Total Ship Systems Engineering Program (TSSE)

Capstone Design Project

Naval Postgraduate School Team 2000

14 December 2000
Presentation Outline

Introduction

TSSE Program

Operational Scenario

Requirements Documents

Technical Evaluation

Design Enablers

Design Drivers

Analysis Of Alternatives

Measures Of Effectiveness

Alternative Architectures

Summary
Navy After Next Potential CONOPS

Phase 0
Submersible Caches: missiles, fuel, ordnance
Assured Access

Phase 1/2
SEA BASE SHIPS

Phase 1
POWER PROTECTION FORCES CVBG
Delivery Boys

Phase 2
CONUS/ALB
Merchant Marine

MPF (F)

DISTANCE
Who We Are

- **TSSE Staff**
  - Prof. Charles Calvano
  - Prof. Dave Byers
  - Prof. Robert Harney
  - Prof. Fotis Papoulias
  - Prof. John Ciezki
- **Other NPS Staff**
  - Prof. Wayne Hughes
  - Prof. Phil Depoy

- **2000 Design Team**
  - LT Howard Markle
  - LT Karl Eimers
  - LT Rick Trevisan
  - LT Tim Barney
  - LTjg Ahmet Altekin
  - LT Chris Nash
  - LCDR Garrett Farman
  - LT Ricardo Kompatzki
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Summary
In addition to other degree requirements, including thesis, the TSSE students take the following eight core courses, which are “the program”.

- TS3000 Shipboard Electrical Power Systems
- TS3001 Fundamental Principles of Naval Architecture
- TS3002 Principles of Ship Design and Systems Engineering
- TS3003 Naval Combat Systems Elements
- TS4000 Naval Combat Systems Engineering
- TS4001 Design of Naval Engineering Systems
- TS4002 Ship Systems Integration
- TS4003 Total Ship Systems Engineering
## Design Project History

<table>
<thead>
<tr>
<th>TEAM</th>
<th>DESIGN PROJECT</th>
<th>TEAM COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AY92</td>
<td>Regional Deterrence Ship</td>
<td>4 USN</td>
</tr>
<tr>
<td>AY93</td>
<td>Large Missile Carrier</td>
<td>5 USN</td>
</tr>
<tr>
<td></td>
<td>(“Arsenal” Ship)</td>
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<tr>
<td>AY94</td>
<td>Littoral Warfare “Mother Ship”</td>
<td>6 USN</td>
</tr>
<tr>
<td>AY95</td>
<td>Combined (USN/USCG)</td>
<td>5 USN, 3 USCG</td>
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<tr>
<td></td>
<td>Patrol Corvette</td>
<td></td>
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<tr>
<td>AY96</td>
<td>Arsenal Ship</td>
<td>10 USN, 4 USCG, 1 USMC</td>
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<tr>
<td>AY97</td>
<td>S-CVX</td>
<td>6 USN, 1 CIV</td>
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<tr>
<td>AY98</td>
<td>MPF Ships for 2010</td>
<td>6 USN</td>
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<tr>
<td>AY99</td>
<td>Surf. Warfare Test Ship</td>
<td>4 USN, 1 Hellenic Navy</td>
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<tr>
<td>AY00</td>
<td>Small Fast Networked combatant</td>
<td>6 USN, 1 Chilean, 1 Turkish</td>
</tr>
</tbody>
</table>
Sea Lance
TSSE Knowledge Scheme

TSSE Courses
- Systems Engineering Principles and Process
- Integration Processes and Techniques

Capstone Design Project
- Realistic, Team-based Application

MS Degree (ME/Physics/ECE) — Foundation Engineering Understanding of Major Elements
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Summary
Seaborne Expeditionary Assets for Littoral Access Necessary in Contested Environments
Expeditionary Grid Gaming
Total Ship Systems Engineering Team 2000

Sea Surface Units

Floating Weapons Buoy Canisters - Strike 2

TLAM:

- **Primary Function:** Long-range subsonic cruise missile for attacking land targets.
- **Contractor:** Hughes Missile Systems Co., Tucson, Ariz.
- **Power Plant:** Cruise turbo-fan engine; solid-fuel booster
- **Length:** 18 feet 3 inches (5.56 meters); with booster: 20 feet 6 inches (6.25 meters)
- **Weight:** 2,650 pounds (1192.5 kg); 3,200 pounds (1440 kg) with booster; 3800 pounds in capsule
- **Diameter:** 20.4 inches (51.81 cm)
- **Wing Span:** 8 feet 9 inches (2.67 meters)
- **Range:** Land attack, conventional warhead: 600 nautical miles (690 statute miles, 1104 km)
- **Speed:** Subsonic - about 550 mph (880 km/h)
- **Guidance System:** Inertial, TERCOM, and GPS
- **Warheads:** Conventional: 1,000 pounds Bullpup, or Conventional submunitions dispenser with combined effect bomblets, or WDU-36 warhead w/ PBXN-107 explosive & FMU-148 fuze

**Ref:** FAS Web Site

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CM Radar Picket

**Antenna:** Array of 6 dipoles @ 150 Mhz VHF
- Height of 6 meters
- Diameter of 6 to 12 inches
- This section 4 to 6 meters

**Electronics**

- **Barrier Geometry**
  - Unit Cell: 3 sensors
  - 2 km
  - 2 km

**Ref:** MITRE (R. Evans)
**Heavyweight Torpedo Batteries**

**Primary Function**  ASW and ASUW Heavyweight torpedo for submarines

**Power Plant**  Liquid (Otto) monopropellant fueled swash plate engine with pumpjet propulsor.

**Length**  19 feet (5.79 meters)

**Weight**  3,695 lbs (1662.75 kg) (MK-48 ADCAP)

**Diameter**  21 inches (53.34 centimeters)

**Range**  Officially "Greater than 5 miles (8 km)"

**Speed**  40 kt 55 kt

**Weapon acquisition range**  1660 yards

**Depth**  Officially "Greater than 1,200 ft (365.76 meters)"

**Guidance System**  Wire guided and passive/active acoustic homing

**Warhead**  650 lbs (292.5 kg) high explosive

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**TAMDA/LFAS Sources**

Assumed: 4 ADCAP-like units per launcher. Size of total package: 40 ft x 4 ft x 20 ft; 20,000 lbs (See Bunker Estimation Technique, previous slide).

