FMC EnergySystems

SOFEC

Terra Nova FPSO: Integration of Model Tests and Global Analysis

Arun S. Duggal
Caspar N. Heyl
Peter F. Poranski

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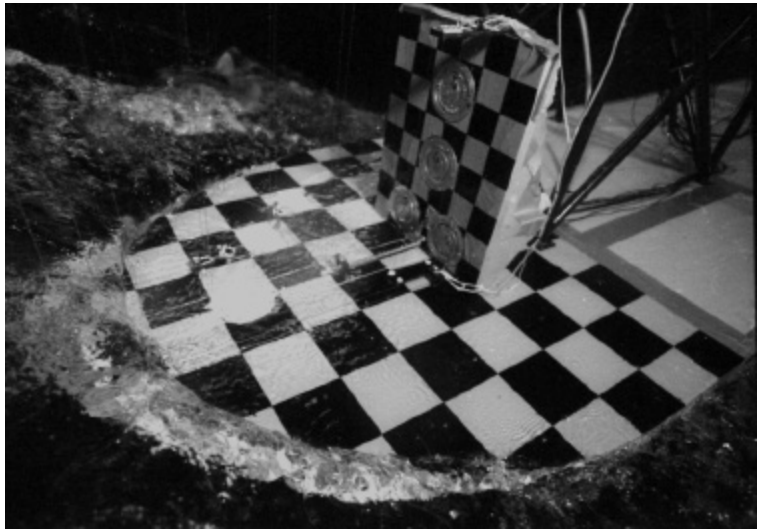
terra nova

Why Model Test?

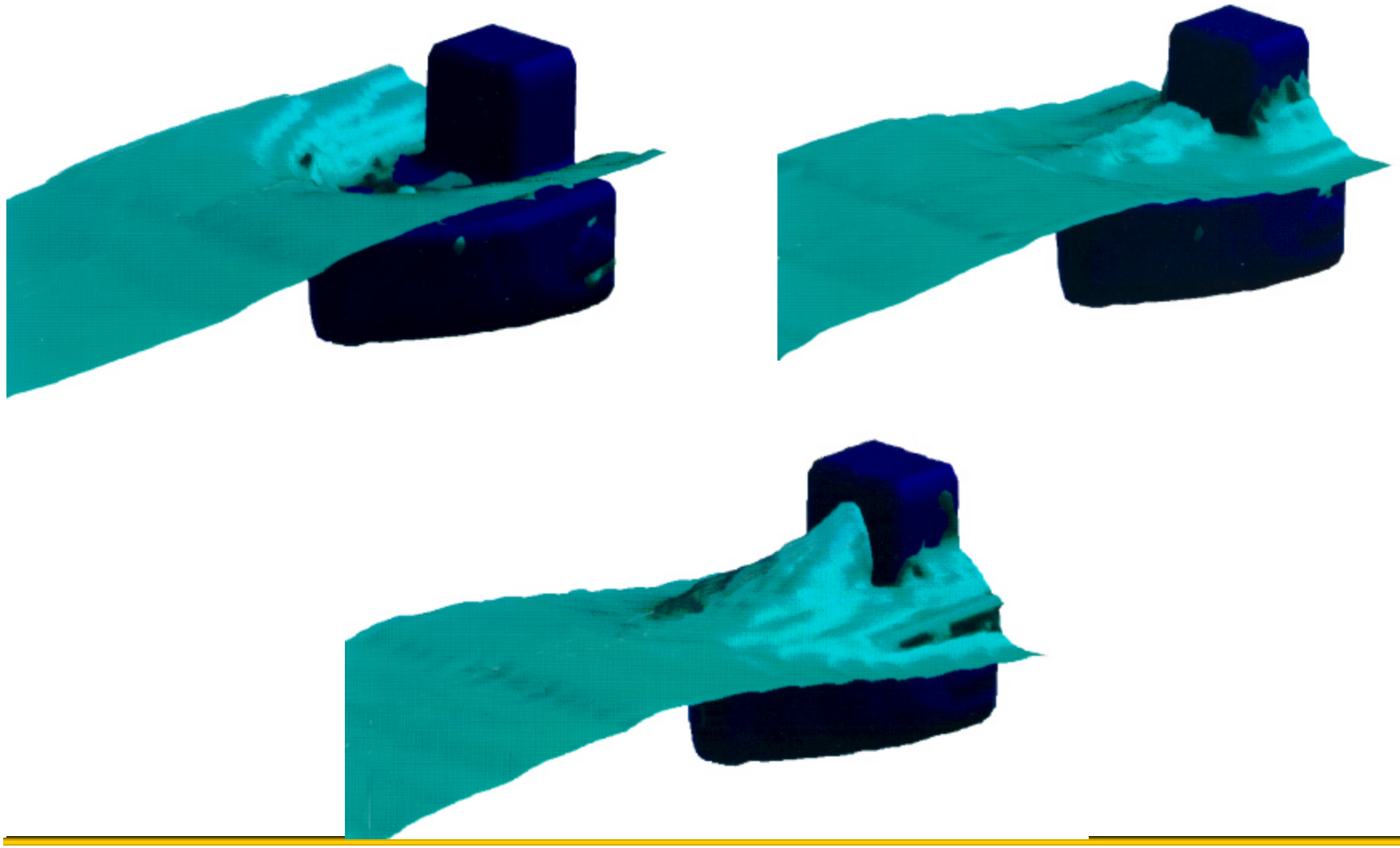
- Input data for global analysis: wind & current coefficients
- Concept development and evaluation
- Provide an independent verification of the system global analysis:
  - vessel motions & offsets, line tensions, turret-vessel loads, etc.
  - DP- thruster system performance
  - installation engineering
- Study & analyze phenomena that are difficult to model analytically or numerically
  - green water & slamming
  - pack ice and iceberg loads
  - multi-body dynamics: offloading to shuttle tankers

