Development of a Parametric Sizing and Synthesis Tool for the Design of Planing Hull Watercraft

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Conceptual design of complex systems can be enhanced, expedited, and expanded through the use of a parametric design environment. Without excessively compromising fidelity, a parametric environment, through the use of historical regressions and empirical equations, can allow for rapid design space exploration and the evaluation of numerous novel concepts. This paper will illustrate the application of a parametric sizing and synthesis design environment to the problem of planing hull watercraft design. The methodology for a weight based, fuel balance sizing routine will be elaborated and applied parametrically to produce a Microsoft Excel based tool, fully capable of the rapid conceptual design of small military monohull planing watercraft.

Nomenclature

\[ L \] Length [ft]
\[ B \] Beam (width of the hull) [ft]
\[ D \] Depth (height of the hull) [ft]
\[ T \] Draft (length of hull below waterline) [ft]
\[ d \] Draft at transom [ft]
\[ \lambda \] Mean wetted length to beam ratio
\[ \rho \] Mass density of water, w/g [lbm/ft\(^3\)]
\[ \nu \] Kinematic viscosity of fluid [ft\(^2\)/s]
\[ g \] Acceleration due to gravity = 32.2 ft/sec\(^2\)
\[ \Delta \] Displacement or Load (also can be interpreted as the current weight of the vessel) [lbs]
\[ \nabla \] Displacement Volume (volume of water displaced) [ft\(^3\)]
\[ \beta \] Angle of deadrise planing surface (angle of craft bottom measured w.r.t. the horizontal)[deg]
\[ \theta_S \] Sidewall angle (angle of the hull sidewall measure w.r.t the vertical) [deg]
\[ \tau \] Trim angle (longitudinal angle between the deck and the waterline) [deg]
\[ C_{L_0} \] Lift coefficient, zero deadrise = \[ \Delta / \rho V^2 B^2 \]
\[ C_{L,\beta} \] Lift coefficient, deadrise surface
\[ V \] Velocity of the craft [ft/s]
\[ V_{\beta} \] Mean velocity at deadrise surface [ft/s]
\[ V_{jet} \] Velocity of water exiting waterjet(s) [ft/s]
\[ Re \] Reynolds number = \[ V \cdot B / \nu \]
\[ C_V \] Speed coefficient = \[ V / \sqrt{gB} \]
\[ C_f \] Shoenherr turbulent friction coefficient
\[ \eta_p \] Propulsive efficiency = \[ 2 \cdot V / V_{jet} / (1 - V / V_{jet}) \]
\[ \eta_{pump} \] Waterjet pump efficiency
\[ \eta_{trans} \] Transmission efficiency
\[ \eta \] Overall propulsive efficiency = \[ \eta_p + \eta_{pump} + \eta_{trans} \]
\[ A_i \] Area of waterjet impeller disk(s)

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\[ \dot{m} = \rho \cdot V \cdot A \text{ [lbm/s]} \]

**Power** [bHp]

**Effective surface area** (used in Grubisic\(^1\) regressions for \(W_{100}\))

**Subscript**

<table>
<thead>
<tr>
<th>OA</th>
<th>Overall (when used with length, indicates total length of ship from bow to stern)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P)</td>
<td>Between perpendiculars (when used with length &amp; straight transom = length at the waterline)</td>
</tr>
<tr>
<td>(WL)</td>
<td>Waterline (the line made by the interface between the hull and surface of the water)</td>
</tr>
<tr>
<td>(X)</td>
<td>Midship (for this application taken to mean the location of maximum beam and draft)</td>
</tr>
<tr>
<td>(FL)</td>
<td>Full Load (the maximum load the vessel can carry, full fuel and payload)</td>
</tr>
<tr>
<td>(LS)</td>
<td>Light Ship (vessel weight with no load; no fuel, payload, operators or passengers)</td>
</tr>
<tr>
<td>(R)</td>
<td>Required</td>
</tr>
<tr>
<td>(Aux)</td>
<td>Auxiliary (when used with power, signifies extra power extracted from engines)</td>
</tr>
</tbody>
</table>

