Decision Support Framework on System of Systems Problems

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What is System-Of-Systems?

• The term “system-of-systems” has no widely accepted definition

• Many suggestions and variations
  – Large geographically distributed assemblages, Eisner 1993
  – Collaborative systems, Maier 1999
  – Family of Systems, CJCS Instruction 3170.01F, 2007
  – …

• Attributes of system-of-systems may include but are not limited to:
  – Multiple components in many layers
  – Complexity in relationships
  – Dynamic interdependencies
  – Multiple objectives
  – Uncertainty in requirements
  – More than just the sum of its parts (emergent behavior)
Systems-Of-Systems Engineering Office

• We focus on architecting, design, analysis and evaluation in support of programs that serve the National interest
  – Particularly in cross-organizational and multiple segment portfolios
  – Application of processes, tools, resources and people for high level decision support

• Current strategy is to enhance and develop capability through
  – Solving relevant problems and performing studies for select program offices
  – Execution of Corporate Strategic Initiative (CSI) project on Decision Support Framework (DSF)
  – Developing SOSE specific models/tools

• Team
  – SOSE Office (Inki Min, Ryan Noguchi, Matthew Ferringer)
  – Draw in talent from various Departments in ETG and other Architects around the company
Corporate Strategic Initiative

Decision Support Framework

– *Develop improved strategic and programmatic decision support techniques that can be used to identify best value opportunities for improving the effectiveness of the portfolio of space systems*
  • Facilitate portfolio, cross-portfolio and cross-agency trades that include non-space elements
  • Determine impact of changes to architecture effectiveness
  • Identify capability gaps, integration and technology insertion opportunities
  • Transition successful techniques into applications and corporate best practices
  • Train next generation of corporate analysts and leaders

– *Example types of problems*
  • Program portfolio management (restructuring, planning, budgeting)
  • Help organize follow-on transition strategies for various budget scenarios

– *Good alignment of SOSE capability goals*
Elements of Decision Support Framework

**Processes**
- Analysis of Alternatives (AoA)
- Aerospace System Architecting Methodology (ASAP)
- Architecture Design & Evaluation (AD&E)
- Concurrent Program Definition Environment (CPDE)
- Concept Development Center (CDC)
- Military Utility Workshop

**Tools**
- Study Planner
- Portfolio Decision Support Tool
- Sand Chart Tool (SCT)
- GRIPS
- Troux Architect
- Model Center
- Program Acquisition Model (PAM)

**Resources**
- Data repositories
- Decision product templates
- Acquisition & management practices
- Center for Space Policy & Strategy
- Project West Wing
- Reference material
- DSF Web page/portal

**People**
- Cadre of experts
- Knowledge & experience building
- Training (The Aerospace Institute)
- Decision maker interfaces
Recent and Planned Activities

• Decision space exploration
  – Mini survey (in-house)

• Resources
  – Study Planner
  – Defense Intelligence System Acquisition – Government processes
  – Previous studies/reports/decisions
  – Product templates

• Capability development/extension
  – Military Utility - STAMP
  – Architecture Integration and dynamic display - Portfolio Decision Support Tool
  – Model Integration and analysis - ModelCenter
  – Portfolio budget trades using multi-objective optimization
  – Affordability Tool - Sand Chart Tool
  – Programmatics - CPDE
  – Strategy, Policy – CSPS, PWW

• People
  – Work group - Inform and get informed

• Decision Support Framework definition
  – Methodology, (study processes, flow diagrams, tools)

• Pilot studies / Data capture
  – Portfolio budget trades using GRIPS, strategic portfolio capture and analysis
  – Program office support

Multiple activities under way - Tool development, Program architecture capture, Capability application
Decision Support Framework – Desired Attributes

General tenets

- Flexible
  - Applicable for different customers and types of studies
- Broad
  - Comprehensive in scope and perspective
- Modular
  - Be able to swap out component analyses as studies change
- Scalable
  - Use on problems of various scope
- Account for robustness
  - changing future
  - uncertain estimates
- Include risk assessment

- Handle multiple objectives
  - Understand trade space & tradeoffs
- Focus on big decisions
  - Understand the real discriminators
- Consider external impacts
- Addresses programmatics
  - implementation and transition issues
- Produces consistent results
  - repeatable structure
  - product
  - look and feel
- Practical
  - Implementable/actionable
  - Convey information at appropriate levels
  - Avoid “overwhelming” details
Decision Support Framework Evolution

- Framework Development
- Pilot Studies
- Operational Studies
- Institutionalized Process

Feedback & Refinement

Process
Tools
Decision Support
Resources
People
Decision Support Approach

Framework Components

Resources
- TAI
- Practices

Process
- Concept Design Center
- Net Assessment
- Architecture Design

People

Tools
- SCT
- GRIPS
- ...

