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Merging Conventionally Navigating Ships and MASS - Merging VTS, FOC and SCC?

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ABSTRACT: Current maritime transportation and shipping is characterized by rapid technological developments effecting the basic concepts of operating ships and even changing traditional paradigms of controlling ships. The e-Navigation concept of the International Maritime Organization (IMO) specifically aims at more comprehensive and reliable support of the human operators on-board and ashore. However, autonomous unmanned ships remote controlled or even autonomously navigating are expected to come soon. In this paper, selected operational aspects of maritime traffic merging conventional and unmanned remote controlled ships in coastal areas are discussed. Furthermore, some preliminary results of experimental simulation studies into a future scenario of maritime traffic are presented and preliminary conclusions in respect to job profiling and training requirements are discussed.

1 INTRODUCTION

Fundamental requirements for all transportation systems are safe, efficient and sustainable move of any goods from a shipper and its entire and timely delivery to the respective client. Nowadays, this is ensured by contributions of the different components and sub-systems of the transportation systems.

The basic components and subsystems are:

- transport means (in maritime transportation: vessels of various types and sizes),
- drivers (ship crews incl. captain, officers, engineers, A.B.'s, Motor men etc.)
- transport paths (open sea, coastal waters and inland fairways)
- traffic management (e.g. ship reporting systems, Vessel Traffic Service systems) and
- organizational components (incl. international and national bodies and institutions like IMO, IHO but also classification societies as well as national water and shipping administrations that provide implement and enforce i.a. standards, rules & regulations).

Until today, according to the established rules and regulations, crews on-board operate the merchant ships. Additionally, especially in areas with high traffic density, ships are monitored and their crews are supported from shore-based surveillance and control centers.

Vessel Traffic Services (VTS) are well known and recognized in this respect. There are IMO Resolutions that provide definitions, standards and guidance on specification of the services (Information Service and optionally Navigational Assistance Service and Traffic Organization Service) and how to implement and to maintain them. From an engineering point of view, VTS can be simplistically considered as a system that collects environmental and traffic data in order to create a traffic image that is continuously analyzed by the operators who assess if there are any developing or already existing risks that require interaction with the traffic. If a VTS operator becomes aware of a vessel, e.g., not complying with the rules, violating regulations, or in case she or he detects a situation with a risk of grounding or collision then VTS can intervene by sending out information, warning/advice or instructions to all or individual vessels using VHF voice communication.

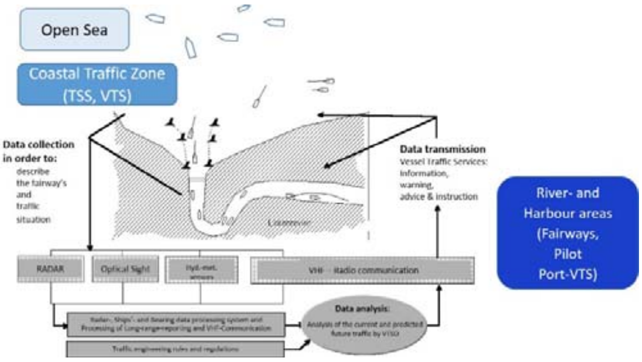

Figure 1. Monitoring vessel traffic and providing services to ensure safe and efficient traffic flow - Functional sketch of a VTS

Besides the recognized monitoring of vessel traffic in sea areas of the national territories by VTS, there are an increasing number of company-based Fleet Operation Centers (FOC). They monitor the safe and efficient progress of company-owned ships as well. In the same way as VTS, an FOC operates 24 hours a day, 7 days a week. On the other hand, contrary to VTS, FOCs even monitor ships on a world-wide scale. So far, the relation between the navigators on board and the operators ashore is characterized by the status quo that the shore operator provides additional information in order to support the decision making processes of the bridge team on-board. However, until now, there is no guidance about any potential relations between VTS and a FOC.

