RT-114: Strategic Planning for Science and Technology Portfolio

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Principal Investigator:
Dr. Robin Dillon-Merrill, Georgetown University

Research Team:
David Arterburn, University of Alabama - Huntsville
Paul Collopy, University of Alabama - Huntsville

Period of Performance: May 12, 2014 to June 30, 2015
ACKNOWLEDGEMENTS

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ABSTRACT

The STRATEGIC PLANNING FOR S&T PORTFOLIOS project, a project of the Systems Engineering Research Center (SERC), was a one-year project that sought to understand best practices for how the Department of Defense (DoD) was managing S&T portfolios and to transition this knowledge to improve the process by developing curriculum material for the Defense Acquisition University.

Technology development is the foundation for the DoD materiel acquisition process. Organizations responsible for this development include DoD laboratories and organizations such as the Army Research Development and Engineering Centers and the Navy Warfare Centers. To maximize their contribution for the warfighting mission, and to most efficiently use resources, Science and Technology (S&T) managers in these organizations must capitalize on effective strategic planning to prioritize technology areas. Within these areas, S&T managers must also develop and manage S&T portfolios to ensure the required technologies are matured for seamless transition to programs of records or directly to the warfighter.

Portfolio management is a challenge for an organization as distributed as the Department of Defense because portfolio management works best when there is a senior leader or leadership team with the decision making capacity to oversee many research portfolios and chose those that support the organization’s strategy and cancel those that do not. The best strategy driven portfolio will balance near-term and long-term needs. Instead of a portfolio management approach, DoD’s stove-piped governance structure where each service generally sets its own priorities is an impediment to using an integrated portfolio management approach.

Numerous interviews were conducted to find the best practices in DoD organizations that focused on R&D portfolios. The results of the project were over 100 Powerpoint slides, 4 detailed case studies, and numerous shorter case studies. This material will be used in a 3 ½ day course taught by DAU starting in Fall of 2015. The materials were developed collaboratively with DAU professors and was tested, reviewed, and refined in an instructor pilot in May 2015 and two student pilots in June and July.

The task specifically supported course development for the Defense Acquisition University (DAU). The pedagogy included case study review, method development lessons, and group exercises through a four-day course curriculum. Material was provided via literature and survey review for identified key skill areas. The coursework instruction material is provided in the subsequent attachment and will be revised under DAU supervision.
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INTRODUCTION

The research was conducted in four phases:

- Phase I: Identified Relevant Strategic Planning and S&T Portfolio Development Content
- Phase II: Developed Course Teaching Content
- Phase III: Developed Exercises and Case Studies
- Phase IV: Taught Research Pilots and Conducted Revisions

RESEARCH RESULTS

Understanding an organization’s strategy is a key component in evaluating an S&T portfolio. Teaching materials to convey this finding were developed in addition to multiple classroom exercises to improve DoD S&T professionals’ skills in portfolio management. These teaching materials will be used in STM 304 which focuses on the strategic planning and technology portfolio management best practices needed to insure the DoD and its components are working on the right projects to maximize the return on the science and technology investment. The course learning objectives are shown in Figure 1.

The research material was organized into six lessons as shown in Figure 2. Lesson 1 focuses on developing an S&T Strategy. Lesson 2 focuses on managing an S&T Strategy. Lesson 3 focuses on Technology Roadmapping. Lesson 4 focuses on portfolio management processes and methods. Lesson 5 focuses on Portfolio Valuing and Prioritizing, and Lesson 6 is a detailed capstone exercise that involves chooses an actual portfolio given detailed project data and a budget constraint. Some of the key topics discussed include:

- Why is S&T Management Challenging?
- Can strategy frameworks developed in industry assist the DoD in their portfolio management efforts?
- How does the DoD’s Better Buying Power Initiative influence S&T projects?
- How do S&T capability requirements translate into development plans and actionable steps?
- What is the difference between push and bull technologies in technology transition?
- What is technology roadmapping?
- What are the best practices of technology roadmapping?
- What are best practices of the portfolio management process?
- What are the challenges with evaluating and balancing technology alternatives in a portfolio?
- How should technology managers think about different strategic bins (e.g., innovative/disruptive, bridging, leap ahead, etc.)
- How can value hierarchies help structure portfolio prioritization?
- What are best practices of portfolio prioritization in the DoD?

Extensive interviews were conducted with many DoD stakeholders who are involved in managing R&D portfolios for the Army, Navy, Air Force, and DTRA. We talked to both senior managers at the service laboratories and in headquarters capacities.
The course material was developed in an iterative process collaboratively with DAU and the future instructors for this course (STM 304). Monthly review meetings were held.

Additionally, as we refined the materials, we tested the materials in an instructor pilot in May 2015 and two student pilots in June and July 2015. The instructor pilot involved Georgetown faculty teaching to DAU instructors who served as the students. The two student pilots involved DAU instructors teaching to students who agreed to take the course recognizing that it was a pilot. Materials were continually refined after each review.

The final results of the project were over 100 Powerpoint slides, 4 detailed case studies, and numerous shorter case studies. This material will be used in the 3 ½ day STM 304 course taught by DAU starting in Fall of 2015.

See appendices for all Powerpoint slides and case studies.
STM 304 Course Learning Objectives

- Evaluate the theory of strategic planning for a technology organization and the current practices within the DoD
- Explain the key steps in managing a S&T strategy
- Apply the principles of technology roadmapping to a technology area
- Given top-level strategic objectives, apply current DoD processes and best practices to construct leadership recommendations for a specific technology portfolio
- Evaluate technology portfolio valuing and prioritizing techniques
- Assess methods to address challenges in developing and managing technology portfolios

Figure 1 - Course Learning Objectives

Course Outline

- Developing S&T Strategy
- Managing S&T Strategy
- Technology Roadmapping
- Portfolio Management Processes and Methods
- Portfolio Valuing & Prioritizing
- Capstone Exercise

Figure 2 - Course Outline
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Leadership in Science & Technology Management Course

Course Objectives
Administration
STM Career Field
DAU Mission & Overview
Exercise

Lesson 0 Outline

Need for Technological Superiority

"Advanced military technologies, from rockets and drones to chemical and biological capabilities, have found their way into the arsenals of both non-state actors as well as previously less capable militaries. Russia, China, Iran, and North Korea have been pursuing long-range, comprehensive military modernization programs to close the technology gap that has long existed between them and the United States."

"These modernization programs are developing and fielding advanced aircraft, submarines, and both longer-range and more accurate ballistic and cruise missiles. They’re developing new and advanced anti-ship and anti-air missiles, as well as new counter space, electronic warfare, undersea and air attack capabilities."

Honorable Ashton Carter, Secretary of Defense, SASC Budget Hearing, March 3, 2015

STM 304 Focus

The level one and level two STM courses focused on best practices managing individual science and technology projects.

This course focuses on the strategic planning and technology portfolio management best practices needed to insure the DoD and its components are working on the right projects to maximize the return on our science and technology investment.
STM 304 Course Learning Objectives

- Evaluate the theory of strategic planning for a technology organization and the current practices within the DoD
- Explain the key steps in managing a S&T strategy
- Apply the principles of technology roadmapping to a technology area
- Given top-level strategic objectives, apply current DoD processes and best practices to construct leadership recommendations for a specific technology portfolio
- Evaluate technology portfolio valuing and prioritizing techniques
- Assess methods to address challenges in developing and managing technology portfolios

STM 304 Course Administration

- Class hours: 0800 ~ 1630 per the lesson schedule
- Competency-based training
- Builds upon the course prerequisites
- Course evaluation is based on individual work, group analyses and essay
- No absences are authorized

And the essentials........
Student Expectations

- Think critically and communicate effectively.
- Learn from each other. Lectures, case exercises and capstone exercise are opportunities to exchange knowledge, experience and ideas.
- Be prepared to engage.
- Expected result: You are better prepared to lead future science and technology development efforts that will deliver capability and value.

Attribution (Non-attribution) Policy

We hope that participants will use the information and knowledge they receive, but if you are making specific attributions, please check with the speakers first.

Course Outline

- Developing S&T Strategy
- Managing S&T Strategy
- Technology Roadmapping
- Portfolio Management Processes and Methods
- Portfolio Valuing & Prioritizing
- Capstone Exercise
Welcome & Complete final exercise from Lesson 4: Lesson 6 Case exercise

Course Introduction Lesson 2

Portfolio Management Portfolio Management

Roadmapping

Lesson 1: Roadmapping Lesson 5: Roadmapping & Portfolio

Lesson 2: Managing S&T Strategy

Lesson 2: Managing S&T Strategy

Portfolio Development

Lesson 6: Case exercise

Pre-work 10

Reflection essay 20

Class participation 10

Lesson 3 group presentation (Roadmap) 20

Lesson 5 group presentation (Portfolio) 20

Lesson 6 group presentation (Capstone portfolio) 20

Total Points Possible 100

Passing is 80% 80

Mandatory DAU End of Course form to evaluate course material, learning environment, and instructors.

On Thursday morning your instructors will provide the URL address to the Metrics that Matter website.
FY16 S&T Managers’ Career Path

Level I
Education: Baccalaureate or graduate degree in a technical or scientific field such as, but not limited to, engineering, physics, chemistry, biology, psychology, mathematics, operations research, engineering management, or computer science. Same for Level II & III

Training: All Web-based
- STM101, Introduction to DoD S&T Management CLM
- CLE068, Intellectual Property & Data Rights CLM
- ACQ101, Fundamentals of Systems Acquisition Management (online)
- SYS101, Fundamentals of Systems Planning, Research, Development, and Engineering (online)

Experience: 1 year of technical experience related to S&T management

Level II
Training: All Web-based
- ACQ202, Intermediate Systems Acquisition Course, Part A (online)
- CLE021, Technology Readiness Assessments CLM
- STM203, Intermediate S&T Management (3.5 days resident)

Experience: 2 years of technical experience in S&T management

Level III
Training: All Web-based
- STM304 Leadership in S&T Management (3.5 days resident)
- CLM014, IPT Management & Leadership CLM
- CLE069, Technology Transfer CLM (new for FY15)

Experience: 4 years of technical experience in S&T management

STM Career Field Statistics

Size: 3401 FY14 3293 FY13 3209 FY12

<table>
<thead>
<tr>
<th>Category</th>
<th>FY14</th>
<th>FY13</th>
<th>FY12</th>
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<tbody>
<tr>
<td>84% civilian, 16% military</td>
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</tr>
</tbody>
</table>

82% do not meet DAWIA requirement, 75.5% do meet requirement; 21.6% are in their 24-month window to attain certification.

77% graduate degree, 27% PhD

Average civilian age 46
Average years experience 17

Retirement eligible now 16%; 21% eligible within 5 years

61% engineer, 23% scientist, 16% other

DAU: TRAINING COURSES... AND MORE

Formal & informal learning at the point of need

Training
- Classroom & online DAWIA, Core Plus, & Executive
- Mission Management Training - On-site & online training on the latest AT&L policies

Continuous Learning
- Targeted Training - Tailored organizational training
- Rapid Deployment Training - On-site & online training on the latest AT&L policies

Knowledge Sharing
- DAP - Online portal to Big A & HCI knowledge
- ACC - DoD’s online collaborative communities
- Knowledge Repository and Acker Archives - Online connection to publications and DAU research resources

Mission Assistance
- Consulting - Helping organizations solve complex acquisition
- Team Training - DoD Acquisition Workshops, MDAP event-driven
- Executive Coaching - For acquisition senior leaders
Helping Your People Earn Their “CL” Points

www.dau.mil/clc

Helping YOU Achieve Better Acquisition Outcomes

Mission Assistance: DAU comes to your organization to provide team training, consulting, and workshops

Learn more at http://www.dau.mil/ma

Mission Assistance Portfolio

Executive Coaching

- Helps Senior Leaders achieve their Extraordinary Futures

- Pre-Milestone/Gate Reviews
  - Preparatory
  - Serves as “dry run” opportunity

- Various Workshops
  - “Hands-on” and collaborative
  - Executive activity
  - Highlights major challenges/strategies

Pre-Milestone/Gate Reviews

DAU Training & CL Courses

Mission Assistance

Better Buying Power

Connect with Our Learning Assets at www.dau.mil

Defense Acquisition Portal

Acquisition Community Connection

DAU Knowledge Repository
S&T Process - Group Exercise

- **Goals**
  - Introductions and Discussion of Participants' experience with S&T Processes

- **Instructions**
  - Discuss and organize the topics on the following slide to show how you view these topics as related (additional categories or sub-categories can be created as needed)
  - Identify where each of your group members work
  - Present the group S&T process and discuss what role each group member has had in S&T processes
Lesson 1 Learning Objectives

• Describe the steps to develop a well-conceived vision
• Compare the major theories of strategic planning
• Discuss how the DoD components conduct strategic planning and what constraints the DoD faces
• Understand how to focus long term interests and strategies of your organization within a DoD context

S&T National Priorities

"Now is the time to reach a level of research and development not seen since the height of the Space Race."  
President Obama, State of the Union Address, January 2013

Multi-Agency Priorities for FY16 Budget:
• Advanced manufacturing and industries of the future
• Clean energy
• Earth observations
• Global climate change
• Information technology and high-performance computing
• Innovation in life sciences, biology, and neuroscience
• National and homeland security
• R&D for informed policy-making and management

Defense Strategic Guidance Key Elements

• The military will be smaller and leaner, but it will be agile, flexible, ready and technologically advanced.
• Rebalance our global posture and presence to emphasize the Asia-Pacific region.
• Build partnerships and strengthen key alliances and partnerships elsewhere in the world.
• Ensure that we can quickly confront and defeat aggression from any adversary – anytime, anywhere.
• Protect and prioritize key investments in technology and new capabilities, as well as our capacity to grow, adapt and mobilize as needed.
2014 Quadrennial Defense Review (QDR)

- Builds upon/adapts the 2012 Defense Strategic Guidance
  - Protect the homeland against all strategic threats
  - Build security globally by projecting U.S. influence and deterring aggressors
  - Project power and win decisively

- Embodies key elements of January 2012 Defense Strategy
  - Rebalance to Asia-Pacific
  - Sustaining commitments to allies in Middle East and Europe
  - Aggressively pursue counterterrorism campaign
  - Emphasis on key threat areas (e.g., cyber, missile defense, special operations, space, capabilities etc.)
  - No longer size forces for large, prolonged stability operations

FY2016 OMB/OSTP S&T Priorities

- S&T: Basic and applied research and advanced technology development are important to DOD’s long-term technological superiority (~$12.3B)
- DARPA: High-risk, high-payoff research is critical contribution to DOD S&T (~$2.9B)
- Advanced Manufacturing: Support of the President’s National Network Manufacturing Initiative to fund six DOD-led manufacturing institutes (~$0.2B)
- Hypersonics: Support of national hypersonics requirements and capabilities
- Prototyping Activities: Support of efforts to reduce technical risk in acquisition programs and maintain workforce skills in design, systems engineering, and prototyping
- Modernizing Laboratory Infrastructure: Recommended DOD work within the MILCON process to secure funding for laboratory projects while also exploring alternative approaches that are consistent with OMB policies and regulations
- Science, Technology, Engineering and Mathematics (STEM) Education: OMB supports K-12 STEM activities and the Science, Mathematics, and Research for Transformation (SMART) program.

