e-Navigation Infrastructure Design Considerations

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E-Navigation Underway Conference
January 31, 2013

The Case for an
Open Source Reference System Architecture

See also the article about this subject in the latest issue of The Digital Ship
Example of an Integrated Navigation System (INS) on a Cruise Ship

Source: Sperry Marine
**Integrated Navigation System (INS)**

- Collision avoidance
- Route monitoring
- Nav. Control Data
- Alert manag.
- Status and Data Display

**Consistent Common Reference System**

- PNT evaluation
- System Data selection
- Active INS Data base (Route information, SENC, Hydrographical, Weather,...)

**Interface to external systems**

- Vessel parameters
- Static data, pre-packed (e.g. ENC data)
- Dynamic / real-time data

**Integrated Radio Communication**

- Radio Resource Management (selection, filtering, routing, signaling and alerting)

**Other bridge systems**

- BAM
- Safety
- ...

**Data Processing Layer**

- Operational Layer, incl. provision of HMIs

**Sensor/Source Layer**

- using CMDS

**Vessel parameters**

- Static data, pre-packed (e.g. ENC data)
- Dynamic / real-time data

**Integrated Navigation System (INS)**

- PNT Sensors
- Depth sensor
- Radar Sensor(s)
- AIS
- ...

**Integrated Radio Communication**

- LF
- HF
- SAT
- MF
- VHF
- ...

**Operational Layer, incl. provision of HMIs**
On-Board Decision Support Applications

- Collision Avoidance
- Route Monitoring
- Conning
- Alert Management
- System Monitoring
- Route Planning
- Mooring
- Etc.

Electronic Navigation Chart Data
Fathometer
Gyro

Radio
AIS
Comms
Other Remote Sensors
Bridge Equipment on a Cruise Ship

VTS
Overarching e-Navigation Architecture

Shipboard environment
- Shipboard user
  - Stated information needs/information items requested
- Data provided in required format

Operational services
- Human-Machine Interface(s)
- Functional links used by Technical services
- Physical links used by Technical services

Shipboard technical equipment supporting e-Navigation
(include its Human-Machine Interfaces)

Common technical shore-based system harmonized for e-Navigation
(include its Human-Machine Interfaces)

Shore-based authority, such as IALA National Member
- VTS Operator
- MRCC Operator
- etc.
- Human-Machine Interface(s)

Stated information needs/information items requested
- Data provided in required format

Data Domain

Information Domain

World Wide Radionavigation System (WWRNS) of IMO (incl. GNSS, GNSS augmentation and terrestrial backup)
What will e-Navigation Infrastructure Requirements be?

**Solutions selected at NAV 59 will likely include:**

- Automated Ship/Shore Information Exchanges (in S-100 format)
- Inter-operability between diverse computing environments (On-Board and Ashore)
- Health & Accuracy “Meta” Data for all Information Sources
- Region/Area Specific Solutions

**Other Likely Requirements**

- Redundancy with Automatic Fail-Over for all Critical Resources
- Use Existing Infrastructure/Technology where possible (On-Board and Ashore)
- Modular & Scalable
- Allow for Encryption of Information Exchanges (i.e. Transport Layer Security or TLS)
- Allow for Non-TCP/IP Protocols (NAVTEX, SafetyNet, DSC, AIS/IEC 61162)
- Must be Technology Agnostic to make it Future Proof (i.e. 3D Head’s Up Display, etc.)
- Technology Life Cycle Tools (Incl. Remote Trouble Shooting and Upgrading)
- Low Total Cost of Ownership (Acquisition, User Training and Maintenance Costs)
- Mix & Match Applications with sensors and other information sources
- Deploy an application on any computing platform without customization
E-Navigation Infrastructure Design should anticipate New Technology

E-Nav Implementation not until 2015-2025 Period

- Technology will change drastically in the meantime

Some Technology Trends are clear

- Cloud Computing is on the rise
- Open Source Reference System Architecture Standards (RSA) are adopted in many industries (Automobile, Aviation, Telecommunications, etc.)

Their effects have been well established

- Increased availability and quality of solutions while reducing their cost
- Marine Industry stands at the cusp of realizing the same benefits
Examples of Reference System Architectures in other Industries

AUTOSAR
AUTomotive Open System ARchitecture

BMW GROUP
BOSCH
Continental
DAIMLER
Ford
GM
PSA PEUGEOT CITROËN
TOYOTA
VOLKSWAGEN

System Architecture
Virtual Integration
Adoption of a Reference System Architecture Standard will

Enable Information Exchanges

- Assure Interoperability between Shipboard and Shore-side Systems
- Provide the Framework for Automatic, Seamless and Secure e-Navigation Information Exchanges irrespective of the systems that are involved in the exchanges

Adopting Inter-Vendor Operability Standards

- Use well established interfacing standards
  - OpenGIS® Sensor Model Language Encoding (SensorML)
  - Universal Plug-n-Play (IEC 29431-1)
  - JSON (Java Script Object Notation)
  - Etc.

