e-Navigation 101:
What is it, Why important, & How should it work?

Dr. Lee Alexander
leealex@ccom.unh.edu
Overview

Three parts:

Part 1 - What is “e-Navigation”
  • Why important?
  • What are some key aspects and components?
  • How should it all work?

Part 2 – Role and responsibility of government agencies
  • Includes both challenges and opportunities
  • Shipborne and shore-based requirements
  • Providers vs. Users

Part 3 – User perspective/involvement
Definition:

“the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment.”
e-Navigation

Definition:
“the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment.”
e-Navigation

Significant outcomes/benefits related to:

1. Shipboard navigation systems
2. Management of VTS and related services
3. Communications infrastructure
e-Navigation (IMO vision)

1. Shipboard navigation systems
   - Integration of ownship sensors
   - Supporting information
   - Standard user interface
   - Comprehensive systems for managing guard zones and alerts

**Core elements include:**
- High-integrity electronic positioning (e.g., GNSS)
- Use of ENCs and ECDIS
- An analysis capability to reduce human error

“All while actively engaging the mariner in the process of navigation while preventing human error.”
## e-Navigation = Mix of Equipment/Systems/Services

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Shore-based</th>
<th>Shipborne</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMDSS - Global Maritime Distress Safety System</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>Radar/ARPA</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>GPS – Global Positioning System</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td><strong>ECDIS</strong></td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>AIS</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>CCTV</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>VHF voice radio [?]</td>
<td>X</td>
<td>x</td>
</tr>
</tbody>
</table>

### Systems

<table>
<thead>
<tr>
<th>Systems</th>
<th>Shore-based</th>
<th>Shipborne</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRIT – Long-range Identification and Tracking</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>SSN - SafeSeaNet</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>GNSS – Global Navigation Satellite System</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>Nav Warnings</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>e-Loran [?]</td>
<td>X</td>
<td>-</td>
</tr>
</tbody>
</table>

### Services

<table>
<thead>
<tr>
<th>Services</th>
<th>Shore-based</th>
<th>Shipborne</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTS</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>VTMIS</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>MRCC – Maritime Rescue Coordination Center</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>Maritime Coastal Radio</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>Weather Service</td>
<td>X</td>
<td>x</td>
</tr>
</tbody>
</table>
e-Navigation Concept of Operation

- Equipment
  - Systems
  - Services

The diagram illustrates the interconnection between equipment, systems, and services in the context of an e-navigation concept.
In the beginning...

The three ‘Where’s:

Where did we start from?
Where are we at?
Where do we go from here?

In 2008, IMO decided that:
“the development of e-Navigation should be user-driven and not technology driven.”

Source: NAV 54/25, paragraph .4
World-wide e-Navigation User Needs Survey

Conducted for IMO by Germany and Canada in 2008-2009
- Questionnaire based on high-level User Needs

Dealt with:
- Maritime Communications
- Reporting Requirements
- Human Machine Interface
- Presentation/filtering of information
- Technical / operational enhancements
- Redundancy for GNSS

Technical / Operational Enhancements

Preferred redundancy for a GNSS

16 The vast majority of the participants indicated a preference for another GNSS as a redundancy for a GNSS (68% in favour, 17% rather in favour). There is also support for the use of radar positioning (42% in favour, 23% rather in favour). Only 8% are in favour of Loran C as a redundancy for a GNSS, 40% are not in favour, 16% rather not in favour.

Figure 20: Frequency of answers [%] for question: “What type of electronic navigation system(s) would you prefer as a redundancy for a GNSS (e.g., GPS)?” (N=324-341)
Technical / Operational Enhancements

Preferred redundancy for a GNSS

The vast majority of the participants indicated a preference for another GNSS as a redundancy for a GNSS (68% in favour, 17% rather in favour). There is also support for the use of radar positioning (42% in favour, 23% rather in favour). Only 8% are in favour of Loran C as a redundancy for a GNSS, 40% are not in favour, 16% rather not in favour.

