



Plans and Status of the CREATE-SHIPS Project: Enabling Required Naval Warship Performance Throughout the Acquisition Lifecycle

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NDIA 13th Annual Systems Engineering Conference

San Diego, CA

27 October 2010



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**



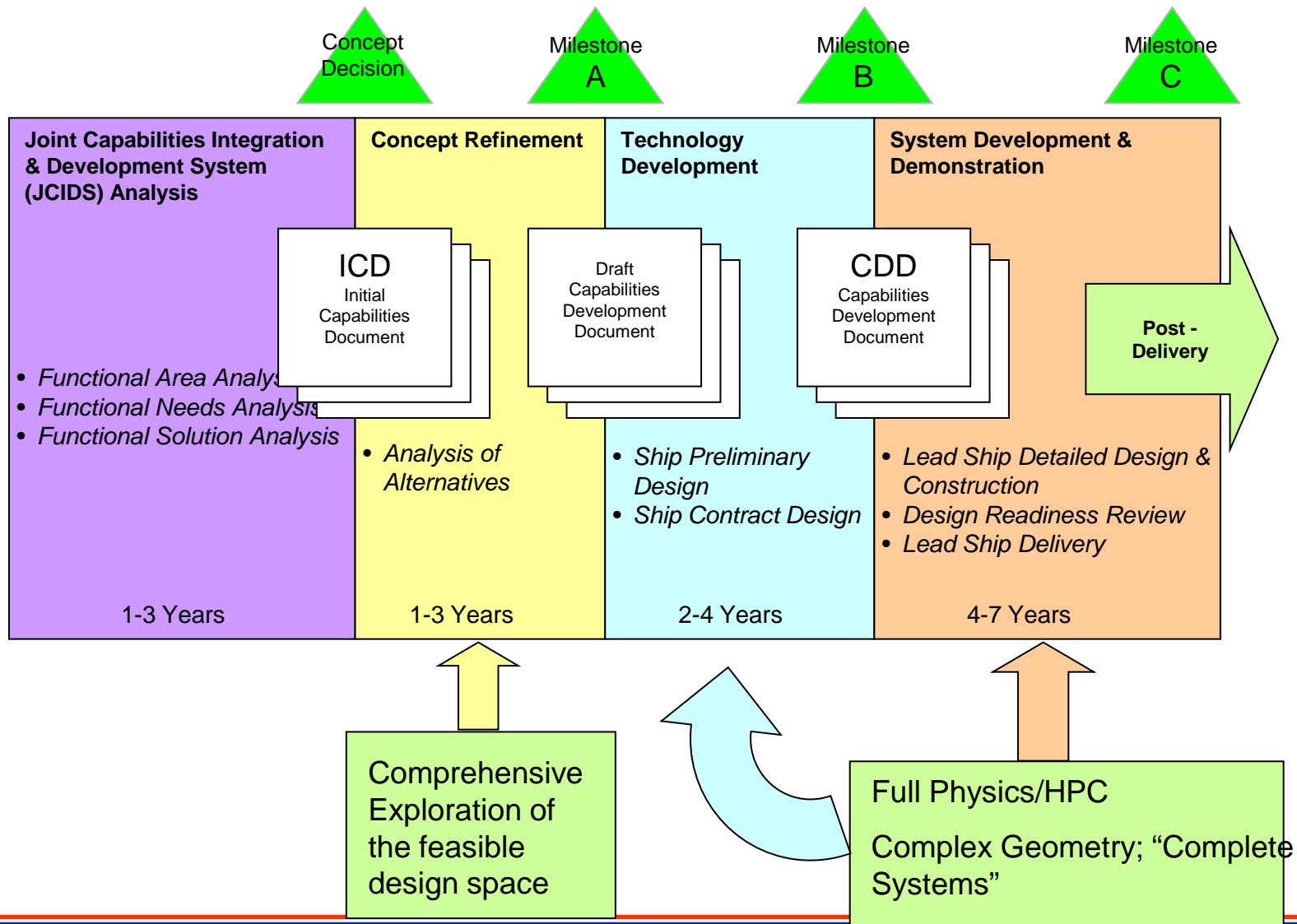
CREATE-Ships Project Objective



- **Primary goal:**
 - 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. **Survivability analysis for severe events**

- **Shock/Damage Product**

- **Lead: Dr. E. Thomas Moyer (NSWC-Carderock)**



2. **Hydrodynamics analysis of new, innovative ship design improvements to existing designs**

- **Hydrodynamics Products (2)**

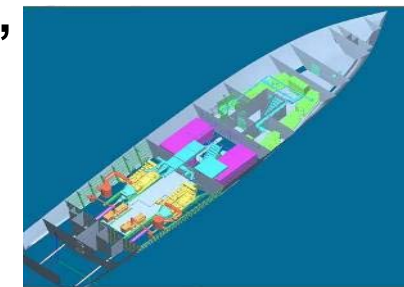
- **Lead: Dr. Joseph Gorski (NSWC-Carderock)**



3. **Timely/confident design tradeoffs in the earlier stages, when life-cycle costs are locked in**

- **Rapid Design and Integration Product**

- **Lead: Mr. Seth Cooper (NAVSEA)**





COMNAVSEA Memo: 4 Feb 08

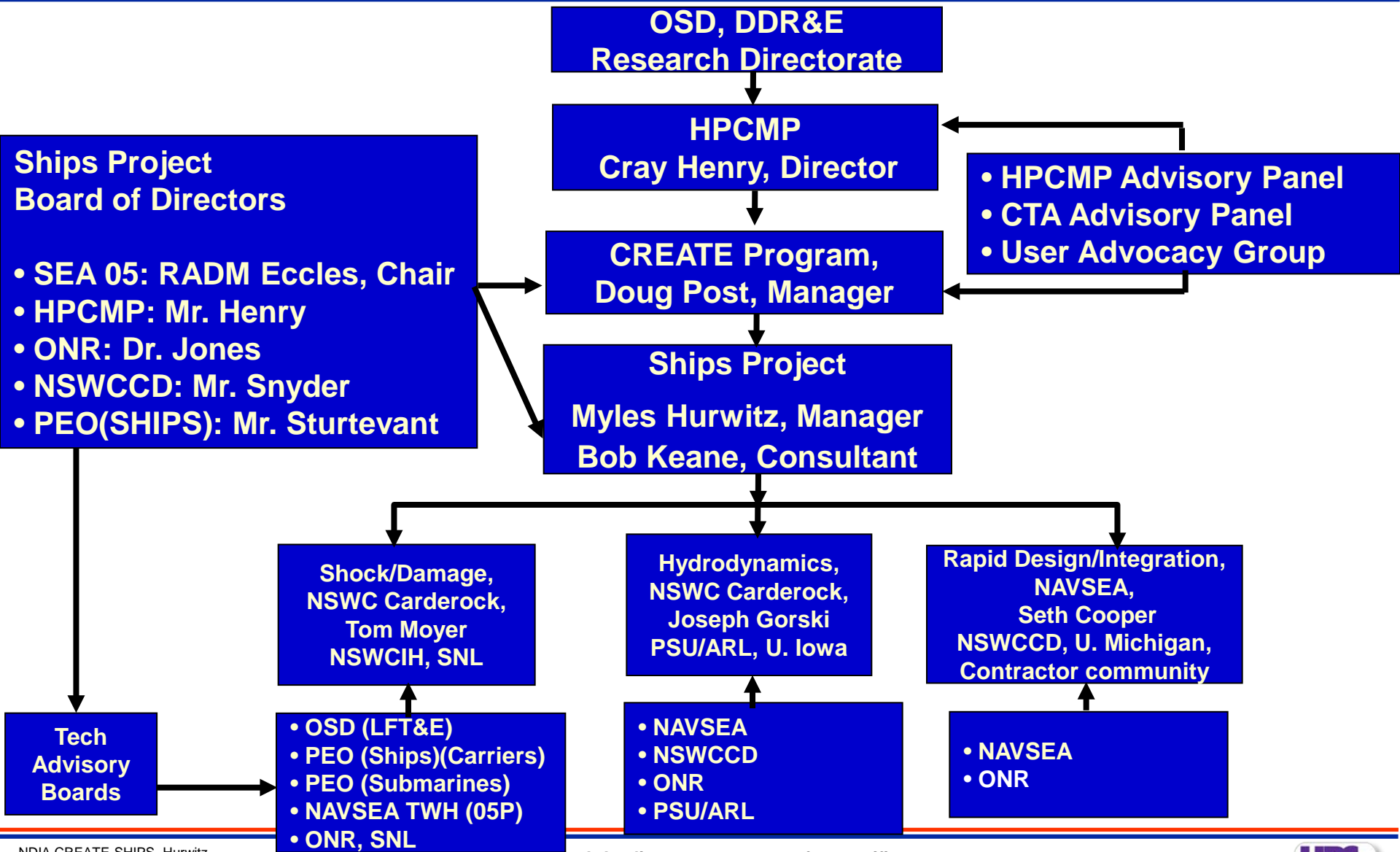
Functionality and Timeliness Objectives – (Reaffirmed Oct 2010 by NAVSEA Chief Engineer for Naval Systems Engineering