Allow use of existing Computing Environments

- An RSA can run alongside legacy applications on the same Platform
- An RSA is Platform Technology Agnostic
- An RSA can accommodate any Protocol on any Network
### Proposed e-Navigation System Architecture

**Derived from a proposal for e-navigation shipboard technical architecture presented by Woo-Seong, Shim, KIOST, Korea**

**Any User Device with intuitive Human Machine Interface including Audio (i.e. INS, Workstation, Heads Up Display, Tablet, etc.)**

**Secure connection to e-Navigation Applications running on the Private Computing Cloud**

<table>
<thead>
<tr>
<th>On-Board</th>
<th>Ashore</th>
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<tbody>
<tr>
<td>• Collision Avoidance/Passage Planning</td>
<td></td>
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<tr>
<td>• Route Monitoring</td>
<td></td>
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<tr>
<td>• Route Planning/UKC/Airdraft/Weather/Fuel</td>
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<tr>
<td>• Conning (Mooring/Anchoring/etc.)</td>
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<tr>
<td>• Alert Management</td>
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<tr>
<td>• Systems Monitoring/Trouble Shooting</td>
<td></td>
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<tr>
<td>• Ship Reporting to Authorities (FAL Reports)</td>
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<tr>
<td>• Information Subscription Management</td>
<td></td>
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<tr>
<td>• CBT including equipment familiarization materials</td>
<td></td>
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<tr>
<td>• Database Search Engine that allows geo-referenced and other searches</td>
<td></td>
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<tr>
<td>• ISM/SMS Application</td>
<td></td>
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<tr>
<td>• Trim &amp; Stability</td>
<td></td>
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<tr>
<td>• Fire Fighting</td>
<td></td>
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<tr>
<td>• (SAR) Messaging</td>
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<tr>
<td>• Etc.</td>
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<tr>
<td>• MSI Publication Management</td>
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<tr>
<td>• Traffic Organization Service (TOS)</td>
<td></td>
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<tr>
<td>• Remote Inspection of Quality of Ships' Instruments</td>
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<tr>
<td>• Navigation Assistance Service (NAS)</td>
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<tr>
<td>• VTS Services Advertising</td>
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<tr>
<td>• MRCC Incident Management</td>
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<tr>
<td>• Marine Domain Awareness (MDA)</td>
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<thead>
<tr>
<th>Cloud</th>
<th>Security</th>
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<tbody>
<tr>
<td>• Information Management System (IMS) with S-10X format subscriptions to Information Services from local &amp; remote sensors and other equipment/sources (i.e. Radar, AIS, GNSS, MSIs, Voyage Plan, Manifest, ENC &amp; Nautical Pubs updates, SAR Sources)</td>
<td></td>
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<tr>
<td>• Ship/Shore Radio Communications Network Router to automate wireless digital information exchanges via any network</td>
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<td>• Ship/Shore Network Connection Status Updates for all available communication networks</td>
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<tr>
<td>• Security Key Manager for encrypted communications</td>
<td></td>
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<tr>
<td>• Any Database Management System and any other Application Services</td>
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</tr>
<tr>
<td>• Engine (Service Broker, Port, Context, HAL, UI Framework)</td>
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<tr>
<td>• Middleware (Any Operating System, Containers, Discovery &amp; Peering, Communications, Load Balancing, other generic services)</td>
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<tr>
<th>Virtualization Layer</th>
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<tbody>
<tr>
<td>• Redundant Physical Servers (Any CPU, Any Storage Hardware or Device)</td>
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<tr>
<td>• Networking &amp; Firewalling, Connections to local Sensors, Radar, Radio Communications Equipment, User Devices and other equipment, using any network protocol (i.e. TCP/IP, all versions of IEC 61162 and all proprietary protocols).</td>
</tr>
<tr>
<td>• Data Center Mechanical &amp; Uninterruptable Power Supply (UPS)</td>
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</tbody>
</table>

**Required Characteristics of the e-Navigation Open Source Reference System Architecture** (similar to AUTOSAR for the auto industry and SAVI for avionics)

1. To make the architecture future proof for industry innovation and to avoid vendor lock-in, it should be technology neutral and thus allow certified e-navigation applications to be deployed on any server hardware, any operating system and any user device without interfering with legacy systems. Also to allow “Mixing and Matching”, certified e-navigation applications from different vendors should not interfere with each other.

