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 SEAr 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. The copyright of the short course is retained by the Massachusetts Institute of Technology. Reproduction, reuse, and distribution of the course materials are not permitted without permission.
Lecture 2
Overview of Classical Methods for Architecting and Design

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

From ISO/IEC 15288
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
Doing this wrong is expensive and hard to fix

from Murman et al., Lean Enterprise Value
Investing “up-front” Pays Off

SE Effort = SE Quality * SE Cost/Actual Cost

Source: Presentation by Werner Gruhl, Office of the Controller, NASA HQ, 1985


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

...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

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

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

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

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

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

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

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

- **Test & Verification**
  - What is our evidence of success?
  - Will the customer be happy?
  - Will the users’ needs be met?

Source: INCOSE
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.

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....