OCEAN2020 Project

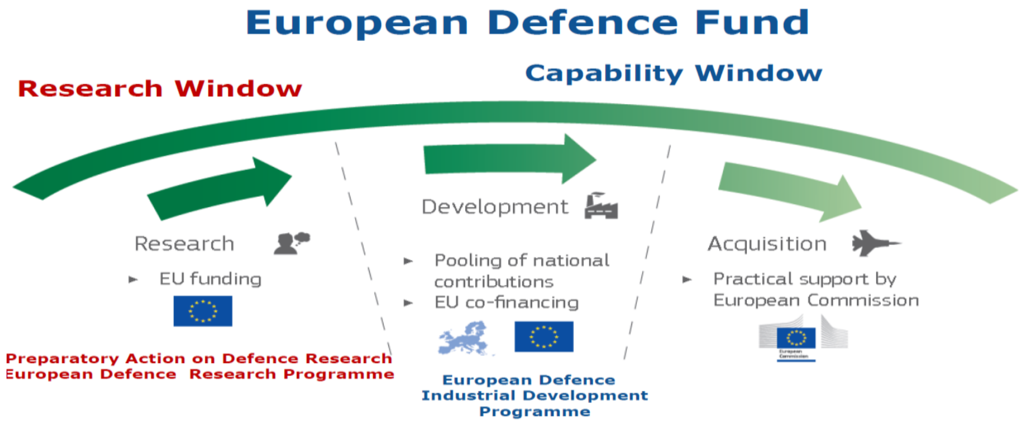
Focus on Modelling & Simulation

30th March 2021

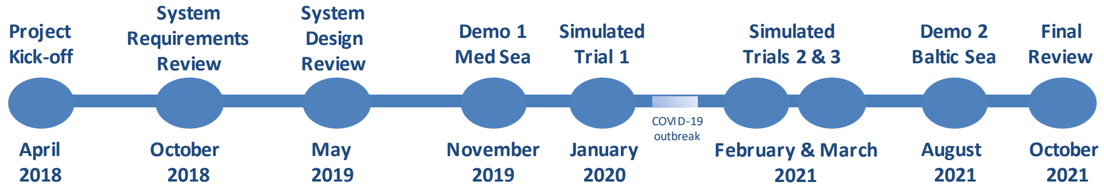
This project has received funding from the European Union's Preparatory Action on Defence Research under grant agreement No 801697

OCEAN2020 Project Context

- ***PADR** is the **1st step** of a **European Defense Research and Capability Development Programme***
- ***PADR** is launched and funded by the **European Commission***
- ***European Defense Agency** is the implementing agency for the PADR*



OCEAN2020: the PADR Project with highest budget (35.5 M€ out of 90 M€ of PADR Budget)



10 National MoDs/Navies supporting OCEAN2020

- *Italian Navy*
- *Hellenic Navy*
- *Spanish Navy*
- *Portuguese Navy*
- *Lithuanian Navy*
- *German MoD*
- *Swedish Navy*
- *French Navy*
- *Polish Navy*
- *Royal Dutch Navy*

OCEAN2020 Project Objectives

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- **Operational objectives**
  - Significant improvement of **maritime Situation Awareness** through the integration of **UXS** (Unmanned Systems) with **ISTAR** (Intelligence Surveillance Target Acquisition and Reconnaissance) payload capabilities
  - **Interoperability** by use of open architecture and recognised standards
- **Technical objectives**
  - **High integration among EU countries and heterogeneous systems**, demonstrated in full-scale live trials
    - ***Mediterranean Sea demonstration in 2019***
    - ***Baltic Sea demonstration in 2021***
  - Development of EU C4ISR **open architecture**
  - Integration of EU/NATO/civil **data framework**
  - Advanced **data and information fusion** techniques for shorter decision time at **CMS** (Combat Management System) and **MOC** (Maritime Operations Centre) levels
  - Increased **autonomy** for UXS, swarm operations, cooperation of assets
- **Cooperation objectives**
  - Diverse EU wide consortium to demonstrate large military R&T effort
  - Improve market position of European defence industry in UXS
  - Involve End-Users in design choices

Expected impact :

- **demonstrate the potential of EU-funded research for defense applications**
- **boost the European industrial capacity in the military unmanned systems market**

OCEAN2020 Consortium

- *15 nations*
- *43 partners*

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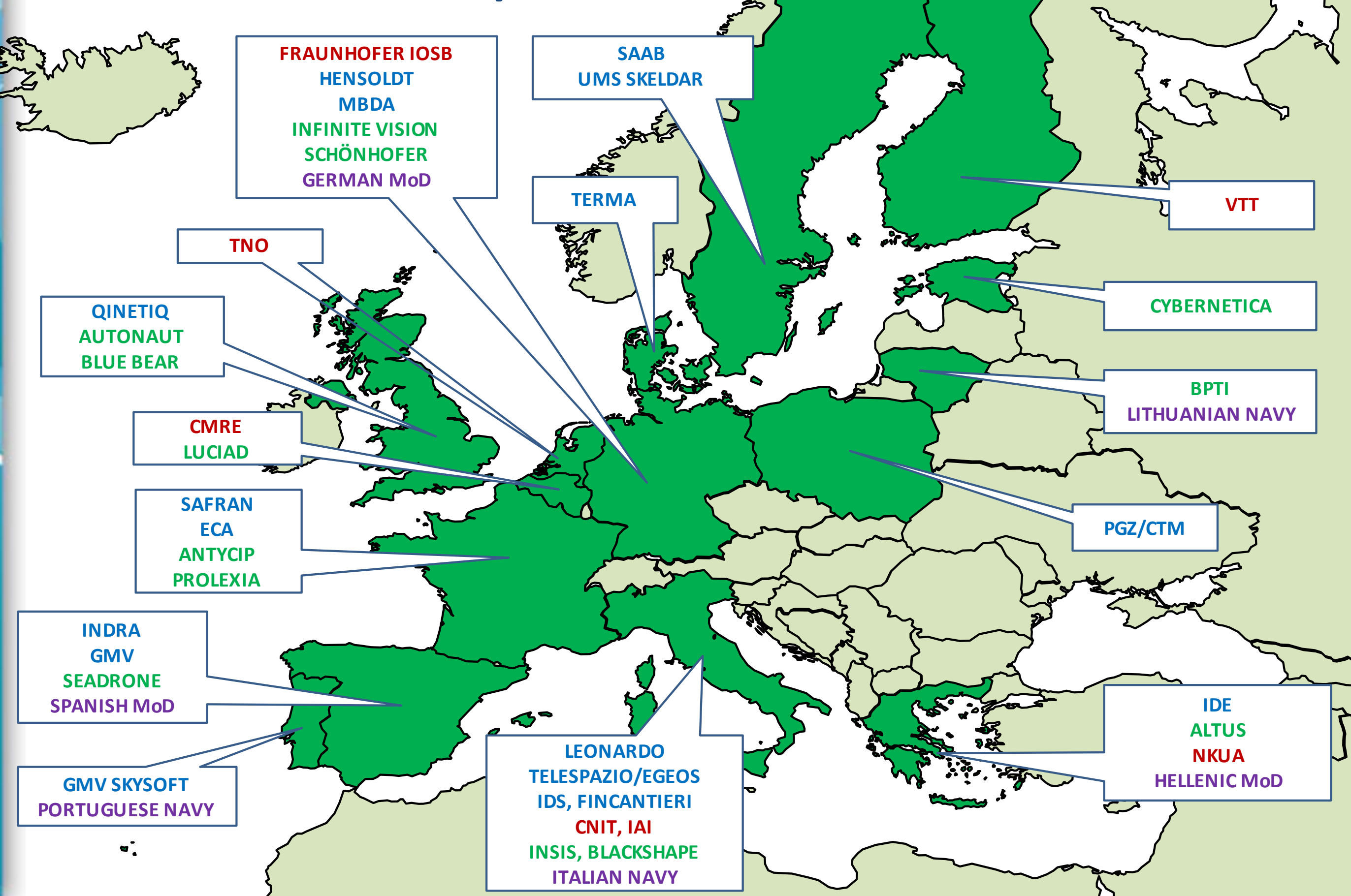
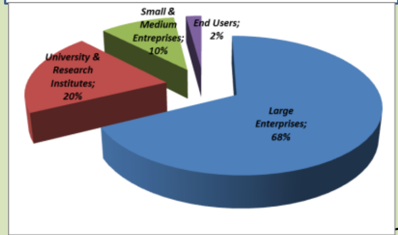


