Lessons from the Field

Applying MIT SEAri methodologies and processes within the Aerospace and Defense Market

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Challenges in Acquisition of Large Government Systems

- **Common Challenges in DoD Systems Acquisition ***
  - Lack of System of Systems (SoS) / Enterprise engineering
  - Lack of intra-program synchronization / integration
  - Diverse, dis-jointed, and dispersed management and authority (US Code, Title 10)
  - Increased system interconnectivity / complexity (i.e. Net-centric Operations)
  - Lack of ability to quantify system "-ilities" (Flexibility, Survivability, Sustainability, Robustness)..
  - Immature multi-stakeholder management techniques
  - Inability to address / plan for dynamic operational environments
  - Limited early-stage understanding of system concepts prior to program initiation

- **Require new Theories, Methods, and Tools capable of addressing system engineering challenges within an ever-changing, dynamic world ("social" and "technical")**
  - Differing operational environments
  - New user needs (i.e. requirements creep)
  - New technologies (supportive and competitive)
  - Shifting organizational priorities, Policy Changes
  - Resource fluctuations

* Gathered from review of DoD GAO Reports

Three Cases

- Business Case Analysis – Fractioned Spacecraft (F6)
- Concept Development / Tradespace Analysis
- Capability Portfolio Management

Fractioned Spacecraft

DARPA's F6 Program: Business Case Analysis

Brown, Long, Shah, and Eremenko, System Lifecycle Cost Under Uncertainty as a Design Metric Encompassing the Value of Architectural Flexibility. AIAA Space 2007 Conference and Exhibit, Long Beach, California.

Background

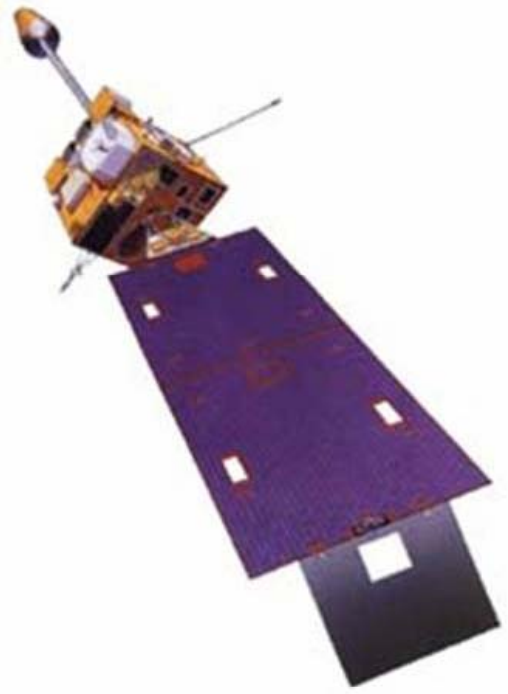
- **What is Satellite Fractionation?**
  - A fractionated architecture is one in which the spacecraft system is decomposed into multiple modules which interact wirelessly to deliver at least the same capability as that provided by a comparable traditional, monolithic system
- **What is the Value of Fractionation?**
  - Diversification of launch and on-orbit failure risk
  - Reliability enhancement through emergent sharing of subsystem resources
  - Scalability in response to service demand fluctuations
  - Upgradeability in response to technological obsolescence
  - Incremental deployment of capability to orbit
  - Graceful degradation of capability on-orbit
  - Robustness in response to funding fluctuations and requirements changes
  - Reduced integration and testing due to subsystem decoupling
  - Production learning across multiple similar modules
  - Enabling spacecraft to be launched on smaller launch vehicles with shorter timescales to launch

Business Case Study

- **Challenge:** Justify the design of a fractioned spacecraft vs. traditional monolith
  - Assumption: Cost of multiple smaller satellites greater than single monolith *(Designing in flexibility requires additional mass and cost).*
  - Traditional cost/benefit analysis would examine **static** systems lifecycle - negating fractionation's value (Flexibility)

