DESIGNING OUT COMPLEXITY EARLY:

A PATH TO AFFORDABLE FLEXIBLE WARSHIPS

Presented by:

Glen R. Grogan, P.E.

Lead System Engineer, DDG 1000 Program, PEO Ships

Timothy S. Mierzwicki

Technical Warrant Holder for Surface Ship Concepts, Naval Sea Systems Command

Co-Authored by:

Robert G. Keane, Jr.

President, Ship Design USA, Inc.

The views expressed herein are those of the authors only and may not represent those of any DoD organization or program.
Statement A: Approved for Release. Distribution is unlimited.

Flexible Warship Initiative (FWI)

Long-term collaboration between Navy-Industry-Societies

- Navy's Program Executive Office (PEO) Ships
- Global Shipbuilding Executives Summit (GSES)
  - GSES I - VI
- America Society of Naval Engineers (ASNE)
    - ASNE Day 2010 - 2015
- Society of Naval Architects and Marine Engineers (SNAME)
  - Ship Design Committee (SDC)
  - Naval Ships SD-8 Panel
- Navy's Center for Innovation in Ship Design (CISD)

Team A established at GSES VI, ASNE Day 2015

Three Tasks Assigned to Team A

- Identify first order Principles for Design of Flexible Warships
  - analysis of foreign naval ships
  - experience of former US shipyard executive
- Assess design tool needs for Design Space Exploration (DSE) of Flexible Warships
  - software development work of DoD High Performance Computing Modernization Program (HPCMP) Computational Research & Engineering Acquisition Tools & Environments (CREATE) – Ships Project
- Propose an approach for addressing distributed systems during DSE for Flexible Warships
  - SNAME SDC/SD-8 workshop to identify design tools and process improvements

Analysis of Foreign Flexible Warships: Danish Standard Flexibility (STANFLEX)

- Foundation on which to build future flexible warships:
  - business practices, requirements, and interfaces
- Danish Navy collaborated closely with shipyard in a public/private partnership
- Requirements stabilized early, faster & cheaper production
- Modules only half of a successful Flexible Warship
- Key is sizing ship infrastructure to support future upgrades
  - significant service-life allowances for power, cooling, structure, weigh, networks (cableways) and space
  - design margins begin with twice as much as usual

Danes Embraced Flexibility Culture by *Focusing on the Sea-Frame*

Foreign Flexible Warships: Damen SIGMA (Ship Integrated Geometrical Modularity Approach)

- Dutch SIGMA class based on the following major principles:
  - "Oversized" hulls reduce installation, operation & maintenance costs
  - Systematic structural layout of standard 24-ft compartments with common modular spaces for ops, habitability, facilities, & payload
  - Mix of military and commercial standards
- Damen concluded it is not ship size but complexity due to high compactness of systems that leads to extreme costs
- Cost of a hull larger than initially anticipated is easily recovered by cost effective installation of systems
- Longer, more slender hull reduces fuel consumption, offers space for cost-effective maintenance & modernizations

Flexibility more than pays for itself:
"STEEL IS CHEAP, AIR IS FREE!"

Principles for Design of Flexible Warships
P. Jaquith, former shipyard executive

- **Focus on Design Space Exploration (DSE)**
  - transform from focus on point designs & accepting first solution
- **Address Cost in Early DSE**
  - look at engrg, matls, and production together as all design driven
- **Reduce Work Scope & Variation in Basic Design**
  - world-class shipbuilders focus on early stage design
- **Introduce "Commonality" in Basic Design**
  - build designs on off-the-shelf equipt & production interim products
- **Define Systems & Arrangements in Basic Design**
  - utilize experienced engineers for defining principal systems & arrgts.
- **Analyze Alternative Arrangements in Basic Design**
  - achieve required performance with reduced work content & variation
- **Develop New Cost Estimating Methods & Metrics**
  - based on work content & alignment with std. production processes

Design Tool Needs for Design Space Exploration (DSE) of Flexible Warships

- Model "flexibility" in concept design for sizing ship
- Relate "flexibility" to Cost Estimating Relationships (CERs)
- Integrate these with Navy early stage ship design tools:
  - **Rapid Ship Design Environment – RSDE**: Ship Concept DSE & Optimization
  - **Advanced Ship & Sub Evaluation Tool – ASSET**: Ship Synthesis Model
  - **Leading Edge Architecture for Prototyping Systems – LEAPS**: Design Analysis Product Model
  - **Integrated Hydrodynamics Design Environment – IHDE**: Hull Form DSE & Optimization
  - **Integrated Structural Design Environment – ISDE:** Ship Structure DSE & Optimization

