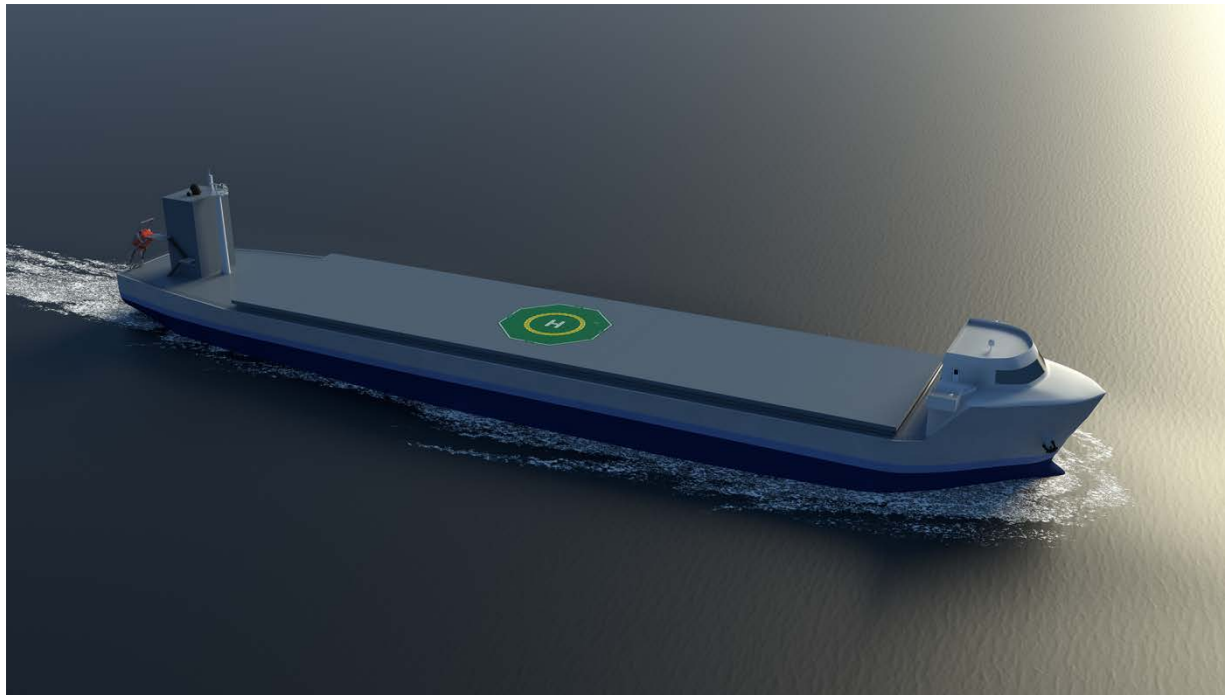# AUTONOMOUS NAVIGATION RESULTS FROM THE MUNIN TESTBED

Dipl.-Wirtsch.-Ing. Univ. Hans-Christoph Burmeister

21.06.2016 – Autonomous Ship Technology Symposium, Amsterdam
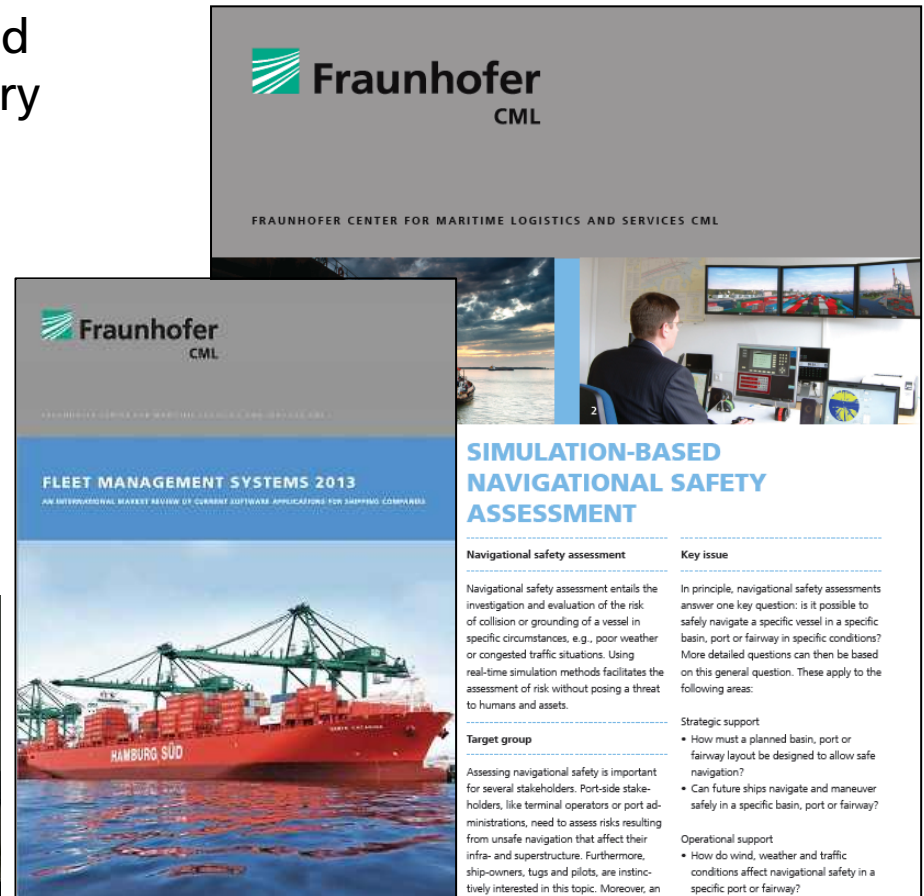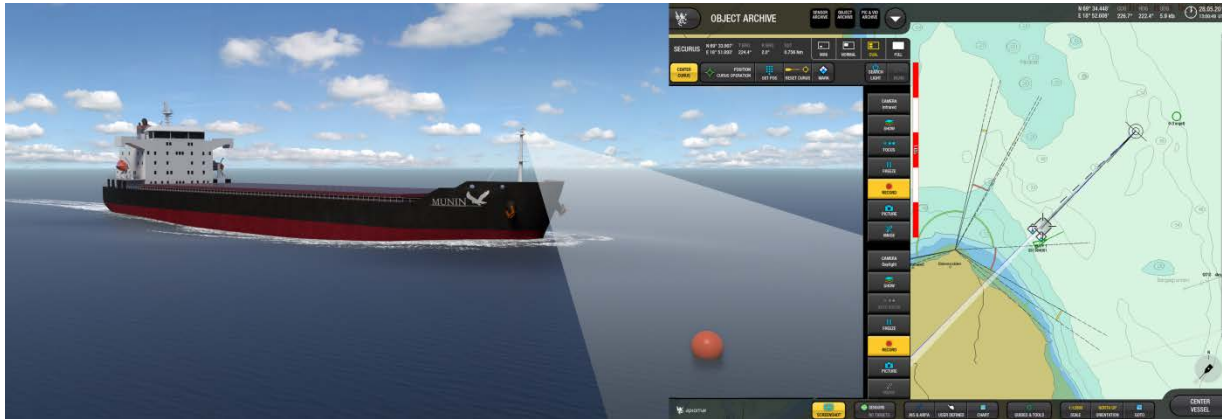
AGENDA

