NSRP RA PROJECT “LIFTSHIP 2”

DATE 14 October August 2022

Final Report Summary
(MS14)
Task Order Agreement 2018-451-003
between
Advanced Technology International
and
Fincantieri Marinette Marine
for
(LiftShip 2)

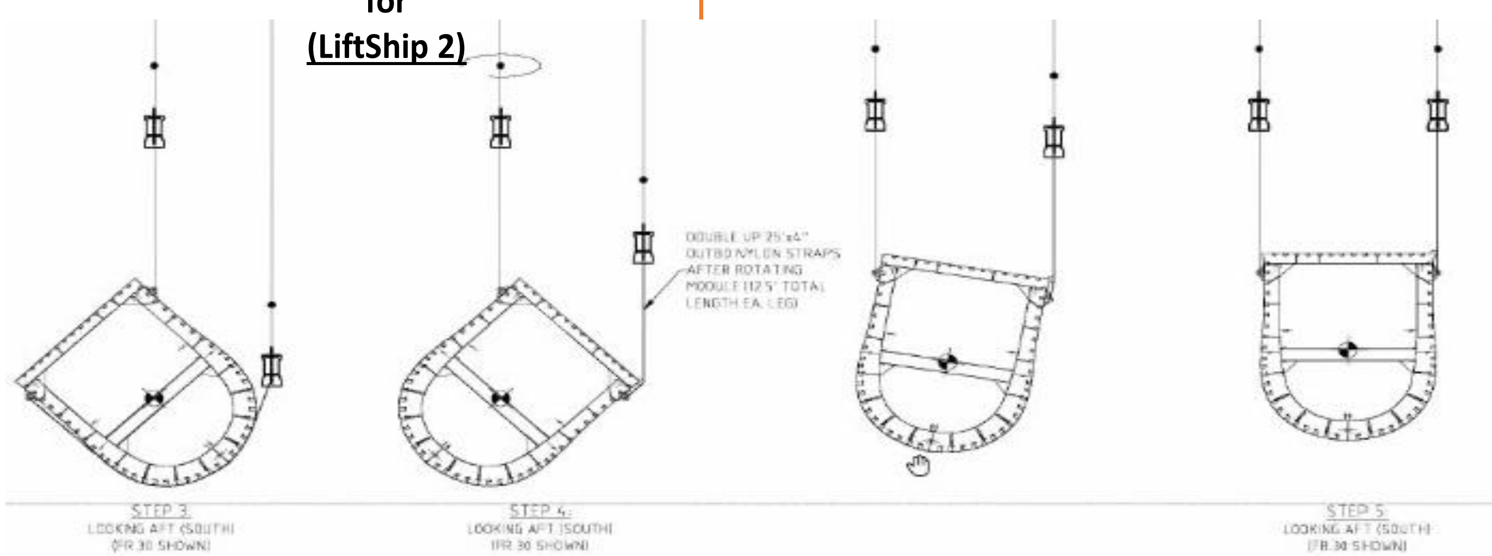


Table of Contents

Contents

EXECUTIVE OVERVIEW

The "LiftShip 2" NSRP RA project provides the shipyards, engineering firms, and design agents with an efficient process automation of Finite Element Analysis model generation and analysis in support of large-scale ship structure lifting and presenting the results in a clear and concise manner for stakeholders.

This project leveraged the model generation from lift drawing output (lifting configuration drawings to coincide with the Finite Element Model being analyzed) and information to support production for the lift.

"LiftShip 2" is a continuation of the 2018 RA project "LiftShip" where the capabilities will be extended further to include:

- Lifts with turning for complex lift operations
- Level of detail changes from the 3D production / design model to the FEA software
- Enhanced visual reporting of the FEA analysis results to the stake holders to allow for improved lift communications

The NSRP RA project "LiftShip 2" results were impressive. Lift Analysis and calculations to support the same which typically took days or weeks was achievable, with superior accuracy, in a matter of hours; typically, in two (2).

PORJECT TEAM CONTACT INFORMATION

The main point of contact is:

Erik Bjorkner
ShipConstructor Software USA
Erik.Bjorkner@ssi-corporate.com

The below table lists the RA "LiftShip 2" Project Team main Point of Contact (POC) information:

Company	Main Point of Contact	e-mail
Fincantieri Marinette Marine (Lead)	Charles Jackson	Charles.Jackson@us.fincantieri.com
Fincantieri Marinette Marine (Lead)	John Krueger	John.Krueger@us.fincantieri.com
VT Halter Marine	Dean Hartmann	Dean.Hartmann@vthm.com
Huntington Ingalls Shipbuilding	John Walks	john.walks@hii-ingalls.com
Austal USA	Shawn Wilber	Shawn.Wilber@austalusa.com
Bollinger Shipyards	Kyle Tyson	kylet@bollingershipyards.com
Ship Architects, Inc.	Altug Basaran	altugb@shiparch.com

Genoa Design International Ltd.	Chris Laughlin	claughlin@genoadesign.com
NAVSEA	Gavin Fidanza	gavin.r.fidanza.civ@us.navy.mil
NAVSEA	Young Hwang	young.c.hwang.civ@us.navy.mil
ATA Engineering	Kyle Zimmerman	zimmermankz@gmail.com
ATA Engineering	Victoria Harris	victoria.harris@ata-e.com
Altair Engineering	Deepak Maddikere	deepakm@altair.com
Altair Engineering	Anil Sharma	anil@altair.com
Altair Engineering	Raymond DelDin	rdeldin@altair.com
ShipConstructor Software USA	Patrick Roberts	Parrick.Roberts@ssi-corporate.com
ShipConstructor Software USA	Erik Bjorkner	Erik.Bjorkner@ssi-corporate.com
ShipConstructor Software USA	Rob Parker	Rob.Parker@ssi-corporate.com
Program Technical Representative	Craig Haverly	craighaverly@gdeb.com

COLLABORATORS

- ShipConstructor Software USA (SSIUSA)
    - Participation Rate of 30%
    - SSIUSA provides many shipyards, design, and engineering firms with 3D design software specifically tailored for the maritime shipbuilding and repair industry.
    - SSIUSA, although not the lead for this project, was the behind the scenes supporting the project for Fincantieri Marinette Marine, the project Lead.
    - SSIUSA, working closely with Altair Engineering and ATA Engineering, enhanced data exchange criteria to better suite the user comments from the project team.
- Altair Engineering
    - Participation Rate 25%
    - Altair Engineering provides engineering services and is a software provider for their HyperWorks suite of FEA software leveraged from their HyperMesh software for reading LiftShip data and to provide meshing and analysis tools.
    - Altair Engineering extended their prior successes from the NSRP RA project "LiftShip"
    - Altair Engineering worked closely with the project team to identify shipyard use cases and the requirements.
- ATA Engineering
    - Participation Rate 25%
    - ATA Engineering provides engineering services and integration expertise with one of the most popular FEA software suites, Siemens Femap.
    - ATA Engineering extended their prior successes from the NSRP RA project "LiftShip"
    - ATA Engineering worked closely with the project team to identify shipyard use cases and the requirements.

- Shipyards, Engineering Firms, Design Firms, and NAVSEA
    - Participation Rate 20%
    - There were two (2) engineering / design firms supporting the project: ShipArchitects and Genoa Design International.
    - There were (5) five Shipyard project participants: Fincantieri Marinette Marine (Lead), Huntington Ingalls Shipbuilding, Austal USA, VT Halter Marine, and Bollinger Shipyards.
    - NAVSEA Caderock, codes 651 (Ship Structures), and 652 (Submarine Structures & Propulsors).
    - This mix provided input, guidance, and examples on use case requirements.
    - This mix provided is/was on current and predicted workflows on complex lift analysis through open and private meetings
    - This mix through meetings, open and private meetings when company information was discussed, and using several questionnaires provided valuable feedback for the project team.

METHODOLOGY

The methodology for the LiftShip RA project was to provide the shipyard and engineering and design firms with an updated application of the original LiftShip platforms, there were two (2) platforms which supported the FEA programs, Femap and HyperWorks. This would be accomplished by ShipConstructor, Altair Engineering, and ATA Engineering updating their existing applications to support the three (3) LiftShip 2 goals:

1. Lifting and Turning support (complex lift operations analysis)
2. Visual (video/animation) reporting of analysis results
3. Imported Level-of-Detail options

During the original LiftShip project the team members expressed a desire to be able to investigate, using FEA, the anticipated loads of a large ship structure during more complex operations than straight lifting. The option to analyze the structure during turning and multiple handling operations was a common request and the prior work in this area will allow the project team to accelerate the ability to handle these requests. Complex lifting scenarios that may require multiple stages are a specific area of concern for shipyards. There are many scenarios where multiple lifting points and components may need to be added/removed to support a given operation (turning). This increases the number of analyses required to fully understand and support each segment

Visual Analysis Reporting supported more complex handling operations the project team will address the visual reporting necessary to communicate the results. With multiple discrete events analyzed as part of a larger mor complicated lift and turn operation, there is a demand for providing the final lifting configuration results in a clear and concise manner that can effectively communicate the outcome of the analysis from the analysts and engineers to stakeholders.

Static images work fine for static lifts, but more complex lifting operations require more complex reporting.

The production model may contain many production-specific details that sometime serve to make the FEM needlessly complex. Often the addition of small holes, corner treatments, or end cuts on structural elements are not required for the scale of FEA being conducted. The problem lies in when those details may be desired to suit the analysis. The project provided a means for the analyst to determine what level of detail they wanted to include in their analysis and to provide tools or automation to clean the model to an appropriate level, or to allow a high level of detail to be included to suit a more detailed analysis being conducted. This was particularly helpful when the analysis was conducted over a much smaller assembly and there is a desire for a high level of detail to be included to suit the operation. This allowed for maximum flexibility to be left to the analyst, who is best suited to determine what the appropriate level of detail should be.

Using the update to the existing applications, the project team tested the updated applications for use with these three (3) project goals in the Test & Evaluation Phase.

PROJECT DEVELOPMENT & TECHNICAL ACHIEVEMENTS

ATA Engineering:

The LiftShip 2 project provided shipyards with an efficient method for analyzing large-scale lifts and turns using finite element analysis. ATA Engineering's role in this project is to develop a tools package that can extract structural information from ShipConstructor and recreate an idealized version of the ship structure in Femap for meshing and analysis, and then automate the process of setting up a lift/turn simulation. ATA Engineering (ATA) is leveraging its previously developed ShipPDX software as part of this process.

Technical Achievements:

Over the course of the LiftShip II program, ATA developed a package of tools known as "ATA LiftShip Tools for Femap" and provided it to shipyards. This package contains five tools:

1. *Femap Model Generator* – Reads a ShipConstructor database for ship structure information and reconstructs the ship layout in Femap.
2. *Trim Curved Plate Intersections* – Assists the user in connecting bulkhead and deck plates to hull plates in locations where the plates do not already intersect properly.
3. *Autoconnect Lumped Masses* – Uses data created by the Femap Model Generator to connect lumped-mass representations of ship equipment to the closest ship structure.
4. *Lift and Turn Manager* – Assists the user in defining the steps of a lift and turn as a Femap static analysis.

5. *Animate Lift* – Animates the steps defined by the Lift and Turn Manager so the user can confirm that the lift and turn is defined correctly.

All five (5) tools run from within the Custom Tools menu in Femap, as shown in Figure 1.

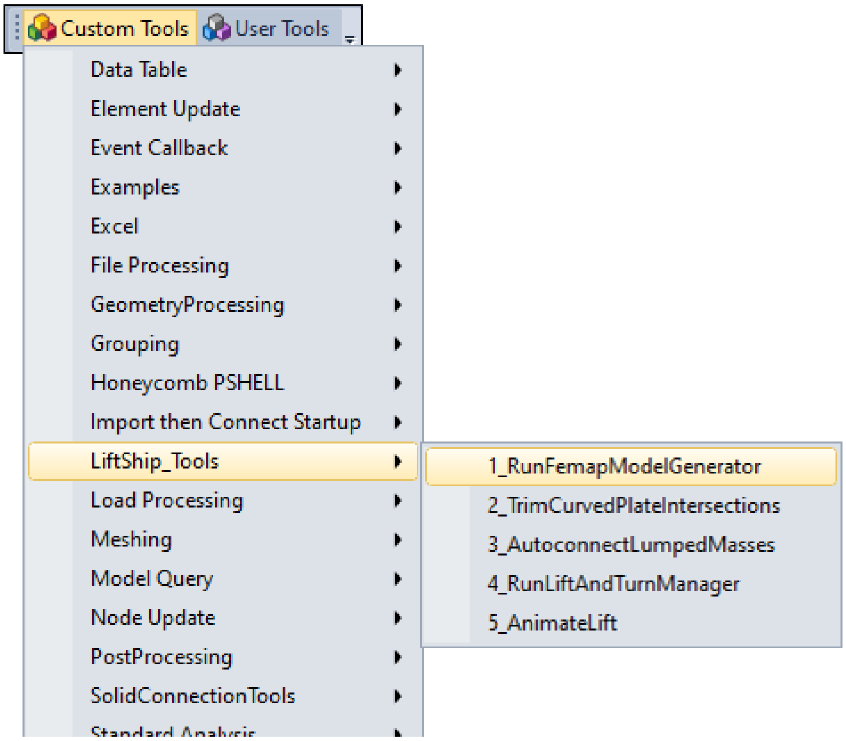


Figure 1. ATA's LiftShip Tools for Femap can be found in the Custom Tools menu.

A detailed user's guide was created as part of the current tools package. The user's guide walks through the entire analysis process from ShipConstructor model to Femap analysis results. The package also includes installation instructions for use by the shipyards' IT departments. A version of the package was released to shipyards for testing on April 25, 2022. Based on feedback from the shipyards, a final version of the package was developed and released to shipyards in September 2022.

The Trim Curved Plate Intersections and Autoconnect Lumped Masses tools were developed during LiftShip I. A brief description of tools 1, 4, and 5 from the list above can be found below; for more details on all of the LiftShip tools, see the LiftShip Tools user's guide.

Femap Model Generator:

Initial development of the Femap Model Generator (FMG) occurred during LiftShip I. Enhancements were made during LiftShip II to add functionality and improve ease of use. The FMG is now executed via a graphical user interface (GUI), shown in Figure 2.

