"CREATE-SH IHDE: Workflow Process Improvements for Hydrodynamics Characterization of Ship Designs"

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Introduction

- **Hydrodynamics is an important enabler in defining a ship design**

- **For new hull form concepts and non-conventional designs experience and data are lacking**

  - **NEED ROBUST TOOLS!**

  - **NEED EFFICIENT WORK FLOW PROCESSES!**

- **The use of simulation tools earlier in the design cycle to help better characterize the ship performance as early as possible could result in significant cost savings by avoiding costly modifications later in the design**

  - **NEED IMPROVED TIME TO SOLUTION!**

  - **NEED TO LOWER BARRIERS TO USER COMMUNITY!**

COMNAVSEA Memo: 4 Feb 2008
Functionality and Timeliness Objectives –
(Reaffirmed Oct 2010 by NAVSEA Chief Engineer for Naval Systems Engineering

- **"This memorandum establishes high-level capability goals for NAVSEA design synthesis and analysis tools in order to guide development efforts within the Navy and for the DoD sponsored CREATE …"**

- **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"

IHDE addresses Concept Refinement and JCIDS through incorporation in Rapid Ship Design Environment (RSDE)
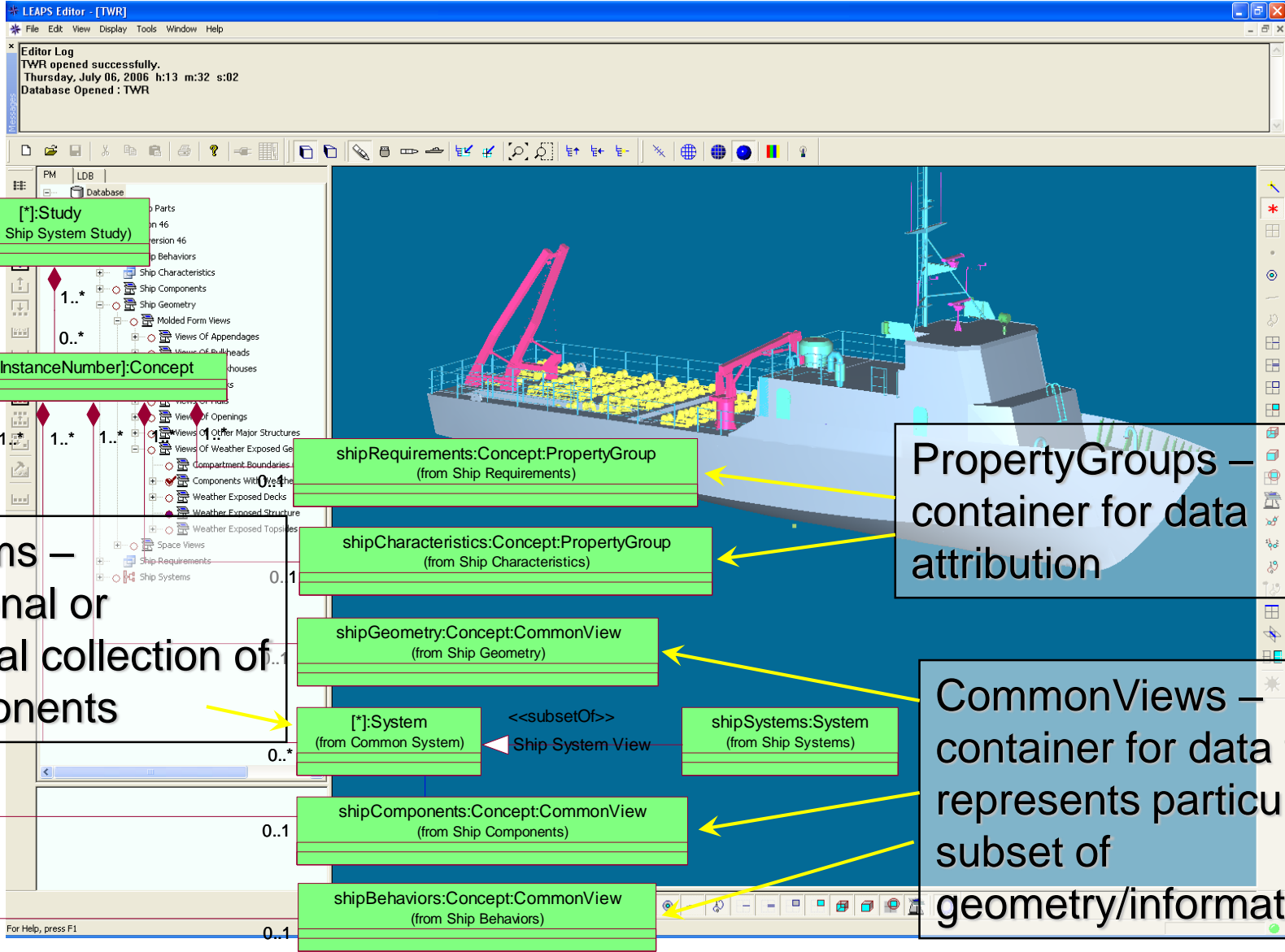
IHDE Description

- **Desktop application that integrates a suite of hull form analysis tools including visualization**
    - Range of accuracy vs. computational expense
    - Integrated visualization capabilities

- **IHDE focused on Hydrodynamics**
    - Use by naval architects and design agents in early design stages
    - Enables more complex analyses by Hydro SMEs at all design stages and efficient way for SMEs to engage the design community
    - Supports hydrodynamic analysis needs for design space exploration and other ship performance domains
        - Rapid Ship Design Environment (**RSDE**)
        - Integrated Structural Design Environment (**ISDE**)

- **IHDE is a workflow process environment**
    - Enabler for analysis tools and information exchange across domains
        - Efficiency improvements vs. SME one-offs
    - Provides integration framework with automation
        - Automated meshing, solution preparation and execution

