Safety of autonomous shipping

COLREGs and interaction between manned and unmanned ships

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NTNU

SAREPTA

SESAME
Solution II

3D visualisation of a MASS, Rolls Royce

The Trondheim autonomous all-electric passenger ferry

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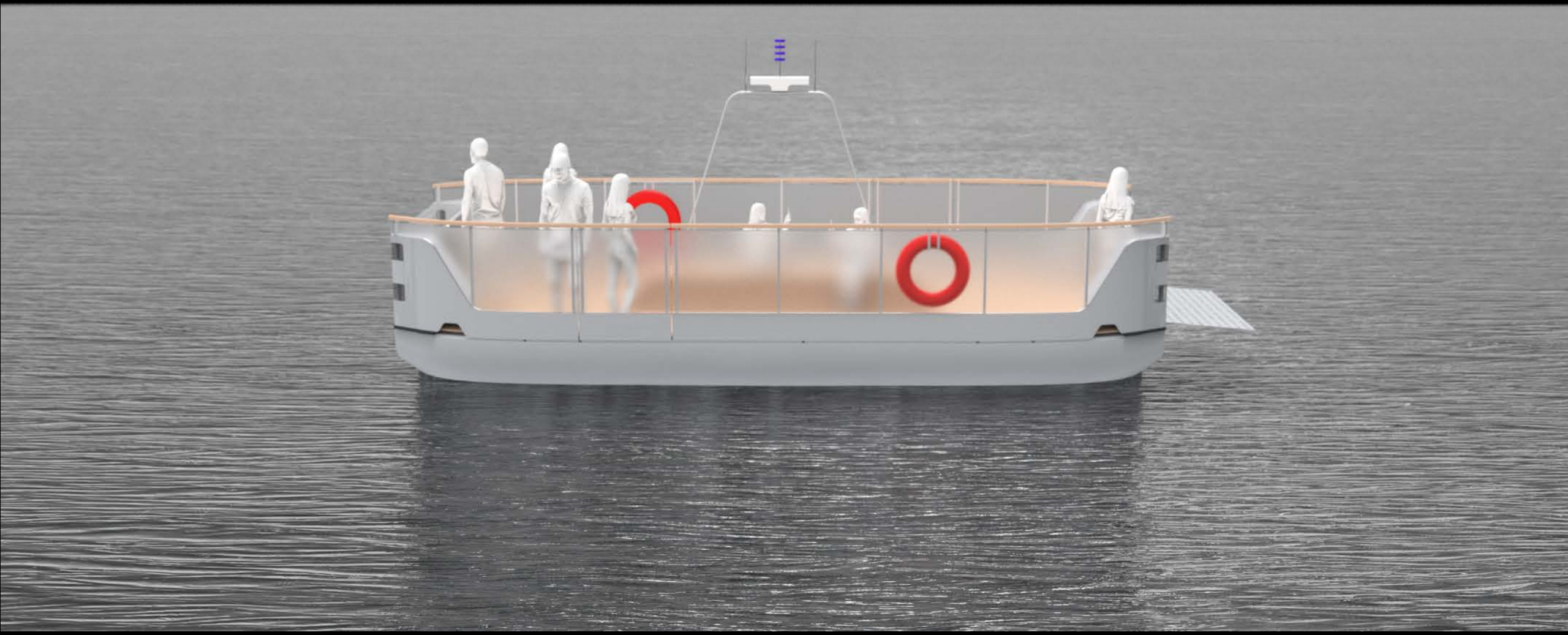
Concept model of the Trondheim AutoFerry, l.o.a. 8.4 m, taking 12 passengers (with bikes)



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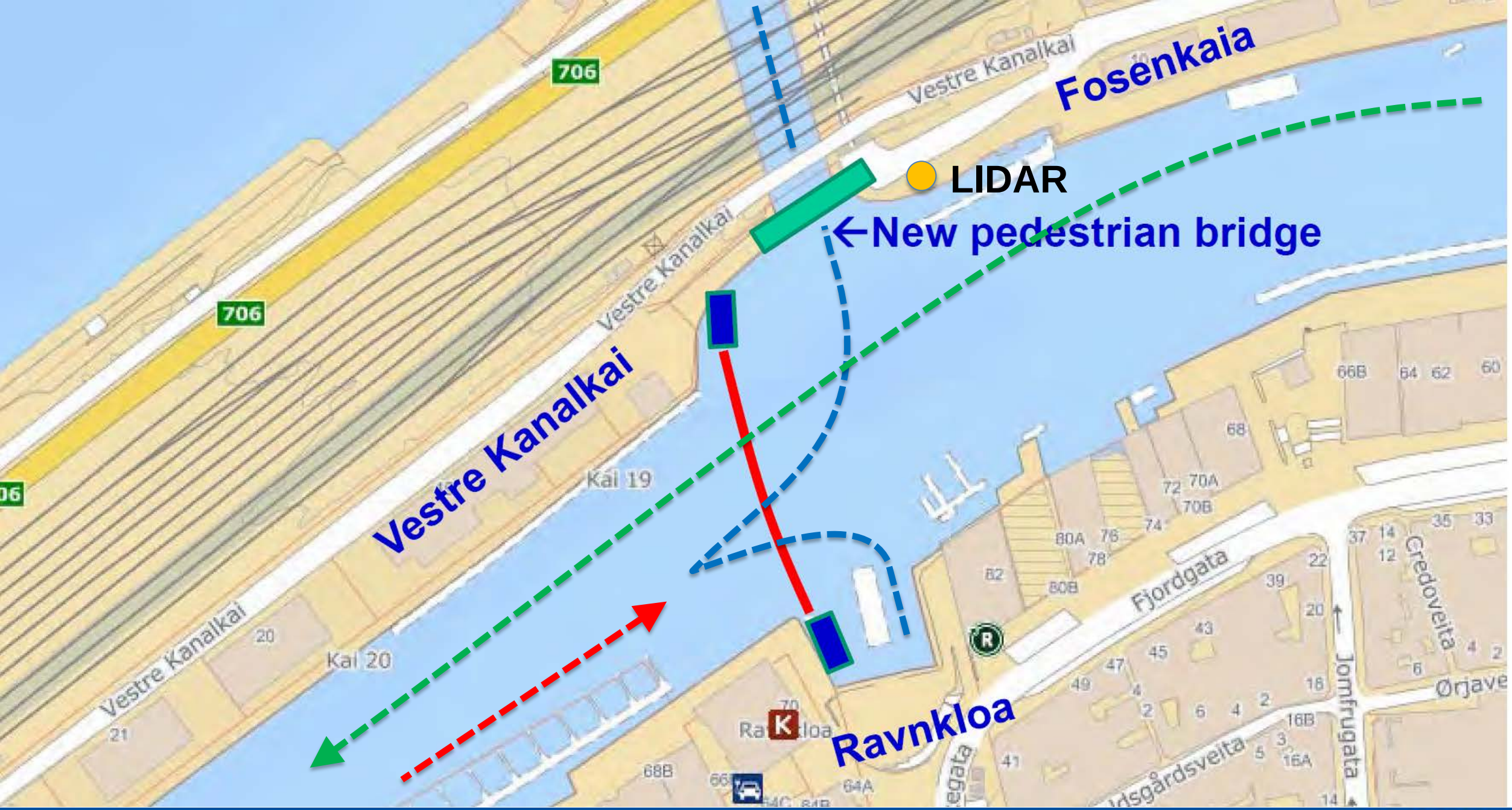

