Computational Research Engineering Acquisition Tools and Environments

Computational Prototyping for Acquisition Innovation

CREATE Overview

Dr. Douglass Post
Associate Director for CREATE

HPCMP Ecosystem

DOD HPC MODERNIZATION PROGRAM

Users

A technology-led, innovation-focused program committed to extending HPC to address the DoD's most significant challenges

DoD Supercomputing Resource Centers (DSRCs)

U.S. Air Force Research Laboratory DSRC

U.S. Army Research Laboratory DSRC

U.S. Army Engineer Research and Development Center DSRC

Maui High Performance Computing Center DSRC

U.S. Navy DSRC

Networking and Security

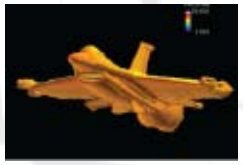
Defense Research & Engineering Network (DREN)

Computer Network Defense, Security R&D, and Security Integration

Software Applications

Core Software

Computational Environments

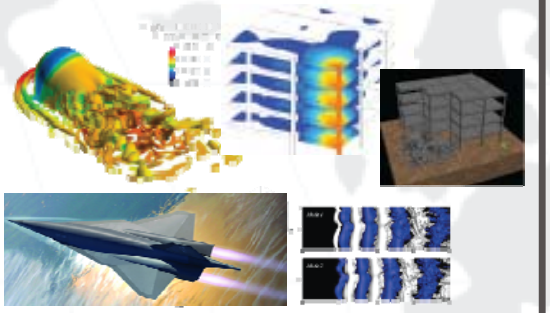


Education and Training

HPC User Support

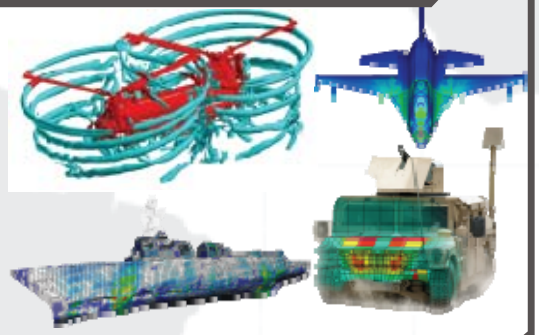
Results

Science and Technology



Test and Evaluation

Acquisition Engineering

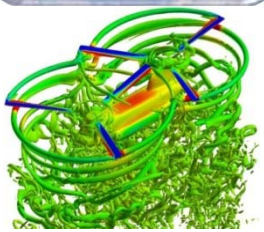


BLUF

- **CREATE is a set of physics-based HPC engineering tools to enable the DoD to develop innovative weapon systems.**
- **CREATE tools enable generation and analysis of computational prototypes of DoD Air Vehicles, Ships, and RF antennas, and in the future, Ground Vehicles, and can accurately predict system performance.**
- **CREATE tools are:**
  - Government-developed, government-owned, and government-supported to enable the DoD to independently evaluate contractor deliverables.
  - Designed for a ~30 year (or more) life cycle.
  - Being adopted by DoD acquisition engineering communities (government and industry), 129 organizations at last count, and are beginning to have significant impact.
  - On the verge of being adopted by Defense Industry for commercial use.
- **CREATE Tools are enabling elements of the DoD Engineered Resilient Systems and AF Digital Thread/Digital Twin Programs and have the potential to improve the effectiveness and efficiency of DoD T&E enterprises by enabling their Virtual Proving Ground (VPG) concept.**

CREATE: Suite of Physics-based HPC Tools for the design and analysis of DoD platforms:

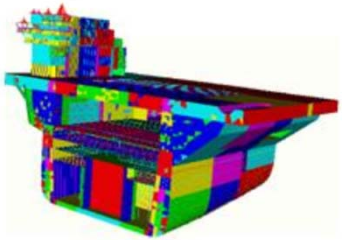
- **Air Vehicles (AV)—Air Force, Army & Navy**
  - Concept design, High Fidelity Fixed-Wing and Rotary-Wing
- **Ships—Navy**
  - Concept design, Shock and Life Fire Vulnerability, Hydrodynamics
- **Radio Frequency (RF) Antennas—Air Force, Army & Navy**
  - RF Antenna electromagnetics & integration with platforms
- **Ground Vehicles (GV) — Army, Marine Corps**
  - Design and evaluation of tactical ground vehicles
- **Mesh and Geometry (MG) Generation**
  - Rapid generation of geometry representations and meshes



CH-47

Design concept

Seakeeping and resistance



Aircraft and aircraft carrier meshes

Military platforms with antennas

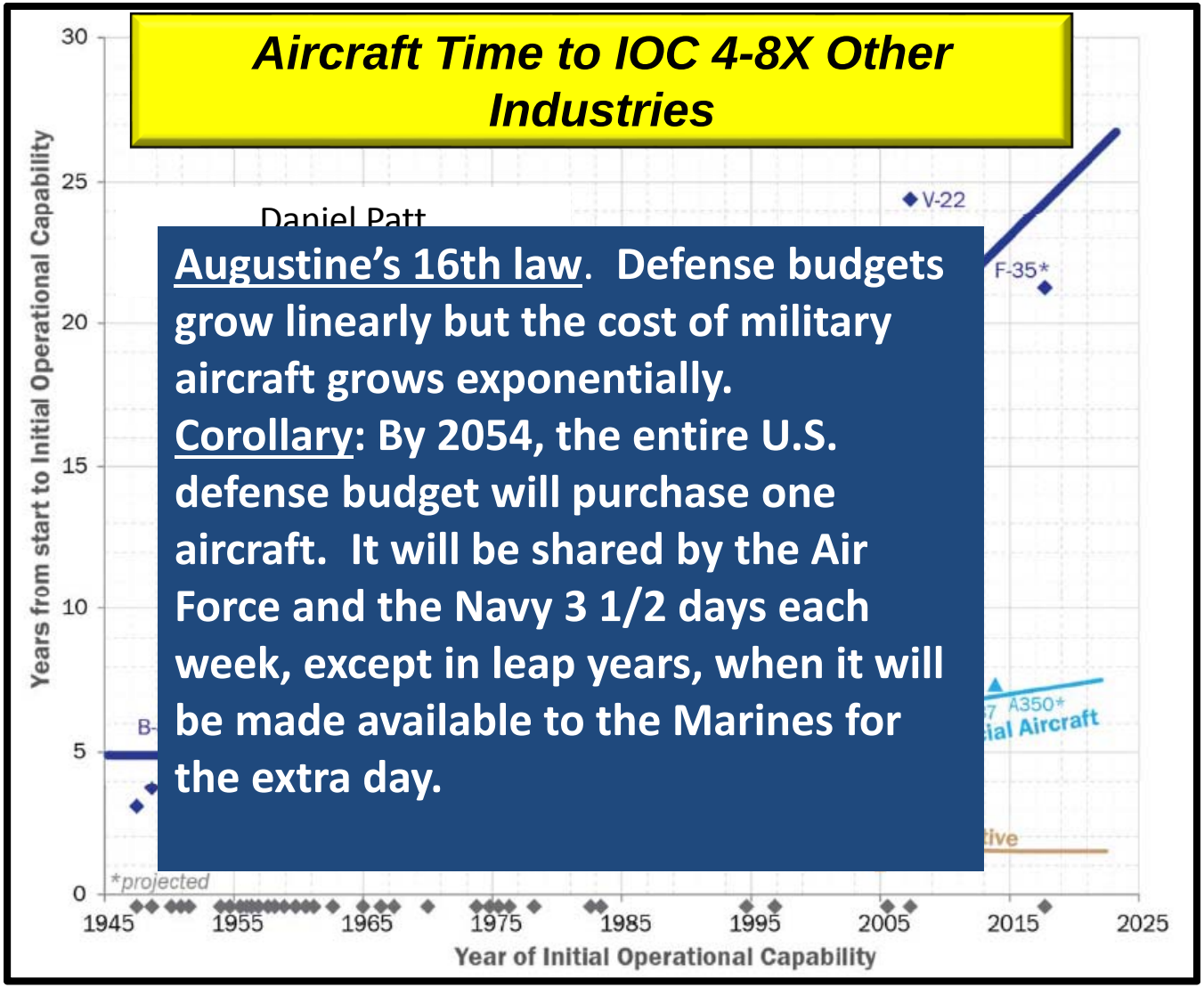
Shock vulnerability

CREATE tools support all stages of acquisition from rapid early-stage design to full life-cycle sustainment and modifications

CREATE Focuses on Reducing MDAP Cycle Time by the Use of Computational Prototypes

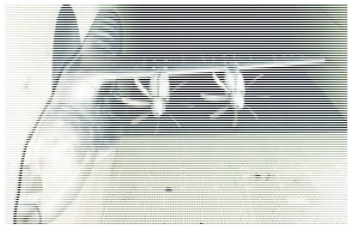
CREATE

- Reduce cycle time through computational prototyping!
- Costs can come down and performance can improve



Existing DoD Paradigm (design, build, test, fix…)

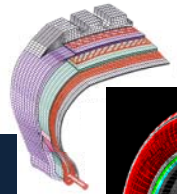
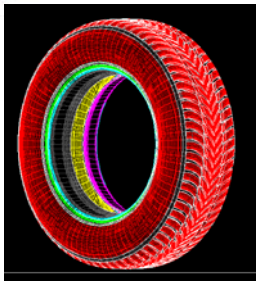
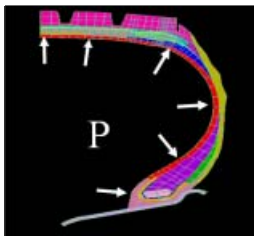





Requirements → Design → Scale-Model Tests → Full-Scale Tests → Production

Goodyear "Innovation Engine" (design, virtual test, fix, build, deploy)

- Reduced product development time from 3+ years to ~9 months or less
- Cut prototype build & test costs by 62%.
- "Innovation engine" new products from 10/year to over 60/year..

Inflation and Seating

Competitive Advantage


Hydroplaning Tests


Flight Radial

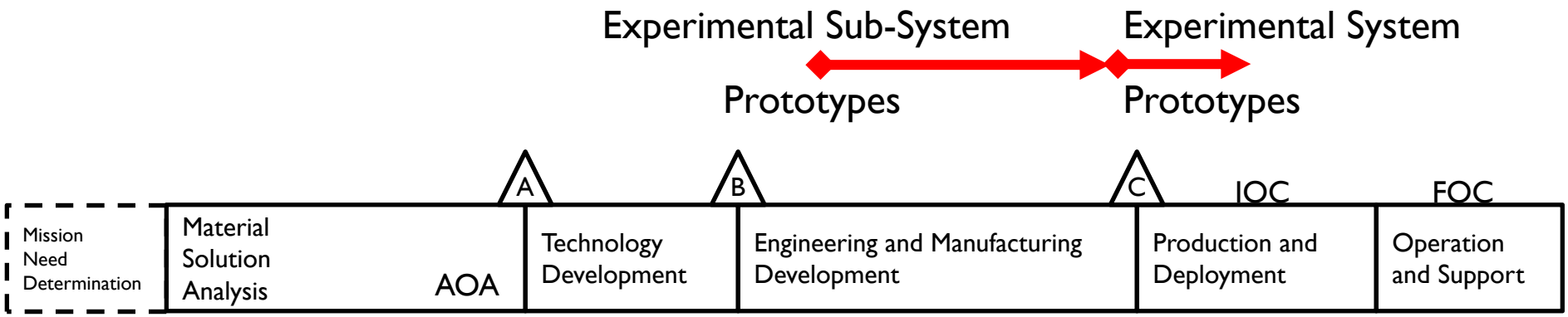
Design & Mesh Computational Prototype → Analyze & Test Computational Prototype → Build & Test Physical Product → Market

Design iterations

See title slide for distribution requirements

Loren Miller, *Simulation-Based Engineering for Industrial Competitive Advantage*, computing in Science and Engineering (2010), May/June, pp. 14-21.