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

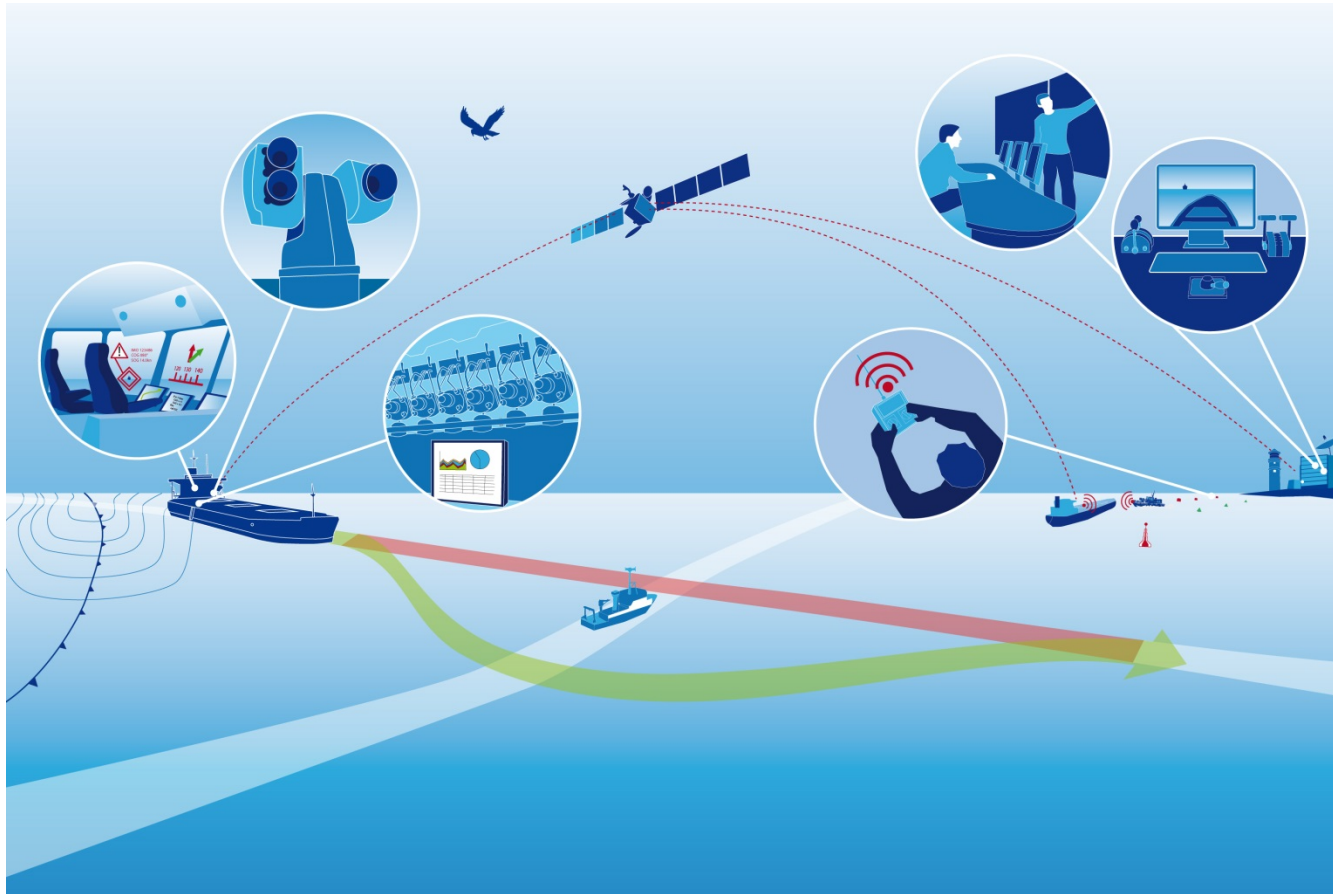 - Ship-shore-integration

  - Ship management

Introduction
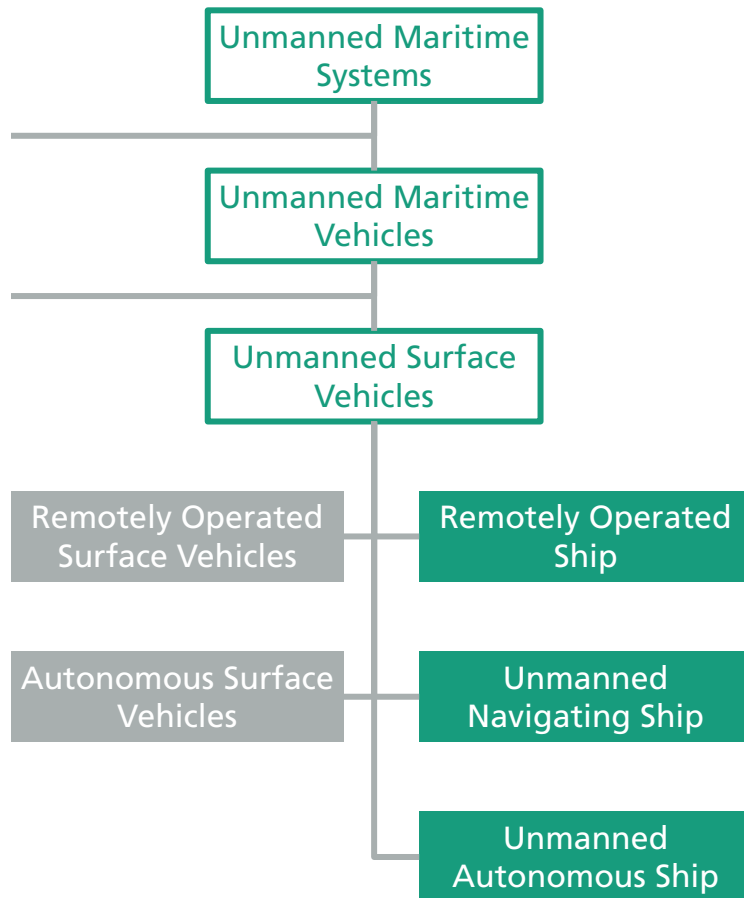## Key facts of the MUNIN project

- **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 taxanomy

```
┌─────────────────────┐
│ Unmanned Maritime   │
│ Systems             │
└─────────────────────┘
          │
┌─────────────────────┐
│ Unmanned Maritime   │
│ Vehicles            │
└─────────────────────┘
          │
┌─────────────────────┐
│ Unmanned Surface    │
│ Vehicles            │
└─────────────────────┘
```

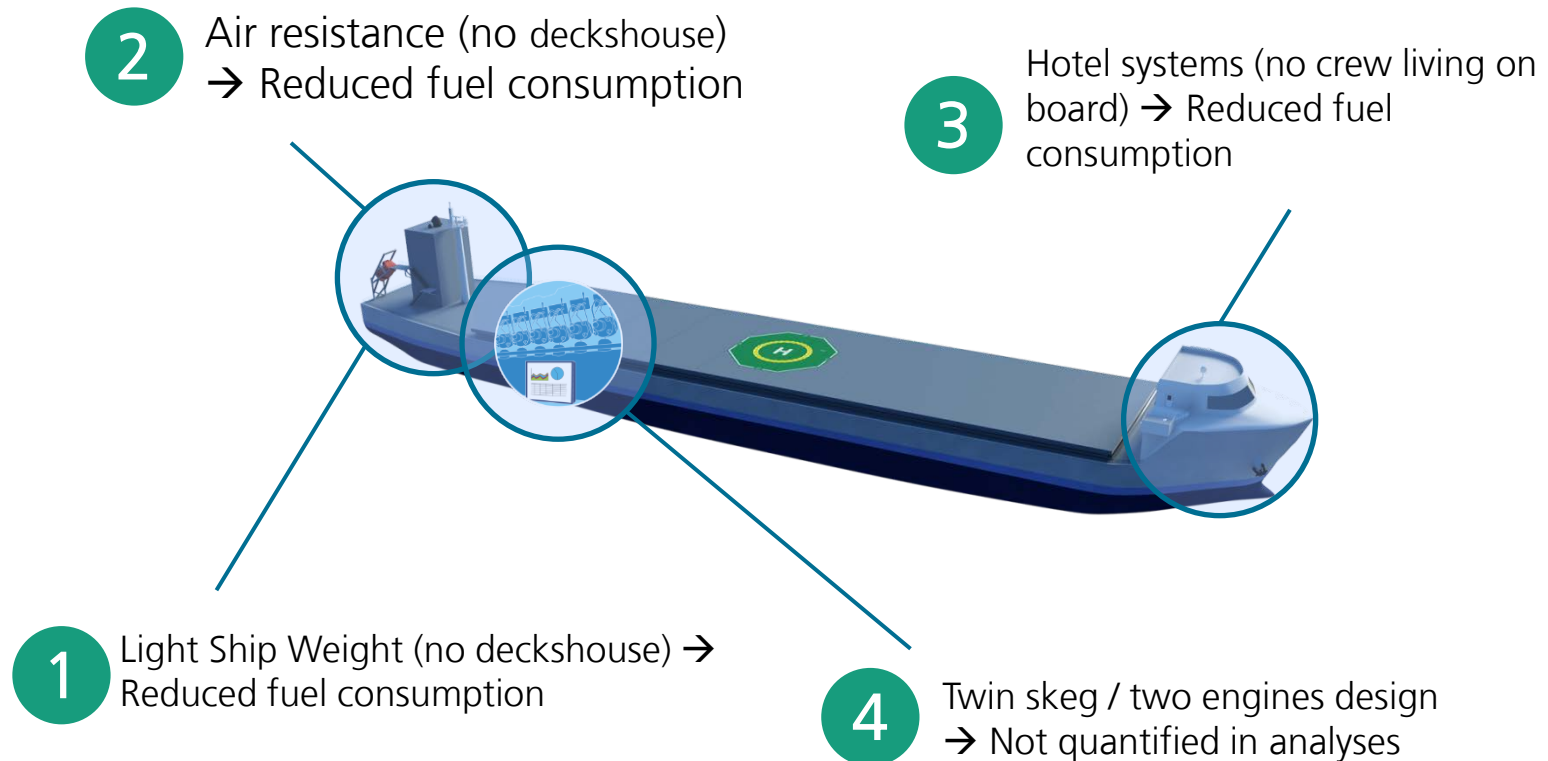| Remotely Operated Surface Vehicles | Remotely Operated Ship |
| Autonomous Surface Vehicles | Unmanned Navigating Ship |
| | Unmanned Autonomous Ship |

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.

