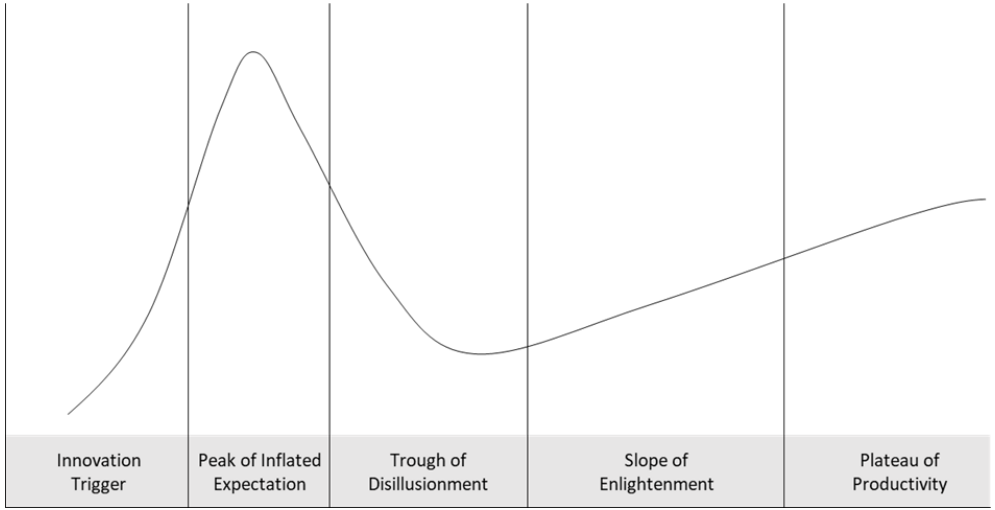
NTNU

Norwegian University of Science and Technology

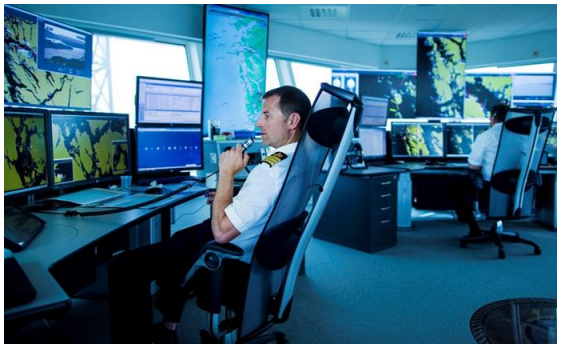
# A systems perspective on maritime autonomy

## The Vessel Traffic Service’s contribution to safe coexistence between autonomous and conventional vessels

# How could a systems perspective enable for autonomy in the maritime industry?

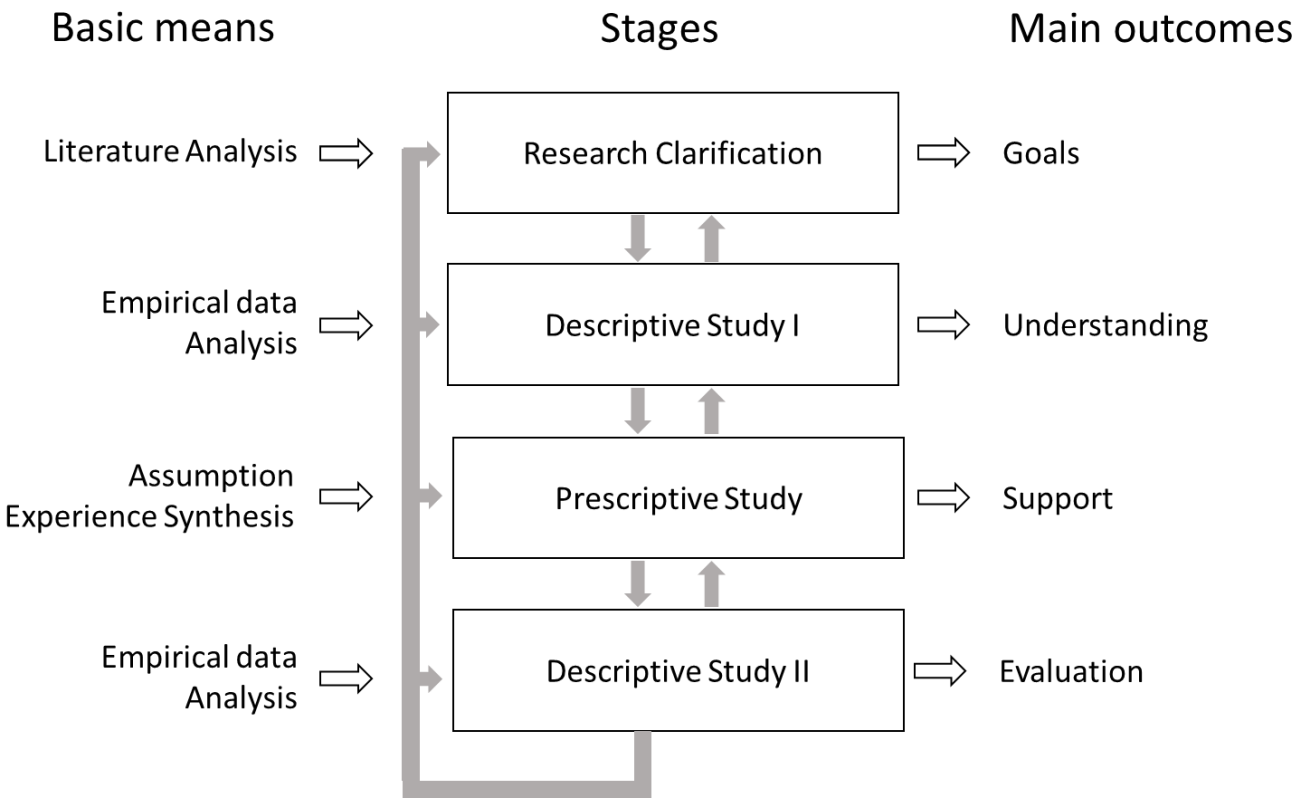






Sources:
- Kongsberg https://www.km.kongsberg.com/ks/web/nokbg0238.nsf/AllWeb/98A8C576AEFC85AFC125811A0037F6C4?OpenDocument
- Linden and Fenn (2003)
- NCA

# The Design Research Methodology




Source: Adapted from Blessing and Chakrabarti (2009)

