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NASA Chief Technologist

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TECHNOLOGY DRIVES EXPLORATION

#321TechOff

Current Chief Technologist Activities

- Strategic Technology Investment Plan Development Process
- ISS Utilization for Technology
- Agency Investment for Low TRL Research
- Science, Engineering & Technology Committee
- Achieving a Balanced Portfolio

Agency Investment for Low TRL Research

- **Need a program for fundamental knowledge discovery**
- **New capability includes both products and processes**
- **Potential processes:**
  - Design and test under uncertainty
  - Integrated, multi-physics modeling
  - Solving the inverse problem
  - Model-based systems engineering
  - Massively computer-aided design environment
- **Perhaps AFOSR can be a model**
  - $350M/yr, 70% extramural, 30% intramural, all competed, MURIs, formal portfolio renewal process, Centers of Excellence
  - How should NASA basic research position itself relative to AF, Navy, Army, DARPA, etc?

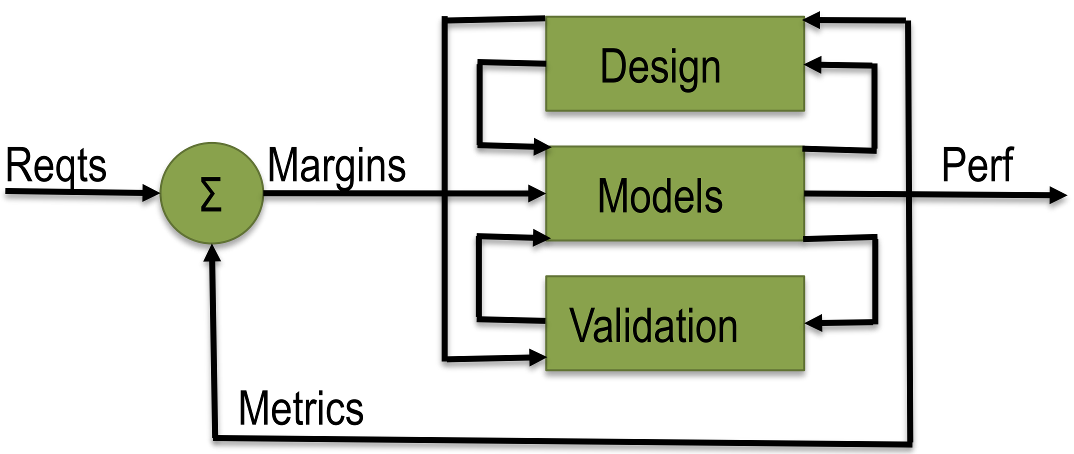
AFOSR Basic Research Program

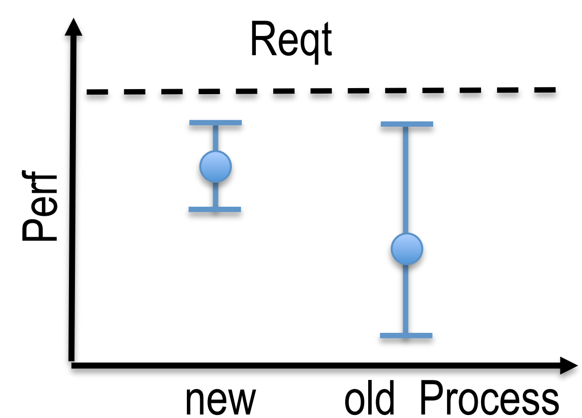
- Attributes: breadth of disciplines, not application specific
- Do we mimic, fill in gaps, be more applied, co-fund?

Dynamical Sys & Control	Quantum & Non-equil Proc	Info, Decision, & Complex Net	Complex Mats & Devices	Energy, Power, & Propulsion
Flow interact & ctrl	Atomic & mole phys	Systems & software	Organic mats chem	Space pwr & prop
Multi-scale struc mech & prognosis	Ultrashort pulse laser matter interac	Science of info, comp & fusion	Aero materials for extreme environ	Circadian & homeo-static reg of perf.
Optimization & discrete math	Lasers & optical physics	Sensing, surveil, & navigation	Mech of multi-func mat & μsystems	Molecular dynamics & theoretical chem
Computational mathematics	Remote sensing & imaging physics	Info operations & security	Natural materials & systems	Human perf & biosystems
Dynamics & control	Biophysics	Complex networks	GHz-THz electronics	Aerothermodynam
Turbulence & transition	Plasma & electro-energetic physics	Dynamic data driven app systems	Photonics & optoelectronics	Dynamic materials & interactions
Test & evaluation	Space sciences	Robust decision making	Quantum electronic solids	Energy conv & combustion sci
	High energy lasers	Trust & influence	Low-density mats	
	Electromagnetics			

Foundational Engineering Science (FES)

- **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**
  - How can new process tools help?
- **Design is analogous to a control system**
  - Actuators, sensors, commands, update rate, model uncertainty, etc.