- Utilize "Value-based" approaches to justify additional expense
  - Sought an alternative metric that captures many of the same aspects of system "-ilities", but without resorting to quantifying value
  - Examined total lifecycle cost to attain a minimum required capability

- Performed a stochastic lifecycle cost study
  - Examined replacement strategies based upon sub-system failures (heterogeneous satellites)
  - Assess total lifecycle cost under a variety of uncertainties



Test Case:
NOAA GOES Satellite

F6 Case Study Lessons Learned

- **At the time (2007), this approach was a new way of examining and justifying program costs – not widely accepted**
- **Since then, these approaches have become more soughed within "high risk", non-traditional, acquisition communities**
  - DARPA, Concept Offices (e.g. SMC/XR)
  - Adopting these approaches within larger, more traditional DoD acquisition communities (OSD/AT&L, CAPE, DDR&E, Services) requires more "proof"
- **Challenges still remain in justifying business cases and applying these methods to more than just cost – Increases / decreases in value**
  - For DoD programs, meeting requirements (value) is what's required
  - Slightly less, while maybe cost-affordable, is unacceptable
  - Delivering more than required, is not needed and tends to be cut
- **Today, evaluating programs on their resulting value is becoming more and more important in program business case analysis**

Satellite Radar Case Study

Concept Development / Tradespace Analysis

Ross, A. M., McManus, H., Rhodes, D. H., Hastings, D., and Long, A. " Responsive Systems Comparison Method: Dynamic Insights into Designing a Satellite Radar System," AIAA Space 2009.

Ross, A. M., McManus, H., Long, A., Richards, M. G., Rhodes, D. H. and Hastings, D., "Responsive Systems Comparison Method: Case Study in Assessing Future Designs in the Presence of Change," AIAA Space 2008, San Diego, CA, 2008

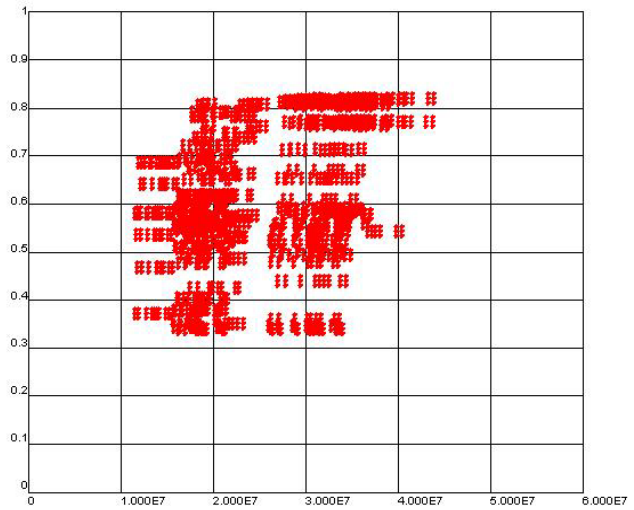
Background

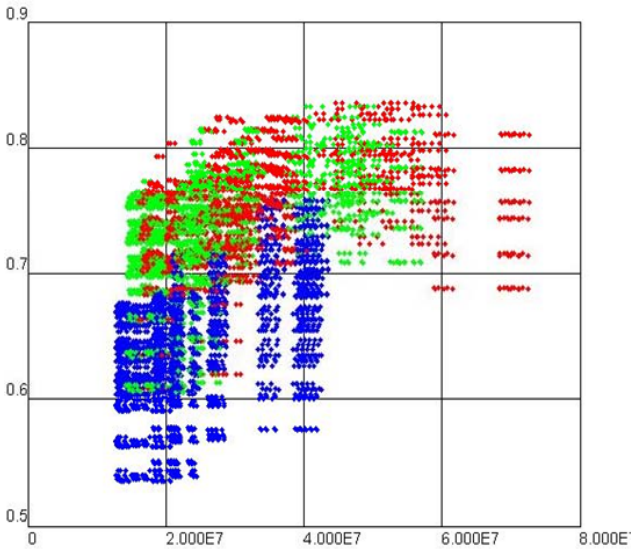
- **Application of MIT SEAri's Responsive Systems Comparison (RSC) methodology to concept development activity in order to gain insights into the ability of the system concepts to deliver value across changing future contexts**
  - **RSC allows decision makers to recognize and to value dynamically-relevant designs, positively impacting program cost, schedule, performance, and risk**
  - **Using an epoch-based analytic approach, the designer is able to think in a more continuous and anticipatory manner in dynamic world**

