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Regulations for the Design of Ship Bridges: Past, Present and Future

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We Have a Problem!

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Multi-Vendor Bridge Systems!

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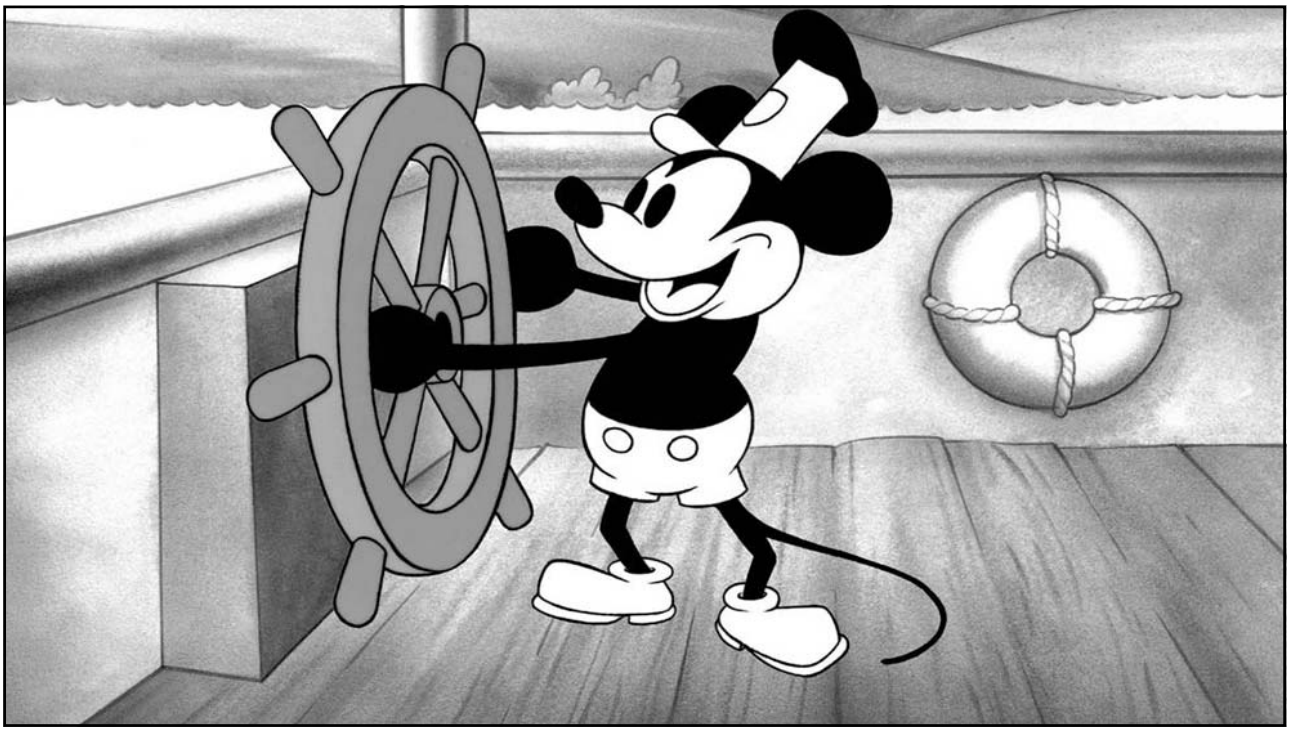
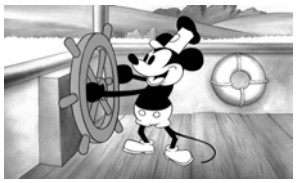


The (ongoing) Problem…

- Equipment found on ship bridges rarely offer consistent user interface design
- **30 + brands** on a single bridge (Oltedal and Lützhöft, 2018)
- Little or no coordinated development of user interfaces (Nordby et al., 2019)

The (ongoing) Problem…

- Importance of interface **design consistency**
  - Reduce human error
  - Increase operator efficiency
  - Increase user satisfaction



(Nielsen, 2014)

- Forces users to (unnecessarily) adapt!
  - Multiple design languages, styles, palettes, etc.
  - Reduces training, familiarzation time

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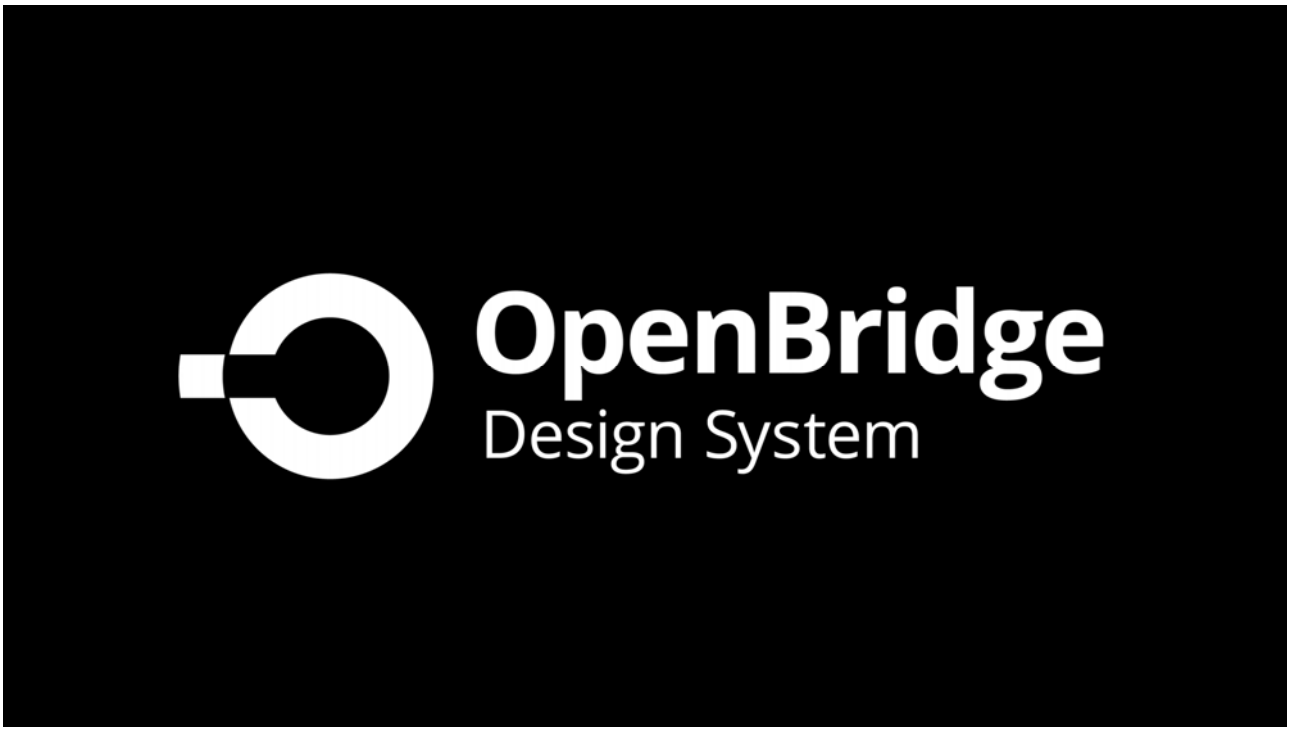

