SERC Ilities Tradespace and Affordability Program (ITAP)

PROJECT DESCRIPTION:

- Build on previous SERC research, other research from Collaborators, and ERS to create MPTs to better analyze tradespace in complex systems

VALUE:

- Being able to quickly and rigorously analyze the tradespace of complex systems, especially with regard to "ilities" such as safety, resilience, and availability, will aid decision makers early in the life cycle in a project when alternative requirements, architectures, and implementation technologies are all under consideration.

STATUS:

- A workshop was held on July 18-19 to shape the specific research
- Project expected to begin in November
- There are several current SERC projects that informed the workshop, including *Valuing Flexibility* (RT-18), *Flexible Vehicle Requirements* (RT-26), and *Software-Intensive System Cost Models* (RT-6). Projects outside the SERC with which the SERC could collaborate were also identified

TEAM:

- USC, MIT, Stevens, Georgia Tech, UVA, Wayne State, AFIT, NPS

PAST AND CURRENT EFFORT:

- Almost $2.5M has been awarded on other SERC projects that informed the July 18-19 workshop that developed the project approach
- $345K from FY12 RDTE funds for first phase of research

FUTURE EFFORT AND TRANSITION:

- Approximately $700K in FY13 RDTE funding requested for second phase of research. Primary focus will be on maturing and piloting strongest existing toolsets.
- Projects outside the SERC with which the SERC may coordinate would provide overall funding several times OSD immediate investment

IMPLEMENTS:

- Thematic Area: *Systems Engineering Transformation*
- Strategies: *Make Smart Trades Quickly*

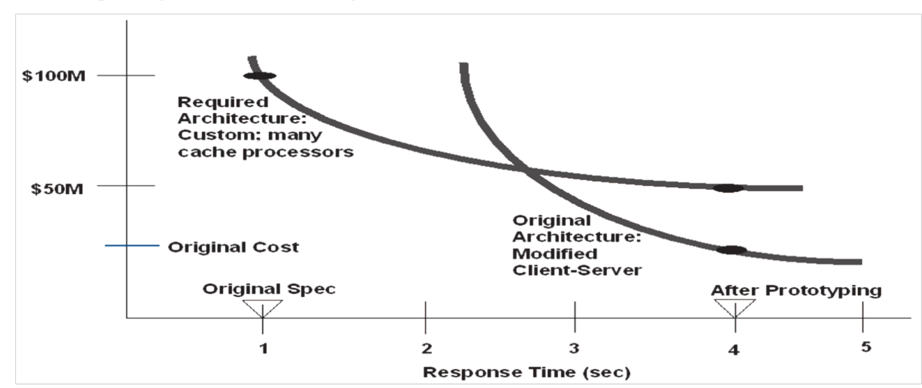
PHASE 1 PRODUCTS:

- Tech report on DoD priorities for ilities and their tradeoffs
- Tailoring and demonstration of current SERC tradespace and affordability toolsets at INCOSE IW, Jacksonville FL, Jan 28, 2013 and CSER, Atlanta GA, March 18, 2013
- Technical report on various frameworks for tradespace and affordability; e.g., value-based, means-ends based, process-based, and architecture-based
- New MPTs on tradespace and affordability

Importance of Ility Tradeoffs

Major source of DoD system overruns

- System ilities have systemwide impact
  - System elements generally just have local impact
- Ilities often exhibit asymptotic behavior
  - Watch out for the knee of the curve
- Best architecture is a discontinuous function of ility level
  - Build it quickly, tune or fix it later highly risky
  - Large system example below



