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Electronic Chart Display and Information Systems for navigational safety in maritime transportation

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Introduction – ENC and ECDIS

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ENC – Electronic Navigational Chart

- Vector charts compiled from a database, standardized as to content, structure and format, of individual geo-referenced objects
- Contains all the chart information necessary for safe navigation
- Issued on the authority of government-authorized hydrographic offices
- Being a database, ENC content may be continuously retrieved by special operational functions in ECDIS to give warnings of impending danger related to the vessel's position and its movements.

ECDIS – Electronic Chart Display and Information System

- System that can be accepted as complying with chart requirements in SOLAS regulations
- Displaying selected information from ENC with positional information from navigation sensors and additional navigation-related information
- Assist the mariner in route planning and route monitoring

Background

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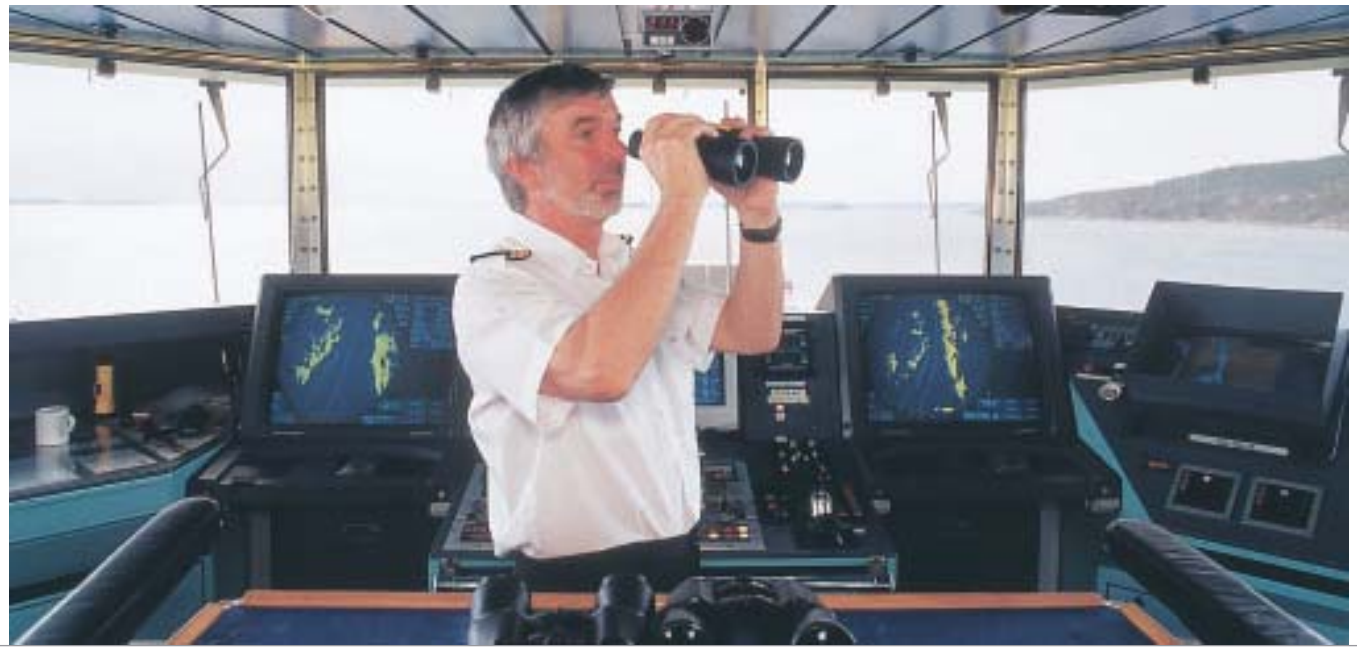
- Previous studies show that collision and grounding accidents are main risk drivers for many shiptypes
- Major risk reductions may be achieved by measures to prevent such accidents – related to safety of navigation
- The risk reducing potential of ECDIS in ship navigation has been demonstrated in previous studies



Background

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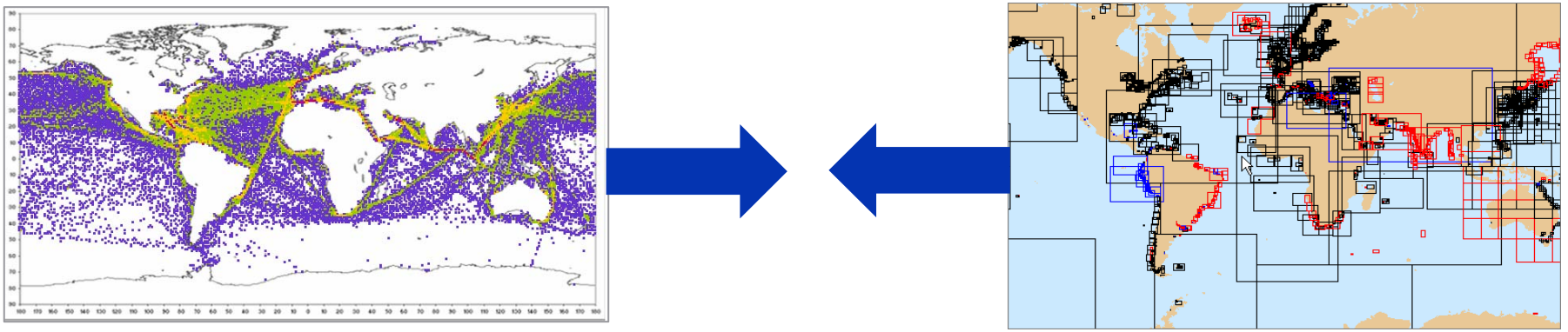
- Previous studies on particular shiptypes have demonstrated that ECDIS is a cost-effective risk control option
  - About 38% risk reduction for grounding
  - Passenger ships, oil tankers, bulk carriers, product tankers, LNG carriers
- However, previous studies assumed full coverage of Electronic Navigational Charts (ENC) along coastal areas - This assumption has been particularly debated

