
Modelling and Simulation Tools for Verification and Validation (V&V) of Autonomous Maritime Systems

Dr. Alain Maguer, Alberto Tremori, Robert Been
NATO STO CMRE

NATO STO CMRE

Centre for Maritime Research and Experimentation



CMRE

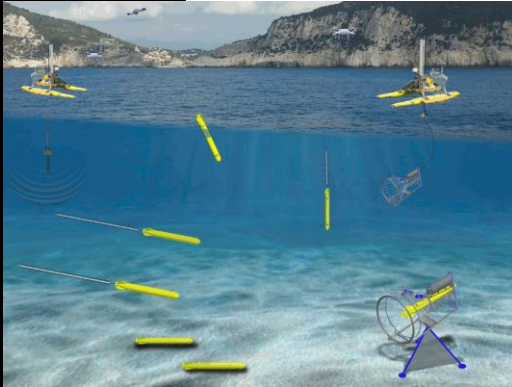
NATO STO Centre for Maritime Research & Experimentation (CMRE) is an established, world-class NATO scientific research and experimentation facility located in La Spezia, Italy.



Introduction

Why use Autonomous or Unmanned systems?

- They work for extended periods of time with limited human intervention.
- They reduce the risks caused by stress and fatigue.
- Reduce human exposition to harmful situation.



Does the system or function meet the specifications (**verification**) and is it fit for purpose (**validation**)?

- CMRE is answering these questions with interoperable M&S providing the opportunity to improve the understanding of the use of autonomous systems in maritime operations.

Modelling and Simulation (M&S)?

