



# **Complexity: Driver of Systems Engineering**

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**Principal Deputy**

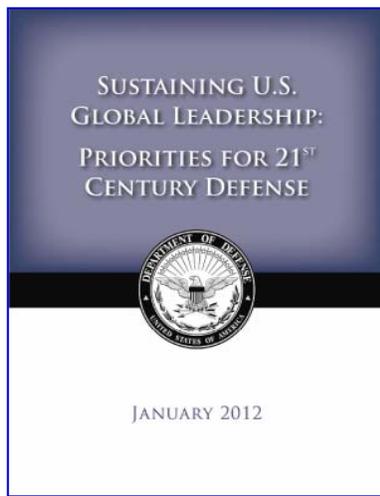
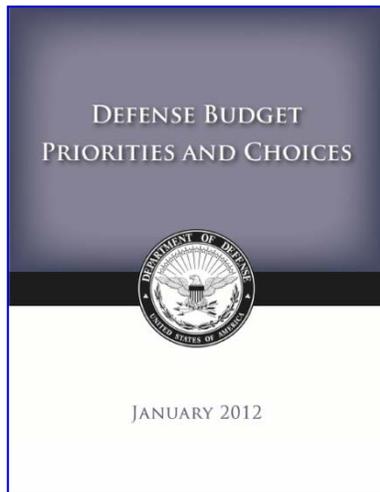
**Office of the Deputy Assistant Secretary of Defense  
for Systems Engineering, OUSD(AT&L)**

**NDIA SE Division Meeting**

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# Reflecting on Defense Strategic Guidance



- The military will be smaller and leaner, but it will be agile, flexible, ready and technologically advanced.
- Rebalance our global posture and presence to emphasize Asia-Pacific regions.
- Build innovative partnerships and strengthen key alliances and partnerships elsewhere in the world.
- Ensure that we can quickly confront and defeat aggression from any adversary – anytime, anywhere.
- Protect and prioritize key investments in technology and new capabilities, as well as our capacity to grow, adapt and mobilize as needed.



# DoD at Strategic Crossroads



**Chuck Hagel**  
Secretary of Defense  
24 Feb 2014

“The development and proliferation of more advanced military technologies by other nations means that we are entering an era where American dominance on the seas, in the skies, and in space can no longer be taken for granted.”

**The strategic question is – will the force of tomorrow be:**

- Larger with diminished capability or,
- Smaller with more technologically advanced capabilities



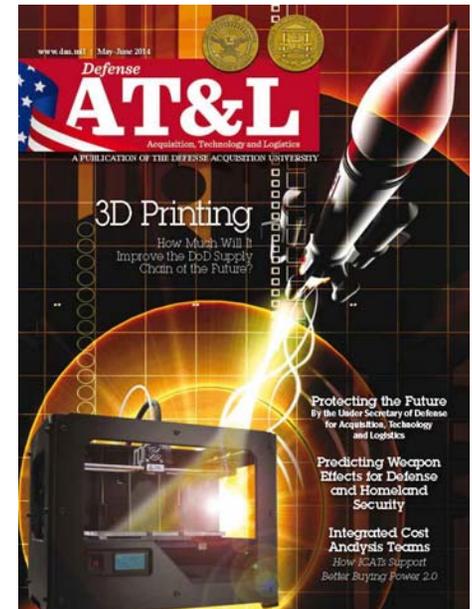
# USD(AT&L) Priority “Protect the Future”



**Frank Kendall**  
USD (AT&L)

***“I am concerned about protecting the adequacy of our research and development (R&D) investments in capabilities and systems that will allow us to dominate on future battlefields and keep engineering design teams who develop advanced defense systems.”***

***“[Peer competitors] are developing cutting-edge military capabilities that are designed to defeat current and planned U.S. capabilities.”***



