# Additive Manufacturing in Military Support – A Defence Logistics Concept Note

## What could the future Defence Support Network look like?

The vision is for a strategically prepared, globally responsive and operationally precise Defence Support Network (DSN). This requires the network that delivers discrete Support functions to be agile, retain a high degree of real-time asset visibility, and hold the capacity to move mass at various operational scales. This must be done over several strategic distances within short timescales, and in accordance with the extant policy-driving demand signal. The network will be distribution-based with information replacing inventory to minimise the need for stockpiles which will result in only a small deployed footprint and will be enabled further by interoperability between the UK military, its industry and its international partners. The network will exploit its digital backbone, connecting people, machines and information to provide accurate situational awareness across the whole network. This will enable effective and timely Command and Control (C2) and allow for informed decision-making at all levels which will reduce the number of nodes, points of friction and human/manual input and activity as far as practicable.

## What does Additive Manufacture (AM) include in Military Support terms?

Additive Manufacturing is a subset of Advanced Manufacturing which uses computer aided design to drive manufacturing machines to add material layers to form structures. Due to the process, it allows more complex shapes to be delivered at a reduced cost compared with reductive manufacturing. Depending on the machine and material, Additive Manufacturing can be conducted for parts manufacture but also for buildings, electrical, munitions and biological material. In support terms, it therefore has applications across the full range of activities within the Defence Support Network enabling a reduced footprint, demand and cost while contributing to increased velocity. This note will consider all elements of the network except medical adoption due to the specialist nature of this field.

## An AM-enabled Defence Support Network of the future.

The Support Network of 2035 has embedded Additive Manufacturing throughout all levels and platforms. The adoption of the technology has enabled major platforms to have their design evolved for greater efficiency and resilience. This has resulted in redesign for strength and lightening creating parts from metals, composites and plastics. The strategic benefits of this are greater efficiency of platforms extending duration, reduced running costs and reduced fatigue. These lighter, stronger and more resilient platforms are performing across all domains.

The rapid projection of forces is achieved every time, with Additive Manufacturing enabling less material needing to be moved over the coupling bridge, with less variance in the support chain deployments are not only faster but easier to partner with other forces following the NATO adoption of AM standards allowing for shared print stock supplies being converted into sovereign spares once deployed. Additionally, the volume of material being shipped by the military has reduced because of the adoption of recycling printing capabilities and the purchase of print stock being delivered to the Joint Operational Area commercially, much as fuel is done today. This will further reduce the demand on the strategic projection assets increasing the speed of deployment.

Theatre enabling will benefit from Additive Manufacturing and in 2035 there will be fewer locations needing to be established due to the smaller storage requirement as ‘E-spares’ will

predominate. These will be digitally stored at printing sites within the deployed manufacturing laydown. This will complement the distribution network and will have a layered approach with complex to simple printing being undertaken based on the mobility of forces required. This approach enables the full range of metals, composites and plastics to be made near the point of need and provides a level of immediate support for forces. The pairing with the distribution network also allows for delivery to be enabled as expeditiously as possible generating greater availability in platforms. The use of recycling further reduces the need for new print stock as the broken parts can be recovered and turned back into print stock, further reducing the demand on the Strategic Base. The in-load to theatre will have used containers, pallets and boxes to move the ranges of equipment however, these will be collected and recycled into the print stock required for the initial phases of the operation. Avoiding the need for further stores to be moved into theatre before operations can begin and making the cost of deployment cheaper through waste management contract changes.

The Joint employment of Additive Manufacturing enables the efficiencies of scale to be realised at printing facilities. This enables some platforms to benefit from a few parts from AM while others are mainly constructed using the process. This creates a reduced cost per part but also has enabled the technology to be adopted sooner with the defence view. Furthermore, in the printing centres the Whole Force has enabled industrial partners to embed supporting the delivery, redesign and rapid modification of equipment's to meet emerging threats in the theatre. This relationship with industry has also enabled the development of the accounting and financial elements of AM supported by smart contracting the pay per print principal and digital twin assurance processes are supported by the excellent information management trained support personnel. The challenges of treasury rules and intellectual property have been resolved with the adoption of the new IT systems.

Within the Services AM has enabled reduced spares to be organically carried improving the dispersal and support reliance. Major platforms are tailored to the crews and specific operations while the formations experience shorter delivery times over the 'last mile'. AM has enabled more availability and less diversion increasing the productivity of forces. Furthermore, AM has enabled new maintenance techniques enhancing BDR and providing maintenance units the opportunity to combine for major assembly repair and manufacture swarming printers within the formation. Shortages of ISR have been reduced with the ability to manufacture drones on demand and the ability to print explosives has enabled operation specific munitions. Obsolescence has been removed as a challenge and the operation of equipment extended to meet operational need.

