Identification of cognitive error types and human-machine interface problems in ship navigation

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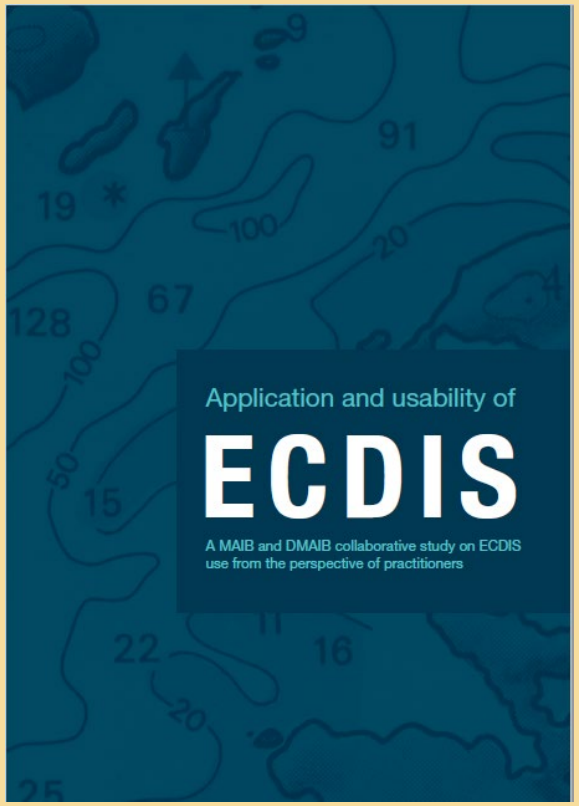
A gap in studies of HMI

Methods exist to help improve the design of HMIs:

(1) **Design review** and **(2) potential error analysis** provide significant improvement in HMI design.

There is a group of problem types which are not susceptible to identification by these methods.

