Satellite Communications in the Future Statutory and Commercial Maritime Communications Market
Workshop on
Future Maritime Communications

08-July-2014
London, UK
Agenda

• Address of Welcome by ESA and Inmarsat
• Overview of the Project (DLR)
• Expected satellite communication systems & services (MARINTEK)
11:00-11:15 Coffee Break
• Use case selection and requirements (Inmarsat)
• e-Navigation (SIRM)
• Arctic Communications (MARINTEK)
12:15-13:15 Lunch
• Autonomous Ship (SIRM)
• Evolution of GMDSS (SIRM)
• First outcomes towards satellite systems, services or technologies addressing future opportunities (DLR)
• Wrap up with open discussions and farewell (DLR)
15:30 End
Project Partners

Coordinator: Deutsches Zentrum für Luft- und Raumfahrt, Germany

Inmarsat, UK

Norwegian Marine Technology Research Institute, Norway

Società Italiana Radio Marittima, Italy

The SatCom4Mar Project is funded by the ARTES 1 ESA Programme
Project Goals

The fundamental questions the project SatCom4Mar will address are:

• Which upcoming satellite communication system could contribute to fulfil the requirements of maritime user applications?

• Are there any technological gaps requiring new developments?

• How could upcoming satellite, terrestrial, and legacy systems be integrated to reduce the burden on the navigator (in terms of amount of radio equipment and related procurement and service costs)?

Project duration until 03-Oct-2014
Project Outcomes

• **Public workshop (July-08, 2014)** to disseminate already achieved results and to discuss and collect further inputs from the maritime communications community

• Development of **road map** towards potential new satellite systems and technology. Release and dissemination to relevant bodies and stakeholders by a **public final report**.
Project’s Selection Process

1. Definition of service criteria
2. Analysis of service requirements
3. Definition of technology criteria
4. Selection of services with potential
5. Assessment of technologies with potential
6. Workshop Feedback
7. Set of services and technologies with potential for further investigation
Expected satellite communication systems & services in 2020

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SatCom4Mar Workshop, Inmarsat, 08.07.2014
Developments and future demands for maritime communications in 2020

• Historically, the maritime industry has been conservative and slow to adopt new technologies.

• Shipping companies have always largely relied on proven solutions, but this situation has changed in the course of the past few years.

• The maritime industry has been moving from traditional communications systems to higher speed IP data networks.
Global maritime SatCom market development predictions

Source: Euroconsult, March 2014
Global maritime SatCom market status

• In 2013 the global maritime SatCom market grew by 4% in number of terminals and 10% in revenues at the satellite operator level

• Currently the total size of the market is about 348 000 active terminals and more than €560m in revenues at the operator level

• Established MSS services and the fast developing VSAT business contributed to the overall growth of the maritime SatCom market
Global maritime market growth predictions

- In 2014 several High Throughput Satellite (HTS) systems will be available ⇒ 3 times more capacity by the end of 2014 and 6 times more capacity by the end of 2016.
- SatCom capacity revenues will nearly double over the next decade, with a CAGR of 7% over the 10-year period, to ~ €1.1bn in 2023 (~610 000 active terminals)
- The growth is expected to be driven mainly by increasing data consumption across all major maritime segments and the adoption of new generation broadband satellite services.

CAGR: Consolidated Annual Growth Rate
The maritime market

Close to 70,000 merchant vessels in operation in 2013
1.4 million seafarers demanding broadband

Commercial Shipping

Always-on communication as a common practice
Strong regional focus and strong seasonality

Leisure

About 6,500 passenger ships worldwide
Up to 25Mbps required for a comfortable voyage

Passengers

More than 9,000 Government vessels in operation in 2011
Military vessels as the core government market

Gov & Military

Maritime Satellite Communication
Market Segmentation

35 million fishers worldwide, mainly in Asia
MSS as predominant solutions, but VSAT solutions in growth

Fishing Boats

More than 750 operational rigs in the world
World off shore oil production to grow over the next decade

Oil & Gas Offshore
Growth in broadband traffic

Exabyte / yr.

