High speed navigation in littoral and archipelago waters

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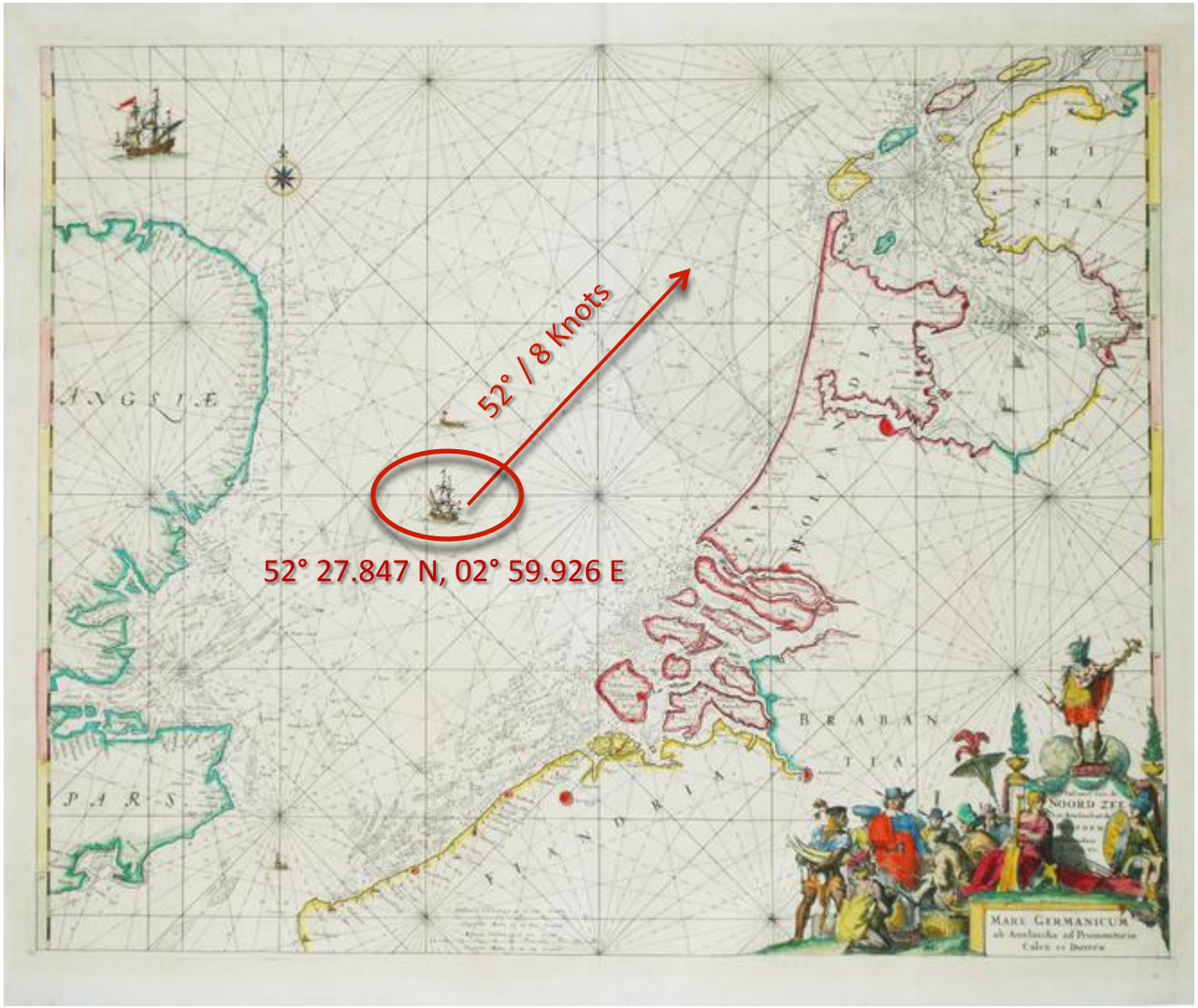
Sea Cross Marine AB, Sweden

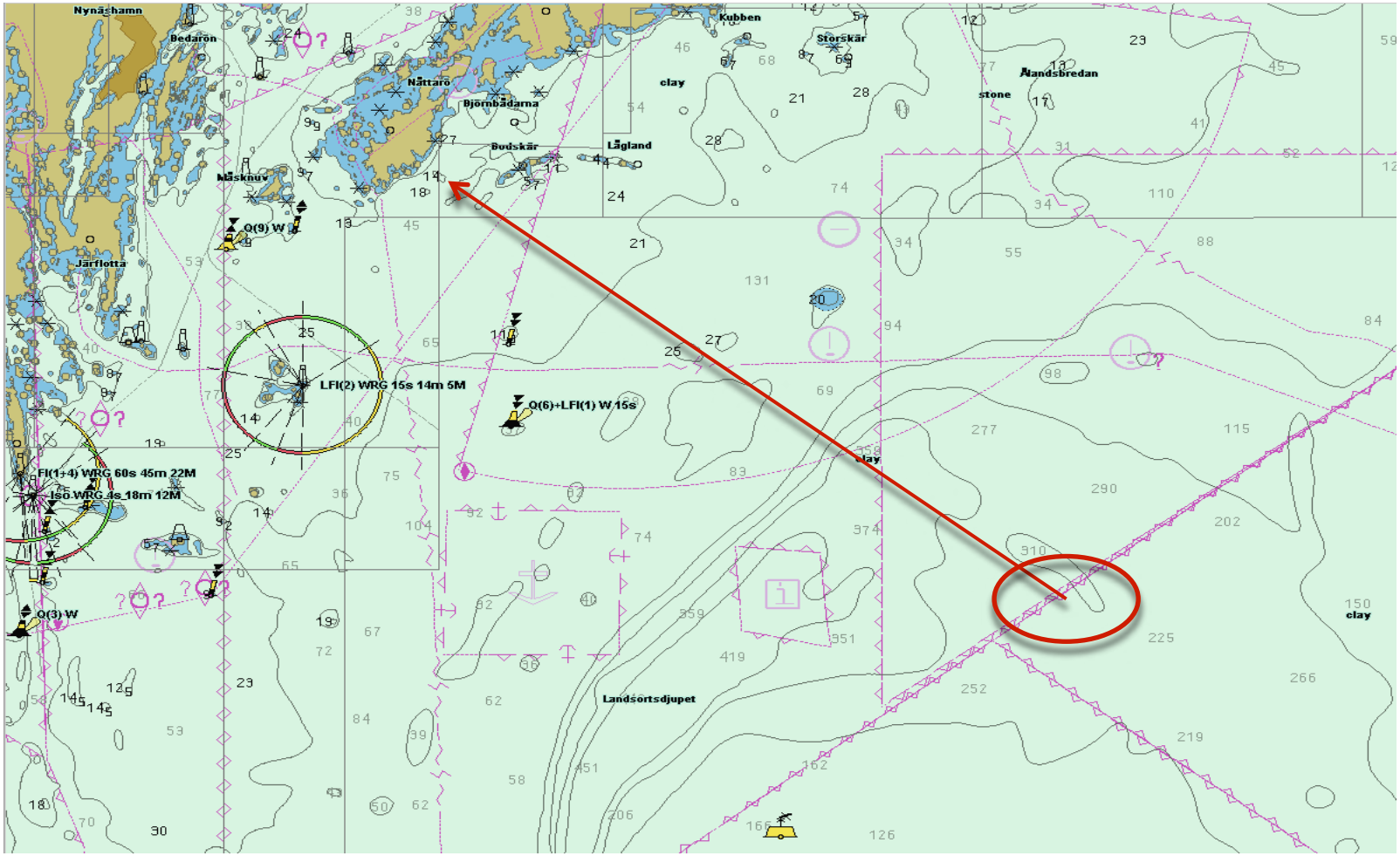
High speed navigation in littoral waters

