Real Options & Value Driven Design in Spiral Development

based on paper of same title, MITRE Public

Approved for Public Release 06-0493 dated March 31, 2006

John Dahlgren
17 March 2006
dahlgren@mitre.org

MITRE

Purpose

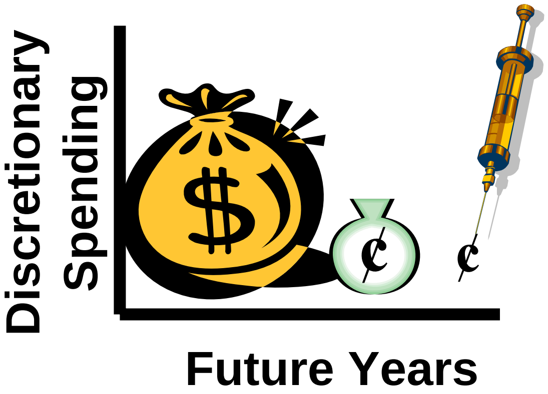
- This briefing discusses the possible relationship of Real Options and Value Driven Design to engineering for Spiral Development
- This briefing is based on a paper of the same title that discusses current and planned work, and is not intended to provide a complete answer. The paper was accepted for the 2006 Command & Control Research and Technology Symposium (CCRTS).

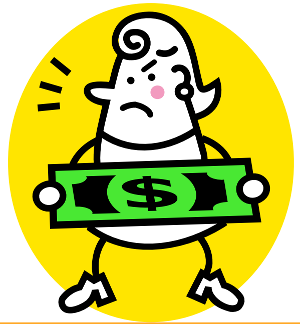
Outline

- Cost & Schedule Overruns in DoD Acquisition
- A Current Problem
- Real Options
- Value Driven Design
- Spiral Development
- Summary & Conclusions

Problem

- Budgetary constraints will force systems to have an increased life cycle and adaptability to a variety of missions
- Predicting user demand is inexact; $P(x) \rightarrow 1$ as $t \rightarrow 0$; $P(x)\downarrow$ as $t\uparrow$
  - x= correctly predicting user demand or new missions
  - Waiting for t=0 is not practical
- Systems engineers need to understand why some systems perform well in the ilities (flexibility, adaptability, upgradeability, reliability, etc.) and others don’t so they can incorporate that thought process into the design, development and spiral development of new systems
- Program Managers need a framework to price an option for incorporating one, some or all of the ilities into their systems to meet user demand while minimizing Life Cycle Costs (LCC)





Context of Research

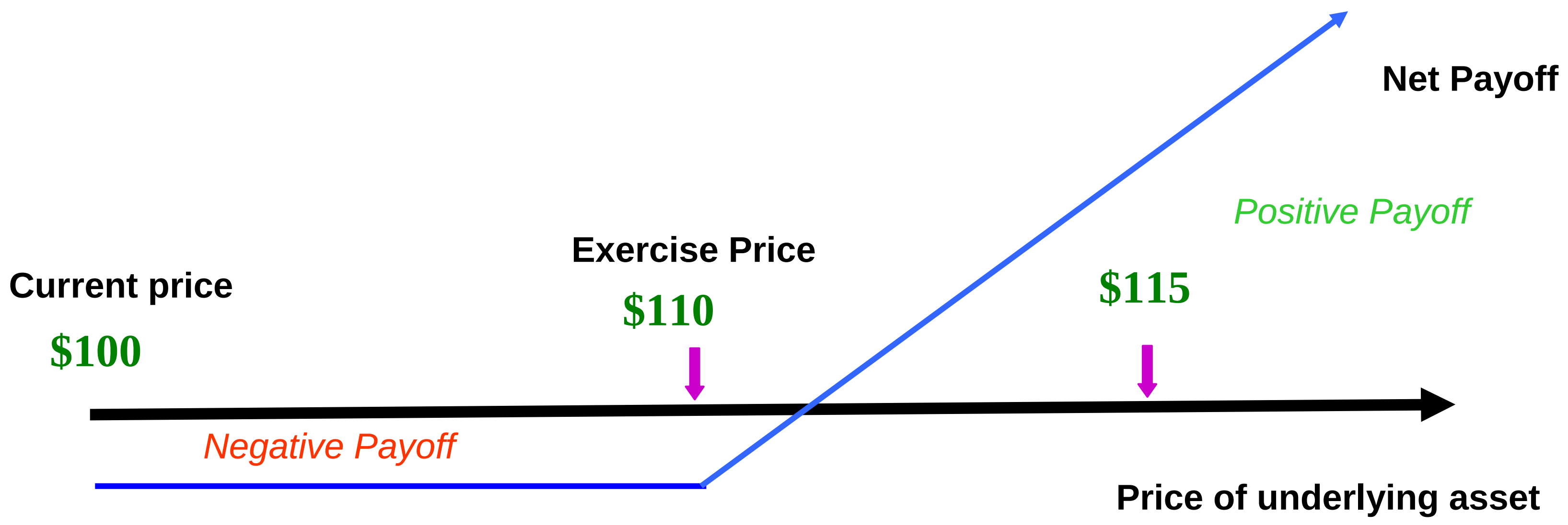
- MITRE has teamed with MIT Engineering Systems Division to look into the application of Real Options to future system design
  - Research being done by a mix of MITRE engineers, MIT PhD candidates, and masters students
  - Goal is to look at historical systems to determine what made them flexible, adaptable, upgradeable, scalable and still reliable
  - After determining design tenets, apply to current system to determine accuracy and applicability of concepts
- Additionally, John Dahlgren is MITRE's representative to the American Institute for Aeronautical and Astronautics (AIAA) Systems Engineering Technical Committee (TC)
  - Also participating on Value Driven Design (VDD) committee
- There may be synergy between the "ilities" research and the VDD efforts