What is OpenBridge???

- Multi-Disciplinary Research and Innovation Project
- Research headed by AHO, SINTEF and USN
- 25+ industry partners
- **Overarching Goals:**
  - Develop an **open platform** that provides better user interfaces on ships
  - **Simplify** multi-vendor integration

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Motivation

- Increasing complexity of **ships /systems / work enviornments**
- Increasing levels of **automation /autonomy**
- Increasing **digitalization** of systems
- Evolving **operator demands**

- **General Assumptions:**
  - Current design approaches generally do not address:
    - Increasing digitalization of modern ship bridges
    - Multi-Vendor System integration

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IMO MSC/Circ. 1091

Standardization

2 Although performance standards exist, many bridge systems, engineering consoles and cargo systems vary greatly in their user interface (layout of controls, displays and symbology) and functionality beyond what is required as a minimum (added features requiring extra controls, menu options or customised symbology). The result of non-standardized controls and displays is an increase in the amount of training needed to make a seafarer familiar with, and effective in, the use of the equipment.

5 The solution is a common interface with standard symbology for common operations and where systems are capable of being customised into non-standard displays, the standard display should be able to be reverted to through a single and obvious control feature.

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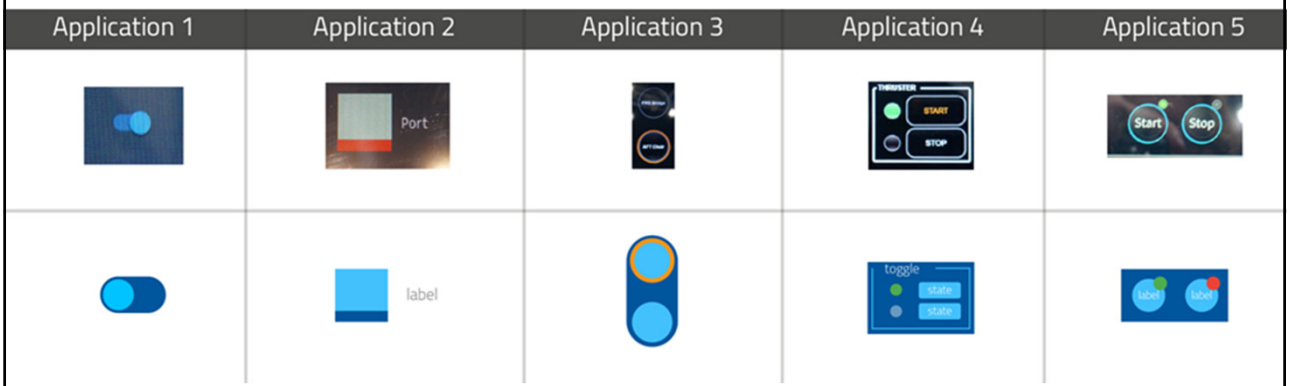
IMO, 2003

Toggle Button Example



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Nordby, K., Mallam, S. C. & Lützhöft, M. (2019). Open user interface architecture for digital multivendor ship bridge systems. *WMU Journal of Maritime Affairs, 18*(2), 297-318. DOI: 10.1007/s13437-019-00168-w

Let's start at the beginning…

- We need to understand the current situation
  - Map what already exists

- Literature search and technical report
  - "***Assessment of Current Maritime Bridge Design Regulations and Guidance***"

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Problem Statement

1. What design-related regulations and guidelines exist for the design of digital workplaces that are well-suited for design practitioners?
   - » Mandatory Regulations
   - » Recommendations and Guidelines
   - » Goal-Based Guidance?
   - » Rule-Based (or Prescriptive) Guidance?

2. Are relevant regulations and guidelines well adapted to support design processes seeking to develop **digital maritime workplaces**?

Aims

1. **Collect and establish a working database** of all design regulations and guidelines specifically focusing on the bridge and bridge equipment

2. Subdivide and **analyze the identified material** to establish the design support within current regulations and guidelines

Overview of Findings

- The literature search of regulations and guidelines expanded to over **75+ documents**

- These are documents issued by a range of entities:
  - Classification societies
  - Professional organizations
  - Governing bodies
  - Defense (naval organizations)

