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A practical approach to risk-based gas monitoring system design for oil and gas offshore platforms

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  - Reference platform design and location
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Introduction

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OBJECTIVE

- The development of practical but rigorous approaches for the **design of a risk-based gas monitoring system for offshore oil and gas platforms**, able to **provide early warnings of gas leakage** to anticipate the occurrence or the escalation of hazardous events

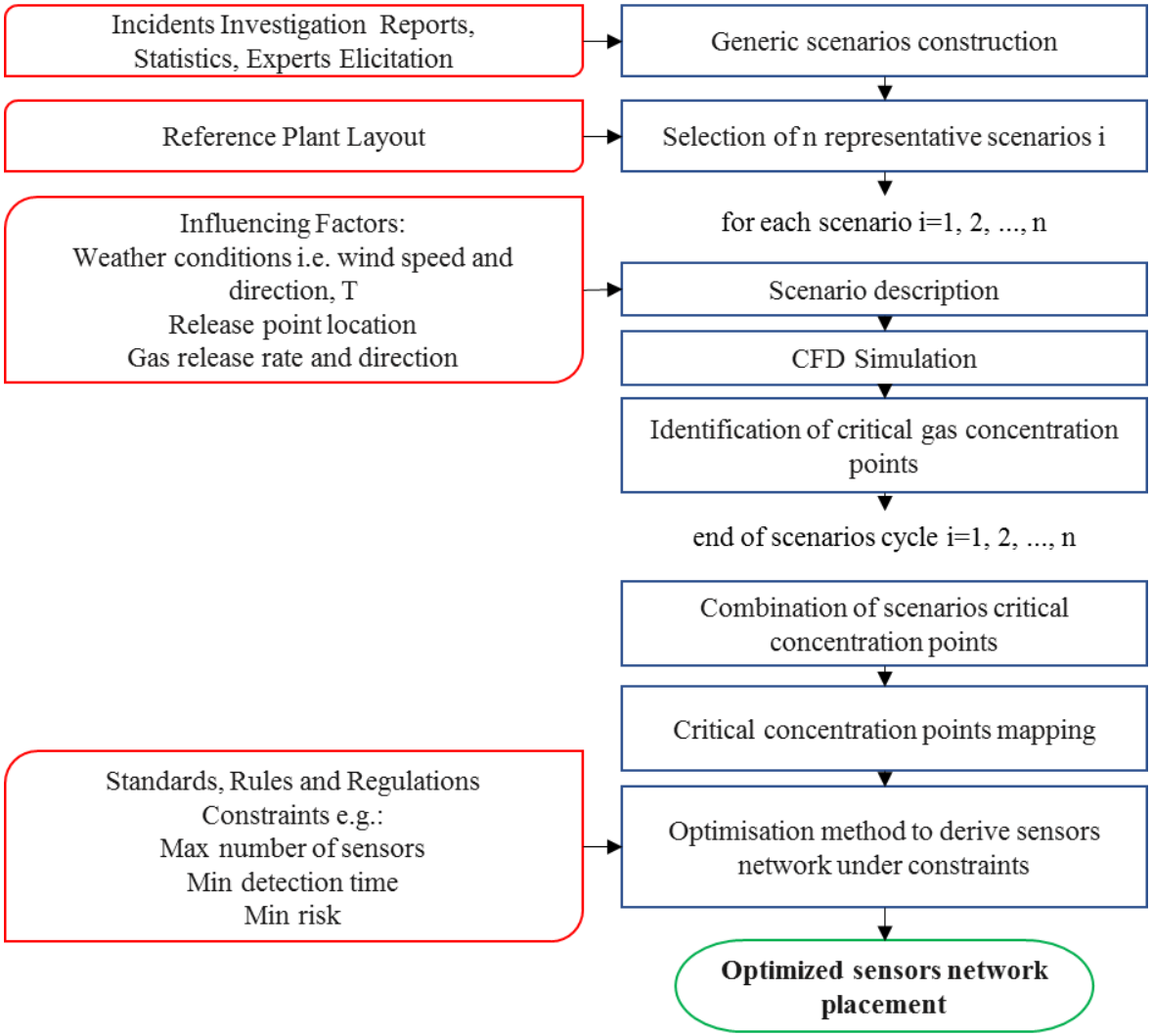
RATIONALE

- The **appropriate placement of sensors** within a specified platform geometry: key factor to **ensure a proper detection of leakages**
- The **methods** most commonly employed for designing network of sensors: **based on heuristic techniques** often not providing an optimized design of the overall monitoring system

