Engineered Resilient Systems

Power of Advanced Modeling and Analytics in Support of Acquisition

NDIA 16th Science and Engineering Technology Conference
March 24-26, 2015
'*Maps and Gaps in DoD COIs*'

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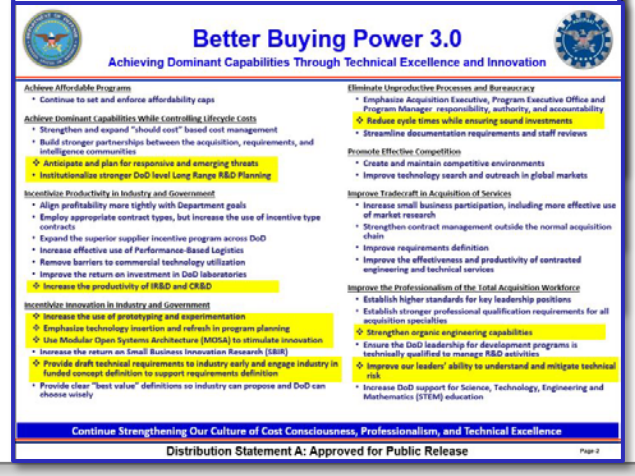
ERS Community of Interest (COI) Lead
Director, US Army Engineer Research and Development Center (ERDC)
Director, Research and Development, US Army Corps of Engineers

ERS Buys Down Acquisition Risk

Acquisition Challenges

- Rapidly changing threats
- Constant technology disruptors
- Changing workforce



Better Buying Power 3.0

Achieving Dominant Capabilities Through Technical Excellence and Innovation

Achieve Affordable Program
- Continue to set and enforce affordability caps

Achieve Dominant Capabilities While Controlling Lifecycle Costs
- Strengthen and expand "should cost" based cost management
- Build stronger partnerships between the acquisition, requirements, and intelligence communities
- ❖ Anticipate and plan for responsive and emerging threats
- Institutionalize stronger DoD level Long Range R&D Planning

Incentivize Productivity in Industry and Government
- Align profitability more tightly with Department goals
- Employ appropriate contract types, but increase the use of incentive type contracts
- Expand the superior supplier incentive program across DoD
- Increase effective use of Performance-Based Logistics
- Remove barriers to commercial technology utilization
- Improve the return on investment in DoD laboratories
- ❖ Increase the productivity of IR&D and CR&D

Incentivize Innovation in Industry and Government
- ❖ Increase the use of prototyping and experimentation
- ❖ Emphasize technology insertion and refresh in program planning
- ❖ Use Modular Open Systems Architecture (MOSA) to stimulate innovation
- Increase the return on Small Business Innovation Research (SBIR)
- ❖ Provide draft technical requirements to industry early and engage industry in funded concept definition to support requirements definition
- Provide clear "best value" definitions so industry can propose and DoD can choose wisely

Eliminate Unproductive Processes and Bureaucracy
- Emphasize Acquisition Executive, Program Executive Office and Program Manager responsibility, authority, and accountability
- ❖ Reduce cycle times while ensuring sound investments
- Streamline documentation requirements and staff reviews

Promote Effective Competition
- Create and maintain competitive environments
- Improve technology search and outreach in global markets

Improve Tradecraft in Acquisition of Services
- Increase small business participation, including more effective use of market research
- Strengthen contract management outside the normal acquisition chain
- Improve requirements definition
- Improve the effectiveness and productivity of contracted engineering and technical services

Improve the Professionalism of the Total Acquisition Workforce
- Establish higher standards for key leadership positions
- Establish stronger professional qualification requirements for all acquisition specialties
- ❖ Strengthen organic engineering capabilities
- Ensure the DoD leadership for development programs is technically qualified to manage R&D activities
- ❖ Improve our leaders' ability to understand and mitigate technical risk
- Increase DoD support for Science, Technology, Engineering and Mathematics (STEM) education

Continue Strengthening Our Culture of Cost Consciousness, Professionalism, and Technical Excellence

Distribution Statement A: Approved for Public Release

ERS Contributes to BBP 3.0

- *Strengthen organic engineering capabilities*
- *Improve decision makers' ability to understand and mitigate technical risk*
- *Remove specific barriers to commercial technology utilization*
- *Improve the return on investment in DoD laboratories*
- *Increase the productivity of IR&D and CR&D*
- *Increase the use of prototyping and experimentation*
- *Use Modular Open Systems Architecture to stimulate innovation*

ERS Investments

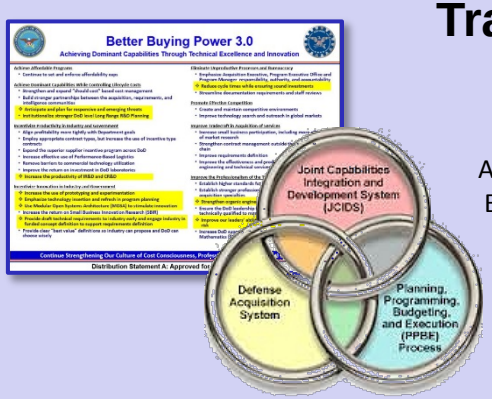
- *Open Systems Architecture*
- *Advanced Modeling and Simulation*
- *Tradespace Tools & Analytics*
- *Virtual Prototyping*
- *Mission Context Tools*
- *Support T&E Community*
- *Knowledge Management*
- *Advanced Training Techniques*

"We are also continuing to implement acquisition reform efforts, most notably through the Better Buying Power initiative that seeks to achieve affordable programs by controlling costs, incentivizing productivity and innovation in industry and government…"