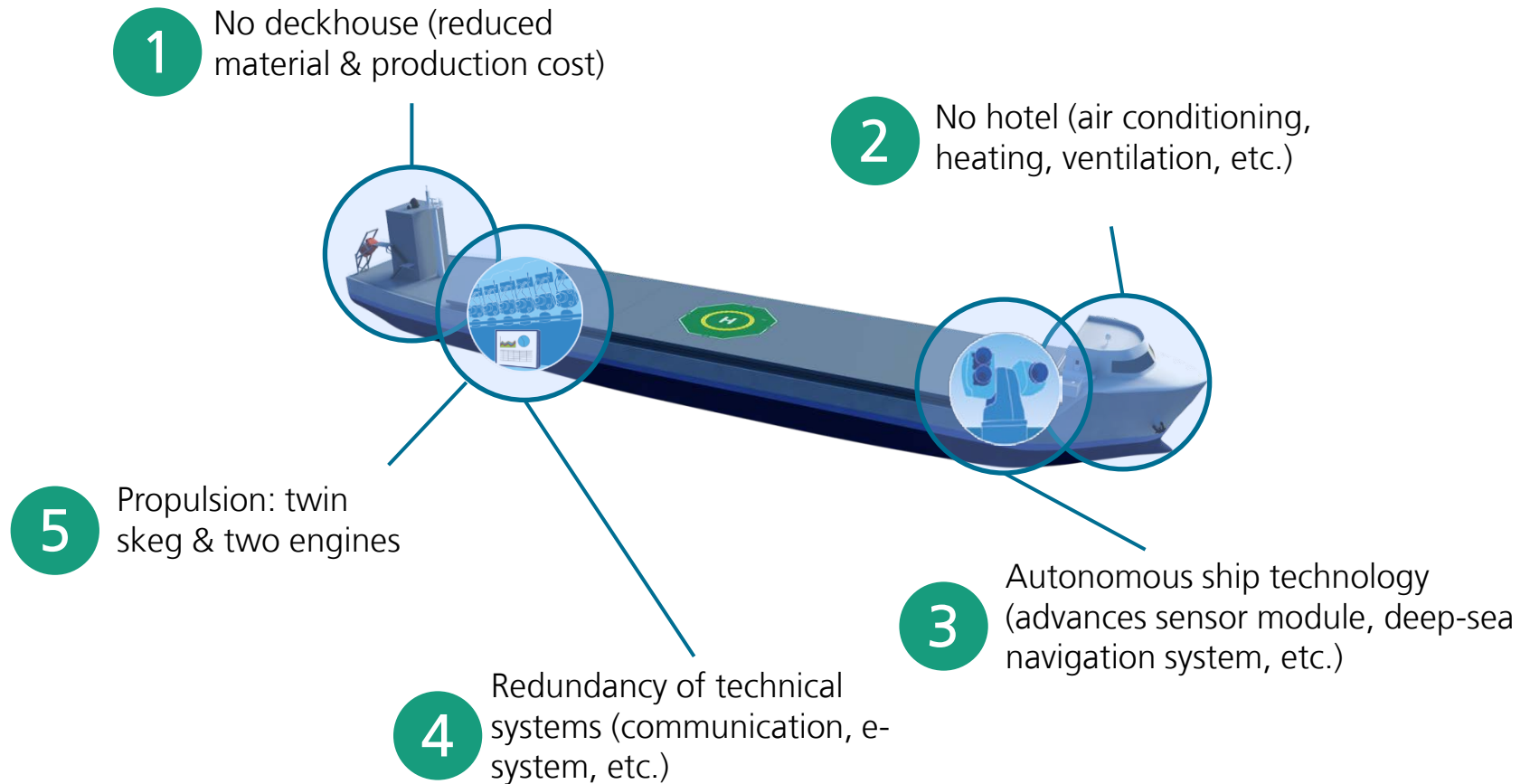- **Unmanned Autonomous Ship (UAS)** is a ship that can be operated completely without crew.

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Introduction
Possible Efficiency Gains Related to Unmanned Ships

2 Air resistance (no deckshouse) → Reduced fuel consumption

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

1 Light Ship Weight (no deckshouse) → Reduced fuel consumption

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

Additionally: Ship intelligence benefits possible

Introduction
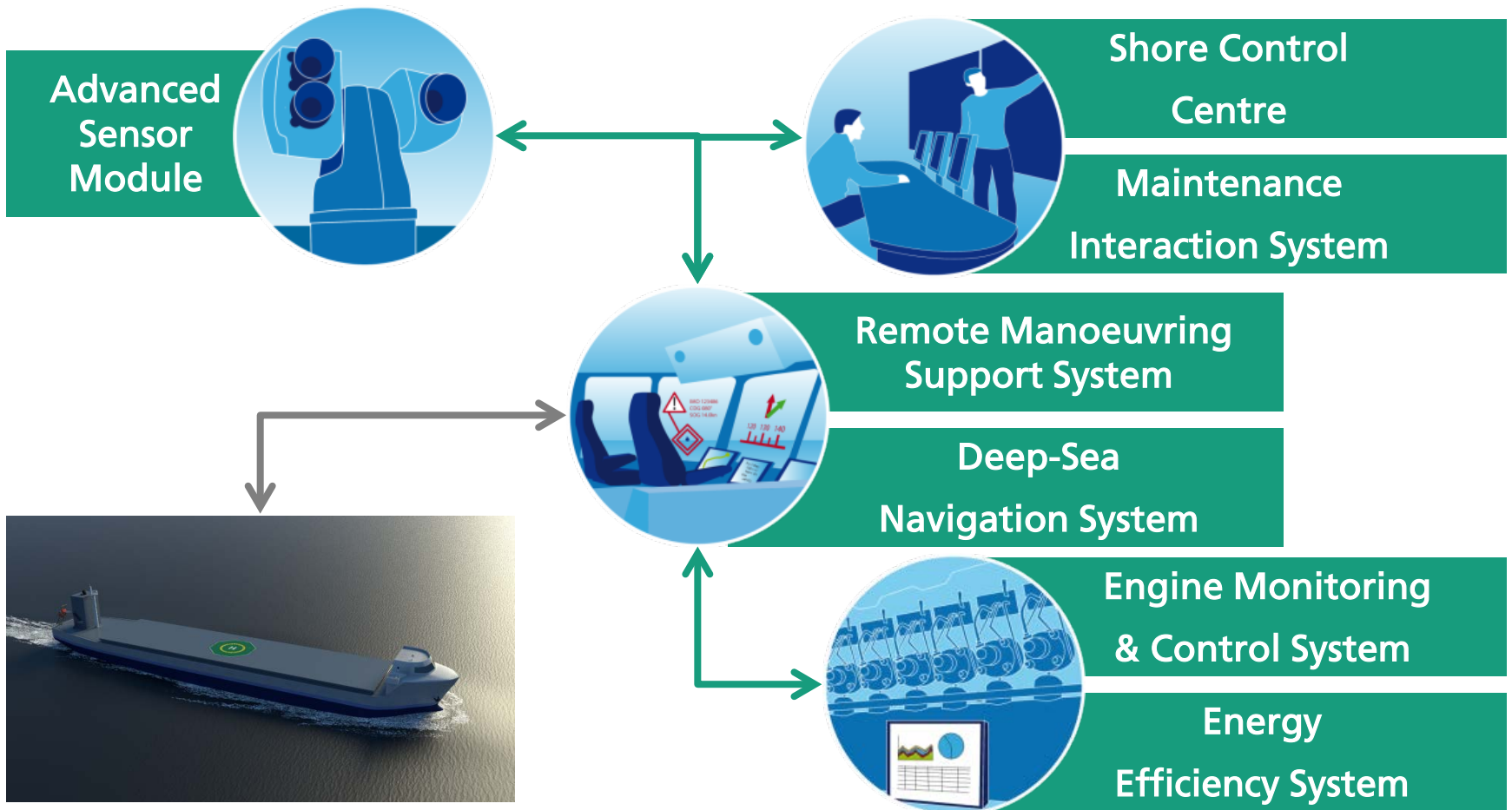## Possible Changes in New Building Cost for Unmanned Ships

