Development of the CREATE Integrated Hydrodynamic Design Environment (IHDE)

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16 November 2011

COMNAVSEA Memo: 4 Feb 08 Functionality and Timeliness Objectives

- **Joint Capabilities Integration & Development (JCIDS)**
  - "… capability to generate and analyze hundreds of ship concepts to a rough order of magnitude level within a period of weeks or months"
- **Concept Refinement**
  - "…accurately portray cost versus capability trade-offs, including uncertainty analysis, for dozens of ship concept options within a six-month period of performance"
- **Technology Development**
  - "… completion of a design iteration in 8 to10 weeks, including insight as to changes needed for the next design iteration. Within the time allocated during a design iteration, analysis tools must comprehensively analyze all aspects of a Navy ship design …"
- **Interoperability with LEAPS (product model data repository and software integrator)**
- **Adhere to rigorous VV&A process**

Hydrodynamics: Top Level Objective

- **To accelerate the hydrodynamic aspects of the naval ship design process and decrease the risk at all stages of design, including in the early stages where significant costs are locked in by design decisions.**
  - Resistance, Powering and Stability analysis needed at the earliest stages
  - Maneuvering, Seakeeping and Loads analysis needed at mid stages
  - Confidently address late-stage design issues and design changes to existing classes
  - Complete computational evaluation before any model testing
  - Hydrodynamic shape optimization throughout

Meeting the CREATE Objectives

- Engineered products are requiring more engineering analysis earlier.
- For complex systems, these analysis go beyond ensuring a product won't break. For Navy ships some of the more specialized applications can drive a design at the early stages.
- Getting there requires that engineers are designing and analyzing many designs quickly, with more computational rigor, using results from one tool as input to another where dependencies exist.

Where are the road blocks?

- **In many cases these codes are not executed in a timely and relevant manner because:**
- **It takes too long to:**
  - Find the right information
  - Extract the information needed for a specific application domain
  - Transform the extracted information to the form required for application software
  - Transmit the information in a form usable by those who need it
- **Accuracy issues:**
  - Understand extracted information (complete product knowledge)
  - Transform/transcribe the extracted information correctly

What we need is….

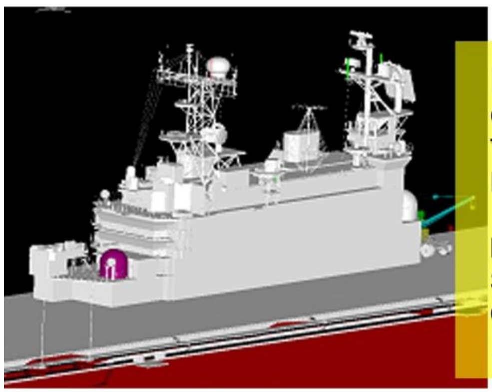
A way we can find the data we need in some "Smart Product Model" environment… where we can quickly and automatically (programmatically) extract the information specific to our tools…. in a form our tools understand… and produce accurate and reliable results that we return to the "Smart Product Model" for sharing with others… or to perform design optimization or set based design studies.

Such an Environment Should…

- Enable
  - ☆ Complete understanding of a product
    - structure
    - components/systems
    - attributes/properties/performance
    - geometric, physical, functional relationships
    - history
  - ☆ Fast extraction/deposit of user-specific information from/to a repository
  - ☆ Fast transformation of extracted information from stored form to that required by applications software

Data Requirements

Design



Requirements
Geometry
Topology
Properties

Materials
Systems
Components
...

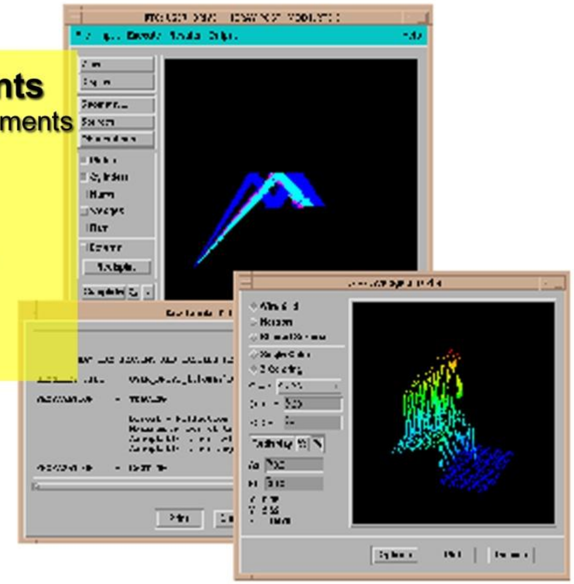
Smart Product Model

?

Requirements
Design Requirements
Plus ...
Scenarios

Performance
Behaviors
Attributes
...

Analysis / M&S



Distribution Statement A

Our Solution is LEAPS

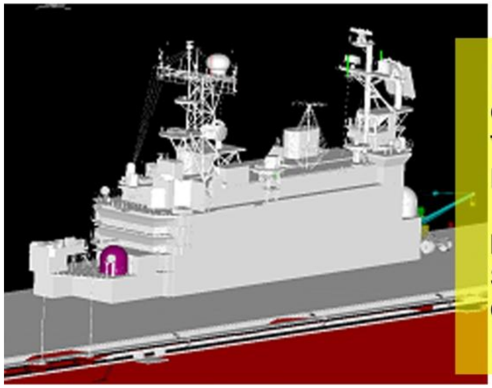
- LEAPS is a software development environment that facilitates modeling, simulating, and analyzing product data
- Provides rich, context-based product information in user-specific views
- LEAPS is data-centric and application independent
- LEAPS is designed to support application integration through formal product object modeling
- LEAPS is not a repository for human digestible content or files

LEAPS Requirements

Design

Smart Product Model

Analysis / M&S



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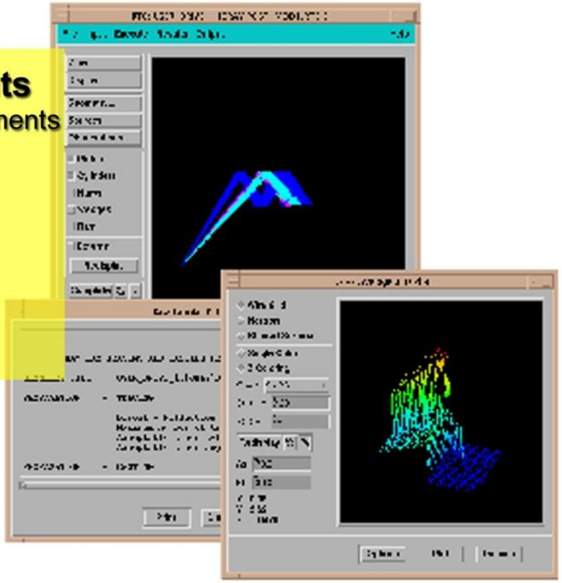
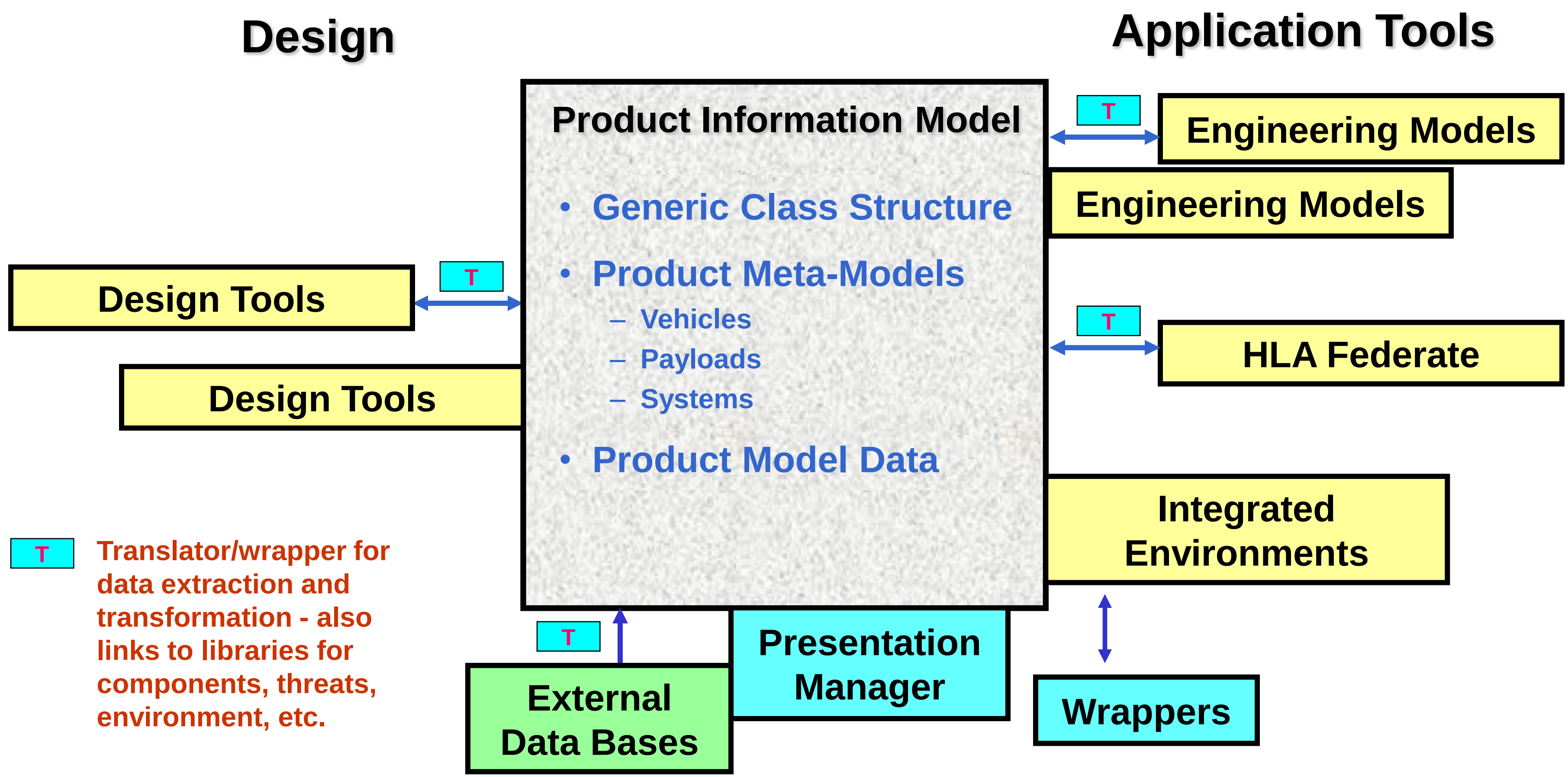


