

Panel #16: Contributions of Systems Engineering to Effective Acquisition



Robust Systems Engineering: Ensuring Successful Acquisition Outcomes Through “Elegant” Design

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12 May 2011

Problem: Naval Ships Cost Too Much To Produce & Own

- “...lack of design maturity...required to rebuild completed areas of the ship...” (GAO 2005)
- “Starting construction without a stable design...volatility leads to costly out-of-sequence work and rework...” (GAO 2009)
- “Shipboard distributed systems such as ... structure... are in wide disrepair throughout the surface force.” (Balisle, 2010)
- Poor design decisions are driving TOC (Keane, 2011)
 - Selecting solutions located at the edge of infeasibility and not backing off from edge to find solution that is optimum and robust
 - Robust design will not become infeasible if ship changes a little

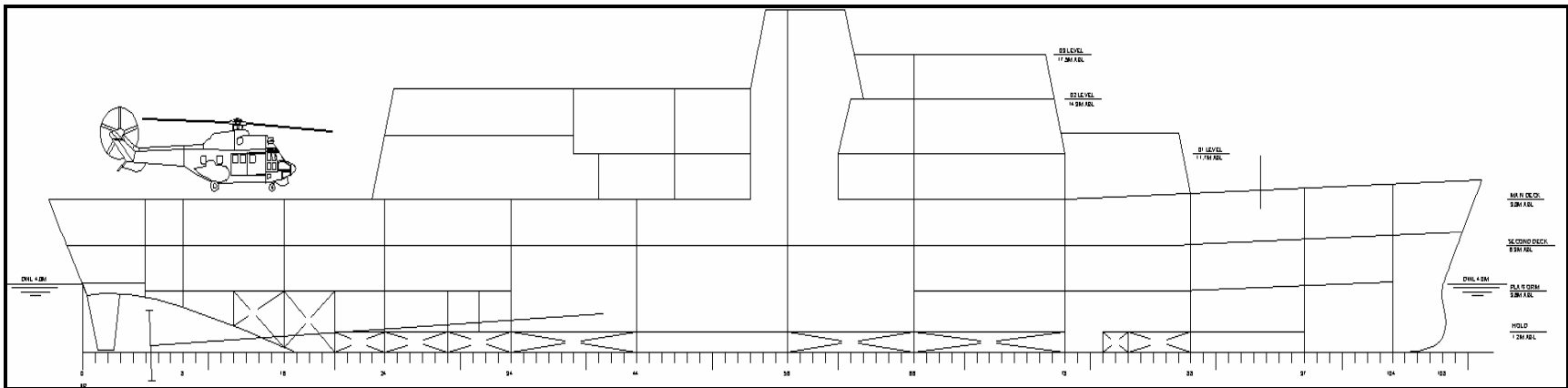
Many ship classes in fleet are at the edge of infeasibility

Bottom Line Up Front (BLUF)

- 1. Less Dense Design**
- 2. Use of Collaborative
Physics-Based Design Tools**
- 3. Design-Build Collaboration**