LARGE ENTERPRISE
SMALL/MEDIUM ENTERPRISE
RESEARCH INSTITUTE
END USER



OCEAN2020 Work Breakdown Structure

Technology Development and System Simulation

Project

- ***Requirement Analysis***
  - Operational Requirement Analysis
  - Analysis of Functional & Performance Requirements
  - Analysis of Environmental Requirements
  - Requirement Demo Plan, Metrics & KPI
- ***System Design***
  - Overarching Design
  - System Info Processing
  - System Transverse Design
  - UAS Identification
  - USS Identification
  - UUS Identification
  - Space Asset Identification
  - MOC Integration Design
  - Naval Integration Design
- ***Tech.Dev. & System Simulation***
  - Technology Development
  - System Resilience Modeling
  - EU MOC Prototype Development & Integration
  - System Simulation
  - Simulated Trials
- ***Integration & Trials***
  - UAS Improvements
  - USS Improvements
  - UUS Improvements
  - MOC Upgrading
  - CMS Upgrading
  - Ship Integration
  - Live Demo Med Sea
  - Live Demo Baltic Sea
- ***Human Factor***
  - System Use Study
  - Operator Interface Design
  - Training Needs Analysis
  - Training Tools Design
- ***Impact Assessment***
  - Result Evaluation, Dissemination & Communication
  - Exploitation
  - Proposed Planning for Reasarch & Capability Development
  - Policy/Standard Recommendations

Technology Development and System Simulation
Involvement of Consortium Partners

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Research Institutes

Fraunhofer IOSB
S&T organization CMRE
TNO
CNIT RaSS National Lab
HELLENIC REPUBLIC National and Kapodistrian University of Athens EST. 1837

Large Enterprises

LEONARDO
indra
SAAB
SAFRAN
IDE INTRACOM DEFENSE
QINETIQ
MBDA MISSILE SYSTEMS
IDS INGEGNERIA DEI SISTEMI
gmv
FINCANTIERI
LUCIAD
HENSOLDT Detect and Protect.

Small and Medium Enterprises

PROLEXIA
SCHÖNHOFER SALES AND ENGINEERING GMBH
ANTYCIP simulation
Infinity Vision DESIGN AGENCY POSTPRODUCTION VISUAL EFFECTS
ALTUS LSA

Modelling and Simulation in OCEAN2020 -1
Aims and Activities, an Overview

- Aims of M&S in OCEAN2020
  - Contribute on removing barriers preventing effective integration of UxSs in tactical naval systems
  - Improved interoperability between manned and unmanned systems
  - Test the overall OCEAN2020 architecture's resilience against environmental, operational, technical and functional obstacles
  - Demonstrate integration of algorithms to improve the overall situational awareness
  - Complement the OCEAN2020 Live Trials through execution of Simulated / Virtual Trials

Modelling and Simulation in OCEAN2020 -2
Virtual Battle-Lab and UxS Deployment Modelling

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- Setting-up a virtual battle-lab environment to evaluate the optimal sensor and effector outfits of the UxS → assessment of their usage with reference to live trials/demos
- Modelling of UxS deployment
  - UAS/USS/UUS autonomous behaviour
  - UAS/USS/UUS swarming behaviour

Modelling and Simulation in OCEAN2020 -3
Innovative Technologies

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- Developing prototypes of innovative technologies
  - Data fusion prototypes
  - Video processing prototype
  - Situation Awareness prototype
- Developing an EU-MOC Prototype
  - Developing an RMP and Situation Awareness application
  - Integrating the innovative technologies prototypes
- Experimentation of airborne radar technologies

Modelling and Simulation in OCEAN2020 -4
System Resilience

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- System Resilience Modelling
  - Communication and Electromagnetic Modelling
    - Effects of Electromagnetic Conditions of a contested environment (including presence of jammers, etc.) on radio communication / data links
    - Modelling electromagnetic protection measures → ensure resilience of data links
  - Environmental Modelling
    - Modelling the effects of meteorological and climatic conditions, sea state and oceanographic conditions on
      - UAS/USS/UUS launch/recovery
      - Data link quality
      - UAV and USV behaviour, performance

Modelling and Simulation in OCEAN2020 -5
System Simulation

- System Simulation
  - Creating a Distributed Simulation ITC Infrastructure
    - Connecting simulation labs via a VPN
    - Setting-up a distributed simulation infrastructure

Modelling and Simulation in OCEAN2020 -6
System Simulation – Operational Scenarios

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- System Simulation
  - M&S of Operational Scenarios
    - Generation of scenarios from live trials and additional more complex simulated trial specific scenarios
    - Integration of
      - UxS platforms simulation
      - UxS launch and recovery simulation
      - Environmental simulation
      - Communication links simulation
      - Airborne, surface, and underwater sensors simulation
      - Data Fusion, Video Analysis, and Situation Awareness Prototypes

      into overall system simulation

Modelling and Simulation in OCEAN2020 -7
Simulated Trials

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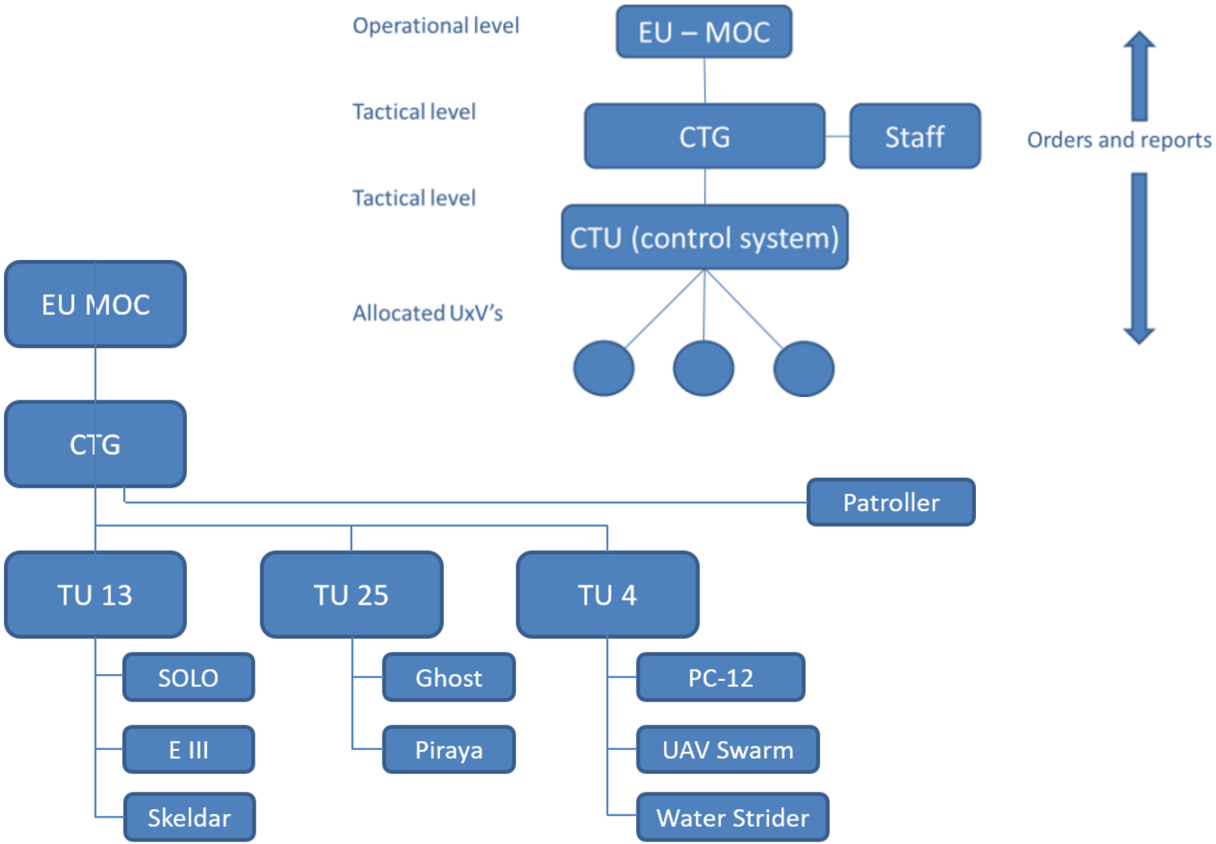
- System Simulation
  - M&S of Operational Scenarios
  - Executing Simulated Trials

Modelling and Simulation in OCEAN2020 -8
Simulated Trials – Command Structure



Modelling and Simulation in OCEAN2020 -9
Simulated Trials – Results Evaluation

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- System Simulation
  - Evaluating results of Simulated Trials
  - Creating lessons learned → Live Trials

Multi-Domain Distributed Simulation in OCEAN2020 -1
Objectives of the Distributed Simulation

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De-risking

"Will the live trials work?"

