CONCEPT STUDIES FOR A JOINT SUPPORT SHIP

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SUMMARY

While all the major NATO navies have been under considerable pressure to downsize following the end of the post-Cold War, the higher degree of political instability world-wide has led to a desire to increase the deployability of the reduced number of naval assets. Thus there has been an increased interest in providing a new generation of naval support vessels as part of each navy's contribution to Coalition peacekeeping. These new support ships are often also required to provide a contribution to amphibious capabilities, including humanitarian tasks, in littoral operations. This means there is a challenging combination of capabilities being sought from the current replacements of traditional afloat support ships.

This paper describes the design work undertaken by the Design Research Centre at UCL, as part of a bid team responding to a Canadian National Defence Department requirement for feasibility studies into a "Joint Support Ship" programme. The UCL task consisted of designing a range of possible design options, to investigate the impact of capabilities on the configuration of this innovative concept, exploring the requirement's two levels of capability, namely, "shall" and "should" as part of designing to cost and capability. A range of concepts was designed using the UCL Design Building Block approach, using the SURFCON module of the Graphics Research Corporation PARAMARINE ship design system. The advantage this approach gave in designing these novel solutions is shown through the ability of the DBB concept approach to balance both technical and configurational features, thereby enabling significantly different ship styles to be readily produced and compared.

1. INTRODUCTION

This paper describes the design work undertaken by the Design Research Centre at UCL, as part of a bid team responding to a Canadian National Defence Department requirement for feasibility studies into a "Joint Support Ship" programme. The UCL task consisted of designing a range of possible ship options, showing the impact of the desired capabilities on the configuration of this innovative concept, exploring the requirement's two specified levels of capability, namely, "shall" and "should", as part of designing to cost and capability.

The Canadian National Defence Department, in considering the requirement to replace its current naval force replenishment ships, has taken account of the need to nationally support Coalition forces in intervention operations "From the Sea". With a highly constrained defence budget, in common with other NATO navies, this has meant that such replacement programmes are looked to provide more than just a straight up date of the existing replenishment capability. Thus the requirement given in the Request for Quotations (RFQ) in July 2006 for a class of Joint Support Ships (JSS) placed significant emphasis, alongside the usual replenishment features, for a substantial level of features associated with the Sealift/Intervention capability (namely: vehicle carriage, containerised cargo, medical support, Joint Forces Headquarters (JFHQ)) alongside the Replenishment demands (including aviation, self defence and command and surveillance) [1].

The UCL Design Research Centre, as part of the Marine Research Group within the Department of Mechanical Engineering at University College London (UCL), has been set up to explore innovative ways of undertaking the design of complex products such as naval vessels. The DRC was approached, by one of the four consortia invited by the Canadian NDF HQ to respond to the JSS RFQ, to undertake a short study in parallel with the consortium's main design studies in response to the RFQ. The UCL study was to use the Design Building Block (DBB) approach, pioneered by the DRC, to explore a range of possible design solutions to the RFQ. It was hoped that these wider explorations would both give confidence that the consortium's solution, being developed in parallel, could be benchmarked by an independent study and any potentially attractive design features, arising from the UCL design studies, could be incorporated in the consortium's RFQ response. Furthermore, it was hoped that the use of the DBB approach's realisation through the Graphic Research Corporation's SURFCON tool could be demonstrated as a useful exploration tool in the subsequent development of the JSS following any contract to develop the JSS.

2. OUTLINE OF THE DESIGN BUILDING BLOCK APPROACH

The UCL Design Research Centre was established in 2000, alongside the MoD sponsored Naval Architecture and Marine Engineering Group, as part of an expanded Marine Research Group at UCL. The DRC's remit is to specifically focus on Computer Aided Design and in so doing has an alliance with the Graphics Research Corporation Limited developing the Design Building Block approach through the SURFCON facility as part of GRC's PARAMARINE Preliminary Ship Design System [2].

The logic behind the SURFCON tool realisation of the Design Building Block approach has been spelt out in a

2003 paper in a RINA journal [3]. In essence this approach focuses on ship architecture and how it is produced alongside the traditional numerical sizing and naval architectural balance. The Design Building Block approach to producing a new ship design was presented in Figure 5 of Reference 4, reproduced at Figure 1. This diagram summarises a comprehensive set of analysis processes most of which are unlikely to be used in the initial setting up of the design or even early iterations around the sequence of building blocks, geometric definition and size balance. In fact several of the inputs shown in Figure 1 are either specific to the naval combatant case, such as topside features, or omit aspects which could be dominant in specialist vessels, such as aircraft carriers or amphibious warfare vessels, where personnel and vehicle flow are likely to dominate the internal ship configuration.

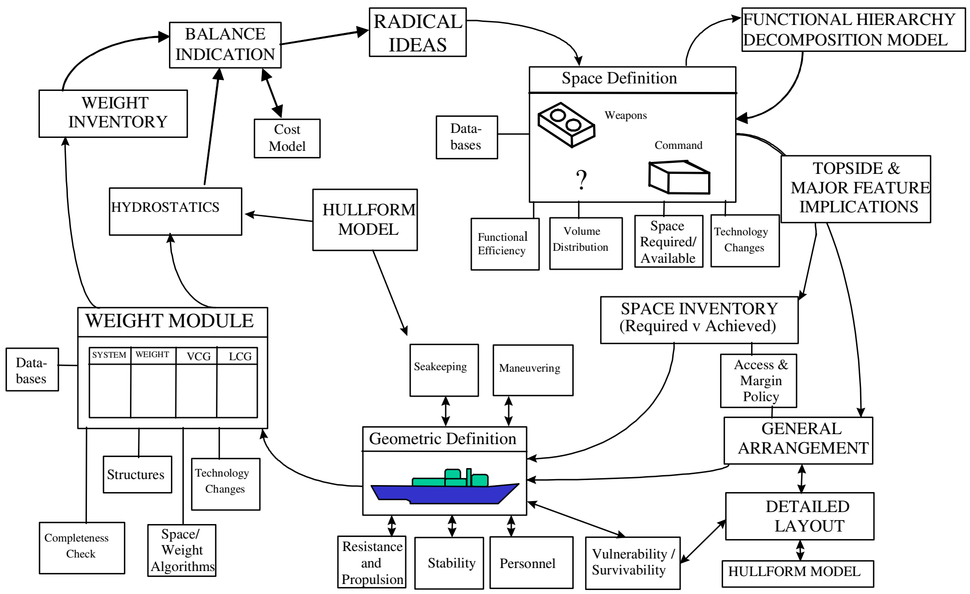

Figure 1 Overview of the Design Building Block Methodology applied to Surface Ships [4]

A further feature of SURFCON is the use of the term Master Building Block to denote how the overall aggregated attributes of the building blocks can be brought together to provide the numerical description of the resultant ship design. The advantage of providing the Design Building Block capability of SURFCON, as an adjunct to the already established ship design suite of PARAMARINE [5], is that the audited building block attributes, within the Master Building Block, can be directly used by PARAMARINE. This means the necessary naval architectural calculations, to ascertain the balance or otherwise of the configuration just produced by the designer, can be performed. Typical information held in the Master Building Block includes:

- Overall requirements: Ship speed, seakeeping, stability, signatures (in the case of a naval combatant);
- Ship characteristics: weight, space, centroid;
- Overall margins: weight, space and their locations for both growth and enhancement.

As the design description is built up and modified, all the features of the building blocks are utilised by the system. The geometric definition (shape and location) is used to constantly update the graphical display, whilst data properties are indicated in a logical tree diagram of the design, as shown in Figure 2. Figure 2 also shows the block representation and a tabular view of typical numerical information from a specific analysis of the design.

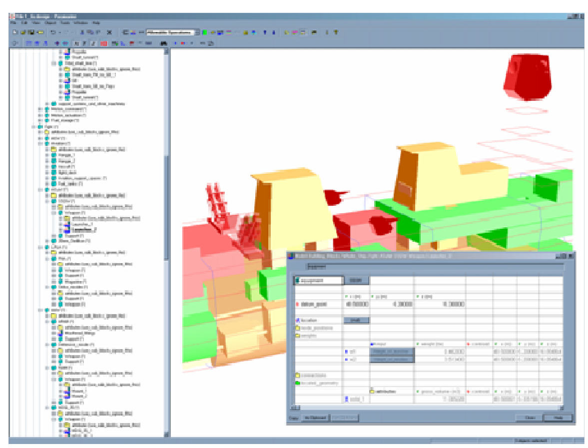

Figure 2 Example of the three screens used in PARAMARINE-SURFCON [6]

The paper the authors presented to last year’s International Marine Design Conference reviewed the wide range of studies undertaken by the UCL DRC in the last five years [6]. These have ranged from investigations in support of requirement elucidation (for the UK MoD) through Design for Production studies involving VT Shipbuilders and Ferguson Shipbuilders (funded by the UK Shipbuilders & Shiprepairers Association) to ongoing studies into design for personnel movement on naval vessels (for the UK MoD and funded by the Engineering and Physical Sciences Research Council). The latter were reported in the RINA Human Factors Conference in March 2007 [7]. Probably the studies undertaken by the DRC that are most relevant to those that are the subject of this paper were reported to the 2004 and 2006 Warship Conferences. The first of these was on a series of Mothership studies undertaken with BMT DSL in 2003 for the UK MoD Future Business Group to explore the possible options for fast deployment to littoral campaigns of small combatant vessels [8]. The DRC task consisted of designing seven discrete ship concept studies, ranging from a heavy lift ship to a stern ramp arrangement to deploy and recover the small combatants once the Mothership had transported them to the operational area. The seven balanced design studies were produced to a reasonable level of definition, as can be seen from the example in Figure 3 and were sufficient to appreciate the feasibility of the concept and compare the distinctly different configurations for what was an immature operational concept. In contrast the Littoral Combatant Ship study undertaken for the US Navy Office of Naval Research was a more in depth study of a single configuration to meet a precise set of requirements. This was for a fast Trimaran of frigate size, where the design issue was more one of balancing the demands of a 40 knot speed with provision for carriage and deployment of a range of small assets from the stern of the vessel, see Figure 4 [9]. It was thus necessary, due both to the technical novelty and the configurational conflicts, to study this one concept in more depth than in the case of the Mothership investigation. The JSS study could be seen as lying midway between these two exercises, in that it was in response to a worked up requirement, all be it with a range of specific capabilities to be explored, but the opportunity was taken to investigate several configurational variants. It was in regard to this latter aspect where it was felt that the UCL DBB approach was particularly advantageous, given its ability to provide naval architecturally balanced design studies driven by the internal arrangement of the major features.

