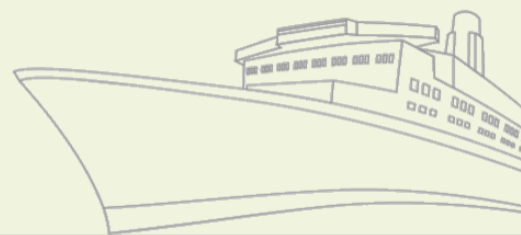




Trustworthy Autonomous Collision Avoidance Decision-Making System for Maritime Autonomous Surface Ships

Key Characteristics

- Shipping 4.0; Autonomous Maritime Transportation; Maritime Autonomous Surface Ships (MASS)
 - Autonomous Collision Avoidance Decision-Making System (ACA-DMS)
 - Artificial Intelligence; Digital Twin
- Collision Accidents; Net Zero Safety; Trustworthiness
 - Critical Internal & External Risk Metrics



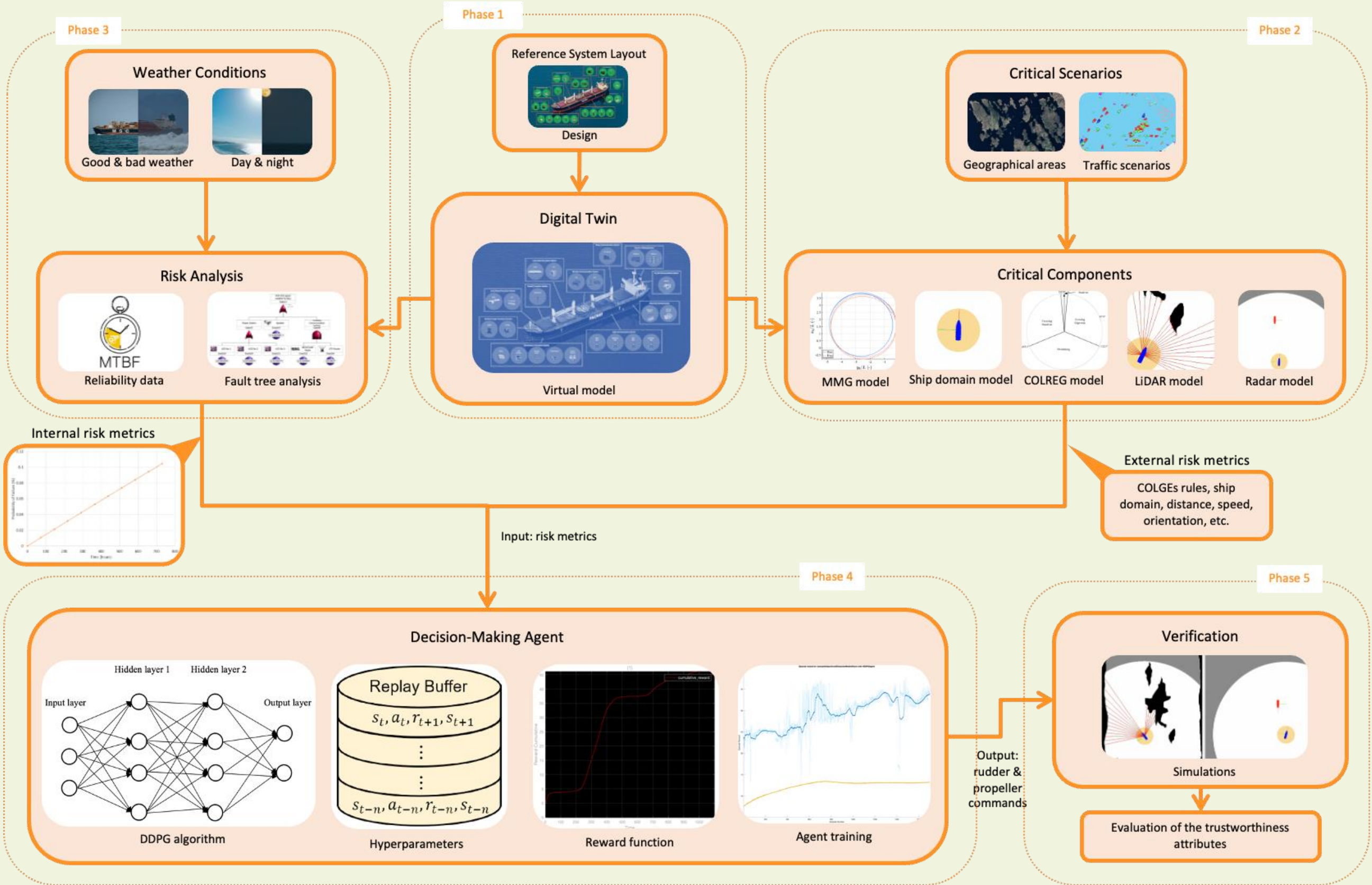
Motivation & Objectives

“Shipping 4.0” through the implementation of MASS is an inevitable reality. However, before the full-scale adoption of MASS their trustworthiness must be verified and validated. One of the biggest challenges that the MASS are called to tackle is the ever-critical collision avoidance problem, which currently is the leading accident category according to conventional maritime accident reports.

The aim of this idea is to develop a trustworthy ACA-DMS that executes the mission-critical autonomous operation of collision avoidance. The objectives are: a) develop a digital twin of a concept MASS to investigate the trustworthiness in a virtual environment; b) identify potential collision scenarios of high-risk; c) develop models that can adequately generate critical external risk metrics; d) analyse the risk associated with the digital twin to generate critical internal risk metrics; e) develop an intelligent agent that is capable of making collision avoidance decisions autonomously without human interference; f) evaluate the trustworthiness of the developed agent when both critical external and internal risk metrics are considered in the decision-making process.

Methodology

The proposed methodology consists of the following 5 phases:



Results

Functionality of ACA-DMS

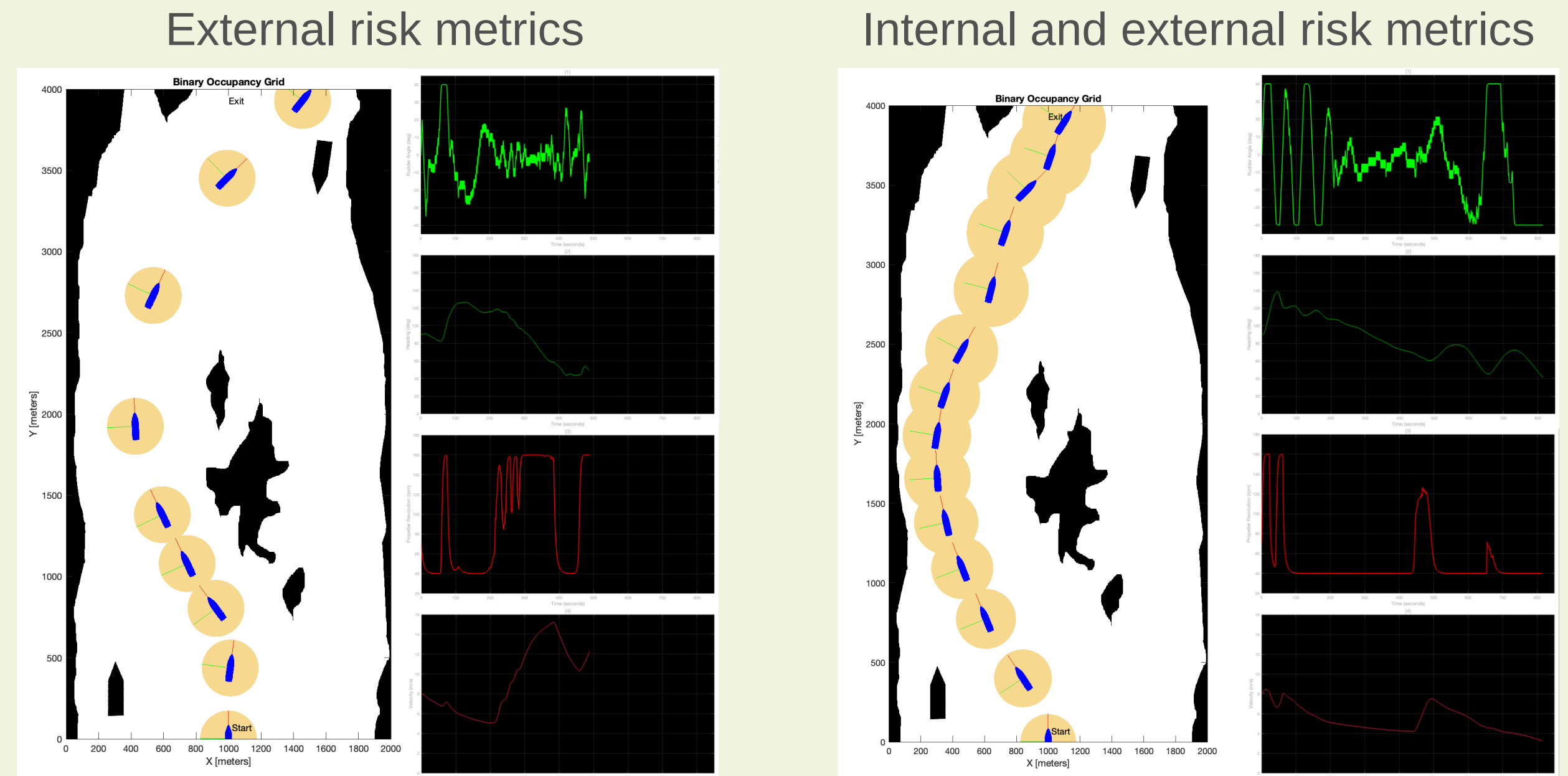


Figure 1. The trained agent is able to generate the appropriate rudder angle and propeller revolution command considering external risk metrics.