ITU-R M.2243 (2011)

Actual traffic


<table>
<thead>
<tr>
<th>$10^n$</th>
<th>Prefiks</th>
<th>Symbol</th>
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</thead>
<tbody>
<tr>
<td>$10^{24}$</td>
<td>yotta</td>
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<td>$10^1$</td>
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</table>
Maritime market by business segment

Source: Northern Sky Research (NSR): "Maritime Satcom Markets, September 2013"
Market segments' dynamics

• Merchant Maritime remains a vital market for maritime SatCom services – with over 800,000 in-service units
• The Internet-connected, always-on movement has permeated even the family vacation – even on the high-seas. Combined the Passenger market will account for almost 60 transponders of FSS capacity demand, and over 6 Gbps of HTS capacity
• The Offshore market continues on a growth-path, adding more than 50,000 in-service units over the next ten years
• Fishing markets represent the largest addressable market – but still remains a limited opportunity for SatCom
• Government and Military markets face near-term budget problems, but are expected to recover by 2022
Technological/architectural impacts

• High Throughput Satellite (HTS) systems, both for FSS and MSS
  – *Intelsat Global Xpress (GX)*, Intelsat Epic, ViaSat-2, Telenor’s THOR 7, O3b, Telesat VANTAGE, ..

• Heterogeneous Satellite- (HAPs/UASs)- Terrestrial Systems

Source: H. Y. Song
Google has allegedly been recruiting a team of satellite engineers (lead by Greg Wyler – O3b Networks's founder) to design a constellation of LEO satellites to provide global coverage broadband.

- The Google-backed company WorldVu Satellites (L5) has filed for the (legacy Skybridge) Ku-band frequency and reportedly secured priority ITU filing.
- ITU shows L5 filings as promising to start service between late 2019 and mid-2020.
- 180 (360?) LEO (800-950 km altitude?) small (100 kg?) polar orbiting satellites (inclusion: 88.3°).
- Total capacity: 1-2 Tbps at full constellation (?)
- Small & cheap user terminals; flat panel antennas such as those being developed by Kymeta (?)

“It could definitely revolutionise the cost of maritime terminals, and the price of capacity could be considerably cheaper” (Tim Farrar, TMF Associates)
Thank you!

Questions?

Comments?

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Use Case Requirements

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Use Cases Requirements

• 1- Tracking/Monitoring (of vessels and in a second stage also goods/oil/persons).
• 2- On-Route information update (destination updates, waypoint and route optimization, maps update, weather info, ice info, currents info).
• 3- Remote Control of vessels (in case of unmanned vessels, but also as help to the crew).
• 4- Safety and Security system/alerts (voice communication, alerting, very precise positioning and orientation of the vessel).
• 5- Worldwide available communication for vessels (missing in some parts of the globe as in the Arctic)
• 6- Crew/Entertainment communication for cargo and passenger ships
• 7- Share of info among vessels during route/after route (firstly among vessels of the same company and secondly also open to partners company or all ships)
• 8- Communication for under building sea platforms/ sea power plants (wind, underwater turbines, others..)
• 9- Regulations and Policies (all the currently required systems as GMDSS, LRIT, AIS)
## Use Cases Selection

<table>
<thead>
<tr>
<th>Case Description</th>
<th>E-Nav</th>
<th>Arctic Comms</th>
<th>Autonomous ship</th>
<th>Evolution GMDSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Tracking/Monitoring</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2- On Route information update</td>
<td>X</td>
<td>(X)</td>
<td>(X)</td>
<td></td>
</tr>
<tr>
<td>3- Remote Control of vessels</td>
<td></td>
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<td>X</td>
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<tr>
<td>4- Safety and Security system/alerts</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>5- Worldwide available communication for vessels</td>
<td></td>
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<tr>
<td>6- Crew/Entertainment communication</td>
<td>X</td>
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<td>7- Share of info among vessels during route/after route</td>
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<td>8- Communication for under building sea platforms</td>
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<td>X</td>
</tr>
<tr>
<td>9- Regulations and Policies</td>
<td></td>
<td>(X)</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Use cases having been assessed

1. e-Navigation (R5, R8)

2. Arctic Communications (R1, R2, R4, R6, R7)

3. Autonomous ships (R1, R3, R5; R2, R4, R7)

4. Evolution of GMDSS (R4, R9; R3, R7)
Use Case Scenario: e-navigation

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IMO project that is underway and looking at a future digital concept for the maritime sector.

