Simulation Team

Simulation Models for Port Safety

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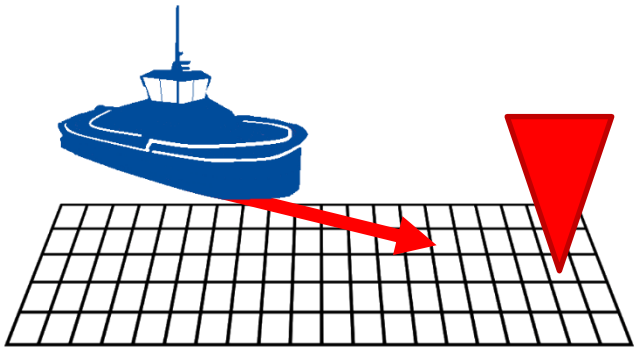
Topics: Ports, Accident & Operation Models



A Sea Port as a System of Systems

Commercial Ports are strategic assets, which contributes to development of territory through flow of goods. Inclusion of ports within a territory has important socio-economic effects as well as environmental impact. In fact, ports are closely linked to urban area, and accidents in ports may have huge impact on population.

Due to the nature of operations, vehicles, and material handled, are required procedures that can guarantee safety. This is not enough, because ports are complex Systems of Systems (SoS); the effects of operations and accidents must be considered in the overall surrounding environment, however the risk of unexpected outcomes is always present. Advanced techniques of analysis are required to assess safety, through planning and training.

Commercial Ports - Accidents

The type of accidents in the port area can be of various nature.

Accidents may be related to:

- **Yard accidents, such as fall of containers**
- **Collisions between equipment**
- **Hazard materials, (e.g Chlorine, LNG)**

Management of dangerous materials is particularly critical, due to impact on people and surrounding environment.

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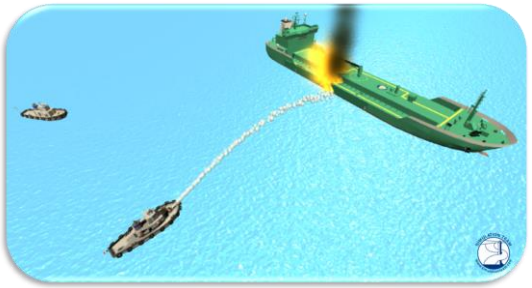
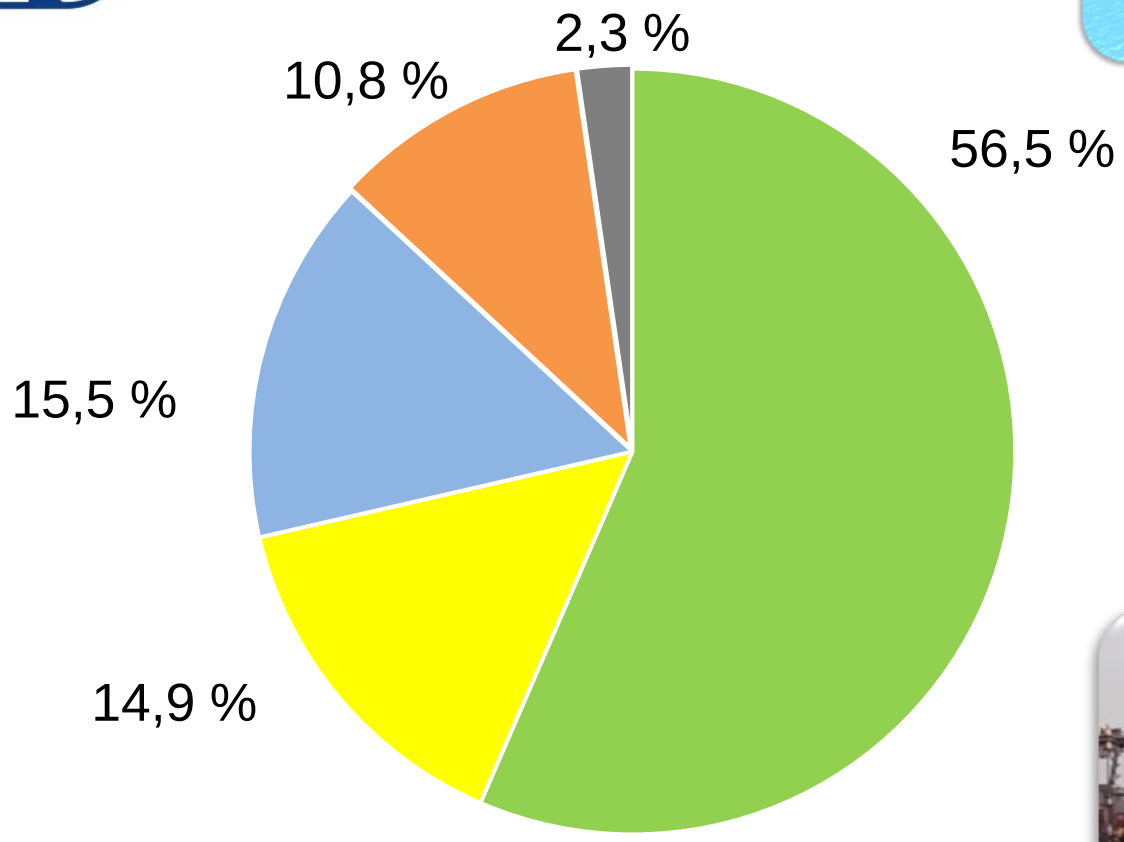
Accidents Causes

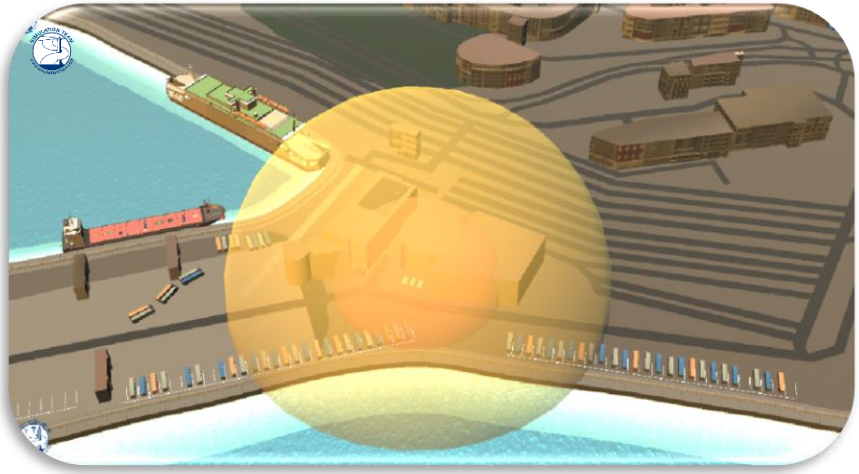




source: Historical Analysis of Accidents in Seaports, R.M. Darbra, J. Casal, Safety Science 42 (2004) 85-98, Elsevier

Decision Support Tools

Due to nature of operations and material handled, planning is necessary to reduce risks, thus avoiding dangerous situations, and mitigate emergencies.
Likewise, it would be useful to study specific crisis scenarios in which to analyze possible intervention measures.
Computer Simulation allows to recreate realistic context and their dynamics to conduct virtual experiments and training sessions.



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ALACRES2

ALACRES2 is a Decision Support Tool for Safety in Ports and it uses MS2G approach for:

- **Planning and training of subjects to manage emergencies**
- **Reduce vulnerabilities, mitigate damage and prevent emergencies**

Decision makers turn able to study specific scenarios related also to what-if cases. Planning can be done studing directly effects of decisions end implementation of contigency plans.