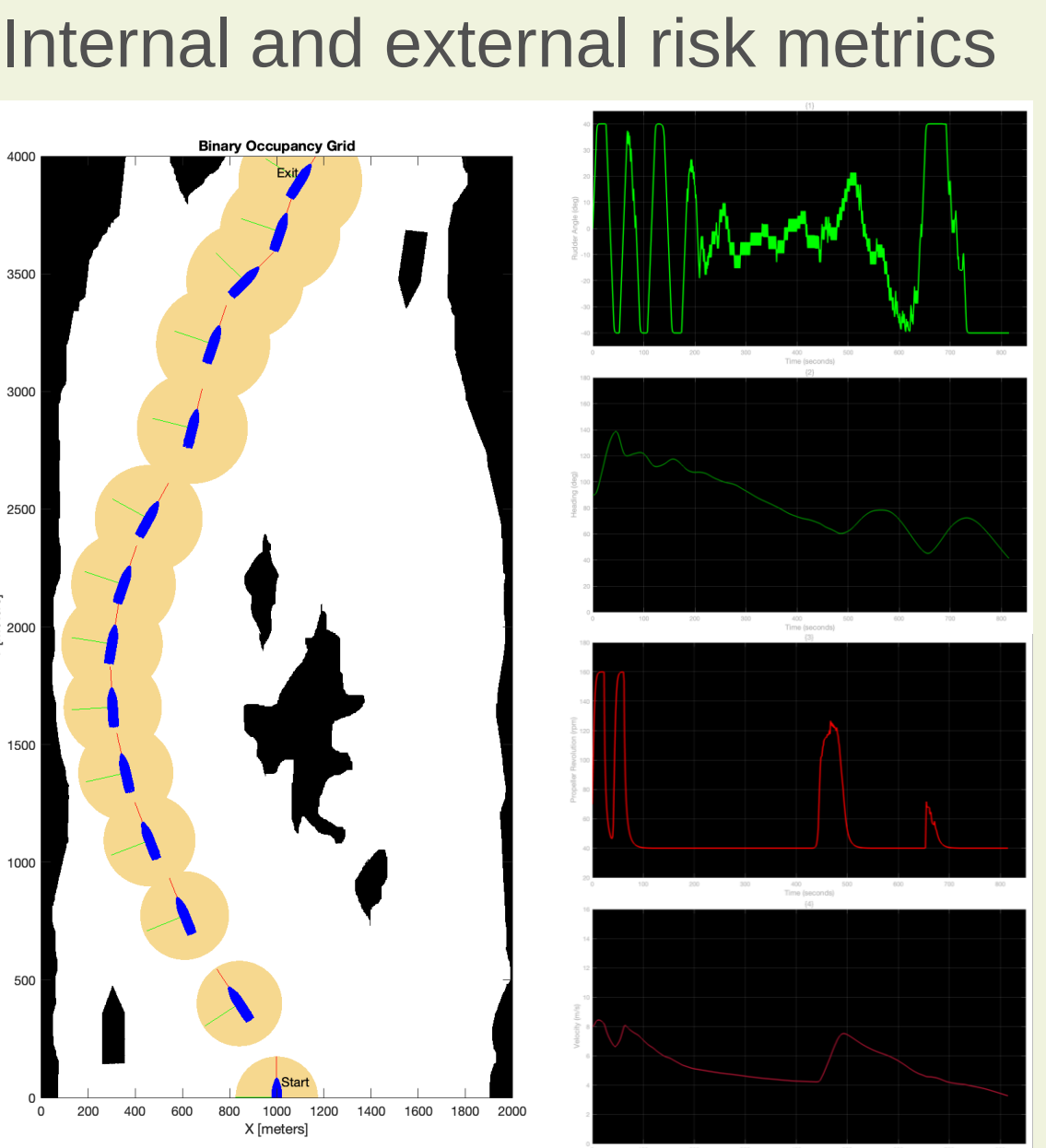


Figure 2. The trained agent is able to generate the appropriate rudder angle and propeller revolution command considering both external and internal risk metrics.

Both qualitative and quantitative evaluation conclude that the consideration of both