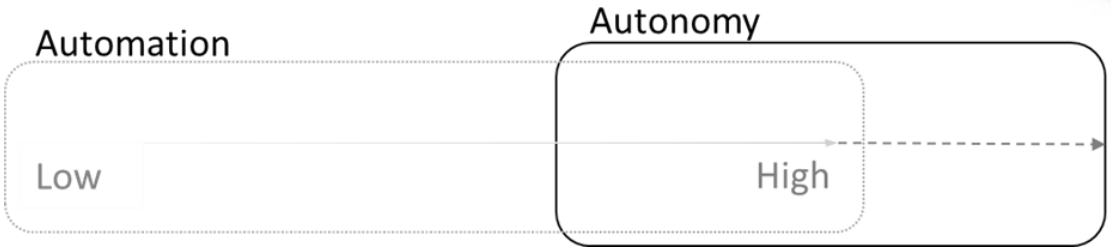
# Research Clarification

| Research Question | Research methods | Deliveries | Results |
|---|---|---|---|
| ***What is the human role in the future maritime system?***<br><br>a) What is autonomy?<br>b) How could a systemic human-technology approach in maritime autonomy be adopted? | Review of literature: Automation, autonomy, human and automation, responsibility and authority | Paper: "A Human Perspective on Maritime Autonomy" in Augmented Cognition: Users and Contexts (2018)<br><br>Presentation at Human-Computer Interaction International Conference, Las Vegas, July 2018<br><br>Presentation at E-nav Conference, Oslo, September 2018 | Discussion and definitions of terms related to autonomy<br><br>Emphasizing the human role to maintain a stable performance in future maritime systems. |

# What is autonomy?

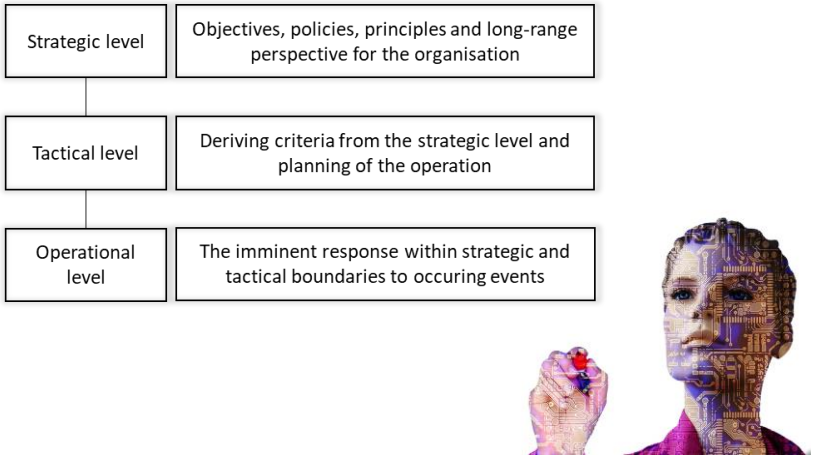

Source:
1. Pixabay
2. Hvalfangstmuseet (http://www.hvalfangstmuseet.no/nyere-hvalbater/)
3. Kongsberg https://www.km.kongsberg.com/ks/web/nokbg0238.nsf/AllWeb/98A8C576AEFC85AFC125811A0037F6C4?OpenDocument

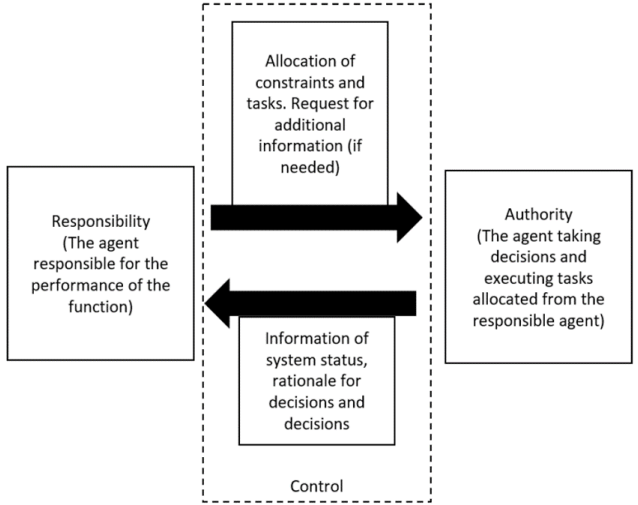
# *Autonomy - to bin or not to bin?*




- *Process rather than a state of being*
- *Digitalisation as the main component in the change process*
- *A significant change to the system*
- *Not a goal itself, but to improve a system's performance*

