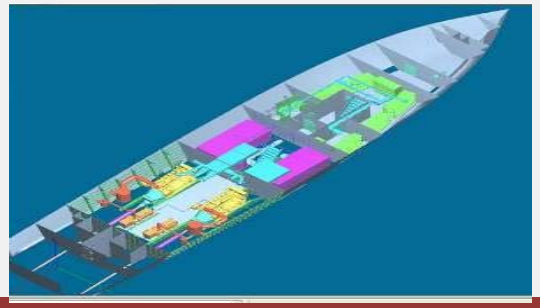
Department of Defense

High Performance Computing Modernization Program (HPCMP)



HPCMP, CREATE Program, and the CREATE-Ships Project

Philadelphia Section
Society of Naval Architects and Marine Engineers
Philadelphia, PA
14 Nov 2012

Myles Hurwitz (myles.hurwitz@hpc.mil)
CREATE-SHIPS Project Manager
DoD High Performance Computing Modernization Program

DOD HPC MODERNIZATION PROGRAM

Goals of the Presentation

- To familiarize the Philadelphia Section of SNAME with:
  - DoD High Performance Computing Modernization Program (HPCMP)
  - HPCMP's CREATE Program
  - CREATE-SHIPS Project

- To inform today's participants of the availability of CREATE software for their use on DoD Programs

SNAME Annual Meeting 2012
SHIP PRODUCTION SYMPOSIUM

Ensuring Successful Ship Construction Outcomes: Using More Physics-Based Design Tools in Early Concept Design

Bob Keane

24 October 2012

DOD HPC MODERNIZATION PROGRAM

HPC Modernization Program

VISION

A pervasive culture existing among DoD's scientists and engineers where they routinely use advanced computational environments to solve the most demanding problems transforming the way DoD does business— finding better solutions faster.

MISSION

Accelerate development and transition of advanced defense technologies into superior warfighting capabilities by exploiting and strengthening US leadership in supercomputing, communications and computational modeling.

DoD HPC Modernization Program (http://www.ccac.hpc.mil/) (formerly OSD, now ERDC)

DoD Supercomputing Resource Centers

Networking

Defense Research & Engineering Network

Army Participation
ARL & ERDC DSRCs
1,343 Users/24 Organizations/
108 Projects
56 DREN Sites
15 Challenge Projects/2 DHPIs
5 Institutes

Navy Participation
Navy DSRC
942 Users/16 Organizations/
197 Projects
38 DREN Sites
13 Challenge Projects/2 DHPIs
1 Institute

Air Force Participation
AFRL & MHPCC DSRCs
1,330 Users/25 Organizations/
199 Projects
24 DREN Sites
11 Challenge Projects/3 DHPIs
3 Institutes

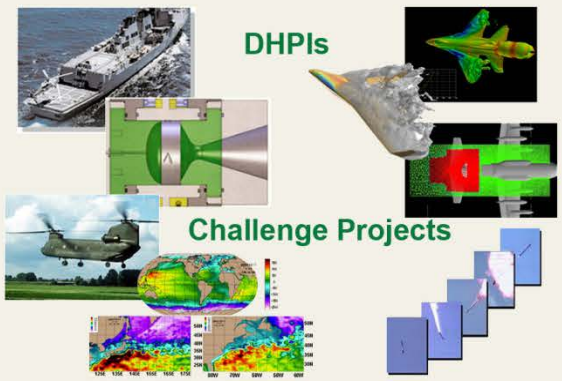
Defense Agencies Participation
DARPA, DTRA, JNIC, JFCOM,
MDA, PA&E & OTE
537 Users/4 Organizations/
29 Projects
28 DREN Sites
2 Challenge Projects/2 DHPIs

Other
ARSC DSRC
68 DREN Sites

Software Applications Support

Resource Management

Requirements & Allocations



A Quick History

- **Program initiation — 1992–1993**
  - HPCMP formed in response to Congressional direction
  - HPC Modernization Plan
  - Initial program structure established, S&T
  - Initial HPC capabilities provided
  - HPCMP established as an ACAT1AM
- **Program formalization — 1994–1995**
  - Program Office established
  - DoD oversight process implemented
  - Program structure and customer base expanded, include T&E and MDA
- **Major acquisitions — 1995–1996**
  - Four major shared resource centers
  - Defense Research and Engineering Network (DREN)
  - Programming Environment and Training (PET) contract established
- **Operations Focus — 1997–2000**
  - HPCMP delegated to DUSD(S&T) for Oversight
  - HPCMP reclassified by ASD(CSI) as an ACAT 1AC
  - Continuous upgrades at HPC Centers
  - Selection of new Distributed Centers (DCs)
  - DoD Challenge Projects established
- **Major contract awards — 2001–2003**
  - HPCMP designated as an MDAP ACAT 1AD
  - DREN contract awarded to WorldCom
  - HPC Centers contract awards
  - New PETT contract awarded
- **Operations Focus — 2003–2006**
  - HPCMP designated as an MDAP and an MAIS
  - Annual OIPT meeting established
  - Pilot End-User Impact Return on Investment (ROI) initiated
  - New DHPIs, Institutes and Portfolios selected
  - Capability Applications Projects (CAPs) established
  - Minority Undergraduate Education and Research Initiative established
  - Value to the DoD study–ROI initiated
- **Major Contracts & Expansion — 2007–2009**
  - HPCMP removed from the Active MDAP list
  - Next-Generation Technical Services (NGTS) contract awarded
  - New DHPIs, Institutes and Portfolios selected
  - Computational Research and Engineering Acquisition Tools and Environments (CREATE) program initiated
  - New PETTT contract awarded
  - New archival storage contract awarded
- **Transition and Major Contracts — 2010–2012**
  - Army ERDC assigned management responsibility of the HPCMP
  - DREN III contract awarded to Qwest
  - Achieved Level III Certification CNDSP
  - DREN Last-Mile Team established
  - CREATE releases of conceptual design tools
  - New DHPIs, Institutes, and Challenge Projects selected
  - 5 DAAs to 1 DAA
  - 6 DSRCs to 5 DSRCs
  - Energy-efficiency initiative launched

Computational Research and Engineering Acquisition Tools and Environments (CREATE) Goal

- **Enable major improvements in DoD Acquisition Engineering Design and Analysis Processes, by developing and deploying scalable physics-based computational engineering software products to:**
  - **Replace empirical design based on historical data and experimental testing with physics-based computational design validated with experimental testing**
  - **Detect and fix design flaws early in the design process before major schedule and budget commitments are made**
  - **Develop optimized designs for new concepts**
  - **Begin system integration earlier in the acquisition process**
  - **Increase acquisition program flexibility and agility to respond to rapidly changing requirements**
  - **Enhance the productivity of the DoD engineering workforce**
  - **Establish an organic capability to develop and deploy physics-based computational engineering software within the DoD**

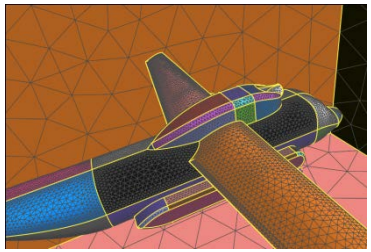
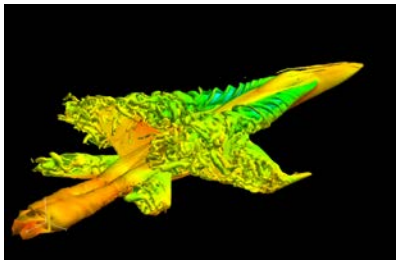
CREATE Concept

- **Use physics-based software to identify design defects throughout the acquisition process thus substantially reducing acquisition time and cost overruns.**

Identify problems and fix them before metal is cut.

CREATE Concept: Use Multi-Physics-Based Tools 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 re-work
  - Systems Integration happens at every step of the process

CREATE Rationale

- **“There is a probability of one that 10 structural failures will be discovered in flight test programs where the cost to rework the defect is maximized.”** -- Ed Kraft, Chief Technologist, AEDC
- **Present designs are based on semi-empirical extrapolations from existing systems—insufficient for new weapons systems**
- **Building and testing physical prototypes and full systems is expensive and takes a long time**

Physics-based computational engineering tools allow performance predictions of virtual prototypes from conceptual design through production and sustainment to augment physical testing

Outreach to Industry Proving Successful

Executive Briefings March 8, 2011

- CREATE Products overview provided to 70 US Defense contractor reps and some military organizations
- Attended by Boeing – Northrop – Lockheed – Raytheon - Rockwell – AAI Corp – Aurora – SAIC – Draper – Battelle – JHU/APL – USAF – USN – USA – KinetX –
- *Overwhelming feedback from all attendees is that the CREATE Project has accomplished state-of-the-art multi-physics-based modeling that should absolutely improve contract performance*
  - High-performance computing and exceptionally talented scientists & engineers, with adequate funding, seems to be the key
- We aren't talking a doubling of capability – we're talking ten-fold and more improvements in our ability to effect designs of ships-submarines - aircraft – engines – airfoils – radar systems – and more

—**Bob Rassa, Raytheon, Chair, NDIA SE Division, IDA Review of HPCMP, April 13, 2011**

Outreach to Industry Proving Successful

Expected Benefits of CREATE

- If we can successfully transition the CREATE products to use within the US Defense industry, we believe we can achieve:
  - Substantial reductions in design time on products that involve physics-based models, computational fluid dynamics, and related
  - Substantial improvements in effectiveness, efficiencies, and overall performance of such products
  - Noticeable reductions in test & evaluation effort with reduced rework due to design issues
  - Reduced contract cost, especially over-runs, in those areas of a given program affected by CREATE capability

—Bob Rassa, Raytheon, Chair, NDIA SE Division, IDA Review of HPCMP, April 13, 2011

NDIA is Assuming a Leadership Role to Establish Physics-based Modeling Paradigm

- Held a 4 day conference Nov. 14-17 2011
- Monday: Tutorials and Tool Seminars
- Tuesday: Plenary talks
  - Keynote speakers: Dr. Jeffrey Holland and Dr. Ed Kraft
  - 1 ¾ hour plenary panel on CREATE
  - RADM Eccles-Lunch speaker
  - CREATE participation in Plenary User Panel
  - Dr. Ed Kraft participation in T&E panel
- Wednesday: Parallel Sessions
- Thursday: Parallel Sessions
  - Parallel Session: 13 CREATE papers
- **Detailed status of CREATE contained in overview and detailed talks**

- Nov. 5-8 2012 (reduced DoD attendance)

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**
  - **RSDE -** 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

The CREATE Approach

- **Software is being built by government-led teams**
- **Each product is released annually following a roadmap**
  - Each year there is a release of a usable application
  - Each release builds on the previous release and adds the increased capability called for in the roadmap
  - Each release is beta-tested by targeted user communities before a broader release
  - Each release goes through a rigorous V&V process and follows software engineering practices developed specifically for technical software
- **Releases are progressively more scalable for massively parallel computers and responsive to user requirements**
- **CREATE Program is guided by DoD service acquisition engineering organizations and their senior leadership and US defense industry**
- **Most of the CREATE software applications will make their third release this calendar year**

CREATE is Guided by Senior Science and Technology Leaders From the Services

HPCMP Executing Agent
John West(Director)

CREATE Program
Douglass Post, IPA (AD-CREATE)
Chris Atwood, IPA (Dep AD-CREATE)

Official HPCMP Advisory Panel

Ships
Myles Hurwitz, IPA (PM)
Robert Keane (con.)

Board of Directors
- ***RADM Thomas Eccles, NAVSEA Chief Engineer**
- Dr. Walter Jones, SES, Executive Director, ONR
- Mr. C.F. Snyder, SES, 33Technical Director, NSWC, Carderock Division
- Mr. Glen Sturtevant, Director, S&T, PEO, SHIPS
- Mr. John West, Director, HPCMP

Air Vehicles
Robert Meakin, IPA (PM)

Board of Directors
- ***Dr. Ed Kraft, ST, Chief Technologist, AEDC/CZ,**
- Dr. Samuel T. Crews, Chief Engineer, Aeromechanics Division, AMRDEC, Redstone Arsenal, AL
- Mr. Richard Gilpin, Director, AIR-4.3 NAVAIR
- Mr. Tom Rudowsky, Director, NAVAIR), (IBST)
- Dr. Michael Scully, ST, Aeroflightdynamics Directorate (AMRDEC), U.S. Army RDECOM
- Mr. John West, Director, HPCMP

RF Antennas
John D'Angelo (PM)

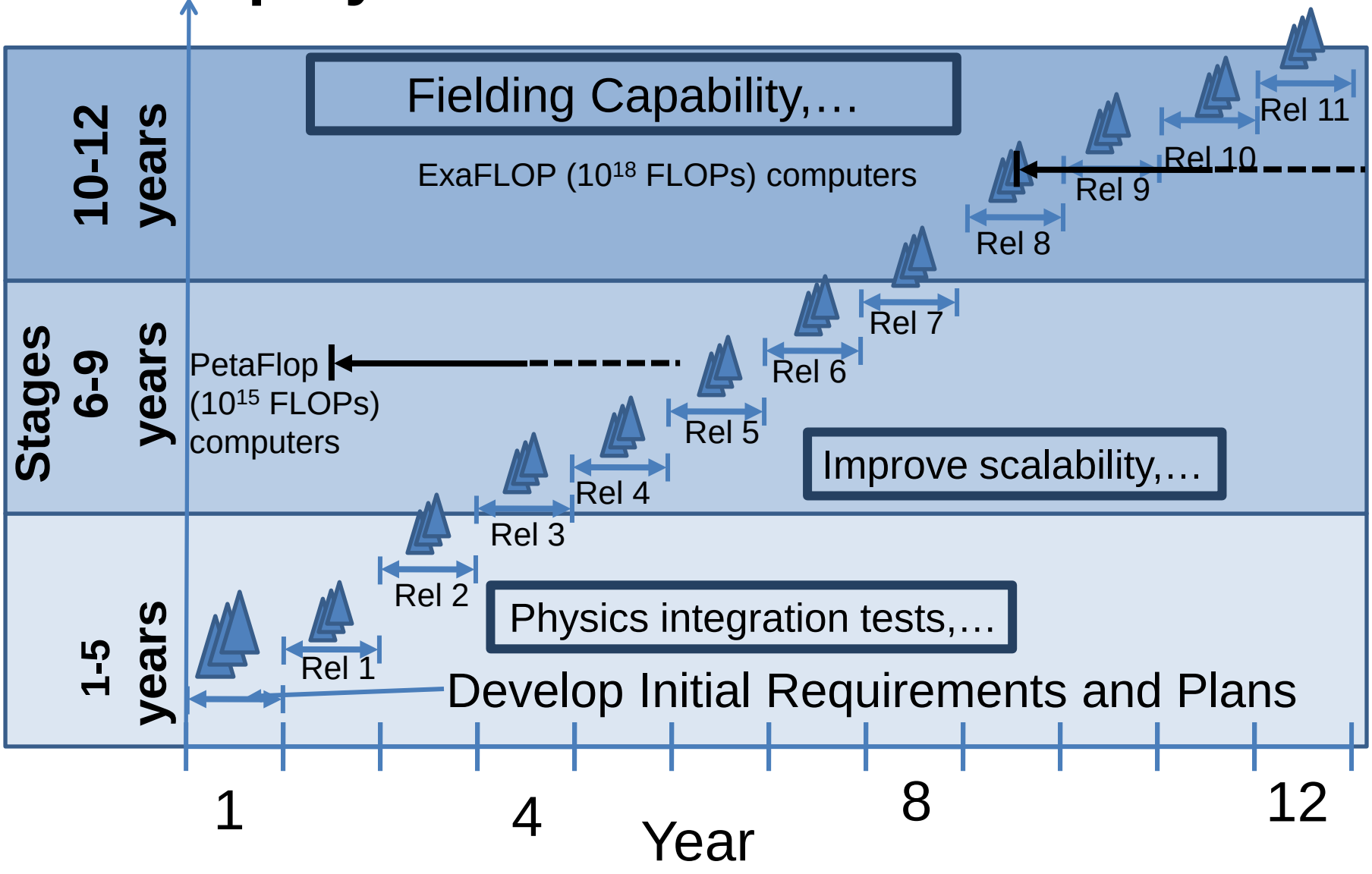
Board of Directors
- ***Mr. Dennis DeCarlo, Chief Antenna Systems Engineer, NAVAIR**
- Mr. Keith Coburn, CERDEC
- Dr. Michael Johnson, SEEKEAGLE, Eglin AFBMr. John West, Director, HPCMP
- Dr. Mark Kragalott, NRL
- Dr. Charles Macon, AFRL-Sensors Directorate, AFRL, WPAFB
- Dr. Robert Peterkin, ST, Chief Scientist, AFRL Directed Energy Directorate, KFB
- Mr. John West, Director, HPCMP