1. Prerequisites for high speed navigation

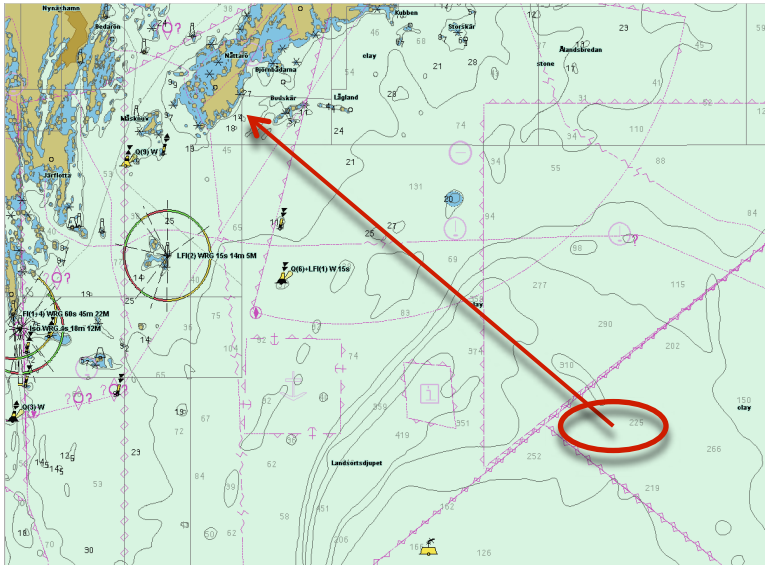
2. Sensor limitations

3. Navigation system limitations





1 : 150 000 Open water navigation



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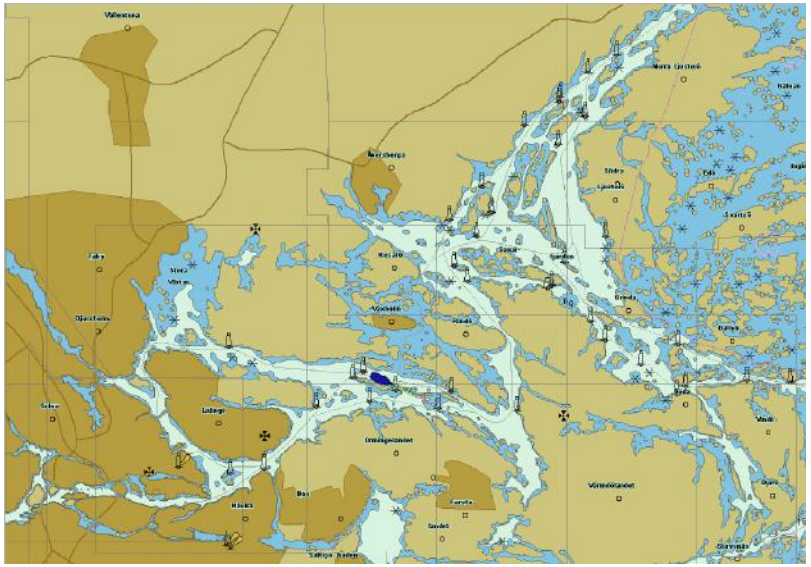
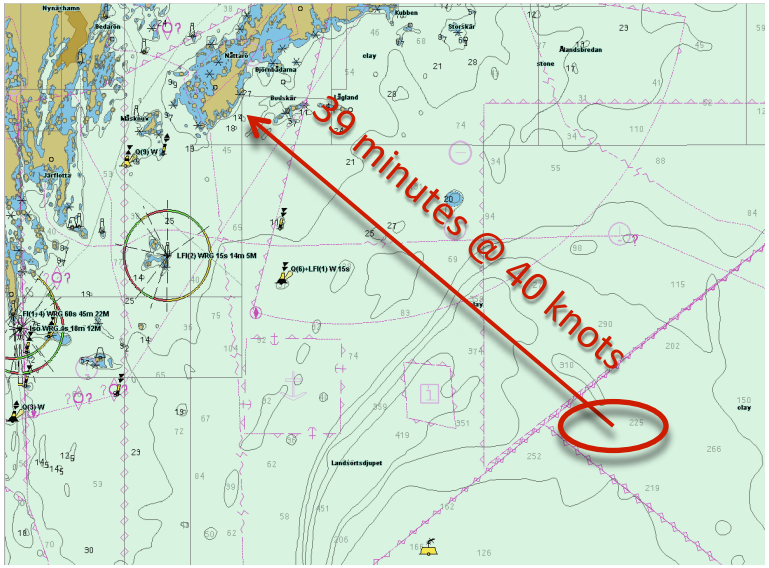


