Development of display system for offshore drilling equipment using digital twin technology

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EKMOA

❖ Pipe related machines on a drill floor



<Drill floor on a drillship 'Blacklion' of Diamond offshore drilling>

Large

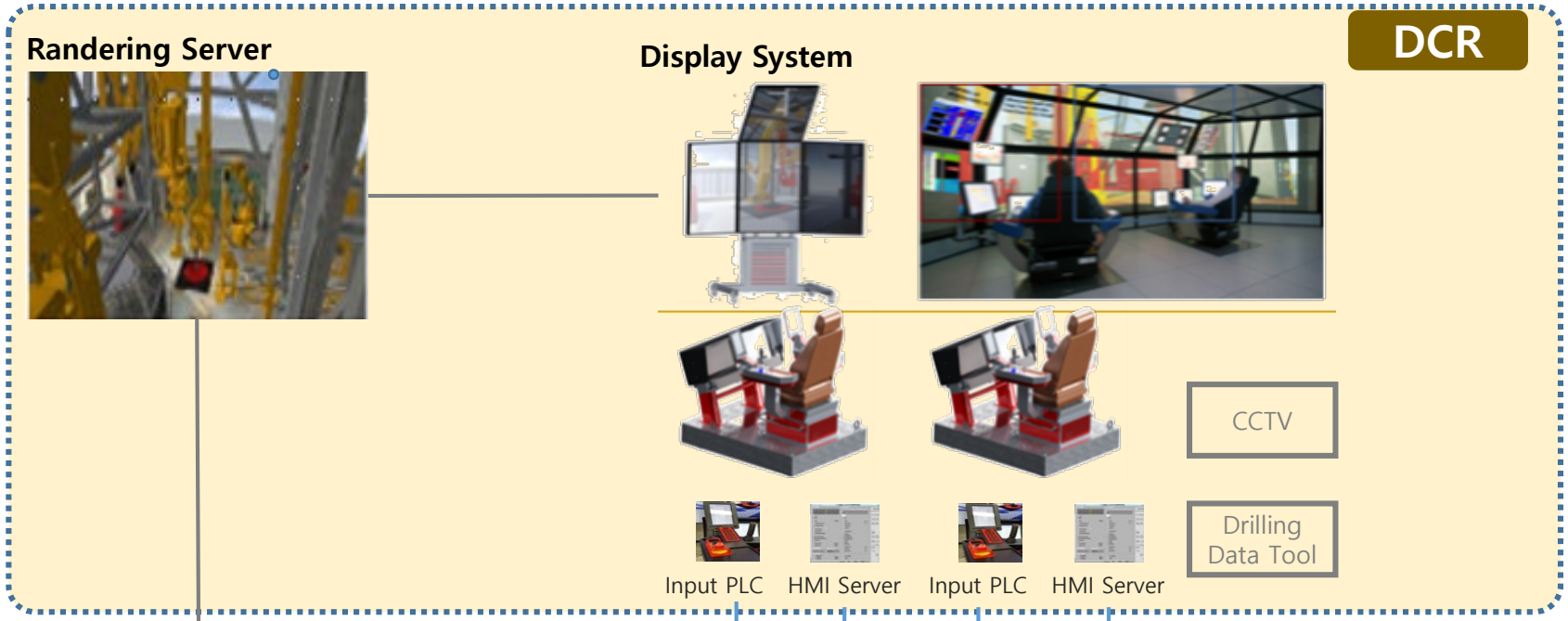
Heavy

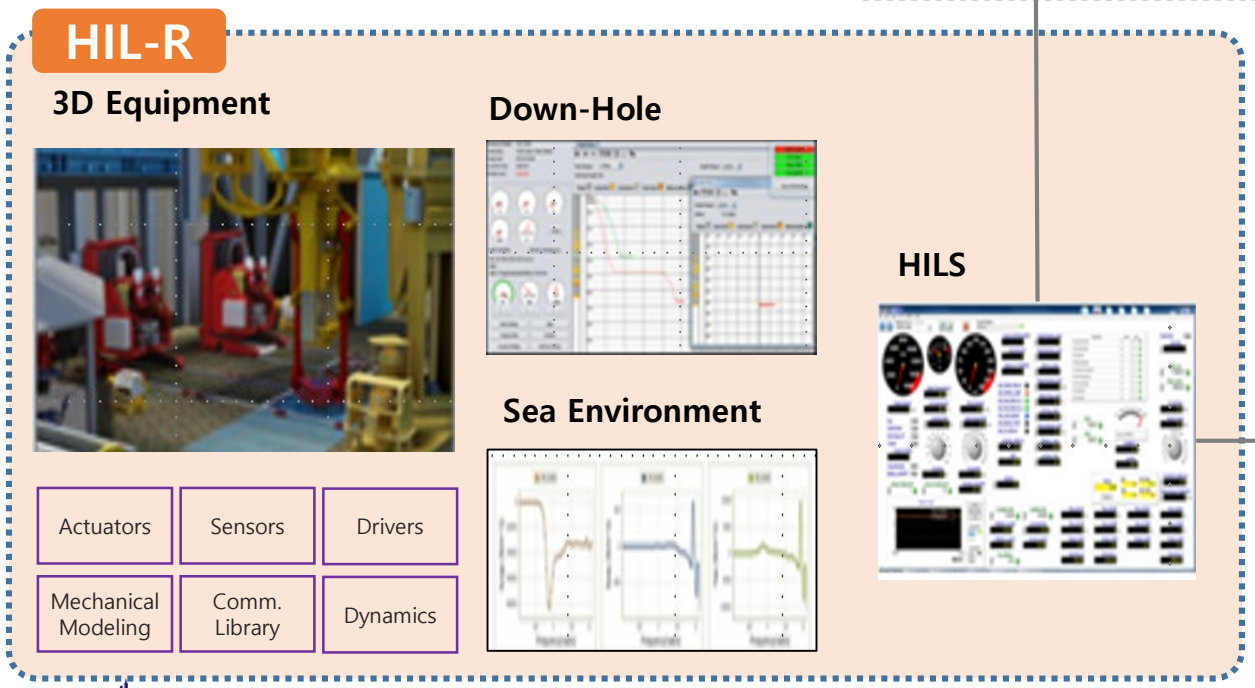
Dangerous

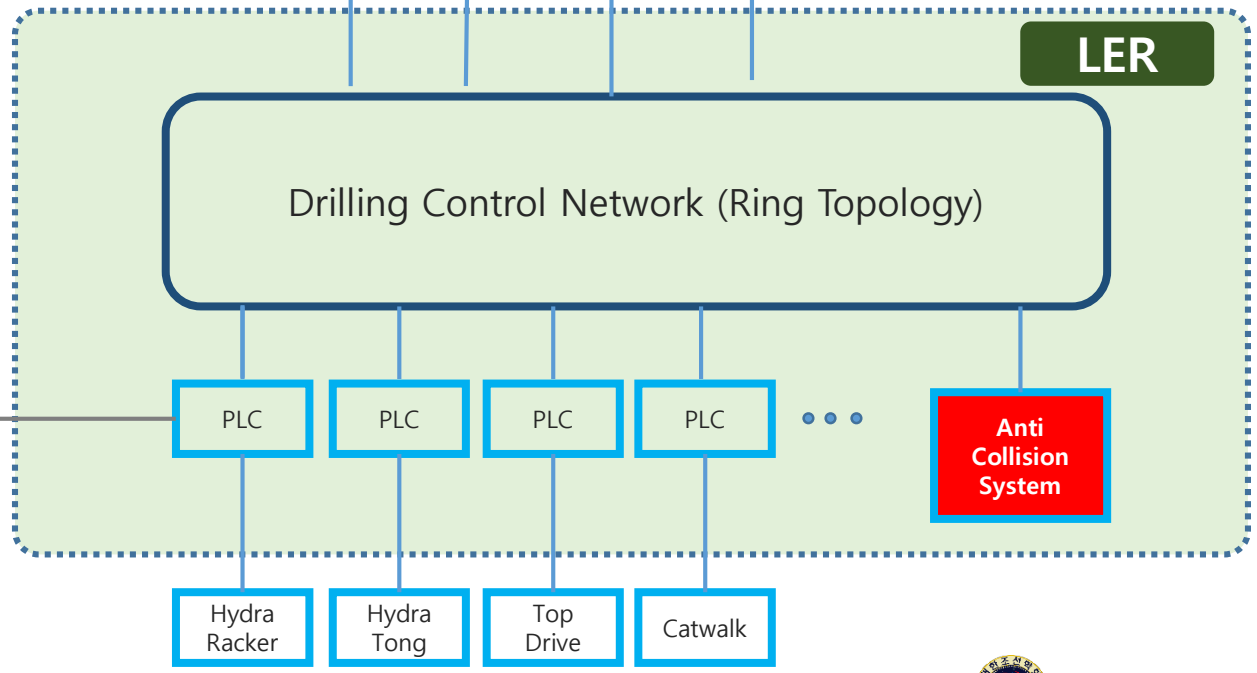
INTRODUCTION

❖ Systems for Offshore Drilling Simulation

DCR: Driling Control Room
HILS: Hardware in the Loop System
HIL-R: HIL Room
LER: Local Equipment Room
PLC: Programmable Logic Controller

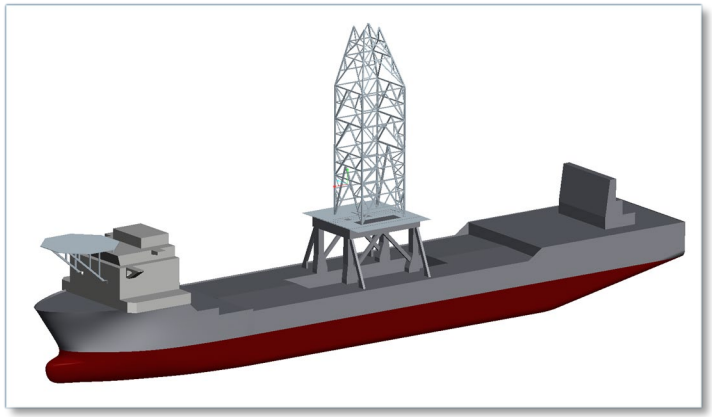






❖ Target Ship and Equipment Modeling

▣ 15K Drillship



3D Modeling

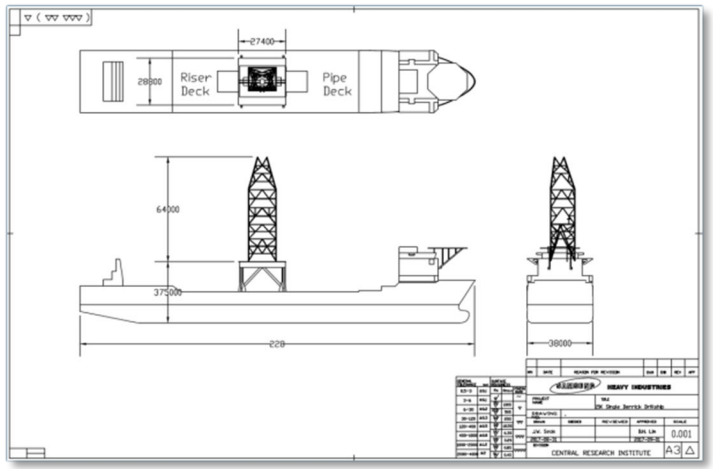
Operational Capacities:

- Water depth: 12.000ft
- Drilling depth: 40,000ft

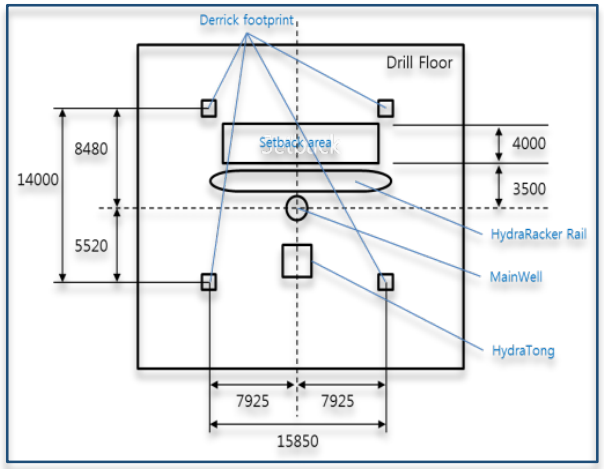
BOP Specification



- 15,000psi
- 6 ram cavities

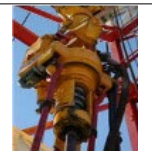


GA(General Arrangement)

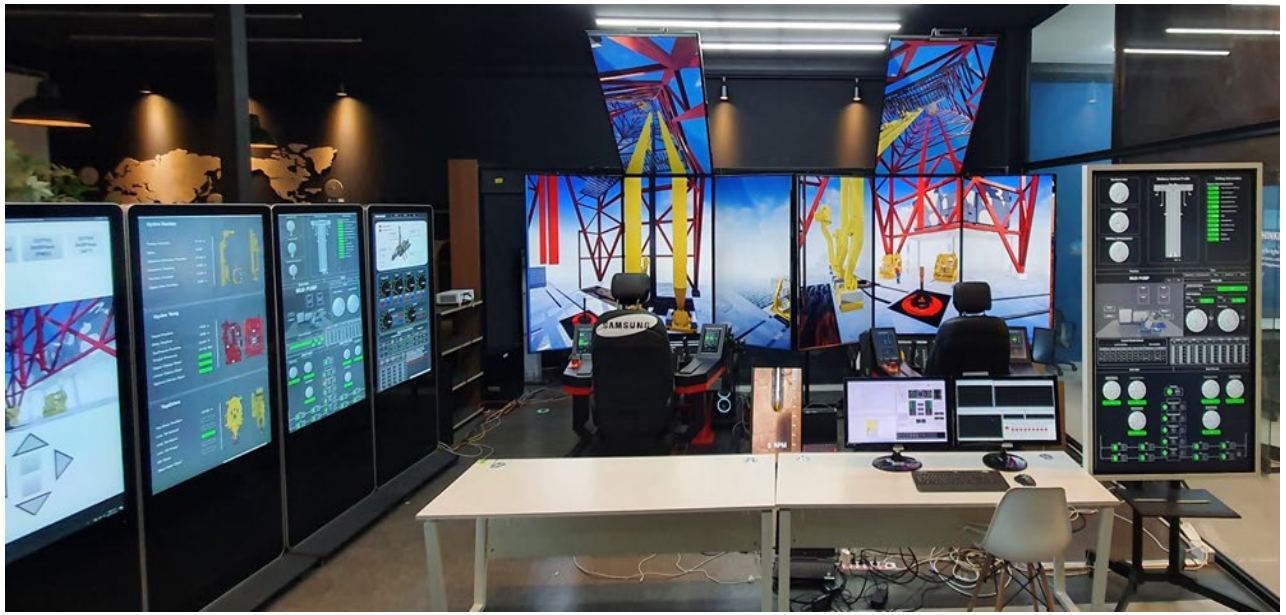


Drill Floor Arrangement

▣ Drilling equipment

Machines	Specification
Derrick(Single)	52 * 55 * 210 ft
Drawworks 	9,000 hp
Top Drive 	Hosting : 1,250 ton Torque : 105,000 ft-lbs
Mud Pump 	Power : 2,200 hp Pressure : 7,500 psi
Hydra Tong 	Max Torque : 200 kNm
Hydra Racker 	Arm reach: 4.8m SWL: 7t@4.8m Moving Speed: 0.33 m/s

❖ Final Simulation Facilities



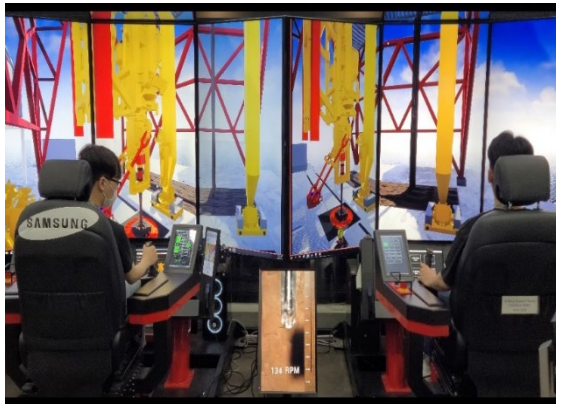
<Integrated Operation and Control Room>



<Local Equipment Room>

Mud Pump and Drilling Simulator

Main Drilling Control System & Rendering System



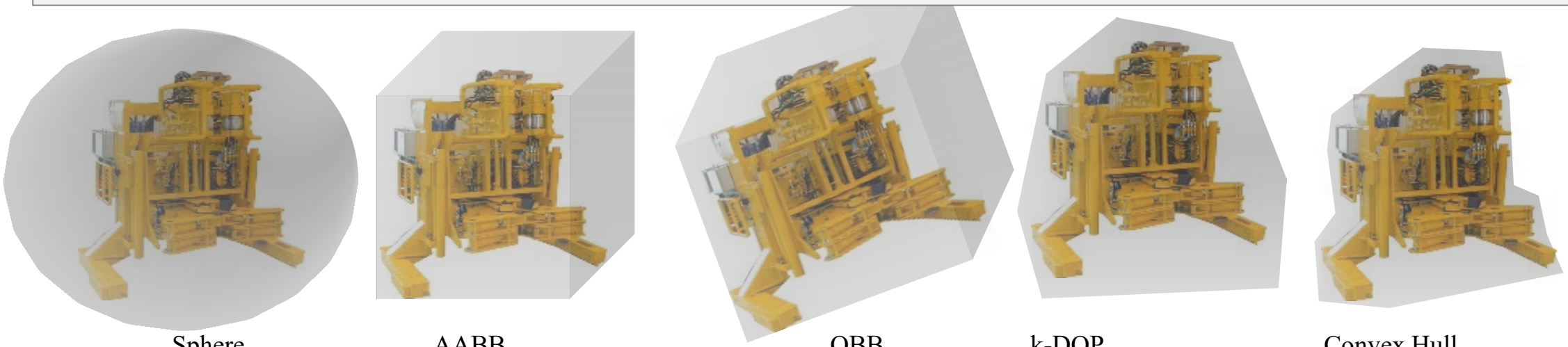


<Remote Monitoring System>

❖ Collision Check

▣ Bounding Box

- commonly used in geometric algorithms as inexpensive filters to avoid processing object pairs that are trivially non-intersecting
- Collision is checked by applying separating axis theorem



Sphere AABB OBB k-DOP Convex Hull

Poor Fidelity **Precise**

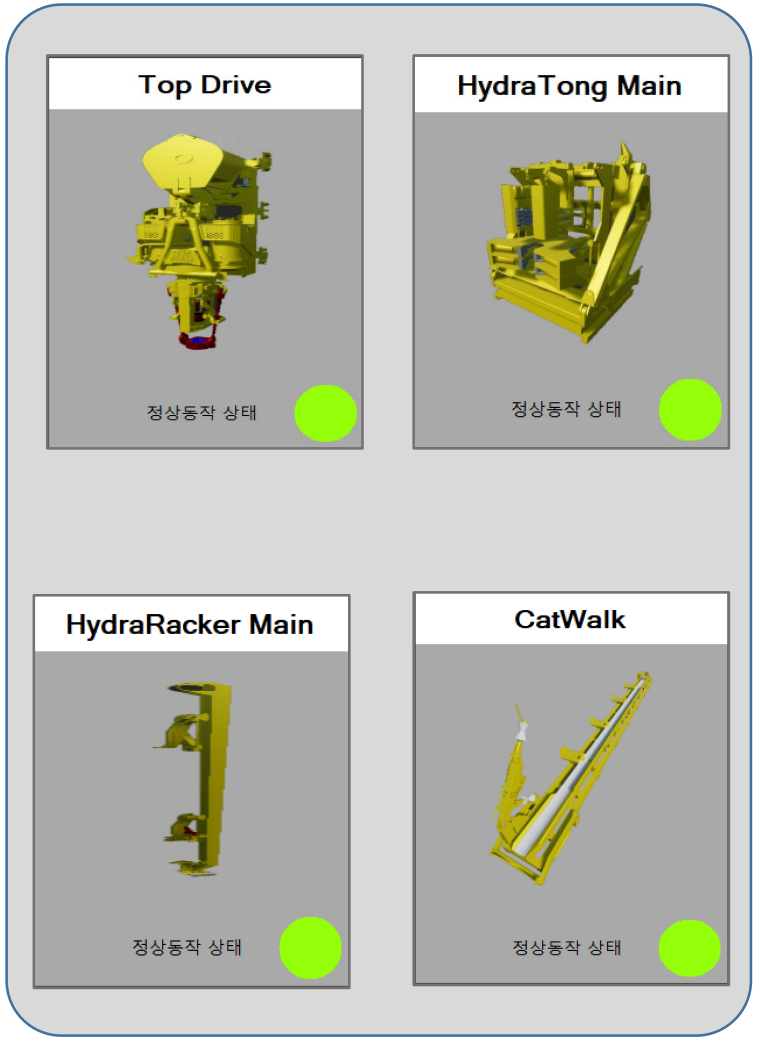
Simple Complexity **Complicated**

- AABB: Axis-Aligned Bounding Box
- OBB: Oriented Bounding Box
- k-DOP: Discrete Orientation Polytopes

❖ Collision Check

▣ Dependency check for subsystems

- **Top Drive**
  - Top Drive
    - Pick Up Elevator
- **Iron Roughneck**
  - Base Frame
    - Tool Frame
      - Spinner
- **Racker**
  - Trolley
    - Column
      - Upper Arm
      - Main Arm
      - Tail Arm
- **Catwalk**
  - Catwalk
    - Skate

