

# Delivering Inspiration: A Digital Transformation Case Study

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## Synopsis

The National Shipbuilding Strategy set out a radical change in the way in which warships will be acquired and built in the UK. Simultaneously, technology has evolved rapidly especially in the fields of CAD/CAM, manufacturing automation, personal electronics and data processing techniques. These drivers, both political and technology, have led to the Type 31 Frigate programme - the Inspiration Class - being the pathfinder programme for modern world class shipbuilding in the UK.

These new technologies have significant impact across the construction value chain from design, engineering, manufacturing, assembly and commissioning, as well as lasting benefits that improve support through the platform's lifetime. The guiding vision for Babcock's digital transformation is to empower close collaboration between all disciplines by integrating processes and assuring continuity by sharing data between teams and systems. A single source of truth that permits effective re-use of digital data wherever it is needed unlocks efficiencies, increases productivity and secures profitability via data-driven processes and decision-making. To enable this, investment has been made in equipment, including robotics and automated panel and pace lines; in people to deliver digital manufacturing techniques and in systems to seamlessly deliver design information to the shop floor. This is the start of the Digital Thread and enables a strong digital foundation that follows the physical asset's life into operation and support.

This paper will cover Babcock's experiences over the last 18 months, outlining the challenges and successes as well as the underlying philosophy in the development and implementation of the Digital Thread with a focus on Design & Build. The approach taken falls under these four headline categories: Skills and Engagement; System Architecture; Workflow and Data; and Process Automation.

Keywords: Digital Twin, Enhanced Decision Making, Integrating Disruptive Technology, Industry 4.0, Digital Manufacturing, Digital Thread

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## **Abbreviations**

API	Application Programming Interface
AR	Augmented Reality
CAD	Computer Aided Design
CAPEX	Capital Expenditure
DW	Data Warehouse
ERP	Enterprise Resource Planning
FLMs	Front Line Managers
HVAC	Heating, Ventilation and Air Conditioning
IFS	An ERP system
IKM	Information & Knowledge Management
LTE	Long Term Evolution (Wireless broadband)
OEM	Original equipment Manufacturer
PDM	Product Data Management
Power BI	Business data Analytics (Data visualisation tool)
R&A	Requirements & Acceptance
R&D	Research & Development
SPx	Smart Production Enterprise system by Hexagon
TDP	Technical data Package
TQs	Technical Queries
VAD	Vessel Acceptance Date
VIP	Very Important Person
VR	Virtual Reality

## 1. Introduction

The Digital Thread is a holistic view of an asset's data throughout its entire lifecycle – its digital DNA. The typical lifecycle of an asset starts in design and build and then progresses into the operational phase, including maintenance and refits/life extension and finally disposal. A powerful open architecture of digital technologies encompassing all elements: concept, design, manufacturing, operation, maintenance, life extension, and retirement is required to ensure an unbroken digital thread. All of the multiple sources of digital data need to come together to allow a seamless transition of information from one phase of a project to another.

The ultimate aim of the Digital Thread is to deploy this framework for making efficient and effective measurements of the product lifecycle in support of data-driven methods (Hedberg, Bajaj and Camelio, 2019). The need for a Digital Thread has been driven by several factors such as; the increase in automation and robotics in the ship building sector, the cost of iterative detailed design, and customer demands including mass personalisation which require manufacturers to maximise productivity while keeping costs down to ensure profitability. Babcock has recently undergone a digital transformation to overcome these challenges in relation to the design and build of large, complex warships.

