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Ice Force Modeling for DP Control Systems

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MTS DP Conference, October 11-12, 2011

National Research Council Canada
Conseil national de recherches Canada
Canada

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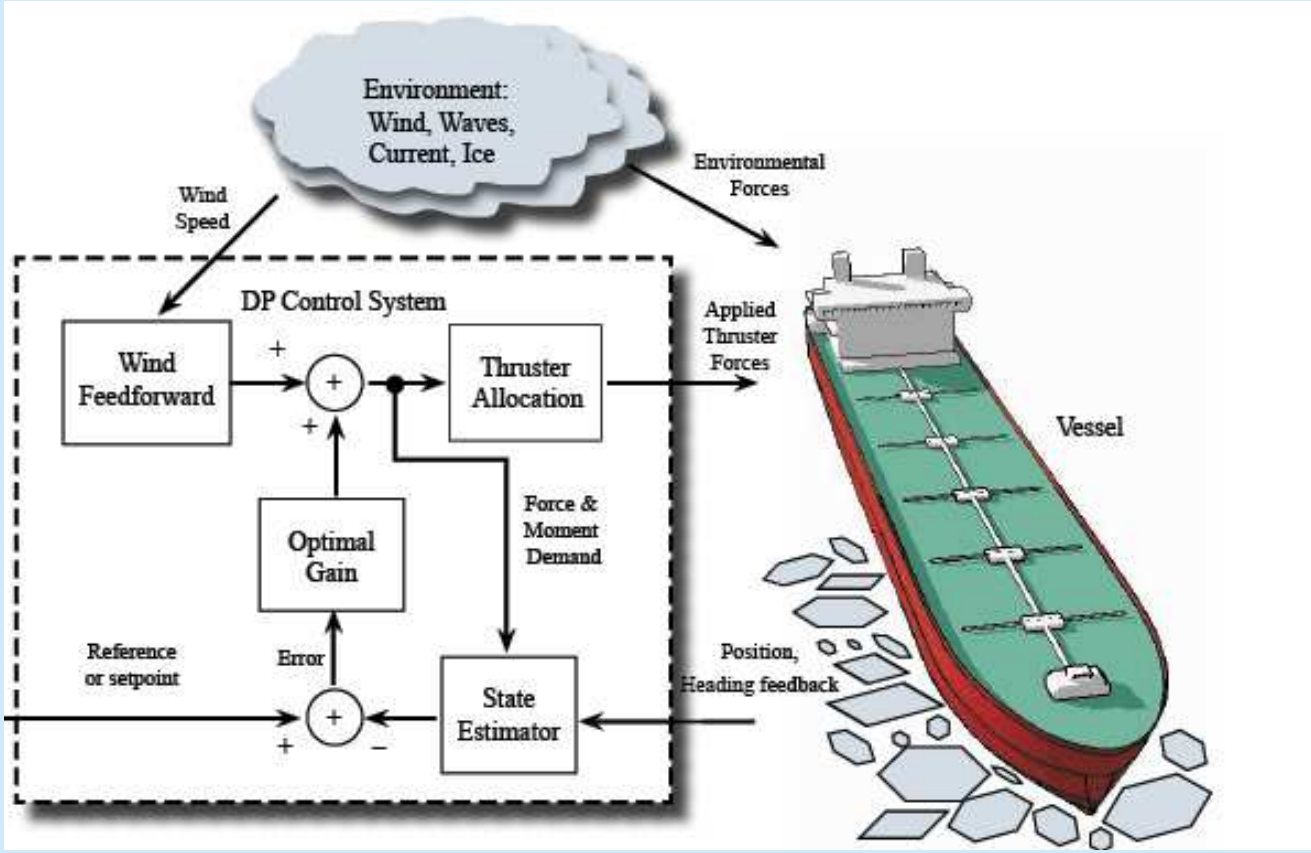
Challenges of DP Stationkeeping in Ice

Traditional DP: Wind, wave and current loads are slowly varying, easy to predict and react to.



Ice Loads are:

- Fast-changing
- Very large

New control system technologies must be developed to address these issues

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Marine Vehicle Control

IOT's Experience: Development, Physical Modeling and Numerical Modeling of Control Systems

- Dynamic Positioning of Vessels (since 1998)
  - Floating Production Storage and Offloading (FPSO)
  - LNG offloading terminal
  - Shuttle tankers
  - Semisubmersible drilling platform
- Autopilots
  - Naval Submarines
  - MCDV
  - Research vessels
  - Fishing vessels
- Ride Control
  - SWATH
  - MCDV roll reduction

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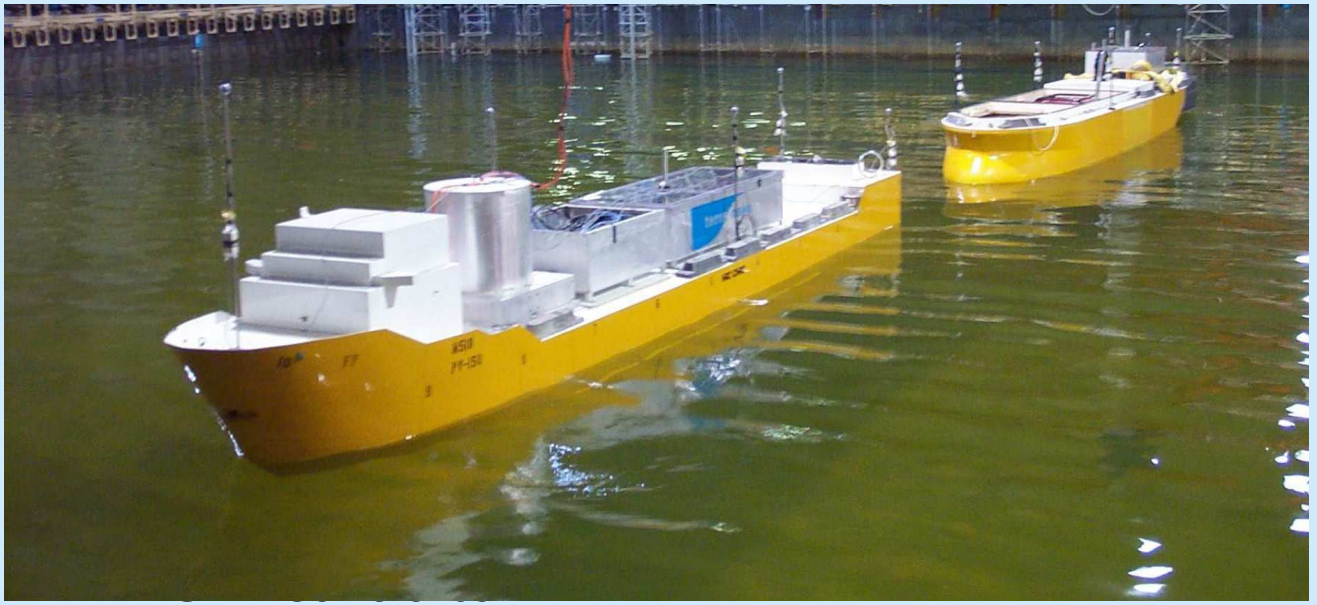

Terra Nova FPSO with DP Shuttle Tanker

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DP In Ice Program

What is the focus?

