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Technical analysis of HMI panels in marine applications

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ABSTRACT:

This bachelor's thesis analyses commercially available HMI panels for WE Tech Solutions' upcoming marine project. HMI panels are analysed based on the technical requirements received from WE Tech. The goal of the research is to find the most suitable HMI solution for WE Tech's next project.

The thesis begins with a review of the background and purpose of the research and a brief description of WE Tech. This is followed by the creation of a theoretical framework that covers the technological concepts of HMI systems. These theories provide a basis for understanding the operation and requirements of HMI panels in this research.

The detailed requirements of the study were based on the needs of WE Tech's upcoming project. The requirements were divided into five main categories: environmental and certification requirements, hardware and system performance, software and communication, and display and usability capabilities.

The research methods used in the study are data collection and analysis, mainly from the datasheets of the HMI panels. The study options are pre-selected based on marine environmental certificates and panel size for deeper analysis. The study evaluates and compares the HMI panels on the market based on the set requirements and presents a summary of the suitability of the HMI panels. At the end of the study, the results and conclusions will summarize the comparison and provide recommendations to WE Tech.

KEYWORDS: HMI, SCADA, OPC UA, Marine certification

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Tiivistelmä:

Tässä kandidaatintutkielmassa analysoidaan kaupallisesti saatavilla olevia HMI-paneeleita WE Tech Solutionsin tulevaa merenkulkuun liittyvää projektia varten. HMI-paneelit analysoidaan WE Techiltä saatujen teknisten vaatimusten perusteella. Tutkimuksen tavoitteena on löytää sopivin HMI-ratkaisu WE Techin seuraavaan projektiin.

Tutkielma alkaa tutkimuksen taustan ja tarkoituksen katsauksella sekä lyhyellä kuvauksella WE Techistä. Tämän jälkeen luodaan teoreettinen viitekehys, joka kattaa HMI-järjestelmien teknologiset käsitteet. Nämä teoriat tarjoavat perustan HMI-paneelien toiminnan ja vaatimusten ymmärtämiselle tässä tutkimuksessa.

Tutkimuksen yksityiskohtaiset vaatimukset perustuvat WE Techin tulevan projektin tarpeisiin. Vaatimukset jaettiin viiteen pääluokkaan: ympäristö- ja sertifiointivaatimukset, laitteiston ja järjestelmän suorituskyky, ohjelmistot ja viestintä sekä näyttö- ja käytettävyysominaisuudet.

Tutkimuksessa käytetään tutkimusmenetelminä tiedonkeruuta ja -analyysia, pääasiassa HMI-paneelien datalehdistä. Tutkimusvaihtoehdot esivalitaan merenkulunalan sertifikaattien ja paneelien koon perusteella syvempää analyysiä varten. Tutkimuksessa arvioidaan ja vertaillaan markkinoilla olevia HMI-paneeleja asetettujen vaatimusten perusteella ja esitetään yhteenveto HMI-paneelien soveltuvuudesta. Tutkimuksen lopussa tulokset ja johtopäätökset tiivistävät vertailun ja antavat suosituksia WE Techille.

AVAINSANAT: HMI, SCADA, OPC UA, Merenkulunalan sertifikaatit

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Abbreviations

HMI = Human Machine Interface

SCADA = Supervisor Control and Data Acquisition

MTU = Master Terminal Unit

RTU = Remote Terminal Unit

LAN = Local Area Network

WAN = Wide-area network

OPC UA = Open Platform Communications Unified Architecture

AddressSpace = OPC UA server storage where it stores nodes

DNV = Det Norske Veritas

1 Introduction

The aim of this study is to analyse the Human Machine Interface (HMI) panels available on the market for WE Tech Solutions' needs. Due to the large market for HMI panels, this analysis will help WE Tech to explore the available options for its next project. The project will not utilize WE Tech's current panels or other systems. The HMI panels will be used on ships in the project, so they must be able to withstand the marine environment. Two to three HMI panels will be used on each ship. The analysis will focus only on the technical features of the HMI system and will not select a system based on user experiences.

In this study, WE Tech presents the requirements for the HMI panel and analyses them according to these requirements. These requirements consist of things like panel size, hardware, software, connectivity, and marine certifications. This research focuses on HMI panels which would match on the future project's quality and performance requirements. Therefore, devices suitable for analysis are selected according to pre-selection, but they are analysed in more detail according to the requirements presented in the study.

WE Tech has also conducted another study on HMI panels on the market, but that study focused on smaller panels and different uses. That study was looking for a new panel to replace the current one, while this study is looking for a panel for a completely new project, focusing on larger panel sizes and new technical requirements.

WE Tech Solutions is a company which is specialized in energy management systems in marine shipping industry. They also make solutions for different frequency drives, DC-link distribution and permanent magnet generator technologies. WE Tech's Solutions can significantly reduce ships' carbon emissions, leading to cost-effective and sustainable life-cycle solutions for the maritime industry. (WE Tech Solutions, 2025)

2 Theoretical framework

This section introduces technologies and concepts that are essential for HMI systems in marine automation solutions. An HMI system consists of several different components and systems. The following subsections delve into these topics in detail and highlight their importance in modern industrial and marine applications.

2.1 HMI

The purpose of the HMI panel is to connect the user and data through a user-friendly interface. The basic idea of an HMI panel is to integrate the necessary programs and components into a single device, eliminating the need for a separate computer. Newer HMI panels have a touch screen, which eliminates the need for separate buttons or switches to control the program. The touch screen makes the system easier to use and speeds up decision-making. The panel can also be controlled with a separate trackball or mouse if necessary. The operating system of the HMI panel is Windows or Linux-based. The system used to track and manage data varies depending on the panel manufacturer and model, as well as the programs supported by the panel. Some panels only support manufacturers own software, and some panels also prefer software from other manufacturers. (Hossain & Zaman, 2012)

2.2 SCADA systems and applications

Supervisor Control and Data Acquisition (SCADA) is a system designed to monitor and control various measuring devices across a wide range of applications. SCADA systems operate based on data they receive from remote sensors and controllers. Once the data is received, it is displayed on screens for users to view and control. In the SCADA system can also make automated process where system can keep for example pressure or temperature on the wanted level. In the past SCADA systems were limited to just a few control systems but with development, its use has increased enormously in various fields. (Yavad. G and Paul. K, 2021)

SCADA consists of hardware components and software programs. According to Yavad and Paul (2021) hardware components includes Master Terminal Unit (MTU), Remote Terminal Unit (RTU), actuators and sensors which gets the data and carry it to the SCADA system and the software program includes the HMI where the data can be monitored and controlled. MTU is the middle link between SCADA and RTU and its work is to control the RTU machine and process and stores RTU data for successive communication. RTU's work is to get data from remote sensors and send it to the MTU which sends it to the SCADA. The HMI acts as a user interface that presents the data collected by the MTU and RTU to the user and enables the sending of control functions. This is the basic idea how the SCADA systems work in the field. The communication between the MTU and RTU is made by Wide-area network (WAN), but the communication can be also made by Local Area Network (LAN) which means that the data can then move wirelessly or wired. This type of communication needs to have some communication protocols which are for example Modbus or Open Platform Communications Unified Architecture (OPC UA). This work focuses more on the OPC UA communication protocol, which will be discussed in more detail in the next section.