"ilities" Definitions (current)
the ability of a system to…

- **Flexibility: ... perform its original mission <u>and</u> additional missions that weren't envisioned in the original design – with only minor changes to the system.**
- **Adaptability: … perform its original mission and additional missions that weren't originally envisioned. This is done with major changes to the system.**
- **Upgradeability: … be changed (or reconfigured) to enable it to perform additional missions or the same mission differently.**
- **Reliability: … be flexible, adaptable, and/or upgradeable while still being able to operate for many years or even decades.**
- **Scalability: … perform its original mission <u>and</u> (to a much greater or smaller extent) serve at least an order of magnitude more or fewer customers, transactions, etc..**

Defining An "Option"

- An option is a financial market contract that specifies the price at which the holder of the option can buy or sell some asset (such as a stock or a commodity) within a specific timeframe.
- An option is a *right*, but not an *obligation*.



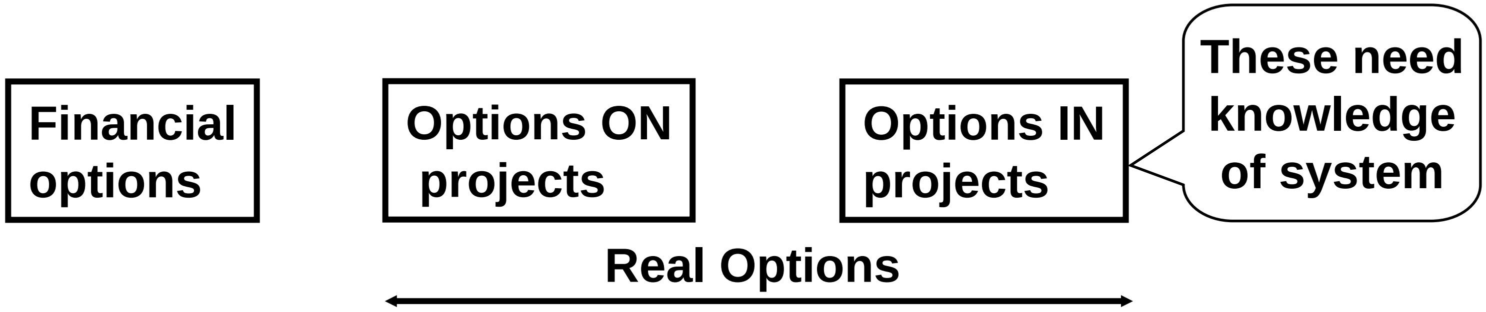
Source: "The Promise and Peril of Real Options", Aswath Damodaran, Stern School of Business

Real Options

- "Real" because they refer to a project
  - Contrast with financial options that are contracts
- Real Options are focus of interest for Design
  - They provide flexibility for evolution of system
- Projects often contain option-like flexibilities
  - Rights, not obligations (e.g.: to expand garage)
  - Exercise only if advantageous
- These flexibilities are "real" options
- Extensive information available at Prof Richard de Neufville's (MIT) web site: http://ardent.mit.edu/real_options/Common_course_materials/papers.html