- **Case Study: Satellite Radar System (SRS) Value Proposition:**
  - **Value Proposition: 24 hour, all weather on-demand "Visibility and Tracking" over things that can be observed**

Exploring Design Concepts

- **Tradespace: Representation of the relationship between Design- and Value-space**
  - Compare varying design concepts within the same value-context (Apples and Oranges)
  - Understand Stakeholder need satisfaction of various design concepts and contexts
  - Gain insights into cost and performance relationships
  - Cost / Schedule As-an Independent Variable (CAIV/SAIV)
- **"Explore" Tradespace to develop intuition into complex design-value relationships**



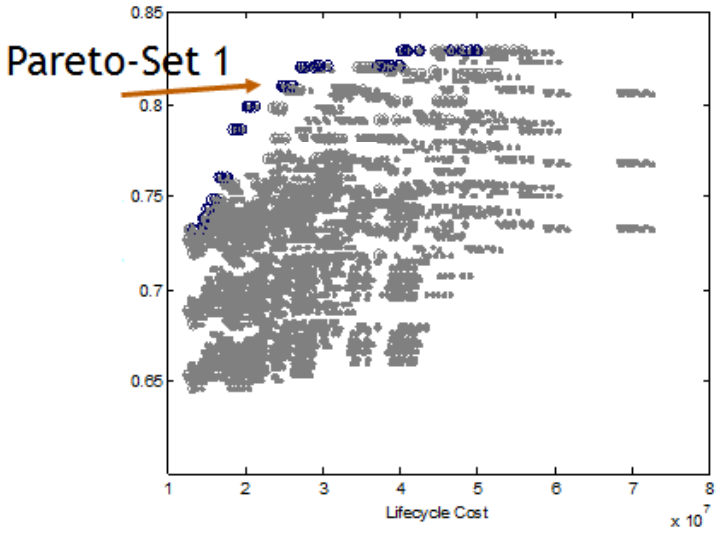


Increased knowledge allows better decisions at critical points in a Program's lifecycle; Positively impacting program cost, schedule, performance, and risk

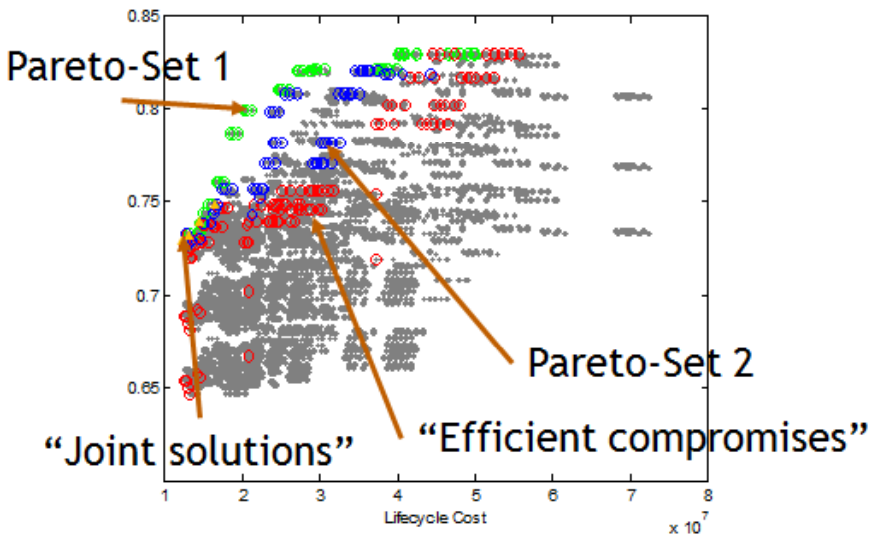
Stakeholder "Compromises" / "Optimal Designs"

