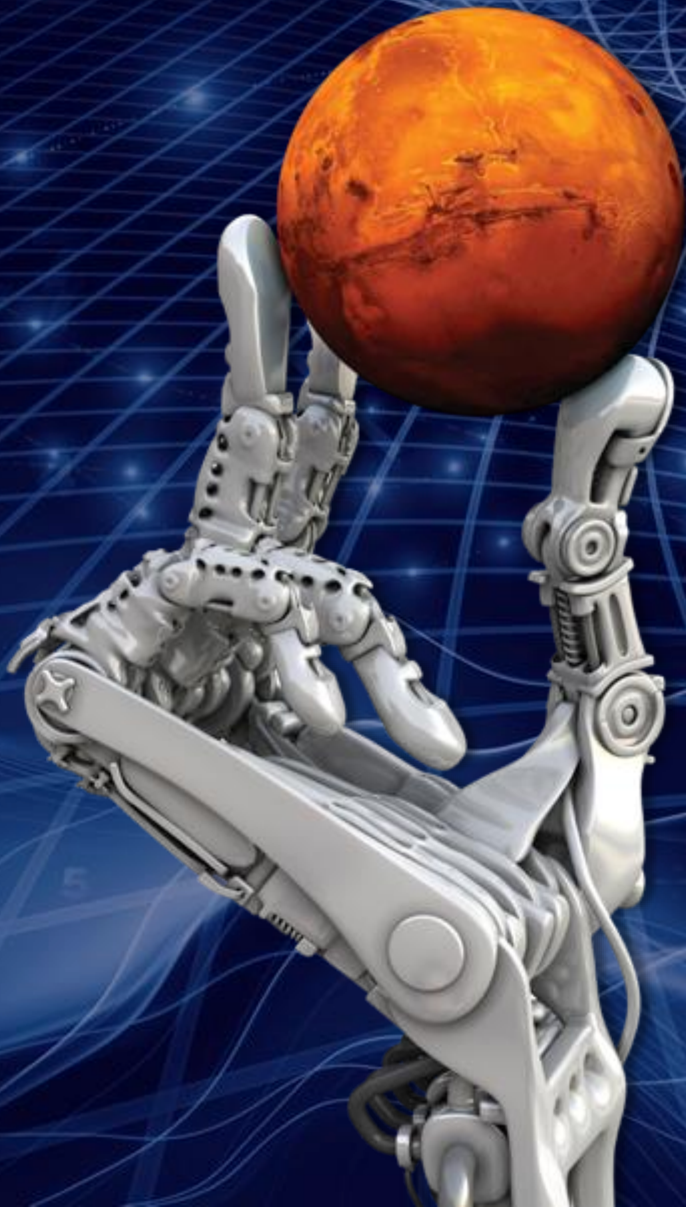
National Aeronautics and Space Administration



Update on OCT Activities

NAC TI&E

David W. Miller

NASA Chief Technologist

July 28, 2015

Outline

- **Model Based Systems Engineering (MBSE)**
- **Space S&T Partnership Forum**
- **The Role of Architecture in Exploration**
- **Education Initiative**
- **Asteroid Grand Challenge**
- **OCT Updates**

Model Based Systems Engineering (MBSE)

- **Gave Plenary talk at JPL MBSE Conference in January 2015**
  - Slides (attached) have been used as supporting material for Inter-Agency Working Group on MBSE
- **OCE selected a Tech Fellow for Systems Engineering in March 2015**
  - Jon Holladay from MSFC
  - Leads Systems Engineering (SE) Technical Discipline Team (TDT) supporting NESC and NASA SE capability health
  - Working to coordinate and integrate Communities of Interest related to MBSE (NASA internal and external)
  - The SE Technical Discipline Team (TDT) will help integrate and proliferate the use of MBSE across the agency.
- **Numerous MBSE related activities are on-going or in planning stage at NASA**
  - JPL, appears to be the furthest along at government level (applying MBSE to ARRM, Europa-Clipper, and Mars 2020)
  - GRC, engaging MBSE on ARRM
  - MSFC, planning to team with JPL and KSC to apply MBSE to launch vehicle interface modeling
  - GSFC, planning to assess MBSE toward sounding rocket development and flow
  - NESC, demonstrating advantage of MBSE on several Explorations Systems Development independent assessments
- **Other communities are actively advancing MBSE**
  - Automotive Industry, Department of Defense, Aerospace Industry (Boeing R&T, Raytheon, Lockheed Martin, etc.)
- **Discussing with STMD possibility of MBSE investments under FES**

Space S&T Partnership Forum

- **Space Partnership Summit requested update on inter-agency technology investment coordination**
- **Space S&T Partnership Forum created to**
  - Identify synergistic efforts/technologies to address pervasive needs
  - Identify "hot" topics for discussion at future Summits
  - Pro-actively coordinate joint messages for Hill and White House to tackle difficult problems
  - Explore mechanisms for collaboration (e.g., personnel exchange, CRADAs, TIMSs across 17 CoIs)
- **Membership**
  - Anchor tenants: Air Force (AFSPC), NASA, NRO
  - Members: AFRL, DARPA, NOAA, OSD
- **History**
  - Space Industrial Base Council (SIBC): maintenance of legacy technologies critical to space community
  - Space S&T Partnership Forum: coordination of investments in future technology development: started in 2015, two meeting thus far, one outbrief to Summit
  - Space Technology Alliance (STA) : started in 1998, ended in 2006, similar charter
  - NASA-NRO Working Group: NRO Office of Policy and Strategy and NASA Office of International and Intergovernmental Relations

The Role of Architecture in Exploration

Motivation

- From an Agency Integration standpoint, NASA does not have resources to invest in all road-mapped technologies or sustain all current engineering capabilities: needs a methodology for prioritizing allocation of resources
- There is potential for exploiting synergies across all MDs at the campaign goal, engineering capability, and technology investment levels in order to attain most value from investments
- Agency-level architectural integration provides a methodology for understanding return on investment (RoI) at Agency level rather than MD level

Objectives

- Promote trades to be conducted by cross-MD architecture team that exploit [modularity] to reduce cost and risk as well as increase cross-MD [affordability] through [commonality] and share a common assessment rubric
- Evaluate cost as an independent variable (CAIV) to understand the relative value of capability development and risk reduction efforts under different assumptions as to available funding
- Understand return on capability investment [technology] and sustainment [engineering] in the context of different mission campaign scenarios [science]
- Identify architectures which share common elements and technologies
- Define a class of missions associated with a campaign between which execution can cost-effectively switch in order to maintain progress towards the campaign goal in the presence of changing internal and external conditions [resilience]
- Recommend risk mitigation options in the Proving Ground [e.g., cis-Lunar space and Mars]

Exploration is about Resilience & Logistical Efficiency

Resilience: Ability to recover from or adjust easily to change

- Changes include funding, political priorities, technological and scientific discoveries
- **Architectural elements that are insensitive or adaptable to change**

Logistics: procurement, maintenance, transportation of materiel, facilities, personnel

- Procurement: multiple uses from fewest unique units, technology refresh
- Maintenance: crew health, self-sufficiency, workforce skill readiness (ops tempo)
- Transportation: launch, interplanetary transfer, orbit capture, landing/ascent (EDLA)

Modularity: standardized units for flexibility and variety of use

- Encapsulate complexity with fewest and simplest interfaces
- Multiple descent/ascent elements, sub-habitats, ISRU and power plants

Commonality: possession of similar features or attributes

- Develop units that serve many purposes across a campaign and other markets
- Common units for Moon and Mars EDLA, space and surface habitats, habitat and rover mobility

