

Rational Structural Dynamic Loads for Optimum High-Speed Multi-Hull Ship Designs

CDI Marine – Systems Development Division

1st Quarter Review

6 June 2007

Scope

“Develop a first-principle cost-effective rational method and associated prediction program to determine structural loads for high-performance vessels”

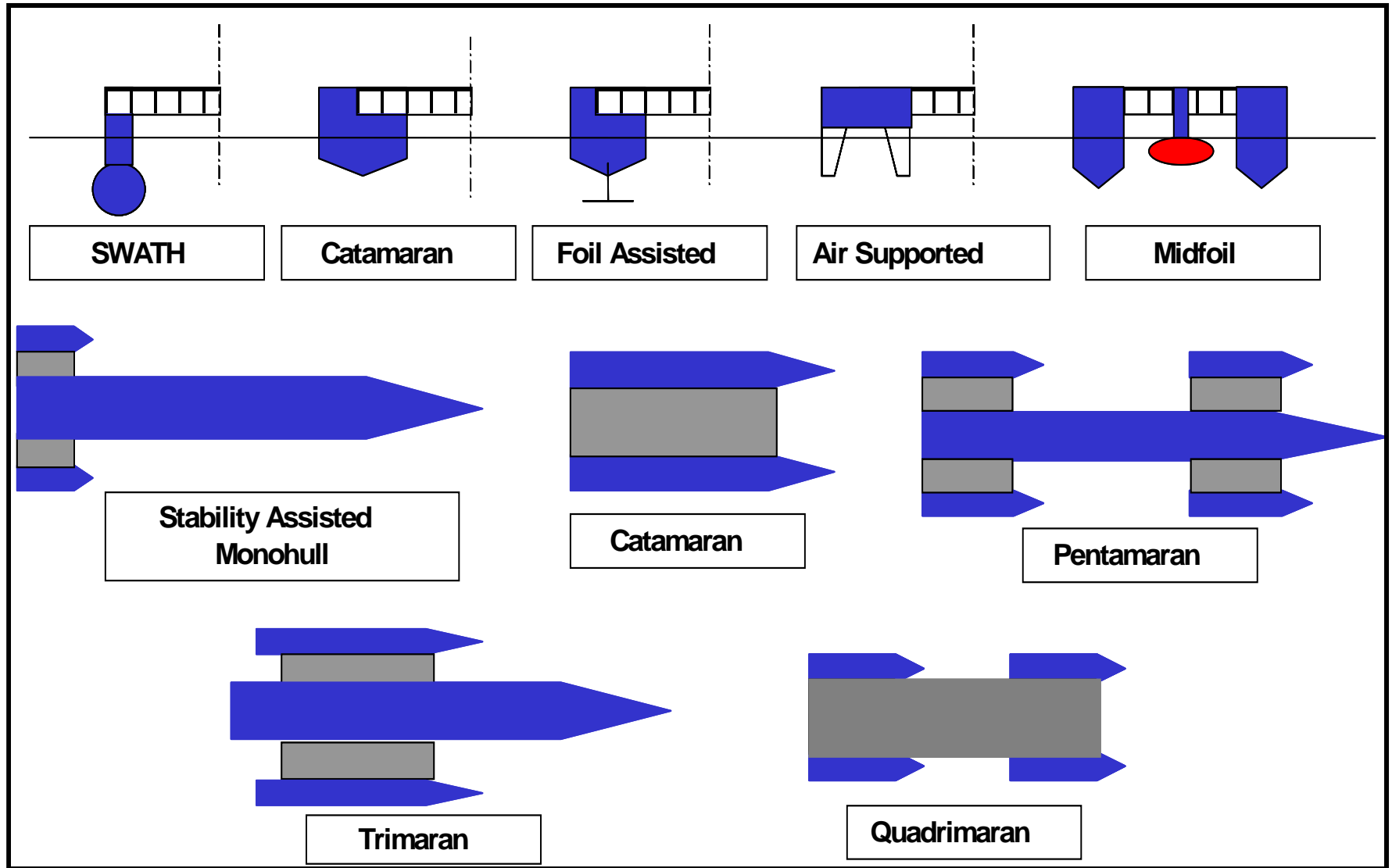
Need Statement For High Speed Transport

Multihulls emerging as preferred hullforms for many commercial applications, in addition to high speed inter- and intra-theater sealift for naval applications

- Novel Hullforms being Evaluated by DOD and International Community
- Operational Requirements such as increasing speed and range capabilities require reductions in structural weight
- Advanced (high-speed) hullforms sensitive to weight

