**Human Factors in Remote Monitoring and Control of Unmanned Vessels (the MUNIN project)**

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**Maritime Unmanned Navigation through Intelligence in Networks**

- EU 7th Framework Program  
- 3 years, Sep. 2012-2015  
- 3.8 M Euros  
- 7 Partners

**INTRODUCTION**

- Daylight and IR cameras  
- Satellite link  
- Autonomous bridge  
- Autonomous engine room  
- Autonomous control  
- Rendezvous control  
- Automatic collision avoidance

**Shore Control Center (SCC)**

- The unmanned / autonomous ship

**TARGET SHIP**

- A simulated, 200 meters long, “Handymax”, dry bulk vessel of 57000 DWT

**KEYWORDS**

- Human Factors in Remote Monitoring and Control of Unmanned Vessels  
- Autonomous bridge  
- Autonomous engine room  
- Autonomous control  
- Rendezvous control  
- Automatic collision avoidance
An autonomous ship

An unmanned ship
No one onboard. Not necessarily under automatic navigation / engine control. Can be remote controlled from shore center.

Objective of the project
To show the feasibility of autonomous/unmanned shipping
To show that an unmanned ship system is at least as safe as a manned.

Motivation
1. Work environment
   Shortage of ship officers
2. Reduction of emissions
   Global warming and emission control: Slow steaming leads to lower emissions and lower fuel costs, (but also less efficient transport capacity). And also longer, socially less acceptable voyage durations.
3. Cost reduction
4. Increased safety
   Reduce "human error"

Human Factors in the Maritime domain.
Fitting the human to the ship, or the ship to the human
Remote bridge concept

120,000 USD per month

Autonomous ship concept

1 very short message per 4sec.
1 long message every 15 - 60 min.

IMO and...
The Navigating Navigator
The Monitoring Navigator

PROBLEMS OF AUTOMATION
The 'problem' with automation: inappropriate feedback and interaction, not 'over-automation'

(Donald Norman, 1990)

Automation bias
Automation complexity
Automation surprise
Automation irony

Over-trust and under-trust

Trust in automation

The more complex a system is the greater the risk that something, somewhere, sometime will fail.
Automation bias
Automation complexity
**Automation surprise**
Automation irony

... and that failure might come as a big surprise

Automation is most reliable in simple tasks. The higher the workload the less reliable is automation.

How to make automation a “team-player”

Task: Design and evaluate a prototype Shore Control Centre

**Situation awareness** (1 vessel/6 vessels)
Work load
Time to get-into-the-loop
Sense of control (COCOM – Hollnagel)
What information needs to be transferred from the vessel to the Shore Control Centre in order to achieve enough situation awareness?

Focus group with 6 nautical officers currently working within nautical education at Chalmers’ department of shipping and marine technology. The participants had a broad seagoing experience from different types of vessels, e.g., cruise ships, car carriers, long and short haul dry and wet cargo and ferries.

145 information items in 9 groups

### METHOD & RESULTS

**Voyage**
1. Voyage plan
2. Itinerary
3. Set AIS transponder static message
4. Fuel

**Sailing**
1. Longitude/Latitude
2. Course over ground
3. Heading
4. Speed over ground/through water
5. Dynamic predictor (min. turn radius, stopping dist., pos. 3/6/9 min. ahead))
6. Rudder angle/rate of turn
7. "Inside nav box" Y/N
8. Bearing/time to next WP
9. Auto/track pilot on/off/settings
10. Navigation lights/horn signals

Nine groups of information
1. Voyage
2. Sailing
3. Observations
4. Safety/Emergencies
5. Security
6. Cargo/stability/strength
7. Technical
8. Shore Control Centre
9. Administration
### Sailing

1. Longitude/Latitude
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### Observations

1. List of targets (ARPA information for each target: name, CPA, TCPA, distance, bearing, COG, SOG)
2. GPS
3. AIS
4. Eco sounder
5. Wind/temperature/humidity/precipitation
6. Visibility (good/restricted)
7. Incoming VHF/MF/HF voice messages/GMDSS
8. Outdoor microphone
9. Radar images
10. Daylight video/IR images
11. Waves
12. Ships motions
METHOD & RESULTS

Safety/emergencies
1. Outdoor/indoor public announcement system
2. Anchors
3. Fire alarms/sprinklers
4. Water ingress/bilge pumps
5. Water tight doors

Security
1. Data security: Log-on to the ship
2. Intruder alarm
3. CCTV cameras
4. Door locks