Quadrennial Defense Review 2014

ERS Attributes

Tradespace Tools & Analytics



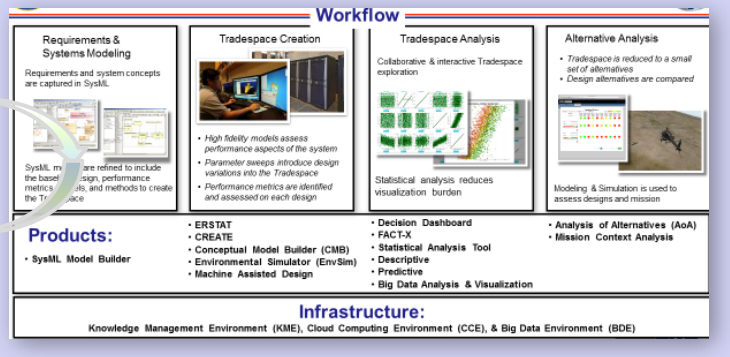
ARCHITECTURE
TRADE ANALYSIS
ADVANCED MODELING
ENV REPRESENTATION
MISSION CONTEXT
...ilities
other

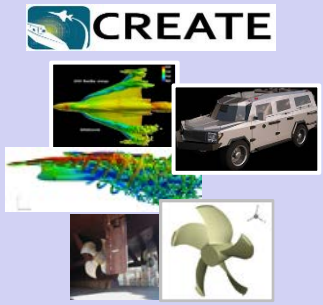
ERS Cloud

10,000X Productivity Improvement In AoA

HPCMP & S&T Resources

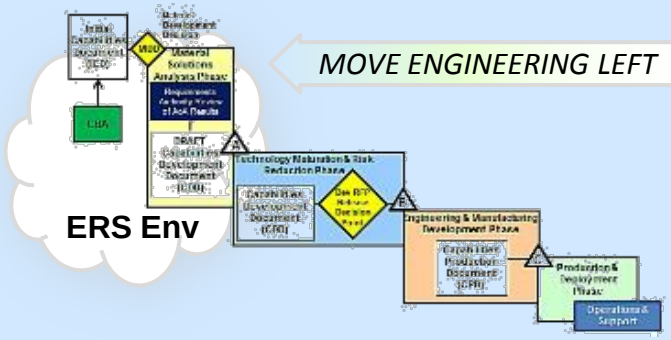
Integrated Capability and Workflow





Decision Support | *Big Data Analytics and Visualization* | *Open Architecture* | *Knowledge Management* | *Data Retention*

