



Integrated Maritime
Autonomous Transport Systems

Scenarios

Scenarios will show how land based Maritime Domain Awareness system and sensors are used to improve situational awareness and decision support tools for operators in a Remote Operation Center for autonomous ships

Scenarios in IMAT

- **Scenario 0 – Plan operation - Situational Awareness**
- Scenario 1 – Normal operation
- ➔ • **Scenario 2 – Deviation from planned route**
- Scenario 3 – Loss of shore sensors (Connectivity)
- ➔ • **Scenario 4 – Mismatch between sensors - situational awareness**
- Scenario 5 – Loss of communication with drone
- Scenario 6 – Redundant ROC's
- ➔ • **Scenario 7 – Close Quarter Detected by Infrastructure**
- Scenario 8 – Approaching harbour



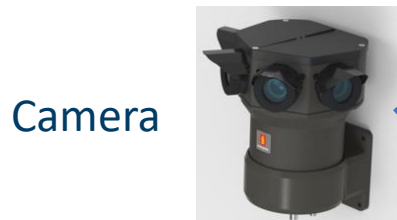
Integrated Maritime
Autonomous Transport Systems

Infrastructure - Sensors - Products Used for Scenarios



ROC – Building the Situational Awareness

Drone sensor package



Radar Interface

Radar Interface

ROC

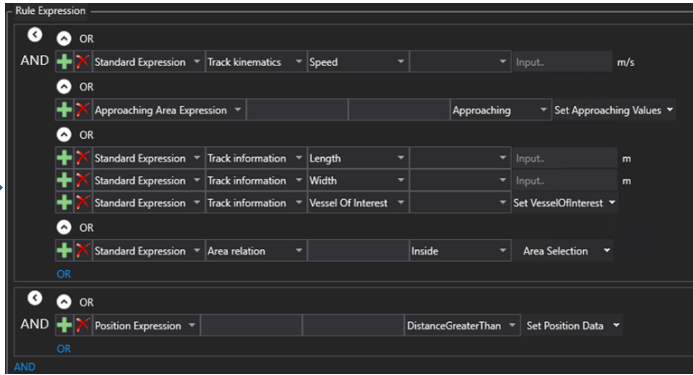


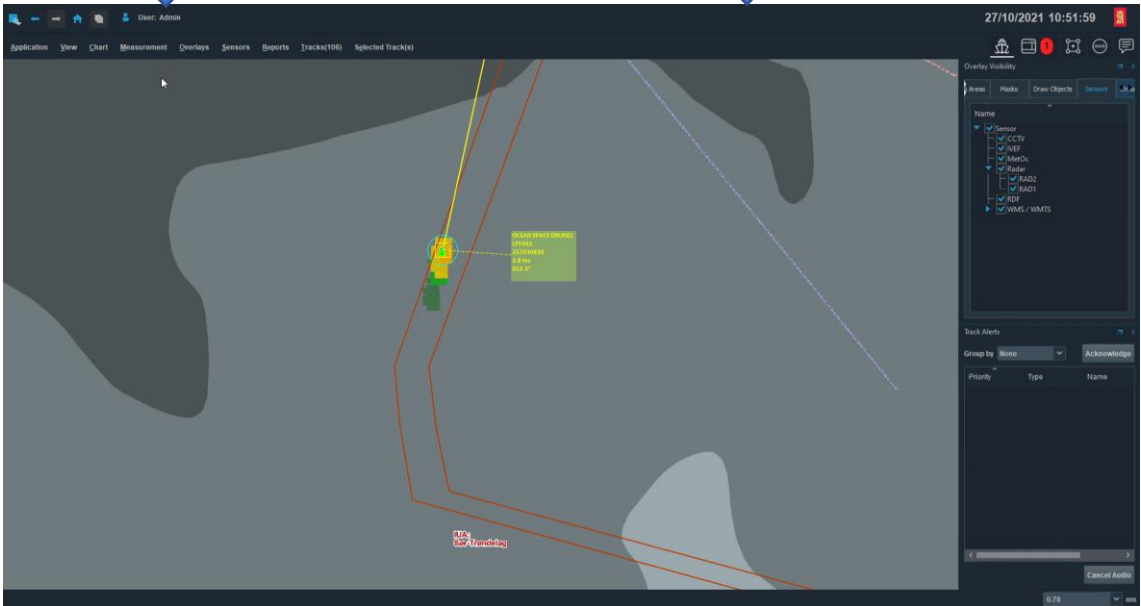
MBR

MBR

Sensor Management & Sensor Fusion

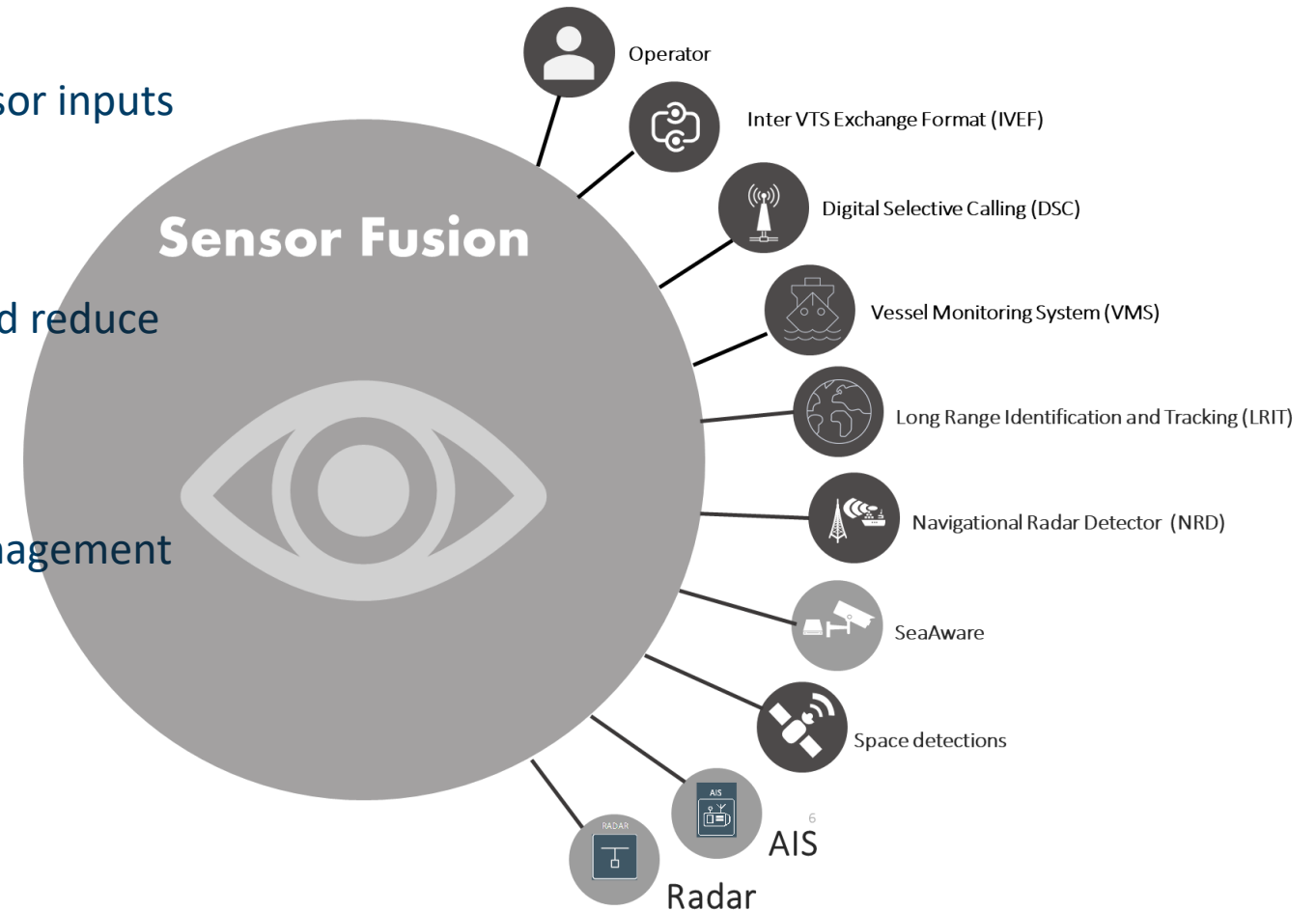
C-Scope





C-Scope Sensor Fusion

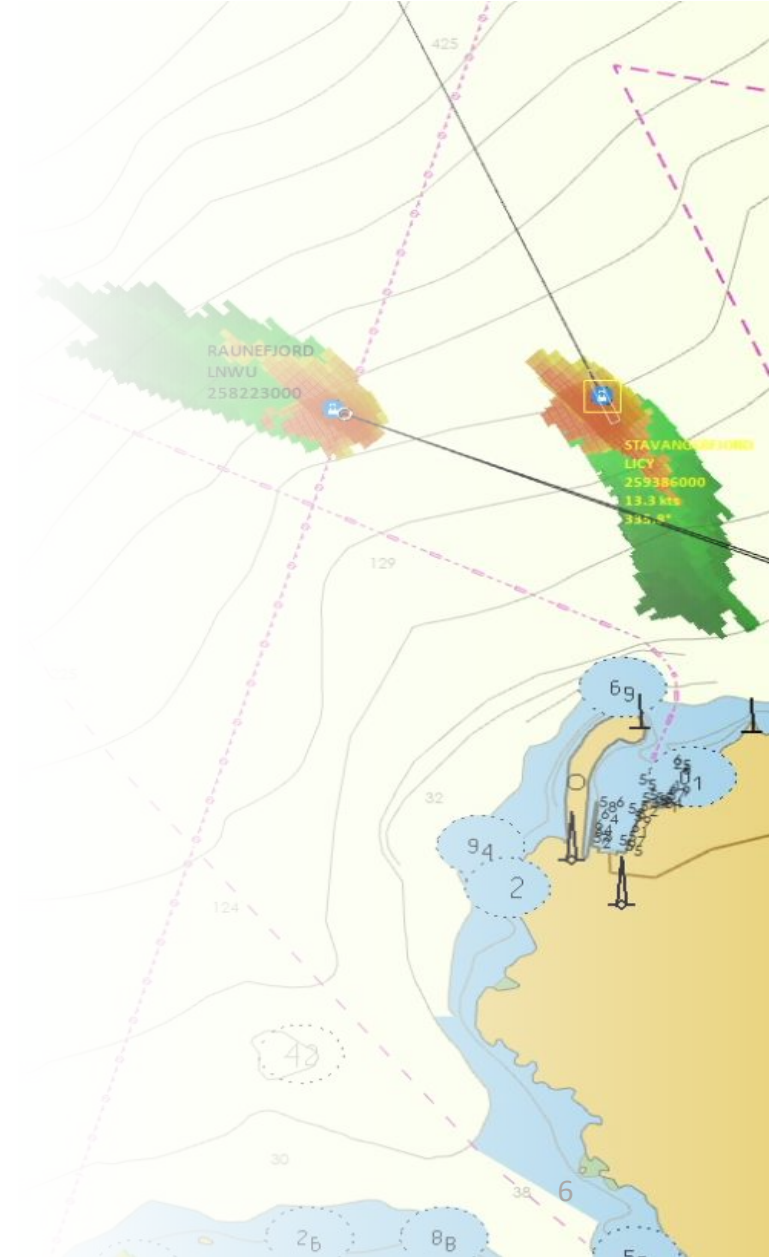
- Best possible situational picture based on sensor inputs
- Correlation analysis of sensor tracks
- Track fusion to utilize available information and reduce uncertainty
- Infolink
 - Updating vessel properties based on Management Information system
- High track capacity
 - Beyond 50.000 tracks



Building situational picture

C-Scope Sensor Fusion

- RADARs offer precise measurements of vessel positions.