Note: These units are assumed to be able to communicate directly with undersea sensor nets (IUSS, ADS, and DADS).

Plays as: Torpedo Launch from point in space, vice submarine or surface platform.

Ref: FAS Web Site

---

TAMDA (surface, roughly sonobuoy size) provides, via a combination of probes, acoustic projections, and receivers acoustic environmental information on Bottom Reflection Loss, Reverberation, Bottom Depth, Bottom Type, Bottom Scattering Strength, sound velocity profile and ambient noise monitoring.

LFAS (bottom, roughly 21” dia and 10 ft long in capsule), acting in conjunction with other receiver sources or LFAS units, can act as an illuminator and receiver for multi-static targeting. It can also provide limited in situ environmental data, particularly direct measurements of propagation loss.

TAMDA or a similar environmental monitoring system will be necessary to plan and place bottom acoustic sensors effectively in the real world. An active source will also be necessary to mount an effective acoustic ASW campaign against modern SSs.

For Loop 3; TAMDA is assumed to be employed as a data-gathering device prior to the planning and placement of any acoustic fields. LFAS is presumed to be placed with each 100x100m DADS array, four to a field.
Notional Adversary

- Population 5 times U.S.
- GDP Comparable to U.S.
- Defense Budget \( \frac{1}{2} \) of U.S.
- Coast Line over \( \frac{1}{2} \) of it’s borders
- Continental shelves extend to a maximum of 100 km offshore

### Weapon Totals

<table>
<thead>
<tr>
<th></th>
<th>Carried</th>
<th>Required</th>
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<tbody>
<tr>
<td>AAW</td>
<td>3,000</td>
<td>3,000</td>
</tr>
<tr>
<td>ASUW (Large)</td>
<td>340</td>
<td>400</td>
</tr>
<tr>
<td>ASUW (Small)</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>ASW</td>
<td>150</td>
<td>100</td>
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<tr>
<td>STRIKE (Long)</td>
<td>300</td>
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<tr>
<td>STRIKE (Short)</td>
<td>700</td>
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</table>

NOTE: The 60 extra ASW weapons were applied to the ASUW (large) weapons requirement.
Weight and Volume

- **Total Volume**: 170,000 ft³
- **Total Weight**: 6,000 LT
- **Total Cost**: ?????

### CNAN Distributed Grid and Craft Payload

<table>
<thead>
<tr>
<th>Number</th>
<th>Total Volume (ft³/element)</th>
<th>Total Weight (Tons/element)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM Radar Picket 1337</td>
<td>23,610</td>
<td>668</td>
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<tr>
<td>DADS 4160</td>
<td>1,602</td>
<td>208</td>
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<tr>
<td>TAMDA 20</td>
<td>8</td>
<td>1</td>
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<tr>
<td>LFAS 20</td>
<td>480</td>
<td>18</td>
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<tr>
<td>UC V Small 15</td>
<td>525</td>
<td>4</td>
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<td>RSTA 12</td>
<td>4,944</td>
<td>148</td>
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<tr>
<td>IR SAM 2000</td>
<td>53,000</td>
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<td>Air Mines 800</td>
<td>3,601</td>
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<td>Tomahawk 300</td>
<td>13,959</td>
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<td>SSDBAT 500</td>
<td>1,200</td>
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<td>FSAM 500</td>
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<td>SM-3/TEMD 1000</td>
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<td>NVM 700</td>
<td>21,889</td>
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<tr>
<td>TORP BATT 40</td>
<td>12,783</td>
<td>399</td>
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<tr>
<td>H RPOON 340</td>
<td>10,540</td>
<td>432</td>
</tr>
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</table>

**Total**: 168,126 ft³ Total LT 5,989
CNAN Geography

- Trip Wire
  - 800 Nm long
- Grid packages
  - (total of 5)
  - 100Nm X 100Nm

- Land Littoral
  - 200 Nm

- Cul de sac
  - < 400 Nm deep

- Forward Base
  - 1000 Nm

- Access Assurance
  - 500 Nm

- Refueling Ops.
  - 600 Nm

- 90,000 ft

- 1000 ft

- 1000 Nm
Notional Adversary

- Population 5 times U.S.
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**NOTE:** The 60 extra ASW weapons were applied to the ASUW (large) weapons requirement.
Tripwire Architecture

800 Nm long Tripwire
Grid Architecture

- Grid packages
- Sensor
- Weapon

100 Nm
Presentation Outline

Introduction
TSSE Program
Operational Scenario
Requirements Documents
Technical Evaluation
Design Enablers
Design Drivers
Analysis Of Alternatives
Measures Of Effectiveness
Alternative Architectures
Summary
Combatant and GDM
Required Operational Capabilities

Sea Lance

Grid Operations
Independent Operations
Special Operations
Escort Operations
Network Centric Warfare

- Inland Littoral (~400 Km)
- Seaward Littoral (~1000 Km)
- Beach
- Surf Zone
- Very Low Altitude
- Near-Surface Depth
- Low Altitude
- Very High Altitude "Safe Zone" (>90kft)
- High Altitude
- Medium Altitude
- Deep Depth
Required Operational Capabilities