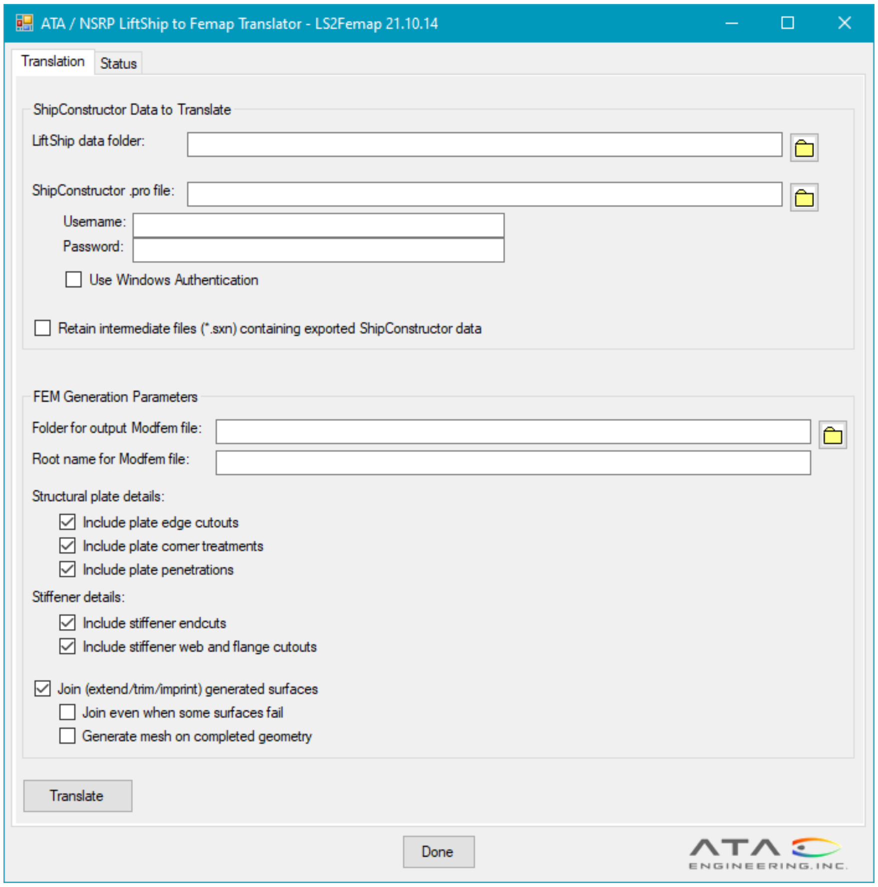


Figure 2. User interface for geometry translation tool.

Other new features in the FMG include the option to include or exclude stiffener corner treatments and cutouts, plate corner treatments and cutouts, and penetrations from the model translation. When creating a finite element model (FEM), the analyst must decide how much detail to include based on the size of the expected size of the model, the level of detail required, and features of interest in likely areas of high stress. The analyst can select which details to include using the checkboxes on the bottom half of the GUI.

The FMG also extracts information about the model units from ShipConstructor and stores that information in Femap for use by the Lift and Turn Manager. Finally, the FMG has been enhanced to handle additional model features such as entity part names, rotated stiffeners, flanges with corner treatments, faceplates with position offsets, and more.

Lift and Turn Manager:

A lift and turn is typically made up of several stages, from the pick step, through the attachment and removal of cables, to the final erection step. ATA has created a new Femap tool that helps the analyst simulate the important steps in a turn as a series of static analyses. The analyst uses ATA's Lift and Turn GUI to define the components of each step in terms that should be familiar to a lift/turn engineer, and ATA's tool converts that information into the loads, constraints, elements, and coordinate systems necessary for a Femap static analysis. The analyst can then solve the static analysis and review the results, checking that the forces at the lifting lugs do not exceed the lug and chain load ratings and that the stress in the module structure does not exceed the material allowable. If the analyst finds problems with the lift, they must either relocate chains and lugs or add supporting structure and then run the analysis again to verify that the changes have solved the problems.

ATA has enhanced the Femap software for lifts and turns with the Lift and Turn Manager, shown in Figure 3. In the first window, the user sets the name of the lift and turn, model units (if necessary), and rotation vector for the turn. If the Femap model was created using the FMG, units information is available in the Femap model and the Lift and Turn Manager will read it automatically. The user will be able to select units from the drop-down menu if they are not defined in the model.

The user next defines a lift step by clicking “Add Lift/Turn Step,” which opens the “Define Lift/Turn Step” dialog. After each lift step is defined, the lift details will appear as a tree in the Lift Steps box. When the user is finished adding lift steps, clicking “Generate Load Cases” will add loads, constraints, and other items needed for the analysis to the Femap model. After reviewing the model, the user can press “Solve” to solve the analysis within Femap.

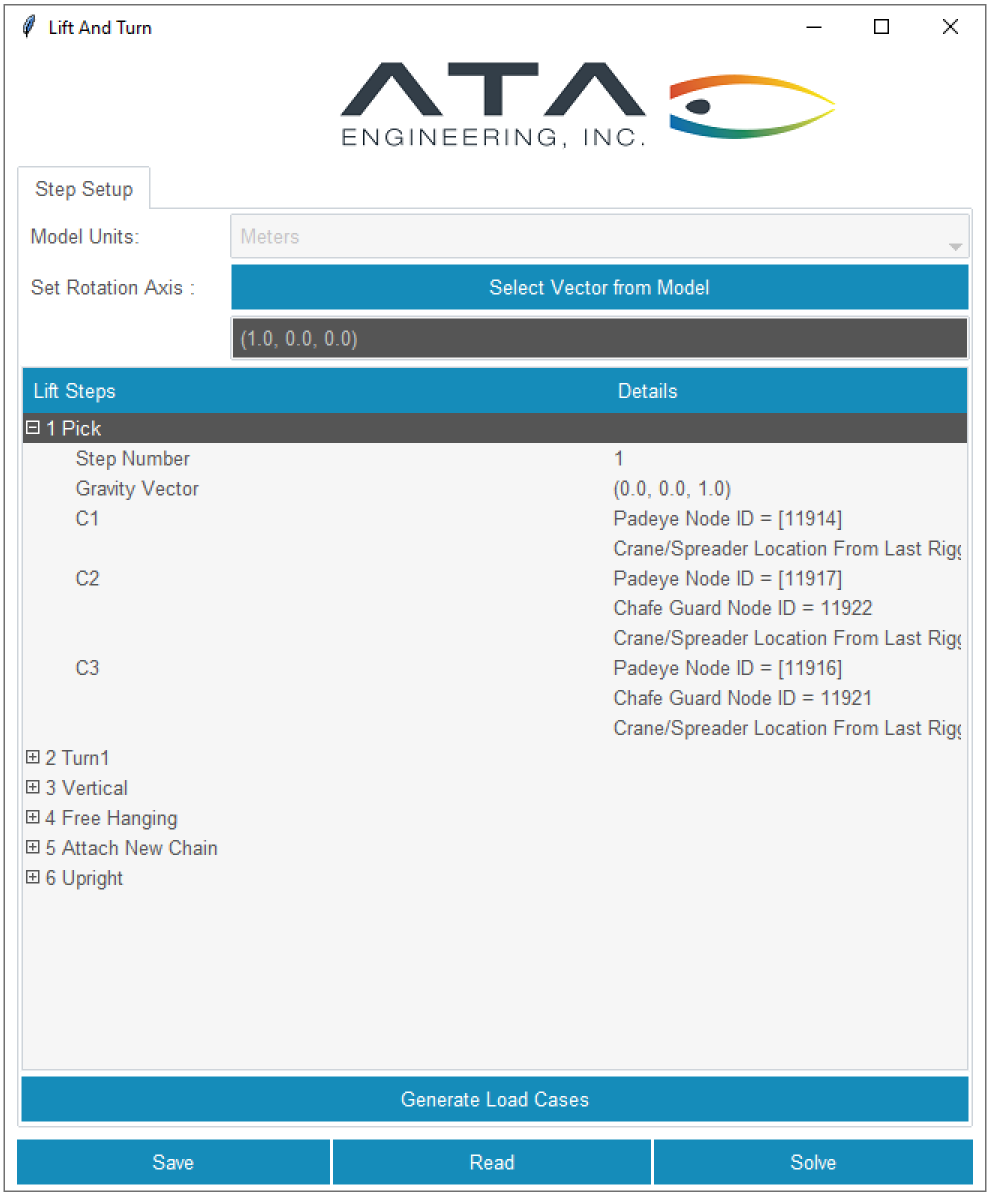


Figure 3. Main window of Lift and Turn user interface.

As stated above, clicking "Add Lift/Turn Step" opens the "Define Lift/Turn Step" window shown in Figure 4. In this window, the user gives the step a name and number (to keep steps in the correct order), selects the gravity vector, and adds cable paths. The user must select a gravity vector because the Lift and Turn tool simulates the rotating of the ship module by changing the reference frame of the analysis for each step (rather than rotating the FEM itself, which would require managing multiple FEMs). For the gravity vector, there are two options: (1) the user can select a vector from the Femap model (appropriate for most lift steps; shown at left in Figure 4) or (2) allow the vector to be calculated (for a free-hanging step; shown at right in Figure 4). If the user chooses the first option, they will need to set the gravity vector by clicking "Select Vector from Model" and selecting a vector using the dialog box that appears in Femap. After the user

DATA CATEGORY B
DISTRIBUTION: Distribution Unlimited

presses "OK" in that dialog, the selected gravity vector will be shown as a unit vector in the black box below the button. If the step is a free-hanging one, the tool will use the padeye locations and center of gravity (CG) from the Femap model to calculate the gravity vector. This gravity vector will be shown as a unit vector in the lift details at the bottom of the main window.

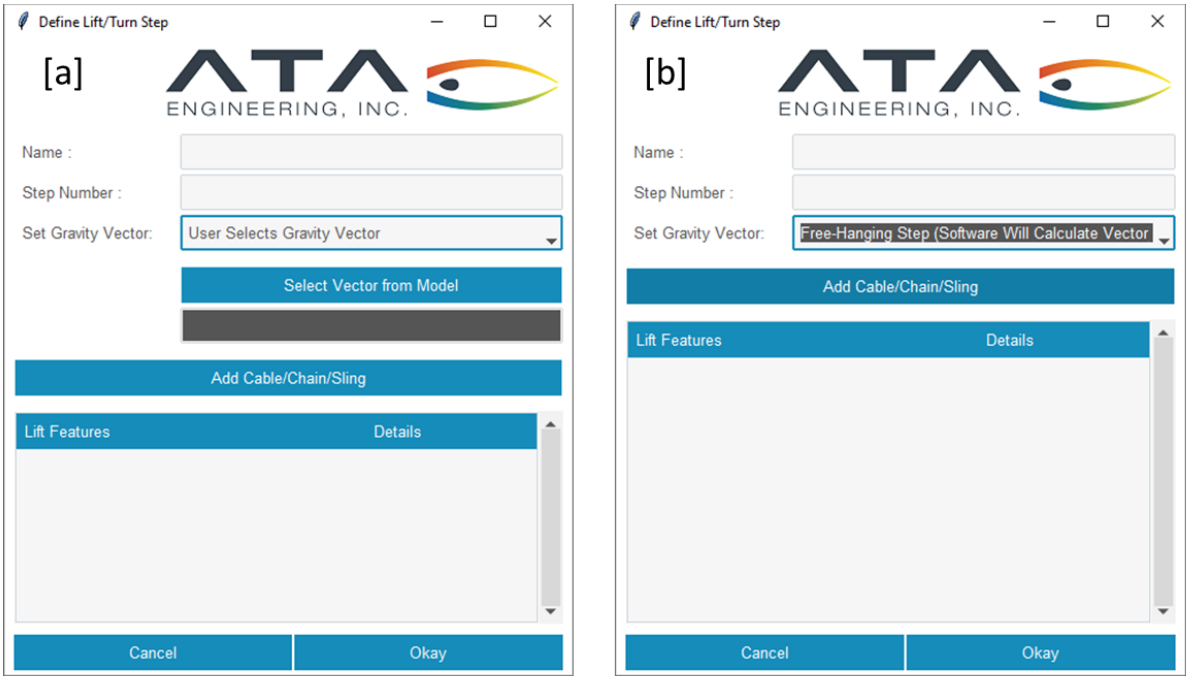


Figure 4. Window to define a lift step where the gravity vector is [a] defined by the user or [b] calculated.

Once a gravity vector is selected, the user can start adding cables. Clicking the "Add Cable/Chain/Sling" button will bring up the window shown in Figure 5, where the user names the cable/chain/sling path and selects the padeye node, chafe guard nodes (if there are any), and crane/spreader bar position. Chafe guards in this context are locations at which the lifting cables/chains make contact with the ship section at locations other than the padeye; typically this happens when a chain gets wrapped around the hull during a turn, and in most of the examples ATA has seen, the shipyard adds a chafe guard to the location on the hull where the chain makes contact in order to reduce friction between the chain and the hull. The Lift and Turn tool assumes that the chafe guards are frictionless and that the tensile force in the chain is the same on either side of the chafing guard.

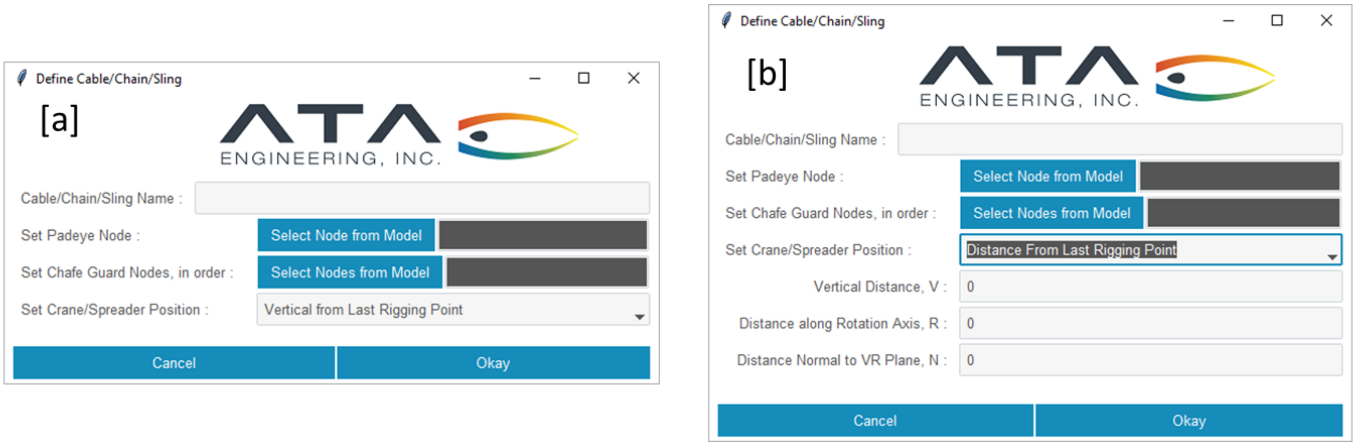


Figure 5. Window to define a cable where the crane position is [a] vertical or [b] relative to last rigging point.

For the padeye, clicking "Select Node from Model" produces a dialog in Femap where the user can input a single node ID (or click the node in the model). For the chafe guards, after the user clicks "Select Nodes from Model," a dialog will appear in Femap that will let the user select as many nodes as needed. If there is more than one chafe guard, these nodes *must* be selected in order along the cable path starting with the one closest to the padeye and ending with the last rigging point before the crane/spreader bar. *If the nodes are not selected in order, the model will be set up incorrectly, which will lead to inaccurate results*. Once the user presses "OK" in the Femap dialog, the node ID(s) will appear in the black box next to the respective button.