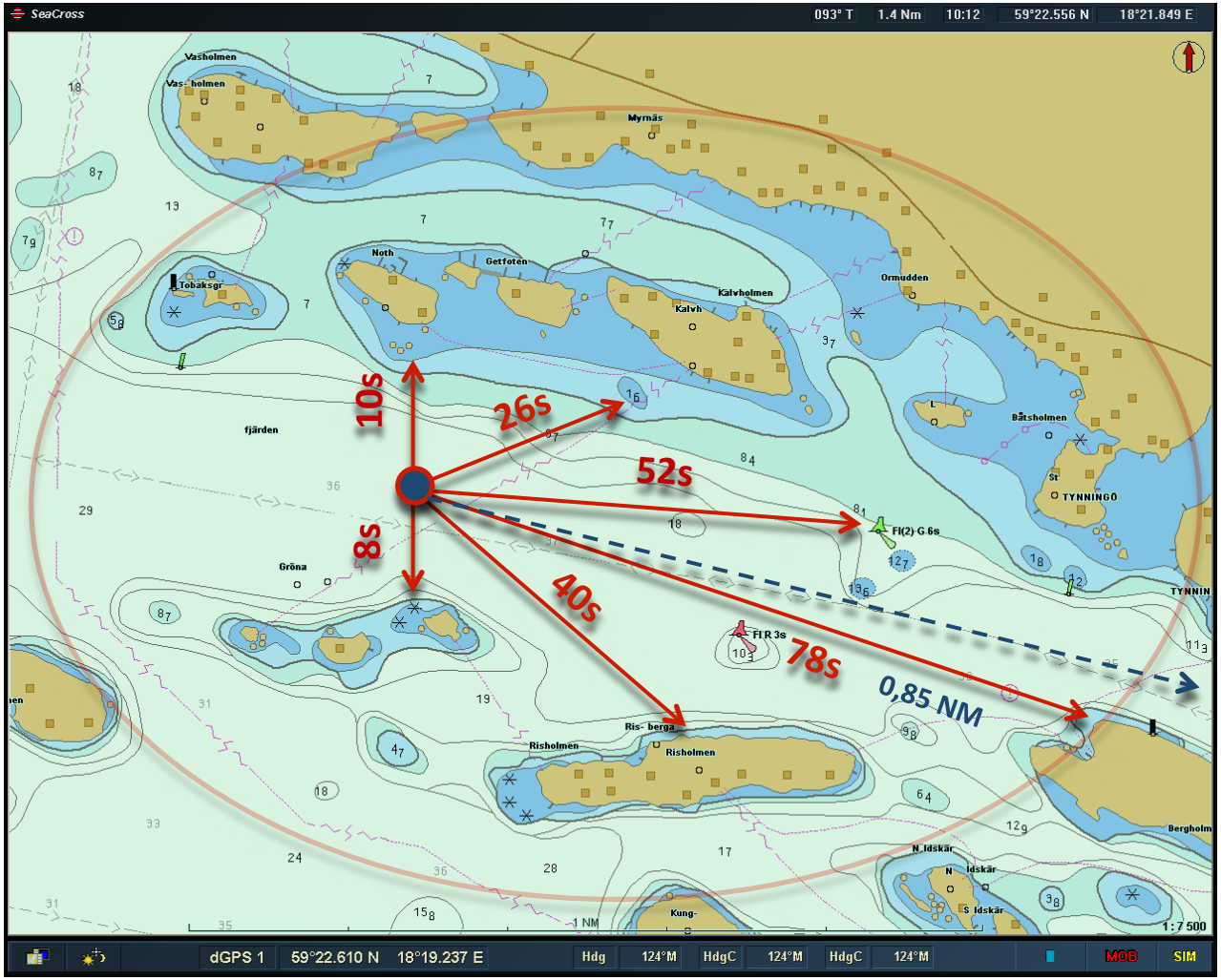
1 : 150 000 Littoral navigation



1 : 150 000 Open water navigation

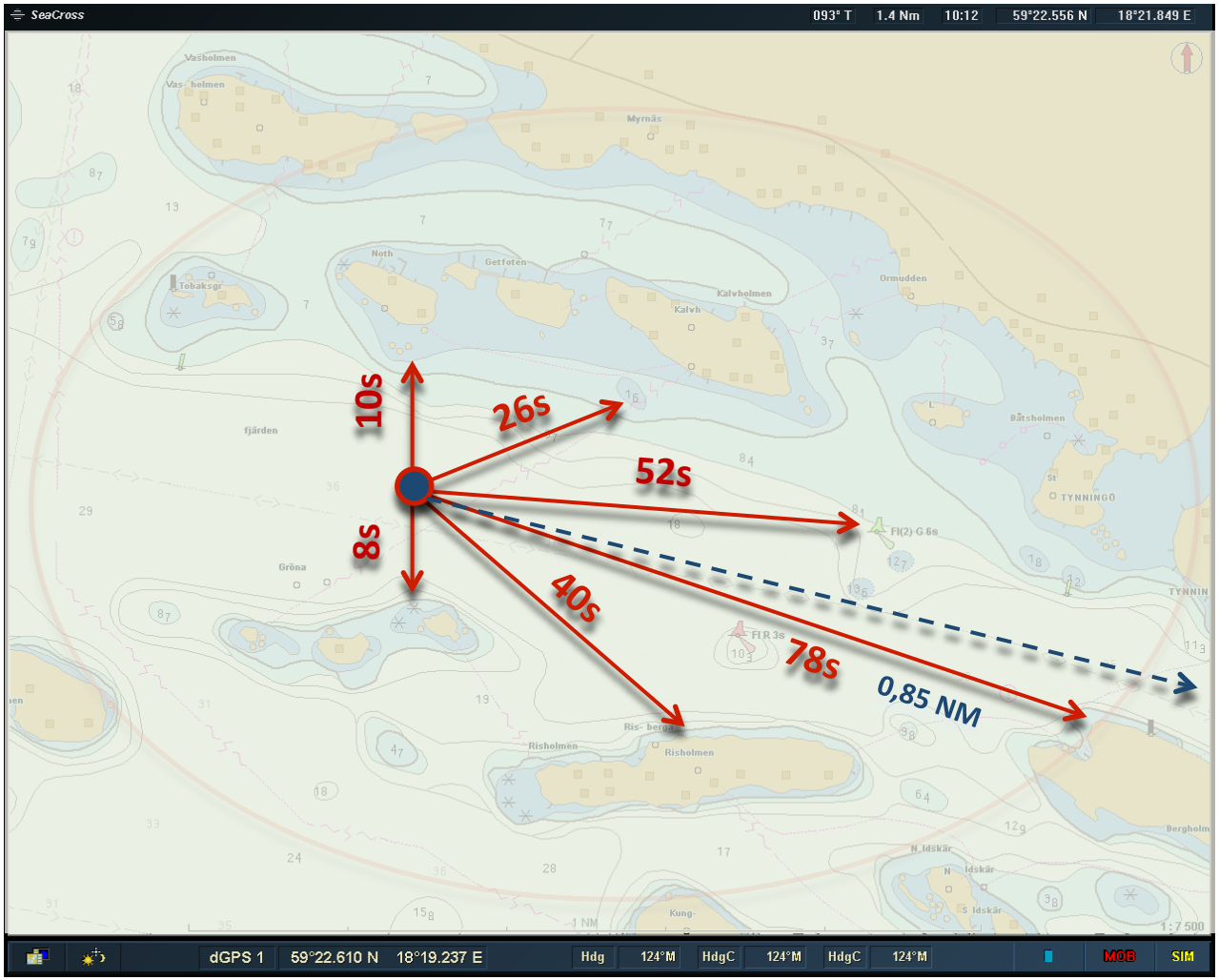
1 : 150 000 Littoral navigation

High speed navigation in littoral waters



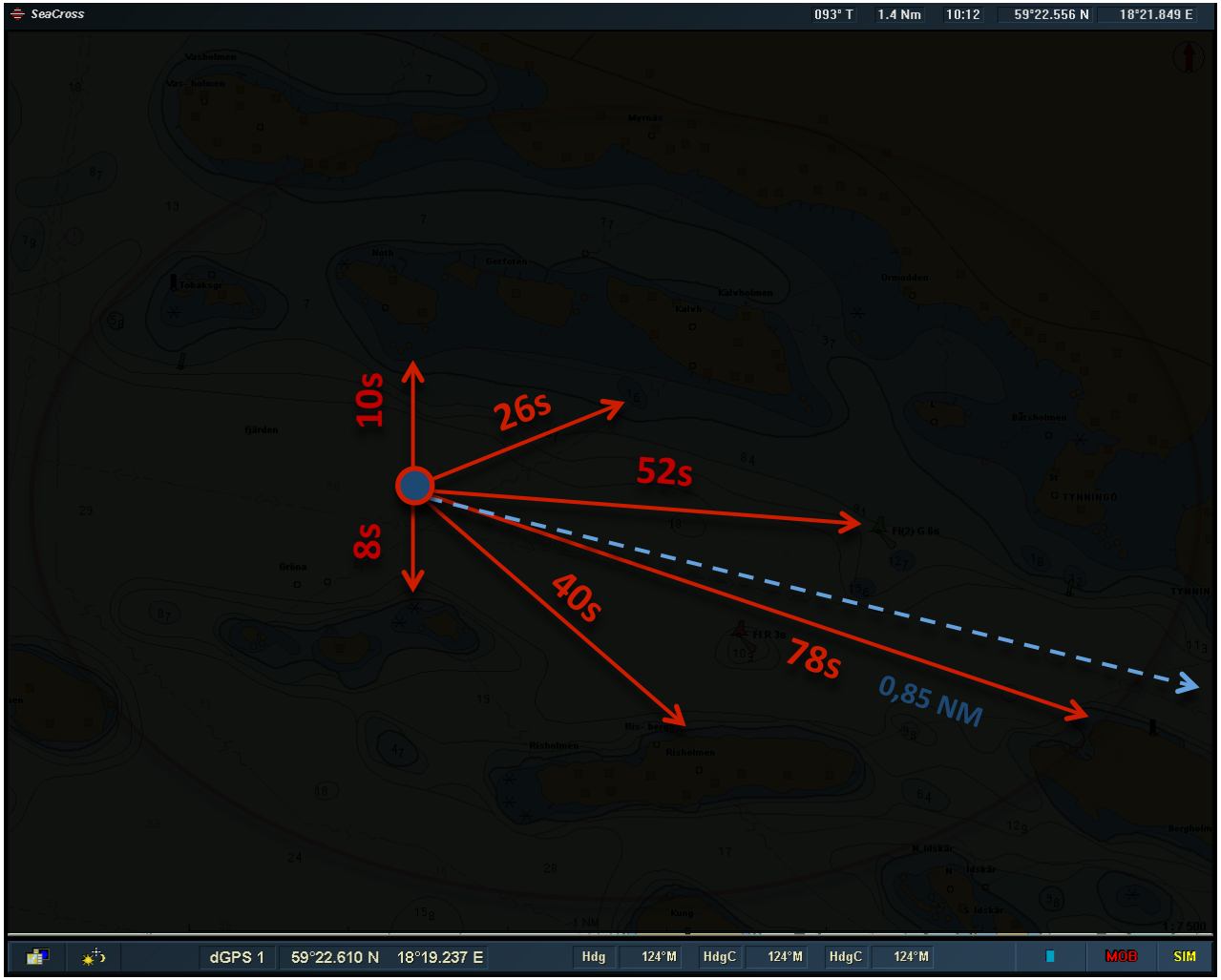
1 : 7 500 **Safety margins in seconds @ 40 knots**