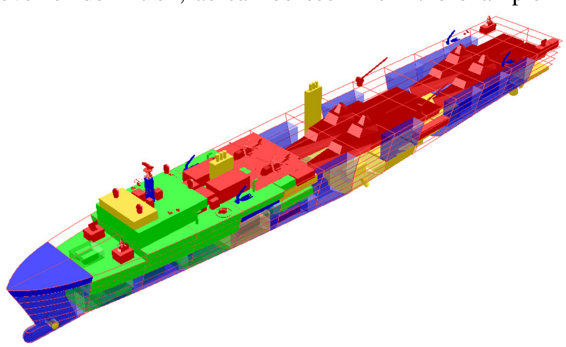

Figure 3 A UCL Mothership Study [8]

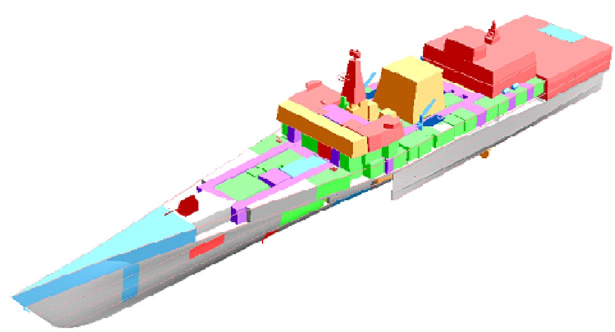

Figure 4 The UCL Study of the Trimaran LCS [9]

3. FOUR INITIAL STUDIES

The design studies undertaken by the UCL team were initially configured to meet the minimum "shall" requirements as specified by the Canadian National Defence Department's JSS Project Management Office (JSS PMO) [10]. However, following a design review with the consortium's bid team, the UCL design studies were reconfigured to meet as many of the "should" requirements as possible, to be in line with the main bid team's proposals, which the UCL studies were intended to inform. The main requirements are summarised in Table 1. The JSS is not intended to meet all these requirements simultaneously, rather there are two main roles; Naval Task Group (NTG), where the JSS provides replenishment, aviation and medical support to a task group; and Joint Force Sealift (JFS), where the JSS transports vehicular and containerised cargo and provides an afloat Joint Forces Headquarters.

Requirements	Shall	Should
Payload		
F76, te	7000	10000
F44, te	650	1300
FW, te	200	400
Task Group Munitions, m2	650	1150
Task Group Supplies, m2	200	500
TEUs	20	100
Lane Metres	1000	1500
Vehicle Ro-Ro	Yes	Yes
RAS		
Heavy RAS Stations	4	4
Light RAS Stations	2	2
Aviation		
Cyclone Stowages	3	4
Flight Deck Spots	1	2
Cyclone Spares, m3	200	200
Performance		
Max Speed, knts	20	22
Cruise Speed, knts	15	20
Cruise Range, nm	10800	17000
Accommodation		
Core Crew	165	165
Mission Crew	158	158
Max Dimensions		
Loa, m	210	185
Boa, m	32	24
Toa, m	9.5	7.5
Air Draught, m	44	44

Table 1 Requirements used at beginning of JSS Studies

It was decided from the beginning to keep the main mission elements of the vessel, described in the DBB approach under the FIGHT Functional Group, as separately defined:-

- Replenishment;
- Aviation;
- Medical Support;
- Sealift;
- Joint Forces Headquarters (JFHQ);
- Self Defence;
- Command and Surveillance.

Several overall stylistic aspects of the design were specified at this stage; the JSS would be a monohull with full sections to allow a large cargo carrying capacity and so an appropriate hullform geometry model was selected. The design used the sizing data from the UCL MSc Ship Design Exercise database [11] and marine engineering systems data was drawn from that held by the UCL DRC. Additionally, a UCL MSc design exercise of a replenishment ship was used as a guide to current RN practice for the replenishment features of the design [12].

The initial layout was developed from a limited number of Building Blocks in the FIGHT and MOVE groups. These were placed by hand, outlining a rough configuration. Four initial configurations were developed as shown in Figures 6, 7, 8 and 9. As these figures indicate, a rough hullform was generated based on the estimated displacement and dimensions of the first configuration. The grid of bulkheads and decks, shown in the figures, was used as an “index” for the positions of the Design Building Blocks and adopted in the subsequent studies. They defined watertight compartments and decks, producing a coherent definition of the design. Figure 5 shows the colour scheme used for the blocks in the JSS designs to identify, in particular, the operational spaces.

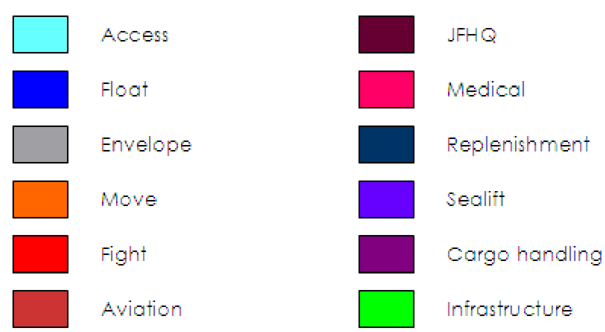

Figure 5: Key to colours used in the JSS Study

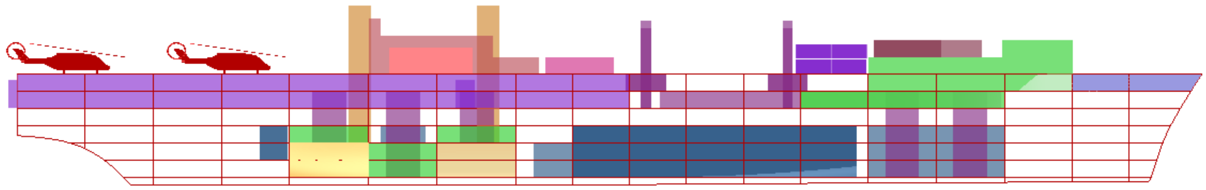

Figure 6: Initial JSS Configuration 1 profile view

Configuration 1 has the following features:

- Half-length full-width vehicle deck;
- Aft machinery spaces separated by one compartment;
- Double spot flight deck and hangar for three Cyclone heavy lift helicopters;
- Midships high cargo tanks (three decks);
- Magazines forward;
- Replenishment at Sea (RAS) rigs forward of amidships with open waists in way;
- RAS rigs and dispersal area on same deck as vehicle deck with munitions passage to forward magazine lifts;
- Accommodation block in hull and superstructure forward;
- Ship's stores aft.

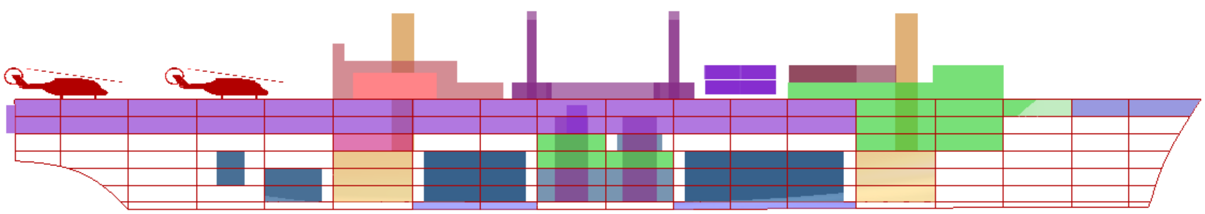

Figure 7: Initial JSS Configuration 2 profile view

Configuration 2 has the following features:

- A reduced width and three-quarter length vehicle deck;
- Split machinery spaces placed well forward and well aft;
- Double spot flight deck and hangar for three Cyclones;
- Cargo tanks split by magazines;
- Midships RAS rigs with continuous upperdeck;
- RAS rigs and dispersal area on upperdeck directly over magazine lifts;
- Accommodation forward in hull and superstructure;
- Ships stores over magazines amidships.

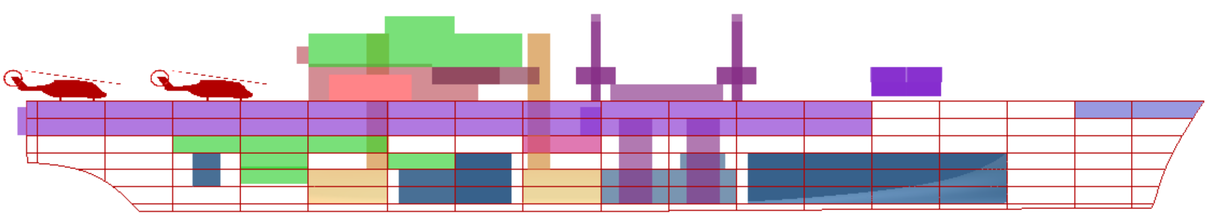

Figure 8: Initial JSS Configuration 3 profile view

Configuration 3 has the following features:

- A reduced width and three-quarter length vehicle deck;
- Aft machinery spaces separated by two compartments;
- Double spot flight deck and hangar for three Cyclones;
- Midships magazines;
- Split cargo tanks, with main block forward;
- Midships RAS rigs with continuous upperdeck;

- RAS rigs and dispersal area on upperdeck directly over magazine lifts;
- All accommodation in superstructure aft over hangar;
- Ship's stores aft;
- Open deck forward with containers exposed.

