

**Safety Analysis of an
Autonomous Mooring
System Using STPA: A Use-
Case Demonstration for
Risk-Based Approval**

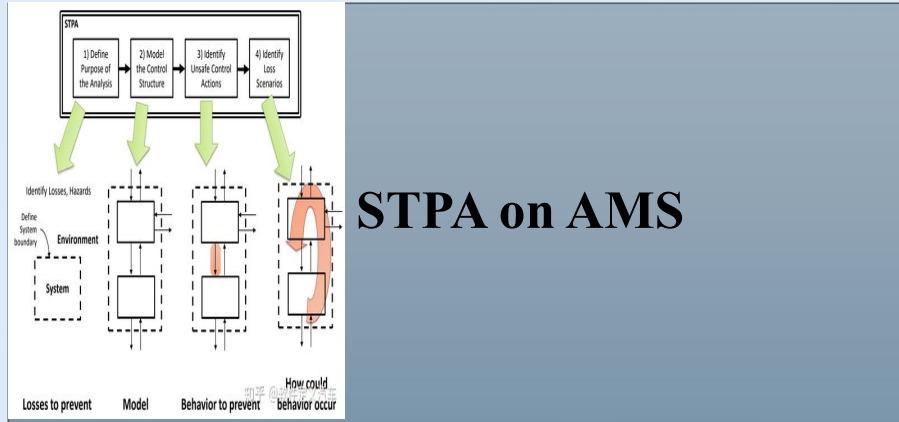


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Research Project: *SEAMLESS* (EU
Horizon Project)



Contents



STPA on AMS



Purpose of the analysis



Challenges



Big picture Solution and Summary

Autonomous Mooring System

General description

Robotic arm

4 bollards

Winch control system

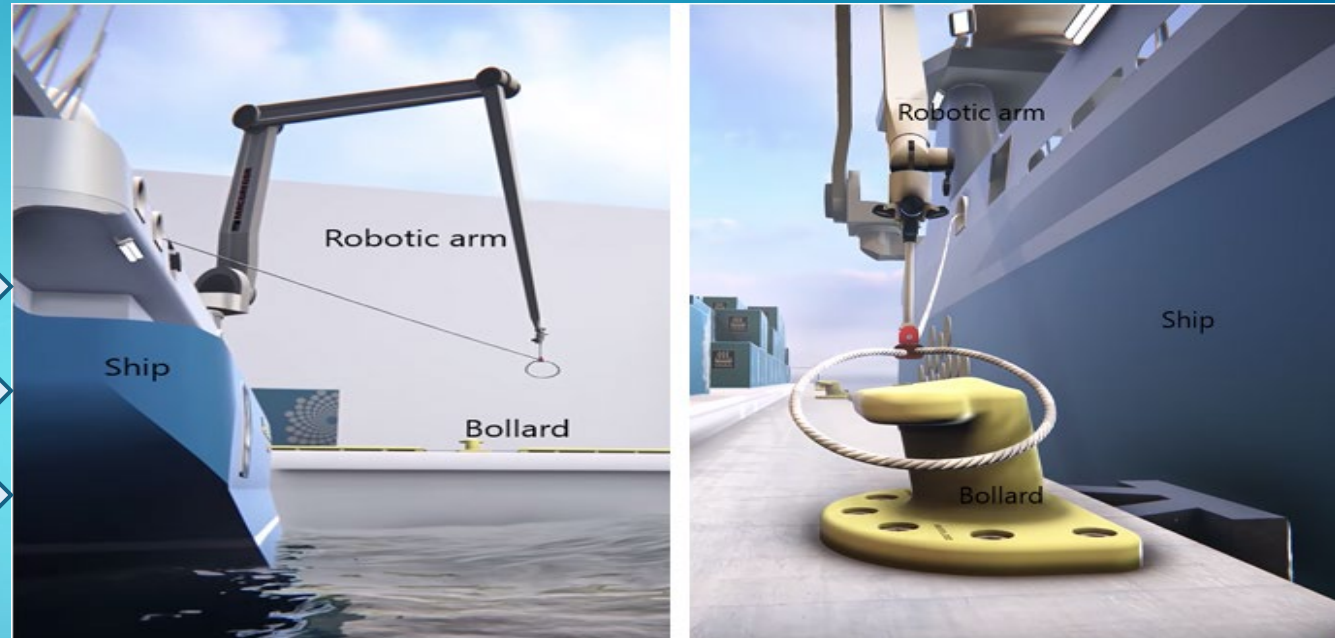


Figure: MacGregor robotic arms-based mooring system

STPA

Step 1

Losses

1. Loss of properties or infrastructure
2. Loss of time

System-level hazards

H-1: The vessel does not maintain a safe distance from nearby objects. [L-1, L-2]

H-2: Robotic arms can not fasten the mooring lines. [L-1, L-2]

System-level constraints

SC1: The vessel must maintain a safe distance from nearby objects.

