Standards for handling Controllable Pitch Propeller failures

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Abstract

The maritime industry follows strict regulations which stipulate standards on ships and their crew, but preparedness in handling system failures stands out in its absence from said legislations. One of the more serious system failures is a Controllable Pitch Propeller failure, which renders the ship unable to steer and/or to effectively regulate her speed. While researching international regulations it is even discovered that audible alarms for this fault are not a requirement by what is accepted as the most important maritime regulation for safety, the Safety of the Life at Sea convention.

When investigating several accident reports, it appears that the bridge teams are not adequately trained to properly handle a situation where a CPP is failing. This lack of training results in severe damages and injuries. To establish how current training legislations prepare Officers of the Watch to handle such failures, this study examined a group of maritime students' performances during a simulated CPP-failure scenario. The students were then questioned about their thoughts of their performances. They appear to understand the failure, but lack the training to rectify the situation under the pressure.

It appears that current maritime regulations contain an oversight within this area. This can cause easily fixable problems to escalate into a disaster.

Language: English Key words: CPP, failure, STCW, training, SOLAS

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Abstrakt

Sjöfartsindustrin följer strikt lagstiftning som stipulerar standarder på fartyg och dess personal, men färdigheter att hantera systemfel sticker ut med dess frånvaro från sådan lagstiftning. Ett av de allvarligare systemfelen är fel i bladstigningen i propellrar med ställbara blad, vilket orsakar fartyget en oförmåga att styra och/eller effektivt kontrollera dess fart. Under djupare granskning av lagstiftelser upptäcks det även att ett sådant fel inte behöver vara utsatt med ljudlarm i vad som uppfattas vara den viktigaste säkerhetsföreskriften i industrin, d.v.s. Safety of the Life at Sea konventionen.

När olika olycksrapporter granskas, verkar brygg-teamets oförmåga att hantera ett sådant systemfel vara ett problem, vilket förorsakar skador på material samt människor. För att undersöka hur nuvarande lagstiftning förbereder styrmän till att hantera ett sådant systemfel, testas sjöfart studerande i en simulerad CPP-fel situation. Efteråt berättar de om deras egna åsikter gällande deras prestation. Studeranden verkar ha förståelse i systemfelet, men saknar praktisk träning att lösa situationen under stress.

Det verkar finnas en översikt i lagstiftningar mellan normalläge och katastrof. Detta kan orsaka lätt lösbara problem att utvecklas till katastrofer.

Språk: Engelska Nyckelord: CPP, failure, STCW, training, SOLAS

Contents

Abbreviations and Glossary

CPP	Controllable Pitch Propeller
Crash Stop	To slow a vessel down as quickly as possible using its propulsion
ECR	Engine Control Room
GT	Gross Tonnage, a volumetric measurement of ships size
IMO	International Maritime Organization
MAIB	Marine Accident Investigation Branch, body of the UK government
nm	Nautical Mile
OOW	Officer Of the Watch
Pier Roundhead	A large, rounded fender at the end of a pier
SMS	Safety Management System
SOLAS	Convention for the Safety Of Life At Sea
STCW	International Standards of Training and Certifications and Watchkeeping

1 Introduction

Nearing the end of my studies in maritime management and holding Officer Of the Watch (STCW II/1) certificates since 2018, with a specific interest for the offshore sector, I attended the Dynamic Positioning course in Tallinn 2022. During this course, I couldn't help but observe that our class of one container ship OOW, one former Navy officer now studying merchant shipping, both Estonian, and me, Finnish, hadn't received any previous training regarding the handling of malfunctioning propulsion. This struck me as odd since main engine emergency shutoff switches exists on every bridge, and every OOW knows of these buttons and their locations, but I couldn't recall them ever being mentioned in school or onboard.

A week before that I was working as the chief officer of a ferry. There I had a conversation with a coworker about the grounding of M/S Amorella, which was instigated by one of the CPP propellers malfunctioning. Our conclusion was something along the lines of "the bridge team was lucky that the camera astern clearly showed the propeller creating reverse thrust, easing their personal responsibility for the accident as it was clearly caused by a mechanical failure".

The Dynamic Positioning course focused on reacting rapidly against exactly these types of malfunctions, and I couldn't help but think that had either of us received this training before, the rhetoric would instead have been "This might have been avoided through the emergency stopping of the malfunctioning propeller". As I begun to research this subject, I discovered that there is virtually no mentioning of propulsion malfunctions in the regulations other than a complete loss. This is when I realized this research should be made into a thesis.

1.1 Preparatory research

By studying international maritime regulations, it could be determined to which extent the current regulations require officers to be trained in managing these situations, and what bridge equipment they are provided to help them restore a state of safe navigation. Accident reports related to malfunctioning CPP systems served to find out how some officers are reacting to situations like this in practice and served as tools to create a realistic and fair simulated scenario for the testing of maritime students.

1.2 Research motive

The intention with this research is to induce a thought about improving maritime regulations so that OOW become better equipped to handle a CPP failure. This would ensure the continued safe operation of the vessel until it is in a suitable circumstance to diagnose and resolve the underlying problem.

1.3 Research Question

Do current international maritime training regulations require officers to be trained to handle CPP failures? Following only minimum requirements, what systems are currently provided to watch officers to aid them in identifying and rectifying a CPP failure? And is there at all a need to implement more stringent regulations regarding CPP failures?

1.4 Research Limitations

This research is limited to maritime management (Captain, 3rd year) and operational (Officer of the Watch, 2nd year) students at the very end of their semester. The simulator system used had some limitations, as it appeared to not be built to perform these types of simulations. What these limitations were and how they were worked around will be explained in 4.2.

