SEAri Short Course Series

Course: PI.27s Value-driven Tradespace Exploration for System Design

Lecture: Lecture 2: Overview of Classical Methods for Architecting and Design

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This course was taught at PI.27s as a part of the MIT Professional Education Short Programs in July 2010 in Cambridge, MA. The lectures are provided to satisfy demand for learning more about Multi-Attribute Tradespace Exploration, Epoch-Era Analysis, and related SEAri-generated methods. The course is intended for self-study only. The materials are provided without instructor support, exercises or "course notebook" contents. Do not separate this cover sheet from the accompanying lecture pages.

Systems Engineering Advancement Research Initiative

[PI.27s] Value-Driven Tradespace Exploration for System Design

Lecture 2
Overview of Classical Methods for Architecting and Design

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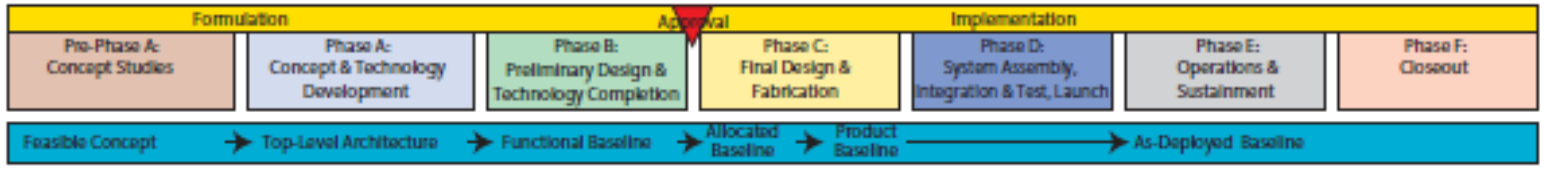
Outline

- Trade studies, tradespace exploration and design in context of system lifecycle
- Basics of architecting and design methods
- Problems with current methods and challenges for improved ones

Design Paradigm: Linear Program Lifecycle

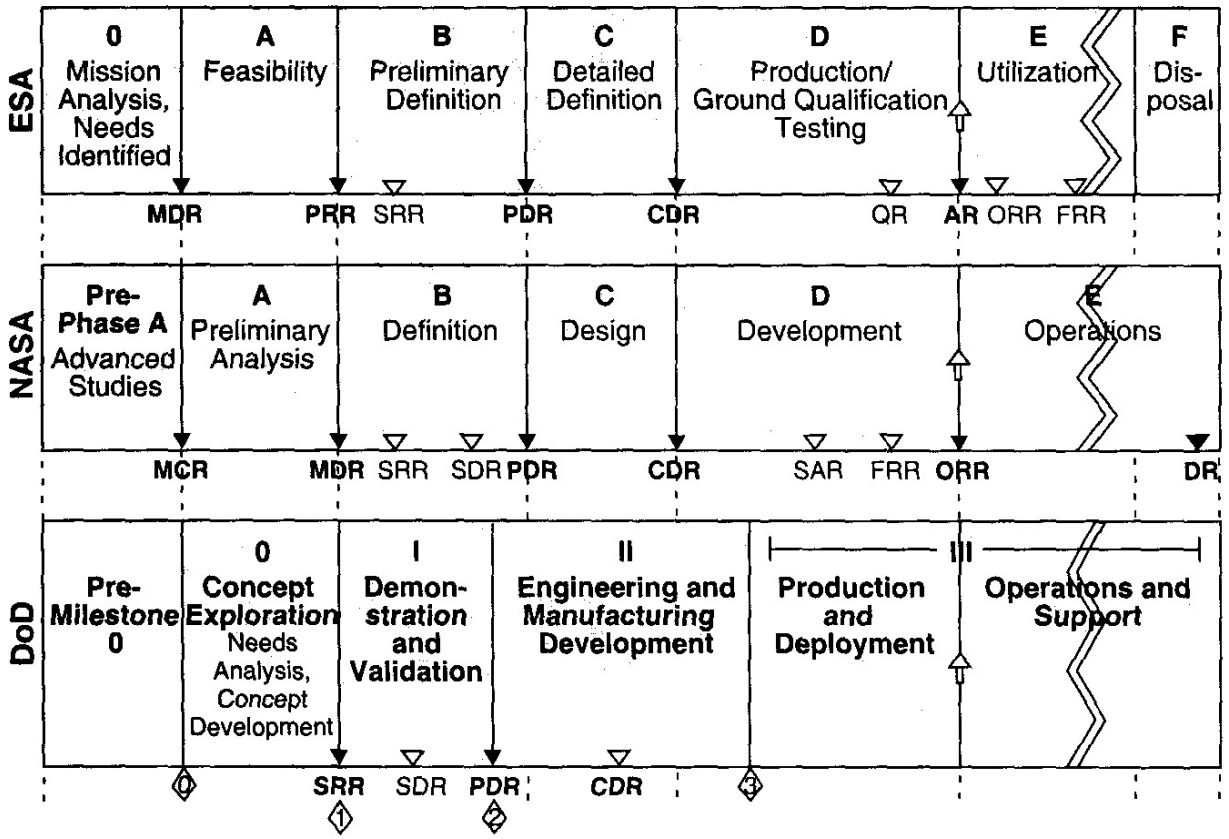
- Linear progression from User Need to End of Life
- Formalized with schedule milestones, gates, reviews
- Many variations on the theme