- ⇨ Development and assessment of the operational scenarios which will be used for the live trials.
- ⇨ Assessment of the architecture of mixed manned/unmanned systems (aerial, surface, underwater).
- ⇨ Assessment of the interoperability and communication needs within the common systems architecture.

Complementing

"Will the architecture work in complex conditions?"

- ⇨ Increased scenario complexity (number of assets, unmanned systems and threats).
- ⇨ System resilience in severe environmental conditions and contested environment.

Integration

"How to assess new technologies developed for the project?"

- ⇨ Demonstrate innovative aspects and technologies of the system (e.g. advanced data processing, swarm algorithms) that could not be implemented in real assets during the project life span.

Demonstration

- ⇨ Demonstrate some of the requirements resulting from the system requirement analysis according to the demonstration plan defined in OCEAN2020 WP1.

Multi-Domain Distributed Simulation in OCEAN2020 -2
Simulation Methodology

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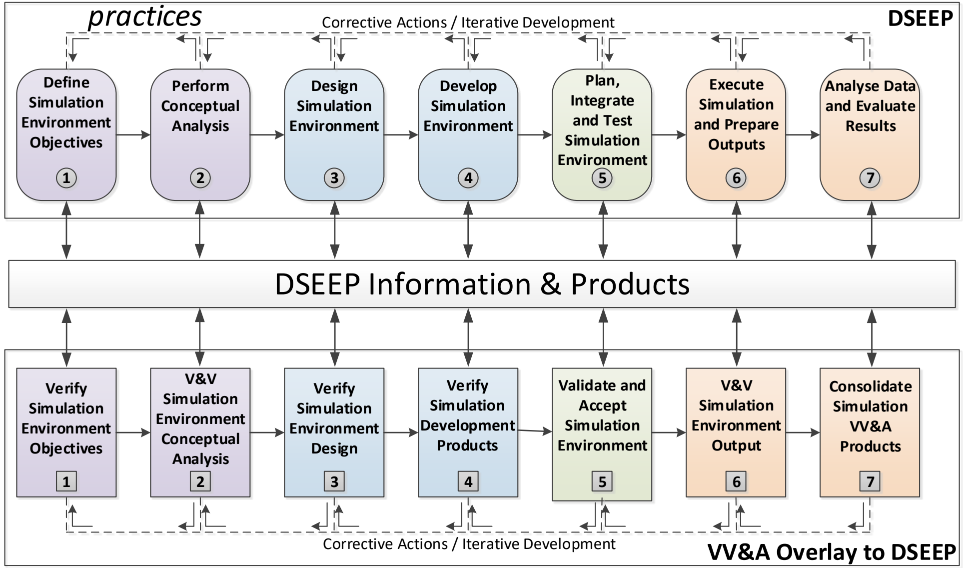
- **Use of IEEE DSEEP process**
  - *Ensure that the M&S environment is designed according to industrial best practices*



Produces OCEAN2020 Deliverables:
D3.8.X System Simulation Design Description

Produces OCEAN2020 Deliverables:
D3.9.X System Simulation Integration Report

Produces OCEAN2020 Deliverables:
D3.5 Electromagnetic Resilience Modelling Report
D3.13 Environmental Resilience Modelling Report
D3.8.X Appendix A UW Platform & Sensor Modelling
D3.8.X Appendix B Launch and Recovery Modelling
D3.8.X Appendix X …

Produces OCEAN2020 Deliverables:
D3.10.X Simulated Trial Planning Report
D3.11.X Simulated Trial Specification Report
D3.12.X Simulated Trial Report

Multi-Domain Distributed Simulation in OCEAN2020 -3
Scenario Simulation Levels

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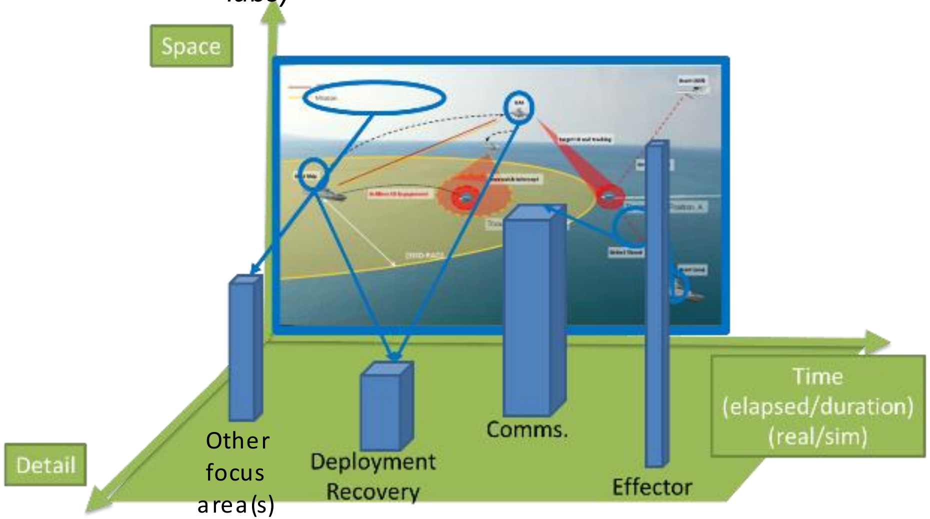
- **Use of IEEE DSEEP process**
  - *Multi-domain, multi-level, multi-format, multi-technology, …*

- **A targeted approach to model detail selected to maximize usefulness**
  - *Level 1: distributed simulation of the scenario over the distributed network*
  - *Level 2: simulation of zoomed-in events (collocated, i.e. performed in classified labs)*



Level 1:
High Level Simulation:
"Play-through of whole scenario"
- Unclassified -

Level 2:
Deep Simulation:
Standalone Simulations of "zoomed in" events.
- Up to Classified -

Multi-Domain Distributed Simulation in OCEAN2020 -4
Simulation Trials, Scenarios & Vignettes

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- Trial #1: Mediterranean Sea 2019
  - ***Scenario #1*** *Threatening Vessel Interdiction*
  - ***Scenario #2*** *Interception of a Mine Laying Vessel before an Amphibious Operation*
- Trial #2: Baltic Sea 2021
  - ***Scenario #3*** *High Speed Surface Threat*
  - ***Scenario #4*** *Unknown Submerged Activity*
- Trial #3: Baltic Sea 2021
  - ***Scenario #5*** *High Speed Surface Threat Extended Version*
  - ***Vignette #6*** *System resilience at High Sea State and Strong Wind*
  - ***Vignette #7*** *System Resilience at Jamming*
  - ***Vignette #8*** *Underwater Mine Countermeasure (MCM) with UUVs*
  - ***Vignette #9*** *Passive Anti-Submarine Warfare Barrier*
  - ***Vignette #10*** *USV Swarm: High Speed Surface Threats*
  - ***Vignette #11*** *USV Swarm: Underwater Intrusion with Mine Delivery*
  - ***Vignette #12*** *USV Swarm: Choke Point Protection*
  - ***Vignette #13*** *USV Swarm: Overcome Jamming Conditions*
  - ***Vignette #14*** *USV Launch Procedure*
  - ***Vignette #15*** *UAV Missile Launch*

Scenario #2 VR-Forces Screenshot

Multi-Domain Distributed Simulation in OCEAN2020 -5

Overview of OCEAN2020 VPN

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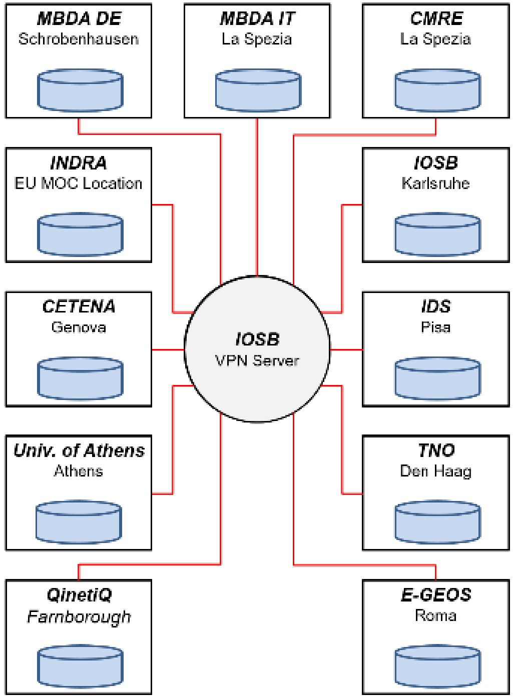
- Simulated Trials performed over a distributed Simulation Network
- Simulation Laboratories from different Consortium Partners will be connected through a VPN



