

**ASRR Conference:
Engineered Resilient Systems Panel**

**Ensuring Engineered Resilient
Total-Ship Systems:
Using More Physics-Based
Design Tools in Early Concept Design**

Bob Keane, Ship Design USA, Inc.

5 October 2011

Opinions are those of the author and not those of any Government agency or program.

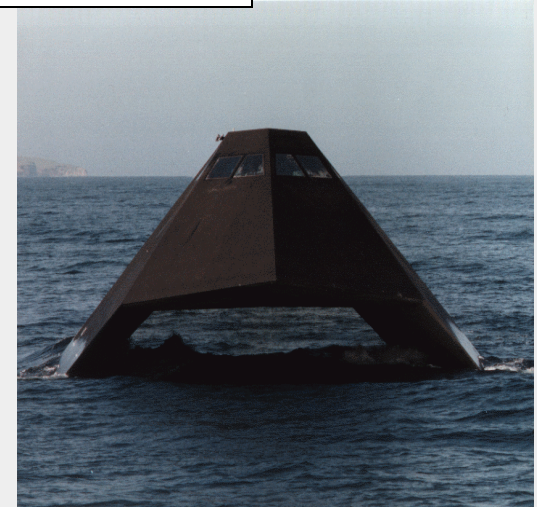
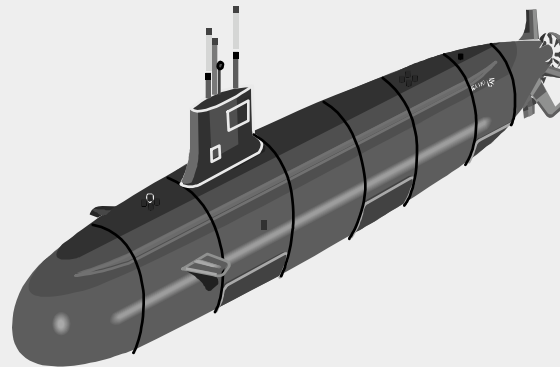
Inseparable Resilience Issues

Dr. Robert Neches, OASD(R&E), 31 March 2011

- **Rapidly Adapting to User Needs**
 - **Warfighter / Engineer Information Exchange**
- **Accelerated Needs Exploration: Conceptual Design**
 - **Co-Evolution of ConOps & Systems for Multiple Alternative Futures**
- **Accelerated Design-to-Build: Capability Engineering**
- **Advances must be embedded in tools and environments accessible to Government and industry – Systems 2020**