CREATE Tools Provide Access to "Test Data," Decision Data Early in the Acquisition Process

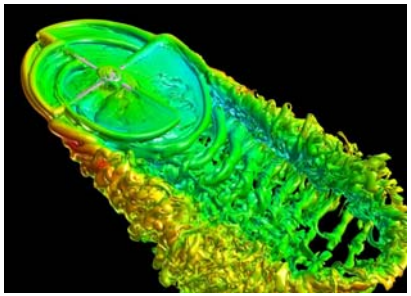
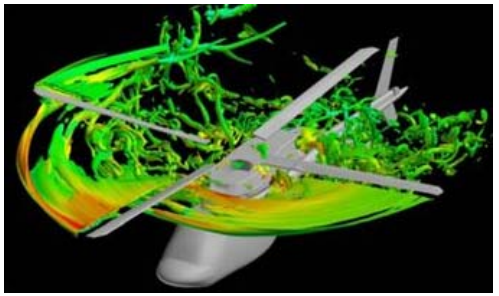


Physics-based HPC Tests of Computational Prototypes—Moves "Testing to the Left (and Right)"

- Replaces "rule-of-thumb" extrapolations of existing designs:
  - with physics-based generation of design options for rapid trade-space exploration and physics-based analysis tools that can assess the feasibility of the design options
- CREATE replaces "failure data from live tests" with "predictions of computational prototype performance," providing timely decision data that identifies design flaws and performance shortfalls early, allowing them to be fixed before metal is cut

A Paradigm Change…

- **Engineering Analysis(example)**
  Launch and Recovery Envelope Generation Process

Launch and recovery flight envelop is a required process to define limits of safe aircraft/ship operations. In the current process…

- ✓ Pilot flies aircraft to ship in increasingly severe conditions until safe limit is identified.
- ✓ Limit so defined is dependent on environmental conditions on day of test.

COMPUTATIONAL launch and recovery envelope generation offers very significant advantages…

- ✓ Risk reduction (pilot, crew, aircraft, ship)
- ✓ Greater shipboard operational capability in varied environmental conditions.
- ✓ Reduced cost and at-sea testing.

CREATE Value Proposition

Computational Prototyping Paradigm enables…

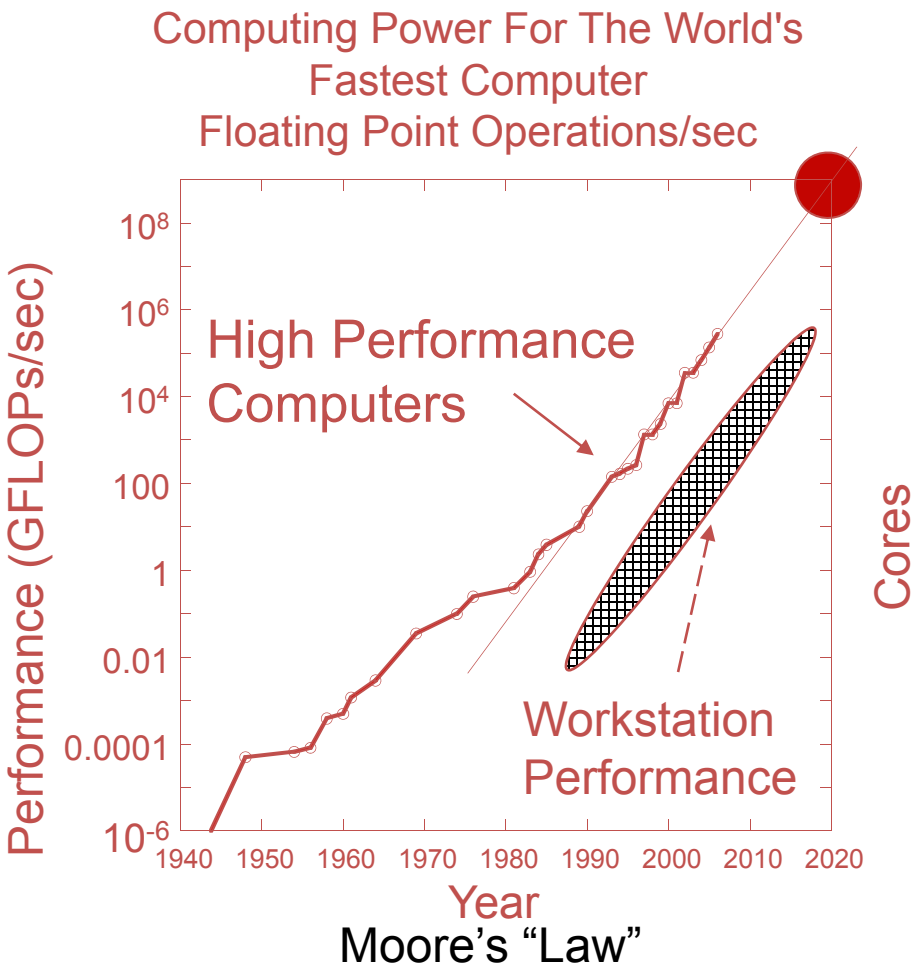
- **Independent Government Assessment (IGA) in Defense acquisition source selection activities and throughout system life.**
- **Ability of DoD Acquisition Programs to minimize the number design cycles, shortening the time (and) cost to develop and field systems that better address Defense requirements including those relating to system sustainment.**

through ability to…

- **Detect & resolve design faults and system performance anomalies prior to fabrication of physical test articles (viz., those for ground-based scale model tests and flight testing of full-scale prototypes).**
- **Plan & rehearse physical tests to maximize the value of data collected during test events needed for design validation.**
- **Establish a high fidelity computational model of the design that is maintainable, and the corresponding ability to execute multi-disciplinary, physics-based simulations in support of all key decision points during product development and throughout the service life of the system after deployment.**
- **Establish "Digital Thread" at the earliest phase of design via a model centric description of the planned system, including geometry, alternative designs considered, and engineering data supporting key design decisions and down-selects.**

Enabling Technology: High Performance Computers

- **The 10^{15-18} increase in computer power over the last seven decades enables codes to:**
  - **Include all the effects we know to be important—multi-physics**
  - **Utilize accurate solution methods with extensive VV&UQ**
  - **Model a complete system**
  - **Complete parameter surveys in hours, rather than days to weeks to months**
- **In ~ 10 years, workstations will be as powerful as today's high-performance computers**



NOW Physics-based HPC applications can accurately predict the performance of DoD weapon systems

CREATE is a Distributed, Multi-Organizational, Multi-institutional Program

13 military sites
48 contracts
2 WFOs (SNL)

HPCMP Director

CREATE Program
Associate Director

Official HPCMP
Advisory Panel

Ships Project
Project Manager
HPCMP Lorton

NavyFOAM
NSWC, Carderock

Integrated Hydro Design Environment
NSWC, Carderock

Navy Enhanced Sierra Mechanics
NSWC, Carderock

Rapid Ship Design Environment
NSWC, Carderock

Air Vehicles Project
Project Manager
HPCMP, Lorton

Kestrel
46th Test Wing, Eglin AFB

Quality Assurance
NAVAIR, Patuxent River

Helios
Army AFDD, Ames

DaVinci
HPCMP, WPAFB

RF Antennas Project
Sensors Directorate, AFRL, WPAFB

SENTRi
Sensors Directorate, AFRL, WPAFB

Mesh & Geometry Project

Capstone
Project Manager
Navy NRL

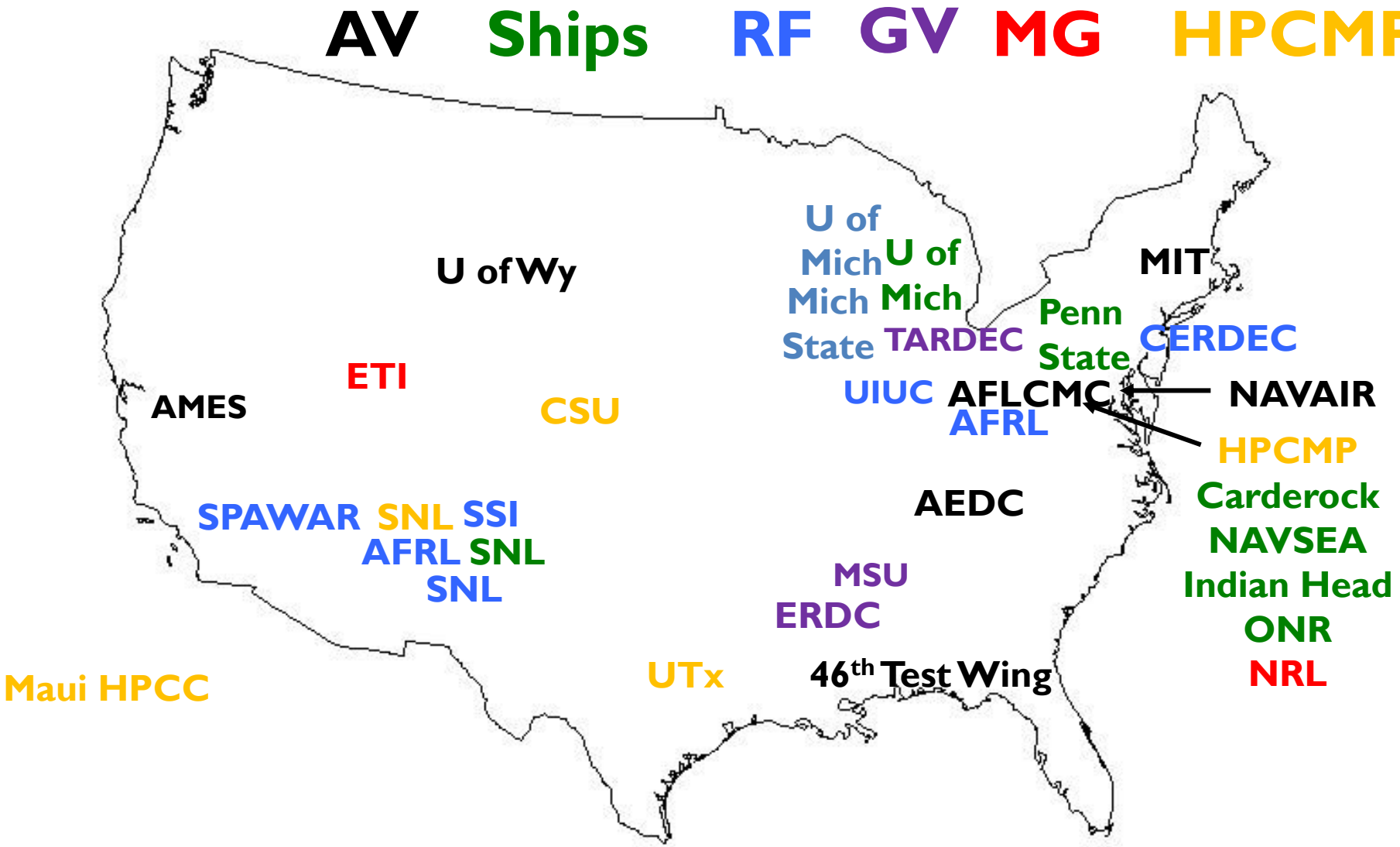
Ground Vehicles Project
Project Manager

Mercury
ERDC

MAT
TARDEC

Distributed Teams Can Work

→But Need Communication, Team meetings,… !



