17ᵗʰ Annual Systems Engineering Conference

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#16901 -
"Integration of Decision Analysis with the System Model shows value of SE with reasonable, defensible actions"

Richard Swanson 10/30/2014

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richard.swanson@engilitycorp.com

Premise

- Decision Analyses are more likely to result in reasonable actions if impacts can be seen within the context of the core Systems, or System of Systems, model

- Similarly the <u>perceived</u> effectiveness of Systems Engineering is directly dependent on whether Decision Makers and project leadership understand how the SE work products are <u>helping them</u> make the right decisions to build the right product within cost, timeline, risk etc.

Background

- This may seem obvious but it's a strength we have lost over time (Presentations from 2012 INCOSE Intl' Symposium)

- Why Johnny Can't Make Good Decisions and What We Can Do About It, C. Robert Kenley
  - 25 years ago the US DoD SE process included Decision Making as a key step

- Role of Decision Analysis in Early Systems Decision Making, William D. Miller
  - Early program decisions to establish the initial system requirements are critical to setting the conditions for successful system development
  - Decision analysis is critical to finding the validated set of requirements for complex systems

Core to the Model concept

- It is of utmost importance that analysts, scientists and engineers across all the specialties work from the single source of truth
  - Facilitates data pull and results push

- These disciplines all benefit from SE best practices such as functional decomposition, requirements engineering and data management but maximum utility is only realized when all specialists use and refine a common data source
  - There can be a learning curve for the specialists, it is up to the Systems Engineer to facilitate

Use SE techniques to capture the work specialists are already accustomed to!

System Model Development

- This architecture will ideally begin with operational, mission and development planning analyses and requirements…then further decomposition into the more traditional SE work products
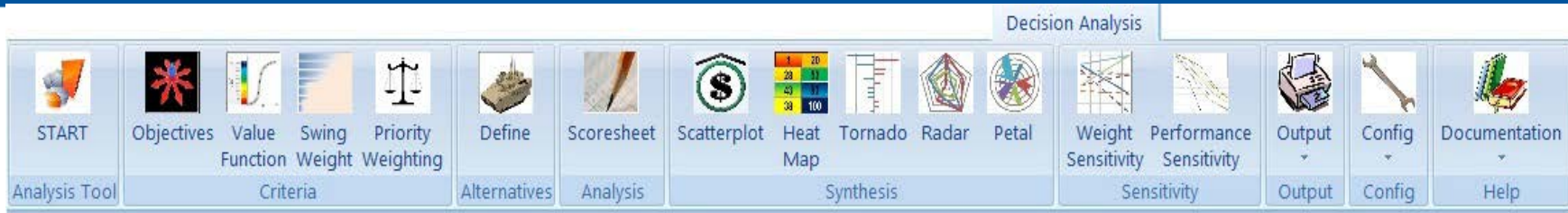
Realization of the Premise
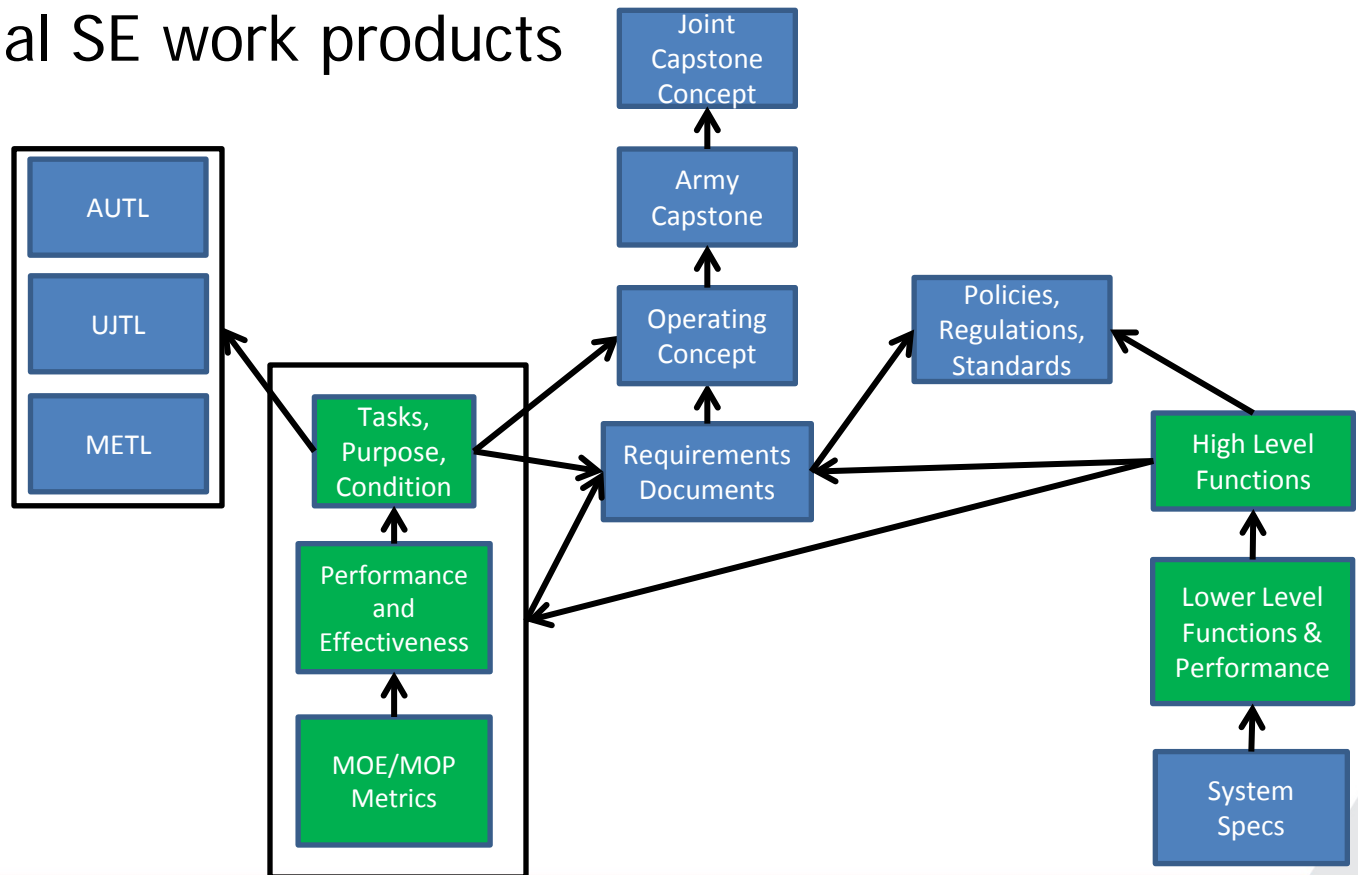
Our solution was integrating a system model, implemented in the SysML language, with a Multi Objective Decision Analysis approach and tool