EXPECTED RESULT

- A pragmatic approach based on **modelling and mathematical formulations** permitting an **optimized and efficient placement of the sensors** in terms of health and safety, costs and compliance

Methodological Approach Framework



Methodological Approach

Details on the following tasks:

- Reference platform design and location definition
- Scenarios numerical simulation method
- Scenarios construction and selection approach
- Influencing factors on propagation of released gas
- Hints on optimization of sensors placement

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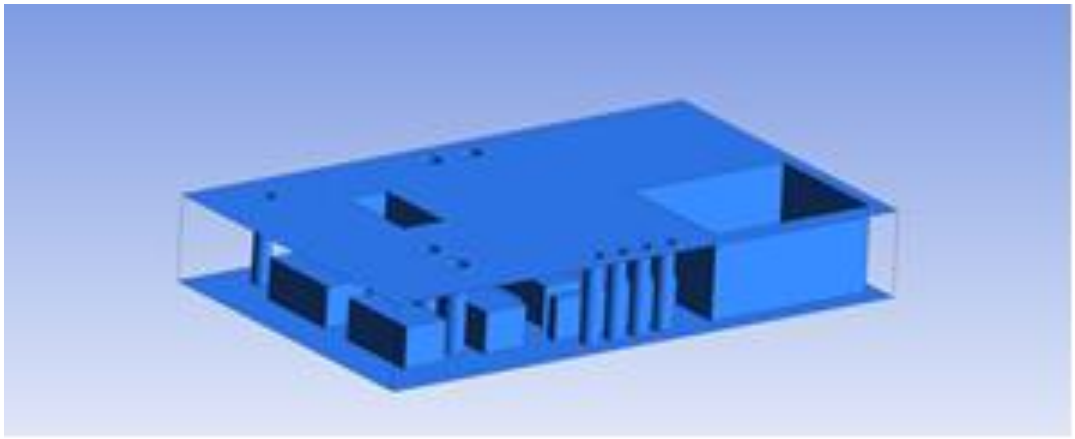
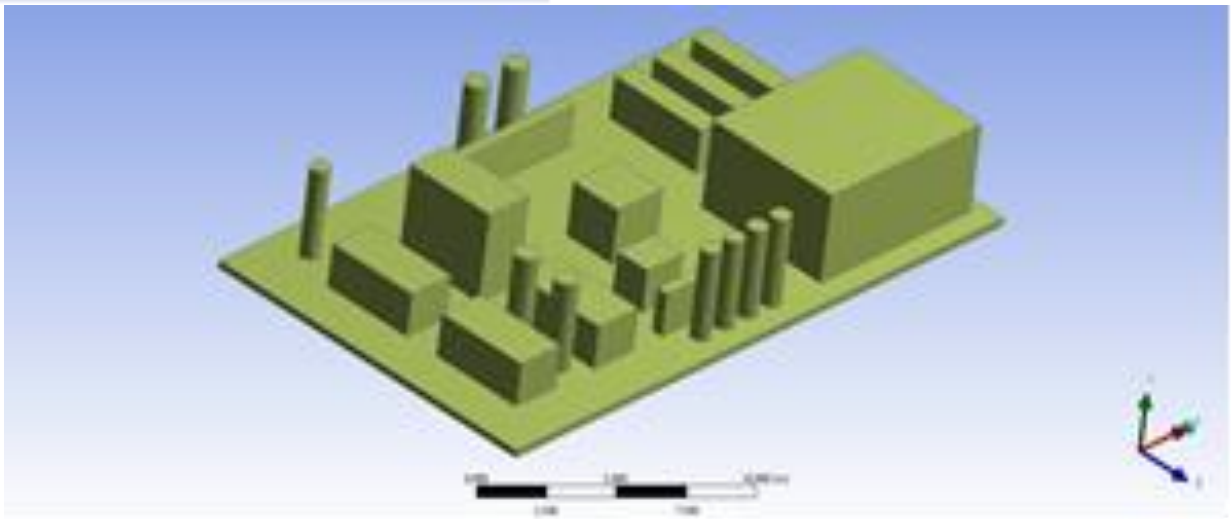
Methodological Approach
Reference platform design and location



Representative platform deck for CFD simulations (with and without ceiling)

Typical location for simulations: central area of the Adriatic Sea (East Italy)