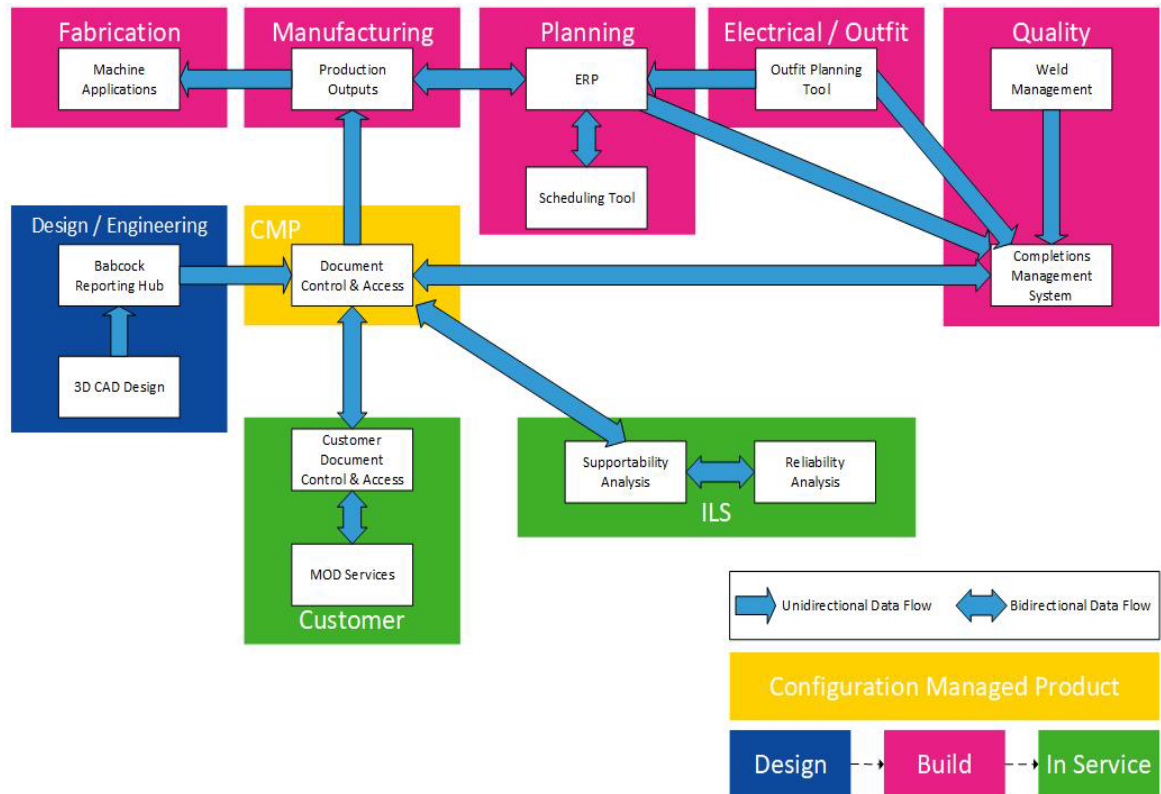
Working at this scale it is essential that there is effective collaboration between business partners, supply chain and industry, and the Digital Thread methodology makes this goal a realisation. In the Type 31 frigate programme, which consists of the design, build, assembly and commissioning of five Inspiration Class frigates, Babcock are responsible for the delivery of these assets, while also planning to be a key long-term partner supporting the warships through life. A consistent Digital Thread will enable the successful transition from the start of the programme through to the operational phase. Whilst delivering value through data during the design phase, Industry 4.0 practices have been employed to help provide a seamless data flow to drive operational efficiencies during the construction phase.

This paper will explore Babcock's implementation of the Digital Thread methodology to support the successful delivery of the Type 31 programme with a focus on the design & build of the assets which supports the set up through life support capability. The Digital Thread and all changes Babcock have implemented in to ensure a successful project execution fall under four categories: Skills and Engagement; System Architecture; Workflow and Data; and Process Automation. These topics, the challenges associated with them and resultant solution benefits will be covered in the following sections.

