directorate ~ $640M

- Advanced Air Vehicles
- Airspace Operations and Safety
- Integrated Aviation Systems
- Transformative Aeronautics Concepts

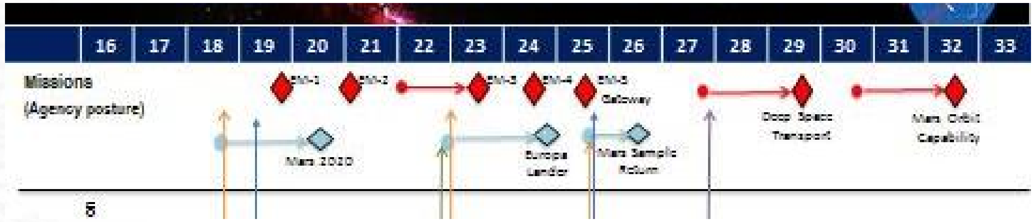
Technology Integration Framework

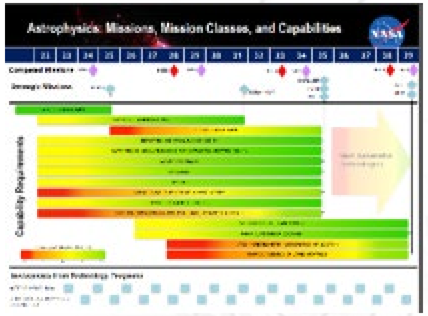
National Aeronautics and
Space Administration

National policy, agency-level strategic plans or other activities that drive missions.

Examples: National Space Council, agency strategic plan, decadal surveys, Exploration Mission

Mission/ Outcomes "Why"





Technical Challenges "What"

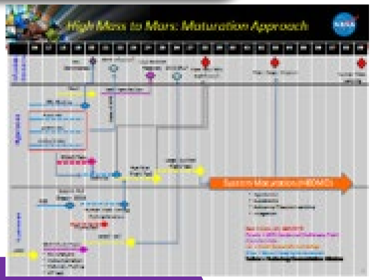
100 m landing footprint, challenging terrains like Europa

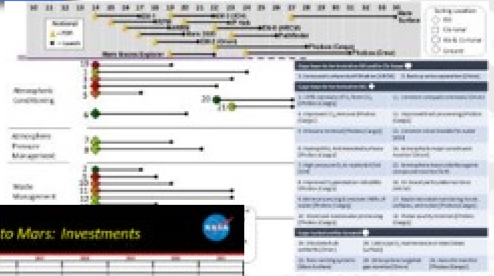
Nuclear Propulsion

Fast Transit Deep Space Transportation

~5 MT to Surface Lander Capability

Strategy for Development "How"





Technology Investment "When"

Technology Integration Framework

National Aeronautics and Space Administration

- Framework concept of four steps completed December 2017
- Proof of concept with data from the Mission Directorates completed August 2018
- Plan to use TechPort for TIF database
- The TIF was presented and approved at NASA Technology Executive Council (NTEC) meeting 16 April

	Mission Directorate			
Framework Step	ARMD	HEOMD	SMD	STMD
1. Goals/Objectives	✓	✓	✓	✓
2. Quantifiable Technical Objectives /Challenges	✓	✓ Some Programs	✓ Most Programs	✓ Most Programs
3. Strategy for Development	✓	× Some gaps	× Some gaps	× Some gaps
4. Technology Investment	✓	✓	✓	✓

Moving Forward

National Aeronautics and
Space Administration

- OCT Technology Integration Framework briefing during NASA leadership retreat, May 2018

- Schedule
  - April - September 1
    - Work with TechPort to accept Framework data
    - Directorates identify and populate TechPort with current
      - Strategic Goals
      - Long Pole Capability Needs
      - Strategies to achieve Needs
    - Develop report out format
    - Develop Roll-out campaign to broad community
  - September
    - Report out at BPR/APMC
      - Framework implementation Status
      - Format for periodic MD reporting
      - Overview on Roll-out to broad community campaign

- Informs the NASA Strategic Technology Investment Plan (STIP)

The Innovation Framework

National Aeronautics and Space Administration

Innovation culture essential to achieving agency missions within budget and schedule.

Outcomes "Why"

- Technical Leadership
- Fiscal Efficiency
- Performance to Cost and Schedule

Required Characteristics "What"

- Provide Feedback loop for innovative ideas
- Identify and support innovation catalyst
- Teams of unlike minds (innovators, doers, crazy ideas)
- Diverse workforce, diverse ideas
- Definition of what success looks like
- Ability to partner and adopt
- Focus where you are good and differentiated
- Customer interaction when possible
- Communication share knowledge
- Identify customer pulls
- Freedom and award workforce innovation
- Don't decide too early
- Path to incorporate new ideas

Innovation Initiatives "How"

NIAC	SAAs	NARI	NASA Tournament Lab	NASA @work	OHC Culture Strategy
CIF	PPPs	Centennial Challenge	CoECI	LaRC Fast Track to Market	STMD BIG Ideas
Early Career Initiative	Innovation Awards	Human Health Risk	Innovational Portal	Flight Opportunities	OCE Tech Fellows

Innovation Plans "When"

NASA Innovation Framework

OCT Survey to Identify Barriers to Innovation at NASA

Potential solutions to barriers identified

Agency innovation efforts cataloged & mapped

EC Decision: "NASA Innovation Framework will be the responsibility of OCT under the direction of the Deputy Administrator"
April 2016