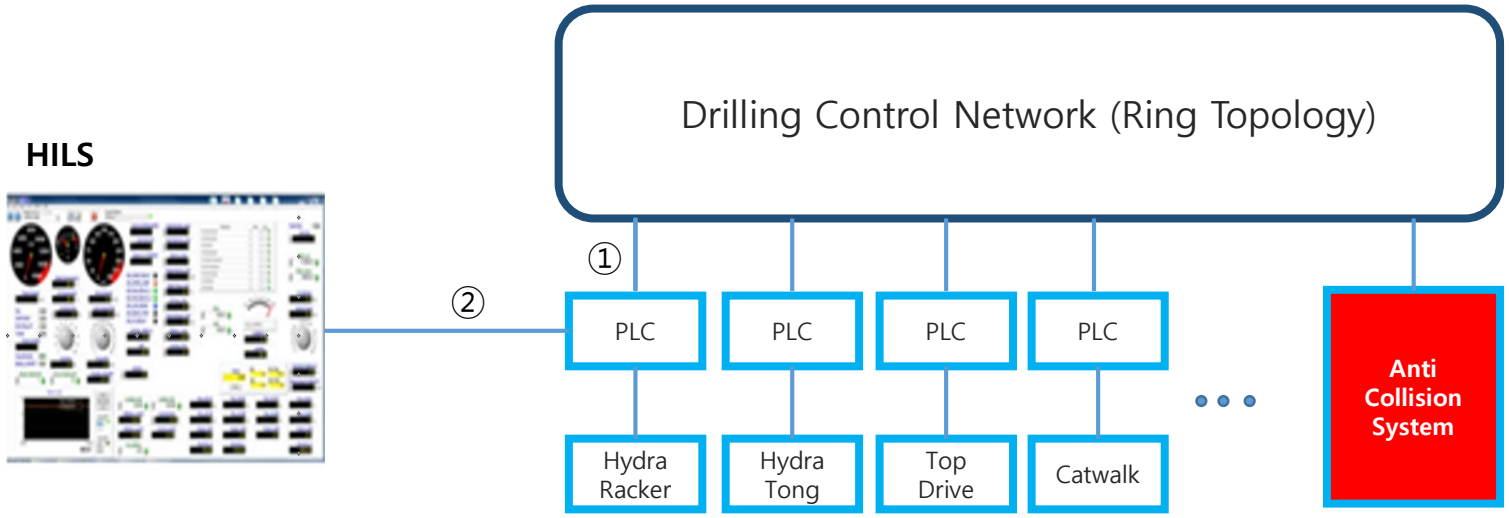


▣ Motion analysis for bounding box setting

Subsystems	Movement	Bounding Box
Top Drive	Vertical	AABB
Spinner	Rotational	OBB
Tool Frame	Translational(y), Vertical	AABB
Base Frame	Translational (y),	AABB
Upper Arm	Translational (local x)	OBB
Main Arm	Translational (local x)	OBB
Tail Arm	Translational (local x)	OBB
Column	Rotational	OBB
Trolley	Translational (x)	AABB
Skate	Translational (x)	AABB

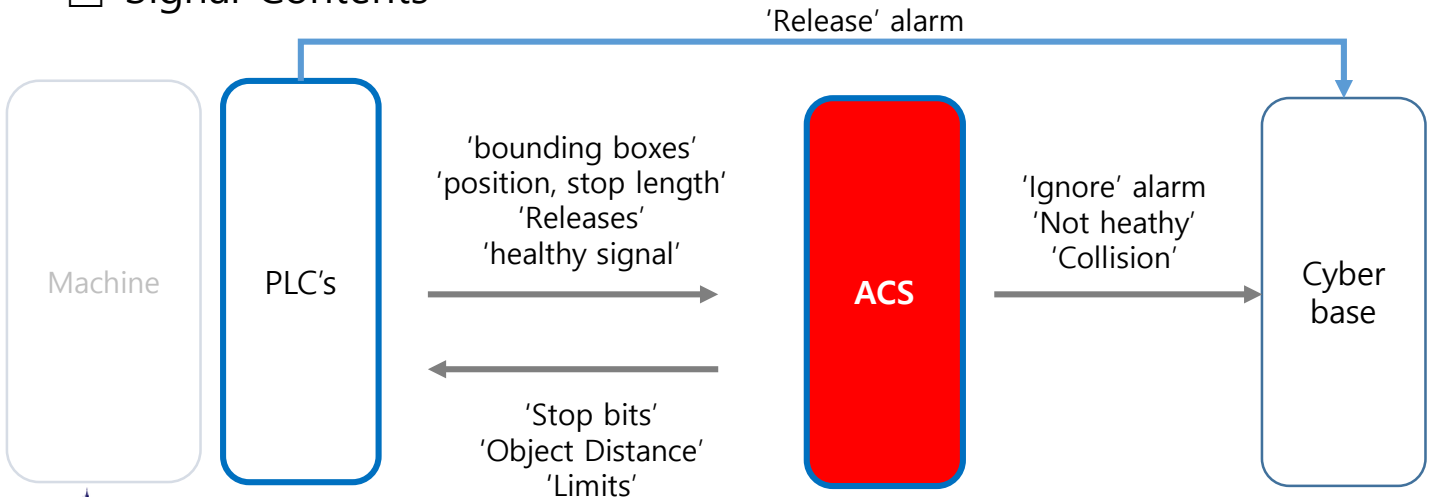
❖ Communication for ACS

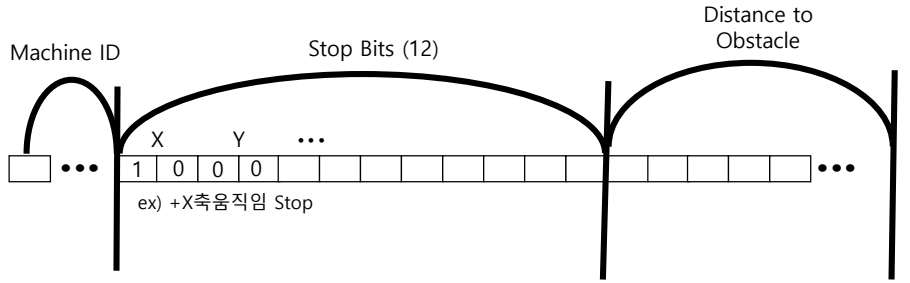
▣ Communication



Machine information for the ACS
① On-site equipment
② Artificial signal

▣ Signal Contents

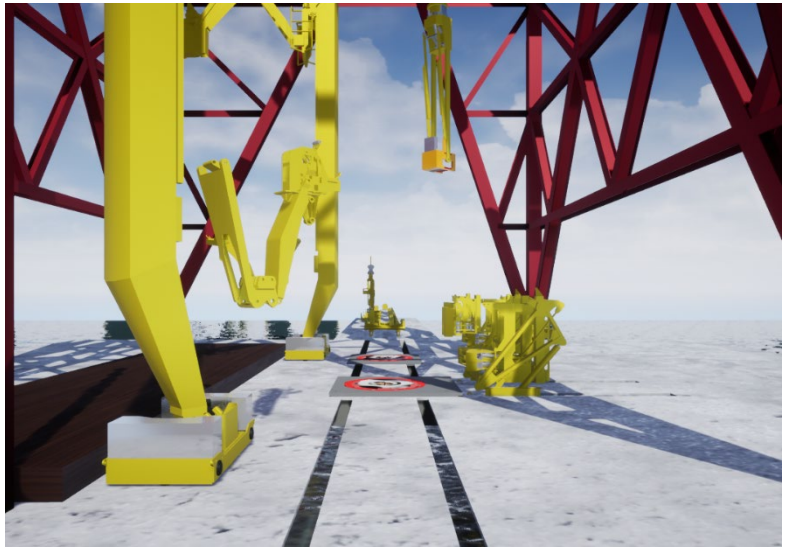
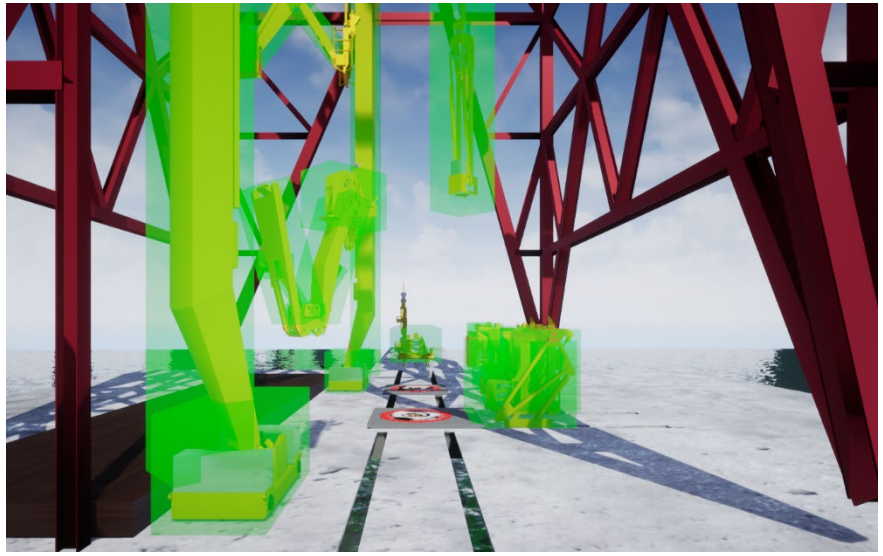
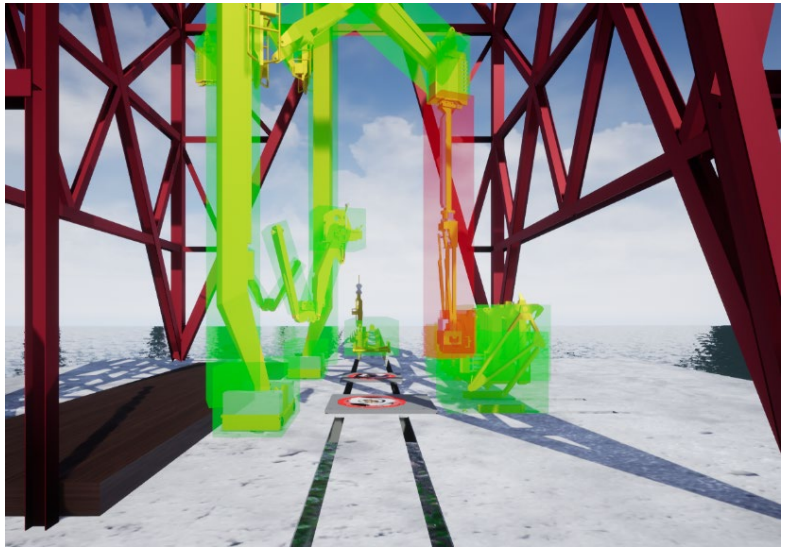




- Two stop bits for each movement direction on each axis in the coordinate system (a total of six) for each movable part of the machine.
- Distance to collision object in X, Y and Z direction
- The machine must be able to receive analog or digital limits for all axis movement directions.

