

Naval Surface Warfare Center Carderock Division

West Bethesda, MD 20817-5700



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Ship Systems Integration & Design Department

Technical Report

Development of a High-Capacity, High-Speed Sealift Hullform

By

John Fishback

Alexander Kan May

NSWCCD-CISD-2007/004



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14. ABSTRACT Sealift vessels are responsible for transporting the bulk of military equipment and vehicles overseas. The aim of this research is to develop a hull capable of reaching an austere destination at high speed while maintaining the high capacity of a sealift ship. A hull form with short longitudinal effective length will generate a high Froude number, of approximately 0.7, at the desired cruise velocity. Theoretically, the wake and frictional resistances will be reduced as a result. To achieve the large displacement of a useful sealift vessel, the hull of the ship will sweep out and back from the centerline of the ship so as to maintain the short longitudinal effective length while maintaining an efficient bow form. Additionally, this design must be capable of landing at an austere port. The austere port is a hypothetical landing site of limited accommodations; superimposing limits on the length, beam, and draft of the vessels landing within it. This research seeks to develop a virtual hull with the eventual goal of model testing. The virtual model will be put through hydrodynamic testing as appropriate for a conceptual ship design at the Naval Surface Warfare Center, Carderock Division (NSWCCD).					
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Naval Surface Warfare Center Carderock Division
Naval Research Enterprise Intern Program
High-Capacity, High-Speed Sealift Hullform

Abstract

Sealift vessels are responsible for transporting the bulk of military equipment and vehicles overseas. The aim of this research is to develop a hull capable of reaching an austere destination at high speed while maintaining the high capacity of a sealift ship. A hull form with short longitudinal effective length will generate a high Froude number, of approximately 0.7, at the desired cruise velocity. Theoretically, the wake and frictional resistances will be reduced as a result. To achieve the large displacement of a useful sealift vessel, the hull of the ship will sweep out and back from the centerline of the ship so as to maintain the short longitudinal effective length while maintaining an efficient bow form. Additionally, this design must be capable of landing at an austere port. The austere port is a hypothetical landing site of limited accommodations; superimposing limits on the length, beam, and draft of the vessels landing within it. This research seeks to develop a virtual hull with the eventual goal of model testing. The virtual model will be put through hydrodynamic testing as appropriate for a conceptual ship design at the Naval Surface Warfare Center, Carderock Division (NSWCCD).

Acknowledgments

This report is the culmination of work conducted by students hired under the National Research Enterprise Intern Program sponsored by the Office of Naval Research. This program provides an opportunity for students to participate in research at a Department of Navy laboratory for 10 weeks during the summer. The goals of the program are to encourage participating students to pursue science and engineering careers, to further education via mentoring by laboratory personnel and their participation in research, and to make them aware of Navy research and technology efforts, which can lead to future employment.

At the Naval Surface Warfare Center Carderock Division, the single largest employer of summer interns is the Center for Innovation in Ship Design (CISD), which is part of the Ship Systems Integration and Design Department. The intern program is just one way in which CISD fulfills its role of conducting student outreach and developing ship designers.

The student team consisted of:

John Fishback



Alexander Kan
May



The team would like to acknowledge their mentors:

- Mr. Gabor Karafiath,
- Dr. Dane Hendrix, and
- Dr. Francis Noblesse.

The team would also like to recognize their fellow student researchers:

- Dennis So Ting Fong, and
- Trevor Blanarik.

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Introduction

The report summarizes the design work undertaken to develop a TwinTail (TT) hull series. There were three primary goals for this hull design. The hull must be capable of:

1. transporting the required cargo,
2. traveling at high velocity across various sea states, and
3. landing at an austere port.

The lead researcher decided that the sealift vessel should have a displacement of at least 20,000 long tons (44,800,000 pounds). The hull form was also to be designed to travel at a cruise speed of 45 knots. Furthermore, the austere port limits the dimensions of the ship to be of length less than 650 ft (ideally 500 ft), beam less than 120 ft (ideally 100 ft), and a draft of less than 25 ft (ideally 15 ft).

The three primary goals significantly influenced the hullform design and the final design represented a compromise between them. The high velocity coupled with the high capacity of the ship was possible to achieve by designing the hull to operate at supercritical Froude numbers (greater than 0.7) thereby lowering the overall resistance.

Early Work and Proposed Solutions

The Rhinoceros 3.0 NURBS modeling program (“Rhino”) was used to generate surfaces to simulate the hull of the proposed ship. A destroyer hull, Model 4787 of Series 64, had already been modeled and was used as the basis for the experimental hull. The destroyer hull was proven to be fast and it was assumed that its profile would be a logical starting point for designing a similarly fast ship by changing aspects of the hull (e.g., beam).

Early designs resembled trimarans with a single deck, partially below the water surface to increase displacement. After further discussion, the student researchers understood that the design would have to be a more streamlined, single hull of a more unique configuration. Figure 1 illustrates an early design concept.

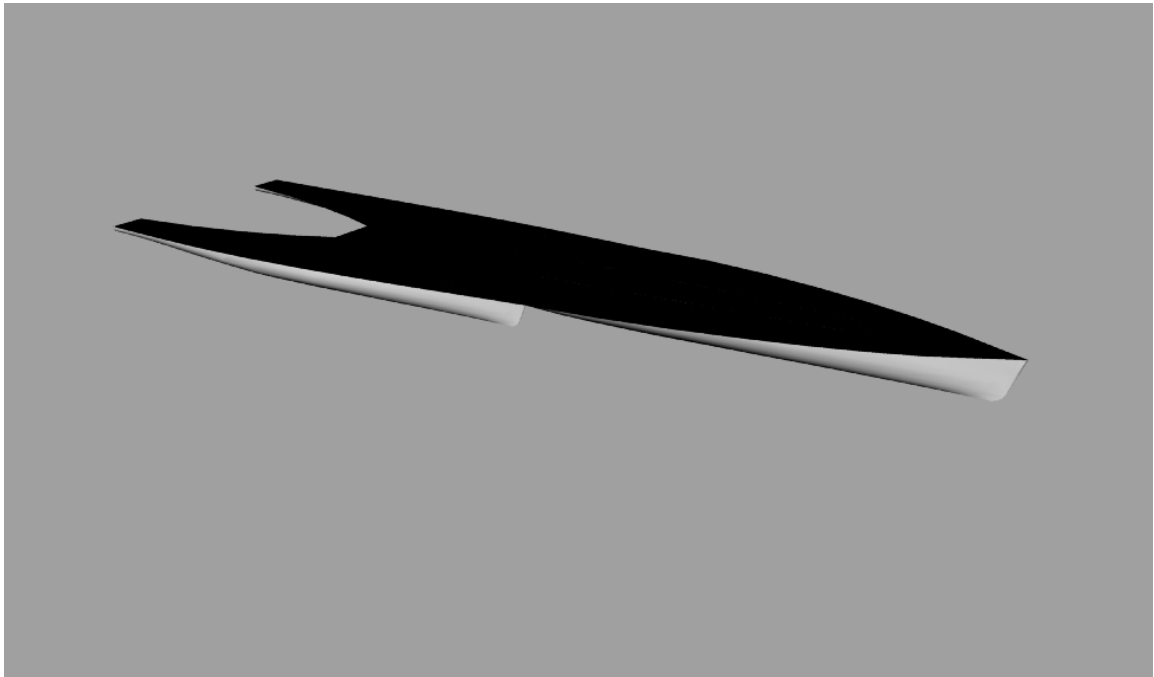


Figure 1: An early design concept, having three hulls and a deck section designed to be partially submerged to increase buoyancy

Attempts have been made in the past to achieve supercritical Froude numbers to reduce overall resistance. The “Sea Slice” vessel (Figure 2) rides on four streamlined submerged hulls connected to the dry deck. In contrast, the TwinTail project focused on designing a monohull vessel capable of high speed and greater capacity with the ability to dock at austere ports.