Product Model

- **Leading Edge Architecture for Prototyping Systems (LEAPS)**
  - Geometry and Engineering Math Library (GEML) as mathematical framework for representation of geometry and data
  - Interoperability amongst all of the different activities that rely on LEAPS product model (e.g., *IHDE*, *RSDE*, *ASSET*)
  - Common taxonomy regarding ship geometry and characteristic information (denoted Focus)
  - Synergy in software development amongst all LEAPS related activities

- **Focus is to improve exchange of product model data between design agents and analysis activities within an integrated framework**
  - Maintain integrity of the data
  - Information exchange across different disciplines in a timely manner

> Significant investment over many years into developing the capabilities and infrastructure of the LEAPS environment has been a significant enabler for all of the applications that use the LEAPS product model.
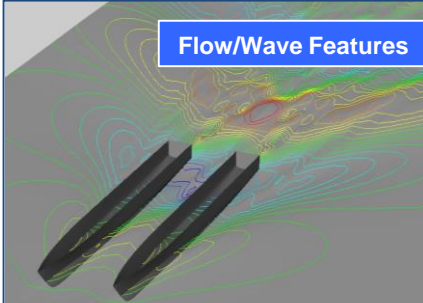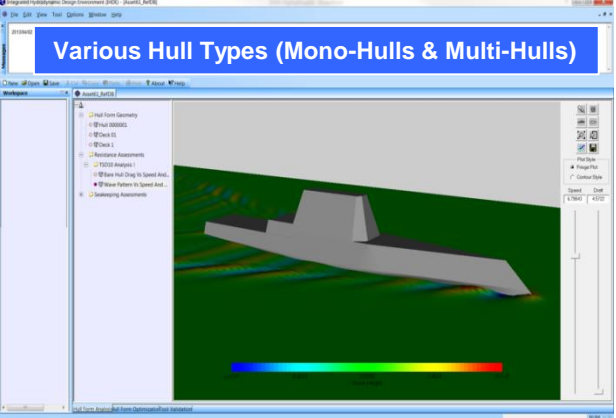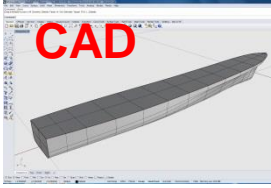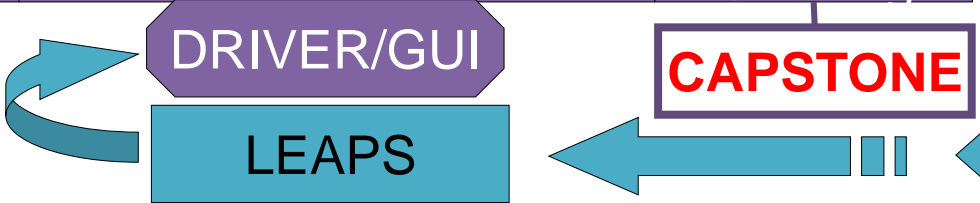
LEAPS Product Model

[*]:Study (from Ship System Study)

ship_[a:InstanceNumber]:Concept

shipRequirements:Concept:PropertyGroup (from Ship Requirements)

shipCharacteristics:Concept:PropertyGroup (from Ship Characteristics)

shipGeometry:Concept:CommonView (from Ship Geometry)

[*]:System (from Common System)

shipSystems:System (from Ship Systems)

<<subsetOf>> Ship System View

shipComponents:Concept:CommonView (from Ship Components)

shipBehaviors:Concept:CommonView (from Ship Behaviors)

PropertyGroups – container for data attribution

Systems – functional or physical collection of Components

CommonViews – container for data that represents particular subset of geometry/information

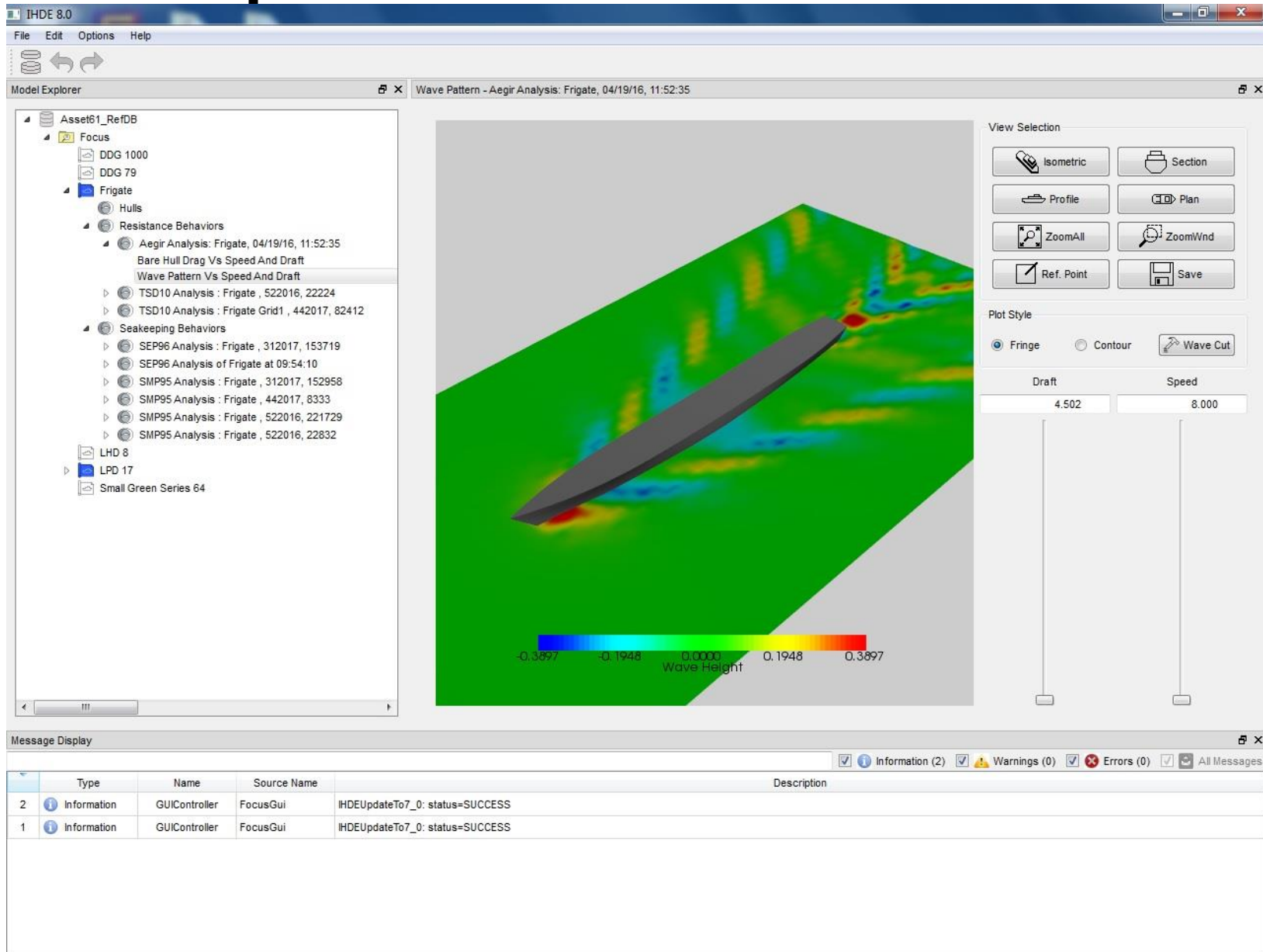# Integrated Hydrodynamics Design Environment (IHDE)

