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RETROFIT SOLUTIONS TO ACHIEVE 55% GHG REDUCTION BY 2030

Risk Assessment Report

WP 4 – Wind Assisted Ship Propulsion
Task 4.2 – Risk assessment and mitigation (M1-M12)
D4.2 – Risk Assessment report
Partners involved: AWS, RINA, LASK, ATD, FSYS, SFD, NTUA
Authors: Greg Johnston (AWS), Amedeo D. Rinaldi (RINA)

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Quality check review

Reviewer (s)	Main changes / Actions
Nikos Themelis (NTUA)	

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Executive Summary

A systematic approach, and a risk assessment have been produced according to the methods described in the RINA GUI015 “Guide for Risk Analysis” to identify, rank and control hazards and/or failure modes potentially affecting the novel technology. Engineering analyses will be used to demonstrate that the design fulfils the general requirements for its intended service.

The objective of the risk assessment is to help “eliminate or mitigate any adverse effect to the persons on board, the environment or the ship”. The risk assessment helps to identify and recommend safeguards that could reduce risks and helps to determine if the risks have been mitigated as necessary.

A HAZID (Hazard Identification Study) of the proposed design of the Wind Assisted Ship Propulsion (WASP) system has been undertaken to help manage safety risks. The principal objective of the HAZID was to increase confidence that safety related aspects of the design are appropriate.

Key expectations concerning the HAZID are:

- Workshop attended by key stakeholders including representation from design and operations
- Workshops involved a structured process to address all hazards and potential accident events at high level
- Adequate time given to the workshop
- There is early focus on risk reduction measures, in particular, inherent safety aspects and major accident event prevention
- The HAZID provides the basis for a risk matrix.

The study identified no significant issues or unacceptable risks associated with the design of the WASP (Wind-Assisted Ship Propulsion). The main results are shown in more in detail in the closing chapter and the consequent risk matrix is reported in Appendix 1.

1 Introduction

The overall objective of RETROFIT55 is to create an advanced web-based Decision Support System (DSS), featuring a catalogue of retrofitting solutions that are up-to-date and ready to be deployed at the end of the project and easily extendable afterwards while developed and demonstrated. The DSS will allow combining retrofitting solutions in order to achieve a GreenHouse Gas (GHG) emission reduction of 35% compared to the original design.

The consortium will focus on solutions to improve the ship efficiency, such as Air Lubrication Systems, Smart Energy Management, holistic Hydrodynamic and Operational optimization, as well as solutions to exploit renewables or zero- and low-emission energy sources, such as Wind Assisted Propulsion, Fuel Cells and hybridization of the propulsion system.

The task to which this deliverable is related will involve a detailed risk assessment based on the existing preliminary designs to identify areas where risk can be mitigated, or risk management plans developed for the Wind Assisted Ship Propulsion system. A scale model of the system will be constructed to allow testing of operational systems and to provide some validation ahead of detailed design. The design of Task 4.1 will be elaborated to produce detailed designs for the construction of the system. The hazard identification has been conducted though a literature review and brainstorming sessions with experts from the classification society and the risk associated with the hazards has been estimated based on conventional methods and fault-tree analysis.

This Report presents the process and the basis of the future step, i.e.the Class Approval in Principle (AIP) of the wind-assisted propulsion system, based upon the definition, application and compliance with rules and regulations. aimed at verifying that this novel technology is feasible, fit for purpose and safe throughout the ship lifecycle. This deliverable will be used for certification and approval for the system, once it is installed onboard operative vessels.

The following chapters are included in this document:

- Chapter 1: Introduction, with an overall objective of the RETROFITT55 goal and a summary of the current task
- Chapter 2: Study objective, where the analyzed system has been shown with a brief explanation of his characteristics.
- Chapter 3: HAZID, where the objective of the HAZID is shown with indication about the study team
- Chapter 4: HAZID study worksheet, where the risks matrix is shown with an introduction about the overall assumption of the study
- Chapter 5: Closing remarks, where the main results of the HAZID study are summarized

2 Study Objective

The risk assessment has been focused on the Wind Assisted Ship Propulsion (WASP) system which is becoming widely accepted as part of the solution for reducing GHG (greenhouse gas) emissions from shipping. There are many vessels in operation that could benefit from a retrofit solution using WASP. One of the challenges in retrofitting WASP is to devise a system which does not impact on the normal operation of the vessel. The objective of this study is to assess the risks associated with the proposed wind propulsion system and, when appropriate, to make recommendations as to the mitigation of these risks.

2.1 System summary

The Advanced Wing Systems (AWS) collapsible wing sail system (Figure 1) is based on the strong experience of AWS in soft wing sail development and testing over many years. To date the AWS wing sail technology has been used on craft from 2 to 22 m in length. It has been used in competitive sailing, including the 36th America's Cup, and a 7,500 nautical mile ocean voyage. The technology enables aerodynamically efficient wing sails with variable wing geometry to be produced using existing materials and construction methods.