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

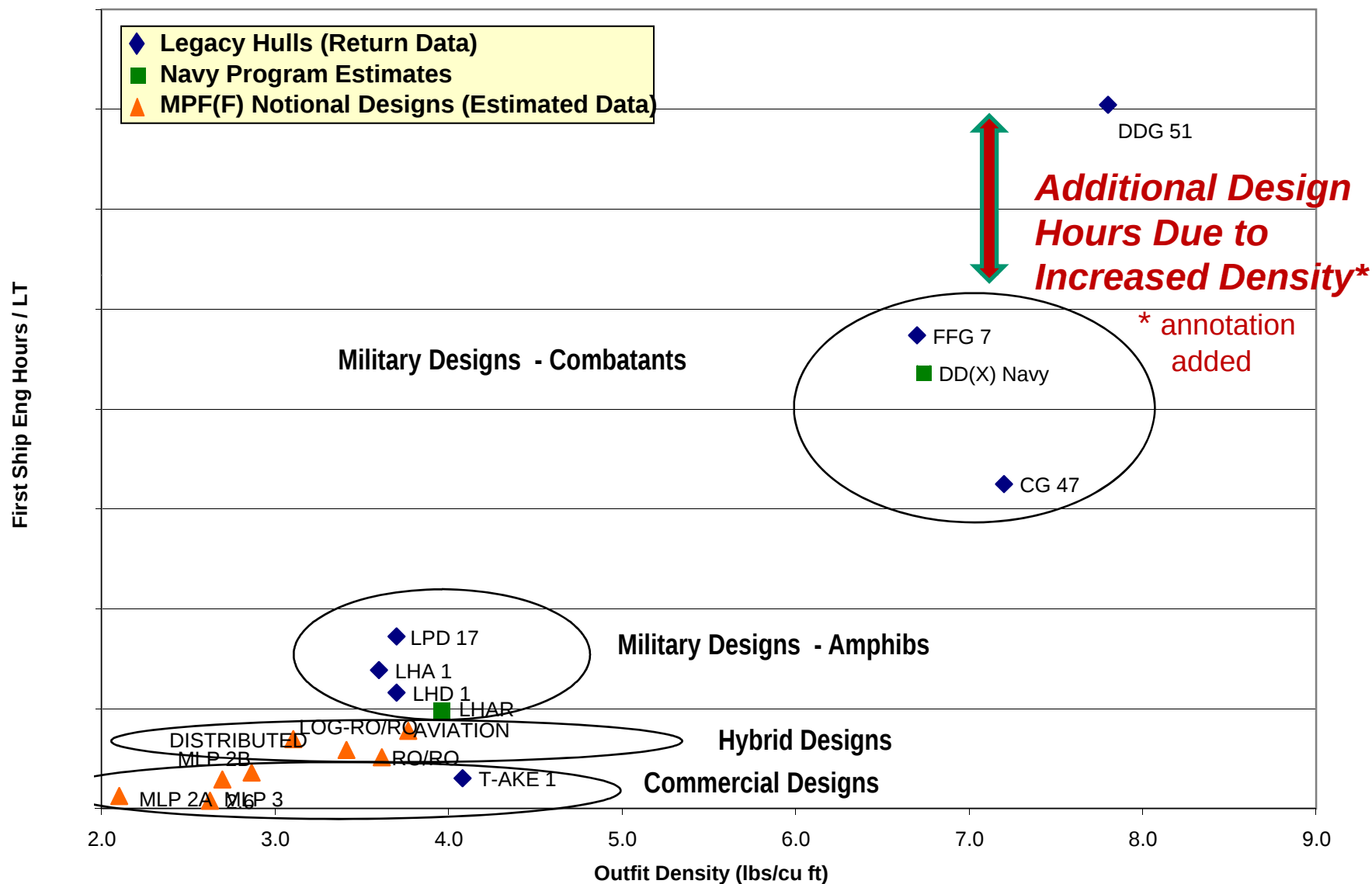
- Hull is sized and shaped in early design based on:
 - unreliable weight and area/volume estimates



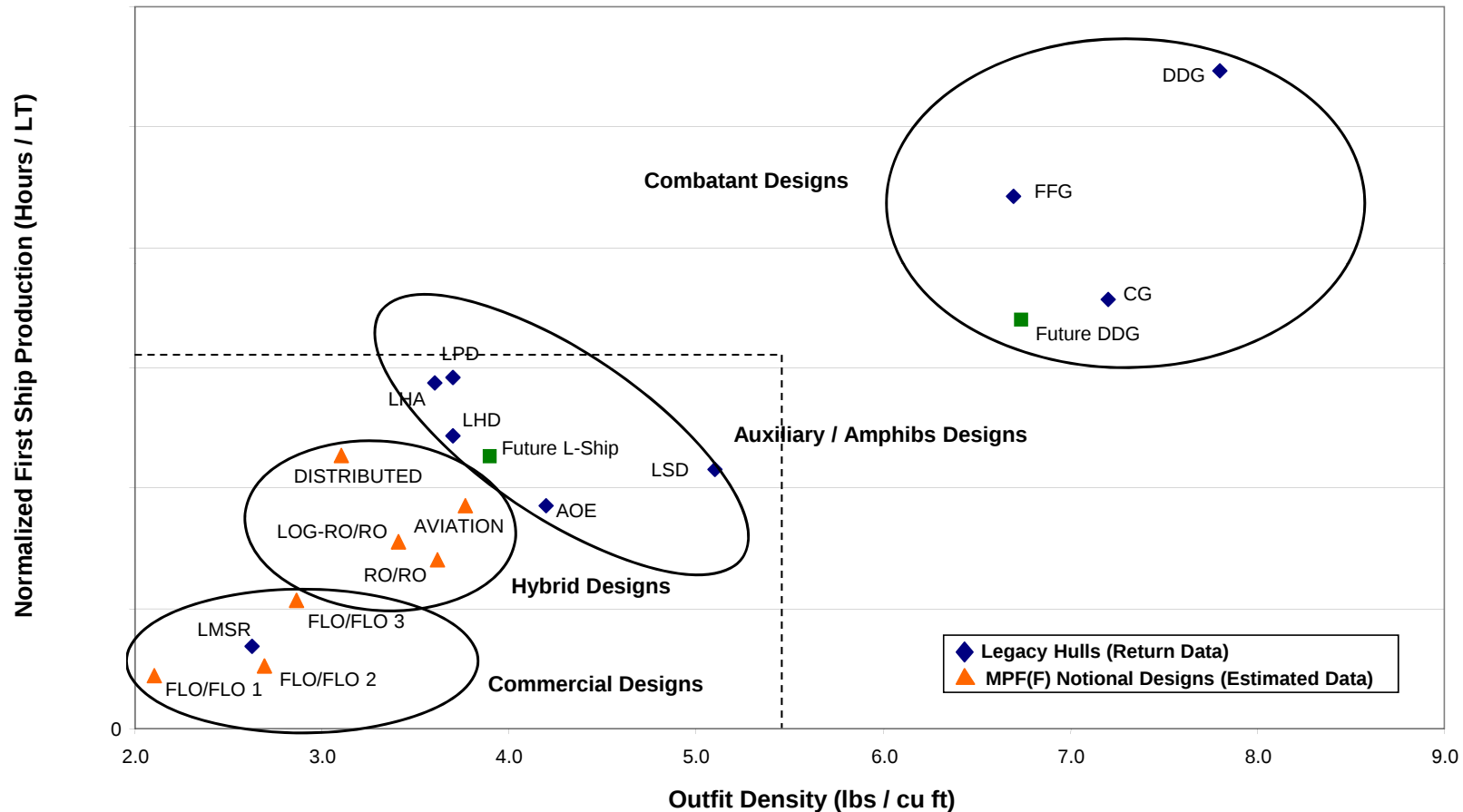
- invalid assumption volume is “arrangeable”
- fallacy that limiting hull size limits ship costs