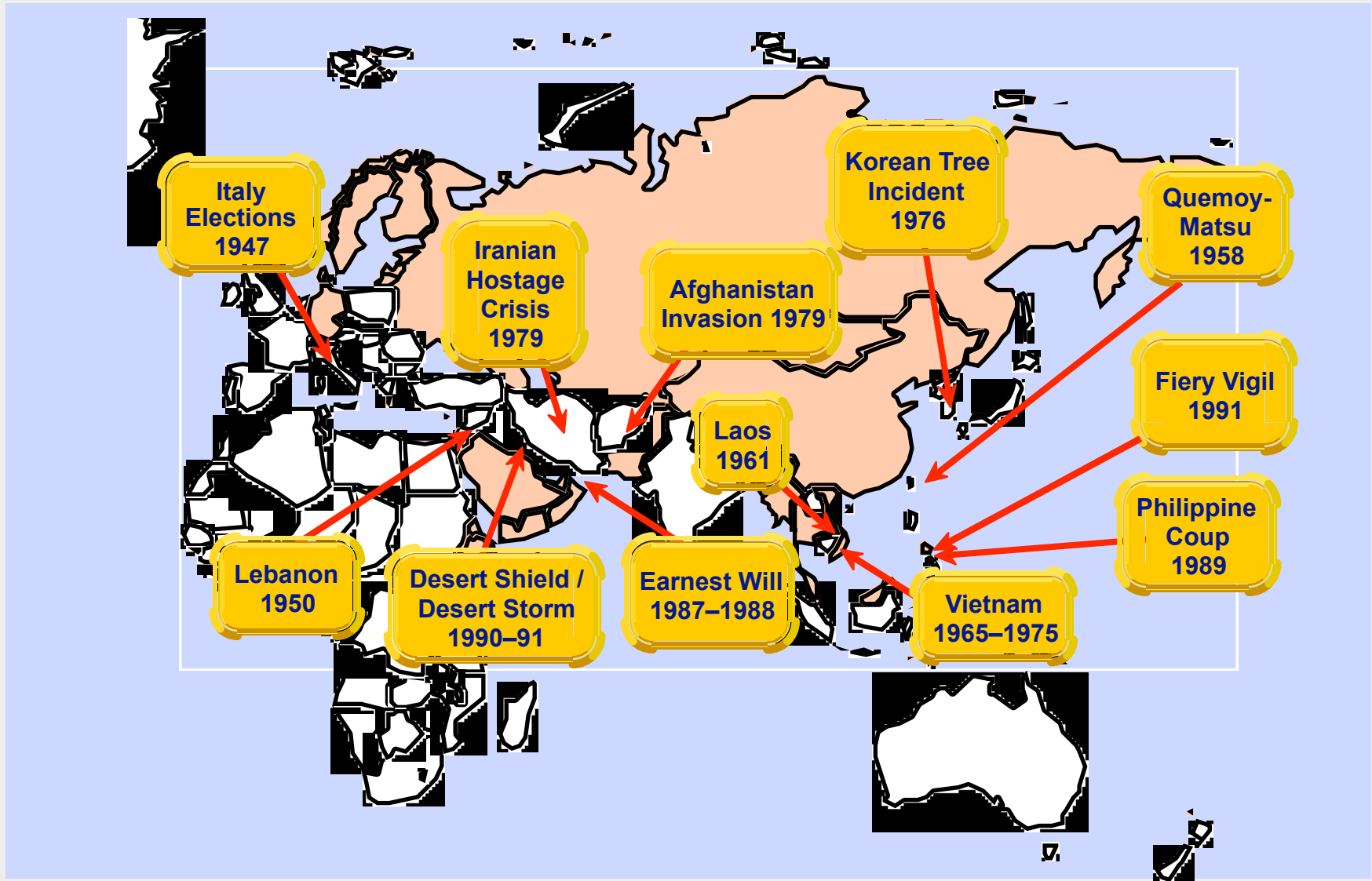
Nature of the Product-A Warship



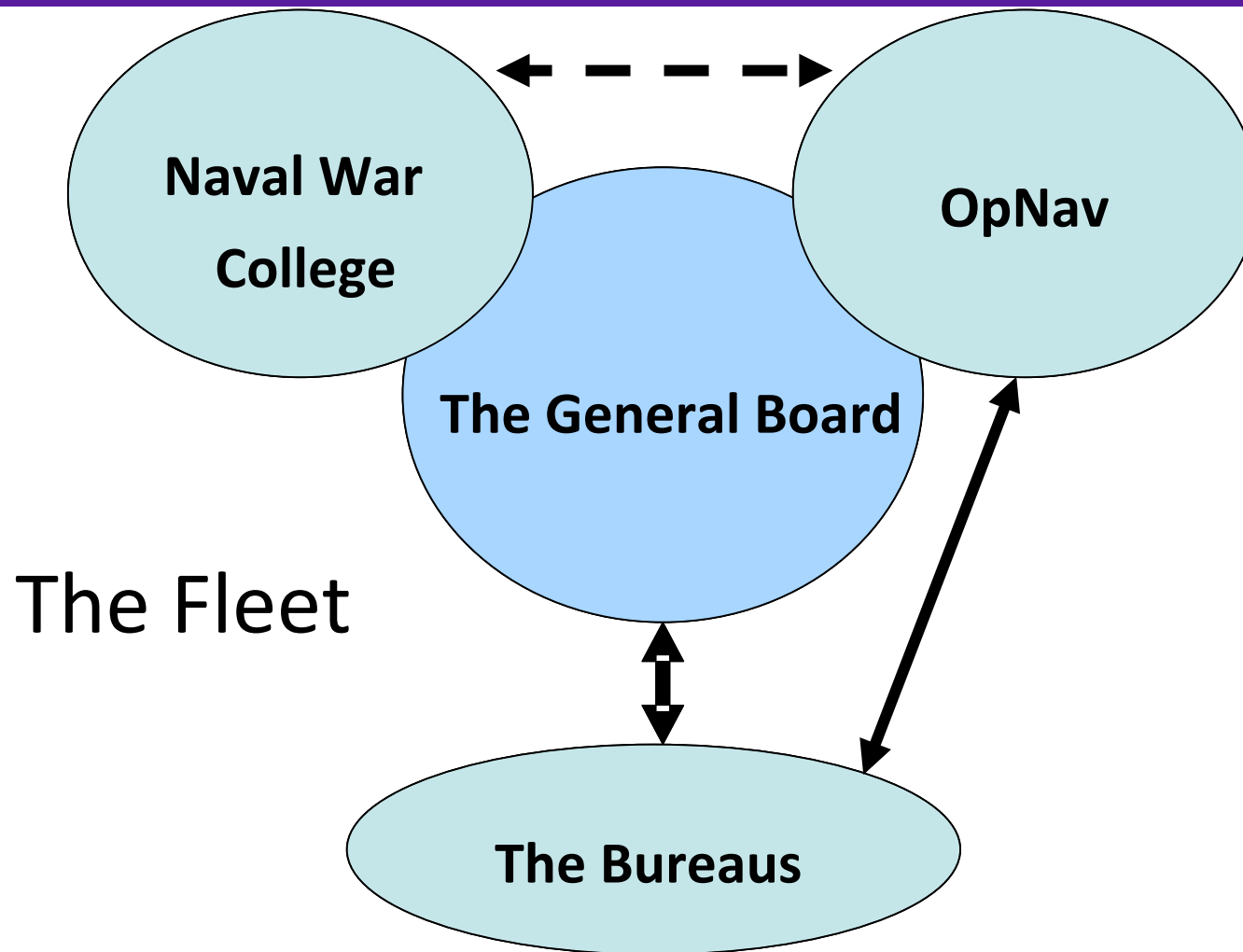
- A “system of systems”: Operate in battle force with older and newer ships
- Very low quantities, high unit cost, long lives
- Extremely complex product: millions of piece parts
- No prototypes, first ship(s) must be fully operational
- Government develops combat/weapons/communications systems
- Government ultimately assumes responsibility for meeting requirements
- Lack of commercial shipbuilding industrial base to build upon
- Intense Congressional oversight



