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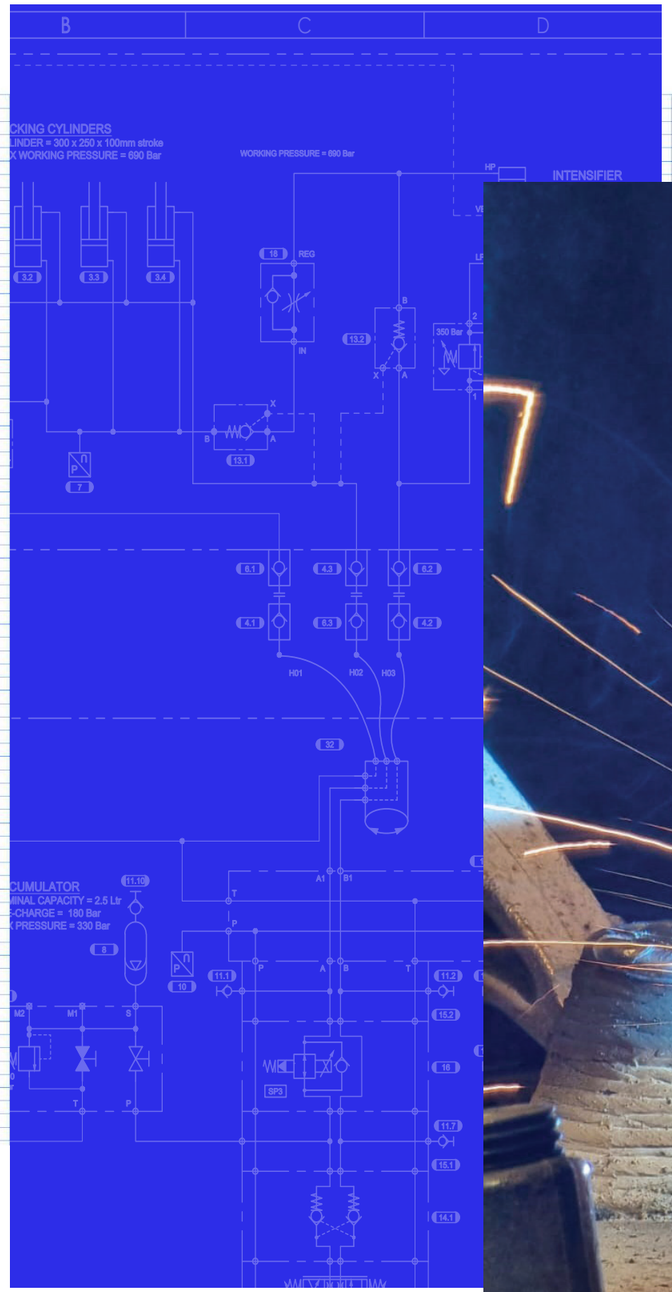



**MALIN GROUP**

HEADQUARTERS
SOUTH ROTUNDA
PACIFIC QUAY, 100 GOVAN
ROAD
GLASGOW
G51 1AY

FABRICATION FACILITY
UNITS 7, 8 AND G2
WESTWAY BUSINESS PARK
PORTERFIELD RD
RENFREW
PA4 8DJ
T: 0141 221 3075

Innovate UK
NMIS National Manufacturing Institute Scotland
ALTAIR
BAE SYSTEMS

Malin
Marine Consultants

# MARILIGHT: MARINE VESSEL LIGHTWEIGHTING

# MARILIGHT: AN INTRODUCTION

## MARILIGHT INVESTIGATES THE FEASIBILITY OF THE ADOPTION OF LARGE-SCALE ADDITIVE MANUFACTURING (LSAM)

The shipping industry is a critical pillar of the global economy, with about 90% of all globally traded goods, from oil and steel, to furniture and iPhones, ferried around the world by sea. To move all of those goods, merchant ships burn approximately 300 million metric tons of dirty fossil fuels[(1)] each year, emitting roughly 1 billion metric tons of carbon dioxide[(2)] in the process, which is roughly equivalent to the annual carbon emissions of Japan.[(3)] MariLight is a feasibility study which aims to lightweight ship structure to reduce CO2 emissions and hence make the industry cleaner for the environment.

