MOSES Shore Tugboat Control Station: Development of a shore-side system to support autonomous tugboat operation

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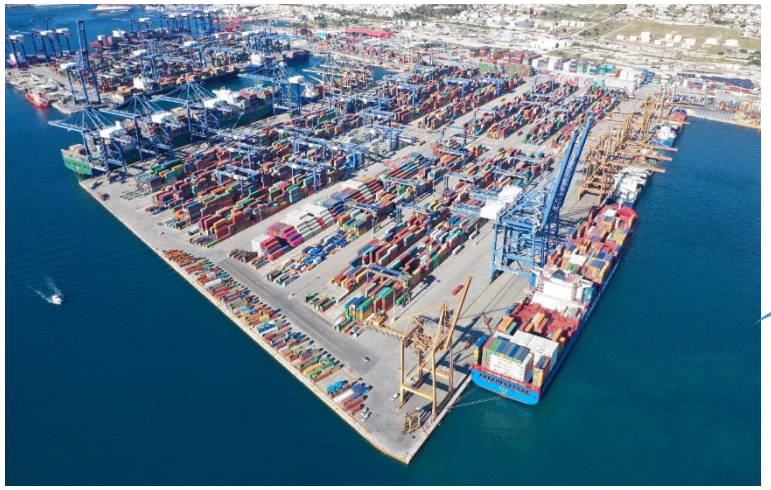
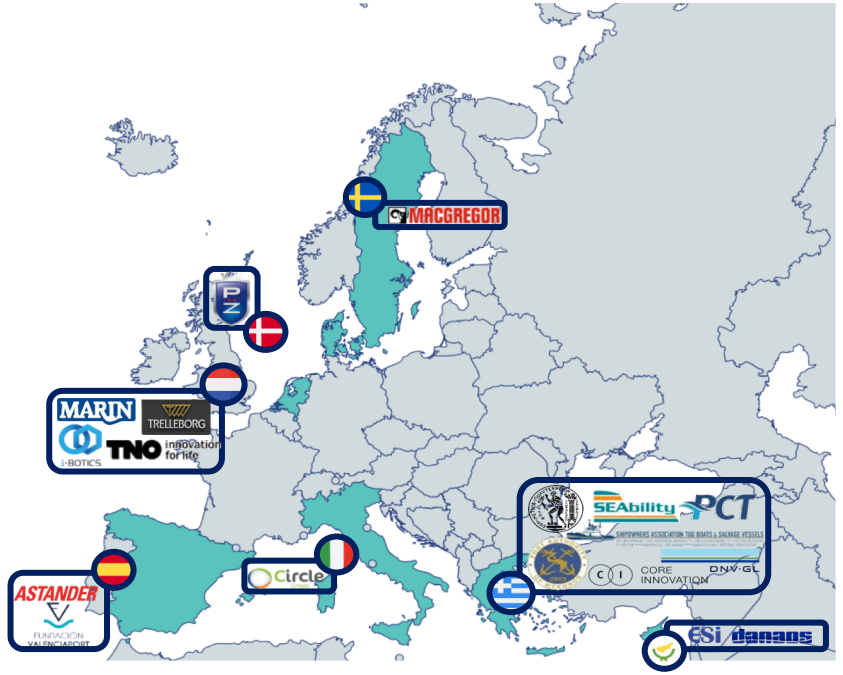
MOSES aims to…



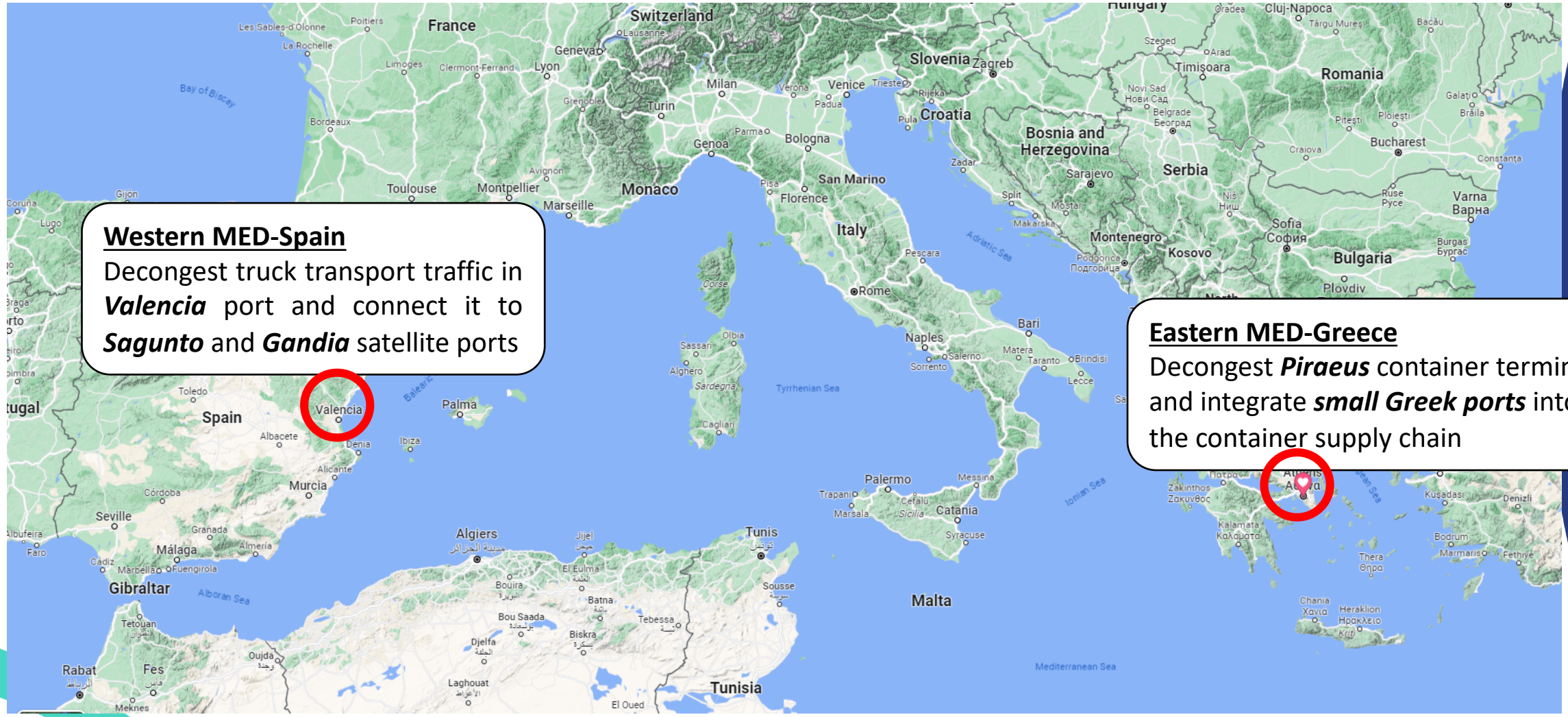
Create sustainable feeder services from large container terminals to **small ports with no infrastructure to replace trucks on Ro-Ro ships**