Reference: Parnell, Gregory S., Cilli, Matthew V., Systems Engineering Tradeoff Study Process Framework, 2014 INCOSE Intl' Symposium and developed as part of the INCOSE DAWG.

Armament Analysis Multiple Objectives Decision Analysis Tool (AAMODAT)

AAMODAT is a MS Excel based applications that automates decision theory computations, data management, trade-space visualizations, and report generation thereby increasing decision efficiency and effectiveness.

Key Features

- Enables Efficient Creation of Value Functions
- Automates Swing Weight Matrix Calculations To Generate Priority Weightings
- Captures Key Design Features Of Considered Alternatives
- Creates Structured Score Sheets To Capture Voice of the SME
    - Captures Rational for assessment
    - Automatically maps performance score to value space using value functions
    - Allows scores to be entered as probability density functions to account for uncertainty
- Generates Compelling Tradespace Visualizations
    - 5 dimensional scatterplots
    - Decision heatmap
    - Radar graphs
    - Tornado graphs
- Conducts one-click sensitivity analyses

System Behaviors -> Decision Criteria

- System behaviors (functionality), traced to stakeholder requirements, become the basis for the decision criteria
  - Most will fall under the Performance aspect of Stakeholder Value but some could have applicability to Development Cost, Sustainment Cost, Growth Potential etc.

- All behaviors / functions are assessed for applicability to the decision at hand
  - Applicable as Decision Criteria, Deferred, Consolidated, Applicable as Screening Criteria (pass/fail) etc.