Data Comparisons

Seakeeping Behaviors

RESISTANCE	POWERING	MANEUVERING	LOADS	SEAKEEPING

LOCAL HPC	DESIGN STUDIES	HPCMP
	SHAPE OPTIMIZATION	
	VALIDATION STUDIES	

TSD	AEGIR	SMP SEP SWMP	TEMPEST	Osprey NavyFOAM	LAMP

Problem Set Up	Conditions	Geometry	Automated Gridding

DRIVER/GUI

CAPSTONE

LEAPS

Morpheus

CAD

Various Hull Types (Mono-Hulls & Multi-Hulls)

Flow/Wave Features
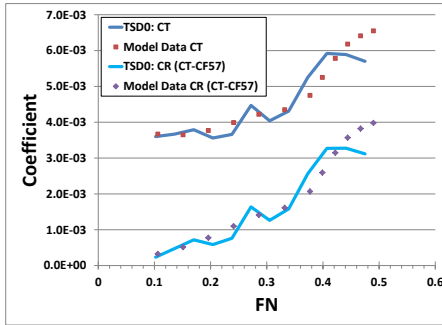
Operability Indices
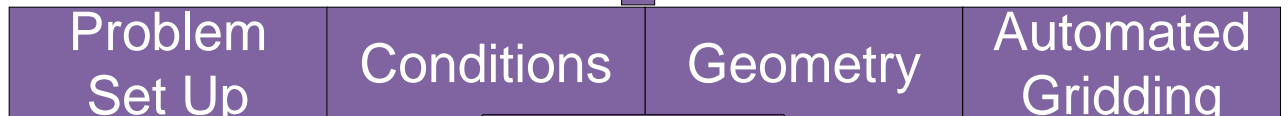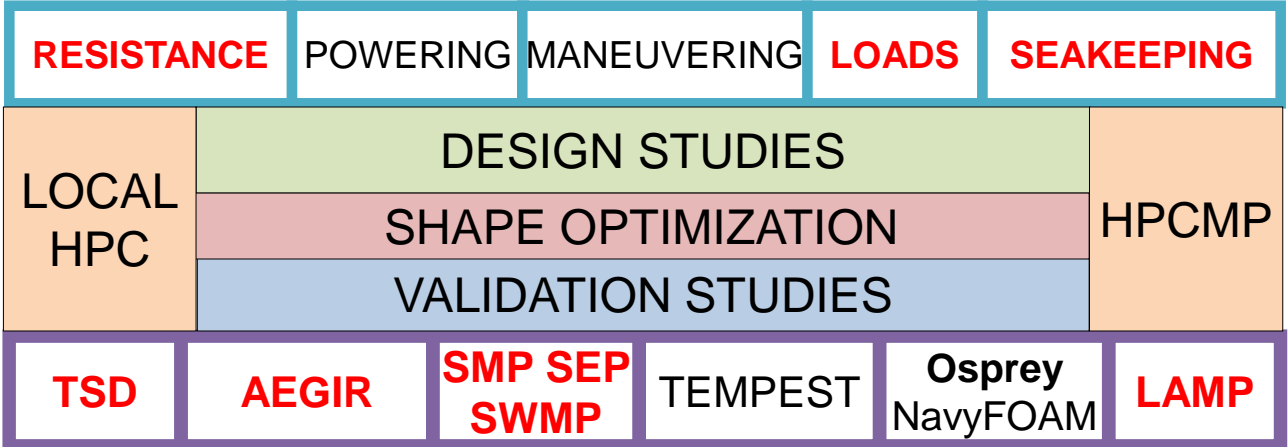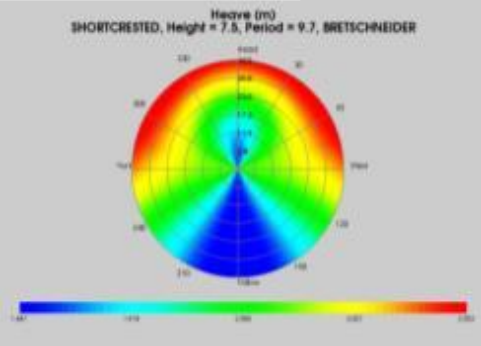
IHDE Graphical User Interface

IHDE Description

- **Usability is important!**
  - Impacts in ship design require robust work flow processes to avoid costly delays

- **Automated analysis preparation and parallel execution**
  - Interactive wizard pages used to create solver inputs (reduces input errors)
  - Prepopulated ship characteristics from product model
  - Remote Execution System (RES) processes analysis jobs in background
  - Automation of complex inputs increases productivity