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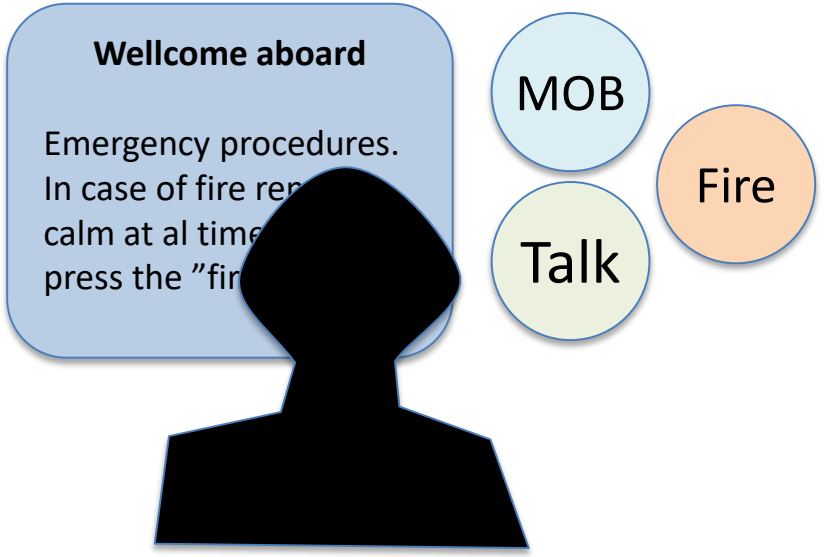
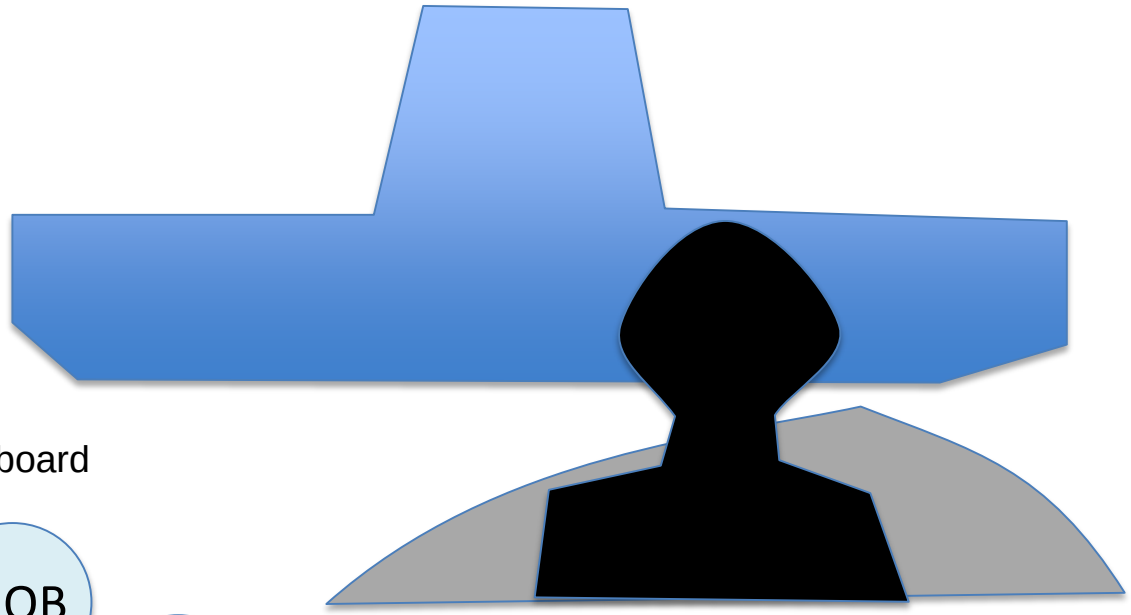
Human-Factors Challenges

Human-machine interface
Shore Control Centre

Passenger-ferry interaction onboard





Interaction between autonomous ferry and other manned vessels and crafts

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The YARA Birkeland autonomous all-electric short-sea container feeder

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Estimated facts & figures	Capacity	Proximity sensors
Main particulars **Length o.a.**: 79,5 m **Length p.p.**: 72,4 m **Width mld.**: 14,8 m **Depth shelter deck**: 10,8 m **Draught (full)**: 6 m **Draught (ballast)**: 3 m **Service speed**: 6 knots **Max speed**: 13 knots	**Cargo capacity**: 120 TEU **Deadweight**: 3 200 mt **Propulsion system**: Electric **Propellers**: 2 Azimuth pods **Thrusters**: 2 Tunnel thruster **Battery pack**: 7 – 9 MWh	Radar Lidar AIS Camera IR camera **Connectivity & Communication** Maritime Broadband Radio Satellite Communications GSM

https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/4B8113B707A50A4FC125811D00407045?OpenDocument [acc. 2018-02-04]

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High Attention View

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Interaction MASS - MASS

Algorithm-based machine-to-machine negotiations (like aviation TCAS)

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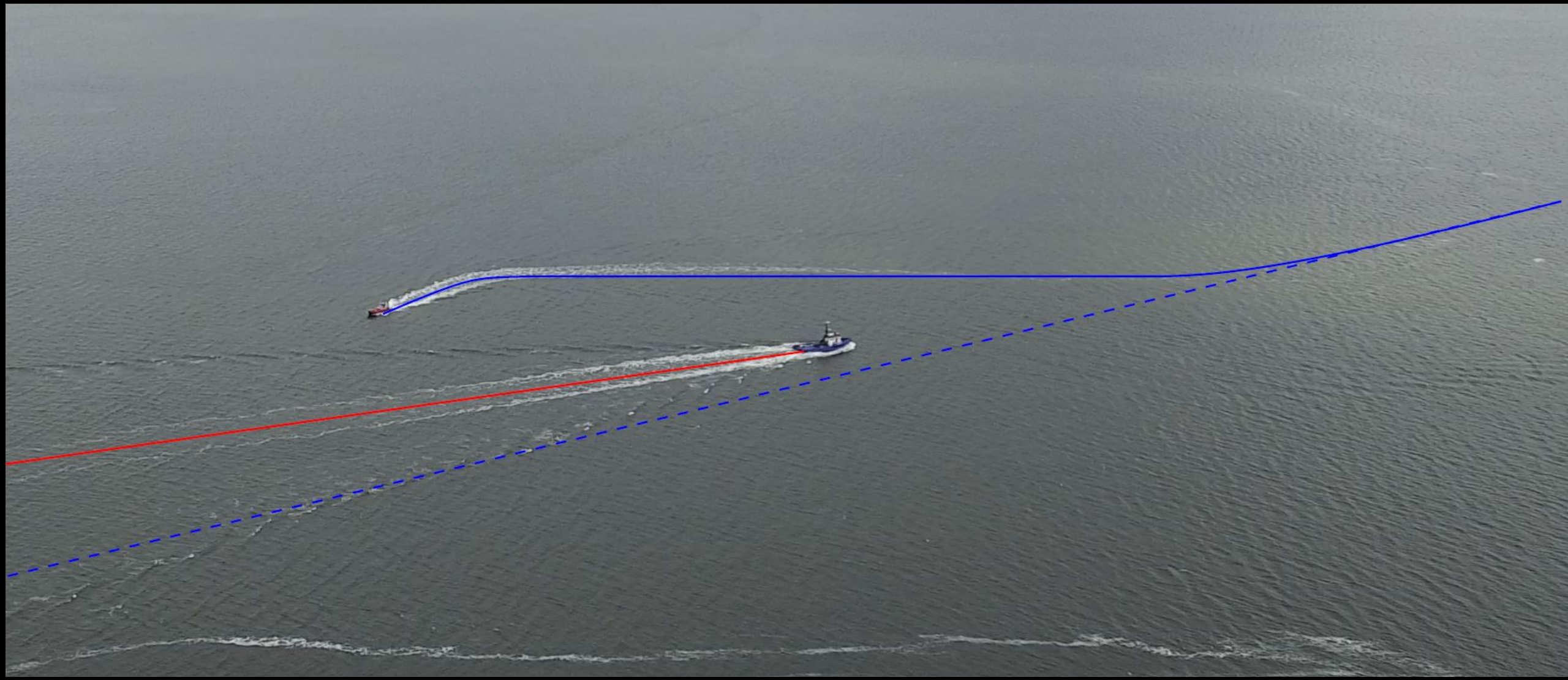

Autosea – Sensor fusion and collision avoidance for autonomous surface vehicles

https://www.ntnu.edu/autosea/

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Interaction MASS - MASS

Algorithm-based machine-to-machine negotiations (like aviation TCAS)

Interaction between MASS and humans

COLREGS

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The International Regulations for Preventing Collisions at Sea 1972

("COLREGS")

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Rule 15: “When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other.”

