Why Smart Ship Technology is the Future of the Australian High Speed Craft Industry

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ABSTRACT

Since the early 1990's the Australian maritime industry has led the world-wide market for large, high-speed, light-weight aluminium craft. However international competition in this sector is significant and growing.

Emerging smart ship technologies offer a once in a generation opportunity for the Australian high speed craft (HSC) industry to continue to build on its successful track record of innovation. Data can help us to build, operate and maintain more efficient, greener and more comfortable ships. The industry needs to move to producing ships that are not only fast but also *smart*.

High speed craft require a smart ship solution tailored to their unique design characteristics and operating conditions. We will describe the journey that Austal and its partners has been on over the last two years to develop MARINELINK-Smart, a smart ship system designed specifically to meet the needs of high speed craft customers.

We will explain how techniques such as optimisation of trim, throttle, route and other ship settings can add up to significant fuel savings and motions improvements for both naval and commercial ship operators.

Finally, we will provide case studies from at-sea installations of MARINELINK-Smart to quantify the financial and operational benefits possible from the application of smart ship technology to high speed ships.

CHALLENGES FACING THE AUSTRALIAN HIGH SPEED CRAFT INDUSTRY

Since the early 1990's the Australian maritime industry has led the world-wide market for large, high-speed, light-weight aluminium craft. Figure 1 shows Australian leadership of the market for HSC over 60 m in length in most years since 1990.

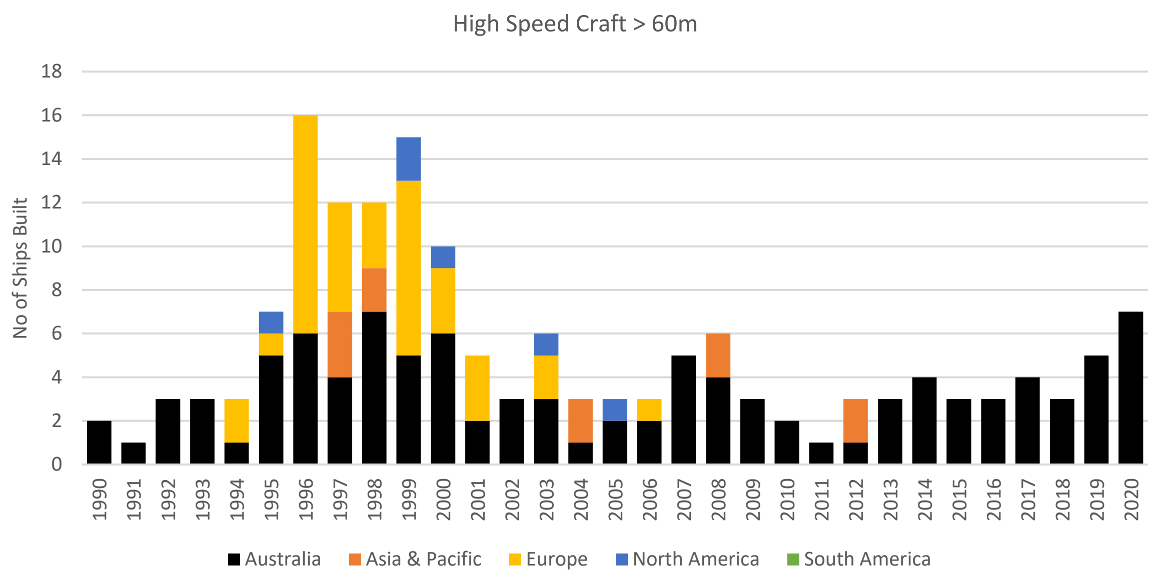

Figure 1 - Annual Large HSC Designs By Country 1990 – 2020 (Commercial & Naval) [1]

The demand for HSC capable of carrying cars and trucks as well as foot passengers led to an increase in the size of HSC in the late 1980's and early 1990's. Australian industry pushed the boundaries of technology, competing to offer customers ever larger, faster and more capable ships. As ferry customers built up confidence in the product and its ability to win revenue from slower speed ships the market for large HSC flourished. This led to the rise of the first competition outside Australia in the mid 1990's, primarily from Europe. Several shipyards produced a range of large HSC designs. However most new entrants to the market found the challenges of successfully welding large aluminium marine structures difficult to overcome and by the end of the decade the majority of large HSC were once again being built in Australia.