Senior Service Leadership Oversight of CREATE

HPCMP Executing Agent
David Horner, CIV Army (Director)

↔ Official HPCMP Advisory Panel

CREATE Program
Douglass Post, IPA-Army (AD-CREATE)

Ships
Richard Vogelsong
IPA-Army (PM)

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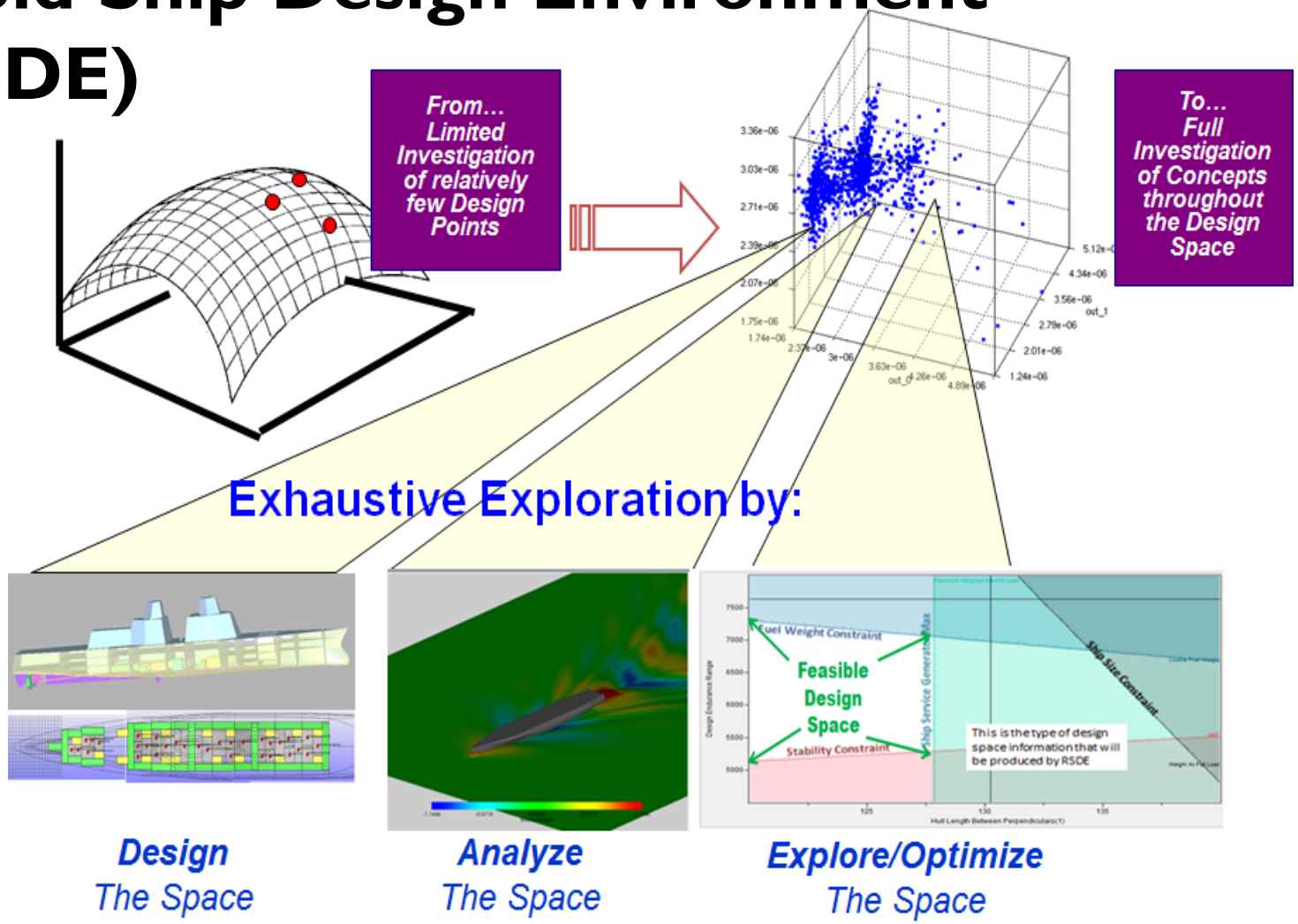
- Dr. David Horner, Director, HPCMP

See title slide for distribution requirements

CREATE 6 Projects: 11 Multi-Physics Software Tools

- **Ships—CREATE-Ships**
  - Rapid Ship Design Environment (RSDE) - Rapid Design and Synthesis Capability
  - Navy Enhanced Sierra Mechanics (NESM) - Ship Shock & Shock Damage Assessment
  - NAVYFOAM - Ship Hydrodynamics — predicts hydrodynamic performance
  - Integrated Hydro Design Environment (IHDE) - Facilitates access to naval design tools
- **Air Vehicles—CREATE-AV**
  - DaVinci - Rapid conceptual design
  - Kestrel - High-fidelity, full-vehicle, multi-physics analysis tool for fixed-wing aircraft
  - Helios - High-fidelity, full-vehicle, multi-physics analysis tool for rotary-wing aircraft
- **RF Antenna—CREATE-RF**
  - SENTRI - Electromagnetics antenna design integrated with platforms
- **Ground Vehicles—CREATE-GV**
  - Mercury – High-fidelity, multi-physics simulation tool for vehicle systems and components
  - Mobility Analysis Tool (MAT) – Analysis tool to evaluate ground vehicle performance metrics
- **Meshing and Geometry—CREATE-MG**
  - Capstone - Components for generating geometries and meshes needed for analysis
- **HPC Portal—Secure access to computers through a browser**

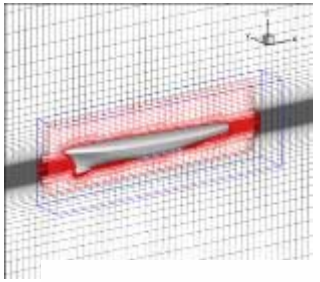
HPCMP CREATE™ – Ships
Rapid Ship Design Environment (RSDE)

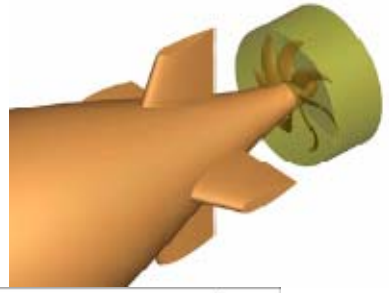


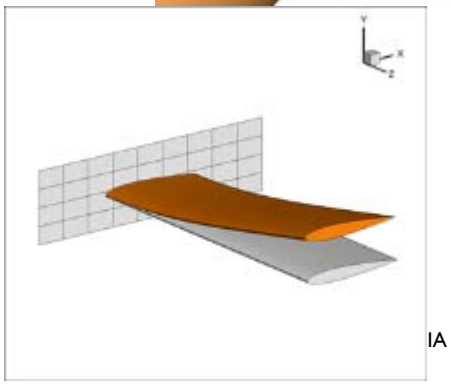
Customers: US Navy, US Army, US Coast Guard, ONI, Shipyards & Design Contractors

NavyFOAM
Features and Capabilities

- Finite-volume discretization for arbitrary polyhedral (unstructured) grids
- Implicit/semi-implicit projection method for incompressible and compressible flows
- RANS, LES, and hybrid URANS/LES turbulence model suite
- GCL-compliant ALE method for moving/deforming grids
- Coupled 6-DOF rigid-body dynamics (RBD) and CFD solutions
- Overlaid-grids
- Sliding-grids & Multiple Rotating Frames (MRF)
- Free-surface-capturing using volume-of-fluid (VOF) method
- Numerical wave tank
- Stratified flows
- Cavitating flows
- Fluid structure interaction



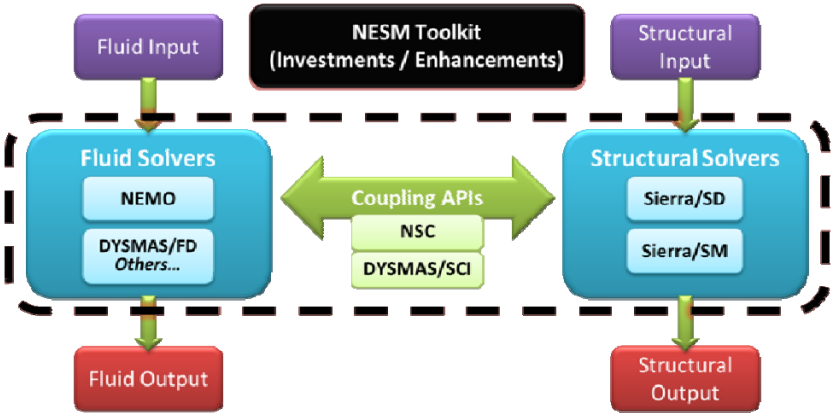




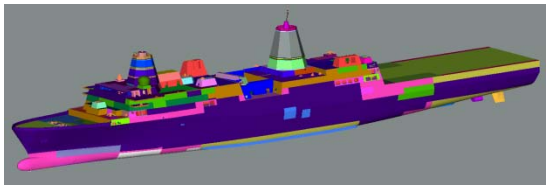
NESM Product Description 2016, v4.0

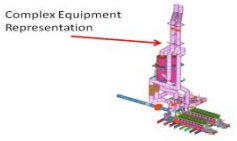
Navy Enhanced Sierra Mechanics (NESM)

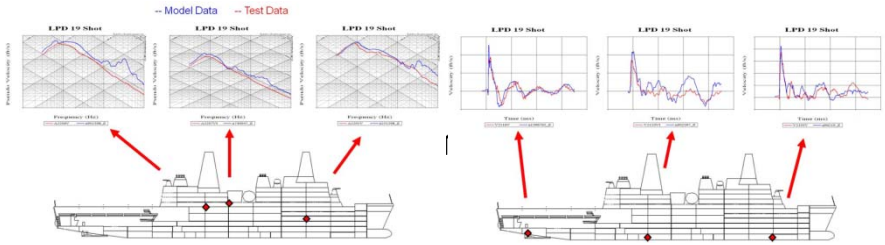
- Massively Parallel, Enhanced, Physics Based M&S Suite For Prediction Of Ship Shock Response & Damage Due To Weapon Engagements
- Modern Software Engineering Designed For Evolution
- Developed To Address Validation Of The Integrated Ship System Shock Hardness IAW OPNAVINST 9072.2A As Well As Live Fire Test & Evaluation (LFT&E) Needs
- Leverages DOE-ASC Investment In Sierra Mechanics
- Leverages ONR Investment In The Implosion Program
- Leverages ONR Investment In The DYSMAS Program
- Planned Funding/Execution Through 2019 (POM '08)

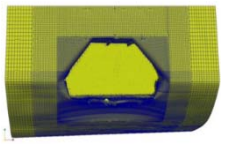


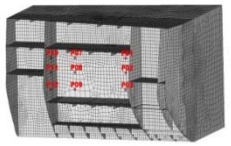
Emphasis on Validation for Both Shock Response & Ship Damage Compared to Physical Testing

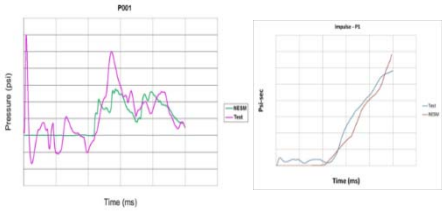








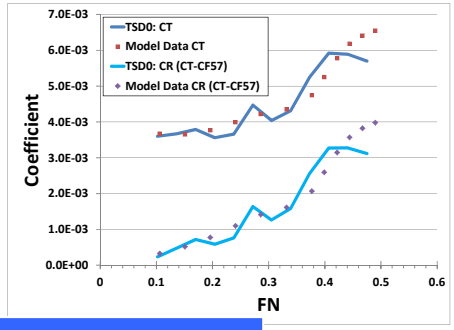




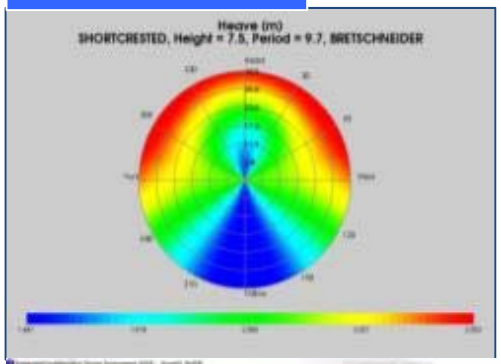
CREATE™ Integrated Hydrodynamics Design Environment (IHDE)