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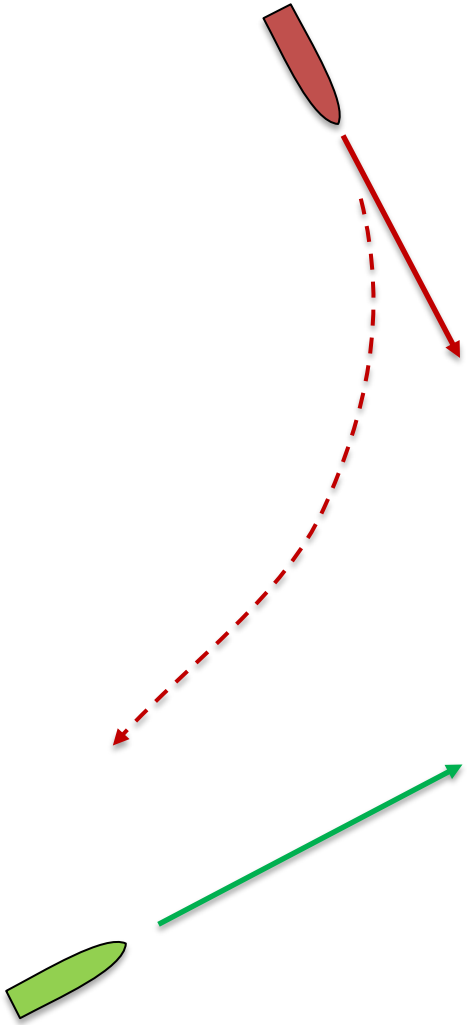

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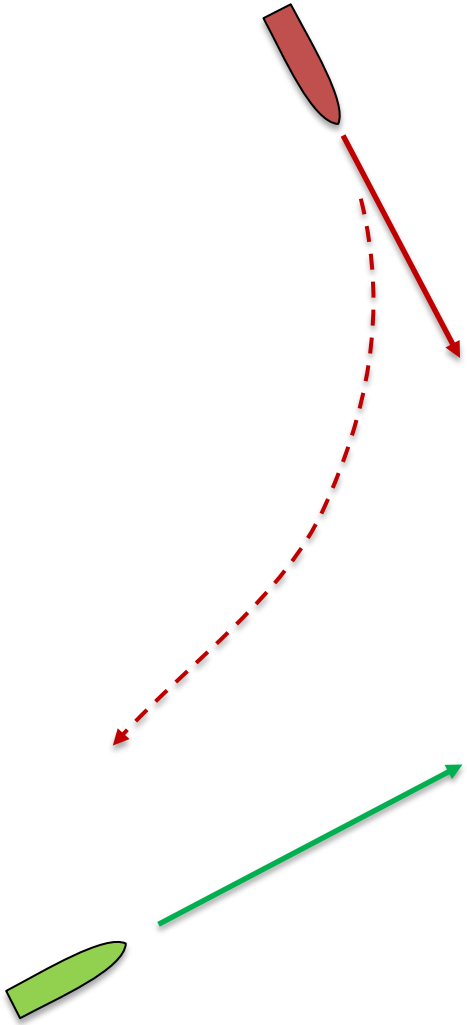

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Rule 16: “Every vessel which is directed to keep out of the way of another vessel shall, as far as possible, take early and substantial action to keep well clear.”

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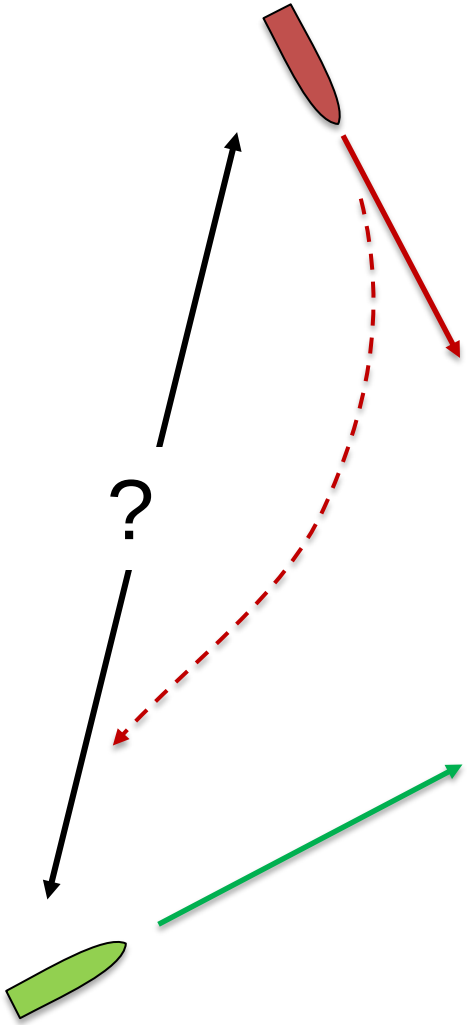

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Rule 2 “the ordinary practice of seamen”

a. “Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precautions which may be required by the ordinary practice of seamen, or by the special circumstances of the case.”

b. “In construing and complying with these Rules due regard shall be had to all dangers of navigation and collision and to any special circumstances, including the limitations of the vessels involved, which may make a departure from these Rules necessary to avoid immediate danger.”

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“As a general guideline, attempt to achieve a CPA of 2 miles in the open sea and 1 mile in restricted waters”

The Nautical Institute

Lee & Parker, (2007), Managing Collision Avoidance at Sea, p. 35)

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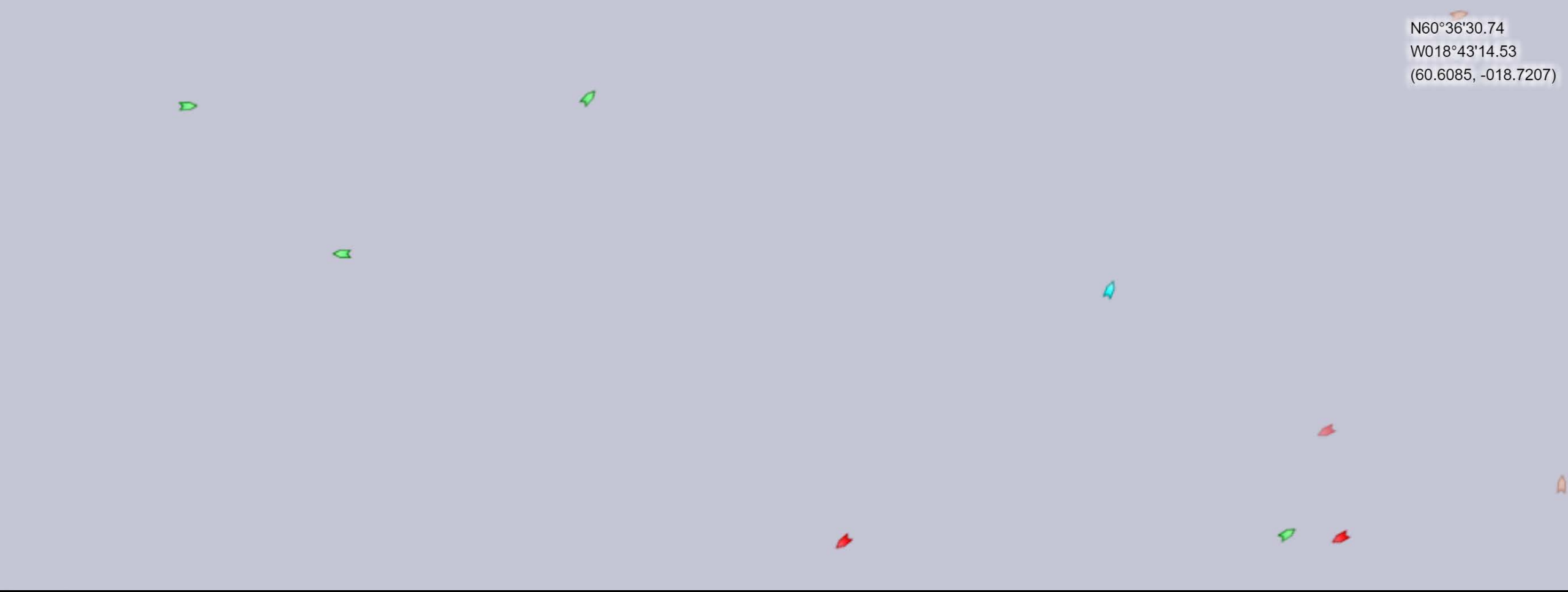

