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Addressing the Accidental Risks of Maritime Transportation: Could Autonomous Shipping Technology Improve the Statistics?

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Based on the paper presented at TransNav 2019

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1

ESREL 2018

At least as safe as manned shipping? Autonomous shipping, safety and "human error"

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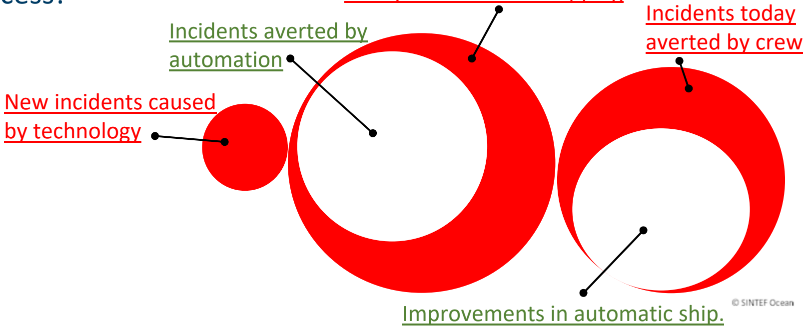
ABSTRACT: A paradigm shift is presently underway in the shipping industry promising safer, greener and more efficient ship traffic with unmanned, autonomous vessels. In this article, we will look at some of these promises. The expression "autonomous" and "unmanned" are often used interchangeably. We will therefore start out by suggesting a taxonomy of automation and manning of these ships. We will then go on examining the promise of safety. An hypotheses of increased safety is often brought forward and we know from various studies that the number of maritime accidents that involves what is called "human error" ranges from some 70-90 percent. If we replace the human with automation, can we then reduce the number of accidents? And is there a potential for new types of accidents to appear? Risk assessment will be a valuable tool, but will only reach as long as to the "known unknowns".

https://www.researchgate.net/publication/328042940_At_least_as_safe_as_manned_shipping_Autonomous_shipping_safety_and_human_error

Background

- MASSs must be at least as safe as manned ships in order to be a success!



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2

The paper

- WHAT IS AN AUTONOMOUS SHIP?
- COMPARISON TO MANNED SHIPS
- ACCIDENT SCENARIOS
- A QUALITATIVE COMPARISON OF AUTONOMOUS AND MANNED SHIPS
- CONCLUSION


Addressing the Accidental Risks of Maritime Transportation: Could Autonomous Shipping Technology Improve the Statistics?

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ABSTRACT: A paradigm shift is presently underway in the shipping industry promising safer, greener and more efficient ship traffic. In this article, we will look at some of the accidents from conventional shipping and see if they could have been avoided with autonomous ship technology. A hypothesis of increased safety is often brought forward, and we know from various studies that the number of maritime accidents that involves what is called "human error" ranges from some 60-90 percent. If we replace the human with automation, can we then reduce the number of accidents? On the other hand, is there a possibility for new types of accidents to appear? What about the accidents that are today averted by the crew? This paper will present a method to assess these different aspects of the risk scenarios in light of the specific capabilities and constraints of autonomous ships.

1 INTRODUCTION

It is commonly believed that human errors are the main causation factor for maritime accidents and incidents. The term "human error" is a broad category covering a wide variety of unintentional unsafe behavior. From Allianz figures a range from 50 to 80% are often seen, with 75% being the figure used by Allianz (2018). With this background, it could be argued that an unmanned and fully autonomous ship should be much safer than a corresponding manned ship. However, there are several parameters which will determine the safety of an autonomous ship and this paper will attempt to present a more complete picture.

Section two will define the types of autonomous ships we believe is the most relevant in the near future, i.e. next 10 years. Section three will compare autonomous ships, as understood by the authors, with manned ships and list the main differences that can also be the basis for comparison of risk factors. Section four discusses types of accidents and causation factors and how this picture will be modified for autonomous ships. Sections five to seven discuss different classes of accidents and try to provide some quantitative expectations for how these classes will change when autonomy is introduced. Section eight will give a summary and conclusions.

