Autonomous ships

Technological Challenges and Human Factors

(A Norwegian perspective)

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Autonomous passenger ferry in Trondheim harbour by 2019 (NTNU)

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Vice chair IALA's e-Navigation Committee, Maritime Service Portfolios working group

EU e-Navigation projects

- BLAST (Norwegian Hydrographic Office) 2009-2012
- EffcienSea (Danish Maritime safety Administration) 2009-2012
- MONALISA (Swedish Maritime Adminstration) 2009-2012
- MONALISA 2 (Swedish Maritime Administration) 2012-2015
- MICE (Swedish Maritime Administration) 2014-2016
- ACCSEAS (General Lighthouse Authorities of UK and Ireland) 2012-2015
- EffcienSea 2 (Danish Maritime Authority) 2015-2018

- MUNIN (Fraunhofer CML) 2012-2015

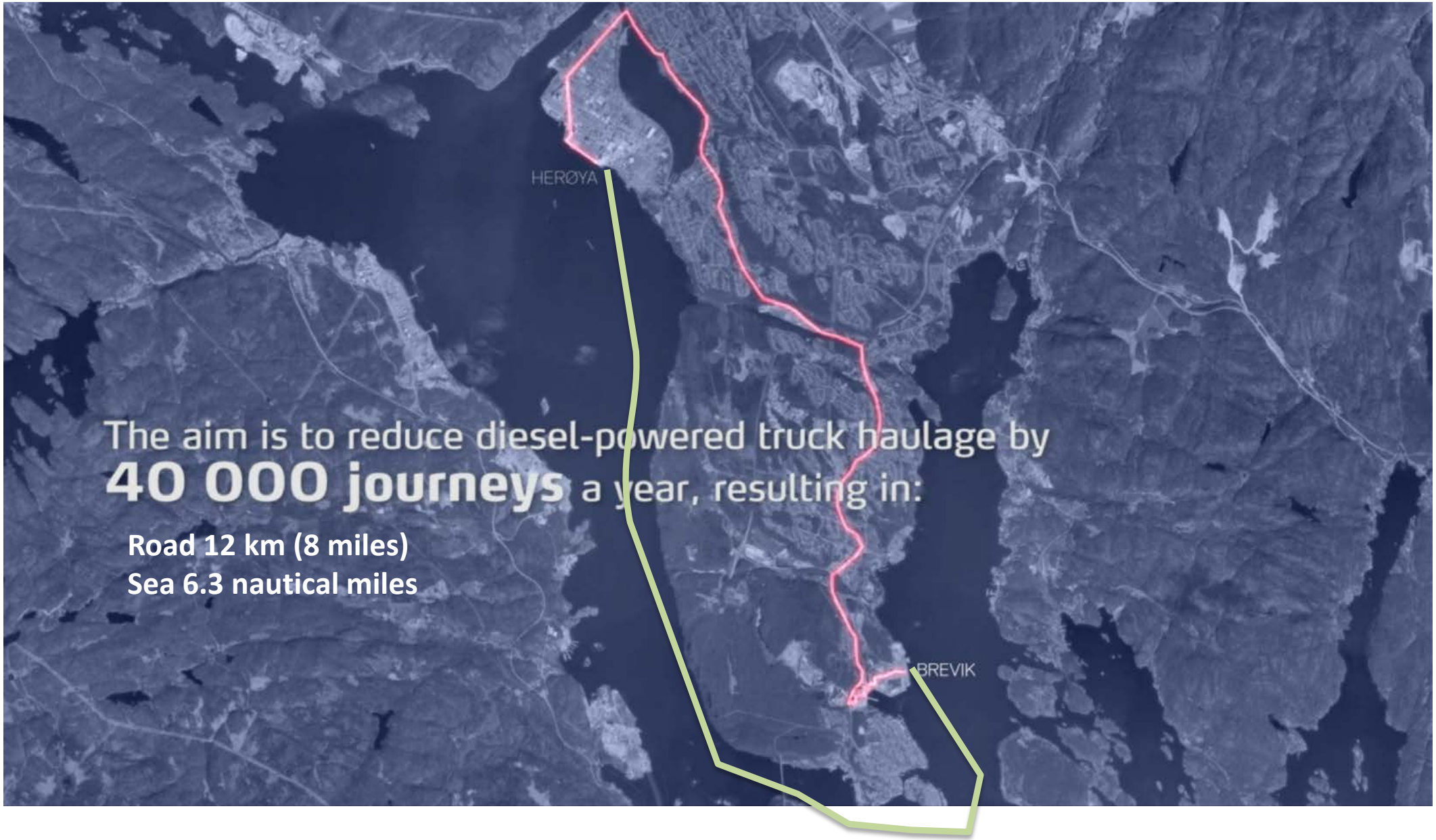
The ReVolt

Concept study, 3 m long demonstrator scale model 2015 (DNV-GL)

Full electric, 60 m long, 6 knots, 100 nm, 100 TEU

https://www.dnvgl.com/technology-innovation/revolt/

May 2017: The vessel Yara Birkeland will be the world's first fully electric and autonomous container ship, with zero emissions. With this vessel, Yara will reduce diesel-powered truck haulage by 40,000 journeys a year. Operation is planned to start in the latter half of 2018 (manned), 2019 (remote control) and 2020 (autonomous) http://yara.com/media/stories/yara_birkeland_vessel_zero_emission.aspx