 - System owner has control of the RADARs.
 - RADAR tracking offers calculation of position, speed and course, and the uncertainties of these.
 - The uncertainty of a track's properties are based on the RADAR's measurement uncertainty in azimuth and range, and the how the track behaves over time.
 - The track's uncertainty is expressed as the quality of the track. Less uncertainty gives higher quality.
-
- AIS is a collaborative system that has the capability to offer great accuracy and low uncertainty of a vessel's position, course and speed.
 - AIS offers identification of vessels.



Decision Support

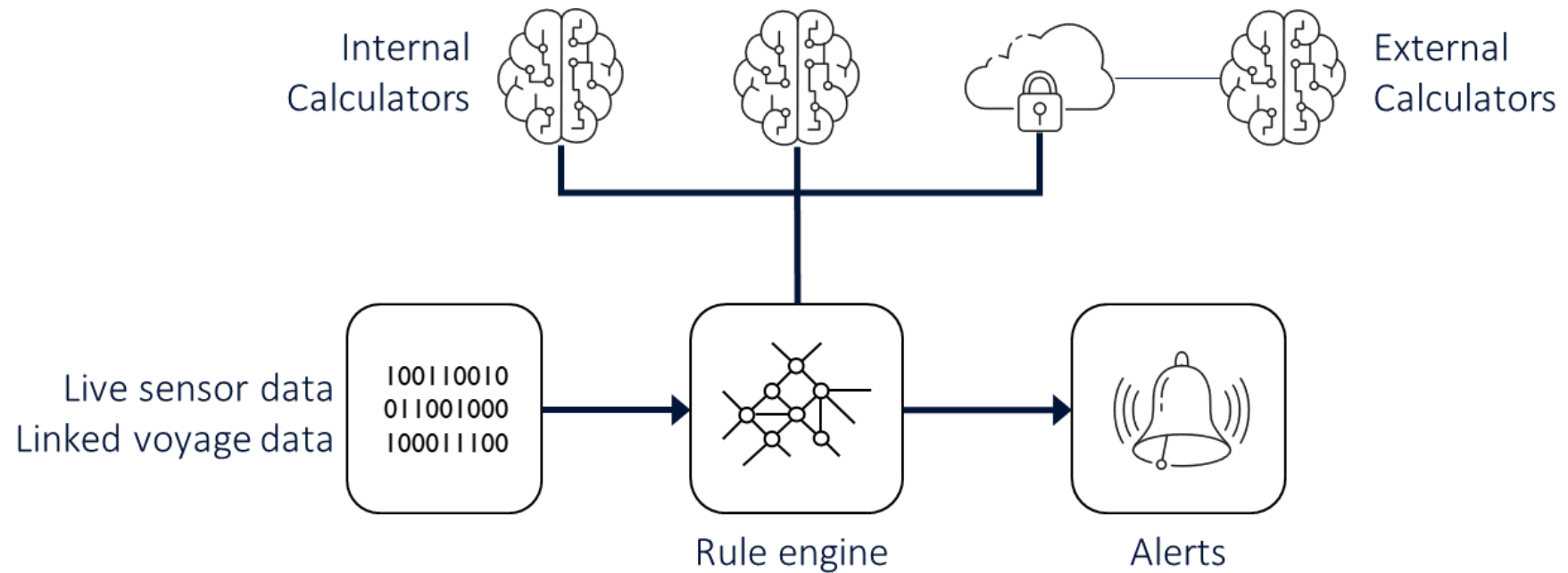
Alert service for automatic monitoring traffic situations

- Next generation automatic traffic situation monitoring
 - A move from static to dynamic rule library
 - Allows for monitoring local legislation
 - Support a large number vessels
- Specialized for meeting changing needs
 - Able to run hundreds of user defined rules
 - Highly configurable to meet specific operational needs
 - Rules can be defined using logical expressions containing
 - Geographic areas
 - Vessel information from RADAR, AIS, databases and more
 - Results from advanced algorithms detecting collision, grounding, COLREGS violation and more

Decision Support

Alert service for automatic monitoring traffic situations

- Supports integration of 3rd party solutions:
 - Plug-in design that facilitates testing out new algorithms. E.g. from research projects.
 - Advanced calculations for situation detection from local suppliers
 - Reporting to external systems like national databases or notification services



