Supporting the ERS Program

Computational Research Engineering Acquisition Tools and Environments

A DoD Program to Aid Acquisition Engineering
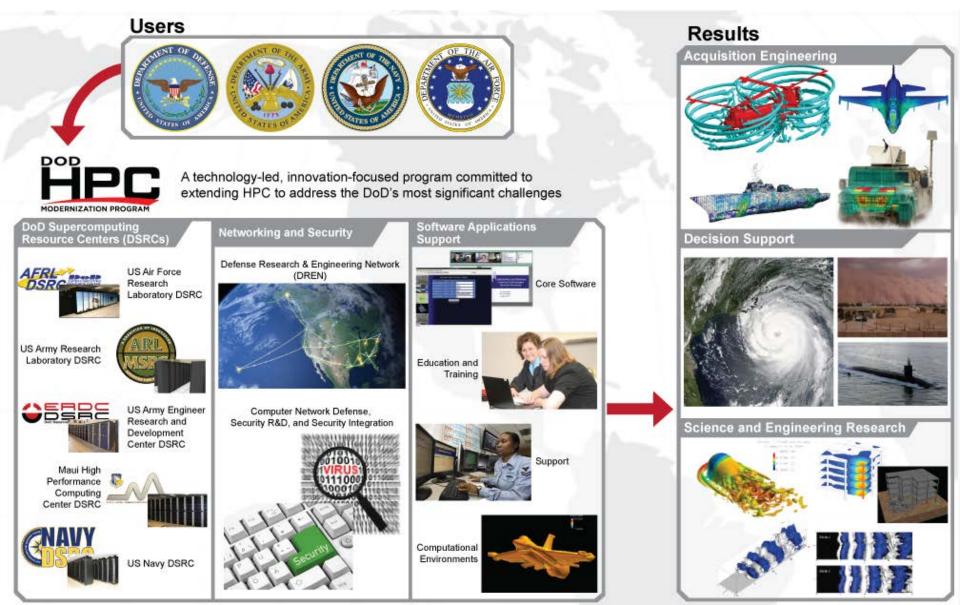
Dr. Douglass Post, CREATE Program

Software Engineering Institute | **Carnegie Mellon University**

BLUF

- **CREATE is a set of physics-based High Performance Computing engineering tools to enable the DoD to develop innovative weapon systems and reduce acquisition risk, cost, schedule and improve system performance.**

- **CREATE tools enable generation and analysis of virtual prototypes of DoD Air Vehicles, Ships, and RF antennas and, in the future, Ground Vehicles, and provide accurate predictions of their 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+ life cycle.
  - Being adopted by DoD acquisition engineering communities (government and industry) and are beginning to have significant impact.
  - On the verge of being adopted by Defense Industry for commercial use.

- **CREATE Tools are enabling the DoD Engineered Resilient Systems and AF Digital Thread/Digital Twin Programs and can improve the effectiveness and efficiency of DoD T&E enterprises by enabling their Virtual Proving Ground (VPG) concept.**

Computational Research and Engineering Acquisition Tools and Environments (CREATE)

CREATE is a multi-phase program that started in 2008, to develop and deploy four (now five) computational engineering tool sets for acquisition engineers

- **Aircraft (AV) Design Tools:** Fixed-wing aircraft, rotorcraft, conceptual design, trade-space exploration and operational testing and transition

- **Ship Design Tools:** Shock/damage, hydrodynamics, early-stage design & trade-space exploration, and operational testing and transition

- **Radio Frequency (RF) Antenna Design and Integration Tools:** Conceptual design and detailed analysis tools relevant to virtually all DOD platforms

- **Ground Vehicles (GV) Tools:** End-to-end mobility solver, provide rapid, physics-based data for design and trade-space analysis

- **Meshing and Geometry (MG) Support:** The geometry and meshing project improves the ease, speed, flexibility, and quality of geometry and mesh generation, and enables the generation of CAD-neutral digital representations and product models of weapons systems & platforms and operational terrains and environments