NEED TOOLS TO DESIGN OPTIMAL STRUCTURAL SCANTLINGS TO SATISFY SAFETY REQUIREMENTS & MEET MISSION NEEDS

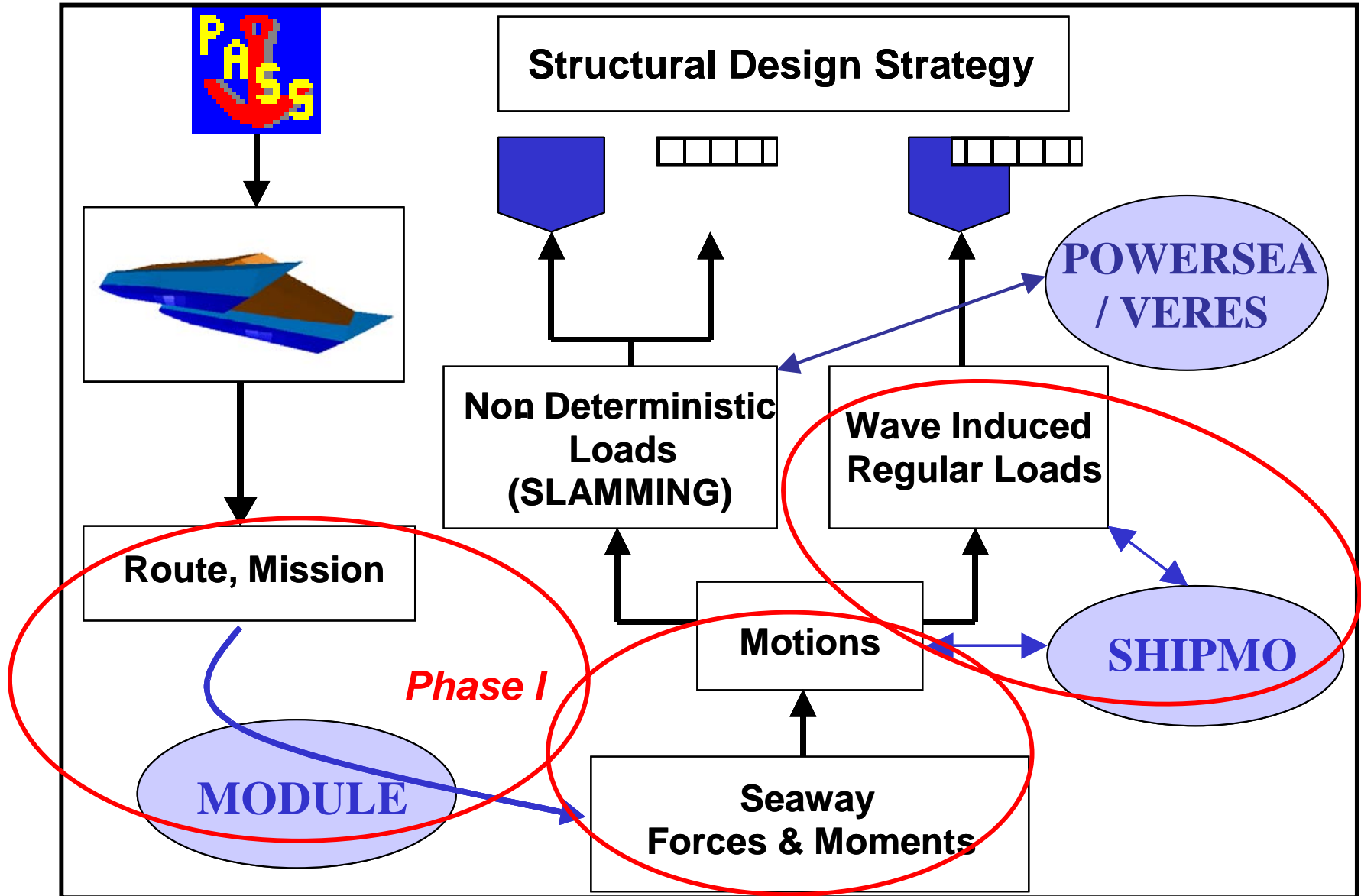
High-performance Novel Hullforms



Overall Program Overview

- Funded by CCDoTT – Phased Development
- Phase I – *a frequency-domain ship motion and loads model, incorporating a route-based mission profile module to provide a description of the ships' overall lifetime loads*
- Phase II – *a time-domain slamming loads prediction model to estimate extreme loads*
- Phase III – *validation of the complete integrated prediction tool using existing experimental and sea-trial data*

Overall Approach





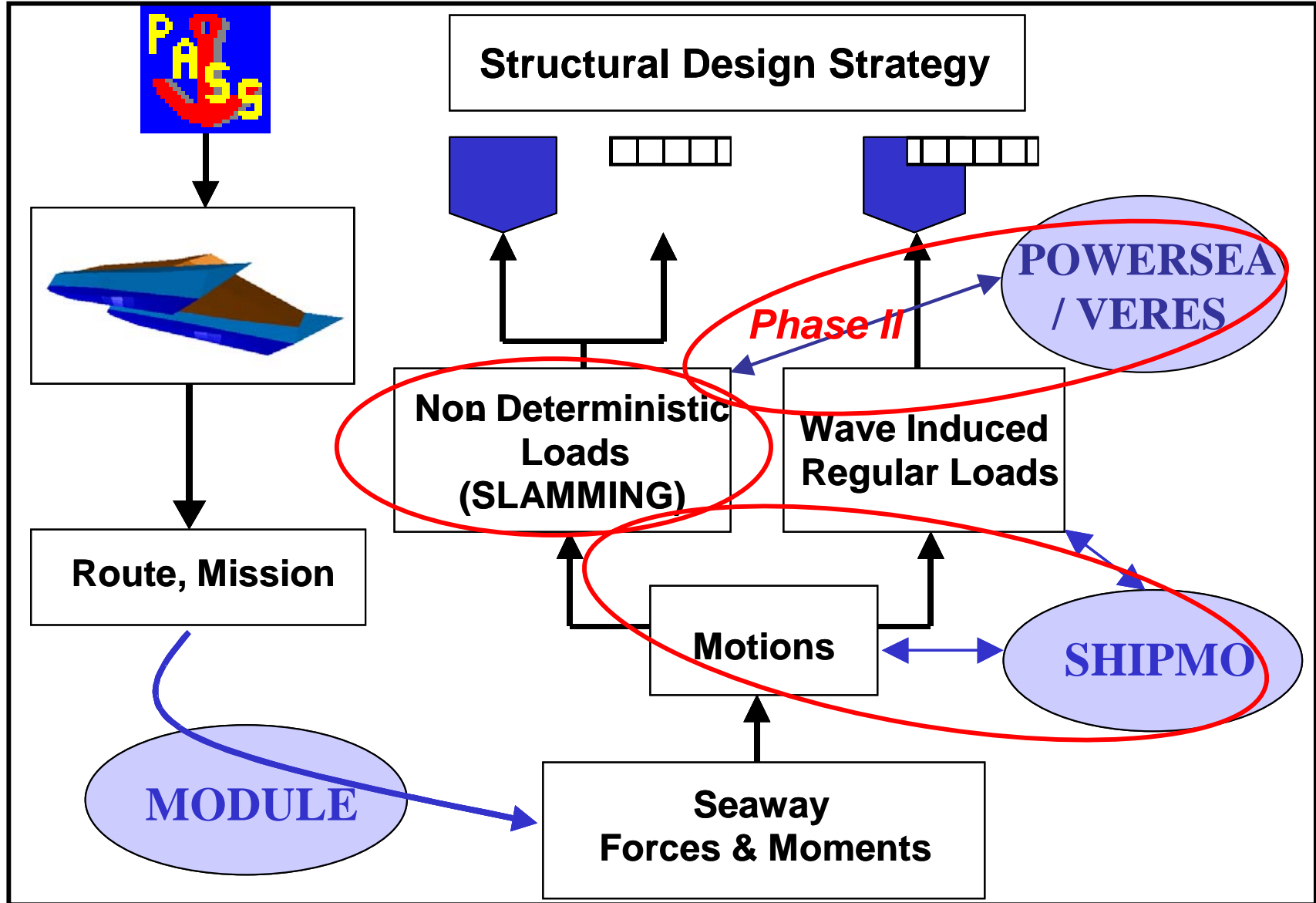
Phase I – Accomplished (2002)