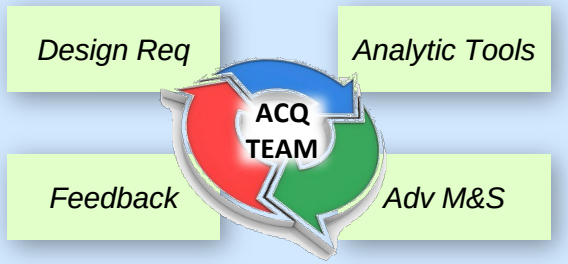
Requirements Generation



Fully Explore & Identify KPPs

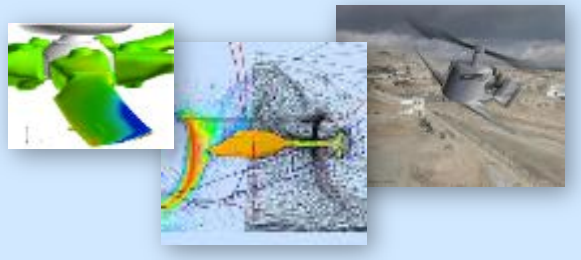
Analysis of Alternatives

Reduces alternatives from thousands to tens or less



Rapidly Distill Alternatives

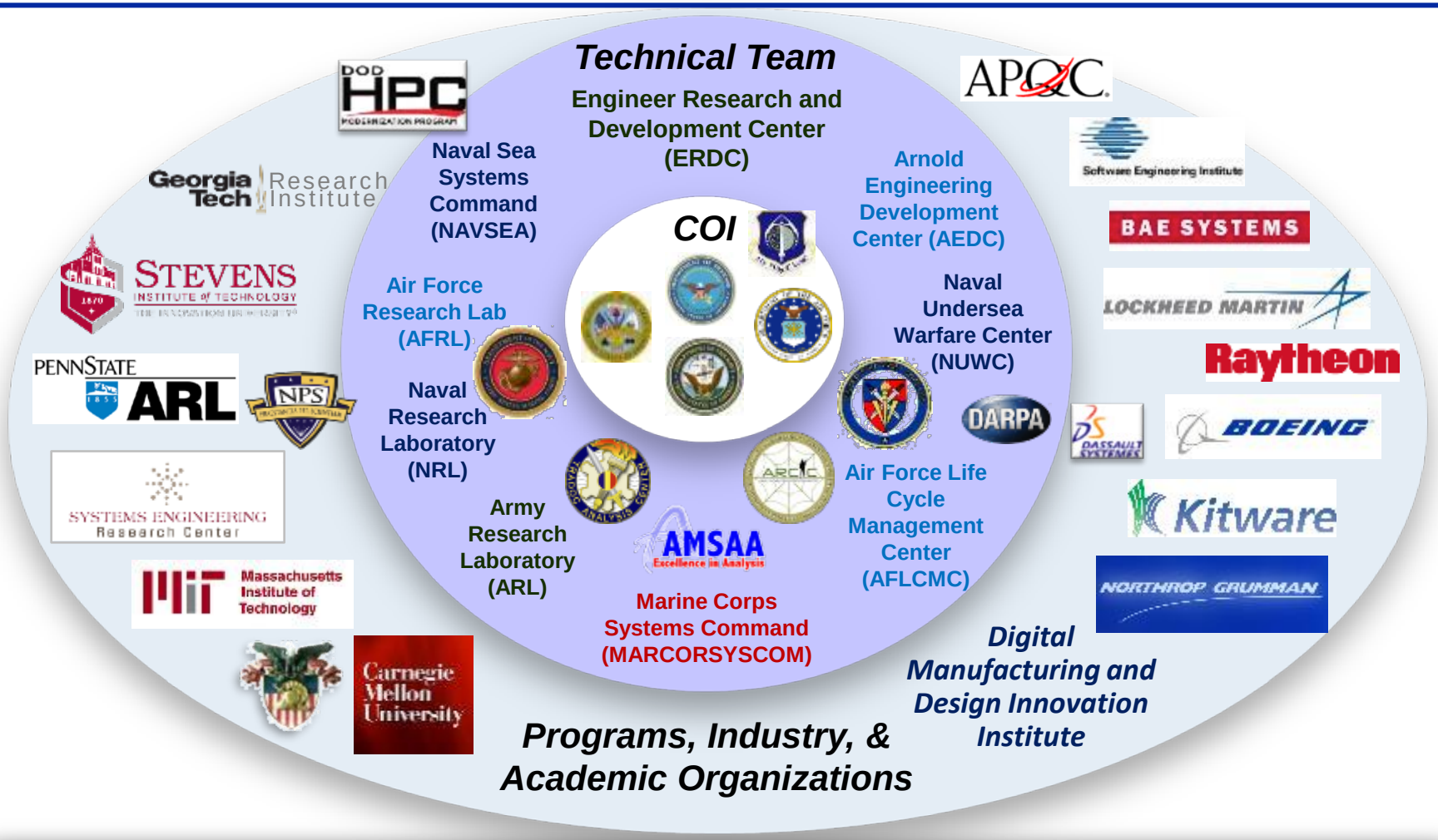
Virtual Prototyping & Evaluation



RAPID PROTOTYPING & RESPONSE

Virtually Warfight

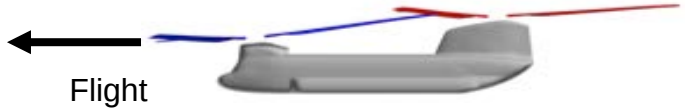
ERS Consortium

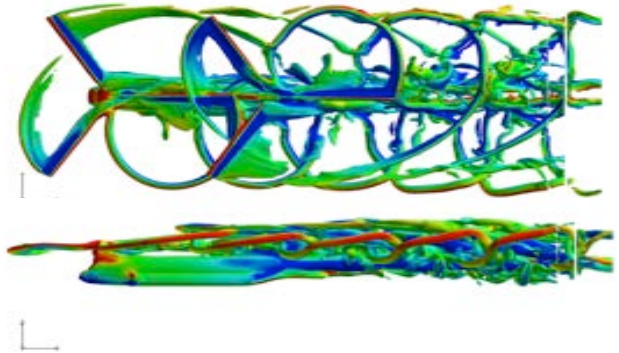


Government, Industry, and Academic Partners

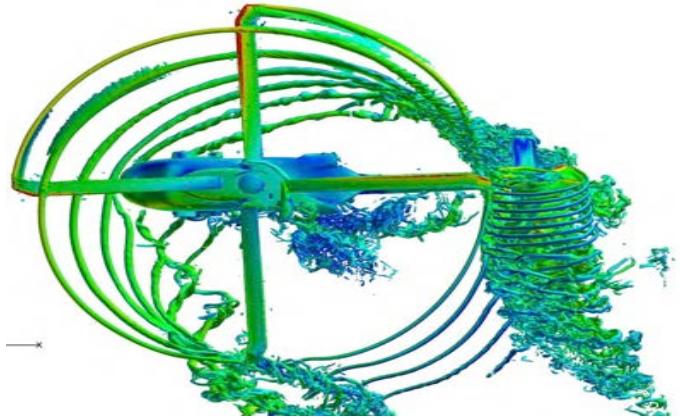
ERS: Demonstrated Capability

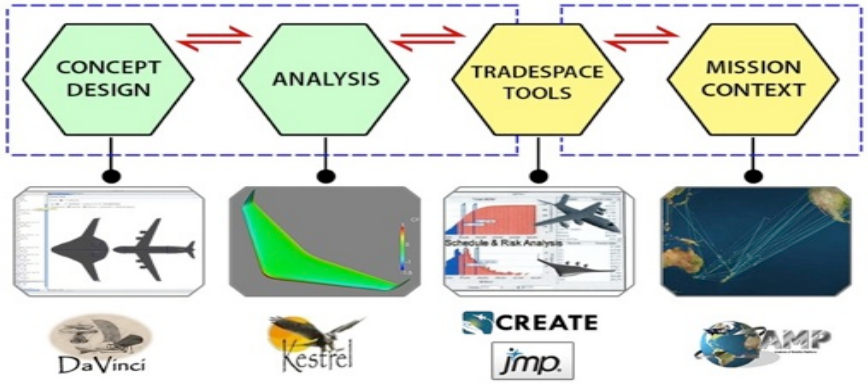
Set-Based Design
- Concept
- LX(R)
- SSCTF





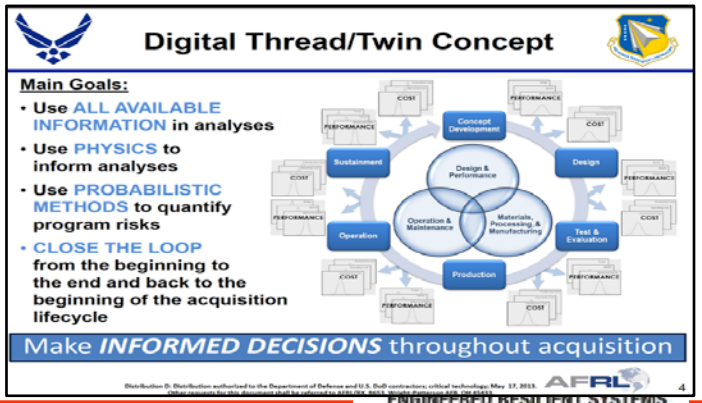
- Industry-Government Collaboration
- New Analysis Tools





Conceptual Design Mission Performance

- Joint Platforms, Partners, and Tools
- Learn from related efforts in other Services

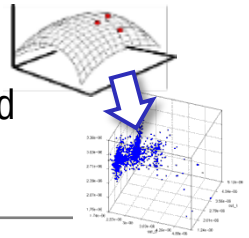


ERS Tools Used in DoD Acquisition

US Navy NSWCCD

ERS Ships Demonstrations

LX(R) AoA
22,000 alternatives analyzed in 6 weeks



Small Surface Combatant
19M designs analyzed in 3 months resulting in 270K feasible alternatives

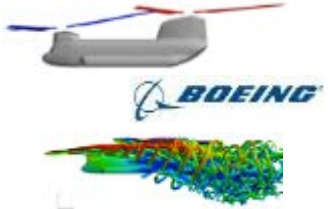
The ERS Cloud Computing Environment (CCE) will improve these speeds by 100X.