These are the problems of operator cognition

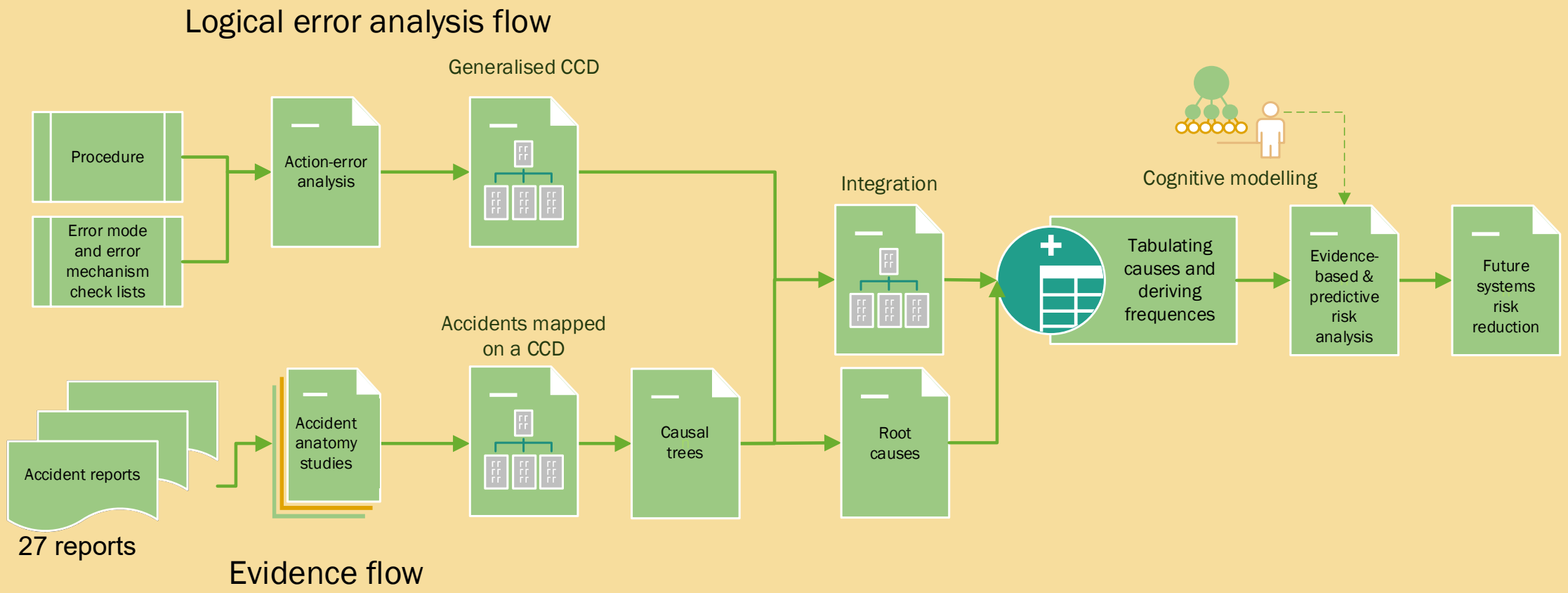


"... automation ... may expand rather than eliminate problems with the human operator."

Motivation for the study

- Operational failures in the use of ECDIS have been a significant cause of groundings
- ECDIS units are gradually becoming more functional, with more aids and more complexity
- Most ECDIS systems can already be connected to vessel autopilots for track following
- Electronic Chart Displays are a requirement for all large ships
- ECDIS is a prototype for future, increasingly autonomous ship navigation systems