Phases of System Lifecycle **From ISO/IEC 15288**



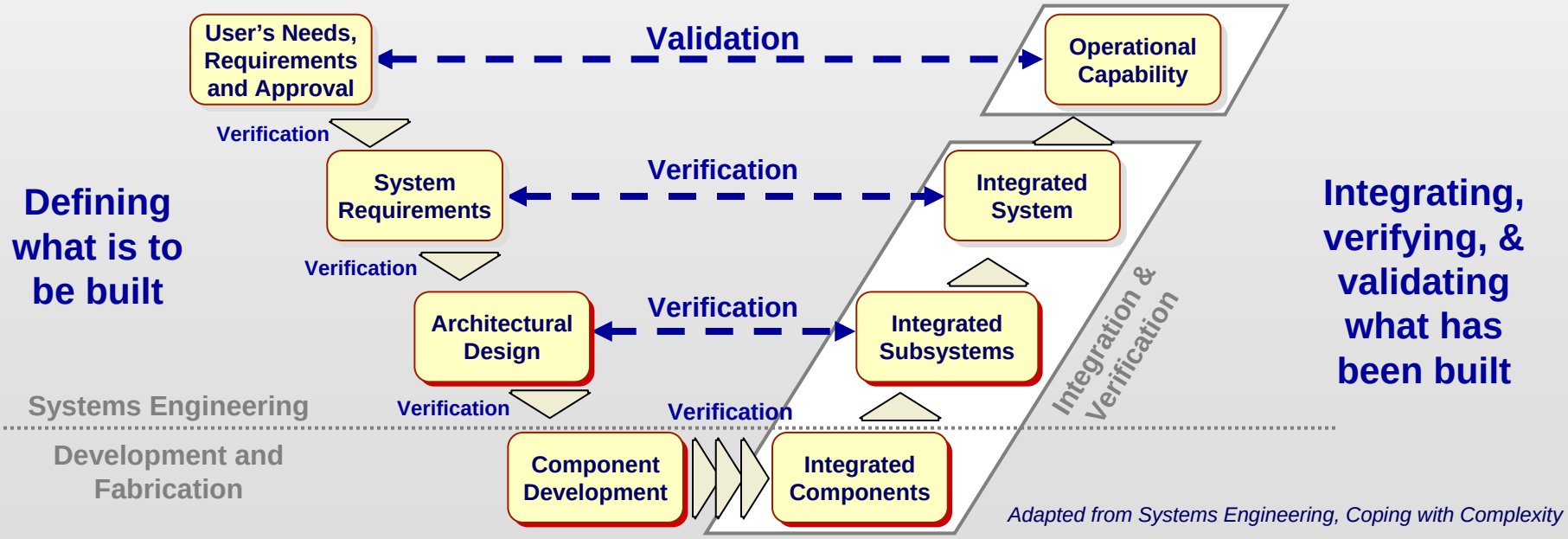
NASA Handbook 2007

NASA, ESA, DoD Versions (from SMAD)



