INTERNATIONAL DESIGN CONFERENCE – DESIGN 2024
https://doi.org/10.1017/pds.2024.24

Implementing an open innovation process in the premium marine industry

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Abstract

Design and manufacturing innovations are important competitive attributes in the premium marine sector. The adoption of an open innovation process has the potential to deliver behavioural and technological transformation. This pilot study illustrates an open innovation approach to explore the benefits of digital innovation when designing new products within the premium marine industry. The research demonstrates how an open innovation approach will flourish when focused on co-creation in collaboration with a network of cross-functional partners.

Keywords: *industry 4.0, open innovation, collaborative design, additive manufacturing, innovation management*

1. Introduction

Innovation is important for global development and economic prosperity (Bessant and Tidd, 2013). For a commercial business it represents investment in a bid to remain competitive. Transforming traditional industries is a key issue for sustainable growth, improving productivity and for the innovation of new products. Travaglioni et al., (2020) identified that digital innovation can transform traditional industries through increased integration of digital technologies into products and processes - this research seeks to address how this can be applied in practice.

The premium marine sector is a traditional industry with challenges to supply chains and production costs using traditional manufacturing methods. As a collaboration between the marine industry and a university this research project investigates barriers to adopting digital technologies by piloting a structured open innovation programme. The study assesses how low risk, unbiased support from a university can provide innovation opportunities for a traditional industry. This paper also explores how adoption of new technologies through open innovation can transform design thinking, creativity, and collaboration.

1.1. Innovation theory

Innovation occurs when knowledge, experience and skills can be mobilised (Bessant and Tidd, 2013), innovation can succeed when managed correctly to encourage creativity and communication as well as empower development teams to make decisions (Pan Fagerlin and Lövstål, 2020). As commercial entities, manufacturing businesses are not only driven by the need to innovate but also operational demands and this can lead innovation activities to be inefficient and even counterproductive (Assink, 2006).

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Digital innovation is being used in many industries globally and has been recognised as an opportunity to disrupt current practice (Travaglioni et al., 2020). It has been described as the next industrial revolution - Industry 4.0 (Jones et al., 2021).

1.1.1. Open innovation

Open innovation was conceived by Chesbrough (2003) and proposes partnerships between internal and external stakeholders to form networks that drive creativity. This is achieved by removing organisational boundaries to improve knowledge flows from outside of organisations. Open innovation therefore involves novel management to collaborate with various organisations including: traditional stakeholders like current suppliers and customers; research organisations such as universities and private research companies; as well as consultants and specialists; and start-ups (Bertello et al., 2023). The use of open innovation by Procter and Gamble is an example where the use of simulation tools have delivered digital innovations (Dodgson et al., 2006).

Approaches to open innovation can be described as inside-out or outside-in depending on whether the source of ideas is internal or external. The internal knowledge within companies is recognised as an essential tool for innovation (Abulrub and Lee, 2012).

Bogers et al., (2017) discusses the recognised challenges to implementing open innovation, these include: not-invented-here syndrome; effective management of stakeholders; and allocation of resource for non-standard processes. When open innovation is applied there is also the challenge of absorptive capacity to assimilate the new knowledge and technology in a way that allows it to be fully exploited (Vanhaverbeke et al., 2008).

1.2. Premium marine industry

Premium marine manufacturing on the south coast of England follows an engineer-to-order model which, by its nature, necessitates bespoke design and manufacture (Rahman and Shariff Nabi Baksh, 2003). A key component to revenue growth in the premium marine sector is the strengthening of product offerings spearheaded by designers (Allinson, 2020). Product innovation is essential within the premium marine sector and typically follows a traditional linear 'stage gate' process first proposed by Cooper (1990) as a framework to control new product development. Best practice for delivering innovation projects in this linear process is through cross-functional teams (Du Preez and Louw, 2008). Traditional organisational processes are often risk-adverse, optimised for day-to-day operations and are unable to handle increased complexity and uncertainty that often comes with innovation (Kotter, 2012). The open innovation process could be used to improve innovation within the premium marine sector without introducing excessive complexity or uncertainty.

