



AUTONOMOUS VESSELS - R&D AND ECOSYSTEM

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SINTEF Ocean

From January 2017, a merger of:

- MARINTEK
- SINTEF Fisheries and Aquaculture
- SINTEF Environmental Chemistry

Not-for-profit, independent

Contract research

360 employees



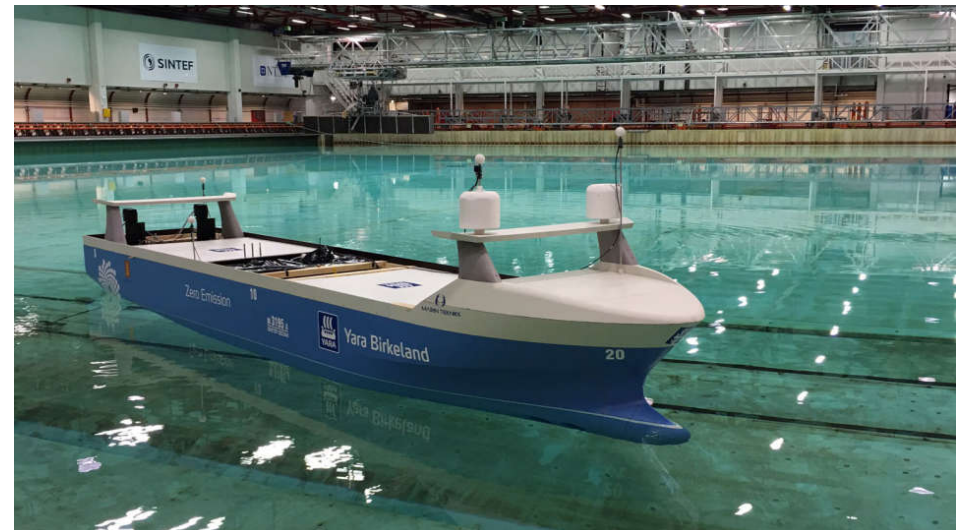
Autonomous systems at SINTEF



Photo: Eelume



Illustrasjonsfoto: Maritime Robotics og SINTEF Fiskeri og havbruk

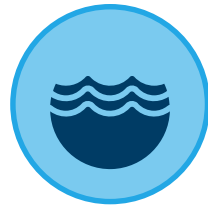


Applied research, technology and innovation

Expertise from ocean space to outer space:



Renewable energy



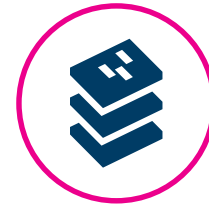
Ocean space



Industry



Buildings and infrastructure



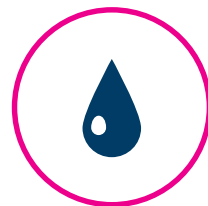
Materials



Micro-, nano- and biotechnology



Climate and environment



Oil and gas



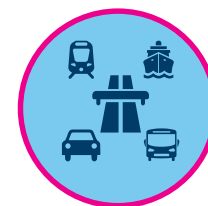
Health and welfare



Society

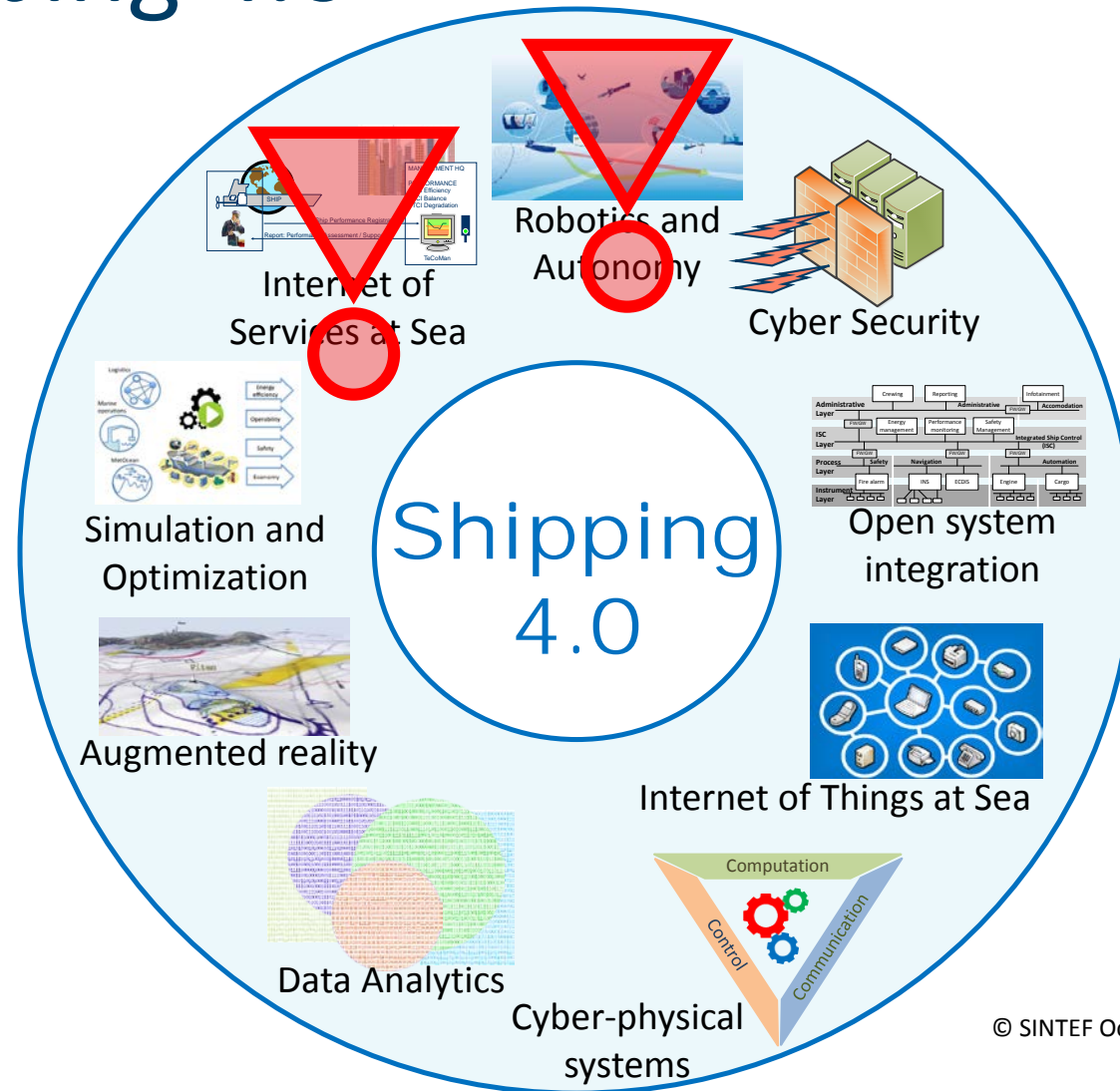


Digitalization



Transport

Shipping 4.0

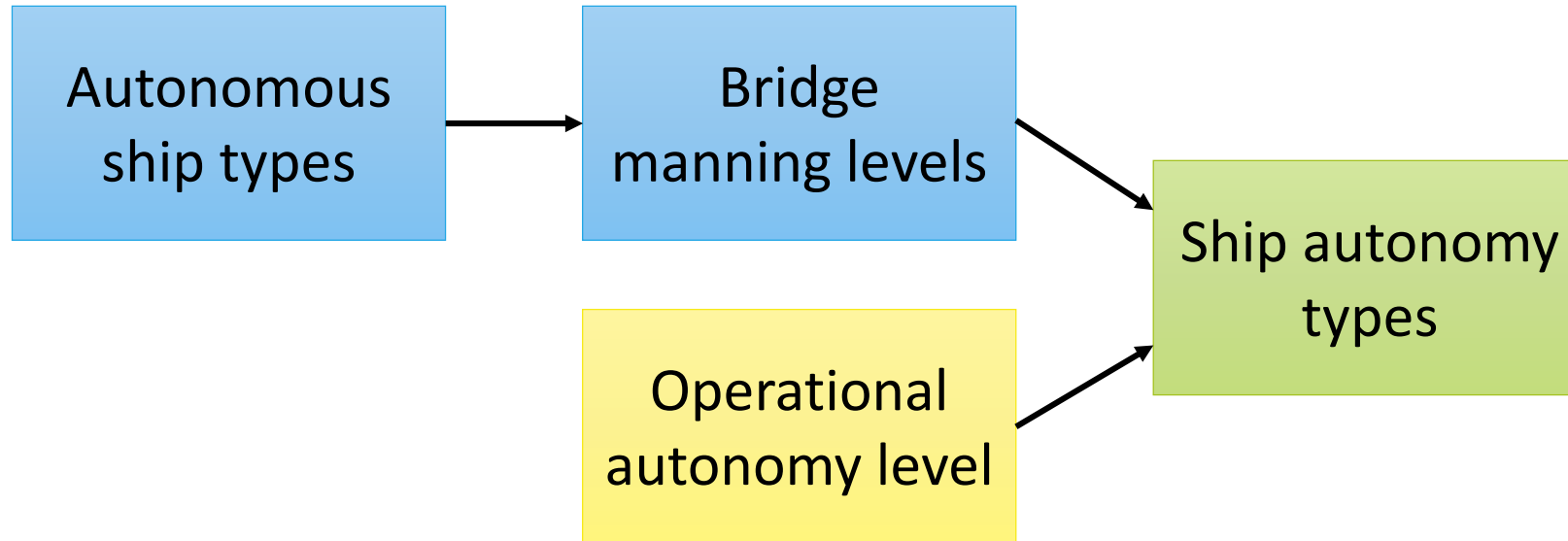


Possible game changers in Shipping 4.0:

- Digitalization of commercial shipping processes
- Autonomous and unmanned ships

What is Ship Autonomy?

"Levels" of autonomy



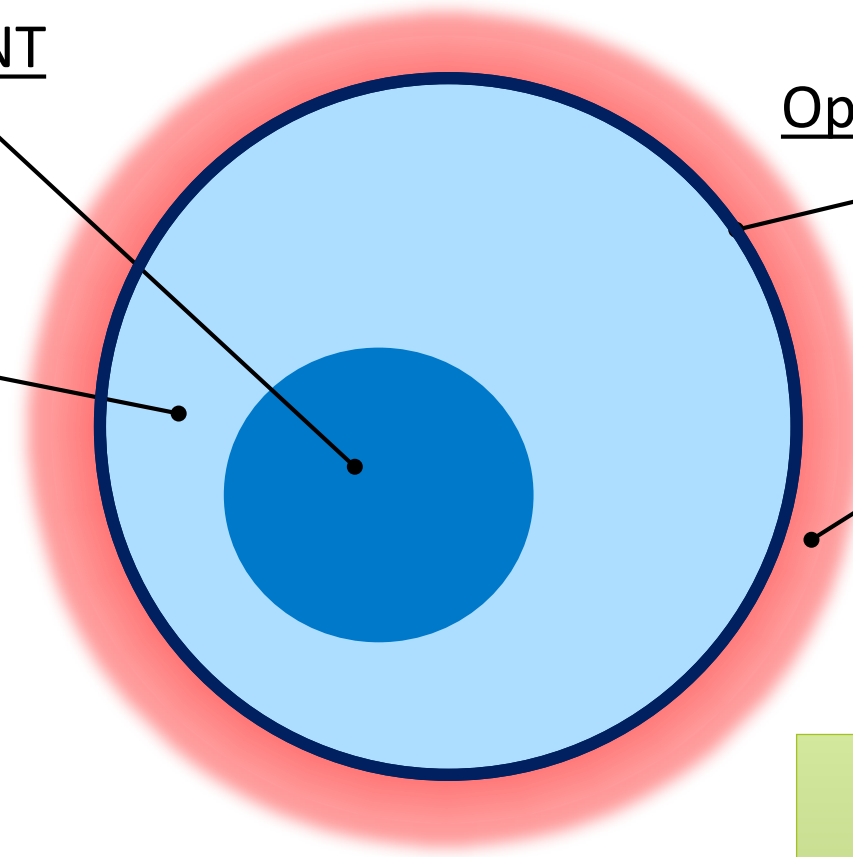
Complexity: Operational Design Domain and Dynamic Navigation Task

Operator Exclusive DNT

Operational Design Domain - ODD

Automatic DNT

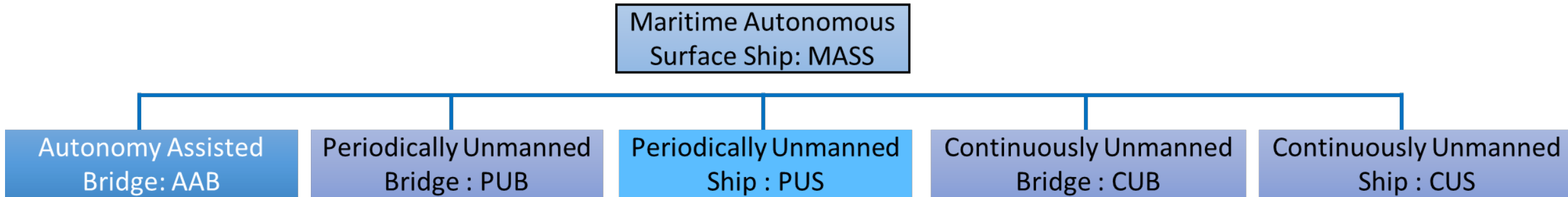
DNT Fallback



System capabilities and complexity defined by OOD and DNT.