Figure 2: “Sea Slice” – An implementation of supercritical Froude number in hull design

(Image courtesy of http://commons.wikimedia.org/wiki/Image:Sea_Slice_returns_to_homeport.jpg)

The proposed method of accomplishing supercritical Froude numbers in the monohull was to design it to have a short effective hull length. The effective hull length is the length of the ship parallel to the centerline, which is used to calculate the Froude number. Usually, the effective hull length is similar to that taken from along the centerline. It is possible that this may not be the case, but for experimental purposes, the effective length will be assumed to be along the centerline. In order to have the capacity required of a sealift ship, this vessel will have its profile stretched aft and out from the short centerline, as preliminarily exhibited in Figure 1. In order for this effective hull length to be valid, the researchers felt it important to have the majority of the flow pass under the hull as opposed to around it. Thus, the fluid surrounding the vessel traverses a much shorter distance in contact with the hull.

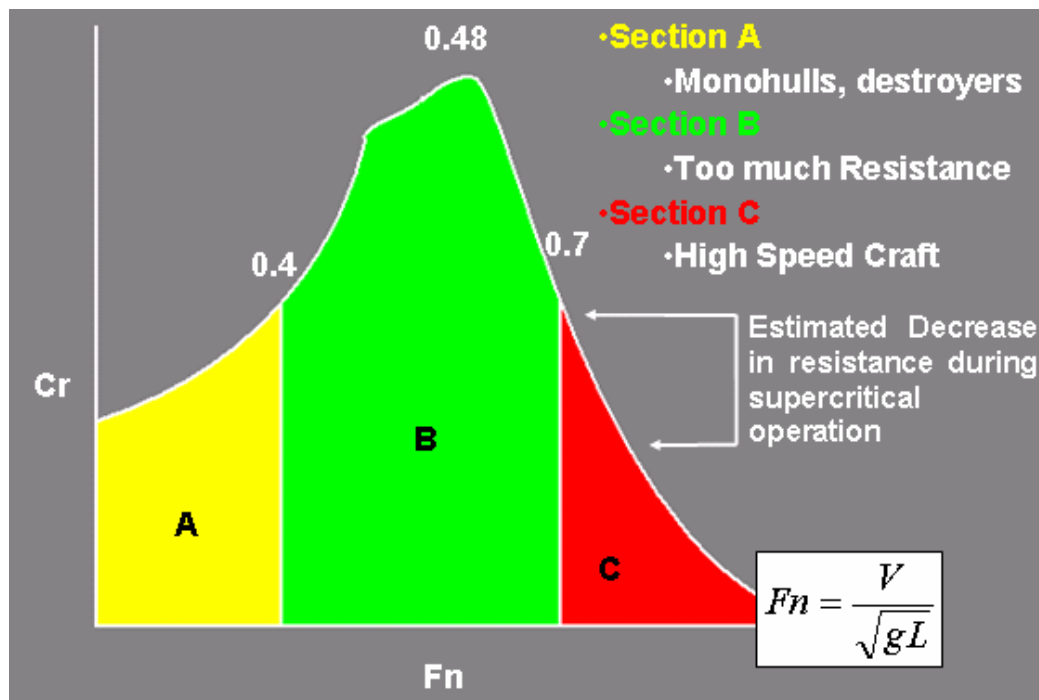


Figure 3: Illustrative Graph of Resistance Vs. Froude Number with Target Values

Rhinoceros Surface Modeling

The task of adequately defining the required volume was one of the most difficult. To create a smooth hull, the basic destroyer hull was discarded. Figures 4 and 5 illustrate the namesake “twin tails” that are the result of sweeping a hull profile out and back from the centerline of the vessel. The mentors for this project supervised the many iterations of this design and offered several explanations concerning the vessel’s hydrodynamics.

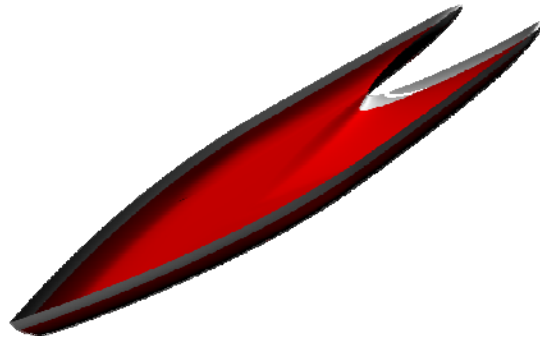


Figure 4: Isometric Underside Views of a Preliminary Hull Form

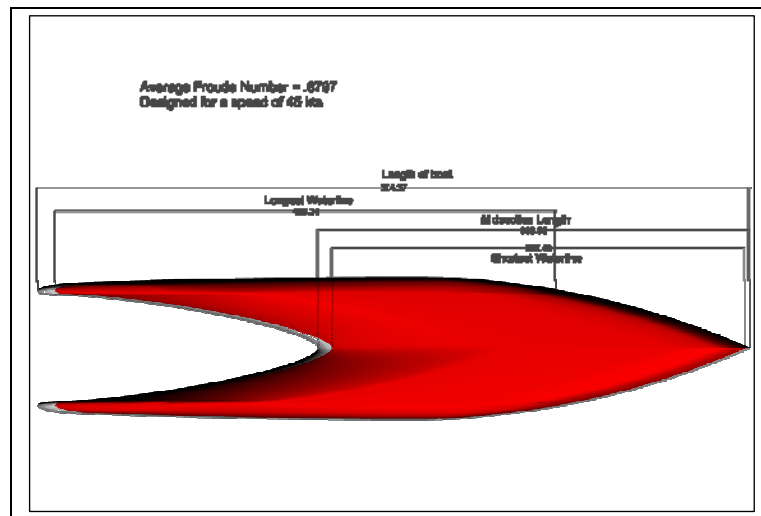


Figure 5: Dimensioned Underside Views of a Preliminary Hull Form

It should be noted that, even in the current models, the longest longitudinal wetted hull section is over 400 ft. However, the centerline wetted hull is relatively short, only about 330 ft. This centerline length is the basis for the Froude number calculation and is theoretically much more significant than the trailing tails, where the hull section is longer. It was also decided that this hull model would be fitted with transoms at the ends of the tails to allow for 15 ft diameter waterjets. Realistic dimensions very close to the constraints of the austere port were chosen and cruise velocity is expected to be between 35 knots and 45 knots. Present power systems indicate that 45 knots is a fairly unrealistic target speed for this size ship.

The models shown in the figures below do not have transoms modeled, but they would have if they were to be produced either in model or full scale. These models are also colored for the reader's reference, separate colors being used to differentiate between the portions above and below the waterline.

