2011 SEAri Annual Research Summit

Overview and Motivations

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October 21, 2011
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Brief Overview of SEAri

Systems Engineering Advancement Research Initiative (SEAri)

SEAri Group Research Mission

Advance the theories, methods, and effective practice of systems engineering applied to complex socio-technical systems through collaborative research

Socio-Technical Decision Making

Designing for Value Robustness

Systems Engineering Economics

Systems Engineering in the Enterprise

2010/2011 Sponsors:

US Air Force, Singapore Defense Sciences & Technology Agency, DARPA, MIT Portugal Program, selected US Government Agencies

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Selected Areas of Research and Research Methods

CONCEPT DESIGN

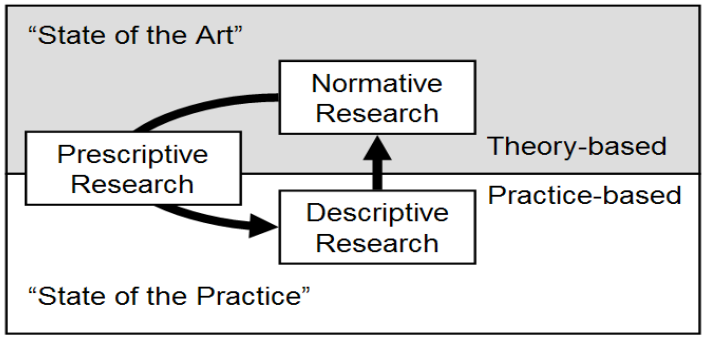
How can operational variables be incorporated into tradespace exploration?	What methods can identify best designs given possible anticipated futures?

DECISION MAKING UNDER UNCERTAINTY

How can multi-stakeholder negotiations be enhanced and accelerated?	What uncertainties impact product platform design and how can they be managed?

SYSTEM PROPERTIES (ilities)

How can we measure adaptability?	How can ilities be traded-off in system decisions?



APPROACH & METHODS

Model-based approaches, advanced analyses, simulations, metrics, MATLAB, Agent-based and STK Models

Empirical studies of historical systems, programs, and current practices

Experiment-based studies: observed decision-making, visualizing complex data sets

Five Aspects of Complex Systems

dynamic strategies consider context, time, perception shifts

STRUCTURAL	Addressed via "state of the practice" systems architecting and model-based systems engineering
BEHAVIORAL	
CONTEXTUAL	**Emerging "state of art"** *Epoch Modeling* *Multi-Epoch Analysis* *Epoch-Era Analysis* *Multi-Dimensional Tradespace Exploration* *Multi-Stakeholder Negotiations* *Comprehension of Complex Datasets* *Cognition-based studies of Decision Makers* *and more….*
TEMPORAL	
PERCEPTUAL	

Achieving Impact

- New constructs, methods, and frameworks
  - Example: Dynamic MATE, Epoch-Era Analysis
- Transition of research to practice
  - Use of methods at several organizations
- Publications – conference/journal papers, guidebooks
- Integrate knowledge into curriculum
  - Academic and professional education
- Access to knowledge assets via website
  - Direct access to softcopy documents
- Promote dialogue across government, industry, and academic units
  - SEAri Summit, technical exchange meetings, workshops
- Attract top students as impact-oriented researchers

SEAri Graduates in the Workforce

Academic Year 2009-2011

- US Air Force
- US Marines
- US Coast Guard
- Consultancy (defense, transportation)
- George Washington University
- Fraunhofer Institute for Sustainable Energy Systems
- JPL
- Lincoln Labs
- MIT Postdoc
- NGA
- Singapore DSTA
- West Point Military Academy

SEAri provides students with a collaborative learning environment focused on real-world problems and collaborating with experts in government and industry …thereby preparing them to contribute to significant systems challenges

Motivations

Research Landscape

Systems of Systems

System of systems is a collection of task-oriented or dedicated systems that pool their resources and capabilities together to obtain a new, more complex, 'meta-system' which offers more functionality and performance than simply the sum of the constituent systems