- **“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**



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**
 - **SURFEX (e.g., USS Cole)**
 - **AIREX**
- **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**

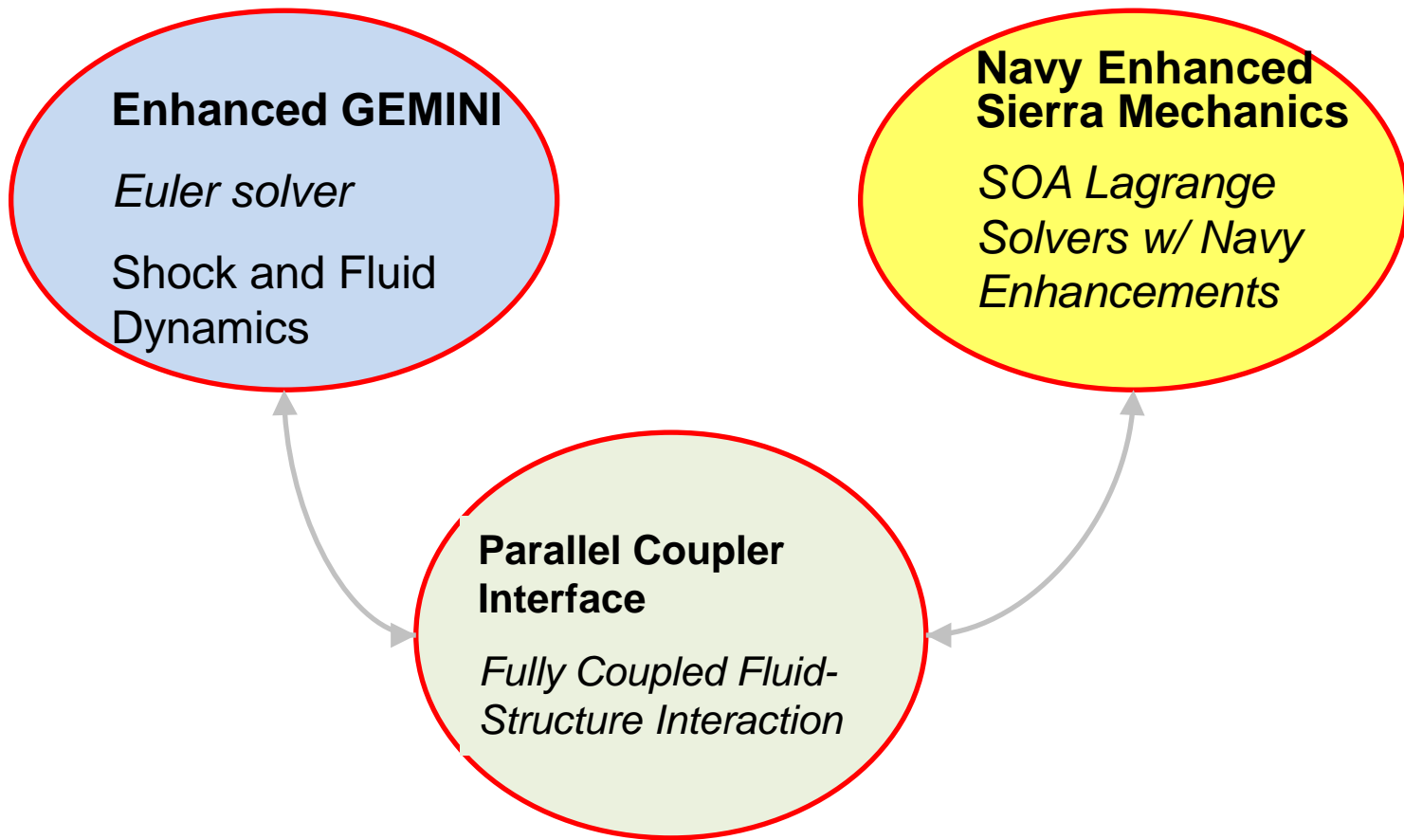


USS Cole – 12 Oct 2000





Evolving Capability - NESM/DYSMAS II

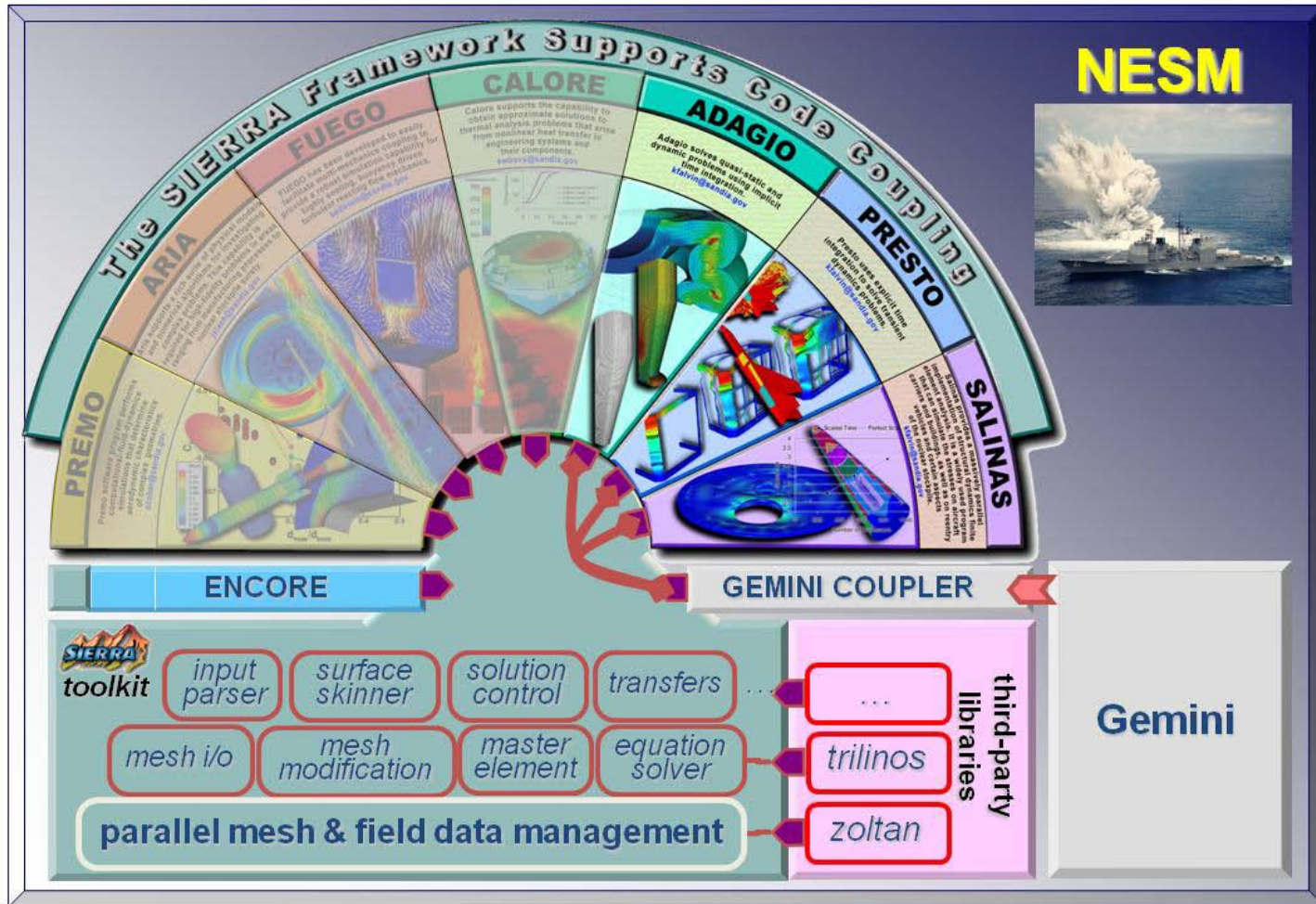