Distribution Statement A

LEAPS "Picture-Architecture"



LEAPS Hydro Activity

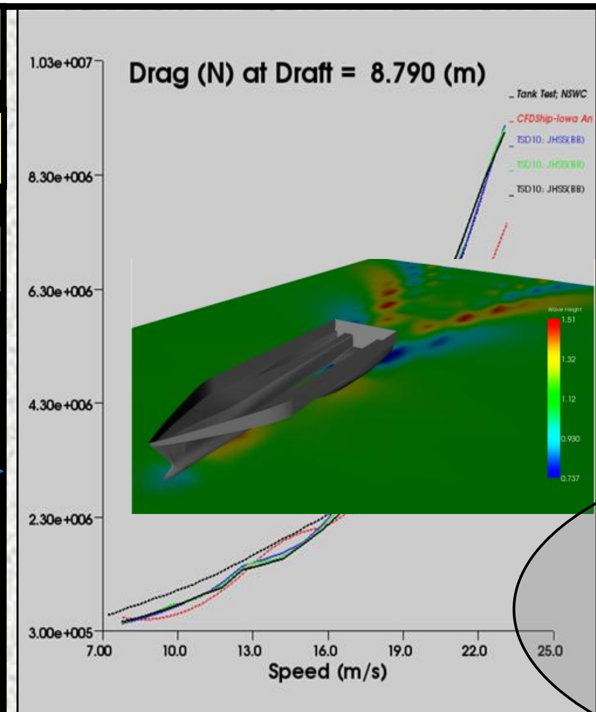
ASSET Surface

ASSET Sub

HullTran

CAD

T



T — Ship Wave Pattern Evaluation (SWPE)

T — Total Ship Drag (TSD)

T — SSF

T — FKS

T — Ship Motions Program (SMP)

T — (VERES)

Integrated Hydrodynamic Design Environment (IHDE)

Ship Motions Program (SMP)

Total Ship Drag (TSD)

FKS

LAMP

Hullform Optimization

Presentation Mgr

LEAPS/Editor

Excel

STEP/IGES

In Development

Beta Code

Existing

Planned

Distribution Statement A

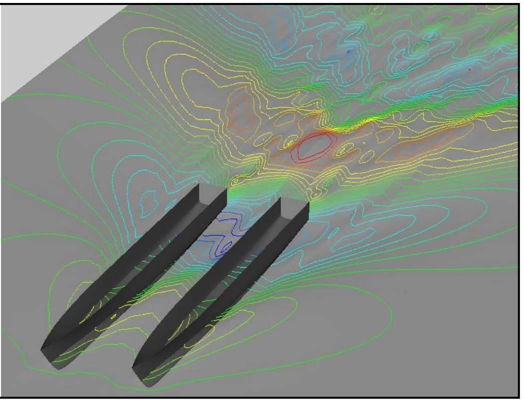
IHDE Product Description

The role of the Integrated Hydrodynamics Design Environment (IHDE) within the CREATE-Ships Project is to give ship designers easy and convenient access to software design-analysis tools to evaluate tradeoffs (often involving thousands of design variables and high performance computers) and make decisions early in the design process, when the impact on future cost is greatest.

IHDE Requirements

- **Functional**
  - Tool Validation
  - Hull Form Design
  - Hull Form Optimization
- **Hydrodynamic Areas**
  - Resistance & Powering
  - Seakeeping
  - Maneuvering
  - Loads
- **Stakeholders**
  - Tool Validator
  - Naval Architect
  - Hydrodynamicists
- **Flow Types**
  - Inviscid
  - RANS
  - LES
  - DNS

Integrated Hydrodynamics Design Environment (IHDE)