The proven expertise of the Australian large HSC industry led to continued export success for Australian ships, designers and equipment suppliers over the next twenty years. Perhaps the most significant example of this was the success Austal achieved in selling Australian-designed ships to the Littoral Combat Ship and Expeditionary Fast Transport programs for the US Navy.

The market for large HSC is now stronger than at any time since the early 1990s. Reasons for this include commercial HSC operators ordering ships to replace the ageing HSC fleet from the previous building boom. However to maintain the Australian HSC industry's leading position as the market continues to grow will require continual innovation to stay ahead of the competition. What options are available to the Australian HSC industry to build on its previous successes?

THE INTERNET OF THINGS AT SEA AS AN OPPORTUNITY TO DIFFERENTIATE

There are a variety of ways in which the Australian HSC industry might differentiate its products. The solution advocated in this paper is that the industry complement more traditional forms of R&D investment (e.g. hydrodynamics) with emerging digital sensor, communications and computing technology to build a differentiated proposition. Now commonly referred to as the Internet of Things, or IoT, this collection of technologies is both a challenge and an opportunity to every manufacturing industry (shipbuilding or otherwise).

Competitors can also design and build ships which integrate off the shelf IoT technologies to gather real-time data on ship operations. But to turn this in to enhanced operational efficiency, reduced fuel bills and improved customer comfort has so far not proven (in Austal's experience at least) to be a simple process. The Australian maritime industry, which has more experience of HSC design and construction than anywhere else in the world, is well-suited to overcome this challenge. In doing so it can built a long-term, competitive advantage which differentiates an Australian designed HSC from the global competition.

WHAT VALUE CAN DATA PROVIDE HSC CUSTOMERS?

The majority of large HSC operating today are commercial ferries carrying either passengers or passengers and vehicles. Operators of passenger ships tend to measure three specific forms of value when considering the performance of their ship:

1. **Efficiency.** Reducing fuel consumption to transport a given load will improve the profitability of the ship operator's business, all other factors being equal. HSC offer passengers faster journeys but generally at additional operational cost per passenger mile. This means that improved efficiency often offers relatively larger profit improvements for operators of HSC compared to ships operating at slower speeds. Improved efficiency is also associated with reductions in greenhouse gas emissions which is becoming increasingly important to operators.

2. **Comfort.** Passengers have choices on whether and how they travel. If they have an uncomfortable journey they may not decide to travel on the ship a second time which will impact a ship operator's revenue. The impact can be magnified if the negative experience is shared with others through social or conventional media. Certain HSC routes have been cancelled because (rightly or wrongly) they developed a poor reputation for motions and hence comfort. More positively a comfortable on-board environment is likely to lead to increased on-board passenger spend.

3. **Reliability.** A ship which is not available to perform its revenue earning function is of little use to the ship operator. As well as the direct impact of lost revenue the operator may suffer the indirect consequences of reputational impact, particularly if passengers have no other travel options. Reduced reliability also impacts planned and unplanned maintenance costs even if it does not lead to the total unavailability of the ship.

Different HSC operators may place different priorities on each of the three value types above. For instance a ship operator who competes directly with airlines may place particular emphasis on the customer experience even if this is creates additional operational expense. In contrast another operator may have an operating licence which is dependent on achieving a certain reliability of service, and so may see maintaining this as paramount.

IoT technologies offer various different possibilities for creating or enhancing each of these types of value. In generic terms IoT is about creating relevant data that was not previously available and then converting this in to actionable information for the operator.

Actionable information can be delivered to different users and on different timescales. For instance advice may be provided to the captain of the ship on adjustments that they can make to reach a more efficient running trim, and thus save fuel. The advice can be provided in a general form which is always broadly applicable (e.g. "always aim for a level static trim when loading"), in a journey specific form for a particular journey ("for the current loading and forecast weather conditions the optimal static trim is 0.2 degrees") or as advice which adapts to the moment-to-moment changing conditions ("reduce the trim tabs by 10 degrees following a 90 degree change of heading").

In another example use case IoT enables a much larger range of equipment condition data to be collected. Cloud computing power can harness these large datasets to forecast availability and drive predictive, rather than periodic or reactive, maintenance strategies. In this case the user of the data is more likely to be the on-shore asset manager, operating on a timescale of weeks, months or even years.

But what if we move away from the paradigm of providing advice to existing human users and automate the actions recommended by IoT systems? This takes us in to the realm of autonomous operations. Whilst significant focus (and maritime industry investment) in recent years has been put in to the development of systems for navigational autonomy, increasing autonomy at the ship system level should also be examined for its potential to deliver enhanced value to ship operators.

