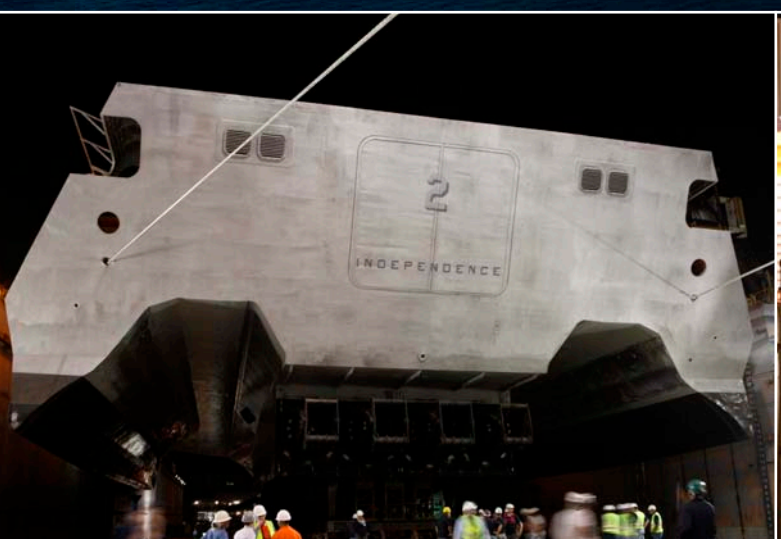
TRIMARAN TECHNOLOGY

AFFORDABLE MULTI-ROLE CAPABILITY

AUSTAL



The bold vision of a young company was borne out at the end of 2010 when the US division of Australian-headquartered aluminium shipbuilder Austal was contracted by the US Naval Sea Systems Command (NAVSEA) to take the world's most advanced multi-mission combatant into series production.

In meeting the US Navy's requirements for a fast, agile and versatile Littoral Combat Ship (LCS), Austal has engineered a seaframe design that breaks the bounds of naval convention. Uniquely, the Austal LCS has successfully synthesised the significant hydrodynamic and seakeeping advantages of the trimaran hullform, with the weight and powering efficiencies of a robust aluminium structure to create a shallow draft warship that truly deserves to be called transformational.

What is just as remarkable is the way in which this technology has been successfully transferred from its high technology commercial parent into the military domain in less than a decade. Indeed, it took just seven years between Austal commencing its initial 90-day Focused Mission High Speed Ship concept study and the 16 January 2010 commissioning of USS Independence (LCS-2), the first of the two LCS Flight 0 ships built by Austal USA at its Mobile, Alabama, shipyard.

That accomplishment – in an engineering realm generally recognised for its innate conservatism - is very much testament to the compelling capabilities, now backed up by at-sea operating experience, advanced by Austal during the formative stages of the LCS acquisition process. In particular, it succeeded in convincing a community previously wary of using aluminium alloys in large ship structures.

Hull 270 has further refined the trimaran hullform

How was this achieved? In the first instance, Austal was able to draw on its extensive commercial pedigree in high speed aluminium multi-hull vessels, including the design and construction of the world's largest trimaran. Second, it could demonstrate a fast and efficient design and manufacture philosophy that has realised a step change in naval shipbuilding practice. And third, it had the vision to articulate the multiple benefits offered by the trimaran hullform in terms of volume, payload, powering, seakeeping and stability.

These groundbreaking approaches to naval ship engineering and production reflect Austal's culture of innovation. And it is this same ability to think 'outside the box' that has given the company such confidence in the potential of aluminium trimaran designs to perform a range of defence and maritime security missions.

That confidence is shared by the US Navy. With USS Independence delivered, and the follow-on Flight 0 vessel Coronado (LCS-4) to launch in mid-2011, the service is now planning to acquire a further 10 Flight 0+ trimaran vessels by means of a FY2010-2015 block buy approved by Congress at the end of 2010. Austal had submitted a bid in June 2010 as prime contractor, and the order for the first of these vessels was confirmed by NAVSEA on 29 December 2010 under a US$432.1 million fixed-price incentive award; contract options for the nine additional vessels to be exercised in the following five years (subject to annual Congressional appropriations) will bring the final contract value up to US$3.5 billion.

John Rothwell, Austal's co-founder and chairman, puts the award in perspective. "This contract has firmly established

trimaran:

Austal as an international defence shipbuilder, is a strong vote of confidence in Austal's aluminium trimaran LCS design, and also reflects the strength and capability of our USA operations and highly-skilled workforce."

