NATIONAL CENTRE ADDITIVE MANUFACTURING

mtc Manufacturing Technology Centre

esa

→ ESA AMBC NEWSLETTER #1 DECEMBER 2018

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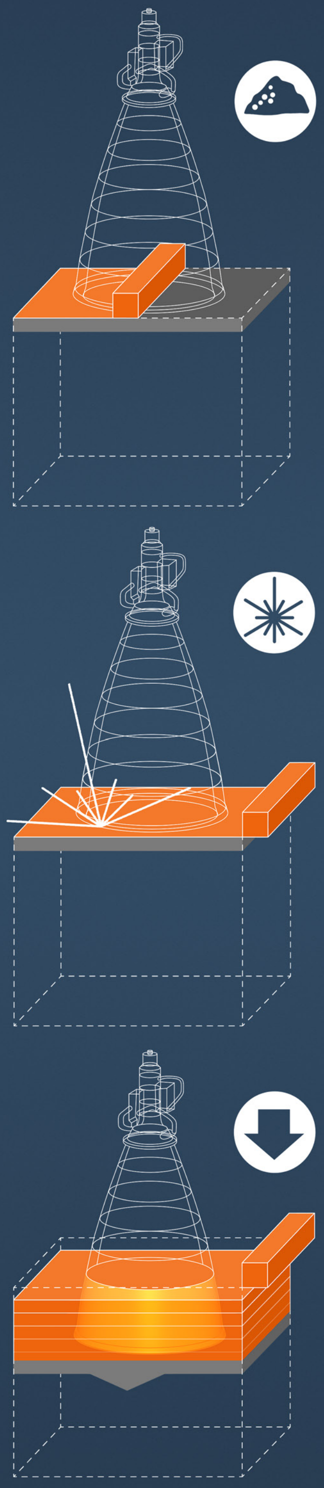
In August 2016, ESA issued a competitive invitation to tender for a Space Additive Manufacturing Benchmarking Centre (AO/1-8738/16/NL/LvH). Among others, a bid was placed by the Manufacturing Technology Centre (MTC) in partnership with The Welding Institute (TWI), Magna Parva, and the Science and Technology Facilities Council Rutherford Appleton Laboratory.

After proposal evaluation this consortium was awarded the contract and the ESA additive manufacturing benchmarking centre (AMBC) was established in May 2017 led by the MTC in Coventry, UK. ESA was guided to set up this centre, with customers and industrial partners questioning them about the best way to explore 3D printing for the first time and examine the maturity of the results for their specific needs and applications. The AMBC provides a simple and easy way for ESA projects and hi-tech companies to investigate the potential of 3D printing for their work.

The idea is that ESA missions and interested companies can investigate this new engineering world up to the point where they can take a decision whether to adopt this technology or not. If the decision is positive, then they can mature the technology further and even in non-space markets and applications, counting on the support and expertise of this centre of excellence. As the UK National Centre for Additive Manufacturing, the MTC is in a unique position to work with ESA as their AMBC and provide the space sector access to state-of-the-art production capabilities and competence to support industrial exploitation. Newsletters are published twice a year to provide an update of the work carried out for the benefit of the space sector. The three projects included in the current issue are: #1 Additively Manufactured ring for International Berthing Docking Mechanism (IBDM), #2 Additive Manufacturing of Hybrid IN718 Parts, #3 Additive Manufactured Copper Materials for Launcher Engines.

A website covering the work of the AMBC can be found here:
http://ncam.the-mtc.org/who-we-are/esa-am-benchmarking-centre



→ ADDITIVELY MANUFACTURED RING FOR INTERNATIONAL BERTHING DOCKING MECHANISM (IBDM)

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Collaborators: **The Manufacturing Technology Centre (MTC), Magna Parva, Cranfield University**
Start Date: **August 2017**
Anticipated Completion Date: **May 2019**

The International Berthing and Docking Mechanism (IBDM) is the European docking mechanism compatible with the future International Space Station (ISS) US Orbital Segment (USOS) docking ports. The IBDM (original component shown in Figure 1) captures the vehicle flying to the ISS and it dampens the residual relative motion between the vehicle and the ISS. Once captured and dampened, the IBDM provides a structural pressurised connection between the vehicle and the ISS. The IBDM also allows berthing of a vehicle to a compatible ISS port by the ISS robotic manipulator. The IBDM consists of the Soft Capture System (SCS) that captures the spacecraft and actively dampens relative motion and misalignment, and the Hard Capture System (HCS) that provides the structural connections and carries the service connections. This project aimed to demonstrate the added value of 3D printing by manufacturing a 1:1 model of the SCS ring integrated with the petals that are part of IBDM ring, by the Wire-Arc Additive Manufacturing (WAAM) process. Introducing the roles of the partners involved in this project, Magna Parva established the product assurance requirements for space environment and monitored the product validation process of the SCS ring; MTC is responsible for co-ordinating the design optimisation of the SCS ring for the WAAM process, validation of design and the final machining of the part; and Cranfield University (CRAN) is responsible mainly for manufacturing of the SCS ring by the WAAM process.