HYDROCODE FOR SIMULATION OF UNDERWATER EXPLOSION EFFECTS

DYSMAS (Dynamic Systems Mechanics – Advanced Simulation)

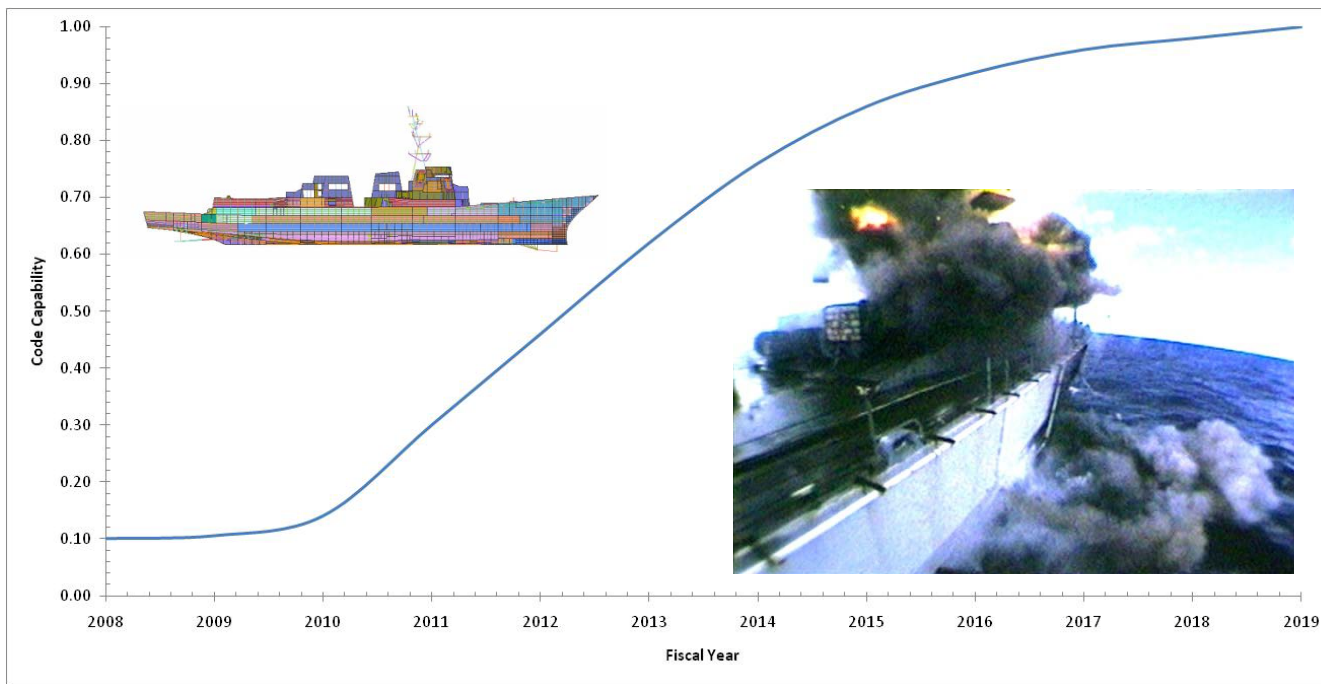


NESM In The Sierra Framework





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





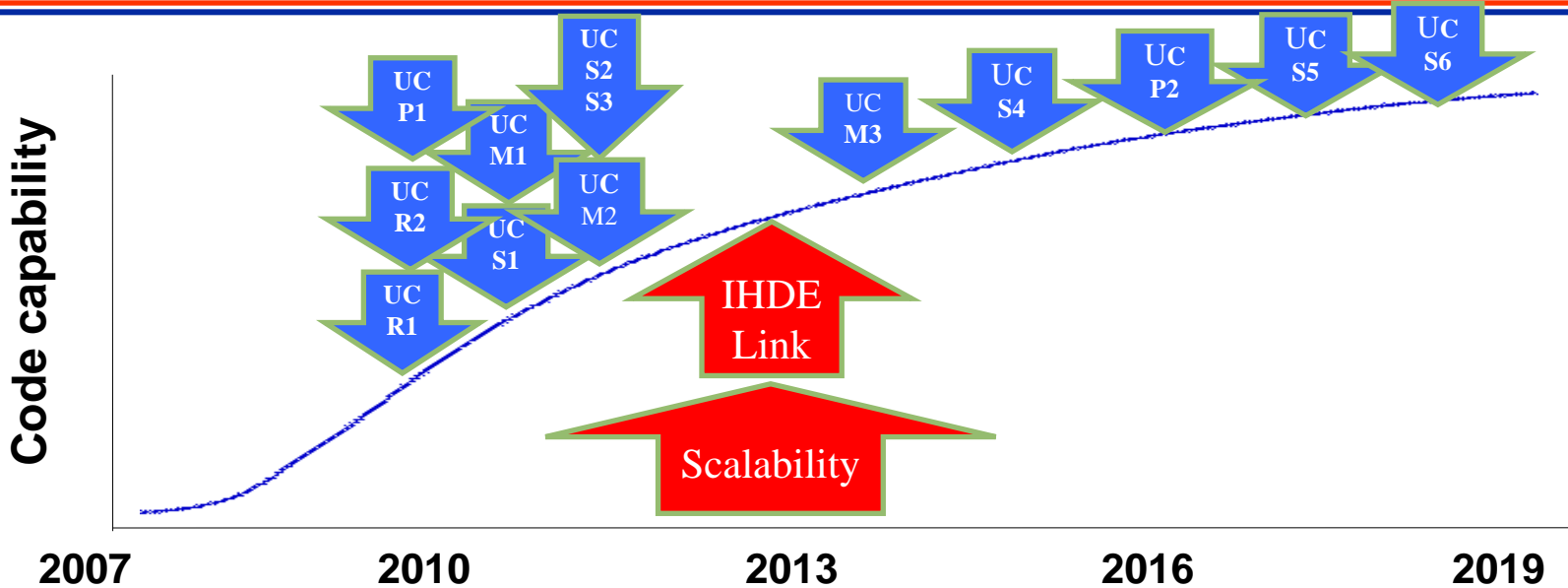
CREATE-Ships Objectives for Hydrodynamics