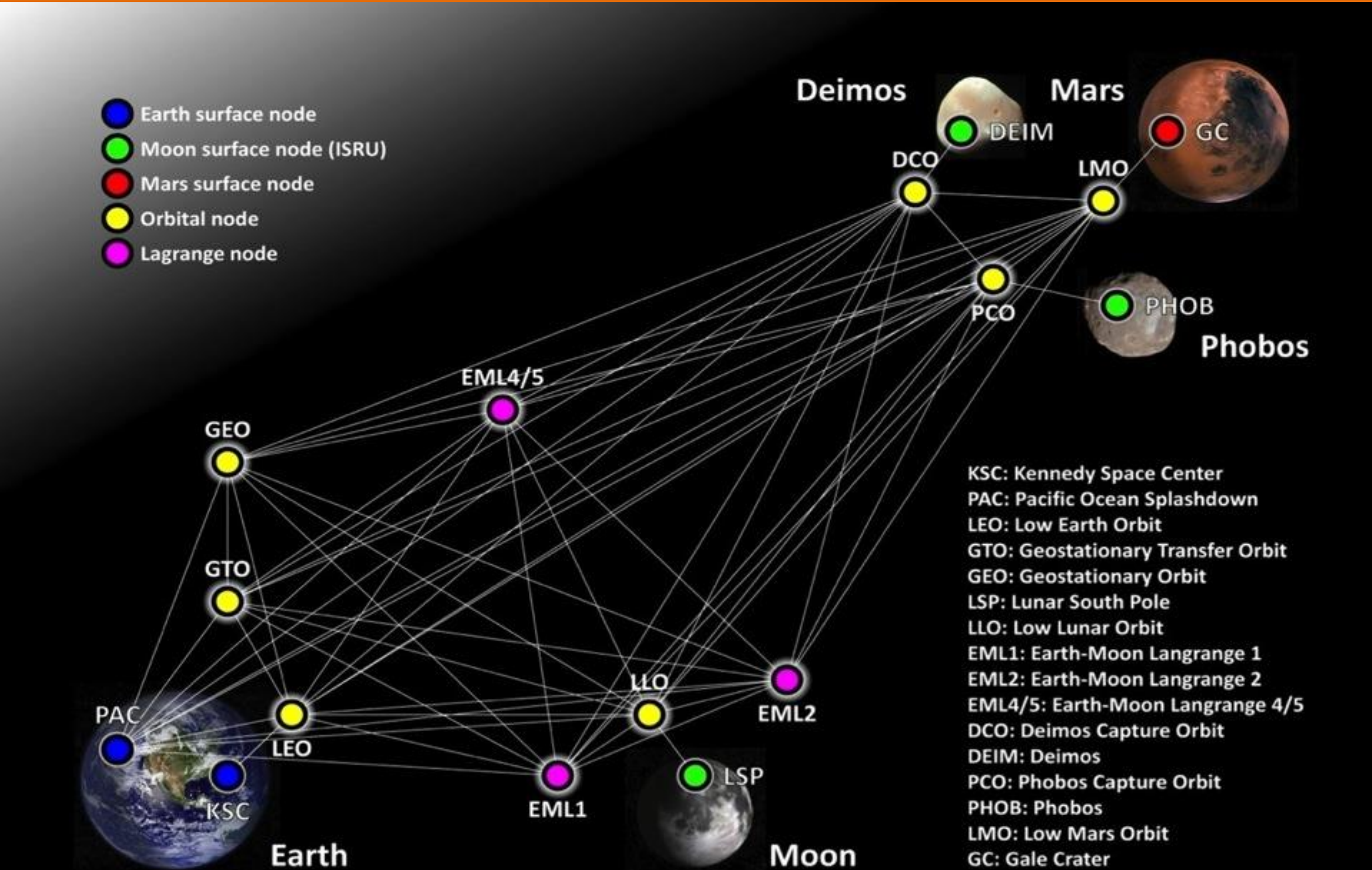
Extensibility: augmenting functionality through minimal additional effort

- Maturation of capability has growth path to full scale need (no dead ends, open architecture)
- Precursor mission deploys the first module of an operational system

Affordability: minimize NRE (fewer unique units) & RE (higher production volume)

- Sacrificing some efficiency (e.g., SWaP) within a unit may increase its use in other applications and thereby gain system-wide efficiency

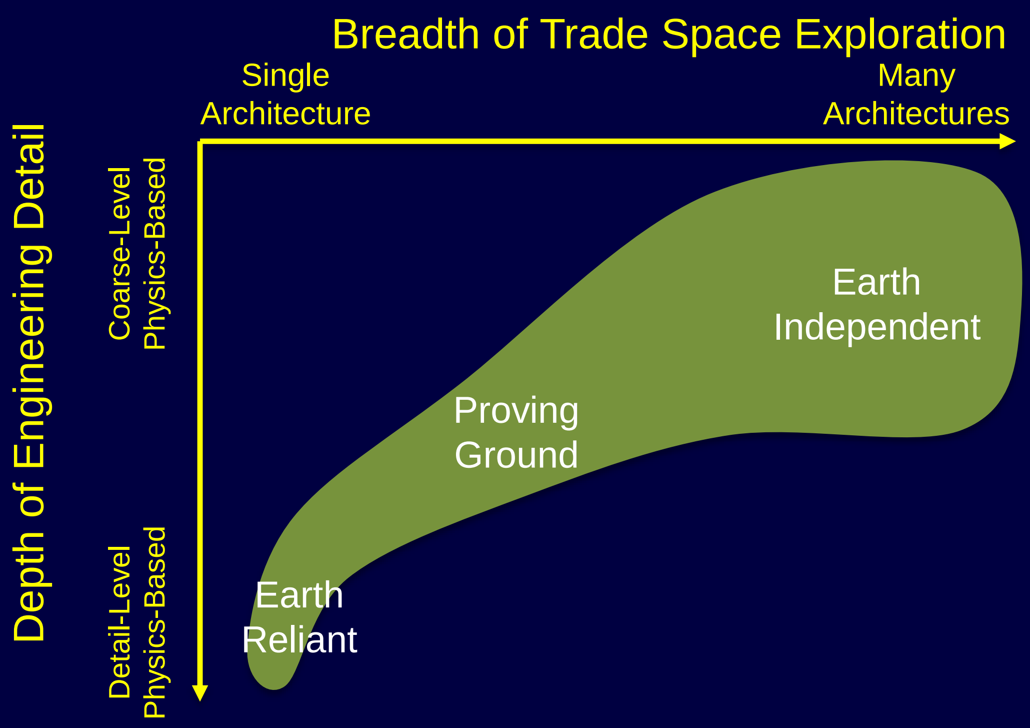
The Role of Architecture in Exploration



Human Space Pioneering Trades - Process

Breadth and depth of architectural analysis needs to be appropriate for phase

- Earth Reliant [2010s]: Architecture well defined requiring small adjustments to implementation
- Proving Ground [2020s]: Narrow architecture now while addressing needs of Earth Independent
- Earth Independent [2030s]: Keep exploration options broad to ensure that architectural elements being developed now can accommodate inevitable changes



