MARITIME SINGAPORE ADDITIVE MANUFACTURING LANDSCAPE REPORT 2022

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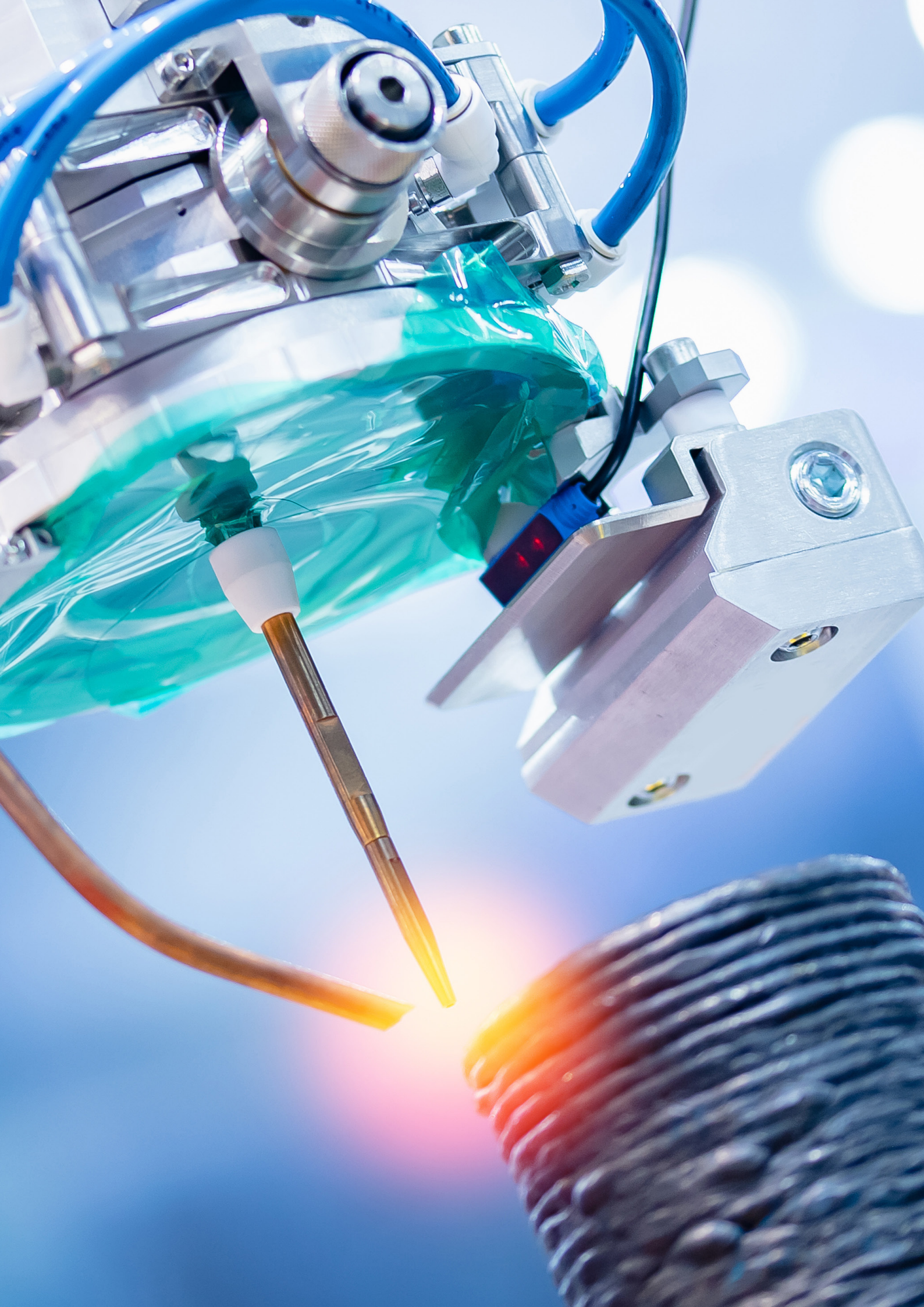
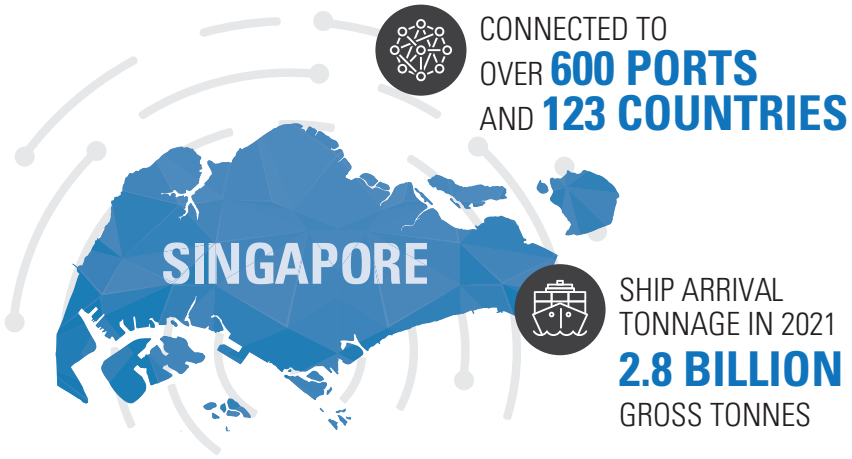


INTRODUCTION

Maritime transport is a key node in the global supply chain, responsible for the transport of more than 80% of world trade by volume[1]. Recent events including the COVID-19 pandemic highlight how profoundly supply chain disruptions could impact our daily lives. Alongside this, the climate change agenda is gaining momentum, and this requires concerted action from all stakeholders in the supply chain to work together to address the challenges. **It is against this backdrop that the adoption of Additive Manufacturing (AM) technology in the maritime sector is both timely and opportune**. This report will share Maritime Singapore's additive manufacturing landscape, and seeks to promote greater awareness, learning and opportunities in the maritime industry.