AutoMated Vessels and Supply Chain Optimisation for Sustainable Short SEa Shipping

- **Duration:** 01.07.2020 - 31.12.2023
- **Budget:** 8 million €
- **Consortium:** 17 Partners
- **Coordinator:** NTUA



The MOSES Use Cases



The MOSES project concept

AutoDock Innovations:

- *Autonomous tugboats and mooring operations*
- ***Shore Tugboat Control Station - STCS***
- *Automoor unit*

MOSES Innovations:

1. **MOSES AutoDock (MOSES Autonomous tugboats + AutoMoor)**
2. **MOSES Recharging Station**
3. **Innovative Feeder Vessel**
4. **Robotic container-handling system**
5. **MOSES matchmaking platform**

Introduction - Remote Control Centers (RCCs) in general

Automated ships are expected to be ***continuously supported*** by shore-based RCCs. In order to ***maintain operational safety***:

- A team of specially ***trained operators*** must ***monitor*** the status of autonomous ships
- ***Real-time data*** streams from ***sensors***
- ***Take over control*** when necessary

Challenges for the operators :

- Deal with ***information overload- misunderstandings***
- ***Overreliance on automation*** and skill degradation - ***Delays in decision making*** (human-out-of- the-loop syndrome)
- ***Boredom*** and ***fatigue***

Solution:

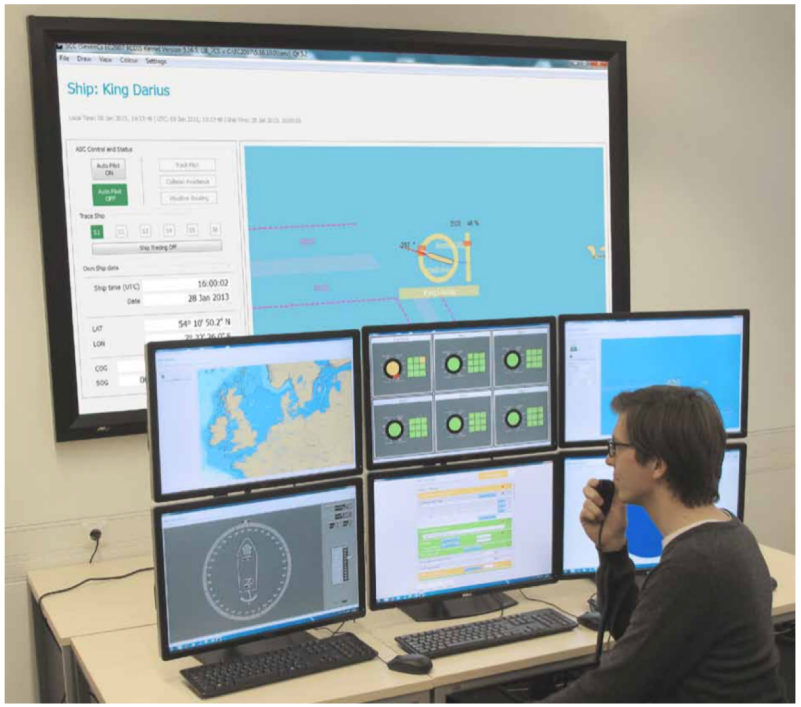
- ***Completely re-designed RCCs***, not duplicates of the ship's bridge
- Focus on ways of maintaining ***situation awareness***

RCC concept by Rolls Royce (for cargo ships)

RCC concepts and prototypes

- The design of RCC concepts for autonomous ships includes ***different approaches*** to create Human Machine Interfaces ***(HMIs)*** and workflows that are ***efficient and supportive*** of human ***decision-making***.
- ***Various prototype interfaces*** have been created in order to convey situation awareness to the operator monitoring remotely in terms of (Porathe, 2014):

1. ***Spatial awareness:*** maps similar to ECDIS
2. ***Temporal awareness: timelines*** in the form of ***slot diagrams***, marking ***tasks*** for the operator, trend lines that provide ***time series*** of important parameters
3. ***Operational awareness:*** a ***ship status indicator*** at various levels (condition of the ship's technical systems), ***colour coded*** top level indicators for different ***ship functionalities***