OCT NAC briefing rolling out "Innovation Framework"
March 2017

National Academies Meetings on Experts – innovation best practices from government and industry
Early 2018

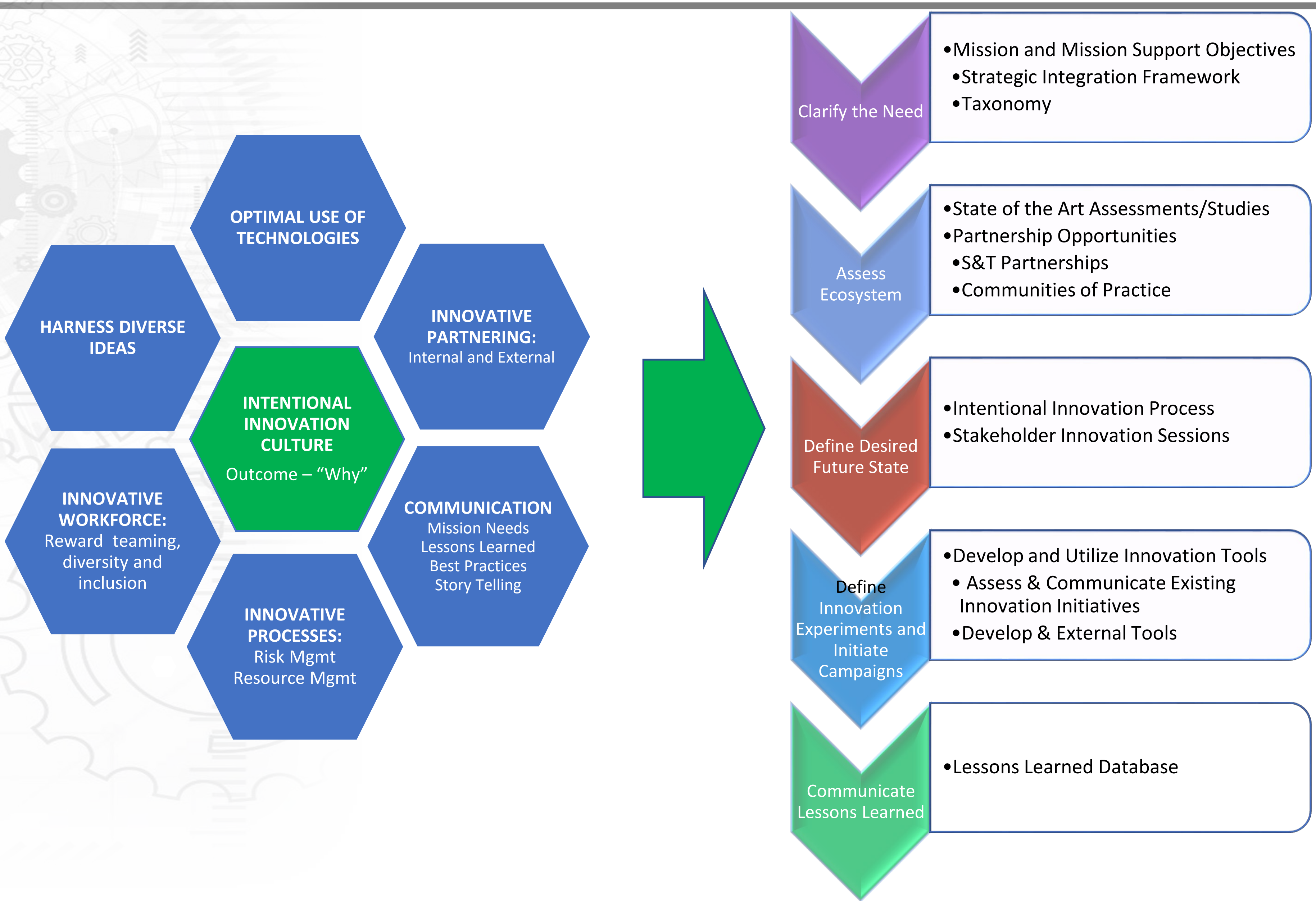
National Academies Innovation Summit
November 2018

Ongoing efforts:

- Innovation Portal
- Innovation Experiments
- Recommend-actions from Summit

2013 2014 2015 2016 2017 2018 2019

Innovation Framework



Innovation Workshop - November 29-30, 2018

- The Continuous Improvement of NASA's Innovation Ecosystem
- Held at the National Academy of Sciences
- Goal was to identify actionable and implementable, phased initiatives that build on NASA's innovation culture to reach a future that ensures continued success in an evolving environment
- Activities included
  - Analysis of NASA's successful transformation to an innovation eco-system that is fully responsive to the evolving environment.
  - Examination of the steps needed to get from our current state to this future successful innovation culture in four distinct tracts:
    1. **People**– How do we reduce/remove barriers to innovation? How do we inspire and retain an innovative workforce? How do we communicate mission challenges to harness diverse ideas from the workforce? How do we grow an innovation culture?
    2. **Partnering** -- How do we forge partnerships to allow NASA to learn from the outside and specialize on what makes us unique? How do we foster collaborative partnerships among Centers?
    3. **Processes** – How do we ensure passion outweighs bureaucracy?
    4. **Portfolio management** – How do we introduce more risk and innovation into our portfolio but still ensure mission success? How do we introduce good shocks to the system? How do we ensure alignment of innovation funding with desired outcomes?