2.3 OPC UA communication protocol

Open Platform Communications (OPC) is a communication protocol designed to simplify and standardise the data exchange between industrial control systems and software applications. According to Cavalieri and Chiacchio (2013), the updates to OPC UA standard to the old standard were that the new was based on allows OPC connections to travel over the internet, no longer being dependent on technology or platform, and allowing for new and easy connections to Linux and embedded systems in various applications. The OPC UA open new possibilities for communication between software applications and industrial environments.

OPC UA communication is based on a communication between OPC UA server and a OPC UA client. OPC UA server work is to monitor and allow access for client to get wanted data. The OPC UA server consists of AddressSpace which consists of Nodes where the client creates entities for data. These nodes represent different kind of things like physical devices, data points or software and system components. Those nodes are hierarchical in structure and the top levels are the same for all servers for to improve communication between client and server. OPC UA client work is to send request services and publishing to the OPC UA server. Request are sent by OPC UA client API to the OPC UA communication stack which transform the calls for messages and sends them to the server. The responses from server to the client is made by the same way so all communication between server and client is made by the communication stack. The client can also create objects on the server that can be used to track certain nodes throughout the application, and subscription where the server sends information to the client if a node's value changes. This kind of architecture enables real-time data transfer between server and client. (Cavalieri and Chiccahio, 2013)

2.4 Marine certification

In the maritime industry, marine certification plays a key role in ensuring the safety, reliability and environmental friendliness of ships, equipment and systems. Det Norske Veritas (DNV) is one of the leading classification societies, providing comprehensive certification services to the maritime industry. DNV operates internationally but is particularly focused on European and Nordic maritime. (DNV, n.d.) DNV offers a variety of technical services, including type approval, design reviews, testing, inspections and expert services. These services can be utilized in all ship components and systems including control and automation systems and software which is important in this research. DNV certification can be used to guarantee the components, and the systems meets high standards for safety and reliability in maritime industry. These standards are very important to ensure that they are suitable for maritime use and make sure the safety of people and the environment. (DNV Control and automation systems and software, n.d.)

DNV is not the only provider of maritime certificates, but there are also many others who offer similar services. These organizations are often part of the International Association of Classification Societies (IACS), which is a global umbrella organization setting unified technical standards for ship design, construction, and maintenance. IACS members cover over 90% of the world's cargo-carrying tonnage, making them crucial for ensuring maritime safety and environmental protection. The IACS membership includes leading classification societies such as Bureau Veritas (BV), American Bureau of Shipping (ABS), Lloyd's Register (LR), Registro Italiano Navale (RINA) and DNV itself. (Bhattacharjee, 2019).

These providers offer similar services to DNV but may have some of their own strengths, such as a wider range of ships or specialization in a particular area such as cybersecurity. As you can see from some of their names, their origin countries are often indicated. All these certificates work internationally, but due to their origin, they can bring added value in that region. BV is from France and RINA from Italy, so they provide value in Europe. ABS is originally from America, which is why it is especially important in American waters and ships. LR and MER are both from the United Kingdom, but MER is a requirement issued by the United Kingdom government for ships to have when moving in UK waters or entering port. The MER came into effect when the United Kingdom left the European Union and is mandatory for ships operating in the United Kingdom. (UK Marine Equipment Regulations, 2022) LR offers marine certifications internationally, but with its UK origins, it is particularly valued in UK maritime areas. (LR, n.d.)

Other relevant certifications for an HMI system would be CE, EMC and UL certifications as well as all the various IEC industry standards. The CE marking is important because it is the manufacturer's declaration that the product complies with EU legislation. It is a requirement for the product to be sold in the European Economic Area (EEA) and facilitates trade between EU countries (CE Marking, n.d.). EMC is part of the CE marking, but its separate certificate ensures the reliable operation of devices and reduces the risk of electromagnetic interference as part of the electrical design. UL is a US-based organization that provides testing and certification services to ensure product safety. UL certification indicates that a product has been tested and meets applicable safety standards. The UL mark increases the credibility and reliability of the product in the marketplace, especially in North America, where it is a widely recognized safety standard. (UL, n.d.)

2.5 IP ratings

The purpose of the IP rating is to provide an indication of a product's resistance to liquids and solid objects. IP ratings are based on the IEC 60529 standard. The IP rating consists of two different numbers, each with its own purpose. The first number, on a scale of zero to six, indicates protection against solid objects and dust. Zero has no protection against objects and dust at all, and six is completely dustproof. The second number, on a scale of zero to nine, indicates protection against liquids. Here too, zero means no protection and nine means protection against high-pressure and hot water jets. The IP rating provides an overview of the product's suitability for use in a specific environment such as dusty industrial sites or locations exposed to water. (International Electrotechnical Commission, n.d.)

3 System requirements for HMI panel

The research requirements for the HMI panel have been obtained from We Tech and focus solely on the technical requirements of the device. The aim of the research is to analyse the HMI panels available on the market through their technical characteristics, which is why the research is limited to them only. The requirements are used to examine all the different parts of the HMI system to find the most suitable solution.

3.1 Environmental and certification requirements

The first requirement for an HMI panel is maritime requirements, and these can be met with official certificates. These certificates can be used to guarantee their security and compatibility with hardware and system requirements. The marine certification section of the theory section reviewed certificates used in the maritime industry. As discussed in the marine certification section, DNV is the leading certification provider, so it is essential to find it in the HMI panel. Other certificates can be used to increase the safety and seaworthiness of the device, as well as increase recognition in different maritime areas.

The next requirement for HMI panel is that the front panel is splash protected. This means that the panel is protected from liquid splashes and liquid cannot enter the screen through the edge. This requirement can be verified by the IP rating of the display. Since the display side of the HMI system only needs to be splash-proof, its IP rating must be at least IP-44. The front side IP rating can also be higher ratings such as IP-54 and IP-67. Since the back side of the HMI system does not need to be water-resistant, its requirement is IP-20.