Live Simulation



Virtual Simulation



Constructive Simulation

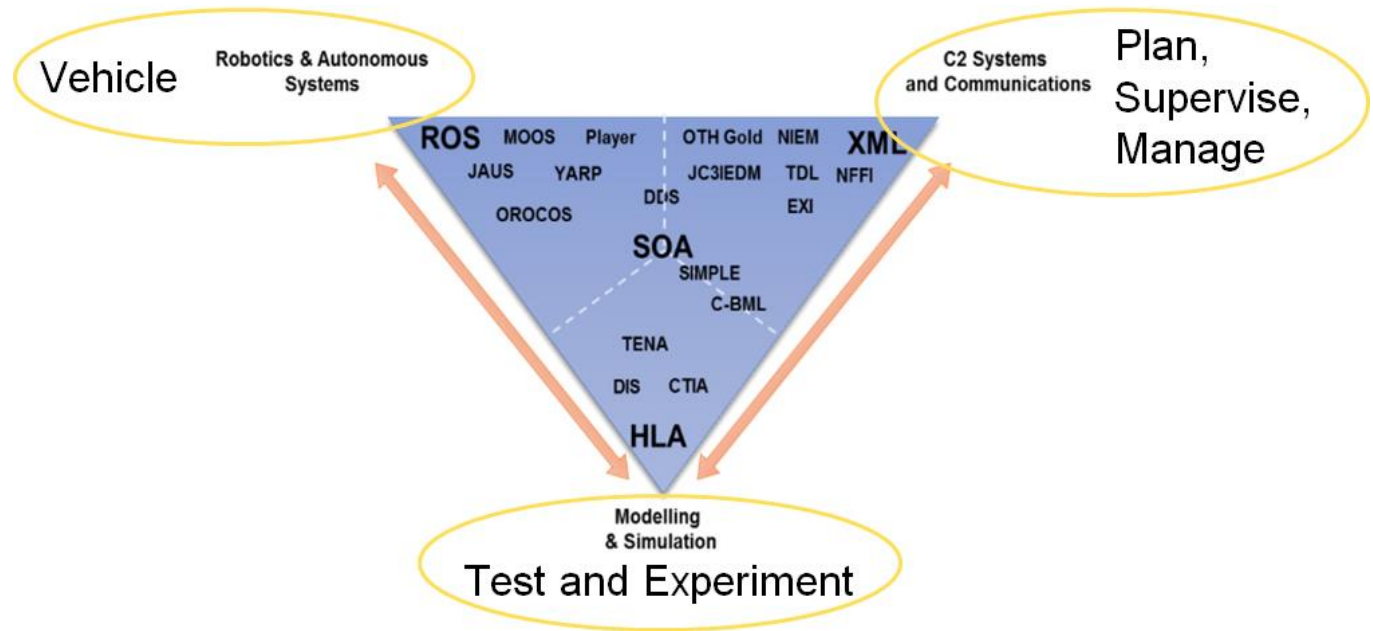


M&S Objectives for autonomous systems

- **Support to Verification and Validation (V&V), by:**
 - Multi-layer interoperable simulation capable to include hardware and software-in-the-loop.
 - Immersion of real robotics and C2 systems in the M&S environment.
- **And:**
 - Support to Concept Development and Experimentation.
 - Training: Robots (machine learning) and Operators – Future

A multidisciplinary approach

M&S capability bring together three communities:



M&S as a backbone using High-Level Architecture (HLA) IEEE 1516.

HW and SW in the loop

M&S – Robotics & Autonomous Systems

- Wrapper for the robotics' middleware to immerse the Unmanned system in the simulation environment.
 - ❖ ROS (Robotics Operating System)
 - ❖ MOOS (Mission Oriented Operating Suite)



The MOOS

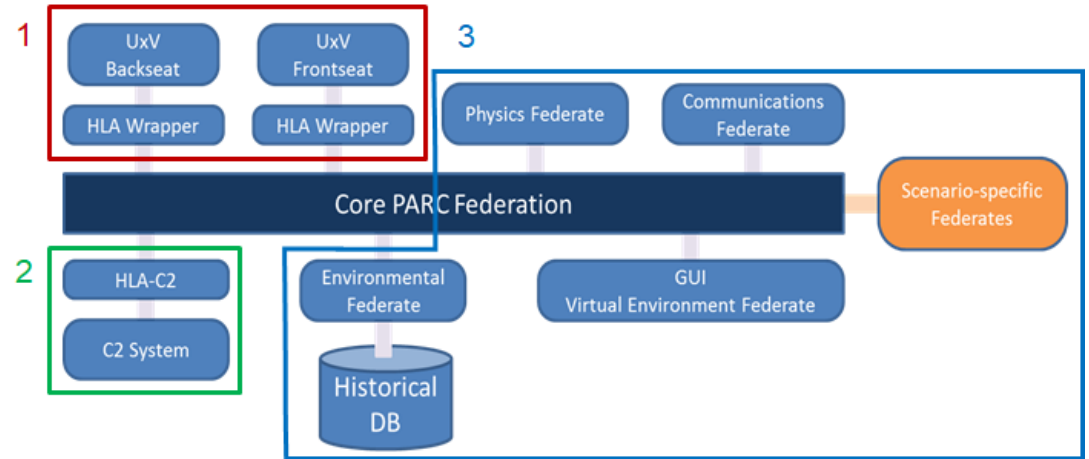
Cross Platform Software for Robotics Research



Core federation

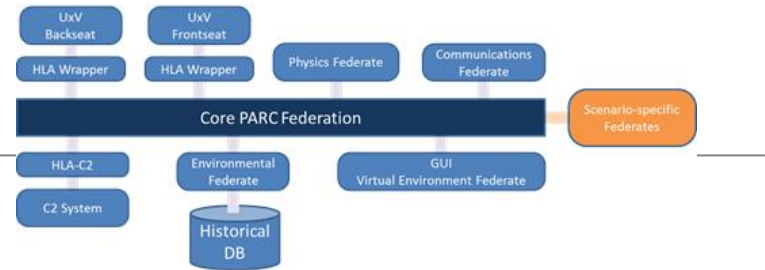
Brings together the three communities.

- HW and SW in the loop ¹
- C2 system ²
- Simulation ³



Ready to connect new federates or modify existing ones to create a new scenarios/missions.