## I. Introduction

In the stages of conceptual design, a means of rapidly evaluating numerous concepts is invaluable to any designer. A parametric sizing and synthesis environment eliminates the restriction of only evaluating a handful of point solutions and allows for the design space to be quickly and thoroughly explored. Due to the fluidity of the design and necessity to evaluate many concepts to find a suitable solution, it is acceptable to utilize faster yet lower fidelity models for complex systems. Regressions can be developed from historical data and other sources to allow for the modeling and rapid evaluation of different designs. This paper will illustrate the utility of parametric sizing and synthesis when applied to the design of a small, planing hull military watercraft as well as document the creation of the design tool in which it is utilized.

### I.A. Purpose

The original intended purpose of the Parametric Sizing and Synthesis Tool for the Design of Planing Hull Watercraft (hence referred to as the Craft Architecture Tool) was to serve as a starting point and initialization module for the integrated modeling and simulation environment generated during the TRIDENNTS project. The tool provides a means to rapidly perform conceptual design of small, planing hull military watercraft as well as model and evaluate existing designs. With inputs such as vehicle requirements (maximum speed, range, payload, etc.), geometry and mission definition, a craft is generated through iterative sizing routines and then displayed in graphical form for the user. The outputs from the tool include: performance metrics, craft transportability, craft dimensions and weight, on-board component information and placement as well as a top and side view of the vehicle. As shown in Figure (1) these outputs are then meant to be fed as inputs to the Signatures and Cost Analysis modules of the TRIDENNTS M&S environment. However, the Craft Architecture Tool can stand alone and provide an environment for the rapid design and evaluation of small craft concepts.

### I.B. The TRIDENNTS Project

The Tactical Reduction in Detection of Electromagnetic and Noise of Naval Transport Signatures project (hence referred to as TRIDENNTS) was tasked with calculating and analyzing the susceptibility of small military watercraft to naval mine threats. The TRIDENNTS effort was initiated as a "Grand Challenge" project (open ended research problem) and undertaken by a team of five first year students at ASDL. The project was sponsored by the Office of Naval Research and then Naval Surface Warfare Center Carderock Division.

**Problem Statement:** Seek to evaluate the capability, feasibility and survivability of new designs and modified legacy designs of small watercraft operating in mined littoral areas. Emphasis will be placed on minimizing vehicle signatures (magnetic and acoustic) as well as vehicle weight and acquisition cost.
**Figure 1.** Chart illustrating the flow of information from each of the modules composing the TRIDENNTS M&S environment. Note that the Craft Architecture tool is the beginning of the data flow and translates requirements and mission parameters into a parametrically defined monohull planing craft for use in all the other modules.

**MOTIVATION:** To use a fast transport craft to enter littoral areas to achieve a strike objective without relying upon minefield intelligence.

**II. Methodology**

The Craft Architecture tool was designed to model vehicles which are a subset of the US Navy’s classification of small craft. Because these vehicles were desired to operate at high speed, a planing craft assumption is made in the creation of each design. In other words, each vehicle design, when at its design speed, develops at least part of its lift through dynamic forces by planing on the surface of the water. Furthermore, each design is sized assuming a ”V-shaped” mono-hull planing hullform with a single chine, marine diesel engine(s), and waterjet propulsors.

The sizing and synthesis of each design is weight based and iterative in nature. Using mission discretization and fuel balance techniques a vehicle is sized based on user requirements. Furthermore, once sized through the determination of the loaded weight of the craft, a volume analysis is performed which determines whether or not the craft is hydrostatically buoyant as well as volumetric parameters associated with the craft. Once sized and its volume analyzed, craft characteristics (dimensions, layout, weight information, etc.), performance (power required, fuel consumption, etc.) and a visual depiction of the vehicle are returned as output to the user. Figure (2) illustrates this methodology.

