Atlas: A Software Framework for the ABS Rules

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1 Introduction

1.1 Overview

This document represents the establishment of software requirements and a design framework for a new client application, *Atlas*, intended to support the process of performing and documenting calculations required by the Classification process (e.g., Naval Vessel Rules, High Speed Naval Craft, Steel Vessel Rules, etc.). The name *Atlas* will be used throughout this paper to reference this software tool. As the development and planning continues and comments are received from key stakeholders, these requirements will be updated. To start, this document will summarize the concept of this NSRP Panel Project, the stated goals and objectives, workflow description, proposed architecture, and nominal project milestones. The project overview will only serve to orient the reader, with the primary content being centered around the software requirements and design framework.

1.2 Background

1.2.1 National Shipbuilding Research Program

The National Shipbuilding Research Program (NSRP) was created by U.S. shipyards at the Navy's request to reduce the cost of building and maintaining U.S. Navy warships. NSRP is a collaboration of several major U.S. shipyards focused on industry-wide implementation of solutions to common cost drivers. The program targets solutions to consensus priority issues identified by the Navy shipbuilding community and industry in undertaking Research and Development efforts that exhibit a compelling business case to increase warship affordability by improving U.S. shipbuilding and ship repair efficiency. Solutions include both leverage of best commercial practices and creation of industry-wide initiatives with aggressive technology transfer to, and buy-in by, multiple U.S. shipyards.

The mission of NSRP is to manage and focus national shipbuilding and ship repair research and development funding on technologies that will reduce the cost of ships to the U.S. Navy and other National Security Customers by leveraging best commercial practices and improving the efficiency of the U.S. shipbuilding and ship repair industry. Further, it provides a collaborative framework to improve ship-related technical and business processes.

1.2.2 Panel Project Concept and Objectives

Within the NSRP, there are 10 panels that correspond to narrow technical and/or process areas while being aligned to the broader major initiatives of the NSRP Strategic Investment Plan. The Executive Control Board typically sets aside a modest amount of money each year to fund relatively small (less than $150k), short-term (12 months or less) projects recommended by the Panel Chairs. This project, *A Software System for the ABS Rules for Building and Classing Naval Vessels*, represents one of the Panel Projects that was awarded in November 2011.

The objective of this *NSRP Ship Design and Material Technologies* (SDMT) panel project is to establish the software requirements and framework necessary for the design and implementation of a software application for performing and documenting rule-based calculations required by ABS. Although this *software framework* can be applied to any ABS *rule set*, it was elected to use the Rules for Building and Classing High Speed Naval Craft as a starting point. The establishment of requirements will be used to initiate the development of a software application prototype (i.e., a *proof-of-concept*) demonstrating the feasibility of such a tool. Using the Agile Software Development Process, user requirements will continuously evolve throughout the project and will result in a software design and development plan for the application.

In essence, this project will act as an exploratory effort, establishing requirements of industry stakeholders (e.g., Shipyards, Design Firms, Class Society, etc.) for such a software application, and initiating design and development of the software framework to support those requirements. The proposed software application framework will ultimately facilitate ABS classification for ship structural design requirements. Further, the software framework/architecture developed in this project will consider future software interfaces and other technical domains (e.g., electrical and machinery).

DRS Training & Control Systems, LLC, Advanced Marine Technology Center (DRS AMTC) will act as the prime contractor and software developer. The following organizations will participate under the direction of DRS AMTC: Huntington Ingalls Shipbuilding (Ingalls) and American Bureau of Shipping Naval Engineering Department (ABS NED).

1.3 Project Milestones and Participants

The nominal milestones and intended participants for this panel project are presented in Figure 1.

TASK 1 Establish Initial Requirements
TASK 1A – Planning/Requirements Definition (All Participants)
TASK 2 Create Software Development Plan
TASK 2A – Develop Use Cases & Work Flows (DRS AMTC)
TASK 2B – Design Application Architecture & Develop Product Model Definition (DRS AMTC)
TASK 2C – Review and Refine Requirements (All Participants)
TASK 3 Develop Application Prototype
TASK 3A – Initiate Prototype Development (DRS AMTC)
TASK 3B – Review and Refine Requirements (All Participants)
TASK 4 Summarize Findings
TASK 4A – Develop Project White Paper (DRS AMTC)

Figure 1: Task Work Breakdown Structure and Participants

2 Software Design Requirements

In software engineering, a *functional* requirement defines a function of a software system or its component. A function is described as a set of inputs, the behavior, and outputs. Functional requirements may be calculations, technical details, data manipulation and processing, and other specific functionality that define what a system is supposed to accomplish. *Behavioral* requirements, describing all the cases where the system uses the functional requirements, are captured in *use cases*. Use cases capture a system's behavioral requirements by detailing scenario-driven threads through the functional requirements. Use cases describe system behavior from a user's point of view. The major functional and behavioral requirements are identified below.

2.1 Functional Requirements

The following list presents the functional requirements identified for Atlas. Section 1.1.1 (Section Modulus requirements for All Craft) of the Primary Hull Strength from the High Speed Naval Craft rules is used as an example; however the framework and steps below are designed to support the various applicable rule sets and their subsections. This is an important point as the following example is a very "simple" one; more complicated computations would be accommodated by this framework.

- **Input Data:** Allow the user to enter information about the vessel (e.g., length, beam, speed, displacement, etc.) through a graphical user interface (GUI) or through an input file. Additional information about the vessel can be provided in subject area specific dialogs.
- **Perform Calculations:** Perform the necessary calculations in order to meet the requirements defined in the section of interest. In this example, the minimum allowed section modulus at amidships would be calculated using the following equation:

$$SM = C_1 C_2 L^2 B (C_b + 0.7) K_3 C Q \tag{1}$$

- **Output Results:** Create a report of the results and whether each section of the classing rules is passed. Provide the option to create an "extended" report with intermediate calculations and input values defined. The extended report would provide values such as C_1 and the equation used to calculate this value. For example, a ship with a length of 75 meters would output:

$$C_1 = 0.044L + 3.75 \tag{2}$$

$$C_1 = 7.05 \tag{3}$$

2.2 Behavioral Requirements/Use Cases

The following list presents the behavioral requirements, or use cases, identified for Atlas.

- The end-user creates a new analysis database by entering values through the GUI.
- The end-user creates a new analysis database by importing an input file.
- The end-user opens an existing analysis database.
- The end-user runs an analysis to determine if the design passes one or more rule sections.
- The end-user creates a full report output of the analysis which includes input values, intermediate calculations, final values, and any rule sections of the design.
- The end-user creates an export file to provide to another user or classification society.

3 Workflow Description

Atlas is intended to be used by shipyards, designers, and classification societies during the process of developing a new ship design, or making modifications to an existing ship. This tool would be exercised in conjunction with the development of engineering plans and drawings (e.g., machinery, structural, etc.). Figure 2 presents a simple, high-level workflow demonstrating where this tool would fit into the overall design process. This tool could be leveraged during all phases of the design process, however the primary focus is in the late concept design phase as well as preliminary and contract design. It will also assist with the communication process between shipyard, designer, and classification society by presenting computations and results in a standard format.