Multi-Domain Distributed Simulation in OCEAN2020 -6
Simulation Architecture

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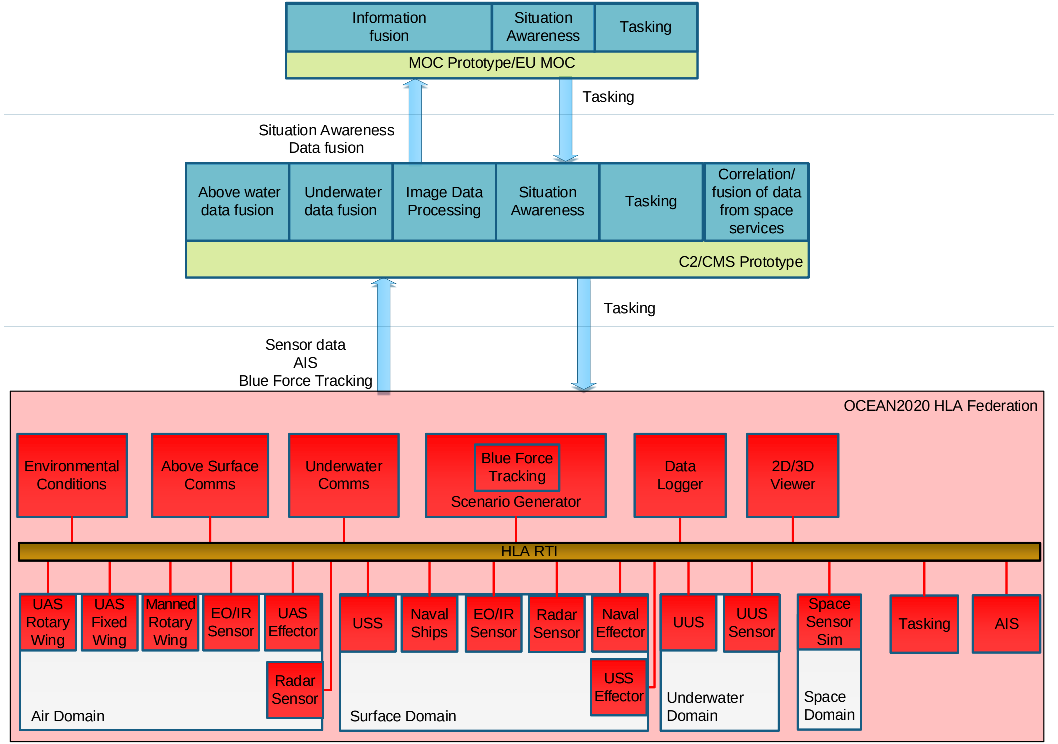
MOC & C2/CMS level:
real prototypes representing the operational network

Simulation level:
HLA federation of different federates simulating air, surface and underwater systems (truth network)



Messages sent in STANAG format:

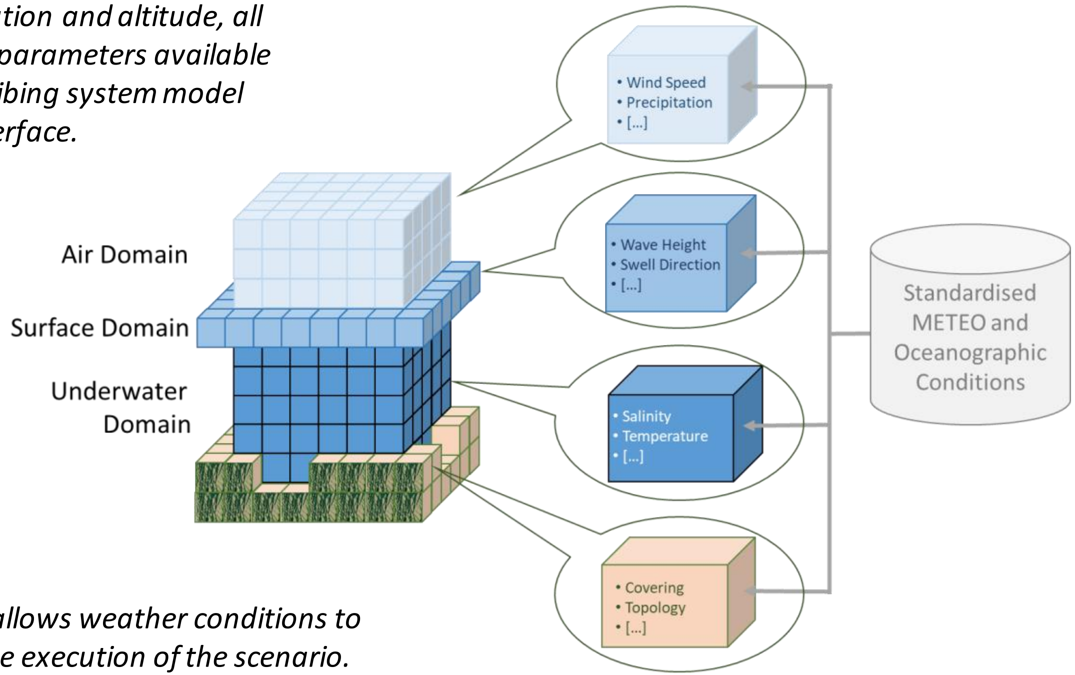
- STANAG 4607 NATO Ground Moving Target Indicator Format
- STANAG 4609 NATO Digital Motion Imagery Standard
- STANAG 4676 NATO Intelligence Surveillance Reconnaissance Tracking Standard

Multi-Domain Distributed Simulation in OCEAN2020 -7
Outcomes of Simulated Trials

- **Consolidation of the simulation environment** built for OCEAN2020 Project, achieved through the cooperation of different European entities (industry and research) providing a significant effort in building and improving the simulation infrastructure.
- **Distributed Modelling and Simulation framework** based on High Level Architecture (HLA) allowing different partners to work from remote using distributed simulations relying on a secure connection (VPN)
- The **potential of a "system-of-systems" approach**, applied to simulation, successfully demonstrated with the integration of different types of simulators and prototypes able to exchange data in simulated scenarios
- **Innovative aspect and technologies of the system** (e.g. advanced data processing, data fusion, video processing) integrated and tested with the simulation environment
- Demonstration of **system resilience in contested environment** performed by setting different environmental conditions (from good weather to bad weather) and adding jammers and checking the impact on simulated EO sensor video streams and radar signal to noise ratio
- **Complement or anticipate and de-risk the Live Trials** by checking the times of the scenario execution and the positions/interactions of simulated assets or simulating phases not performed in the Live Trials

Multi-Domain Environmental Model -1
Multi-domain environmental simulator

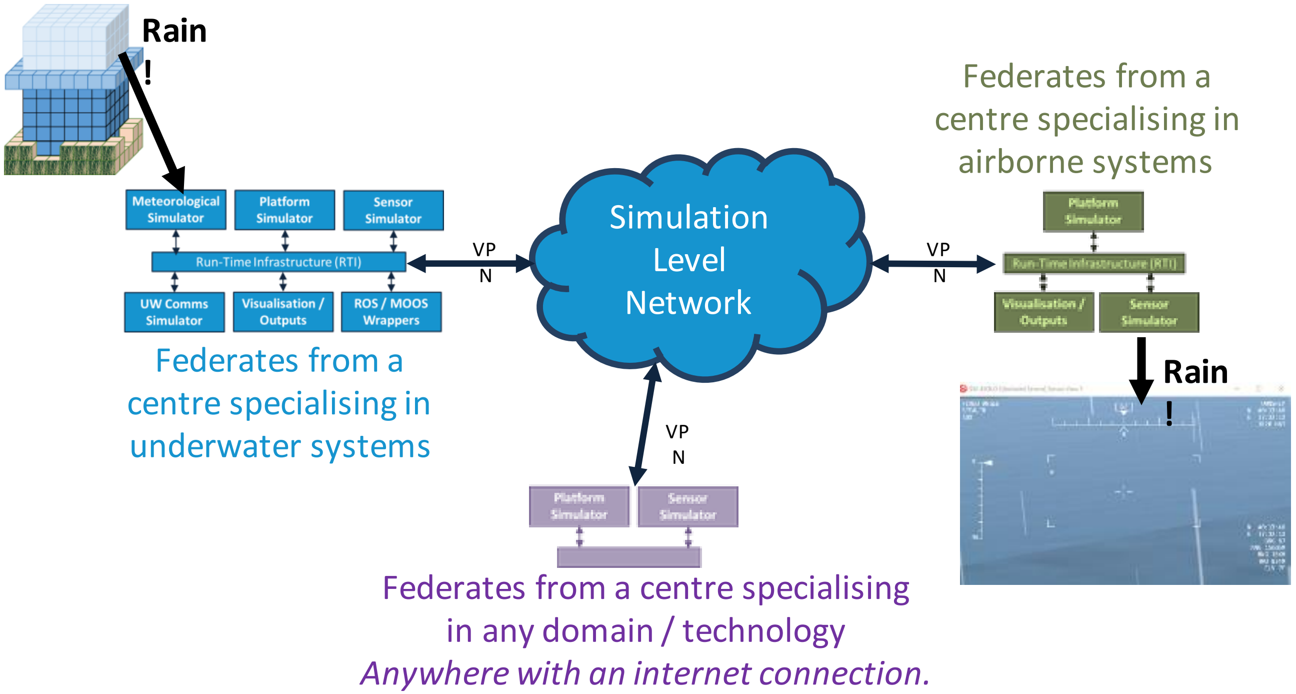
- **A single, complete, multi-domain environmental simulator has been developed.**
  - *Data is imported from a range of standardised interfaces, allowing specialist datasets to be combined into a single, coherent model.*
  - *Gridded by location and altitude, all environmental parameters available to every subscribing system model via the HLA interface.*