2 WHAT IS AN AUTONOMOUS SHIP?

Autonomy literally means "self-governing" and comes in very different forms. Rødseth (2018) discusses this topic and provides a characterization scheme for autonomy in ships. Maritime Autonomous Surface Ship (MASS) is by IMO defined as a ship that, to a varying degree, can operate independently of human interaction. Autonomy is also closely connected to unmanned operation: Having a completely unmanned ship is desirable as it realizes significant gains by removing the hotel section and associated energy use, removing much safety equipment and reduces crew costs and by that also allows easier scaling down of ship sizes (Rødseth 2018b). Central in this is also the use of a shore control center (SCC) as discussed in Man et al (2015). In this context, autonomy is important to enable operators in the control center to monitor and control several ships and by that reduce costs of operations in the SCC.

It is theoretically possible to design a fully autonomous ship without any human oversight at all, but this is extremely unlikely in all but very special cases, due to the resulting extreme demands on the on-board technology. Being able to operate with "constrained autonomy" (Rødseth 2018) and having humans as back-up in cases where operational demands exceed the automation system's capabilities is a much more likely alternative. In addition, current public and private law and regulations associated with safety of ship operations

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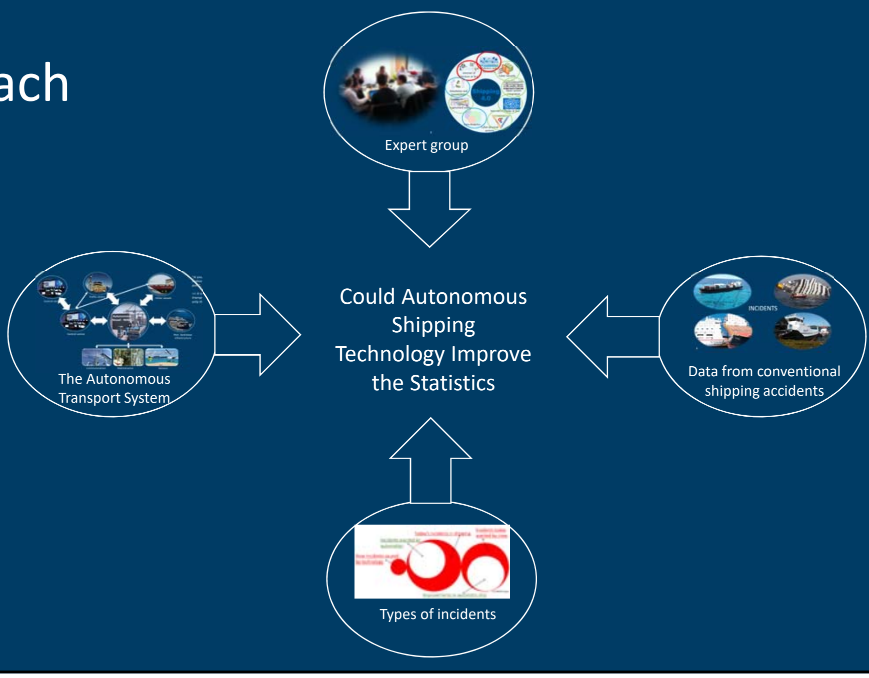
3