"The methods used for this [LX(R)] study were so comprehensive that the results of the study were 'irrefutable.'"
Ray Mabus, Sec of the Navy

US Army AMRDEC

ERS Rotorcraft Demonstration

Evaluated Boeing's IRAD-produced CH-47 rotor blades



Full, accurate assessments achieved in hours/days rather than weeks/months with ERS tools & CREATE Helios models.

ERS and CREATE tools ready for transition to Future Vertical Lift program

US Air Force AFLCMC

Lifecycle Cost Models
USAF Cost Capabilities Analytics (CCA) insert lifecycle intelligence into decisions

Proposed ERS Support to AoA processes

T-X Training Platform

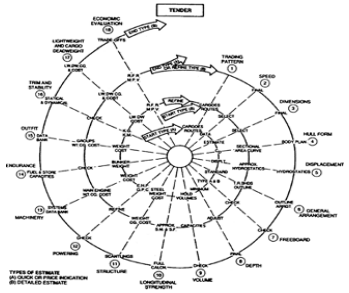
JSTARS Recap

ERS Applications to Ships

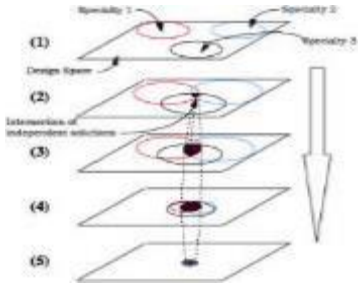
Design Experiment

FY14 Joint ERS/NSWCCD Effort: Demonstrated advantage of tradespace-informed, set-based design techniques.

Point Design Process (spiral design)



Set-Based Design Process



Set-Based Design

Point Design

Workforce benefit articulated by Navy:

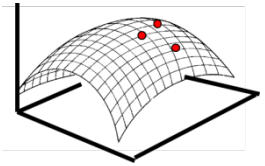
- *Point Design team weighted with more experienced engineers;*
- *Set-based teams overcame experience gap with ERS approach.*

LX(R) Amphibious Assault Ship

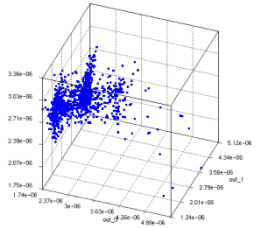
$16B+ Buy, 11 Ship Total

- **FY14/15 – Joint ERS/NSWCCD Effort**
- **Traditional AoA Process**
  - Few ship design points developed
  - Difficulty answering complex cost vs. capability questions
- **New AoA Process: Exploration of more robust design space**
  - 22,000 alternative designs generated in 2 months.
  - Performed cost vs. capability analysis
  - Informed Navy's decision on the next amphibious assault ship

Traditional AoA



New AoA



Small Surface Combatant

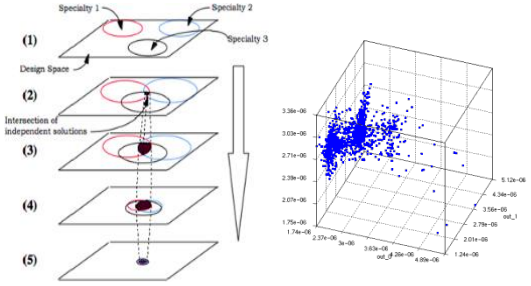
$10B+ Buy, 20 Ship Total

Over 2 billion designs reviewed using ERS Cloud Computing Environment

- Identified 280,000 resilient designs
- Decision time reduced by 1000X
- Cost versus capability data will inform RFI/RFP process
- Designs briefed to CNO, ASN(RDA), DEPSECDEF

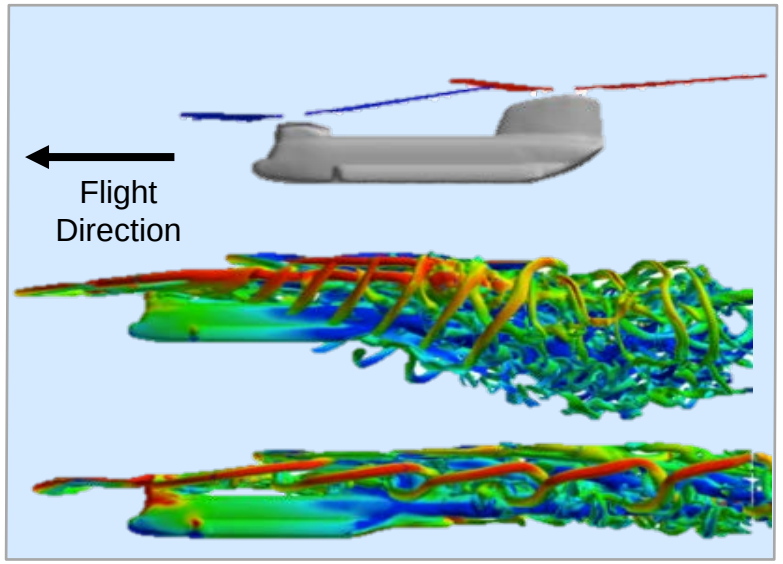
Set-based design approach for mission systems

