Enhancing Internal Battle Operations Through the Battle Damage Repair Tool

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Synopsis

In today's maritime industry, the operational environment is undergoing a significant transformation characterized by increasing complexity, smaller ship crews, and more sensor-generated information. As ships become more technologically advanced, the volume of data available to crew members will skyrocket, presenting both opportunities and challenges. Amidst this backdrop, there is a pressing need for streamlined communication channels and efficient data management systems to ensure the operational continuity.

To address some of these challenges, the authors have developed a digital solution within our 'Golden Triangle' of collaboration between knowledge institutions, industry and defence: the Battle Damage Repair Tool (BDR tool). Unlike traditional methods reliant on handwritten notes from defect managers, the BDR tool leverages advanced digital capabilities to streamline the reporting process. By digitizing defect reports and centralizing information in a user-friendly platform, the BDR tool eliminates the inefficiencies associated with manual documentation and enhances shared situation awareness. Now, critical information regarding ship defects is readily available to crew members and directors alike, facilitating swift decision-making.

The research aims to assess the effectiveness of the BDR tool in improving internal battle operations in a high stress environment. The authors have identified several key findings. Firstly, the implementation of the BDR tool has led to the development of the Mobile Support Tool (MST) which will lead to a significant reduction in reporting delays, enabling faster response times to prioritized issues. Secondly, the centralized nature of the tool has enhanced collaboration among crew members, fostering a culture of transparency. Moreover, the real-time accessibility of defect information has facilitated more informed decision-making processes at all levels of the organization. Overall, our research underscores the transformative potential of digital solutions like the BDR tool in optimizing maritime operations amidst an evolving operational landscape.

Keywords: Battle Damage Repair Management, Decision Support, Internal Battle, Lean Damage Control

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1. Introduction

Battle Damage Repair (BDR) on a naval vessel follows the OODA-loop (observe, orient, decide and act) (Geertsma, 2018). After impact an assessment of damage has to be done. Traditionally, this is done by the crew, in buddy pairs, checking each compartment; the so called Blanket Search (BS). In recent years, the Royal Netherlands Navy (RNLN) has adapted this procedure to fit business operation on specific ships (e.g. reduced crew size, lack of redundancy of system specialists or larger ships). However, the RNLN always relies on personnel on the spot to assess damage (incidents or malfunctions). Sensor or operator information can provide useful insights of the ship's status and remaining capabilities quite quickly, but can hardly provide detailed information on repairs required after a significant impact. Sending personnel to damaged compartments will always be part of business operations.

Once a team or specialist arrives at a (potentially) damaged compartment or system, they start gathering information in a structured way. To assure this structure, they use a so-called "5-point brief" to write down observations. All the information on the '5-point brief' is reported to a Defect Manager (DM) in the Engineering Office (EO). Current ships use a phone line or plotline for this. Having multiple teams on a BS- round, the single line of communication acts as a bottleneck and causes delays. To mitigate the effects (people shall only call once), much focus is put in training on first completing the ' 5-point brief', before calling in an incident or malfunction.

The DMs in turn report all damage to their Director, often using a plotline. Limiting here is the speed Directors can process (and write down) information, combined with the DM ability to prioritize information. Finally, the BDR officer combines the information of his or her Directors to the top-3 of most pressing issues at the moment. Hereby focusing in the first stage primarily on 'Command Aim killers'.

The use of digital technology has two distinct, immediately recognizable advantages: crew can share information whenever available and information is readily available for all crewmembers. This forms the starting point for the development of the BDR Support Tool (BDR ST). Section 2 of this paper describes the collaboration between Government, Knowledge Institutes and Industry, the so called 'Golden Triangle', that enabled the flexible and result-oriented development of the BDR ST. Section 3 outlines how the requirements have been drawn up by the knowledge institution and government, which have been implemented and adopted by the Industry (see section 4). Section 5 describes the conclusions and future ideas about the development process of the BDR ST.

2. Result-oriented development in collaboration

The traditional waterfall method, where the customer provides a set of requirements and a budget, only to receive a product several years later, is long gone. The result often ends up being a product that does not quite meet expectations or fails to satisfy revised insights. Furthermore, there are limited opportunities to prevent errors due to misinterpretation of specifications.