RESISTANCE	POWERING	MANEUVERING	LOADS	SEAKEEPING

LOCAL HPC

DESIGN STUDIES/ RESPONSE SURFACES > METAMODELS

SHAPE OPTIMIZATION

AUTOMATED VALIDATION CASES

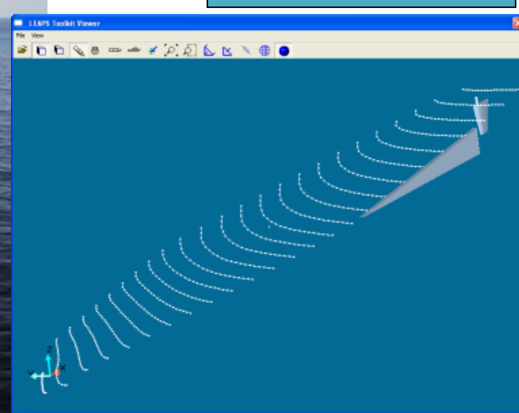
HPCMP

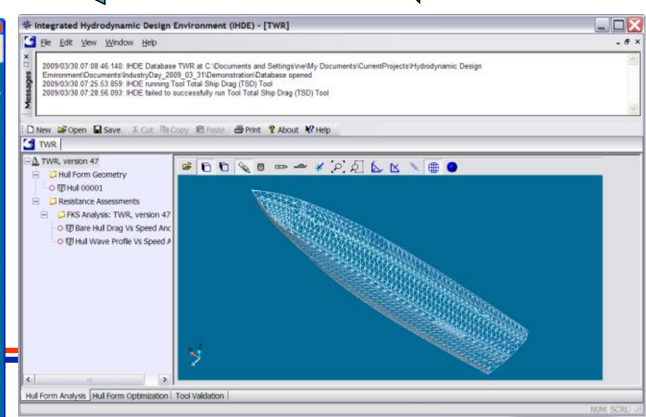
SSF TSD	AEGIR DAS BOOT	SMP VERES	FREDYN TEMPEST	CFDSHIP NEW CODE	LAMP

Problem Set Up	Conditions	Geometry	Automated Gridding

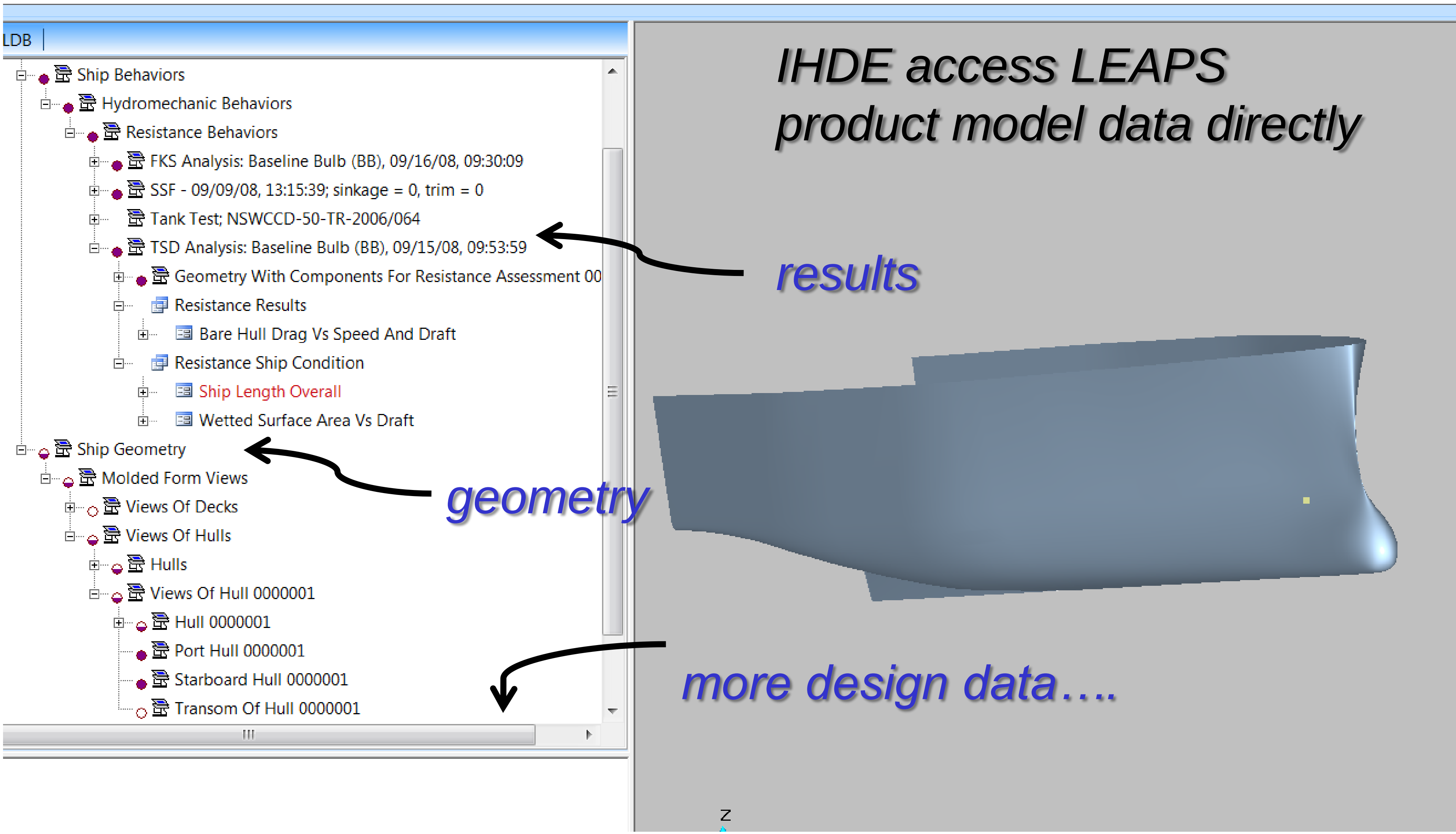
DRIVER/GUI

LEAPS





LEAPS Product Model Data



Distribution Statement A

Current IHDE Capabilities

- **Analysis Tools (IHDE V2.1)**
  - Thin ship theory resistance predictions
    - Fourier-Kochin Slender (FKS)
    - Total Ship Drag (TSD)
  - Multi-hull capability for resistance
  - Seakeeping predictions using Ship Motions Program (SMP)
- **Integrated solution and visualization capabilities**
  - Predicted resistance vs. speed
  - Hull wave profile
  - Free surface wave elevations vs. speed
  - 6-DOF ship responses, absolute motions and accelerations
  - Relative motion response for specified locations on ship
  - Direct comparison inside IHDE to model data or external analysis data
  - Real-time evaluation of input sensitivities

IHDE Requirements

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Hydrodynamic Areas
- Resistance & Powering
- Seakeeping
- Maneuvering
- Loads

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- Tool Validator
- Naval Architect
- Hydrodynamicists

Flow Types
- Inviscid
- RANS
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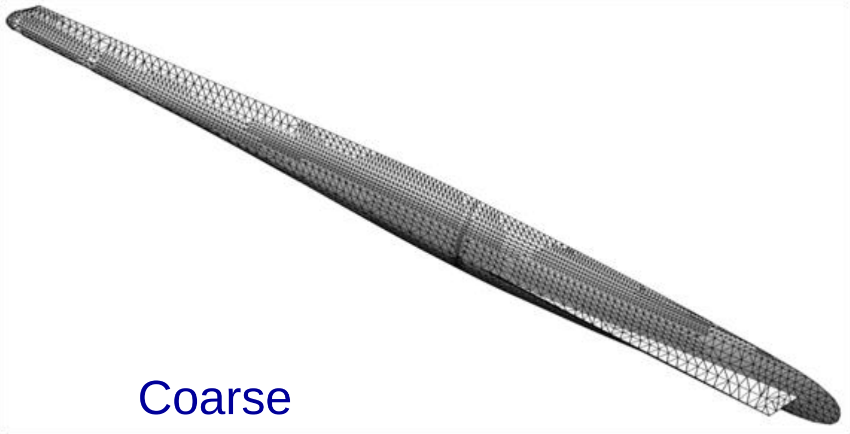
Current Functionality

Version 3.0

IHDE Meshing

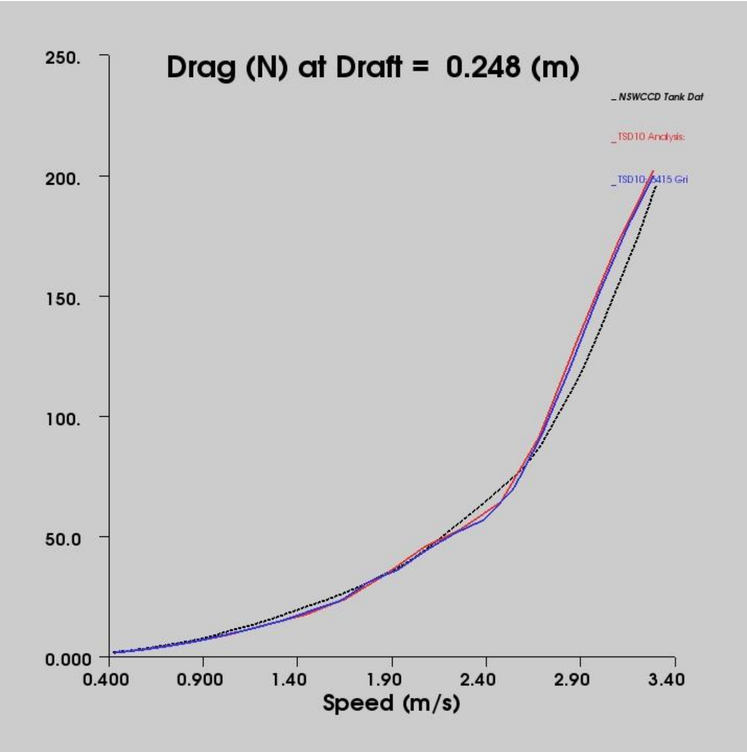
- **Automated Meshing capability**
  - Meshing directly from LEAPS database (NURBS representation)
  - Several options available in IHDE to control mesh density and methodology


Coarse

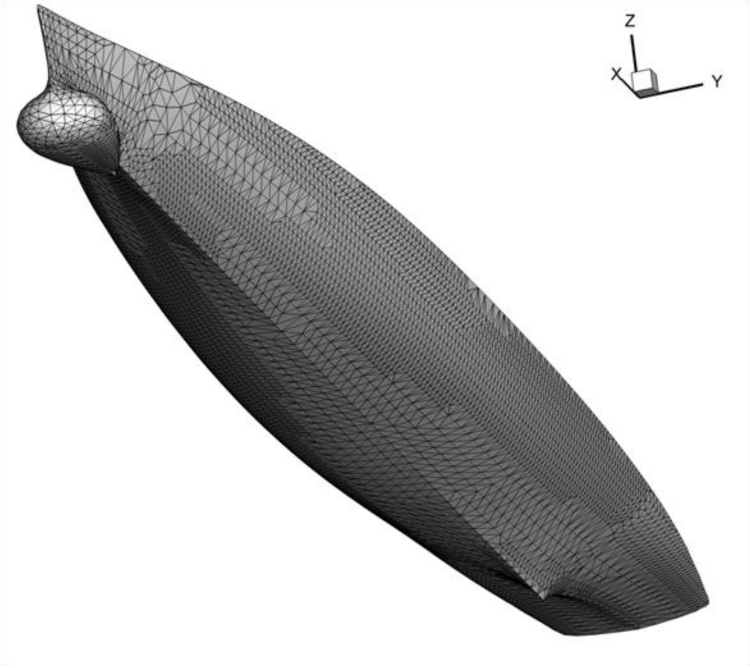

Fine

Significant time savings vs. manual grid generation methods!