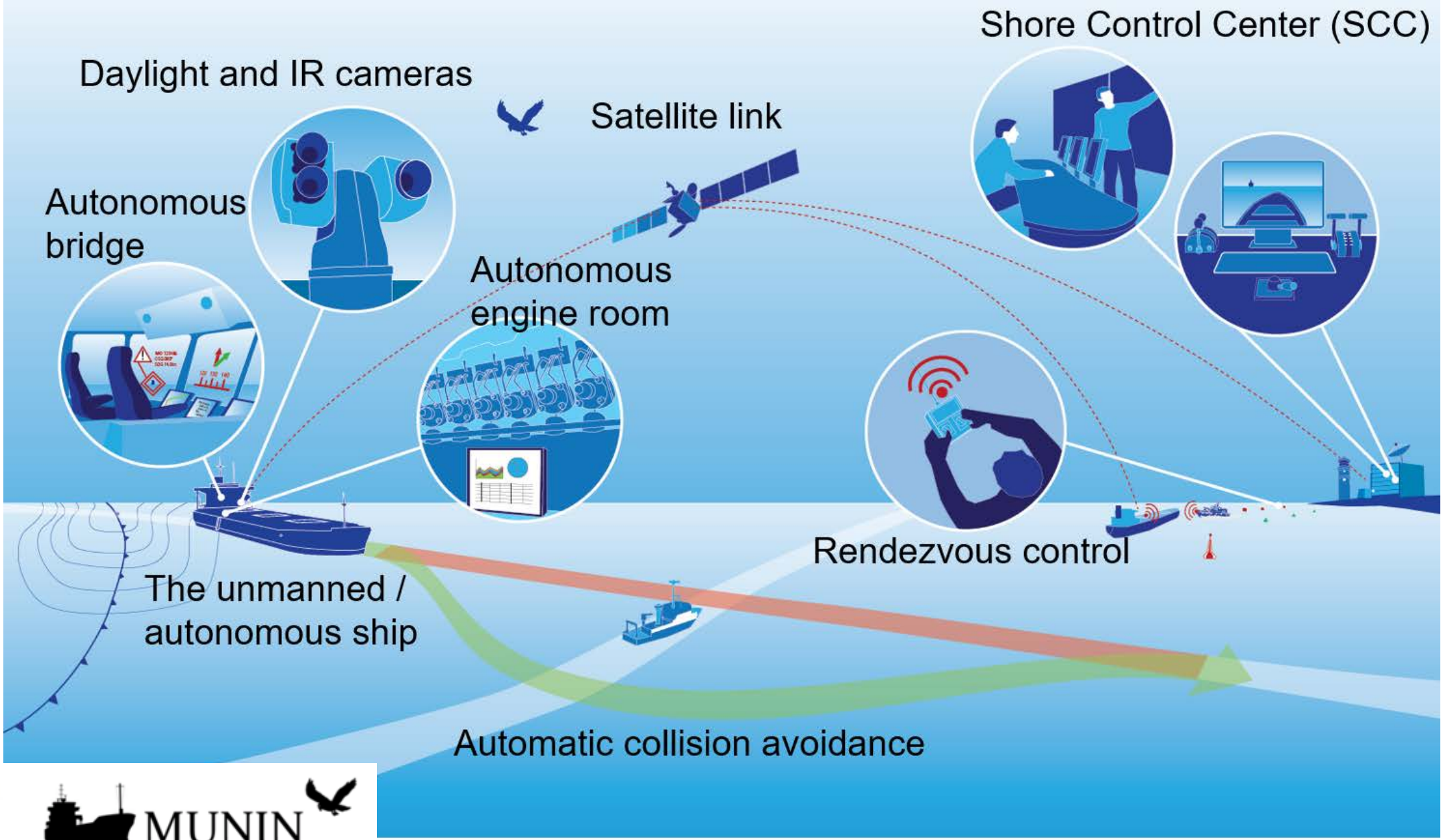

HERØYA
BREVIK
The aim is to reduce diesel-powered truck haulage by
40 000 journeys a year, resulting in:
Road 12 km (8 miles)
Sea 6.3 nautical miles

First full size unmanned ship to be built through UK and Norwegian co-operation
Offshore vessel ‘Hrönn', contracted January 2017 and in operation in 2018 (Kongsberg)

KONGSBERG

Rolls-Royce

https://www.rolls-royce.com/products-and-services/marine/ship-intelligence/overview/remote-and-autonomous-operations.aspx#section-overview



SEVENTH FRAMEWORK PROGRAMME

MUNIN

2012-2015

http://www.unmanned-ship.org/munin/

Motivation

1. **Shortage of ship officers**
2. **Reduction of emissions** - Global warming and emission control: Slow steaming leads to lower emissions and lower fuel costs, (but also less efficient transport capacity). And also longer, socially less acceptable voyage durations.
3. **Cost reduction** - Lower manning costs
4. **Increased safety** – Reduction of “human error”
5. **Technology development**