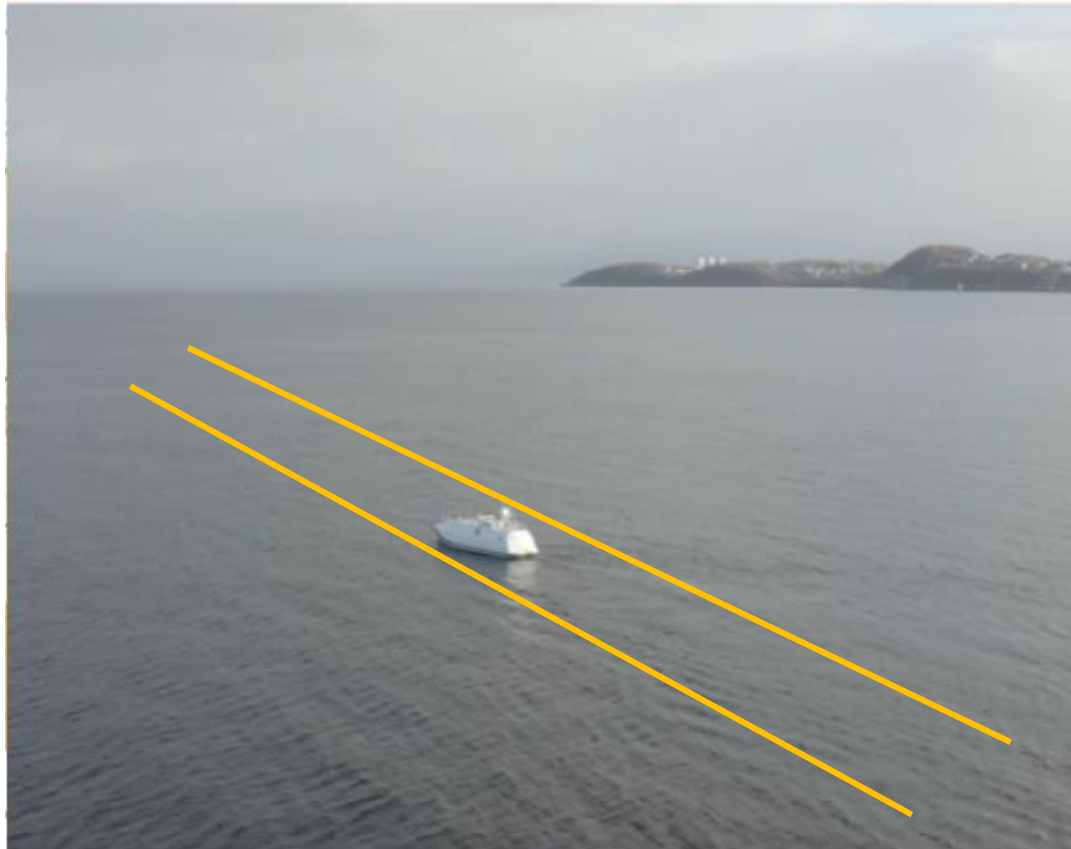
Scenarios in IMAT

- **Scenario 0 – Plan operation - Situational Awareness**
- Scenario 1 – Normal operation
- **Scenario 2 – Deviation from planned route**
- Scenario 3 – Loss of shore sensors (Connectivity)
- **Scenario 4 – Mismatch between sensors - situational awareness**
- Scenario 5 – Loss of communication with drone
- Scenario 6 – Redundant ROC's
- **Scenario 7 – Close Quarter Detected by Infrastructure**
- Scenario 8 – Approaching harbour

Motivation

Example case:

A vessel is sailing autonomously within a given route.



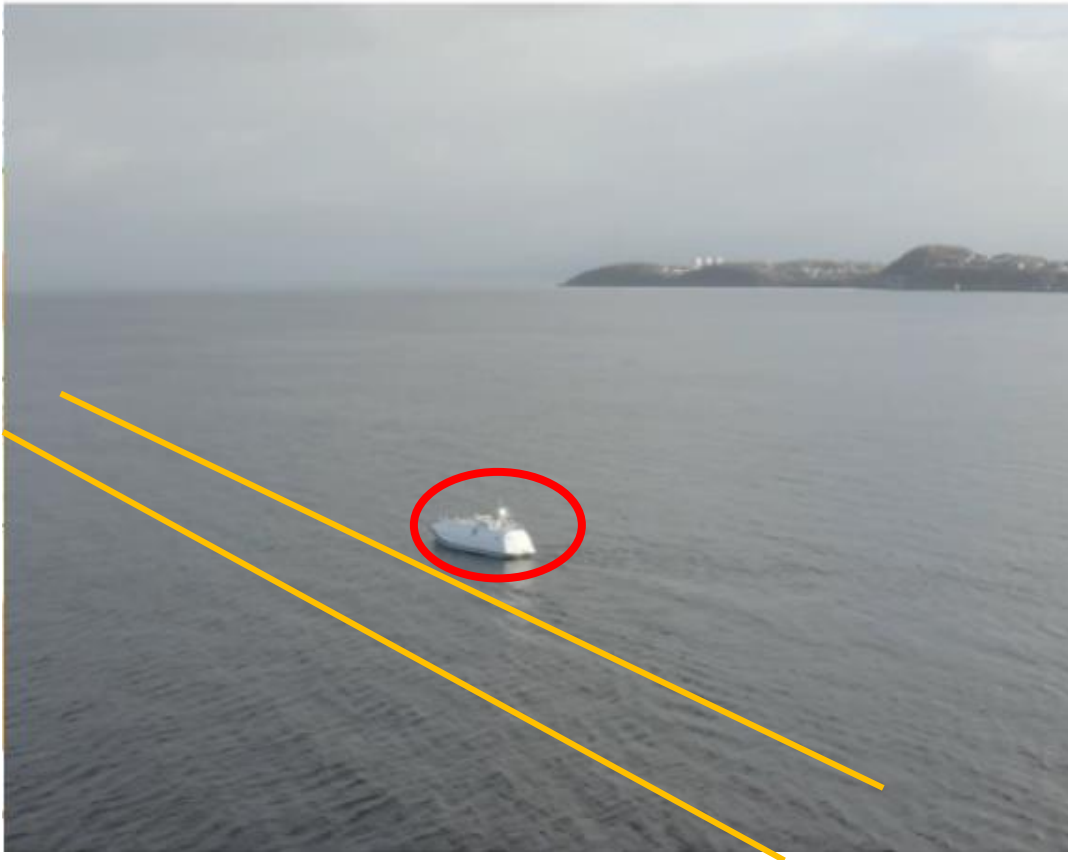
ROC



Motivation

Example case:

A vessel is sailing autonomously within a given route.

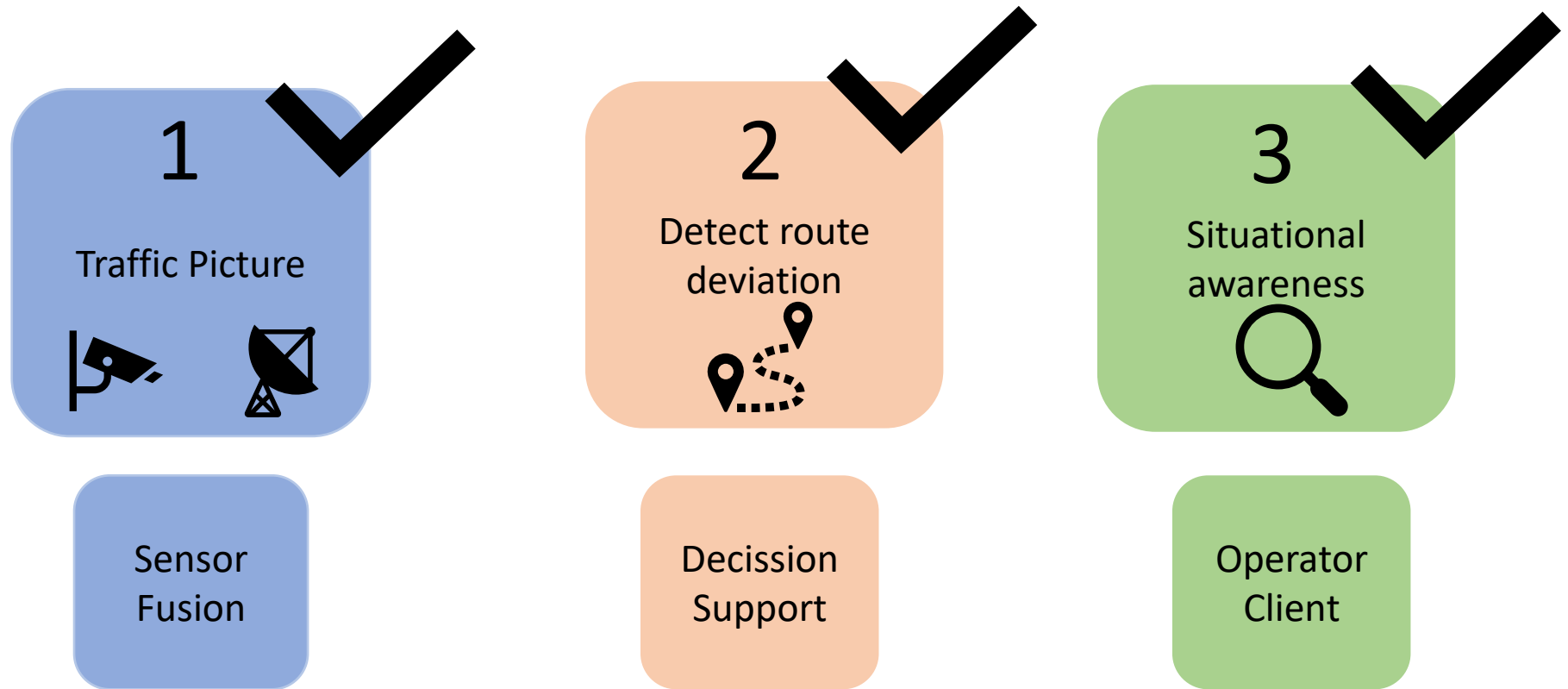


ROC



What happens if the vessel deviates from planned route?