What We Heard

- Be more intentional – leadership can make a real difference
- Leadership should “Seek, Support and Celebrate” innovation
- Irrelevance is failure for NASA
- Develop ways to introduce “good shocks” to the system
- Make sure passion outweighs bureaucracy

Moving Forward

National Aeronautics and
Space Administration

- May 30 Leadership Retreat session on Innovation
  - Present findings and forward plan for innovation initiative
  - Leadership discuss four theme areas and identify gaps
  - Solicit leadership feedback and buy-in
- Complete development and deploy Innovation Portal by September
  - Serves a digital framework to link innovations initiatives
  - Provide single point access to innovation ecosystem
  - Enables cross-center access and sharing of innovation tools
- Conduct high-impact innovation experiments to drive change
  - Center innovation funding applied to cross-agency projects
  - Partner with Mission Support Architecture initiatives

Science & Technology Partnership Forum

In-Space Assembly Topic:
Findings, Recommendations, and Transition

NASA Advisory Council

Technology, Innovation and Engineering Committee

April 30, 2019

Credit: NRL

S&T Partnership in-space assembly team

Dr. Erica Rodgers

Office of the Chief Technologist

A New Paradigm for Spacecraft Development and Operation

- **Traditional way of building spacecraft leads to cycles of spiraling costs**
  - Higher-cost payloads -> higher-reliability launch vehicles -> increased launch costs
  - Larger payloads mandate larger and heavier-lift launch capabilities
- **Low-cost commercial launch systems have potential to break spiral**
  - iSA will take advantage of these launch systems
- **Advances in automation and robotics make iSA possible**
  - Building up large structures beginning with relatively simple components
- **Technologies will reduce cost of developing & launching new systems**
  - Enable repair or upgrade satellites

In-Space Assembly (iSA)

In-Space Servicing (iSS)

In-Space Manufacturing (iSM)

→ Significant economic impact and performance benefits

Current state-of-the-art (SOA)

5-10 year-old technology at launch

25+ year-old technology at end of mission life

Ensure capabilities remain on the cutting edge

iSA and iSS enable advancements beyond SOA

A New Paradigm for Spacecraft Development and Operation

Benefits of In-Space Assembly and Servicing

Assembly

Bring about new capabilities enabled by spacecraft dimensions, masses, or configurations that cannot otherwise be launched from Earth

TALISMAN is critical to the CIRAS project, which seeks to enable space-based, robotic assembly of flight hardware and space systems. (Northrop Grumman/Orbital ATK, NASA, NRL)
Credits: NASA/LaRC

TALISMAN = Tension Actuated Long-reach In-Space Manipulator
CIRAS = Commercial Infrastructure for Robotic Assembly and Servicing

Servicing

Individual spacecraft can evolve in response to new knowledge, techniques, and technologies

Mission success less dependent on launch and less susceptible to on-orbit failure -> options for recovery -> which in turn could reduce the costs of making systems extremely reliable

---

Reduce Cost

Improve Performance

Limit Risk

- Structures assembled in space designed for **operational loads**, not launch loads
- Avoid system complexity and parasitic mass of on-orbit deployment
- **Extensible/reusable** spacecraft support broader range of missions and conditions
- **Remove/replace** modules during operation -> improve life cycle costs & mission risk
- **Modularity** enables launches of small components on lower cost comm vehicles
- Only lose modular elements if failure, not entire spacecraft
- **Incremental buildup** distributes cost across time -> pay as you go approach
- **Facilitates cost sharing** by multiple programs and multiple government agencies

A New Paradigm for Spacecraft Development and Operation

In-Space Assembly and Servicing

Persistent and resilient space assets to be assembled and routinely upgraded in space

Transform space operations capabilities with economic and performance benefits for both U.S. Government and commercial space endeavors

Common core of high-leverage capabilities provide path towards a robust and flexible capability for the spectrum of users

Strategic forum established to identify synergistic efforts and technologies

Interagency Science & Technology Partnership Forum

Leverage synergies and influence agency portfolios

DARPA - Affiliate Partners - NRL

Identified and prioritized pervasive goals that focus on key game-changing technologies across government space

Other Topics

- Small Satellite Technology
- Big Data Analytics
- Cybersecurity

1. **Facilitate** cross-agency collaboration and **strategize** on technical solutions to common pervasive needs
2. **Maintain awareness** of each agency's space S&T investments to reduce duplication and identify areas worthy of collaboration
3. **Identify impediments** to collaboration and **formulate solutions**

In-Space Assembly

DARPA = Defense Advanced Research Projects Agency   NRL = U.S. Naval Research Laboratory

