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SAFETY AT SEA – TRAINING SEAFARERS ON EFFECTIVE IMPLEMENTATION OF THE ISM CODE

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Abstract. The International Safety Management (ISM) Code concerns safety at sea and marine environment protection primarily regarding SOLAS class vessels. This paper outlines the key findings of an ongoing Erasmus+ Project, OPTIMISM, concerning a training programme for effective implementation of ISM Code and focuses on a very specific and often neglected accidents in confined spaces. This latter work is a project sponsored by IUK to develop a series of scenarios using Virtual Reality. A range of research and data collection methods have been employed with specific use of Pareto analysis and virtual reality animation and simulation. The results include analysis of some 200 accidents at sea and in ports. This paper makes special references to a taxonomy model identifying the key factors contributing to accidents and incidents at sea focusing again on accidents in confined spaces, as the core of the proposed training programme.

Keywords: ISM Code Implementation; Audit Non-Conformities; Port Inspection Deficiencies; Accidents in Confined Spaces.

1. INTRODUCTION

The maritime industry operates under a complex framework of international regulations designed to ensure the safety of life at sea and the protection of the marine environment. Central to this regulatory architecture is the International Safety Management (ISM) Code, adopted under Chapter IX of the International Convention for the Safety of Life at Sea (SOLAS). The ISM Code requires shipowners and operators to establish a Safety Management System (SMS) that promotes safety culture, ensures compliance with mandatory regulations, and facilitates continuous improvement in ship operations (International Maritime Organisation [IMO], 2018).

Despite its structured approach, effective implementation of the ISM Code remains a challenge across the sector. Audit reports and accident investigations often reveal recurring non-conformities – including poor risk assessment practices, inadequate training and communication failures (Berg, 2020). In response to these challenges, the Erasmus+ funded OPTIMISM Project was developed to improve ISM Code implementation through the creation of an accredited, modular training course. This course draws from literature reviews, case studies, field research, and real-world incident analysis to support a more robust safety system onboard vessel.

The OPTIMISM project also aims to bridge gaps identified in port inspections and ISM Code audits by aligning training with standards such as ISO 9000 and ISO 14000. It incorporates novel assessment methods – including self-assessment, assignments, and oral examination – and is designed for international recognition though alignment with ECVET/ECTS credit systems. A key innovation in the project is its integration of Virtual Reality (VR) technologies to simulate high-risk scenarios and reinforce practical learning outcomes.

One area of particular concern within maritime safety – and a focal point of both OPTIMISM project and the associated VR Emergency @ Sea initiative – is the risk posed by confined spaces aboard ships. Confined or enclosed spaces, such as cargo holds, ballast tanks, pump rooms and chain lockers, are characterised by restricted entry and exit points, poor ventilation, and unsuitability for continuous occupancy (UK MCA, 2022). These spaces can rapidly become lethal due to oxygen deficiency, toxic gases, or flammable atmospheres.

Despite international regulations, the dangers associated with confined spaces persist. Since 1996, approximately 350 seafarers and third-party workers have lost their lives in enclosed space incidents, with 70 fatalities from 43 accidents occurring between 2022 and 2025 alone (Gard, 2024). Alarmingly, many of these incidents involved experienced officers such as Masters and Chief Officers, indicating that procedural knowledge alone does not suffice.

To address these risks, the UK introduced the Merchant Shipping and Fishing Vessels (Entry into Enclosed Spaces) Regulations 2022, mandating comprehensive risk assessments, structured safety procedures, and regular drills for all vessel types (UK MCA, 2022). However, traditional training approaches — such as classroom lectures and periodic drills — often fall short in replicating the urgency and complexity of real-world emergencies. As such, enhancing training for confined space entry and emergency response through immersive and experiential learning has become a possible methodology for consideration.

2. IDENTIFYING KEY RISKS: INSIGHTS FROM ISM CODE AUDITS AND PORT STATE CONTROL INSPECTION

Maritime safety is profoundly affected by organisational, personal, and behavioural factors, which often serve as root causes of accidents and non-conformities in the case of audits and deficiencies in case of port inspections.