Green Water & Slamming

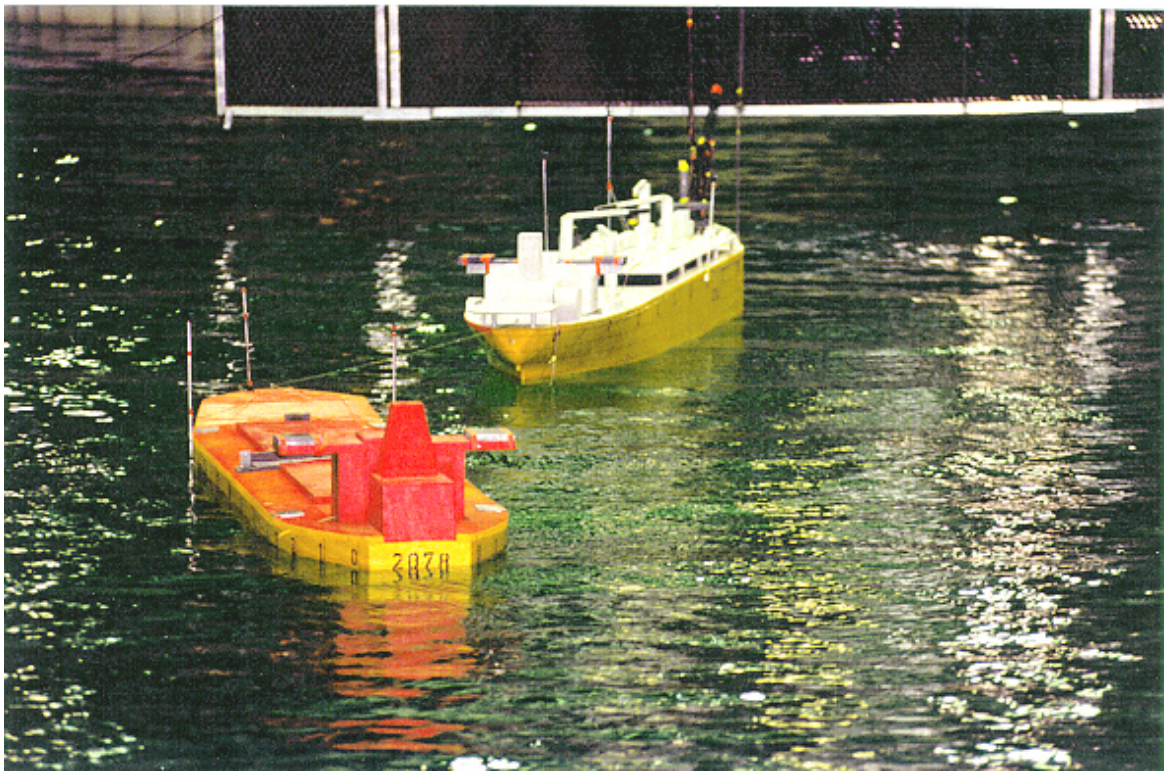
Green Water: Model Tests



Green Water: Numerical Simulations



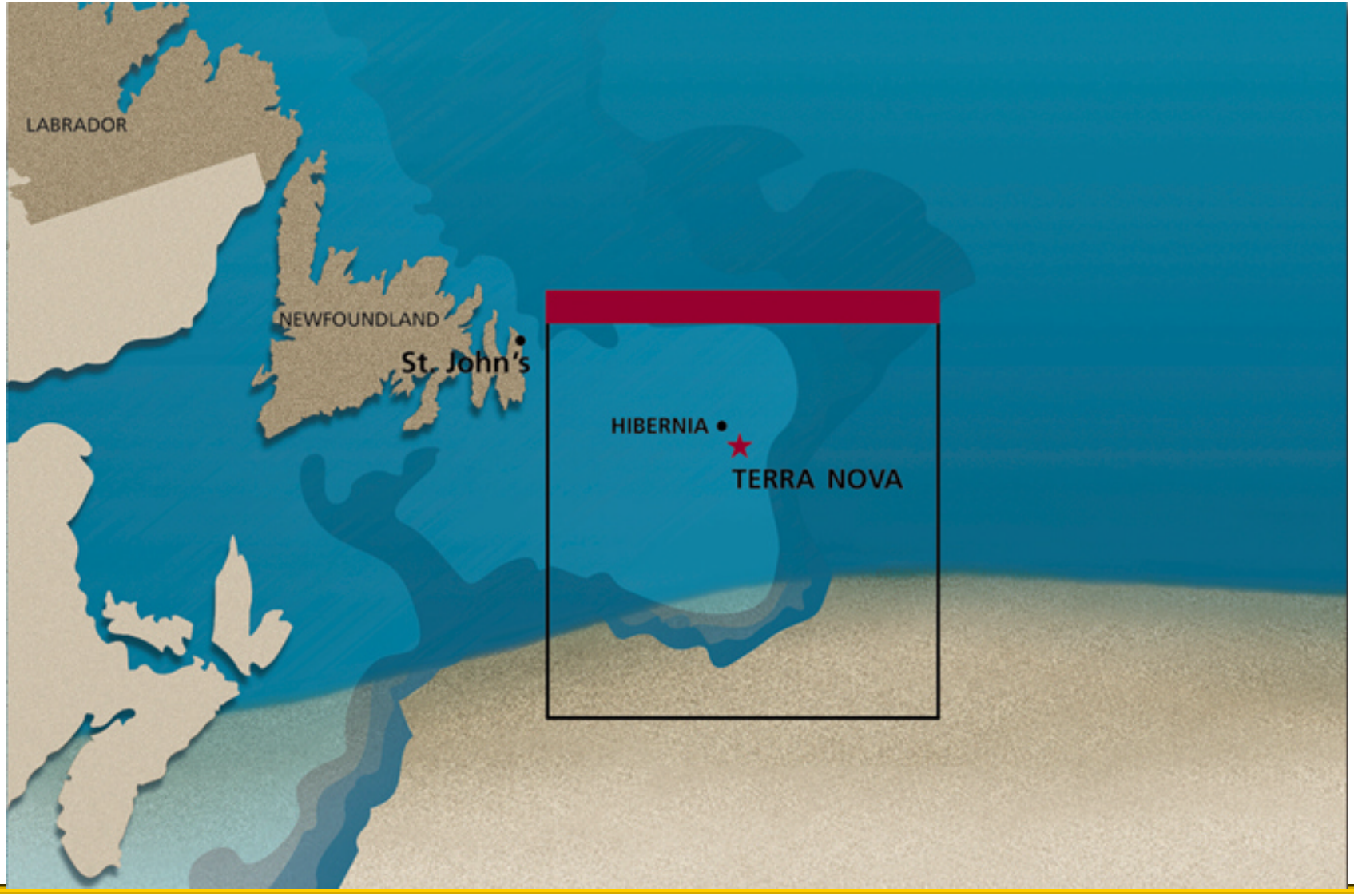
Tandem Offloading: Fishtailing



Station Keeping Design Basis

- FPSO located on the Grand Banks - one of the most severe design environments in the world
- FPSO to stay on station during the 100-year storm
- FPSO to disconnect from mooring and risers to avoid icebergs and pack-ice
  - controlled disconnect in 4 hours
  - emergency disconnect in 15 minutes
  - re-connect to mooring & riser system without assistance
- 19 risers and umbilicals
- 25 year design life

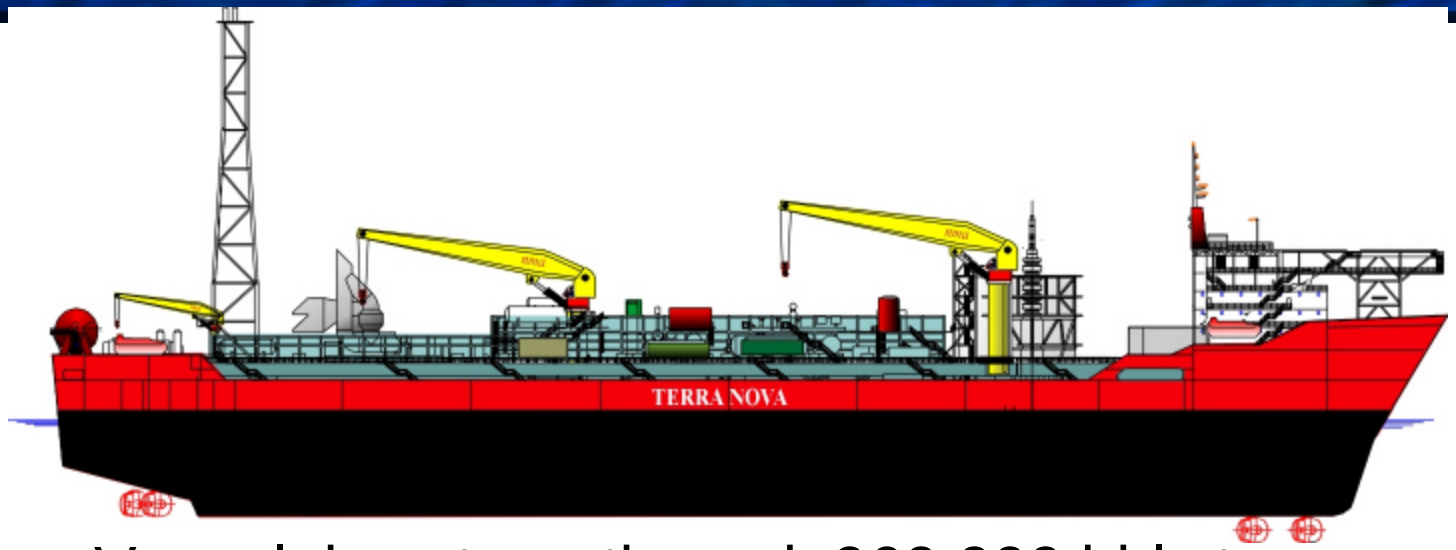
The Grand Banks



Design Environment

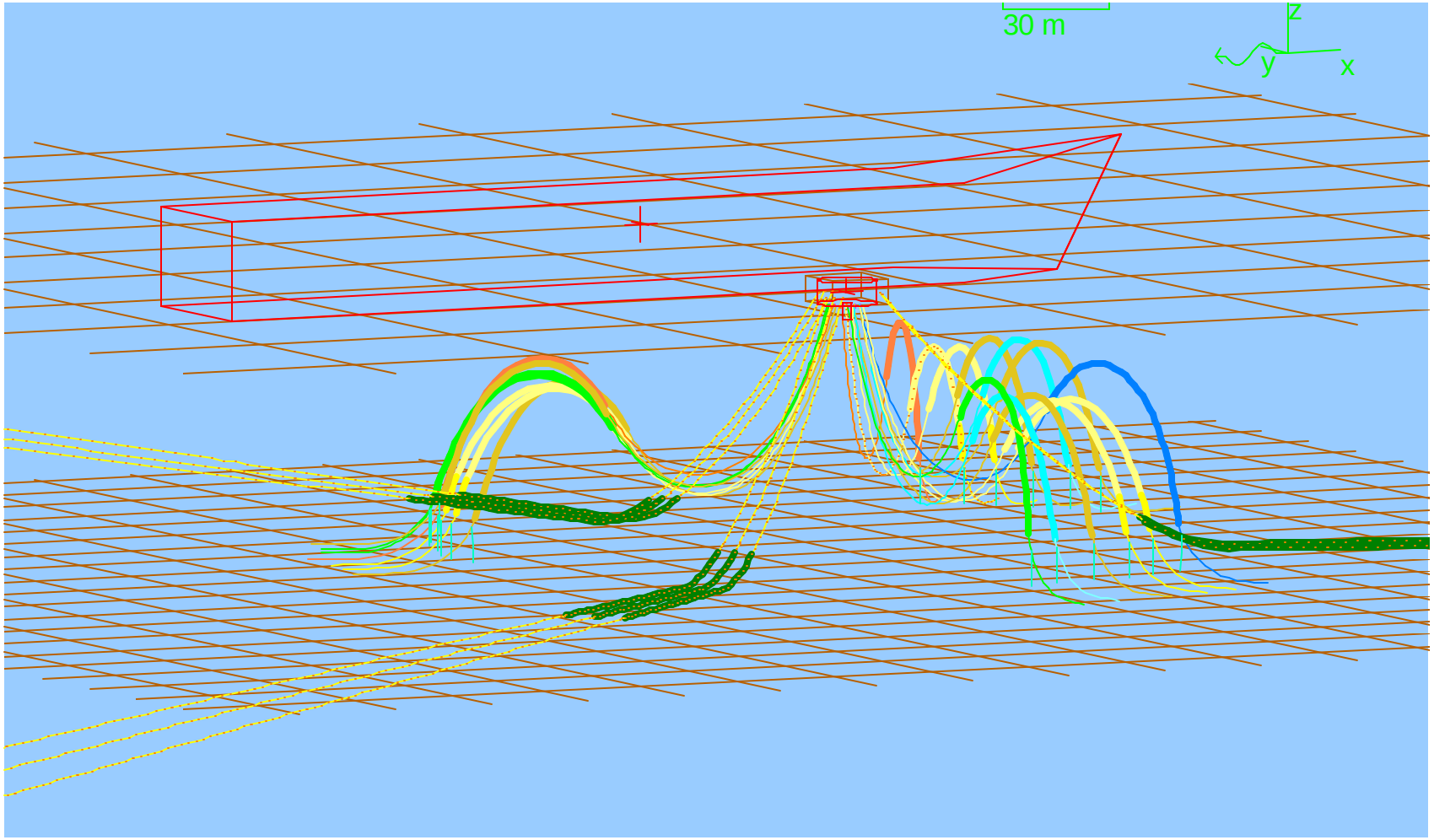
	1-Year	100-Year
Waves	Hs = 10.9 m Tp: 12.9 – 16.0 sec	Hs = 16.0 m Tp: 15.7 – 20.2 sec
Wind	Vw = 28.8 m/s	Vw = 39.6 m/s
Current	Vc = 1.0 m/s	Vc = 1.3 m/s
Pack Ice	0 – 30%	> 50 – 70%
Icebergs	<100,000 MT	>100,000 MT