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	Internal Ref Code	Document Obtained by Project	Entity	Published Title Code	Full Title
1	ABS1	Y	ABS		Guidance Notes On The Application of Ergonomics to Marine Systems (2013, updated 2014)
2	ABS2	Y	ABS		Guide for Bridge Design and Navigational Equipment/Systems (2018), updated 2014)
3	ABS3	Y	ABS		Guidance Notes On - Ergonomic Design of Navigational Bridges (October 2003)
4	ASTM5	N	ASTM	F1166-07 (2015)	Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities
5	DNVGL1	Y	DNVGL		Rules for Classification: Part 6: Additional class notations: Chapter 1: Navigation, maneuvering and position keeping
6	DNVGL2	Y	DNVGL		Rules for Classification: Part 6: Additional class notations: Chapter 8 : Nautical Safety [various sections of interest for bridge equipment/design]
7	DNVGL3	Y	DNVGL		Rules for Classification of Ships (2002): Safety of Navigation (Part 4, Chapter 11)
8	DNVGL4	N	DNVGL		Rules for Classification and Construction – Ship Technology: Bridge Arrangement and Equipment on Seagoing Ships (2012 Edition)
9	IACS1	Y	IACS	Rec. No.132	Human Element Recommendations for structural design of lighting, ventilation, vibration, noise, access and egress arrangements
10	IACS2	Y	IACS	N101(Rev2)	One man bridge operated (OMBO) ships
11	IACS3	Y	IACS	No.95	Recommendation for the application of SOLAS Regulation V/15 bridge design, equipment arrangement and procedures (BDEAP)
12	IACS4	N	IACS	UI SC181	Bridge Design, Equipment Arrangement and Procedures (EU/MRN TG/ WITHDRAWN PENDING FURTHER DEVELOPMENT WORK)
13	IEC1	N	IEC	IEC 1162-8	Ships and marine technology - Gyro-compasses for high-speed craft
14	IEC2	N	IEC	IEC 1632 (1)(COPIAS 1989-1:2017)	Ships and marine technology – Degrees of protection provided by enclosures (IP Code) (Ships and marine technology – Specifications for gas detectors intended for use on board ships — Part 1: Portable gas detectors for atmospheric testing of enclosed spaces)
15	IEC3	N	IEC	IEC 60079-0-3	Luminaires - Part 3: General Requirements and tests
16	IEC4	N	IEC	IEC 60827-2 [all parts]	Maritime navigation and radiocommunication equipment and systems – Radar plotting aids
17	IEC5	N	IEC	IEC 60936 [all parts]	Maritime navigation and radiocommunication equipment and systems – Radar
18	IEC6	N	IEC	IEC 62065	Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results
19	IEC7	N	IEC	IEC 61023	Maritime navigation and radiocommunication equipment and systems – Marine speed and distance measuring equipment (SDME) - Performance requirements - Methods of testing and required test results
20	IEC8	N	IEC	IEC 61097-7 [all parts]	Global maritime distress and safety system (GMDSS)
21	IEC9	N	IEC	IEC 61108 [all parts]	Maritime navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS)
22	IEC10	N	IEC	IEC 61162 [all parts]	Maritime navigation and radiocommunication equipment and systems – Digital interfaces
23	IEC11	N	IEC	IEC 61174	Maritime navigation and radiocommunication equipment and systems - Electronic chart display and information system (ECDIS) - Operational and performance requirements, methods of testing and required test results
24	IEC12	N	IEC	IEC 61209	Maritime navigation and radiocommunication equipment and systems - Integrated bridge systems (IBS) - Operational and performance requirements, methods of testing and required test results
25	IEC13	N	IEC	IEC 61924	Maritime navigation and radiocommunication equipment and systems – Integrated navigation systems - Operational and performance requirements, methods of testing and required test results
26	IEC14	N	IEC	IEC 61993-2	Maritime navigation and radiocommunication equipment and systems – Automatic identification systems (AIS) – Part 2: Class A Shipborne equipment of the universal automatic identification system (AIS) - Operational and performance requirements, methods of test and required test results
27	IEC15	N	IEC	IEC 61996	Maritime navigation and radiocommunication equipment and systems – Shipborne voyage data recorder (VDR) - Part 2: Simplified voyage data recorder (S-VDR) - Performance requirements, methods of testing and required test results
28	IEC16	N	IEC	IEC 61996-2	Maritime navigation and radiocommunication equipment and systems – Shipborne voyage data recorder (VDR) – Part 2: Simplified voyage data recorder (S-VDR) - Performance requirements, methods of testing and required test results
29	IEC17	N	IEC	IEC 62065	Maritime navigation and radiocommunication equipment and systems - Track control systems - Operational and performance requirements, methods of testing and required test results
30	IEC18	N	IEC	IEC 62288	Maritime navigation and radiocommunication equipment and systems – Displays for the presentation of navigation-related information - general requirements, methods of test and required test results
31	IEC19	N	IEC	IEC60945	Maritime Navigational and Radiocommunication Equipment and Systems – General Requirements – Methods of Testing and Required Test Results
32	IMO1	Y	IMO	MSC.191(79)	Performance Standards for the Presentation of Navigation-Related Information on Shipborne Navigational Displays
33	IMO2	Y (online)	IMO	SOLAS Chapter V (Regulation 15)	Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures
34	IMO3	Y	IMO	MSC.128(75)	Performance Standards for a Bridge Navigational Watch Alarm System (BNWAS)
35	IMO4	N	IMO	MSC/Circ. 1061	Guidance for the operational use of the Integrated Bridge Systems (IBS)
36	IMO5	Y	IMO	COLREGS (Annex III)	Convention on the International Regulations for Preventing Collisions at Sea (COLREGs), Annex III, Technical details of sounds signal appliances
37	IMO6	Y	IMO	MSC/Circ.982	Guidelines on ergonomic criteria for bridge equipment and layout
38	IMO7	Y	IMO	Circ. 1091	Issues to be considered when introducing new technology on board ship
39	IMO8	Y (online)	IMO	SOLAS Chapter V (Regulation 22)	Navigation Bridge Visibility
40	IMO9	Y	IMO	A 10.21	Code on Alerts and Indicators, 2009
41	IMO10	Y	IMO	ISM Code	International Safety Management Code (ISM Code)
42	IMO11	Y	IMO	MSC. 64(67)	Adoption of New and Amended Performance Standards (Annex 1: Recommendation of Performance Standards for Integrated Bridge Systems (IBS))
43	IMO12	Y	IMO	Polar Code	International Code for Ships Operating in Polar Waters (Polar Code)
44	IMO13	Y	IMO	Circ.265	Guidelines on the application of SOLAS regulation V/15 to INS, IBS and bridge design
45	ISO1	N	ISO	ISO 613	Ships and marine technology – Magnetic compasses, binnacles and azimuth reading devices – Class B
46	ISO2	N	ISO	ISO 8728	Ships and marine technology – Marine gyro-compasses
47	ISO3	N	ISO	ISO 9875	Ships and marine technology – Marine echo-sounding equipment
48	ISO4	N	ISO	ISO 11674	Ships and marine technology – Heading control systems
49	ISO5	N	ISO	ISO 16273	Ships and marine technology – Safety vision equipment for high-speed craft – Operational and performance requirements, methods of testing and required test results
50	ISO6	N	ISO	ISO 16328	Ships and marine technology –Gyro-compasses for high-speed craft
51	ISO7	N	ISO	ISO 16329	Ships and marine technology – Heading control systems for high-speed craft
52	ISO8	N	ISO	ISO 17894	Ships and marine technology – Searchlights for high-speed craft
53	ISO9	N	ISO	ISO 17894	Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications
54	ISO10	N	ISO	ISO 17899	Ships and marine technology – Marine electric window wipers
55	ISO11	N	ISO	ISO 19018	Ships and marine technology – Terms, abbreviations, graphical symbols and concepts on navigation
56	ISO12	N	ISO	ISO 19019	Seagoing vessels and marine technology – Instructions for planning, carrying out and reporting sea trials
57	ISO13	N	ISO	ISO 20672	Ships and marine technology – Rate of turn indicators
58	ISO14	N	ISO	ISO 20673	Ships and marine technology – Electric rudder angle indicators
59	ISO15	N	ISO	ISO 22090 (all parts)	Ships and marine technology – Transmitting heading devices (THDs)
60	ISO16	N	ISO	ISO 22472	Ships and marine technology – Guidelines for the operation and installation of voyage data recorders (VDR)
61	ISO17	N	ISO	ISO 22554	Ships and marine technology – Propeller shaft revolution indicators – Electric type and electronic type
62	ISO18	N	ISO	ISO 22555	Ships and marine technology – Propeller pitch indicators
63	ISO19	N	ISO	ISO 19842:2004	Ships and Marine Technology – Ships' Bridge Layout and associated Equipment – additional requirements
64	ISO20	N	ISO	ISO 8468:2007	Ships and marine technology – ship's bridge layout and associated equipment - requirements and guidelines
65	LR1	N	LR	SKU/M138/SQG/254	The Human-Centred Approach – A Best Practice Guide for Ship Designers and Builders (2013)
66	MIL1	N	MIL	MIL-1-22540 Revision C	Intercommunication Systems (Hands Free Operated Reply Reproducer) Naval Shipboard – Revision C
67	MIL2	N	MIL	MIL-1-24078	Intercommunication Systems Naval Shipboard
68	MIL3	N	MIL	MIL-PRF-1203 B Revision A	Shipboard Furniture, Fixtures, Fittings, And Accessories – Revision A
69	TRB1	Y	TRB	Special Report 273	Shipboard Automatic Identification System Displays: Meeting the Needs of Mariners
70	UL1	Y	UL		Chapter 23 - Navigation: Bridge Visibility, Bridge Arrangement, and Equipment (2015)
71	UMS14	Y	IMO	NAV 55/12 (2009)	Guidelines on the Layout and Ergonomic Design of Safety Centres on Passenger Ships
72	UMS15	Y	IMO	NAV 55/21 (2009)	Report to the Maritime Safety Committee
73	UMS16	Y	IMO	UN, I.C.V., 284	GUIDELINES FOR BRIDGE EQUIPMENT AND SYSTEMS, THEIR ARRANGEMENT AND INTEGRATION (BES)
74	UMS17	Y	IMO	SN/Circ.243	GUIDELINES FOR THE PRESENTATION OF NAVIGATION-RELATED SYMBOLS, TERMS AND ABBREVIATIONS
75	UMS18	Y	IMO	MSC. 302(87)	Adaptation of performance standards from Bridge Alert Management
76	EU1	Y	EU	2017/306	Commission Implementing Regulation (EU) 2017/306 of 1 February 2017 indicating design, construction and performance requirements and testing standards for marine equipment
77	IHO	Y (online)	IHO	S-52	Specifications for Chart Content and Display Aspects of ECDIS
78	IHO	Y (online)	IHO	S-64	IHO Test Data Sets for ECDIS