North Atlantic 12 June 2019

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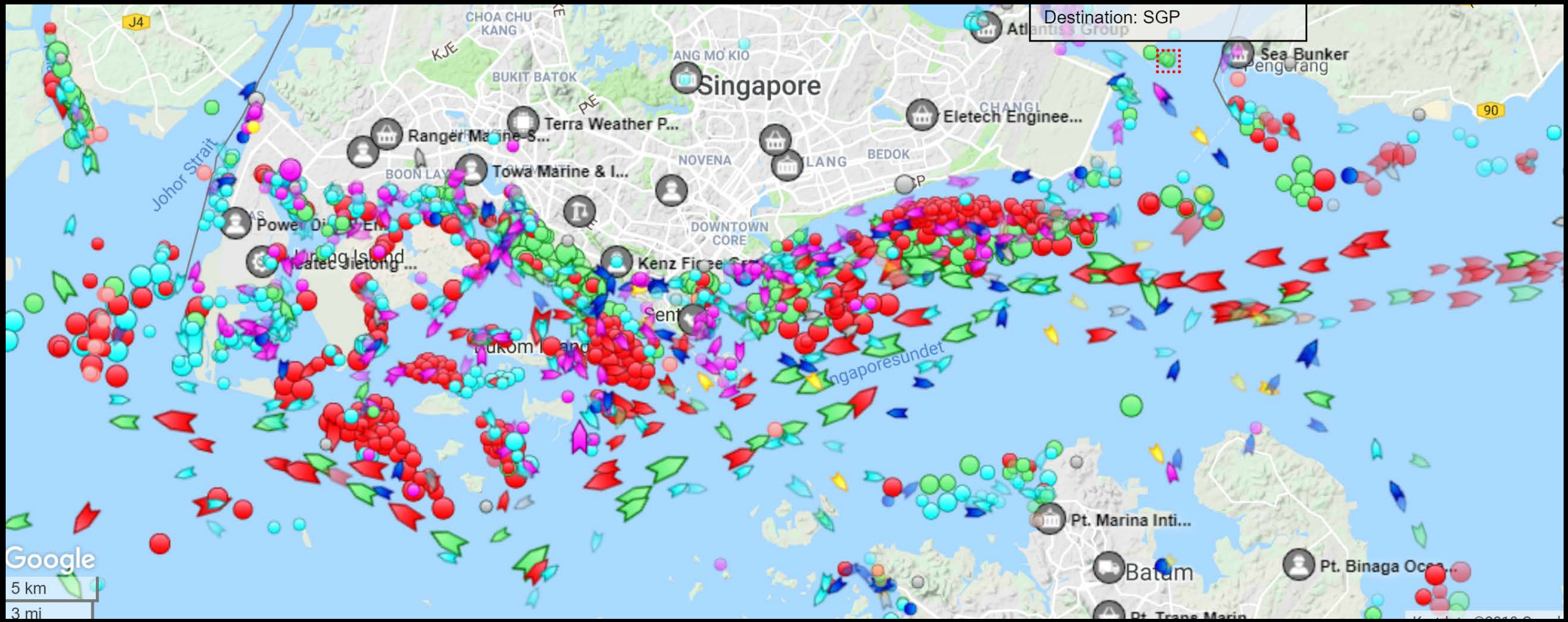

Singapore Strait, 25 March 2019

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Examples of qualitative enumerations in COLREGS

Rule 2: ”…precautions which may be required by the ordinary practice of seamen, or by the special circumstances of the case.”

“… due regard shall be had to all dangers of navigation and collision and to any special circumstances”

Rule 8: “Any action to avoid collision shall be taken in accordance with the Rules of this Part and shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship.”

Rule 19: “Conduct of vessels in restricted visibility.”
“Every vessel shall proceed at a safe speed adapted to the prevailing circumstances and conditions of restricted visibility.”
“(d) A vessel which detects by radar alone the presence of another vessel shall determine if a close-quarters situation is developing and/or risk of collision exists. If so, she shall take avoiding action in ample time…”

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Should we develop machine-readable COLREGS?

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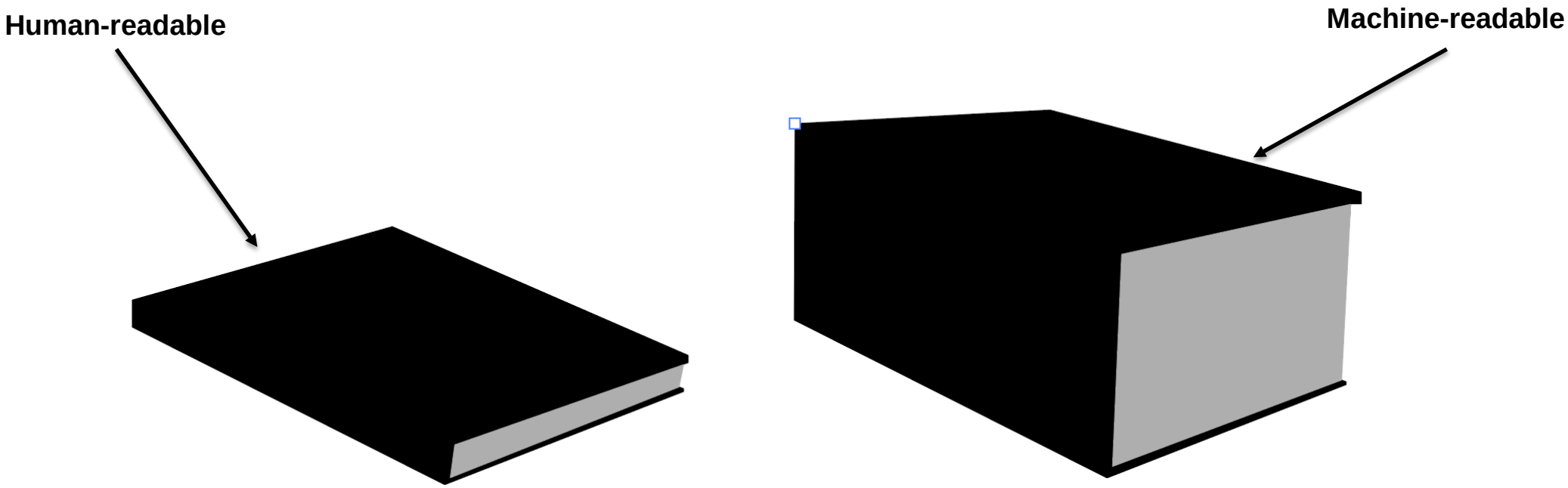

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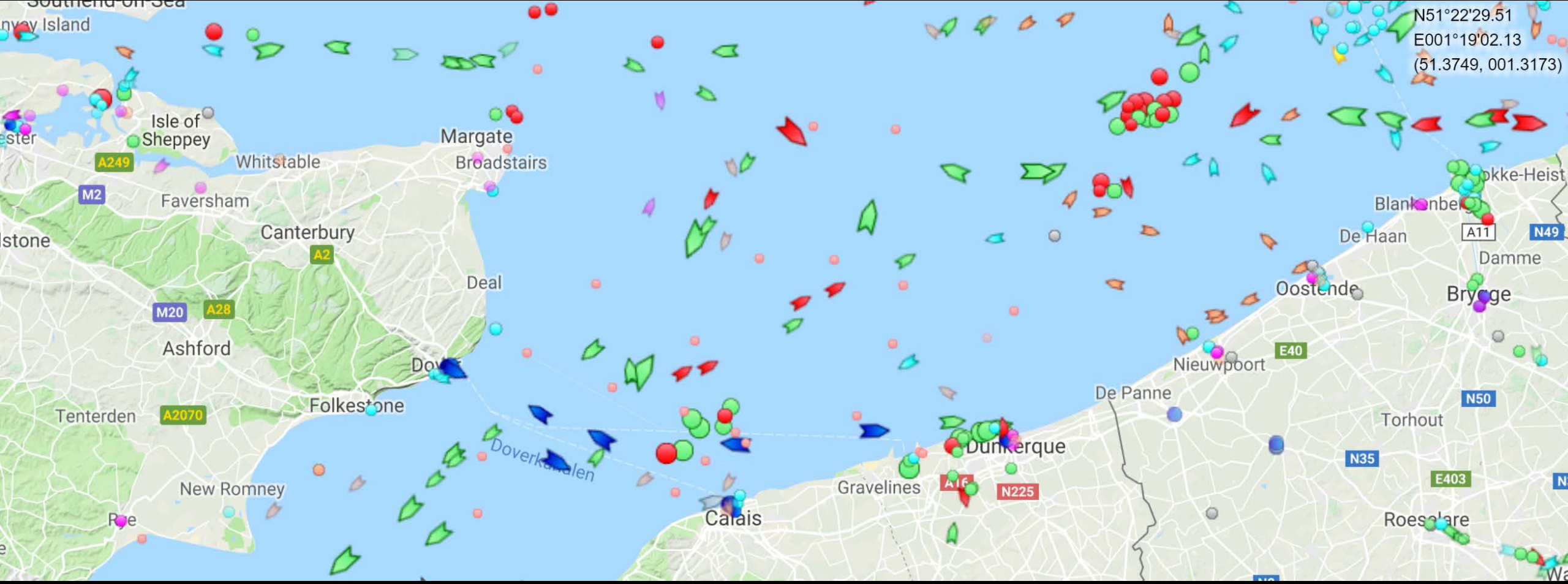