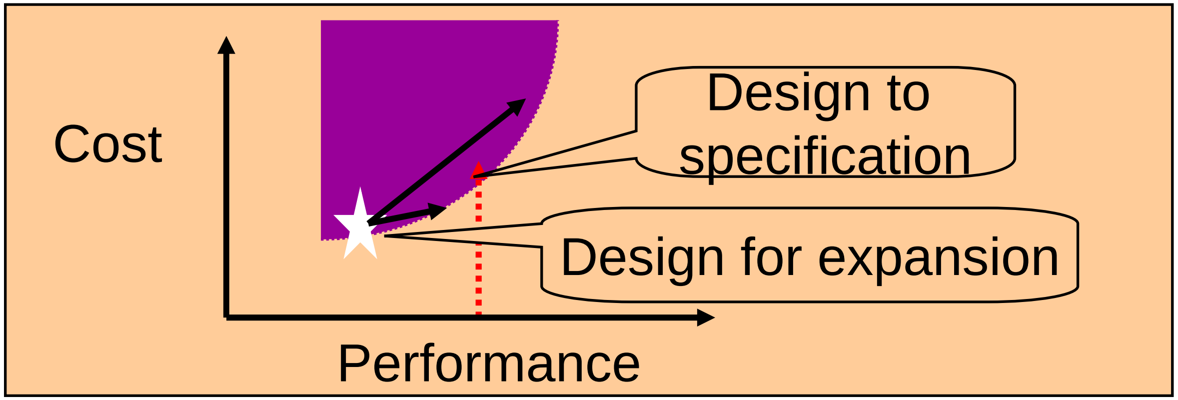
Two Types of Real Options

- Those concerning projects, in contrast to financial options, they are “ON” projects
  – E.g.: the option to open a mine
  – These do not get into system design
  – Most <u>common in literature</u>
- Those concerning design, “IN” projects
  – E.g.: ways of staging satellite system
  – These require detailed understanding of system
  – Most <u>interesting to system designers</u>



Traditional vs. Flexibility

- Typical focus is on design to specification and Pareto optimization
- Sometimes “performance” represents over 10,000 requirements – does Pareto really attempt to represent a single point on a graph with 10,000 dimensions?
- Real Options represents a real change in concept of design and management of engineering systems over time because
- Instead of designing to a spec, we design for a range of possible levels of performance, and let the system evolve



Cost As an Independent Variable (CAIV)

- A well meaning concept that is often done too late in a program
- Generally, customer develops operational requirements, and first level technical requirements
- Vendor (in DoD) develops more detailed technical requirements to provide a system that meets ALL of the customers' operational and technical requirements
- Often, vendor cannot meet all of the customers' requirements, then
- Negotiations take place when various requirements cannot be met, or it will take much more money to meet those requirements
- These last negotiations are, though not meant to come out this way, where much CAIV activities take place
- Moving away from Pareto and towards a "performance / capability space" should aid in moving CAIV to the requirements development step
- RO and VDD should aid in moving CAIV left on the schedule

Parking Garage Example

- **Projected Demand is uncertain**
  - **750 spaces at start**
  - **750 spaces over next 10 years**
  - **could be +/- 50% off the projections,**
  - **Annual volatility for growth is 10%**

- **Costs can be considered fixed…**
  - **Operating costs = $2,000 /year/space**
  - **Land lease = $3.6 Million/year**
  - **Construction = $16,000/space + 10% for each higher level**

Comparing designs with and without flexibility

Metric $, millions	Design		Comparison
	No Flexibility	Flexible	
Initial Investment	22.74	14.48	Flexibility Better
Expected NPV	2.87	5.12	Flexibility Better
Minimum NPV	-24.68	-12.62	Flexibility Better
Maximum NPV	13.78	14.80	Flexibility Better

Wow! Everything is better! How did it happen?

Root cause: change the framing of the problem, recognize uncertainty, add in flexibility thinking

Value Driven Design (VDD)

- An teaming effort of the Systems Engineering, Economics, and Multidisciplinary Optimization technical committees under the American Institute of Aeronautics and Astronautics (AIAA)
- Goal is to answer the question: "When told to decrease the weight of an aircraft by 100 pounds, how do the systems engineers and program managers determine the relative impact of decreasing 10 pounds from the landing gear as opposed to 10 pounds from the avionics system?"
- Though hypothetical, this scenario touches on analogous situations faced by most programs regarding a system's weight, size, program funding, etc.
- The team's goal is to develop a tool that helps answer the above question