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Methodological Approach
Scenarios numerical simulation

- A **hybrid CFD model** proposed to deal with the fluid dynamic problem of **supersonic releases** combined with subsequent **dispersion**
- Two steps approach involving:
  - **parametrization the release phase** (supersonic), i.e. single phenomenon evolving within a geometric domain defined starting from the release dynamic characteristics. Creation of **catalogue of "source boxes",** also hosting obstacles
  - **CFD simulation of the dispersion phase t**hat starting from the gas molar profile and the flow field results calculated on the surface of the source box, is carried out in a domain that is large enough to include the whole remaining deck/platform

Methodological Approach
Scenarios numerical simulation

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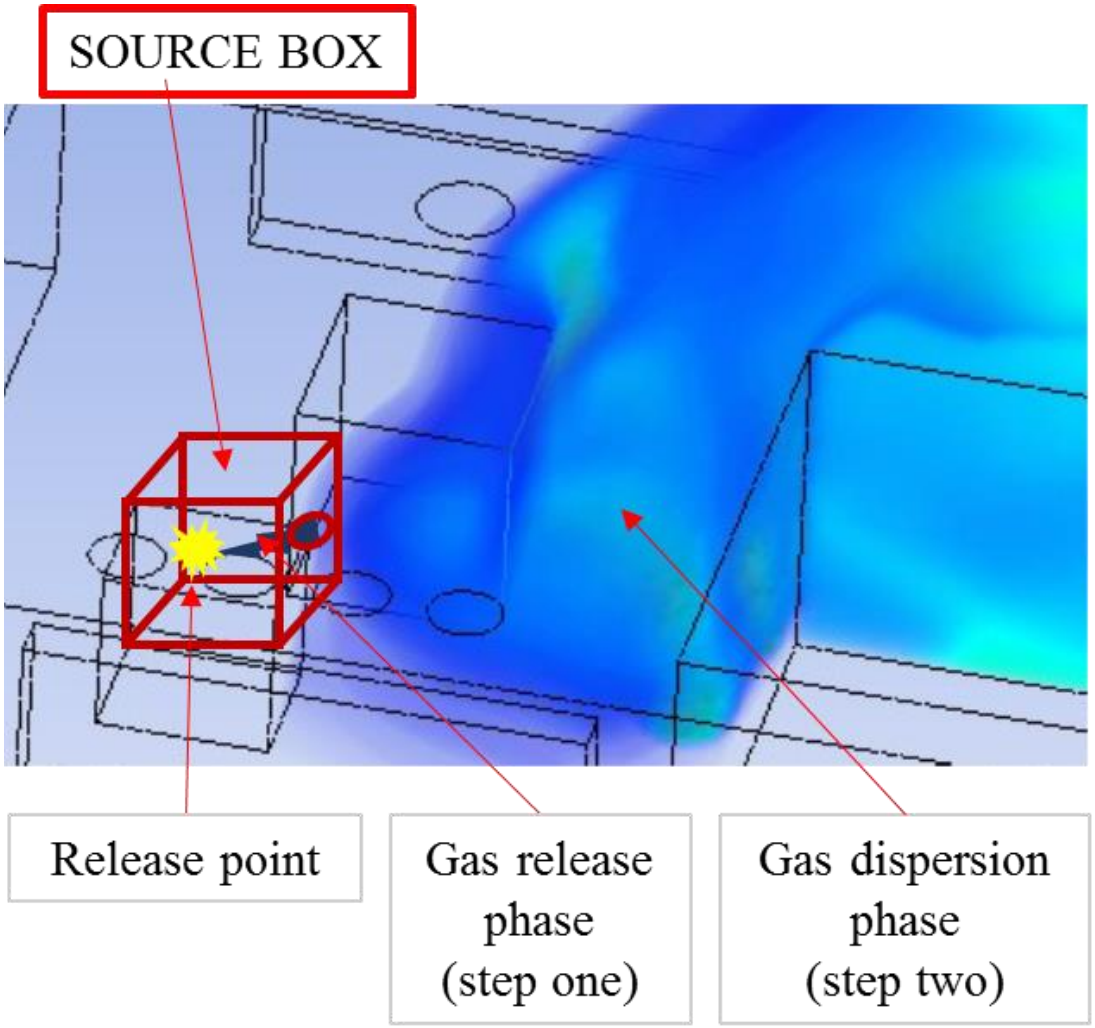