2. To achieve redundancy, multiple reference architecture instances should be hosted on each physical server with automatic load balancing and failover.

3. To avoid the need to customize e-navigation applications for the local and remote portfolio of sensors and other devices, they should comply with well-established interfacing standards (SensorML, UPnP, etc.) Sensors and devices should be replaceable on-the-fly with automatic discovery & peering.

4. To securely manage complex information exchanges and to allow encryption where necessary, a Pub/Sub messaging pattern should be used.
E-Nav will likely require significant investments

**Modify Decision Support Applications**

- Process information received from remote sensors and other sources
- Receive and process health and accuracy information for all sources
- Present this information on-demand in an intuitive, task-oriented manner

**New Applications**

- Automatic message routing via available communications networks
- Information Management System
- Etc.

**Modify Sensors, Information Sources and Network**

- Built-In Integrity Testing (BIIT) and reporting of health status
- Accuracy Reporting
- IEC 61162 (NMEA) cannot handle these (or S-100 messages)
Ship Owners and Port & Coastal Authorities may be hesitant to embrace e-Navigation

They will likely be required to fund Implementation
- Solution Carriage Requirements for new tonnage
- Solution Implementation Schedule for Port & Coastal Authorities

Product Bundling and Vendor Lock-In are problems
- Proprietary Apps with Proprietary Connections to Proprietary Sensors
- Inability to select best Application or Sensor (No Mixing and Matching)
  - Inter-Vendor Operability using IEC 61162 (NMEA) is problematic
  - Impossible for video (Radar, Video Cameras, etc.)
- Vendor sometimes charges a premium for Service & Upgrades
- Complete refit usually postponed until operational calamities occur

Maintenance and Training Cost are Significant
- Remote trouble shooting and upgrading software is still rare
- Additional, more complex equipment will increase maintenance costs
- Additional, more complex equipment will increase training costs
Adoption of a Standard RSA could turn Ship Owners and Port & Coastal Authorities into e-Navigation Champions

Reduce Total Cost of Ownership
- Use (existing) Commercial Off The Shelf (COTS) computing environment
- Significantly reduce the need for proprietary, single function black boxes
- Allow trouble shooting and upgrading without traveling service engineers

Allow Mixing & Matching of Components
- Use well established interfacing standards (Universal Plug-n-Play, OpenGIS® SensorML, etc.) to eliminate Inter-Vendor Operability Problems and allow replacing Applications & Electronic Equipment On-The-Fly

Turn e-Nav Solution Market into a Buyer’s Market
- Unbundle applications from computing platform and from sensors/sources of information
- Expand development of e-Navigation Solutions beyond Vendors of Electronic Equipment
- Increase availability and quality of solutions while reducing their cost
Recommended Next Steps

Specify e-Navigation Infrastructure Requirements

- Develop detailed CONOPS (aka “Use Cases”) for each Potential Solution
- Use FSA Criteria to select from Potential Solutions (NAV 59)
- Derive e-Navigation Infrastructure Requirements from Solutions’ CONOPS

Identify Alternative Infrastructure Options

- Ask a panel of Independent Software Engineering Experts from inside and outside the Maritime Industry to identify candidates
- Test candidates in ACCSEAS, Mona Lisa, MEH and others
- Use e-Navigation Objectives to evaluate candidates

Implement Selected Infrastructure Option

- Develop Minimum Shipboard Solution Portfolio
- Develop Minimum Performance Standards for the e-Navigation Shipboard and Shore-side Infrastructure
- Develop Infrastructure Implementation Plan
An Open Source RSA like MARSSA meets all requirements

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- Low Total Cost of Ownership (Acquisition, User Training and Maintenance Costs)
- Mix & Match Applications with sensors and other information sources
- Deploy an application on any computing platform without customization
Platform as a Service (PaaS)

Source:
Ms. Craig-Wood
http://www.katescomment.com

Notes:
Brand names for illustrative / example purposes only, and examples are not exhaustive.
* Assumed to incorporate subordinate layers.
Shipboard Computing Environment

Ship A
- Windows Applications
  - e-Mail
  - HR/Payroll/Time Keeping
  - Stores Inventory/Purchasing
  - Maintenance Planning
  - Inspection Planning
  - On-line forms
  - Etc, etc.