MG
Saikat Dey (PM)

Board of Directors
- ***Dr. Robert Meakin, PM CREATE Air Vehicles**
- Mr. Myles Hurwitz, CREATE Ships Project Manager
- Dr. Sudip Sodanjh, Computational Engineering Leader, SNL
- Dr. John D'Angelo, CREATE RF Antenna Project Manager
- Mr. John West, Director, HPCMP

*Board of Director Chairs

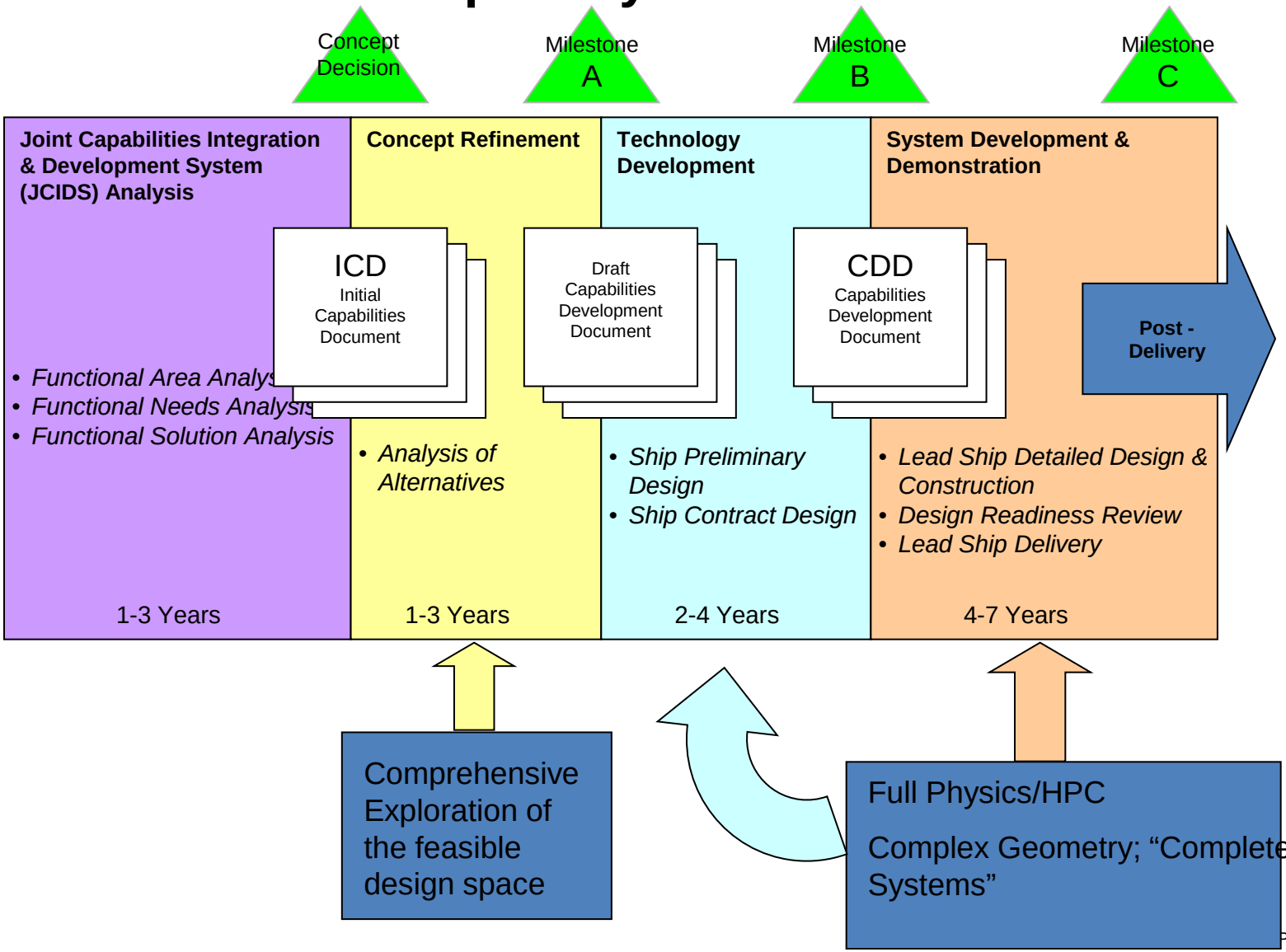
Incremental Development and Deployment in Annual Releases



CREATE-Ships Project Objective

- **Primary goal (ICD):**
  - develop the engineering software required to support a reconfigurable ship design and acquisition process that will enable the Navy to develop cost-effective ship designs on schedule and within budget, and that will perform as required and predicted.
- **Overall approach:**
  - develop, using high performance computing engineering tools, an optimized total warship design through properly designed hull, mechanical, and electrical systems integrated with combat and other mission systems earlier in the acquisition process than is possible today.
  - **Time to solution**
    - Scalability for high end codes
    - Embarrassingly (pleasantly) parallel for early stage codes exploring the feasible design space

Acquisition Process – Use HPC and Full-Physics-Based Tools in the Ship Design Process for Complex Systems Evaluations



Typical Definition and Evaluation Processes Through Contract Design

Geometry Definition	Selection of Other Ship Design Analyses
Hullform Design	Airflow Analysis
Compartmentation and Arrangements	Combat Systems Engineering
Structural Definition	Communications Systems Analysis
Location of Key Components	Control Systems Engineering
Routing of Key Distribution Systems	Deck Systems Engineering
Hydrodynamics	Deckhouse Systems Engineering
Resistance and Powering Analysis	Electromagnetic Engineering
Seakeeping and Loads Analysis	Hull Girder Ultimate Strength Analysis
Maneuvering Analysis	Fluid Systems Engineering
Dynamic Stability Analysis	FEA Structural Analysis
Damage Stability Analysis	Manning Analysis
Propulsor Performance Analysis	Power Systems Analysis
Survivability	Propulsion Systems Analysis
Susceptibility	RM&A Analysis
Acoustic Signature Analysis	Steering and Maneuvering Controls
Infrared Signature Analysis	Structural Cost and Producibility Assessment
Magnetic Signature Analysis	Total Ship Cost Analysis
Radar Cross Section Analysis	Underway Replenishment Analysis
Vulnerability – UNDEX-Shock/Damage	Weapons Handling and Aircraft Support
Recoverability	Weight and Moment Analysis

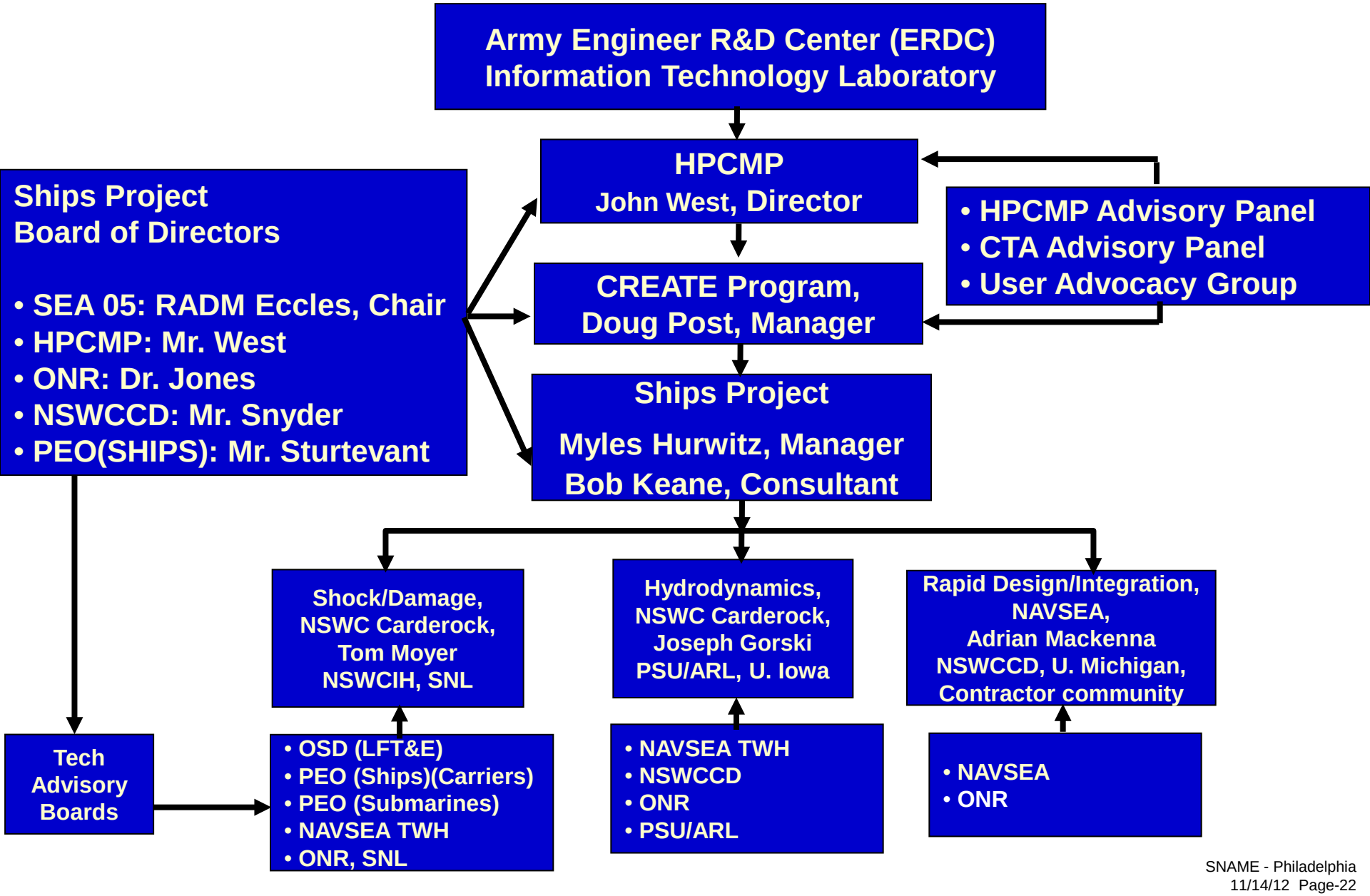
- From D. Billingsley – former NAVSEA lead for design tools, and
- From H. Fireman presentation to CREATE, 6 Apr 2007

The CREATE-Ships Project

- **Addresses three primary challenges**

1. Shock/Damage response for a wide range of explosive events
   - Shock/Damage Product (NESM: Navy-Enhanced Sierra Mechanics)
     - Lead: Dr. E. Thomas Moyer (NSWC-Carderock) (Senior Research Scientist for Ship Survivability M&S)
2. Hydrodynamics analysis of new, innovative ship designs and improvements to existing designs
   - Integrated Hydrodynamics Design Environment Product (IHDE)
   - Full-physics RANS Product (NavyFOAM)
     - Lead: Dr. Joseph Gorski (NSWC-Carderock) (Head, Computational Hydromechanics Division)
3. Rapid Design and Integration : Comprehensive/Timely Concept Design Space Exploration
   - Rapid Ship Design Environment Product (RSDE)
     - Former Lead: Mr. Seth Cooper (NAVSEA) (Technology Group Tools Project Manager)
     - Lead: Mr. Adrian Mackenna (NSWC-Carderock) (Team Lead, Ship Design Tools Implementation)

CREATE-Ships Project Governance



CREATE-Ships Objectives for Shock/Damage

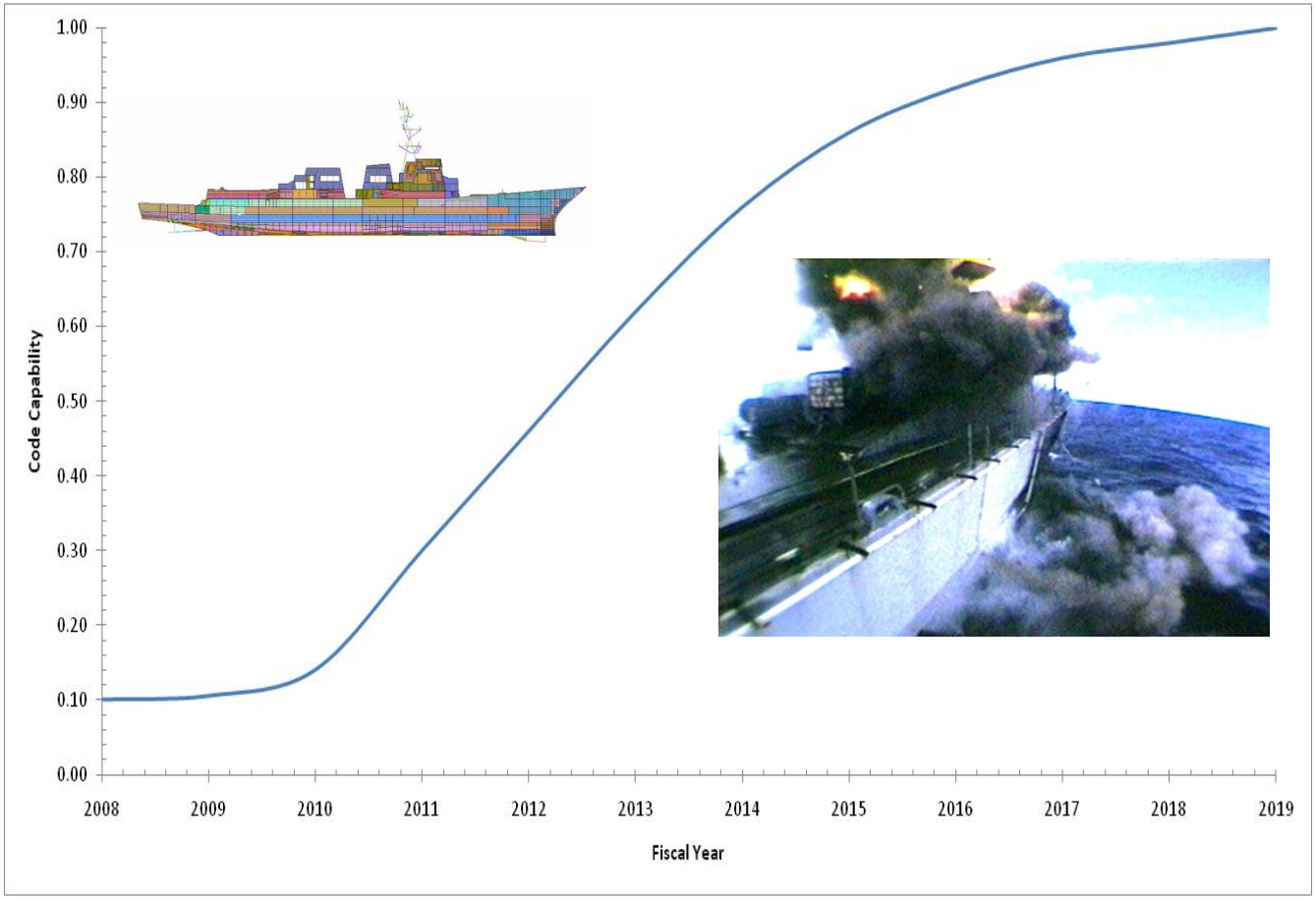
- Develop robust capability to predict the response of surface ships & submarines to underwater explosion (UNDEX) loading for:
  - System/Component Environments
  - Structural Response & Damage
  - Scenarios
    - Stand-Off UNDEX
    - Close-In UNDEX (e.g., USS Roberts)
    - SURFEX (e.g., USS Cole)
    - AIREX (e.g., USS Stark)
- Interface w/ Ship State Modeling in earlier stages of design with tools such as:
  - ASAP/ARM (Advanced Survivability Assessment Program/Advanced Recoverability Module)
  - FASST (Fully Automated Ship Shock Tool – fast computational model preparation)