A review of accidents reported by De Melo Rodriguez et al. (2024) led to identifying root causes of and contributing factors to accidents at sea. As shown in Figure 1, this taxonomy breaks down causes into five main domains: Quality Assurance (QA) Errors, Non-QA Errors (Mistake), System Work Environment Errors, Nature, and Psychological/Physiological/Behavioural (PPS) Factors. Each of these categories is broken down into specific areas such as policy failures, procedural lapses, supervisory issues, and operational or personal vulnerabilities. For example, QA errors are often associated with inadequate documentation, poor planning, or missing procedures, while non-QA mistakes frequently arise from personal or leadership shortcomings. By mapping out these interconnected causes, the C4FF taxonomy, shown below, enables a holistic understanding of how safety breakdowns occur and where preventive interventions can be most effective.

Using the developed taxonomy (De Melo Rodrguez, G., et al. 2024) as shown in Figure 1, 25 top root causes and contributing factors to accidents were identified. As shown in table 1, the analysis of 40 case studies from a pool of over 200 maritime accidents revealed recurring patterns many also connected with non-conformities noted and deficiencies observed in both ISM Code audits and Port State Control (PSC) inspections.

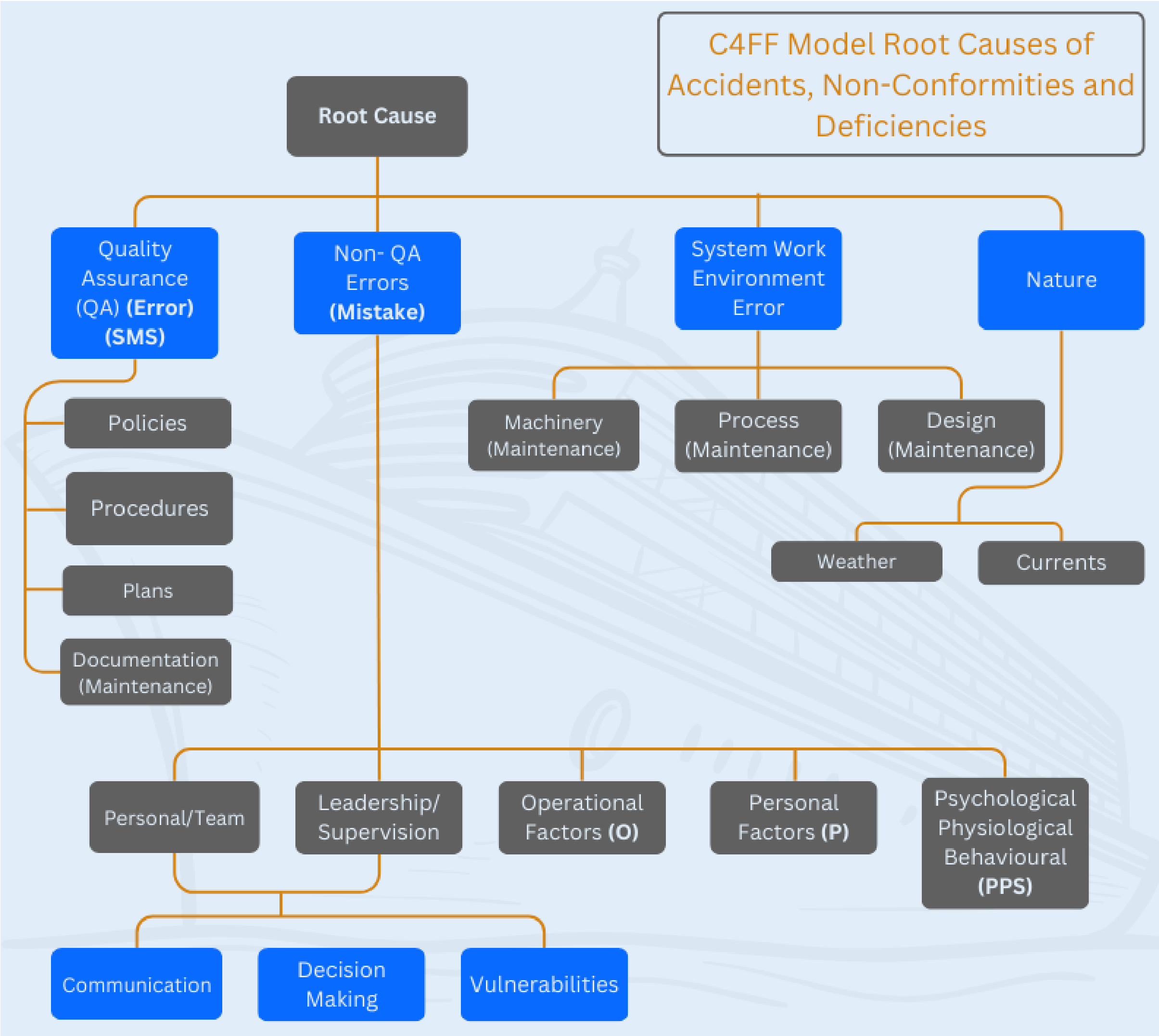

Figure 1. Root Causes of Accidents.
(Source: M'aider 2010, ACTs 2015 and ACTS Plus 2017 & OPTIMISM 2024 – www.mairfuture.org)