Traditionally the industry uses glass reinforced plastic (GRP) as the predominant material of the hull, decks and many components on the boats (Rubino et al., 2020). The manufacture of components at low volumes is labour intensive and challenging to manage. Historical reliance on GRP within the premium marine industry has resulted in the collective knowledge, skills, expertise, and supply chains being optimised and narrowed to processes that suit GRP. This focus on traditional innovation and manufacturing methods presents a challenge when met with the demands of industry 4.0. Current production methods are manual and the sector transitioning to digital methods has proved challenging. Specifically, there is a lack of knowledge and access to digital fabrication equipment within the sector - this has proven to be a barrier to proving feasibility of materials and processes given the incumbent skillset. This is compounded by high brand equity resulting in a low-risk appetite to transition to new digital methods.

1.2.1. Driving innovation

Premium marine customers expect increasing levels of customisation and more integrated technology. This not only requires innovations to the product but can also demand advances in the manufacturing and assembly in order to deliver the increased complexity. A key aspect is to develop the competencies in the business that can take advantage of digital manufacturing technologies (Saarikko et al., 2020).

This research investigates how the premium marine industry can be transformed through open innovation practices and how this can deliver digital innovation.

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2. Methodology

The scope of this research was to investigate how an open innovation model can be implemented while utilising digital innovation. A case study methodology was used to evaluate a pilot project conducted between two stakeholders:

1. A traditional yacht manufacturing business
2. A university which specialises in creative innovation.

The pilot project aims to produce results that the yacht manufacturer can exploit commercially (Perkmann and Walsh, 2007).

2.1. Pilot study

A single case study evaluating the implementation of the pilot study formed the basis of this research. The rationale for the single case study design was that innovation theory could be tested as a critical case (Yin, 2009). The pilot study explored the application of innovation theory to the marine industry with a focus on the technical transformation and changes in behaviour.

The pilot project was the most appropriate method to create tangible benefits for the partner company, while also allowing assessment of both how the technology was used and how the team at the partner company changed their practice. A pilot study methodology was chosen for this research as it allowed a number of complex ideas to be applied and assessed (Barata et al., 2018) such as: proof of design concepts; demonstrating feasibility of materials and manufacture in production; and the organisational transformation of the business.

An open innovation process was applied as a pilot project between a premium yacht manufacturer and a university that specialises in creative innovation. The two organisations were co-located in the same region which assisted in building strong relationships between the two organisations (Moallemi et al., 2020). For this paper the premium yacht manufacturer will be named under the pseudonym 'Premier Yachts'. The impact of introducing an open innovation process has been assessed using a mixed methodological approach. Observations and feedback gathered from stakeholders at Premier Yachts was used as qualitative data. This is discussed in relation to the established theory to assess the behavioural transformation within the company. Quantitative outputs from the project were used to explore technical transformation at Premier Yachts. The outcomes of the pilot study will be discussed in terms of exploration, demonstration, optimisation and dissemination (Barata et al., 2018).

3. Additive manufacture of yacht components

The needs of Premier Yachts were aligned with the capabilities of the partner university. Additive manufacturing was identified by Premier Yachts as a key area for development.

The project was initiated for 3 key reasons:

1. Cost - Premier Yachts needed to explore new methods of component manufacture to relieve pressure and reduce costs in traditional supply chains. New knowledge and the capacity to explore novel methods were required.
2. Performance - Premier Yachts wanted to give their staff more freedom when designing new products to realise higher performing solutions that are new to the industry. Digital manufacturing methods provide greater freedom to achieve geometric forms - removing constraints associated with the established legacy manufacturing methods.
3. Speed - The Premier Marine Market demands new products each year, therefore the time to develop and test new concepts is short. The open collaborative approach to new product development promised an increased agility to realise creative solutions through rapid prototyping and increased confidence in conceptual design work.

In order for Premier Yachts to engage in open innovation activity, it was clear that a new structure was required. Therefore, good communication between stakeholders and management of development workstreams needed to be established.

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3.1. RAMP programme and scope

The Research into Additive Manufacturing Programme (RAMP) was a 2-year initiative developed by Rob Fanner as a vehicle to introduce Premier Yachts to the benefits of working with an open innovation process. It was formed as an outside-in partnership (Abulrub and Lee, 2012) between a premium marine manufacturer and a university to kick start digital innovation, prototyping capability, digital skills development, networking opportunities and research support. The academics, technicians and staff at the university provided a complementary 'innovation service' to Premier Yachts to enable new open innovation processes to be trialled.