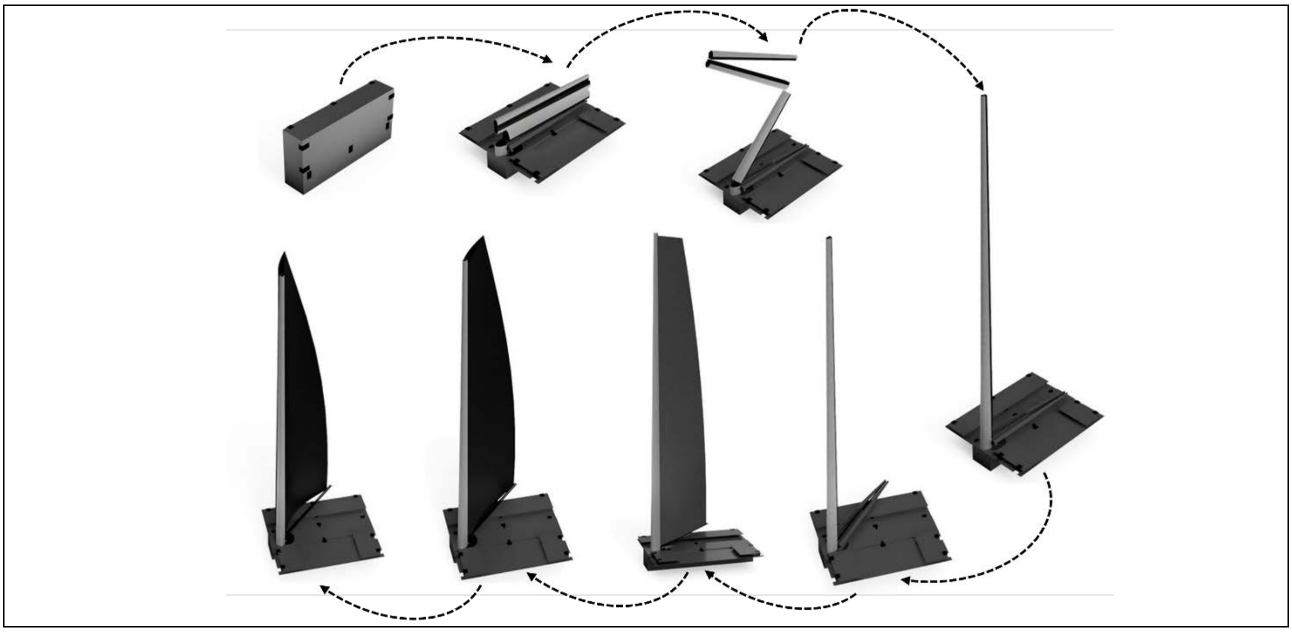

Figure 1: Advanced Wing System

The innovation applied here is to have made the wing sail system completely collapsible in a way that such a large device can be stowed to a small deck footprint. This allows larger wing sails to be deployed while having minimal impact on docking and loading operations. Further, the AWS wing sails can be designed to collapse into a housing that is of suitable size and weight for transport as container cargo.

Such a feature coupled with the ability to make the wing system completely self-contained simplifies the production and optimizes maintenance operations.

A deck mounting frame is the only part customized to the vessel. With appropriate design, the deck mounting frame can be fitted into the vessel without the need for dry docking and welding.

The AWS wing sail technology allows large cross sections of the mast to be used with little or no aerodynamic penalty. The resulting wing sections can produce very high lift and excellent lift-to-drag characteristics.