A review of Table 1 shows the leadership concern, "Inadequate risk assessment, inadequate team composition, inappropriate pressure to perform a task and a directed task with inadequate qualification, experience or equipment." was discovered to be the main reason for mishaps.

When constructing Table 1, it was evident that in majority of accidents three of the key contributing factors or the cause of accidents were leadership, supervision and/or person-to-person communication. Effective communication is still a major cause or contributing factor to accidents and incidents at sea. In a study carried out by Ziarati (2008), it was established that one third of the accidents are caused or impacted by poor linguistic deficiencies.

Table 1. Frequency occurrence of the top 25 root cause of non-conformities, deficiencies and contributing factors to accidents and incidence

Legend	•	=	Applies

NO	Vessel	Accident type	Working Environment				Personal										Leadership				Organisation						
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		Loss of Stability								•	•	•	•		•		•	•	•	•		•	•	•	•		•
2		Human Factor			•	•									•		•	•	•				•			•	
3		Collision			•						•						•	•	•		•	•	•	•	•	•	•
4		Operational Accident		•	•					•			•				•	•	•		•	•	•		•	•	
5		Operational Accident		•	•									•				•	•		•	•	•			•	
6		Collision		•			•											•			•	•	•				•
7		Grounding		•									•				•	•			•	•	•	•		•	•
8		Collision		•						•			•		•			•			•	•	•			•	
9		Grounding								•			•	•				•	•		•	•		•			
10		Capsize		•			•	•	•	•	•		•	•	•		•	•	•	•	•	•		•			•
11		Capsize and Grounding							•	•	•						•	•	•		•	•	•	•	•		
12		Fall from 18m height	•		•					•			•	•			•	•									
13		Overflow and Pollution		•	•					•	•				•			•	•	•			•				
14		Collision		•	•					•			•					•	•				•				
15		Ent. Into enclosed space							•	•	•		•	•	•		•	•	•		•	•	•	•			
16		Ent. Into enclosed space							•	•				•			•	•	•			•	•				
17		Operational Accident		•						•			•		•		•	•	•		•	•	•	•			
18		Operational Accident		•			•			•			•	•	•		•	•	•	•	•	•	•	•	•	•	
19		Operational Accident		•						•				•				•						•			
20		Grounding					•	•	•	•	•			•			•	•	•	•	•	•	•	•			•
21		Fire in Engine Room		•					•			•						•			•	•	•	•			
22		Collision			•							•	•														
23		Sinking while Towage	•	•	•				•	•	•										•	•	•				
24		Container over board	•	•								•	•	•							•	•	•	•			
25		Collision		•								•	•	•			•										
26		Accident in Drills							•	•								•	•			•	•				
27		Lifeboat Failed			•																						
28		Lifeboat Failed			•																						
29		Engine Room Accident						•	•		•																
30		Overboard Accident	•	•					•	•							•	•			•	•	•	•	•	•	
31		Collision										•	•	•	•												
32		Crew Member Died	•									•	•									•		•			
33		Man fell overboard																									
34		Man fell from height																									
35		Operational Accident		•					•									•	•								
36		Operational Accident	•							•			•					•							•		
37		Operational Accident	•	•					•	•		•							•								
38		Operational Accident		•					•	•			•				•	•	•			•	•				
39		Death of Passenger			•																		•			•	
40		Operational Accident							•				•		•			•	•		•	•	•	•			
TOTAL			7	19	12	1	4	3	14	21	9	8	19	12	10	0	16	27	20	5	18	23	24	16	7	9	6

3. ISM CODE AUDITS AND PORT INSPECTION

In an effort to reduce accidents at sea, significant attention has been devoted to audits and ship port inspections (Ziarati, 2024). The International Association of Classification Societies (IACS) have kindly agreed for C4FF to use their data regarding ISM Code non-conformities during their audits in the last five years in the OPTIMISM training programme. It is interesting that their data only concerns non-conformities at elemental level. However, Lloyd's Register as shown in table 2, identifies non-conformities at sub-element level. When reviewing IACS data it is clear that top-recurring non-conformities relate to maintenance followed by shipboard operations.