There are two options for the crane head position: (1) vertical from the last rigging point (padeye or chafe guard) (2) or any direction relative to the last rigging point. If the crane location is relative to the last rigging point, the user has to specify the distances in the vertical direction, along the rotation axis, and in the direction normal to the vertical and rotation vectors. At this time, the user must calculate the correct angles and distances for off-vertical chains manually, and errors in those calculations can lead to unbalanced loads and large lateral displacements during the analysis, so the user *must* check for large displacements to determine whether off-vertical chains have been set up correctly. Automatic calculation of these chain angles could be added to the tool during a potential LiftShip III effort.

When a user has created a cable, the details will appear as a tree in the Features box at the bottom of the window. The user can create as many cables as needed and can edit them later by selecting the cable, right-clicking, and choosing "Edit."

Once the user has finished defining all the lift steps and cables, they can review the details in the main window by clicking the plus-symbol button (+) next to all the steps, as shown in Figure 3. A step can be edited or deleted by selecting it in the Lift Steps box, right-clicking, and selecting edit or delete. To save a lift for later, click "Save" to save to a text file. This file can be read in by clicking "Read." These features are useful if a lift needs to be analyzed many times.

If the lift details look correct, the user can then click “Generate Load Cases” to create the loads, constraints, elements, and coordinate systems in the Femap model. For each step, the tool also creates a group with the coordinate systems, nodes, elements, and constraints needed for that step. Figure 6 shows a lift step in a Femap model with the step’s group highlighted. Using these step groups, the user should check each step’s setup and ensure that the constraints are in the correct places (on the last rigging points), the coordinate systems at the constraints are pointing in the correct directions (with the Z direction pointed toward the crane position), and the spring and rod (if there are any chafe guards) elements are in the correct locations.

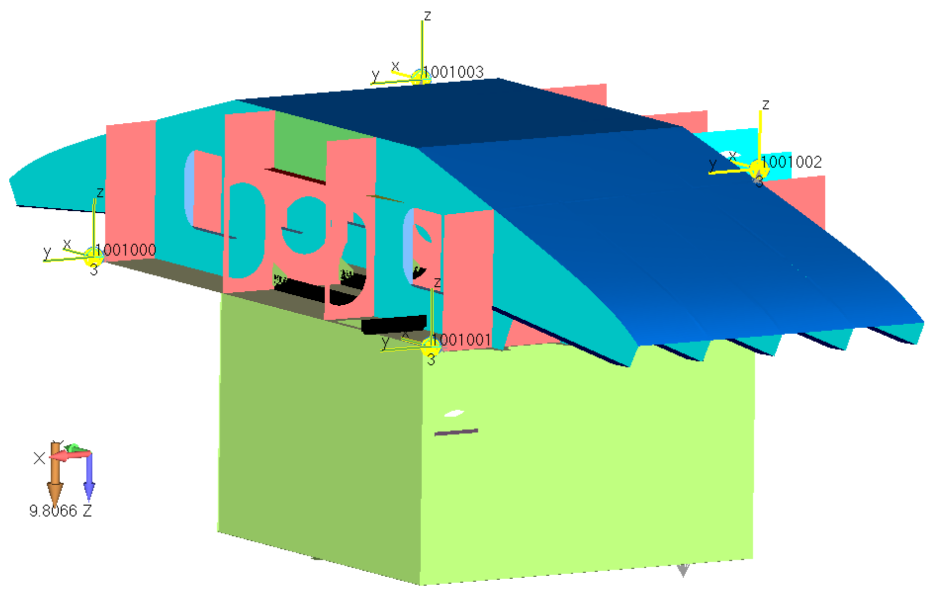


Figure 6. Lift step setup in Femap.

If the model appears correct, the user can then solve the analysis by clicking “Solve” in the GUI. This selection will start solving the analysis within the Femap application. When it is finished, the results will be saved to the model for review. The default results include stress, force, and displacement.

Animate Lift:

The final tool developed during LiftShip II is the Animate Lift tool, which animates the lift steps defined in the Lift and Turn Manager so that the analyst can confirm their defined lift matches their expectations. After selecting AnimateLift from the LiftShip_Tools menu, the user is prompted to select which load cases to include in the animation; the user should select all steps defined by the Lift and Turn Manager, as shown in Figure 7. The tool then automatically animates the lift by rotating the model according to the gravity vector defined in each lift step.

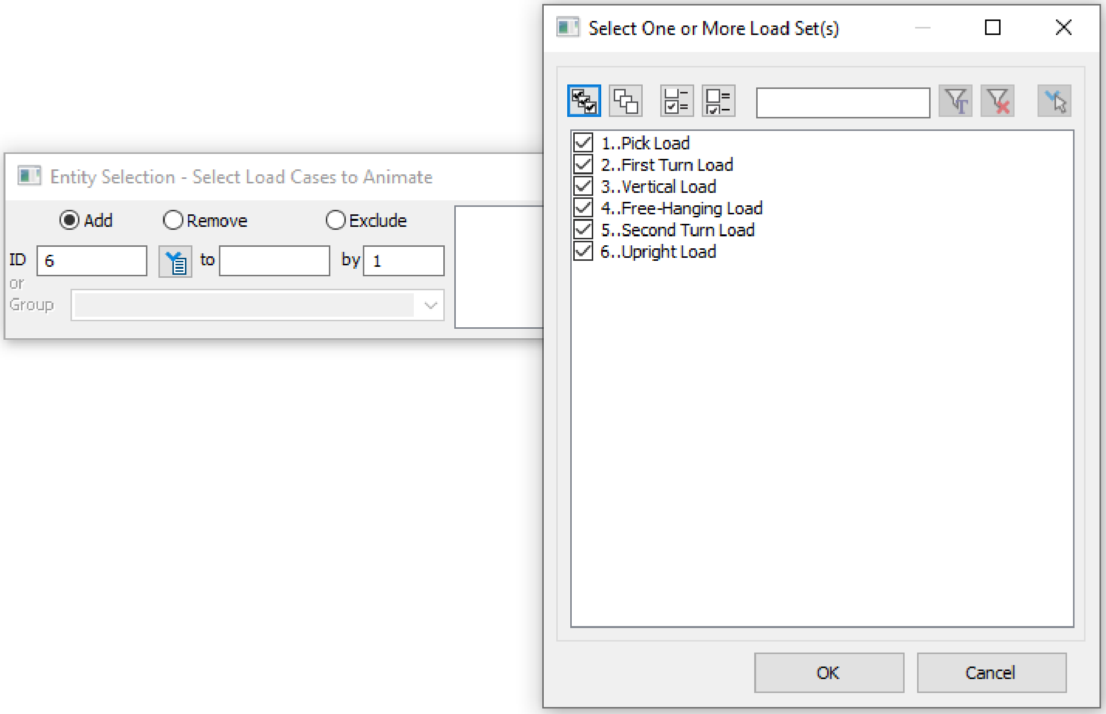


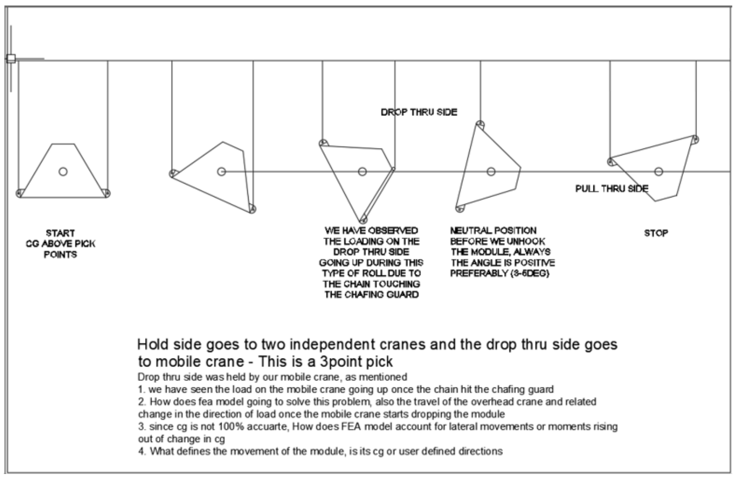
Figure 7. Animate Lift prompts the user to select load cases for animation.

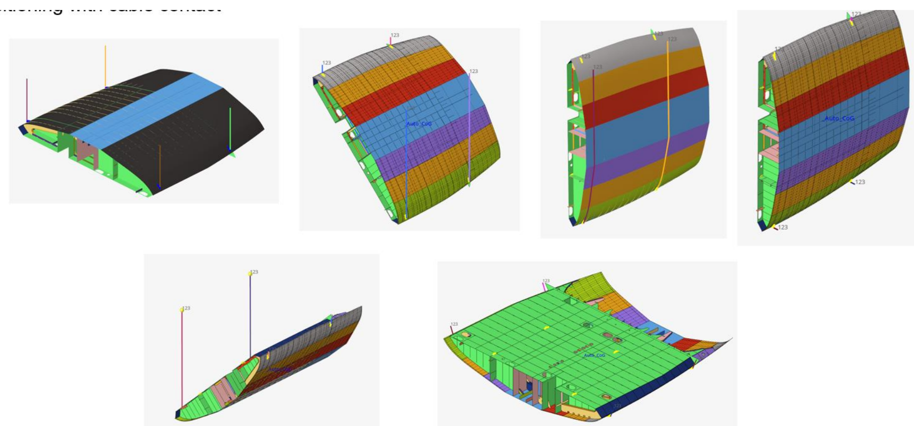
Femap Training Material:

In addition to the LiftShip Tools package, ATA also developed an on-demand tutorial that walks the user through the basics of using LiftShip for geometry import, model checks and clean-up, meshing, application of loads and constraints, and postprocessing of results. This tutorial aimed to bring new shipyards up to speed and to refresh memories at the shipyards that participated in LiftShip I. The tutorial package consists of a video and written directions. For the shipyards with limited finite element analysis experience, ATA also developed a one-day on-demand Introduction to Femap class. This class consists of eight hours of video, accompanying slides, and several workshops that demonstrate the basics of Femap to the user.

Altair Engineering – HyperWorks:

The LiftShip project is NSRP funded program for automating the process of Finite Element Analysis model generation and analysis in support of large ship structure lifting and presenting the results in a clear and concise manner for stakeholders. The project leverages the model generation from lift drawing output (lifting configuration drawings to coincide with the Finite Element Model being analyzed) and information to support production for the lift. Feedback from shipyards with an established FEA process for lift analysis form the basis for this projects approach. This project allows the shipyards and software creators to map the existing processes and develop solutions to gain the largest benefit for the shipyard in cost avoidance and time savings.





In cooperation with SSI, the developers of ShipConstructor, Altair has developed HyperWorks LiftShip 2 (HWLS22). It is a process oriented and user-friendly toolset for the HyperWorks environment for the purposes of pre-processing, analyzing and post-processing ShipConstructor models. HWLS22 guides the user through a series of steps beginning with the import of ShipConstructor CAD, and is followed by geometry cleanup, meshing, quality checks, load case creation, and OptiStruct solver submission. In addition to this toolset the wealth of standard features of HyperWorks are also available for all preprocessing tasks.

Relevant Altair Technology:

Altair HyperWorks is used as the foundation software for pre and post operations of LiftShip analysis. Altair OptiStruct is used for performing structural lift analysis. Their fundamental capabilities are explained below which complements the LiftShip project.

HyperWorks is a market-leading, multi-disciplinary finite element pre-processor which manages the generation of the largest, most complex models, starting with the import of a CAD geometry (Eg: STEP, IGES, NX, Catia) to exporting ready-to-run solver file (Eg: OptiStruct, Nastran).

HyperWorks is an industry proven and leading finite element model pre-processor for concept and high-fidelity modeling. The advanced geometry and meshing capabilities provide an environment for rapid model generation. The ability to generate high quality mesh quickly is one of HyperWork's core competencies. Industry trends show a migration to modular sub-system design and continued exploration of new materials; HyperWorks has advanced model assembly tools capable of supporting complex sub-system generation and assembly, in addition, modeling of laminate composites is supported by advanced creation, editing and visualization tools. Design change is made possible via mesh morphing and geometry dimensioning. HyperWorks is a solver neutral environment that also has an extensive API which allows for advanced levels customization.

It is also a complete post-processing and visualization environment for finite element analysis, CFD and multi-body system data. HyperWorks enables you to visualize data interactively as well as capture and standardize your post-processing activities using process automation features. HyperWorks combines advanced animation and XY plotting features with window syncing to enhance results visualization. HyperWorks also saves 3-D animation results in Altair's compact H3D format so you can visualize and share CAE results within a 3-D web environment using HyperWorks Player. Repetitive evaluations can be significantly accelerated by by using result templates. Automatically generated presentations provide additional time savings.

Building on more than 25 years of innovation, OptiStruct is a proven, modern structural solver with comprehensive, accurate, and scalable solutions for linear and nonlinear analyses across statics and dynamics, vibrations, acoustics, fatigue, heat transfer, and multiphysics disciplines. It is used globally at industry-leading companies to drive design with optimization and validate structural performance.

Commercially introduced in 1994, OptiStruct is a first-to-market simulation technology that seamlessly integrates structural optimization and analysis. OptiStruct solves both linear and nonlinear problems using an enhanced proprietary version of NASTRAN and a modern proprietary nonlinear formulation developed and maintained by Altair.
For the past two decades, OptiStruct topology optimization has driven the lightweight and structurally efficient designs of products you see and use every day. OptiStruct offers many other structural optimization methods and a broad range of essential manufacturing constraints for traditional processes, composites, and additive manufacturing.