Further LCS production is anticipated in the years beyond 2015, and there is also potential for additional international orders through US government Foreign Military Sales (FMS). Austal, as the designer and builder, is best placed to contend with changes to the Flight 0+ design for future Flight upgrades, or for FMS opportunities.

But for Austal, LCS is just the start. Buoyed by its success in the United States, the company sees worldwide applications for suitably scaled aluminium trimaran designs serving warfighting, theatre support and constabulary missions.

Accordingly, Austal has continued to mature its ITAR-free, Australian-developed trimaran technology, as evidenced by the third generation hullform developed for the private venture Hull 270 launched in 2010. The end result is a series of versatile platform designs, ranging in size from 50 m to 127 m, able to meet a variety of littoral security needs. All derived from the same technology base, they lend themselves to an infinite variety of roles including, but not limited to, anti-submarine warfare, surface surveillance, Exclusive Economic Zone patrol, search and rescue, special forces support, hydrographic survey, mine countermeasures, intra-theatre logistics, amphibious support and humanitarian relief.

What's more, the aluminium trimaran seaframe is ideally configured to enable the rapid interchange of modular mission payloads. The result is a supremely agile and cost effective 'open architecture' platform that transcends traditional vessel typologies to deliver unmatched operational flexibility and significant through-life cost benefits.

Already recognised as the world's largest and most experienced designer and builder of aluminium ships, Austal is now pioneering a brand new platform concept that opens up a raft of possibilities to military and paramilitary customers. Trimaran technology is on the bow wave of a naval revolution.

In 2000 Austal embarked on a comprehensive research and development project aimed at developing a new hull design that would be capable of high speeds in rough seas while at the same time offering unprecedented level of passenger comfort. Analyses identified the trimaran hullform as combining the best attributes of monohull and multi-hull designs to deliver superior seakeeping.

Hitherto, the conventional monohull had been the only option for unrestricted operation in oceans and high sea states, but only at lower speeds. To increase the speed of a monohull the slenderness of the hull has to be increased, however this introduces stability problems.

Trimarans are in principle stabilised monohulls, using outriggers on either beam to enable both high speeds and excellent seakeeping performance. Recognising the potential of this approach, Austal undertook extensive model tests in order to understand and optimise the hull and propulsion system with respect to seakeeping behaviour, fuel consumption and speed in a seaway.

The physical result of this intensive trimaran R&D effort was Benchijigua Express, a 127 m vehicle/passenger ferry that began service with Fred Olsen S.A. in 2005. It was from this baseline that Austal subsequently developed its successful Littoral Combat Ship design.

From the military user's perspective, the inherent advantages of the trimaran bring numerous benefits, including a large payload bay, flexible layout, shallow draft, excellent manoeuvrability, and high speed in a seaway. Furthermore, outstanding seakeeping performance results in enlarged aviation and watercraft operating envelopes, and ensures that crew and embarked forces do not suffer from motion-induced fatigue or seasickness.

the **future** is now

Austal's trimaran LCS is breaking the bounds of naval convention

As the world's first operational trimaran warship, the Austal-built Flight 0 Littoral Combat Ship (LCS) USS Independence (LCS-2) is today blazing a trail for a new genre of versatile surface combatant that will form the backbone of the US Navy in the decades ahead. It is also opening their eyes of navies worldwide to the enormous potential offered by advanced aluminium seaframes – and enabling them to reassess the assumptions and preconceptions that have historically narrowed the options concerning the design, build and operation of front-line warships.

It was back in 2002 that the US Navy, having identified a series of gaps in its ability to establish and maintain maritime dominance in choke points and shallow water regions around the world, launched an accelerated acquisition programme for a fast, manoeuvrable, focused-mission platform optimised for operations in the complex environment of the littoral. Its objective was to deliver an affordable, modular capability that could be forward employed to take on and defeat 'asymmetric' anti-access threats such as mines, quiet diesel submarines and fast surface craft.

So was born the concept of the LCS. Conceived to operate and fight in the crowded, shallow water environments found close to shore, it would combine an agile, high speed 'seaframe', capable of deploying independently to distant operating theatres, with a set of interchangeable equipment packages each tailored to a specific mission.

The bar was set high. LCS had to combine high sprint speed and outstanding manoeuvrability without compromise to efficiency, range, seakeeping, shallow draft and high payload capacity. It also had to promote an open architecture – in terms of both structure and computing infrastructure – that could readily accept alternative mission equipments and information systems, and be operated by a core complement significantly smaller than that of a typical frigate-size vessel.