CREATE-AV

Aircraft (AV) Design Tools

CREATE-SHIPS

Ship Design Tools

CREATE-RF

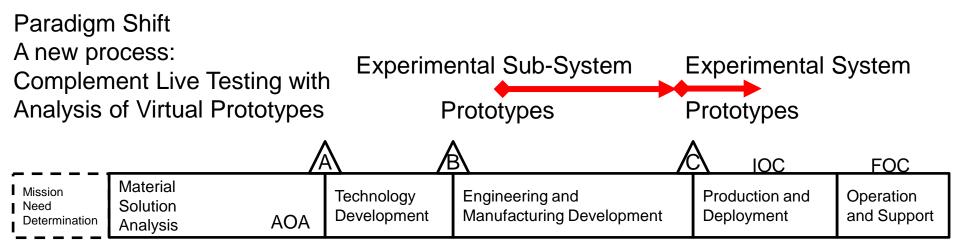Radio Frequency (RF) Antenna Design and Integration Tools

CREATE-GV

Ground Vehicle Design Tools

CREATE-MG

Meshing and Geometry (MG) Support

ENGINEERED RESILIENT SYSTEMS
DEPARTMENT OF DEFENSE

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

Paradigm Shift
A new process:
Complement Live Testing with
Analysis of Virtual Prototypes

Experimental Sub-System
Prototypes

Experimental System
Prototypes

	A	B	C	IOC	FOC
Mission Need Determination	Material Solution Analysis AOA	Technology Development	Engineering and Manufacturing Development	Production and Deployment	Operation and Support

Physics-based Computing Tests of **Virtual Prototypes** — Moves "Testing to the Left (and Right)"
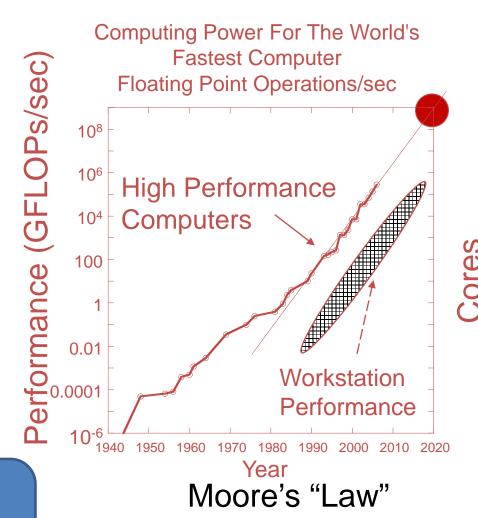
- Replaces "rule-of-thumb" extrapolations of existing designs:
    - with physics-based generation of design options for rapid trade-space exploration and physics-based analysis tools that assess the feasibility of the design options

- CREATE replaces "failure data from live tests" with "predictions of virtual prototype performance," providing timely decision data that identifies design flaws and performance shortfalls early, allowing them to be fixed before metal is cut

DoD HPC
MODERNIZATION PROGRAM

- **The $10^{15\text{-}18}$ 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 and analyses in an hour that took months in 1995 & days in 2005**

  - In ~ 10 years, workstations will be as powerful as today's high performance computers

CREATE codes can accurately predict the physical performance of Air, Naval and RF Antenna full-scale weapon systems

Computing Power For The World's Fastest Computer
Floating Point Operations/sec

Performance (GFLOPs/sec)

High Performance Computers

Workstation Performance

Cores

10^8

10^6

10^4

100

1

0.01

0.0001

10^{-6}

1940 1950 1960 1970 1980 1990 2000 2010 2020

Year

Moore's "Law"

CREATE Tools are now being used by over 110 DoD organizations to assess the performance of more than 70 DoD Weapon Systems
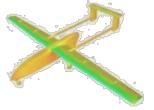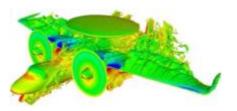

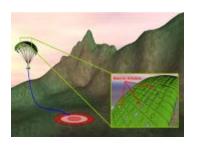NAVSEA: DDG-1000 Destroyer, the CVN 78 and 79 Aircraft Carriers, and the Ohio Submarine Replacement and the LX(R) programs.
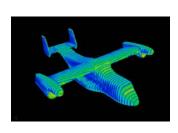