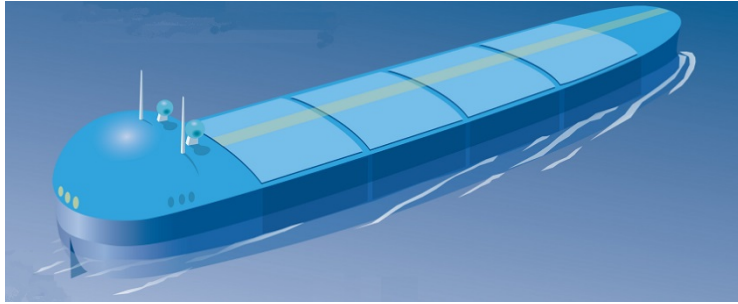
Derived from SAE J3016

Types of autonomous ships – manning levels

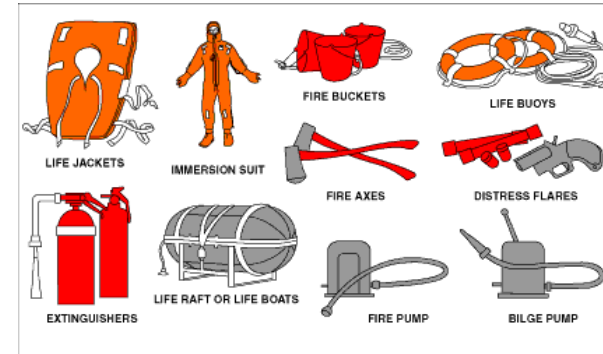


Ship type	Always on Bridge	Available on Ship	Never on Bridge
AAB	x		
PUB		x	
PUS			x
CUB			x
CUS			x

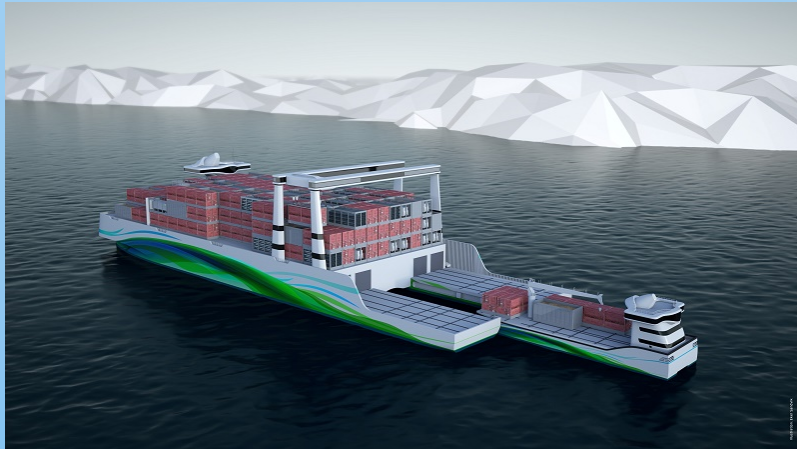
Completely unmanned gives largest benefits!



No accommodation
Less power
More cargo



No safety equipment
New constructions



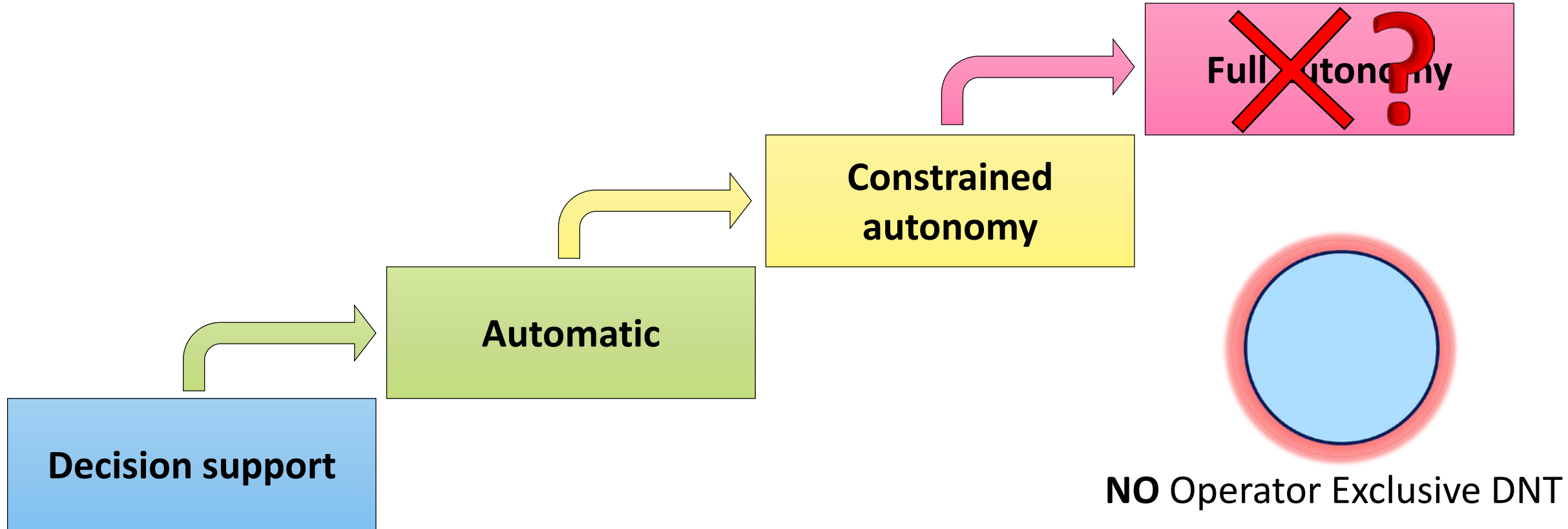
Enables completely new transport system concepts

NCE Maritime Clean Tech & NCL

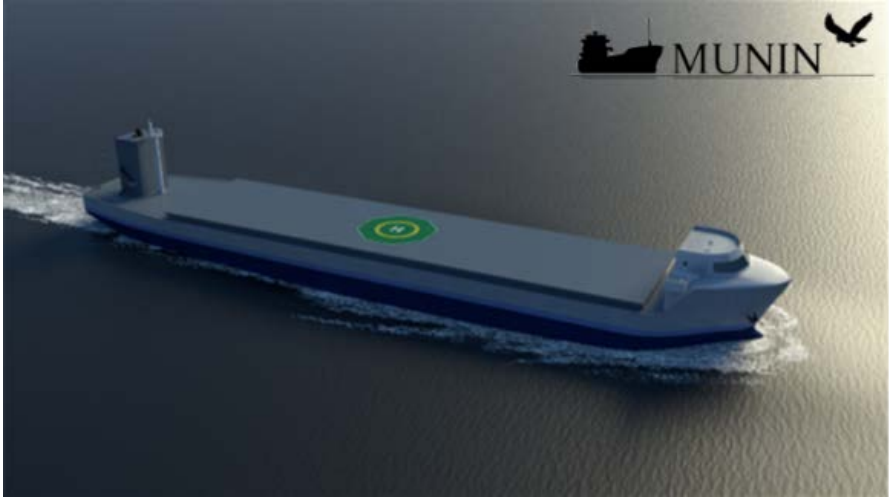
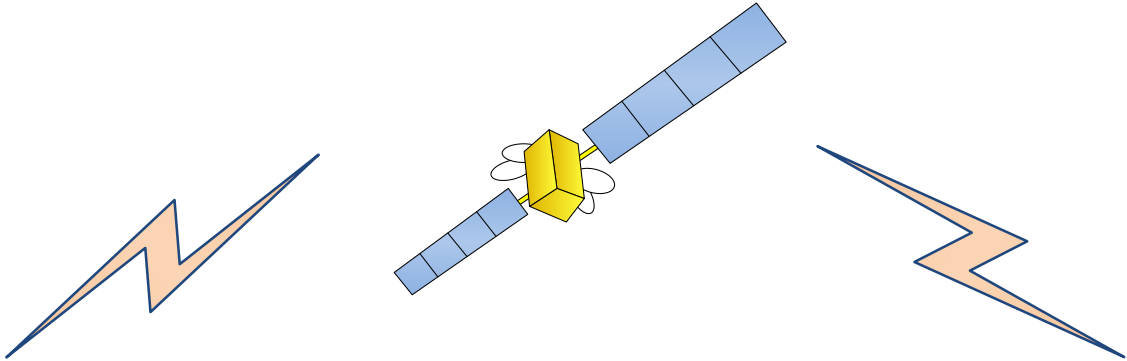
No crew
No crew related costs