Fundamental Engineering Science

- **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**
  - How can new process tools help?
- **Design is analogous to a control system**
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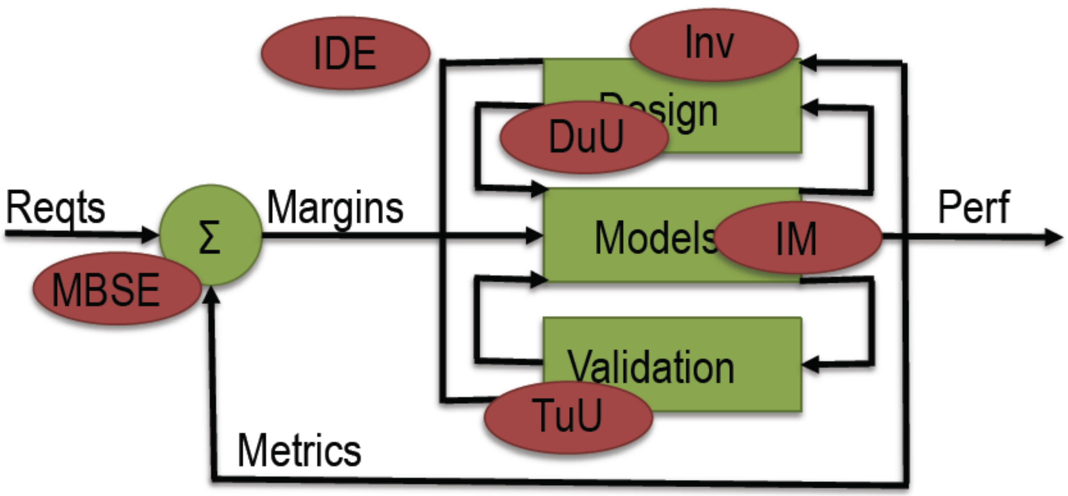
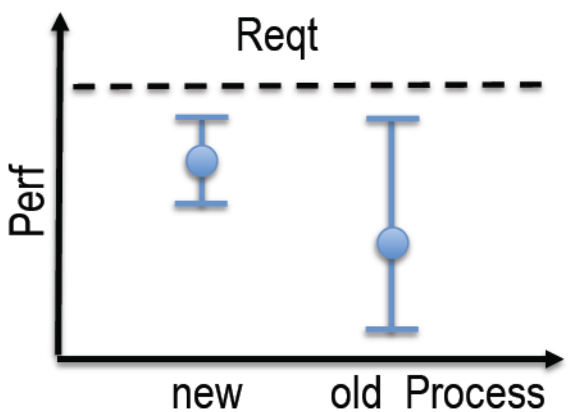
- **Facilitate the design process through tool development**





Integrated Multi-Physics Modeling

- **Current Practice**
  - Separate CAD and analysis tools used for each discipline
  - Interactions assessed, trades developed between domain experts
- **Proposed Process**
  - Couple CAD and analysis tools for disciplines that exhibit potential coupling (e.g., temporal, spatial), considering hybrid scales
    - Ensuring comparable accuracy over comparable parametric ranges
    - Validate coupling behaviors
  - Evaluate performance and conduct trades using appropriate metrics and optimization tools
- **Potential Benefit**
  - Identifies potential detrimental couplings earlier in design process
  - Permits solutions that leverage favorable couplings
  - Allows broad and rapid trade-space exploration

Solving the Inverse Problem

- **Current Practice**
  - Design parameters are inputs, performance metrics are outputs
  - Designs are optimized based upon experience at sub-system level
  - Designs are analyzed using high fidelity simulations
- **Proposed Process**
  - Performance metrics are inputs, design parameters are outputs
  - Use high fidelity, integrated models that capture system behavior
  - Embed these models (or surrogates) in an optimization problem
    - E.g., reduced order models, describing functions
- **Potential Benefit**
  - High fidelity, integrated models used directly in the design process
  - Can contour the iso-performance design space

Model-Based Systems Engineering

- **Current Practice**
  - Requirements, designs, analyses, data captured in documents
    - Not amenable to data extraction, independent analysis & assessment
  - They are not "living" documents that can easily adapt over a project or be leveraged by follow-on projects
- **Proposed Process**
  - Formalized application of modeling to support system development (e.g., requirements, data analysis, V&V) throughout the lifecycle
  - Capture these products in interactive modeling framework
    - Discoverable design revision history, lessons learned, trade-able requirements, extractable raw data with available analysis code
- **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