Analysis of Documentation

- ***Physical Components***
  - All components that make up the physical workplace.
- ***Application Components***
  - UI components and patterns, style, layout, types, etc.
- ***Integration System***
  - The relationship between user interfaces and applications

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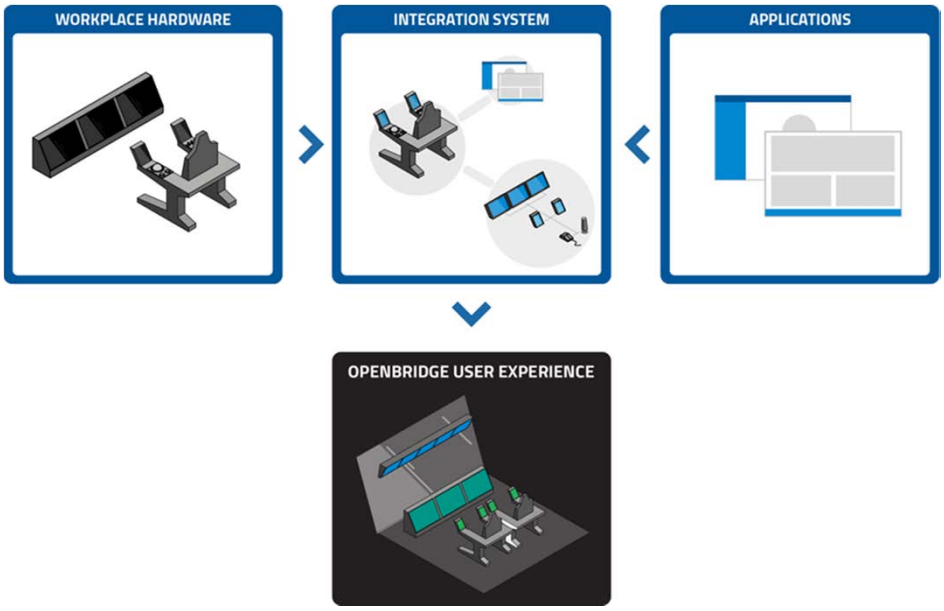