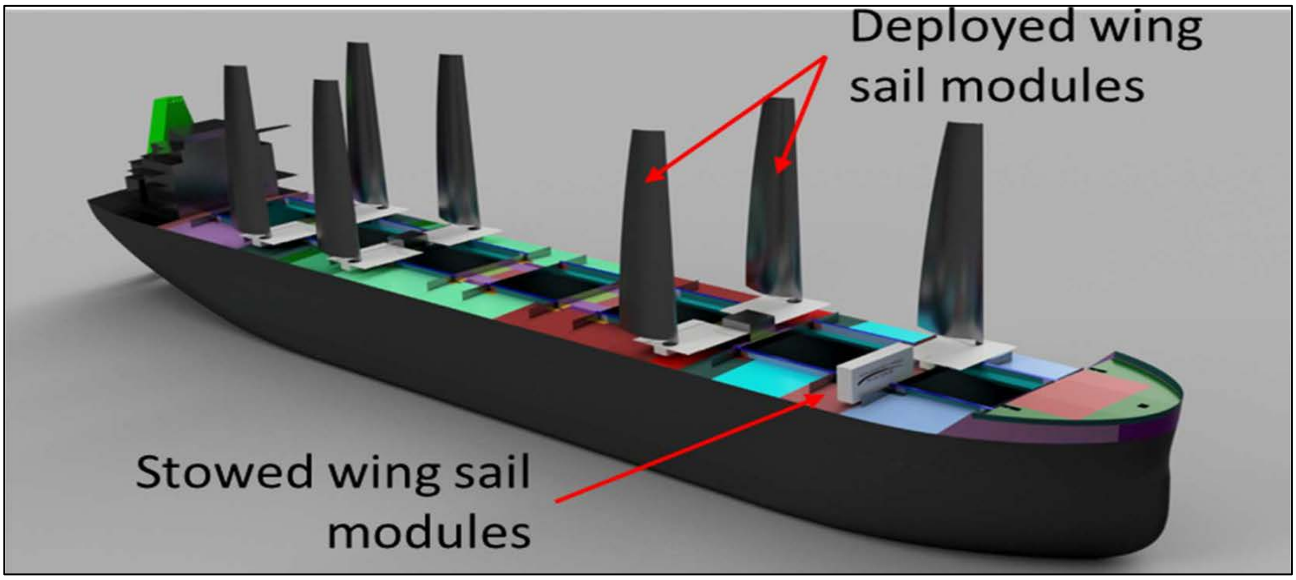

Figure 2: Sail installation concept

Figure 2 shows a conceptual arrangement of a wing sail module in stowed and semi-deployed configurations with eight modules, seven of which are unstowed and one which is in the stowed configuration.

The installation position should consider access to the existing deck equipment such as capstan winches used during docking operations, helideck locations, visibility, etc. Further, exposure to “green water” when at sea should be considered and the installation of baffles to prevent excessive loads on the deployed structure should be considered.

3 HAZID

3.1 HAZID Objective

The objectives of the HAZID are to identify:

1. hazards and how they can be caused (i.e. the accident scenarios – What can go wrong and how)
2. the consequences that may result
3. existing measures/safeguards that minimize leaks, ignition and potential consequences, and maximize spill containment
4. recommendations to eliminate or minimize safety risks.

3.2 Study team and attendance

The study has been facilitated and scribed by RINA Services on a one-day meeting on 17th October 2023. The HAZID study team consisted of a range of Subject Matter Experts (SMEs) with knowledge and experience of such a design. The team members, a summary of their attendance at the meeting is reported below.

An essential role of the HAZID facilitator is to ensure that the HAZID methodology is used effectively and productively. Because of this, the facilitator needs to have a deep understanding and considerable experience in the HAZID study, as well as proven technical competence.

Table 1: Summary of the HAZID workshop

Meeting title	**Retrofit55 WP4 Meeting - Task 4.2**
Participants	12
Start time	10/17/23, 9:00 AM
End time	10/17/23, 3:00 PM
Meeting duration	6h
Average attendance time	4h 30m

Table 2: HAZID meeting participant list

Name	Log-in time	Log-out time	Time spent online
Amedeo D. RINALDI (RINA)	10/17/23, 8:49:31 AM	10/17/23, 3:06:23 PM	6h 16m 51s
Alessandro IAFRATI (CNR)	10/17/23, 8:49:42 AM	10/17/23, 3:06:17 PM	6h 13m 7s
Roger Armson (ARM)	10/17/23, 8:57:55 AM	10/17/23, 1:39:16 PM	4h 41m 21s
Greg Johnston (AWS)	10/17/23, 8:59:49 AM	10/17/23, 3:06:19 PM	6h 6m 30s
Alessandro MACCARI (RINA)	10/17/23, 9:00:08 AM	10/17/23, 3:01:00 PM	5h 59m 31s
Reuben DSouza (SFWD)	10/17/23, 9:00:18 AM	10/17/23, 3:06:19 PM	6h 6m 1s
Laura Herrera (ATD)	10/17/23, 9:00:50 AM	10/17/23, 2:54:24 PM	5h 53m 33s
Edoardo MOREA (RINA)	10/17/23, 9:20:10 AM	10/17/23, 3:32:55 PM	6h 12m 44s
Emanuele Spinosa (CNR)	10/17/23, 10:19:59 AM	10/17/23, 3:08:41 PM	4h 48m 42s
Nikos Themelis (NTUA)	10/17/23, 10:28:36 AM	10/17/23, 3:06:21 PM	4h 37m 45s
Manolis Angelou (NTUA)	10/17/23, 10:37:54 AM	10/17/23, 3:05:59 PM	4h 28m 5s
Armin Milad (LJMU)	10/17/23, 1:46:26 PM	10/17/23, 2:46:42 PM	1h 0m 16s

4 HAZID Study Worksheet

4.1.1 Overall HAZID Assumption

A number of overall assumptions is generally made for such a type of HAZID:

- the personnel involved with operation and maintenance of the WASP system shall be competent, therefore it is important that the personnel have been trained in the use and maintenance of any new equipment
- safety systems will be designed to achieve an appropriate level of safety and reliability; this includes any shutdown system or any process alarm
- the personnel shall respond to the alarms within the due time and shall take appropriate actions
- HAZID is part of the formal Risk Based Design (RBD) methodology, aimed at demonstrating an equivalent level of safety in case of deviations or unavailability of prescriptive regulation; it was assumed that any other applicable regulation, rule, code or standard for the safe design and operation of the vessel is to be complied with.

4.1.2 Risk Rating

A preliminary assessment of the available information on the technology under investigation should be performed to gain a general understanding of the level of deviation from proven designs.

Consequently, the novelty of this installation, the consequent lack of historical/statistical data and the high levels of uncertainty about the frequency of occurrence of potential failures in marine environment challenged the Risk Assessment Team, who had to rely on the extensive use of judgment of experts, supported by technical and operational experience, also gained outside the maritime field.