Protecting the Future,  
Defense AT&L Magazine,  
May-June 2014, Pg. 2



# What Drives Complexity in Defense Systems?



<b>Contributors</b>	<b>Complicated By</b>
<b>Operations</b>	<b>Assuring current mission performance while maintaining ability to support predicted and unknown future operational needs</b>
<b>Fiscal Realities</b>	<b>Reduced forces, reduced budgets; ensuring affordability as part of the systems tradespace</b>
<b>Software</b>	<b>Critical dependence on software; sheer amount of code; can we develop, integrate, maintain and assure our software?</b>
<b>Systems of Systems</b>	<b>Integration of multiple systems to achieve mission effects which may or may not be their primary design requirement</b>
<b>Security</b>	<b>The threat has unprecedented access to our technical data - - and can capitalize on this</b>



# How Does Complexity Drive SE?



## Critical attributes of DoD Systems Engineering

- Flexible designs that adapt and are resilient to unknown missions and threats
- Ability to quantify cost and affordability attributes of the design trade space
- Systems of Systems, and Enterprise contexts driving requirements from multiple stakeholders
- Responsive, and able to balance agility with rigorous analysis and data
- Safeguarding critical information while designing for interoperability and global markets
- Applied across significantly diverse domains

**Balancing these attributes is challenging to SE, drives the state of the practice, and stresses critical workforce capacity**



# Defense Research & Engineering Strategy



## Technology Needs

### 1. Mitigate new and emerging threat capabilities

- Cyber
- Space Capability
- Electronic Warfare
- Counter-WMD

### 2. Affordably enable new or extended capabilities in existing military systems

- Systems Engineering
- Prototyping
- Developmental Test
- Modeling and Simulation
- Interoperability

### 3. Develop technology surprise through science and engineering

- Autonomy
- Human Systems
- Data-to-Decisions
- Basic Research

The screenshot displays the Defense Innovation Marketplace website. The top section features a network diagram with nodes and connections, overlaid with a 3D visualization of a military vehicle and its associated systems. Below this, the website header includes the title 'DEFENSE INNOVATION MARKETPLACE' and a navigation menu with icons for various domains. The main content area is titled 'CONNECTING INDUSTRY & GOVERNMENT' and contains text describing the marketplace's role in connecting industry and government. A large image of a military vehicle is visible on the right side of the page. At the bottom, there are several bullet points listing technology needs.

- Cyber / Electronic Warfare
- Engineering / Modeling and Simulation
- Capability Prototyping
- Protection & Sustainment
- Advanced Machine Intelligence
- Anti-Access/Area Denial



# Inter-agency Cooperation

## Inter-agency Working Group for Engineering of Complex Systems

- Develop common understanding of problems
- Collaborate, share expertise and resources
- Position Paper at [iawg.info](http://iawg.info)

### Current Participants:

- National Science Foundation
- National Aeronautics and Space Administration
- Department of Defense
- National Institute of Standards and Technology
- Department of Energy
- Department of Transportation
- Department of Homeland Security
- Federal Aviation Administration

“We need to investigate the core principles of engineering & science that lay the foundation for significant, next generation advances in cross-discipline engineering practice and education in multi-scale environments.”

*IAWG Joint Statement*





# Systems Engineering Research



- **DoD established the SERC, a University Affiliated Research Center (UARC) in September 2008**
  - Long term, strategic relationship with DoD and the Intelligence Community to advance systems engineering research
  - Five-year contract with Stevens Institute of Technology with 22 collaborating universities
- **2014-2018 Technical Plan aligns Research Strategy with DoD SE needs in 4 research thrusts:**
  - Systems Engineering and Management Transformation
  - Enterprise Systems & System-of-Systems
  - Trusted Systems
  - Human Capital
- <http://www.sercuarc.org>



