CREATE-SHIPS: Integrated Hydrodynamics Design Environment (IHDE)

Adrian Mackenna – presenting for Wesley Wilson

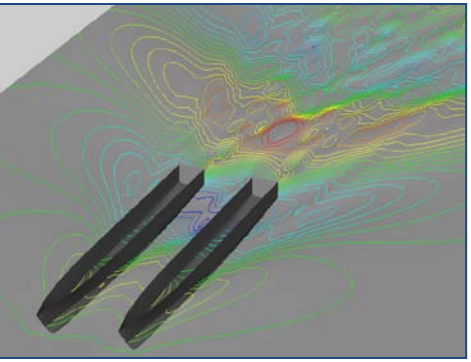
CREATE-Ships Objectives for Hydrodynamics

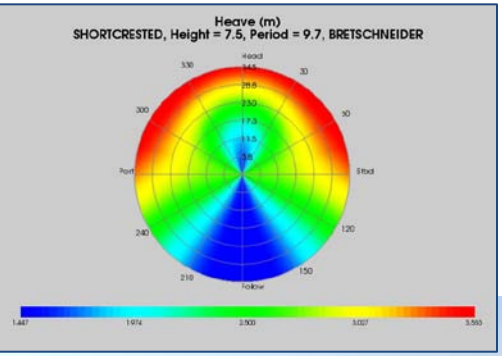
- **Provide the US Navy community with a suite of analysis methods that can be used to impact design and analysis**
  - Existing and evolving semi-empirical methods for fast turnaround needs
  - Use of existing high-end methods where appropriate, within required timeframes
  - New CREATE-developed high-fidelity capability with a minimum of empiricism
- **Provide an integrated user design environment for using these different levels of fidelity methods by users in both the design and analysis domains**
  - Simultaneously optimize and evaluate different disciplines (e.g., resistance, powering, maneuvering, seakeeping)

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.

Integrated Hydrodynamics Design Environment (IHDE)





RESISTANCE | POWERING | MANEUVERING | LOADS | SEAKEEPING

LOCAL HPC

DESIGN STUDIES

SHAPE OPTIMIZATION

AUTOMATED VALIDATION CASES

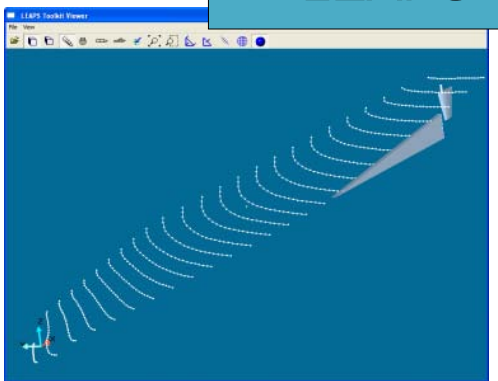
HPCMP

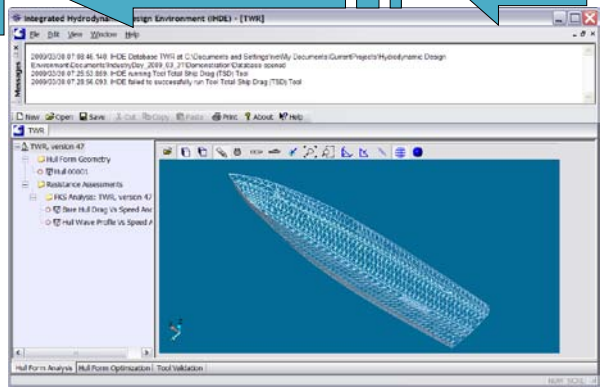
FKS TSD | AEGIR DAS BOOT | SMP VERES | FREDYN TEMPEST | NavyFOAM | LAMP

Problem Set Up | Conditions | Geometry | Automated Gridding

DRIVER/GUI

LEAPS





IHDE Release Products

IHDE V2.1

Approved for public release (NSWCCD-20-TR-2012/01):

Includes only publicly available analysis tools: **FKS**, **TSD**, **SMP**

Available for use by universities and students

Distributed to students in MIT-2n program as part of **ASSET** training course (Aug 2012)

IHDE V3.0

Current Production Release (Dec 2011)

New capabilities:

Basic ship loads capability with **LAMP-2**: Large Amplitude Motions Program (time domain)

Parallel processing capability initiated (ties into Aberdeen Portal)

IHDE V4.0

Upcoming Production Release (Dec 2012)

New capabilities:

Improved visualization capabilities for decision-making

Seakeeping Evaluation Program (SEP)

Improved capability for resistance

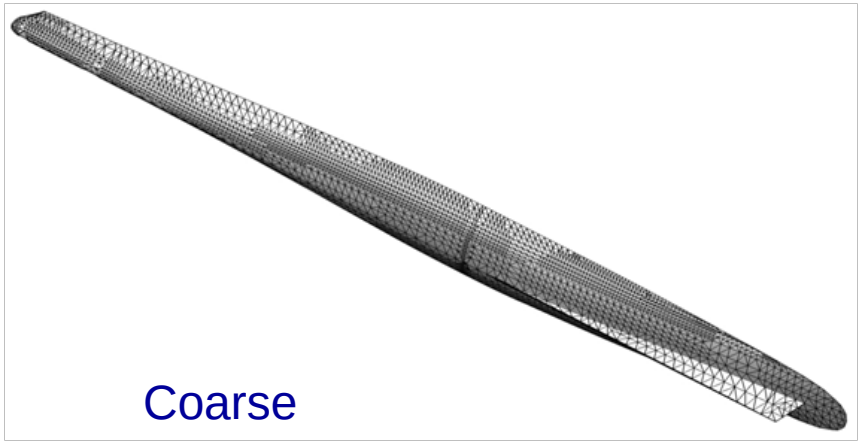
Das Boot (parallel processing for multiple speeds/drafts)

IHDE V2.1 Capabilities

- **Analysis Tools (IHDE V2.1)**
  - Slender 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 Meshing

