AUTONOMOUS NAVIGATION
RESULTS FROM THE MUNIN TESTBED

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AGENDA

1. Introduction
2. MUNIN Test-bed
3. MUNIN Results
4. Outlook
Introduction

Fraunhofer CML’s conducts applied research for the industry

- Fraunhofer CML conducts applied research for the maritime industry
- Activities (amongst others)
  - Navigational safety and risks
  - Decisions support tools
  - Ship-shore-integration
  - Ship management
Introduction
Key facts of the MUNIN project

- European FP7 project from Sep 2012 to Aug 2015
- 8 partners with 2.9 million € funding
  - Develop a concept for an unmanned merchant vessel
  - Validate concept in a simulator set-up
Introduction
Vision of an unmanned deep-sea voyage
Introduction
Scope of MUNIN within the UMS taxonomy

MUNIN D4.7
- **Remotely Operated Ship (ROS)** is a fully humanly controlled ship, but controlled remotely via a communication link.
- **Unmanned Navigation Ship (UNS)** is a ship that can be navigated automatically or autonomously by onboard systems. Crew will be onboard for technical maintenance and operations and possibly for more complex navigational tasks.
- **Unmanned Autonomous Ship (UAS)** is a ship that can be operated completely without crew.
Introduction
Possible Efficiency Gains Related to Unmanned Ships

1. Light Ship Weight (no deckhouse) → Reduced fuel consumption

2. Air resistance (no deckhouse) → Reduced fuel consumption

3. Hotel systems (no crew living on board) → Reduced fuel consumption

4. Twin skeg / two engines design → Not quantified in analyses

Additionally: Ship intelligence benefits possible
Introduction
Possible Changes in New Building Cost for Unmanned Ships

1. No deckhouse (reduced material & production cost)
2. No hotel (air conditioning, heating, ventilation, etc.)
3. Autonomous ship technology (advances sensor module, deep-sea navigation system, etc.)
4. Redundancy of technical systems (communication, e-system, etc.)
5. Propulsion: twin skeg & two engines
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MUNIN overview
The new MUNIN sub-systems

- Advanced Sensor Module
- Shore Control Centre
- Maintenance Interaction System
- Remote Manoeuvring Support System
- Deep-Sea Navigation System
- Engine Monitoring & Control System
- Energy Efficiency System

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MUNIN Test-bed
Integrated simulations for validation

- Advanced Sensor Module
- Shore Control Centre
- Remote Manoeuvring Support System
- Deep-Sea Navigation System
- Engine Monitoring & Control System
- Maintenance Interaction System
- Energy Efficiency System
- Ship handling simulation

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MUNIN Test-bed
Ship handling simulators at Fraunhofer CML

Stealth View
Function: Free perspective

Ship Handling Simulator
Function: Real-time and interfaceable ship handling simulation

Data Base Generating Station
Function: Modelling of ship hydrodynamics, ENCs und 3D objects

Virtual Ship Handling Simulator
Function: Multi-ship simulation

Exclusively used for research and development projects
MUNIN Advanced Sensor Module
Sensor fusion approach

COLREG §5
Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate [...]

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MUNIN Deep-Sea Navigation System

Harsh weather handling

Weather routeing

- Determine optimal route and service speed profile
  - Routeing restrictions, fuel efficiency and safety included

- Avoid unfavorable weather conditions
  - Ship responses optimised
MUNIN Deep-Sea Navigation System
Collision avoidance approach

Collision avoidance

- Prevent close ship to ship encounters
  - COLREG-compliance required
- Evade other obstacles on the ship’s track
  - Not covered by COLREG

Collision Avoidance Log

<table>
<thead>
<tr>
<th>Head-on</th>
<th>Overtaking</th>
<th>Crossing</th>
<th>Nav. Status</th>
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<td>COLREG 13</td>
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</table>

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MUNIN Shore Control Center
Shore-side monitoring of up to six vessels

Human-in-the-loop

If x else
a --> 2.5
b =! 3.04
... {notify}
$ship_env
waiting…
MUNIN Remote Maneuvre Support System
Transfering the maneuvering awareness ashore

- Support SCC during direct remote control
- Provide maneuvering limits for autonomous control
MUNIN Test-bed
What has been done in MUNIN
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Results
Technology exists incl. implemented and integrated prototypes

- Deep-Sea Navigation System (TRL 3)
- Remote Manoeuvring Support System (TRL 3)
- Engine Monitoring & Control System (TRL 2-3)
- Maintenance Interaction System (TRL 3)
- Shore Control Centre (TRL 3)
- Energy Efficiency System (TRL 3)
- Advanced Sensor Module (TRL 4-5)

Ship handling simulation
Results
Commercial use case depends on the concrete vessel and case

MUNIN vs conventional bulker
HFO scenario // Deep-Sea

- Higher newbuilding cost: +3.4 mUSD
- Crew cost: -10.5 mUSD
- Land based services: +2.8 mUSD
- Better fuel efficiency: -2.8 mUSD
- MUNIN: -7.1 mUSD

MDO scenario // Deep-Sea

- Higher newbuilding cost: +3.4 mUSD
- Crew cost: -10.5 mUSD
- Land based services: +2.8 mUSD
- MDO as fuel: +33.9 mUSD
- MUNIN: +29.6 mUSD

Cost-NPV (mUSD)

Ship intelligence not considered
Results
Safety gains shall pave the way for legal adjustments

Risk Assessment

<table>
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<th>RISK</th>
<th>Collision</th>
<th>Foundering</th>
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</table>

Legal and Liability assessment

- Master’s responsibility
- ANS responsibility
- SCC operator responsibility

Main issues
- How to change master’s responsibility
- COLREG compliance of an ANS
- Cargo salvage during outages
- Cyber risk and hull insurance
Results
Next steps, e.g. large scale safety assessment within the EMSN
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Application areas
Alternative types might be beneficial for UAS

MUNIN vs conventional bulker
MDO scenario // Short-Sea

- Higher newbuilding cost: +3,4 mUSD
- Crew cost: -10,5 mUSD
- Land based services: +2,8 mUSD
- Better fuel efficiency: -4,2 mUSD
- MUNIN: -9,6 mUSD

MUNIN vs conventional bulker
Crew effect; no efficiency // Deep-Sea

- Higher newbuilding cost: +3,4 mUSD
- Crew cost: -10,5 mUSD
- Land based services: +2,8 mUSD
- Additional port call cost: +3,2 mUSD
- MUNIN: -1,1 mUSD
Outlook
Intermediate steps expected e.g. B0

B0 - Periodical unattended vessel

- Less manning on-board
- Flex time for nautical officer
Outlook
Continuous research on B0-technologies together with DSME
Outlook
Intermediate steps expected e.g. shore side shipping
Outlook
How does it look - tomorrow

Is it totally unmanned? We will see …
Thank you for your attention
MUNIN received funding under FP7-GA314286