Lloyd's Register data from 2017-2023 highlighted systematic issues in safety management documentation, risk assessment protocols, and personnel training. The total number of non-conformities recorded over the seven-year period is 7,986, reflecting widespread and persistent challenges in the implementation of the ISM Code. Based on the Pareto Analysis conducted by Ziarati, et. al. (2024), Compliance with Rules and Regulations was the most frequent issue, which highlights ongoing difficulties in adhering to legal and regulatory frameworks followed by maintenance and in third place shipboard operations. The above clearly indicates that it is important to identify non-conformities at sub-elemental level.

When conducting the IMO Study on the effective implementation of the ISM Code, one of the key areas was management faults and minimum manning levels. However, in the OPTIMISM Project, equal importance was given to crew-related faults as shown in Table 2 below.

Table 2. ISM Non-Conformities Observed 2017-23. (Source: Lloyd's Register)

ISM Code - Non-conformities observed	**Years**							**Grand**			**Pareto**	**CoR vs.**	**ISM**
Row Labels	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**		**%**	**Ranking**	**CrR**	**Element**
1.2.2.1 - Safe Working Practices	4	43	25	26	24	22	5	149		1.87%	14	CoR	
1.2.2.2 - Safeguards against identified risks	25	70	58	60	109	83	37	442		5.53%	5	CoR	
1.2.2.3 - Safety Management skills & preparing for emergencies	1	2	3	2	4	1	2	15		0.19%		CoR	1
1.2.3.1 - Compliance with rules & regulations	48	217	168	151	206	189	84	1063		13.31%	1	CrR	
1.2.3.2 - Taking into account of codes, guidelines & standards	7	22	24	17	18	23	6	117		1.47%		CrR	
1.4 - Functional Requirements	2	6	7	6	7	8	2	38		0.48%		CoR	
10.1 - Establish procedures to maintain the ship	31	103	124	83	102	109	50	602		7.54%	3	Cor	
10.2.1 - Inspections held at the proper interval	19	101	76	85	91	92	45	509		6.37%	4	Cor	
10.2.2 - Deficiencies reported	8	37	30	44	32	53	25	229		2.87%	12	CoR/CrR	
10.2.3 - Appropriate action on deficiencies taken	11	45	48	36	34	53	30	257		3.22%	11	Cor/CrR	
10.2.4 - records of activities maintained	5	33	32	25	32	38	20	185		2.32%	13	CoR	
10.3 - Identification & Measures for critical equipment	11	35	17	11	19	24	21	138		1.73%		CoR	
10.4 - Inspection routines & follow up incorporated in the maintenance routines	8	35	21	17	13	29	15	138		1.73%		CoR	10
11.1 - Establishing document & data control	16	54	52	39	33	48	39	281		3.52%	9	CoR	
11.2.1 - Valid documents available on relevant locations	15	53	53	53	65	54	19	312		3.91%	8	CoR	
11.2.2 - Review & approval of (changes to) documentation	2	8	7	4	1	6	1	29		0.36%		CoR	
11.2.3 - Obsolete documents promptly removed	2	19	7	8	9	9	3	57		0.71%		CoR	
11.3 - Suitable & effective SMS maintained		3	2	3	2	6	1	17		0.21%		CoR	11
12.1 - Internal audits at 12 month intervals	14	35	46	39	43	36	16	229		2.87%		CoR	
12.2 - Personnel undertaking tasks in conformity with Companys responsibilities	1	2	3	1	3	6		16		0.20%		CrR	
12.3 - Management review	2	8	4	12	7	14	4	51		0.64%		CoR	
12.4 - Audits and corrective actions in accordance with procedures	3	10	21	24	9	10	6	83		1.04%		Cor/CrR	12