Sea Lance

- Grid Operations
- Independent Operations
- Special Operations
- Escort Operations
- Network Centric Warfare
Required Operational Capabilities

Sea Lance

- Grid Operations
- Independent Operations
- Special Operations
- Escort Operations
- Network Centric Warfare
Required Operational Capabilities

Sea Lance

Grid Operations
Independent Operations
Special Operations
Escort Operations
Network Centric Warfare
Required Operational Capabilities

Sea Lance

Grid Operations
- Deploy Grid

Independent Operations
- Monitor Grid

Special Operations
- Protect Grid

Escort Operations
- Control Grid

Network Centric Warfare

Deploy Grid
Monitor Grid
Protect Grid
Control Grid
Required Operational Capabilities

Sea Lance

Grid Operations

Deploy Grid

Deploy Sensor Grid

Deploy Weapons Grid

Monitor Grid

Deploy Weapons Grid

Protect Grid

Deploy Tripwire

Control Grid

Deploy Weapons and Sensor Grid

Indep. Ops

Spec Ops

Escort Ops

NCW

Deploy Grid

Deploy Sensors

Deploy Weapons

Grid Monitor

Grid Protect

Grid Control

Deployed Weapons and Sensor Grid

Required Operational Capabilities
Functional Groupings

- Similarities throughout branches of the capabilities breakdown
- Created Functional Groupings
**Functional Groupings**

**Combatant**
- Maximum Speed 38 knots
- Range 3000 Nm at 13 knots
- Max crew size of 20
- Under $100 Million dollars
- Max displacement 1000 LT
- Transit in sea state 6, deployment in sea state 4

**Sea Lance/Grid System**
- Anti-ship missile defense
- Area air defense
- Interoperable with any Joint/Combined Task Force
- Operate in mined waters
- Perform precision strike
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- Measures Of Effectiveness
- Summary
Alternative Architectures

- Medium Combatant (450 LT) with Tow (450 LT)
- All Medium Combatants (600 LT)
- A Mixture of Medium (800 LT) and Small (250 LT) Combatants
Measures Of Effectiveness/Performance

- Flexibility
- Versatility
- Lethality
- Survivability
- Deployability

Analysis of Alternatives
Measures Of Effectiveness/Performance

- Determine Factors which affect each MOE/MOP
  - Cost
  - Organic Weapon & Sensor Capability
  - Seakeeping
  - Speed

<table>
<thead>
<tr>
<th>Measures Of Effectiveness/Performance</th>
<th>Flexibility</th>
<th>Versatility</th>
<th>Lethality</th>
<th>Survivability</th>
<th>Deployability</th>
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</thead>
<tbody>
<tr>
<td>1. Range</td>
<td>X</td>
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<td>2. Speed</td>
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<td>3. Grid Deployment Order</td>
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<td>4. Payload Capacity</td>
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<td>5. Sea Keeping</td>
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<td>6. Organic Sensor Capacity</td>
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<td>7. Cost</td>
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<td>8. Multiple Mission Capability</td>
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<td>9. Modularity</td>
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<td>10. Craft Organic Weapons</td>
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<td>11. Weapons Load Out</td>
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<td>12. Stealth</td>
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<td>13. Susceptability</td>
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<td>14. Vulnerability</td>
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<td>15. Endurance</td>
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<td>16. Habitability</td>
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<td>17. Logistic Support</td>
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</table>

Determine Factors which affect each MOE/MOP

Recurring Factors
  - Cost
  - Organic Weapon & Sensor Capability
  - Seakeeping
  - Speed

Recurring Factors
  - Cost
  - Organic Weapon & Sensor Capability
  - Seakeeping
  - Speed
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Summary
Doubling displacement increases cost by a factor of 1.5

\[
Cost = (1.8066)(\text{Displacement}^{0.585})
\]

- 800 LT Option = \((1.8066)(800^{0.585}) = 90,192,000 \approx 90\) Million
- 600 LT Option = \((1.8066)(600^{0.585}) = 76,222,000 \approx 76\) Million
- 450 LT Option = \((1.8066)(450^{0.585}) = 64,416,000 \approx 64\) Million
- 250 LT Option = \((1.8066)(250^{0.585}) = 45,672,000 \approx 46\) Million

**Option I (450 LT with 450 LT Tow):**
- 50 Craft (400 LT)
- 50 GDM (400 LT)
- \$4.17 Billion

**Option II (600 LT):**
- 60 Craft
- \$4.57 Billion

**Option III (250 LT and 800 LT):**
- 45 Craft (250 LT)
- 45 Craft (800 LT)
- \$6.11 Billion
Equalize option costs based on most expensive option

Option I (450 LT Combatant): $64 Million per craft
Additional $1.94 Billion
30 Additional Craft

Option II (600 LT): $76 Million per craft
Additional $1.54 Billion
20 Additional Craft

Option III (250 LT and 800 LT): Additional $0 Billion
0 Additional Craft
Analysis of Alternatives

250 LT and 800 LT

Advantages:
- Fighter and Freighter
- Plenty of Volume/Weight
- No Tow Speed Limitations

Disadvantages:
- Combatant Capabilities
- 800 LT Utility
- 800 LT Liability
- Relative Stealth
- Expensive

Deployability | Survivability | Lethality | Versatility | Flexibility

14 December 2000 Sea Lance
Analysis of Alternatives

450 LT with 450 LT Tow

Advantages
- Good Payload Fraction
- Plenty of Volume
- Genuine Combatant
- Increased Range
- Commonality of Hull Forms

Disadvantages
- High risk
- Combatant/Tow Motions
- Reduced Speed

Deployability | Survivability | Lethality | Versatility | Flexibility
Analysis of Alternatives