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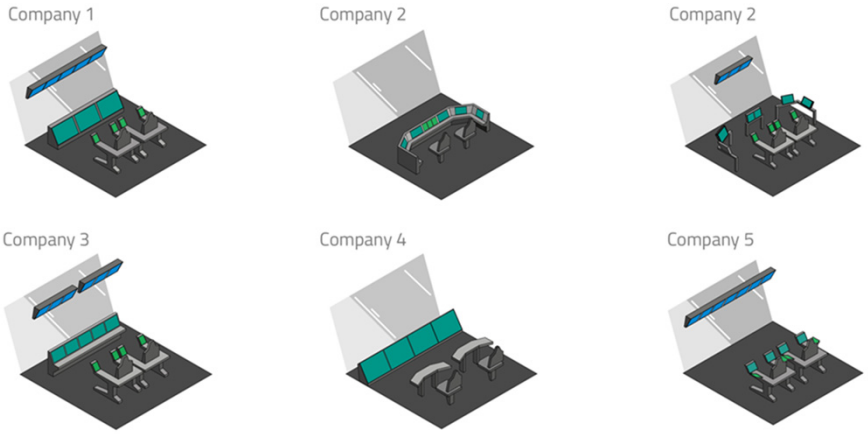
Physical Components



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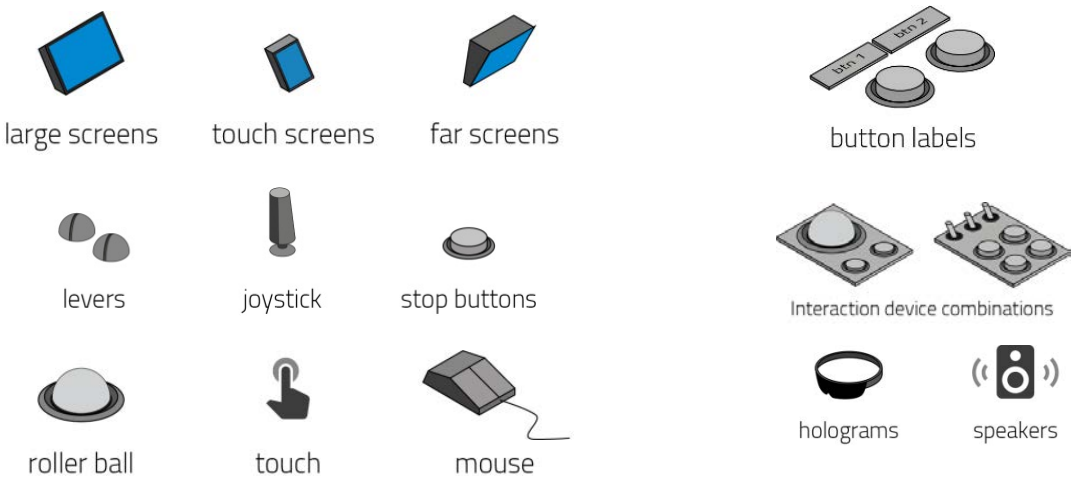

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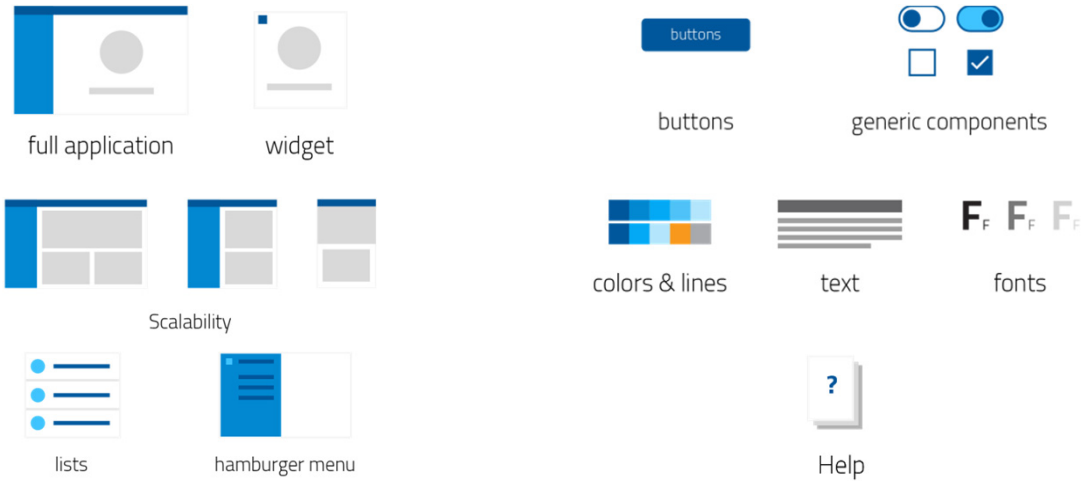
Application Components



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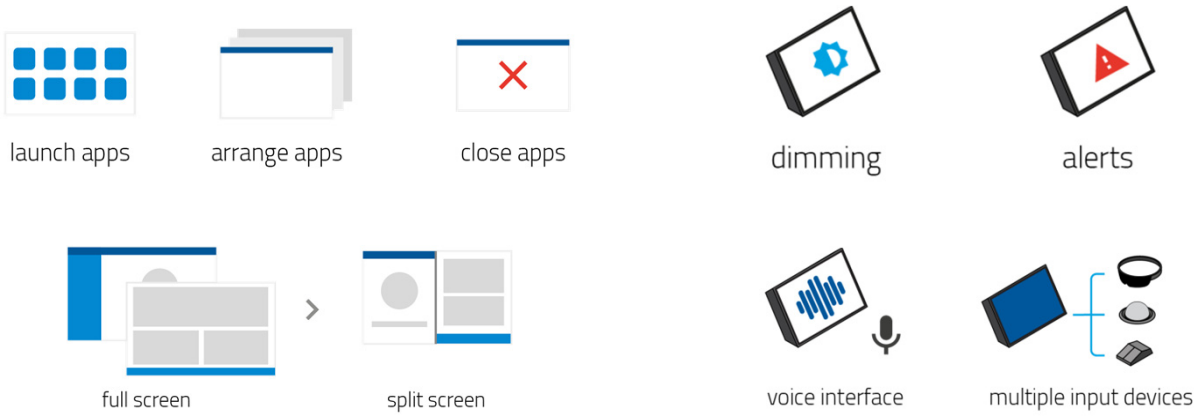
Integration Components