*Shaping the future of systems engineering*



# Initiatives Addressing SE and Complexity

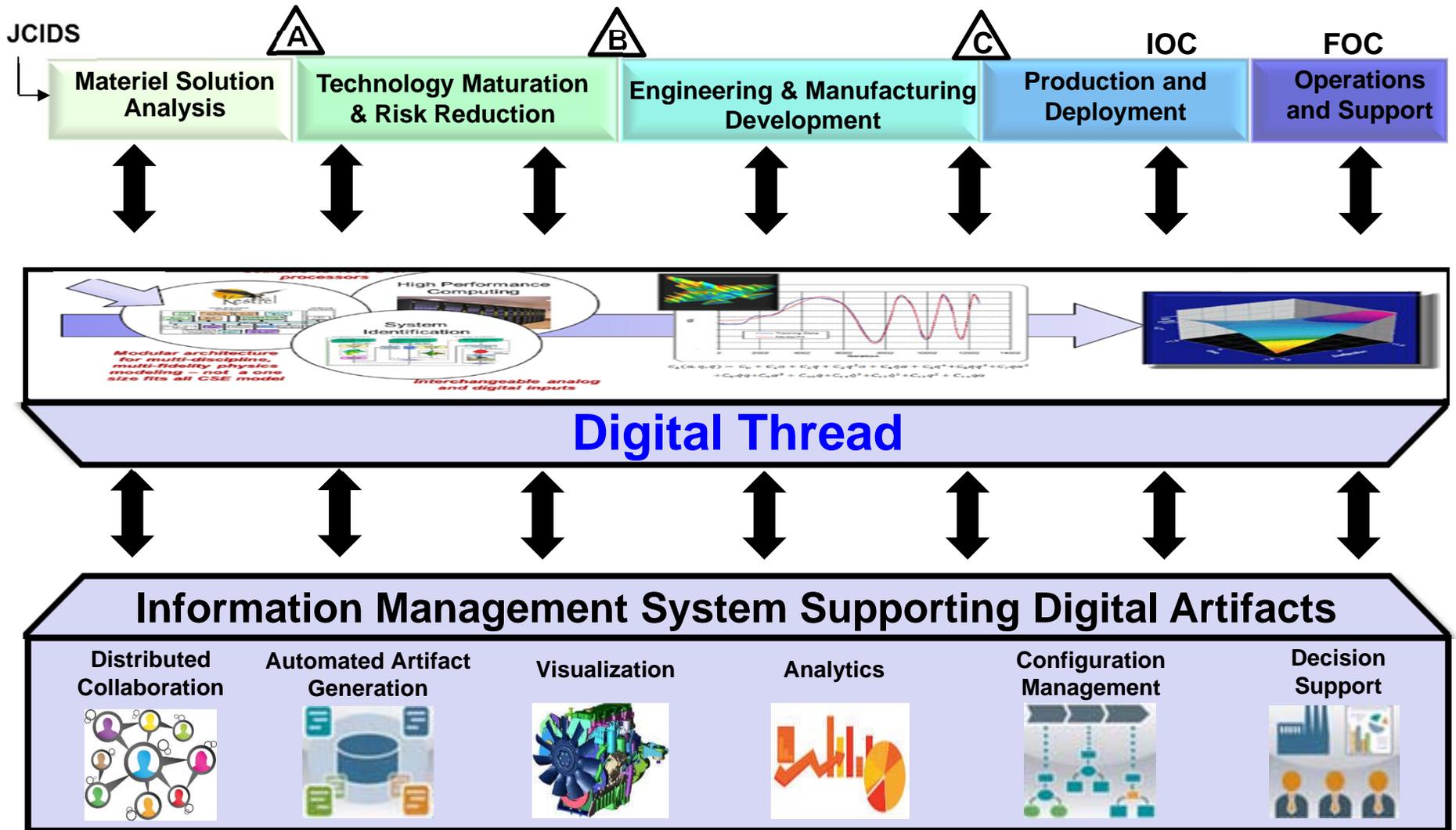


**In addition to outreach and research efforts in this area, several DoD initiatives also focus on complex engineering challenges:**

- Digital System Model
- Engineered Resilient Systems
- Open Systems Standards
- Safeguarding Technical Information and Supply Chain Security