2 Theoretical Starting Points

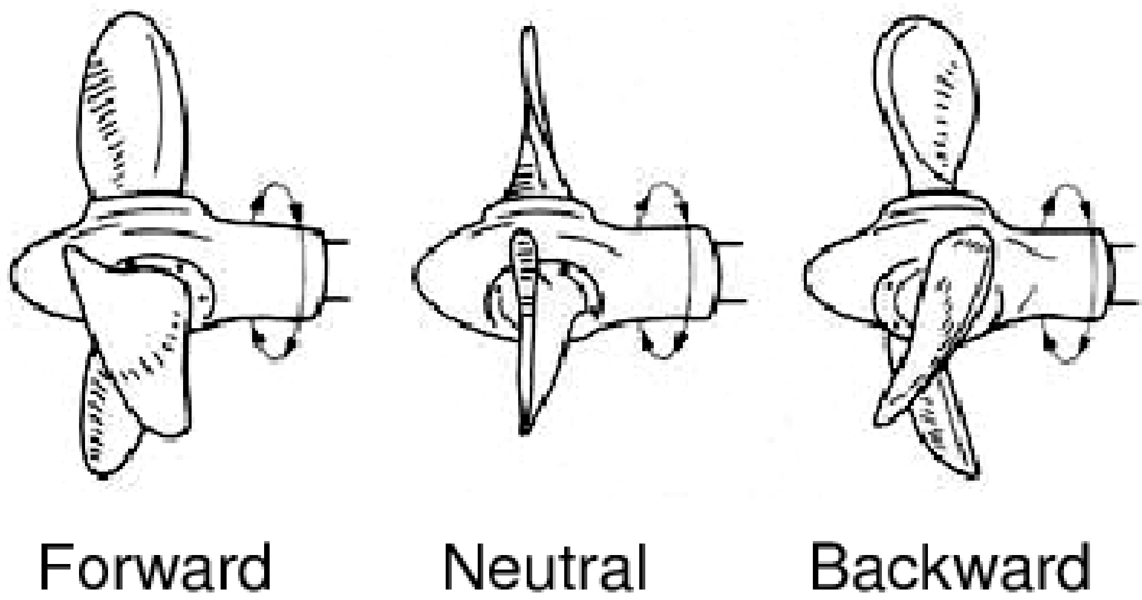

Figure 1, Controllable Pitch Propeller

Controllable pitch propellers produce thrust the same way conventional “fixed” propellers do. Where they differ is how they regulate the amount and direction of thrust. On CPPs the propeller blades themselves change their angle of attack relative to their travel through water (see Figure 1), while the direction and rotation of the propeller remains constant. This system is beneficial in providing more precise and rapid adjustments of thrust especially while maneuvering. As a result, the controllable pitch propeller has increased in popularity over the past 40 years to hold a 35% share of the maritime propeller market (Carlton, 2012). It is especially popular on passenger carrying vessels (Carlton, 2012).

2.1 CPP Failure

Since the CPP is electronically controlled and hydraulically actuated, there are multiple points of failure between the telegraph and the CPP. When a CPP fails, it will either be stuck in its current position, change to its default position, which can be anywhere between full ahead to full astern depending on the specific model (Maritime Cyprus, 2021), or change to a completely random position. These types of failures will cause a severe degradation in the ships handling if they aren’t stopped promptly, not only in its speed but also its steering, as will be seen in chapter 3.

2.2 Mechanical consequences of an emergency stop

To confirm that an emergency stop wouldn't do more damage than it can prevent, an Aboa Mare lecturer of maritime engineering was consulted regarding what mechanical consequences an emergency stop or emergency clutch-out would have on a ships propulsion system and power plant. They assured that an emergency stop under load won't lead to any issues, but an emergency clutch of the propeller could possibly lead to the engine over speeding due to the sudden loss of resistance. This information was confirmed in the engine room simulator on multiple types of machinery, where all engine values remained within safe levels in both situations. We concluded that an emergency stop is essentially not much different from shutting down the main engine under normal conditions.

2.3 SOLAS equipment requirements

In response to the 1914 M/S Titanic disaster, the International Safety Of Life At Sea (SOLAS) convention was formed. SOLAS is regarded as the most important international treaty regarding the safety of ships. It specifies the minimum standards of the construction, equipment, and operation of a ship. (IMO, 2019)

SOLAS chapter II-1 regulation 31 "Machinery controls" together with regulation 49 "Control of propulsion machinery from navigation bridge" stipulate that the main machinery for propulsion must have an emergency stop button on the bridge, which is completely independent from the bridge control system. The bridge must also be equipped with indicators for the pitch and rotational speed of the propellers, with an alarm if the remote system fails. "Alarm" has no definition by SOLAS. (SOLAS, 1974)

2.4 STCW convention

The STCW Convention sets the international qualification standards for seagoing personnel. Adopted by the International Maritime Organisation in 1978, it has since had two major revisions, the first in 1995 and the second in year 2010. (IMO, 2019)

The Convention divides requirements up by using a code of numbers. Each requirement starting with the roman number II applies to the deck apartment, and the number after it defines rank. In this study the focus was on: II/1, Officer in Charge of Navigational Watch on Ships of 500 Gross Tonnage or more, and II/2, Master and Chief Mate 500 Gross Tonnage or more.

2.5 STCW Code

The STCW code is a list of requirements implemented by the Convention (STCW Manila 2010, 2023). The code serves to prevent issues stemming from differing interpretations. It does so by dividing the rules into Part A and Part B. (IMO, 2019)

Part A covers the mandatory competence each rank shall possess. In plain language, every sailor shall be able to demonstrate knowledge in everything stated in part A of their STCW rank. Part B serves as recommended guidelines for how the convention wishes training to be caried out by its parties. (STCW Code, 2023) Whether a rule is mandatory or recommended guidance can therefore be identified by its numbering. If it is e.g., A-II/1, it covers mandatory competences for an OOW.

In Part A chapter II Table A-II/1 Emergencies are mentioned, but these are limited to aftermath of accidents like *"grounding, collision, man overboard, protecting passengers and aiding other vessels in distress"* (STCW Code, 2023). No mentions of engine malfunctions are made in the A-II/1 section.

Part A chapter II Table A-II/2 does mention *"The type and scale of any problem is promptly identified and decisions and actions minimize the effects of any malfunction of the ship's systems"* (STCW Code, 2023). However, as problems with the vessels thrust (except "emergency towing") is not listed as required knowledge, it can be assumed that this does not extend to a malfunctioning CPP system. Unlike some other listed requirements, simulator runs aren't mentioned as a method to demonstrate competence of this requirement.

Part B part B-II/1 (also applies to II/2) does mention the following:

Point 11.8:

"*11. A candidate for certification who is required to have received special training and assessment of abilities and skills in navigational watchkeeping duties should be required to provide evidence […] that the skills and ability to perform as officer in charge of a navigational watch in at least the following areas have been acquired, namely to: […]*
.8 initiate action to be taken in event of malfunction or failure of major items of equipment or plant (e.g., steering gear, power, navigation systems)". (STCW Manila 2010, 2023)

This is a recommendation on how a training institute may comply with the requirements of the Convention, it can be interpreted that its guidance is limited to the competences stipulated in Part A chapter II.

3 Theoretical Background

To determine the consequences potentially caused by the lack of regulations regarding the training of crew in the matter of CPP malfunctions, several relevant accident reports were investigated. The UK Governments Marine Accident Investigation Branch proved a particularly valuable resource for information.

Finding publicly available accident reports was challenging and relied mostly on finding one reliable report from a list of google results and browsing through its “similar incidents” report numbers to find further reports. Some reports referenced by news articles weren’t found even by searching the reports full title, number, and its authors’ name. It appears as if there are case reports which are not made public.