Future Gaps for DoD Portfolio

The DoD Research and Engineering Enterprise Guidance Document (2014) identifies several enabling technologies and capabilities being developed world-wide that could restrict the US ability to project our armed forces:

1. Electronic warfare (new jammers, different frequency radars, and new communication links)
2. Loss of assured access to space (kinetic and non-kinetic capabilities that degrade access to space-based assets)
3. Proliferated theater and cruise missiles (high number of advanced capability missiles)

Defense R&E Strategy

1. Mitigate current and anticipated threat capabilities
   - Cyber
   - Counter Space
   - Missile Defense

2. Affordably enable new or extended capabilities in existing military systems
   - Systems Engineering
   - Capability Prototyping
   - Developmental Test & Evol.
   - Interoperability
   - Power & Energy

3. Create technology surprise through science and engineering
   - Autonomy
   - Data Analytics
   - Human Systems
   - Quantum Systems
   - Basic Sciences

What are your experiences with guidance and meeting guidance?
DEVELOPING A VISION IN A CHALLENGING ENVIRONMENT

Why is S&T Management Challenging?

- Competing interests among and within services
- Multiple requirement sources including from different communities of interest (COIs)
- Funding challenges and the PPBE cycle
- The challenge of prioritizing investments
- Changing external threats
- Changing leadership

Do you have other experiences that are not reflected in this list?

Empowering the Planning Continuum: Need for planning integration

Planning, Programming, Budgeting, Execution (PPBE)
(Warfighter needs, technically feasible, fiscal reality)

Out Year Planning
(Concepts, thrust area focus, long-range vision, emerging technologies & capabilities)

Near-term 0-2 years 2-7 years 6-12 years 10-20 years Mid-term Long-term

S&T Planning Activities

- Science and Technology planning
- Strategic Planning
- Service Planning
- Resource planning (PPBE)
- Other planning activities
- Capabilities based planning

- How are these multiple activities integrated?
- What are the integration challenges?
- How do these different plans apply to you?
Collins' Vision Framework

**Envisioned Future**
- 10 to 30 year BHAG (Big, Hairy, Audacious Goals)
- Vivid description

**Core Ideology**
- Core values
- Core purpose

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**Do Current DoD Services S&T Visions Fit the Framework? Why? Or Why not?**

**Air Force Vision**
- Sustained global advantage that ensures Global Vigilance, Global Reach and Global Power in, through and from air, space and cyberspace

**Army Vision**
- Foster invention, innovation and demonstration of technologies to enable Future Force Capabilities while exploiting opportunities to transition technology enabled capabilities to the current force

**Navy Vision**
- Discover, develop, and deliver decisive Naval Capabilities, in the near and long term, by investing in a balanced portfolio of promising scientific research, innovative technology and talented people

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**Enduring Principles from “DoD Research and Engineering Enterprise”**

- Mitigate or eliminate new and emerging threats to national security
- Affordably enable new or extended military capabilities
- Create technology surprise through science and engineering

*How well do these principles align with your experience and your service?*

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**Collins' Vision Framework Components**

- **Vision Level BHAG**
  - Is clear and compelling
  - Serves as unifying focal point of effort
  - Acts as a catalyst

- **Vivid Description**
  - Is vibrant, engaging and specific
  - Paints a picture with words

- **Core Purpose**
  - Organization’s reason for being
  - Inspires change

- **Core Values**
  - Organization’s essential and enduring tenets
  - Usually 3 to 5

- **Core Ideology**
  - Is clear and compelling
  - Serves as unifying focal point of effort
  - Acts as a catalyst

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Source: James C. Collins and Jerry I. Porras, "Built to Last: Successful habits of visionary companies" Chapter 11
Examples of How DoD Uses some of these Strategy Development Frameworks

**Five Forces of Competition**

- Army's Armed Reconnaissance Helicopter

**Strategy Matrix**

- Leadership
  - Problem Child
  - Star
- Core Competencies
  - Exit
  - Dependable performers
- Technology Alignment with Capability Gap
  - Lower
  - Higher

**Comparison of Four Major Strategy Development Frameworks**

<table>
<thead>
<tr>
<th></th>
<th>SWOT Analysis</th>
<th>Five Forces of Competition</th>
<th>Core Competencies</th>
<th>Strategy Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus/ Applicability</strong></td>
<td>Defining Future Strategy</td>
<td>Understanding Competition</td>
<td>Core competency capitalization</td>
<td>Portfolio balancing, portfolio prioritization</td>
</tr>
<tr>
<td><strong>Analysis Criteria</strong></td>
<td>Match threats and opportunities with capability of the organization</td>
<td>Industry and competitive factors</td>
<td>Prospects with respect to core capabilities and links to end products</td>
<td>Future growth potential and current profitable technologies</td>
</tr>
<tr>
<td><strong>Original Author(s)</strong></td>
<td>Kenneth A. Andrews</td>
<td>Michael Porter</td>
<td>Gary Hamel &amp; C.K. Prahalad</td>
<td>BCG and Arthur D. Little</td>
</tr>
</tbody>
</table>

How could each framework benefit your service, your organization, or your contractors?
Do factors of the theoretical strategic frameworks appear in these processes?
Do you see common themes or significant differences across the approaches described for the different services?
Difference Between Strategy & Tactics

**Strategy**
- Determines strategic direction for technology innovation
- Selects focus areas for innovation

**Tactics**
- Tools by which strategy is implemented
- Plan to move a new product project from discovery to warfighter/fielding

Source: Robert G. Cooper (March 2001), "Winning at new products: Accelerating the Process from Idea to Launch" chapter 1

A Model for Components of the Strategic Plan and the Plan’s Nested Documents

- Mission
- Vision
- Objectives
- Initiatives
- Measures
- Targets

Why we exist
What we want to be
What we must achieve to be successful
Specific outcomes expressed as how and in assessable terms (NOT activities)
Planned actions to achieve Objectives
Performance indicators to monitor success
Desired level of performance and timelines

A Model for Components of the Strategic Plan and the Plan’s Nested Documents

- Strategic Plan
- Action Plans
- Evaluate Progress

Source: DTRA strategy presentation provided by Reed Grassowich

Steps In SWOT Analysis

- Environmental Scan
- Internal Analysis
- External Analysis

- Strengths
- Weaknesses
- Opportunities
- Threats

SWOT Matrix
Quadrennial Defense Review Exercise

- Read the executive summary provided from the Quadrennial Defense Review
- Based on the QDR, as a team, identify 3 threats and 3 opportunities for the DOD S&T enterprise and then identify 3 strengths and 3 weaknesses related to those threats and opportunities. Each participant should also identify one threat and one opportunity for his/her organization.

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<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<table>
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<tr>
<th>Opportunities</th>
<th>Threats</th>
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</table>
Lesson 1 Summary

• Integrating planning continuum among different agencies is critical to address S&T management challenges
• Core ideology and envisioned future are key components of vision creation
• Each DoD service/agency uses different combination of strategy development frameworks
  – SWOT analysis is most commonly used among them
Lesson 2 Learning Objectives

- Understand how to align an organization with its strategic goals when managing an S&T strategy
- Understand how the Better Buying Power Initiative influences S&T
- Understand how we can promote innovation
- Explore translating S&T capability requirements into development plans and actionable steps
- Understand the important distinction between push and pull technologies in technology transition

Leadership in Science & Technology Management

Strategic Alignment and Better Buying Power
Moving from Strategy to Implementation

Strategy Creation is entrepreneurial and capability gap-oriented

Implementation is operations oriented

Moving from Strategy to Implementation requires attention to a number of structural, personnel, and resource issues

Source: Harvard Business School Press
“From Strategy to Implementation: Seeking Alignment” chapter 5

Elements of Strategy Alignment for Implementation

People | Culture | Strategy Goals | Leadership | Incentives | Structure | Supportive Activities
---|---|---|---|---|---|---

Alignment Checklist

<table>
<thead>
<tr>
<th>Elements</th>
<th>Criteria</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>Our people have the necessary skills to make the strategy work.</td>
<td></td>
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<tr>
<td></td>
<td>They support the strategy.</td>
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<tr>
<td></td>
<td>Their attitudes are aligned with the strategy.</td>
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<td></td>
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<tr>
<td></td>
<td>They have the resources they need to be successful</td>
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<tr>
<td>Leadership</td>
<td>Our top leadership is responsible for changing the organization’s culture to better align it with a new strategy.</td>
<td></td>
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<tr>
<td>Incentives</td>
<td>Our rewards system is aligned with the strategy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Everyone has performance goals aligned with the strategy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>Units are optimally organized to support the strategy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supportive Activities</td>
<td>The many things we do around here — identifying technology gaps, the way we handle warfighter needs, transition technology, etc. — support the strategy.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culture</td>
<td>Our culture and strategy are well matched.</td>
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</tbody>
</table>

* For every "no" response, specify the problem and what needs to be done to correct it.


Aligned for Innovation?

We are continually being asked to do more innovation. Does the DoD have the right alignment for innovation?
Better Buying Power (BBP)

- Is based on the principle that continuous improvement is the best approach to improving the defense acquisition enterprise
- Has progressed over time
  - BBP 1.0 (2010) – Use Best Practices
  - BBP 2.0 (2013) – Help acquisition professionals think critically and make better decisions as they confront complex situations
  - BBP 3.0 (2015) – Focus on initiatives that encourage innovation and promote technical excellence with the overarching goal of ensuring that the United States’ military has the dominant capabilities to meet future national security requirements
- Implies that acquisition professionals have to be able to think on many levels, integrate inputs from many perspectives, balance competing needs (trade-offs), and satisfy many stakeholders and customers

From Your Pre-work...

What BBP 3.0 initiatives did you highlight as relevant to your organization? How will these (and other) initiatives improve the S&T portfolio process?

Key Factors for Innovation Success

- Using cross-functional teams
- Doing upfront work prior to development stage
- Building in customer needs
- Getting a well defined technology definition
- Project selection decisions
- Portfolio management techniques

Successful Technology Innovation

- How well does your organization support innovation?
- How does your organization currently choose the right projects?
What Are Drivers of Innovation for Industry and DoD?

1. Do the right things
2. Do things right
3. Do things better (Improving)
4. Do away with things (Cutting)
5. Do things others are doing (Adapting/benchmarking)
6. Do things no one is doing (Different)
7. Do things that can’t be done (Impossible)

Source: "The 7 Levels of Change: Different Thinking for Different Results", Rolf Smith

PLANNING FOR TRANSITION

DoD Technology Management

What is the difference between technology transition and progression?
“Types” of Technology Transition

- S&T Focus
  (Technology push)
  No clear customer

- Capability Focus
  (Demand pull)
  Customers ask for it

- What does it mean to transition?
- Do all technologies eventually need to be “pull” in order to transition?

Technology Transition Exercise

- What technologies have you seen transition successfully from your lab or research center?
  - Describe the Technology and Development
    - Was this a push versus a pull?
    - Describe where the technology transitioned?
    - Why was it successful?
    - What were the challenges?

Lesson 2 Summary

- A successful strategy must align strategic goals with a set of supporting practices and structures
- BBP integrates inputs from many levels/perspectives, balances trade-offs, and focuses on stakeholder/customer needs
- Industry and DoD have some common innovation drivers and challenges and some differences
- The use of portfolio based analysis/planning improves portfolio development and is useful to transition from strategy to tasks
- Technology transition can happen at different stages of TRLs based on current priorities but in all cases should be planned for early in the S&T process
Lesson 3 Learning Objectives

- Define and explain the purposes of technology roadmapping
- Learn the types and steps of technology roadmapping
- Analyze the best practices of technology roadmapping
- Illustrate the benefits of roadmapping to researchers and customers
- Discuss key DoD initiative: Reliance 21 and Communities of Interest (COI's)
What is a Technology Roadmap?

- Identifies technologies that are critical for future customer & product needs
- Assists leadership in deciding needed technologies, funding levels (prioritization and urgency)
- Allows leadership to better position their development activities with limited resources
- Used by industry to remain competitive and responsive
- Used by Department of Defense to plan activities for technology insertion into programs

Inputs for Roadmapping

- Directive
  - DoD Strategic Technology Plan
  - Service Strategic Technology Plan
  - Lab Strategic Technology Plan
- Derived
  - Validated warfighter capability gaps (requirements)
  - Threat assessments (may not be reflected in capability gaps)
  - Commanders’ inputs (CoCOMs, DoD, etc.)