Design space exploration approach for ship designs



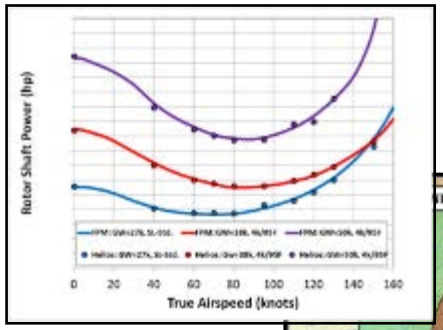
ERS ENGINEERED RESILIENT SYSTEMS

ERS Application to Rotorcraft



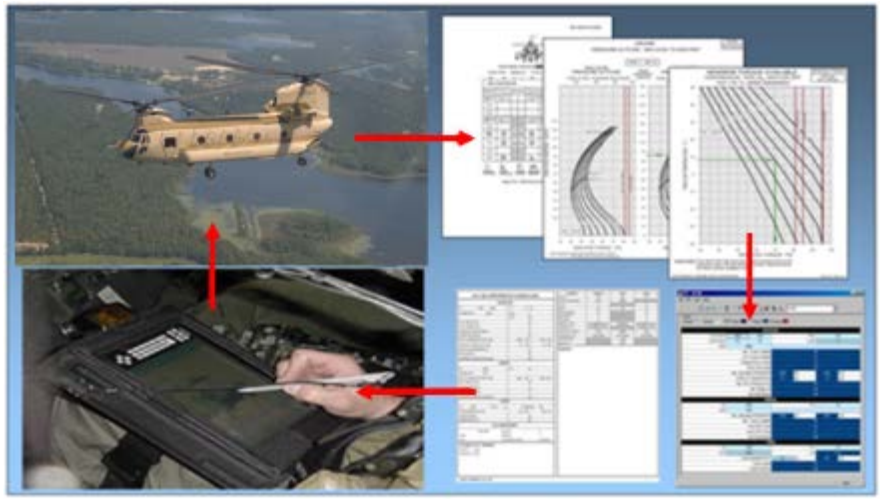
Initial experiment demonstrating value of virtual prototyping using validated, high-fidelity models

Rotor Performance Map



Mission Analysis

ERStat team wrote a wrapper around Helop mission tool to now perform 1000's "missions".



Future: Integrate mission planning data/tools into ERSTAT. Empowers mission data with more robust datasets.

FY14 and Prior

- Boeing proposed new CH-47 rotor blade
- CREATE-AV Helios validated on old blade design
- CREATE-AV Helios confirmed added lift of new blade design
- Paved way for larger projects in virtual prototyping (potential: Future Vertical Lift)

FY15: CREATE-AV Helios

- Analyzed payload allowance and maximum forward velocity characteristics
- Pre-flight test validation
- ERSTAT (ERS-built tradespace) generated and analyzed 1000's of missions in a matter of minutes

FY16 and Beyond:

- Live flight tests with new rotor blade will be informed by early computational analyses
- Integrate Rotor Performance Maps into real-time mission planning tools from ERS work

Details of Current Capabilities

Architecture and Workflow Products

Workflow

Requirements & Systems Modeling

Requirements and system concepts are captured in SysML

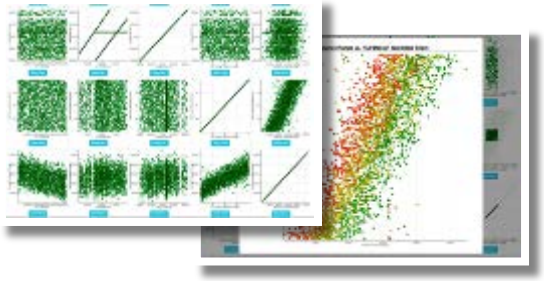
SysML models are refined to include the baseline design, performance metrics, models, and methods to create the Tradespace

Tradespace Creation

- *High fidelity models assess performance aspects of the system*
- *Parameter sweeps introduce design variations into the Tradespace*
- *Performance metrics are identified and assessed on each design*

Tradespace Analysis

Collaborative and interactive Tradespace exploration



Statistical analysis reduces visualization burden

Alternative Analysis

- *Tradespace is reduced to a small set of alternatives*
- *Design alternatives are compared*

Modeling and Simulation is used to assess designs and mission

Products:

- **SysML Model Builder**
- **ERSTAT**
- **CREATE**
- **Conceptual Model Builder (CMB)**
- **Environmental Simulator (EnvSim)**
- **Machine Assisted Design**
- **Decision Dashboard**
- **FACT-X**
- **Statistical Analysis Tool**
  - **Descriptive**
  - **Predictive**
- **Big Data Analysis & Visualization**
- **Analysis of Alternatives (AoA)**
- **Mission Context Analysis**

Infrastructure:

Knowledge Management Environment (KME), Cloud Computing Environment (CCE), and Big Data Environment (BDE)

DoD Enclave and Community Interfaces

DEVELOPMENT TEAM

DoD, Industry, Academia

Distributed product development teams

PRODUCT DISTRIBUTION PROCESS

THREE CURRENT SERVICES

- ***Tools and Models***
- ***Data and Information***
- ***Virtualized Environments***

1. PRODUCT DELIVERY

2. HOSTED SERVICES
(to DoD, Industry, Academia)
Access to ERS tools via configured environment on ERS Cloud

ERS CLOUD
Cloud Computing Environment
(CCE)
ers.hpc.mil

Secure DoD Environment

3. FEDERATED SERVICES
ERS Cloud interacts with Industry and Academic Clouds to accommodate models with IP or licensing restrictions.