Interface

Decision-Makers
Processes

Aerospace Systems Architecting Methodology

Raw Needs, Constraints

Enterprise Architecture Modeling

Architecture Design & Evaluation Process

Analysis of Alternatives

Formulate Assumptions

CDC System Architecture Team (SAT) Modules/Process

Effectiveness Analysis

Cost-ANALYSIS

GRIPS Many-objective Design Analytics Process

Stakeholder Interviews

Application Program Interfacing (API)

Identify existing/aerospace tools that model

Design Parameters

Key Objectives

Constraints

Assess feasibility for GRIPS integration w/ the API

Build new models if necessary

Wrap models into GRIPS via API

Multi-objective optimization

KEY

Existing

De novo

Search potentially billions of alternatives using Evolutionary Algorithms with parallel computing

Find non-dominated traded-off solutions

Explore, Visualize, Communicate

Provide an accessible visualization roadmap of key tradeoffs to Decision Maker

Engage Decision Maker in real-time "what-if" analysis

Watch architectures evolve and identify key interactions between design parameters, objectives, and constraints

Identify Design Parameters

Design Parameters

Enable informed tradeoffs to be made by the Decision Maker
Architecture Design & Evaluation Process

**Problem Definition**
- Scope, WBS
- Objectives, Metrics
- Decision Criteria
- Capabilities, Constraints

**Implementation & Operational Context**
- CONOPS, Environment
- Missions, Needs
- Requirements, Policy
- Politics, Acquisition Strategy
- Infrastructure, Technology

**Alternatives**
- Trade Tree
- Screening
- Concepts selection

**Systems Definition**
- "Architecture" Design
- Interdependencies
- Programmatic

**Analysis & Evaluation**
- Cost, Schedule
- Risk, MOPs
- Performance
- Utility, MOEs
- Other impacts

**Summary**
- Tradeoffs
- Comparison Presentation

**Output**
- Tradeoffs
- Blanket
- Spider

**Tools**
- ProTree
- GRIPS
- CDC, CEM
- Enterprise Arch
- STAMP
- SEAS
- CASA
- USCM
- CPDE
- Stoplight
- Blanket
- Spider
Tools

- Many existing tools
  - various types and at various levels
- Current CSI focus on
  - Study Planner
  - Portfolio Decision Support Tool (PDST)
  - Strategies to Tasks to Architecture Measures of Performance (STAMP)
  - GRIPS application to portfolio problems
  - ModelCenter for integrated system modeling and analysis
  - Sand Chart Tool (SCT) application to NSS problems
Backup
**DOD SoS Terminology (1 of 2)**

- **System of Systems (SoS)**
  - A set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities

- **Family of Systems (FoS)**
  - A set of systems that provide similar capabilities through different approaches to achieve similar or complementary effects. [CJCS, 2007(1)] A family of systems lacks the synergy of a system of systems. The family of systems does not acquire qualitatively new properties as a result of the grouping. In fact, the member systems may not be connected into a whole.

- **SoS Systems Engineering (SoSE)**
  - SoSE deals with planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into an SoS capability greater than the sum of the capabilities of the constituent parts. Consistent with the DoD transformation vision and enabling net-centric operations (NCO), SoS may deliver capabilities by combining multiple collaborative and autonomous-yet-interacting systems. The mix of systems may include existing, partially developed, and yet-to-be-designed independent systems

DOD SoS Terminology (2 of 2 – Types of SoS)

“In DoD and elsewhere, SoS can take different forms. Based on a recognized taxonomy of SoS, there are four types of SoS which are found in the DoD today [Maier, 1998; Dahmann, 2008]. These are:

• Virtual. Virtual SoS lack a central management authority and a centrally agreed upon purpose for the system-of-systems. Large-scale behavior emerges—and may be desirable—but this type of SoS must rely upon relatively invisible mechanisms to maintain it.

• Collaborative. In collaborative SoS the component systems interact more or less voluntarily to fulfill agreed upon central purposes. The Internet is a collaborative system. The Internet Engineering Task Force works out standards but has no power to enforce them. The central players collectively decide how to provide or deny service, thereby providing some means of enforcing and maintaining standards.

• Acknowledged. Acknowledged SoS have recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches. Changes in the systems are based on collaboration between the SoS and the system.

• Directed. Directed SoS are those in which the integrated system-of-systems is built and managed to fulfill specific purposes. It is centrally managed during long-term operation to continue to fulfill those purposes as well as any new ones the system owners might wish to address. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the central managed purpose.”