Terra Nova FPSO

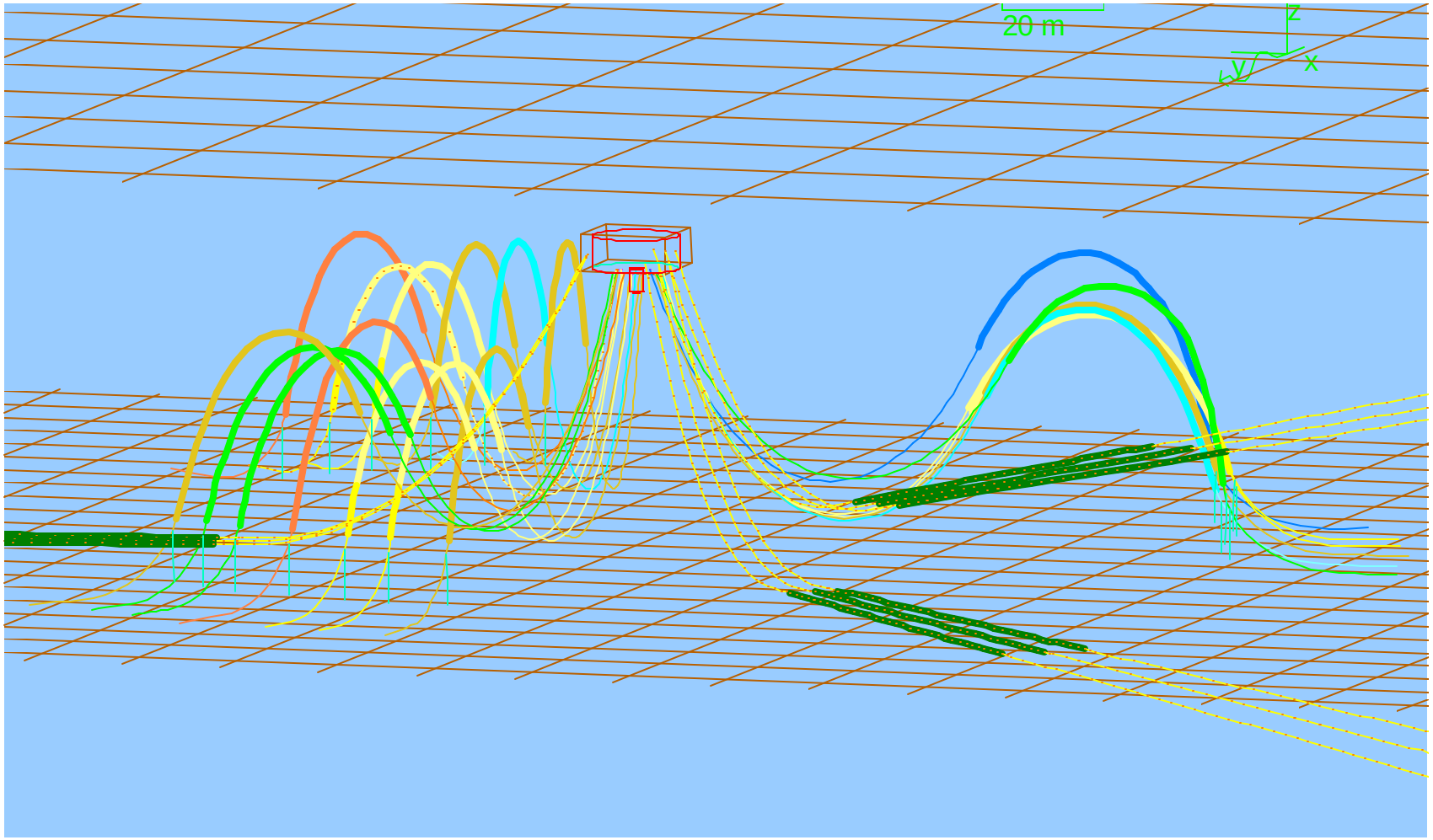


- Vessel: ice-strengthened, 960,000 bbl storage
  - L=292 m, B=45.5 m, D=28.2 m
  - 5 azimuthing thrusters @ 5 MW each
- Disconnectible turret system
- Thruster assisted 3X3 mooring system
- 19 risers & umbilicals

