NDIA Conference: “Physics-based Modeling in Design & Development for U.S. Defense”

Physics-based Modeling in Ship Design: Where are we headed?

Bob Keane

6 November 2012

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

DOD HPC MODERNIZATION PROGRAM

AT THE CROSS ROADS:

- WHERE WE ARE TODAY
- HOW WE GOT HERE

SHIP DESIGN

SYSTEMS ENGINEERING

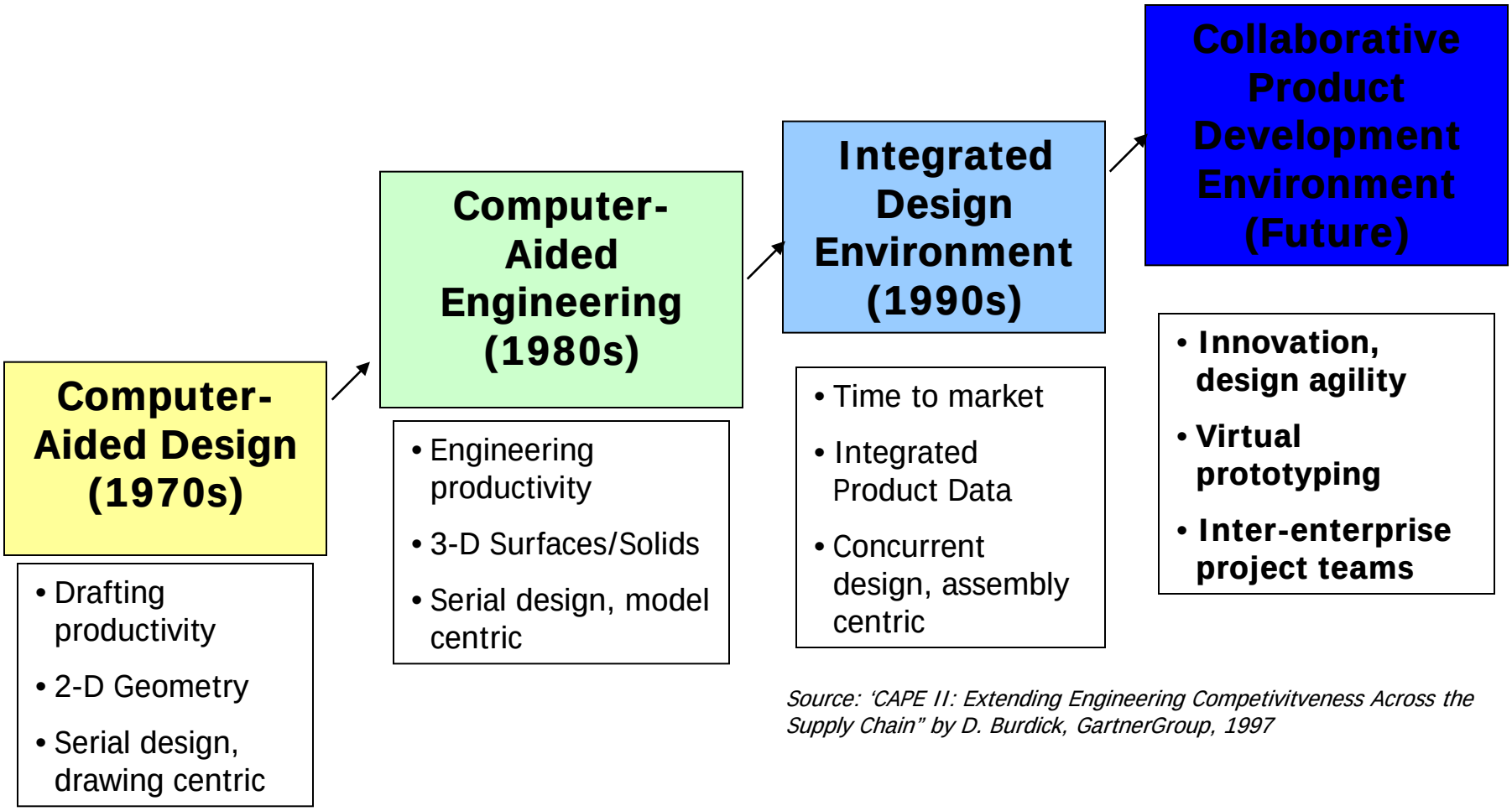
- WHERE WE NEED TO GO
- INITIATIVES TO GET THERE

WHERE WE ARE TODAY: Naval Ships Cost Too Much!

- Early “framing assumptions” put acquisition programs on an initial path for success or failure. (DoD AT&L, 2012)
- Common incorrect “framing assumption” made by failed programs was “design is mature”.
- Consequences of incorrectly assuming “design is mature”
  - Production and development can be concurrent
  - Weight is known and will not increase as usual
  - Design can be refined for affordability - will reduce production cost
- “Starting construction without a stable design...leads to costly out-of-sequence work and rework...” (GAO 2009)

“It ain't what you don't know that gets you into trouble. It's what you know for sure that just ain't so.” Mark Twain

HOW WE GOT HERE: Capability Development



Source: 'CAPE II: Extending Engineering Competivitveness Across the Supply Chain" by D. Burdick, GartnerGroup, 1997