Advantages
- Only one Hull Design
- No Tow Speed Restriction
- Smaller RCS than 800LT

Disadvantages
- Limited after Deployment
- Weight/Volume Limitations
- Fighter and Freighter
- Relative Stealth
- Expensive

600 LT

Deployability | Survivability | Lethality | Versatility | Flexibility

14 December 2000

Sea Lance
Analysis of Alternatives

Catamaran

Advantages
- Proven Technology
- Stability/Deployability
- High Speed Performance
- Increased Volume/Deck Area
- Stealth Attributes

Disadvantages
- Higher risk
- Weight Limitations
- Accelerations

Deployability | Survivability | Lethality | Versatility | Flexibility
Analysis of Alternatives

Diesels Vs. Gas Turbine

Water Jets Vs. Propellers
Matching Enablers to Drivers

Design Drivers
- Weight & Volume of Grid
- Ship Endurance
- Draft
- ETC.

Capability Requirements
- Provide Access
- Assurance...

Design Enablers
- Sea Lance
- Catamaran
- Tow
- ETC.

Functionally Group the Drivers
Weight the Drivers
Review Driver Interactions

Grid Ops
- Deploy Grid
- Monitor Grid
- Protect Grid
- Control Grid
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Technology to Capability

- Propulsion/Electrical
- Network-centric Link
- SWAN
- Hull type/material
- Organic Weapons/Sensors
- Human factors/Habitability
- Expeditionary Grid Systems

Capability
Technology to Capability

- Propulsion/Electrical
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Capability
Diesel Vs. Gas Turbine

- Fuel Consumption
- Weight
- Reduction Gear
- Intakes / Exhaust
- Maintenance
- GT Break-through?
Conventional Vs. Electric Drive

- **Fuel Efficiency**
  - 7% Transmission loss
  - 5% Best Case SFC bonus

- **Weight**
  - Extra Electric Motors
  - Larger Generators and Rectifiers

- **Cost & Risk**
  - Dovetail DD21
Propulsors

- Propeller
  - Size & Reduction Gear
  - Performance while planing
- Conventional Waterjet
  - 15 knot efficiency
- Bird-Johnson AWJ21
  - Efficiency / Cavitation
  - Risk
Bird-Johnson AWJ21
Electric Power System

- TOSA
  - Flexibility & Upgrades
- PTO Power Generation
  - Simplicity & Weight savings
- DC Zonal Distribution
  - Simplicity & DD 21 Dovetail
DC Zonal Distribution

Port Prime Mover

Propulsion

Step Up Gear

PTO

FW SM

AC

Rectifier

DC

Inport/ Emergency Genset

Cross - Connect

DC-AC Inverter

DC-DC Buffer

DC-AC Inverter

DC-AC Buffer

DC-AC Inverter

DC-DC Buffer

DC-AC Inverter

DC-DC Buffer

DC-AC Inverter

DC-DC Buffer

DC-AC Inverter

DC-DC Buffer

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Technology to Capability

- Propulsion/Electrical
- Network-centric Link
- SWAN
- Hull type/material
- Organic Weapons/Sensors
- Human factors/Habitability
- Expeditionary Grid Systems

Capability
Sea Lance C4ISR

- Grid “Teamnet”
- Notional Idea
  - Acoustic Modems
  - RF Gateways
- Exterior Net
  - Tadil J/Link 16
Sea Lance C4ISR

- Combatant Comms
  - Ship to Ship/Air
    - VHF
    - UHF
  - Satellite
    - EHF (MILSTAR)
    - Global Broadcast System
  - Data Links
    - Teamnet
    - Tadil J/Link 16
Combatant Onboard Network
Combatant Onboard Network

- Fast Ethernet Mesh LAN
  - Reliable & Inexpensive
- Functional Separation
  - Flexibility & Up-gradable
- Total Integration
  - Operational systems
  - Engineering control & sensing
  - Combat Systems
  - Administrative
Combatant Onboard Network

Fast Ethernet Backbone

- CO/TAO Console
- Console
- Console
- Console
- Training System
- Entertainment System
- Auxiliary Systems
- Propulsion System
- Engineering Control Computer
- Electrical System
- DC System
- Combat Systems Computer
- Sensor Systems
- Nav System
- Weapon Systems
- Comms Computer
- Crypto
- Xcvr
- Antennas
Control Spaces

- Control Center/Bridge
  - All watchstanding
- Engineering Station
  - Maintenance/Diagnostic Station
Control Center/Bridge
Engineering Station

- One per Engine Room
- Battery back-up & Alternate data paths for “no power” ops.
- Maintenance only (not manned)
Technology to Capability

- Propulsion/Electrical
- Network-centric Link
- SWAN
- Hull type/material
- Organic Weapons/Sensors
- Human factors/Habitability
- Expeditionary Grid Systems

Capability
# Combatant/GDM Characteristics

**Combatant**
- Wave-Piercing Catamaran
- Full Load Disp.: 450 LT
- Light Ship Disp.: 283 LT
- LCB/LCG: 16’ aft CL
- VCG: 10’ above keel
- Submerged Length: 158’
- Length at Waterline: 146’
- Length Overall: 167’
- \( C_B : 0.625 \)
- \( C_P : 0.857 \), \( C_X : 0.729 \)

**GDM**
- Wave-Piercing Catamaran
- Full Load Disp.: 450 LT
- Light Ship Disp.: 146 LT
- Other characteristics similar to combatant
### Table of Offsets/Body Plan

**Sea Lance Table of Offsets for B=10' T=8'**

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Motions Summary

- Vertical Accelerations are an issue
  - Above NAVSEA requirements
    - Utilize wave piercing catamaran
    - Utilize ride stabilization system
    - Anticipate results similar to other commercial designs
- Other vertical and lateral motions are within reasonable limits
Bridge Accelerations