- **Automated mesh generation**
  - Access to CREATE-MG Capstone methods
  - Improved time to solution

- **Integrated visualization capabilities**

Capstone Grid
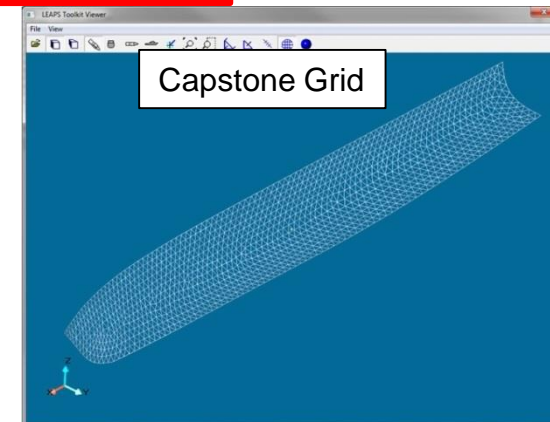
User Interactivity
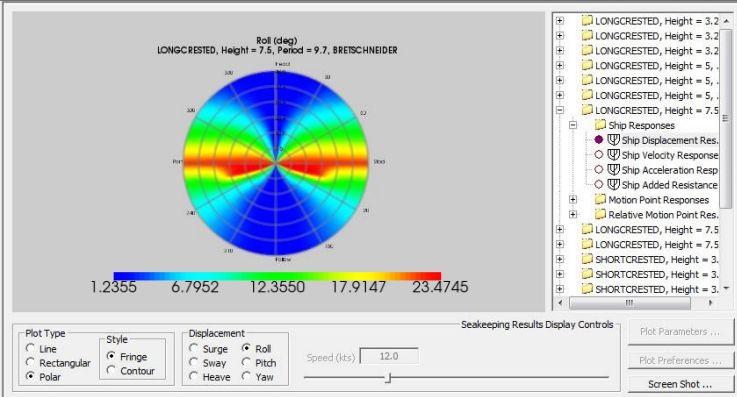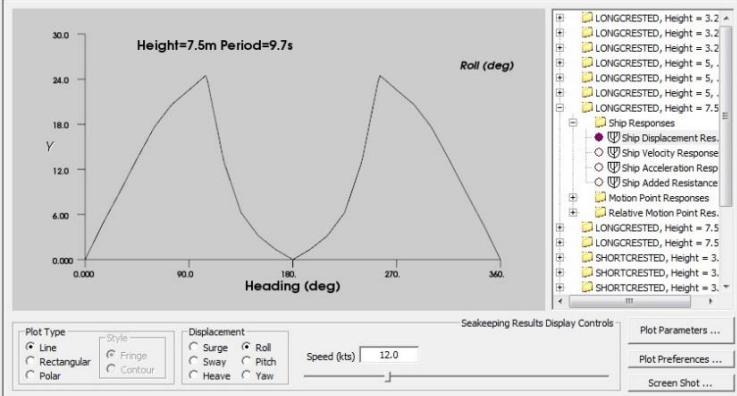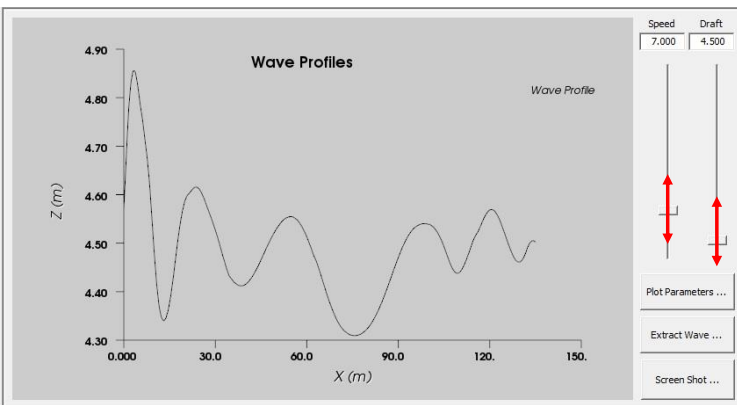
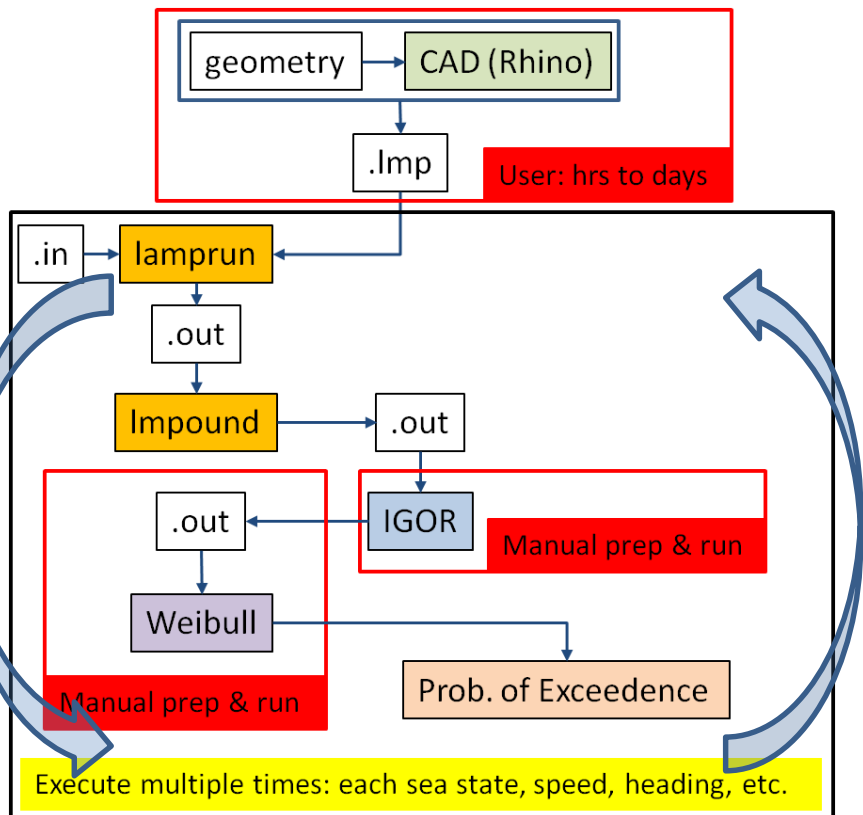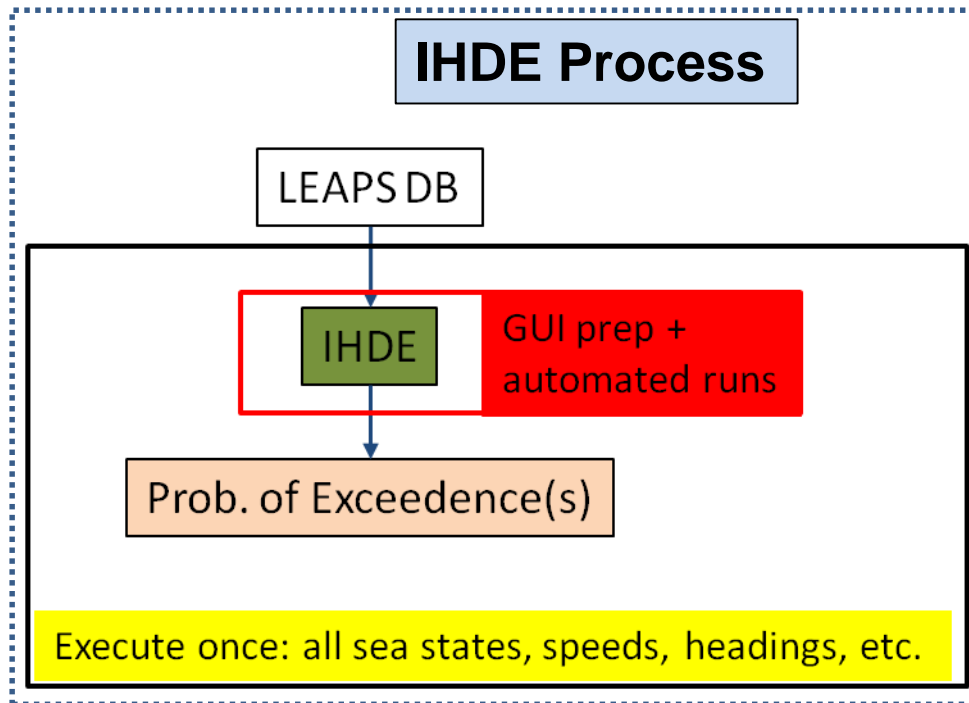

