DoD's Engineered Resilient Systems (ERS) S&T Priority

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A Quote from the former Secretary of Defense, Dr. Robert Gates

The Honorable Dr. Robert M. Gates, 22nd Secretary of Defense, interview at The American Enterprise Institute, carried on CSPAN, 24 May 2011

...our record of predicting where we will use military force since Vietnam is perfect. We have never once gotten it right.

There isn't a single instance ... where we knew and planned for such a conflict six months in advance, or knew that we would be involved as early as six months ahead of time.

So my mantra actually has been for the last several years in the department that, as we train and as we equip, we need to have in mind the greatest possible flexibility and versatility for the broadest range of conflict....

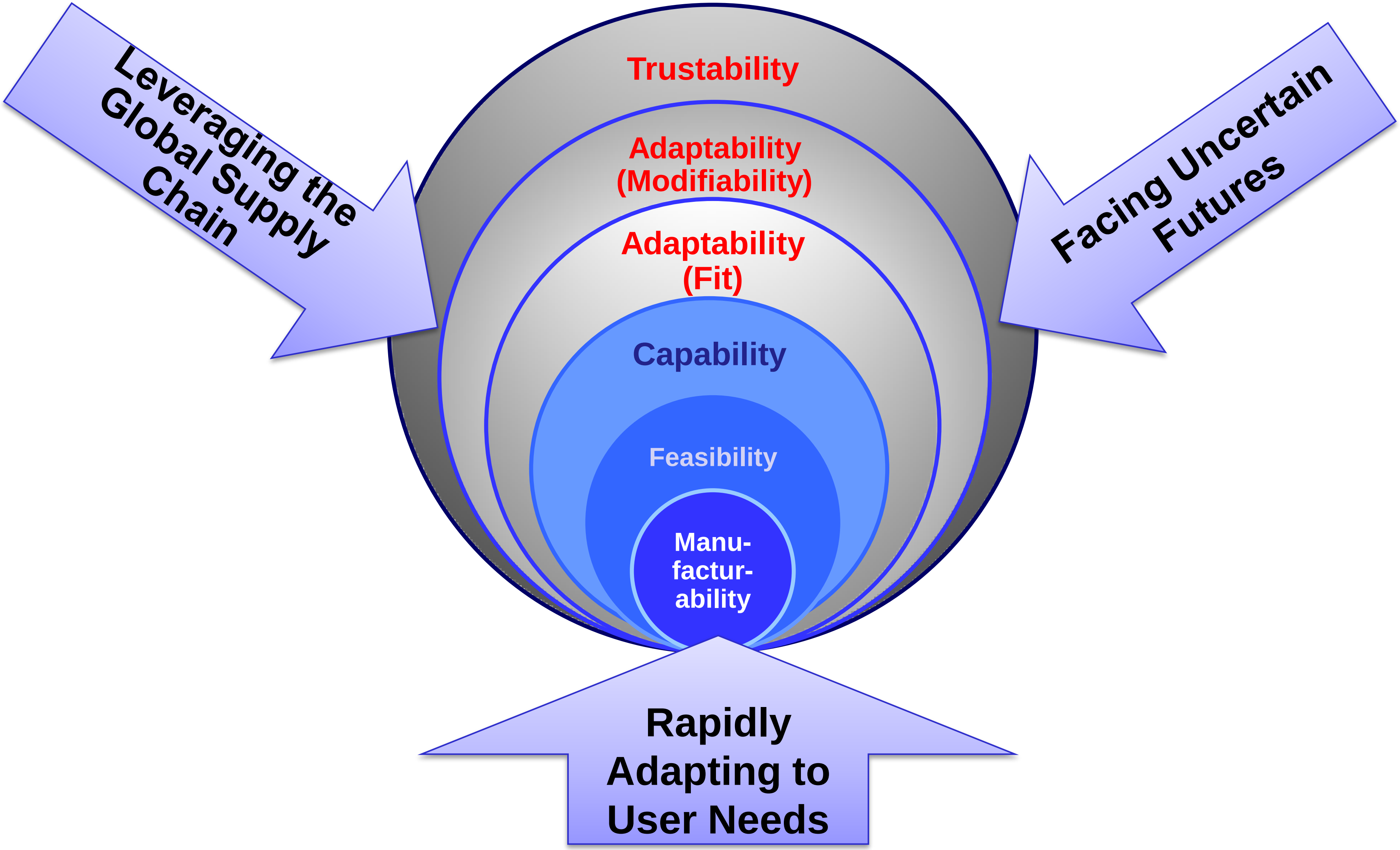
Engineered Resilient Systems Problem Statement

Uncertain futures & threats outpace our ability to create & field affordable, effective systems