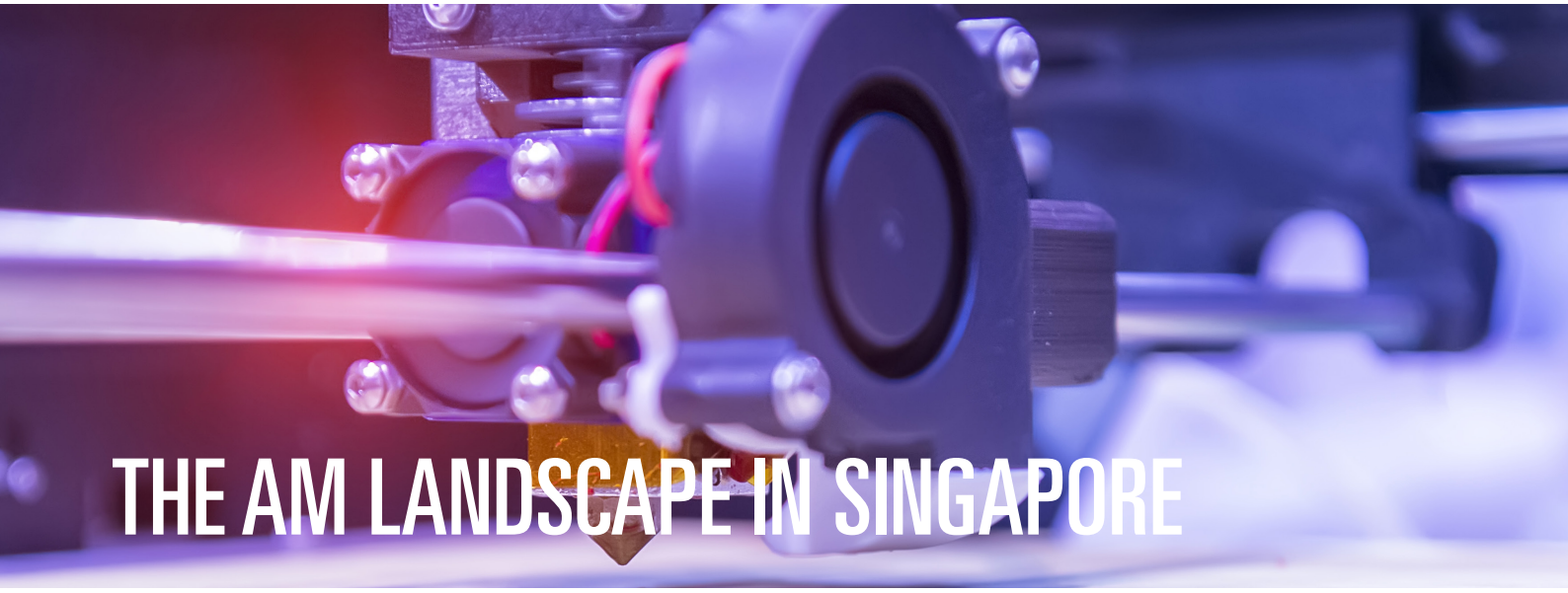
Singapore is a major international maritime transport hub. Connected to over 600 ports and 123 countries, the Port of Singapore is currently the world's second busiest port in terms of container throughput, handling 37.5 mTEUs of containers and with ship arrival tonnage exceeding 2.8 billion gross tonnes in 2021. Singapore is also one of the world's leading bunkering and maritime services hubs, and with a vibrant maritime cluster. In addition, innovation and R&D are key thrusts in Singapore's growth as a leading maritime nation. In the Leading Maritime Cities of the World Report 2022[2] by DNV and Menon Economics, Singapore was ranked as the top maritime city, and top in the maritime technology pillar.

[1] *United Nations Conference on Trade and Development (UNCTAD)*

[2] *https://www.dnv.com/maritime/publications/leading-maritime-cities-of-the-world-2022.html*

At the same time, manufacturing is a key segment of Singapore's economy, contributing about 20% of the national GDP. Of this, AM technology is an integral part of the Smart Nation and supports Singapore's ambition to be a leading hub for digital manufacturing. To this end, the Singapore government has injected resources into the manufacturing sector to support its growth and enhance the competitiveness of various industries. National Additive Manufacturing Innovation Cluster (NAMIC), a national AM agency, was incepted in 2015. Its aim is to transform and enhance industry competitiveness by orchestrating breakthrough strategies for the future of production, jumpstarting public-private collaborations, and helping companies to lower barriers for hybrid and additive manufacturing technology adoption.

