Physics-Based Modeling For T&E

Computational Research and Engineering Acquisition Tools and Environments

DOD HPC MODERNIZATION PROGRAM

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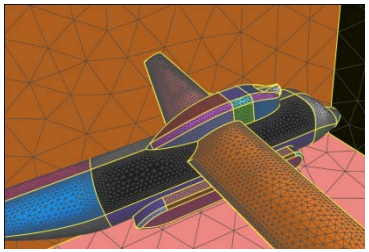
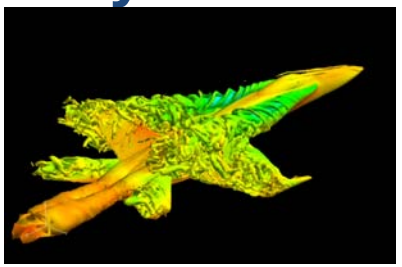
T&E Challenge—"Do More with Less!"

- "The Department of Defense is responsible for providing the military forces needed to deter war and protect the security of our country."—DoD Mission Statement
- **Each new weapon system needs to have "game-changing" potential to deter war**
  - T&E requirements increasing
- **DoD and T&E facing severe resource constraints**
  - "Fiscally Constrained Environment"
- **T&E community needs to increase productivity**
- **Physics-based high performance computing tools for performance analysis and prediction have proved to be successful in the DoD and other venues**
  - Use computational tools to identify the operational conditions that have the most uncertainty and are the most important for detailed study
  - Devote more effort to understanding basic phenomena that determine performance, lifetime, logistics requirements, resiliency,….

CREATE Concept: Use MultiPhysics-Based Tools with High Performance Computing To Increase Productivity for Complex Systems