Roadmapping Captures Both Strategic and Tactical Aspects

- Technology Options Evaluated
- Roadmap Creation
- Defined Targets
- Project Proposals
- Identification of Technology Available/Feasible/Possible

Adapted from: “Technology roadmapping—A planning framework for evolution and revolution,” Robert Phaal, Clare J.P. Farrukh, David R. Probert, 26 May 2003

Adapted from: Petrick, Irene J. (PENNSTATE case study,) “Developing and Implementing Roadmaps – A Reference Guide”
Roadmapping Process Steps

1. Planning
   - Define inputs, outputs, units of analysis
   - Select from inputs technologies to roadmap
   - Identify participants and senior leaders
   - Identify existing technology transfer agreements
   - Identify new programs of record required to field technologies
   - Create schedule

2. Define Technology Thrust Areas
   - Assess technology strategy
   - Identify group and prioritize technology thrust areas
   - Identify technology gaps
   - Identify mission needs
   - Consider strategic context
   - Develop time line
   - Generate roadmap
   - Support with Technology Transfer Agreements (TTAs)
   - Develop approaches to address TGs
   - Assess technology performance expectations
   - Identify and assess the impact of technology on internal/external drivers
   - Develop approaches to address TGs
   - Assess resources
   - Generate unrealized
   - Select/eliminate unprioritized approaches
   - Document technology strategy
   - Select and assess the impact of technology on gaps
   - Prioritize technology features and technology gaps
   - Select and assess the impact on gaps
   - Prioritize/eliminate technology features and technology gaps
   - Select/eliminate unprioritized approaches
   - Document technology strategy

3. Define technology gaps (TGs)
   - Define if redundancy is needed to reduce risks
   - Assess technology performance expectations
   - Identify, group and prioritize internal/external drivers
   - Define known risks
   - Conduct SWOT analysis
   - Consider strategic context
   - Define technology gaps (TGs)
   - Identify known risks
   - Conduct SWOT analysis
   - Consider strategic context
   - Define if redundancy is needed to reduce risks
   - Assess technology performance expectations

4. Implementation
   - Define inputs, outputs, units of analysis
   - Select from inputs technologies to roadmap
   - Identify participants and senior leaders
   - Identify existing technology transfer agreements
   - Identify new programs of record required to field technologies
   - Create schedule
   - Process results in a “first-cut” roadmap together with identification of key knowledge gaps, and implementation factors
   - Analysis grids are often used to gather data, define structure and “language”, and to span

Adapted from: "Technology roadmapping—A planning framework for evolution and revolution" Robert Phaal, Clare J.P. Farrukh, David R. Probert, 26 May 2003

Types of Roadmap

- Narrow
- Technology Thrust Area
- Lab/R&D Center
- Service
- Broad
- DoD Communities of Interest

What level are you working at?

Examples of Technology Roadmap Planning Formats

- Tables
- Global Horizons Final Report, 2013
- Flow Charts
- Global Horizons Final Report, 2013
- Bars
- Global Horizons Final Report, 2013

Air Force Space Technology Roadmap

<table>
<thead>
<tr>
<th>Area</th>
<th>Near (FY13-17)</th>
<th>Mid (FY18-22)</th>
<th>Far (FY23-27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disaggregation</td>
<td>Demonstrator (E.)</td>
<td>Demonstration (E.)</td>
<td>Microsatellites (F.)</td>
</tr>
<tr>
<td>Inexpensive Launch</td>
<td>104kg to LEO for $5-30M (N)</td>
<td>GEO and LEO (F)</td>
<td>Launch new materials (E)</td>
</tr>
<tr>
<td>Space Cyber</td>
<td>Tools (E.)</td>
<td>Space HASPE (F)</td>
<td>Agile and Resilient (E)</td>
</tr>
<tr>
<td>Architectures</td>
<td>Deployable antenna (E.)</td>
<td>Synoptic antennas (F)</td>
<td>Composable constellations (E)</td>
</tr>
<tr>
<td>Communications</td>
<td>AEHF (E.), V/W band (E.)</td>
<td>Laser communications (E)</td>
<td>Quantum computing (F)</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Radiation-hard (E.)</td>
<td>Additive manufacturing (F)</td>
<td>Build in space (E.)</td>
</tr>
</tbody>
</table>

Source: Global Horizons 2013
Brought together a group of local engineering managers and executives

Create foundation of engineering and programmatic criteria partitioned by TRL

Integrated with technology development and selection
Integrated with stage-gate and other execution processes
Incorporate awareness or (better) collaboration with other technology development organizations
Clear distinction between a presentation of the lay of the land (passive observation) versus a plan for changing the landscape (active intervention)
Roadmapping can be used for either
Reviewed by high-level leadership
Articulates a collaboration strategy with all stakeholders
Linked to portfolio analysis and risk analysis

What are the challenges that you have seen?
Research Planning to Support Roadmapping

- Research program planning works inside your walls:
  - Plan/manage your resources (people, equipment, budget, etc.)
- Technology roadmaps connect your work to other programs, for example
  - Acquiring nascent technologies from industry or academia
  - Collaborating with related projects in other services or other agencies
  - Transitioning to new weapon systems of upgrades of fielded systems
- Technology roadmaps connect your work to broad technology advances in your discipline, for example impact of:
  - Integrated circuit technology on your embedded controllers
  - Autonomous control technology on your vehicles
  - New materials on your sensors

Reliance 21 and Communities Of Interest

Reliance 21 (http://www.acq.osd.mil/chieftecnologist/reliance21.html) is the overarching framework of the DoD’s S&T joint planning and coordination process

17 Communities of Interest (COIs) established (http://www.acq.osd.mil/chieftecnologist/COIs.html)
What do COIs Achieve?

- Deliver strategic plans and roadmaps with a 10 year horizon that capture technical goals and mission impact
- Identify common S&T needs and show
  - Where they are being addressed
  - Where there are gaps or future opportunities
  - Plans are used to guide long-term budget decisions and to influence near-term program priorities in each of the Services
- Work closely with program executives and warfighters throughout the Department
- Are also expected to coordinate international S&T engagement for their technical area
- Are considered mission-critical to the effective conduct of the Department’s S&T program

Roadmapping Exercise

1. In this exercise, you will help Joshua, in the case study, plan technology development in the context of completed, ongoing, and planned technology projects in other agencies
2. Joshua has the option of
   a. developing technology in his own branch
   b. depending on another lab or agency to develop the technology
   c. collaborating with the other agency and modifying their plans
3. There are several technology gaps, and closing them is far too expensive for Joshua’s lab going solo, so creativity will be required
4. A great deal of technology development has already been done on scramjet propulsion for hypersonic vehicles.
5. The result of this effort should be (1) a technology roadmap and (2) a plan for next steps
Lesson 3 Summary

- Technology roadmapping is the process as well as the end product
  - Links Strategy to project proposals
  - Has 4 steps from planning to implementation
- Internals and external inputs have to be considered when developing technology roadmaps
- There are multiple standard types of technology roadmaps based on their planning purpose
Lesson 4 Learning Objectives

- Discuss key pieces of portfolio management process
- Describe the technology portfolio development/management processes used by the DoD Services and Agencies
- Discuss the challenges with evaluating and balancing technology alternatives
- Understand the roles of different strategic “bins” in a portfolio (e.g., innovative/disruptive, bridging, leap ahead)
- Compare processes for identifying technology gaps and requirements

Challenges Selecting the Best Portfolio

- Assume patrons of a steakhouse are asked to rank-order the menu items based on what they like most. The results:
  1. Steak
  2. Shrimp
  3. Prime rib
  4. Cake
  5. Pie
  6. Macaroni and cheese
  7. Ice cream
  8. Mashed potatoes
  9. Creamed spinach
  10. Broccoli

What set of items would you choose to make your meal? How is that different from the best set of items?
Definitions of Portfolio Management Share Common Themes

Portfolio -- a range of investments held by a person or organization (Webster)

Portfolio Management -- a dynamic decision process where more than one S&T project is managed within resources available and strategy

- Resource allocation – need to do more with less, so technology resources are too scarce to allocate to the wrong projects so must try to select the best portfolio.
- Strategy – if the wrong projects are pursued, you fail to implement your strategy. This commonly requires some balance (mix between risk versus return, maintenance versus growth, short-term versus long-term, etc.)
- Periodic reviews of the total portfolio of all projects – making ongoing Go/Kill decisions on individual projects is necessary for ultimately developing good projects.

What Is Portfolio Management?

- Does your organization employ an explicit portfolio management approach?
- Is it consistently applied across all appropriate projects?
- Are the rules clear and understood?

Pharma’s Portfolio Problem

In the early 2000’s, most large pharma companies focused on cheap, easy and quick to deliver products giving up on longer-term potential new drug platforms. Their focus was too much on:

1. applying existing products to new diseases
2. developing similar drugs to competitors (“me too” products)
3. creating market-driven product extension.

Not enough focus was spent on the long-term strategy.

By mid-decade the new product pipelines were depleted and the large firms scrambled to buy smaller firms to create a long-term pipeline of products.

Why do we care? Big Pharma is analogous to DoD, both investing nearly $65B and $70B into R&D annually.

Pharma Challenges

Pharma Product lines are:

- Extremely high risk (fewer than 10% make it to market)
- Expensive (a single project can cost hundreds of millions of dollars)
- Long time frames (typically 3-8 years)

Portfolio management needs to:

- Choose the best set of projects to achieve the organization’s goals not just the best projects.
- Terminate projects that are not progressing rather than cutting funding and leaving “zombie projects” in a semi-active state.

* S&T 12.2 Billion
** Too 5 pharmaceutical companies with highest R&D spending
The Pharmaceutical Industry Portfolio Management Method (Stage-Gate Process)

**Popular method for assessing and valuing a project within Pharmaceutical development**

**Implied decisions**
If trial results in meeting or exceeding hurdles, continue to fund next stage of development

- **Discovery**
- **Pre-Clinical (animal testing)**
- **Phase 1: Safety Clinical Trials**
- **Phase 2: Proof of Concept Clinical Trials**
- **Phase 3: Regulatory Clinical Trials**
- **Launch New Drug**

**Misses Hurdles**

* Implied decisions
* If trial results in meeting or exceeding hurdles, continue to fund next stage of development

**DoD Capability Portfolio Management Directive**

- Established that DoD shall use capability portfolio management to advise the Deputy Secretary of Defense and the Heads of the DoD Components on how to
  - optimize capability investments across the defense enterprise
  - minimize risk in meeting the Department’s capability needs
- Applies to:
  - OSD
  - Office of the Chairman of the Joint Chiefs of Staff and the Joint Staff
  - Office of the Inspector General of the Department of Defense
  - Combatant Commands
  - Defense Agencies
  - DoD Field Activities
  - Military Departments

This directive applies to capability portfolios. Are technology portfolios different? Does this directive apply to S&T?

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**D&I Investments Map to the Naval S&T Plan’s Focus Areas**

**Naval S&I Focus Areas**
- Access to the Maritime Battlepace
- Autonomy and Unmanned Systems
- Exploration and Information Dominance
- Platform Design and Survivability
- Power and Energy
- Power Projection and Integrated Defense
- Total Ownership Cost
- Warfighter Performance

**National Naval Responsibilities**
- Ocean Analytics
- Undersea Weapons
- Naval Engineering
- Defense Medicine
- Sea-Based Aviation
- Emergent Research Areas
- Autonomous Sciences
- Bio-Inspired Sciences
- Cognitive, Human, & Training Technologies
- IT Sciences
- Advanced Computing
- Counter-IED Defenses
- Other naval relevant areas, e.g., correlation

---

**Army S&T Investment Portfolios**

- Basic Research
- Development
- Advanced Acquisition
- Operation
- Manufacturing
- Transition
- Revitalize
- Cyber
- Command & Control
- Intelligence
- Sustainment
- Training
Common themes for portfolio management across services?

Identify at least one strength and one weakness that you observed in the previous portfolio management examples.

Key Pieces of a Portfolio Management Process

- **Strategy**
  - Successful strategy implementation requires that the right projects are pursued

- **Resource Allocation**
  - DoD always needs to do more with less, so technology resources are too scarce to allocate to the wrong projects

- **Balance**
  - Mix between risk versus status quo, maintenance versus innovation, short-term versus long-term

- **Periodic Reviews**
  - Of total portfolio of projects with ongoing Go/Kill decisions on individual projects

Iterate

Portfolio Needs/Gaps Coverage Matrix

<table>
<thead>
<tr>
<th>Requirement Type</th>
<th>Capability Gap 1</th>
<th>Capability Gap 2</th>
<th>Capability Gap 3</th>
<th>Capability Gap 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEM Demonstrator</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>TPS Enhancement</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training Officer</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training Officer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How could you improve this portfolio?
What is Project Portfolio Balance?

**Key Parameters**

- Cost Savings
- Risk
- Innovative
- Short Term
- Long Term

**Blend of Investment Decisions**

---

How the Armament Research Development & Engineering Center thinks about Balance

**Strategic Relevancy Lenses**

---

**Bubble Diagrams – Visualizing Balance**

- Bread and Butter
- Gold Mine
- White Elephants
- Oysters

**Example Results from a POM Prioritization Analysis – comparison of 2 criteria**

**Strategic Fit: Urgency vs. Technical Risk**

- Largest = $30M
- Smallest = $1M
Strategic Bins or Buckets

- Translate strategy into clearly defined areas and define how many resources to allocate to each area
- What percentage of resources should go to new product development? To platform development? To fundamental research? To maintenance-type projects? To process improvements?

STEPS:
- A consistent process is required to establish desired spending levels for each technology/mission (i.e., the buckets that specify levels of spending)
- Projects are then prioritized within buckets

Steps in Strategic Binning Approach

- Step 1: Understand strategic priorities and status quo funding
- Step 2: Define allocation of resources
- Step 3: Review lists of potential projects across time and roll up
- Step 4: Iterate and improve the portfolio

Consequences of Having Poor Portfolio Management

Root Cause
- A reluctance to kill projects, many projects added to the list, a total lack of focus

Proximate Cause
- Too many projects — resources spread thin
- Quality of execution suffers
- Too many low value projects, good projects starved for resources
- Projects lack strategic direction, projects are not strategically aligned
- Arbitrary technology selection based on emotion, politics

End Result
- Increased time to develop projects from a poor quality portfolio
- Too few successful projects to support acquisition
- Funding wrong projects (e.g., too many in same area)
- Many failures from a poor quality portfolio
Lesson 4 Summary

• Choosing the correct portfolios are critical to meeting the strategic goals
• In this complex DoD environment, balanced portfolios will need to consider many attributes:
  – Risk versus status quo
  – Maintenance versus innovation
  – Short-term versus long-term
• Identifying gaps can help prioritize and balance the portfolio
Lesson 5 Learning Objectives

- Learn how to use value hierarchies to structure prioritization
- Compare different prioritization procedures based on relevant criteria (e.g., complexity, transparency, etc.)
- Practice presenting results of prioritization and risk management processes

PORTFOLIO PRIORITIZATION CRITERIA

Three Goals in Portfolio Management

Maximize Benefit
- Likelihood of success, meet mission goals, etc.
- Evaluate Technology Alternatives
- Rate projects

Achieve Balance
- Long-term vs. short/lazy projects
- High risk vs. lower-risk sure bets,
- Different project types

Align with Strategy
- Consistent with strategic direction
- Support strategy implementation and goals
- Resource allocation reflects strategic goals

How does this match your experience in DoD prioritizing portfolios? Are there other factors considered?
Generally using ranking processes but not strict scoring processes to get prioritized lists

Ranking processes generally focus on goals or evaluation criteria but without explicit measures for each

“Essentially, all models are wrong, but some are useful”
– George Box, 1987

All prioritization models need:
• Individual Projects
• Feasible Portfolios
• Resource Constraints
• Evaluation Criteria that will identify an attractive mix of projects in a portfolio

Developing Criteria
• Criteria will be used to prioritize projects
• Different strategic bins of projects may require different criteria to prioritize
• Sources for identifying criteria:
  – Interviews and brainstorming with decision makers
  – Reviews of strategy documents and mission guidance
  – Prior analyses

Good criteria would be…

Comprehensive
Measurable
Sensitive
Practical
Understandable

Cover the range of relevant concerns, but the evaluation framework remains systematic and manageable and there are no redundancies in criteria
Consistently applied to allow consistent comparisons across projects

Where information can be obtained to assess them (i.e., data, models or expert judgment exist or can be readily developed)

Criteria and any corresponding trade-offs can be understood and communicated by everyone involved
Portfolio Criteria Exercise

What are the top 10 factors that you would use to come up with for developing a portfolio for your organization? Reviewing the course slides to this point should help you identify these factors.