Leveraging both our strengths in maritime and AM, **Singapore could play an instrumental role in spearheading AM innovation for the global maritime industry and enabling efficient supply of marine/port spare parts from Singapore and partners globally.**



THE AM LANDSCAPE IN SINGAPORE

Additive Manufacturing, commonly referred to as 3D printing, is a technology that builds solid objects from three-dimensional software designs, layer upon layer. The unique process of additive manufacturing allows the printing of complex parts in more efficient ways that achieve greater functionality, reduce wastage of material, and allow easy customisation of manufactured parts to meet specific requirements. The ability to produce components 'on-demand' almost instantaneously across the globe in the form of digital files could reshape manufacturing flows and supply chains in some industries. With this also comes the rise of the 'digital inventory'.

In Singapore, NAMIC has since raised substantial amounts of private-public funding which have supported start-ups and initiatives covering platform solutions, product development, standards development, and certification. These have been co-developed with the industry, with more than 240 industry projects curated.

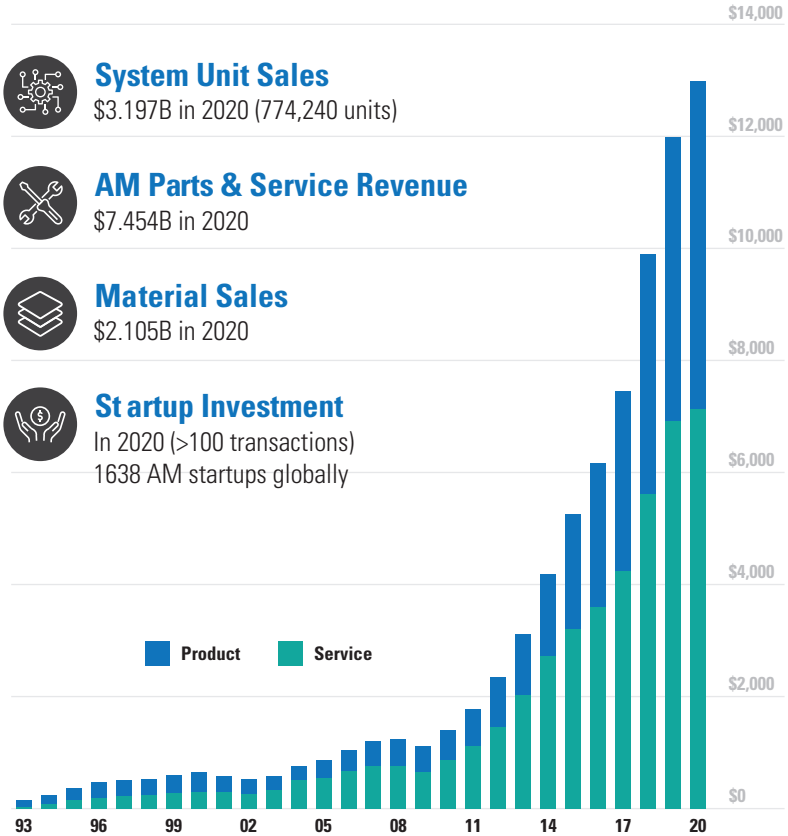
Worldwide adoption of AM has grown rapidly over the years and this technology is maturing into a viable manufacturing technology. **2020 revenue was recorded at $12.8 billion with year-on-year growth of 7.5%**[3]. Global AM market projects are estimated between $40 - $120 billion[4] by 2025. Today's AM adoption is primarily in prototyping, tooling and fixturing, but increasingly in end-product production as well.

System Unit Sales
$3.197B in 2020 (774,240 units)

AM Parts & Service Revenue
$7.454B in 2020

Material Sales
$2.105B in 2020

St artup Investment
In 2020 (>100 transactions)
1638 AM startups globally



[3] *Wohlers Report 2021*
[4] *Various Estimates – BCG, Wohlers, Lux, Ark, Smartech, McKinsey*

Within ASEAN, Singapore is leading the way in AM market size of approximately 40%[5]. Within Asia Pacific, Singapore has been identified as one of the few highly innovative regions and ranked 8th in the global innovation index[6]. In Singapore, AM is being applied across sectors and domains, to support product development and high-value manufacturing.

Currently there are more than 170 companies[7] across the AM value chain within the NAMIC portfolio. 30% of the global AM companies including thyssenkrupp, Molyworks, EOS GmBH, DMG-Mori, NTopology, and Hyperganic GmBH have chosen to set up their operations in Singapore. In the ecosystem, over 80 are startups, about 50 are SMEs, and more than 40 are either LLEs or MNCs. They support the local AM value chain as material suppliers, equipment and software OEMs, product and service bureaus, and standards and certification bodies.

To support product development and on-demand manufacturing opportunities, Singapore has also developed a suite of AM infrastructure including University, Polytechnics, Public Research Organizations, Original Equipment Manufacturers (OEMs), and Industry Technical Centres. Various programmes from NAMIC, government agencies Enterprise Singapore (ESG), and Maritime and Port Authority of Singapore (MPA) are also being set up to support companies' AM development, adoption, and commercialisation.

STRENGTHENING THE ECOSYSTEM

Singapore's maritime cluster comprises the **twin pillars of Hub Port and International Maritime Centre (IMC)**. As the world's largest container transhipment hub and the world's leading bunkering port, it is supported by a strong ecosystem of port services. In addition, Singapore's IMC consists of a diverse group of international players, and is home to over 170 international shipping groups, over 30 leading international shipbroking firms, over 30 law firms with shipping practices, about 20 international banks with shipping portfolios, and 10 IG Protection and Indemnity Clubs. This diverse ecosystem includes the major stakeholders involved in the maritime AM supply chain – classification societies such as the American Bureau of Shipping, Bureau Veritas, Lloyds Register, and DNV, international ship managers with presence in Singapore, and about 330 ship chandlers/ suppliers.