This was achieved through digital innovation practices, which were predominantly explored in parallel to the main commercial production. Development workstreams that were identified as suitable for the RAMP programme were components used in complex system assemblies and cosmetic 'styling' components that were costly to produce via traditional manufacturing methods. For components in complex system assemblies, traditional manufacturing methods included casting of metallic materials or injection moulding of plastics; the objective was to introduce additively manufactured components to provide Premier Yachts with a more versatile design solution. For cosmetic components, the traditional manufacturing method was GRP lamination using mould tools; the objective here was to utilise the new manufacturing capability offered by additive manufacturing to reduce the amount of material and time required to produce the component.

3.2. RAMP implementation

The development workflow for both the complex system components and cosmetic components were similar in nature. The workflow is described in figure 1.

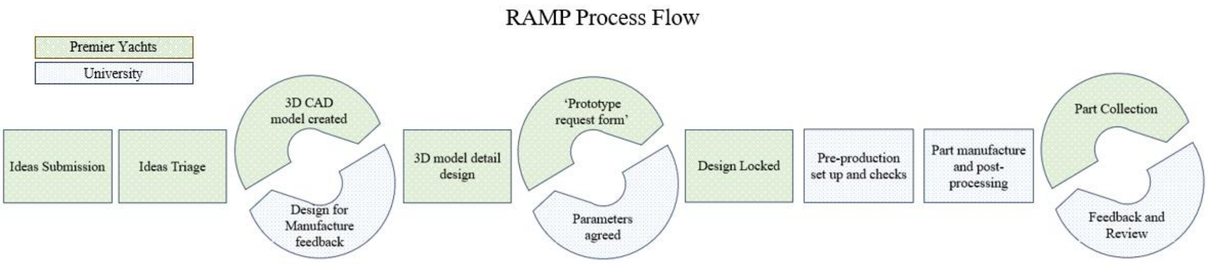

Figure 1. Ramp workstream process flow

The initial jobs for consideration were submitted internally at Premier Yachts and triaged for suitability for the RAMP programme. Selection was based on the capabilities at the university, which included parameters such as materials, volumes required and physical size. For candidate RAMP components, the workflow began with Premier Yachts creating an approximate digital 3D model of the new component they wanted to develop using additive manufacturing. This 3D model was then shared with the staff at the partner university, who transferred knowledge back to Premier Yachts with respect to appropriate additive manufacturing technologies and how they could be harnessed effectively to manufacture the component. The digital 3D model would then be developed and refined following open discussions between the partner university and Premier Yachts, which covered technical aspects such as how the component could be designed for different types of additive manufacturing methods and respective materials, as well as economic considerations surrounding the commercialisation of the component within the supply chain. Following this development, the manufacturing parameters would be agreed by both Premier Yachts and the university before locking down the design ready for processing. Once manufactured by the university, the component would then be collected in person by Premier Yachts, culminating in reflective discussion over the prototyping result and feedback for future design iterations.

The partnership allowed for multiple physical prototypes to be produced in conjunction with the digital 3D model development. This enabled Premier Yachts to conduct physical testing on the prototypes, which led to the realisation of minimum viable product solutions. The knowledge gained by Premier Yachts subsequently directed commercialisation decisions and aided the development of a new supply network for components produced utilising additive manufacturing methods.

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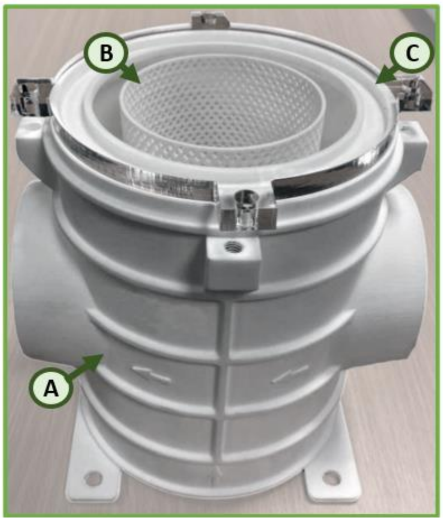
3.3. RAMP output

Components produced during RAMP were a mixture of prototype and production components. All 15 jobs that went through the RAMP process used additive manufacturing and included: systems components such as manifolds; custom fixtures for example brackets; electrical housings; and cosmetic styling features for the exterior of the yacht. A summary of the RAMP output is provided in table 1.