High speed navigation in littoral waters

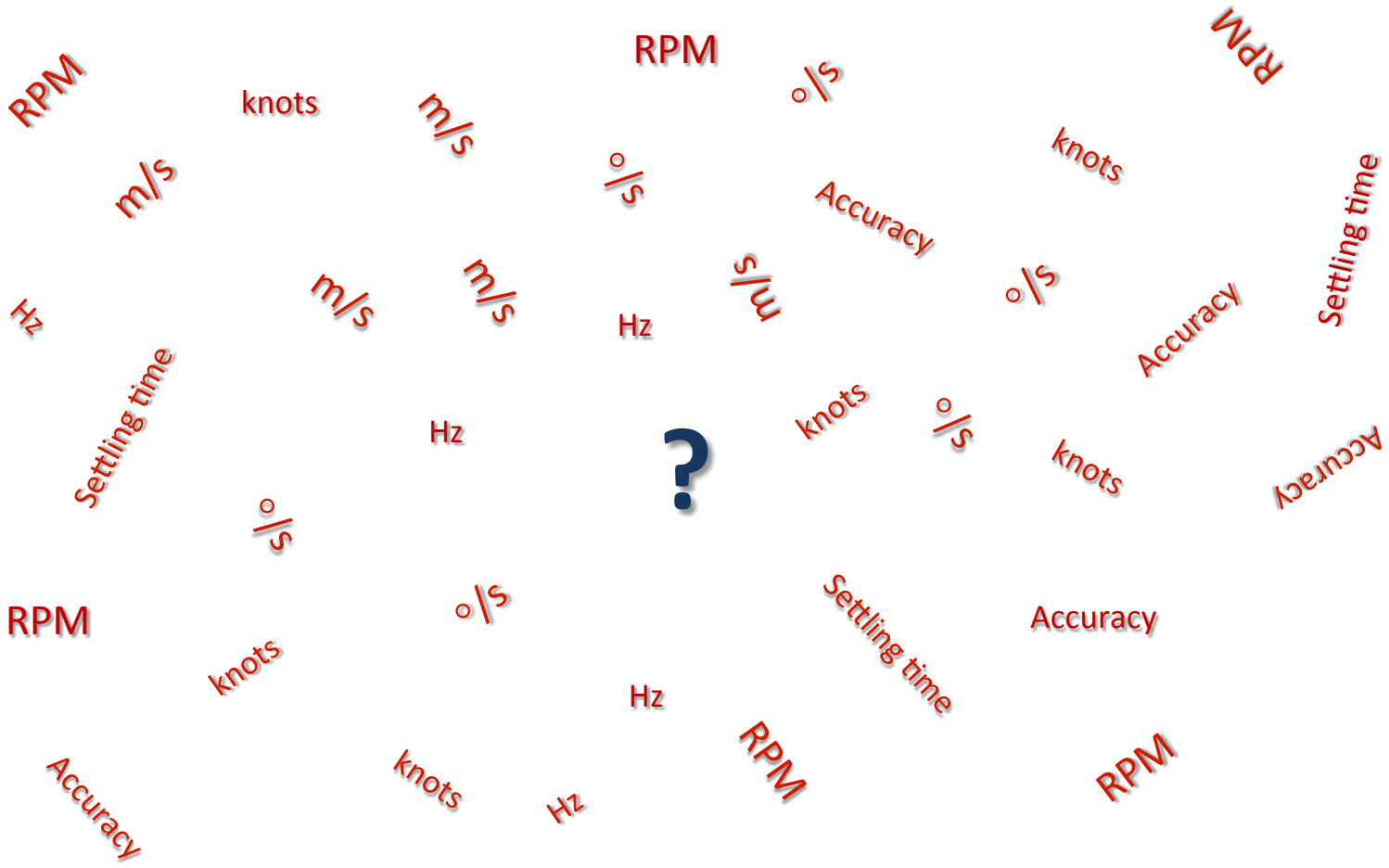


1 : 7 500 **Safety margins in seconds @ 40 knots**

High speed navigation in littoral waters



1 : 7 500 **Safety margins in seconds @ 40 knots**



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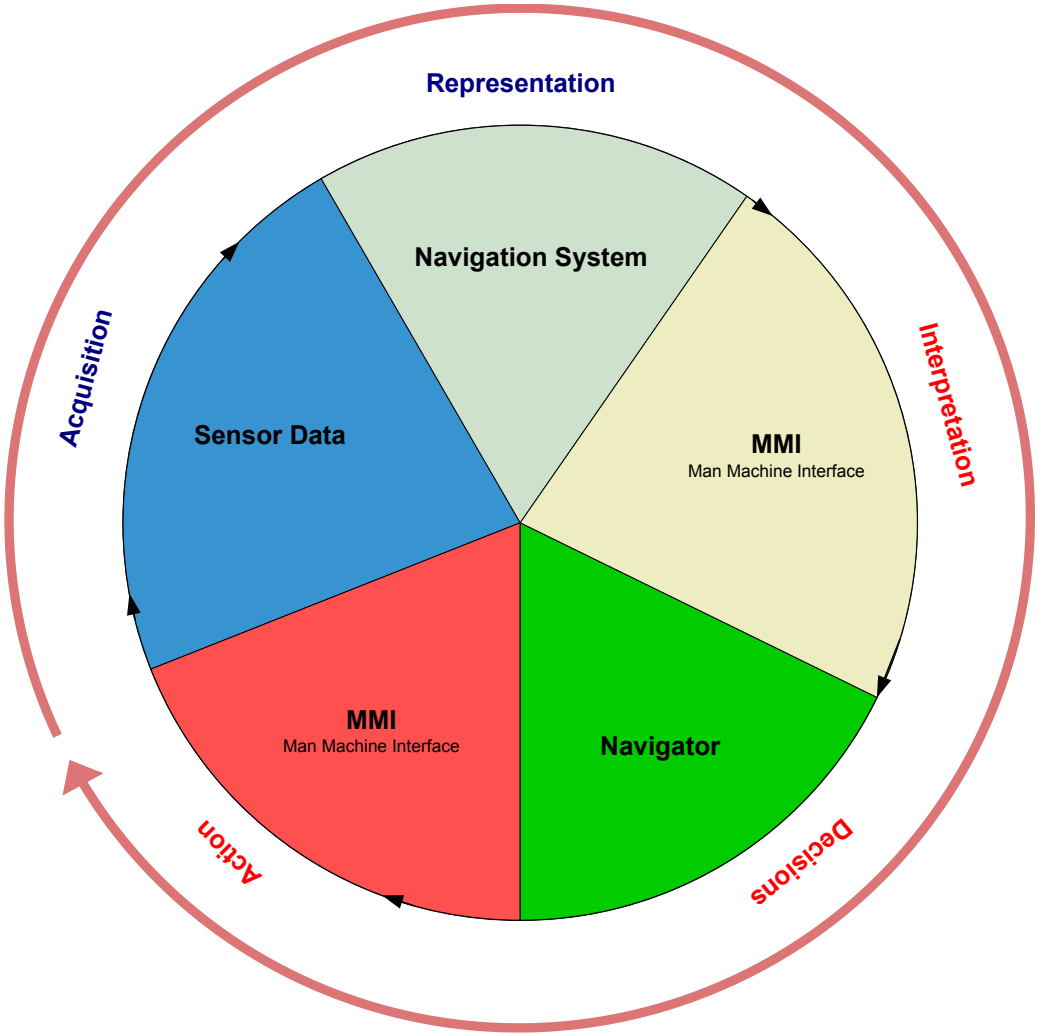
Navigation Process



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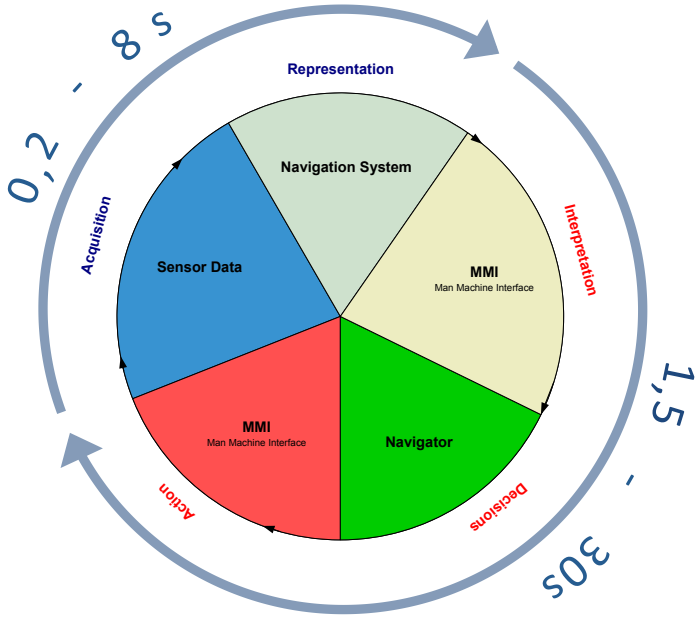
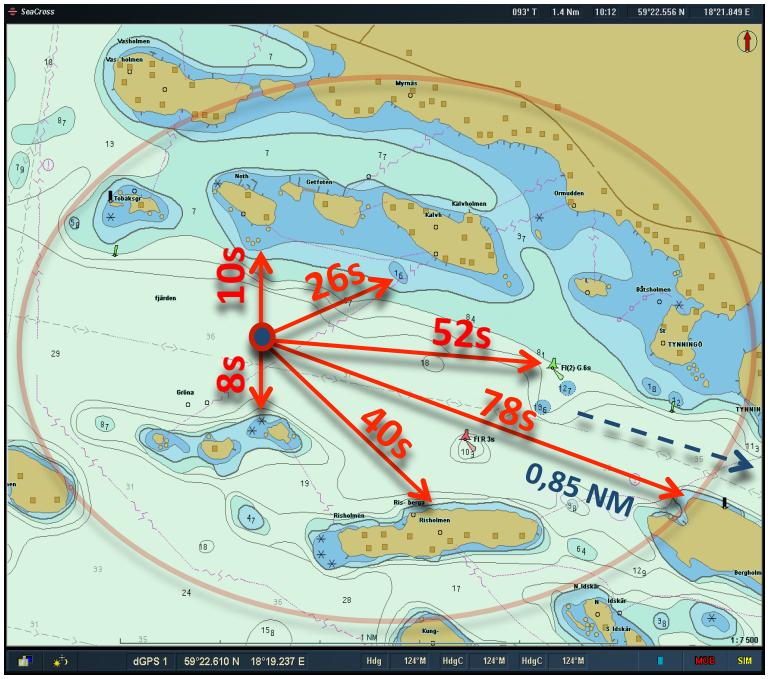
Navigation Process Latency

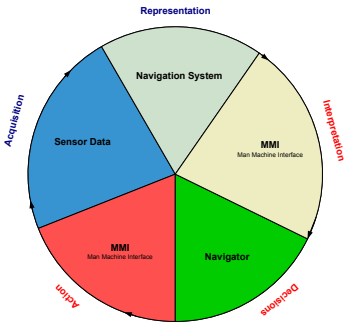




Step	System	Latency / Cycle rate (typical)
Acquisition	Sensors	0,1 – 3 s
Representation	Navigation system	0,1 – 5 s
Interpretation	Navigation system / Navigator	0,5 - 10 s
Decision	Navigator	0,5 – 10 s
Action	Navigation system / Navigator	0,5 – 10 s
Total		**1,7 – 38 s**

Example – Navigation process latency

So then, what is it that actually matters?