CREATE-Ships Products Critical to Flexible Warships

Elements of Ship Construction Costs for Flexible Warships

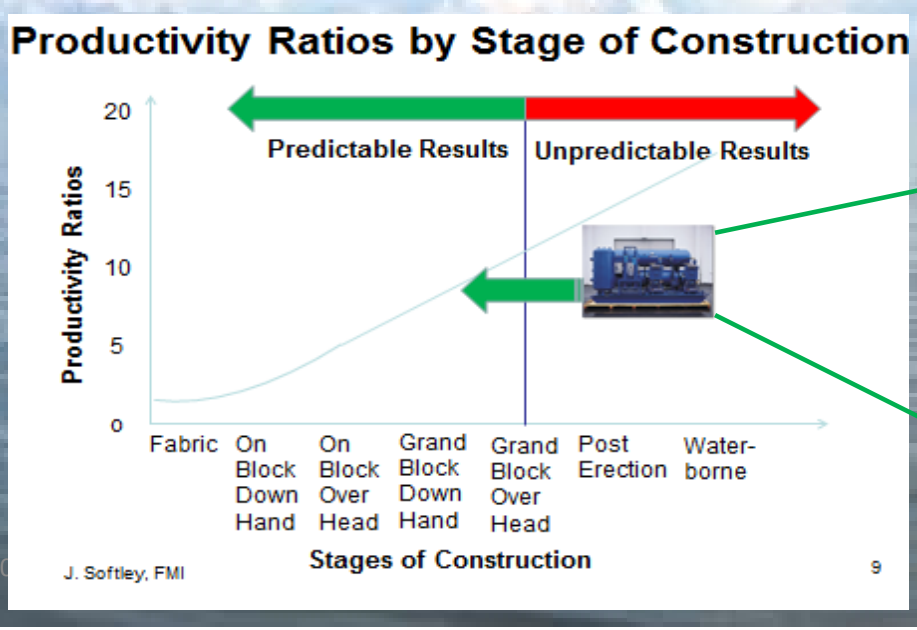
Basic HM&E Systems Costs
(Standard Shipbuilding CERs)

+ CER Adjustments for Military Requirements
- Mil-Spec Material
- Gen-Spec Reqts.
- Redundancies
- CBRN Requirements
- Arctic Service Requirements

+ Add Military Systems
- Weapons Systems
- C4ISR
- Special Coatings

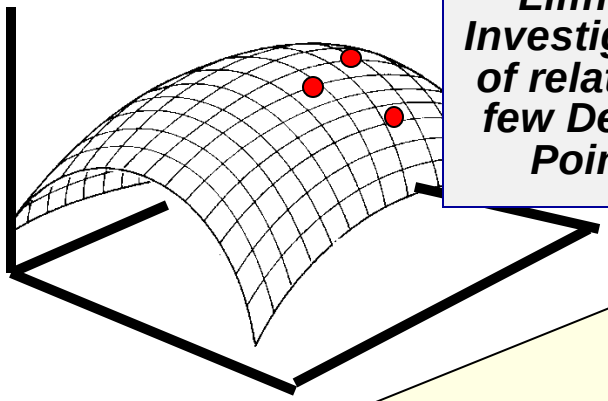
X Adjustments for Productivity
- Engineering Quality
- Commonality
- Constr. Stage
- Outfit Density

+ Cost Risk
- Engineering Performance
- Production Performance
- Management Performance
- Potential Impact of Schedule