A more modern approach is the Agile methodology, which involves iterative work towards a final product. However, it is important to note that the budget is often static, and any changes entail risks. Typically, this means that if something new needs to be added, something else must be removed. This could involve removing a functionality entirely or stripping it down. It is crucial for all parties involved to understand that maintaining scope is vital to prevent an endless implementation cycle. The goal should always remain to develop a product that could add the most value with the minimal required effort. The 'Minimal Viable Product' (MVP) (just enough features to be useable on board a ship by users who can then provide feedback) should be rolled out as soon as possible.

To be flexible and result-oriented throughout the whole development phase it is necessary that government (defence), knowledge institutes and industry, which each of their specific contributions, work closely together. This collaboration, the so called 'Golden Triangle', allows efficiently aligning the strengths and weaknesses of the partners. The 'Golden Triangle' establishes a structural feedback loop. It is essential to clarify who needs to be briefed at what stage to track progress and brainstorm solutions to challenges collaboratively.

The Software is collaboratively developed with three key stakeholders: Defence as the client, Knowledge Institutes for theoretical expertise and specifications, and the industry to build an operational applicable product.

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The strongest contribution for Defence in the creation of this product is domain knowledge. A risk is the frequent turnover within Defence. New individuals join a project with different priorities and perspectives on the challenges already addressed. In a development project like BDR ST, numerous such turnovers can occur.

Knowledge Institutes' key contributions are their scientific knowledge and fundamental approach to a problem. This enables a thorough analysis and complete consideration of all relevant factors. The outcome is a set of specifications, to serve as a guideline for implementation. A downside can be the time required and a too theoretical approach to the operational context. The result of the trade-off between writing specifications or documenting all researched alternatives and the rationale behind all decisions, can later lead to incorrect decisions when seeking a more 'efficient' way to implement a particular requirement.

The industry possesses the most knowledge of software development and the potential risks. A risk of the industry is the ambition to be able to re-use the software for a wider target, extending certain features or making certain parts more flexible at the cost of the current projects budget.

The collaboration between these three partners within the 'Golden Triangle' has led to the result-oriented development of a digital tool to manage Battle Damage Repair on board naval vessels; the BDR Support Tool.

3. Requirements decision for the Battle Damage Repair Support Tool (BDR ST)

The current internal battle damage repair procedure is robust and flexible. However, due to the great amount of communication required, there is a significant delay in information flow throughout the hierarchy and the chance of miscommunication is high. Currently, at every location involved in the internal battle damage repair process there is a paper overview to keep track of defects and incidents. The duplication of all these overviews requires a lot of verbal communication, is often messy, stressful, and does not provide any opportunity to connect information sources for technical support or automation. The current process thus poses the risk of providing incorrect or outdated information and advice to the Commanding Officer (CO), increasing the chance of setting incorrect priorities, and decreasing the chance of mission success.

The aim of the BDR ST is twofold: (1) the tool should improve rapid and accurate situational awareness for making the right decision in determining the top-3 ship repair priorities, and (2) to guide the onboard personnel to respond to emergencies to be resolved using the necessary information.

The BDR ST enhances situational awareness for the internal battle, since it supports digitally managing incidents and defects from combat damage. Therefore, the BDR ST facilitates a reliable and quick command advice (see Figure 1). The main goals of the BDR ST therefore are:

1. Coordinating damage assessment (Blanket Search (BS)) after weapon impact;
2. Recording system malfunctions and incidents as a result of impacts, and monitoring the resolution of these defects and incidents;
3. Prioritizing the repair of defects and incident response;
4. Managing electrical isolation in support of incident response;
5. Coordinating the deployment of personnel for incident repairs, incident response and electrical isolations.