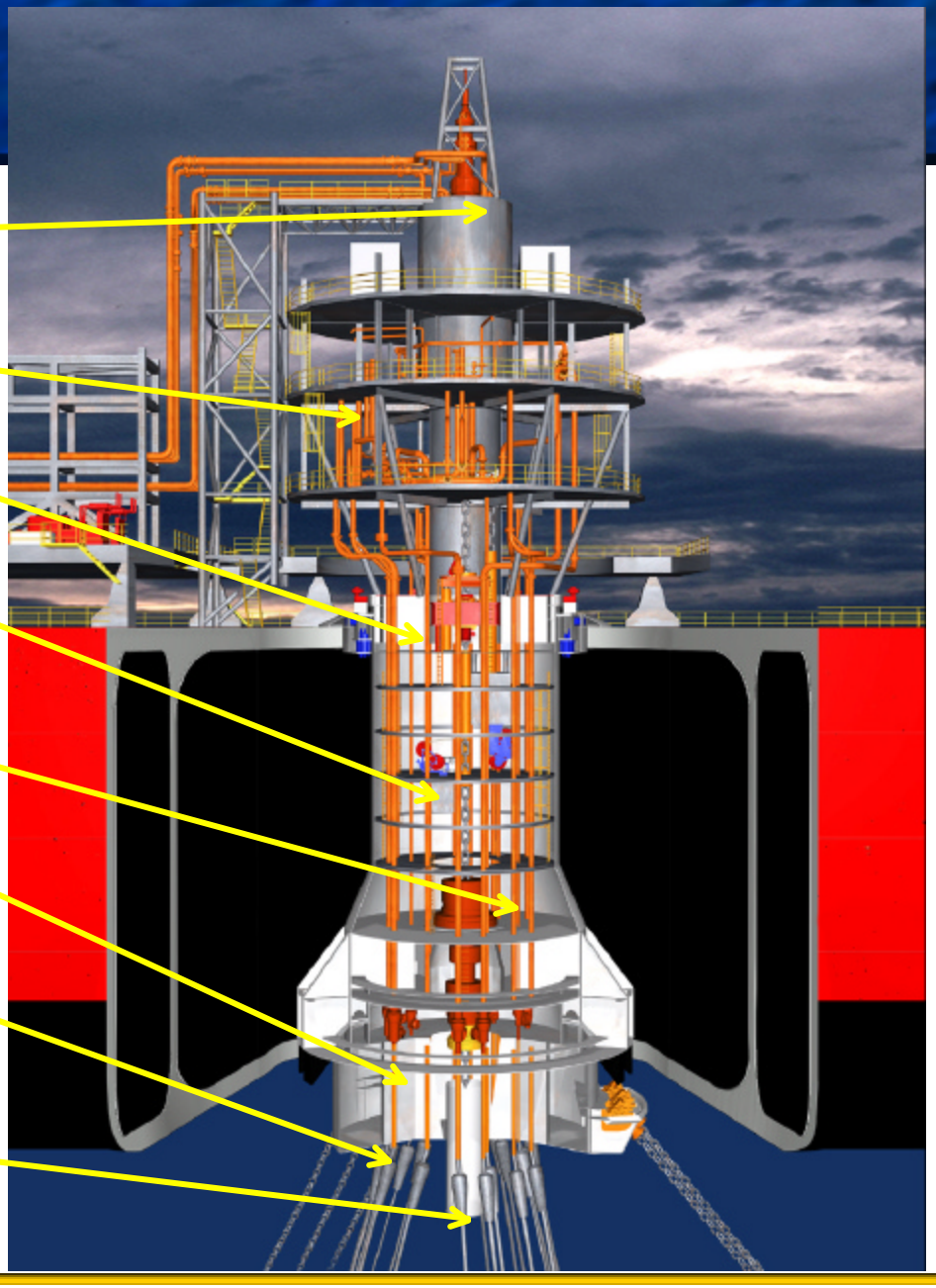
Terra Nova FPSO System



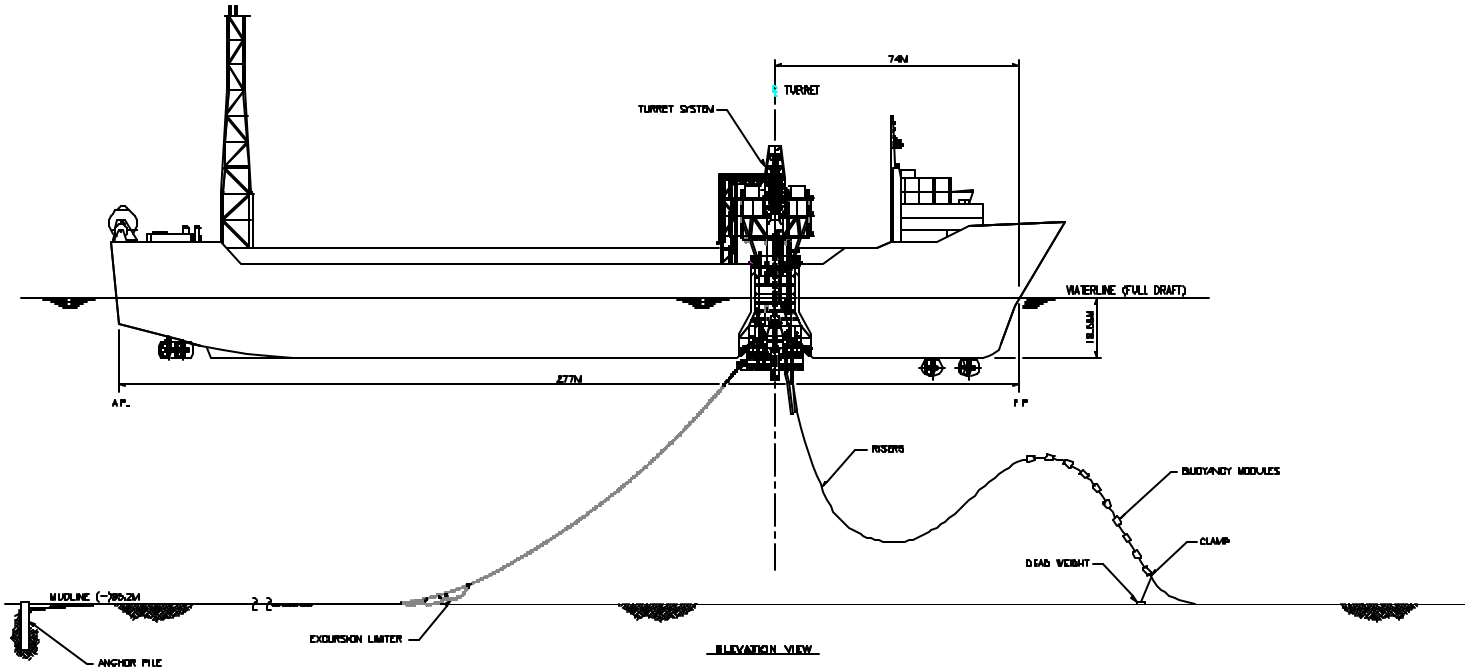
Spider Buoy



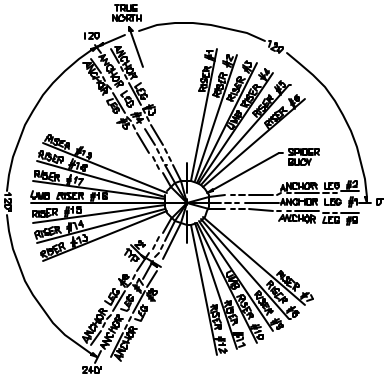
Terra Nova Turret



General Arrangement: Mooring System

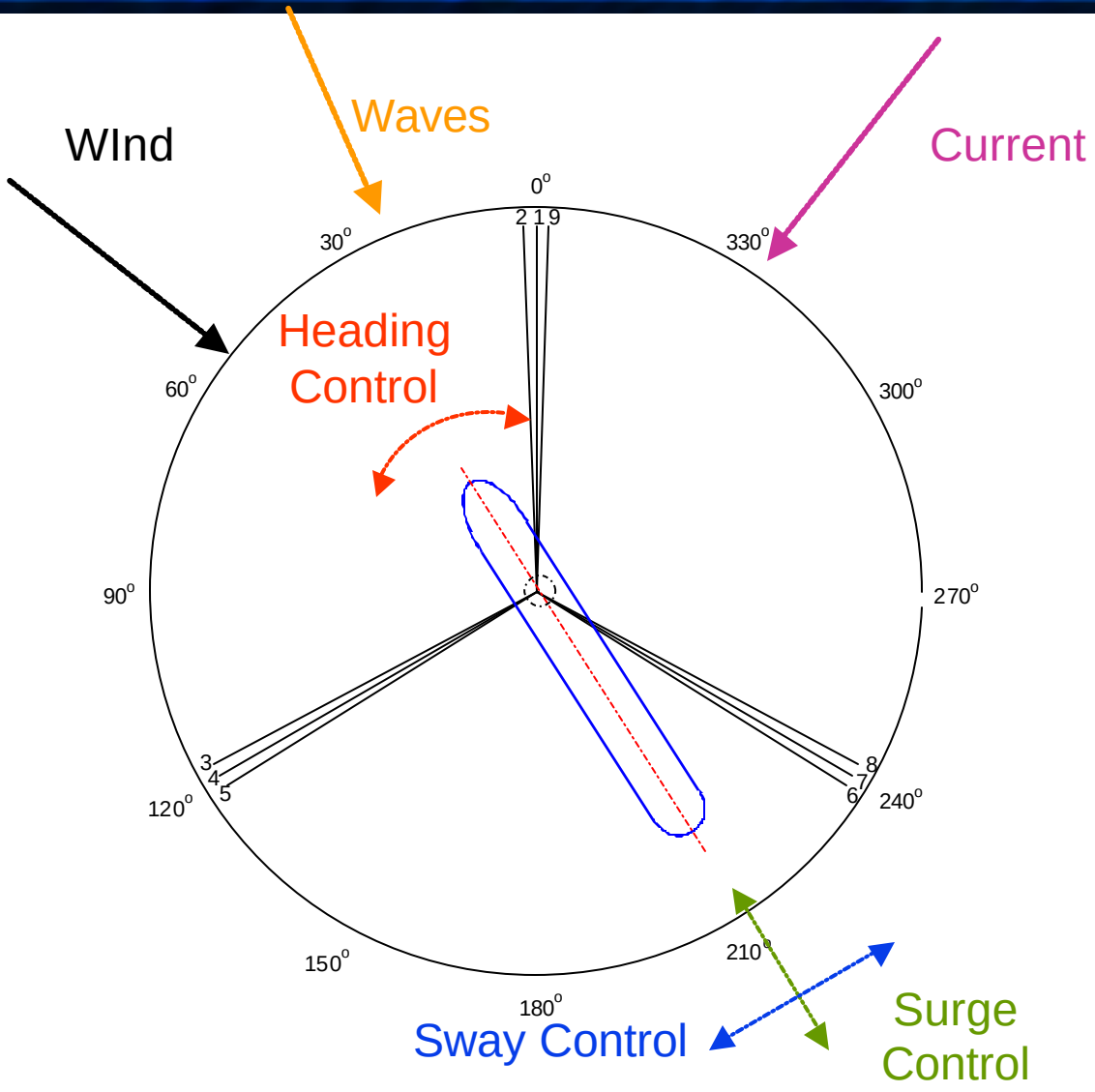


ELEVATION VIEW



PLAN VIEW AT ANCHOR LEGS AND RISERS

Thruster-Assist Terminology



Global Analysis Requirements

- Survival conditions
  - FPSO global analysis & loads: 1-year and 100-year storm
  - Spider buoy motions (disconnected): 1-year storm
- Operational conditions
  - fatigue analysis
  - FPSO system response during offloading
- Spider buoy behavior during disconnect & reconnect
  - transient buoy drop motions
  - pull-in dynamics and loads
- Installation analysis

Global Analysis Methodology

- Frequency domain analysis
  - second-order forces and moments
  - wave frequency vessel motions
  - parametric study of FPSO system response
  - FPSO global analysis
- Time domain analysis
  - detailed mooring analysis and turret loads
  - spider buoy response during disconnect & reconnect
  - thruster-assisted mooring and DP simulations
- Model testing

Model Test Program

Integrated with global analysis effort:

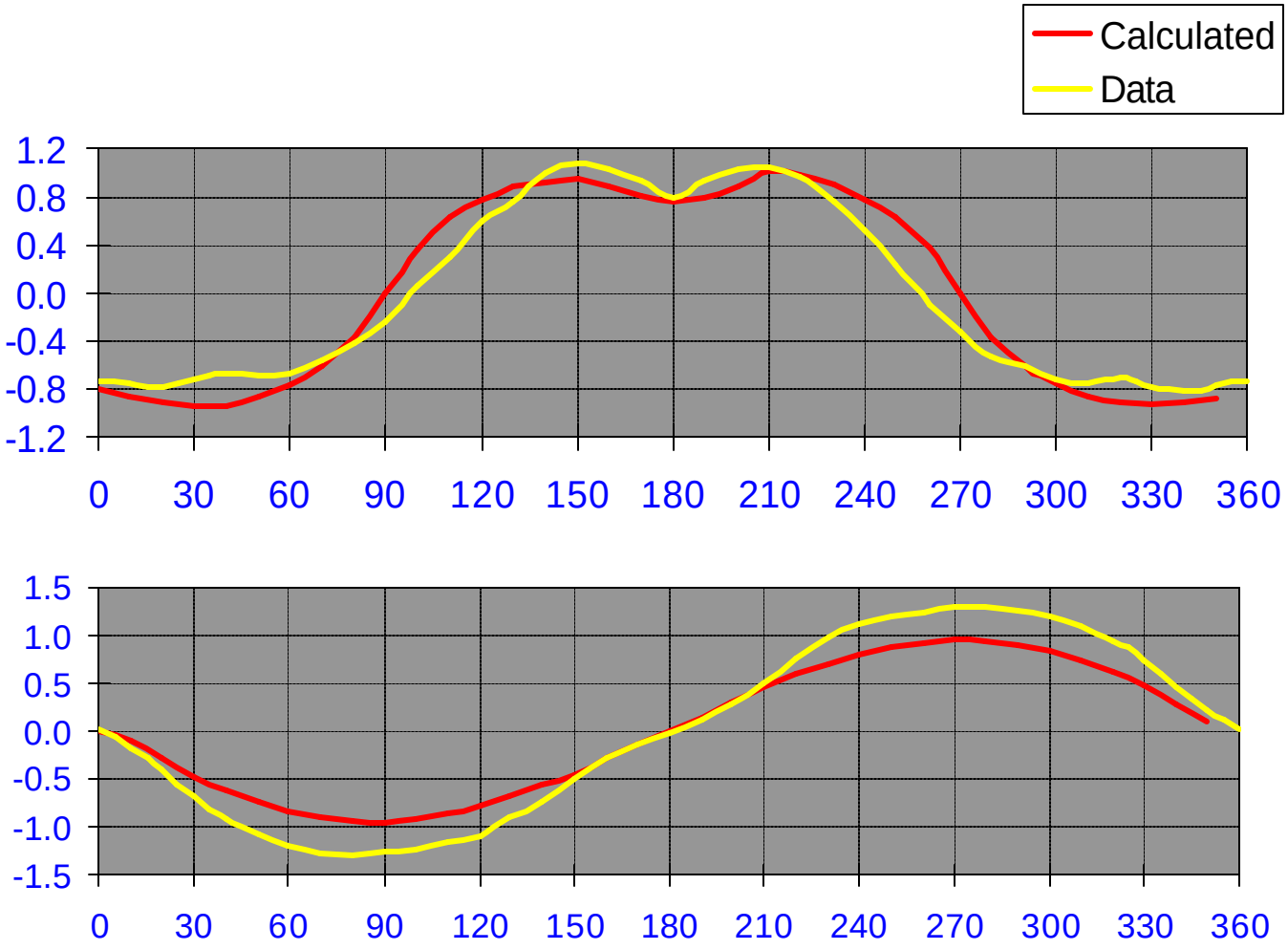
- *input data for analysis*
- *independent verification of global analysis*

- Wind tunnel tests (1997)
- Survival environment tests (1997, 1998)
- Resistance and propulsion tests (1997)
- Pack ice and iceberg impact tests (1997, 1998)
- Buoy disconnect & reconnect tests (1998)
- Installation tests (1998, 1999)