SINGAPORE INTERNATIONAL MARITIME CENTRE

170+ INTERNATIONAL SHIPPING GROUPS

10 IG PROTECTION AND INDEMNITY CLUBS

~20 INTERNATIONAL BANKS WITH SHIPPING PORTFOLIOS

30+ LAW FIRMS WITH SHIPPING PRACTICES

30+ LEADING INTERNATIONAL SHIPBROKING FIRMS

[5] *thyssenkrupp 2019 report on "Adding Up Growth Opportunities for ASEAN"*
[6] *https://www.ipos.gov.sg/resources/singapore-ip-ranking*
[7] *AM Business Network Online Directory, NAMIC Singapore*

As the maritime sector faces challenges in the external environment including geopolitical uncertainties, global supply chain disruptions, the pressing needs of decarbonisation, seafarer welfare and talent shortages, it needs to continually transform itself through digitalisation and adoption of new technologies and new ways of working. To this end, the MPA will continue to invest in maritime innovation, R&D and talents to meet the evolving needs of the sector. This involves nurturing a vibrant innovation ecosystem, comprising maritime technology developers, start-ups, venture capitalists and research institutes. Through creating an enabling environment to support the development of new solutions, growing new technology enterprises, and building deep technological capabilities, MPA seeks to drive competitiveness and new growth areas for the maritime cluster.

Specifically, to further explore the potential of AM technology in the maritime sector, MPA partnered with NAMIC and the Singapore Shipping Association (SSA) to promote greater awareness and adoption of this technology.

In 2018, MPA signed a Memorandum of Understanding (MOU) with NAMIC and SSA to collaborate on the development of AM applications towards adoption in Singapore's maritime industry.

THE OPPORTUNITIES OF AM IN MARITIME

Additive Manufacturing brings many potential opportunities for the maritime industry, such as in the supply, materials, design, printing, testing, certification, inventory management, and repair of marine parts for vessels. Some of the benefits that AM could bring are as follows:

Re-design opportunities for improved functionality and longer life cycle of parts. AM allows for parts to be redesigned more effectively, without the constraints of traditional casting and manufacturing methods. This creates potential for topology optimisation or different lattice structures, hence reducing the weight and cost of parts, or improving their functionality. In addition, with the potential to use composite materials or custom alloys, AM could enhance the material strength and/or the life cycle of parts.

On-demand printing for reduced lead time for parts and more efficient inventory. AM is particularly effective for low-volume high-value production. Without having to meet minimum order quantities, procurement managers could have greater flexibility to order parts on-demand, and not be hindered by long lead times. In addition, it could reduce the need to keep a large number of stores and spares onboard the vessel, hence having a more efficient inventory.

Address parts obsolescence. As of 2020, the average age of the world merchant fleet was just over 20 years. Many of the older vessels face delays in the delivery of spare parts due to limited part availability and part obsolescence. This often leads to higher operating costs as the eventual wear and tear of an obsolete part often results in an entirely new machinery being required. With the potential for 3D scanning of parts and reverse engineering, parts obsolescence could be more effectively addressed, resulting in time and cost savings for shipping companies and manufacturers.

Emissions savings due to more efficient supply chains. As AM allows for distributed manufacturing of parts, it reduces the need for cross-border movements of parts via air, land or sea, which hence reduces the emissions footprint of each part, and overall a more efficient supply chain. Furthermore, advancements in AM technology allow for the recycling of materials as printing feedstock, resulting in a more sustainable parts supply chain. Towards greater sustainability, AM could help to realise the adoption of recycled materials, end-of-product-life-cycle solutions, and the use of eco-friendly products.

Shorter turnaround times. As a transhipment port which also provides a suite of maritime services including the supply of marine parts, on-demand printing could allow for shorter turnaround times as vessels may be able to obtain their spare parts more quickly, without the need for long layovers in the Port of Singapore. For capital-intensive assets, this has potentially attractive cost savings.

Continued advancements in AM technology in terms of printing techniques, materials and qualification methods will continue to lower the barriers to adoption for AM in maritime.

BUILDING THE FOUNDATIONS

MPA's collaboration with NAMIC and SSA precipitated the launch of Joint Industry Programmes (JIPs), bringing together diverse stakeholders along the value chain. This approach has proven useful in providing learnings across the industry. The JIPs are co-funded by MPA's Maritime Innovation and Technology (MINT) Fund, and the project development work has been conducted in Singapore.

Cover page of the JIP 1 Market Feasibility Study on AM for Marine Parts, launched in October 2019

https://go.gov.sg/amjip1report

Scan QR to View

JIP PHASE 1

JIP Phase 1 was a market feasibility study that sought to identify the opportunities of AM in the maritime sector and promote greater learnings among the industry. Led by DNV[8] and in collaboration with tech providers Ivaldi, SpareParts 3D, Sembcorp Marine and Wartsila, it brought together a consortium of 10 shipowners, operators and managers[9]. The objective of the pre-competitive study was to identify a list of commonly used ship parts that are (a) 3D printable without class certification, (b) 3D printable that require class certification, (c) not suitable for 3D printing in the next 2 years. This would serve as a starting point for discussions internally, and for maritime companies to begin to explore the opportunities of AM. Through questionnaires, interviews and validation workshops with maritime companies, DNV assessed a list of 100 parts based on their value proposition, frequency of demand, inventory portfolio and supply chain considerations. The outputs of the study are published on MPA's website.