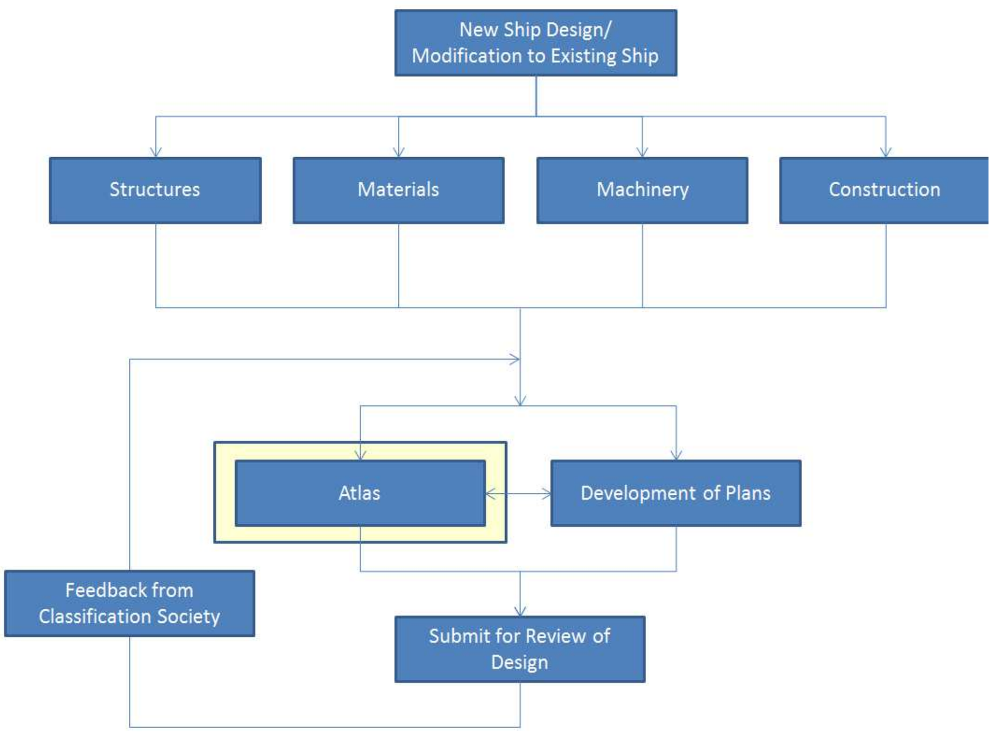


Figure 2: High Level Workflow

The notional workflow looking at just the steps specific to Atlas has been identified in Figure 3.

The workflow begins with the user creating a new analysis database or opening an existing database. The user can enter or select general information about the analysis, such as the name of the vessel, the user, units, the rule set of interest, etc. which will define the required

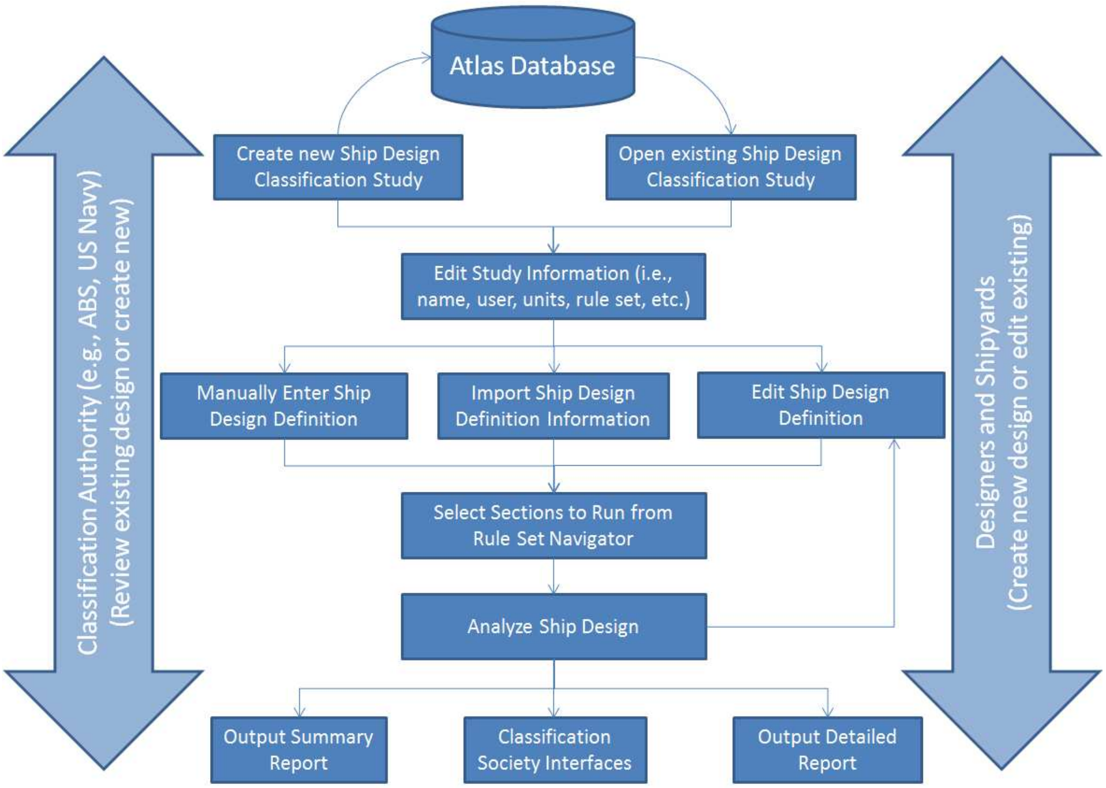


Figure 3: Atlas Workflow

inputs and outputs. The units and rule set can be changed at anytime and all unitized values will be converted appropriately.

The user is then able to input general information (i.e., length, beam, draft, displacement, etc.) about the vessel or edit the existing data. This general information can also be populated using an input file, whose format will be pre-determined. Once the general input information is defined, the user can navigate through the various functional areas and input additional information as needed. For example, shell plating and scantlings would be defined using input files or directly through the GUI functional area dialogs. Depending on the rule set chosen, the required input fields will be highlighted to visually inform the user which fields are necessary for a particular calculation. All of this information will be serialized and persisted so that the database can be saved and opened at a later time, or used with other rule sets.

The next step is to open the Rule Set Navigator and select the specific rule sections or subsections to perform the analysis on. This rule set navigator will update automatically each time the rule set is changed in the study information dialog. This allows the user to run the entire rule set or only specific sections at a time.

Once the inputs are defined, the analysis can be run using the rule set sections selected in the navigator. Using the results from the analysis, the user can either export the results or return to the ship design definition if a rule requirement is not met, or the design is inadequate. In a situation like this, the Rule Set Navigator could be used to only re-run the analysis on the sections that did not originally pass or have since been edited.

The last step provides the user three options for exporting the results of the analysis: as a "quick" report, as an "extended" report, or as an analysis results file. The "quick" report will simply output whether each of the rule sections have passed. The "extended" report will expand on the "quick" report by providing the input data, intermediate calculations and final results. The analysis results files will allow the user to export the data to a predetermined list of file formats that can be read by a classification society's in-house tool, or other design and analysis software (as an example, data might be exported to the ABS Software Product Line (e.g., SafeHull, Web Calc, DLA/SFA System, ABS Freeboard, ABS Eagle, etc.)), although actual export formats have not yet been identified. This framework will also support importing data from these same tools.

4 Proposed Architecture

The Atlas architecture will be based on a Smart Product Model (SPM) framework. Unlike traditional product models that are geometry- and data-centric, the SPM is object-centric and is defined by functional interfaces and patterns of collaboration. This object-oriented approach allows a complex problem to be broken down into more manageable, individual pieces which interact with each other using interfaces. For example, classes have been created to represent a vector or matrix object and their associated operators, which makes it easier to follow matrix or vector mathematics in the code. Unlike an Excel spreadsheet that might have formulas which reference several cells on multiple sheets, this approach makes code easier to read by someone not intimately involved in the development process.

The SPM framework logically divides the code into three tiers: a client tier, a business tier, and a data tier. The client tier is how the user (i.e., the designer, shipyard, or classification society) interfaces with the business and data tiers. One of the benefits of the multi-tier approach is the ability to layer different client tier interfaces on top of the same underlying business tier core logic so that, for example, a manager might be presented with a different graphical user interface (GUI) than a design engineer. The data tier is where the objects, or data, are stored and persisted in the database. In the case of Atlas, examples of these potential objects could be the plate or scantling definitions which would be stored in the database. The business tier is where the calculations occur using the objects from the data tier. An example of these calculations could be using the plate objects to calculate the minimum thickness using a specified rule set.

Communication between these tiers will be provided through well defined interfaces. Each of these interfaces will be implemented by one or more framework base classes and collectively will define most common engineering, modeling, simulation, and analysis activities.