Entanglement of Systems and Enterprises

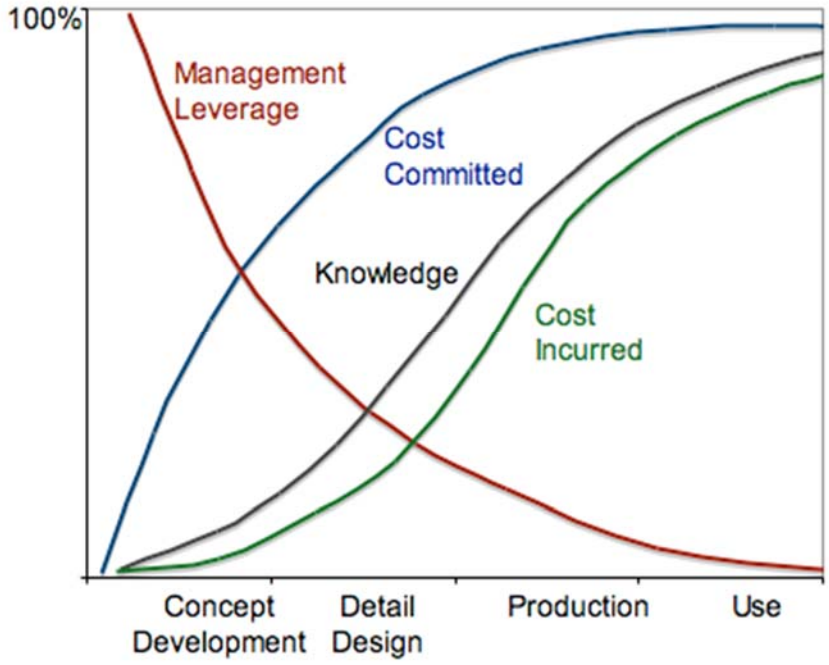
The understanding of the organizational and technical interactions in our systems, emphatically including the human beings who are a part of them, is the present-day frontier of both engineering education and practice.

Dr. Michael D. Griffin

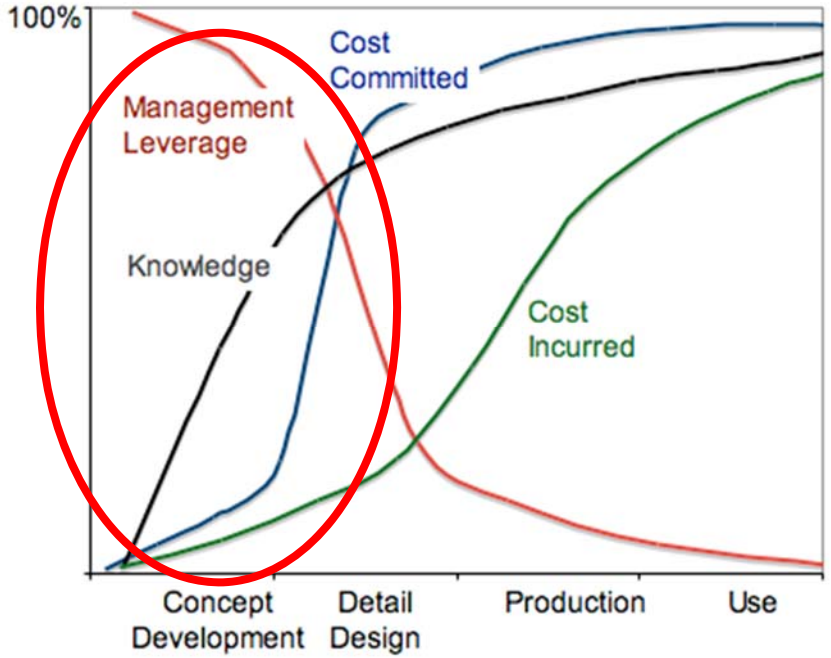
Dynamic Global Environment

- The engineering environment of this century involves collaboration across regions and nations, and coping with changes in policies, resources, markets, technologies, economies, and stakeholder demographics