HOW WE GOT HERE: Over 50 Years of Warship Design and Acquisition

DOD HPC MODERNIZATION PROGRAM

1990's
"Acquisition Reform"
DOD Oversight/AOA
Concurrent Engineering

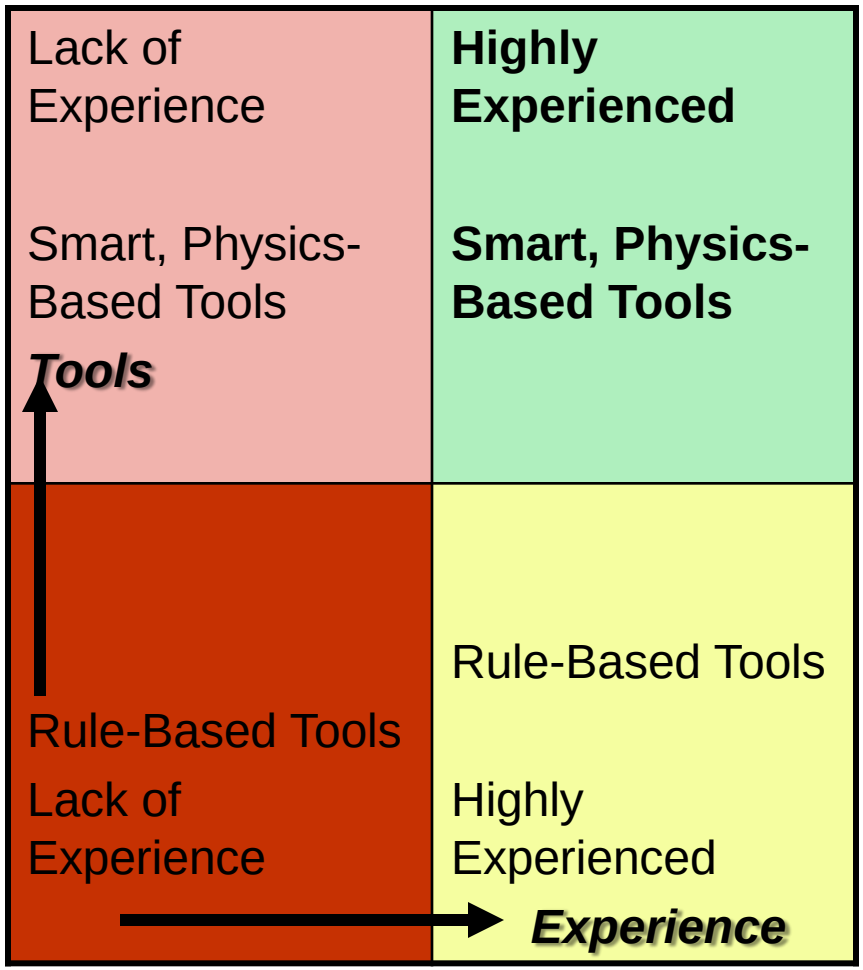
1980's
"Acquisition Streamlining"
Computer Aided Design
Collocated Design Teams

1970's
"Design to Cost"
NAVSEA Design Management
Navy Tech Codes/Design Agents

1960's
"Total Package Procurement"
Systems Analysis
"ilities"

1950's
NAVSEA In-House Design
Preliminary Design
Contract Design

Experience and the Right Tools Make A BIG Difference



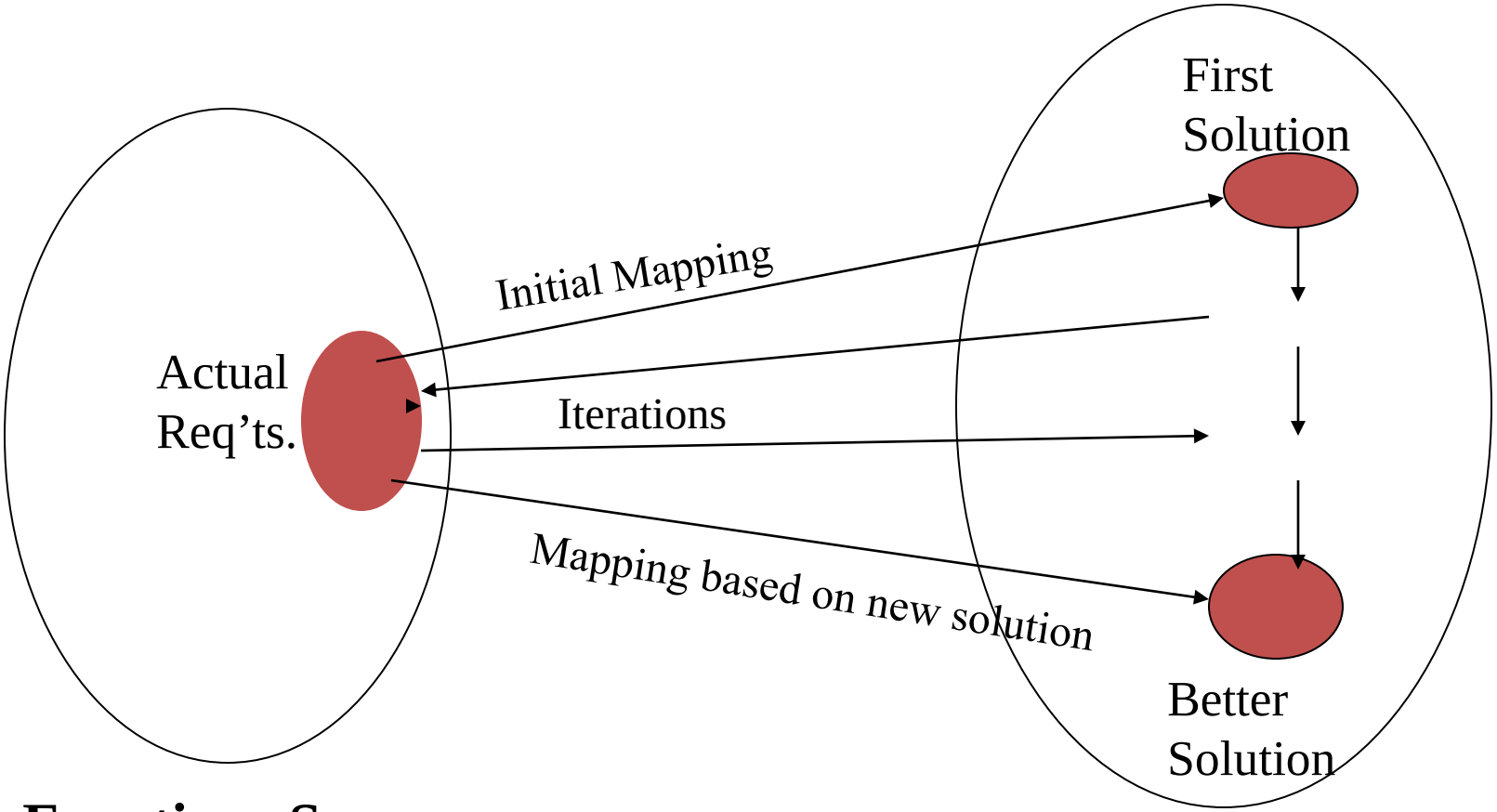
- **1980s Reagan Buildup: Average Cost Growth for Lead Ship was 10%****
  - NAVSEA Highly Experienced Ship Design Workforce
  - User-Driven Design
- **1990/2000s Acquisition Reform: Average Cost Growth for Lead Ship was 50%****
  - Inexperienced Industry Design Teams
  - Manufacturer Driven Design