➔ A new study was initiated to investigate the effect of gaps in ENC coverage on the effect of ECDIS

  - Compares global ship traffic densities to actual ENC coverage



Grounding scenarios and risk models

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- Description of grounding scenarios adopted from previous studies. Drift groundings not prevented by ECDIS – only powered grounding are considered
- Probability models using Bayesian Networks and Excel spreadsheets previously developed in other studies were slightly modified and employed
  - Probability models influenced by ENC coverage
- Consequence models:

A) Fatality probabilities from previous risk models (/crewmember/grounding):
   - 2×10^{-4} for oil, chemical and LNG tankers and container vessels
   - 6×10^{-4} for bulk carriers and general cargo ships

B) Accident costs based on established cost models
   - Assuming 75% non-serious, 22.7% serious and 2.27 % total losses

C) Environmental damage based on the CATS approach (Cost of Averting a Tonne of oil Spilt)
   - USD 60,000 per tonne

- ECDIS cost estimates: Initial cost (acquisition and installation), maintenance and training
  - Based on information from ECDIS suppliers

Ship traffic data sources

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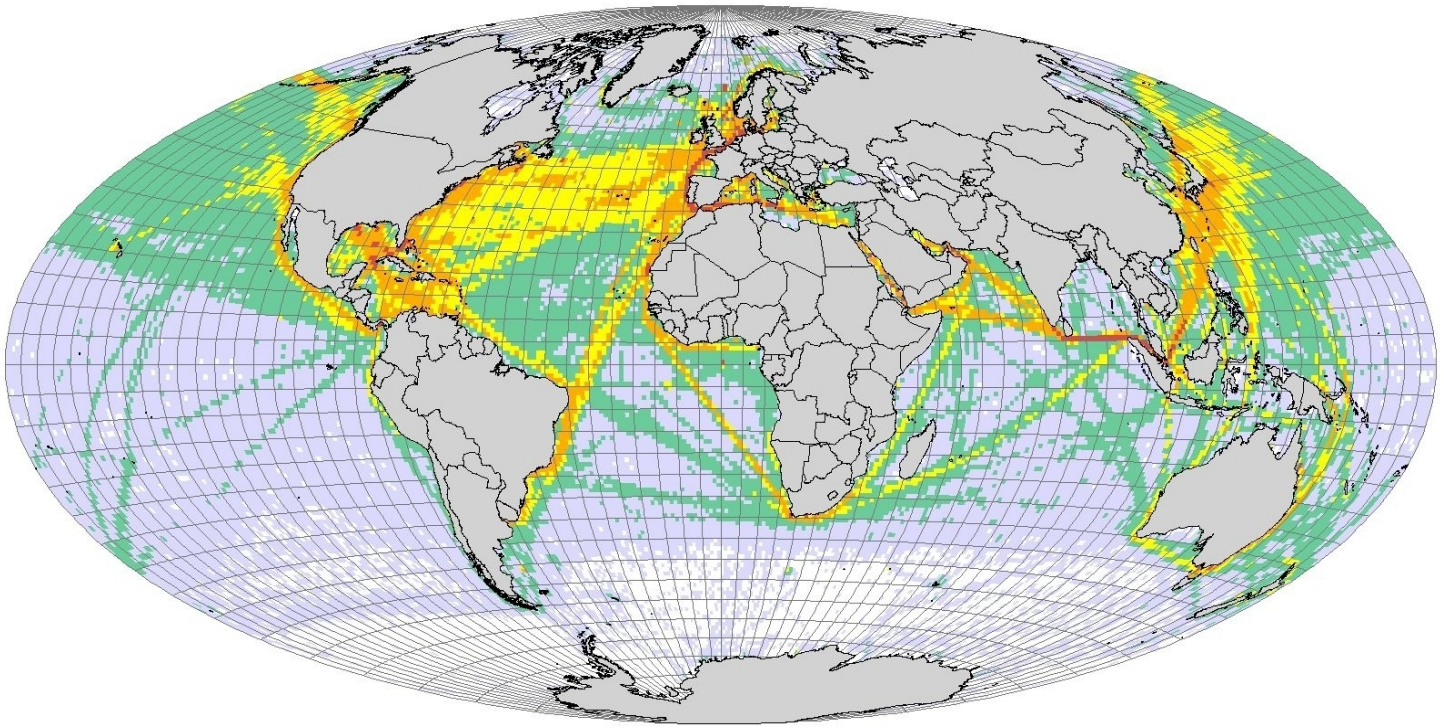
- Global ship traffic data
  - Joint dataset from AMVER and COADS for a complete year (2000/2001)
    - AMVER: Tracking the position of > 12,000 merchant ships
    - COADS: Ship location data based on reporting of meteorological observations from approx. 7000 vessels



