Towards a Modelling & Simulation capability for training autonomous vehicles in complex maritime operations

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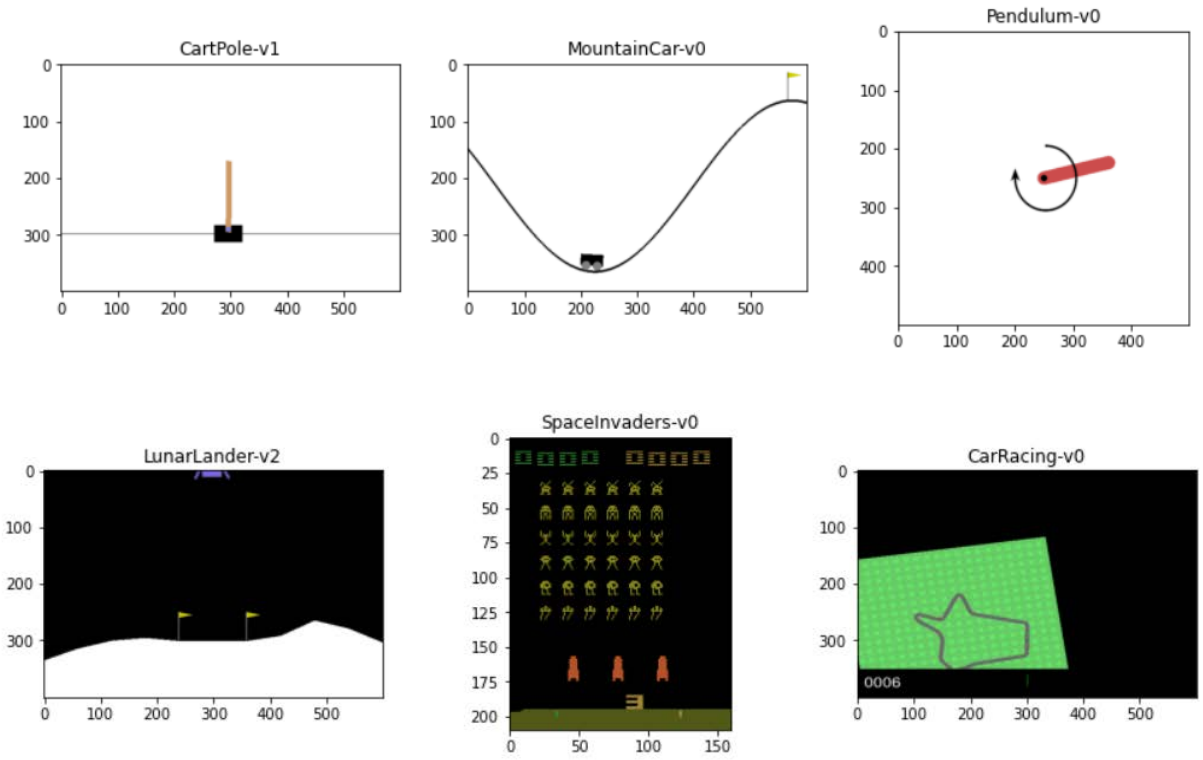
Introduction

- Autonomous Systems (AS) use Machine Learning algorithms to tackle the more complex tasks.
- Modelling and Simulation (M&S) is a key element in the creation of high quality and realistic training environments for AS.
- M&S can be a supporting tool in the learning process:
  - Generating extensive synthetic datasets when real data is difficult or costly to obtain limiting the learning capabilities.
  - Providing a safe-to-fail and interactive environment where the systems can receive feedback minimizing risks.