** SEA 05C, June 2008

WHERE WE NEED TO GO?

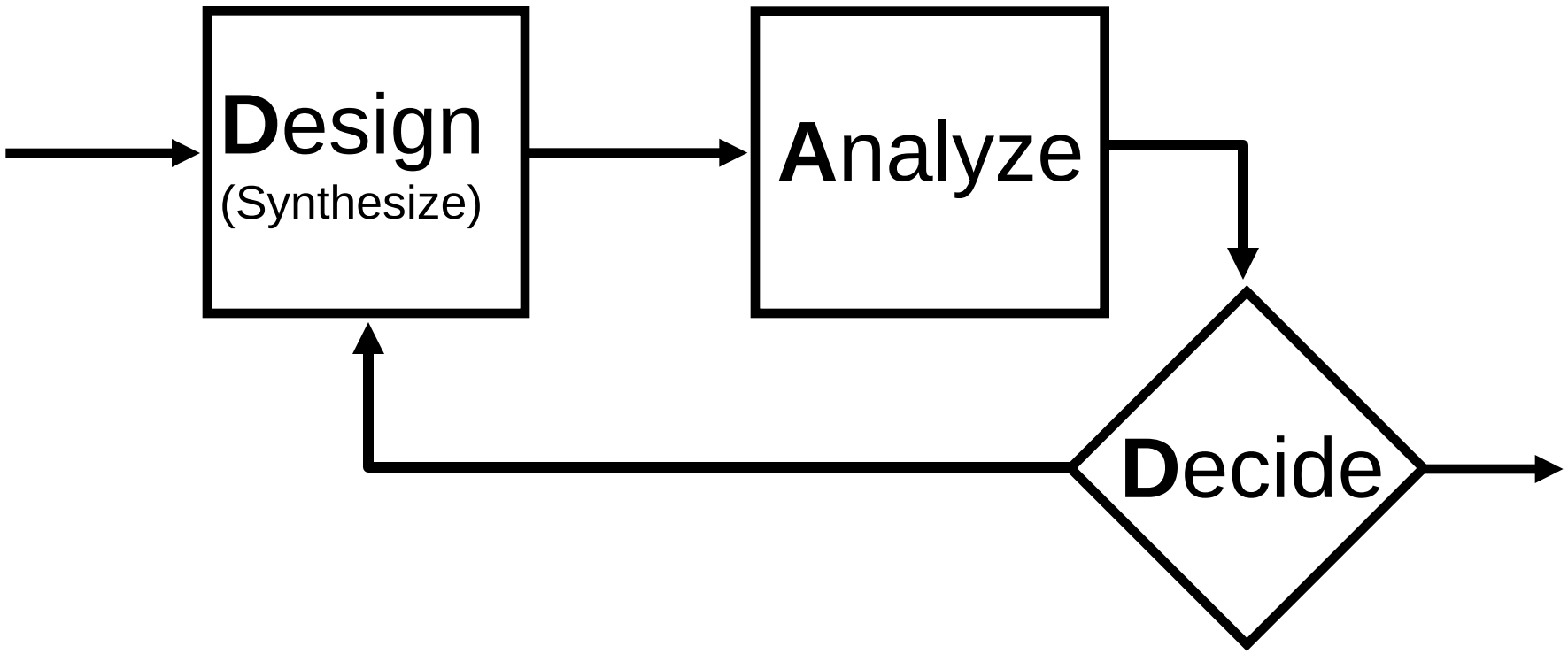
- **According to an old proverb, if we do not change our direction, we might end up where we are headed.**

Design: Mapping Requirements to Solutions



(From reference 1)