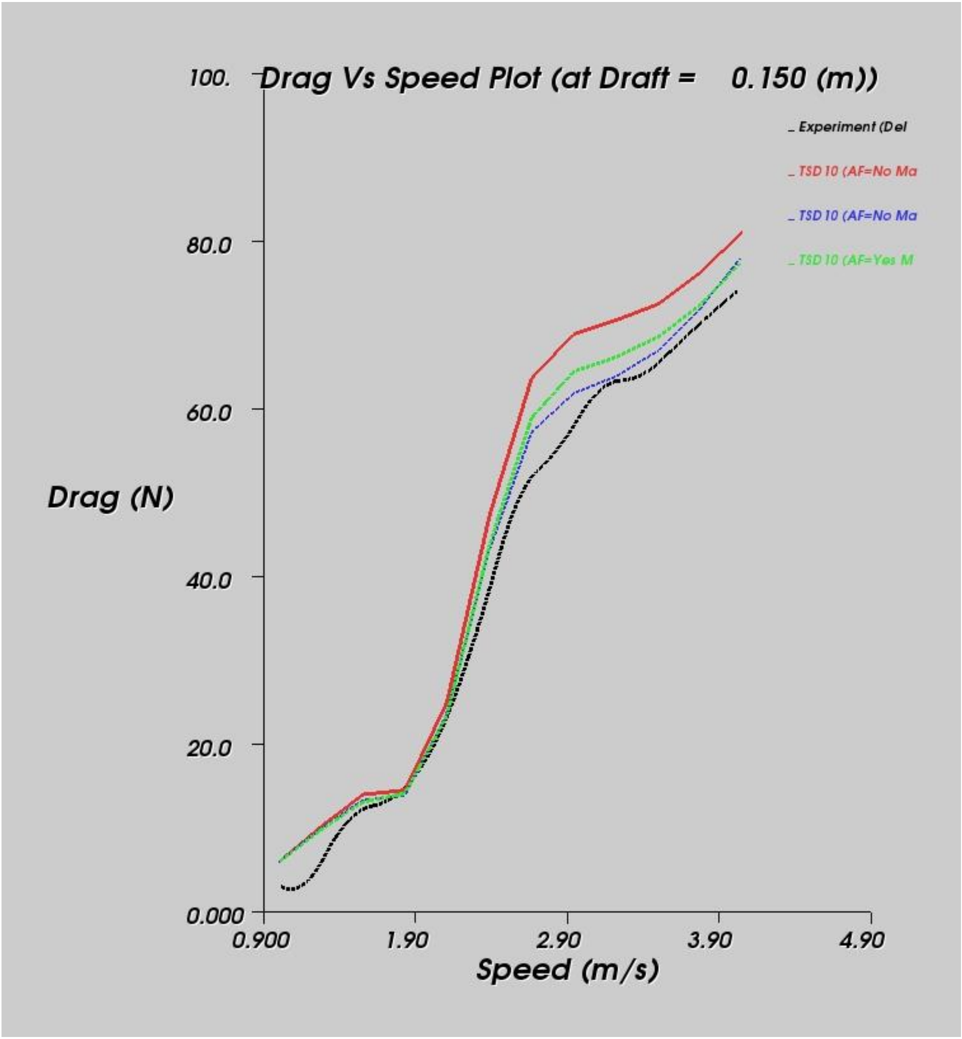
IHDE V2.1 Validation: Model 5415



- **Automated mesh capability does good job resolving high curvature regions like bow dome**



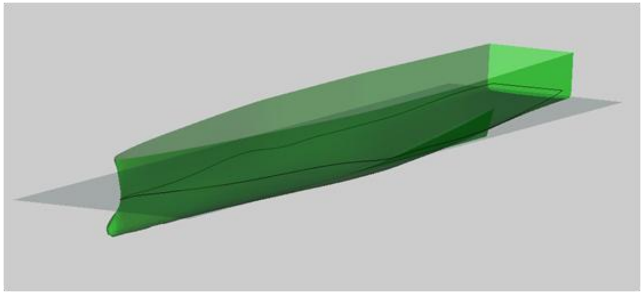
IHDE V2.0 Validation: Delft Catamaran

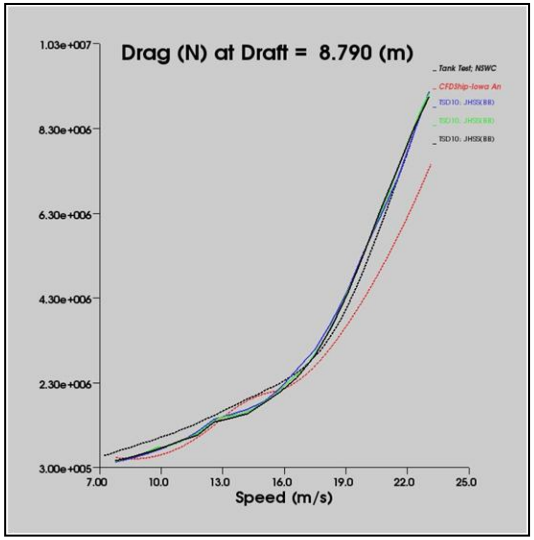


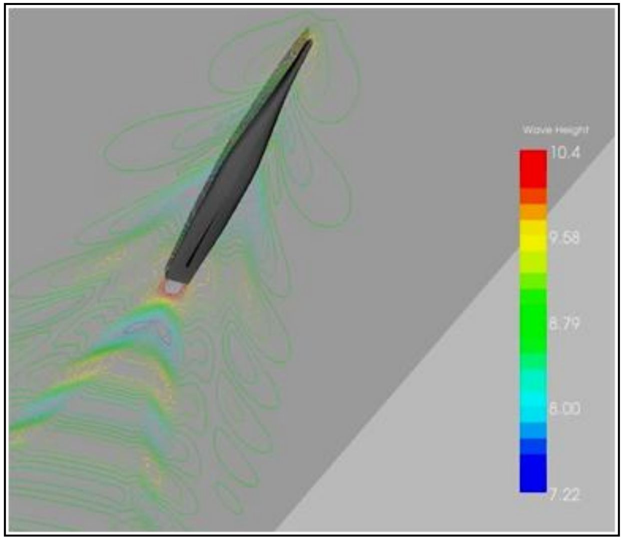
- **IHDE includes two different automated mesh generation methods**
  - Superface
  - Advancing Front
- **Mesh controls**
  - Maximum coincidence angle
  - Maximum aspect ratio
  - Maximum Pcurve length
- **Comparison of results from different meshes and different mesh generation methods provides insight into impact of mesh on accuracy of predicted resistance**

IHDE – Resistance

- **Resistance: Total Ship Drag (TSD)**
  - Thin ship theory
  - Predicted wave drag, friction drag from ITTC (1957)
  - Empirical models for form, transom, spray drag
  - Two different execution modes
    - Mode 1: fast, robust
    - Mode 2: slower, increased accuracy
  - Predicts hull wave profile and free surface wave elevations