- improved, harmonized and user-friendly bridge design with improved reliability, resilience and integrity of bridge equipment and navigation information together with integration and presentation of information in graphical displays such as that received via communication equipment;
- improved reliability and resilience of on-board Position, Navigation and Timing (PNT) systems;
- improved shore-based services with means for standardized and automated ship-to-shore reporting, improved access to relevant information for Search and Rescue (SAR), and improved communication of VTS (vessel traffic system) information.

At the present time IMO is developing a strategy implementation plan

The plan will be based on, where possible, the existing navigation and communication equipment and systems.
E-Navigation: User Requirements

Existing Navigation Requirements to be maintained in the future:

• Long Range Identification Tracking (LRIT)
• Automatic Identification System (AIS) and Satellite AIS
• GNSS
• Vessel Traffic Services (VTS)
• Vessel Monitoring Systems (VMS)
Possible additional E-Navigation requirements

- Improved access to navigational safety

| UR1 | "new" e-navigation (IMO): Maritime Safety Information (MSI) received by a ship should be applicable to the ship’s specific voyage |
| UR2 | "new" e-navigation (IMO): Notices to Mariners, ENC updates and corrections to nautical publications should be received electronically without delay in delivery. |
| UR3 | "new" e-navigation (IMO): Specific services providing information to specific regions (e.g., Maritime Service Portfolios) should be mapped to those regions with status and access requirements |

- Low Cost Communication

| UR 6 | On-board Low cost communication services available to crews which will also allow them to access streaming data such music, video, radio podcast or specific applications via WiFi on-board the vessel. Differential billing per on-board users is required. Priority and pre-emption capabilities should be available in order to combine navigation and commercial services within the same User terminal infrastructure. |

- Integration of Communication Infrastructures

| UR 4 | "new" e-navigation (IMO): Provide harmonised on-board integration of navigation systems and displays. |
| UR 5 | "new" e-navigation (IMO): Harmonise integration of all communication infrastructures with satellite infrastructures when in High Seas, Coastal Approach or Polar regions (when no other means of communication are available) |

- Low Cost Satellite VHF data

| UR 7 | A satellite based data exchange system which can use the commonly carried VHF equipment on the ship. These equipment would therefore use the terrestrial VHF network when available or satellite VHF network out of terrestrial coverage. |
E-Navigation: High level architecture drivers

Starting from requirements the following points have been taken into account in defining the architecture:

• Flexibility
• Use of consolidated application technologies
• Communication link interoperability
E-Navigation: High level architecture
E-Navigation: High level Architecture

Content Delivery Network

Used for sending data to group of user
For example:
• ENC Update / Correction
• Multimedia Stream
E-Navigation: High Level Architecture

Integrated Application

Client Layer

Application Front End

Process Layer

Enterprise Service Bus

Service Layer

Access Manager
ENC
TUGS Services
MSI
VTS
Port Services
Data Storage
E-Navigation: High level Architecture
VDE
E-Navigation: High level Architecture
On Board Architecture
The major impact on the existing architecture is expected to be related to integration of all communication infrastructures with satellite infrastructures.

- It seems likely that a combined satellite and terrestrial system may give best trade-off between benefits and drawbacks.
- A terrestrial infrastructure may provide low cost solutions for the coastal fleet which may be an important argument for developing nations.
- Special systems are required to cover the Polar Regions beyond GEO satellites coverage. LEO or HEO satellites systems may be most appropriate.
- Rate of data transfer (capacity of transmission).
An ideal e-Navigation communications system would operate automatically, selecting the best communications technology, channel, and characteristics compliant with the ship’s location, and the type of data to be exchanged. This automatic process would be managed in accordance with rules and the needs of the mariner that might include the following:

• Need to avoid latency, e.g. when exchanging safety and navigation data with other vessels or receiving it from electronic systems ashore or at sea;
• Ability to delay the transmission or receipt of data, e.g. transfer of non-urgent administrative data, or the receipt of chart corrections for the current voyage, a subsequent voyage or for a port to be visited later during the pertinent voyage;
• Value / cost of communications;
• Rate of data transfer (capacity of transmission).
Questions?
Use Case Scenario: Arctic Communications