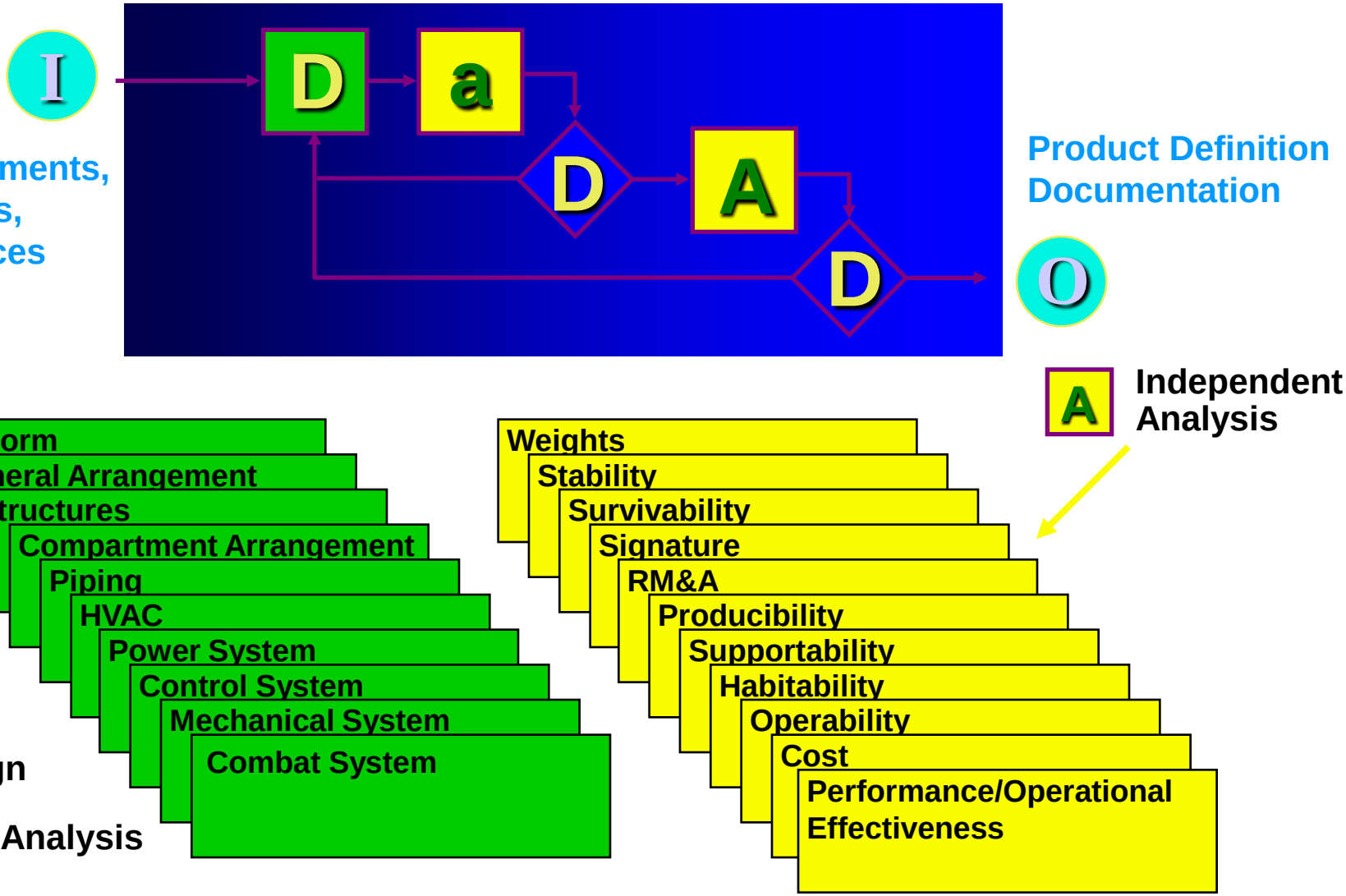
Fundamental Design Process



Synthesis-Aspect of Design that attracts Naval Architect

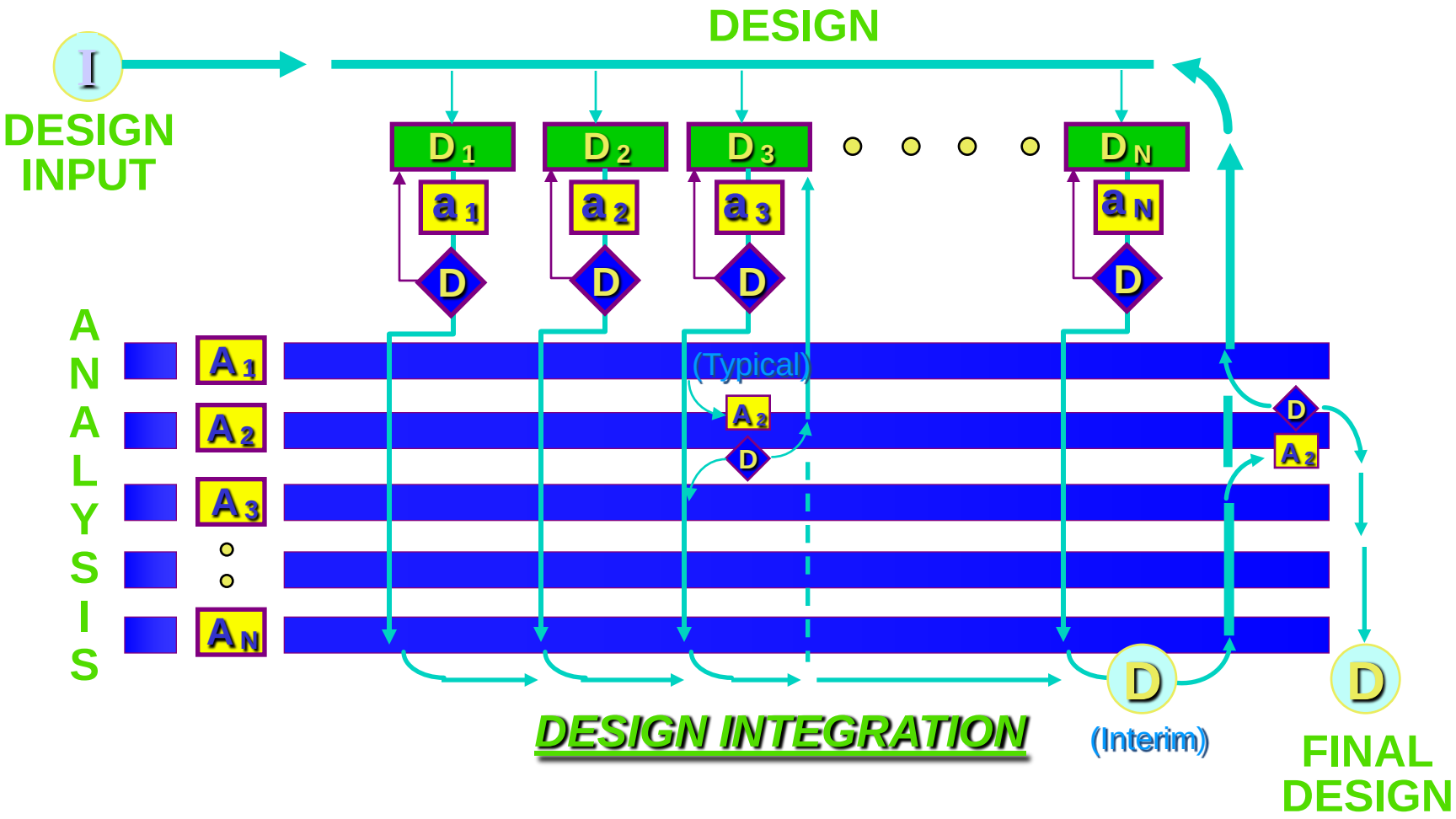
- **The real innovative nature of design is "synthesis"**
  - Create something new
  - Put things together into something new
  - New architecture at the total system level, e.g. hull form
- **Another important element of design is "analysis"**
  - A lot of analysis in ship design
  - Break the total down into analyzable parts
- **Must decide what you want in the alternatives to be created and analyzed, depending on stages of design**