## 2. System Architecture

The system architecture is an integral part of realising the Digital Thread. To achieve this, a properly structured and fully connected infrastructure that links all the different applications required throughout the asset life-cycle needs to be implemented. The approach taken was the implementation of an Information & Knowledge Management (IKM) solution. The IKM architecture is built up of the key stages of vessel delivery starting with engineering design before manufacture & build and then into commissioning and future support services where applicable. It should be noted that not all information created and captured throughout the IKM solution will necessarily be required for through-life support due to the breadth of information being managed. For example weld joint information, while necessary for internal operational requirements, will not support any decisions being made after vessel handover and therefore won't be any of interest to the customer. Any through-life support activities will call upon relevant data created and managed within the IKM structure. The main interfaces in the delivered system architecture are displayed in Figure 1. Similar such frameworks have been proposed before in relation to manufacturing automation and digital twins (Qin, Lu and Ramesh, 2021). At the centre of the whole asset lifecycle is the document control application - Autodesk Vault 2022 product data management (PDM) was the software of choice for the development of the IKM solution. All files within the technical data package (TDP), including CAD models and drawings, are controlled in a fully configured data pack in PDM with all R&A data captured & supported for VAD. This PDM acts a single point of truth, which can be referenced throughout any stage of the design, manufacture and delivery of an asset and can then be used to support in-service operations such as maintenance or supportability and reliability assessment to support mission operations.

By creating interfaces between different applications as the asset goes through this life-cycle through the use of APIs, data is able to flow automatically and seamlessly through all business functions and processes. Some of the benefits realised include; the removal of manual copying of the same data between different applications, the right data being delivered to the right functions in the desired format, allowing for both internal and customer requirements being met with greater quality leading to improved control and management of data created and consumed across the different business functions.



It is worth mentioning there are several companies that offer a combination software packages that perform the purpose of the IKM solution. The reliance on a single software solution was not desirable for the Babcock as the system architecture would not only have to support the T31 programme, but other large and complex projects in Babcock. Babcock's preferred option of an open architecture allows for optimisation of each and every software application, ensuring that the use of software currently used in any Babcock projects did not have to be compromised.

This approach naturally came with its own challenges. Internal processes had to be re-evaluated in order to ensure suitability of integration between different functions in a digital versus manual interface. It was key that each function understood; what data it required, when the data was required, who was responsible for creating the data and who was the information asset owner.

The development involved the creation of an end-to-end process map for all functions, phases of ship delivery, data and document requirements and internal/external requirements. Such a process done correctly is time costly, however it was necessary in ensuring all processes were well understood and therefore the IKM solution was built and integrated correctly to serve those process needs. A high-level abstract of the end-to-end process map is shown in Figure 2. Columns in the process map represent the linear progression of the project starting from the Concept Design Phase at the beginning through to Acceptance & Handover and Project Close Out. Rows in the process map represent key business functions. Process steps flow from left to right only in the project sequence but freely move vertically up and down between business functions.

Figure 2 gives an illustration of how processes flow between functions for a section of the Build Phase, with each process being represented by a box. For each of these processes every function has specified what inputs they require to carry out the respective process and what outputs they expect to produce. These outputs were validated as inputs for the next process. This exercise allows for a complete, holistic view of data requirements across the project, which support the meeting of contractual and operational obligations.