Operational autonomy levels



A Shore Control Centre (SCC) is normally needed



Ship autonomy types

Level \\ Crew	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

Types of autonomous ships

Yara Birkeland



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

Autonomous Ship Transport at Trondheimsfjorden (ASTAT)

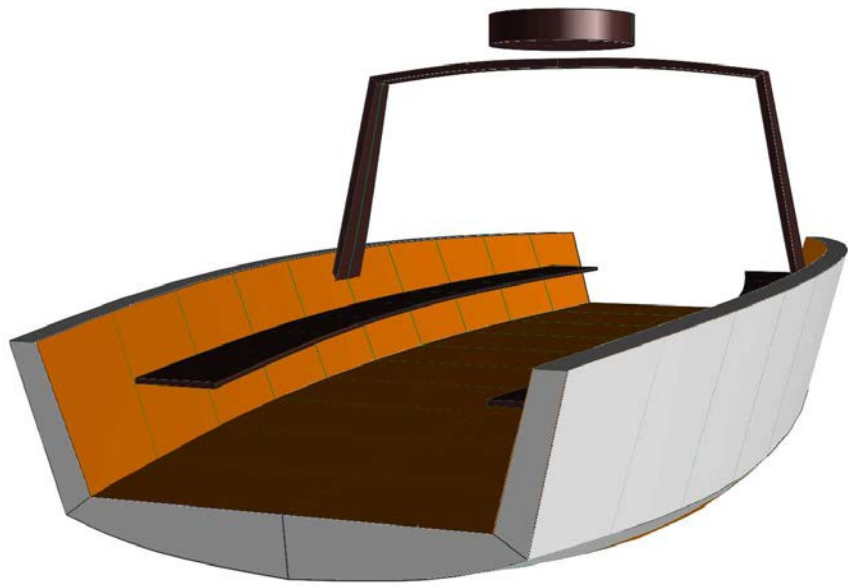
- Short voyages
- 12-50 TEU
- Inland, fjords/sheltered
- Low cost: Wait in port
- Legs 4-12 hours
- Port cranes
- Automated berthing
- Batteries



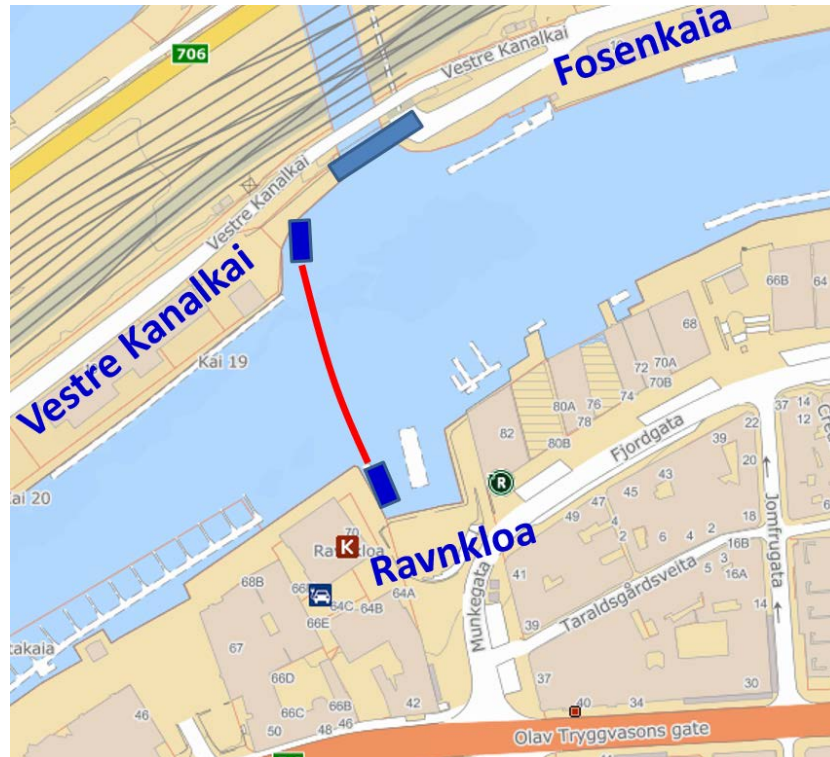
Hrönn: Unmanned offshore vessel



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



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



Linking center of Trondheim to
seaside and rail station

Highway car ferries

Coordinated car arrival (ITS)

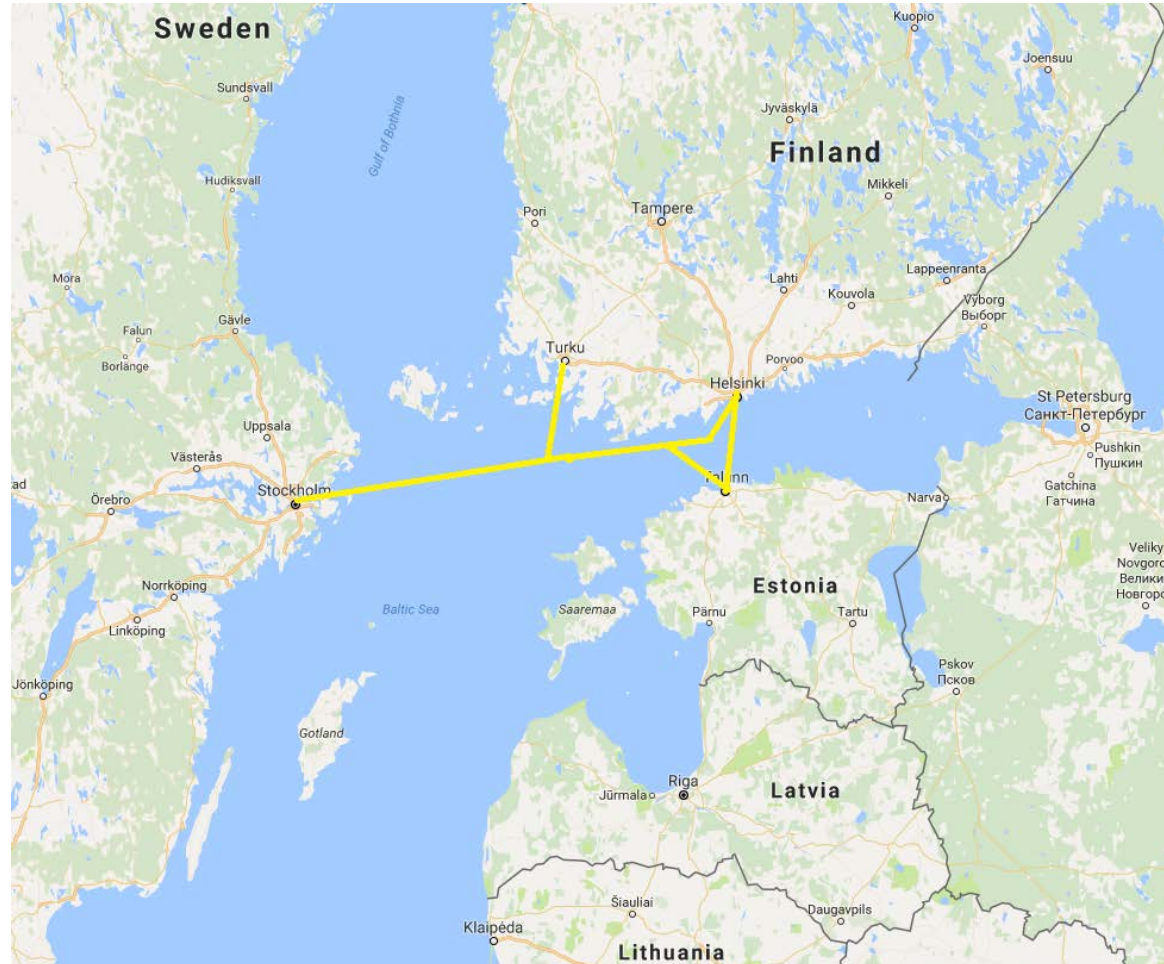


Flexible capacity

On demand for small communities



Medium distance unmanned RORO



For trucks changing driver at national borders or when rest is needed.