When the screen is splash-proof, it is possible for liquid to remain on the screen and not drain away. Therefore, cleaning the screen must be easy, and that is why it is the next requirement. Cleaning can be made easier by having low or no screen edges. Low edges make it easier to clean the screen and make it easier to remove liquid from the edges.

When the panel is used in the machine room, it must be protected from moisture, dust and vibration. The following requirement relates to these points to ensure that the panel is suitable for the desired environment. This requirement is closely related to the above requirements, as humidity, dust and vibration are tested in all marine certificates. If any of the marine certificates are found, it can be stated that the panel is resistant to humidity, dust and vibration. The IP rating also tells you how well it protects against dust and moisture. Separate tests can also be performed on the HMI panel to check how much vibration it is promised to withstand. However, when analysing, it is worth checking the data sheet to ensure that the panel is resistant to dust, moisture and vibration.

3.2 Hardware and system performance

In terms of hardware and system, the requirements are a bit open-ended, as it is difficult to determine one specific solution that would be the best option for the system. The performance of the HMI system must be sufficient to ensure that the system operates quickly and without interruption. The speed of performance is affected by the efficiency of the processor (CPU) and Random Access Memory (RAM).

Processor requirements include support for multitasking and OpenGL acceleration, and it must be able to operate with a user interface response time of no more than 250 Ms. Multitasking can ensure that the system can perform, for example, PLC functions in the background without disrupting other system operations. The processor should have OpenGL acceleration so that graphic images and possible 3D views in the SCADA system run smoothly without lag. With a sufficiently fast response time, the system processor performs tasks quickly enough, which is important to the user. However, these requirements make it difficult to say the exact processor model, as the system performance also depends greatly on the load of the various SCADA systems. The processor must be powerful enough and support OpenGL acceleration to meet the necessary requirements. It would also be good if the panel had the option to choose from different processors to find the right one for the desired purpose.

Determining RAM requirements is similar to determining processor requirements. It is difficult to say exactly how much RAM-memory you will need, as it depends a lot on the software you are using and the system load. The minimum RAM requirement can be set at 2 GB, as this capacity allows most common systems to run smoothly. However, the amount of RAM should be expandable if necessary, according to different needs. For this reason, it is recommended to maintain flexibility in the amount of RAM-memory, which ranges from 2 GB to 16 GB.

The smooth operation of a system is affected by the temperature of the components. If the temperature of the components can be maintained at an appropriate level, they will operate at their best performance. Therefore, cooling is a requirement for the HMI system. Cooling can be implemented with or without a fan. Fanless cooling works better in this study because it reduces dust and dirt from entering the equipment and is more resistant to vibrations that are typical in machine rooms.

3.3 Software and communication

The next requirement for an HMI system is that it must be a Linux-based system. The operating system is preferred to be Linux because it is an open-source operating system and offers flexibility for customizing software. Linux is also a good choice for a closed system in terms of security due to receive regular updates and it is very stable to run without downtime. There are many different Linux-based operating systems, and it would be useful if the system had different options for using it, but the primary preference would be for a well-known operating system such as Linux Ubuntu. Another essential aspect of Linux is its lifecycle. It is good to know whether the system is active in terms of updates and security and how long the system will be developed. For this reason, well-known Linux systems are preferred so that their security and lifespan can be verified.

Another important requirement for the panel is that it has a user interface for controlling the framework process. A SCADA-type solution is best suited for this need, as discussed in the theory section. There are also other requirements associated with SCADA. The SCADA system must have ready-made components that can be used directly to create the user interface. The system must also allow the user to create components and lightweight animations themselves. These will help to get the desired user interface without having to start building it from scratch.

Another important requirement for SCADA systems is that they must support alarm and event logging. In addition to logs, the system must also have a data recorder that stores data for at least three months. These allow events and alarms to be recorded and retrieved later, which is important for troubleshooting purposes, for example.

There are also many types of SCADA-type user interfaces, and some manufacturers may have restrictions on what can be used in an HMI system. However, this study does not take a position on individual software choices but rather examines the requirements of the systems at a general level.

One of the main tasks of an HMI system is to present information to the user, which requires the system to interact with communication protocols. There are many different options for implementing this requirement. As discussed in the theory section, OPC UA would be a suitable implementation for this purpose. OPC UA could be used to create a secure and functional solution either wired or wirelessly.

One of the most important requirements for an HMI system is support for redundancy. Redundancy means that the system continues to operate even if one of its components, such as a panel, breaks down. The upcoming project will use multiple HMI systems, so it is important that in the event of an error, data from one system can be transferred to another system without any problems. For redundancy to work effectively, the user interface software should be able to detect hardware failures. If a failure occurs, such as a loss of connection to the panel, it is important that the system detects it and notifies the user so that operations can continue with minimal disruption. Redundancy improves system reliability and is especially important in marine environments where it can take a long time to resolve a hardware problem.

3.4 Display and usability

The next requirement for the panel would be that it be large enough to display enough things on the panel and that they can also be viewed from a distance. Since the screen should not be too small or too large, it is a good idea to divide the screen into the entire area within which it should be found. Suitable panel sizes for this purpose would be between 20" and 29". The size of the panel in between is large enough and perfectly suited for the required use.

The panel's requirements also include that it be a touchscreen. This requirement also includes additional points, such as that the touchscreen can be used with gloves and when hands are dirty. Since the panel will be in the engine room, it is important that the user can simultaneously use the panel and perform, for example, some maintenance without having to take off their gloves or clean them. This requirement is difficult to implement without practical testing, but a few features can ensure that the contact is good enough for the required conditions. First, the panel must support multitouch, which allows multiple touch points to be used simultaneously on the panel. Multitouch makes it easier to use with gloves because multiple touch points can compensate for the inaccuracy of a single touch. The second feature is a projected capacitive touchscreen. This makes the touch feature accurate, fast, and works through glass, allowing the screen to be protected with thick glass.

Even if the panel works with a touch screen, it can sometimes be difficult to use, because the ship can rock a lot with the waves. Therefore, the panel should also have other options for use. The problem would be solved with a trackball and keyboard. A trackball is a better solution than a mouse, because it can be used without having to move it like a mouse. It is also good that the solution has a keyboard connection option if you need to type something into the program. The easiest way to connect these to the system is via a USB port. However, it must be ensured from the system that the use of such external control devices as part of the operating system works smoothly and easily.

Since the panel is placed in the machine room, its viewing angles should be wide enough so that the workers can see the necessary information from different angles. For this reason, the angles should be wide enough. Since there is no user experience in this study, it is not possible to set the exact minimum angles that the panel should have. However, based on general use, the size of the sufficient angles can be set tentatively. The panel should have angles of at least 160º in the width and length directions.