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SatCom4Mar Workshop, Inmarsat, 08.07.2014
Major drivers for Arctic Communication developments

• Oil and Gas (O&G) exploitations
• Exploitations of minerals
• Fisheries (renewable resources)
• New shipping routes
• Tourism
The 22nd and 23rd Norwegian licensing round - closing up on the polar ice rim
The northernmost findings in the Barents Sea so far
Block 7324/8-1 in the Hoop area

Illustration: Heidi Bredesen
Ships, oil and gas - and e-com services
SatCom4Mar: Users' requirements list

• Distress and Safety
  – An alternative system to HF communications which can be adopted by the IMO and which can provide timely distress and safety communication functions for latitudes above 76°N

• Maritime Safety Information (MSI)
  – A new MSI service which can be received by ships sailing above 76°N and can additionally provide ice information

• Communications
  – Communications circuits providing reliable communication capability for ships sailing above 76°N and capable of multi-Mbps data rates.
## Arctic wireless e-com coverage limitations

<table>
<thead>
<tr>
<th>System</th>
<th>Characteristics</th>
<th>Polar (&gt; 80°N)</th>
<th>Sub-polar (70°N - 80°N)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Terrestrial systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HF (500 kHz)</td>
<td>NAVTEX (safety related messages)</td>
<td>Unsuitable for digital communications (&lt;0.1 kbps)</td>
<td></td>
</tr>
<tr>
<td>HF (500 kHz)</td>
<td>NAVDAT (safety related messages)</td>
<td>Currently unavailable; NAVTEX architecture for narrowband data (10-20 kbps)</td>
<td></td>
</tr>
<tr>
<td>HF, MF</td>
<td>Safety related messages and voice only</td>
<td>Unuitable for digital communications</td>
<td>Unsuitable for digital communications</td>
</tr>
<tr>
<td>VHF, Digital VHF</td>
<td>Line-of-sight voice and narrowband data</td>
<td>No base stations</td>
<td>Few base stations</td>
</tr>
<tr>
<td>GSM, 3G</td>
<td>Line-of-sight voice and narrowband data</td>
<td>No base stations</td>
<td>Very few base stations</td>
</tr>
<tr>
<td>LTE/4G, WiMAX</td>
<td>Line-of-sight voice and broadband data</td>
<td>No base stations</td>
<td>Insignificant deployment</td>
</tr>
<tr>
<td><strong>SatCom systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEO (Inmarsat, VSAT)</td>
<td>Medium capacity - low to moderate latency</td>
<td><strong>Unavailable</strong></td>
<td>Limited availability and quality</td>
</tr>
<tr>
<td>LEO (Iridium)</td>
<td>Narrowband data communications – high and variable latency</td>
<td>Potential problems with capability/quality</td>
<td>Potential problems with capability/quality</td>
</tr>
<tr>
<td>HEO</td>
<td>Properties comparable with GEO</td>
<td>Currently unavailable, but expected to provide good coverage and</td>
<td>properties comparable to GEO systems at lower altitudes (&lt; 60°N).</td>
</tr>
</tbody>
</table>
Future Northern hemisphere SatCom system

HEO’s ! (?)

- Quasi-stationary perspective
- Apogee height ~ GEO

  ➔ GEO technology can be reused (slightly modified)
  - Cost savings
  - Risk reduction

- Best possible high-latitude coverage per satellite
  - Fully complements GEO data; no LEO-like latitudinal coverage gaps
  - Little time “wasted” over lower latitudes adequately seen from GEO

- Relatively simple ground segment; real-time dissemination can be achieved with a single primary ground station, as for GEO
Possible SatCom developments in the High North (> 75°N)

Iridium NEXT

PCW?
(Canadian)
(~2020 – (25?))

Arktika?
(Russian)
(~2020- (25?))