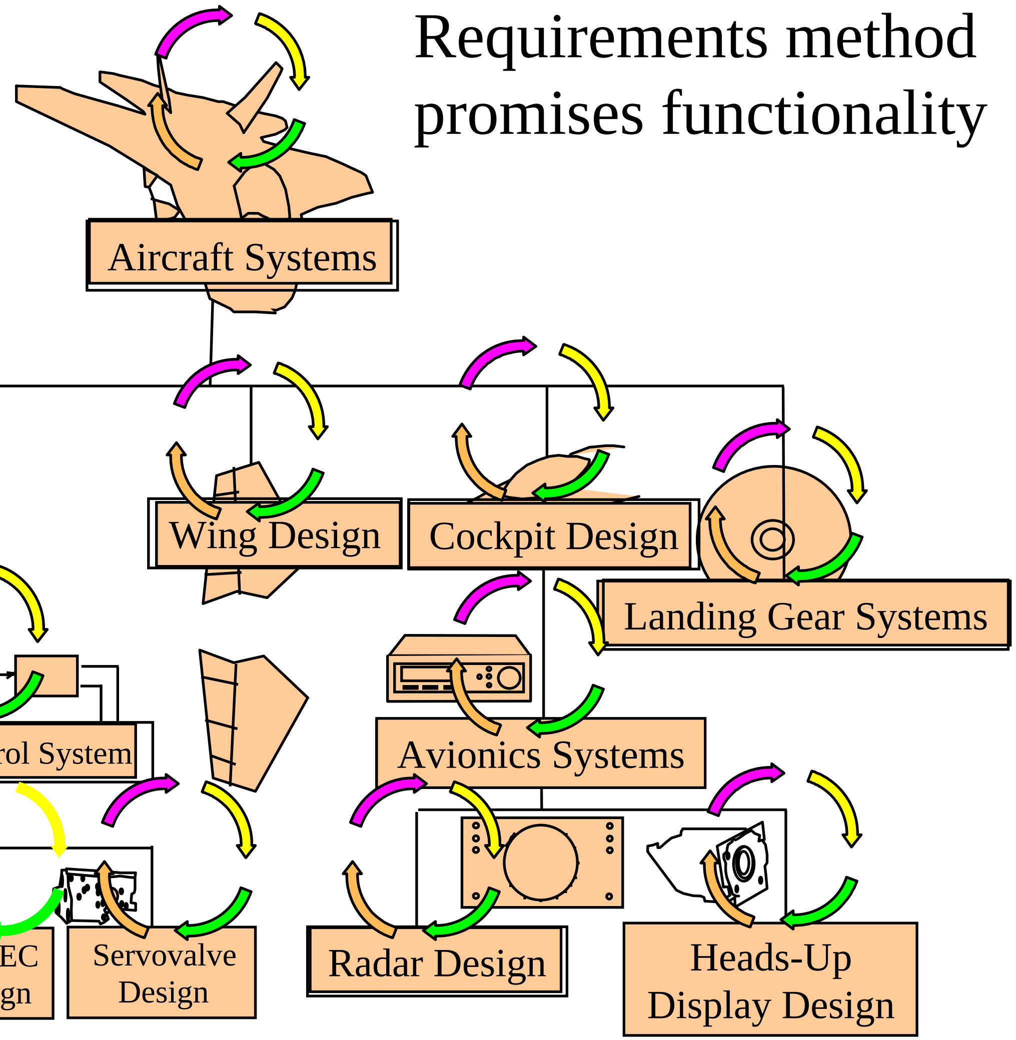
What is VDD?

- Value-driven design (VDD) is an improved design process that uses requirements flexibility, formal optimization and a mathematical value model to balance performance, cost, schedule, and other measures important to the stakeholders to produce the best outcome possible.
  - Requirements flexibility – while traditional design focuses on point requirements, VDD opens up an entire solution space
  - Formal optimization – allows system and component design engineers to discover the best design in the entire solution space
  - Mathematical value model – expresses all stakeholder values (customer, business, society) and their interactions into a single measure to convey the needs of the project to every member of the design team.