Process



Demonstration

- Goal: verify route deviation based on land-based infrastructure and algorithms in C-scope

imat

Integrated Maritime
Autonomous Transport Systems



SINTEF

NTNU



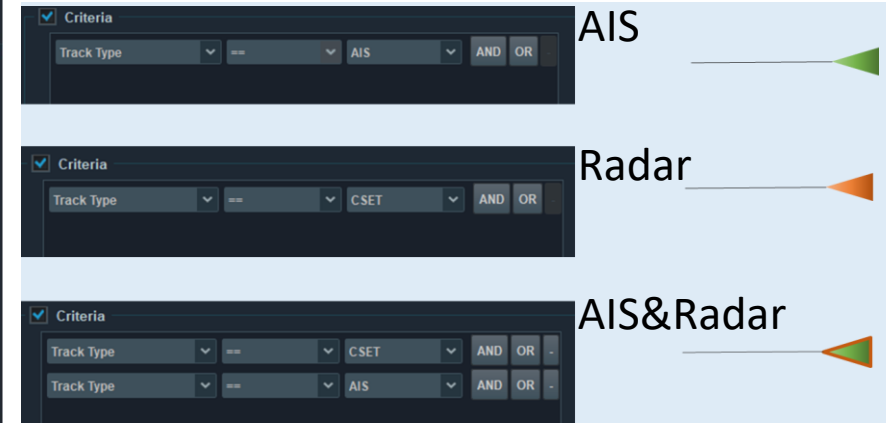
Verify technical infrastructure availability

C-Scope



The screenshot shows the C-Scope interface with a map view. A central track is highlighted in yellow and labeled 'SPACE ORION 1'. The interface includes a menu bar (Application, View, Chart, Measurement, Overlays, Sensors, Reports, Tracks(105), Selected Track(s)), a toolbar, and several panels: 'Overlay Visibility' (showing a tree of sensors like CCTV, IVEF, MetOc, Radar, RAD2, RAD1, RDE, WMS/WMTS), 'Track Alerts' (with Group by and Acknowledge options), and a status bar at the bottom with coordinates and other data.

Track Portrayal



Three examples of track portrayal criteria are shown, each with a corresponding colored arrow pointing to the right:

- AIS**: Criteria: Track Type == AIS AND OR
- Radar**: Criteria: Track Type == CSET AND OR
- AIS&Radar**: Criteria: Track Type == CSET AND OR, Track Type == AIS AND OR

Verify video stream from vessel in ROC



Verify that vessel is following route

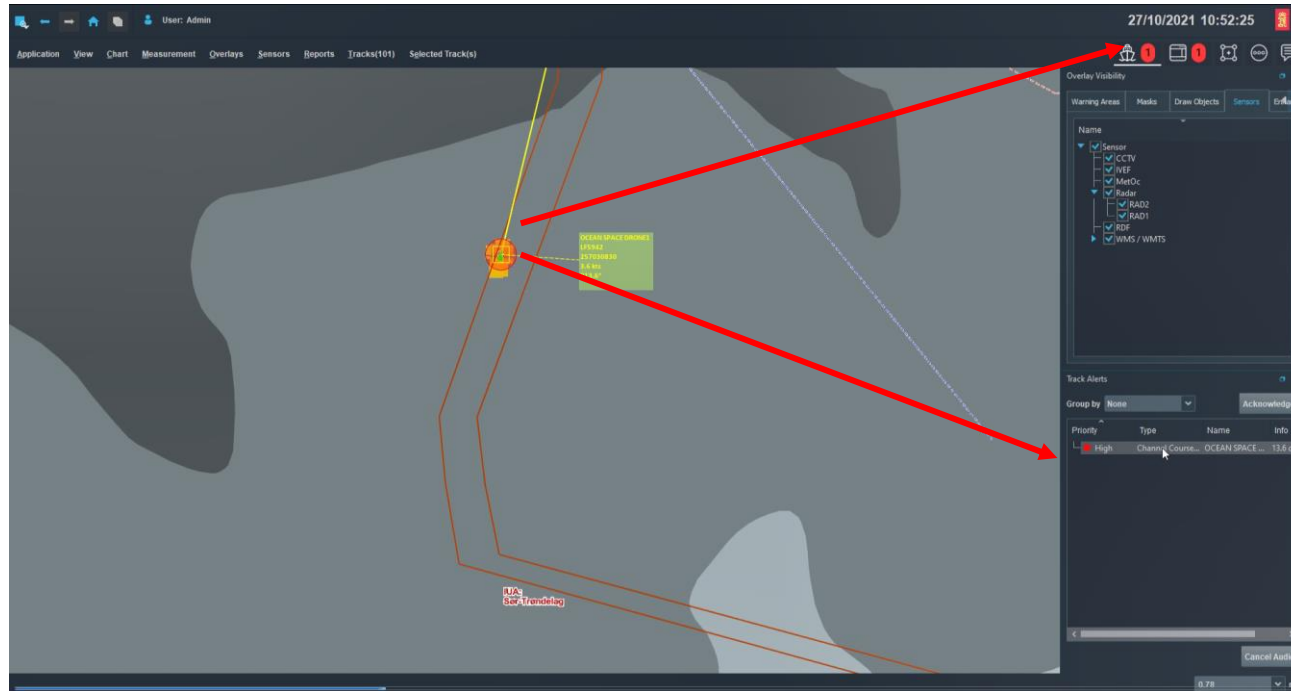
C-Scope

Alert the operator if anomalies are detected

Verify that the vessel continues operation on track after warning is off

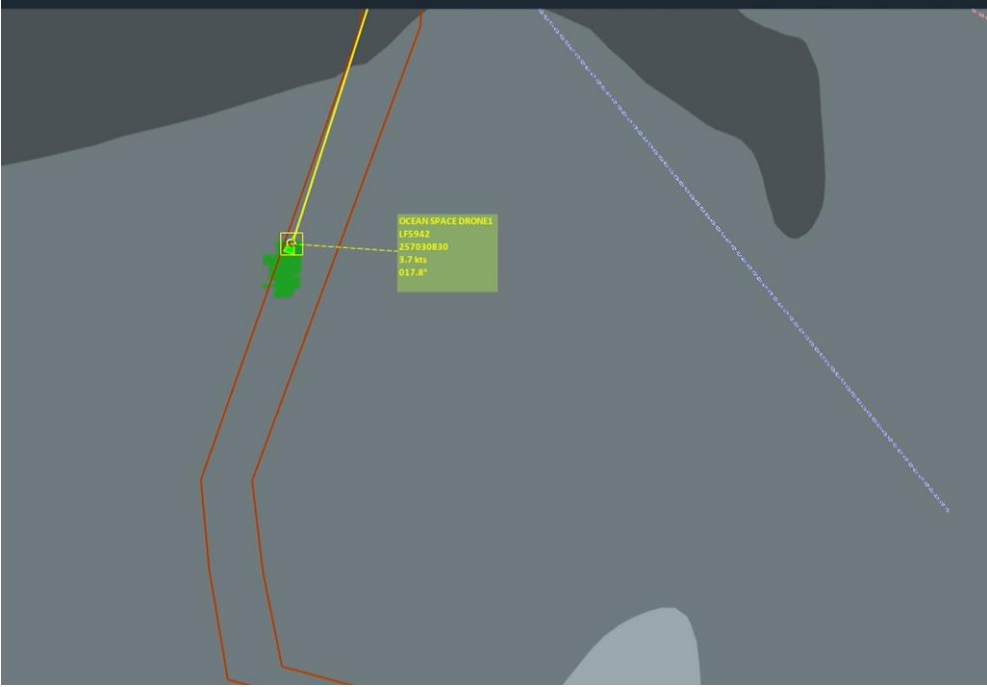
1

Drone is outside route -> Warning



2

Drone goes back to the route



Scenarios in IMAT

- **Scenario 0 – Plan operation - Situational Awareness**
- Scenario 1 – Normal operation
- **Scenario 2 – Deviation from planned route**
- Scenario 3 – Loss of shore sensors (Connectivity)
- **Scenario 4 – Mismatch between sensors - situational awareness**
- Scenario 5 – Loss of communication with drone
- Scenario 6 – Redundant ROC's
- **Scenario 7 – Close Quarter Detected by Infrastructure**
- Scenario 8 – Approaching harbour





25. SEPTEMBER 2021 – [64 KOMMENTARER](#)

Norske marineskip ble manipulert inn i russisk farvann

Det siste året har et mysterium utspilt seg til sjøs: På uforklarlig vis har krigsskip fra Norge og en rekke andre Nato-land tilsynelatende seilt i russisk farvann.