USS MIDWAY 50-Year Global Crisis Response



Collaborative Innovation in Fleet Design, 1922-1941

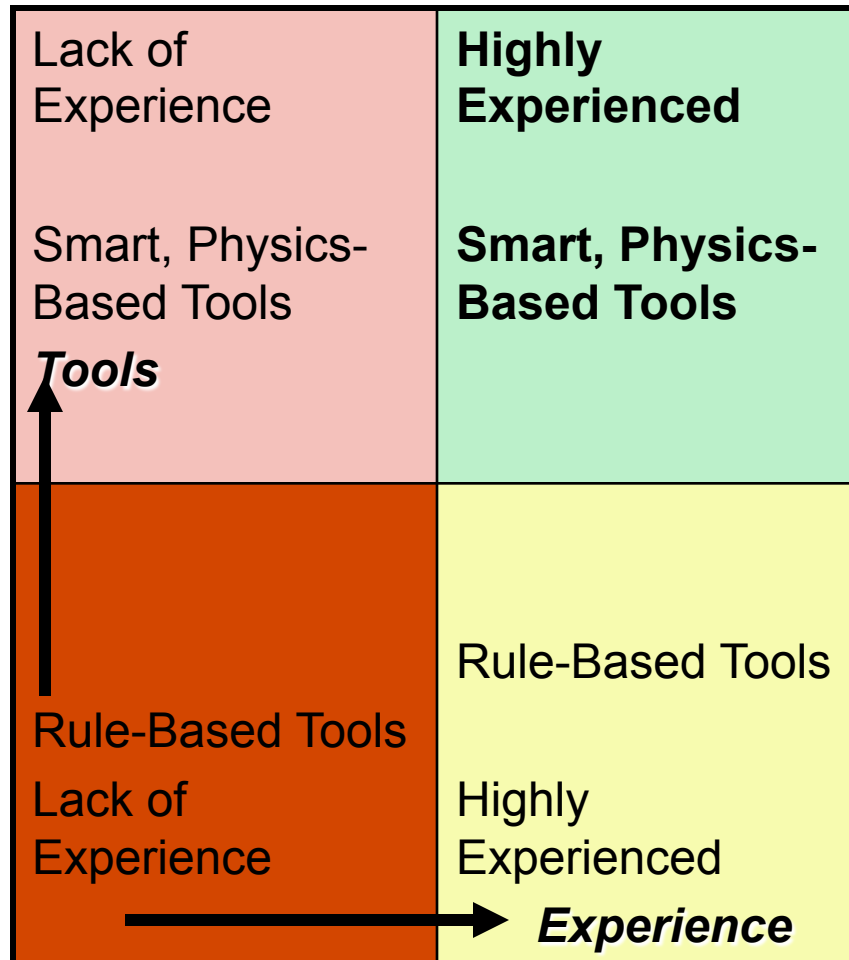


Agents of Innovation: The General Board and the Design of the Fleet That Defeated the Japanese Navy, John T. Kuehn, Naval Institute Press, 2008

MIT'S VON HIPPEL: INNOVATION, LEAD USER ANALYSIS, CUTTING CONCEPT TIME & COST

- **“...sometimes it's a waste of time and resources to try to understand customer needs...**
- **sometimes it's less expensive and more efficient to**
 - **let your customers define the needs,**
 - **limit yourself to offering solutions, and**
 - **let the customers design based on that.”**

Experience and the Right Tools Make A BIG Difference



- **1980s Reagan Buildup: Average Cost Growth for Lead Ship was 10%****
 - NAVSEA Highly Experienced Ship Design Workforce
 - User-Driven Design
- **1990/2000s Acquisition Reform: Average Cost Growth for Lead Ship was 50%****
 - Inexperienced Industry Design Teams
 - Mfr.-Driven Design

** SEA 05C, June 2008

Seaway Loads for Design of Surface Combatants: Rule-Based Design

- Structural Design of FFG 7, CG 47, DDG 51 Classes
 - Interested more in extreme loading conditions than actual loads which contribute to fatigue
 - Worked with simplified loading envelopes
 - Deterministic analysis resulted in scantlings for maximum load expected
 - Highly random wave-induced loads were set of simplified hydrostatic loads under extreme seas

No Physics-Based Computations nor Seakeeping Model Tests to Determine Actual Seaway Loads

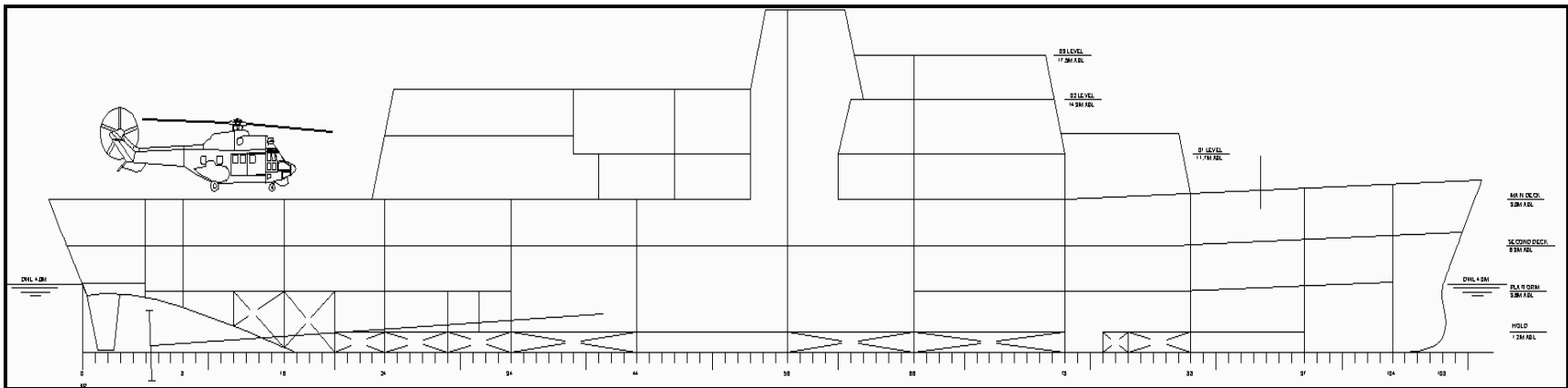
Lack of Physics-Based Design Tools: Increased Ownership Costs