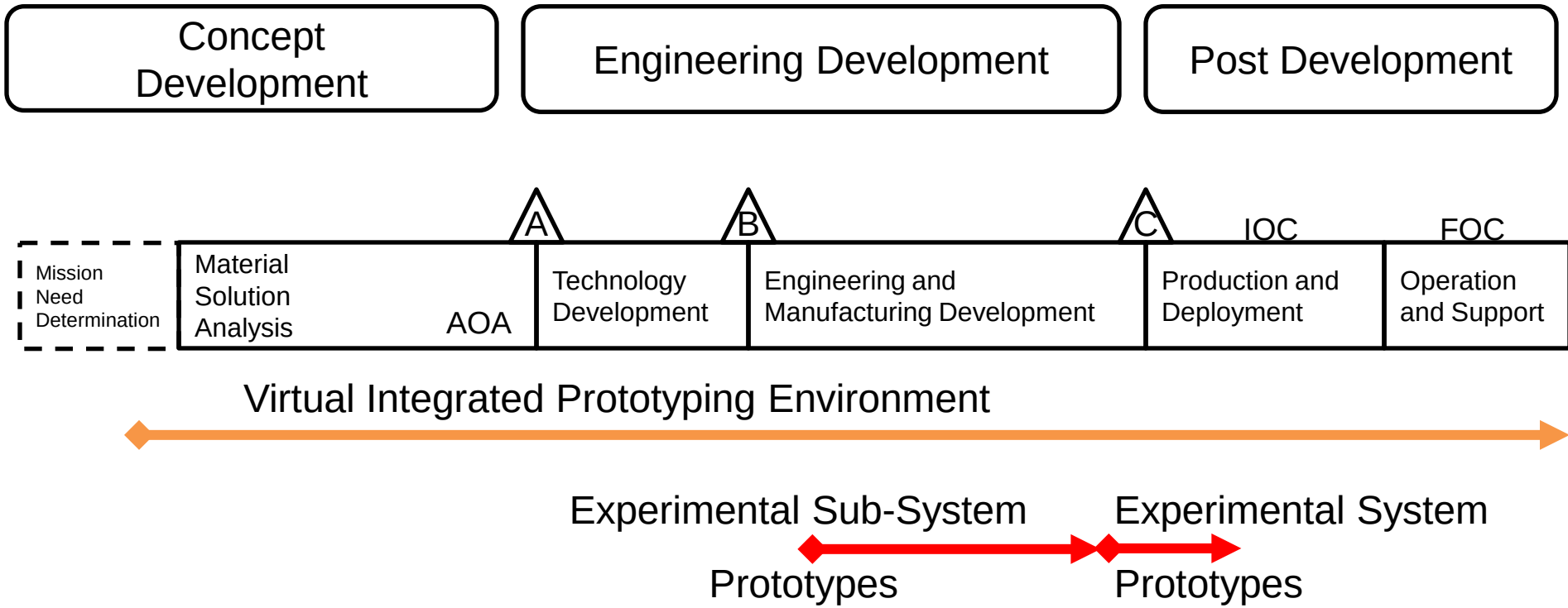

Requirements → Design on Computer → Build Mesh → Analyze Performance → Ground-based and Flight Tests

(Many) Design iterations

Manufacture, Sustain, and Modify

- **Reduced design and development time**
  - Highly scalable computational performance analysis of virtual prototypes reduces the need to test real prototypes
- **Process converges much faster**
  - Process is flexible, very responsive to new requirements
  - Identify and correct design flaws early in process reducing rework
  - Systems Integration happens at every step of the process

Performance Analysis of Virtual Prototypes Is the Key



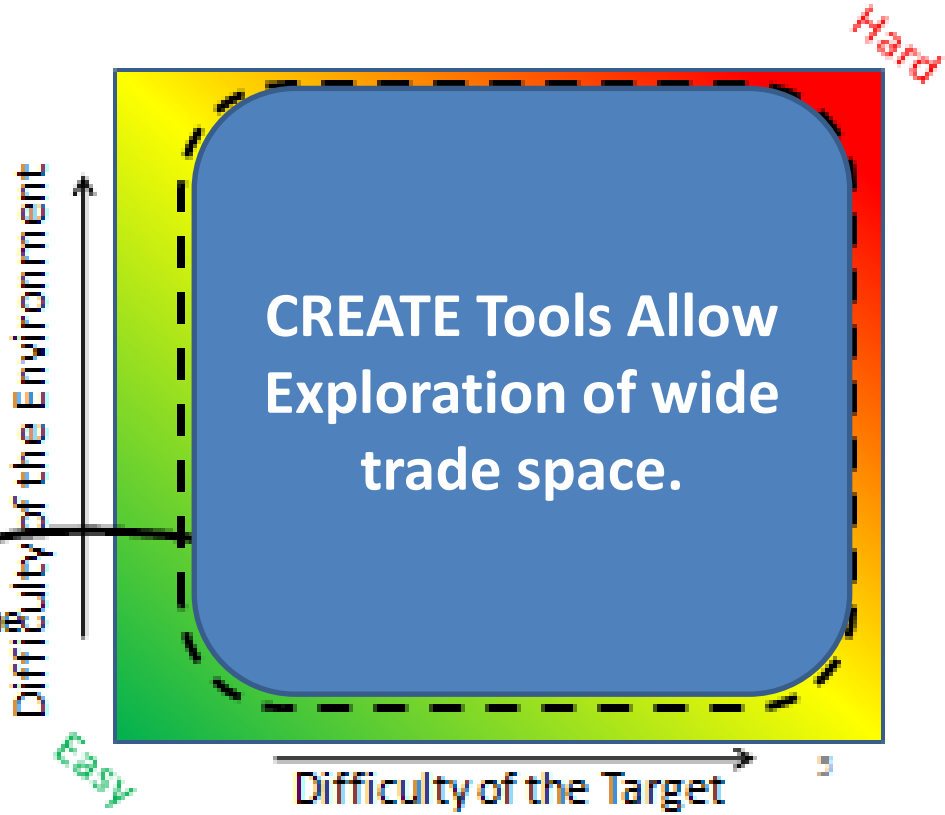
- **Replace "rule of thumb" extrapolations of existing designs with designs validated by physics-based performance prediction.**
- **Inject physics into design early and all through the process!**
- **By the time prototype testing reveals a problem, it's too late in the process to make timely and cost effective changes.**