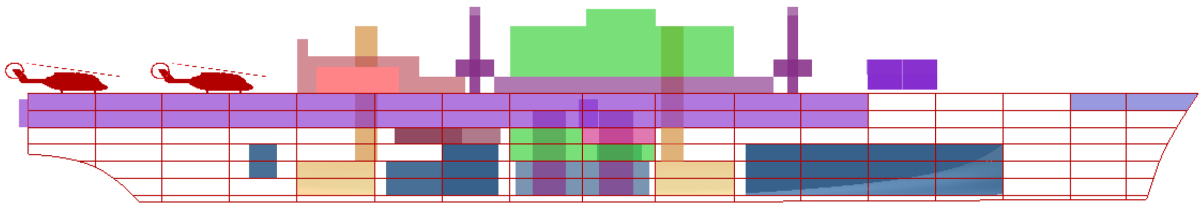

Figure 9: Initial JSS Configuration 4 profile view

Configuration 4 has the following features:

- A reduced width and three-quarter length vehicle deck;
- Machinery spaces amidships and aft separated by four compartments;
- Double spot flight deck and hangar for three Cyclones;
- Midships magazines;
- Split cargo tanks, with main block forward;
- RAS rigs split forward and aft of superstructure block with continuous upperdeck;
- RAS dispersal area on upperdeck linking RAS rigs and magazine lifts;
- Accommodation in superstructure block amidships;
- Ship's stores over magazines;
- Open deck forward with containers exposed;

All these initial configurations were designed to meet the "shall" criteria, although in each case it was possible to accommodate a double flightdeck. Table 2 summarises the principal particulars of the four configurations. At this stage all the designs used the same basic hull, hence the overall hull dimensions were the same, since at this level of detail no hull parametric survey had been conducted. The final entry in the table, Lmin is the minimum length required based on the current layout. The next logical step in developing each of the designs would be to reduce the hull dimensions to those required by each distinct layout. In addition to the common hull, the machinery configuration was the same for each of these initial designs, with two main machinery spaces each containing two diesel generators (the exact power to be specified later in the design process). The propulsors were not specified at this stage, but from the initial configurations it was clear that accommodating a conventional shaft line in the hull could prove difficult, which suggested the adoption of podded propulsors.

Table 2 also compares the number of entities (Building Blocks and Equipment Items) used to define each initial configuration. A lower number implies a simplified configuration with fewer, large tanks and accommodation flats. Although 100 items is more than would normally be used to define an initial design, it should be noted that 30 of these are essentially repeated items, representing TEUs and Lane Metres on the vehicle deck. In addition there are many Design Building Blocks representing individual tanks in large groups. These are shown in Table 2 and indicate that between 30 and 40 "discrete" entities were actually used to define the initial configurations. Table 2 omits a comparison of tankage capacities and requirements as, at this stage in the design, the tanks were sized to meet a required capacity and then the hull "wrapped" around them, rather than moving tanks around in a pre-defined hullform. However, the hullform generation tools produce a fair hullform, so the tankage definition was altered to accommodate the hydrodynamic needs of the design. This can be seen in Figures 8 and 9, where the forward tanks have a shape that follows the hullform, as opposed to the simple block tanks nearer amidships.

Configuration	1	2	3	4	
Lwl	200	200	200	200	m
Loa	210	210	210	210	m
Bwl	27	27	27	27	m
Boa	30	30	30	30	m
Thull	8.9	8.9	8.9	8.9	m
Displacement	31428	31428	31428	31428	te
Number Entities	100	96	90	90	
Grouped Entities	30	30	30	30	
Tanks and Stores	29	27	27	27	
Discrete Entities	41	39	33	33	
Lmin	189	189	178	178	m

Table 2: Summary of the particulars of the four initial JSS configurations

At this early stage in the process, the integrated spatial and numerical models allowed the four configurations to be assessed for resistance and powering, intact and damaged stability. For the stability assessments, the centre of mass was derived from those items that had been placed in the design together with an assumed centroid for the currently unplaced items (structure, distributed systems, etc). At this early stage free surface effects from fluids in tanks were neglected (although they could have been modelled if required). The main concern was whether sufficient freeboard remained after damage to prevent submergence of the vehicle deck. With the initial bulkhead spacing, the 10m "shall" damage length led to a two-compartment damage case. In none of the eighteen damage cases examined did the vehicle deck become submerged, although in the worst-case of damage aft, freeboard to the vehicle deck was reduced to approximately 1.5m. In addition to these numerical assessments, the spatial model allowed the designs to be assessed for the practicality of the configurations, both at this early stage and the potential for problems to occur as each design was developed. The four configurations were all considered for future development and it was decided that Configurations 2 and 3 were the most effective configurations.

4. TWO REFINED STUDIES

As with the initial designs, these were assessed for various aspects of performance, including resistance and powering, area available and required, intact and damage stability. For the stability assessments, free-surface effects in tanks were now included, although only three loading conditions were used, 95% (Deep), 5% (Light Sea Going), 0% (Light). Given the two main roles of the vessel (Afloat Support and Sealift) this gives a minimum of six intact stability cases. Both remaining configurations passed all six cases, but ballast was required forward to prevent excessive trim by the stern in the Light and Light Sea Going cases for both configurations. As with the initial configurations, both designs were assessed for two-compartment damage cases, with particular attention paid to the freeboard to the vehicle deck. The following descriptions concentrate on the overall configuration and performance of the vessel.

Figure 10 shows an overview of the refined Configuration 2 design with all Design Building Blocks visible. This refined design retained the overall configuration initially developed, but introduced further definition along with additional details, such as superstructure arrangement and propulsion equipment location.

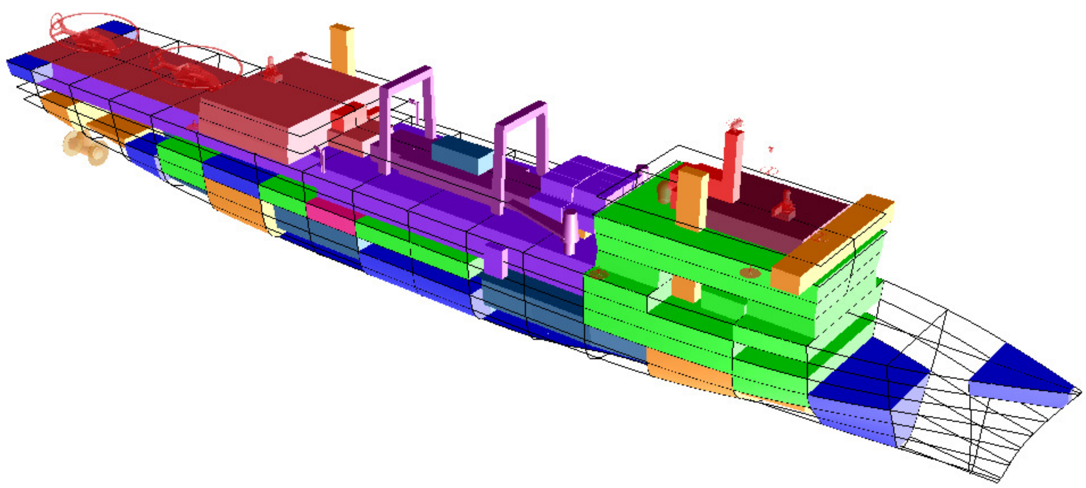

Figure 10 Perspective view of the refined JSS Configuration 2 design

As Figure 10 shows, all the accommodation was moved into the superstructure, with provisions stores and personnel support spaces in the hull underneath it. The superstructure sides were sloped at 7 degrees from the vertical to reduce Radar Cross Section and flared out to increase the area on the accommodation decks. In addition to placing equipment items, such as the CIWS and propulsion machinery, the introduction of more detailed stability analysis led to the sizing of ballast and trim tanks for the light load conditions. Table 3 lists the principal particulars of the refined design and Table 4 compares the design against the numerical requirements.

Dimension	Value	Unit
Length WL	199.5	m
Length OA	209.5	m
Beam WL	26.2	m
Beam OA	29	m
Double Hull Separation	1.5	m
Depth Midships	19.3	m
Max Draught	8.9	m
Max Air Draught	36.4	m
Min Deckhead	3	m
Enclosed Volume	99654	m3
Deep Displacement	31224	te

Table 3: Principal particulars of the refined JSS Configuration 2 design

Requirements	Required (Shall)	Achieved	Unit
F76	7000	7500	te
F44	650	653	te
FW	200	274	te
Task Group Munitions	650	691	m2
Task Group Supplies	200	200	m3
Cyclone Spares	200	200	m3
TEUs	20	20	
Lane Metres	1000	1013	
Power for 20kts	21.4	-	MW
Power for 15kts	8.3	-	MW
Hotel Power	2.1	-	MW
Total Power 20kts	23.5	29.5	MW
Total Power 15kts	10.4	11.1	MW
JSS Fuel	1386	1426	te
JSS Stores	812	723	m2
CO	1	1	
XO	1	1	
HoD + mission HoD	6 + 3	6 + 3	
O + mission O	12 + 67	12 + 67	
Cox	1	1	
CPO + mission CPO	7 + 9	7 + 9	
PO + mission PO	33 + 32	33 + 32	
JR + mission JR	104 + 47	104 + 47	
Loa	210	209.5	m
Boa	32	29	m
Toa	9.5	8.9	m
Air Draught	44	36.4	m

Table 4: Comparison of requirements and performance of the refined JSS Configuration 2 design

Table 4 shows that the refined Configuration 2 design exceeds the required cargo capacities in most areas, except that of the JSS stores. Given the presence of available deck area in the hull forward, this could easily be resolved in a subsequent iteration. Considering the overall arrangement, it was concluded that the excessive cargo capacity was due to the location of the tankage in the widest spaces amidships, compared to the other configurations where the tankage was forward or aft of midships.