3.1 Hebrides grounding

On the 25th of September 2016, the crash stopping ro-ro passenger ferry Hebrides of 99.4m LOA with 45 passengers and 32 crewmembers onboard, passed its berths pier roundhead at 8 knots speed, after which it collided with nearby mooring pontoons and finally grounded with 5 knots of speed. Soon after grounding, it started to move astern, running over the pontoons once more, and eventually made hard contact with the pier. After this it reversed out to more open waters, and after about 20 minutes returns to make a safe controlled landing alongside its berth. Luckily, the damages were merely material. (Marine Accident Investigation Branch, 2017)

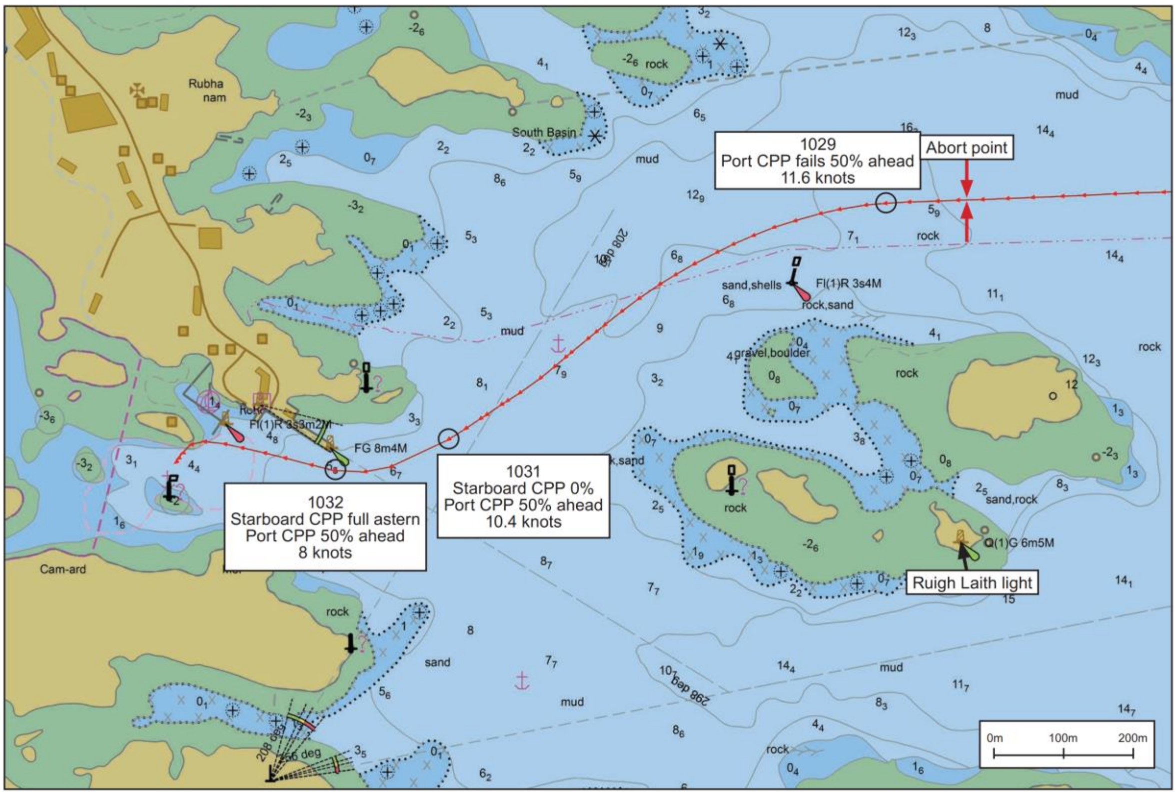

Figure 2, Approach to Lochmaddy

Leading up to this incident, the master, chief officer, second officer and third officer were on the bridge preparing for the upcoming landing and cargo operation at Lochmaddy quay. The master and the third officer were on navigational watch. At 10:29 the master transferred the controls of the vessel to the port bride wing console and reduced the pitch of both CPP to 40% ahead. At this time, the electrical device controlling the pitch lever in the engine room for the port propeller failed because a locking pin about the size of an air-gun pellet had been incorrectly installed. This resulted in the port CPP becoming stuck at 50% ahead, which went unnoticed by the crew. (Marine Accident Investigation Branch, 2017)

10:31 the master places the port CPP to 70% astern, presumably to decelerate and turn the vessel to port in preparation for reversing to the quay ramp. He notices that his speed isn't reducing, and soon after the third officer informs him that the port CPP indicator still shows 50% ahead. The master reacts by immediately ordering both CPPs full astern. This causes the vessel to turn starboard, as the actual thrust is starboard 100% astern; port 50% ahead. At this point, the vessel is 200m from the pier roundhead. (Marine Accident Investigation Branch, 2017)

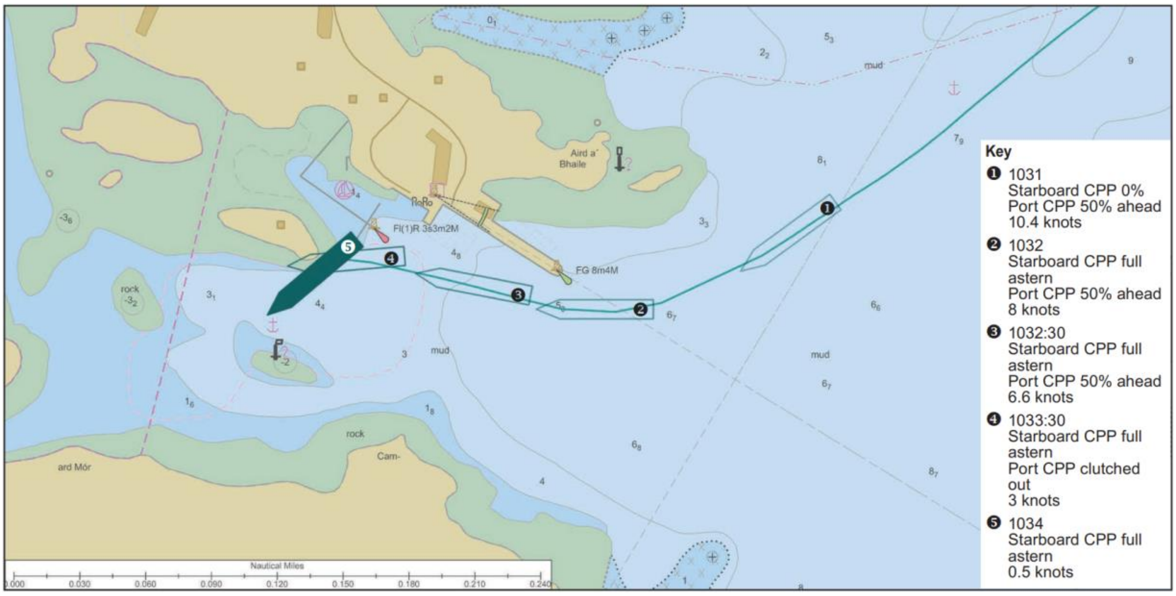

Figure 3, Hebrides track after loss of control

10:32, as the Hebrides passes the roundhead, the third officer prompts the master to de-clutch the port propeller, but this proves unsuccessful. A minute later, 10:33:30, this issue is solved, and the propeller clutched out. It was however too late, and the vessel ran over the nearby yachting clubs' pontoons and grounded itself. (Marine Accident Investigation Branch, 2017)

Post grounding, the master leaves the starboard CPP to 100% astern, causing the Hebrides to break free, reversing over the pontoons once more. The master ran to the port wing console and took the control there, attempting to land the ferry at the quay. As the vessel closed in alongside the pier, he re-engaged the clutch to the port CPP, causing the vessel to gain a headway of 3 knots. He became reluctant to the attempt and de-clutched the port CPP once more, after which the ferry made heavy contact with the piers fendering. The master manoeuvred the vessel out to safe water, where the crew inspected for damages to tanks. After none were found, the master safely landed the Hebrides using only the starboard CPP. (Marine Accident Investigation Branch, 2017)