Maritime unmanned navigation through intelligence in networks project

Approaches to RCC design

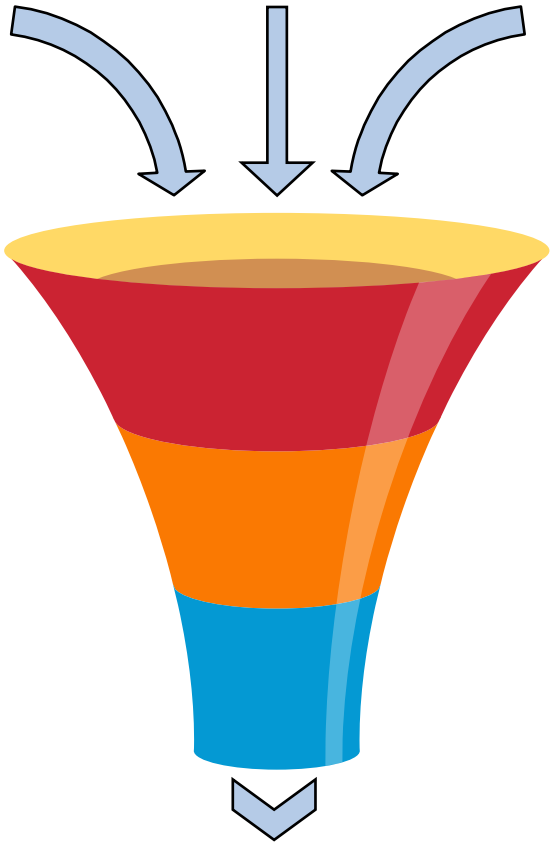
Human-Centred Design (HCD) *(Hoem et al., 2022)*	**HCD approach (different approach)** *(Veitch et al., 2021)*	**Structured Analysis and Design Technique (SADT)** *(Rutledal (2021)*	**Extending the *Systems Theoretic Process Analysis (STPA)*** *(Cheng et al., 2023)*
Evaluate the HMI of a prototype land-based control center for an autonomous ferry in its early design stages *(Based on **Risk-Based Design** (RBD) principles and Crisis Intervention and Operability study (CRIOP) framework)*	Define the operational context, derive user ***requirements*** through expert ***workshops***, prototype, and evaluate the design *(Based on the **ISO** 9241-210 **standard** on ergonomics of human-system interaction)*	**Identify** and ***analyse*** the ***functionalities*** and tasks that need to be performed by an RCC for an autonomous ferry	***Hazard identification*** method that can provide input to "human-oriented design and development of SCC", ***modelling*** of the remote operator's cognitive processes

STCS development process

1 General requirements from the Classification Societies

2 Required functionalities for the system to accomplish its mission

3 Requirements derived from the analysis of 3 use cases



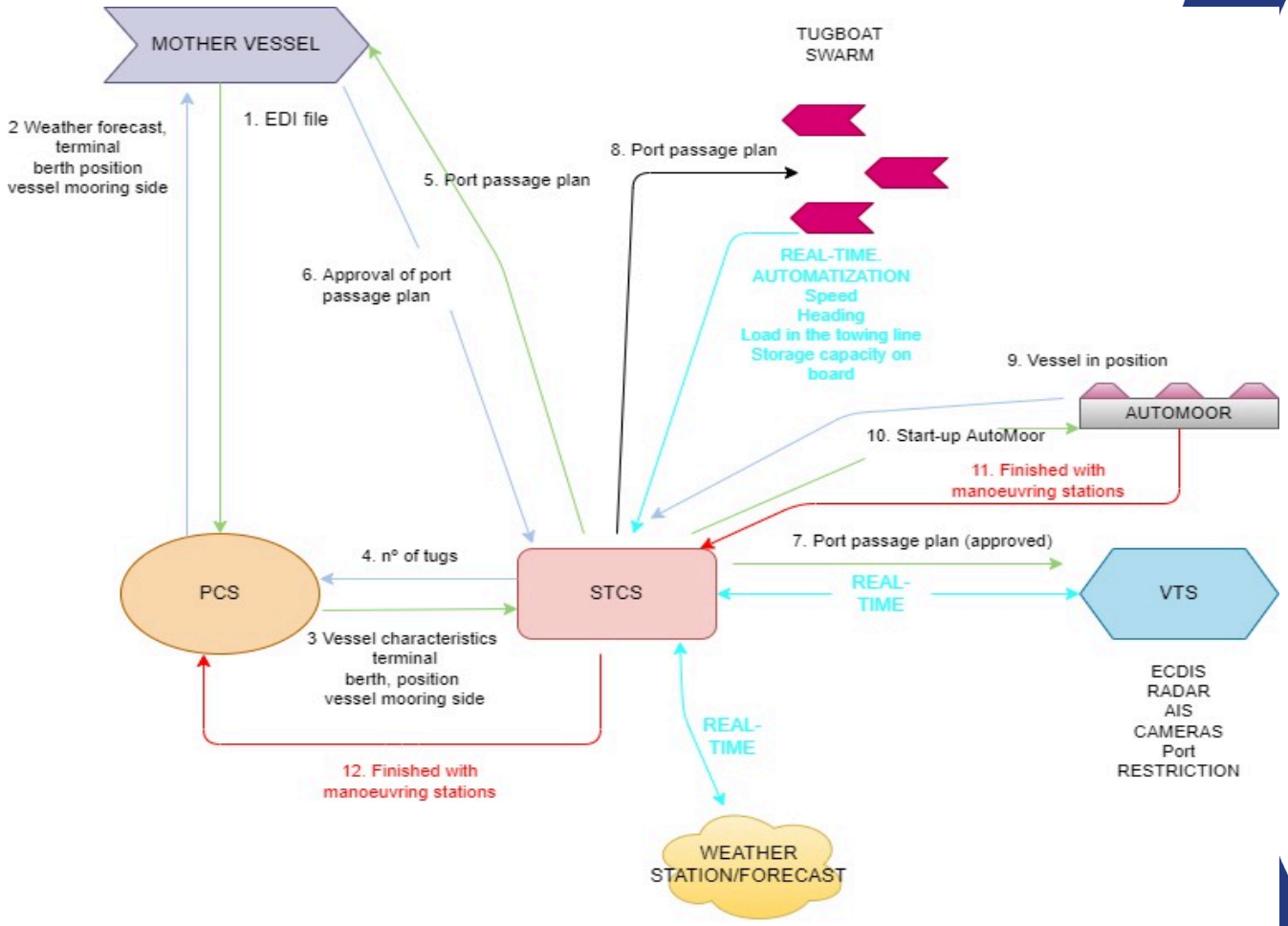
Development of the initial design for the MOSES STCS HMI