The total installed power also exceeds the required power for propulsion and services at the maximum speed of 20 knots, although the two are more closely matched at the cruise speed of 15 knots. This is due to a prime mover selection of four identical units from the Wartsila range, on which data was available. This was accepted at this stage in the design for the following reasons:

- The use of discrete engines within a range limited the number of combinations available;
- Past design work has shown it is easier to remove installed power than to add it to a design, thus in the next iteration if the power required was to increase, it would be catered for. However should this decrease then alternative machinery configurations would be investigated.

Figure 11 shows an overview of the refined Configuration 3 design with all Building Blocks visible. This refined design also retained the overall configuration initially developed, but introduced further definition along with additional details, such as superstructure arrangement and propulsion equipment location.

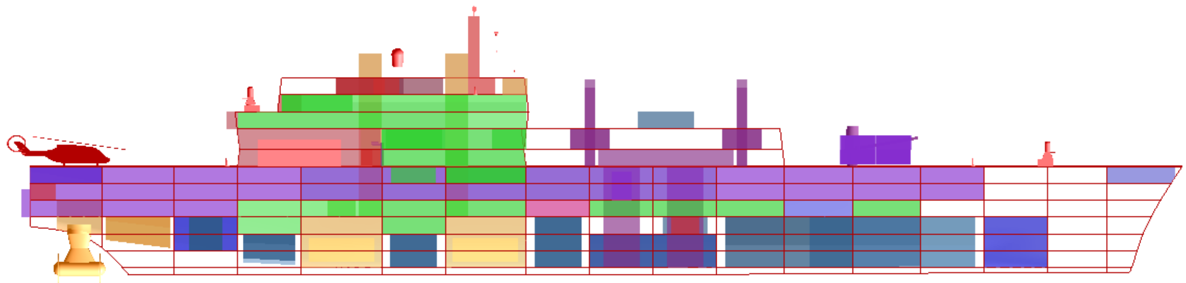

Figure 11: Profile of the refined JSS Configuration 3 design

This figure shows that a number of changes have been made to the design from the initial configuration:

- Main machinery spaces have been moved closer together (still separated by one compartment for survivability);
- The main superstructure block has been enlarged to contain all accommodation spaces with the JFHQ spaces on the uppermost deck;
- The midships superstructure block containing the RAS equipment has been enlarged by an additional deck;
- Auxiliary machinery spaces and ship's stores occupy a large part of the aft hull in this configuration, whereas they were spread over the midships and forward areas in Configuration 2;
- The overall length has been reduced from the initial configuration, however, there is still void volume in the hull forward and there appeared to be potential to reduce the length further;
- The flight deck has been reduced to a single spot in reducing the ship's length.

Table 5 lists the principal particulars of the refined design, and Table 6 compares the design against the numerical requirements

Dimension	Value	Unit
Length WL	195	m
Length OA	205	m
Beam WL	27	m
Beam OA	30	m
Double Hull	1.5	m
Depth MS	19.3	m
Max Draught	8.9	m
Max Air Draught	36.4	m
Min Deckhead	3	m
Enclosed Volume	107304	m3
Deep Displacement	32245	te

Table 5 Principal particulars of the refined JSS Configuration 3 design

Requirements	Required (Shall)	Achieved	Unit
F76	7000	6993	te
F44	650	689	te
FW	200	205.2	te
Task Group Munitions	650	709	m2
Task Group Supplies	200	200	m3
Cyclone Spares	200	200	m3
TEUs	20	20	
Lane Metres	1000	1002	
Power for 20kts	22.2	-	MW
Power for 15kts	8.4	-	MW
Hotel Power	2.1	-	MW
Total Power 20kts	24.3	29.5	MW
Total Power 15kts	10.5	11.1	MW
JSS Fuel	1403	1472	te
JSS Stores	812	782	m2
CO	1	1	
XO	1	1	
HoD + mHoD	6 + 3	6 + 3	
O + mO	12 + 67	12 + 67	
Cox	1	1	
CPO + mCPO	7 + 9	7 + 9	
PO + mPO	33 + 32	33 + 32	
JR + mJR	104 + 47	104 + 47	
Loa	210	205	m
Boa	32	30	m
Toa	9.5	8.9	m
Air Draught	44	36.2	m

Table 6 Comparison of requirements and performance for the refined JSS Configuration 3 design

This design has insufficient JSS stores and tankage for F76 fuel. The latter is due to the position of the tanks relatively further forward in a shorter hullform. This design required more ballast in the trim tanks forward when in the Light Load Condition, due to the aft position of the main machinery and accommodation. The aft concentration of support spaces and stores was of concern regarding the practicality in developing this design further, particularly the amount of volume available for auxiliary machinery spaces. As can be seen in Figure 11, some support spaces were placed in the narrow wing compartments outboard of the vehicle deck, which was not considered a satisfactory solution. The original concept adopted a narrow vehicle deck giving these spaces a useful width, but this arrangement was shown to be inefficient in accommodating the maximum lane metres in the ship's length.

5. THE FINAL DEVELOPED CONFIGURATION

5.1 GENERAL DESCRIPTION (INCLUDING MARGINS)

The final developed design was based on the development of Configuration 2 outlined in the previous section. The final development exhibited split main machinery rooms, taking advantage of Integrated Full Electric Propulsion (IFEP) and podded propulsors to separate machinery spaces. This configuration also allowed the concentration of munitions stores and tankage in the widest parts of the ship, amidships, with the aviation spaces aft and accommodation forward. Figure 12 illustrates the overall profile of the vessel, and Table 7 provides a summary of the principal particulars of the developed design. This design was developed with two main priorities: to reduce the ship's length and to increase the cargo capacity to match the "should" requirements for the JSS. This led to changes to the configuration when compared with the intermediate design stage described in the previous section.

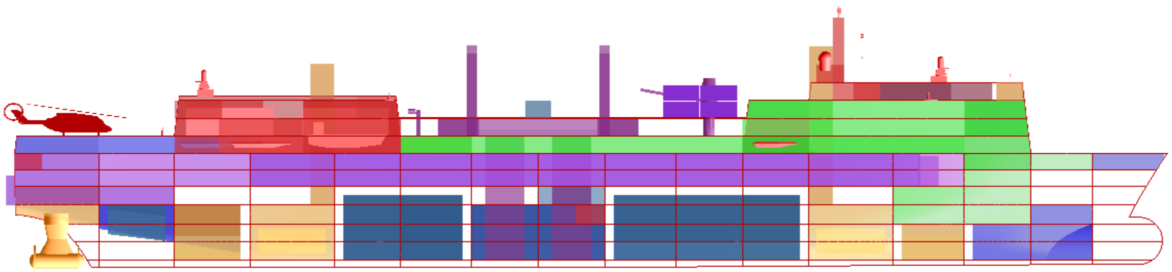

Figure 12 Profile with all blocks visible of the Developed JSS Design

Dimension	Value	Unit
Length WL	186	m
Length OA	196	m
Beam WL	29.8	m
Beam OA	31	m
Double Hull	1.5	m
Depth MS	19.3	m
Max Draught	9.3	m
Max Air Draught	39	m
Min Deckhead	2.75	m
Enclosed Volume	121600	m3

Condition	Displacement	Unit
NTG		
Deep	33297	te
Light	21602	te
Light Sea Going	20728	te
Working	26879	te
JFS		
Deep	26193	te
Light	21602	te
Light Sea Going	22208	te
Working	23125	te

Table 7 Principal particulars of the Developed JSS Design

Following the design review with the main bid team, the development of Configuration 2 was changed to meet as many of the "should" cargo requirements as possible to be consistent with the emerging bid design. Table 8 summarises the numerical requirements for the design (including the accommodation requirements) and the degree to which they were met.

Requirements	Required (Should)	Achieved	Unit
F76	10000	9778	te
F44	1300	1369	te
FW	400	404	te
Task Group Munitions	1150	1058	m2
Task Group Supplies	500	1052	m3
Cyclone Spares	200	217	m3
TEUs	100	24	
Lane Metres	1500	1500	
Power for 20knt	22.4	-	MW
Power for 15knt	8.9	-	MW
Hotel Power	2.1	-	MW
Total Power 20	24.5	29.5	MW
Total Power 15	11	11.1	MW
JSS Fuel	1470	1499	te
JSS Stores	812	863	m2
CO	1	1	
XO	1	1	
HoD + mHoD	6 + 3	6 + 3	
O + mO	12 + 67	12 + 67	
Cox	1	1	
CPO + mCPO	7 + 9	7 + 9	
PO + mPO	33 + 32	33 + 32	
JR + mJR	104 + 47	104 + 47	
Loa	210	196	m
Boa	32	31	m
Toa	9.5	9.3	m
Air Draught	44	39	m

Table 8 Design requirements and achieved values for the Developed JSS Design

Tables 9 and 10 provide a weight breakdown of the developed design, using both the Functional Hierarchy and the UCL Ship Design Exercise breakdown structure. (This is very similar to the UK MoD NES 140 breakdown [13].) The values in Tables 9 and 10 are for the deepest load condition with margins and the origin for centroid positions is at the transom location on the baseline (lowest part of the keel).

