



NASA Innovation & Technology Initiative: Enabling NASA's Future and Addressing National Needs

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DISCLAIMER!!



- The following material is preliminary pending on-going study and decisions yet to be made regarding the Agency's response to the Augustine Report and policy and budget decisions by the Administration and Congress
- The details including specific investment areas are likely to change but the following gives a snapshot of the current thinking assuming some significant budget augmentation in the relevant areas



- Issue: In the last decade, within constrained budgets, NASA has been challenged in embracing highly innovative solutions across its programs
 - Focus has been on near term research and technology activities to meet the immediate needs of space flight programs
 - Innovative aeronautics concepts and technologies developed by NASA have not received adequate level of support for effective and timely tech transfer
- Outcome:
 - NASA has achieved some highly innovative solutions to complex mission problems but has had limited ability to change the game
 - NASA has not been able to embrace a broader mission to drive innovation across the economy and contribute to solving the nation's problems
- Key Goal: NASA should return to its roots as a preeminent R&D agency through creation of more R&D and mission opportunities for disruptive innovation, contributions to meeting National challenges and broader engagement of non-government innovators

Key Augustine Recommendation



- The Augustine Committee recently strongly endorsed increased investment in innovative technologies and approaches to achieving broadly defined NASA and National goals
- This technology and innovation investment was included in *all* new Program Options suggested by the Augustine Committee

The Committee strongly believes it is time for NASA to reassume its crucial role of developing new technologies for space. Today, the alternatives available for exploration systems are severely limited because of the lack of a strategic investment in technology development in past decades. NASA now has an opportunity to develop a technology roadmap that is aligned with an exploration mission that will last for decades. If appropriately funded, a technology development program would re-engage the minds at American universities, in industry and within NASA. The investments should be designed to increase the capabilities and reduce the costs of future exploration. This will benefit human and robotic exploration, the commercial space community, and other U.S. government users.

Recent NRC Recommendations (1 of 2)



- Many groups (NRC, Aldridge Commission, etc.) have recommended appropriate investment in advanced technologies and innovative approaches to meet NASA and National Needs
- OSTP also encouraging NASA attention to this area
- Recently released NRC report “America’s Future in Space” specifically speaks to this issue:

*4. **Advanced space technology.** NASA should revitalize its advanced technology development program by establishing a DARPA-like organization within NASA as a priority mission area to support preeminent civil, national security (if dual-use), and commercial space programs. The resulting program should:*

- a. Be organizationally independent of major development programs;*
- b. Serve all civil space customers, including the commercial sector;*
- c. Conduct an extensive assessment of the current state and potential of civil space technology; and*
- d. Conduct cutting-edge fundamental research in support of the nation’s space technology base.*

Recent NRC Recommendations (2 of 2)



- Newly released Congressionally mandated NRC report “Fostering Visions for the Future: A Review of the NASA Institute for Advanced Concepts” is also highly relevant:

Key Recommendations:

- *NASA should reestablish a NIAC-like entity (“NIAC2”)...to seek out visionary, far-reaching, advanced concepts with the potential of significant benefit to accomplishing NASA’s charter and to begin the process of maturing these advanced concepts for infusion into NASA’s missions*
- *NIAC2 should report to the Office of the Administrator, be outside mission directorates, and be chartered to address NASA-wide mission and technology needs. To increase NIAC2’s relevance, NASA mission directorates should contribute thematic areas for consideration. The committee also recommends that a NIAC2 organization should be funded and administered separately from NASA development programs, mission directorates, and institutional constraints.*
- *Future NIAC2 proposal opportunities be open to principal investigators or teams both internal and external to NASA*

NASA Capacity for Increasing Innovation



- NASA has the base capabilities to scale up current investments to include more highly innovative, high-payoff activities
 - Laboratories, engineers, scientists, and technical management expertise are in place, and already drive ideas and basic research into the applied capabilities required to execute NASA's programs
 - As a result of NASA's mission execution focus, our community (civil servants, universities and industry) is uniquely positioned to carry out use-inspired research and infuse it into appropriate application to the benefit of our National competitiveness
- NASA's expertise in energy, biomedical research, advanced information technology, sensors, materials, and aerospace technology directly support the President's Science and Technology Priorities for the FY 2011 Budget
 - NASA's STEM Education programs and Technology Transfer programs can also be enhanced to support delivering NASA's innovations to the National economy, driving job creation and economic growth
- With the extension of the ISS, NASA provides a National Laboratory for innovative research and technology through the next decade
- Fulfills NASA requirements under the America Competes Act

A New Vision for Innovation & Technology



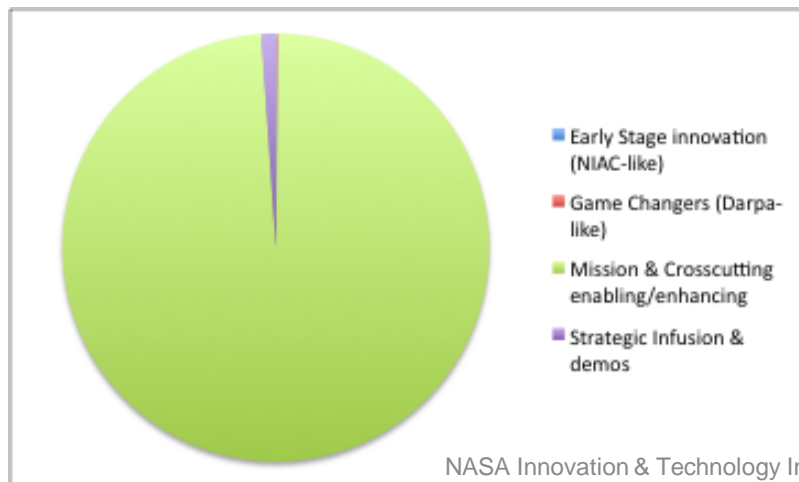
Where are we now?