Group them into the 5 most important and 5 less important.

AFRL Portfolio Criteria

- Some criteria used by AFRL
  - Balance among BA1, BA2, BA3
  - Balance across the technology directorates
  - Fund highest priority technology gaps and core customer areas
  - Take into account leadership “big bets” e.g. Directed Energy
  - Maintain funding in technology centers of excellence
  - Balance between high risk and low risk
  - Minimize technology overlap between directorates
  - Embrace cross directorate collaboration

Army Portfolio Criteria

- Some criteria used by the Army
  - Align with strategy
  - Likelihood of success
  - Areas where the Army must lead
  - High/low risk
  - Near term/far term
  - Uniqueness for early research
  - Transition opportunity for later technology development

SCORING MODELS
A Scoring Model with Attributes

- Attributes need to be quantifiable, and the set of attributes used by a value model need to be represented mathematically by an ordered set of quantities/scales.
- All projects will need to be scored on the attribute scales.
- For most attributes considered in an R&D prioritization model, a constructed scale will be appropriate. For example:
  1. There is no interagency collaboration in the project.
  2. The project has an interagency collaborator but is not receiving any funding.
  3. The project has an interagency partner who is sharing less than 25% of the costs of the project (find priority).
  4. The project has an interagency partner who is sharing 25% to 50% of the costs of the project (big bets).
  5. (Best): The project has an interagency partner who is sharing greater than 50% of the costs of the project.

Weight Assignment

- Weights – should capture the importance and impact on the decision of the range of variation in the criteria measured.
- A criterion that is very important to the decision should be weighted higher than a measure that is less important.
- A criterion that differentiates between alternatives (i.e., in which the ranges vary significantly) will have a greater effective weight than a measure that does not differentiate between alternatives.

Calculating the Overall Value

- Commonly a weighted average is computed for each score on each objective:
  - Simply multiply an objective’s weight by the rating of the performance of the project on that objective, and then sum over all objectives (HINT: Excel’s SUMPRODUCT function will calculate this weight and rate approach).
  - The recommended alternative is the one with the highest resulting overall value.

EXAMPLE: AFRL Aerospace Systems (RQ)

- RQ’s mission is to “develop, integrate and transition power, propulsion, and military flight technologies for air and space dominance.”
- Their guidance sources include (but are not limited to): National Defense Strategy, USAF Technology Horizons, AFRL Corporate Investment Strategy, National Plans, and MAJCOM Core Function Support Plans (CFSP).
- In 2014, RQ used six criteria to prioritize their strategic portfolio.
**EXAMPLE: RQ Strategic Portfolio Evaluation Criteria**

<table>
<thead>
<tr>
<th>Core Competencies/In-House Capabilities</th>
<th>Future Revolutionary Capability</th>
<th>Customer Requirements and Commitment</th>
<th>Executability</th>
<th>Investment Risk vs Mission Payoff</th>
<th>Commitment Accountability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit of measure:</strong> Subjective scale to measure the likelihood that the technology can be developed successfully.</td>
<td><strong>Unit of measure:</strong> Subjective scale reflecting degree of uniqueness.</td>
<td><strong>Unit of measure:</strong> Subjective scale reflecting level of accountability.</td>
<td><strong>Unit of measure:</strong> Risk-Payoff Matrix</td>
<td><strong>Unit of measure:</strong> Risk-Payoff Matrix</td>
<td><strong>Unit of measure:</strong> Subjective scale reflecting degree of initiative.</td>
</tr>
<tr>
<td>1 = Failure to honor commitment results in no consequences</td>
<td>9 = Failure to honor commitment results in unacceptable consequences</td>
<td>9 = Program enables closing a gap</td>
<td>1 = Incremental: Little or no difference in approach</td>
<td>9 = Revolution: Totally different approach</td>
<td>1 = Expressions of interest, and enables closing a gap</td>
</tr>
<tr>
<td>2 = Failure to honor commitment results in insufficient to completely close a gap</td>
<td>8 = Failure to honor commitment results in insufficient to completely close a gap</td>
<td>8 = Codified in MAJCOM Roadmap, requirements document (ICD, CCD), CFSP, or signed TTP, and enables closing a gap</td>
<td>2 = High Payoff, Low/Medium Risk</td>
<td>2 = High/Medium Payoff, High/Low Risk</td>
<td>2 = Expressions of interest, and enables closing a gap</td>
</tr>
<tr>
<td>3 = Failure to honor commitment results in insufficient to completely close a gap</td>
<td>7 = Failure to honor commitment results in severe consequences</td>
<td>7 = Failure to honor commitment results in severe consequences</td>
<td>3 = Medium/Medium Payoff, Medium/Low Risk</td>
<td>3 = Medium/Low Payoff, Medium/Low Risk</td>
<td>3 = Expressions of interest, and enables closing a gap</td>
</tr>
<tr>
<td>4 = Failure to honor commitment results in manageable consequences</td>
<td>6 = Failure to honor commitment results in manageable consequences</td>
<td>6 = Failure to honor commitment results in manageable consequences</td>
<td>4 = Low Payoff, High/Medium Risk</td>
<td>4 = Low Payoff, High/Medium Risk</td>
<td>4 = Expressions of interest, and enables closing a gap</td>
</tr>
</tbody>
</table>

**EXAMPLE: RQ Detailed Criteria (1 of 2)**

**Core Competencies/In-House Capabilities**

- Unit of measure: Subjective scale reflecting degree of uniqueness.
- 1 = Incremental: Little or no difference in approach
- 2 = Evolutionary: Some difference in approach
- 3 = Revolutionary: Totally different approach

**Future Revolutionary Capability**

- Unit of measure: Subjective scale reflecting degree of uniqueness.
- 1 = Incremental: Little or no difference in approach
- 2 = Evolutionary: Some difference in approach
- 3 = Revolutionary: Totally different approach

**Customer Requirement and Commitment**

- Unit of measure: Subjective scale reflecting level of accountability.
- 1 = Expressions of interest, and enables closing a gap
- 2 = Expressions of interest, and enables closing a gap
- 3 = Expressions of interest, and enables closing a gap

**Investment Risk vs Mission Payoff**

- Unit of measure: Risk-Payoff Matrix
- 1 = High Payoff, Low/Medium Risk
- 2 = Medium/Medium Payoff, Medium/Low Risk
- 3 = High/Low Payoff, Medium/Medium Risk

**Executability**

- Unit of measure: Subjective scale reflecting degree of initiative.
- 1 = Incremental: Little or no difference in approach
- 2 = Evolutionary: Some difference in approach
- 3 = Revolutionary: Totally different approach

**Commitment Accountability**

- Unit of measure: Subjective scale reflecting degree of initiative.
- 1 = Incremental: Little or no difference in approach
- 2 = Evolutionary: Some difference in approach
- 3 = Revolutionary: Totally different approach

**Future Revolutionary Capability**

- Unit of measure: Subjective scale reflecting degree of uniqueness.
- 1 = Incremental: Little or no difference in approach
- 2 = Evolutionary: Some difference in approach
- 3 = Revolutionary: Totally different approach

**EXERCISE: A Pilot Example from Practice**

- **One DoD Agency used a value scoring model for the FY 14 RD Program Evaluation and POM Prioritization Process**
- **Review the provided model and critique the approach**
  - How sound is the reasoning underlying the prioritization model?
  - Does the model consider the correct criteria? How well do the criteria meet the standards for good criteria?
  - How appropriate are the changes to the criteria between the different strategic priorities?
  - How appropriate are the weights used?
  - Does the model provide information that can support the POM decisions?
  - Develop a scale for either a criteria that you feel is missing or rewrite a scale for the criteria that you feel is most problematic.
  - What three recommendations would you make to improve the model and its implementation?
General Lessons Learned by the DoD Agency from the Pilot Process

- The majority of programs cluster tightly
  - Indicates similarity in evaluation criteria & scoring standards
- In the end, the scoring created 3 tiers of alternatives, and was not used to create an explicit ranked list
- Any adjustments beyond the clustering should be a leadership decision
- Evaluation criteria, scoring standards and criteria weighting should be revisited before next iteration

Criteria for Good Scoring Models

- **Repeatability**
  - For identical set of attributes, the model always provides the same results
- **Transparency**
  - Clearly being able to perceive and understand why the model behaves as it does
- **Differentiability**
  - The model can differentiate between the programs and projects that are being ranked

Some Metrics to Consider for Evaluating a S&T Portfolio

- On-time performance (measured at key review points)
- Time efficiency to the field
- Success rates of projects launched to the field
- Delivered costs versus forecasted costs
- Alignment with customers
- Technology Agreement Status
- Fulfillment of technical objectives

CASE EXERCISE: Your Turn

- You are the manager responsible for recommending which programs should be funded for the Army’s C3I portfolio. Your team of analysts have provided you with data scoring the projects on provided criteria (see provided spreadsheet).
- Given your group’s focus and budget, which portfolio of projects do you fund? What weights do you assign to the different evaluation criteria?
Lesson 5 Summary

- There are several ways to rank portfolios based on multiple criteria and sources.
- Portfolio management has three main goals:

<table>
<thead>
<tr>
<th>Maximize Benefit</th>
<th>Achieve Balance</th>
<th>Align with Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Likelihood of success, meet mission goals, etc.</td>
<td>• Long-term vs. short/lust projects</td>
<td>• Consistent with strategic direction</td>
</tr>
<tr>
<td>• Evaluate Technology Alternatives</td>
<td>• High risk vs. lower-risk sure bets, different project types</td>
<td>• Support strategy implementation and goals</td>
</tr>
<tr>
<td>• Rate projects</td>
<td></td>
<td>• Resource allocation reflects strategic goals</td>
</tr>
</tbody>
</table>

- It is critical to assess and assign unbiased weights when evaluating portfolios.
Lesson 6 Learning Objectives

- Practice evaluating a portfolio for a budgetary decision
- Practice presenting results of prioritization and risk management processes

CASE EXERCISE: Your Turn

- You are the manager responsible for recommending which programs should be funded for the Army’s Aviation Portfolio in the Aviation and Missile Research, Development and Engineering Center at Redstone Arsenal. You are facing a significant budget cut and you must choose which projects to cut and which to protect.
- Task 1: Develop a strategy for evaluating the portfolio submission.
- Task 2: Prepare a brief for your senior leadership that explains what the cuts will be and what the impact will be to each of the three R&D organizations.
Road-mapping Science and Technology Projects

This exercise addresses the rapid planning of a set of science and technology development projects which can be coordinated through a roadmap to enable a warfighter capability. Your road-mapping template is provided as a Powerpoint file. You should add activities and interactions.

There is no correct answer to this exercise. There are better roadmaps and less good roadmaps. Each group should be prepared to present their road-map along with a list of the assumptions that you used to complete the road-map. Also be prepared to discuss what information you believe is missing, and how your group thought about the funding issue.

Joshua had just returned from a meeting where the latest Quadrennial Defense Review was discussed, and was prepared to brief his branch chief, Cynthia.¹

“It sounds like we are considering some kind of high speed reconnaissance craft.”

Cynthia nodded. “I have been in three conversations about relevant technologies in the past week. They are contemplating an advanced reconnaissance sensor package on a Mach 5.5 platform cruising at 75,000 feet with a combat radius of 1400 nautical miles. If our research facility wants to contribute to this effort, we need to have technologies available for a program initiation in 48 months, or at worst, show where the technology is lacking.”

Joshua clarified, “48 months is the latest we could deliver technologies to be relevant to the program management office?”

Cynthia again nodded. “But remember our technologies could apply to other projects too.”

“Who is the customer for this?” he asked.

“They are talking about forming up a Joint Program Office for High Speed Reconnaissance. It will be run out of OSD Acquisition at first.”

Joshua thought for a moment. “I suppose there is funding to support this?”

¹ Assume Joshua and Cynthia are working in a large research facility for your service.
“If they move forward, I believe we will get $200 million.”

“That sounds like a lot, but it barely scratches the surface. We have a whole heap of technology gaps, and the only way to convincingly demonstrate any of this is in flight. I don’t think $200 million will buy a single flight test.”

Cynthia was undeterred. “Tell me about the technology gaps.”

“First, there are basic materials issues for the nozzle. We could use conventional nickel superalloys, which require little development, but we would have more payload margin if we used ceramic matrix composite structures. There are decades of work there, but we still have durability problems at the temperatures we would be facing on a vehicle like this.

“Next, we need to understand supersonic combustion better. We have several fuel options, but the spray patterns have not been optimized with any of them to achieve combustion efficiencies necessary for a vehicle with any real range. The hardest part is getting the combustor lit, and then stabilizing the flame.”

“We face an array of integration problems, the worst of which is thermal management. At Mach 5.5 we can probably use fuel to cool the aerodynamic surfaces, but it will be tricky, and depending on the fuel, we could have coking problems or fuel stability issues.