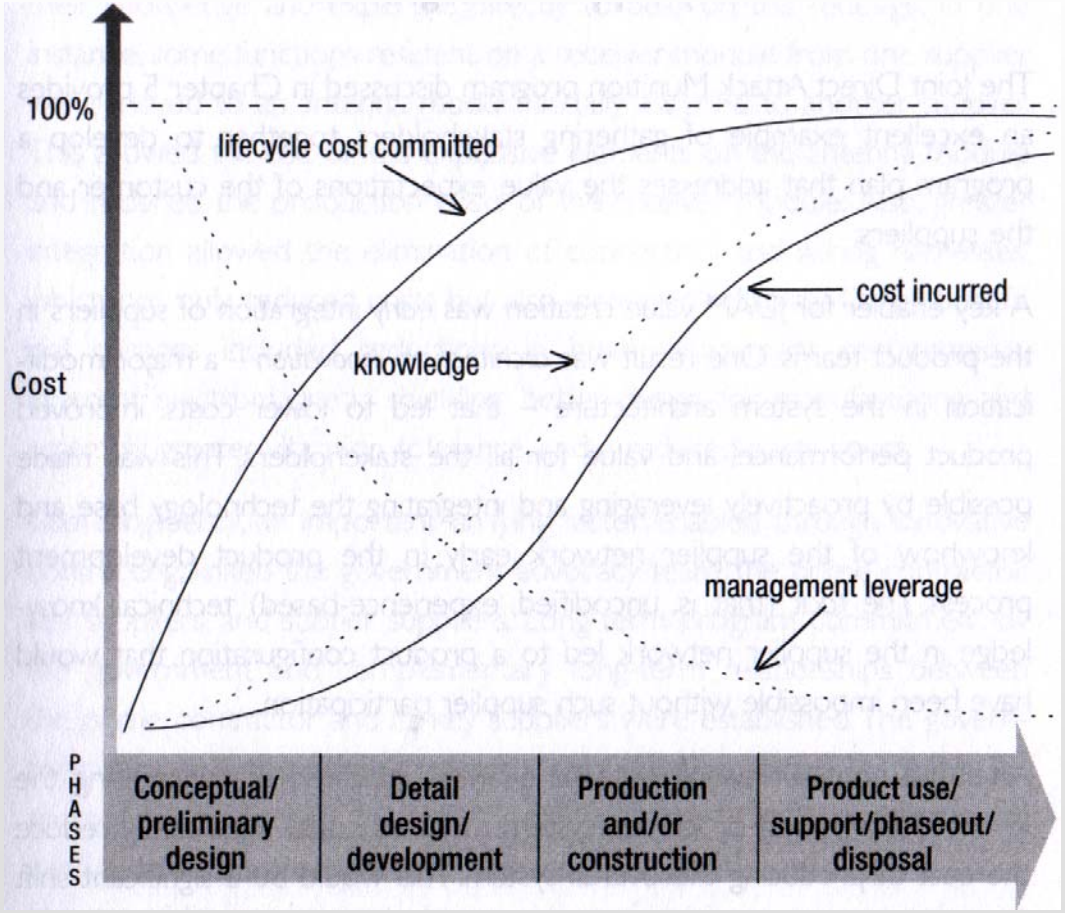
Focus of Up-front Effort: Defining and Decomposing Requirements