- **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)



NavyNS Development Roadmap

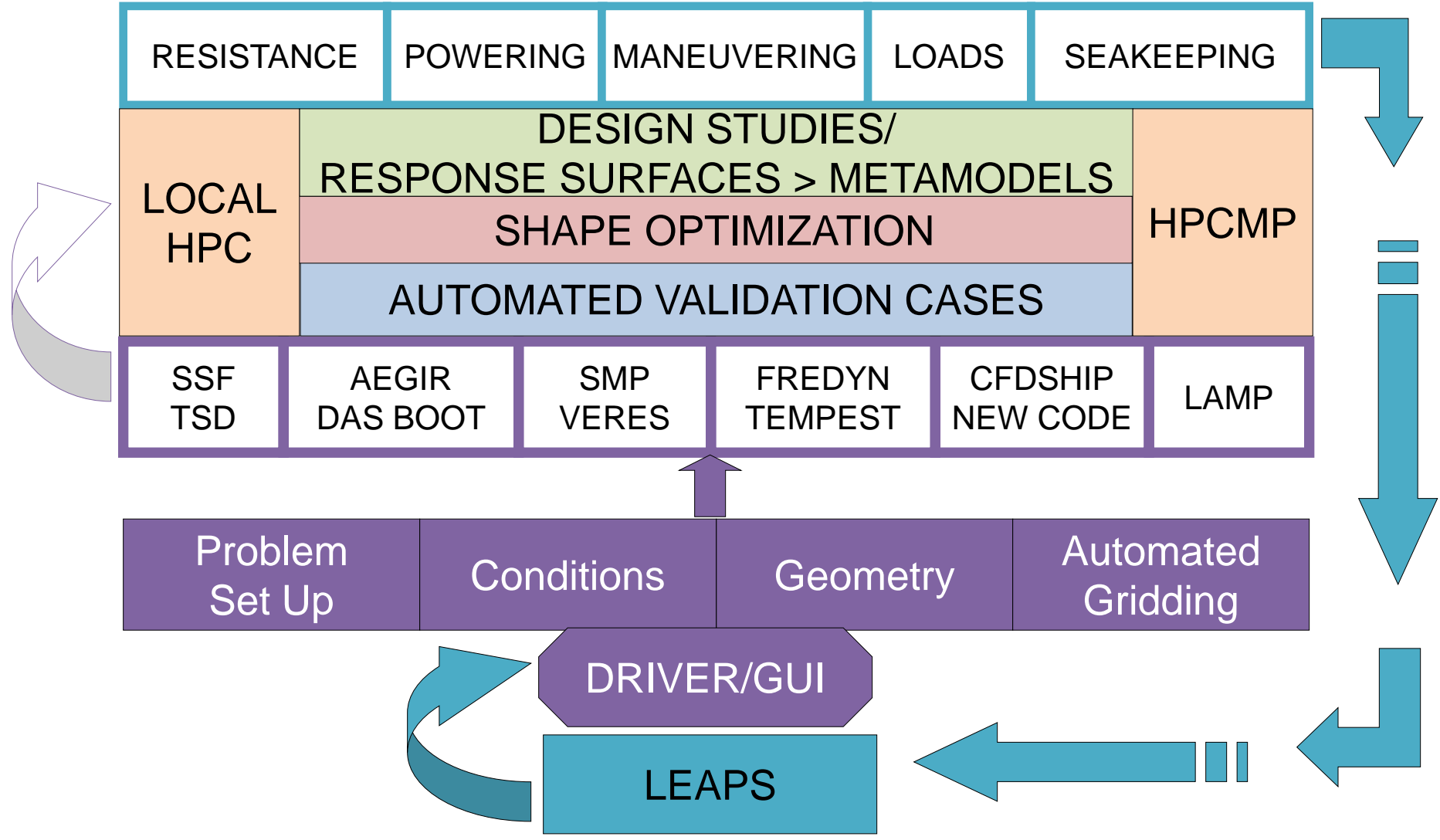


- Resistance Related
 - UCR1: Hull with fixed ship sinkage and trim
 - UCR2: Hull with computed sinkage and trim
- Powering Related
 - UCP1: Body force model for propulsor
 - UCP2 : Full propulsor modeling
- Maneuvering Related (motions in calm water)
 - UCM1: Rotating arm steady turning motion
 - UCM2 : 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



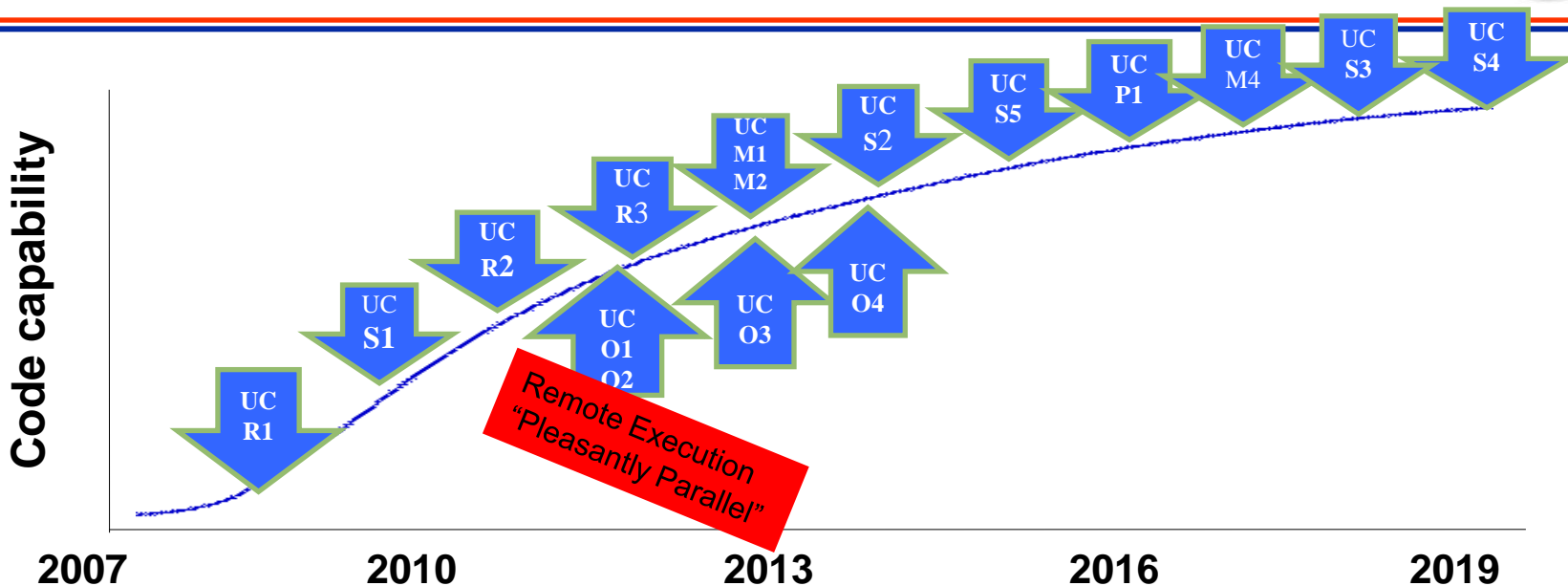


Integrated Hydrodynamics Design Environment





IHDE Development Roadmap



2007

2010

2013

2016

2019

- 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)