This was an ambitious capability requirement that clearly pushed the boundaries far beyond the steel displacement monohulls that have for so long typified warship design. The Naval Sea Systems Command, as the US Navy's acquisition agent for the LCS, recognised the need to depart from conventional naval ship design practice and capture techniques, technologies and expertise from outside the defence realm.

So it looked instead at alternative 'game-changing' approaches that emphasised the cost-effective pull-through of proven high speed vessel technologies accessible 'off the shelf' from the international marketplace. And it enshrined innovation as a means by which to deliver new and more affordable ways of doing business that would achieve the win/win of better value for the taxpayer and improved capability on the front-line.

Austal was quick to advance the candidacy of its aluminium trimaran technology. In 2002 it participated in concept-level Focused Mission High Speed Ship studies and, with Benchijigua Express offering a commercial design benchmark, the company's advanced trimaran design was in 2004 downselected as one of two LCS seaframes.

Austal's LCS trimaran seaframe has pushed out the frontiers of naval vessel design. The slender centre hull and two smaller side hulls give the vessel the operational characteristics of a larger displacement craft, providing greater stability in rough seas and operational conditions.

What should also be remembered is that the LCS is designed to go into harm's way, which means it must be fit to fight, and capable of sustaining and surviving combat damage. To achieve this, the trimaran seaframe has been designed and built to American Bureau of Shipping (ABS) Naval Vessel Rules, marking their first application to a surface combatant.

The vessel's aluminium structure – certified by ABS for a 30-year service life based on a detailed spectral fatigue analysis – provides a large roll-on/roll-off accessible mission bay area offering superior mission flexibility, rapid reconfigurability, improved damage protection and ample margins for future growth. Above the mission bay is the largest flight deck on any US Navy surface combatant, capable of conducting dual H-60 helicopter operations and accommodating the CH-53 (the service's largest rotary-wing aircraft).

This elevated aviation area benefits from reduced sea spray as well as the inherently superior seakeeping performance of the trimaran so as to enlarge the helicopter operating envelope in higher sea states. Similarly, the stability afforded by the trimaran platform will enable manned and unmanned watercraft to be launched and recovered in conditions up to Sea State 4.

A power-dense Combined Diesel and Gas Turbine main propulsion system comprises two MTU 8000 series diesel engines and two GE LM2500 gas turbines driving four Wärtsilä waterjets. This machinery arrangement combines delivers an outstanding 45 knot sprint speed at full power, and extended range and fuel efficiency in an economical diesel-only cruising regime.

A variety of task-orientated payloads can be embarked to meet specific mission needs. In addition, the trimaran Austal incorporates a core mission suite including a 57 mm dual-purpose gun, a SeaRAM inner-layer missile system, soft-kill decoys, a 3-D surveillance radar, an electro-optical/infrared director and electronic surveillance measures.

General Dynamics Advanced Information Systems has led the integration of the core mission system, built on an open architecture computing environment. This flexible information technology backbone adheres to the use of industry standards and maximises the use of commercially available products and published interfaces, allowing for the rapid insertion of new systems and applications.

First of class Independence was launched from Austal USA's yard on 28 April 2008 and, following

deliver

Coronado takes shape inside Austal USA's facility

Series production of the trimaran LCS, together with existing orders and commitments for the US Department of Defence's Joint High Speed Vessel (JHSV) programme, will see Austal USA significantly increase the capacity and labour resource at its state-of-the-art facility in Mobile, Alabama.

Since its establishment in 1999, the Mobile site has gradually taken on more complex ship construction projects, initially for the commercial market. This began with workboats and smaller catamarans, later stepping up to two 107 m Hawaii Superferry ROPAX catamaran ferries and LCS Flight 0 first-of-class USS Independence.

Over that same period, the facility has benefitted from a significant and sustained programme of investment to create a 'best practice' ship manufacture plant able to deliver the volume and quality requirements of the US Navy with unrivalled efficiency. Key to this new shipbuilding process is seamless production line workflow that ensures the right materials, equipment and personnel are available at the right time, at the right workstation.

In 2005 Austal USA embarked on a development plan to expand its production capability and improve its productivity by building a new Module Manufacturing Facility (MMF). Opened in late 2009, the MMF houses a fully covered manufacturing facility, with two fully commissioned production lines, that provides the yard with the additional manufacturing capacity to allow the yard to handle a throughput of up to three large aluminium vessels – such as LCS or JHSV – per year.