Table 1. RAMP output summary

RAMP jobs	
Systems	5
Cosmetic	5
Custom fixtures	4
Electrical housing	1
RAMP parts produced	
Total number of parts	400
Production volumes	1 to 300
RAMP materials and process	
Manufacturing (3D printing)	SLS, FDM, SLA
Materials	Nylon, filled PLA, PLA, Resin
Largest component manufactured	200mm x 200mm x 300mm

Production components could be produced within a short lead time, without tooling costs. Prototypes produced during RAMP enabled Premier Yachts to undertake a formal assessment of the design before committing to production. Premier Yachts did not use the full range of capabilities offered by the university and the Nylon SLS printer proved to be the favoured material and process due to accuracy, surface finish and robustness. The 3D printed parts demonstrated the capability of the additive manufacturing systems and provided a level of confidence and understanding to the design team at Premier Yachts about the capabilities and opportunities of current technology.
A good example of a RAMP output is the sea water strainer illustrated in figure 2. This sees the open innovation process applied to the development workflow for systems components within Premier Yacht products.



Name:	Sea Water Strainer
Level:	Prototype
Description:	3 Part assembly of a filter as part of a yacht water cooling system.
Purpose:	For evaluation by Premier Yachts to understand fit and function.

Sea water strainer assembly			
Component	**Description**	**Material**	**Process**
A	Housing	Nylon	SLS 3D Print
B	Filter Mesh	Nylon	SLS 3D Print
C	Cover	PMMA	Laser cut

Figure 2. RAMP output - Sea water strainer assembly

Traditionally, sea strainers are produced using metallic casting or injection moulded plastic methods, resulting in a standardised component. While these commercial off-the-shelf components are optimised for cost, they lack versatility in regard to placement and integration into Premier Yacht products. By

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utilising additive manufacturing, a more versatile design of sea water strainer could be realised that was more appropriate as it accommodated the specific configurations required by the Premier Yacht's system. The partnership allowed for several prototypes to be made, ensuring the tolerances achieved on the 3D printed component produced an effective solution.
Over the course of the RAMP programme the number of prototypes produced by Premier Yachts significantly increased, since prior to RAMP, there were limited means of prototyping within Premier Yachts. This enablement of prototyping empowered the Premier Yachts designers to adopt new behaviours and a new way to technically transform the organisation's products.

4. Open innovation results

The results of implementing the open innovation process via RAMP have been to accelerate acceptance of new digital manufacturing through 3D printing of components. The key to this transformation has been the development of new processes within the company to promote behaviours aligned with open innovation, and promote digital innovation through increased knowledge of new manufacturing methods, providing a route to accept change within Premier Yachts and its supply chain.
The partnership provided an opportunity to engage in de-risked innovation; specifically, a low-cost method of trialling new materials and manufacturing processes without the need for Premier Yachts to commit to capital investment or taking on new employees for speculative work streams.

4.1. Behavioural transformation

The innovation service offered by the university brought with it a level of neutrality and expression free of commercial pressures faced by Premier Yachts, which resulted in project stakeholders taking a more open approach to understanding the challenges and opportunities under review. Three main benefits of the RAMP were identified as improvements within the open innovation process in:

1. Collaboration - forming cross-functional working relationships across organisations.
2. Creativity - Catalysing creativity through rapid prototyping.
3. Design Thinking - Becoming immersed in the full experience of the customer.

The design process and management of the open innovation process was owned and applied by Premier Yachts. The university's advisory role as a facilitator meant the university provided knowledge and feedback on the designs provided. Ownership of RAMP by Premier Yachts helped to establish the genuine acceptance and adoption of the process by staff at the company - helping to overcome challenges such as not-invented-here syndrome (Bogers et al., 2017) as well as improving absorptive capacity (Vanhaverbeke et al., 2008).