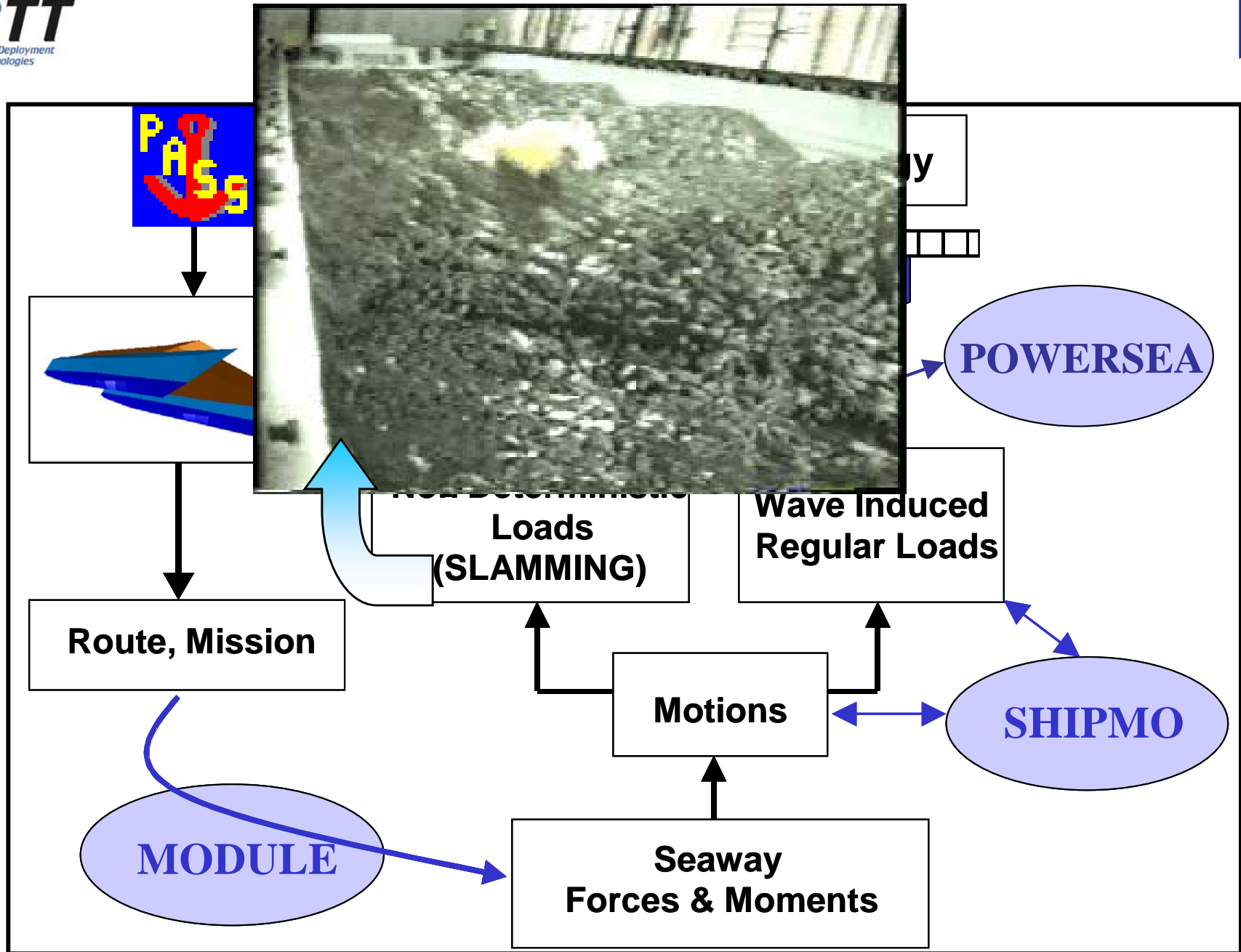
Developed an overall working model of a Frequency-Domain ship motion and loads prediction, incorporating a Route-Based Mission Profile module to provide a description of the ships' overall lifetime loads