Architecture is the Organizing Theme

Know the customer —

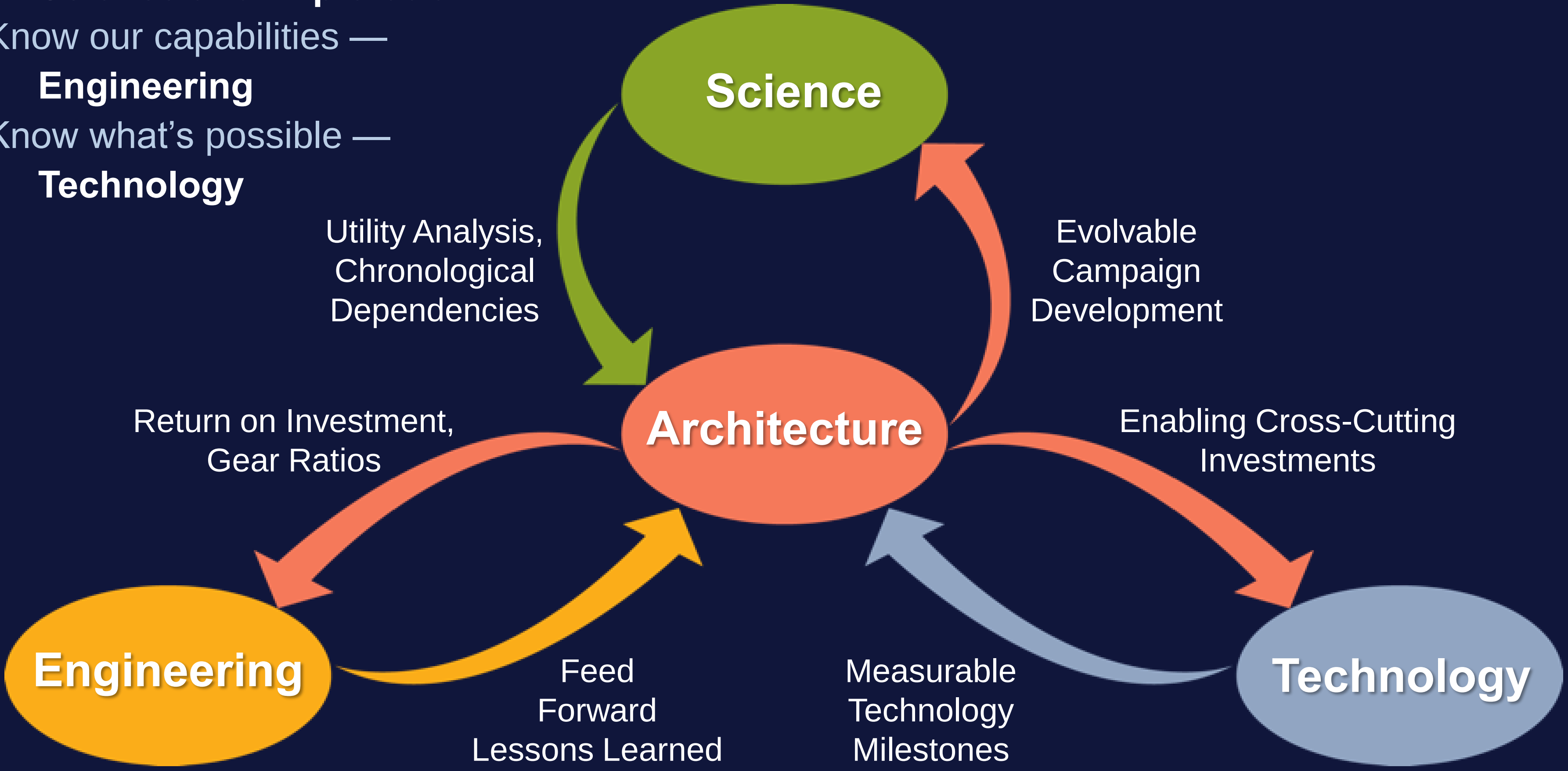
Science and Exploration

Know our capabilities —

Engineering

Know what's possible —

Technology



Given that change is inevitable, architecture must be resilient — able to recover from, or adapt to, change.

NASA Supported On-Line Classes

Objective

- TO use unique NASA resources to enhance educational benefit at all levels (K-12-PhD)
- BY integrating NASA video and data with physical laws and simulation into on-line courses
- WHILE teaming with educational organizations (e.g., Kahn Academy) to develop a curriculum
    - Identify science, technology, and engineering topics for which current videos and data are not currently available and develop a cross-Agency plan for acquiring them cost-effectively

Benefits

- Marry the use of mathematics and physics to predict behavior with the actual visualization and measurement of objects undergoing that behavior
- Seeing is believing, understanding model-data correlation, designing using correlated models
- NSF developed visualization for aerodynamics videos in the 1950's
- In the 2010's, on-line education, NASA HD videos, embedded animation coming together

Challenges

- Need to team NASA video content with on-line education with educational content with funding
- Need to develop curriculum, determine what is supported by existing video, capture new video

Next Steps

- Fund a pilot activity of several lectures as a collaboration between NASA, on-line, and .edu
- Approach NSF and others with pilot to seek further support

Highlighted OCT Activity

ASTEROID GRAND CHALLENGE

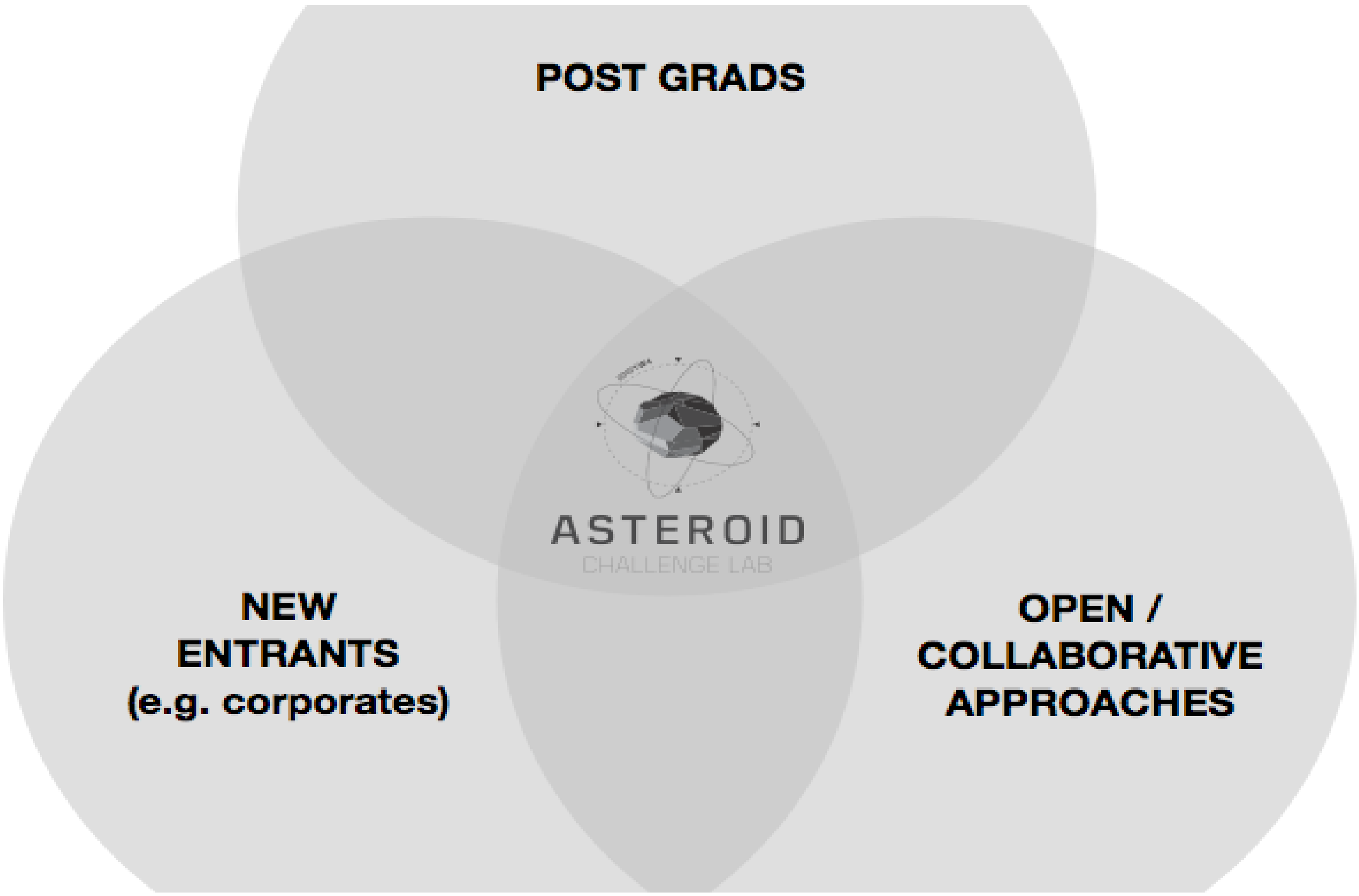
JASON KESSLER

Asteroid Grand Challenge FY15 Update

ROSES Citizen science Asteroid Data, Education, and Tools (CADET)

It seeks innovative proposals to adapt, develop, and web-enable software tools for asteroid data analysis and to make them accessible and easily usable by non-professionals, including amateur astronomers, students, and citizen scientists.

Asteroid Challenge Lab
Summer Fellowship Program



Asteroid Grand Challenge FY15 Update

Asteroid Grand Challenge FY15 Update

Asteroid Grand Challenge FY15 Update

Asteroid Grand Challenge FY15 Update

Asteroid Grand Challenge FY15 Update

FY15 Q3 Updates

OTHER OCT ACTIVITIES

2015 NASA Technology Roadmap

Technology Roadmap Updated

Considers
- Updates in Science Decadal surveys
- Human Exploration capability work
- Advancements in technology

Includes:
- State-of-art
- Capability needs
- Performance goals

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

2015 Technology Roadmaps Facts:

340 people contributed (authored content). This included input from all NASA Centers, organizations, industry and government. Others provided edits during Center and HQ reviews.