Atlas will leverage an existing framework, known as TurksHead, that has been developed and used extensively at the DRS AMTC to support and develop applications based on the SPM framework. The TurksHead framework also contains support class libraries for geometry, math, and application infrastructure, including XML database capabilities. Using this existing framework as a starting point for development will greatly reduce the time and cost in developing the Atlas tool.

5 Tutorial

This section is intended to walk through the process of using Atlas to determine the requirements for section modulus and moment of inertia based on the rules found in Part 3, Chapter 2, Section 1 Primary Hull Strength of the *ABS Rules for Building and Classing High Speed Naval Craft (HSNC)*. The tutorial will encompass the procedure of entering the data into Atlas, running the analysis, and creating a report. The specific sections covered in this tutorial are 1.1 *Section Modulus*, 1.3 *Extension of Midship Section Modulus*, and 1.5 *Moment of Inertia*.

The purpose of the tutorial is to demonstrate the complete process described in Figure 3. A specific area of the rules is focused on for brevity; however the general steps would be applicable to all aspects of the rules which could eventually be supported by Atlas.

For purposes of this tutorial, a generic high speed crew boat will be used for realistic input values. An existing finite element model of the crew boat was used to recover the longitudinal sectional properties.

5.1 Atlas Graphical User Interface (GUI)

The Atlas tool is a standalone Windows based program with a series of menus and dockable windows. A screenshot of the GUI is below:

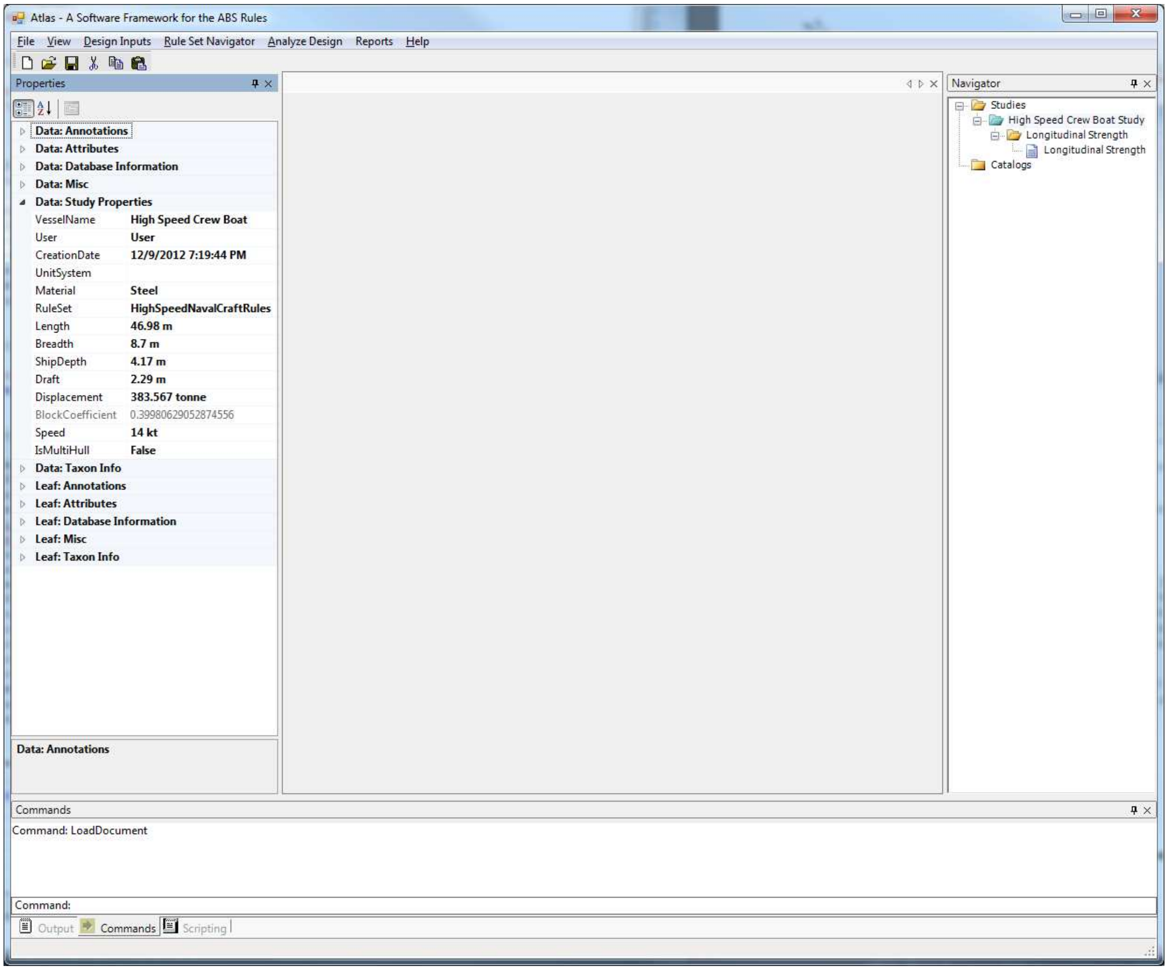


Figure 4: Atlas Graphical User Interface

Different functions of the tool can be performed using the menus, toolbar icons, or the command window at the bottom of the Atlas GUI window.

Navigator Window

The Navigator window, on the right-hand side of Figure 4, provides the organizational overview (i.e., product model) of the current study or studies, and is updated as new commands are executed. Similar to Windows Explorer, the data in the Navigator window is a series of folders and subfolders. Folders can be opened by clicking the "+" sign next to the folder name and collapsed by clicking the "-" sign. This window is also used interactively when prompted for selections by certain commands.

The Atlas framework allows for multiple studies to be created within one database. This would allow multiple ship designs to be stored and analyzed in a single database. An example of this extension of the framework is shown in Figure 5 below.

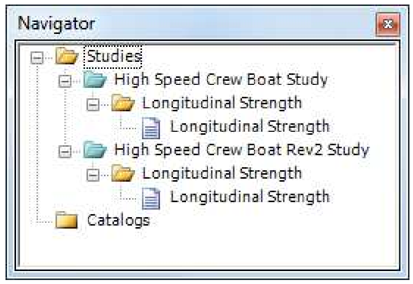


Figure 5: Multiple Atlas Studies

Properties Window

The Properties window, on the left-hand side of Figure 4, provides the attributes of the selected item from the Navigator window. The grayed out data is read-only, but the data in black bold font is editable, if desired. Similar to the Navigator window, sections can be expanded and closed by clicking the "+" or "-" sign.

Commands Window

The Commands window, at the bottom of Figure 4, can be used to enter a command to be executed as well as to prompt the user for additional inputs. When starting to type a command, all commands that match the typed characters will display in a pop-up window and can be clicked or scrolled through with the keyboard to complete the command. Right-clicking in the command window will pop up a list of recently run commands that can be selected to run.

All of the data entered and calculated in Atlas is stored and persisted in an XML database which can be easily transferred between users.

A new database can be created by running the command "CreateNewDocument," clicking the "New Document" icon, or selecting **File** > **New Document** from the menu. Similarly, an existing document can be opened by running the command "LoadDocument," clicking the "Open File" icon, or selecting **File** > **Open...** from the menu. When a new document is created, the Navigator window will be automatically populated with two folders: "Studies" and "Catalogs." A catalog serves as a location to store other components (e.g., Ship Design Classification Studies) which can be easily accessed during an analysis.