SC2: Robotic arms should fasten the mooring lines.

SC3: Robotic arms should fasten the mooring lines on the appropriate bollards.

Step 2

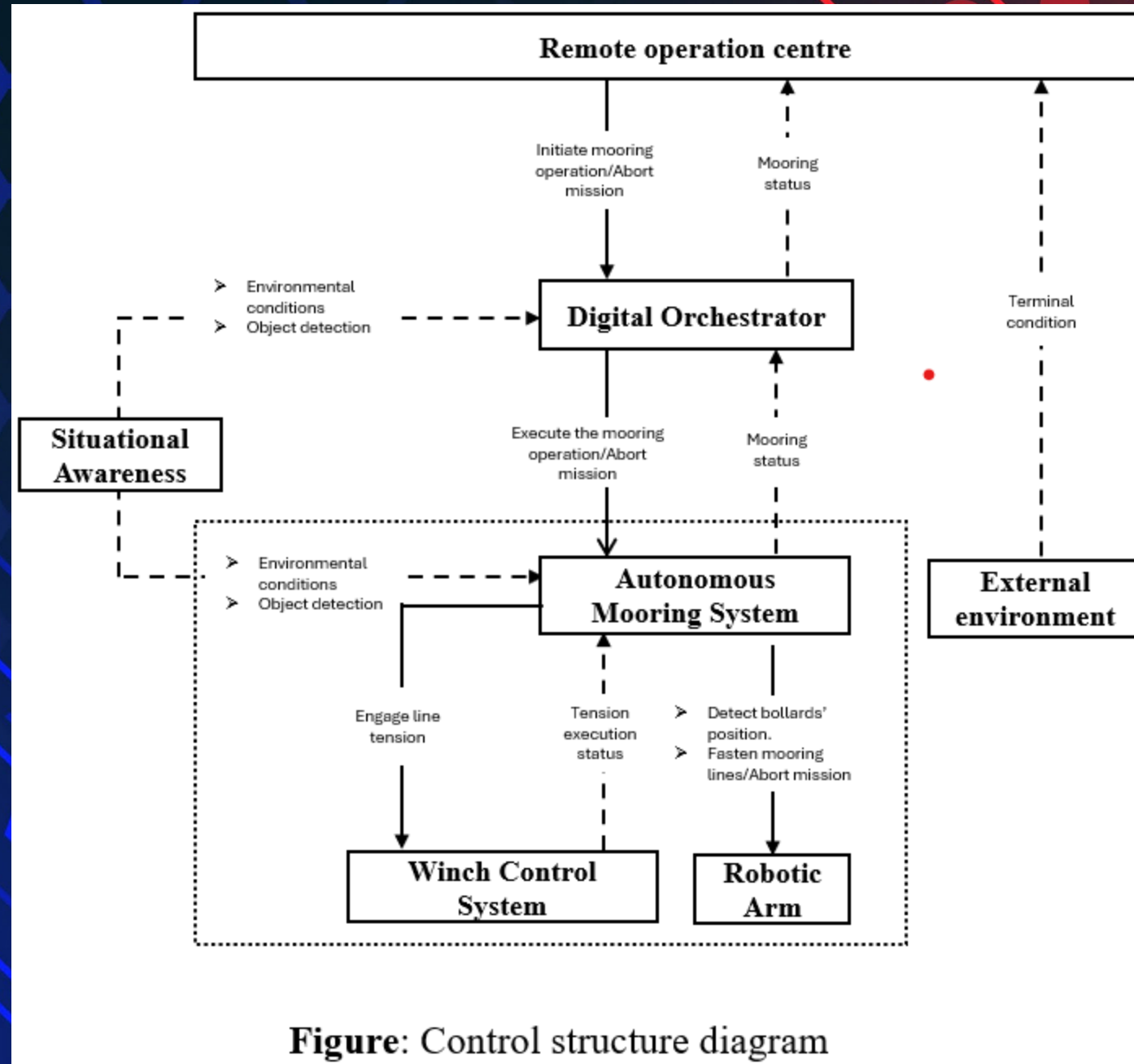


Figure: Control structure diagram

Step 3

Unsafe control actions: **16**

Controller	Control action	No of UCAs	UCAs ID with hazards
ROC	Initiate mooring operation	3	UCA1 (H-2), UCA2 (H-1,2), UCA3 (H-2)
DO	Execute the mooring operation	4	UCA4 (H-1,2), UCA5 (H-1,2), UCA6 (H-1,2), UCA7 (H-1,2)
AMS	Detect bollard's position	3	UCA8 (H-1,2), UCA9 (H-1,2), UCA10 (H-2)
	Fasten mooring lines	5	UCA11 (H-2), UCA12 (H-1,2), UCA13 (H-1,2), UCA14 (H-1,2), UCA15 (H-1,2)
	Maintain line tension	1	UCA16 (H-1,2)

Example: (UCA-12)
AMS provides the Fasten mooring lines action before detecting the appropriate bollard.
[H-1, H-2]

