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Data and situational centric "apps" to improve ship navigation

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Abstract

The current systems supporting navigation on board of ships are built on the classic concept for equipment: the system is developed, tested, type approved and installed; and from that time on it is used with no or little modifications. The systems are using data, but the data streams do not influence the system behavior. Looking at other industries, a regime of software and system maintenance has been established which allows more rapid updates. System development in the IT arena is moving towards a more modular approach, encapsulating individual components to ease the implementation and delivery of updates with a limited system-wide impact. This key concept is lately often referred to as the "app-concept". In addition, more and more systems are using data to adjust system behavior to support a situational centric approach for decision support. The e-Navigation development asks for exactly that: a way to improve innovation, while ensuring system stability for the navigational components used by the navigator on the bridge, and a concept to increase situational awareness. A key aspect of the success of new systems will be the ability to convert data into information as needed in any given situation, creating the necessary knowledge for intelligent decision making and increasing the competence of a navigator. The paper will focus on the following topics: the classic monolithic equipment paradigm; modern system architecture, using components and app-concepts; advantages of using data streams to enable situational driven tool enhancements; and the app-concepts supporting the situational centric information presentation.

The app-concept

The development of IT technology is rapidly changing to adapt to growing needs for quality, efficiency and effectiveness of systems and their lifecycle. In the early days of computer programming, the actual commands were coded on punch cards, which were inserted into readers one by one to instruct the computer as to what it had to do. As IT systems faced growing requirements, these commands were later stored on tapes and eventually on hard drives, but they still followed the concept of the one by one command, which required the same commands to be repeated over and over throughout the execution of a program.

To reduce programming time and increase the ease of maintenance, the program structure was changed to reference different sections. This was possible as the hard drive reader could easily locate certain portions of the code and execute it as needed. This structural approach revolutionized the way programs worked. Function calls, rather than repetition of code, made it possible to increase functionality drastically. In fact, the terminology changed as well. IT now started to talk about applications, rather than programs (Campbell-Kelly & Aspray, 1996; Ceruzzi, 2000).

Further development resulted from the introduction of the programming language C++, which increased the efficiency and effectiveness of software applications. The creation of a modular approach allowed the use of sections of software in different applications, and therefore actually allowed applications to interact with each other as needed.

IT had reached the point where it had migrated from an isolated and monolithic system architecture to component based, integrated systems.

A layer concept is the basis for any software system. The foundation layer is the hardware. Within this hardware layer, the system software provides the basic functionality needed to run any application. The actual applications build an additional layer, which uses standardized application programming interfaces (API) to exchange data and other relevant information and run the functional tasks.

This concept allows developers to focus on building blocks, which can be grouped together to perform the requested functions. When updating systems, only those building blocks affected require changes, meaning the other components can be left untouched. The result has been a faster development, allowing rapid changes and reducing the test cycles of IT systems (Frechette, 2013).

It is not only easier to update existing systems, however; adding other components and functions is also easier to accomplish. Additional building blocks can be added, as long as they stay within their layer and are compliant with the standards and API structure of the overall system.

This system already includes a certain level of encapsulation. As long as it does not involve changing basic parameters, hardware can be exchanged without affecting the system and application software. As such, the hardware has a certain level of encapsulation. The same is true for system software and the application layer. Only if the APIs are changing, do you need to exchange both layers; otherwise, independent updates are possible.

This concept is not new and it is already used in quite a few existing bridge systems. However, the concept of encapsulation, and its use for component type approval has not necessarily been enabled.

More recently, the electronic industry moved towards the concept of app architecture, in appropriate areas. This concept was first developed for consumer products, such as tablets, smartphones and similar devices. Therefore, the app-concept is mainly known in the area of so-called mobile devices, but it is not limited to mobile computing.

Towards the beginning of the decade, application software was introduced. The concept behind it is to develop software components, which execute certain functions within a shell application. They cannot run by themselves, but rather run within the parent software. Prominent examples in the PC world are MS Word and MS Excel, both of which run within MS Office. The parent application provides commonly used functions, such as save to disk, copy to clipboard or certain user interface functionality, to name only three examples.

The essential component, which enables the success of the app-concept, is the creation of a fourth layer: the Shell Application. As explained above, the traditional architecture used three layers: hardware, system software and application software. The app-concept utilizes a division of the application layer into the parent application, which builds basic functionality. This layer manages the input devices, such as keyboard, touch screen, GPS sensors, motion sensors and so on. It also provides display functionality, pull-down menus and other user interface aspects. As such, this layer ensures a common look and feel for the human machine interface.