Designing a Complex System – A Warship



(From reference 2)

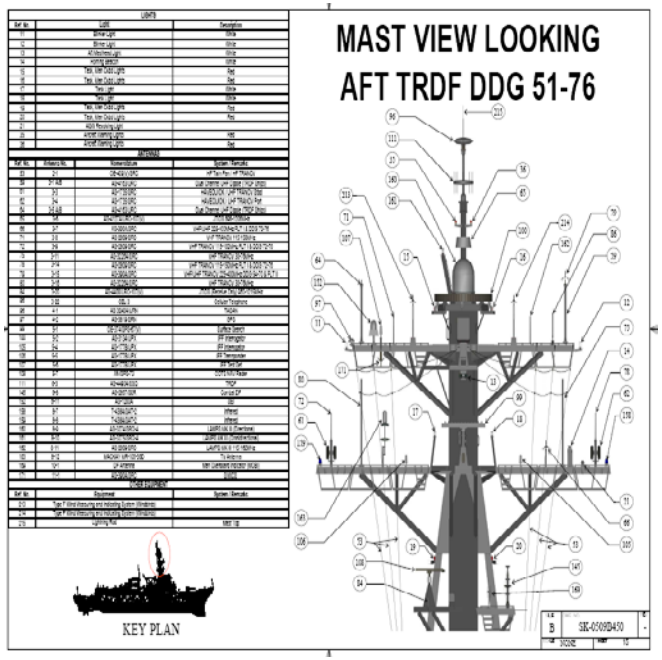
Designing a Complex System: Design Integration

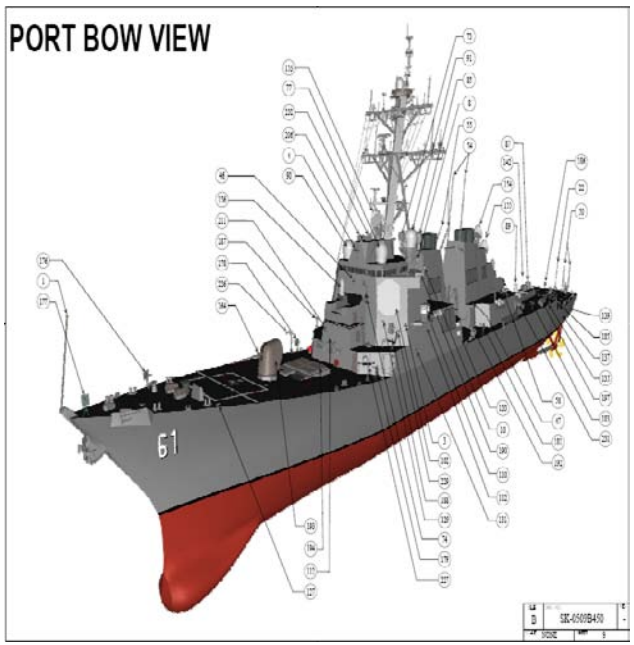


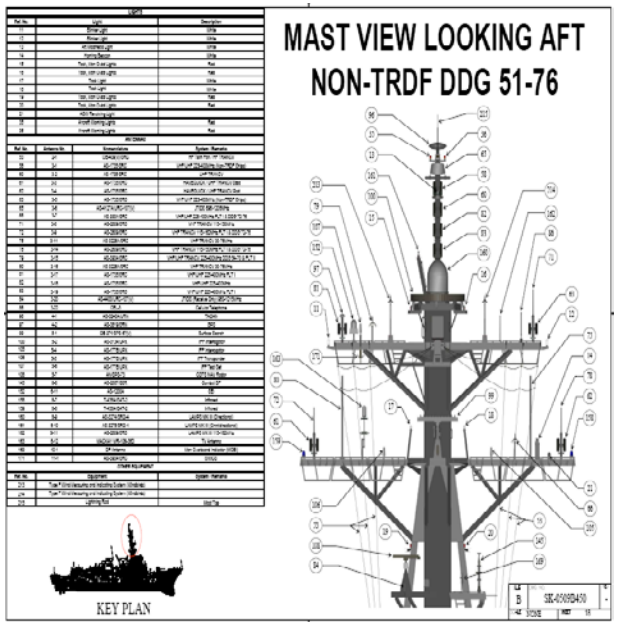
(From reference 2)

RF Integration Challenges

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.