Local machine-readable COLREGS

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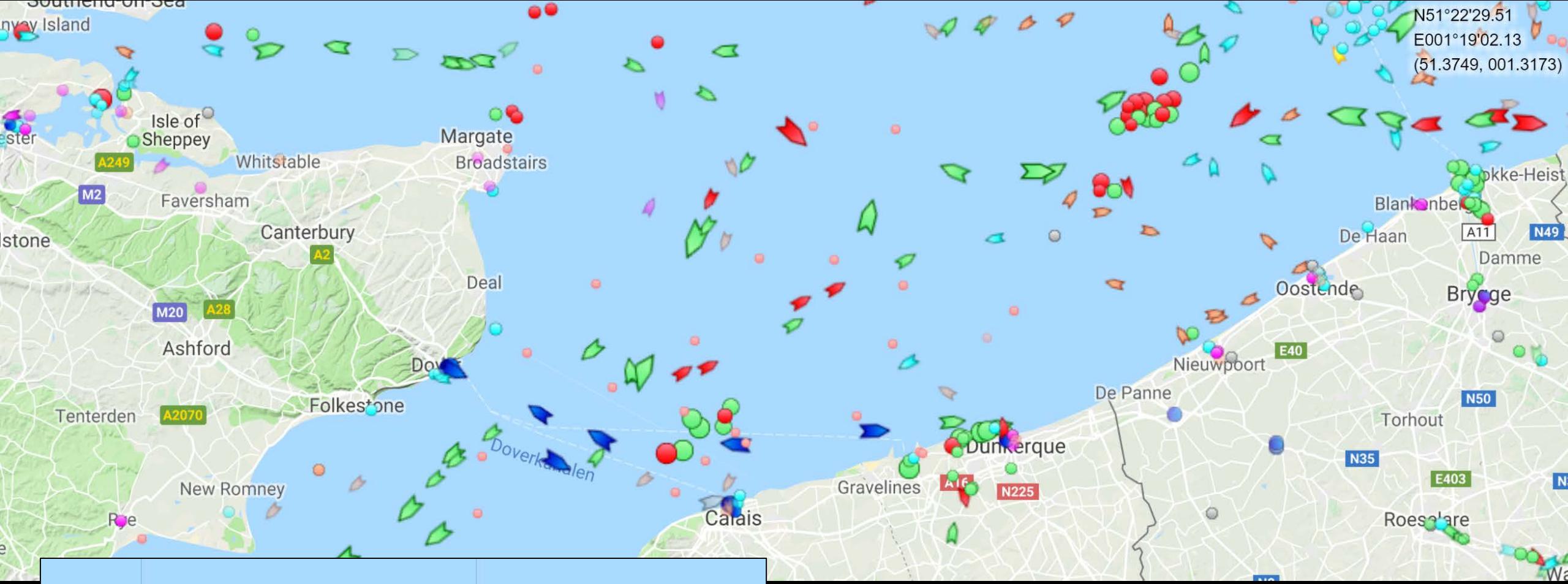

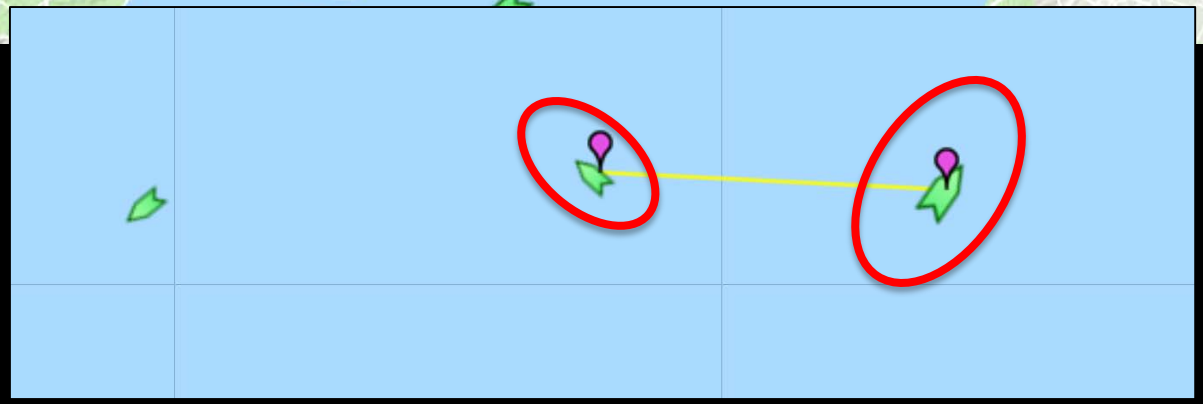

Local machine-readable COLREGS

Computing ”Safety zones”

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Automation transparency

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Examples of Automation Transparency

1. **Traffic separation.** Dedicated fairways. Dedicated times.

2. **Identification**. This is a ship in autonomous mode (marking)

3. **Sharing intentions.** What is the autonomous ship's intentions?