external and internal risk metrics enhances the trustworthiness of the developed ACA-DMS!

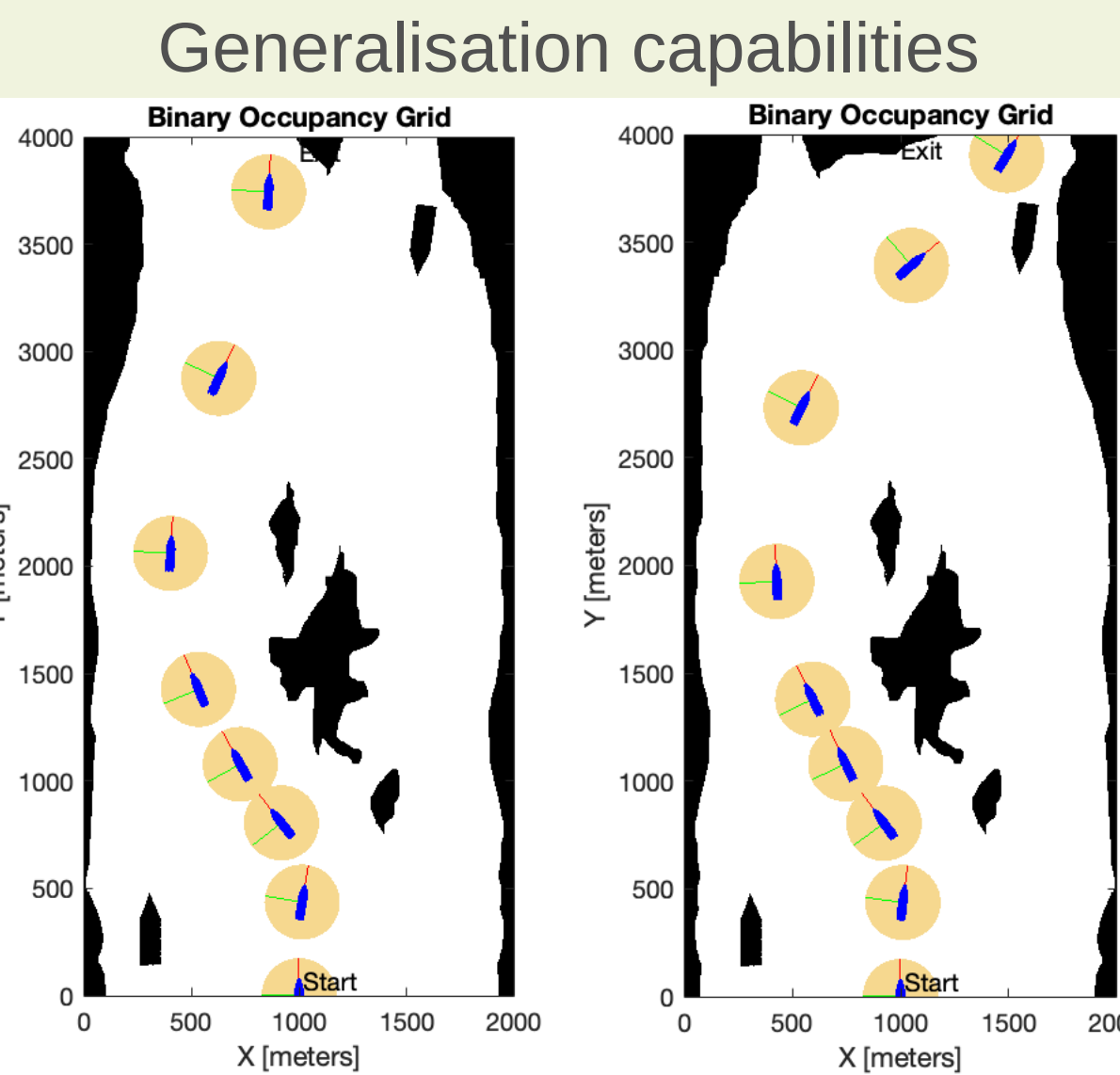


Figure 3. The trained agent is able to generalise the knowledge acquired in previous training and perform collision avoidance in new environments prior unknown.