4.1.1. Collaboration

The pilot project suggested that visualising potential solutions helps project stakeholders to better comprehend and critically contribute to the development of new products when collaborating. The activity resulting from the use of digital tools for the open innovation process helped re-shape the working practices of Premier Yachts over time, pulling project stakeholders together in a way which was more adaptable and configurable when compared to the conventional approach of gate reviews. This aligns with Lyytinen et al., (2016), who argue digital systems should focus on loosely-coupled networks to foster collaboration, and digital collaboration has the power to mediate and shape actors.
When engaging in open innovation, the frequency of interaction between cross-functional teams increased too, enabling these teams to develop an awareness of each other’s level of autonomy, which in turn increased their collective capacity to realise creative solutions.

4.1.2. Creativity

In regard to the current process of developing new products within the premium marine sector, the open innovation process via the RAMP programme revealed that introducing a more accessible, lean approach to prototyping and testing of ideas was beneficial. The research revealed that project stakeholders expressed a desire to be more engaged with other design disciplines during the NPD process in order to develop creative practices, and this was made possible through the innovation service

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offered by the university. The physical prototypes made as a result of the partnership proved valuable to Premium Yachts to progress the development of a number of projects and demonstrated benefits supported in other studies including: help to frame problems and stimulate discussions (Dell'Era et al., 2020); aid project stakeholders to answer questions (Thompson and Schonthal, 2020); promote continuous learning; enhance the imagination of decision makers; and create an environment where ideas were more amenable for critical consideration (Micheli et al., 2019).
The opportunity to engage in this creative capacity resulted in a new practice of co-creation, whereby non-designers at Premier Yachts could be more readily invited to critically review prototypes. What appeared critical here was design staff at Premier Yachts being actively aware of the constraints and opportunities associated with the design activity they were engaged in, whether these were commercial, technical, or operational. Premier Yacht's design teams' holistic understanding of the NPD process was heightened and as a result their capacity to realise creative solutions improved. This new level of generativity brought about by digital innovation helped to connect previously unrelated knowledge sets (Lyytinen et al., 2016). As well as offering a more dynamic, creative process model (Lages et al., 2020), the partnership appeared to be beneficial at an individual level as employees felt more confident in facing challenges as well as developing a more intrinsic motivation to conceptualise ideas (Roth et al., 2020).

4.1.3. Design thinking

The research highlighted the need for designers within the premium marine sector to explore the efficacy of customised solutions more frequently. By providing designers with an open outlet for digital innovation exploration, this encouraged more prototyping and testing of product concepts, thereby allowing design staff to develop a more intimate understanding of the journey of build crews, operators and owners of products during the NPD process. Using visualisation methods to explore scenarios is supported by Dell'Era et al. (2020), who claim such methods help organisations search for new meanings of their products, which in turn improves customer experiences.
The literature also presented a mixed view on the use of visualisation tools in product development processes. Whilst Thompson & Schonthal (2020) claim visualisation techniques help employees see the deep structure of problems, Roth et. al (2020) warns that 'work design' characteristics and the environment can influence the effectiveness of design thinking. Whilst staff at Premier Yachts seldom visited the university in person, the interaction and dialogue in this 'digital' open innovation approach did appear to promote a new way of thinking about creating value.

4.1.4. Summary of key behavioural changes

The collaborative capacity that resulted from the partnership helped inform Premier Yacht of sustainable investments in the supply chain. The opportunity for Premier Yachts to make prototypes quickly and easily increased levels of engagement between cross-functional teams, cultivating appreciative intelligence and a view to seek iterative pathways. This shifted behaviour from advocacy to enquiry when searching for new solutions. The opportunity to trial new digital technologies encouraged designers at Premier Yachts to think divergently and progressively, which, in turn, brought about the emergence of the organisation's evolutionary potential. Ultimately the partnership gave confidence that new value could be created in non-traditional ways through open innovation.

4.2. Technical transformation

The RAMP programme has provided the premium marine manufacturer with the knowledge and understanding of 3D printing that enables the business to make informed decisions about how to use 3D printing within the product. This has enabled an increase in the number of 3D printed components introduced onto products - providing a benefit in terms of:

- Customisation - Bespoke components can be created for customers without large set up costs.
- Capability - Increasing the manufacturing options which helps to optimise design solutions.
- Cost - Reducing manufacturing lead times and removing set up costs such as tooling.