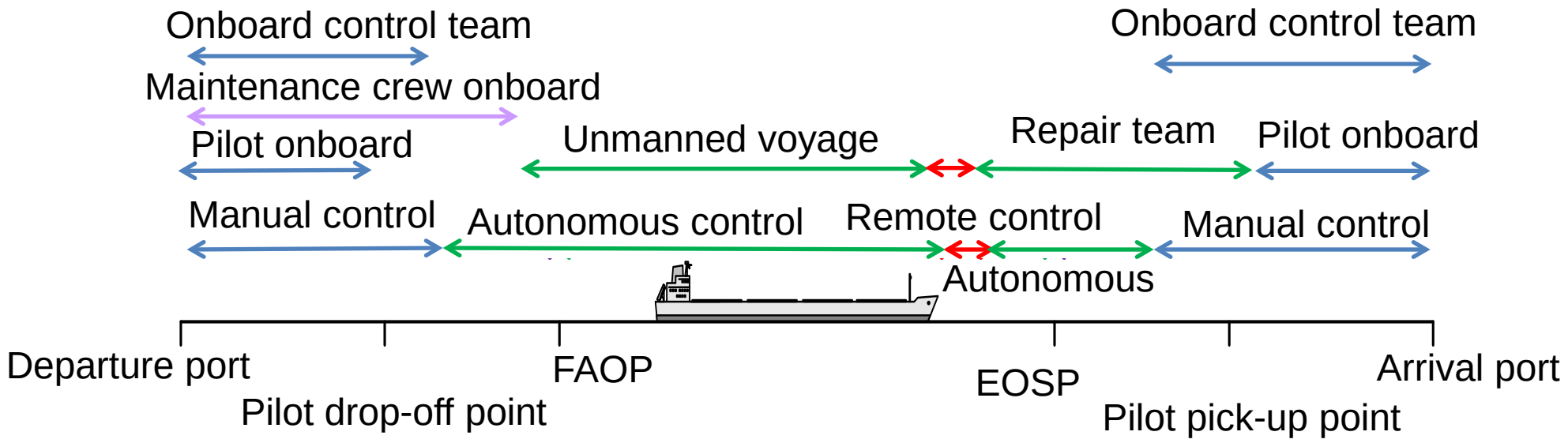
The Unmanned/Autonomous Ship

An **autonomous** ship

Automatic navigation and collision avoidance. Automatic engine control. Not necessarily unmanned. Can house maintenance and repair crew. Even be partly manned.

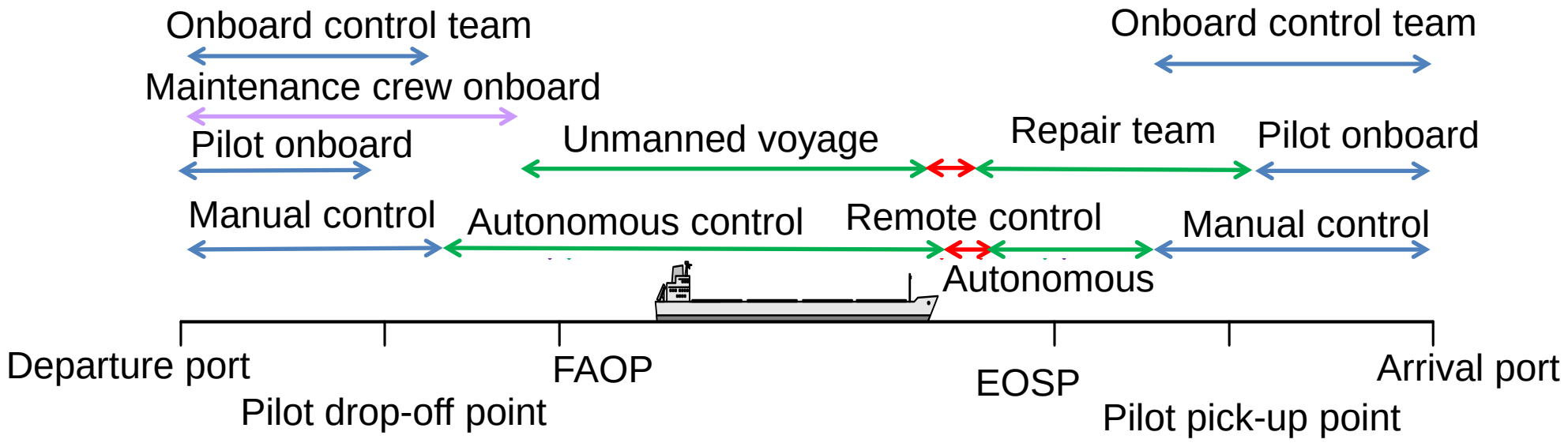
An **unmanned** ship

No-one onboard. Not necessarily under automatic navigation / engine control. Can be remote controlled from shore center.