1 No deckhouse (reduced material & production cost)

2 No hotel (air conditioning, heating, ventilation, etc.)

5 Propulsion: twin skeg & two engines

3 Autonomous ship technology (advances sensor module, deep-sea navigation system, etc.)

4 Redundancy of technical systems (communication, e-system, etc.)

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AGENDA

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

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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

Fraunhofer CML

MUNIN Test-bed
Integrated simulations for validation

Advanced Sensor Module

Shore Control Centre

Maintenance Interaction System

Remote Manoeuvring Support System

Deep-Sea Navigation System

Engine Monitoring & Control System

Energy Efficiency System

Ship handling simulation
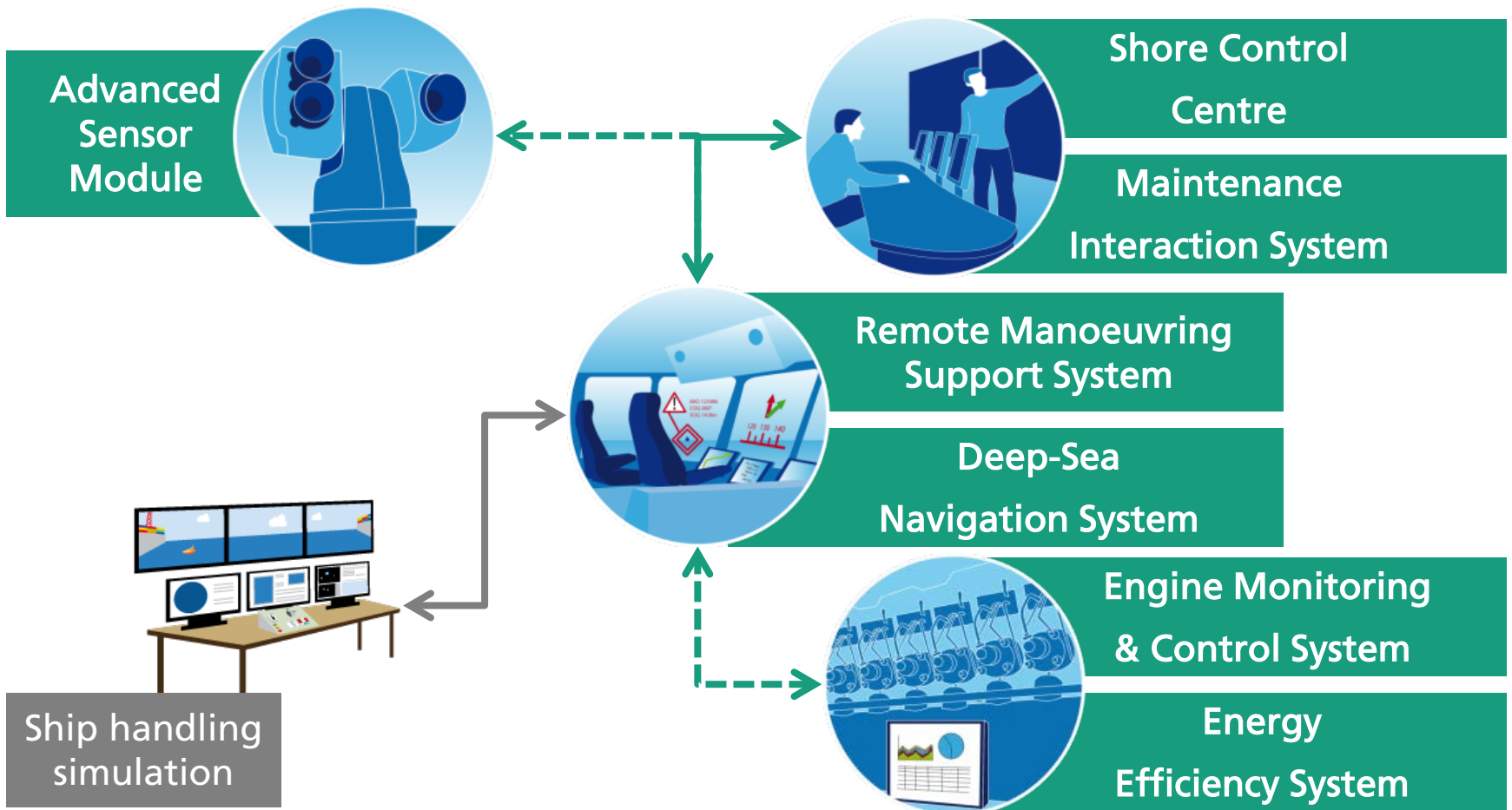
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MUNIN Test-bed
Ship handling simulators at Fraunhofer CML

Stealth View
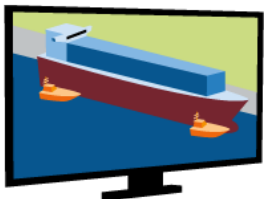
Function:
Free perspective

Ship Handling Simulator

Function:
Real-time and interfaceable
ship handling simulation

**Data Base Generating
Station**
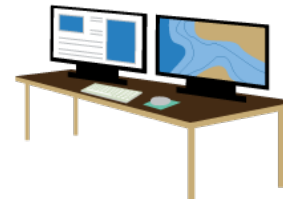
Function:
Modelling of ship hydro-
dynamics, ENCs und 3D objects

**Virtual Ship Handling
Simulator**

Virtual SHS

Function:
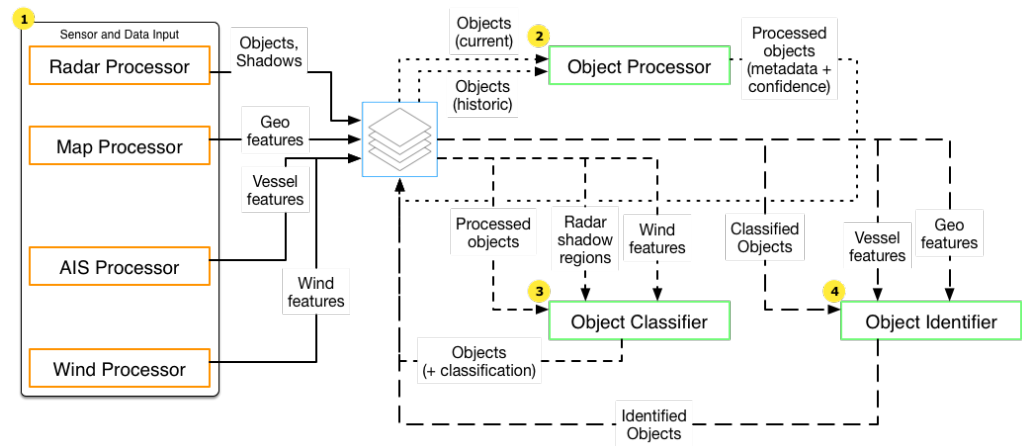Multi-ship simulation

Exclusively used for research and development projects

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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 […]
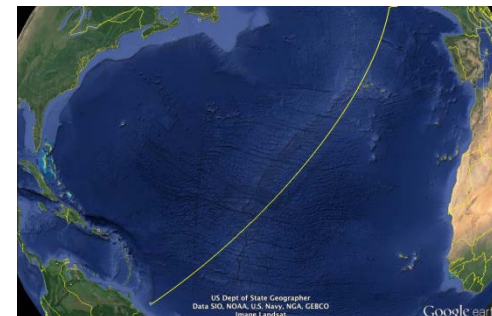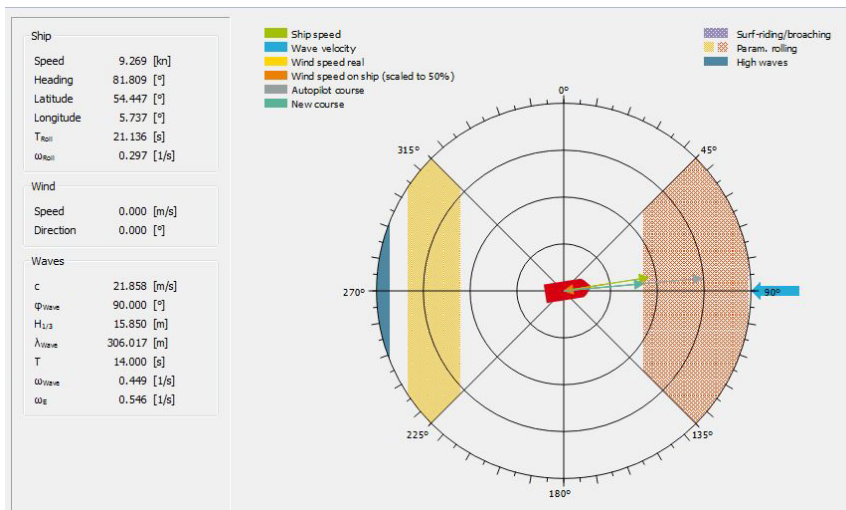
MUNIN Deep-Sea Navigation System
Harsh weather handling