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In regard to customisation, the open innovation via the RAMP programme enabled designers at the Premier Yachts to have more freedom over the 'form' of design solutions. Free from traditional manufacturing limitations such as mould tool release angles for GRP lamination techniques, 3D printed components were able to achieve an aesthetic more in-keeping with the desired style of the yacht exterior.

The open innovation partnership via RAMP also bolstered the manufacturer's capability across multiple development workstreams. The introduction of 3D printing into the design of products resulted in a completely new supply chain, which in itself provided opportunity for new, diverse relationships to be formed with Premier Yachts and the combination of new knowledge sets.

Finally, Premier Yachts has since realised significant cost savings in the development and production of new components. One cosmetic component in particular has saved six figures over the lifetime of the product.

5. Conclusion

The open innovation process utilising RAMP was a success in that it allowed Premier Yachts to explore the capabilities and process flows of additive manufacturing within the existing design process. In demonstrating the new possibilities with 3D printing at the university, this provided a low-risk environment for new design approaches to be explored. The process increased understanding of 3D printing which gave senior stakeholders at Premier Yachts the confidence to progress with production of commercially printed parts and has also provided the design teams at Premier Yachts with the technical knowledge of 3D printed parts and how they can be integrated into future products.

The RAMP process itself provided valuable clarity for the project scope and avoided risks of additional complexity and uncertainty. Key benefits were observed during evaluation of the RAMP programme trial:

1. Behavioural transformation - open innovation process utilising the RAMP programme trial encouraged collaboration, creativity and design thinking.
2. Technical transformation - The output of the RAMP programme demonstrated benefits with regard to customisation, capability and cost. These can be attributed to the digital innovation of using additive manufacturing.
3. Knowledge transfer - The open innovation pilot project facilitated Premier Yachts to understand the capabilities of a range of 3D printing methods and materials. It also enabled the limitations of current additive manufacturing technology to be understood, especially where 3D printing is not suitable for all components - for example where surface finish does not meet cosmetic specification. Consequently, this allowed Premier Yachts to provide appropriate direction to the development of their supply chain which they rely upon to manufacture components.

The technical changes observed were driven by the transformation of behaviours. In this regard RAMP has resulted in progress by Premier Yachts to explore and further develop additive manufacturing through the open innovation process.

5.1. Wider implications

The technical and behavioural transformation observed during the RAMP programme provide a structured approach to developing digital knowledge and skills as well as fostering creativity and design thinking within the premium marine sector. This collaborative, low risk approach can be used within other industries where reliance on traditional approaches to manufacture has proven a barrier to adoption of digital technologies.

5.2. Further work

The RAMP programme has established a feasible process for developing greater digital innovation at Premier Yachts. The knowledge and approach developed through RAMP have embedded a core methodology for Premier Yachts which can enable the company progress to a long-term strategy of digital development in additive manufacture. The manufacturing capability at the university is predominantly limited to modest research and development volumes, it is therefore expected that

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reliance on the university's capability will transition into commercial relationships. It is anticipated that the working relationship between Premier Yachts and the university will continue as the company evolves and embeds the new digital innovation approach into the standard practice, with the university providing input in the form of monitoring and evaluation as well as a complementary research and design capability in an advisory role.

Following the success of the RAMP programme the development of a collaborative research and development study will be conducted with a larger scale component assembly. This study will establish and benchmark not only the impact of the digital innovation in practice within the company but also put that method into the context of the manufacturing supply chain and production journey to establish next steps in fully integrating digital innovation within the company's design and manufacturing approach. This second stage project will build on the RAMP programme and is anticipated to take 18 months. The open innovation partnership can also be expanded to include other organisations that offer complementary skills and expertise allowing exploration of creative technologies and digital capabilities.

As a boat manufacturer Premier Yachts produces a large number of low volume parts using traditional processes. There is additional potential to use open innovation and digital technologies to improve Premier Yacht's manufacturing capability, for example tooling and assembly aids can be 3D printed to complement the hand crafted with industry 4.0 technology. There is also opportunity beyond 3D printed parts to explore technology such as AI, VR and 3D scanning.

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