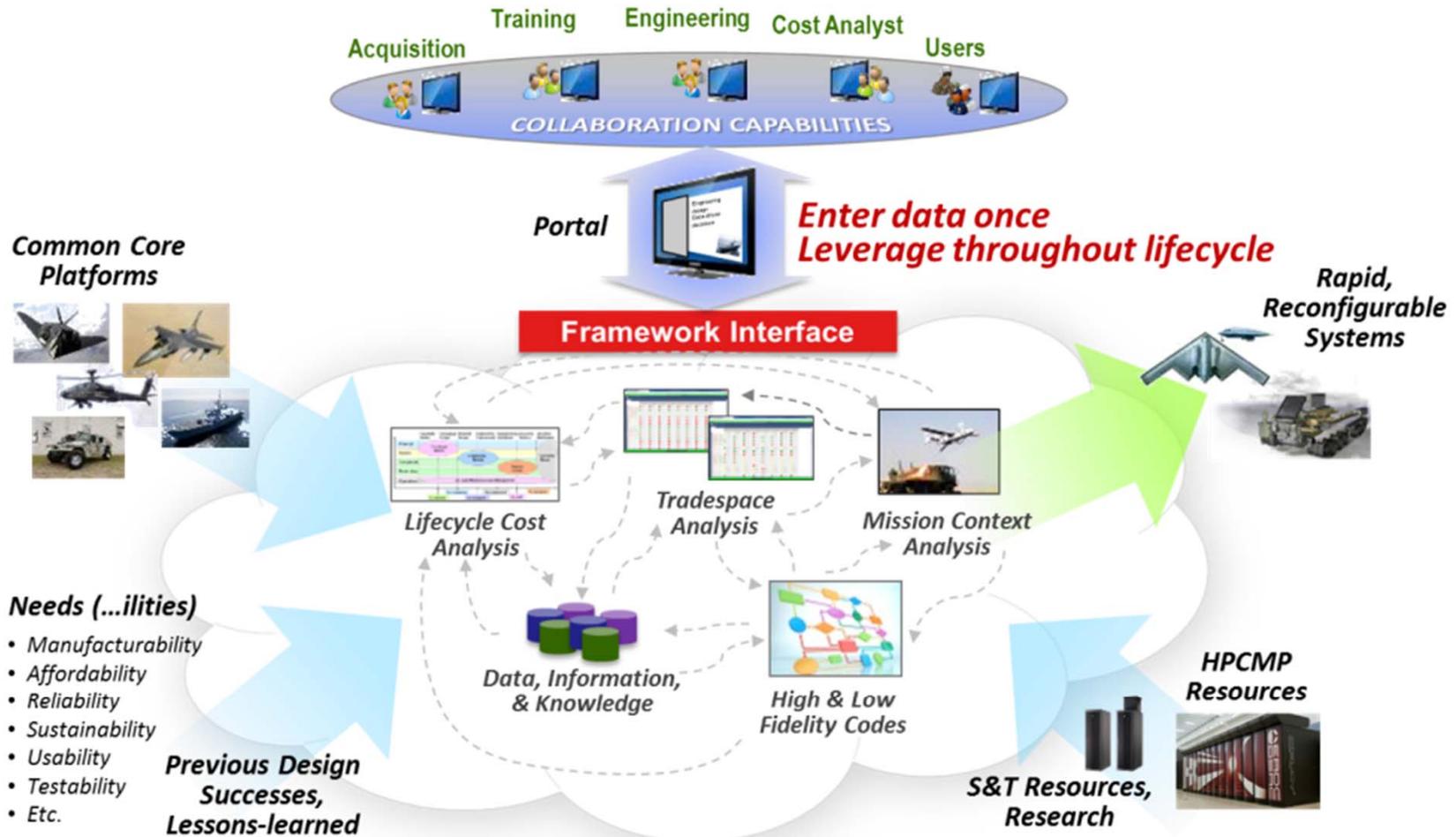


# Digital System Model





# Engineered Resilient Systems



**Science and technology to increase engineering productivity  
to address changing threats and missions**



# Engineered Resilient Systems Major Investment Areas



## Mission-Relevant Tradespace Analysis



**Cross-domain Tradespace Analytics, Cost/Lifecycle Analysis, Integration of Manufacturability, Producibility, and other “-ilities”**