ENC coverage data sources

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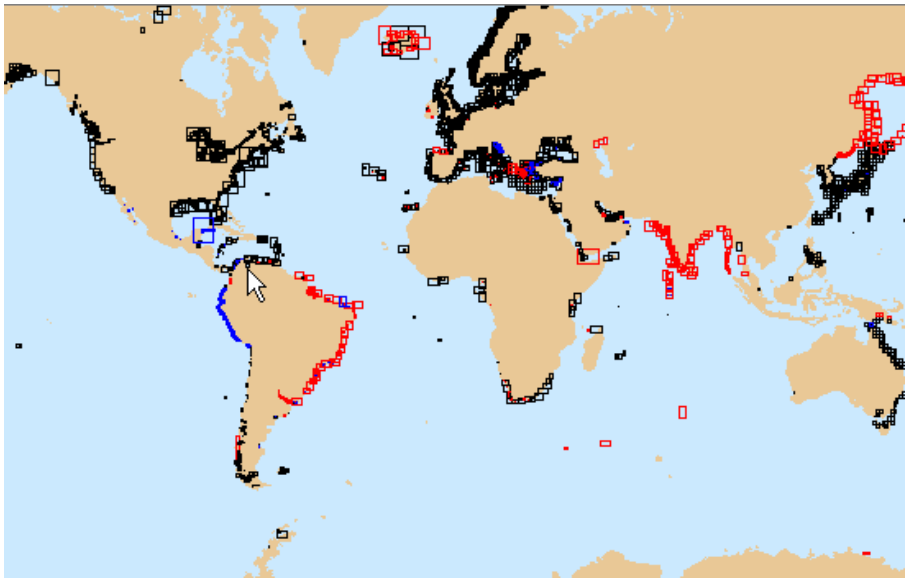
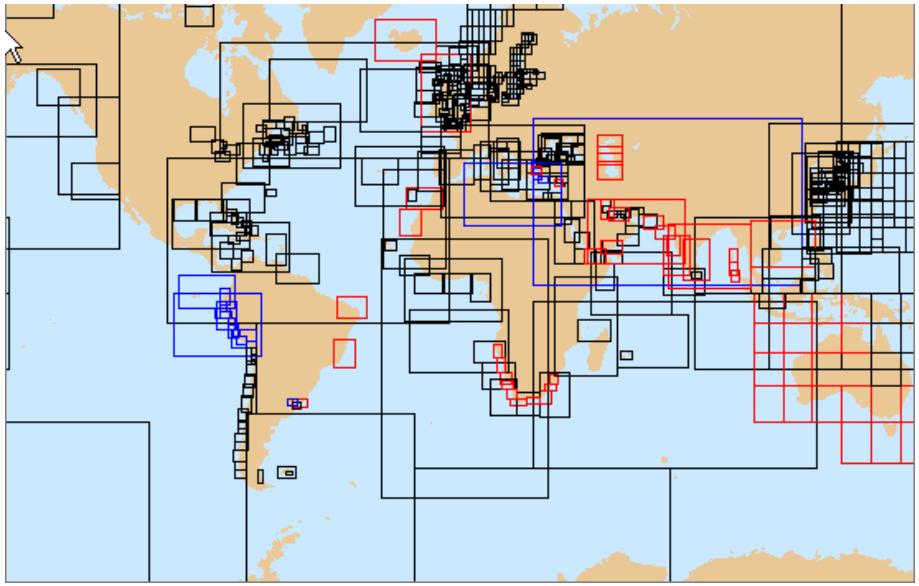
- International Hydrographic Organization ENC catalogue
- Different detail levels: distinguish between resolutions higher and lower than “Coastal”
- Commercially available or in/planned for production



ENCs “Coastal” and better



ENCs “Overview” and “General”