Background

- Machine learning-based frameworks:
  - Some cases incorporate benchmarking problems



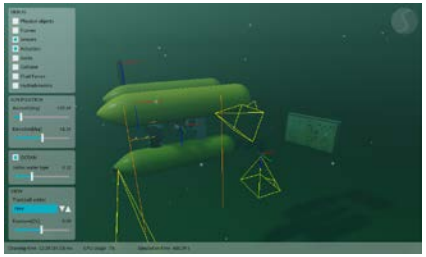
OpenAI Gym Environments

Background

- Machine learning-based frameworks:
  - Or they can be integrated with ad-hock solutions to integrate Simulation for Underwater Unmanned Systems:

UWSim

C++ / OpenGL
ROS

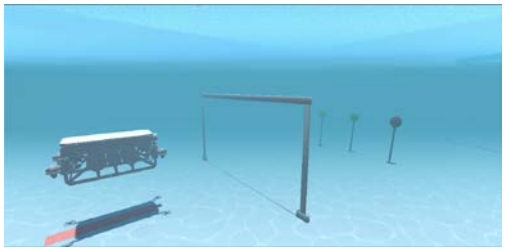


Stonefish

C++/ Bullet
ROS

URSim

Unity3D
ROS



Rock-Gazebo

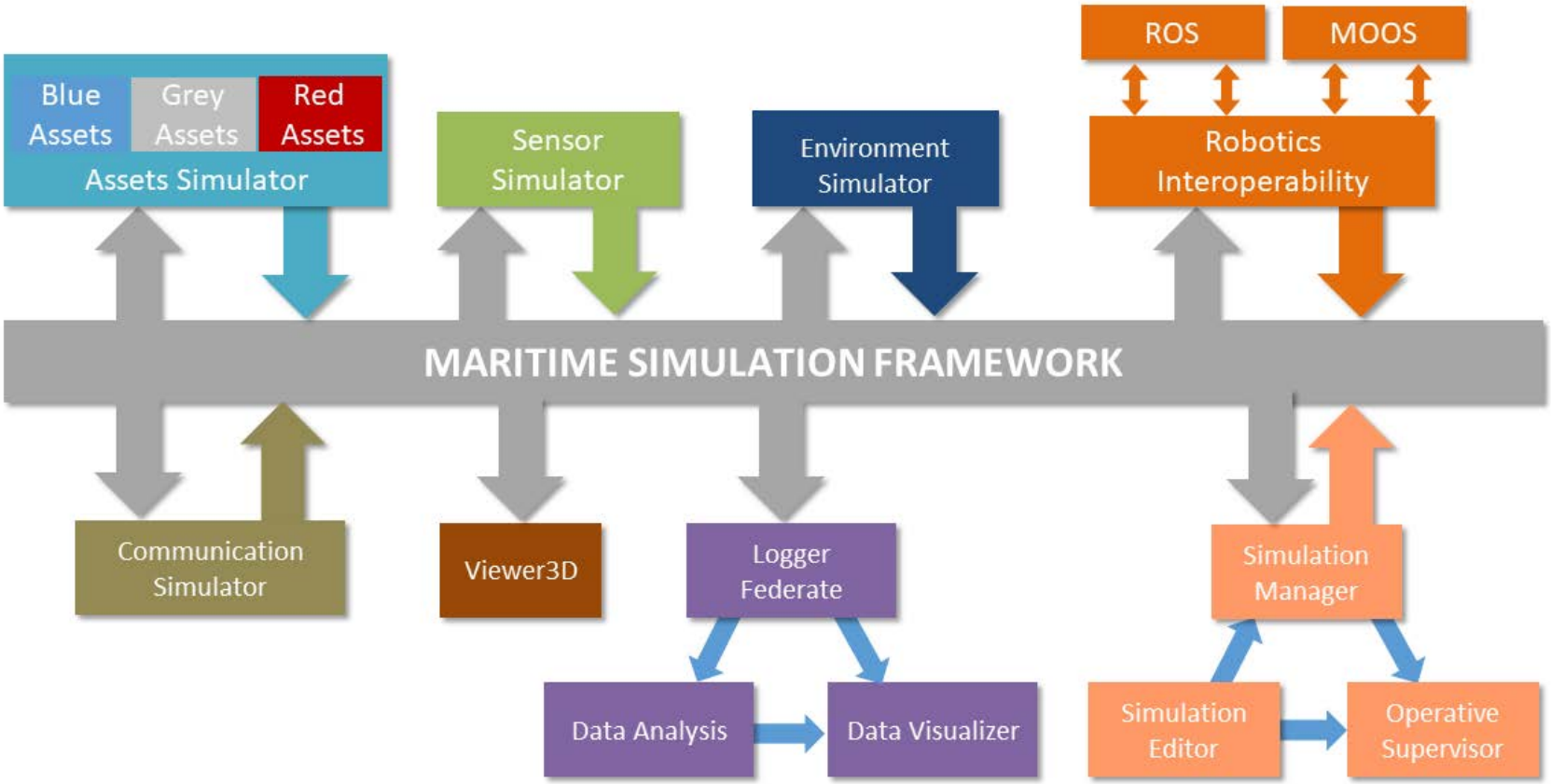
C++
ROS

Challenges

- These approaches present some limitations:
  - Narrow the learning capabilities.
  - Limit the discovery of possible interactions.