The expected outcomes from MariLight include a potential 13% vessel weight saving, which would in turn deliver global fleet savings of 7.7m tonnes of steel, over 90% manufacturing lead time reduction, 60% production fuel/energy savings and 20% reduction in production time. "Lightweighting" also addresses challenges associated with the introduction of revolutionary green propulsion solutions by reducing the total power required to propel a vessel, whilst improving efficiency and increasing its range.

The project team, composed of experts from consortium partners Malin Group, Altair Engineering, BAE Systems, Lloyd's Register, and the National Manufacturing Institute Scotland (NMIS), believe that the adoption of Large-Scale Additive Manufacturing (LSAM) will propel the marine fabrication industry towards advanced manufacturing. Topology optimisation is the process that spatially optimises material layout within a given 3D geometrical design whilst fulfilling required constraints. The ability to fabricate complex designs using LSAM will move the industry from conventional fabrication that requires labour-intensive, manual work, to an automated, more resilient, and flexible manufacturing route that lends itself to topology optimisation. The project will also develop a robust business case and cost analysis that quantifies the expected risks and opportunities associated with the transition to LSAM, and will capture the benefits in terms of costs, times, processes, and emission savings. One of the major obstacles to the adoption of printed marine components is the lack of clear rules and regulations regarding LSAM parts; project partner Lloyd's Register will develop a regulatory framework as part of MariLight to address this. The project seeks to create a cleaner, more sustainable fabrication solution for the shipping industry.


Source: (1), (2), and (3) 'The shipping industry faces a climate crisis reckoning – will it decarbonize? | Environment, ' The Guardian, November 2021

# MARILIGHT PARTNERS

**MARILIGHT BRINGS TOGETHER A HOST OF PARTNERS, LED BY MALIN MARINE CONSULTANTS, TO DELIVER THIS INNOVATIVE STUDY**

Underpinned by a wealth of expertise and knowledge, and a presence in the marine industry stretching back over 100 years, Malin Group offers a comprehensive range of services and capabilities focusing on marine technology and marine innovation. Malin Group offer seamless support to clients across the full range of design consultancy, marine operations and shipping, installation, and site maintenance services. Malin Group's contribution to MariLight consists of managing the project, involvement in supplying robust information of in-service vessels, and conducting a vigorous business case focusing on cost modelling, $CO^2$ emissions, energy consumption, market analysis, and project outcomes.

The National Manufacturing Institute Scotland (NMIS) focus on industry-led manufacturing research and development facilities with a network of partners across Scotland brought together to boost the manufacturing community. NMIS aim to revolutionise skills, productivity, and innovation to help attract investment and make Scotland and the wider UK a global leader in advanced manufacturing. NMIS's role in MariLight is to deploy large-scale additive manufacturing, and automation in delivering lighter and more sustainable components for marine vessels.

Altair Engineering have a simulation-driven approach to innovation which is powered by an integrated suite of software which optimises design performance across multiple disciplines including motion, fluids, and system modelling, while also providing data analytics and true-to-life visualisation and rendering. Altair's contribution to MariLight is to develop optimised structural designs of ship components for LSAM. This includes analysis of design requirements and creation of an optimised design which was coupled with large-scale additive manufacturing processes to produce an innovative structure.

Lloyd's Register is a global professional services company specialising in engineering and technology for the maritime industry. Lloyd's Register's Marine and Offshore business is a leading provider of classification and compliance services to the marine and offshore industries. Lloyd's Register contribute to MariLight by regulatory assessment, selecting the current appropriate standards and guidelines, and overlooking the new methods of design and manufacture to create a guide to certification.

World leading defence contractor, BAE Systems, provide some of the world's most advanced, technology-led defence solutions. BAE Systems develop, engineer, manufacture, and support products and systems to deliver military capability, protect national security, and keep critical information and infrastructure secure. BAE Systems role in MariLight is to offer support and advice with their huge amount of shipbuilding knowledge.

# OUR PROJECT MILESTONES

## JANUARY 2023

**Award and Project Kick off**

The consortium consisting of Malin, Altair, NMIS, Lloyd's Register, and BAE Systems are awarded support through the CMDC2 competition, with funding of £250,000.

