A Research Agenda for Systems of Systems Architecting

Dr. Elliot Axelband, RAND/USC, Elliot_Axelband@rand.org
Dr. Ricardo Valerdi, MIT, rvalerdi@MIT.org

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Background

- Inaugural USC CSSE Convocation
  - October 23-26, 2006
- Affiliate sponsorship & broad participation
  - 250 from Industry, government, and academia
- Presentations, Workshops, and Schmoozing
- Plenary Addresses
  - President of USC
  - President of NSF
  - Former DoD CIO
- This presentation reports on the outcome of the Workshop on developing a SoS Architecting Research Agenda
  - Convocation web address is in the IS conference paper

Co-authors and participants

Thomas Baehren
thomas.baehren@de.bosch.com

Barry Boehm - CSSE Director
boehm@usc.edu

Dave Dorenbos
dave.dorenbos@motorola.com

Scott Jackson
jackessone@cox.net

Azad Madni
amadni@IntelSysTech.com

Gerald Nadler
nadler@usc.edu

Paul Robitaille
paul.robitaille@lmco.com

Stan Settles - CSSE Co Director
settles@usc.edu

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SoS Research Agenda

1. Resilience
2. Illustration of Success
3. System vs. SoS Attributes
4. Model Driven Architecting
5. Multiple SoS Architectural Views
6. Human Limits to Handling Complexity
7. Net-Centric Vulnerability
8. Evolution
9. Guided Emergence
10. No Single Owner SoS

1: Resilience

The attribute of a SoS that makes it less likely to experience failure, and more likely to recover from failure