- DP Control system design and tuning
- Prediction and estimation of Ice loads
- Prediction of DP Stationkeeping capability
- Rapid-acting propulsion, power plant designs

How will the development proceed?

- Model testing
  - Proof of concept for DP designs
  - Provide parameters to simulations
- Numerical Modeling
  - Development of DP algorithms
  - Capability/operability prediction

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Model Drillship or FPSO

- Model (Scale 1:40 – 1:30)
  - Drillship (or FPSO)
  - LWL: 200 m
  - Beam: 40 m
  - Draft: 12 m
  - Displacement: 101,200 tonnes
  - 6 azimuthing thrusters
  - 1.3 MN Thrust each
  - 50 MW installed propulsion power

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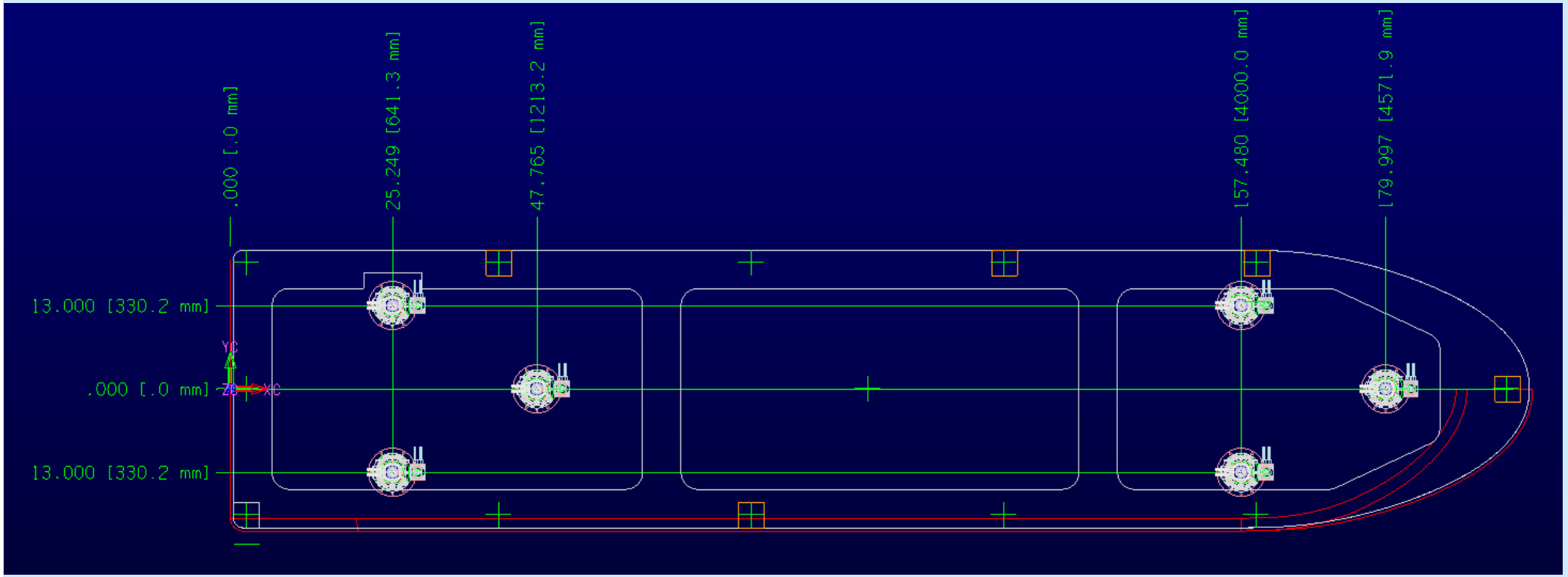
Thruster Layout



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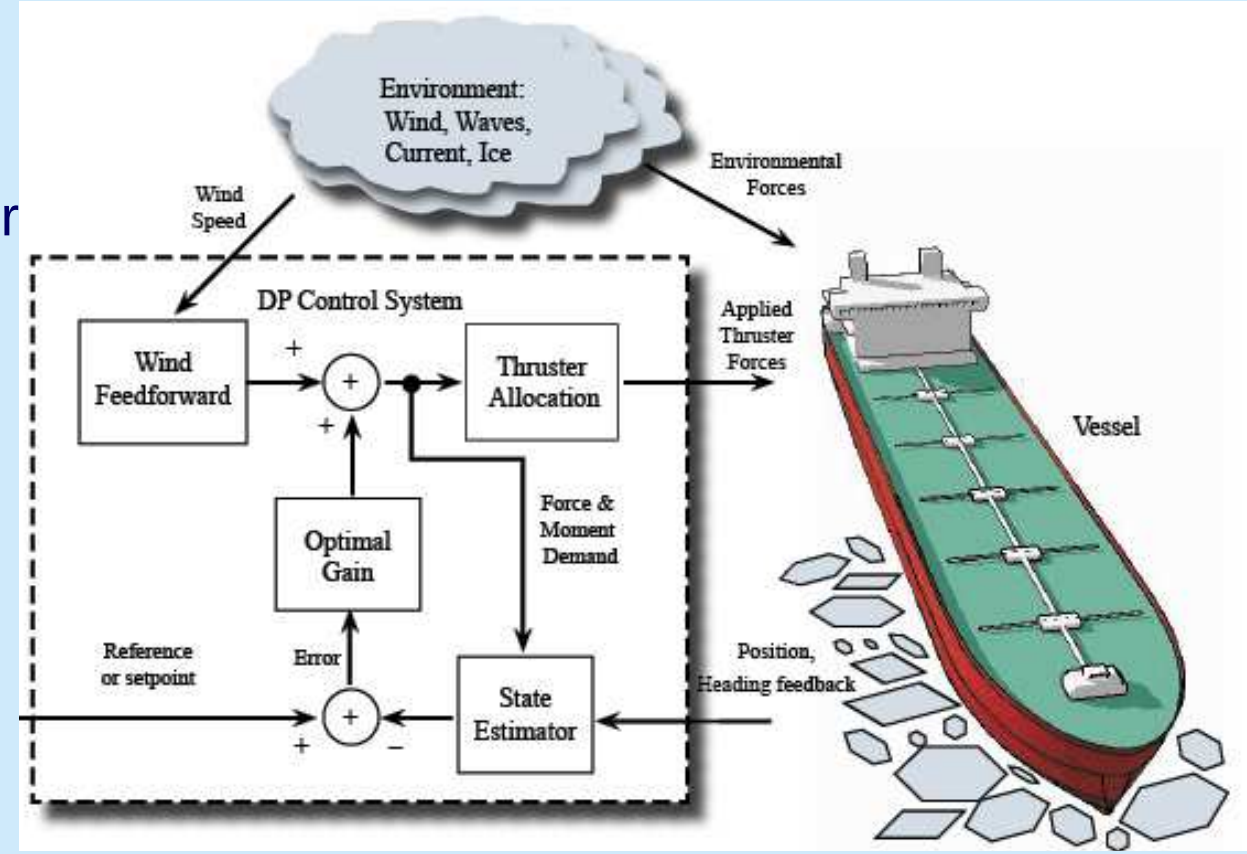
Model DP System