Operations error analysis



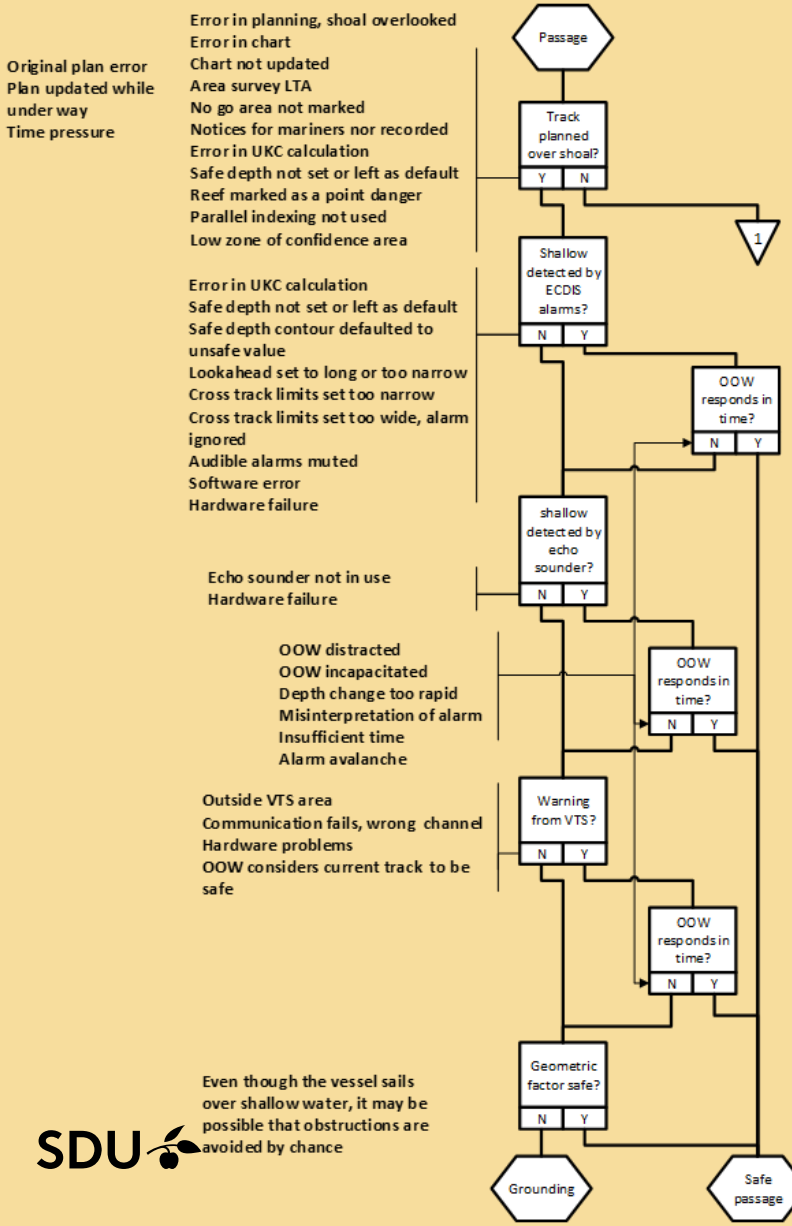
Some conclusions

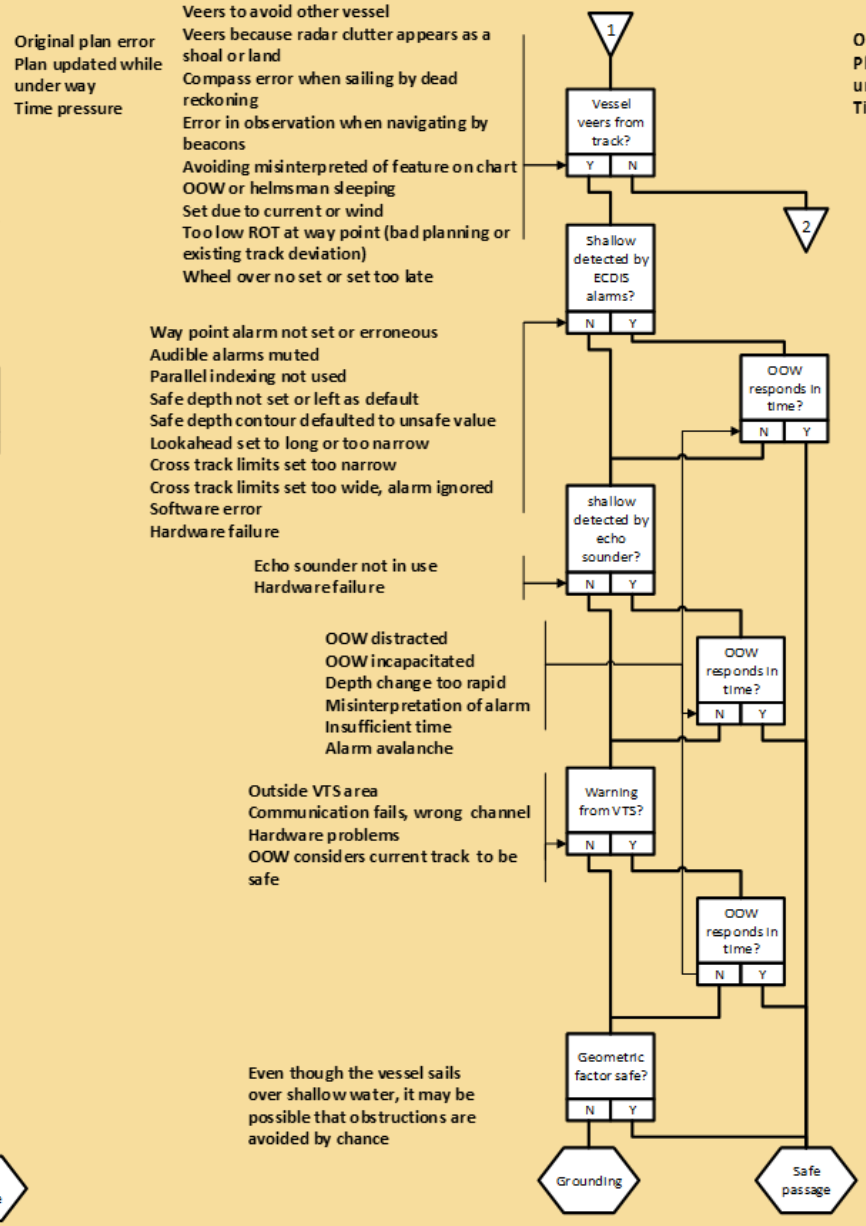
Among many results and conclusions, one is that there is a repeated pattern in many accidents:

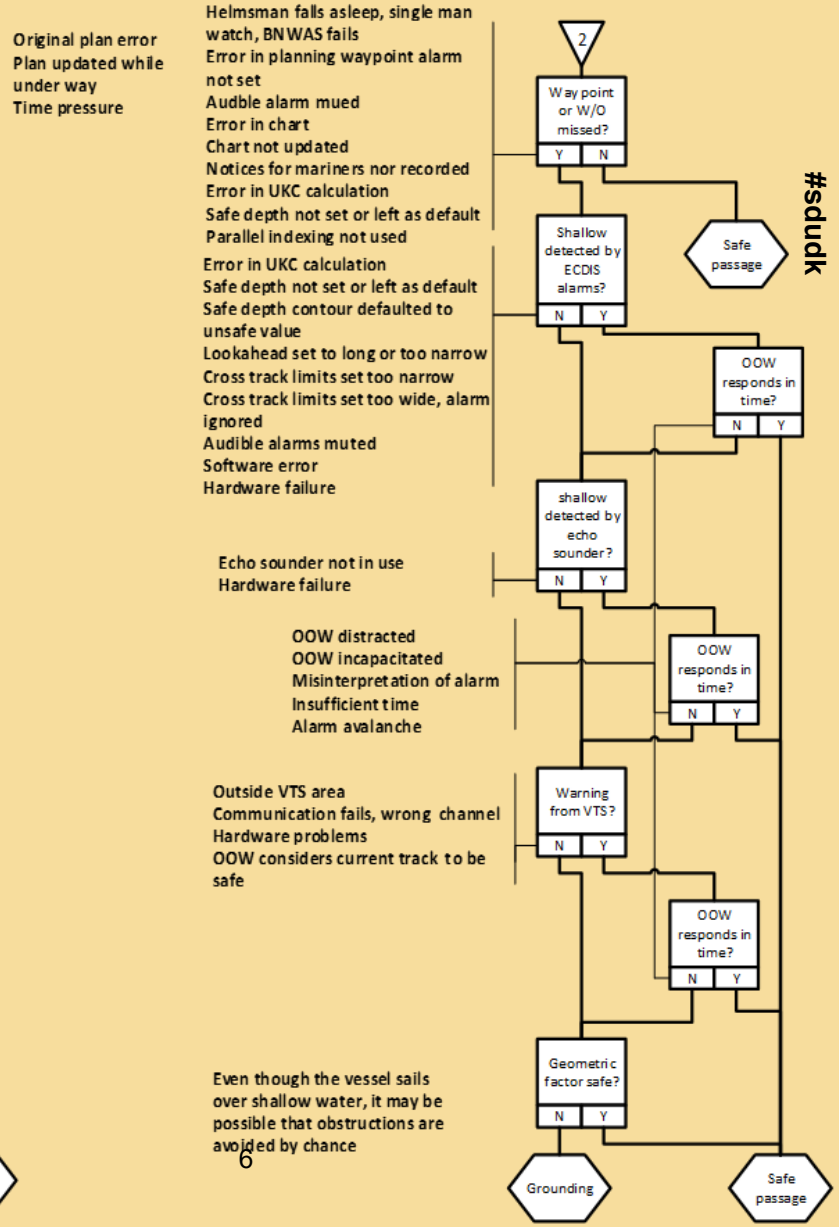
- A technical failure,
- An operator error,
- Omission of setting of operation standards by management, or lack of enforcement of existing operation standards, and
- A design weakness or error.

The focus on “operator error” can be misleading and we should consider “operations error”