❖ Collision Check

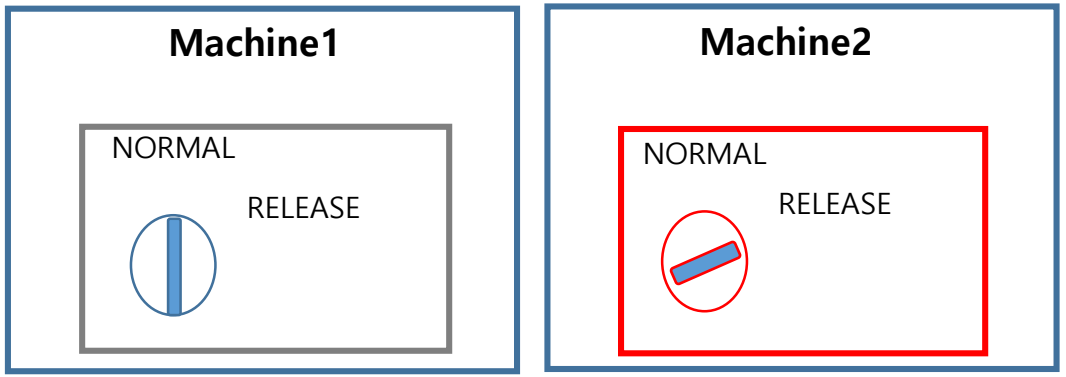
▣ Bounding Box

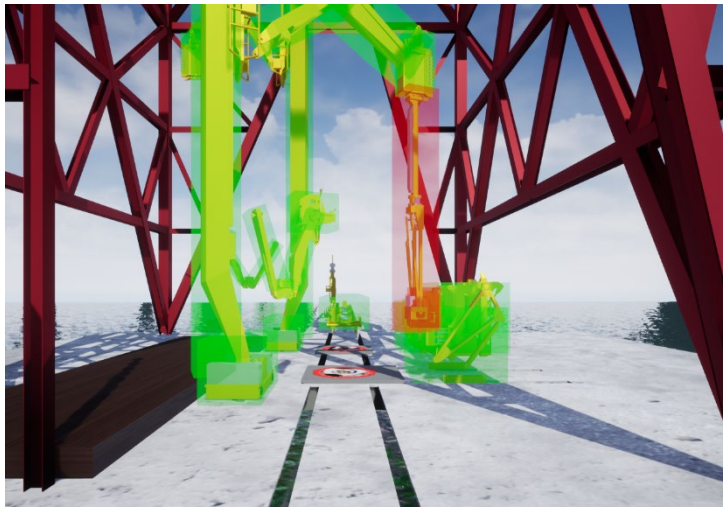




ANTI-COLLISION SYSTEM: CORE

❖ Override (Bypass)

▣ Release (Blind)





ACS:

- Send stop signals to the machine PLCs

Machine 1:

- Comes to a halt by the ACS' stop signal
- (Response to other machines are done by ACS)

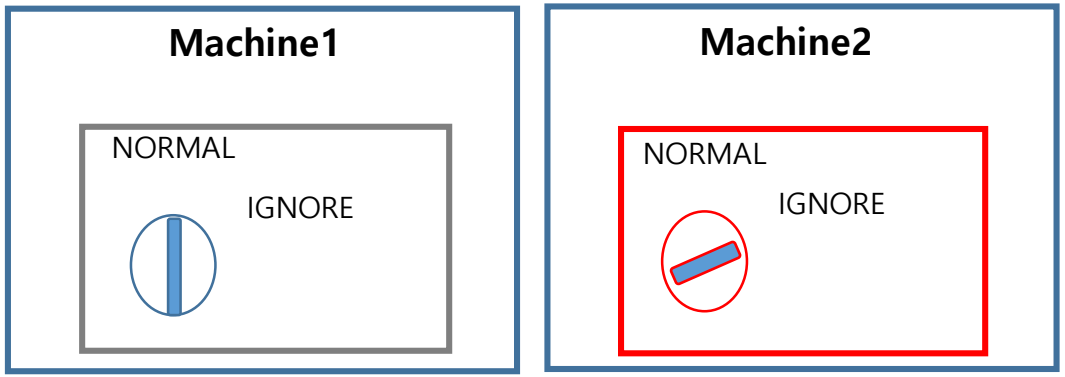
Machine 2:

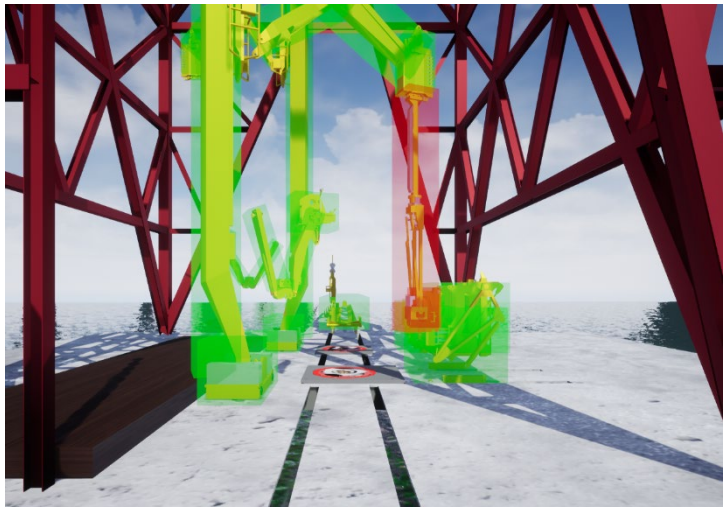
- Freed from ACS => can make a movement by operators

ANTI-COLLISION SYSTEM: CORE

❖ Override (Bypass)

▣ Ignore (Invisible)





ACS:

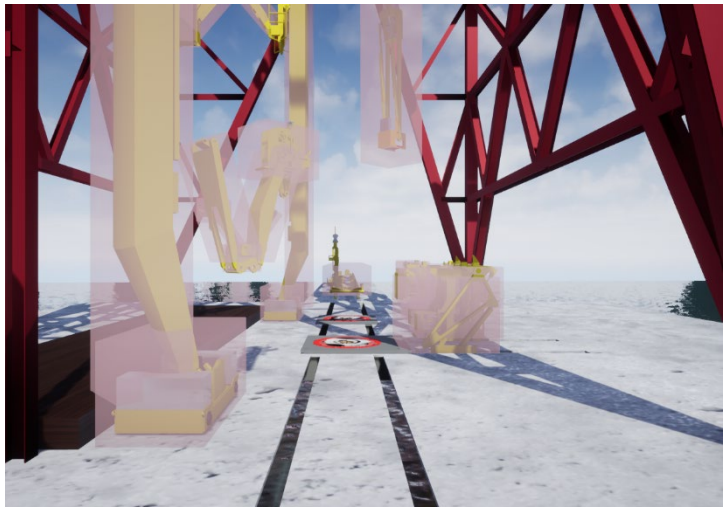
- Ignore the position information from the machine 2
- Do not generate **STOP** signal

Machine 1:

- Can move because there is no STOP signal from ACS

Machine 2:

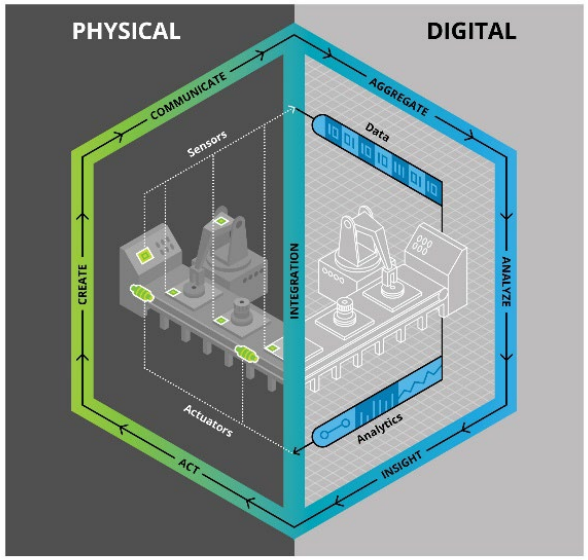
- Invisibile to other machines



DIGITAL TWIN

❖ Definition of Digital Twin

Imaginary twin logically operated in a computer system for **Physical object** (product, process, system)



❖ Advantages of Digital Twin

- Store digitalized object information
- Reuse the data quickly
- Application
  - Improve efficiency
  - Reduce product release time
  - Flexible production
  - Quality improvement
- Involved in decision-making process

❖ Steps of Digital Twin

3 steps*

3D visualizaiton → **Realtime monitoring** → **Optimization**

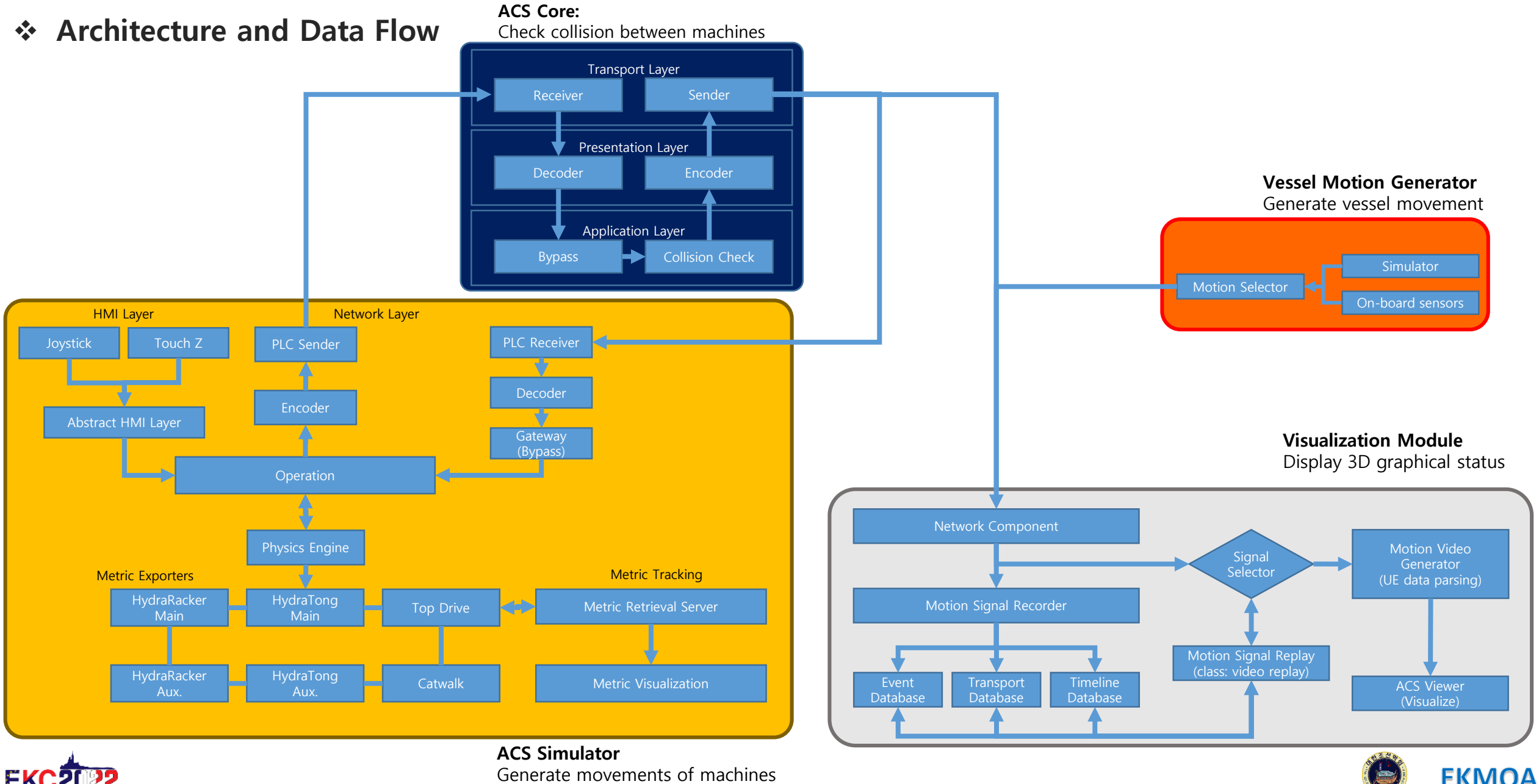
5 steps

Mirroring → **Monitoring** → **Modelling & Simulation** → **Federation** → **Autonomy**