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Findings – Examples – Physical Components

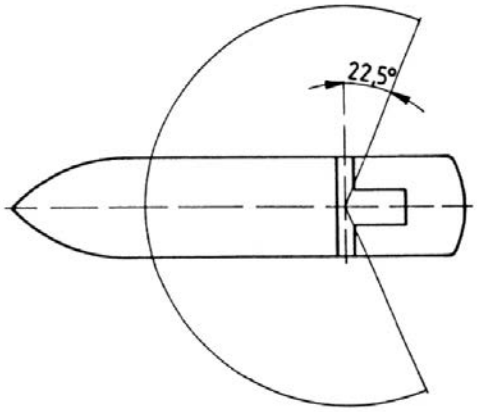
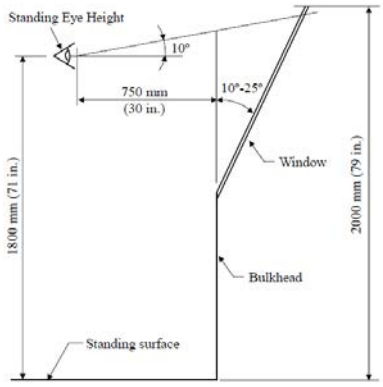


Fig. 3
Horizontal field of vision from the workstations for monitoring and navigating & manoeuvring

DNV, 2011

Findings – Examples – Physical Components

FIGURE 1
Example of Height of Upper Edge of Front Window in Relation to Eye Height



ABS, 2003

Findings – Examples – Physical Components

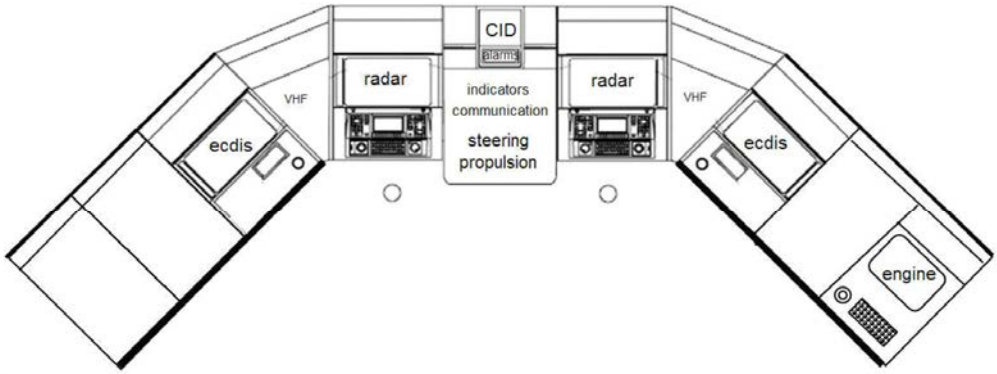


Fig. 18
Example: -joint arrangement of workstations for monitoring and navigating & manoeuvring

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DNV, 2011

Findings – Examples – Physical Components

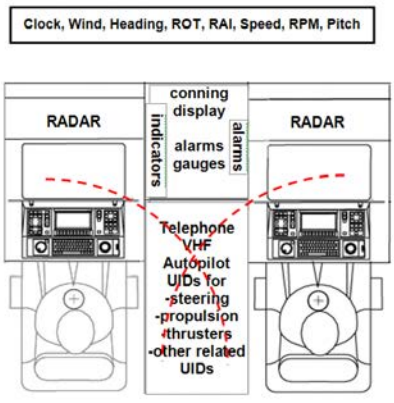

Fig. 17
Shared UIDs and information displays

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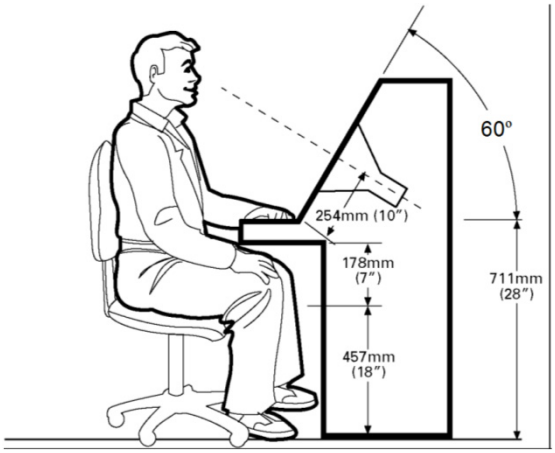
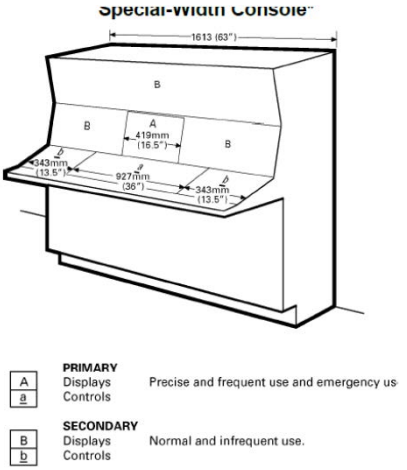
DNV, 2011