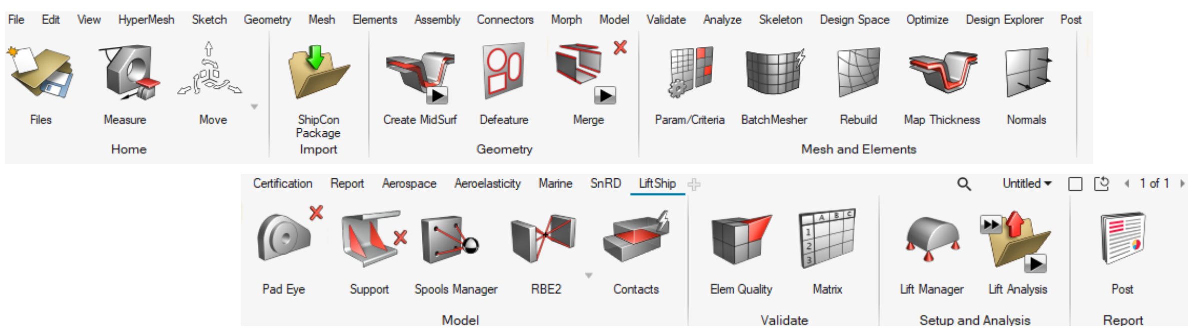
Project Key Feature Summary:

- Data exchange from ShipConstructor to HyperWorks via an “export package” which contains a defined file structure containing meta data (XML format) and geometry data (STEP format)
- Import log of progress, errors, warnings and model units (SI and Imperial supported)
- Finite element model checks
    - Check for duplicate surfaces or solids
    - Check for availability of metadata such as weight and CG
    - Check (Visual) to ensure that the parts are in the right locations.
    - Check for consistency of units across the model
    - Check for availability materials in the metadata, if not assign notify and assign placeholder materials in FEA tool
- Toolset (i.e. tool ribbon) comprised of core tools, optimized core tools, and tailor made for shipyard lifting processes (e.g. attachment of mounting lugs)
- Ability to model supporting structure is implemented. discussed with shipyards. They can be modelled as 3D representations such as standard beam sections and mounted at user defined locations on the main model
- “Spools manager” has been implemented to account for Contribution of weight due to cables , pipes and other equipment
- “Loadcases module” allows user to define lift analysis Loadcases such as
    - Lift simulation (linear static)
    - Normal modes simulation
    - Turn simulation including cable contact (non-linear static)
- Post-processing tools provide ability to generate displacement plots, stress contours, factor of safety and export a report for Go-noGo decisions.
- Flexibility to study ‘what if’ scenarios by adjusting supporting structure, part modifications, pad eye lift locations, added mass (i.e. CG modification)

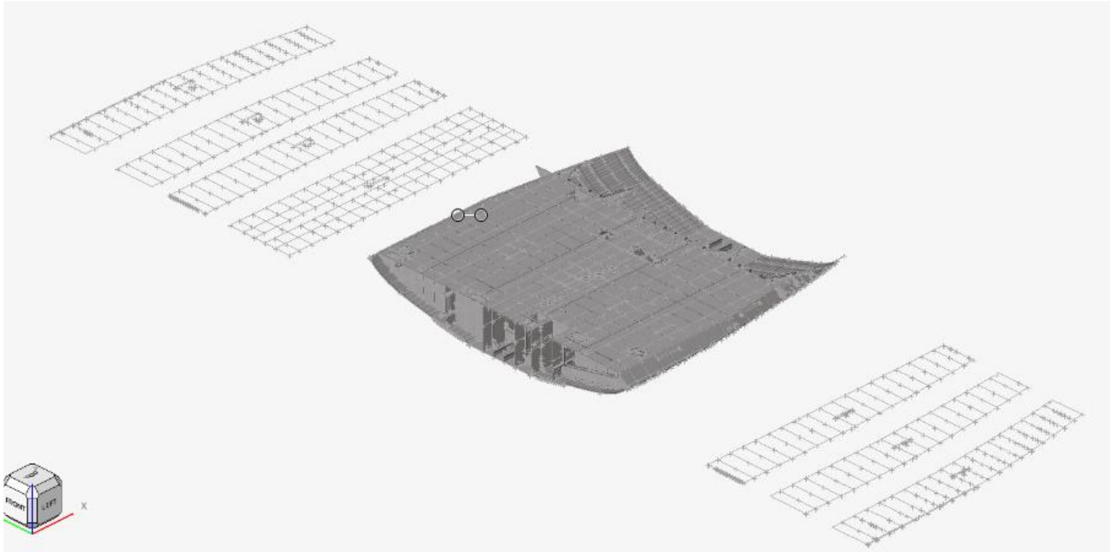
Key Highlights of LiftShip 2 Program:

The customized ribbon for LiftShip is illustrated below. Toolsets are organized and grouped based on process. The first set, Import, handles the importing of the ShipConstructor model. The following tools entail creating a midsurface, geometry cleanup, meshing, creation of masses to model systems, Pad Eye and stiffener creation, contacts, load and boundary conditions, and job-submission.

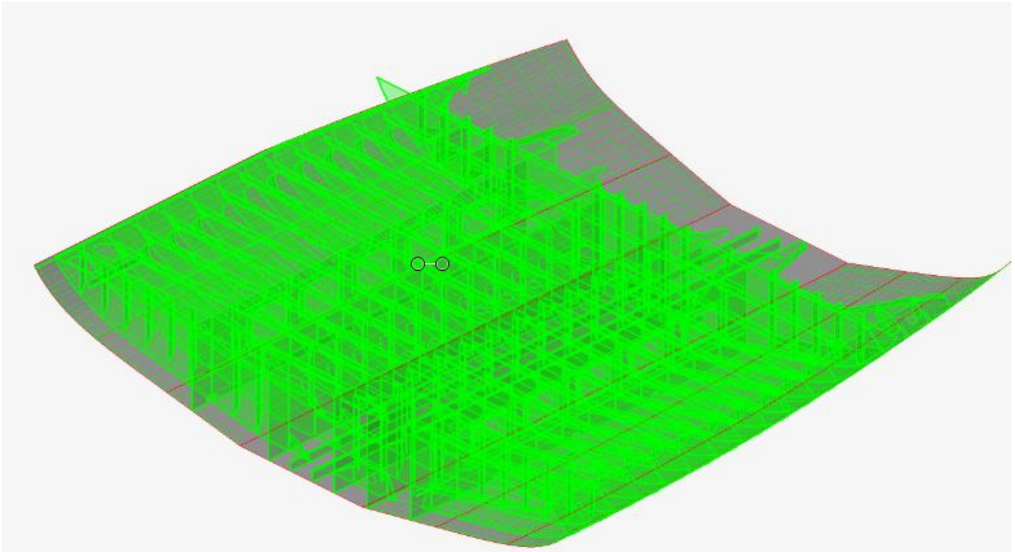
HyperWorks – The Next Generation UI:
In the second LiftShip program Altair's next generation user interface – HyperWorks – is utilized which greatly improves the user experience. Tools have been organized into common workflows, options are easily accessible, in-app helps newer users, and overall efficiency (e.g. mouse clicks/ movement) has been improved.



Enhancements to importing and organize ShipConstructor models:
The ShipContructor to HyperWorks package has been simplified to containing only the necessary geometry STEP files and reporting of the meta data units. Upon import a log file is generated which notifies the user of progress, errors, warning and recommendations on the units to use. The ShipCon model organization is imported into HyperWorks and any parts which had errors (e.g. missing property data) are organized to help users quickly interrogate and prepare their model



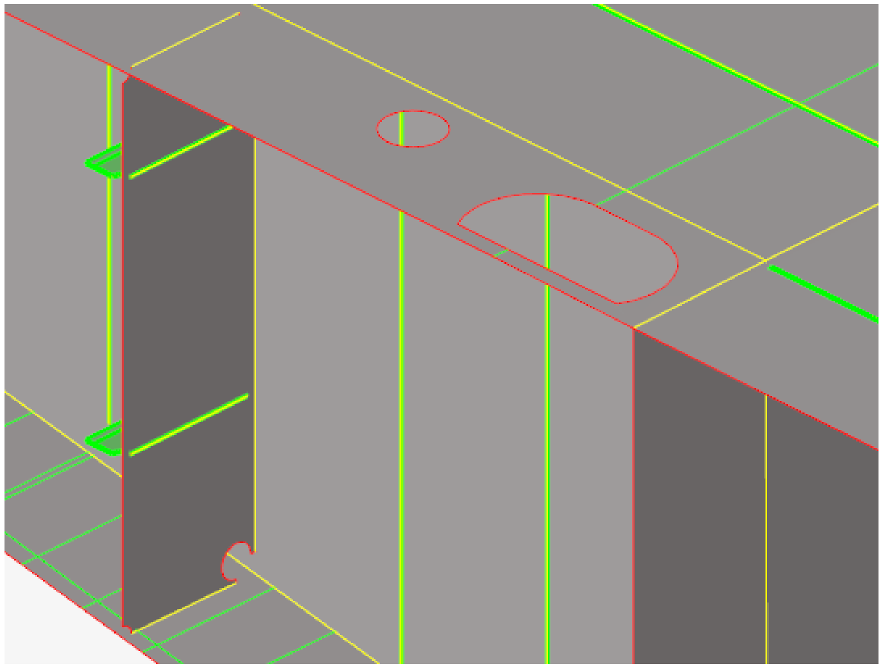
Import of ShipConstructor data



Model prepared for geometry preprocessing

Geometry Preprocessing:

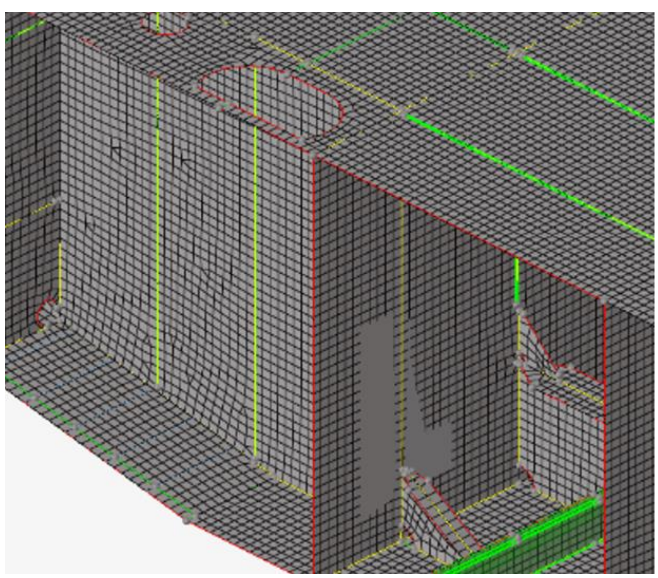
The geometry toolset proceeds from generating midsurfaces from the solid parts, defeaturing of holes and cut outs (globally or user selected) and finally to "stitching" the geometry together. These three stages are semi-automated such that users are aware of their steps and able to quickly undo/ redo them if the results do not meet their preprocessing goals.



Geometry surface topology “stitched”

Meshing:

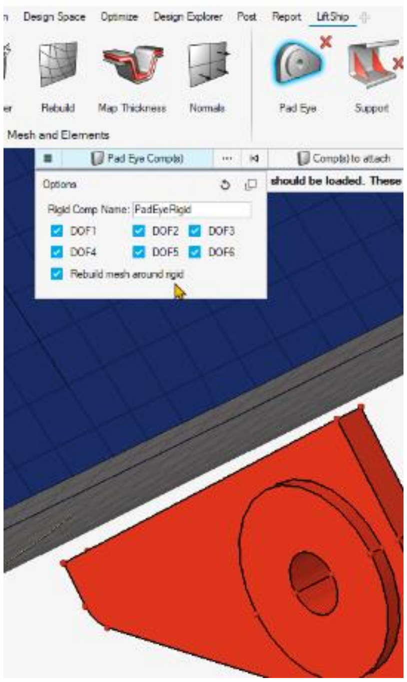
Automated “batch” meshing has been implemented with HWLS2 to generate a high quality, solver compatible mesh. The batch mesher requires two files for final geometry preparation and meshing to meet solver criteria. Users may modify and saved as needed - the default HWLS2 files have been optimized for the SI (mm, MPa) system. After conclusion of the batch meshing minimal final element cleanup is required – greatly reducing user time and effort. Additional optional tools, in the “mesh and elements” section, are available which help mesh and apply meta data to parts which may have had warnings or errors during import (e.g. thickness).

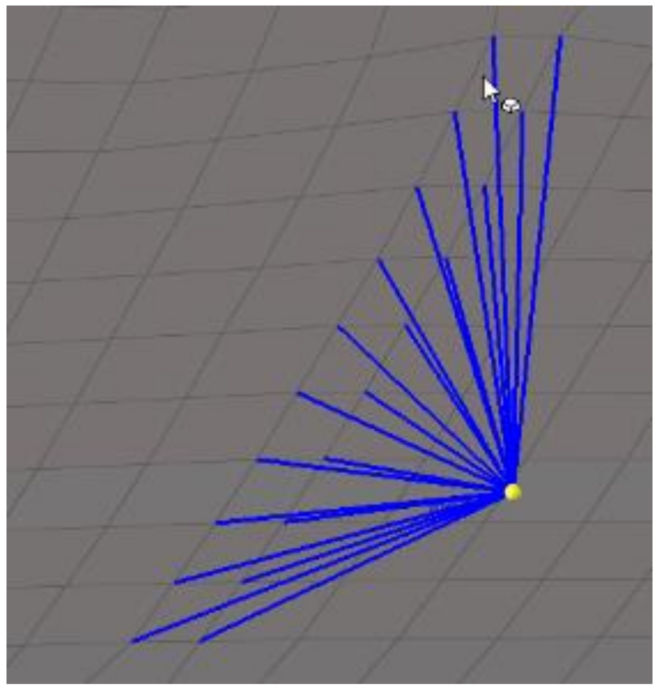


Quality mesh from batch process (color grey meets requirements)

Pad Eye Placement:

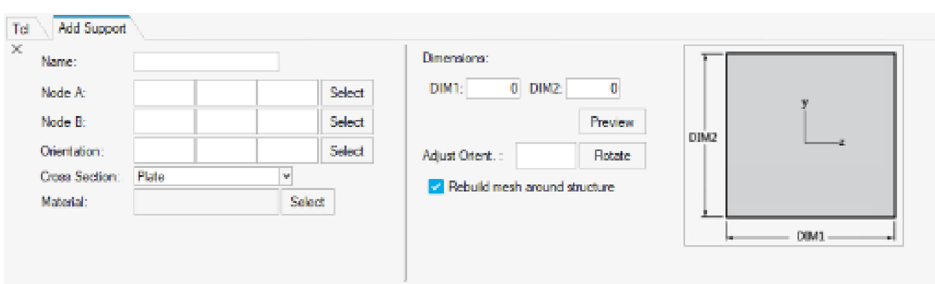
A variety of pad eyes (i.e. lugs) are used to lift a module, but generally they have a cylindrical lift point and a face to mount to the module structure. Based on these features an automated tool was created to quickly convert the lifting part to a rigid finite element.



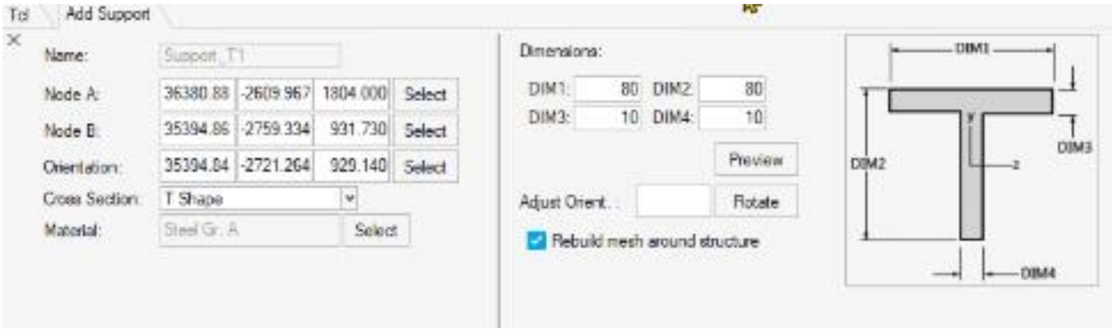


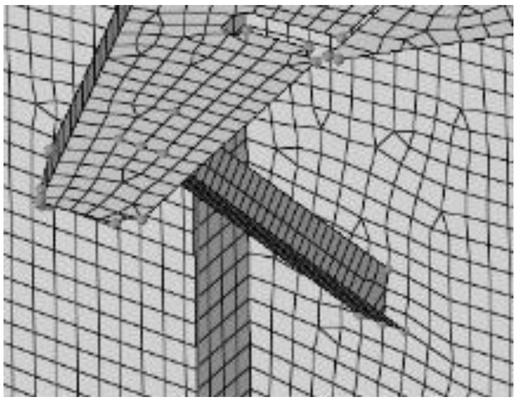
Support Structure

Important consideration in lift analysis is the contribution of supporting structure to the weight and stiffness of the lifting module. The supporting structures are typically beams of various cross sections. HWLS2 allows creation and placement of user defined supporting structures of standard cross-section types.