With its recent expansion, Austal USA is today the largest manufacturing company in Mobile, and the largest aluminium shipbuilder in the world. Now, in order to meet the concurrent needs of the LCS and JHSV programmes, the company has commenced preparatory work for a further US$140 million facility expansion, which will double the size of the MMF to 70,000m2 and add two additional final assembly sheds that will eventually allow for up to six 100 metre-plus vessels to be built each year. In parallel, Austal USA will more than double its workforce to around 4,000 employees.

extensive alongside testing of propulsion, communications, navigation and core mission systems, began first sea trials in early July 2009. A second and final series of builder's trials was successfully concluded on 18 October, with NAVSEA formally accepting the vessel on 18 December 2009.

LCS-4, the future USS Coronado, is currently under construction to a firm fixed-price contract. Lessons learned during the construction of Independence are being leveraged to improve productivity and schedule performance, with delivery to the US Navy set for late 2012.

Follow-on Flight 0+ production will further capitalise on the experience accrued during the manufacture of the initial Flight 0 units, with the build strategy being evolved to reflect the continued development of the Mobile facility. The average cost per ship, including government-furnished equipment and margin for potential cost growth, is US$440 million per ship – well inside a Congressionally-mandated cost cap. Austal's ability to take on this taut fixed-price contract reflects the mature design, stable production volume, and continuous process improvement.

USS Independence is the first of a new breed

ring on the promise

Matching finite budgets to an ever-widening range of maritime security and warfare enabling tasks is a problem that continues to challenge navies worldwide. Many forces are discovering that the one-to-one replacement of existing minor war vessel types – patrol vessels, mine countermeasures craft and survey ships – is both unaffordable (in terms of acquisition cost) and undesirable (given the training, logistics, organisation and manning overheads that aggregate through-life from a series of unique, niche and largely bespoke platforms).

The potential offered by aluminium trimaran seaframes is only just beginning to be realised. With the experience of the LCS programme, and its strong track record in commercial high-speed vessels, Austal sees itself uniquely positioned to bring its pioneering expertise to the military marketplace.

Moreover, the company's continued maturation and refinement of its world-leading trimaran technology comes at a time when many navies and coast guards are searching for new answers. Almost all are being forced to consider how to do more with less, driving them to think afresh about the delivery of capability though-life.

Austal has certainly not stood still in its efforts to push out the envelope of aluminium trimaran design. In 2010 it launched Hull 270, a 102 m third-generation trimaran hullform that incorporates a series of performance innovations reflecting lessons from the operation of Benchijigua Express and continuing R&D investment. These include a modified hull shape (offering reduced hull resistance), an enhanced ride control system with forward and aft T-foils (contributing to improved stability and seakeeping), an economical three engine propulsion system, and a versatile vehicle deck arrangement.

What this brings, Austal believes, is a sound base from which to further exploit the trimaran hullform in the naval context. Furthermore, the company also recognises that, just like commercial ferry operators, military users must look hard at the bottom line; operating costs are a key concern for all navies, and ships must now operate for more years, at lower cost and accommodate a greater range of mission capabilities.

Many forces are discovering that the one-to-one replacement of existing vessels is both unaffordable (in terms of acquisition cost) and undesirable (given the training, logistics and manning overheads that aggregate through-life from a series of unique, niche and largely bespoke platforms). As a consequence, there is a significant shift in thinking towards the concept of a modular and reconfigurable seaframe that confers an ability to be re-configured to satisfy a range of different roles according to the specific mission payload embarked.

Such reconfigurability is increasingly attractive to navies that want to be able to adjust the balance of roles and missions performed by individual platforms in a flotilla as tasking priorities evolve over time. This offers improved capability with increased flexibility through life.

A number of emergent platform/capability requirements reflect this trend. For example, Australia's Project SEA 1180, as a core component of the Royal Australian Navy's Force 2030 vision, plans to replace legacy patrol boat, mine countermeasures, hydrographic and oceanographic forces with a single modular multirole class of Offshore Combatant Vessels.

It is a model that Austal is already familiar with through its LCS experience. Now, by capitalising on its unique insight into the engineering and architecture of modular, reconfigurable platforms, the company is advancing a scalable Multi-Role Vessel (MRV) concept that combines the efficiencies and layout advantages of the trimaran hullform with a system of modular mission payloads. The result is a supremely agile and cost effective 'open architecture' littoral combatant geared to the needs of the 21st century navy.