Worldwide ENC coverage

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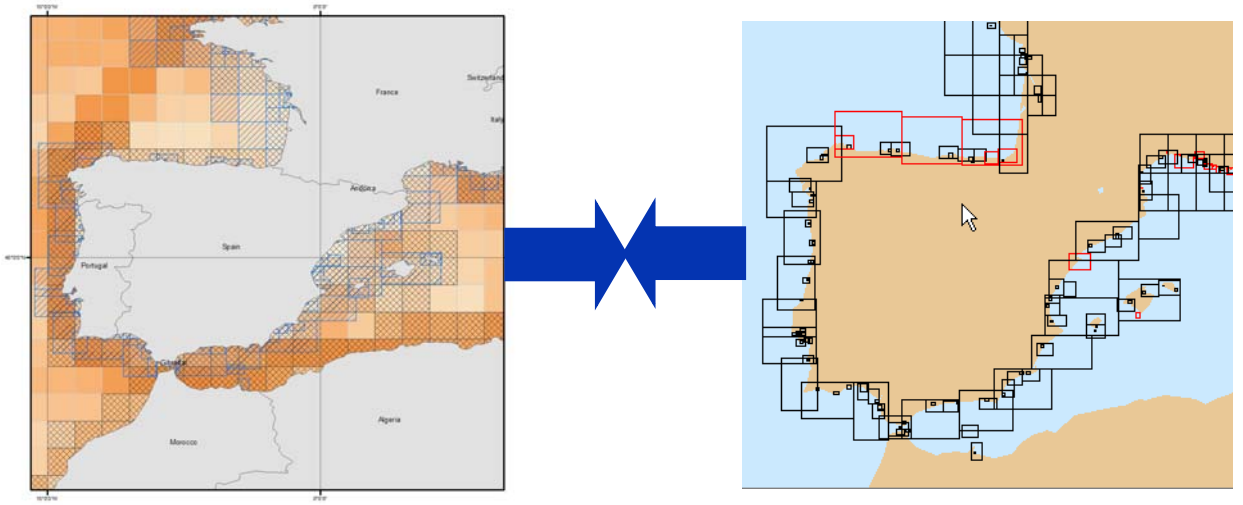
- "Suitable ENC coverage":
  - < 20 nautical miles from shore: ENC *"Coastal"* or better
  - Open waters > 20 nm from shore: ENC *"General"* or *"Overview"* sufficient
- Mapping global ENC coverage to global ship traffic distributions to estimate percentage of SOLAS ships sailing with "suitable ENC coverage":
  - 2007: between 82% and 94%
  - 2010: between 85% and 96%

Traffic densities



ENC coverage

Selected representative shipping routes

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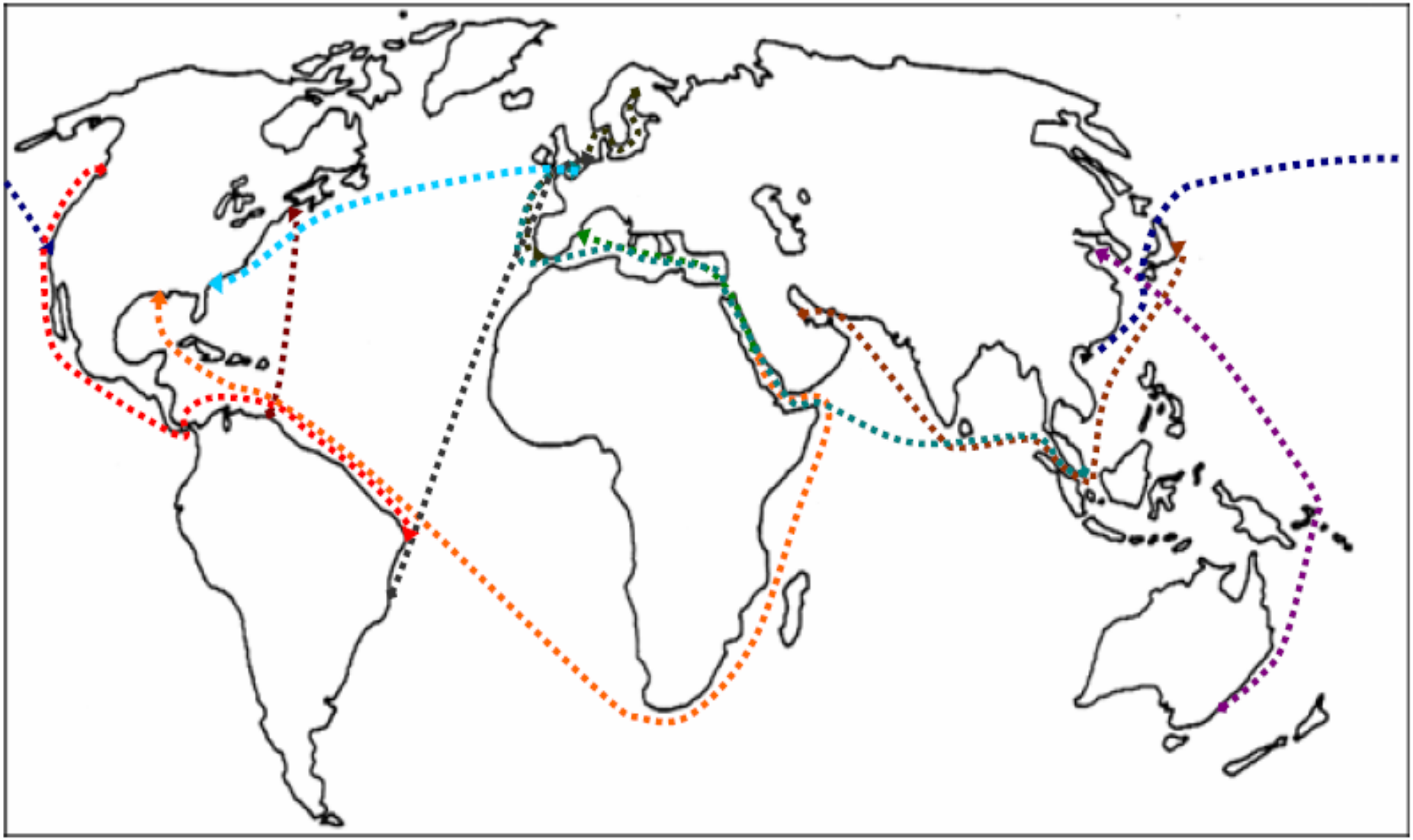
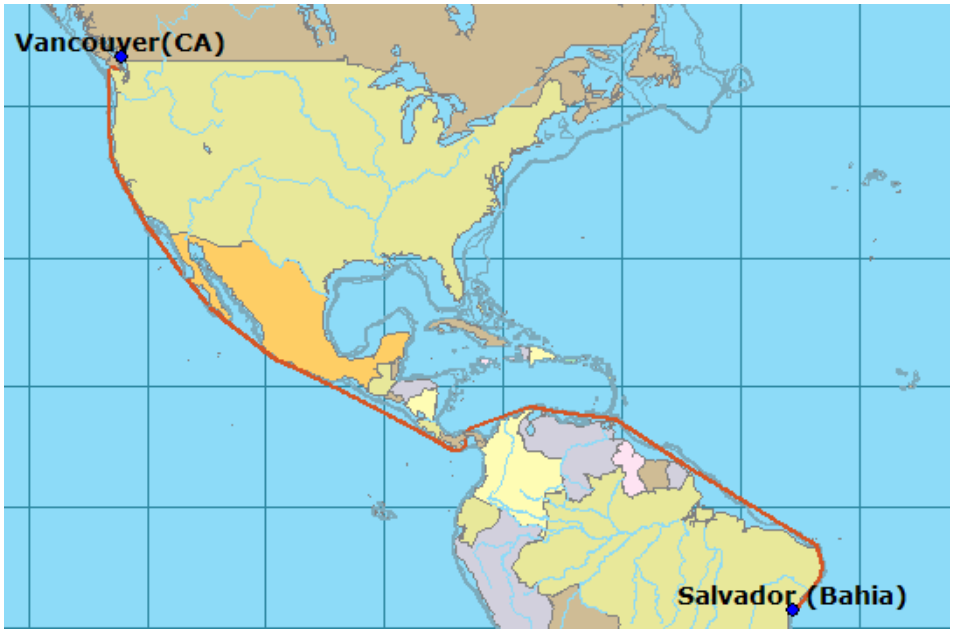


