National Shipbuilding Research Program

Project Final Report

Milestone 11

LiftShip 3

TASK ORDER AGREEMENT #2019-483-010

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19 MAY 2025

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1.0 Background

1.1 Synopsis

The LiftShip 3 project seeks to increase efficiency and further improve usability of the LiftShip 2 [2018-451] Research Announcement (RA) project. This project will provide the user with increases in technical functionality of data sourced from the 3D model and provide seamless digital transfer between the 3D model and finite element analysis (FEA) software. The additional functionality this project proposes is directly from the ECB LiftShip 2 project shipyards and is fully supported by the LiftShip 2 team. This project will provide a means to transfer changes made by the analyst to the Finite Element Model (FEM) in a graphical representation to the 3D design model.

1.2 The Problem

Lifting large-scale ship structures currently requires either engineers with specialized knowledge of hand-calculating anticipated forces through a simplified model or FEA analysts to re-create the ship structures as FEA-specific models to run an analysis against it. Both options are not an ideal solution with modern computing capabilities and software.

Hand calculations by nature require increasing simplifications of the actual model as the complexity grows. These simplifications may not represent the best state of the stresses flowing through the model during a lifting operation and may miss important areas of stress concentrations on geometry. This in turn can lead to unexpected deformations in the structure during and after the lift, or in the worst-case scenario a catastrophic failure of the lifting operation.

To address the issues of manual calculations an analyst can use FEA software to calculate the stresses in much finer detail. This requires an FEA model to be built for input to the computational solver. Historically this model would need to be built from scratch by the analyst to match the structure as designed. This is extremely time-consuming and possibly error-prone, as the analyst is basically re-creating the design model in the FEA system. Unfortunately, due to these time constraints, a full FEA model may not be created for most lifts in the shipyard and might only be conducted for extremely large lifts. This misses the opportunity to avoid deformation or failure problems with these lifts (i.e., smaller lifts would be done based purely on hand calculations or engineering judgment where deformations requiring expensive re-work may occur even without a failure of the lift arrangement).

In addition to the problems with calculating expected results from a lift scenario, there wasn't an easy means to leverage the existing design model for detailing how the lift should be constructed in production. When an arrangement is determined there were no standard drawing packages created from the design model to communicate the required equipment and their orientation for conducting the lift.

In summary, the prior state of manual calculations or manual re-modeling was both time-consuming and error prone. As a result, the use of FEA for verification of a lift configuration was usually reserved for especially large or concerning lift scenarios and missed the opportunity to reduce deformation and failures for many common shipyard lifting configurations.

The prior LiftShip and LiftShip 2 projects worked to address the needs noted above by supporting automation of the creation of an FEA model directly from the 3D product model for two FEA software solutions used in the US shipbuilding industry (Siemens Femap and Altair HyperWorks). To enable this automation of FEA model creation, the scope of the initial project included adding functionality to ShipConstructor to 1) extend the functionality of the ShipConstructor product design environment to support generating "Lift Arrangement" output drawings detailing lifting configurations, and 2) support the creation and re-use of lifting components (pad-eyes, spreader beams, etc.). Including listing them as items on Bills of Material (BOMs). The second project added further functionality in response to end user comments at the conclusion of the first project. The improvements included support of turning operations for complex lifts, visual reporting of FEA analysis results, and the ability for users to adjust the level of detail as needed.

The two prior projects improved the status quo and enabled significant cost avoidance for performing the FEA analyses. Nevertheless, the process of modifying the 3D detail design production model in response to deficiencies found in the FEA analysis was not automated. The structural engineers and designers are still required to review the analysis results and make manual changes to the model.

1.3 The Solution

The current project seeks to provide users with improved technical functionality of data from the 3D model and provide additional seamless digital data transfer to and from the 3D model as well as to and from the FEA software. This project will provide a means to transfer changes made by the analyst within the FEM into a graphical representation to the 3D design model. This will support the capability to push changes made to the FEA mesh model back into the 3D detail design production model so the structural designer can easily incorporate the change into the model. This improved functionality will support model changes due to lifting arrangements to be worked in line with the base construction efforts. Backup structure for lifts could be built into the original structure and could remain in the vessel following the lift with distributed systems routing around it rather than the backup structure hindering distributed system installation in an efficient manner such as on a jig.

The proposed solution would require the FEA software to collaborate with SSI to define a common data model to manage the structural changes, and padeye and/or chaffing guard relocations performed during FEA. An efficient mechanism would need to be built to communicate those changes back to the ShipConstructor model.

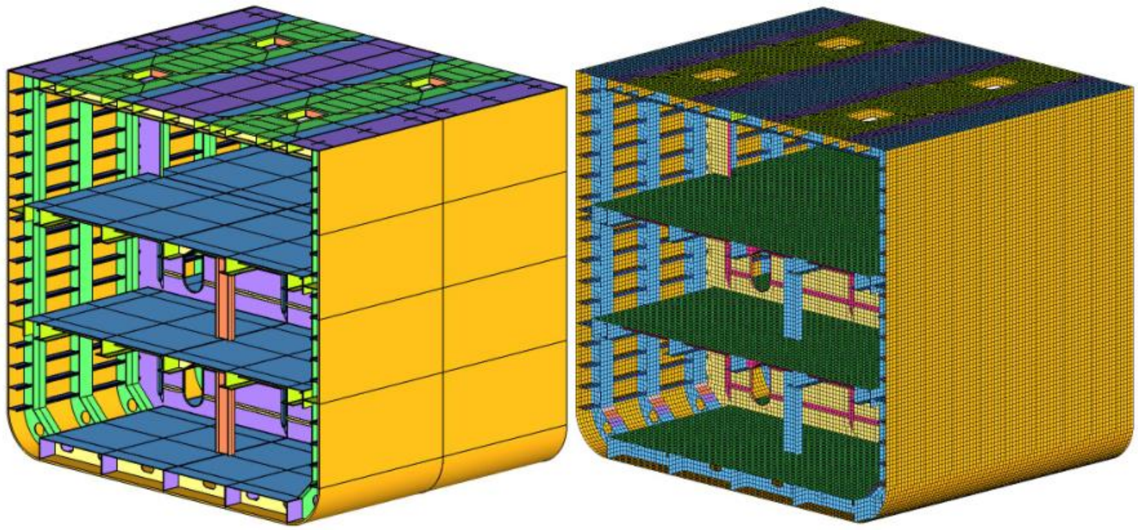

Figure 1: Production design model (left) to FEA model (right)

2.0 APPROACH

The two main approaches to realizing a solution to this problem focused on related and parallel requirements: extending functionality in ShipConstructor to receive the proposed changes to structure and the proper data exchange between the FEA software systems and the product model. There is a distinct separation available between the extended functionality and the data exchange that allowed for parallel and rapid development. That said, the development effort was preceded by soliciting feedback and requirements from the end-users (shipyards and design agents).