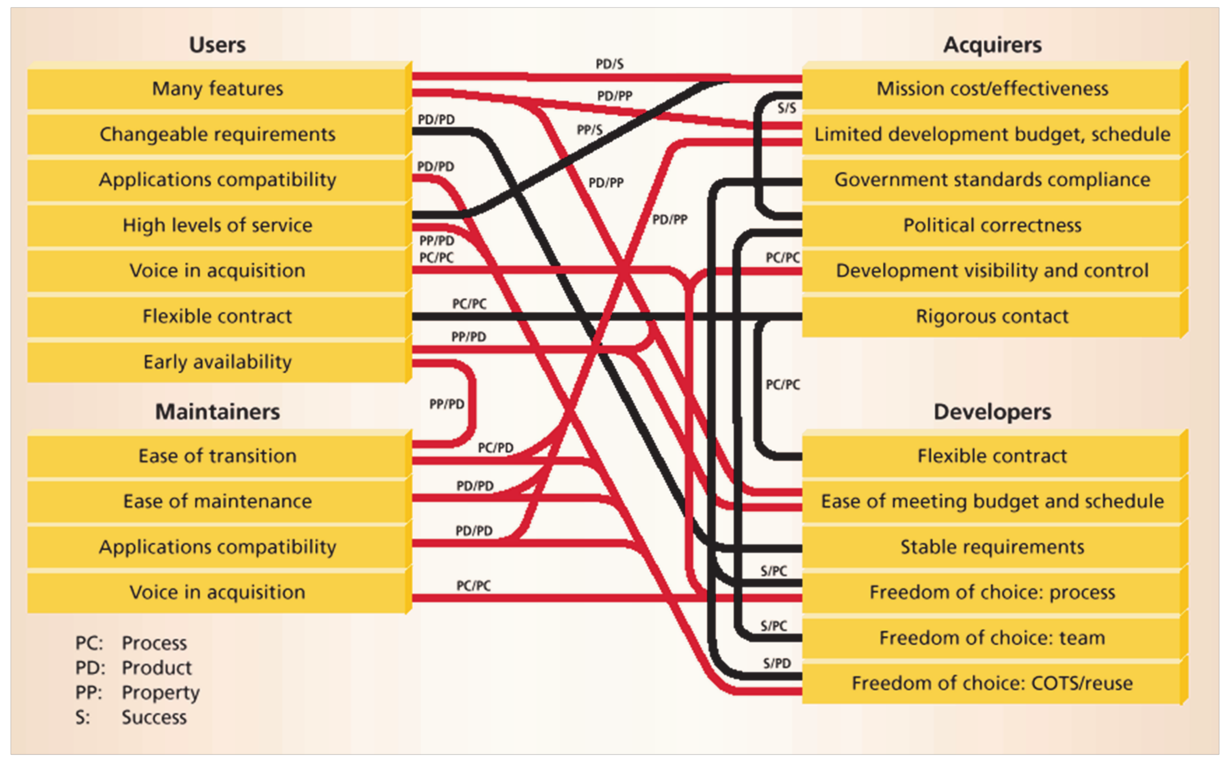
SERC Value-Based Ilities Hierarchy

Based on ISO/IEC 9126, 25030; previous SERC research

- Individual Ilities
  - **Quality of Service:** Performance, Accuracy, Usability, Scalability, Versatility
  - **Resource Utilization:** Cost, Duration, Personnel, Scarce Quantities (size, weight, energy, …)
  - **Protection:** Safety, Security, Privacy
  - **Robustness:** Reliability, Availablilty, Maintainability
  - **Flexibility:** Modifiability, Tailorability/Extendability, Adaptability
  - **Composability:** Interoperability/Portability, Openness/Standards Compliance, Service-Orientation
- Composite Ilities
  - **Suitability:** all of the above
  - **Dependability:** Quality of Service, Protection, Robustness
  - **Resilience:** Protection, Robustness, Flexibility
  - **Affordability:** Quality of Service, Resource Utilization

Role-Based Ilities Value Diversity

Bank of America Master Net: DoD?