Integrated Design Environment

- **Current Practice**
  - Disciplinary design teams working separately and exchanging results infrequently by “throwing their results over the transom”
  - Early arrival at point design that requires subsequent “band aids”
  - Integrated multi-disciplinary conceptual design (e.g., Team-X)
- **Proposed Process**
  - Turn the preliminary design process (and beyond?) into a real-time conversation between domain experts
    - Assume computation power is infinite and cost is insignificant
  - Exploit MBSE, Integrated multi-physics and multi-scale models, Inverse solution and iso-performance techniques
  - Complement DARPA Adaptive Vehicle Make (AVM) program
- **Potential Benefit**
  - Could dramatically reduce time and cost of custom design
  - Carry multiple, substantially different designs to mitigate risk

Design and Test under Uncertainty

- **Current Practice**
  - Models, H/W & S/W developed, UFs are levied, and subjected to often worst case, conservative environments
  - Models tuned, workmanship assessed, requirements validated
- **Proposed Process**
  - Models inform test design which improves model predictive accuracy
  - For example,
    - Models, uncertainties, performance metrics developed and likelihood of meeting requirements assessed
    - Sensitivities of metrics from model & uncertainty parameters inform both model-based redesign and test campaign designs, respectively
    - Tests designed to reduce parametric and identify non-parametric uncertainties
  - Algorithms w/limited application, tool development-validation needed
- **Potential Benefit**
  - Test campaigns more efficient, uncertainty quantified, data archived
  - Reduced conservatism leads to more capability or lower cost

Science, Engineering & Technology Committee (SETC)

- Each plays a vital yet distinct role
  - Technology develops the new engineering tools,
  - That enable the engineers to build more capable missions,
  - That answer the increasingly challenging and fundamental questions of science

Science

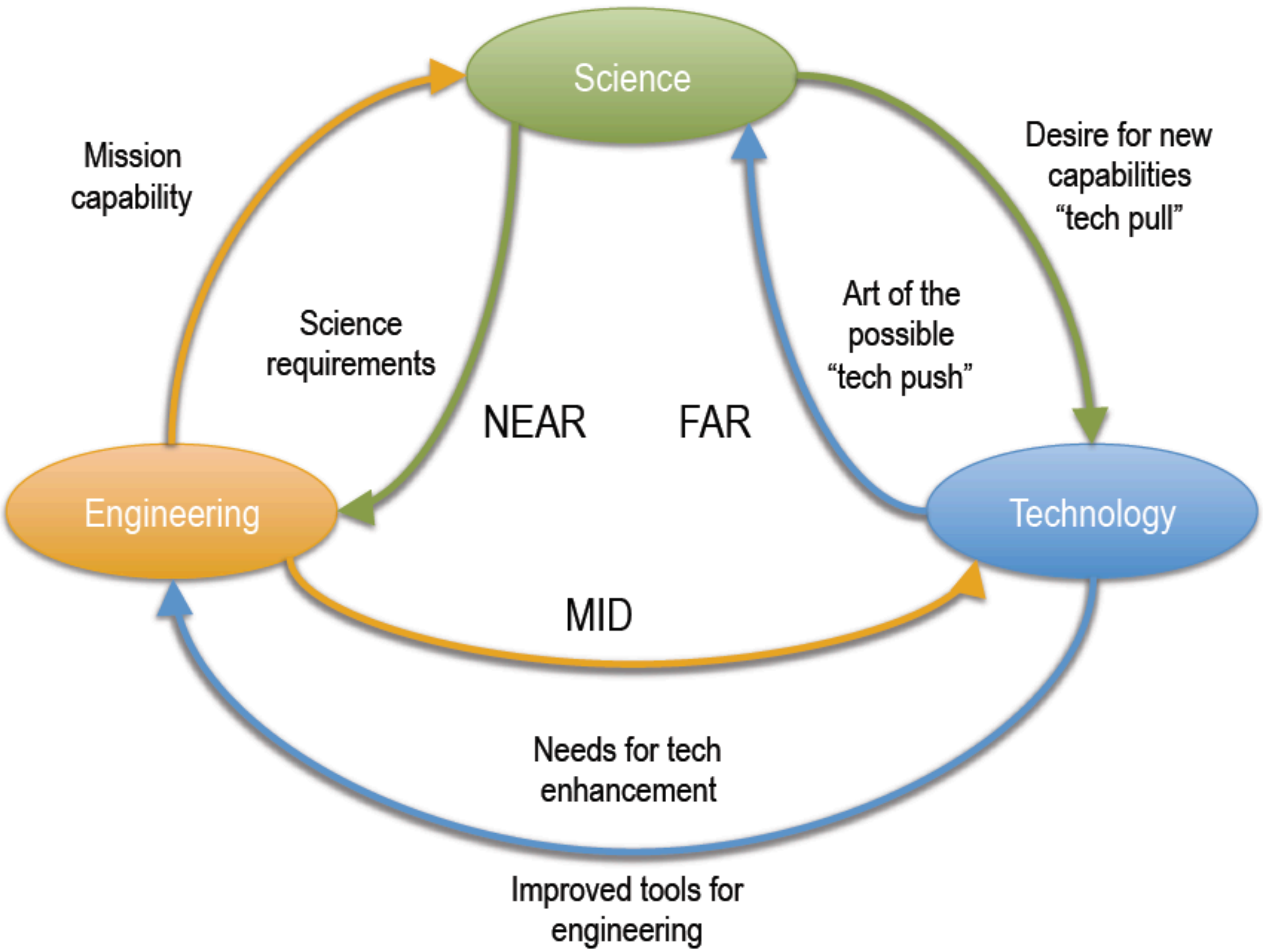
- All three dialogues are essential
  - Science and Engineering to best satisfy mission requirements
  - Engineering and Technology to improve driving SWaP, cost and risk elements
  - Technology and Science to identify game changers