2.1 SOFTWARE REQUIREMENTS

The project team held a LiftShip 3 workshop on 30 and 31 August 2023. The first day of the project included a tour of the Austal USA production facilities, which helped frame the issues with shipyard lifts and turns. This was followed by a discussion with team members to determine end user requirements for the project. The project team split into two groups on the second day. The shipyards and design agents received hands-on training on the LiftShip 2 process. Meanwhile, based on the findings from that discussion, the software vendors met to devise methods to address the objectives of the project and to define necessary data exchanges. The full project team came back together, and the shipyards and design agents were briefed on the output of the software vendor discussion and had an opportunity to comment. The output of the software vendor discussions is captured graphically in the flow chart shown in Figure 2 below. The primary data exchanges between the software systems are indicated in the flow chart with yellow shaded boxes.

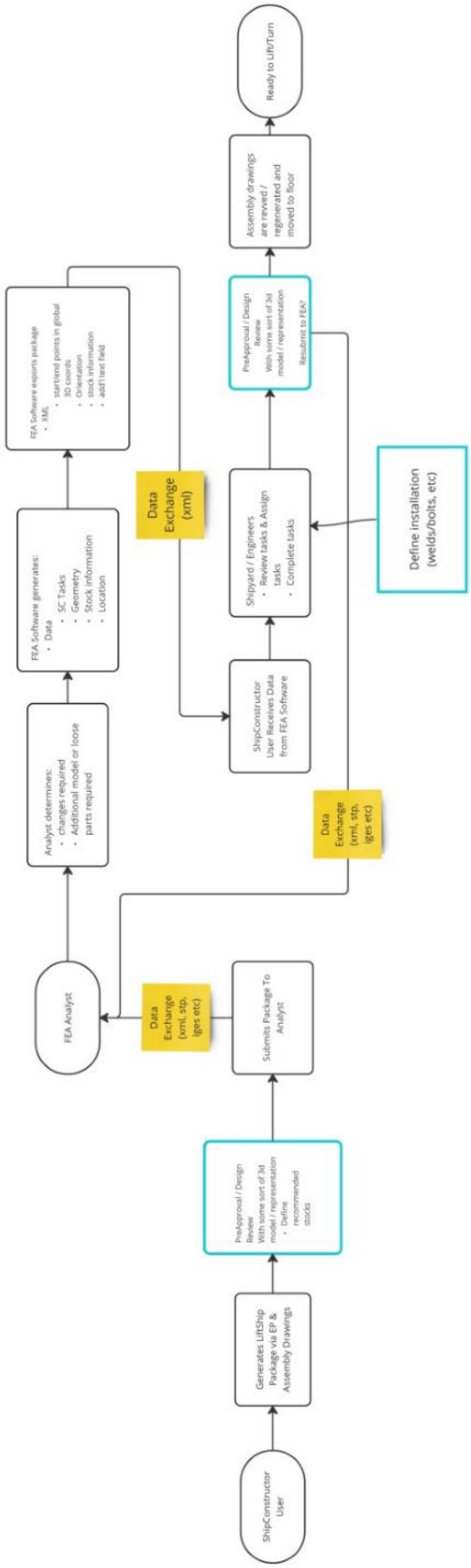

Figure 2. Flowchart of the Proposed LiftShip 3 Process

Based on the data exchange definitions, each software vendor began to develop the code required to support said data exchanges. This effort was supported by bi-weekly technical team (i.e., software vendor) meetings and monthly full project team meetings to ensure that the software development stayed on track.

2.2 Extending ShipConstructor

In the prior two LiftShip projects, a major focus for ShipConstructor was to export relevant structural data from the design tool to the FEA software systems. However, to support this project's objective, it was necessary to develop software that would import the results of the FEA and any resultant changes to structural elements back into the design tool.