- **Explore how unique designs provide varying levels of value for differing stakeholders**
  - Identify Pareto-efficient designs for a given stakeholder
  - Compare Pareto-efficient stakeholder sets to identify "joint solutions"
  - Calculate multi-stakeholder Pareto-surfaces to identify "efficient compromises"
- **Identify "high tension" design-tradeoffs between stakeholders**
  - **Provide starting point for design negotiations**

Single Stakeholder Pareto-Set



Multi-Stakeholder Pareto-Sets and "efficient compromises"



Lessons Learned: Application of RSC

- **Typical challenge**
  - Well understood technical design space
  - Multiple stakeholders w/ conflicting system preferences, needs, etc
  - Design activities driven by designer presumptions, not stakeholder needs
  - Lack of structured approach for identifying valuable, responsive, adaptable, and flexible joint concepts across conflicting stakeholders
    - Common to examine a few epochs (Missions)
    - Very rarely adjust capability requirements and / or stakeholder preferences across epochs
  - Activities require 9-24 months
  - Combine stakeholder preferences into a single capability requirement set
    - Assumes stakeholder alignment and agreement across all contexts
    - Alternative – "benevolent dictator"

- **Recurring "value" provided by RSC**
  - Ensures designs are driven by stakeholder needs
  - Traceable understanding of stakeholder need satisfaction to design concepts
  - Discover technical design "Compromises" across stakeholders
  - Maintains Stakeholder separation and manages divergent stakeholder requirements
  - Gain valuable insights in a fraction of the time / effort

Capability Portfolio Management

A Systems-of-Systems (SoS) Application

DoD Portfolio Management Pilot: DoDD 7045.20

- **"….The role of Capability Portfolio Managers is to manage a portfolio by integrating, coordinating and synchronizing programs to optimize capability within time and budget constraints."**
  - Develop recommendations to address synchronization issues
  - Rebalancing actions within the portfolio
  - Cross-portfolio considerations

Nine Capability Portfolios

1. **Force Application**
2. **Battlespace Awareness**
3. **Command & Control**
4. **Net-Centric**
5. **Force Support**
6. **Protection**
7. **Building Partnerships**
8. **Logistics**
9. **Corporate Management & Support**

The use of portfolio management is to improve synchronization, interoperability & integration --balance cost, schedule, & performance across the portfolio

Applying MIT SEAri's Epoch - Era Analysis to Portfolio Management

"Epoch-Era Analysis is an approach for conceptualizing system timelines using natural value centric timescales, wherein the context and expectations define the timescales" (Ross and Rhodes, 2008)

- **Modification:** Epoch-Era Analysis is an approach for conceptualizing *capability-delivery* timelines using natural value centric timescales, wherein the context, *solutions*, and expectations {capabilities} define the timescales
- An **Epoch** becomes a period of time for which there is a fixed context, feasible solutions, and fixed capability requirements
- Portfolio Management becomes the process of developing and managing to a Capability Delivery Plan (**Era)**, which is the logical assemblage of Epochs.
  - Decision makers develop investment strategies for selecting solution(s) to satisfy the Capability Delivery Plan

The "Three pillars" of Portfolio Management

- **Capabilities (Demand):** Characterization of Stakeholder Value
  - Quantifiable and Measurable (i.e. Utility, Attributes)
  - Solution independent
  - Vary with respect to time (Usually defined within Capability Increments)
- **Solutions (Supply):** Concepts to satisfy Capability needs
  - New programs, Legacy, COTS, DOTmPLF, System-of-Systems Concepts
  - Quantifiable Performance – Context independent
- **Contexts:** Characterization of the operational architecture / environment
  - CONOPS, Missions, OPLANS, etc.
  - Measures of Performance (MOPs) – Measure of how a given solution performs within a given context (i.e. - # of supported network nodes)
  - Measure of Effectiveness (MOEs) – Range of acceptable stakeholder value within the given context (i.e. – Objective/ Threshold # users)