  - *Time evolution allows weather conditions to evolve during the execution of the scenario.*

Multi-Domain Environmental Model -2
Simulation of environmental effects

- **The simulation user can control all environmental effects from a single model.**
  - *The environmental data is propagated throughout the simulation, allowing domain specific models to behave accordingly in the scenario.*



Underwater Domain Simulation Capabilities -1
Underwater Sensors

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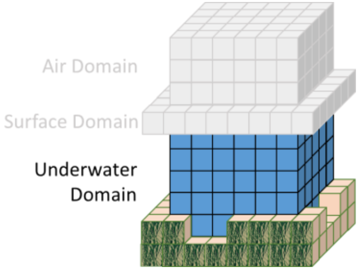
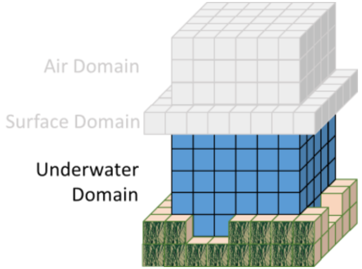


- **The sensor’s ability to detect a range of targets across a range of environments provided by the asset providers.**
  - *Inputs collected from all participants via survey and interview sessions.*
  - *All inputs implemented into a range of specialized sensor models.*

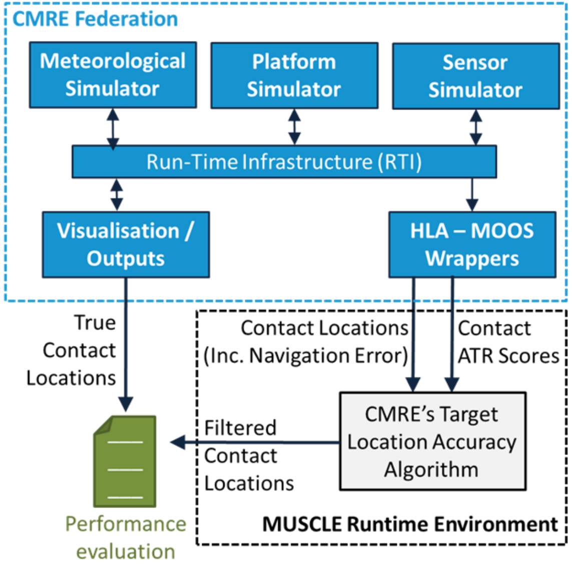
Probability Calculation	Baseline Success Probability	x	Factor due to background Terrain Type	x	Factor due to range	x	Factor due to environmental conditions	x	Factor due to [...]	=	Success Probability
Stage Description	The probability that a sensor can correctly detect, classify or identify a specific target.		A factor that is applied to the baseline success probability due to terrain type surrounding the target.		A factor that is applied to the baseline success probability due the range of the target from the sensor. This includes field of view parameters.		A factor that is applied to the baseline success probability due to the environmental conditions in the area.		Provision is made for any sensor or technology specific factors that may be identified.		
Worked Example	The probability of a side scan sonar being able to detect of a cylindrical mine is 0.7.		If the mine is laying on rippled sand, the probability decreases slightly. (Factor = 0.9)		The mine has an equal chance of detection anywhere within the sensor field of view. (Factor = 1.0)		If the operation is conducted in sea state 4, the probability of detection decreases significantly. (Factor = 0.6)		If the mine is laying in line with the sand ripples, the probability of detection decreases slightly. (Factor = 0.9)		The probability that the target is detected during a simulated pass is 0.7 x 0.9 x 1 x 0.6 x 0.9 = **0.34**

Underwater Domain Simulation Capabilities -2
Underwater Platforms

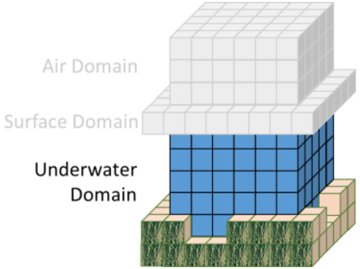


- **Kinematic models for all OCEAN2020 assets developed.**
  - *Two categories of kinematic model identified:*
    - *Hovering - All free axes have independent degrees of freedom. There are no cross couplings between axes.*
    - *Torpedo - Yaw and pitch motions are a function of forward speed.*
  - *All parameters populated with asset provider data*

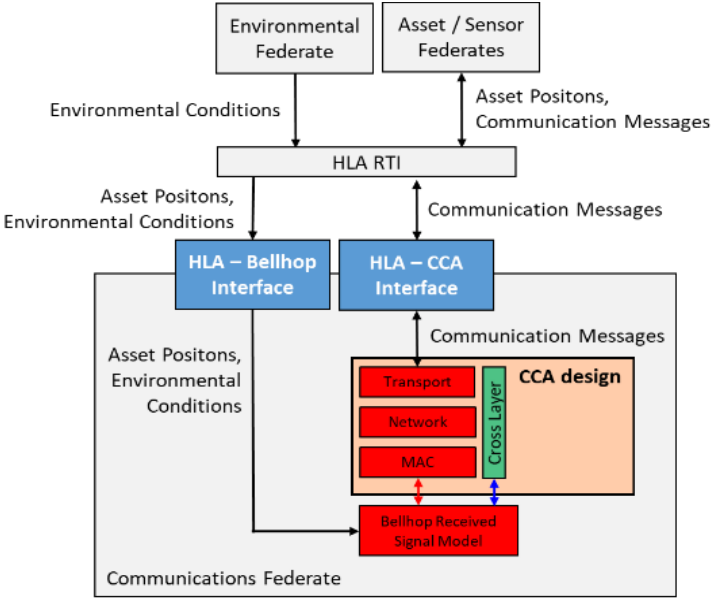
- **Allows the integration and test of in mission software and algorithms**
  - *Example: The CMRE Target Location Accuracy Algorithm*
    - *The platform effects of navigation error was modelled as a specialist input.*
    - *On-board mission software, running in the loop, was challenged with representative data.*
    - *The mission level benefits of the specialist underwater algorithm can be communicated and understood at the CMS and MOC level.*
  - *Many other examples implemented in OCEAN2020!*



Underwater Domain Simulation Capabilities -3
Underwater Communications



- **High fidelity underwater communications simulator developed.**
  - *Simulator allows messages to be passed between underwater and surface assets.*



- **The updated underwater communications simulator enables an exciting new capability!**
  - *The inclusion of the BELLHOP Model has been achieved and tested*
    - *A specialized environmental propagation model provides high fidelity ray tracing in the simulated environment.*
  - *This paves the way for the inclusion of communications software in the loop, such as the Software Defined Cognitive Communications Architecture (CCA).*

Above Water Domain Simulation Capabilities -1
Air and Surface Platforms

- Configurable Medium Fidelity Models for
  - Naval Platforms
  - Unmanned Surface Vehicles (USV)
  - Unmanned Air Vehicles (UAV)
- High Fidelity Models for
  - Naval Platforms used for the simulation of specific events such as UxV launch and recovery from Naval Platform
  - Unmanned Air Vehicles (UAV)