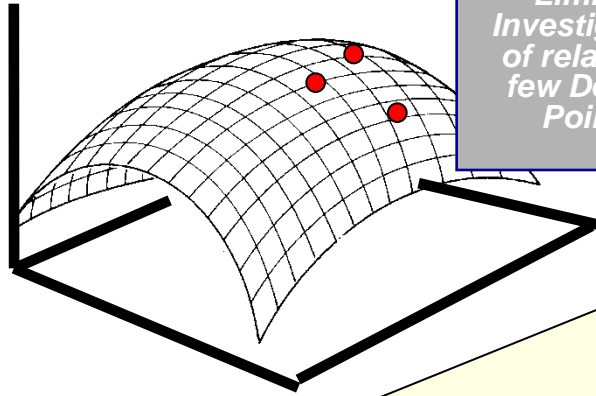


- **Comprehensively explore alternative design solutions while there is still a maximum range of options available**
- **Provide greater definition for each ship in a range of possible design solutions**
- **Perform detailed, physics-based and HPC-based analysis early on in the design cycle for each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

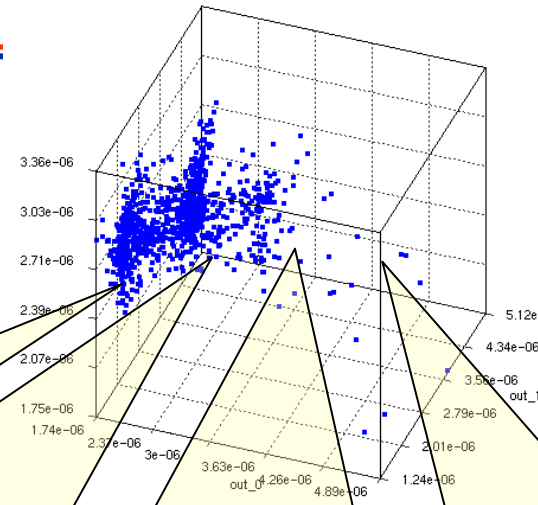
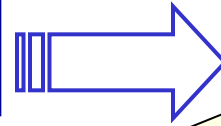




Design Space Exploration

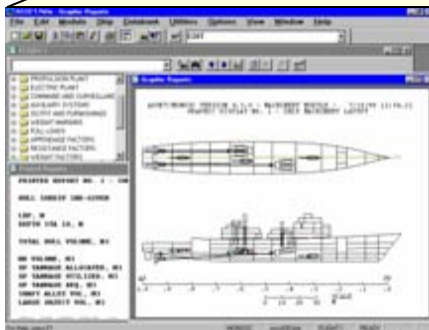


From...
Limited
Investigation
of relatively
few Design
Points

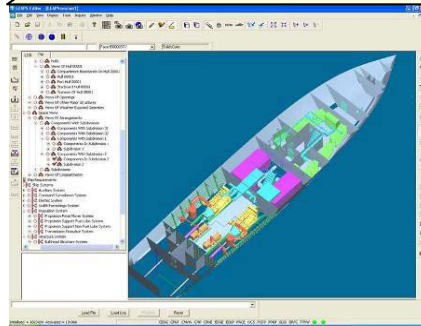


To...
Full
Investigation
of Concepts
throughout
the Design
Space

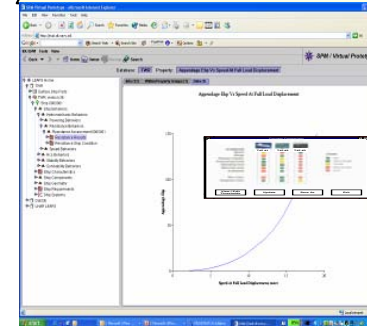
HPC Enables Exhaustive Exploration by:



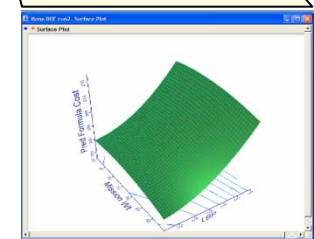
*Generating
The Space*



*Exploring
The Space*



*Evaluating
The Space*



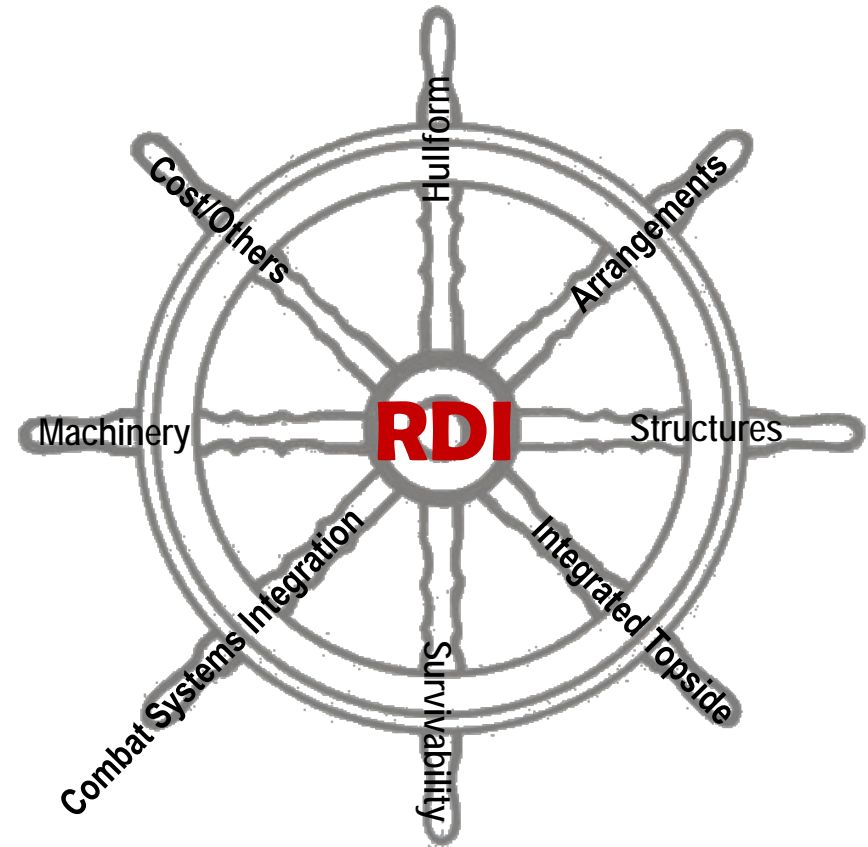
and Visualization



Rapid Design and Integration Enabling Concepts

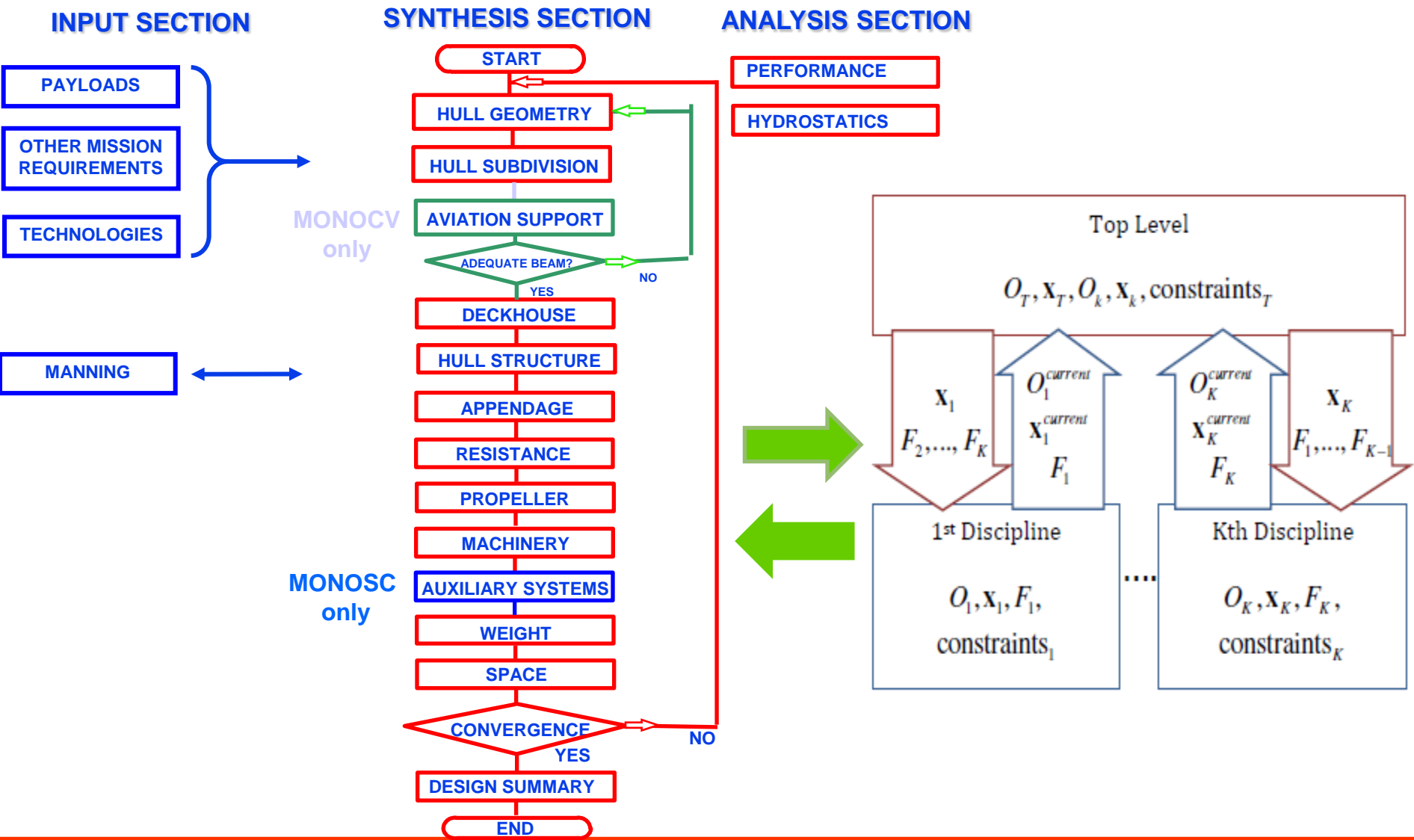


- **Design Space Exploration, Optimization and Visualization**
 - Hullform Transformation
 - Hullform Generation
 - Arrangements (Interior and Topside)
 - Behavior Models/Response Surfaces/Neural Nets/Kriging
 - Multidisciplinary Optimization
- **Standard Product Model Data Structure**
 - Analysis Activity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





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

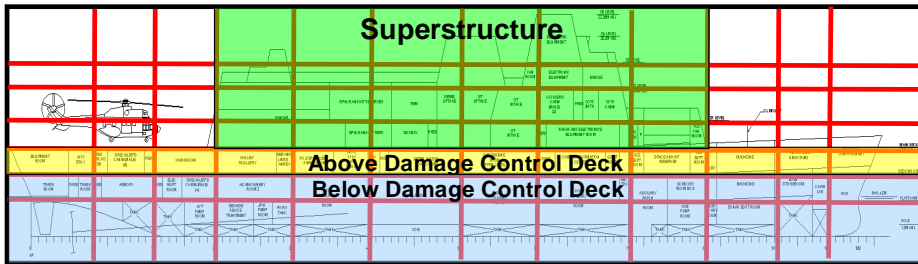




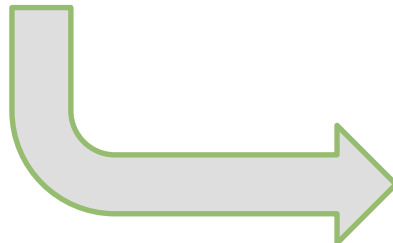
Intelligent Ships Arrangements (U. of Michigan): Ninth International Marine Design Conference -2006 (funded by ONR)



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.



				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		
Superstructure											
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
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
Below Damage Control Deck	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0



• 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

		SHIP SUBDIVISIONS (COLUMNS)																	
		1	2	3	4	5	6												
SHIP DECKS (ROWS)	1	1		26 38 28 41 30	49 58 54 31 50		6							SUPERSTRUCTURE					
	2	7	27 42 43	32 34 36	13 57 14 51		10	11	12							SUPERSTRUCTURE			
	3	04 07 05 08 06 10	13	01 24 29	35 39 45	48 52 53	16	55 56 46 60 59	17	47 67 62 68 66	18							HULL	
	4	16 19 23 25 17 20 18 22	19	02 21 03 09	20	33 40 44	21	11 37 12 15	22	63 65 64 69	23	61 64 70	24						
		STERN AMIDSHIPS AMIDSHIPS BOW																	



RDI Use Cases



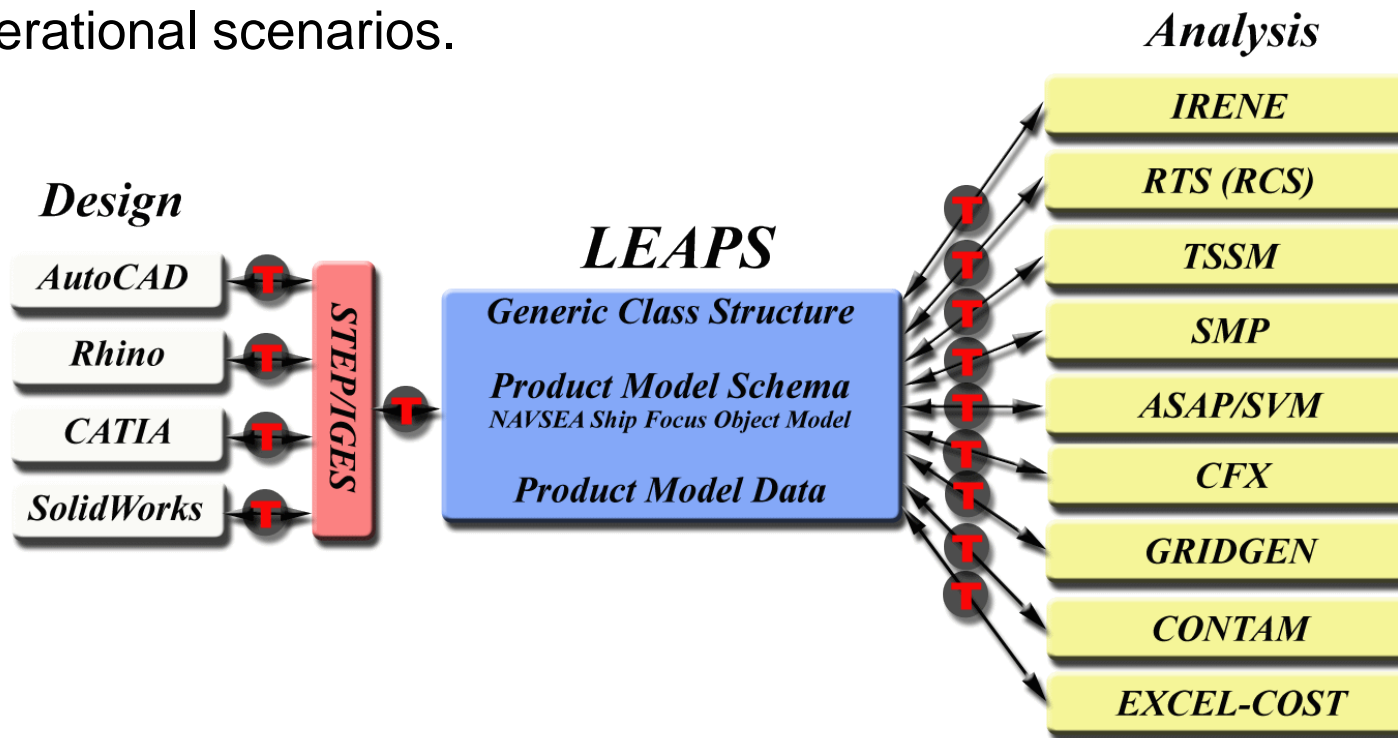
Use Cases	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18	FY 19
	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs	Number of Ship Designs
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+