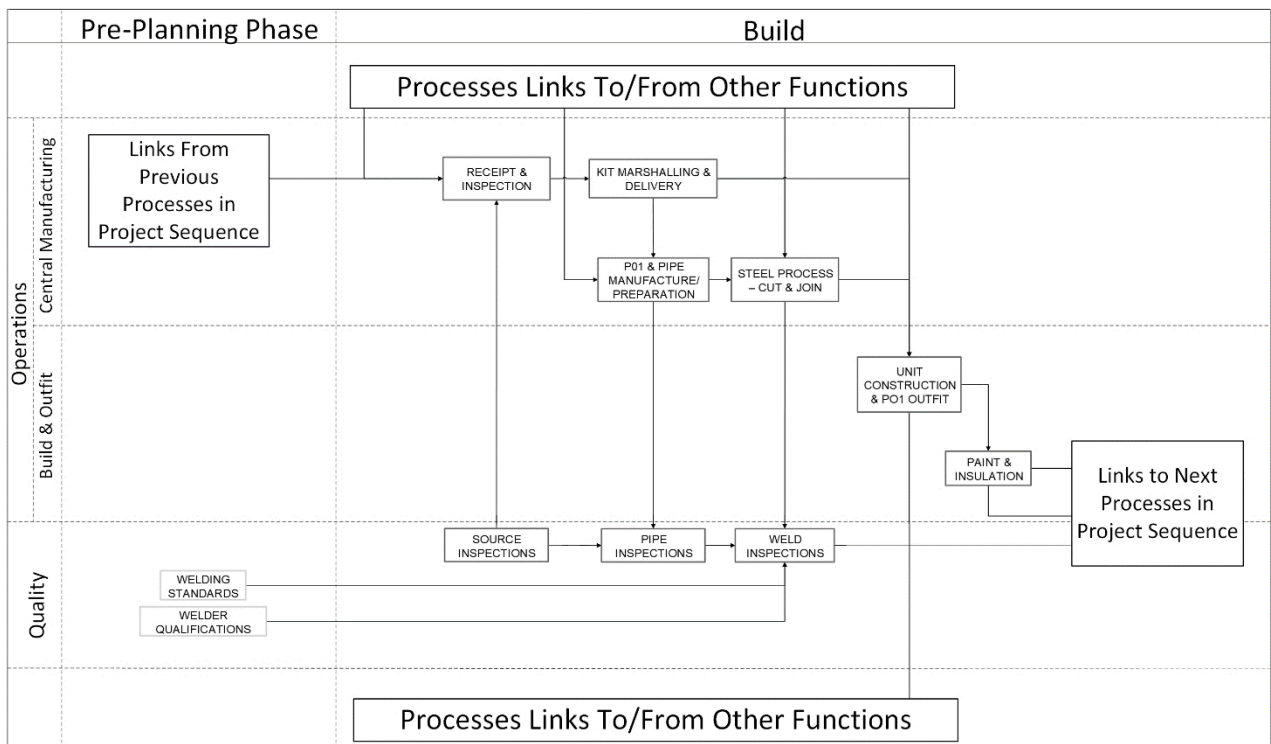


Figure 2: Abstract from End-to-End Process Map for the Type 31 Project

Another point of interest of the IKM solution is the inclusion of Babcock's in-house engineering reporting tool: the Babcock Reporting Hub. The Babcock Reporting Hub was developed for previous ship building projects but was previously used in isolation as a data quality-reporting tool for the Engineering department. The Reporting Hub is now integrated as part of the data flow for the project. The tool is still used for flagging up database issues but now also generates data from the CAD software such as file names that follow a predetermined convention before sending the data onto Vault. The flexibility of the Babcock Reporting Hub allows for great reporting functionality which the CAD tool doesn't have the capability of producing. Examples include; deleted objects report, out-of-date objects report and any ship subsystem status reports such as piping, HVAC, structural, etc.

This has been taken a step further for the Type 31 project with the connection to the Babcock Data Warehouse (DW). The DW is a centralised database system that has direct links to the data stored across the different applications within the IKM solution. It acts as a mirror to the data stored within the applications. The DW can be used to link data directly to reporting dashboards using Microsoft's Power BI for live project reporting functionality or the Babcock Reporting Hub can be configured to query different datasets within the DW again allowing for personalised reports to be specified which the base application might not be able to provide. This functionality removes the need for traditional spreadsheet pre-processing and reporting and allows for more efficient and accurate data reporting coming from a single point of truth.

The IKM solution also has the benefit of being transferrable to other ship building projects. Although developed in conjunction with one specific warship design, the end result will be used as a blueprint for future design & manufacture projects. This is particularly useful for the ship-building industry as ships are in effect built-to-order, but with many similar components, products and structures (Woo et al., 2021).

The modularity of the IKM architecture also has additional benefits. There is a great understanding of all the functions, processes and general requirements for ship building and this understanding allows for more efficient changes of applications as the data requirements are well known. If the ERP system was no longer fit for purpose for example perhaps due to new customer requirements: there is already a complete map that can easily show how this part of the solution currently communicates with other applications and what the data requirements of those applications are meaning that the ERP software can be swapped out and those additional requirements added in to the new API calls.

This goes a step further as different sections of the IKM can then be packaged up and provided as services allowing for cross-company collaboration. This adaptive approach to ship building allows for greater personalisation and flexibility of services that can be offered to the customer. However the implementation of the IKM solution in isolation is not enough. The real value comes from being able to leverage the information to build up complete knowledge of the asset and to then make better decisions from that knowledge. This has been achieved through investment in infrastructure, technology & people.