Phase II Objective

Complete the ultimate load model and the structural design model developed in Phase-I by including the prediction of slamming and impact loads, along with validation, for high-speed multi-hulls structures

Overall Approach





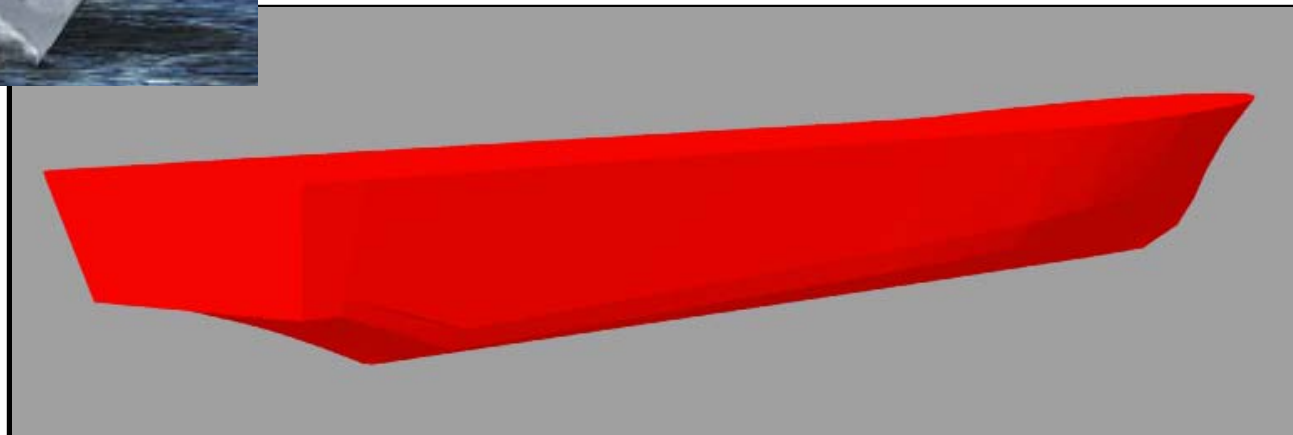
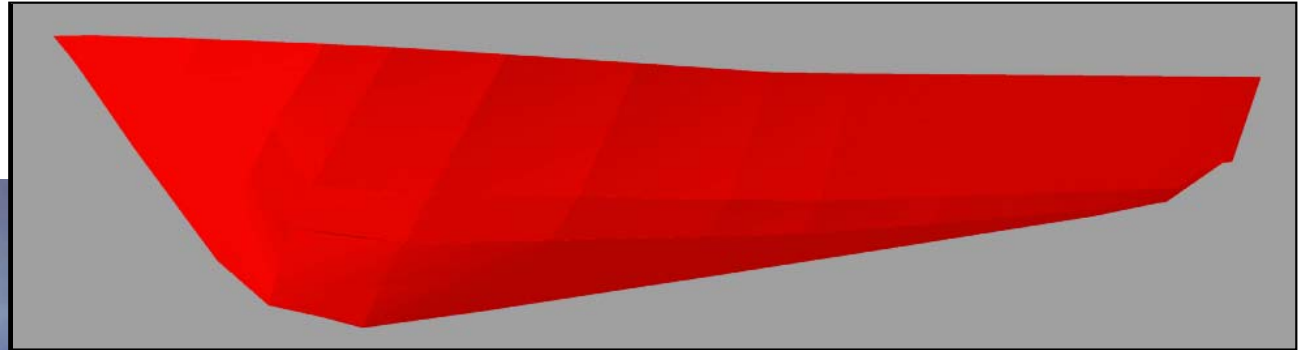
Program Area “High-Speed Sealift”