Approach



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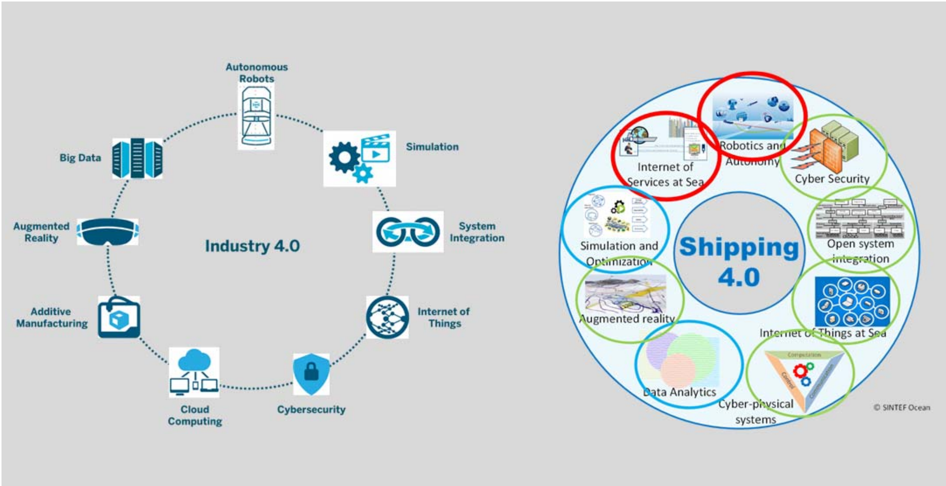

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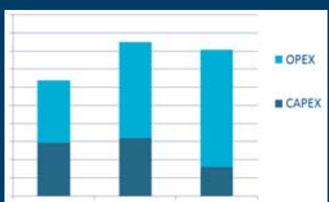
5

Why autonomous ships ?

Less dangerous exposure for crew

Less damage related costs

Fewer large oil spills



Lower costs ?

Lower emissions

New ship types

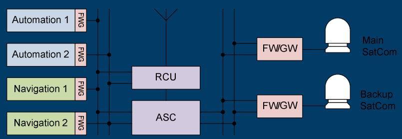
http://nfas.autonomous-ship.org/why-en.html#H2 and Rødseth Ø.J (2018) Assessing Business Cases for Autonomous and Unmanned Ships. In: Technology and Science for the Ships of the Future.

6

Improved technical resilience

Machinery Redundancy

Minimize complex systems onboard



Automation and Electronics Redundancy

No heavy fuel oil

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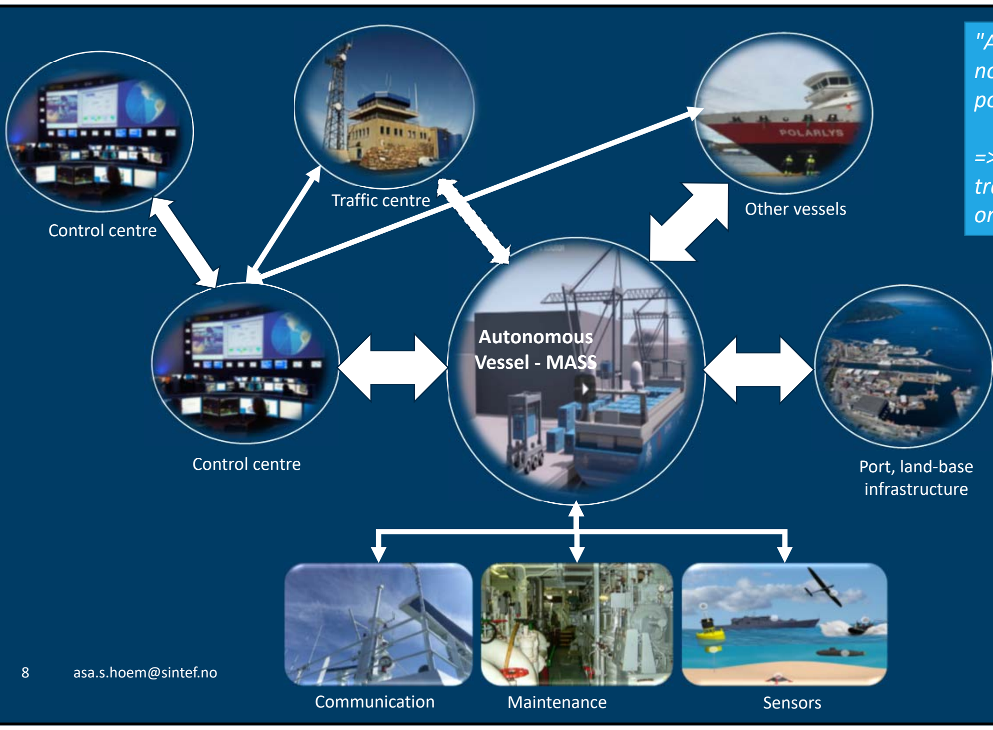
7