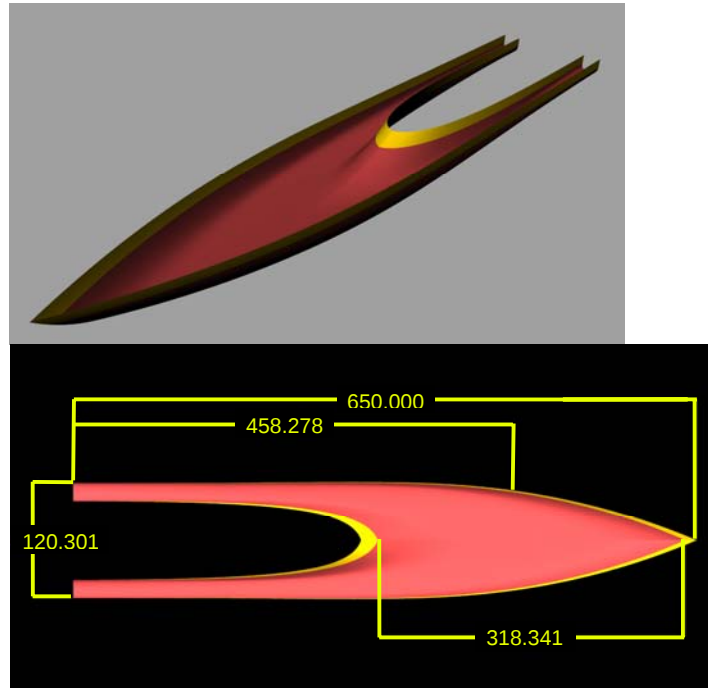


Figure 6: Isometric and Dimensioned Underside Views of TT001

The TwinTail hull design designated as TT001 was evaluated using Hydrostatics and Flow Code programs. The applied revisions included adding a transom to the area between the tails, widening the tails, and further reducing the angle of the bow. This set of revisions is referred to as design iteration TT002.

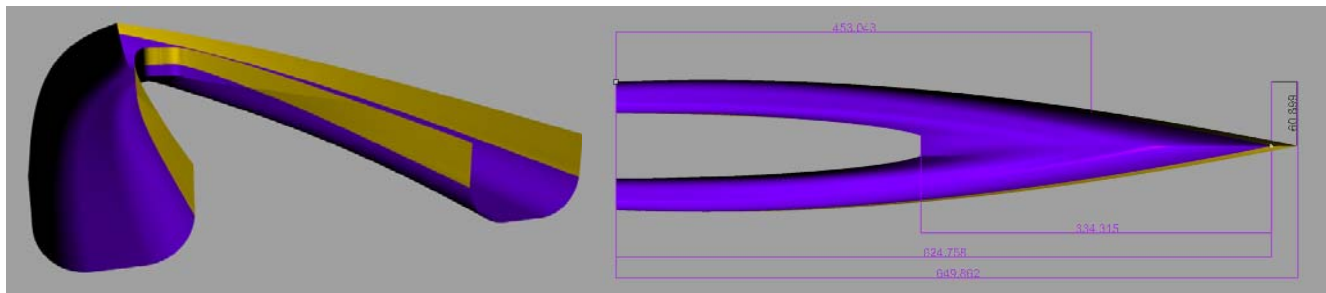


Figure 7: Isometric and Dimensioned Underside Views of TT002

Hydrostatics Analysis

The results of the Hydrostatics program are coefficients associated with the dimensions of the ship. One of the most useful results is a graph of the cross-sectional area against section number. The topmost plot of Figure 8 gives the reader an idea of the distribution of cross-sectional area on TT001. After seeing these Hydrostatics results, the mentors suggested that the vessel would have better performance if the largest cross-sectional area occurred closer to station 10 rather than station 8.

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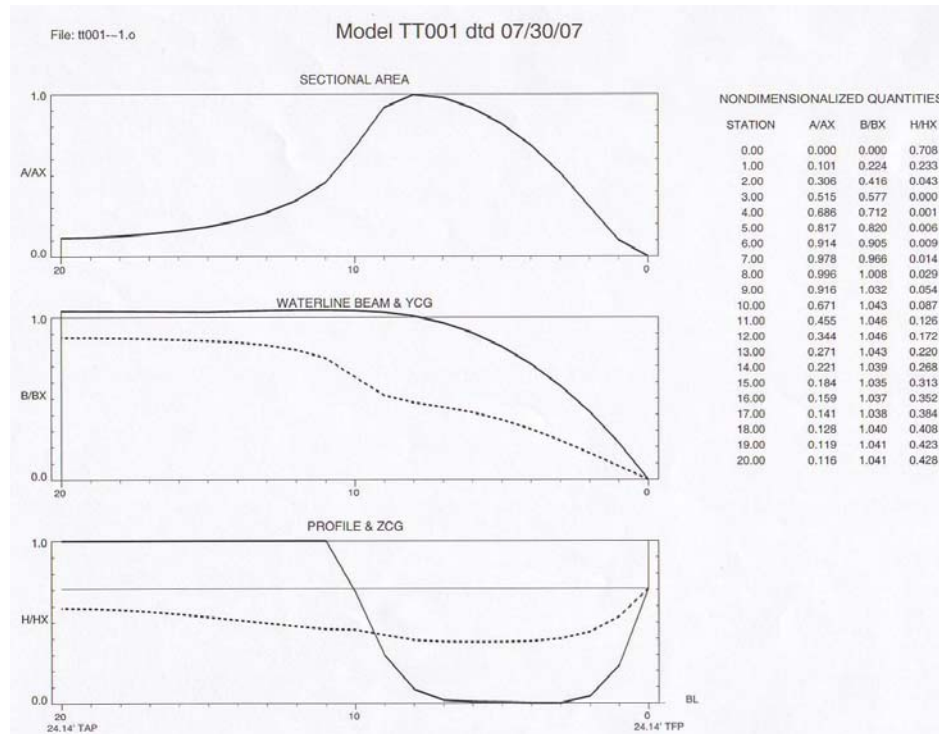


Figure 8: Distribution of Sectional Area, Waterline Beam, and Profile versus Station as Depicted by Hydrostatics (TT001)

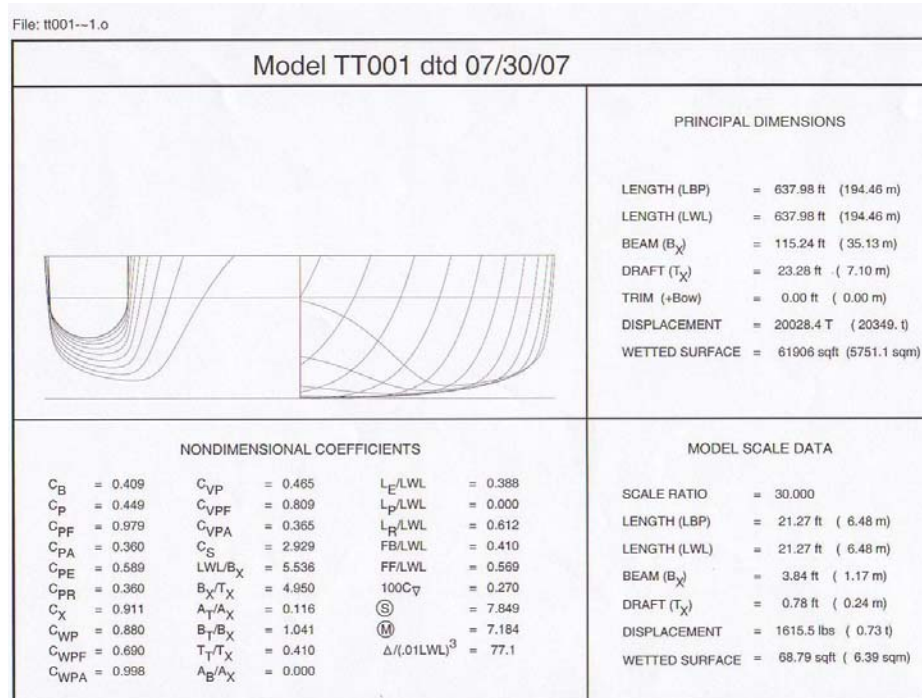


Figure 9: Ship Contours and Coefficients as Depicted by Hydrostatics (TT001)

After the revisions discussed in the Rhinoceros Surface Modeling section were made, the result was called TT002. It has an interior transom, wider tails, and a more shallow entrance angle. The improvements may be partially viewed through a comparison of the distribution of sectional area between Figure 8 and Figure 10. Not only has the maximum sectional area shifted aft, but the overall distribution is far more even. This should further improve the buoyancy characteristics of the hull form.