4 Research approach

In this study, HMI panels are pre-selected for deeper analysis based on marine certifications and panel resolution The aim of pre-selection is to filter out options that do not meet the basic requirements, allowing for a more focused deeper analysis. Therefore, the device must meet the required certifications and provide sufficient visibility and usability in challenging conditions. The deeper analysis will take a closer look at the detailed technical requirements of the HMI panel. The technical requirements are based on the requirements received from WE Tech. These requirements are defined to confirm that the selected HMI panels have the necessary features for the upcoming project.

Research data is primarily collected from the manufacturers' data sheet, certification documents and the device's own official websites. These data sources can be used to standardize information between different evaluated options. The data collected for each option is systematically documented in an Excel spreadsheet specifically created for this study. In the evaluation table, all candidates are compared based on the same requirements. This facilitates a consistent comparison of options to find the most suitable solution. In the evaluation table, if a certain requirement is met for an option, an 'X' is marked in that box. If the feature is not met, the field in the table is left blank. Each 'X' represents one point, and the cumulative score shows the best fit of the options based on the requirements.

5 Evaluation of market-available HMI panels

This section will review the criteria according to which panels are reviewed. The table lists all the necessary features of an HMI system and analyses their importance. Following this, a deeper analysis is performed individually for the selected HMI panels.

5.1 Fulfilment table based on requirements

For the study, tables have been created based on HMI system requirements. The tables list the most important requirements that can be used to determine the appropriate HMI system for a new project. Difficult to interpret requirements, such as processor functionality and SCADA capabilities, have been excluded from the tables. The tables are divided into areas according to the requirements.

Environmental factors are one of the most important considerations in a maritime HMI system. Therefore, the HMI system must be able to operate even in difficult conditions. Table 1 shows the main points related to environmental requirements. As discussed in the requirements, DNV certification is essential for equipment used on ships. Therefore, requiring DNV certification is the first thing on the table. DNV certification is also supported by an IP rating and resistance to moisture, dust and vibration. Finally, the table includes a check for low edges to make the panel easy to clean. These requirements can help ensure that the HMI system is suitable for the desired conditions.

Table 1. Environment and certifications

		Environment and certification			
Brand	**Model**	**DNV marine certification**	**Front IP rating min IP44**	**Resistance to humidity, dust, vibrations**	**Low edges**

Table 2. shows the desired system performance characteristics. These characteristics can be used to ensure that the system has enough power to run various SCADA programs

and small animations. The first section looks at the processor power. A multi-core processor allows for smooth and fast operation while multiple processes are running. The minimum processor requirement is four cores, which is a prerequisite for a smooth user experience. The list also includes criteria for processor’s OpenGL acceleration and scalabilities. These are important components for smooth operation. The amount of memory also affects smooth and fast operation. As mentioned in the requirements, 2 GB of RAM is enough to run most common systems. The amount of RAM must be scalable to the desired need. The amount of RAM and scalability are checked in the table. Finally, the table ensures that the HMI system has cooling so that the components can operate at the correct temperature.

Table 2. Hardware and system Performance

Hardware and system performance					
4-core or higher processor	**CPU OpenGL**	**CPU scalable**	**Minimum 2GB ram**	**Scalable RAM**	**Fanless cooling**

Table 3 is used to ensure the necessary communication capabilities and software for the system. The requirements discuss why Linux is the right solution for this HMI solution. That is why Linux is the first item in the table. As discussed in the theory section and requirements, the importance of SCADA and OPC UA in the HMI system is emphasized, which is why they are the next two items in the table. The system must be compatible with SCADA software, as it is a key control and monitoring solution. OPC UA is a key part of the communication between the system and the measuring devices. OPC UA can be used to create a standardized and secure connection. Finally, we look at the redundancy of the system. This item is a bit difficult to check through the datasheet, but if something related to it is found, it will be added to the table.

Table 3. Software and communications

Software and communications			
Linux	**SCADA**	**OPC UA**	**Support Redundancy**

The display and usability table ensures that the system meets all the features required at the installation site. One of the requirements for the HMI panel was a minimum screen size of 20 inches, to make the screen easier to view when there is a lot of data on the screen. However, the panel must not be too large, which is why the first item in Table 4 addresses the panel size of 20-29 inches. The next two items in Table 4 look at the usability of the panel. First, the panel must have a touchscreen feature that works with gloves and dirt/moisture. Second, the system must be operable in ways other than touch, such as with a trackball. Therefore, the next two items check for usability for the user. Usability of the panel also includes sufficient viewing angles, which is why sufficiently large viewing angles ensure a good user experience. The last item in Table 4 ensures sufficiently large viewing angles.

Table 4. Display and usability

Display and usability			
Screen size 20"- 29"	**Multitouch Screen**	**External input device compatibility**	**Panel view angles minimum 160º/160º**

5.2 Examined HMI Panel Options

5.2.1 Option 1

First option comes from Deif A/S. Deif is a Danish company which is specialized to the energy consumption and automation solutions. The company provides a complete range of electrical appliances to different kind of purposes. The AGI 400 series HMI panel from DEIF was selected for the study. The AGI 400 series HMI panel is designed to provide versatile user interface solutions for various control and monitoring applications. The

AGI 400 series panels are divided into normal and M series. The only difference between M and normal is that the M series has a better processor. Therefore, this study examines the M version. (DEIF A/S, n.d.)

In the environmental and certification section, Deif's HMI system meets all requirements (Table 5). In addition to DNV certification, the device has CE, UCKA and UL/ULC certifications. The HMI system has an IP rating of IP66 on the display side and IP20 on the back. This makes it highly dust resistant. The technical specifications also include sections for humidity and vibration. The panel's minimal depth makes cleaning easier. (DEIF AGI 400M datasheet, n.d.)

Table 5. DEIF AGI 400M Environment and certification fulfilment table

		Environment and certification			
Brand	**Model**	**DNV marine certification**	**Front IP rating min IP44**	**Resistance to humidity, dust, vibrations**	**Low edges**
Deif	AGI 400	X	X	X	X

In the hardware and system table, the AGI 400 only fills a few slots. In table 6, the datasheet only listed a quad-core processor and at least 2 GB of RAM. The device runs on a 64-bit RISC quad-core processor and has 2 GB of RAM. There was no mention of the processor's OpenGL acceleration. There was also no mention of different processor options, RAM expandability, or cooling. (DEIF AGI 400M datasheet, n.d.)