The main objective of this project is the redesign of the IBDM SCS ring to improve the overall performance in terms of reduced mass, manufacturing cost and delivery time with minimal impact on the environmental and mechanical performance. The titanium alloy Ti6Al4V was the selected material for this work (the original component was manufactured using aluminium alloy Al7075). The design optimisation task has been completed and it is in the final stages of getting design and drawings ready for manufacturing.

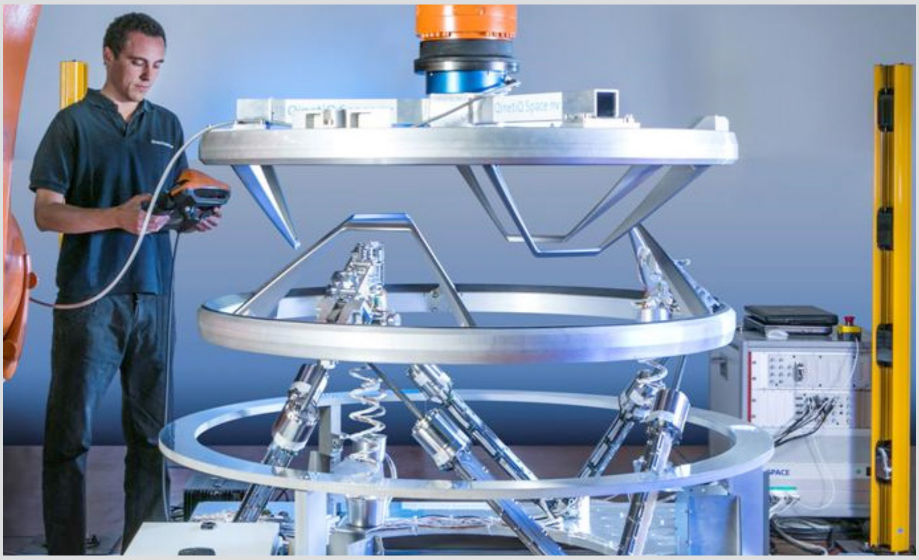
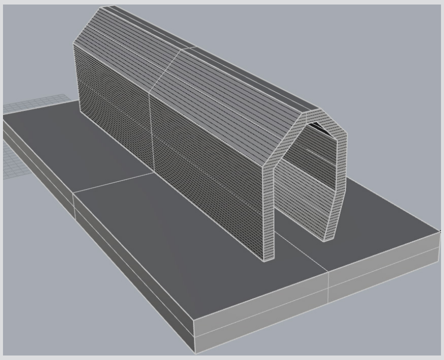


Figure 1
IBDM SCS System Ref: QinetiQ

Cranfield University has finished the preliminary initial raw material and coupon testing covering tensile & hardness testing only (after stress relieving heat treatment and in as-built condition) and is currently working on optimising the manufacturing strategy for the trial representative ring sections, the 1/3rd of a ring and the full final ring. Figure 2 shows the outcome of the first of these tasks.

The Manufacturing Readiness Review (MRR) took place in April'18, where the optimised design of IBDM ring by MTC and WAAM approach prepared by CRAN was reviewed by ESA. Figure 3 shows the result of the design optimisation task and final CAD geometry through topology optimisation. A weight reduction of 15% has been achieved as compared to the current design manufactured by traditional fabrication methods and mechanical joining. The ring and petals were designed as an integrated part, which illustrates an additional benefit of part consolidation by using AM along with weight reduction.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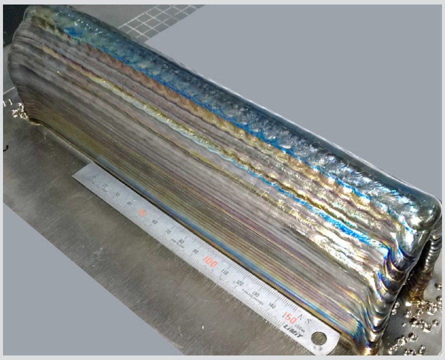
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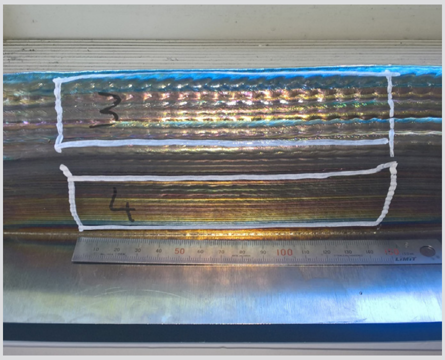