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



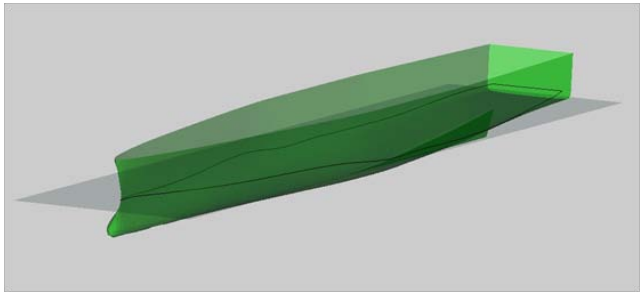
Coarse

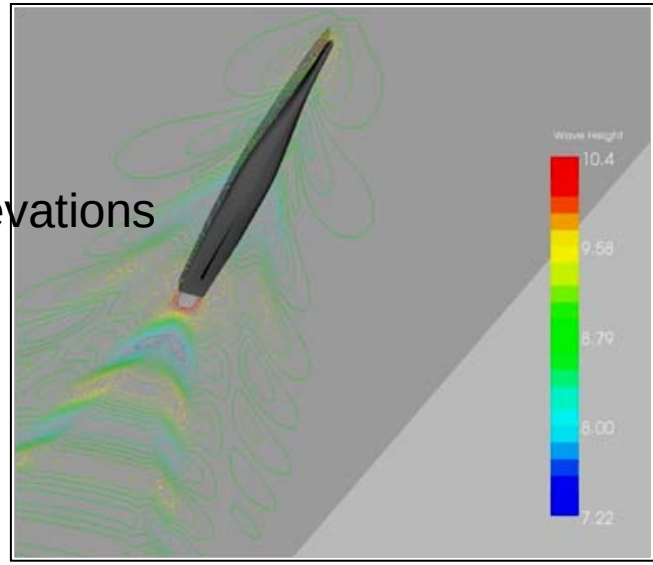
Fine

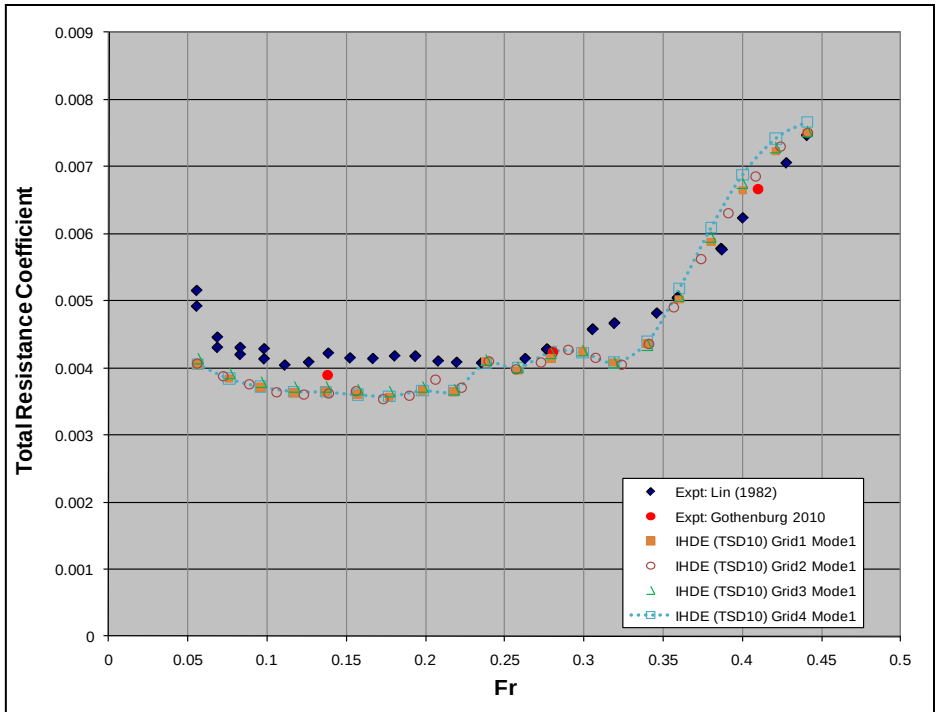
Significant time savings vs. manual grid generation methods!

IHDE – Resistance

- **Resistance: Total Ship Drag (TSD)**
  - Slender 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



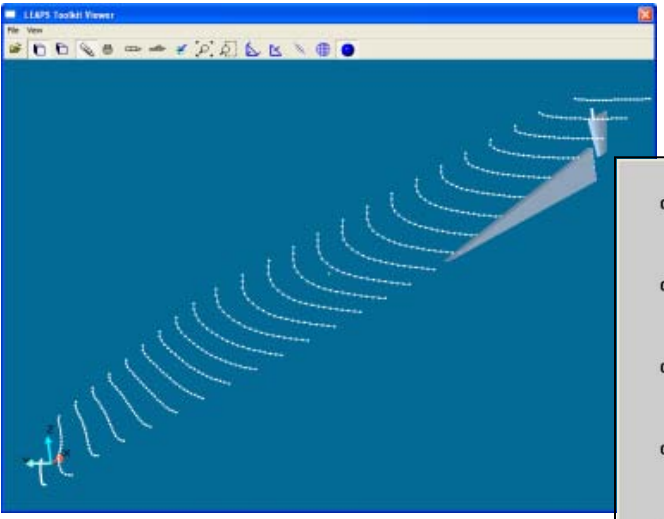


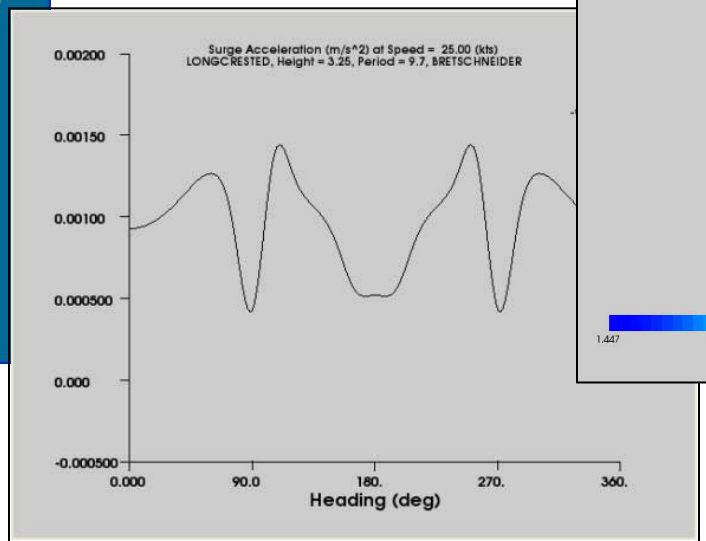


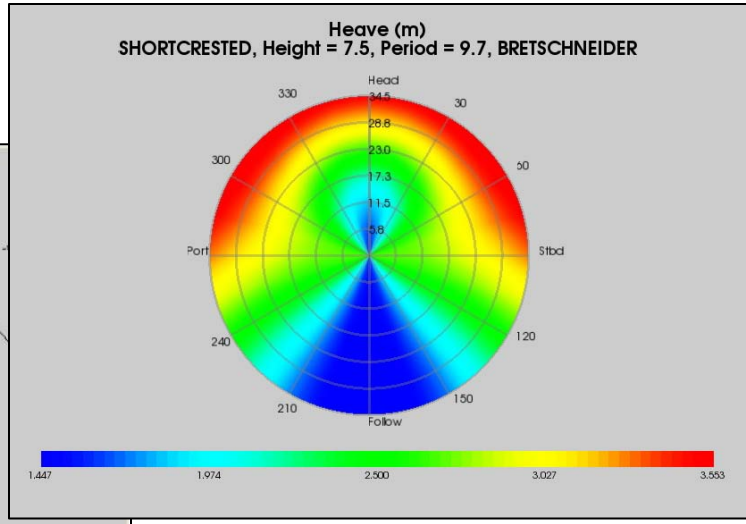
Sample Validation (Model 5415)
Reference: **NSWCCD-50-TR-2011/067**