# A systemic human-technology approach in maritime autonomy



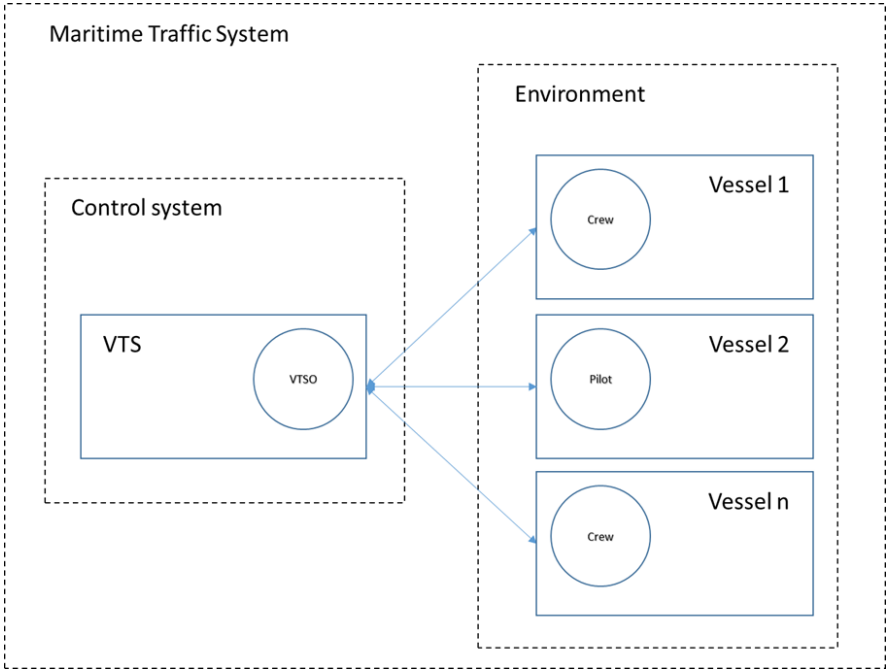

*Humans will strengthen the system*

*Humans in new loops but being responsible*

# Descriptive Study I

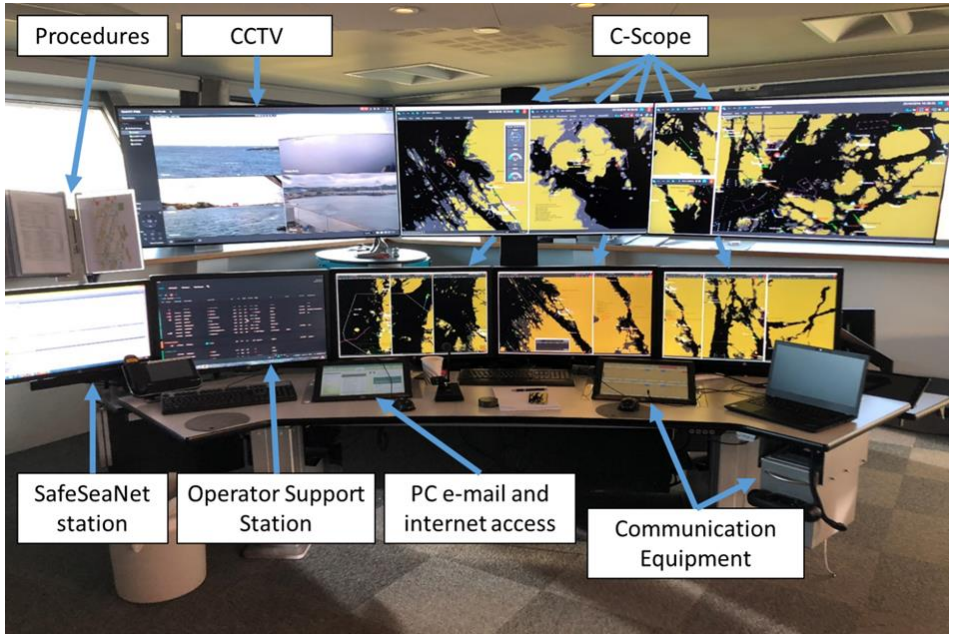
| Research Question | Research methods | Deliveries | Results |
|---|---|---|---|
| ***What is the Vessel Traffic Services' role in the maritime system?***<br><br>a) How do the VTS contribute to the maritime traffic system?<br>b) How do VTS operators use expert knowledge and strategies in the interaction with vessels? | Review of literature:<br><br>VTS procedures<br><br>Field study:<br><br>Cognitive Task analysis of VTS operators at Kvitsøy VTS<br><br>Review of literature: Literature related to traffic systems and human responsibility for system performance | Paper: "How vessel traffic service operators cope with complexity – only human performance absorbs human performance" in Theoretical Issues in Ergonomics Science (2019)<br><br>Presentation at European Safety and Reliability Association Conference, Oslo, March 2019<br><br>Presentation at IALA VTS47 meeting, Paris, September 2019 | Defining the VTS role as the control system in the Maritime Traffic System (MTS)<br><br>Exploring the use of VTS operator's expert knowledge and strategies to meet the demands in the MTS<br><br>Discussing the requisite and unnecessary variation of operator's performance |

# The Vessel Traffic Services' role in the maritime system




*How do the Vessel Traffic Services contribute to the maritime traffic system?*

# The Vessel Traffic Services' role in the maritime system




- Operator experience
- Teamwork
- Organisational knowledge
- Communication

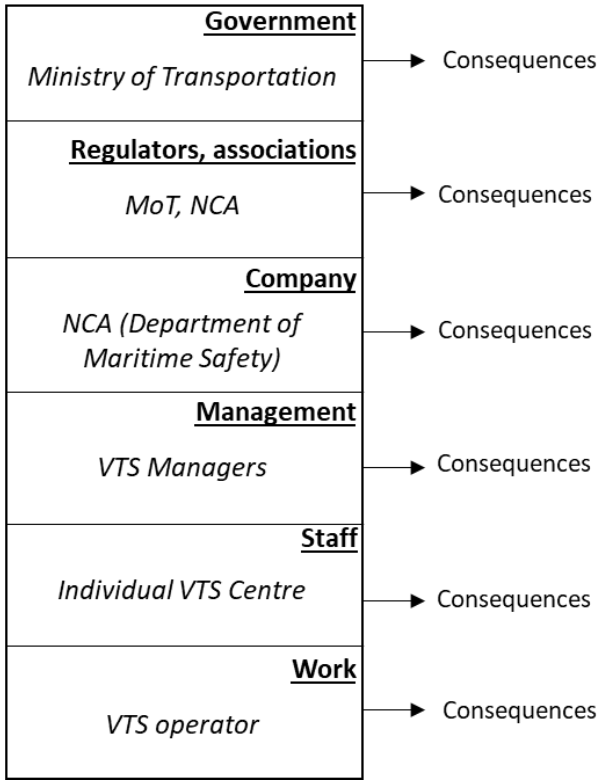
*How do VTS operators use expert knowledge and strategies in the interaction with vessels?*

# Prescriptive Study

| Research Question | Research methods | Deliveries | Results |
|---|---|---|---|
| ***Which approach can support design of the future VTS?***<br><br>a) How can a socio-technical systems approach focusing on a democratic process, and systemic evaluation of internal and external consequences, be used in the early design phase of the future VTS? | Review of literature:<br><br>Socio-technical systems theory, system-of-systems theory and participatory design | Paper: "A socio-technical perspective on the future Vessel Traffic Services" in Necesse (2019)<br><br>Presentation at Human Factors in Control Conference, Trondheim, October 2019 | Describing the MTS as a system-of systems and outlining an approach to design the future VTS that emphasizes both internal and external effects for the VTS<br><br>Highlighting the distinctive characters when designing a control system in a system-of-systems |

# How can a socio-technical systems approach, be used in the early design phase of the future VTS?

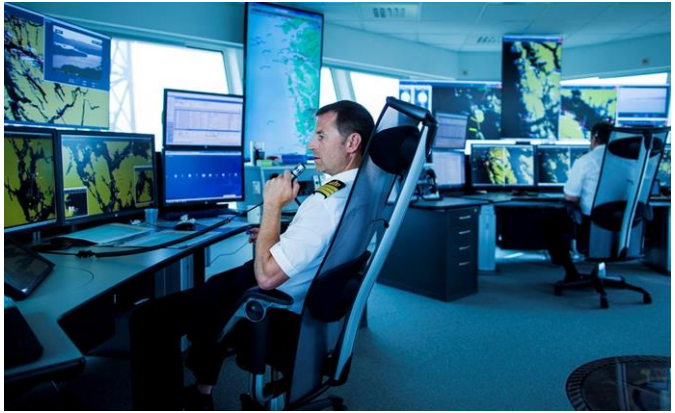
- A systemic evaluation of internal and external consequences
- Internal effects:
  - socio-technical levels
  - A democratic process
- External effects
  - The MTS is a system-of-systems
  - Architectural principles for SoS should be applied