## FEBRUARY 2023

**Component Selection**

In the early stages of the project, an important phase was to consider a range of ship parts and structures and their eligibility for the project. This stage ensured a component with the potential for lightweighting was selected.

## APRIL 2023

**Design Analysis and Topology Optimisation for Weight Saving**

After the component evaluation stage, three structures which are currently used on ships were selected. This included a windlass foundation, bilge pump foundation, and bulbous bow. Altair then analysed the conventional designs and optimisation was carried out with the relevant boundaries of loads and impacts in place. The new designs show between 24% to 53% weight saving as well as some desirable increases in aspects including structural strength.

## JUNE 2023

**Wall Printing and Material Testing**

The welding wire material was chosen and NMIS printed a wall to allow for material testing to be carried out for verification of the material properties.

**Test Part Printing and Testing**

To allow for testing, the critical region (section identified to hold the most stress when loads are applied) was printed and destructive testing carried out, allowing for Lloyd's Register to evaluate the results, make comments and inform the framework for certification.

## AUGUST 2023

**Regulatory Framework Complete**

Lloyd's Register created a regulatory framework for Large-Scale Additive Manufacturing to be used on ships.

## SEPTEMBER 2023

**Project ends and successor project considered**

Project ends and a follow-on proposal of MariLight is created.

**Printing of the Final Demonstrator (Scaled) & Final Report**

NMIS print the final demonstrator and production of the final report, documenting all activities, business case, cost modelling, and conclusion for the feasibility project.

# MARILIGHT: OUR OUTPUTS & IMPACT

## THE PROJECT HAS A NUMBER OF KEY DELIVERABLES, EACH WITH A MEASURABLE IMPACT

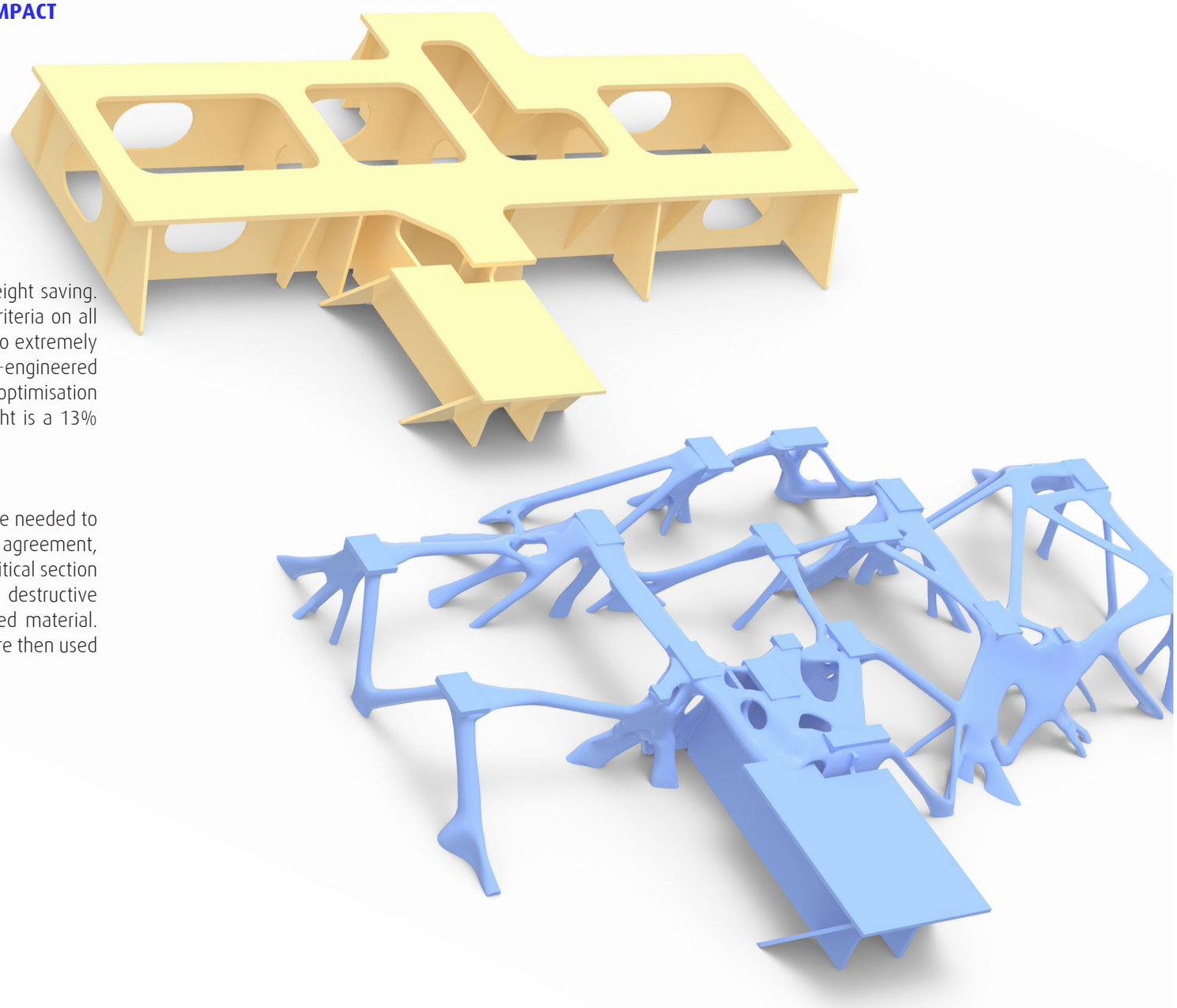
1. Validation of topology optimisation in providing weight saving
2. Validation of Large-Scale Additive Manufacturing (LSAM) material properties
3. Demonstrate viability of printing scaled marine structures
4. Establish regulatory approval framework
5. Evaluate commercial viability
6. Develop follow-on work package