AV Integration Challenges

- **Dynamic Interfaces between ship and aircraft**

Integrated Topside Design & Analyses

- Needed superstructure size
- Radar/array configurations & placements
- Stack Height, ship air wake
- Kingposts, cranes, boats, guns, launchers
- Mast height, size
- Intact/Damage Stability
- Aviation-Ship Dynamic Interfaces
- EMC/EMI/RADHAZ
- Deck wetness
- Hull Flexure – Array Alignment

INITIATIVES TO GET US THERE

- **Computational Research & Engineering for Acquisition Tools & Environments (CREATE) – Ships Project**
  - Replace empirical design with validated physics-based computational design
  - Begin system integration earlier in acquisition process
- **ONR's National Naval Responsibility for Naval Engineering (NNRNE)**
  - Collaboration of naval engineering universities
  - "High interest" in ship design technologies
- **Navy's Center for Innovation in Ship Design (CISD)**
  - Sustain Nation's warship design capabilities
  - Focus on learning-by-doing design

NAVSEA
NAVAL SEA SYSTEMS COMMAND
Carderock Division

The Virtual Ship Life Cycle

DOD HPC MODERNIZATION PROGRAM

OPERATION

ACQUISITION

OPERATIONAL & LOGISTICAL SIMULATIONS

LESSONS LEARNED

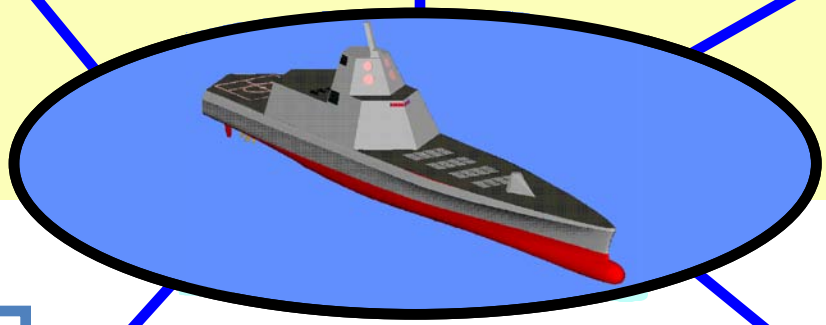
DEPLOYABLE SYSTEM

WARFARE ANALYSES / AOA

TRAINING SIMULATIONS

REQUIREMENTS

OPERATIONAL SYSTEM



THE PRODUCT-MODEL BASED VIRTUAL WEAPONS SYSTEM

SIM-BASED DESIGN SHIP ENGINEERING

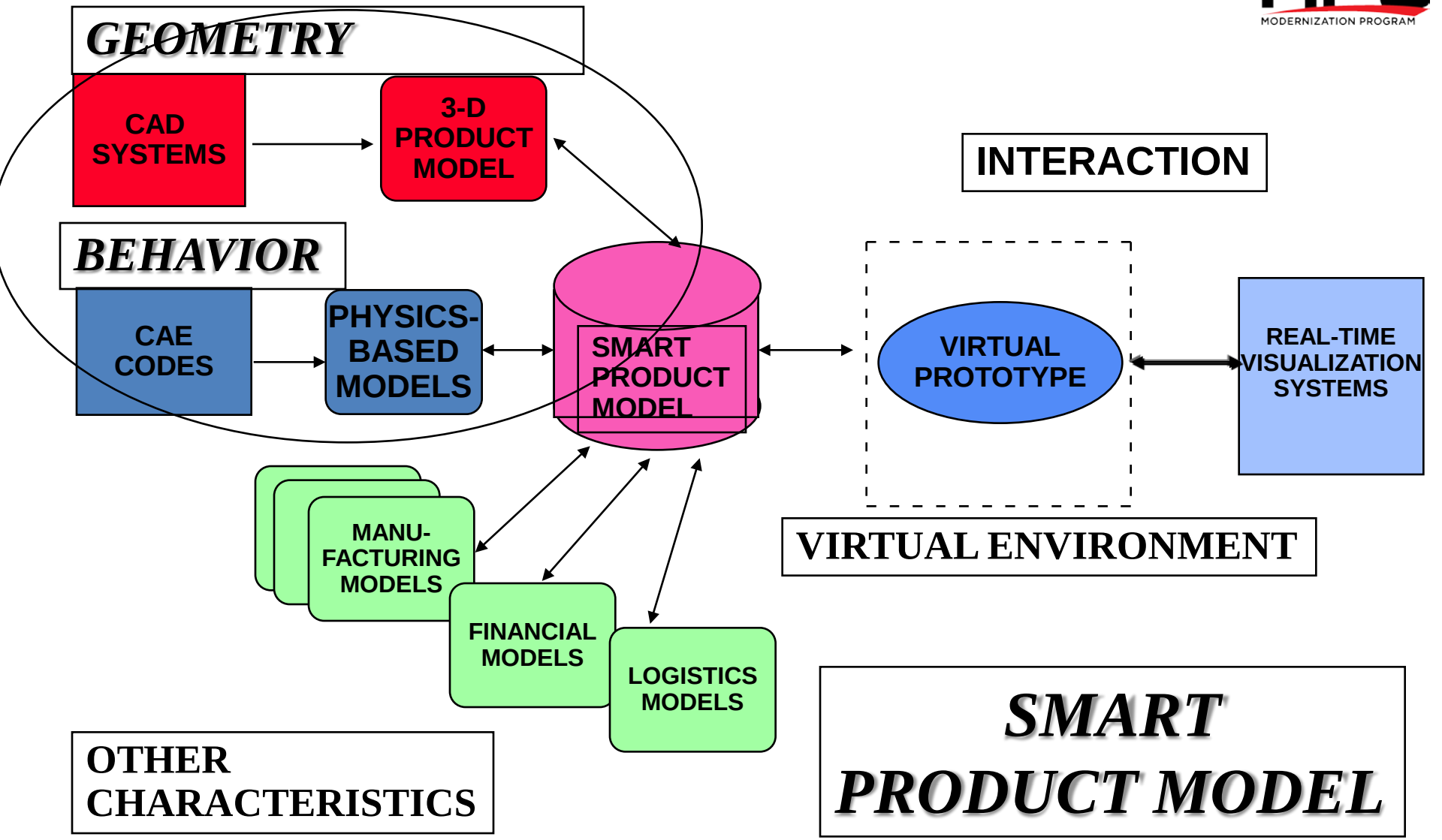
VIRTUAL TESTING

PRODUCT DEFINITION

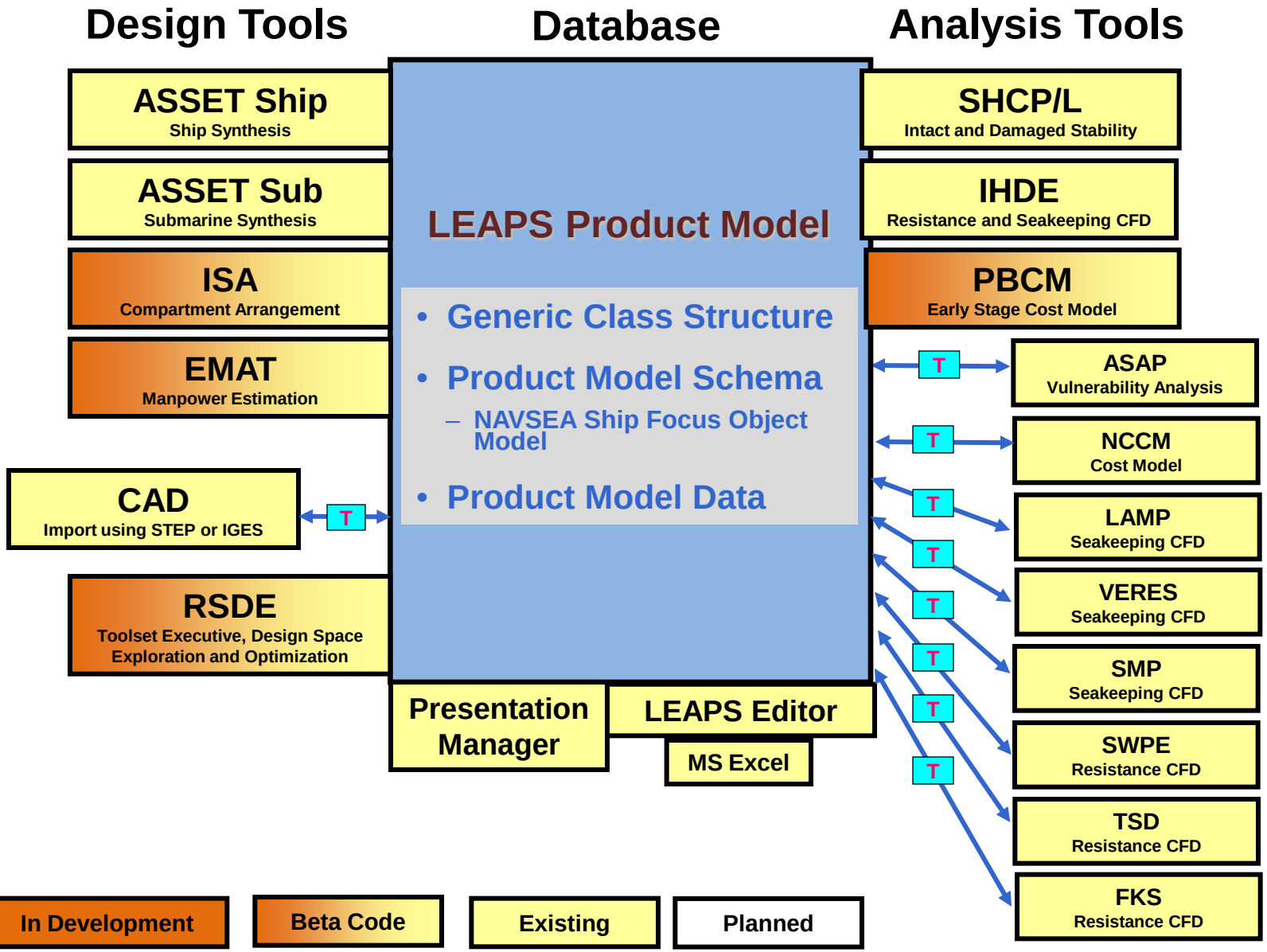
VIRTUAL MANUFACTURING

WEAPONS SYSTEM

VISION: CONCEIVE, DESIGN, BUILD, TEST, TRAIN, AND OPERATE A WEAPONS SYSTEM IN A COMPUTER BEFORE CUTTING METAL


GEOMETRY
CAD SYSTEMS
3-D PRODUCT MODEL
BEHAVIOR
CAE CODES
PHYSICS-BASED MODELS
SMART PRODUCT MODEL
INTERACTION
VIRTUAL PROTOTYPE
REAL-TIME VISUALIZATION SYSTEMS
VIRTUAL ENVIRONMENT
MANU-FACTURING MODELS
FINANCIAL MODELS
LOGISTICS MODELS
OTHER CHARACTERISTICS
SMART PRODUCT MODEL