**II.A. Weight Based Sizing**

The iterative weight based sizing routine is based on the concept of fuel balance over a discretized or segmented mission. To begin, the total or loaded weight of the craft is estimated through an initial guess. The craft, as defined by requirements, is then initially run through the mission with the craft starting weight set to the initial guess. Figure (3) illustrates the iterative weight based craft sizing process, which will be further enumerated in later sections.

**II.B. Volume Based Sizing**

The Volume based sizing aspect of the Craft Architecture Tool is largely a check for hydrostatic buoyancy and basic stability/seaworthiness. However, the volume analysis also determines what volumes are required within the hull for the installation/storage of payload, fuel and subsystems/components. For each design, the bow and stern of the craft are discretized into sections. Bow sections are conservatively estimated simply as inverted triangles with their bases defined by the deck (beam at the given section) and the tip of the
triangles defined by the keel line. The keel line itself is approximated as a scaling of the deck line, thus the depth of the keel at any section along the hull is assumed to equal the beam of that section scaled by the ratio of the maximum hull depth to maximum beam \((D_{section} = B_{section} \cdot \frac{D}{B_M})\). Stern sections are estimated using the user input parameters defining the planing surface of the hull \((D, \theta_S\) and \(\beta\)). The planing surface of the stern sections are clearly defined by a hard chine which marks the intersection of the hull sidewall with the deadrise surface. The geometry of the bow and stern sections is illustrated in Figures (4) and (5) respectively.

To obtain the total hull volume, the area for each bow section and stern section is calculated, then the areas of two adjacent sections are averaged and multiplied by the distance between sections to obtain a segment volume. All the segment volumes are then summed as a middle Riemann Sum which provides an approximation of the hull volume. Once the total hull volume is obtained, it is checked against the displacement volume \((\nabla)\) to ensure that the total hull volume is greater than \(\nabla\), and thus the hull is hydrostatically buoyant (Eqn. (1)). A fraction is then applied to the hull volume to account for hull thickness, structure, bulkheads, and otherwise unusable hull volume in order to calculate usable hull volume (Eqn. (2)).

\[
V_{TotalHull} \geq \nabla = \frac{\Delta_{FL}}{\rho} \tag{1}
\]

\[
V_{UsefulHull} = 0.9 \cdot V_{TotalHull} \tag{2}
\]

II.B.1. Waterline Calculation
The location of the static waterline is determined by an iterative routine which compares the volume of the hull below the waterline to the volume of water that the craft is required to displace for hydrostatic equilibrium. The calculation of the waterline provides maximum static draft and fully loaded static freeboard values. The maximum static draft value can be compared to the maximum draft constraint input by the user to determine if the craft is meeting performance requirements. If the maximum static draft is more than allowed, the user should either increase the submerged volume of the craft by altering its geometry or lighten the craft by removing payload or relaxing speed and/or range constraints. The fully loaded static freeboard value provides a notional metric for craft seaworthiness. If the craft has very little freeboard then the deck may be swamped by even small waves, which may lead to taking on water. However it should also be noted that very large static freeboard values may also not be indicative of stability if their is sufficient weight above the waterline (this can cause the craft to capsize).

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Figure 3. Chart illustrating the methodology behind the iterative weight sizing process. The process is iterative in nature because the totalled weights at the end of each iteration are compared with the fully loaded weight guess from the beginning of the iteration. If there is a discrepancy larger than a specified tolerance between these two values the weight guess is altered and another iteration performed.