Step 4

Loss scenarios: 64

UCA 12 \rightarrow 4 LSs

Unsafe
control
behavior

Unsafe
feedback
path

Unsafe
control
path

Unsafe
controlled
process
behavior

Purpose



Challenges



Challenges



Challenges



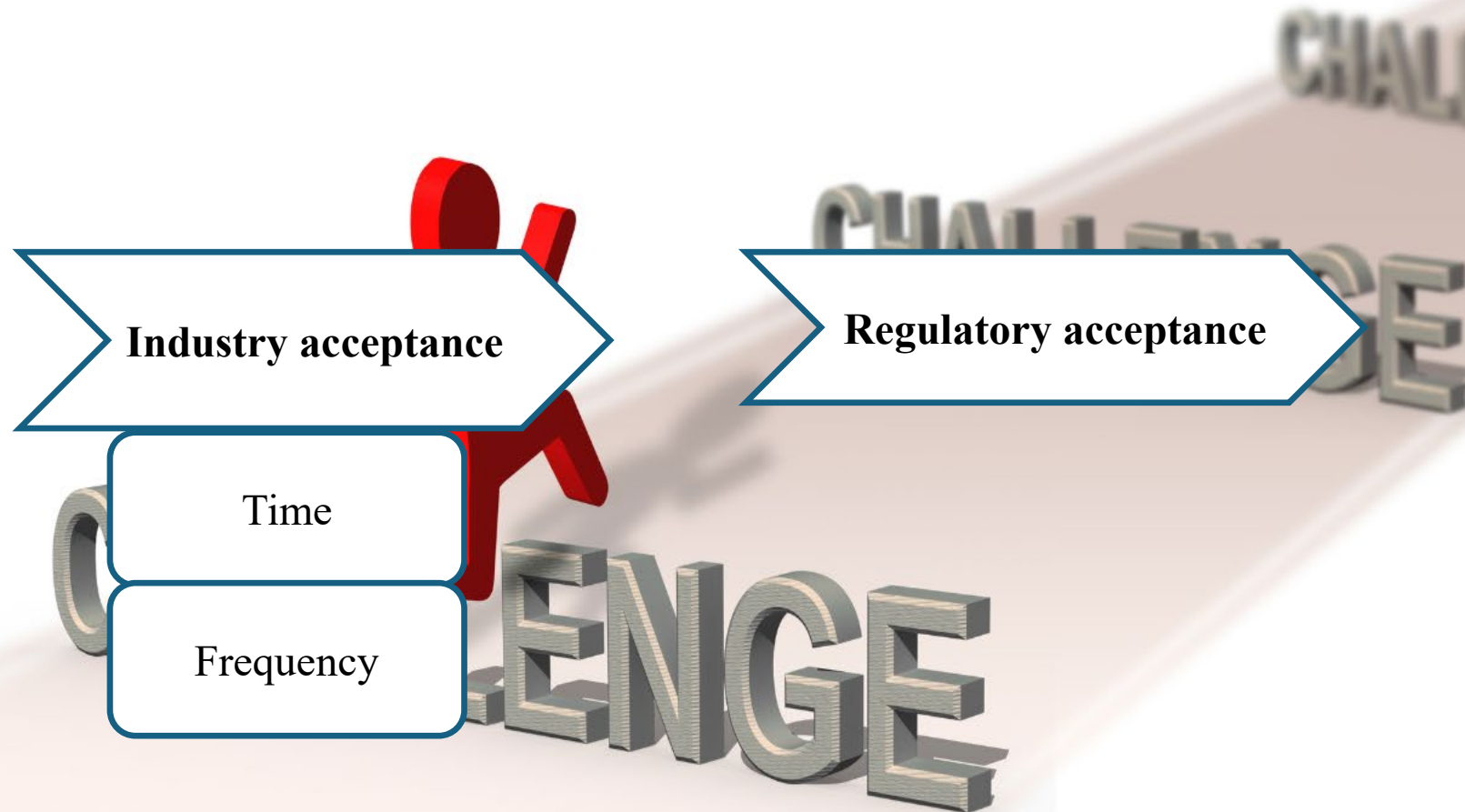
Industry acceptance

Regulatory acceptance

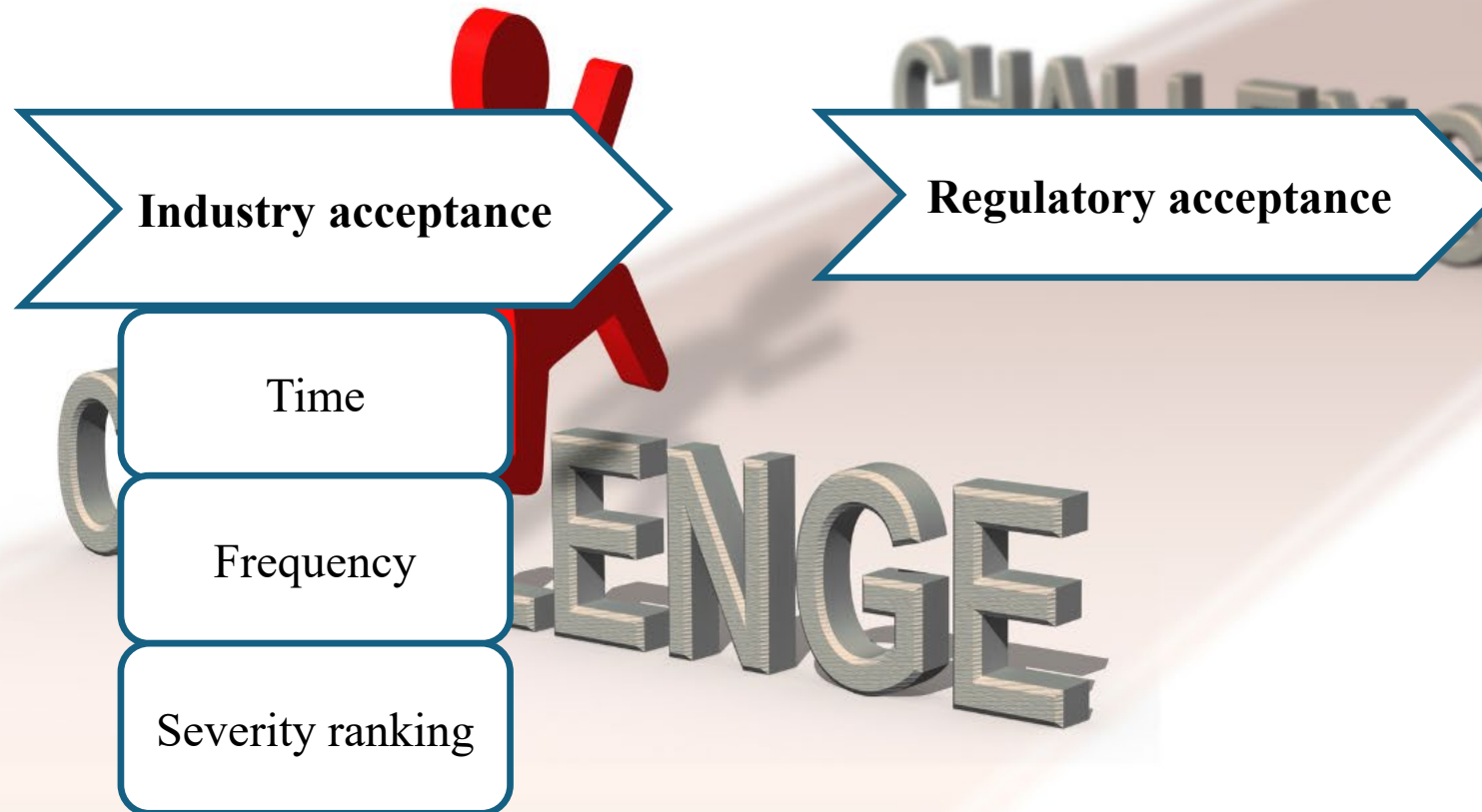
Challenges