A prime candidate for this is the adaption of ride control system settings, since many aspects of the operation of these systems are already highly autonomous. A 'smart' (i.e. IoT enabled) ship has a far wider range of sensor and off-board information sources (such as external weather model data) accessible to inform the changes to a ride control system's settings. The smart ship can make a much more sophisticated assessment of the adaptions to the ride control settings necessary as the environmental conditions around the ship change.

The objective in developing Australian HSC in to smart ships is not to identify one specific adaptation to the ship which will revolutionise its value to an operator. Instead it is to put in place a hardware and software platform which allows for the systematic gathering, analysis and action upon as much relevant data as possible. This can then be used and re-used to generate a broad variety of different forms of information, advice or autonomous actions. Together these features will make the ship a highly appealing product. Furthermore, the in-built connectivity makes the ship able to continually update and improve (both hardware and software) as IoT technology continues to develop and evolve.

Figure 2 summarises some of the ways in which Smart Ships can significantly improve HSC customer value.

Figure 2 – Ways in which Smart Ships can Improve HSC Customer Value

AUSTAL'S JOURNEY IN PIONEERING IOT AT SEA FOR HIGH SPEED CRAFT

As IoT came to prominence in other adjacent industries (for example aerospace, power generation and rail) Austal launched an internal initiative to identify the implications for the future of HSC. This led to a broad review of both the potential customer value possible and the ability of emerging technology to deliver against this.

The company decided to look outside of industry to academia to see if their skills could help build a roadmap for the implementation of IoT to HSC. Austal partnered with Curtin University for a week long Design Thinking 'sprint' where academics, Austal engineers and customer representatives were taken through a structured workshop to tease out the main features of the proposed system. The final output of this process was a series of software mock ups which became the 'first draft' of the IoT system proposed.

The final result was the creation of the Austal MARINELINK-Smart platform. MARINELINK-Smart is a combination of new on-board sensors, ship data gathering hardware and software, cloud-computing storage and analysis, and live advice delivered to both ship crews and shore-side operational staff. The MARINELINK-Smart platform is summarised in Figure 3.

Figure 3 – Austal's MARINELINK-Smart IoT platform

Austal realised that they would need to deploy MARINELINK-Smart and prove its value quickly if they were to succeed in convincing customers of the value inherent in the platform. To achieve this the company formed two important partnerships with operators. The first was with Rottnest Express, a fast ferry operator local to Austal's Henderson headquarters. The ships operated by Rottnest Express are not built by Austal. However the company was able to trial various sensors for understanding ship motions and sea state on Rottnest Express vessels. Many important lessons on how to build a robust IoT system at sea were learned as a result of this first trial.

The first full deployment of the MARINELINK-Smart system, providing crew advice as well as gathering data, would require a vessel capable of gathering a much broader dataset. This would be easiest and fastest to prototype on an Austal-built vessel.

Fred Olsen SA is Austal's largest commercial customer. They are also one of the world's largest and most sophisticated HSC operators, currently operating a fleet of 6 large HSC. Therefore they were a natural choice to partner with in the development of MARINELINK-Smart. Fred Olsen SA currently operate three Austal-built ships whilst two more trimarans are currently under construction by Austal.

A customer partnership means the company can ensure the development of MARINELINK-Smart remains focussed at all times on the needs of the customer, who can provide rapid feedback on the utility (or not) of the new features of the system as they are deployed.

The connection to academia has also continued in to the development of the system. The MARINELINK-Smart development team consists of carefully chosen software developers, control engineers, data analysts and naval architects who work on campus at the University of Western Australia. Being on-campus enables the team to access leading academic developments in relevant disciplines such as machine learning, sensor technologies and oceanography.

EXAMPLES OF VALUE FROM HSC SMART SHIP TECHNOLOGY

Austal's MARINELINK-Smart is now in-service gathering HSC operational data across a number of ships and operators. As the data set available grows so too does the evidence of the value that the system is able to deliver to the ship's crew.

The first use case that MARINELINK-Smart was applied to is the provision of dynamic trim setting advice to HSC crew. Dynamic trim can be adjusted on an HSC through altering static trim (either by moving vessel payload if possible, or filling and emptying ballast tanks if available) or by adjusting the setting of a trim setting device such as a trim tab or transom mounted interceptor. An interceptor is a vertical plate parallel to the transom which creates a 'wedge' of water in front of it when deployed. It has a similar lift and drag effect to a trim tab.