Source: Canadian Space Agency

ARHTIKA SYSTEM. NPO LAVOCHKIN ILLUSTRATION
Arktisk satellittkommunikasjon (ASK)

- Telenor and the Norwegian Space Centre (NSC) have initiated a project to assess the Norwegian possibilities to introduce Arctic broadband with two HEO satellites.
- MARINTEK has carried out studies for Telenor examining the potential user benefits and requirements associated with Arctic SatCom.
- Seamless roaming between GEO and the HEO satellites is being assumed.
- Capacity: Typical 2-4 Mbps.
- The cost of the Norwegian project has been estimated to 1-3 billion NOK.
Arctic HEO system realisation challenges #1

• No commercial SatCom operator/service provider envisages a market of sufficient size to risk the deployment investments on its own
• Lack of public national and/or international leading initiatives
• Hesitating multi-sectorial user communities
  – Most companies prefer to buy services when available, which is typical for the maritime industry like cruise and ferry, fishing, shipping, waterborne transportation, etc.
  – The O&G industry might be more willing to commit at an earlier state, depending on when the oil/gas fields further north in the Arctic are deemed accessible for explorations, and on the mobile data capacity needed during the (initial) exploration, appraisal and development phases ☞ ☞ ☞ ☞ ☞
The five major phases of an oil and gas (O&G) exploration and production (E&P) company's operations

<table>
<thead>
<tr>
<th><strong>Phase</strong></th>
<th><strong>Duration</strong></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Exploration</em></td>
<td>2-5 yrs</td>
<td>No dedicated e-com infrastructure is normally applied during this phase. Large amounts of data are stored on board the survey vessels to be processed ashore upon delivery. This phase comprises careful planning of the production phase and its facilities, and hence also decisions regarding the e-com infrastructure solutions, from the more mobile exploration/appraisal stages to a fixed infrastructure supporting the installations for a long period (i.e. installation of fiber). An assessment scrutinizing the cost/benefit of pertinent communication solutions to meet the operational requirements is consequently needed to specify the infrastructure, the equipment, and to issue an RFP. Subsequent decisions on suppliers and follow-up on deliveries and installations, including testing, are additional crucial tasks in this phase.</td>
</tr>
<tr>
<td><em>Appraisal</em></td>
<td>2-4 yrs</td>
<td><strong>No dedicated e-com infrastructure</strong> is normally applied during this phase. The dynamic positioning (DP) operations are central in a drilling process. Large amounts of data are stored on board the drilling vessels to be processed ashore upon delivery. The drilling activities are very costly and must be planned with a long perspective. The drilling rigs are hired by the operators.</td>
</tr>
<tr>
<td><em>Development</em></td>
<td>5-8 yrs</td>
<td>When production starts fixed fiber cables connecting the main offshore installation to the shore is normally installed, and both fiber cables and radio links are used to connect surrounding installations to this main hub. Previous studies have revealed current capacity demands around 100 Mbps for typical oil rigs in the North Sea. Operative predictions indicate significantly increased use of remote operations and control in the future, which again brings about higher bandwidth demands.</td>
</tr>
<tr>
<td><em>Production</em></td>
<td>15-40 yrs</td>
<td>Decommissioning is a large and complex multi-discipline project. Each decommissioning project is unique and each platform has its own unique challenges. Consideration for decommissioning should start in the concept phase of a new asset to ensure no unnecessary cost liability is placed on the operator. Decommissioning in design can increase the net present value of an asset significantly by making informed decisions in the design stage.</td>
</tr>
<tr>
<td><em>Decommissioning</em></td>
<td>2-5 yrs</td>
<td></td>
</tr>
</tbody>
</table>
Arctic HEO system realisation challenges #2

• Based on experience from the O&G developments further south there are plausible reasons to assume that *fibre communications* will be supplied to offshore installations in the north when production is commencing.
  – Hence crucial e-com services during the exploration, appraisal and development phases are bound to rely on wireless solutions
  – However, during production wireless is deemed to be required (only) for back-up purposes and communication with mobile supply units and similar assets

• No evident viable multinational PPP cooperative approach on the horizon

• Attempting the 'INMARSAT model' from the late 1960's?
Intermediate/concurrent alternatives (?)
Heterogeneous Satellite-HAPs/UASs-Terrestrial Systems
Hybrid Space-Terrestrial (HST) Concept

• GEO
• HEO
• (MEO)
• LEO

Terrestrial Core Network

~0.5 – 20 km

~600 – 40,000 km
Thank you!