- The "Vee model shows decomposition from need to component development



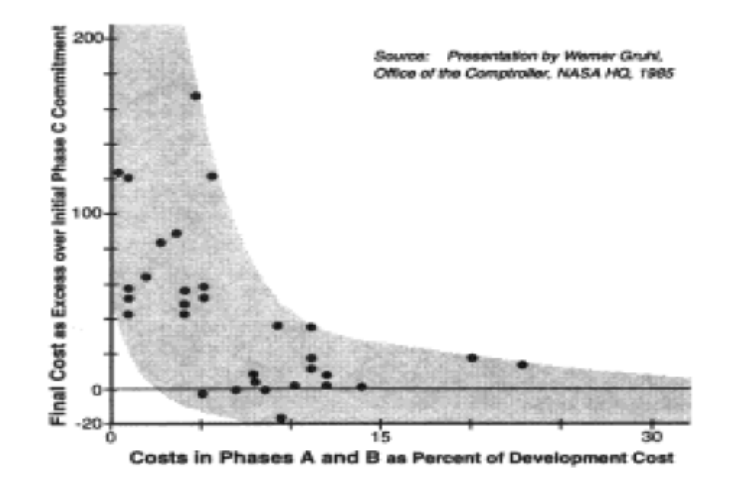
Adapted from Systems Engineering, Coping with Complexity

Doing this wrong is expensive and hard to fix

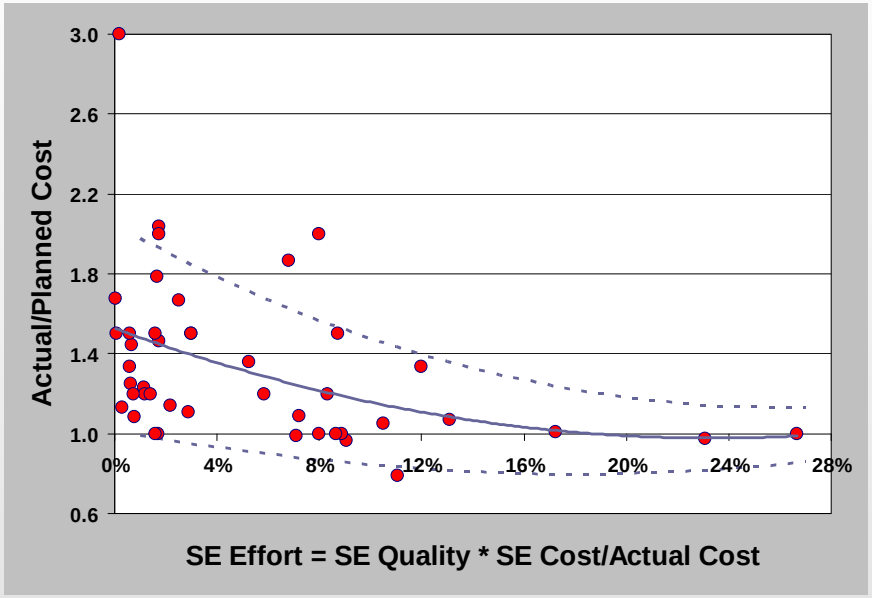


from Murman *et al.*, *Lean Enterprise Value*

Investing “up-front” Pays Off



NASA Handbook (1995)



Honour, Value of SE Report, 2004

What is a Trade Study?

Trade Study: An objective evaluation of alternative requirements, architectures, design approaches, or solutions using identical ground rules and criteria (former MILSTD 499)

Trade studies are performed throughout the lifecycle, but play a particularly important role in early lifecycle.

Tradespace exploration can aid in identifying key trade studies.