Navigation process

Sensor and system update rates

- Own position
- Heading
- Radar

Interpretation and execution

- MMI / Man Machine Interface
- Navigator response and execution

Own position

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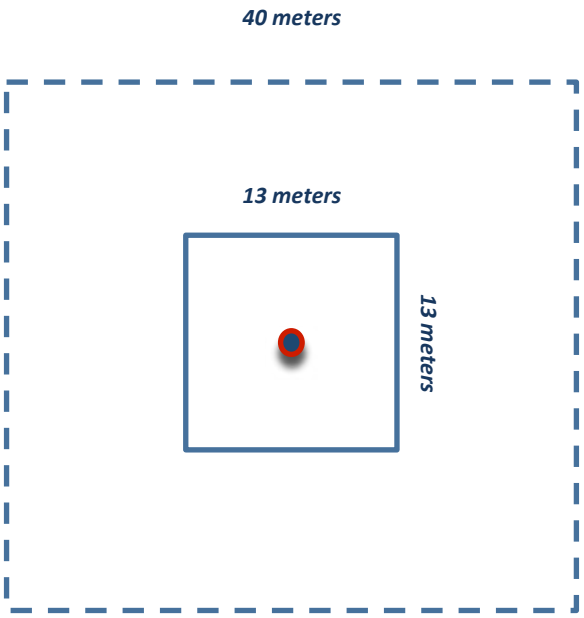
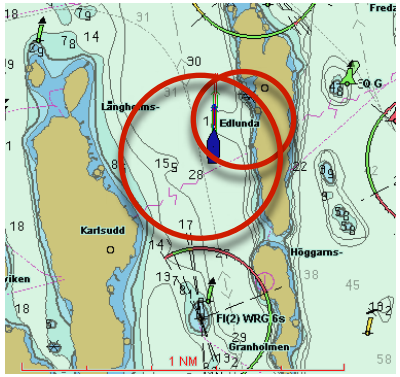
Own position

Accuracy (typical)

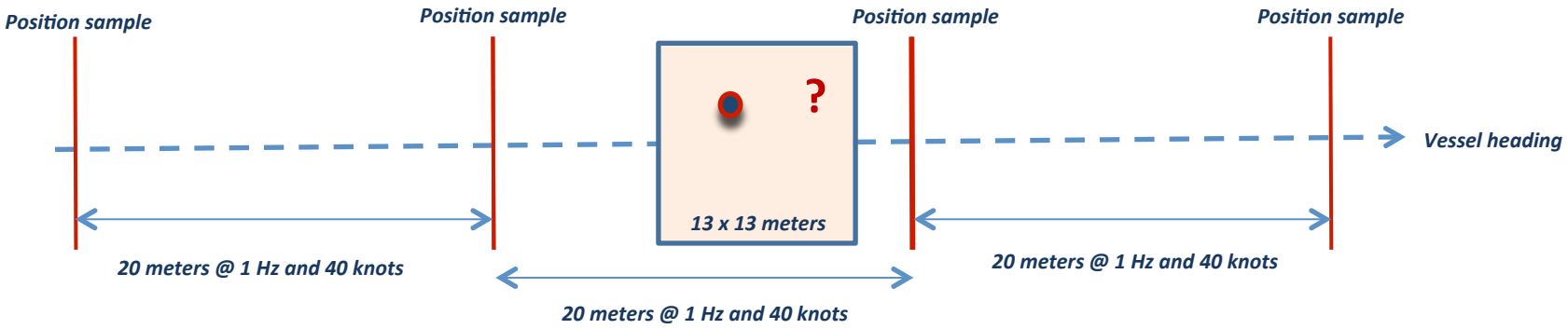
dGPS antenna WAAS/EGNOS +/- 7m, no correction +/- 15m	+/- 2m
Sea Chart NOOA: 1 mm of scale, +/- 5 m @ 1:10 000	+/- 4 m
Plotter algorithms $GPGLL +/- 9m	+/- 0,5 m
Total (Worst case +/- 20 m or more)	+/- 6,5 m





Own position

Update rate



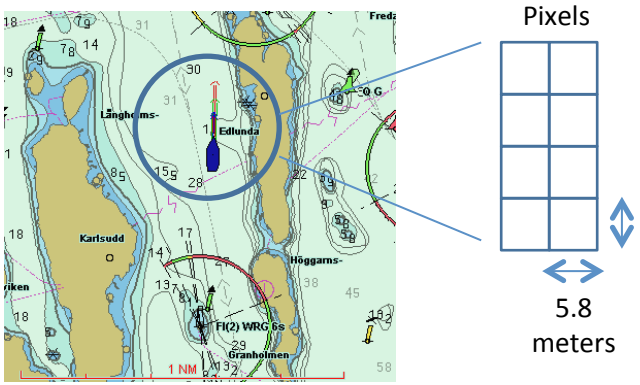
The vessel cannot alter its transversal speed dramatically in between samples.

The vessel cannot alter its longitudinal speed dramatically in between samples.

- Own position update rate is not paramount
- GPS derived position accuracy is less critical than the chart accuracy

Own position

Display resolution



Typical pixel size is 0.29mm, which leads to

Scale	1 mm = in meters	meters/pixel
1:10 000	10	3,4
1:15 000	15	5,1
1:25 000	25	7,5
1:50 000	50	17
1:75 000	75	26

Except at small scales, display resolution is often detrimental to the accuracy achieved by GPS and chart.

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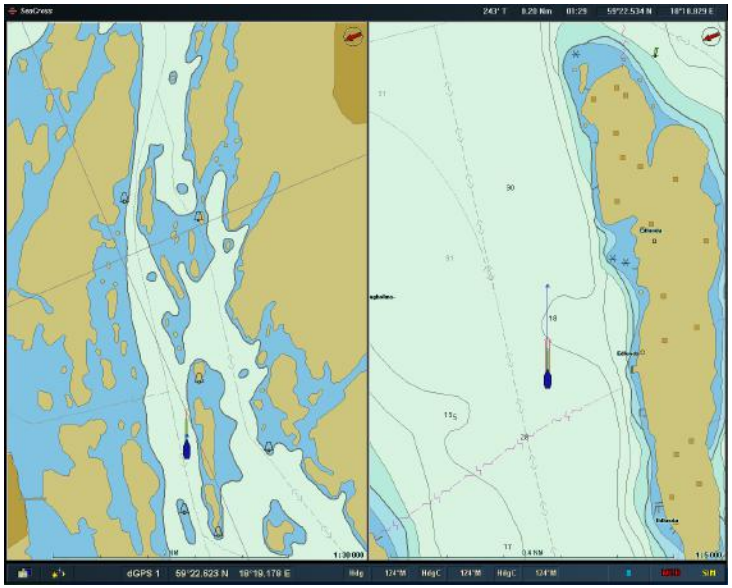
Own position



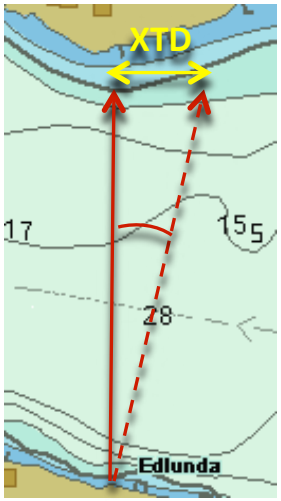
- High speed navigation systems must be capable of simultanously showing multiple charts at different scales.

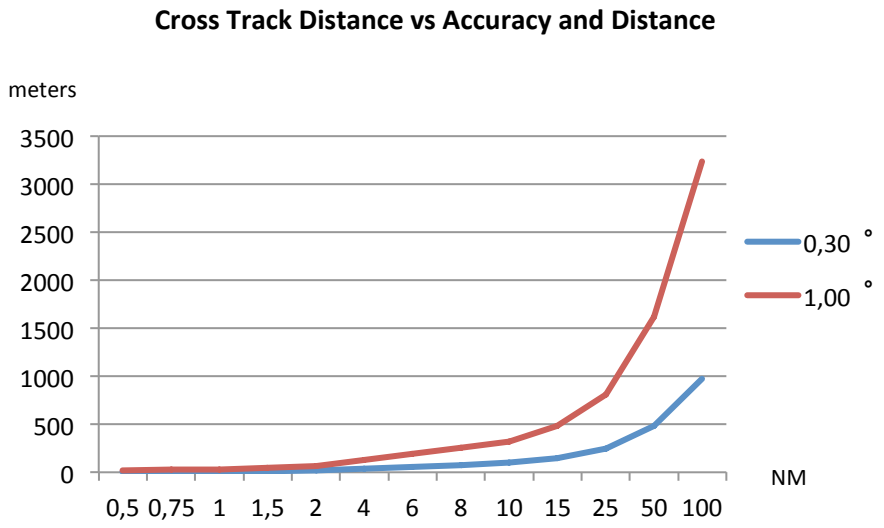
- Displays should be large enough (15”+) to display charts at readable scales and resolutions.