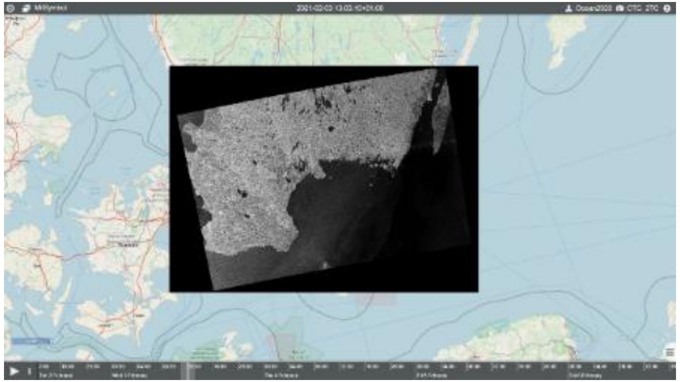
Attribute		Description	Unit
Size	Lenght		m
	Width		m
	Height	Height over sea	m
Mass			kg
Maximum Speed		The top speed of the entity	km/h
Default Speed		The speed the entity will move when tasked, unless or until changed by a set speed command	km/h
Maximum Reverse Speed		The maximum speed at which an entity can move in reverse	km/h
Maximum Acceleration		The maximum acceleration rate for the entity	m/s^2
Maximum Deceleration		The maximum (braking) deceleration for the entity	m/s^2
Maximum Lateral Acceleration		The maximum lateral (turning) acceleration for the entity	m/s^2
Turning Radius		Minimum turning radius for low-speed turns (at high speed, lateral acceleration limits minimum turn radius)	m
Endurance		Speed	Km/h
		Maximum range as a function of previously defined speed	km
Fuel	Tank Capacity		liters
	Average Fuel consumption		liters per hour

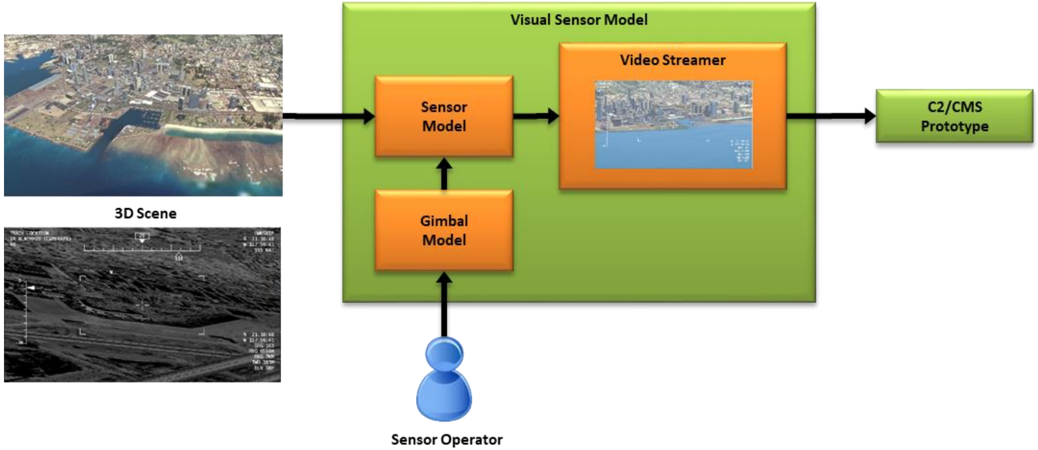

Simulation of UAV Recovery on a Frigate


Simulation of USV Recovery operation

Above Water Domain Simulation Capabilities -2
Space, Airborne and Naval Sensors

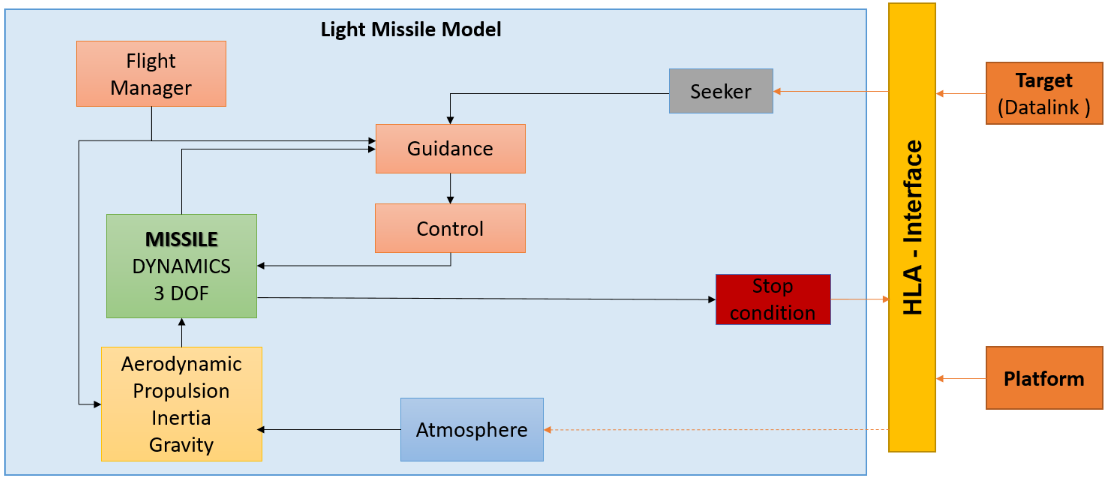
- SAR Sensor for Satellite
- Visual Sensors (Electro Optical or Infrared) for UAV and USV
  - Affected by environmental conditions
  - Supporting STANAG 4609 for video stream to C2/CMS prototypes
- Radar Sensors for UAV and USV
  - Taking into account Radar Cross Sections and environmental conditions
  - Supporting STANAG 4607 for radar tracks to C2/CMS prototypes





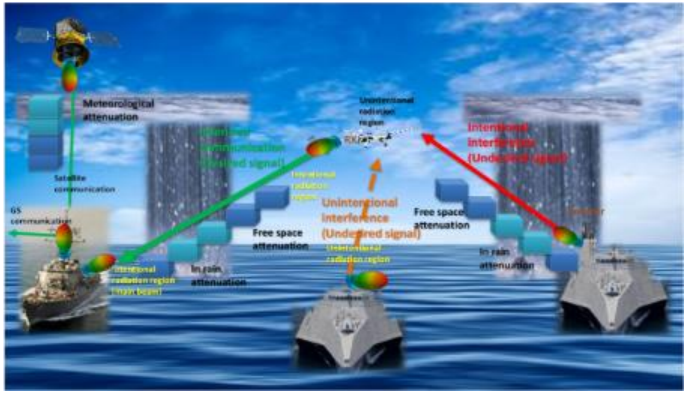
Above Water Domain Simulation Capabilities -3
Airborne and Naval Effectors

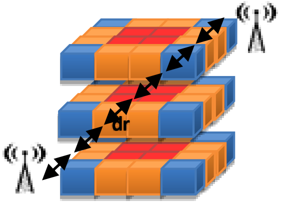
- Parametric models for Missile Effectors
  - Light Missile Effector (LME) for UAV/USV
  - Medium Missile Effector (MME) for UAV
- Supporting different engagement modes (Lock On Before Launch, Lock On After Launch) and guidance laws
- Furthermore, a large number of environmental conditions (i.e. sea states, wind intensity and sea current) are taken into account, allowing a more accurate and realistic vessel simulation.

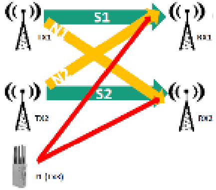


Above Water Domain Simulation Capabilities -4
Above Water Communications

- The above water communications model evaluates the status/quality of the communication links between simulated UAV/USV and simulated ship based control station or coastal base is composed by :
  - **<u>Communication (COMM) module</u>** to evaluate the electromagnetic propagation between the simulated assets antennas taking into account:
    - Free Space attenuation
    - Meteorological events (oxygen, vapor, rain, temperature) induced attenuation
    - Sea surface multipath
  - **<u>Contested Environment (CE) module</u>** to evaluate the status/quality of the communication links taking into account:
    - The effects of jammers and interference (unintentional)
    - The Signal to Noise (S/N) ratio improvement according to the adopted anti-jamming technique (Electronic Protection Measures)