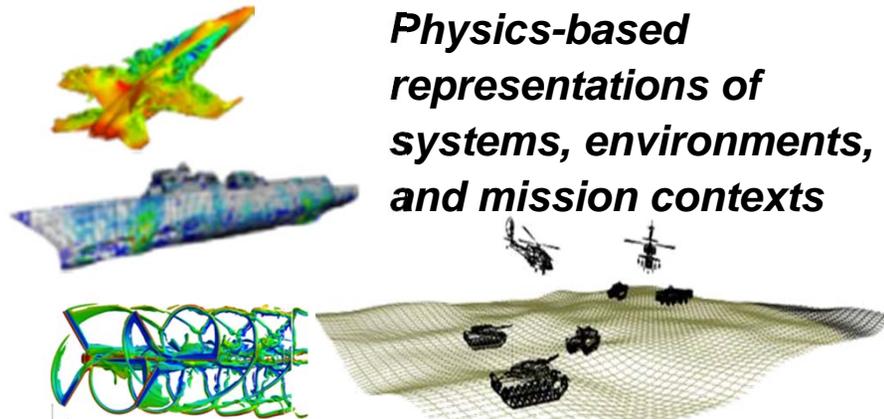
## Collaborative Analysis and Decision-Making



**Knowledge management and decision support across communities**



## Conceptual, Computational, and World-Wide Environmental Representation



**Physics-based representations of systems, environments, and mission contexts**

## ERS Capability Integration and Demonstration



**Open, extensible architectural framework that integrates representations, tradespace, and analysis tools**

**Continual technology insertion --  
Continual demonstration**



# Open Systems Considerations in Development



## Establish an Environment for Change

- Be clear about intent to compete/re-compete
- Establish a flexible contracting approach
- Incentivize good behavior among contributing contractors

## Focus Systems Engineering for Openness

- Develop common architectures across a product line or across related product families
- Functionally decompose legacy capabilities



## Leverage and Exercise Data Rights

- Assess current and needed data rights
- Confirm that data rights restrictions are correct and assert rights
- Use government purpose rights (GPR) for next competition

## Explore Business Architectures and Sound Competition Approaches

- Create alternatives
- Inject OSA through technical insertions
- Consider alternative integration concepts
- Ensure incentives align with desired behaviors
- Reward reuse

***Open Systems – A Key Contributor to a Resilient Design  
- Increasing the Cycles of Innovation -***



# Many Supply Chain Risks to Consider



## Quality Escape

Product defect/inadequacy introduced either through mistake or negligence during design, production, and post-production handling resulting in the introduction of deficiencies, vulnerabilities, and degraded life-cycle performance.

## Reliability Failure

Mission failure in the field due to environmental factors unique to military and aerospace environment factors such as particle strikes, device aging, hot-spots, electro-magnetic pulse, etc.

## Fraudulent Product

Counterfeit and other than genuine and new devices from the legally authorized source including relabeled, recycled, cloned, defective, out-of-spec, etc.

## Malicious Insertion

The intentional insertion of malicious hard/soft coding, or defect to enable physical attacks or cause mission failure; includes logic bombs, Trojan 'kill switches' and backdoors for unauthorized control and access to logic and data.

## Anti-Tamper

Unauthorized extraction of sensitive intellectual property using reverse engineering, side channel scanning, runtime security analysis, embedded system security weakness, etc.

## Information Losses

Stolen data provides potential adversaries extraordinary insight into US defense and industrial capabilities and allows them to save time and expense in developing similar capabilities.

***Systems Security Engineering is a critical discipline of SE, addressing a spectrum of security risks that are magnified by complex system attributes***



# Managing Challenges of Complexity



- **Lay solid foundations...create opportunities**
- **Envision multiple futures...enable flexible choices**
- **Design and build systems with focus on lifecycle cost**
- **Protect our critical defense “intellectual property”**
- **Strengthen the workforce's capacity to lead and implement critical engineering practices**



# Systems Engineering: Critical to Defense Technologies



***Innovation, Speed, Agility***  
<http://www.acq.osd.mil/se>