Heading

Heading

Accuracy



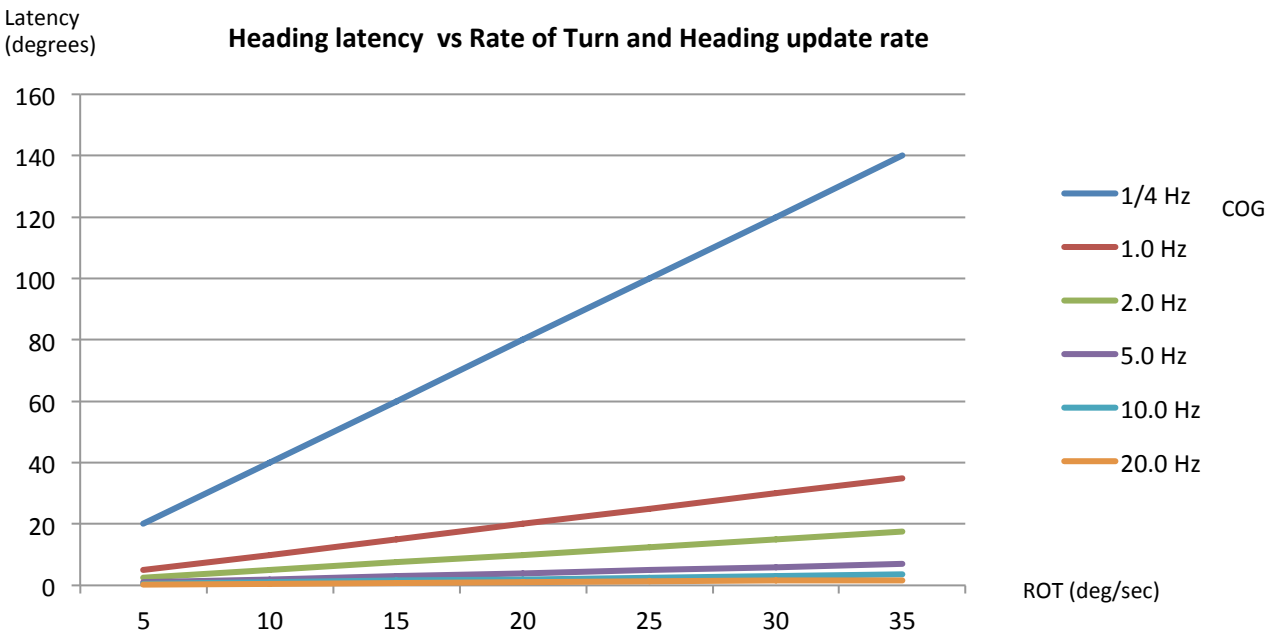


Crossing a 2 NM wide bay will yield a cross track error at the point of destination of approximately +/- 5m or +/- 16 m for heading sensor accuracies of 0,3° / 1.0° respectively.

- Heading sensor accuracy is not critical to littoral navigation performance
- Heading sensor accuracy is of importance for target tracking

Heading

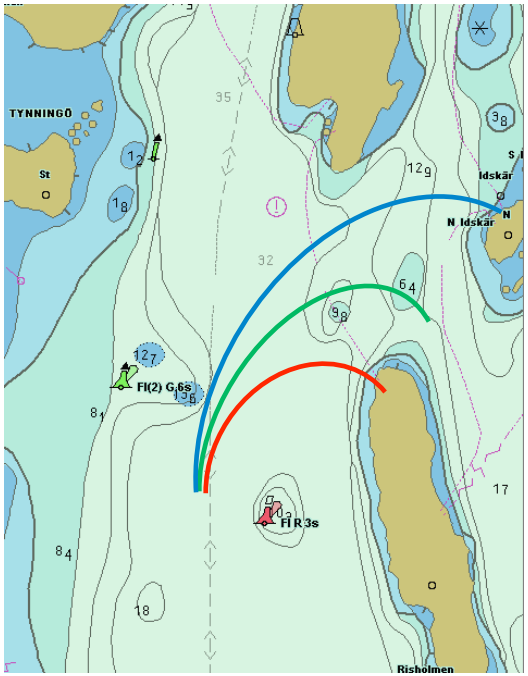
Update rate – dangerous latencies



Heading sensor update rate is of paramount importance to safety in high speed navigation systems

Heading

Low update rate – risks and consequences



Intended heading

Displayed Heading

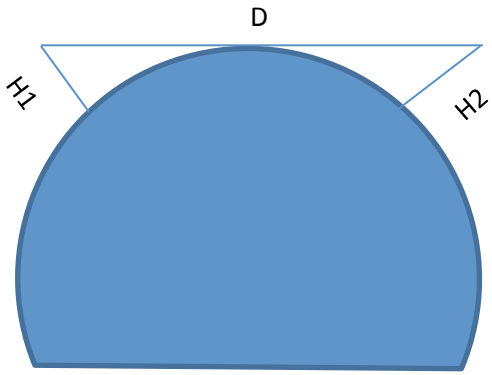
Actual heading

Heading sensor update rate is of paramount importance to safety in high speed navigation systems

Radar

Radar

Range



D = 2.08 x SQRT(H1+H2)

Mounting height	Distance to horizon
1 m	2,0 NM
2 m	3,0 NM
3 m	3,6 NM
4 m	4,1 NM
5 m	4,7 NM
6 m	5,1 NM
7 m	5,5 NM

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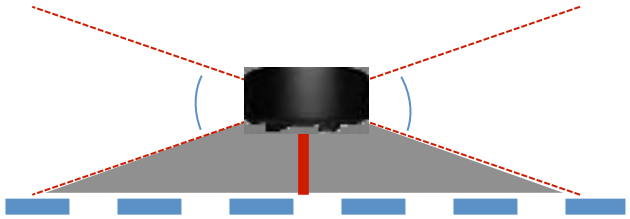
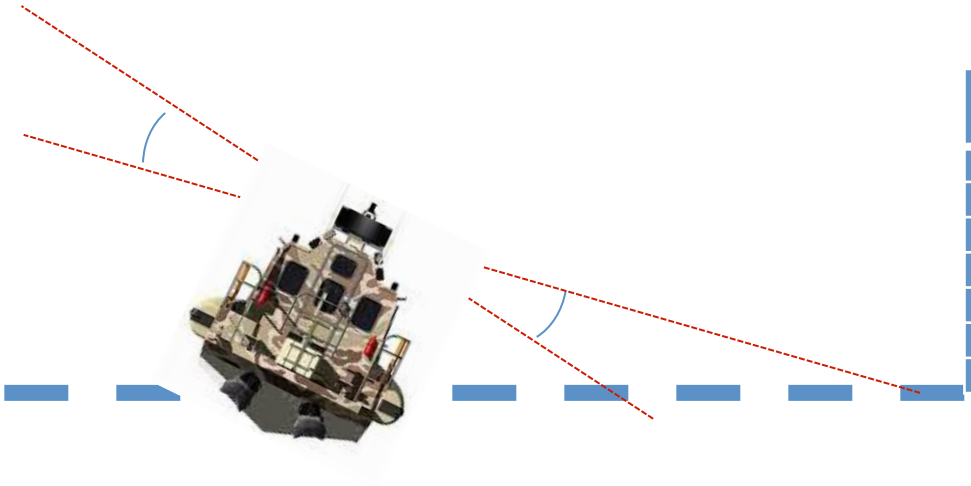
Radar - Limitations

Blind zone



Mounting height	Blind zone radius
2 m	9 m
3 m	13,5 m
4 m	16,8 m
5 m	22,6 m
6 m	27,1 m
7 m	31,5 m



Roll > Vertical lobe angle / 2

Mounting height	Roll	Distance to "horizon"	Roll	Distance to "horizon"
1 m	12°	0,03 NM	15°	0,01 NM
2 m	12°	0,06 NM	15°	0,02 NM
3 m	12°	0,09 NM	15°	0,02 NM
4 m	12°	0,12 NM	15°	0,03 NM
5 m	12°	0,15 NM	15°	0,04 NM
6 m	12°	0,18 NM	15°	0,05 NM
7 m	12°	0,21 NM	15°	0,05 NM

Values are influenced by unevenly distributed radiation energy

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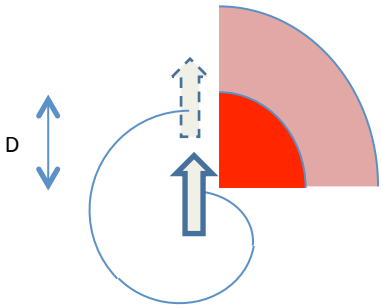
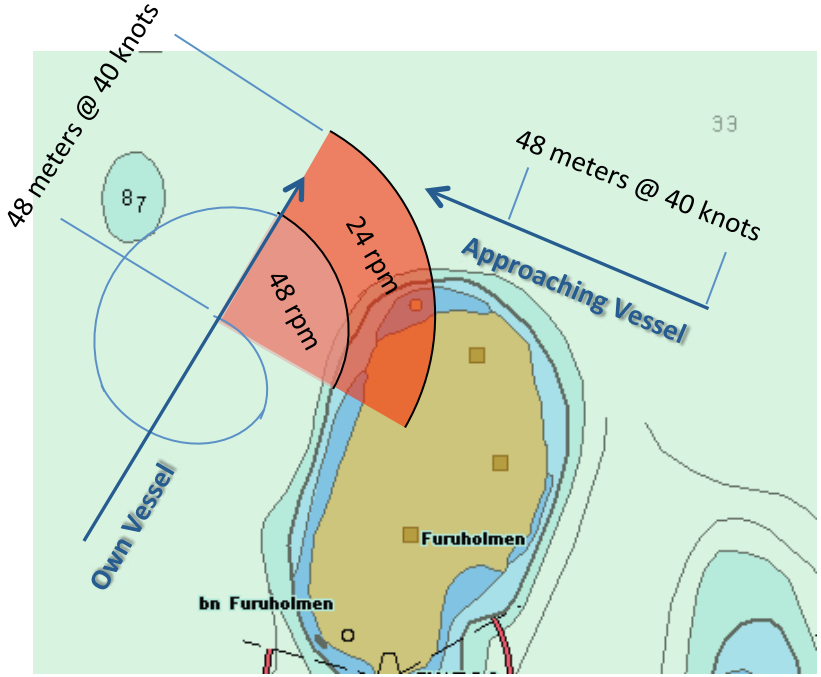
Radar - Limitations