The 2015 NASA Technology Roadmaps are comprised of:
16 sections
15 technical areas
2,100 pages
1,273 technology candidates

Since the 2012 Roadmaps were released, the 2015 Roadmaps have been expanded to include:
- ✓ 1 new Technology Area, TA 15 Aeronautics
- ✓ 7 new level 2 Technology Areas
- ✓ 66 new level 3 Technology Areas
- ✓ 1,273 Technology Candidate Snapshots
- ✓ Detail about crosscutting technologies (requested in NRC's previous roadmap review)

- ✓ 2015 draft Technology Roadmaps Released to the Public on May 11, 2015
- ✓ Request for Information Closed and Comments Incorporated

Final 2015 NASA Technology Roadmaps Released

Roadmap Next Steps

National Research Council Status

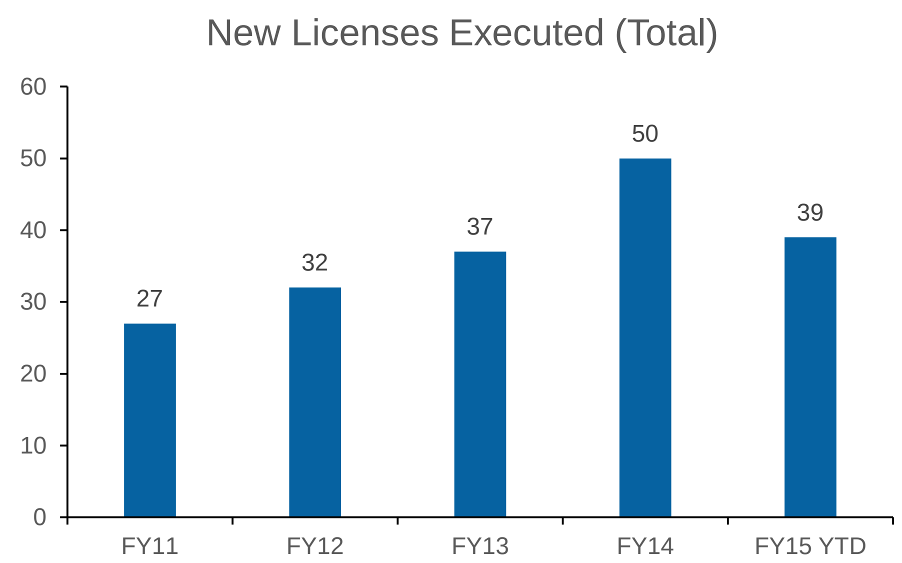
- Statement of Work (SOW) was Approved by NASA Technology Executive Council (NTEC) – Focus of SOW to prioritize new technologies in 2015 Technology Roadmaps
- **NRC Contract Awarded on 05-27-2015**
- Currently, NRC is putting together the committee

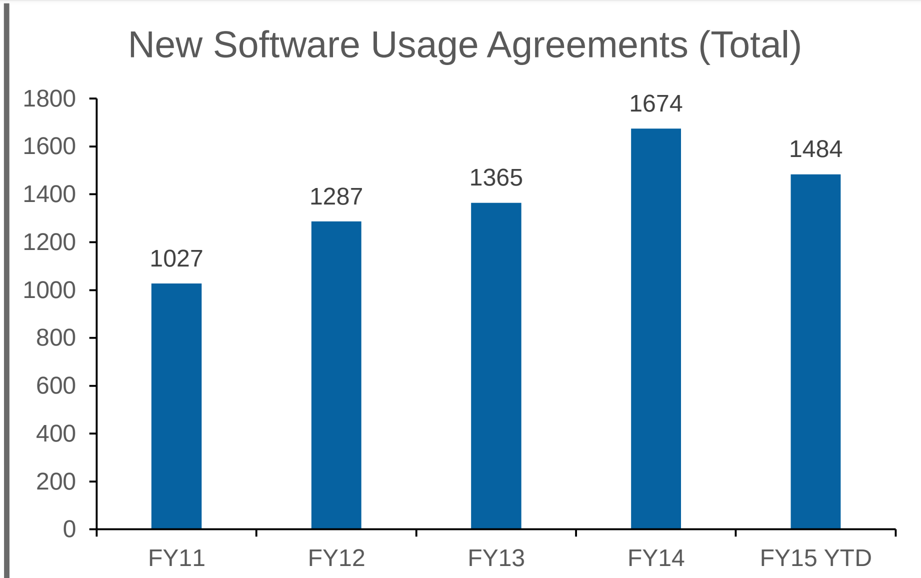
- Schedule
  - 8/10/2015 Committee membership approved
  - 9/28/2015 First Meeting, Washington, D.C.
  - 11/1/2015* Second Meeting, location TBD
  - 1/1/2016* Third Meeting, location TBD
  - 3/1/2016* Fourth Meeting, location TBD
  - 4/1/2016 Development of Consensus Draft
  - 5/1/2016 Report Sent to External Review
  - 7/15/2016 Report Review Complete
  - 8/1/2016 Report Delivered to Sponsor (Prepub)
  - 10/1/2016 Report Delivered to Sponsor (Published copies)

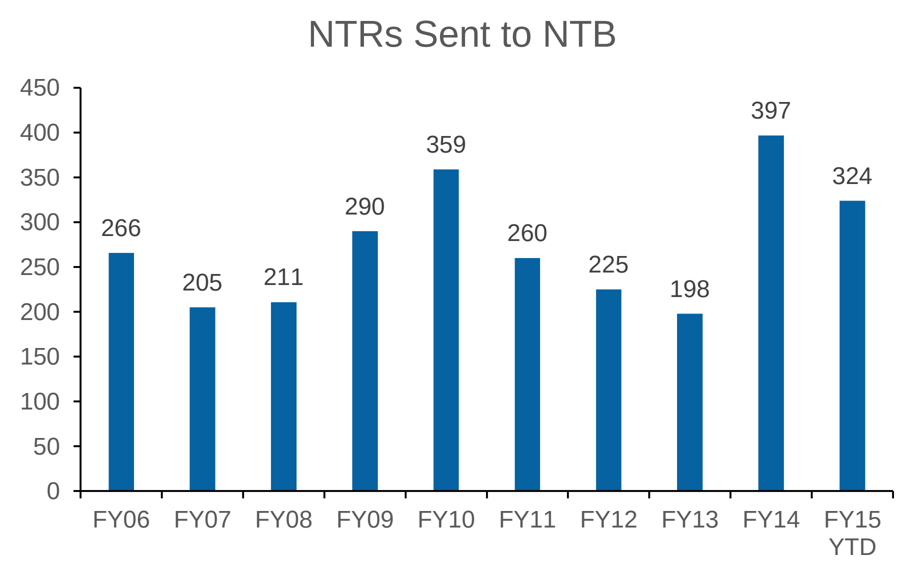
Note: NASA Updates the Strategic Technology Investment Plan (STIP) every 2 years.
We are currently updating the STIP. We will be using 2015 new technology candidates and 2013 NC priorities for FY2016 STIP. The STIP in FY2018 will include NRC's 2016 recommendations.