**Forfalskede data for KNM Gnist og KNM Storm.
Kilde: NRK, med data fra Marine Traffic.**



*Can use of land-based surveillance systems and sensor infrastructure increase **safety** and **efficiency** for navigation at sea?*

AIS spoofing

Program to introduce real time changes in the vessel AIS position - spoofing

SINTEF Ocean - AIS Spoofing

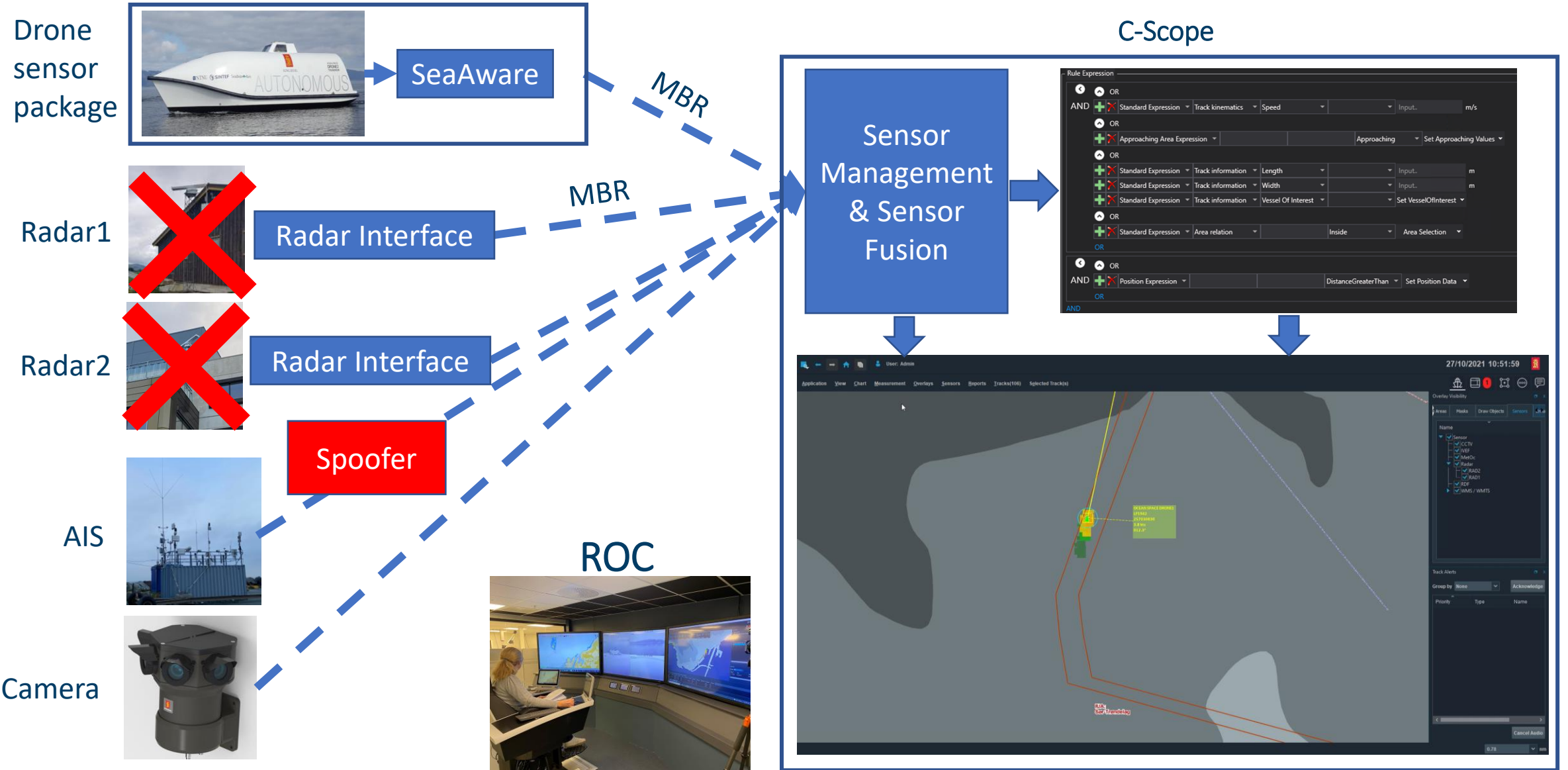
Vessel to manipulate	<input type="text" value="257161700"/>	MMSI
Added Heading	<input type="text" value="0.00"/>	deg <input type="checkbox"/>
Added SOG value	<input type="text" value="0.00"/>	kn <input type="checkbox"/>
Added Latitude value	<input type="text" value="0.00"/>	m <input type="checkbox"/>
Added Longitude value	<input type="text" value="0.00"/>	m <input type="checkbox"/>