5.2 Create New Ship Design Classification Study

This tutorial assumes that a new Ship Design Classification Study will be created using the steps above, as opposed to opening an existing database. Once a new database is created, the next step is to create the study which will define the general information about the design. To create a new study, type the command "CreateNewStudy" or select **Design Inputs** > **Ship Design Study** from the menu. The prompt will be to select the location for this study. Click the "Studies" folder in the Navigator window and the Ship Design Classification Study dialog will open:

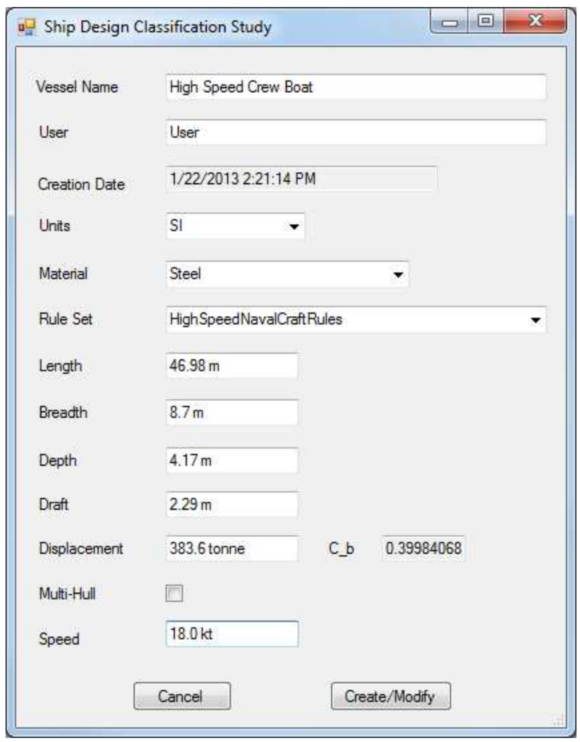


Figure 6: Ship Design Classification Study

The user is able to set the name of the vessel, the database user, units, material, and rule set. The creation date is automatically populated with the current date and time. For this tutorial, the units will be "SI," the material "Steel," and the Rule set "High Speed Naval Craft Rules."

The Finite Element (FE) model of the generic high speed crew boat is shown below in Figure 7 for reference.

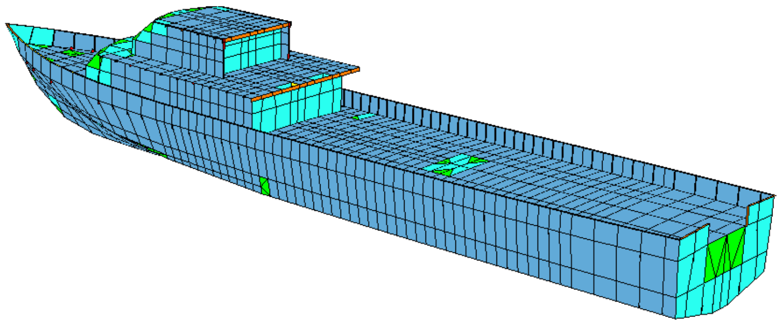


Figure 7: High Speed Crew Boat FE Model

The principal dimensions for this vessel are below and would be entered into the Ship Design Classification Study dialog:

Length	46.98 m
Breadth	8.70 m
Depth	4.17 m
Draft	2.29 m
Displacement	383.6 MT
Speed	18.00 kt

The block coefficient is automatically calculated from the length, beam, draft and displacement and is a read-only property. Currently the program assumes the environment the vessel operates in to be seawater, however future development will allow the user to specify the water density to use in the analysis.

Clicking "Create/Modify" will create the new study and place a new folder under "Studies" in the Navigator window with the name of the vessel followed by "Study."

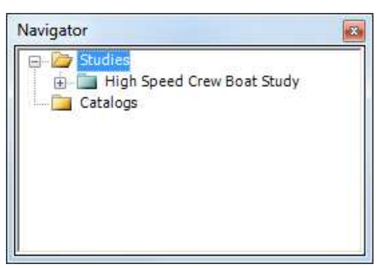


Figure 8: New Atlas Study in Navigator Window

At any time, the database can be saved by typing the command “SaveDocument,” clicking the “Save” icon, or selecting **File** > **Save** from the menu.

5.3 Entering Longitudinal Strength Sections

Once the study is defined, the “offered” properties of the longitudinal strength sections can be entered. By expanding the “High Speed Crew Boat Study” folder in the Navigator window, a “Longitudinal Strength” folder will appear, as well as a new object representing the longitudinal strength data, which have been automatically created with the study.

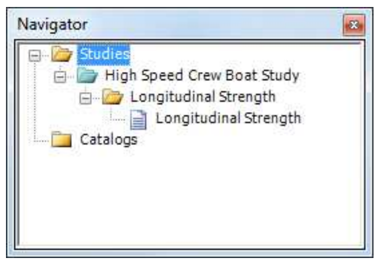
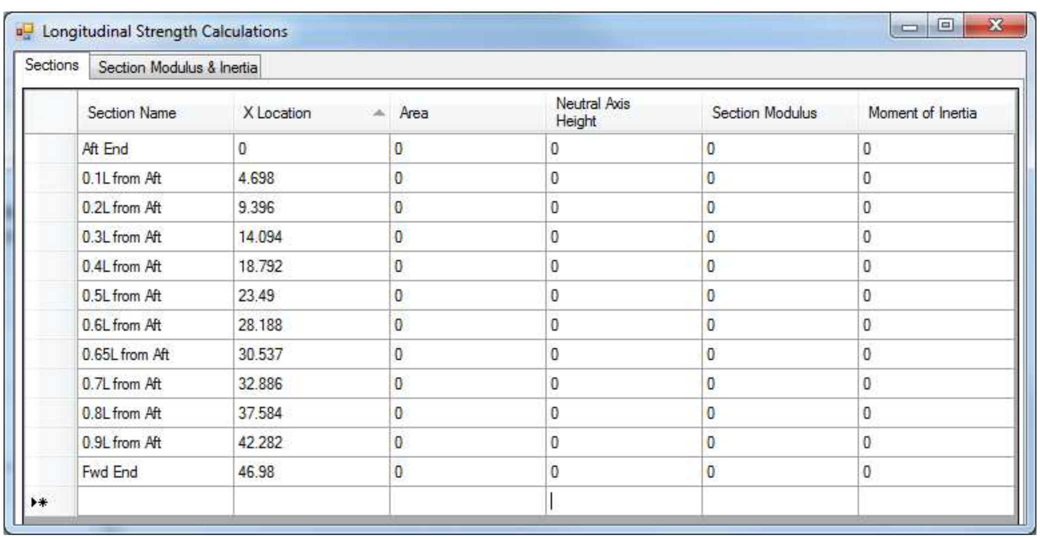


Figure 9: Atlas Longitudinal Strength Object in Navigator Window

To open the Longitudinal Strength dialog, select the Ship Design Classification Study in the Navigator window and type the command “LongitudinalStrengthCalculations” or select **Analyze Design** > **Longitudinal Strength** from the menu.



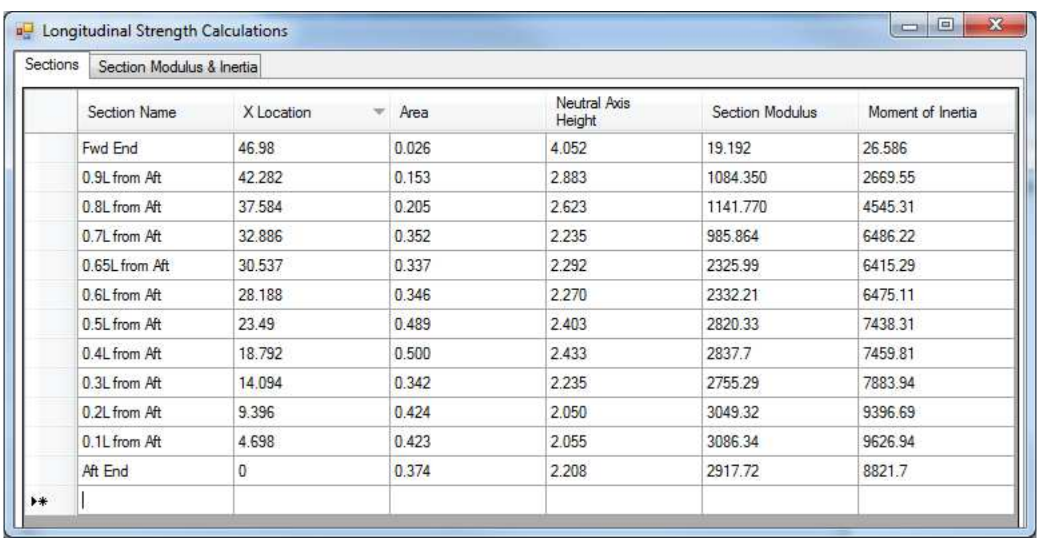
Section Name	X Location	Area	Neutral Axis Height	Section Modulus	Moment of Inertia
Aft End	0	0	0	0	0
0.1L from Aft	4.698	0	0	0	0
0.2L from Aft	9.396	0	0	0	0
0.3L from Aft	14.094	0	0	0	0
0.4L from Aft	18.792	0	0	0	0
0.5L from Aft	23.49	0	0	0	0
0.6L from Aft	28.188	0	0	0	0
0.65L from Aft	30.537	0	0	0	0
0.7L from Aft	32.886	0	0	0	0
0.8L from Aft	37.584	0	0	0	0
0.9L from Aft	42.282	0	0	0	0
Fwd End	46.98	0	0	0	0