- Technology program aligned with near-term mission needs.
- Little opportunity for completely new ideas
- Little pioneering research
- Limited opportunity to identify & invest in game changing approaches & technology
- Most work done with few partnerships
- Limited applications across aerospace community
- Limited use of the International Space Station as a research laboratory and test bed for human exploration.
- No opportunity for addressing other national needs

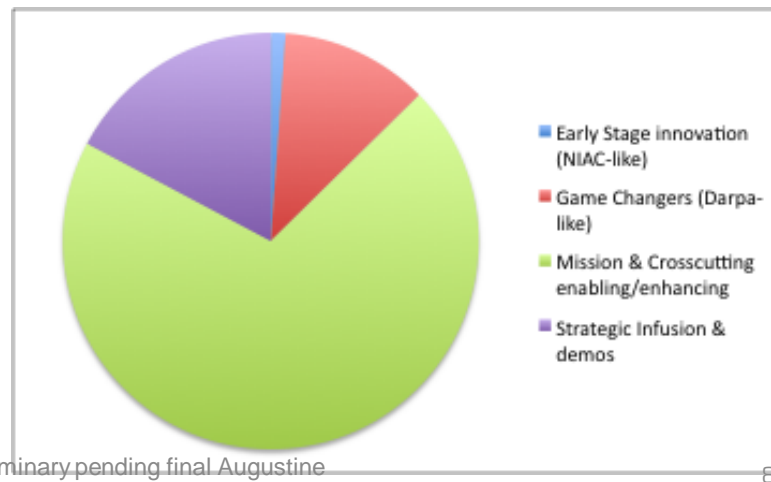
Where can we be?

- Technology program enables far-term capabilities.
- New ideas routinely solicited
- NASA leadership in key research areas
- Partnering and investing in ways to change the game
- Partner with and leverage all willing communities
- Strong investments in developing and infusing advances for the broad aerospace community .
- Use the International Space Station as a stepping stone.
- NASA plays a strong role in a brighter future.