The MAIB concludes:

"*The master's actions were focused entirely on countering the effects of the pitch of the port CPP remaining at 50% ahead rather than eliminating the problem. The options of switching to the emergency pitch control system then de-clutching the port engine were not instinctive and were overlooked at this stage*." (Marine Accident Investigation Branch, 2017)

and:

"*Hebrides's bridge and ECR teams were not sufficiently prepared or practised to deal quickly and effectively with the loss of pitch control in the confined waters of Lochmaddy. […] It is likely that these measures would have made initial actions to regain control more instinctive, helped to identify the communication problems between the bridge and the engine room and given the master more confidence in the use of reversionary methods of pitch control*." (Marine Accident Investigation Branch, 2017)

3.2 Amorella grounding

The 20th September 2020 passenger ferry M/S Amorella of 169m LOA was approaching a very narrow section of the archipelago fairway from Turku to Mariehamn. The bridge was manned by one Pilot, one Officer of the Watch and one lookout. (Onnettomuustutkintakeskus, 2021) (in Swedish)

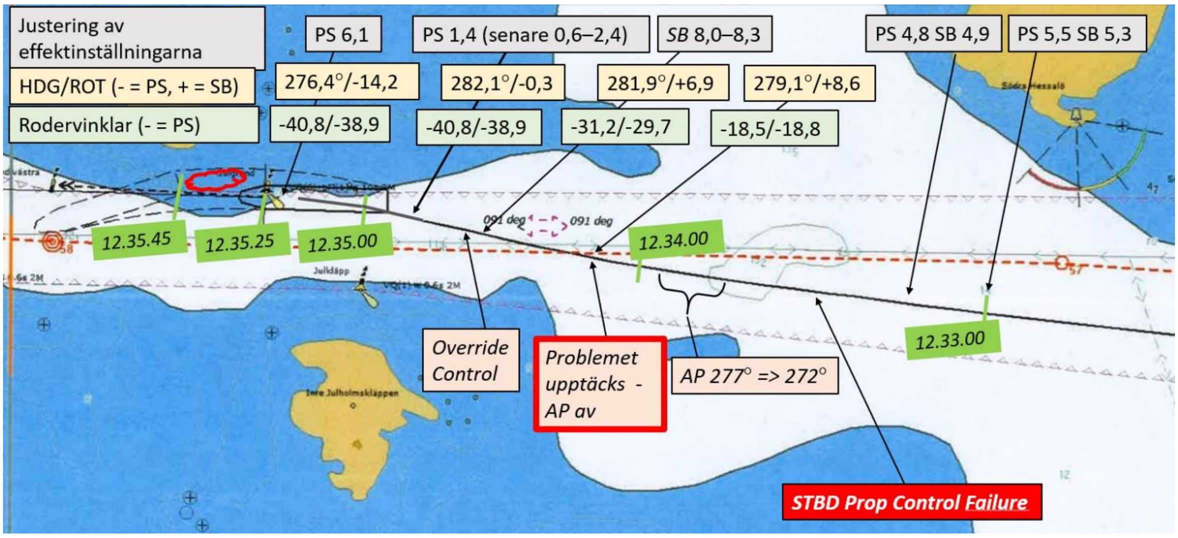

Figure 4, Amorellas grounding

At 12:33:18 the starboard CPP failed and began to produce reverse thrust, this was indicated on the control panel through the pitch indicator and an adjacent warning light, but it went unnoticed as it did not produce an audible alarm on the bridge. Roughly half a minute later, the autopilot was set to change course to Port, but could not do so due to the countering forces of the starboard propeller. A few seconds past 12:34:00, the bridge team noticed that the rudders were turned, but the vessel wasn't turning, so they switched over to hand steering. As this approach didn't yield results, at 12:34:30 they switched to override control and steered hard to Port. This was also unsuccessful, so the Pilot tried to increase power to the starboard propeller in an effort to steer, and soon reduced power to port propeller as well. At 12:35:25 the vessel ran outside of the fairway and struck the seafloor with a speed of 7,5 knots. About at the same time the CPP became functional once again. There were 281 persons onboard at the time of the accident, but no one was injured. The vessel punctured her hull with tens of meters long rips under the waterline, bent one of her propeller blades, and scratched another. (Onnettomuustutkintakeskus, 2021) (in Swedish)

During the investigation it was found that the Officer of the Watch had received a call from the Engine room roughly a minute after the initial failure with the intention to ask if the reverse thrust was on purpose. The OOW listened to the Engineer, didn't ask any follow up questions, and after the call notified the bridge team that there was some problem in the engine room. The bridge team never knew the CPP had failed until the day after the accident when checking video recordings from the ships side. (Onnettomuustutkintakeskus, 2021) (in Swedish)

The accident investigation report listed, amongst others, bad placement of propeller pitch indicators and poor communication between the bridge and ECR as the leading causes to this accident. It is also mentioned that the company does train its crew using simulators, but only in the use of the backup systems, not in learning the logics of the systems function. The vessels handbook does not list emergency stop of the engines as a possible action to take during CPP failure. This report further states that based on the anonymous ForeSea reporting system, CPP failures appear to be more common than previously thought, and it goes on to mention that failures are likely still underreported due to these reports being voluntary, and that the incidents which are reported are often lacking in information. Amorella, who is a user of the ForeSea system, did not make a report about this CPP failure. (Onnettomuustutkintakeskus, 2021) (in Swedish)

3.3 Atlantic Huron collision with quay

On the 5th of July 2020, the single propeller, self-unloading bulk carrier Atlantic Huron of 224m LOA and 25 crew members, was approaching the Soo Lock of Michigan USA. The weather was calm, and the ship was proceeding as normal under the con of its master, who was alco certified as a pilot for this stretch of water. (National Transportation Safety Board, 2021)

Figure 5, Atlantic Huron collision with pier

As the master was conning the vessel to berth, he noticed that the CPP pitch indicator was acting erratically, and soon later realized that the vessels speed was increasing. He did not order an emergency stop of the engine until 4 minutes later under suggestion from the ECR, when the speed had increased to 7,1 knots and one stern anchor as well as both bow anchors had been dropped. The vessel finally made contact with the pier at 6,8 knots. Damages caused were estimated at $2,2 million, no human injuries were sustained. (National Transportation Safety Board, 2021)

The accident investigation report notes that had the engine been stopped upon the start of the failure or soon after and anchors deployed, the vessel would likely have avoided the collision. It also states that the stressful scenario would have affected the master’s ability to come up with a solution to the issue, and that a crew trained for a situation like this would be more capable to make the decision of emergency stopping the engine in time. The SMS did not contain any procedures on how to respond to loss of pitch propeller control. (National Transportation Safety Board, 2021)

3.4 Case from Swedish P&I

An anonymous vessel was about to depart the berth to proceed to a lock, when the stressed out OOW didn't test the CPP system as part of the pre-departure procedures. The master and pilot took over the command for and the Officer proceeded to his mooring station. Shortly after the vessel let go all lines. (The Swedish Club, 2019)