### 3. Workflow and Data

#### 3.1. Shop Floor Digitisation

A key factor to achieving a Digital Thread is the flow of digital data from engineers using 3D modelling software to the industrial workforce and SMART machinery on the shop floor. Using the fully functional System Architecture as the foundation, the next step was to implement new technology and processes that enabled workers to solve problems as they arise with access to real time information and feedback mechanisms whilst on the shop floor. In the past the production environment worked on traditional manual processes which relied heavily on paper-based transfer of information. This affects the speed of communication between customer, engineer and shop floor, slowing down the process. In turn, if information such as manufacturing drawings are updated to a new revision within the time lag in updates this can lead to costly rework. This lack of efficiency within a high paced environment leads to avoidable waste in the process and higher costs.

To achieve the flow of digital data throughout the build, seamless connectivity throughout the various physical build locations of the T31 project are required: New Assembly Hall, Syncro Hall, Manufacturing Bays, New Pipe shop and Warehousing. Through collaboration from the business, the requirements identified that conveniently located Ethernet points would be installed for the smart machinery, shop floor PC terminals, digital signage and smart vending machines as well as having strong WIFI throughout each T31 area for handheld devices. Furthermore, the use of a 5G private LTE network will be explored in the future.

##### 3.1.1. Front Line Manager- 2 in 1 Devices

FLM's are at the forefront of the manufacturing and production environment within Babcock Rosyth, ensuring that everything runs smoothly coordinating with both production managers and operators, and as such they tend to work in both the office and production environment. The digital solution specifically picked for FLM's, HP Elite x2 '2 in 1' device, ensured that they would have access to real time information both on the go and at their desk with a key functionality being the ease of transfer between the office and shop floor environment on a singular device. An added benefit of selecting a windows based device as the solution, which runs exactly the same Windows 10 and software that is standard on all Babcock computers already, meant that limited/no training was required. Other benefits of this solution include reducing time spent walking to-and-from their desks and helping to go paper-less on the shop floor.

##### 3.1.2. Panel Line Operators- Shop Floor PC Terminals

Within the new Manufacturing areas, Panel-Line operators have a set work area next to one of the new cutting edge machines. It was evident that a solution was required in which a team of operators could access information in a set location eliminating the need to leave their area of work. The solution that met the requirements in this case were ruggedized shop floor PC terminals which host a 22" touchscreen and IP65 rated keyboard that allow operators to easily navigate through 2d/3d work instructions on the shop floor. The key function of the PC Terminals are for the operator to access Shop Orders via IFS Work Bench, drawings through the PDM system Vault and SPx.

##### 3.1.3. Industrial Workforce - Apple iPad

Throughout the production areas, the Industrial workforce are always on the shop floor/on-board and as such they require a mobile solution that will allow them to access digital data whilst on the go. The driving factor to give them access to digital data is to remove paper from the shop floor and provide access to the most up-to-date information relevant to their job. Whilst still in the trial phase, it is intended enable each user access to work orders via the ERP system and drawings via the PDM system. To achieve this, a robust maintenance and distribution system would be required.



Figure 3: FLM using 2 in 1 in Test environment

### **3.2. Dataflow – Material Tracking**

One small yet powerful investment that has been made is the tracking of material, which will be done in a number of stages. This has a tremendous effect on the Digital Thread and managing the supply chain, for if the level of inventory can be shared with the front line operators then stock levels can be better managed and the bullwhip effect can be mitigated by smoothing demand signals. This also can feed into the lessons learned aspect of each ship where there has been a build-up of inventory and the number of handling points, which can be removed.

#### *3.2.1. Dataflow – 3D CAD on the shop floor*

While the modern manufacturing automation is reliant on the flow of 3D CAD data, when drawings and information packs for the shop floor teams (referred to as production outputs) are created these are most commonly 2D representations of 3D digital data. Even with paperless approaches to work instructions there is still little use of interactive data on the front line in shipbuilding. Virtual Reality (VR) is an excellent tool for familiarising workers with tasks and assemblies in ‘real scale’ and can be invaluable at the design review stage, however feedback from the front line is that it is overkill and not yet streamlined enough to be truly be a routine tool on the shop floor. Augmented Reality (AR) has excellent potential to bridge the gap between the virtual and real world for shipbuilding and is an active area of advanced R&D, however more simple solutions are in development that will bring benefits sooner.