Table 6. DEIF AGI 400M System performance fulfilment table

Hardware and system performance					
4-core or higher processor	**CPU OpenGL**	**CPU scalable**	**Minimum 2GB ram**	**Scalable RAM**	**Fanless cooling**
X			X		

The AGI 400 HMI system meets the requirements of Linux and OPC UA in terms of software and communications (Table 7). The device uses the Linux RT distribution. In addition to OPC UA, the device has many other communication protocols. As for the SCADA system, the device's introductory text mentions its suitability for a small SCADA system, but the data sheet does not directly mention its support. There is also no mention of redundancy. (DEIF AGI 400M datasheet, n.d.)

Table 7. DEIF AGI 400M software and communications fulfilment table

Software and communications			
Linux	**SCADA**	**OPC UA**	**Support Redundancy**
X		X	

In terms of display and usability, the AGI 400 HMI system meets almost all the requirements (Table 8). All other requirements are met except for the requirement for an external control device. The device is available in a 21.5-inch size that meets the requirements exactly. The device supports multitouch and the panel is made of real glass with a projected capacitive surface. The device also meets the requirements for sufficiently large viewing angles, which are 178º/178º for the panel. There is no section in the datasheet about support for an external control device, but the device has two USB slots. (DEIF AGI 400M datasheet, n.d.)

Table 8. DEIF AGI 400M display and usability fulfilment table

Display and usability			
Screen size 20"- 29"	**Multitouch Screen**	**External input device compatibility**	**Panel view angles minimum 160º/160º**
X	X		X

5.2.2 Option 2

Second option is from Winmate Inc. Winmate is a Taiwanese company that specializes in implementing rugged industrial computers and display solutions for various environments. Their products have been developed for several different sectors, one of which is the marine industry. They manufacture panels, computers, and panel PCs for the marine industry. The Winmate W24IAD3S-MRA2FP model panel PC was chosen for this study. This model is part of Winmate's series of panels designed for marine, which are available in several different panel sizes. (Winmate, n.d.)

In the table 9, which deals with the environment and certifications, the W24IAD3S-MRA2FP meets all the requirements. The device meets DNV requirements and addition to that has IEC60945 4th Edition, IACS E10, CE and FCC certifications. The panel has an IP66 rating and is resistant to moisture, vibration and dust. The panel has minimal edges, making it easy to clean. (Winmate W24IAD3S-MRA2FP datasheet, n.d.)

Table 9. Winmate W24IAD3S-MRA2FP environment and certification fulfilment table

		Environment and certification			
Brand	**Model**	**DNV marine certification**	**Front IP rating min IP44**	**Resistance to humidity, dust, vibrations**	**Low edges**
Winmate	W24IAD3S-MRA2FP	X	X	X	X

In terms of hardware and system performance, the W24IAD3S-MRA2FP meets almost all requirements (Table 10). According to the datasheet, the device is powered by an Intel® Core™ i5-1335U processor, which is quite powerful. The datasheet did not mention OpenGL acceleration or other processor options. The device has a minimum of 8 GB of RAM, and it can be expanded to 16GB or 32 GB. The device's cooling system is fanless cooling, which is the desired system for cooling. (Winmate W24IAD3S-MRA2FP datasheet, n.d.)

Table 10. Winmate W24IAD3S-MRA2FP hardware and system fulfilment table

Hardware and system performance					
4-core or higher processor	**CPU OpenGL**	**CPU scalable**	**Minimum 2GB ram**	**Scalable RAM**	**Fanless cooling**
X			X	X	X

Table 11. shows the software and communication features of the W24IAD3S-MRA2FP model. The device only meets the first requirement, which is Linux. It is possible to

choose the Linux Ubuntu 22.04 version as the operating system for the device, which meets the requirement. However, the device does not support SCADA, OPC UA or redundancy. (Winmate W24IAD3S-MRA2FP datasheet, n.d.)

Table 11. Winmate W24IAD3S-MRA2FP software and communications fulfilment table

Software and communications			
Linux	**SCADA**	**OPC UA**	**Support Redundancy**
X			

In terms of display and usability, the W24IAD3S-MRA2FP model meets most of the requirements. From Table 12. it can be stated that the device meets the other requirements except for the control device. The device is available in 24- and 27-inch sizes. The device panel is a projected capacitive multi-touch display, which meets the touchscreen requirement. The device has viewing angles of 178º/178º, which meets the requirement well. (Winmate W24IAD3S-MRA2FP datasheet, n.d.)

Table 12. Winmate W24IAD3S-MRA2FP display and usability fulfilment table

Display and usability			
Screen size 20"- 29"	**Multitouch Screen**	**External input device compatibility**	**Panel view angles minimum 160º/160º**
X	X		X

5.2.3 Option 3

The third option comes from Kontron. Kontron is an English company that specializes in industrial and embedded computer solutions. They manufacture devices for many different industries. The Kontron FlatClient MAR series marine panel PC was chosen for the study. It is designed specifically for marine use, so it meets the relevant certifications. The FlatClient MAR series panel computers are divided into ECO and PRO lines, and their only differences are in processors and RAM scalability. In this study, we will look at the device from the PRO line. (Kontron, n.d.)

The first thing to consider is the environmental and certification requirements. The FlatClient MAR series panel computer meets all environmental and certification requirements (Table 13). The device is DNV certified, as well as CE and UL certified. The front glass is IP65 rated and resistant to salt spray. The device is resistant to vibration, moisture and dust. The device has a thin edge between the panel and the edge, making it easy to clean. (Kontron FlatClient MAR datasheet, n.d.)

Table 13. Kontron FlatClient MAR environment and certification fulfilment table

		Environment and certification			
Brand	**Model**	**DNV marine certification**	**Front IP rating min IP44**	**Resistance to humidity, dust, vibrations**	**Low edges**
Kontron	FlatClient MAR	X	X	X	X

Table 14. lists the hardware and system requirements for the FlatClient MAR model. The FlatClient MAR meets all other requirements except OpenGL acceleration. The device has two processor options, Intel® Core™ i5-7300U and Intel® Celeron® 3965U. Both options are powerful and suitable for the upcoming project. RAM is available from 4 GB to 16 GB, with an additional 32 GB available as an option. The device features passive fanless cooling, which meets the cooling requirements. (Kontron FlatClient MAR datasheet, n.d.)

Table 14. Kontron FlatClient MAR system and hardware fulfilment table

Hardware and system performance					
4-core or higher processor	CPU OpenGL	CPU scalable	Minimum 2GB ram	Scalable RAM	Fanless cooling
X		X	X	X	X

The FlatClient MAR device meets only one software and communication requirement (Table 15). A Linux Ubuntu operating system option is available for the device, which meets the Linux requirement. Otherwise, there is no section in the datasheet on SCADA, OPC UA communication protocol, or redundancy. (Kontron FlatClient MAR datasheet, n.d.)