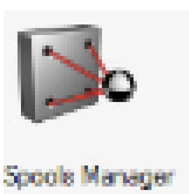
DATA CATEGORY B
DISTRIBUTION: Distribution Unlimited

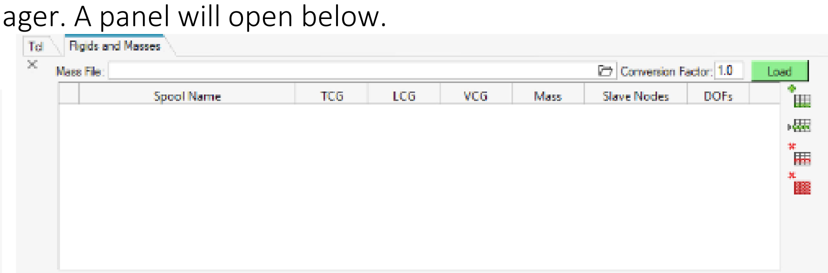




Spools Manager:

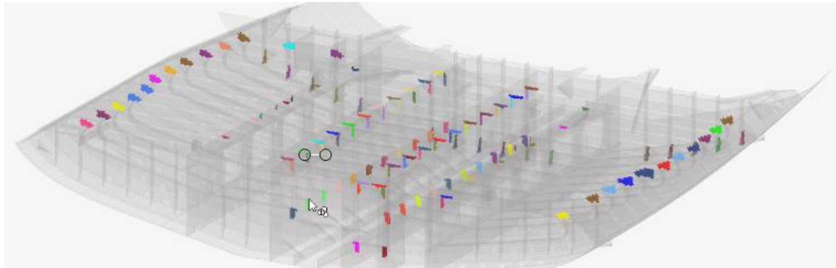
HWLS2 supports the import of a .tsv file exported from ShipConstructor which contains the location, CG and mass/ weight information of ship systems (e.g. spools). The objective of this is to simplify the modeling by idealizing systems as masses attached via rigid elements. Click on Spools Manager. A panel will open below.





Contact:

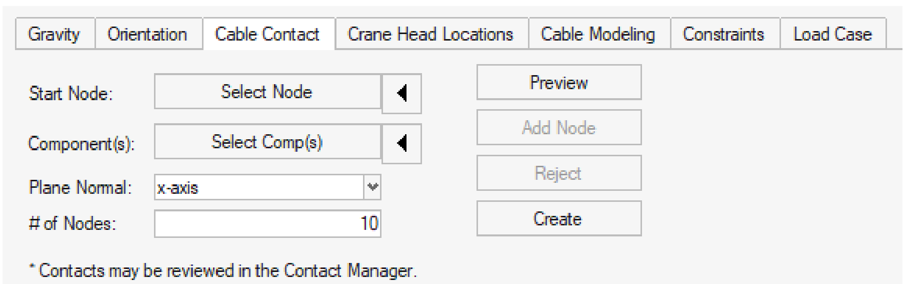
To retain the fidelity of the part location auto-contact has been incorporated into the workflow. Co-planar parts which have been midsurfaced will be separated and have no connection. Contact can help resolve this. The auto-contact tool does this quickly by generating the necessary solver inputs.



Contact illustrated

Lift Manager:

A process oriented "lift manager" has been designed for the LiftShip 2 program in which loading, module orientation, lifting points, cable contact and load cases may be defined. Each tab of the manager automates the setup and requires minimal user knowledge of the processing or solver requirements. Creation of a lift arrangement may be saved and the user may go back to creating a subsequent orientation.



Lift Manager (Cable Contact tab)

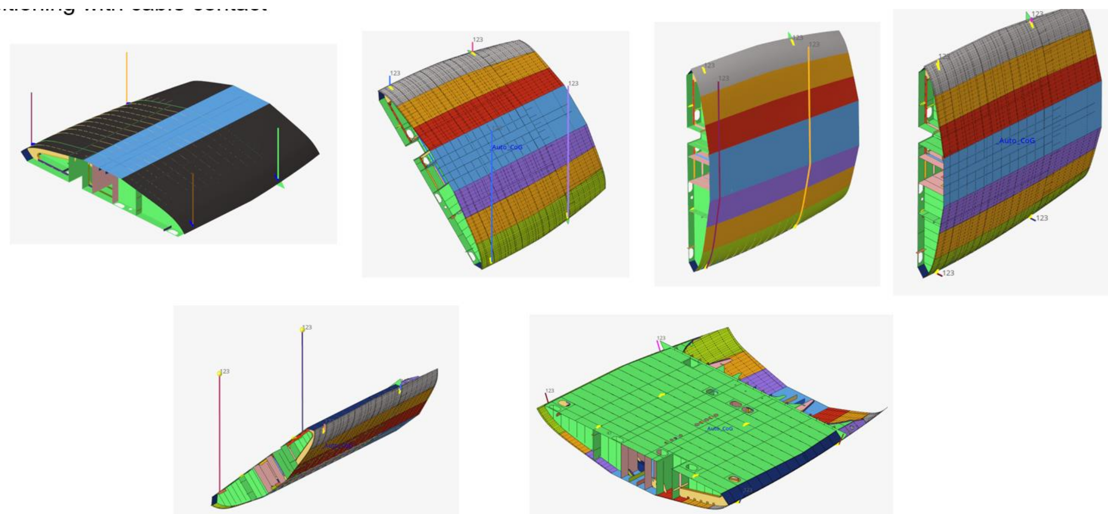


Illustration of different lift orientations

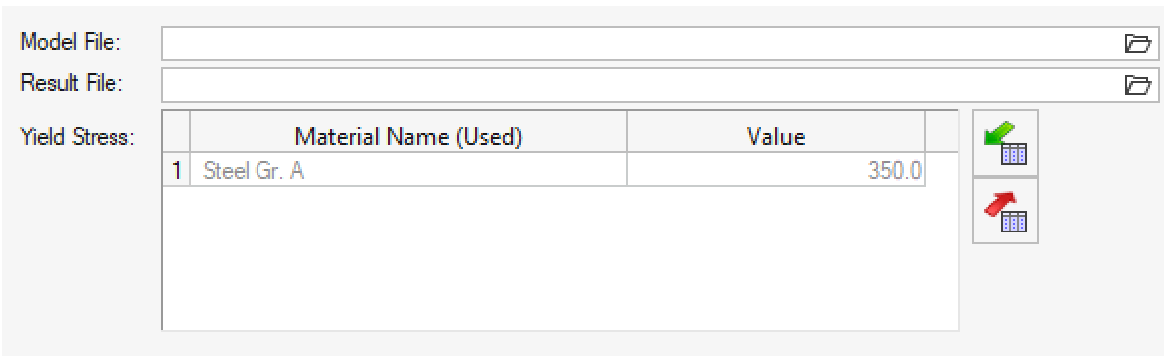
Lift Analysis:

Taking into consideration several scenarios for job submissions the Lift Analysis tool allows users to submit and manage several jobs (fast forward icon), export the solver deck (folder icon), or submit a single job (play icon).

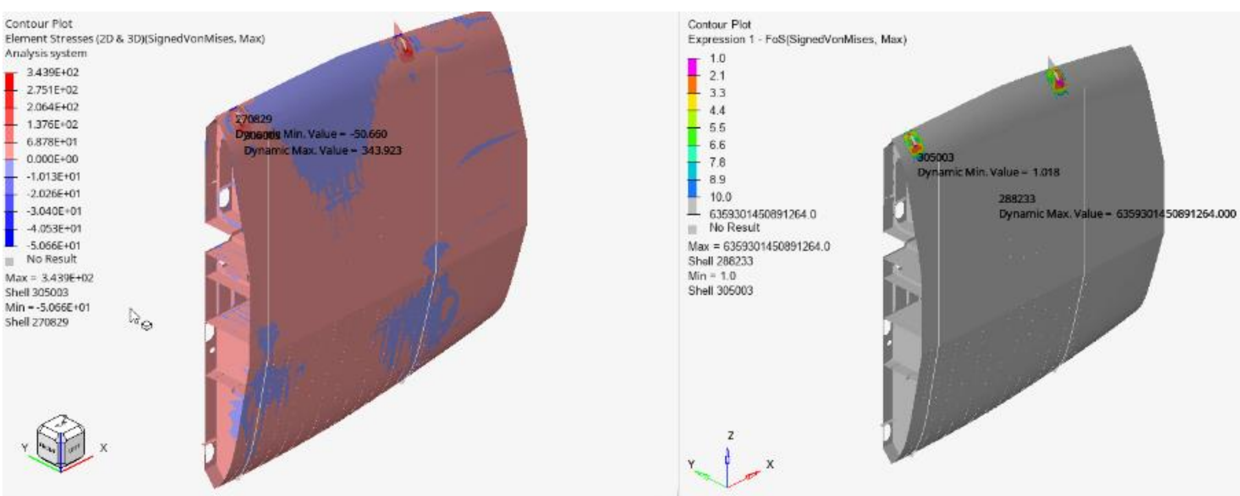
Multi Action Icon

Post Processing:

The go-no-go post processing allows users to select the model and results file of interest for review. Once loaded a template will be loaded automatically displaying the results required (e.g. Von Mises, displacement, factor of safety, lifting forces, cable contact forces).



Loading results in the Post tool



Von Mises and Factor of Safety

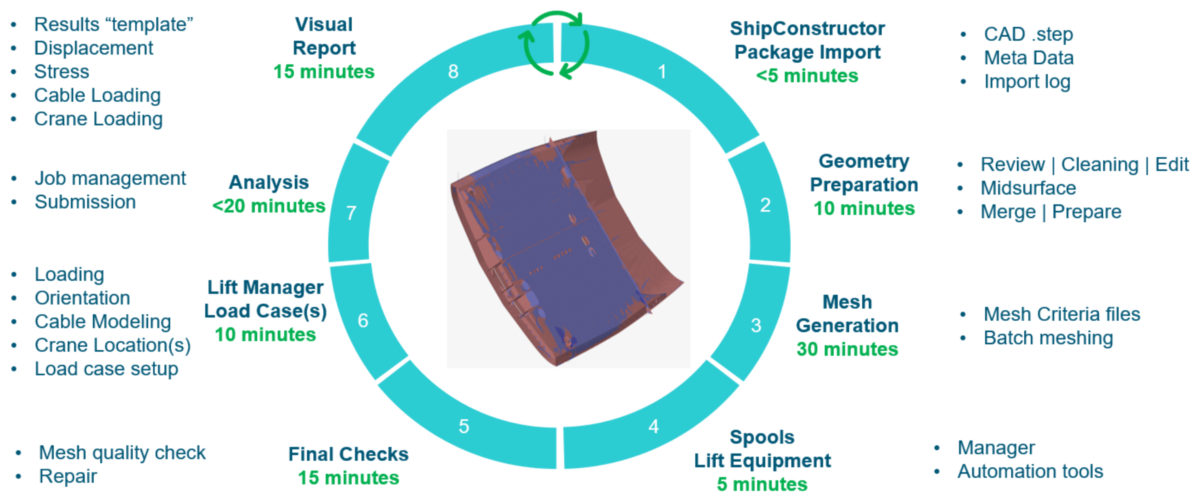
LiftShip Workflow Time Saving:

From import to results the process developed for HWLS2 is an improvement over not only traditional best practices, which take days, but over the previous Lift Ship 1 program. The

HWLS2 toolbox has upgraded the ShipCon reader, the UI, added new tools and new analysis capabilities (e.g. cable contact) and improved go-no-go results.

Modeling & Simulation Workflow

ShipConstructor → FEM Modeling → Analysis → Visual Report → Design Modifications



ShipConstructor Software:

ShipConstructor simplified the setup process for standing up LiftShip as a new install and updating existing users with the required files to support an upgrade such as EnterprisePlatform enabling project files.

ShipConstructor performed many behind the scenes upgrades to allow more efficient transfer of data from various tables. ShipConstructor also streamlined the users experience by simplifying the required steps to select the objects that will form the basis of the FEM. For instance, when a user imports the LiftShip operations, the user no longer has to specify a template file to determine how the part is converted to STP file. This creates a lot less confusion on how the user must make the template and where to store the STP file. The user can still use the template file if the user wants to keep an object that requires more customization control; however, the default now will provide the results needed by to support either of the FEA software. Additionally, material output unit selection were added where the default display units for length, width, and pressure are initially used and displayed. Thus, the materials XML file generated will by default use the display units (length, weight, pressure). There no longer is a requirement to update the operations xml to specify what units to use. Again, and with many of the ShipConstructor basis positions, the user can override the operations file if the user desires more control; however, the need is not expected to ever be required. These will be built into EnterprisePlatform and occur automatically provided user has AutoCAD mechanical installed. The other advantage for both these changes is if an organization / user performs and works in both metric and imperial projects, the user will not have to make any changes to the operations files to accommodate each individual project meaning there is less of an opportunity for errors and rework.

ShipConstructor supported ATA Engineering with their geometry translation software update which allowed the capability to import ShipConstructor part names to associate with the corresponding Femap geometry. The ShipConstructor part names are assigned to Femap solids.

REQUIRED RESOURCES

To implement LiftShip 2 is relatively simple and very straight forward, that is install the software, take some straightforward training, and use it.

As stated, LiftShip 2 requires software, specifically AutoCAD Mechanical, and ShipConstructor (version SSI R2022 R2.2) with EnterprisePlatform (enabled). Additionally, one of the two (2) Finite Element Analysis (FEA) software packages is required; Altair HyperWorks or Siemens Femap.

Regarding personnel and training, it is assumed the organization has the skilled personnel to use the ShipConstructor software and has personnel who are knowledge with FEA software. The LiftShip 2 ShipConstructor functionality easily leverages the same ShipConstructor skills of a typical user without requiring extra formal training since the skills are the same for most other ShipConstructor operations. At most, a short introduction to the new functions available to ShipConstructor users and the specific sequencing required when selecting objects from within the 3D model is sufficient to bring users up to speed on selecting the objects for FEA. Further, it is expected the organization has analysts who are structural engineers or naval architects familiar with the nuances of FEA software, Femap and / or HyperMesh. If not, there is simple and efficient training available from ATA Engineering, and Altair Engineering regarding Hyperworks and Femap.

Further, there are comprehensive specific training materials, user guides, and instructions to install the software available from ATA Engineering, Altair Engineering, and SSIUSA, which were delivered to ATI to be provided to organizations upon request.

- User’s Guide for ATA LiftShip Tools for Femap
- Installation Guide for ATA LiftShip Tools for Femap
- HyperWorks for LiftShip 2 (Reference & Tutorial Guide)
- SSI LiftShip 2 Training Script

Altair Engineering has the below links established to support implementation:

- Altair’s YouTube “How Tube” channel: https://www.youtube.com/c/AltairHowTo, will have a dedicated channel.
- Altair’s website will have a dedicated website: https://www.altair.com/, will have a dedicated page.