IHDE - Seakeeping

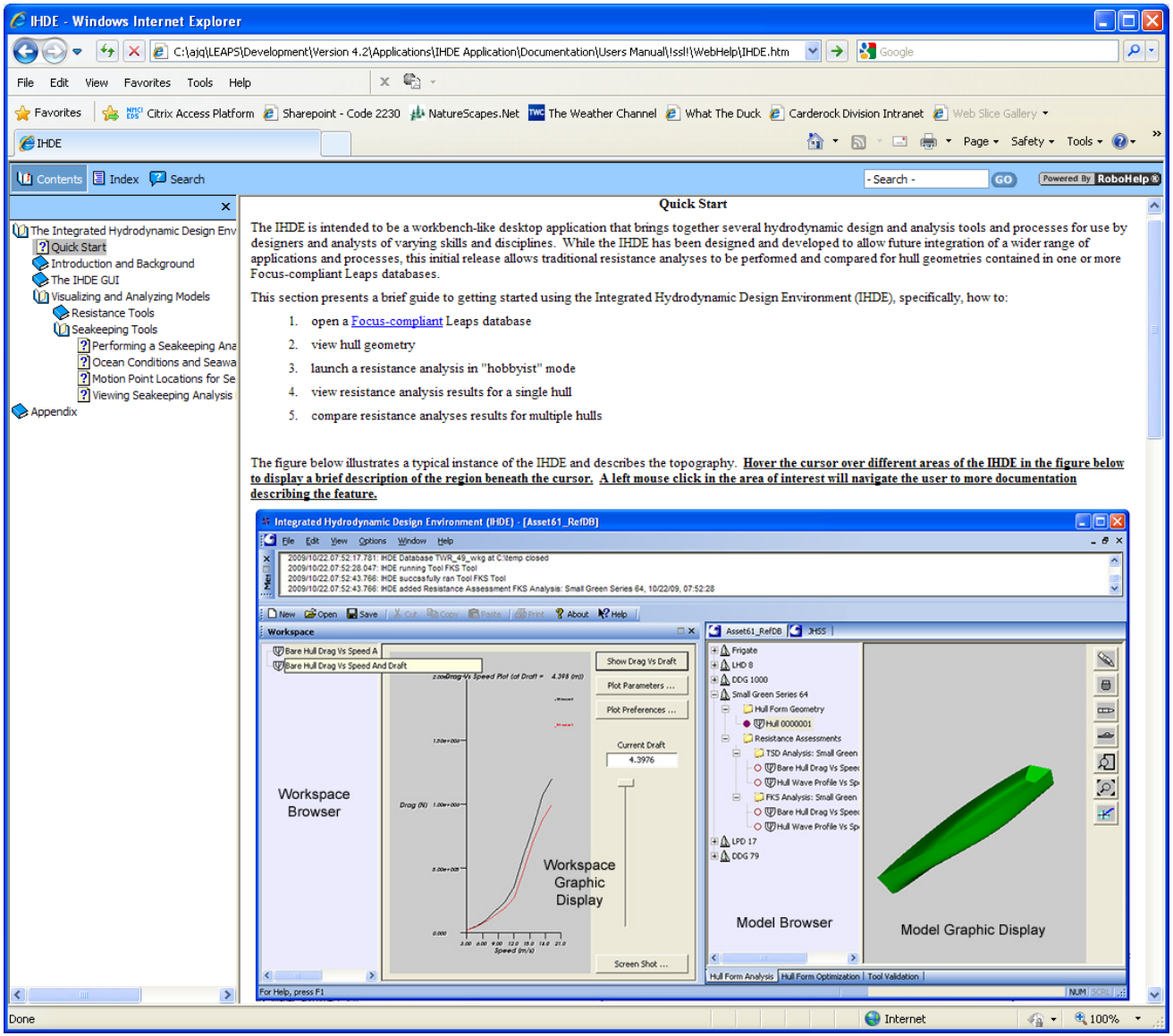
- **Seakeeping: Ship Motions Program (SMP)**
  - Ship advancing at constant speed and heading in a seaway
  - Predicts 6-DOF responses, absolute motions and accelerations
  - Predicts relative motion response for specified locations on ship
  - Inclusion of skeg, rudders, bilge keels (nominal)
  - Multiple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







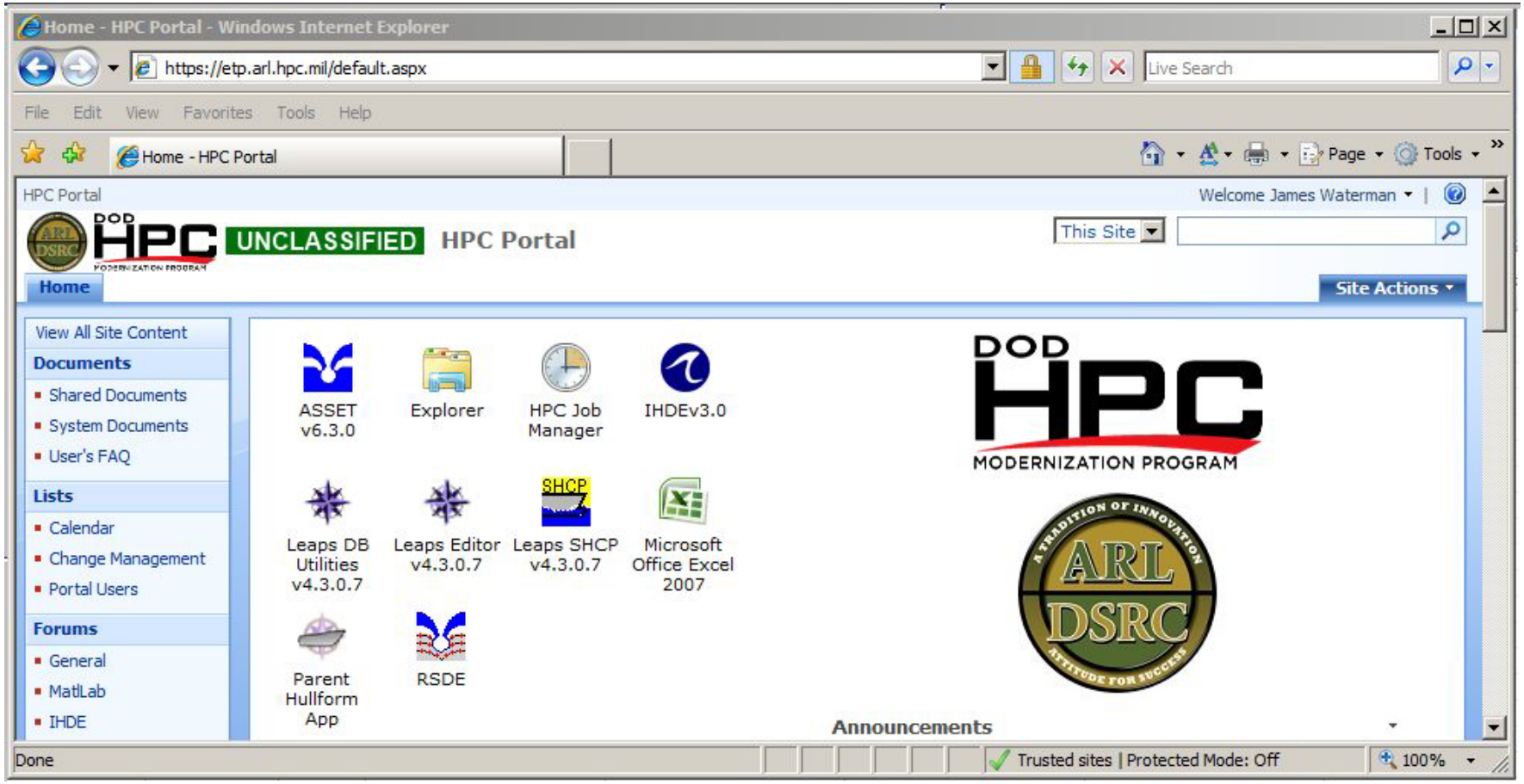
IHDE - Help


IHDE - Windows Internet Explorer
Quick Start
The IHDE is intended to be a workbench-like desktop application that brings together several hydrodynamic design and analysis tools and processes for use by designers and analysts of varying skills and disciplines. While the IHDE has been designed and developed to allow future integration of a wider range of applications and processes, this initial release allows traditional resistance analyses to be performed and compared for hull geometries contained in one or more Focus-compliant Leaps databases.
This section presents a brief guide to getting started using the Integrated Hydrodynamic Design Environment (IHDE), specifically, how to:
1. open a Focus-compliant Leaps database
2. view hull geometry
3. launch a resistance analysis in "hobbyist" mode
4. view resistance analysis results for a single hull
5. compare resistance analyses results for multiple hulls
The figure below illustrates a typical instance of the IHDE and describes the topography. Hover the cursor over different areas of the IHDE in the figure below to display a brief description of the region beneath the cursor. A left mouse click in the area of interest will navigate the user to more documentation describing the feature.
Workspace Browser
Workspace Graphic Display
Model Browser
Model Graphic Display

Engineering Tools Portal (ETP)

- The CREATE project has a unique opportunity to bring HPC resources to a community of users that typically don't use HPC computers; and to do so in a way that is familiar and easy.
- Indirectly address IT security issues.
- This opportunity is being made available from the Army Research Lab (ARL) via the HPCMO program in the form of a Windows based HPC computer.
- The HPC computer will provide an interactive Portal for acquisition program engineers needing access to computational applications that run in the Windows Environment.