Capability Based Planning / Portfolio Management Framework

Capability Delivery Timeline

09-10 11-12 13-14

Capability Requirements
- Vary over time
- Organized into increments

Solutions

Solution Portfolio:
- Concepts that satisfy given Capability Requirement
- Gap -> New Solution

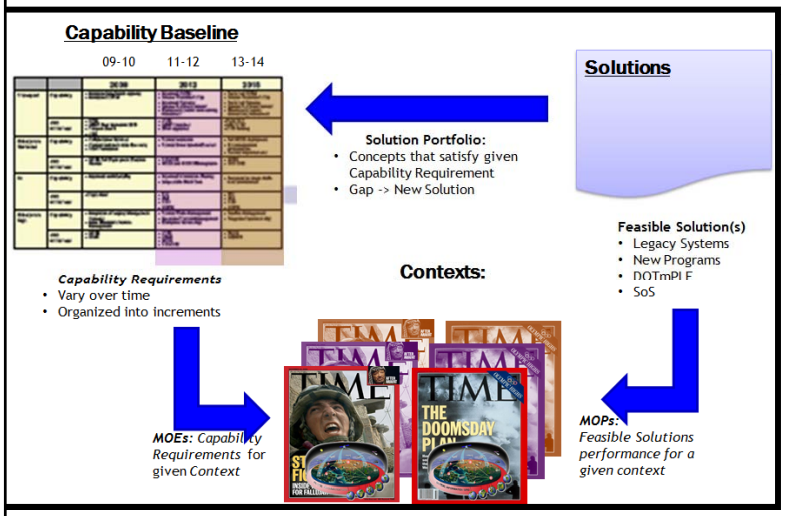
Feasible Solution(s)
- Legacy Systems
- New Programs
- DOTmPLF
- SoS

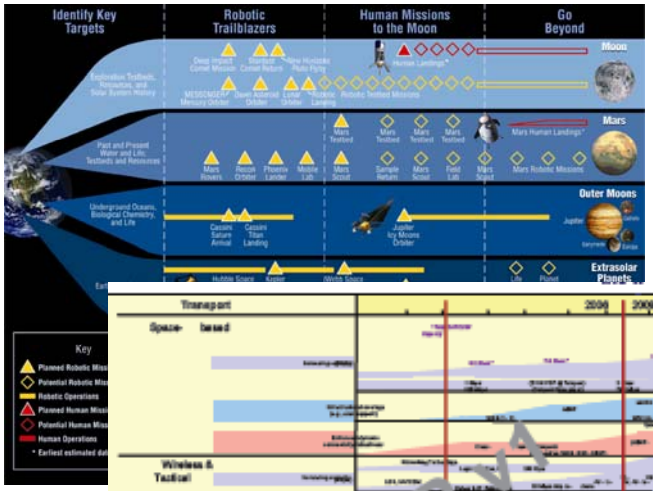
Contexts:

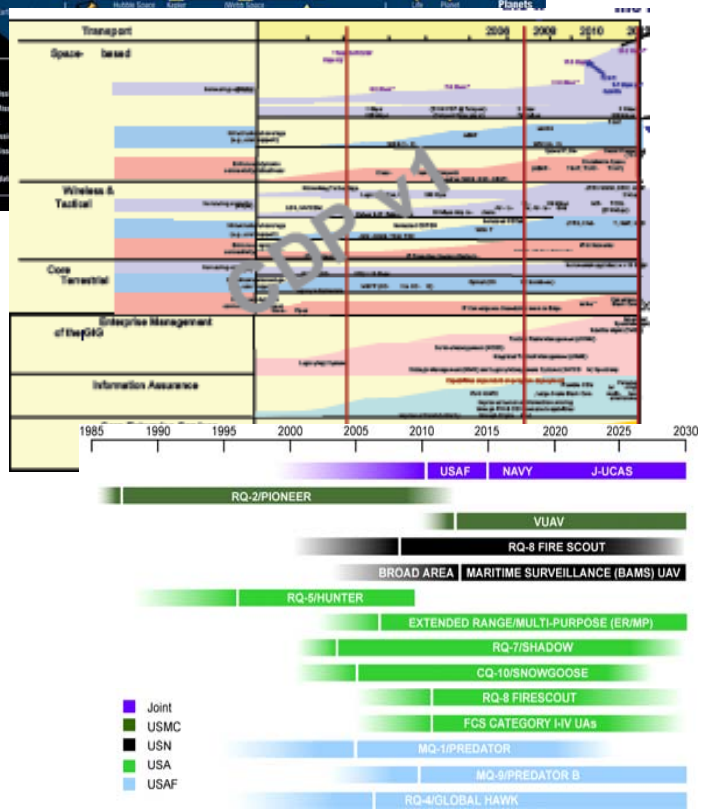
MOEs: Capability Requirements for given *Context*