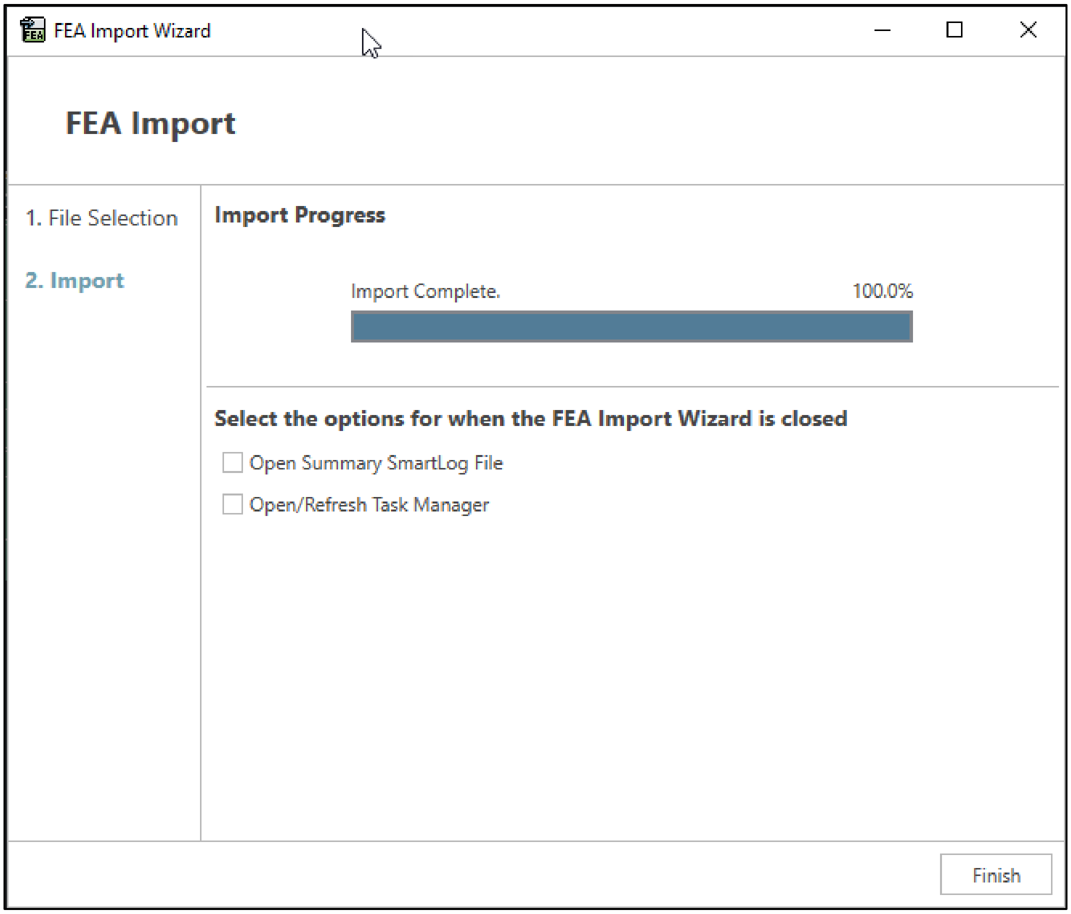

Figure 3. ShipConstructor FEA Import Dialog

SSI began by determining the parameters for the data exported from the FEA software. SSI chose to structure the extensible markup language (XML) data import in a similar fashion to the Genesis application protocol interface (API) which is a pattern familiar to the ShipConstructor development team.

Using Unit 201 of the SSI Training Project (a commercial ship design), SSI created an example set of support structures that would simulate the output that might be generated by a finite element analyst in FEM software. The geometry and metadata of these parts were used to generate an example of the XML that we could expect from the output from either ATA or Altair. SSI used internal tooling to allow quick comparison of object fidelity between the lifting structures and the original 3-dimensional product model.

The SSI team held some internal discussions regarding whether an end-to-end dry run testing effort would be necessary to validate the newly developed software capability. Ultimately, the SSI team decided not to pursue this approach.

SSI typically issues multiple software releases in a year. After testing, the LiftShip 3 software capability was incorporated into one of the scheduled software releases.

After the applicable software release was issued, SSI sought to distribute that software release (along with the latest version of the software developed by ATA and Altair) to the project team members to enable end user testing of the software solution. The software was distributed early in Phase 2. SSI, ATA, and Altair developed and distributed user surveys to gather feedback on how well the tools were working and on how they could be improved. There were some responses from project team members, but none of the comments were considered major issues that required significant revisions to the software systems. Project team members were also given the opportunity to test the software on laboratory computers at SSI's office during the final project workshop in April 2025. Any new comments regarding software functionality from the workshop will be referred to the software vendors for post-project incorporation.

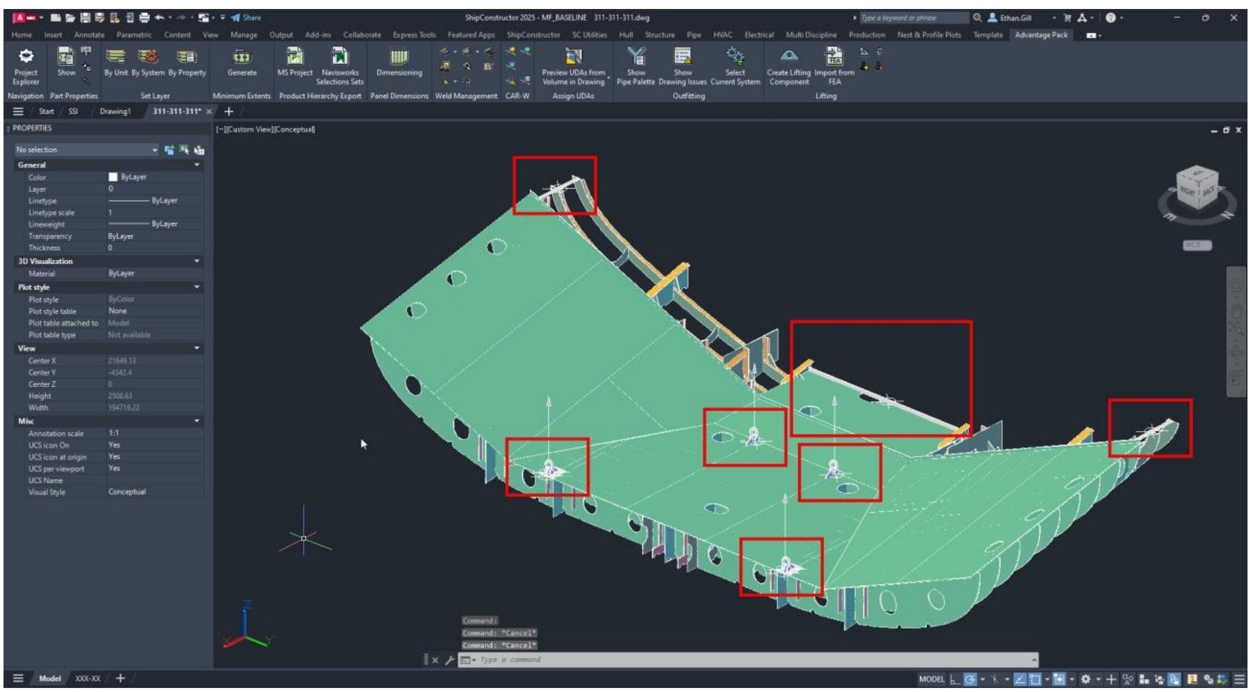

Figure 4. ShipConstructor assembly drawing with imported lifting components

2.3 EXTENDING FEMAP

ATA Engineering developed the Support Structure Export tool to export the FEA results and any resultant structural changes back to the product model. This tool uses a stock parts library imported from ShipConstructor to define the parts options available to the FEA analyst as they make any changes to the FEA model.

The Support Structure Export tool development was largely completed during Phase 1. The tool functions as follows:

1. The user selects a stock library exported from ShipConstructor, and the tool populates the main graphical user interface (GUI) window with a list of the available plate and extrusion stocks (shown in Figure 3 below).