Illustration of hybrid CFD model: two steps simulation

Methodological Approach
Scenarios construction

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- Based on Sklet [1] classification and OGP Risk Assessment Data, identification of **initiating events** producing a comprehensive set of release scenarios:
  - latent failure introduced during maintenance,
  - maintenance of hydrocarbon system requiring disassembling
  - technical/physical failures
  - process upsets
- Starting from the selected initiating events, definition of an **initial generic list of potential release events**
- Use of Monte Carlo method to **generate individual scenario** input data for numerical simulation

[1] Sklet, S. Hydrocarbon releases on oil and gas production platforms: Release scenarios and safety barriers. Journal of Loss Prevention in the Process Industries, Volume 19, Issue 5, pp. 481-493. https://doi.org/10.1016/j.jlp.2005.12.003, (2006)

Methodological Approach
Representative scenarios selection

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General criteria for the construction of the **space of scenarios**:

- at least one scenario per relevant potential release event to be selected;
- release events with higher frequency of occurrence covered by a greater number of scenarios;
- events located in areas where the influence of the external factors (e.g. wind direction, speed, T) is high, to be covered by a greater number of scenarios.

The **plant-related scenarios** built by considering the following:

1. selection of **realistic events** from the set of generic release events;
2. identification of the **most probable locations** for release occurrence;
3. **map** of the selected **points of release**

Methodological Approach
Influencing factors

- **Weather conditions**, i.e. atmospheric temperature and wind direction and intensity
- **Gas flow rate and direction**, considering:
  - **low to high pressure fluids** on a production deck. Assumptions to evaluate flow rates and dispersion patterns:
    - A range of release pressures, varying from 5 to 100 bars,
    - A set of rupture diameters, as standardized for risk analysis 1mm to 100mm.
  - **direction of the release**. Horizontal and vertical upward or downward directions chosen as the extreme most representative cases.

Methodological Approach
Scenarios construction

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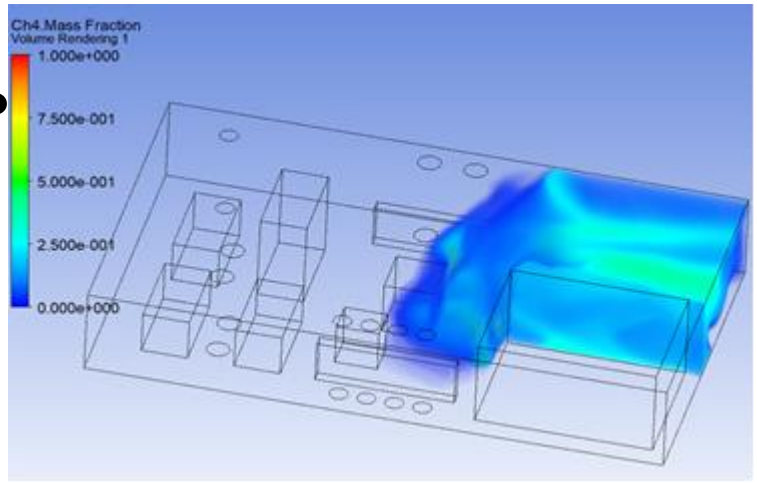
Example of scenario characterization for numerical simulation

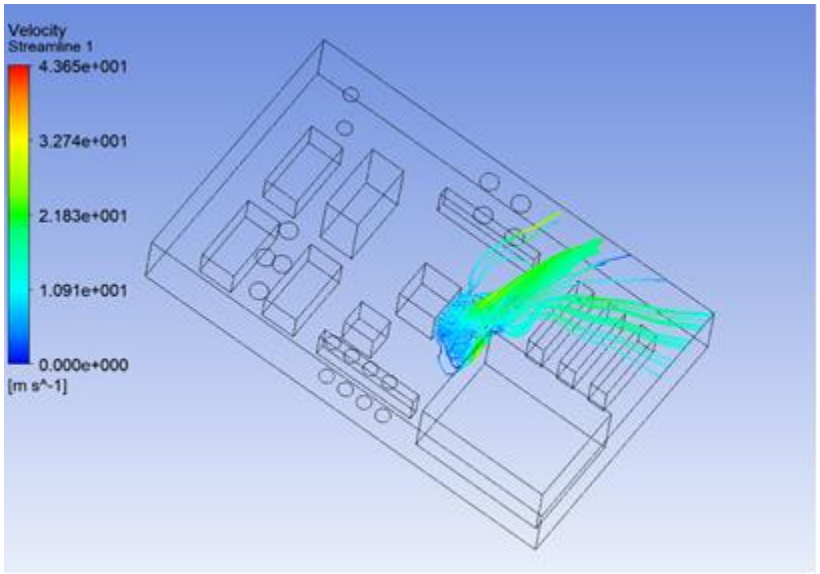
Scenario # i	
Initiating event	"Degradation of valve sealing (release event)"
Release Point Location	Equipment in the central area of the deck
Gas Composition	100% CH_4
Pressure Release[1]	50 bars
Rupture Diameter[1]	30 mm
Release Direction[1]	Horizontal
Wind speed (at 25 m above sea level)[1]	6 m/s
Wind Direction[1]	North
Temperature (on the deck)[1]	28°C
Note[1]: each of these factors have been randomly selected according to the criteria set above	