Update rate



Distance made good during one revolution



@ 24 rpm	25 meters to CPA from first detection
@ 48 rpm	60 meters to CPA from first detection

Radar - Limitations

High ROT - Rate of Turn

Clockwise turn – ROT at which blank sectors are generated

Sector resolution	1 deg lobe	2 deg lobe	3 deg lobe	4 deg lobe
4096	10 °/s	20 °/s	30 °/s	40 °/s
2048	5 °/s	10 °/s	15 °/s	20 °/s

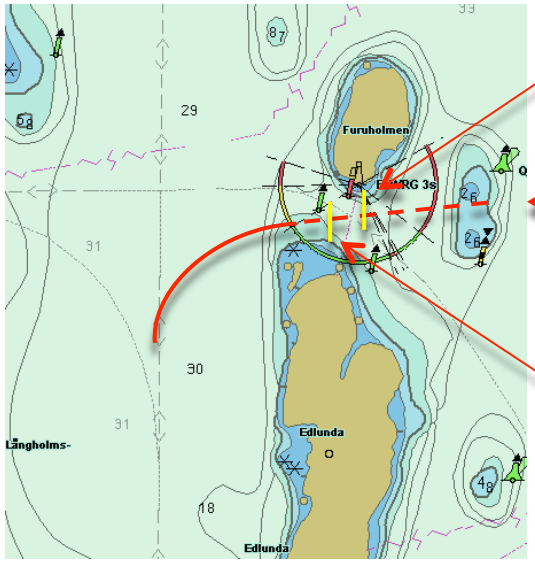
Counter Clockwise turn – Update rate reduction

	ROT 10 °/s	ROT 20 °/s	ROT 30 °/s	ROT 40 °/s
RPM	-1,7	-3,3	-5	-6,7

High ROT distorts image and / or slows down radar image update

Radar - Limitations

High ROT - and recovery



Recovery point
@ 24 RPM / 40 knots

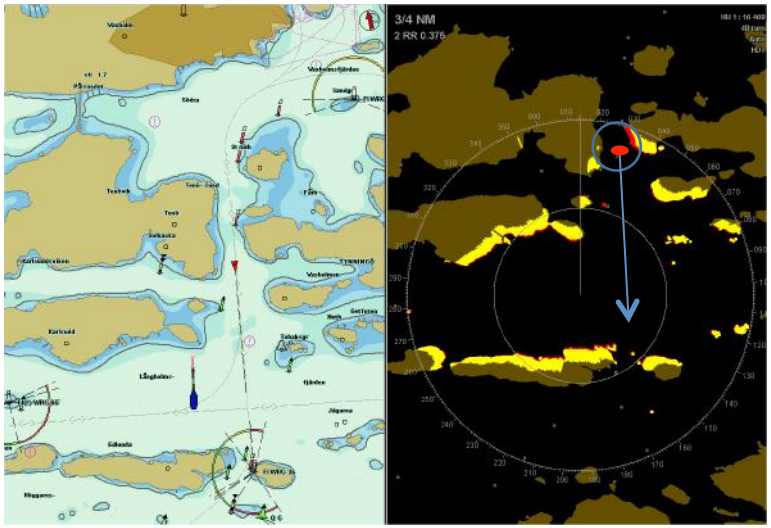
Course following turn

Recovery point
@ 48 RPM / 40 knots

High ROT distorts radar images. High RPM yields shorter recovery time

Radar

Target acquisition



HS-ARPA Target acquisition latency

@ 24 RPM ⇔ 12-24 s

@ 48 RPM ⇔ 6 -12 s

Example, distance 1000 m

Own+Target speed	CPA
20	100 s
40	50 s
60	30 s
80	12 s

High RPM yields quicker target acquisition

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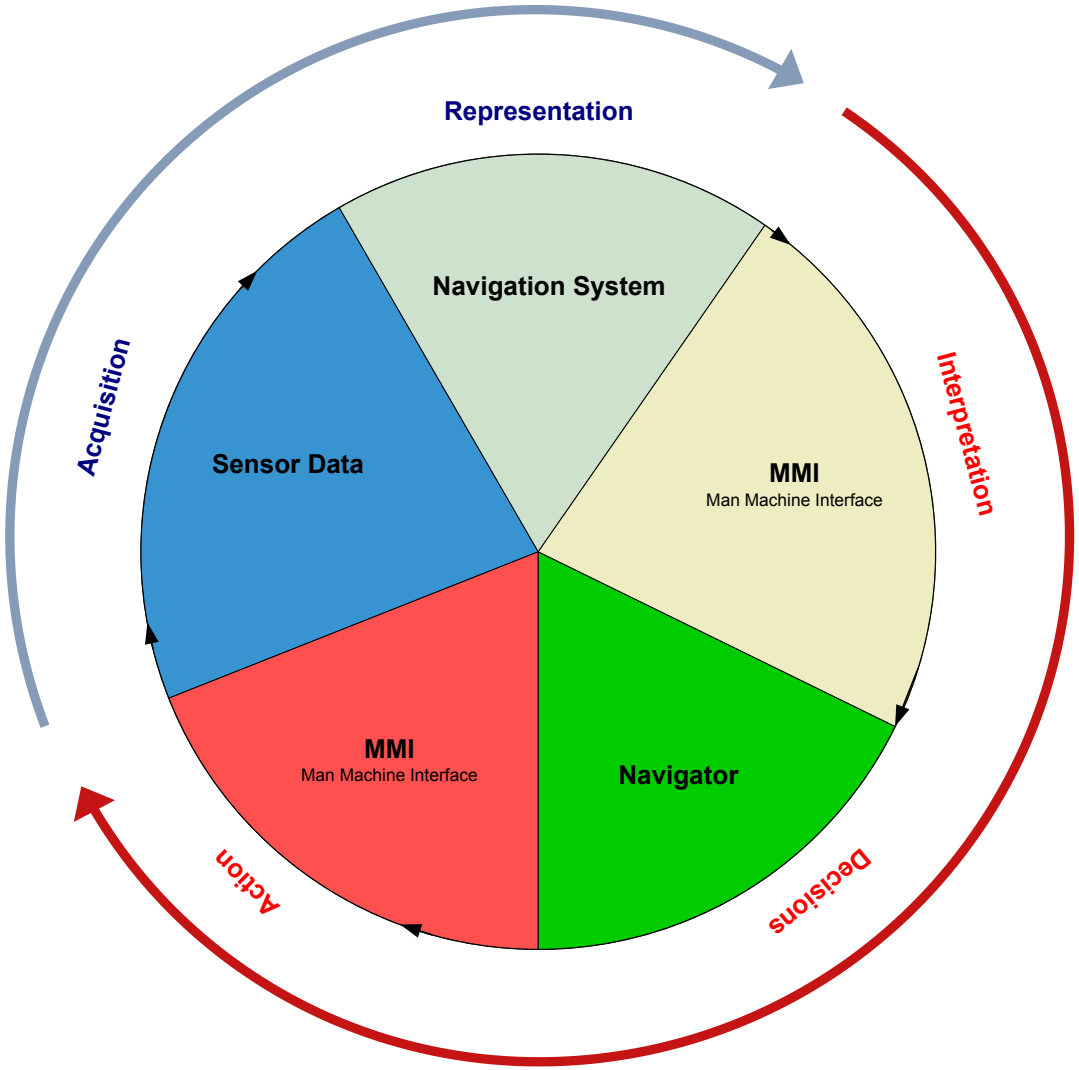

Interpretation and Execution

”Traditional bridge”

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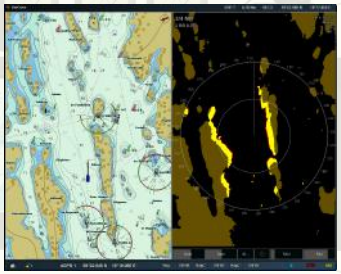
Integration