Figure 20: Frequency of answers [%] for question: “What type of electronic navigation system(s) would you prefer as a redundancy for a GNSS (e.g., GPS)?” (N=324-341)
User Needs and Priorities for e-Navigation were identified by IMO in 2010

1. **Shipboard**
   - **Human Machine Interface**
     - Standard Interface
     - Familiarization Requirements
     - User-Selectable Presentation of Information Received via Comms Equipment
     - Maritime Safety Information (MSI)
     - Alert Management
     - Indication of Reliability
   - **Operational Issues**
     - Improved Reliability
     - Standardized and Automated Reporting
     - Improved Target Detection
     - Guard Zones
     - Reduction of Administrative Burden and Increase Use of Electronic Documentation
     - Automated Updating of Base Line Data and Documents
     - Effective and Robust Communications

2. **Shore-based**
   - Collection of Information
   - Management of Information
   - Provision of Information to Vessels
   - Quality Assurance
   - Shore to Shore Information Exchange
   - Effective and Robust Communications

3. **Search and Rescue (SAR)**
   - SAR should have access to relevant information contained within the e-Nav domain
   - Effective comms and information sharing
   - Priority for distress comms
   - SAR authorities need access to details of relevant onboard comms equipment

*Source: NAV 56/20, paragraph 8.46*
Key Elements for e-Navigation*

1. Architecture
2. Human element
3. Conventions and standards
4. Position fixing
5. Communication technology and information systems
6. ENCs
7. Equipment standardization
8. Scalability

* To be based on User Needs

Source: IMO MSC 85/26/add.1, annex 21
e-Navigation Technical Framework

In 2008 IMO recognized that:

“The overall conceptual, functional and technical architecture will need to be developed and maintained, particularly in terms of process description, data structures, information systems, communications technology and regulations.”

Source: MSC 85/26/add.1, annex 20, paragraph 9.1.1

In 2012, a **Technical Framework** was approved by IMO.

It included:

1. **an overarching architecture**
2. developing a Common Maritime Data Structure (CMDS)
3. use of IHO S-100 standard as a baseline for creating a framework for data access and services under the scope of SOLAS

Source: MSC 90/28, paragraph 10.9 – 10.10
Figure 1 - The complete e-navigation architecture (NAV 57/WP.6)
Gap Analysis

**Purpose:** “Determine the space between where we are and where we want to be, and serve as a means to bridge that space.”

**Goal:** Identify e-Navigation solutions

*Source: NAV 57/6, annex 2*

Final list of e-Navigation **gaps** was completed by IMO in July 2012

*Source: NAV 58/14, annex 7*
### Annex 2: GAP ANALYSIS AND PRACTICAL E-NAVIGATION SOLUTIONS WITH HUMAN ELEMENT CONSIDERING HEAP

#### USER FIELD

<table>
<thead>
<tr>
<th>Related User Needs (NAV 55/WP.1 Rev.1 Annex 2.3)</th>
<th>Relationship strategy</th>
<th>Existing equipment, systems, technologies</th>
<th>Operational area</th>
<th>Proposed practical e-navigation solutions to address identified gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related Functions (NAV 55/WP.1 Rev.1 Annex 2.3)</td>
<td>NA (for Human element, ref. HWAP e-nav table ‘7 &amp; ‘R’)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

#### SHIPBOARD USER

<table>
<thead>
<tr>
<th>User Needs</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

#### UNIT/COMM DATA MANAGEMENT DATA FORMATS

<table>
<thead>
<tr>
<th>User Needs</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

#### NAUTEX SafetyNet

<table>
<thead>
<tr>
<th>Operational area</th>
<th>Existing equipment, systems, technologies</th>
<th>Proposed practical e-navigation solutions to address identified gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

#### TECHNICAL

<table>
<thead>
<tr>
<th>NA</th>
<th>na</th>
<th>na</th>
<th>na</th>
</tr>
</thead>
</table>

#### REGULATORY

<table>
<thead>
<tr>
<th>NA</th>
<th>na</th>
<th>na</th>
<th>na</th>
</tr>
</thead>
</table>

#### TRAINING

<table>
<thead>
<tr>
<th>NA</th>
<th>na</th>
<th>na</th>
<th>na</th>
</tr>
</thead>
</table>