The actual app can then focus on specific functionality, with or without the user frontend.

As a large amount of functionality is already handled by the parent application, the app development can focus on the specific functionality. This concept highly increased the innovation speed in this kind of architecture.

The second key component for the success of the app-concept is the manifestation of encapsulation on the parent application level. While the traditional systems, as explained above, established a certain level of encapsulation between the three components of hardware, system software and application software, the app architecture created another encapsulation. This ensures that the processes of changing existing apps or adding new apps do not negatively influence the existing installed software. This ensures system stability and the uninterrupted execution of established system components, while updating or adding functionality.

In industries like aviation this concept is well established. For years, a growing number of airplanes are equipped with an electronic information management device known as electronic flight bags (Figure 1). These systems use app architecture to allow the inclusion of additional functionalities with reduced type approval needs (Bergmann, 2015).

Even in very strict environments, such as the aviation industry, the speed of innovation is very much growing with the use of mobile devises and app driven systems.

It seems to be logical that the maritime world is also taking full advantage of these new state-of-the-art developments. Unfortunately, the existing type approval concept does not recognize this level of encapsulation; and, as such, it requires full type approval if new apps are developed and installed or if certain apps are updated. This type approval regime needs to change to allow the maritime world to take

Figure 1. The electronic flight bag (Jeppesen, 2012)

advantage of the increasing innovation speed and to ensure that maritime transport is not left behind.

This situation has been recognized by those groups working on e-Navigation, like the IMO e-Navigation Correspondence Group, the IALA e-Navigation Committee and the CIRM e-Navigation Working Group (Bergmann, 2013).

Limitations of the traditional "monolithic" view on equipment

Chapter V of the International Convention for the Safety of Life at Sea (SOLAS V) by the International Maritime Organisation (IMO) is the regulatory foundation of any bridge equipment development. The IMO type approval regime is essential for new and updated bridge systems. This regime currently requires full certification by the manufacturers of new or substantially changed equipment in order for them to be allowed to install it. Additionally, the type approved systems need on-ship certification prior to operational use. Figure 2 illustrates the concept.

IMO's SOLAS V and VI require that equipment must be "type approved by the administration" (IMO, 2009). It also clarifies that IMO Performance Standards are the minimum required (IMO, 2009). Finally, it needs to be understood that the International Electrotechnical Commission (IEC) provides harmonized tests for these Performance Standards, which allows certification bodies to approve systems according to this regime (IEC, 2002; 2007; 2008; 2012; 2014).

For further clarification, IMO has published the IMO MSC 1/Circ 1221 (IMO, 2006). In this circular, IMO specifies the minimum steps required. In detail, per this circular, the equipment must meet the following criteria (IMO, 2006):

"1. engineering evaluation;

2. witnessing the manufacturing and testing processes;

3. evaluating the manufacturing arrangements;

4. issuing of a Type Approval Certificate generally valid for not more than 5 years which may be subject to annual inspections or verification of the manufacturer's process after all the above-mentioned procedures have been satisfactorily completed."

One of the results of this highly regulated detail process are the long development cycles for new equipment, which further results in a reduction of development speed. Originally, this was an intended effect, so as to avoid unstable equipment and unreliable tools on bridges. At that time, innovation on the bridge was not yet seen as a method to help improve navigational safety and ship operational efficiency, and therefore was not taken into consideration at all. In the modern world, however,