Figure 10: Longitudinal Strength Dialog Section Inputs

Sections at the aft end, forward end, and every 0.1L are automatically generated. Additional sections can be added by the user as needed. Using the Crew Boat FE model, the following section properties were recovered:

Section Name	**X Location** (m)	**Area** (m^2)	**NA Height** (m)	**SM** ($cm^2 - m$)	**I** ($cm^2 - m^2$)
Aft End	0.0	0.374	2.208	2917.720	8821.700
0.1L	4.70	0.374	2.2055	3086.340	9626.940
0.2L	9.40	0.424	2.050	3049.320	9396.690
0.3L	14.09	0.342	2.235	2755.290	7883.940
0.4L	18.79	0.500	2.433	2830.700	7459.810
0.5L	23.49	0.489	2.403	2820.330	7438.31
0.6L	28.19	0.346	2.270	2332.210	6475.110
0.65L	30.54	0.337	2.292	2325.990	6415.290
0.7L	32.89	0.352	2.235	985.864	6486.220
0.8L	37.58	0.205	2.623	1141.770	4545.310
0.9L	42.28	0.0153	2.883	1084.350	2669.550
Fwd End	47.0	0.0260	4.052	19.192	26.586

These section properties can be entered manually, copied and pasted, or future development will allow the user to import a text or Excel file with the sections and properties defined.

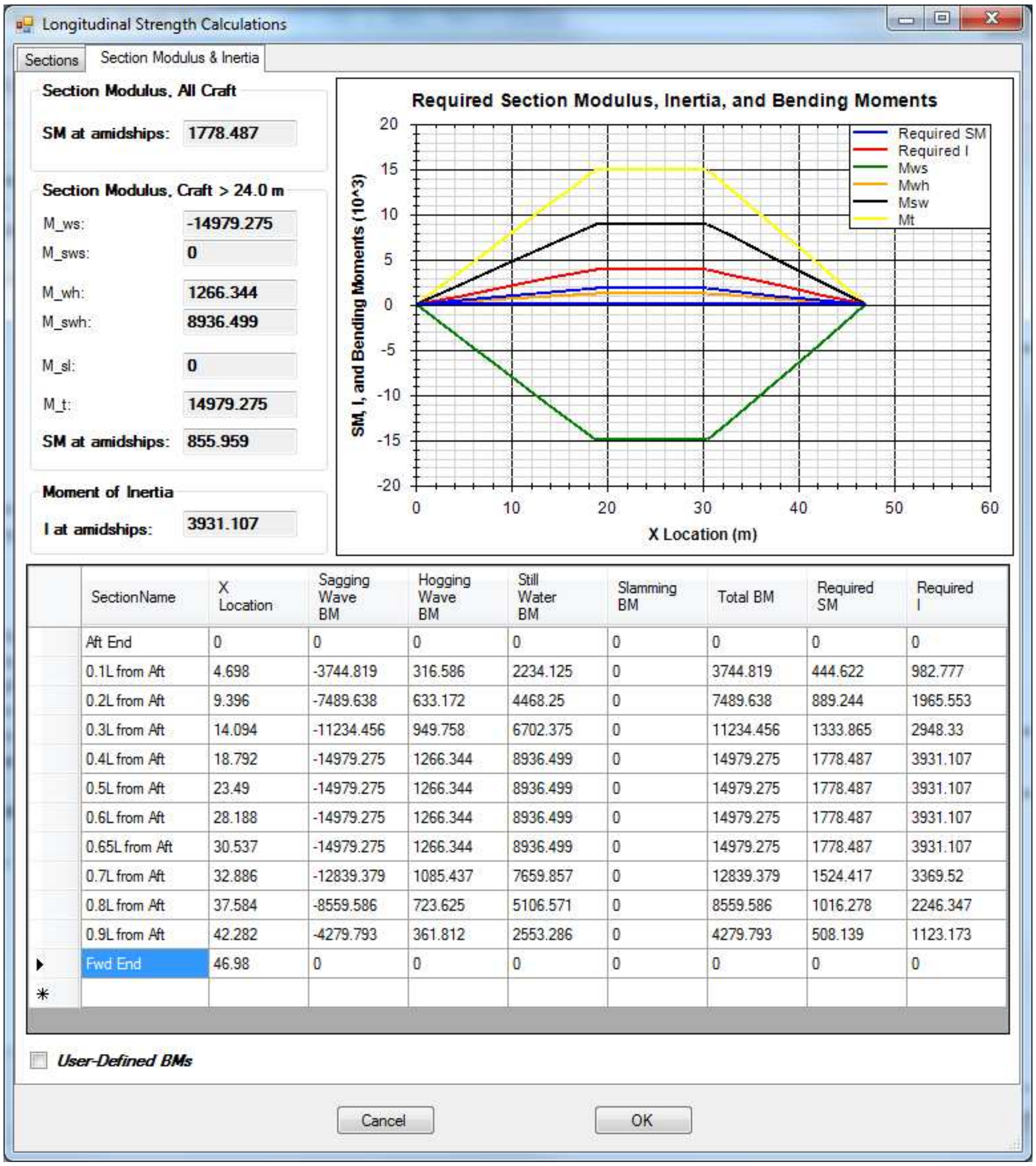


Section Name	X Location	Area	Neutral Axis Height	Section Modulus	Moment of Inertia
Fwd End	46.98	0.026	4.052	19.192	26.586
0.9L from Aft	42.282	0.153	2.883	1084.350	2669.55
0.8L from Aft	37.584	0.205	2.623	1141.770	4545.31
0.7L from Aft	32.886	0.352	2.235	985.864	6486.22
0.65L from Aft	30.537	0.337	2.292	2325.99	6415.29
0.6L from Aft	28.188	0.346	2.270	2332.21	6475.11
0.5L from Aft	23.49	0.489	2.403	2820.33	7438.31
0.4L from Aft	18.792	0.500	2.433	2837.7	7459.81
0.3L from Aft	14.094	0.342	2.235	2755.29	7883.94
0.2L from Aft	9.396	0.424	2.050	3049.32	9396.69
0.1L from Aft	4.698	0.423	2.055	3086.34	9626.94
Aft End	0	0.374	2.208	2917.72	8821.7

Figure 11: Longitudinal Strength Dialog Section Input Data

5.4 Analyzing Longitudinal Strength Requirements

Once the sectional data is input, the next step is to review the required section modulus and moment of inertia calculated using the rules. Click the "Section Modulus & Inertia" tab of the Longitudinal Strength Calculations dialog.