***Change happens* – *we need to design for it*.**
But, today, instead...

- **Adaptability, trustability and affordability are not sufficiently considered** when making tradeoffs
  - ...and are also not maintained when modifications occur during design, manufacturing, and fielding
- **Effective design is hobbled:** engineers hear too little about warfighters' / stakeholders' needs; and too little information about design feasibilities and opportunities gets fed back
- **Cost/schedule slip is highly likely when problems arise, requirements change, or adaption is needed:** Too few alternative designs are considered in depth, nor are they kept active very long
- **Uncertainties compound when planning horizons grow:** long design-test-build-field-adapt lead-times exacerbate uncertain futures problems, overload designs, and lock out new technologies

21st Century Dynamics Require New Design Constraints



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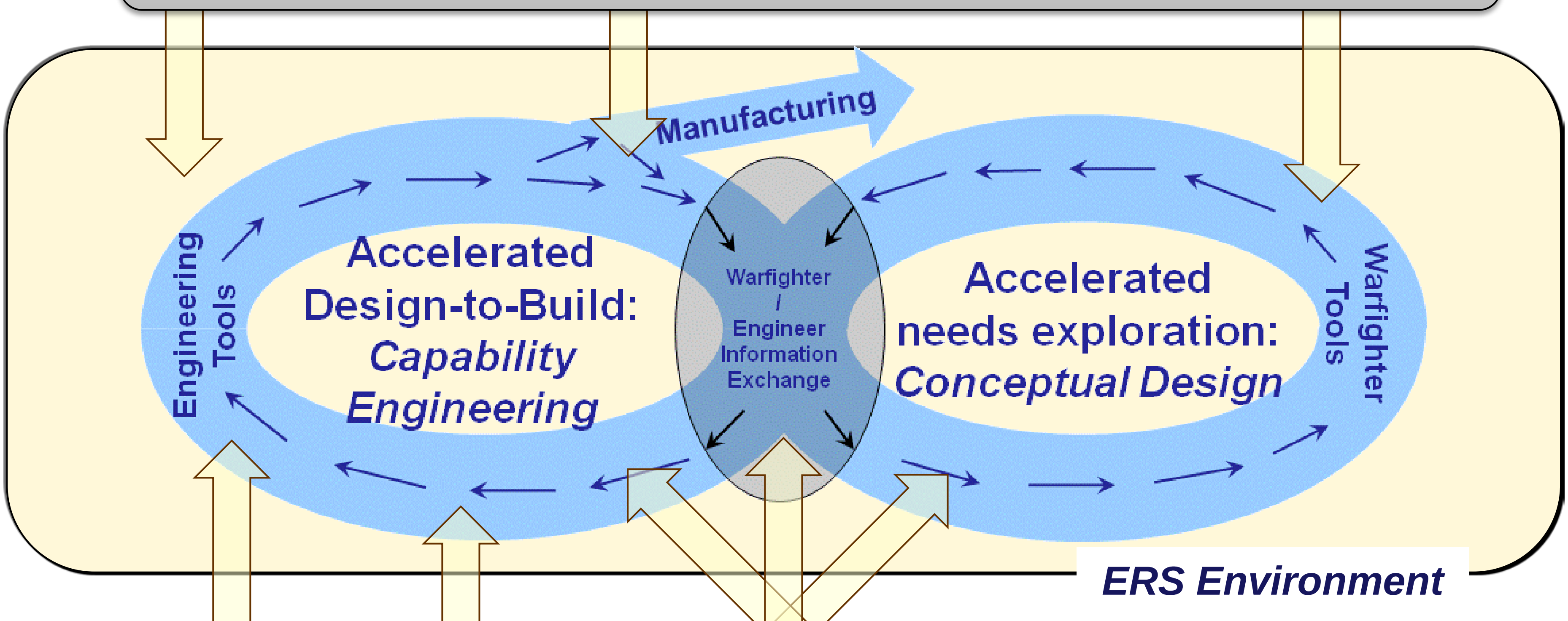
ERS: Tools and Technologies to Facilitate Adaptability & Trustability

ERS Technology Toolbox

1. Trustability: design patterns, analytic tools

4. Tying design, physical and computational testing

6. Instrumented virtual and live environments



2. Platform-Based analysis & architecting

3. Model-Based tools: analysis and simulation

5. Tradespace exploration

ERS Technology Toolbox

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Goals / End States

Engineering of Defense Systems Capable of Supporting Rapidly Changing Warfighter Needs

R&D in ERS enables agile and cost effective design, development, testing, manufacturing, and fielding of trusted, assured, easily modified defense systems

ERS delivers science, engineering concepts, processes, and design tools to:

- **Continuously coordinate design, testing, and production with warfighter review to facilitate earliest possible safe field use of needed capabilities**
- **Generate an efficient set of design points spanning the design space**
- **Ensure that tradeoffs among alternative designs are better understood, and that tradeoffs bearing on time, cost, trust and adaptability get appropriate consideration**
- **Facilitate adaptability via both reconfigurable product families and design diversity**
- **Consider a wide range of conditions and ConOps during design and testing**
- **Protect against unintentional or malicious compromise of weapon systems through the supply chain**
- **Reduce the time needed to reconfigure, substitute or otherwise adapt systems to rapidly changing conditions or operational concepts**
- **Provide a distributed collaborative engineering environment with seamless two-way transfer of data between tools enabling design, engineering, production/manufacturing, and operational evaluation**

Enabling Technologies for Making Informed Decisions about Systems Designed for Trustability and Adaptability – with Timely and Affordable Results

Synthetic Environments for Assessment
(Mission Centric Design Support)

Early Warning Systems for Downstream Issues:

- **Tradespaces**
- **Testing sufficiency**
- **Computational Test and Validation of Process Plans (e.g., Manufacturability, Supply Chain Risk,...)**

Cross-level consistency / interoperability of models (scale, physics)

Efficient, sufficiently veridical Physical & Engineering (product, environmental) Models
(System Centric Design Support)

(Distributed Infrastructure Support)
Configurable Collaborative Engineering Environments and Processes
Human-provided Guidance and Coordination Mechanisms

Emerging Technical Opportunities

1. **Trustability: design patterns and tools**
   Adapt/extend reliability-inspired methods
   - Integrating reliability and cost approaches
   - Reasoning about risk and uncertainty
   - New sensitivity localization algorithms

2. **Platform-Based analysis & architecting:**
   New analysis tools for designing platforms, rapidly adapting systems
   - Identifying high-impact variables, and likelihoods of emergent interactions
   - Algorithms for measuring adaptability
   - Risk-based cost-benefit analysis tools for platforms and designs, "uncertainty bars"

3. **Model-based tools: analysis & simulation**
   New products / product line options
   - On-demand composition of models and simulation/analysis workflows
   - Maintaining consistency across hybrid models (not unintelligible monolithic models)
   - Using semantic features to create and repair mappings between modeling systems

4. **Tying design, physical/computer tests**
   Linked temporal & physical models
   - Simulations combining live and virtual elements
   - Acquisition and cross-integration of physics-based vs. statistical models
   - Critical new models: e.g., deformable and moving objects

5. **Tradespace exploration:**
   Collaborative options exploration
   - Guiding automated searchs
   - Advanced algorithms and massive computing for exploring alternative options
   - Envisionment of multi-dimensional tradespaces

6. **Instrumented live and virtual environments for ConOps Exploration**
   - Game and scenario writing tools
   - Discussion, annotation, collaboration in augmented reality environments
   - Visualization and explanation tools to assist in prioritizing tradeoffs, explaining decisions