RCCs and Classification Societies – Level of safety

Workstation layout	**Two remote operators** with separate workstations for remote ***navigation*** and ***engineering*** functions
Situation awareness	• ***Real-time information*** provided by sensors, data to substitute human senses • ***Equivalent to or better than conventional*** local ***situation awareness*** • Sufficient ***overview of status of ship functions*** (e.g. colour code) • ***Decision support functionalities*** when needed
Hazard identification	Alarms should ***only be used when actions are required*** and should clearly indicate required actions
Data logging	Key vessel function data ***electronically logged and stored*** (cyber-attacks protection)

The MOSES STCS

- The ***objective*** of the MOSES STCS is to ***supervise*** the ***towing, manoeuvring*** and ***docking*** process of the assisted vessel.
- ***Real time connection of the remote human operator in the STCS*** with involved actors:
  - Tugboats
  - Assisted vessel
  - Automoor
  - Vessel Traffic Service (VTS)
  - Port Community System (PCS)
  - Meteo service
- ***Clear communication flow*** between STCS and other components



Requirements for the STCS - Main implemented functions

Situation awareness

Real-time data exchanges, efficiently monitor the status of the tugboat swarm, as well as the status of the tugboats relative to the assisted vessel (VHF etc.) and the port infrastructure

Mission scenario management

The STCS needs to ***provide*** the autonomous tugboats with a ***pre-determined berthing position*** and once the process has been completed, send a ***mission achievement signal*** to the tugboats and the automated mooring units

Switch between levels of autonomy

Requires the STCS to send a control signal to the tugboats and to verify the switch with the personnel onboard the tugboats (if any)

Fail-safe operation

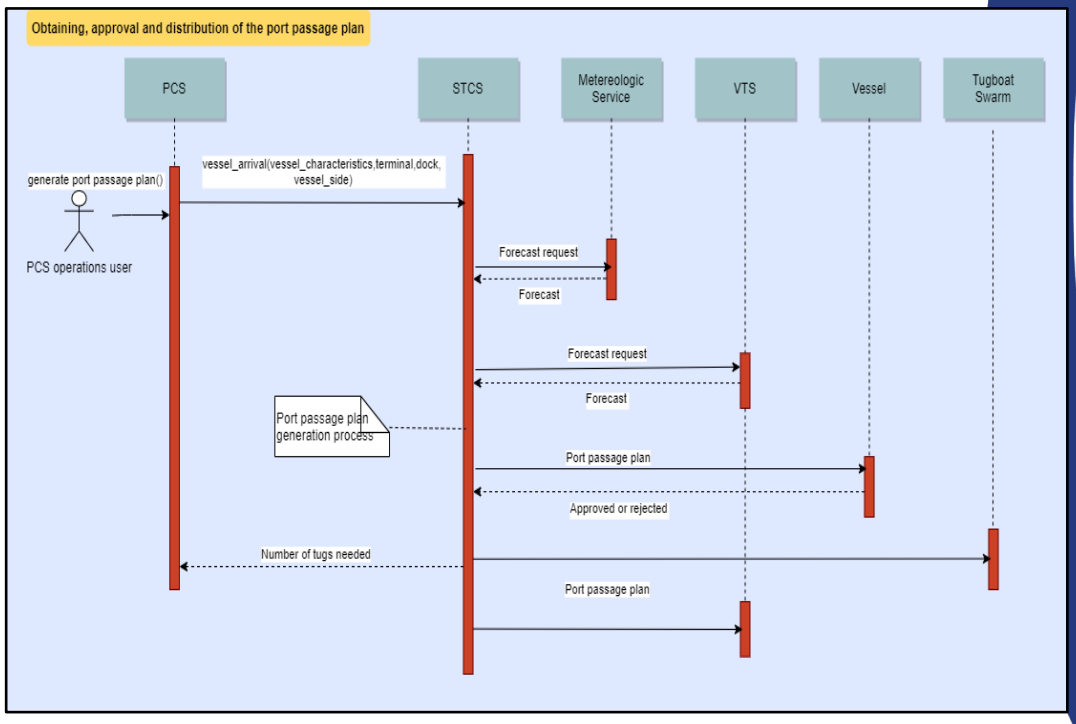
Take control of each tugboat remotely by first disengaging autonomous control mode, ***depending on the type of failure***

Use cases analysis

The whole process is divided in ***3 phases,*** so ***3 use cases*** (1 for each phase) are analysed, in order to identify the type of information that needs to be exchanged