"A smart vessel has nothing to do in a stupid port", Alop Anatoli

=> It is about the transport system, not only the vessel

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8

The importance of CONOPS

- A Concept of Operation (CONOPS) refer to the a
- It gives the perception of an event with respect the system behavior (actual and future).
- A CONOPS will address the human factors in the
  - Situation and automation awareness
  - The understanding between automation and human role
  - User experiences and usability of the solutions
  - Trust in automation
  - Graphical user interface and visualization
  - Hazards reflections

- Hazards for the voyage
- Hazards for the navigation
- Hazards for the detection
- Hazards for the communication
- Hazards for the ship integrity, machinery and systems
- Hazards for the cargo and passenger management
- Hazards for the remote control
- Hazards for the security

Bureau Veritas Guidelines for Autonomous Shipping
https://www.bureauveritas.jp/news/pdf/641-NI_2017-12.pdf

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Hazards mapped with land-based sensor infrastructure

Green = Sensor Site can assist in decision support

Yellow = Neutral

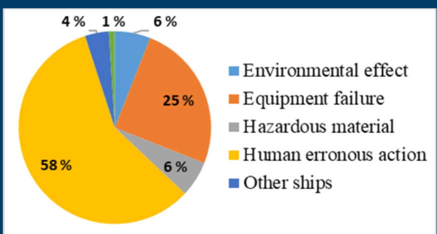
Red = Will not lead to a difference

		Sensor Site
Hazards for the voyage	Human error in input of voyage plan	Green
	Failure of updated information (nautical, weather, publications)	Green
	Failure in position fixing (due to e.g. GPS selective availability)	Green
Hazards for the navigation	Heavy traffic	Green
	Heavy weather or unforeseeable events (e.g. freak wave)	Green
	Low visibility	Green
	infrastructures	Green
	Collision with floating objects	Yellow
	Collision with marine wildlife (e.g. whales, squids, carcasses)	Yellow
	Collision with onshore infrastructures or failure in mooring process	Green
	Loss of intact stability due to unfavorable ship responses (e.g. to waves)	Red
	Loss of intact stability due to icing	Red
Hazards for the detection	Failure in detection of small objects (wreckage)	Yellow
	Failure in detection of collision targets	Yellow
	Failure in detection of navigational marks	Yellow
	Failure in detection of ship lights, sounds or shapes	Yellow
	Failure in detection of semi-submerged towed or floating devices (e.g. seismic gauges, fishing	Yellow
	Failure in detection of discrepancy between charted and sounded water depth (e.g. wreckage)	Yellow
	Failure in detection of discrepancy between weather forecast and actual weather situation	Green
	Failure in detection of slamming or high vibration	Red