Example route: Vancouver - Salvador



← Voyage

ENC coverage

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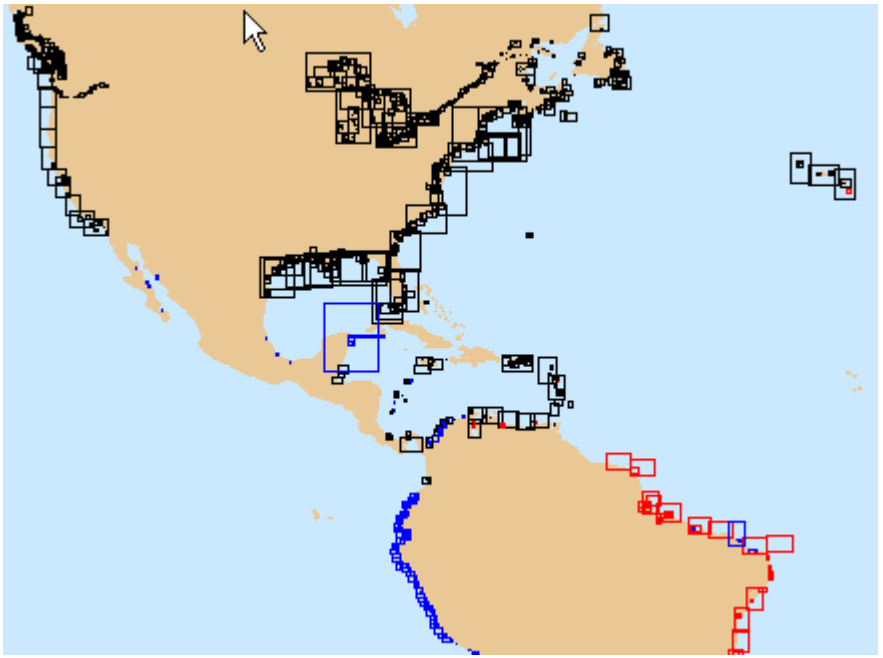

Route characteristics

	Total	< 20 nm	< 5 nm	< 2 nm
Distance				
(nm)	7600	3400	790	90
(%)	100	45	10	1
ENC coverage				
2007		46%	49%	95%
2010		57%	70%	100%

Vancouver – Salvador: Grounding frequencies

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- Route characteristics incorporated in the risk model to obtain
  - Probability of critical course
  - Annual grounding frequencies with and without ECDIS for 2007 and 2010

	Without ECDIS	With ECDIS – Assume 100% ENC coverage	With ECDIS - Actual coverage 2007	With ECDIS - Anticipated coverage 2010
Frequency (per shipyear)	4.3×10^{-2}	2.7×10^{-2}	3.5×10^{-2}	3.2×10^{-2}
Frequency reduction (%)	-	38%	19%	26%
Groundings averted (per shipyear)	-	1.6×10^{-2}	7.9×10^{-3}	1.1×10^{-2}