CAD software is not intuitive to use for those that are not routinely using it, and even changing between different software packages can be challenging for seasoned 3D designers. Very positive feedback has been received from participants in a test of a prototype software and hardware setup that uses off-the-shelf game controllers, gesture controllers and context-aware buttons to explore 3D ship models Figure 4. By treating the device as more of an appliance than a computer program it simplifies the modes of input and lowers the perceived barriers to use. Building on the electronic access to drawings, this development would allow team briefings to be conducted using the 3D model on a large screen, looking for potential issues and final checking of the build sequence at the point of work. This would also permit Technical Queries (TQs) to be raised by the teams in context of the 3D model, where issues have been found. This can help get queries onto the correct engineer’s desk quicker, minimise production waiting time and reduce the need for what has been a sizeable ‘Engineering Liaison’ team to field walk-up queries and mark up drawings.

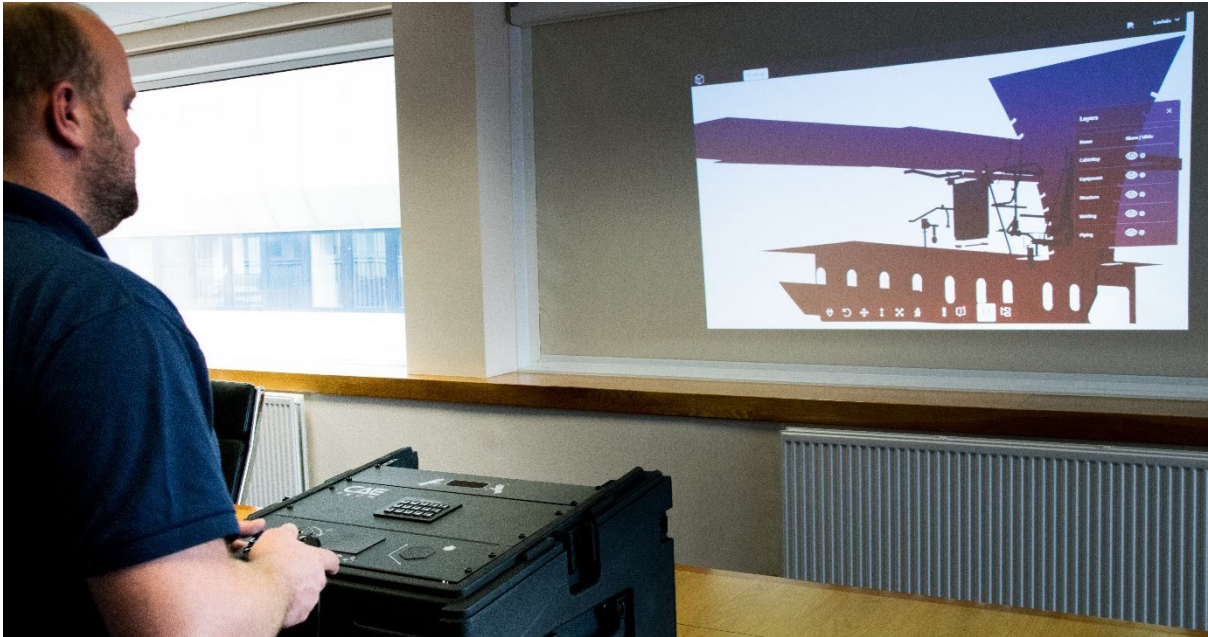


Figure 4: Shop Floor CAD Demo

#### 4. Process Automation

When discussing automation and modern manufacturing there is a strong tendency to focus on the physical robotics and machinery, while the real challenge always lies in the detail of the implementation. It's only natural that these items themselves draw focus - large CAPEX costs, long lead times, disruptive infrastructure works, etc. all draw significant attention from management and frontline alike, and tend to be the centrepiece of VIP tours. However it is worth noting this equipment is far from the plug-and-play simplicity that people are so used to now with consumer equipment. Beyond just mapping data flows from CAD to machine (as discussed above) it should be noted that significant effort of testing and troubleshooting is required to reach production ready status.