ERS USER COMMUNITY

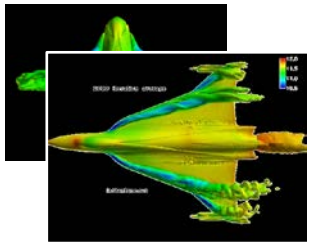
DoD, Industry, Academia

Engineering Design Teams

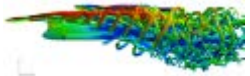
PEOs/PMs/Industry Cloud Services

ERS Leverages Computational Research & Engineering Acquisition Tools and Environments (CREATE) Program

Aircraft (AV) Tools:



Fixed-wing aircraft, rotorcraft, conceptual design, and operational testing and transition

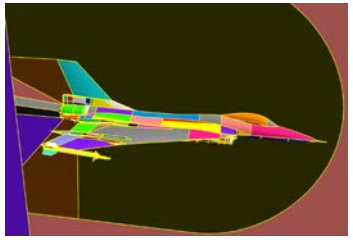


Ground Vehicle (GV)

Autonomous navigation and operational testing

Meshing and Geometry (MG) Support:

CREATE MG improves the ease, speed, flexibility, and quality of geometry and mesh generation



CREATE

Fully Validated on Real Problems

CREATE-AV
Aircraft (AV) Design Tools

CREATE-SHIPS
Ship Design Tools

CREATE-RF
Radio Frequency (RF) Antenna Design and Integration Tools

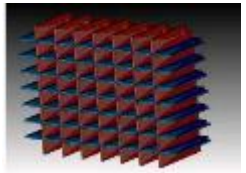
CREATE-MG
Meshing and Geometry (MG) Support

CREATE-GV
Ground Vehicle (GV) Design Tools

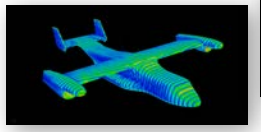
Ship Design Tools:

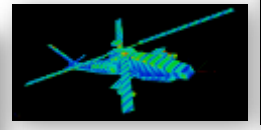
Shock/damage, hydrodynamics and early-stage design, and operational testing and transition

Radio Frequency (RF) Antenna:



Conceptual design and detailed analysis tools for myriad DoD platforms





ENGINEERED RESILIENT SYSTEMS

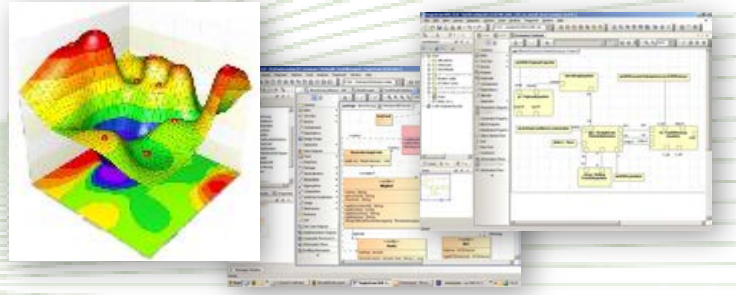
FY15-16 ERS
Planned Developments

Major S&T Building Blocks

Science & Technology Components Impact Engineering Approach

Tradespace Analytics

Big data analyses and visualization

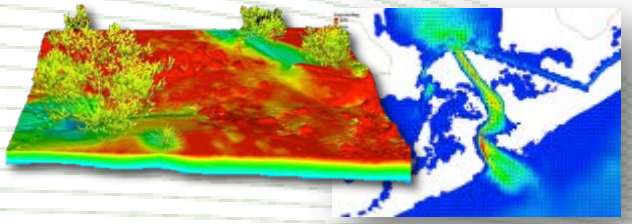


Open Architecture

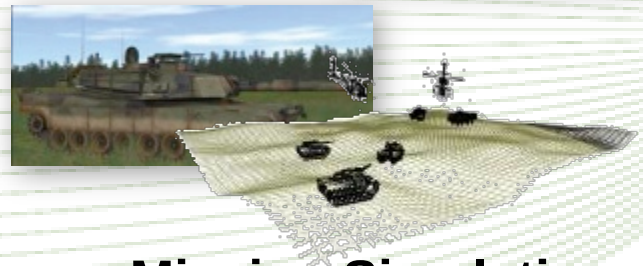
Integrating capabilities

Environmental Representation

Physical understanding of the world



Knowledge Management



Mission Simulation

Evaluate ability to warfight

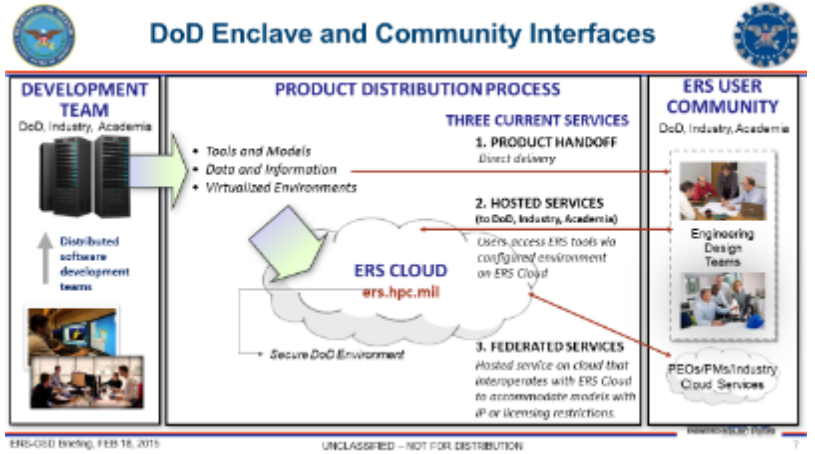
Advanced Modeling & Simulation

Multi-effects, virtual behavior

FY15-16: Open Architecture

- ***Continued focus on Integrating New and Existing Tools & Capabilities***
- ***Support Transition***

- **Architecture Documentation – V.1 (Sep 2015)**
- **ERS CONOPS Documentation – V.1 draft (Apr 2015)**
- **System Design**
  - Government, Industry, and Academia in Architecture Working Group
  - Identify use cases, quality attributes, requirements, and interfaces
- **Initial Lifecycle Cost Modeling to be inserted (Oct)**
- **Industry Pilots**
  - Joint projects with multiple industry partners
- **Intellectual Property Management**
- **ERS Demonstration: November 2016 (Washington, DC)**



ERS Architecture Working Group
Cross-service, Acquisition Representatives

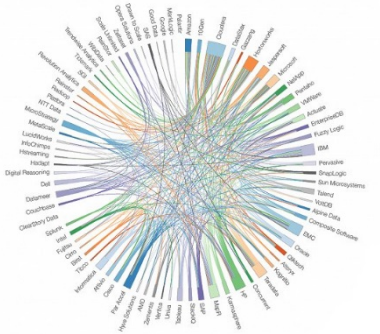
- *Define Quality Attributes*
- *Develop Use-cases*
- *Address Test/Eval Metrics*