Figure 2. Sample of a Fleet Operations Centre (Snapshot taken from https://www.cruiseindustrynews.com/cruise-magazine/feature-magazine-articles/18343-fleet-operations-centers.html)

IMO's e-Navigation initiative makes an effort to introduce state-of-the-art technologies to improve and harmonize the collection, processing and presentation of data and information to support human operators on-board and ashore to ensure safety of navigation from berth-to-berth [1]. Even though e-Navigation clearly addresses the human operators; the captain, the OOW and the whole bridge team as well as the VTS supervisor and his watch standing operators in shore-based centers, e-Navigation is obviously supporting even more enhanced services [2]. Together with the increasing level of digitalization and automation it is supporting the introduction of autonomous navigating and even unmanned ships. Making them a reality will fundamentally change the existing transportation system [3].

2 ONGOING TECHNOLOGY AND REGULATORY DEVELOPMENTS

The current technological developments and research mention 'unmanned' but also 'autonomous' ships often synonymously. IMO at the recent sessions of its Maritime Safety Committee (MSC) has introduced the abbreviation, term MASS for "Maritime Autonomous Surface Ships" and recognized the need for a clear definition of unmanned ships and shall also address different levels of automation, including semi-autonomous and unmanned ships as well [4].

However, per definition, unmanned ships have no crew, nor even any human operator on-board. An unmanned ship can be remote controlled from any monitoring and control center either ashore or on another mobile station or it is in autonomous mode. A ship in autonomous mode has systems, which steer the ship and "decide" about any change of the control settings by her own. Autonomous operating ships not necessarily have to be unmanned [5].

As in all other transport modes also in the maritime sector, a range of autonomy and its potential to manning levels are suggested. Typically, the level ranges from fully-manned to unmanned vessels, and definitions have been suggested by several institutions as e.g. by Lloyd's Register [6] or by Scandinavian Maritime Administrations. However, a working group of the global standard setting maritime organization IMO has defined the following four levels of operation for MASS:

1 Ship with automated processes and decision support
2 Remotely controlled ship with seafarers onboard
3 Remotely controlled ship without seafarers onboard and
4 Fully autonomous ship

Moreover, IMO provided guidelines for MASS trials by the end of 2018 and intends to deliver draft specific regulations for MASS by 2025. It is expected that regulations take into account all aspects of operation. Training and education issues might be addressed as well, but it is not yet on the agenda. Experiences and related studies are obviously lacking. Also; while remote controlling of ships is addressed, the interaction with VTS is not.

Present concepts proposing and researching the introduction and operation of MASS usually contain a kind of shore-based control center that monitors the status of such ships and the navigational and technical processes. In the MUNIN project [7], such a center was named Ship Control Centre (SCC) and provided for direct remote control options in case of its need [8].

However, the introduction of such transportation systems has not only various technical-technological, but also administrative-organizational [13] and human factor related challenges. While the technical-technological aspects are very well addressed by numerous research and technical development projects (see i.a. [14]), the consideration of the operational aspects, e.g. about the interaction with other conventional ships and with a VTS is still just beginning and in a rather initial phase of studying. First efforts have been made and provided good basis for further research into the topic ([23]-[27]).

So far, it has not been considered in very detail and is comparably seldom subject to ongoing studies and research activities. Operational and human factor related aspects are, on the other hand, on the research agenda [9], [11].

One of the major challenges is seen in the field of addressing the interaction of SCC and VTS. If, e.g., there will be no spatial separation of unmanned and remotely controlled ships from conventionally manned and navigating ships certain communication needs will arise and needs to be addressed in detail at least on basis of series of case studies for specified scenarios or by systematic consideration of potential situation and environmental parameters of traffic scenarios. Those challenges include among others technical ways of and procedures for communication between VTS and SCC operators or even a MASS; not to raise the question who will be the responsible party in case of any accident that might happen. Will there be a need for overriding rights for any of the involved parties? Shall such questions given to coastal states and be governed by national rules and regulations exclusively? Is there a need for an overall harmonized approach and provision of a framework of operational procedures? To just mention a few samples.