Table 15. Kontron FlatClient MAR software and communications fulfilment table

Software and communications			
Linux	SCADA	OPC UA	Support Redundancy
X			

Table 16. lists the display and usability requirements for the FlatClient MAR panel computer. The FlatClient MAR meets all the requirements except for the requirement for an external peripheral. The panel has 3 USB ports, but the datasheet does not mention the use of an external controller. Otherwise, the device is available in a 21.5-inch size. The device uses a projected capacitive touch feature, which meets the multi-touch requirement. The panel has viewing angles of 178º/178º, so it meets the requirement. (Kontron FlatClient MAR datasheet, n.d.)

Table 16. Kontron FlatClient MAR display and usability fulfilment table

Display and usability			
Screen size 20"- 29"	**Multitouch Screen**	**External input device compatibility**	**Panel view angles minimum 160º/160º**
X	X		X

5.2.4 Option 4

The fourth option also comes from Denmark and is manufactured by ISIC A/S. ISIC specializes in a wide range of computer and display solutions that are suitable for demanding conditions. The panel computer from ISIC's DuraPANEL S-line series was chosen for the study. The DuraPANEL s-line is designed specifically for marine use. (ISIC systems, n.d.)

First, the DuraPANEL s-line device is examined in terms of environmental and certification requirements. Table 17. shows that the DuraPANEL s-line meets all environmental and certification requirements. In the datasheet, the device is still awaiting DNV certification, but a device in the same product family with a smaller panel size has received DNV certification, so the requirement can be met, as certification is presumably coming. Other important certificates in this study are IEC 60945 ed. 4 and IACS E10 rev. 9. These certificates are related to marine use. The front panel of the device is IP56 rated and has thin edges. The device is sealed against moisture and dust, but there is no separate marking for vibration in the data sheet. However, with the upcoming DNV certification, the vibration requirement can be met. (ISIC DuraPANEL 24” s-line datasheet, n.d.)

Table 17. ISIC DuraPANEL s-line environment and certification fulfilment table

		Environment and certification			
Brand	**Model**	**DNV marine certification**	**Front IP rating min IP44**	**Resistance to humidity, dust, vibrations**	**Low edges**
ISIC A/S	DuraPANEL s-line	X	X	X	X

The hardware and system of the DuraPANEL s-line part meet almost all the requirements. According to Table 18, all other requirements are met except for the cooling requirement. There are several processor options available for the motherboard, but three out of the four meet the requirement of more than four cores. The processor options include the Intel Core i3-9100TE, i5-9500TE and i7-9700TE. The datasheet also includes a section on OpenGL 4.5 support, which meets the requirement. The device can be equipped with up to 32 GB of RAM depending on your needs. The datasheet does not include a section on the device's cooling. (ISIC DuraPANEL 24” s-line datasheet, n.d.)

Table 18. ISIC DuraPANEL s-line system and hardware fulfilment table

Hardware and system performance					
4-core or higher processor	**CPU OpenGL**	**CPU scalable**	**Minimum 2GB ram**	**Scalable RAM**	**Fanless cooling**
X	X	X	X	X	

Table 19. shows the DuraPANEL s-line software and the fulfilment of the communication requirements. DuraPANEL s-line only fulfils the first item in the table. The device's

operating system is Linux Ubuntu, which fulfils the requirement. Otherwise, there is no section in the data sheet for SCADA, OPC UA communication protocol and redundancy. (ISIC DuraPANEL 24” s-line datasheet, n.d.)

Table 19. ISIC DuraPANEL s-line software and communications fulfilment table

Software and communications			
Linux	**SCADA**	**OPC UA**	**Support Redundancy**
X			

Regarding display and usability, the DuraPANEL s-line meets all other requirements except for a separate control device (Table 20). The device is available in 24- and 27-inch sizes. The device's panel supports the projected capacitive multi touch feature, which meets the touch-related requirement. The panel's viewing angles are 178º/178º, which meets the requirement. The device has four USB ports, but there is no provision for using an external control device. (ISIC DuraPANEL 24” s-line datasheet, n.d.)

Table 20. ISIC DuraPANEL s-line display and usability fulfilment table

Display and usability			
Screen size 20"- 29"	**Multitouch Screen**	**External input device compatibility**	**Panel view angles minimum 160º/160º**
X	X		X

5.2.5 Option 5

The fifth option comes from Exor International. Exor international is an industrial automation-based company that strives to provide advanced solutions to improve efficiency and competitiveness in the market. Exor international not only produces HMI devices but also offers solutions for IoT gateways and industrial software. Exor international offers a couple of different opportunities to this research, which would be eX721 and eX721M HMI. The only difference between them is the processor and the size of the flash memory. The M version has a better processor but less flash memory. If necessary, storage space can be added to the device with an SD card. Therefore, the M version is more suitable for research. (Exor International, n.d.)

Table 21. shows the environmental and certification characteristics of the eX721M. The device meets all environmental and certification requirements. In addition to DNV certification, the device has CE, ATEX, IECEx, UL and RCM certifications. The IP rating of the front panel of the device is IP66 and the rear panel is IP20, which also makes the device resistant to humidity and dust. The data sheet did not specifically mention vibration, but the DNV certificate found on the device guarantees vibration resistance. (Exor eX721M data sheet, n.d.)

Table 21. Exor eX721M environment and certification fulfilment table

		Environment and certification			
Brand	**Model**	**DNV marine certification**	**Front IP rating min IP44**	**Resistance to humidity, dust, vibrations**	**Low edges**
Exor International	eX721M	X	X	X	X

In terms of hardware and performance, the eX721M only meets a few requirements according to the datasheet. The device has a 64-bit RISC quad-core processor, but there are no other processor options, and OpenGL support is not mentioned. The device has 2 GB of RAM and 64KB of FRAM. The datasheet does not provide information on expanding the RAM or cooling. (Exor eX721M datasheet, n.d.)

Table 22. Exor eX721M system and certification fulfilment table

Hardware and system performance					
4-core or higher processor	CPU OpenGL	CPU scalable	Minimum 2GB ram	Scalable RAM	Fanless cooling
X			X		

The table 23. lists the software and communication requirements for the eX721M. The eX721M meets all requirements except redundancy. The Linux distro was not described in more detail in the datasheet. The hardware meets SCADA requirements, but only Exor's own JMobile system can be used in the hardware. (Exor eX721M datasheet, n.d.)

Table 23. Exor eX721M software and communications fulfilment table

Software and communications			
Linux	SCADA	OPC UA	Support Redundancy
X	X	X	

In terms of display and usability, the datasheet states that the system meets two requirements (Table 24). The datasheet does not mention a separate control device or viewing angles. A separate control device can work in the device without any problems, but the datasheet did not mention this. The HMI system is available in a 21.5-inch size, which fits just right in the required size. The display supports multi-touch, which ensures the necessary touch operation. (Exor eX721M datasheet, n.d.)