MOPs: Feasible Solutions performance for a given context

Portfolio Management Process results in Capability Delivery Plan ("Roadmap")

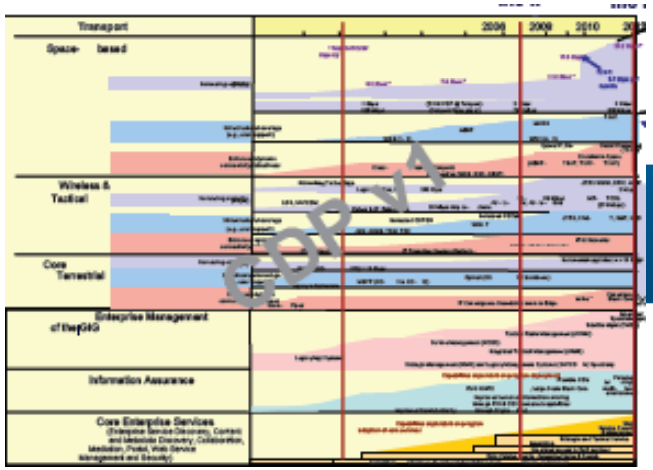






Manage Portfolio Acquisitions according to CDP

"Baseline"



Portfolio Analysis

Synchronization Analysis

Dependency Analysis

Capability Gap Analysis and Trade Study

Systems Engr. Projection

Resource Recommendations

Outputs

Recommendations, Plans, Policy, etc.

Investment Adjustments

DoD PPBE Process

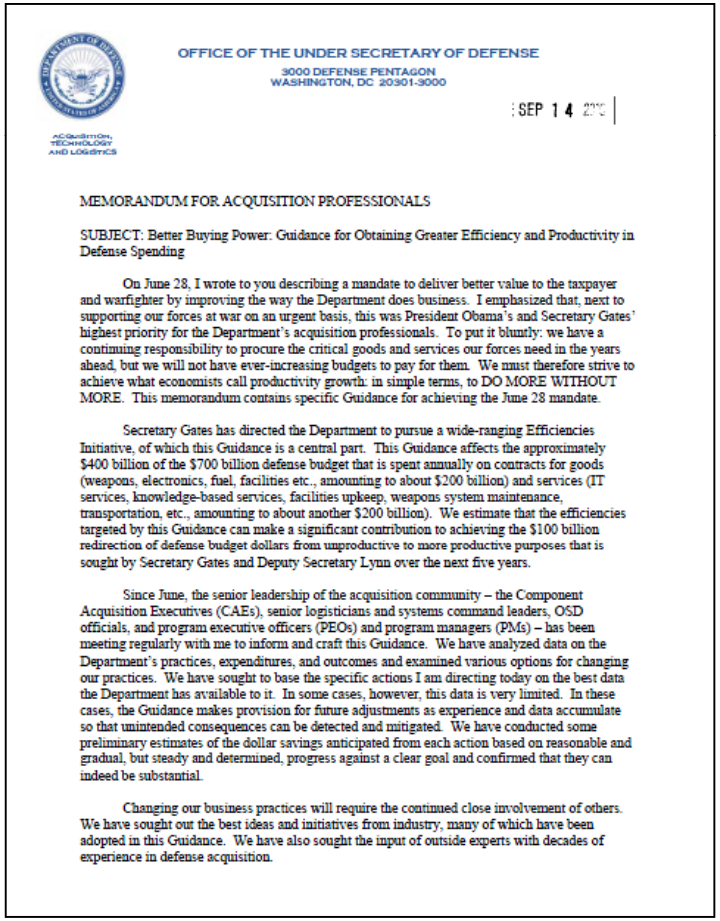
Lessons Learned
Comparison between Commercial and DoD Acquisition Processes