“The worst integration problem on these vehicles is always the inlet. How will we get flow started, and how will we keep the flow from surging or stalling? If we do need to restart the inlet in flight, how will that work?”

Cynthia sat quietly for a few moments, thinking. “We need to do some concept studies, and that will require about $60 million of the $200 million budget. With the remainder, we can pull off several laboratory projects, here or at our contractors’ shops, plus maybe one big ground test.”

“A ground test at hypersonic flow conditions?”

“No,” she replied. “We can only hope for supersonic flow at best.”

“This is impossible,” Joshua grumbled.

“It would be,” Cynthia replied, “except that we have friends. From DARPA, I have heard that they are probably going to get the green light for a Mach 8 flight test next year. They have been prepping for three years, and their vehicle is half built. A recent briefing that I saw showed a schedule like this:”
“But Mach 8 is not Mach 5.5. The inlet will be completely different, the fuel may be different, thermal management is in another zone, and the structural materials they use for three minute flights will never be durable enough for us.”

“Could we use their fuels?” Cynthia probed.

“They would not be ideal,” he answered.

“There is also, apparently, a hypersonic development project going on at NASA.”

“What speed?” he asked.

“It is a space launch system of some sort, so at Mach 3 or 4 this scramjet lights off and accelerates the whole thing to Mach 10 or thereabouts, then turns it over to a rocket stage.”

“Are they going to build this?”

“I doubt it, but they are planning a lot of ground testing in their heated tunnel at Langley.”

“I wish we had a tunnel that size. Any idea what kind of ground testing?”

“The plan that I saw looked like this.”
“The testing is to focus on inlet starts and restarts and combustor tests. Isn’t that what you would do first?” she asked.

“That’s right. I wonder what sort of inducement it would take for them to pause at our lightoff speed, and then at Mach 5.5, and do an extended series of tests?”

Cynthia stood up. “Now you are thinking. I want a technology roadmap, showing a plan for our lab, how we can connect to NASA and DARPA, what they can do for us, and where we need funding. The $200 million is not going to walk in here on its own, we must show the need and a plan. Make sure you are clear in your plan about:

• What product or products are we going to develop to meet the customer’s need?
• How must the technology meet the product?
  – Including time critical connection points and need dates
  – Including levels of maturity required
• What technology development projects are needed to develop and mature the technologies?
  – Including what are the time frames (need dates).”

“That will take three weeks.”

“You have two hours,” she said as she showed him to the door. “And make sure you advance our strategic priorities in multifunctional structures and active control.”

Joshua returned to his workspace and stared at two slides he had posted on his wall. One was a slide he created to brief the basic challenges of hypersonics. The second was a slide he created to brief the basic of road-mapping.

Next, he came up with a plan on who to contact to acquire more information.

The following sheets describe additional information acquired by Joshua to help with his planning.
Hypersonic Fundamentals

- Thermal Heating must be managed at the inlets
- Combustion with hypersonic air flow must be controlled and stable
  - Depends on fuel and combustor design
- Combustor and nozzle must be durable at extreme temperatures
- Ground testing at hypersonic conditions is extremely difficult but
- Flight testing is extremely risky with little or no recovery possible

Example Roadmap

Critical Elements: 1) Time, 2) Technologies, 3) Connections to Products, 4) Timelines for Technology Projects
Materials Development

Joshua emailed his friend Pat in the Materials Directorate at AFRL to ask for any history he might have on the cost of developing a ceramic matrix composite structure. He received an answer almost immediately:

– What TRL are you trying to get to? –

Joshua emailed back

– We need TRL 6. We are going to fly it. –

He put the materials question aside and worked on other aspects of his plan. After 45 minutes, an email came in from Pat:

– We have been working with this ceramic matrix composite (CMC) structure for thirty years, but precious little has made it to flight test. We spent three years on a CMC combustor for a high speed missile. We put in maybe $40 million, but that wasn't nearly enough, and when we walked away from it, it still was not structurally sound. I mean, it had a life of a few minutes on a good day. We have a turbine blade that works, it's in production. That was maybe $100 million. It is a really simple blade—no cooling or anything very clever. We have done nozzle liners. A simple rectangular plate looks pretty viable, but every structural design you do is completely different. We just do not understand this stuff well enough to predict what structures will crack in thermal transients and what will not. –

– Pat, how long will this take? –

– The time is very uncertain. I would want to allow at least seven years. –

Joshua considered Pat's data. He wasn't sure he believed it all, because it did not really line up with his own experience, where materials development seemed to go faster.
Starting and Transient Testing

Joshua remembered that Sara down the hall had done an IPA at NASA in aerodynamics. He knocked on her partition wall.

“Hey Sara, when you were at NASA, did you get involved in any of the hypersonics programs or testing work?”

“Oh, hi Josh! No I didn't do anything that fast. There was some of that stuff in the planning stages that a couple of guys in our group worked on.”

“Would you know anything about the technical challenges to getting to flight?”

“Well, we would have these bi-monthly technical interchange meetings where we briefed each other on what we were doing.”

“I saw one briefing that discussed the hardest thing about ramjets and scramjets is that you have to start them when you are already traveling at high speed. They tend to be very draggy if you let the air go through the combustor without lighting it off, but if you bypass the airflow around the combustor, for example, by shutting a door at the inlet, then when you want to light it, you open the door and there is this big transition with a lot of forces in directions you don't like and a nasty tendency to stall or get flows stopping or running backwards, and if you can't get the combustor to light you are done. If you do get air flowing the right way through the inlet, sometimes it stops flowing because you lit the combustor. So these things have a nasty tendency to kill themselves.”

“That sounds awful. Has anybody gotten one of these to work?”

“Well, there was a NASA/DARPA program that hit some pretty high Mach numbers. They had problems in flight, but they successfully started the inlet and lit the combustor. They even got the vehicle to accelerate on its own power. But that was after they did a lot of inlet starts and combustor lights in the wind tunnel. The NASA Langley wind tunnel is good for this. They can get sixty second tests, and that is long enough to do transients and combustor lights.”

“If the tunnel was testing a vehicle that operates over a wide speed range, do you think they could concentrate some starts and lights at appropriate speeds for my application?”

“It is possible.”

Joshua thought hard about this as he walked back to his desk. Sara had confirmed everything he had heard about the problems with mode transitions, inlet starts, and combustor lights in hypersonic flight. He wondered why everyone was so gung ho about hypersonics if it was really this hard.
Combustor and Fuel Development

Joshua needed to review his combustion textbooks, but there was no time, so he called his college professor, Selene Marks, who he knew was doing a tour at FAA in their Energy and Environment office.

“Hi Dr. Marks! This is Joshua Gramble. I got myself a job at one of the service labs. I have been here about seven years, and I am trying to do some very rough planning for developing a hypersonic platform. I was hoping you could answer some questions about combustors and fuel.”

“Sure. There are two issues raised by supersonic combustion. One is that supersonic flow is fast – obviously – so the oxygen and the fuel have very little time to react. You need a fuel that will combust very rapidly at the temperatures and pressures you expect to be present in the supersonic combustor. The second issue is cooling. Structural cooling is a big issue in hypersonic vehicles because the atmosphere heats up the vehicle skin. The easiest solution is to use fuel to cool the structure the way we use liquid hydrogen to cool big rocket nozzles. But fuel is limited in how much heat it can absorb. So there is a lot of research in endothermic fuels. These absorb heat without getting hotter. Instead, the fuel molecules soak up the heat by breaking down into smaller molecules. So you want to find endothermic fuels that break down into fuel molecules that combust very quickly.”

Josh replied, “That suggests a lot of useful testing I should pursue, but I don’t have a supersonic combustion test facility.”

“Well, Josh, the interesting thing is that you can test a lot of this in a subsonic combustion facility for probably $500,000. The heat absorption of endothermic fuel isn’t a supersonic thing, it is just a thing. And you can measure the reaction rate of your fuel combustion in a subsonic facility. No reason to believe it would be that different at high speed, except the mixing pattern will be different, and you can analyze the mixing in a computational fluid dynamics model.”

“How long will a program like that take?” Joshua asked.

Dr. Marks thought, and then answered, “About 18 months to acquire the test articles and equipment, and usually a year for testing. It always looks like the tests could be done in several weeks, but things happen, and it almost always takes much longer.”

“I have heard that there is coking problems with high temperature fuels.”

“Josh, that is old data. I do not think you should see any problems at all. But it is not hard to pull together a coking test also. The fuel tube material and processing matter, and then it is just time and temperature.”

“Thank you, Dr. Marks. That is so helpful.”
Flight Testing

As a last minute attempt to get some handle on ways that he could get some technology benefit from the DARPA program, Josh called the program manager, Lt. Col. MacNichol. He reached an administrative assistant who said MacNichol was TDY, but connected him with the colonel’s deputy, a Dr. Cooper. Cooper passed him off to a systems support person named Barry who was negotiating the test plan with the prime contractor.

Josh and Barry quickly worked through introductions and background. Then Josh got to the point:

“Barry, if you are flying a Mach 8, is there anything you will learn or demonstrate that would support us developing a platform that flies at Mach 5.5?”

“Well, yes Josh, there is a lot. You are lucky. If it was the other way around, and you were trying to use Mach 5.5 data for Mach 8, well that would be a lot thinner. But we will be flight testing a lot of systems concepts and equipment that should really reduce your risk.”

“Such as?”

“All of the avionics and communication equipment will be at TRL 6 after flight. Likewise for the electrical power system. The flight control actuators will have survived a hotter environment than your project requires, so maybe those are proven out also, but that is a little trickier – you will need to do a loads analysis and all that. Maybe you can also claim risk reduction on flight control surfaces, but that is even more of a reach.”

“Thanks, Barry, this is really helpful.”

“Anytime, Josh. Wait, not really anytime. We are really busy here. But, glad to help.”
Exercise: A Pilot Study from Practice

One Department of Defense Agency used a value scoring model for the FY 2014 R&D Program Evaluation and POM (Program Objective Memorandum) Prioritization Process. The prioritization process was developed and vetted through the agency’s POM working group with multiple reviews by the agencies’ Deputies Council. A description of the model and its results are provided. Your task is to review the described model and critique the approach. In particular, you should address the following questions:

- How sound is the reasoning underlying the prioritization model?
- Does the model consider the correct criteria? How well do the criteria meet the standards for good criteria?

- How appropriate are the changes to the criteria between the different strategic priorities?
- How appropriate are the weights used?
- Does the model provide information that can support the POM decisions?
- Develop a scale for either a criteria that you feel is missing or rewrite a scale for the criteria that you feel is most problematic.
- What three recommendations would you make to improve the model and its implementation?

The Prioritization Model

In the first step of developing a prioritization model, the agency recognized that there were three different strategic types of R&D projects that they needed to consider and that these projects should not be ranked against each other. A balanced portfolio would include a portion of each of the three different strategic bins. There three bins were categorized as:
- Technology Push: Those R&D projects that increase the knowledge of scientific phenomena or develop innovative technology solutions to satisfy capability and technology gaps.
- Technology Pull: Those R&D projects that develop solutions to satisfy documented warfighter/user capability requirements/gaps.
- Enabling: Those activities and functions that facilitate and sustain an effective R&D organization. They include laboratory / test & evaluation infrastructure, advisory & assistance services, expertise, and information system backbone.

Thus, the process designed would prioritize projects only within the three bins and not across bins. For each of the strategic bins, separate evaluation criteria and scoring scales were developed. The following details the evaluation criteria and scoring scales for the three different strategic bins.

**Technology Push Evaluation Criteria**

To prioritize the technology push category of projects, six high level criteria were identified (Strategic Fit, Transition Potential, Technical Certainty, Innovation, Technical Approach, and Collaboration) with Strategic Fit further decomposed into three criteria: Urgency, Proponency, and Unique Niche, as shown in the figure below. The prioritization model will score each project on each criteria, but each criteria are not weighted equally. The weights for each criteria are also shown in the figure below.

For each of the evaluation criteria, scoring scales (between 1 (worst) to 5 (best)) were developed. The table below describes the scales used to score the projects in the Technology Push strategic category.
### Criteria/Scoring Scales

#### 1. Strategic Fit:
This criterion measures the alignment of the project with DoD through RD strategy and guidance, and the importance of the requirement. Preference is given to projects with direct linkages to Service requirements and strategic goals.

| 1A. Urgency: | 2- Threat has a credible chance of being realized in 1-5 years or an operational work around is difficult to implement. | 3- Threat is likely to be realized within a year or an operational work around is unreliable. | 4- Threat is likely to be realized within the next year and operational work around will likely not be effective. | 5 (Best)- Threat is imminent and no operational work around is possible. |

#### 1B. Proponency:
This criterion measures the alignment of the project to an end user's desire to have the product

| 1- No proponent. | 2- Low-level proponent. | 3- Mid-level proponent. | 4- High-level proponent. | 5 (Best)- Proponency from the highest levels of the federal government. |

#### 1C. Unique Niche:
This criterion measures the alignment of the project to an area where there is little incentive for other government, commercial and/or academic investment. Who else would do this work if we did not?

| 1- There are other government or service activities who are better suited and are pursuing the same effort | 2- Many other government or service activities are pursuing a similar if not parallel path | 3- Another organization is pursuing this technology which can be used as a hedge against technology success | 4- Other organizations are pursuing similar technology but are substantially less mature or robust | 5 (Best)- No other organization is pursuing this technology |

#### 2. Transition Potential:
The criterion is a measure of the potential for a customer to take the project science and/or technology and utilize it: for further academic research or advanced technology development; within industry; in a system acquisition program; or within a program of record.

| 1- The science or technology is too immature and no concept of application has been developed | 2- No transition customer identified yet, but a concept of application has been developed | 3- Transition customer has been identified and the customer is INTERESTED and involved in developing concepts for application | 4- Transition customer has been identified and INTENDS to develop concepts for application OR there is a draft transition agreement in development | 5 (Best)- Transition customer is committed to transition and is pursuing a signed transition agreement |
### 3. Technical Certainty: This criterion assesses the certainty of the science behind the project to achieve its technical goals. Does the enabling technology exist? How high are the technical hurdles?