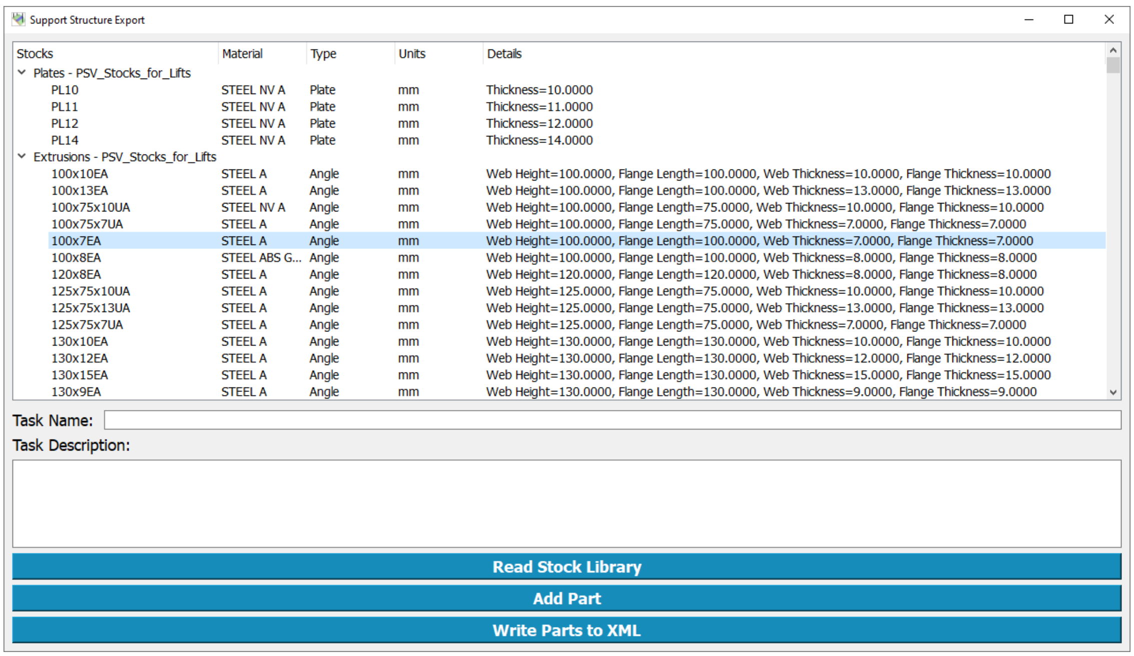

Figure 5. Support Structure Export GUI showing example stock library

2. The user selects a stock from the list and clicks "Add Part" to create material and physical properties in Femap.
3. The user creates new structures in Femap using the newly created properties.
4. Steps 2 and 3 are repeated until the user has finished adding new parts.
5. The user adds a task name and description in the main GUI window, if desired.
6. The user clicks "Write Parts to XML," and the Check Parts for Export window opens, displaying a list of new parts as shown in Figure 4 below. The user checks that the information presented matches their expectations and adds notes to each part if necessary.

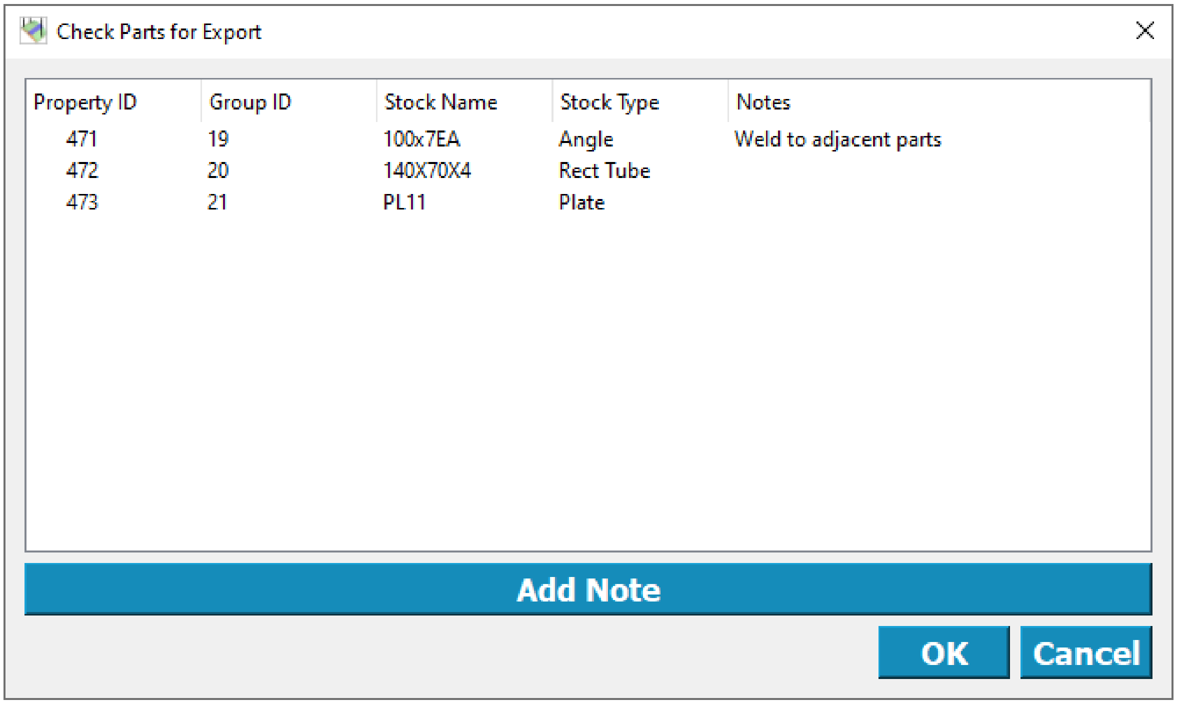

Figure 6. Check Parts for Export Window

7. The user clicks "OK," and the new part information is written to an .xml file. This file will be imported into ShipConstructor.

The Support Structure Export tool has the capability to handle multiple new parts assigned to the same physical property in Femap. Users can assign as many new parts as they wish to a single property. The software identifies individual parts from the existence of free edges on groups of elements.

The Support Structure Export tool also includes model unit checks to confirm that the stock library units are compatible with the existing Femap model units. Femap itself does not track model units, but the Femap Model Generator (FMG) extracts unit information from the ShipConstructor database it is translating and stores the information in Femap, and the Support Structure Export tool compares that information to the part and material units in the user-imported stock libraries to ensure consistency.

ATA has performed internal beta testing of the new tool and also exchanged files with SSI to confirm that the exported .xml file is compatible with the new ShipConstructor functionality.

In addition to these efforts, ATA implemented several upgrades to the FMG tool. The first upgrade improves the importing of curved plates (hull plates). Previous versions of the FMG had difficulty handling curved plates due to incompatibility between the ShipConstructor representation of the curved plates and Femap's geometry handling capabilities. The FMG has been upgraded to take advantage of the geometry tools available in the latest release of Femap, and testing shows a significant improvement in curved surface representation.