What is LEAPS?

The NAVSEA Product Modeling Environment

Leading **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)

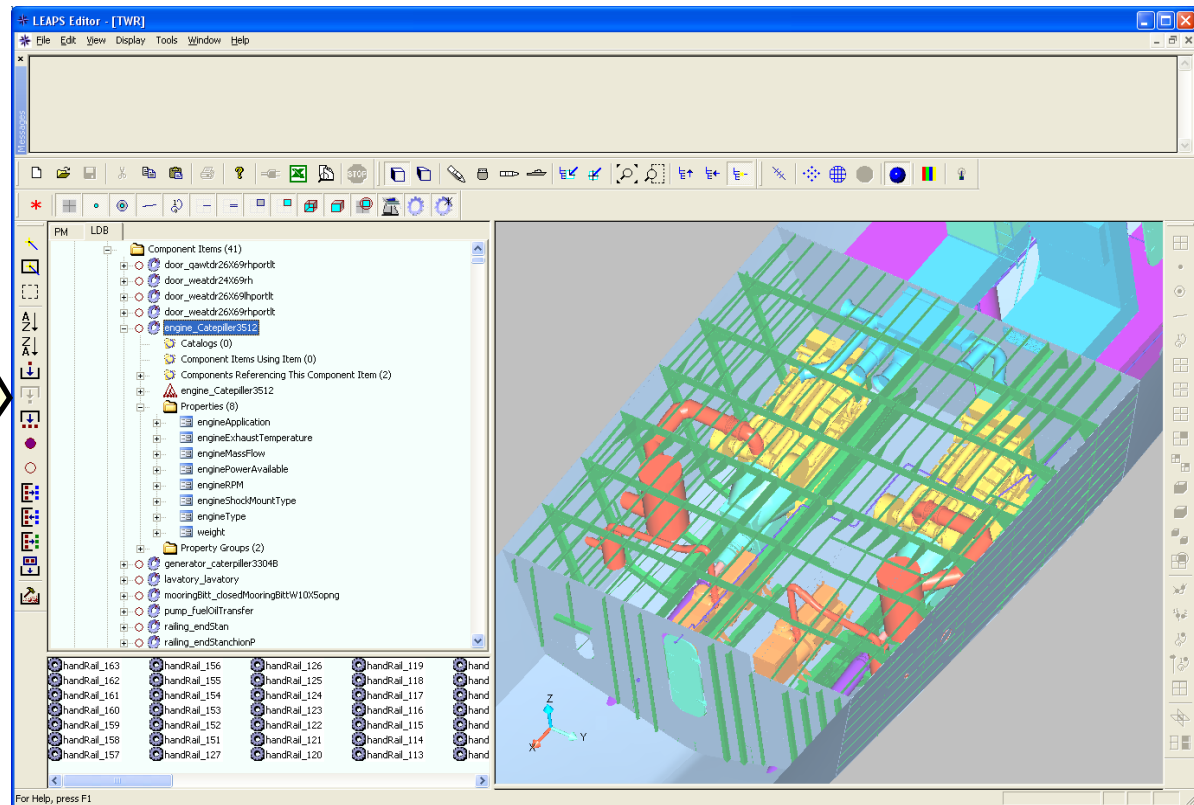
Design Definition (12 cylinder 4 stroke diesel engine)

Physical (Geometry, material connections, etc.)

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

Process Definition (Starting instructions, shaft alignment)

Logistics Support (FGC, SCLISIS, etc.)



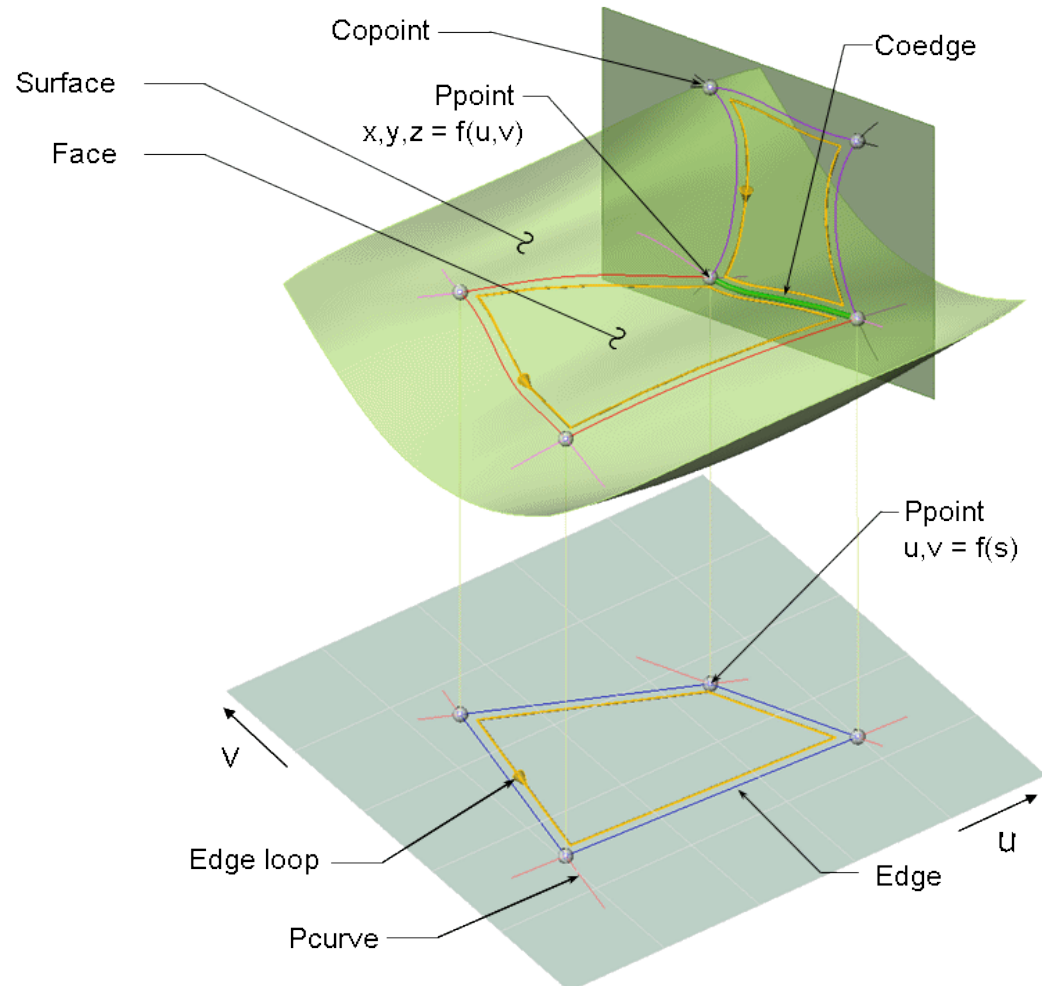
Advocates anticipate substantial economies from Product-Model-based design, construction, and service-life support activities due to better integration and reduction of engineering effort to locate, verify, and transform information.