Based on the above considerations, the approach used by the team members in the allocation of risk levels was marked by extreme caution, often recommending the implementation of additional protection barriers even for failure scenarios that fell within the tolerability range of the risk matrix.

During the HAZID meeting each hazard/accident scenario that had the potential to cause significant harm to personnel, environment and asset was rated with respect to the severity of the consequences. Following the study, the 'likelihood of occurrence' of each of these scenarios was rated.

The level of agreement reached by the team during the HAZID sessions was unanimous throughout the entire process and the criteria, in the form of risk matrices, are based on the work undertaken by RINA during an extensive review of the risk assessment procedures for the maritime sector. For each Node, a combination of Guidewords and Parameters were used to identify possible scenarios.

HAZID prompts and ‘What if?’ scenarios, which had been prepared prior to the workshops, were applied, encouraging discussion on possible events that may lead to unplanned outcomes. These prompts are based upon previous experience and indicate the types of hazards that were deemed necessary to consider.

For each item in the list and for any other question arisen during the workshop the team considered realistic scenarios that could lead to an accident and identified possible causes and outcomes from the accident. After evaluating the potential consequences of the accident scenarios, the measures that would be expected to be in place for their prevention, control and mitigation were identified. If these measures were thought to be inadequate or if insufficient information was available, items for further consideration were raised.

Table 3 shows the number of scenarios rated under each risk category that could harm persons on board.

Table 3: Risk scenarios

			Consequence				
			C1	C2	C3	C4	C5
			Minor Injury	Major Injury	Single Fatality or Major injuries	2-10 Fatalities	11+ Fatalities
Likelihood	L7	Extreme Likely					
	L6	Very Likely					
	L5	Likely					
	L4	Unlikely					
	L3	Very Unlikely					
	L2	Extremely Unlikely					
	L1	Remote					

High	The level of risk is not acceptable and risk control measures are required to move the risk figure to the previous regions.
Medium	The level of risks is acceptable, provided that further reduction measures are considered to be not practically applicable (ALARP).
Low	The level of risks is acceptable, applying the safeguards provided or general control measures.

This rating provides levels of risk that can be compared against criteria and they can be evaluated in the following Table 4 and the risk category legend in Table 5.

Table 4: Risk levels compared against criteria

	Effect on:			
	People	**Assets / Production**	**Environment**	**Reputation**
Negligible 1	Slight health effect / injury	No disruption to operations / business	No stakeholder impact or temporary impact on the area. Involved area < 0.1 sq mile Spill (1) < 1 m3 - no sensitive impact on ground	Limited impact - some local media / political attention. Effect will last a few days only
Low 2	Minor health effect / injury	Possible short disruption of operations / business: repair cost < 200,000 USD; production downtime < 1 day	Some local stakeholder concern or 1 year for natural recovery or impact on small no. of not compromised species. Involved area < 1 sq mile Spill < 10 m3 - impact on localised ground	Considerable impact - adverse attention in local media / local government /action groups
Medium 3	Major health effect / injury	Unit needs repair/ replacement to resume operations: repair cost < 2,500,000 USD; production downtime > 1 week	Regional stakeholder concern or 1-2 years for natural recovery or 1 week for clean-up or threatening to some species or impact on protected natural areas. Involved area < 10 sq miles - Spill < 100 m3	Significant national impact and public concern - Extensive adverse attention in the national media. Effect could last a few months and likely to spread to close industry partners
High 4	Permanent Total Disability or 1 fatality (small exposed population)	Long time / Major change to resume operations / business: repair cost < 25,000,000 USD; production downtime < 3 months.	National stakeholder concern or natural recovery or up to 5 months for clean-up or threatening to biodiversity or impact on interesting areas. Involved area < 100 sq miles - Spill < 1000 m3	Serious international impact and public attention
Major 5	Multiple fatalities (exposed groups)	Total loss of operations / business. Revamping necessary to resume the process; production downtime > 3 months.	International stakeholder concern or > 5 years for natural recovery or > 5 months for clean-up or reduction of biodiversity or impact on special conservation areas. Involved area > 100 sq miles - Spill > 1000 m3.	Prolonged international impact and public attention

Table 5: Risk category legend

L1 Remote	**L2 Extremely Unlikely**	**L3 Very Unlikely**	**L4 Unlikely**	**L5 Likely**	**L6 Very Likely**	**L7 Extreme Likely**
$\leq 10^{-6}$	$\leq 10^{-6}$ to 10^{-5}	$\leq 10^{-5}$ to 10^{-4}	$\leq 10^{-4}$ to 10^{-3}	$\leq 10^{-3}$ to 10^{-2}	$\leq 10^{-2}$ to 10^{-1}	$\leq 10^{-1}$ to 10^{0}
Ship Years ≤1000000	Ship Years ≤100000 - 1000000	Ship Years ≤100000 - 10000	Ship Years ≤10000 - 1000	Ship Years ≤1000 - 100	Ship Years ≤100 - 10	Ship Years ≤ 10

5 Closing remarks

The activities performed during Task 4.2 were performed with the aim of defining a risk assessment (APPENDIX 1) of the Advanced Wing Systems WASP solution, to be manufactured and validated in the next phases of the project.