Commercial Practice	Result	DoD Practice	Result
• Disciplined, integrated approach to prioritize market needs	• Avoid pursuing more products than resources can support, optimizes ROI	• Lacking Integrated, Portfolio-Based Approach	• Too many programs competing for limited resources
• Identifying and prioritizing market opportunities lays foundation for right product mix	• Investments are addressed collectively from enterprise level	• DOD assesses warfighting needs and their funding implications under separate decision-making processes	• Impede DOD's ability to prioritize needs • Considerations are addressed through separate budgeting / acquisition processes. • Lack of focus on the cost and feasibility of acquiring the capability
• Investment decisions are revisited throughout product development in gated review process	• Ensures products are still of high value. • If not, make tough decisions to defer or terminate investments	• Although policy provides for a series of early reviews, DOD commits to a solution earlier and with less knowledge	• Programs build momentum towards development with little department-level costs and feasibility assessment • Contributes to poor cost, schedule, and performance outcomes • Destabilizes acquisition programs as DoD attempts to pay for poorly performing programs by taking funds from others.
• Strong governance with committed leadership, empowered decision makers, and effective accountability	• Accountability at all levels of the organization	• Service-centric structure and fragmented decision-making processes	• Portfolio Management functions operate within DOD's existing framework do not allow for sufficient authority and control over resources to effectively influence investments.

Insights from GAO-07-388: BEST PRACTICES: An Integrated Portfolio Management Approach to Weapon System Investments Could Improve DOD's Acquisition Outcomes

Value-Centric Analysis coming into vogue:

Office of the Under Secretary of Defense for Acquisition, Technology and Logistics



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SEP 14 2010

ACQUISITION, TECHNOLOGY AND LOGISTICS

MEMORANDUM FOR ACQUISITION PROFESSIONALS

SUBJECT: Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending

On June 28, I wrote to you describing a mandate to deliver better value to the taxpayer and warfighter by improving the way the Department does business. I emphasized that, next to supporting our forces at war on an urgent basis, this was President Obama's and Secretary Gates' highest priority for the Department's acquisition professionals. To put it bluntly: we have a continuing responsibility to procure the critical goods and services our forces need in the years ahead, but we will not have ever-increasing budgets to pay for them. We must therefore strive to achieve what economists call productivity growth: in simple terms, to DO MORE WITHOUT MORE. This memorandum contains specific Guidance for achieving the June 28 mandate.

Secretary Gates has directed the Department to pursue a wide-ranging Efficiencies Initiative, of which this Guidance is a central part. This Guidance affects the approximately $400 billion of the $700 billion defense budget that is spent annually on contracts for goods (weapons, electronics, fuel, facilities etc., amounting to about $200 billion) and services (IT services, knowledge-based services, facilities upkeep, weapons system maintenance, transportation, etc., amounting to about another $200 billion). We estimate that the efficiencies targeted by this Guidance can make a significant contribution to achieving the $100 billion redirection of defense budget dollars from unproductive to more productive purposes that is sought by Secretary Gates and Deputy Secretary Lynn over the next five years.

Since June, the senior leadership of the acquisition community – the Component Acquisition Executives (CAEs), senior logisticians and systems command leaders, OSD officials, and program executive officers (PEOs) and program managers (PMs) – has been meeting regularly with me to inform and craft this Guidance. We have analyzed data on the Department's practices, expenditures, and outcomes and examined various options for changing our practices. We have sought to base the specific actions I am directing today on the best data the Department has available to it. In some cases, however, this data is very limited. In these cases, the Guidance makes provision for future adjustments as experience and data accumulate so that unintended consequences can be detected and mitigated. We have conducted some preliminary estimates of the dollar savings anticipated from each action based on reasonable and gradual, but steady and determined, progress against a clear goal and confirmed that they can indeed be substantial.