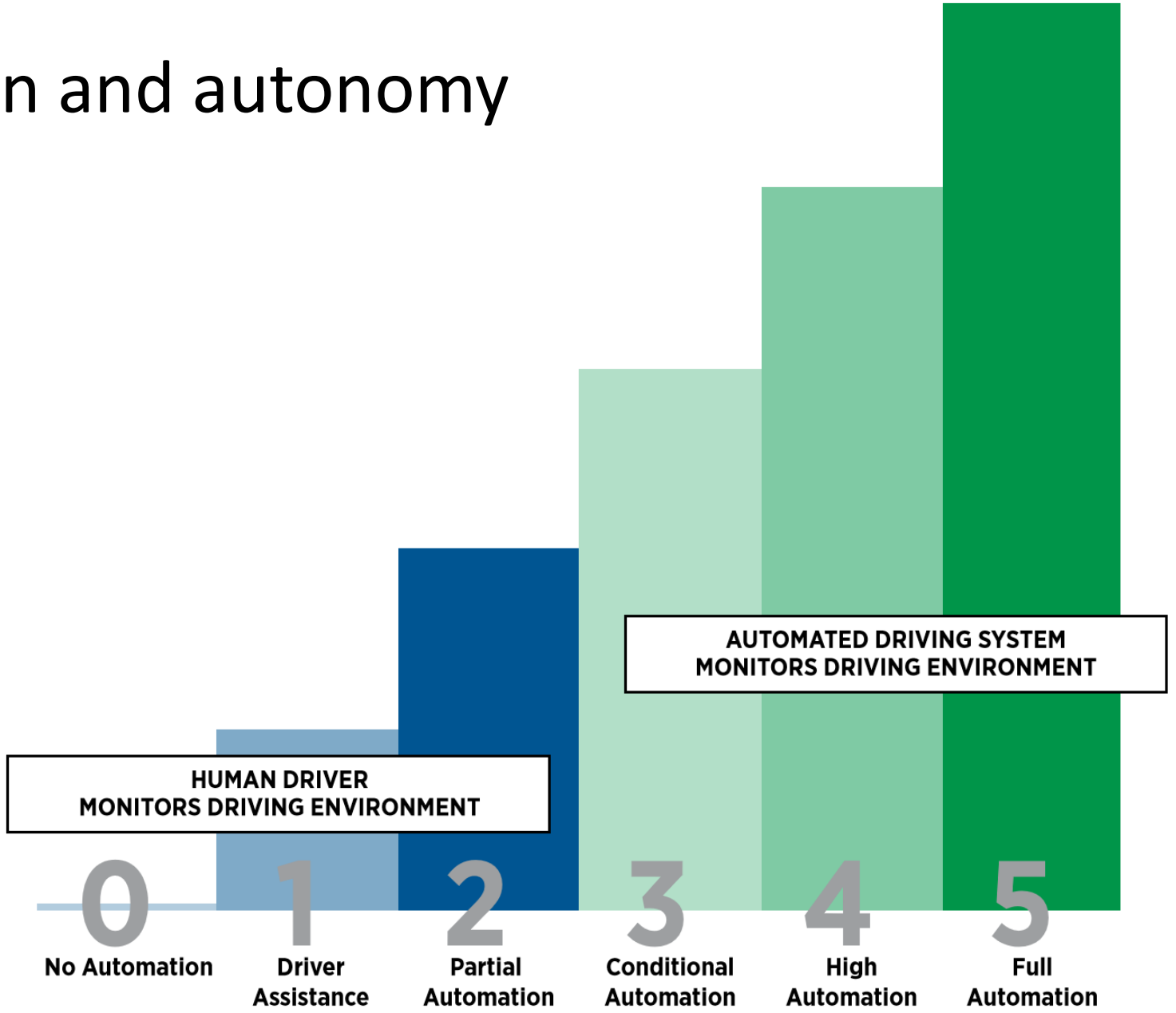
Control modes

- **Manual control**
- **Automatic execution (autopilot in track-following mode)**
- **Autonomous control (onboard AI)**
- **Remote control**
- **Fail to safe**



Automation and autonomy

SAE J3016



SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***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 intervention 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 *human driver*	System	System	System	**All driving modes**

NFAS Norwegian Forum for Autonomous Ships

About | Members | Groups | Conferences | Projects | Other links | Intranet

Projects carried out by members of NFAS

- ⇒ Test area Trondheimsfjorden
- ⇒ Test area Grenland
- ⇒ NTNU AMOS - Centre of Excelent Research
- ⇒ MUNIN - Concept study for unmanned bulk ship
- ⇒ AAWA - The Advanced Autonomous Waterborne Applications
- ⇒ AUTOSEA - Sensor Fusion and collision avoidance for advanced ships
- ⇒ ENABLE*3 Shore based bridge concept

These pages will provide briefing on projects related to autonomous ships that NFAS members participate in. This applies to both completed and ongoing projects.

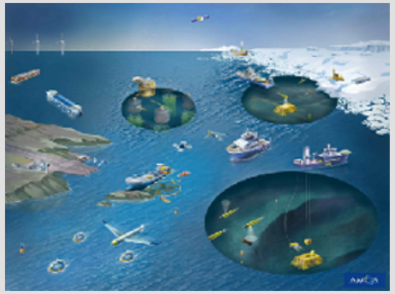
Test area Trondheimsfjorden

Through an agreement between national authorities and the industry and research organizations in the Trondheim region, a partnership has been established to develop Trondheimsfjorden into a test area for autonomous vessels. The agreement was signed aboard the research vessel Gunnerus 30th September 2016. The purpose of the agreement is to facilitate the testing of fully or partly unmanned vessels and to exchange experience and data to facilitate the development and use of such vehicles. More information in English can be found, among other sites, on the Maritime Administration's web site.

Test area Grenland

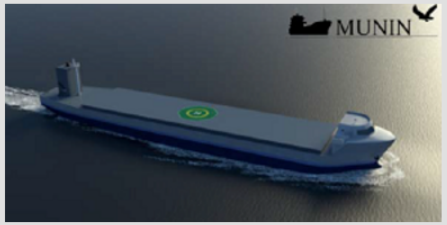
In May 2017, the port authorities in the Grenland area applied for test-area status. This area has much more traffic than Trondheim and will in particular be useful to test more developed concepts in heavy traffic environments. The area also includes an VTS which will further add to the usefulness as a test-area. There is also significant maritime industry and research going on in the area and they will get test facilities much closer to home.

NTNU AMOS - Centre of Excelent Research



NTNU AMOS is a centre of excellence which is led by the NTNU in Trondheim. It has a wide range of partners, many members also of NFAS, and is supported by the Norwegian Research Council. AMOS stands for "Centre for Autonomous Marine Operations and Systems". Here, the future technology is developed while new researchers get their specialization in the subject. AMOS covers all forms of autonomy, on land, in the air, at sea and under the sea. More information is available at the NTNU web pages.