Overview

What

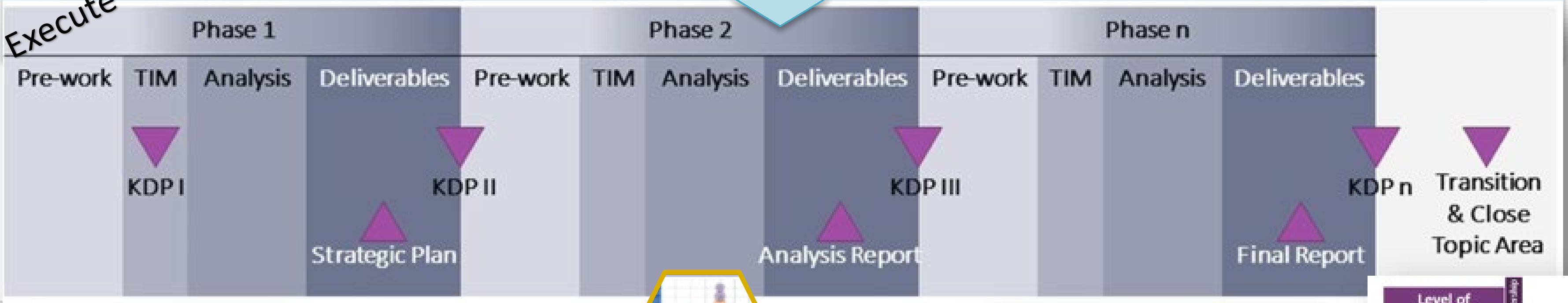
S&T Partnership Goals

- Coordinate S&T issues across space agencies (Leverage synergies)
- Efficiently and effectively mange S&T resources (Influence agency portfolios)

How

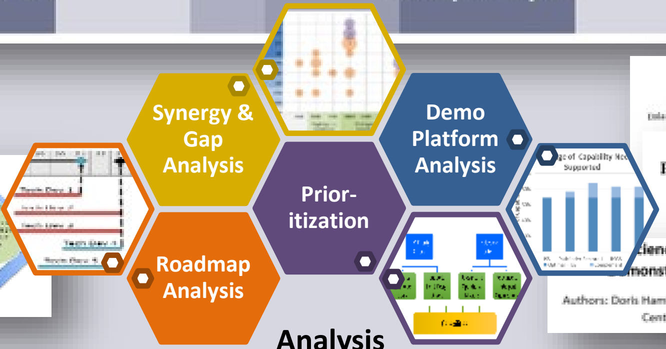
S&T Partnership Objectives

- Facilitate synergistic collaborations
- Strategize technical solutions
- Maintain awareness of S&T investments
- Identify impediments and formulate solutions



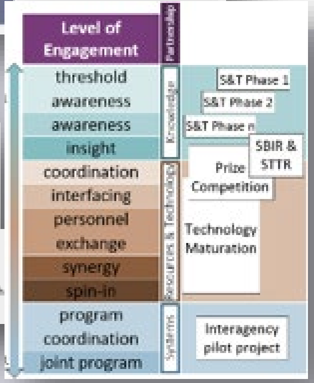
Govt Papers

Value Proposition



Analysis

Public Papers



Partnering

PHASE 1

- Establish baseline of govt iSA work
- Collectively describe benefits of iSA
- Establish value for partnering on iSA
- Communicate and document

PHASE 2

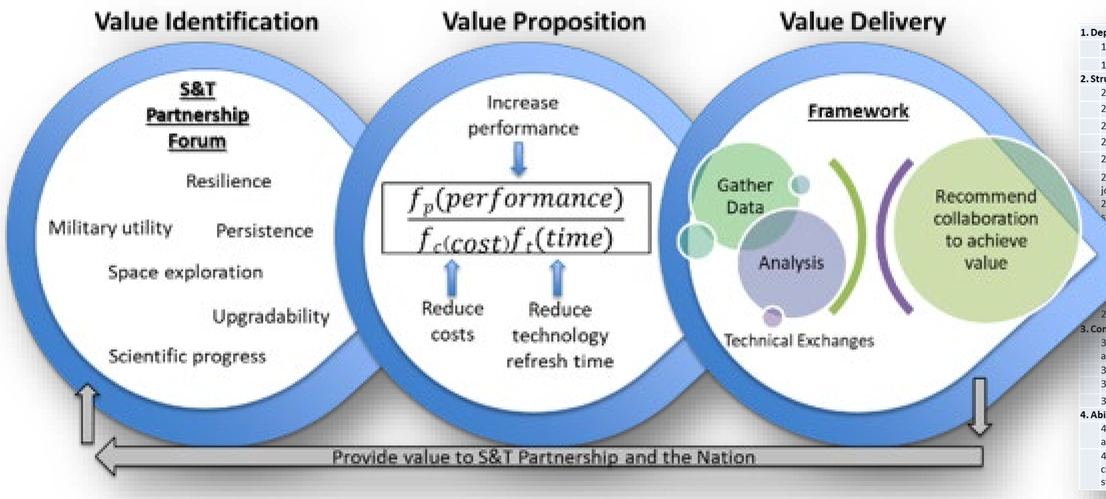
- Collect and prioritize data
- Perform govt iSA capability analysis
- Assess potential iSA demo platforms
- Communicate results / make recs

PHASE 3

- Collect commercial iSA data
- Perform commercial iSA capability analysis
- Assess potential commercial demo platforms
- Make govt/commercial partnering recs