JIP PHASE 2

Riding on the momentum, MPA, NAMIC and SSA jointly embarked on JIP Phase 2, which focus on the fabrication, testing, inspection and certification of marine parts. Its objective is to bring together key players along the value chain to showcase the potential of AM technology for maritime/ marine parts by printing and certifying parts and installing them onboard vessels for actual operational use. The Call for Proposals was launched in March 2020, and 6 consortiums were awarded, bringing together over 35 industry partners. The projects are underway and due to complete by end 2022.

MPA, NAMIC AND SSA ARE JOINTLY CATALYSING THE GROWTH OF MARITIME AM ECOSYSTEM

Through the projects, a wide range of marine parts are being trialled and tested, including critical and non-critical parts, with and without the involvement of the Original Equipment Manufacturers (OEMs). Innovations in AM technologies for maritime are also being explored, including parts re-design, material change and reverse engineering, as well as AM simulation software to facilitate part redesign and design optimisation, new approaches for removal of support structures, and streamlined certification processes.

[8] *Formerly known as DNV-GL*

[9] *Anglo Eastern, Bernhard Schulte Ship Management, CMA CGM, Eastern Pacific Shipping, OSM Maritime, Pacific International Lines, Synergy Marine Group, Thome Group, Wilhlemsen Ship Management and Zeaborn Ship Management.*

CASE STUDY

Fuel Oil Pump Shaft by Consortium led by thyssenkrupp

thyssenkrupp is leading a consortium together with Sembcorp Marine, DNV, Synergy Marine, OMC Shipping, Zeaborn, Forefront AM, Optomec and Hamworthy Pumps. The goal of the project is to implement a viable chain of operations to ensure that the processes utilised and components derived from AM could be implemented successfully for the maritime industry.

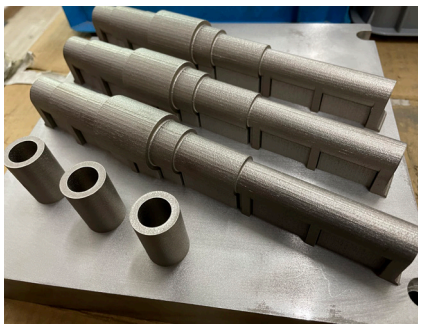


Figure 1: Printed Shaft

The **Fuel Oil Pump Shaft** was one of the components selected for the project. It has tight dimension requirements, high strength and hardness requirements. The part was printed using powder bed fusion (PBF) technology, in maraging steel material. It was hardened and subsequently machined down to the required dimensions. The part will be sent to DNV for testing, followed by installation onboard OMC Shipping's bulk carrier by 1H 2022.

With AM, the shaft is hardened throughout the entire component (as opposed to hardening of the case only), and hence is expected to be more resistant to localised damages. The project also demonstrates the use of AM for a load-bearing component, and the learning points from this piece could be translated to other similar semi-critical components.

Figure 2: After Machining

CASE STUDY

Pump and Valve parts by Consortium led by American Bureau of Shipping

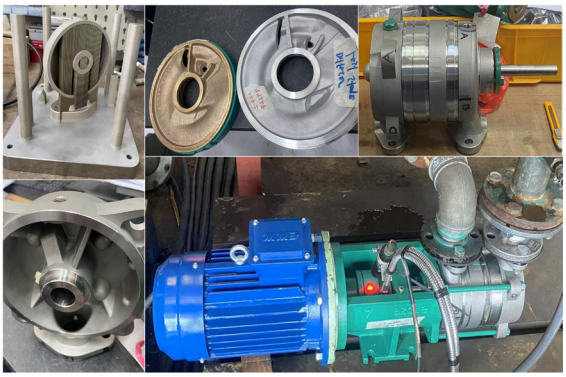


Figure 3: Pump assembly using AM-built parts

Figure 4: Valve assembly using AM-built parts

American Bureau of Shipping (ABS) is leading a consortium together with 3D Metalforge (3DMF), POSH Fleet Services Pte Ltd (POSH) and ShipParts.com Singapore Pte Ltd (SP).

The consortium chose to print valve and pump parts as these are fast-moving spares typically used in marine systems of low criticality, making it ideal for AM. A **straight flanged screw-down non-return valve** and a **self-priming multi-stage pump** for the domestic freshwater system onboard vessel were chosen.

The consortium used reverse engineering tools, design optimisation and build simulation for these marine parts to produce the AM digital build files for Laser Powder Bed Fusion using Stainless Steel 316L. They had also involved the original manufacturer for determining critical features during functional testing. ABS' Guide for AM and ASTM/ISO standards were used in developing the inspection test plan for the AM-built parts and the printing machine, with tests performed on qualification coupons, and inspection and dimensional checks on the parts.

Once testing is completed, the valve and pump parts will be installed onboard POSH's Offshore Support Vessel for a 3-months trial. The consortium is also conducting a commercial study on the scalability of distributed manufacturing to prove cost and time savings to end users, and savings on carbon emissions across the supply chain.