However, operational integration, quite obviously requires addressing legal and operational aspects as well as technic-technological issues. Experimental studies are to approach such challenges in a systematic way.

3 EXPERIMENTAL STUDIES INTO OPERATIONAL ASPECTS OF UNMANNED SHIPPING

3.1 *Experiment Design*

In order to gain more knowledge and experience in researching how unmanned ships can be integrated into the currently existing traffic flow of conventional ships along coastal areas and fairways to ports, a pilot simulation trial was designed assuming a scenario with a typical traffic load under usual normal environmental conditions. One aim of the trials was to provide different set of equipment for monitoring and remote controlling the unmanned ship and to test different compositions of the control teams in respect to the operators' seafaring background. One of the groups was with experience as a navigating officer and the other group was without background of navigating a ship. The basic initial event of the scenario was a breakdown of the autonomous mode on board the unmanned ship and the need to take over command by remote controlling the ship from the shore center.

The traffic scenario for the simulator study was created using historic AIS/radar data from a VTS service, and consisted of more than 15 targets. The simulated area was the German Bight, with good visibility in daylight, moderate wind (<2 BFT), calm sea-state (2), and no current. The ship model used for the experiment was an average 4.000 TEU Panamax Container ship (length 218 m; breadth 32 m) with standard engine, single screw propeller and bow thrusters, nowadays in usually operating for feeder services.

3.2 *Briefing of Participants*

Participants came from Asia, Europe, North- and South America and have various cultural backgrounds as well as of the main languages.

The participants were briefed on the objective of the study. They were further informed that there was a breakdown of the autonomous mode on-board the unmanned ship, and that they had to take over remote-control from the SCC. They were asked to sail as safely and efficiently as possible from an origin of the ship to a fixed destination point. All participants were briefed with a voyage plan and introduced to the basic maneuvering characteristics of the ship to be remotely controlled. The unmanned ship steered remotely in this simulation was a typical 4000 TEU containership. The following figure shows the initial situation of the designed traffic scenario. The autonomous unmanned ship to be controlled by the participants is marked by the circle symbol.

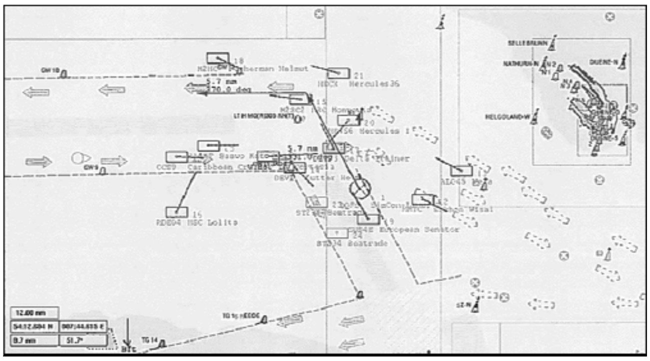

Figure 3. Sea area and initial traffic situation for sim trials

The voyage plan was provided and explained during the briefing sessions and an introduction to the basic maneuvering characteristics of the ship to be remotely controlled was integrated using a fast-time simulation training tool.

During the first series of simulation runs a total of 24 participants were divided into 12 groups. Six groups consisted of two experienced seafarers each, whilst the other six groups consisted of two non-seafarers each; there were no mixed groups (i.e. no groups with a seafarer and a non-seafarer).

3.3 *Conduction of Simulation Runs*

On the first day, the groups of had access to a certified full-bridge simulator, with conventional handles for steering and maneuvering the ship (including engine, propeller, thruster control levers). In this runs also out-of-bridge-windows view was available to the attendees. The remaining six groups had access solely to a synthetic ECDIS screen that included the radar and had software-based handles to input rudder angle and engine revolution commands by using a keyboard and mouse instead of the levers.