- *Model* DP System
- Kalman filtering: smooth velocity and position estimates
- Thruster allocation: simple least-squares solution
- Gains: calculated for appropriate stiffness, damping
- No integral terms

Factors Influencing DP Similitude

- Static Effects
  - Thruster size/placement
- Dynamic Effects
  - State estimation first order wave filtering)
  - Control gains
  - Thrust/power system dynamics
- DP Operating Modes
  - Heading priority
  - Damping only
  - Station keeping vs. track following



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Modeling Philosophy

Type of Experiment	Control over independent variables	Measurement of dependent variables	Validity of results	Cost
Physical Model Tests	Good	Very Good	Very good	$$
Numerical Model	Excellent	Excellent	Poor	$
Full Scale Trials	Poor	Good	Excellent	$$$

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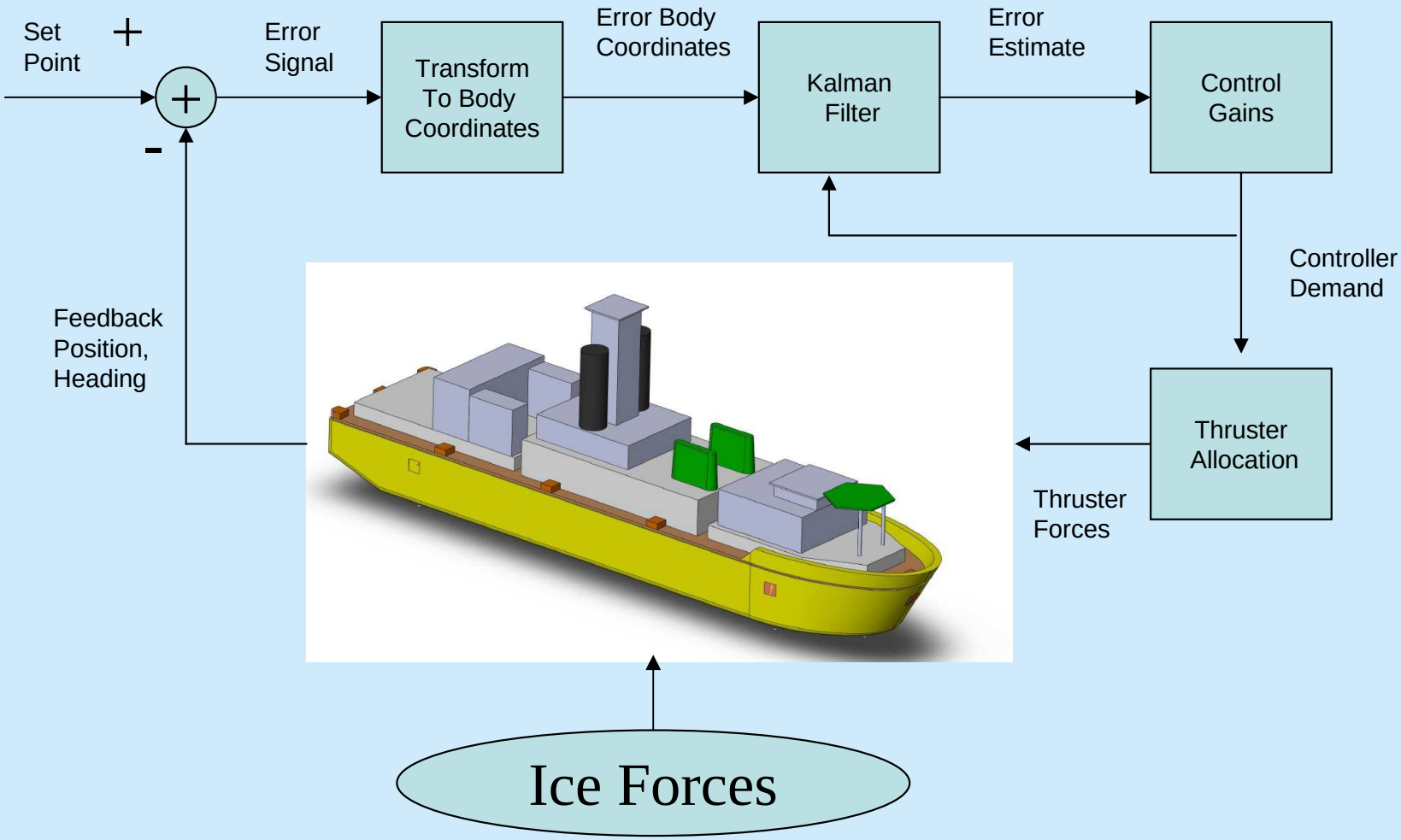
DP System Overview



