Identifying Hidden Requirements in System of Systems
SUMMARY

• System of Systems (SoS) Architecture Synthesis Process Naturally Exposes Hidden or Derived Requirements

• Include Early Architecture High Level Views as Part of SoS Concept System Selection Trade Space

• Expert Judgment Vital for SoS Concept Selection Analysis of Alternatives (AOA)

• Paired Comparison Methods Ideal for AOA in SoS Concept System Selection

• Paired Comparison AOA Example
**Simple SOS Architecture Synthesis Cycle**

**Synthesis Process and Outcomes**

- Develop high level SoS architecture alternatives
- Uncover SoS hidden requirements
- Update candidate architectures to address the uncovered requirements
- For SOS this process continues throughout the life cycle
- Include candidate architectural views for early concept trade space inclusion

In practice SoS architectural synthesis is an evolutionary process
WHY EXPERT JUDGMENT IS VITAL DURING SOS CONCEPT PHASE?

• Early program decisions have huge life cycle cost implications
• Constituent system perspectives - experts hold unique sets of domain expertise
• SMEs can communicate tacit and lessons learned knowledge
• SME domain support is critical for decision gates such as U.S DoD Milestone A decision.

Figure from DoDI 5000.02

For U.S. DoD AoA is mandatory for major material development programs to support milestone A decision.
SOS CONCEPT SYSTEM SELECTION AOA TRADE SPACE

- Key Early Architectural Views
- Cost & Schedule Estimates
- Capability Objectives
- Affordability
- Risk (TRL)

DoDI 5000.02 recommends AOA trade space includes estimates for cost, schedule, key capability performance, affordability and risk.
WHY EXPERT JUDGMENT FOR SOS AOA

- **Expert Elicitation** is Crucial in Reducing SoS Undesirable Emergent Behavior Which Increases Program Technical, Cost and Schedule Risk. *(modified from INCOSE HB v4.0 page 12)*

- Interaction Amongst SMEs can Uncover Constituent Systems Undocumented Features, Constraints and Assumptions
WHY PAIRED COMPARISON METHODOLOGY FOR SOS AOA?

• Mythology was Developed to Elicit Expert Judgment for Decision Analysis

• Favorable Methodology for Relative Assessments

• Paired Comparison Methodology is Ideal for Contextual Trade Space
  • Such as Affordability, Cost-Effective Capability and Risk

• Enables Judge or Respondents Reliability Checking

• Models are Available to Support Hypothesis Testing
PAIRED COMPARISON AOA EXAMPLE

- In this example there are two platforms, two radar systems and two EO/IR SoS candidate architectures for comparison.
- Populate paired scoring sheets for each SoS concept candidate (6 in this example).
- Respondents select system preference for each pair of candidate concept solutions (15 paired comparisons in this example).
- Configure aggregate preference matrix.
- Verify respondent consistency and reliability learned from the data.
- Use models for hypothesis testing.
SIMPLE PAIRED COMPARISON DECISION EXAMPLE

Let there be 20 respondents and one score sheet for each

Respondent aggregate score matrix

Column-wise aggregate shows candidate system solution 4 is most preferred

Mean = Sum/20 judges
Proportion = Sum/20*(#items-1)
PAIRED COMPARISON MODELS

Respondent Data

• Consistency – consistence with expected values
  • A measure of constancy with the law of comparative judgment

• Reliability – test for circular triads
  • Since paired comparisons are IID some amount of circular triads are acceptable

• Retest Reliability
  • Repeat a small number of paired comparisons and evaluate any inconsistencies

SoS Candidate Data

• Preference Significance – test for preference
  • Is the preferred candidate statistically significant?

• Goodness of fit – chi square distribution of candidate least squared error
QUESTIONS?

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REFERENCES