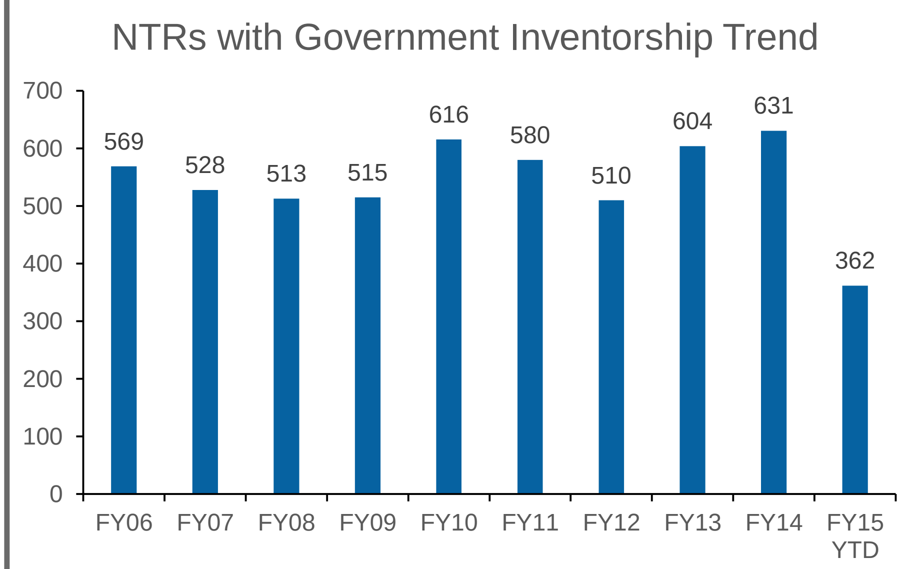
Tech Transfer FY15 Q3 Metrics Highlights

TECHNOLOGY TRANSFER PROGRAM







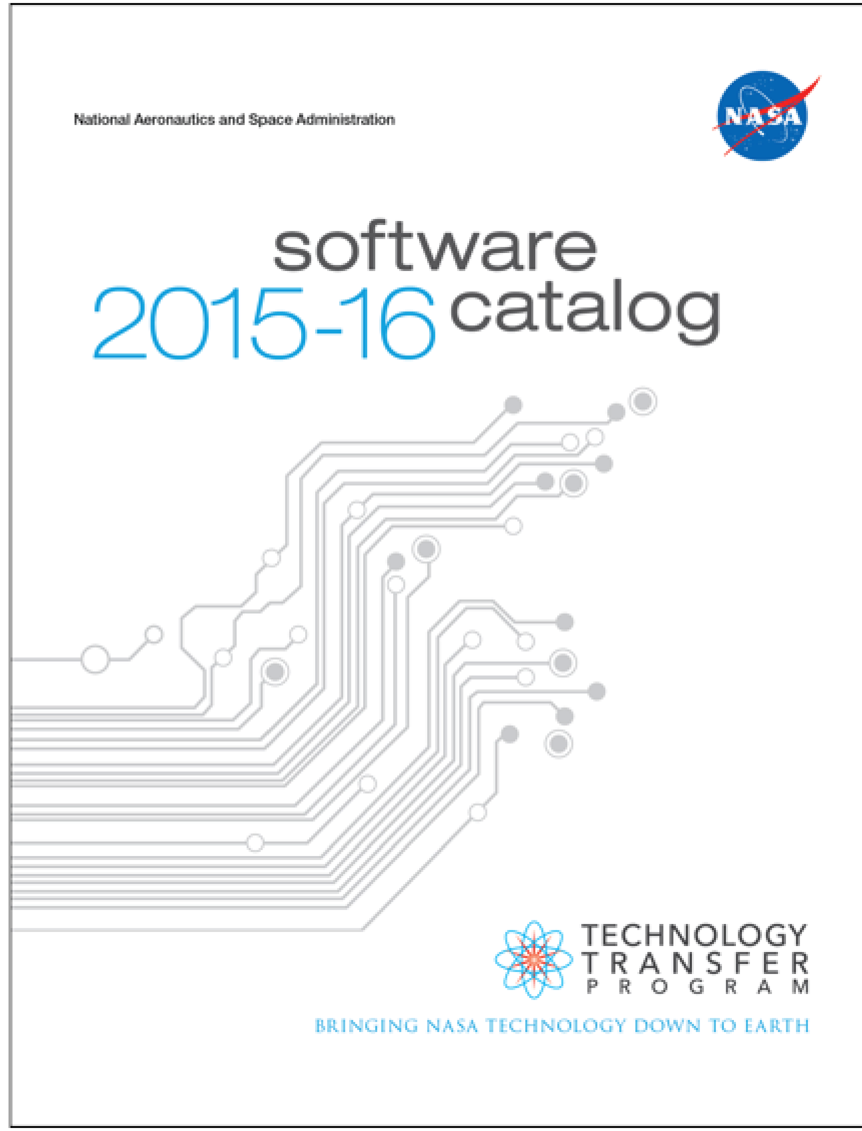


Significant Boost in Software Requests

Software Catalog Release

TECHNOLOGY TRANSFER PROGRAM

- Centers have seen a significant increase in software requests after the release of the new catalog.
- Publicity on Gizmodo and White House blog plays a big part.
- Copies are being mailed out to engineering programs across the U.S.
- Available for download at software.nasa.gov



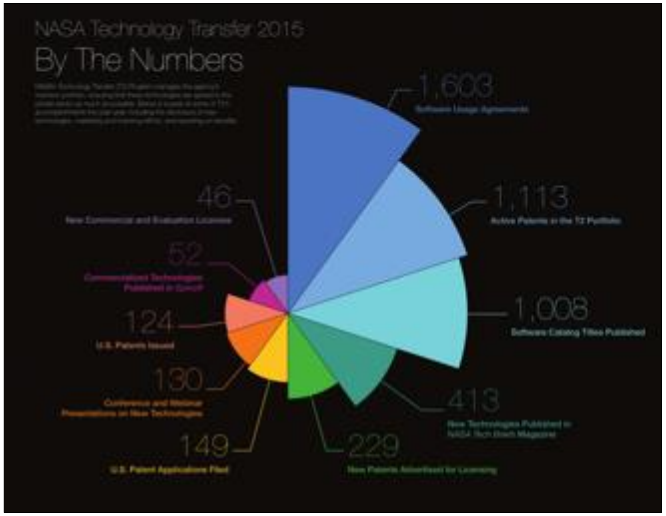
Link to Gizmodo article:http://bit.ly/1FqiL40

Link to White House Blog: http://1.usa.gov/1EF4T2g

Spinoff

TECHNOLOGY TRANSFER PROGRAM

- ***Spinoff* 2016 draft under review at HQ**
  - 52 spinoff stories
  - Marked increase in spinoffs from licenses and software releases (more than 30% of stories)
  - 20 technologies in “Spinoffs of Tomorrow”
  - Feature article and infographic on T2 program achievements in 2015
- ***Spinoff* 2017 is underway**
  - Close to 20 strong leads already in the works

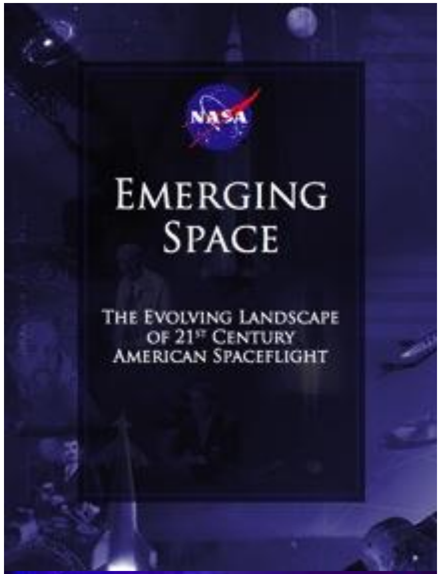


Prizes, Challenges and Crowdsourcing

- **NASA@work is an agency wide platform that allows NASA employees to easily engage across centers, helping each other solve important problems and issues within the agency.**
  - Through efforts initiated last year by the Prizes and Challenges Program Executive, both the Kennedy Space Center and the Goddard Space Flight Center have officially established NASA@Work Infuser roles to assist with center-specific use and communications associated with the continued evolution of the platform.
  - A new release of NASA@Work with an improved user interface and improved functionality was completed in May 2015.
- **NASA's Center of Excellence for Collaborative Innovation (CoECI) works to leverage crowdsourcing-based challenges to enhance the mission of NASA and other federal agencies.**
  - The NASA Open Innovation Services multi-vendor IDIQ acquisition was completed in June with an award of 10 contracts. All platforms are now considered part of the NASA Tournament Lab (NTL). Awardees are: Appirio/TopCoder, Common Pool, HeroX, InnoCentive, Kaggle, Luminary Labs, NineSigma, OpenIDEO, Patexia, Tongal.
  - To stimulate use of challenges and pilot the new acquisition strategy, OCT is co-funding 5 of the initial challenges to be launched on NTL. Integrated Outreach Plan TBD.
    - The Asteroid Grand Challenge Video Challenge (HQ, AGC)
    - Robonaut Vision Tool Manipulation Algorithm Challenge (JSC, Robonaut/STMD)
    - Technique for Processing Surface Materials (KSC, Swampworks)
    - Wear-Testing Textiiles for Exploration Missions (JSC, Advanced Eva Suits)
    - Towared Bio-inspired Approaches for Compact and Efficient Advanced Exercise Concepts for Exploration (GRC, Human Research Program)
  - OCT funding pilot of micro challenges on FreeLancer platform to determine scope of challenges and efforts appropriate for smaller credit-card level crowdsourcing.