Logical Architecture -> Product Structure

- The logical architecture (traced to required behaviors) becomes the basis of the Decision Analysis product structural elements. Intent is for this to be design independent
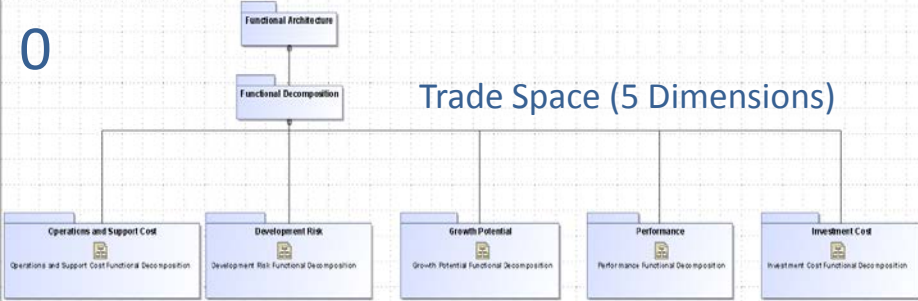
A generic alternative solution is comprised of these logical elements (such as propulsion type, warhead type etc.)
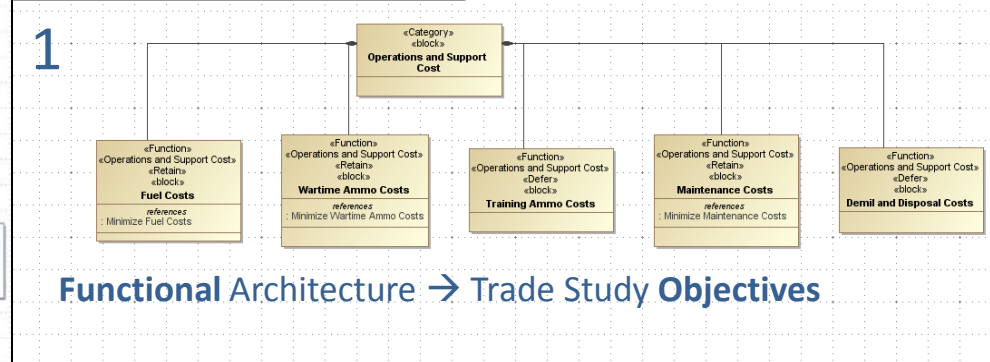
Physical Architecture -> Design Alternative

- The design alternatives under analyses are developed and documented as physical architectures (instantiating the logical architectures)
  - i.e. Design Alternative 1 has a 10lb composition XYZ warhead as its instantiation of the Product Structural Element/Logical Component "Warhead Type"
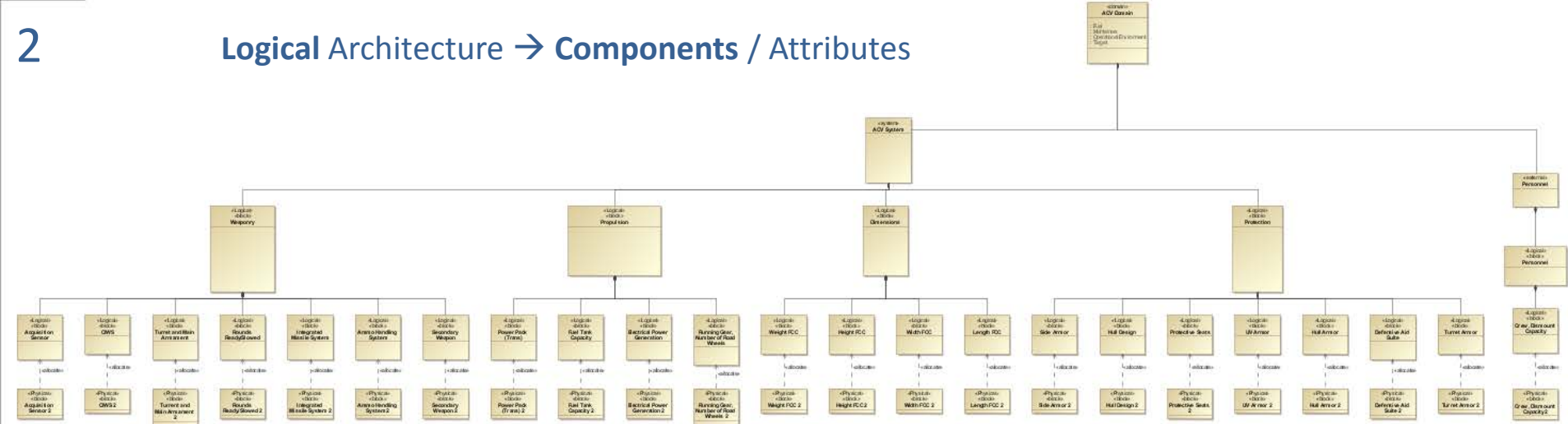
System Model Snapshots