- For this particular route: ECDIS would represent an 19% reduction in grounding risk
  - Anticipated to increase to 26% within 2010

Averting groundings on selected routes

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Route	ENC Coverage (< 5 nm to shore) 2007	ENC Coverage (< 5 nm to shore) 2010	Grounding frequency reduction 2007	Grounding frequency reduction 2010	Groundings averted (per shipyear) 2007	Groundings averted (per shipyear) 2010
1. Dammam – Yokohama	41%	65%	15%	25%	7.2×10^{-3}	1.1×10^{-2}
2. Yanbu – Galveston	57%	77%	22%	29%	1.8×10^{-3}	2.4×10^{-3}
3. Yanbu – Barcelona	94%	94%	36%	36%	2.6×10^{-2}	2.6×10^{-2}
4. Singapore – Rotterdam	63%	68%	24%	26%	1.5×10^{-2}	1.6×10^{-2}
5. Hong Kong – Long Beach	100%	100%	38%	38%	3.1×10^{-3}	3.1×10^{-3}
6. Newcastle – Qinhuangdao	28%	28%	11%	11%	1.3×10^{-3}	1.3×10^{-3}
7. Vitoria – Hamburg	65%	84%	25%	32%	8.7×10^{-3}	1.1×10^{-2}
8. Vancouver – Salvador	49%	70%	19%	26%	7.9×10^{-3}	1.1×10^{-2}
9. Helsinki – Cadiz	100%	100%	38%	38%	1.2×10^{-2}	1.2×10^{-2}
10. Rotterdam – Savannah	100%	100%	38%	38%	8.9×10^{-3}	8.9×10^{-3}
11. Point Fortin – Everett	100%	100%	38%	38%	8.1×10^{-3}	8.1×10^{-3}

- Some observations:
  - 4 of 11 routes already have 100% ENC coverage in coastal areas
  - 6 of 11 routes sees no anticipated change in ENC coverage from 2007 – 2010
  - Grounding frequency reduction between 11 - 38%
  - ENC coverage between 28 - 100% (Global average ≈ 84 – 96%)

Risk reduction on selected routes

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- Assuming a representative ship for each route in order to estimate risk
  - 3 oil tankers, 2 container ships, 3 bulk carriers, 1 general cargo, 1 chemical tanker and 1 LNG carrier
  - Sizes from 2,500 – 80,000 GT
  - Bunker capacity from 350 – 8000 ton (and one boil-off gas)
  - Crew from 15 - 30

Route	*Groundings averted (per shipyear)*	*Average grounding accident cost (USD million)*	*Risk reduction*	
			Accident cost (USD per shipyear)	*# Fatalities (per shipyear)*
1. Dammam – Yokohama	7.2×10^{-3}	29	210,000	4.3×10^{-5}
2. Yanbu – Galveston	1.8×10^{-3}	57	100,000	1.1×10^{-5}
3. Yanbu – Barcelona	2.6×10^{-2}	15	390,000	1.5×10^{-4}
4. Singapore – Rotterdam	1.5×10^{-2}	1.8	27,000	6.0×10^{-5}
5. Hong Kong – Long Beach	3.1×10^{-3}	5.5	17,000	1.7×10^{-5}
6. Newcastle – Qinhuangdao	1.3×10^{-3}	1.9	2,500	2.3×10^{-5}
7. Vitoria – Hamburg	8.7×10^{-3}	1.3	11,000	1.5×10^{-4}
8. Vancouver – Salvador	7.9×10^{-3}	0.89	7,000	1.2×10^{-4}
9. Helsinki – Cadiz	1.2×10^{-2}	0.51	6,100	1.1×10^{-4}
10. Rotterdam – Savannah	8.9×10^{-3}	1.2	11,000	4.1×10^{-5}
11. Point Fortin – Everett	8.1×10^{-3}	3.2	26,000	4.2×10^{-5}

Cost-effectiveness assessment

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Indicators of Cost-effectiveness

1. **GCAF**

   (Gross Cost of Averting a Fatality)

$$GCAF = \frac{\Delta Cost}{\Delta Risk}$$

Criteria for cost-effectiveness

1. **GCAF < USD 3 million**

2. **NCAF**

   (Net Cost of Averting a Fatality)

$$NCAF = \frac{\Delta Cost - \Delta EconomicBenefit}{\Delta Risk}$$

2. **NCAF < USD 3 million**

NCAF < 0 indicates that the cost is less than the economic benefit of implementing a measure

Cost effectiveness of ECDIS on selected routes

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- GCAF > USD 3 million for all routes
  - Limited potential for saving lives on cargo ships due to low fatality rates
- NCAF < 0 for all routes except one
  - Indicates that ECDIS is cost effective
- For cargo ships: Most significant effect is environmental and property protection from averting groundings
- NCAF > USD 3 million for the route with poorest ENC coverage only.
  - ECDIS will only cease to be cost effective for routes with very poor ENC coverage

