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The AMC Test for Maritime Autonomous Navigation Systems

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Abstract

The rapid development and testing of autonomous navigation technologies in the maritime industry requires standardised evaluation methods to ensure safe and efficient operations. This paper highlights examples of class approvals granted to autonomous technologies, underscoring the industry's progress in adopting these systems and introduces the AMC Test, a comprehensive assessment framework for Maritime Autonomous Navigation Systems (ANS). The paper argues for the need for an in-depth standardised test to evaluate compliance with the International Regulations for the Prevention of Collisions at Sea (ColRegs). The proposed AMC Test consists of 80 simulator scenarios categorised into Power Driven Vessel (PDV) Open Sea, Restricted Visibility, Coastal, and Complex Navigation sections. The testbed, built upon the Frazer Nash ColRegs framework, assesses the ANS system's understanding of the situation, adherence to ColRegs, consideration of the impact on other vessels, and anticipation of their actions. Assumptions based on relevant research support the realistic scenarios created during the test. By providing a comprehensive evaluation framework, the AMC Test enables stakeholders to assess the performance and safety of ANS systems in accordance with established regulations and industry accepted practice.

Keywords: Autonomous Navigation, AMC Test, Maritime Safety, ColRegs Compliance, Simulator Evaluation

1 Introduction

The development of autonomous navigation systems for maritime vessels has been a major focus for engineers and scientists over the past decade. Autonomous navigation systems have the potential to revolutionise the shipping industry, they can increase the safety of life at sea by assisting the Master or officer of watch (OOW) by continually maintaining a look-out and assessing the risk of collision of targets, and eventually allowing vessels to navigate without the need for a human crew.

Despite the potential benefits of these systems, there have been a number of safety concerns raised about their reliability and accuracy. These systems compile a full analysis of situations by simultaneously plotting all targets in the declared range, thereby reducing the risk of collisions, and calculating the safe course or speed in accordance with the ColRegs, aiming at passing from all targets clearly (Zhang et al., 2021). To ensure the safety of vessels using autonomous navigation systems, a standardised test for these systems must be developed.

2 Background

Autonomous navigation systems are computerised systems capable of controlling a vessel's navigation from start to finish, without the need for a human intervention. These systems use a combination of sensors, cameras, and other data sources to provide the vessel with real-time information about its environment and its route. Autonomous navigation systems have the potential to offer significant benefits to the shipping industry, including improved efficiency, increased safety, and cost savings.

Kongsberg Maritime, a technology provider from Norway, showcased various remote and autonomous technologies aboard a cargo vessel off the Norwegian coast. The impressive demonstration lasted for 13 hours, during which the vessel successfully embarked on a voyage beyond Kristiansund, situated on Norway's northwest coast. Departing from Avery port, the ship navigated to the world's pioneering ocean fish-farm and returned to port, covering a total distance of approximately 160 nautical miles (Mandra & Mandra, 2023).

However, there are still a number of safety concerns that need to be addressed before autonomous navigation systems can be widely adopted. These safety concerns include the accuracy of the navigation system, its ability to avoid obstacles in accordance with ColRegs, and its ability to respond safely to unexpected events. To ensure the safety of vessels using autonomous navigation systems, a standardised test must be developed to ensure the systems are reliable and accurate.

The advancement of autonomous technologies in the maritime industry has prompted the need for clear guidelines and regulations to ensure their safe and effective operation. Several classification societies and regulatory bodies have started approving autonomous technologies, such as autonomous vessels and related systems, through comprehensive evaluation processes. An example of this is the Approval in Principle (AiP) of Hyundai Heavy Industries' (HHI) Hyundai Intelligent Navigation Assistant System (HiNAS 2.0) by the Korean Register (KR) and the Liberian Registry (LISCR) (The Maritime Executive, 2023). This demonstrates the industry's progress in adopting autonomous navigation solutions.

3 The need for a Standardised Test

Unpredictable or incorrect actions may lead to confusion and potentially catastrophic collisions among other marine traffic. An autonomous vessel should be able to make these same decisions based largely on sensor information if it is to be lawfully operational at sea without a human operator or crew physically present onboard (Naeem et al., 2016).

At present, there is no standardised test for autonomous navigation systems. Each system is tested independently, with the results of these tests used to determine whether or not the system is suitable for use in a real-world environment. Recent examples of this include a 9,000-ton university training ship called the 'Segero' outfitted with Samsung Heavy Industries' remote autonomous navigation system, which demonstrated 29 collision avoidance manoeuvres, while sailing it over 500 nautical miles in Korean waters (The Maritime Executive, 2022), and the 'Soleil', a 200m long ferry completing a fully autonomous 240km voyage, including auto-berthing, at speeds of up to 26 knots and conducting 10 collision avoidance situations. (BachmannHR Group Ltd, 2022).

However, this process can be time-consuming and costly, and there is no guarantee that the results of the tests are accurate or reliable. The adherence to international maritime law is crucial for all vessels operating in the ocean, The International Maritime Organization (IMO) established the Convention on the International Regulations for Preventing Collisions at Sea (ColRegs) in 1972 as a legal framework to govern ship encounters, which applies to all vessels.

Research on ship collisions indicates that a significant percentage (75-96%) of maritime collisions and casualties are caused by human errors, with 56% of major collisions involving violations of the ColRegs. It is important for future ships to continue following these rules and regulations in encounter situations. As collision avoidance decisions will be made by ship intelligence with the support of decision-making systems, it is necessary to assess the behaviour of such vessels by testing their systems against established performance standards (Perera, 2020).