0 — Trade Space (5 Dimensions)

1 — Functional Architecture → Trade Study Objectives

2 — Logical Architecture → Components / Attributes

3 — Physical Architecture (>1) → Alternative Solutions

- Modeling & Simulation Analyses are crucial to then assess each alternative's design against the Decision Criteria
  - Data needs should be found in the common system model that includes operational requirements, as well as system descriptions
  - The M&S "System of Analysis" can also be documented and traced within the system model to describe how each criteria was analyzed

- In turn the M&S expertise and findings should be used to refine the system model, develop better alternatives and improve stakeholder and team member understanding

Visualizations traced to Engineering

- Most importantly for the topic at hand, Decision Makers will gain the ability to see traceability from high level Decision Analysis visualizations to the actual engineering models, system designs and operational requirements that are driving the value space and trade study results.

End-State Attractiveness Assessment Matrix			Maximize Lethality Given an Engagement			Engagement Opportunities		Unit Cost	Risk	OS Cost	Growth Potential
			Lethality vs. Truck	Lethality vs. LAV	Lethality vs. Tank	Maximum Range	Forward Observer Position Flex	AUMC	Technical Maturity	Munition OS Cost	Munition Upgradability
ID	Name	Image	0.07	0.02	0.05	0.06	0.02	0.02	0.01	0.01	0.01
1	Agile Jack		75	100	42	91	80	59	43	59	54
2	Big Bang		94	11	42	26	25	28	100	36	37
3	ColdStare		91	13	96	57	54	72	11	23	59
4	Big Boom		95	4	51	61	96	8	13	49	68
5	Budget Blast		0	48	49	58	95	12	29	68	26
6	Costly Cannonball		18	55	18	31	46	98	8	74	47

Functional Decomp

Operating Concept

Alternative Descriptions

Requirements Documents

System of Analysis

Lessons Learned & Thoughts
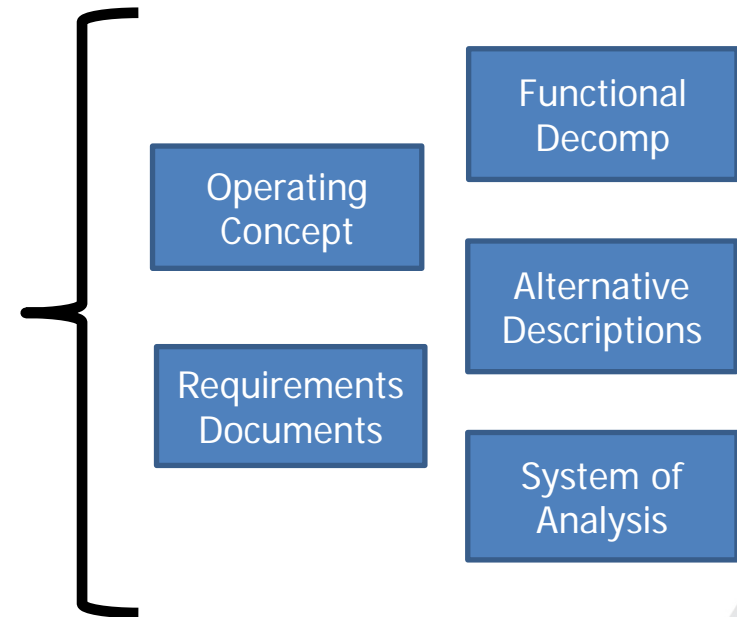
- A role of the SE is to learn what data the specialists use, include it in the system model, and then provide it in a digestible manner
  - Create custom views using their words, but maintain traceability to the core SE model
- Some specialty data may not "live" in the system model, but at a minimum capture that it exists, what it is used for and the source (ex. 6 DOF aero model)
- Stress to all members of the IPT that the system model must capture everyone's knowledge. Encourage discussion on how it should be refined or corrected
- Physical integration of the specialists tools can bring additional strengths, and difficulties along with an Infrastructure/Startup burden
  - I encourage you to consider this "Data Use" approach as a beginning

Summary

- A two-way street
  - System model can facilitate integration of Decision Analysis back into the core SE process
  - Decision Analysis and M&S feeding from the system model in turn helps show the value of SE to Decision Makers
- System Model -> Decision Analysis
  - Functional → Objectives
  - Logical → Components
  - Physical → Alternatives
- The value comes from using a common, traced set of data, and from refining the system model till it includes everyone's "truth" not just that of the SE