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Figure 2a
Trial representative geometry: CAD of section

Figure 2b
Trial representative geometry: Section manufactured by WAAM

Figure 2c
Trial representative geometry: Tensile specimen extraction locations

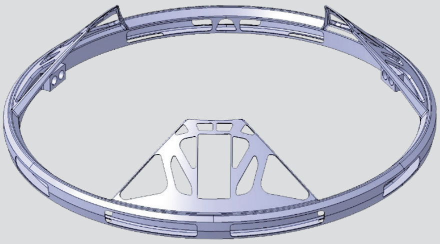

Figure 3
Optimised geometry of SCS ring

→ ADDITIVE MANUFACTURING OF HYBRID IN718 PARTS

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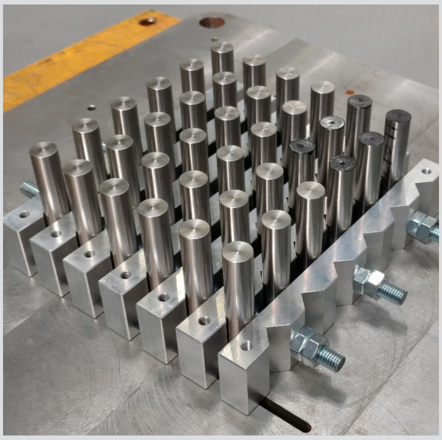
Start Date: **October 2017**
Completion Date: **February 2018**

This project was a feasibility study investigating the combination of laser powder bed fusion (LPBF) additive manufacturing (AM) and traditional manufacture into a "hybrid" manufacturing process. AM is often well suited to complex geometries and traditional manufacture is more suitable for simple geometries, with parts often consisting of regions of low and high complexity. This opens up opportunities for a hybrid process that incorporates both traditional and AM techniques, ultimately leading to cost and lead time reduction.

For the purposes of the feasibility study, simple IN718 bar geometries were used; extruded bar to represent a traditionally manufactured structure, extended with a LPBF bar built on top. These were intended to be post machined into tensile test samples to investigate the interface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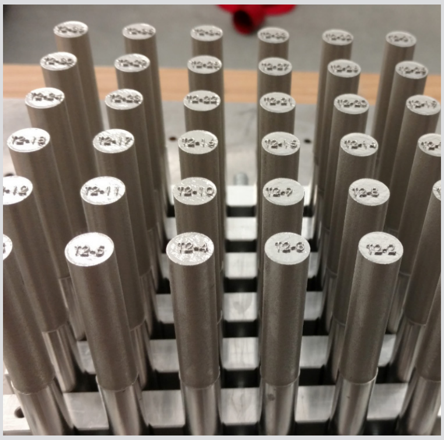
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Figure 4a
Bars fixed in mounting jig before AM process

Figure 4b
Bars mounted on build plate after successful AM build

between the extruded and AM parts. The EOS M400-4 quad laser LPBF machine was selected to create the samples which had validated parameters for IN718 at the MTC. This machine possesses no native ability to fix or locate pre-existing parts in the build chamber, so a standard build plate was modified to hold a mounting jig to clamp the extruded IN718 bars upright in a measurable and repeatable position in the build chamber. Tight tolerances were required and optical metrology was used before the build in order to accurately measure the positions of the bars on the build plate and position the CAD for the AM build. The extruded bars themselves were parted off from a single longer piece and machined to equal height above the build plate to a tolerance of ±5 µm. This was to ensure a consistent coating of powder on all the bars in the build and avoid recoater blade collisions. Each build consisted of 36 bars, and two builds were carried out. Images of the mounted bars both before and after the AM build are shown in Figure 4.

The new manufacturing technique was found to be successful at creating hybrid parts, with analysis from ESA showing a fully dense, fused interface between the extruded and AM bars. CT analysis conducted by ESA is shown in Figure 5. Accurate placement of base structures in the build chamber was found to be essential. In this project, a metrology step was required because the LPBF machine possessed no locating ability itself. In addition to accurate placement on the build plate, the 10 µm bar height range tolerance was found to be effective in ensuring consistent powder coverage. A number of further investigations are possible as a result of this work. Firstly, the same tests could be repeated for additional materials and processes; both additional LPBF machines and other types. Once mechanical testing is complete on the IN718 bars created in this project, further work could take place in other areas, such as process parameter optimisation and part design. This would involve the selection of appropriate parts that might benefit from this process and their redesign in order to fully exploit its benefits, as well as suitable means of attaching a more complex part to the build plate.