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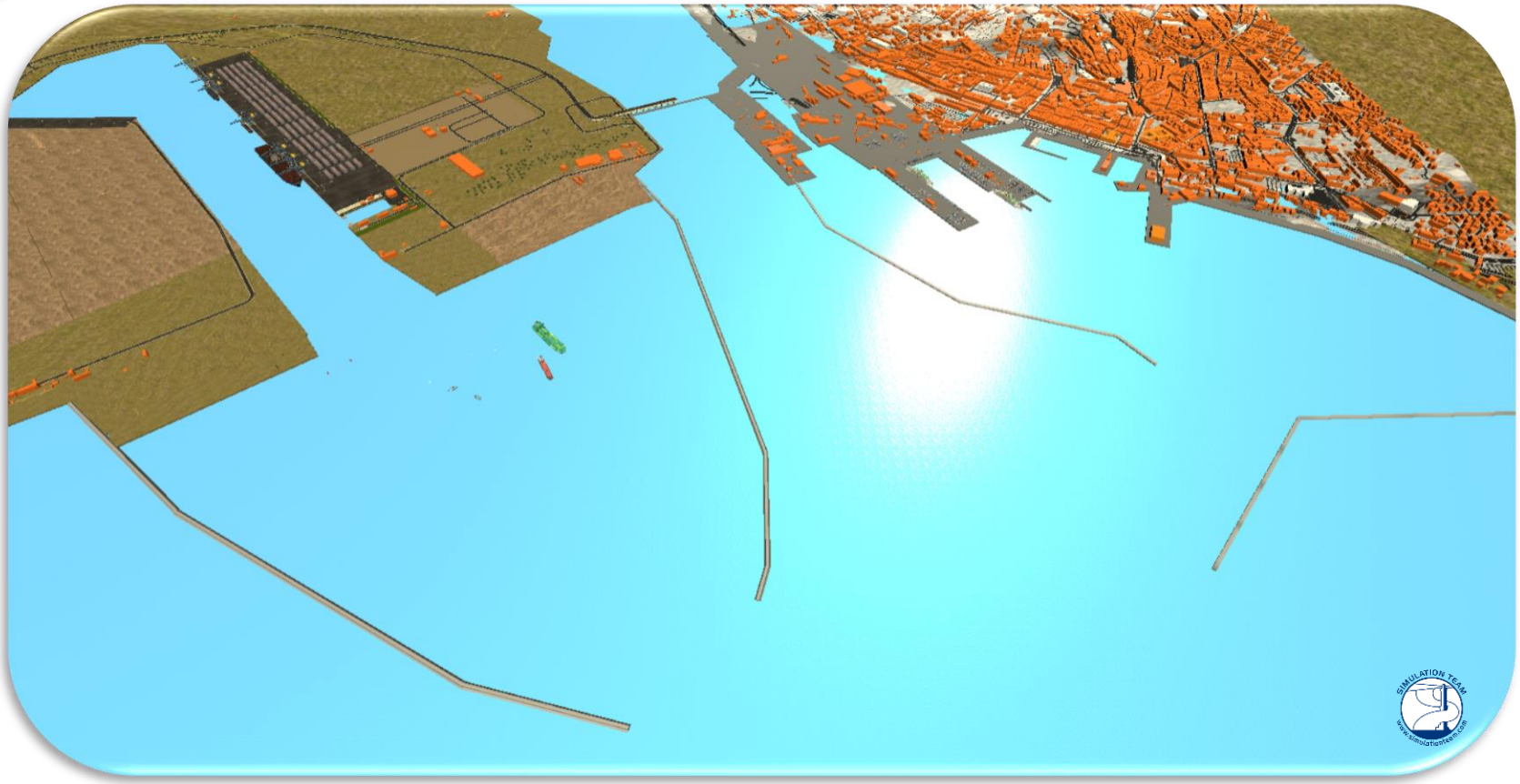
ALACRES2 – 3D Map Models



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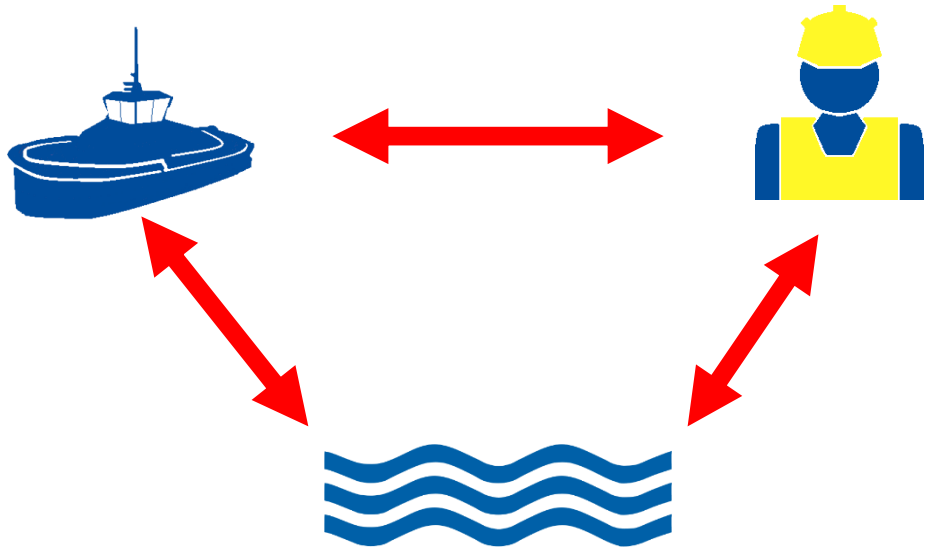
ALACRES2: Models 8 Objects

ALACRES2 required specific models in order to achieve its goals guaranteeing realism and performances of the simulation; so all major entities, actors and even environment turn into Virtual Objects with Dynamic Models, Physics & Behaviors These Models have been developed also in order to ensure interoperability, able to interact with all elements and between each other.



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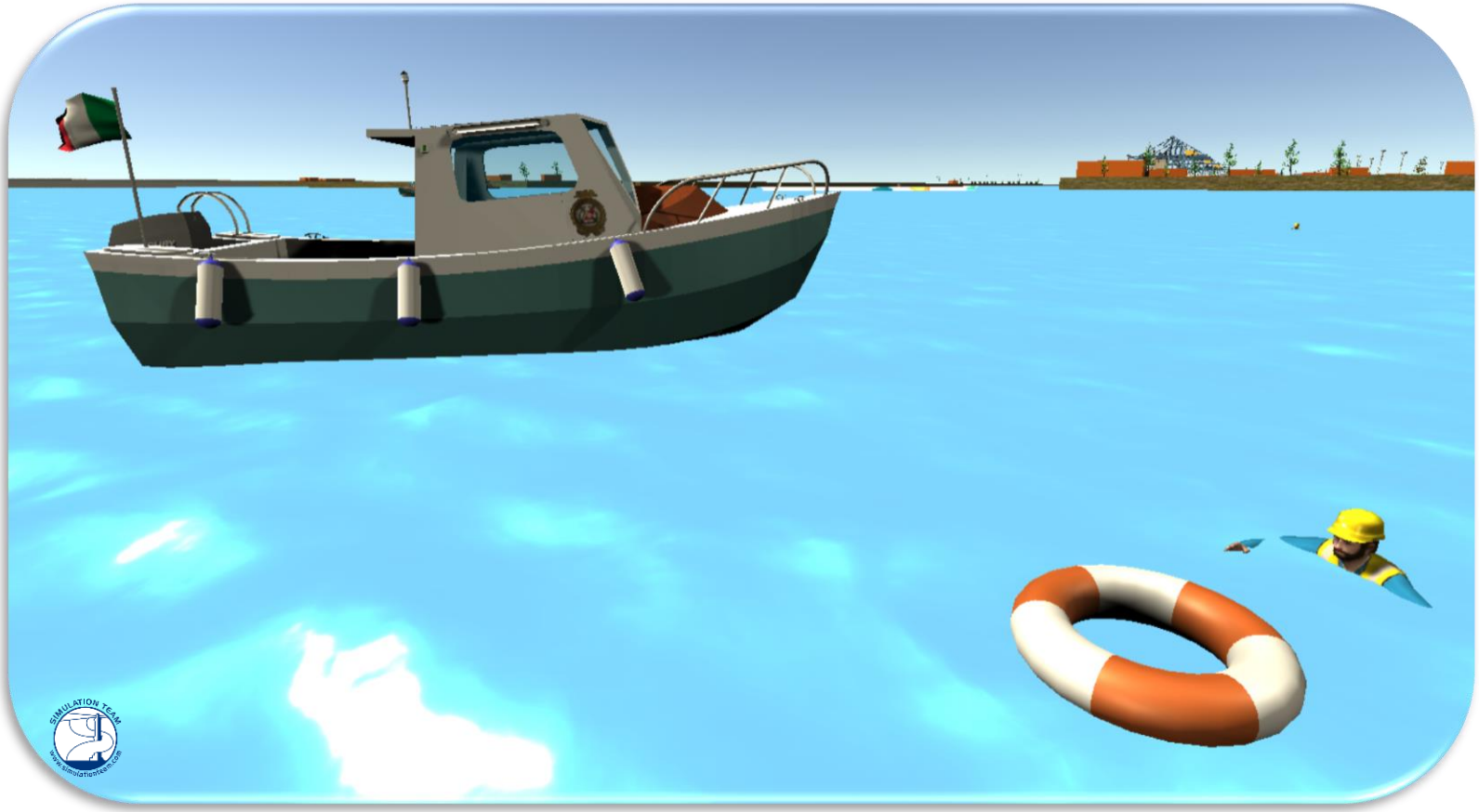
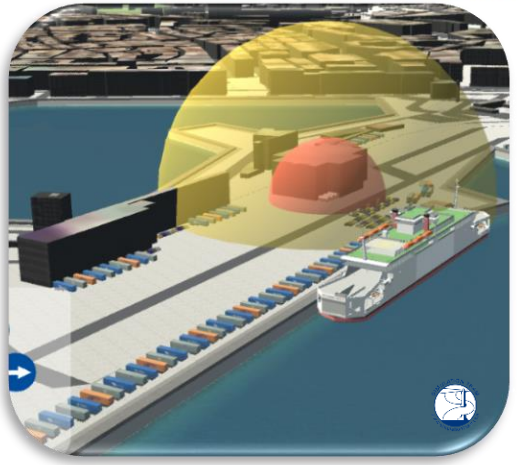
Interoperability



Modeling



Modeling activity means reproduction of a real system. To develop a model is necessary to follow activities which can be summarized:

- **Establish Requirements: the model have requirements such as characteristics or performance**
- **Process Analysis: study of the real system in order to understand variables**
- **Conceptual Model: representation of the real system through variables and mathematical equations**
- **Validation: consistency of the conceptual model is tested**
- **Implementation: the model is implemented through computer systems**
- **Verification: the implemented model is a good representation of real system, and can be used for established purpose**

This is not a *una tantum* activity, but it is a loop that allows to improve the model pregressively

Oil Spills I

The dispersal of substances attributable to hydrocarbons are very important due to their environmental impact and their danger.
Many accidents happens; Deepwater Horizon in 2010 was one of the biggest, and offers a very important example to understand impact at socio-economic level, as well as environmental.