		Sensor Site
Hazards for the communication	Reduction of communication performance (e.g insufficient bandwidth)	Green
	Communication failure (e.g. with SCC, with relevant authorities, with ships in vicinity)	Green
	Communication failure with an other ship in distress	Yellow
	Failure in data integrity (e.g. error in data transmission)	Green
Hazards for the ship integrity, machinery and systems	Water flooding due to structural damage or watertightness device failure	Red
	Fire	Red
	Sensor or actuator failure	Red
	Temporary or permanent loss of electricity (e.g. due to black-out)	Red
	Propulsion or steering failure	Red
	Failure of ship's IT systems (e.g. due to bugs)	Yellow
	Failure of ship's IT infrastructure (e.g. due to fire in the server room)	Yellow
	Failure of anchoring devices when drifting	Green
Hazards for the cargo and passenger management	Too many cargo or passenger aboard (overload)	Green
	Loss of intact stability due to shift and/or liquefaction of cargo or due to cargo overboard	Red
	Passenger overboard	Yellow
	Passenger illness	Red
	Passenger injured during arrival or departure	Red
	Passenger interfering in an aboard system	Red
Hazards for the remote control	Unavailability of SCC (fire, environmental phenomenon...) or of operators (faitness, emergency situation, etc.)	Green
	Human error in remote monitoring and control (e.g. through situation unawareness,	Green
	Human error in remote maintenance	Yellow
…for the security	Willful damage to ship structures by others (e.g. pirates, terrorists)	Green
	Attempt of unauthorised ship boarding (e.g. pirates, terrorists, stowaways, smugglers)	Green
	Jamming or spoofing of AIS or GPS signals	Green
	Jamming or spoofing of communications,	Green

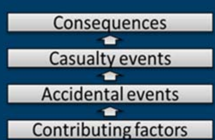
11

Accidents Scenarios



Accidental events from EMPIC (EMSA 2018)
http://www.emsa.europa.eu/fc-default-view/tagged/85-annual-overview.html

- Human errors are the main causation factor for maritime accidents and incidents. Figures a range from 50 to 80% are often seen, with 75% being the figure used by Allianz (2018).



EMCIP elements (EMSA 2018)

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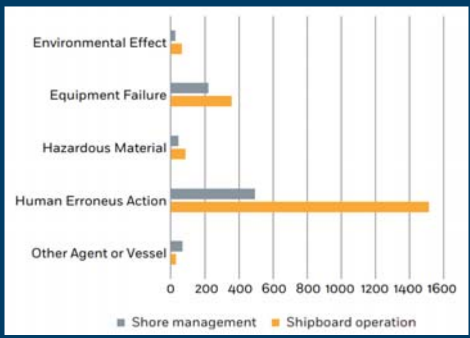
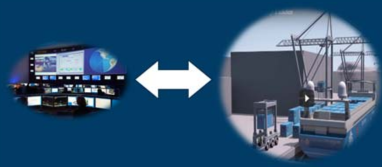
12

Accidents Scenarios



Relationship between ship and shore as contributing factor for marine casualties in general (EMSA 2018). Around 2900 contributing factors have been analyzed.



- Humans still need to intervene with a MASS vessel, however the human element of the operations seem often to be forgotten when designing a MASS.

http://www.emsa.europa.eu/fc-default-view/tagged/85-annual-overview.html

A QUALITATIVE COMPARISON OF AUTONOMOUS AND MANNED SHIPS

	Main differentiating factors	Brief description of effects	New	Today's	Averted
	Fully unmanned				
1	Higher demand on sensors, automation and shore control as one lack some of the "personal touch", both on environment, ship and technical systems' performance.	More technology means more complexity and possibility for technological failure, but will also improve on some of today's operators errors (human error).	R	G	Y
2	Less exposure to danger for the crew.	40% of deaths at sea are occupational hazards.	Y	G	G
3	May be unable to inspect equipment or systems that report errors or problems.	This may cause problems, especially if sufficient back-up systems are not in place.	R	Y	Y
4	Slightly lower risk of fires in accommodation, galleys, laundry and waste systems.	Improvement on today's accident events, but more difficult fire handling and control.	R	G	Y
	Constrained autonomy				
5	More limited, but also more deterministic response from sensors and automation.	Better HAI, due to time to get situational awareness before action.	Y	G	Y
6	Dependence on shore control operators' performance and situational awareness.	Always rested, but not directly in the loop.	R	Y	Y
7	Dependence on communication link to shore.	Loss of communication may cause new accident types, but high integrity req. and clear operational design domains will help.	R	Y	Y
8	Dependence on high quality implementation of fallback solutions and definition of minimum risk conditions for the ship.	More conservative and hence safer operational procedures.	Y	G	G
	Shore control center				
9	Dependence on good cooperation in the shore control center.	Training and resource management is critical.	Y	G	R
10	Intervention crew do not have to worry about personal risk and adverse conditions on board.	May be likely to find solutions to critical problems that would otherwise be lost.	Y	G	Y
	Higher technical resilience				
11	More technical barriers against technical faults.	In case of trouble, backup systems shall be in place.	Y	G	Y
12	Much improved technical systems with built in predictive maintenance functionality.	Less chance of trouble	Y	G	Y
13	Dependent on maintenance at shore.	Something may be forgotten	R	G	Y
	Improved voyage planning				
14	Less chance of surprises during voyage.	Better planned voyage	Y	G	G
15	More support from other functions on shore	Improved traffic regulation	Y	G	G