SectionName	X Location	Sagging Wave BM	Hogging Wave BM	Still Water BM	Slamming BM	Total BM	Required SM	Required I
Aft End	0	0	0	0	0	0	0	0
0.1L from Aft	4.698	-3744.819	316.586	2234.125	0	3744.819	444.622	982.777
0.2L from Aft	9.396	-7489.638	633.172	4468.25	0	7489.638	889.244	1965.553
0.3L from Aft	14.094	-11234.456	949.758	6702.375	0	11234.456	1333.865	2948.33
0.4L from Aft	18.792	-14979.275	1266.344	8936.499	0	14979.275	1778.487	3931.107
0.5L from Aft	23.49	-14979.275	1266.344	8936.499	0	14979.275	1778.487	3931.107
0.6L from Aft	28.188	-14979.275	1266.344	8936.499	0	14979.275	1778.487	3931.107
0.65L from Aft	30.537	-14979.275	1266.344	8936.499	0	14979.275	1778.487	3931.107
0.7L from Aft	32.886	-12839.379	1085.437	7659.857	0	12839.379	1524.417	3369.52
0.8L from Aft	37.584	-8559.586	723.625	5106.571	0	8559.586	1016.278	2246.347
0.9L from Aft	42.282	-4279.793	361.812	2553.286	0	4279.793	508.139	1123.173
Fwd End	46.98	0	0	0	0	0	0	0

Figure 12: Longitudinal Strength Dialog SM & I Calculations

The upper left hand section of the dialog shows the required section modulus, bending moments, and moment of inertia at amidships based on the rules for all craft and for craft over 24.0 m. The upper right section of the dialog shows a plot of the required section modulus, bending moments, and moment of inertia at each section based on the extension defined in section 1.3 *Extension of Midship Section Modulus*. The bottom of the dialog shows the list of sections, their calculated bending moments, required section modulus, and required moment of inertia. The user can check the box "User-Defined BMs" at the bottom of the dialog and manually enter values for the bending moments at each section. The plot will automatically update with new values as well as the values for amidships, if the midship sectional values are updated. Un-clicking the "User-Defined BMs" box returns the section values to those defined by the rules.

Clicking OK will save the inputs to the longitudinal sections as well as any user-defined bending moments and their resultant section modulus and moment of inertia.

5.5 Creating a Longitudinal Strength Report

Once all of the data is entered, the last step is to run the analysis report. Future development will include the rule set navigator dialog, which will allow the user to select the specific sections of the rules to run. In this tutorial, the focus is on a single rules section, Longitudinal Strength, so the report will always include these calculations.

To run a report, select the study in the Navigator window and type the command "Create-AnalysisReport" or select **Reports** > **Run Report** from the menu.

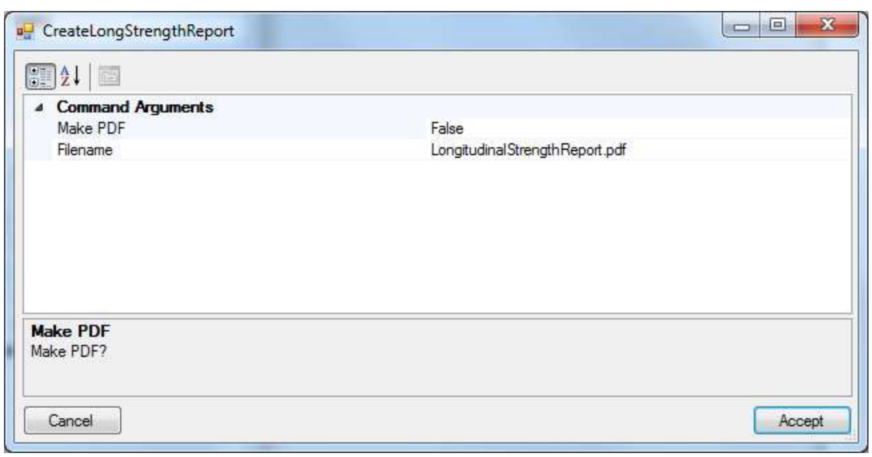


Figure 13: Analysis Report Dialog

The dialog allows the user to also create a PDF of the report and select the file name and location. Clicking "Accept" will run the report and display it in Atlas. Once created, the report can be exported to a PDF file, if not saved originally.

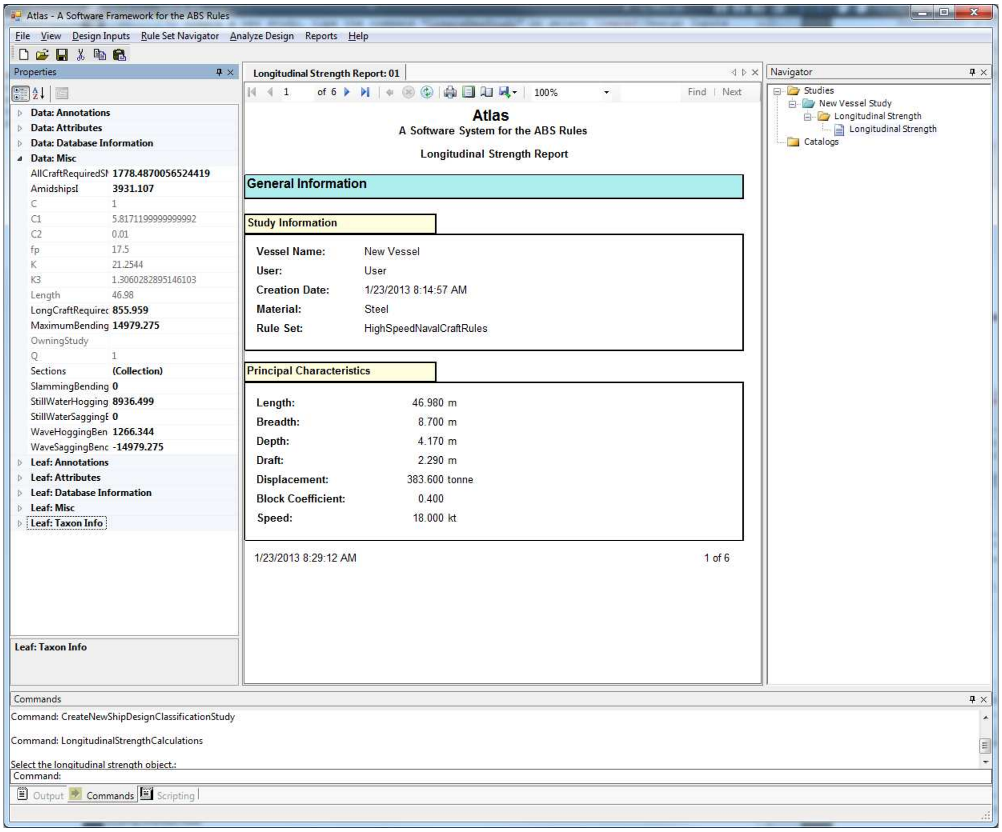


Figure 14: Analysis Report in Atlas GUI

The following 6 pages will show the sample report covering the Longitudinal Strength calculations of the high speed crew boat.