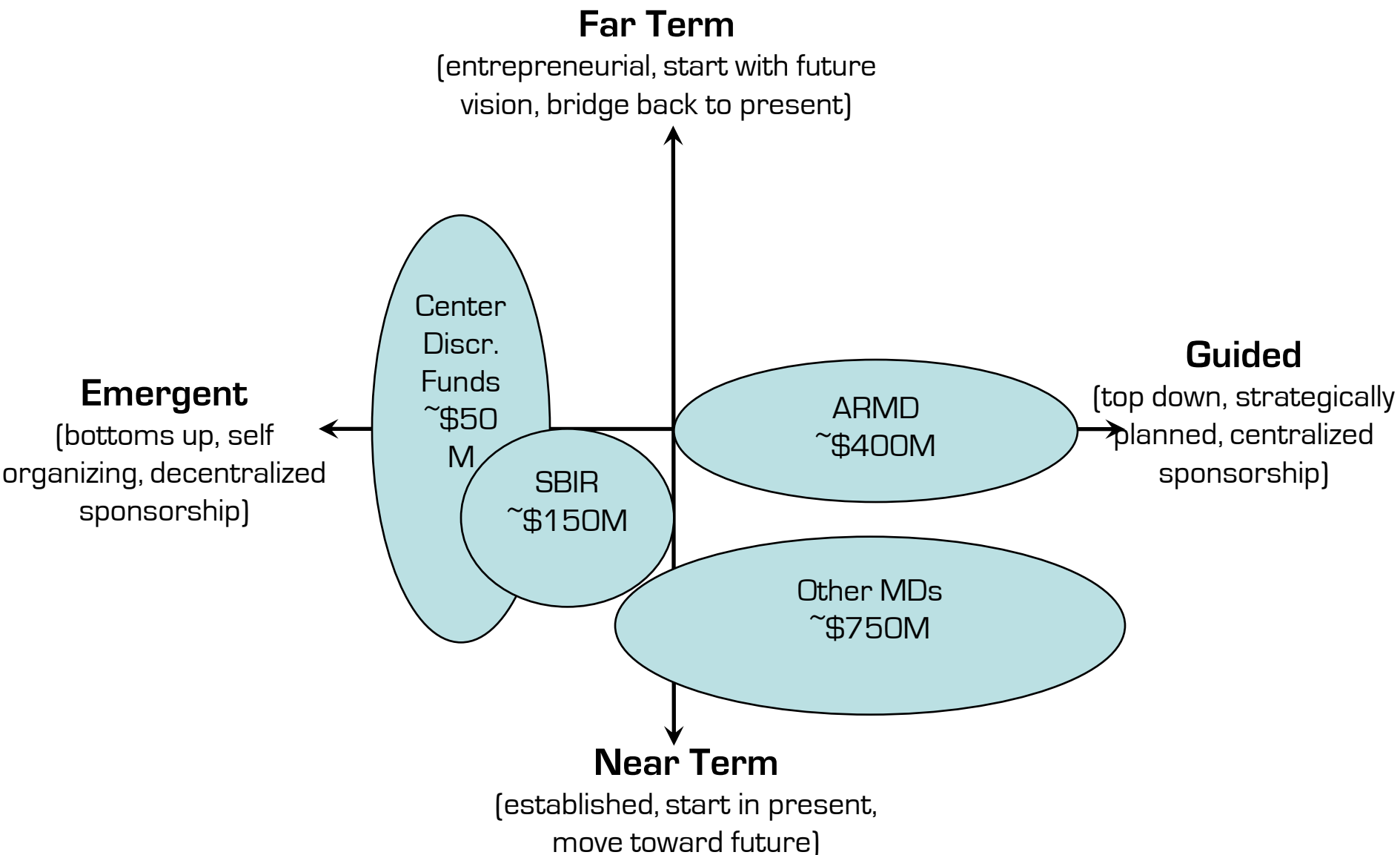
Today



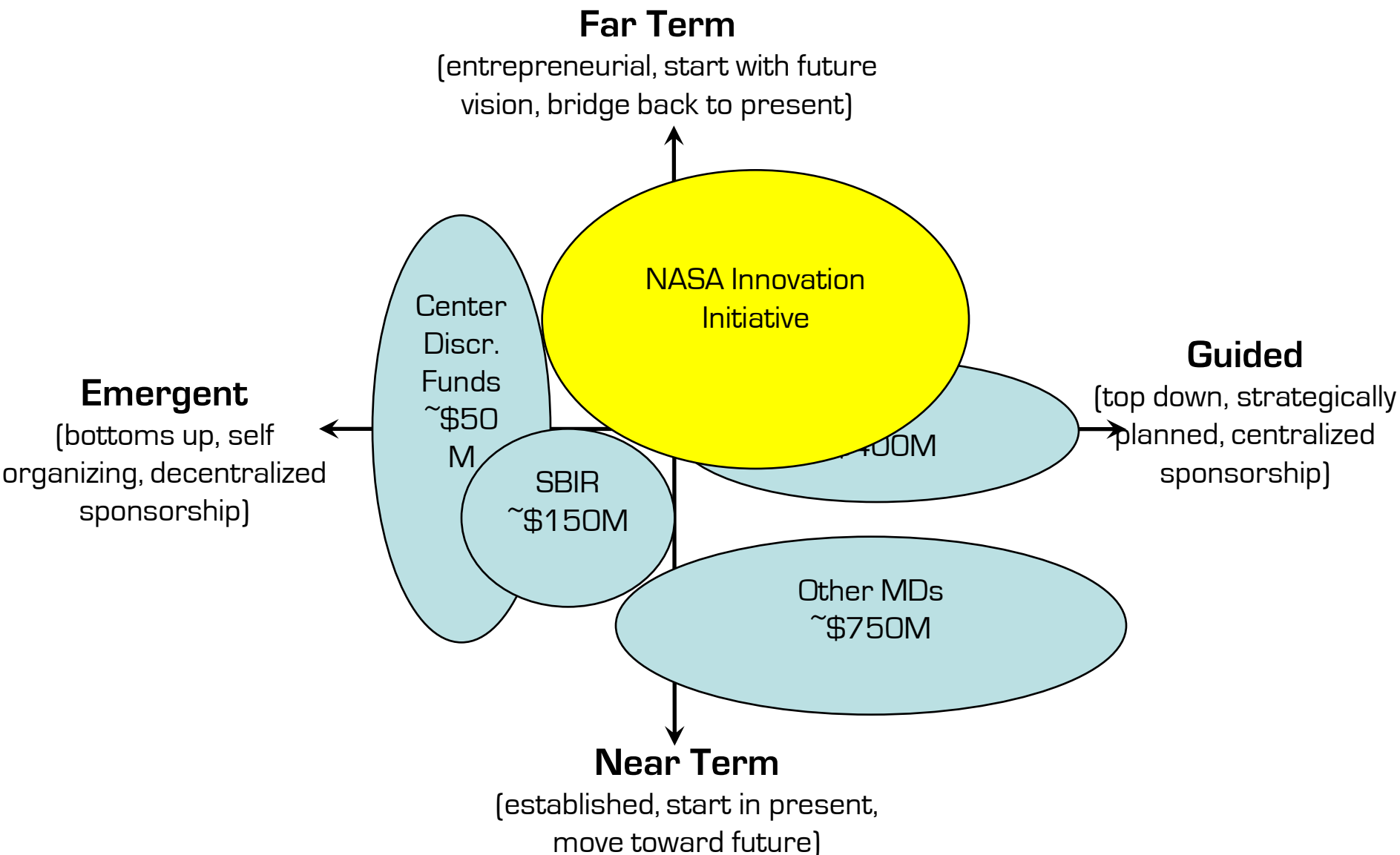
Possible Future



Visualizing the Problem: Current State



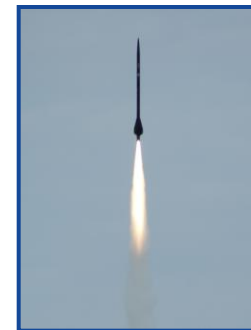
Visualizing the Problem: Proposed State



New NASA Innovation Initiative



- NASA is considering a new innovation initiative to increase long-term investments in research and technology in support of NASA's future mission programs, civil and commercial space operations, and broader National needs
- Integrates existing technology activities with new investments, using new types of engagement, and partnering with new communities, in pursuing early-stage, cross-cutting and game-changing innovations
- Increases use of the ISS as a National Laboratory and recognizes that STEM Education is key to future technology innovation
- Details are being worked with OMB and OMB and OSTP as part of the Agency FY11 Budget Submit



Barriers to Innovation at NASA: Common Issues and Solutions

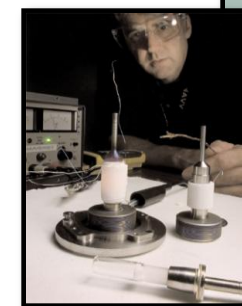
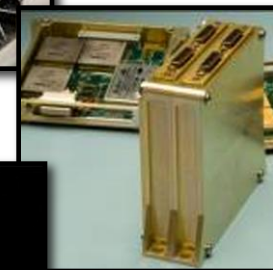


Issue	Proposed Solution
<i>Instability of technology programs / technology project support</i>	New focus on innovation and technology at all levels; Fenced budget with lead Agency Chief Technology Officer reporting to Administrator
<i>Inadequate focus on strategic investment (long-term, high-risk, high-payoff)</i>	Subdivisions within new program to include investments in very early-stage (NIAC-like) and and game-changing (DARPA-like) innovations
<i>Cultural and organizational barriers to innovation; failure not accepted</i>	New reward structures, communication mechanisms, fail-fast-forward approach
<i>Inadequate technology infusion</i>	Technology Coordination Council provides governance and facilitates agreements with flight programs and other users and funding exists for demos on ISS and elsewhere to increase infusion
<i>Inadequate coordination/portfolio management at the agency level</i>	Technology Coordination Council gives visibility into investment decisions at highest levels
<i>Inadequate partnering & leveraging of external innovation/innovators</i>	Many new investments to be competed broadly; Program sufficiently staffed to be effective catalysts for partnerships/leveraging