Oil Spills II

Despite big accidents, smaller releases still happens. Causes of oil spills are be many: inefficiencies, malfunctions, releases and, of course, collision between ships. Tanker vessels are the most widely used ocean transport system, with vessels capable of reaching 500,000 tons of crude oil capacity. Tankers represent constant danger to environment.
In ALACRES2 is modeled an oil spill from a tank located on a ship.

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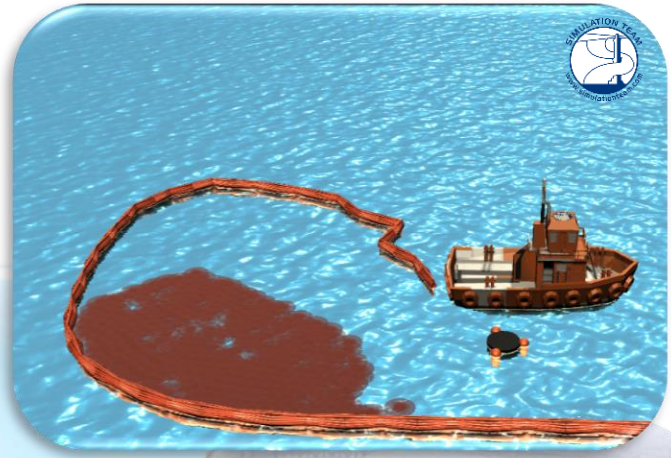
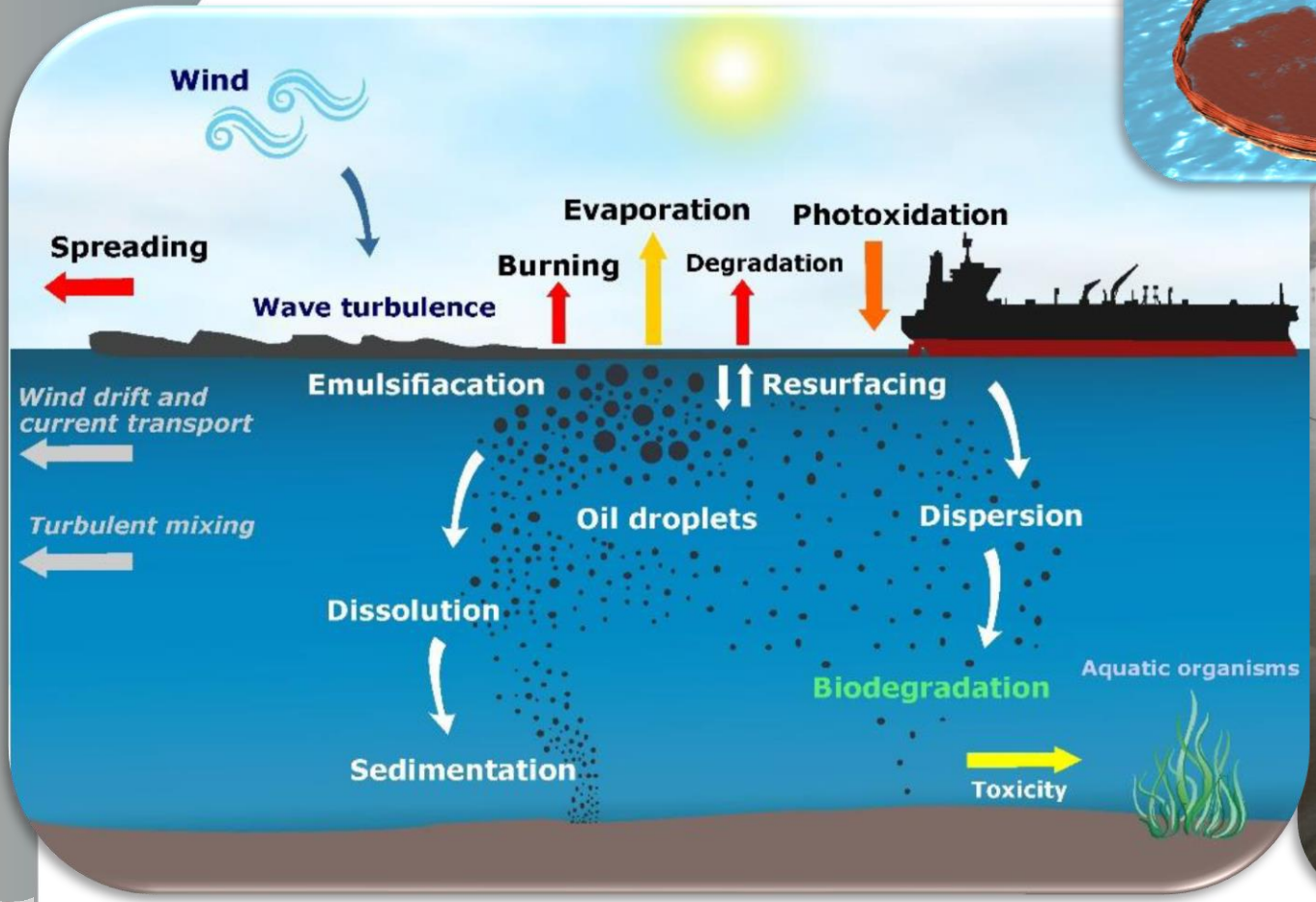
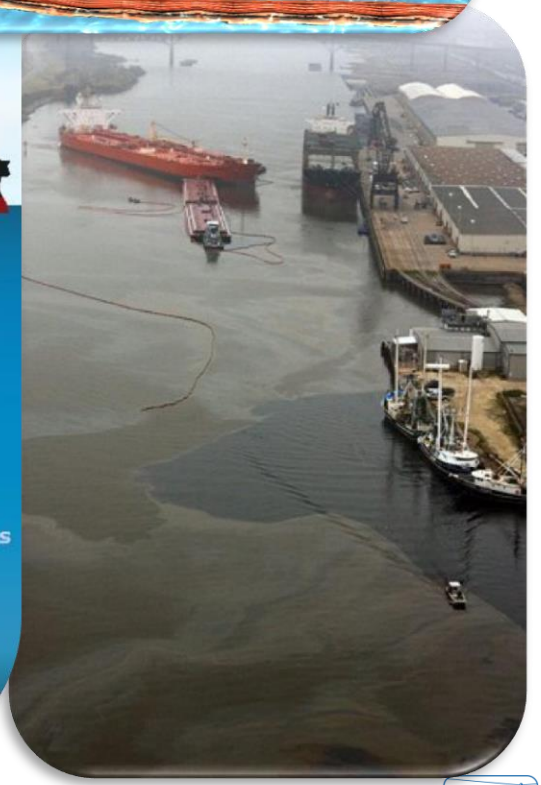
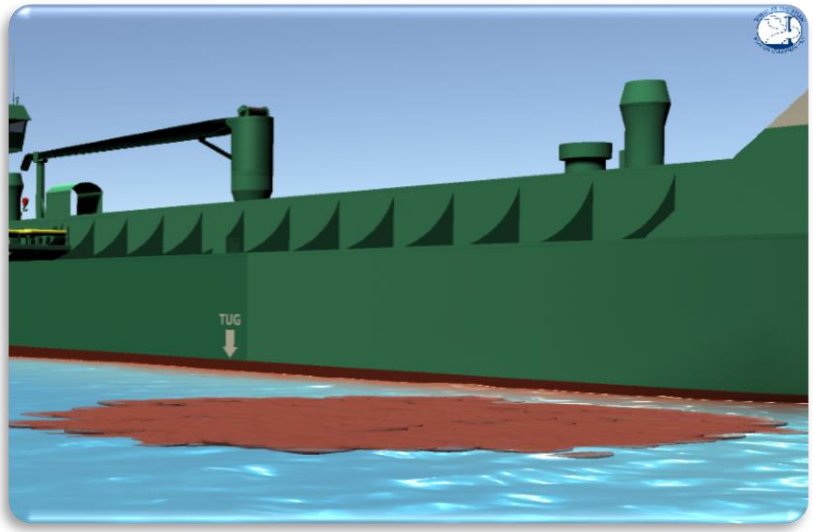
Oil Spills and their Models