Findings

Value in Active Interagency Partnering



Mutual Interagency Interest

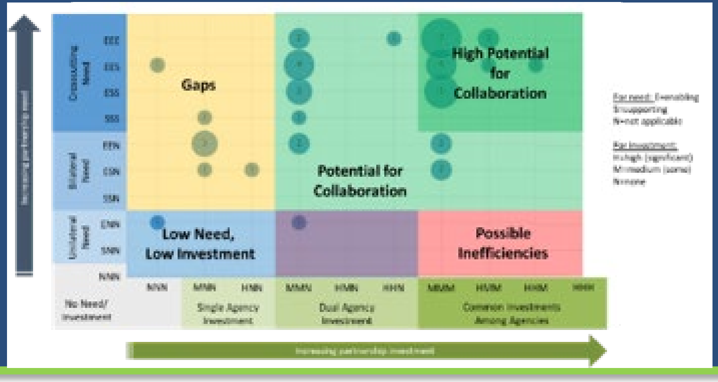
14 Capability Areas
46 Capabilities

1. Deployable modules
   - 1.1 Deployable subsystems
   - 1.2 Inflatable components
2. Structural Assembly
   - 2.1 Robotic assembly with joining
   - 2.2 Long-reach manipulation
   - 2.3 Ability to assemble low mass structures
   - 2.4 Ability to assemble high strength structures
   - 2.5 Ability to assemble high stiffness structures
   - 2.6 Ability to assemble structures with micr… joints
   - 2.7 Ability to assemble structures with high … stability
   - … Ability to assemble structures with near …
   - … ity to assemble structures on planeta… …n, Mars)
   - … ability to deploy hybrid assembly and i… …rication processes, such as additive manu…
   - 2.11 Conductive heat transfer across assembled joints
3. Connecting utilities
   - 3.1 Ability to route electrical power and data across assembled joints
   - 3.2 Ability to route coaxial cables across joints
   - 3.3 Ability to route fiber optical conductors across joints
   - 3.4 Ability to route fluids across joints
4. Ability to disjoin
   - 4.1 Ability to reversibly assemble structural, electrical, and fluid connections.
   - 4.2 Ability to disconnect structural, electrical, and fluid connections without propagating damage to other system components.
5. Sensing, Modeling, Simulation, Verification
   - 5.1 Means of verifying the continuity of interface connections / disconnections.
   - 5.2 Sensors to accurately and precisely measure the quality of the build-up in progress.
   - 5.3 Sensors to accurately and precisely measure the as-built configuration.
   - 5.4 Sensors to detect failures and/or unacceptable quality of the assembly process after it has been completed.
   - 5.5 Modeling and simulation for verification and …
   - … systems.
7. Automation/Autonomy
   - 7.1 Intelligence to make stereotyped decisions correctly without human input.
   - 7.2 Intelligence for full autonomy
   - 7.3 Fail-safe modes of behavior on failure detection.
   - 7.4 Multi-agent autonomy (distributed situation assessment & coordinated control)
8. Precision
   - 8.1 Jigging and joining processes capable of achieving a high level of precision open-loop.
   - 8.2 Known precision limits of any and all assembly agent elements across the assembly site's environmental envelope
9. Adaptive Correction
   - 9.1 Tools and approaches to alter a build-up in progress to correct build up errors.
10. Design
   - 10.1 Tools and component parts capable of accommodating a continuous spectrum of design options.
   - 10.2 Assembly agent geometries, systems, and tools that do not preclude dimensional or mass growth of the client system.
   - …lar design
   - … for assembly
   - … for serviceability
   - … y to accommodate structural …ith active length control.
   - … to accommodate power and data …erfaces associated with active …embers.
   - 11.3 Ability to accommodate TBD sensors for length and/or structural geometry.
12. Stability
   - 12.1 Ability to accommodate passive vibration damping.
13. Standard Interfaces
   - 13.1 A limited number of standard mechanical, electrical, thermal, and fluid connection approaches with well-characterized properties.
14. Docking/Berthing
   - 14.1 Soft docking / berthing of modules

Interagency Prioritization

1. Relevance to:
   - •Organization
   - •Operational mission
2. Stakeholder goals & Design drivers

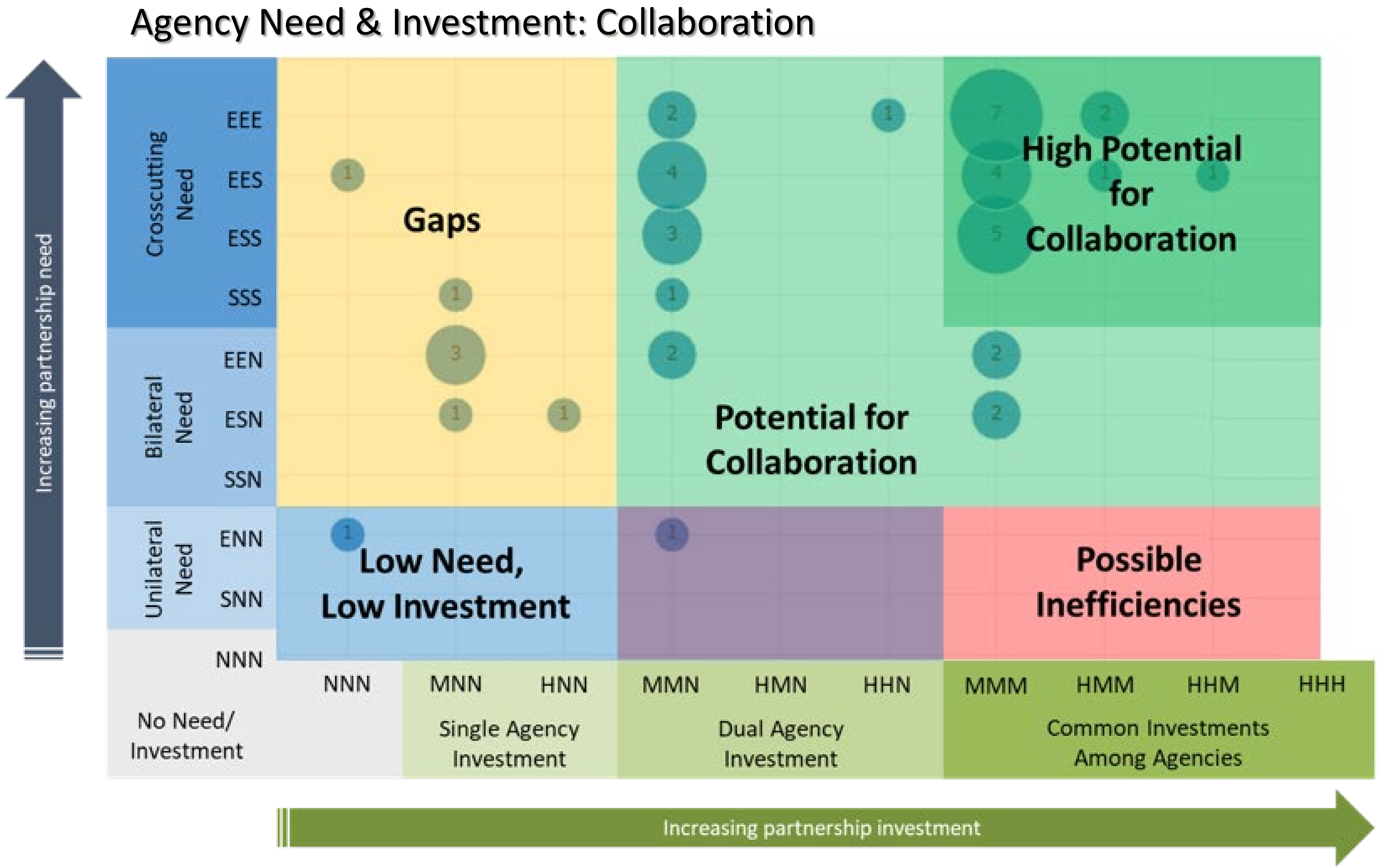
Capability Areas with potential for interagency collaboration