The VTS coverage related to the traffic flow was integrated by VHF communication and was integrated in all simulation runs. VTS communication included regular standard weather and traffic reports. The participants as the operators in the shore control center could listen to the reports but unable to communicate with to the VTS station as well as with targets.

Simulation runs on the second day used exactly the same traffic scenario except for the equipment set-up switched around between groups. For example, groups that had access to the full bridge on Day 1 worked with limited controls on Day 2, and vice versa.

In the experiment, the unmanned ship to be steered remotely was a usual 4.000 TEU containership. The two equipment options used were a control center with complete bridge equipment provided by a certified desktop ship-handling simulator including the bridge view out of the window simulated as remotely transmitted video signal.

The second equipment option was restricted to a synthetic standard ECDIS-based traffic display with soft control settings for rudder angle and engine revolutions only. VTS coverage was integrated by VHF communication related to the traffic flow.

4 DISCUSSION OF SELECTED RESULTS AND SOME PRELIMINARY CONCLUSIONS

For purposes of discussion we use samples of recorded tracks from the first round of the simulation trials. The recorded tracks focus on the action taking by the remote operators when controlling the unmanned ship. As the studies are still ongoing, for now, we focus on selected aspects and discuss the samples qualitatively and remain quantitative analysis for a later stage.

Figure 4 presents exemplarily the track recorded from trials by a team of experienced navigators using a clear and almost complete turning circle to starboard side and a speed reduction in order to avoid a developing close encounter with a crossing vessel approaching from her port side. According to the rules of the road this would be a maneuver of the stand-on vessel, when it give-way vessel is not taking appropriate action.

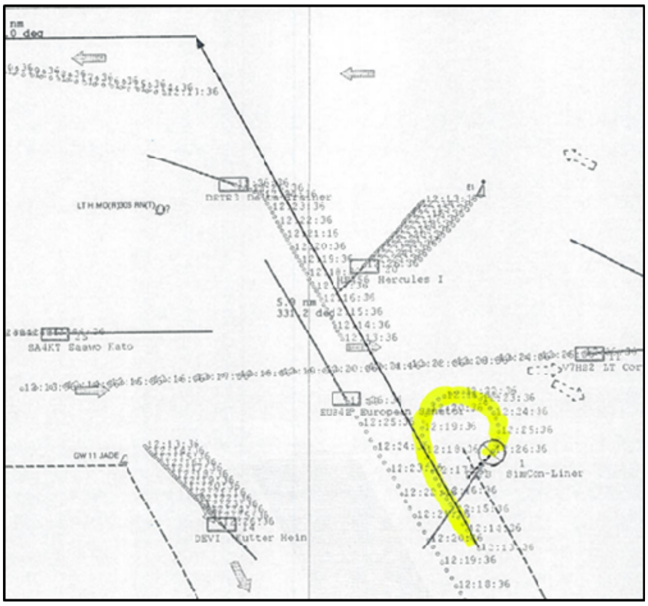

Figure 4. Sample scenario track record (track of remote controlled ship highlighted in yellow) of a starboard maneuver to avoid dangerous encounter with ship crossing from port-side

Figures 5 and 6 contain another two samples of other teams. The recorded tracks in Figure 5 show tracks for the same situation but the teams had available different kind of equipment to conduct the task. The recorded tracks of the remote controlled ship (highlighted in light blue) presents sample outcome when the operators have only the standard ECDIS-based display available for monitoring and remote controlling the ship. The left snapshot is taken from a trial of the "unexperienced" group. The snapshot on the right hand side is from a trial conducted by a team with navigational experience.