Building Block	Weight	Centroid		
	(te)	x (m)	y (m)	z (m)
master_BB	32048.7	91.79	-0.03	10.71
float	12786.3	92.05	0.00	12.82
move	2990.6	73.09	0.00	5.42
fight	13323.7	93.03	-0.02	8.77
infrastructure	2948.0	103.99	-0.20	15.65
Board & Growth Margins	1248.4	91.14	0.00	14.64
Total	33297.0			

Table 9 Weight breakdown for the Developed JSS Design using UCL Functional Hierarchy

Item	Weight	Centroid		
	(te)	x (m)	y (m)	z (m)
UCL_SDE	33297.02	91.76	-0.03	10.85
1_hull	12948.24	92.22	-0.01	13.20
2_personnel	270.25	138.99	0.48	22.36
3_ship_systems	1191.49	98.55	0.00	12.06
4_main_propulsion	1290.90	58.64	0.00	5.13
5_electric_power	975.52	93.00	0.00	15.18
6_payload	946.00	90.25	-0.41	27.65
7_variable	14426.25	92.94	-0.03	7.23
Board & Growth Margins	1248.4	91.14	0.00	14.64
Total	33297.02			

Table 10 Weight breakdown for the Developed JSS Design using UCL weight breakdown structure

Three types of weight margins were used in the UCL JSS designs:-

- Design margins: These were applied where required to Building Blocks. Access margins on accommodation flats were applied as a design margin, and a 5% margin was applied to structural weight. (Based on UCL practice.)
- Growth margin: This is a margin for through life growth. A figure of 5% lightship weight was used, i.e. 10 year assurance, assuming ½ % annual unplanned growth.
- Board Margin: This is a margin for future requirement additions to the vessel, historically assigned for Royal Navy vessels by the Admiralty Board. A figure of 2% lightship weight was used. This margin is based on UCL practice for smaller surface warships, such as frigates and destroyers, and so may not be appropriate for this type of vessel, however this would depend on typical Canadian Navy practice in this area.

Table 11 gives a breakdown of the area and volume allocations in the design. It should be noted that some of the space requirements, such as access and systems, were only compared against the overall volume in the envelope, and were not modelled directly at this stage in the design.

Building Block	Area	Volume
	m2	m3
master_BB	9828.6	68672.3
float	1106.1	5717.8
move	211.5	10711.9
fight	2387.5	48843.1
infrastructure	2948.0	3399.5
Total	9828.6	68672.3

Table 11 Area breakdown using UCL Functional Hierarchy for the Developed JSS Design

5.2 HULL CHARACTERISTICS

The JSS hullform was generated using the "Quickhull" functionality in PARAMARINE [2]. This tool generates a hull surface to meet a target Cross Sectional Area (CSA) curve. Although Quickhull is most suitable for frigate and destroyer hulls, it also has a capability for generating the fuller hullforms found in merchantships and naval auxiliaries. GRC are currently implementing a more generally applicable hull generation tool known as "Intellihull", which is equally suited to naval vessels and merchant ships. In addition to these specialist tools, the surface editing and modelling tools within PARAMARINE can be used to generate hullforms by hand, or by using a numerical geometry model to distort a parent hull.

The advantage of the Quickhull and Intellihull tools is that they allow the hullform to be rapidly altered to reflect changes in the design, which was particularly important in the UCL study. The lines of the final hullform provide a full midships section and parallel midbody to increase cargo tank volume within a given length. However, the forward waterplanes are very narrow and resemble those of a surface combatant more than a support vessel. This could be readily remedied by using one of the alternative approaches mentioned above, or by careful editing of the inputs utilised by Quickhull. (There was insufficient time in this quick investigation.) Table 12 provides a summary of the main hullform coefficients based on a smooth curve of areas.

Midships Coefficient	0.915
Block Coefficient	0.651
Prismatic Coefficient (Aft)	0.727
Prismatic Coefficient (Fwd)	0.695
Prismatic Coefficient (Overall)	0.711
Waterplane Coefficient	0.855

Table 12 Summary of main hull coefficients for the Developed JSS Design

5.3 FUNCTIONAL BREAKDOWN

Figure 13 provides a simple view of the ship design. PARAMARINE-SURFCON enabled interrogation of a genuine 3-D description from any view.

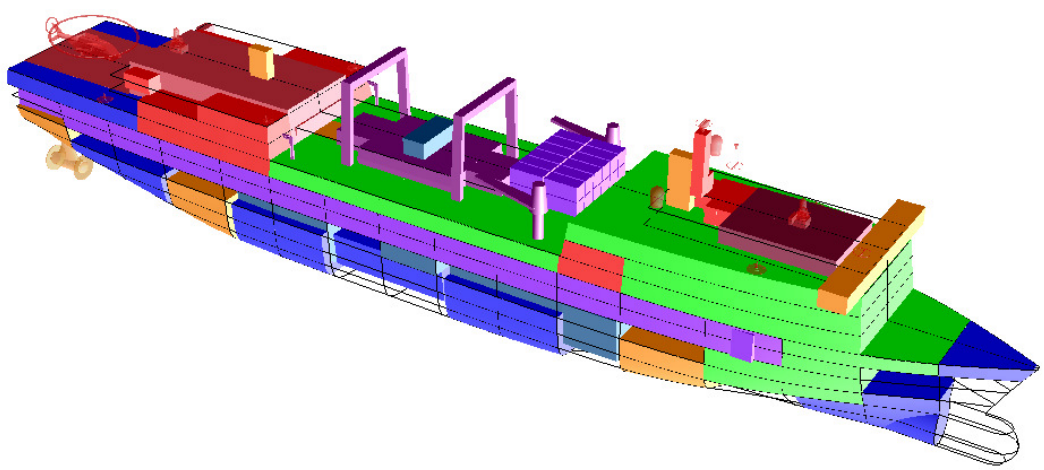

Figure 13 Design Building Block model of the Developed JSS Design with all blocks visible

A complete AutoCAD General Arrangement drawing of the vessel was also provided to the main bid team along with a series of sections through the vessel. The remainder of this sub-section of the report describes the vessel by function, using the Functional Hierarchy provided by the Design Building Block approach to ship design [4].

Figure 14 shows the FLOAT Functional Group, with the main issues:-

- Trim tanks in the bow and stern: The intact stability analysis showed that the JSS does not require ballast to maintain stability, but does require it to control trim. The tanks were sized based on the minimum amount of ballast required to maintain a trim of between 0.6m and 1m by the stern. Figure 14 also reveals that ballast tanks are provided outboard of the cargo fuel tanks (in the double hull). However, subsequent stability analysis for a range of loading conditions showed that these were probably not required.
- JSS workshops aft under the flight deck: The workshops were sized using UCL data and placed under the flightdeck, as they are least affected by aircraft noise.
- Mooring and hose / cable fleeting spaces forward and aft: The quarterdeck aft is used for mooring and stern refuelling operations. It is placed on No 1 Deck, in the superstructure, to provide a clear vehicle deck. This is at a greater height above the waterline than is typically the case for UK Royal Fleet Auxiliaries (RFA) and may affect astern refuelling operations.
- Side protection systems amidships around the munitions stores: These were based on torpedo protection systems developed for the CVA-01 aircraft carrier design of the 1960s'[14] and consist of an outer void space (double hull), double longitudinal bulkheads filled with seawater and a further inner void with a holding bulkhead. This is intended to provide protection against attack by explosive-laden boats (as in the case of the attack on USS Cole) or Rocket Propelled Granades (RPG). The overall configuration is consistent with structural continuity of the main cargo tanks and has a maximum depth transversely of 6.25m. The total weight of this arrangement is estimated to be 590te.
- Vertical access "island" on the centreline in the vehicle deck: To prevent structural complications arising from deck penetrations near the side shell, all vertical access routes and uptakes passing through the vehicle deck are grouped on the centreline, with a central "island". If this central feature is structurally integrated to be made effective then it will also reduce the unsupported span over the vehicle deck.

For this early-stage study, the structural weight of the vessel was estimated using the volume of the hull, superstructure and double hull sections plus an associated structural weight density drawn from the UCL database. The resulting structural weight fraction is 59% of lightship, slightly higher than a typical RFA replenishment vessel but does include a 5% weight margin.

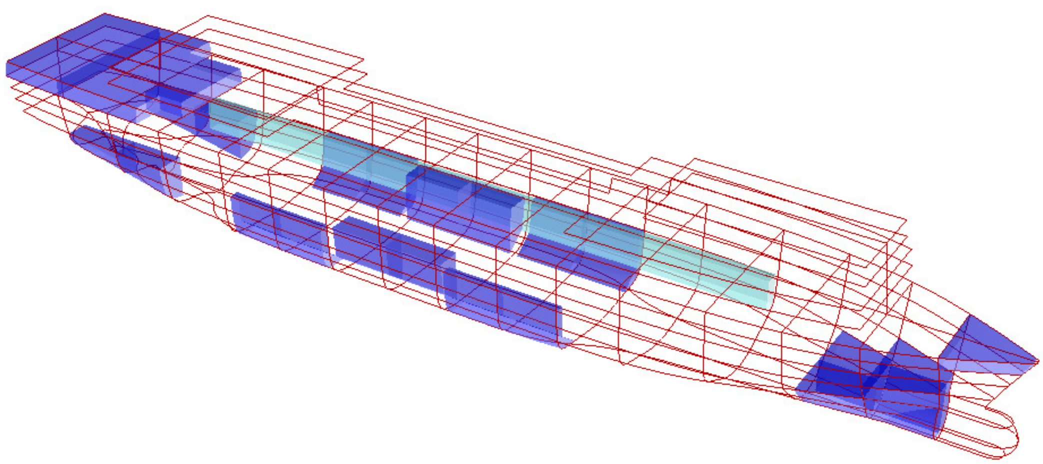

Figure 14 FLOAT and ACCESS functional groups for the Developed JSS Design

In the MOVE Functional Group the two main machinery spaces were split forward and aft to allow the cargo to be concentrated amidships (see Figure 15). Similarly the JSS F76 fuel tanks were split forward and aft and co-located with the machinery spaces. Resistance and powering were estimated using the objects provided in PARAMARINE. For the maximum speed of 20 knots a propulsive power of 22.45MW was required, decreasing to 8.94MW at the cruise speed of 15knots. The main machinery configuration consists of four Wartsila 16V32 diesel generators, each producing 7.37MW, arranged with two in each machinery space. These are connected in an IFEP arrangement to two podded propulsors, assumed to be the Shottel SSP14 14MW type. The two main architectural issues associated with the Move function are the interaction between the pods and the aft ramp, and the interaction of the uptakes with the vehicle deck. Figure 16 shows how the aft vehicle ramp, used to offload vehicles onto the Landing Craft while at sea, cuts through the pod machinery space on the centreline. However, as the pods are located outboard, this was felt to be an acceptable arrangement. The uptake issue was resolved by the use of the centreline "island" in the vehicle deck, as just outlined.