Manipulation on? False

Client connected? False

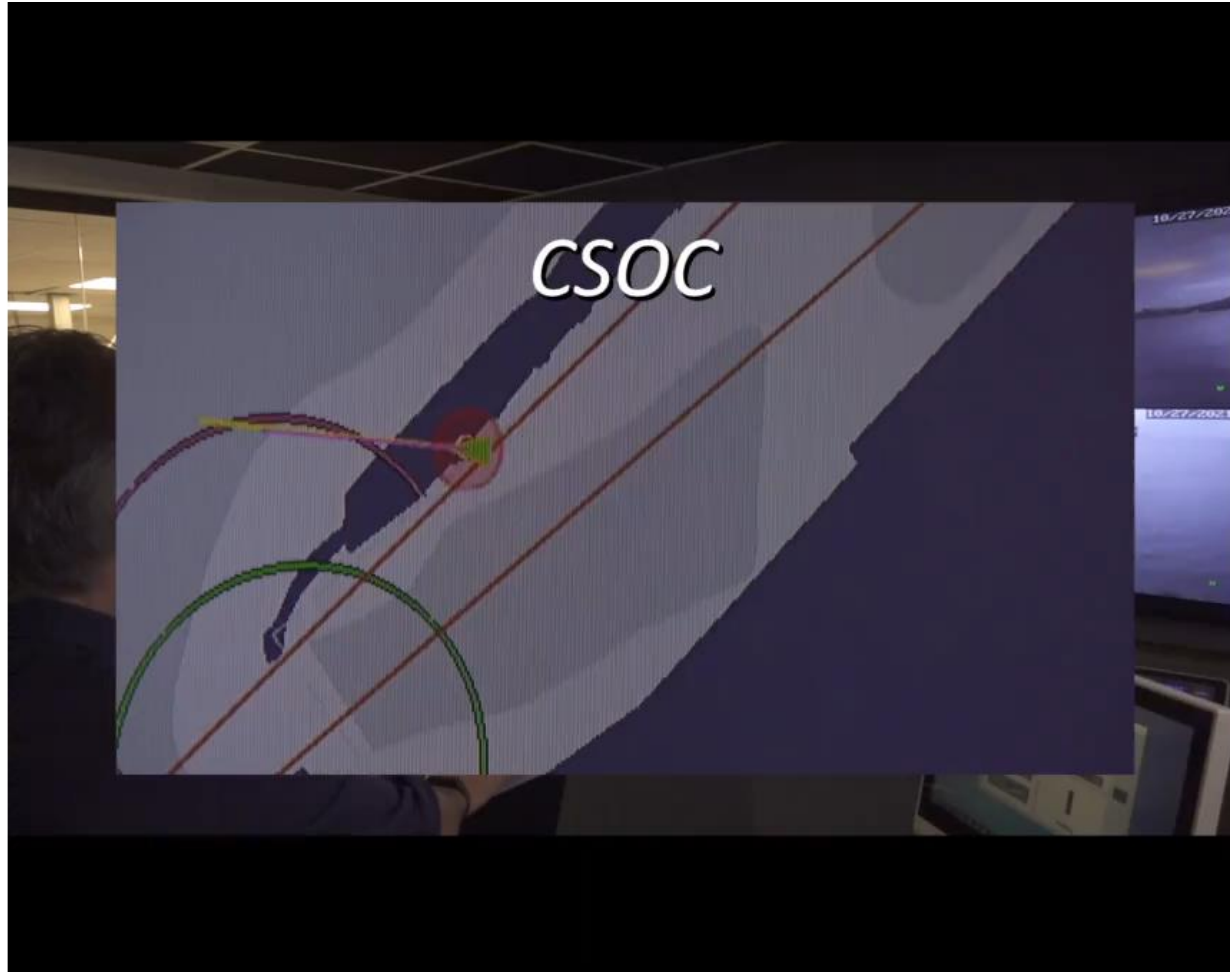
Scenario 4a – Subject to AIS spoofing

Outside radar coverage



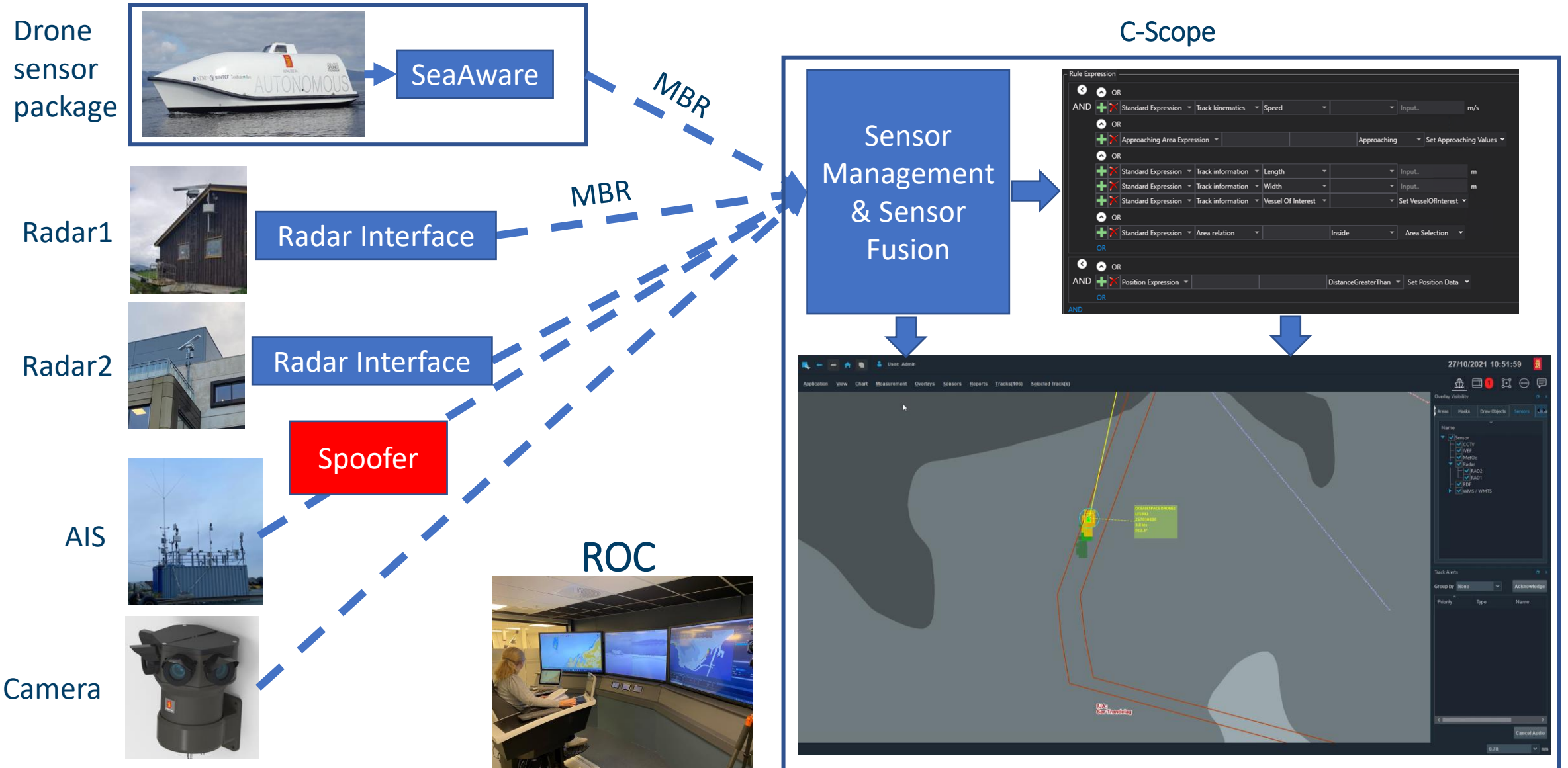
Scenario 4a – Subject to AIS spoofing

Outside radar coverage



Scenario 4b – Detect spoofing in AIS

Inside radar coverage



Scenario 4b – Detect spoofing in AIS

Inside radar coverage

The screenshot displays the CSOC (Control Room) interface. At the top, the user is identified as 'Admin' and the date/time is 27/10/2021 14:02:38. The main map area shows a radar coverage area with several tracks. Two tracks are highlighted with green labels: 'M237147200' and '237147200'. The interface includes a 'System Alerts' panel on the right, which shows a table of alerts. Below this is an 'Overlay Visibility' panel with a tree view showing 'IVEF', 'MetOc', 'Radar', and 'RAD2' are checked. At the bottom, there is a 'Track List' table and a 'Track Query List' panel.

Alert	Type	System	DateTime
Error: Co...	No Connection	AIS Manager	27/10/2021 14:00:57
Not rece...	Missing Video f...	RVS IMAT	27/10/2021 13:22:25

Name	Callsign	Position: Lat/Lon	Speed (kts)	Course (°)	Asset of Interest	Ship Type	Length (m)	Beam (m)	ClassB	Vendor	AIS Category	Track Type
TRONDHEIM	LGEF	63°30'34.6"N ...	0.0 kts	000.0°		Passenger Ve...	97m	16m	Class A		AIS	
TALUPO	LFFJ	63°38'10.2"N ...	0.0 kts	000.0°		Uninfolined	43m	12m	Class A		AIS	
ORFJORD	LDAA	63°43'39.8"N ...	0.0 kts	000.0°		Fishing Trawler	35m	10m	Class A		AIS	

Name	Callsign	Position
TRONDHEIM	LGEF	63°30'34.6"N ...
TALUPO	LFFJ	63°38'10.2"N ...
ORFJORD	LDAA	63°43'39.8"N ...

Scenario 4b – Detect spoofing in AIS

Inside radar coverage

C-Scope

The screenshot displays the C-Scope interface with a central radar map showing several tracks. A track with MMSI 257147200 is highlighted. The interface includes a top menu bar with options like Application, View, Chart, Measurement, Overlays, Sensors, Reports, and Tracks(68). On the right side, there are several panels: System Alerts, Overlay Visibility, and Track Alerts. The System Alerts panel shows an error message: 'Error Co... No Connection AIS Manager 27/10/2021 14:00:57'. The Overlay Visibility panel shows a tree view with 'MetOc', 'Radar', 'RAD2', and 'RAD1'. The Track Alerts panel is currently empty. At the bottom, there are two tables: 'Track List' and 'Track Query List - Unsaved Query'. The Track List table has columns for Name, Callsign, Position, Speed, Course, MMSI, Ship Type, Length, Beam, ClassB, Vendor, AIS Category, and Track Type. The Track Query List table has columns for Name, Callsign, and Position.

Integrated	AIS	Radar	Active Voyage Plans	Surv. Buoy	Own Virtual AtoN	Fixed Object						
Name	Callsign	Position: Lat/Lon	Speed (kts)	Course (°)	MMSI of Interest	Ship Type	Length (m)	Beam (m)	ClassB	Vendor	AIS Category	Track Type
VILHELM THO...	TFCM	63°43'44.5"N ...	0.0 kts	000.0°		Fishing Trawler	88m	16m			Class A	AIS
TRONDHEIMS...	LAPB	63°26'17.8"N ...	0.0 kts	000.0°		High Speed C...	24m	8m			Class A	AIS
TRONDHEIM	LGEF	63°30'34.6"N ...	0.0 kts	000.0°		Passenger Ve...	97m	16m			Class A	AIS

Integrated	AIS	Radar	Active
Name	Callsign	Position	
VILHELM THO...	TFCM	63°4...	
TRONDHEIMS...	LAPB	63°2...	
TRONDHEIM	LGEF	63°3...	