#### Source: NAV 58/6, Annex 2, page 1 of 29
e-Navigation Solutions

Based on the results of the Gap Analysis, nine (9) potential Solutions were initially identified:

S1 Improved, harmonized and user-friendly bridge design
S2 Means for standardized and automated reporting
S3 Improved reliability, resilience and integrity of bridge equipment and navigation information
S4 Integration and presentation of available information in graphical displays received via communication equipment
S5 Information management
S6 Improved access to relevant information for Search and Rescue
S7 Improved reliability, resilience and integrity of bridge equipment and navigation information for shore-based users
S8 Improved and harmonized shore-based systems and services
S9 Improved communication of VTS service portfolio

At NAV 58 (July 2012), these were presented, but considered “work in progress.”

Source: NAV 58/14, annex 7
Prioritized Solutions

In July 2013, five (5) were prioritized and ‘endorsed’ by IMO NAV 59:

S1  Improved, harmonized and user-friendly bridge design
S2  Means for standardized and automated reporting
S3  Improved reliability, resilience and integrity of bridge equipment and navigation information
S4  Integration and presentation of available information in graphical displays received via communication equipment
S5  Information management
S6  Improved access to relevant information for Search and Rescue
S7  Improved reliability, resilience and integrity of bridge equipment and navigation information for shore-based users
S8  Improved and harmonized shore-based systems and services
S9  Improved communication of VTS service portfolio

Source: NAV 59/20, paragraph 6.30
As of April 2014…

**Ongoing IMO Activities** (by e-Nav Correspondence Group)
- Identification of Risk Control Options (RCOs)
- Formal Safety Assessment (FSA)
- Risk and cost/benefit analysis
  - **Maritime Service Portfolios (MSPs)**
- Draft Guidelines on:
  - Human Centred Design (HCD) for navigational equipment/systems
  - Usability evaluation of navigational equipment
  - Software Quality Assurance (SQA)
  - Harmonization of test beds reporting
- **Strategy Implementation Plan (SIP)**
Strategy Implementation Plan (SIP)
- Sets objectives and specific timelines during 2015-2019
- Facilitates coordination of efforts by:
  IMO sub-committees
  International Organizations
  Member States
  Regional bodies
  Maritime Industry

Three Phases to the SIP:
1 – Model development (2015-2016)
2 – Standardization (2017-2018)

Source: NAV 59/WP.8, Annex
IMO has described key tasks for present/future shipborne navigation systems:

1. Route Planning/Grounding Avoidance
2. Route Execution
3. Maintaining Situational Awareness
4. Operational Mode Awareness
5. Collision Avoidance
6. Emergency & SAR
7. Reporting

* IMO NAV 54
e-Navigation-related
Equipment, Systems and Services

IMO has identified some existing components and potential “building blocks” *

Radar
ECDIS/IBS
Electronic Navigational Charts (ENCs)
Communications
Positioning, Navigation and Timing
Situational Awareness
Maritime Information Systems
Human Factors

* IMO NAV 54
ECDIS implementation schedule

- **2009**: Deadlines existing ship
  - Passenger Ships ≥500 GT
  - Tankers ≥3000 GT
  - Cargo ships ≥10 000 GT

- **2010**: Cargo ships 3-10 000 GT

- **2011**: Cargo ships 10 - 20 000 GT

- **2012**: Cargo ships 20 - 50 000 GT

- **2013**: Cargo ships ≥50 000 GT

- **2014**: Deadlines new ship
Some ECDIS Challenges

1. Until ECDIS is fully implemented, there will be a mix of ECDIS and ECS systems.

2. Uncertainty/confusion about use of ENCs, SENCs, and RNCs.
   - coverage, availability, suitability, cost, NtoM/updating services, etc.