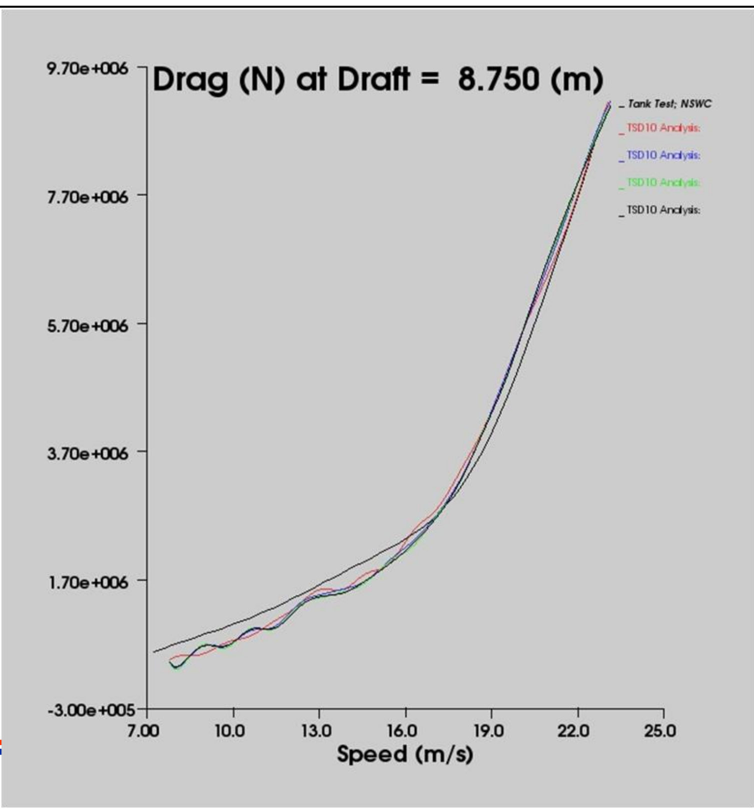


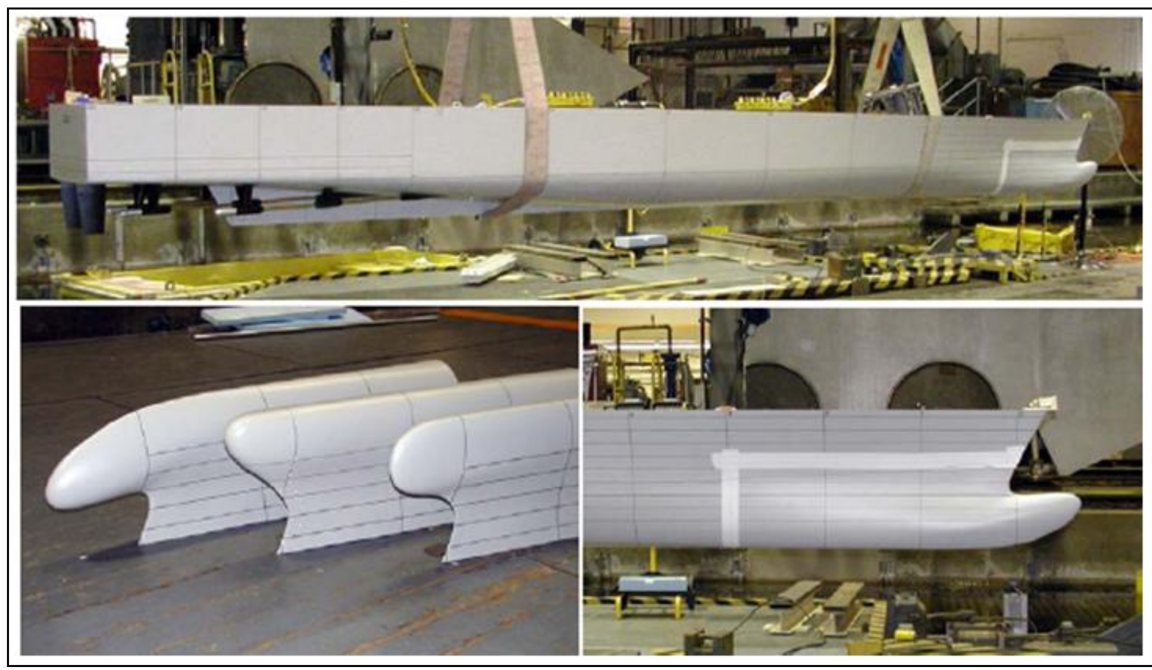
IHDE Validation

- **Verification and validation testing**
  - Joint High Speed Sealift (JHSS) ship concept
  - DTMB Model 5415 (pre-contract DDG 51 hull)
  - Delft Catamaran
- **Comparisons with model test data and results from other analysis tools**
  - Inclusion of data in LEAPS behavior object allows direct comparisons from inside the IHDE environment

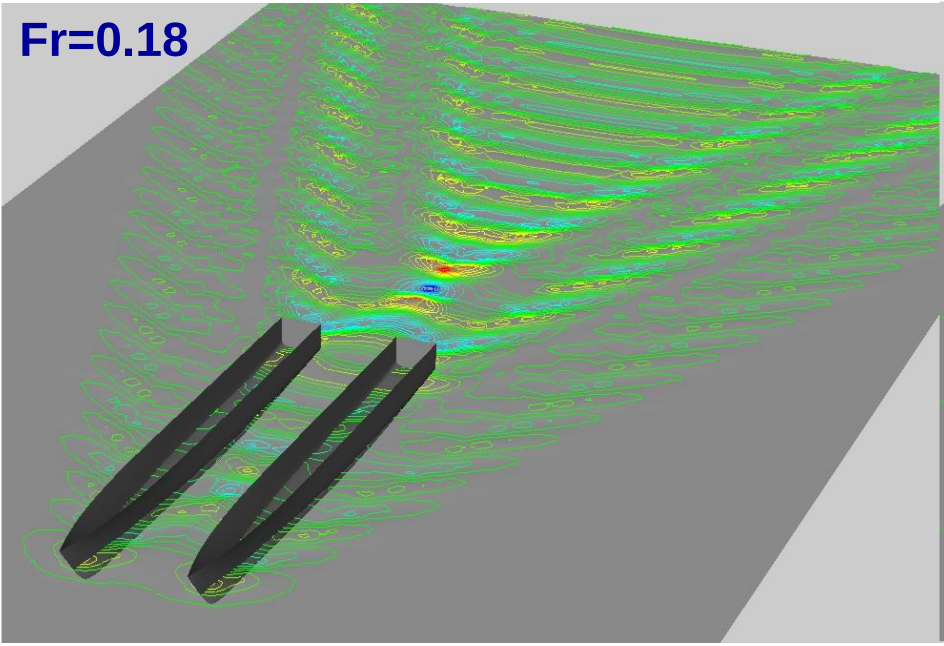
IHDE V2.1 Validation: JHSS

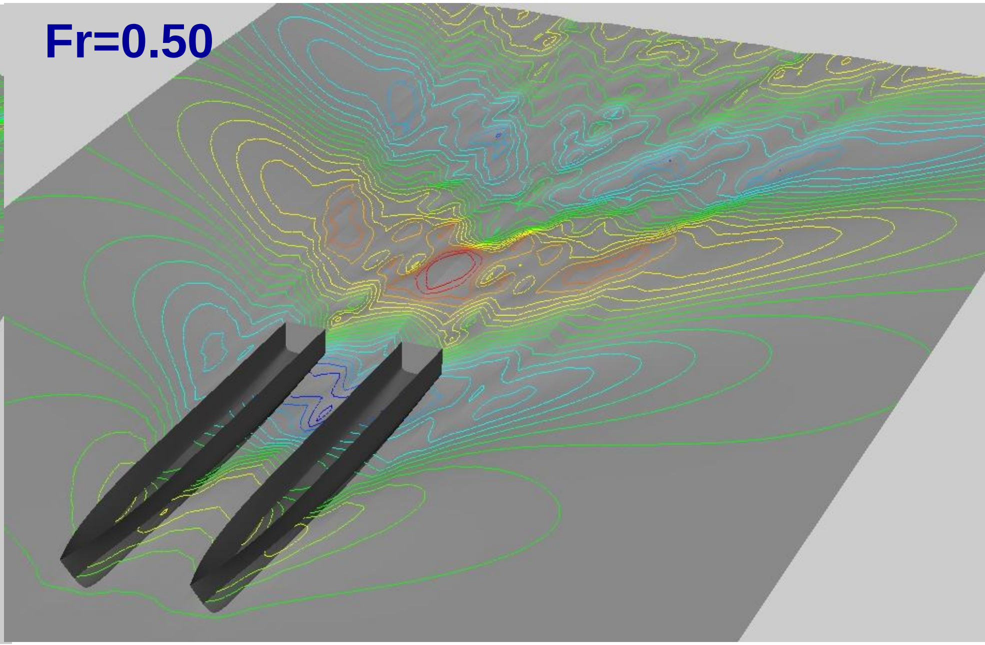
- **Several bow variants tested at NSWCCD**
- **Baseline Bulb: Results using TSD showed little sensitivity to mesh density**