Requirements Flowdown -- Today

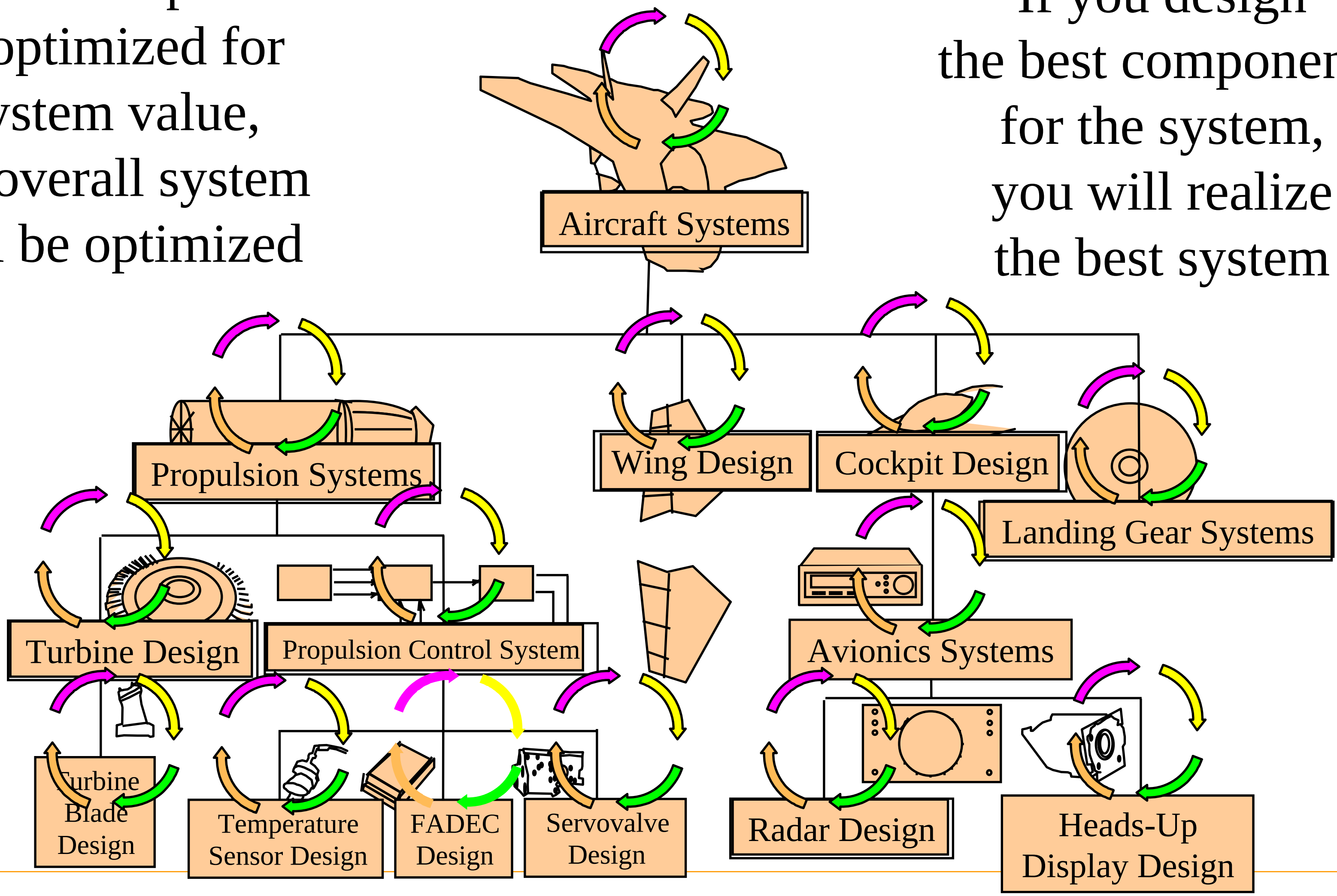
If each module
meets its requirements,
the overall system will
meet its requirements

Requirements method
promises functionality



Distributed Optimal Design

If each component is optimized for system value, the overall system will be optimized



If you design the best components for the system, you will realize the best system

Thoughts to Ponder

- The “best” system may not be one where every component needs to be optimized
  - Component optimization might be that it is good enough to get the job done
  - Lack of total optimization might free up money to invest on other components, or for Research & Development to aid in future spiral development of the individual components or total system
  - Loose Coupling between components is probably more important to long-term system performance than is optimizing each component in the initial design
- How do you determine operational value?
- Can value always be monetized?
- How can the VDD tool support determining the relative and absolute value of where to implement Real Options in a system, system-of-systems, or an Enterprise