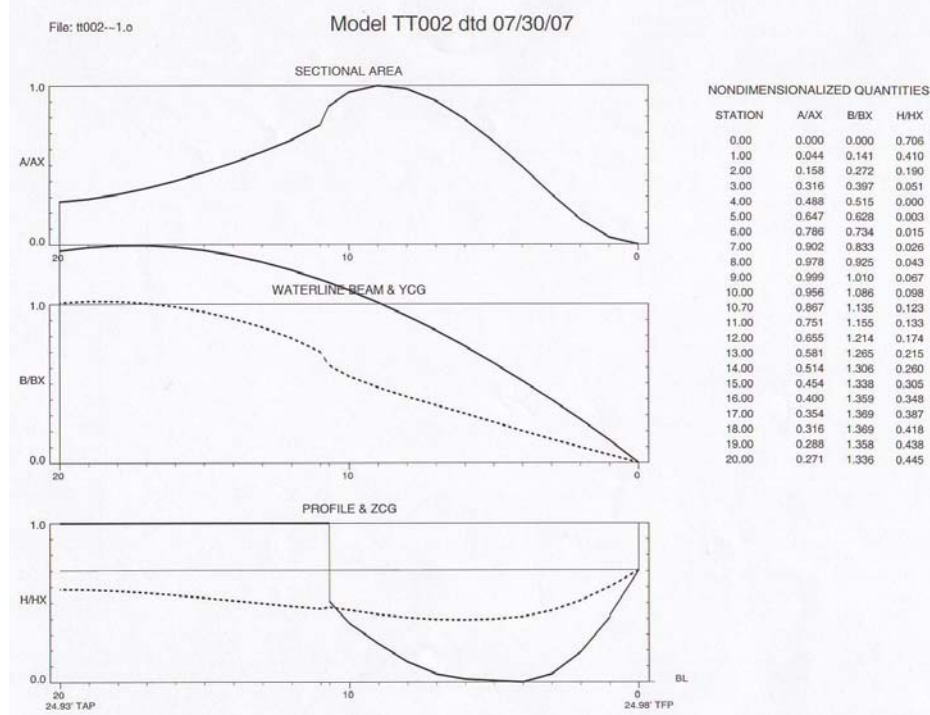


Figure 10: Distribution of Sectional Area, Waterline Beam, and Profile versus Station as Depicted by Hydrostatics (TT002)

Flow Code Analysis

The results of the Flow Code program include a diagram of the hull, colored according to a gradient of low-to-high resistances (and accordingly, pressures). Using the diagram from TT001, the student researchers were able to implement mentor-suggested modifications. Primarily, the areas of concern on TT001 were the area between the tails at the end of the centerline, and at the middle portions of the tails. At the lower Froude number of 0.45, these areas had high and low resistances (respectively). To remedy these stress concentrations, a transom was created between the tails to allow flow separation and the tails were widened. To further encourage fluid to flow beneath the hull, the angles of the leading portions of the ship were further reduced.

The Flow Code Analysis of TT002 and subsequent models will help determine whether modifying the hull form has made a positive influence.

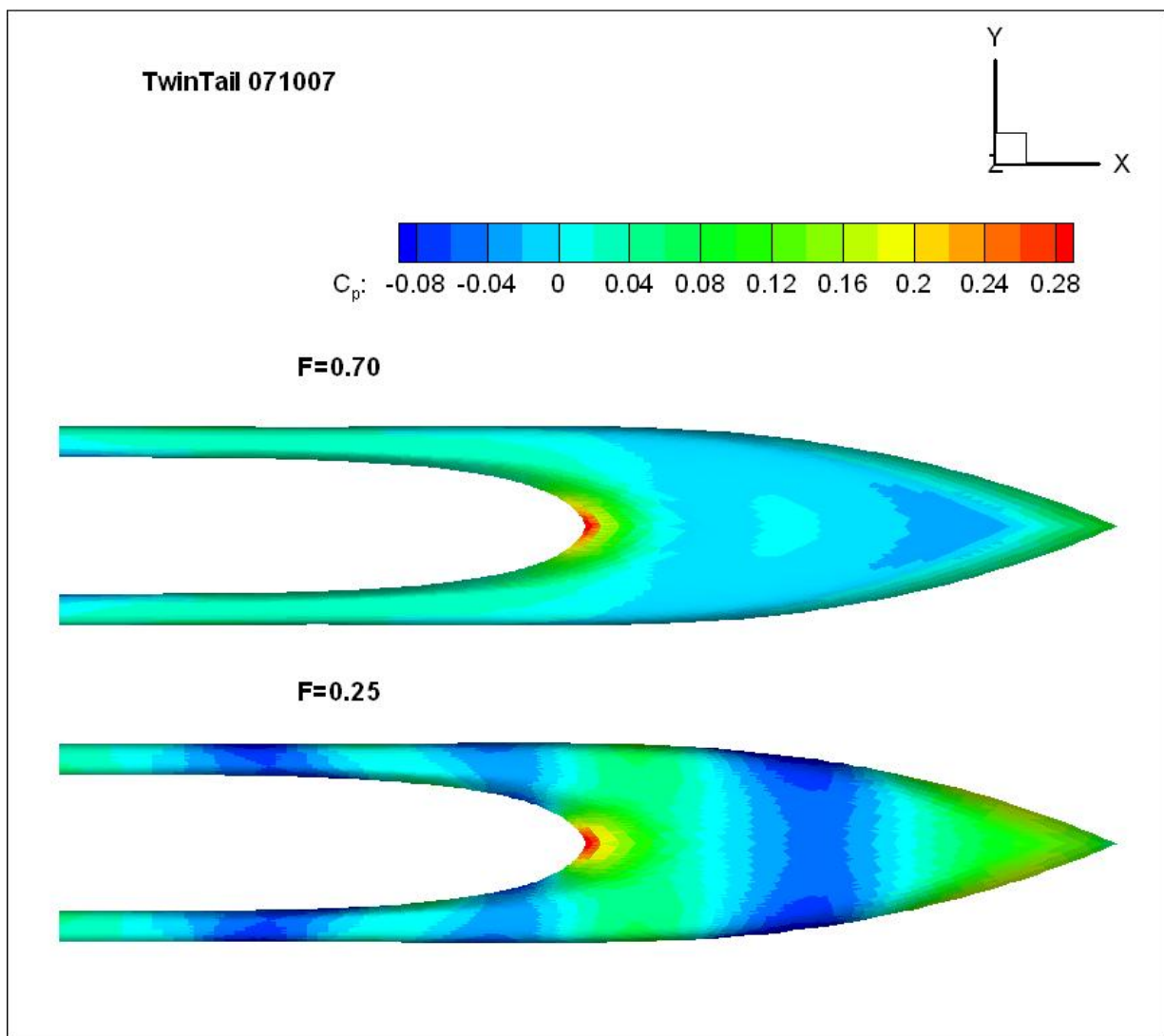


Figure 11: Flow Code Analysis of TT001

Hydrodynamically-Similar Hull Form

Dr. Noblesse recommended that a hydrodynamically similar hull be modeled. This meant preserving as much as possible the buttocks profile and the basic features of displacement and length. It was also deemed important to make the hulls have similar stability characteristics. This was achieved by determining the transverse metacenter and transverse metacentric height. The transverse metacenter helps give an idea as to the rolling or heeling characteristics of the vessel. This hull will be used to compare the TT series to more conventional monohulls.