**Supporting benefits hypotheses**

The future use of AM, as described in this Concept Note and compared to current practices, relies on several hypotheses which require verification. It is therefore expected that for the following areas AM will:

**Velocity**

- Speed of parts delivery will be improved by pairing distribution and manufacturing nodes.
- Speed of modification to equipment's with be increased.
- Improved obsolescence resolution.
- Notice to Effect will be shorter because less spares need to be moved.
- Delivery times for parts will be reduced.

**Reduced Cost**

- Storage of spares will be reduced and change to increase ‘E-spares’.
- Transportation of print stock will be largely removed from the coupling bridge because it can be purchased and delivered to the JOA.
- Waste disposal will be reduced as items are redesigned for recycling.
- Recycling will enable new packaging to be developed and reused.
- Major equipment’s will spend less time out of use due to awaiting spares and undertaking logistics related tasks.

**Reduced Footprint**

- Variance in support chain will be reduced and enable greater interoperability with allies.
- Stock holding sites will become smaller therefore easier to move and manage.
- NATO Logistics support chains will use print stock and manufacture sovereign items near point of need.
- Redesign of platforms will further enable reductions in weight and operating costs while increasing endurance and reducing fatigue.

**Wider Benefits**

- Reduced demand on the strategic base.
- Greater whole force interaction with smart contracting.
- Quicker prototyping and adoption of modifications.
- Ability to swarm will enable: printing at speed or the manufacture of many items at the same time. (these could be offensive in nature to enable force mass or reduce porosity of ISR - UAV).

## Assumptions

The use of AM as described in this Concept Note will require the following assumptions to be realised:

- Adoption of material standards will be agreed by the Military to enable adoption and certification. As machines and printing methods develop the materials will remain qualified.
- The Military will seek to operationalise Plastic, Metal, alloy and composite materials.
- Adoption will take place in phases. 1st non-safety critical items through to airworthiness cleared parts.
- IPR management and part numbering will be addressed to enable billing and management.
- Defence prime early adoption will be encouraged within platform design / re-design.
- Policy will be written to enable changes for HMG and Defence.
- Digital improvements will enable systems and storage of E-spares and maintain the digital twins for assurance and security. With personnel being trained to meet these new requirements.
- The technology will be adopted by maintainers into main platforms through DE&S procurement.
- parts will be treated as any other part with different serial numbers and NSN?
- AM will have both Joint and sS adoption under a Defence Programme.
- Accounting for Tax purposes has been established to enable AM production away from the UK and imported parts brought home with no penalty.

**Current evidence – supporting examples**

Many elements of the DSN of the future already exist within commercial organisations or are being developed around the world by industry, academic institutes and militaries. Examples include:

**3D printing for airliners**. Airbus are currently developing 3D printed components for its upcoming A350 with around 2700 plastic parts already being produced for the aircraft whilst they work with the European Aviation Safety Agency to qualify titanium components produced through AM. Amongst this are more than 1000 parts which were only available for production using the technique, creating new lightweight parts, to airline safety standards, to reduce both production time and associated costs. With Airbus' collaboration with Materialise to produce 3D printed parts in the cabin, the company saw a 15% reduction in material weight in some parts. The use of the technology also reduced the lead time for part production, the delivery of small batch and customised parts, and the development of complex internal structures at no additional cost.

**Obsolescence management**. The US Air Force has recently sought to develop its 3D printing technology through its Air Force Research Laboratory in partnership with Renaissance Services, Inc. In a $2.9 million deal they have committed to integrating 3D printing into their legacy aircraft maintenance program by using ceramic tooling to develop aerospace grade parts. The project, titled RECHARGE, combines ceramic 3D printing with traditional casting methods to produce legacy unsupported part to ensure older aircraft remain flying. This has been found to reduce component lead time by up to 90% printing directly from a component CAD file and has included work on the F-16, A-10 and C-130.

**Infrastructure**. The use of 3D printing for buildings is becoming a reality with companies like BatiPrint developing a 3D printing method to build social housing by printing with expansive foam and concrete up to height of 7m. The USMC have started building barracks from concrete using 3D printing and WASP are working on sustainable 3D printing through its project BigDelta which eventually aims to extrude straw and earth allowing for buildings to be made from naturally sourced materials. Even NASA have recently funded competitions to assess the viability of a 3D printed habitat for use in space as part of the 3D-Printed Habitat Centennial Challenge. This saw teams submit proposals on how they could create 3D printed buildings on other planets and is scheduled to culminate in one-third scale printed habitat as proof of concept.

**Reduction in running costs**. One of the greatest benefits to AM is the reduction in running costs and this has already been seen through the USMC production of a 3D printed part for the the F-35 which saves $70,000 in costs per jet. The printed part, which was part of the landing gear door, could not be bought separately resulting in the requirement to procure the larger part at a greater cost but was instead printed for only 9 cents. Recycling also provides the opportunity to reduce the logistics footprint by reusing basic products and the USMC are already demonstrating this with shredders and granulators to develop 3D parts from recycled bottles.

**Additional activity**. In addition to the benefits above 3D printing is already being used to print tissues with blood vessels, low-cost prosthetic limbs, drugs, replacement bones, heart valves and ear cartilage to better assist the medical supply chain, and low-level drones and UAVs, amongst other objects.