Requirements & Acquisition Process

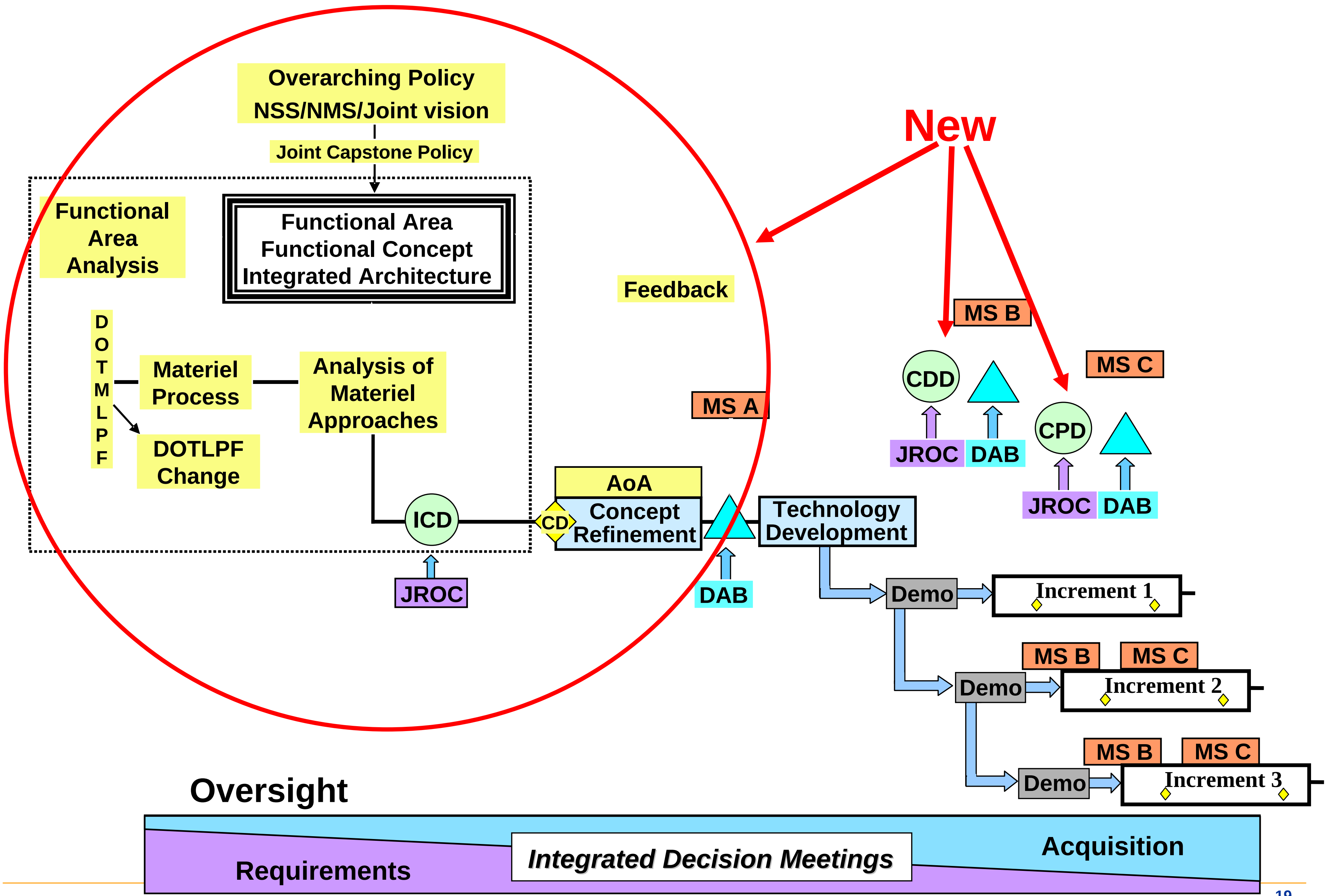