# Descriptive Study II

| Research Question | Research methods | Deliveries | Results |
|---|---|---|---|
| ***Can the Vessel Traffic Services facilitate safe coexistence in the future maritime system?*** | Workshop with subject matter experts to identify future traffic system | Paper: "The Vessel Traffic Services contribution for safe coexistence between automated and conventional vessels" | Suggesting a different role for the future VTS. |
| a) Can the future VTS apply traffic organisation and traffic regulation measures to facilitate for safe coexistence between conventional and autonomous vessels? | Simulation of future traffic scenario | | Evaluating VTS safety measures for safe coexistence between conventional and autonomous vessels. |
| | User-involved design process of the future VTS | | Developing a prototype of a future MTS with an automated vessel |

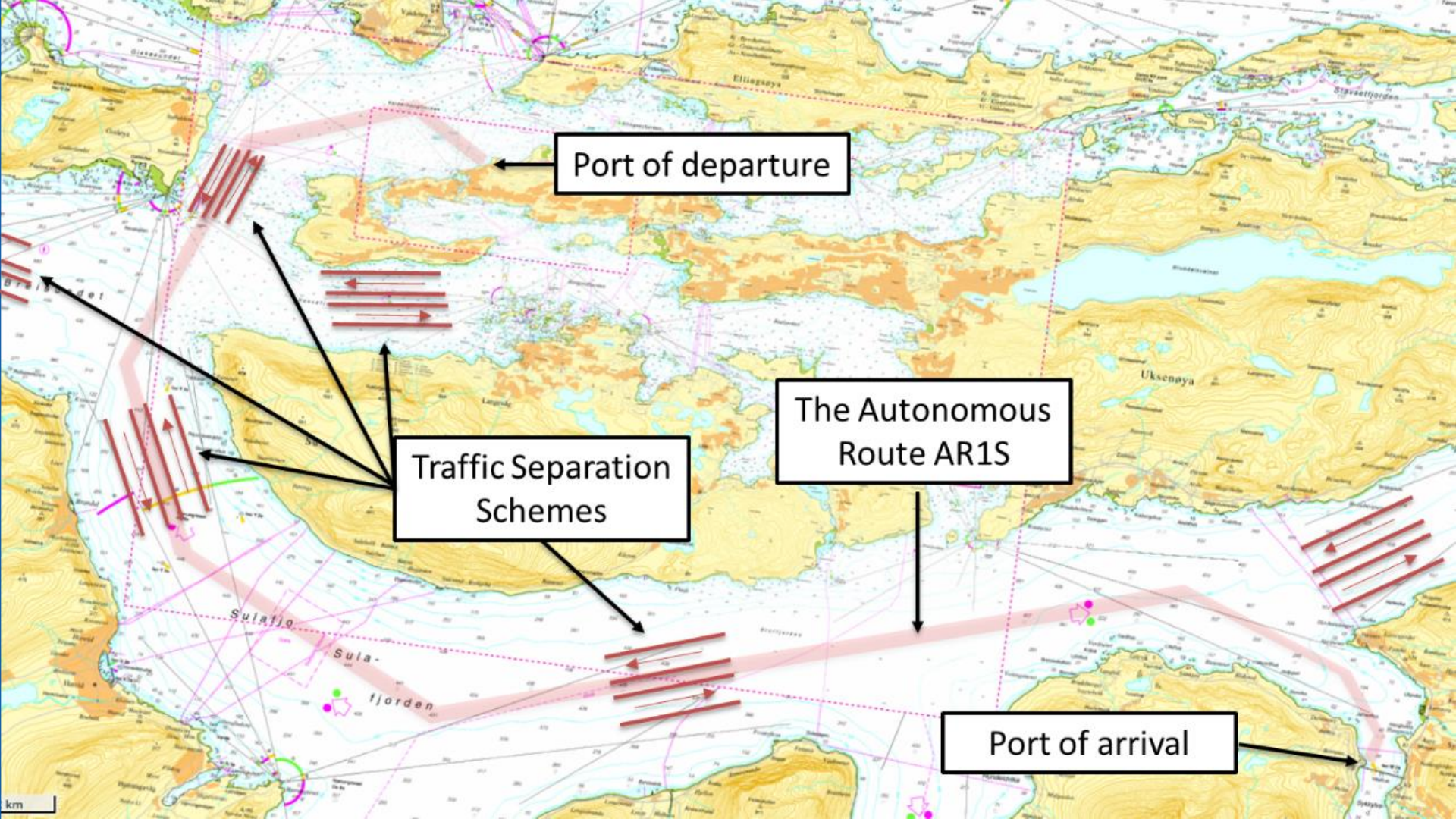

Automated vessel

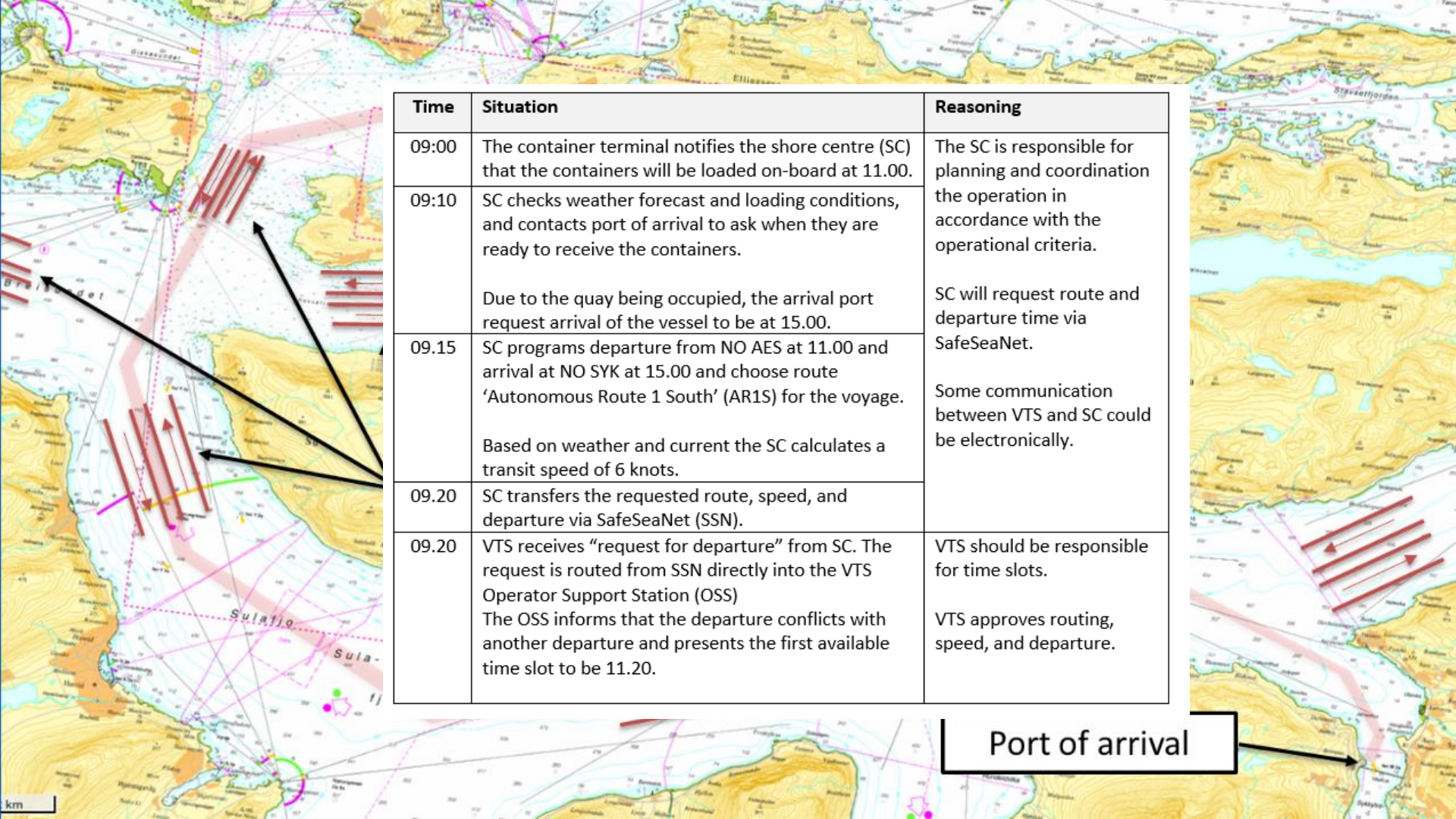


Vessel Traffic Services

Shore Control Centre

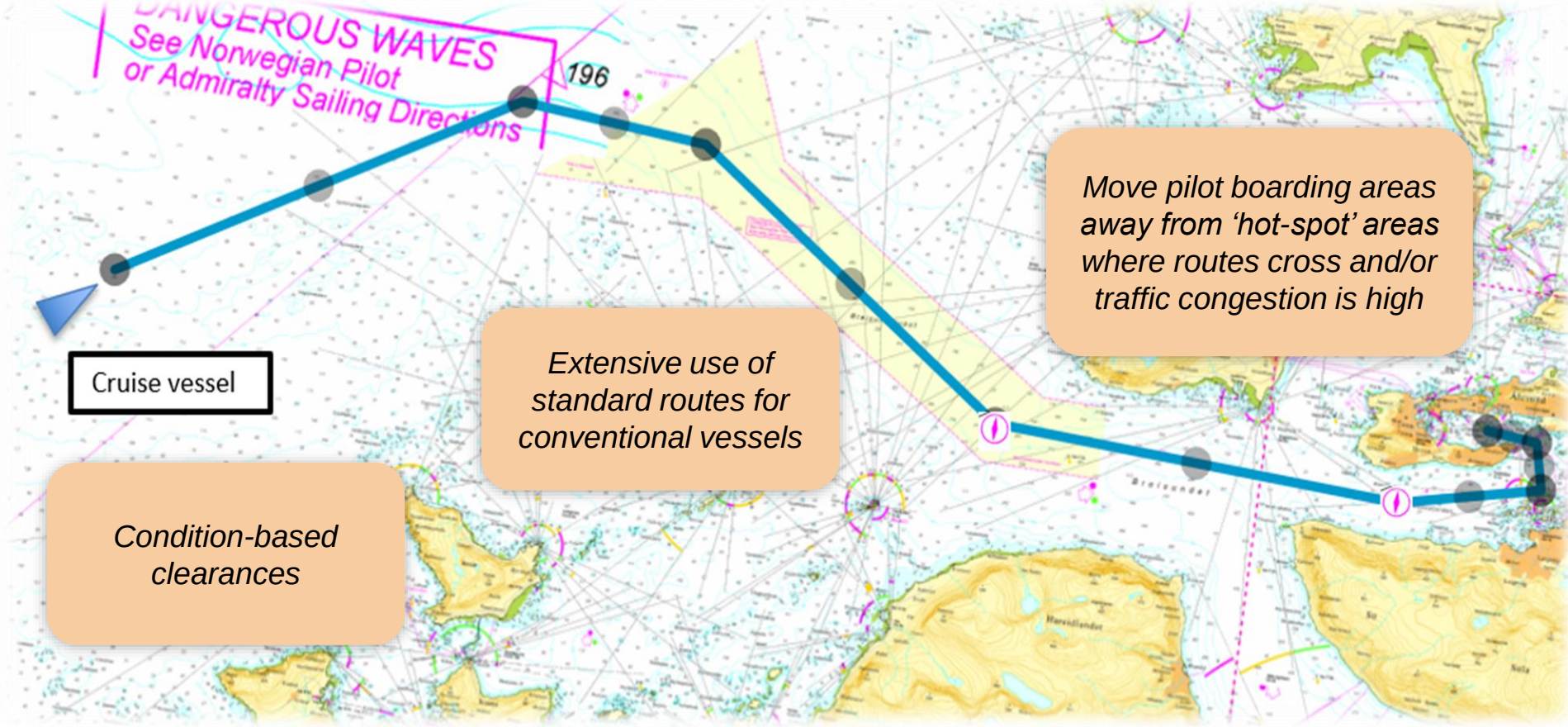
Conventional vessel

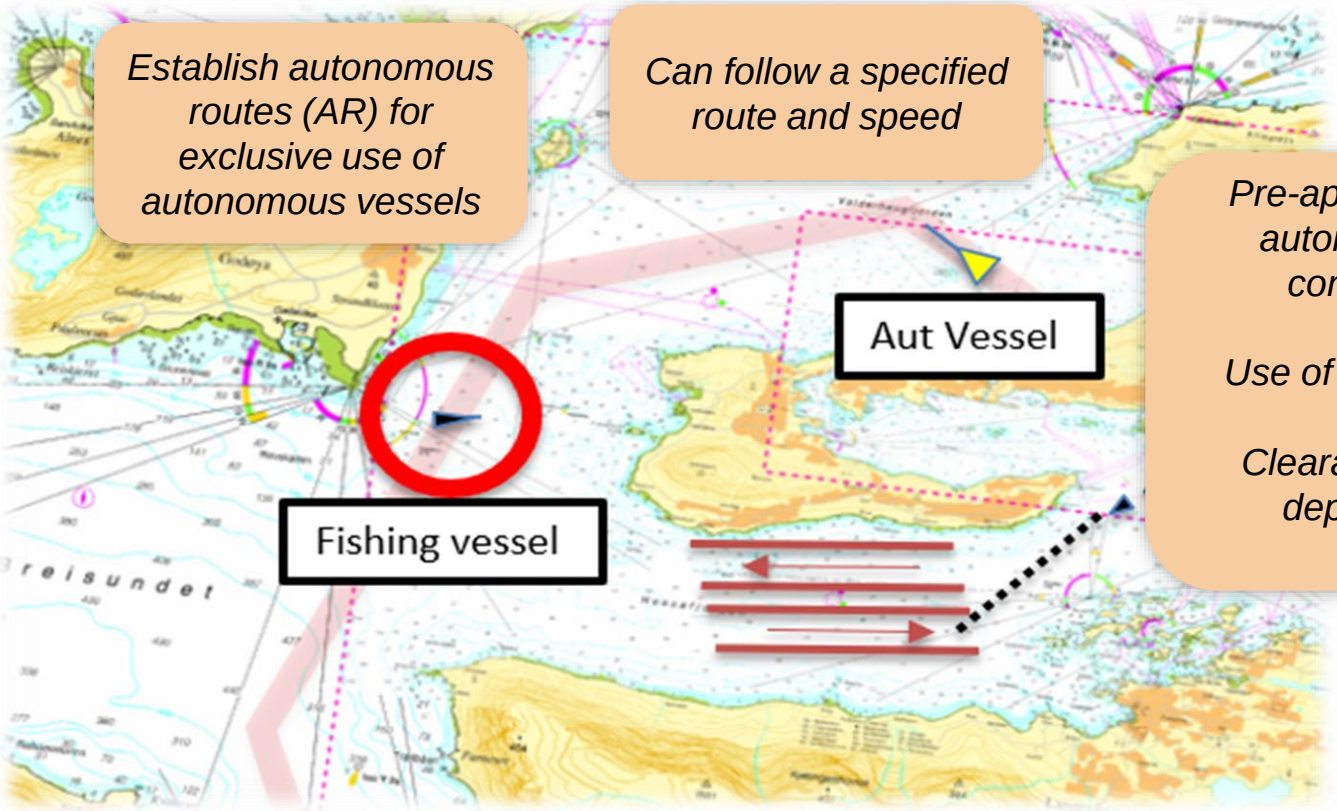

Port of departure
Traffic Separation Schemes
The Autonomous Route AR1S
Port of arrival
Sulafjo
Sula-
fjorden
Ellingsøya
Uksenøya
km

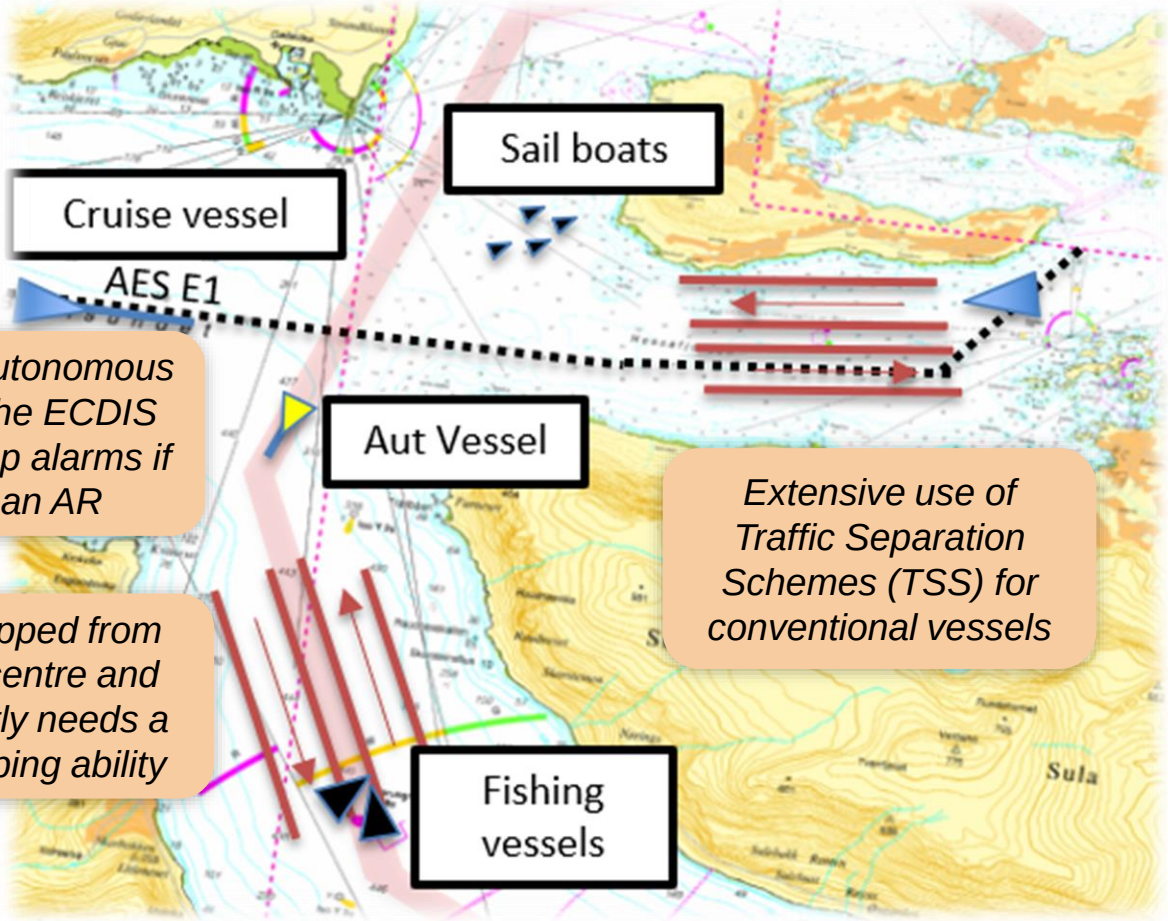


| Time | Situation | Reasoning |
|---|---|---|
| 09:00 | The container terminal notifies the shore centre (SC) that the containers will be loaded on-board at 11.00. | The SC is responsible for planning and coordination the operation in accordance with the operational criteria.<br><br>SC will request route and departure time via SafeSeaNet.<br><br>Some communication between VTS and SC could be electronically. |
| 09:10 | SC checks weather forecast and loading conditions, and contacts port of arrival to ask when they are ready to receive the containers.<br><br>Due to the quay being occupied, the arrival port request arrival of the vessel to be at 15.00. | |
| 09.15 | SC programs departure from NO AES at 11.00 and arrival at NO SYK at 15.00 and choose route 'Autonomous Route 1 South' (AR1S) for the voyage.<br><br>Based on weather and current the SC calculates a transit speed of 6 knots. | |
| 09.20 | SC transfers the requested route, speed, and departure via SafeSeaNet (SSN). | |
| 09.20 | VTS receives "request for departure" from SC. The request is routed from SSN directly into the VTS Operator Support Station (OSS)<br>The OSS informs that the departure conflicts with another departure and presents the first available time slot to be 11.20. | VTS should be responsible for time slots.<br><br>VTS approves routing, speed, and departure. |