The Federates



- AUV Front-seat: it integrates the low-level software in charge of controlling the AUV.
- AUV Back-seat: it integrates the high-level software modules in charge of defining the behaviours of the AUV. Back seat is where typically the autonomous behaviour sits.
- C2 System: it emulates the capabilities of a C2 system - (SOA) approach.
- Underwater Communication Simulator: it simulates the communication channels between the different assets
- Physics and Environmental Simulators: movements and interactions of the simulated assets in a realistic environment
- Virtual Environment: it provides a graphical and 3D representation of the overall scenario simulated by the federation.

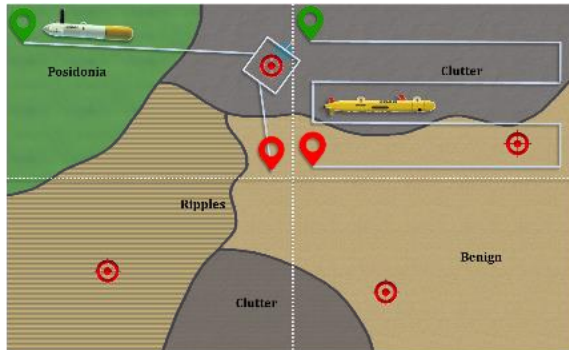
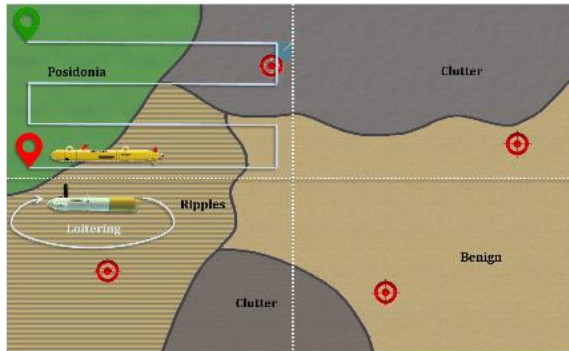
V&V Goals at CMRE

CMRE's goals for V&V include:

- decomposition of the V&V process into parts, identifying those that will have to be **addressed using M&S**,
- reduction of the number of **scenarios to be simulated** (since the state space is expected to be very large) by using smart, e.g. adaptive sampling, techniques,
- definition of the **appropriate metrics**,
- design and analysis of an **appropriate use case**.

Two Operationally relevant scenarios

Mine Countermeasures (MCM)



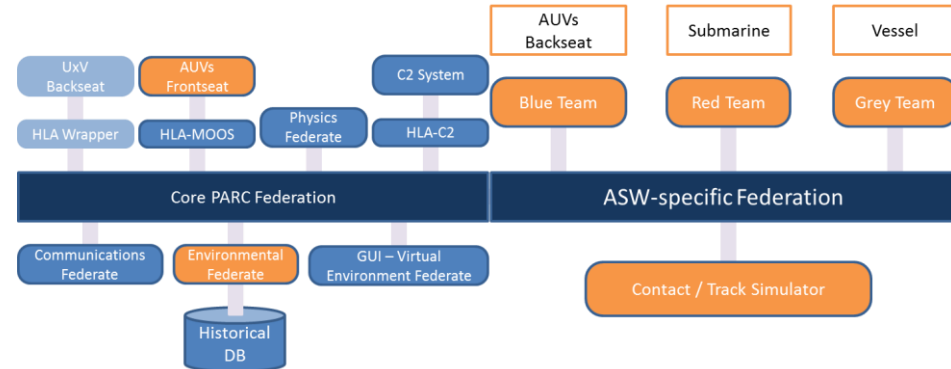
Antisubmarine Warfare (ASW)



Operationally relevant scenario - ASW

Multivehicle cooperation ASW scenario

- Surveillance of a chokepoint.
- Cooperation between Underwater and Surface Unmanned Vehicles.