- Verify that C-Scope identifies the mismatch between AIS signals and radar
- Spoofed AIS message is ignored in C-Scope since there is a mismatch between AIS and the radars
- Land based infrastructure ensure continued safe operation

Scenarios in IMAT

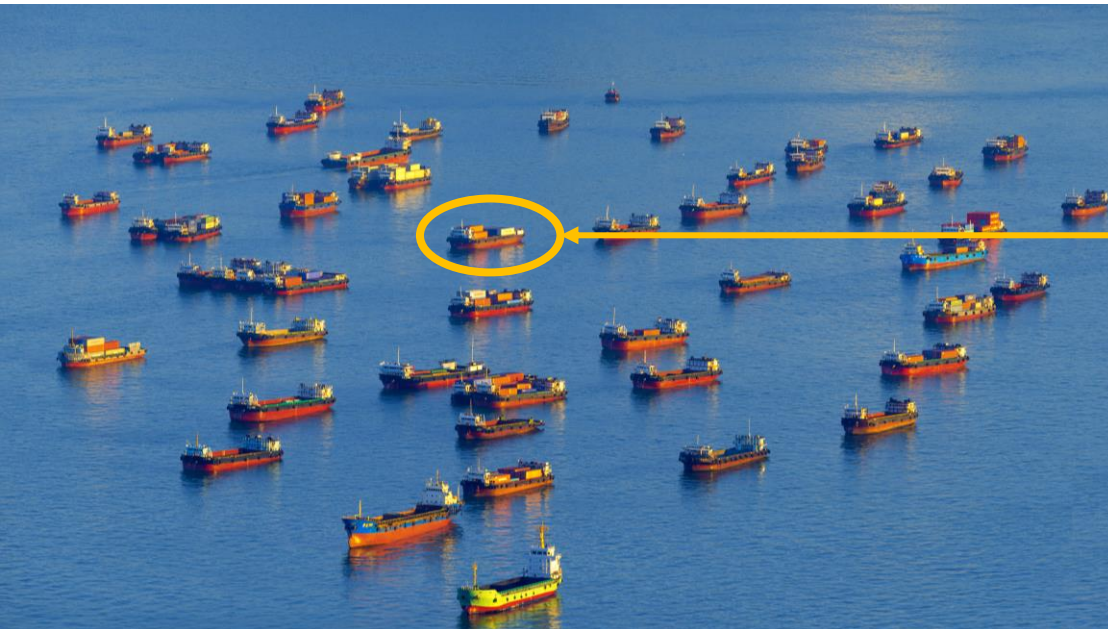
- **Scenario 0 – Plan operation - Situational Awareness**
- Scenario 1 – Normal operation
- **Scenario 2 – Deviation from planned route**
- Scenario 3 – Loss of shore sensors (Connectivity)
- **Scenario 4 – Mismatch between sensors - situational awareness**
- Scenario 5 – Loss of communication with drone
- Scenario 6 – Redundant ROC's
- **Scenario 7 – Close Quarter Detected by Infrastructure**
- Scenario 8 – Approaching harbour



Motivation

Example case:

Autonomous vessel is being monitored from a ROC.



ROC



How can the ROC operators early detect possible collisions?

Method/Process

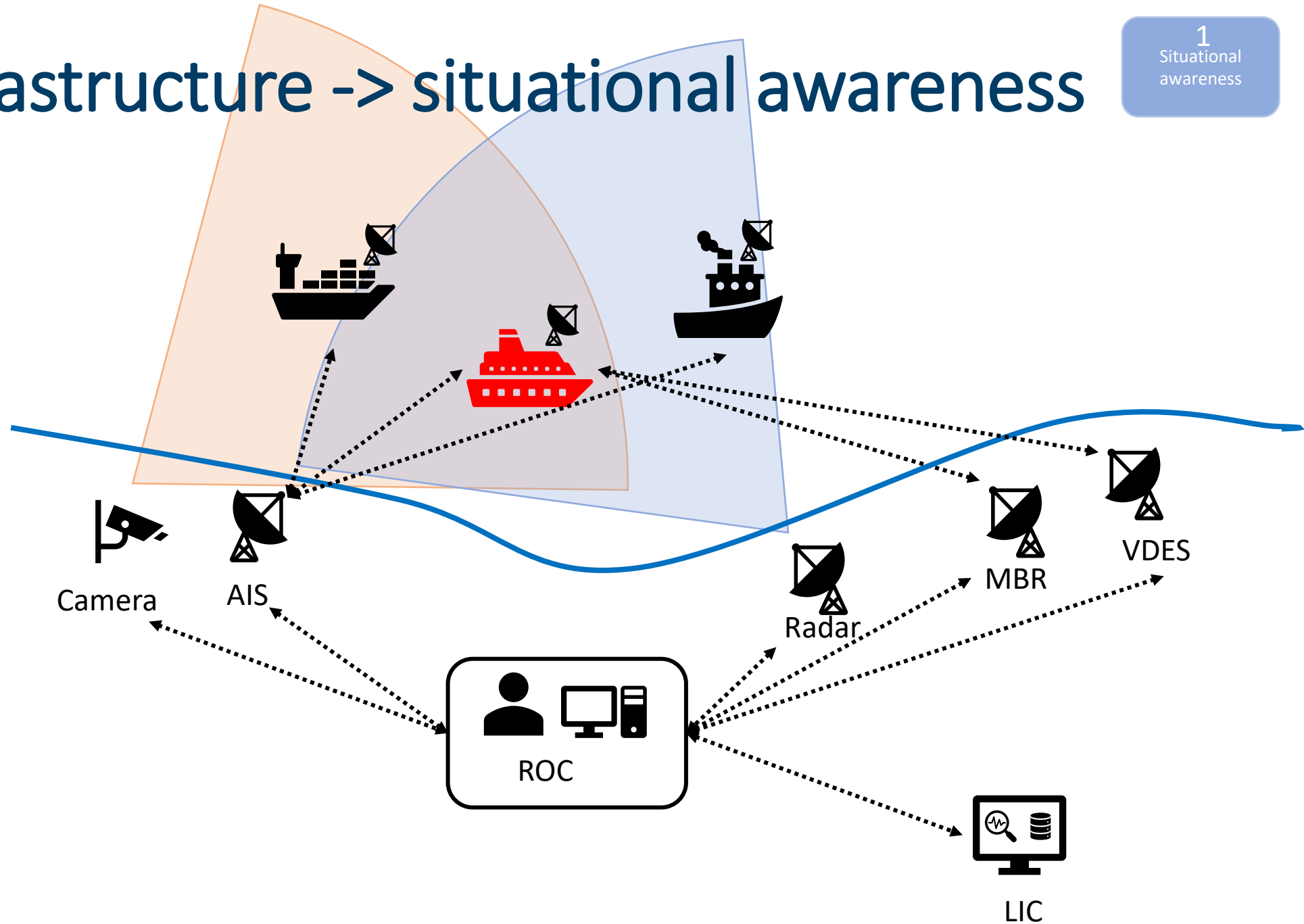
1
Situational
awareness

2
Predict traffic

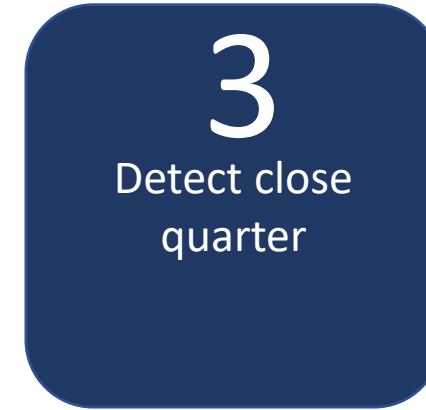
3
Detect close
quarter

Infrastructure -> situational awareness

1
Situational
awareness

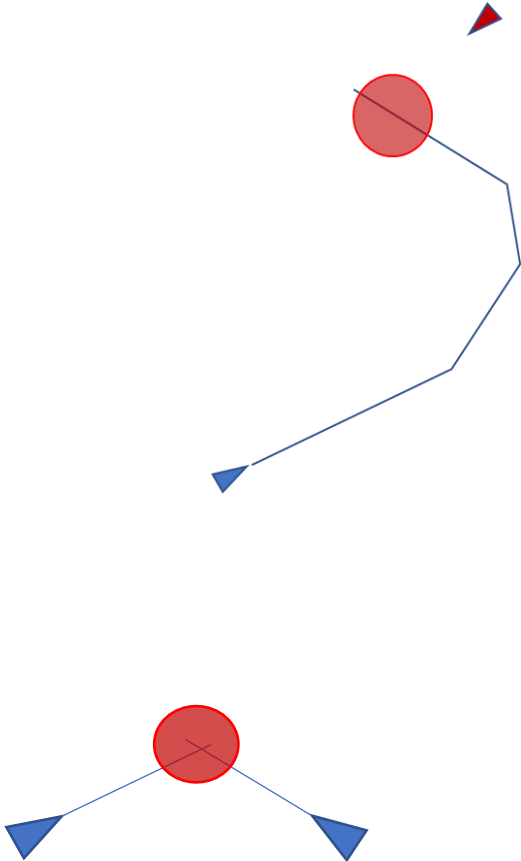
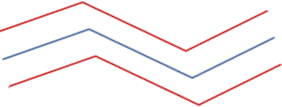
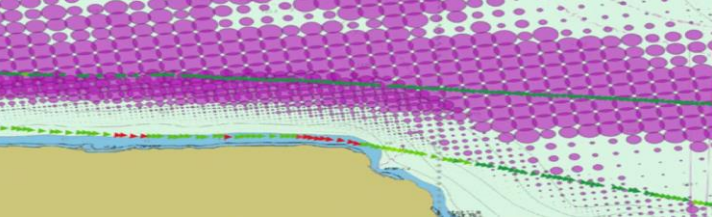
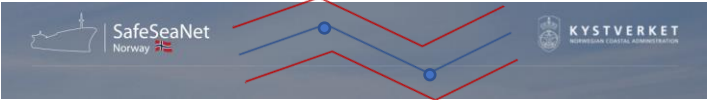