Questions?

Comments?

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Use Case Scenario: Autonomous Ships

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An autonomous vehicle is a vehicle that is capable of functioning on its own. It may be manned or unmanned or it may be remotely controlled from a manned station.

Why Autonomous Ship? Unmanned merchant ships on intercontinental voyages are an attractive future application as the world is facing a shortage of seafaring personnel while the number of ships is growing.

Why SatCom? There will be a need for communications technology that will enable wireless monitoring and control functions both on and off board.

Challenges: technical +regulatory
Autonomous Ship: User Requirements

Remote Operations

**UR 1**
Secure communications in order to prevent the ship being hijacked by other parties

**UR 2**
High availability so that any special situations can be handled in a timely manner

**UR 3**
Latency of less than one second so that the ship can be remotely controlled in real time

**UR 4**
Bandwidth of up to 4 Mbps so that radar and video pictures can be sent to the shore

**UR 5**
Redundancy of the equipment on board the ship with fail to safe procedures in case of equipment failure

Improved reliability and resilience of on-board Position, Navigation and Timing (PNT) systems

**UR 1**
Secure communications in order to prevent the ship being hijacked by other parties
Autonomous Ship: System High Level Architecture

Data sent from the vessel to the SCC

- PNT, for tracking purposes; Telemetry data, Cargo information; Environmental information, such as radar, video images, weather conditions, traffic information, AIS data; Safety data, Security information;

Data sent from SCC toward the vessel

- Navigation plans and relevant updates; Remote commands to pilot the vessel in real time, Telecommands to act on other on board system.
# Autonomous Ship: Communication Needs

<table>
<thead>
<tr>
<th>Stream</th>
<th>Type</th>
<th>Bandwidth (kbps)</th>
<th>Latency (s)</th>
<th>Security</th>
<th>Reliability</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rendezvous</td>
<td>LOS</td>
<td>2</td>
<td>0.05</td>
<td>High</td>
<td>High</td>
<td>Ship→Ship</td>
</tr>
<tr>
<td>Remote Control</td>
<td>LOS/SatCom</td>
<td>2</td>
<td>1</td>
<td>High</td>
<td>Medium</td>
<td>Ship↔Shore</td>
</tr>
<tr>
<td>Telemetry</td>
<td>LOS/SatCom</td>
<td>32</td>
<td>1</td>
<td>Medium</td>
<td>Medium</td>
<td>Ship→Shore</td>
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<tr>
<td>Radar and Targets</td>
<td>LOS/SatCom</td>
<td>75</td>
<td>1</td>
<td>Medium</td>
<td>Medium</td>
<td>Ship→Shore</td>
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<tr>
<td>HD Video</td>
<td>LOS/ SatCom</td>
<td>3000</td>
<td>2.5</td>
<td>Medium</td>
<td>Low</td>
<td>Ship→Shore</td>
</tr>
</tbody>
</table>
Autonomous Ship: Communication Security Issue

Three types of security issues will be considered:

- **Confidentiality**: This is the absence of unauthorized disclosure of information. For personal communication and business communications, confidentiality is of high importance.

- **Integrity**: This is the absence of improper system alteration. For communication systems, this may be malign or accidental insertion of false data or corruption of data.

- **Denial of service (DOS)**: This is the possibility of an attack on components of the communication system that inhibits the use of the system to exchange data.
## Autonomous Ship: Communication Security Issue

Indicative security quality classification for the carriers

<table>
<thead>
<tr>
<th>Carrier</th>
<th>Confidentiality</th>
<th>Integrity</th>
<th>Denial of service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inmarsat</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>VSAT</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Iridium OpenPort</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>AIS</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Digital VHF</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>WiMAX</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>GSM 3G-4G</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Autonomous Ship: High Level Network Architecture (1/2)
Autonomous Ship and SCC high level network
Autonomous Ship: expected impact on existent architectures

**Today**

The ship is required to be equipped with various communication systems to satisfy relevant international legislation:

- Automatic Identification Systems (AIS), VHF Radio with Digital Selective Call (DSC) which includes automatic distress alerting.
- NAVTEX is a MF technology for sending warnings to ships in areas close to cost while SafetyNET is an Inmarsat based system with similar functionality for ships in deep sea areas.
- The ship will also have to have Emergency Position Indication Radio Beacon (EPIRB) equipment for emergency signalling to other ships, airplanes and the COSPAS/SARSAT system of satellites.