MUNIN - Concept study for unmanned bulk ship



MUNIN was an EU project that ran from summer 2012 to summer 2015. The purpose was to do a concept study for a completely unmanned Handymax bulk carrier. The project came right at the start of the great interest that autonomous ship later created, and has published a number of articles and open reports. MARINTEK (now SINTEF Ocean) was technical coordinator of MUNIN. More information is available at http://www.unmanned-ship.org/munin/.

AAWA - The Advanced Autonomous Waterborne Applications

The AAWA project was started by Rolls Royce to develop specifications and possible designs for the next generation completely or partially autonomous ships. A press release from Rolls Royce can be found here along with links to a "white paper" and illustrations.

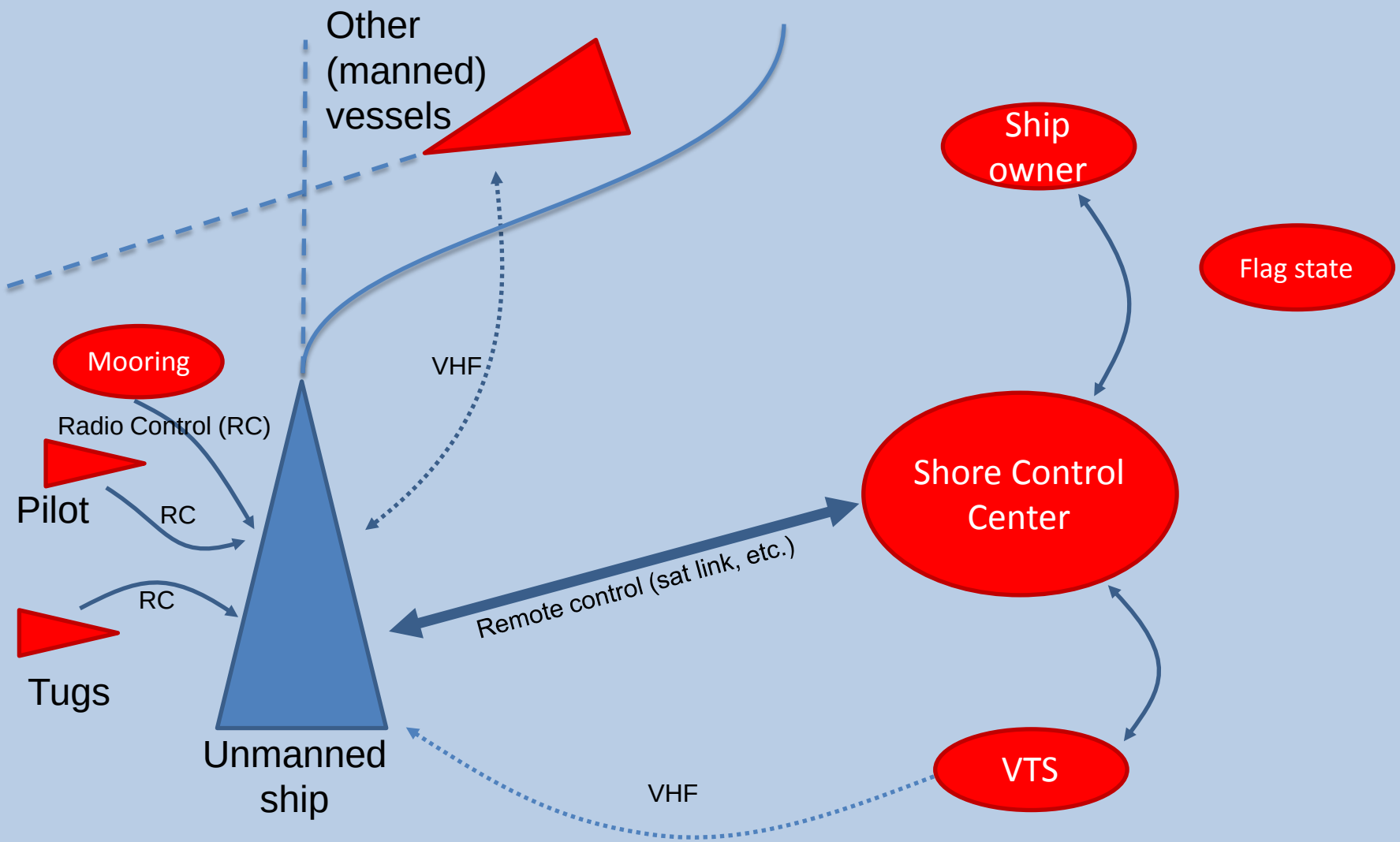
AUTOSEA - Sensor Fusion and collision avoidance for advanced ships

AUTOSEA is a collaboration between NTNU, Kongsberg Maritime, DNV GL and Maritime Robotics to develop technology and knowledge for automated situational awareness for ships. The purpose is as much to improve sensors and decision support aboard conventional ships as to develop new systems for autonomous vessel. Description of the concept can be found on Kongsberg's web-pages and at NTNU.