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
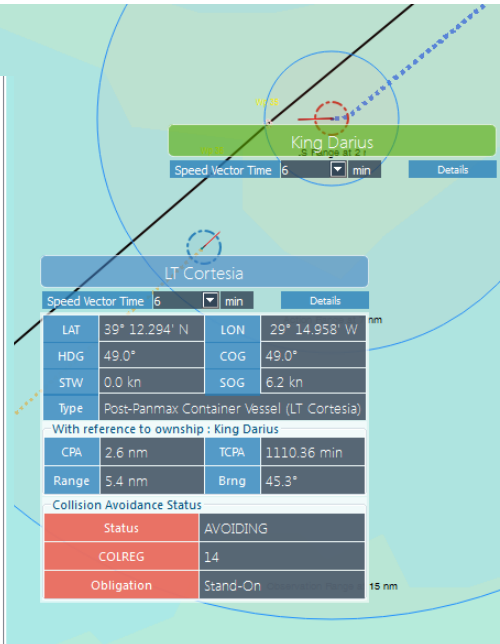## Collision avoidance approach

Collision avoidance

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

Head-on COLREG 13	Overtaking COLREG 14	Crossing COLREG 15	Nav. Status COLREG 18	Restricted COLREG 19

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…
```
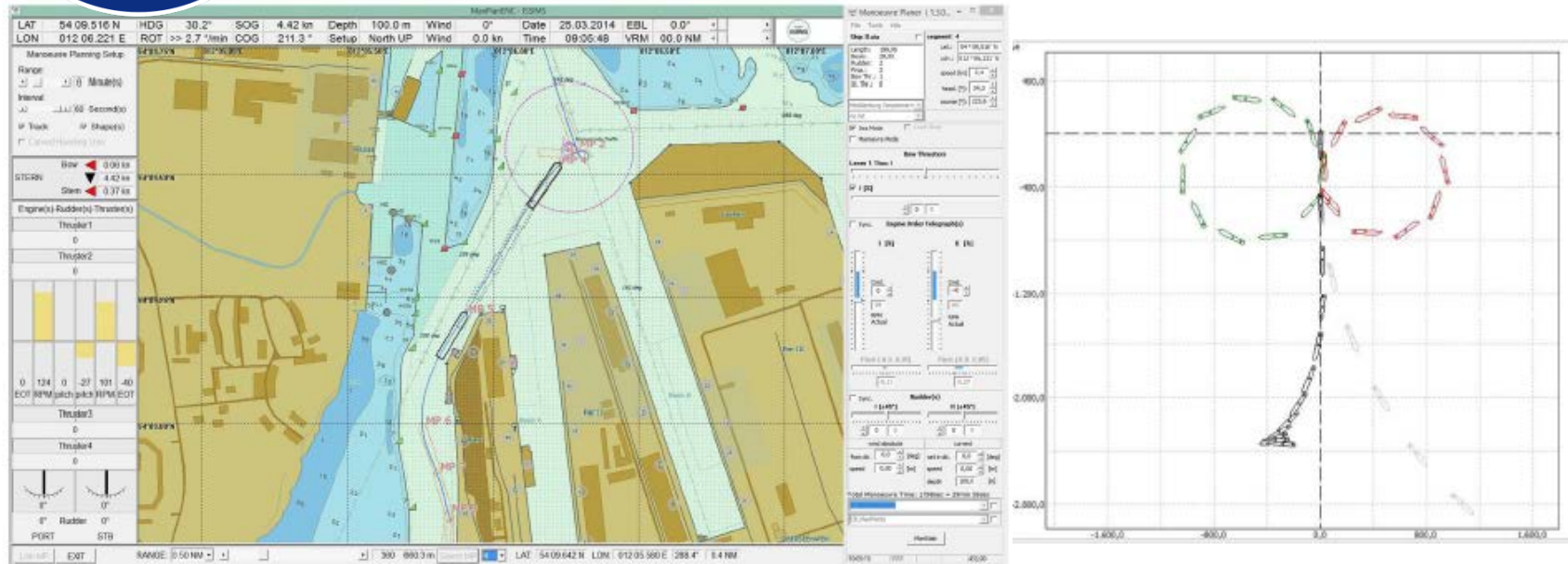
§

€

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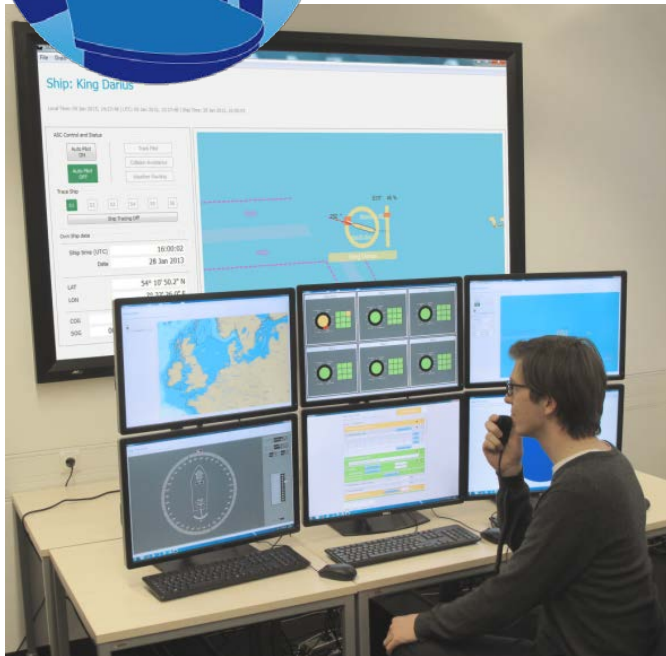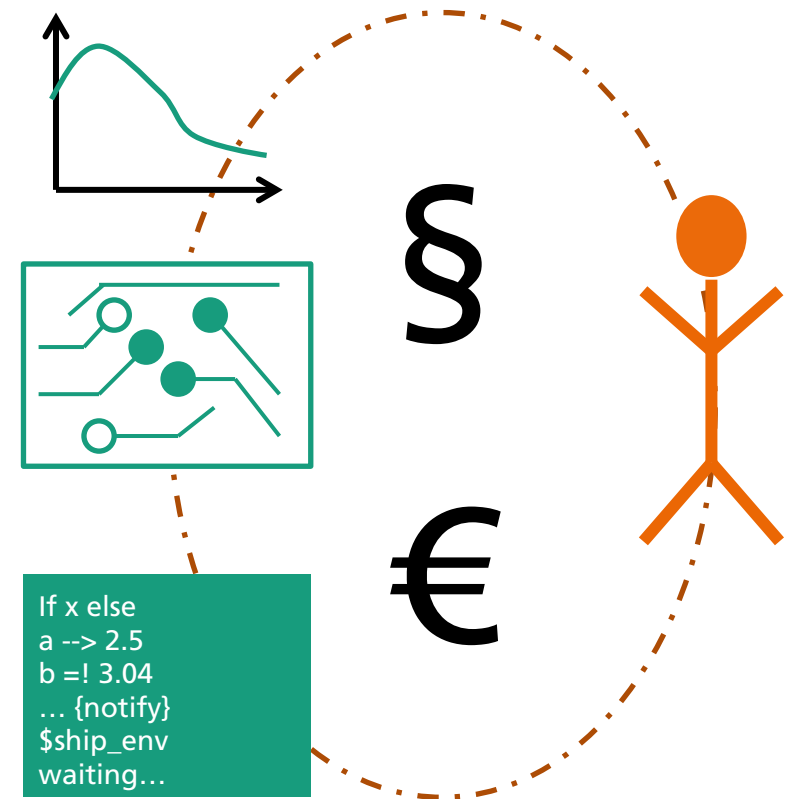
MUNIN Remote Maneuvre Support System
Transfering the maneuvering awareness ashore

- Support SCC during direct remote control
- Provide maneuvering limits for autonomous control

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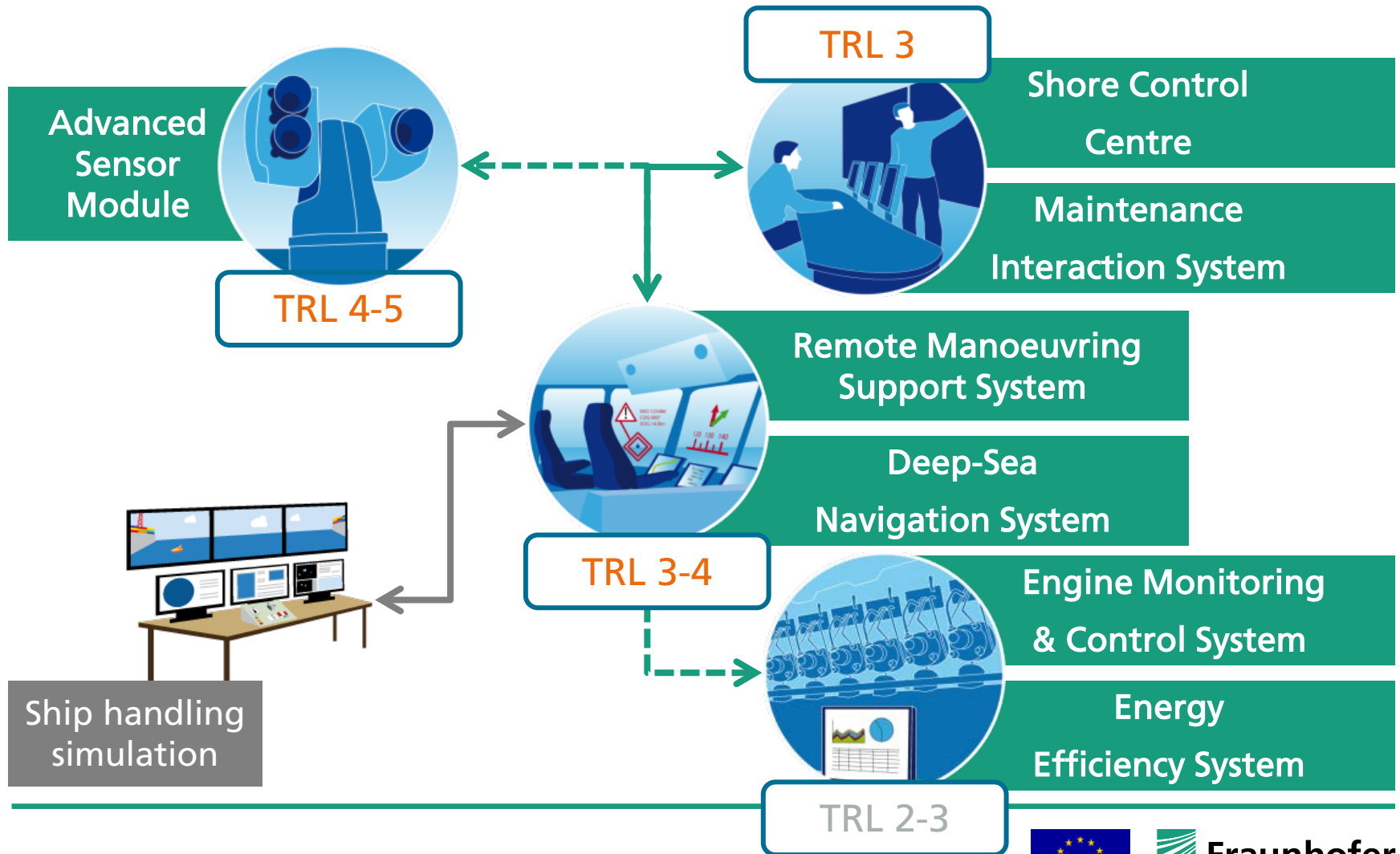# MUNIN Test-bed
What has been done in MUNIN

AGENDA

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

CML

Results
Technology exists incl. implemented and integrated prototypes

Advanced Sensor Module — TRL 4-5