Requirements & Use Cases

- **Define Development Plan & Requirements Based On Six (6) Use Cases**
  - **UC I => Ship Response To Standoff UNDEX Where Structure Remains Predominantly Elastic (minimal damage)**
  - **UC II => Ship Response to UNDEX Causing Moderate Structural Damage**
  - **UC III => Ship Response To UNDEX Causing Severe Structural Damage (including SURFEX)**
  - **UC IV => Ship Response To AIREX Causing Moderate Structural Damage**
  - **UC V => Ship Response To AIREX Causing Severe Structural Damage**
  - **UC VI => Ship Response To Unconventional Weapon Attacks**

USS Cole – 12 Oct 2000

NESM 12 Year Roadmap



- FY-08 => Planning, Start UC I
- FY-09 => UC I Development
- FY-10 => UC I Improvement
- FY-11 => UC I Production
- FY-12 => UC II Improvement
- FY-13 => UC II Production
- FY-14 => UC III Production
- FY-15 => UC IV Development
- FY-16 => UC IV Improvement
- FY-17 => UC IV Production
- FY-18 => UC V Production
- FY-19 => UC VI Production

NESM Development Approach

Enhanced GEMINI

Euler solver

Shock and Fluid Dynamics

Navy Enhanced Sierra Mechanics (NESM)

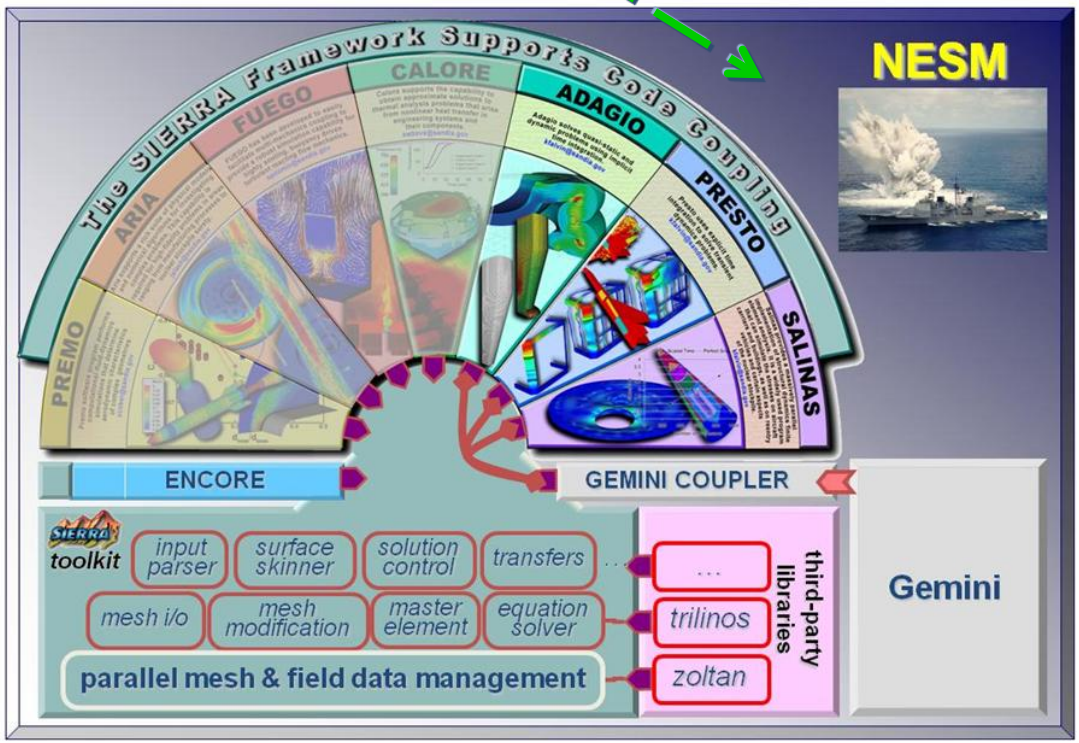
SOA Lagrange Solvers w/ Navy Enhancements

Leveraging DOE (SIERRA) Investment

Evolving Coupler Interface

Optimized Fluid-Structure Interaction

Leveraging Navy Dynamic System Mechanics Advanced Simulation (DYSMAS) Investment



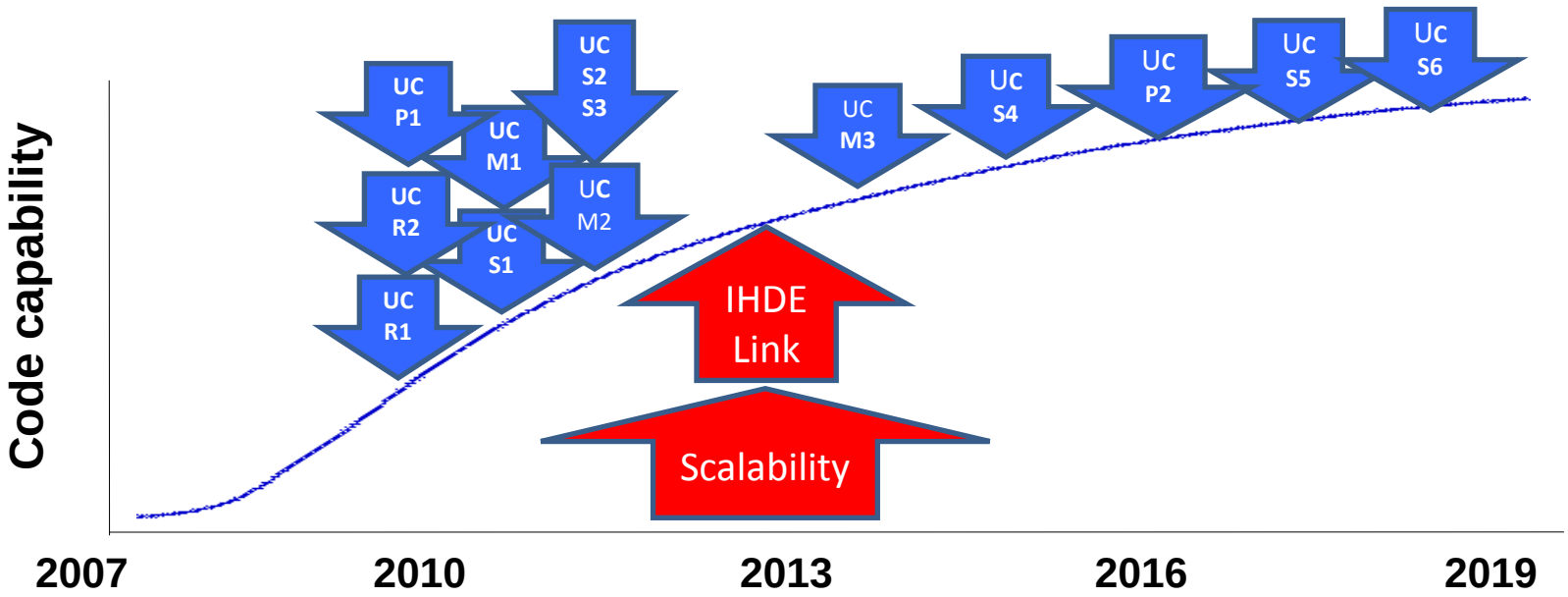
CREATE-Ships Objectives for Hydrodynamics

- **Provide the US Navy community with a suite of analysis methods that can be used to impact design and analysis**
  - Existing and evolving semi-empirical methods for fast turnaround needs
  - Use of existing high-end methods where appropriate, within required timeframes
  - New CREATE-developed high-fidelity capability with a minimum of empiricism
- **Provide an integrated user design environment for using these different levels of fidelity methods by users in both the design and analysis domains**
  - Simultaneously optimize and evaluate different disciplines (e.g., resistance, powering, maneuvering, seakeeping)

CREATE-Ships Hydrodynamics Products

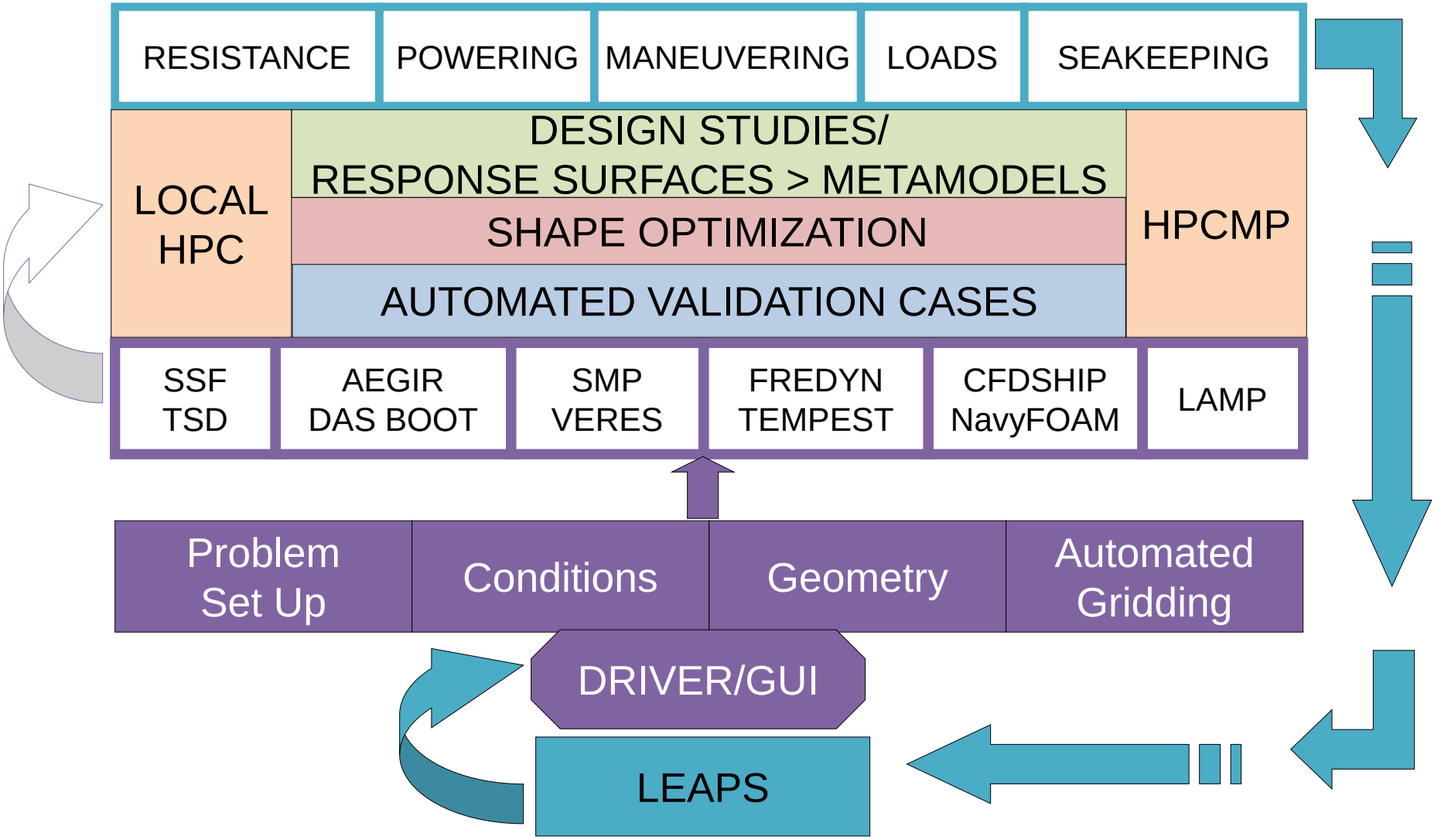
- **NavyFOAM**
  - High-end (full physics) code, Reynolds Averaged Navier-Stokes (RANS) as well as large eddy simulation (LES) capabilities
  - Based on open source code OpenFOAM (significant international user base)
  - Applicable to ships, submarines, propulsors.
  - Currently geared towards typical RANS experts
- **Integrated Hydrodynamics Design Environment (IHDE)**
  - Automated work flow process of using existing hydrodynamic analysis tools
  - Interoperability with LEAPS (Leading Edge Architecture for Prototyping Systems)
  - Focus on surface ships and earlier stages of design process
  - Geared toward designers (also improved process for current users of candidate codes)
- **Use Cases associated with Resistance, Powering, Maneuvering, and Seakeeping**

NavyFOAM Development Roadmap

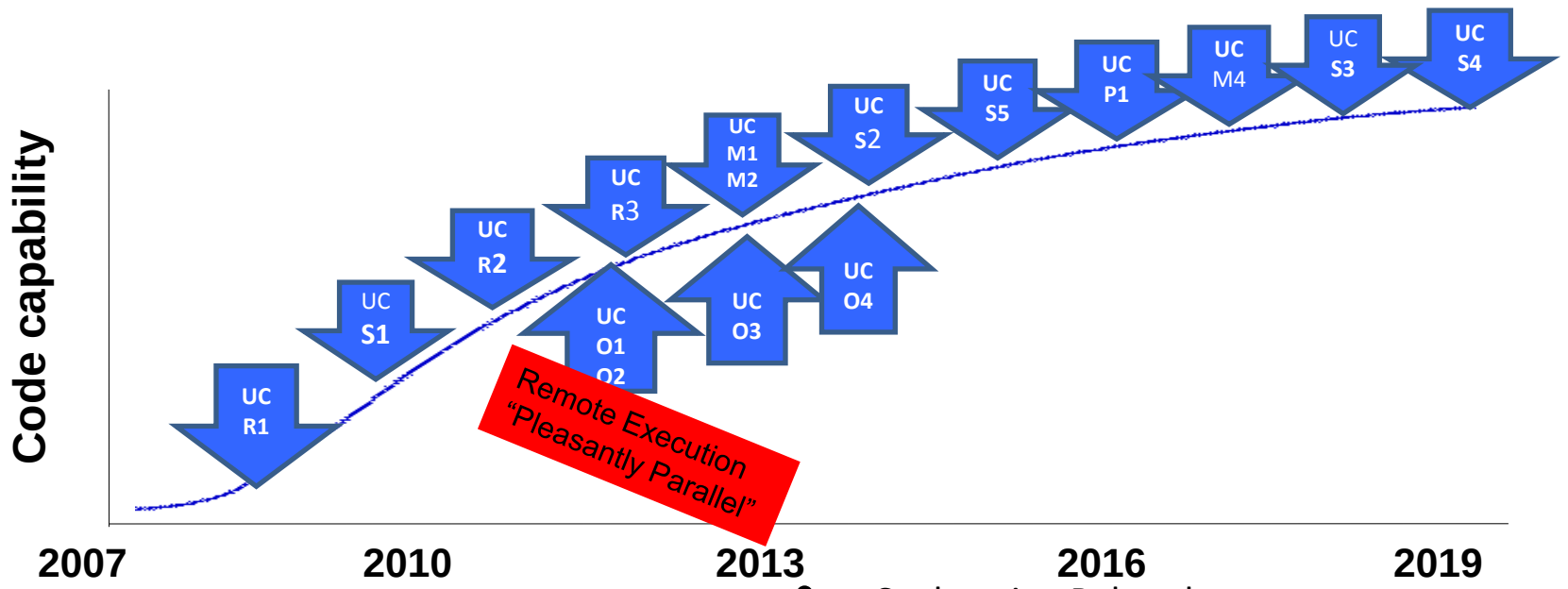


- Resistance Related
  - UCR1: Hull with fixed ship sinkage and trim
  - UCR2: Hull with computed sinkage and trim
- Powering Related
  - UCP1: Body force model for propulsor
  - UCP2 : Full propulsor modeling
- Maneuvering Related (motions in calm water)
  - UCM1: Rotating arm steady turning motion
  - UCM2 : Planar Motion Mechanism (PMM)
  - UCM3 : Moving appendages and controller
- Seakeeping Related (involves waves)
  - UCS1 : Prescribed trajectory in regular waves
  - UCS2: Hull responds to regular waves
  - UCS3 : Prescribed trajectory in irregular waves
  - UCS4 : Predicted motions with moving appendages in waves
  - UCS5: Seaway loads with one way coupling to structures code
  - UCS6: Seaway loads with two way coupling to structures code