Emerging Space August-2015

- **Economic Research for Space Development 2015 NASA Research Announcement Released in NSPIRES**
  - **Proposals due August 31, 2015**
  - **Total Estimated Funding Available: $500,000**
    - **Ceiling Amount: $100,000**
  - **New Areas of Research Solicited for 2015:**
    - **Sociological and economic research into the socioeconomic environment for space entrepreneurship**
    - **Logistics for in-space propellant production and supply with space exploration and development architectures**
    - **Econometric analysis of the impact of space activities and R&D on regional development and clusters**
    - **Empirical demand-side assessments of the relative size of potential revenue sources for commercial LEO space stations**
    - **Methods for developing manufacturing and production applications in microgravity**




Questions?

David W. Miller
NASA Chief Technologist

MBSE: Harnessing Technology to Revolutionize NASA's Engineering Practice

TECHNOLOGY DRIVES EXPLORATION

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Model-Based Systems Engineering

Current Practice

- Requirements, designs, analyses, data captured in documents
    - Not amenable to data extraction, independent analysis & assessment
- Not “living” documents easily adaptable over a project or leveraged by others

Proposed Process

- Formalized application of modeling to support system lifecycle development
    - e.g., requirements, data analysis, verification & validation
- Capture these products in interactive modeling framework
    - Discoverable design revision history, lessons learned, trade-able requirements, extractable raw data with available analysis code
    - System design space exploration, integrated mission- and system-level performance assessments by tying into integrated multi-physics and detailed design models.

Potential Benefit

- “What-ifs” posed by stakeholders could be answered in real time
- Design decisions could be revisited, raw data re-analyzed
- Enhance productivity & quality, reduce risk, improve communications, more in-depth independent assessment

Intersection of Science, Engineering & Technology

MBSE is a new engineering methodology

- That sits at the intersection of science, engineering and technology
- Whose development does not sit squarely in any one NASA Mission Directorate, yet benefits all NASA Mission Directorates
- Ideally, developed under institutional investment, to retain multi-mission benefit
  - Otherwise, project pioneers shoulder initial framework development costs and resulting frameworks run risk of being overly tailored to these projects

Challenges in advancing MBSE to practice include

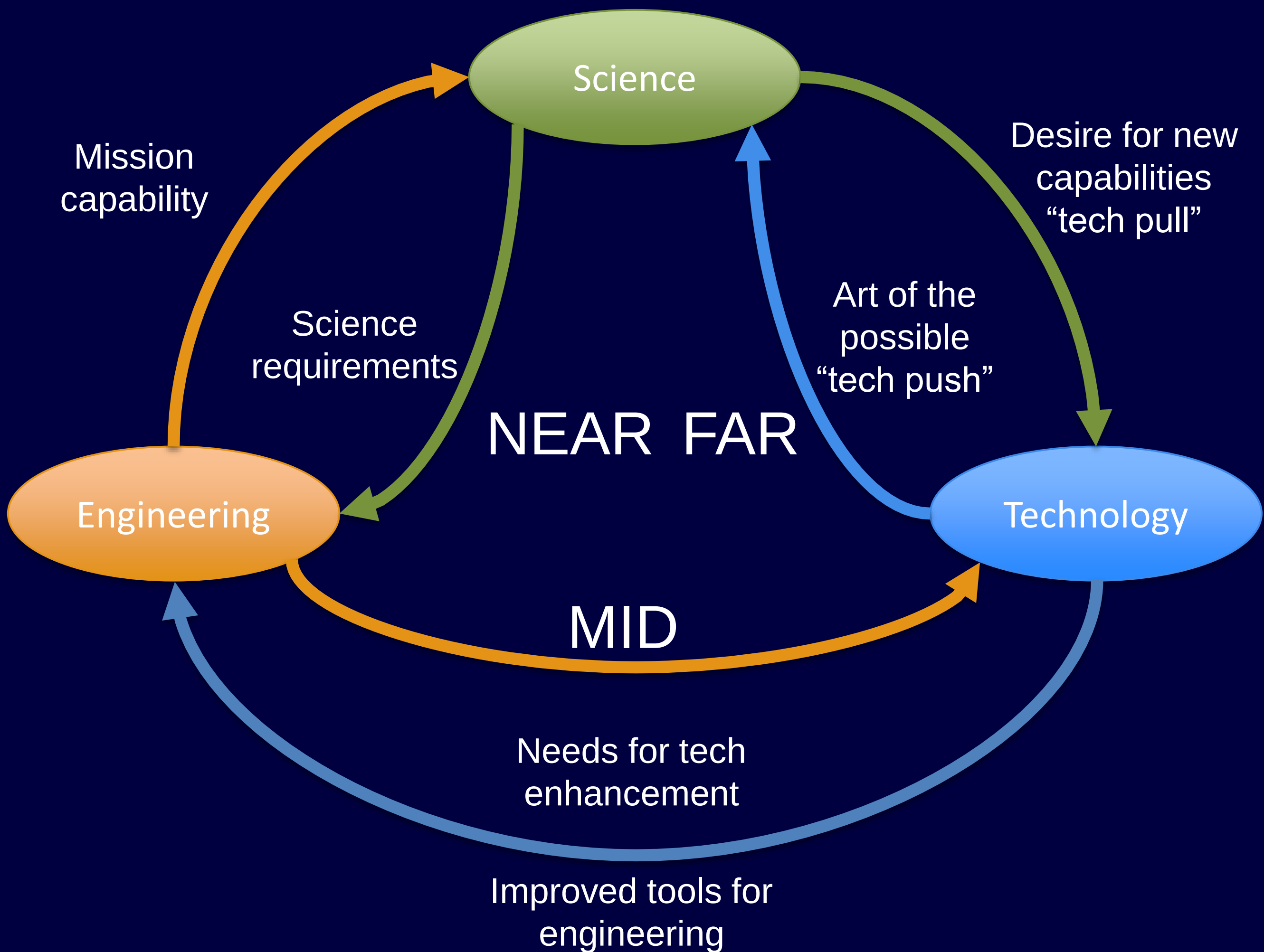
- Articulating the value to the engineering community and its customers
- Formulating a staged deployment of capability without substantially disrupting current practices
- Avoiding the perils of over-modeling
- Validating MBSE tools on authentic engineering problems
- Finding a sponsoring organization, or organizations
- Training the next generation of engineers to view MBSE not as a disruptive process but as “the way to do business”

Please help me answer the Heilmeier Questions!

Heilmeier Questions

1. What are you trying to do?
2. How is it done today, and what are the limits of current practice?
3. What's new in your approach and why do you think it will be successful?
4. Who cares?
5. If you're successful, what difference does it make? What impact will success have? How will it be measured?
6. What are the risks and the payoffs?
7. How much will it cost?
8. How long will it take?
9. What are the midterm and final "exams" to check for success? How will progress be measured?