Accelerations at the Bridge

![Graph showing wave/ship length vs. acceleration (g's)]
Hogging and Sagging conditions computed to determine the maximum longitudinal and transverse bending stress

- Aluminum (5086-H34) used for the majority of design
- Composites used in the central control station and the mast
- Steel used for reinforcement where necessary
- Hull structural weight validation performed against similar catamaran ferry designs

- 125 LT structure vice 128 LT
Longitudinal Weight Dist.
Floodable Length

Compartment Center vs. Floodable Length

with Draft = 8 ft, VCG = 10.59 ft, Permeability = 0.95
and Margin set at 3 inches below Main Deck (14 ft)
Stability Assessment

Righting Arm vs. Heel Angle
for Displacement = 450 LT, VCG = 10.59 ft and Trim = 0
### Combatant Weight Breakdown

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<td>CARGO MUNITIONS</td>
<td>0.0</td>
</tr>
<tr>
<td>780</td>
<td>AIRCRAFT RELATED WEAPONS</td>
<td>0.0</td>
</tr>
<tr>
<td>790</td>
<td>SPECIAL PURPOSE SYSTEMS</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td><strong>Group Total:</strong></td>
<td><strong>31.7</strong></td>
</tr>
</tbody>
</table>
## Combatant Weight Breakdown

<table>
<thead>
<tr>
<th>SWBS</th>
<th>Description</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>F10</td>
<td>SHIPS FORCE+EFFECTS</td>
<td>4.7</td>
</tr>
<tr>
<td>F20</td>
<td>MISSION RELATED EXPENDABLES+SYS</td>
<td>24.7</td>
</tr>
<tr>
<td>F30</td>
<td>STORES</td>
<td>0.8</td>
</tr>
<tr>
<td>F40</td>
<td>FUELS+LUBRICANTS</td>
<td>104.0</td>
</tr>
<tr>
<td>F50</td>
<td>LIQUIDS, NON-PETRO BASED</td>
<td>16.1</td>
</tr>
<tr>
<td>F60</td>
<td>CARGO</td>
<td>0.0</td>
</tr>
</tbody>
</table>

- **Full Load (LT):** 433.6
- **Margin:** 6.5%
- **Full Load Displacement (LT):** 449.9
- **Light Ship (LT):** 283.2
- **Dead Weight (LT):** 150.3
- **Payload Fraction:** 35%

- **Design Margin:** 6.5 %
- **Full Load Disp.:** 449.9 LT
- **Light Ship:** 283.2 LT
- **Payload Fraction:** 35 %
# GDM Weight Breakdown

<table>
<thead>
<tr>
<th>SWBS</th>
<th>Description</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>SHELL + SUPPORTS</td>
<td>64.1</td>
</tr>
<tr>
<td>120</td>
<td>HULL STRUCTURAL BULKHEADS</td>
<td>20.0</td>
</tr>
<tr>
<td>130</td>
<td>HULL DECKS</td>
<td>12.0</td>
</tr>
<tr>
<td>140</td>
<td>HULL PLATFORMS/FLATS</td>
<td>3.2</td>
</tr>
<tr>
<td>150</td>
<td>DECK HOUSE STRUCTURE</td>
<td>2.4</td>
</tr>
<tr>
<td>160</td>
<td>SPECIAL STRUCTURES</td>
<td>13.0</td>
</tr>
<tr>
<td>170</td>
<td>MASTS+KINGPOSTS+SERV PLATFORM</td>
<td>3.0</td>
</tr>
<tr>
<td>180</td>
<td>FOUNDATIONS</td>
<td>1.0</td>
</tr>
<tr>
<td>190</td>
<td>SPECIAL PURPOSE SYSTEMS</td>
<td>10.0</td>
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<tr>
<td></td>
<td><strong>Group Total:</strong></td>
<td><strong>128.8</strong></td>
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<tr>
<td>230</td>
<td>PROPULSION UNITS</td>
<td>0.0</td>
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<tr>
<td>240</td>
<td>TRANSMISSION+PROPULSOR SYSTEMS</td>
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<tr>
<td>250</td>
<td>SUPPORT SYSTEMS</td>
<td>0.0</td>
</tr>
<tr>
<td>260</td>
<td>PROPUL SUP SYS - FUEL, LUBE OIL</td>
<td>0.0</td>
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<td>290</td>
<td>SPECIAL PURPOSE SYSTEMS</td>
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<td></td>
<td><strong>Group Total:</strong></td>
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<tr>
<td>310</td>
<td>ELECTRICAL POWER GENERATION</td>
<td>1.5</td>
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<td>320</td>
<td>POWER DISTRIBUTION SYS</td>
<td>1.5</td>
</tr>
<tr>
<td>330</td>
<td>LIGHTING SYSTEMS</td>
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<tr>
<td>340</td>
<td>POWER GENERATION SUPPORT SYS</td>
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<td>390</td>
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<td></td>
<td><strong>Group Total:</strong></td>
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<tr>
<td>410</td>
<td>COMMAND+CONTROL SYSTEMS</td>
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<tr>
<td>420</td>
<td>NAVIGATION SYSTEMS</td>
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<tr>
<td>430</td>
<td>INTERIOR COMMUNICATIONS</td>
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<td>440</td>
<td>EXTERIOR COMMUNICATIONS</td>
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<tr>
<td>450</td>
<td>SURF SURV SYS (RADAR)</td>
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<tr>
<td>460</td>
<td>UNDERWATER SURV SYS</td>
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<tr>
<td>470</td>
<td>COUNTERMEASURES</td>
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<tr>
<td>480</td>
<td>FIRE CONTROL SYSTEMS</td>
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<tr>
<td>490</td>
<td>SPECIAL PURPOSE SYSTEMS</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td><strong>Group Total:</strong></td>
<td><strong>2.4</strong></td>
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</table>