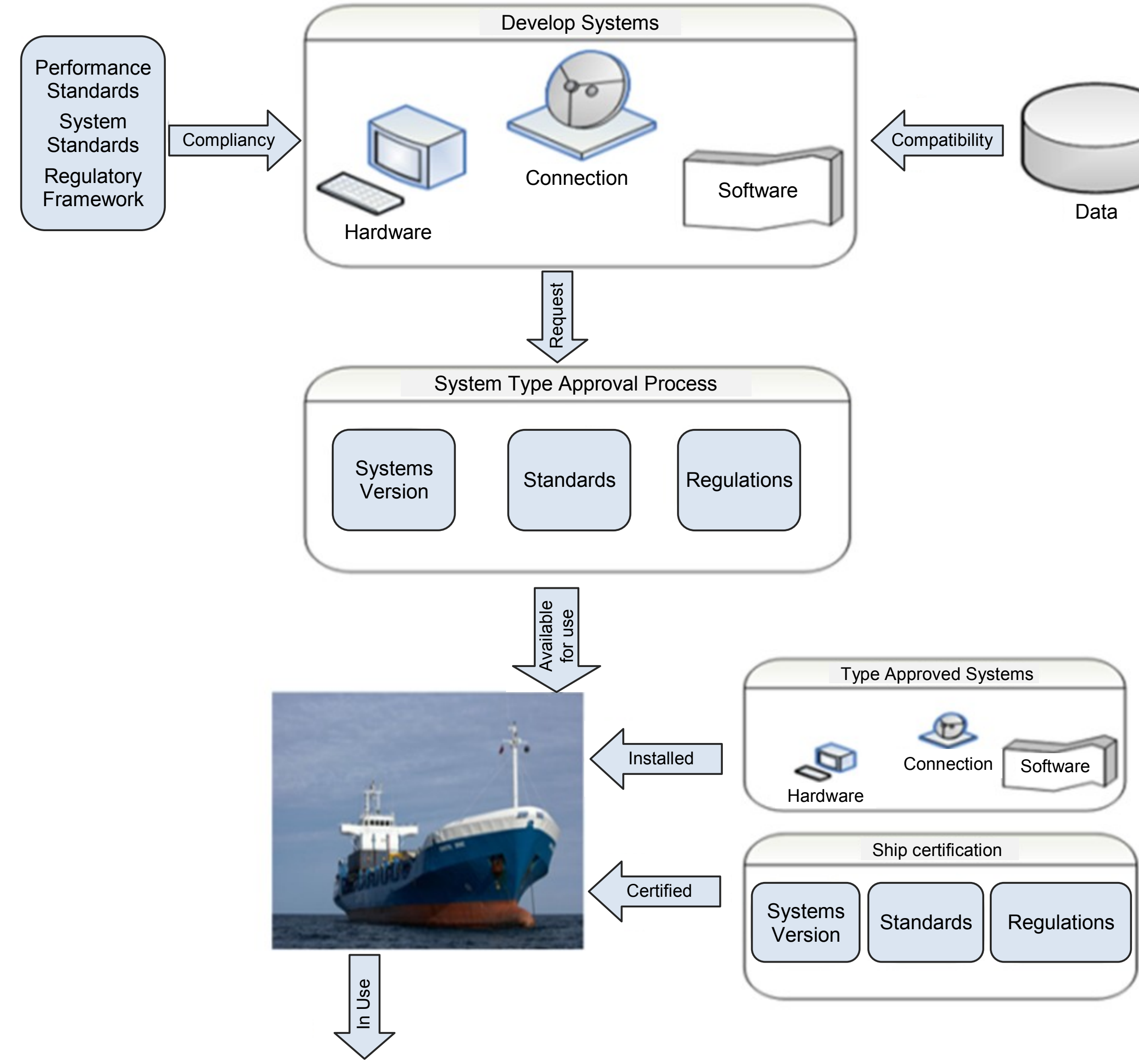

Figure 2. Current type approval process (Bergmann, 2015)

this approach results in huge disadvantages: the current bridge systems are based on aged architecture; it does not bring the latest technological benefits to the mariner; and the gap between bridge systems and systems used in other areas, both private and business, is growing.

A comparison with other industries, where the use of state of the art systems is common, illustrates this negative situation. Figures 3 and 4 show built-in systems, as well as the use of a tablet device in modern airline aircraft cockpits.

In essence, the analysis shows that the current systems installed on today's ships have often been installed years ago, and continue to be used without substantial updates, using the so-called Grandfather Clause to keep type approval once installed.

IMO tried to improve the situation by adapting a new regulation on Integrated Navigation Systems (INS) (IMO, 2009). While these systems allowing different INS Modes and integrate different functionalities, they still rely on individual units, like radar or the Electronic Chart Display And Information System (ECDIS), which are then combined in a semi-integrated way. However, the integration

Figure 3. Integrated "electronic flight bag" (Jeppesen, 2012)

Figure 4. Tablet use in aviation (Jeppesen, 2013)

of these systems usually occurs simply by means of exchanging of data streams, rather than fully integrating the different components. Instead, they share the display by allowing the system to switch from mode to mode.

As the type approval regime still applies even in this concept, full type approval is required if a new component, such as a new display mode, is introduced (IMO, 2006).