High-Speed Hullforms -- Selected

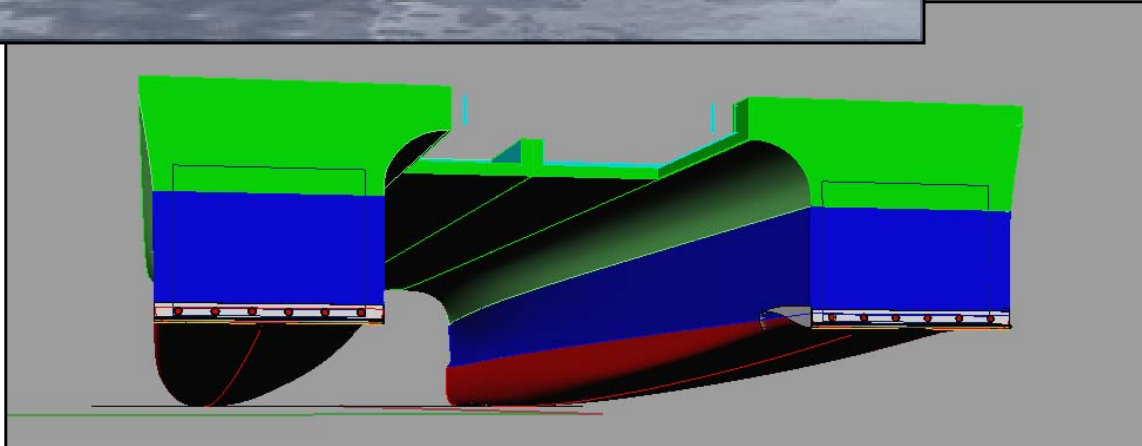
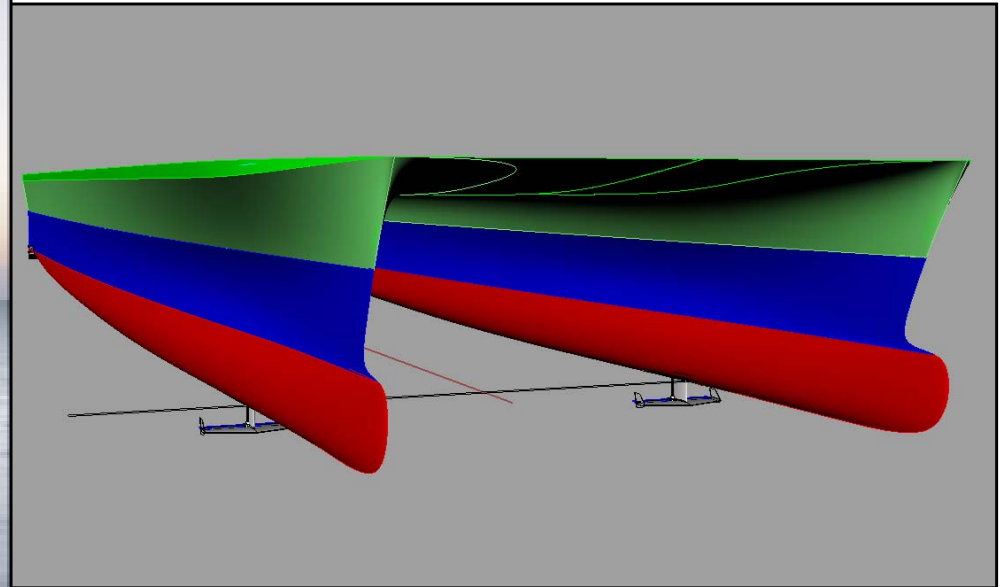
Ships Principal Characteristics

		Deep-V	Catamaran	Trimaran	
Length at Waterline	LWL	100.2	76.0	121.2	m
Length Overall	LOA	115.6	78.4	127.1	m
Beam at Waterline	BWL	13.7	21.1	10.9	m
Beam Overall	BOA	17.5	22.0	30.4	m
Draft - Design	DWL	3.3	3.5	4.5	m
Depth	Depth	10.0	7.8	8.7	m
Displacement	Δ	2,315	950	3,201	MT
Block Coefficient	C _b	0.547	0.735	0.629	

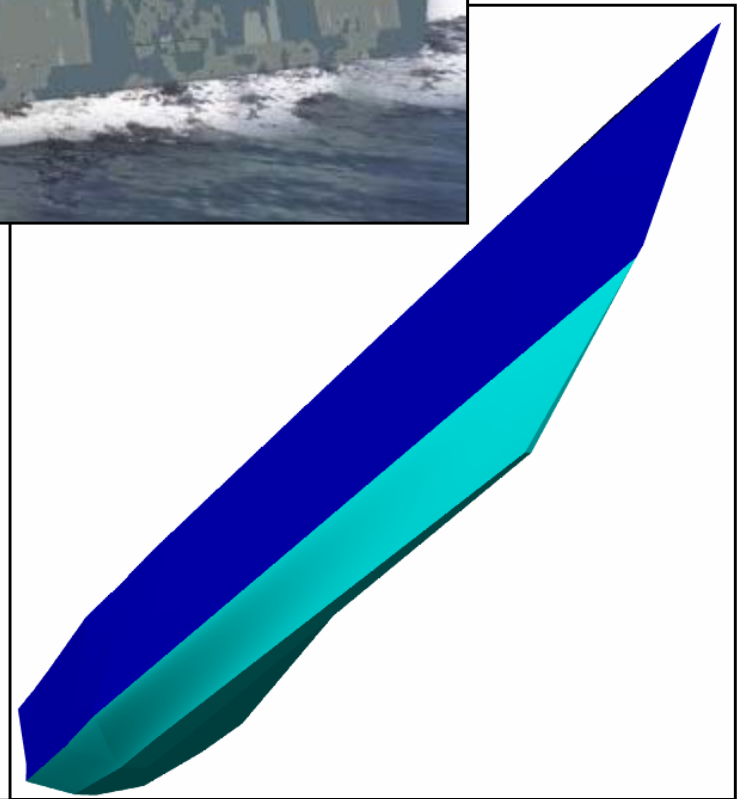
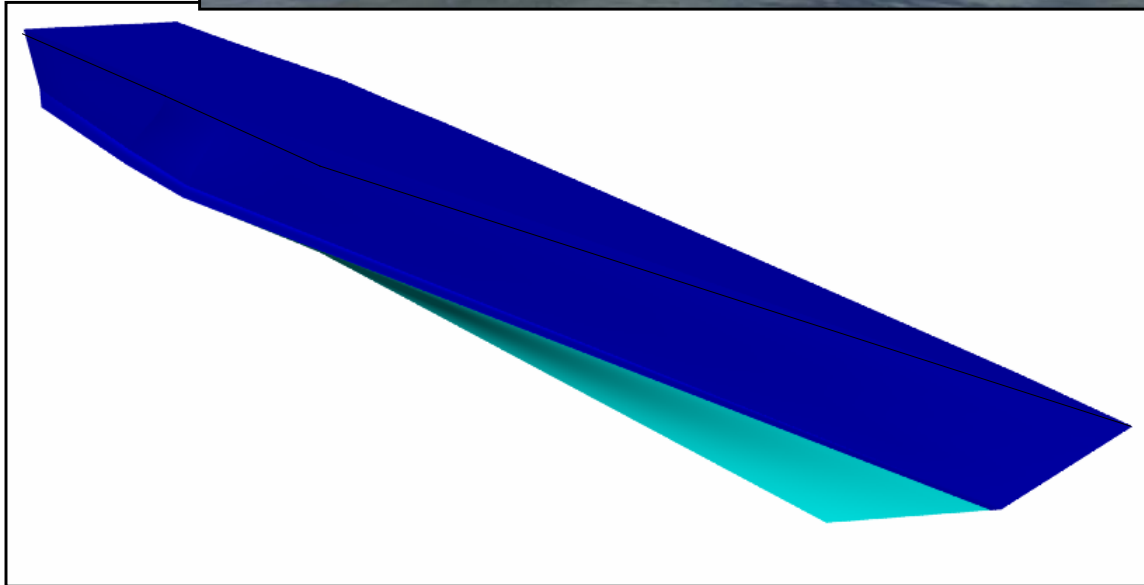
Deep-V Monohull (LCS-LM) modeled in SHIPMO



