

SAFE HUMAN INTERACTION IN AUTONOMOUS SHIPPING

Human Factors in Control, Trondheim 17/10 2017

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Why autonomous ships ?



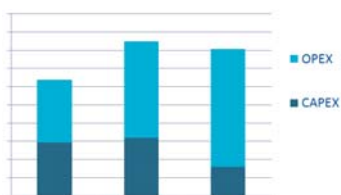
Less dangerous exposure for crew



Less damage related costs



Fewer large oil spills



Lower costs ?



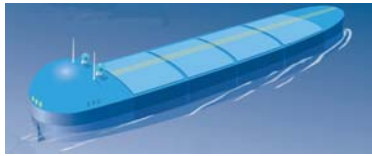
Lower emissions



New ship types



Completely unmanned gives largest benefits!



No accommodation
Less power
More cargo



No crew
No crew related costs



NCE Maritime Clean Tech & NCL

Enables completely new transport system concepts



No safety equipment
New constructions



Levels of autonomy?



Other areas?

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Mode)
Human driver monitors the driving environment						
0	No Automation	The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or observation systems.	Human driver	Human driver	Human driver	N/A
1	Driver Assistance	The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.	System	System	Human driver	Some driving modes
4	High Automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.	System	System	System	Some driving modes
5	Full Automation	The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a driver.	System	System	System	All driving modes

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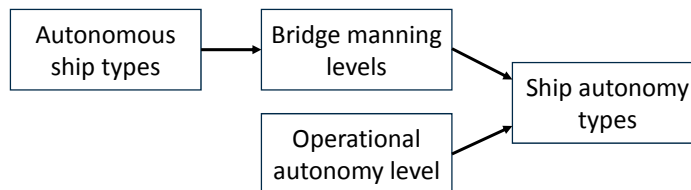
... and many more

Level	Description
High	10. The computer decides everything, acts autonomously, ignoring the human.
	9. The computer informs the human only if it, the computer, decides to.
	8. The computer informs the human only if asked, or
	7. The computer executes automatically, then necessarily informs the human, and
	6. The computer allows the human a restricted time to veto before automatic execution, or
	5. The computer executes that suggestion if the human approves, or
Low	4. The computer suggests one alternative
	3. The computer narrows the selection down to a few, or
	2. The computer offers a complete set of decision/action alternatives, or
	1. The computer offers no assistance; the human must take all decisions and actions.

Level	Name	Description
1	Human Operated	A human operator makes all decisions. The system has no autonomous control of its environment although it may have information-only responses to sensed data.
2	Human Delegated	The vehicle can perform many functions independently of human control when delegated to do so. This level encompasses automatic controls, engine controls, and other low-level automation that must be activated or deactivated by human input and must act in mutual exclusion of human operation.
3	Human Supervised	The system can perform a wide variety of activities when given top-level permissions or direction by a human. Both the human and the system can initiate behavior based on sensed data, but the system can do so only if within the scope of its currently directed tasks.
4	Fully Autonomous	The system receives goals from humans and translates them into tasks to be performed without human interaction. A human could still enter the loop in an emergency or change the goals, although in practice there may be significant time delays before human intervention occurs.



