Communication Architecture for an Unmanned Merchant Ship

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http://www.unmanned-ship.org

SST.2012.5.2-5: Grant no. 314286
E-guided vessels: The 'autonomous' ship
Content

- Introduction into MUNIN
- Autonomous operation modes on-board and ashore
- Available communication systems
- Communication requirements
- Conclusion on the architecture
MUNIN key facts

- European FP7 project from Sep 2012 to Aug 2015
- 8 partners with 2.9 million € funding
- Focus:
  - Develop a concept for an unmanned merchant vessel
  - Validate concept in a simulator set-up

*Maritime Unmanned Navigation through Intelligence in Networks*
MUNIN rationale

- Economics: Reduced manning costs
- Social: Shifting jobs ashore
- Environmental: Increase slow steaming

<table>
<thead>
<tr>
<th>Route</th>
<th>Porto de Tubarao -&gt; Hamburg (Charter = forecast until 2016)</th>
<th>Change due to slow steaming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance [nm]</td>
<td>5446</td>
<td>-31%</td>
</tr>
<tr>
<td>Speed [kn]</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Time [d]</td>
<td>14,2</td>
<td>20,6</td>
</tr>
<tr>
<td>Fuel [t]</td>
<td>624,0</td>
<td>288,8</td>
</tr>
<tr>
<td>CO2 [t]</td>
<td>1.978,1</td>
<td>915,5</td>
</tr>
<tr>
<td>Charter [US$]</td>
<td>230.935,0</td>
<td>335.905,4</td>
</tr>
<tr>
<td>Bunker [US$]</td>
<td>405.613,5</td>
<td>187.722,0</td>
</tr>
<tr>
<td>Total [US$]</td>
<td>636.548,5</td>
<td>523.627,4</td>
</tr>
<tr>
<td>Manning [US$]</td>
<td>33.456,0</td>
<td>48.663,3</td>
</tr>
<tr>
<td>Manning/Total</td>
<td>5,26%</td>
<td>9,29%</td>
</tr>
</tbody>
</table>

Distances by www.vesseldistance.com
MUNIN Vision
Content

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Operational modes on-board

Manned operation

Autonomous execution

Unintended event solved

Human support no longer required

Remote control

Interaction possibility restored

Fail to safe

Crew disembarked

Unintended event detected

Human support required

Interaction possibility lost

Critical situation waiting for response or interaction possibility lost

Emergency crew embarked
SCC: Operational modes

- Remote monitoring
- Remote operation
- Status investigation and ASC Updates
- Intervention
SCC: Monitoring in practice

Status indicators:

- Location
- Weather
- Visibility
- Collision
- Grounding
- Communication
- Stability
- (engine-related indicators)
# SCC: Status investigation

- **Collision**
- **Grounding**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Detailed description elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Position, heading, speed, distance from planned position as well as a position quality flag.</td>
</tr>
<tr>
<td>Weather</td>
<td>Wind speed/direction, wave and swell height/length/direction</td>
</tr>
<tr>
<td>Visibility</td>
<td>Visibility IR/Normal, radar range and clutter. COLREG status of ship.</td>
</tr>
<tr>
<td>Collision</td>
<td>Vectors to targets, status/heading/speed of targets.</td>
</tr>
<tr>
<td>Grounding</td>
<td>Depth measurement</td>
</tr>
<tr>
<td>Comm</td>
<td>Critical communication directly to ship, e.g., on VHF, GMDSS.</td>
</tr>
<tr>
<td>Stability</td>
<td>Trim, heel, draft, watertight integrity, void space, water ingress.</td>
</tr>
</tbody>
</table>
**SCC: Types of remote operation**

**Indirect control**
Operator adjusts route, track is followed by autopilot

**Direct control**
Operator adjusts speed and heading directly

**Situation room**
Operator connects bridge to Full-mission bridge, where the ship is controlled by a complete bridge team
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State-of-the-art satellite communication

- MUNIN focus on deep sea voyage, thus satellite communication is the main communication channel

- Available satellite communication links and bandwidth limits
  - Inmarsat 432 kbit/s
  - Global Xpress 5-50 Mbit/s
  - Iridium 134 kbit/s
  - VSAT Intelsat 4 Mbit/s

- Challenges
  - Not all systems provide global coverage
  - Signal transit disturbances
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Ship status indicators

- Three dimensions per flag
  - **Functional Status Index**: Status of the function fulfillment
  - **Technical Status Index**: Capability of technical system to support function fulfillment
  - **Technical Condition Index**: Indication of expected change of the degree of supporting capability