ATA also enhanced the FMG to translate information about planks from ShipConstructor databases into Femap. Plank parts are more complex than plates or extrusions; typically, they look like a combination of plates and extrusions. The ShipConstructor database does not include as much construction information about them as about plates or extrusions, however, so it is not possible to recreate them from scratch in Femap (which is the usual method of geometry creation). Instead, the planks are now exported as STEP (Standard for the Exchange of Product model data) files from ShipConstructor, imported to Femap, and automatically midsurfaced. The FMG then moves them to sit on the part moldline, and the part name and physical properties are automatically assigned. Figure 5 below shows two planks translated into Femap from SSI’s “Complex Structure” model.

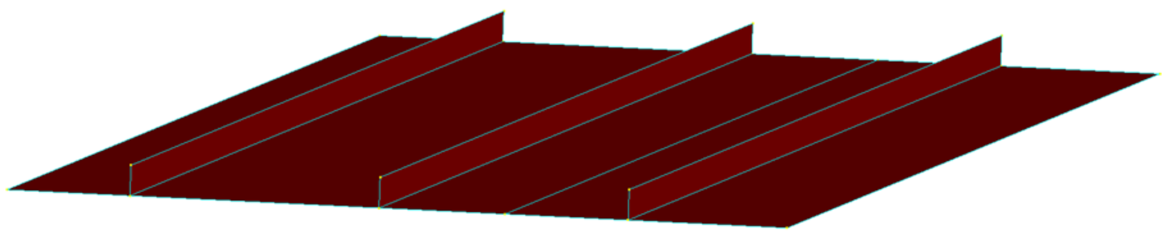

Figure 7. Translated planks in Femap (from the SSI "Complex Structure" model)

2.4 Extending HyperWorks

Altair also needed to implement a stock parts catalog into Hypermesh-Liftship to support the project requirements. A particular focus of the Altair development effort was on incorporating bulb flat stiffeners as acceptable parts for the structural model. These are used primarily on commercial ship types as an alternate to tees or angles, and Unit 201 of the SSI Training Project includes some of these stiffeners. Altair also worked on their methodology for creation of support structure elements and definition of thickness metadata. There was also a need to work with the SSI technical team and to enhance the HyperMesh CAD reader to address changes that SSI has incorporated to their file structure and associated metadata.

Altair also worked to update user documentation as needed to reflect the enhancements to their software as they relate to project outputs.

LiftShip3 provided additional seamless digital data transfer to and from the 3D model as well as to and from HyperMesh. This phase enabled means to transfer changes made by the analyst within the Finite Element Model (FEM) in a graphical representation to the 3D design model.

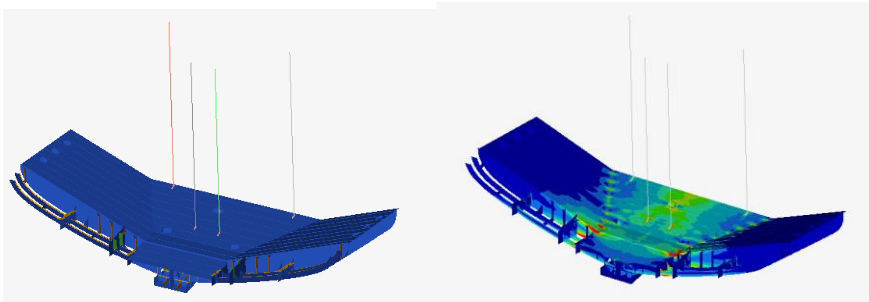

Figure 8. FE model and FE results in HyperMesh

TECHNICAL UPDATES IN DETAIL:

Enhancements to HyperMesh-ShipConstructor data exchange:

Altair collaborated with SSI in developing a mechanism to seamlessly transfer stocks metadata (plates & extrusions) from ShipConstructor to HyperMesh.

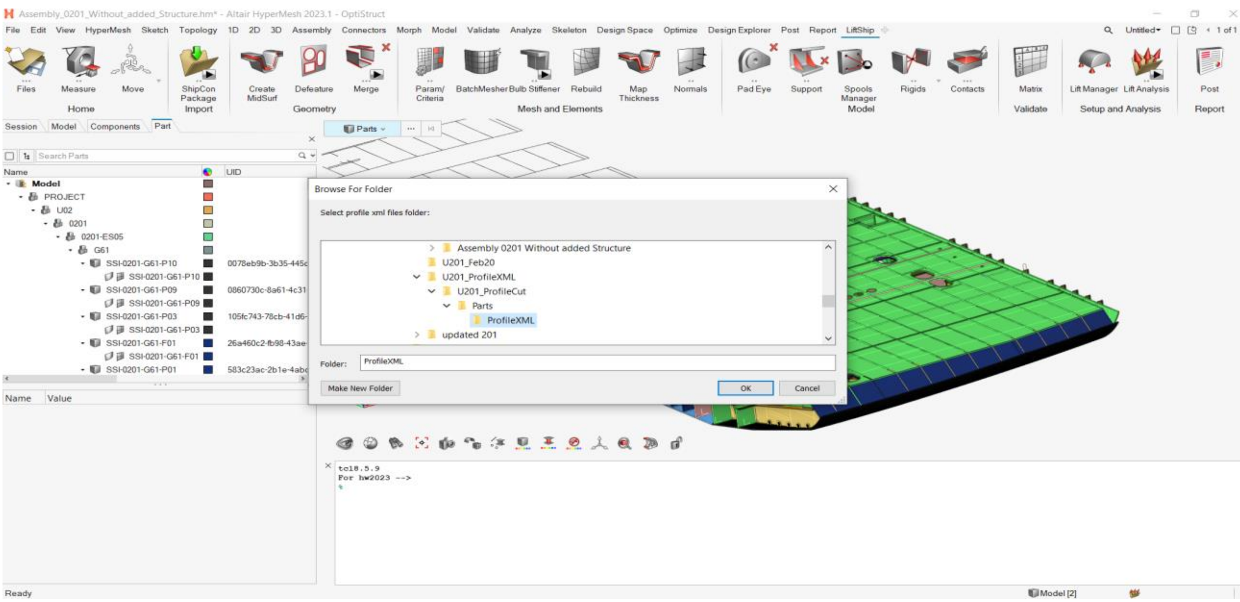

Figure 9. HyperMesh LiftShip Interface

```xml
<ProfileStocks>
  <ProfileStock StockName="FB 100x10">
    <ProfileType>FlatBar</ProfileType>
    <SpecializedType>None</SpecializedType>
    <StockDescription />
    <MaterialGrade>Steel Gr. A</MaterialGrade>
    <WebHeight>100</WebHeight>
    <WebThickness>10</WebThickness>
    <FlangeLength>0</FlangeLength>
    <FlangeThickness>0</FlangeThickness>
    <FilletCornerRadius>0</FilletCornerRadius>
  </ProfileStock>
</ProfileStocks>
```

Figure 10. Stocks XML Metadata

Altair developed a parser to parse an XML file containing stocks metadata, exported from ShipConstructor.