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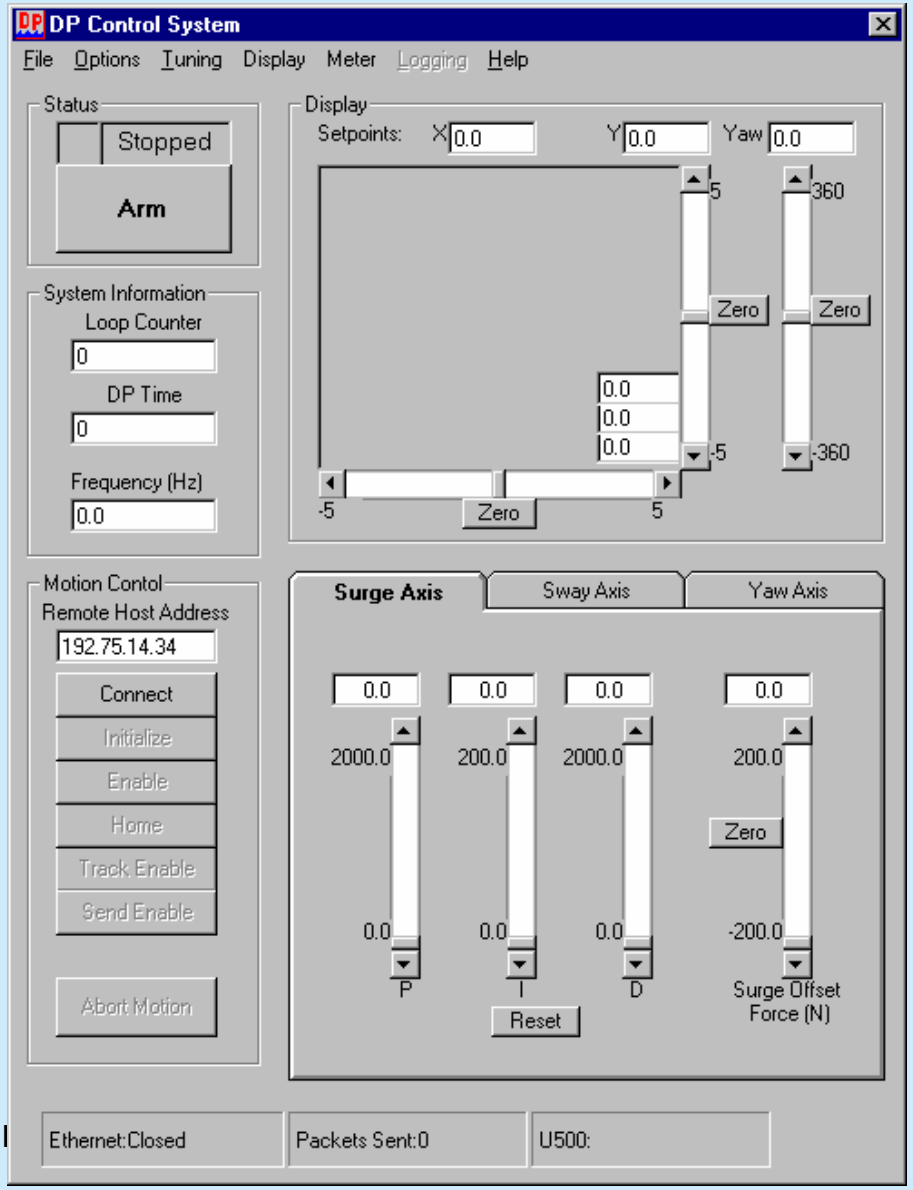
IOT Model DP System

- Windows Graphical User Interface
- Mouse, Keyboard and Joystick operation
- Real-time display of heading, position
- State estimation (Kalman filtering) for removal of first-order wave effects
- Optimal or PID control gain