Table 24. Exor eX721M display and usability fulfilment table

Display and usability			
Screen size 20"- 29"	**Multitouch Screen**	**External input device compatibility**	**Panel view angles minimum 160º/160º**
X	X		

6 Analysis of HMI panel options

This study compares five different HMI panel options for WE Tech's future project. The options were DEIF AGI 400M, Winmate W24IAD3S-MRA2FP, Kontron FlatClient MAR, ISIC DuraPANEL s-line and Exor International eX721M. The requirements are divided into four main categories: environmental and certification compliance, hardware and system performance, software and communication, and display and usability. Each option was evaluated based on the given requirements to determine its suitability for marine applications and WE Tech's upcoming project. However, it is important to note that even if all requirements are initially scored equally using a simple scoring system, a more in-depth analysis of the results will reveal which features are more critical to WE Tech's project.

6.1 Environmental and certification compatibility

In the environmental and certification section, all five options met the relevant requirements, making them desirable for marine use (Table 25). All options had DNV certification, but the ISIC DuraPANEL s-line model was still pending, but presumably will receive it. The front panel requirement was at least IP44, and the options had IP ratings between IP56 and IP66. All the others had direct mentions of moisture, dust and vibration resistance in the datasheet, except for the ISIC, which did not have a separate vibration section, but that was presumably missing due to pending DNV certification. The low edges requirement was met for each option. Other certifications were also considered for each option, and based on these, the Exor International eX721M model had the most comprehensive certifications for the device.

Table 25. Environmental and certification fulfilment table for all candidates

		Environment & certification			
Brand	**Model**	**DNV marine certification**	**Front IP rating min IP44**	**Resistance to humidity, dust, vibrations**	**Low edges**
Deif	AGI 400	X	X	X	X
Winmate	W24IAD3S-MRA2FP	X	X	X	X
Kontron	FlatClient MAR	X	X	X	X
ISIC A/S	DuraPANEL s-line	X	X	X	X
Exor Inter-national	eX721M	X	X	X	X

6.2 Hardware and system performance

There was some variation between the options in the hardware and system section. Table 26. shows how the different options met the requirements. The FlatClient MAR offered two strong different options for Intel® Core™ i5-7300U and Celeron® 3965U processors, 4-32 GB scalable RAM, and fanless cooling, but lacked support for OpenGL acceleration. The DuraPanel s-line again offered strong performance with Intel® Core™ i3/i5/i7 processors, OpenGL 4.5 support, up to 32 GB scalable RAM, but lacked cooling. Next on the list was Winmate's W24IAD3S-MRA2FP, which featured an Intel® Core™ i5-1335U processor, 8-32GB of expandable RAM, and fanless cooling, but no other processor options or OpenGL support. The final two are the DEIF AGI 400M and Exor International's eX721m, which feature the same 64-bit RISC quad-core processor, 2GB of non-scalable RAM, and do not support OpenGL or cooling. Winmate and Kontron offer good scalability to hardware, while ISIC stands out due to its OpenGL support. DEIF and Exor are less competitive with other options due to limited scalability and missing specifications.

Table 26. System and hardware fulfilment table for all candidates

Hardware and system performance					
4-core or higher processor	**CPU OpenGL**	**CPU scalable**	**Minimum 2GB ram**	**Scalable RAM**	**Fanless cooling**
X			X		
X			X	X	X
X		X	X	X	X
X	X	X	X	X	
X			X		

6.3 Software and communication capabilities

There is also variation in requirements in the software and communication section. From table 27. you can see that none of the options support redundancy. Exor eX721M supported Linux, SCADA via Jmobile system and OPC UA communication protocol. DEIF AGI 400M supported Linux RT and OPC UA communication, and the possibility of SCADA but there was no direct point for it. Winmate W24IAD3S-MRA2FP, Kontron FlatClient MAR and ISIC DuraPANEL s-line only supported Linux operating system. The strongest in this section was Exor due to its support for SCADA and OPC UA and a strong follower was DEIF due to its partial compatibility. Winmate, Kontron and ISIC are limited to Linux only.

Table 27. Software and communications fulfilment table for all candidates

Software and communications			
Linux	**SCADA**	**OPC UA**	**Support Redundancy**
X		X	
X			
X			
X			
X	X	X	

6.4 Display and interaction

In the display and usability section, there was more consistency between the different options. As you can see in Table 28, the only difference is in the case of the Exor eX721M, whose panel viewing angles were not found in the device datasheet. Of the options, the DEIF AGI-400M, Kontron FlatCient MAR and Exor eX721M were 21.5 inches in size, while the Winmate W24IAD3S-MRA2FP and ISIC DuraPANEL s-line were 24 or 27 inches in size. All options used a projected capacitive panel that met the multi-touch requirement. Viewing angles were 178º/178º in all but the Exor. As for the external control device, there was no option for it, but each had USB ports. In this section, Winmate and ISIC were the strongest, offering several options for panel sizes.

Table 28. Display and usability fulfilment table for all candidates

Display and usability			
Screen size 20"- 29"	Multitouch Screen	External input device compatibility	Panel view angles minimum 160º/160º
X	X		X
X	X		X
X	X		X
X	X		X
X	X		

6.5 Overall evaluation

Based on the completed requirement tables, points can be calculated for each option based on the fulfilled requirements. Table 29. shows the total fulfilled requirements for each option. Of the options, Kontron FlatClient MAR and ISIC DuraPANEL s-line received the most points, collecting 13/18 points. Next come Winmate W24IAD3S-MRA2FP and Exor eX721M with 12 points. Last is DEIF AGI-400M with 11 points. Based on the points, Kontron or ISIC HMI systems can be recommended for the project.

However, when looking at the different options in more detail, shortcomings are observed. These shortcomings strongly highlight the limitations of the unweighted scoring system. Although the Kontron and ISIC options received the highest cumulative scores, they completely lacked the SCADA and OPC UA requirements that are important for the future project. As highlighted in the theory and requirements sections, SCADA and OPC UA play an important role for the future project. Their absence directly affects the overall suitability of the HMI panel, regardless of other strengths. Based on this, the Exor and DEIF-HMI systems would be better options for the future system, but these options are significantly weaker in terms of hardware.