Oil Modeling



In literature is possible to find many approaches to model oil fluid:

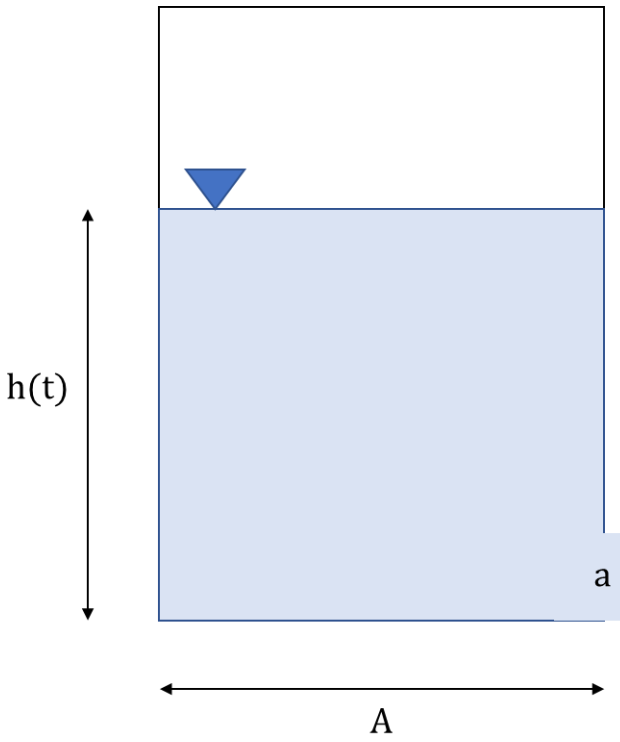
- Eulerian: focus on control volume, function of space and time
- Lagrangian: volume is divided in independent particles
- Mixed: take advantage of both with heuristics methods
- Lattice Boltzmann: flow is divided in microscopic particles which propagate and collide in a mesh

Particular attention is devoted to:

- Interoperability between models
- Integration with other system and input data

The approach to be chosen must assure interoperability, as well as performance and interaction with other models employed in ALACRES2.

Oil Spill Tank Model



$$p + \rho \frac{v^2}{2} + \rho g h = cost$$

$$\begin{cases} \rho g h(t) = p_A + \rho \dfrac{v_A(t)^2}{2} \\ \dfrac{d V(t)}{d t} = v_A(t)\, a \end{cases}$$

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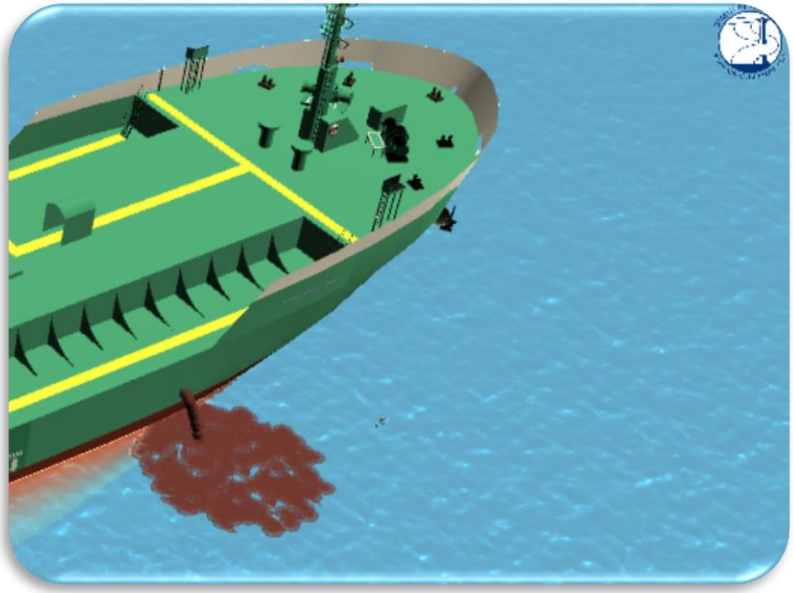
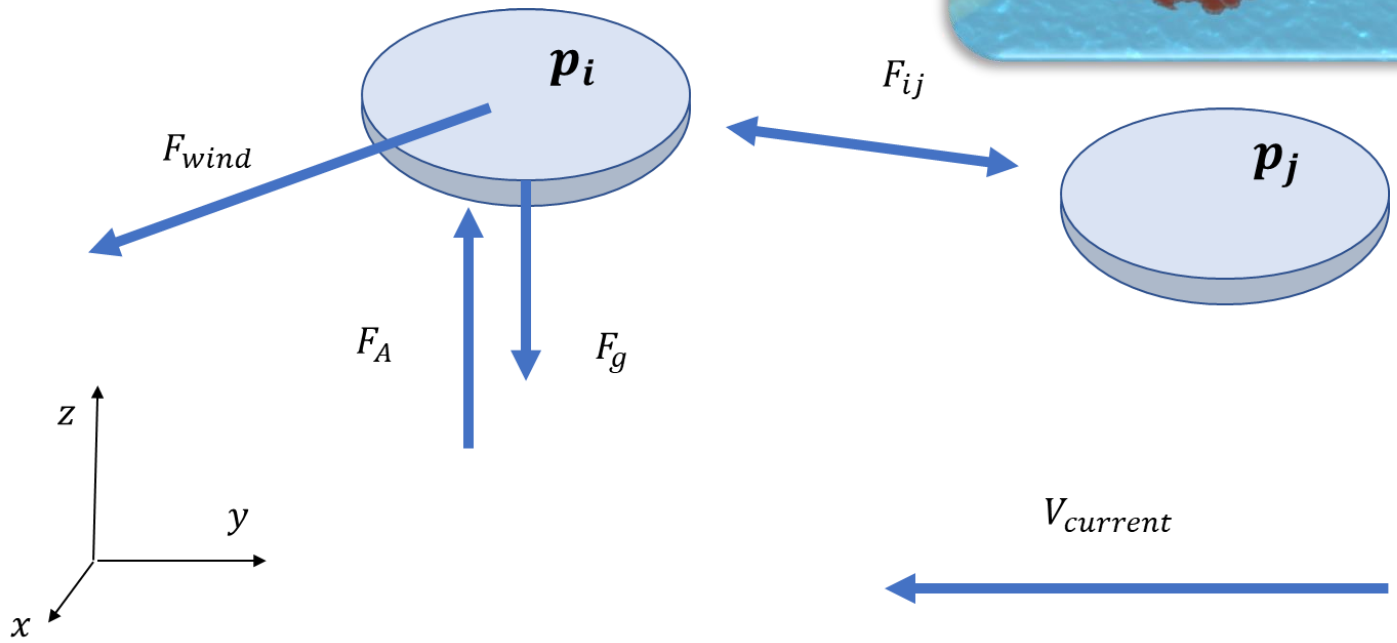
Oil Particle Model





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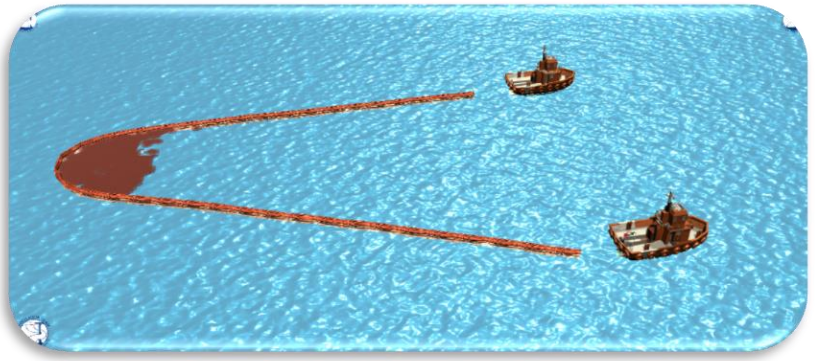
Oil Spill Dynamic Simulation

Recovery Systems



Oil spill must be recovered in the shortest possible time and in the most effective way.
There are mainly
three systems for cleaning the marine surface:

- Skimming: collection of oil with skimmers
- Burning: oil is burned in-situ
- Chemical Dispersant: oil is broken in droplets by chemical agents

Each of these systems has its own advantage, however it should be selected carefully considering the situation and operational conditions.
The model explained will consider collection operation with skimmers helped by boom.

Oil Boom I

Containment Boom is a floating barrier which is installed to contain surface pollutants through mechanical action.
The barrier is composed by several modules linked to each other; can differ in size, material and it is suitable for different zones, thanks to its versatility. The barrier can be fixed or movable; in this last case two vessels may drag and steer it.