ATA Engineering has the below links established to support implementation:

- XXXXXXX

As a note and disclaimer: the project did not review or endorse specific lift strategies or lift criteria as to what makes an acceptable and safe lift for these are the responsibility of the organizations and their personnel.

IMPLEMENTATION TIME ESTIMATE

LiftShip can be implemented very quickly, within a couple of days.

There are several milestones for implementation. The first is installing the software, which is typically is the critical path for without the software properly installed, there is no LiftShip. In order to install the software, it must be on hand; therefore, the proper software must be selected and procured. The below are the main POC's to ensure the proper software is selected:

- SSIUSA
  - Robert Parker Robert.Parker@ssi-corporate.com
- ATA Engineering
  - Victoria Harris victoria.harris@ata-e.com
- Altair Engineering
  - Raymond DelDin rdeldin@altair.com

Therefore, with the software on hand, the installation including Enterprise enabling a project could occur in a couple of days.

User training on the processes supporting LiftShip in the ShipConstructor software and the FEA software takes a day. There is training available in the form of videos and user guides in pdf format for each software. Further, ATA Engineering and Altair Engineering have a website dedicated to LiftShip.

Should the organization require training on the FEA software, Femap and / or HyperWorks, ATA And Altair have training available.

EVALUATION AND ANALYSIS

The primary goal of the project was to facilitate the export of an assembly design model to the FEA systems and make them ready to mesh. The actual process workflow and indicator of success was driven by the shipyard participants and their requirements. Care was taken early in the project to include the shipyards and their analysts as a means for understanding the domain of the problem for them and how they would view a successful project for implementation. There was a shipyard questionnaire circulated to the team members that was used as an initial baseline for requirements and subsequent meetings and follow-ups allowed the team to clarify any further questions.

The primary means of evaluating the project as successful was the ability to perform the tasks as determined early in the project timeframe. The results of this project successfully export ShipConstructor design models into each of the FEA systems and make them immediately available to the users for meshing and analysis. This was demonstrated

LIMITATIONS OR CONSTRAINTS

Any shipyard using ShipConstructor and Femap and / or HyperMesh will realize a benefit from this project. If the organization is performing the work is currently using hand calculations, then LiftShip 2 will allow them to get a full FEA model in a fraction of the time with highlyu detailed and accurate results allowing the analysts to focus on the actual lift configuration, that is the placement of the lifting lugs and any required backup structure. If an organization is developing a FEM by hand, then the organizations will be able to create an FEM for use in the FEA much faster than they could ever manually.

The constraint or limitation is a 3D detail model must exist, currently in ShipConstructor.

MAJOR IMPACTS ON SHIPYARD

Implementation of LiftShip 2 will provide a significant impact on the schedule and accuracy of lift applications for the smallest of lifts to the most complicated through the use of the existing ShipConstructor 3D design model and with the FEA tool Femap or HyperWorks. In all cases a quicker and more accurate analysis is performed for lifting plan(s) so more comprehensive analysis is possible to determine and select the most proper configuration.

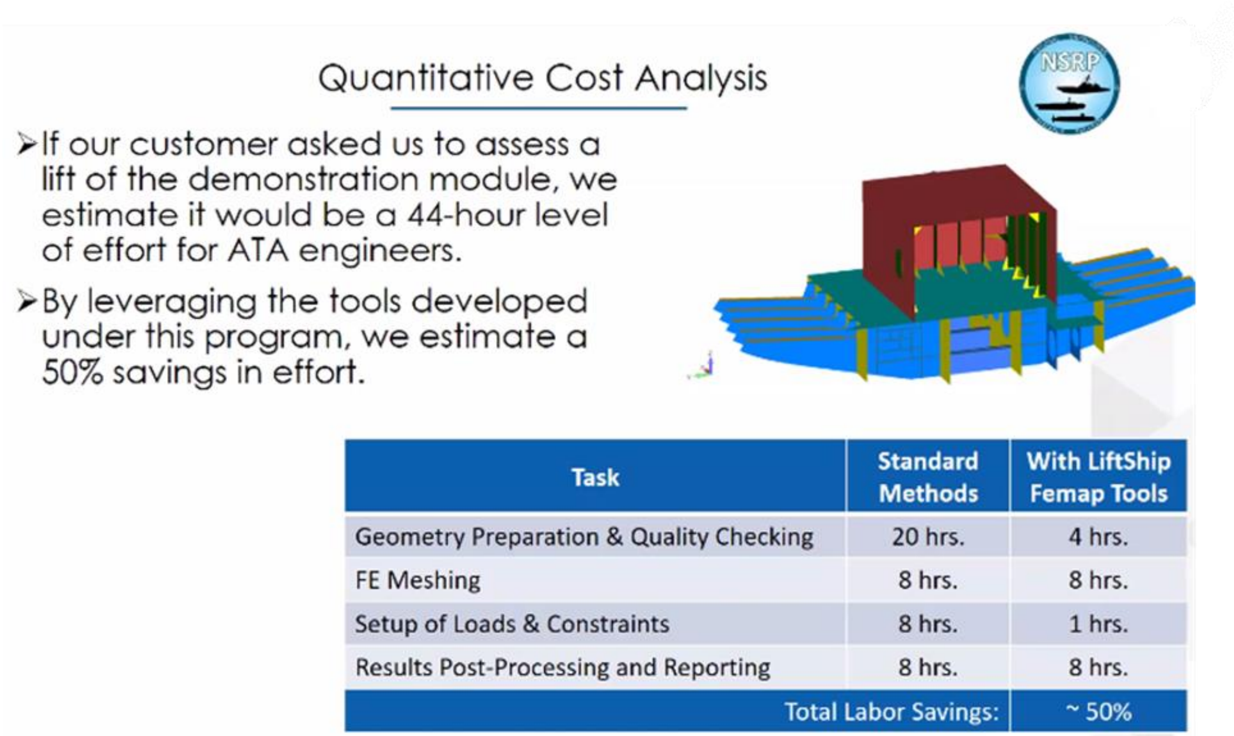
Once the FEA model (FEM) is created from the 3D design model, the FEM can also be modified extremely rapidly for alternative scenarios for lifting where required to assess alternative lifting solutions, this can be accomplished in a fraction of the time using legacy processes.

COST BENEFIT ANALYSIS / ROI

The primary cost benefit analysis per the project proposal was a 75% reduction in analyzing complex lifts, and a 50% reduction to set up the FEM. This equaled a cost savings of:

Cost Category	**As-Is Baseline**	**Post-Implementation**
Labor: 75% reduction analyzing complex lift operations ($70/hr/analyst) [2 analysts, 80 hrs/lift, 12 lifts/year]	$134,400 /year	$33,600 /year
Labor: 50% reduction FEM setup for complex lift [2 analysts, 20 hrs/lift, 12 lifts/year]	$33,600 /year	$8,400 /year
Total:	$168,000 / year	$42,000 / year
Return:	400%	

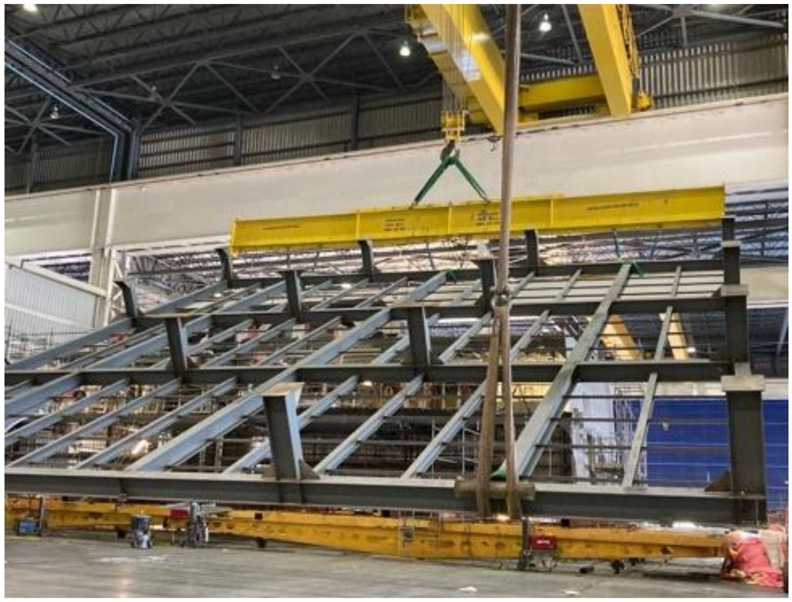
Initial project results, given ATA Engineering's initial analysis, see below, was a labor savings of 50% given ATA Engineering's estimated savings for a typical project where LiftShip 2 would have and could have been utilized.



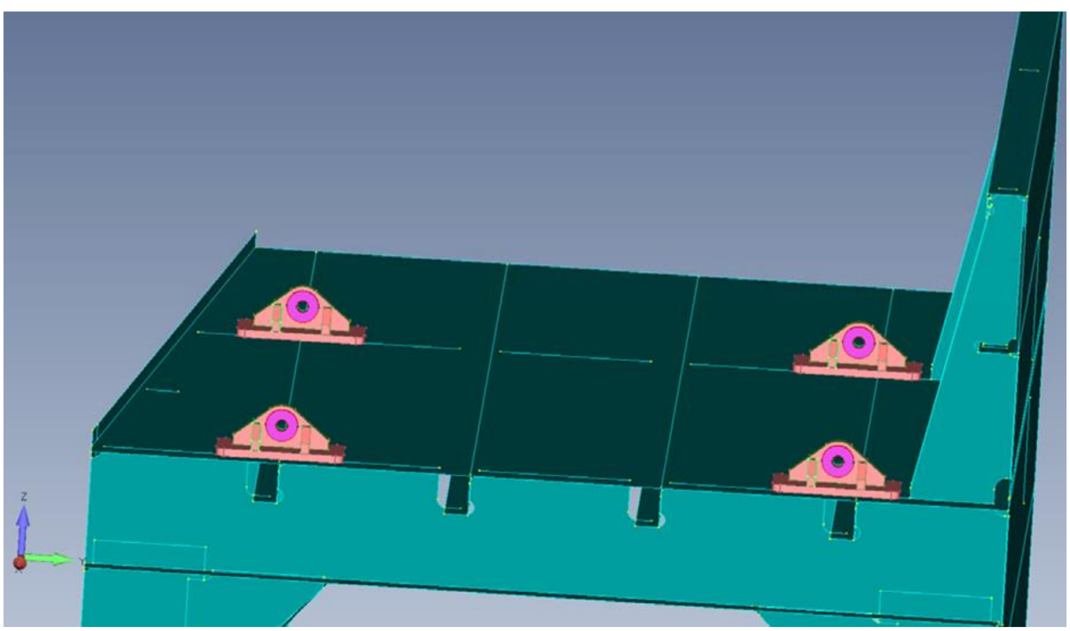
Task	Standard Methods	With LiftShip Femap Tools
Geometry Preparation & Quality Checking	20 hrs.	4 hrs.
FE Meshing	8 hrs.	8 hrs.
Setup of Loads & Constraints	8 hrs.	1 hrs.
Results Post-Processing and Reporting	8 hrs.	8 hrs.
Total Labor Savings:		~ 50%

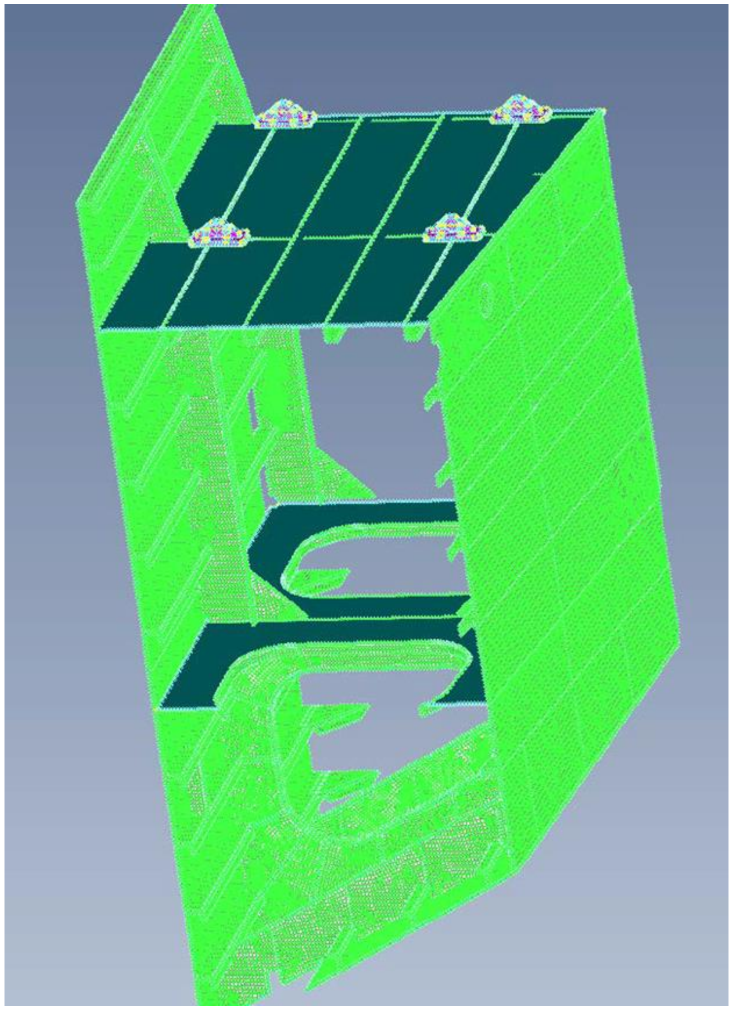
The actual results were as follows:

- A shipyard performed hand calculations to support lifting and turning a steel jig or fixture, see below picture. The 3D model file and hand calculations, for comparison purposes, and a rough detail of the labor expended on the various calculation iterations of the fixture's hand calculations were provided to SSIUSA. SSIUSA developed a project for the 3D model and provided the export file to Altair, which took less than an hour. Altair's effort was also less than an hour, which was to setup the LoadCase and perform the FEA calculations. The combined effort was under 2 hours. From the data provided, the estimated savings was 75 hours per hand calculation iteration. The initial labor efficiency reduction on this use case is over 3,000%. Assume a fictitious labor rate of $70/hr to simplify the calculations, the cost savings using on this use case is $5,250 per iteration. Using the standard 12 lifts per year per the proposal, to keep the analysis apples to apples, the cost savings for one vessel is almost $63,024 per year.