Ultimately, each option has its own strengths and weaknesses, so it is difficult to choose one specific option. However, this helps you understand the options reviewed and what kind of technology they have. Of the options, Kontron and Winmate offer versatile options regarding processors and RAM scalability. In addition to scalability, ISIC offers OpenGL support. Exor and DEIF are strongest in communication and software. Each option is a good option for the project in its own area and the final decision depends on what will play an important role in the project. If it is important for the project that the device works quickly with a good processor, the choice will turn towards Winmate, Kontron and ISIC. If communication and the user interface are important in the project, the choice will then go towards Exor and DEIF.

Table 29. Results for all candidates

Brand	**Model**	**Total points**
Deif	AGI 400	11
Winmate	W24IAD3S-MRA2FP	12
Kontron	FlatClient MAR	13
ISIC A/S	DuraPANEL s-line	13
Exor International	eX721M	12

7 Discussion

This study examined the requirements of five different HMI panels in terms of environment, hardware performance, communication features and display usability. The alternatives in the study were DEIF AGI 400M, Winmate W24IAD3S-MRA2FP, Kontron Flatclient MAR, ISIC DuraPANEL S-line and Exor international eX721M. As a result of the study, Kontron and ISIC received the highest scores (13/18 points) according to the requirements due to good hardware scalability and environmental compliance. Exor and DEIF stood out by offering good communication and software features.

The key findings of the study were the differences in hardware scalability and data transfer capabilities. The options that supported OPC UA and SCADA were not hardware scalable, while the options that did not support OPC UA and SCADA were stronger in hardware and scalability. This may be because the HMI panels that supported OPC UA and SCADA were designed for specific types of systems that focus more on software efficiency than computing power to ensure low latency data transfer. The HMI panels that did not support OPC UA and SCADA may have been designed for a variety of systems that require hardware and computing power.

The purpose of the study was to analyse the market potential of the HMI panel for the next project. The study was based on the requirements received from WE Tech, based on which a new HMI panel is being sought. The study used only the data sheets of the alternatives and did not perform functional tests on the HMI panels. A limitation of the study was that the data sheets were missing information such as vibration of the ISIC device, viewing angles of the Exor and cooling information for many devices. Also, none of the alternative data sheets had information on redundancy or external control devices. Another significant limitation was that the study gave equal weight to all system requirements. This meant that, for example, a critical feature such as OPC UA could have played a more important role in the project than a less critical feature such as cooling. This highlights that the cumulative score may not necessarily support the true suitability when prioritizing certain requirements. Datasheets alone are also not sufficient to fully explore the actual performance or cost aspects.

Based on the research, a few different options proved to be suitable for different purposes. The research could be continued with a few different options. One possibility for continuing the research is to study the requirements that were left out of the research. Another could be practical testing that could simulate a real-world situation, which would help find which of the options would best suit the desired purpose. On the other hand, the research could be continued by looking for new options or investigating whether another solution could work for this project, such as by looking more closely at panel PCs or marine computers and panel solutions.

References

We Tech Solutions. (n.d.). Retrieved March 4, 2025, from https://wetech.fi/

Hosain, A., & Zaman, T. (2012, June). *HMI Design: An Analysis of a Good Display for Seamless Integration between User Understanding and Automatic Controls.* 2012 ASEE Annual Conference & Exposition Proceedings, 25.697.1-25.697.14. https://doi.org/10.18260/1-2--21454

Yadav, G., & Paul, K. (2021). *Architecture and security of SCADA systems: A review.* International Journal of Critical Infrastructure Protection, 34, 100433. https://doi.org/10.1016/j.ijcip.2021.100433

Cavalieri, S. & Chiaccio, F. (2013). *Analysis of OPC UA performances.* Computer standards & interfaces, 36(1), 165-177. https://doi.org/10.1016/j.csi.2013.06.004

Bhattacharjee, S. (2019, July 3). *What is International Association of Classification Societies (IACS)?* Marine Insight. https://www.marineinsight.com/maritime-law/what-are-international-classification-society-international-association-of-classification-societies-iacs/

UK marine equipment regulations. (2023, May 25). GOV.UK. https://www.gov.uk/government/collections/uk-marine-equipment-regulations

DNV, (n.d.). Retrieved April 10, 2025, from https://www.dnv.com/about/

DNV Control and automation systems and software. (n.d.). Retrieved April 7, 2025 from https://www.dnv.com/services/control-and-automation-systems-and-software-2681/

LR. (n.d.) Retrieved April 7, 2025, from https://www.lr.org/en/

CE marking (n.d.). Retrieved April 7, 2025, from https://single-market-economy.ec.europa.eu/single-market/ce-marking_en

UL. (n.d.) Retrieved April 8, 2025, from https://www.ul.com/

International Electrotechnical Commission. (n.d.). *Ingress protection (IP) ratings*. Retrieved April 17, 2025, from https://www.iec.ch/ip-ratings

DEIF A/S (n.d.). Retrieved May 15, 2025, from https://www.deif.com/

DEIF AGI 400M datasheet. (n.d). Retrieved May 15, 2025, from https://deif-cdn-umbraco.azureedge.net/media/2djajbnf/agi-400-m-mhb-series-data-sheet-4921240679-uk.pdf?rnd=133742533198770000&v=9

Winmate (n.d.). Retrieved May 19, 2025, from https://www.winmate.com/en

Winmate W24IAD3S-MRA2FP datasheet. (n.d.). Retrieved May 19, 2025, from https://www.winmate.com/en/product/exportHtml/W24IAD3S-MRA2FP

Kontron (n.d.). Retrieved May 21, 2025, from https://www.kontron.com/en

Kontron FlatClient MAR datasheet. (n.d.). Retrieved May 21, 2025, from https://www.kontron.com/download/download?filename=/downloads/datasheets/f/flatclient-mar_datasheet.pdf&product=161619

ISIC Systems. (n.d.). Retrieved May 23, 2025, from https://isic-systems.com/

ISIC DuraPANEL 24" s-line datasheet. (n.d.) Retrieved May 23, 2025, from https://isic-systems.com/media/catalog/product/file/DuraPanel_24_S-Line_210824.pdf

Exor International (n.d.). Retrieved from May 26, 2025, from https://www.exorint.com/

Exor International eX721M datasheet. (n.d.). Retrieved May 26, 2025, from https://exorinternationalspa.sharepoint.com/sites/TechDocuments/Shared%20Documents/Forms/AllItems.aspx?ga=1&id=%2Fsites%2FTechDocuments%2FShared%20Documents%2FTech%20Documents%2FeX700M%20Series%2FeX721M%2FDATASHEET%2Fptn0732%5FeX721M%2Epdf&viewid=74358452%2D0471%2D494c%2D85fc%2Dbf78b97a5a9e&parent=%2Fsites%2FTechDocuments%2FShared%20Documents%2FTech%20Documents%2FeX700M%20Series%2FeX721M%2FDATASHEET