DOD HPC MODERNIZATION PROGRAM

Data Comparisons



Seakeeping Behaviors



RESISTANCE	POWERING	MANEUVERING	LOADS	SEAKEEPING

LOCAL HPC

DESIGN STUDIES

SHAPE OPTIMIZATION

AUTOMATED VALIDATION CASES

HPCMP

FKS TSD	AEGIR DAS BOOT	SMP SEP	TEMPEST	NavyFOAM Strand	LAMP

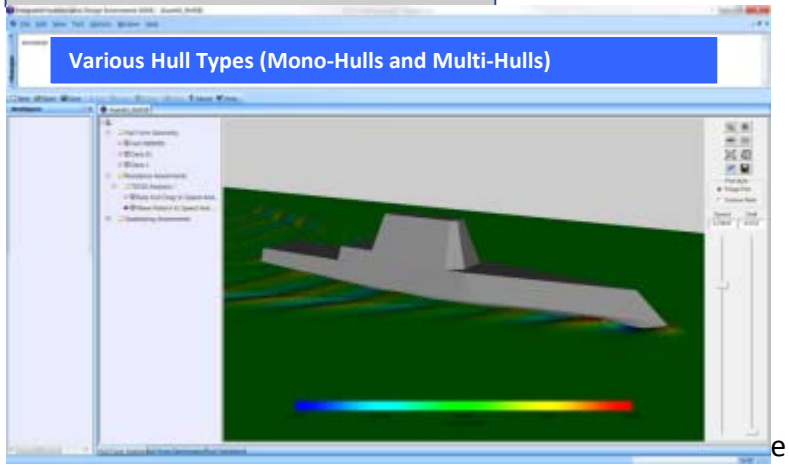
Problem Set Up	Conditions	Geometry	Automated Gridding

DRIVER/GUI

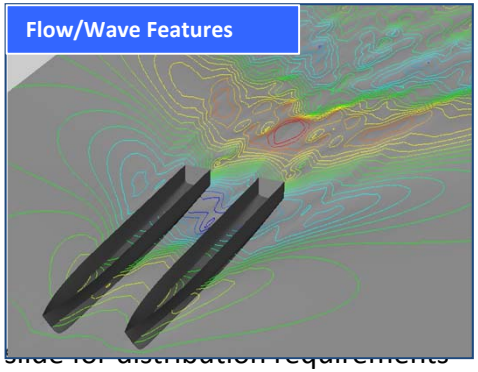
LEAPS

CAPSTONE

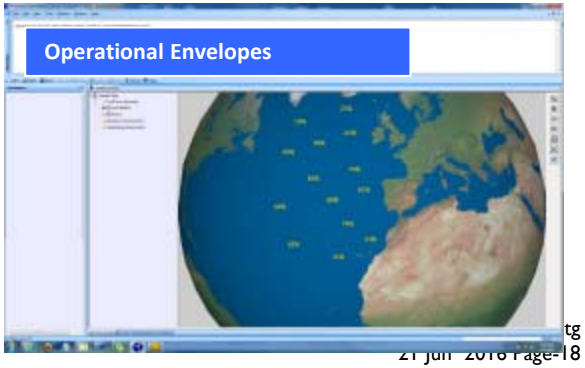
Various Hull Types (Mono-Hulls and Multi-Hulls)



Flow/Wave Features

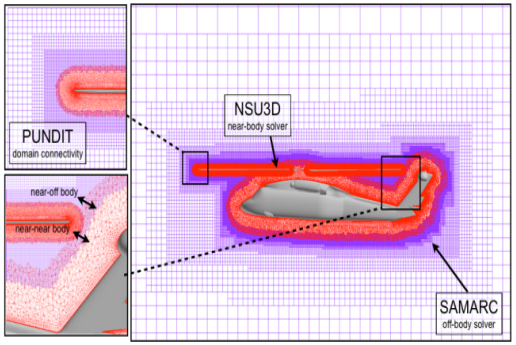


Operational Envelopes



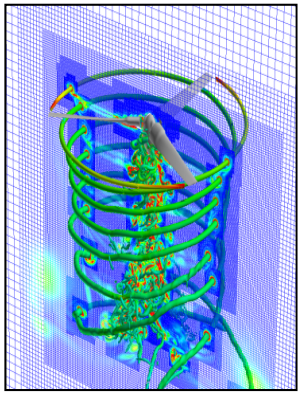
Helios Solver for Rotorcraft Aeromechanics

Dual Mesh Paradigm



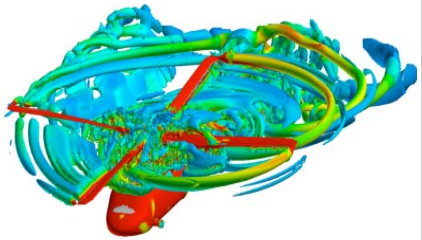
Unstructured grids for near-body complex geometry
Cartesian adaptive grids for off-body rotor wakes

Adaptive Mesh Refinement



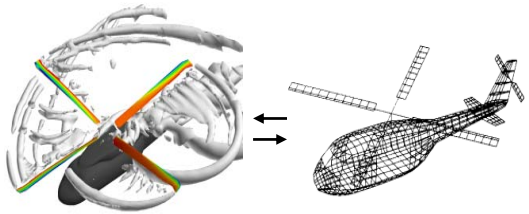
To resolve unsteady rotor wakes

Moving Body Overset



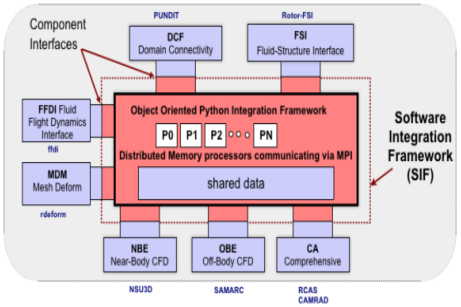
Interactional aerodynamics between multiple rotors and fuselage

Aero and Structural Dynamics Coupling



RCAS and CAMRAD structural dynamics models for rotors including full vehicle trim

Advanced Software Infrastructure

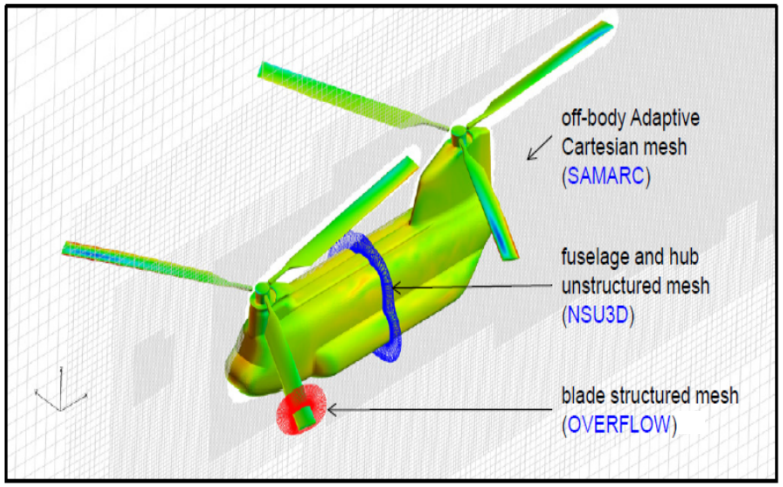


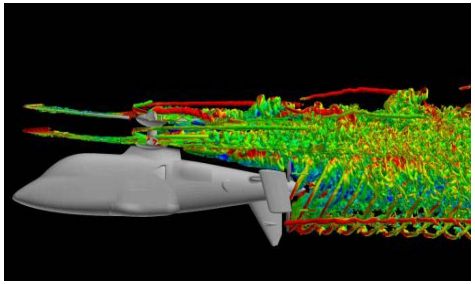
Python-based infrastructure readily supports addition of new software

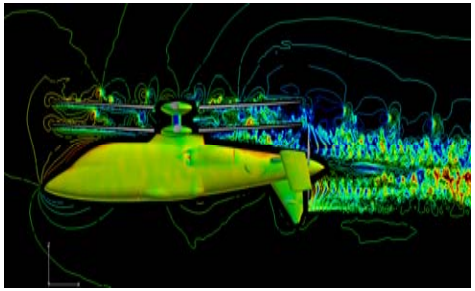
High Performance Computing

Runs on HPC hardware with focus on parallel scalability

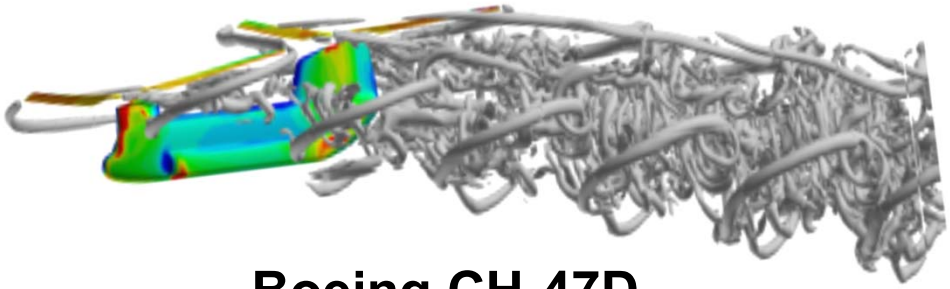
Helios Simulations for Complete Rotorcraft







Sikorsky X-2

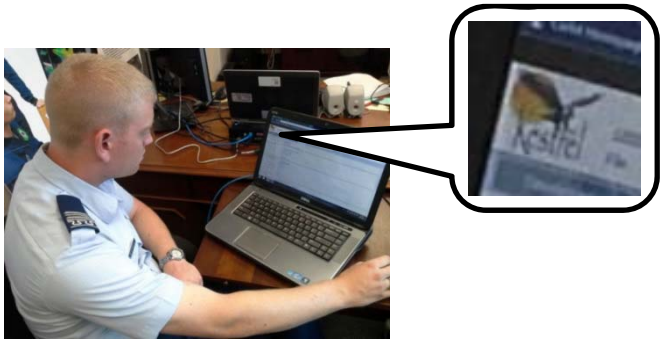


Boeing CH-47D

Helios is currently providing engineering support for ongoing rotorcraft acquisition programs including the Army's Joint Multi Role Technology Demonstrator (JMR-TD) program and the CH-47F Chinook ACRB replacement rotor system

HPC Portal–Supercomputing via a Browser

- **Most DoD computer users restricted to Windows, MS Office and a Browser**
- **Solution: HPC Portal for Browser Access**