Engineering Tools Portal (ETP)



Application of IHDE in FY11-FY12

- **US Navy's Center for Innovation and Ship Design (CISD)**
  - T-AGOS-19
  - Hospital ship (Mercy) replacement design
  - Salvage Tow & Rescue (T-STAR)
  - Green Arctic Patrol Vessel (GPAV)
  - Medium Affordable Surface Combatant (MASC)
  - Optimized MASC

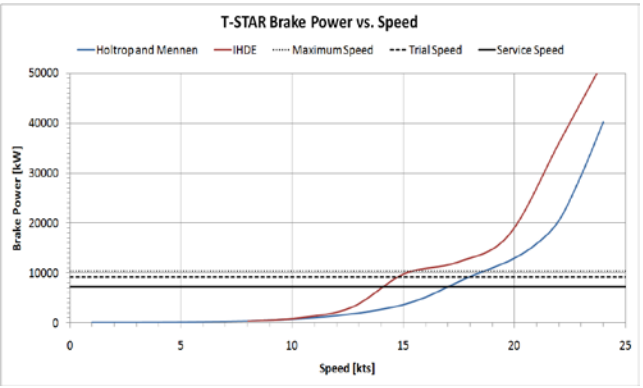
T-AGOS-19: Image courtesy of Navsource.org archive photos.

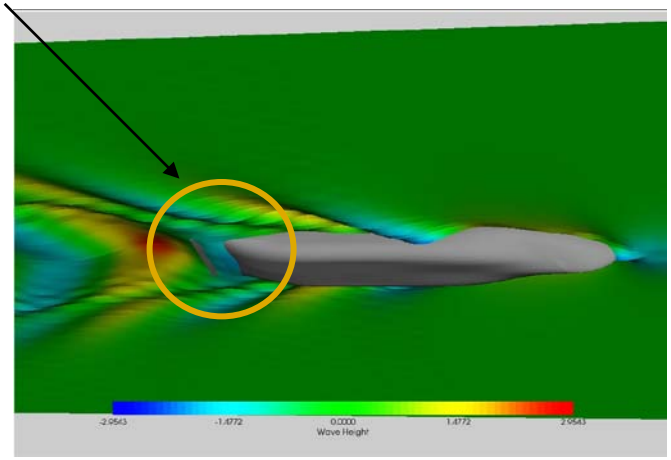
- **DDG-51 Flight III bow bulb design**
- **Support upcoming DARPA program**

USNS Mercy (T-AH-19) : Image courtesy of US DoD Defense.gov news photos.

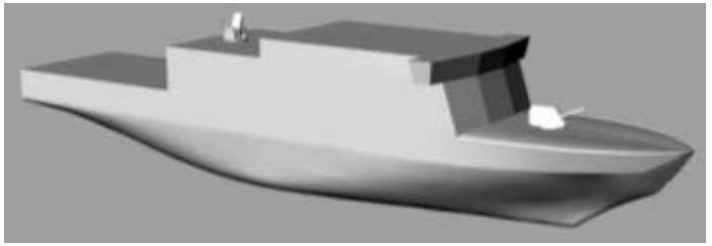
Application of IHDE in FY11-12

- **Salvage Tow & Rescue (T-STAR)**
  - Courtesy of Brandon Laing (CISD)
  - IHDE used for resistance evaluations
  - Discovered interesting stern wetting feature



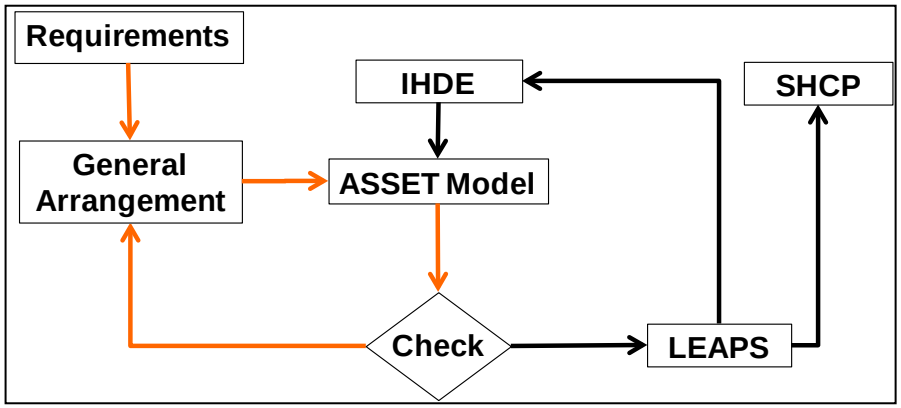


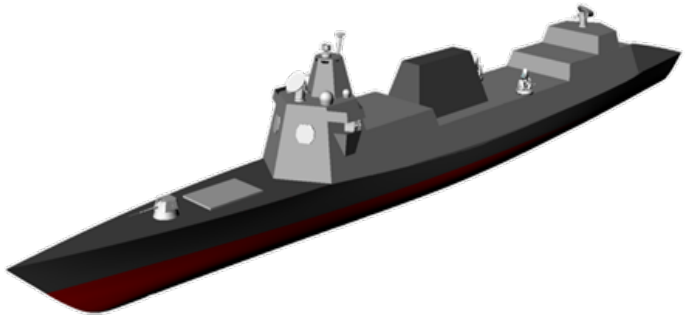
- **Green Arctic Patrol Vessel (GAPV)**
  - Courtesy of Alan Shane (CISD)
  - IHDE used for resistance assessments
  - Unusual bow section designed for ice breaking operations
  - LEAPS database constructed fairly easily by iges import from Rhino

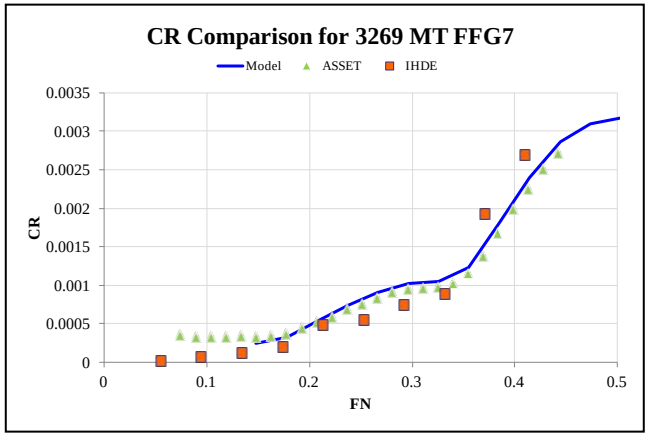


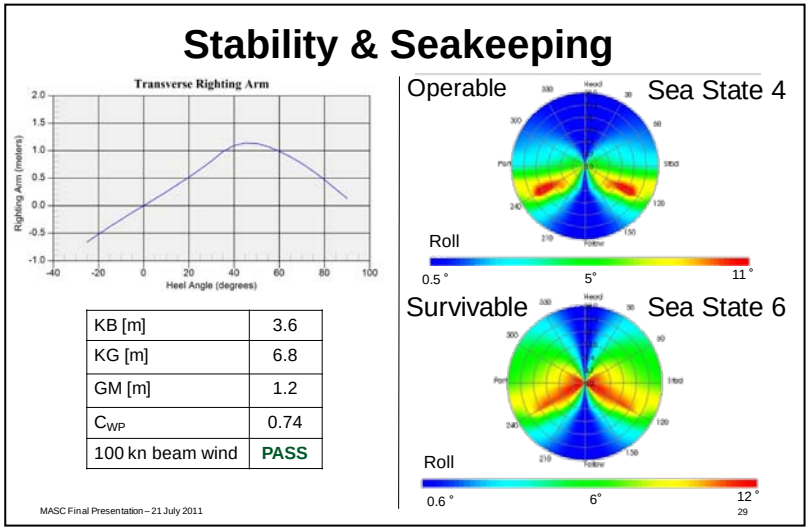
Application of IHDE in FY11-12

- **Medium Affordable Surface Combatant (MASC)**
  - Courtesy of Charles (Henry) Dorger (CISD)
  - IHDE used for resistance assessments as part of ASSET design synthesis process
  - IHDE used to characterize seakeeping behavior (No seakeeping module in ASSET)