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Progress highly unpredictable. Many unknown unknowns. Pushing the laws of physics</td>
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<tr>
<td>2</td>
<td>Unknowns well characterized but will require breakthrough enabling technology development to yield success</td>
</tr>
<tr>
<td>3</td>
<td>Moderate degree of uncertainty in required technological advancement.</td>
</tr>
<tr>
<td>4</td>
<td>Technical objectives are likely to be achievable.</td>
</tr>
<tr>
<td>5</td>
<td>Very high probability of success with predictability akin to Moore’s law.</td>
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### 4. Innovation:
This criterion measures the alignment of the project to research that contributes to the body of knowledge in new or different ways that others have not previously exploited or considered.

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<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Follows the same pattern of thinking used in the past</td>
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<tr>
<td>2</td>
<td>Next logical step in thinking</td>
</tr>
<tr>
<td>3</td>
<td>Builds on previous research in a novel way</td>
</tr>
<tr>
<td>4</td>
<td>Incorporates significant novel thinking</td>
</tr>
<tr>
<td>5</td>
<td>Significant departure from prior thinking; could revolutionize the field</td>
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### 5. Technical Approach: This criterion measures the maturity of the execution plan to achieve the technology results. It addresses the reasonableness of the plan considering documentation, team experience, and research methodology.

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<tr>
<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Plan has significant ambiguities; aspects of the plan are unproven.</td>
</tr>
<tr>
<td>2</td>
<td>Plan is complex and has some ambiguities; some past experience; many uncertainties</td>
</tr>
<tr>
<td>3</td>
<td>Plan appears comprehensive, but complex; most aspects have positive past experience, some uncertainties.</td>
</tr>
<tr>
<td>4</td>
<td>Comprehensive plan; positive past experience; minor uncertainties</td>
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<tr>
<td>5</td>
<td>Proven Plan; no uncertainties</td>
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### 6. Collaboration:

**International Partnership Capacity:** The criterion measures how much a project supports building partner capacity in the international technical community. The value function is built to reflect leadership preferences for R&D projects that collaborate with International Partners.

**OR**

**Interagency Collaboration Capacity:** The criterion measures how much a project supports building partner capacity in the interagency environment. The value function can be built to reflect the leadership preferences for R&D projects that collaborate with other non-DoD agencies.

| 1- There is no international collaboration in the project. OR There is no interagency collaboration in the project. |
|---|---|---|---|---|
| 2- The project has an international collaborator but is not receiving any funding. OR The project has an interagency collaborator but is not receiving any funding. |
| 3- The project has an international partner and is sharing less than 25% of the costs of the project. OR The project has an interagency partner and is sharing less than 25% of the costs of the project. |
| 4- The project has an international partner and is sharing 25% to 50% of the costs of the project. OR The project has an interagency partner and is sharing 25% to 50% of the costs of the project. |
| 5- The project has an international partner and is sharing greater than 50% of the costs of the project. OR The project has an interagency partner and is sharing greater than 50% of the costs of the project. |

#### Technology Pull Evaluation Criteria

The same process was repeated to develop criteria and scoring scales for the second strategic bin: Technology Pull. In this case, the criteria were similar but modified to consider the differences between push and pull technologies. Six high level criteria were again used (Strategic Fit, Transition Potential, Technical Risk, Payoff Potential, Technical Approach, and Collaboration) with Strategic Fit further decomposed into three criteria: Urgency, Proponency, and Appropriateness, as shown in the figure below.
For each of the evaluation criteria, scoring scales (between 1 (worst) to 5 (best)) were developed (or if the same criteria was considered for Push Technology, the same scales were also used. The table below describes the scales used to score the projects in the Requirements Pull strategic category.

### Criteria/Scoring Scales

#### 1. Strategic Fit
This criterion measures the alignment of the project with DoD through RD strategy and guidance, and the importance of the requirement. Preference is given to projects with direct linkages to Service requirements and strategic goals.

**1A. Urgency:**
This criterion measures the alignment of the project's success to neutralize/overcome/counter an identified threat capability which has a finite probability of realization.

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<thead>
<tr>
<th>Scale</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Threat has little chance of being realized within the next 5 years or an effective operational work around exists.</td>
</tr>
<tr>
<td>2</td>
<td>Threat has a credible chance of being realized in 1-5 years or an operational work around is difficult to implement.</td>
</tr>
<tr>
<td>3</td>
<td>Threat is likely to be realized within a year or an operational work around is unreliable.</td>
</tr>
<tr>
<td>4</td>
<td>Threat is likely to be realized within the next year and operational work around will likely not be effective.</td>
</tr>
<tr>
<td>5 (Best)</td>
<td>Threat is imminent and no operational work around is possible.</td>
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**1B. Proponency:**
This criterion measures the alignment of the project to an end user's desire to have the product

<table>
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<th>Scale</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>No proponent with money and influence</td>
</tr>
<tr>
<td>2</td>
<td>Mid- or high-level proponent without funding in place.</td>
</tr>
<tr>
<td>3</td>
<td>Mid- or high level proponent with planned POM funding.</td>
</tr>
<tr>
<td>4</td>
<td>Mid-level proponent with money.</td>
</tr>
<tr>
<td>5 (Best)</td>
<td>Proponency from the highest levels of the federal government with funding in place.</td>
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</table>
1C. Appropriateness:
This criterion measures the alignment of the project to deliver technology supporting the agency’s main missions.

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<tr>
<th>Rating</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>No tie to agency’s main mission</td>
</tr>
<tr>
<td>2</td>
<td>Can be loosely interpreted to tie into agency’s main mission</td>
</tr>
<tr>
<td>3</td>
<td>Can be tied to agency’s main mission</td>
</tr>
<tr>
<td>4</td>
<td>Indirectly addresses agency’s main mission area</td>
</tr>
<tr>
<td>5 (Best)</td>
<td>Directly addresses agency’s main mission areas</td>
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2. Transition Potential: The criterion is a measure of the potential for a customer to take the project science and/or technology and utilize it: for further academic research or advanced technology development; within industry; in a system acquisition program; or within a program of record.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Technology development effort is within 1 year of completion. Transition customer not committed but a concept of application has been developed and interest has been assessed.</td>
</tr>
<tr>
<td>2</td>
<td>Technology development effort is within 2 years of completion. Transition customer not committed but a concept of application has been developed and interest has been assessed.</td>
</tr>
<tr>
<td>3</td>
<td>Technology development effort is within 2 years of completion. Transition customer has been identified, and is actively involved in developing the transition plan &amp; concepts for application.</td>
</tr>
<tr>
<td>4</td>
<td>Technology development effort is within 1 year of completion. Transition customer has been identified, is actively involved, and there is a transition agreement is in development.</td>
</tr>
<tr>
<td>5 (Best)</td>
<td>Technology development effort will complete this year. Transition customer identified and a signed transition agreement exists, or customer has POM’d inclusion of the technology.</td>
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3. Technical Risk: This criterion assesses the risk of the project not achieving its technical goals.

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<th>Rating</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Project is assessed as very complex with multiple knowledge and technology unknowns e.g. novel technologies or research, AND requires high level of integration to be successful, and there is little to no technological skill base within the Government or Industry for this type of research.</td>
</tr>
<tr>
<td>2</td>
<td>Project is assessed as very complex with multiple knowledge and technology unknowns e.g. novel technologies or research, OR requires high level of integration to be successful, or there is little to no technological skill base within the Government or Industry for this type of research.</td>
</tr>
<tr>
<td>3</td>
<td>Project is assessed as moderately complex with some knowledge AND technology unknowns, and/OR may require some level of integration to be successful, AND/OR there is a little to moderate level of technological skill base within the Government or Industry for this type of research.</td>
</tr>
<tr>
<td>4</td>
<td>Project is assessed as low complexity with proven technology, there is limited integration required, AND there is moderate Government and Industrial skill base to complete the effort.</td>
</tr>
<tr>
<td>5 (Best)</td>
<td>Project is assessed as low complexity with proven technology, there is no integration required, and there is extensive Government and Industrial skill base to complete the effort.</td>
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</table>
4. Payoff Potential: This criterion measures how good or extensive the benefit to the agency’s main mission would be if the technology was successful. This will be scored independent of Technical Risk. This would describe the leadership preference to invest some portion of the portfolio in game changing technologies. Typically this must be balanced against the technical risk associated with these types of projects.

| 1- Project success would result in little to no improvement in existing technology. | 2- Project success would result in a minor improvement or incremental change to an existing technology. | 3- Project success would result in a new application of an existing technology or system. | 4- Project success would result in the application of a new technology that significantly reduces a capability gap or threat but not the entire gap or threat. | 5- Project success would result in a breakthrough or game changing technology or knowledge which would eliminate a capability gap or threat. |

5. Technical Approach: This criterion measures the maturity of the execution plan to achieve the technology results. It addresses the reasonableness of the plan considering documentation, team experience, and research methodology.

| 1- Plan has significant ambiguities; aspects of the plan are unproven. | 2- Plan is complex and has some ambiguities; some past experience; many uncertainties | 3- Plan appears comprehensive, but complex; most aspects have positive past experience, some uncertainties. | 4- Comprehensive plan; positive past experience; minor uncertainties | 5 (Best)- Proven Plan; no uncertainties |

6. Collaboration:

**International Partnership Capacity:** The criterion measures how much a project supports building partner capacity in the international technical community. The value function is built to reflect leadership preferences for R&D projects that collaborate with International Partners.

**OR**

**Interagency Collaboration Capacity:** The criterion measures how much a project supports building partner capacity in the interagency environment. The value function can be built to reflect the leadership preferences for R&D projects that collaborate with other non-DoD agencies.

| 1- There is no international collaboration in the project. OR There is no interagency collaboration in the project. | 2- The project has an international collaborator but is not receiving any funding. OR The project has an interagency collaborator but is not receiving any funding | 3- The project has an international partner and is sharing less than 25% of the costs of the project. OR The project has an interagency partner and is sharing less than 25% of the costs of the project. | 4- The project has an international partner and is sharing 25% to 50% of the costs of the project. OR The project has an interagency partner and is sharing 25% to 50% of the costs of the project. | 5- The project has an international partner and is sharing greater than 50% of the costs of the project. OR The project has an interagency partner and is sharing greater than 50% of the costs of the project. |
Enabling Technology Evaluation Criteria

The process was repeated for the final time to develop criteria and scoring scales for the third strategic bin: Enabling Technology. In this case, the criteria were very different than the two previous strategic bins and a much simpler prioritization model was developed with three high level criteria: Dependence/Users, Technical Approach, and Technical Excellence, as shown in the figure below. Note: the rationale for giving a relatively low weight to technical approach is that there is generally low technical risk associated with enabling projects.

For each of the evaluation criteria, scoring scales (between 1 (worst) to 5 (best)) were developed. Technical Approach used the same scale as was defined for the Requirements Pull strategic category. The table below describes the scales used to score the projects in the Enabling Program strategic category.

<table>
<thead>
<tr>
<th>1 Dependence/Users:</th>
</tr>
</thead>
<tbody>
<tr>
<td>This criterion measures the level of dependence of other projects (RD, other agency enterprises or external agencies) on the enabling/support capability.</td>
</tr>
<tr>
<td>1- This project / Function / capability provides limited to no support to other projects.</td>
</tr>
<tr>
<td>2- This project / Function / capability directly supports an internal project which utilizes the capability or another alternative is available.</td>
</tr>
<tr>
<td>3- This program / Function / capability directly supports multiple internal projects which utilize the capability and no other alternatives are available which would require significant investment to replace.</td>
</tr>
<tr>
<td>4- This project / Function / capability directly supports an internal/external project which utilizes the capability and no other alternative is available which would require significant investment to replace.</td>
</tr>
<tr>
<td>5- This project / function / capability directly supports multiple internal/external projects which utilize the capability and no other alternatives are available which would require significant investment to replace.</td>
</tr>
</tbody>
</table>
2. **Technical Approach:** This criterion measures the maturity of the execution plan to achieve the technology results. It addresses the reasonableness of the plan considering documentation, team experience, and research methodology.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plan has significant ambiguities; aspects of the plan are unproven.</td>
</tr>
<tr>
<td>2</td>
<td>Plan is complex and has some ambiguities; some past experience; many uncertainties</td>
</tr>
<tr>
<td>3</td>
<td>Plan appears comprehensive, but complex; most aspects have positive past experience, some uncertainties.</td>
</tr>
<tr>
<td>4</td>
<td>Comprehensive plan; positive past experience; minor uncertainties</td>
</tr>
<tr>
<td>5</td>
<td>(Best)- Proven Plan; no uncertainties</td>
</tr>
</tbody>
</table>

3. **Technical Excellence:** This criterion measures the residuals of this work in terms of staff expertise or physical capabilities that provide RD with competitive advantage and core competencies.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Does not provide RD a unique expertise or capability. Skills can be easily and quickly reconstituted</td>
</tr>
<tr>
<td>2</td>
<td>Provides RD a unique expertise or capability but not often used; can be easily and quickly reconstituted</td>
</tr>
<tr>
<td>3</td>
<td>Provides RD a unique capability or expertise. Used frequently. Difficult to reconstitute</td>
</tr>
<tr>
<td>4</td>
<td>Elevates or maintains RD as one of a few recognized leaders in a technical area/field.</td>
</tr>
<tr>
<td>5</td>
<td>Elevates or maintains RD as the undisputed leader in a technical area/field.</td>
</tr>
</tbody>
</table>

The next three figures show the Evaluation Sheets used in the process:

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Strategic Bin</th>
<th>Criteria</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements Pull</td>
<td>1 Strategic Fit, Urgency</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2 Strategic Fit, Proponency</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Strategic Fit, Appropriateness</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Transition Potential</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Technical Risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Payoff Potential</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 Technical Approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 Collaboration</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Program Name

<table>
<thead>
<tr>
<th>Strategic Bin</th>
<th>Criteria</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Push</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>Strategic Fit: Urgency</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Strategic Fit: Propensity</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Strategic Fit: Unique Niche</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Transition Potential</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Technical Certainty</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Innovation</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Technical Approach</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Collaboration</td>
<td></td>
</tr>
</tbody>
</table>

### Program Name

<table>
<thead>
<tr>
<th>Strategic Bin</th>
<th>Criteria</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabling</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>Dependence/Users</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Technical Approach</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Technical Excellence</td>
<td></td>
</tr>
</tbody>
</table>
## Results

The next three figures show the results from the process for each of the three strategic bins.