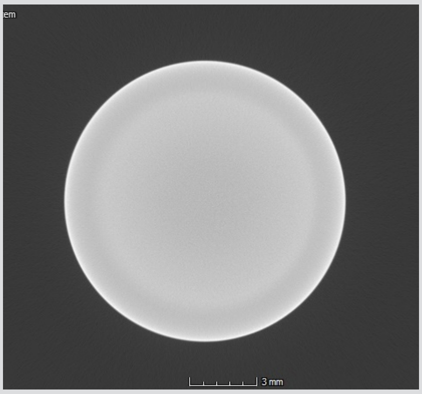

Figure 5a
CT image showing Radial cross-sectional view of AM bar to extruded bar interface (b) Axial cross-sectional view of AM bar to extruded bar

Figure 5b
CT image showing Bars mounted on build plate after successful AM build

→ ADDITIVE MANUFACTURED COPPER MATERIALS FOR LAUNCHER ENGINES

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Collaborators: **The Manufacturing Technology Centre (MTC), Fraunhofer Institute of Laser Technology (ILT)**
Start Date: **February 2018**
Anticipated completion date: **October 2019**

This project is a feasibility study for manufacturing of Thrust Chamber Assembly (TCA) liners, which are commonly produced with copper alloys, using additive manufacturing.

Liquid propulsion for launchers often requires rather complex TCAs, commonly produced of copper (Cu) alloys and reinforced with high-strength materials. Production of these components through traditional manufacturing techniques is considered challenging and incurs significantly high cost and lead time, a case study where AM technologies can provide great added value. The specific AM technology being used for this work is laser powder bed fusion (LPBF) using Cu. In this study, a new design for the TCA liner will be proposed by ESA and MTC.

The design work will consist of design for improved performance, taking advantage of the geometric design freedom that AM provides, whilst also considering design for manufacture, with the geometry being constrained by the design rules of the LPBF process, such as minimum feature size / wall thickness, overhangs, surface roughness, and material properties. Finite element (FE) modelling techniques will be used to analyse the structural and thermal performance of the TCA liner. The material property data used in the analysis model will be based on the data extracted from mechanical testing of samples built by the same process as the TCA liner. Fraunhofer ILT will use LPBF to build samples, cut-outs and sub-scaled TCA liners out of Cu alloys (example shown in Figure 6) to investigate the applicability of such processes for liquid launcher propulsion systems. The LPBF system to be used in this work is a modified Trumpf TrumaForm system at ILT, which is suited to the needs of Cu processing. Process parameters for Cu alloys have to be optimised due to its high thermal conductivity and low absorptivity (depending on laser wavelength used).

After selection of the optimised process parameters, test samples will be manufactured for tensile, low cycle fatigue and creep testing. These samples will be tested at room and elevated temperatures and the results will be fed into the design work. In order to assess manufacturability of crucial features including cooling channels and overhangs, cut out sections, a TCA liner downscaled to 75 mm in height and a complete sub-scaled TCA liner with the height of 200 mm will be manufactured.