http://nfas.autonomous-ship.org/projects-en.html

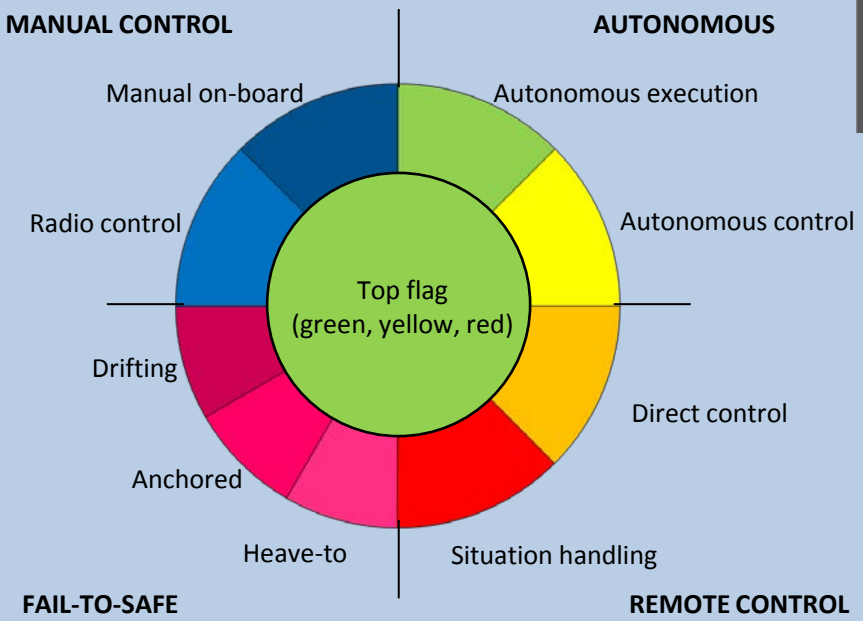
Challenges: Human Factors

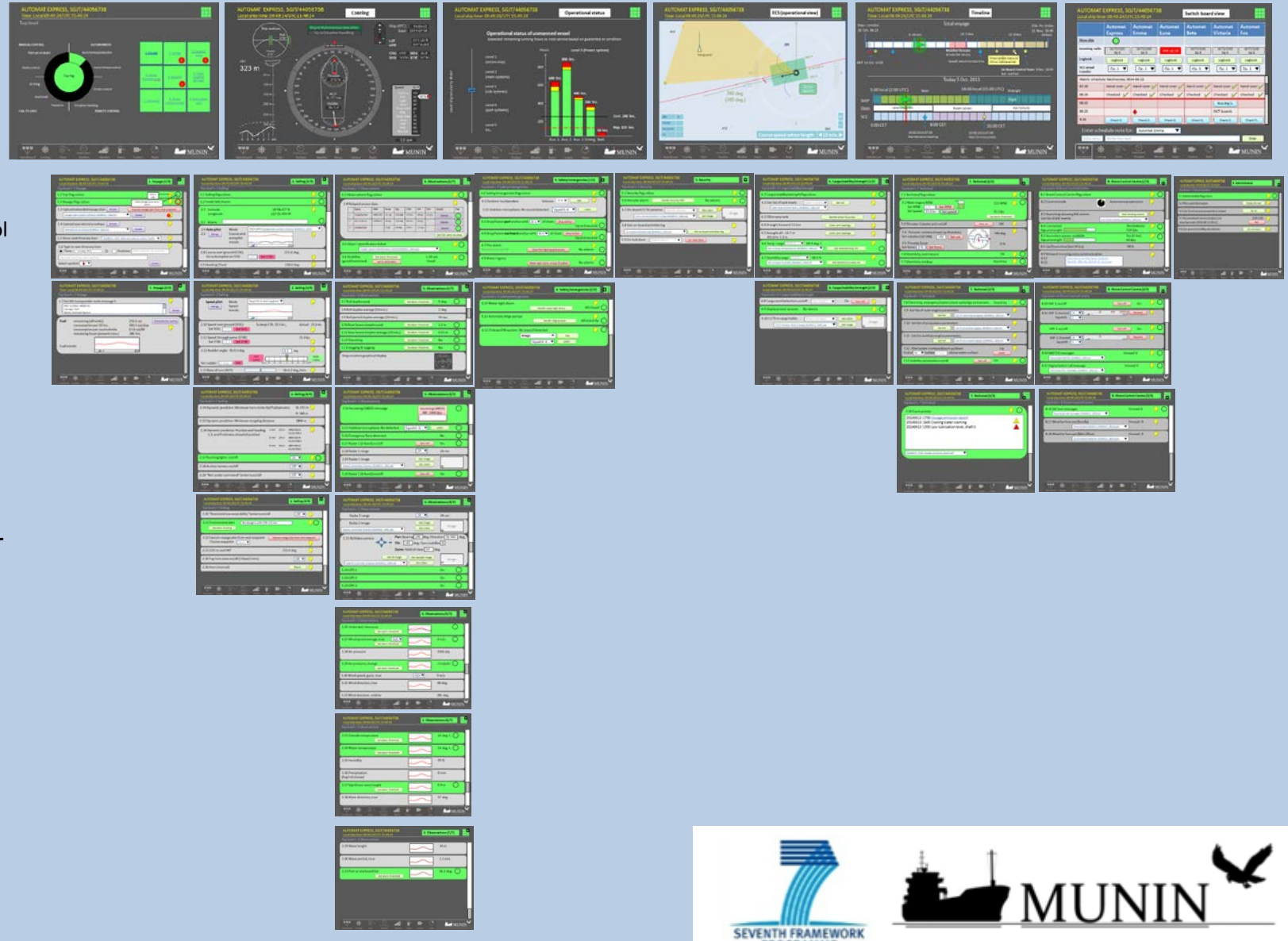
Humans in the unmanned ship system



Challenges: Human Factors

- Remote monitoring and control





MUNIN
Complete HMI for a Shore Control Centre for autonomous ships

SEVENTH FRAMEWORK PROGRAMME

MUNIN

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NTNU

Challenges: Human Factors

- Remote monitoring and control
- “Human error”