4. **Moving havens**

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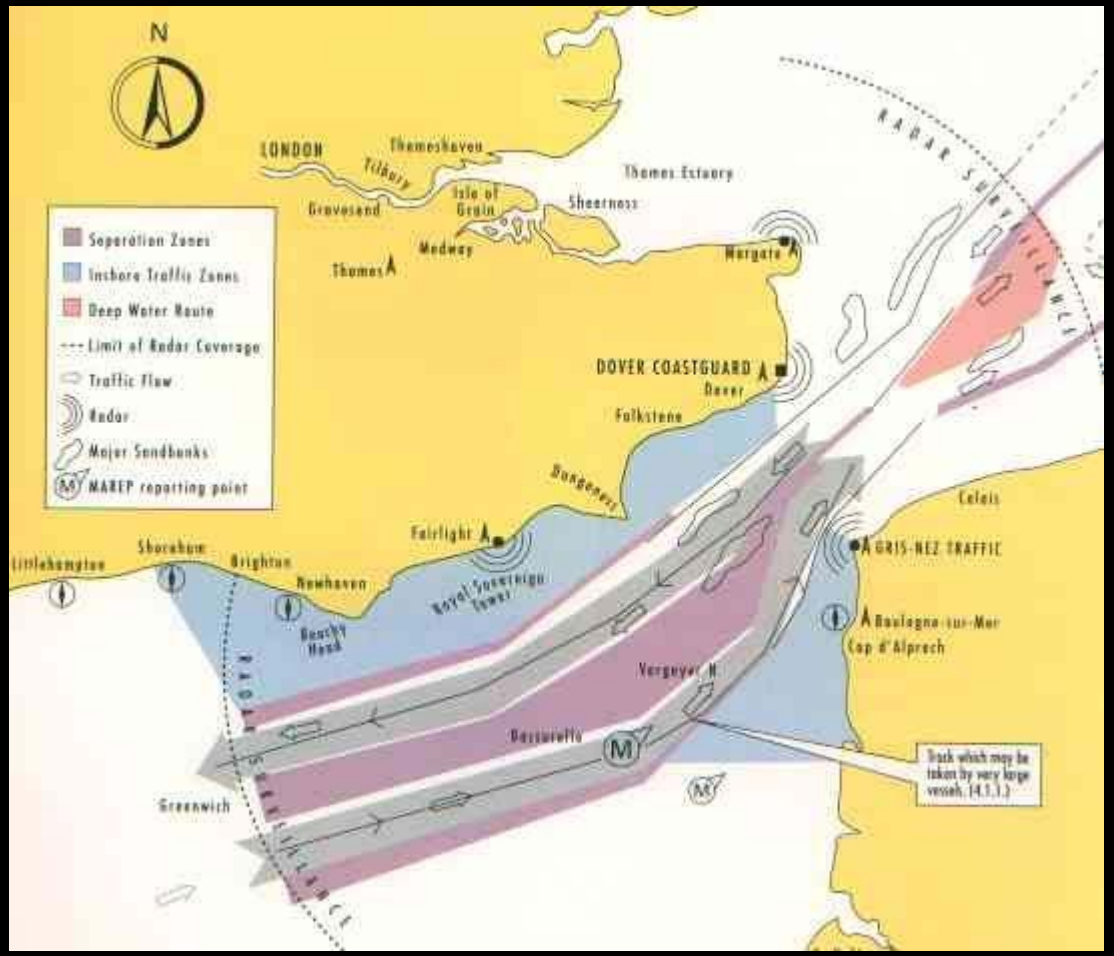
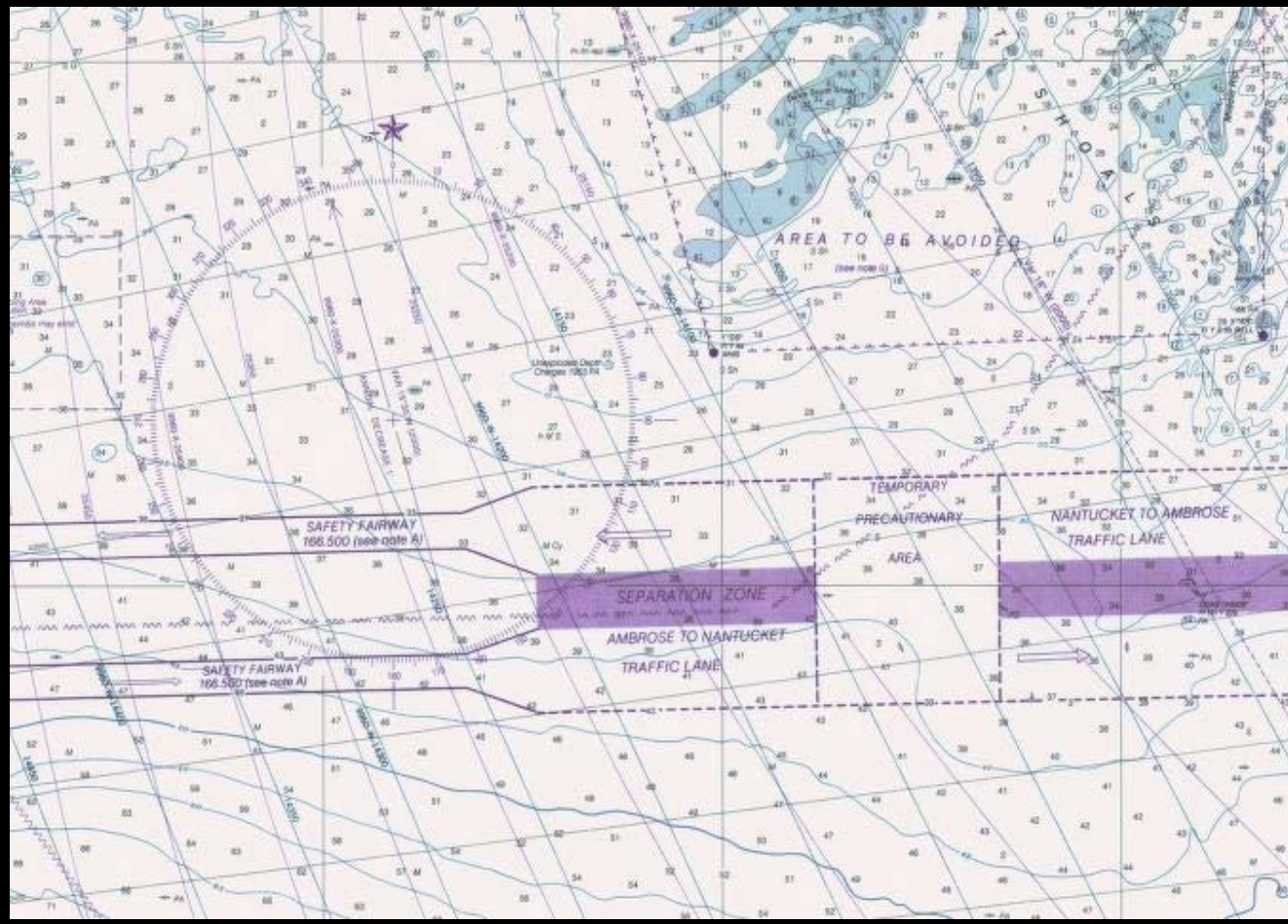
Traffic Separation Schemes





Dover Strait TSS (1967)

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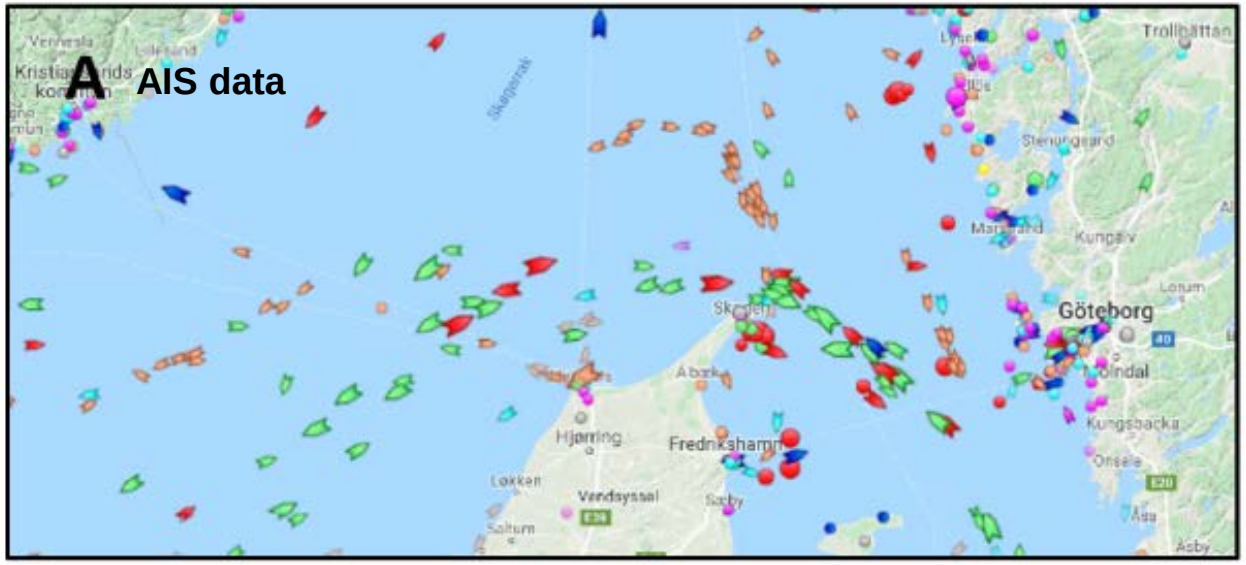