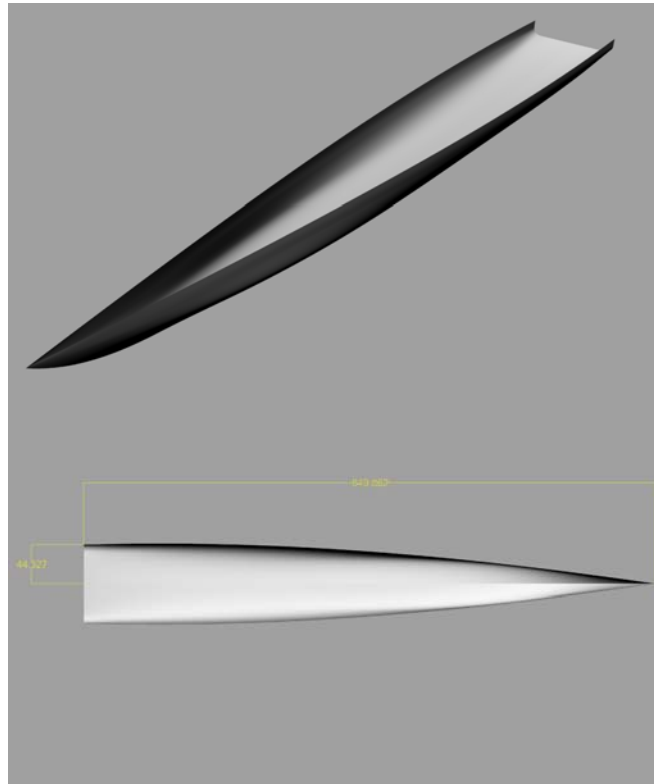


Figure 12: Isometric and Dimensioned Underside Views of a Comparison Hull Form

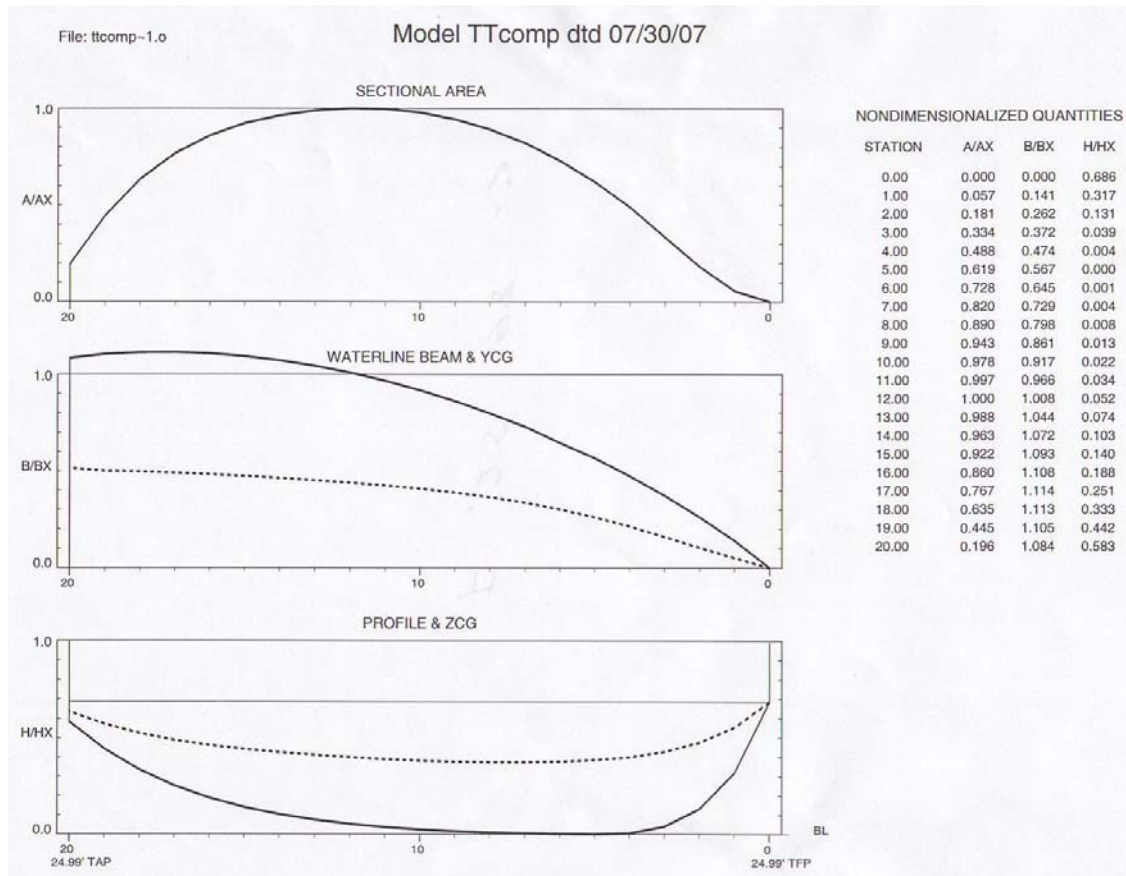


Figure 13: Distribution of Sectional Area, Waterline Beam, and Profile versus Station as Depicted by Hydrostatics (TTcomp)

Future Work

The design developed requires further iterations to produce a fully satisfactory hull form satisfying the design requirements. When the hull form has been adequately modified, a model may be made to measure resistance and determine the powering requirements of the vessel.