- FFG 7 Class
 - Hull girder doubler plates & ballast added
 - Extensive deckhouse fatigue cracking
- CG 52 Class (with VLS)
 - Serious hull cracking and buckling problem
 - Extensive superstructure fatigue cracking
- DDG 51 Class
 - Bow structure buckling and cracking issue
- **Operational loads exceeded rule-based design loads**

\$100M' s in repairs for sustaining service-lives

***“Outside-In Design”* – Start with Hull Form, Then Cram Everything into Hull**

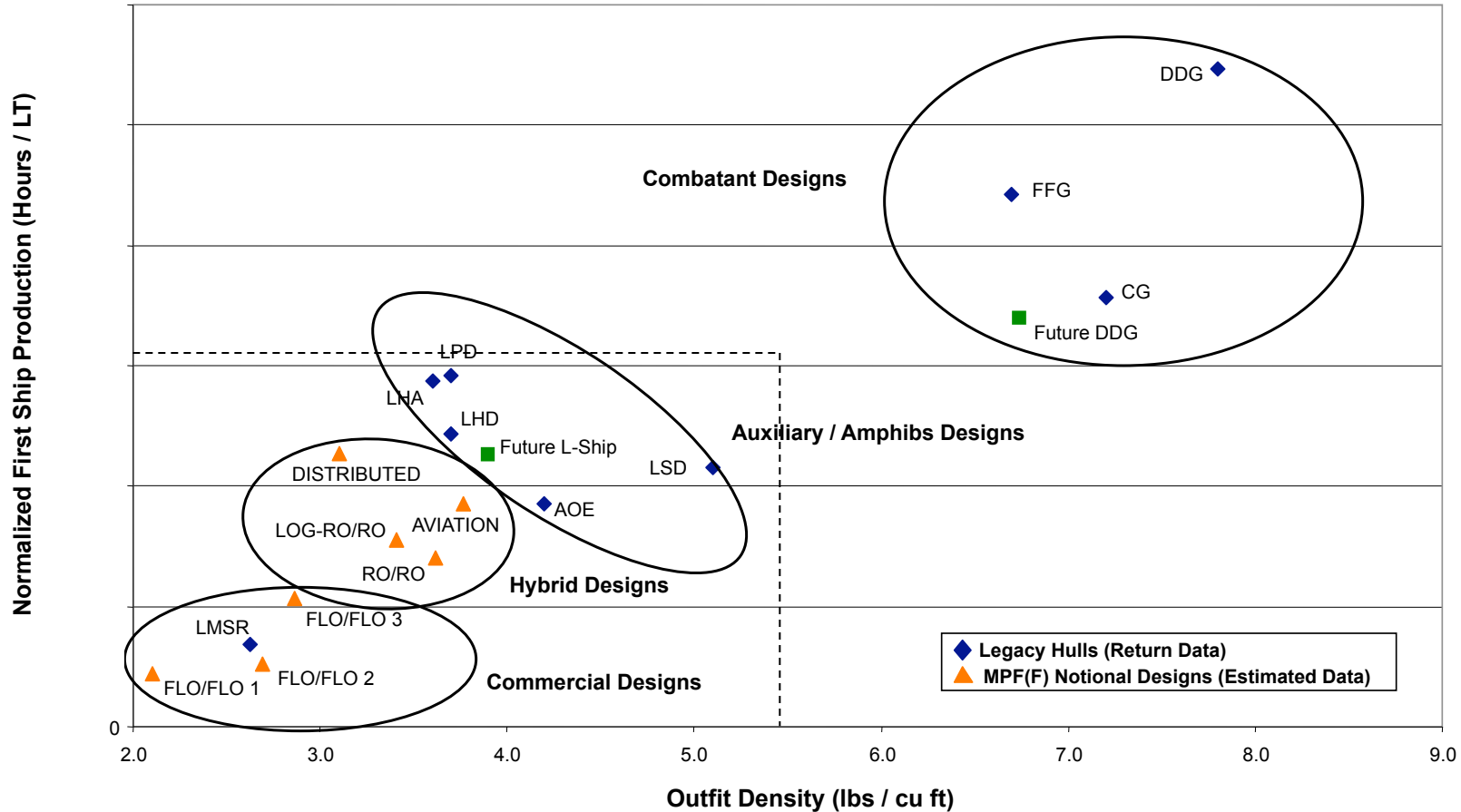
- Hull is sized and shaped in early design based on:
 - unreliable weight and area/volume estimates