Means-Ends Framework: Affordability

Affordability Improvements and Tradeoffs

- Get the Best from People
  - Staffing, Incentivizing, Teambuilding
  - Facilities, Support Services
  - Kaizen (continuous improvement)
- Make Tasks More Efficient
  - Tools and Automation
  - Work and Oversight Streamlining
  - Collaboration Technology
- Eliminate Tasks
  - Lean and Agile Methods
  - Task Automation
  - Model-Based Product Generation
- Eliminate Scrap, Rework
  - Early Risk and Defect Elimination
  - Evidence-Based Decision Gates
  - Modularity Around Sources of Change
  - Incremental, Evolutionary Development
  - Value-Based, Agile Process Maturity
  - Risk-Based Prototyping
- Simplify Products (KISS)
  - Value-Based Capability Prioritization
  - Satisficing vs. Optimizing Performance
- Reuse Components
  - Domain Engineering and Architecture
  - Composable Components, Services, COTS
  - Legacy System Repurposing
- Reduce Operations, Support Costs
  - Automate Operations Elements
  - Design for Maintainability, Evolvability
  - Streamline Supply Chain
  - Anticipate, Prepare for Change
- Value- and Architecture-Based Tradeoffs and Balancing

Architecture-Based Framework: Flexibility

From SERC RT-18, Valuing Flexibility

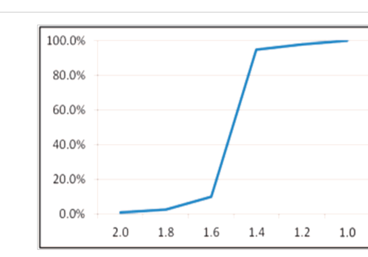
Flexibility Arch. Strategy	Synergies	Conflicts
High module cohesion; Low module coupling	Interoperability Reliability	High Performance via Tight coupling
Service-oriented architecture	Composability, Usability, Testability	High Performance via Tight coupling
Autonomous adaptive systems	Affordability via task automation; Response time	Excess autonomy reduces human Controllability
Modularization around sources of change	Interoperability, Usability, Reliability, Availability	Extra time on critical path of Rapid Fielding
Multi-layered architecture	Reliability, Availability	Lower Performance due to layer traversal overhead
Many built-in options, entry points	Functionality, Accessibility	Reduced Usability via options proliferation; harder to Secure
User programmability	Usability, Mission Effectiveness	Full programmability causes Reliability, Safety, Security risks
Spare/expandable capacity	Performance, Reliability	Added cost
Product line architecture, reusable components	Cost, Schedule, Reliability	Some loss of performance vs. optimized stovepipes

AFIT: CEVLCCC Tool

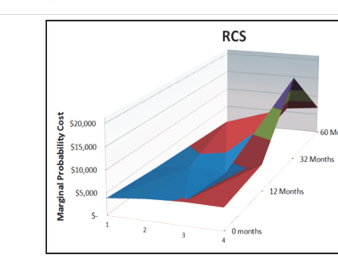
1. Specify design options

2. Identify reqmnts that will be useful for discriminating between designs

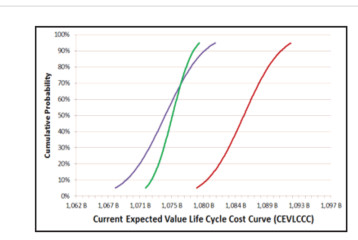
3. Estimate probabilities of threshold value changes in each reqmnt