Dialogue between Science, Engineering & Technology



MBSE can facilitate these three very different dialogues

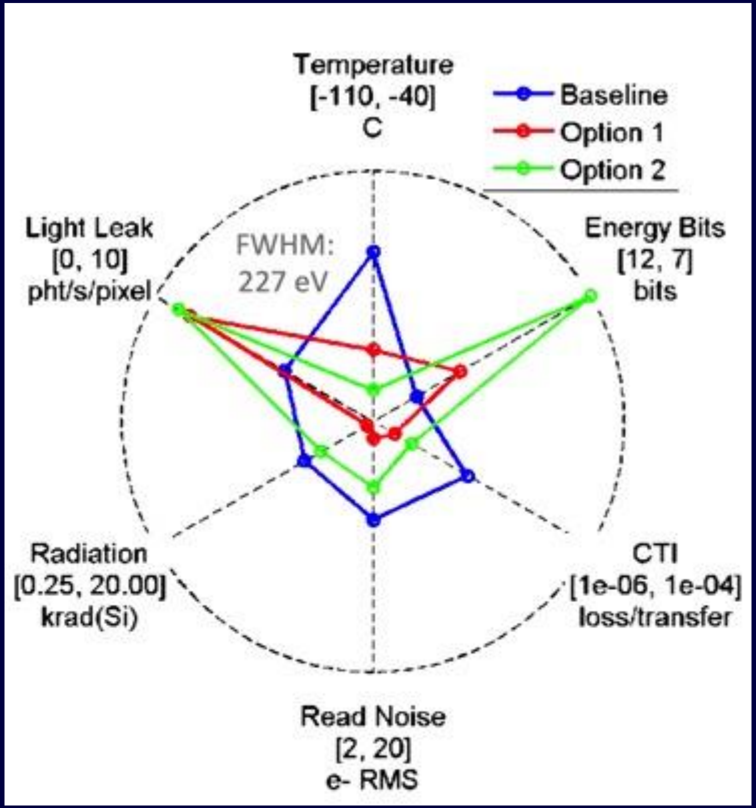
Notional Dialogues between Science & Engineering

Requirements dialogue

- There exist many ways to satisfy a requirement
- Formalize iso-performance analyses that identify most cost-effective lower level requirements

Performance-to-Plan dialogue

- Assess the degree to which RED & YELLOW identified in Implementation Phase were detectable during Formulation Phase
- Review the process used for P-to-P assessment during Formulation Phaseß



Three lower level requirements allocations that satisfy same higher level spectral resolution requirement

Notional Dialogues between Engineering & Technology

Common drivers dialogue

- Identify elements that most challenge project engineering
  - E.g., batteries, reaction wheels, and communications
- Identify technical solutions and level of improvement needed

Proj #1	Proj #2	Proj #3	Proj #4
batteries	RW	CCD	batteries
RW	thermal	mirrors	EDL
comm	batteries	RW	comm
prop	relays	batteries	comp

TRL dialogue

- Assess TRL and mission criticality of proposed technology
- Identify ways to mature needed technology with lower cost & risk

Rank-ordered list of design drivers for each project revealing cross-cutting issues warranting technological improvement

Notional Dialogues between Technology & Science

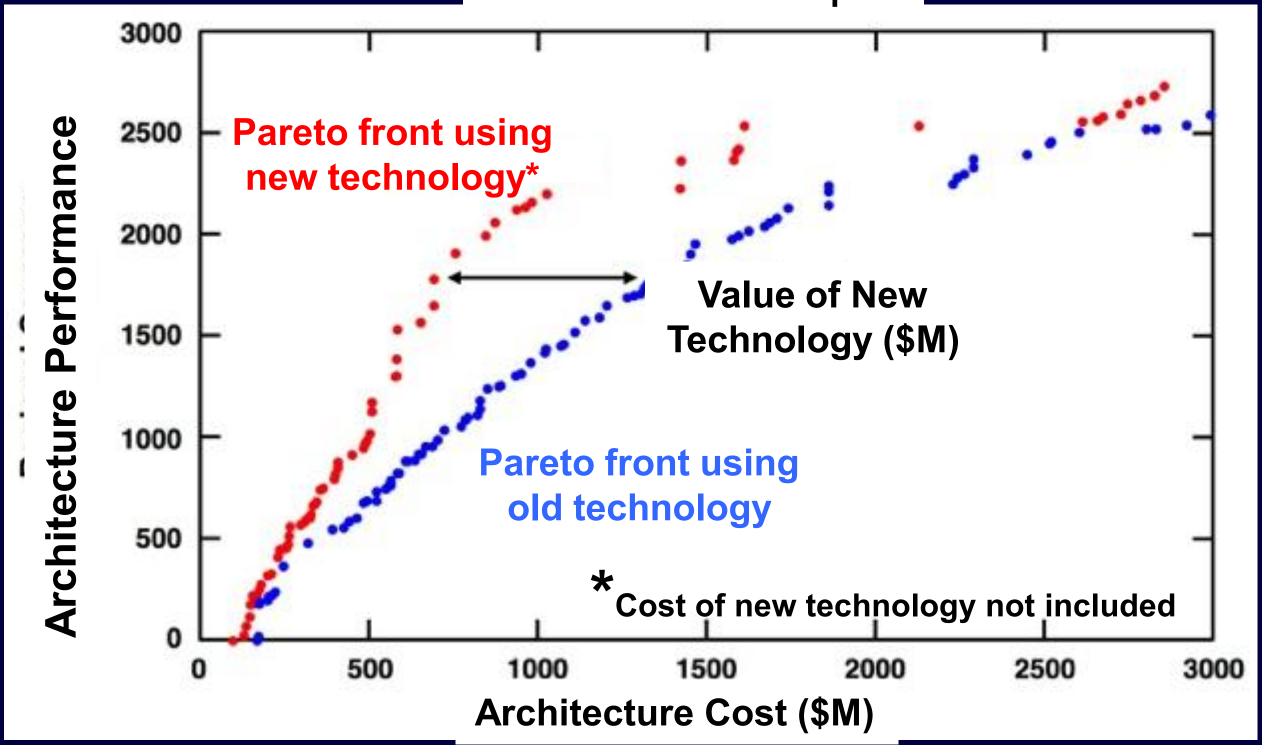
Capabilities dialogue

- Identify landscape of potential technical solutions to needed capabilities for far term missions

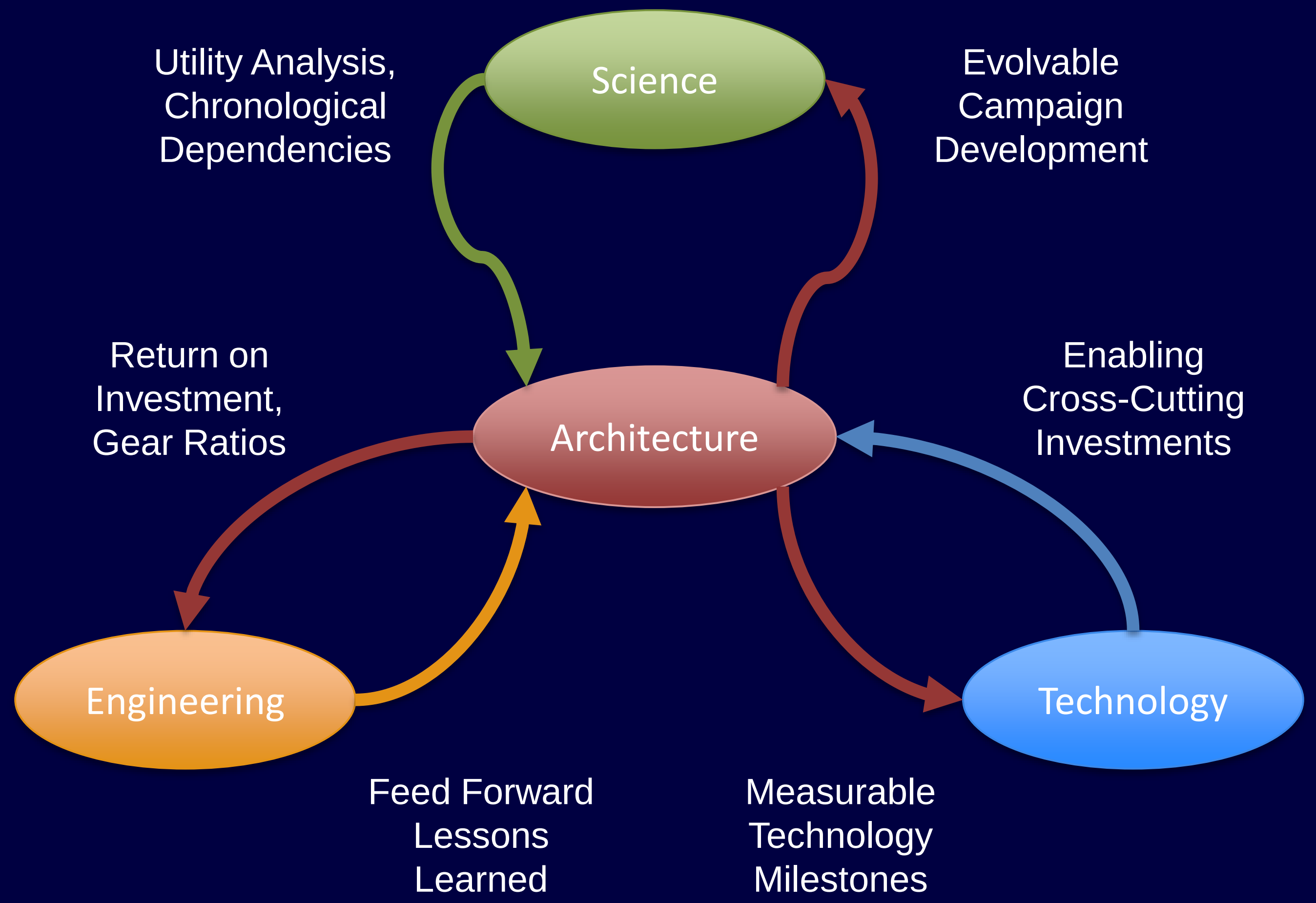
Technology RoI dialogue

- Assess potential value within a mission
- Determine whether other missions would also benefit