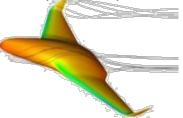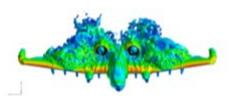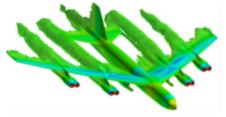NAVAIR: Aerostar & Raven UAVs, F/A-18E, E-2D

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
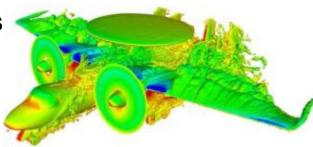
Karem

Bell

AVX

Sikorsky/ Boeing

- JMR is the Army's science and technology effort for the Future Vertical Lift (FVL) program of record
  - FVL goal is to field speedy, long-range successors to the Army's helicopter fleets
- In June 2014, Army engineers used CREATE-AV Helios to help evaluate the full-vehicle aeromechanics designs from the four initial JMR industry partners
- The Bell and Sikorsky/Boeing designs were chosen to move forward to technology demonstration in 2017
- Government and US industry engineering teams are currently using Helios to model performance and interactional aerodynamics effects for both of these designs

Sample FY15 Accomplishments
CREATE Applications

- **Supported adding combat capability to C-130J**
  - Using CREATE Capstone for problem setup and CREATE Kestrel for carriage and launch simulation, NAVAIR 4.3.2.1 was able to obtain flight clearance for use of Hellfire missile from C-130J

- **Provided hi-fidelity modeling data to improve flight simulators and assess potential operations (E-2D, F/A-18, KC-46)**
  - CREATE Kestrel develops aerodynamic data for configurations (e.g. landing gear deployed, etc.) not represented in current flight simulator databases (E-2D, F/A-18)
  - KC-46 program to evaluate various flight regimes in FY-16

E-2D vorticity

- **Established independent government analysis capability for U.S. Navy Primary Trainer (T-45)**
  - NAVAIR can now use CREATE Capstone and Kestrel software to support planned and future upgrades to T-45 Goshawk

Distribution A: Approved for Public release; distribution is unlimited.

Sample FY15 Accomplishments
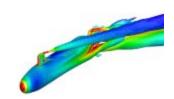## Software Applications *(continued)*

- **To support the Navy's CVN 78 Program, improved computational efficiency of CREATE NESM by over an order of magnitude.**

  – Efficiency improvement required to demonstrate high performance computing as a practical approach to predict ship damage due to weapon engagement

  – Provided ship damage predictions due to threat weapon engagement in support of the CVN-78 Program Live Fire Test & Evaluation study

- **Provided high-fidelity CFD modeling and simulation in support of Navy acquisition programs**

  – Provided resistance and powering estimates to the U.S. Marine Corps Amphibious Combat Vehicle (ACV) program of hull designs under consideration.

  – Provided maneuvering force estimates for operational turning conditions in support of the design development of the Ohio Class Submarine Replacement Program.

  – Developed the capability to predict the added resistance associated with waves, important in estimating the power and energy needs of ships and in assessing hydrodynamic approaches to reducing power and energy requirements.

Sample FY15 Accomplishments
Software Applications *(continued)*

- **Advanced outreach to the defense industrial base. Boeing, Bell Helicopter, Northrup-Grumman, Pratt-Whitney, and Sikorsky are all using CREATE AV and RF tools.**
  - Developed a policy for commercial use of HPCMP CREATE-AV tools
  - Bell Helicopter used HPC Portal 150+ times over a 6 month period to study novel rotor configurations with CREATE Helios. 1.6M CPU core hours on DSRCs.
  - Pratt and Whitney bought two 1,000 processor computers to conduct ~1,000 runs/week of CREATE SENTRi

- **Provided rapid design-space generation for the Navy's Medium Surface Combatant Analysis of Alternatives study. (CREATE RSDE)**
  - Generated 15 sets of design alternatives with each set having a unique baseline design and roughly 1000 design concepts

- **CREATE SENTRi has become an important tool for analysis of electromagnetics phenomena for 41 DoD engineering organizations (government and industry)**