*: Gartner, **Use the IoT Platform Reference Model to Plan Your IoT Business Solutions**, 2016

ANTI-COLLISION SYSTEM (ACS)

❖ Architecture and Data Flow

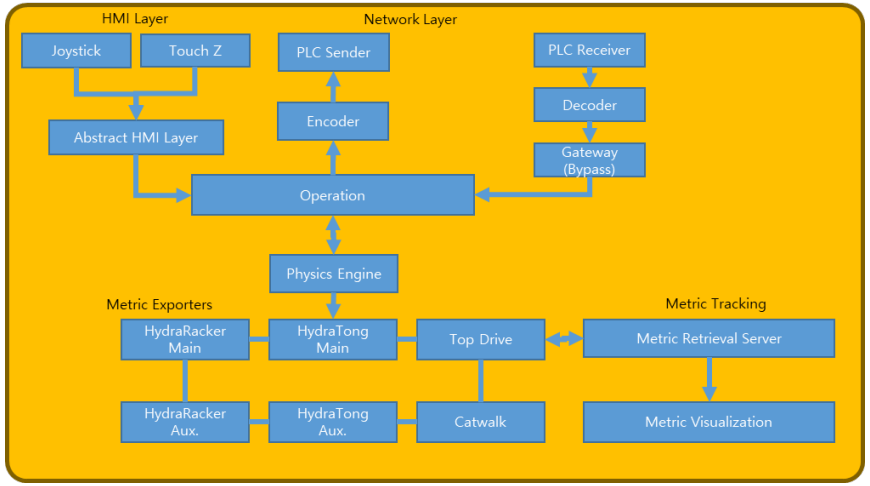


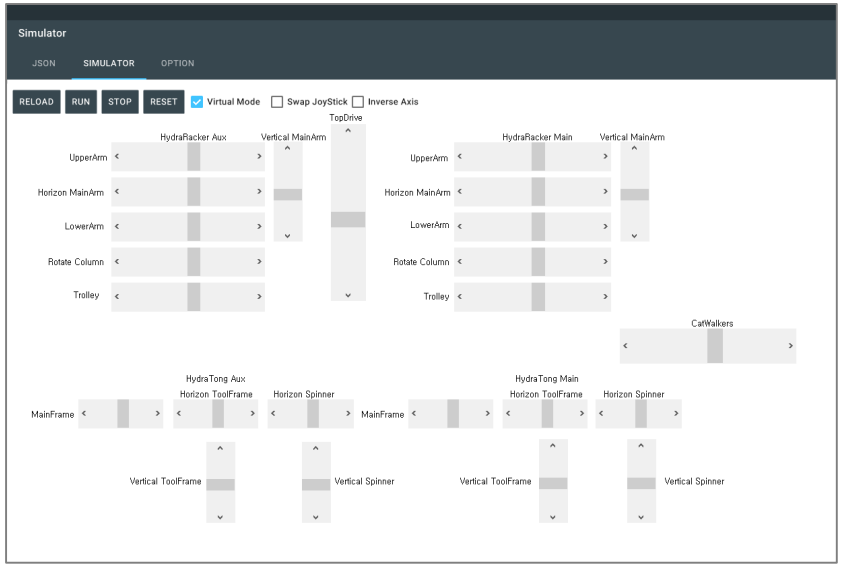
ANTI-COLLISION SYSTEM: MACHINE SIMULATOR

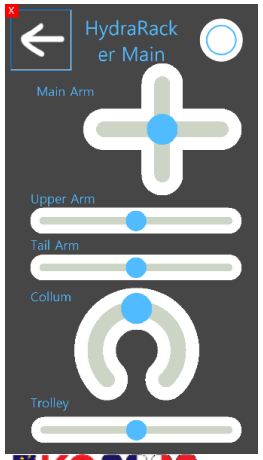
❖ GUI Design

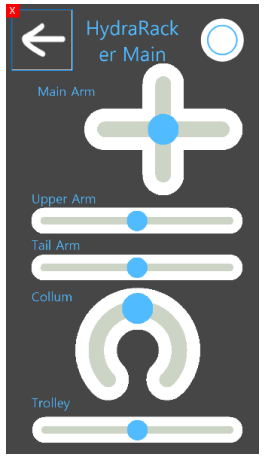
▣ Input & Display

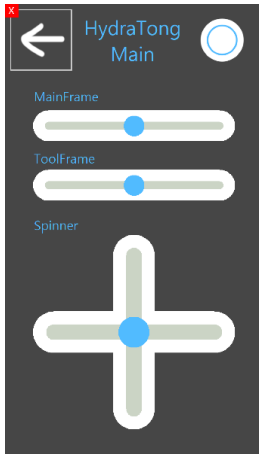


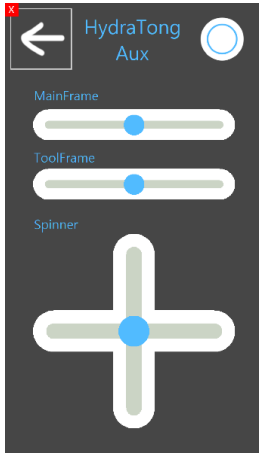


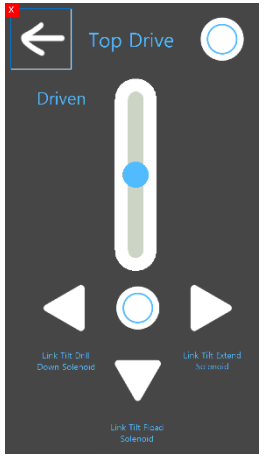


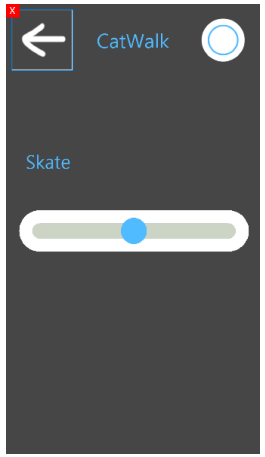








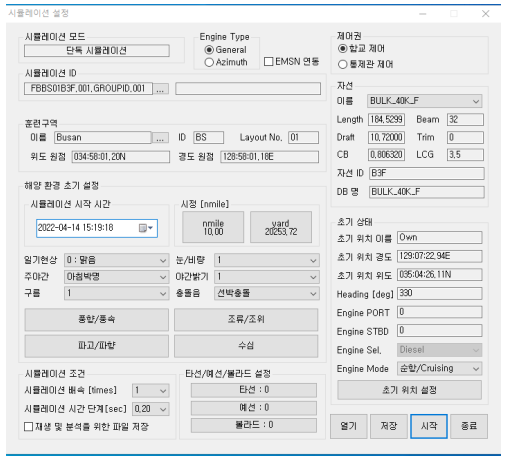




ANTI-COLLISION SYSTEM: VESSEL MOTION GENERATOR

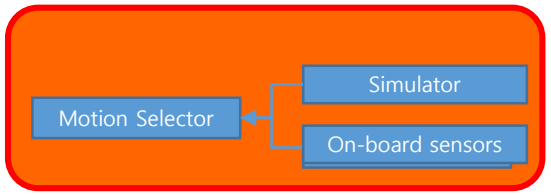
❖ STR Simulator

▣ Simulation Setting



▣ Simulation Controller

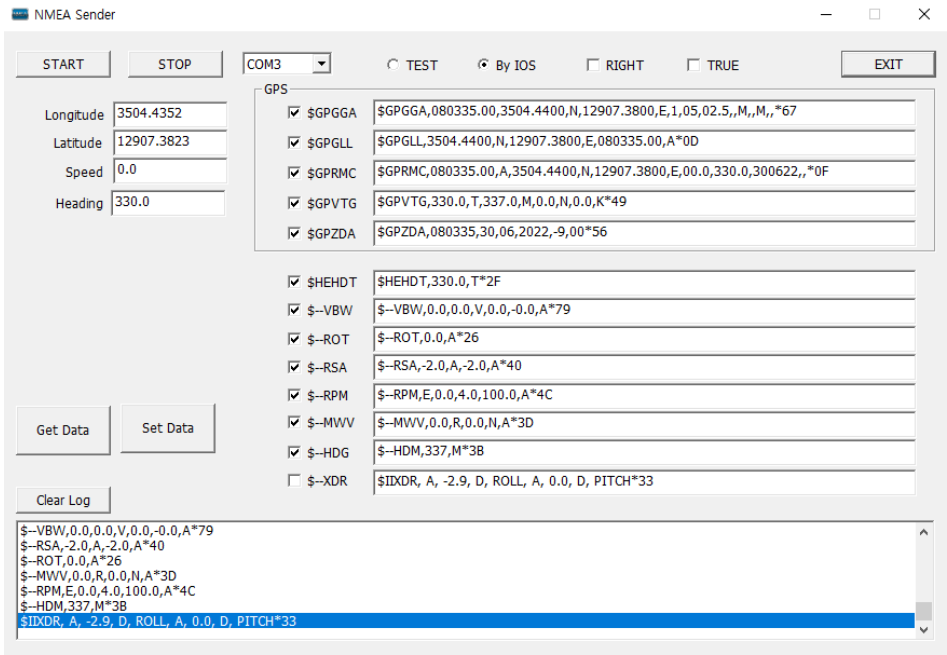






▣ NMEA Sender

- NMEA 0183 format
- Basis for AIS (Automatic Identification System)