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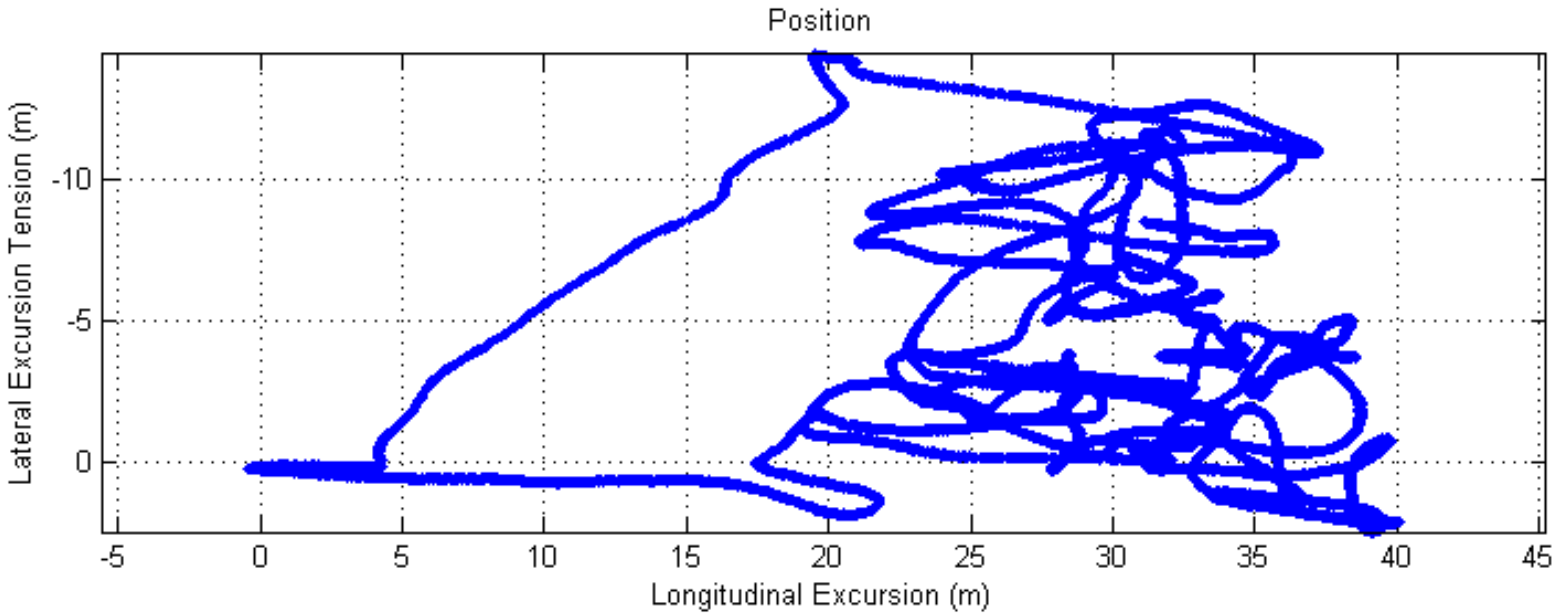
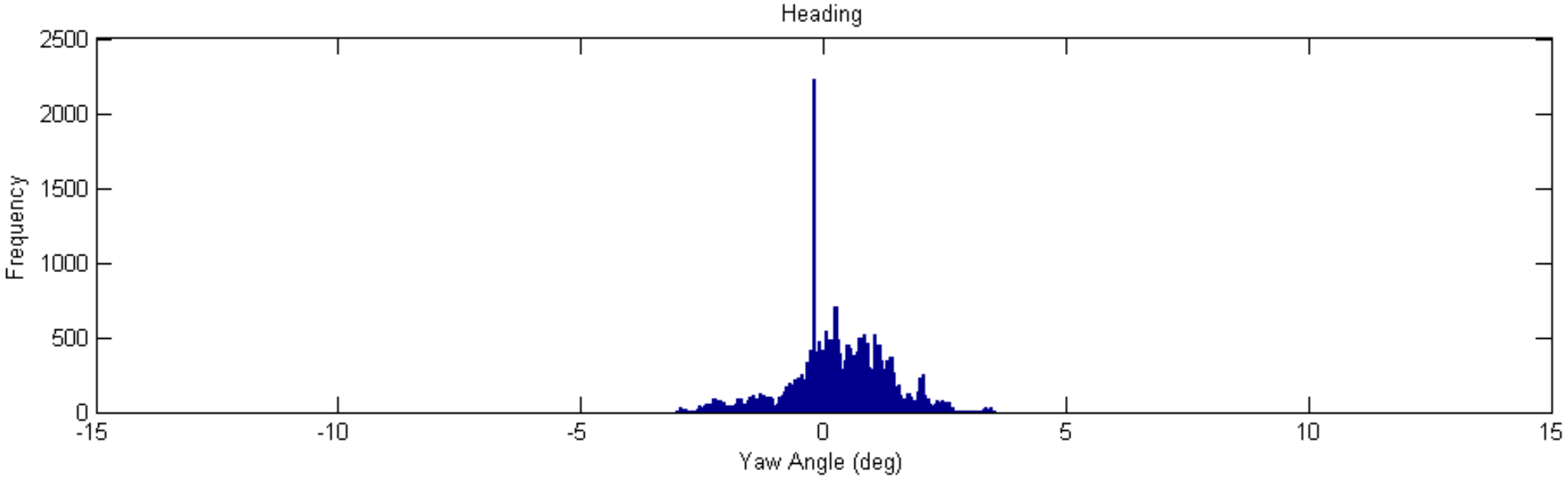
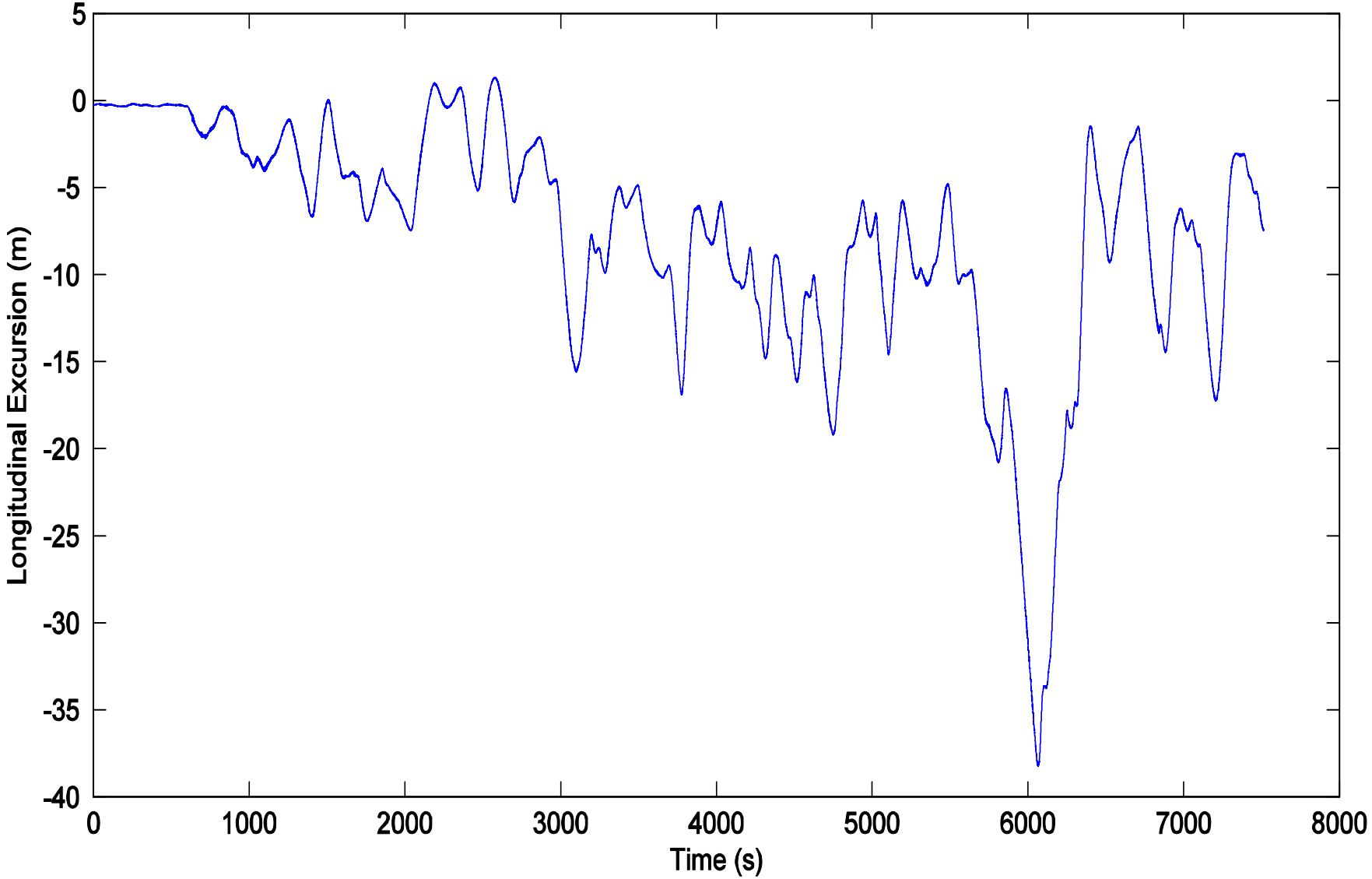
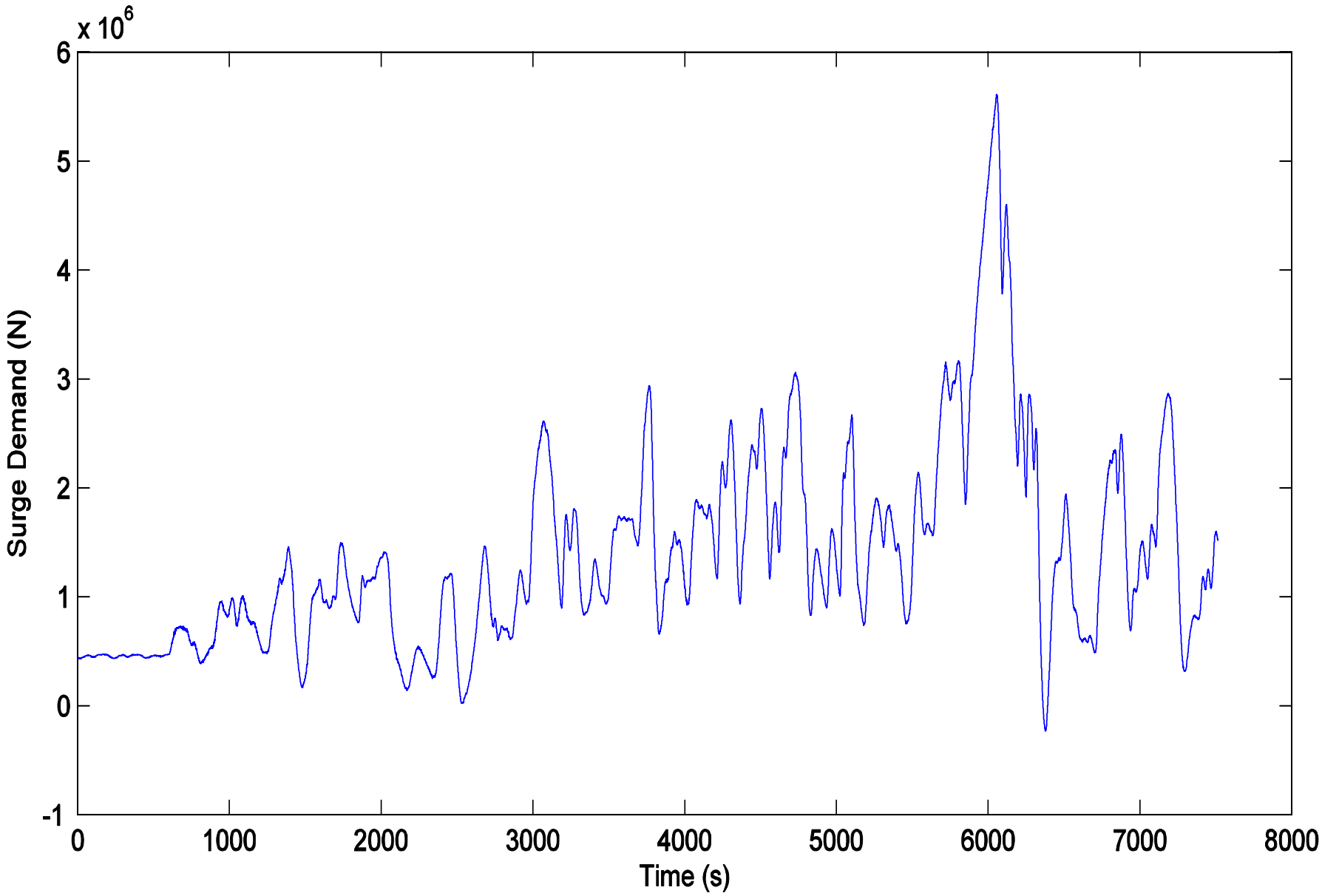
Recording