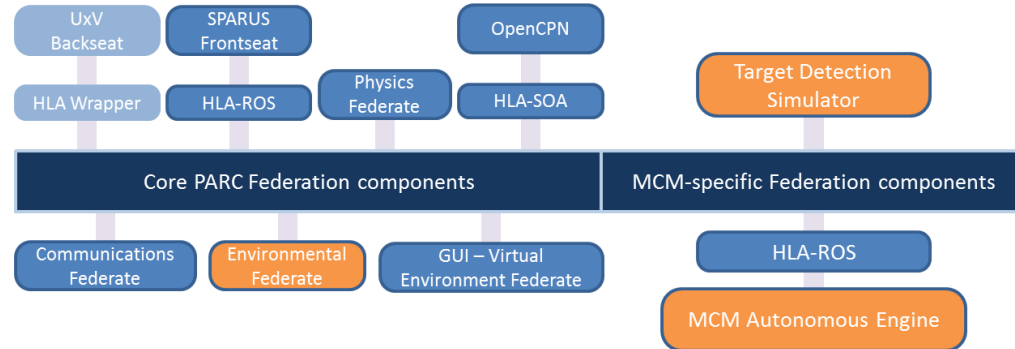
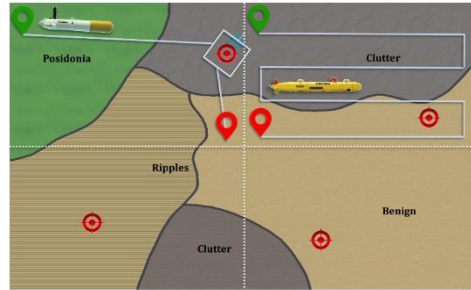
Operationally relevant scenario - ASW



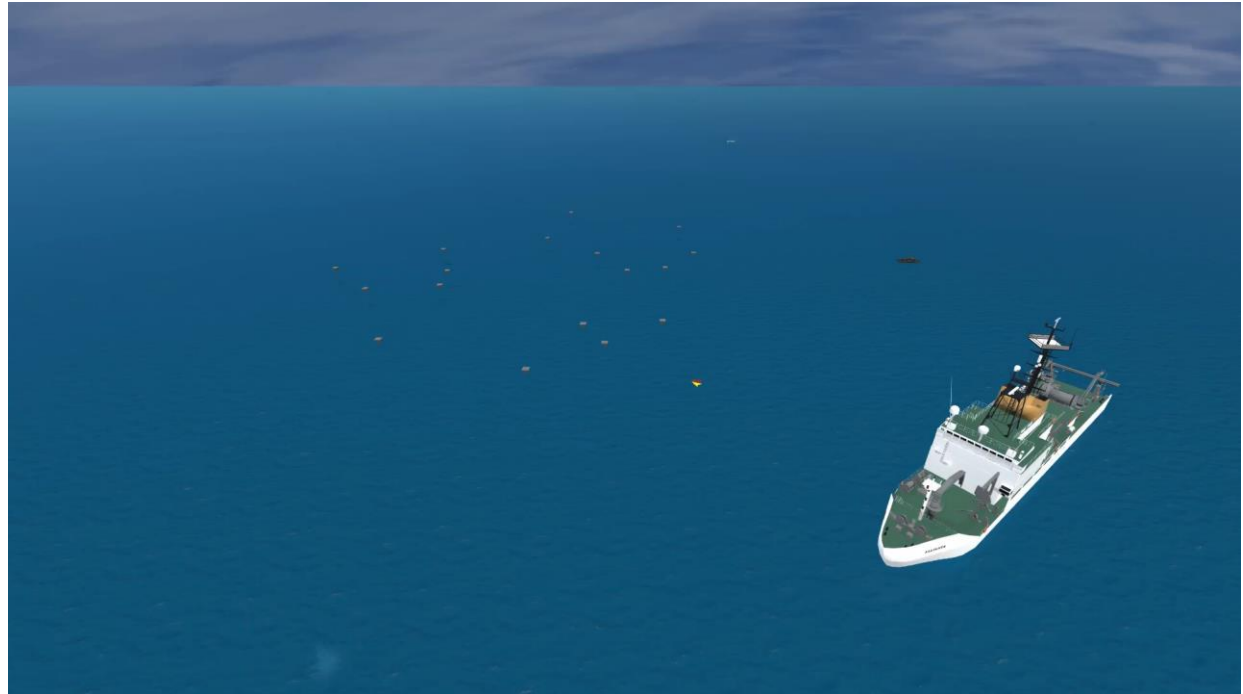
Operationally relevant scenario - MCM

Multiphase and multivehicle MCM mission

- Survey of a Q-route.
- Cooperation between different underwater unmanned systems.