TRL 3

Shore Control Centre

Maintenance Interaction System

Remote Manoeuvring Support System

Deep-Sea Navigation System

TRL 3-4

Engine Monitoring & Control System

Energy Efficiency System

TRL 2-3

Ship handling simulation

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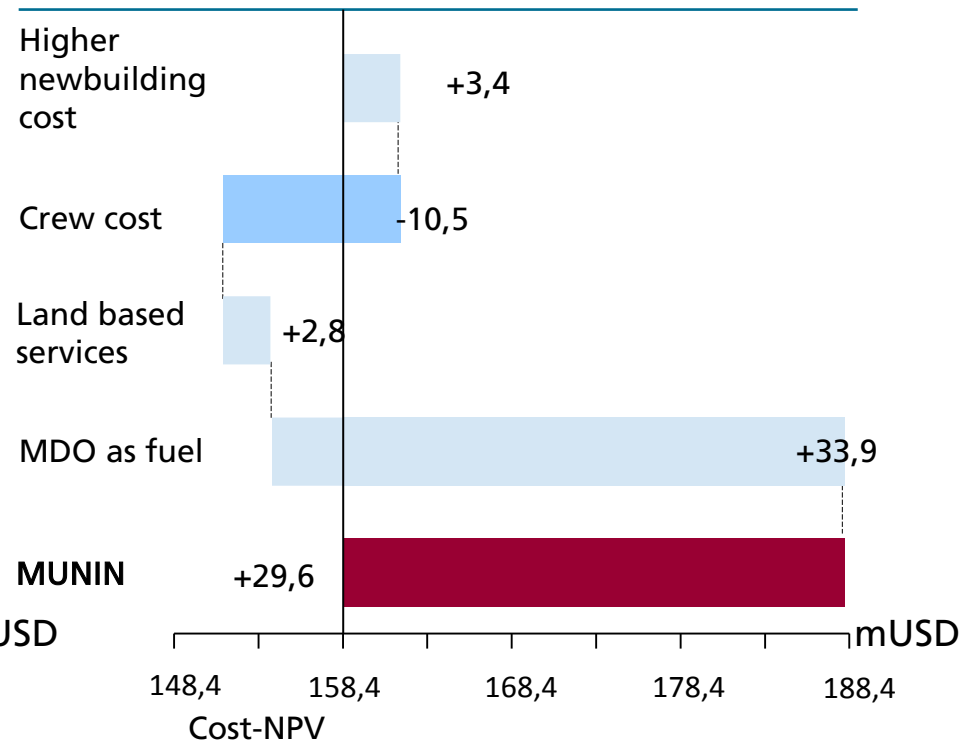CML

Results
Commercial use case depends on the concret vessel and case

MUNIN vs conventional bulker

HFO scenario // Deep-Sea

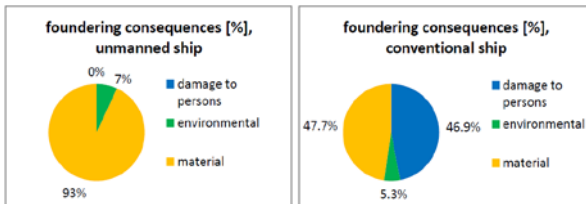|	
Higher newbuilding cost	3,4
Crew cost	-10,5
Land based services	+2,8
Better fuel efficiency	-2,8
MUNIN	-7,1

Ship intelligence not considered

mUSD

148,4 150,9 153,4 155,9 158,4 160,9 163,4

Cost-NPV
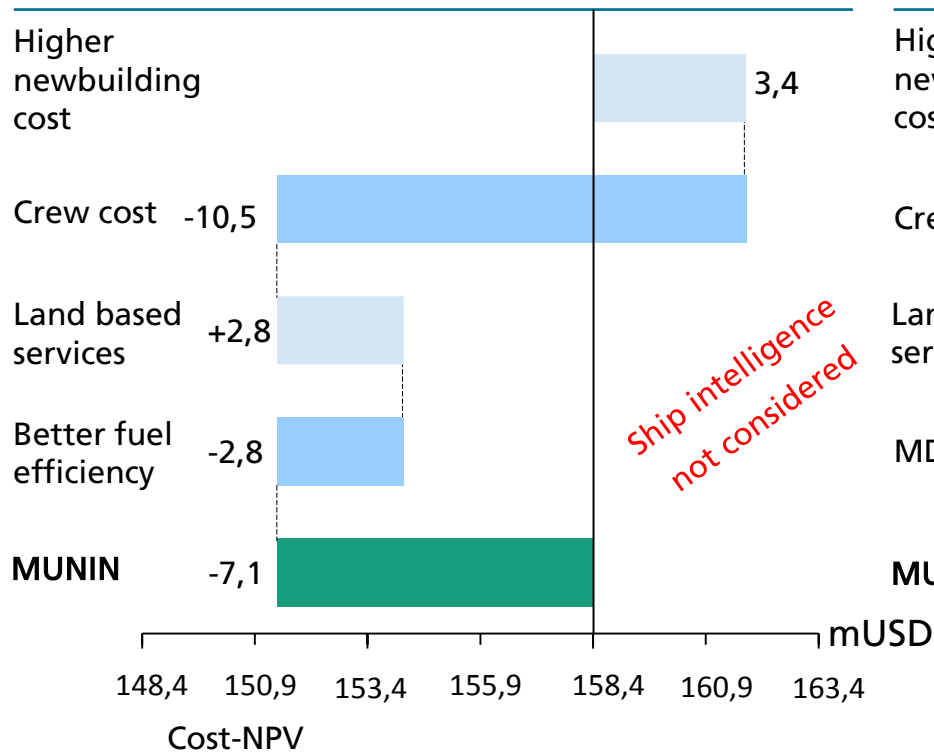
MUNIN vs conventional bulker

MDO scenario // Deep-Sea

Higher newbuilding cost	+3,4
Crew cost	-10,5
Land based services	+2,8
MDO as fuel	+33,9
MUNIN	+29,6

mUSD

148,4 158,4 168,4 178,4 188,4

Cost-NPV

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Results