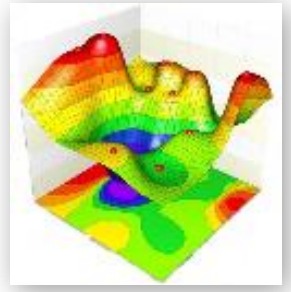
FY15-16: Big Data Environment (BDE)

Solutions for Big Data Challenges and Enhancements to Analytics

- **Ongoing investigation of innovative techniques to support growing dataset size and complexity**
- **Integrating open source capabilities to scale to petabyte-sized data sets**
  - Employ Hadoop Ecosystem (open source algorithms for distributed storage and processing of very large data sets on computer clusters)
  - Insert big data capabilities in ERS Cloud to do more sophisticated analyses – scalability of data requests, more precise and sensitive analytics
  - Integrate big data processing with Kitware Visualization Tool

Hadoop Ecosystem





Big Data Visualization

ENGINEERED RESILIENT SYSTEMS

FY15-16: Tradespace Analytics

Two-fold Effort: ERS Tradespace Toolset and Tradespace Analytics

Tradespace Toolset

Tradespace toolset framework for the DoD community

Enables:

- True characterization of "resilience"
- Scenario-specific needs context
- Risk mitigation through option buy-in and forecasting

FY15-16:

- Integrated with EASE
- Transitioned initial capability to users
- Link SysML behavior to Modeling and Simulation
- Deliver & test on new platforms (GV, Fixed Wing, LEO satellite)
- Integration of CREATE/HPC assets

Tradespace Analyses

Executable Architecture Systems Engineering (EASE)

Links analytical, experimental, and training objectives with modeling and simulation tools

FY15-16:

- Enhancements of FACT and EASE
- Use-case Development
- Alignment of use case to Maneuver Support Center of Excellence (MSCoE) for Phase II demonstration

Target Users

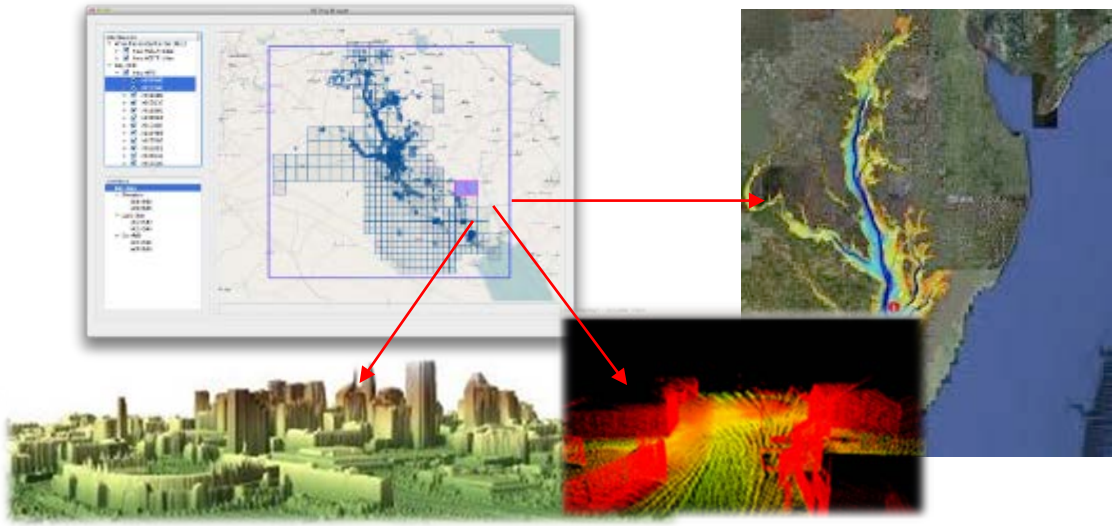
Visualization for multiple user types

Primary Users
- *SMEs – engineering analysts*
- *Operations Research Systems Analysts*

Secondary Users
- *General engineering analysts*
- *Stakeholder PMs (CONOPS, TTPs)*

Tertiary Users
AoA PMs and high-level Decision-makers – budget, warfighting, requirements, "what if" drills

FY15-16: Environmental Representation and Mission Context Immersion



Purpose

Environmental Simulator provides:

- Ability to represent any area of interest above, on, or under the earth
- Supports virtual prototyping and simulation under a variety of environmental conditions early in the acquisition process
- Predicts system performance in a variety of geographic settings under a variety of environmental conditions

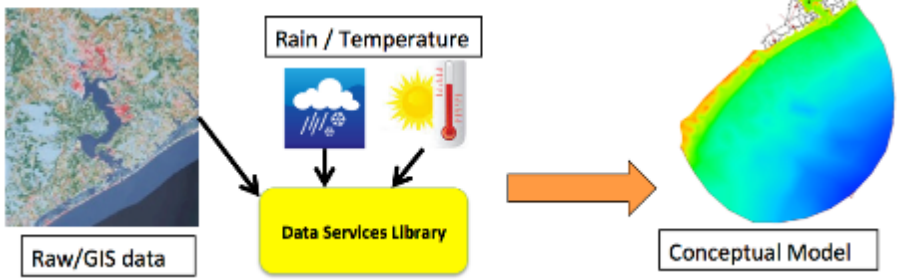
Description

The Environmental Simulator:

- An integrated computational modeling suite; provides robust high-fidelity, physics-based engineering analyses
- Assesses the impact of numerous environmental factors on military operations to support the DoD acquisition process

Modules to be demonstrated in FY15-16:

- Data Services Library
- Model Development Environment
- Model Coupling Interface
- Simulation Workflow Manager



FY15-16: Knowledge Management

- ***Launch DoD Techspace and Expand ERS Knowledge Hub Information***
- ***Address Information Assurance Challenges between ERS Hub and Federated Clouds***