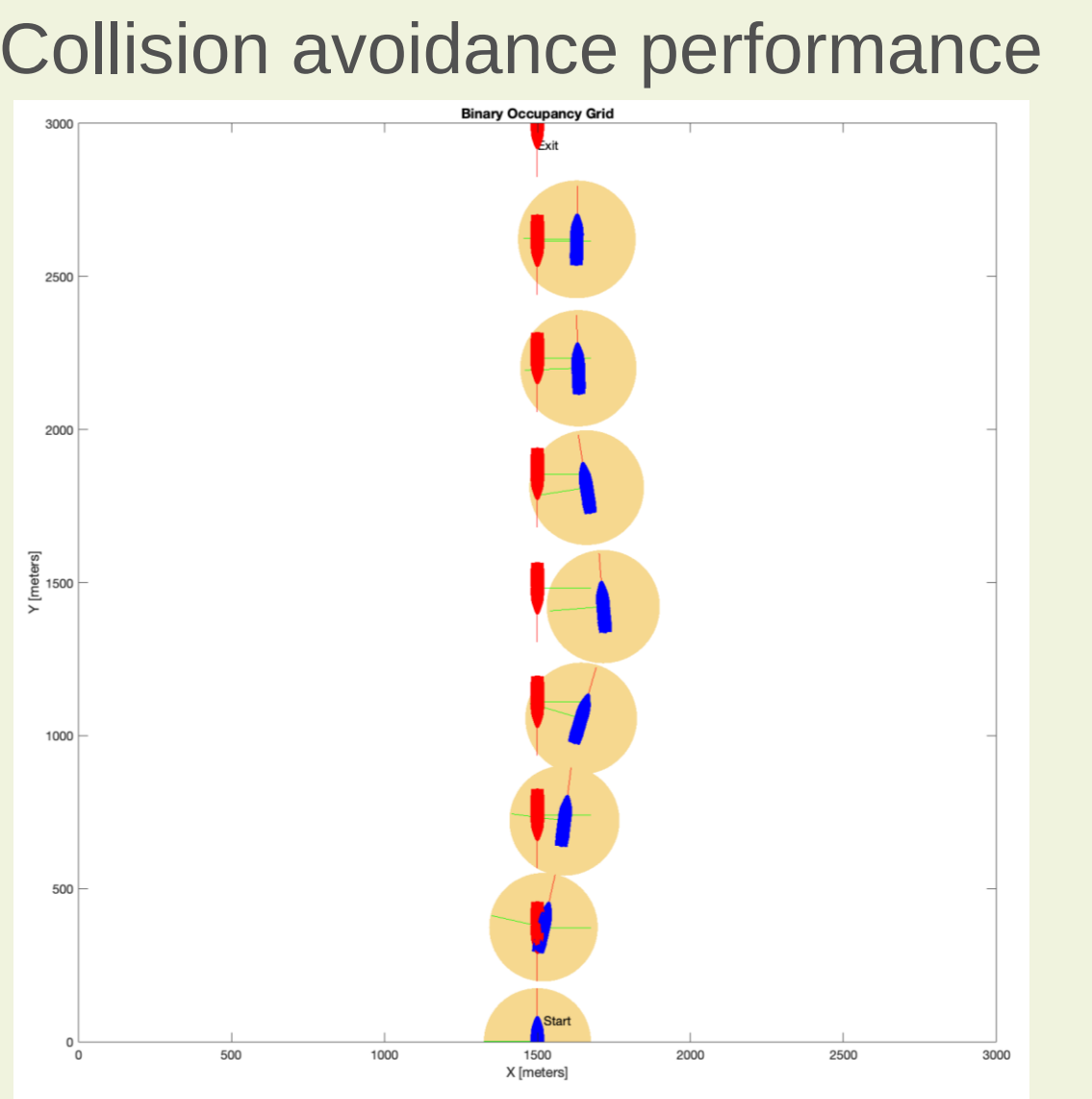


Figure 4. The trained agent is able to successfully execute critical collision scenarios, such as heading scenario when the other ship is not complying to the navigational rules.