- **Results of analyses are persisted in LEAPS DB as behavior models**
  - Multi-dimensional splines
    - Example: Drag vs Speed vs Draft
- **IHDE provides multiple ways to interact with results**
  - 2D line plots
  - 2D fringe plots
  - 2D speed polar plots
  - 3D wave elevation contours
- **Slider bars effect real-time interrogation of multi-dimensional splines**
  - Dynamic user feedback

Example: Improved Process for Primary Loads using Large Amplitude Motions Program (LAMP)

Previous Process

- geometry → CAD (Rhino)
- .Imp
- User: hrs to days
- .in → lamprun
- .out
- Impound → .out
- IGOR
- Manual prep & run
- .out
- Weibull
- Manual prep & run
- Prob. of Exceedence
- Execute multiple times: each sea state, speed, heading, etc.

IHDE Process

- LEAPS DB
- IHDE
- GUI prep + automated runs
- Prob. of Exceedence(s)
- Execute once: all sea states, speeds, headings, etc.

Significant time savings
- **Manual preparation time reduced**
- **Less chance of input errors**
- **Parallel execution of individual runs**

Time to solution reduced from Hours/Days → minutes!

Other User Community Barriers

- ## Validation of Analysis Tools

  - It is important for users to understand when different tools are applicable

  - Need to verify the pedigree of any geometry or data being used

  - IHDE Validation Engine in V6 and later provides a means for users to assess the accuracy of analysis tool predictions through comparisons with experimental model test data and best-practice pre-computed solutions

- ## One of the major challenges is getting geometry into LEAPS Focus-compliant format

  - Previous process required to import user-defined geometry was very labor intensive and represented a significant barrier to new users

  - **Morpheus** application available in LEAPS V5 provides streamlined process for geometry import

    - Rhino .3dm or .iges formats

IHDE Validation Engine

- **Validation is a key component in understanding and demonstrating the applicability of different tools to different types of problems**
  - IHDE vision is to provide a suite of different analysis tools that balance accuracy with computational expense

- **We are leveraging a wealth of experimental model test data taken over decades at NSWC Carderock**
  - Care must be taken to establish pedigree of geometry and data

- **User workflow process for performing comparisons**
  - Pre-computed ship resistance analysis vs. included model test data
    - Does not require any new predictions on the part of the user
    - **IHDEValidationDB** provided with IHDE installation
  - Wave cuts can be extracted from wave elevation behavior objects for comparison with model test data

IHDEValidationDB Monohulls

Model	Description	Ship Scale		Model Scale	
		Length (ft)	Beam (ft)	Length (ft)	Beam (ft)
5415	Pre-contract DDG 51	465.9	62.5	18.77	2.52
5653	JHSS Baseline Bulb (BB)	950.5	104.9	27.85	3.08
5653	JHSS Gooseneck Bulb (GB)	950.5	104.9	28.71	3.08
5365	*R/V Athena I*	154.0	22.6	18.67	2.74

5415

5653(BB)

5653(GB)