- Possible statuses
  - **Green: Monitoring**: No specific action from the SCC operator needed
  - **Yellow: Attention**: SCC operator should get familiar with the situation
  - **Red: Intervention**: Autonomous ship requires assistance of the SCC operator

- One status update each five seconds
- Only intervention necessity is indicated
<table>
<thead>
<tr>
<th>Indicator</th>
<th>Detailed description elements</th>
<th>Data reference</th>
<th>FSI Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Position, heading, speed, distance from planned position as well as a position quality flag.</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Weather</td>
<td>Wind speed/direction, wave and swell height/length/direction</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>Visibility</td>
<td>Visibility IR/Normal, radar range and clutter. COLREG status of ship.</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Collision</td>
<td>Vectors to targets, status/heading/speed of targets.</td>
<td>5 ships/objects in vicinity</td>
<td>40</td>
</tr>
<tr>
<td>Grounding</td>
<td>Depth measurement</td>
<td>Depth, distance to shore,</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>complexity</td>
<td></td>
</tr>
<tr>
<td>Comm</td>
<td>Critical communication directly to ship, e.g., on VHF, GMDSS.</td>
<td>GMDSS, NAVTEX, DSC, AIS specials</td>
<td>270</td>
</tr>
<tr>
<td>Stability</td>
<td>Trim, heel, draft, watertight integrity, void space, water ingress.</td>
<td>-</td>
<td>20</td>
</tr>
</tbody>
</table>
## Detailed description elements (Engine)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Detailed description elements</th>
<th>Data reference</th>
<th>FSI Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Env.</td>
<td>Environmental performance and emissions to air and sea.</td>
<td>NOx, SOx, PM, Waste, Oil, GHG</td>
<td>12</td>
</tr>
<tr>
<td>Economy</td>
<td>Fuel use and potential for late arrival/off hire etc.</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Hull Equipment</td>
<td>Hull and equipment status, anchor, towing, ladders.</td>
<td>Hull monitoring, corrosion, etc.</td>
<td>12</td>
</tr>
<tr>
<td>Propulsion</td>
<td>Propeller and steering systems</td>
<td>Direction, speed anomalies</td>
<td>4</td>
</tr>
<tr>
<td>Machinery</td>
<td>Engine, auxiliaries, piping, fuel.</td>
<td>Power, steam, auxiliary, hydraulic etc</td>
<td>10</td>
</tr>
<tr>
<td>Electric</td>
<td>Electric power systems, switchboards, emergency power.</td>
<td>Generators, switchboard, emergency</td>
<td>6</td>
</tr>
<tr>
<td>Safety</td>
<td>Fire, evacuation, extinguishing, escape.</td>
<td>Main fire zones</td>
<td>16</td>
</tr>
<tr>
<td>Cargo</td>
<td>Cargo status</td>
<td>Temperature, humidity, levels, 5 holds</td>
<td>30</td>
</tr>
</tbody>
</table>
Additional image data

<table>
<thead>
<tr>
<th>System</th>
<th>Resolution</th>
<th>Image (kByte)</th>
<th>Update (Hz)</th>
<th>Compressed flow (kbit/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar and AIS-plot</td>
<td>1024x1024</td>
<td>375</td>
<td>0.4</td>
<td>100</td>
</tr>
<tr>
<td>AIS</td>
<td>Raw</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>IR camera</td>
<td>640x512</td>
<td>330</td>
<td>1-10</td>
<td>300-1000</td>
</tr>
<tr>
<td>Video</td>
<td>720x568</td>
<td>415</td>
<td>1-10</td>
<td>300-1000</td>
</tr>
<tr>
<td>HDTV</td>
<td>1920x1080</td>
<td>2600</td>
<td>2</td>
<td>800-1500</td>
</tr>
<tr>
<td>Automation</td>
<td>4000 tags</td>
<td>12</td>
<td>0.1-1</td>
<td>1-10</td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

- Communication requirements
  - Full remote control: 4 Mbit/s
  - Reduced operation: 125 kbit/s
  - Higher bandwidth requirement for ship-to-shore link
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Redundant system is required

- Communication systems for the unmanned ship:
  - Main communication channel: at least 4 Mbit/s needed (e.g. VSAT)
  - Backup channel: at least 128 kbit/s needed (e.g. Inmarsat or Iridium)
  - Dedicated and independent rendezvous communication channel
- Redundant power supply and on board system
Further requirements

- Data integrity and security
  - Encrypted communication to avoid digital pirates or hijacking
- Robust software architecture
  - Independency of Rendesvous Control and Autonomous Controller
- Redundancy ashore
  - Multiple SCC’s or SCC systems
- Communication to other vessels
  - Light and shape extension
  - New navigational status for AIS
... MUNIN has already arrived in Bergen