Integrated Hydrodynamics Design Environment



IHDE Development Roadmap

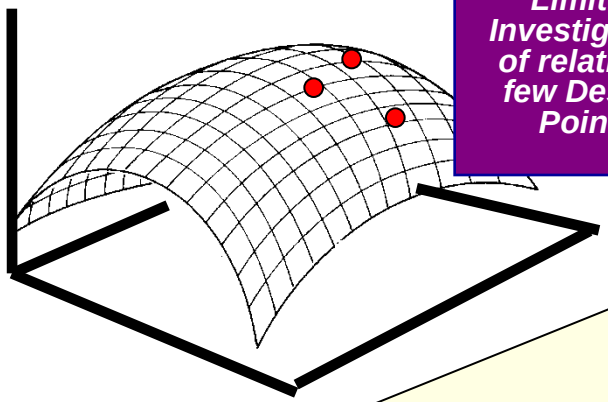


- Resistance Related
  - UCR1: Bare Hull thin ship theory
  - UCR2: Bare hull with the BEM
  - UCR3: Bare hull with RANS
  - UCR4: Fully appended hull with RANS
- Powering Related
  - UCP1: Body force model for propulsor
- Maneuvering Related
  - UCM1: Empirical based models
  - UCM2: Bare hull steady turns
  - UCM4: turning circles, overshoots, zig-zag
- Seakeeping Related
  - UCS1: Inviscid codes in the frequency domain
  - UCS2: Inviscid code in the time domain
  - UCS3: RANS at specified headings
  - UCS4: RANS predictions with moving appendages
  - UCS5: Seaway loads with inviscid code
- Optimization Related
  - UCO1: Single objective optimization for resistance
  - UCO2 : Single objective optimization for seakeeping
  - UCO3 : Multi-objective optimization
  - UCO4 : Multi-objective optimization for user-specified parameters

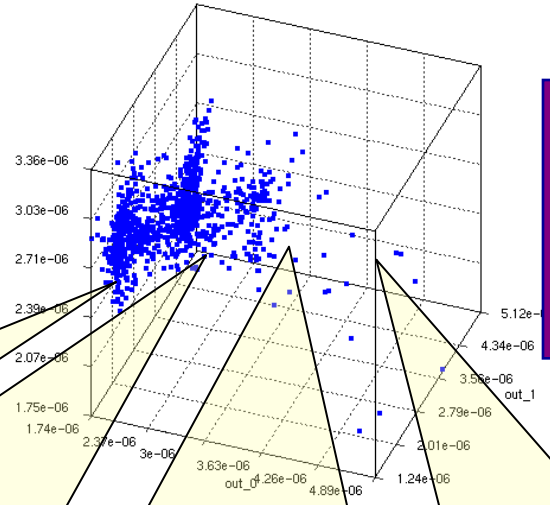
CREATE-Ships Objectives for Rapid Design and Integration (RDI)

- Comprehensively explore alternative design solutions while there is still a maximum range of options available
- Provide greater definition for each ship in a range of possible design solutions
- Perform detailed, physics-based and HPC-based analysis early on in the design cycle for each ship in a range of possible design solutions

Design Space Exploration

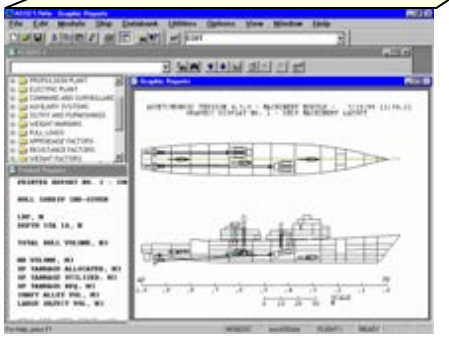


From… Limited Investigation of relatively few Design Points

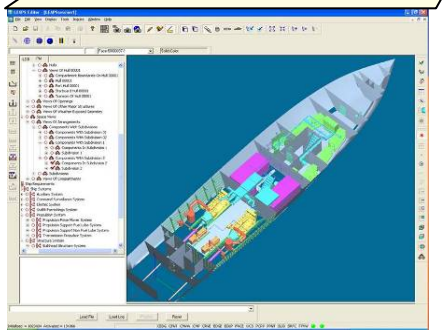


To… Full Investigation of Concepts throughout the Design Space

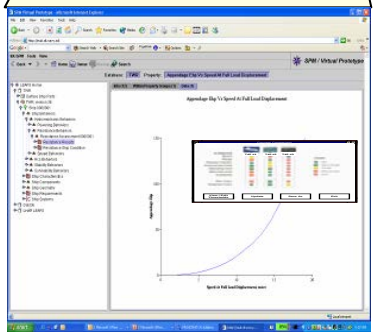
HPC Enables Exhaustive Exploration by:



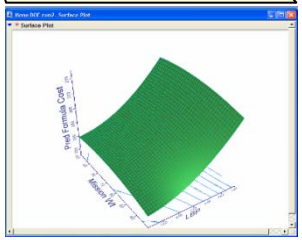
Generating *The Space*



Exploring *The Space*



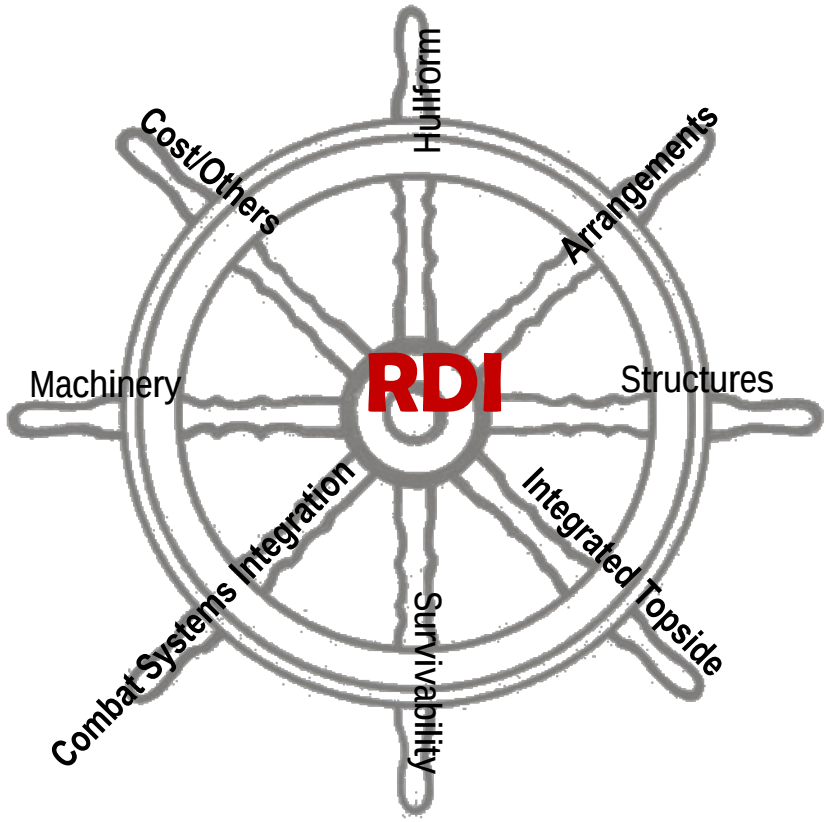
Evaluating *The Space*



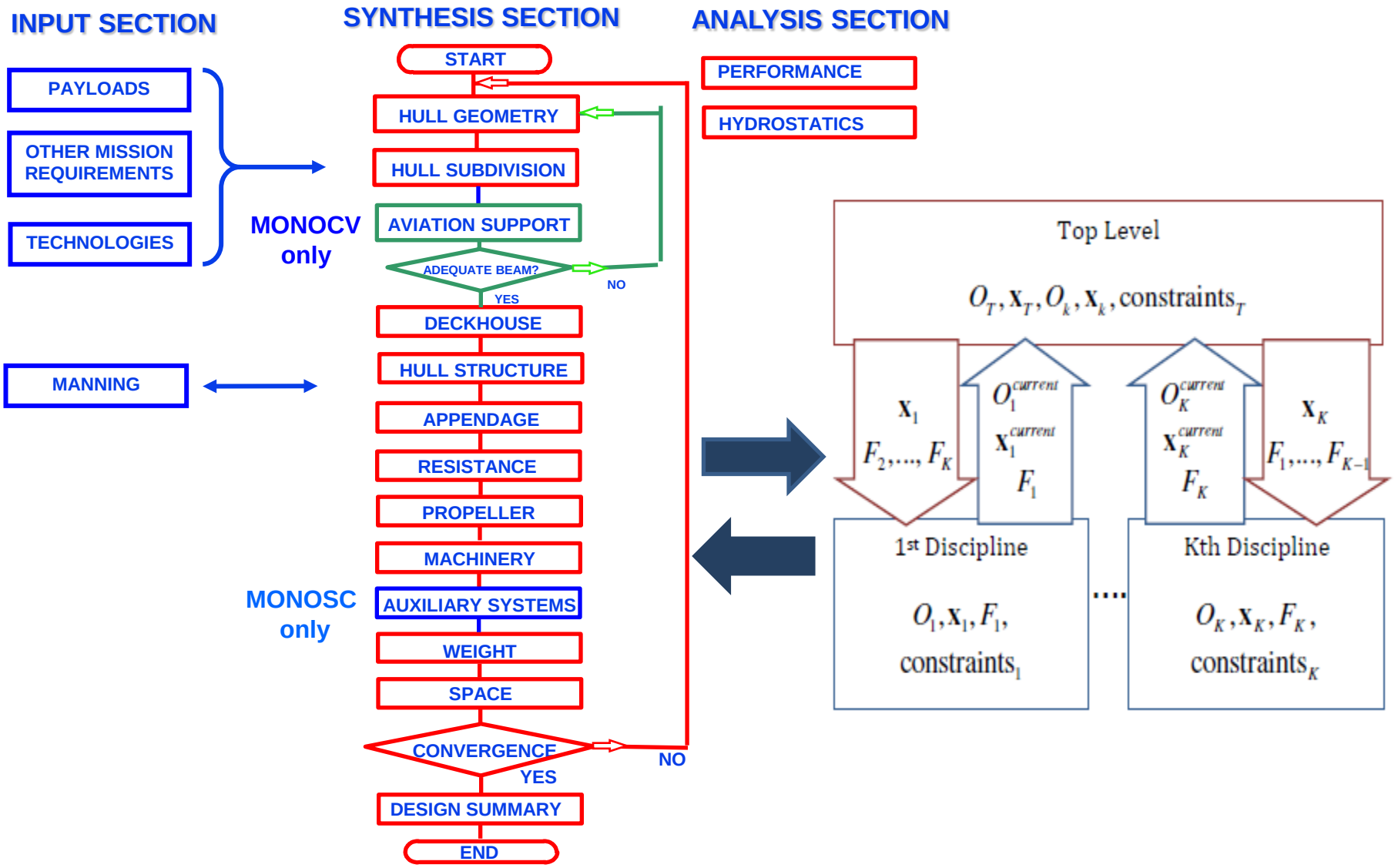
*and **Visualization***

Rapid Design and Integration (RDI) Enabling Concepts

- **Design Space Exploration, Optimization and Visualization**
  - Hullform Transformation
  - Hullform Generation
  - Arrangements (Interior and Topside)
  - Behavior Models/Response Surfaces/Neural Nets/Kriging
  - Multi-disciplinary Optimization
- **Generate, Explore, Evaluate**
- **Standard Product Model Data Structure**
  - Analysis Activity Integration

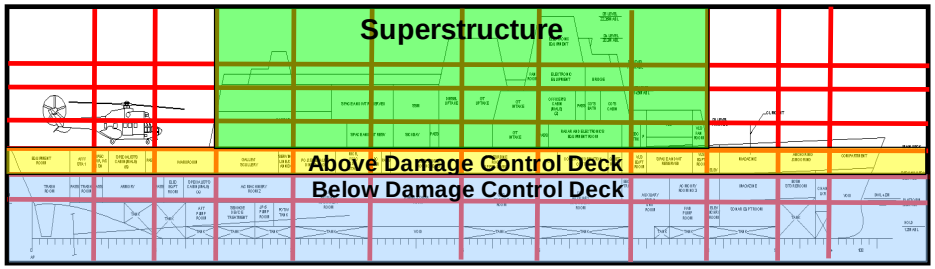


Migrate traditional ship design spiral synthesis approach to multi-disciplinary optimization approach, using behavior models as surrogate analysis modules



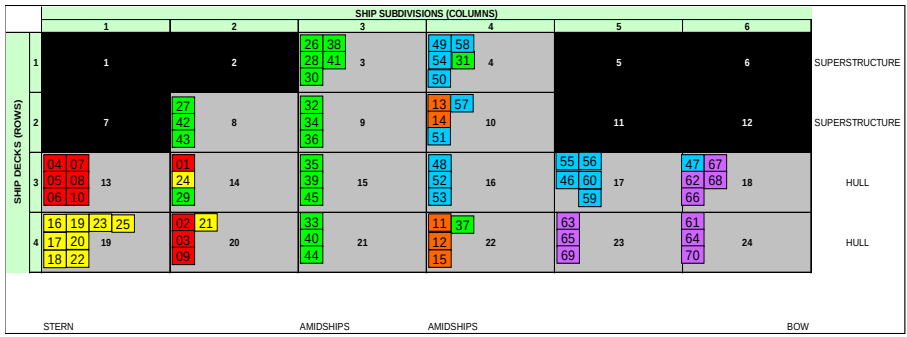
Intelligent Ships Arrangements (U. of Michigan): Ninth International Marine Design Conference -2006 (funded by ONR)

Fuzzy Global Location Preference Map Example: **Space A prefers to be either just forward or aft of amid ships and above the damage control deck within the hull.**

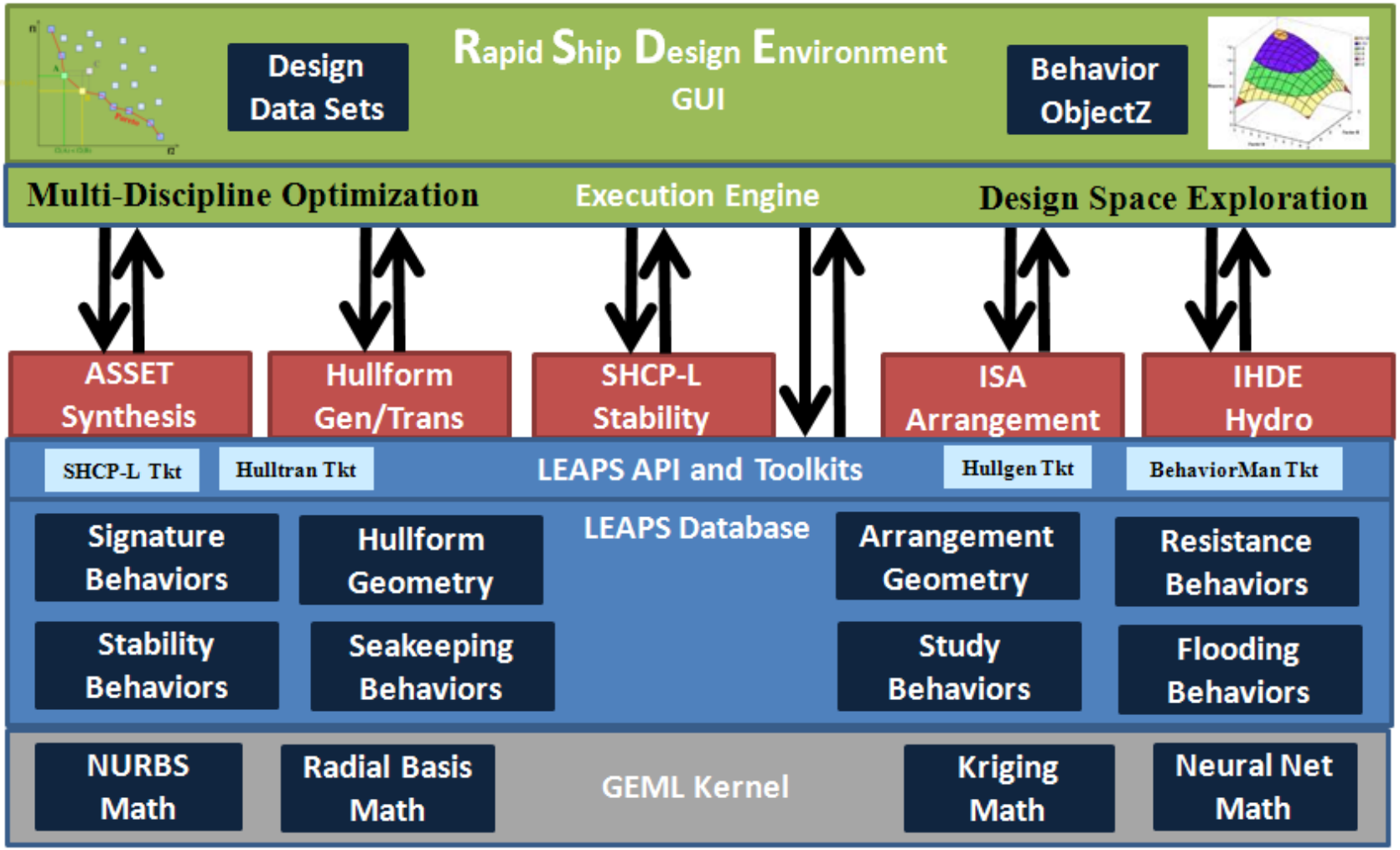


Superstructure				0.00	0.0	0.0	0.0	0.1	0.00			
				0.00	0.0	0.0	0.0	0.2	0.00			
				0.00	0.1	0.3	0.3	0.3	0.00			
				0.00	0.1	0.5	0.5	0.5	0.1			
Below Damage Control Deck	0.05	0.2	0.6	0.9	0.6	0.6	0.9	0.6	0.4	0.2	0.1	0.05
Below Damage Control Deck	0.05	0.05	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.05
	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.00