Evaluation of ACA-DMS Trustworthiness

Qualitative metrics

Table 1. Qualitative evaluation of the trustworthiness main attributes (● not achieved, ● improved, ● achieved)

Main attributes of trustworthiness	Internal risk metrics not considered	Internal risk metrics considered
Reliability	●	●
Availability	●	●
Safety	●	●
Confidentiality	●	●
Integrity	●	●
Robustness	●	●
Maintainability	●	●
Adaptability	●	●
Usability	●	●
Timeliness	●	●
Leanness	●	●
Reactivity	●	●
Proactiveness	●	●

Quantitative metrics

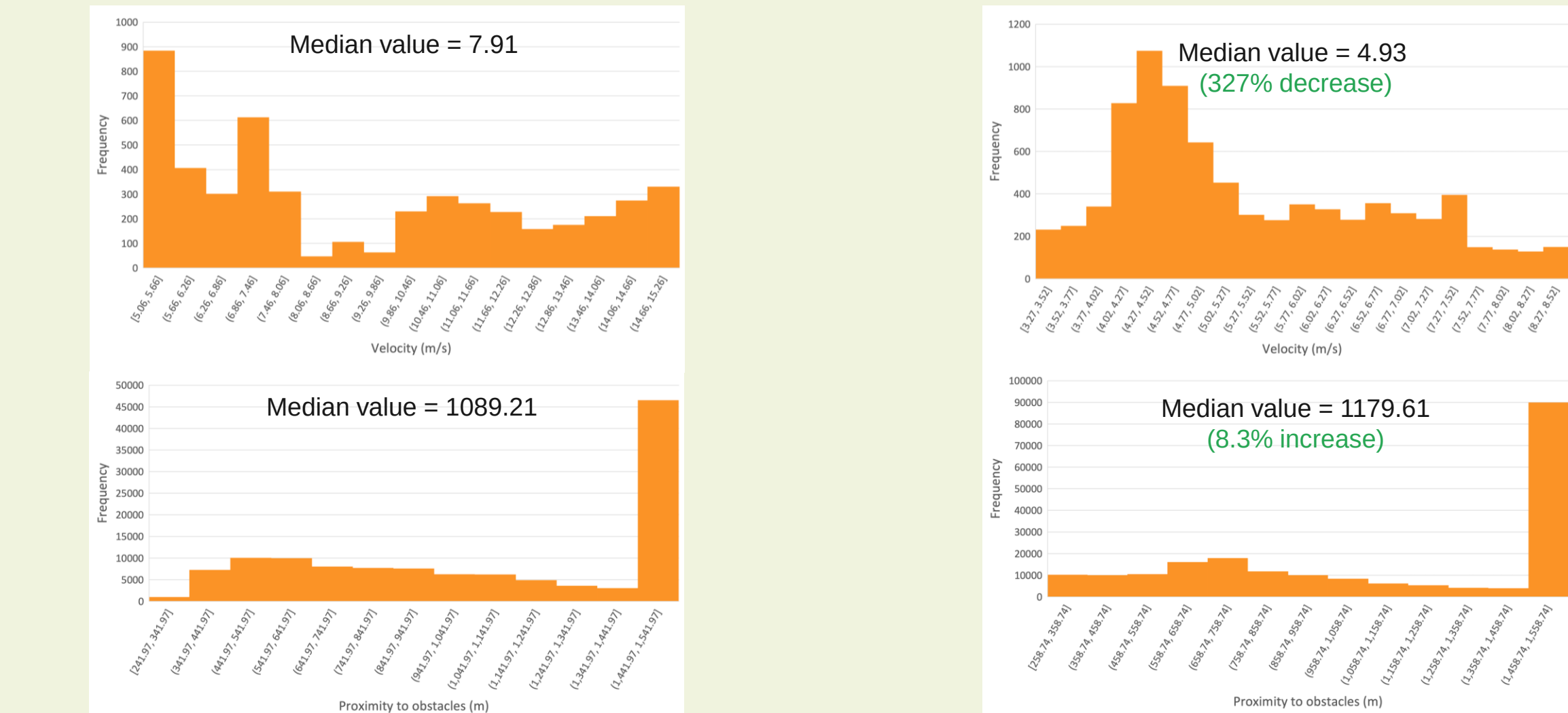


Figure 5. Histogram chart of the velocity and proximity to obstacles distributions when only external risk metrics are considered.