Safety gains shall pave the way for legal adjustments

Risk Assessment

RISK

Collision

10^{-5} ● 10^{-6}

Foundering

10^{-1} ● 10^{-2}

foundering consequences [%], unmanned ship
- damage to persons
- environmental
- material
0% 7% 93%

foundering consequences [%], conventional ship
- damage to persons
- environmental
- material
47.7% 46.9% 5.3%
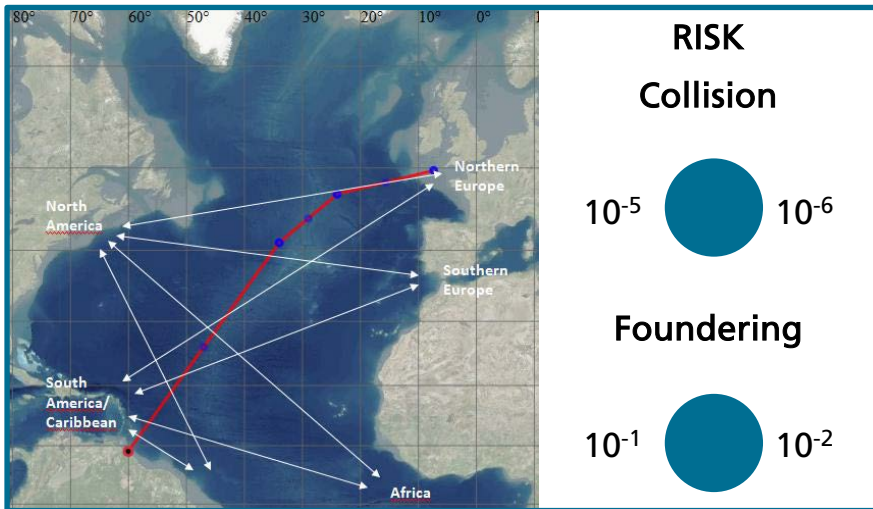
Legal and Liability assessment

Master's responsibility
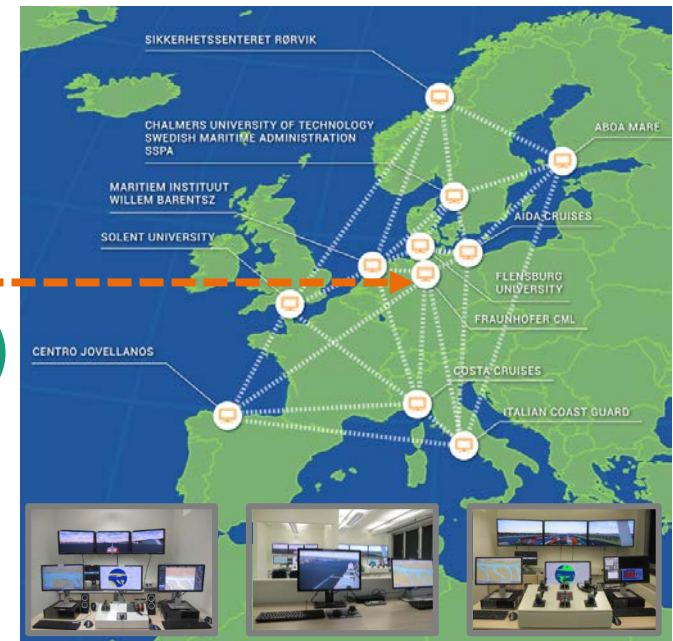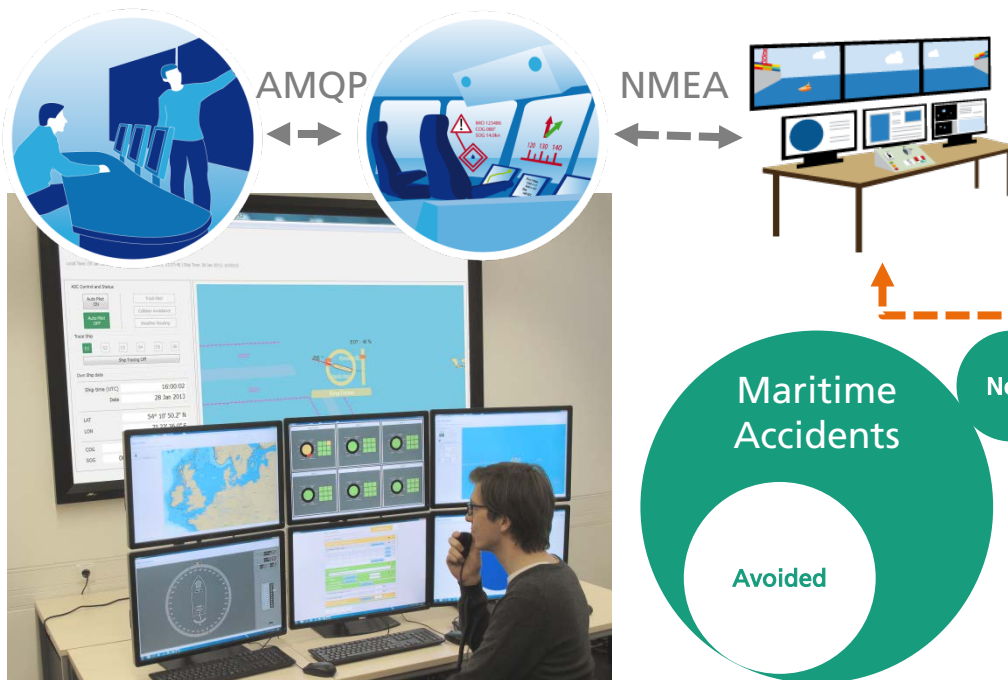
ANS responsibility   SCC operator responsibility
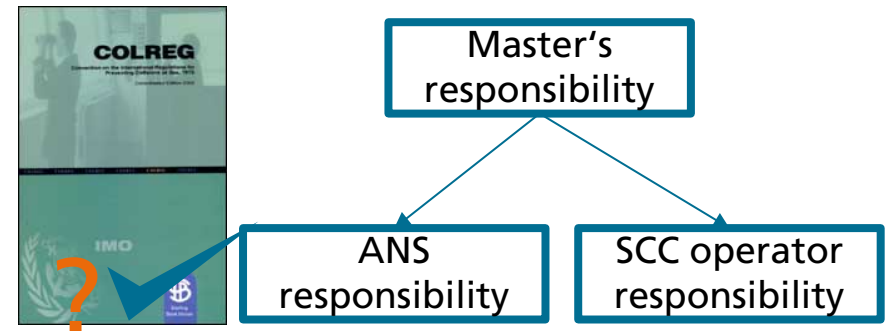
Main issues

- How to change master's responsibility

- COLREG compliance of an ANS

- Cargo salvage during outages

- Cyber risk and hull insurance

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Results
Next steps, e.g. large scale safety assessment within the EMSN

AMQP

NMEA

Maritime Accidents
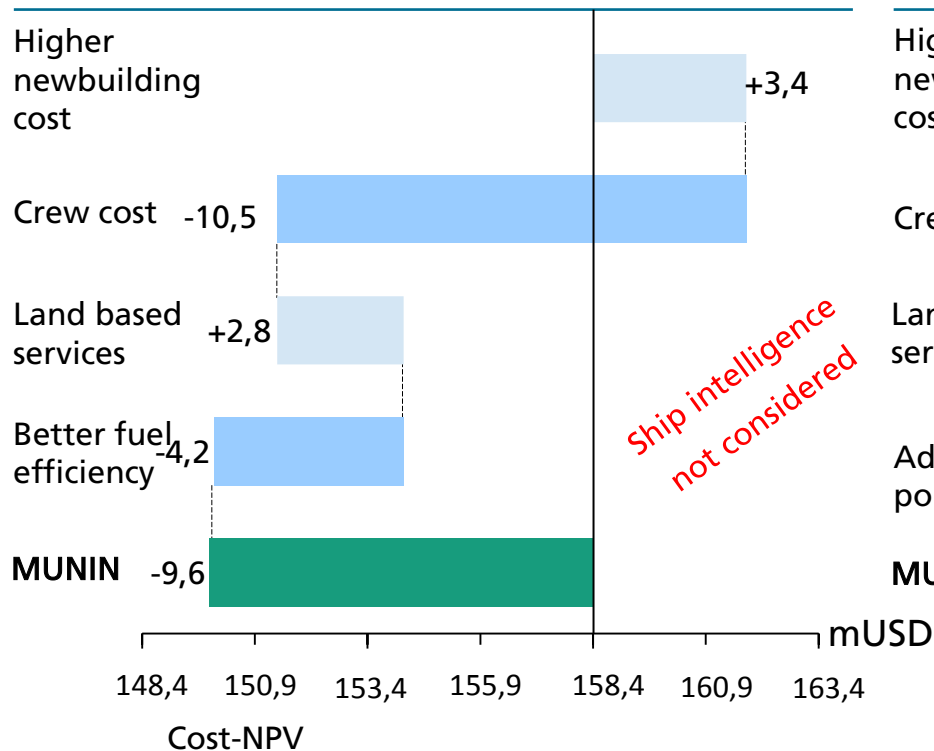
New

Avoided

AGENDA

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