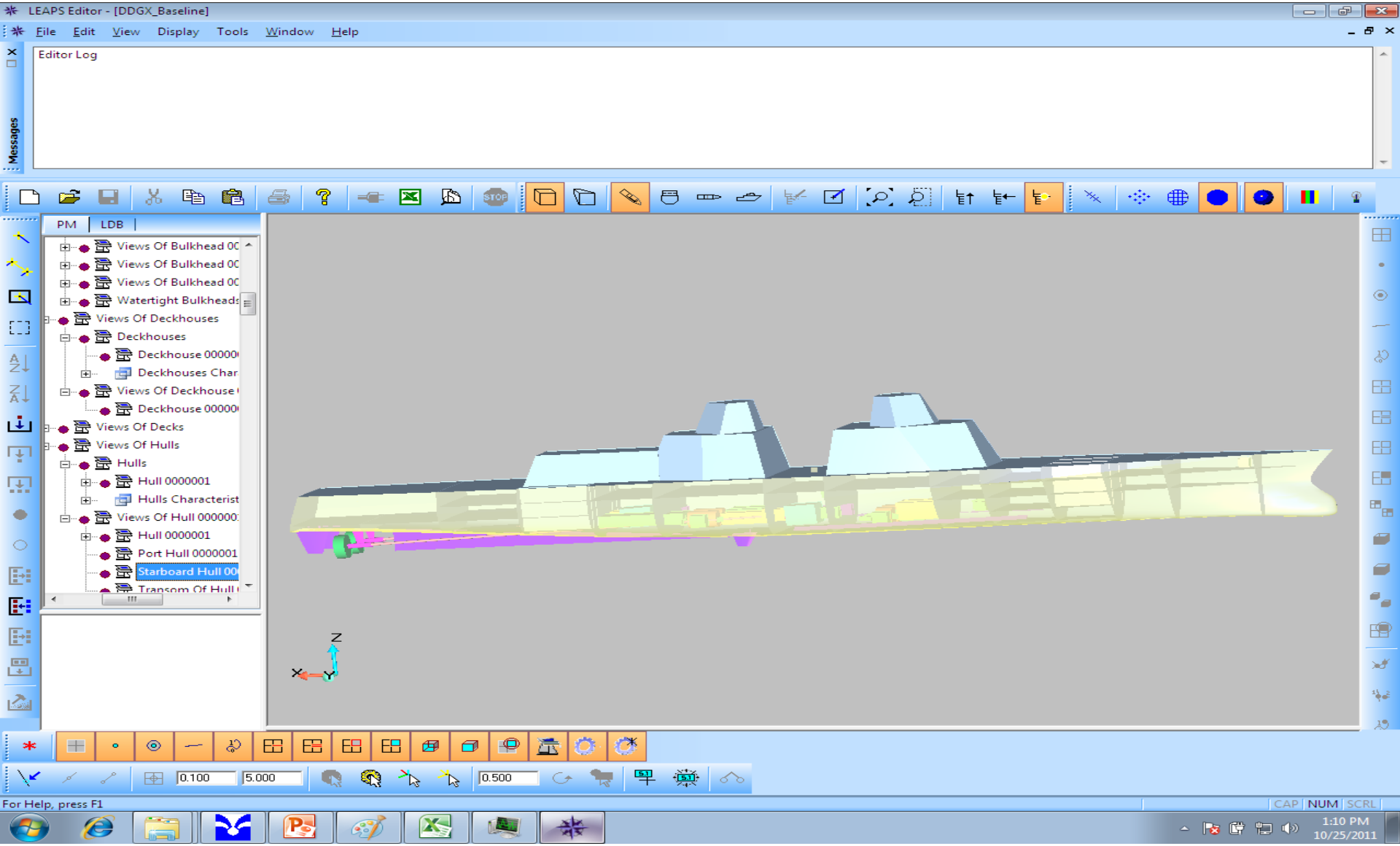
- **17 Zone-deck/70 compartment results**
  - Combinatorial Search Space 17^{70} = 1.35E+86
  - Unknown global optimum – too large for full enumeration in practical amount of time



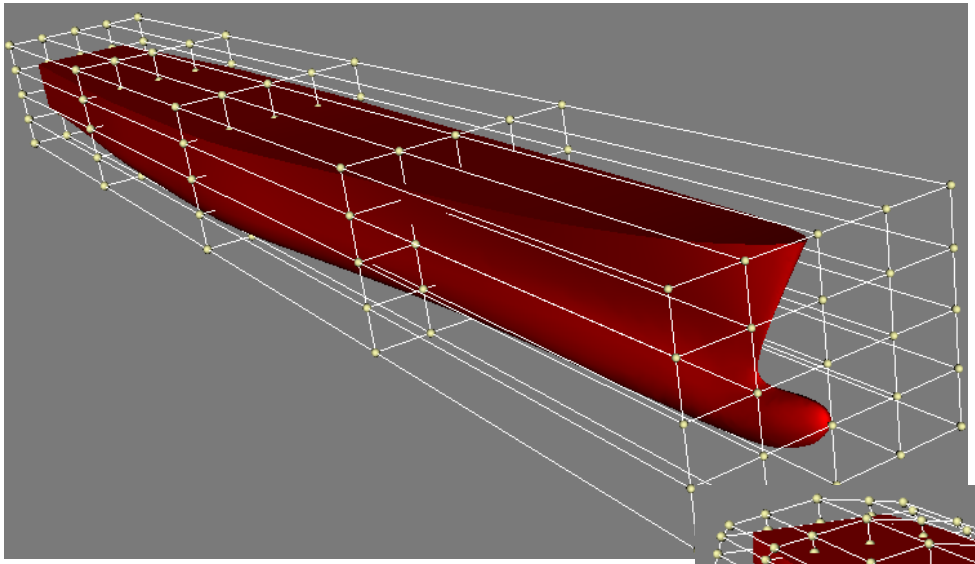
RSDE - Product Architecture

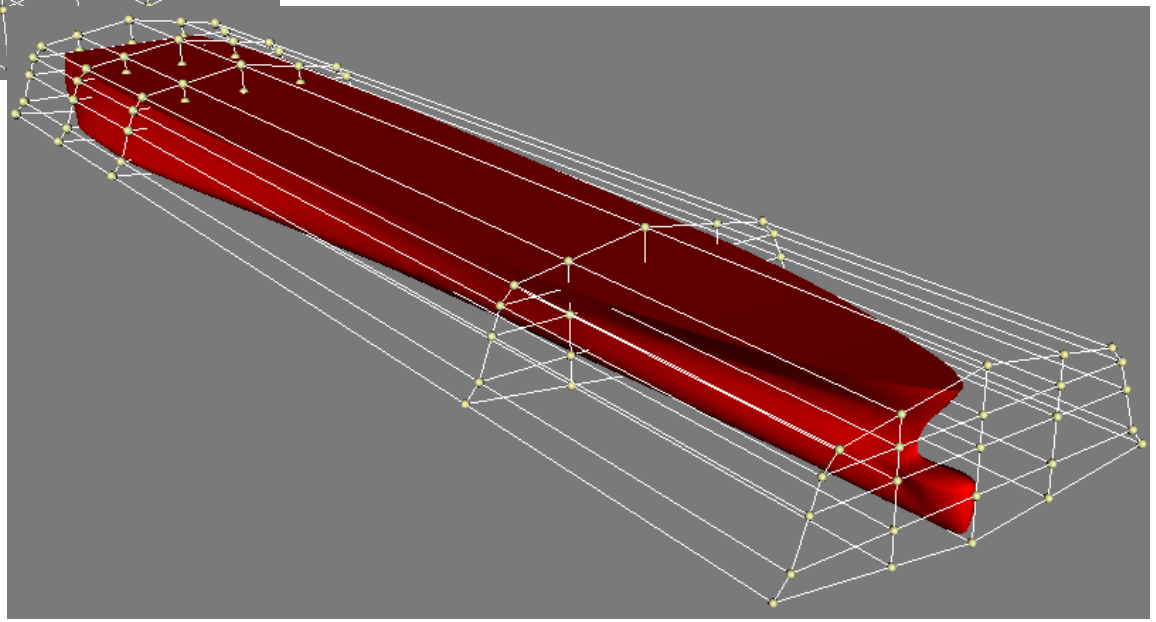


Ship Synthesis (using ASSET)