**Tomorrow**

In addition to the mandatory systems described the following communication systems are hence expected to be used for the unmanned ship:

- One main communication channel based on a commercial VSAT service operating in C-, Ku- or Ka-band (4 Mbps)
- Backup channel based on L-band Inmarsat or Iridium OpenPort (in the future: Iridium NEXT) with a capacity of 128 kbps or more.
- A dedicated and independent rendezvous communication channel based on, e.g., AIS or digital VHF technology.
Autonomous Ship: advantages and challenges

**Advantage**
- Much of the technology needed for autonomy is already available.
- Economic sustainability
- Social sustainability
- Environmental sustainability

**Challenge**
- Unmanned shipping requires new technology on board and ashore
- A shore-side control center (SCC) is also required
- Reliable communication links and a robust communication architecture required
- Unmanned shipping requires the definition of new International Regulations
Questions?
Use Case Scenario: Evolution of GMDSS

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The Global Maritime Distress and Safety System (GMDSS) is the radio system whose techniques and frequencies are defined by the ITU and for which mandatory equipment carriage requirements has been adopted by the IMO for commercial vessels. There is currently a project within the IMO to review and modernize the GMDSS in the period 2012-2017. To date, a high level review has been completed which has concluded that the functional requirements of the GMDSS are still appropriate. The project is currently conducting a detailed review addressing issues including:

- the evolution of Maritime Safety Information (MSI) broadcast systems;
- problems which might arise due to lack of HF stations in the future;
- future definitions of Sea Area A3 (currently within geostationary satellite footprint) and Sea Area A4 (currently outside geostationary satellite footprint);
- integral use of voice communications;
- improved shore to shore communications between Rescue Coordination Centres.

The final phase will be a modernization plan.
GMDSS: User Requirements

**UR 0.1 Existing Functional requirements of the GMDSS are:**

- Every ship, while at sea, shall be capable:
  - of transmitting ship-to-shore distress alerts by at least two separate and independent means, each using a different radio communication service;
  - of receiving shore-to-ship distress alerts;
  - of transmitting and receiving ship-to-ship distress alerts;
  - of transmitting and receiving search and rescue coordinating communications;
  - of transmitting and receiving on-scene communications;
  - of transmitting and, receiving signals for locating;
  - of transmitting and receiving maritime safety information;
  - of transmitting and receiving general radio communications to and from shore-based radio systems or networks
  - of transmitting and receiving bridge-to-bridge communications.

All these requirements are expected to remain mandatory for passenger ships and cargo ships (>300T). The system is however available to use by any ship in the world. It should be noted that ships may have a need for reception of certain maritime safety information while in port.
Evolution of GMDSS

- **Handheld satellite device**

  | UR 1 | The system shall be designed on the functional requirements regardless of the equipment specifications in order to be able to port some distress and safety functional requirements on a hand-held device for usage onboard small craft (for e.g.). |

- **Satellite communication technologies**

  | UR 2 | The IMO carriage requirement for satellite terminals on ships specifies the carriage of equipment working in L-band. Larger ships typically also carry newer technology VSATs which operate in other frequency bands but which are not always globally available. The evolution of GMDSS will require a frequency band agnostic solution satisfying IMO existing functional and performance requirement. |
Evolution of GMDSS

- **GMDSS satellite provider diversity**

  | UR 3 | Capability of working with different satellite service providers (either global or regional).