  - Hamper the overcoming of the reality gap.

- CMRE proposal to overcome them:
  - Maritime Simulation Framework (MSF), a multidisciplinary standard-based distributed simulation environment for underwater autonomous systems.

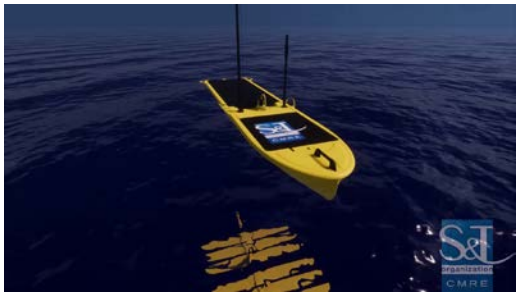
Martime Simulation Framework (MSF)



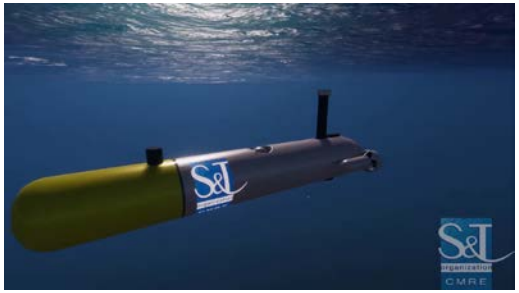
Martime Simulation Framework (MSF)

- **Asset Simulator**
  - Simulate movable assets
  - Three domains:
    - Underwater, surface, and air
  - Three conceptual categories:
    - Hovering, torpedo, glider
  - Guidance types:
    - Steering commands
    - Waypoint mission
    - Trackline mission