Situational driven tools – advantages for next generation systems

In the last 50 years, sea traffic has been undergoing drastic changes:

- The volume of maritime transport is massively increasing.
- The ship sizes are increasing.
- Sea transport is under increasing economic pressure, which in turn results in the reduction of crew members and has led at times to one-person bridges.
- Carbon footprint and other environmental factors are adding complexity.
- The navigable waters are reduced as other stakeholders are claiming sea areas and blocking them for sea traffic (e.g. offshore installations, sensitive sea areas).

These developments have increased the complexity of ship navigation and are making the tasks of ship masters and navigators more and more complex.

In order to manage these challenges in navigating commercial ships, the usage of ship and shore based sensors and real-time data to increase awareness of navigators is essential. The traditional assets of a navigator, like lookout, terrestrial positioning, experience and reading the sea and ship, no longer allow a mariner to make educated decisions. The integration of static data (e.g. electronic navigational charts) and real time data (e.g. weather or tidal information) is paramount to allow a mariner to fully realize the situation he is in. Unfortunately, as the human ability to digest information is limited, the amount of useful data would lead to a data overload; this could even be counterproductive, reducing situational awareness rather than helping.

Just as in maritime transport, however, this is also true in aviation or car navigation.

The industry has started to develop tools to help manage this situation. Functions which analyze sensor data and react automatically to provide the driver with information as needed are nowadays standard in car navigation systems. The navigational system automatically zooms in or out depending on speed, if that function is enabled. The system also provides certain information in advance depending on speed: it notes the next turn two kilometers ahead if on high speed, or just 100 meters or less before the turn if on very low speed.

Public transportation systems like trains or subways have for quite some time implemented traffic systems where brakes are activated if a train is passing a stop sign or is driving too fast. The train driver will be overruled by situational driven tools.

Even more situational centric focus is used in aviation, especially in military combat systems, where decisions have to be made in fractions of a second without a chance for the pilot to correctly analyze all incoming data. Heads-up displays, allowing a simultaneous lookout and systems view, are often used, while data analysis by systems only present to the aviator what is essential in the current situation.

While a ship navigates at much slower speed, which may allow more time to analyze the situation, the task is not necessarily easier. As such, the lessons learned in other industries have already inspired the maritime manufacturers to develop situational centric tools. Due to the type approval regime, however, it is currently not always possible to bring those systems onto the bridges and use them for primary navigation.

The discussion on e-Navigation is circling around these topics and is starting to move the IMO regulatory world slowly towards the necessary changes. Experts and decision makers are grouping together to further develop the understanding that situational centric tools can provide the mariner with the necessary information, just it is needed, without endangering decision making through data overload (Bergmann, 2013; IMO, 2014).

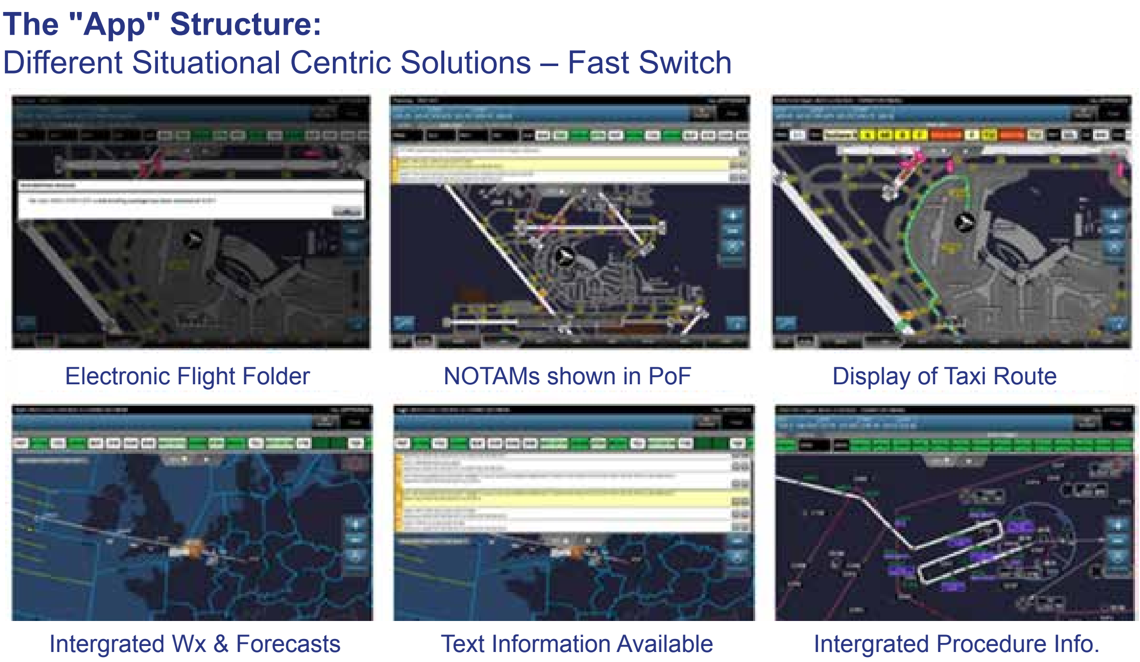

Figure 5. Aviation apps and situational centric display (Jeppesen, 2013)