<table>
<thead>
<tr>
<th>Program</th>
<th>Dir</th>
<th>FY 2014</th>
<th>Total FYDP</th>
<th>Strategic Bin</th>
<th>Total Score</th>
<th>Total Weighted Score</th>
<th>Rank Order - Weighting by Strategic Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD-2</td>
<td>RD-C</td>
<td>$24,300</td>
<td>$129,600</td>
<td>Tech Push</td>
<td>19.5</td>
<td>3.81</td>
<td>1</td>
</tr>
<tr>
<td>AE</td>
<td>RD-C</td>
<td>$7,300</td>
<td>$36,000</td>
<td>Tech Push</td>
<td>21.25</td>
<td>3.73</td>
<td>2</td>
</tr>
<tr>
<td>AV-5</td>
<td>RD-A</td>
<td>$4,300</td>
<td>$21,500</td>
<td>Tech Push</td>
<td>21</td>
<td>3.57</td>
<td>3</td>
</tr>
<tr>
<td>BA-1</td>
<td>RD-B</td>
<td>$9,721</td>
<td>$50,038</td>
<td>Tech Push</td>
<td>20.88</td>
<td>3.56</td>
<td>4</td>
</tr>
<tr>
<td>BA-4</td>
<td>RD-B</td>
<td>$11,325</td>
<td>$58,292</td>
<td>Tech Push</td>
<td>21</td>
<td>3.56</td>
<td>5</td>
</tr>
<tr>
<td>BA-3</td>
<td>RD-B</td>
<td>$9,922</td>
<td>$51,070</td>
<td>Tech Push</td>
<td>20.5</td>
<td>3.46</td>
<td>6</td>
</tr>
<tr>
<td>AV-4</td>
<td>RD-A</td>
<td>$21,000</td>
<td>$130,800</td>
<td>Tech Push</td>
<td>16.5</td>
<td>3.4</td>
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<tr>
<td>BA-5</td>
<td>RD-B</td>
<td>$5,512</td>
<td>$28,372</td>
<td>Tech Push</td>
<td>20.25</td>
<td>3.4</td>
<td>8</td>
</tr>
<tr>
<td>AV-1</td>
<td>RD-A</td>
<td>$11,000</td>
<td>$39,000</td>
<td>Tech Push</td>
<td>14.63</td>
<td>3.33</td>
<td>9</td>
</tr>
<tr>
<td>BA-2</td>
<td>RD-B</td>
<td>$9,020</td>
<td>$46,427</td>
<td>Tech Push</td>
<td>19.75</td>
<td>3.29</td>
<td>10</td>
</tr>
<tr>
<td>AV-2</td>
<td>RD-A</td>
<td>$17,200</td>
<td>$84,900</td>
<td>Tech Push</td>
<td>18.75</td>
<td>3.04</td>
<td>11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Program</th>
<th>Dir</th>
<th>FY 2014</th>
<th>Total FYDP</th>
<th>Strategic Bin</th>
<th>Total Score</th>
<th>Total Weighted Score</th>
<th>Rank Order - Weighting by Strategic Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP</td>
<td>RD-C</td>
<td>$29,900</td>
<td>$151,098</td>
<td>Req Pull</td>
<td>25.13</td>
<td>4.62</td>
<td>1</td>
</tr>
<tr>
<td>CR</td>
<td>RD-C</td>
<td>$27,553</td>
<td>$154,593</td>
<td>Req Pull</td>
<td>24.88</td>
<td>4.37</td>
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<tr>
<td>CT-1</td>
<td>RD-C</td>
<td>$12,383</td>
<td>$68,080</td>
<td>Req Pull</td>
<td>25.5</td>
<td>4.33</td>
<td>3</td>
</tr>
<tr>
<td>WE</td>
<td>RD-C</td>
<td>$18,500</td>
<td>$79,300</td>
<td>Req Pull</td>
<td>24.5</td>
<td>4.29</td>
<td>4</td>
</tr>
<tr>
<td>NW-1</td>
<td>RD-A</td>
<td>$2,300</td>
<td>$12,300</td>
<td>Req Pull</td>
<td>24.13</td>
<td>4.28</td>
<td>5</td>
</tr>
<tr>
<td>CT-2</td>
<td>RD-C</td>
<td>$5,965</td>
<td>$30,668</td>
<td>Req Pull</td>
<td>26.13</td>
<td>4.26</td>
<td>6</td>
</tr>
<tr>
<td>NF-2</td>
<td>RD-A</td>
<td>$9,400</td>
<td>$49,000</td>
<td>Req Pull</td>
<td>19.88</td>
<td>4.13</td>
<td>7</td>
</tr>
<tr>
<td>NF-3</td>
<td>RD-A</td>
<td>$10,800</td>
<td>$81,400</td>
<td>Req Pull</td>
<td>19.5</td>
<td>4.11</td>
<td>8</td>
</tr>
<tr>
<td>RH</td>
<td>RD-A</td>
<td>$12,900</td>
<td>$69,500</td>
<td>Req Pull</td>
<td>21.13</td>
<td>4.01</td>
<td>9</td>
</tr>
<tr>
<td>CT-4</td>
<td>RD-C</td>
<td>$27,516</td>
<td>$126,910</td>
<td>Req Pull</td>
<td>24.38</td>
<td>3.99</td>
<td>10</td>
</tr>
<tr>
<td>RC</td>
<td>RD-C</td>
<td>$9,200</td>
<td>$48,400</td>
<td>Req Pull</td>
<td>22.38</td>
<td>3.99</td>
<td>11</td>
</tr>
<tr>
<td>CT-3</td>
<td>RD-C</td>
<td>$12,295</td>
<td>$65,354</td>
<td>Req Pull</td>
<td>25.5</td>
<td>3.97</td>
<td>12</td>
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<tr>
<td>NF-1</td>
<td>RD-A</td>
<td>$19,800</td>
<td>$79,800</td>
<td>Req Pull</td>
<td>22.25</td>
<td>3.94</td>
<td>13</td>
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<tr>
<td>FI</td>
<td>RD-C</td>
<td>$4,100</td>
<td>$21,200</td>
<td>Req Pull</td>
<td>23.13</td>
<td>3.79</td>
<td>14</td>
</tr>
<tr>
<td>WA</td>
<td>RD-C</td>
<td>$14,100</td>
<td>$74,300</td>
<td>Req Pull</td>
<td>21.25</td>
<td>3.75</td>
<td>15</td>
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<tr>
<td>SY</td>
<td>RD-A</td>
<td>$5,800</td>
<td>$32,000</td>
<td>Req Pull</td>
<td>20.88</td>
<td>3.74</td>
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<tr>
<td>NC</td>
<td>RD-D</td>
<td>$6,200</td>
<td>$39,300</td>
<td>Req Pull</td>
<td>21</td>
<td>3.64</td>
<td>17</td>
</tr>
<tr>
<td>AM-1</td>
<td>RD-A</td>
<td>$3,600</td>
<td>$18,000</td>
<td>Req Pull</td>
<td>18.13</td>
<td>3.13</td>
<td>18</td>
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<tr>
<td>AM-3</td>
<td>RD-A</td>
<td>$1,000</td>
<td>$5,900</td>
<td>Req Pull</td>
<td>10.75</td>
<td>2.2</td>
<td>19</td>
</tr>
</tbody>
</table>
The following figure shows the break-down of projects to be evaluated by strategic bin.

![RD Portfolio Strategic Allocation](image)

<table>
<thead>
<tr>
<th>Program</th>
<th>Dir</th>
<th>FY 2014</th>
<th>Total FYDP</th>
<th>Strategic Bin</th>
<th>Total Score</th>
<th>Total Weighted Score</th>
<th>Rank Order - Weighting by Strategic Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE</td>
<td>RD-C</td>
<td>$9,900</td>
<td>$52,100</td>
<td>Enable</td>
<td>14.25</td>
<td>4.86</td>
<td>1</td>
</tr>
<tr>
<td>HS</td>
<td>RD-A</td>
<td>$5,600</td>
<td>$28,000</td>
<td>Enable</td>
<td>14.38</td>
<td>4.84</td>
<td>2</td>
</tr>
<tr>
<td>TB</td>
<td>RD-C</td>
<td>$3,600</td>
<td>$18,400</td>
<td>Enable</td>
<td>13.75</td>
<td>4.79</td>
<td>3</td>
</tr>
<tr>
<td>TT</td>
<td>RD-C</td>
<td>$15,400</td>
<td>$75,200</td>
<td>Enable</td>
<td>13.75</td>
<td>4.71</td>
<td>4</td>
</tr>
<tr>
<td>RB</td>
<td>RD-D</td>
<td>$19,400</td>
<td>$112,500</td>
<td>Enable</td>
<td>13.63</td>
<td>4.71</td>
<td>5</td>
</tr>
<tr>
<td>NW-2</td>
<td>RD-A</td>
<td>$15,700</td>
<td>$82,700</td>
<td>Enable</td>
<td>12.5</td>
<td>4.33</td>
<td>6</td>
</tr>
<tr>
<td>MS</td>
<td>RD-D</td>
<td>$7,100</td>
<td>$39,800</td>
<td>Enable</td>
<td>11.75</td>
<td>4.2</td>
<td>7</td>
</tr>
<tr>
<td>Int Eng</td>
<td>RD-D</td>
<td>$3,158</td>
<td>$15,790</td>
<td>Enable</td>
<td>10.5</td>
<td>3.92</td>
<td>8</td>
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<tr>
<td>AV-3</td>
<td>RD-A</td>
<td>$3,158</td>
<td>$95,000</td>
<td>Enable</td>
<td>8.25</td>
<td>2.74</td>
<td>9</td>
</tr>
<tr>
<td>EX</td>
<td>RD-A</td>
<td>$19,000</td>
<td>$27,400</td>
<td>Enable</td>
<td>7.25</td>
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<td>CL</td>
<td>RD-B</td>
<td>$1,500</td>
<td>$3,000</td>
<td>Enable</td>
<td>7.38</td>
<td>2.18</td>
<td>11</td>
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<tr>
<td>SE</td>
<td>RD-D</td>
<td>$3,000</td>
<td>$14,500</td>
<td>Enable</td>
<td>6.63</td>
<td>2.17</td>
<td>12</td>
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<tr>
<td>WG</td>
<td>RD-D</td>
<td>$1,700</td>
<td>$12,600</td>
<td>Enable</td>
<td>6.13</td>
<td>1.96</td>
<td>13</td>
</tr>
</tbody>
</table>

*Final results*
In the end the value of the prioritization was not a single absolute ranking, but additional information to help create clusters and funding tiers as shown in the following three figures for each strategic category.

Technology Push Clustering

![Technology Push Clustering Diagram]

Requirements Pull Clustering:

![Requirements Pull Clustering Diagram]

Enabling Clustering:

![Enabling Clustering Diagram]
The following figure slices the portfolio by funding tiers:

3 Tech Push
6 Req Pull
3 Enabling

5 Tech Push
5 Req Pull
3 Enabling

This tiered priority of programs was used to recommend which projects would and which projects would not be included in the FY2014 POM.
Portfolio Evaluation for Command Control Communications and Intelligence (C3I)

Assume you are the manager responsible for recommending which programs should be funded for the Army’s C3I portfolio. Your team of analysts have gathered and provided you with the following data.

After reviewing all relevant guidance documents, the following strategic goals have been identified for this portfolio:

- Technologies should significantly increase sensing, electronic warfare, communications, and mission command effectiveness
- Technologies should provide assured position navigation and timing in a contested environment.
- Next generation integrated high-definition sensors should provide situational awareness for target identification, weapons cuing and platform protection against a wide spectrum of threats.
- Technologies should increasingly integrate communications, electronic warfare, and signal intelligence with the goal of full interoperability.

Additionally, the portfolio should meet the Secretary of Defense’s broad strategic goals as outlined in the most recent Quadrennial Defense Review. Specifically, programs are evaluated for their affordability, impact to military operations, and benefits to future technologies.

The set of programs were evaluated on the following set of objectives that balance the strategic impact of the programs with their probabilities of technical success.¹

₁ Although there are no “right” or “wrong” evaluation criteria, there are better and worse ones, or at least more useful and less useful ones. The characteristics of good evaluation criteria are (adapted from Keeney and Gregory, 2005):
   - Comprehensive but concise, meaning that they cover the range of relevant concerns for the portfolio evaluation but the evaluation framework remains systematic and manageable and there are no redundancies in criteria.
   - Measurable and consistently applied to allow consistent comparisons across projects. This means the criteria should be able to distinguish the relative degree of desirability for each project.
   - Understandable, in that the criteria (and any corresponding trade-offs) can be understood and communicated by everyone involved.
   - Practical, meaning that information can practically be obtained to assess them (i.e., data, models or expert judgment exist or can be readily developed).
   - Sensitive to the projects under consideration, so that they provide information that is useful in comparing alternatives.

This set of criteria are not the only ones that could be used but fit the above characteristics of good evaluation criteria, and all participants should be able to interpret the evaluation criteria in the same way for a repeatable process with consistent results.
The following attribute scales were used to evaluate the projects and programs.

**Strategic Fit:**

<table>
<thead>
<tr>
<th>Rating Scale</th>
<th>1</th>
<th>3</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attributes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congruence with current portfolio goals</td>
<td>Only peripheral fit with portfolio’s strategic goals</td>
<td>Modest fit, but not with a key element of the portfolio’s strategic goals</td>
<td>Good fit with one key element of portfolio’s strategic goals</td>
<td>Strong fit with several key elements of portfolio’s strategic goals</td>
</tr>
<tr>
<td>Affordability</td>
<td>Comparison of affordability constraints and cost estimates indicate high level of affordability risk</td>
<td>Comparison of affordability constraints and cost estimates indicate moderate level of affordability risk</td>
<td>Comparison of affordability constraints and cost estimates indicate low level of affordability risk</td>
<td>Program can clearly be produced and supported within reasonable expectations for future budgets</td>
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</tbody>
</table>
Impact to military operations

| Impact to military operations | Minimal impact: no noticeable harm if program is dropped | Moderate impact to meeting future goals for military operations | Significant impact; difficult to meet goals of future military operations if program unsuccessful or dropped | Future of military operations depends on this program |

Future Strategic Leverage

| Future Strategic Leverage | One-of-a-kind technology/meets only immediate need | Modest contribution to new technology opportunities | Strong contribution to one new technology opportunity | Fundamental technology that opens up multiple new technology opportunities |

Probability of Technical Success

<table>
<thead>
<tr>
<th>Rating Scale</th>
<th>1</th>
<th>3</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attributes</td>
<td>Program Complexity</td>
<td>Technology skill base</td>
<td>Difficult to define; many hurdles</td>
<td>Some R&amp;D experience but probably insufficient</td>
</tr>
<tr>
<td></td>
<td>Technology new to lab; (almost) no skills</td>
<td>Easy to define; many hurdles</td>
<td>Selectively practiced in labs</td>
<td>Widely practiced in labs</td>
</tr>
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</table>

Separate from the objectives, the program managers provided the annual cost of investment and TRL (technology readiness level) for each program. The following spreadsheet details the attribute scores for the programs:

Additionally, the program managers identified two pairs of synergistic projects. If both radio-based automated situational awareness and battlefield situational awareness software are selected, the combined cost of both programs is $19.5 million. If both mobile networks and enhanced mobile bandwidth technology are selected, the combined cost of both programs is $10 million.