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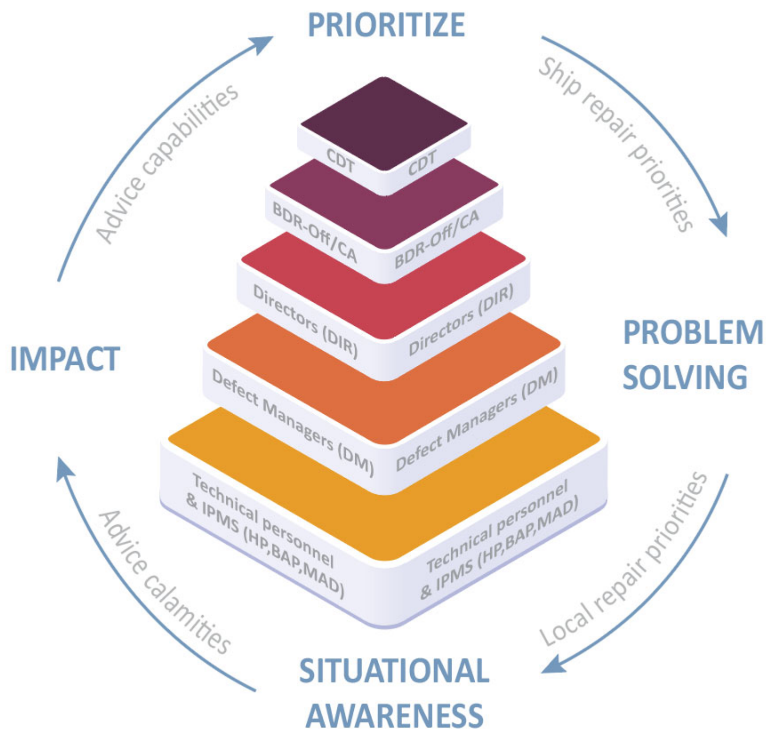

Figure 1: The internal battle repair process: illustration of decision making

In this paper the authors focus on giving more insight in the way the damage assessment is coordinated and managed. The process of collecting system defects and incidents by the BS-specialists has been further studied and specified with and without the use of a handheld device by each crew member. The three main parts to come to these clear requirements includes the approach, the challenges faced and the user tests.

3.1. Approach

The written requirements for the BDR ST have been iteratively developed in a methodology, in which part of the requirements were tested and visualised by prototyping. The knowledge institute TNO, the Defence Material Organisation (nowadays COMMIT) and a representative number of end users were involved intensively, which resulted into approved requirements. All the requirements were stored in Confluence (*ATLASSIAN, Confluence (www.atlassian.com)*), so that it can be used for bringing it in production.

From the beginning the ultimate product should reflect the predefined 10 golden rules. Some of these 10 golden rules are read as follows: (1) the user is always is control, the system should therefore facilitate and should not restrict the user, (2) the system must support business operations, not impose them, (3) the system should be flexible in use, (4) the user must stay informed at all times, (5) speed of entering information is leading.

After an impact on a ship the BS is a process in which the ship is systematically searched for incidents and defective systems by the crew. All irregularities are reported to the Defect Manager (DM). The progress of the BS is important in assessing the uncertainty that remains about the status of the ship and therefore of the situational awareness.

3.2. Workflow

As already mentioned in the introduction, the functionality of the BDR ST is to increase internal situational understanding during damage control. After mapping the system malfunctions and incidents such as fires, flooding and injuries the ship's status is known, increasing the crews situational understanding. The internal situational understanding enables decision making and prioritizing the system malfunctions and incidents, based on the Command Aim. The Defect Managers and the higher echelons (directors, BDR officer, Command Advisor and CO) are involved in this process (see Figure 1). It should be noted that everyone (whether dispersed or not) on board has the same information. The BDR ST makes this possible, because real time information is digitalized and everyone can also expand the tickets with relevant information. Initiating the malfunction-tickets or incidents-tickets can be done by the DM, but also by technical personnel.

At every level, except local, priorities can be set in the system. Each DM had a top-3 tickets, which go one echelon up, where a director combines the top-3 of all his DM's into his own top-three of incidents and malfunctions. The BDR-officer in turn, combines all top-3 from his directors into the overall repair priorities, which the BDR-officer proposes to the Command Advisor and CO).

Once priorities are set, the repair process begins by resolving the overall repair priorities first. The technical personnel will be assigned by the DM to the system malfunction- or incident tickets. The progress of resolving these tickets will also be monitored so that the DM and higher echelon are aware of the progress of the repair process. This is done by means of, among others, the Estimated Time Back on Line (ETBOL).

The BDR ST consist of workstations (fixed monitors) for the DMs and the higher echelon. The technical personnel will be equipped with the handheld, because they have to do their work spread across the ship. The user interfaces are optimized for the role of personnel, so they can immediately see where their responsibilities lie and how they can manage the status of "their" tickets.