3. “Minimum” Performance Standards limit increased functionality.
   - Dynamic ENC
   - AIS Application Specific Messages
   - Improved colour scheme
High-density bathymetry → Bathymetric Surface
Decimeter Soundings and Depth Contours produced from a *Bathymetric Surface*
Tide/Water Levels in St. Lawrence River, Canada

Source: Gilles Ringuette, Canadian Coast Guard, Quebec
Approach to Portsmouth, New Hampshire, USA

Dynamic ENC

Ship’s safety contour

Depth contours @ 1m intervals

Approach to Portsmouth, New Hampshire, USA
AIS display limitations

No effective means to display new AIS application-specific messages for:

- Dangerous cargo indication, addressed
- Extended ship static and voyage related data, broadcast
- Area Notice, addressed or broadcast
- Route Information, addressed or broadcast
- Text Description, addressed or broadcast
Displaying AIS Application- Specific Messages

At present, SOLAS vessels not required to have specific equipment to display AIS application-specific messages (ASMs).

- AIS Minimum Keyboard Display (MKD) can only display text information.

But, some AIS ASM information already being displayed on:

ECDIS (primarily being operated as an ECS)

Integrated Navigation Systems (INS)

Portable Piloting Units (PPUs)
Portable Piloting Unit (PPU)

PPU = eNAV display
Additional Display for e-Navigation Information onboard *MS Silja Serenade*

Test facilities for information exchange at the **Gulf of Finland Traffic Centre**

Pilot plug
IHO S-52 Colours and Symbols

“Bathymetric Blue”
New/improved Colour Schemes

Available in the 2012 release of HYPACK SHELL & the ENC EDITOR.

Source: Pat Sanders, HYPACK, Inc.
### Display Options for AIS Application Specific Messages

<table>
<thead>
<tr>
<th>Application</th>
<th>Alpha-numeric (text &amp; numbers)</th>
<th>Graphical (time-series graph)</th>
<th>Symbol (or icon)</th>
<th>Geo-spatial (Point, line, or area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteorological and Hydrographic</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tidal window</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weather Report from Ships</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area Notice - broadcast</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Area Notice - addressed</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*Met/hydro applications in IMO SN.1/Circ.289*

*Display options from IMO SN.1/Circ.290*
AIS ASM Broadcast Testbed – Tampa Bay

NOAA PORTS* → AIS ASM broadcast

* Physical Oceanographic Real-time System (PORTS)
Met/Hydro NOAA PORTS in Galveston, TX

Valid Time: 0754 (CDT) 06/06/01

Water Levels at North Jetty
- Observed Height: 2.04 ft.
- Predicted Height: 2.05 ft.

Currents at Bolivar Roads
- Knots
- Along-channel (292° T)
  - Observed Current: 0.47 Knots
  - Predicted Current: 1.71 Knots
- Cross-channel (22° T)

Ancillary Data at North Jetty
- WIND SPEED: 17 KNOTS
- GUSTING TO: 20 KNOTS
- AIR TEMP: 76.5 °F
- AIR PRESS: 1007.5 mbar
- Salinity: N/A
- Spec. Gravity: N/A
- Water Temp: 78.3 °F
Tidal Currents in the St. Lawrence River, Canada

Predicted (current tables)
Real-time (via AIS Broadcast)
Forecast
Nowcast

Source: Atlas of Tidal Currents – St. Lawrence Estuary, Department of Fisheries and Oceans, Canada
Simulation provided by: Canadian Hydrographic Service - Maurice Lamontagne Institute, Mont-Joli, Quebec
‘Murphy’s Laws’ *

First Law:
Anything that can go wrong ...will. Usually at the worse time!

Glib’s Laws of Unreliability

1. Computers are unreliable, but humans are even more unreliable.
2. Any system that depends on human reliability -- is unreliable.
3. Undetectable errors are infinite in variety, in contrast to detectable errors that by definition are limited.

Software Myth
There are two ways to write error-free software. Only the third one works.

* ...and other ‘un-natural laws for scientists and engineers
e-Navigation and Software Quality Assurance (SQA)

Displaying real-time water level information
1. Measured by tide gauge sensor
2. Converted into a binary format
3. Broadcast from an AIS Base Station as an AIS-ASM
4. Received by shipborne/shore-based AIS transceiver
5. Displayed on e-Nav equipment (e.g., ECDIS, INS, or a Portable Piloting Unit)

Every step in the process involves software...