AF SMC
Advanced Space-based Testbed

NASA
On-orbit Servicing Assembly Manufacturing

Agency Need & Investment: Collaboration

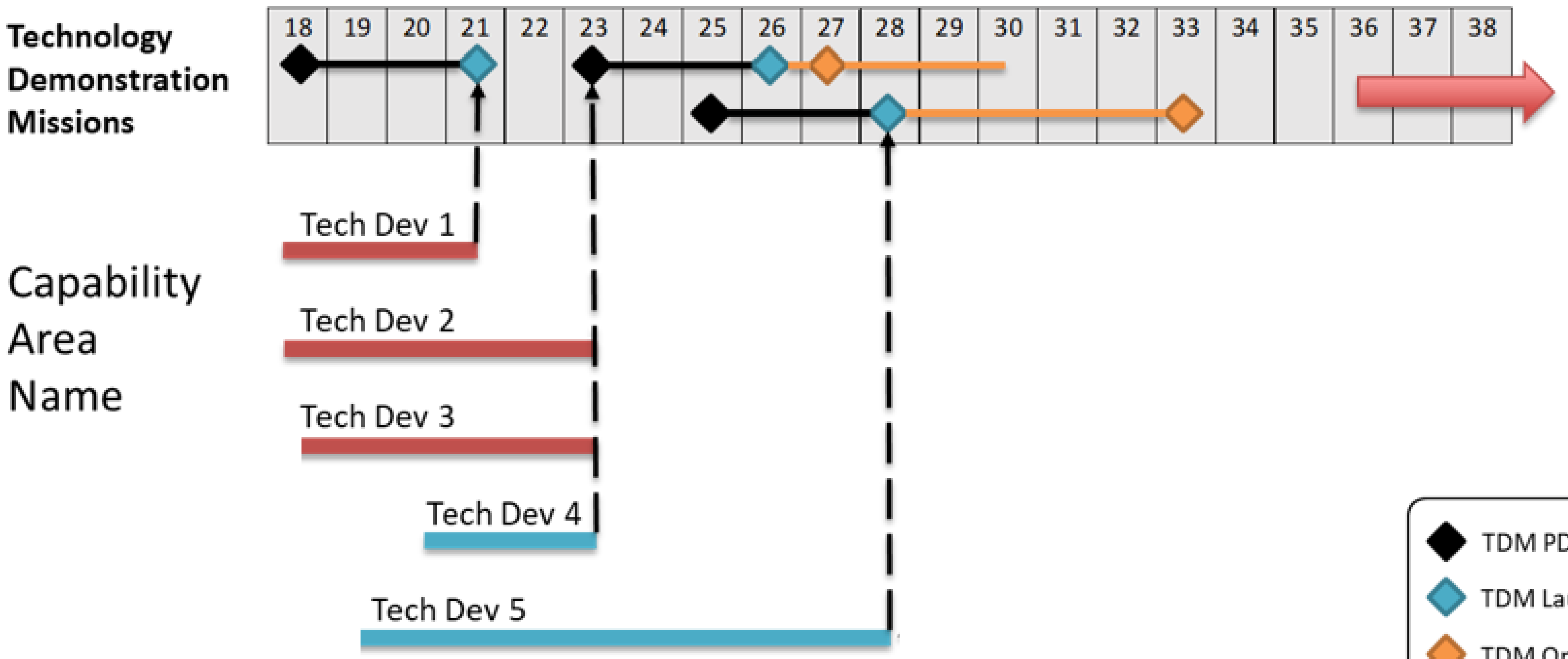


For need: E=enabling
S=supporting
N=not applicable

For investment:
H=high (significant)
M=medium (some)
N=none

Findings

Identified current government landscape of in-space assembly

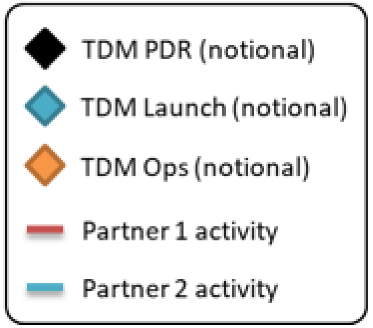


Potential Operational Missions

NASA
- Concept A
- Concept B

DARPA
- Concept C

Air Force
- Concept D
- Concept E

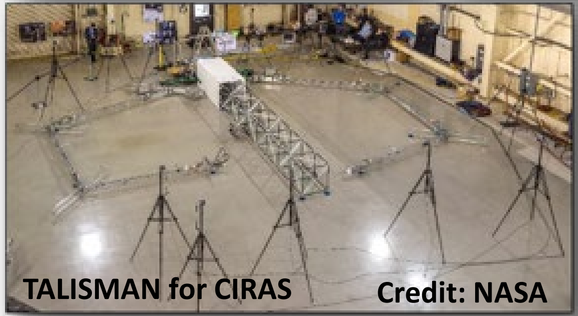


- Specific technology development activities the various Agencies are working
- Technology demonstration missions (TDMs) that are underway or planned

Cadence of in-space assembly Technology Demonstration Missions → **Map to future operations missions**

Findings

Evaluated how well various platforms could demonstrate prioritized capability needs

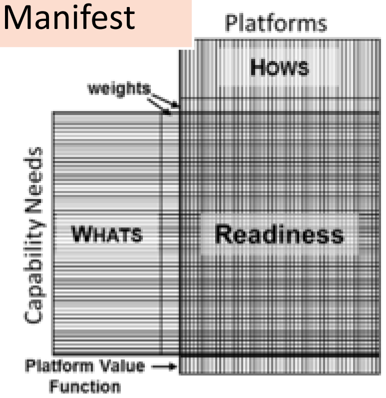


TALISMAN = Tension Actuated Long-reach In-Space Manipulator
CIRAS = Commercial Infrastructure for Robotic Assembly and Servicing

All 5 government demonstration platforms can be modified (cost, time, programmatic realism) to demonstrate prioritized iSA capability needs

Platform Evaluation	
Platform Access Costs	
Certification Costs	Programmatic Realism
Timeframe	Access to Manifest

Capability Needs Evaluation
Payload Cost
Payload Certification Costs
Payload Launch Mass Cost Factor



Recommendations

S&T Partnership Forum → Transition → Partnership Execution

Strategic

Continue to strengthen partner agency relationships

Develop coordinated approach to better align govt/industry efforts

Transition

- Data
- Analyses
- Relationships

iSA → OSAM

OCT will lead NASA coordination team (SMD, HEOMD, STMD)

- Provide NASA strategic oversight
  - Leadership & Guidance
- Work with the S&T partner agencies

iSA = In-Space Assembly
OSAM = On-Orbit Servicing, Assembly, & Manufacturing

Programmatic

Establish interagency pathway forward to developing architectures and capabilities