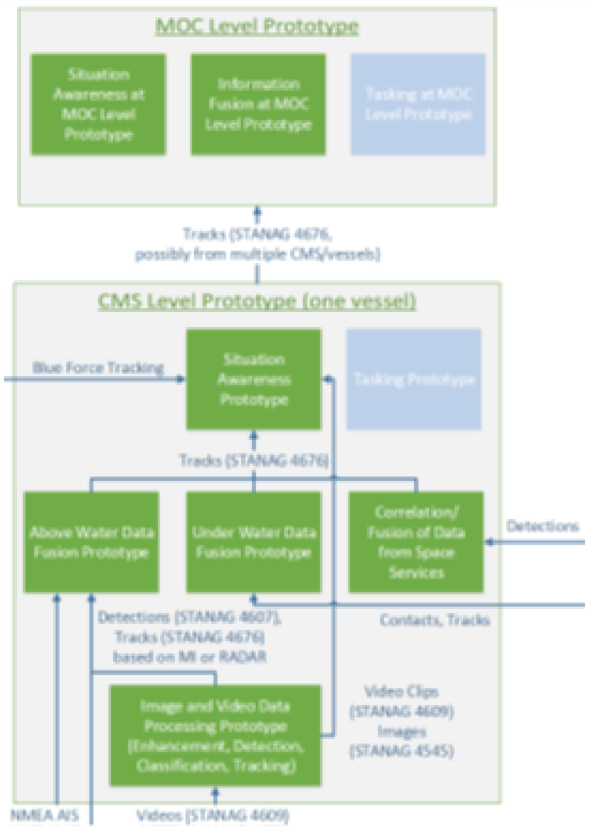






Data Fusion and Situation Awareness Prototyping -1
Overview of Prototypes and Functions

- Above Water Data Fusion Prototype
  - Localization, Tracking and Track Correlation
  - Integration
- UW Data Fusion Prototype
  - Localization and Correlation
- Satellite Data Fusion Prototype
  - Localization, Analysis
- Situation Awareness Prototype
  - RMP Compilation and Representation
  - Analysis and Assessment



Data Fusion and Situation Awareness Prototyping -2
Architecture

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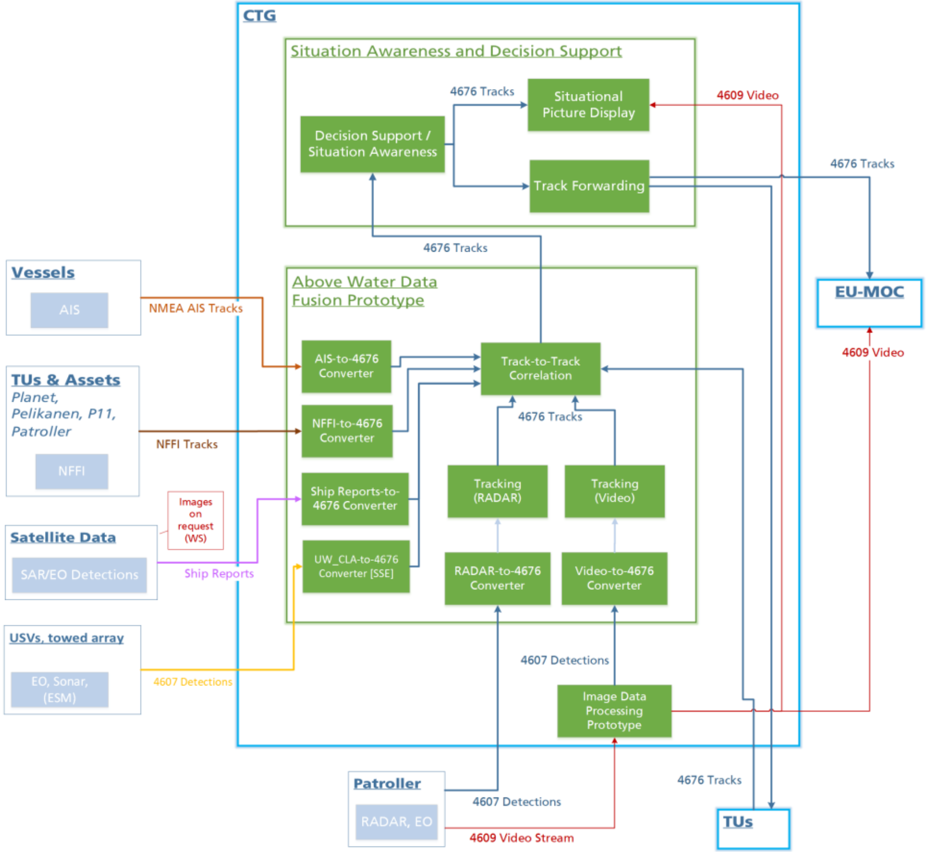
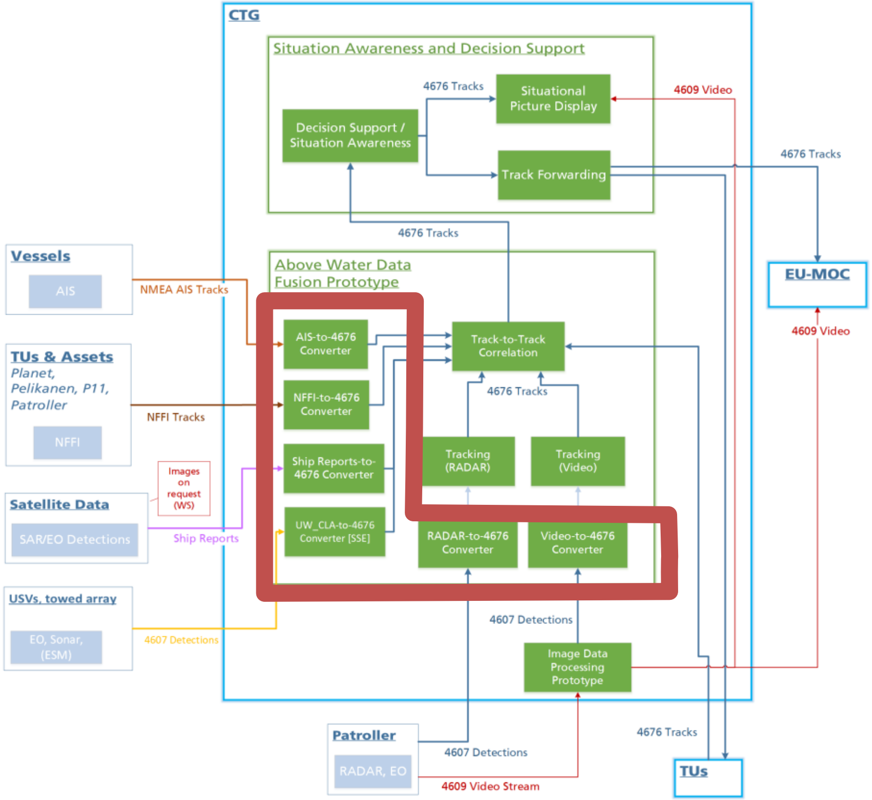


Data Fusion and Situation Awareness Prototyping -3
Gathering Information

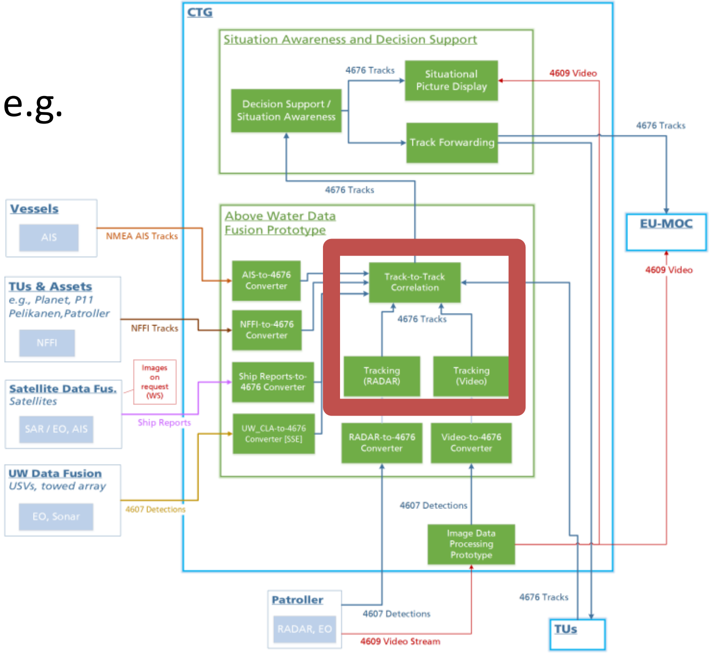
- Collecting information from assets by following standards
  - NMEA for AIS
  - STANAG 5527 for NFFI
  - STANAG 4607 for RADAR/EO Detections
  - STANAG 4545 for still images
  - STANAG 4609 for video streaming
- Tracks converted to STANAG 4676 for Track Correlation



Data Fusion and Situation Awareness Prototyping -4
Tracking

- Tracking: Combine 4607 detections to 4676 tracks
  - Probabilistic tracking
  - Track quality also depends on data properties, e.g. uncertainty of measurements
  - Different sensor accuracies