In one example catamaran installation MARINELINK-Smart measured speed, fuel consumption, static trim, interceptor setting and a variety of other factors over a 4-month period to build a baseline model of the ship's fuel consumption performance. This model was then used to determine the optimal interceptor setting, and hence dynamic trim angle, to minimise fuel consumption in different loading and weather conditions. The model indicates that fuel savings of up to 4% may be possible through applying the optimum trim device setting for specific journeys.

Other forms of customer value have become clearer as Austal has built up experience with customers on the use of the MARINELINK-Smart data platform in-service. For example customers are provided with a dashboard which provides access to the data gathered by the system. This led to a number of conversations with customers on how this data could be used to summarise and track fleet performance against KPIs such as fuel consumption, estimated passenger sickness and on-time arrival. An example of a customer dashboard developed to meet this customer requirement is shown in Figure 4.

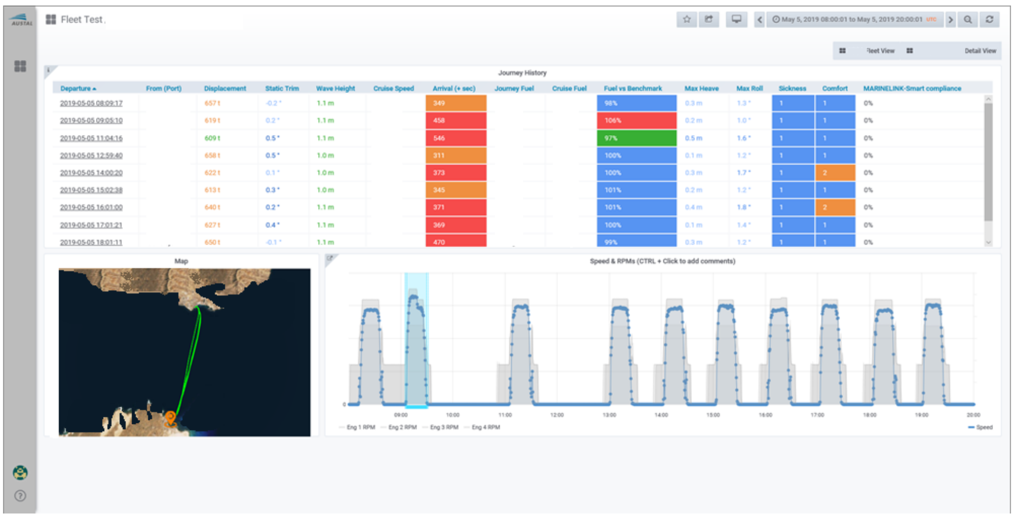

Figure 4 – Fleet Dashboards to Track Ferry Customer Journey KPIs

IMPLICATIONS FOR THE DEFENCE MARKET

Austal has a long history of pioneering technology for commercial customers and then offering this to the Defence market. This was most notable in the development of the trimaran hull form, which was first used on the 127m Benchijigua Express (launched 2004) before being incorporated in to the US Navy Independence-class Littoral Combat Ship.

In this example the end users were different but many of the things they valued were similar. HSC as ferries offer customers a faster passage, whilst the USN was interested in speed to deploy ships and equipment. Comfort is important for commercial customers to ensure their passengers will continue to choose to travel with them, whilst for the USN operational effectiveness of crew was an important concern [2].

There are similar analogies we can draw for the current smart ship developments. The fuel saving features of the system (such as trim and throttle optimisation) will also deliver enhanced range and endurance for a Defence vessel. Improvements to comfort from adjustments to ride control system settings will improve habitability, crew effectiveness and ultimately crew retention. Improved reliability, delivered by providing the necessary infrastructure on-board for comprehensive and continual condition-monitoring of equipment, will improve ship availability.

Austal has recognised this and so is working with the Royal Australian Navy to trial the deployment of the MARINELINK-Smart data gathering system to a RAN-operated patrol boat. In this first stage the system will provide a proof of concept of the secure transfer of ship data to shore, as a basis for building the value-adding services described above. In parallel Austal is working with development partner SMEC on an Enterprise Asset Management System (EAMS) to provide fully digital maintenance management, enhanced asset oversight and actionable predictions of equipment future state. MARINELINK-Smart will also provide the secure interface to the ship's data for this system. This will ensure a consistent flow of information and understanding of asset condition between the ship and shore operational teams.