<table>
<thead>
<tr>
<th>SWBS</th>
<th>Description</th>
<th>Weight</th>
</tr>
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<tbody>
<tr>
<td>510</td>
<td>CLIMATE CONTROL</td>
<td>0.0</td>
</tr>
<tr>
<td>520</td>
<td>SEA WATER SYSTEMS</td>
<td>0.0</td>
</tr>
<tr>
<td>530</td>
<td>FRESH WATER SYSTEMS</td>
<td>0.0</td>
</tr>
<tr>
<td>540</td>
<td>FUEL/LUBRICANTS, HANDLING+STORAGE</td>
<td>3.0</td>
</tr>
<tr>
<td>550</td>
<td>AIR, GAS+MISC FLUID SYSTEMS</td>
<td>0.0</td>
</tr>
<tr>
<td>560</td>
<td>SHIP CNTL SYSTEMS</td>
<td>0.0</td>
</tr>
<tr>
<td>570</td>
<td>UNDERWAY REPLENISHMENT SYSTEMS</td>
<td>1.0</td>
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<tr>
<td>580</td>
<td>MECHANICAL HANDLING SYSTEMS</td>
<td>0.8</td>
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<tr>
<td>590</td>
<td>SPECIAL PURPOSE SYSTEMS</td>
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<tr>
<td></td>
<td><strong>Group Total:</strong></td>
<td><strong>5.6</strong></td>
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<tr>
<td>610</td>
<td>SHIP FITTINGS</td>
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<tr>
<td>620</td>
<td>HULL COMPARTMENTION</td>
<td>0.2</td>
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<tr>
<td>630</td>
<td>PRESERVATIVES+COVERINGS</td>
<td>1.8</td>
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<tr>
<td>640</td>
<td>LIVING SPACES</td>
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<tr>
<td>650</td>
<td>SERVICE SPACES</td>
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<td>660</td>
<td>WORKING SPACES</td>
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<tr>
<td>670</td>
<td>STOWAGE SPACES</td>
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<td>690</td>
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<td><strong>Group Total:</strong></td>
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<tr>
<td>710</td>
<td>GUNS+AMMUNITION</td>
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<tr>
<td>720</td>
<td>MISSLES+ROCKETS</td>
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<tr>
<td>730</td>
<td>MINES</td>
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<tr>
<td>740</td>
<td>DEPTH CHARGES</td>
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<tr>
<td>750</td>
<td>TORPEDOES</td>
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<tr>
<td>760</td>
<td>SMALL ARMS+PYROTECHNICS</td>
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<tr>
<td>770</td>
<td>CARGO MUNITIONS</td>
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<tr>
<td>780</td>
<td>AIRCRAFT RELATED WEAPONS</td>
<td>0.0</td>
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<tr>
<td>790</td>
<td>SPECIAL PURPOSE SYSTEMS</td>
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</tr>
<tr>
<td></td>
<td><strong>Group Total:</strong></td>
<td><strong>0.0</strong></td>
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</table>
# GDM Weight Breakdown

<table>
<thead>
<tr>
<th>SWBS</th>
<th>Description</th>
<th>Weight (LT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F10</td>
<td>SHIPS FORCE+EFFECTS</td>
<td>0.0</td>
</tr>
<tr>
<td>F20</td>
<td>MISSION RELATED EXPENDABLES+SYS</td>
<td>0.5</td>
</tr>
<tr>
<td>F30</td>
<td>STORES</td>
<td>0.0</td>
</tr>
<tr>
<td>F40</td>
<td>FUELS+LUBRICANTS</td>
<td>103.0</td>
</tr>
<tr>
<td>F50</td>
<td>LIQUIDS, NON-PETRO BASED</td>
<td>0.0</td>
</tr>
<tr>
<td>F60</td>
<td>CARGO</td>
<td>190.0</td>
</tr>
</tbody>
</table>

- **Full Load (LT):** 440.0
- **Margin:** 6.5%
- **Full Load Displacement (LT):** 449.5
- **Light Ship (LT):** 146.5
- **Dead Weight (LT):** 293.5
- **Payload Fraction:** 67%

- **Design Margin:** 6.5%
- **Full Load Disp.:** 449.5 LT
- **Light Ship:** 146.5 LT
- **Payload Fraction:** 67%
## Cost Estimation (in 2000 $)

### Total 2000 Acquisition Cost

<table>
<thead>
<tr>
<th>Total 2000 Acquisition Cost</th>
<th>( R )</th>
<th>( y )</th>
<th>( X )</th>
<th>( y X )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-recurring Engineering Cost</td>
<td>$82.9</td>
<td>$0</td>
<td>$82.9</td>
<td>$82.9</td>
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<tr>
<td>Lead Ship:</td>
<td>$64.5</td>
<td>$19.4</td>
<td>$83.9</td>
<td>$101.5</td>
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<tr>
<td>Second Ship:</td>
<td>$64.2</td>
<td>$19.3</td>
<td>$83.5</td>
<td>$101.1</td>
</tr>
<tr>
<td>Third Ship:</td>
<td>$64.1</td>
<td>$19.2</td>
<td>$83.3</td>
<td>$100.9</td>
</tr>
<tr>
<td>Fourth Ship:</td>
<td>$64.0</td>
<td>$19.1</td>
<td>$83.1</td>
<td>$100.8</td>
</tr>
<tr>
<td>Fifth Ship:</td>
<td>$63.9</td>
<td>$19.1</td>
<td>$83.0</td>
<td>$100.7</td>
</tr>
<tr>
<td>Sixth Ship:</td>
<td>$63.9</td>
<td>$19.2</td>
<td>$82.9</td>
<td>$100.6</td>
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<tr>
<td>Seventh Ship:</td>
<td>$63.8</td>
<td>$19.0</td>
<td>$82.9</td>
<td>$100.5</td>
</tr>
<tr>
<td>Eight Ship:</td>
<td>$63.7</td>
<td>$19.0</td>
<td>$82.7</td>
<td>$100.4</td>
</tr>
<tr>
<td>Ninth Ship:</td>
<td>$63.7</td>
<td>$19.0</td>
<td>$82.7</td>
<td>$100.4</td>
</tr>
<tr>
<td>Tenth Ship:</td>
<td>$63.7</td>
<td>$19.0</td>
<td>$82.7</td>
<td>$100.4</td>
</tr>
</tbody>
</table>