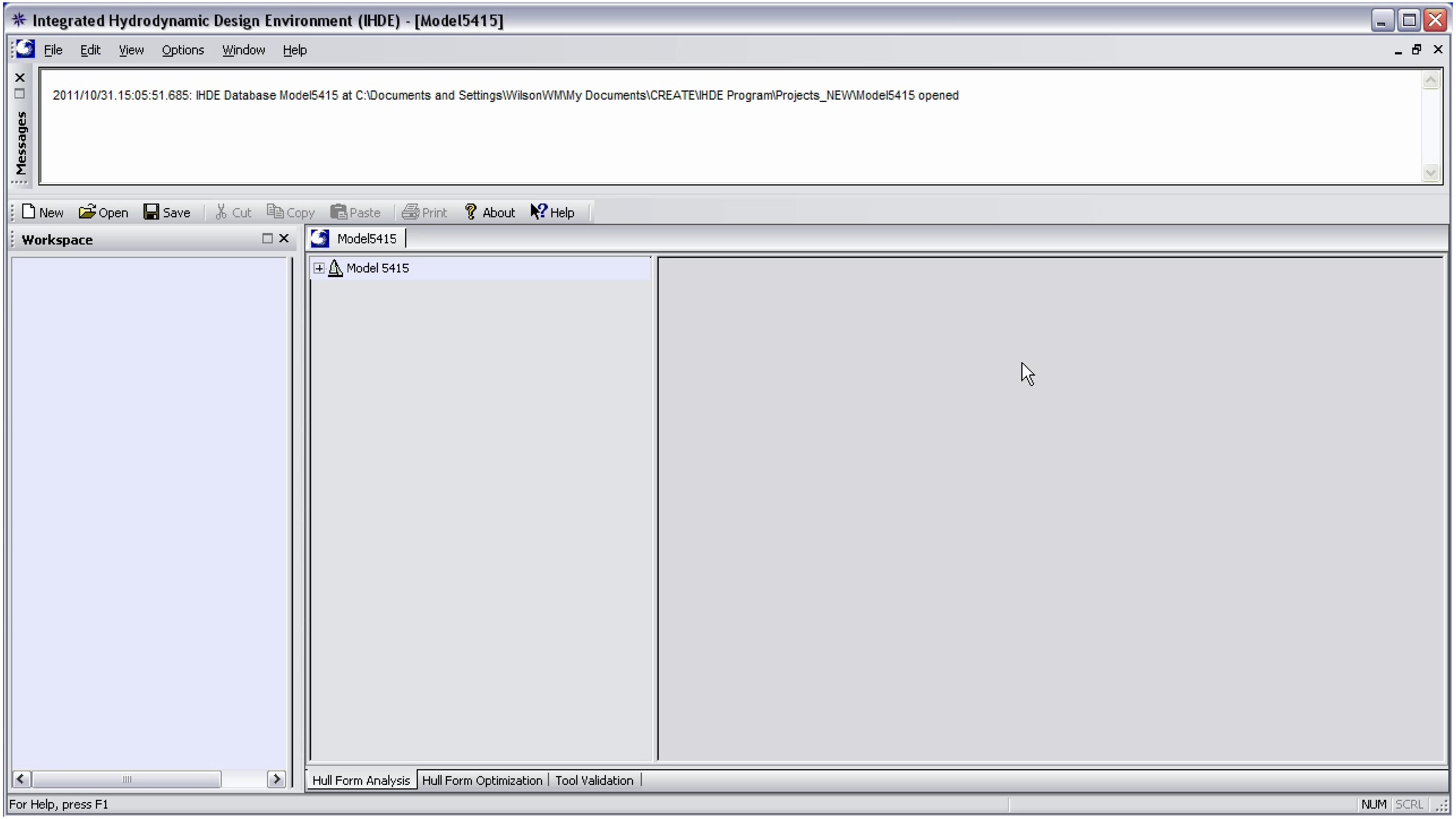
IHDE V2.1 Validation: Delft Catamaran





- **Predicted free surface wave elevations using moderate mesh size**
- **Results indicate appropriate behavior with changing speed**

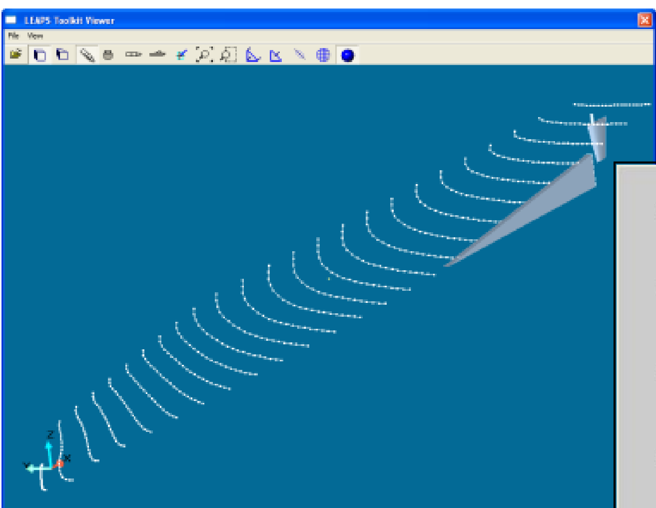
IHDE Resistance

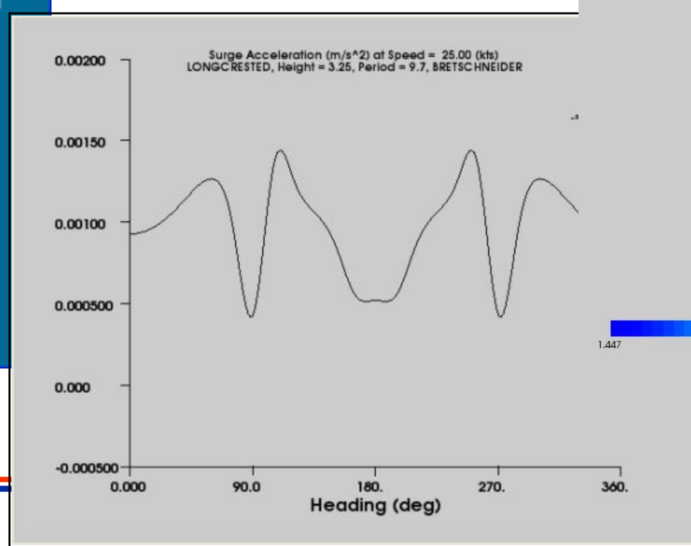


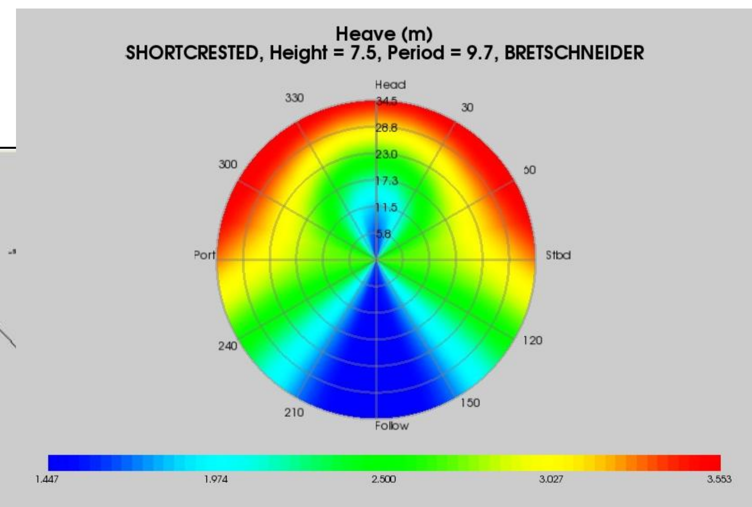
Distribution Statement A

IHDE - Seakeeping

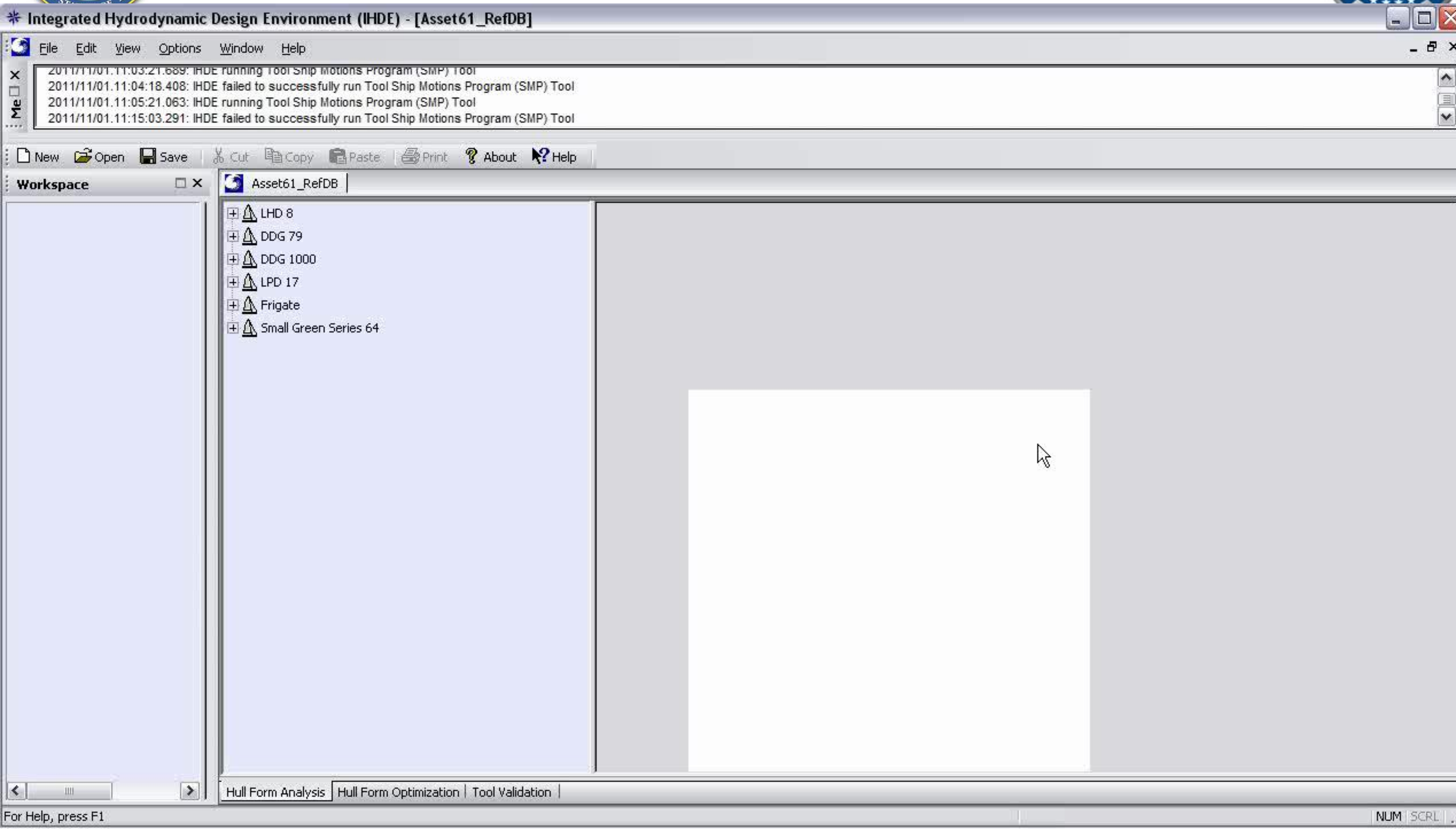
- **Seakeeping: Ship Motions Program (SMP)**
  - Ship advancing at constant speed and heading in a seaway
  - Predicts 6-DOF responses, absolute motions and accelerations
  - Predicts relative motion response for specified locations on ship
  - Inclusion of skeg, rudders, bilge keels (nominal)
  - Multiple methods for data presentation: line, fringe, polar plots