Deep sea is feasible, but not first mover ?

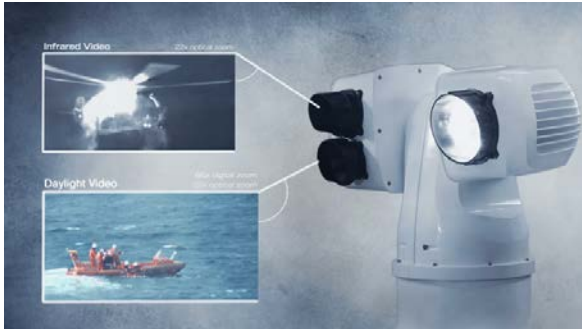
- 10 000 TEU container vessel
- Shanghai – Los Angles
 - Two states involved
 - 6000 nm, open sea
 - No channels
 - Short port approach
 - Remote control to port
- Dual propulsion systems
- Two stroke diesels
- Biofuel, methanol ...



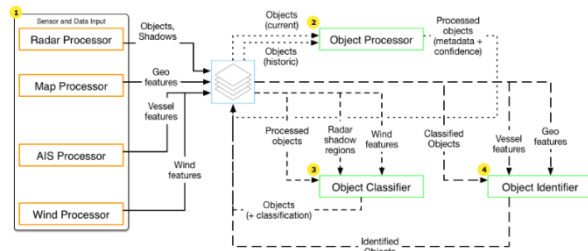
... but, autonomous ships are not conventional ships without crew.

Some prioritized research areas

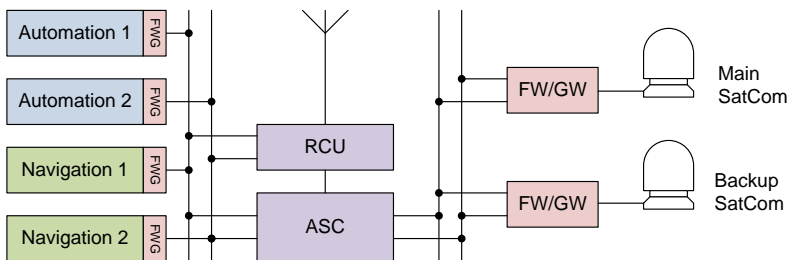
Advanced sensor and control systems



New detectors in IR and daylight video.
Improved radars.



Sensor fusion and classification: AIS, Radar and video
Automatic manoeuvring and anti-collision.



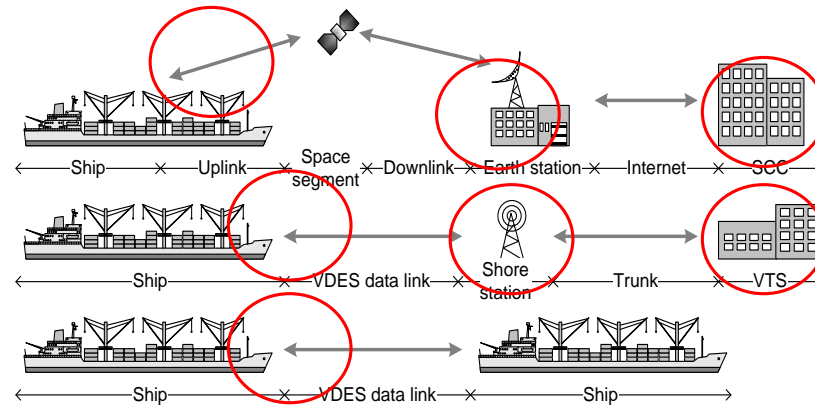
General ship system redundancy and
communication systems integration.