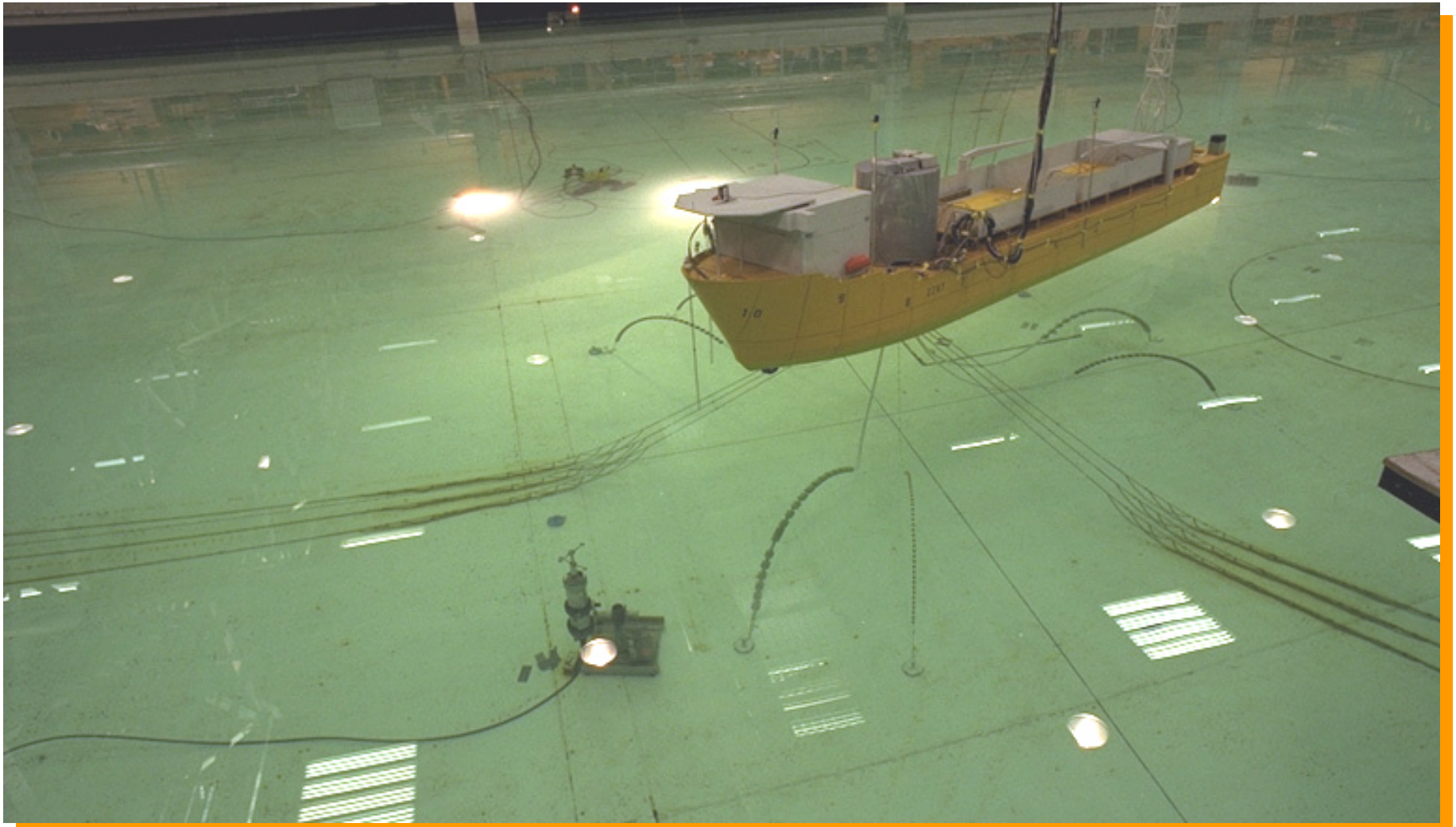
Wind Tunnel Tests

- Wind
- Current
- Helideck Airflow
- Vessel Exhaust

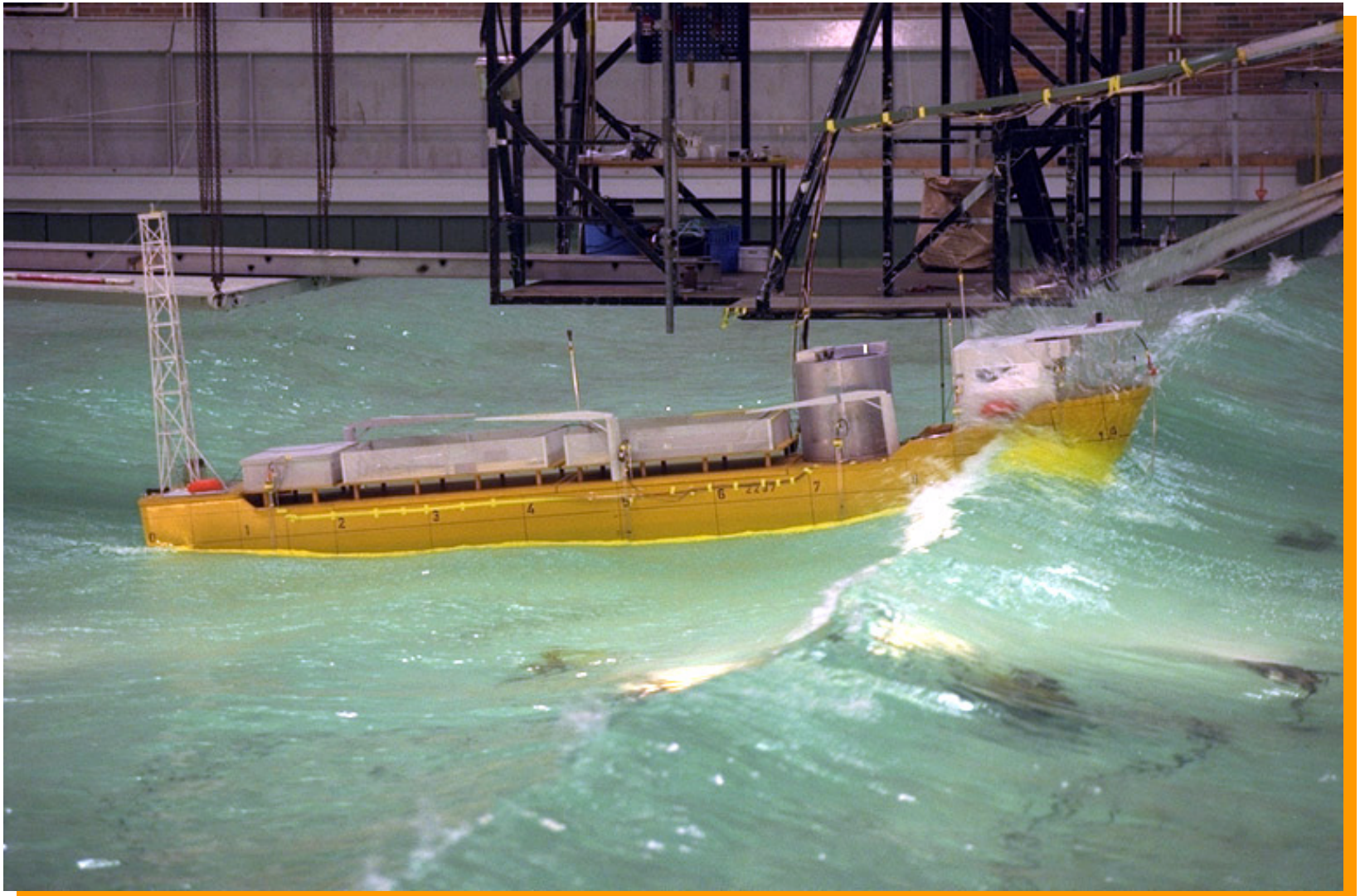
Sample Wind Tunnel Test Results



Set-Up for Survival Testing



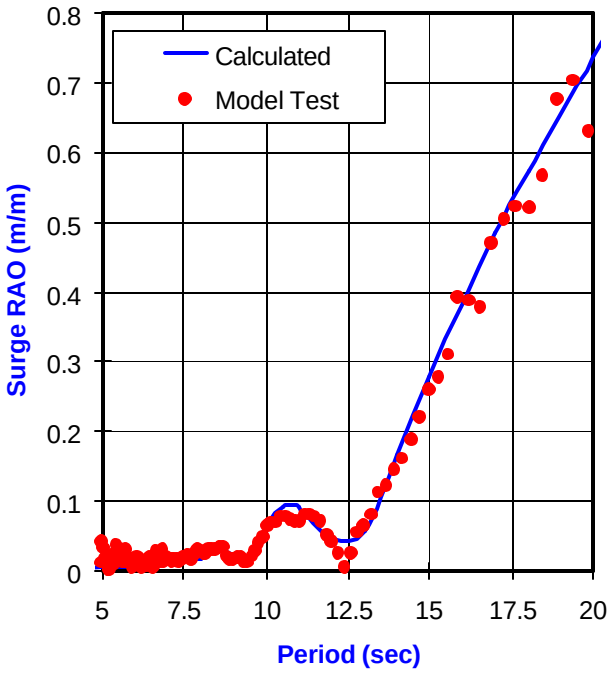
Survival Model Testing

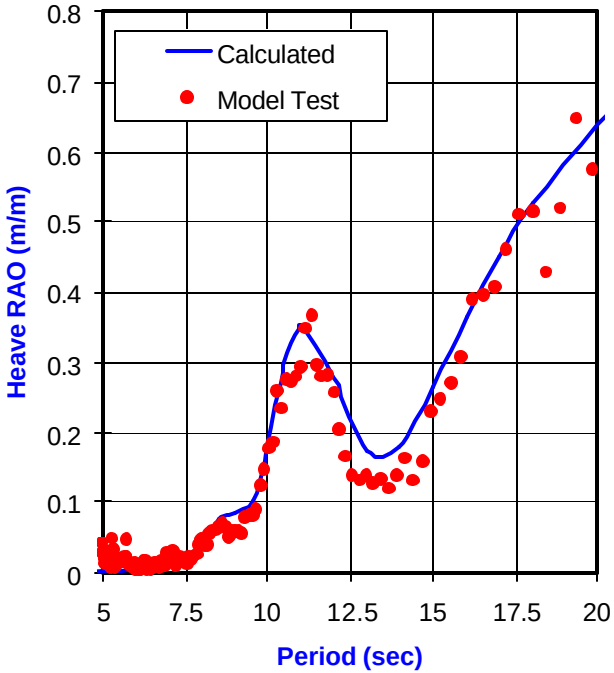


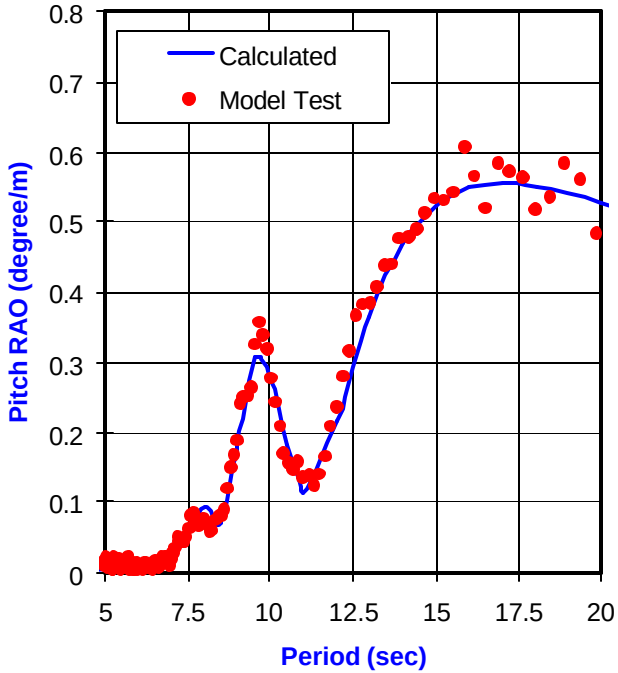
Survival Test Results (100-year)

3-Hour Maximum	Full Load		Ballast Load	
	Model Test	Prediction	Model Test	Prediction
Vessel Horizontal Offset	-20.6	-20.8	-20.9	-19.7
Vessel Pitch	7.3	7.1	7.5	7.2
Anchor Leg Tension	640	688	696	743