SEAri Research Seeks to "Change the Picture"



Classic paradigm



New paradigm

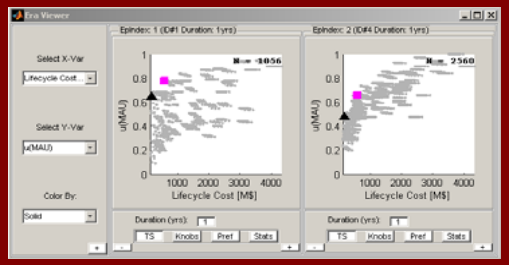
ESSENTIAL ELEMENTS

Appropriate **competencies** in workforce

Advanced **methods** for anticipatory analysis, decision making, and architecting

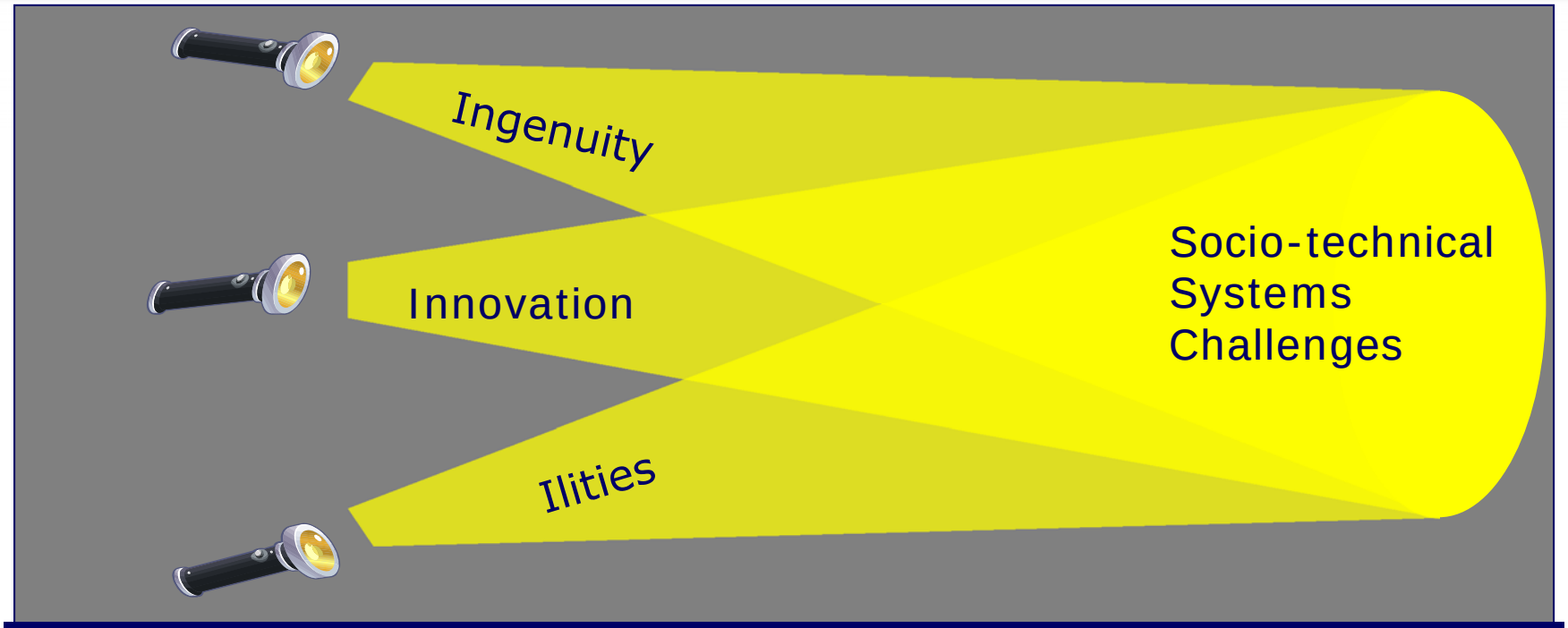
Enabling enterprise strategies and model-based **environments**