12.5 - Independence of internal auditors	1	4		1	2	2		10		0.13%		Cor/CrR	
12.6 - Reporting results of internal audits and reviews	3	5	3	4	3	3		21		0.26%		Cor/CrR	
12.7 - Timely corrective action on findings noted	2	6	10	8	13	8	4	51		0.64%		Cor/CrR	
2.1 - Establishing a safety & environmental policy	3	5	4	4	1	8	2	27		0.34%		CoR	
2.2 - Implementing the SMS Policy		13	10	4	6	7	5	45		0.56%		CrR	2
3.1 - Ship owner assigning ISM responsibility		1	5	1	5	1		13		0.16%		CoR	
3.2 - Defining & documenting responsibilities	1	4	5	4	6	11	3	34		0.43%		CoR	
3.3 - Adequate resources for the DPA	3	3	3	4	5	4	1	23		0.29%		CoR	3
4 - Role of the DPA	2	1	2		2	7		14		0.18%		CoR	4
5.1.1 - Master implementing the SMS Policy		4	1		1		2	8		0.10%		CoR	
5.1.2 - Master motivating the crew		1	1		1	1		4		0.05%		CoR	
5.1.4 - Master verifying SMS related activities	1	7	6	3	3		4	24		0.30%		CoR	
5.1.5 - Master periodically reviewing the SMS	4	20	16	13	19	18	13	103		1.29%		CoR	
5.2 - Use and knowledge of the overriding authority	1		1	1				3		0.04%		CoR/CrR	5
6.1.1 - Master properly qualified for command		1						1		0.01%		Cor/CrR	
6.1.2 - Master fully conversant with SMS	1	2	3	3	5	1		15		0.19%		CoR/CrR	
6.1.3 - Master given necessary support		3	1	5	1	5		15		0.19%		CoR	
6.2.1 - Ship manned with qualified and medically fit personnel	7	23	22	23	28	28	11	142		1.78%		CoR/CrR	
6.2.2 - Ship appropriately manned to safely cover all operations	8	19	17	16	21	16	7	104		1.30%		CoR	
6.3 - Crews familiarisation on board	2	26	18	26	34	39	24	169		2.12%		CoR/CrR	
6.4 - Adequate knowledge of rules and regulations	9	15	19	13	16	9	9	90		1.13%		CoR/CrR	
6.5 - Identification of training needs	4	21	21	22	24	24	10	126		1.58%		CoR	
6.6 - Working language used		3	2	5	2	3	2	17		0.21%		CoR/CrR	
6.7 - Effective communication used	1	8	10	4	6	6	5	40		0.50%		CoR/CrR	6
7 - Shipboard Operations	23	155	104	114	131	139	72	738		9.24%	2	CoR/CrR	7
8.1 - Identification of contingency plans	3	17	21	8	8	10	5	72		0.90%		CoR/CrR	
8.2 - Drills & exercise planning for emergencies	14	57	55	45	45	71	27	314		3.93%	7	CoR/CrR	
8.3 - Companys ability to respond to emergencies	7	19	20	21	13	23	9	112		1.40%		CoR/CrR	8
9.1 - Reporting, investigating, analysing accidents, NCs, etc.	19	75	70	69	64	68	50	415		5.20%	6	CoR/CrR	
9.2 - Implementation of corrective actions	10	52	43	51	48	43	32	279		3.49%	10	CoR/CrR	9
Grand Total	**364**	**1511**	**1321**	**1218**	**1376**	**1468**	**728**	**7986**		**100.00%**			

Table 3. PSC Paris MoU Observed deficiencies – Review of Inspections 2019 – 2021

	Year		
	2019	**2020**	**2021**
Number of inspections	17,916	13,168	15,387
Number of individual ships inspected	15,447	12,092	13,797
Number of deficiencies	39,821	28,372	36,113
Number of detainable deficiencies	3,015	2,182	3,274
Detentions in % of the total number of inspections	2,98	2,92	3,43
Number of refusals of access to ports	25	8	11

As shown in Table 3, port inspections conducted for example by Paris Memorandum of Understanding identified some 105000 deficiencies about 10000 of them were ISM related. Key deficiencies were inadequate procedures, poor recordkeeping, improper PPE usage, and emergency preparedness (Ziarati et al., 2024).