MS Windows
- MS SQL
- Dell

Ship B
- Unix Applications
  - e-Mail
  - HR/Payroll/Time Keeping
  - Stores Inventory/Purchasing
  - Maintenance Planning
  - Inspection Planning
  - On-line forms
  - Etc, etc.

HP-UX
- HP
- Oracle
Private e-Navigation Cloud with Legacy Applications

- Legacy Windows Applications
  - Windows VM
- Hypervisor
  - Standard e-Navigation Service Applications
    - App Services
    - Engine
    - Middleware
- Hardware Environment
  - Storage
  - CPU
  - Router & Network
  - Firewall
Automate Ship Reporting to Authorities

e-Navigation Community Cloud

Ship's Website
  * Static Information
  * Voyage Information
  * Dynamic Information

Atom
S-100 Format

Vessel Traffic Control
Search & Rescue
Security
Environmental Protection

Subscription
Subscription
Subscription
Subscription

Publish Updates
Ship
ARCHITECTURAL FOUNDATIONS

Implementing e-Navigation

Copenhagen-Oslo-Copenhagen, 29-31 January 2013
Geir Fagerhus, CEO & Co-founder MARSEC-XL

MARSEC-XL Foundation is a not-for-profit organization.

We are NOT a vendor. We are NOT promoting any products.

Career-long work with software dependency:

— Maritime, Automotive, Aeronautics, Defense, Telecom.

Co-creator of MARSSA (together with Krystyna & MARSEC-XL core team, 2007-2011)

Founder of Q-Labs


Mariner, commercially licensed
WHAT WE STAND FOR

Vision: MARSEC-XL shapes the digital future of the maritime industry and **contributes** to establishing **open standards**.

Mission: **To bring systems & software engineering competencies** to the maritime industry and drive **MARSSA open architecture** adoption by the maritime industry.
DEFICIENCIES IN THE MARITIME SECTOR

Integration and interoperability problems

Too many proprietary systems, Too few standards

Insufficient End-user orientation

Far too high Total Cost of Ownership (TCO)

Insufficient innovation

Missing competencies and focus on systems software engineering

Lack of adequate industry acquisition processes and evaluation methods

Old and inadequate business models

Lack of “Living Labs”: no continuous technology testing and validation off-board.

*Market Survey by MARSEC-XL 2007-2009*
3 ARCHITECTURES NEEDED
3 DIFFERENT VIEWS OF THE SAME SHIP

NAVAL ARCHITECTURE

INTERIOR ARCHITECTURE

MARINE SYSTEMS SOFTWARE ARCHITECTURE
**MARSSA** = MARine Systems Software Architecture

First Community Driven Open Reference Architecture project in & for the maritime industry.

Created & Hosted by MARSEC-XL

**MARSSA mission:** To dramatically lower the TCO and at the same time increase the quality of marine electronic systems by providing an Open Reference Architecture facilitating full interoperability across all system components. MARSSA is the quality enabler facilitating continuous technology insertion.

**MARSSA vision:** MARSSA becomes a recognized & adopted standard across the maritime industry for integration of electronic systems.

MARSSA is well suited to support the implementation of global eNavigation.
The MARSSA Open Reference Architecture: a blueprint for the design & implementation of software systems and their integration on marine vessels and related onshore maritime operations.

The blueprint will tackle the non-functional properties by providing a platform upon which innovation and integration can take place.

Open Reference Architecture ensures that end users / owners are not locked into a proprietary technology or a single-vendor solution. It is future-proof.

Collaborate on low-value add - P. Odence, Black Duck Software @ IOOI2012

Collaborate on shared, domain-specific middleware - Prof. Conradi, NTNU
MARSSA BENEFITS

Radically Increased Quality

Full Interoperability
High Reliability
Redundancy
Robustness
Scalability
Flexibility
Radically Reduced TCO
Continuous Technology Refresh & Rapid Insertion
Can Improve & Ease Reporting (logistics, operations, performance, emissions)
MARSSA MODULE VIEW

MARSSA Virtual Machine

MARSSA applications & services
MARSSA domain & usage specific services
MARSSA engine
MARSSA middleware

MARSSA security

Hardware virtualization layer

Hardware

Legacy Systems!
Open Standards can help make a market that goes beyond an individual company. They provide a platform in which vertical applications are built.

US Navy Open Architecture program: up to 80% reduction in Total Cost of Ownership (TCO). Continuous Technology Insertion: complete renewal of onboard electronic systems every 4th year.
We are Open!
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