As the vessel left berth, the master soon noticed that the CPP was stuck at 40% ahead, with the vessel rapidly accelerating towards the lock. He tried to recover control, but to no avail. This panicked the master who was now unsure on what to do, so he shouted on the radio for the crew to get the lines ashore, while the pilot ordered the standby tugboat to push the vessel into the locks berth to slow it down through friction. The crew only managed to set the forward spring line, which soon parted in a loud bang. The vessel finally made contact with the lock gate at a speed of roughly 3 knots. Not until 40 seconds after collision was the emergency stop initiated. The lock gate was destroyed, and the vessel damaged her bulbous bow. (The Swedish Club, 2019)

The company had previously had four other near misses on sister vessels which were caused by the CPP system. The company had not made any adjustments to the vessels maintenance systems nor any instructions regarding this issue to any vessels in its fleet. (The Swedish Club, 2019)

3.5 P&OSL Aquitaine

On the 27th of April in 2000, the passenger ferry carrying 1241 passengers and 123 crew was entering the port of Calais in fair weather with good visibility. With the master on the con and OOW assisting, on the approach to the berth the master noticed that the vessel was moving faster than expected, so to slow down he ordered the pitch of both propellers astern. (Marine Accident Investigation Branch, 2001)

Instead of the vessel slowing down, it started to sheer starboard, heading towards other vessels in the harbour area. To avoid the other vessels in the harbour, and assuming the CPP were operational, the master momentarily ordered starboard engine ahead to steer, and when later placing it back to full astern, the vessel sheered starboard once more. The port side CPP had failed and gotten stuck on 70-80% ahead up to an hour ago, but this had gone unnoticed by the bridge team since there was no audible alarm installed. The senior masters standing orders state that the officer assisting the master shall monitor that the helm and engine orders are correctly executed by monitoring the indicators, however, neither the officer nor the master had done so. (Marine Accident Investigation Branch, 2001)

Two minutes after initially noticing something was wrong, the vessel struck the berth at approximately 7 knots, injuring 209 persons and hospitalizing 58 out of which 7 stayed for one night or longer. Some had been knocked unconscious and five had broken limbs. Many more of the injured were treated in the vessel’s hospital and on the dock. The report does state that the situation could have had far worse and even fatal consequences. About 200 vehicles were damaged, the vessel was being repaired over a period of 2 months and the berth was out of use for several months. (Marine Accident Investigation Branch, 2001)

4 Method

The Aboa Mare school provides student arranged “Simulator nights”, where volunteering students may host simulator runs for other students. This provides opportunities for the students to further train their skills in navigation outside of the curriculum, through building their own scenarios which they would like to try out. Through there simulator nights, a pool of test subjects for this research could be found.

4.1 Sample demographics

The test subjects were categorized into two groups: Operational level (II/1), and management level (II/2). The tests were performed at the end of the semester, so the students had likely studied most of their respective level’s material at the time of testing. Management level students are students who have passed the academic requirements for OOW. These demographics were used as a gauge to see whether the training requirements as of today improve the ability of students to handle this situation, by comparing operational and management to each other.

4.2 Equipment

The instructor monitored the simulations in a separate instructor room where he can control everything regarding the simulation, while simultaneously monitoring all bridge monitors, as well as what the test subjects were doing on the bridge through a CCTV camera system.

The simulation was run on Aboa Mares Transas 3000 system. This system did not have a built-in function for initiating a CPP failure where thrust is set to full astern. To replicate one, the researcher using the instructor’s simulation computer manually ordered the port CPP to full astern and locked it in place with a “remote-control failure”. The bridge was not installed with a pitch deviation alarm light, but as will be seen later in 4.4, the subjects were orally informed about the issue halfway through the failure scenario.

The vessel model used in the simulations was a small research vessel named “Research Ship” in Aboa Mares Transas 3000 system. It is equipped with two CPP propellers. This vessel proved to be the only model in the simulator program that showed a dramatic degradation in handling when the failure was initiated. This is likely due to how the other vessel models in the Transas 3000 system were programmed. When the failure was initiated with them, their autopilot would just order the rudder(s) 5 degrees or less to starboard to offset the turning forces, after which the ships continued straight but with reducing speed up until they had nearly stopped. This was much unlike any of the examples in chapter 3, even on vessel models similar to Amorella and P&OSL Aquitaine.

The bridge had a VHF radio as well as an intercom phone system much like the ones used onboard real vessels. The bridge was also equipped with emergency stop buttons, but these were not connected to the simulation program itself, so the researcher instead monitored the bridge teams movements closely on the CCTV to see if the test subjects press it. To prevent oversights, the test subjects were immediately after the run asked how they could regain control. If they didn’t mention the emergency stop button, they were informed about that option. The researcher was looking for a “but we did press it and it didn’t work” reaction to rule out mistakes in the process.

4.3 Pre-conditioning

To gather as genuine data as possible, the students were at the time of the simulator runs not made aware that they were taking part of a study, but assumed it was part of the student simulator night program. To prevent the students from thinking that there may be a fault with the simulator, or that someone is messing with them, they were informed that this simulator run is intended to be as realistic as possible, and that “instructor room” doesn’t exist once the simulation starts. They were tasked to navigate and act like they would in real life when approaching the harbour, and informed that they could call e.g., the bosun over the intercom if they want.

As the scenario started and ended in the same fairway, which is on approach to the harbour, route plans were not required to be made before the exercise. The subjects were instead given time to familiarise themselves with the bridge, and with the fairway using the ECDIS chart. After signalling that they were ready to start, the simulation began, after they had 5 further minutes to sail before the failure was initiated.

4.4 Scenario

The bridge was manned by two navigators to fulfil the requirements of STCW A-VIII. This gave them sufficient resources to both wrestle controls and problem solve at the same time. The navigators, both from the same demographic, were instructed to approach the Vuosaari harbour. The simulation was set to daytime with no wind or current and good visibility. At the failure point shown in Figure 6 (next page), with another outbound vessel meeting them, a malfunction on the port CPP to full astern was simulated as per 4.2, and the researcher set his timer.

Figure 6 (next page) shows the track of a simulation in one-minute intervals from the moment of CPP failure until the third minute, at which time the simulation was stopped. The red vessel on the bottom is the test subject's vessel, the black vessel coming from above is the outbound vessel. In all runs, the research vessel began to turn port uncontrollably towards the oncoming vessel around 40 seconds after initial failure. In the run shown the starboard pitch propeller was left at 100% ahead throughout.

90 seconds after the malfunction, if no emergency stop had been performed, the researcher acting as the ECR called the bridge on the intercom to ask if they are aware that the port pitch propeller is stuck in full reverse, after which he informed that the ECR is looking into the issue. No suggestions were given on how they should react, but the ECR asked them to let him know if they want him to do something. After 3 minutes had passed, the simulation was stopped, and the researcher went to the bridge to have a debriefing (see 4.5). The 3-minute time limit was based on how little time the vessels in chapter 3 had before the problem escalated into a disaster.