Unmanned Air Vehicle



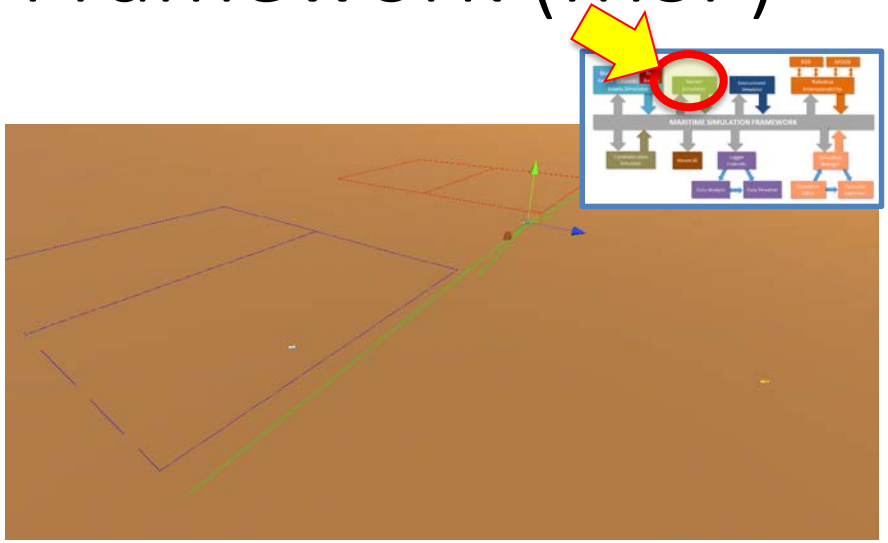
Unmanned Surface Vehicle



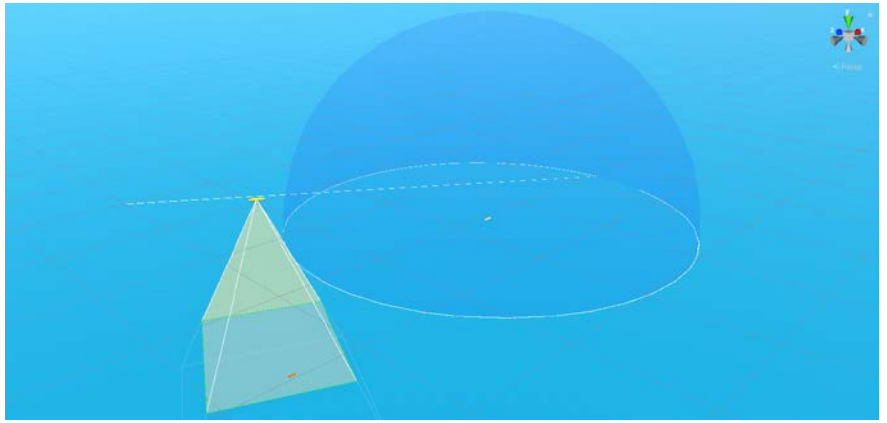
Unmanned Underwater Vehicle

Martime Simulation Framework (MSF)

- **Sensor Simulator**
  - It uses statistical models for detection and classification.
  - It considers:
    - Sensors features
    - Target features
    - Environmental conditions
  - It can also integrate external tools developed by SMEs.



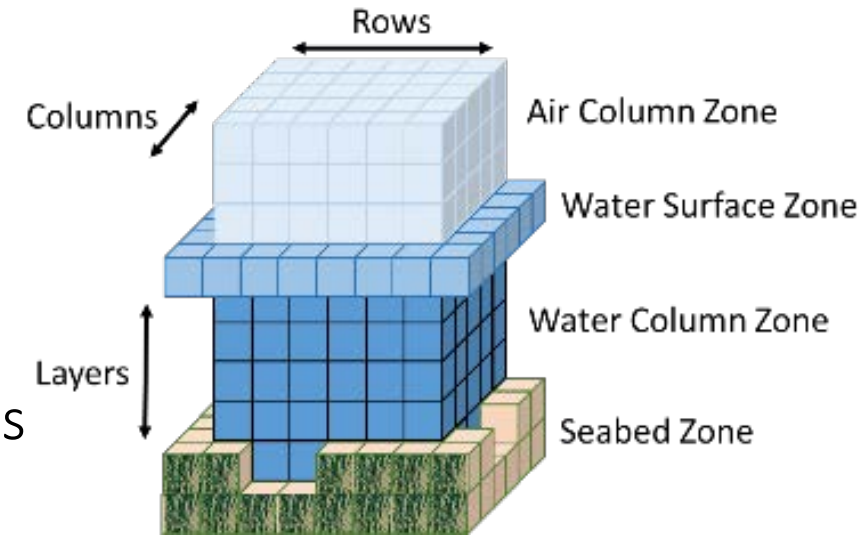
Side Scan Sonar Sensor Simulation



Camera and Passive Radar Simulation

Martime Simulation Framework (MSF)