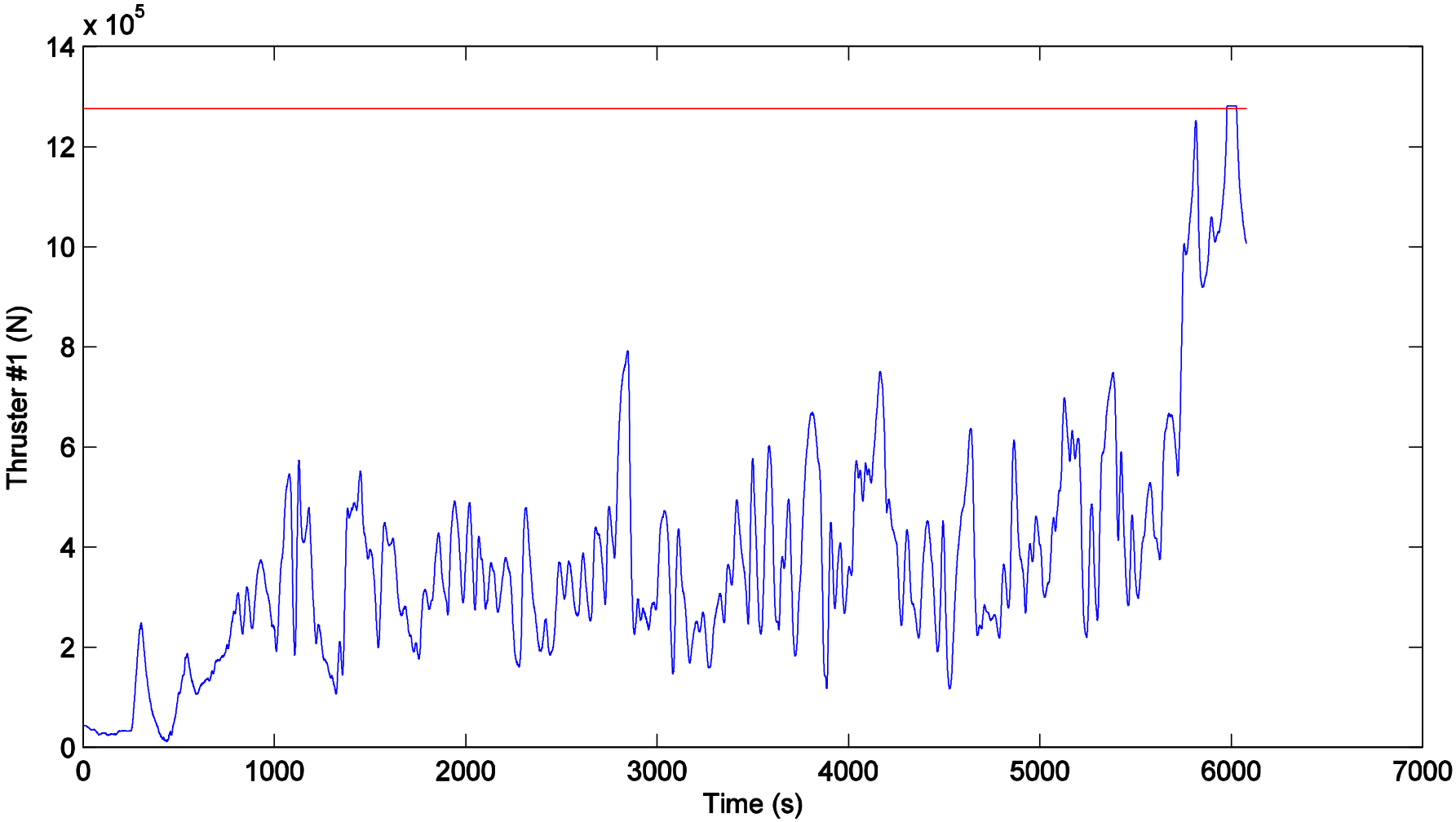
- Absolute frame X,Y, Heading
- Error in body frame: Surge, Sway, Yaw
- Kalman filter estimates of Surge, Sway, Yaw error and rates
- Controller Demand vector, Surge, Sway force, Yaw moment
- Allocated Thrust (6), Allocated Azimuth (6)