Given the complexity and potential risks associated with autonomous navigation, there is a growing necessity for a rigorous and standardised test to evaluate the performance and compliance of Maritime Autonomous Navigation Systems. While existing approvals focus on specific aspects, a comprehensive assessment that covers all relevant aspects of the International Regulations for the Prevention of Collisions at Sea (ColRegs) is required to ensure safe autonomous operations. The proposed AMC Test aims to fulfill this need by providing an in-depth evaluation process for ANS systems.

4 Benefits of a Standardised Test

The development of a standardised test for autonomous navigation systems would provide a number of benefits. Firstly, it would provide a consistent and reliable method of assessing the performance of the systems, reducing the time and cost associated with testing. Secondly, it would ensure that all autonomous navigation systems meet a certain level of safety and reliability. Finally, it would provide a benchmark for the development of future autonomous navigation systems, allowing manufacturers to ensure that their systems meet the necessary safety standards.

5 The AMC Test

The AMC Test comprises 80 simulator scenarios designed to assess the system's performance across different navigational scenarios. Due to the complexity of the test the scenarios are divided into four grades, with each grade building upon the previous and targeting specific aspects of the ColRegs, these are as follows:

- Grade 1 - PDV Open Sea (32 scenarios),
- Grade 2 - Restricted Visibility (8 scenarios),
- Grade 3 - Coastal (20 scenarios), and
- Grade 4 - Complex Navigation (20 scenarios).

To ensure a comprehensive evaluation of the rules, each scenario will be completed three times with different vessels. These vessels differ in size, turning circle, and minimum acceptable closest point of approach (CPA). While there is no standard or documented minimum CPA for vessels, as each situation is different and assessed on a case-by-case basis, feedback from industry suggests the following is an acceptable indication of current industry practice:

- Vessels over 200m – from 1.5 to 2NM
- Vessels 100 to 200m – from 1.0 to 1.5NM
- Vessels less than 100m – from 0.8 to 1.0NM

Therefore, the vessels used in the AMC Test are a 250m vessel with a minimum CPA of 2NM, a 150m vessel with a minimum CPA of 1.5NM, and a 50m vessel with a minimum CPA of 1NM. Due to the size of the vessels, their associated turning circles will also differ, accordingly to the manoeuvring characteristics of the vessel.

The AMC Test takes into account various navigation aspects to evaluate vessel behavior effectively. This includes, assessing collision risks between the vessels, determining the distance and time to potential collision or close encounter situations, analysing the course-speed vectors of both vessels, examining the bearing vector between the vessels, evaluating the timing and execution of decisions made by the autonomous vessel, observing and comparing the predicted and actual behavior of both vessels, and assessing the satisfaction level of decisions and actions taken by both vessels within the established perfomance standards.

The result for each scenario will be either a pass or a fail through the use of a comprehensive checklist based on the Frazer Nash ColRegs Framework developed for the Australian Code of Practice for the Design, Construction, Survey, and Operation of Autonomous & Remotely Operated Vessels (Trusted Autonomous Systems, 2022), appendix 1 shows an example assessment sheet for the first scenario. Any failed scenario will provide details as to why it failed and provide recommendations for improvement.

6 Conclusion

In conclusion, a standardised test for autonomous navigation systems is needed to ensure the safety and reliability of these systems. The proposed AMC Test serves as a vital tool for assessing the compliance and performance of Maritime Autonomous Navigation Systems. By encompassing various sections and scenarios that address different aspects of the ColRegs, the test provides a comprehensive evaluation framework. Based on assumptions grounded in research and industry expertise, the test enables ANS system developers, regulatory bodies, and stakeholders to confidently evaluate the capabilities and safety of autonomous navigation technologies.

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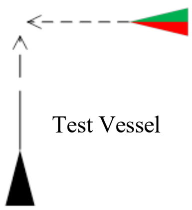
Appendix 1 – Test Page for Scenario 1
Scenario 1 – PDV Crossing situation



Applicable rules

7			8								9		
a	d(i)	d(ii)	a	b	c	d	e	f(i)	f(ii)	f(iii)	b	c	d
	x		x	x	x	x							

9		10			13				14			15	16
e	f	d	i	j	a	b	c	d	a	b	c		
												x	x

17				18						19		
a(i)	a(ii)	b	c	a	b	c	d	e	f	d(i)	d(ii)	e

Run 1 – 250m vessel	Required	Actual	Result
Did the vessel maintain a safe passing distance?	2 NM		
Was the action to avoid collision bold and obvious?			
Was the action to avoid collision taken early?	12 mins		
Was a course alteration favoured over speed reduction?			
Did the vessel comply with Rule 15?			
Did the vessel return to course once past and clear?			
Was there any ambiguity with the vessel's actions?			
Run 2 – 150m vessel	**Required**	**Actual**	**Result**
Did the vessel maintain a safe passing distance?	1.5 NM		
Was the action to avoid collision bold and obvious?			
Was the action to avoid collision taken early?	12 mins		
Was a course alteration favoured over speed reduction?			
Did the vessel comply with Rule 15?			
Did the vessel return to course once past and clear?			
Was there any ambiguity with the vessel's actions?			
Run 3 – 50m vessel	**Required**	**Actual**	**Result**
Did the vessel maintain a safe passing distance?	1 NM		
Was the action to avoid collision bold and obvious?			
Was the action to avoid collision taken early?	12 mins		
Was a course alteration favoured over speed reduction?			
Did the vessel comply with Rule 15?			
Did the vessel return to course once past and clear?			
Was there any ambiguity with the vessel's actions?			

Comments: **Result: Pass / Fail**