Engineering

Technology

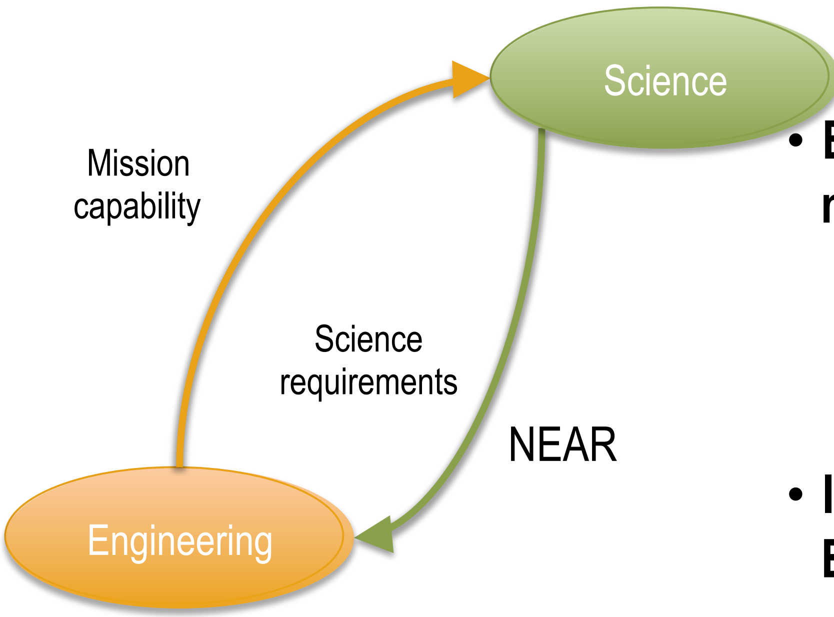
These three dialogues are essential in advancing exploration, as well as technical know-how and engineering capability

Dialogue between Science, Engineering & Technology



These three very different dialogues must exist to ensure that we can build the missions of today and realize the vision of tomorrow

Dialogue between Science & Engineering



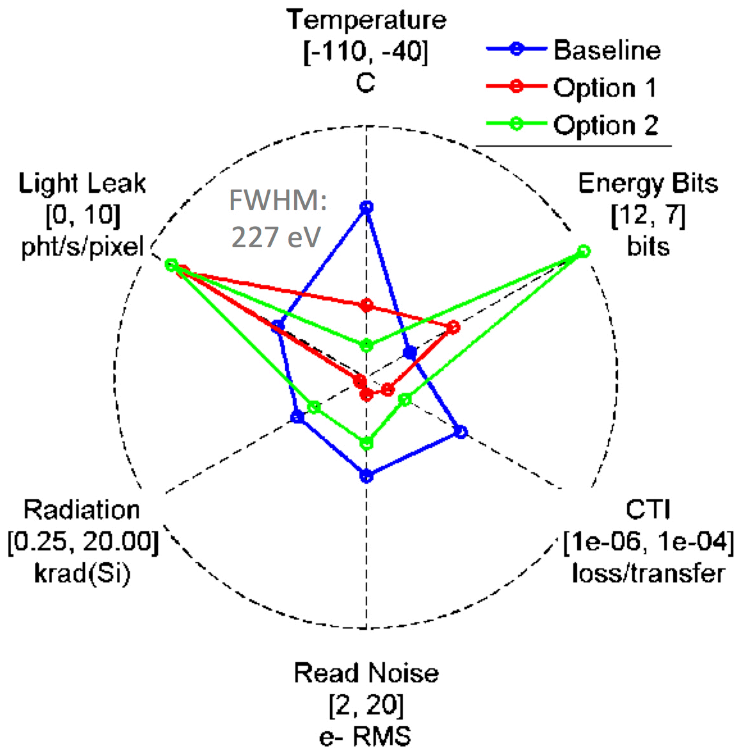
- **Ensures science requirements are met by mission engineering**
  - Requirements Validation
  - Needed capability identification
- **In absence of dialogue between Engineering & Technology**
  - More science without new engineering capability
  - E.g., same model of rover exploring different sites