The main results can be summarized as follows:

- the HAZID of the proposed design identified no significant issues or unacceptable risks associated with the design of the system.
- the subjects analyzed covered all safety aspects and hazards such as, Equipment, Location, Environment, Operations, Structures, Stability, Materials and Operational hazards.
- the risk ranking shows a percentage of 1.5% for no-risk hazards, 31% for low-risk hazards, 19% for medium-risk hazards and 1.5% for high-risk hazards. Each of them has been mitigated with appropriate measures requiring additional studies and/or procedures to be provided. Moreover, the high-risk ones do not require a substantial increase in the installation costs.
- recommendations for further consideration have been identified. The responses to these items along with details of potential failure scenarios and safeguards identified in the study will further improve the design from a safety and operability perspective.
- the HAZID Study Team agrees that the Advanced Wing System installation subjected to the Risk Assessment meets the safety objectives and functional requirements and therefore ensures a level of safety and reliability.
- possible revisions can be performed in case of any significant modification that may affect the current analysis.

References

[1] RETROFIT55_D4.1_System Design and Layout

[2] RINA GUI015 “Guide for Risk Analysis”

[3] RINA GUI019 “Guide for Approval in Principle of Novel Technologies”

[4] RINA GUI023 “Guide for Failure Mode and Effect Analysis”

[5] RINA Rules for the Classification of Ships

Appendix 1

WP 4 – Wind Assisted Ship Propulsion
Task 4.2 – Risk assessment and mitigation (M1-M12)
D4.2 – Risk Assessment report
Partners involved: AWS, RINA, LASK, ATD, FSYS, SFD, NTUA

Wind Assisted Ship Propulsion (RETROFIT55)	
Project	Retrofit55
Node	**WP4 - T4.3 - D4.2**
Date	nov-23

Item/Activity	HAZID Guidewords	Hazards/Causes	Consequences	Safeguards/Control Measures	Risk Ranking S (P)	L	Risk	Recommendations Actions	Responsibility	Comments/Notes
1 Equipment	1.1 Equipment failures	1.1.1 Mechanical failure of the system	- Potential harm to crew onboard - Navigation limitations	- The actuating system will be equipped with a fail safe system preventing mechanical failure and emergency closing - Automatic audio and visual signal/alarm to emergency closing procedure in case of: potential loss of stability, heavy weather condition, ship's motions - Sensor for detection of wind gusts and accellerometers to calculate moment value will be installed on the sail mast in order to castantly control the system parameters - The actuating system will be integrated with the ship's automation system. This will include the possibility to share data through the systems and a software integration will be required.	C3	L3	Medium	1. Consider to include a fail safe procedures in the actuating system emergency action and closing procedures in case of failure		Fail safe procedures will orientate head to wind direction and will collapse the system when the acting force is out of a range for safe procedure.
					C2	L3	Low	6. Seakeeping analysis to be performed in order to evaluate a range of parameter for WASP safe operations		The seakeeping analysis will include: - A range of max wind speed for safe use of the system - The crash stop and turning effect as per seatrial - A time range for the system to respond to emergency ship's manoeuvring - The limitations to be added for ship motions
		1.1.2 Fall of equipment or components due to their breakage or mechanical failure caused by poor maintenance, corrosion in the marine environment, unsuitable materials.	- Potential harm to crew onboard	- Inspection and maintenance plan based risk approach during life time of the equipment - Use of the PPE is required for the crew operating in the system area - No extra PPE are required, base equipment already required for ship's operations are suitable for the use of WASP - To be analysed the reliability for the material throw the life cycle of the sail system	C3	L1	Low	2. Consider to develop a detailed procedure with clear instructions for equipment maintenance		
					C3	L1	Low	7. Crew and WASP operators should be aware of the correct use of PPE while operating the system		
		1.1.3 Overpressure on the hydraulic system	- Potential harm to crew onboard	- Automatic power reduction controlled by the actuating and automation system to avoid overpressure on the hydraulic system	C1	L2	Low	4. Consider to include a fail safe procedures in the actuating system including action to avoid overpressure in the system		Proposal for an electric motor is under consideration. The motor will be equipped with battery backup storage to react at any emergency scenario independently (idea also for solar panels). For the battery (actual proposal is phosphate type) a separate HAZID should be done and the p&id diagram will be provided.
					C1	L2	Low	5. Consider to develop a detailed procedure with clear instructions for the safe manual operation of the manual valves installed in the pressure reducing station.		
	1.2 Control System failures	1.2.1 Inability to operate and control the system	- Collision with other ships - Navigation error	- Provide emergency procedures to mechanically manoeuvre the system - Emergency mechanic procedure to collapse the system using own weight to pull down the sail and manually disengage the mast components - Control systems redundancy, including bridge	C2	L5	Medium	3. Consider scheduling periodic drills to simulate mechanical closing operation to the use of the WASP		
	1.3 Electrical System failures	1.3.1 Loss of power supply to the system or ship's blackout.	- Collision with other ships - Navigation error	- Emergency power supplier to be installed - Provide emergency procedures to mechanically manoeuvre the system	C2	L5	Medium	3. Consider scheduling periodic drills to simulate mechanical closing operation to the use of the WASP		
		1.3.2 Electrical fire	- Potential harm to crew onboard	-Short circuit water ingress overheating	C2	L5	Medium	8. Consider to develop a detailed procedure with clear instruction to inspect the system ensuring any possible material ingress into the system such as water, dust…, with regularly interval and anytime after ship/cargo operations		