Anticipatory Capacity

MINDSET	METHODS	ENVIRONMENT
Ability to think deeply about 'systems in context' Enhance ability to think about 'systems in time' Use *situational leadership* to make decisions at multiple system levels	Perform dynamic tradespace exploration Model-based approach to derive alternative futures Apply methods at varying levels of fidelity	Computing power/toolsets to enact methods Support multi-stakeholder negotiations in tradespace exploration Enable comprehension of complex data sets
		

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

Addressing Challenges in Socio-Technical Systems



Given the complexity and lifespan of modern systems and systems-of-systems, along with changing budgets, technologies, and missions, creating the right system capabilities for the right time is essential, not just during the design phase, but throughout full operational life.

Three complementary approaches to enable this imperative are ingenuity, innovation, and ilities-based strategies.

Definitions

Ingenuity

Clever inductive and deductive strategies applied to solve a problem

Innovation

Creation of better or more effective products, technologies, services or processes that are accepted by markets, governments, and society

Ilities

System properties describing some essential quality of a system that goes above and beyond typical cost, schedule, and performance expectations for the system development and operation

Ingenuity - Innovation - Ilities

Focus Areas of Our Research

Ingenuity - Innovation - Ilities
As Focus Areas of Our Research

Ingenuity

- *What factors and conditions encourage ingenuity in individuals, teams, and enterprises?*

Innovation

- *What are effective pathways for innovation in different types of organizations?*

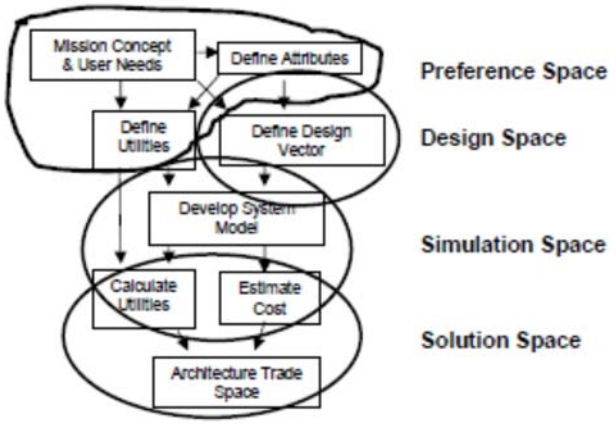
Ilities

- *Can the ilities be more precisely defined and measured, and incorporated into early trade-off decisions?*

Ingenuity - Innovation - Ilities

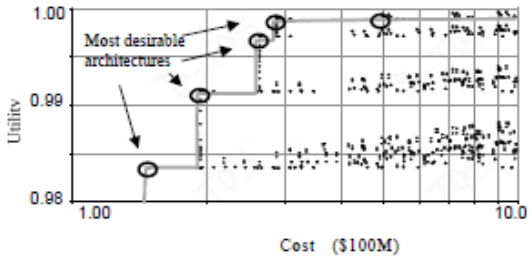
Influence in Our Research

Basic Research Phase
Ingenuity in Academic Research



Is there a better way to assess utility and cost of a large space of possible system architectures