Challenges: Human Factors

- Remote monitoring and control
- “Human error”

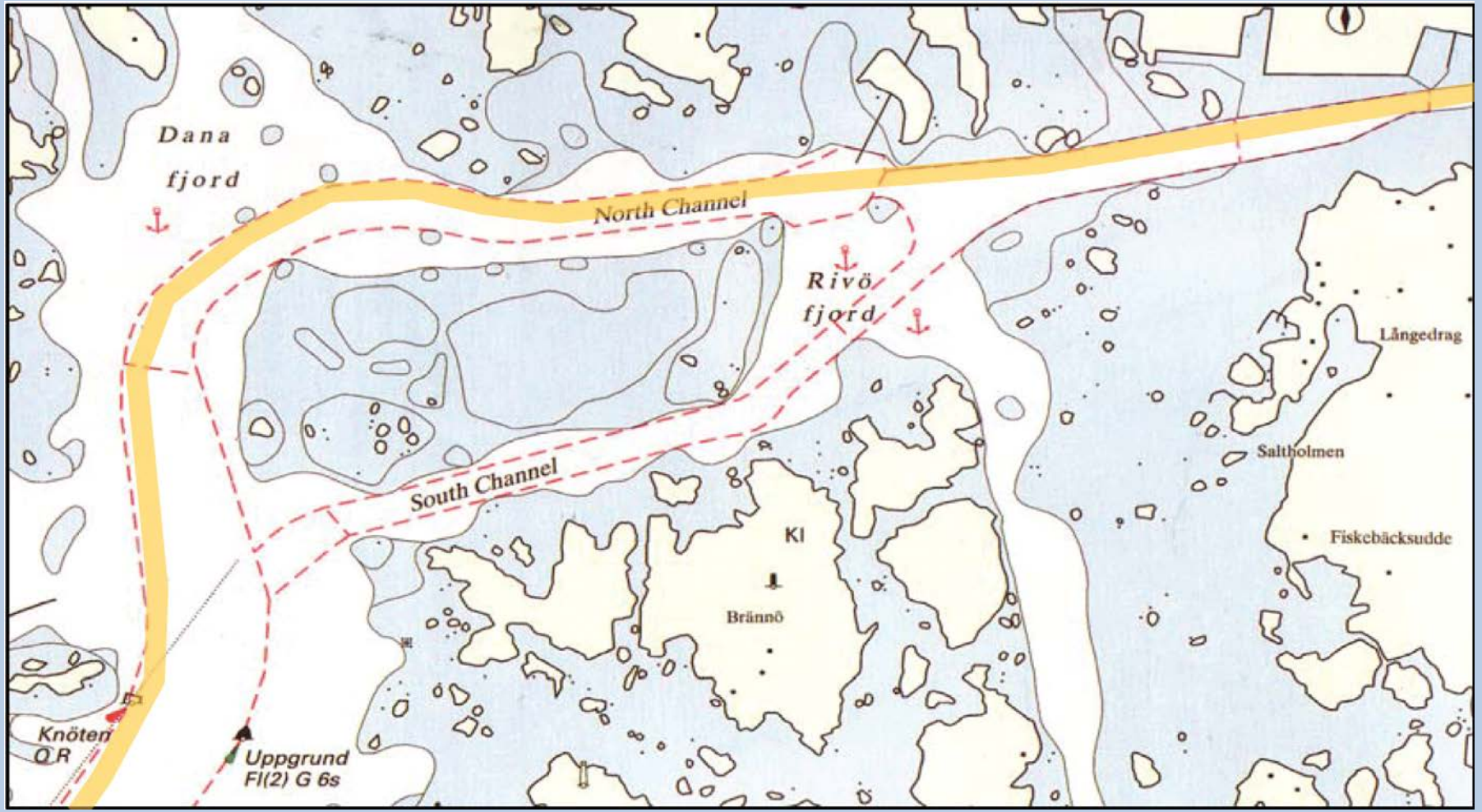
1. **Situation awareness** in the SCC: mistakes due to not understanding the true situation of the vessel
2. **Misunderstandings in interaction with manned vessels**: latency in VHF communication, bad communication links, language issues same as for manned systems, but worsened by lack of situation awareness.
3. Delays in decision making due to lengthy time for operator to get into the loop (**human-out-of-the-loop syndrome**).
4. **Stress and information overload** because several ships might need the operators attention at the same time.
5. Human error due to “**carry over effects**” between two vessels as operator monitors several vessels at a time.