Route	*GCAF (10^6 USD)*		*NCAF (10^6 USD)*	
	2007	*2010*	*2007*	*2010*
1.	63	41	< 0	< 0
2.	247	194	< 0	< 0
3.	18	18	< 0	< 0
4.	45	43	< 0	< 0
5.	160	160	< 0	< 0
6.	118	118	54	54
7.	18	14	< 0	< 0
8.	23	16	< 0	< 0
9.	25	25	< 0	< 0
10.	66	66	< 0	< 0
11.	65	65	< 0	< 0

Global Cost effectiveness of ECDIS

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Assumptions:

- Global grounding frequency reduction = average for the 11 routes
- Average accident costs per GT
  - Oil tankers: 720 USD/GT
  - Other cargo ships: 120 USD/GT
- Average fatality rates = 0.01 /grounding
- Average expected lifetime = 25 years
- Valid for all SOLAS ships > 500 GT

➔ Generic cost-effectiveness estimates for new and existing ships may be carried out

Cost effectiveness for new ships

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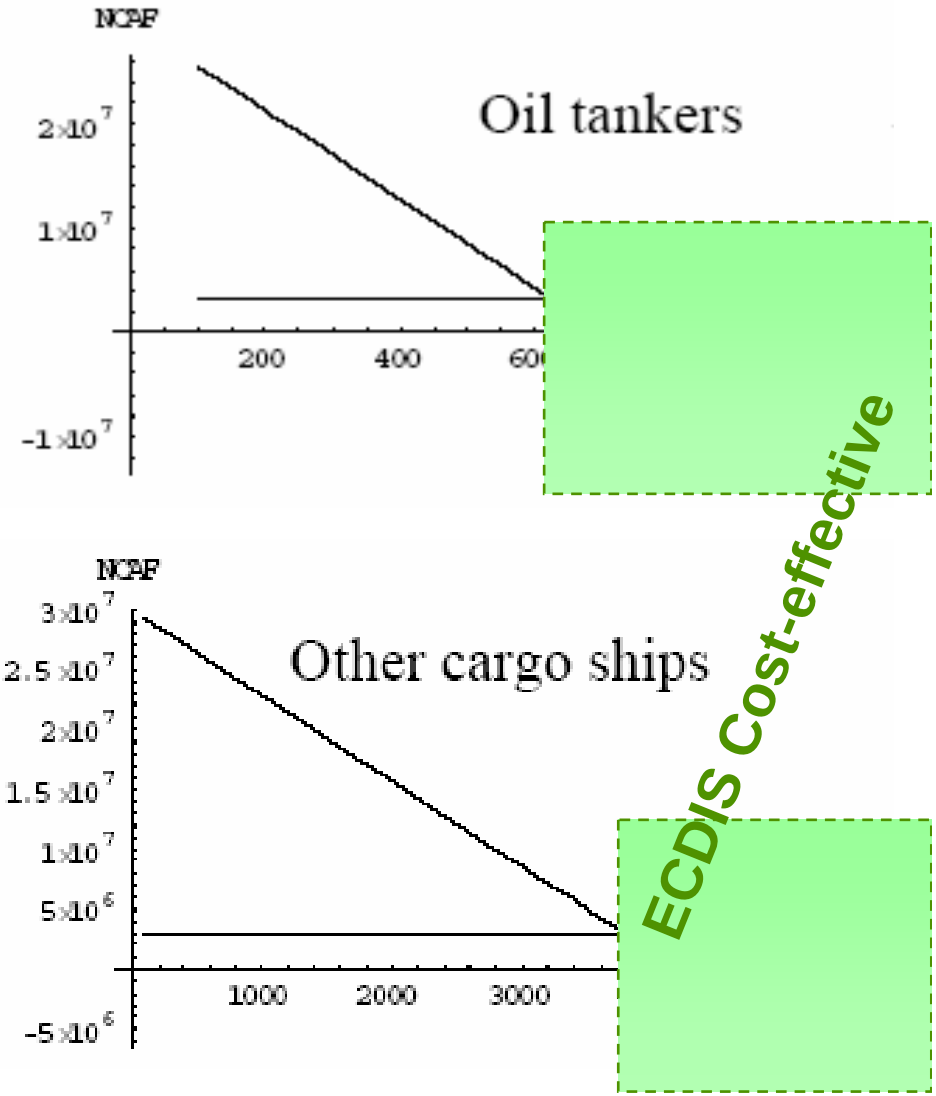
- GCAF = USD 30M
- NCAF = Function of shiptype and size
- NCAF < USD 3M
  - Oil tankers > 630 GT
  - Other cargo ships > 3,800 GT
- NCAF < 0
  - Oil tankers > 700 GT
  - Other cargo ships > 4,200 GT