**Future planned activity**

Efforts should aim to prove or disprove the benefits hypothesis included in this note to inform work which will build increased use of Additive Manufacture throughout the DSN over three timeframes:

**Near-Term (0-2yrs):**

- Develop the Defence Strategy for adoption and further demonstrators.
- Increase awareness of Support, Commercial and Design teams of the technology.
- Develop Defence Standards for materials to enable adoption.
- Enable/request current Primes to increase adoption of AM on current platforms.
- Seek new platform design to include adoption of AM.
- Study the Defence inventory to discover what can be printed now.
- Seek to increase the range of items than can be produced through AM.

**Mid-Term (3-5yrs):**

- Start to develop AM capabilities for employment in the deployed space
- Align with distribution doctrine and seek standards for movement including RAS.
- Redesign current systems to enable greater adoption of AM materials.
- Deploy AM capabilities on exercise and provide operator assurance.
- Introduce recycling of polymers.
- AM into core training for all support trades, including information management.

**Long-Term (5-10yrs):**

- Maintain AM capabilities within the force structure.
- Deploy on operations.
- Introduce recycling of metals.
- AM friendly platforms into service.

**Further reading**

More detail on the use of AM in both a military and civilian context head to these websites:

- ‘Adding value with 3D printing’ - https://www.aero-mag.com/airbus-a350-xwb-a320-neo-3d-printing-aerospace-sector-stratasys-ultem-9085-fused-deposition-modelling-fdm/

- ‘Airbus had 1000 parts 3D printed to meet deadline’ - https://www.bbc.co.uk/news/technology-32597809

- ‘3D printing sees Airbus reduce material weight by 15%’ - https://www.themanufacturer.com/articles/airbus-reduces-material-weight-15-due-3d-printing/

- ‘$2.9M 3D printing contract recharges US Air Force legacy planes’ - https://3dprintingindustry.com/news/2-9m-3d-printing-contract-recharges-u-s-air-force-legacy-planes-127955/

- 'Top Five Teams Win a Share of $100,000 in Virtual Modeling Stage of NASA's 3D Printed Habitat Competition' - https://www.nasa.gov/directorates/spacetech/centennial_challenges/3DPHab/five-teams-win-a-share-of-100000-in-virtual-modeling-stage

- 'The 11 best 3D Printed House Companies – 3D Printing Entire Buildings' - https://www.3dnatives.com/en/3d-printed-house-companies-120220184/

- 'The Marines Printed a Concrete Barracks' - https://www.popularmechanics.com/military/research/a22877745/the-marines-3d-printed-a-concrete-barracks/

- 'World's First Class Approved 3D Printed Ship's Propeller Unveiled' - https://www.damen.com/en/news/2017/11/worlds_first_class_approved_3d_printed_ships_propeller_unveiled

- '6 Ways to Cut Costs with Industrial 3D Printing' - https://www.protolabs.co.uk/resources/design-tips/cutting-costs-with-industrial-3d-printing/

- 'US Marines 3D print F-35 part which will save $70,000 in costs per fighter jet' - https://www.3ders.org/articles/20180821-us-marines-3d-print-f-35-part-which-will-save-70000-in-costs-per-fighter-jet.html

- 'Higher Performance 3D-Printed Bionic Propeller' - https://www.cadmicro.com/storage/pdfs/whitepapers/Bionic-Propeller_eBook.pdf

- '12 things we can 3D print in medicine right now' - https://3dprintingindustry.com/news/12-things-we-can-3d-print-in-medicine-right-now-42867/

- 'Manufacture of an Unmanned Aerial Vehicle (UAV) for Advanced Project Design using 3D Printing technology' - http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.871.6745&rep=rep1&type=pdf

- '3D Printed Drone Parts – All You Need to Know in 2019' – https://all3dp.com/3d-print-drone-parts/

- '3devo recycles 3D printed plastics with Shred It technical specifications and pricing' - https://3dprintingindustry.com/news/3devo-recycle-3d-printed-plastics-with-shr3dit-technical-specifications-pricing-107423/

- 'US Army is Recycling Plastic Bottles for 3D Printing' - https://all3dp.com/us-army-recycling-plastic-3d-printing/

The following documents were also used to shape this Concept Note:

- '3D Printing and the Future of Supply Chains: a DHL perspective on the state of 3D printing and implications for logistics' - http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_trendreport_3dprinting.pdf

- ‘Additive manufacturing: mapping UK research into 3D printing’ - https://www.gov.uk/government/publications/additive-manufacturing-mapping-uk-research-into-3d-printing

- ‘Additive Manufacturing UK National Strategy 2018-25’ - https://am-uk.org/additive-manufacturing-national-strategy-sets-establish-uk-world-leader/

- ‘Just do it…yourself: Implementing 3D Printing in a Deployed Environment’ - http://www.dtic.mil/dtic/tr/fulltext/u2/1042209.pdf