1. Port arrival:

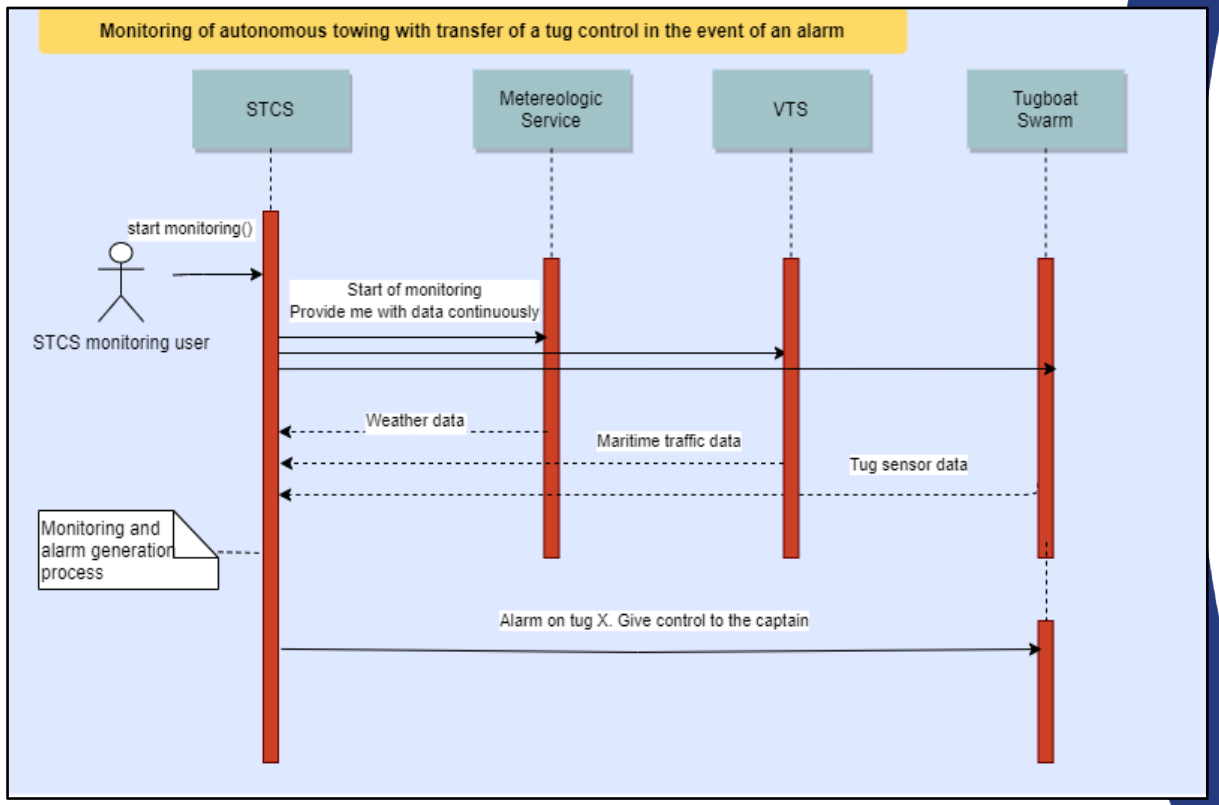
- *Port Community System (PCS)*: ***Terminal***, ***dock*** and ***which side*** of the ship will be moored, according to ship parameters
- *STCS*:
  - Request ***weather forecast*** from meteo service, prediction of ***maritime traffic*** from the ***VTS***
  - Generates the port passage plan, the ***maximum deviation limits*** with respect to that path, calculates the ***required number of tugboats*** and sends this information to the PCS
  - Once approved, the STCS ***sends the port passage plan to the autonomous tugboats*** and the VTS



Use case analysis

2. Manoeuvering phase:

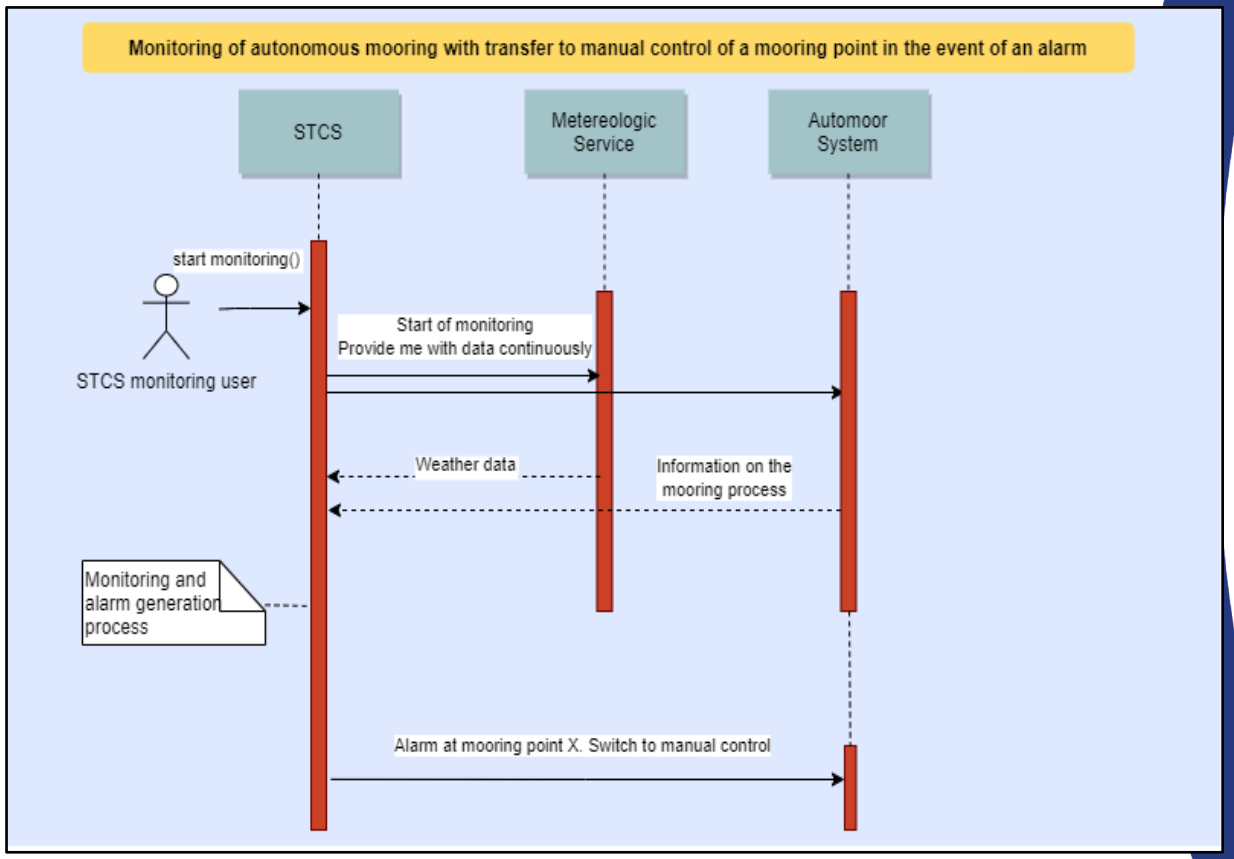
- ***Supervise*** autonomous ***towing*** operations in real-time, through **sensors**
- Real-time information on ***weather data***, the ***status of maritime traffic*** in the port from the VTS
- In case an ***alarm*** is triggered to indicate hazardous conditions, an order will be sent to the tugboat in question to ***assume remote control or transfer control to the tugboat captain onboard*** (if any)