Port of arrival


DANGEROUS WAVES
See Norwegian Pilot
or Admiralty Sailing Directions
196
Cruise vessel
Condition-based clearances
Extensive use of standard routes for conventional vessels
Move pilot boarding areas away from 'hot-spot' areas where routes cross and/or traffic congestion is high

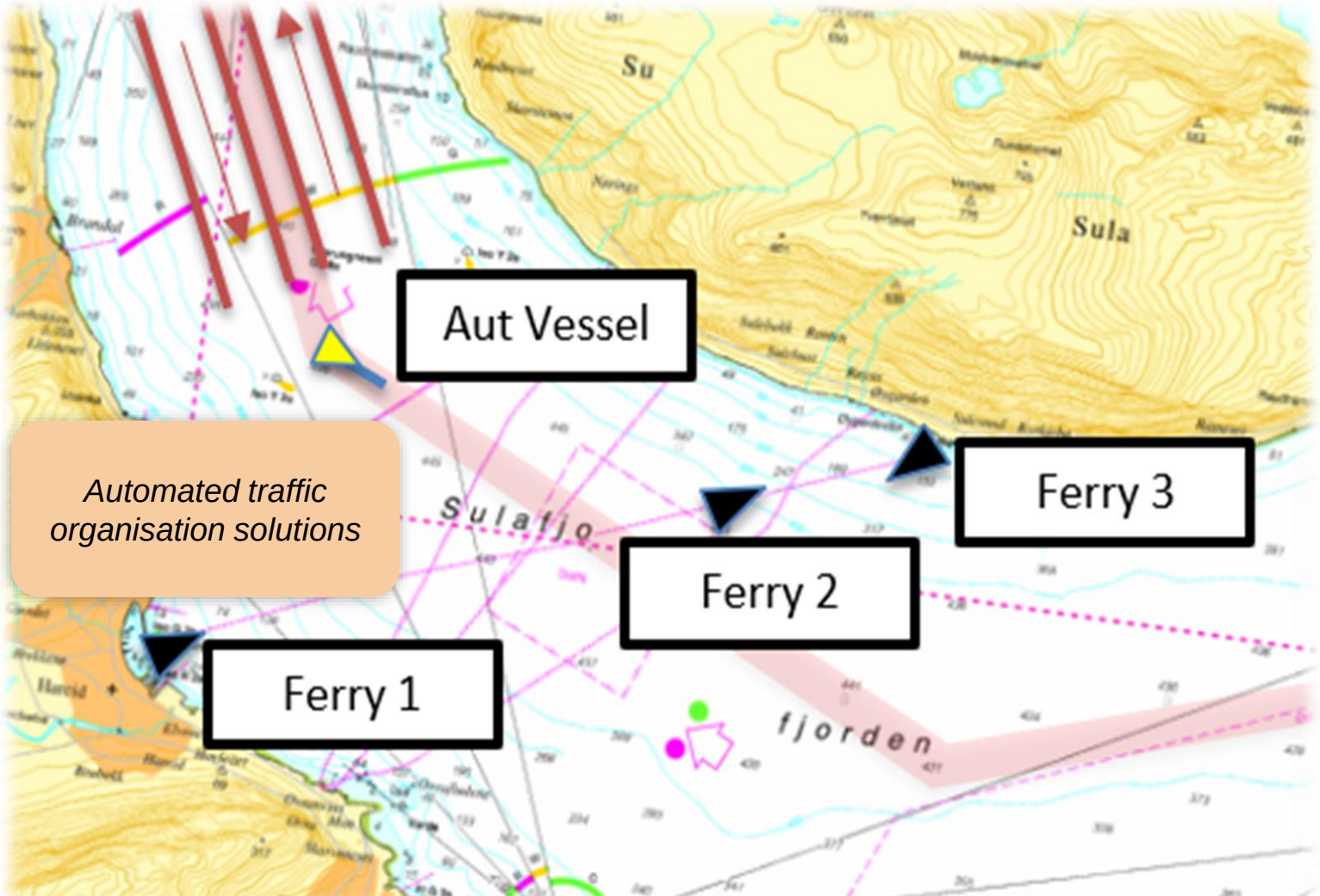

Establish autonomous routes (AR) for exclusive use of autonomous vessels
Can follow a specified route and speed
Pre-approval for autonomous concepts
Use of time slots
Clearances for departure
Aut Vessel
Fishing vessel




*Displaying Autonomous Routes on the ECDIS and setting up alarms if entering an AR*

*Can be stopped from the shore centre and consequently needs a station keeping ability*

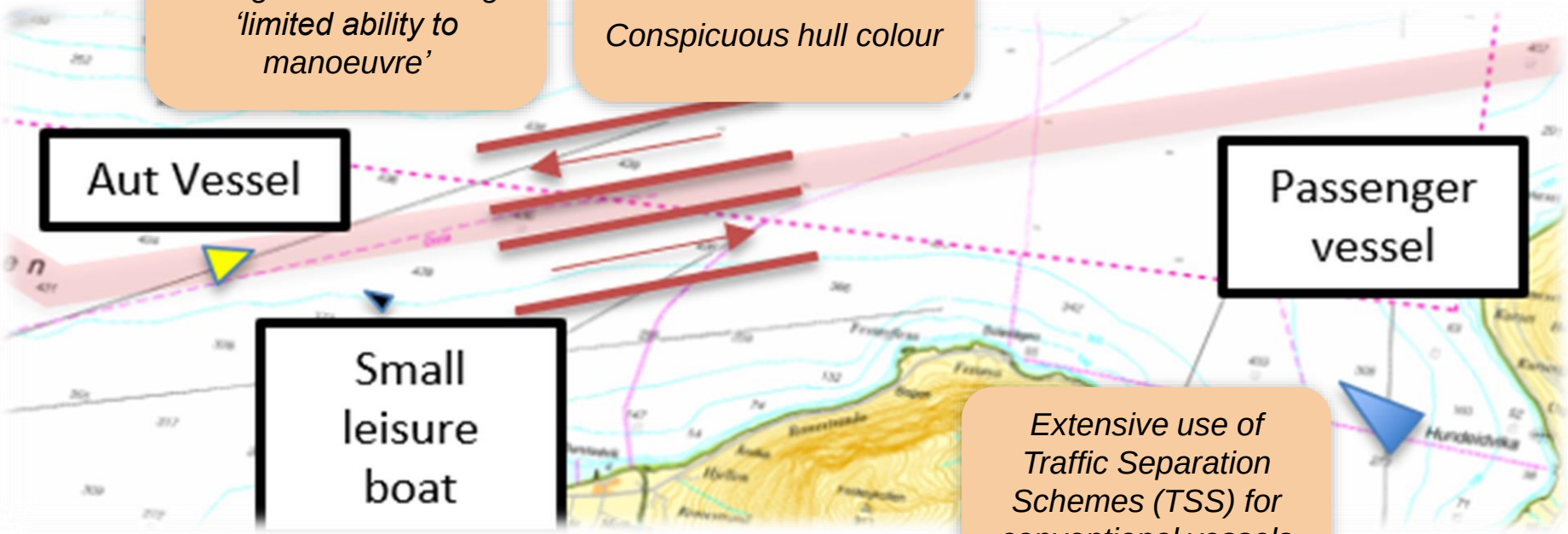
*Extensive use of Traffic Separation Schemes (TSS) for conventional vessels*