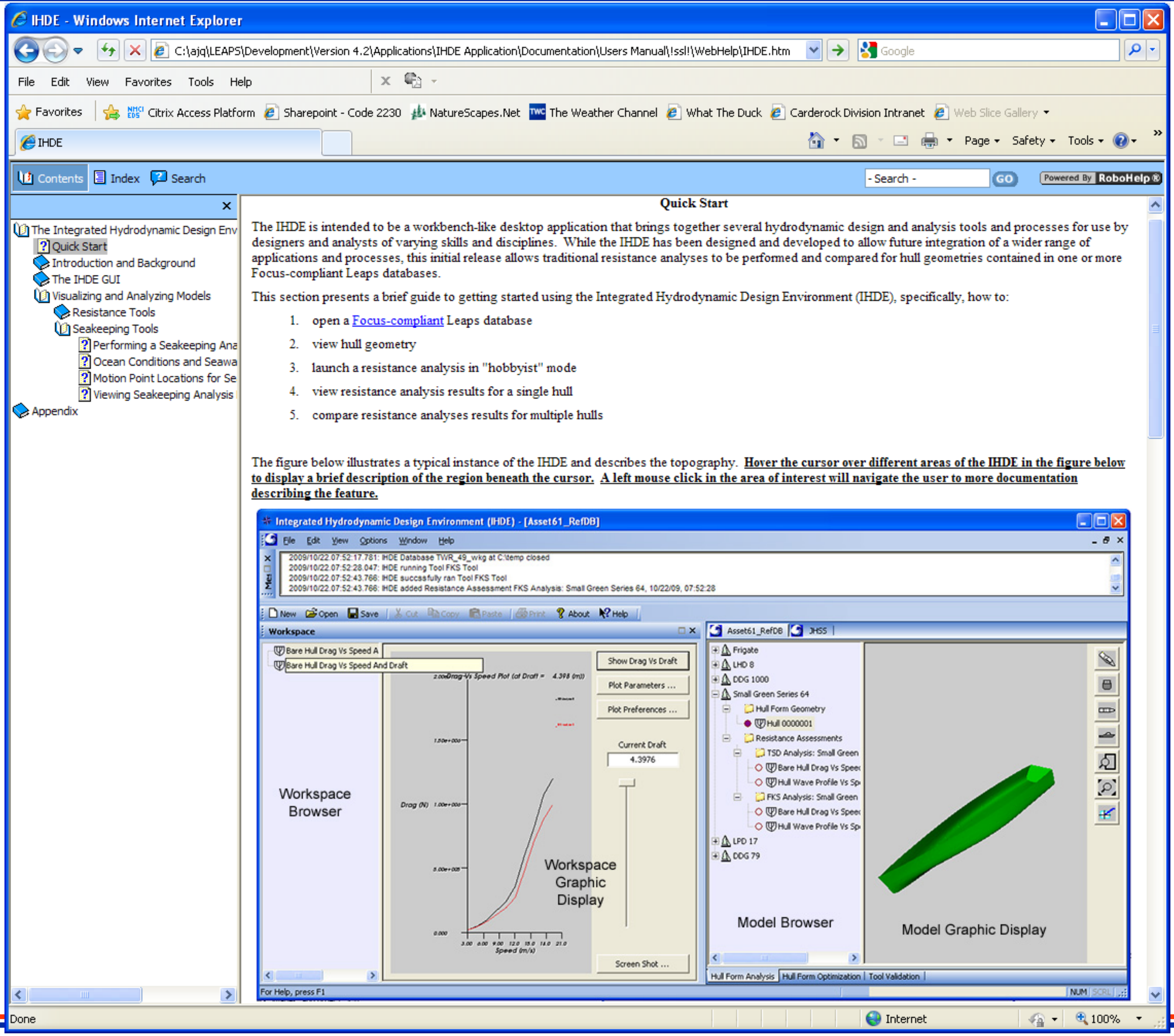


IHDE V2.1: Seakeeping



Distribution Statement A

IHDE - Help



Distribution Statement A

Next Release IHDE 3.0 (Q1 FY2012)

- **Additional Analysis Capability (IHDE V3.0)**
  - Implemented basic ship loads capability
    - Linear and non-linear ship-wave interactions in time domain
    - Focused on implementation of LAMP-2
      - Approximate body non-linear solution
      - Disturbance potential solved over mean wetted hull surface
      - Hydrostatics/Froude-Krylov forces calculated over instantaneous wetted hull surface under the incident waves
    - Includes execution of slam2d to get combined loads
    - Weibull analysis used to predict lifetime fatigue and statistics for probability of exceedence for various parameters
- **Additional integrated solution and visualization capabilities**
  - Remote Execution Engine to IHDE for parallel processing at HPC DSRC's.
    - for rapid evaluations and generation of behavior objects while also facilitating timely hullform design optimization.
    - This will bring HPC resourses to the desktop of naval architects during early stage design.
  - Improved visualization and usability

Distribution Statement A

Future Development Plans

- **Looking Beyond V3.0:**
  - Hullform shape optimization
    - Leveraging **LEAPS HullTran** and MDO Tooklits
  - Improved capabilities for resistance and seakeeping
    - Das Boot
    - AEGIR
    - TEMPEST
    - NavyFOAM
  - Improved visualization capabilities for decision-making
    - Ship Evaluation Program (SEP)
  - Deployment on Windows HPC Portal (DSRC Maui)

IHDE Requirements

Functional

- Tool Validation
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- Hull Form Optimization

Hydrodynamic Areas

- Resistance & Powering
- Seakeeping
- Maneuvering
- Loads

Stakeholders

- Tool Validator
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- Hydrodynamicists