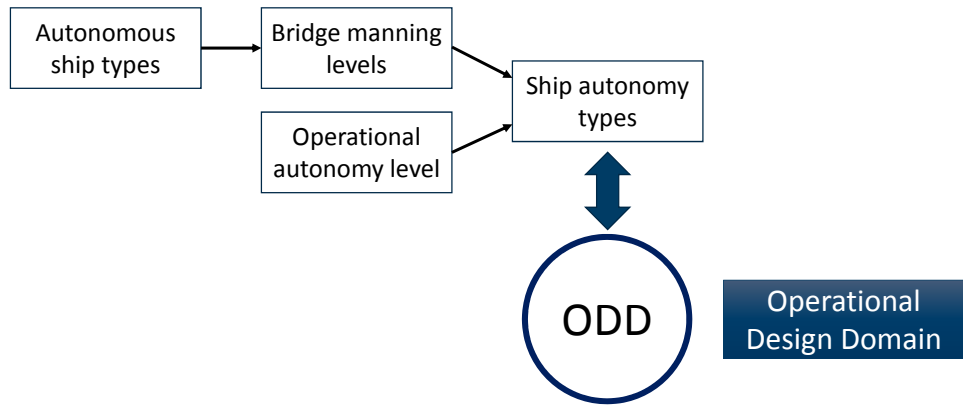
NFAS' approach



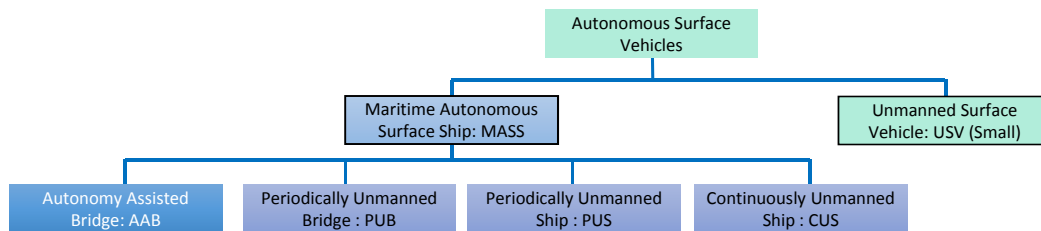
Complexity ?



NFAS' approach



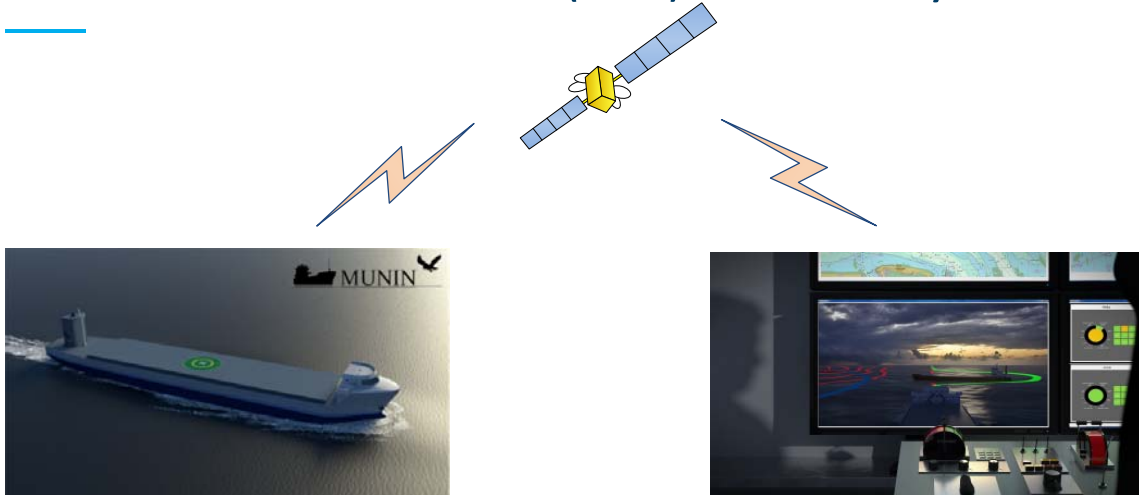
Types of autonomous ships – manning levels



Ship type	Always on Bridge	Available on Ship	Never on Bridge
AAB	x		
PUB		x	
PUS			x
CUS			x