In LiftShip3, new stiffener cross sections were supported as part of the data exchange between ShipConstructor and HyperMesh. FEA workflow was updated to convert these new cross sections to meaningful FE entities such as element types and properties.

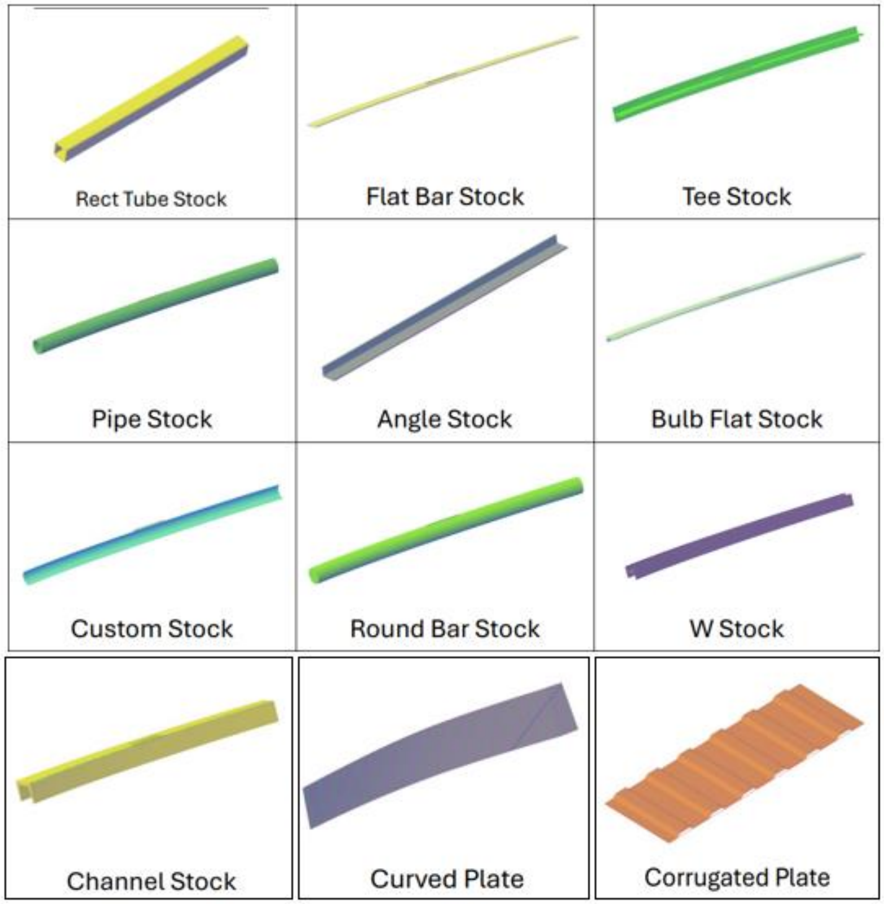

Figure 11. Stocks Stiffener Profiles Supported

FEM modifications imported back into 3D Design Model

Altair developed an interface to populate supporting structure metadata and allow users to create supporting structure as part of FEA set up.