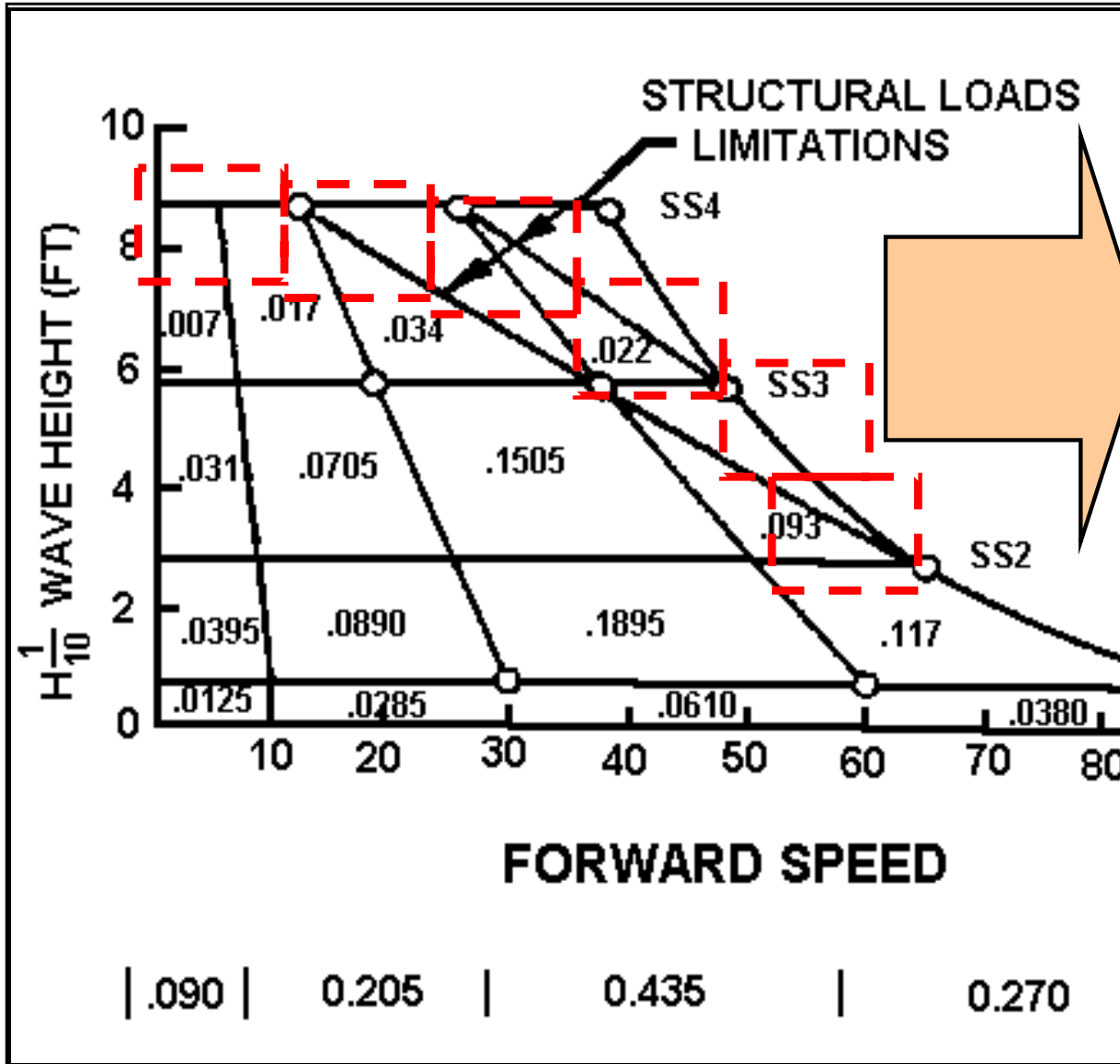
Catamaran Hullform (X-Craft) modeled in SHIPMO



Trimaran Hullform (LCS-GD) modeled in SHIPMO



Slam Event Determination -- Illustration



- Determine the Environmental & Operational Elements for Slam
- Develop short-term statistics for motions for these Env./Op. cells
- Input to Time-Domain Code for Slam Pressure calc.