5365

IHDEValidationDB Multi-hulls

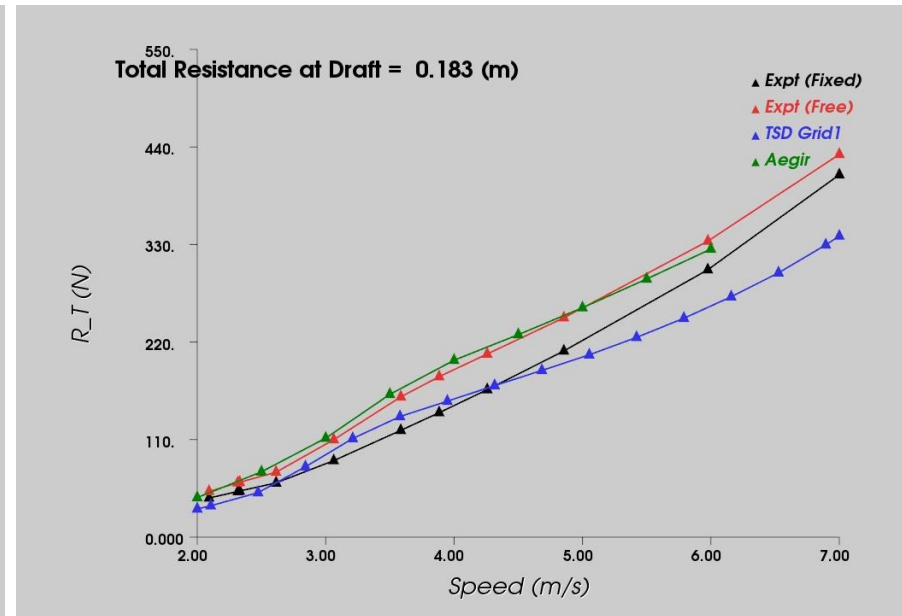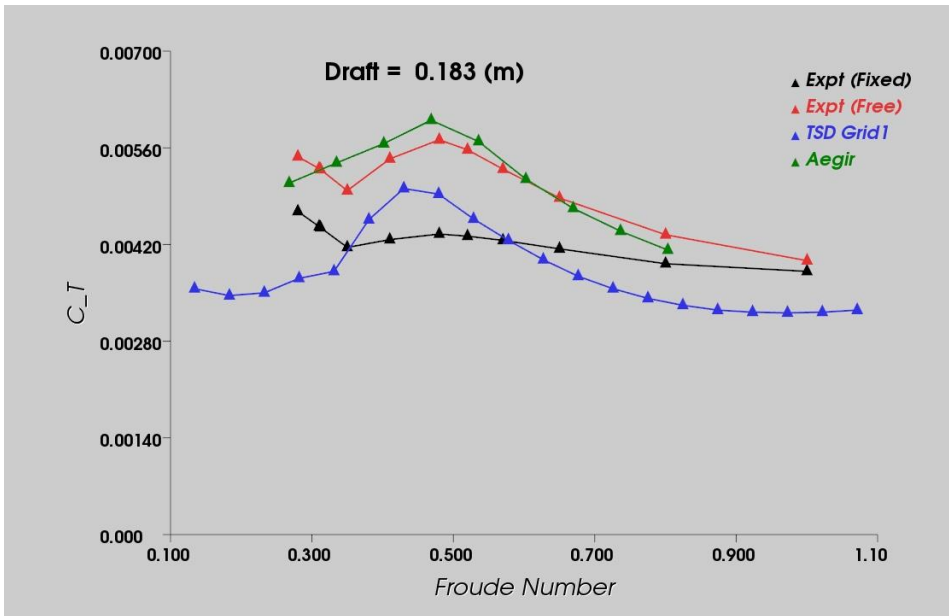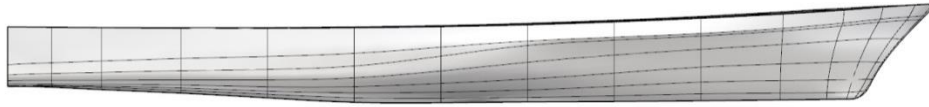| Model	Description	Ship Scale		Model Scale	
		Length	Beam	Length	Beam
372	Delft 372 Catamaran	---	---	9.84 ft	3.08 ft
5594	HSS (High Speed Sealift) hull concept	1059 ft	128.6 ft	23.6 ft	2.86 ft

372
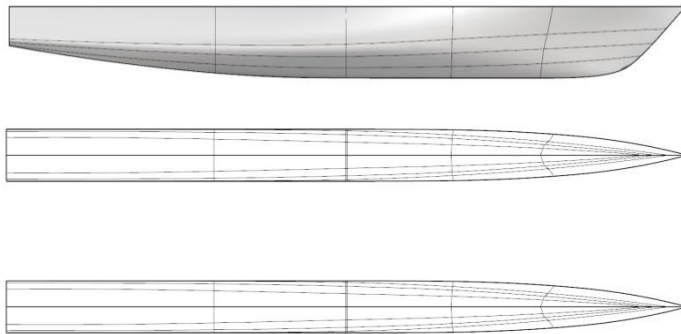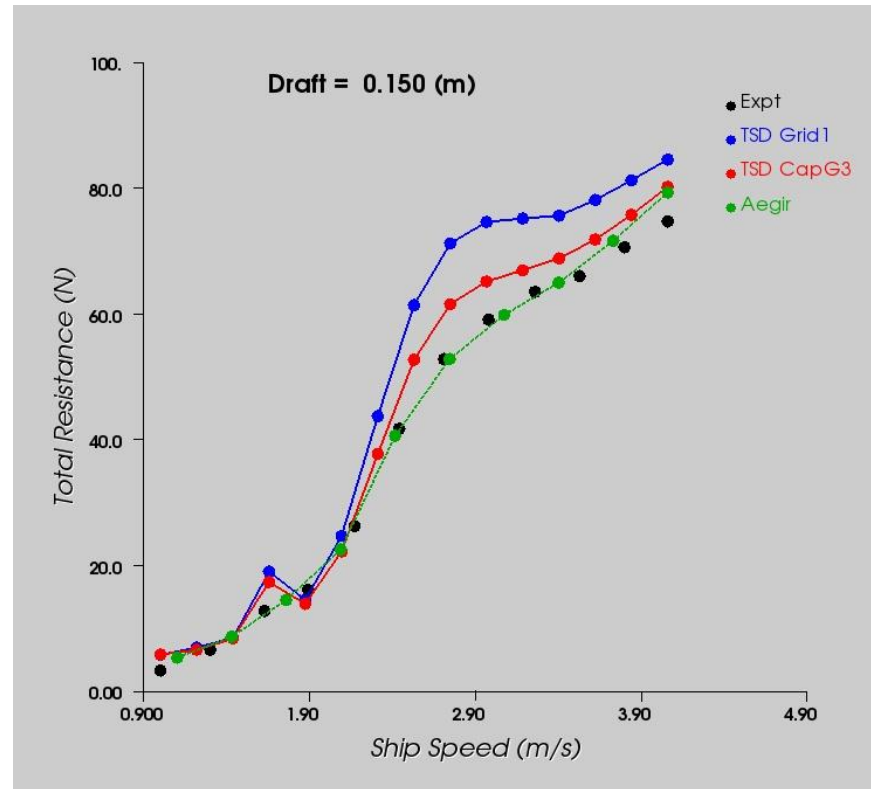