3.3. Challenges

Of the challenges during the requirements phase (specification phase), the available hardware was an important aspect. Some users are stationed at a fixed post, while others are expected to gather information by surveying the ship. Depending on the readiness state of the ship, users wear gloves and other protective equipment. The personnel who are surveilling the ship may even carry firefighting equipment or "prop" kits for the first attack of incidents such as leaks and fires. The DM up to the Command Advisor (see Figure 1) will be using fixed monitors, with touch screens, mouse and keyboard. The engineering personnel will be equipped with handhelds, touch screens, and preferably using voice commands. Figure 2 shows possible user interfaces related for fixed monitors and handhelds (Mobile Support Tool (MST)).

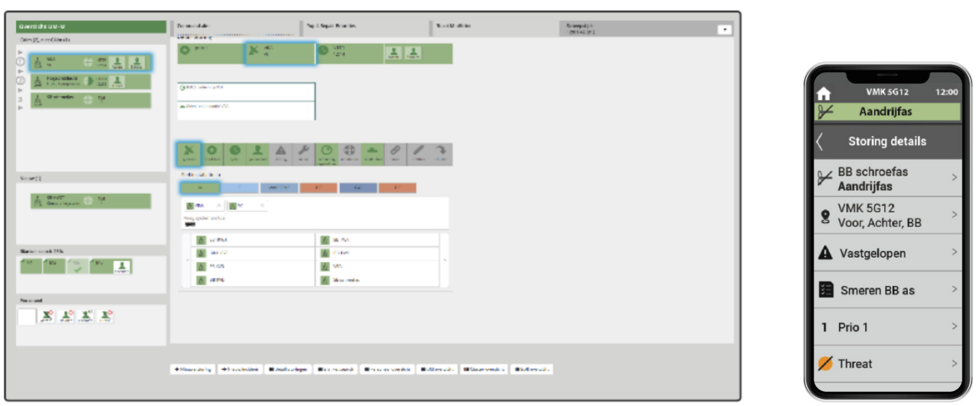

Figure 2: Snapshots (ticket view) of the BDR ST from a fixed monitor and handheld (an example)

The functionalities of the static stations were first investigated, next specified and finally tested before the handheld was included, since the information and tasks on a static workstation are the most extensive. Special attention has been paid to the HMI (Human Machine Interface), including incorporation of communication integration (Voice or Text) and integration with other applications such as an Electronic Incident Board and Automatic Decision Support applications. (Geertsma R.D. and Badon Ghijben N.A., 2014)

Crewmembers performing Blanket Search (BS) must be guided through the ship (from initial predefined known BS route map to flexible route map), the DM and higher echelon want to see the progress of all the BS-routes, and the BDR ST should be fed with all the defects and incidents. All requirements regarding the processes have been established via clear user stories. Examples of visualizations on fixed screens and handhelds were considered, where interaction was an important facet. Tickets should be generated by the BS specialist during the BS with the help of the handheld. The BS specialist, but preferably her or his device, should be aware of its location in the BS route. At any time, the BS specialist can be ordered to do something else by receiving a new command or assignment. A change in tasking must be confirmed. Interactions between crew in the ship and the DM is primarily through the BDR ST, but the mobile support device can also be used for communication by voice. All this, must not distract a crewmember from his most important task, finding, reporting and execute first response actions.

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3.4. User tests

Before testing the ideas of a digitalised BDR ST, workshops and explorations were held in 2016. The DM-level of the BDR ST (without the interaction with higher echelon or the technical personnel) has been pilot-tested at the Royal Netherlands Navy Engineering Training Centre “Koninklijke Marine Technische Opleidingen” (KMTO) with experienced instructors as users. The focus was on the digitization of the information collected by the Defect Manager and how the information can be optimally presented for the user, in this case the Defect Manager. The results of the test were both positive and constructive. Especially situation awareness of officers increases as all information is readily available for everyone. The stand-alone prototype BDR ST (without the handheld) has been tested by the Zr.Ms. Evertsen crew in an experiment at the end of 2017. In this case the total decision process to come to the top-3 repair priorities by the BDR Officer was tested, based on information and assessment of the Defect Managers and directors. The experiment signaled the need to convert the demonstrator into a usable (integrated) tool on board naval vessels. These have led to the specifications for creating a BDR ST, as drawn up by TNO. Finally, the stand-alone prototype BDR ST including the handheld (Mobile Support Tool) has also been successfully tested by the HNLMS (Zr.Ms.) Evertsen crew in an experiment at the end of 2018. Figure 3 illustrates the successive test and evaluation moments towards the production of the BDR ST.