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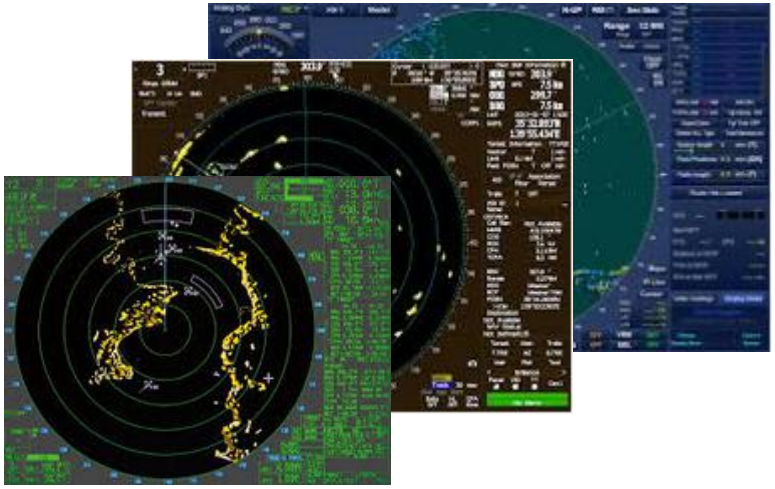
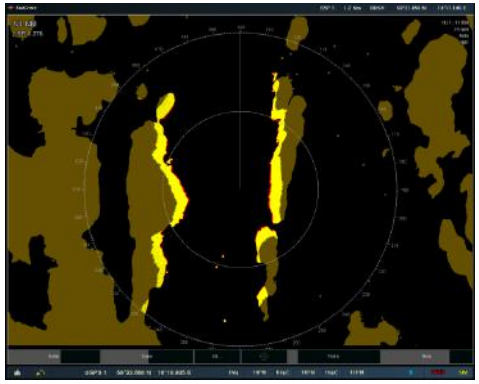
Interpretation – Relevant data



Typical open water radar displays



High speed navigation, radar display

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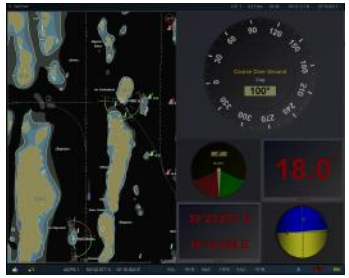
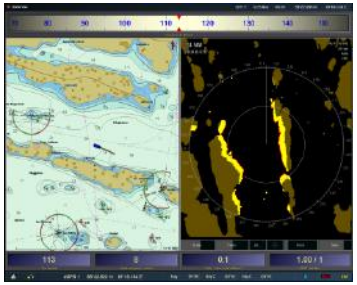
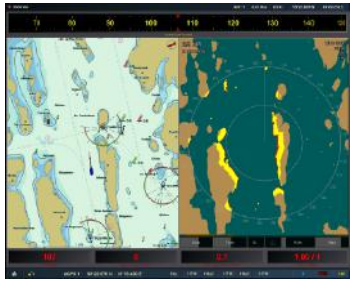
Interpretation – Readable data

Typical open water displays







High speed navigation, displays

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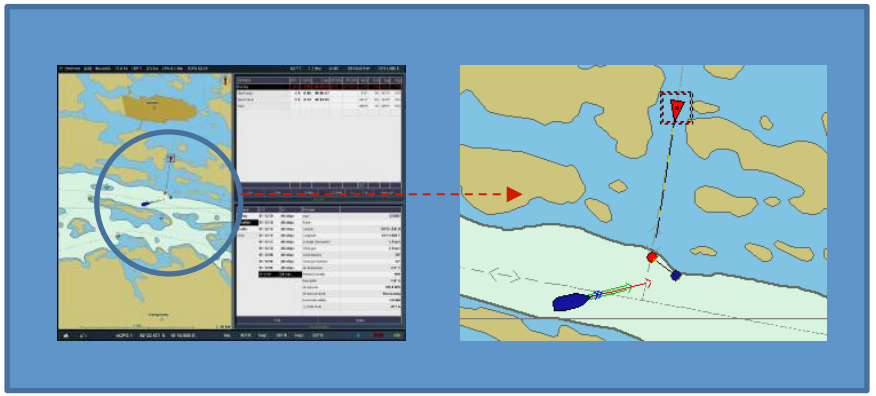
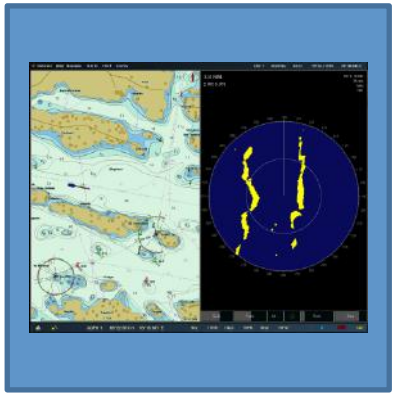
Interpretation – Intuitive data

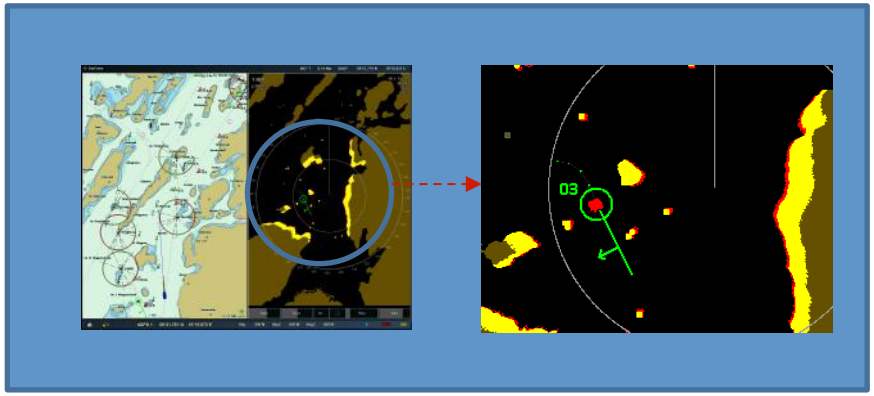
Typical AIS/ARPA cpa display



High speed navigation, AIS/ARPA cpa display



Typical radar display



High speed navigation radar display

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Execution – Maneuverability

Typical open water system's user interfaces

High speed navigation, control devices

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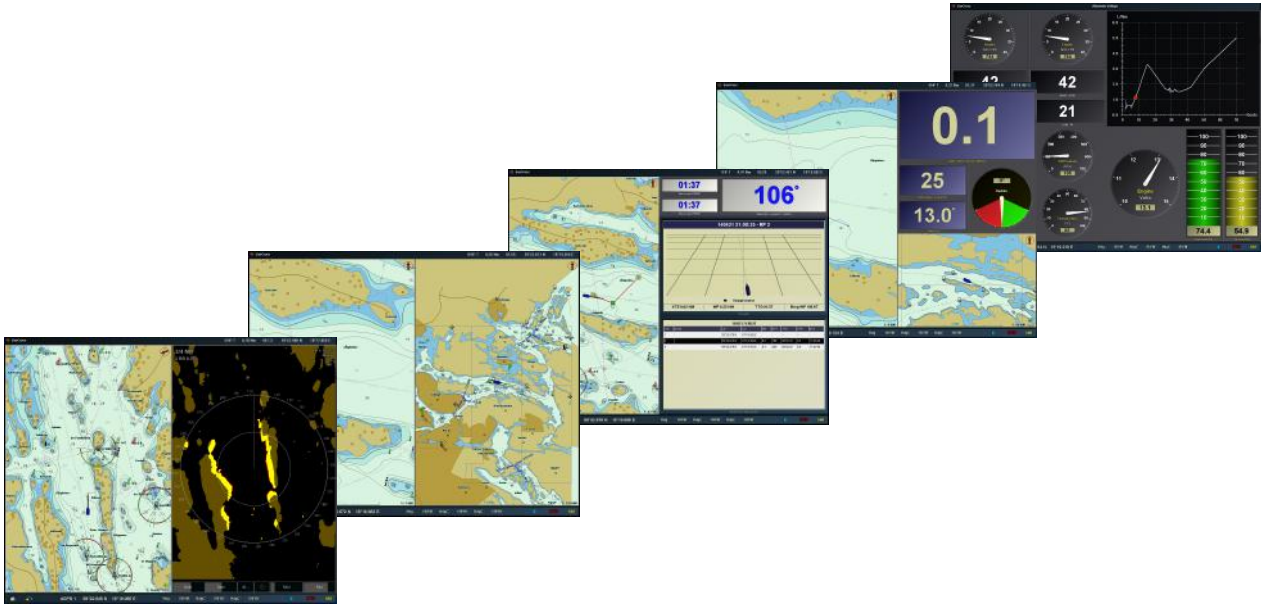
Execution – Accessability



High speed navigation, “one click away” templates

Conclusions

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Conclusions

Sensor performance

Sensor	Required	Preferred	Importance
Position – update rate	1 Hz	5 Hz	2
Position – accuracy	< 5 m	< 4 m	2
Heading sensor – update rate	10 Hz	10 Hz	1
Heading sensor – accuracy	< 0,5 degrees	< 0,5 degrees	2
Radar – update rate	45+ RPM < 1.5 NM	48 RPM < 1.5 NM	1
Radar – range	6+ NM	24 NM	1
Display size (at 0.29 mm pixel size)	15”	19”	1

System performance

System update rates ≥ sensor update rates, i.e. >20 Hz

MMI – Man machine interface

- **Relevant data output**
- **High readability**
- **Intuitive data representation**
- **Noncomplex user controls operable in all sea states**
- **Preplanned user selectable display layouts**

Thank you!