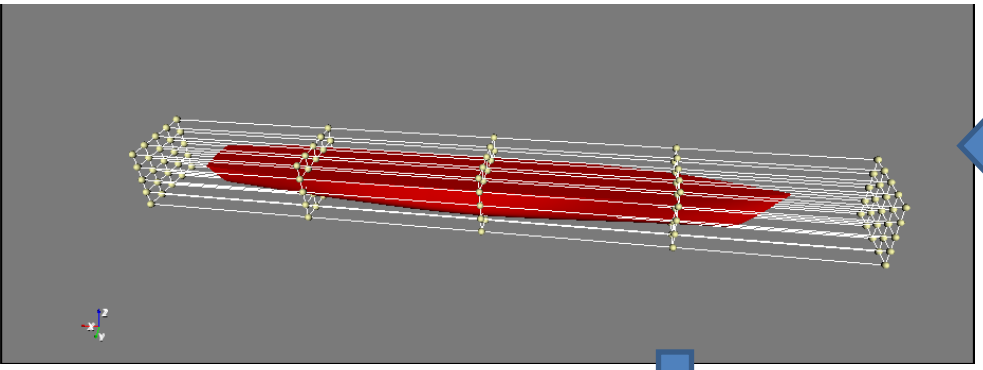


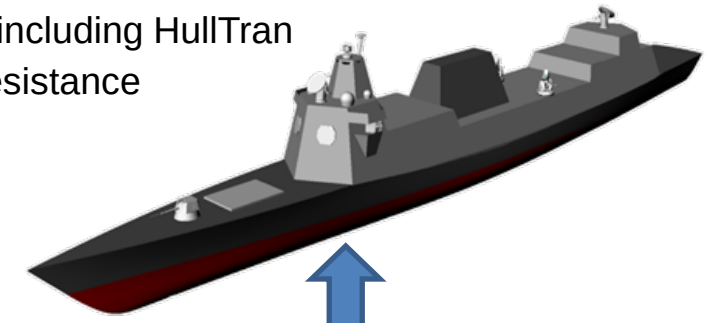


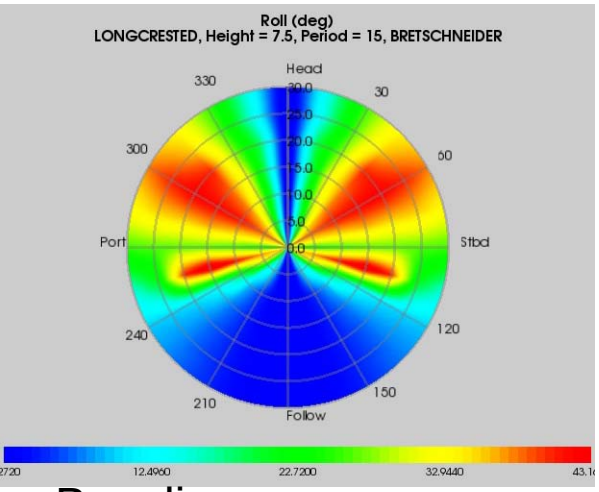


Application of IHDE in FY11-12

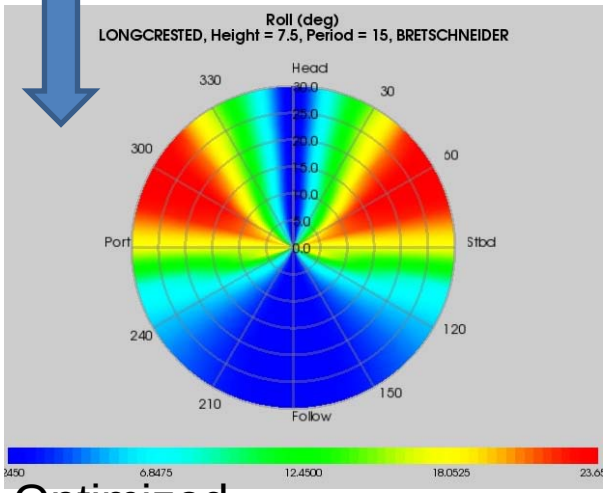
- **Optimization of MASC Design**
  - Used IHDE, ASSET, and Parent Hullform Application (PHA) including HullTran
  - Objective was to improve seakeeping with small impact to resistance
  - Candidate hullforms were ranked based on Bales Index







Baseline

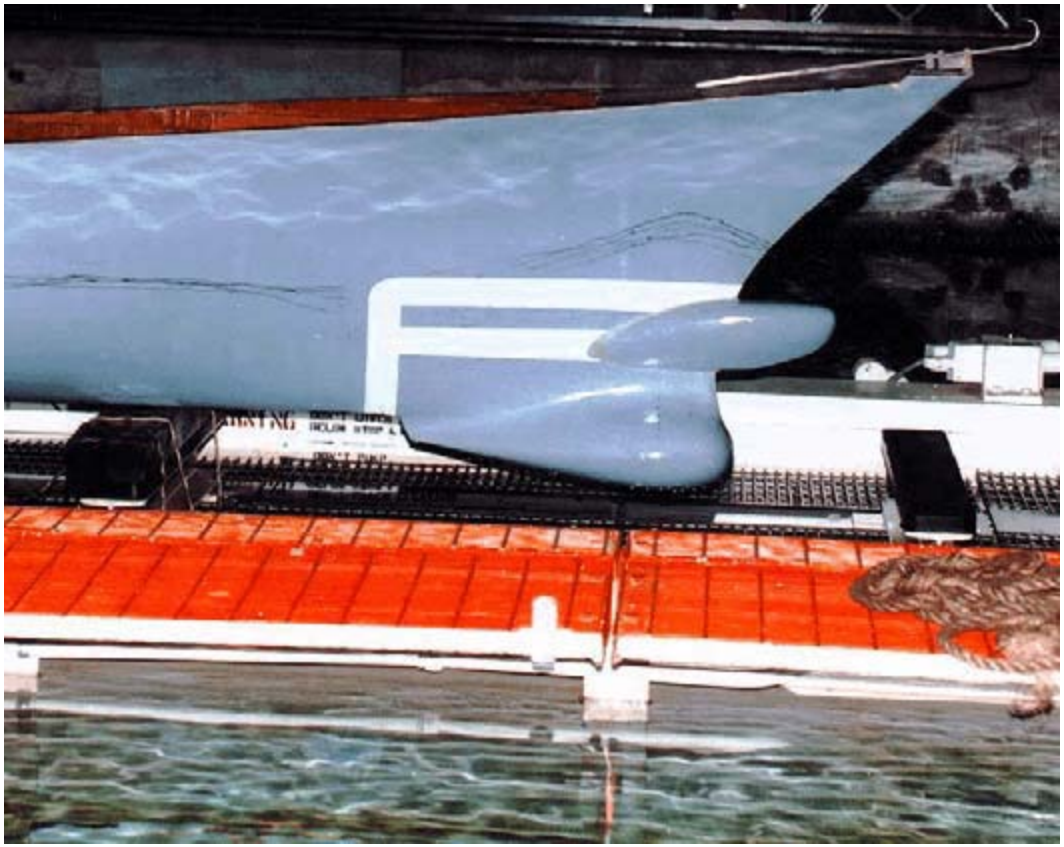


Optimized

Max roll angle decreased by 43%
Max pitch angle decreased by 14%
Significant shift in roll RAO
Small resistance penalty at high Fr
Displacement increased 8%