Figure 3: Evaluation / user test moments of TNO and DMO (COMMIT) during the BDR ST specifications.

After the specification had been sufficiently developed and user tests yielded positive results, the implementation of the BDR ST began. The determination of scope and approach for the implementation is described in the following section.

4. Implementation of the BDR ST

The next phase of the development of the BDR ST is the implementation phase, in which the software is developed. First, scope was determined at both hardware and software level. Subsequently, communication lines were established to ensure that what was specified was created and possible deviations were addressed through proper consultation. How this was done is described in this section.

4.1. Approach

After completing the thorough specification, the practical implementation phase could finally commence. Due to financial limitations, this was later than from an engineering perspective would have been optimal. Given the extensive scope of the specification, which encompasses multiple applications, a deliberate strategy was employed to break it down into more manageable segments. This section provides insights into the methodology employed to achieve this segmentation, emphasizing the significance of this approach in navigating the complexities of the implementation process.

4.2. Determining Milestones

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The overarching objective is to enhance stakeholder engagement on a regular basis. Empowering training centers to contribute their insights on the readiness of the software for training purposes accelerates the progress towards the goal. One pivotal milestone is to enhance the software's functionality to a level where it can seamlessly integrate into a demonstration setup at the training centers, encouraging active participation in the process. Another critical milestone involves preparing a version capable of engaging the training center students actively, facilitating practical training sessions leveraging the demonstration setup. The final milestone before reaching the Minimal Viable Product (MVP) is a version that enables the crew to start using it. The MVP will be considered successful once the software can be deployed operationally.

4.3. Where to begin

As previously mentioned, the specification encompasses two major applications: a desktop application for the DMs and higher echelons, and a mobile support tool application for engineers. Both applications share a considerable amount of functionality and data, thus they will share a backend. During the requirements phase, it became evident that the initial focus would be on the Engineering office (EO), where various defect managers administer and prioritize defects and incidents. Therefore, it seemed logical to commence development here, since here the base of the process is preformed; collecting and managing ‘5- point briefs’.

Within the desktop application, there is a vast array of functionalities to choose from. To make decisions about which functionalities fit within the milestones, significant cuts were made. Priority was given to building a shared situational understanding: capturing the current situation as comprehensively as possible to determine priorities for resolving the issue.

The MVP constitutes of ticket creation, prioritization and personnel deployment. With this functionality, a complete BS would not be directly supported. Instead, the results of the blanket search could be utilized to create a shared situational awareness. All ‘5- point briefs’ generated from the blanket search can be logged and prioritized, allowing for the assignment of personnel accordingly.

After defining the scope of the MVP, the method for feedback to ensure seamless communication could be established. In the next section this feedback loop is covered.

4.4. Future Proof architecture

Transitioning from a paper-based process to a digital system involves more than just digitizing forms; it requires rethinking the entire architecture to support scalability, flexibility, and integration. The BDR ST had to be designed to handle increasing demands, Future integration with various applications, and react to real-time events. This chapter explores the technical challenges involved, focusing on microservices architecture, event sourcing, virtualization and Kubernetes, and data redundancy.

4.4.1. Microservices Architecture

The BDR-ST adopts a microservices architecture, breaking down the application into smaller, independent services. Each microservice handles specific functionality, allowing for greater flexibility and scalability. However, this shift introduces challenges such as managing inter-service communication, ensuring fault tolerance, and orchestrating distributed transactions.

4.4.2. Event Sourcing

Event sourcing is implemented to capture every change as an immutable event, enabling precise state reconstruction at any time. This approach, while providing a comprehensive audit trail, requires careful management of large event volumes, consistency across services, and handling the evolution of event schemas.

4.4.3. Virtualization and Kubernetes

Virtualization is crucial for resource efficiency and scalability. Containers are used to standardize the environment across different deployments, while Kubernetes (www.kubernetes.io), automates the management and scaling of these containers. This setup, however, brings challenges such as complex configuration management, security, and ensuring reliable storage.