II.C. Planing Hull Modeling

All watercraft modeled by the Craft Architecture Tool are assumed to have a planing monohull construction. Because planing hull vehicles develop some of their lift and resistance through interaction with hydrodynamic forces it is necessary to model their passage through fluids different than that of pure displacement hulls. Empirical equations developed by Savitsky in his 1964 paper describe the lift, drag and wetted area of planing surfaces as a function of vehicle speed, trim angle, hull deadrise angle and loading.$^2$

II.C.1. Resistance and Dynamic Lift from Savitsky Equations$^2$

Starting with an initial weight guess $W_0$ the empirical planing hull equations are used in the iterative, weight based, mission discretized sizing routine to calculate the lift coefficient of the deadrise surface for a given speed, trim angle, deadrise angle, and craft beam (Eqn. (3)). This deadrise lift coefficient is then transformed into a flat-plate or zero-deadrise lift coefficient through iteratively sloving Eqn. (4). With $C_{L0}$ known, the wetted length to beam ratio is now iteratively solved for using Eqn. (5). With $\lambda$ now known the draft $d$ is determined by rearranging Eqn. (6). $\lambda$ is also used to calculate the resistance or drag through Eqn. (9). Since the craft is assumed to be in a steady state, the drag is equated to thrust which allows for the determination of the waterjet exit velocity through the use of Eqn. (10). Finally, using Eqn. (11) the power required from the engine(s) is computed once $V_{jet}$ is used to calculate the propulsive efficiency. This power value is then fed into the regression illustrated in Figure (6) to determine the weight of the engines (other regressions provide the volume and fuel consumption for a given power).

$$W_0 = \Delta = L = \frac{1}{2} \rho V^2 B^2 C_{L\beta}$$ (3)
\[ C_{L_\beta} = C_{L_0} - 0.0065 \beta (C_{L_0})^{0.60} \]  
(4)

\[ C_{L_0} = \tau^{1.1} \left[ 0.0120 \lambda^{1/2} + \frac{0.0055 \lambda^{5/2}}{C_V^2} \right] \]  
(5)

\[ \lambda = \frac{\left( \frac{d}{\sin \tau} \right) - \frac{B \tan \beta}{2\pi \tan \tau}}{B} \]  
(6)

\[ V_{1_\beta} = V (1 - \frac{C_{L_\beta}}{\lambda \cos \tau})^{1/2} \]  
(7)

\[ C_f = 0.075 \left( \frac{\log_{10} \text{Re}}{2} - 2 \right)^2 \]  
(8)

\[ D = \Delta \tan \tau + \frac{\rho V_{1_\beta}^2 C_f AB^2}{2 \cos \beta \cos \tau} \]  
(9)

\[ D = T = \dot{m} (V_{jet} - V) = \rho V A_t (V_{jet} - V) \]  
(10)

\[ P_R = \eta TV + P_{Aux} \]  
(11)
II.D. Detailed Weight Estimation

Two methods were analyzed for their applicability in small craft weight prediction. Since only the payload weight is specified by the requirements (albeit indirectly through actual payload items) the other system weights must be either calculated or estimated. The propulsion system weight can be determined through the use of the iterative weight based sizing and engine and propulsor regressions. Fuel consumption can also be determined via regression for an engine at a certain power setting (same for a generator too), thus given the range the fuel required can also be calculated. The weights of other subsystems/components may also be calculated as detailed in later sections, however, the hull and superstructure weight must be estimated along with outfit and support weights. The next two sections detail two different approaches for obtaining these weight estimations.

II.D.1. High-speed Planing Monohull Weight Fractions

When performing parametric conceptual design it is often common to use weight fractions for unknown elements of the total vehicle weight. These weight fractions are often based on an amalgamation of historical data obtained for analogous vehicles or systems. In a paper presented to the Society of Naval Architecture and Marine Engineers in Athens, Greece in 2003, Savitsky provides weight fractions for different elements of planing hull craft. The following table lists these weight fractions (Table 1). The hull & superstructure as well as outfit & auxiliary systems weight fractions are used within the iterative sizing routine to estimate the weight of those divisions of the total loaded ship weight.