Mismatch of Requirements and Evaluation

—Dr. Catherine Warner

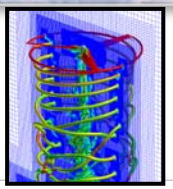
- Evaluation of systems against specific requirements versus performance across the operational envelope
  - Often requirements are narrowly-focused, don't cover the envelope
  - Static in time and do not keep pace with evolving threat
  - Test scope is often limited to the system under test while the system will be operated as a system-of-systems in a joint environment
  - Conversely, if requirement is "xx% success" across the envelope but we only test in one condition

Tests designed to requirements alone could limit examination of system performance



CREATE Focuses on Four Project Areas

- **Air Vehicles (AV)—Air Force, Army & Navy**
  - Aerodynamics, structural mechanics, propulsion, control, …
- **Ships—Navy**
  - Shock vulnerability, hydrodynamics, concept design
- **Radio Frequency (RF) Antennas—Air Force, Army & Navy**
  - RF Antenna electromagnetics and integration with platforms
- **Mesh and Geometry (MG) Generation**
  - Rapid generation of mesh and geometry representations needed by analysis

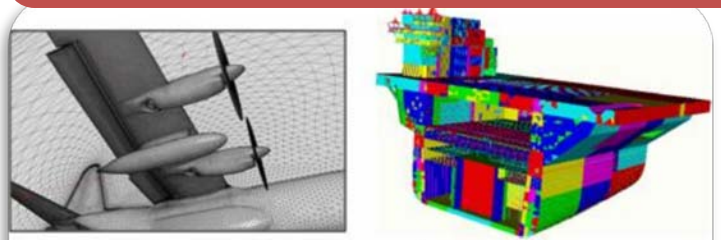



Design concept


Seakeeping and resistance


Shock vulnerability

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


Aircraft and aircraft carrier meshes

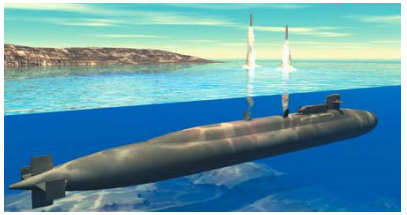

Military platforms with antennas

CREATE –
Four Projects → Ten Products

- **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
  - **Firebolt -** Module for propulsion systems in fixed and rotary-wing air vehicles
- **Ships—CREATE Ships**
  - **RDI -** Rapid Design and Synthesis Capability
  - **NESM -** Ship Shock & Damage-predict shock and damage effects
  - **NAVYFOAM -** Ship Hydrodynamics-predict hydrodynamic performance
  - **IHDE -** Environment to facilitate access to Naval design tools
- **RF Antenna—CREATE RF**
  - **SENTRI -** Electromagnetics antenna design integrated with platforms
- **Meshing and Geometry—CREATE MG**
  - **Capstone -** Components for generating geometries and meshes

CREATE Tools Being Applied To:





- **NAVSEA: DDG-1000 Surface Combatant, the CVN 78 and 79 Aircraft Carriers and the Ohio Replacement Submarine program;**



- **NAVAIR: E-2D, F/A-18E, JSF, F/A-18 MALD, Fire Scout, and Small UAV PMA**



- **Army Rotorcraft: UH-60, CH-47 (ACRB), OH-58**


- **Air Force ASC: F-15 SA/DB-110, B-1B/ELLA, Strategic Airlift CP&A, JSF**

Summary

- **Physics-Based computational engineering tools can provide performance analysis and predictions throughout the design and development process, including the early stages of design → long before physical prototypes become available**
- **Supplement physical testing, identify design flaws & avoid rework, achieve system integration earlier,…**
- **Enable T&E community to concentrate on validating system performance and understanding the basic phenomena that determine performance**
- **T&E essential for validating physics-based models (V&V)**
- **CREATE and similar tools featured at NDIA PHYSICS-BASED MODELING IN DESIGN & DEVELOPMENT FOR U.S. DEFENSE CONFERENCE *"Design Innovation to Improve DoD Acquisition" Nov 15-17, 2011, Denver, CO***
  http://www.dtic.mil/ndia/2011physics/2011physics.html

Enabling Technology

- **The $10^{15\text{-}18}$ increase in computer power over the last seven decades enables codes to:**
  - **Utilize accurate solution methods**
  - **Include all the effects we know to be important**
  - **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**