- **New EPIRB technology**

  | UR 4 | GMDSS should be able to operate with the new EPIRB service. Refer UR 10

- **Alternative to HF communication**

  | UR 5 | An alternative to HF communications which supports voice and is capable of working from the ship’s reserve battery supply. (For e.g.: Inmarsat introducing next generation maritime safety voice and data service over the BGAN Fleetbroadband system)
GMDSS: High level architecture drivers

Starting from requirements the following points have been taken into account in defining the architecture:
• Flexibility
• Use of consolidated application technologies
• Communication link interoperability
GMDSS: High level architecture
GMDSS: High level architecture
Current MSI Service
GMDSS: High level architecture
MSI over XMPP

vessel1@vessel.com

vessel.com (XMPP server)

vessel2@vessel.com

vessel3@vessel.com

provider1@provider.com

provider2@provider.com

provider3@provider.com

provider.com (XMPP server)
GMDSS: High level architecture

SAR

Satcom Segment (Ku/Ka/C/L/VHF)

Cosmpas Sarsat

GNSS (Galileo)

SAR Return link

406 MHz

GNSS SIS

Distressed Vessel

EPIRB

Mission Control Center

Satcom Operator

LUT

Rescue Coordination Center
GMDSS: High level architecture
On board architecture
GMDSS: High level architecture

On board architecture: GMDSS
GMDSS: expected impact on existent architectures

IMO has now opened the GMDSS for the widest possible consideration, leading potentially to the greatest changes in maritime safety communications and technology ever since the original GMDSS was developed – changes that will add measurably and significantly to safety of life at sea.

- Current maritime safety relies upon a broad mix of technologies, both satellite and terrestrial, and this mix will remain the basis of a future revised GMDSS.
- For backup the aging MF/HF technology needs to be renewed (a.o. digitized), complemented and/or superseded by more modern solutions, if those substitutes prove adequate and compliant with the coming GMDSS requirements.
- The revised GMDSS needs to be based upon a holistic mix of the latest technologies, satellite and terrestrial, with modernized MF/HF radio as the back-up and, in addition to Cospas-Sarsat EPIRBs, an independent means of alerting.
- The specific impacts pertaining to the Arctic is further outlined in the relevant presentation.
Questions?
First outcomes towards satellite systems, services or technologies addressing future opportunities

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Aim and focus

• Define at high level possible architectures and technologies that can provide the requirements for all the use cases

• Focus is on the satellite related technologies as well as on integration between satellite and terrestrial

• Hybrid opportunities are also under investigation (HAPs, or other space-based relay assets) where applicable
General Architectures
General Architectures
Example: E-Navigation

• The User Requirements show the need of
  – Bi-direction communication link (from ship-to-shore and from shore-to-ship)
  – The communication is needed along the entire vessel route
  – The communication is needed also for new services e.g. VDES, therefore there is a need to introduce a forward link (from shore-to-ship)
  – Eventually the communication between ships can be also beneficial (need of multi-hop heterogeneous networks and mesh networking)
Example: E-Navigation

- The system architecture can be divided into:
  - Satellite Segment
  - Ground Segment
  - Ship Segment
Example: E-Navigation

• **Satellite Segment**
  - GEO, LEO and probably also HEO satellites are needed for providing world coverage, particularly where terrestrial is not available
  - Inter-satellite links will be required, at least for LEOs
  - Multi-hop communication has to be supported, at least for LEOs
  - Integration with terrestrial communication needs to be supported

• **Future scenarios might include**
  - HAPs or other space-based relay assets that might act as micro-cells for the terrestrial system
    - Can be used for caching in a multi-hop scenario
    - Can be used for enhancing the available bandwidth on board
    - Can be exploited for extending the connectivity among ships providing high data rates
  - A large number of small satellites and/or cluster constellations
Example: E-Navigation

• Ground Segment

  – Multiple gateway scenario shall be supported

  – The capability to support huge small satellite constellation can be a futuristic but real necessity

  – Integration with terrestrial communication networks in order to allow seamless connections between satellite and terrestrial links
Example: E-Navigation

• Ship segment

  – Simplified equipment, to reduce:
    • The duplication of information
    • The difficulty for the captain and crew to retain useful information
    • The cost due to training
    • The response time in case of threats/emergencies

  – The ability to utilize duplicated systems (with single visualization) for
    • Integrity check of the information
    • Redundancy in case of HW/SW failures
    • Increased safety on board

  – Seamless switching between available links depending on the best performance provided
Conclusions

• The user requirements show the need of
  – New satellite configurations with increased flexibility
  – Integration with terrestrial networks

• The recent technologies needs to be considered and integrated in satellite systems for maritime

• The simplification for human to machine interaction is a driver for ship equipment