mindshift



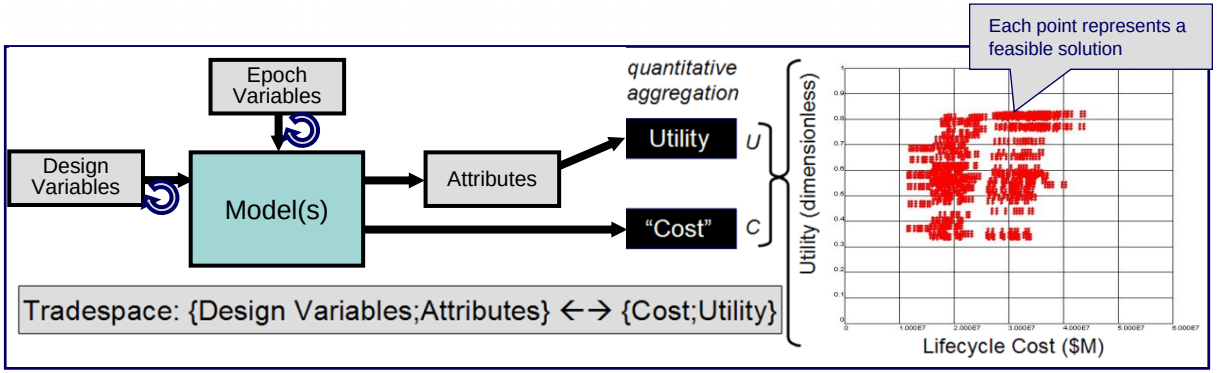
Ingenuity

Is there a clearly identified and scoped problem for which there are promising fundamental concepts and constructs that may lead to a new method?

Method Development
Innovation in Academic Research

Table 1-1 Missions analyzed

Mission Name	Purpose	Configuration	Analyses Used	References
Techsat 21	Moving ground target detection	Constellation of identical vehicles	GINA; MMDOSA, uncertainty analysis	93, 88
Terrestrial Planet Finder (TPF)	Search for Earth-like planets in other solar systems	1 large, or 4 formation-flying vehicles	GINA; MMDOSA	70, 124
Broadband	High Bandwidth Communication	LEO, MEO or GEO constellations	GINA; MMDOSA; uncertainty analysis	93, 88
Terrestrial Observer System A (A-TOS)	Three in-situ ionospheric measurements	Swarm of identical vehicles	Modified GINA with utilities; uncertainty analysis	93, 92, 91
B-TOS	Topside sounding of ionosphere and other missions	Swarm with central mother and small daughters	MATE with MAU; policy impact analysis	54, 94
C-TOS	Design vehicles for mission similar to B-TOS	Same as B-TOS	ICE with virtual co-location, risk chair	3
X-TOS	In-situ ionospheric measurements	1 or 2 independent vehicles	MATE-CON	14
Space Tug	Inter-orbit mass mover	Single or multiple vehicle	Simplified MATE-CON	57, 122
Small Diameter Bomb	Stand-off weapon	Single	MATE-CON with design evolution	Darleth Thesis
Space-Based Radar	Orbital surveillance and tracking	Constellation	MATE-CON with design evolution	65, Roberts Thesis
Generic launch customer base	Exercise launch policy model	Many vehicles and functions	Launch policy model	163
Actual launch vehicle histories	Provide data for Bayesian risk model	History of launch success/failure	Bayesian risk model	4
Generic satellite program	Exercise management risk model	One vehicle	SAM management risk model	139

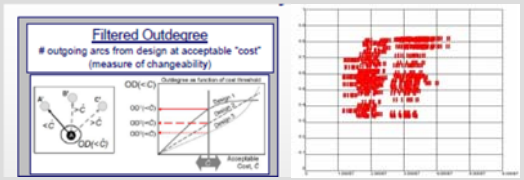


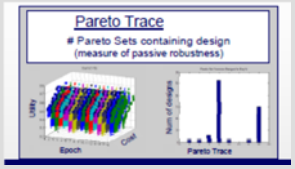
Innovation

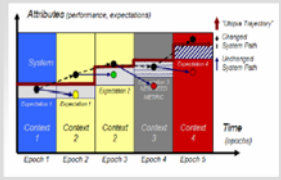
Has the method been sufficiently defined and elaborated as demonstrated by application in multiple cases?