<table>
<thead>
<tr>
<th>Component</th>
<th>Variable</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull &amp; Superstructure</td>
<td>$W_s^\Delta$</td>
<td>0.30</td>
</tr>
<tr>
<td>Propulsion System</td>
<td>$W_p^\Delta$</td>
<td>0.36</td>
</tr>
<tr>
<td>Outfit &amp; Auxiliary Systems</td>
<td>$W_{oa}^\Delta$</td>
<td>0.12</td>
</tr>
<tr>
<td>Light Ship Total</td>
<td>$W_{LS}^\Delta$</td>
<td>0.78</td>
</tr>
<tr>
<td>Useful Load (Payload &amp; Fuel)</td>
<td>$W_{ul}^\Delta$</td>
<td>0.22</td>
</tr>
</tbody>
</table>

II.D.2. Small Craft Weight Prediction from Regressions

In addition to the high-speed planing monohull weight fractions presented by Savitsky, there is another method for estimating the different subgroup/component weights of small planing craft. In a paper presented at the 6th International Conference on High-performance Marine Vehicles (Hyper ’08), Izvor Grubisic, provides regressions for component weights broken down using the USN SWBS system. These regressions are determined from a database of small craft gathered by Grubisic and separated into appropriate categories. For the purpose of the Craft Architecture Tool, coefficients corresponding to military/naval vessels were used in each of the regressions. The regressions and the SWBS groups they describe can be seen in Table 2.

II.E. Subsystem, Component and Payload Modeling

The hull specifies the shape, structure and displacement capacity of a craft, but in order to construct a working and useful vehicle, subsystems, components and payload must be integrated with the hull. These items include but are not limited to: engines, propulsors, generators, navigation and communication equipment, personnel (crew and passengers), armament, armor, launching craft and their equipment, and also fuel. Each of these items differ in composition, weight, geometry, and utilization, thus it is important to establish distinct means of modeling different components.

II.E.1. Propulsion System

The propulsion system (engines and waterjet propulsors) is sized through the use of power vs. weight regressions for modern marine diesel engines and waterjet propulsors (Example: Fig. 6). The total craft
Table 2. Weight Regressions by SWBS groups for small craft [SI units]

<table>
<thead>
<tr>
<th>Component</th>
<th>SWBS group</th>
<th>Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hull Structure &amp; Superstructure</td>
<td>$W_{100}$ &amp; $W_{150}$</td>
<td>$K_0 \cdot E^{1.33}<em>{SWBS} \cdot (L\cdot B \cdot D)</em>{SWBS}^{0.45}$ [tons], $K_0 = 0.0112$</td>
</tr>
<tr>
<td>Propulsion</td>
<td>$W_{200}$</td>
<td>$(L\cdot B \cdot D)_{SWBS}^{0.45}$ [tons]</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>$W_{300}$</td>
<td>$0.00053 \cdot L^{2.254}$ [tons]</td>
</tr>
<tr>
<td>Electronics</td>
<td>$W_{400}$</td>
<td>$0.000772 \cdot (L \cdot B)^{1.784}$ [tons]</td>
</tr>
<tr>
<td>Auxiliary Systems</td>
<td>$W_{500}$</td>
<td>$0.000772 \cdot (L \cdot B)^{1.784}$ [tons]</td>
</tr>
<tr>
<td>Outfit</td>
<td>$W_{600}$</td>
<td>$0.0097 \cdot L^{2.132}$ [tons]</td>
</tr>
<tr>
<td>Special Systems</td>
<td>$W_{700}$</td>
<td>$0.00333 \cdot (L \cdot B \cdot D)^{1.422}$ [tons]</td>
</tr>
<tr>
<td>Variable (Payload &amp; Consumables)</td>
<td>$W_{800}$</td>
<td>$0.00369 \cdot (L \cdot B)^{1.67}$ [tons]</td>
</tr>
</tbody>
</table>

Weight is used in conjunction with design speed and physical craft dimensions specified by the requirements to calculate the resistance or drag on the hull (through the use of plaining hull equations developed by Daniel Savitsky). This resistance can then be said to equal to the thrust that the craft must generate to maintain speed (Eq. (12)) and thus, the power required from the engines may be determined (Eq. (13)). This power value can then be applied to geometric regressions obtained from data from the same engines to parametrically determine the length, width, and height of the engine(s). With these dimensions the volume of the engine(s) can be calculated and ultimately applied to the component total volume.