(See actual spreadsheet provided)

Your instructor will assign your group to either Group A, B or C. Each group has a different strategic focus.

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2 This programs are notional and created for this case study. This was done to avoid classification issues. Similar non-notional data would be classified. Any similarities to real programs are coincidental.
Group A: Your focus is on bridging, quick reaction S&T with a 1-2 year time horizon to address urgent war-fighter needs. Your budget is $25M. What is your recommended portfolio of programs?

Group B: Your focus is on leap ahead innovations with a 4-6 year time horizon. It is expected that your projects will result in innovative prototypes. Your budget is $25 M. What is your recommended portfolio of programs?

Group D: Your focus is on building the basic research and science that will be needed to support the war-fighter in the next 7-20 year time horizon. Your budget is $25 M. What is your recommended portfolio of programs?

Given your group’s focus and budget, which portfolio of projects do you fund? How did you think about weighting the different evaluation criteria?

Be prepared to brief your results in 1-2 Powerpoint slides. Assume you are briefing your organization’s senior leadership.

Also, for discussion (not to be part of the senior leadership briefing), be prepared to provide three suggestions to improve the portfolio scoring model, and to discuss if this process could actually happen today in your organization.

Your presentation will be judged:

5 points: Recommendations (Is the solution feasible to implement? Are the participants aware of any risks or limitations to their plan?)

5 points: Portfolio analysis (Have the participants adequately analyzed the available data to support their recommendations?)

5 points: Presentation completeness (Have the participants answered all of the questions in the briefing?)

5 points: Overall quality of the presentation (Is this briefing of appropriate quality and level of detail for senior leadership to make decision?)
Recommending a Portfolio in a Budget Constrained Environment

You are the new manager for the Army’s Aviation Portfolio in the Aviation and Missile Research, Development and Engineering Center at Redstone Arsenal. The Aviation Portfolio includes manned systems, manned-unmanned teaming, and unmanned aerial systems. The FY01 budgets from your three directorates (directorates are summarized in Table 1) consist of numerous 6.1 and 6.2 projects and 6.3 advanced technology demonstration programs. These organizations have numerous projects focused on supporting the warfighter in theatre, projects focused on technologies with applicability to next generation capabilities, and projects critical to the proposed Future Vertical Lift planned for fielding in the FY16 timeframe. The Future Affordable Technology Engine, Joint Multi-role Technology Demonstrator and Degraded Visual Environment Mitigation Program are three distinct technology demonstration projects that have high visibility by DoD leadership and/or Program Managers of the current fleet. The Future Affordable Technology Engine program is an extension of older S&T efforts and may have more funds than needed to complete the desired demonstration effort of the 6.3 program. Your 6.1 and 6.2 programs are largely led by many technology experts who have PhDs and are the leaders in their respective fields. Your projects are spread across three directorates in four geographically dispersed locations. Each facility has unique capabilities and lab facilities that depend on project funding to remain viable. Two facilities are collocated with NASA facilities and another has strong partnerships with another NASA facility. Each directorate houses unique lab facilities including over 20 aircraft and unmanned aerial systems, wind tunnels, weapons integration and ballistic test facilities and engine facilities to name a few. The 6.3 programs are all major contracts with industry and fund many of your employees and contract staff. A summary description of the R&D Organizations that support your portfolio are shown in Table 1.

The Focus Area leads within your portfolio recognize they must be responsive to the Aviation S&T Strategic Plan. This Aviation S&T Strategic Plan was built upon an earlier Aviation S&T Strategic Plan, the Future Vertical Lift Medium S&T Investment Strategy, and Aviation S&T community input. The aviation S&T community includes the Air Force, Army, Coast Guard, Defense Advanced Research Projects Agency (DARPA), Marine Corps, Navy, National Aeronautics and Space Administration (NASA), and Special Operations Command (SOCOM) as they relate to vertical lift rotorcraft manned and unmanned aerial systems S&T, as well as low-speed, low-altitude, short- and medium-range tactical unmanned aerial system platforms.

The Aviation S&T Strategic Plan requires all portfolios align with the nine overarching thrust areas that the Focus Area portfolios are intended to support.

This case was prepared solely for the purposes of class discussion. It is based on a real challenge faced by a component the Department of Defense but names have been disguised and identifying information changed.
Table 1 – R&D Organizations

<table>
<thead>
<tr>
<th>Directorate</th>
<th>Core Competencies</th>
<th>Core Facilities</th>
<th>Core Partnerships</th>
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<tbody>
<tr>
<td>Aeromechanics and Basic Research</td>
<td>- Aeromechanics and aerodynamics Research, Wind Tunnels, Flight Controls and Handling Qualities, Leaders in rotary wing concepts analysis and advanced design. Significant accomplishments in Air Mobility enhancements from tilt rotors to advanced sling load designs. Heavily involved in design and testing of Degraded Visual Environment solutions from a symbology and flight controls point of view. Advanced control development for autonomous landing of unmanned systems from small unmanned aerial systems to full scale aircraft.</td>
<td>- Wind tunnels of all sizes including the largest full-scale wind tunnel in the US. Flight project office with aircraft specialized in flight control and handling qualities research. World class experts in rotorcraft concepts including tilt rotors, compound vehicles and vehicle performance of all classes.</td>
<td>- Joint NASA facilities and research at two different NASA facilities. Runs the National Rotorcraft Technology Center with organizes academic partnerships with Universities. Works with NASA Aerodynamics teams on joint aeromechanics work as well as NASA experts in high performance computing, autonomy and human factors work.</td>
</tr>
<tr>
<td>Research Directorate</td>
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<tr>
<td>Aviation Research and Development</td>
<td>- Focuses on 6.2 and 6.3 programs especially the integration of technology, and strong structures, propulsion, drive train and development of new weapons concepts for lethality, range and teaming fires with unmanned platforms. Leader of development programs in rotors, engines, drive train and mission equipment integration. Strong relationship with user community with well-established capability of pushing development programs to the field when needed to meet mission requirements.</td>
<td>- Flight project office with diverse aircraft fleet used for technology integration and 6.2 and 6.3 testing and demonstrations. Large facilities for building and testing prototypes of components and conducting weapons testing and ballistic tolerance testing of armor, fuel cells and other aircraft structures and components. Strong expertise in integrating mission systems in support of air crews and contracting for software and electronic systems.</td>
<td>- Works with NASA facilities that are nearby. Strong relationship with industry partners and the user community.</td>
</tr>
<tr>
<td>Directorate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviation Science and Technology</td>
<td>- Location of the organization’s headquarters. Program management.</td>
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<td></td>
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<tr>
<td>Technology Directorate</td>
<td>- No critical facilities funded solely by this program.</td>
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<tr>
<td></td>
<td>- Software engineering and numerous integration and simulation facilities located in and around the facility that support various programs. Leads the three Vertical Lift Research Centers of Excellence.</td>
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</table>

The nine thrust areas in the Aviation S&T Strategic Plan identify the areas required for S&T projects to support the future of combat aviation brigades. Failure to support any of these thrust areas will impact the future performance and capabilities of aviation units. The nine thrust areas are:

1. **Fly faster and farther while carrying more**: fully support all Future Vertical Lift initiative capabilities as part of an overall integrated family of systems to include the current fleet, Future Vertical Lift Family of Systems aircraft and unmanned aerial systems

2. **Operate in complex environments**: beyond just the night, own weather and other complex environments

3. **Develop the next generation of unmanned aerial systems**: actively engage in the development of the next generation of vertical lift unmanned aerial systems capabilities
4. **Demonstrate autonomy:** mature autonomous decision-making capabilities and confidence to allow traditionally manned missions to become unmanned, and for all systems to operate in complex, denied-link environments

5. **Redefine the interface between pilot and aircraft:** develop adaptive cyber-physical interfaces between the pilot and the aircraft

6. **Balance low- and zero-maintenance:** support ultra-reliable designs for no maintenance over a significant useful life, and optimize selection of maintenance approaches to balance between zero maintenance and rapid, efficient maintenance actions, as part of an overall reduction in required logistics and sustainment costs

7. **Shift the propulsion paradigm:** advance engine/drive configuration technologies that move beyond traditional turbo-shaft engine and power transmission architectures to provide significant changes in platform mission capability

8. **Reduce fielding timelines:** improve transition time from S&T to the field by enabling shorter certification durations and contributing to improvements in the airworthiness certification process

9. **Enhance in-house capabilities:** sculpt the government workforce, facilities and equipment to develop diverse in-house capabilities

The Deputy Assistant Secretary of the Army for Research and Technology provided emphasis areas to focus on critical challenges that arise in the extreme operational and threat environment in which the Army performs in testimony to Congress. “...the Army is placing increased emphasis in research areas to support the Army’s role in the National Military Strategy, such as vulnerability assessments, Anti-Access/Area Denial technologies and long range fires. We are mindful however that the Army will continue to be called on for missions around the globe. The Army is currently deployed in about 160 countries conducting missions that range from humanitarian support to stability operations to major theater warfare.” Army aviation platforms such as Joint Multi-role Technology Demonstrator, new designs and rotorcraft concepts with greater speed and range contribute to the Anti-Access/Area Denial emphasis area. Long range fires and use of manned/unmanned teaming contributes to the long range fires emphasis area.

This Congressional testimony by the Deputy Assistant Secretary of the Army for Research and Technology also outlined ten persistent challenges facing the Army now and in the future to which the Army S&T community is committed to ensure the Army can fight and win on the current and future battlefields. Of the ten challenges outlined, the following eight challenges are related to the Army S&T portfolio:

- Enabling greater force protection for soldiers, air and ground platforms, and bases (e.g., lighter and stronger body armor, helmets, pelvic protection, enhanced vehicle survivability)
- Enabling timely mission command and tactical intelligence to provide situation awareness and communications in ALL environments (mountainous, forested, desert, urban, jamming, etc.)
- Create operational overmatch (enhance lethality and accuracy)
- Reduce logistic burden of storing, transporting, distributing and retrograde of materials
• Achieve operational maneuverability in all environments and at high operational tempo (e.g., greater mobility, greater range, ability to operate in high/hot environment)
• Enable the ability to operate in Chemical, Biological, Radiological, Nuclear, and Explosives (CBNRE) environments
• Improve operational energy (e.g., increased fuel efficiency engines)
• Reduce lifecycle costs of future Army capabilities

For the FY01-07 POM, the Deputy Assistant Secretary of the Army for Research and Technology defined risk areas for S&T research. These risk areas of research are defined as areas that might be targeted for budget cuts due to the current mission environment. The risk areas in aviation are passive survivability, lethality, and propulsion projects. Cutting these programs completely would result in a significant loss of key technical personnel for lethality and propulsion areas since these areas are a major portion of the S&T portfolio for Aviation Research and Development Directorate. Additionally, propulsion has continued to be expressed as a critical need by the warfighters coming out of theatre and among the Army user community.

Task 1: Strategy for Determining the Portfolio

As you prepare for the preparation of next year’s budget submittal covering FY01-07, you understand that budgets for FY01-07 are to be reduced 20%. Develop a strategy for evaluating the portfolio submission of your three S&T organizations to determine what programs will stay and which ones should be reduced or eliminated to achieve a 20% reduction in your portfolio from FY01-07. You are NOT allowed to recommend every program accept a 20% cut across the board. Your strategy should include a logic for evaluating the portfolio relative to the guidance provided by the Deputy Assistant Secretary of the Army for Research and Technology, the Aviation S&T Strategic Plan guidance and the impact to personnel, facilities and key organization partnerships among your three R&D organizations.

You have an hour to develop your strategy. Develop 1-2 slides to outline the guidance. Each team will present their strategy to the class. Your guidance should include how much or how little programs should be cut, how you intend to address the needs of critical personnel and critical infrastructure across the three research centers and direction on completely eliminating, deferring or delaying programs.

Task 2: Portfolio Cuts

Your focus area leads have provided the attached portfolio overview for your use in addressing the 20% budget cut to your portfolio. Use your guidance approved by your instructor and the spreadsheet provided to determine the cuts required for your FY01-07 POM submission. You have two hours to prepare the modifications to your portfolio. Identify and justify the changes to the portfolio as well as any modifications made to your initial strategy guidance. Show the projects assigned to each organization by year for FY01 and beyond. You also need to prepare a brief for your senior leadership that explains what the cuts will be and what the impact will be to each of the three R&D organizations. Remember:

1. A zeroing of any project means the project is gone forever.
2. Deferment of a project to later years is acceptable, but may subject that program for deletion in coming budget submissions.
3. You are not allowed to simply recommend an across the board 20% cut to all projects.

Additionally, the Army Acquisition Executive notified your leadership that the Degraded Visual Environment and Future Affordable Technology Engine programs were of prime importance to program managers for integration in the existing fleet and suggested that those programs be fully funded but the rest of your program must be cut by 20% for FY01-07. How would your recommendations change to be responsive to this request from the Army Acquisition Executive? Explain your recommended portfolio with and without this request and the impact of complying with the request.

Your presentation will be judged:

5 points: Recommendations (Is the solution feasible to implement? Are the participants aware of any risks or limitations to their plan?)

5 points: Portfolio analysis (Have the participants adequately analyzed the available data to support their recommendations?)

5 points: Presentation completeness (Have the participants answered all of the questions in the briefing?)

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5 Recommending a Portfolio Capstone