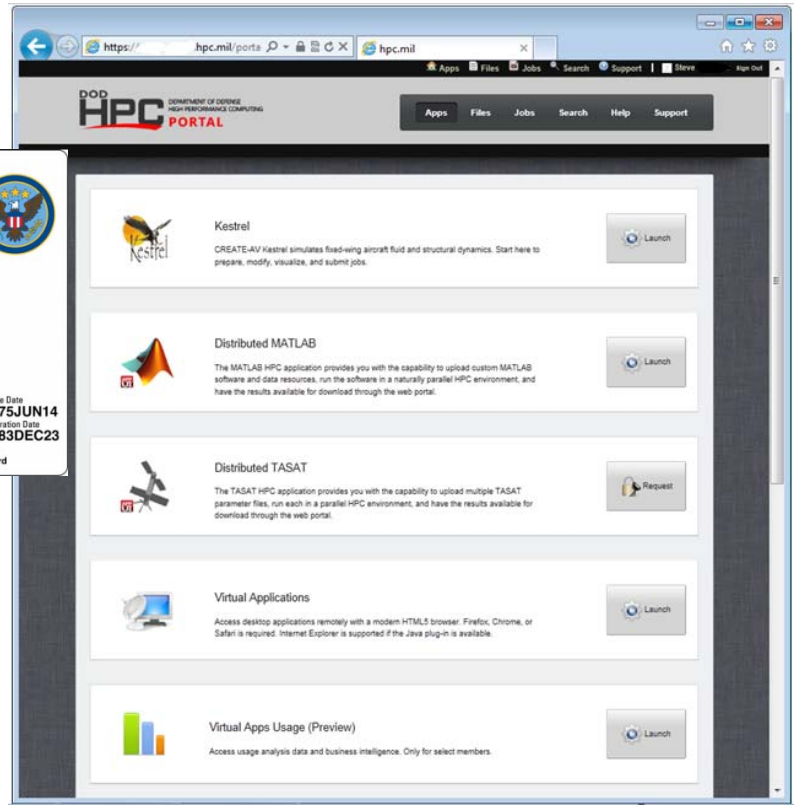


Easy

- Similar to a webmail interface
- No user-installed software or patches
- Integrated tutorials, community forums, and help

Secure

- No desktop install is a security best-practice
- Quick DoD CAC-authentication
  - Yubikey for University and Industry
- Secured at one server vs many desktops

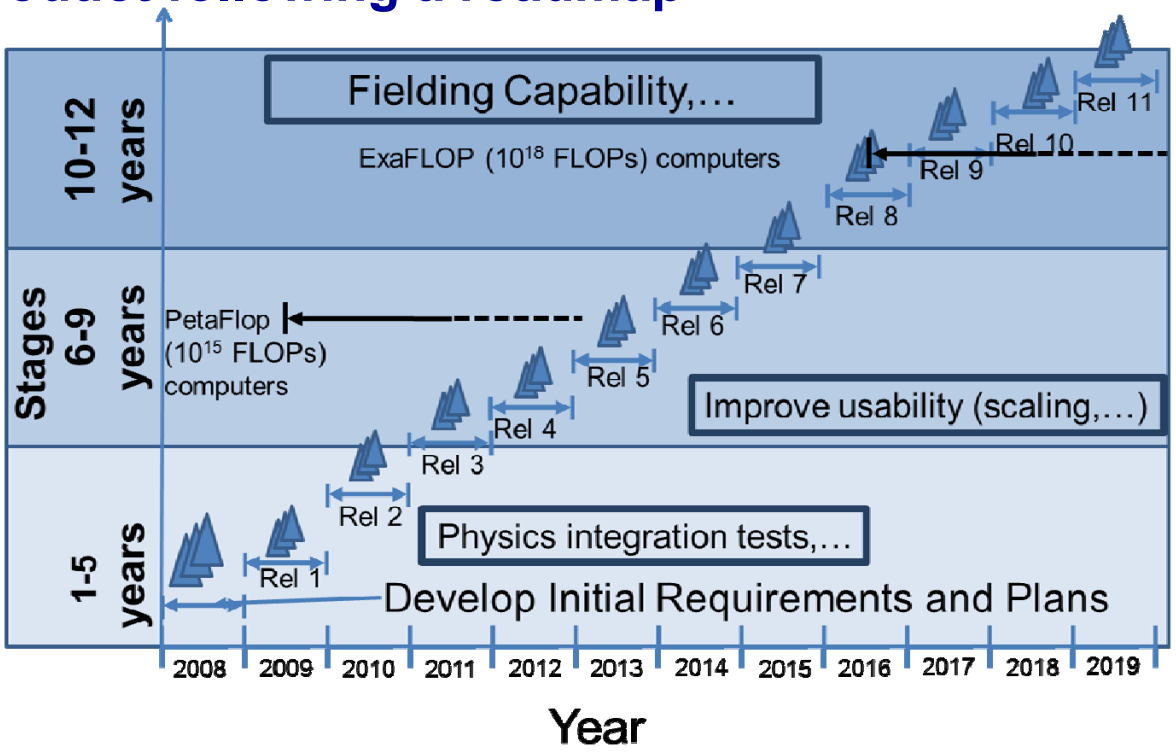


Build the Right Software, and Build it Right!

- **Software built by government-led teams of 5 to 10 staff**
  - **Strong teams and team leaders embedded in customer institutions**
  - **Oversight by customer institutions**
- **Agile, But Highly Disciplined Software Development Practices**
  - **Strong emphasis on software quality (maintainable, extendable,…)**
  - **Supportive code development environment—virtual clusters, central servers and code repository, dedicated high performance computers...**

Annual releases of each product following a roadmap

- Increased capability annually
- Extensive beta-tests of each release
- Rigorous V&V process
- Improved scalability for massively parallel computers
- Improved usability
- Responsive to evolving requirements
- Extensive documentation



Well-Documented Applications

Annual Project Baseline

Application Technical Description

Annual Software Development Plan

Developer's Guide

User's Guide

Test Plan

Test Report

See title slide for distribution requirements

Project Management

- **Emphasize Leadership over Management**
  - Facilitate success of each team
- **Achieve balance between control and delegation**
  - Delegate authority and initiative to development teams—Agile process
  - But require accountability and an organized development and deployment process
  - Annual releases and management by walk-around and vtc
- **Embed team leaders and teams in customer organizations**
- **Execute pilot projects by customer organizations to:**
  - Establish utility, value, and impact of the CREATE tools
  - Understand customer priorities and workflows
  - Acquaint customers with CREATE tools

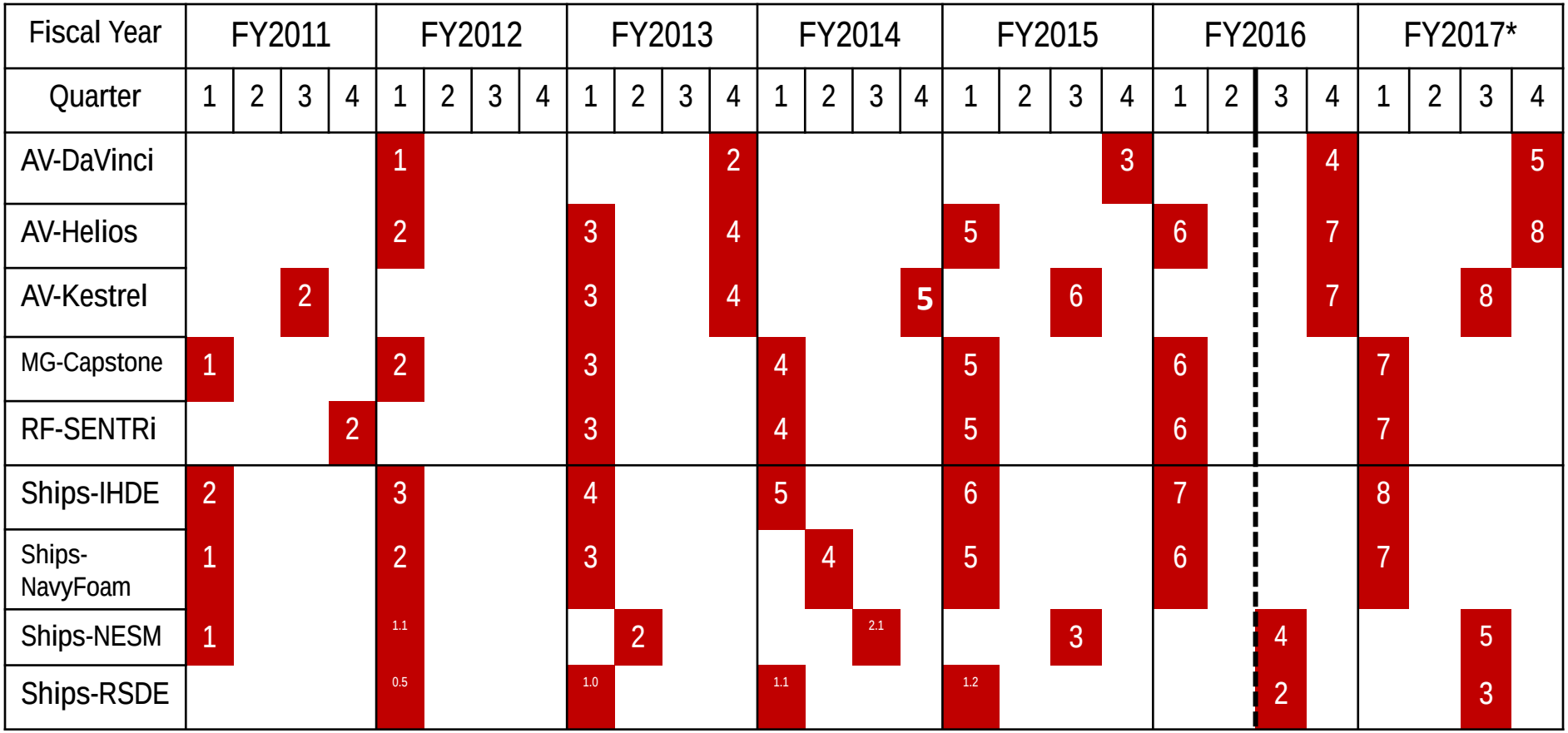
CREATE Tactical Team

- Experienced Scientific and Engineering Software Engineers
- Experienced DoD Program Managers
- IP and Legal SMEs