\[
\text{Resistance} = \text{Thrust} \quad (12)
\]

\[
\text{Power Required} = \text{Overall Propulsive Efficiency} \cdot \text{Thrust} \cdot \text{Velocity} + P_{Aux} \quad (13)
\]

Figure 6. Plot of Power vs. Weight for modern marine diesel engines. Linear regression parameters are obtained via a trendline through the data. Data obtained from MTU engine datasheets.
II.E.2. On-board Components

The sizing of on-board components is accomplished through the use of regressions obtained in a similar fashion as those used to model the engines and propulsors. If specified by requirements, a generator, navigation/communications package (NavCom), and Combat Rubber Raiding Craft (CRRC) outboard engines may be placed in or on the craft. The location and size of these components was built into the tool primarily for the purpose of passing the information onto the Electromagnetic Signature Tool which would then calculate the magnetic signature generated by each component.

The generator is sized based on the generator power requirement and its weight and dimensions are determined through quadratic regressions. The NavCom weight and power requirement are specified in a drop-down menu on the tool dashboard, and the dimensions are simply determined by notional scaling parameters which proportionally increase each dimension with weight. In a higher fidelity analysis, the individual subsystems (Fluxgate compass, navigation equipment, Radar, VHF, UHF) that compose the NavCom suite could be parametrically modeled with regressions of their own based on technical specification data for those systems. However it was deemed acceptable to lump these subsystems so as not to place unnecessary detail in concepts when trying to rapidly evaluate numerous designs. The CRRC engines were modeled after common 55 Hp outboard marine gasoline engines and weigh approximately 243 lbs each.

II.E.3. Payload

The weight of the payload is determined from summing the weights of all payload (personnel and materiel) input as a requirement for the craft on a particular mission. All armaments, ammunition, armor, launching craft (CRRCs), etc. are translated into their respective weights and then added together. For turreted weapons such as the 7.62 mm, 12.7 mm guns and the 40 mm grenade launcher, the weight of the turret/mount is included if the corresponding weapon is onboard. Ammunition and armor are simply added as weight. The only payload items that are considered as taking up hull volume to stow on the craft are the CRRC’s their fuel, and their engines. The stowed CRRC volume is assumed to be that of a folded CRRC, and the fuel volume is modeled as 1.1 · $V_{fuel}$ to account for gasoline and tank volume. All other payload (personnel, armament and armor) are assumed to be located above deck or in the superstructure, thus while these components contribute to weight, they do not subtract from usable hull volume.

II.E.4. Fuel

Fuel weight is determined at the end of each iteration through the usage of a Power vs. Fuel Consumption regression (Fig. (7)). During each iteration, the fuel required for each mission segment is determined based on the fuel consumption of the engine(s) during that segment. As the craft transits between mission segments the craft gets lighter as it burns fuel, thus at the next mission segment the power required from the engine(s) is less and thus the fuel consumption decreases. In terms of volume, fuel is simply modeled as requiring 1.1 · $V_{fuel}$ to account for the diesel fuel and tank volume.

III. Implementation

Now that the parametric sizing and synthesis methodology has been laid out, the techniques can be put to use and an environment assembled. Microsoft Excel was chosen as the program in which the design environment would be created because of its familiarity and ease of use with most users. Furthermore, the four other modules of the TRIDENNTS integrated M&S environment were designed to function within Excel and it was believed that this would provide for easier module integration. The Craft Architecture Environment generated through the implementation of the above methodology allows for rapid design space exploration and concept evaluation in a user friendly and parametric environment. The final tool was named DEPPTH (Design Environment for Parametric Planing Transport Hulls) and its user interface or dashboard can be seen in Figure (8).
III.A. Inputs

Referring to the DEPPTH shown in Figure (8) the inputs can be seen on the left side of the dashboard as a series of slider bars and drop down menus. The combination of requirements, constraints, and options define the small military monohull planing craft. These inputs range from performance requirements such as design speed and range, to geometric constraints which define the vehicle’s dimensions to mission requirements and options which define the craft loadout or even what material the hull is made of. While not the only inputs to the parametric environment, they are the most high level and encompass what is needed for a thorough design space exploration in the conceptual design phase.