Use case analysis

3. Mooring phase

- ***Supervise*** autonomous ***mooring*** operations in real- time, through ***sensors***
- Keep receiving real-time information on ***weather data*** from the meteo service, and the ***status from the automated mooring system***
- In the event that any of the automated mooring units enters an alarm state, the STCS sends the order to ***switch to manual control***



Result: The STCS design - interface

The interface consists of ***3 separate components*** for fulfilling the following functionalities:

1. Supervising the autonomous ***towing phase***
2. Supervising the autonomous ***mooring phase***
3. Logging operational data and ***reporting***

The STCS interface will include different dashboards for ***engineering*** and ***navigation*** for each of the ***two separated workstations*** that will be physically located at the STCS:

1. One for an ***engineer watchkeeping officer***: designed to duplicate actual marine automation workstations, which are currently widely implemented on-board vessels for relevant machinery functions (e.g. alarm and monitoring, power management, auxiliary machinery control, etc.)

2. One for a ***navigation watchkeeping officer***

STCS interface – Navigational dashboard

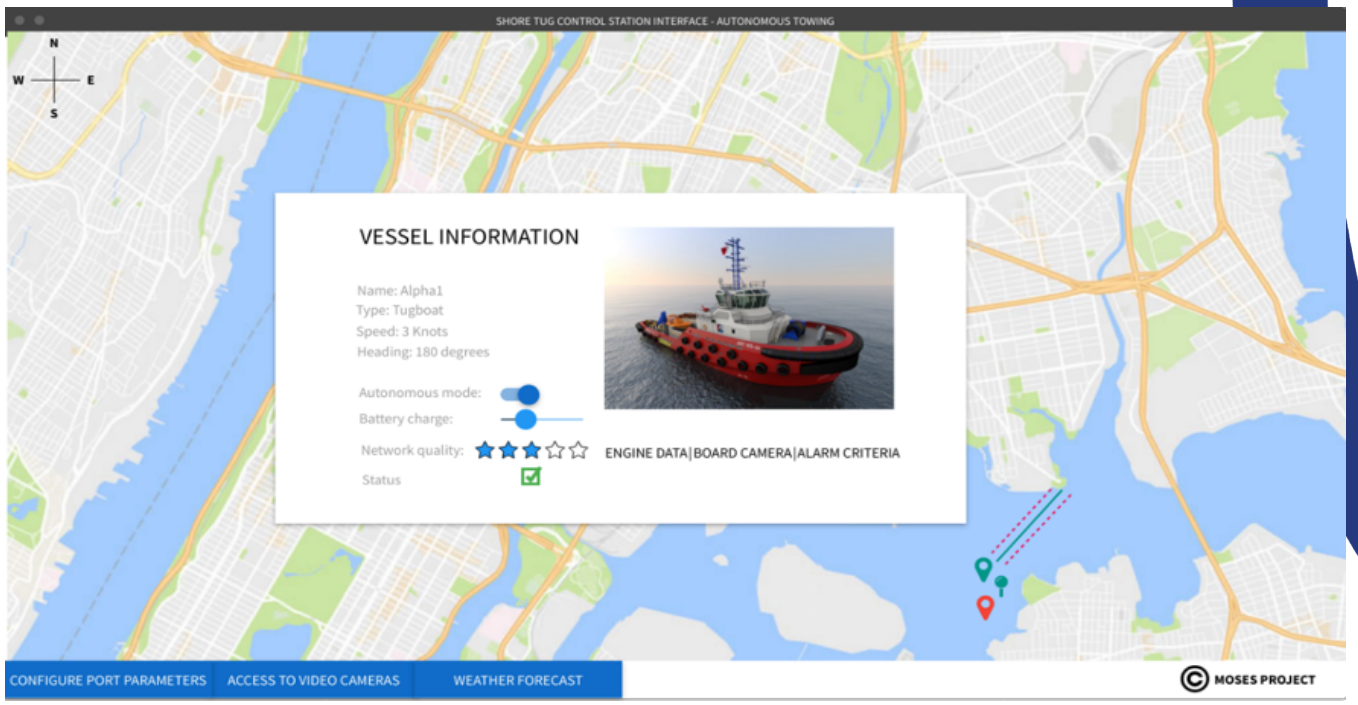
1. *Autonomous towing phase component*

- Plotted planned route up to the mooring point to be followed by the assisted vessel ***(continuous green line)***
- Plotted “safe corridor” ***(dashed red lines)***
- Plotted position, speed and heading of each tugboat and the assisted vessel
- If the “safe corridor” is violated by the assisted or another vessel, an alarm will go off