While scientifically useful, cannot drive towards answering more challenging and fundamental science questions

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

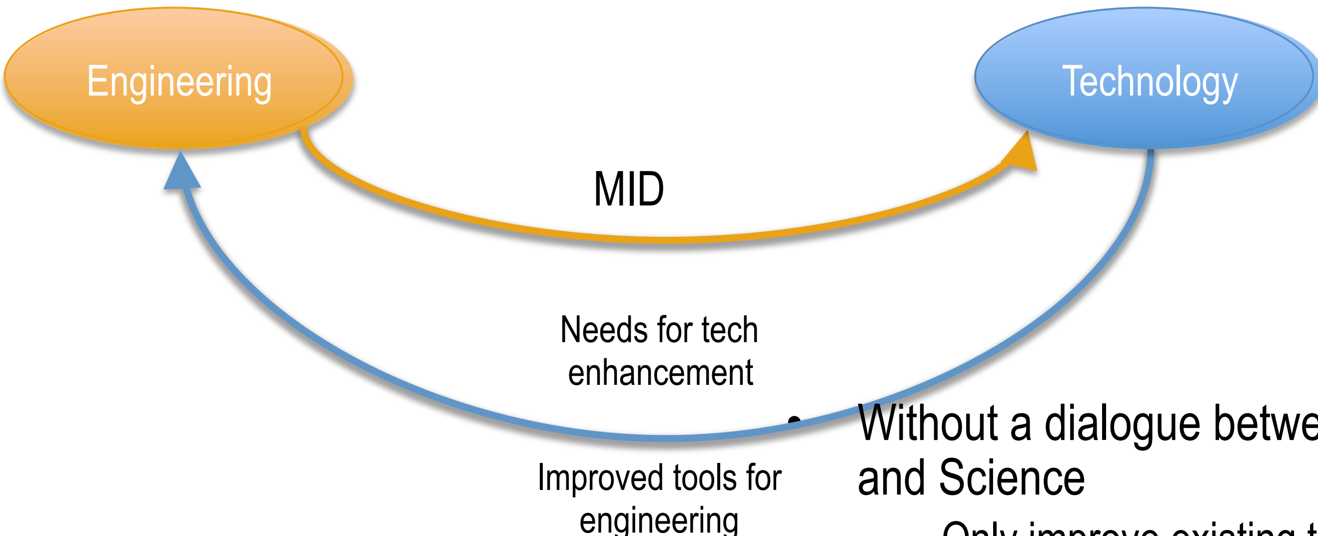


Three lower level requirements allocations that satisfy same higher level spectral resolution requirement

Dialogue between Engineering & Technology

Enhances more Science
but doesn't enable
game-changing breakthroughs

- Ensures development of new technology to address those engineering elements that limit scientific productivity
  - Technical Capability Assessment



- Without a dialogue between Technology and Science
  - Only improve existing tools
  - E.g., better batteries, detectors

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

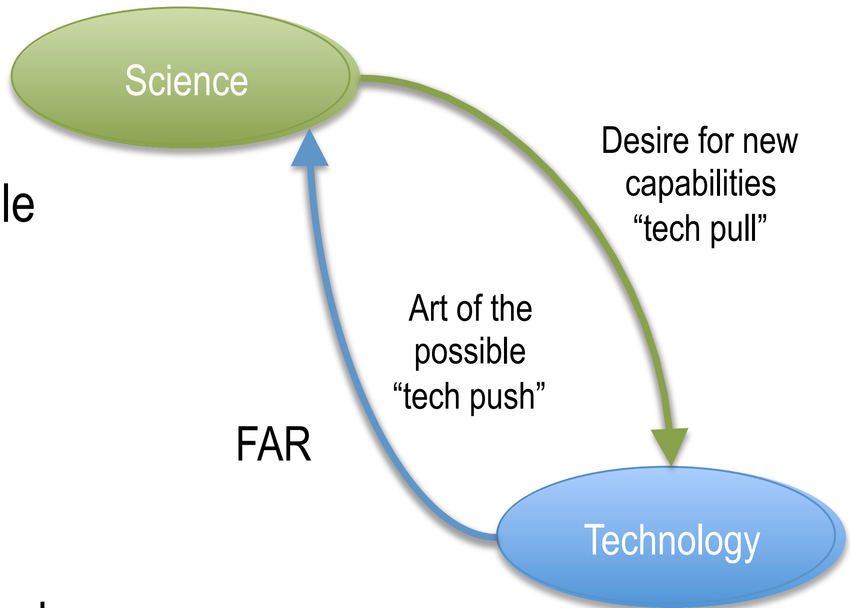
Rank-ordered list of design drivers for each project revealing cross-cutting issues warranting technological improvement