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Oil Boom II

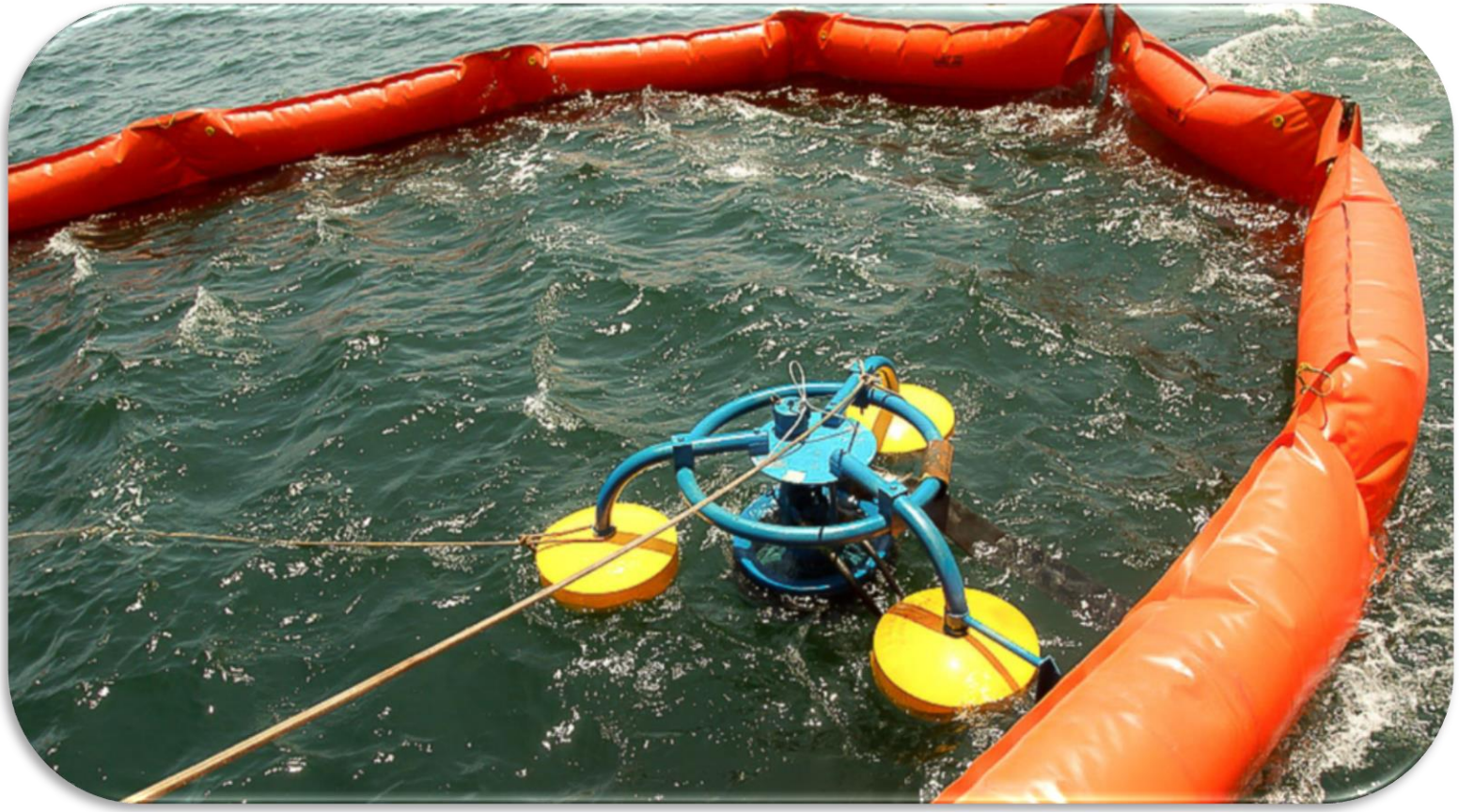
When is dragged by two vessels, the first carries the boom until it needs to be put in place at the desired location.

Coordination between two or more vessels is crucial to constraint the oil within limited and smaller area; otherwise it is now possible to collect the pollutant with skimmers.

The model developed considers the following operational phases:

- Installation of the barrier
- Drag and steering of the barrier to target zone
- Containment and collection of material

Skimmer



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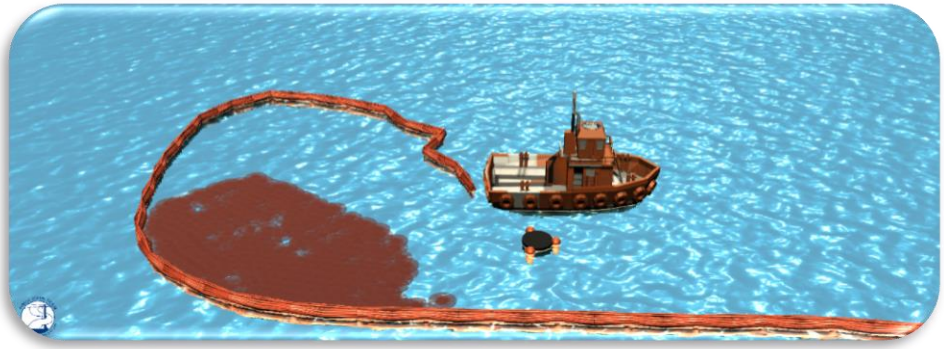
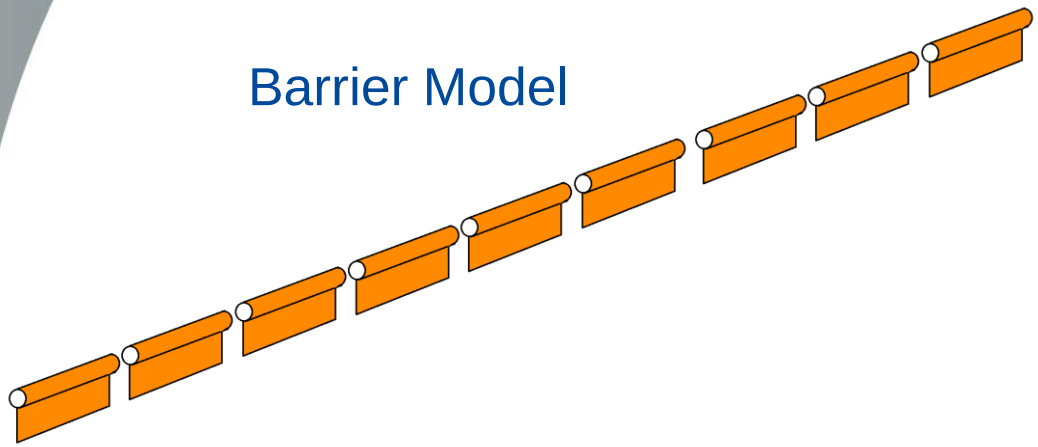
Recovery Model

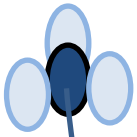


Barrier Model



Tug Boat Model

Tug Boat Model



Skimmer Model

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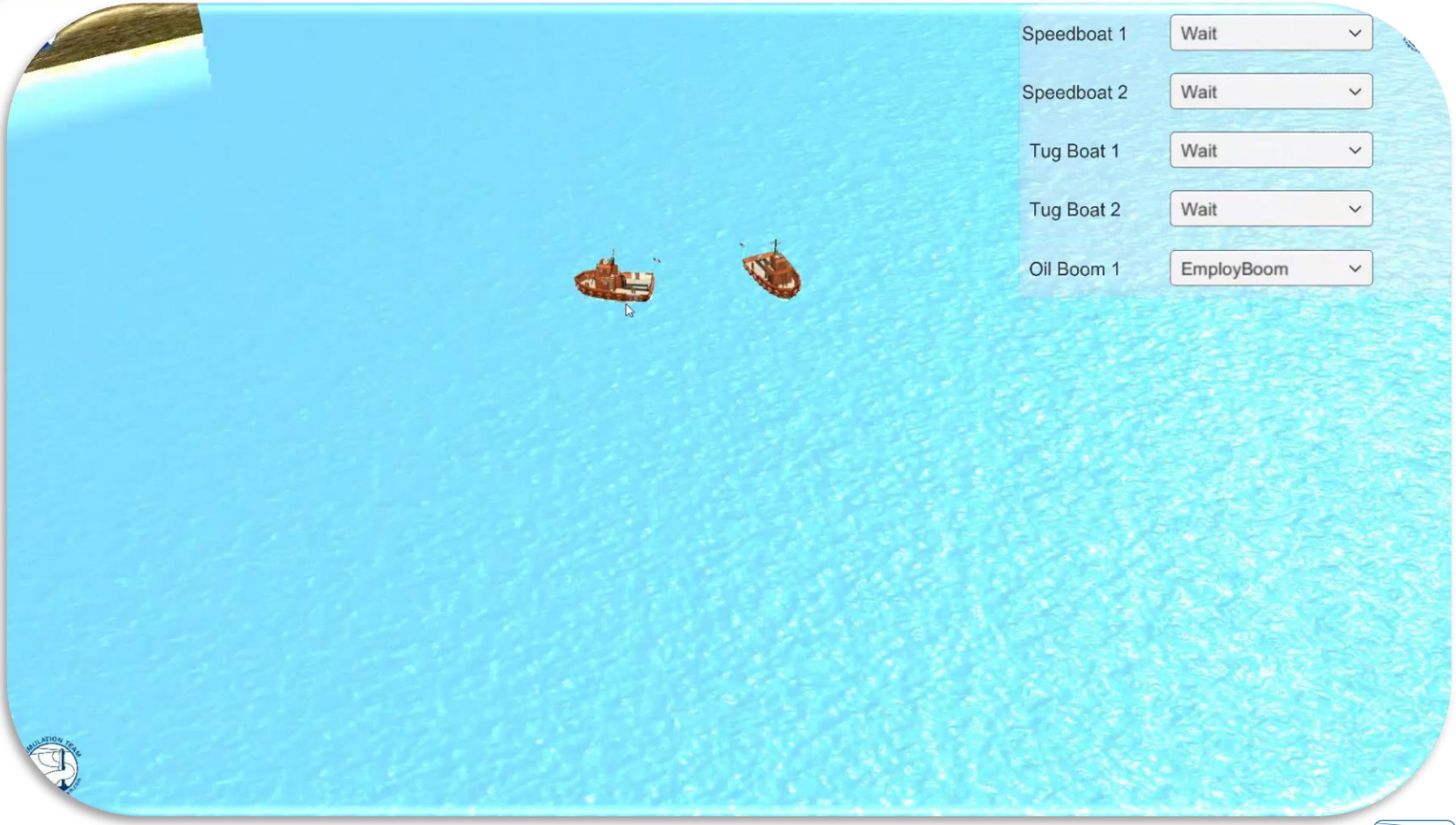
Boom Simulation