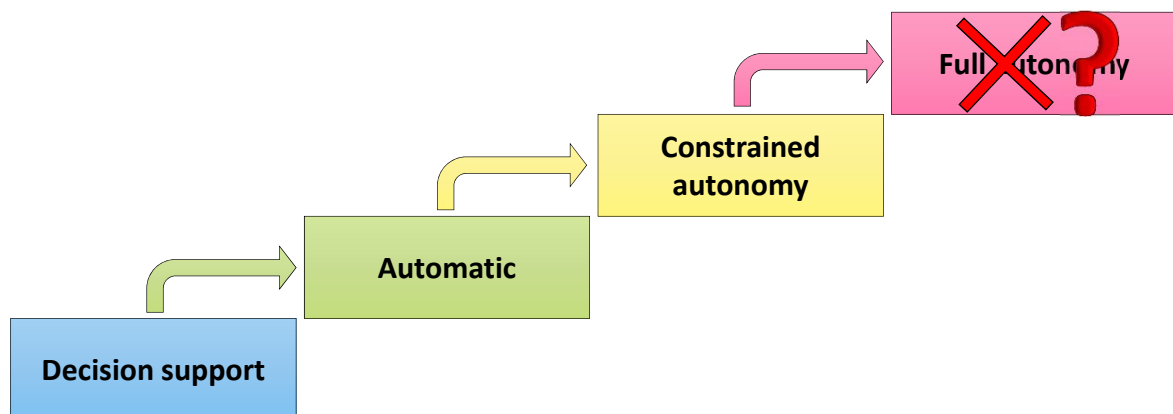


A Shore Control Centre (SCC) is normally needed



SINTEF

Operational autonomy levels



SINTEF

Ship autonomy types

	Always on bridge	Available on board	Never on Bridge
Decision support	Decision Support	Remote Control	Remote Control
Automatic	Automatic Bridge	Automatic Ship	Automatic Ship
Constrained autonomy	-	Constrained Autonomous	Constrained Autonomous
Full autonomy	-	-	Fully Autonomous

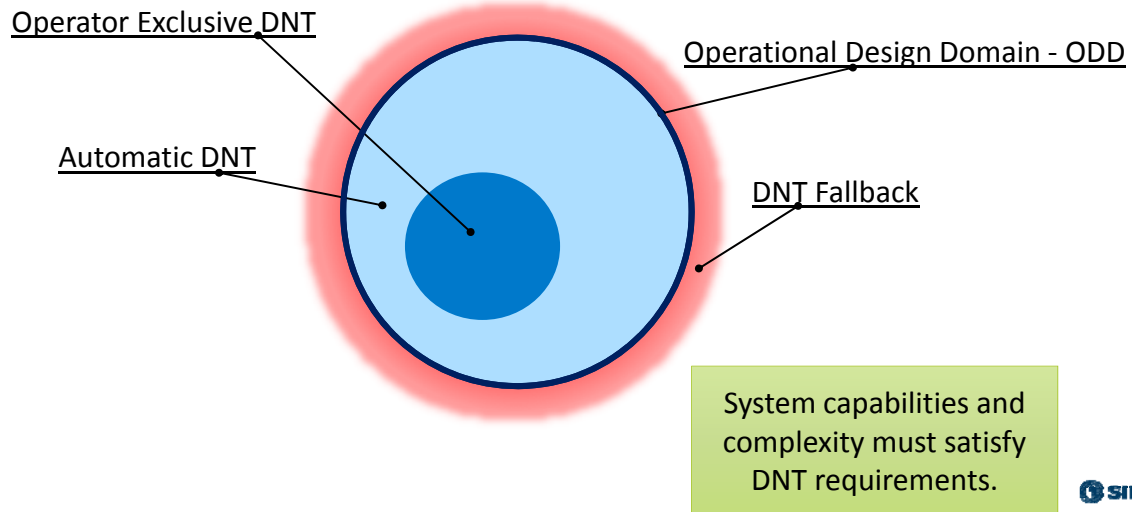


Ship autonomy types - ordered

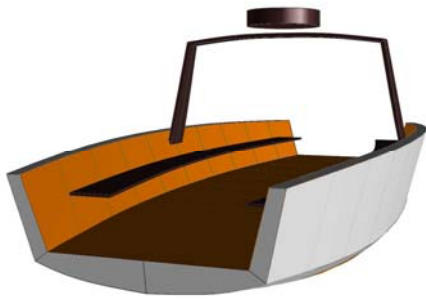
- ✓ **Decision support:** Decision support and advice to crew on bridge. Crew decides.
- ✓ **Automatic bridge:** Automated operation, but under continuous supervision by crew.
- ! **Remote control:** Unmanned, continuously monitored and direct control from shore.
- ! **Automatic ship:** Unmanned under automatic control, supervised by shore.
- ! **Constrained autonomous:** Unmanned, partly autonomous, supervised by shore.
- ✗ **Fully autonomous:** Unmanned and without supervision.