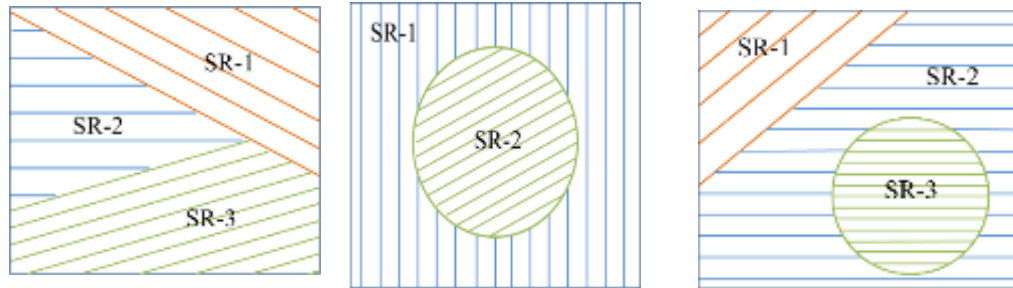
Operationally relevant scenario - MCM



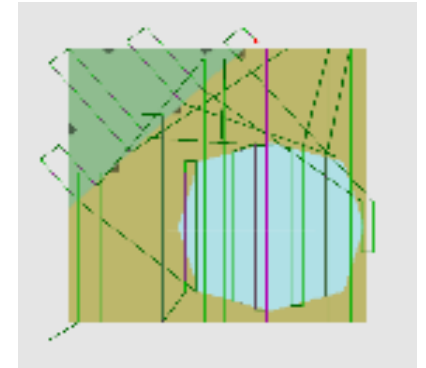
Sample of MCM experimentation

Evaluation of an adaptive path planning algorithm for the mine detection stage: Adaptive Conformal Exploratory Survey (ACES):

- Twelve simulated trials
- Quantitatively assessment performance



Environmental Conditions



Sample of the behaviour

Formal and Experimental V&V

Experimental V&V (M&S)

Formal V&V

X	X
X	?

Conventional autonomous
(complicated state machine)

Autonomous (supervised
machine learning included)