Atlas
A Software System for the ABS Rules

Longitudinal Strength Report

General Information

Study Information

Vessel Name:	New Vessel
User:	User
Creation Date:	1/23/2013 8:14:57 AM
Material:	Steel
Rule Set:	HighSpeedNavalCraftRules

Principal Characteristics

Length:	46.980 m
Breadth:	8.700 m
Depth:	4.170 m
Draft:	2.290 m
Displacement:	383.600 tonne
Block Coefficient:	0.400
Speed:	18.000 kt

Figure 15: Analysis Report Page 1

Atlas

A Software System for the ABS Rules

Longitudinal Strength Report

1.1 Section Modulus

1.1.1 All Craft

$$SM = C_1 C_2 L^2 B (C_b + 0.7) K_3 C Q$$

$C_1 = 0.044L + 3.75 \qquad L < 90\,m$

$C_1 = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5} \qquad 90\,m < L$

$C_1 =$ 5.817

$C_2 =$ 0.010

$$K_3 = \left(0.70 + 0.30\left[\frac{V/\sqrt{L}}{2.36}\right]\right)$$

$K_3 =$ 1.306

C = 1.000

Q = 1.000

SM = 1,778.487 $cm^2 \cdot m$

Figure 16: Analysis Report Page 2

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A Software System for the ABS Rules

Longitudinal Strength Report

1.1.2 Craft 24 m in Length and Over

1.1.2(b) Wave Bending Moments Amidships

$M_{ws} = -k_1 C_1 L^2 B(C_b + 0.7) \times 10^{-3}$ Sagging Moment

$M_{wh} = +k_2 C_1 L^2 B C_b \times 10^{-3}$ Hogging Moment

$k_1 = 110$

$k_2 = 190$

$M_{ws} =$ -14,979.275 kN-m

$M_{wh} =$ 1,266.344 kN-m

1.1.2(c) Stillwater Bending Moment

$M_{sws} = 0$ Sagging Moment

$M_{swh} = 0.375 f_p C_1 C_2 L^2 B(C_b + 0.7)$ Hogging Moment

$f_p = 17.5\ kN/cm^2$

$M_{sws} =$ 0.000 kN-m

$M_{swh} =$ 8,936.499 kN-m

Figure 17: Analysis Report Page 3

Atlas

A Software System for the ABS Rules

Longitudinal Strength Report

1.1.2(d) Slamming Induced Bending Moment

$$M_{sl} = C_3 \Delta (1 + n_{cg})(L - l_s)$$

$C_3 = 1.25$
$l_s = A_R / B_{wl}$
$A_R = 0.697\, \Delta / d \;\; m^2$

$M_{sl} =$ 0.000 kN-m

1.1.2(e) Section Modulus Amidships

$$SM = \frac{M_t C Q}{f_p}$$

$M_t = Max\ Bending\ Moment:$
$= M_{swh} + M_{wh}$
$= -M_{sws} - M_{ws}$
$= M_{sl}$

$M_t =$ 14,979.275 kN-m

SM = 855.959 $cm^2 \cdot m$

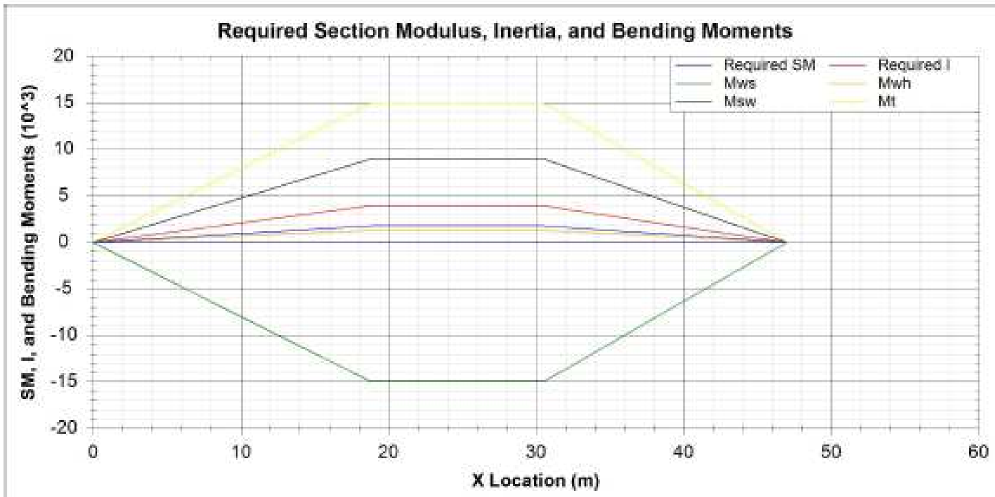
Figure 18: Analysis Report Page 4

Atlas

A Software System for the ABS Rules

Longitudinal Strength Report

1.3 Extension of Midship Section Modulus



1.5 Moment of Inertia

$$I = \frac{L}{QC}\frac{SM}{K} \quad cm^2 \cdot m^2$$

SM =
1778.4870056524
4

K = 21.2544

I = 3931.107 $cm^2 \cdot m^2$

Figure 19: Analysis Report Page 5

Atlas
A Software System for the ABS Rules

Longitudinal Strength Report

Offered Sections

Name	X Location	SM Offered	I Offered	Mt	SM Required	I Required
Aft End	0.000	2917.720	8821.700	0.000	0.000	0.000
0.1L from Aft	4.698	3086.340	9626.940	3744.819	444.622	982.777
0.2L from Aft	9.396	3049.320	9396.690	7489.638	889.244	1965.553
0.3L from Aft	14.094	2755.290	7883.940	11234.456	1333.865	2948.330
0.4L from Aft	18.792	2830.700	7459.810	14979.275	1778.487	3931.107
0.5L from Aft	23.490	2820.330	7438.310	14979.275	1778.487	3931.107
0.6L from Aft	28.188	2332.210	6475.110	14979.275	1778.487	3931.107
0.65L from Aft	30.537	2325.990	6415.290	14979.275	1778.487	3931.107
0.7L from Aft	32.886	985.860	6486.220	12839.379	1524.417	3369.520
0.8L from Aft	37.584	1141.770	4545.310	8559.586	1016.278	2246.347
0.9L from Aft	42.282	1084.350	2669.550	4279.793	508.139	1123.173
Fwd End	46.980	19.190	26.590	0.000	0.000	0.000

Figure 20: Analysis Report Page 6

The report is intended to provide the user with all of the general information about the design, as well as the calculations from each subsection of the rules. This includes the interim calculations and values for the variables (e.g., C_1, C_2, etc.) used in calculating the final values (e.g., required section modulus). The last page of the report gives a summary of the offered and required values for each of the defined longitudinal sections. In the event that an offered value is less than required, the cell will automatically turn red to quickly flag the user, as is the case for the section named "0.7L from Aft."

6 Conclusions

In addition to defining the software framework and developing a proof of concept to facilitate the structural design computational and approval process, a feasibility questionnaire was sent to other stakeholders as potential users of such a tool. The stakeholders included the other team members on this project, Huntington Ingalls Shipbuilding, and the American Bureau of Shipping Naval Engineering Department.

The questionnaire was intended to help measure how beneficial and practical it would be to develop a single software application framework. A list of the questions posed, stakeholder feedback, and DRS responses are below:

1. How many man hours are spent creating/or recreating computations for a given design during the structural design approval process?

- Not an insignificant amount. Hundreds or thousands of hours are spent verifying designs through drawing review and calculations depending on the magnitude and complexity of the vessel or design.
- This is a pretty broad question. There really isn't a given design, since we have 4 different product lines at this shipyard, with really four different customers (USCG, PMS 400, PMS 377, PMS 317). The level of detail and analysis for a Coast Guard cutter's structural design is not the same as an LPD 17 or LHA ship. The approval process is very much a product of what CDRLs are asked for and what the requirements are, which all differ by each ship type and customer. You'll note that the NVR doesn't specify a standard SOW or CDRL, which is to be provided in the contract clauses. What phases of design are we talking about? For Concept, Preliminary, and Contract design, that will be rather difficult data to obtain, as those design phases for our current product line were either performed by a subcontractor or by the USN's subcontractor. For detail design, the man-hours are a function of the size of the ship, the requirements, and the customer (see above). If you have a situation where a CDRL is repeatedly rejected, it might take 3-4 times what you estimated it would take to perform the task based off other ships. Are you trying to create a business case for this effort? That might be difficult, as most of the current classes of ship under construction are NOT NVR ships, so your baseline is limited. The only ships that are designed to NVR (that I am aware of) are the DDG 1000, LCS 1 and 2, and the high speed test ships. The NASSCO ships are all standard ABS SVR classed. NSC, LPD, LHA, DDG 51, CVN, SSN are all in accordance with the pre-NVR mil spec/MIL-STD approach. So this question is rather difficult to answer.

DRS Response: What phase of design are we talking about? I would think this tool would be leveraged during all phases, but perhaps more so in late concept design phase and certainly preliminary and contract design. The motive for the question is to try and quantify (or establish) a metric for time savings this tool could provide. It may be impossible to quantify... Yes, I am trying to create a business case for this effort. The US Navy (and NSRP) wants to know how panel projects (or the ideas within projects) save the US Navy money. Remember, this software would use the same GUI for different "rule sets" or requirements (e.g., commercial, versus government). I can imagine including mil specs into the software.