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Wind Assisted Ship Propulsion (RETROFIT55)	
Project	Retrofit55
Node	**WP4 - T4.3 - D4.2**
Date	nov-23

Item/Activity	HAZID Guidewords	Hazards/Causes	Consequences	Safeguards/Control Measures	Risk Ranking			Recommendations		
					S (P)	L	Risk	Actions	Responsibility	Comments/Notes
2 Location	2.1 Location hazards	2.1.1 Fire outbreak on main deck which cause fire on the WASP system	- Potential harm to crew onboard	- Limited amount of combustible material on main deck - Limited amount of ignition sources - Ship's fire detection system - Ship's fixed fire extinguishing system	C3	L4	Medium	11. Ensure that any furniture items placed temporarily in the main deck have low flame spread characteristics.		
		2.1.2 Fire outbreak on the WASP system	- Potential harm to crew onboard	- System main dimensions causes difficulty to operate in case of fire. For this reason, a system closing operation has been added in the fire procedures - System material with low flame limit	C3	L4	Medium	12. Consider scheduling periodic drills to simulate fire scenarios related to the use of the WASP		
					C3	L4	Medium	13. Consider to add a procedure for closing the system before the fire system will start fire fighting operations with an emergency shutdown procedures which can be activated from the bridge		
				- Dedicated Portable fire extinguishers in most of the ship spaces surrounding the system -Dedicated Fixed fire system to be installed. No water/sprinkler, but it can be foam also with a "plug-in" solution	C3	L4	Medium	9. Dedicated fire extinguisher systems to be analysed and provide evidence of the safety and functionality of the fire fighting system		
		2.1.3 Potential explosion	- Potential harm to crew onboard	To be considered only for oil tankers, crude carriers, LNG, LPG and other chemical tankers in which ATEX standards have to be satisfied	C5	L2	High	14. Avoid ATEX zones		
					C5	L2	High	15. Gas detection system leading to alarms and automatic shut-down		
					C5	L2	High	16. ATEX requirements for all the electrical equipment		
	2.2 Navigation	2.2.1 Bridge visibility limitation	- Navigation limitations - Collision with other ships	- System design should take obstacle free the bridge visibility	C2	L2	Low	17. Possibility to install cameras to cover blind areas		SOLAS Regulation 22 - Navigational bridge visibility, should be followed as applicable
	2.3 Location interference	2.3.1 Interference with other systems	- Potential harm to crew onboard - Reduced visibility - Navigation limitations - Collision with other ships - Ships operation limitations	Risk of interference with ships systems to be avoided. This can include interference with: - Deck's outfitting's - Hatches - Walkways	C3	L3	Medium	18. Actions to be made during design phase in order to avoid interference and whenever it is possible to study modifications needed to the ship system		For this hazards focus on the test vessel has been made. Following a short brief of other possible ships category hazards: · Cruise / Ferry / Ro-Pax - Risk of interference: - Passengers area - Cars / trucks on deck · Tankers - Risk of interference: - Pipes on main deck - Ladders and passageways - Bunker station
				Risk of interference with ships port or cargo operation to be avoided. This can include interference with: - Cargo holds opening system - Cargo cranes manoeuvring - Containers positioning	C3	L3	Medium	19. Actions to be made during design phase in order to avoid interference and consider to develop a detailed procedures to safe cargo or port operations taking into account any possible interference with the WASP system		
		2.3.2 Interference with helicopter operational area	- Unsuccessful rescue - Potential harm to crew onboard	- Helicopter operational area to be kept obstacle free. Depending on the WASP placement location , wing sails might be an obstacle or not.	C3	L3	Medium	20. Actions to be made during design phase in order to keep obstacle free the helicopter operational area as per rules and regulations requirements		Helicopter landing area only for ferry ships, other ships type (ex. cruise) a pickup area (winch only) is required - CAP437 "Standards for offshore helicopter landing areas"