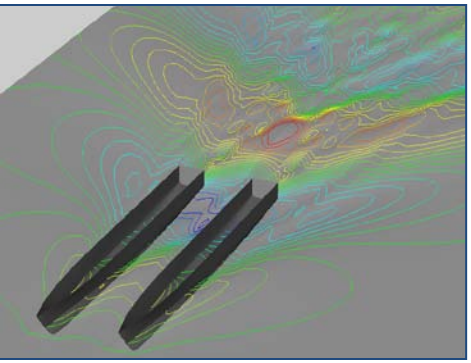
Big improvement in seakeeping with little penalty!

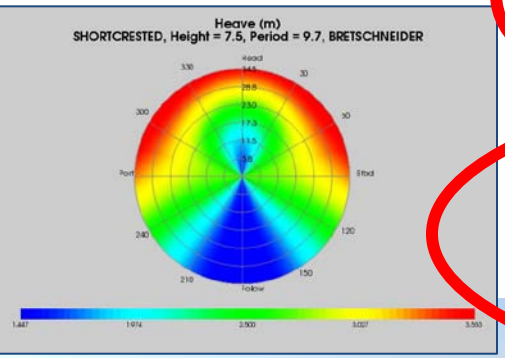
DDG 51 Flight III Bulbous Bow



- **Picture from CRS Report for Congress: "Navy Ship Propulsion Technologies: Options for Reducing Oil Use – Background for Congress," Dec 11, 2006**

Integrated Hydrodynamics Design Environment (IHDE) V3.0





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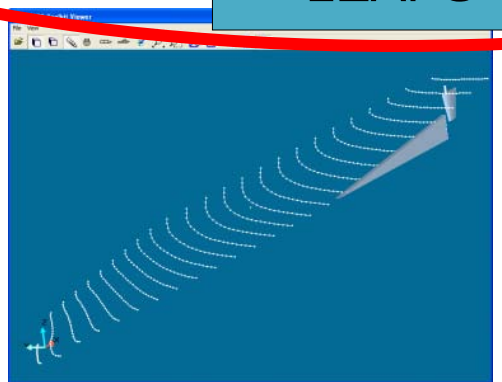
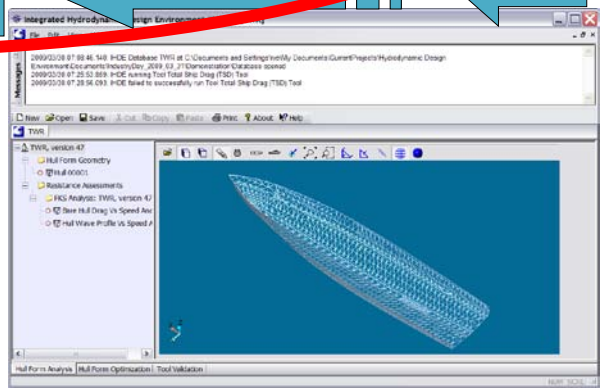