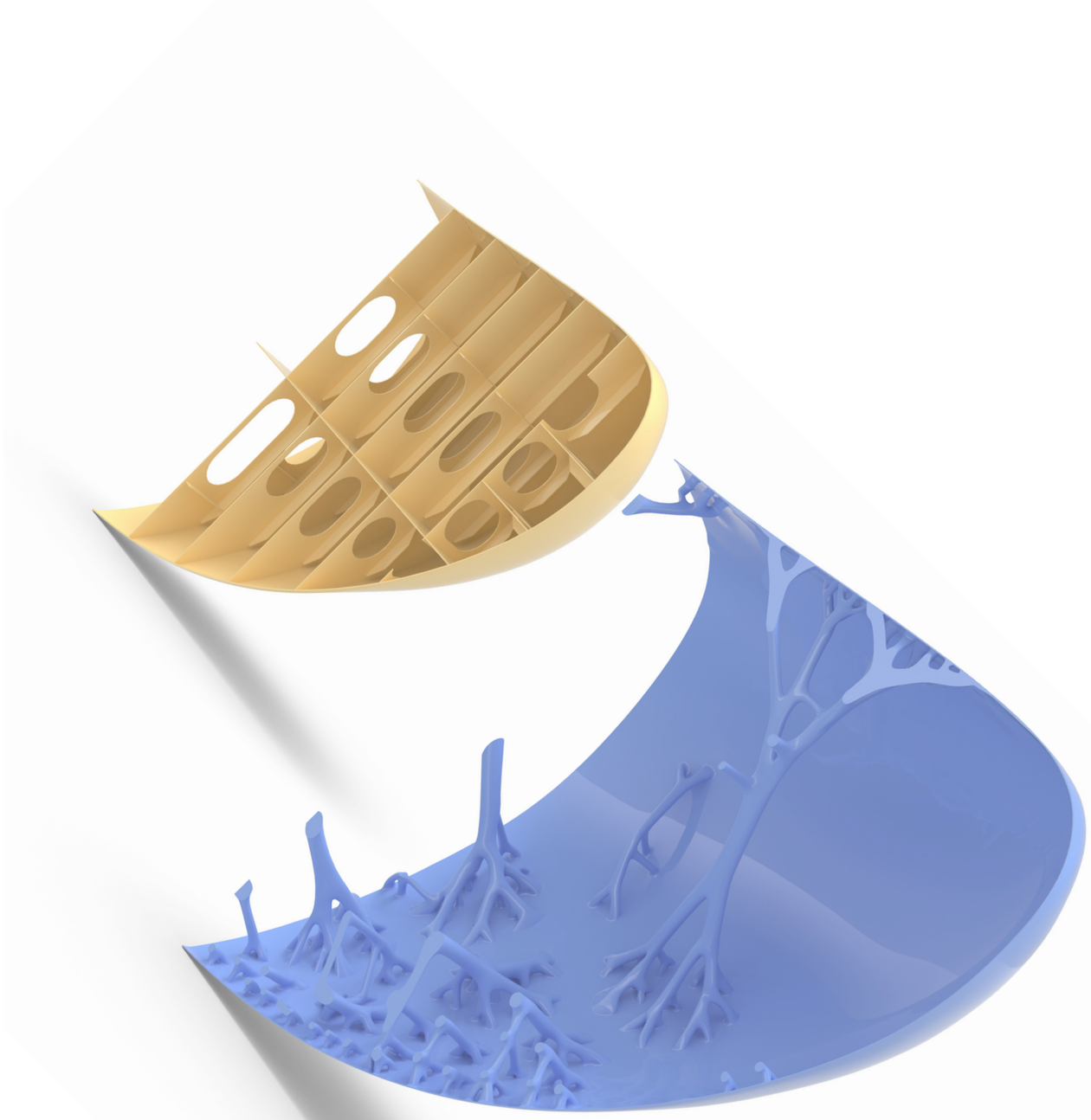
**Validation of Topology Optimisation**

Altair Engineering used their advanced software to create topology optimised designs for weight saving. To carry out the optimisation, an agreement was made on the load cases and acceptance criteria on all structures being evaluated before being optimised. The method of topology optimisation led to extremely impressive results which range from 24% weight saving for a bilge pump seat and 38% for a re-engineered bulbous bow, through to a 54% saving for a free-size optimised windlass foundation. If topology optimisation is applied on other ship components and structures, the potential impacts on the ship weight is a 13% reduction of a ship overall structure.

**Validation of Large-Scale Additive Manufacturing (LSAM) Material Properties**

For Lloyd's Register to be able to consider an approval process for an LSAM produced part, there needed to be a consensus on the material properties, both expected and achieved. In order to reach this agreement, NMIS developed an integrated test plan involving two printed parts; a thin wall section and a critical section of the demonstrator part. Test coupons were extracted from the printed parts and sent for destructive testing in accordance with that plan and to establish the mechanical properties of produced material. These tests were witnessed by LR as required, and both the results and the lessons learned were then used to inform the approval process.





**Establish Regulatory Approval Framework**

Lloyd's Register has developed a draft regulatory approval process for marine components fabricated using additive manufacturing which covers full design-production-installation cycle. This framework to certification is both a huge and necessary step for the marine industry as we move towards the installation of approved LSAM components on vessels.  LR intends to develop this into a formal, approved process.

**Evaluate Commercial Viability**

A robust business case was produced which evaluates the commercial aspects of these LSAM developments, including a cost model and environmental impact assessment. The team carried out a lifecycle analysis, comparing traditional shipyard manufacturing and new LSAM methods and the results will be used to demonstrate the environmental benefits of moving away from traditional manufacturing processes.  This work is still in progress, but early results suggest that adoption of LSAM in marine fabrication facilities could deliver emission savings of more than 95%, and this is before the through life emissions savings that are estimated at 20%, resulting from the 13% decrease in lightship weight.

**Develop Follow on Work Package**

MariLight is a feasibility study which has, to date, discovered that there are significant benefits to be achieved by transitioning from traditional marine fabrication methods to large scale additive "printing" processes. The project has also identified a series of barriers to widespread adoption, and these will have to be addressed before we see the industry move forward with LSAM technology.  The team has developed a proposal for a follow-on project that will address these obstacles and enable further work, designed to understand and address issues across a range of areas, including finishing of LSAM-produced parts, topology optimisation process documentation, investment cases, and in-service repair and testing. The follow on project is expected to pave the way for the commercial adoption of LSAM in the marine industry.