Systematic approach to operation error analysis







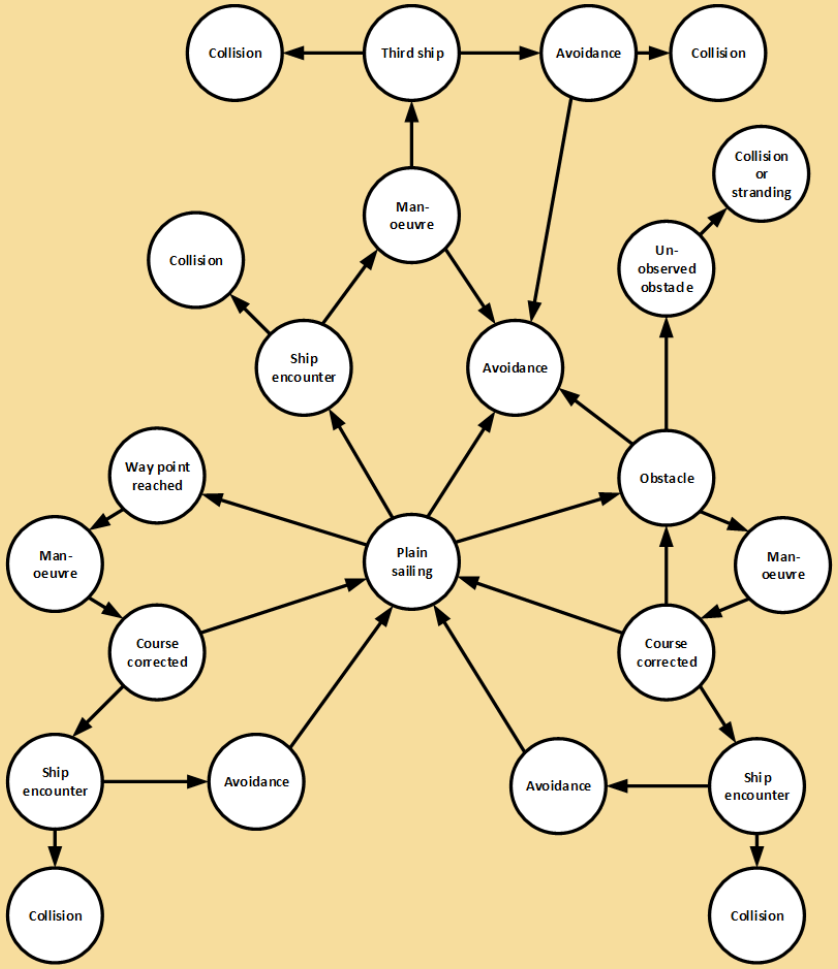
HMI deficiencies, causes and error modes

Some Causes of HMI Deficiencies	HMI Deficiencies	Error modes
Simplified design approach, display all process parameters, threshold exceedance alarms, annunciations, with no plan, consideration of context or priorities	itical event or condition due to other task	Failure to observe a critical event or condition
Failure to relate the HMI to needs during performance of a procedure	condition not indicated on HMI	Erroneous interpretation or recognition of an event or condition
Failure to relate the HMI to a risk analysis or HAZOP	condition submerged in alarm list	Association of an observation with an erroneous response
Failure to implement recommendations from HAZOP	condition hidden on HMI, not on the selec	Failure to associate an observation with a necessary response
Inadequate implementation of recommendations from a HAZOP	us or erroneous indication	Failure to diagnose te cause of an observation
Failure to make indications of critical conditions prominent	iations or alarms difficult to understand, a	Erroneous diagnosis of the cause of an observation
Poor use of language, obscure or ambiguous		Failure to make a decision
Failure to indicate the true plant situation, inadequate consideration of situations	f display changes or alarms	Erroneous decision
Poor or no indication of instrument failure		Erroneous plan
No indication or poor indication of disabled instruments or controls	f critical events or conditions	Omission of an action in a plan or procedure
Inadequate consideration of appropriate display selections	tions	Erroneous action (wrong, too much, to little, too fast, too slow etc.
Poor ergonomics, see HMI assessment check list	tion of cues for action	Failure to check the result of an action
	uous feedback	Erroneous conclusion from checking
	Misleading presentation of the overall situation	Failure to identify the need for corrective action
	Incomplete presentation of the overall situation	

How to uncover the causes of problems in human-machine interaction?

1. Making a hazard analysis and assessing the ability of the HMI to properly display the hazard scenarios;
2. Observing the performance of operators in real environments or on simulators;
3. Extracting the needed information from accident reports;
4. Developing a **virtual operator** (**cognitive model**) and observing its performance by running simulations.