5594
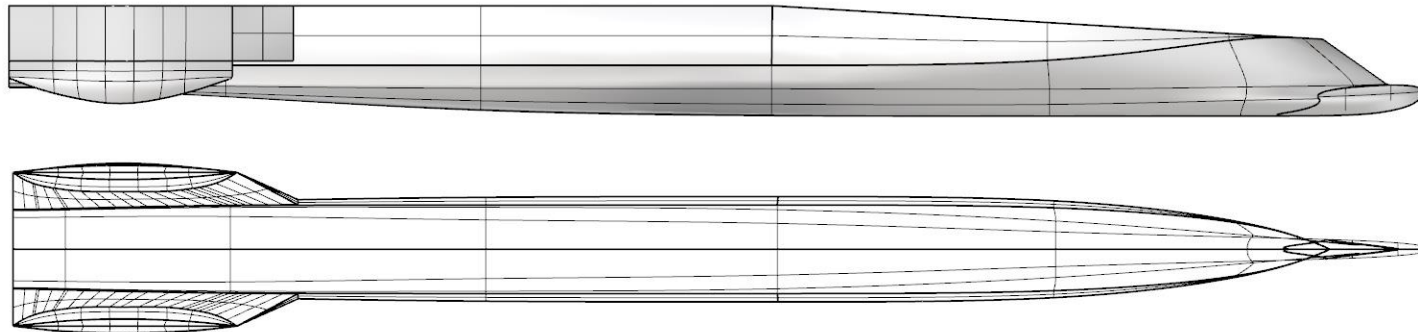
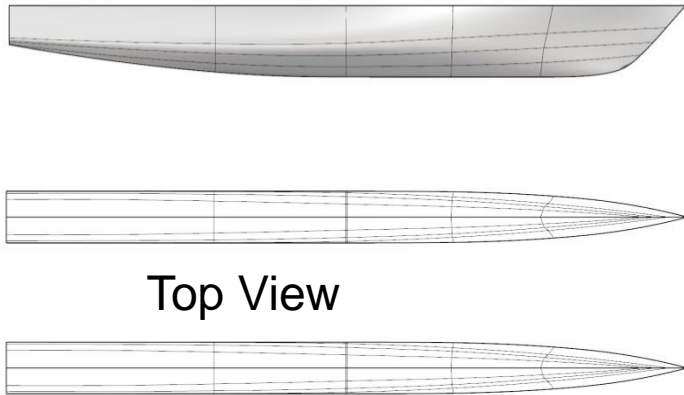# Example: Model 5365 (R/V Athena)

Comparisons with experimental data both fixed and free to sink and trim
  -- TSD does not account for ship motion
  -- TSD under-predicts resistance at higher Fr

  -- Aegir accounts for ship motion and shows much improved comparison vs. TSD

Example: Delft 372 Catamaran


Top View

Draft = 0.150 (m)

- **Comparison of different grid methods:**
  - "CapG3" Capstone mesh shows improved accuracy for TSD predicted resistance

- **Comparison of different analysis tools**
  - Aegir shows improved accuracy vs. TSD

LEAPS Geometry Pre-Processor

- **Morpheus is a key enabler to lowering the entry point to IHDE!**

  – Supports .iges and Rhino .3dm

  – Drag-and-drop hull view associations

  – Geometry validation compliancy checks for all LEAPS products

  – Automatically creates LEAPS database with correct geometry associations and attributions

- **Morpheus also enables simple hull form modifications from parent hull form**
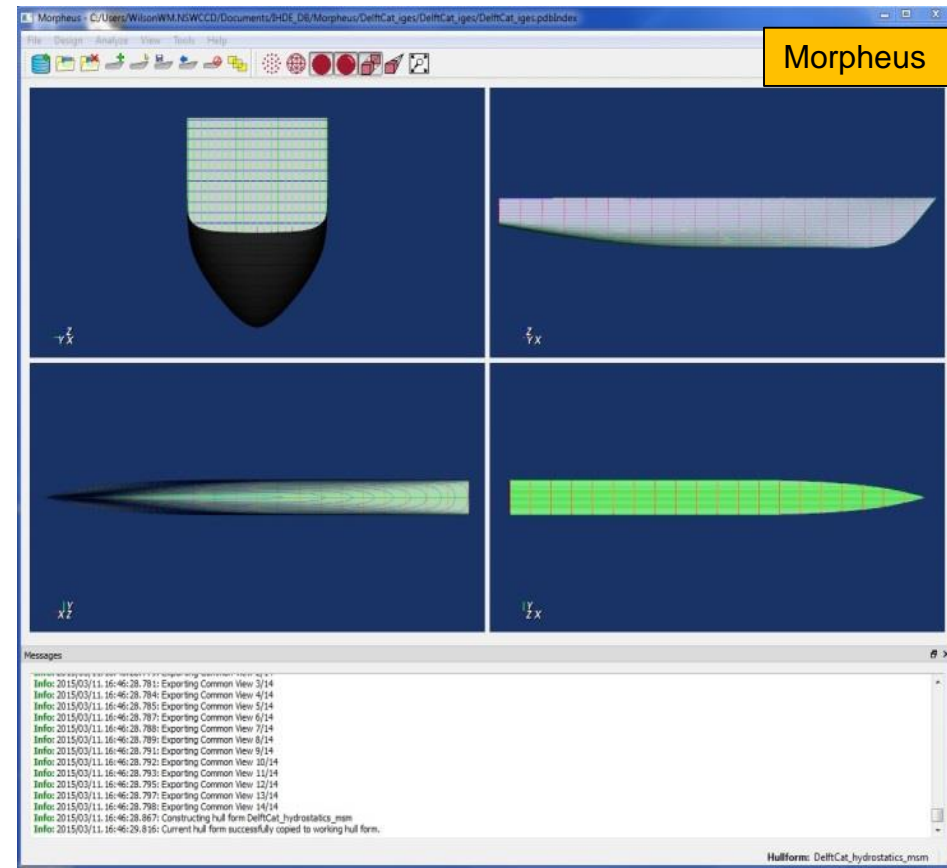
LEAPS database that is IHDE compliant can be generated in minutes!