Changing our business practices will require the continued close involvement of others. We have sought out the best ideas and initiatives from industry, many of which have been adopted in this Guidance. We have also sought the input of outside experts with decades of experience in defense acquisition.

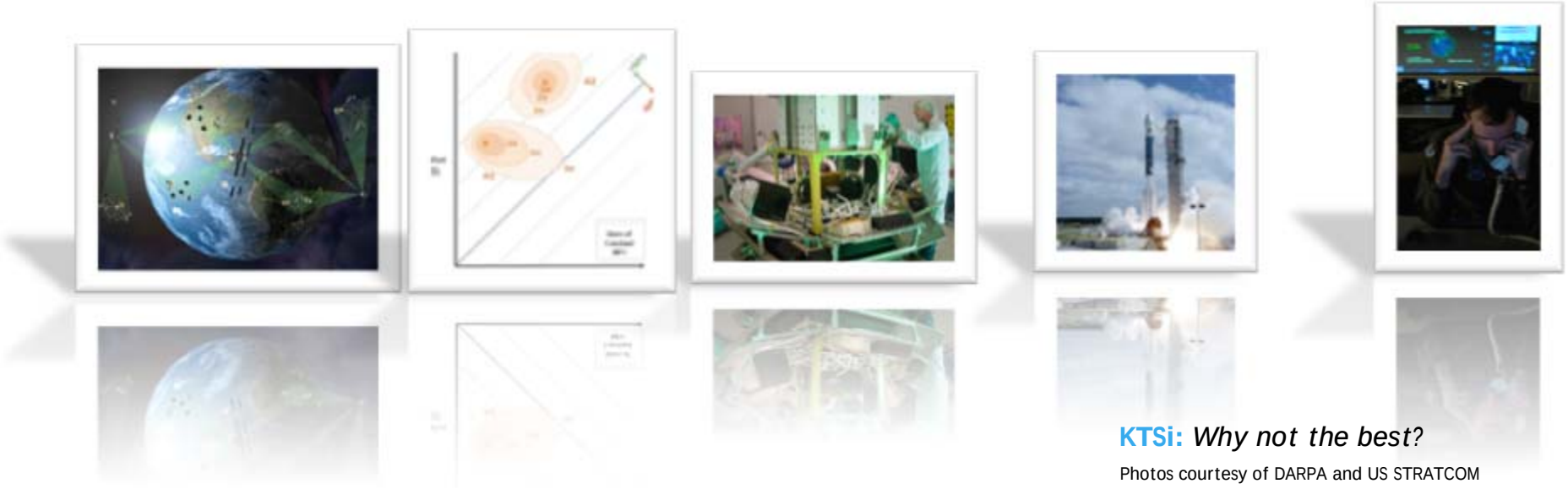
- **Mandate affordability as a requirement**
- "… at Milestone A, my Acquisition Decision Memorandum (ADM) approving formal commencement of the program will contain an affordability target to be treated by the program manager (PM) like a Key Performance Parameter (KPP) such as speed, power, or data rate – i.e., a design parameter not to be sacrificed or compromised without my specific authority. At Milestone B, when a system's detailed design is begun, I will require presentation of a systems engineering tradeoff analysis showing how cost varies as the major design parameters and time to complete are varied."

Dr. Ashton Carter (USD/AT&L)
OSD/AT&L: Memorandum for Acquisitions Professionals: Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending, September 14,2010

Questions ?

Kinsey Technical Services Inc. (KTSi)

Founded in 2003, KTSi is a Systems Engineering and Technical Assistance (SETA) company that supports DoD, IC, and NASA. Committed to exemplary lifecycle support through technical excellence, innovation, and hard work.



KTSi: *Why not the best?*

Photos courtesy of DARPA and US STRATCOM