Methodological Approach
Example of Design Specific CFD Results



CH4 Concentration Field

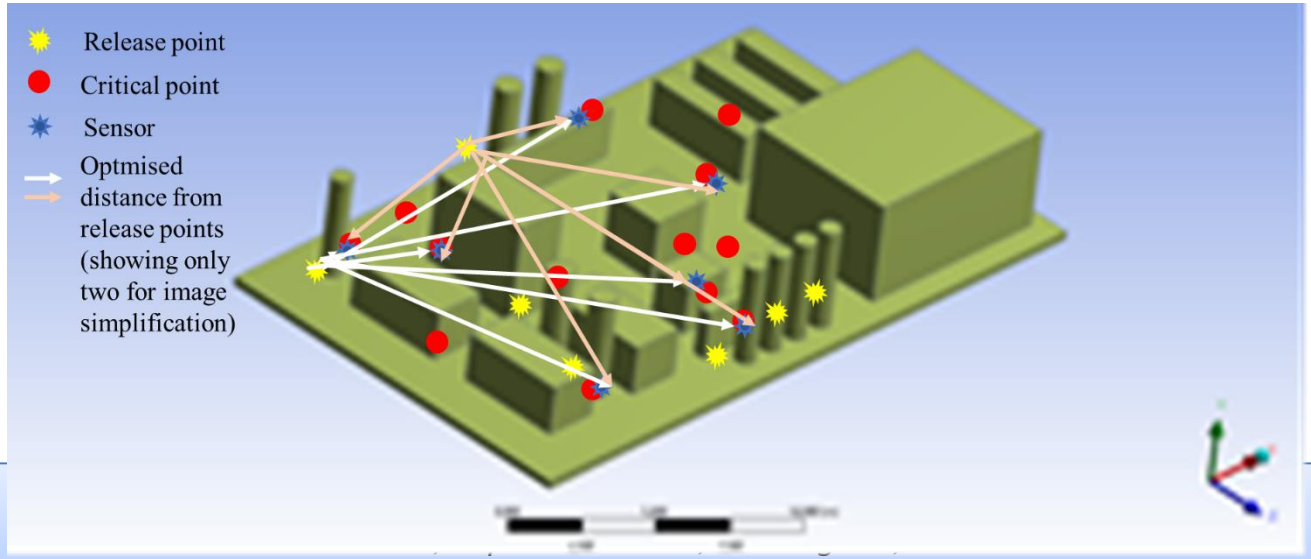
CH4 Velocity Field



Methodological Approach
Optimization methods for sensors placement

After **mapping the critical gas concentration points**/areas for each scenario considered, development of an **optimization formulation for gas detectors placement** by minimizing, e.g. the expected detection time over all scenarios, the maximum number of sensors, the risk or others

Exemplified representation of an optimized network of sensors



Conclusions

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- A **risk-based process for the design of an optimized network of gas sensors** for an oil and gas offshore platforms presented
- The process **combines a set of methods and practices** currently or in future use by the industry
- The process main **composing blocks**:
  - A method to build a **comprehensive set of gas release scenarios**
  - A **hybrid approach employing CFD methods** for gas release and dispersion simulation
  - An **optimization method** to facilitate the design of a gas sensors network
- The **implementation** of the process is underway **with an engineering mindset**
- The approach should contribute to the **enhancement of the design practices of gas sensors networks** i.e. pragmatic method complying with regulations, if the numerical burden could be accommodated during the design phase of a commercial O&G platform