As in all industries, a high-degree of automation is only financially viable when the volume of throughput is high enough. The initial processing steps of raw plate and bar sections have been easy to automate for some time, and with the shift to modular build methods it is common to see fully automated panel and bulkhead assembly equipment in modern ship build facilities worldwide. Although highly customised and configurable, such assembly equipment is now available essentially as off-the-shelf from specialist suppliers. These have significant benefits in terms of production efficiency, but have also proven popular with the operators who can continue to use their specialist trade knowledge and skills but in a safer and less physically demanding way of work.

However, downstream of the panel assembly the application of process automation drops off rapidly. The volume of repetitive work progressively tails off as production progresses through the erecting of panels and bulkheads into units, completing hot work outfitting, and the stages of module integration into a complete ship structure. Because of the highly variable nature of these types of work it's likely that the traditional 'robot arm' would see more application here as a versatile tool, compared to the bespoke systems that mass-produce the assembled panels.

The challenge faced here is one of scale – working with physically heavy structures and long weld lengths means any fully robotic solution would itself need to be heavy and relatively immobile. Smaller, man-portable robotics are a rapidly emerging technology and 'co-bots' where robot and operator work together on a task are showing potential at being suitable at least for some of the welding processes, even if not the lifting and moving of steel modules themselves.

#### 5. Discussion

As previous sections have illustrated, how each aspect contributes to the Digital Thread, this section will look at the wider issues surrounding the digital transformation and the impact of the decisions made. Before diving deeper into the underlying issues, this is one of the few open source papers that the authors are aware of that is done by a user not an OEM or consultancy which is based on experience of implementation trying to integrate multiple complex systems. The vast majority of the literature available is based on buying

into particular single provider ecosystems. From the start Babcock decided to use a software agnostic approach while keeping as much familiarity as possible. The advantages of this approach allowed for the scoping of various projects as a greater level of design maturity was reached, as well as getting end users able to specify what features and products they wished to use, for example where possible solutions were chosen that were already available in Babcock. Finally data sovereignty and control was retained, which will be mined for valuable insight and enhanced decision making. This decision avoids the significant cost of implementation and upheaval of day to day business.

There were also a number of unforeseen project challenges for example the current global chip shortage which extended lead times, and developing and integrating not only software but also processes which brought out the complexity of the work. This latter challenge was by far the biggest and most challenging. This required the creation of a complete end to end mapping of all processes from design to support. This required a whole T31 team engagement effort not only to map the process but also to understand how the process would change when the new system architecture, machines and shop floor digitisation would be in place.

The final challenge is the new dynamic of Industry 4.0, organisational roles changing and the increased importance of IT in the project delivery and set up. This initially caused some challenges as the scope, scale and the difference of engagement severely challenged the organisation. This goes to highlight the importance of Figure 2.