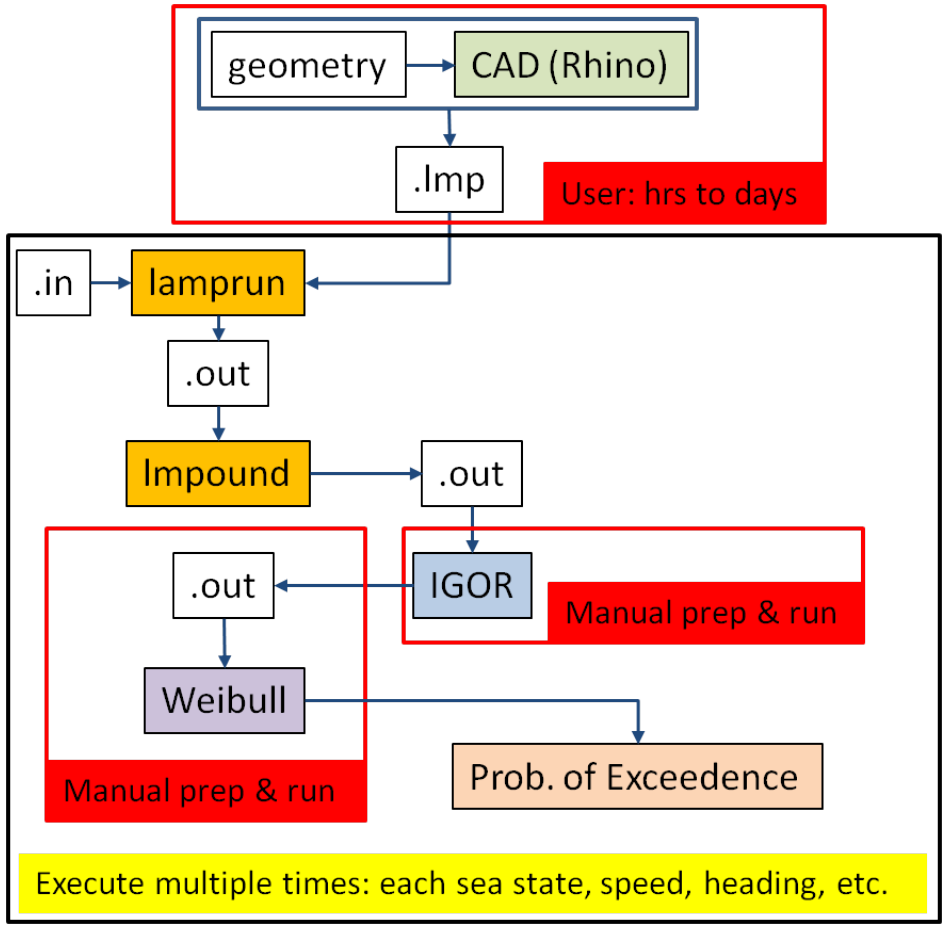


IHDE Current Releases

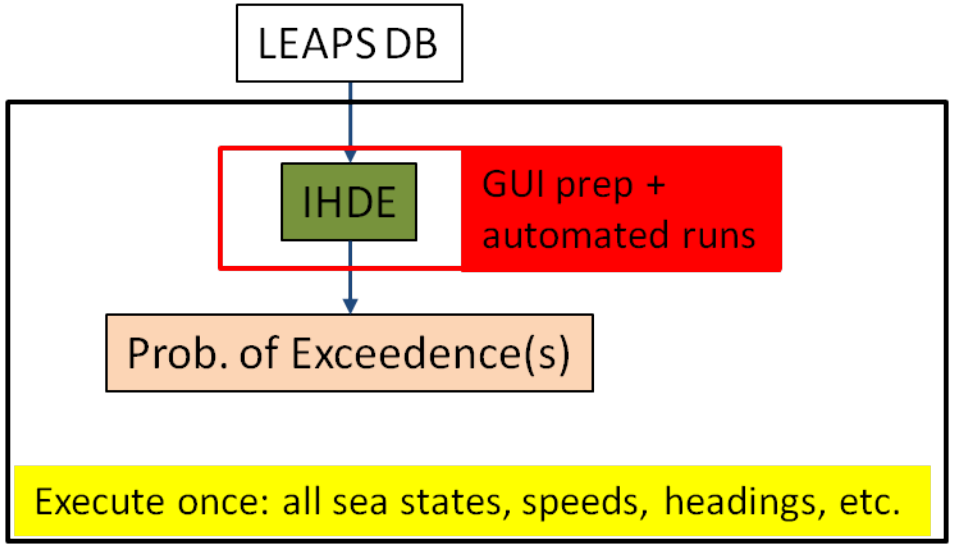
- **Production Release IHDE V3.0 (Dec 2011)**
  - V1.0: Basic Resistance
    - TSD: Total Ship Drag (based on slender ship theory)
  - V2.0: Basic Seakeeping added
    - SMP: Ship Motions Program (frequency domain)
  - V3.0: FY11 additions
    - Basic ship loads capability using LAMP-2: Large Amplitude Motions Program (time domain)
    - Parallel processing capability initiated (ties into Aberdeen Portal)
- **Plans for V4.0 (Dec 2012)**
  - Improved visualization capabilities for decision-making
    - Seakeeping Evaluation Program (SEP)
  - Improved capability for resistance
    - Das Boot (parallel processing desired; e.g. speeds x drafts)
- **Future versions**
  - Improved prediction capabilities (codes under consideration)
    - AEGIR
    - TEMPEST
    - NavyFOAM
  - Shape Optimization

Example: Improved Process for Running Large Amplitude Motions Program (LAMP)