Although the use of pods introduced the potential for spatial conflict aft, it was deemed advantageous for the following reasons:

- To recover some of the machinery efficiency lost by the choice of an IFEP propulsion system by placing the propellers in a better flow field than for the case of a propeller fit;
- To reduce the internal space needed for the propulsion motors and allow flexibility in the layout of machinery spaces and cargo tanks, by avoiding long shafts or an additional motor room;
- Improved manoeuvrability through the use of azimuthing propulsors.

The disadvantages identified were as follows:

- Increased technical risk, as large pods have not yet been used on a naval vessel, despite being widely used in a variety of civilian vessels;
- Potential spatial conflict aft;
- Increased trim by the stern in light loaded conditions due to the concentration of weight aft;
- Increased length of High Voltage IFEP cable runs, leading to increased cabling weight and expense due to conversion machinery located above the pods.

In addition, given the hullform was designed for cargo capacity not propulsion, the aft lines may need to be modified in order to realise the potential efficiency improvements of podded propulsion.

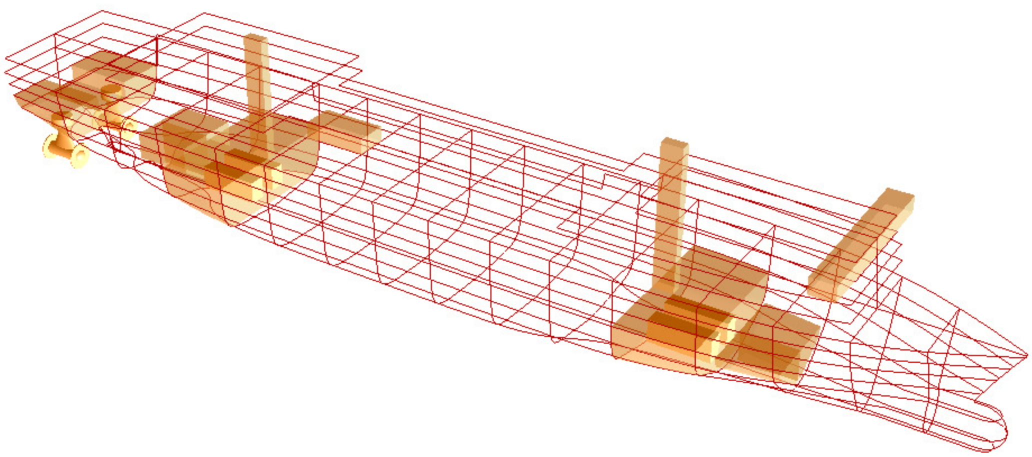

Figure 15 The MOVE functional group for the Developed JSS Design.

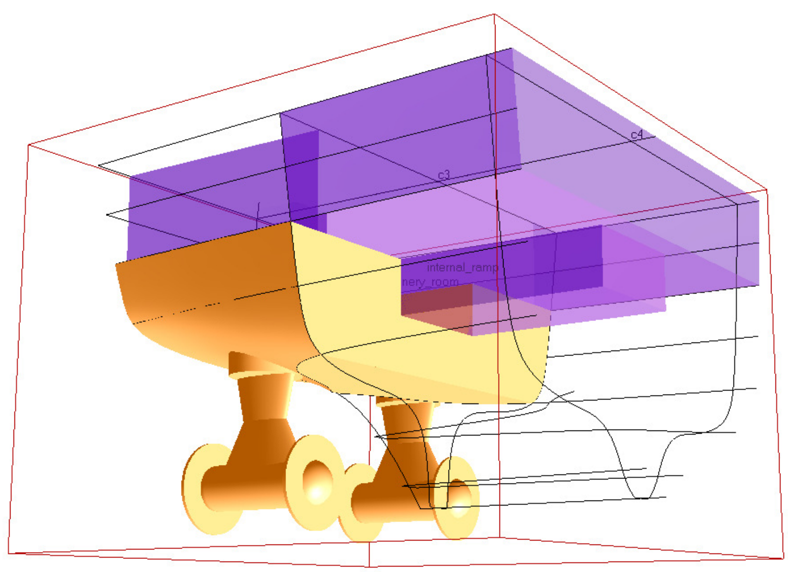

Figure 16 Pod machinery space, vehicle deck and ramp envelope aft for the Developed JSS Design

Figure 17 shows the FIGHT functional group, which consists of several sub-functions identified from the requirements documentation. Figure 17 illustrates the extent to which the FIGHT Building Blocks dominate the JSS design. Figure 18 shows the replenishment function, consisting of the cargo tanks, munitions stores, and RAS equipment on the upperdeck. The cargo was placed in the amidships section of the vessel to provide the greatest cargo capacity with short piping routes to the RAS rigs amidships. This location was also chosen to reduce the trim produced when the tanks were emptied, thus reducing the amount of ballast required. The flight deck was placed aft to provide a conventional approach for the helicopters. The hangar is capable of housing three Cyclone helicopters, all stored fore and aft. The medical bay was initially placed on the same deck as and forward of the hangar, with a clear access through the hangar for moving casualities arriving via helicopter. However, the reduction in length from the refined level design necessitated the placing of this space to below the hangar, on No 1 Deck. This would require the provision of a lift to move casualties to the medical complex.

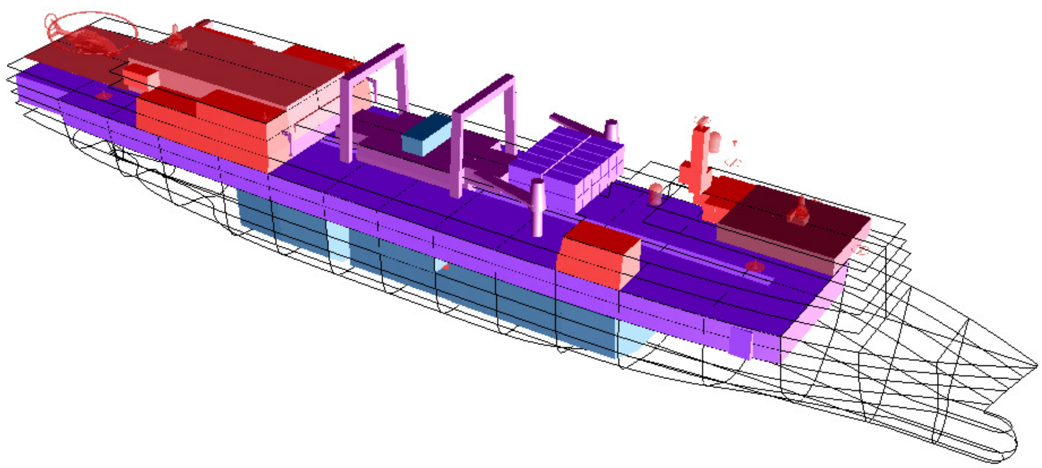

Figure 17 FIGHT functional group for the Developed JSS Design

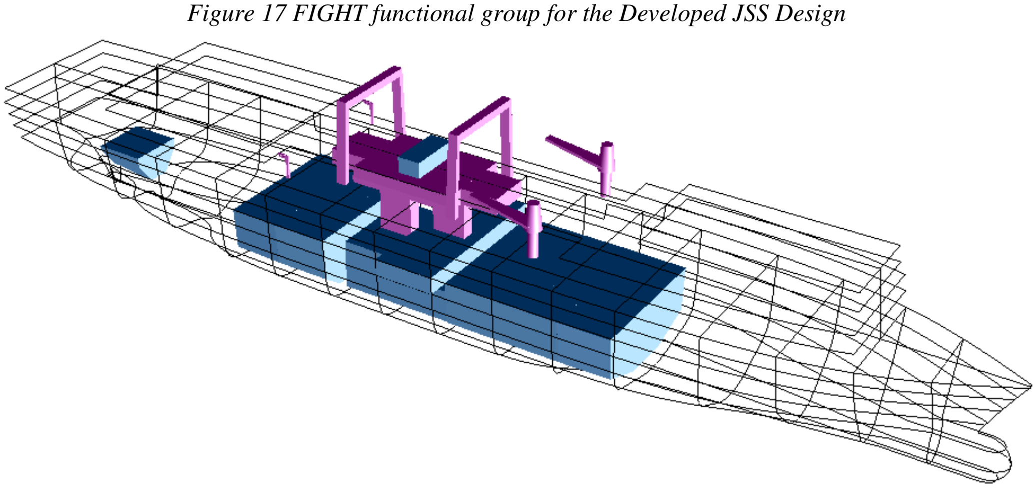

Figure 18 Replenishment function for the Developed JSS Design

Figure 19 shows the Sealift function, consisting of the vehicle bay and the upperdeck stowage of TEUs. The developed configuration provides 1500 Lane Metres on a single full width vehicle deck. The single deck configuration was utilised in preference to a two-deck solution due to concerns about the impact of large open vehicle decks on the vessel's damage stability. The single deck also provides a simple loading arrangement and frees up volume down in the lower hull for tankage and machinery spaces. The length of the vehicle deck is a significant driver on the ship's configuration and size. Since the Lane Metres have a fixed width, additional beam cannot always be used to reduce the length of the vehicle deck. The initial configurations had a narrower vehicle deck with wing compartments, but as the vehicle deck was increased to achieve the "should" requirement of 1500 Lane Metres, this became increasingly inefficient as the side compartments were too narrow to use for functional spaces, while the longer vehicle deck used the available space forward.