Next steps and challenges

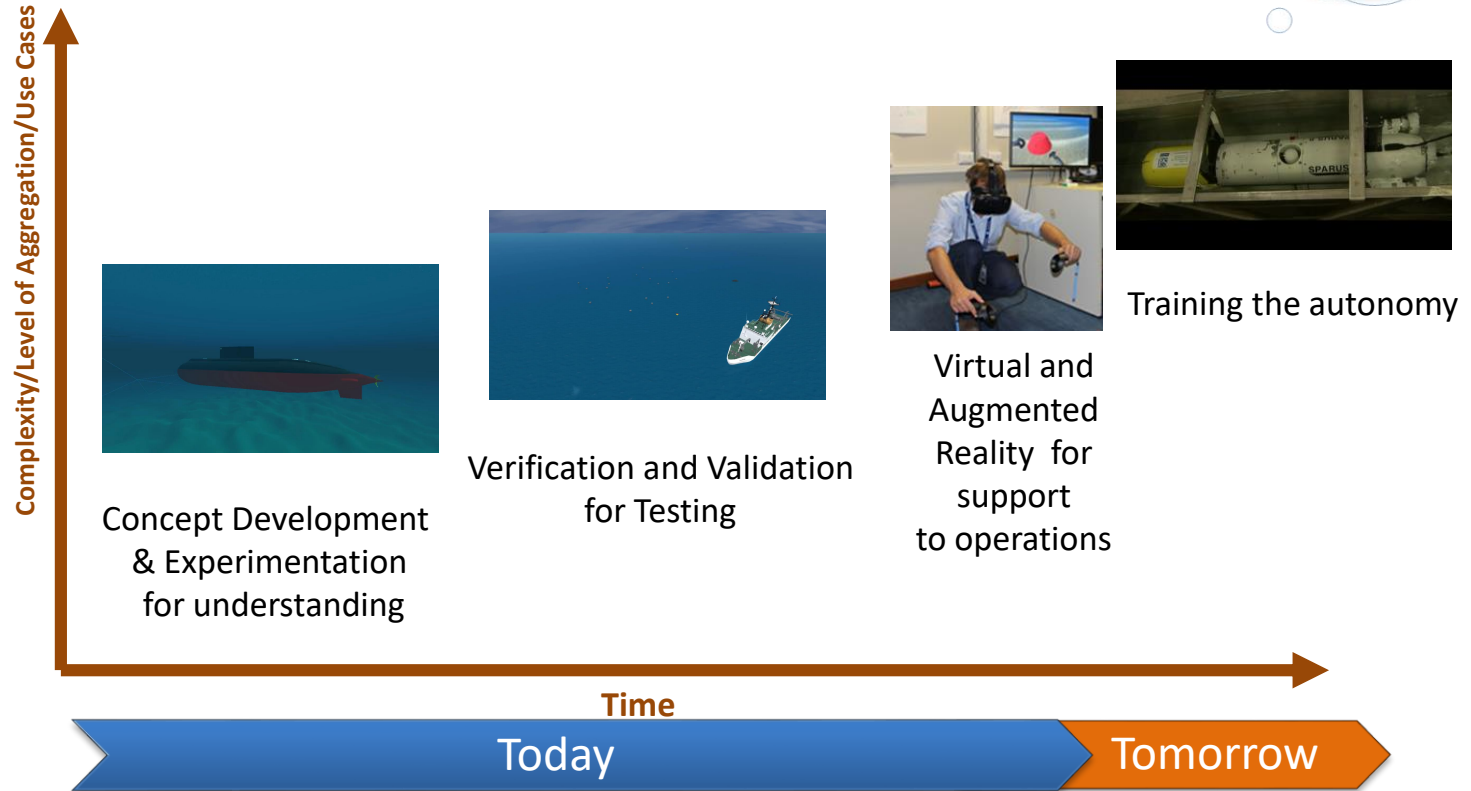
- Consolidation and Experimentation of the MCM environment
- Development and Testing of ASW scenarios.
- Expand the M&S environment to support other warfare areas.
- Continue the investigation of the following topics:
 - AR/VR to support operations and training... *and build trust.*
 - Serious Games for the analysis of the human decision making process.
 - Simulation for training autonomous systems.

Thank you for your time!

Any questions?