• Operational status of tugboats		
Working autonomously correctly	Manually operated	Alarm state

Alarm state diagnosis:

- Assume remote control or
- Transfer control to the tugboat captain (if any)



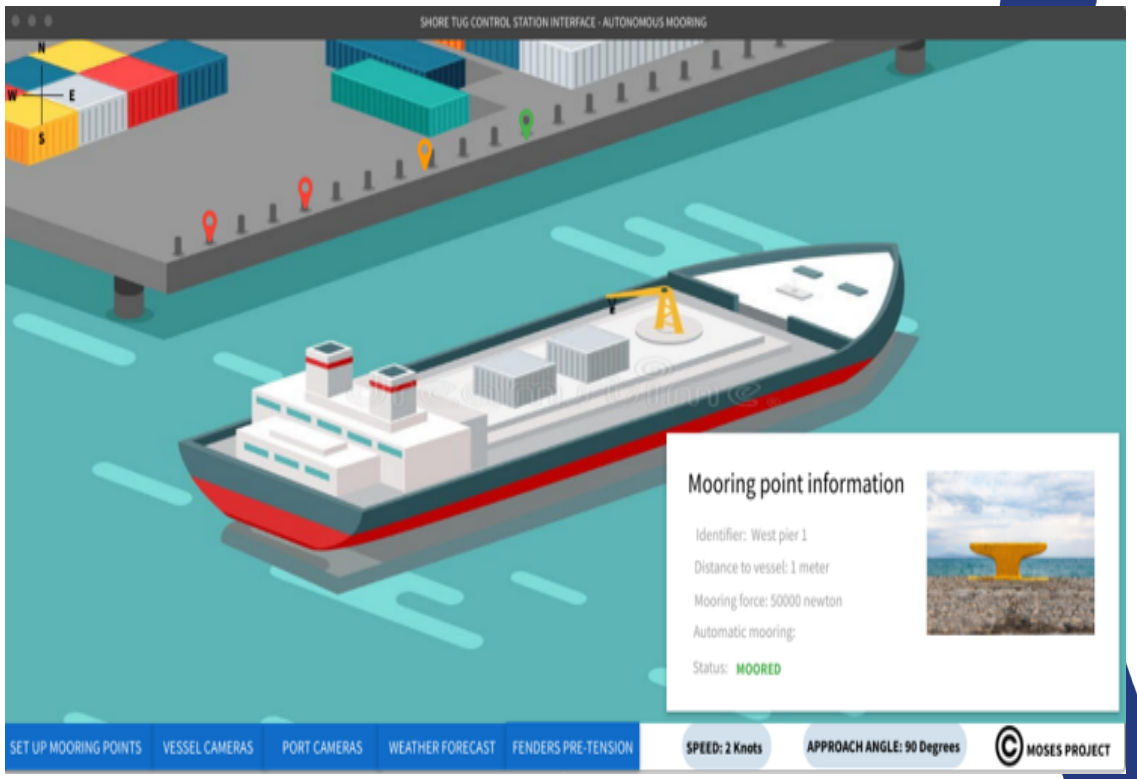
STCS interface

2. Mooring phase component:

- When the assisted vessel is close to the dock, the STCS interface will automatically switch to the autonomous mooring view
- ***Distance*** to the berth, ***angle of approaching*** and ***speed***

• Markers - Position of the automated mooring units			
Over 5m	Between 1 and 5m	Less than 1m	The ship is securely moored