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

Dialogue between Technology & Science

- Ensures that new technology areas can be identified that enable new science
  - Technical Gap Analysis
  - E.g., lasers, FPGAs, SEP

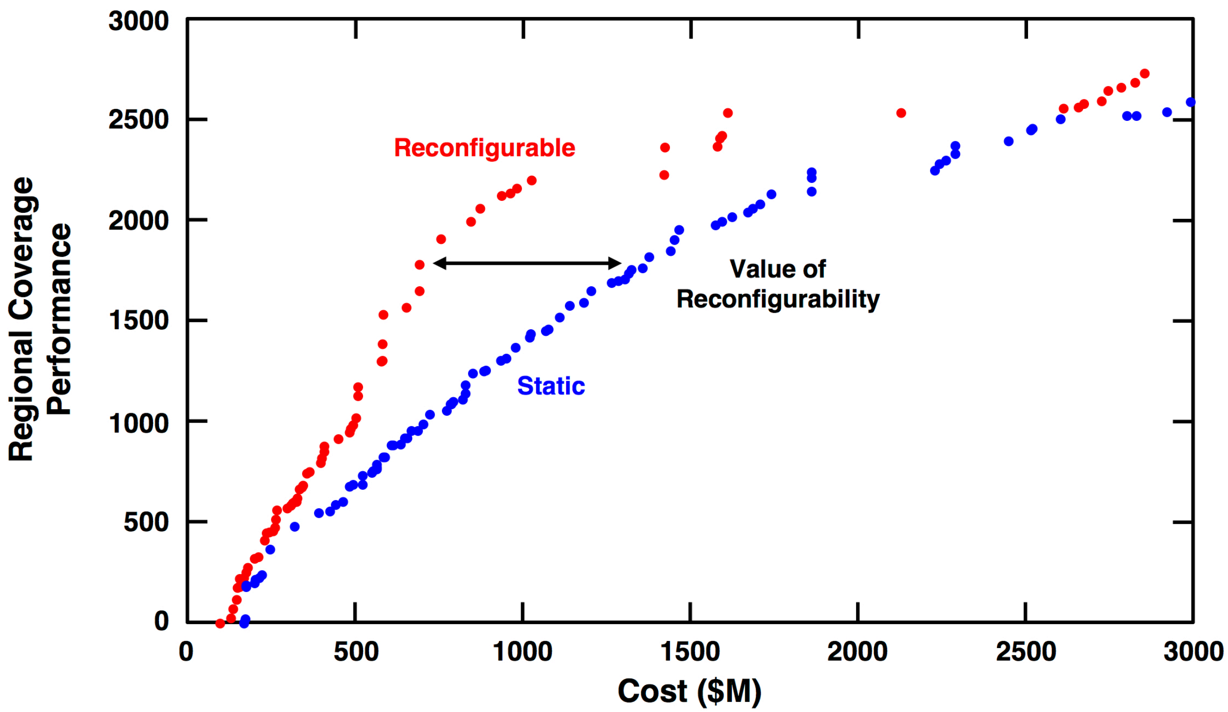
- Without all three dialogues, capability advancement is impeded leading to
  - More of the same
  - Incremental improvement
  - Valley of Death