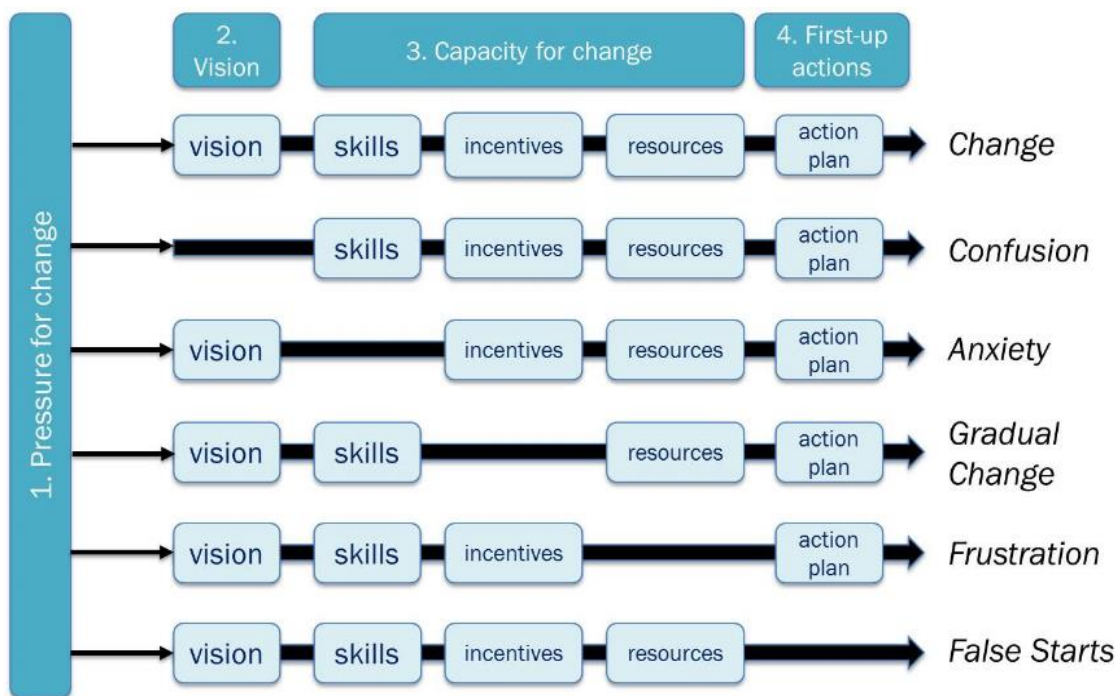


Figure 5: Pressure for Change

Figure 5 above shows the building blocks for a successful change programme, there must be a clear vision, the correct skills, the right incentives, supported by adequate resources and a plan of action. So in relation to digital transformation, each aspect must have each level in order to achieve cross team support as it will most often be a case of external teams working with functional areas to deliver the change.

All of this is required to achieve the Digital Thread which will be stitched together though all these strands coming together and being used in the real world. With this being done and working then during the support and maintenance phase for the Type 31 after delivery to the customer, Babcock is in a position to apply a range of digital technologies and data analytics to deliver value for the customers through Babcock's iSupport360 framework. The advanced analytics that underpin iSupport360 help simplify complex problems, reduce risk and inform the customer at every stage of the asset's life, providing a fully immersive support service. The iSupport360 framework will draw on a large range of data as called upon by the Digital Thread including relevant sections elements from the IKM solution and any live in-service information available.

## 6. Conclusion

The Digital Thread is a holistic view of an asset's data throughout its entire lifecycle – its digital DNA. The typical lifecycle of an asset starts in design and build and then progresses into the operational phase,

including maintenance and refits/life extension and finally disposal. The need for a Digital Thread has been driven by several factors such as; the increase in automation and robotics in the ship building sector, the cost of iterative detailed design, and customer demands which require manufacturers to maximise productivity while keeping costs down to ensure profitability. Babcock has recently undergone a digital transformation to overcome these challenges in relation to the design and build of large, complex warships.

This paper covered Babcock's implementation of a Digital Thread solution to support the successful delivery of the Type 31 programme. This paper has demonstrated that the connected nature of all of these systems makes these projects enterprise level in terms of scale and requires the full support of the business as well as the buy in from the all stakeholders. Each aspect has their own dependencies and opportunities however they are ultimately all dependent upon each other, and therefore must be able to accommodate changes in scope from each other.

## 7. References

- Hedberg, T., Bajaj, M. and Camelio, J., 2019. Using Graphs to Link Data Across the Product Lifecycle for Enabling Smart Manufacturing Digital Threads. *Journal of Computing and Information Science in Engineering*, 20(1).
- Qin, Z., Lu, Y. and Ramesh, A., 2021. DIGITAL THREAD ENABLED MANUFACTURING AUTOMATION TOWARDS MASS PERSONALIZATION. *Manufacturing Science and Engineering Conference, MSEC2020-8429(V002T07A008)*.
- Woo, J., Zhu, H., Lee, D., Chung, H. and Jeong, Y., 2021. Assessment Framework of Smart Shipyard Maturity Level via Data Envelopment Analysis. *Sustainability*, 13(4), p.1964.