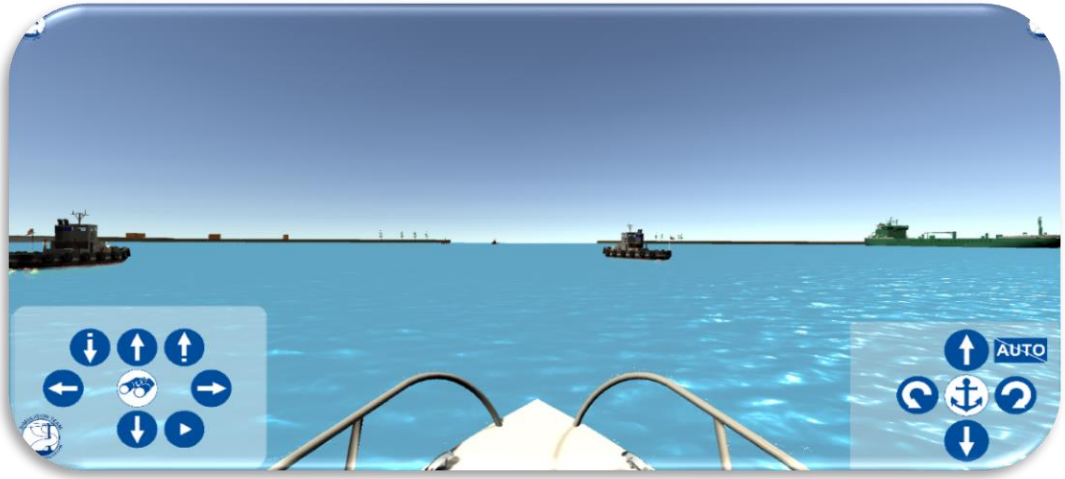
Navigation in Ports

Within port areas there are predefined procedures and rules about the navigation that ships and boats must follow in order to avoid accidents.

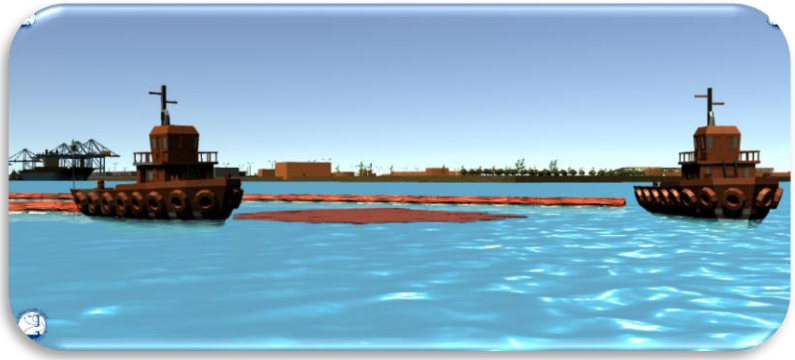
This behavior must be recreated within the simulation so that the global behavior can be recreated.

In an applied way, this behavior must be recreated effectively, so that it can be managed in a manner consistent with the decisions of the decision maker.

The category of problems to be solved pass through path finding, precedence and obstacle avoidance.

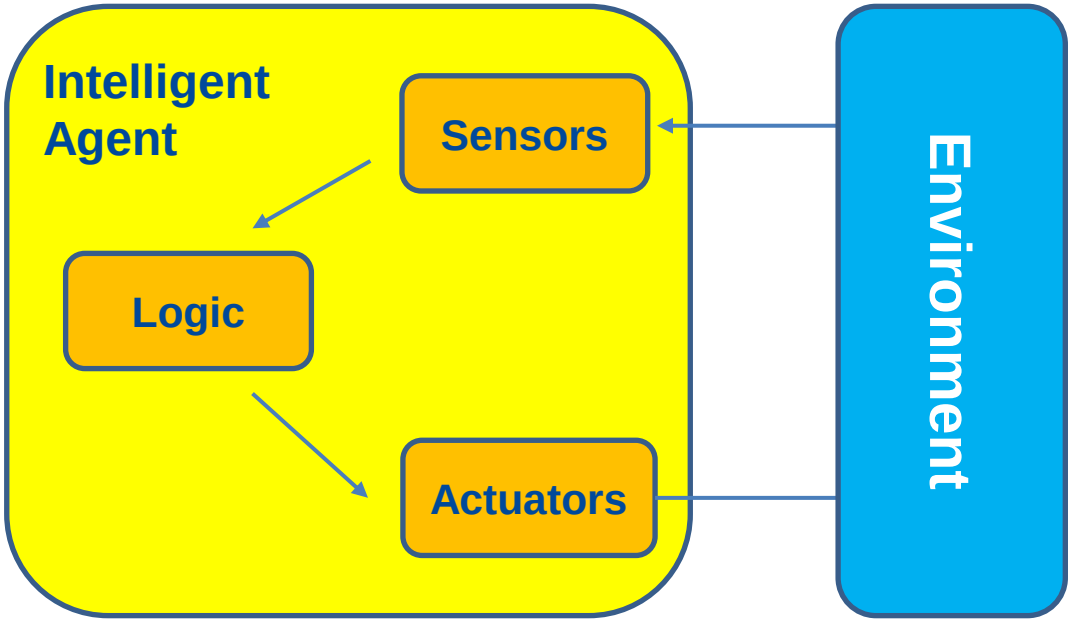


Intelligent Agents



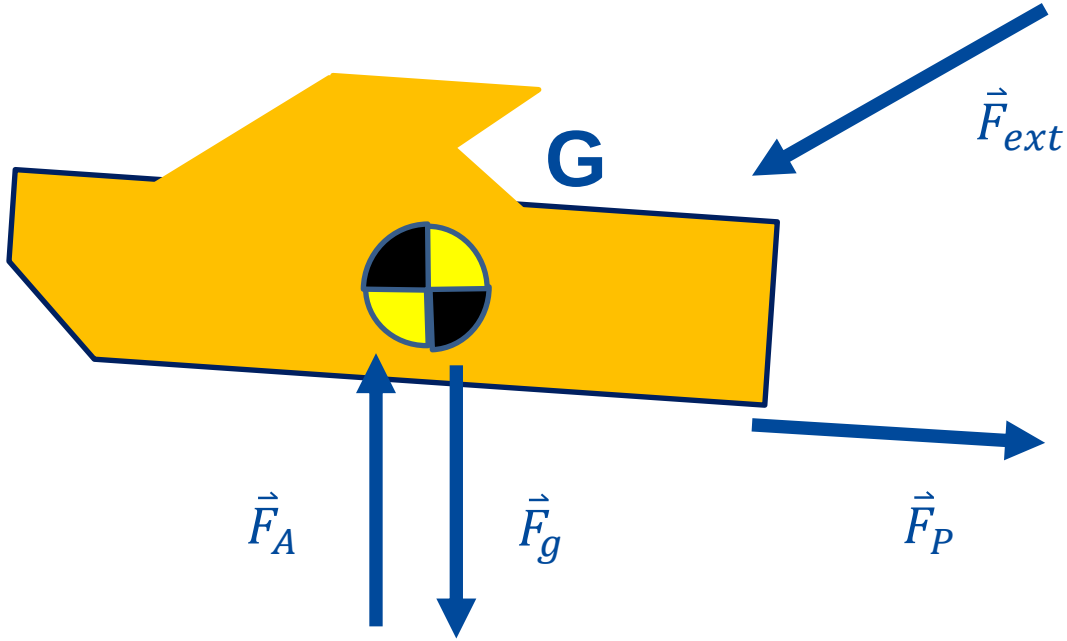
Artificial Intelligence offers innovative solutions to address problems in complex Systems reproducing decisions, actions and reactions