- invalid assumption volume is “arrangeable”
- fallacy that limiting hull size limits ship costs

Need architectural tools to optimize arrangements

Ships Possessing Greater Density Increase Production Cost



Ship Production hours increase with density and fall into predictable groupings.

WHERE WE NEED TO GO



- According to an old proverb, if we do not change our direction, we might end up where we are headed.

Systems Engineering – Ensure “Elegant” Designs*

- **Effective** – it does what it is supposed to do
- **Efficient** – to produce, operate, maintain
- **Robust** - insensitive to variations in operations
- **Minimal Unintended Consequences** – few band aids required to fix it in-service

*M. Griffin, Former NASA Director, Dean’s Seminar, SIT,
“How do we fix System Engineering?”, 13 Dec 2010

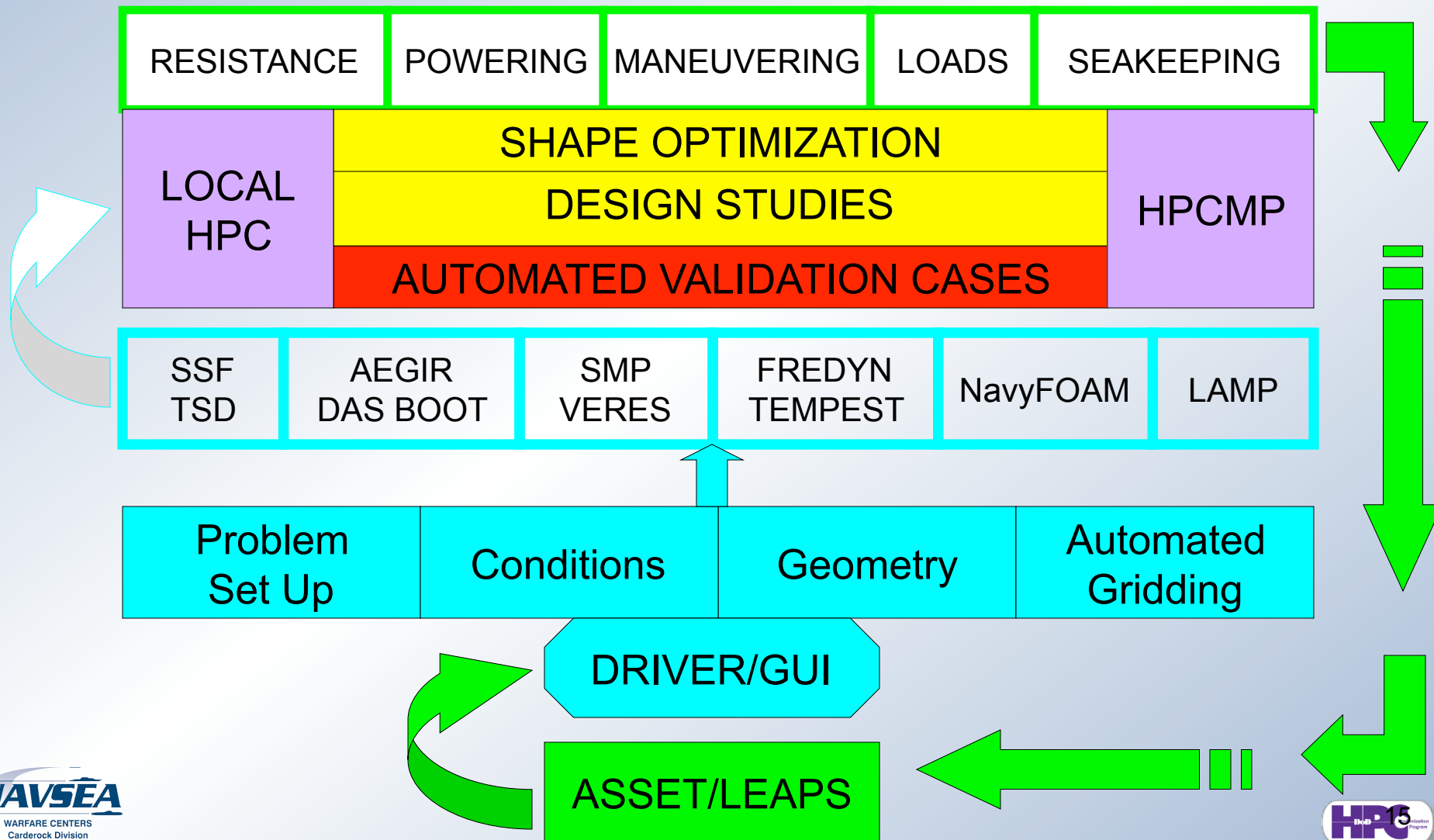
Toward Robust Systems Engineering: CREATE-SHIPS Project