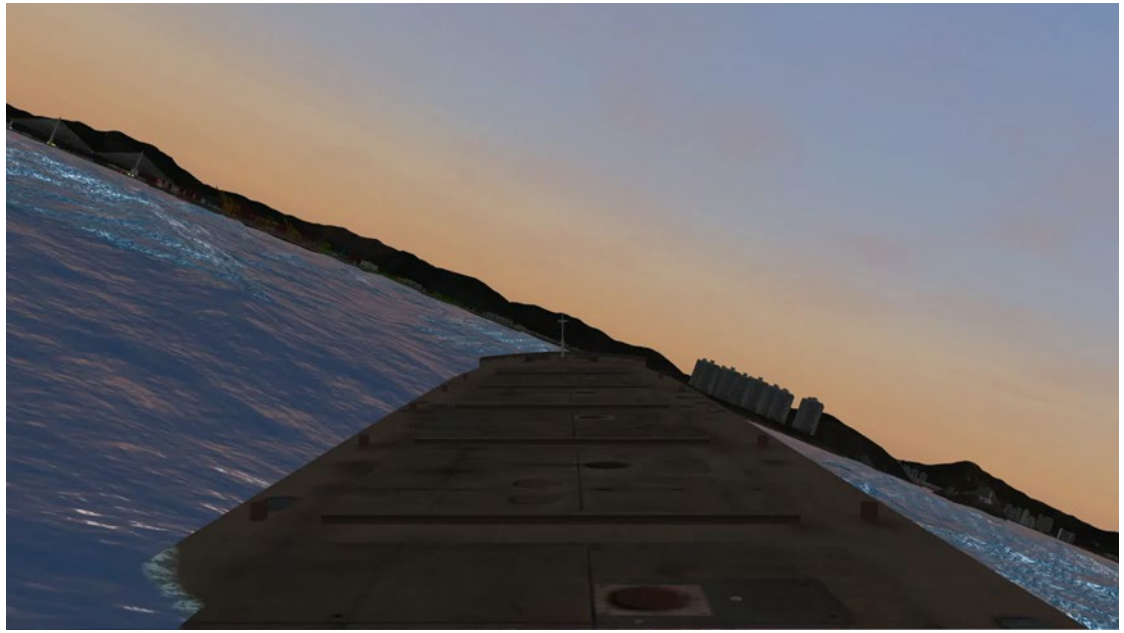


ANTI-COLLISION SYSTEM: VESSEL MOTION GENERATOR

❖ STR Simulator

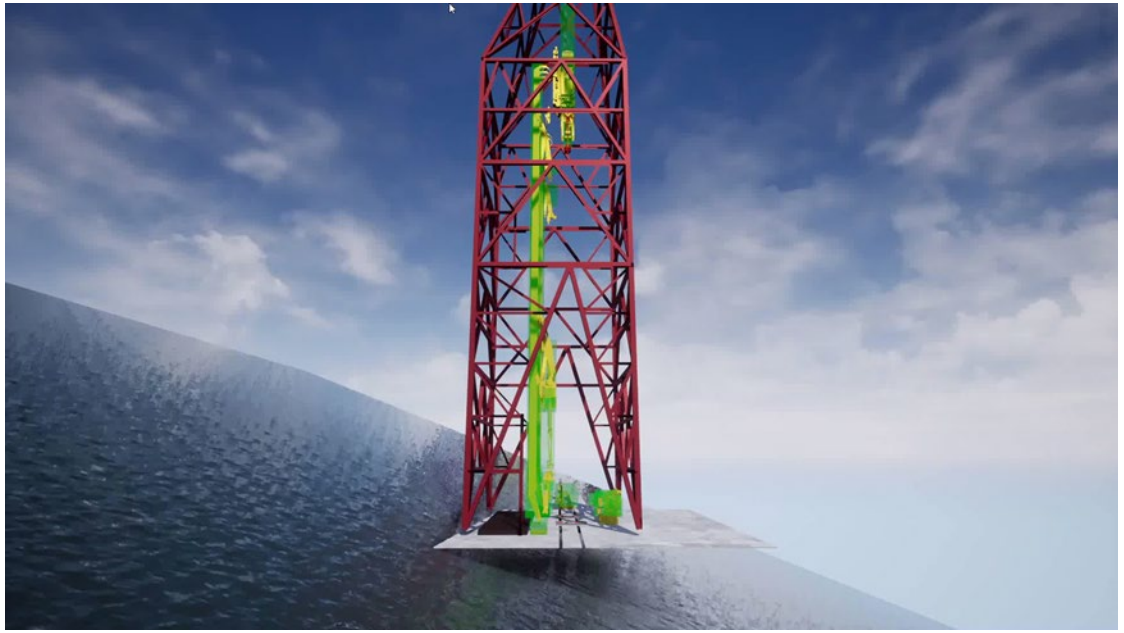
▣ Connecting two systems

<STR Simulator>



UDP

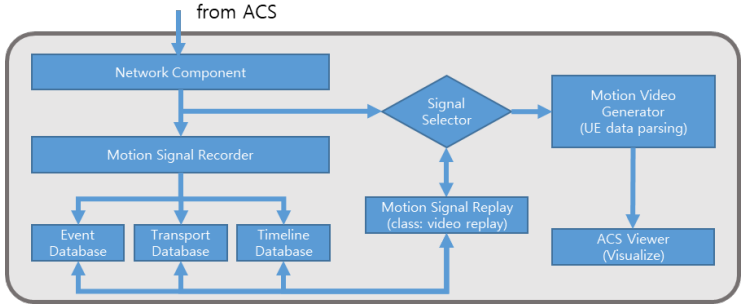
<Visualized Anti-Collision System>



ANTI-COLLISION SYSTEM: VISUALIZATION MODULE

❖ Motion Signal Recorder

▣ mongoDB based recording system

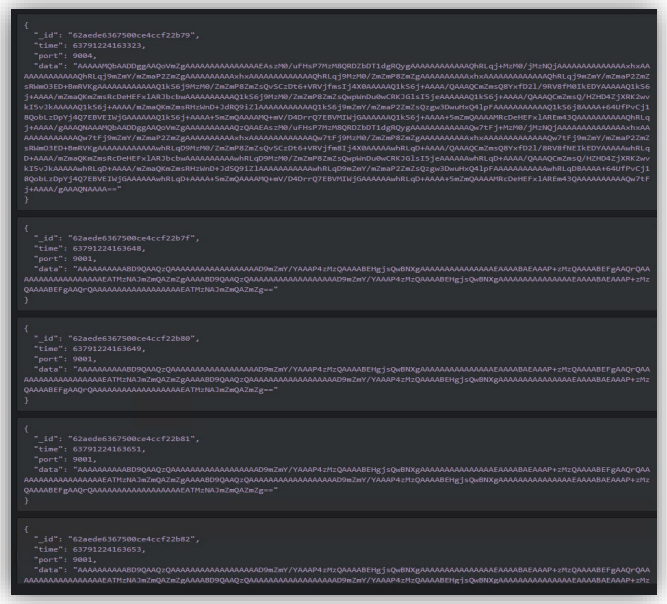


mongoDB

- Document based non-relational database mangagement system
- 10~100 times faster than RDBMS

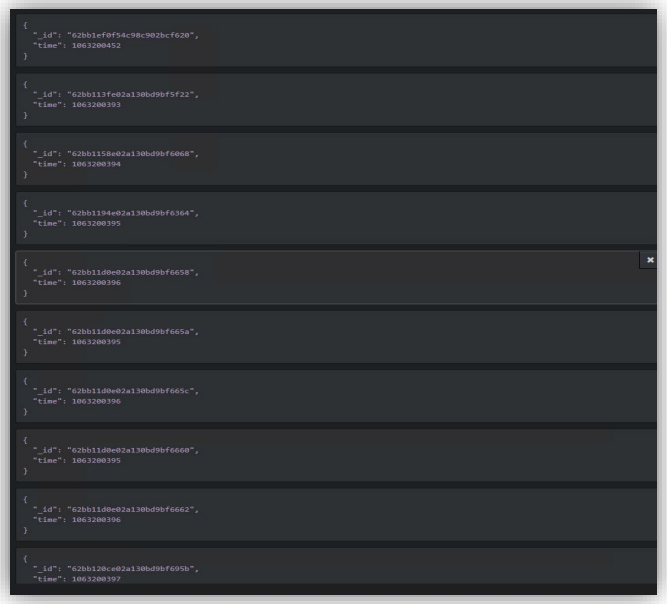
3 collections (tables in RDBMS)

- Transport collection, Event collection, Timeline collection



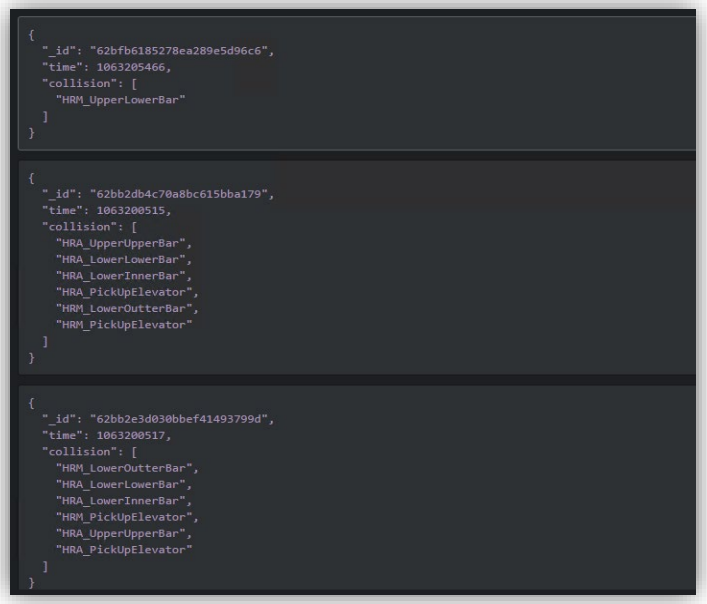
Transport collection

- Store all the data from the networks
- id+time(ms)+data



Event collection

- Store information in case of collision
- id+time



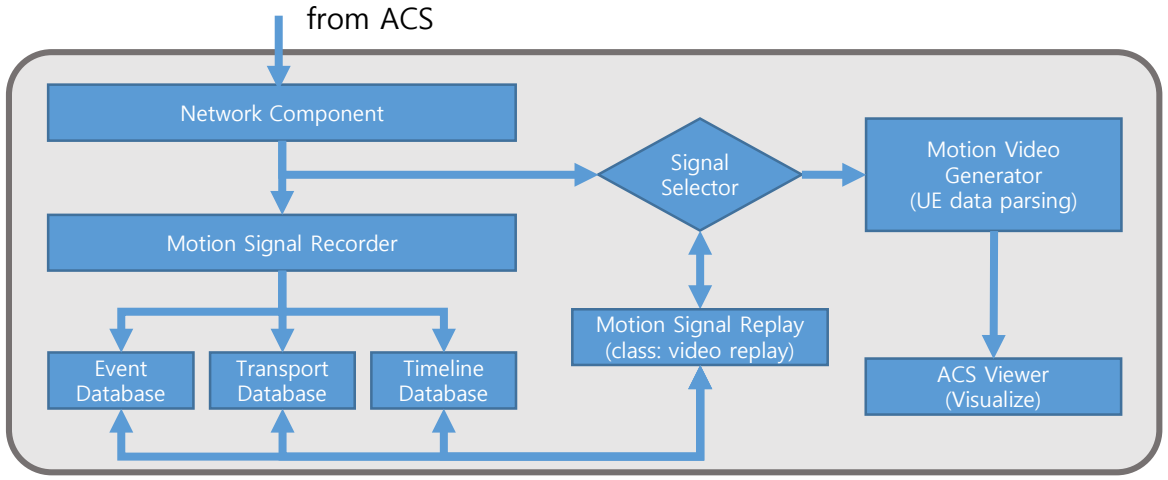
Timeline collection

- Contain every 1 minute
- Id+time+data

Visualization Module

❖ Motion Signal Recorder

▣ mongoDB based recording system



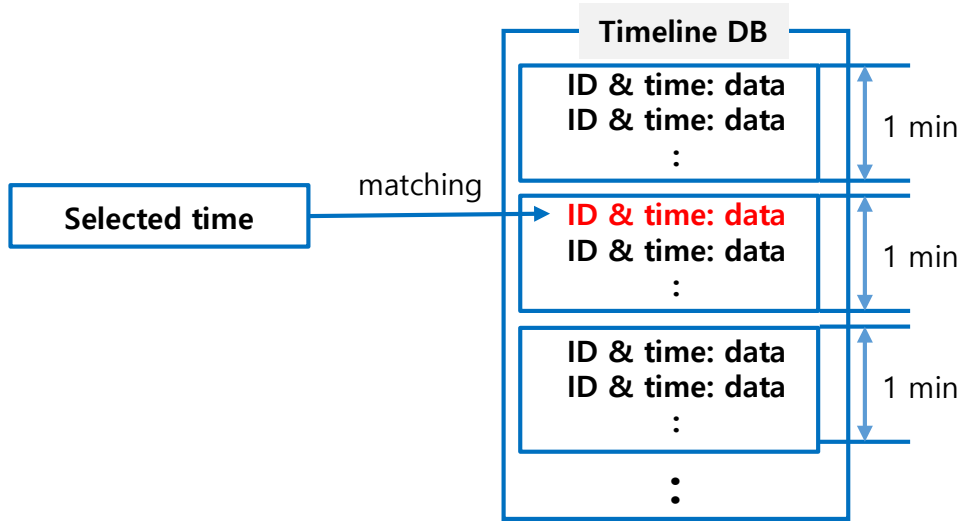
Signal Selector:
- Real time data vs. DB stored data