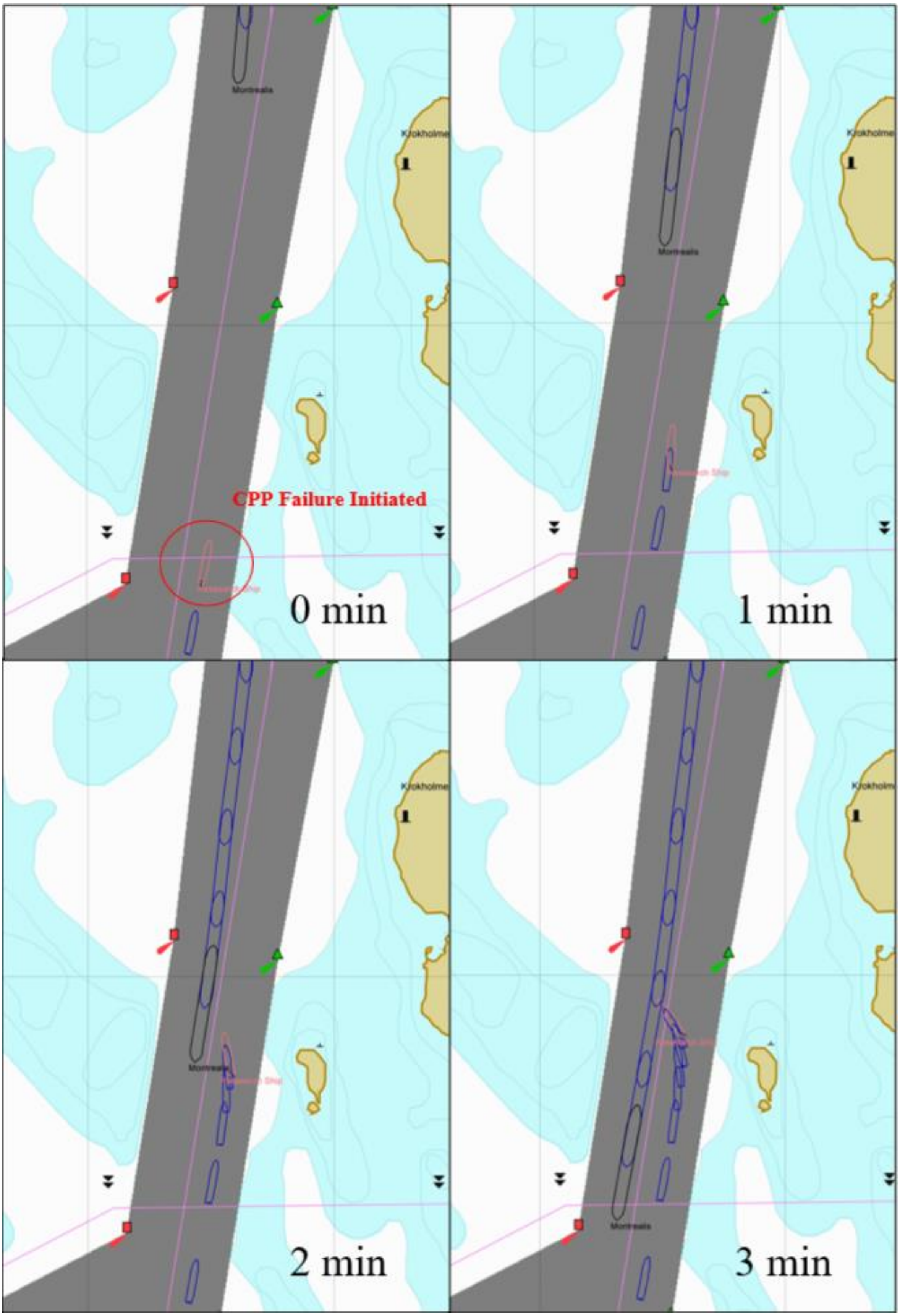

Figure 6, a CPP failure simulator run, starboard propeller left at 100% ahead throughout and autopilot switched on.

4.5 Record keeping

The test's main objective was to see whether the students emergency stopped the engine within 3 minutes, out of which the last roughly 1 minute and 20 seconds (accounting for the time it takes to orally deliver information) was with the knowledge that their port CPP is stuck in full astern. To record this and other information, the researcher timed and recorded the bridges actions on a pre-made template (see Appendix 2: Score/Record template for all eventualities recorded).

4.6 Debriefing

After the run was complete, the test subjects were immediately told that this was a test to see how they would react to a CPP failure, and not to worry about their performance as it fully complies with the STCW code which doesn't require them to be able to handle it. The test subjects were then asked what they could do to regain control of the vessel. If they were unable answer, after a little pushing, the researcher informed them about the emergency stop option, and how since they have two propellers, they can keep going on only one.

The test subjects were then asked if they had heard of this test before, and after confirmation that they hadn't, were given self-assessment forms to individually fill in (see Appendix 1: Self-assessment form). This was done to properly gauge their state of mind and opinions with the emotions of the situation still intact. After the form had been filled, it was placed at random in a folder containing both filled and empty forms. This was done to shuffle the order of the filled forms, ensuring their anonymity. Their names were then recorded on a separate list to prevent the same subject being tested twice, and after a little chatting (if interested), the simulator evening was commenced as normal.

5 Results

Four simulator runs were performed, with a total of 8 students attending: 4 Operational and 4 Management. The researcher had hoped to get more tests done for a larger sample size, but other obligations got in the way.