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 relevant to the Product Model Definition of a ship than any other non graphical attribute.

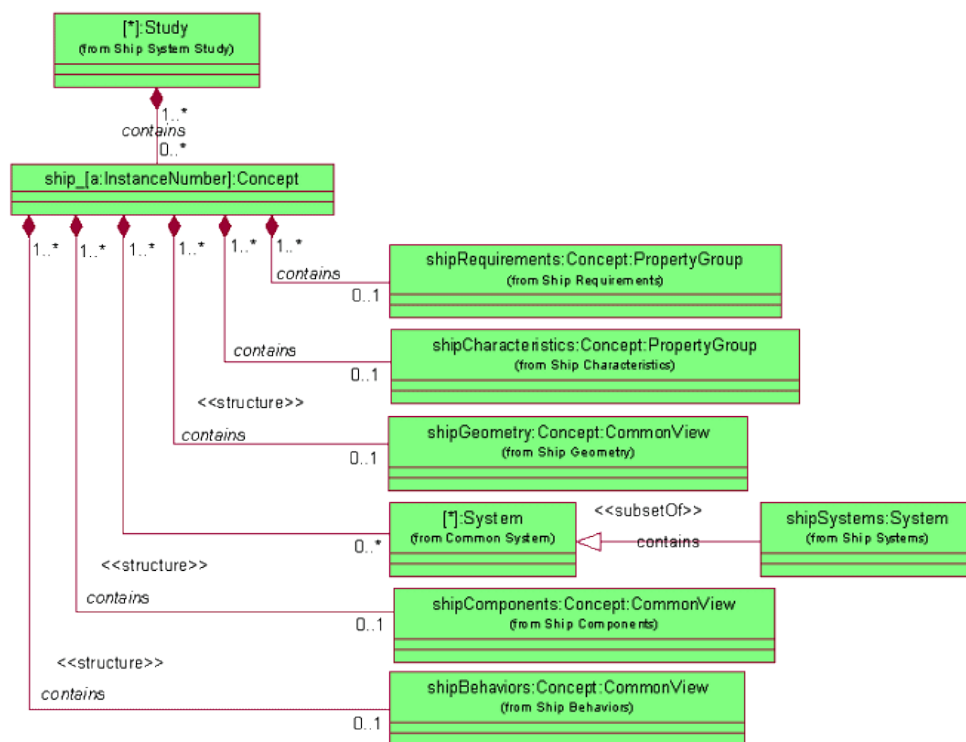
Requirements are a property group that capture information that can be obtained from an AoA, ICD, and other high level program document.

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.

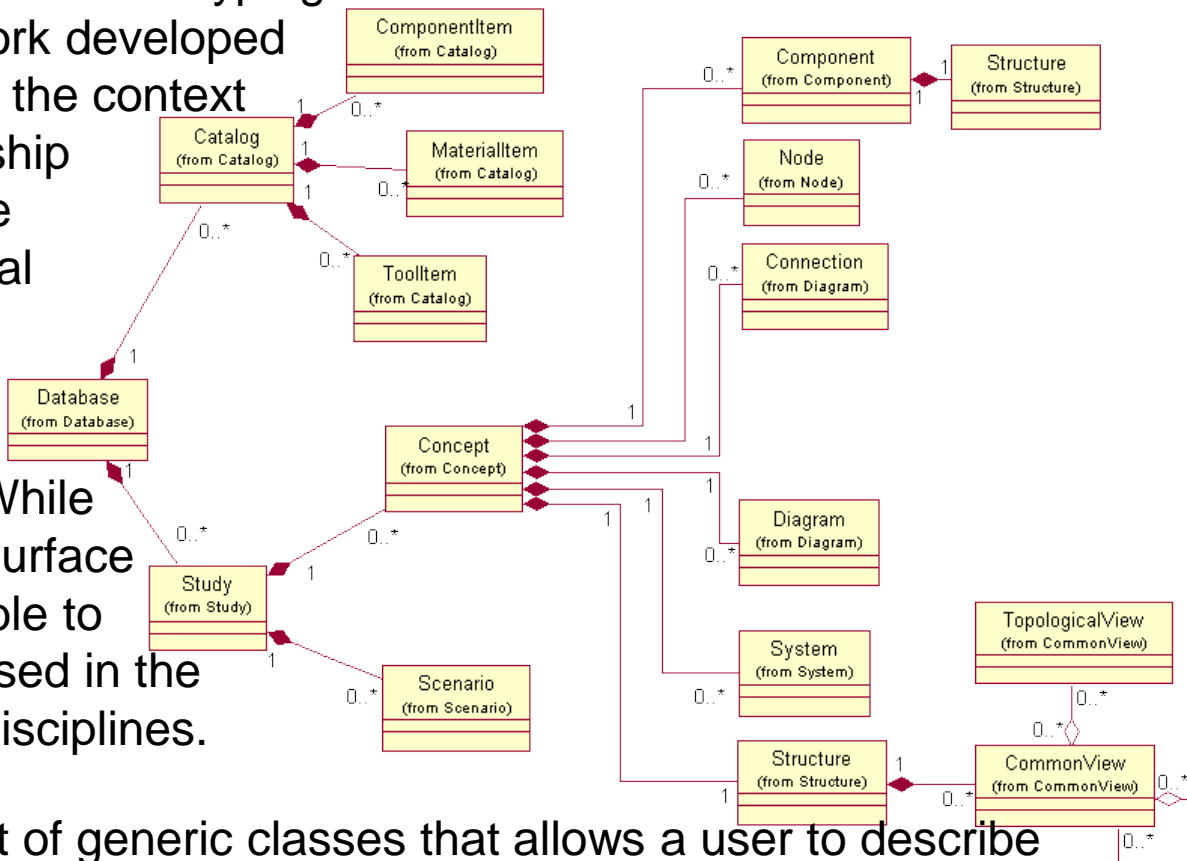




What is LEAPS?

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.



CREATE-SHIPS Interactions with Other CREATE Projects



- **RF Antennas: CREATE-RF**
- **Air Vehicles: CREATE-AV**
- **Mesh/Geometry: CREATE-MG**



Interactions with CREATE-RF

Our Topside Real Estate Reality

Part No.	UIC	UIC	Location
1	000000	000000	000000
2	000000	000000	000000
3	000000	000000	000000
4	000000	000000	000000
5	000000	000000	000000
6	000000	000000	000000
7	000000	000000	000000
8	000000	000000	000000
9	000000	000000	000000
10	000000	000000	000000
11	000000	000000	000000
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99	000000	000000	000000
100	000000	000000	000000

MAST VIEW LOOKING AFT TRDF DDG 51-76

KEY PLAN

SEC-6105B-410

PORT BOW VIEW

KEY PLAN

SEC-6105B-410

MAST VIEW LOOKING AFT NON-TRDF DDG 51-76

KEY PLAN

SEC-6105B-410

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