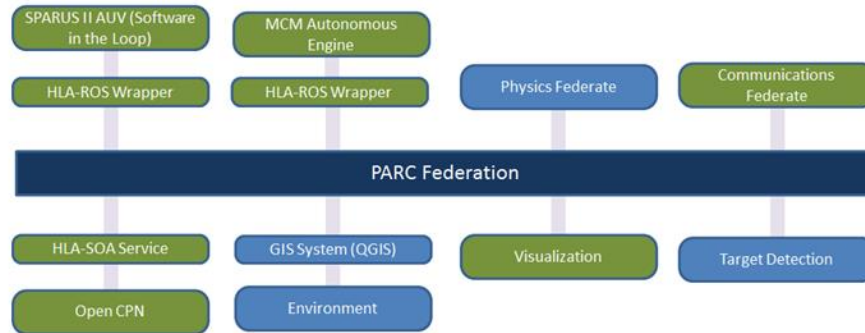
SPARE SLIDES

M&S as a technological bridge



Distributed experiment over the internet

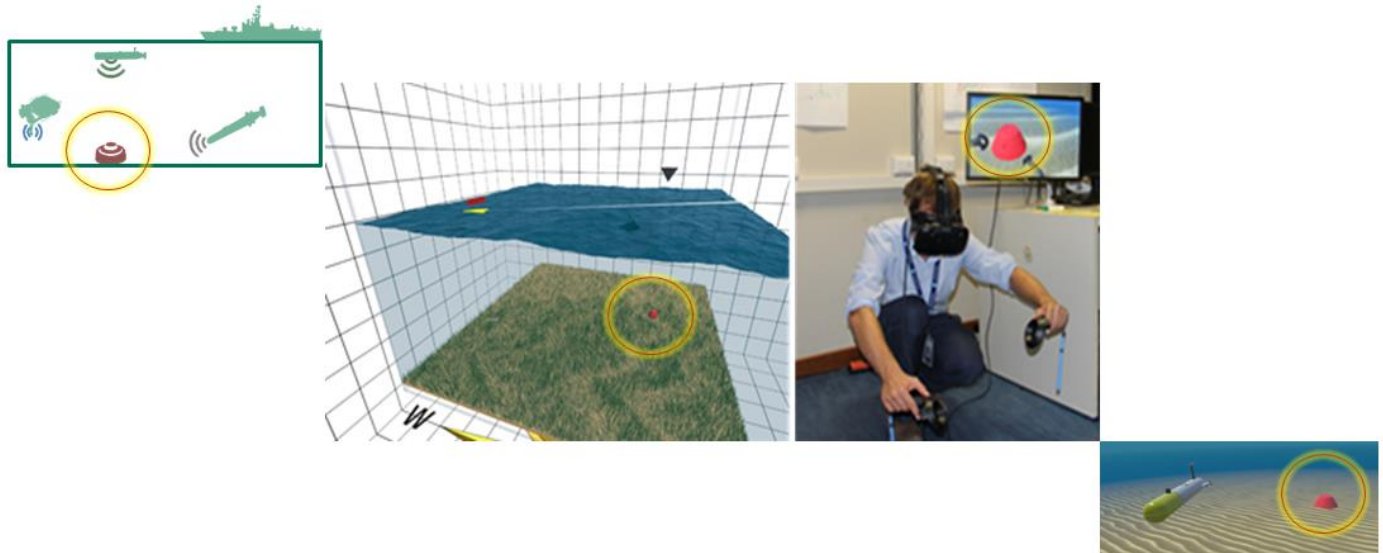
- The design of the Core Federation supports distributed experiment over the internet.
(Test during I/ITSEC 2017)



- Performed through HLA (and SOA compl.).
 - The network is designed to prevent security and confidentiality issues.
 - Execution of NATO Unclassified experiments.

Virtual and augmented reality to support operations

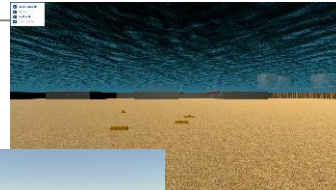
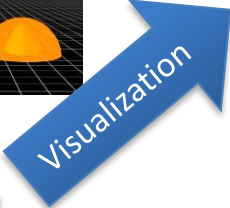
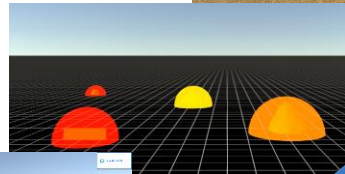
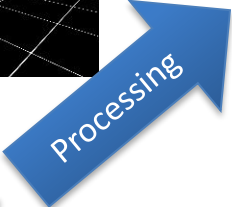
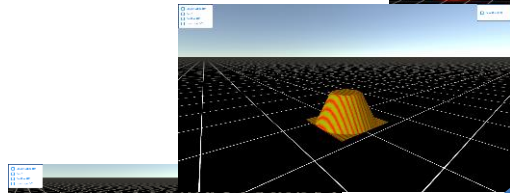
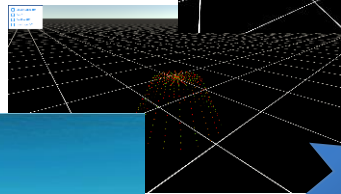
- Enriched representation of sensor data.
- New way to deal with information and manage deployed assets.



Applications of AR/VR

An Example to Aid Identification

Reality



Virtual
(Augmented)
Reality