It is important to also recognise the differences between commercial and defence customers. All customers desire strong security and strict access controls to their operational data. However defence customers will tend to have their own specific handling requirements for data, and probably also a hierarchy of data security requirements. This may mean that some data items have to be segregated from the majority of the ships data, and enhanced security procedures applied to this (ship location as reported by GPS being a prime example). Defence customers may also have additional questions on where there data resides if it is stored in the cloud, or may insist on shore storage on their own servers exclusively.

These challenges can be significant but they must be balanced against the potential benefits of IoT to navies. Ultimately a Navy's goal is to deploy a superior capability at an affordable cost. If an adversary is prepared to harness emerging IoT and other technologies to achieve a capability advantage then the investigation of the benefits at least is well worth doing.

WHERE NEXT FOR HIGH SPEED, SMART SHIPS?

Predicting the future direction of technology development is notoriously fraught. The final chapter of the 1993 reference book 'Worldwide High Speed Ferries' [3], entitled the 'The Future', got many things right. The author predicting the growth of vessel sizes and the expansion of the large, car and truck carrying variants of HSC.

Less accurate were forecasts of the uptake of Surface Effect Ships (hybrids of hovercraft and catamarans) by operators (see Figure 5). Surface effect ships (SES) proved unable to deliver comfort and efficiency to operators and so in the end had little impact on the HSC industry, despite the initial excitement around the potential of the technology. Smart ship technology is certainly currently subject to a lot of hype. In the end will it go the way of the SES, or will it be a game-changer as the light-weight catamaran before it proved to be?

Figure 5 – 1990 SEC Designed Surface Effect Ship Concept (image courtesy SEC) [3]

There are reasons to believe that the impact of IoT technology on the HSC industry will be significant and sustained. Unlike novel hull forms or even lightweight diesel engines the technologies of IoT are applicable to almost every industry. Therefore large investments are being made in the technology, and the costs of deploying IoT are reducing as a result. The relatively low (and ever reducing) costs mean that the benefits have to be relatively modest to justify the investment.

However to have a revolutionary impact on the industry IoT will need to offer more than simply a standard suite of incremental efficiency and comfort improvements at an affordable price.

Austal foresee potentially the most significant impact of IoT as being its use in combination with other emerging technologies, particularly propulsion technologies. Making efficient use of hybrid and battery technologies will depend on a much tighter integration of operational and propulsion system management information.

The high energy density of conventional fossil fuels has meant the amount of stored energy in the fuel tanks has been of limited operational concern beyond ensuring the ship has sufficient range to make the next bunkering opportunity. But the equivalent weight of electric energy storage makes the viability of electric propulsion much more dependent on an efficient use of the energy stored on-board. The optimal balance between vessel schedule, charging time and range is therefore closely coupled with ship loading, environmental conditions and propulsive efficiency. To operate efficiently and safely low or zero-emission ships will increasingly rely on highly accurate forecasting of their energy usage, which will in turn be dependent on sophisticated performance models which bring together engineering analysis and read-world ship data.

Efficiency will also be measured at the fleet rather than individual ship level for electric ships and extend to a consideration of the through-life costs incurred through operations. For instance the depth of battery discharge can have a significant impact on battery life. Therefore decision-making at the fleet level (i.e. choosing to switch ships between routes to minimise through-life battery costs) will require an aggregation of data at the fleet level. This is simply not possible without a shore data repository and IoT platform. To assist operators on preparing for this future Austal offers not only an IoT solution for new Austal ships but also a standalone IoT data collector which can be retrofitted to other ships in an operator's fleet.

CONCLUSIONS

The question ship operators should ask themselves is whether they can afford *not* to invest in IoT for their fleet. Every journey operated where data is not gathered is a potential missed opportunity to build a data set from which future efficiency, comfort and reliability improvements can be derived. Austal believes that the costs of IoT are now sufficiently low that every HSC Austal builds should be gathering this data set for their customers from the moment it enters service. Therefore every new Austal large HSC has MARINELINK-Smart installed. This also includes an Ethernet smart-sensor network throughout the vessel, which enables new sensors and equipment to be easily installed and integrated with the MARINELINK-Smart platform as these become available. This 'future proofs' Austal HSC for our customers, since the IoT devices available now are likely to very different to those available to our customers in 10 or 20 years' time.

Austal's objective in investing in IoT technology is to differentiate its ships in an increasingly competitive global market. The company recognises that this cannot be achieved in isolation and that a much more compelling proposition can be built by working with customers, academia and other industry to collaboratively build the IoT platforms of the future, for the benefit of the Australian HSC industry as a whole.

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