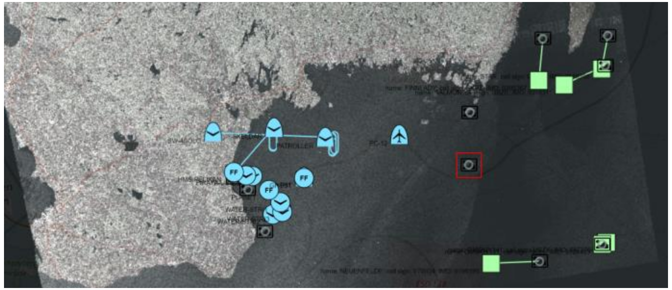
- Track-to-Track Correlation
  - Correlate different tracks for same vessel
  - Create system tracks for dissemination
  - Also depends on data

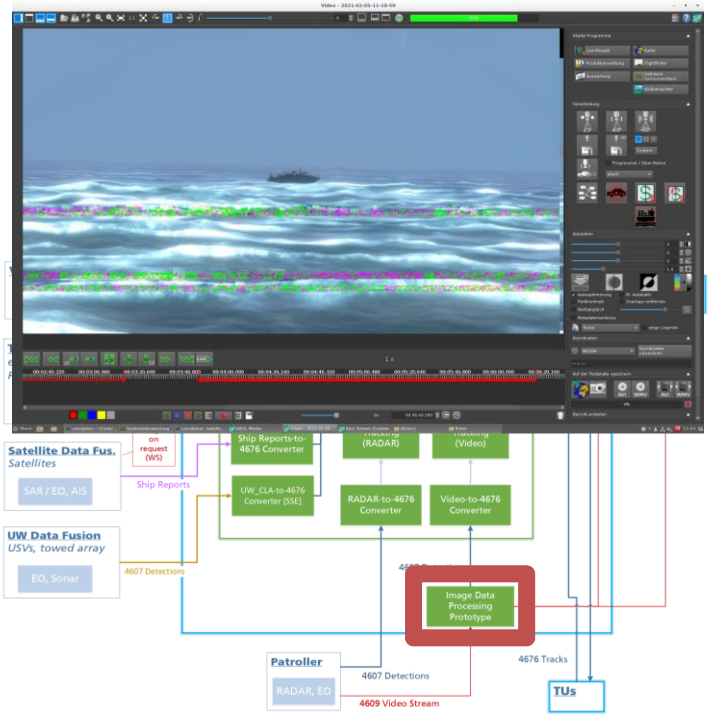


Data Fusion and Situation Awareness Prototyping -5
Image Processing

- Image Data Processing
  - Detect vessels from 4609 video streams
  - Calculate locations based on stream metadata

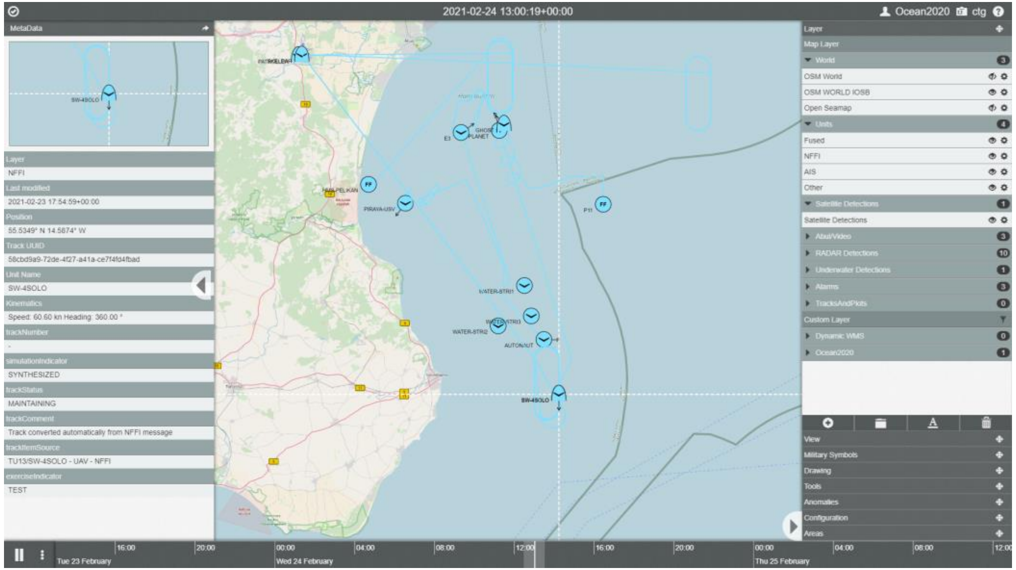
- Satellite Data Fusion
  - Detect vessels from satellite EO/SAR images
  - Correlate with satellite received AIS data
  - Create XML-based ship reports

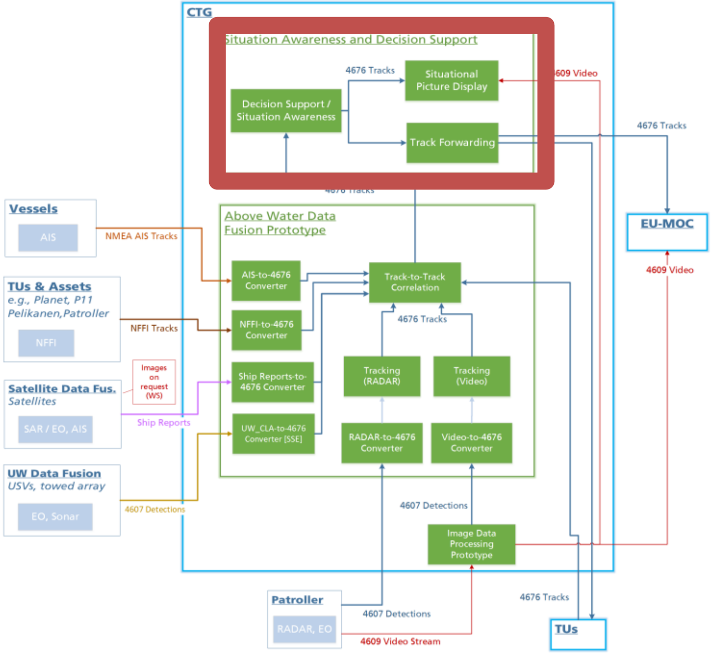




Data Fusion and Situation Awareness Prototyping -6
Situation Awareness

- Display available data
  - Different sources for CTG, TUx, …
- Support for automatic alert generation





Use of M&S Outcomes for Improving Prototypes -1
Early Testing of Interfaces

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- Evaluation as “hardware in the loop”
  - The prototypes are tested with the Live Trials in mind
- M&S provides data to test prototypes usable on syntactical, semantical and pragmatic level
- Validating formats, interfaces and basic processing:
  - Input from sensors can be robustly processed:
    - Radar detections (STANAG 4607)
    - NFFI messages (STANAG 5527) and AIS messages (NMEA)
  - Conversion to STANAG 4676 as common exchange format
  - Input to tracking and track correlation (STANAG 4676)
  - Imagery data (STANAG 4609 / 4545)
    - can be received, displayed and forwarded
- Besides syntactical aspects, also common understanding of standards can be tested

Use of M&S Outcomes for Improving Prototypes -2
Early Testing of Functions

- Image Data Processing
  - Simulated video streams for validating generation / sending / receiving of detections
    - Testing basic functionality
    - Reception of video stream
    - Metadata processing of video streams
    - Dissemination of video-based detections in a standardized way
    - Forwarding of video streams
  - Using simulated video data shows feasibility of detection algorithms
    - Yet, validation is only possible with a bias towards simulated data

Use of M&S Outcomes for Improving Prototypes -3
Evaluation and Improvement of Algorithms

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- Prototyping and evaluating data fusion algorithms such as tracking and track-to-track fusion
  - Basic functionality
  - Specificities of the different sensors
  - Specific technical aspects (Timing and delays, uniqueness of IDs etc.)
- In addition, M&S allows to use specialized test setups
  - Only specific aspects of a scenario (wrt. sensors, TUs, targets etc.)
  - Scaled versions of a scenario (e.g., increased number of objects)
  - Gives good understanding of algorithm‘s quality, robustness etc.
- Depending on the quality of the sensor simulation, results can be directly transferred to the real world application

Use of M&S Outcomes for Improving Prototypes -4
RMP Display and Dissemination

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- Situation Display
  - Testing of capabilities regarding e.g. amount of data, sampling time of simulated sensors etc.
  - Evaluation-Test-Setup: "Hardware in the loop"
  - Early recognition of misconfigured time sync and others
  - Evaluation of data interaction
  - Visually verifying simulated sensor behaviour
- Results Dissemination
  - Testing forwarding of RMP contributions
  - Testing hierarchical data dissemination and filtering of not-originator information (“reporting responsibility”)

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