Method/Process

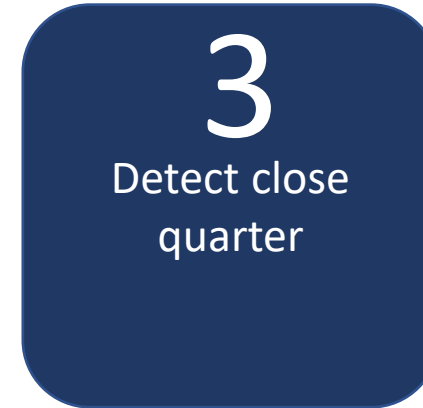
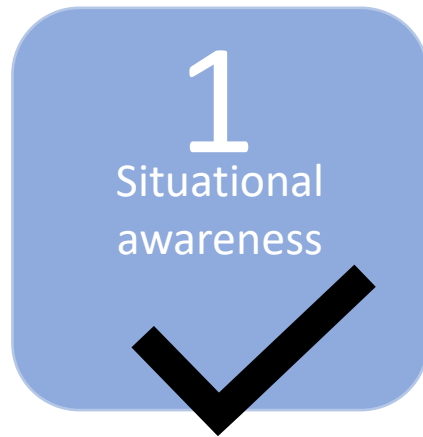


How is traffic predicted using C-Scope?

- Automatic surveillance assignments
- Using sailing plan (if available)
- Sailing plan options:
 - Received from nav/bridge system (or national singel window)
 - Calculated median-route (big data)
 - Manual assigned route template
- Linear prediction if no sailing plan



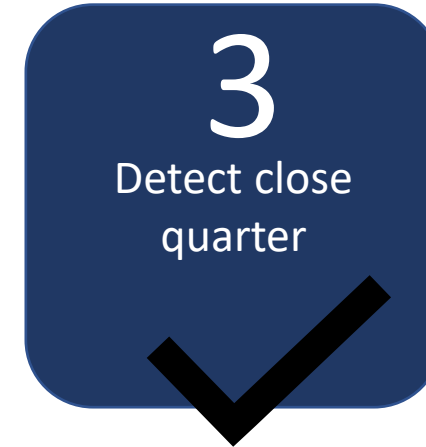
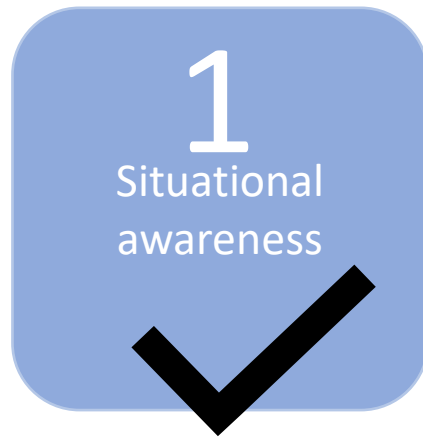
Method/Process



How is close quarter detected in C-Scope?

- Rule-based CPA/TCPA parameter settings
 - Criteria examples : vessel type, dimention, day/night

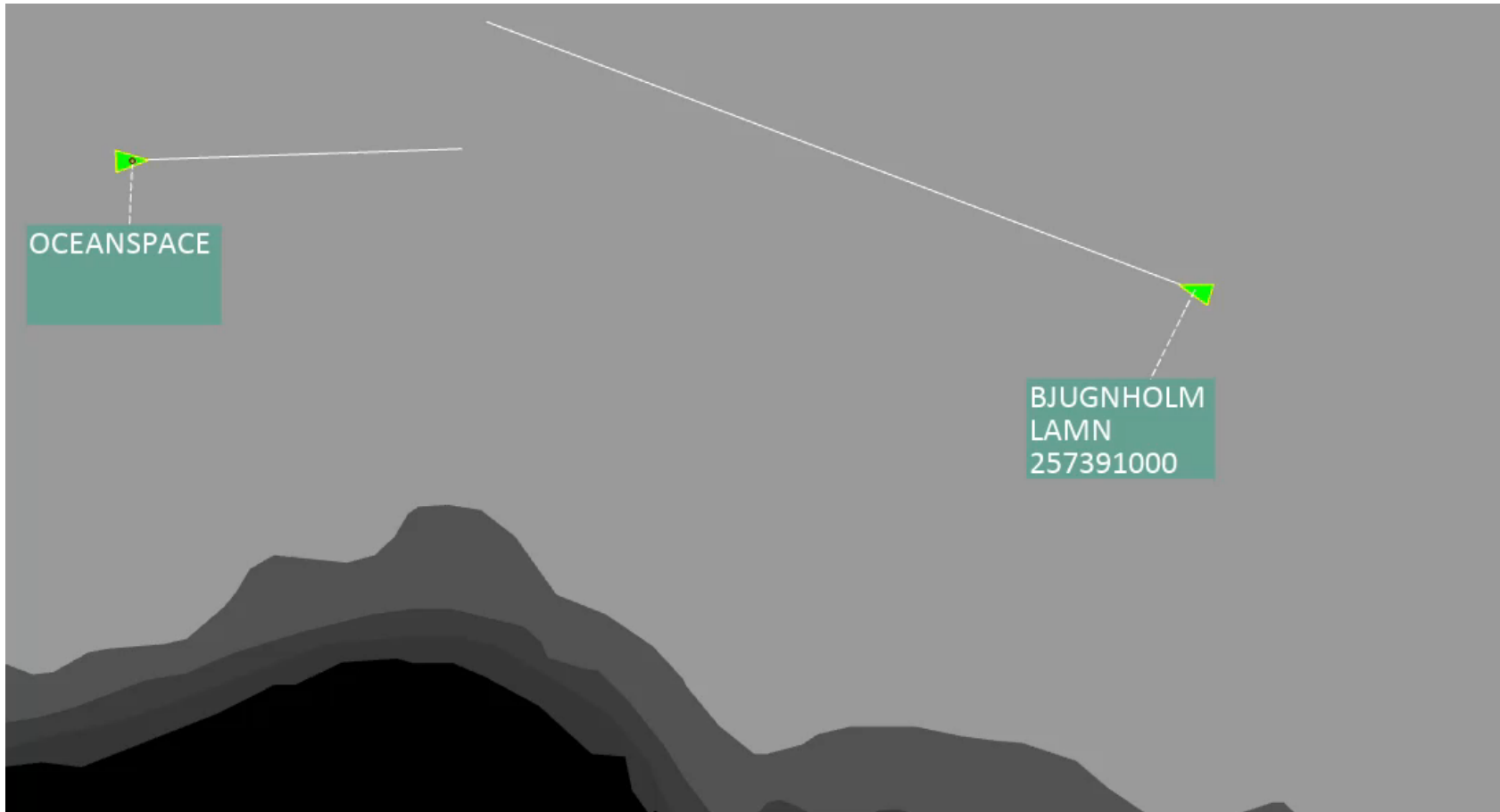
Method/Process



Demonstration

- Simulate a close quarter (possible collision)
- See if C-Scope alerts operator of close quarter.

Close Quarter



Track Alerts

Group by **None** Acknowledge

Priority	Type	Name	Info	Ack
Alarm	Collision Prediction	OCEANSPACE	1 vessel(s) {BJUGHOLM [...]	No

Conclusion

- Observe vessels using the installed infrastructure
- Can detect route deviation from pre-defined route using C-scope in ROC.
- Close quarter algorithm works
- Early alert to the operator if a situation is evolving
- Important with land-based sensors to cover situational awareness around an autonomous vessel – even with ships and objects that do not have AIS transponder onboard (i.e kayak, leisure vessel)
- Observe vessels using the installed infrastructure
- Can detect route deviation from pre-defined route using C-scope in ROC.