Complexity: OOD and Dynamic Navigation Task



Types of autonomous ships



- On-demand passenger ferry
- Max 12 persons + bicycles
- Electrical propulsion, battery
- Inductive charging at quay

NTNU
Kunnskap for en bedre verden

NTNU AMOS
Centre for Autonomous Marine
Operations and Systems

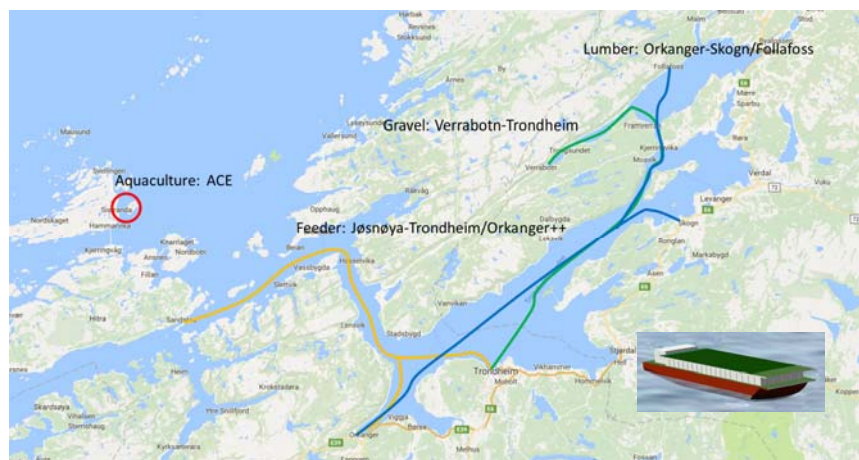


Linking center of Trondheim to
seaside and rail station

SINTEF

Autonomous Ship Transport at Trondheimsfjorden (ASTAT)

- Short voyages
- 12-50 TEU
- Inland,
fjords/sheltered
- Low cost: Wait in port
- Legs 4-12 hours
- Port cranes
- Automated berthing
- Batteries



SINTEF

Yara Birkeland

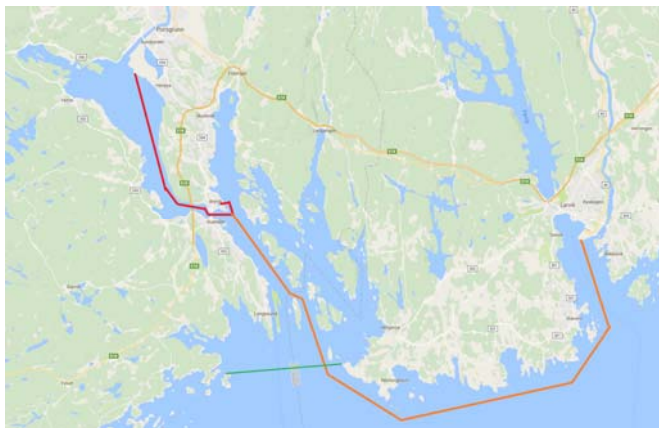


- Yara fertilizer
- Fully electric
- Replaces 40 000 truck trips a year

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Yara Birkeland Operation



- Features
 - 100-150 TEU, 70 m x 15 m
 - Batteries – Fully electrical
- Staged implementation
 - Manned after 1 year
 - Remote after 2 year
 - Autonomous after 3 year
- Operational area
 - Herøya-Brevik – 7 nm
 - Herøya-Larvik – 30 nm
 - Within Brevik VTS area

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Hrönn: Unmanned offshore vessel



- Light-duty, offshore utility ship
- Commissioned in 2017, in operation 2018
- Initially for man in the loop applications
- Tested in Trondjemsfjorden test area

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Deep sea is feasible, but not first mover ?

- 10 000 TEU container vessel
- Shanghai – Los Angles
 - Two states involved
 - 6000 nm, open sea
 - No channels
 - Short port approach
 - Remote control to port
- Dual propulsion systems
- Two stroke diesels
- Biofuel, methanol ...



... but, autonomous ships are not conventional ships without crew.