Findings – Examples – Physical Components





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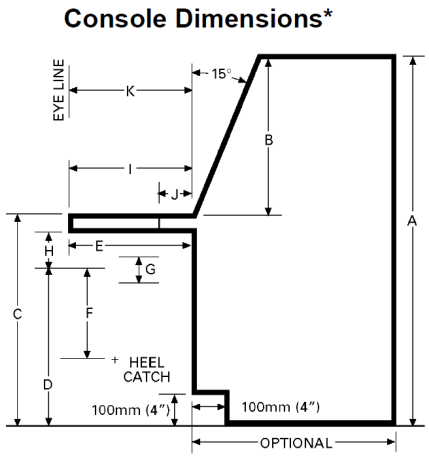
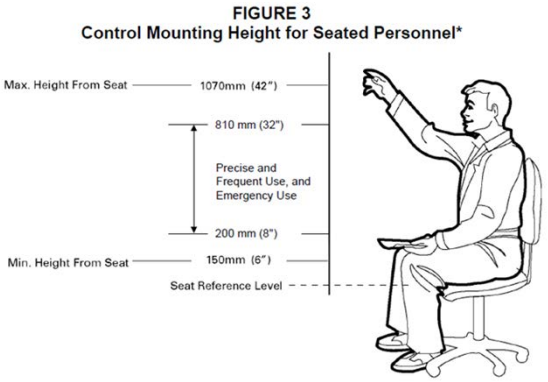
ABS, 2014

Findings – Examples – Physical Components





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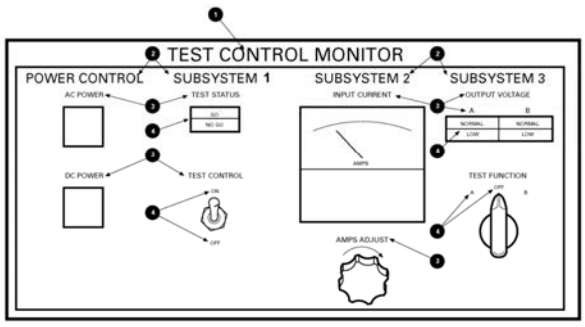
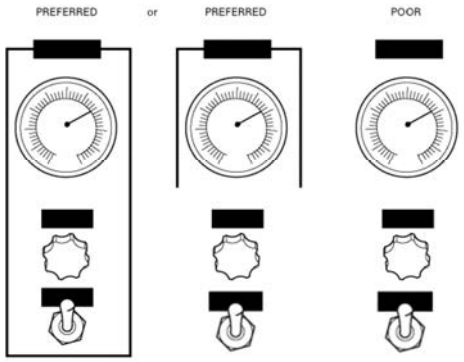
ABS, 2014

Findings – Examples – Physical Components

Guidelines for Labels on Consoles and Panels



Control and Display Group Labels



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ABS, 2014

Findings – Examples – HMI Principles

E. Human machine interface

E 100 General

101 Equipment and systems shall be designed as simple as possible in line with the prevailing principles of ergonomics.

Guidance note:

Equipment designed with simplicity in mind is generally more reliable and easier for personnel to operate. When different designs are compared from a human factors view, the simplest design usually has less potential for human error.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

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DNV, 2011

Findings – Examples – Arrangement of Information

5.3.3.4 Consistent Arrangement

The arrangement of functionally similar or identical controls should be consistent from workstation to workstation, panel to panel throughout the bridge.

5.3.3.5 Spacing Between Controls

Appropriate spacing between the controls should be provided.

IMO, 2000

Findings – Examples – Arrangement of Controls

5.3.3 Arrangement and Grouping of Controls

5.3.3.1 Control Placement

Controls requiring frequent or accurate settings should not be placed more than 675 mm from the front edge of the console.

IMO, 2000

Findings – Examples - RADAR

6.3 Presentation of radar information

6.3.1 Radar images should be displayed by using a basic colour that provides optimum contrast. Radar echoes should be clearly visible when presented on top of a chart background. The relative strength of echoes may be differentiated by tones of the same basic colour. The basic colour may be different for operation under different ambient light conditions.

6.3.2 Target trails should be distinguishable from targets and clearly visible under all ambient light conditions.

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IMO, 2004

Findings – Examples – Information Display

5.6.1.8 Uncluttered Displays

Displays should be as uncluttered as possible.

5.6.1.9 Display of Important Information

Highly important and/or frequently used information should be permanently displayed.

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IMO, 2000

Findings – Examples – Information Display

5.6.2.2 Grouping of Information in a Display

Information on a display should be grouped according to obvious principles, e.g., by task, system, function, sequence, etc., based upon the user's requirements in performance of the ongoing task.

IMO, 2000

Findings – Examples – Colour Coding

Color Coding Recommendations for Displays

Color	*Meaning*	*Explanation*	*Typical Applications*
Red	Danger or Alarm	Warning of potential danger or a situation that requires immediate action.	Failure of pressure in a lubricating system. Temperature outside specified limits. Activation of a safety system.
Amber/ Yellow	Caution	Change or impending change of conditions.	Pressure or temperature different from normal level. Run/running out of time – where time is limited.
Green	Safety	Indication of a safe situation or authorized to proceed	Cooling liquid circulating. Automatic boiler control in operation. Machine ready to be started.
Blue	Instruction/ Information	Any meaning not covered by the above colors.	Motor ready to start, pump in standby re-circulation, Ro-Ro Ramps deployed
White	No specific meaning assigned (Neutral)	Any meaning. May be used where doubt exists about the application of red, green or yellow/amber. Often used for confirmation.	Telephone calls. Synchronizing lamps (for A/C bus alignment).

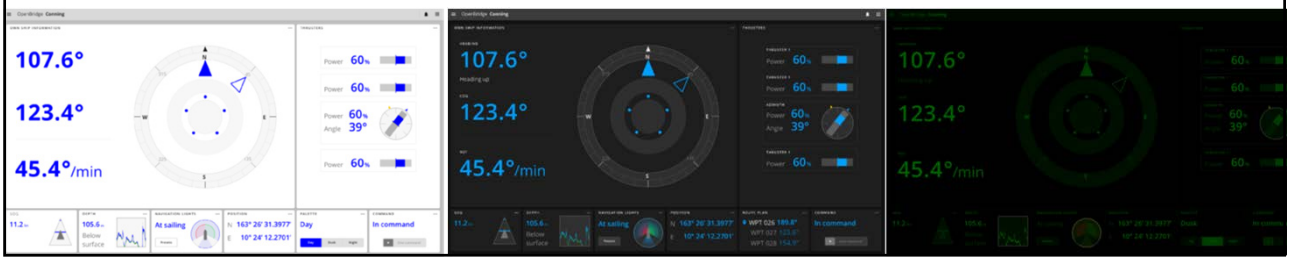
ABS, 2003

Findings – Examples - Palettes

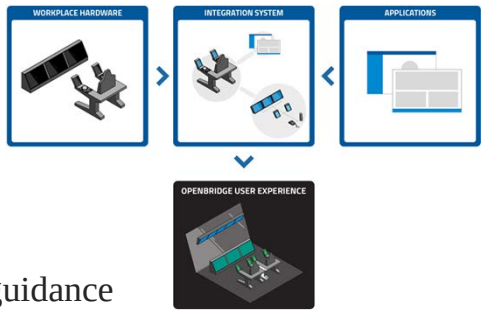
6.3 Instrument Lighting

Instruments that provide information should be presented on a background of high contrast. They should emit as little light as possible and have light text on a dark, non-reflecting background during nighttime operations.