### Price of First Squadron:

- Delivered: $914
- Deployed: $1,090

### Price of Following Squadrons:

- Delivered: $827
- Deployed: $1,004
Sea Lance Exterior
Interior Spaces

- Boat Deck
- Tow Equipment Room
- Line Locker
- 51-cell SA/SS
- Potable Water
- Main Engine Room
- Auxiliary Machinery Room
- Fuel Tanks
- 4-Cell Harpoon/SLAM
- Refueling Probe
- Decoy Launcher
- Chain Locker
- Inport/Emergency Generator
- Line Locker
- 30 mm Gun
- Electronics Space
- Central Control Station
- Habitability Spaces
- Decoy Launcher
- Cleats
- Fuel Tanks
Sea Lance Exterior
Interior Spaces

- RHIB Boat/Davit
- 25-Person Life Raft
- Oily Waste Holding Tanks
- Gray/Black Water Storage/Treatment Tanks
- Mine Detection Sonar/Acoustic Modem
Technology to Capability

- Propulsion/Electrical
- Network-centric Link
- SWAN
- Hull type/material
- Organic Weapons/Sensors
- Human factors/Habitability
- Expeditionary Grid Systems

Capability
### Weapons and Sensor Data

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Range</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Range SSM</td>
<td>67 nm</td>
<td>Active</td>
</tr>
<tr>
<td>Dual Purpose SAM/SSM</td>
<td>15 nm</td>
<td>Active/Semi-active/IR</td>
</tr>
<tr>
<td>30 mm Gun (fore)</td>
<td>2 nm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Range</th>
<th>Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air/Surface/Missile detection</td>
<td>54 nm</td>
<td>2-4 GHz</td>
</tr>
<tr>
<td>Fire Control (fore)</td>
<td>20 nm</td>
<td>27-40 Ghz</td>
</tr>
<tr>
<td>Fire Control (aft)</td>
<td>20 nm</td>
<td>27-40 Ghz</td>
</tr>
<tr>
<td>IRST</td>
<td>20 nm</td>
<td>3-5 &amp; 8-12 um</td>
</tr>
<tr>
<td>EO Suite (starboard)</td>
<td>10 nm</td>
<td>TV/IR 8-12 um/LRF 1.064 um</td>
</tr>
<tr>
<td>EO Suite (port)</td>
<td>10 nm</td>
<td>TV/IR 8-12 um/LRF 1.064 um</td>
</tr>
<tr>
<td>ESM</td>
<td>-----</td>
<td>2-18 GHz</td>
</tr>
<tr>
<td>Navigation Radar</td>
<td>25 nm</td>
<td>8-10 Ghz</td>
</tr>
<tr>
<td>Mine Avoidance Sonar</td>
<td>&gt;350 yds</td>
<td>250 KHz</td>
</tr>
</tbody>
</table>
Combatant Weapons

- 4-Cell Harpoon/SLAM
- 51-cell SS/SA
- 30 mm Gun
Enclosed Mast

- Enclosed Mast
- Infrared Search and Track (IRST)
- Air and Surface Search Radar
- Navigation Radar
- (2) Fire Control Radars
- ESM Suite
- (2) Electro-Optical Sensors
- Phased Array Comms. Antennae
- TACAN
- Forward

14 December 2000 Sea Lance
RCS Analysis

Comparison of Average RCS

- SEA LANCE TOTAL: 24.7 dBsm
- SEA LANCE (=0): -13.1 dBsm
- SEA LANCE (<45 & >0): -1.3 dBsm
- SEA LANCE (=45): 5.4 dBsm
- SEA LANCE (>45 & <90): 0.0 dBsm
- SEA LANCE (=90): -1.3 dBsm
- SEA LANCE (>90 & <180): -1.3 dBsm
- SEA LANCE (=180): 32.0 dBsm
- 450 LT combatant: 32.0 dBsm
- Large bomber aircraft: 32.0 dBsm
- Large fighter aircraft: 16.0 dBsm
- Small fighter aircraft: 7.8 dBsm
- Small single engine aircraft: 3.0 dBsm
- Missile: -3.0 dBsm
- Small open boat: 17.0 dBsm

RCS [dBsm]
Technology to Capability

- Propulsion/Electrical
- Network-centric Link
- SWAN
- Hull type/material
- Organic Weapons/Sensors
- Human factors/Habitability
- Expeditionary Grid Systems

Capability
Crew

- “SeaLanceman” Rate
  - Applicants from other rates
  - General & Specialized Training
- Officers & Enlisted
  - CO
  - Officers (2)
  - Enlisted (10)
- Accomplished with 13 person crew
  - Maximum use of automation technology
Crew

- Squadron Staff
  - Commodore and Staff
- Watchstanding
  - TAO
  - Ship Control/OOD
  - Assistant TAO & Engineer as required
  - Embarked Staff
- Ship Board Operations
  - Sea & Anchor
  - UNREP
  - MIO
  - SOF Insertion
Habitability Spaces