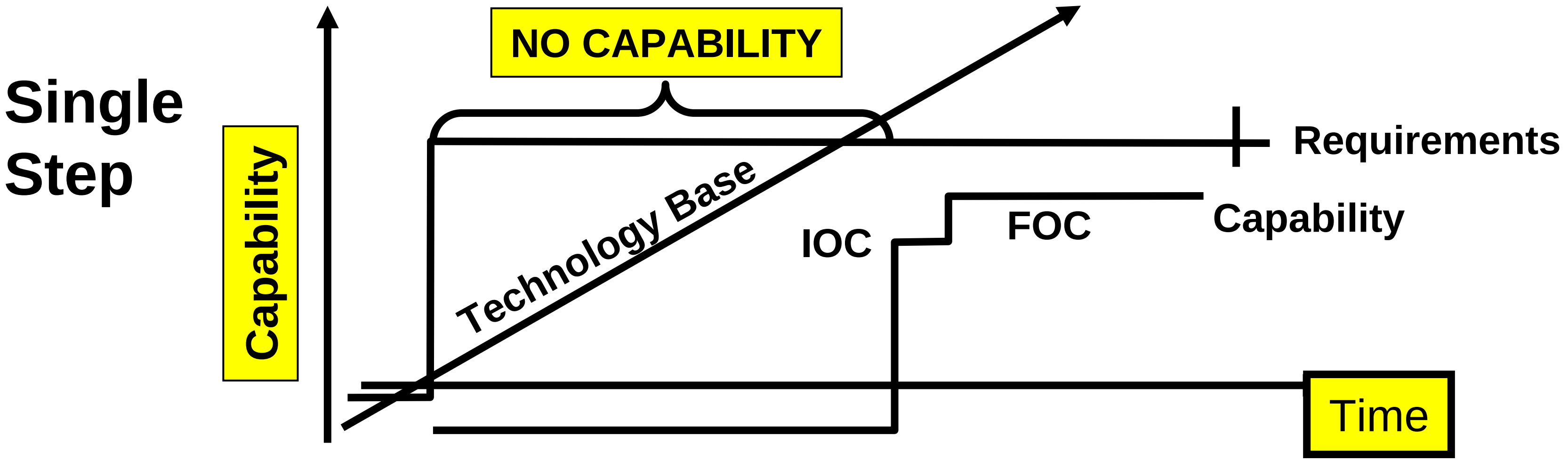
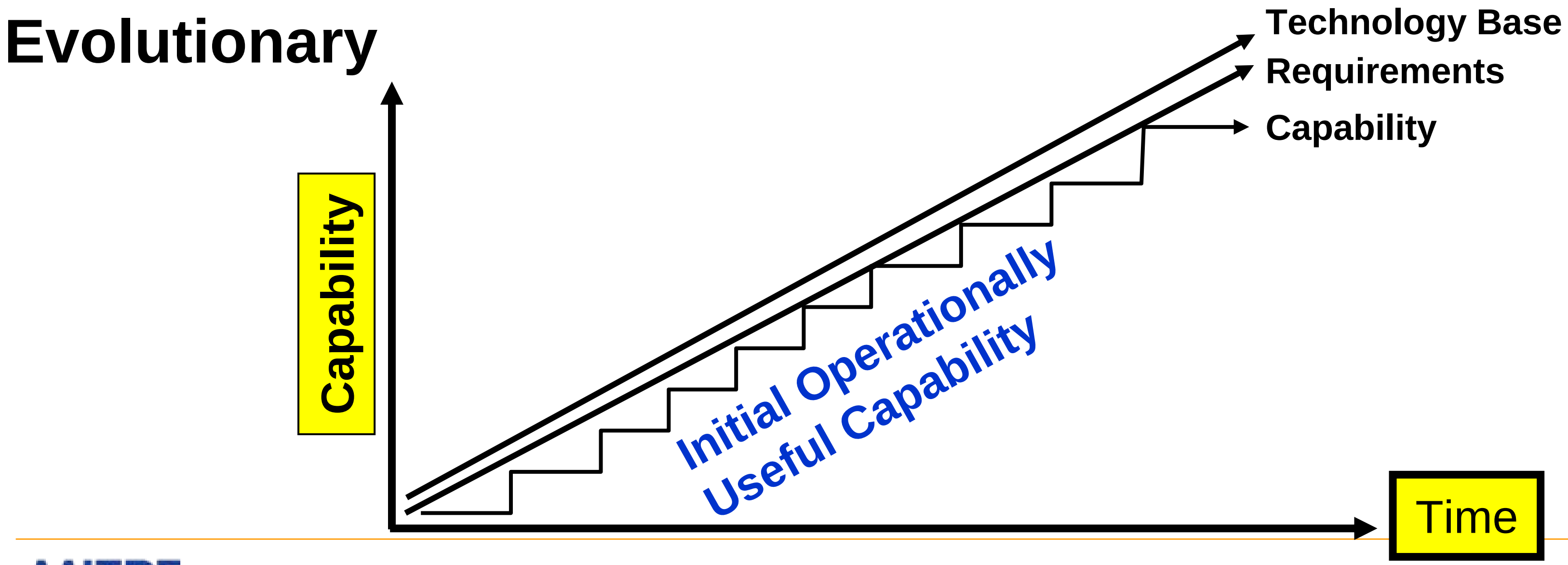