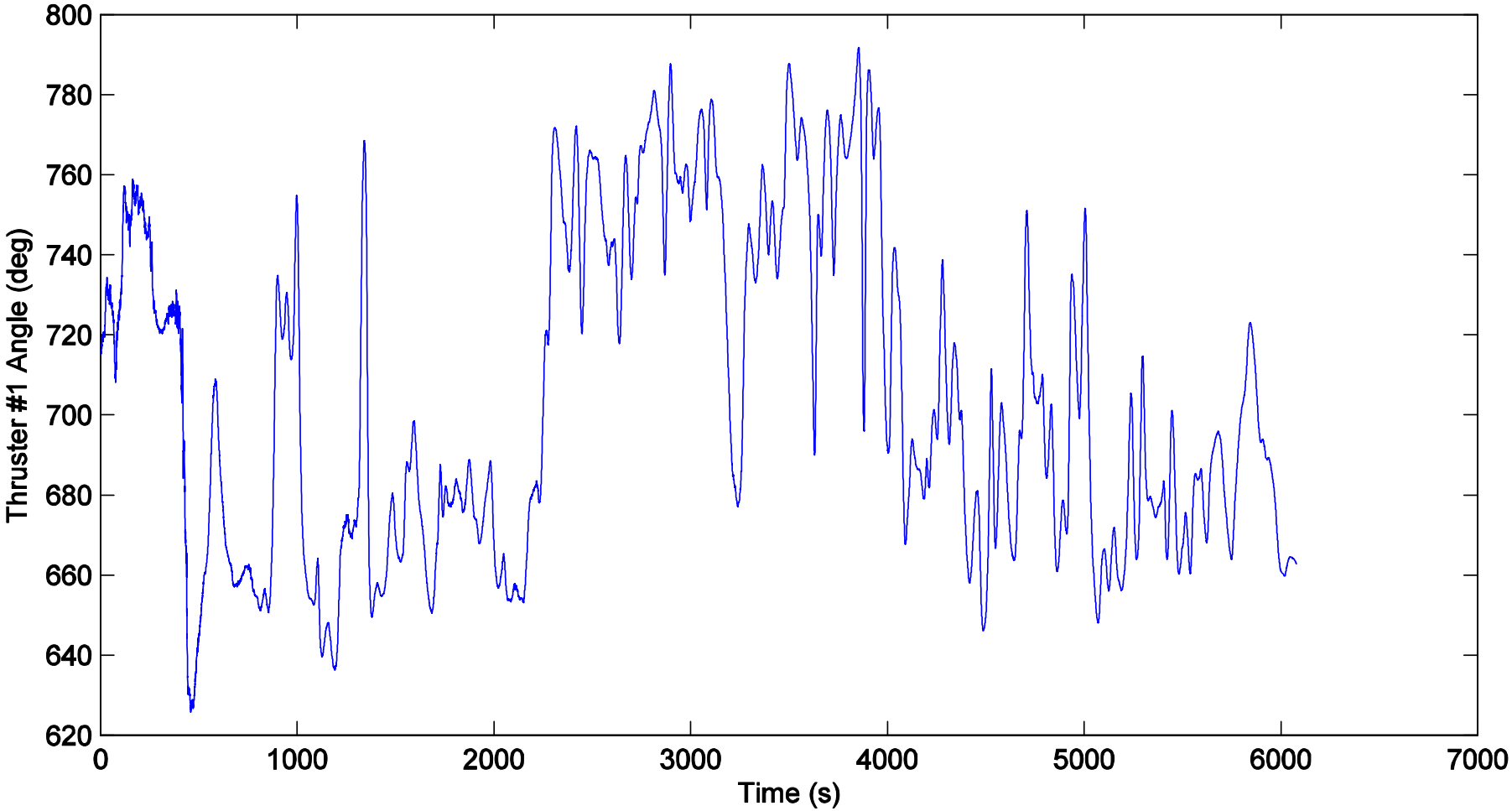

Position
Lateral Excursion Tension (m)
-10
-5
0
-5
0
5
10
15
20
25
30
35
40
45
Longitudinal Excursion (m)


Heading
Frequency
2500
2000
1500
1000
500
0
-15
-10
-5
0
5
10
15
Yaw Angle (deg)


Longitudinal Excursion (m)
Time (s)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
1000
2000
3000
4000
5000
6000
7000
8000


x 10^6
6
5
4
3
2
1
0
-1
Surge Demand (N)
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (s)


x 10^5
14
12
10
8
6
4
2
0
Thruster #1 (N)
0
1000
2000
3000
4000
5000
6000
7000
Time (s)


800
780
760
740
720
700
680
660
640
620
Thruster #1 Angle (deg)
0
1000
2000
3000
4000
5000
6000
7000
Time (s)

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Ice Vision System

- Stereo machine vision system
  - Real time
  - Concentration
  - Statistics:
    - mean size
    - std. dev.
  - Detailed Tracking
    - Size
    - Centroid location

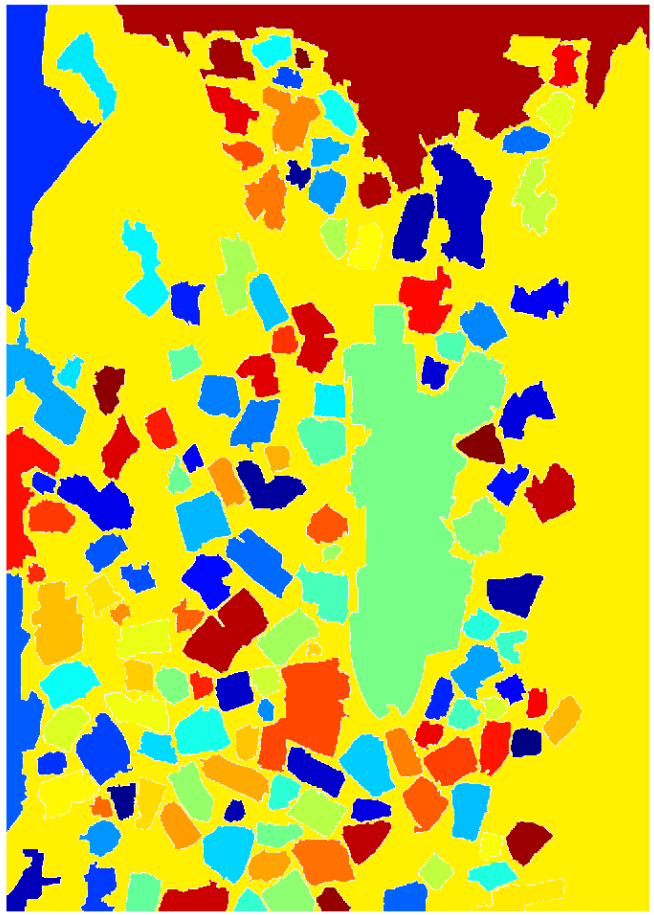

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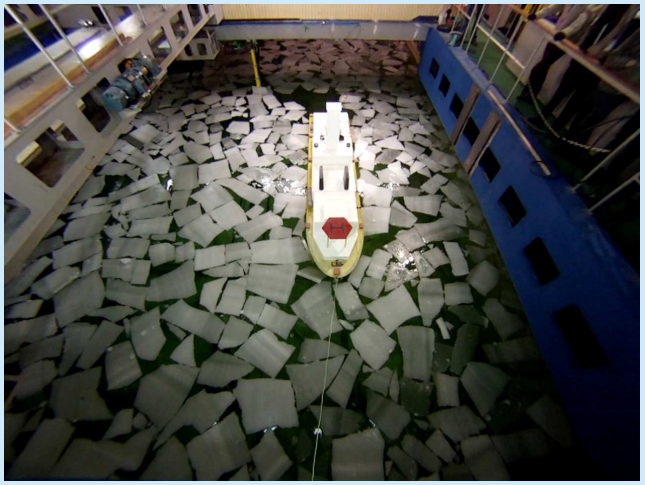
Image Prcoessing