Preliminary Slam Prediction

➤ Route & Mission Cells of Interest – Catamaran

Significant Vertical Motion

	Speed	5 kts		10 kts		15 kts		20 kts		30 kts		40 kts
	Heading	0	30	0	30	0	30	0	30	0	30	60
Sea State	4				6.45						3.88	4.91
	5			5.26	10.3			10.4	5.89	7.36	6.53	
	6			10	6.83	11.9	8.24	11.1	7.59			
	7	7.55	7.37	9.86	11.6	15.7	11.2					

Significant Vertical Velocity

	Speed	5 kts		10 kts		15 kts		20 kts		30 kts		40 kts
	Heading	0	30	0	30	0	30	0	30	0	30	60
Sea State	4				8.65						6.37	8.06
	5			6.52	13.5			14	7.76	11.5	9.33	
	6			13	8.07	15.4	10.5	14.9	9.63			
	7	7.48	6.76	11.3	13.8	19.9	13.4					

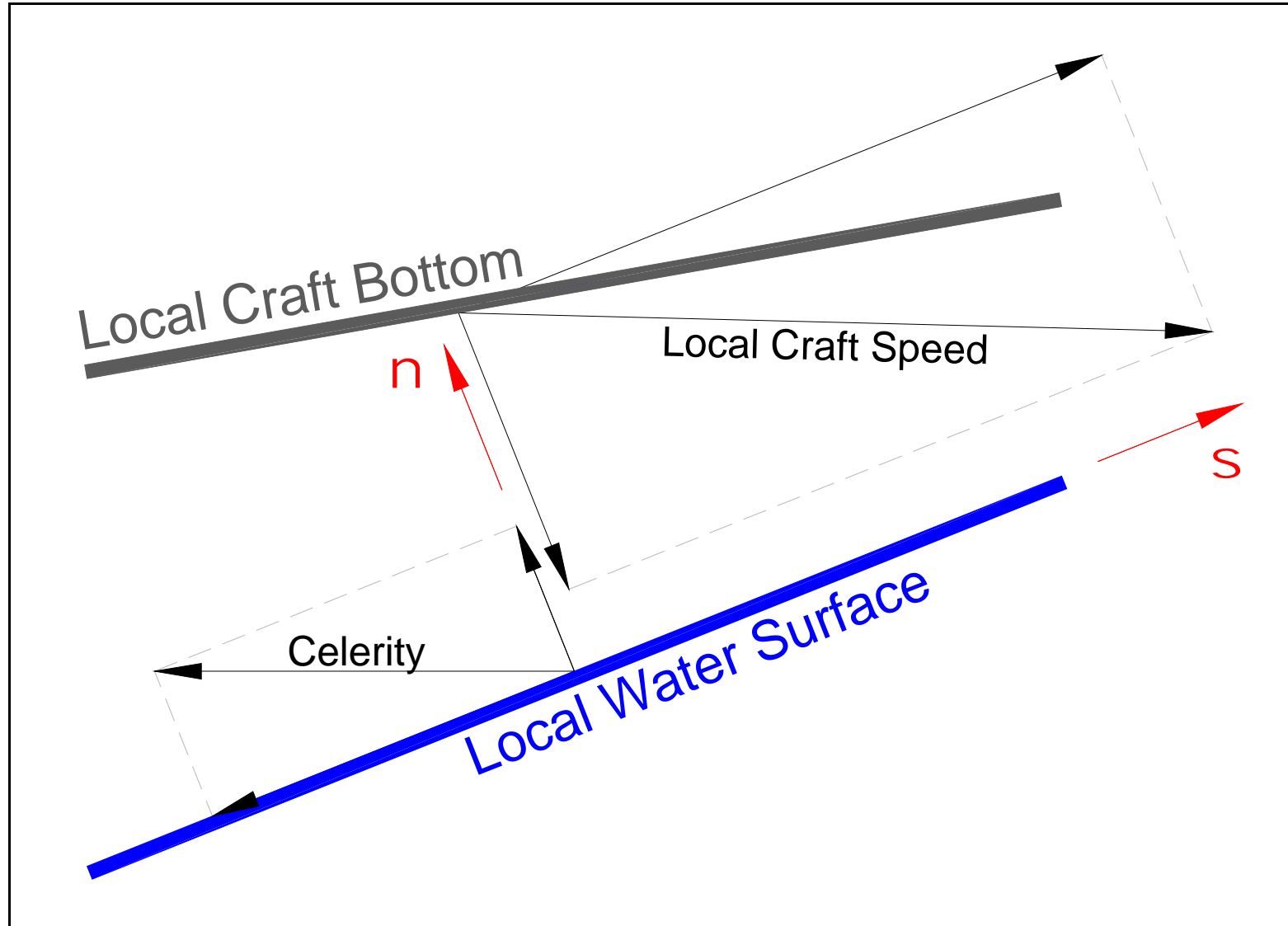
Significant Vertical Acceleration

	Speed	5 kts		10 kts		15 kts		20 kts		30 kts		40 kts
	Heading	0	30	0	30	0	30	0	30	0	30	60
Sea State	4				11.7						10.5	13.3
	5			8.39	17.9			19	10.7	18.3	13.9	
	6			17.1	10.1	20.2	13.9	20.4	12.9			
	7	8.79	7.47	14.1	17.6	26.2	17.3					

Slam Load Prediction Module

- **A Hierarchical Approach to Achieve Reasonable Accuracy with Fast Turnaround Time**
 - Route/Mission Cells from SHIPMO – Slamming likely to occur
 - Time Domain Strip Theory Code – Select Simulations
 - Time History of Ship Motions
 - Emergence and Reentry of Points of Interest
 - Wave Heights – Linear combinations of wave spectrum components
 - Slam Pressure Algorithms
 - Using output of the Time Domain Code and geometric information
 - Geometry in the form of Stereo Lithography (STL) file