Flow Types

- Inviscid
- RANS
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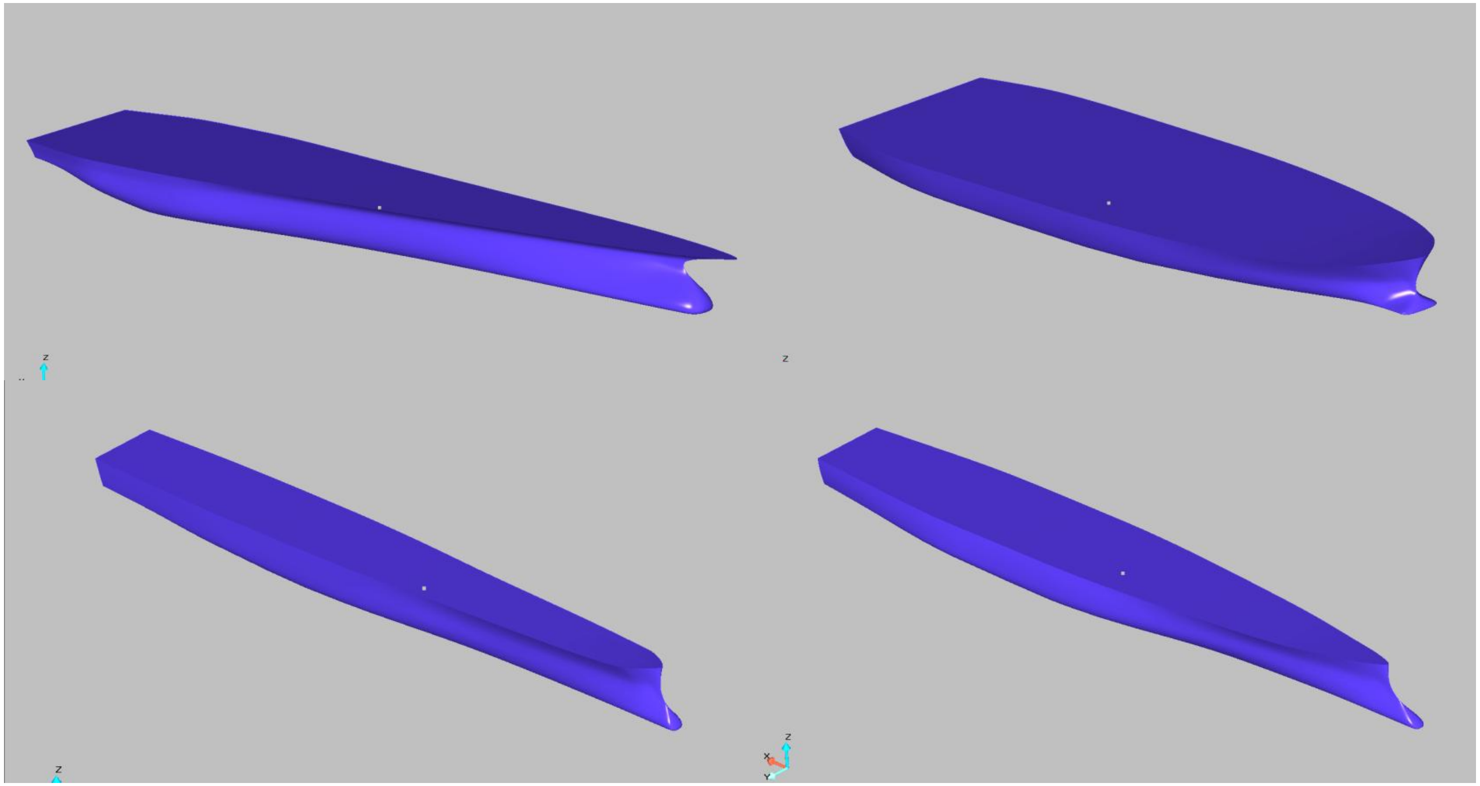
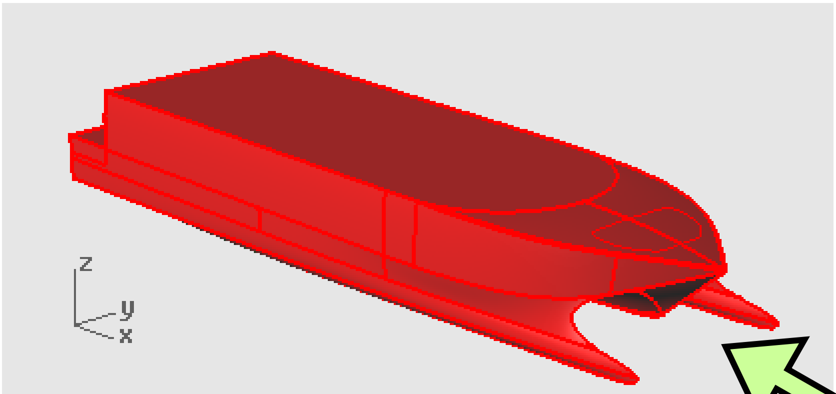
Hullform Transformation (HullTran)

- **HullTran is a LEAPS Toolkit that allows for global distortion of complex NURBS geometry**
- **First application will be Rapid Ship Design Environment RSDE 1.0 (later presentation – Adrian Mackenna)**

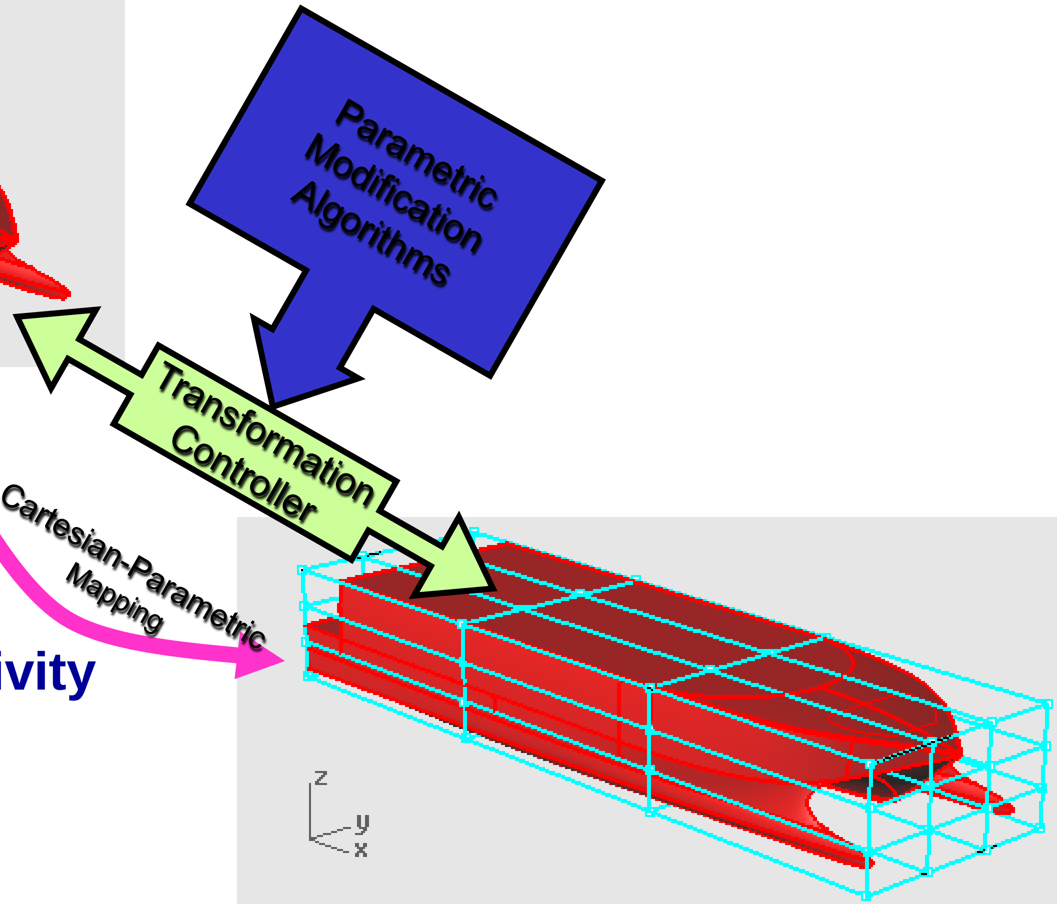


Distribution Statement A

Hull Transformation Approach



GOBS Topology



- **Maintains GOBS Connectivity**
- **Maintains fairness**
- **Facilitates extensibility**

Known Mapping Topology
(3-Parameter B-Spline Volume)

GOBS – **G**eometry **O**bject **S**tructure

HullTran Methodology

Analysis Process

Traditional/current Process

- **Find someone to run TSD (expert)**
  - Find IGES file, clean up in Rhino
  - Generate surface grid (Gridgen)
  - Run TSD
  - Post-process (Tecplot)
  - Repeat for different waterlines
- **Sometime later …. Find someone to run SMP (different expert)**
  - Find IGES file, clean up in Rhino
  - Ensure same as above
  - Generate input file
  - Post-process with visual SMP other
- **Pros/Cons:**
  - Pro: have experts running the code who should understand the results
  - Con: time consuming, limited people who can do the job, number of ancillary codes needed, geometry hand-off problematic

IHDE Process

- **Find someone to run IHDE (non-expert)**
  - Ideally already have geometry in LEAPS (e.g. via ASSET)
  - IF not find IGES file, goborize
  - Learn to run IHDE (~ 1 hour)
  - Run TSD/SMP and visualize results(~1 hour depending on cases/conditions)
- **Pros/Cons:**
  - Pro: Have streamlined entire process and made available to many people, consistent geometry, no need to learn multiple codes
  - Con: Person may not understand results or have garbage by using code for inappropriate problem, new geometries may require some additional preparation

Analysis Process (Con't)

Traditional/current Process

- **Find *another* person to run LAMP**
  - Find IGES file, clean up in Rhino
  - Generate LAMP mesh, input file
  - Run LAMP
  - Post-process (Impound + slam2d) to get combined loads
  - Use another in-house program to normalize the data and get max/min amplitudes from time history
  - Use another in-house program to estimate the lifetime loads using Weibull analysis
- **Pros/Cons:**
  - Pro: have experts running the code(s) who should understand the results
  - Con: time consuming to generate mesh, limited people who can do the job, variety of different tools used, easy to make mistakes in input file, etc.

IHDE Process

- **Find someone to run IHDE (non-expert)**
  - Ideally already have geometry in LEAPS (e.g. via ASSET)
  - IF not find IGES file, goborize
  - Learn to run IHDE (~ 1 hour)
  - Run LAMP and visualize results
    - At this point still requires use of some LAMP tools for visualization outside of IHDE for certain things
- **Pros/Cons:**
  - Pro: Have streamlined entire process and made available to many people, consistent geometry, no need to learn multiple codes
  - Con: Person may not understand results or have garbage by using code for inappropriate problem, new geometries may require some additional preparation

Questions