- Officer’s Stateroom
- Common Sinks
- Male Head
- Female Head
- Galley
- Laundry
- Gym
- Refer/Freezer
- CO’s Cabin
- Officer’s Stateroom
- 3-Person Berthing
- Mess Decks
- Dry Stores
- Multi-mission Space
Total Ship Information Systems Architecture

- Operations
- Maintenance
- Expanded ICAS (Integrated Condition Assessment System)
- Combat Systems
- Administrative
- Supply
- Equipment
- Sensors
- Wireless micro sensors
- Ship-Wide Area Network (SWAN)

Wireless micro sensors

Smart Link
Maintenance Communications Backbone

- NAVICP, Supply Chain
- CINCs, TYCOMs
- ISEAs
- SWAN
- R&D Centers
- Training
- Maint/Log Managers
- OEMs
- HQ, PEOs

Total Ship Systems Engineering Team 2000
Grid Deployment Module
Total Ship Systems Engineering

Grid Deployment Module

Decoy Launcher

Cleats

Electronics Space

Inport/Emergency Generator

Line Locker

Chain Locker

Winch Rooms

Fuel Tanks

Half Modules
### Grid Component Distribution

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Size</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>18' x 22' x 9'</td>
<td>3564</td>
</tr>
<tr>
<td>Half</td>
<td>18' x 11' x 9'</td>
<td>1782</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Individual Size</th>
<th>Module Type</th>
<th>Units per module</th>
<th>Weight of full module</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM Pickett</td>
<td>1' x 20'</td>
<td>Full</td>
<td>128</td>
<td>64</td>
</tr>
<tr>
<td>Tomahawk</td>
<td>2' x 20'</td>
<td>Full</td>
<td>32</td>
<td>60.8</td>
</tr>
<tr>
<td>SM3</td>
<td>2' x 21'</td>
<td>Full</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>Torpedo</td>
<td>4' x 4' x 20'</td>
<td>Full</td>
<td>8</td>
<td>80</td>
</tr>
<tr>
<td>RSTA</td>
<td>4' x 5' x 20'</td>
<td>Full</td>
<td>6</td>
<td>73.8</td>
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<td>Harpoon</td>
<td>2' x 11'</td>
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<td>32</td>
<td>40.6</td>
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<td>NTACM</td>
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<td>32</td>
<td>72</td>
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<tr>
<td>FSAM</td>
<td>.5' x 10'</td>
<td>Half</td>
<td>288</td>
<td>21</td>
</tr>
<tr>
<td>LFAS</td>
<td>2' x 10'</td>
<td>Half</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>DADS</td>
<td>.4' x 3'</td>
<td>Half</td>
<td>864</td>
<td>43.2</td>
</tr>
<tr>
<td>TAMDA</td>
<td>.4' x 3'</td>
<td>Half</td>
<td>864</td>
<td>43.2</td>
</tr>
<tr>
<td>Air mines</td>
<td>1' x 1.5' x 3'</td>
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<td>240</td>
<td>60</td>
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<tr>
<td>UCAV small</td>
<td>2.5' x 3' x 5'</td>
<td>Half</td>
<td>30</td>
<td>7.5</td>
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</tbody>
</table>
Notional Half Module
Connection Force

- Solve for heave/pitch amplitudes:
  \[
  \eta_{3,S} = \mu_{3,S} + \nu_{3,S} f \\
  \eta_{5,S} = \mu_{5,S} + \nu_{5,S} f \\
  \eta_{3,K} = \mu_{3,K} + \nu_{3,K} f \\
  \eta_{5,K} = \mu_{5,K} + \nu_{5,K} f
  \]

- Apply matching condition:
  \[
  f = T \frac{\xi_S - \xi_K}{l}
  \]

- Form the absolute motion at the connection points:
  \[
  \xi_S = \eta_{3,S} - \eta_{5,S} x_S \\
  \xi_K = \eta_{3,K} - \eta_{5,K} x_K
  \]

Solve the linear equation for \( f \)
Tow Bar Forces

- 20 foot tow bar
  - 5 knots
- 20 foot tow bar
  - 15 knots

Tow Bar Force at 5 knots

- 50 tons
- 75 tons
- 100 tons

Tow Bar Force at 15 knots

- 75 tons
- 100 tons
- 125 tons
- 150 tons
Combatant and GDM
Tow Assembly
Tow System Findings

- Tow length determined by geometry
- Bar length used in strip theory
- Maximum forces for given length dictate thickness
- Turn angle limited by moment cable tension
- Thickness is yield stress-limited to 2/3"
Presentation Outline

- Introduction
- TSSE Program
- Operational Scenario
- Requirements Documents
- Alternative Architectures
- Technical Evaluation
- Design Enablers
- Design Drivers
- Analysis Of Alternatives
- Measures Of Effectiveness
- Summary
In the team’s opinion, the design has fulfilled all of the requirements set forth by the sponsor and as specified in the requirements document.

We have completed a loop around the design circle and in some specific instances several iterations have been made.

The combatant could fill some essential gaps in the current fleet and is a cheap, flexible and capable alternative to large CRUDES ships.

The tow is a viable option which needs further physical and computational experiments to validate its utilization.
The tow is at risk mostly due to lack of good data to thoroughly evaluate the alternative.

The AWJ-21 is currently in the design phase at Bird-Johnson.

Some catamaran data was extrapolated from commercial designs.

Validate the assumption that wave-piercer and ride stabilization system will reduce accelerations.

Human Factors
Test and evaluate wave-piercing catamaran hull-forms
Test and evaluate short, semi-fixed tows
Continue composite structure analysis
Develop catamaran ASSET module
Replace CER data in ASSET
The Technical Review will commence after lunch at 1300 in the ME Conference Room.
Corsair and SEA LANCE