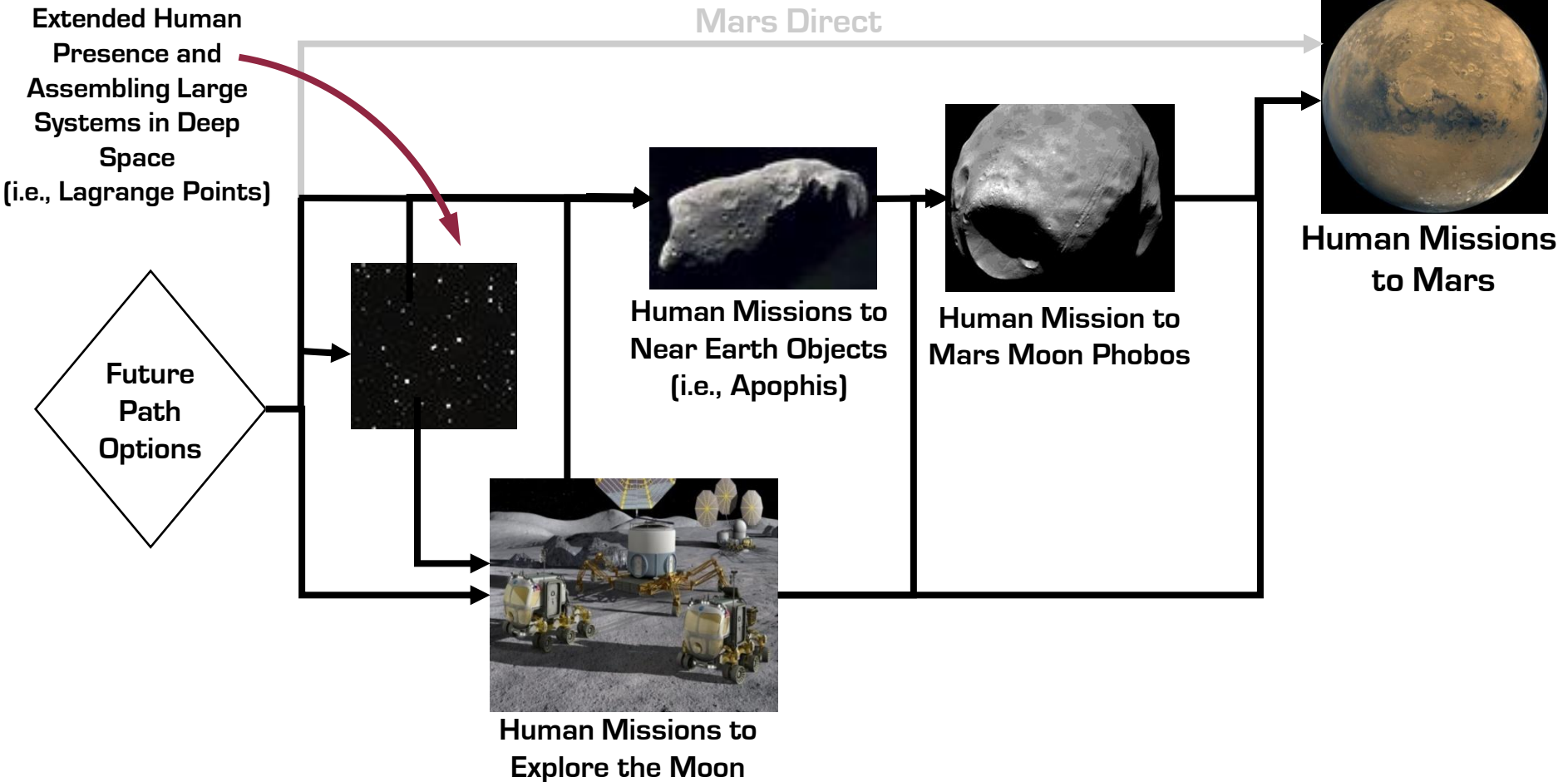
NASA Innovation Initiative Goals



- Revitalize NASA as a preeminent R&D organization through significant investment in longer term technical or process innovations free from instability due to mission growth
- Encourage innovative application of NASA capabilities to address broader national needs such as energy and climate, economic prosperity, health and wellness, national security, and STEM education
- Stimulate a vibrant commercial space sector through helping to create new types of engagement, creation of new markets, and investments in future technologies
- Generate excitement about NASA's work by investing in lots of highly creative activities with potential for disruptive breakthroughs
- Provide exciting hands-on work for students and new employees