HPC Portal–Supercomputing via a Browser

- **Most DoD computer users restricted to a Windows PC, MS Office and a Browser**

- **Access CREATE tools and DoD supercomputers prohibited!**

- **Solution: HPC Portal for Browser Access**

Easy

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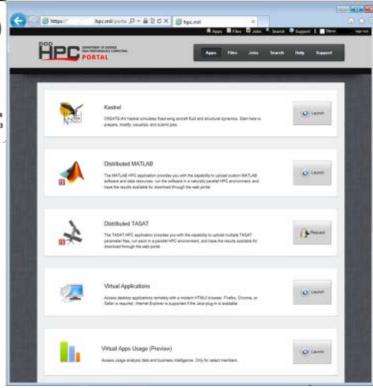- Integrated tutorials, community forums, and help

Secure

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

Powerful

- Access to >> 10,000 CPU Cores with software near increasingly large datasets
- Applications at one link with a shell for power users

Air Force Cadet running Kestrel over the portal

CREATE Tools Are Widely Adopted!

- **High level of use and steady growth**

- **~600 active licenses on HPCMP computers in FY15**
  - plus ~ 30 paper licenses

- **116 DoD organizations (government and industry) using CREATE tools**
  - AV 32; Ships 38; RF 41; MG 5 +AV, Ships & RF

- **CREATE being applied to ~ 100 DoD weapon systems**
  - ~ 70 unclassified and ~ 30 classified

- **Beginning to have major impact**

- **Services and OSD establishing major programs based on CREATE (ERS and AF Digital Thread/Digital Twin)**

- **CREATE is a foundational element of a new process being introduced to DoD acquisition by ERS to facilitate development of innovative weapon systems**
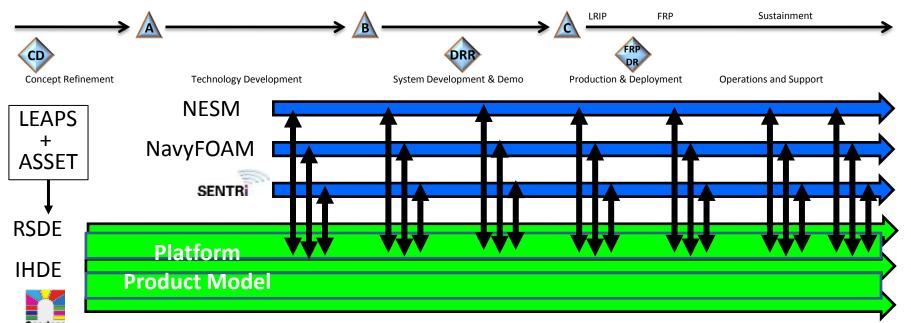
With HPC and multi-disciplinary, physics-based simulation tools, we have the capability to:

- ✓ Validate and assess requirements
- ✓ Fully explore design option space
- ✓ Materially contribute to the design of next-generation naval vessels
- ✓ Verify design prior to key decision points (and prior to fabrication of test articles or full-size ships)
- ✓ Plan/rehearse wave-tank, shock trials, and full-scale ship tests (more bang per test dollar)
- ✓ Evaluate planned (or potential) operational use scenarios
- ✓ Perform initial naval performance assessments (e.g., vulnerability, seaworthiness, maneuverability, etc.)
- ✓ Persist design intent and key engineering data throughout the whole ship lifecycle

CREATE Summary

- Developing and deploying tools with the desired new features for the DoD Air Vehicle, Ship, and RF acquisition engineering communities

- Acquisition engineering community interest and customer use growing exponentially
  - CREATE tools now in use by over 110 DoD acquisition engineering organizations (government, industry and academic)

- Continuing to contribute to the analysis and design of more than 80 important DoD systems

- Major progress in major challenges: user support, intellectual property, deployment capability, software engineering,…
  - ⇨ On tract to achieve key goals → provide DoD acquisition engineering communities (government and industry) a new process to enable them to reduce risk, cost, time and rework and to improve system performance

- A key enabler of the DoD Engineered Resilient Systems and the AF Digital Thread & Digital Twin Programs and potentially a key enabler of the DoD T&E community Virtual Proving Ground Initiative.