Turret Horizontal Load	1,804	1,884	1,978	2,053
Turret Vertical Load	-1,764	-1,806	-2,212	-2,100

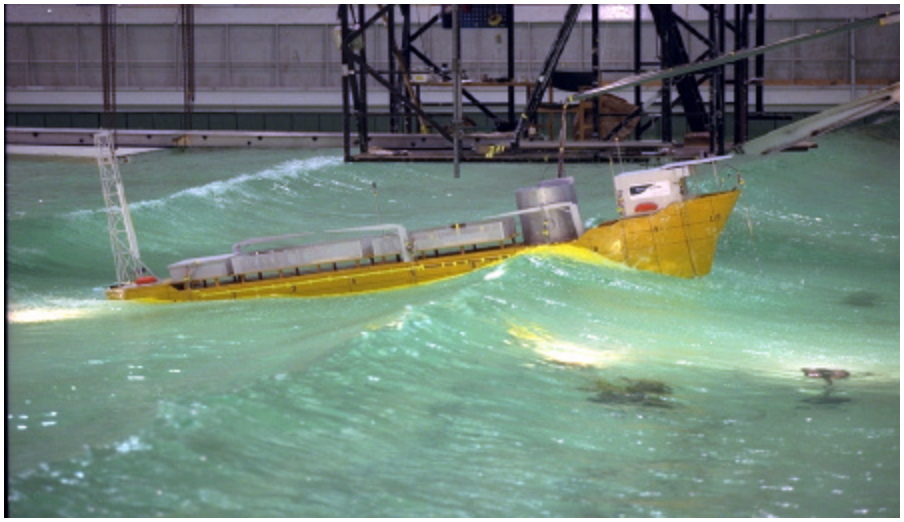
Vessel RAOs

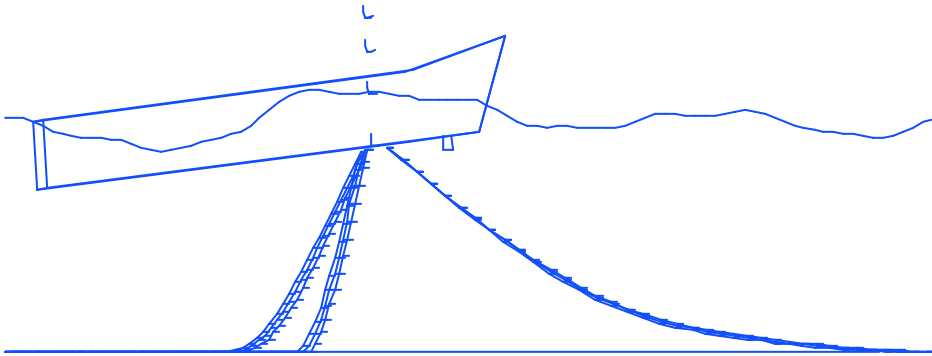

Calculated
Model Test
Surge RAO (m/m)
Period (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
5
7.5
10
12.5
15
17.5
20


Calculated
Model Test
Heave RAO (m/m)
Period (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
5
7.5
10
12.5
15
17.5
20

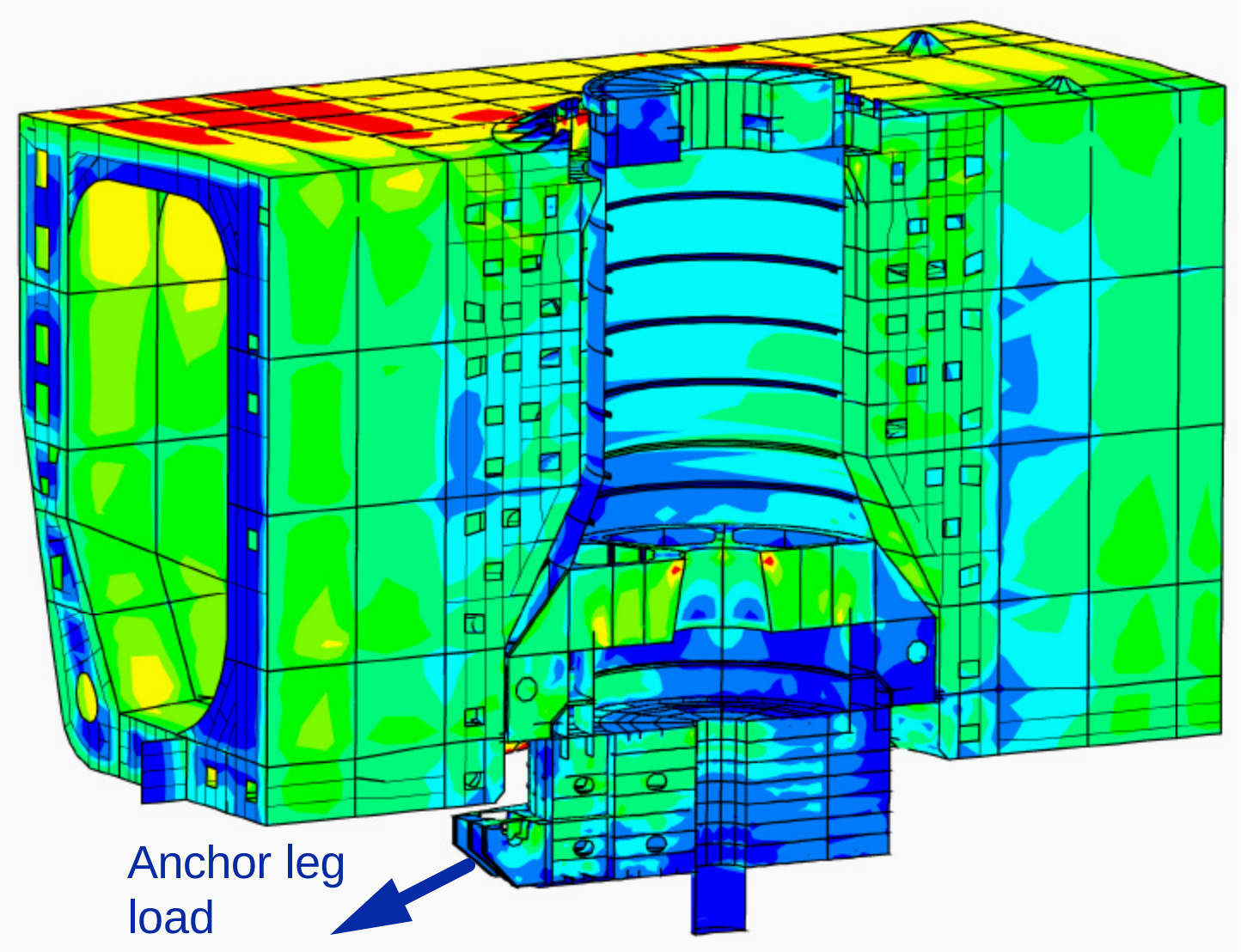

Calculated
Model Test
Pitch RAO (degree/m)
Period (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
5
7.5
10
12.5
15
17.5
20