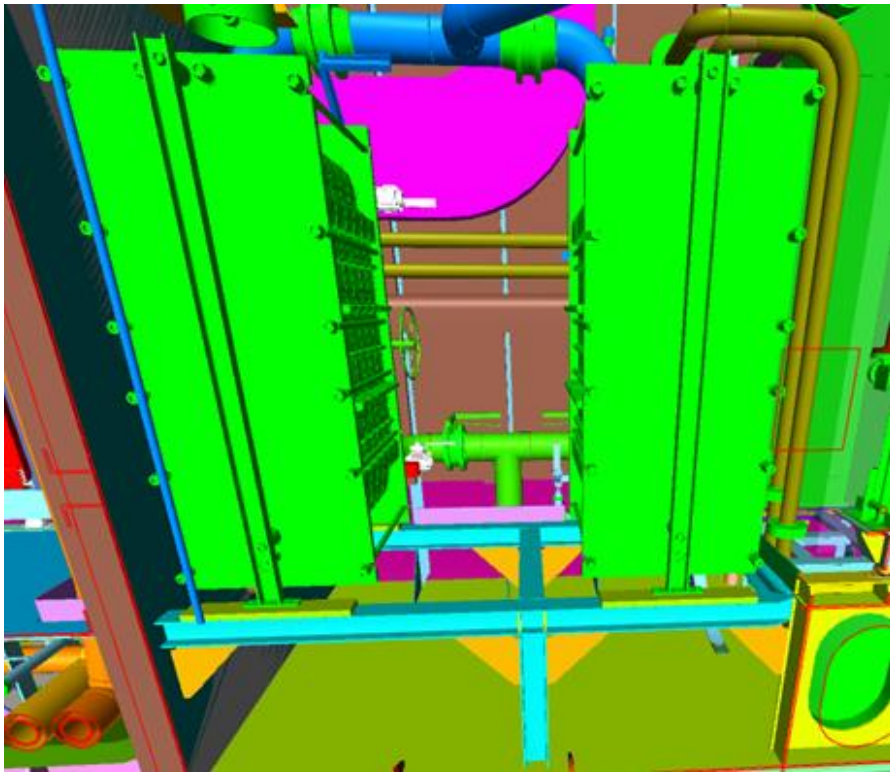
- Ship Architect (SAi) performed two (2) analysis evaluations on lifts with turns, see the two below pictures. The overall outcome was as follows:
  - The time to identify the objects in ShipConstructor and prepare the FEM was 5 minutes using the ATA Femap application and 20 minutes supporting the Altair Engineering HyperWorks.
  - The time to run the FEA application, approximately 20 minutes.
  - Total time, less than an hour. For calculation purposes, let's use 45 minutes.
  - The legacy time to perform the same would be approximately 40 hours. The savings is 39.25 hours. Using the same rate and number of lifts, the savings per lift is $2,607.50 and for a year of 12 lifts provides an annual savings of $31,290.

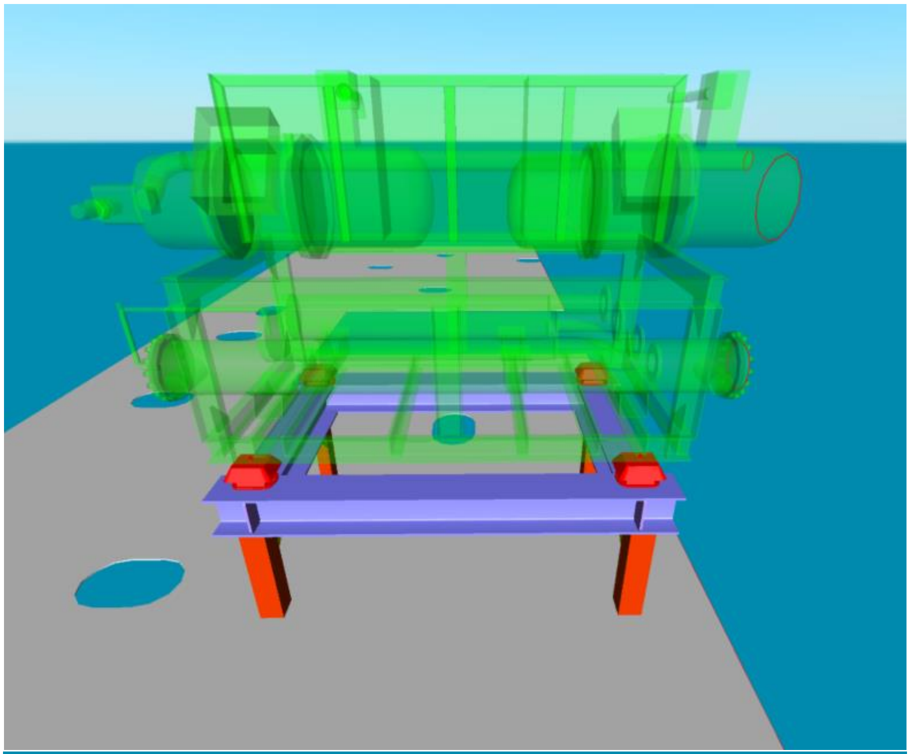


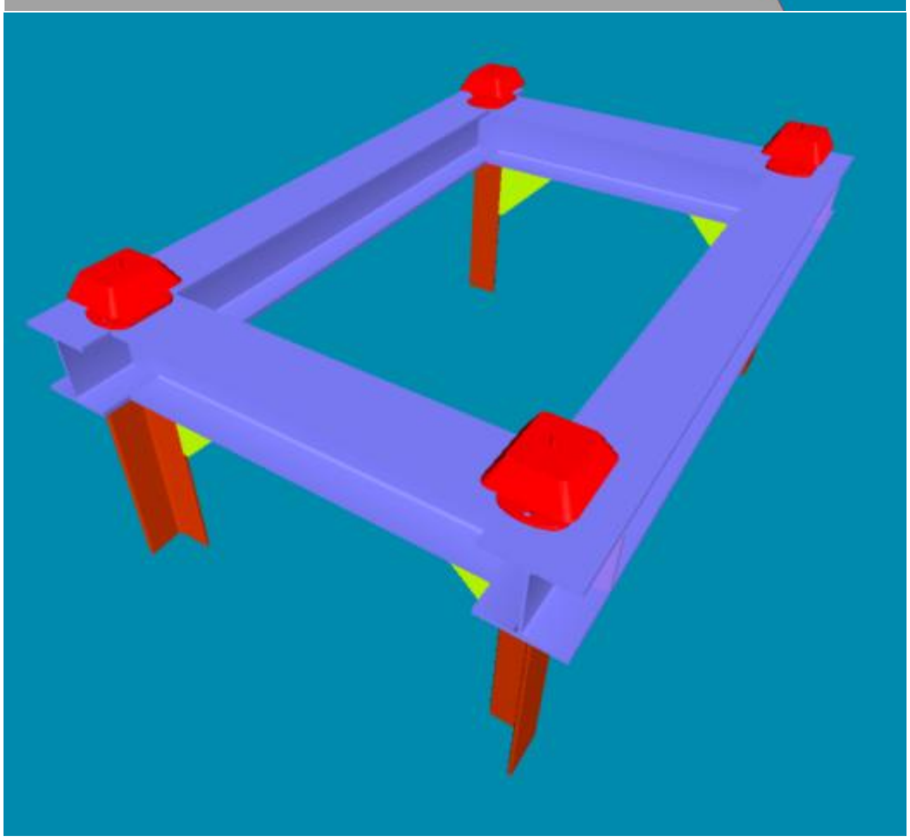


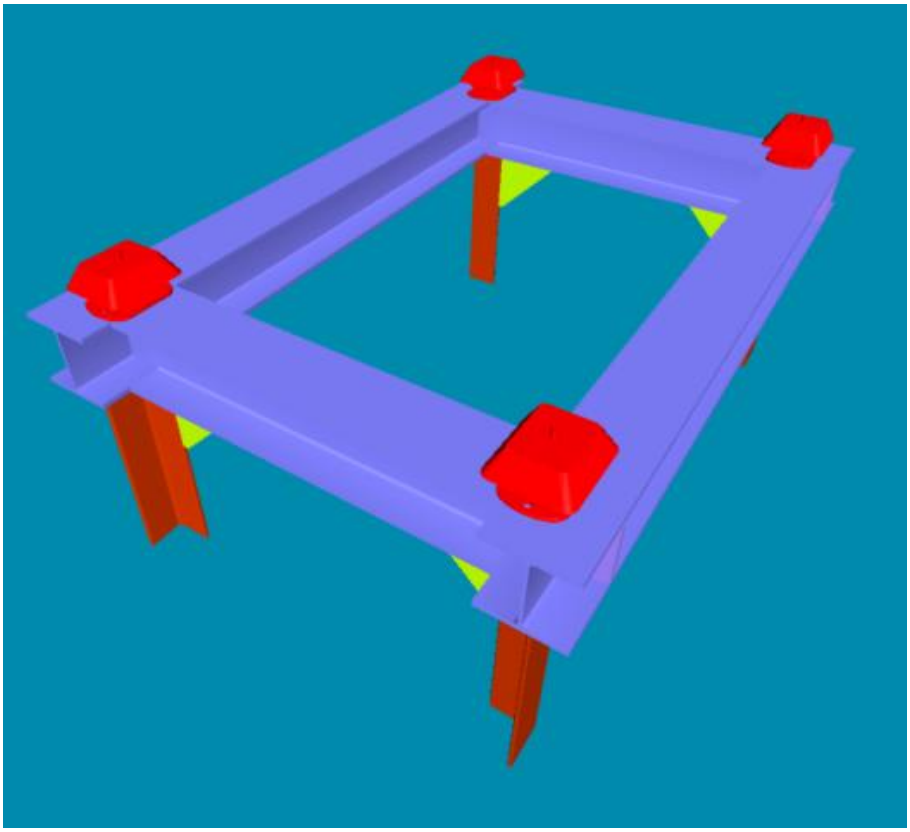
- Genoa Design International performed two (2) FEA evaluations on foundations. The LiftShip project also supports FEA on anything structure contained within the 3D ShipConstructor model. Since Genoa Design International does not perform calculations for lifts and turns often, they used the project applications to support FEA calculation on structural foundations, see the below pictures. The results of the performed a FEA on a foundation for a 90 ton chiller is below:
    - The overall outcome was as follows:
        - The time to identify the objects in ShipConstructor and prepare the FEM was 1 hours for the ATA Femap application and 1 hours for Altair Engineering's HyperWorks.
        - The time to run the FEA application, approximately 4.5 hour for the ATA Engineering Femap and 4 hours for the Altair Engineering HyperWorks.
        - Total time, less than an hour. The time recorded supported two (2) iterations, the initial and a second adding resilient mounts in the FEM. For calculation purposes, let's use 2 hours per iteration which would support the manual modifications in the FEM adding the resilient mounts.

- Given Genoa typically does not perform structural calculations, it was estimated that this effort would take between 2 and 3 days or 16 to 24 hours per iteration. To stay on the conservative calculation side, 16 hours was used for a savings of 12 hours. Using the same rates, the cost savings per iteration is $840. Estimating 12 FEA foundation calculations are required per year per ship, the annual savings is $10,080.









Now the calculated returns do not quite represent apples and apples with the initial project proposal. The initial proposal assumed two (2) people supporting the calculations. In the aforementioned examples, there was one analyst. Therefore, those savings can be hypothetically doubled.

To calculate the NAVY ROI, a few items should be noted and explained. The twelve (12) lifts per year is low and the actual number of lifts depends upon the build strategy which differs for each shipyard. A more accurate number would be around 20 lifts per year per vessel.

With a cost savings of $2,607.50 per lift calculation, using SAi's figures, and each lift calculation will have two (2) iterations, to take into account the efficiency and accuracy of an FEA lift configuration to optimize the arrangement, the cost savings is {$2,607.50 * 20 *2] = $109,900 savings per vessel per year or for a 5 year estimate of $549,500. To expand this value to the shipyards on the project; HII, Bollinger, FMM, VT Halter Marine, and Austal USA, we have an extrapolated total cost savings for 5 years of $2,747,500.

The funding was $1,101,491.

The Navy ROI calculation:

ROI = [2,747,500 – 1,101,491] / 1,101,491] = 16.2

LESSONS LEARNED

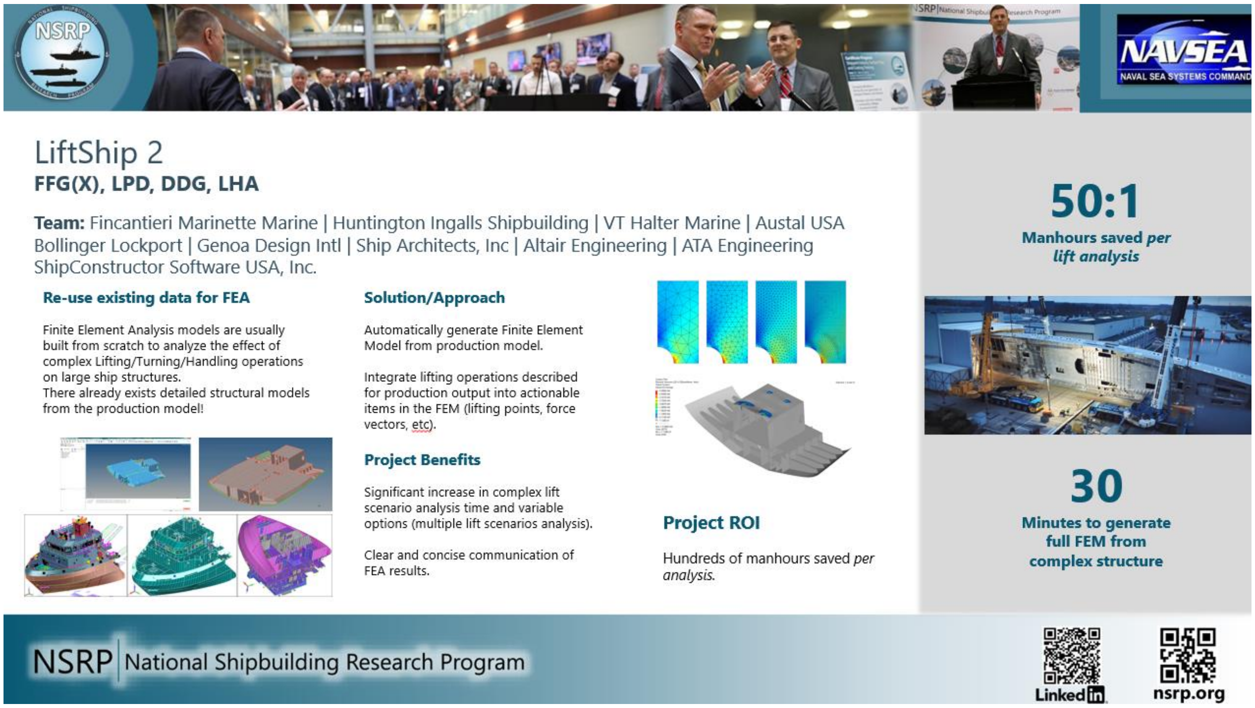
The major lessons learned were:

- The project participant organizations must install the software in a timely manner. Several organizations participated with earnest until the latest software was released. The organizations IT departments did not install the updated software for a variety of reasons. Without the final software, individuals within those organizations could not perform the necessary Test & Evaluation.
- Organizations have turnover and reassign individuals to other tasks or departments. Several organizations experienced turnover of the Naval Architectural department. The individuals who left were closely following and participating on the project. Other organizations reassigned personnel to support other tasks and therefore lost the knowledge if those participating. The result was these organizations did not perform Test & Evaluation.
- And another lesson earned was the lack of thorough use cases. The project started out with many excellent use cases from all of the project organizations. However, it was noticeable as the Testing & Evaluation efforts were underway, the efforts being used to support the Test and Evaluation efforts were different than the use cases provided. This created immediate updates from the three software organizations in an effort to correct any short comings so the Testing and Evaluation efforts could continue.