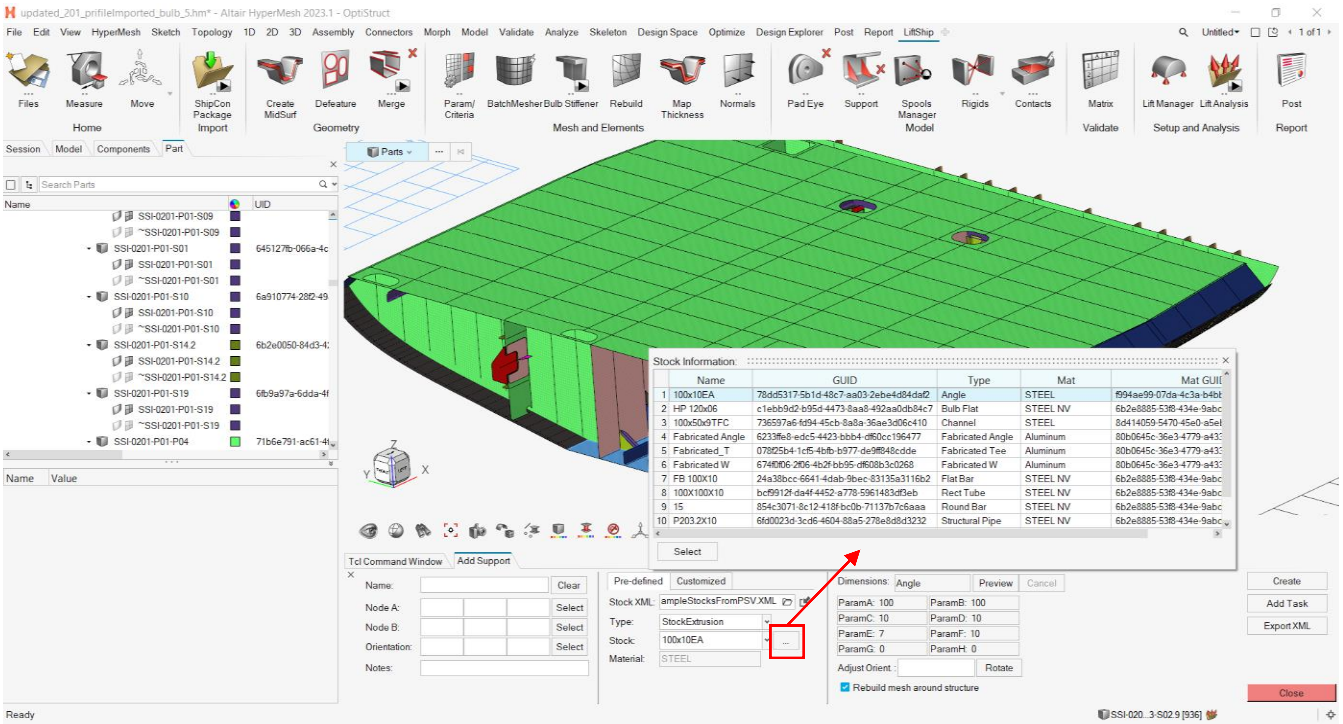

Figure 12. Interface to Manage Support Structures

Altair developed an export mechanism to export supporting structure from HyperWorks, in a file format that ShipConstructor can import back.


```xml
<?xml version="1.0" encoding="utf-8"?>
<LiftingComponents xmlns:xds="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Plates/>
  <Extrusions>
    <Extrusion>
      <StockID>2aecb98a-5006-479f-817e-27df2bf754dd</StockID>
      <ConnectedParts/>
      <Notes>Note1</Notes>
      <WebVector>
        <X>-0.001550</X>
        <Y>-0.046472</Y>
        <Z>-0.998918</Z>
      </WebVector>
      <FlangeVector>
        <X>-0.999997</X>
        <Y>0.001965</Y>
        <Z>0.001460</Z>
      </FlangeVector>
      <MoldLine>
        <Point3D>
          <X>27917.267402</X>
          <Y>748.226735</Y>
          <Z>827.033161</Z>
        </Point3D>
        <Point3D>
          <X>27914.436402</X>
          <Y>-743.773265</Y>
          <Z>896.449161</Z>
        </Point3D>
      </MoldLine>
    </Extrusion>
  </Extrusions>
  <ShipConstructorTasks>
    <ShipConstructorTask>
      <Name>Task1</Name>
      <Description>ffggg</Description>
    </ShipConstructorTask>
  </ShipConstructorTasks>
</LiftingComponents>
```


Figure 13. Supporting Structure Data Exchange Format

Improved methodology for bulb stiffener modeling:

Altair made improvements to the way bulb stiffeners were converted to FE elements in HyperMesh.

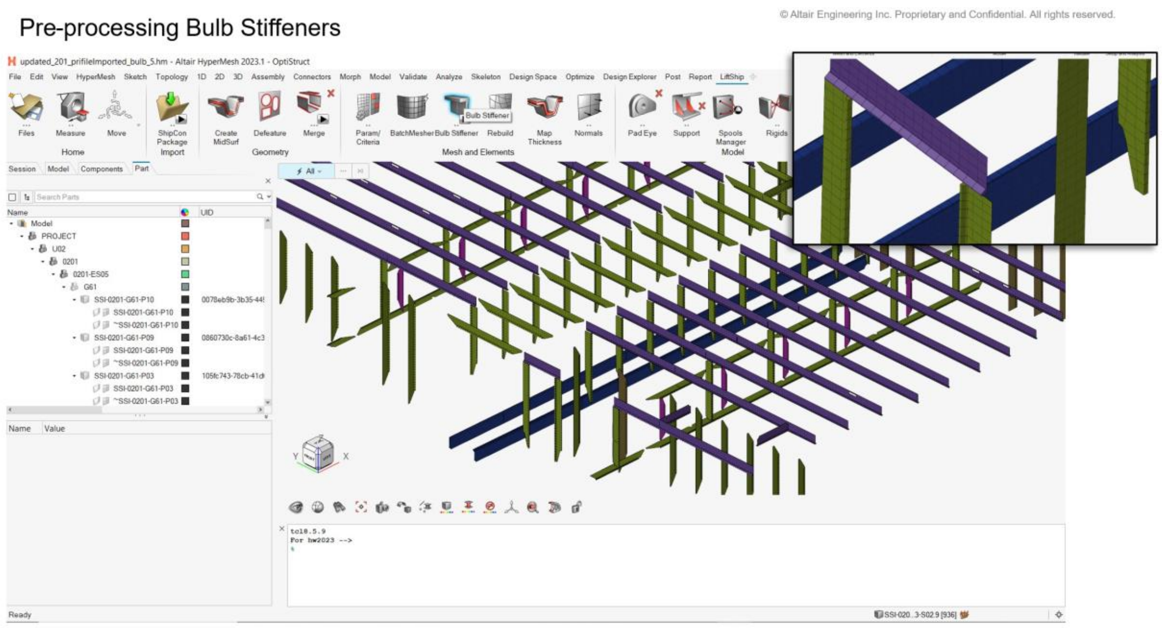

Figure 14. Bulb Stiffeners in HyperMesh

Altair implemented the midsurface creation for the stiffeners with twisted profile: W, Bulb, Angle, Channel. They also improved package importing, midsurface creation and the bulb (straight) processing.

Altair upgraded the toolbox to HyperWorks 2024.1 to make use of improved mid surfacing functions, meshing and analysis set up tools.

2.5 Technology Transfer

The project team had several opportunities for external technology transfer during the period of performance. Most of these were opportunities to provide a project status update at NSRP Panel meetings.

The project team gave a presentation at the Business Technologies (BT) and Ship Design and Material Technologies (SDMT) Joint Panel meeting in Suffolk, VA from 30 April to 2 May 2024. The team also delivered a project update briefing at the BT and SDMT Joint Panel meeting in North Vancouver, BC from 20 to 22 August 2024. The project team gave a final status briefing at the BT Panel breakout session of the NSRP All Panel Meeting in Charleston, SC from 25 to 27 February 2025. The presentations noted above are all available for download from the NSRP website and are not incorporated in this report.

SSI gave both a presentation and a workshop for interested users on this project at the SSI World Shipbuilding Conference 2024 – Americas from 24 to 26 September 2024 in Biloxi, MS.

The project team held a final project workshop from 9 to 10 April 2025 at the SSI office in Mobile, AL. A virtual option was available for portions of the workshop (morning of day 1 and wrap-up session after lunch on day 2). The morning of day 1 included overviews of the LiftShip process by SSI, ATA, and Altair with respect to the use of their software to execute the overall process. The afternoon of day 1 and the morning of day 2 included a hands-on workshop for in-person participants to exercise the software on laboratory computers. Representatives of SSI, ATA, and Altair were available to coach those working with the software and resolve any user issues.

3.0 Results

The project team was able to develop software to support the semi-automated import of new structural components resulting from the FEA back into the ShipConstructor product model.

3.1 Metrics/Benefit Realization

In the initial project proposal and Statement of Work, the Benefits realization table had four major sections that were anticipated as a benefit for shipyards. However, only one of those major sections corresponded to the scope of work that was ultimately approved by the NSRP Executive Control Board. That section had to do with synchronization of FEA changes to lift components and backup structure back to ShipConstructor. There was no baseline ability to perform said synchronization, and the project team has developed the necessary data exchanges to synchronize the FEA changes back to the product model.