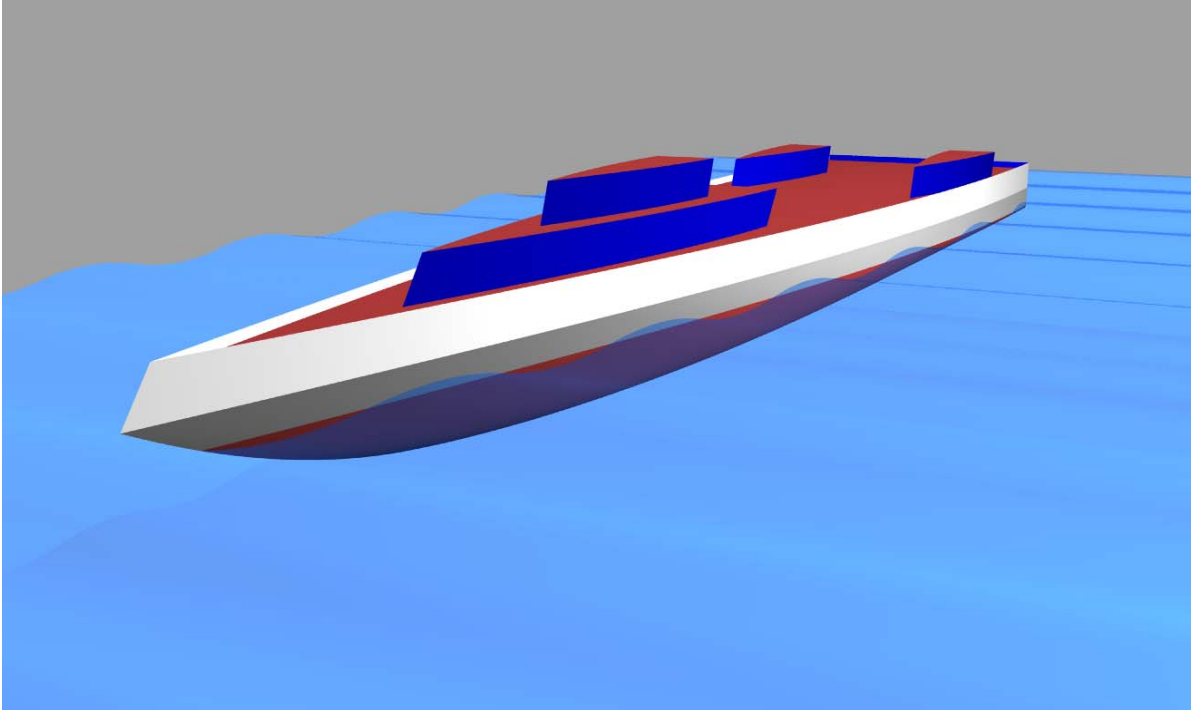


Figure 14: John Fishback's Artistic Interpretation of the Completed TwinTail

Conclusions and Results

A concept hull form was developed from concept to testing phases. The design is undergoing further revisions by Mr. John Fishback during the remainder of his internship at NSWCCD. The students represent the educational results of this project. During the summer of 2007, the student interns learned about the engineering design processes, how to use Rhinoceros to model designs with surfaces, and some critical aspects of hull design. In addition, they became familiar with some evaluation software used by naval architects at the NSWCCD and how they pertain to ship design.

The results of the project include a series of virtual hull forms (created in Rhinoceros 3.0), Hydrostatics and Flow Code analyses, and a hydrodynamically-similar hull form for comparison purposes. Additionally, this report exists to provide some insight as to the work completed by Mr. John Fishback and Mr. Alexander Kan May as NREIP interns between May and August of 2007; under the mentorship of Mr. Gabor Karafiath, Dr. Francis Noblesse, and Dr. Dane Hendrix.

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High-Capacity, High-Speed Sealift Hullform

Appendix 1: Hydrostatics Results

```

FILE: tt001--1.off
Model TT001 dtd 07/30/07

TANK_ID :
HULL_ID :
MOD_ID :
COND_ID :

PRINCIPAL DIMENSIONS
SHIP MODEL SHIP MODEL
LOA (ft) : 637.98 21.266 B MAX (ft) : 120.58 4.019
LBP (ft) : 637.98 21.266 BX (ft) : 115.24 3.841
LWL (ft) : 637.98 21.266 BM (ft) : 120.23 4.008
LKEEL (ft) : 0.00 0.000 TFP (ft) : 24.14 0.805
DEPTH (ft) : 34.09 1.136 TAP (ft) : 24.14 0.805
VOL (ft^3) : 700443.1 25.942 TRIM (ft) : 0.00 0.000
DISP (lt) : 20028.4 0.721 TX (ft) : 23.28 0.776
WS (ft^2) : 61906.8 68.785 TM (ft) : 21.18 0.706
VDES (knts) : 0.0 0.000 TNAV (ft) : 24.14 0.805
SCALE RATIO: 30.0000 RHOM : 1.9367

COEFFICIENTS
D_L : 77.13 CPF : 0.979 LWL/BX : 5.536 ABT/AX : 0.000
CB : 0.409 CPA : 0.360 BX/TX : 4.950 ABL/ABT : 0.000
CP : 0.449 CPE : 0.589 LE/LWL : 0.388 AT/AX : 0.116
CX : 0.911 CPR : 0.360 LP/LWL : 0.000 TT/TX : 0.410
CWP : 0.880 CWP : 0.690 LR/LWL : 0.612 BT/BX : 1.041
CVP : 0.465 CWP : 0.998 LCB/LWL : 0.410 BTUPD/BX : 0.529
CS : 2.929 CVP : 0.809 LCF/LWL : 0.569 CIRC_S : 7.849
100CV: 0.270 CVPA: 0.365 V/LWL*.5 : 0.000 CIRC_M : 7.184

ANGLES
IE (deg): 22.07 IE_UPD (deg): 20.60 STA_FP (deg): ??????
IR (deg): -0.10 FLARE (deg): 6.73 STA_AP (deg): 0.000
IB (deg): 0.00 ROF (deg): -3.89 TAY_T : 0.000

ARRAYS
STATION A/AX B/BX G/(BX+2TX) YCG/BX ZCG/TX
0.00 0.000 0.000 0.000 0.000 1.000
1.00 0.101 0.224 0.259 0.081 0.746
2.00 0.306 0.416 0.429 0.162 0.610
3.00 0.515 0.577 0.560 0.239 0.548
4.00 0.686 0.712 0.666 0.310 0.526
5.00 0.817 0.820 0.751 0.368 0.520
6.00 0.914 0.905 0.816 0.413 0.519
7.00 0.978 0.966 0.862 0.446 0.522
8.00 0.996 1.008 0.893 0.475 0.537
9.00 0.916 1.032 0.922 0.519 0.582
10.00 0.671 1.043 0.987 0.633 0.630
11.00 0.455 1.046 0.746 0.748 0.636
12.00 0.344 1.046 0.651 0.799 0.661
13.00 0.271 1.043 0.581 0.829 0.689
14.00 0.221 1.039 0.525 0.846 0.717
15.00 0.184 1.035 0.477 0.855 0.745
16.00 0.159 1.037 0.440 0.863 0.771
17.00 0.141 1.038 0.411 0.868 0.793
18.00 0.128 1.040 0.389 0.872 0.811
19.00 0.119 1.041 0.375 0.875 0.822
20.00 0.116 1.041 0.370 0.876 0.826

CHECKS
(LF+LA)/LWL = 1.000000 CX/CM*(AM/AX)/(BM/BX)/(TM/TX) = 1.000000
(LE+LP+LR)/LWL = 1.000000 (CPF+CPA)/(2*CP)*AM/AX = 1.000000
(VF+VA)/VOL = 1.000000 (CPE*LE+CPR*LR+LP)/(LWL*CP) = 0.998614
(VE+VP+VR)/VOL = 0.998614 (CWP+CWPA)/(2*CWP)*BM/BX = 1.000000
(AWF+AWA)/AWT = 1.000000 CB/CWP/CVP = 1.000000
CP*CX/CB = 1.000000
((CVPA*AWA*TMA/TX)+(CVPF*AWF*TMF/TX))/(CVP*AWT) = 1.000000