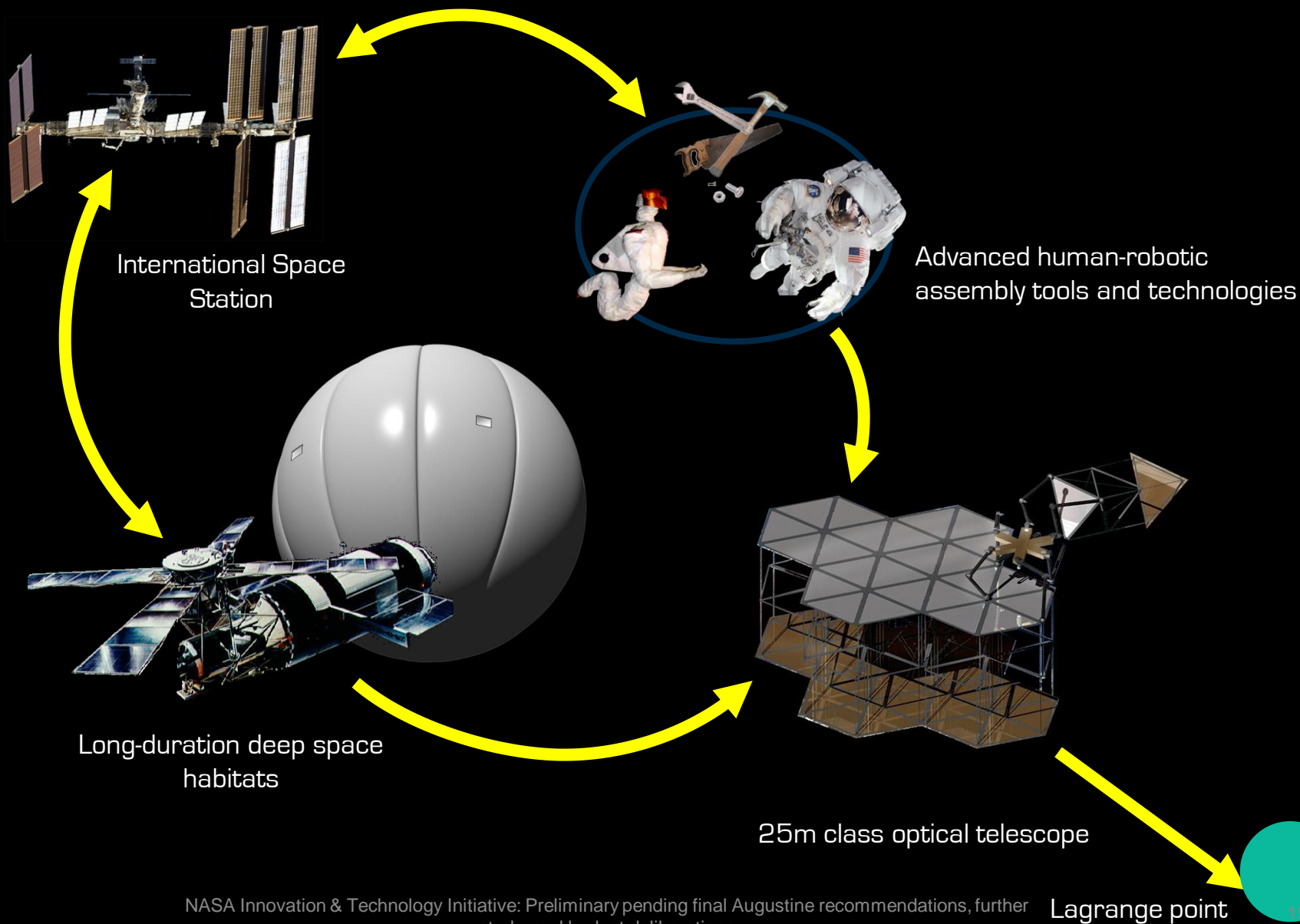


Agency Opportunities That Drive Innovation & Technology Developments

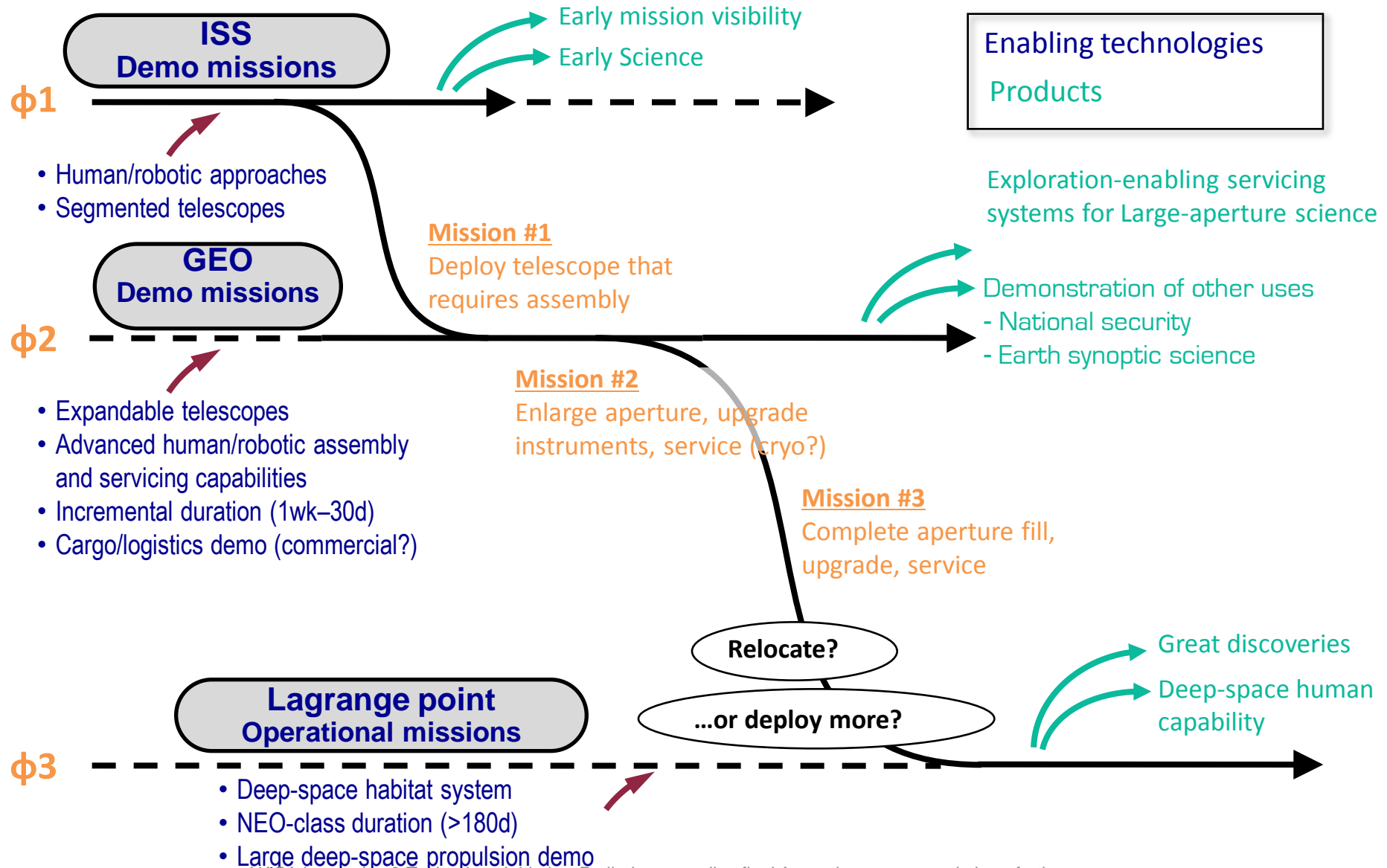
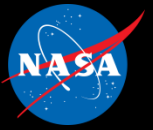


The Mission Drives Innovation and Innovation Enables the Mission

Large Space Telescope Assembly & Servicing Extends Human Capabilities in Operations, Distance, & Mission Duration



Notional Deep Space Roadmap: Technology Demo, Great Science and Advanced Human Capabilities



Near Earth Asteroids as a Destination: Developing Deep Space Capabilities & Protecting the Planet



• What are NEOs?

- Asteroids (99%) & comets (1%) in near-Earth space
- Very diverse: weak rubble piles to iron slabs
- Comets & many asteroids have ices, water-bearing minerals, and organics
- ~20,000 NEOs are considered capable of regional destruction (>140 m size).
 - ~1% chance of impact in next 50 years
 - By contrast, we personally insure at much lower %'s