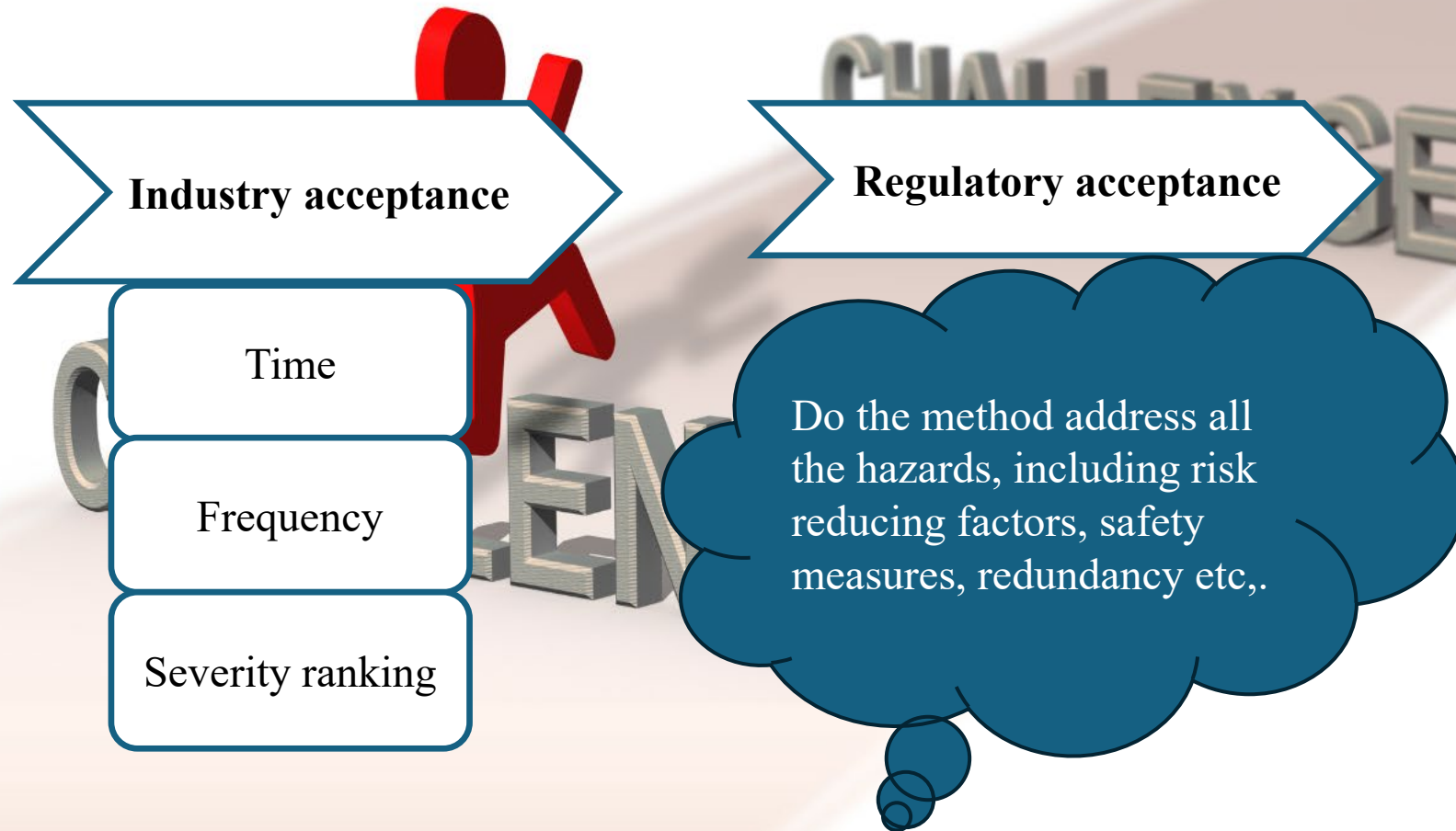
Challenges



Challenges



Challenges



Big picture, Solution and Summary

Use of
MBSE

CONOPS

Safety case

Test case

STPA

Safety case

Claims

Arguments

Evidence

“AMS does not provide the Fasten mooring lines action before detecting the appropriate bollard” is correctly and completely enforced by the system design.

How this safety constraint is violated and requirement refinement support this claim.
«The AMS shall validate bollard detection inputs before enabling the “Fasten mooring lines” action»

System model, Safety analysis, Test cases outcomes, operational experience.

UCA

Loss
Scenario



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