The baseline 80 m MRV has been designed to capitalise on this pedigree, providing users with a versatile yet cost effective littoral seaframe that exploits the inherent attributes of the trimaran hullform to offer significant advantages over a similar-size monohull. These include improved hydrodynamic performance and greater propulsion efficiency, increased internal volume for a flexible mission/logistics deck, and a large and optimally sited flight deck and hangar for helicopter and/or unmanned air vehicle operations and support.

Austal's concept combines these features with a scalable combat system for situational awareness and self-defence, and a ship service infrastructure that supports interfaces to a wide range of mission payloads suited to specific naval, maritime security, theatre logistics, law enforcement, and humanitarian roles. The result is a seaframe that offers end users a highly adaptable asset that can be rapidly reconfigured to deliver role-specific capability across the full spectrum of operations.

Work undertaken by Austal has demonstrated the suitability of the 80m MRV to deliver the offshore security, mine countermeasures and hydrographic capabilities required of the projected Offshore Combatant Vessel. The ship arrangement has been developed with input from various naval customers, together with experience from the LCS programme, and the hull form optimized using Shipflow numerical analysis: this has included centre hull optimisation; identification of a target metacentric height for the platform; and an examination of dif-

setting a course to

ferent main hull beam and outrigger sizes to address hull interference issues.

Over 15 MRV hullform options have been assessed. The hull lines have been optimised for a medium speed (30 knots) propeller arrangement minimising transom immersion, while a detailed stability assessment has verified compliance with IMO requirements.

However, it is not just a matter of the seaframe. Austal also brings a deep understanding of the need to carefully manage mission systems integration, be it as a core fit or a 'plug-in' module, in order to strike the right balance between cost and capability. In this regard, the company's extensive experience from LCS contributes to the definition of a value-for-money MRV design.

Furthermore, the company enshrines a commercial acumen and project management discipline that is focused on cost-effective and timely delivery. Its approach is based on a fixed-price contracting model that ensures that the contract proceeds in accordance with the schedule and budget. Furthermore, it upholds a rigour in minimising in-process change so as to avoid requirements creep and limit cost growth.

Offering hitherto unimaginable versatility, the MRV concept marks a paradigm shift in its ability to deliver a fleet of modern, affordable lightweight hulls with low operating costs and a holistic integrated logistics support approach. The future, based on Austal's aluminium trimaran technology, is now within grasp. Navies will never look the same again.

Having been embraced by commercial high speed vessel operators, the operational advantages of marine aluminium are now increasingly recognised by operators and engineers alike in the defence and security sectors. Indeed, Austal believes that many of the myths and misconceptions surrounding the use of aluminium material in naval hull structures are now being overcome as a growing body of evidence is accumulated on its performance and behaviour.

Aluminium offers a range of benefits, including reduced structural weight, better fuel economy and improved corrosion resistance. It is also an extremely robust material; in recent drop tests, the company conclusively demonstrated the superior damage tolerance of marine aluminium against steel plate, a result explained by the ductility of aluminium.

In these trials, the heavy duty aluminium panel exhibited a highly localised response, which would result in less referred damage to other surrounding structures. Testing of an equivalent steel panel, however, indicated steel's ability to transmit load to adjacent members is quite considerable.

Translated to repair costs, this means the extent of the damage on an aluminium vessel is concentrated around the impact area. On a steel vessel, referred energy from an impact may unseat engines or degrade shaft alignment.

In terms of material properties, steel offers increased mechanical strength – but at a significant weight penalty when compared with aluminium panels. Conversely, an aluminium vessel can easily be made as strong as a steel vessel but need not be as heavy. Reduced ship displacement ultimately requires smaller engines and substantially reduces the operating and maintenance costs of the platform throughout its service life.

Perhaps the single biggest misunderstanding concerns aluminium's behaviour in the event of fire. Aluminium and steel are alike in that both materials are non-combustible and do not burn. The key behavioural difference is that aluminium alloys lose strength at a lower temperature than steel (degradation starting at temperatures between 150oC and 180oC).

Austal recognises that aluminium's increased susceptibility to fire damage demands increased structural fire protection, which is delivered through a ceramic fibre wool materiel and the installation of active fire suppression systems. However, the substantial difference in structural weight more than offsets the weight of additional fire protection measures.

Austal's 80 m MRV offers cost effective versatility

the **future**