- **Computational Research & Engineering for Acquisition Tools & Environments (CREATE):**
 - **Replace empirical design with validated physics-based computational design**
 - **Detect and fix design flaws early in design process**
 - **Develop optimized designs for new concepts**
 - **Begin system integration earlier in acquisition process**
 - **Increase acquisition program flexibility and agility to respond to rapidly changing requirements**

DoD High Performance Computing Modernization Program

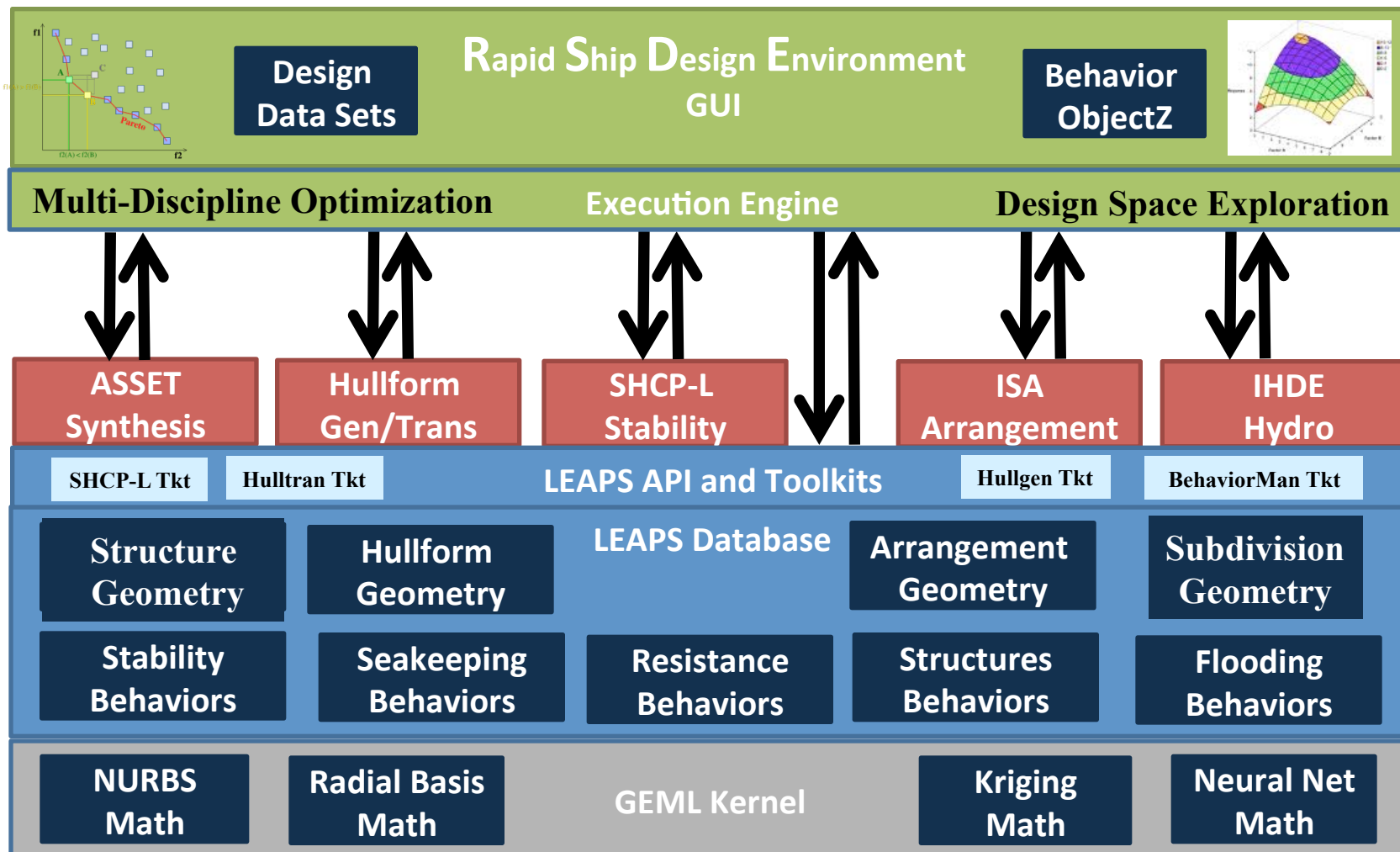
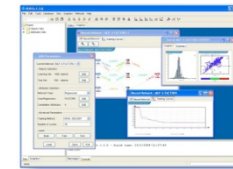


