SHIP DESIGN AND NAVAL ARCHITECTURE

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Why I am Presenting

• The stance of a Naval Constructor
• Over 30 years involvement in naval ship and submarine design and acquisition
• Project Manager and Project Director for - UK Amphibious Programme (incl new Royal Yacht), Concept designs of emerging UK fleet, Trimaran, Future Surface Combatant.
Royal Navy Landing Ship Helicopter
(HMS Ocean)
Future Surface Combatant
(Early Trimaran Concept – by UK MoD Concept Group)
Artist’s Impression of a New Royal Yacht
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• Project Manager and Project Director for - UK Amphibious Programme, Concept designs of emerging UK fleet, Trimaran, Future Surface Combatant
• Analyst of naval ship design and acquisition
• Professor at UCL developing an integrated approach to preliminary ship design – the Design Building Block approach (SURFCON CAD implementation in Paramarine CASD).
NDP OPV Studies

(Pawling & Andrews RINA Warship 2010)
UCL DBB study of USN LCS for ONR

<table>
<thead>
<tr>
<th><strong>Number of DBB</strong></th>
<th>343 (in c. 25 SBBs and 11 grouped BBs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Displacement</strong></td>
<td>3212te</td>
</tr>
<tr>
<td><strong>Enclosed Volume</strong></td>
<td>19500m³ (R) 2600m³ (A)</td>
</tr>
<tr>
<td><strong>Length, main hull, waterline</strong></td>
<td>136.3m</td>
</tr>
</tbody>
</table>
SHIP DESIGN AND NAVAL ARCHITECTURE

Outline

• Ship Design – S5 - Style
• Naval Architecture as an Engineering Discipline
• NA as Science applied to Ship design – S4
• Ship Design as a special case of engineering design – NSD
• The critical importance of the Concept phase of NSD
• Why the concept phase of Naval Ship Design must and can be architecturally led - Design Inside Out
S5
## Table 1. Listing of style topics relevant to a naval combatant design

<table>
<thead>
<tr>
<th>Stealth</th>
<th>Protection</th>
<th>Human Factors</th>
<th>Sustainability</th>
<th>Margins</th>
<th>Design Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic signature</td>
<td>Collision resistance</td>
<td>Accommodation standards</td>
<td>Mission duration</td>
<td>Space</td>
<td>Robustness</td>
</tr>
<tr>
<td>Radar cross section</td>
<td>Fire fighting</td>
<td>Access policy</td>
<td>Crew watch policy</td>
<td>Weight</td>
<td>Commercial standards</td>
</tr>
<tr>
<td>Infra-red signature</td>
<td>Above water weapon effect</td>
<td>Maintenance levels</td>
<td>Stores level</td>
<td>Vertical centre of gravity</td>
<td>Modularity</td>
</tr>
<tr>
<td>Magnetic signature</td>
<td>Underwater weapon effect / shock</td>
<td>Operation automation</td>
<td>Maintenance cycles</td>
<td>Hotel Power</td>
<td>Operational serviceability</td>
</tr>
<tr>
<td>Visual signature</td>
<td>Contaminants protection</td>
<td>Ergonomics</td>
<td>Refit philosophy</td>
<td>Ship Services</td>
<td>Producability</td>
</tr>
<tr>
<td></td>
<td>Damage control</td>
<td>Upkeep by exchange</td>
<td>Design point (growth)</td>
<td>Adaptability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corrosion control</td>
<td>Replenishment at Sea</td>
<td>Board Margin (upgrades)</td>
<td>Aesthetics</td>
<td></td>
</tr>
</tbody>
</table>
Examples of Style

• Signatures – RN Type 23 Frigate
• Accommodation – USN “Super Carriers”
• Margin Policy – Future Aircraft on RN INVINCIBLE Class
• Adaptability – Mission bays
Figure 3  Mission Bay Arrangement for an RN Type 26 Design Study
(Broadbent & Binns 2006)
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Figure 4
Bruce Archer’s Representation of Design as the Third Culture
Modelling the Ship Design Process

A representation of the full preliminary ship design process with continual feedback, showing not just design activities but also “decisions/selections” (conscious or not)

(full description Andrews COMPIT 2013)
Modelling the Ship Design Process

A Simple Numeric Ship Sizing Iterative Sequence with Feedback

ASSUMPTIONS & SOURCES

(Andrews 1986)
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Figure 7
A (partial) representation of the ship design process and ship definition (Andrews 2003)
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Naval Ship Design is Unique

- There is no prototype

- The warship is a multirole, virtually self sufficient entity, with sustained habitation in extreme conditions – so a level up in system complexity

- Most ships are an assembly of many systems and equipments - selection and integration comes after the capability, provided by the overall design, has been frozen

- Much of the capability (e.g. susceptibility, survivability, mobility, seakeeping) comes from the gross ship characteristics – defined early and hard to demonstrate
The Nature of NSD

- Diversity of ship types, seen in terms of design complexity and usage
- the many issues that ship designs have to address – so bespoke
- Difficulty, particularly for multirole naval combatants, of requirement identification or elucidation
- The multitude of ship performance issues, alongside the main operational mission(s) that the design must address, including “style”
- The naval architect is both the “hull engineer” and the ship’s overall architect
- Political environment in which naval ship procurement operates
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The Concept Phase is Different