Tracked annual releases coordinated with Annual Program Baseline goals and plans

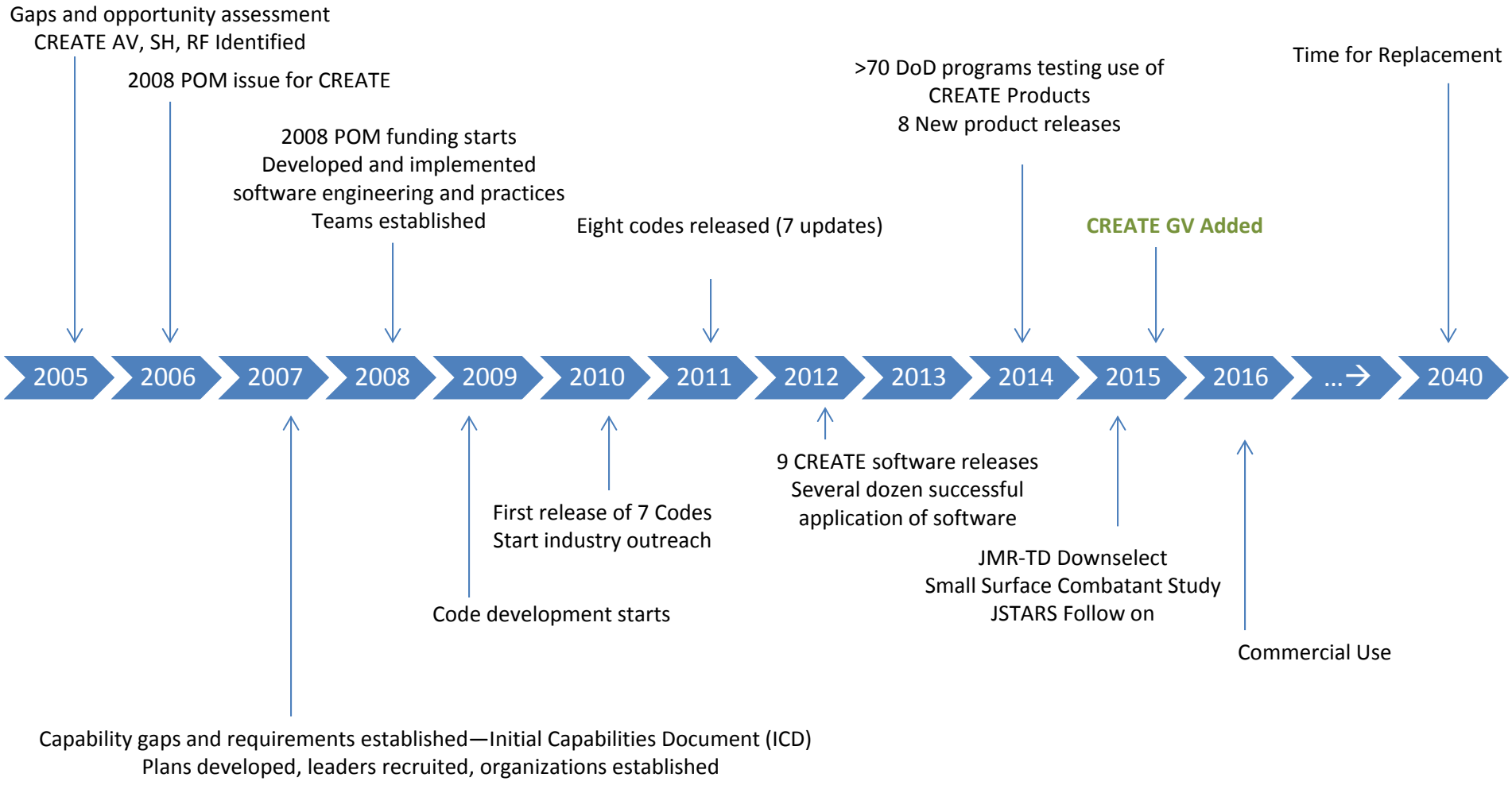
Annual CREATE Product Release Cadence

17 June 2016



- **Approximately every year, a fully-tested upgraded code with the new features identified in the roadmap is released**

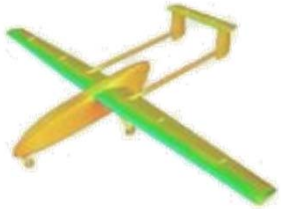
CREATE Roadmap
Code Development Takes a Long Time (ten years or more), and Never Ends

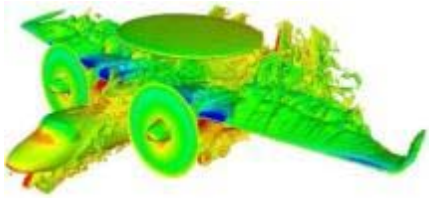


At latest count, CREATE Tools in use by 129 DoD organizations to assess the performance of more than 70 DoD Weapon Systems



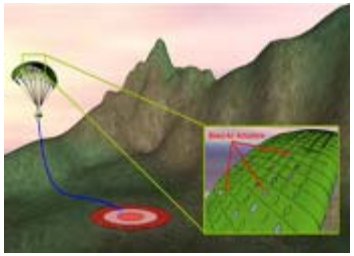
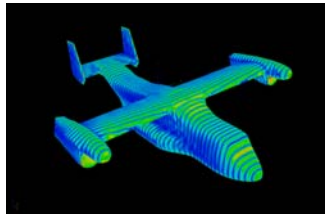

NAVSEA: DDG-1000 Destroyer, CVN 78 & 79, and Ohio Replacement and the LX(R) programs.



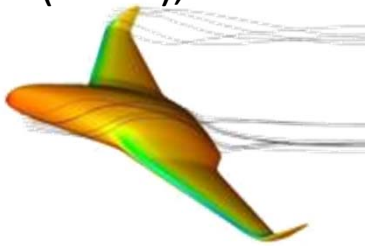
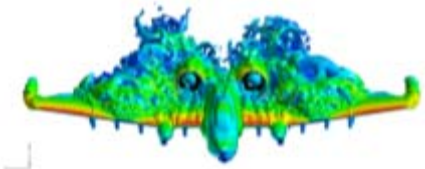
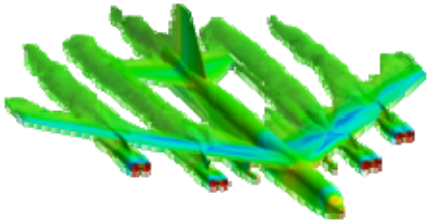



NAVAIR: Aerostar & Raven UAVs, F/A-18E, E-2D



Army: UH-60, CH-47 (ACRB), Guided Airdrop (RDECOM), V-22

AF LCMC: F-15 SA/DB-110, Strategic Airlift CP&A, A-10, B-52

See title slide for distribution requirements

At Last Count, 129 Organizations Use CREATE Tools

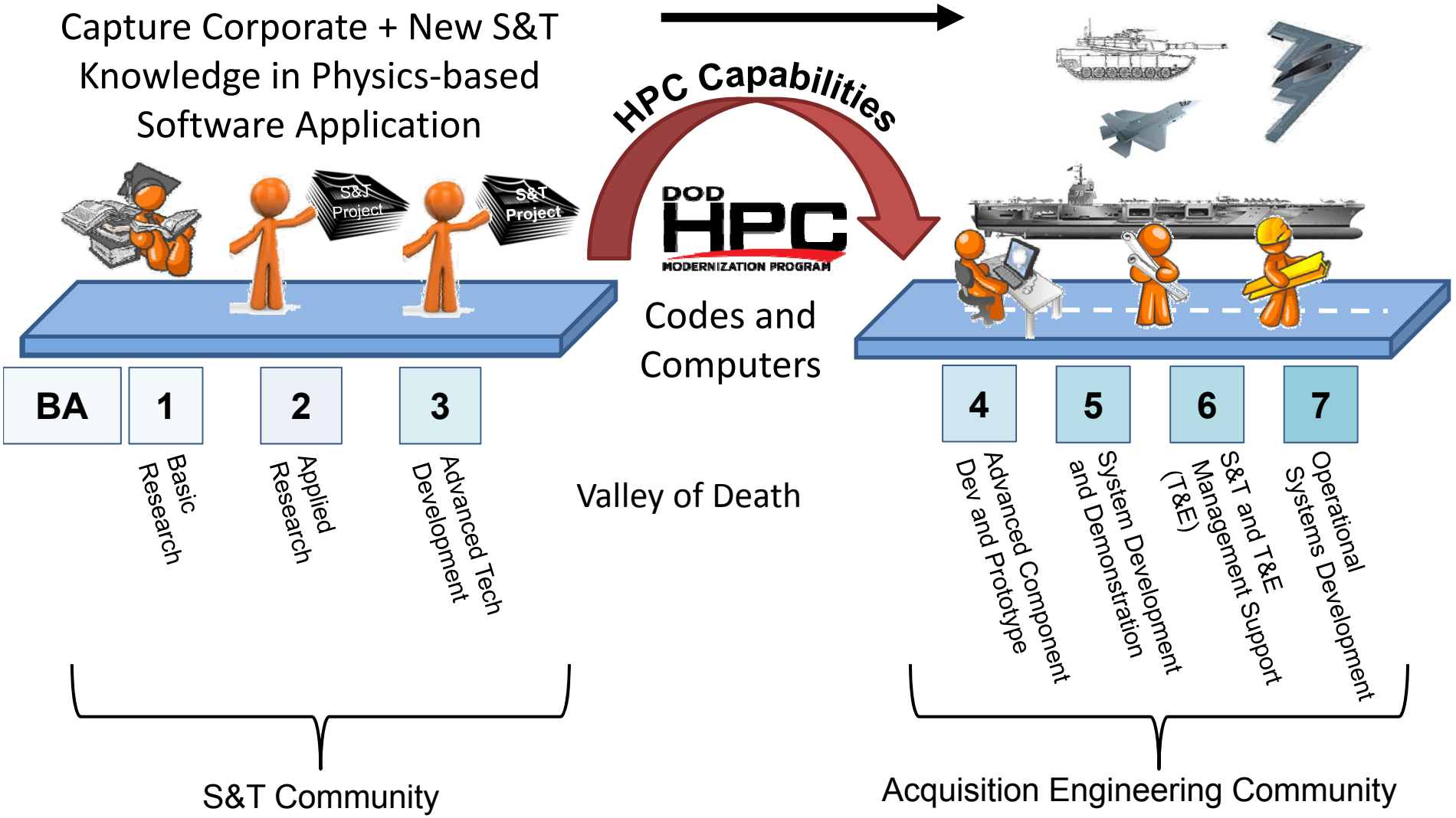
HCPMP CREATE™ Ships: (38) Allion Corporation, Cardinal Engineering, DRS Corporation, DYNAFLOW Corp, **General Dynamics/Electric Boat Division,** Hi-Test Laboratory, **Northrop Grumman Corp Undersea Systems** , Classified Program NSWC Carderock Code 65 , Classified Program NSWC Carderock Code 66 , Naval Underwater Warfare Center, Sandia National Laboratories, Weidlinger & Associates, General Dynamics Land Systems, Hydromechanics Division Naval Surface Warfare Center Carderock Division, Bath Iron Works (shipyard), BMT-Syntek, Bollinger (shipyard), Booz Allen Hamilton, CSC (NAVSEA/PEO engineering contractor), DRS (NAVSEA/PEO engineering contractor), Gibbs and Cox (NAVSEA/PEO engineering contractor), **HII (Newport News and Pascagoula shipyards), Lockheed Martin**, NASSCO (shipyard), NAVFAC (Naval Facilities), **Northrup Grumman,** Office of Naval Intelligence, University of Michigan, US Army Corps of Engineers, US Coast Guard, MIT-Department of Naval Architecture , NSWC Carderock Division, Center for Innovative Ship Design, US Coast Guard and Coast Guard Academy, Texas A&M, Naval Postgraduate School, U. of Washington, Virginia Tech, Georgia Tech,

HPCMP CREATE AV: (32) AFLCMC/EN, AFLCMC/XZ, AFAEDC, AFSEO, AF Edwards, AF Hill, AF Holloman, AFRL, NAVAIR/4.3, NAVAIR/4.10, NAVAIR/Carderock, Army/ADD (Moffett Field), Army/AED (Redstone Arsenal - Aviation), Army/SSDD (Redstone Arsenal - Missiles), Army Research Laboratory (ARL), Army/Nadick Soldier Systems Center), AF Academy (USAFA), AF Institute of Technology (AFIT), USNA, GaTech, BYU, NASA ARC, **Boeing Philadelphia/Mesa (Helicopters), Boeing St Louis (Fixed-Wing), Lockheed-Martin, Northrop-Grumman, Raytheon, Sikorsky, Bell Helicopters**, Textron, Karem Aircraft, Inc, Mercer Engineering, and Bihrle Applied Research Company

CREATE RF: (54) A&E Partnerships, Aerospace Testing Alliance, **AFRL Aerospace Systems Directorate** , Air Force Institute of Technology, Army AMRDEC, Army CERDEC, Army CERDEC, ATK, **Ball Aerospace, Boeing,** Cobham Defense Electronics, **DoD Missile Defense Agency**, General Atomics, General Electric, Georgia Tech Research Institute, Global Analytics, Harris Corporation, Inc., Integrity Applications Inc (Pacific DS), Lawrence Livermore National Laboratory, **Leidos, Lockheed-Martin**, MDA Information Systems LLC, Michigan State University, **MIT Lincoln Lab, MITRE Corporation,** NASA - Glenn, NASA - Langley, Nation Air and Space Intelligence Center, National Institute of Standards and Technology, Naval Research Lab, Naval Surface Warfare Center, Navy - Airborne Threat Simulation Organization (ATSO), Navy NAVAIR, Navy NR NIOC GEORGIA - GREAT LAKES, Navy SPAWAR, Navy's Center of Excellence for Information Operations , Northrop-Grumman, NSWC-Carderock West Bethesda, Nuvotronics, Office of Naval Research, Pratt & Whitney, Raytheon, Rolls-Royce / Libertyworks, Signature Solutions, Sikorsky Aircraft Corp., Sotera, TechFlow, The Ohio State University, U.S. Army Research Lab, University of Dayton Research Institute, US Army Natick Soldier Research Development and Engineering Center, USAF AFMC AFLCMC/XZE , Vencore, XL Scientific

MG: (5+ CREATE AV, Ships and RF) Navy Research Lab (NRL)/ Low-Frequency Broadband (LFBB) Program, NRL/ Strategic Environmental Research and Development Program (SERDP), NRL/ Jet-noise reduction program, Engineering Research and Design Center(ERDC)-CREEL: Unattended Ground Sensors Programs, ERDC-ITL: Terrain Modeling

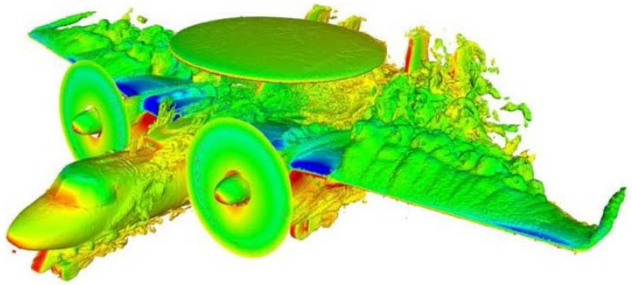
HPCMP and CREATE: Transitioning S&T to Acquisition Engineering & Design



E-2D SIM Database Development

Context The E-2D SIM database is the basis of the E-2D flight simulator used for pilot training and is the authoritative reference for E-2D aircraft aerodynamics. The database is a composite of data from wind-tunnel tests, analytic methods, and physics-based simulation (CFD).