III.B. Outputs

The outputs of the DEPPTH come in two forms numerical and graphical. The numerical outputs are grouped into three categories: Performance and Weight, Volume Analysis and Transportability. The Performance and Weight category provides the craft’s maximum speed, range, propulsive power required at full load, fuel consumption at full load, lightship weight, payload weight, fuel weight and the full load weight of the craft. The Volume Analysis category contains the total hull volume (including hull thickness and structure but excluding any superstructure), the displacement volume, the hull volume occupied by the payload, fuel and all hull mounted components, the usable hull volume, the static draft at full load and the static freeboard at full load. The Transportability category simply displays a list of transports/carriers which are able to accommodate the craft in its current geometry and full load weight.

The graphical outputs are composed of two views of the craft, one looking down on the craft from above, and the other looking edge on at its port side. Both views provide the user with a notion of the craft geometry, placement and size of shipboard systems. The side view conveys even more information as it shows the waterline along the x (longitudinal) axis and provides a visual depiction of the the static draft and the static freeboard at full load.

III.C. Functions and Subroutines

The DEPPTH is supported by a calculator and an array of functions and subroutines which run automatically when the user modifies an input parameter. Below is a list of the functions that support the DEPPTH and a brief description of their workings.
Figure 8. Dashboard of the Design Environment for Parametric Planing Transport Hulls (DEPPTH).

C\textsubscript{0iterate} is the function which solves Eqn. (4) iteratively and returns the value of $C_{L0}$.

\texttt{lamdaiterate} is the function which solves Eqn. (5) iteratively and returns the value of $\lambda$.

\texttt{weightiterate} is the main function which performs the mission discretization and weight based sizing. It solves Eqns. (3) through (11) while calling \texttt{Cl0iterate} and \texttt{lamdaiterate} in two large while loops which run through the mission segments and converge the weight. This function returns all the parameters of interest for the fully loaded craft.

\texttt{Ellipiseiter} solves for segments of ellipses which are used to draw the contours of the craft (deck and keel lines).

\texttt{Transport} looks at the weight and geometry constraints of each of the listed transports/carriers and determines which ones can accommodate the current design.

\texttt{Waterline} calculates the location of the waterline by matching the required displacement with the volume of a section of the hull measured from the keel up. It assumes a level deck and returns the waterline depth below the deck.

\texttt{MKVpreset} is the subroutine which sets all the inputs in the DEPPTH to those corresponding to the Mk V Special Operations Craft used by the United States Navy.

\texttt{RHIBpreset} is the subroutine which sets all the inputs in the DEPPTH to those corresponding to the 11m Rigid Hull Inflatable Boat used by the United States Navy.

\texttt{SOCRpreset} is the subroutine which sets all the inputs in the DEPPTH to those corresponding to the Special Operations Craft - Riverine used by the United States Navy.

\texttt{IV. Conclusion}

Though limited by many assumptions and regressions, the DEPPTH provides an intuitive, fast and reliable environment for design space exploration and conceptual design of small military monhull planing
watercraft. Furthermore, its Microsoft Excel based nature allows it to be a portable, easily edited and integrated tool. It is able to provide needed inputs to the TRIDENNTS integrated M&S environment and grants the Aerospace Systems Design Laboratory of Georgia Tech a new and valuable capability: the parametric conceptual design of small planing hull watercraft.

Appendix

The file which contains the DEPPTH is: DEPPTH_FINAL_JKizer.xls This file may be distributed only with written consent from the author and may not be used for commercial purposes outside of the Aerospace Systems Design Laboratory of the Georgia Institute of Technology. However, you may contact the author through email if you would like a personal copy of the software.

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References