ABS, 2003



Document Analysis



- **Physical infrastructure**
  - Most well-developed aspect of bridge design guidance
- **Digital interface** design guidance was far less prevalent
  - Relatively shallower content
  - More open-ended

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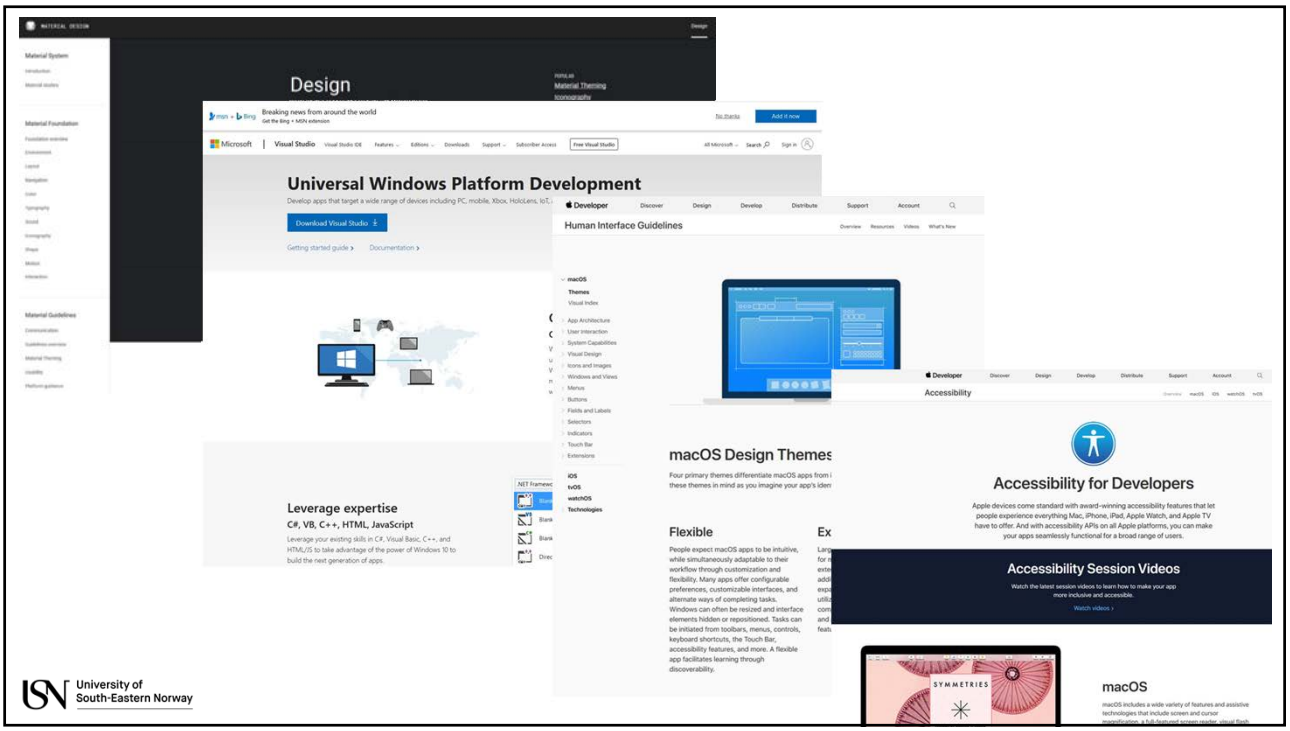
Nordby, K., Mallam, S. C. & Lützhöft, M. (2019). Open user interface architecture for digital multivendor ship bridge systems. *WMU Journal of Maritime Affairs, 18*(2), 297-318. DOI: 10.1007/s13437-019-00168-w



Moving Forward

- Generalized bridge design **guidelines/principles** can be useful in transferring to digital interfaces
  - General layout (workstation and equipment)
  - Readability
  - Visual contrast
  - Symbol consistency
- Far less **explicit guidance** is provide for Applications Components and Integration System Components
  - Provides an opportunity to adapt a web/digital design guidance philosophy for consistency in MBS

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Next Steps

- Expansion and updating of database
- Further analysis of documentation
  - Integrating relevant regulations and design guidance into OpenBridge
- **Utilize knowledge of current gaps to optimize OpenBridge method & design guidelines**

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OpenBridge
Design System

Resources & Deliverables

- **Related Journal Article**
  - Nordby, K., Mallam, S. C. & Lützhöft, M. (2019). Open user interface architecture for digital multivendor ship bridge systems. WMU Journal of Maritime Affairs, 18(2), 297-318. DOI: 10.1007/s13437-019-00168-w
- **Technical Report**
  - Mallam, S. C. & Nordby, K. (2018). *Assessment of Current Maritime Bridge Design Regulations and Guidance*. Report Prepared for the OpenBridge Project: The Oslo School of Architecture and Design.
- **Regulations Database**
- **Industry Publication**
  - Harmonising maritime workplace design through collaboration, new technologies and open innovation. *The Naval Architect: International Journal of the Royal Institution of Naval Architects.* March 2019 Issue, p.p. 22-24.
- **Medium Article**
  - "*Lack of UX Design Regulations for Ships' Bridges*"

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Regulations for the Design of Ship Bridges: Past, Present and Future

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