All three dialogues must exist led by experts in the disciplinary areas involved

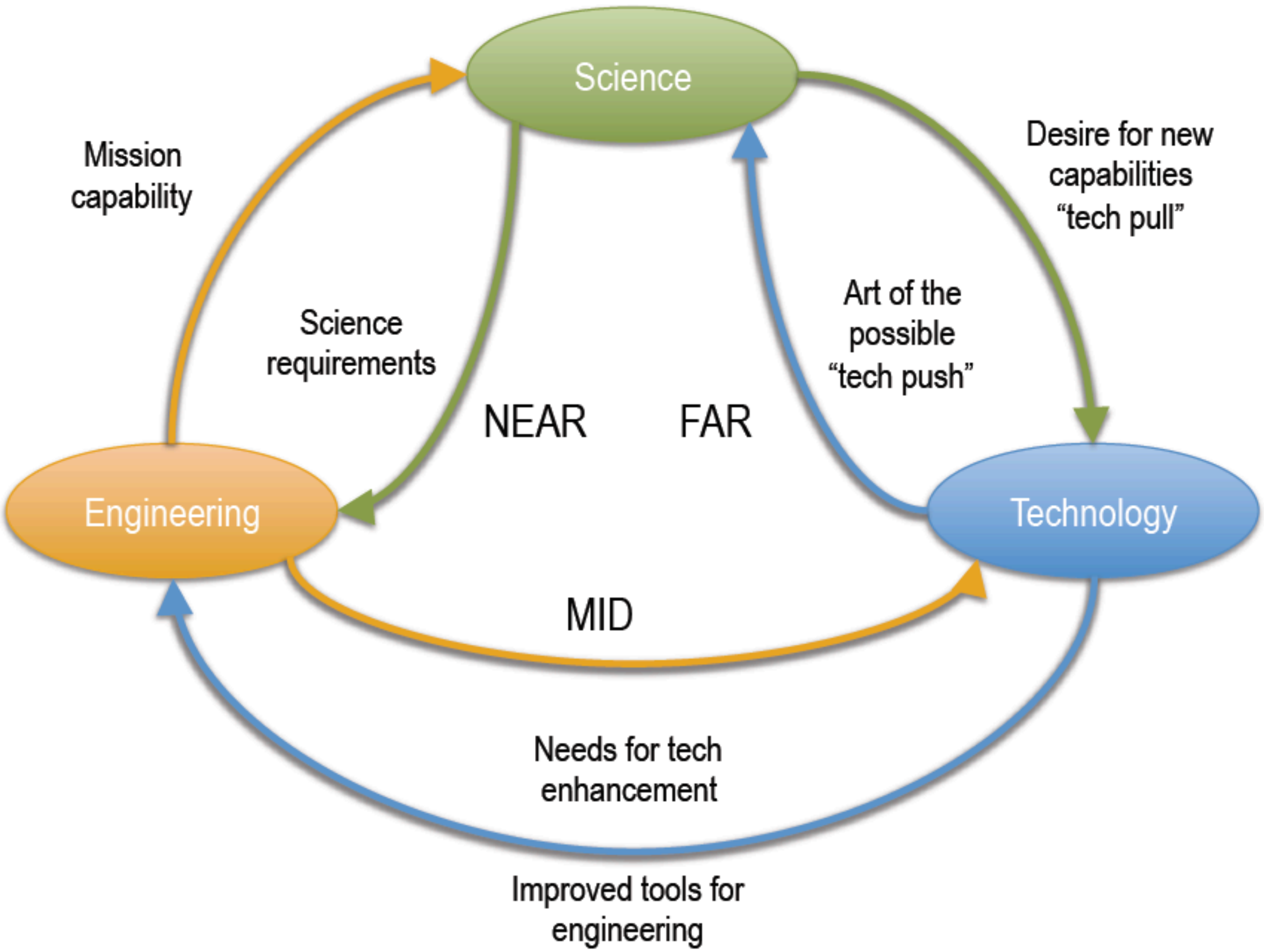
Notional Dialogues between Technology & Science

- **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



Value of constellation reconfiguration technology for persistent Earth observation