4. Relative to each design, estimate cost impacts for each potential threshold value change



5. Evaluate expected LCC curve (CDF) and choose design that corresponds to most favorable curve

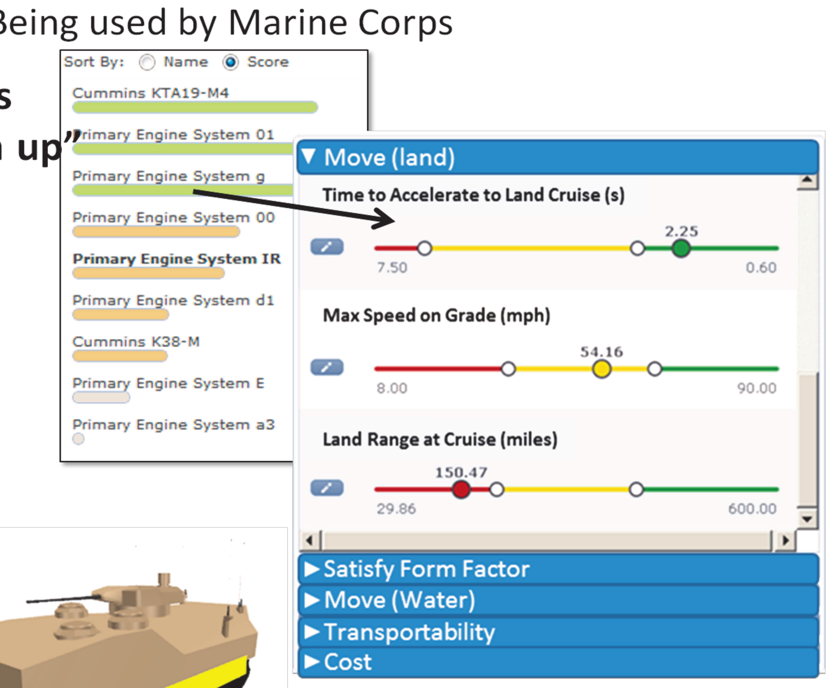


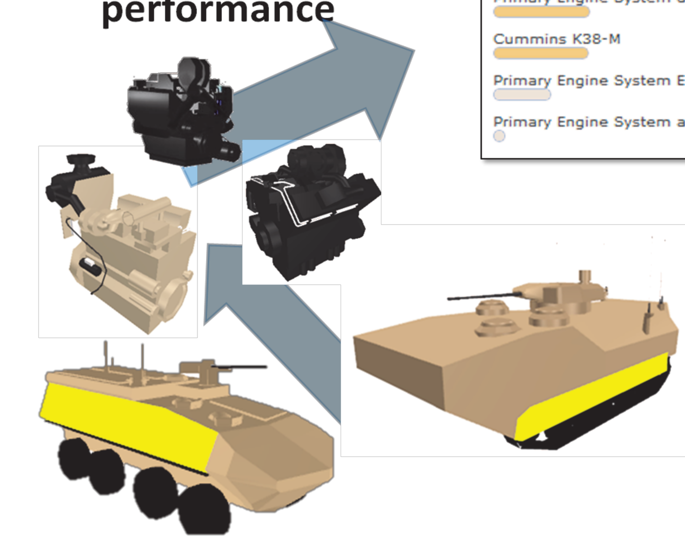
GaTech – FACT Tradespace Tool

NOT FINAL: DRAFT FOR PEER REVIEW

Being used by Marine Corps

- Configure vehicles from the "bottom up"
- Quickly assess impacts on performance