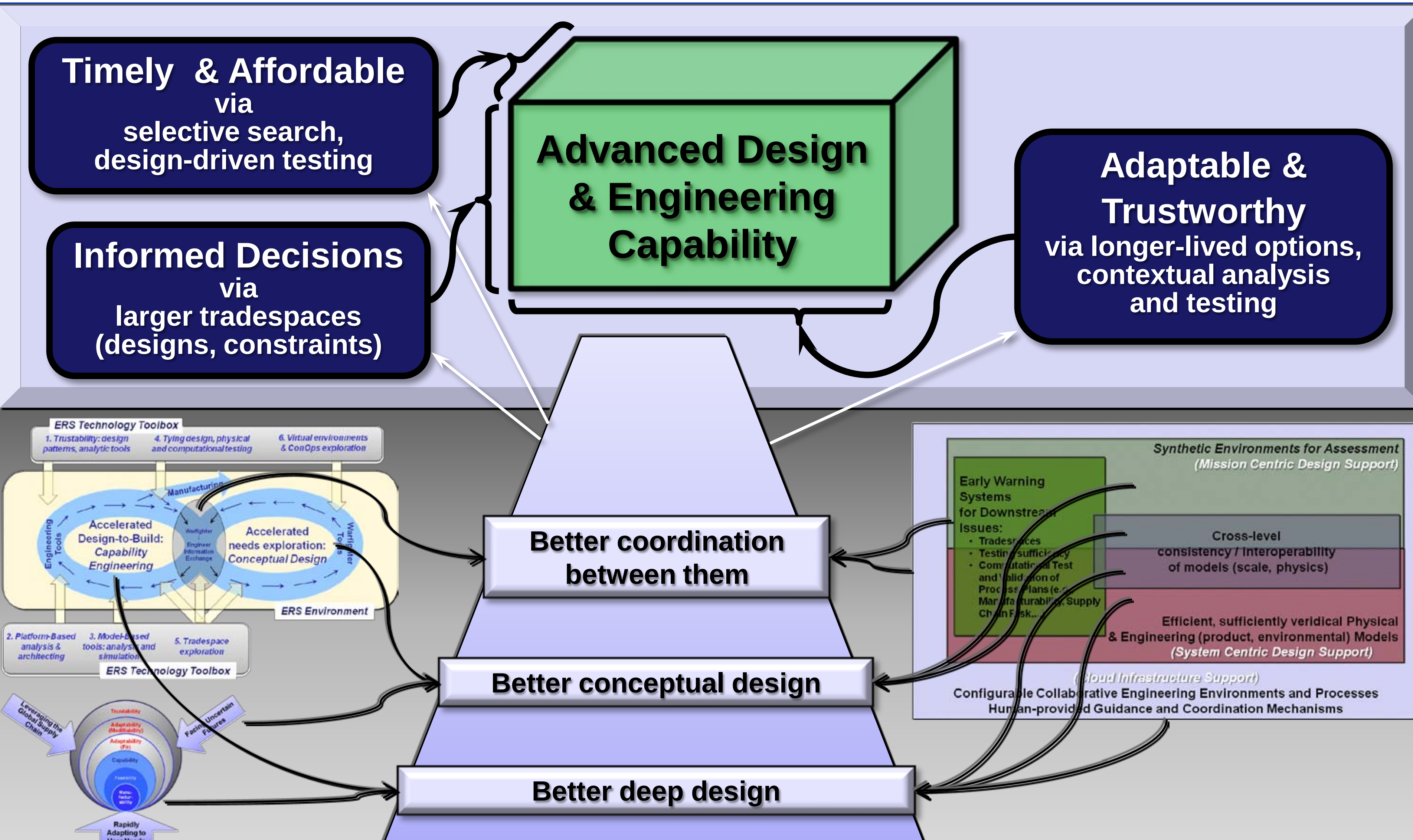
Basic Science Issues

- **Scale and Complexity mean that humans cannot do the job unassisted**
  - Algorithms for selective search of intractably large spaces are needed to manage the combinatorial explosion
  - Human-guided search, and social networking techniques will also play a role
- **New challenges for large distributed architectures**
  - Efficient execution and coordination of large processing that is widely distributed and highly stochastic but partly parallel
- **New technology of interchange between discrete event, process and mathematical models will be needed to further manage tractability**
  - Models will need to be learned and refined from instrumenting physical tests and live systems
- **New human interface tools and approaches for decision support**
  - How do we help people understand the extent of coverage of mission possibilities?
  - How do we help people understand impact of requested design features/properties/capabilities and their interactions on affordability, delivery time, cost, and mission range?
- **New mathematical and statistical approaches to testing complexity and model validation**
  - Uncertainty representation and analysis (risk and confidence intervals)
  - Game theoretic approaches to finding design tradeoff win-wins
- **Physics and engineering disciplines**
  - Understanding the actual phenomena we want to capture in multi-scale, multi-physics models
  - Validating multi-scale, multi-physics models

Novel Elements of Approach

- **Focus on re-design: retrofit/upgrade/adapt faster and cheaper**
- **Selectively explore feasible variations, reconfigurations, extensions**
- **Three lines of defense against change and uncertainty:**
  - Mission-oriented design for adaptability, with testing against broad range of missions and environments, prepares for the “known unknowns”
  - Diversity from *longer retention* of *multiple* designs avoids fragility of monoculture
    - Increases chances of having options that will address any “unknown unknowns”
    - Forcing the entire process to be open to alternatives, architects the engineering process to facilitate as rapid and agile a response as possible -- even in the worst case
  - Reduced engineering times enable tighter (therefore less uncertain) planning horizons
- **Focus on design and testing *in context, with stakeholders***
  - Model more of the operating environment
  - Explore and evaluate current and future scenarios, jointly with associated CONOPS
  - Design and evaluate for *mission capability* rather than disjoint technical parameters

The Path to Achieving, "Agile and cost effective design, development, testing, manufacturing, and fielding of trusted, assured, easily modified defense systems"



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Key ERS Goals, Concepts and Notional Roadmaps

Informed Decisionmaking

- Increasing the availability of engineering choices and the ability to assess consequences of of those choices

Trustworthy and Adaptable Design

- Encouraging design for reliability, testing designs across many contexts (including degraded functioning), keeping options open, and learning from inspecting alternatives

Affordable and Timely

- As fast as possible for the problem addressed – minimizing unnecessary effort both reduces time and the cost of standing armies of engineers