We anticipated that we would take the existing Technology Readiness Level (TRL) from 5 (*Component and/or breadboard validation*) to 7 (*System prototype demonstration in an operational environment*). The project team has exceeded the expected increase of the TRL from 5 to 7. The testing and evaluation of the software solution both prior to and during the final workshop provides a basis for elevating the final TRL to at least 8 (*Actual system completed and qualified through test and demonstration*).

3.2 Objective

The project objective as stated in the Statement of Work is to provide an efficient means to push changes made to the FEA mesh model back into the 3D detail design production model so the structural designer can easily incorporate the change into the model.

The project team has successfully met that objective. Each of the FEA software packages used in the project can add structural parts found in a ShipConstructor parts library to add local reinforcement and eliminate structural deficiencies. Each software package can also export the resultant parts back to ShipConstructor, and ShipConstructor users can recognize the changes and easily incorporate them into the product model.

3.3 Implementation

The benefit of continuing to synthesize multiple software systems together for this project is that each of the systems were already available to shipyards as Commercial, Off-The-

Shelf (COTS) software. In the case of ShipConstructor, the results of this project have already been integrated into the latest public release of the software. Any users who update their ShipConstructor systems to the latest version (2025 R2.1) will be able to get the functionality developed in this project. The functionality will continue to be supported by SSI in the future and will be included with future versions of the software. Altair and ATA are finalizing software patches to complete their inclusion of the functionality.

These software systems are already in use in multiple US shipyards and design agents, but each of those companies has their timetable for testing and implementation of new software releases. The results of this project are pushed to the publicly available software systems and ready for use upon adoption of the applicable software releases by the end users.

4.0 ADDENDUM

4.1 SHIPYARD QUESTIONNAIRES

The questionnaires shown below were developed by the software providers on the project team to seek end user feedback on the software solution.

4.1.1 SSI Questionnaire

General

1. **Identification**
   a. Name: ____
   b. Title: ____
   c. Shipyard/Engineering Firm: ____

2. **Training and Workflow**
   a. How well did the training material meet your needs?
   ____
   ____
   b. How could the training material be improved?
   ____
   ____
   c. Training workflow
      i. Did the workflow divert from your shipyard's standard operating procedure?
      ____
      ii. If so, how?
      ____
      ____
      ____
      iii. How could the workflow be improved?
      ____

3. **ShipConstructor and the FEA partners currently support structural elements in conjunction with lifting components.** Which of the following additional part types would you like to see supported? Place a number beside the desired part types from highest (1) to lowest (4).

   a. HVAC _____
   b. Pipe _____
   c. Electrical ____
   d. Equipment _____

4. **In addition to the assembly drawing, what other artifacts (data) are you providing to the lift and turn engineer (or other personnel conducting the lift and turn)?**

   a. Weight Studies - What format?
   ____
   b. Other ____________________

5. **Support**

a. Did you have any issues during the process? ____________________________
b. If so, what were the issues?
____
____
c. Were the issues adequately addressed? _________________________________
d. If not, provide details:
____
____

6. **How did you retrieve support?**
a. KB ____
b. SSI USA / Canada Contact via Teams ____________________________________
c. Were you satisfied with the support? _____________________________________
d. If not, provide details:
____
____
______

7. **Are there any additional properties on the lifting component required?**
a. If so, what are those properties?
____

8. **Did you make use of the post-import log file?** ____
a. Did it have the information you needed? ____
b. If not, what was missing?
____
____

9. **Can you provide any other thoughts/comments/concerns/requirements?**

____
____
____
____
____

4.1.2 ATA Questionnaire

LiftShip3: Questions for Shipyards

1. Have you been able to install ATA’s LiftShip Tools for Femap? If not, what issues are you having?

2. Have you used the Femap Model Generator to translate a model from ShipConstructor to Femap?

    a. Does the tool work for your model?

    b. Does the workflow make sense to you?

    c. Do you have any suggestions for enhancements for better functionality and/or a better user experience?

3. Have you used the Lift and Turn Manager to define and analyze a lift?

    a. Does the tool work for your model?

    b. Does the workflow make sense to you?

    c. Do you have any suggestions for enhancements for better functionality and/or a better user experience?

4. Have you used the Support Structure Export tool to export new parts back to ShipConstructor?

    a. Does the tool work for your model?

    b. Does the workflow make sense to you?

    c. Do you have any suggestions for enhancements for better functionality and/or a better user experience?

5. Have you used the other tools? (TrimCurvedPlateIntersections, AutoConnectLumpedMasses, AnimateLift)?

    a. Does the tool work for your model?

    b. Does the workflow make sense to you?

    c. Do you have any suggestions for enhancements for better functionality and/or a better user experience?

6. Have you used the Installation Guide or User Guide?
    a. Do you have any comments or suggestions for improvement?

7. Do you have any additional suggestions, comments or questions about the ATA LiftShip Tools for Femap?

4.1.3 Altair Questionnaire

Altair Questions

1. **How intuitive is the user interface of LiftShip?**
    - Could you identify any specific areas where the interface could be improved?
2. **How well does LiftShip integrate with your existing software and workflows?**
    - Are there any compatibility or integration issues you have encountered?
3. **Have you experienced any performance issues or slowdowns with LiftShip?**
    - If so, could you describe the scenarios or specific operations that cause these issues?
4. **How accurate are the calculations and simulations provided by LiftShip?**
    - Do they meet your requirements for precision in ship lifting and handling tasks?
5. **How useful are the reporting and data output options in LiftShip?**
    - Are there any additional reporting features or data formats you would like to see?
6. **Does LiftShip improve efficiency or reduce the time required for lifting and handling operations?**
    - Can you provide examples of how it has impacted your workflow?
7. **How would you rate the software's ability to identify and address potential safety concerns?**
    - Are there any additional safety-related features or alerts you would recommend?
8. **What kind of training did you need to get started with LiftShip, and was it sufficient?**
    - What additional resources (e.g., tutorials, documentation) would be helpful?
9. **Have you encountered any bugs or technical issues while using LiftShip?**
    - If yes, could you describe them and the frequency with which they occur?
10. **Do you see HM-LS workflow flexible enough to set up other similar analysis?**
    - What new features or improvements would you prioritize for future updates to LiftShip? Are there specific tasks or challenges in ship handling that you wish the software addressed?