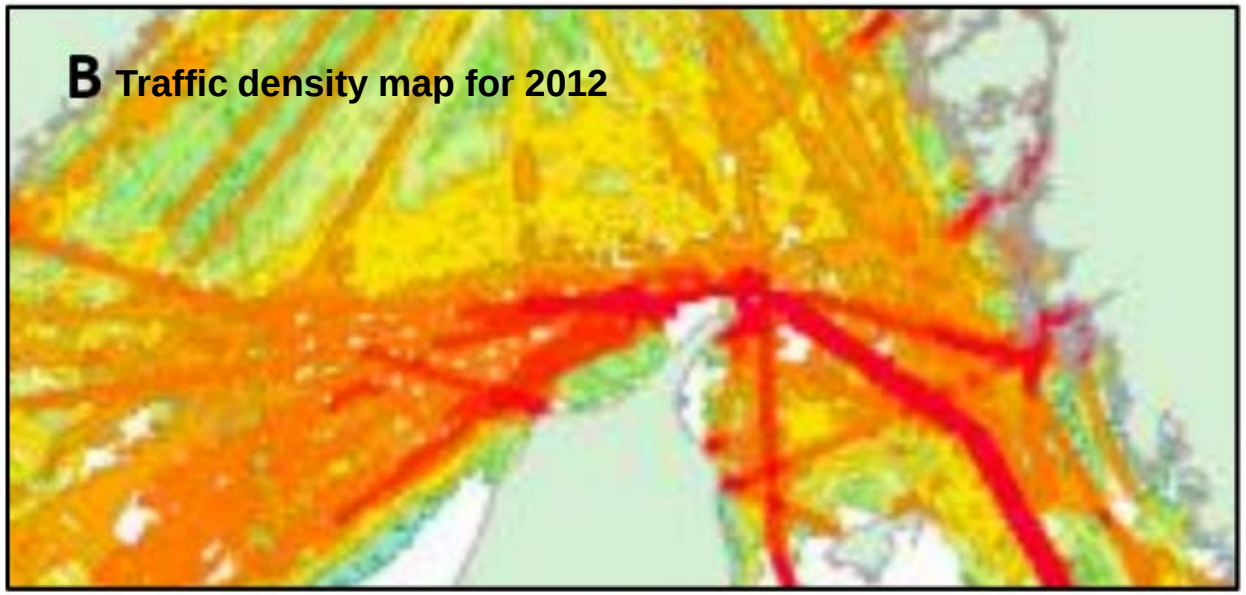

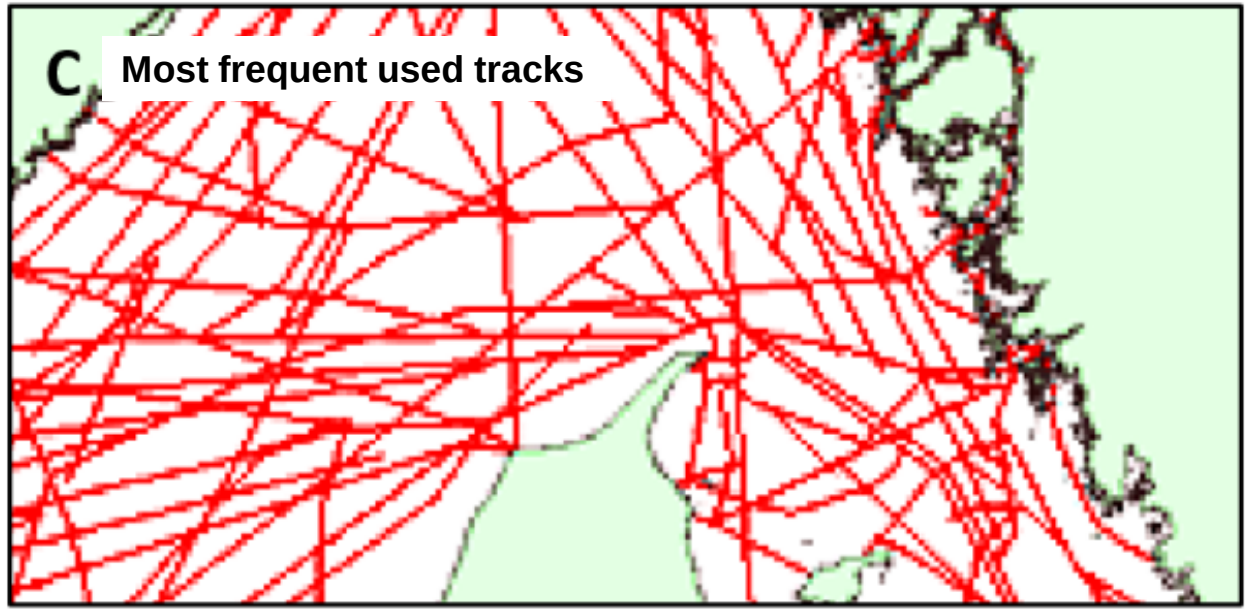

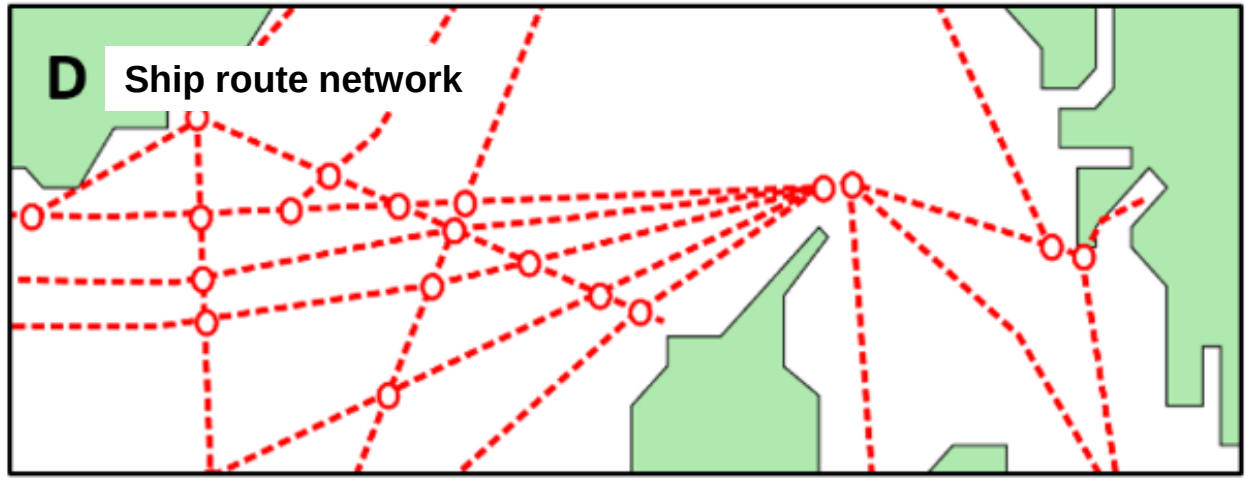

”Motorways of the Sea”. A route network topology for Skagerrak (ACCSEAS project 2015)

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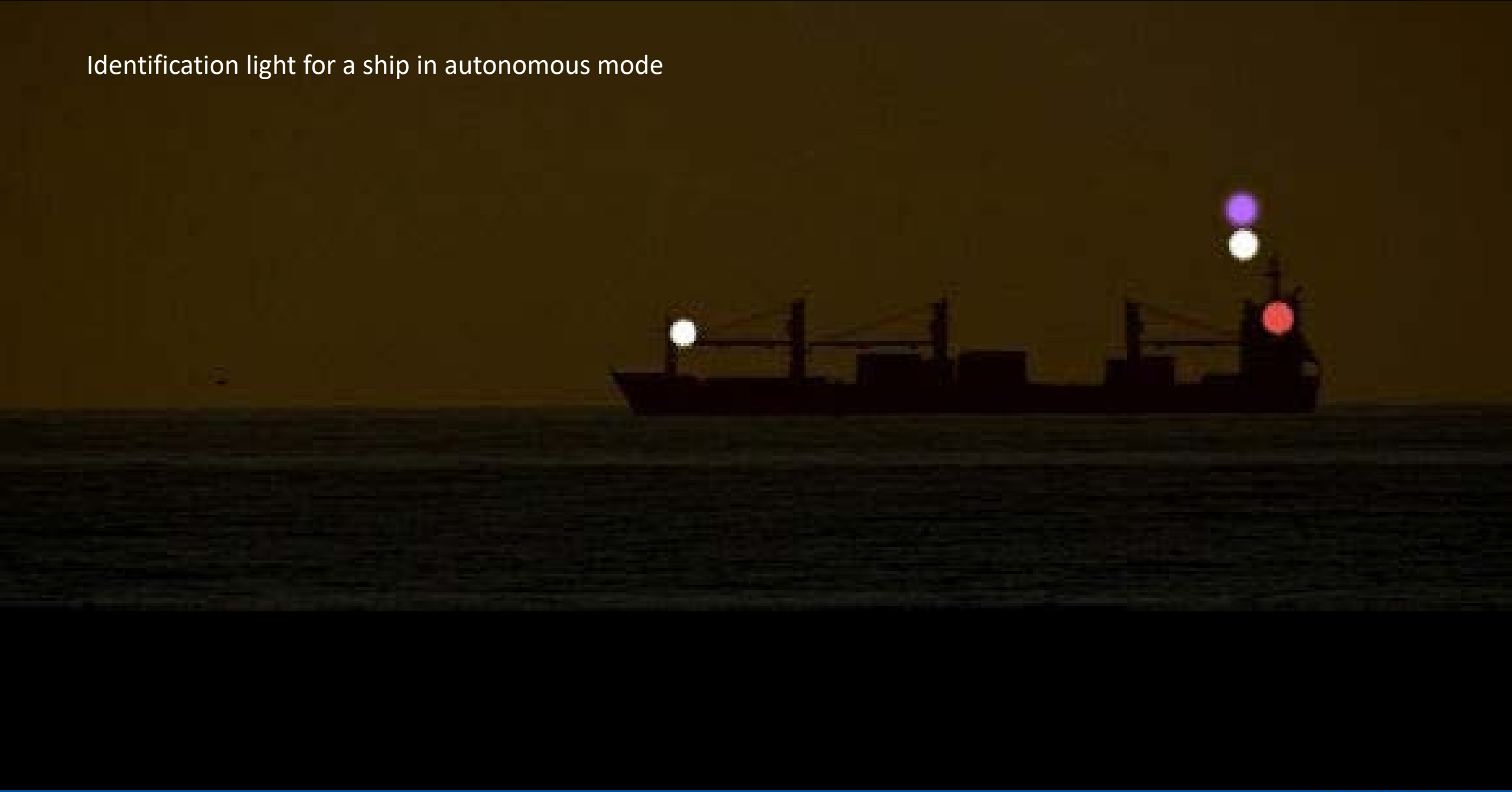
Identification light for a ship in autonomous mode