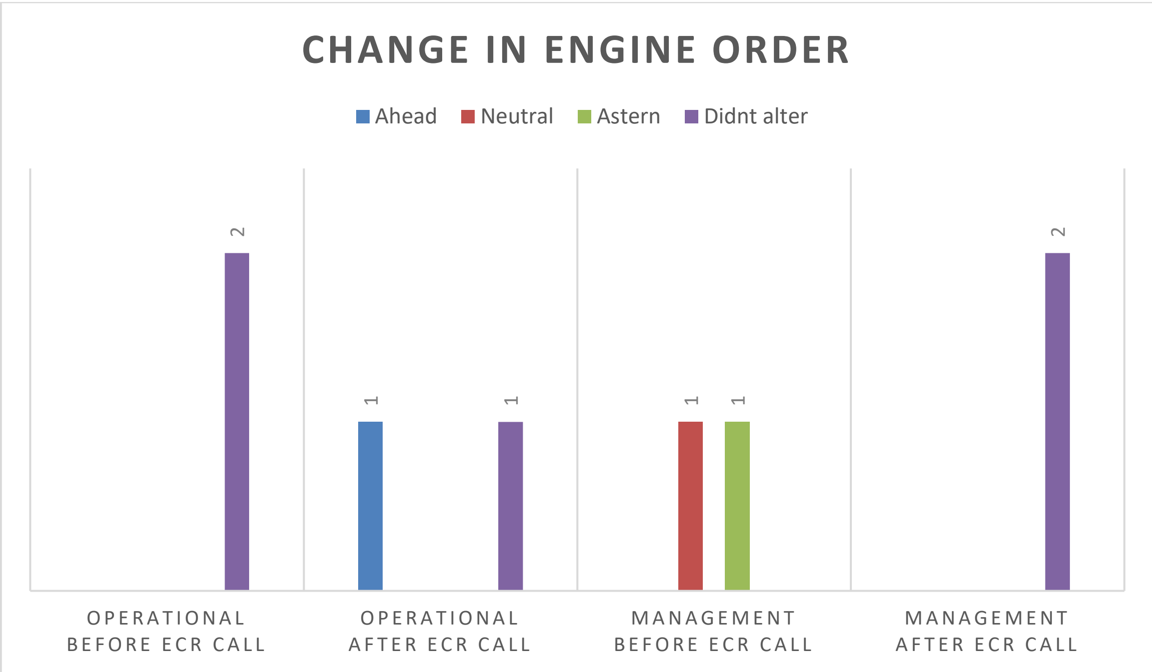

Figure 7, Change in engine order

All students displayed clear reactions to the vessel behaving strangely between 40 and 45 seconds after initial failure, but none contacted any department of the vessel during the following 45-50 seconds before the ECR called them. None of the bridges initiated an emergency stop within 3 minutes of initial failure. However, in the debriefing, both management bridges did after a little thinking state that emergency stopping the engine could have regained control, the operational bridges did not. From the changes in engine orders seen in Figure 7, Change in engine order, it shows that the management students made quicker decisions and stuck to those decisions after the ECR called. There doesn’t appear to be any correlation with what engine order was given.

5.1 Self-assessments

The researcher had given one of the operational bridges the incorrect forms, therefore only two responses from operational students were recorded although four had been tested.

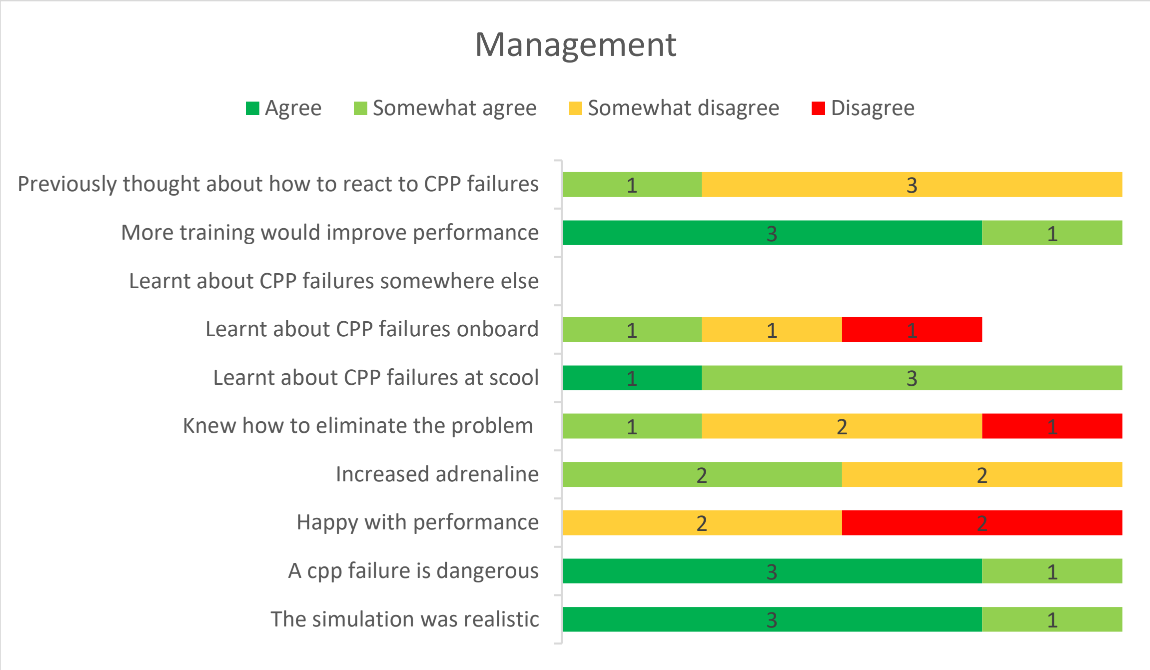

Figure 8, Self-assessment results Management

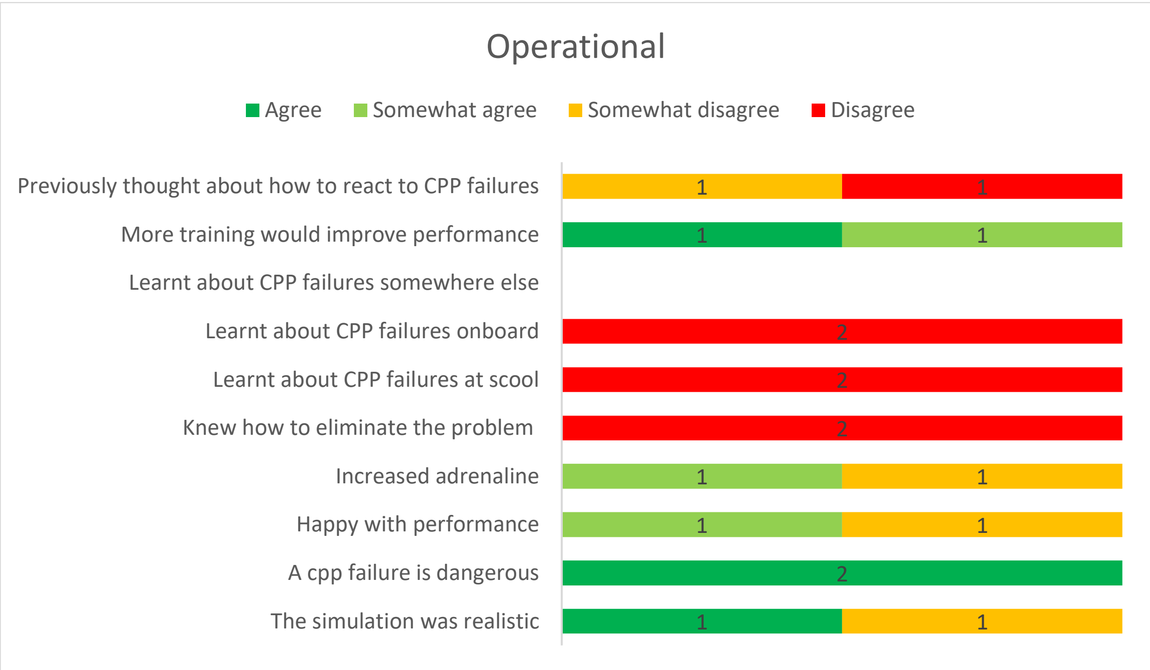

Figure 9, Self-assessment results Operational

Figure 8 and Figure 9 show how management and operational students respectively answered in their assessment forms (Appendix 1: Self-assessment form). The colour represents the answer they gave and the number how many of each answer was given. The colours were chosen to allow the reader to effortlessly scan the trend of answers given to each question. The greener the bar is, the more students agree, the redder the bar is, the more they disagree.