Traditional Trade Studies

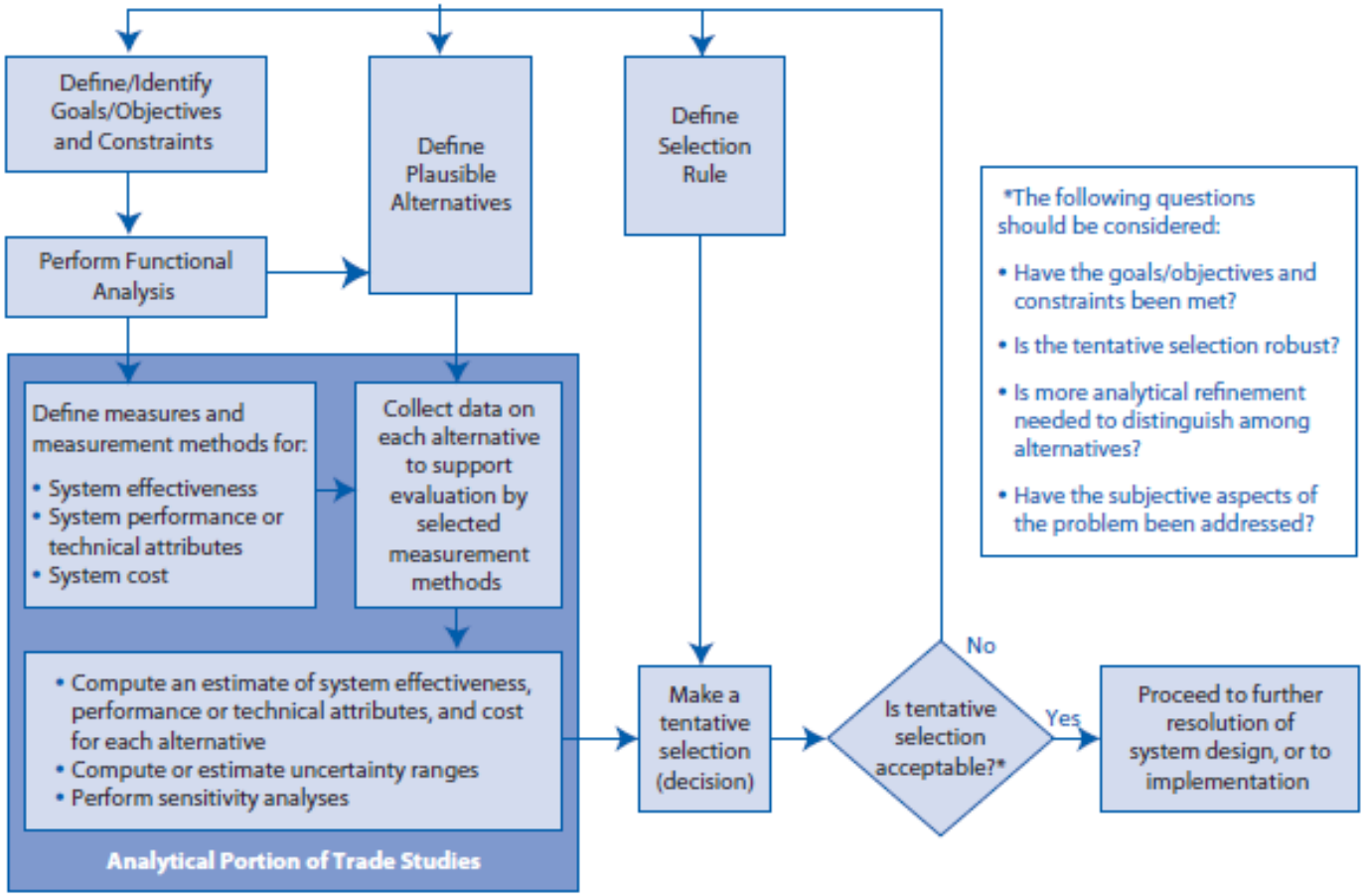


Figure 6.8-5 Trade study process

from NASA Systems Engineering Handbook, 2007

…focus on a few alternatives or variations on point designs

Possible Pitfalls: When Iteration Used to Add Detail

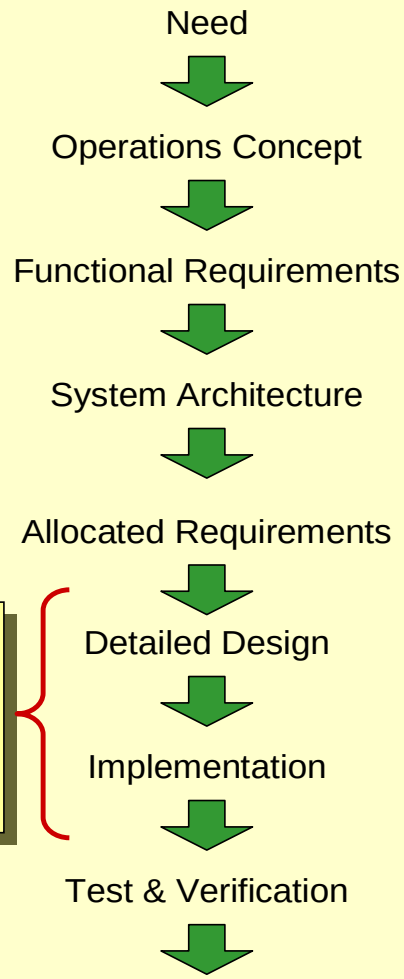
- Coarse decisions (the important ones!) made and implemented first
- Further refinement may be adding detail to the wrong concept
- Lack of formal process may make this good idea ineffective - “Spiral of Doom”

NASA Handbook, 1995

Architecture and Design in Lifecycle

- ***Focus of Systems Engineering***
  - ***From Original Need***
  - ***To Final Product***
    - ***The Whole System***
    - ***The Full System Life Cycle***

- Focus of Component Engineering
  - On Detailed Design
  - And Implementation



- ***What needs are we trying to fill?***
- ***What is wrong with the current situation?***
- ***Is the need clearly articulated?***

- ***Who are the intended users?***
- ***How will they use our products?***
- ***How is this different from the present?***

- ***What specific capability will we provide?***
- ***To what level of detail?***
- ***Are element interfaces well defined?***

- ***What is the overall plan of attack?***
- ***What elements make up the overall approach?***
- ***Are these complete, logical, and consistent?***

- ***Which elements address which requirements?***
- ***Is the allocation appropriate?***
- ***Are there any unnecessary requirements?***

- ***Are the details correct?***
- ***Do they meet the requirements?***
- ***Are the interfaces satisfied?***

- ***Will the solution be satisfactory in terms of cost and schedule?***
- ***Can we reuse existing pieces?***

- ***What is our evidence of success?***
- ***Will the customer be happy?***
- ***Will the users' needs be met?***

Source: INCOSE

Systems Engineering Methods Traditional vs Advanced

TRADITIONAL SE

- Transformation of customer requirements to design
- Requirements clearly specified, frozen early
- Minimizing changes
- Design to meet well specified set of requirements