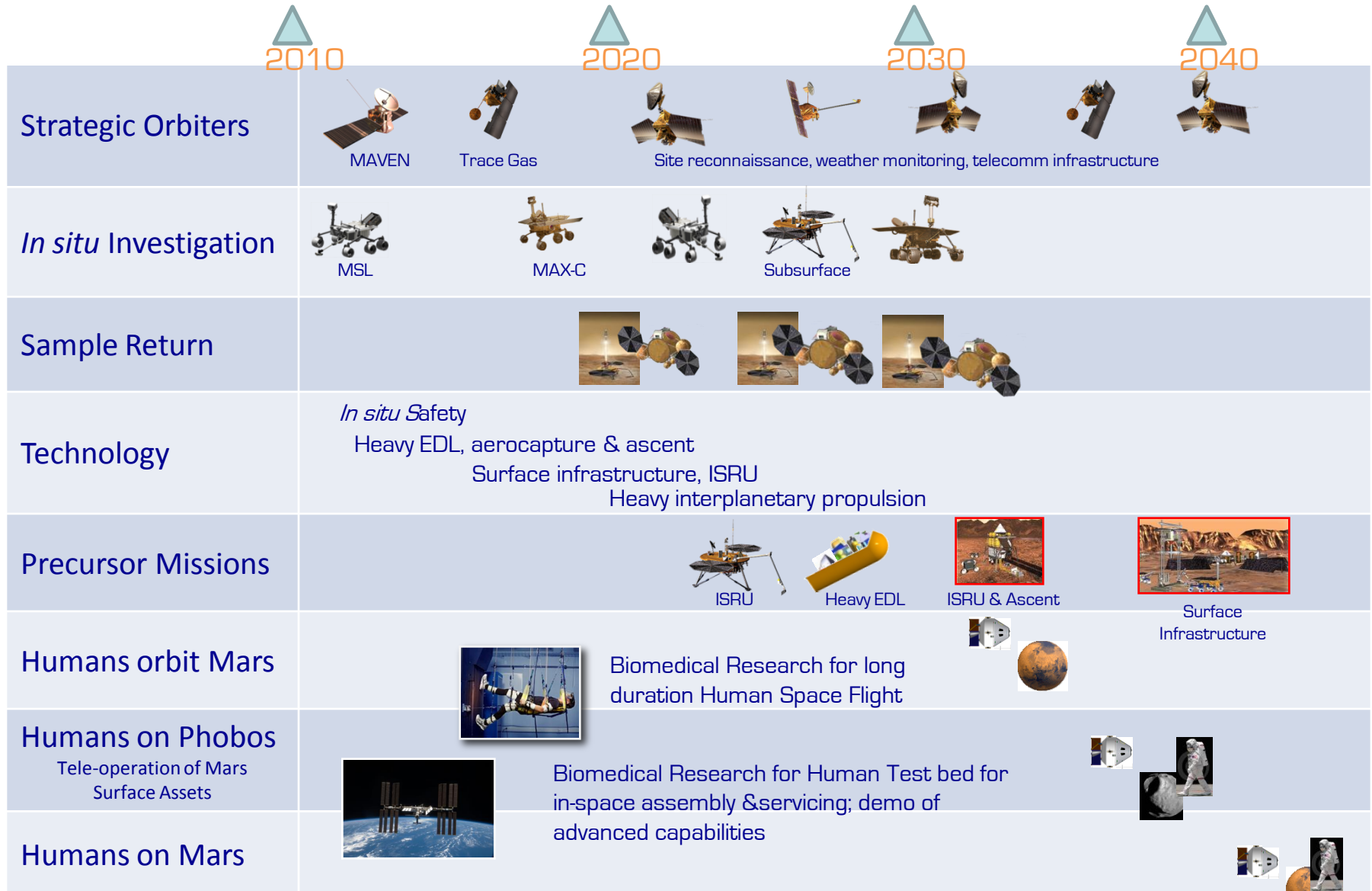
• Program Objectives

- **Catastrophic Impact Avoidance**
 - Find them all
 - Characterize them
 - Develop and test deflection methods
- **Science**
 - Solar system formation
 - Sources of Earth's organics & water
 - Meteorite collection ground truth
- **Human Exploration Feed Forward**
 - Long duration human space flight
 - Long lag-time operation
 - Asteroid/comet resource utilization
 - Small body operations



Asteroid Itokawa, 540 meters long
For comparison ISS, 100 m

Destination Mars: Notional Roadmap Integrates Science & Human Spaceflight to Support Bold Goals



NASA Innovation & Technology Initiative: Preliminary pending final Augustine recommendations, further study, and budget deliberations



Low TRL / Game-Changing Technologies

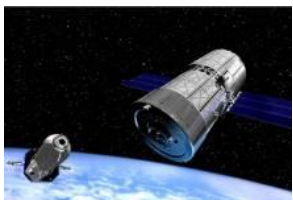
Time Phasing – Available 15+ years



- **Advanced Propulsion:** Development of concepts and technologies for advanced propulsion systems to enable rapid transport of crew and efficient transport of cargo on deep space missions. Technology development would include concepts for nuclear thermal propulsion systems, high temperature materials, and high power electric propulsion.



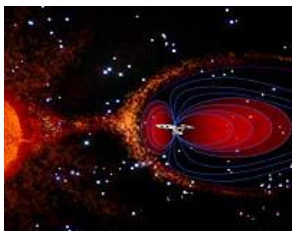
- **Entry, Descent, and Landing:** Development of system concepts and technologies for landing large payloads on the surface of Mars, including aerocapture systems, advanced thermal protection system materials, rigid and inflatable aeroshells, aerothermodynamic modeling and analysis tools, and supersonic retro-propulsion to brake the descent vehicle after it separates from the aeroshell.



- **Propellant Depots:** Development of zero boil-off cryogenic propellant storage and cryogenic fluid transfer technologies to enable in-space propellant depots to refuel exploration vehicles. The ISS would be used as a test bed for demonstrating prototype cryogenic propellant storage and handling systems.



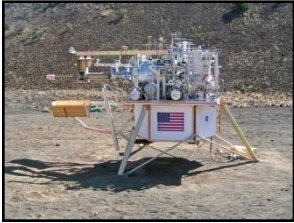
- **Closed-Loop Life Support:** Development of air revitalization, water recycling, and waste recovery systems for enabling closed-loop life support. These systems will minimize the mass of consumables such as water and oxygen that must be launched from Earth to sustain long-duration missions. Closed-loop life support systems technologies would be demonstrated on the ISS.



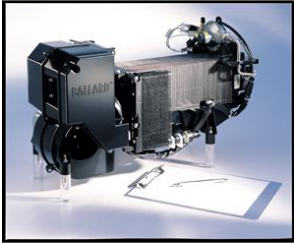
- **Radiation Protection:** Development of lightweight radiation shielding materials and anti-radiation drugs to protect astronauts on long-duration missions, radiation transport models to predict radiation exposure, and research into the effects of space radiation on human health.

Low TRL / Game-Changing Technologies

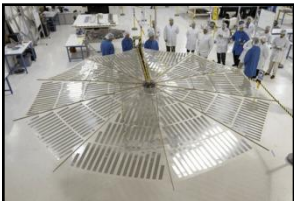
Time Phasing – Available 15+ years



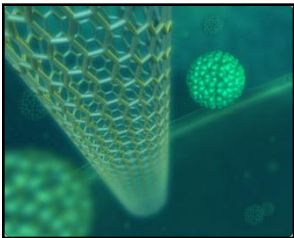
- **In-Situ Resource Utilization:** Development of chemical processes and prototype systems for producing rocket propellants and manufacturing components from in-situ resources.



- **Energy Storage Technologies:** Development of advanced energy storage systems for both in-space and surface systems. Technologies include advanced High-energy density batteries, ultracapaciters, and advanced regenerative fuel cells.



- **Energy Generation Technologies:** Development of advanced energy generation technologies for both in-space and surface systems. Technologies include nuclear, next generation solar cells,



- **Advanced Nanotube-based Materials:** Development of nano-based materials for lighter weight, more robust structures for in-space and surface systems. Development of nano-based propellant to be used for in-space transportation.



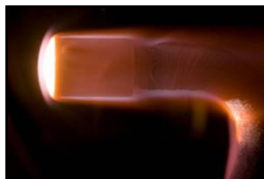
- **Collaborative Environments:** Development of wide-ranging and easily accessible collaborative environments for internal analyses and for public engagement for participatory exploration

Higher TRL Technology Developments

Time Phasing – Available 5+ years



- Structures, Materials & Mechanisms: Structural concepts for lunar habitats, radiation shielding materials, and low temperature mechanisms.