Dialogue between Science, Engineering & Technology

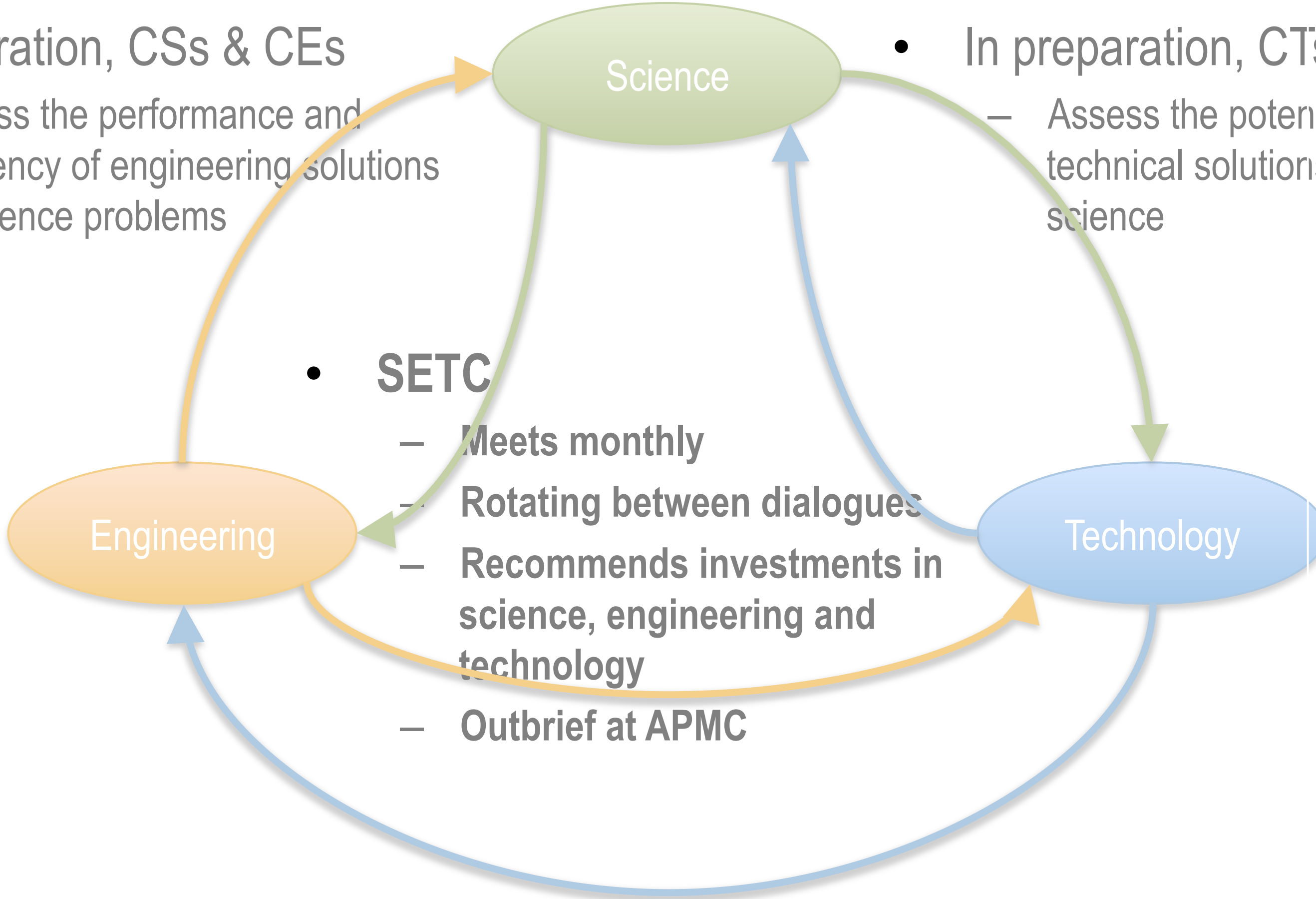


All three dialogues must exist led by experts in the disciplinary areas involved. The goal is to facilitate these dialogues.

Facilitating these Dialogues over Three Month Cycle

- In preparation, CSs & CEs
  - Assess the performance and efficiency of engineering solutions to science problems

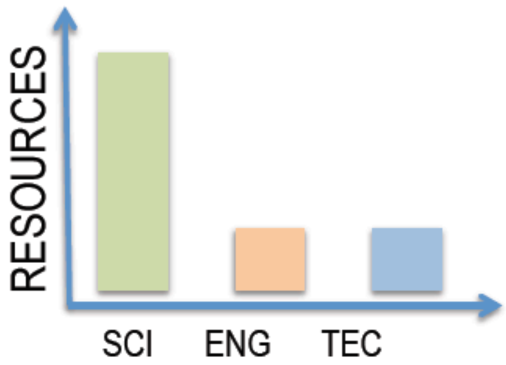
- In preparation, CTs & CSs
  - Assess the potential for emerging technical solutions to enable new science



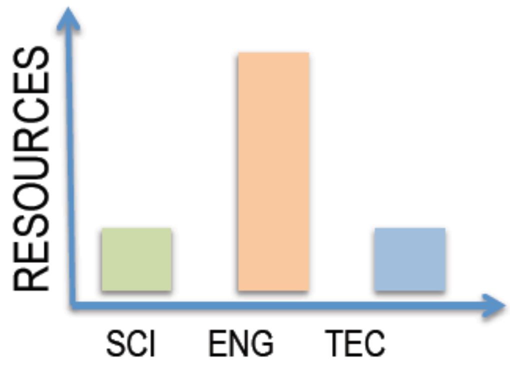
- **SETC**
  - **Meets monthly**
  - **Rotating between dialogues**
  - **Recommends investments in science, engineering and technology**
  - **Outbrief at APMC**

- In preparation, CEs & CTs
  - Assess how technology enhancements can reduce SWaP, cost and risk of existing engineering drivers

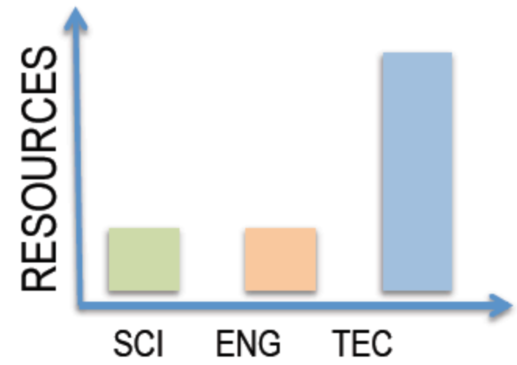
Achieving a Balanced Portfolio



- Engineering and technology are insufficient to support
  - Capabilities do not improve
  - Costs overrun
  - Schedules stretch
  - Missions are cancelled



- Science has insufficient need and technology does not innovate
  - Facilities and expertise are unused
  - Maintenance and labor costs dominate
  - Morale drops



- Science has insufficient need and engineering customer disappears
  - Developed without a goal
  - Limited opportunity to mature
  - Becomes a sandbox

Finding the proper balance is essential

Thank You!

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