```

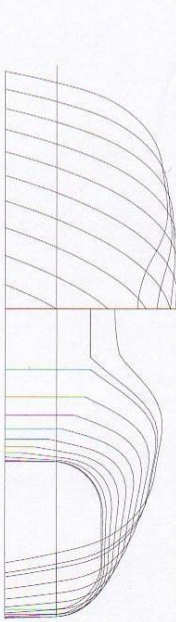
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File: tt001--1.0

Model TT001 dtd 07/30/07

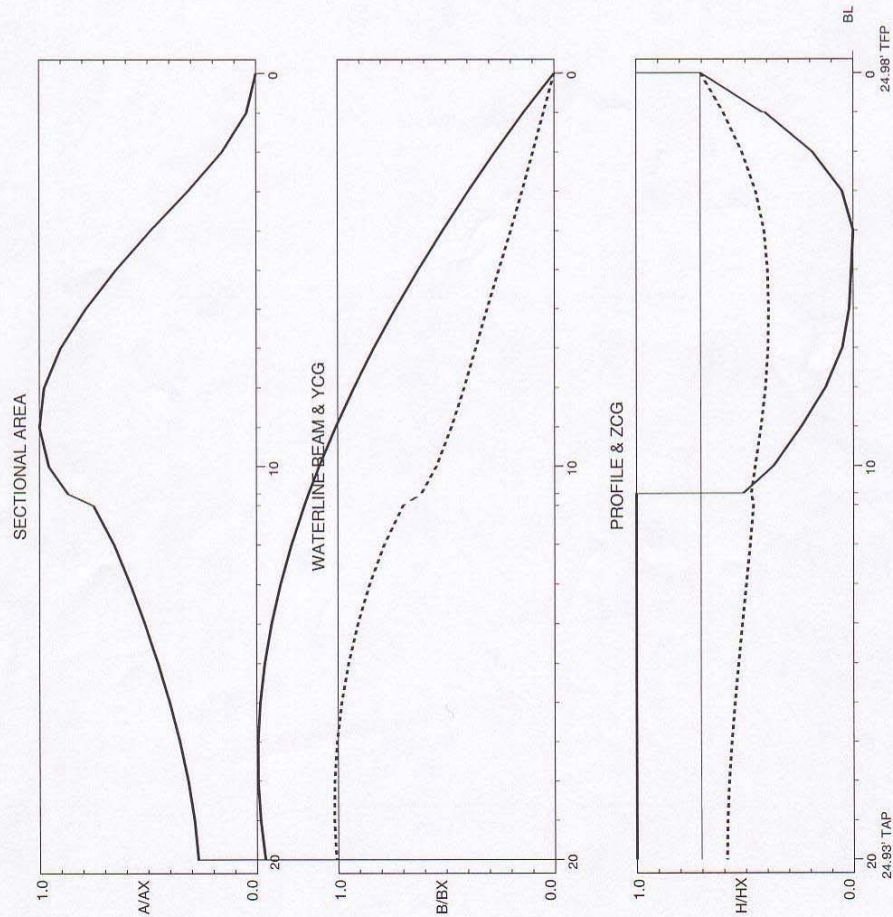
Model TT001 dtd 07/30/07		PRINCIPAL DIMENSIONS
		LENGTH (LBP) = 637.98 ft (194.46 m) LENGTH (LWL) = 637.98 ft (194.46 m) BEAM (B _X) = 115.24 ft (35.13 m) DRAFT (T _X) = 23.28 ft (7.10 m) TRIM (+Bow) = 0.00 ft (0.00 m) DISPLACEMENT = 20028.4 T (20349. t) WETTED SURFACE = 61906 sqft (5751.1 sqm)
		SCALE RATIO = 30.000 LENGTH (LBP) = 21.27 ft (6.48 m) LENGTH (LWL) = 21.27 ft (6.48 m) BEAM (B _X) = 3.84 ft (1.17 m) DRAFT (T _X) = 0.78 ft (0.24 m) DISPLACEMENT = 1615.5 lbs (0.73 t) WETTED SURFACE = 68.79 sqft (6.39 sqm)
NONDIMENSIONAL COEFFICIENTS		MODEL SCALE DATA
C _B = 0.409 C _P = 0.449 C _{PF} = 0.979 C _{PA} = 0.360 C _{PE} = 0.589 C _{PR} = 0.360 C _X = 0.911 C _{WP} = 0.880 C _{WPF} = 0.690 C _{WPA} = 0.998	C _{VP} = 0.465 C _{VPF} = 0.809 C _{VPA} = 0.365 C _S = 2.929 LWL/B _X = 5.536 B _X /T _X = 4.950 A _T /A _X = 0.116 B _T /B _X = 1.041 T _T /T _X = 0.410 A _B /A _X = 0.000	L _E /LWL = 0.388 L _P /LWL = 0.000 L _R /LWL = 0.612 FB/LWL = 0.410 FF/LWL = 0.569 100C _V = 0.270 S = 7.849 M = 7.184 Δ/(.01LWL) ³ = 77.1

File: tt002--1.0

Model TT002 dtd 07/30/07		
		PRINCIPAL DIMENSIONS LENGTH (LBP) = 624.76 ft (190.43 m) LENGTH (LWL) = 624.76 ft (190.43 m) BEAM (B_X) = 91.14 ft (27.78 m) DRAFT (T_X) = 22.88 ft (6.91 m) TRIM (+Bow) = 0.05 ft (0.02 m) DISPLACEMENT = 16339.9 T (16601. t) WETTED SURFACE = 56908 sqft (5286.8 sqm)
NONDIMENSIONAL COEFFICIENTS C_B = 0.443 C_P = 0.537 C_{PF} = 0.605 C_{PA} = 0.518 C_{PE} = 0.528 C_{PR} = 0.544 C_X = 0.824 C_{WP} = 0.947 C_{WPF} = 0.553 C_{WPA} = 1.192 C_{VP} = 0.467 C_{VPF} = 0.725 C_{VPA} = 0.505 C_S = 3.012 LWL/B_X = 6.855 B_X/T_X = 4.019 A_T/A_X = 0.271 B_T/B_X = 1.336 T_T/T_X = 0.404 A_B/A_X = 0.000 L_E/LWL = 0.444 L_P/LWL = 0.000 L_R/LWL = 0.556 FB/LWL = 0.503 FF/LWL = 0.821 100C₇ = 0.234 Ⓢ = 8.264 Ⓜ = 7.529 Δ/(.01LWL)³ = 67.0		MODEL SCALE DATA SCALE RATIO = 30.000 LENGTH (LBP) = 20.83 ft (6.35 m) LENGTH (LWL) = 20.83 ft (6.35 m) BEAM (B_X) = 3.04 ft (0.93 m) DRAFT (T_X) = 0.76 ft (0.23 m) DISPLACEMENT = 1318.0 lbs (0.60 t) WETTED SURFACE = 63.23 sqft (5.87 sqm)

Model TT002 dtd 07/30/07

File: tt002--1.o



NONDIMENSIONALIZED QUANTITIES			
STATION	A/AX	B/BX	H/HX
0.00	0.000	0.000	0.706
1.00	0.044	0.141	0.410
2.00	0.158	0.272	0.190
3.00	0.316	0.397	0.051
4.00	0.488	0.515	0.000
5.00	0.647	0.628	0.003
6.00	0.786	0.734	0.015
7.00	0.902	0.833	0.026
8.00	0.978	0.925	0.043
9.00	0.999	1.010	0.067
10.00	0.956	1.086	0.098
10.70	0.867	1.135	0.123
11.00	0.751	1.155	0.133
12.00	0.655	1.214	0.174
13.00	0.581	1.265	0.215
14.00	0.514	1.306	0.260
15.00	0.454	1.338	0.305
16.00	0.400	1.359	0.348
17.00	0.354	1.369	0.387
18.00	0.316	1.369	0.418
19.00	0.288	1.358	0.438
20.00	0.271	1.336	0.445