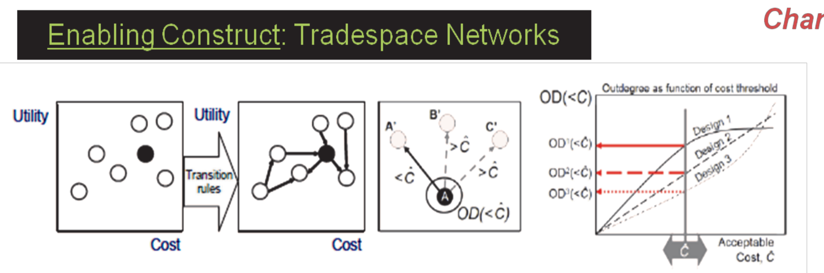




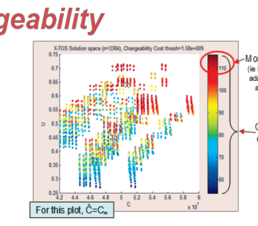
MIT: Ilities in Tradespace Exploration

Based on Lean Aerospace, DARPA research

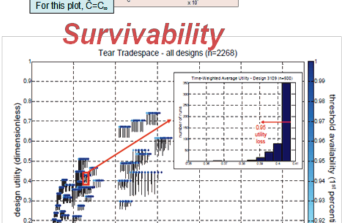
Enabling Construct: Tradespace Networks



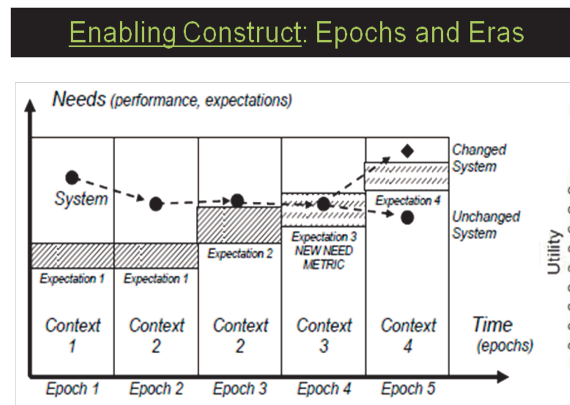
Changeability



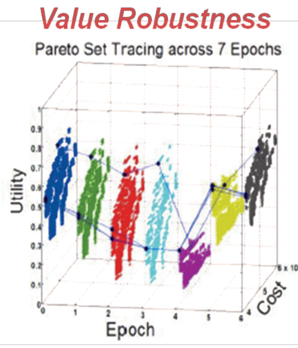
Survivability



Enabling Construct: Epochs and Eras



Value Robustness



Set of Metrics

Value Aspect	Acronym	Stands For	Definition
Robustness via "no change"	NPT	Normalized Pareto Trace	% epochs for which design is Pareto efficient in utility/cost
Robustness via "no change"	fNPT	Fuzzy Normalized Pareto Trace	Above, with margin from Pareto front allowed
Robustness via "change"	eNPT, efNPT	Effective (Fuzzy) Normalized Pareto Trace	Above, considering the design's end state after transitioning
"Value" gap	FPN	Fuzzy Pareto Number	% margin needed to include design in the fuzzy Pareto front
"Value" of a change	FPS	Fuzzy Pareto Shift	Difference in FPN before and after transition
"Value" of a change	ARI	Available Rank Increase	# of designs able to be passed in utility via best possible change
Degree of changeability	OD	Outdegree	# outgoing transition arcs from a design
Degree of changeability	FOD	Filtered Outdegree	Above, considering only arcs below a chosen cost threshold
Survivability	TWAUL	Time-weighted Average Utility Loss	Measure of central tendency of value losses over time for a design, as a result of experienced disturbances
Survivability	AT	Threshold Availability	% of lifetime for which design delivers utility above minimum acceptable levels before, during, and after a disturbance

NPS-USC Reusability ROI Model

Payoff multiplies with #products, operational lifetime

SYSTEMS ENGINEERING Research Center

Systems Product Line Flexibility Value Model

Preferences

Welcome SERC Collaborator

Open | Save | Save As

System Costs

Average Product Development Cost (Burdened $M): 5 — Ownership Time (Years): 3

Annual Change Cost (% of Development Cost): 10 — Interest Rate (Annual %): 7

Product Line Percentages

Unique %: 40

Adapted %: 30

Reused %: 30

Relative Costs of Reuse (%)

Relative Cost of Reuse for Adapted: 40

Relative Cost of Reuse for Reused: 5

Investment Cost

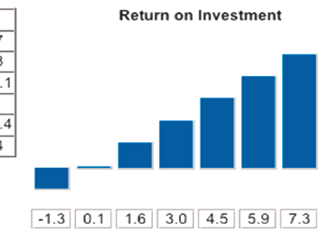
Relative Cost of Developing for PL Flexibility via Reuse: 1.7 — Sensitivity: Off