Motion Signal Replay:
- Identify the replay mode (timeline or event)
- Retrieve stored data from DB

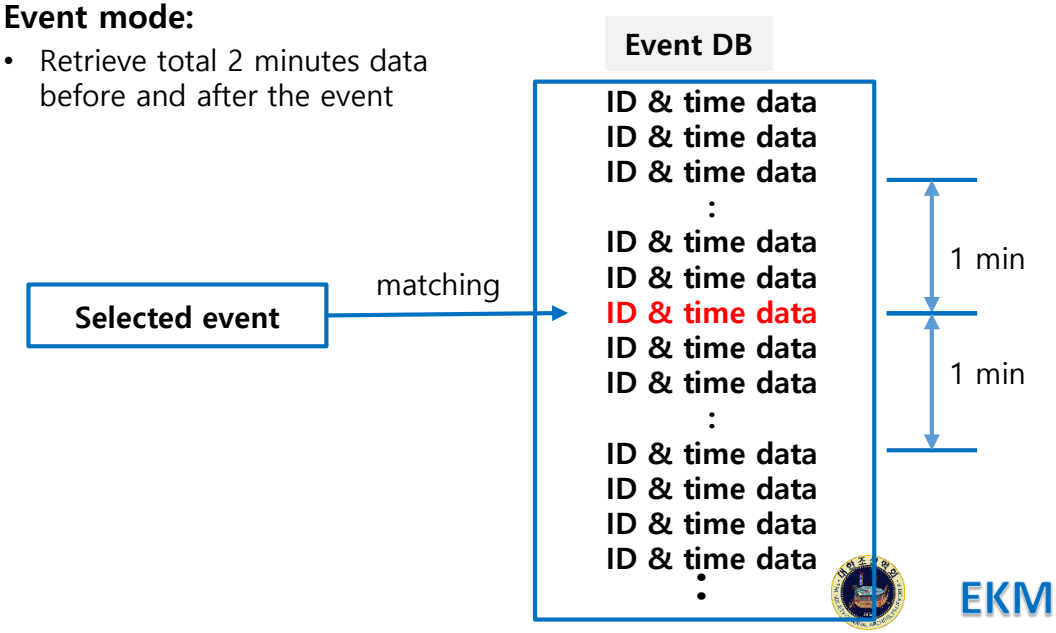
Motion Video Generator:
- Data parsing for Visualization SW (Unreal Engine)

ACS Viewer:
- Display parsed data sequentially

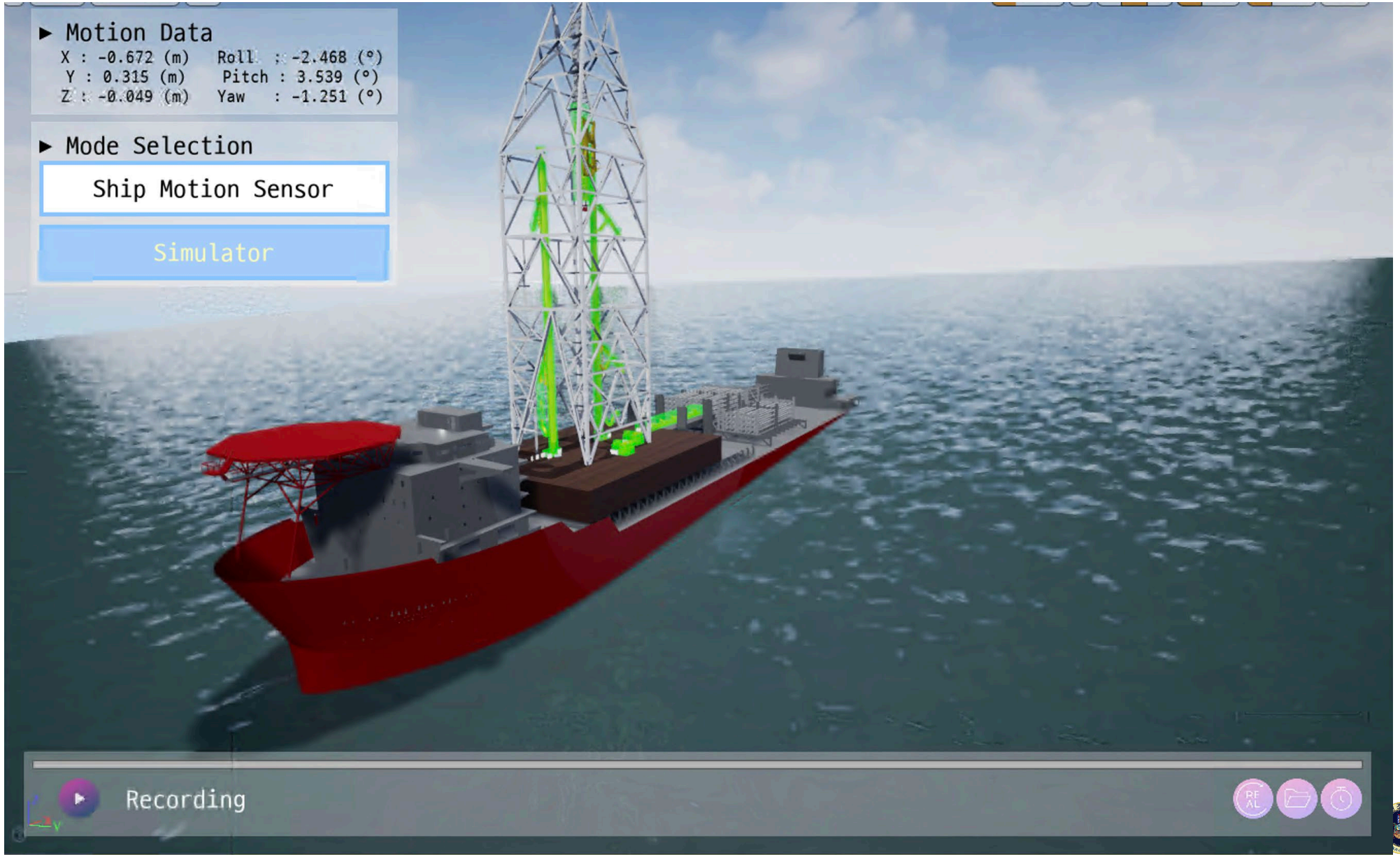
Timeline mode:
- Match the required time data with the first time information of each column in the DB



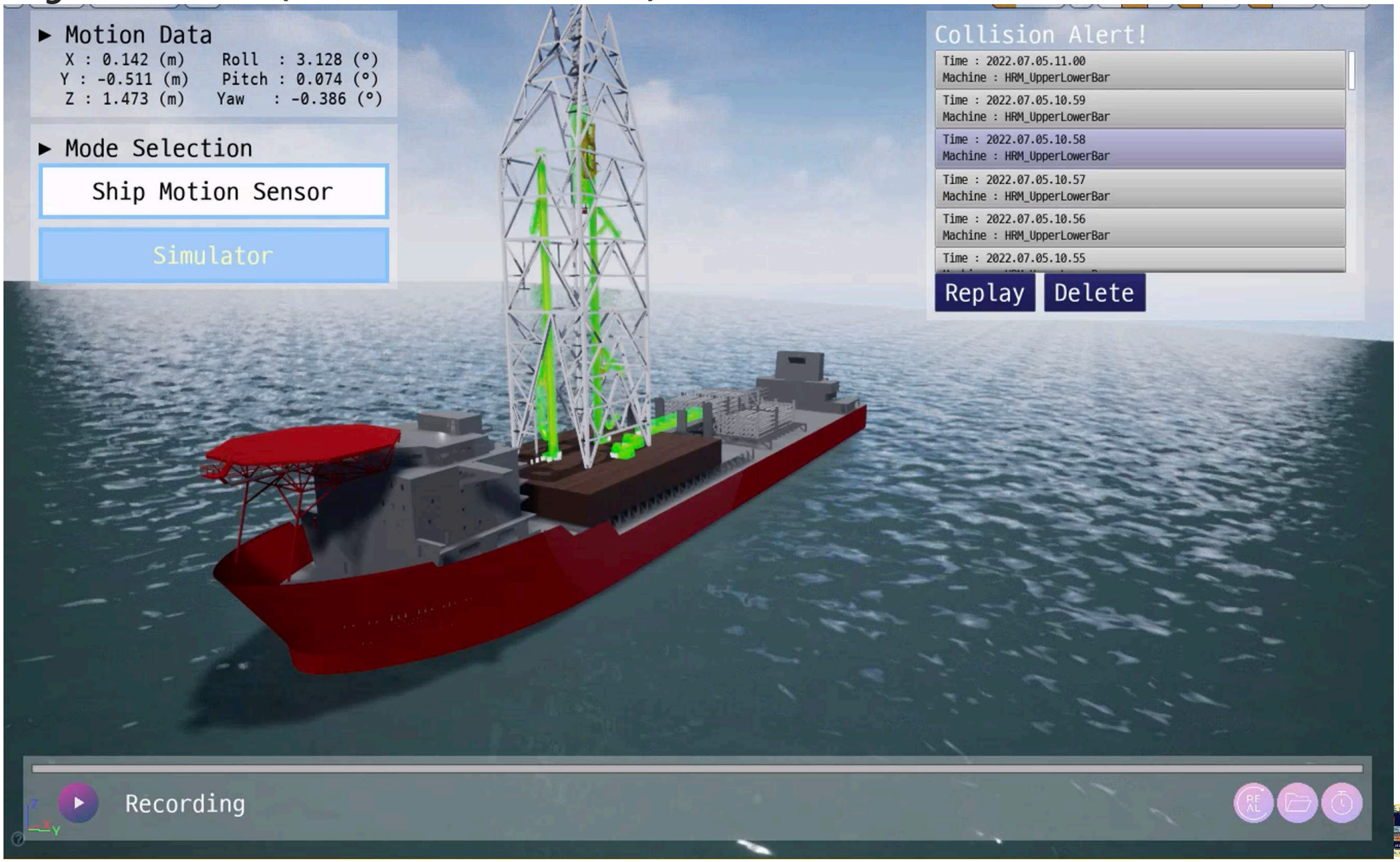
Event mode:
- Retrieve total 2 minutes data before and after the event