- **Environmental Simulator**
  - It generates meteorological and oceanographic data to simulate the effects of environmental conditions on assets and sensors.
  - Data is imported using standards from public sources (Copernicus, Meteo-France, and EMODN)



Martime Simulation Framework (MSF)

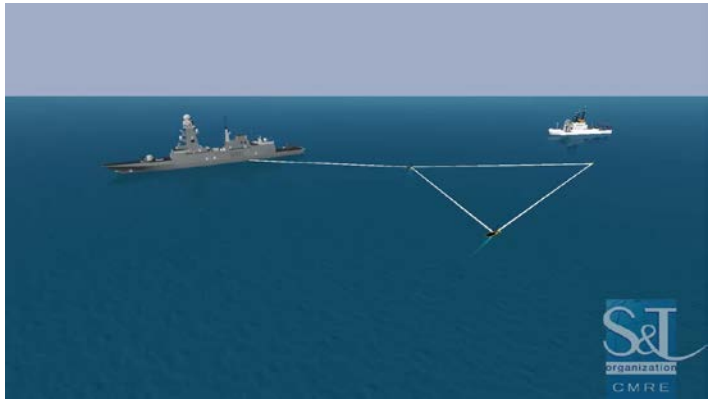
- **Robotics Interoperability**
  - The control architecture in the AS usually follows a modular and layered approach.
  - This requires communication between processes, provided by middleware.
  - The MSF can replace some of this modules or layers allowing a seamless integration of AS software.

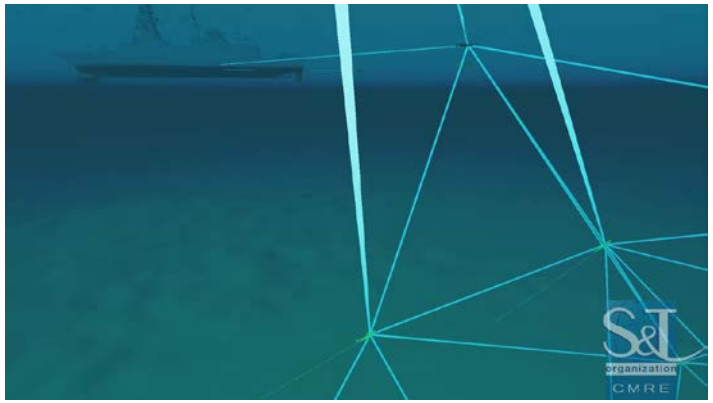
ROS

MOOS-IvP

Martime Simulation Framework (MSF)

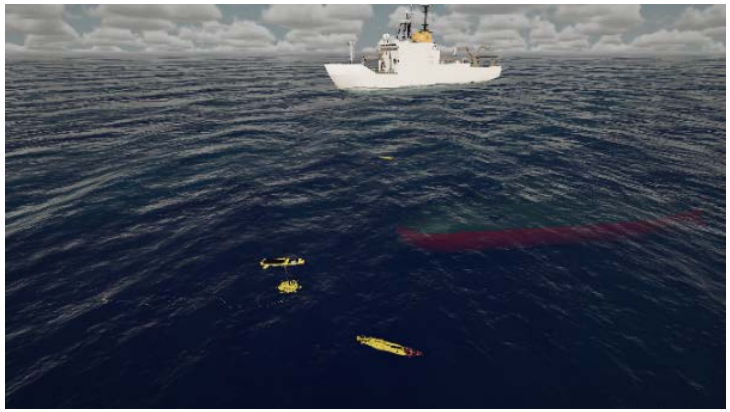
- **Communications Simulator**
  - It simulates the transmission of data between assets.
  - The probability of transmission a message is estimated using a BELLHOP model.
  - It is compatible with DCCL message encoding.