Detailed Numerical Simulations

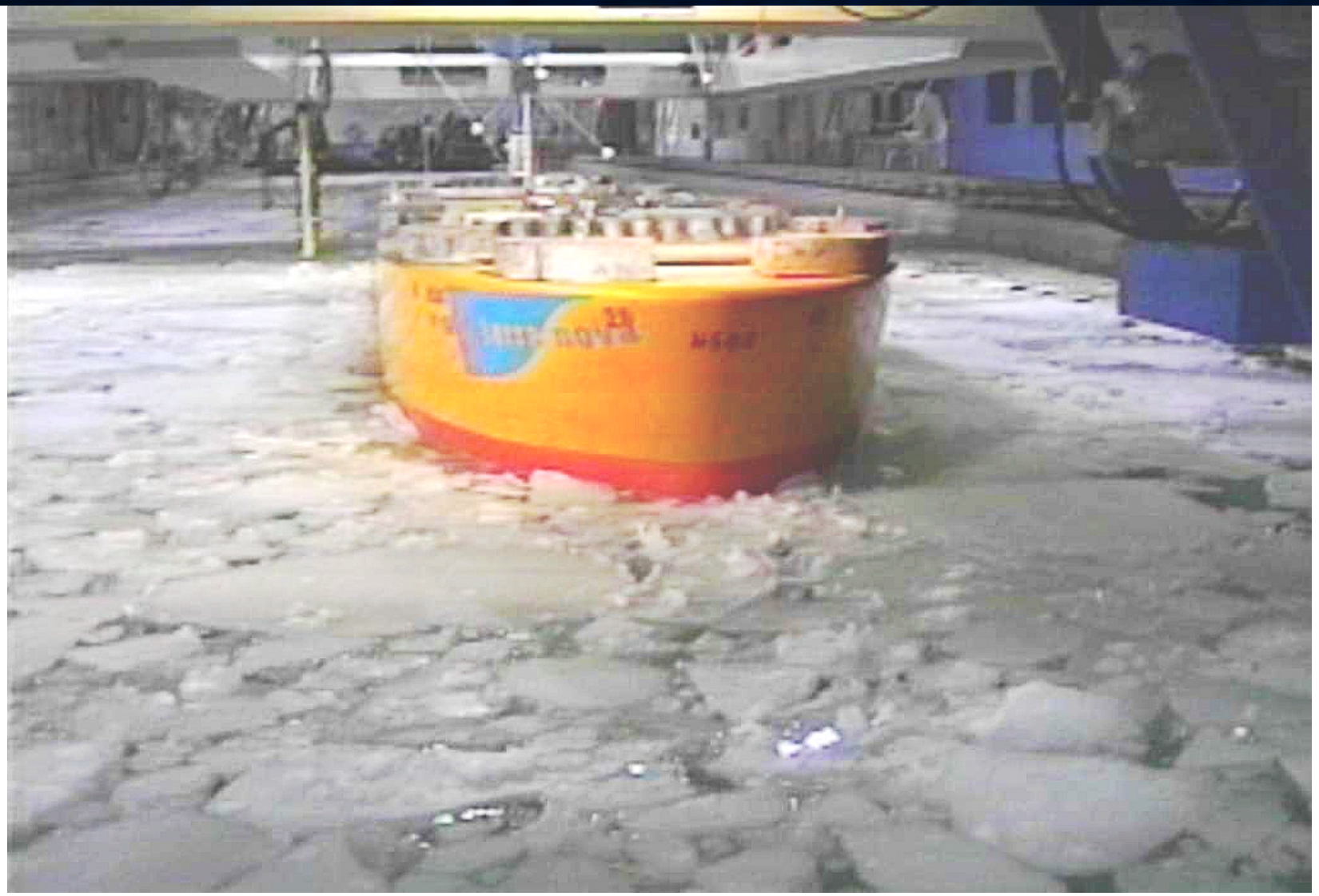




FEA of Turret-Vessel System

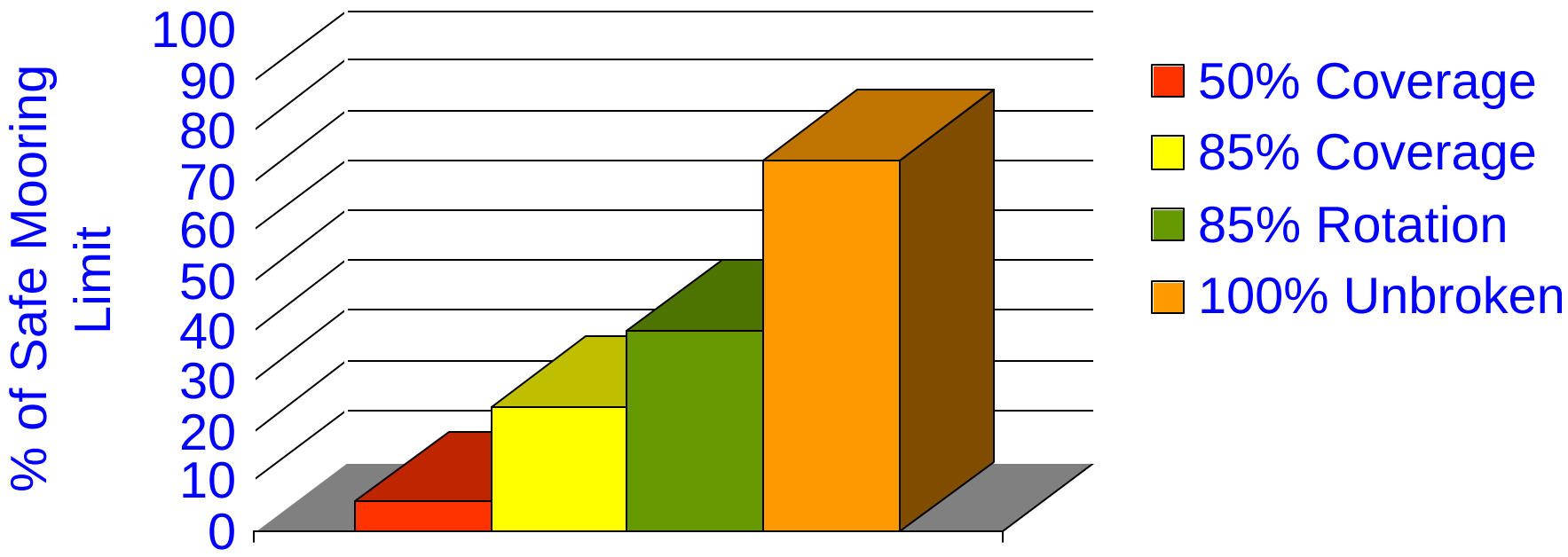


Pack Ice Tests

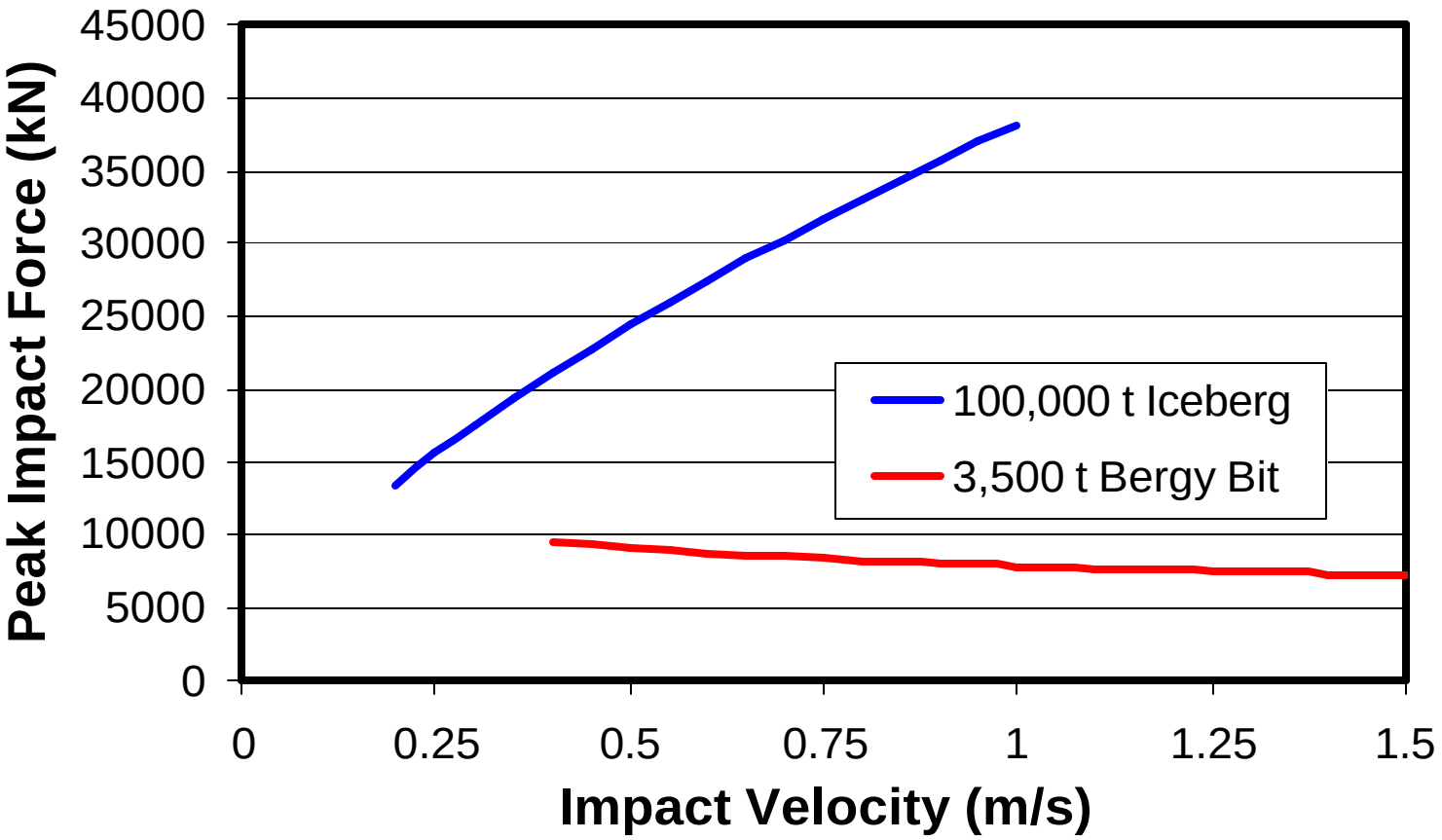


Pack Ice Load on Moored FPSO

Floe Thickness = 1.0 meter



Iceberg & Bergy Bit Impact Loads

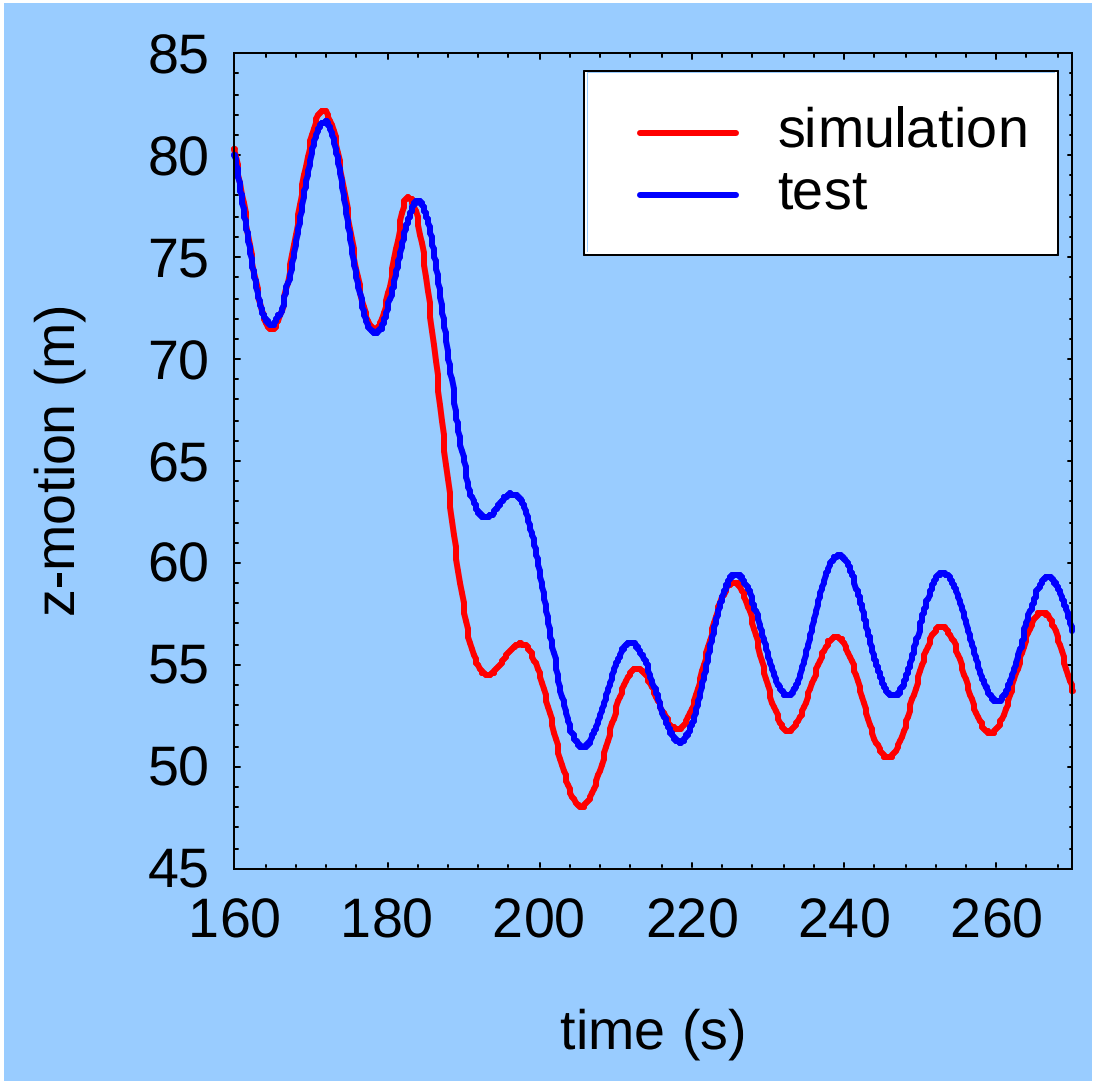


Iceberg Impact

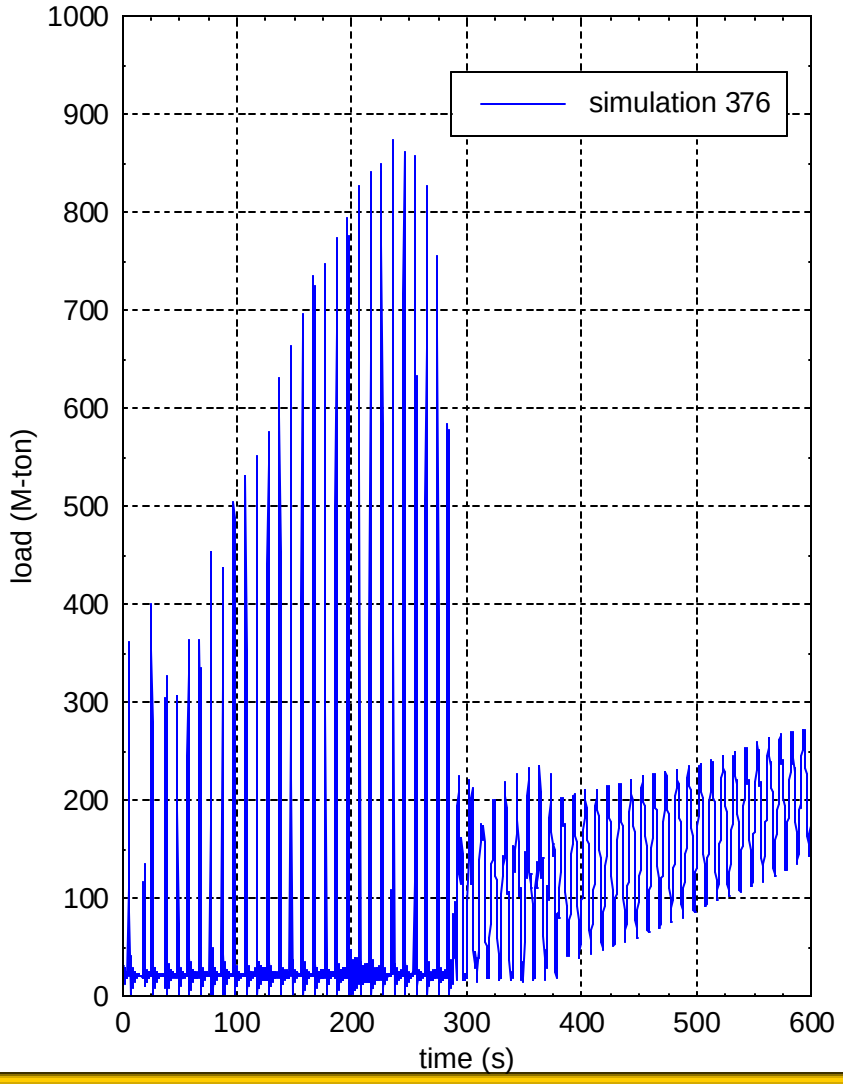
Spider Buoy Disconnect & Reconnect Analysis

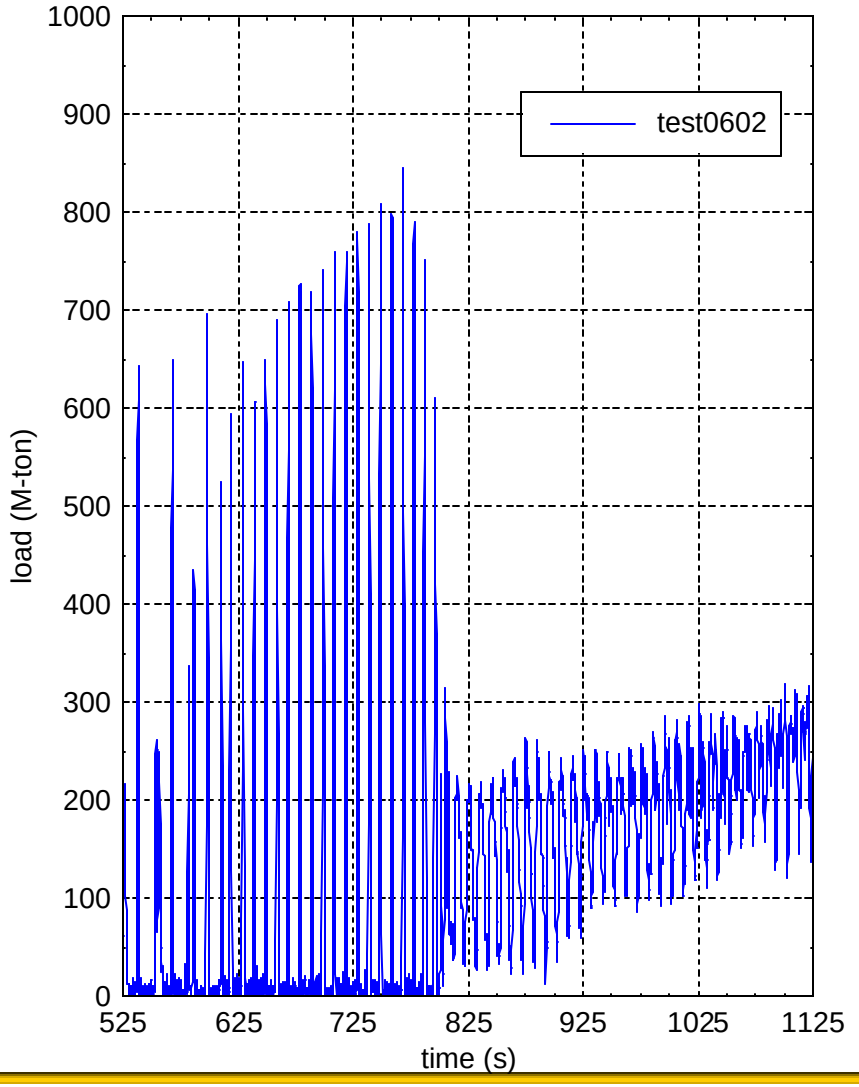
- Spider buoy disconnect
  - Analysis of disconnect in up to a 1-year storm
  - Buoy motions with & without risers
- Spider buoy retrieval
  - Buoy motions and loads during retrieval
  - Buoy-turret interface loads
- Installation analysis

Simulating Buoy Disconnect



Reconnect Loading





Spider Buoy Tow-out

Spider Buoy Installation

Spider Buoy Installation

Summary

- Model testing still plays an important role in the development of floating systems
  - input data for analysis
  - independent verification of analysis
  - concept development and evaluation
  - study complex phenomenon
- Integration of system analysis with a model test program optimizes the design of the system
- Development of new approach & techniques important for model testing of deepwater systems