- Performance objectives specified at project start
- Focus on reliability, maintainability, and availability

ADVANCED SE

- Effective transformation of stakeholder needs to fielded (and sustainable) solution
- Focus on product families and systems-of-systems
- Complex interdependencies of system and enterprise
- Importance of systems architecting
- Designing for dynamic relevance
- Emphasis on expanded set of "ilities" and designing in *robustness, flexibility, adaptability* in concept phase

Critique of Concept Design Methods Has Informed MATE Development

- *A priori* design selections without analysis/consideration of other options
- Inadequate technical feasibility studies in the early stages of design
- Insufficient regard for key decision maker preferences
- Disconnects between perceived and actual decision maker preferences
- Pursuit of a detailed design without understanding the effects on the larger system
- Limited incorporation of interdisciplinary expert opinion and diverse stakeholder interest.

Diller, N. P., *Utilizing Multiple Attribute Tradespace Exploration with Concurrent Design for Creating Aerospace Systems Requirements*, SM in Aeronautics and Astronautics, Cambridge, MA, Massachusetts Institute of Technology, 2002

Benefits of Tradespace Exploration

- Quantitative tool for aiding systems architecture development
- Creates realistic estimates of system performance and cost before decisions are made that “lock in” costs
- Allows exploration of the impacts of risks and uncertainties
- Quantifies cost/performance/risk trade-offs
- Permits assessment of strategies for adaptability, flexibility, platform or modular design, and other “ilities”

Increased knowledge allows better decisions

Key Challenges for New Methods

- Justifiable return-on-investment for effort
- Seamless integration with legacy methods
- Ability to deal with high levels of complexity
- Scalable to time/available resources
- Problem/domain independency
- Affordability of enabling environment

MATE as evolving method strives to address these challenges….