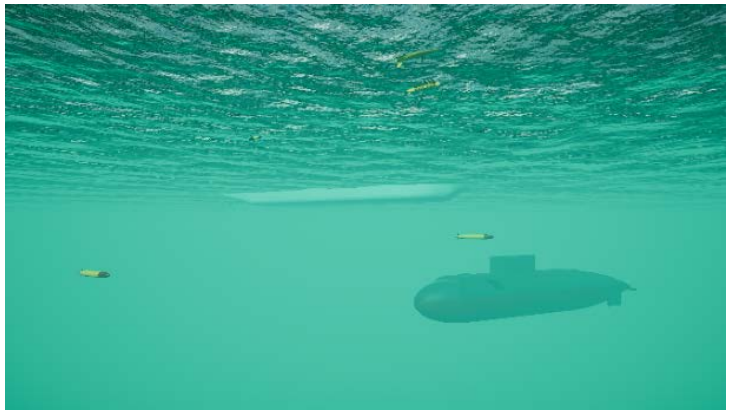




Martime Simulation Framework (MSF)

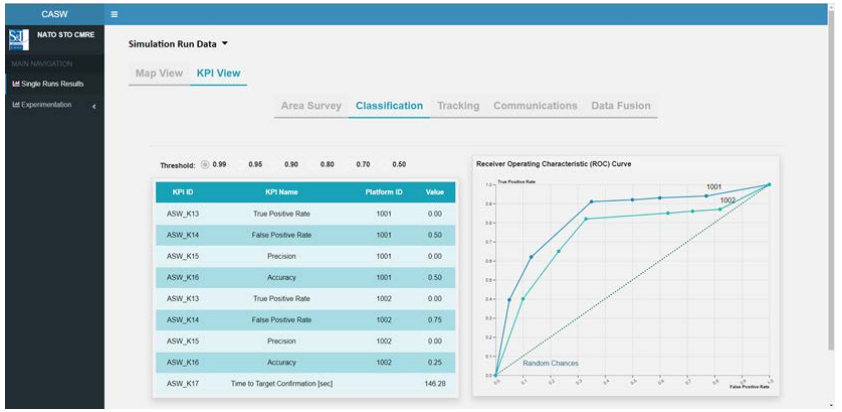
- **Viewer 3D Federate**
  - It displays an intuitive 3D representation in a virtual environment of the entire simulated scenario.
  - It is compatible with traditional displays and Virtual Reality Headsets.

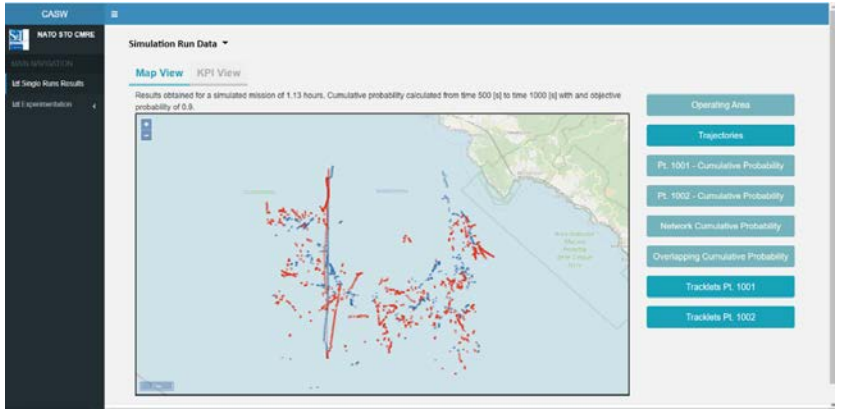




Martime Simulation Framework (MSF)

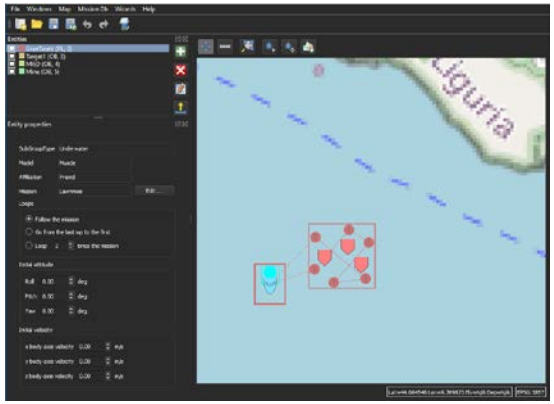
- **Logger Federate**
  - It collects all the relevant information that is generated in the simulation runs.
- **Data Analysis and Visualization**
  - It processes raw data to compute metrics and Key Performance Indicators (KPIs).
  - It displays raw and processed data in a user friendly way.