Challenges: Human Factors

- Remote monitoring and control
- “Human error”
- Interaction between manned and unmanned ships

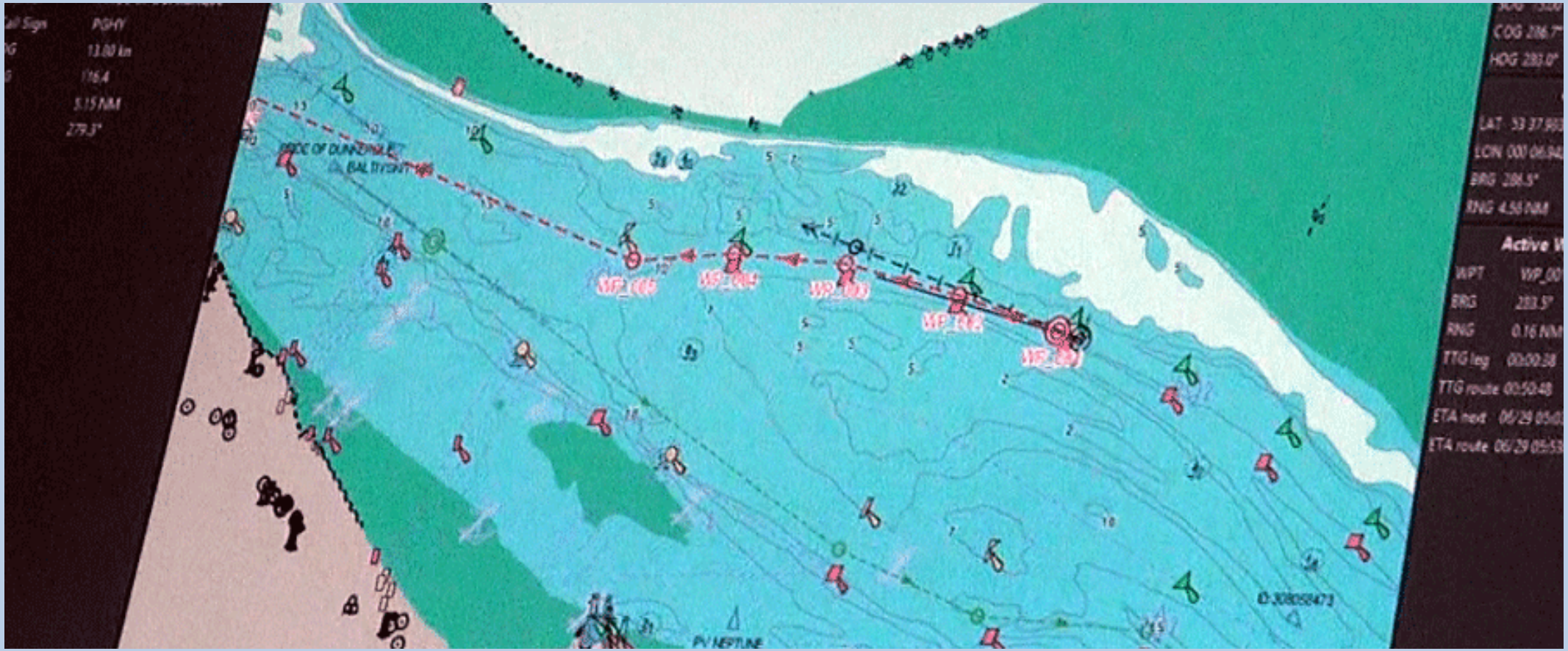
Technical Challenges:

Collision avoidance



Dedicated fairways for autonomous vessels

Collision avoidance & Route exchange



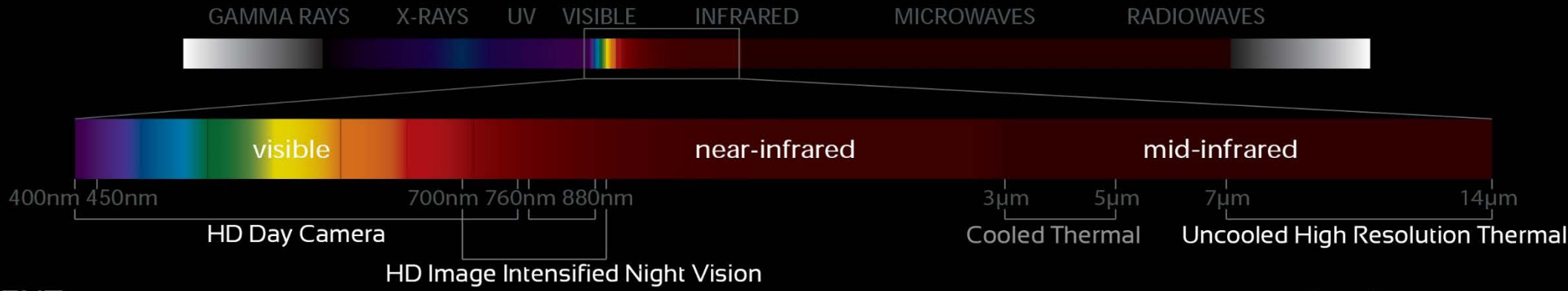
ACCSEAS project 2014: Simulations using the EPD (e-Navigation Prototype Display) Humber Estuary
http://www.accseas.eu/

Technical Challenges:
Object detection/identification

Tom Hanks in the movie Castaway

New types of sensors and sensor fusion

3 Cameras, 3 Spectrums, deliver an image in the widest variety of atmospheric conditions



CURRENT corporation

night navigator™

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NTNU

Planned research

Phase 1.
Remote monitoring from shore of manned ship

Transfer of radar, IR/video, VHF from ship. Text and voice communication from shore

Phase 2.
Remote monitoring and control of manned ship

As in previous service, but control of autopilot, speed, and VHF from shore.

Phase 3.
Remote monitoring and automatic control of partly manned ship

As in previous service, but automation will be alone on the bridge, however with operators onboard

Phase 4.
Remote monitoring and control of fully autonomous unmanned ship

As in previous service, but automation will be alone onboard

IALA

Standardisation within the IALA realm


“Have you seen me?”
“I want to report my position to you.”
“What are your intentions?”
“What do you want me to do?”