A model for ship collision risk for the Great Belt West Bridge



Model was used for Monte Carlo simulation of ship traffic and OOW/helmsman behaviour

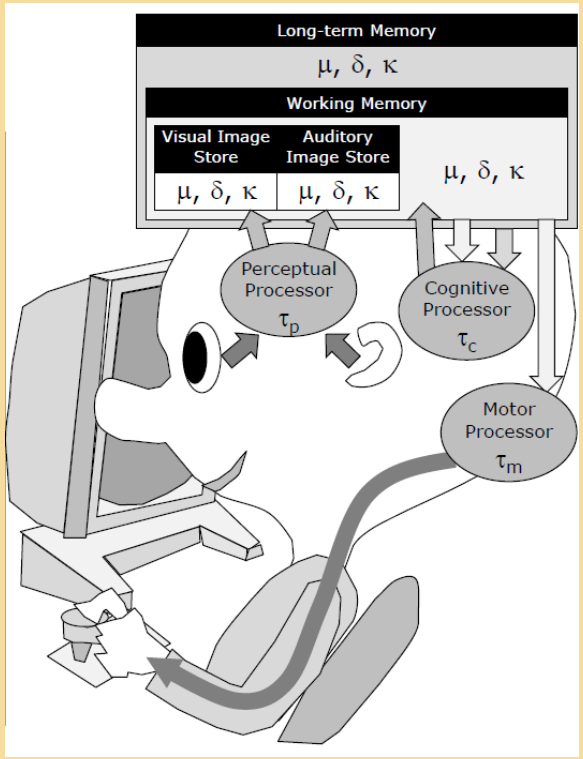
Model predicted the three actual collisions with probability within a factor 1.4 of actual

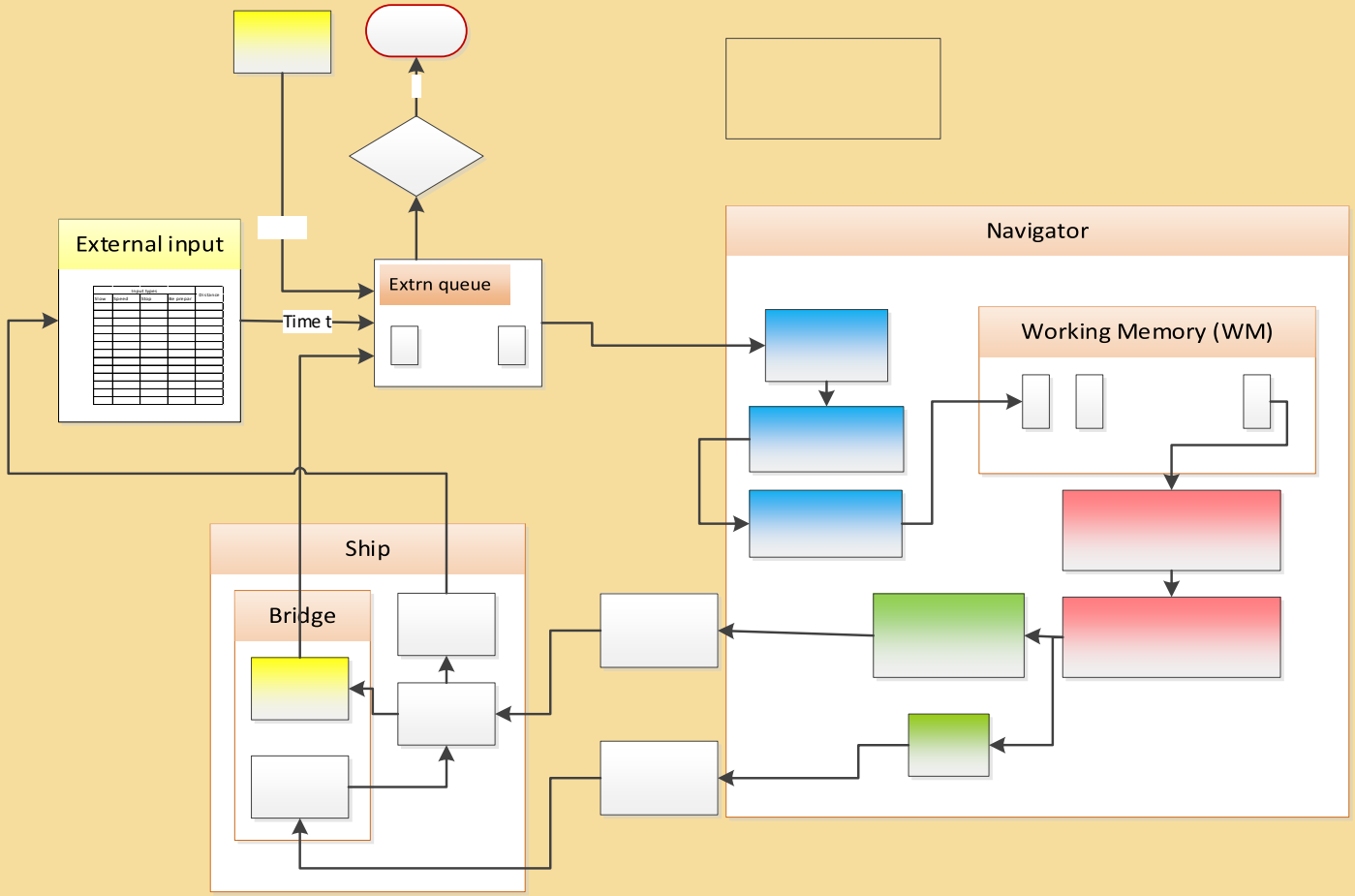
Model agreed with statistical/physical modelling by COWI to within a factor 1.2 (the background statistics for developing the models were the same)