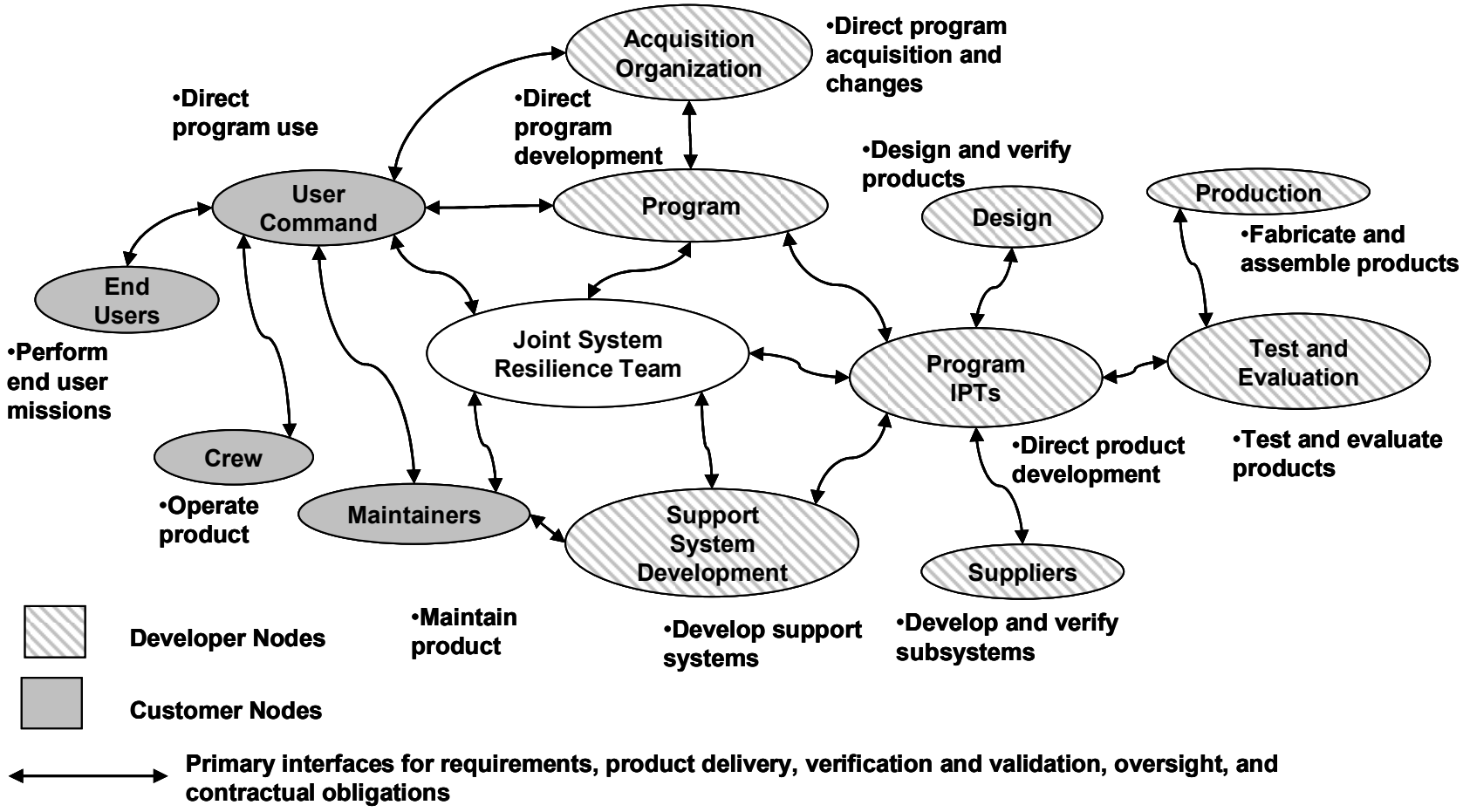

Figure 1 Operational View of the System Resilience Infrastructure

2: Illustration of Success

- “The way we go about engineering large systems - divide and conquer - precludes a holisitic approach”, paraphrased from Lucky
- Research undertaken in planning and design has led to the formulation of holistic approaches
- The research methodologies used in those studies should be adapted to SoS Engineering

3: System vs. SoS Attributes

- Research challenge #1: How can an SoS architect identify and manage the broad range of ilities inherent in the SoS (explicit) and introduced by the operational environment (implicit)?
- Research challenge #2: How can an SoS architecture be modeled to include the ability to perform tradeoffs between ilities?
- Research challenge #3: How can SoS ilities be measured and tested
- Context: Illities reflect the interest of users, e.g. adaptability, flexibility, agility, scalability, modularity, sustainability, supportability, transportability, etc, and there can be a very large number of users

4: Model-Driven Architecture

- Analytical models for estimating cost, schedule, quality, productivity and other value attributes associated with applying model-driven approaches to developing large scale software-intensive systems.
- Methods to determine and validate whether existing models can be modified for this purpose or whether a new model and a different cost framework are required.
- Multi-dimensional Mathematical Model Manager methods and tools, employing graph theory–and its offshoot, constraint theory–to determine model consistency and computational "allowability" within models containing tens of thousands of variables.
- Evolutionary computation and generic algorithms to search the vast trade space for satisfying designs.
- Quantitative risk management, based on decision theory, to converge on designs with the balance of cost, performance and risk preferred by the stakeholders
- Value and preference models to translate the diverse requirements of the stakeholders as well as their risk assessments into acceptance test standards that the model can verify.

5: Multiple SoS Architectural Views

- Scalability of Views, what to deemphasize
- The ilities in general, and their reconciliation
- View consistency assurance
- View update propagation with incremental tools
- Unviewables,, e.g. proprietary and COTs
- *Harmonization of views*

6: Human Limits to Handling Complexity

- The limits to complex SoS/human interaction; how to overcome them
- AOC as an example - 1500 people, 2 shifts, large information and computational capability - have to make decisive, timely and accurate decisions of great consequence in a rapidly changing dynamic environment with complex rules of engagement
- The development and use of tools such as “sensemaking” to allow individuals to be alert, resilient and flexible so that they can detect abberant conditions while they are new, small and insignificant, and take action to prevent them from being highly consequential

7: Net-Centric Vulnerability

- Civilization begat cities that begat plagues that took a long time to tame.
- Net-Centricity has woven us all together into a hyper-efficient network that is increasingly vulnerable to information attacks that are expensive and harmful, and nullify many of the benefits networks provide.
- We know of no guaranteed solutions, and appear to be forever committed to information defense
- All these issues are magnified by SoS
- Now is the time to address them in a SoS context

8: Evolution

- SoS evolve, are often not pre-planned, and have emergent properties, sometimes negative ones. Research is needed to:
  - Develop methodologies to cope with SoS emergent properties
  - Develop new contractual mechanisms to handle systems of systems evolution - e.g. contract for the long run
  - Better employ the processes of evolutionary acquisition and spiral development

9: Guided Emergence

The ability to steer emergence

- Consider cities as a metaphor for SoS
- Cities emerge as the result of individual actions - e.g.constructing buildings - systems within the SoS
- For SoS coherence,these individual actions are guided by policies - e.g. zoning laws
- In a larger sense, the equivalent of zoning laws are needed to guide SoS, as approriate for the context

10: No Single Owner SoS

- Developing SoS where the user community is vast - e.g. Health Care, Public Authorities
- What will carry over from single owner SoS and new needs to be researched and developed.

Difficulty & Value of Proposed Topics

Difficulty = Intrinsic Difficulty, Resource Available, Funding