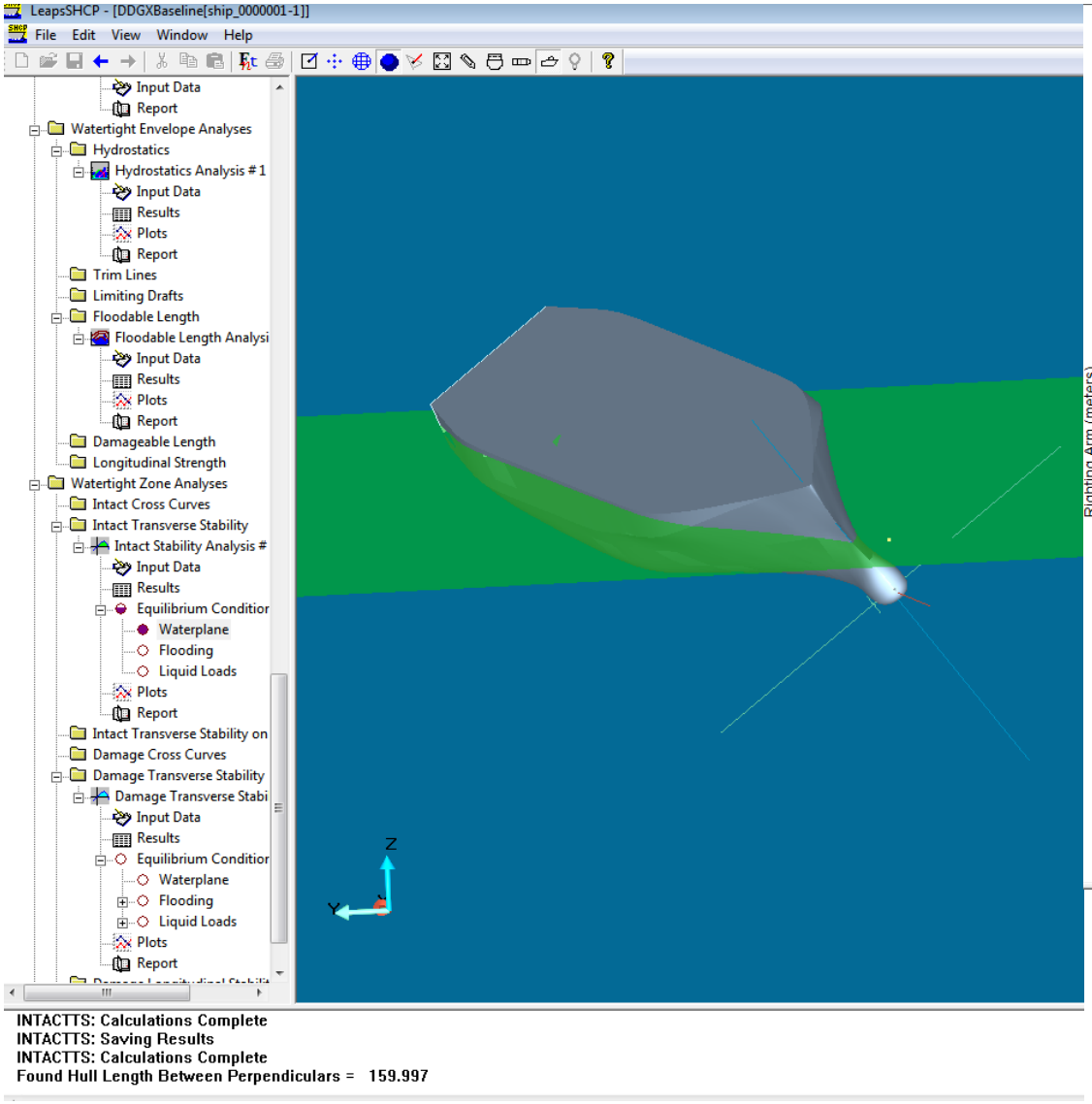


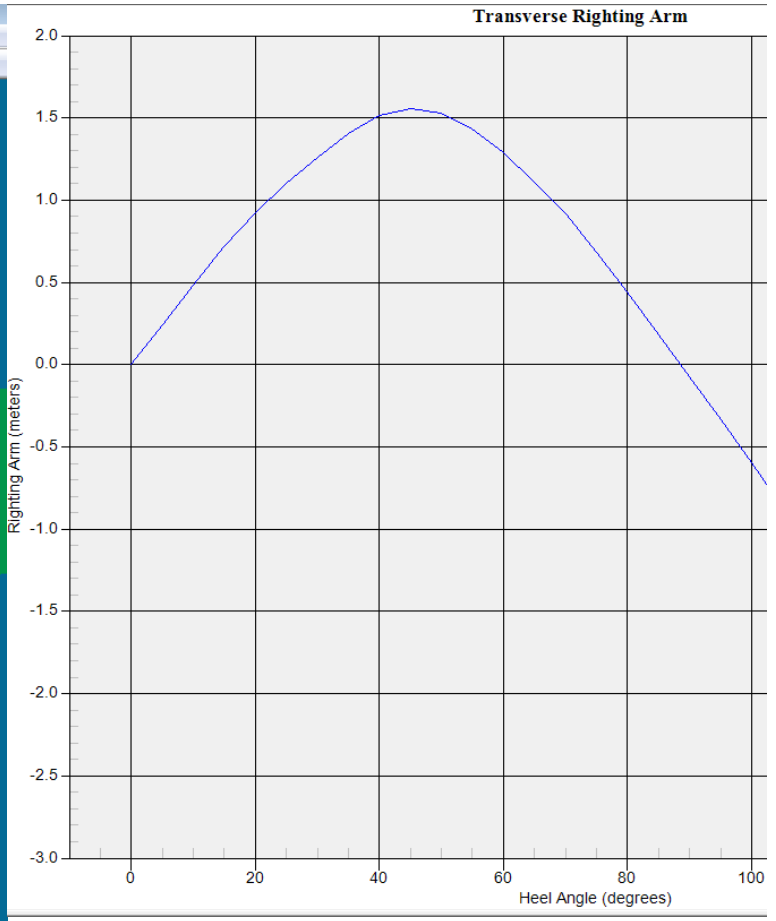
Hull Transformation Approach



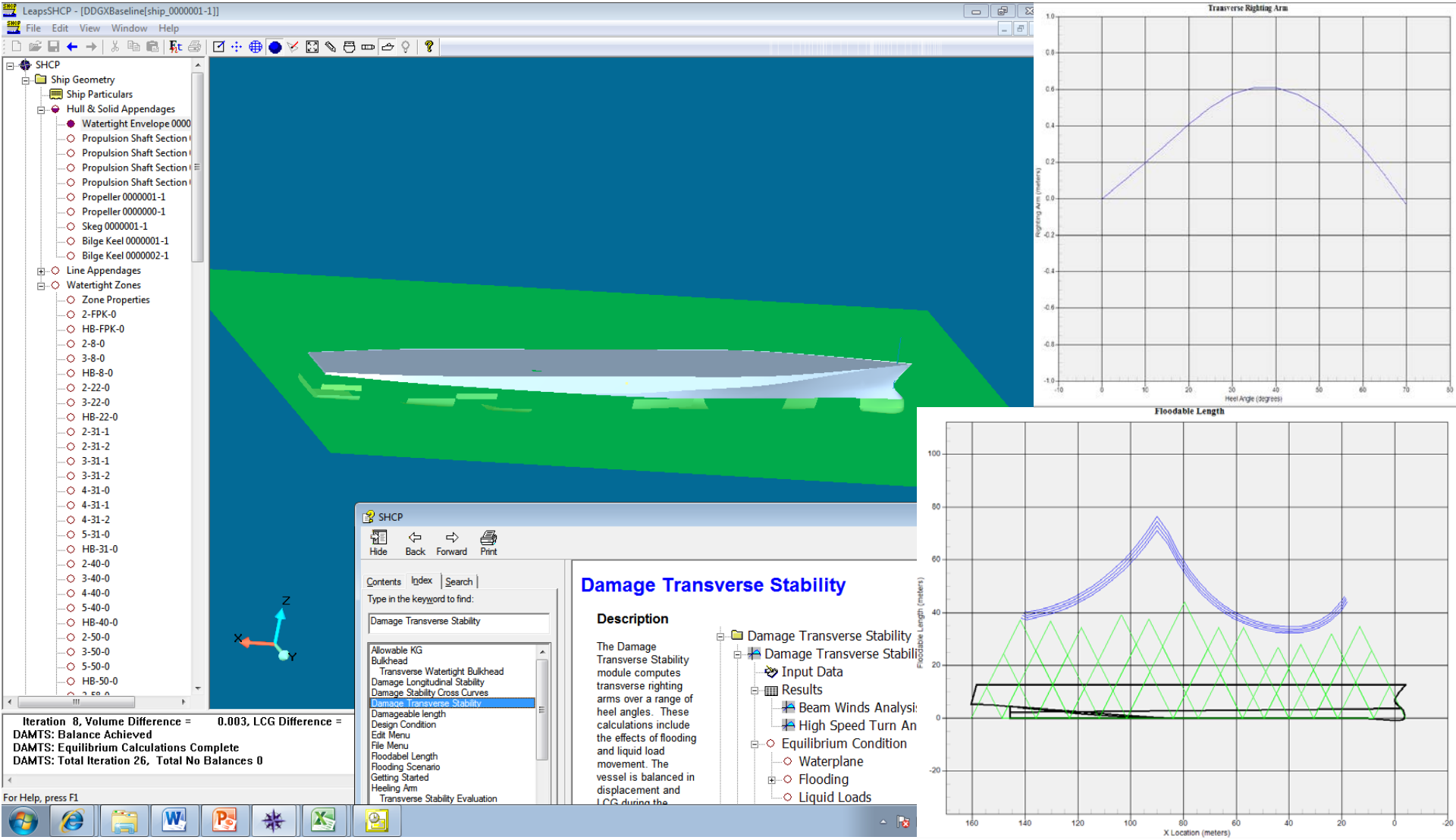


Intact Stability using SHCP-L

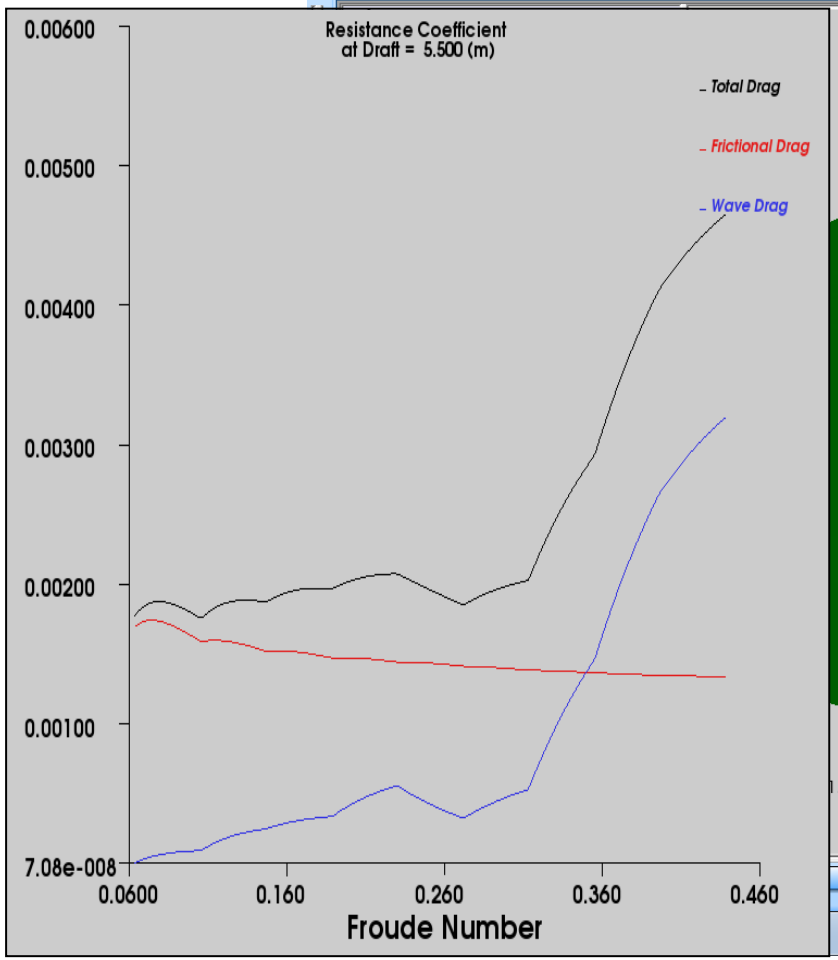




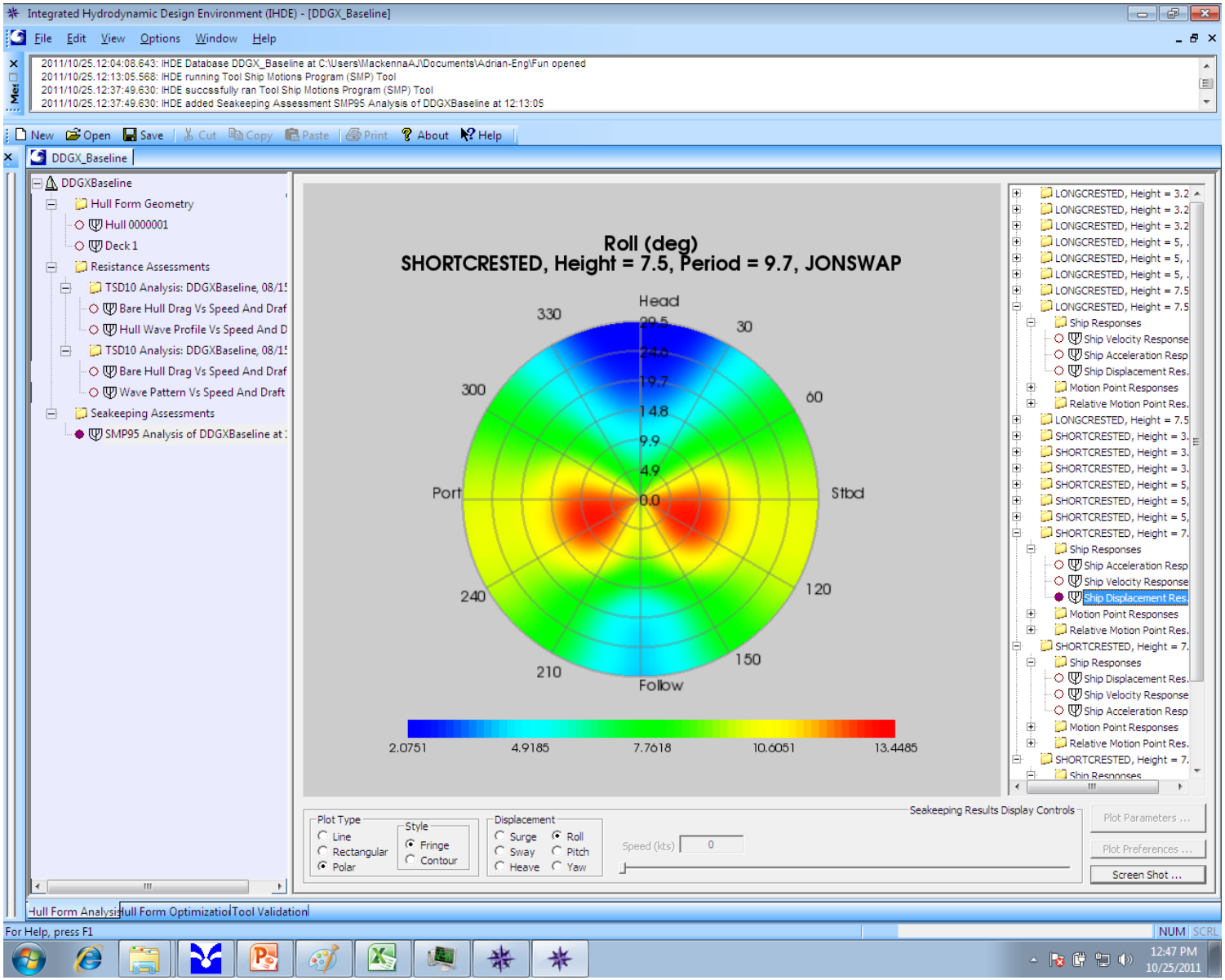
Damage Stability using SHCP-L



Resistance Analysis using IHDE

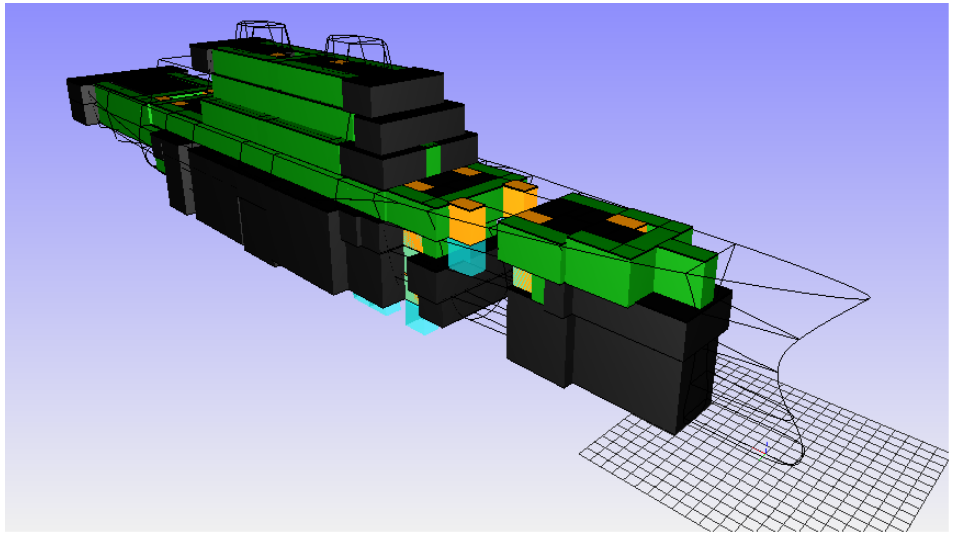


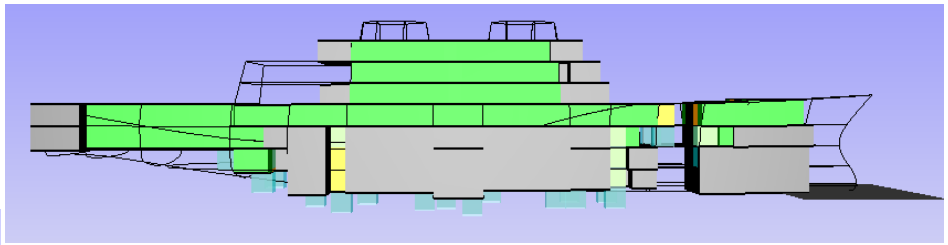
Seakeeping Analysis using IHDE

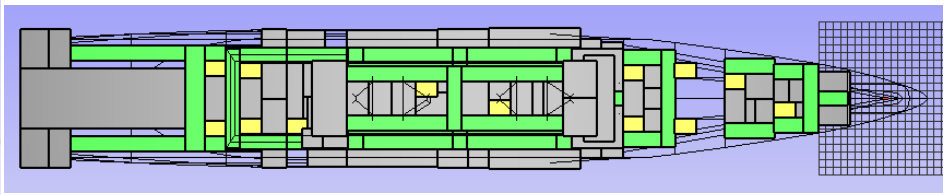


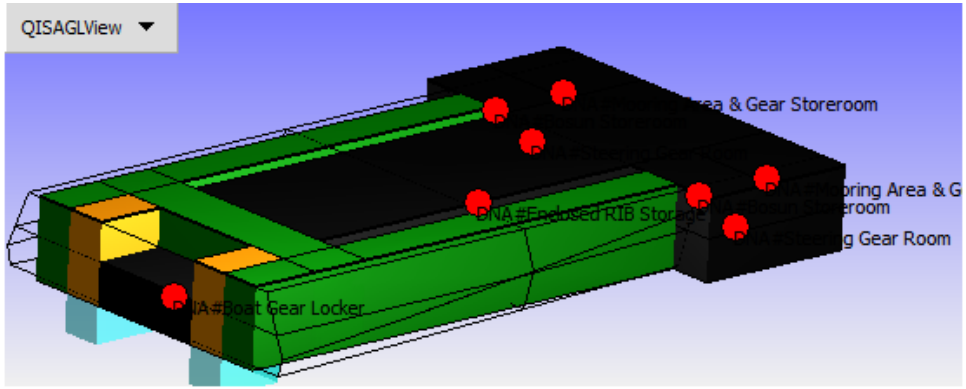
Intelligent Ship Arrangements (ISA)

- **Capabilities of ISA:**
  - LEAPS database as input for ship geometry and requirements
  - Arrangement requirements are input as a constraints database
  - Passageways are laid out using an initial lattice network
  - ISA performs allocation and arrangement of ship compartments
  - Fuzzy logic is used to lay out and optimize arrangement
  - 3D arrangements model is populated back to LEAPS