The cognitive modelling predicted the collision causes precisely

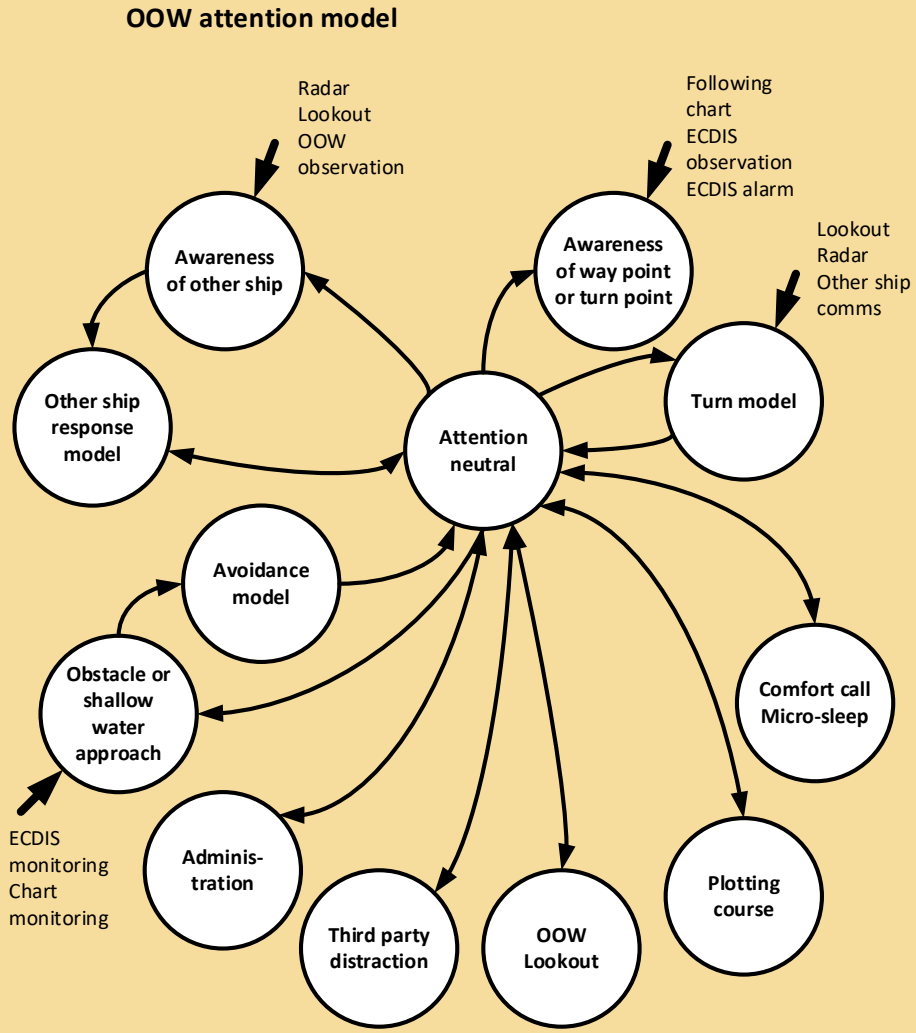
Results justified implementation of VTS and a guard ship.