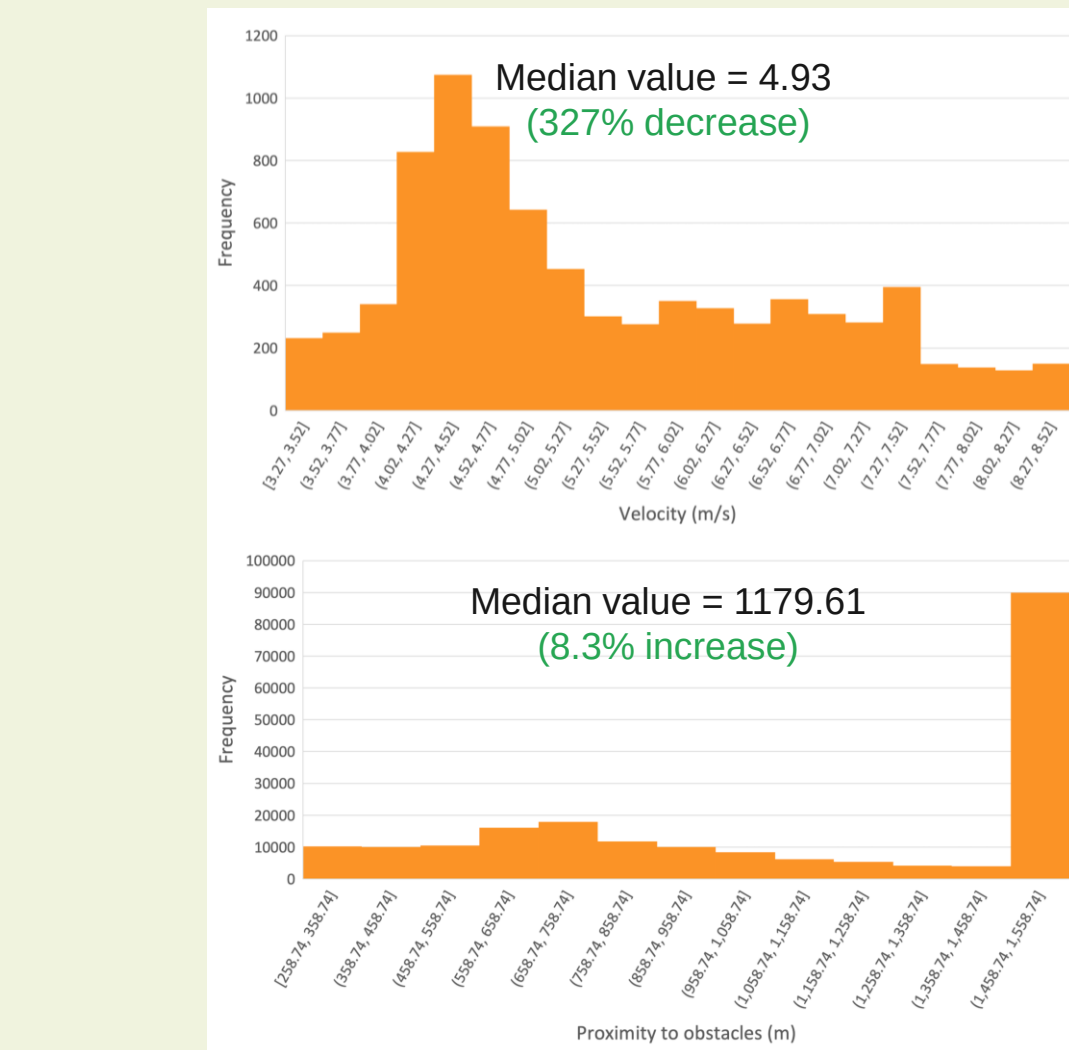


Figure 6. Histogram chart of the velocity and proximity to obstacles distributions when both external and internal risk metrics are considered.

Research Outlook

Future research include: a) identification of more critical and unpredictable scenarios, such as unknown unknowns; b) consideration of more critical internal risk metrics, such as uncertainty of input data; c) investigation of higher failure rates of critical components considering MTBF distribution; d) development of a wholistic and quantitative trustworthiness metric; and e) development of more complex digital twin.