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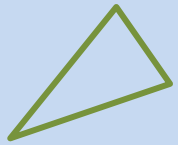
Sharing intentions



A

Own ship

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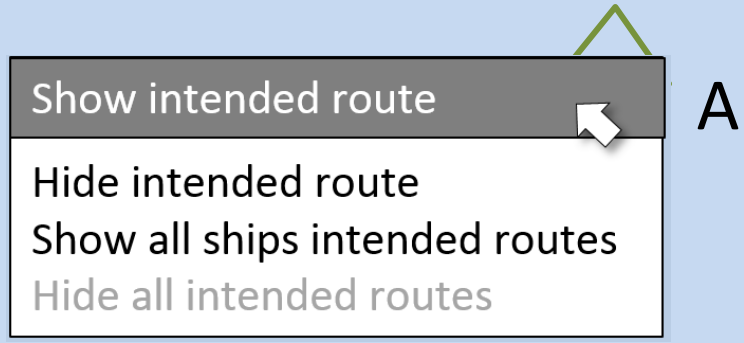
Sharing intentions



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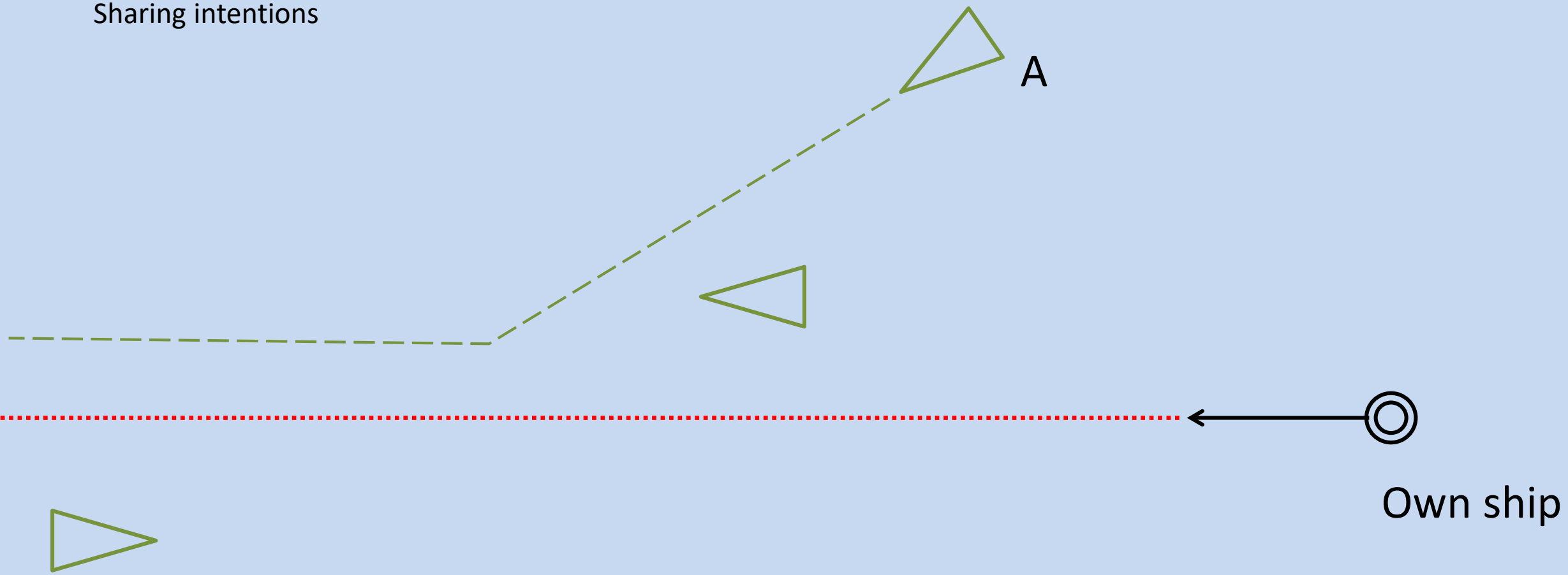

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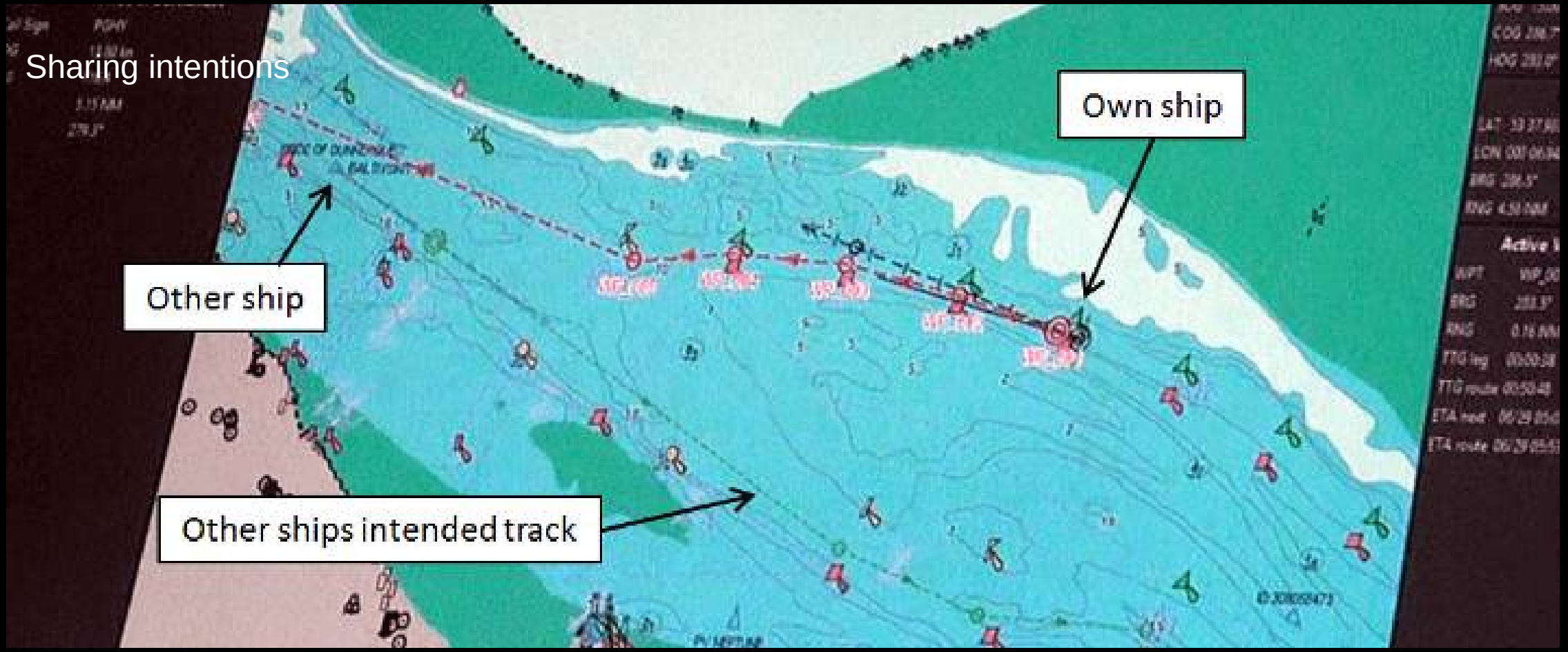

Porathe, T. (2012). Transmitting intended and suggested routes in ship operations: cognitive off-loading by placing knowledge in the world. Work, 41 (Supplement: 1) pp. 4873-4878.

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The concept of ”moving havens”

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Conclutions

Tools of human-autonomous ship interaction

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2. **Traffic separation schemes.** Dedicated fairways. Dedicated times.

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