Aut Vessel
Ferry 3
Ferry 2
Ferry 1
Automated traffic organisation solutions
Sulafjo
fjorden
Sula
Su

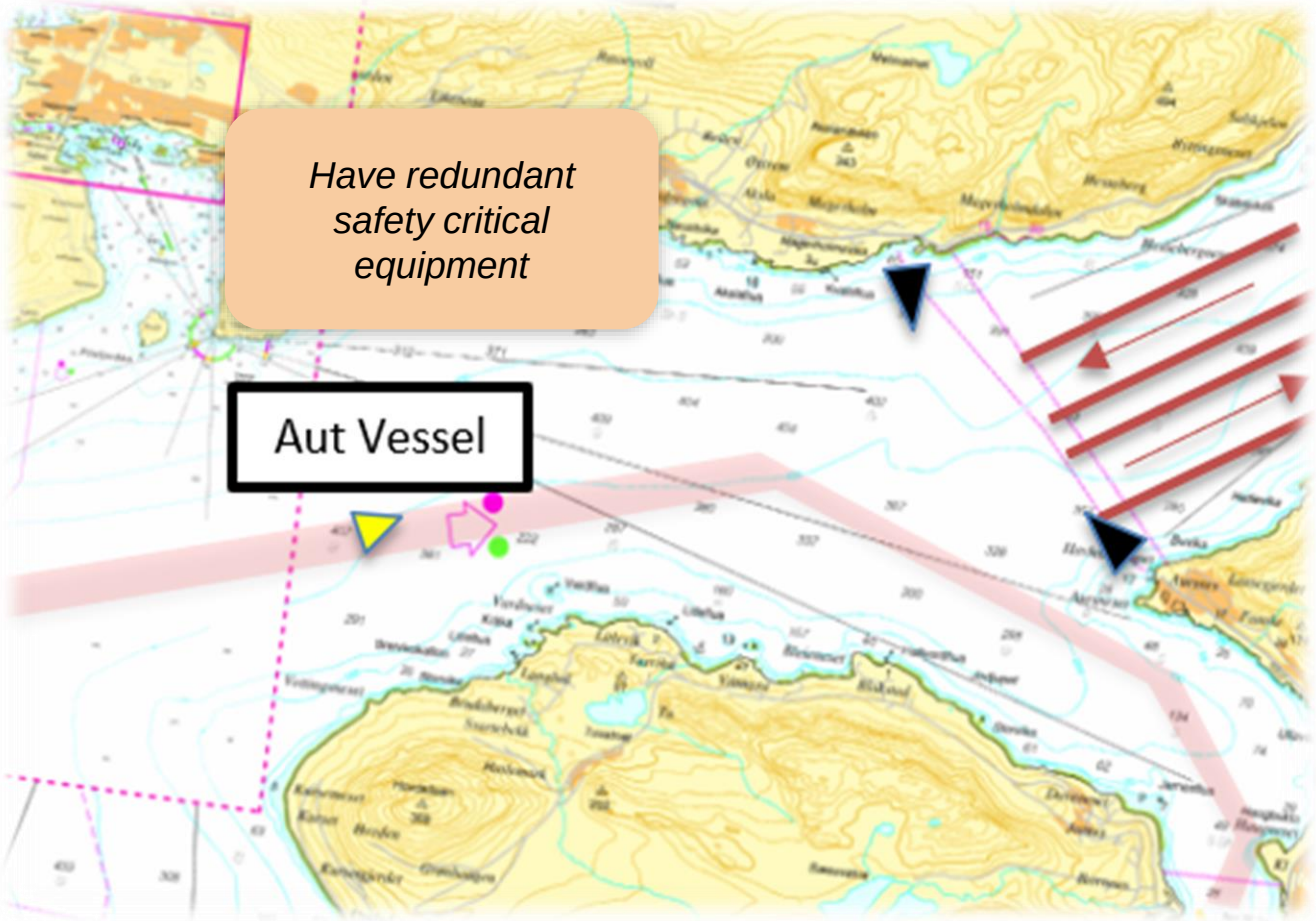
*Assess if an automated vessel needs to be categorised as having 'limited ability to manoeuvre'*

*Marked with a distinct AIS-tag*

*Conspicuous hull colour*




*Extensive use of Traffic Separation Schemes (TSS) for conventional vessels*


Have redundant safety critical equipment
Aut Vessel

# Contribution

**Scientific contribution**

- Resilient performance as an overlapping topic

**Methodological contribution**

- Combination of a Design Research Methodology, systems thinking and design thninking
- Internal and external description of systems to address complex systems

**Industry contribution**

- The potential in a shift from ad-hoc to a tactical controller
- Proving that the VTS can play an important role for the development of maritime autonomy

# Future work

- A more specific guidance on when to change perspective between system and humans
- Wider application, more users, different contexts
- Identify convergence between objective and subjective claims

# Conclusions

- Autonomy, might be a useful term, but needs further specification for detailed use
- The human will continue to strengthen systems, even when technology are taking new roles
- The coexistence between vessels can be considered as a system-of-systems, and the VTS can contribute for safe coexistence
- Regulating traffic, both conventional and autonomous, is a prerequisite for safe coexistence.
- A consequence is a different distribution of the responsibility for separation between vessels than in the present MTS.
- The prototype shows that the VTS can be a major contributor to a safe coexistence, and taking a new role is not perceived futuristic nor unrealistic – *“it is not difficult, we could do it tomorrow”*