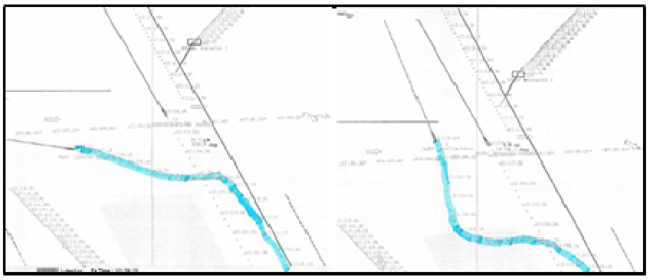

Figure 5. Samples of scenario track records for remote control of an unmanned ship, having only integrated ECDIS information available in SCC (track on the left hand side: team 'no seafaring experience'; right: team with seafaring experience)

Figure 6. Samples of scenario track records for remote control of an unmanned ship, having available full bridge equipment in the SCC (left team 'no seafaring experience'; right: team with seafaring experience)

Figure 6 presents tracks for the same group but having available the full set of navigational equipment and steering handles for rudder and engine.

A second series of simulation runs is ongoing and the same is for the detailed analysis of tracks and other recorded data. However, overall as an interim resume, it can be stated that observation show that with only one exemption all teams were able to steer the remote ship safely through the traffic of the remote area. Groups with navigational background took action in a rather strategic and more pro-active manner, also tending to use VHF in order to coordinate maneuvers with other ships. Experienced navigators seem to take into account maneuvering characteristics more sensible and also observe the response to a maneuver more carefully. This may become a training issue for operators.

From recorded feedback of the participants it seems to be that there is a preference to make use of the full range of the bridge navigational equipment. Participants with seafaring background expressed that they prefer cross-check of displays using view out of the window.

It seems to be another interesting subject to investigation, how more enhanced equipment, like e.g. virtual reality based decision support systems may or may not have impact on the outcome of remotely controlled unmanned ships.

Regarding the operational integration of MASS into existing traffic it was observed that, in principal, the behavior of the two groups and the provided technical infrastructure resulted in different strategies to manage the traffic situations and to solve identified conflicts. From the observed behaviors and the feedback provided by the participants a need for clear operational procedures, especially for communication was identified. Communication lines and means needs to be specified very clearly and need to take into account the various operators of a scenario on board and ashore. A draft concept is provided in the figure below.

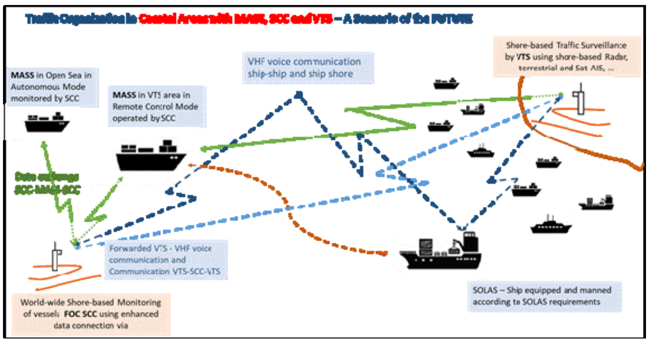

Figure 7. Sketch of existing and potentially required communication lines for a future traffic scenario merging MASS and conventional ships in a coastal area with VTS coverage

In respect to collision avoidance situations participants expressed uncertainties about what the other ship intends to do and would prefer to speak to a person on board or the remote controller if needed or have an indication for the action the automated system will or is carrying out in addressing an encounter situation.

The challenge regarding information exchange and distribution of data is seen rather in terms of the operational integration than in the provision of the technical environment for this.

Algorithms and technical systems specifically addressing collision avoidance are well under way and proposals for solutions are under preparation for further discussion on international level (e.g. [15]-[18]). However, solutions need to take into account not only COLREGS but also objectives and operation of shore-based traffic management either of a private company like FOC and SCC respectively or a governmental institution like e.g. a VTS. Especially the reference to COLREGS although welcomed was seen critical by participants as the rules not covering all potential situations and moreover not all possible combinations of traffic and environmental parameters. Approaches for technical solutions also taking into consideration of the ship and situation specific maneuvering characteristics when taking action and maneuver to avoid collisions are subject to ongoing research studies and allow for provision of action times and distances respectively when such action need to be taken at the latest. Such solutions (e.g. [19]-[22]), however needs to be adapted and investigated for situations with MASS involved as well.