- And developing CREATE tools for Ground Vehicles design and analysis

BLUF

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Questions?

Additional Information

BLUF

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116 DoD 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: (41) A&E Partnerships, Air Force Institute of Technology, ATK, **Ball Aerospace, Boeing,** Cobham Defense Electronics, **General Electric,** Georgia Tech Research Institute, **Harris Corporation, Lockheed-Martin**, MIT Lincoln Lab, **Pratt & Whitney, Raytheon, Leidos**, Rolls-Royce / Libertyworks, Signature Solutions, Inc., **Sikorsky Aircraft Corp**., TechFlow, MITRE Corporation, The Ohio State University, **Northrop-Grumman**, University of Dayton Research Institute, Vencore, DoD Missile Defense Agency, Navy SPAWAR, Integrity Applications Inc (Pacific DS), Navy NAVAIR, U.S. Army Research Lab, Navy's Center of Excellence for Information Operations , AFRL Aerospace Systems Directorate , Aerospace Testing Alliance, NSWC-Carderock West Bethesda**,** Nation Air and Space Intelligence Center, Naval Research Lab, Army CERDEC, USAF AFMC AFLCMC/XZE , Naval Surface Warfare Center, Sotera, Michigan State University, NASA - Langley, NASA - Glenn

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

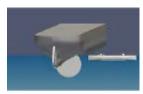## Selection of Recent Highlights

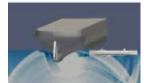**Customer Communities:** Service Stakeholders and US Naval Vessel Industry

H.L. Hunley Sinking Assessment

NSWC Carderock is supporting a forensic study of the sinking of the Confederate submarine H.L. Hunley in February, 1864. The multi-command study enables the Navy History and Heritage Command to understand the ship loss event. The study (funded by ONR and NSWCCD) also strengthens the development of M&S capabilities to perform advanced analyses to facilitate an ever-increasing ability to design against or evaluate future threats to Navy assets.

The NAVSEA Technical Warrant (for Shock/Ships) concurs that NESM is the appropriate and technically acceptable modeling and simulation (M&S) tool which meets the M&S requirements to support current and future surface ship shock applications.

Extensive Navy Usage to Support:

- Full Ship Shock Trials (FSST) Alternative (PEO Ships & PEO Carriers)
- Littoral Combat Ship (LCS) Live-Fire Test & Evaluation (LFT&E) Test Design/Support
- USS Cole Validation Study (ONR/HIT)
- Assessment Of CSS H.L. Hunley Sinking
- Nuclear Aircraft Carrier (CVN) 78/79 LFT&E Support

NESM is being used to analyze CVN-78, the first of the new Gerald R. Ford carrier class, for Ship Shock Resilience

ASNE* Recognized CREATE Engineers

- **American Society of Naval Engineers, March 4, 2015**

- **Theresa Shafer—CREATE-AV Software Quality Team, NAVAIR Pax River, received the 2014 ASNE Rosenblatt Young Engineer Award**

- **Adrian Mackenna, CREATE Ships RSDE team lead, NSWC Carderock, received the 2014 ASNE Gold Medal Award**

Mr. Rudowski, Theresa Shafer, and CAPT Ashe   CAPT Ashe, Adrian Mackenna, and RDML Fuller

Also Dr. Christopher C. Bassler, 2014 ASNE Solberg Award, CREATE researcher and user

*https://www.navalengineers.org/awards/annualawards

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*

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
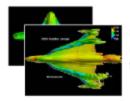
CREATE: An ERS Cornerstone

DoD HPC
MODERNIZATION PROGRAM

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:

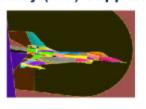Fixed-wing aircraft, rotorcraft, conceptual design, and operational testing and transition

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

Flow/Wave Features

Radio Frequency (RF) Antenna:

Conceptual design and detailed analysis tools for myriad DoD platforms

12

ERS ENGINEERED RESILIENT SYSTEMS