Design unstable-cannot freeze arrangements early

First Ship Engineering MH / LT vs. Outfit Density



Ships Possessing Greater Density Increase Production Cost



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

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

Root Cause of Wrong Technical Decisions: “Outside-In” Design

- Some in the Navy...*”tacitly assumed that ship size could be equated to ship cost...”*
- *”the central assumption, that size and cost inevitably go together, is often false.”*
- Based on supposition that *“only a shrunken ship would be sellable”*
- *“...modern warships are much more volume - than weight - critical...”*
- Nevertheless, this philosophy of constraining hull size continues even to today.

Adverse Impacts of “Outside-In” Design Inefficient Designs to Build and Own

- **Increased Detail Design and Construction costs**
- **Costly exotic, lightweight materials, difficult to weld**
- **Increased energy consumption and Fleet fuel costs**
- **Insufficient service-life allowances**
- **Increased maintenance and repair costs**
- **Increased modernization costs**
- **Reductions in years of expected service-life**
- **Many “Band-Aids” to keep ships operating**
- **Operational restrictions**

WHERE WE NEED TO GO



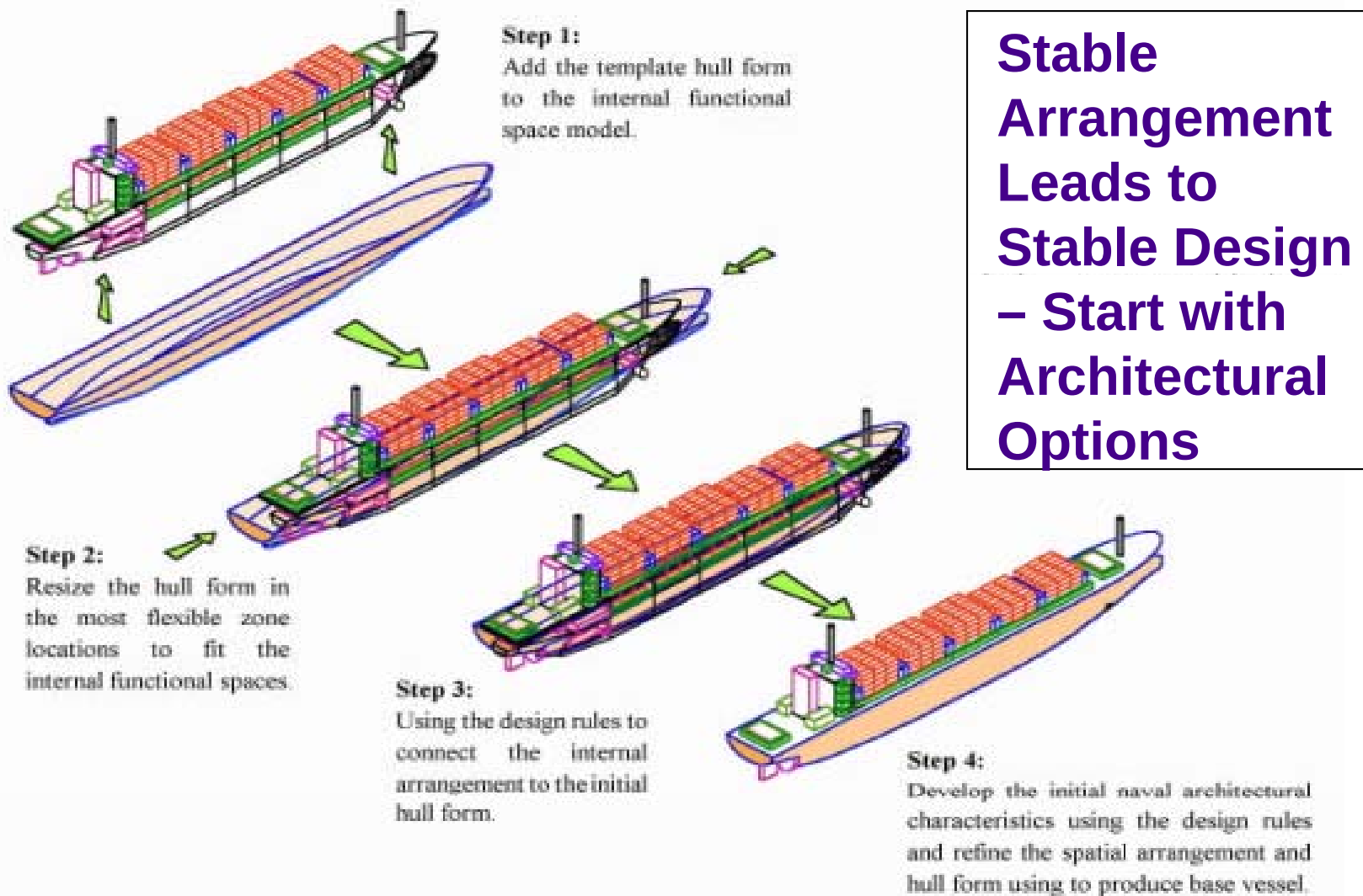
- According to an old proverb, if we do not change our direction, we might end up where we are headed.

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

***“Inside Out Design”*: Create internal arrangement, then fit hull form: NSRP Project 21**



Collaborative Design-Build leads to Early Stable Arrangements

- LMSR Engine Room Arrangement Module (ERAM)
 - Sealift engine room cost reduced 57% (\$58M to \$25M)
 - Design time reduced 45% (27 weeks to 15 weeks)
 - Manufacturing man-hours reduced by 40%
 - Design process supported 18-month build strategy
 - 20% reduction in piping, cabling & equipment realized
 - 60% increase in level of standardization
 - Doubled amount of equipment installed off vessel
 - Off vessel testing increased from 5% to 40%

Lead LMSR delivered on time, under budget

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

CREATE-SHIPS: Leading The Way Toward “Elegant” Design

- **Concept Design High Quality, Physics-Based Software**
 - **Intelligent Ship Arrangements (ISA):** a new surface ship architectural optimization system
 - **Weapons Effects (Shock) & Seaway Loads Predictions**
 - **Integrated Hydrodynamic Design Environment (IHDE):** hull form design and evaluation
 - **Integrated Structural Design Environment (ISDE):** incorporate reliability-based structural design
 - **Rapid Ship Design Environment (RSDE):** higher fidelity design definition & physics based analyses

A HPCMPO – NAVSEA – ONR Collaboration

The Way Ahead: To Efficiently Produce And Own A Warship

- **Less Dense Design**
 - Develop minimal cost design, not minimal size.
 - Size ship to reduce costs due to increased volumetric density and complexity.
- **Collaborative Physics-Based Design Tools**
 - Recognize functional arrangements must be developed before hull form is sized and shaped.
 - Use architecture to partition high technical risks and define design interfaces.
- **Design-Build Collaboration between Navy & Builder**

Invest Early in More Robust Ship Design

Warfighting in the Ocean Battlespace



“...In time of war, when combat objectives rise above all other priorities ...Planes do not stay grounded and fleets do not run scared because of ugly weather...”

CDR George Kosco, ADM Halsey's Chief Meteorologist, *Halsey's Typhoon: The True Story of a Fighting Admiral, an Epic Storm, and an Untold Rescue*, 2008