Cost effectiveness for existing ships

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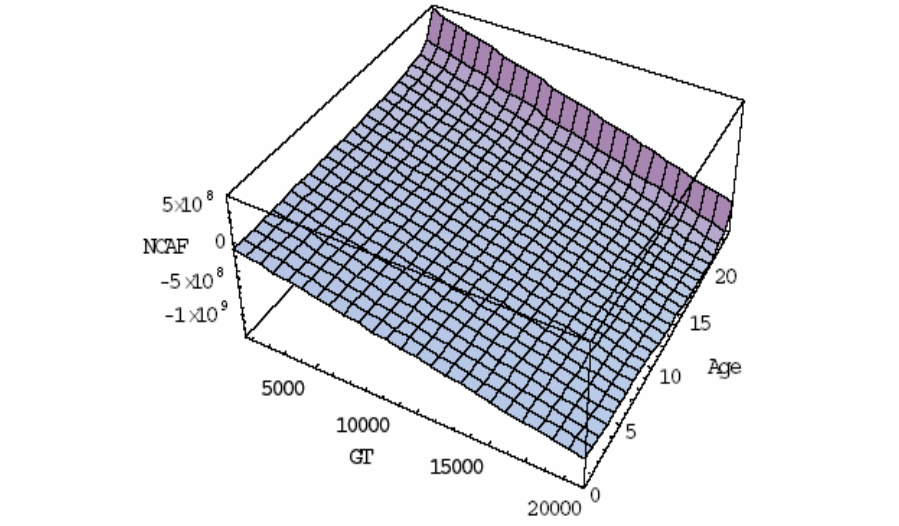
- GCAF will never be < USD 3M
- NCAF = function of ship type, size and age

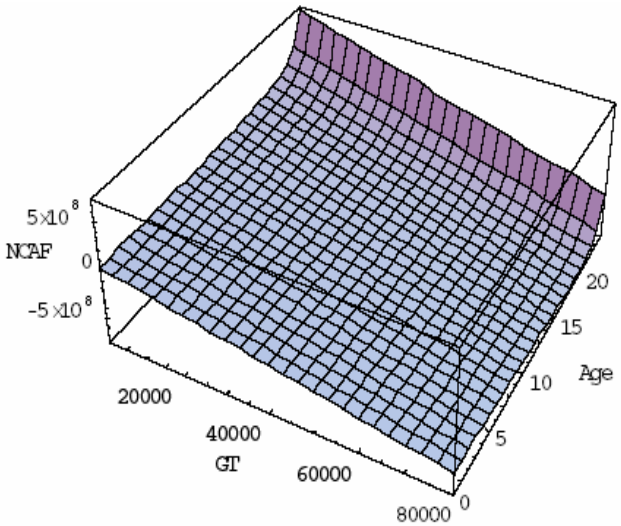
NCAF as function of age and size

Oil tankers



NCAF as function of age and size

Other cargo ships



Cost-effectiveness for existing ships

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Sizes corresponding to NCAF < USD 3M and NCAF < 0

OIL TANKERS

Ship age	*Size (GT) (NCAF < USD 3 million)*	*Size (GT) (NCAF < 0)*
Newbuilding	630	700
5 years	720	780
10 years	870	920
15 years	1,200	1,200
20 years	2,000	2,100
24 years	9,300	9,300

OTHER CARGO SHIPS

Ship age	*Size (GT) (NCAF < USD 3 million)*	*Size (GT) (NCAF < 0)*
Newbuilding	3,800	4,200
5 years	4,300	4,700
10 years	5,200	5,500
15 years	7,000	7,300
20 years	12,000	13,000
24 years	56,000	56,000

Summary and recommendations

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- Cost-effectiveness of ECDIS to prevent grounding has been assessed for cargo ships
  - Cost effectiveness for passenger ships has been established in previous studies
- Actual coverage of ENC has been considered
- Major differences between oil tankers and other types of cargo ships
  - Due to the potential of major oil spills in grounding accidents
- Recommendations submitted to NAV 53 by Nordic countries:
  - ECDIS should be made mandatory for all new oil tankers of 500 gross tonnage and upwards
  - ECDIS should be made mandatory for all new cargo ships, other than oil tankers, of 3,000 gross tonnage and upwards
  - ECDIS should be made mandatory for all existing oil tankers of 3,000 gross tonnage and upwards
  - ECDIS should be made mandatory for all existing cargo ships, other than oil tankers, 10,000 gross tonnage and upwards

NAV 53 discussions → NAV 54

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- Main conclusions were basically supported by Japanese and Russian studies (Russian study not published)
- Division: some are positive towards adopting ECDIS as a carriage requirement – others are still somewhat sceptical.
- Main objections related to
  - Availability of ENC
  - Availability of ECDIS Training
  - ENC Pricing and distribution schemes
  - Harmonisation of Flag State requirements on back-up arrangements
  - Paper charts are not broken – why fix them?

- Actions on carriage requirements of ECDIS postponed until next NAV-meeting (2008)

Rebuttal to main objections

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Availability of ENC

- Our study concluded that availability of ENC is sufficient to make ECDIS cost-effective
- IHO: Availability of ENC by 2010 will be greater than assumed in the study

Availability of ECDIS Training

- A number of educational institutes provides the IMO model course on ECDIS
  - Ref: ARPA implementation

ENC Pricing and distribution schemes

- Preliminary studies indicate that ENC will not be more expensive than paper charts
- Conclusions of cost-effectiveness assessment are robust even if an additional cost is ascribed to ENCs compared to paper charts
- Distribution schemes of ENC more flexible than for paper charts
- <10% of SOLAS fleet currently use ENCs – service will improve and prices will decrease when usage increases

Harmonisation of Flag State requirements on back-up arrangements

- This is no argument against mandatory ECDIS – national additional requirements already exist in many other areas
- No Flag States have so far required additional paper back-up as far as we know

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