ALACRES2 is based on a discrete event stochastic agent driven simulation.
Indeed, in this computer simulation, Intelligent Agents are used to create Autonomous Agents, in order to act, react and execute orders even without requiring men in the loop



Ship Model & Buoyancy

Ship model is constituted by two logical parts; one is the physical module, the second is related to intelligence.
Physical module is responsible for movement and interaction by surrounding environment.



$$\begin{cases} F = m\,a \\ M = I\,\alpha \end{cases}$$

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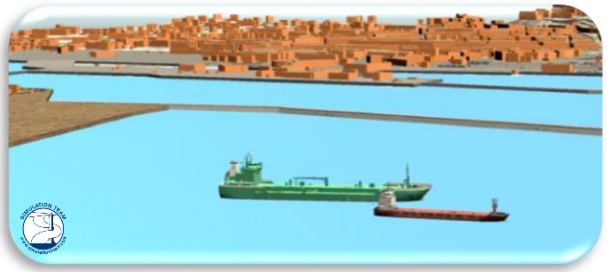
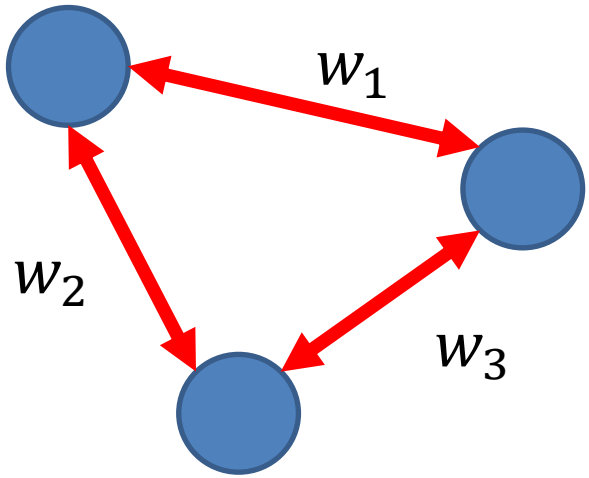
Path Finding: A*

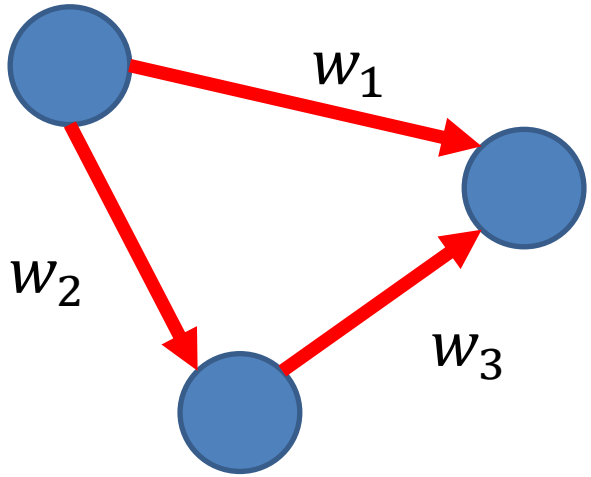


A* is a well known algorithm that can be used effectively for path finding. A* uses oriented graph, and it is variation of Dijkstra algorithm.

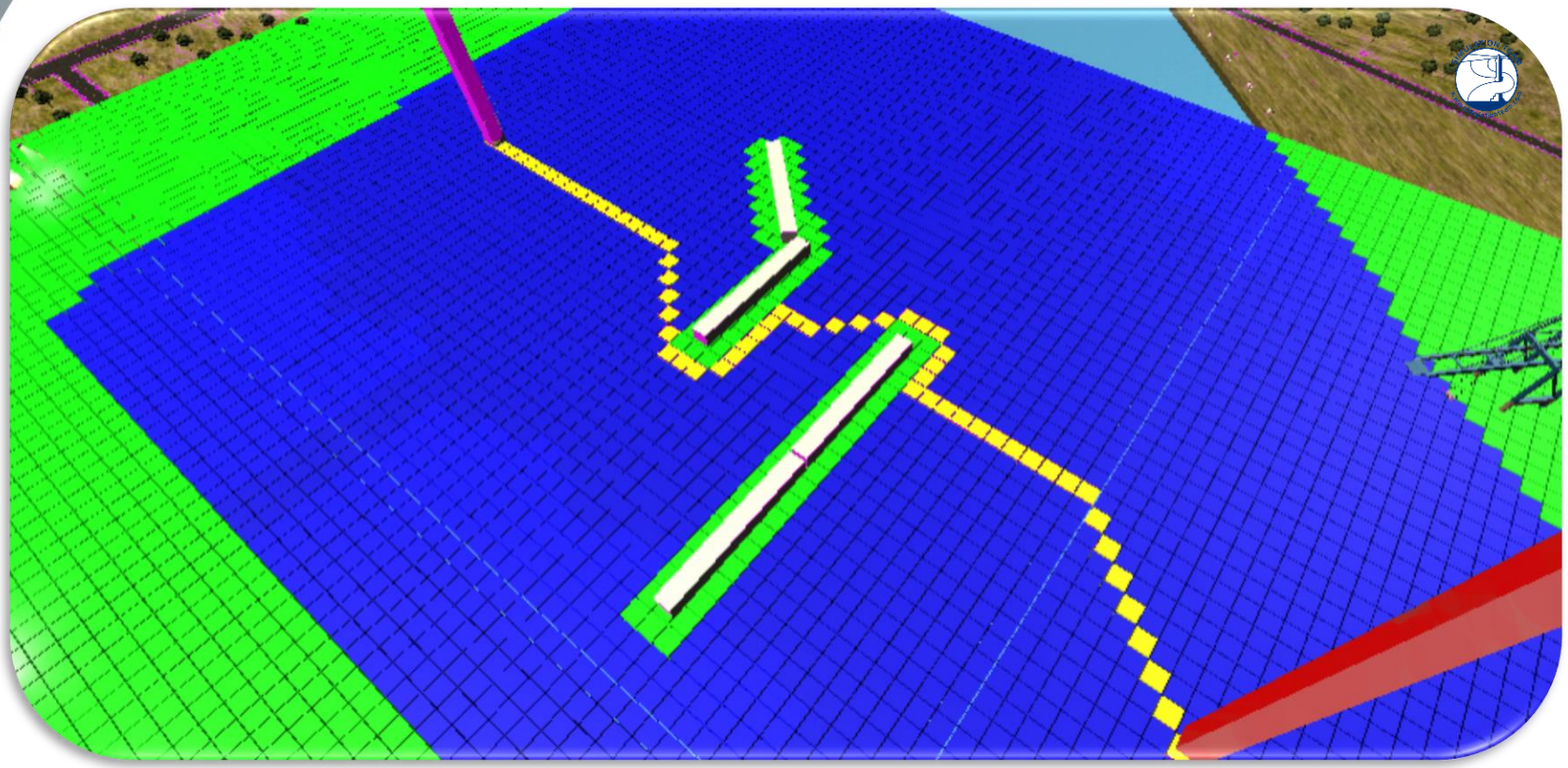
- **Weighted Graph; divided in nodes with associated weights.**
- **Objective function:** $f(n) = g(n) + h(n)$

  where: g cost of the path to node n, h is heuristic cost and f cost to minimize





Path Finding



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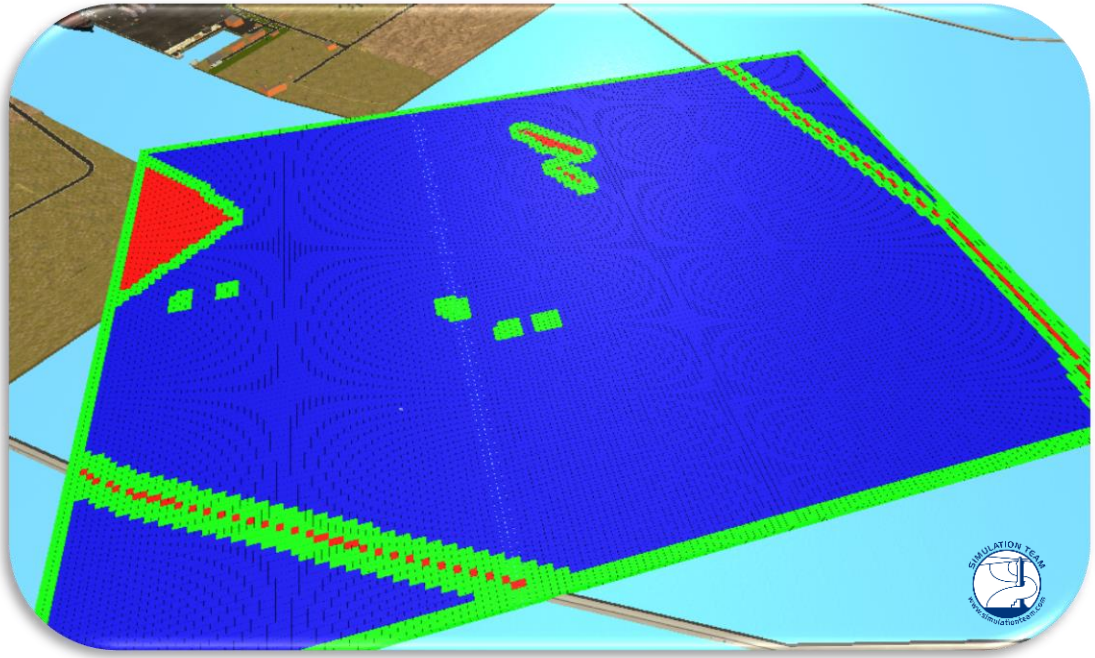
Oriented Graph Creation

An Oriented Graph was built on 3D Map of the Port based on layout processing. Different Nodes where selected, in order to made available the nodes/arcs and arcs not connected to main map (such as obstacles). Weighed graph also allowed to recreate speed rules in ports, based on the port zone considered.