4. VIRTUAL REALITY AND THE VR EMERGENCY @ SEA INITIATVE

To address the limitations of traditional instruction, the IUK-sponsored VR Emergency @ Sea project introduced an immersive training programme using virtual reality simulations. These allow seafarers to experience high-risk scenarios—such as gas leaks, fire outbreaks, and oxygen-deficient environments—within a safe, controlled virtual setting. By placing seafarers in real-life situations, under stress and urgency a series of scenarios were developed to ensure seafarers become familiar with practicing correct procedures, effective teamwork and clear communication. More importantly, this project directly targets repetitive root causes of accidents outlined in table 1. For instance, procedural non-compliance can be addressed by trainees repeatedly practicing correct protocols in varied emergency contexts, thereby reinforcing experimental learning.

4.1. Learning from Real Incidents

A cornerstone of the VR application is the integration of real-world incidents into immersive learning scenarios as shown in Figure 2. This pedagogical strategy draws from the maritime sector's long-standing principle of learning from loss—whereby past accidents and near-misses are analysed to prevent future occurrences. By incorporating actual case studies into virtual environments, trainees are exposed not only to the technical failures that contributed to past incidents but also to the human, procedural, and cultural dimensions of maritime accidents.

One case study which led to the development of this training programme is the fatal cargo tank incident, where a Chief Officer lost his life due to asphyxiation during routine checks, Root cause analysis revealed multiple systematic failures, including:

- Absence of Gas-freeing Procedures: The tank was not properly ventilated or tested for toxic and flammable gases prior to entry.

Figure 2. A screenshot from VR Emergency @ Sea scenario

- Lack of Personal Protective Equipment (PPE) and Gas Detection Equipment: The officer entered the space without appropriate personal protective equipment or a gas detector.
- Inadequate Risk Assessment: The entry was not preceded by a structured hazard evaluation or sign-off procedure.
- Deficient Safety Culture and Supervision: The incident reflected a broader organizational failure to enforce safety protocols and challenge unsafe practices.
- Training Gaps and Complacency: The officer's experience may have led to overconfidence, bypassing essential checks in a familiar yet deadly environment.

Trainees are tasked with performing a safe entry under the same conditions, guided through correct procedures such as: conducting pre-entry atmospheric tests; selecting and donning appropriate PPE; identifying and controlling hazards; communicating with a standby team and using emergency equipment and performing real-time decision-making in a deteriorating environment (e.g., unexpected gas readings or loss of communication)

The training programme addresses a critical gap in safety training: the lack of safe environments to practice error recognition and emergency response. In real life, such situations are too dangerous to simulate without risk. VR, however, allows users to safely fail and learn from their mistakes, fostering a safety-first mindset that is both personal and situational. By grounding its curriculum in documented incidents, VR Emergency @ Sea serves a dual function: it preserves institutional memory of high impact events and uses them as teaching tools to build a proactive safety culture. This aligns with the IMO's emphasis on continuous improvement in safety management systems and supports the broader objectives of the ISM Code by turning procedural requirements into behavioural habits.

4.2. Scenario-based Skills Development and Emergency Response

The VR training progresses from foundational knowledge-building to more complex decision-making and emergency response containing four Training modules. Early in the training, learners are introduced to the critical steps required before entering an enclosed space as shown in Figure 3. This includes a detailed walk-through of essential safety procedures such as verifying the atmosphere using gas detection equipment, identifying the correct type of PPE for various hazards, and ensuring proper communication protocols with standby personnel. Guided by a virtual Chief Officer, trainees engage with realistic equipment, such as multi-gas monitors, radios, and entry permits, while being promoted to perform safety checks through interactive tasks and applied learning exercises.

Once trainees have demonstrated familiarity with safety steps and equipment, they are challenged to apply this knowledge in a realistic manner onboard ship as shown in Figure 3. In this stage of training, they must independently carry out a full risk assessment and execute all preparatory procedures before attempting to enter a cargo hold simulated to be at sea. Real-time performance feedback is provided, allowing users to identify areas for improvement and strengthen their situational awareness. The scenario encourages critical thinking and reinforces the importance of adhering to established safety procedures even in routine operations. It also promotes personal accountability and decision-making under realistic constraints.