Fig. 2, DoDI 5000.2

Single Step & Evolutionary Approaches





Spiral Development and Risk Management

- Spiral development gets some capability to the customer early, instead of waiting many years for some product
- Risk of customer incorrectly stating requirements is decreased since requirements are stated closer to when capability is needed
- Predicting user demand is inexact; $P(x) \rightarrow 1$ as $t \rightarrow 0$; $P(x) \downarrow$ as $t \uparrow$
  - x= correctly predicting user demand or new missions
  - Waiting for t=0 is not practical
- RO may enable engineers to design systems that meet initial requirements and can be spiral developed as user requirements are better known
- Cost constraints won't allow engineers to design every subsystem to incorporate RO concepts
- Therefore, the VDD tool may help engineers to determine which subsystems are best designed with RO concepts

Research Activities

- Konstantinos Kalligeros, MIT, is developing his PhD dissertation on platforming concepts
- Jason Bartolomei, MIT, is researching Hot/Cold Spot analysis
- Mike Cokus, MITRE, is researching VISA International subsystem and system evolution related to Loose Coupling
- Michel-Alexandre Cardin (MIT) and John Dahlgren (MITRE) are doing top down research on Global Positioning System (GPS)
- Future topics for research may include Google, eBay, Air and Space Operations Center (AOC), B-52, etc.
- Researching systems that are sufficiently complex and that appear to be uncorrelated to determine if common design tenets exist across the systems engineering discipline
- Potential current systems/Enterprises to apply this research include the Airborne Network, throughput solutions to a theater of operations, software systems, etc.
- Research may have applicability to organizational design

Conclusions/Recommendation

- VDD, RO and Spiral Development can
  - decrease program risk
  - aid program managers and systems engineers to make wise short-term and long-term decisions
- Moving away from a point solution based on Pareto optimization and towards a solution space should reduce program risk
- RO should
  - decrease initial program costs
  - Enable PMs to field capabilities in a much shorter time period
- The tool being developed by the VDD committee should aid systems engineers to determine which subsystems to implement RO
- Evolution of RO, VDD and Spiral Development should aid in the evolution of complex systems, especially at the Enterprise level

Bibliography

- Allen, T., J. Moses, et al, 2001, "ESD Terms and Definitions (Version 12)", Working Paper Series, ESD-WP-2002-01, Massachusetts Institute of Technology Engineering Systems Division, 19 October.
- Collopy, P., 2005, "Value Driven Design", Briefing presented at the AIAA Value Driven Design Program Management meeting, Lockheed Martin, Orlando, FL, 16-17 Aug.
- Collopy, P., J. Sturges, et al., 2005, Notes from the AIAA Value Driven Design Program Management meeting, Lockheed Martin, Orlando, FL, 16 -17 Aug.
- De Neufville, R., J. Clark, F. Field, "Real Options" (Briefing), Engineering Systems Analysis for Design Course, Massachusetts Institutes of Technology.
- De Neufville, R., J. Clark, F. Field, "Real Options II" (Briefing), Engineering Systems Analysis for Design Course, Massachusetts Institutes of Technology.
- De Neufville, R., 2005, *"USE of 'OPTIONS' in DESIGN",* Briefing presented to the MITRE Corporation, Massachusetts Institute of Technology, January.
- De Neufville, R., S. Scholtes, T. Wang, 2005, "Real Options by Spreadsheet: Parking Garage Case Example", Manuscript IS/2004/22436.
- De Neufville, R., "Black-Scholes Valuation" (Briefing), Engineering Systems Analysis for Design Course, Massachusetts Institute of Technology.

Bibliography (completed)

- **De Weck, O., R. de Neufville, M. Chaize, 2005, "Enhancing the Economics of Satellite Constellations via Staged Deployment" (Briefing), Unit 4, MIT Industry Systems Study Communication Satellite Constellations, Massachusetts Institute of Technology, Space Systems Laboratory, 25 Jan.**
- **De Weck, O., R. de Neufville, M. Chaize, "Enhancing the Economics of Communications Satellites via Orbital Reconfigurations and Staged Deployment", AIAA-2003-6317, Proceedings of the AIAA Space 2003 Conference and Exposition*.***
- **Greden, L., R. de Neufville, L. Glicksman, 2005, "Management of Technology Investment Risk with Real Options-Based Design: A Case Study of an Innovative Building Technology", Draft submission for proceedings of the 9th Annual Real Options Conference, 21 Feb.**
- **Hassan, R., R. de Neufville, O. de Weck, D. McKinnon, "Value at Risk Analysis for Real Options in Complex Engineered Systems".**