Cargo/stability/strength
1. Tank levels
2. Ballast/tank pumps
3. Temperature/humidity/ventilation fans in cargo holds
4. Displacement sensors in cargo holds
5. CCTV cameras in cargo holds
Technical
1. Main engine RPM
2. Thruster (water jet) on/off
3. Thruster force
4. Thruster rotation
5. Electricity main board/emergency board/battery
6. Engine parameters…
7. Pilot ladder starboard/port up/down

Shore Control Centre
1. Control mode (Manual on-board, Autonomous, Remote controlled and Fail-to-safe)
2. Communication system…
3. Secondary communication system…
4. Incoming voice communication (VHF/MF/HF/…)
5. Incoming NAVTEX

Administrative
1. Pilot card information
2. Logs
3. Accumulated communication costs

Assumptions
The Shore Control Centre (mature technology)
1. SCC per 100 vessels
2. 1 operator per 6 vessels
3. 1 relieve operator per 5 operators
4. 1 supervisor per 30 vessels/5 operators
5. 1 situation room per 30 vessels
6. 1 engineer per 30 vessels
7. 1 bridge team (captain + the operator) per 30 ships
### Shore Control Center (SCC)

<table>
<thead>
<tr>
<th>Vessel 1</th>
<th>Operator</th>
<th>Vessel 2</th>
<th>Operator</th>
<th>Vessel 3</th>
<th>Operator</th>
<th>Vessel 4</th>
<th>Operator</th>
<th>Vessel 5</th>
<th>Operator</th>
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**Situation Team**
- Captain
- Chief Engineer
- Operator

### Electronic Nautical Chart

- Predictor
- "Safe haven" ships time slot
- Predicted maximum turn radius

### Shore Control Center

- Monitoring
- Indirect control
- Direct control
- Situation handling
METHOD & RESULTS

- Monitoring
- Indirect control
- Direct control
- Situation handling

Situation room: Team work, Immersion

3-D Nautical Chart

Picture insert from video/IR camera

Shore Control Center

3-D Nautical Chart

Voyage overview (spatial)

Voyage overview (temporal)

Conning display

London Venezuela

Email oct@orinocco.vz 24 hrs. before arrival

MONTH 2014

London Venezuela

Total voyage

Venezuela

London

Conning display

19:00 2014.07.03

Maintenance meeting

02:00 2014.07.04

Mail Orinoco pilots

Today 5 Oct. 2013

0:00 CET

18:00 local (15:00 UTC)

5:00 local (2:00 UTC)

16:00 local (11:00 UTC)

Noon

Midnight

Night

Day

Conning display

email oct@orinocco.vz 24 hrs. before arrival
Ship status

Operational status of unmanned vessel
Expected remaining running hours to next service based on guarantee or condition

- Level 1 (entire ship)
- Level 2 (ship departments)
- Level 3 (whole systems)
- Level 4 (part systems)
- Level 5 (etc.)

Hours
Level 1 (entire ship)
100
200
300
400

Maintaining critical life 200 hrs.

Time left to destination 240 hrs.

Possible repair Grand Canarias 135 hrs.

Click on bar to go down to lower level

Weather

Ship motions

Weather

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Watch schedule

- Time
- Automat Express
- Automat Emma
- Automat Luna
- Automat Beta
- Automat Victoria
- Automat Fox

Situation handling
- Anchored
- Drifting
- Radio control
- Drifting
- Autonomous control
- Autonomous on-board
- Top flag (green, yellow, red)

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Major research question:

We know that the vast majority of all accidents at sea to some degree depends on "human error." If we remove the human from direct operation of vessels, can we then remove "human error"?
### Human factors issues related to remote monitoring and control of unmanned ships

1. **Situation awareness** in the SCC: mistakes due to not understanding the true situation of the vessel.

2. **Misunderstandings in interaction with manned vessels**: latency in VHF communication, bad communication links, language issues same as for manned systems, but worsened by lack of situation awareness.

3. Delays in decision making due to lengthy time for operator to get into the loop (human-out-of-the-loop syndrome).

4. Stress and information overload because several ships might need the operators attention at the same time.

5. Human error due to "carry over effects" between two vessels as operator monitors several vessels at a time.

6. **Adverse weather** manual steering.

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### No unmanned ships in the Singapore strait

(for a long time)
Low hanging fruits

Power nap during the dog watch in the North Atlantic

An extra eye on the chart/radar in the Dover strait