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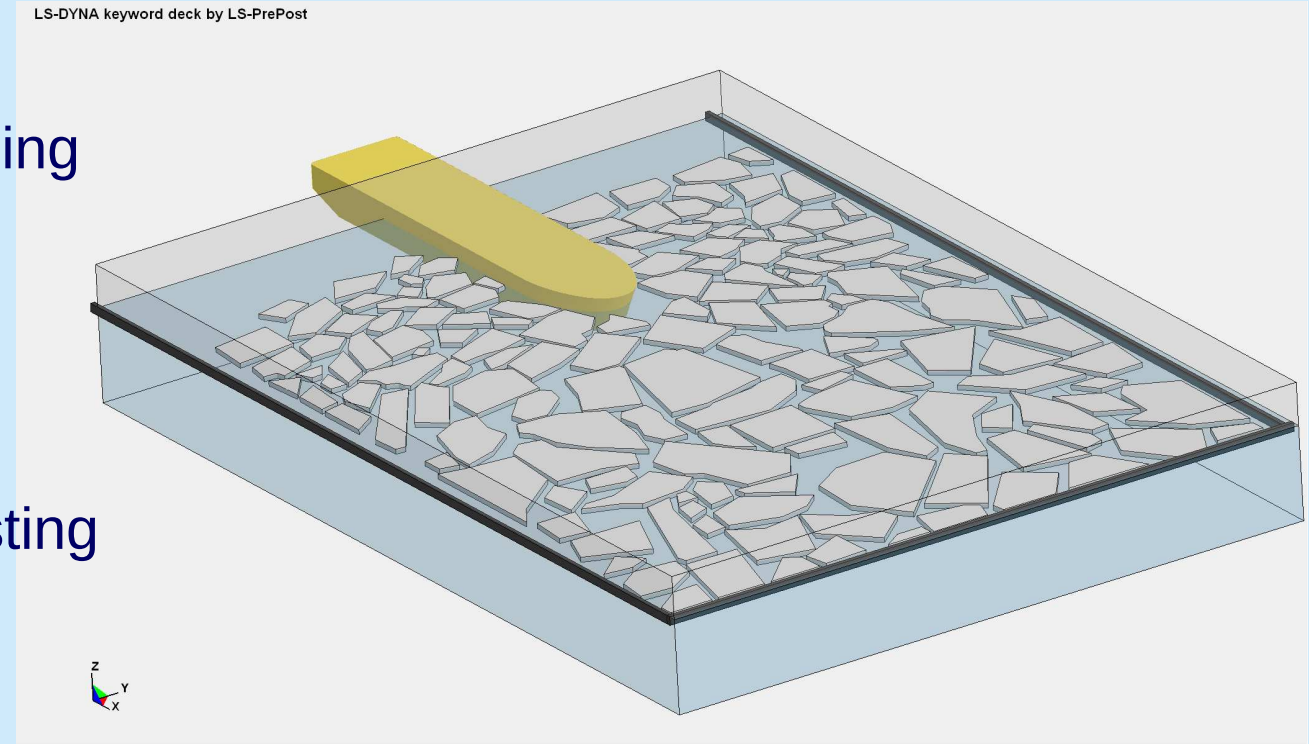
Numerical Modeling

- Multi-physics simulation using LS DYNA
- Water-Air simulation using Arbitrary Lagrangian Eulerian Method
- Ice pieces was roughly imitated from model testing video clips



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Numerical Modeling

- Rigid modeling for ship and ice
- No DP control system applied – virtual towing test
- No constraint was applied to ice pieces
- Boundaries in both sides and back to keep the concentration

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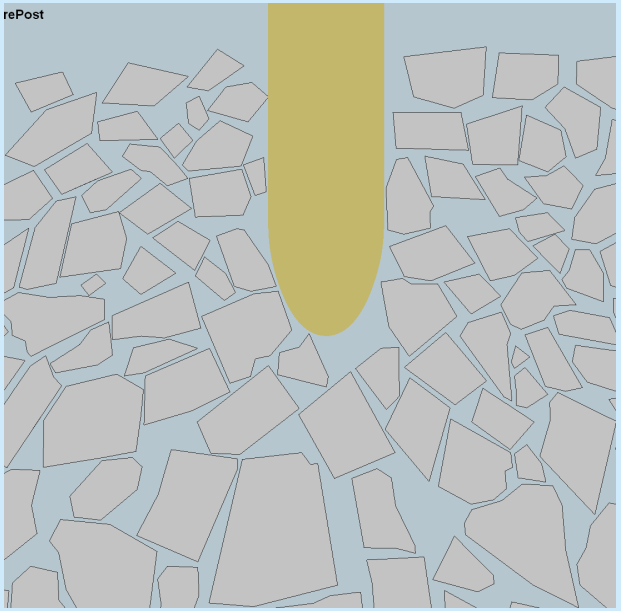
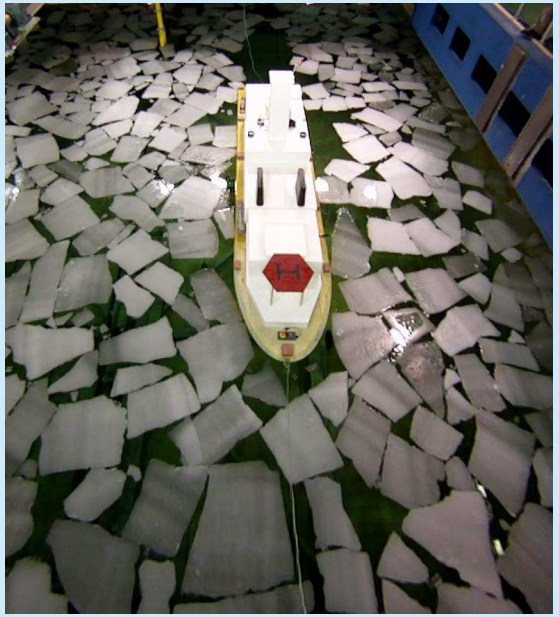
Numerical Modeling

- Preliminary ice movement comparison





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Questions?