- Main differentiating factors:
  - Fully unmanned
  - Constraint autonomy
  - Shore Control Centre
  - Higher technical resilience
  - Improved voyage planning
- New, Today's and Averted issues

Red = increased risk contribution
Yellow = neutral impact
Green = lesser impact/likelihood

Fully unmanned

The most interesting autonomous ship projects are associated with fully unmanned operations. While there will be provisions for having people onboard during maintenance and port operations, unmanned voyages have a number of important effects.

Important effects:

1. Higher demand on sensors, automation and shore control as operators in SCC lack some of the "personal touch", both on environment, ship and technical system's performance.
2. Much lower exposure to danger for the crew.
3. May be unable to inspect equipment or systems that report errors or problems.
4. Lower risk of fires in accommodation, galleys, laundry and waste systems, which is relatively high on manned ships.

15

Fully unmanned

	Main differentiating factors	Brief description of effects	New	Today's	Averted
	Fully unmanned				
1	Higher demand on sensors, automation and shore control as one lack some of the "personal touch", both on environment, ship and technical systems' performance.	More technology means more complexity and possibility for technological failure, but will also improve on some of today's operators errors (human error).	R	G	Y
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3	May be unable to inspect equipment or systems that report errors or problems.	This may cause problems, especially if sufficient back-up systems are not in place.	R	Y	Y
4	Slightly lower risk of fires in accommodation, galleys, laundry and waste systems.	Improvement on today's accident events, but more difficult fire handling and control.	R	G	Y

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16

Constrained autonomy

Important effects:

1. More limited, but also more deterministic action responses from sensors and automation.
2. Dependence on shore control operators' performance and situational awareness.
3. Dependence on communication link to shore.
4. Dependence on high quality implementation of fallback solutions and definition of minimum risk conditions for the ship.

Autonomy will be limited for the onboard systems and the ship will be dependent on occasional support from the SCC. To avoid known problems with human-automation interfaces (HAI) in the shore control center, the ship automation will have "constrained autonomy". The assumption is that this also helps in testing and qualifying sensor and automation systems to specified performance level.

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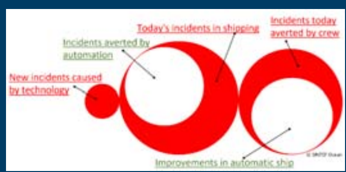
17

Constrained autonomy



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Human-automation interfaces (HAI)

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18

Shore control center

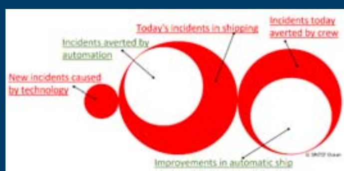
Important effects:

1. Dependent on good training and cooperation in the shore control center.
2. Intervention crew do not have to worry about personal risk and adverse conditions on board.

The SCC will be manned with supervision operators as well as specialist intervention teams that are activated in cases of special demands from a ship.

19

Shore control centre (SCC)



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20

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21

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Teknologi for et bedre samfunn

22