TECHNOLOGY TRANSFER

There have been many official and unofficial Technology Transfer Events supporting LiftShip 2:

- There has been one official Technology Transfer Event, the 2021 NSRP All Panel Meeting for the Business Technologies Panel on 24 March 2021.



- SNAME selected “LiftShip 2” as a White Paper candidate for the 2021 SNAME Maritime Convention (SMC) in Providence, Rhode Island in October 2021.

- An unofficial Technology Transfer event was conducted on July 28th, 2021, Electric Boat’s Quonset Point locations inquired through Craig Haverly and Altair Engineering to provide a brief overview and workflow of “LiftShip” and “LiftShip 2” given the current use of the Altair Engineering HyperWorks software.

- At the 2021 Sea-Air-Space convention on August 2nd through the 4th, a mini poster, really a brochure supporting “LiftShip” and “LiftShip 2” was provided to ATI for display at the NSRP booth.

- There was a Technology Transfer event conducted at the NSRP Business Technologies / Ship Design & Materials Technologies – Joint Panel Meeting held in San Francisco, CA on 15 September 2021 where the history of “LiftShip” was provided along with the current status of the “LiftShip 2” project. ATA Engineering, Altair Engineering presented remotely while ShipConstructor presented in person.

- A Technology Transfer event was conducted on 29 October 2021 at the SNAME Maritime Convention (SMC) 2021 in Providence, Rhode Island. Presenting were Erik Bjorkner of ShipConstructor Software USA, Victoria Harris of ATA Engineering and Rajesh Bishnoi of Altair Engineering. A White Paper was submitted for publishing to SNAME by Erik Bjorkner for SMC 2021.

- An unofficial Technology Transfer event entailed as ShipConstructor Software USA

(SSIUSA) staffed a booth at SMC 2021. At that booth, SSIUSA personnel discussed "LiftShip" and NSRP as a whole as appropriate with those who presented themselves to the booth.

- Another Technology Transfer event was the End of Phase I Review and Demonstration meeting held in New Orleans, LA in conjunction with the international Workboat Show on Thursday December 2nd, 2021. The meeting had in-person and remote attendance using the WebEx platform. There were 14 people who attended the meeting in person and approximately 30 on the video conference.

- ATI requested the project to provide a poster and video for ATI's booth at this year's Navy League's Sea-Air-Space Expo in National Harbor from 4-6 April 2022. The LiftShip poster, shown below, was developed and submitted to ATI on 11 March 2022. A video was also requested for the project to play in a loop at the ATI booth on a screen. ShipConstructor Software USA developed the video.

NSRP | National Shipbuilding Research Program

LiftShip & LiftShip 2

Shipbuilding & Sustainment

Team: LEAD - Fincantieri Marinette Marine | Huntington Ingalls Industries | VT Halter Marine | Austal USA | Bollinger Shipyards | Conrad Shipyard | Ship Architect | Genoa Design International | ATA Engineering | Altair Engineering | ShipConstructor Software USA | NAVSEA - Carderock

Problem:

Reduce the effort required to perform lift calculations and to develop lift arrangements which will reduce / eliminate structural distortion or catastrophic failures.

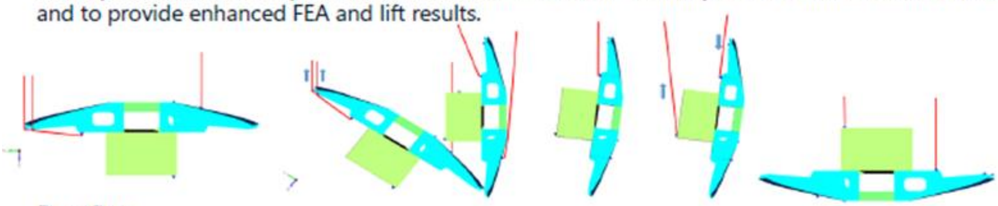
Solution:

LiftShip:

Developed an efficient and user-friendly process to create the finite element mesh model using the existing digital information / data from the 3D Design / Production Model.

LiftShip 2:

Expand the original LiftShip efficiencies further by supporting lifts with turns, develop a user-friendly manner to modify the mesh model level of detail for analysis at a various detail levels, and to provide enhanced FEA and lift results.



Benefits:

Reduce the duration and labor effort to perform calculations and analyze the FEA results of structural lifts to ensure there are no structural deformations due to the lift arrangement.

LiftShip allows lift calculations and arrangements earlier in the design phase whereby backup structure could be added in the earliest phases construction for additional producibility efficiencies.

Initial **ROI** indicates a labor savings of at least 50% for performing the initial calculations.

Linkedin nsrp.org

Contact the NSRP Team at: nsrp@ati.org

ATA ENGINEERING, INC. Altair HyperMesh Femap SHIPCONSTRUCTOR®

- There was a LiftShip 2 Live Demonstration held in Marinette, WI at the Fincantieri Marinette Marine (FMM) in Marinette Wisconsin on August 16th and 17th, 2022 at the Fincantieri Marinette Marine Annex where ShipConstructor Software USA, ATA Engineering and Altair Engineering all demonstrated the LiftShip 2 solution to in person and virtual attendees. The event was a two (2) day event, where SSIUSA and ATA performed their demonstrations followed by a tour of FMM where the LiftShip 2 in person attendees witnessed a lift and turn of a module. The second day consisted of SSIUSA and

Altair performing a live demonstration.

- LiftShip 2 was presented by Erik Bjorkner, Victoria Harris, and Joshua Pennington at the joint Business Technologies (BT) Panel & Ship Design Material Technologies (SDMT) Panel meeting. Erik, SSIUSA, participated in person while Joshua, Altair, and Vicki, ATA, participated remotely. There were many excellent questions from those who were attending in person. An individual from NASSCO was so interested in the project that NASSCO may possibly actively follow LiftShip 3 or participate in an unfunded capacity.

- LiftShip 2 was presented on September 28, 2022, at the SNAME's Maritime Conference (SMC) in Houston, Texas based on the paper Erik Bjorkner developed titled "LiftShip 2 Results and Follow-on". Erik Bjorkner, SSIUSA, and Joshua Pennington, Altair Engineering, co presented a brief on LiftShip, LiftShip 2 and the future, LiftShip 3. There were many excellent questions. In fact, Bollinger Shipyard representative, attended the presentation and was regretful that Bollinger was not more active on LiftShip 2 given Bollinger was focused on Lifts with Turns for several projects which consumed much of the time of the people who would have been following LiftShip 2. The representative stated a week or two was typically required to analyze a Lift with Turn, Erik explained that effort could be accomplished in roughly two hours. Needless to say, Bollinger Shipyards may jump back on LiftShip 3 as an unfunded participant. Others at SNAME showed an interest in LiftShip such as Netsco, Martin Ottaway, NAVSEA NSWCCD Code 823, and Andy Schuster (Naval Architect Consultant).

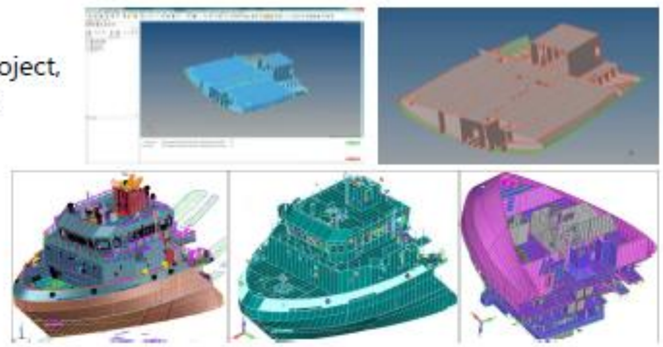
LiftShip 2

Team: Fincantieri Marinette Marine (FMM) | Austal USA | Huntington Ingalls Shipbuilding | VT Halter Marine | Bollinger Shipyards | Genoa Design Intl | Ship Architects, Inc. | ATA Engineering | Altair Engineering | ShipConstructor Software USA, Inc (SSIUSA)

Problem Statement

Extend the successful previous project, "LiftShip", to encompass shipyard requirements:

- Turning and Complex Lifts
- Enhanced Visual Reporting
- Import Level of Detail

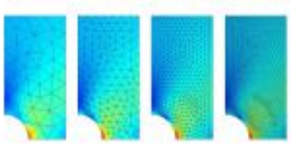


Solution/ Approach

Multiple discrete lifting operations can be combined to describe more complex lifting operations (including turns).

Better visual reporting of FEA results and recommendations.

Variable Level-of-Detail choices analysts to import elements.

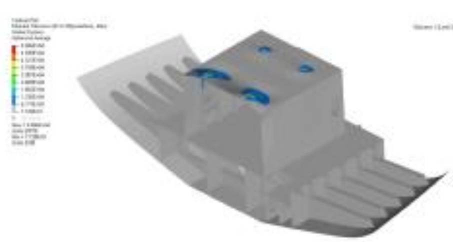


Project Benefits

Significant increase in complex lift scenario analysis time and variable options (multiple lift scenarios analysis).

Clear and concise communication of FEA results.

Tools for analysts to modify level-of-detail options accordingly for model import.



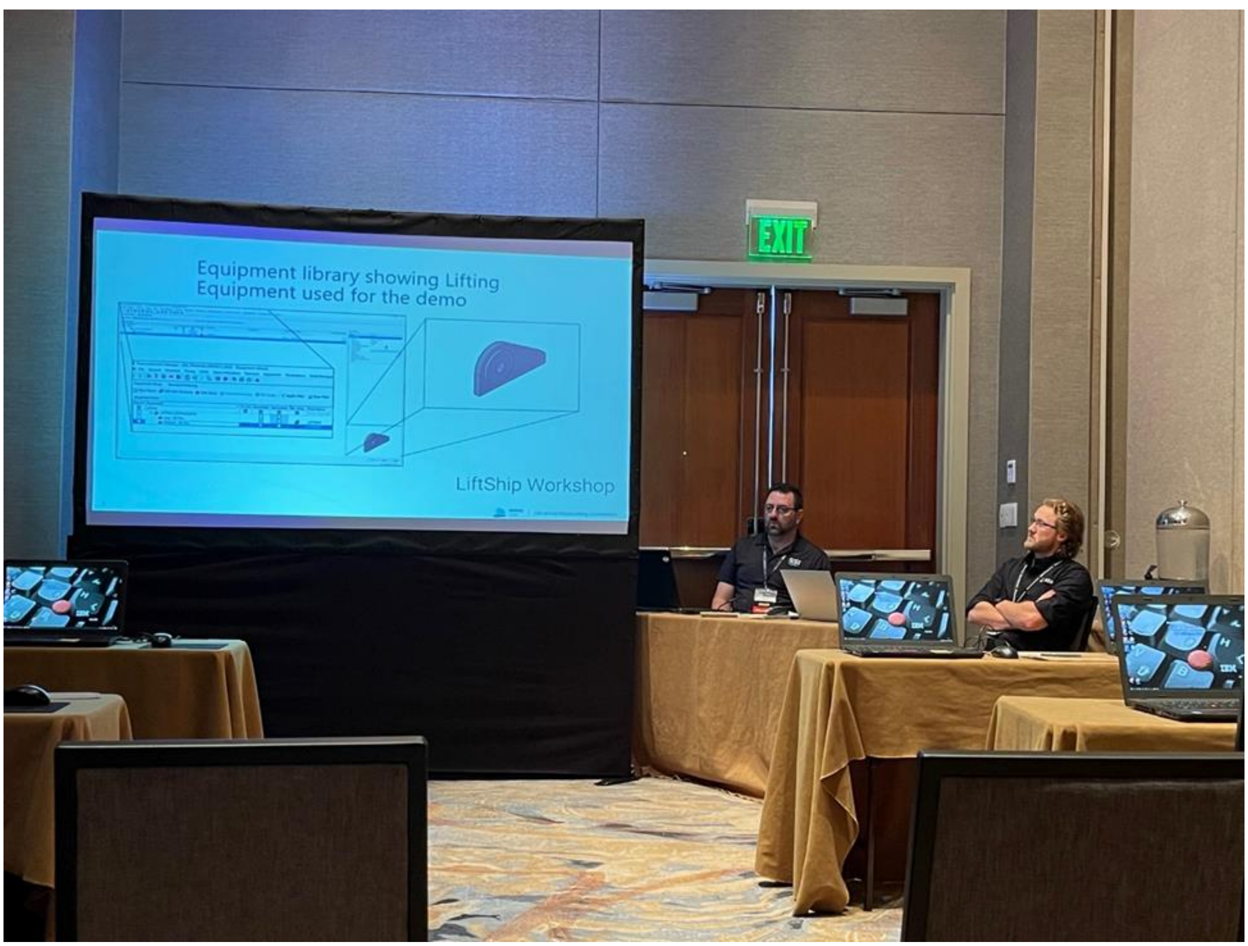
NSRP | National Shipbuilding Research Program

Questions?

Contact the NSRP Team at: nsrp@ati.org

- An unofficial Technology Transfer Event was at ASME FMMS 19 through 21 September in Virginia Beach, VA where Erik Bjorkner and Patrick Roberts spoke with engineering and design firms about the benefits of using LiftShip on ship repair projects. For instance, a laser scan could be accomplished then pulled into ShipConstructor where a model is developed, it's not automatic or exact; however, it could then be detailed enough to support the framework for a FEM to which a FEW could be run. The feedback was excellent.

- SSI World Shipbuilding Conference, in Mobile Alabama on Thursday 6 October 2022. Altair Engineering, Raymond DelDin, provided a summary of the LiftShip and LiftShip 2 to over 125 people consisting of many US shipbuilders, ship repair companies, engineering firms and design firms throughout North America. Ray provided overviews of the ATA Engineering and Altair Engineering aspect of LiftShip and LiftShip 2. Following the presentation, Altair Engineering, along with SSIUSA, provided a breakout training session supporting LiftShip 2 with the Altair Engineering HyperWorks application based on the final version of HyperWorks for LiftShip 2, which was led by Kory Soukup of Altair Engineering and Darren Guillory of SSIUSA. Five (5) people attended representing but not limited to HII, Genoa Design International, and Halter Marine.



IMPLEMENTATION

The results of the LiftShip 2 project are immediately available from any shipyard, engineering / naval architecture and / or design form. The software supporting LiftShip 2 is immediately available from the three (3) software vendors; ShipConstructor Software USA, ATA Engineering, and Altair Engineering. ShipConstructor has already included all the results and functionality of this project in their latest public software release (2022R2.0) and the same is true of Altair Engineering with HyperWorks and ATA Engineering supporting Femap.

The current project participants using LiftShip 2 are Ship Architects Inc., and Genoa Design International, Ltd. Huntington Ingalls Industries, Ingalls Division, stated they will continue their evaluation of LiftShip 2. Austal USA and Bollinger Shipyards are expected to use LiftShip 2.