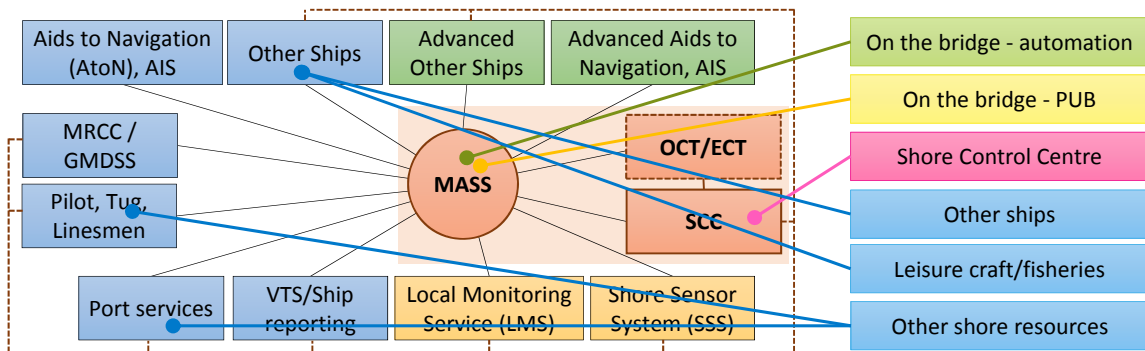


Human Interaction ?

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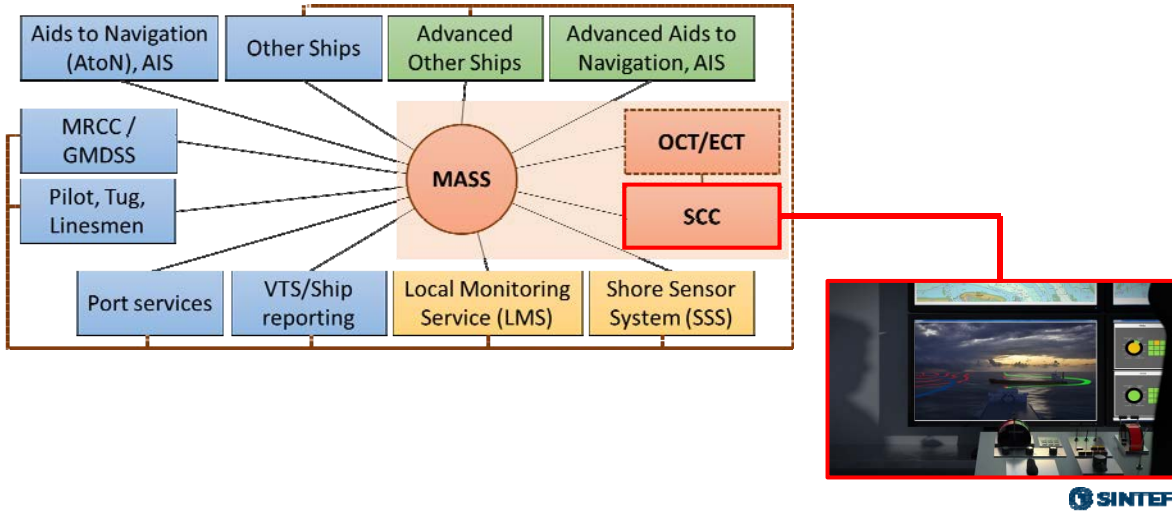
Human interaction where?