CASE STUDY

Auxiliary Engine Turbocharger Nozzle Ring by Consortium led by Lloyds Register

Lloyds Register (LR) is leading a consortium together with LRQA, 3D Metalforge (3DMF), Singapore Polytechnic, Neptune Pacific Lines, Kompressorenbau Bannewitz GmbH and Professional Testing Services (PTS).

The consortium chose to print an **auxiliary engine turbocharger nozzle ring**. As a part that operates under harsh conditions of high temperature and faces erosion and corrosion due to direct contact with engine exhaust flow, regular maintenance is necessary but is at the expense of downtime and lost efficiency. Procurement of a new part for replacement requires a lead time of approximately six weeks, and inventory management of such high value components requires precise planning. The consortium therefore deemed that the part is suitable for AM, in order to optimise the lifespan and performance of the part.

Figure 5: Top and bottom views of AM printed turbocharger nozzle ring

The consortium utilised a qualified blown powder direct energy deposition (DED-LB) facility for fabricating the selected nozzle ring. The project included an AM production workflow, from DED-LB process development to manufacturing, post-processing, inspection and testing. If successful, it would lead to a leaner production process.

The part will be installed onboard Neptune's container vessel for three months.

The consortium had also explored data provenance protection through embedment of security features, reverse engineering and repair options. The project also demonstrated the production of high-performance powder feedstock by Singapore Polytechnic's in-house gas atomisation facility.

CASE STUDY

Cooling Water Pipe Connector by Consortium led by Wilhelmsen

Wilhelmsen Ships Services is leading a consortium together with thyssenkrupp to explore and trial 3D printed spare parts onboard vessels. One particular part, a **cooling water pipe connector**, involved research partner Ivaldi, OEM Kawasaki, end-user Bernhard Schulte Ship Management, and classification society DNV.

As a part that traditionally faces corrosion issues commonly found in the harsh maritime environment, the consortium chose to print the part using stainless steel 316L, through laser powder bed fusion technology. This strengthens the part and could enhance its lifespan. In addition, with a manufacturing lead time of 5 days, it is significantly faster than traditional means, leading to a lower logistics cost for users.

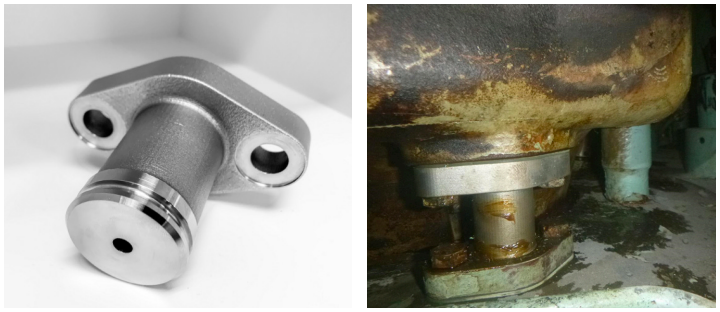


Figure 6: Printed cooling water pipe connector (left), and installation onboard bulk carrier (right)

The part is currently installed onboard Bernhard Schulte Ship Management's Bulk Carrier vessel for testing. A 3.1 certification by DNV certified that the printed part met OEM requirements, withholding an hour of pressure testing (up to 7 bar). These certification processes ensure that the parts are fit-for-purpose and ready for commercial use.

CASE STUDY

Seawater Pump Impeller by Consortium led by 3DMetalforge

Figure 7: Installation of printed pump impeller

3DMetalforge (3DMF) is leading a consortium together with PSA Corporation, PSA Marine, Bureau Veritas and Professional Testing Services (PTS).

The consortium focused on selecting parts that could be made cost competitively through AM and were suitable to continue in real commercial use after the project. One of the parts selected is a seawater pump impeller. The objective is to use a more corrosion and wear resistant material to extend the service life of the impeller.

The impeller was printed using Powder bed fusion in Inconel 718.

The impeller has been functionally tested and inspected by BV and is currently being installed onto a seawater pump at PSA Marine workshop. It will be installed onto a live tugboat for field test of 1 month or 500 hours, by the first half of 2022.

CASE STUDY

Wecco Connector by Consortium led by Bureau Veritas

Bureau Veritas Marine & Offshore, Innovation, Centre of Alternative and Renewable Energy (iCARE), is leading a consortium comprising 3DMetalforge (3DMF), POSH Fleet Services Pte Ltd (POSH) and Professional Testing Services (PTS). Through the JIP, the team aims to identify parts that can be printed and tested, and with potential to continue creating commercial viability and new processes after the project. The consortium therefore chose to select parts that are sustainable and operationally effective for POSH, that would result in an improvement in their supply chain management.

Figure 8: Printed Connectors after NDT Testing

One of the parts selected is the Wecco connector. The product is an early inventory need that requires quick turnaround, yet often faces longer lead times. In addition, many variations of the part are required to adopt to various manifold types. To cater to and meet these requirements of offshore operations, the consortium partners sought to facilitate better inventory management, and utilise re-engineering to lower the weight of the part and shorten the turnaround time for production.

Through the project, it was successfully reverse engineered, design optimized for AM via Laser Powder Bed Fusion, with design approved by the consortium. AM was shown to improve the product lifecycle through redesigning the specifications, manufacturing process and supply chain logistics for the end user.

The connectors will be installed onboard POSH's Anchor Handling Tug by 1H 2022 for trial and testing after the final checks and hydrostatic testing is completed.