The maritime app-concept

As explained in section 1, the app-concept is a proven technology to improve flexible and rapid development by maintaining the highest level of quality and reliability of mission critical systems. It also allows the user to use both situational centric and situational agnostic apps and switch seamlessly between the two.

Figure 5 shows different apps in the aviation electronic flight bag. The pilot is in a position to switch rapidly between different situational centric displays to better support the necessary speed in decision making, but easily switch back to a static display if it is seen to be beneficial.

Given the specific situations on board a slow moving ship in a complex and sometime hostile environment, it is beneficial for a mariner to have access to both situational centric and static information. This will allow the navigator to utilize the tools for fast information digestion in critical situations, but also allow deeper analysis during the less stressful phases of a voyage, for example during route planning and optimization.

As said above, the app-concept caters for this maritime requirement. In addition, the app-concept can be used to reduce the administrative burden on the bridges, one of the goals IMO tries to archive with e-Navigation. Background apps, whether automatically or manually triggered, make possible the exchange of ship data with short side services, allowing Vessel Traffic Centers (VTS) to provide educated guidance or satisfy legal reporting requirements. Here, just as in other usage areas, the app-concept with a modified type approval regime will allow updates of systems to meet new legal or operational requirements, without the financial, organizational and timing risk of full type approvals of systems and ships. In addition, the maritime app-concept will reduce training requirements when installing new apps, as the parent application will ensure a common touch and feel, and intuitive usage of the new functionality within its context (Bergmann, 2015).

An additional aspect of the app-concept, which provides benefits in other industries, is allowing different devices to be used to meet the requirements of different situations. Figure 6 shows an aviation handheld navigational device, as well as a smart

Figure 6. Navigational and fatigue prevention apps (Jeppesen, 2014)

phone, being used to manage fatigue prevention. While an uninterrupted view of the navigational relevant information is possible, a quick check of the fatigue situation to improve cockpit resource management is easily possible. Marine bridges have already implemented the concept of both individual displays (e.g. radar), as well as switchable displays, as in INS. What has not yet been considered is the utilization of individual and common apps in both mounted as well as handheld devices.

Conclusions

Maritime transportation, just as other industries, is growing ever increasingly complex. Mariners need to manage the growing challenge of safe and efficient navigation in a more and more complex environment.

To be able to manage this challenges, all available data from the ship sensors, but also from other ships and from shore, need to be made available to the navigating crew when and where beneficial. The e-Navigation concept was launched by IMO to help utilize this flood of data in the best way without overloading bridge teams. In addition, the maritime industry needs to realize that our world, and with it the maritime transport, is challenged with a speed of change not seen before. The maritime industry is adapting to this speed of change, as are the industries of the transport sectors. This is a necessary result of the growing interdepenancy within the multi-modal transport eco system.

Modern systems on the bridges are aiming to address these challenges. In future, they need to be able to handle and integrate a large amount of data into useful and digestible information. Only then can the bridge teams successfully execute their tasks. Another emerging requirement is that they need to be flexible enough to keep up with the growing speed of change and innovation. This includes adaptions to accommodate the changing habits of user, which is part of the discipline of human centered design.

This is not only a phenomenon of marine transport, however, and other industries have already managed to work through some of this issues. The best practices of others, like the aviation industry, can be utilized. Best practices of the electronic industry, especially the migration from monolithic architecture to component based architecture and towards an app structure, are to be taken in consideration. Through the encapsulation of apps, this enables easy integration of new functions and features without interruption of the existing running systems.

Situational centric system functionality can filter incoming data and integrate it into information, as needed in real time.

Besides the full utilization of this development and adapting it as needed into marine specific systems, the regulatory framework – performance standards, updating regimes and type approval concepts – needs to be reviewed, and the necessary adaptions to support these developments need to be implemented as soon as possible.

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