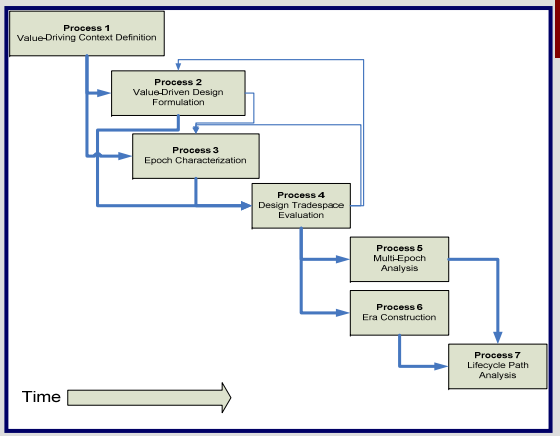
Multi-Method Synthesis
Innovation in Academic Research

Using Multi-Attribute Tradespace Exploration, Epoch-Era Analysis, and other approaches, a coherent set of processes were developed into the RSC method









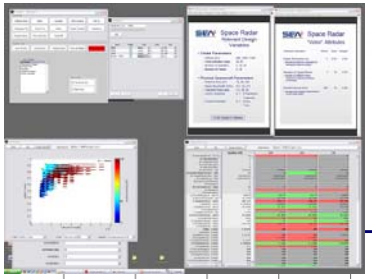
RSC seven processes:

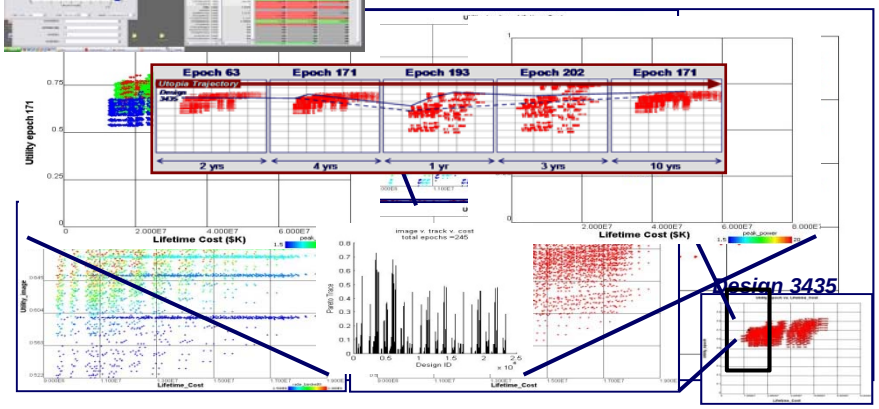
1. Value-Driving Context Definition
2. Value-Driven Design Formulation
3. Epoch Characterization
4. Design Tradespace Evaluation
5. Multi-Epoch Analysis
6. Era Construction
7. Lifecycle Path Analysis

Innovation **(combinatory)**

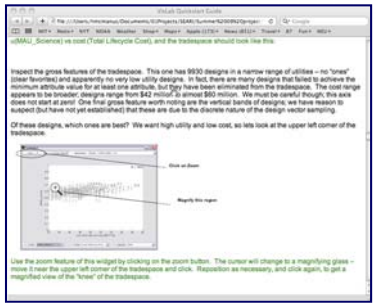
Can multiple research outcomes be combined (including with existing application practice/techniques) into a comprehensive new approach?

Real-world Application Phase
Ilities in Academic Research

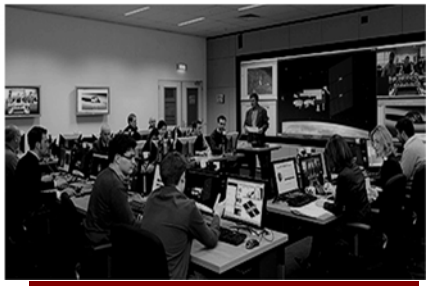




Methods and toolsets



Course materials and templates



Application in Laboratory

Ilities

Has the method been developed in consideration of its reliability, adaptability, evolvability, transferability, affordability….?