Slam Pressure – Illustration



Phase 2 B – Effort

- Develop Time-Domain Motion and Slamming Loads Prediction Program
- Integrate the Frequency-Domain Program with the Time-Domain and Slamming Loads Program
- Predict Short-term and Long-term Estimates of Slam Load and perform some Preliminary Verification
- Continue Collaboration with NSWCCD & ABS for comments & feedback and for extensive verification during follow-on phase

Time Domain Codes

- CFD Codes (RANS) – *Fluent, CFX*, etc.
- 3-D Potential Flow Codes – *LAMP, SWAN, Trident*, etc.
- 2-D Strip Theory Codes – *PowerSea, VERES*, etc.
- Reasonable compromise between the speed of Frequency Domain Codes and accuracy of CFD/3-D Potential Flow codes for limited number of runs
- *PowerSea* used during Phase II-A
- *VERES* to be used in the current phase

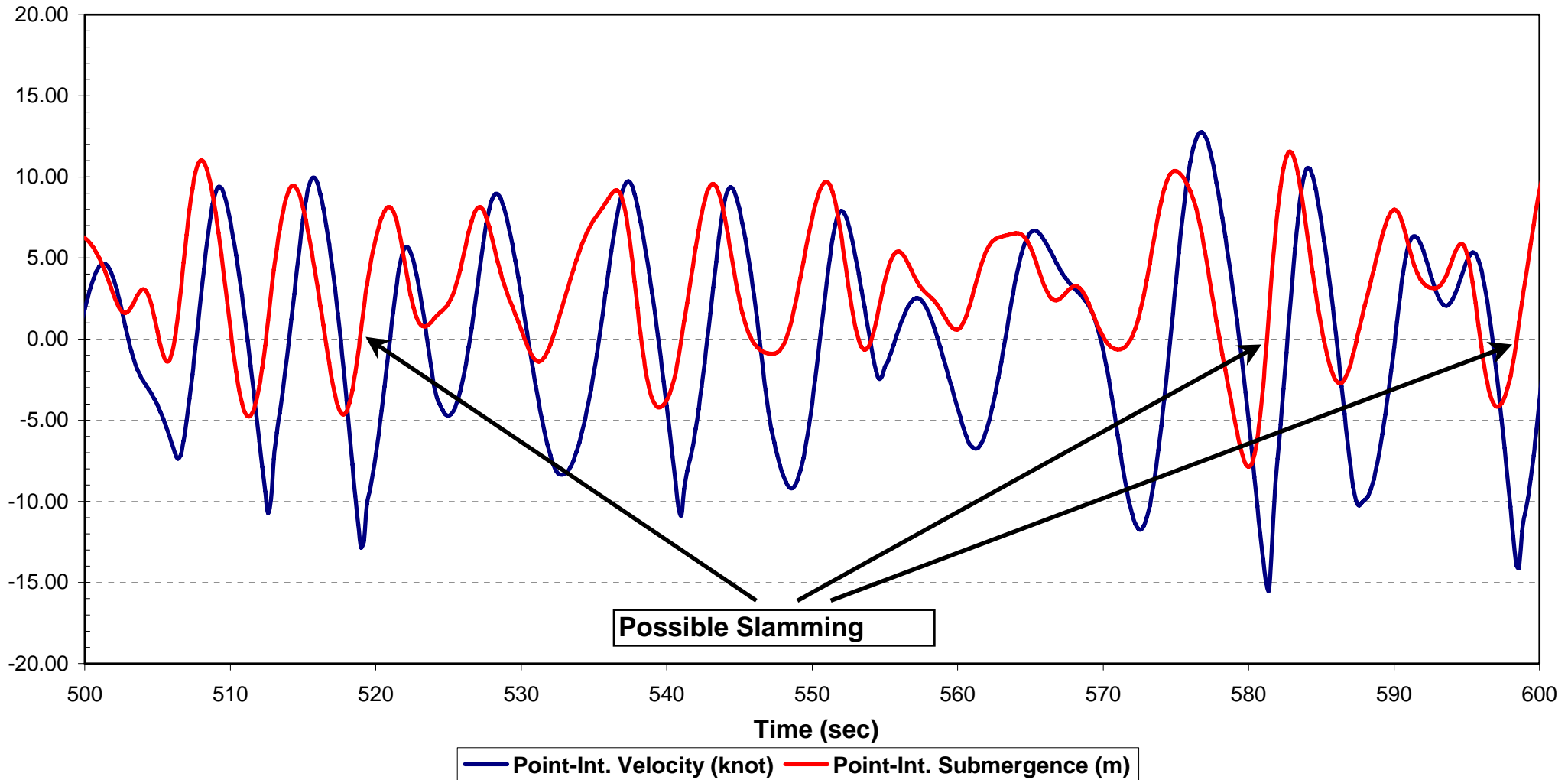
Slam Pressure Module - Methodology

For each time-step of motion history →

- Determine if the Point-of-Interest has emerged and reentered & if Relative Velocity exceeds threshold for slamming
- If both above conditions are true: For each panel in the STL file near Point-of-Interest
 - Calculate Relative Hull/Wave Velocity vector normal to panel
 - Calculate Wave Velocity vector normal to wave surface
 - Based on Angle between the vectors, use Coefficients in Chuang, et-al to determine Slam Pressure
- From determined pressures, Forces can be calculated for regions of hull – Bow, Cross-Structure, etc.

Time Domain Response

Deep-V Monohull (SS-7, Head Seas, 15 kts)
Dynamic Response





Potential Partners & End-Users

NAVSEA

ONR

NSWC

Classification Societies – ABS, DnV, etc

Commercial Interests – Ferries, Short-Sea Shipping, etc.

USCG

MSC

SOCOM

TACOM

USADCSLOG