Wind Assisted Ship Propulsion (RETROFIT55)										
Project		Retrofit55								
Node		**WP4 - T4.3 - D4.2**								
Date		nov-23								
Item/Activity	**HAZID Guidewords**	**Hazards/Causes**	**Consequences**	**Safeguards/Control Measures**	**Risk Ranking S (P)**	**L**	**Risk**	**Recommendations Actions**	**Responsibility**	**Comments/Notes**
3 Environment	3.1 Ambient conditions	3.1.1 Low temperature. Accumulation of ice on the ship structure in the vicinity of the system area	- Potential harm to crew onboard	- WASP system not allowed to use when low temperature with ice accretion are foreseen	C2	L3	Low	21. Develop an operational procedure specifying under which weather and sea conditions the use of the WASP can't be allowed.		
		3.1.2 Low temperature. Formation of ice on the WASP system	- Potential harm to crew onboard	- WASP system not allowed to use when low temperature with ice accretion are foreseen	C1	L4	Low	6. Seakeeping analysis to be performed in order to evaluate a range of parameter for WASP safe operations		For seakeeping analysis see comment to hazard 1.1.1
					C1	L4	Low	22. Consider to provide instruction to close the system if the temperature decrease rapidly and analyse possible issue to close the system in case of icing		May affect vessel's stability, see HAZARD 6.1.2
	3.2 Weather conditions	3.2.1 Lost of manoeuvrability	- Persons falling overboard - Collision with other ships	- WASP system not allowed to use when heavy weather conditions are foreseen	C2	L3	Low	6. Seakeeping analysis to be performed in order to evaluate a range of parameter for WASP safe operations		
		3.2.2 System failure consequent to heavy weather conditions	- Potential harm to crew onboard - Collision with other ships - Navigation error	- Automatic audio and visual signal/alarm to emergency closing procedure in case of: potential loss of stability, heavy weather condition, ship's motions - WASP system not allowed to use when heavy weather conditions are foreseen - Lightning protection system to be installed on top of the mast	C2	L3	Low	6. Seakeeping analysis to be performed in order to evaluate a range of parameter for WASP safe operations		For seakeeping analysis see comment to hazard 1.1.1
4 Operations	4.1 System operations	4.1.1 System operation limitations	- Potential harm to crew onboard - Persons falling overboard - Collision with other ships - Navigation limitations	- Potential lack of stability during WASP operations - Evaluate possible licence or certificate to be required by the crew to be involved to the use of the WASP system - To be programmed a training period to each crew member to be involved to the use of the WASP system	C3	L4	Medium	23. Consider scheduling periodic drills to simulate WASP operations		
		4.1.2 System parameters control limitations	- Potential harm to crew onboard - Persons falling overboard - Collision with other ships	- Continuous monitoring of parameters - Monitoring systems redundancy, including bridge - To be integrated with ship's automation system	C2	L3	Low	24. Ship's automation software's should be updated in order to be integrated with the WASP system		
		4.1.3 High/Low temperature	- No significant causes identified							
	4.2 Ships operations	4.2.1 Narrow water	- Reduced visibility or no visibility from bridge causing potential harm to personnel and/or grounding	- Use of WASP system should be limited in narrow waters	C3	L4	Medium	10. Consider to develop a list of navigational area not allowed to the use of the system, such as ports, narrow water and maritime congested area		
					C3	L4	Medium	25. Consider to develop an operation procedures for narrow waters		
		4.2.2 Night operations	- Reduced visibility or no visibility from bridge causing potential harm to personnel and/or grounding	- Constant monitoring of radar e navigational equipment during night hours	C3	L4	Medium	26. Ensure that the working area is adequately illuminated to allow safe operations and that the lighting system is redundantly powered from the ship's emergency power source		
		4.2.3 Cargo load/unload operations	- Potential harm to crew onboard	- WASP system closed and stored during cargo operation, no test or maintenance are allowed - To minimise the build up of loose cargo on the system. WASP container and marked during cargo operation in order to highlight at cargo operators to avoid the area - Prevention of dust ingress by housing design - The housing should resist damage of the system due to cargo spillage	C2	L5	Medium	8. Consider to develop a detailed procedure with clear instruction to inspect the system ensuring any possible material ingress into the system such as water, dust..., with regularly interval and anytime after ship/cargo operations		
		4.2.4 Reaching ports and costal area	- Potential harm to crew (injuries and persons falling overboard due to ship motions and accelerations caused by waves or swell)	- WASP system to be closed and stored in safe area and anytime before to reach ports or navigations in costal area	C3	L4	Medium	10. Consider to develop a list of navigational area not allowed to the use of the system, such as ports, narrow water and maritime congested area.		

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Wind Assisted Ship Propulsion (RETROFIT55)

