IEEE Systems Conference Panel

Systems Engineering of Complex Systems of Systems

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SoS Key Challenges

….. it does not matter that they have got it wrong

What matters is their capacity to get it right quickly when the moment arrives

Sir Michael Howard (1974)

- Nature of dynamic environment
- Shifting profile – constituents enter/exit
- Distributed knowledge/decision making
- Decisions under extremes on uncertainty

….leading to the need for continuous ***anticipation*** *regarding SoS future*

What is Anticipation?

- Ability to look forward in order to take a future decision or action
- Visualization of a future event or state

An anticipatory system is "*a system containing a predicative model of itself and/or its environment, which allows it to change state in an instant in accord with the model's prediction of itself and/or its environment*"

(Robert Rosen, 1985)

Important aspect of anticipatory systems is their dependence on predicted future states, and not only past states as would be the case for purely reactive systems

Anticipatory Capacity

important capability needed in SoS enterprises

Anticipatory Capacity is the capacity to continuously develop and apply knowledge acquired through a structured approach to : (1) anticipate changing scenarios as stakeholder needs and systems context change over time; (2) to consider their consequences; and (3) to formulate design decisions in response.

Rhodes, D. and Ross, A., Anticipatory Capacity: Leveraging Model-Based Approaches to Design Systems for Dynamic Futures, 2nd Annual Conference on Model-based Systems, Haifa, IL 2009

Three Enablers for Anticipatory Capacity

1. Existence of appropriate dynamic systems **competencies** in workforce
2. Advanced **methods** for performing anticipatory thinking, analysis, and decision making in design of systems
3. Model-based **environment** to enable anticipatory design and decision making

Competencies

Four Examples

1. Ability to think deeply about systems in their context

2. *Situational Leadership* – make decisions at multiple system levels and across time periods
   - Local versus global value delivery trade
   - Understanding context in which decisions are made

3. Enhanced ability to think about ‘systems in time’ in more rigorous and extensive manner

4. Collaborative systems thinking at team level

METHODS

examples from MIT research

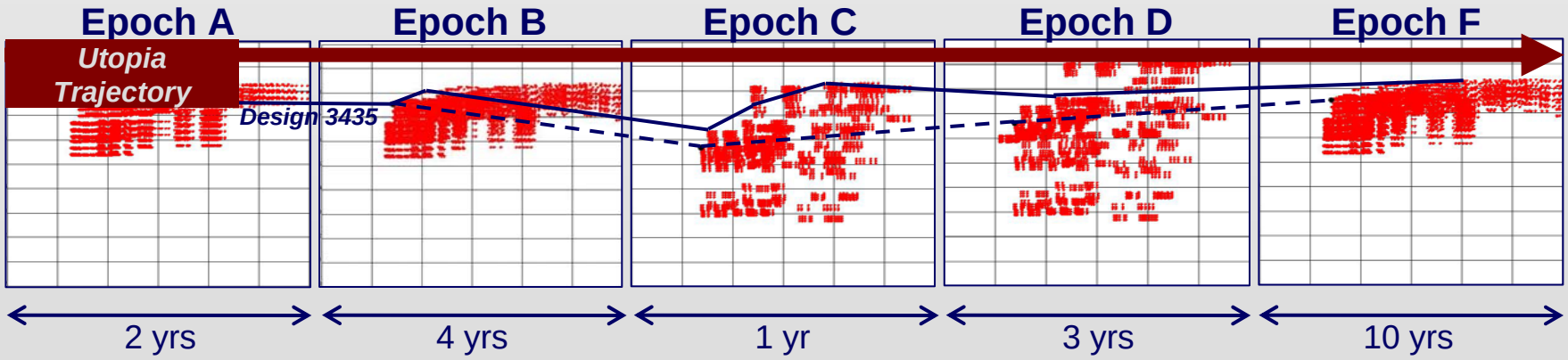
Anticipation of dynamic futures of systems at any significant depth, depends upon model-based approaches

Dynamic Multi-Attribute Tradespace Exploration

Ross, A.M., and Rhodes, D.H., "Architecting Systems for Value Robustness: Research Motivations and Progress," 2nd Annual IEEE Systems Conference, Montreal, Canada, April 2008. (Best Paper)

Epoch-Era Analysis

A.M Ross and D.H. Rhodes, "Using Natural Value-Centric Time Scales for Conceptualizing System Timelines through Epoch-Era Analysis" INCOSE International Symposium 2008, Utrecht, The Netherlands, June 2008 (Best Paper)



Enabling Environment

Enhancing Anticipatory Capacity

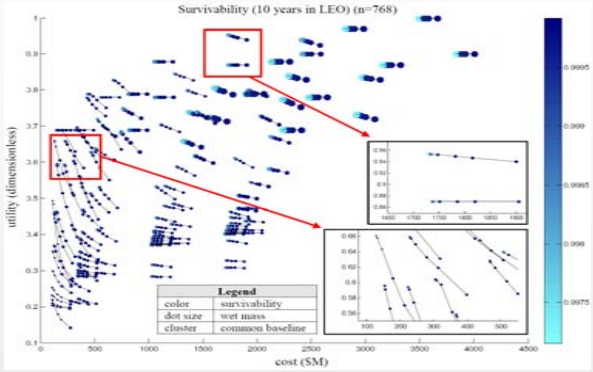
- Physical collaboration venue brings together relevant stakeholders
- Provides computing power and toolsets needed to enact anticipation methods
- Enables effective display of complex data sets and analyses to facilitate dialogue and decision making

Anticipatory capacity of an engineering organization will be enhanced by ….

Tradespace exploration laboratories for creating models so that dynamic futures can be elaborated and their implications considered

Research Directions

1. Further investigation of how anticipation approaches from other disciplines are used
2. Display of complex tradespace information to enable effective decision making
3. Studies of anticipation, learning and decision making in laboratory experiments
4. Discovery of how anticipations occur in collaborative systems thinking teams
5. Further research on methods for anticipation for SoS



Underlying motivation is to enable enterprises performing complex SoS engineering to establish anticipatory capacity