Based on the information gathered in Figure 8 and Figure 9, Aboa Mare students appear to become more aware about CPP failures during the management level semester, and report that they have received this awareness from school, not from onboard training. Students from both levels almost unanimously agree that more training would have significantly improved their performance, yet the management students were more disappointed with their performance than the operational students. Only one Management student somewhat agrees that they immediately knew how to eliminate the problem, but determining from 5, had not acted on it. A small to moderate increase of adrenaline was reported by all students, suggesting that cognitive impairment was likely successfully induced. All students agree that this failure has the potential to be very dangerous, and all but one agreed that the scenario was realistic.

5.2 Students' comments

About half of the students tested asked more about the subject, and some independently voiced interests in having a course where all types of simulated failures are trained. Students showed concern when hearing that no mention of an audible pitch deviation alarm or similar requirement was found in SOLAS nor any other regulation, finding it strange that such a failure is allowed to potentially go completely unnoticed by the bridge team.

5.3 Interesting observations

When the students were asked what they could do in this situation as per 4.6, if they did answer, they would list "imminent disaster" procedures like calling in a Pan-Pan, signal not under command and so forth quite well. The students who did listed emergency stopping the engine didn't do so before being nudged towards thinking how they could have regained the control of the vessel.

6 Discussion

Since the controllable pitch propeller has become very common on ships, and similar risks apply to faults in diesel electric fixed propulsion as well, it is of my opinion that training for propulsion malfunctions, along with other system failures, should become part of the standard training procedure for mariners. The crew need more standardized awareness of how serious implications a malfunction of these systems can have, so that they know to prepare for one, and hold their companies accountable to put enough effort into preventing a failure from happening in the first place.

Requiring shipping companies to take active part in the safety of their fleet is a very good idea, however I believe that this fault is too dangerous to be neglected by the regulatory bodies. Afterall, before SOLAS was written, shipping companies were also relied on to independently determine the necessary number of lifeboats needed onboard their vessels. Based on the cases in Theoretical Background, some companies show signs of underestimating the potential danger of CPP malfunctions. The sister ships to the anonymous vessel from Swedish P&I had previously had four near misses caused by CPP failures, but no concrete measures had been taken to rectify the issue.

The lack of requirements for audible alarms likely has effect on the mariner's abilities to react to this issue. In the case of Amorella grounding, Atlantic Huron collision with quay, and P&OSL Aquitaine, the bridge teams weren't initially aware that the CPP had failed. In the case of P&OSL Aquitaine they had sailed for up to an hour completely oblivious to the CPP failure. Had they learned that information immediately when the actual pitch deviated from ordered pitch, they would have had more time to solve the problem. I believe that this is especially relevant to the cases of Atlantic Huron and Aquitaine.

During the time period of creating this thesis, I had chats with coworkers regarding CPP failures as well as the lack of an audible alarm. When moving further into the topic of alarms, an almost unanimous complaint was that one can't tell critical alarms apart from low priority warnings, because almost all of them have a near identical high pitch sound. Many instruments even have their respective buzzer located on the inside of the bridge panel they are installed on, which causes the sound to echo in a way which makes it very hard to tell from where the sound is coming from. This causes the source of alarms to be hard to locate, and pulls attention away from navigation since the navigators can't tell if the alarm is serious or not until the source of the sound is found.

Adam Zupkos research paper on Innovation of Maritime Safety and Emergency Systems (Zupko, 2022) studies this very issue, together with other potential solutions which may be of relevance to the implementation of regulations regarding CPP failures. I wish, should an audible alarm for CPP failures be implemented in maritime legislation, that it is of the aural variety which Zupko is referring to, where a recorded voice reads out the name of the alarm, e.g., "Pitch deviation alarm" or "Controllable Pitch Propeller Failure".

The results from the test runs were as expected. Having myself gone through the same training as the students had, and recognizing my own lack of abilities to handle system failures in the DP course (which isn't a required course for the vast majority of vessel types), it wasn't a far stretch to assume that the students wouldn't possess the tools required to handle a CPP failure. What was unexpected was the management students reports on having been taught about CPP failures at school. I wish I had asked an open-ended question to figure out more precisely where that knowledge comes from. I was happy to see that a rise of adrenaline was reported, I interpret it as the students having had some level of panic going on during the situation, as was also the case in the real-world scenarios studied. In my opinion, the fact that the Transas 3000 simulator system wasn't equipped to simulate this failure, but multiple workarounds had to be "invented" to be able to do the simulator tests at all, crowns how this eventuality is overlooked in maritime training.

I extend my gratitude to Aboa Mare for their efforts in teaching students how to use the simulator as an instructor and allowing students to arrange simulator nights in their facilities. This thesis would likely not have been possible without this effort, along with the teacher's great voluntary help in understanding how the simulator program works.

Mariners refresh certificates for life saving courses every five years and perform drills onboard at least once a week because it's well known that in a stressful situation, humans only function in accordance with previous training due to being cognitively overloaded by the stress they are under. Why do we not train the bridge to stop resolvable problems to develop into disasters in the first place?

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7.1 List of Figures

Appendix 1: Self-assessment form

Study Level:

O Operational O Management O Officer of the Watch

This form and the records of the test run you just experienced are separated and physically shuffled with others' answers and records. Noone, not even the researcher of this experiment, will be able to track either of them back to you.

Please enter your <u>opinions</u> of the simulated scenario you just experienced below:

	Agree			Disagree
1. The simulated failure scenario is realistic.	○	○	○	○
2. The failure, if not eliminated, would cause great danger on a real vessel and the persons onboard.	○	○	○	○
3. I am happy with my performance.	○	○	○	○
4. Upon realizing the issue, I felt an increase in adrenaline.	○	○	○	○
5. When I found out that one propeller is going astern, I instantly knew what to do to eliminate (not counteract) the problem.	○	○	○	○
6. I have been trained for this specific or similar situation:				
At school	○	○	○	○
Onboard vessels	○	○	○	○
Other (where) ________________________	○	○	○	○
7. More training would have significantly improved my performance.	○	○	○	○
8. I have previously thought about this type of failure happening and how to react to it.	○	○	○	○

**(Measures: 1: Awareness, 2: Understanding, 3, 7: Assessment, 4: Startle Effect, 5 & 8: Ability, 6: Training)*

Appendix 2: Score/Record template

Operational Management OOW

- ☐ Did not hear of this test before

Before Engine room calls:

- ☐ Students display awareness of a problem. Time: ________________
- ☐ Communication is established. ____
- ☐ Engine telegraph altered: O Crash stop. O _______________________________________
- ☐ Emergency stopped/clutched: O Faulty propeller. O Non-Faulty. O Both. Time: ________________ O Immediately after crash stop
- ☐ Grounded/Collided. ____
- ☐ ____
- ☐ ____

After Engine room calls:

- ☐ Engine telegraph altered: O Crash stop. O _______________________________________
- ☐ Emergency stopped/clutched: O Faulty propeller. O Non-Faulty. O Both. Time: ________________ O Immediately after crash stop
- ☐ Grounded/Collided. ____
- ☐ Did not emergency stop/clutch within 3 minutes.
- ☐ ____
- ☐ ____