- The process is characterised as a *wicked problem*
- This is a key phase where major decisions are made
- The need to ensure that a comprehensive and challenging concept design process has been conducted, before commencing trade-off studies
- Crucial aspect is identification of style - advances in computer highlight ‘softer’ design concerns
- The final aspect is that of *requirement elucidation*
The “V Diagram”
The Nature of Ship Concept Design –
the implications for Concept Tools

– **Believable** solutions should be produced, i.e. solutions which are both technically balanced and sufficiently descriptive;

– Solutions should also be **coherent**, meaning that the dialogue with the customer should be more than merely a focus on numerical measures of performance and cost, and should include a comprehensive visual representation;

– The method should be **open**, in other words the opposite of a ‘black box’ or a rigid/mechanistic decision system, so that it is responsive to those issues that matter to the customer, or capable of being elucidated from customer/user teams;

– It should also be **revelatory**, so that likely design drivers are identified early in the design process to aid design exploration in initial design and beyond;

– Finally it should be **creative**, in that the method facilitates as wide an exploration as possible to ensure the eventual choice emerges from a divergent investigation rather than predisposed solutions.
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Why Ship Synthesis has been 2 Dimensional (at best)

- Initially computers speeded up iterative balance of weight and space
- More numerical options generated
- Computerised naval architecture
- Better analysis but insufficient good data?
Why Ship Synthesis can be 3 Dimensional

- Computer Graphics
- Hull form generation and IPM
- Optimisation - do it because we can - should be more about insight than precise answers
- Future – approach to ship design – should be responsive to a demanding need (better, cheaper, faster into service)
Why Ship Synthesis should be 3 Dimensional
- Wider issues

• Many issues ought to be addressed? – Does synthesis become too complex?

• If adopt 3-D approach should you move more quickly to greater detail?
  – No, better to see the design evolve through the steps.

• Is it better to invest in first principles NA at concept?
  - What is more important to the user?
  Better NA early or operational factors being addressed from the start?

• The real need is to improve design exploration and to de-risk ship concept design by early avoidance of potential problems downstream.
Why Ship Synthesis should be 3 Dimensional
- Improve Initial Design

- Naval ships need to be less costly - need to better understand what is wanted - achieve through 3-D informed dialogue
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• More information rich to avoid mistakes by better articulation through 3-D dialogue
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• More information rich to avoid mistakes by better articulation through 3-D dialogue

• Better articulate design issues to wider world

(Stakeholders - wider Navy, Defence, the rest of government and to parliament, the media and the public)
UK FSC Mothership Studies
(Andrews & Pawling RINA Warships 2004)
Why Ship Synthesis should be 3 Dimensional
- Improve Initial Design

- Naval ships need to be less costly - need to better understand what is wanted - 3-D informed dialogue
- More information rich to avoid mistakes by better articulation through 3-D dialogue
- Better articulate design issues to wider world (Stakeholders)
- Improve Ship Design professionals status – Naval Architect first amongst equals in Ship Design - true Total Ship Systems Engineering –
  the conclusion from Systems Architecture
Why Ship Synthesis should be 3 Dimensional
- Improve Initial Design

• Naval ships need to be less costly - need to better understand what is wanted - 3-D informed dialogue
• More information rich to avoid mistakes (see DJA UK list) by better articulation through 3-D dialogue
• Better articulate design issues to wider world (Stakeholders)
• Improve Ship Design professionals status - NA first amongst equals in SD - true TSSE
• But also need to be Creative
A Synthesis of Art and Science
The UCL Design Building Block approach
The Paramarine Realisation of the UCL Design Building Block approach
Architectural representations for the LCS study at the end of each DBB design stages
The Stages of the UCL architecturally driven Design Building Block ship synthesis

(Andrews & Pawling IJME 2009)
Final Design Functional Groups

- Float
- Move
- Access
- Fight
- Infrastructure
Paramarine-SURFCON Carrier Representation
Figure 11.
A section through the carrier concept showing the three dimensional conflicts between hangar, machinery and air ordinance lift arrangements (Andrews 2004)
DRC Research Areas

**Survivability**
- Vulnerability
- & Full Safety Analysis
- Recoverability

**Design Methods & Tools**
- GUI Development
  - + Design Sketching
- Layout Tools
  - + Submarine Configurations
- Costing Efficiency

**Simulation in Design**
- Dfor Production
- Machinery Impact
- EMI & Topsides
- Fire Safety: FIREPROOF
- Personnel Movement

Commercial Style
The UCL Design Research Centre

• Focus on the Design Building Block Approach
  – Architecturally centred configurational model
  – Interactive graphical display

• Rapid concept design studies

• Detailed technical studies

• Long term research projects in last decade (bold current projects)
  – Design for production (SSA DTi – VT/Ferguson/Tribon/GRC)
  – Simulation integration (Joint EPSRC – SSG partner)
  – CASD (ONR NICOP - NAVSEA)
  – FIREPROOF (EU FP7 - 12 partners)
  – Commercial style (BMT DSL - CASE )
  – Survivability (Dstl - CASE)
  – Topside (UCL Impact - NDP)
  – Sub UUV Mothership (UCL Impact – Babcock)
  – FAROS (EU FP7)
  – DfLayout (ONR NICOP – UMich, TUDelft)
  – GT for Shipping (RR Marine CASE) – Df Support/UXV studies (BAES CASE)
Thank You