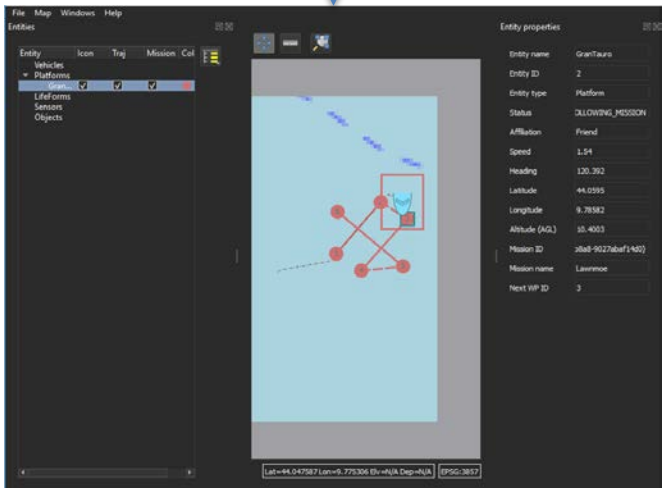


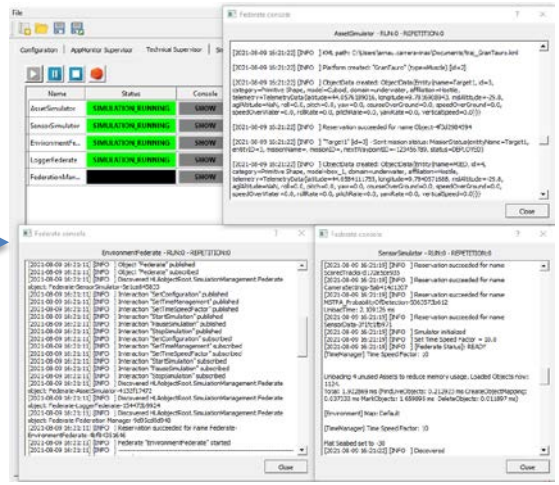


Martime Simulation Framework (MSF)

- Simulation Editor
- Simulation Manager
- Operational Supervisor







Martime Simulation Framework (MSF)

- MSF has been designed and built to perform Verification and Validation (V&V) and Concept Development and Experimentation (CD&E) of innovative behaviours for maritime AS.

- With minor modifications it can adapted to generate datasets to train ML algorithms or modified to train ML algorithms that interact with the environment.

Use Cases and Applications

- **Proof of Concept**
  - MSF was part of a multinational distributed simulation that generated a range of datasets.
  - The datasets allowed the SME to train, test and improve their algorithms in advance of a series of real-life sea trials.
- **Possible future use cases**
  - Protection of a choke point
    - A team of assets needs to coordinate in order to detect and track a possible threat try to enter the area.
  - Survey of a Q-Route
    - Train algorithms that need to adapt to evolving seabed .

Conclusions

- MSF is a modelling and simulation framework that:
  - Is based on HLA and interoperable with AS standards,
  - Simulates Complex Maritime Operations,
  - Is focused on the usage of Autonomous Systems,
  - Includes models developed by SMEs.
- MSF offer a rage of simulation modules developed in conjunction with SMEs to provide a rich simulation environment for training AS.
- The possibility to extend the MSF from V&V and CD&E usage to ML training has been tested.

Thank you for your attention

Questions, suggestions, comments…

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