Source: Dr. LEE, Seojeong - Korea Maritime & Oceanographic University
Trend Display of Navigation-related information on ECDIS
Trend in Display of Navigation-related Information on ECDIS

At present …
Trend in Display of Navigation-related Information on ECDIS
ECDIS in the future?: 3-D Visualisation
Desirable outcomes → Major Challenges

1. Ensuring the availability of all components – and using them effectively!
2. Incorporate new technologies in structured manner.

Challenges (& realities)

• Integrating more components into a “system” often leads to increased complexity -- and less reliability.
• With increasing amounts of information, tendency is to display more -- not less -- information.
• Just because someone wants to provide information they think is useful -- does not make it so.
• Trying to integrate “new” technologies with existing systems and services initially causes more problems than it solves.
e-Navigation Implementation Challenges

What is (or should be) the role/responsibility of government?

A major complicating factor is that two groups are involved:

**Providers** – Those responsible for providing necessary e-Nav services.

**Users** – Those who will actually use (and rely) on them.

Implementation dilemma:

- Government **providers** are hesitant to commit resources to establish an infrastructure without commitment by industry to use (and pay for?) the service.

- Conversely, **users** are reluctant to use until government is committed to build the infrastructure, and provide necessary services.
e-Navigation ‘Realities’

e-Navigation should be regarded as an evolutionary – not revolutionary – change.

- When change impacts ‘tried-and-true’ maritime navigation systems or practices, the process may be a ‘bumpy’ ride.
- Possibly, e-Nav will be similar to the transition from visual to instrument flight rules (VFR and IFR) that occurred in the aviation industry.

If so, what are the implications?

- Will mariners be required to take e-Nav training to become ‘e-Nav certified’?
- Will there be e-Nav modes of operation whereby e-Nav capable vessels are given preferential treatment (e.g., under-keel clearance, all-weather transits, preferred routing/port entry)?
- If critical navigation safety-related info exists, will the government take full responsibility to provide in a timely, reliable manner – and in a format that can be used with existing shipboard navigation systems?
Has e-Navigation steered out of the channel?


Raises the question: “...has the concept of e-Nav been hijacked by interests that are unfriendly to ship operators and mariners, and lack sufficient understanding of ship navigation?”

He recommends three things:

1. The ship operating industry needs to become more involved.
2. e-Navigation should be re-focused on the needs of the mariner.
3. IMO and IALA should abandon their central planning approach to e-Navigation.
In the end...

The three ‘Where’s:

Where did we start from?
Where are we at?
Where do we go from here?

In 2008, IMO decided that:

“the development of e-Navigation should be user-driven and not technology driven.”

Source: NAV 54/25, paragraph .4
Let Mariners decide…

1. What are the User Requirements? (that are not being currently met)
   - User Needs + Tasks \(\rightarrow\) Information Needs \(\rightarrow\) [Services]
   - Shipborne and shore-based

2. What are (or should be) e-Nav equipment, systems and services?
   - Relatively few \(\leftrightarrow\) [Realistic] \(\rightarrow\) “anything and everything…”
   - Shipborne and shore-based

3. What are (or will be) major e-Nav implementation issues?
   - Recognize limitations of current shipborne equipment/systems standards.
   - Identify harmonization challenges & opportunities.
   - Develop guiding principles/best practices.
   - Commit to implementation
Thinking Like a Mariner…

**Mariners vs. Developers**
“A system is only as good as who is using it, and what it is being used for.”
“Give a good system to a mariner, and they will figure out how to use it better than those who developed it.”
Capt. Lee Alexander, USN (ret)

**Maritime Information – The “Wants”**
“I don’t want more information, I want better!”
“Don’t tell me what was, tell me what is -- or will be.”
Capt. Jean-Luc Bedard, Port of Montreal

**Electronic Chart - a paradigm shift.**
“With paper charts, you have to figure out what is your position and what to avoid. With ECDIS, it shows you where you are -- and where it’s safe to go.”
Capt. Dave McLeish, USCG (ret)

**Portable Piloting Units**
“Never do something with one of these systems that you would not do without it.”
Capt. Wayne Bailey, Delaware River Pilots