4.4.4. Data Redundancy

The architecture of the BDR ST incorporates data redundancy through distributed databases, and replication to ensure data availability and resilience. A key challenge is balancing strong consistency for data accuracy with eventual consistency, which enhances performance during peak demand.

4.5. Feedback loop

Within the Industry partner, a development team has been established with various disciplines to develop the different functionalities. Development is conducted using the Scrum methodology in iterations (sprints) of 3 weeks each. During these sprints, work is estimated, developed, and tested. This team is led by a Product Owner who reports to the stakeholders.

Every 6 weeks a stakeholder meeting takes place to demonstrate progress, determine upcoming tasks, and address inquiries from the development team. A software developer attends to ensure transparency regarding the hidden effort in 'simple changes'. Every 13 weeks, the entire 'Golden Triangle' convenes. During these meetings, specific features are clarified by discussing the rationale behind them, and the Knowledge Institute can assess if their ideas are becoming reality.

Once the first milestone is reached and enough product is available for practical use, trainers from the Royal Netherlands Navy Engineering Training Centre (KMTO) are added to the working group. As progress moves towards the second milestone, more input is sought from personnel within the training division. Additionally, it becomes possible to undergo certain (adjusted) training sessions using the software. As the final milestone approaches, it becomes increasingly important to actually train crew members. Trainers can gather feedback and share it in the stakeholder meetings. It is crucial to ensure that the scope remains broad enough to be genuinely operationally deployable at all times.

After a certain foundation of the BDR ST was established and the process became digitally available, various ideas for automation and opportunities for more efficient manpower management emerged. These opportunities will be addressed in the following section.

5. Conclusions and the way forward

What is currently set with the MVP is merely a foundation that is already usable for operational deployment. The desktop application of the MVP needs to be expanded to the full application in order to, for example, support the full-fledged blanket search but also to gain insight into and utilize capabilities and the command aim. Additionally, the mobile application for the technicians also needs to be fully developed.

As result of the MVP of the BDR ST, the following conclusions may be drawn in general:
1. Verbal communication reduces;
2. Quicker distribution of information;
3. Minimal chance of mistakes and miscommunication;
4. Simplification of the BDR management process becomes possible;
5. A tool can be created that is as easy to use as the current paper process.

The MVP of the BDR ST applications was not so much intended to reduce manpower but rather to reduce stress and communication during the mapping of the current situation. When all information is available for everyone, it is much easier to assist a colleague who is struggling and get him or her back on track. A downside is that is also enables micromanaging. Directors must be aware of this risk and focus on their role.

5.1. Adding automation and intelligence

Working digitally, even at MVP level of software, automation can easily be applied. For instance, automatic ticket generation based on platform alarms, and with a command aim integration, they could even be prioritized to a certain extent. Integration with other applications, such as *smart rooms* or *indoor positioning* can ensure that incident tracking, for example, happens integrally. An overall process optimization made possible by utilizing smart room and location tracking is a dynamic BS.

When it becomes possible to partially automate building the shared situational awareness, it brings the possibility of making the BS dynamic. Instead of going through predetermined routes and determining whether there are defects or incidents to report per room, the system, with the help of smart rooms, can determine which rooms do not need attention, thus generating a shortened route and forming a overview more quickly. With every crew member's location known using an indoor positioning system, the routes can be further optimized by sending crew who are closer.

5.2. Enhance collaboration

Throughout the process the value of close cooperation between the Defence, Knowledge Institutes and Industry has proven valuable. The flexibility and result-oriented approach provides the best possible product for crews on board. In future projects, it is foreseen to further intensity the cooperation and integrate the specification and development phase. For this project, the decision was made to initially elaborate on the specification and then allow the industry partner, in consultation with the Navy, to cherry-pick an MVP.

In future projects, the specification will consider staged delivery, enabling potential MVP definition at an earlier stage. This approach also enables the industry to start development earlier in the process, which enhances collaboration.

References

Geertsma F.D.: "Integration of Battle Damage Repair management in an Integrated Mission Management System", proceedings INEC 2018.

Geertsma R.D. and Badon Ghijben N.A., 'Experiences on implementation of electronic incident boards in the Royal Netherlands Navy', proceedings INEC 2014

Atlassian, Confluence, https://www.atlassian.com/software/confluence

Kubernetes, https://www.kubernetes.io

 https://doi.org/10.24868/11207