Cyber security

- GNSS spoofing



University of Texas at Austin



- Communication system security



- Virus and other malware

Improved maintenance planning & management



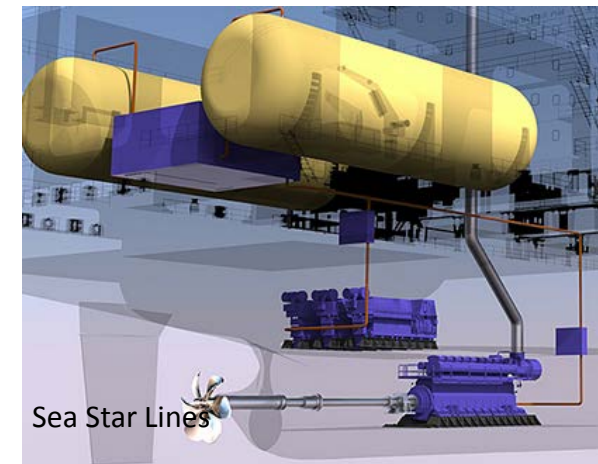
Redundancy



Minimize complex systems onboard



Maintenance systems

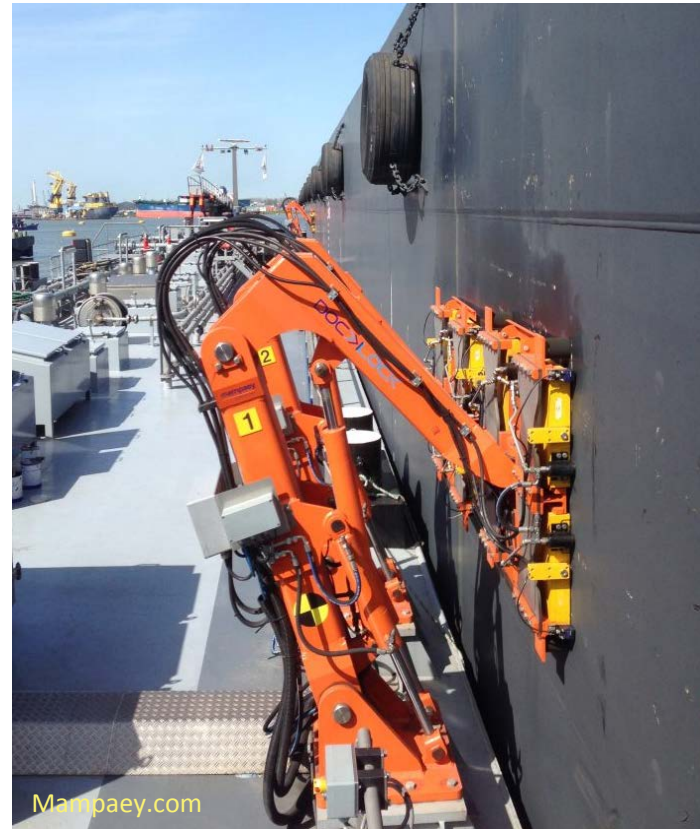


No heavy fuel oil

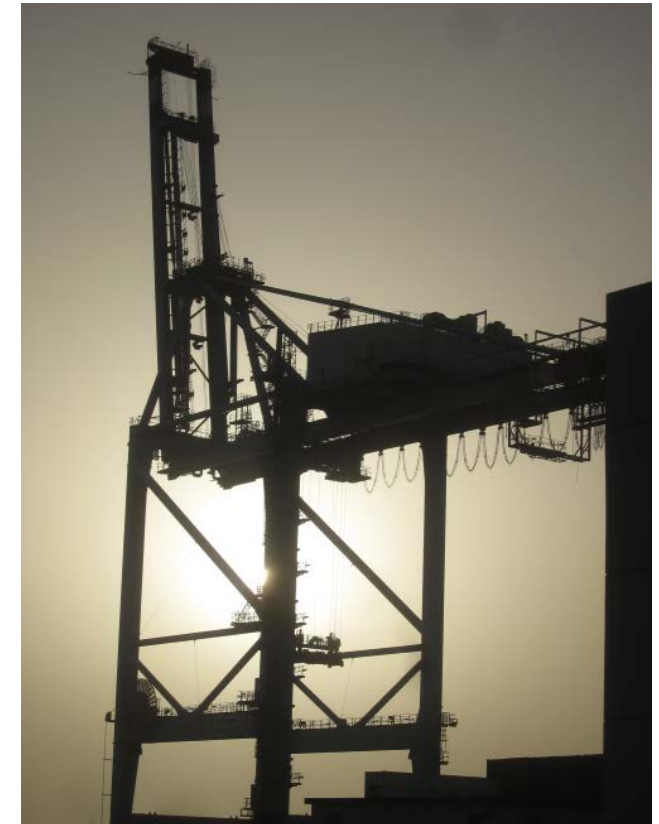
Efficient infrastructure on shore



Shore control, VTS interface

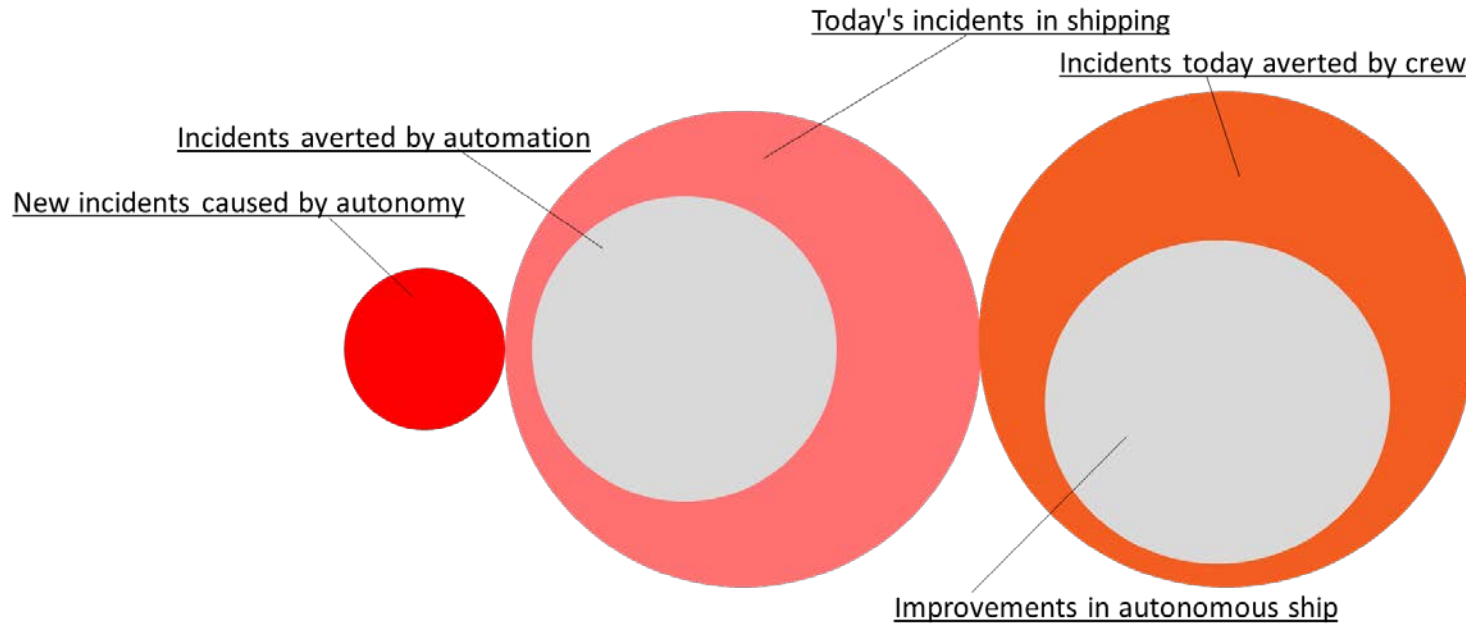


Tugs, docking, mooring



Loading and discharge of cargo

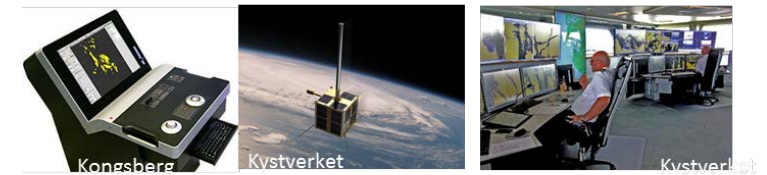
Risks and accept criteria for autonomous ships



Comparisons between modes (car vs. ship)



Things are bigger and move slower



Advanced technology already in place



More space, less obstacles

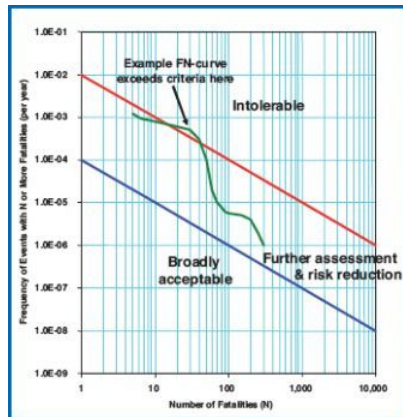


Fig 1 – Illustrative FN-Criteria

General failure causation.

Technical and societal risk criteria.