PORT APPLICATIONS

Whilst the partnership with NAMIC and SSA focuses on AM for marine parts for vessels, a parallel effort is underway to trial AM for port applications. Since 2019, MPA, ESG, PSA Corporation, 3D Metalforge, and NAMIC have collaborated on a project to develop AM capabilities for the port, including an AM facility within the PSA's terminal. This represents the world's first AM facility within cargo terminal, outfitted with printing technology to enable just-in-time delivery of spare parts to support port operations.

Figure 9: WAAM Twistlock Pin (left), and Operational use of WAAM Twistlock Pin (right)

Together with the Singapore University of Technology and Design (SUTD), the consortium has worked on the printing of two parts to be used in PSA's quay cranes and yard cranes. Firstly, the printing of twistlock pins (length of more than 400mm) using Wire Arc Additive Manufacturing, as these are the most critical components in the crane spreader, and load-bearing member in direct contact with containers. Secondly, the polymer printing of large rollers (diameter more than 200mm) using Fused Deposition Modelling. The use of AM will reduce the lead time of procuring these parts and reduce critical downtime of these equipment. The project includes an ongoing series of extensive fatigue tests, field tests, and qualification checks to ensure a high level of assurance. Through the project, PSA staff have also been trained on AM strategy, AM parts design, quality and compliance.

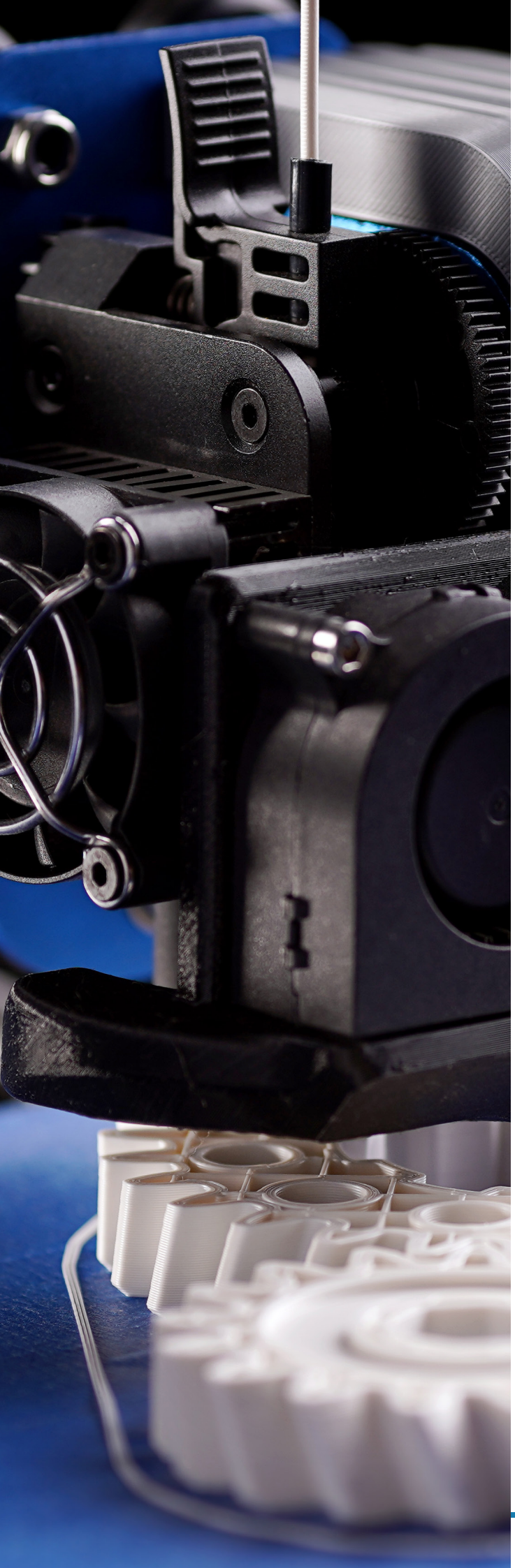
In time, this capability can be proliferated across PSA's global locations to build a network of AM facilities which can be further integrated with PSA Cargo Solutions offerings. Put together, this can create a greener and more sustainable and resilient manufacturing supply chain.

CHARTING THE WAY FORWARD

With these foundations in place, the next steps towards greater adoption include (i) building strong capabilities, (ii) building greater awareness, and (iii) forging partnerships. MPA, NAMIC and SSA seek to continue to encourage and facilitate the adoption of AM in the maritime sector. The approach of 'mission-centric' consortiums across the value chain has served well in the earlier years and will continue to guide the efforts going forward.

NAMIC, in its 2nd tranche of funding from the RIE2025 MTC Strategic & Translational Research Fund (STRF), will continue to champion AM technology in key sectors, including maritime. At the same time, NAMIC has moved under A*STAR's organisation structure in April 2022 to effectively orchestrate the consolidated strategies for Singapore AM ecosystem. NAMIC will also expand from 3 to 8 satellite hubs. These are National University of Singapore (NUS) [existing], Nanyang Technological University (NTU) [existing], Singapore University of Technology and Design (SUTD) [existing], Singapore Institute of Technology (SIT), Industrial Additive Manufacturing Facility (IAMF@A*STAR), Nanyang Polytechnic (NYP), Temasek Polytechnic (TP) and Singapore Polytechnic (SP). The expansion aims to maximise value creation and capture to accelerate pull-through of AM technologies to business outcomes. NAMIC will continue to expand its strategic focus on coordinating public sector AM research priorities, enabling new global-leading AM technologies and digital solutions, and accelerating solution industrialisation.