Integrated Hydrodynamics Design Environment - IHDE





Rapid Ship Design Environment (RSDE) Architecture



Modeling Warships in the Ocean Battle Space: Way Ahead



- Need to start co-evolution of ConOps & systems for multiple alternative futures long before Milestone A
 - Continuing process not tied to specific acquisitions
- Need engineers to have unfettered access to warfighters
 - Accelerated exploration during concept formulation
 - Collaborative process exploring new/radical innovations
- Need more physics-based tools for concept design with
 - Timely pre-processing of system geometry
 - Timely post-processing of results into decision aids
- Need to reconstitute DoD S&T infrastructure
 - DoD Labs resume their advanced development role



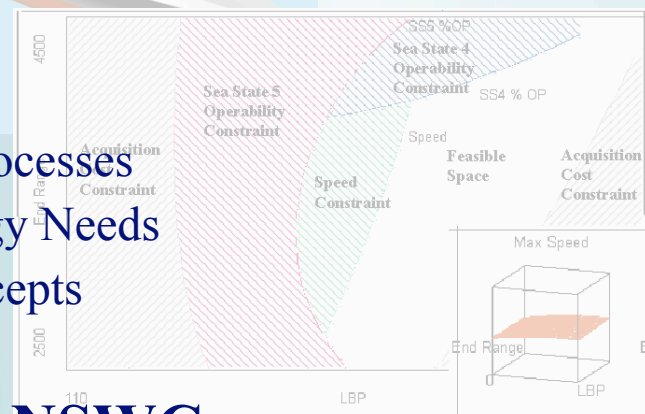
Center of Innovation in Ship Design is:

The hub of a national collaborative enterprise combining the best ideas and experience of government, industry, and academia in ship design

CISD Mission: Ensure the Future Capability (People, Tools and Knowledge) of the Nation to Develop Innovative Ship Designs to Effectively Meet Defense Needs

Focus Areas: Navy of the Future

- Develop Future Ship Designers
- Knowledge Base / Design Tools & Processes
- Future Ship & Ship Design Technology Needs
- Develop Innovative Ship Design Concepts



Chartered by ONR, NAVSEA 05 & NSWC