Technical

Digital Transformation Initiative

National Aeronautics and Space Administration

Update to the NASA Advisory Council
Subcommittee on Technology, Innovation and Engineering

DT Recommendations

Approve the proposed Digital Transformation **strategy**, **conceptual approach** and six **prioritized initiatives** as the basis for completing an **implementation plan** to be **recommended by the Chief Technologist**, as OIC of the implementing organization, in **partnership with the Chief Information Officer**, and **approved by a joint APMC/MSC**.

The final plan will include:

- Definition of **the scope**, **organizational approach and resourcing** of the Digital Transformation effort as **a virtual office**, reporting to the OCT to coordinate and integrate the function.
- Proposed **updated charter for the NTEC** as the advisory body for the DT effort, realigned to the APMC or MSC, as appropriate
- Definition of **how investment opportunities for the effort will be accommodated within existing resources** through collaboration, both for areas **within OCIO's IT investment decision authority and governance** (Information Technology Council), and areas outside the ITC's decision authority, **including Mission Directorates, Mission Support Directorates, and Centers**.

Outline

- BLUF
- Quick Reminder: What is DT?
- Proposed NASA DT Strategy - Vision, Goals, Strategic Initiatives
- DT Ecosystem and Proposed Governance
- Funding DT
- DT Implementation - next 18 months
- Recommendations to APMC

DT Working Definition:
Employing digital technologies to transform a process, product, or capability so fundamentally that it brings substantial performance improvements

DT Example

Data Access/Integration for EVA Safety

Astronaut on spacewalk had serious water leak in helmet. To assess incident after the fact, **it took 6 contractors 2 weeks** to gather all related data from file cabinets, hand written notes, and contractor and NASA databases.