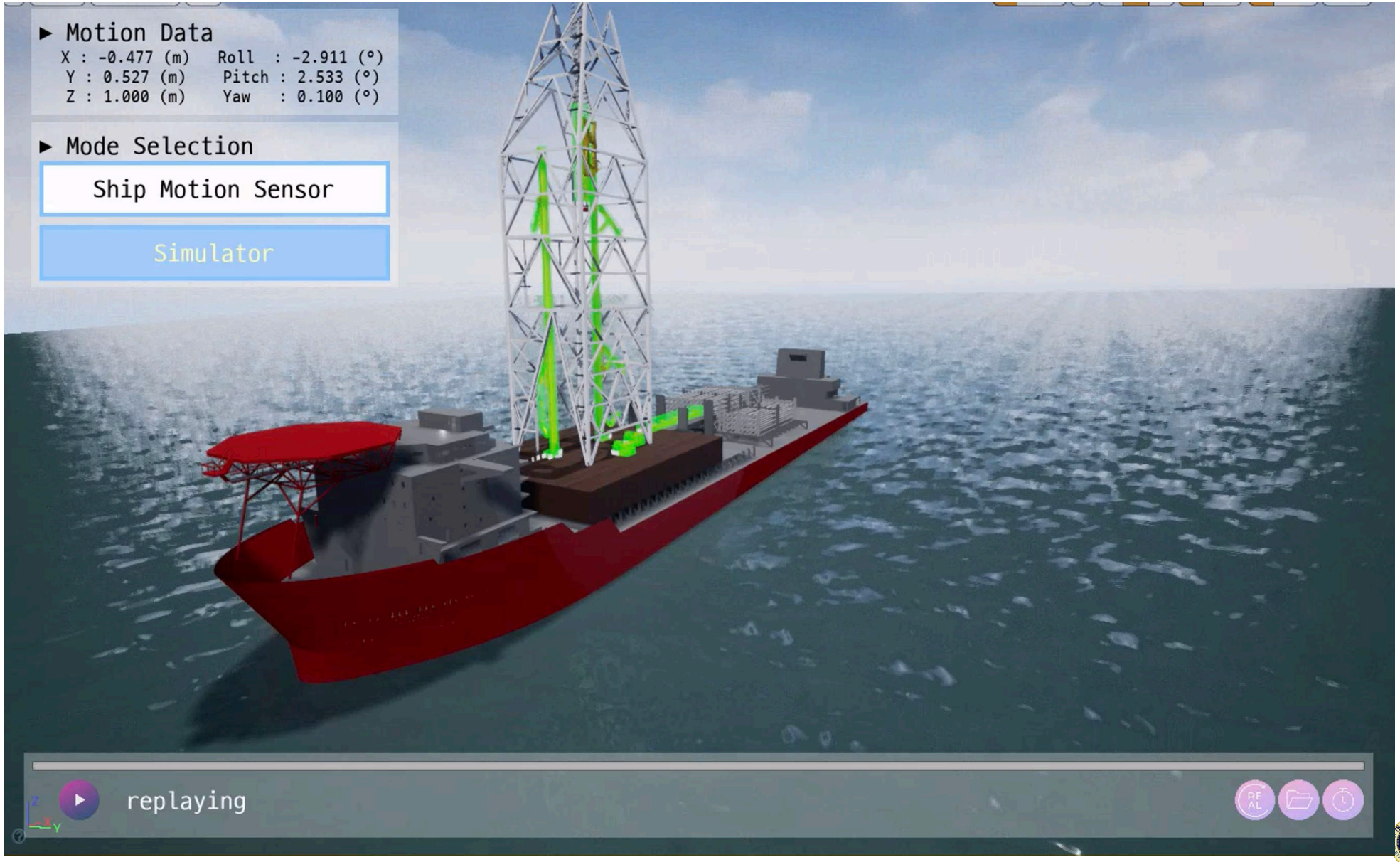
❖ Motion Signal Recorder (Real time operation)



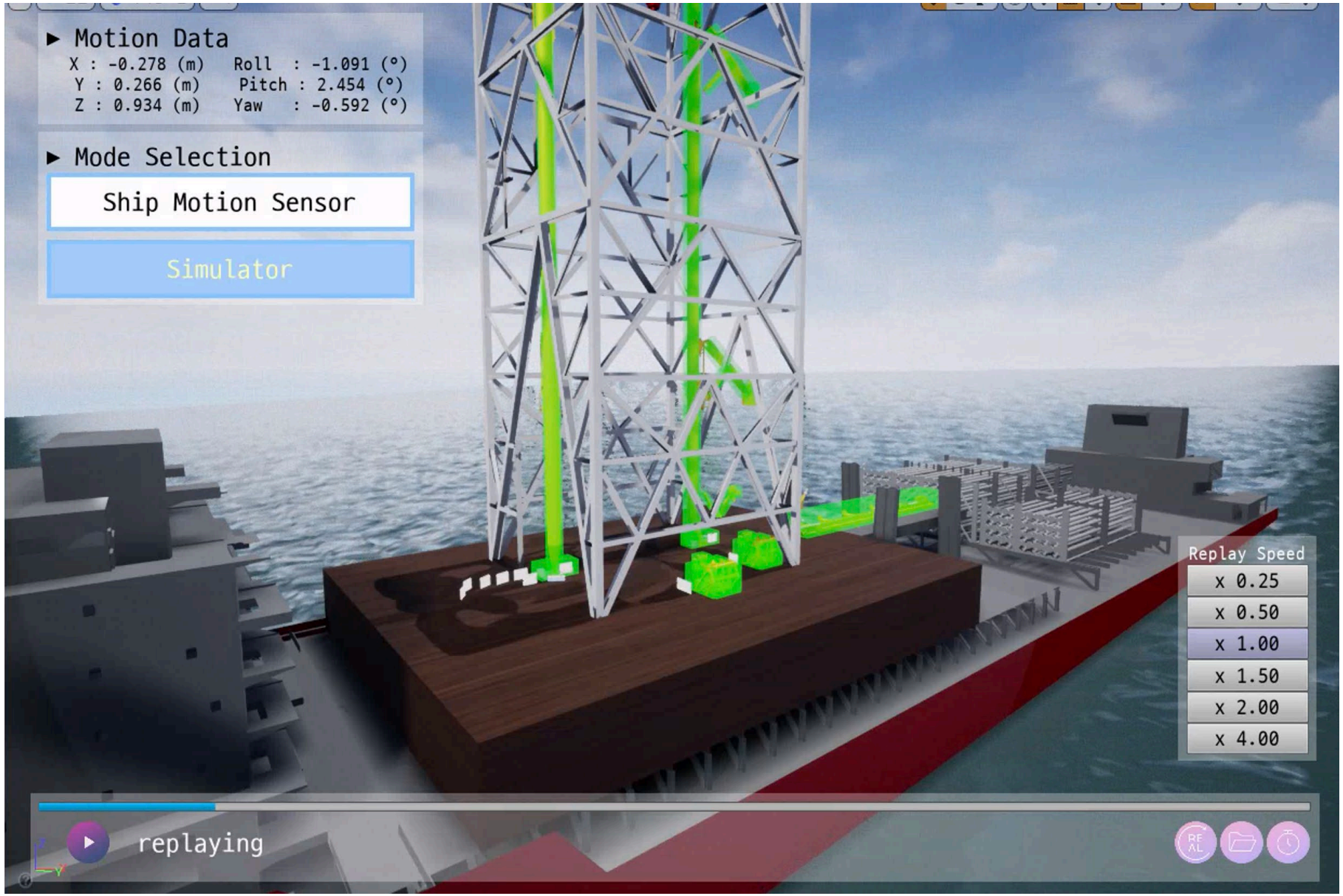
❖ Motion Signal Recorder (Alert list and selection)



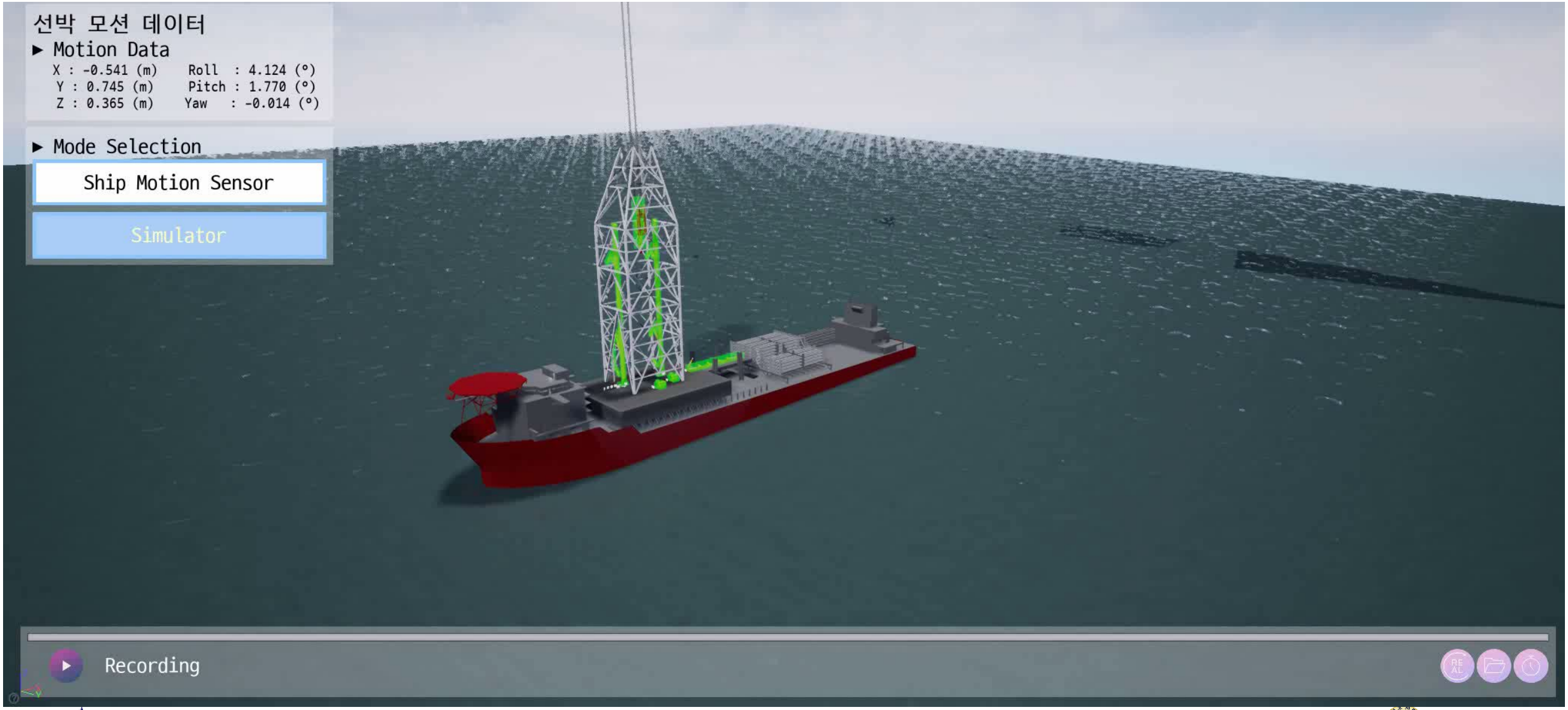
❖ Motion Signal Recorder (Replaying)



❖ Motion Signal Recorder (Replay speed)



❖ Motion Signal Recorder (Example)



❖ Motion Signal Recorder (Example)



CONCLUSION

❖ System enhancement

- Upgraded Anti-Collision System with the concept of digital twin
- Controlled virtual input: Vessel Motion Generator, Machine Simulator
- Viualization: DB + Interactive GUI

❖ Application

▣ Safety

- Analyze accidents occurred during the operation by replacing limited visibility of CCTV system
- Derive the design parameters for safety systems (sensors, communication tools, …)
- Utilize as a testbed for a safe and smart drilling process by proving data
- Verification
- Federation with other subsystems