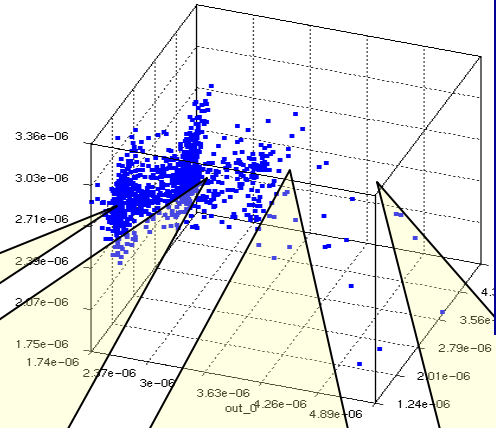


Flexible Designs: Can move work to more productive construction stages

Design Space Exploration (DSE) via HPCMP CREATE-Ships RSDE

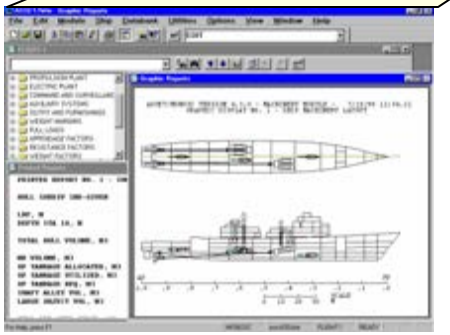


From…
Limited Investigation of relatively few Design Points

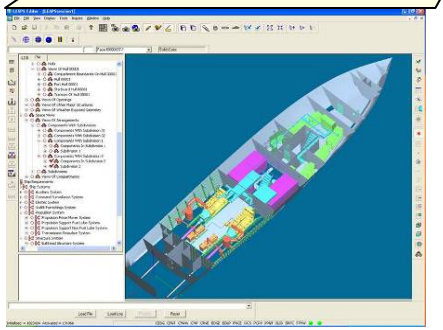


To…
Full Investigation of Concepts throughout the Design Space

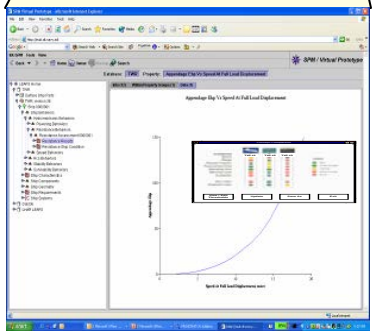
Explore Levels of Flexibility/Complexity During DSE



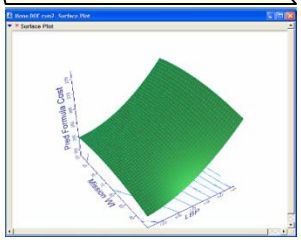
Generating
The Space



Exploring
The Space



Evaluating
The Space



Visualizing
The Space

Ship Design Characteristics for Assessing Complexity - SNAME SDC/SD-8 Workshop

- Design Complexity Characteristics for Ship Concept Design
  - Technical maturity, extent of commonality, number of components and systems
  - Ship densities by ship types and systems (e.g., power)
  - Complexities of design strategy/approach, e.g.,
    - multiple competitive early designs by shipbuilders
    - use of legacy designs
  - Imposed design constraints, e.g.,
    - limit size of ship or dimensions of hull
  - Architectures and ease of routing of Distributed Systems

Ship Density, Systematic Commonality, Distributed Systems Critical to Right Sizing Flexible Warships

Shortcomings In Distributed Systems Design Tools - SNAME Workshop

- ASSET does not allocate space for Distributed Systems
- Design rules limit innovations in Distributed Systems
- Lack of trade-offs between architectures
- Lack of area & volume data of existing Distributed Systems
- Inconsistent as to when M&S of Distributed Systems begins
- Questions about validity of physics-based M&S tools
- Greater trade-off between ship arrangement definition and large number of alternative ship concepts during DSE

Lack of Knowledge about Distributed Systems in Early Stage Ship Design

Distributed Systems Design Tools Recommendations - SNAME Workshop

- Obtain data on Distributed Systems space for existing ships
- Modify ASSET to improve space allocations for Dist. Sys.
- Include a ship arrangement design capability in ASSET
- Integrate more physics-based M&S Tools for Distributed Systems In RSDE/LEAPS
- Develop Dist. Sys. design margins & service-life allowances
- Establish exit design definition criteria for Distributed Systems at each stage of design & production planning
- Obtain labor-hour data for routing Dist. Sys in dedicated space vs practice of routing them in overly dense spaces
- Include a Distributed Systems Engineer in the design team along with Topside Design & Ship Arrangement Design Engrs