Notional Example



Architecture is the Organizing Theme



Architecture provides context to these dialogues, MBSE provides the framework for these dialogues

A Controls Perspective on MBSE

Innovation includes not only products but also processes, such as design

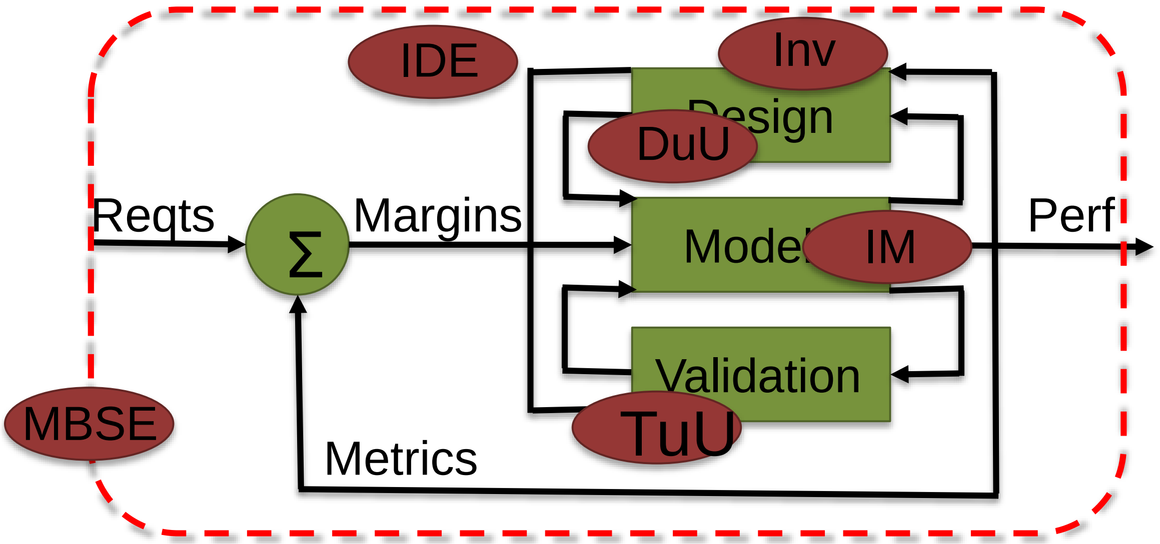
Many of NASA's missions are custom designs which incur substantial labor cost and time

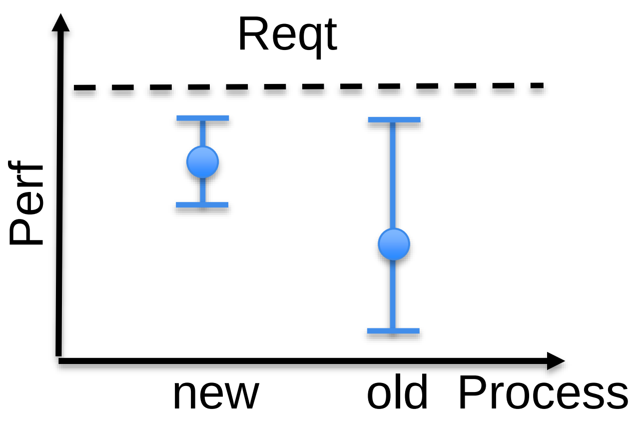
- Increasingly ambitious, thus increasingly complex
- How can new process tools help tame this complexity and reduce cost/risk?

Design is analogous to a control system

- Actuators, sensors, commands, update rate, model uncertainty, etc.

Facilitate the design process through methodology and tool development





MBSE Context and Vision

Context

- Integrated design environments demonstrate effectiveness of teams of experts with direct access to data in formulating, through a real-time conversation, high fidelity conceptual designs
- Algorithms have emerged for modeling, simulation, optimization, inverse solutions, uncertainty quantification, design for uncertainty, and design for "illities"

Fundamental question

- How to mature and extend these tools to entire systems engineering process and subsequently the manufacture, assembly, integration and test of new products?

Vision

- Computation becomes sufficiently powerful and inexpensive to automate routine aspects of systems engineering
  - Permit a team of experts to formulate design questions at PDR/CDR level and receive answers and options commensurate with a real-time conversation
  - Relegating design option and FOM definition, quality assessment, and decision-making to the engineers and customers
- Identify and mature multiple designs in parallel that meet same objectives
  - Yet are sufficiently different in how they meet those FOMs, to provide design adaptation (i.e., a hedge) against unforeseen challenges
- Extend to manufacturing, assembly, integration and test to transition from "rapid prototyping" to "streamlined formulation to delivery"
  - With the seamless hand-off of models to operations

Thank You!

TECHNOLOGY DRIVES EXPLORATION

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BACK-UPS

Office of the Chief Technologist Responsibilities

- **Provides the strategy, leadership, and coordination that guides NASA's technology and innovation activities**
  - Develops and implements NASA technology policies, roadmaps, and Strategic Technology Investment Plan (STIP).
  - Coordinates technology needs across the NASA Mission Directorates
- **Documents, Tracks, and Analyzes NASA's technology investments**
  - Develops and Operates the TechPort Database, which provides capability to share information about NASA's technology investments within the Agency and to the public
- **Coordinates with other Government agencies and the emerging commercial space sector to maximize benefit to the Nation**
- **Provides Agency-level leadership and coordination of the use of prizes and competitions to spur innovation**
  - Pilot new approaches to technology innovation and track their success
- **Leads technology transfer and technology commercialization activities across the agency**

Technology Roadmaps

Strategic Technology Investment Plan

DoD NRL FAA NRO Space Command DoE AFRL DARPA

Technology partnerships

TechPort

Develop & operate the TechPort database

Tech Transfer, Partnerships and Commercialization Activities

Prizes, Competitions and Grand Challenge

Download the SSTIP at: http://www.nasa.gov/offices/oct/home/sstip.html

OCT Division Functions

Innovation Office

- Technology Transfer - supports an office at each of the field centers, as well as a full intellectual property management tool, the NASA Technology Transfer System (NTTS), and the Spinoff Program Office.
- Prizes and Challenges - keeps NASA at the cutting edge of new business practices, while supporting realistic pilots to enable implementation at scale. The function currently drives two major sets of innovation activities within NASA:
    1. Drive the appropriate use of prizes, challenges and crowdsourcing (open innovation) as additional, unique tools within NASA and the aerospace industry
    2. Facilitate, catalyze, and lead the implementation of special technology initiatives and strategic concepts, including Grand Challenges and Launch
- Emerging Space - provides economic intelligence on the emerging commercial space ecosystem. Advises NASA HQ on the economics of space development and commercial space

Strategic Integration

- Roadmaps – A set of documents that consider a wide range of needed technologies and development pathways for the next 20 years. The roadmaps focus on “applied research” and “development” activities.
- Strategic Technology Investment Plan (STIP)– An actionable plan that lays out the strategy for developing the technologies essential to the pursuit of NASA”s mission and achievement of National goals. This plan provides the prioritization and guiding principles of investment for the technologies identified in the roadmaps.
- Technology Coordination-Coordinates technology needs across the NASA Mission Directorates and communicates with other Government agencies to identify opportunities for technology collaboration
- TechPort – Web-based software system that serves as NASA’s integrated authoritative technology data source