5 MARITIME TRAINING AND EDUCATION – A BACKNONE OF MASS OPERATION

Overall as an interim finding, it can be stated that the observations have clearly shown that – with only one exception – all teams were able to remotely steer the ship safely through the traffic area in this sample scenario. However, this by all means, does not mean that providing traffic services and remote controlling ships can be performed by personal without seafaring experience and a background limited to basics of ships steering and traffic management.

Taking into account the selected focus of the exercise to remotely steer the ship through a given area with a medium dense traffic scenario we have to notice, that this is just only one process of several others belonging to the complex task of navigating a ship from berth-to-berth. The derived preliminary findings are therefore just very basic and to be interpreted as one initial beginning of more in-deep studies needed to get insight of the challenges of mixing traffic of conventional manned and steered ships with those remotely controlled or autonomously navigating!

Groups with navigational background took action in a rather strategic and more pro-active manner, also tending to use VHF in order to coordinate maneuvers with other ships. Experienced navigators seem to take into account maneuvering characteristics more sensibly and also observe the response to a maneuver more carefully. This seems to present us with a strong argument that training and experience among others specifically in ship-handling is a significant issue for future remote operators.

From promotion materials published and presented at several commercial events as well as scientific and academic conferences, remote operators are presented as sitting in a multifunctional chair containing the steering handles designed in various ways and watching the situation the environment presented as live TV-camera view on huge multimedia wide screens. However, equipment, no matter how user-friendly or sophisticated it might be, will remain purely as supporting tools for the safe operation of ships, to be realized by the correct and proper action of the operator when in remote control mode. Familiarization with the handling of such systems needs to become part of basic training, but moreover knowledge and skills of the constraints and limits are needed.

Almost all participants expressed the need for direct contact preferably by voice communication with vessels in the vicinity. This request implies that remote control operators need to be provided with the communication skills of navigating officers and VTS operators respectively. However, a challenge for operational integration of MASS and its joint operation in areas with conventional vessels requires a solution of the communication paths. Further specific research is needed of potential options, like VTS as a relay station, use of combined VHF and sat-communication and other communication means.

The given feedback contains remarks that training for controlling remotely certainly needs to include training of safety and emergency procedures. From observations and the feedback of the participants it becomes apparent that sufficient training must be provided in regard to legal frameworks operational procedures, the rules and regulations to be applied globally and regionally when remotely steering a ship. This includes not only COLREGS but especially the operational regimes in place in the VTS areas worldwide.

As an overall outcome in respect to the draft and development of job profiles it seems that shore-based operators need to have a profile with enhanced skills and knowledge of VTS operators. Presently, they have to be holder of a Certificate of Competence as a navigating watch officer as a prerequisite. In this respect, existing STCW requirements for watch keeping officers could form the basis for deriving first minimum training standards and programs or even study curricula. Consequently, the IALA model courses for VTS operators seems to be the starting point for the development of training programs for shore based remote control operators. Further operational aspects of the integration of MASS into conventional traffic have been identified. However, this requires more detailed research and in-depth studies that shall follow from the pilot studies presented in this paper.

6 SUMMARY

In this paper we introduced investigations and selected interim results of a simulation experiment which studied for the very first time traffic scenarios consisting of conventional manned and future unmanned ships. Simulation trials have been planned, designed and implemented in order to study different equipment options for monitoring and remote controlling unmanned ships navigating in a coastal VTS-monitored area.

In a pilot study the first trials have been conducted with experienced seafarers and non-experienced personnel from the maritime domain. Qualitative and quantitative analysis of the first set of simulations runs are still ongoing. For purposes of analysis first principle comparison of different groups and equipment options are presented. The planning, conduction and outcome of these trials is discussed in the light of evolutionary needs of control centers and requirements from human operators when remotely operating unmanned ships in areas with conventional traffic.

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