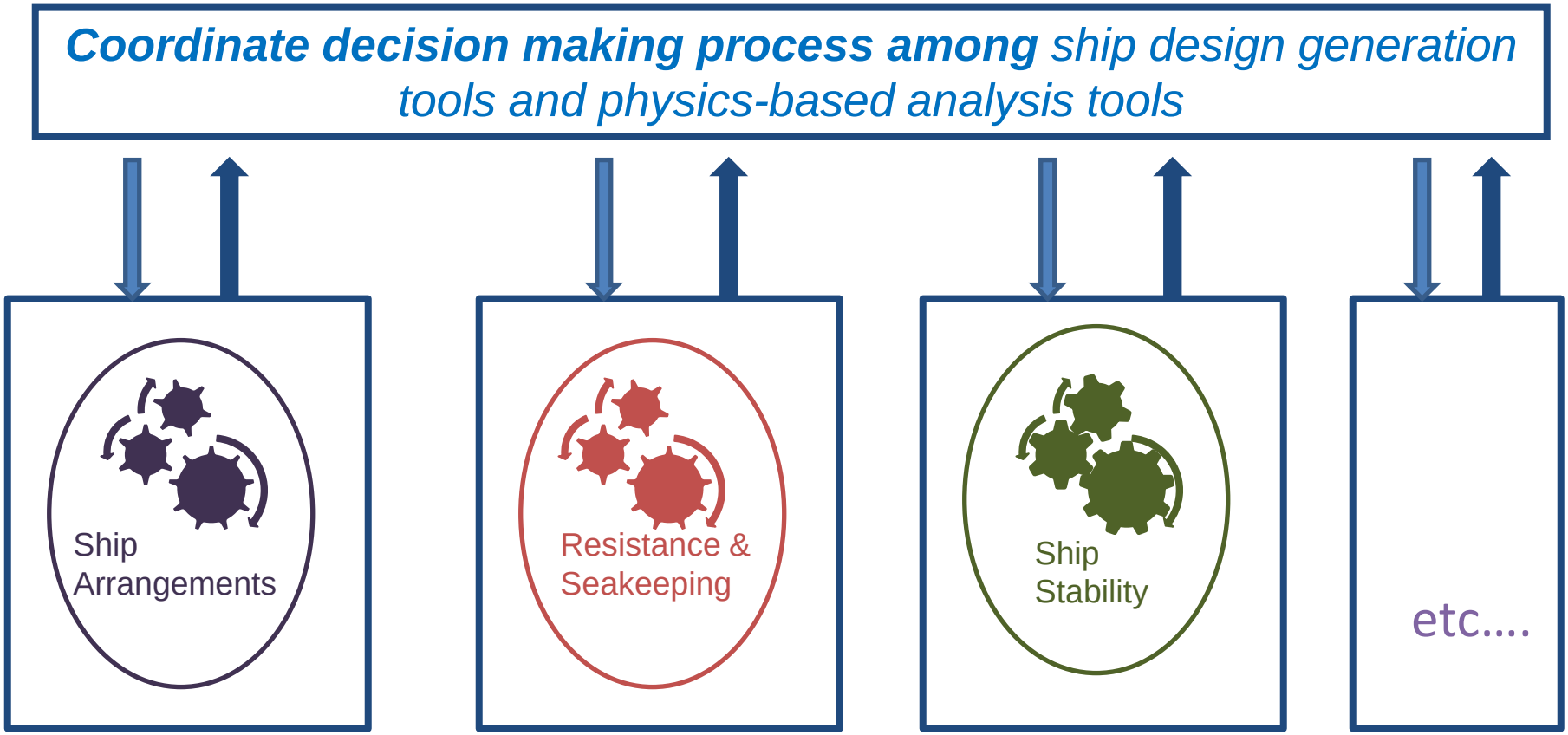






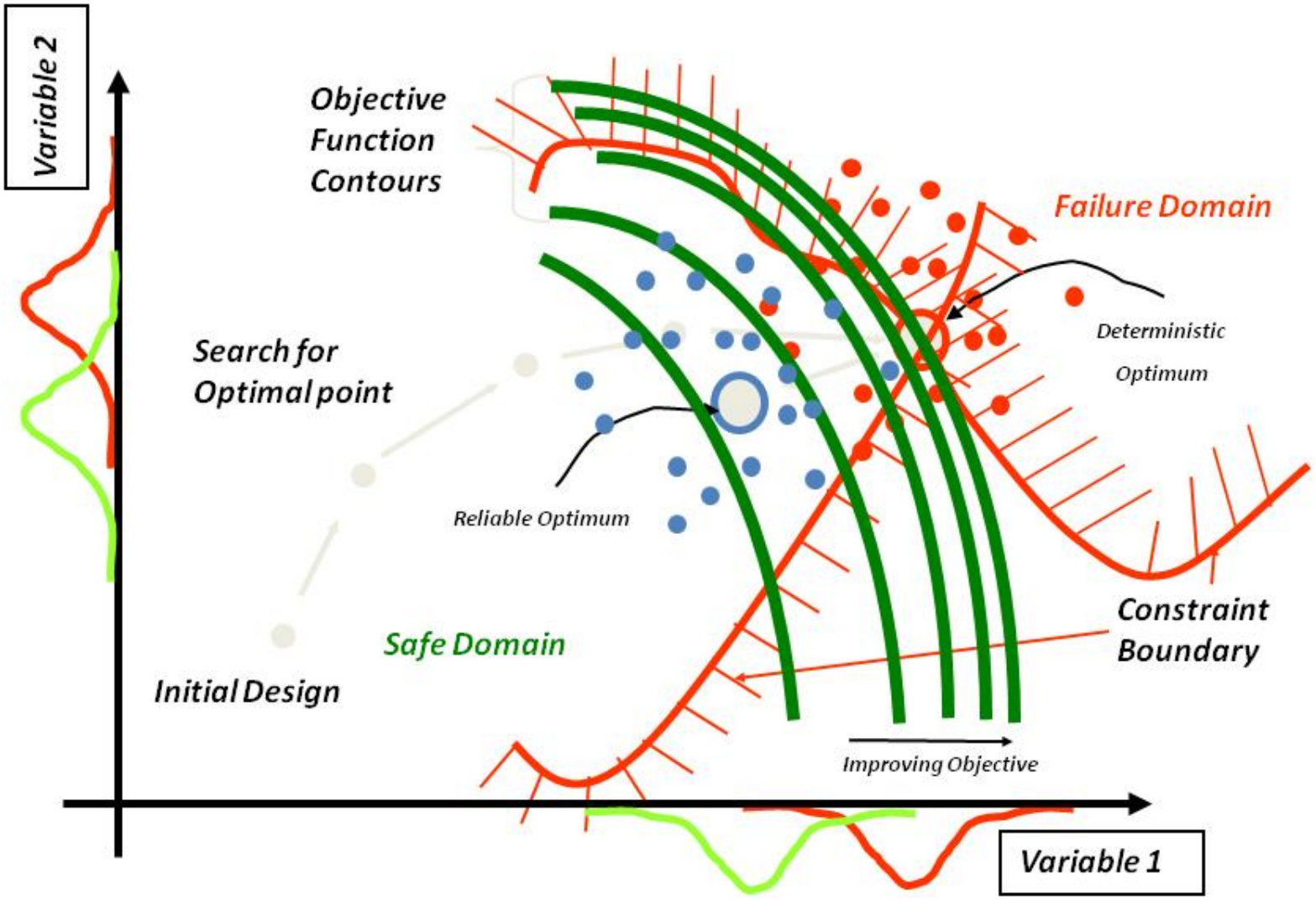
Multi-Disciplinary Synthesis

MDS (Multi-Discipline hierarchical Systems engineering)



Exchange of information and interaction among disciplines; effects of uncertainty; sharing of design variables; coordination of mutually competing objectives and constraints.

Multi-Disciplinary Synthesis

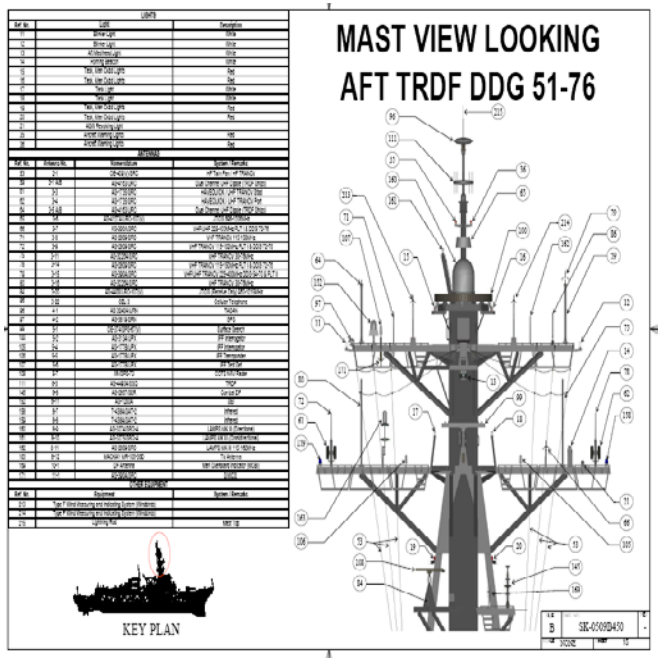


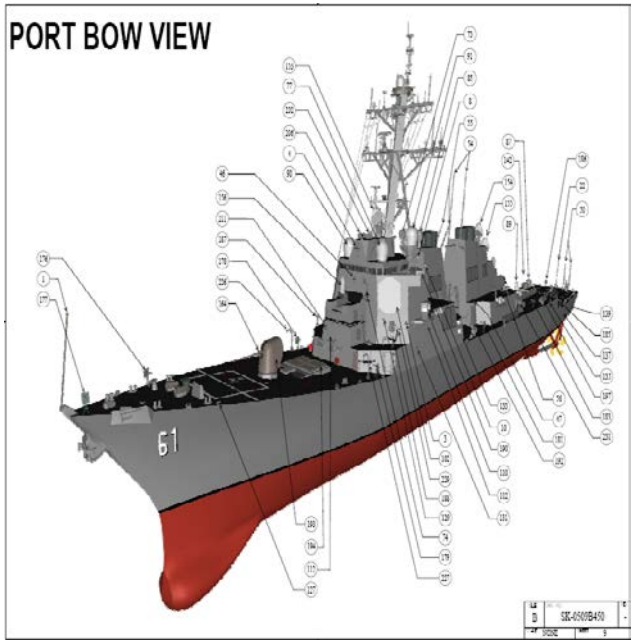
RDI Use Cases

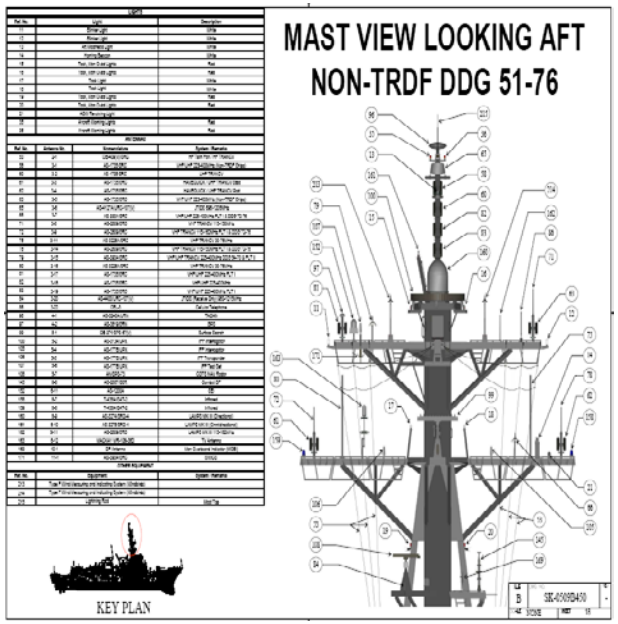
Use Cases	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18	FY 19
	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs
ASSET Synthesis	100+	100+	100+	100+	100+	100+	100+	100+	100+	100+
Hullform Transformation		1	100+	100+	100+	100+	100+	100+	100+	100+
Hullform Generation				1	100+	100+	100+	100+	100+	100+
Hullform - Intact and Damaged Stability	1	1	1	100+	100+	100+	100+	100+	100+	100+
Hullform - Resistance Analysis	1	1	1	1	1	100+	100+	100+	100+	100+
Hullform - Maneuvering Analysis					1	100+	100+	100+	100+	100+
Hullform - Seakeeping Analysis		1	1	1	1	100+	100+	100+	100+	100+
Hullform - Structural Analysis					1	1	1	1	1	1
Arrangement - Internal Compartments (Outside in)					1	100+	100+	100+	100+	100+
Arrangement - Component Placement						1	1	100+	100+	100+
Arrangement - Routing of Distributed Systems							1	1	100+	100+
Arrangement - Internal Compartments (Inside out)									1	100+

Interactions with CREATE-RF

Our Topside Real Estate Reality







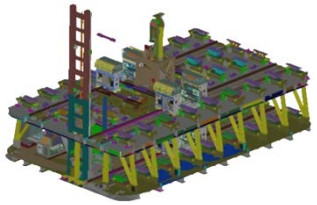
Numerous antennas competing for limited space and coverage result in a complex electromagnetic environment (EME), presenting a challenge for effective topside integration and maintaining the topside baseline.

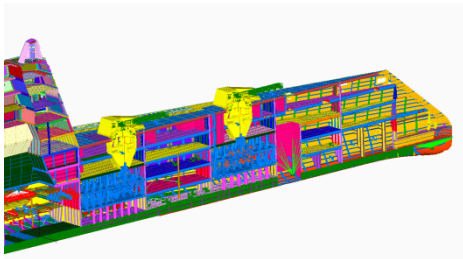
Interactions with CREATE-AV

- **Dynamic Interface**

Interactions with CREATE-MG

- **Mesh and Geometry (MG)**
  - **Geometry clean-up and de-featuring**
  - **Multi-scale model integration**
    - **Large numbers of surfaces to be "cleaned and de-featured" prior to meshing – and then integration with other large numbers of surfaces**
  - **Accurate/fast meshing for hydro boundary layers**
  - **Adaptive Mesh Refinement to allow as much "hands-off" capability to ship designers as possible**





COMNAVSEA Memo: 4 Feb 08 Functionality and Timeliness Objectives –

- **"This memorandum establishes high-level capability goals for NAVSEA design synthesis and analysis tools in order to guide development efforts within the Navy and for the DoD sponsored CREATE …"**
- **Joint Capabilities Integration & Development (JCIDS)**
  - "… capability to generate and analyze hundreds of ship concepts to a rough order of magnitude level within a period of **weeks or months**"
- **Concept Refinement**
  - "…accurately portray cost versus capability trade-offs, including uncertainty analysis, for dozens of ship concept options within a **six-month** period of performance"
- **Technology Development**
  - "… completion of a design iteration in **8 to10 weeks**, including insight as to changes needed for the next design iteration. Within the time allocated during a design iteration, analysis tools must comprehensively analyze all aspects of a Navy ship design …"
- **Interoperability with LEAPS (product model data repository and software integrator)**
- **Adhere to rigorous VV&A process**

From: RADM T. Eccles, Chief Engineer and Deputy Commander, NAVSEA 8/23/11

- This memorandum **reaffirms a NAVSEA commitment** to the High Performance Computing Modernization Program's (HPCMP) Computational Research and Engineering Acquisition Tools and Environments ship design and analysis tools program (CREATE-Ships). NAVSEA 05 will continue to take an active part in setting software requirements and ensuring the continued use and an adequate level of support for the tools, including those developed for Hydrodynamics, Shock Analysis, and Rapid Design and Integration.
- **CREATE-Ships represents an integral part of NAVSEA's strategy** to remain world leaders in ship design. Analysis tools developed through CREATE are currently being used on the DDG-1000 Surface combatant, the CVN 78 and 79 Aircraft Carriers, and the Ohio Replacement Submarine program, and are planned for use in many upcoming ship programs …

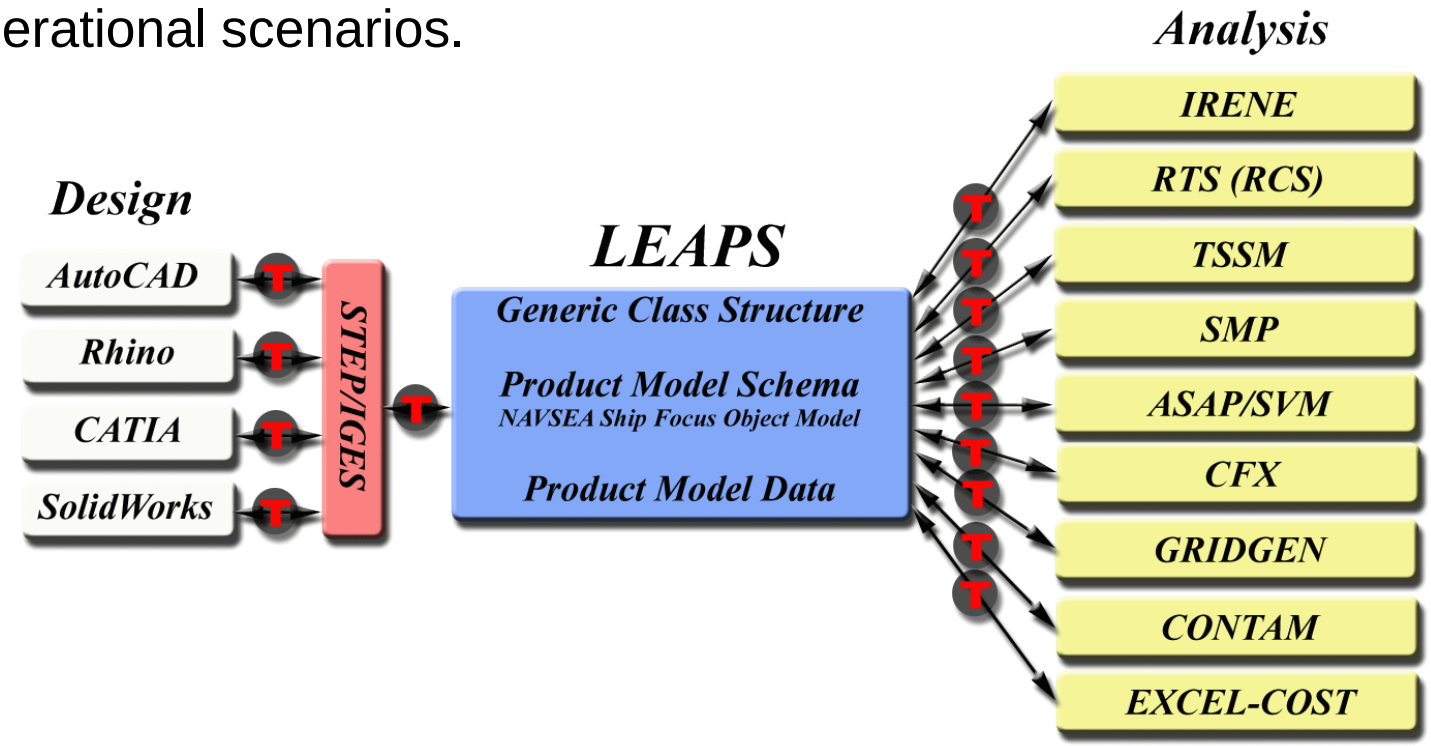
From: RDML D. Lewis, Program Executive Officer (SHIPS) - 2/23/12

- This letter **reaffirms PEO(SHIPS) commitment** to the High Performance Computing Modernization Program's (HPCMP) Computational Research and Engineering Acquisition Tools and Environments ship design and analysis tools program (CREATE-Ships). PEO(SHIPS) has participated as member of the CREATE-SHIPS Board of Directors since 2008 due to the importance of this program to our ship acquisition programs. **PEO(SHIPS) remains committed to the development and transition of CREATE tools to the Navy.**
- **CREATE Tools are and will continue to be a critical enabler to PEO(Ships) acquisition programs.**

What is LEAPS?