Previous Process



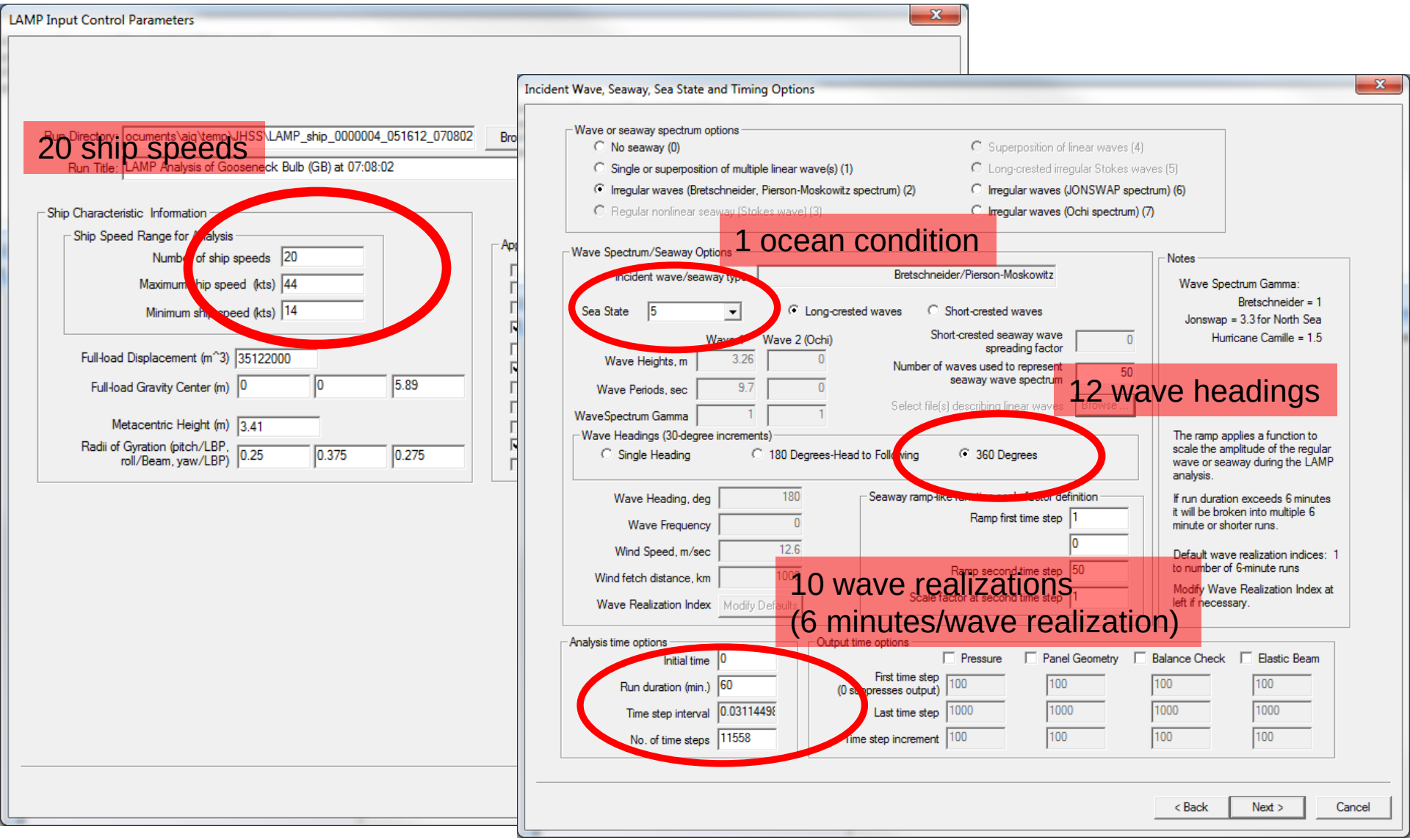
IHDE Process



Significant time savings

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

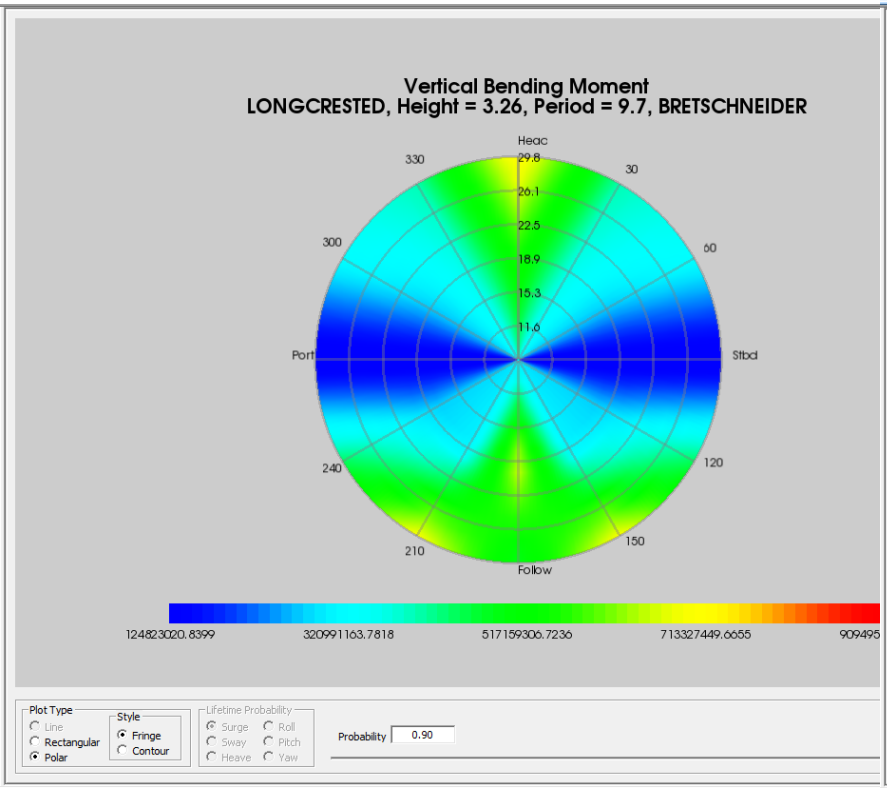
IHDE Input Screens: LAMP



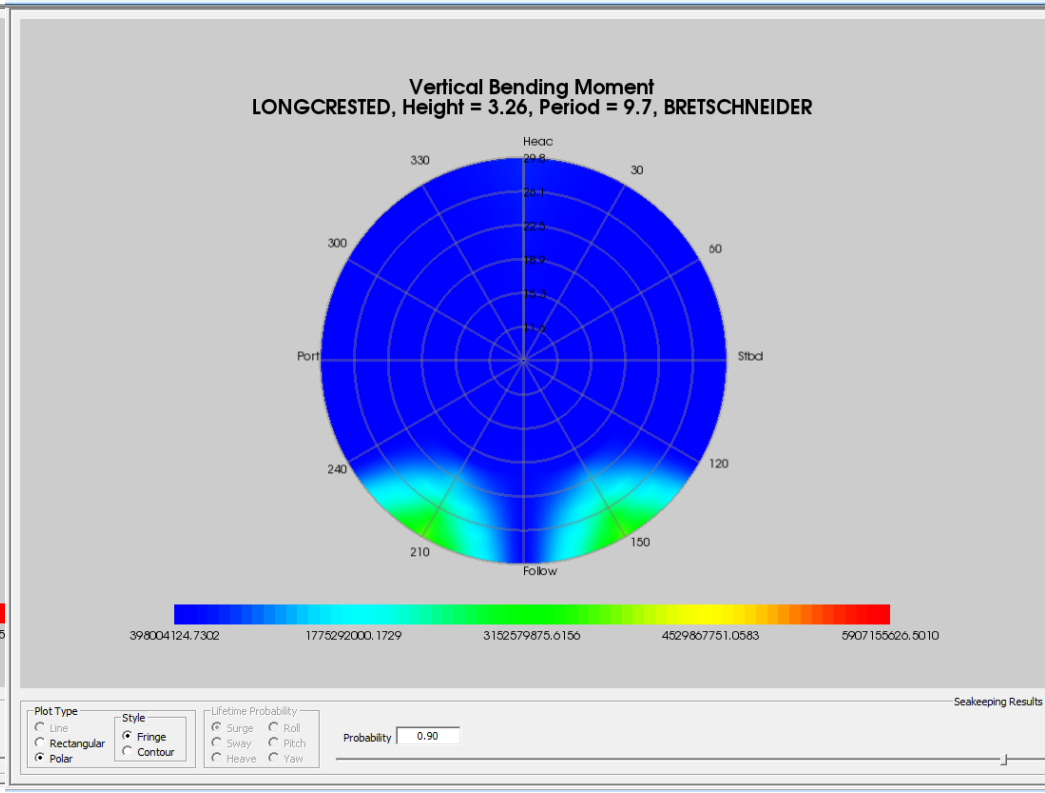
- **Number of runs = #speeds X #wave headings X #wave realizations**
- **= 20 X 12 X 10 = 2400 (want to run in parallel → Aberdeen Portal)**

Lifetime 90% Non-exceedence Bending Moment

Hogging Bending Moment

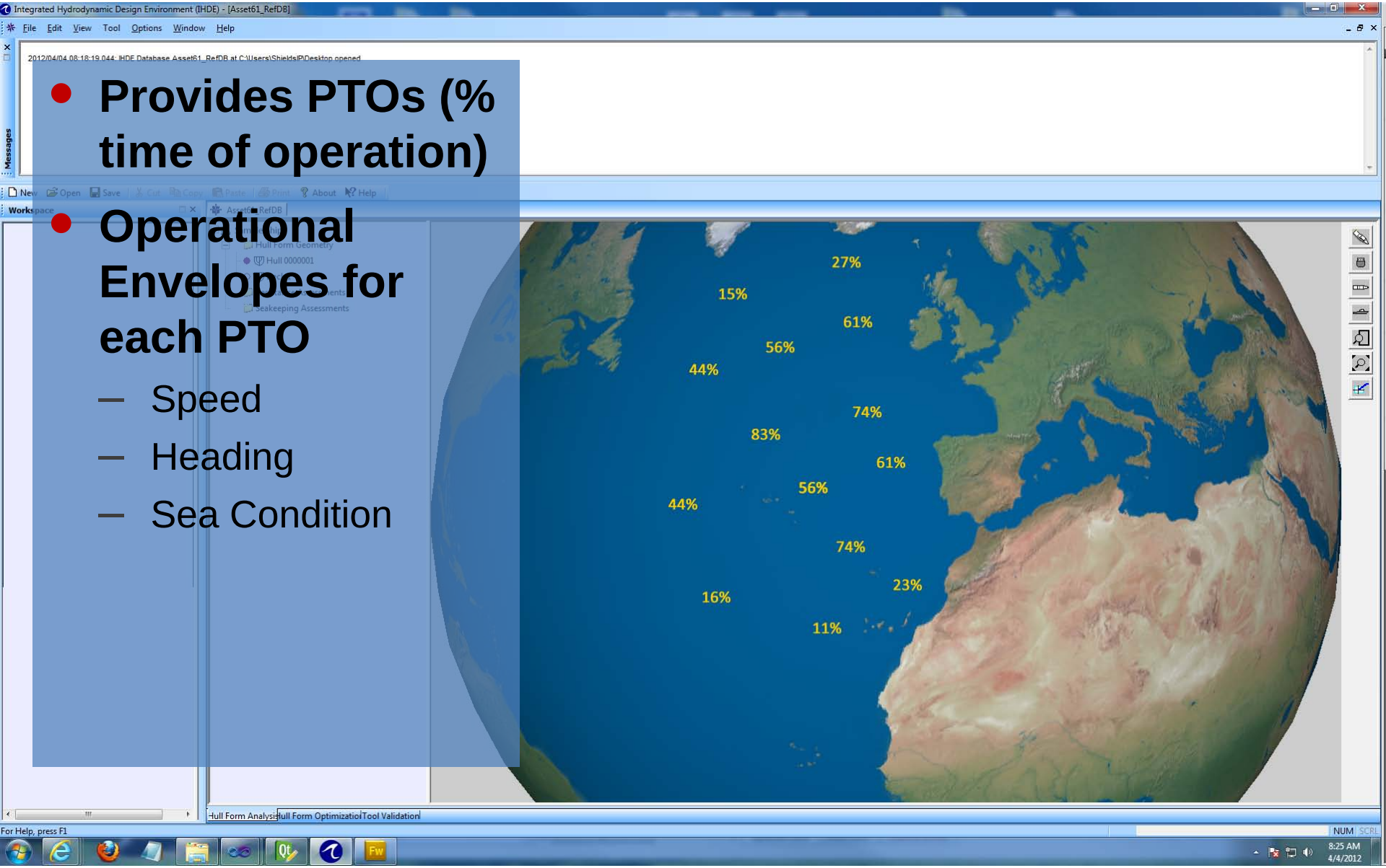


Sagging Bending Moment



Notional Implementation of Seakeeping Evaluation Program (SEP): FY12 IHDE Effort

- **Provides PTOs (% time of operation)**
- **Operational Envelopes for each PTO**
  - Speed
  - Heading
  - Sea Condition



How do I get IHDE?

- **Government employees and contractors may request access through CREATE portal website:**

https://portal.create.hpc.mil

Wrap-up

- Usability is key in IHDE!
- Impacts in ship design require tools that are robust and easy to use to avoid costly delays
- Already we are demonstrating how IHDE can help ship design agents and naval architects make more informed decisions about ship concepts at an early stage
- As we extend the capabilities available in IHDE we will continue to stress usability