Each agent, once that target is known, is able to find a feasible path; then it follows the arcs up to reaching the final destination.



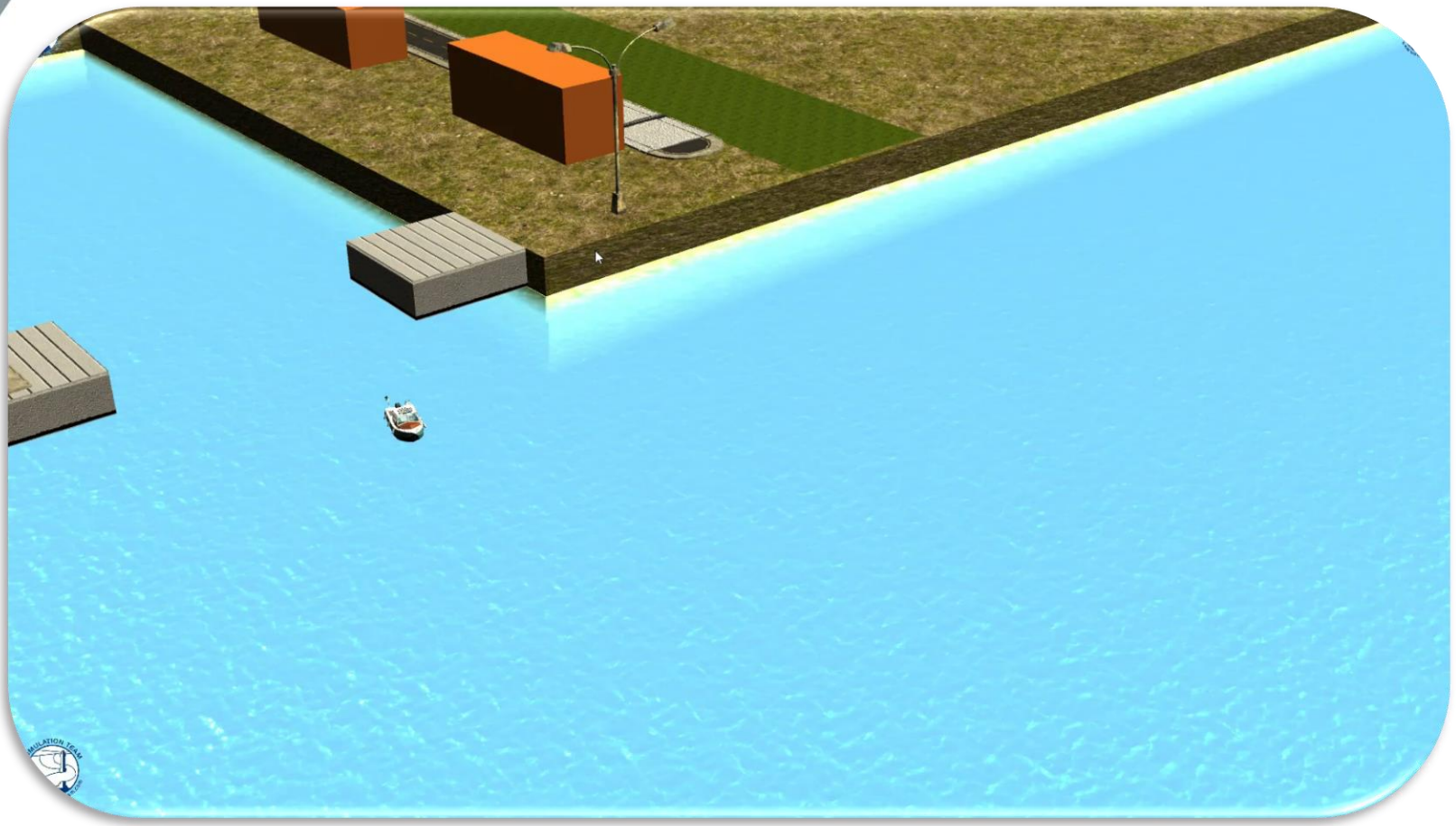
Obstacle Avoidance

Static obstacles not represents difficult problem for ships; the obstacle can be mapped and excluded from research space (oriented graph). Thus, if a journey is long, the path may be recalculated several times.

Instead, moving objects such as ships can collide when overlapping paths. This problem has many variables, such as position, velocity, time and size of the autonomous agents involved.

Each ship has an object detection system, by which they can check if there are colliding ships and eventually stop or change trajectory.

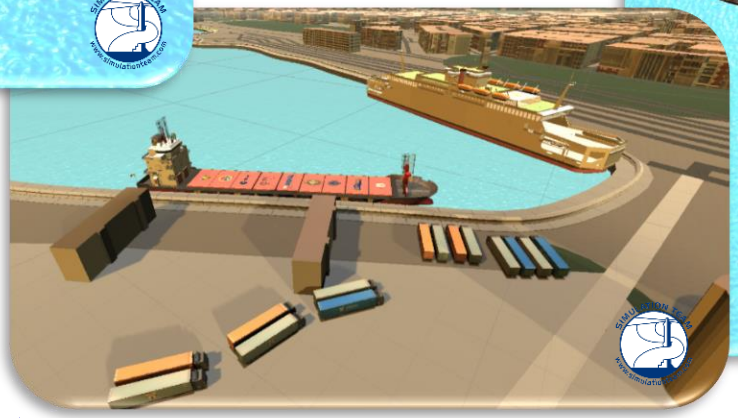
Navigation Video

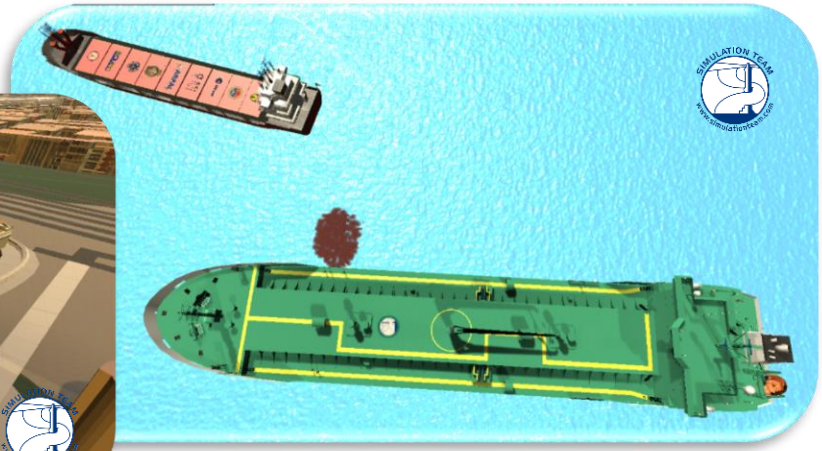


Conclusions

Presented Models allowed to recreate real systems, satisfying the requirements and achieve the project Goals.
The Modeling Activity is a continuous process and improvements and updates are always possible to address new Uses and Objectives.

Thank You for the Attention !!!!





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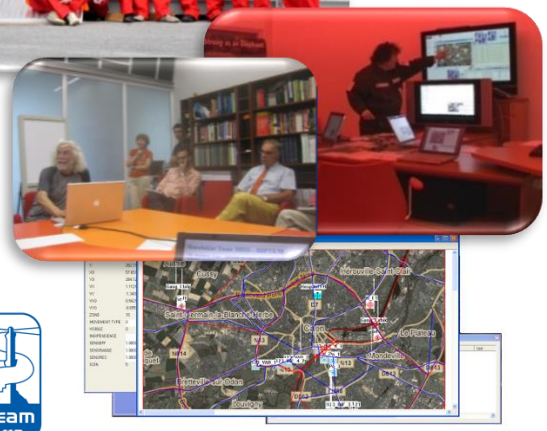
References



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