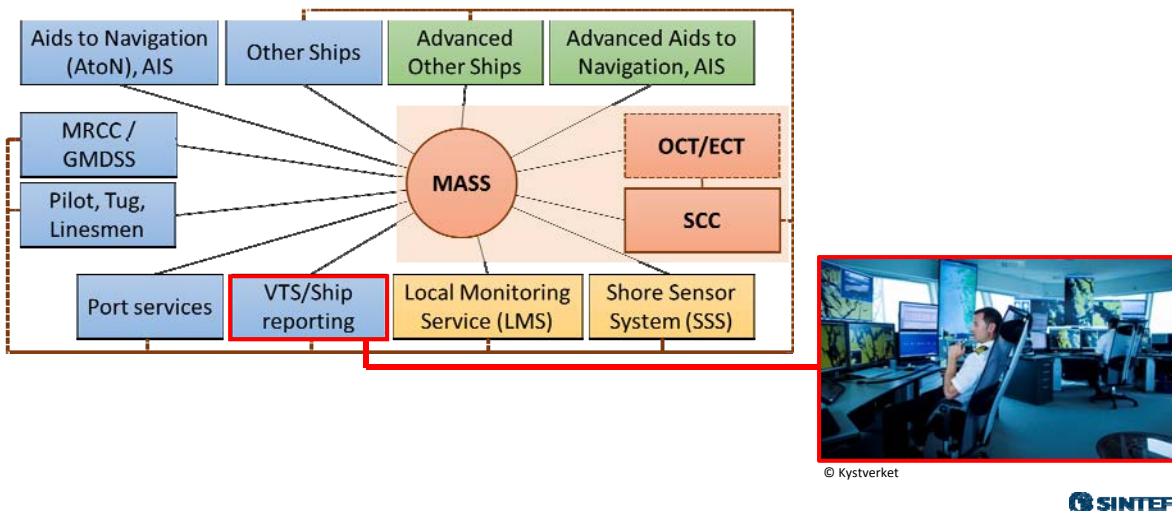
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A Shore Control Centre (SCC) is normally needed

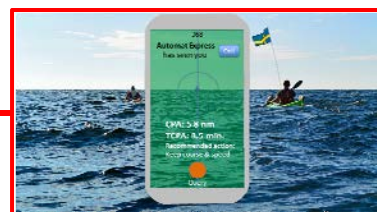
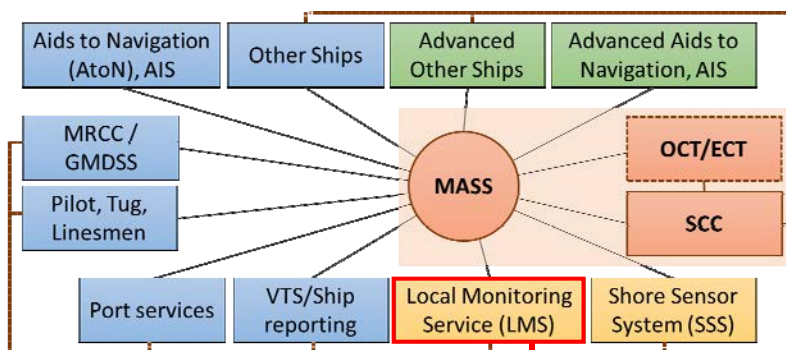


VTS may be used to interface to other vessels



© Kystverket

And maybe LMS as interface to leisure/fisheries

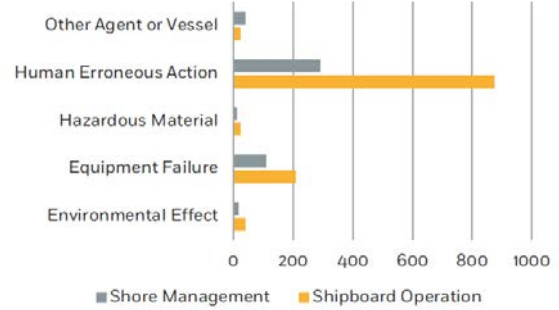
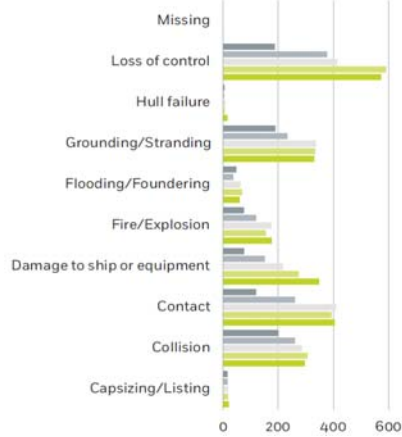


© Thomas Porathe, NTNU



Safe Human Interaction ?

What can go wrong ?