The most advanced segment of the training presents a fully immersive emergency situation, combining multiple hazards that might occur during confined space operations as pictured in Figure 4. This scenario includes not only atmospheric emergencies—such as sudden drops in oxygen levels or unexpected toxic gas release—but also incorporates a fire outbreak within the confined space. Trainees must recognize

Figure 3. Screenshot from Module 1 – PPE Training and Module 2 – PPE Practice

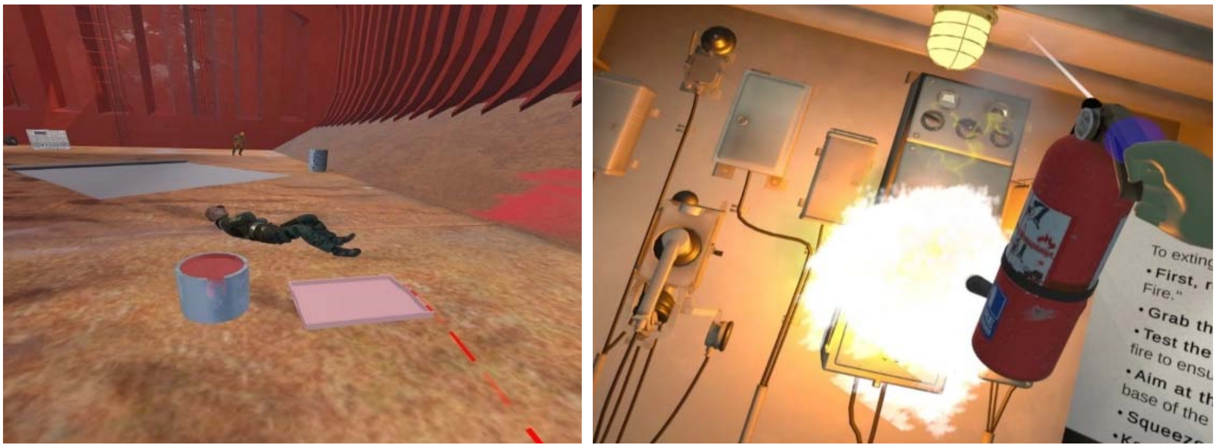

Figure 4. Screenshot from Module 3 (on the left – Enclosed Space Emergency) and Module 4 (on the right – Fire Fighting Training)

the onset of danger, prioritize response actions, and deploy appropriate firefighting techniques while maintaining communication with the command team.

As part of the paper presentation, a live demonstration of the VR application will be delivered, showcasing one of the confined space emergency scenarios. This hands-on experience will allow attendees to observe how the training simulates real-world hazards and supports experiential learning. Additionally, a leaflet detailing the different training scenarios developed within the VR Emergency @ Sea programme will be distributed to all attendees for further reference.

5. CONCLUSION

Despite decades of regulatory advancements and international frameworks such as the ISM Code, confined space incidents continue to pose a severe threat to maritime safety. The recurrence of fatalities in enclosed environments underscores the limitations of conventional training methods and highlights a critical gap in how safety practices are internalised and applied in real-world settings. While the ISM Code provides the necessary structure for managing shipboard safety, effective implementation demands more than procedural compliance—it requires a deep, situational understanding of risk and the ability to act decisively under pressure.

The OPTIMISM project responds to this challenge by enhancing ISM Code training with a blended learning model that includes regulatory foundations, case-based learning, and the integration of immersive technologies. Central to this approach is the VR Emergency @ Sea initiative, which transforms traditional safety instruction into interactive, experience-driven learning. By simulating realistic scenarios based on actual incidents, this training methodology addresses not just what seafarers should do, but how they behave in high-risk environments.

The virtual scenarios—ranging from routine entry checks to emergency responses involving gas leaks and onboard fires—enable learners to practice decision-making, master critical safety procedures, and develop the confidence to manage confined space operations safely. This experiential learning model reinforces procedural discipline while cultivating the situational awareness and safety culture demanded by the ISM Code.

Virtual reality poses a challenge in training because based on experience of validating some of the scenarios many users find it difficult if the scenarios are too long viz more than 20 minutes. To this end, the training programme was divided into modules of short training programme focusing on PPE Training, PPE Practice, Fire Handling and Enclosed Space Emergency Response.

To further illustrate the impact of this approach, a live demonstration of the VR application will be presented during the paper session, featuring one of the confined space emergency scenarios in action. A leaflet summarising the training modules will be distributed to attendees. This leaflet includes insights from the C4FF analysis of over 160 accident reports, a detailed case study, and explanations of how the VR application directly addresses known safety gaps.

In conclusion, integrating immersive technologies such as VR into maritime safety training represents a significant advancement in reducing confined space incidents and enhancing ISM Code compliance. The combination of research insights from the OPTIMISM project and the practical application of VR provides a scalable, effective, and future-ready solution to one of the most persistent challenges in seafaring safety.

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