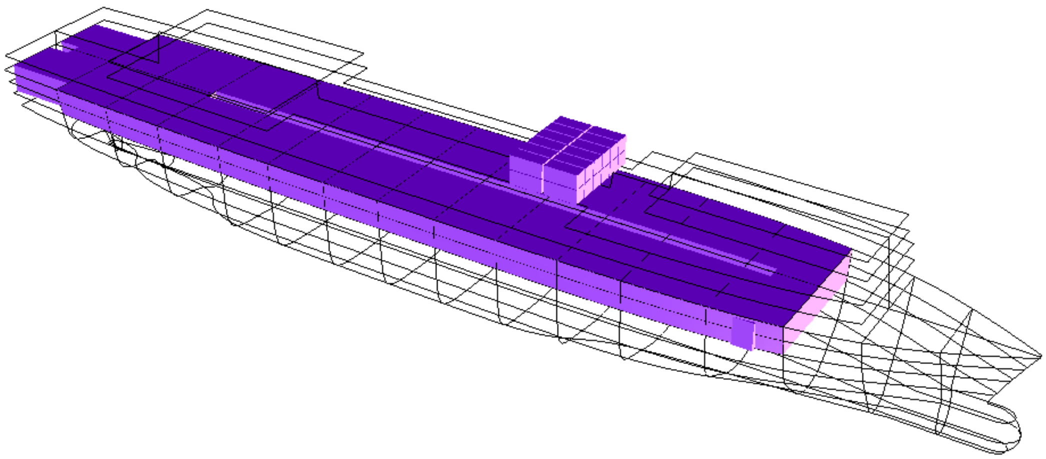

Figure 19 Sealift function for the Developed JSS Design

In the developed configuration the larger vehicle deck led to placing all accommodation in the superstructure, with only stores and support spaces remaining in the hull. Although this resulted in a larger superstructure, it had the benefit of moving all accommodation above the damage control deck, improving access. Figure 19 shows the TEUs stored in a single block just aft of the superstructure. The developed configuration can transport 24 TEUs, somewhat less than the "should" requirement of 100. The stowage of TEUs was found to be more demanding than originally anticipated, since the chosen locations must be accessed by cranes or other loading apparatus, limiting the possible locations. Using the current configuration, as a baseline, it is estimated that stowage of 100 TEUs would require an increase in upperdeck length of approximately 10m and the fitting of cranes with greater reach, leading to noticeably increased ship size and cost. The Joint Forces HQ and JSS Command, Control and Communications functions are easily accommodated and have a relatively small impact on the overall ship design. They have been grouped as a complex in the superstructure, above the Officers and COs' accommodation and aft of the bridge, simplifying ship coordination. The sensor and communications equipment is grouped on the forward superstructure around the forward mast but this layout could easily be changed to resolve any interference issues with the self-defence equipment carried, which also has small effect on the overall design. The Phalanx Close in Weapon System mounts were positioned on the superstructure blocks forward and aft to provide the maximum overlapping arcs of fire. Figure 20 shows the locations of the boat bays. Both Landing Craft Vehicle & Personnel (LCVP)s are housed in large bays outboard of the hangar, as are three of the Rigid Hull Inflatable Boats (RHIB). The fourth RHIB is stowed forward on the starboard side of the superstructure as the Sea Boat, to facilitate its rapid launch. This forward location also allows for direct observation from the starboard bridge wing. Although the aft location of the main boat bays is not ideal, it resulted from the overall topology of the layout, with the accommodation occupying the entire forward superstructure and the RAS equipment amidships. The main boat bay design has not been examined in detail, but it is proposed that the boats would be launched and recovered by extending davits.

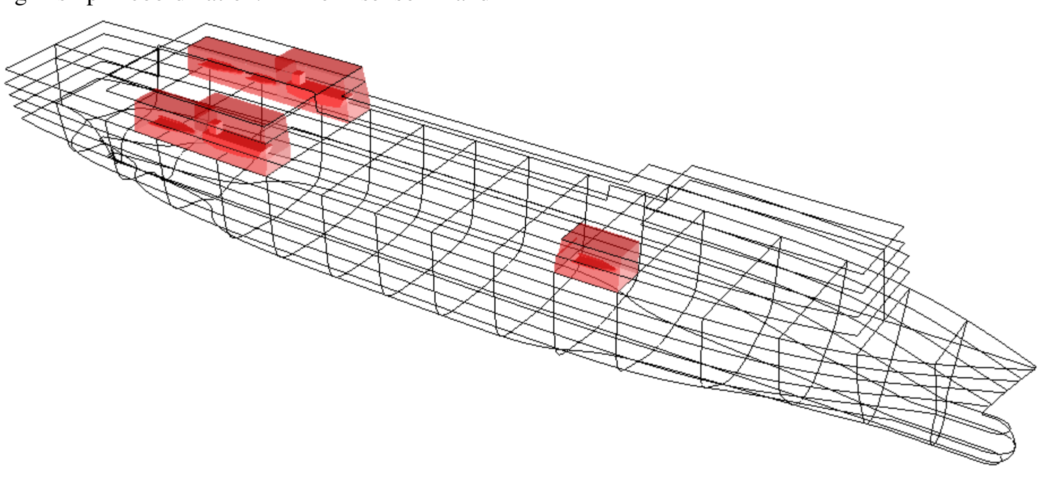

Figure 20 Boats and craft arrangements for the Developed JSS Design

Figure 23 shows the INFRASTRUCTURE Functional Group which consists of the accommodation, ship's stores and provisions, auxiliary machinery spaces and systems. The accommodation was concentrated in the superstructure. The Galley is on No 1 Deck, with Senior and Junior Rates Dining Halls adjacent to it. The Wardroom is above the Galley on No 3 Deck, adjacent to the Officers' accommodation, and would be served by a lift from the Galley. As far as possible, provisions and JSS stores are on No 1 Deck, allowing for easy access and movement of stores. A separate group of stores is placed forward in the hull, adjacent to the crew support spaces (Gym, Canteen etc). Two Auxiliary Machinery Rooms (AMRs) were placed under the superstructure to reduce piping runs for fresh water, sewage etc. The AMRs are large – both over 1400m^3 in volume – based on past UCL SDE experience which indicates that in future naval vessels auxiliary machinery, particularly waste disposal systems, are likely to be larger than current standards [8]. A disadvantage of this arrangement is that the AMRs are adjacent, increasing systems vulnerability. However with the current configuration it is difficult to improve this.

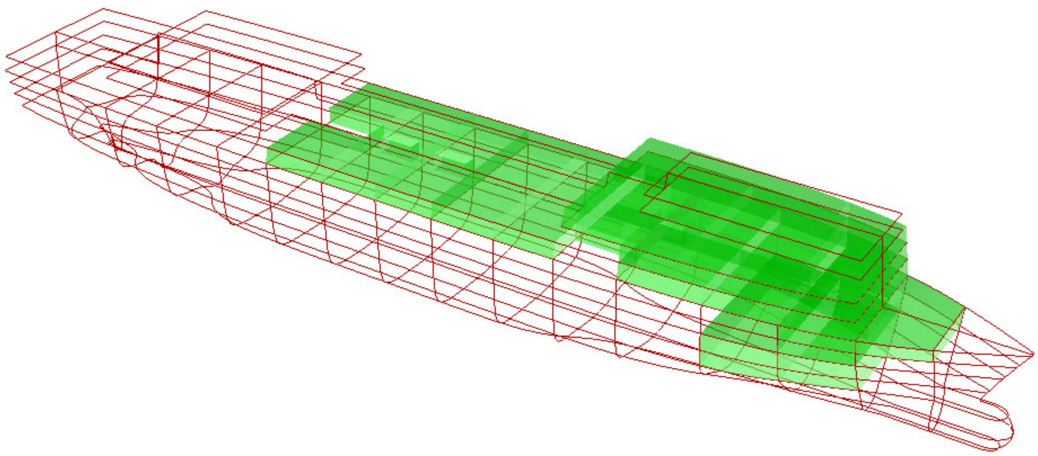

Figure 21 INFRASTRUCTURE functional group for the Developed JSS Design

There are several points to be noted with regard to the algorithms used to size the INFRASTRUCTURE Design Building Blocks:-

- Accommodation spaces were sized using the JSS area requirements provided;
- Accommodation was split into large flats containing cabins and bathrooms, dining and messing;
- In the Cabin flats a 30% area margin was added to allow for access. This is based on past UCL SDE experience with designs incorporating large blocks of cabins, where space for access accounted for between 20 and 40% additional area;
- Distributed systems were sized using the UCL MSc SDE algorithms;
- Distributed systems spaces, such as Electrical Distribution Cabinets (EDCs) and Air Treatment Units (ATUs), were not modelled, although their area and volume demands were calculated and incorporated in the total enclosed volume.

The weights of these and other systems were placed in the most appropriate of several locations (e.g. overall centroid of the machinery spaces (if the system is likely to be in both spaces), centroid of specific machinery space (if the system is likely to be in one space only), centroid of envelope volume (if the system is evenly distributed), a combination of a specified deck and longitudinal position (amidships, under forward superstructure etc) when the likely location of the system can be estimated from its function (e.g. sewage piping is under the forward superstructure accommodation)).