Legal and liability issues



- UNCLOS
- SOLAS



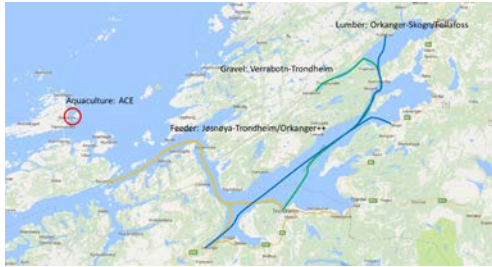
- Contracts

- Insurance
- Liability

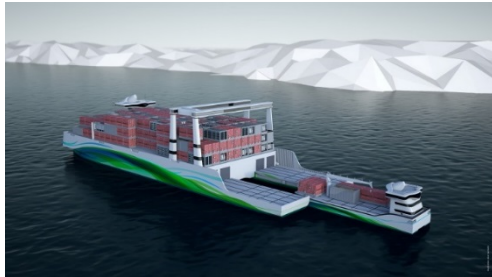


[wikimedia.org/paolodefalco75](https://commons.wikimedia.org/wiki/File:Paolodefalco75)

New transport system design



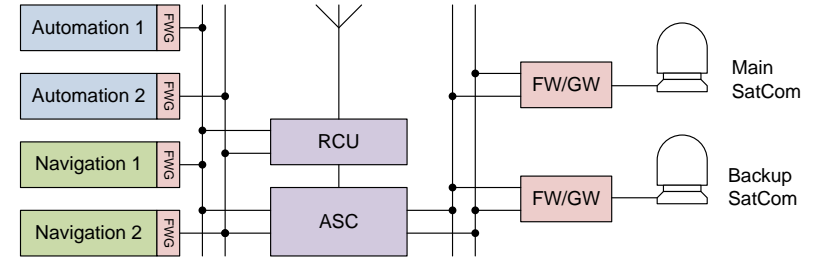
Logistics



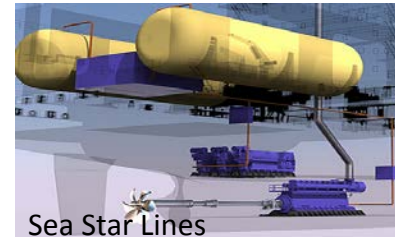
Process changes



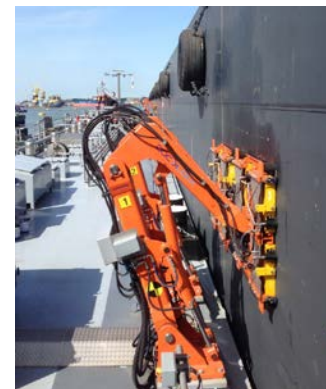
Automation and crew costs



More complex ship systems



No maintenance on board



Shore Infrastructure

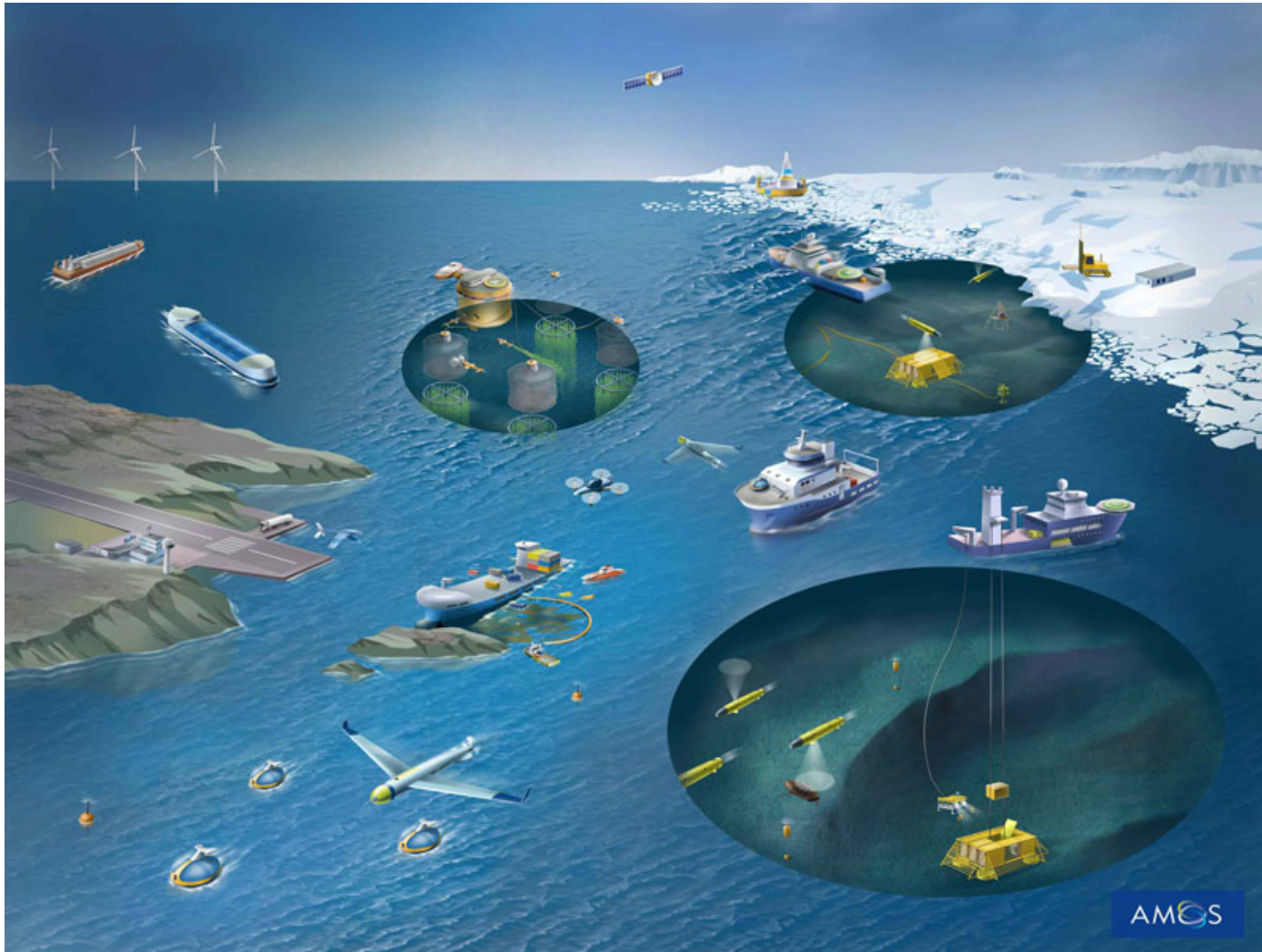
National and international ecosystem

MUNIN: A concept study for a fully unmanned handymax dry bulk carrier on intercontinental voyage.

- Duration: 01.09-2012 – 31.08.2015
- Funding: 2.9 million EUR of budget 3.8 million EUR
- Activity code: SST.2012.5.2-5: E-guided vessels - the 'autonomous' ship



NTNU AMOS



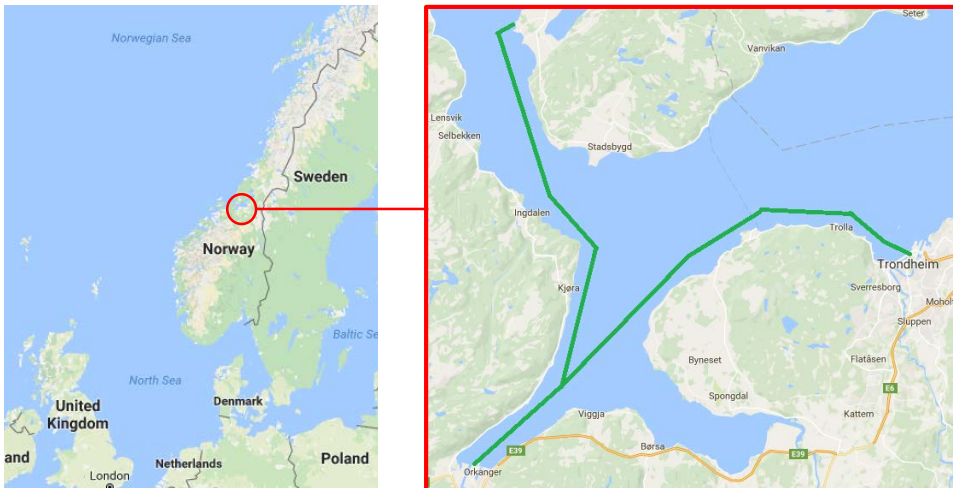
- Supported by Norwegian Research Council
- Norwegian "Centre of Excellence"
- Established 2013
- Planned for 10 years
- Total budget approx. EUR 80 million