Technical challenges (why DT was needed):

- **Access to authoritative data**: disparate data sources, various formats and standards; data not integrated, accessible
- **Interoperability**: no integrated search, analytics

Approach (how DT was employed):

- Created **unified data access** with cognitive search, 3D graphical browsing, intelligent linking, provenance, metadata management
- Flexible architecture to **leverage Gov Cloud**, **industry standards** and **open source** software

Benefits to date:

- Enables product data lifecycle management and model-based systems engineering
- Decreases EVA readiness review time
- **Resolves anomalies accurately, in time**
- New space suit is using same approach

Lessons learned, best practices:

- **Integrated data** is key to reducing cost and risk
- **Data management** approach definition is needed
- **Senior management** commitment important

What We Found

- DT is about **reinventing** processes and products to take full advantage of data and state-of-the-art IT technologies
- NASA is **already engaged** in DT initiatives
  + Mostly bottoms-up, innovation/ experimentations
  + Many OCIO projects are already enabling DT
  + All potential DT technologies are investigated
  + Some Centers have DT focused staff/org
- DT is **an enabler** of the Agency Mission

Scale-up challenged by:

- **Stovepipe developments**
- Resistance to change
- Lack of resources for start-up/scale-up
- Limited awareness of DT and best practices across the Agency

Considerable potential for:

+ Focused efforts and collaborative developments
+ Integrated approach to acquisition and developments

What We Propose

- **Embrace** DT to transform Agency processes, to bring substantial benefits
- **Focus** efforts in selected strategic directions, driven by Mission needs
- **Engage** involved communities in designing enterprise solutions
- **Implement** DT collaboratively, every organization has a role in DT
- **Seek** critical DT skills through hiring, training, judicious partnering
- **Realign** process, process improvement resources to process transformation
- **Fund** early wins/jump-start efforts
- **Employ** light touch governance, to advocate for DT, steer, and coordinate efforts

DT Drivers, Vision, Goals

Drivers

Digital Convergence	Mission Leadership	Big Data Challenges
Collaboration Needs	Mission Complexity	Research Complexity
Resource Constraints	Workforce Competition	Cybersecurity

Vision

NASA employs powerful digital practices and strengthens its culture of innovation on a transformation journey to enhance efficiency, agility, and insight in the advancement of NASA's mission.

- Advance DT through opportunity-driven transformative strategic initiatives
- Establish and infuse an Agency-wide, high-impact DT Initiative
- Coordinate and align with mission-enabling, secure, agile enterprise IT services

DT Strategic Initiatives

- Based on inputs collected during the fact-finding phase of this effort, the DT working group selected 6 Strategic Initiatives (SI):
  1. Data
  2. Collaboration
  3. Model Based x
  4. Process Transformation
  5. Culture (and Workforce)
  6. AI/ML
- Empower a working group for each SI to engage the associated Agency communities, and develop, by the end of CY2019, :
  - a **detailed enterprise strategy** to reach digital maturity for the initiative
  - a **roadmap**, goals, objectives, schedules, and metrics
  - a plan to engage the **capabilities required** to enable the strategic initiative
  - advance **early win** initiatives

DT Strategy

Drivers

Vision

Advance DT through opportunity-driven transformative strategic initiatives	Establish and infuse an Agency-wide, high-impact DT initiative	Coordinate and align with mission-enabling, secure, agile enterprise IT services
Data Strategy	DT Ecosystem	OCIO, MDs, and MSD Activities, Center
Collaboration Strategy	Governance Model	
MBx Strategy		
Process Transformation Strategy		
AI/ML Strategy		
Culture and Workforce Strategy		

NASA’s Digital Transformation Ecosystem

Proposed DT Office (DTO) Facilitates Robust Coordination, Communication, and Support

OCIO

Insert DT in IT Strategic Plan

Lead DT SI, strategy, policy, as needed

Provide Enterprise IT infrastructure for DT

Design/Fund/Implement

- Unique IT-focused DT solutions
- Cross-cutting DT solutions (jointly)

Mission Support Directorate

DT elements into org plans

Lead DT SI, strategy, policy as needed

Enable DT education and training

Design/Fund

- Unique MSD-centered DT solutions
- Coordinate with DT for MAP
- Workforce, Infrastructure strategies
- Cross-cutting DT solutions (jointly)

DTO

Mission Directorates

Insert DT element in program plans

Lead DT SI, strategy, policy, as needed

Design/Fund

- Unique MD-centered DT solutions
- Cross-cutting DT solutions (jointly)

Centers

Insert DT into strategic plans

Lead DT SI, strategy, policy, as needed

Design/Fund/implement

- Unique Center DT solutions
- Cross-cutting DT solutions (jointly)

OCT, OCE, OCS…

What We Propose To Do

Pre-formulation - Complete

By 3/2018 APMC

- ✓ Scoping assessment
- ✓ Benchmarking
- ✓ Management models

Output:

- ✓ Recommendations on next steps and management model

Formulation - Complete

By 4/2019 APMC

- ✓ Engage mission directorates, Centers, and functional offices
- ✓ Create awareness. Conduct internal inventory
- ✓ Benchmark industry
- ✓ Conduct analysis and assessment
- ✓ ID candidate technologies/concepts
- ✓ ID early wins

Output:

- ✓ Draft Strategic Plan
- ✓ Draft high-level implementation framework

Begin Implementation & Institutionalization

By 7/2019 APMC/MSC

DT Implementation plan

- DTO Virtual Office
- Updated NTEC charter
- Investment approach

By 9/2020 (sampling)

- Set up **DTO** (4Q/FY19)
- Charter **SI WGs** (3Q/FY19)
- Approve **SI Strategic Plans** (2Q/FY20)
- **Early wins** (3Q/FY19), (1Q/FY20)
- **Videos** (3Q/FY19, 2QFY20)
- **DT status** (4Q/FY19, FY20)