Objective Apply the HPCMP CREATE™ -AV multi-disciplinary, physics-based simulation tools Kestrel and Helios to the E-2D in order to improve the physical accuracy of the E-2D SIM Database for targeted flight regimes – low-speed, gear-down, take-off/land configurations.



Brad Green (NAVAIR 4.3.2.1)

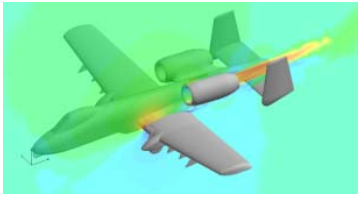
Impacts

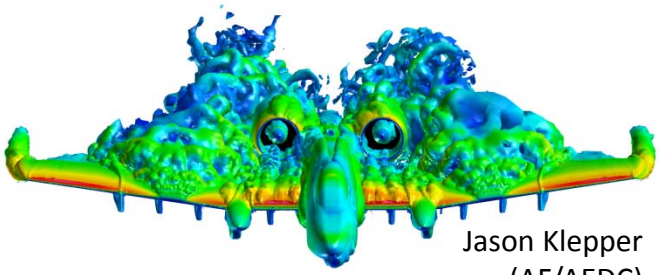
- ✓ Improved flight simulator for pilot training and aircraft performance assessments.
- ✓ Validated a process that enables decision makers to rely on physics-based simulation for flight clearance data supporting future modifications to the E-2D, reducing time to deployment. (Can be between 6-12 months)
- ✓ Develop aerodynamic data for configurations that cannot be safely flight tested.

A-10 Engine Inlet Flow Distortion

Context The A-10 System Program Office (SPO) is exploring enhancements to the aircraft's current inboard leading edge slat system. The A-10 mission requires operation at high angles-of-attack and high sideslip, which increases the likelihood of engine inlet flow distortion.

Objective Apply HPCMP CREATE-AV™ Kestrel to simulate the A-10 with baseline and alternative wing leading-edge configurations to assess potential for improvements realizable from the planned enhancement. Explore wind-tunnel scale and full-scale conditions with both flow-through nacelles and the integrated TF34-GE-100 0-D engine model.



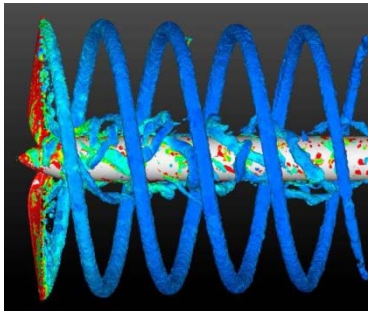


Jason Klepper
(AF/AEDC)

AEDC provided the A-10 SPO with engine inlet distortion data associated with various wing leading-edge designs. Analysis of the simulation results have identified the contributing sources of engine inlet distortion that could not be determined from wind tunnel data alone. The A-10 enhancement program is still in progress. AEDC engineers have demonstrated that HPCMP CREATE™-AV Kestrel is a valuable tool in design validation testing.

Small UAV Power Effects

Context UAV propellers shed turbulent flow onto wing and/or control surfaces which profoundly influence control effectiveness and overall forces and moments on the aircraft. Physics-based simulation is the only viable cost effective means of gathering needed engineering data.



Eric Lynch & Theresa Shafer
(NAVAIR 4.3.2.1)

Objective Apply the HPCMP CREATE™ -AV multi-disciplinary, physics-based simulation tools Kestrel and Helios to a set of propeller powered UAV aircraft to develop and demonstrate a process that can be used by PMA-263 (Small Tactical UAV's) to obtain engineering data necessary for flight clearance – including Power Effects, Stability and Control, Aerodynamics, and Mission Performance.

Impacts

- ✓ **Enabled flight clearance of small UAV**. This is really significant since small UAVs typically are granted air worthiness certifications (i.e., restricted flight envelope and flying conditions) due to lack of supporting data.
- ✓ Minimize risk and loss of assets. Therefore reduce overall time and cost.
- ✓ Increased mission effectiveness by more accurately defining vehicle performance.

CREATE Summary

- Developing and deploying software with the new features needed by the DoD Air Vehicle, Ship, Ground Vehicle and RF engineering communities
- Acquisition community interest and customer use growing exponentially (AF, Navy & Army Engineers, Boeing, LMC, NG, Raytheon, Sikorsky, Bell, Pratt & Whitney, AFLCMC, AMRDEC, NAVAIR, NAVSEA, C-130/C-17 Cargo Release, F/A-18E, ARL, SPAWAR, Ball Aerospace)
- Already contributing to the analysis and design of dozens of important DoD systems (CH-47 rotor-blade retrofit, Ohio replacement submarine, CVN-78 shock test, NAVAIR UAV flight certification, AF next-generation cargo plane)
- Major progress in major challenges: user support, intellectual property, deployment capability, software engineering
- Achieving initial goals → potential to revolutionize the way the DoD procures major weapon platforms
- Actively participating in and supporting the ERS Program and the AF Digital Thread

CREATE Future 2008→2019→2040…

- **Initial CREATE goal: base capability to establish the value of physics-based design tools, √ done**
- **CREATE now provides a foundation to fill many other DoD acquisition capability gaps**
  - OSD Engineered Resilient Systems
  - AF Digital Thread/Digital Twin
- **Enhance existing products: e.g. Kestrel—Hypersonics, RSDE/DaVinci—Life cycle costs and lifetime prediction & major aspects of new designs**
- **With additional funding, new CREATE products:**
  - Space Satellite performance, rocket design, structural design, electronic warfare,…
- **CREATE worked out a process for the DoD to develop and deploy robust engineering tools for acquisition**

Questions?

BLUF

- **CREATE is a set of physics-based HPC engineering tools to enable the DoD to develop innovative weapon systems.**
- **CREATE tools enable generation and analysis of virtual prototypes of DoD Air Vehicles, Ships, and RF antennas, and in the future, Ground Vehicles, and can accurately predict system performance.**
- **CREATE tools are:**
  - Government-developed, government-owned, and government-supported to enable the DoD to independently evaluate contractor deliverables.
  - Designed for a ~30 year (or more) life cycle.
  - Being adopted by DoD acquisition engineering communities (government and industry), 116 organizations at last count, and are beginning to have significant impact.
  - On the verge of being adopted by Defense Industry for commercial use.
- **CREATE Tools are enabling elements of the DoD Engineered Resilient Systems and AF Digital Thread/Digital Twin Programs and have the potential to improve the effectiveness and efficiency of DoD T&E enterprises by enabling their Virtual Proving Ground (VPG) concept.**

- **Reference slides**

Dr. Edward Kraft, AEDC/CZ-AF HPC User Forum

"High Performance Computing and the AF Digital Thread / Digital Twin"

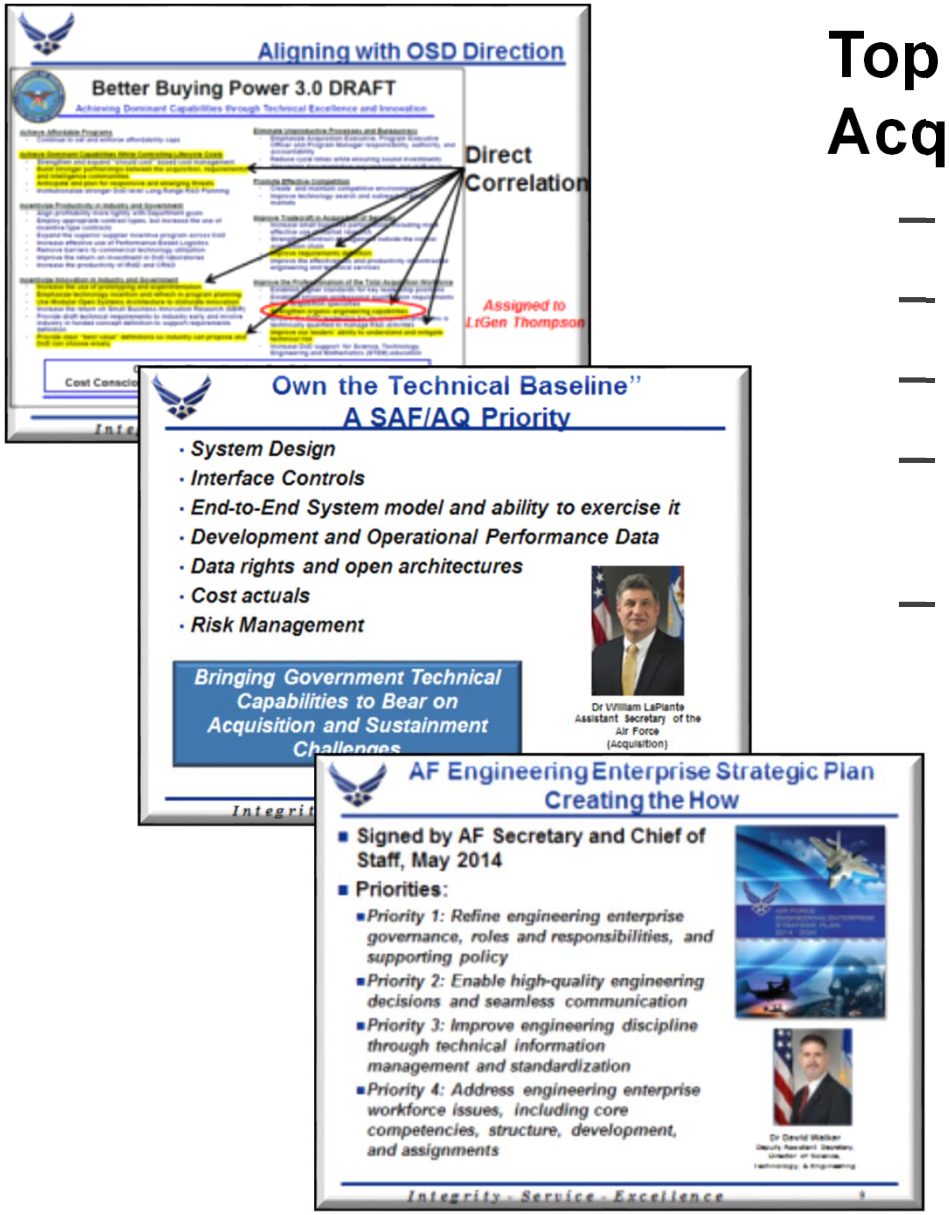
Three Activities that Enabled a Revolution