2. What analysis inefficiencies exist in the current structural design approval process?

- From the design approval process, major inefficiencies occur by way of redundancies in calculations, taking design measurements for drawing packages, and by far the differences in design assumptions by the reviewer and designer. Assumption variations range from end fixities to load application to allowable stress criteria.
- You asked about the approval process, which isn't really an "analysis" process. For approval, the majority of the problems come from poor communication of requirements or repeated rejection of CDRLs. ABS and the USN don't always see eye to eye on the requirements. You might have a requirement that was included in the NVR by ABS, that you don't really meet, and the USN says, "well, that's between you and ABS." This gets to a situation where the shipyard has two approval organizations that it cannot satisfy simultaneously. The technical inefficiencies in the structural design process are not insurmountable, but largely have to do with a given product model package not being able to import directly to a separate and disparate FEA package in such a way that meshing can immediately begin. In concept/preliminary design, you are not really importing models, you are creating geometry from 2D drawings, so that takes a large amount of time. In detail design, you are importing a 3D product model from CATIA, Intergraph, ShipConstructor, etc. and then you need to remove all the details that complicate meshing (tight radii, holes, etc) that don't have an effect on the results and slow the meshing/solving down for no added value. It would be value added if there was an automated way of doing this, but there isn't (that I know of). That consumes engineering labor hours, like 60-90 percent of your engineering labor for FEA is spent on getting the model cleaned up, meshed, and running.

DRS Response: My question is in the context of "analysis," which is in fact the primary objective of the tool. The tool will facilitate analysis/computations within the approval process. For example, you (the designer) uses the tool to effectively "compute" the scantlings, the tool self documents/reports the results, you hand the electronic file to ABS, ABS opens the file within the tool and reviews. This tool will assist with the communication process in that it is a standard presentation of computations and results. The inability of ABS and

USN to see eye-to-eye cannot of course be addressed with a software tool. It is envisioned that this tool could/should talk directly to FEA packages, hull surface tools, seakeeping tools, etc. The sky is the limit...how should this tool "push" or "pull" data to support other analyses at different design phases?

3. How can a software application framework, like the one being investigated in this project, address those inefficiencies?

- I believe a more streamlined effort can be achieved by a unified, transparent, Rule based software package that can somehow integrate the design drawing package with the prescriptive design Rules. I do not believe a software package will ever be able to verify a holistic approval of a design, and can only aide in verifying compliance with strength, stiffness, and buckling criteria.
- That may be very difficult. I originally thought that the intent of this project was to codify all the "non-direct" analysis that is required by the NVR. It was very much a "calculation" solution vice a "approval" solution. I interpret the language above to signal a shift toward the "approval" side. I am afraid that due to the culture of the customer and shipyard, that might be difficult to gain approval. To be clear, I am fine with the Requirements document that you sent out in June of this year, and that document describes a "calculation" solution. Maybe I misinterpreted the wording in the document. "To define the feasibility of developing a single software application framework that facilitates the structural design approval process mandated by ABS rules" sounds like an "approval" solution...

DRS Response: The motivation is to codify all the "non-direct" analysis required by NVRs and/or any other rule set. It is a calculation solution that brings more efficiency to the approval process. In my view a "calculation" solution contributes to a better "approval" solution doesn't it?? No shift in scope...we are addressing "calculations" here. The feasibility language is nothing more than to communicate that the outcome of this project is essentially a feasibility study through the development of a proof-of-concept and collection of requirements for a software framework addressing calculations. We aren't (and couldn't possibly) developing the entire system with current funding, but taking the first step, which is defining the requirements and establishing the feasibility of such a development.

4. Are the software design artifacts being developed as part of this project, sufficient to evaluate the feasibility of the application framework? What additional artifacts (e.g., process/workflow diagrams, software prototype, etc.) would help evaluate feasibility?

- I am not sure this can be addressed without a working prototype of the application framework. The proof must be in the pudding when dealing with this type of idea.
- I am not aware of where the artifacts that will be developed have been described. Maybe I deleted that email? Can you please provide these software design artifacts?

DRS Response: Artifacts would include the requirements document and proof-of-concept description/tutorial. They are our project deliverable. The question is, is this enough OR does their need to be more concept development to determine whether it would make sense to full-out develop this software.

5. What are the alternatives to a single and unified software application framework for processing the structural design computations mandated by the ABS rules? Would organization management support the proposed software application framework?

- Independent verification of design using Rule criteria, known principles, and existing engineering software (FEA, Seakeeping, etc.) I am not sure at this point. The compelling point would be to have a working prototype that answered key questions. How will it work? What level of adaptability will it have to any given design? Who will be monitoring it? How much will it cost?
- The alternative is the status quo: Analysis is conducted by separate and disparate software analysis tools, then compiled into other separate and disparate CAD tools (AutoCAD) and submitted to the customer in a configuration management tool (Teamcenter). I think that the organization would support a new process if it were required by contract, or had buy-in across the engineering organization.

DRS Response: Can you draw up (in a diagram) your "analysis is conducted by separate(Teamcenter)" process? THEN, can you draw another diagram showing WHERE this tool can potentially contribute/participate/enter/communicate? Buy-in across the engineering organization is what we want. Can you create a similar diagram of the different elements of the "across the engineering organization?" THEN perhaps comment on what each element would require for "buy-in."

Team Member Response: Buy in across the organization would be gained by a demonstrated and proven value added, either by saving engineering man-hours, a much higher CDRL acceptance rate, or markedly increased quality. It will take more than one program to gain this "buy-in" at a large shipyard, who has been through several software packages that offer savings.

6. How would end-users feel about using such a system? If not agreeable with end-users, how could this be overcome?

- Second question above would be key...What level of adaptability will it have to any given design? We have numerous spreadsheets that already compute prescriptive ABS Rule requirements, so how will this system differ from our internal tools?
- Working level engineer end users would use this system if it were required by contract or via engineering organization processes. Engineering management would use the system if there was a demonstrated and proven added value via increased quality or decreased engineering labor hours.

7. How would the use of such a system change the working environment, and would engineers and management adapt to the change?

- This is yet to be seen, the potential in streamlining design review is definitely there.
- This system could have a large impact. Without understanding the scope of the entire process, it is hard to answer this question, as the individual analyses have very different approaches.

8. Does this team possess the necessary technical collaboration? What additional collaboration would be needed?

- I believe a good foundation has been set, but expansion will be necessary from the Classification side to other clients as well as other ABS departments in order to have management "buy in" as has been asked in questions 5 and 7 above.
- The team has the bare minimum technical collaboration to demonstrate feasibility. Additional collaboration would be needed in the engineering management of the structural engineering organizations of the various stakeholders (Naval Technical Authority, Classification Society, Shipyard or Design Agent).

9. Is this proposed software development practical in your view?

- Hypothetically speaking, it is a great idea, but based on past attempts by others it has yet to be successfully completed and maintained.
- Yes.

The proof of concept presented in this report demonstrates the feasibility and value of a tool designed to exercise the ship design classification rules. The flexibility of the framework allows for multiple rule sets to be implemented, while reusing common components between the different sets. Although it is difficult to quantify the number of hours spent on creating or recreating the computations this tool intends to produce, it seems there is a consensus from the team members that it is not an insignificant part of the classification process. By having all of the stakeholders (i.e., designers, shipyards, and classification societies) using a single tool, this duplicate effort can be eliminated, saving both time and money.

7 References

NSRP ASE - an Applied Research Program Reducing Ship Construction and Repair Costs. U.S. Navy and the U.S. Shipbuilding Industry. Web. 29 May 2012. http://www.nsrp.org/.

Rules For Building and Classing High Speed Naval Craft. Part 3. Hull Construction and Equipment. Houston, TX: American Bureau of Shipping, 2007. Print.