Calculate

Results

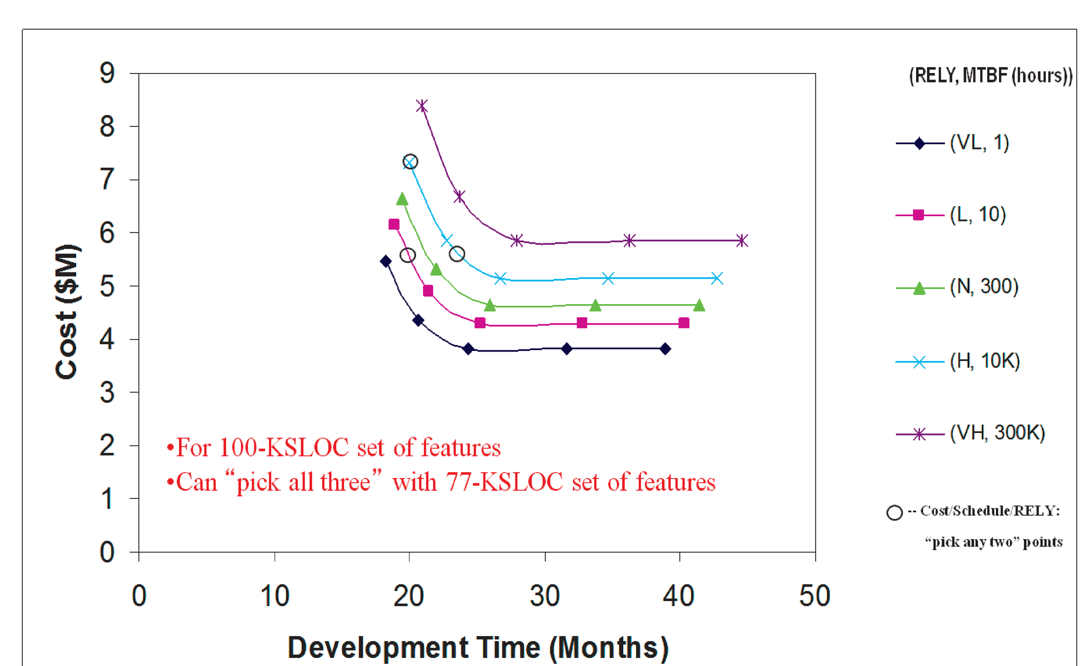
# of Products	1	2	3	4	5	6	7
Development Cost ($M)	$7.1	$2.7	$2.7	$2.7	$2.7	$2.7	$2.7
Ownership Cost ($M)	$2.1	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8
Cum. PL Cost ($M)	$9.2	$12.7	$16.2	$19.7	$23.1	$26.6	$30.1
PL Flexibility Investment ($M)	$2.1	$0	$0	$0	$0	$0	$0
PL Effort Savings	($2.7)	$0.3	$3.3	$6.3	$9.4	$12.4	$15.4
Return on Investment	-1.30	0.14	1.58	3.02	4.46	5.90	7.34

Return on Investment



USC: COCOMO II-Based Tradeoff Analysis

Better, Cheaper, Faster: Pick Any Two?



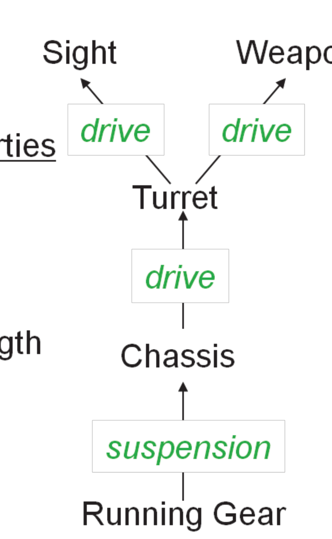
WSU: Versatility Factors and Physical Organization

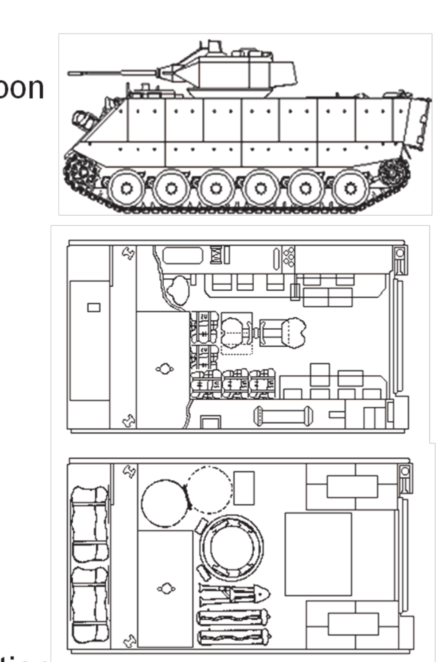
Components that Can be in Different Positions or Orientations

Isolated or Separated Compartments

Mass & Structure Properties

- Mass
- Angular moments
- Imbalances*
- Load bearing wall strength
- Deck surface area
- Interior volumes**
- Interior surface areas**





*Angular moments of the CG about axes of rotation

** By crew station and compartment