- Protection Systems: Prototype ablative heat shield for the CEV, and dust mitigation technologies.



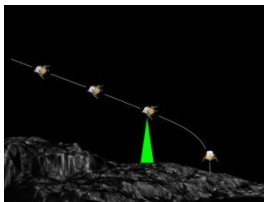
- Non-Toxic Propulsion: Cryogenic propulsion systems for the Lunar Lander using non-toxic liquid hydrogen, oxygen, and methane propellants.



- Energy Storage: High-energy density lithium-ion batteries, regenerative fuel cells.



- Thermal Control: Heat pumps, evaporators, and radiators for thermal control of the CEV and lunar surface systems



- Avionics & Software: Radiation hardened and low-temperature electronics, autonomous precision landing and hazard avoidance systems, and tools to produce reliable software.

Higher TRL Technology Developments

Time Phasing – Available 5+ years



- **Environmental Control & Life Support:** Technologies for atmospheric management, environmental monitoring and control, advanced air and water recovery systems.



- **Crew Support & Accommodations:** Technologies for advanced EVA suits.



- **ISS Research & Operations:** Flight experiments that use ISS as a research facility and as a test bed for exploration technologies



- **Fission Surface Power Systems:** Concepts and technologies for affordable fission surface power systems



- **In-Situ Resource Utilization:** Technologies for regolith excavation and handling, production of oxygen from regolith, and collection and processing lunar ice



- **Robotics, Operations & Supportability:** Technologies for surface mobility and equipment handling, human-system interaction, and supportability of lunar surface systems.

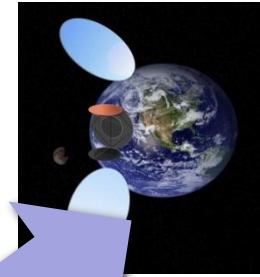
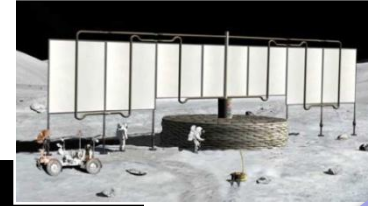
Technology Innovations for New Sources of Energy



Technology Development / Maturation

- Advanced Batteries & Energy Storage
- Advanced Fly Wheels
- Regenerative Fuel Cells
- Hydrogen Storage
- Thermal Energy Storage
- Stirling Power Converters
- High Efficiency Photovoltaics
- Advanced Solar Power Generation
- Intelligent Power Management & Distribution
- Wireless Power Transmission
- Space Solar Power Systems
- Embedded Power Technologies
- Electric Vehicles for Surface Mobility

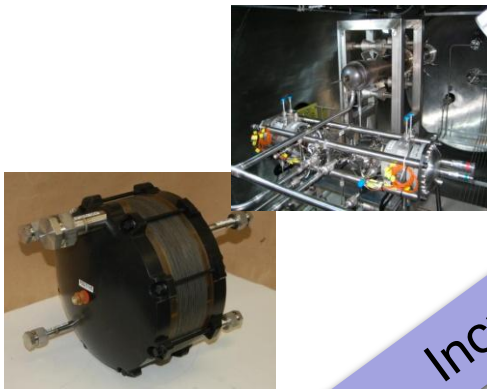
Enabling Human Missions



Increasing Levels of TRL and Mission Application

Terrestrial Applications

- Electric vehicles
- Green buildings
- Facility backup power systems
- Compact power sources for consumer electronics
- Solar power generation
- Power generation from waste heat
- Smart power grid
- Small nuclear power systems



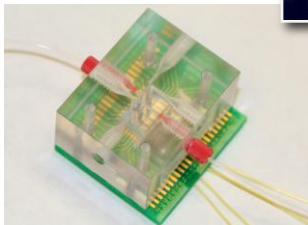
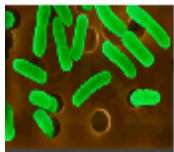
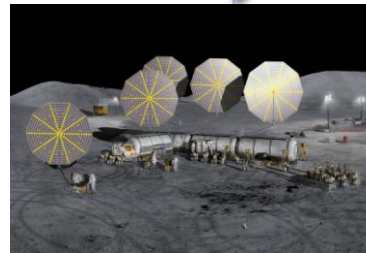
Innovations in Biomedical Research



Biomedical Research for Human Space Flight

- Remote medical technology
- Miniaturized diagnostic instruments
- Non-invasive biomedical sensors
- Real-time microbial sensors
- Biosensors for EVA
- Bioinformatics simulation & modeling
- Integrated human physiology modeling
- Radiation effects on cancer
- Advanced food technology
- Countermeasures for microgravity effects
- Behavior health & performance monitoring

Enabling Human Missions



Increasing Levels of Mission Application

Benefits for Public Health Care

- Remote medical care
- Non-invasive tests
- Real-time diagnostic instruments
- Vital signs monitoring
- Portable trauma care systems
- Renal stone formation
- Countermeasures for osteoporosis
- Muscle & cardiovascular fitness
- Predictive models of human physiology
- Improved understanding of aging
- Bioinformatics for patient records
- Cancer risk from radiation exposure



Changing the Game for Access to Space: Enabling New Commercial & National Capabilities



Technology Development / Maturation

- Green propellants
- Storable propellants
- Robust thermal protection systems for intra-atmospheric flight and entry
- Advanced wide speed range air-breathing engine technology
- Advanced materials for lightweight robust airframes
- Advanced controls systems for autonomous vehicles

Low cost access to orbit for space tourism, commercial and civil payloads

Rapid deployment of National Security Assets

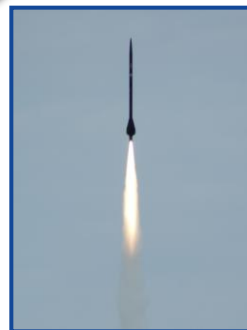


Commercial Over-the-top Intercontinental Transport

Applications

- Commercial intercontinental high speed transport
- Rapid response national security transport
- Low cost access to low earth orbit for commercial and government payloads
 - Re-useable air-breathing first stage
 - Flexible upper stages for higher orbit insertion