STAKEHOLDER & COMMUNITY DEVELOPMENT

DoD Stakeholders
- Army
- Navy
- Air Force
- OSD

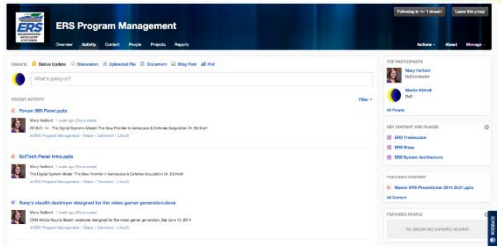
CAC Authentication

External Stakeholders
- Industry
- Academia
- Fed Agencies

Username Password

DoD Techipedia COI

DoD TechSpace



Input & Knowledge

ERS ENGINEERED RESILIENT SYSTEMS

KNOWLEDGE HUB

Management
Knowledge Base
Standards
Policies
Tutorials
Engineering Tools
Analytical Tools
Models
Insights
Wiki
Chat
Research
…

ersWiki

DEMONSTRATION ENVIRONMENT

Acquisition & Engineering Communities

Formats, standards, solicitations, engineering data

ERS CLOUD Projects
ers.hpc.mil

Government
Industry
Research

Challenges to Address FY15/16:

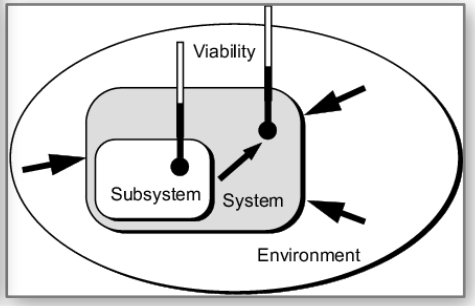
- Information Assurance between DoD Acq environments
- Non-DoD access/use of HPC CREATE Models

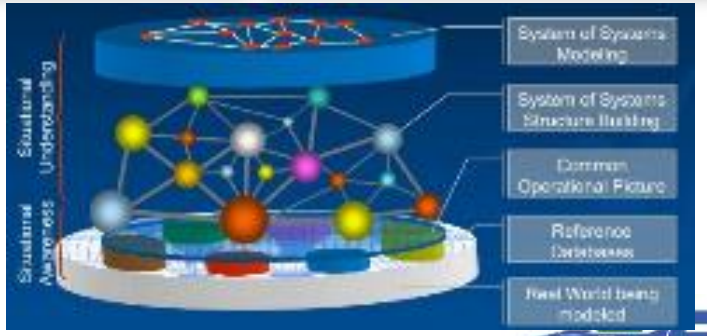
ERS ENGINEERED RESILIENT SYSTEMS

Future Capabilities and Challenges

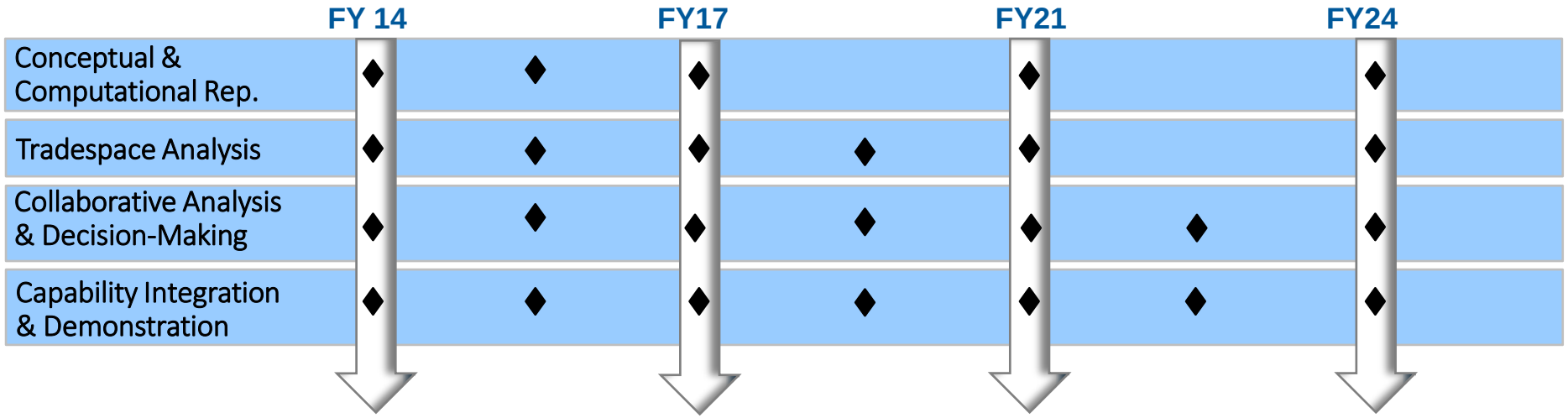
Future Work – Technical Challenges

- Virtual Prototyping
- Modeling Sub-Systems
- Material Life and Failure
- Lifecycle Cost Modeling
- System-of-Systems Analysis
- Modeling Manufacturing





10-Year Plan



Versions	V1	V2	V3	V4
	• Initial tradespace tools for Ships • Launched prototype KM environment • Initial integrating architecture • Linked physics-based models and environmental data	• 2nd gen tradespace tools for Ships, GV, AV • KM Environment • Industry linked to architecture env • Risk representation and mitigation • Env simulation • Initial cost modeling • Initial mission tools	• User-configured analytics • Env simulation anywhere on Earth • Manufacturability & Producibility Tools • Lifecycle cost tools • Novel weapons systems modeling • Mission context tools	• Modeling of entire acquisition cycle • Validated cost representation • Virtual prototyping of all materiel alternatives • Portfolio analyses of trades at increasing echelons • Cognitive computing
Demos & Transitions	• Ships – LX(R) • Ships – SSCTF • Helo – CH-47 blades	• Ground vehicle • Air vehicle cost model • Ships – modular vessel • Helo – UH-60	• Support new platforms	

Major Versions

Significant Milestones