Test area Trondheimsfjorden



- Established September 30th 2016

- Industry, university, research
- Port of Trondheim
- Norwegian Maritime Administration
- Norwegian Coastal Administration



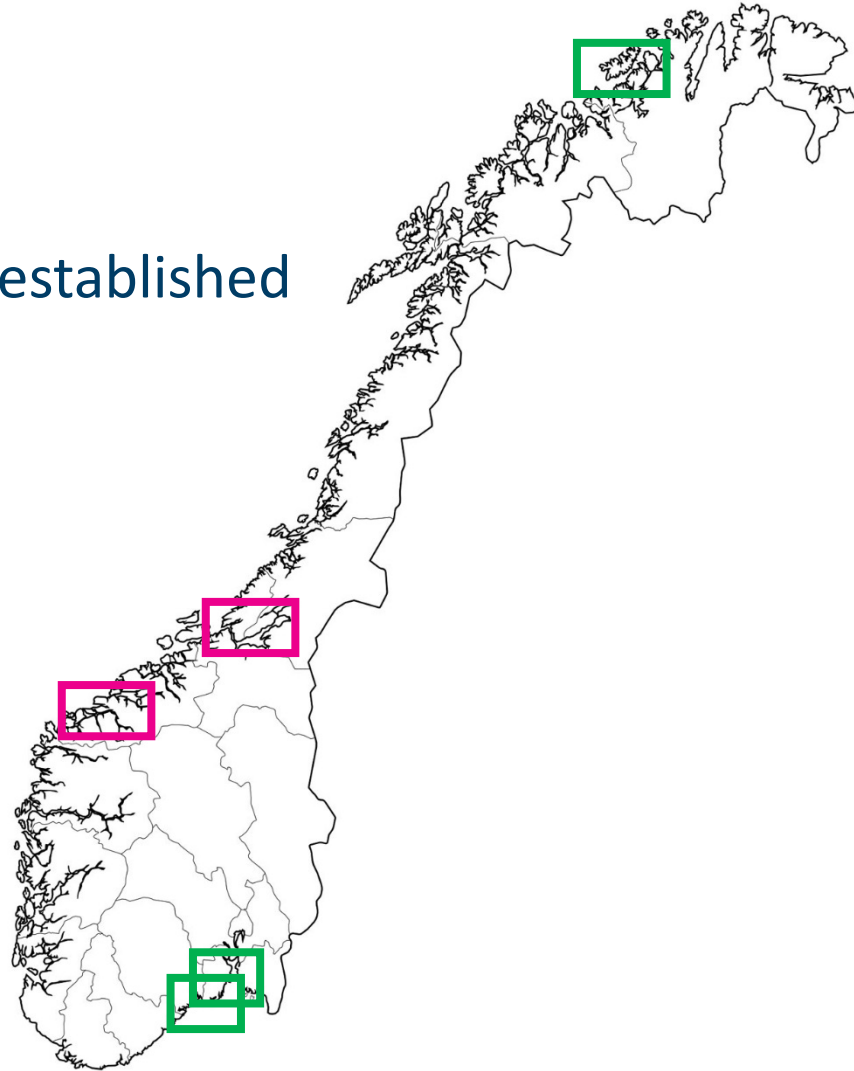
- Area covers Trondheimsfjorden

- Permits
- Instrumentation and communication
- Exchange of experience

<http://navtar.no/>

Test areas - status

- Trondheimfjorden and Storfjorden are established
- Horten to be announced shortly
- Grenland to be announced next year
- Tromsø possible next



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>

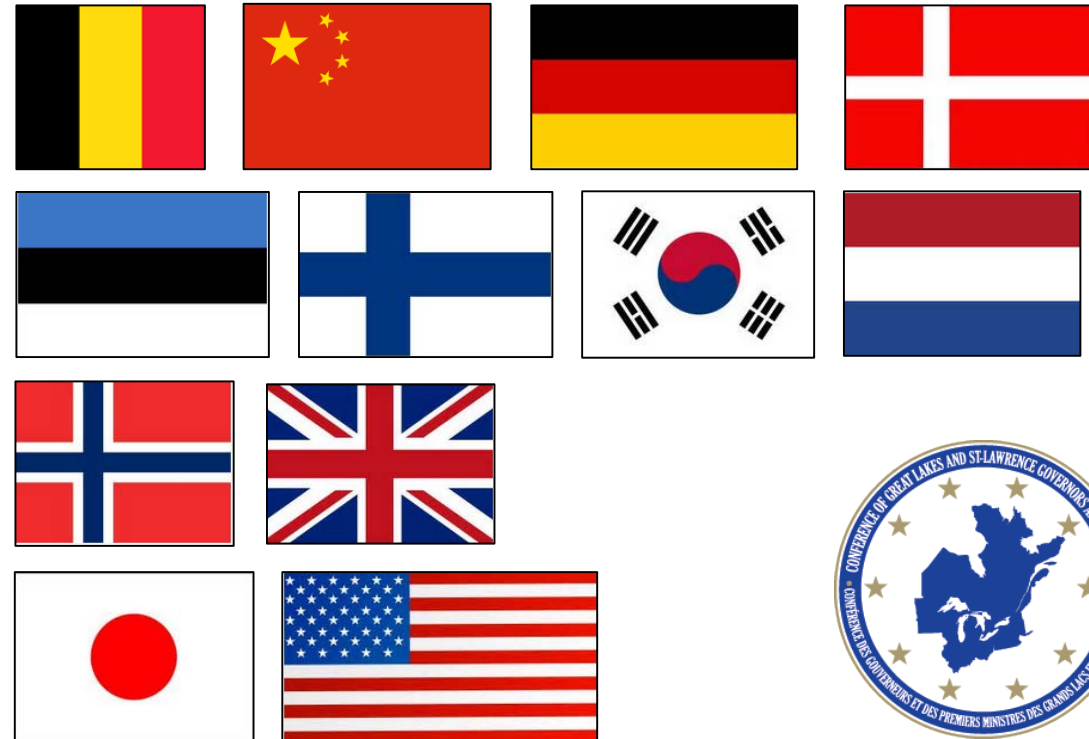
National and international collaboration



International Network for Autonomous Ships



- Agreed on at meeting in Oslo Oct. 30th 2017
- Hosted by NFAS and SINTEF Ocean
- 22 participants and 10 countries at meeting
- 2 correspondent countries
- First inland meeting in Trondheim November 6-7



Conclusions



- Shipping 4.0 will be a game changer in autonomy and digitalization.
- Development of autonomous ships is rapidly progressing.
- Current projects based on new business models.
- Many research challenges, competitive and non-competitive
- International cooperation is being established.



Technology for a better society