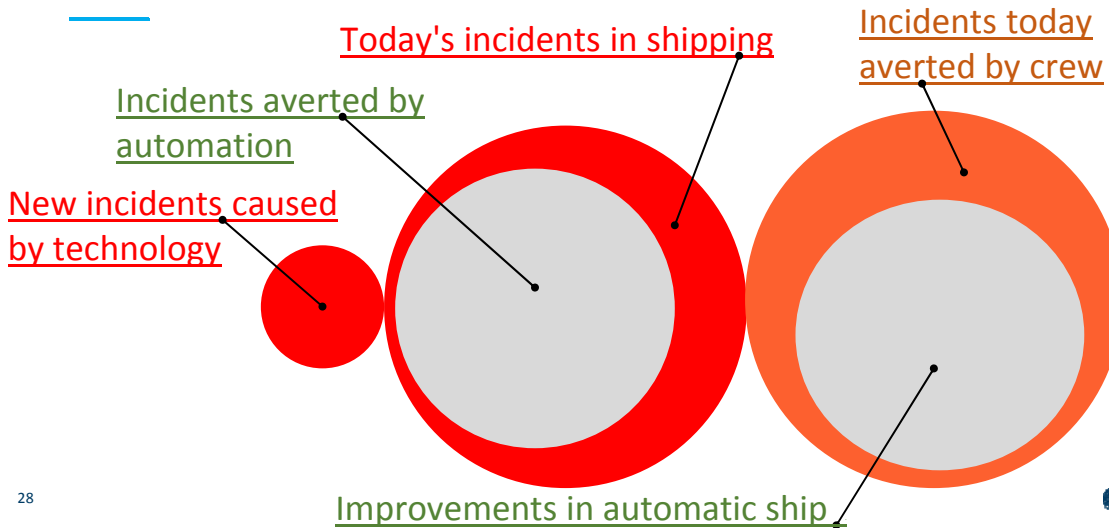
... and why

EMSA: Annual Overview of Marine Casualties and Incidents 2016



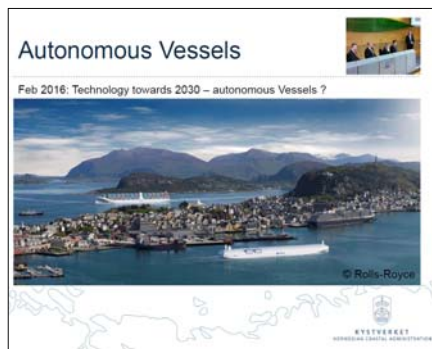
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Is this the full picture ?

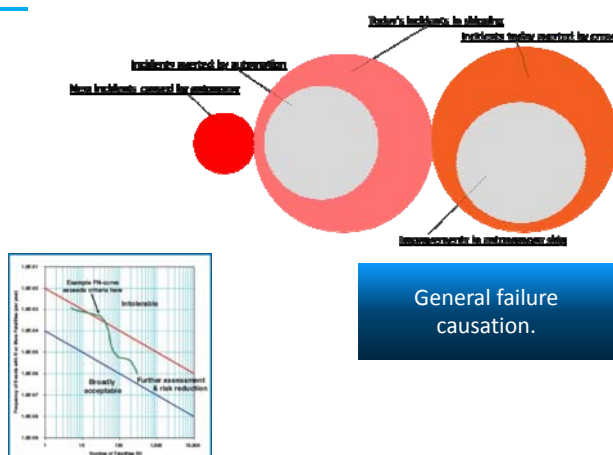


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Authorities need to set requirements



Based on acceptable risk levels



Things are bigger and move slower



Advanced technology already in place



More space, less obstacles

Technical and societal risk criteria.

Particulars of nautical operations



However, there are also additional liability issues



- Contracts

- Insurance
- Liability



[wikimedia.org/paolodefalco75](https://commons.wikimedia.org/wiki/File:Paolodefalco75)

To conclude

Conclusions

No answer to the question of safety in human interactions related to autonomous ships.

- Need to consider ship and ship autonomy type.
- Complexity is an additional attribute.
- Need to consider different types of human interaction.
- Need to consider different types of risks.



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Norwegian Forum for Autonomous Ships

- Established October 4th 2016
- Operated as a joint industry project at SINTEF Ocean.
- General Manager is Mr. Ørnulf Jan Rødseth.
- A board of governors overseeing operations. General assembly approves budgets and strategies.
- 42 Institutional Members
 - Including Industry, authorities, class, insurance research, universities, ports ...
 - 2 other institutions as personal members

NFAS Norsk Forum for
Autonome Skip

<http://nfas.autonomous-ship.org>

National and international strategy



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Technology for a better society