**Naval Surface Warfare Center Carderock Division
Naval Research Enterprise Intern Program
High-Capacity, High-Speed Sealift Hullform**

FILE: ttcomp~1.off

Model TTcomp dtd 07/30/07

TANK_ID :
HULL_ID :
MOD_ID :
COND_ID :

PRINCIPAL DIMENSIONS

	SHIP	MODEL		SHIP	MODEL
LOA (ft) :	633.26	21.109	B MAX (ft) :	88.52	2.951
LBP (ft) :	633.26	21.109	BX (ft) :	79.44	2.648
LWL (ft) :	633.26	21.109	BM (ft) :	72.87	2.429
LKEEL (ft) :	0.00	0.000	TFP (ft) :	24.99	0.833
DEPTH (ft) :	36.45	1.215	TAP (ft) :	24.99	0.833
VOL (ft^3) :	675418.2	25.015	TRIM (ft) :	0.00	0.000
DISP (lt) :	19312.8	0.695	TX (ft) :	23.24	0.775
WS (ft^2) :	54967.1	61.075	TM (ft) :	24.20	0.807
VDES (knts) :	0.0	0.000	TNAV (ft) :	24.99	0.833
SCALE RATIO:	30.0000		RHOM :		1.9367

COEFFICIENTS

D_L : 76.05	CPF : 0.567	LWL/BX : 7.972	ABT/AX : 0.000
CB : 0.578	CPA : 0.835	BX/TX : 3.418	ABL/ABT : 0.000
CP : 0.686	CPE : 0.621	LE/LWL : 0.589	AT/AX : 0.196
CX : 0.842	CPR : 0.779	LP/LWL : 0.000	TT/TX : 0.161
CWP : 0.797	CWPF : 0.579	LR/LWL : 0.411	BT/BX : 1.084
CVP : 0.725	CWPA : 1.158	LCB/LWL : 0.561	BTUPD/BX : 0.574
CS : 2.658	CVPF : 0.817	LCF/LWL : 0.611	CIRC_S : 7.140
100CV: 0.266	CVPA : 0.757	V/LWL^1.5: 0.000	CIRC_M : 7.218

ANGLES

IE (deg): 10.03	IE_UPD (deg): 7.85	STA_FP (deg): ??????
IR (deg): 0.08	FLARE (deg): 10.49	STA_AP (deg): 9.127
IB (deg): 6.88	ROF (deg): 2.48	TAY_T : 0.000

ARRAYS

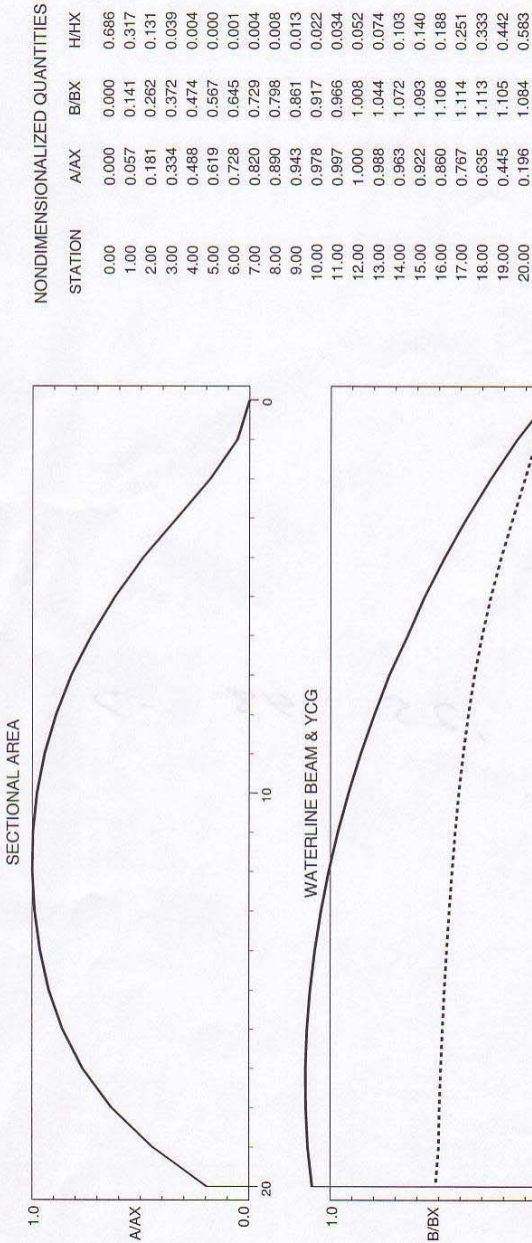
STATION	A/AX	B/BX	G/(BX+2TX)	YCG/BX	ZCG/TX
0.00	0.000	0.000	0.000	0.000	1.000
1.00	0.057	0.141	0.232	0.051	0.793
2.00	0.181	0.262	0.372	0.105	0.671
3.00	0.334	0.372	0.474	0.160	0.597
4.00	0.488	0.474	0.559	0.214	0.552
5.00	0.619	0.567	0.628	0.261	0.530
6.00	0.728	0.645	0.685	0.301	0.517
7.00	0.820	0.729	0.728	0.336	0.512
8.00	0.890	0.798	0.761	0.364	0.511
9.00	0.943	0.861	0.786	0.387	0.516
10.00	0.978	0.917	0.804	0.407	0.524
11.00	0.997	0.966	0.817	0.424	0.537
12.00	1.000	1.008	0.825	0.439	0.552
13.00	0.988	1.044	0.831	0.452	0.571
14.00	0.963	1.072	0.833	0.463	0.593
15.00	0.922	1.093	0.832	0.474	0.618
16.00	0.860	1.108	0.825	0.482	0.650
17.00	0.767	1.114	0.810	0.490	0.691
18.00	0.635	1.113	0.786	0.497	0.746
19.00	0.445	1.105	0.749	0.500	0.822
20.00	0.196	1.084	0.703	0.515	0.922

CHECKS

(LF+LA)/LWL = 1.000000	CX/CM*(AM/AX)/(BM/BX)/(TM/TX) = 1.000000
(LE+LP+LR)/LWL = 1.000000	(CPF+CPA)/(2*CP)*AM/AX = 0.999808
(VF+VA)/VOL = 0.999808	(CPE*LE+CPR*LR+LP)/(LWL*CP) = 0.999864
(VE+VP+VR)/VOL = 0.999864	(CWPF+CWPA)/(2*CWP)*BM/BX = 0.999925
(AWF+AWA)/AWT = 0.999925	CB/CWP/CVP = 1.000000
CP*CX/CB = 1.000000	
((CVPA*AWA*TMA/TX)+(CVPF*AWF*TMF/TX))/(CVP*AWT) = 0.999808	

Model TTcomp dtd 07/30/07

File: ttcomp-1.o



IS

(193.02 m)
(193.02 m)
(24.21 m)
(7.08 m)
(0.00 m)
(19622. t)
ft (5106.4 sqm)

(6.43 m)
(6.43 m)
(0.81 m)
(0.24 m)
(0.71 t)
(5.67 sqm)