Our choice: Model human processor





Officer Of the Watch attention model



Arena Training & Evaluation Mode - Commercial Use Prohibited

FILE | Home | Animate | Draw | Run | View | Tools | Developer

Attach | Detach | Paste | Cut | Copy | Select and Zoom | 75% | Submodel | Find... | Replace... | Layers... | Connect | Auto-Connect | Smart Connect | Connector Arrows | Select All | Expression Builder | Arrange | Check Model | Review Errors | Arena Help | Release Notes | Arena Product Manuals

Template | Clipboard | Navigation | Connections | Editing | Run | Help and Manuals

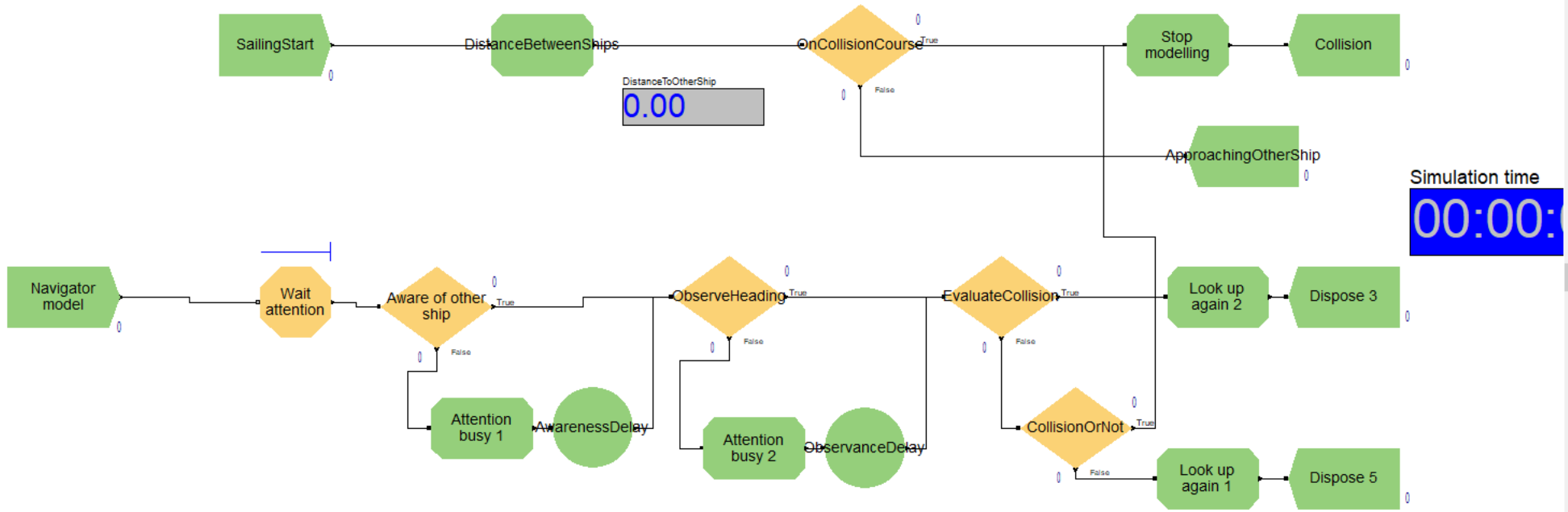
Project Bar

Discrete Processing

- Assign
- Assign Attribute
- Clone
- Create
- Delay
- Disperse

Decisions | Animation | Data Definition | Grouping | Input Output | Material Handling | Reports | Navigate

MyFirstModel.doe | MyFirstModel.doe - Errors/Warnings



	Name	Assignments	Comment
1	DistanceBetweenS	1 rows	Ship's speed is 36 km/hour equal to 10 m/sec. Assumed collision course
2	Stop modelling	1 rows	
3	Look up again 1	1 rows	
4	Look up again 2	1 rows	

Animate Bar

- MyFirstModel.doe
  - Status
    - Levels
  - Waiting
    - Queues
    - Storages
  - Pictures
    - Resources
    - Globals
    - Entity Pictur
    - Transport...
  - Locations
    - Stations
    - Intersectio...
  - Paths
    - Routes
    - Segments
    - Distances

For Help, press F1

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Humans make errors due to cognitive processes which is the factor they cannot control