Project	Retrofit55
Node	**WP4 - T4.3 - D4.2**
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Item/Activity	HAZID Guidewords	Hazards/Causes	Consequences	Safeguards/Control Measures	Risk Ranking S (P)	L	Risk	Recommendations Actions	Responsi bility	Comments/Notes
		4.2.5 Dynamic Positioning (DP) System in operation or DP malfunction during the use of the WASP causing unexpected movements and high accelerations of the ship	- Potential harm to crew onboard - Persons falling overboard	- Not allowed simultaneous	C2	L3	Low	27. This scenario is considered as not credible as the use of the DP System of the ship simultaneous with the system is not planned and it will be not allowed		Further studies will analyse if the WASP system may be able to be used to improve DP
		4.2.6 Operation in close proximity to other vessels	- Potential harm to crew onboard - Collision with other ships		C3	L4	Medium	10. Consider to develop a list of navigational area not allowed to the use of the system, such as ports, narrow water and maritime congested area.		
		4.2.7 Lost of manoeuvrability	- Persons falling overboard - Collision with other ships		C2	L3	Low	6. Seakeeping analysis to be performed in order to evaluate a range of parameter for WASP safe operations		
		4.2.8 Air draft limitations	- Navigation limitations	- Before to sail, while planning the route, evaluate any possible restriction for air draft limitation such as bridges or natural obstacle - In case of any route deviation, a new evaluation for the air draft limitation should be made as soon as possible and in case of new limitation founded, the system shell be closed and stored	C2	L2	Low	28. Include in the operations for planning the navigation route a control measure to ensure any possible air draft limitations on the planned route		
5 Structures	5.1 Structure failure	5.1.1 System structure failure	- Potential harm to crew onboard	- Undertake preliminary structural calculation with combinations of environmental and ship loads. - All the possible failure modes should be analysed	C2	L5	Medium	29. Provide evidence of structural calculation with combinations of environmental and ship loads		
		5.1.2 Ship structure failure	- Potential harm to crew onboard	- Undertake preliminary structural calculation with combinations of environmental and system loads. - All the possible failure modes should be analysed - Fatigue analysis	C2	L5	Medium	30. Class approval in principal will have a dedicated section on structural calculations		
					C2	L5	Medium	31. Modular systems will be proposed for approval. Structural calculations will include combinations of solutions including system supported by deck webs / girders cross or structural bulkheads below the deck.		
6 Stability	6.1 Intact stability	6.1.1 New load conditions calculation and effect on the vessel's stability booklet	- Potential harm to crew onboard - Navigation limitations	- All load conditions to be analysed due to new CoG position and weight with WASP closed and in use - New load conditions should include max heeling moment due to WASP in operation condition - Lost of cargo due to heel analysis to be included in new SIB	C3	L5	High	32. Consider to develop an update of the Vessel's SIB to include WASP system operation and weight added.		- 2nd generation of intact stability requirements to be evaluated - The WASP may offer dynamic stability control to reduce the impact of the system on intact stability
		6.1.2 Weather condition which may affect vessel's stability	- Potential harm to crew onboard - Navigation limitations	- Vessel's SIB to be updated with new loading conditions with ice accretion on WASP system	C2	L3	Low	6. Seakeeping analysis to be performed in order to evaluate a range of parameter for WASP safe operations		For seakeeping analysis see comment to hazard 1.1.1
	6.2 Damage stability	6.2 WASP system possible effect on damage stability	- Potential harm to crew onboard - Navigation limitations	- Damage stability analysis will be performed in order to evaluate possible effect on ship damaged condition	C3	L3	Medium	33. Consider to performed analysis in order to evaluate possible effect on ship damaged condition		
7 Materials	7.1 Flammable materials	7.1.1 WASP system material	- Potential harm to crew onboard	- Design the sails of a less flammable material - Leaks in the hydraulic system can be avoided with the use of an electric motor - The lithium iron phosphate battery (LiFePO4 battery)	C3	L4	Medium	12. Consider scheduling periodic drills to simulate fire scenarios related to the use of the WASP		For the battery separate HAZID to be done with the p&id diagram
	7.2 Toxic materials	No hazardous scenarios identified as toxic materials are not present								
	7.3 Corrosive materials	No hazardous scenarios identified as corrosive materials are not present								
	7.4 Inerts	No hazardous scenarios identified as inerts are not present								

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Item/Activity	**HAZID Guidewords**	**Hazards/Causes**	**Consequences**	**Safeguards/Control Measures**	**Risk Ranking**			**Recommendations**		
					S (P)	**L**	**Risk**	**Actions**	**Responsibility**	**Comments/Notes**
8 Operational hazard	8.1 Design phase	8.1.1 Operations hazards	- Potential harm to crew onboard - Persons falling overboard - Collision with other ships	- Provide emergency procedures to prevent potential harm to the crew and potential crew errors related to WASP operations - Evaluate possible licence or certificate to be required by the crew to be involved to the use of the WASP system - To be programmed a training period to each crew member to be involved to the use of the WASP system - Sensor to be installed for monitoring the system and evaluate maintenance requirement	C3	L4	Medium	23. Consider scheduling periodic drills to simulate WASP operations		
					C3	L4	Medium	34. Design system redundancy in order to minimize the maintenance		
					C3	L4	Medium	35. Develop a procedure to the use of the PPE		No particular requirements for extra PPE. Sail climbing not allowed
					C3	L4	Medium	36. System actuators and automation should be designed with high level of automatic software control in order to minimize human error		
		8.1.2 Non-durability of the system life cycle	- Potential harm to crew onboard	- Inspection and maintenance plan based risk approach during life time of the equipment - System design will include a life cycle optimization	C2	L4	Medium	2. Consider to develop a detailed procedure with clear instructions for equipment maintenance		
		8.1.3 Inefficient Maintenance	- Potential harm to crew onboard	- Specific procedures in order to facilitate maintenance - Design adequate space to system's equipment to performed maintenance	C2	L3	Low	2. Consider to develop a detailed procedure with clear instructions for equipment maintenance		Most of the maintenance can be done not onboard. Easy WASP container replacement

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