At the same time, regular industry surveys and focus group discussions will be held, to better understand industry views and jointly identify the directions forward. Based on an industry survey conducted by SSA in Mar 2022, industry players shared that building strong AM capabilities would be most important.



BUILDING STRONG CAPABILITIES

The first 2 JIPs have highlighted technological and capability gaps that could help to build greater confidence in AM technology. On the technology front, this includes design optimisation of selected parts, part qualification procedures, part identification and printability analysis, certification workflow, application reliability, and material development to widen AM adoption[10]. Future JIPs could therefore be structured around addressing these gaps.

Surveyed Technology Gaps prior to SSA's Joint Webinar on AM for the Maritime Sector, in Mar 2022

In addition, talent capabilities need to be built up amongst the maritime and AM landscape. This includes AM service providers having a better understanding of the needs of the maritime sector, and maritime players being able to better appreciate the opportunities of AM.

NAMIC's dedicated AM career portal, launched in 2020, provides a platform that aims to enable aspiring talents to fulfil their AM career aspirations and employers to harness the growing pool of AM talents. Under RIE2025, Workforce Transformation will be one of NAMIC's key focus areas. NAMIC will establish an AM Academy to formalise an AM job competency framework and roll out a national AM workforce accreditation with Skills Future Singapore (SSG) and Workforce Singapore (WSG). Various programs will be launched to train and develop individuals through direct AM industrial exposure and position them to fill immediate industry needs on different AM specialities. NAMIC also supports overall ecosystem development efforts through 3 key components of 'Thought Leadership', 'Outreach', and 'Internationalisation', for industry partners to learn, share, and collaborate in strengthening the entire AM ecosystem.

[10] *These were corroborated through SSA's industry survey conducted in Mar 2022.*

THOUGHT LEADERSHIP

NAMIC AM Summit
AM.SG Week
Sector Specific Workshops
Certification Courses
Round Table Discussions
Start-Up Innovation Forum

ECOSYSTEM DEVELOPMENT

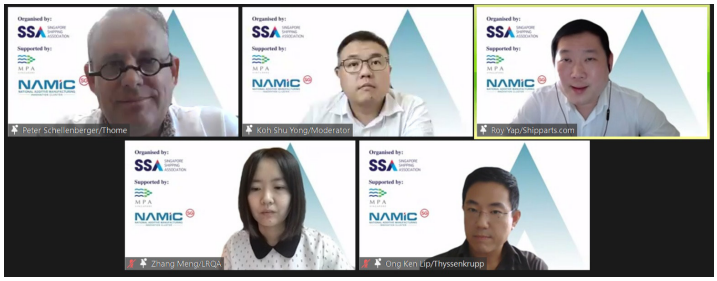
INTERNATIONALISATION

Partnerships
MOUs
Study Missions
Consultancy

OUTREACH

NAMIC AM Directory
Quarterly Newsletter
AM Design Competitions

SSA Learning Journey to NAMIC at NTUitive in Dec 2019



Panel discussion at SSA's Joint Webinar on AM for the Maritime Sector, in Mar 2022, from Top to Bottom, Left to right Peter Schellenberger (Thome), Koh Shu Yong (BV), Roy Yap (ShipParts.com), Zhang Meng (LRQA), and Ong Ken Lip (thyssenkrupp).

BUILDING GREATER AWARENESS

Awareness and acceptance of new technology takes time, and to build greater awareness, SSA has supported industry workshops including learning journeys and webinars. Thus far, industry appetite is gaining momentum in AM trials and adoption. According to SSA's industry survey conducted in Mar 2022, about half of the industry respondents have either embarked on the journey or are at the forefront of commercialisation and deployment. .

FORGING PARTNERSHIPS

Beyond Singapore, MPA and NAMIC also seek to build stronger partnerships with overseas ports and maritime centres exploring AM technology. If ports could be linked in such a global service, shipping lines could be supplied with on-demand spare parts at various ports of call, hence multiplying the gains for all. Through MPA's MOU partners and international platforms such as the Port Authorities' Roundtable, MPA looks forward to connecting with like-minded parties on building AM networks.

In addition, strategic partnerships with technology and service providers will allow access to new and advanced AM technologies that benefit the industry and strengthen supply chain resilience. Every player brings different expertise and resources towards shaping the AM ecosystem. NAMIC has signed several local and international MOUs spreading across the AM value chain. These MOUs have translated into existing projects and pipelines, with more to be developed.

CONCLUSION

AM technology has great potential to transform the maritime industry and the ship supplies value chain. Through Maritime Singapore's journey of learning, trials and pilots, we have gleaned useful insights and catalysed new industry capabilities. As Singapore continues to invest in the development and deepening of tech and talent capabilities, it will create more opportunities for companies locally and internationally. Through close partnership with private and public stakeholders, and the lowering of barriers relating to materials supply chain, quality assurance and technological know-how, AM can address major industry-wide challenges and enhance the resilience of shipping, the backbone of world trade.

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- Consortium led by thyssenkrupp
- Consortium led by Wilhelmsen Ships Services
- PSA Corporation Ltd

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