5.4 STABILITY ASSESSMENT

Eight different intact stability cases, four NTG and four JFS cases (see beginning of Section 3) were examined:-

1) NTG Deep (Start of mission)
2) NTG Working
3) NTG Light Sea Going (Worst case)
4) NTG Light (End of mission)
5) JFS Deep (Start of mission)
6) JFS Working
7) JFS Light Sea Going (Worst case)
8) JFS Light (End of mission)

The designs were assessed against the IMO GZ shape criteria (which are identical to the specified criteria), although a user-defined criteria functionality exists in addition for a range of merchant ship and UK MoD criteria (IMO, MARPOL, DNV, SOLAS, NES109). The design passes all the GZ curve assessments. However, as no ballast is permitted in the Light Sea Going conditions the vessel trims excessively (greater than 1.5m) by the stern in these cases. The ballast / trim tanks forward were sized such that they are 95% full in the NTG light, JFS deep and JFS light conditions. A total of seventeen damage cases were defined and assessed in the NTG Deep, JFS Deep and NTG Light Sea Going loading conditions. In the aft damage cases it was assumed that the vehicle deck was open to the sea, however the analyses showed it was never submerged, so this had no effect. The NES109 criteria [15] were used to assess the shape of the resulting GZ curves, but as noted above, user defined criteria could be entered. PARAMARINE provided a visual analysis, with warning points to alert the designer when openings become submerged. Due to the flare on the hullform, the vessel easily passed the NES criteria, as shown in Table 13. Although the three compartment damage cases that would result from a 15m damage length were not assessed, initial inspection suggested that the vessel would pass the NES 109 damaged GZ criteria in most, if not all, cases.

			Actual value stbd	Actual value port	Limiting value
angle_of_list_or_loll (deg)	PASS	**pass_if_less_than_limit**	0.212	-0.212	20.000
GZc_on_GZmax	PASS	**pass_if_less_than_limit**	0.088	0.087	0.600
A1 (mrad)	PASS	**pass_if_more_than_limit**	0.519	0.531	0.012
A1_on_A2	PASS	**pass_if_more_than_limit**	6.198	6.340	1.400
GMlf (m)	PASS	**pass_if_more_than_limit**	367.489	367.489	0.000

Table 13: NES109 Damaged GZ curve criteria assessment

6. DESIGN DRIVERS, UNCERTAINTIES AND THE UTILITY OF THE DBB APPROACH

6.1 DESIGN DRIVERS

The four initial designs indicated that a limited number of aspects drove the design and the interactions between these were further explored in the Developed Design. The main aspects were considered to be:

- Aviation spaces (hangar and flight deck);
- RAS rigs (Rigs and dispersal area);
- TEU storage (TEUs and cranes);
- Accommodation (Accommodation, catering and personnel support);
- Vehicle deck;
- Magazines (Cargo munitions);
- Main machinery spaces (Main diesel generator spaces and uptakes);
- Tanks (Cargo F76, F44 and JSS F76 fuel).

Within this list there are horizontal interactions and vertical interactions. The main example of the former is that the upperdeck length is determined by the aviation, RAS rigs, TEU storage and superstructure accommodation. In the initial configurations with a two-spot flight deck, the resulting upperdeck length drove the size of the ship, rather than the internal volume required for tankage or the vehicle deck. Adopting a single spot flight deck reduced the overall length. This introduced a new limit on minimum length, however, by reducing the hull volume that could be used for tankage and machinery. Although some void volumes exist in the final configuration, these are at the ends of the ship and it would be difficult to use them for useful tankage. This may also be due to the use of the Quickhull tool, which produces hullforms with finer forward sections than would be desirable for maximum internal volume on a given length. Any future studies would make use of an alternative procedure to alleviate this problem. Certain key vertical relationships exist in the design. The two main relationships are between the machinery spaces and the superstructure and between the magazines and the RAS rigs. The machinery uptakes must be integrated into the upperdeck configuration and this effectively constrains the machinery spaces to be under each of the superstructure blocks. In Configuration 2, developed for the final design, the use of two main superstructure blocks allows flexibility in the location of the machinery spaces. Given that Configuration 3 has a single large aft superstructure block, this degree of flexibility was not possible. The other main vertical relationship is to achieve the shortest route between the RAS rigs and the deep magazines. The location of the magazines amidships under the RAS rigs provided both the shortest route and the maximum beam for magazine side protection. These effectively became fixed features of the design.

The vehicle deck was found to have little influence on the overall dimensions of the vessel, as other spaces could either be placed over (accommodation) or under (machinery, tankage), the full-width deck. The vehicle deck drove the freeboard of the hull, however, and could be a concern in some damage cases more severe than those investigated. Also, ballast tanks were not found to be a significant driver. This is due to the placement of the tanks in large groups close to midships, which reduces the trim when at light loads. The use of podded propulsors, although not in compliance with the Canadian NDF HQ requirements, was found to be exceptionally useful in removing the need for an internal motor room. This would have been placed in the fuller sections of the hull, reducing potential tankage volume. Free surface effects on stability of the fluid in the tanks were found not to be of concern, due to the use of subdivided tanks (with cross connections through the double bottom). The hull also has a small amount of flare, although this reduced to 3.5 degrees as the midships sections were widened to increase tankage.

6.2 AREAS OF UNCERTAINTY IDENTIFIED

One of the main areas for future investigation would be the production of a hullform with fuller lines forward. This would provide additional internal volume that could be utilised in a number of ways:

- Reduction in ship's length;
- Increase in speed to meet the "should" criteria, requiring an increase in machinery size and JSS F76 tankage;
- Use of internal motors and conventional shafts with minimal change to the overall configuration.

Seakeeping and manoeuvring were not assessed in this study and this would be a point for future investigation. Further studies could investigate the complete impact on the design of increasing the TEU stowage so that the ship meets all the "should" criteria. As was noted earlier, this could mean an increase in overall length. There are also some void spaces between the vehicle deck and the deep magazines and machinery spaces. Some of these have been used to provide storage in excess of the requirement, but a further study would investigate whether it was possible to use these spaces in a more efficient manner.

The other main area for future investigation would be to develop the aft superstructure Configuration 3 design, using the knowledge that has been gleaned from the development of the Configuration 2 based design. An area of uncertainty in this investigation is the justification for the algorithms used to size the vessel. The main source of data in the UCL studies was the database of sizing algorithms used in the UCL MSc Ship Design Exercise. These are based on an analysis of surface combatants in the Royal Navy, for example the Type 22 frigate. Previous studies of larger vessels, both in MSc design exercises and UCL DRC work, has shown that although these algorithms give an overall displacement and gross distribution across the weight groups that are correct, the individual weights estimated may not be sufficiently accurate. In any future investigations, this could be resolved by the following:

- Comparing the weights estimated, as percentages of the overall displacement, with similar vessels and applying factors to the sizing algorithms, as appropriate;
- Altering the algorithms used based on different system designs or styles adopted (e.g. extent of fire fighting equipment on the vehicle decks);
- Utilisation of algorithms derived from alternative sources, such as regression from similar "as-built" ships or shipyard data.

In addition to an examination of the estimates for systems weights, any future studies would make use of a more complete database of marine engineering equipment, such as propulsion diesels, allowing more machinery configurations to be investigated.

6.3 THE USE OF DBB APROACH IN CONCEPT STUDIES

This study has demonstrated several key advantages of the use of the Design Building Block approach to the initial design of such naval auxiliaries:

- Interactions between the configuration, tank capacity, trim and hullform design can rapidly be assessed using the spatial model;
- The overall configuration and the spatial interactions within it can be readily visualised;
- The flexibility of the model allows multiple configurations to be rapidly generated and compared;
- This same flexibility allows both feed-forward into later design stages and feedback to alternative configurations produced at an earlier stage, although in this study only a single configuration was chosen to be advanced to a more detailed level of definition.

7. CONCLUSION TO THE CONCEPT STUDIES USE OF THE DBB APPROACH

Comparison with the earlier concept studies is informative. These studies, in their range of configurations explored, are not as wide ranging as in the case of the Mothership studies, undertaken in conjunction with BMT DSL and reported in the 2004 Warship Conference [8]. This is consistent with these studies being a subset of a larger exercise by the main consortium design team and being in response to the RFQ from the Canadian NDF HQ following considerable in house study. Whereas the Mothership study was a first look by a consultancy team, including the UCL DRC, for the UK MoD on a highly speculative concept to meet a far from emergent operational concept. In that case there was a need to explore a wide range of possible Mothership solutions, in terms of lifting a range of possible small to medium combatant assets from the UK to potential Littoral operational locations. Thus the need was to see what was possible, rather than in the JSS case where a reasonably precise requirement was given and the task was to explore potential configurations in terms of style rather than produce a range of quite different ship types (e.g. heavy lift through to crane ships). In this way the UCL JSS studies can be seen as intermediate between the wide ranging Mothership options and the much more detailed single configurational option of the Trimaran Littoral Combatant Ship (LCS) undertaken by the DRC for the US Navy Office of Naval Research [9]. It is still felt by the authors that this less wide exploration, than the Mothership studies, and less extensive than the single LCS design exploration, still reveals the benefit of the DBB approach in early stage design when it is good design practice to explore a range of significantly different arrangement options. From such an exploration, as the discussion in Section 6 indicates, the subsequent development of the emergent configuration can be undertaken with a higher degree of confidence. Not only have a range of configurations been explored, issues (such as the primary design drivers, remaining areas of uncertainty and a more integrated design description) have been produced, giving greater confidence in the subsequent design development.

The design studies presented here are a further set of actual preliminary designs produced by the UCL DRC for a specific industrial/government customer of a different type of sophisticated requirement. These studies further extend the demonstration in the real design environment of the Design Building Block approach to preliminary ship design, using the SURFCON tool. This has revealed again the significant advantage in the rapid production of the integrated design description, that is afforded by the design building block representation, when it is combined with a numerical ship concept which is balanced in the aspects of primary ship performance.

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