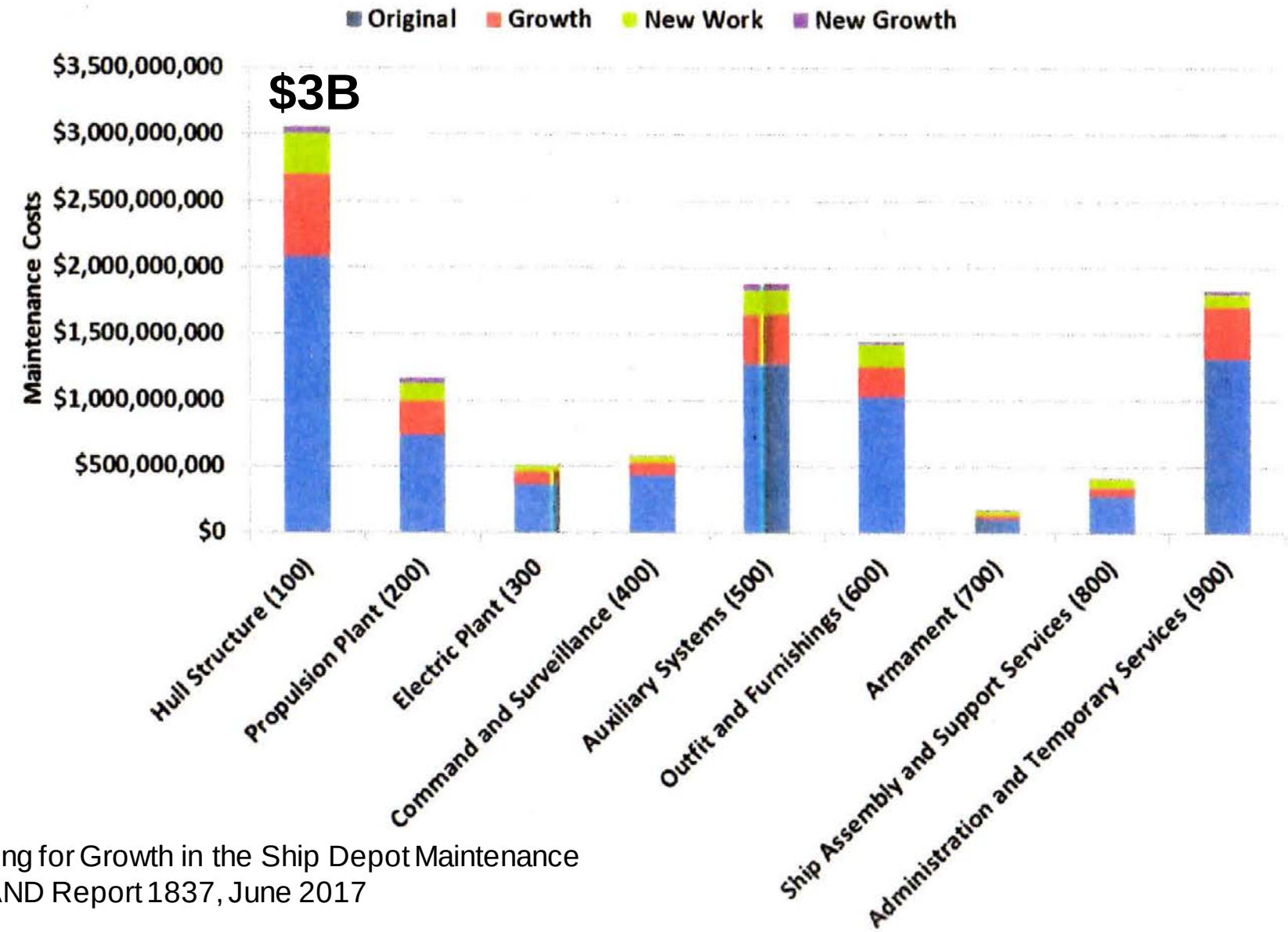
Solution: Design Out Complexity Early During Design Space Exploration (DSE)

- Expand education & training of acquisition personnel in the Principles for Design of Flexible Ships during DSE
- Incorporate in DSE tools measures to compare levels of flexibility of alternative warship concepts
  - Ship Densities, Distributed Systems, Ship Arrangements, Design Margins, Service Life Allowances
- Incorporate in work content/cost models ship density, design maturity, systematic commonality, other productivity factors
- Integrate these higher fidelity process-based work content/ cost models with Navy early stage ship design tools

A Path to Flexible Warships easier to build, operate, maintain & modernize throughout their <u>full</u> service-life

- **Back - up**

Largest proportion of maintenance costs occurs in hull structure, but proportional across work areas*



- "Accounting for Growth in the Ship Depot Maintenance Account", RAND Report 1837, June 2017