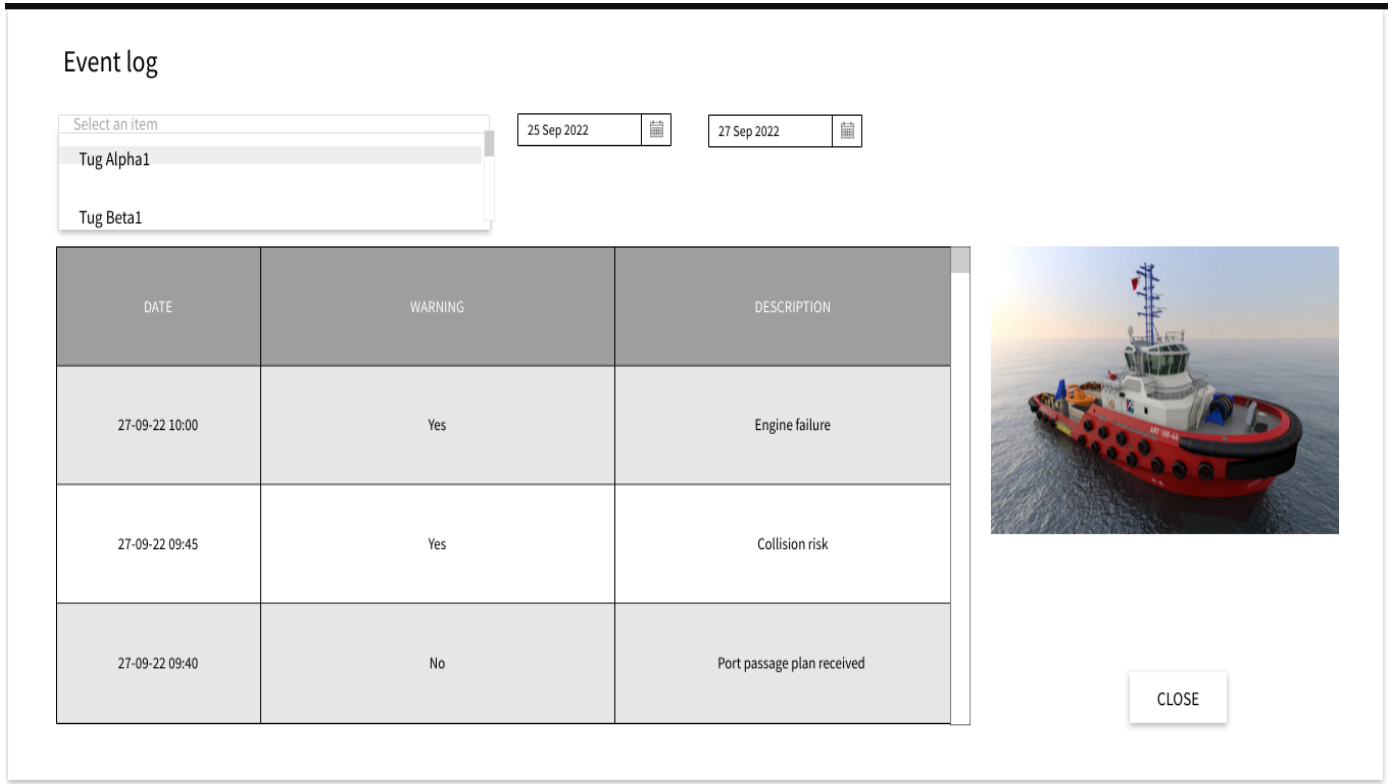
- Markers: ***applied force, stress values***
- Access to ship's and port's ***cameras***
- ***Weather forecast***



STCS interface

3. Logging operational data and reporting component:

- Centralized view to look into the ***events history***, whether there are warnings and alarms related to the autonomous tugboats or the automated mooring units

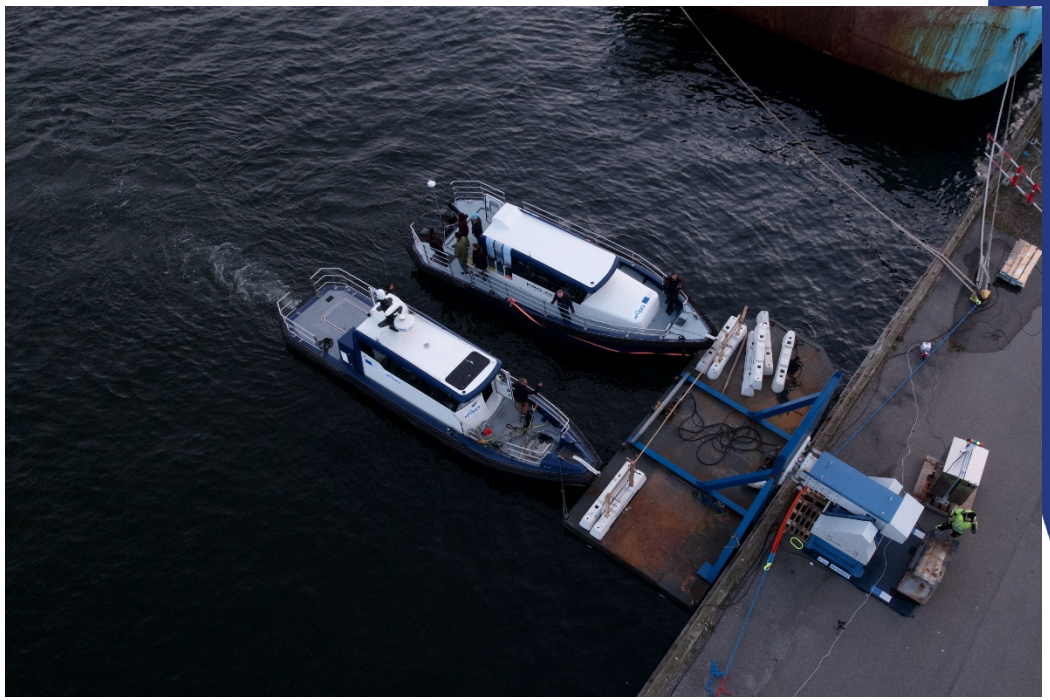


Executed pilot

- Port of Faaborg, Denmark
- October 16-20, 2023
- Involved partners: NTUA, TUCO, CORE, ESI, TRELLEBORG

Demonstrated operations:

- Autonomous tugboat operations (trained algorithm)
- Automooring
- Real time data transfer to STCS mock-up at port of Valencia



Conclusions

The most important aspects for the MOSES STCS:

- ***Visual overview*** of the operations ***– maintain situation awareness***
- ***Positions*** and ***movements*** of the tugboats and the assisted vessel
- Understanding of the ***weather conditions***
- The ***communication network*** *(speed connectivity,* communication breaks, *cybersecurity*)

MOSES is paving the way for the automation of tugboat operations

www. moses-h2020.eu

MOSES project2020

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MOSES Project

Thank you for your attention!

If you have any questions or require further information, please contact me:

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