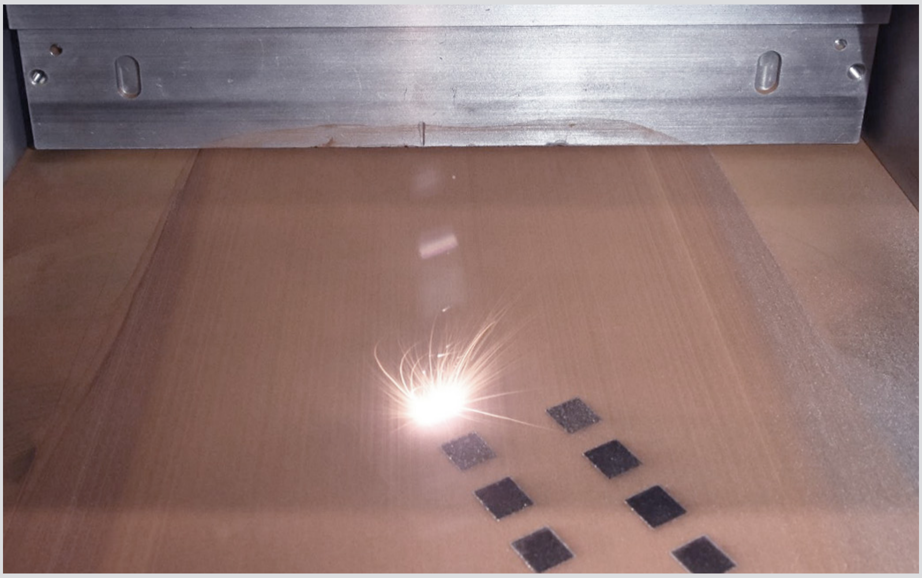
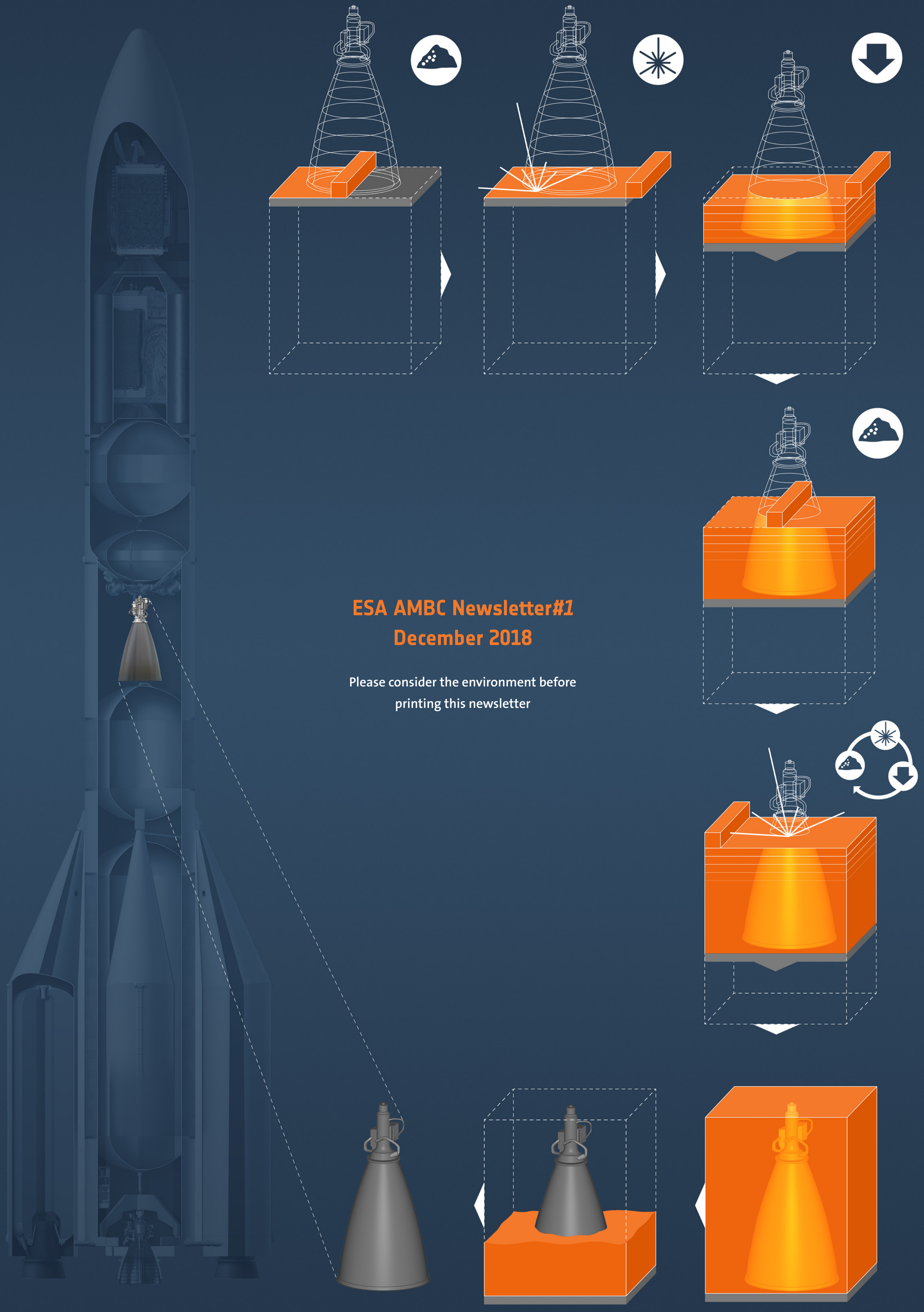


Figure 6
Example of LPBF process for Cu alloys at Fraunhofer ILT



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