Leading Edge Architecture for Prototyping Systems (LEAPS) Toolset



Integrated Tools: “We Shape Our Tools And Our Tools Shape Us”

- Accelerate use of physics-based models by design engineers in early design
- Achieve an Integrated Design Environment (IDE) for early stage design
- Implement a design analysis product model - LEAPS (Leading Edge Architecture for Prototyping Systems)
- Integrate Design, Production and Support
- Capitalize on 3-D Product Model Technology

Structure IDE to Design-Build Process

Lean Design Processes

- Understand Variability (or Risk)
- Excess Capacity to Manage Design Queues
- Reduce Batch Size
- Use Cadence and Synchronization
- Accelerate Feedback
- Use More Frequent Informal Reviews
- Decentralize Flow Control

More Iterations, Reductions in Cycle Time

Enterprise-Wide Communications

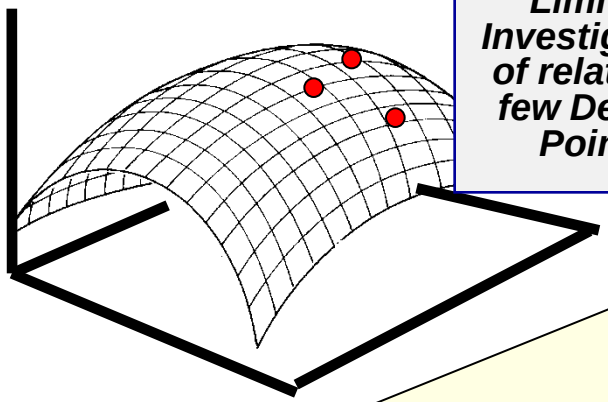
- Usable information to make good decisions
- Reduce the need for communications:
  - well-partitioned architecture,
  - fewer interfaces in ship architecture,
  - more standard and stable interfaces
  - well-defined responsibilities on design team,
  - having dedicated team members,
  - virtual collocation comparable to physical collocation

Requires architectural design analysis tools

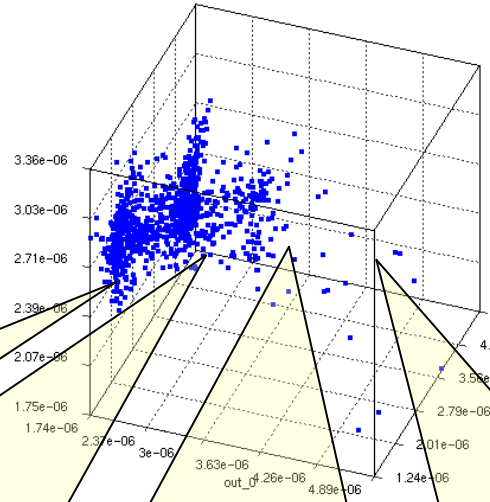
CREATE-Ships Objectives for Rapid Design and Integration (RDI)

- 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

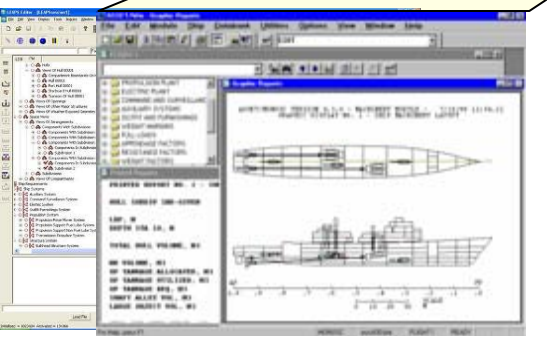


From…
Limited Investigation of relatively few Design Points

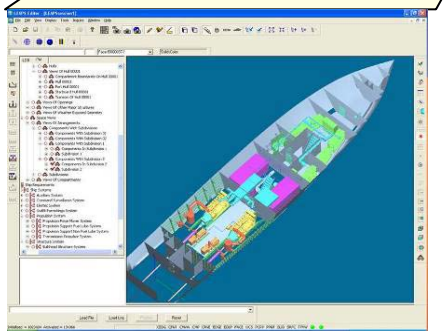


To…
Full Investigation of Concepts throughout the Design Space

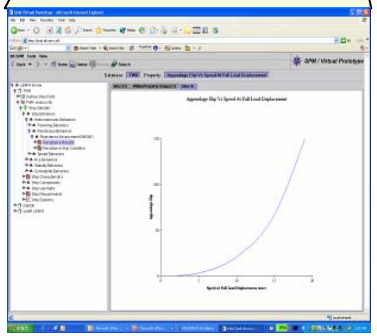
HPC Enables Exhaustive Exploration by:



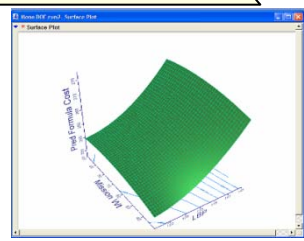
Generating
The Space



Exploring
The Space



Evaluating
The Space



*and **Visualization***

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