Increasing Levels of TRL and Mission Application



High Bandwidth Communications



Technology Development / Maturation

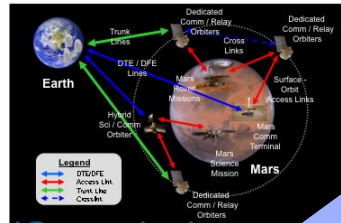
- Ultra high frequency solid state processing electronics and RF components
- High frequency phased array antennas
- High speed photon counting detectors
- Large lightweight receiving telescopes
- Space rating of commercial lasers
- Advanced encoding for many bits per photon optical and high compression RF
- End to end demonstrations
- Multi-aperture receive arrays
- Multi-aperture transmit arrays



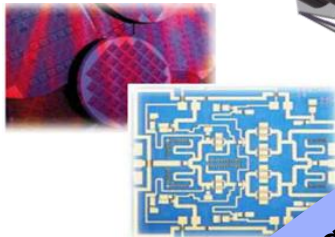
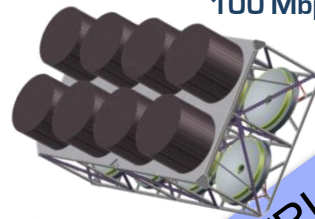
Enabling new types of Earth observations



Participatory exploration



- Optical Communications to 100 Mbps - 1 Gbps (Mars)



- Up to 1.2 Gbps cis-lunar (optical)



Enabling new types of space science observations

Increasing Levels of TRL and Mission Application

Applications

- High rate near earth RF and Optical for commercial and National Security applications
- Ultra small terminals
- Telepresence for STEM engagement
- High spatial, spectral and temporal resolution measurements enabling new Earth science
- High range/rate comm to enable new space science

Attributes of a Reinvigorated Innovation & Technology Program



- **ISS Utilization through 2020**
 - Implement research priorities of NRC Decadal Study of Life and Physical Sciences.
 - Grow projects that support utilization of ISS as a test bed for exploration and science (Life Support, Cryogenic Fluid Management, SMD Science)
 - Human research to reduce crew health and performance risks for long-duration missions and to develop countermeasures for microgravity effects
- **Technology Innovation for Flexible Capabilities Human Exploration**
 - Provide NASA the flexibility to implement various options studied by the Augustine Committee to extend human presence beyond low Earth orbit.
- **NASA Innovation Applied to Broader National Needs**
 - Application of NASA capabilities and technology for applications in energy and climate, health and wellness, National security
- **Expand Development of Mission-pull Technologies in Mission Directorates**
 - Maintain current projects that support Constellation Program development of Orion and Ares V (Adv. Composites, Life Support, Autonomy for Mission Ops).
 - Specific acquisition strategies to be developed by individual Directorates according to their best practices
- **Precursor Demonstrations**
 - Demonstrations of prototype systems and key capabilities on SMD and international robotic missions to reduce risk for future human exploration and more ambitious science missions
- **Expanded Commercial Sector Engagement**
 - NACA-like approach to developing investment strategy in opening long-term commercial markets



- Designed to stimulate highly innovative, low maturity ideas
- A competitive program, modeled on previous successes (NIAC, RASC)
- Separate internal and external competitions (budgets), but common evaluation – encourage partnering
- Phase 1 and Phase 2 awards – many small Phase 1 (\$100K), few large Phase 2 (\$500K)
- Phase 2 proposals should consider infusion likelihood to either:
 - MD Programs
 - Game changing program
- Design will purposely seek to invigorate STEM connections and early career innovators

Game Changing Innovation



- A DARPA-like Program
- Intended to be aggressive, well-funded efforts targeted at maturing game changing ideas that can either address near-term or farther term goals:
 - mission needs
 - focused revolutionary technologies
 - process or other “institutional” improvements
 - adaptation of NASA capabilities for National needs
- High level goals and guidance would be sought broadly through external advisory boards and internal technology council
- Program would seek explicit crosslinks to DARPA, IARPA, ARPA-E to capitalize on obvious synergies and opportunities for co-investment
- Relatively high level of autonomy for Director (like DARPA)
- Could include Center-focused component largely at CDs discretion
- Could include Prizes and VC programs

Expanding NASA Partnerships to Enable Future Success



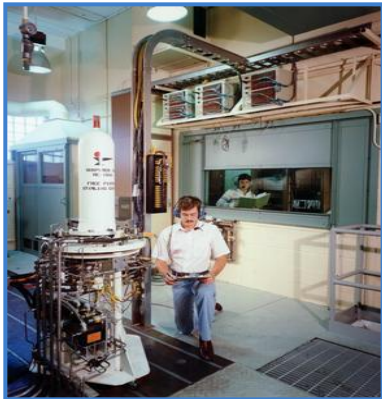
- **Commercial: Traditional & Non-, NewSpace**
 - Robust interest in deep space systems: cargo/logistics, depots, power, comm/nav, robotics, habitation, and collaborative data environments (e.g. Google, Falcon)
- **Other Government Agencies**
 - Leveraging other government programs and technologies to minimize costs
 - Partner and collaborate to maximize application of NASA innovations to address broader National Needs
 - (e.g. DoD, DOE, DARPA, NOAA, NSF)
- **Academia**
 - Engage Universities especially in early stage technology work and to increase STEM education impact
- **International Partnerships**
 - Leverage existing ISS relationships and Global Exploration Strategy (GES): 14 Int'l Space Agencies
 - Canada, Europe, and Japan = most progress; dialogue with Russia, China and India still immature



NASA Capabilities & National Needs: Capitalizing on Synergy



- Nearly all areas of innovation for NASA Programs have broader application to national needs for example in energy and climate, health & wellness, national security, economic competitiveness
- Innovation initiative would allow seed investments to enable development broadly applicable capabilities, and partnerships to transition these capabilities to relevant agencies, commercial partners, and users
- Examples include: Green aviation, Biofuels, Large space structures for national security, Advanced fuel cells, photovoltaics, & energy storage technologies, Nuclear systems, Integrated data visualization and decision support and many more



Advanced Stirling heat engines for solar, geothermal & nuclear power systems



Closed loop hydrogen oxygen regenerative fuel cell system



Offshore, single-blade wind turbine concept



Advanced photovoltaics

Summary: NASA Drives National Innovation



- America's economic competitiveness and high standard of living are based on decades of investment in innovation
- Investment in innovation in NASA communities will drive a more affordable yet aggressive future mission portfolio
- NASA innovators will address broader national needs in health, energy and climate, national security, STEM education
- Innovative research and technology, tied to exciting missions with national importance, is a strong motivator for students in STEM disciplines, and a strong attraction for new hires
- Our potential innovation program will:
 - Be responsive to Augustine and NRC recommendations,
 - Position NASA to explore beyond low earth orbit,
 - Be highly engaging of our academic and industrial partners, and the emerging commercial space sector
 - Result in new inventions, new capabilities and creation of a pipeline of innovators trained to serve future national needs