- **1991 – formation of the HPCMP**
- **2005 HPCMP Users Group Meeting in Nashville –**
  - Question – how does HPCMP justify peta-scale computing in the DoD
  - Answer – scalable software focused on applications to defense acquisition
  - Result – CREATE Program (CREATE-AV, -Ships, -RF)
- 2013 AF Digital Thread concept emerges from AF Chief Scientist's "Global Horizons" report and AF Chief Engineer's Engineering Strategic Plan as vision for instantiation of physics-based modeling in life cycle management

BLUF – The AF Digital Thread/Digital Twin is the analytic framework that brings physics-based modeling to the forefront of using High Performance Computing to improve defense acquisition and sustainment

E. Kraft cont.

Right Tools, Right Time, Right Place



Top Down Drivers for Changing Acquisition and Sustainment

- Better Buying Power 3.0
- AF "Own the Technical Baseline"
- Bend the Cost Curve
- AF Engineering Enterprise Strategic Plan
- OSD Systems Engineering Digital System Model

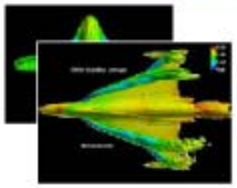
The AF Digital Thread / Digital Twin, enabled by physics-based modeling capabilities like CREATE-AV, is gaining traction as an approach to meeting these challenges

CREATE: An ERS Cornerstone

Dr. Jeffery Holland, "Engineered Resilient Systems—*Power of Advanced Modeling and Analytics in Support of Acquisition"*, NDIA 16th Science and Engineering Technology Conference, March 24-26, 2015

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

Aircraft (AV) Tools:



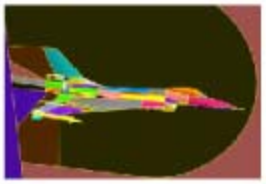
Fixed-wing aircraft, rotorcraft, conceptual design, and operational testing and transition

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

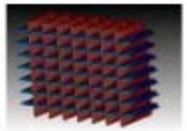
CREATE-MG
Meshing and Geometry (MG) Support

CREATE-GV
Ground Vehicle (GV) Design Tools

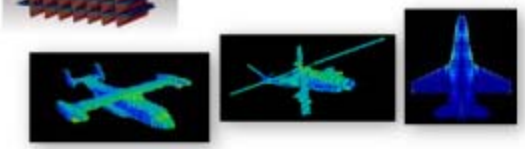
Ship Design Tools:

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

Radio Frequency (RF) Antenna:



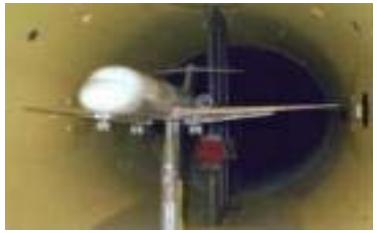
Conceptual design and detailed analysis tools for myriad DoD platforms



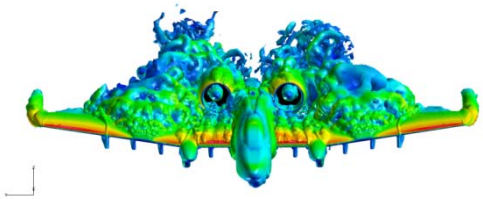
ERS ENGINEERED RESILIENT SYSTEMS

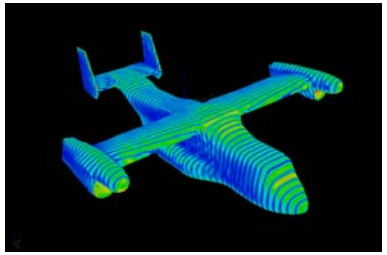
The CREATE Vision: Physics-Based Virtual Prototyping Provides Early Decision Data

- Supplement experimental testing of physical prototypes ***with***

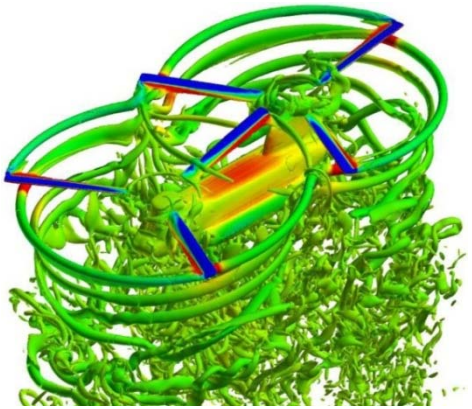



physics-based tools and high performance computers to make **accurate** predictions of platform performance


A-10


V-22

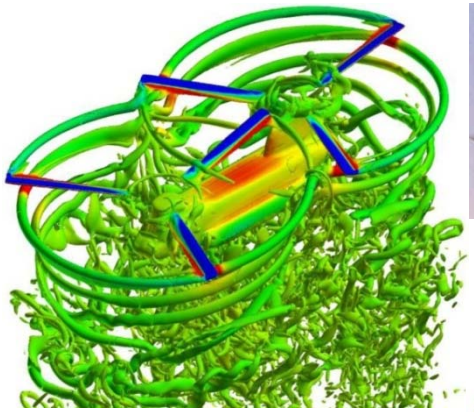

LX(R)


CH-47F Hover

- Faster and cheaper evaluation of far more design options [LX(R) 6→22,000]
- Provides performance data early → identify and fix flaws before metal is cut

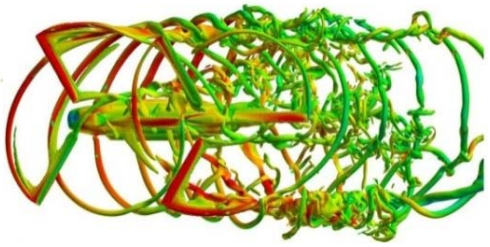
CH-47F Performance Improvement

Increasing helicopter hover thrust performance normally trades-off with forward flight performance. Army AMRDEC/AED and Boeing used HPCMP CREATE™ -AV Helios software and three million CPU-hours on DSRC supercomputing hardware to confirm Boeing's predictions of improved and isolated rotor performance and then, for the first time, verified computationally the integrated rotor/rotor and rotor/fuselage interactional aerodynamics and installed performance of the new rotors.



Hover

Forward Flight



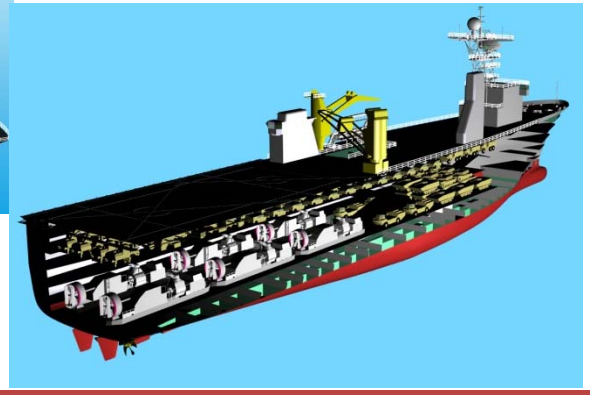
HPCMP CREATE™ resources enabled:

- **Virtual testing of the integrated CH-47F with new rotor via high fidelity analysis early in the design process, including aft pylon height and blade indexing.**
- **Flight test planning in advance of scheduled test events.**

HPCMP CREATE™ resources and expertise enabled early design stage predictions of helicopter performance that project up to an estimated 2,000 pounds improved hover thrust for 400+ Chinooks with limited degradation of forward flight performance.

Trade Space Analysis of LX(R) Design Concepts

- The Navy acquisition community needed a rapid and robust exploration of the trade space surrounding the point design concepts developed during the initial LX(R) Analysis of Alternatives (AoA).
- The trade space exploration was conducted using HPCMP CREATE-SHIPS™ RSDE, the Rapid Ship Design Environment tool, with support from ERS.
- The concept design results were utilized to build behavior models representing the feasible design space, which included the point designs from the initial AoA. These results facilitated Pre-Milestone A investigation of the trade-offs among design requirements including19 different design performances, build specifications, and cost.
- The LX(R) program office was particularly interested in the trade-offs in cost and performance for five different levels of build specifications ranging from “enhanced military” (similar to the LPD 17) to “tailor low” (using commercial structures and equipment).

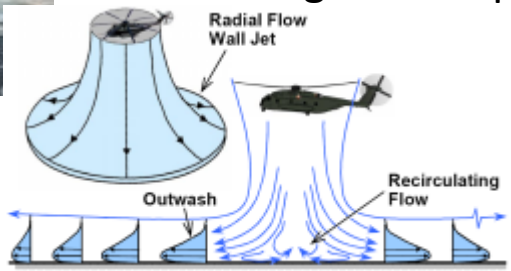


HPCMP resources enabled:

- **22,000 conceptual designs to be produced and evaluated within a period of 3 months.**
- **Understanding of the trade-offs among 19 ship performance attributes, survivability specification levels, and cost.**
- **Creation of behavior models to predict performance versus cost for design variations.**

The Navy benefited from a detailed understanding of LX(R) requirements, performance, and cost trade-offs for 22,000 different design concepts – all produced and evaluated within 3 months.

CH-53K Outwash Modeling



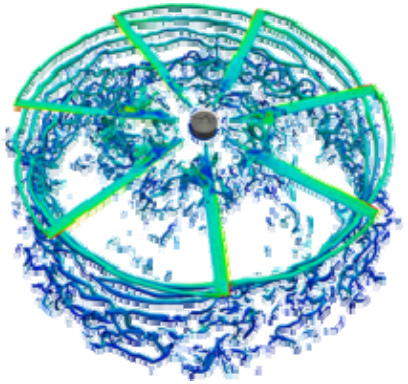
Context The outwash flowfield of high-disk loading rotorcraft, such as the CH-53K, represents significant operational concerns – including mission effectiveness and safety of personnel, effect on ground equipment, structures, materials, and equipment.

- ✓ Current approach of analysis based on curve-fits to existing outwash datasets are inadequate since they derived from limited/coarse data.
- ✓ Empirical methods cannot be universally used with confidence since most applications are unique.

Objective Validate HPCMP CREATE™ -AV Helios capability to predict unsteady outwash of the CH-53K at various aircraft loadings and hover heights by comparison with experimental data.

Impacts

- ✓ Demonstrated predictive tool for the CH-53K as well as other fielded and planned rotary-wing vehicles.
- ✓ Increased operational safety by providing flight restrictions.
- ✓ Increased mission effectiveness by determining outwash effects on personnel and the environment.



Eric Hayden & Jennifer Abras (NAVAIR 4.3.2.1)

CREATE Has Defined Core Software Engineering Practices for DoD Physics-based HPC Engineering Software Applications

Development Team

1. Lean (<10), close-knit development teams led by technical experts.
2. Transparency in development across CREATE projects.

Customer Focus

3. Oversight by senior stakeholder and user representatives.
4. Pilots to solicit customer reaction and feedback.
5. Frequent reporting to stakeholders.

Technical Maturity

6. Proven technologies and customer-defined use cases.
7. VVUQ in alignment with NRC (NAS/NAE) best practices for scientific codes.

Development Methods

8. Milestone-driven workflow management with agile flexible workflow execution and annual releases.
9. Configuration management.
10. Code builds based on tests.
11. Adequate code documentation.

Requirements Definition

12. Reliance on prototypes and use cases to define requirements.

Present Process is Unstable to Process Growth

- Program n overruns budget, schedule,,
- Add more oversight, reviews, process to Program n+1, loop