Planned IHDE @ HPC Portal

- **Web portal delivery method**
  - No local installs
  - Single sign-on for authentication using CAC
  - Provides easy access to larger HPC resources
  - Future enabler for design engagement of CFD methods

Prototype Screen Capture (NMCI computer)
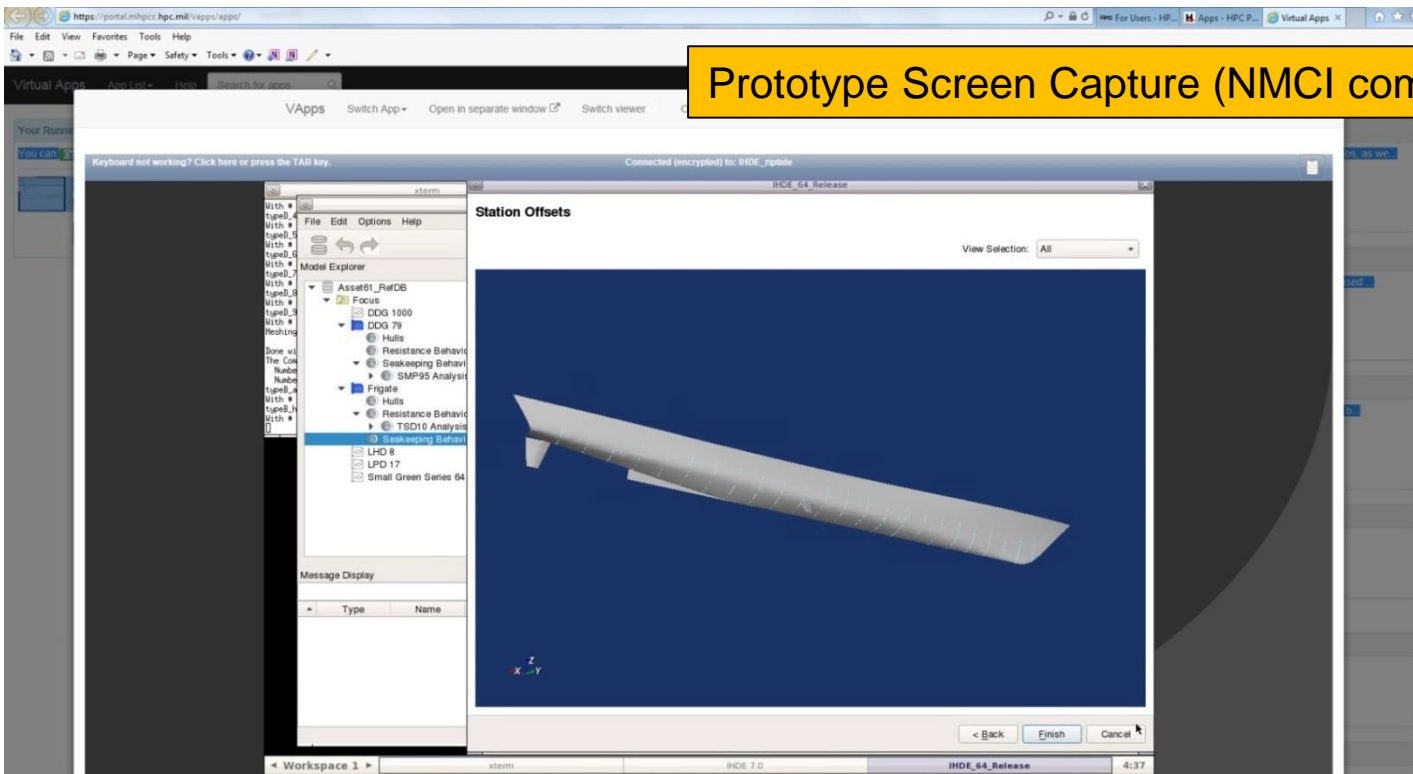
Summary

- **IHDE is a desktop application that integrates a suite of hull form analysis tools including visualization**
  - Ship performance areas: Resistance, Seakeeping, Hydro Loads, Operability

- **LEAPS product model:**
  - Provides single unified representation of the ship model and maintains the integrity of the data used for analysis
  - Enables Information exchange across different disciplines in a timely manner

- **End-state vision of IHDE is integrated suite of design and analysis tools to fully characterize a ship design with appropriate level of definition**
  - Range of fidelity = accuracy vs. computational expense
  - Automated meshing and analysis preparation & parallel execution
  - Integrated visualization
  - Efficient workflow processes and data exchange at all levels of design

- **IHDE enables direct link between hydrodynamics SMEs and ship design agents for improved ship designs**

Questions?

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