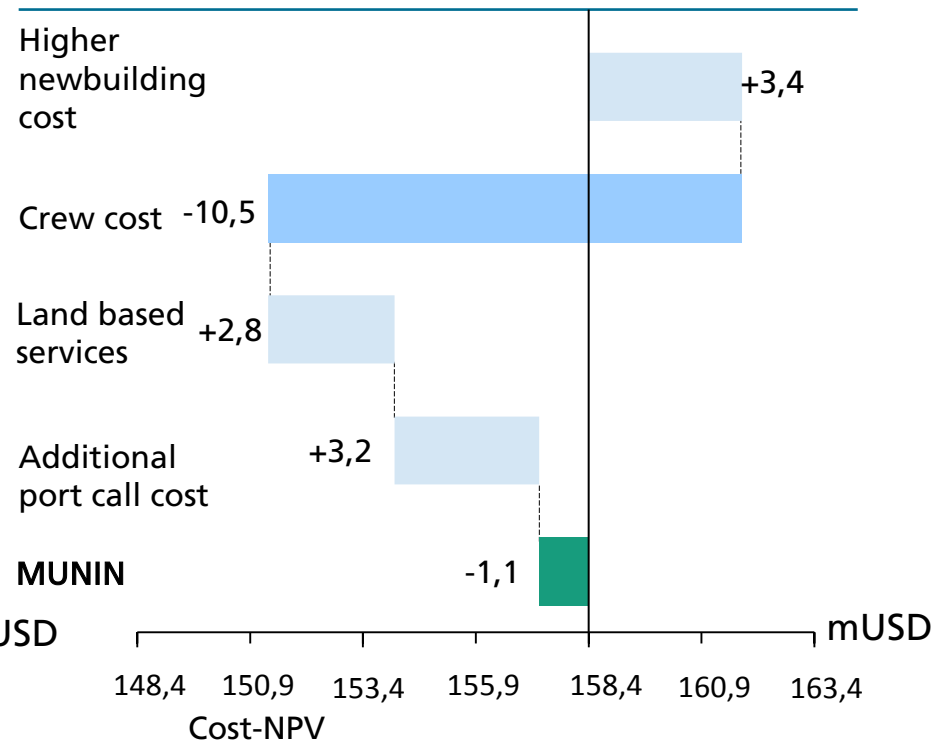# Application areas
Alternative types might be beneficial for UAS

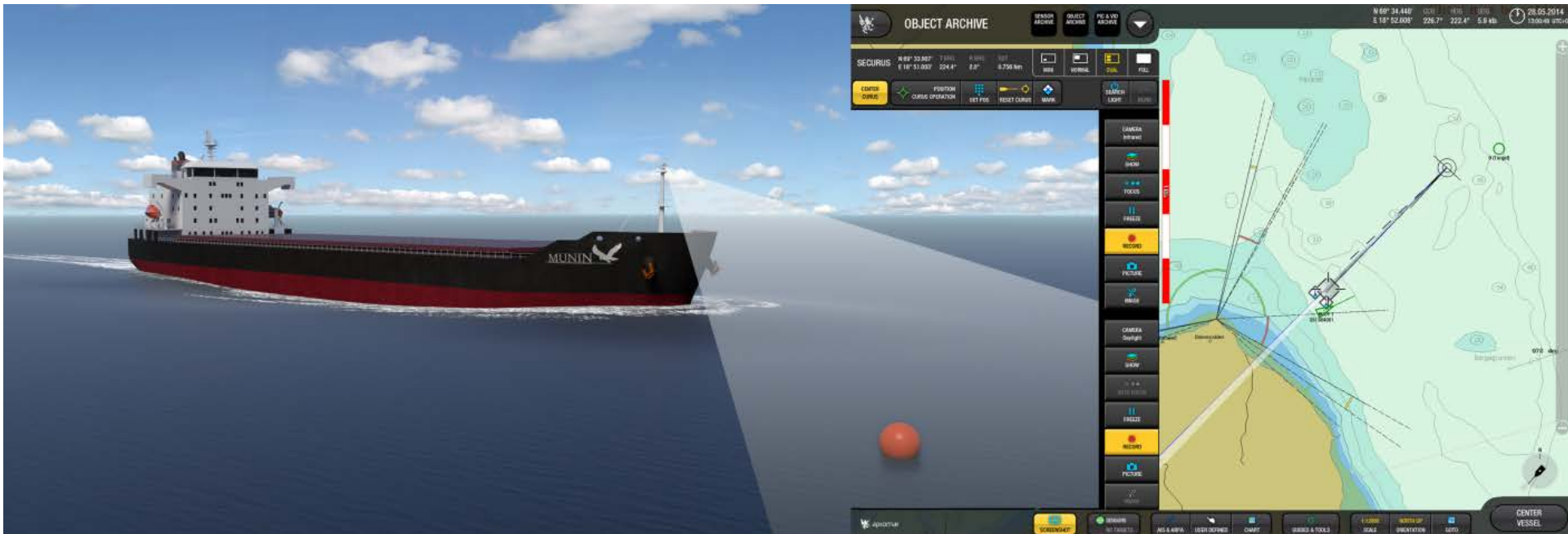### MUNIN vs conventional bulker
MDO scenario // Short-Sea

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

mUSD

148,4 150,9 153,4 155,9 158,4 160,9 163,4

Cost-NPV

Ship intelligence not considered

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

Higher newbuilding cost	+3,4
Crew cost	-10,5
Land based services	+2,8
Additional port call cost	+3,2
MUNIN	-1,1

mUSD

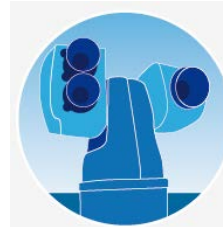148,4 150,9 153,4 155,9 158,4 160,9 163,4

Cost-NPV

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Outlook
Intermediate steps expected e.g. B0

B0 - Periodical unattended vessel

- Less manning on-board
- Flex time for nautical officer

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Outlook
Continious 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

Fraunhofer CML

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