The NAVSEA Product Modeling Environment

*L*eading *E*dge *A*rchitecture for *P*rototyping *S*ystems, is the product model repository used by the Naval Sea Systems Command. LEAPS is based on an extensible information meta-model. It is designed to provide product model data to support modeling and simulation tools used by Navy Ship Designers. The current focus is concept studies, analysis of alternatives, and operational scenarios.



Product Model Data

A Simple Definition

Product Model data is the combination of 3D geometry and non-graphic attributes to define ship objects such as a piece of equipment, deck, bulkhead, etc. Product Model data can be organized to define interim products and ultimately the entire ship.

Part & System Definition (Caterpillar 3512, Starboard Main Engine, Propulsion System)

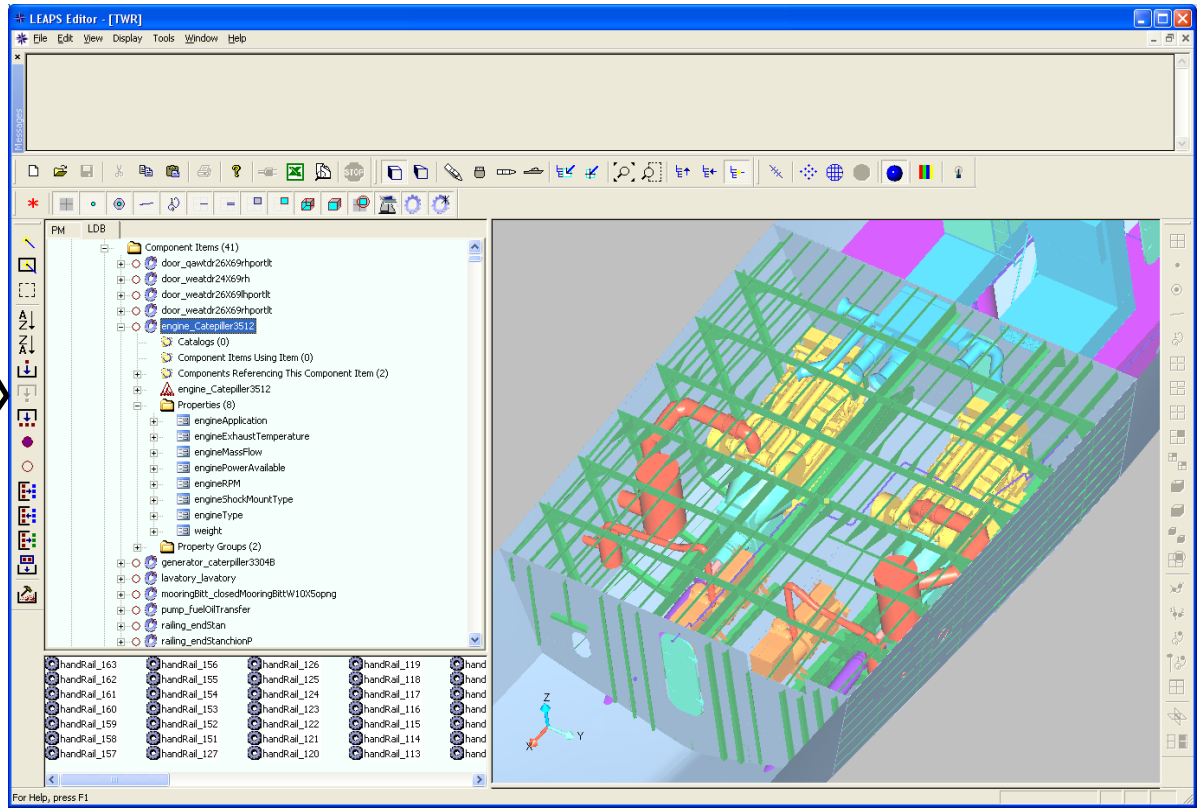
Design Definition (12 cylinder 4 stroke diesel engine)

Physical (Geometry, material connections, etc.)

Engineering Definition (1175 HP, 6464kg, 170mm bore, 190mm stroke)

Process Definition (Starting instructions, shaft alignment)

Logistics Support (FGC, SCLSIS, etc.)

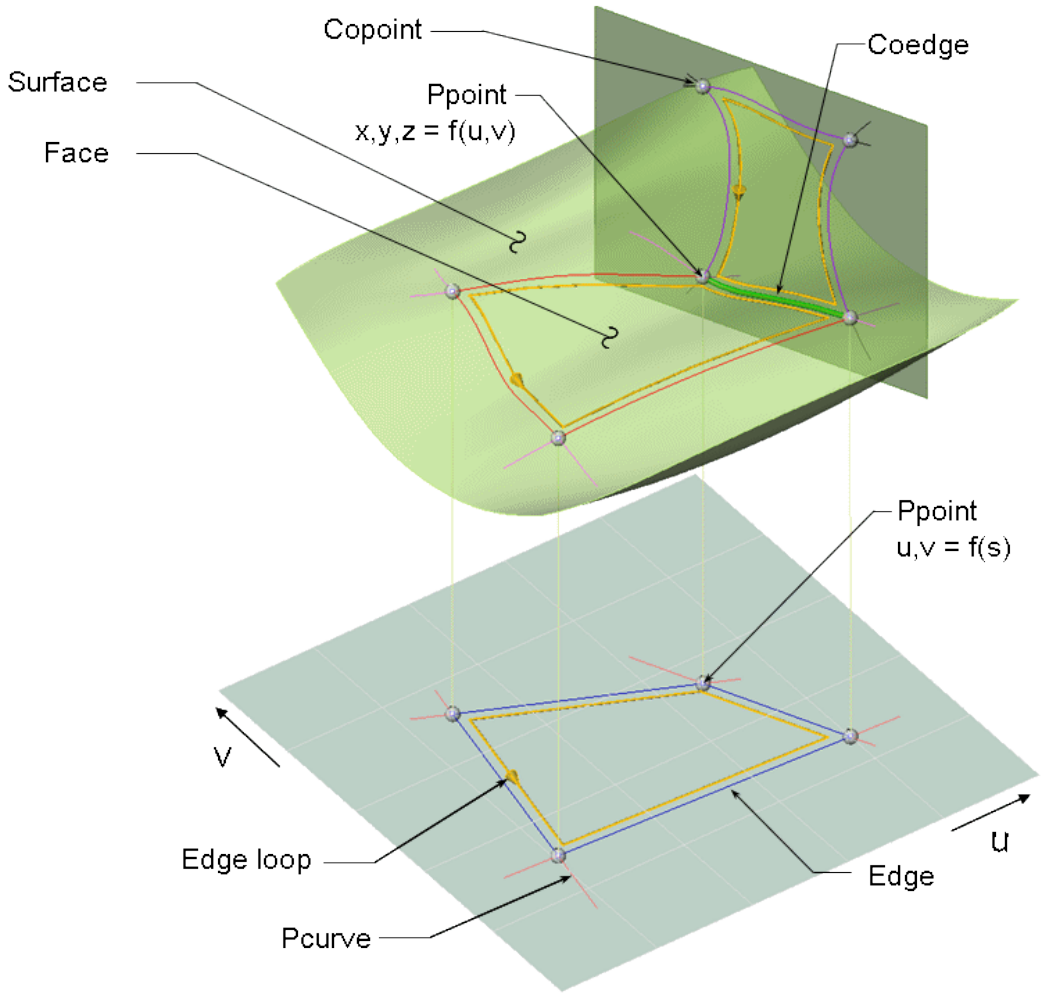


Advocates anticipate substantial economies from Product-Model-based design, construction, and service-life support activities due to better integration and reduction of engineering effort to locate, verify, and transform information.

Geometry Object Structure

Entities and Topology

Solid	A manifold BREP (boundary representation) solid defined by a single OrientedClosedShell
Surface	An untrimmed 3D NURBS surface used to define any shape.
Oriented ClosedShell	A set of Face objects that form a closed shell that is oriented.
Face	A region of a surface represented as a trimmed NURBS surface.
EdgeLoop	A set of connected Edge objects that form a closed loop that is not self intersecting. This loop is also oriented.
Edge	A region or segment of a Pcurve. The collection of contiguous Edges is used for composing paths, loops, or topological boundaries.
Pcurve	A parametric curve defined by means of a 2D curve in the parameter space of a surface.
Ppoint	A parametric point lying on a Pcurve object.
Coedge	The relationship between two or more Edges. The CoEdge is used to allow traversal across Surfaces or Faces and defines explicitly an association between two or more Surfaces or Faces.
CoPoint	The Cartesian Location equivalent for a list of Ppoint objects.

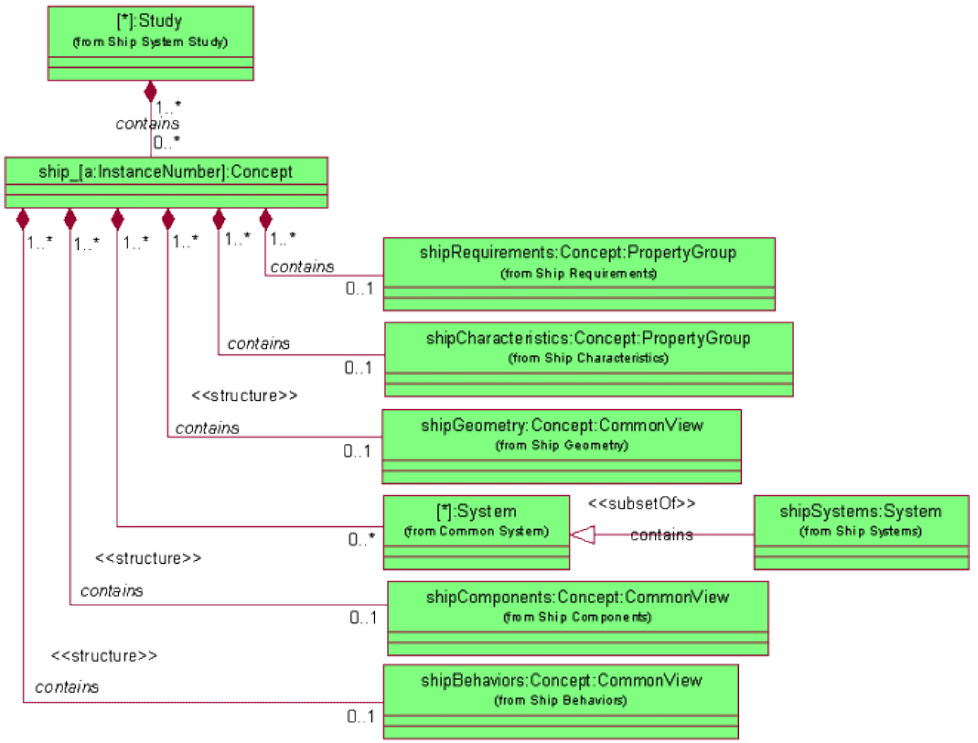


What is LEAPS?

Geometry is just a small part

Geometry is important as it provides the spatial definition and is critical in supporting visualization. However it is important to realize geometry is no more relavent to the Product Model Definition of a ship than any other non graphical attribute.

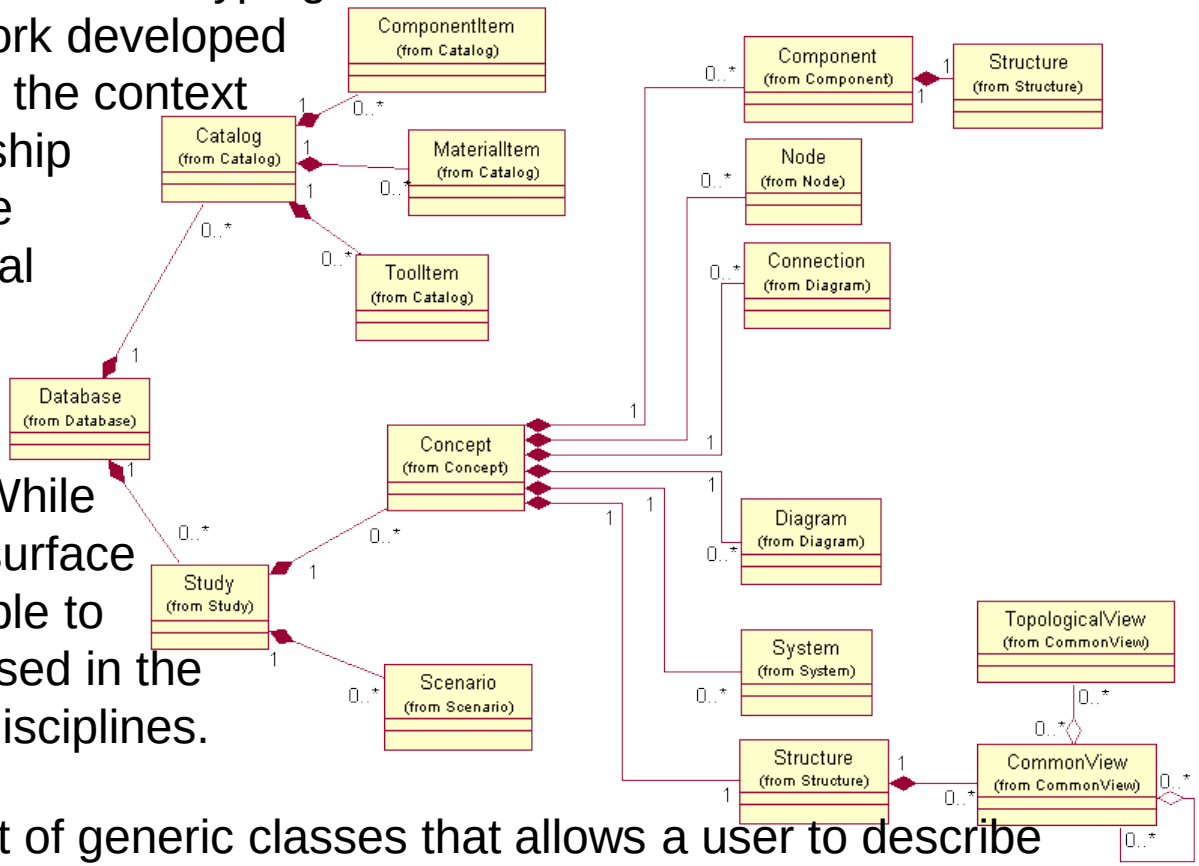
- Requirements are a property group that capture information that can be obtained from an AoA, ICD, and other high level program document.
- Characteristics are a property group that capture conditions related to the total ship. Examples of characteristics are curves of form, hydromechanics, mission profile, and stability.
- Systems are a combination of components, connections, subsystems, and functional relationships.
- Components are a collection of geometry and characteristics. Components can have multiple representations, and may have a system equivalent.
- Behaviors are a collection of geometry, conditions, environmental definition, and results.



What is LEAPS?

The meta model

The Leading Edge Architecture for Prototyping Systems (LEAPS) is a framework developed to support virtual prototyping in the context of conceptual and preliminary ship design and analysis. Due to the complexity and diversity of naval ship design and analysis, the LEAPS architecture takes a "meta model" approach to product model development. While originally developed for naval surface combatants, LEAPS is applicable to other products and has been used in the aviation and urban structures disciplines.



The LEAPS MetaModel is a set of generic classes that allows a user to describe physical and/or functional representations of objects and methods that can be applied to the development of the NAVSEA Ship product model.