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Perspective

Expert insights on a timely policy issue

Additive manufacturing and obsolescence management in the defence context

Edited by Jon Freeman and Giacomo Persi Paoli

Foreword

The concept of obsolescence in the industrial sector has many facets that can be summarised in the general definition provided by the International Institute for Obsolescence Management (IIOM): obsolescence is the unavailability of parts, or services, that were previously available (IIOM 2015).

The need to understand, plan and mitigate obsolescence (i.e. obsolescence management) is particularly relevant in the defence sector where traditional long lead times are combined with expected life-cycles in the order of decades.

In this context, the improvement of additive manufacturing (AM) techniques has generated a lot of interest within the industrial sector, as well as in the end users' community, as a potential powerful new tool for treating some aspects of obsolescence.

By building up objects layer-by-layer using three-dimensional printing techniques, AM offers the exciting potential to create articles of novel shapes and properties that in many cases could not be achieved through traditional manufacturing processes.

Is the challenge of sourcing spare parts about to become history? The answer is "perhaps".

Defence institutions are already engaging in research to support the adoption of AM in equipment support processes. Given

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the costs of supporting in-service equipment are often greater than the upfront procurement costs, there is a clear benefit-case for AM research that supports the sustainment of existing components in addition to research that is pioneering the development of radically new components. This research will include the development of techniques for manufacturing obsolescent components, but it should go further. Being able to qualify those components as safe to use is just as important. Regulatory and legal aspects need also to be considered, for example, there needs to be clarity over how intellectual property rights apply to additively manufactured components. And because AM technologies and techniques are evolving rapidly, thought needs to be given to ensuring that the AM approaches of today enable, rather than constrain, the AM possibilities of tomorrow.

With a view to raising awareness on the issue of obsolescence management in the defence sector and on the role that AM plays today and could play tomorrow, this RAND Perspective Paper includes four contributions from experts in different sectors, bringing different analytical approaches to and perspectives on the issue.

The first paper from armasuisse provides an overview of the Swiss military context and the opportunities and challenges that AM could represent. The second paper from RAND Europe illustrates the concept of obsolescence management in the defence sector and introduces the potential game changer role that AM could play in this field. The third paper by the US Army provides an insight into current use and future developments of AM from a more practical perspective. Finally, the paper from Cranfield University elaborates on the costs of obsolescence and on the role that AM could have in obsolescence management in the future.

While many questions remain to be explored, the following main observations can be drawn from the four papers to inform discussion as to what AM could offer obsolescence management.

Observation 1: The management of components that are no longer available to support a system, or obsolescence management (OM), is a significant challenge for defence. The OM costs can arise even before equipment comes into service.

Observation 2: Additive manufacturing (AM), the process of building items layer by layer, is a much-discussed technology and this is extending to discussions about obsolescence management and how it could be applied to defence.

Observation 3: Additive manufacturing could help manage obsolescence, especially for mechanical components, but it is not clear to what extent it could help manage other types of obsolescence (e.g. electronics).

Observation 4: To become more applicable for obsolescence management in defence, research should focus on developing AM techniques that will create a greater range of components, qualification of AM products, and ensuring standards for AM are used to develop obsolescence management plans.

The Swiss perspective on emerging technologies of importance for the Swiss military

Quentin Ladetto – armasuisse Science and Technology[1]

With a population of approximately 8 million people mainly located in the Geneva-Bern-Zurich corridor and an area of 41,285 km^2, Switzerland is a direct democracy with military armed forces of 180,000 people (active and reserve). The annual military budget in 2015 was 3.8 billion Swiss francs (CHF) divided roughly into 65% operational costs and 35% for investments. Because of the rather low probability of a conventional attack against Switzerland, the main defence mission of the armed forces is to maintain and develop the competences and the necessary know-how such that, in case of conflict, full military capabilities can be re-built. Simultaneously, its operational tasks are the air police service, peace support operations, disaster relief, and conference and facility security. In this context, armasuisse Science and Technology (S+T) ensures the availability of expertise to enable objective technological decisions, to minimise the risks on investments and to keep the different stakeholders informed on the future technologies.

To fulfil its mission armasuisse S+T is organized into centres of competences mastering the present technologies (sensors, communication & command systems, protection assessment, explosives, information technologies & cyberspace, modelling & simulation, ammunition surveillance) and pre-empting the future with research activities in the following areas: reconnaissance & surveillance, communication, autonomous systems, cyberspace & information, effect-protection-security. The purpose of the additional research program "technology foresight" is orienting and anticipating the implications and consequences of defence future technologies (DEFTECH) on the national security as well as on military technology requirements. To this end, the development and participation in thematic-oriented national and international research clusters as well as networks of experts is key.

The program considers around 100 technologies and themes classified into six main domains as suggested by the American National Defence University: Biotechnology, Robotics, Information Technology, Nanotechnology and Materials, Energy & Resources and Systems (BRINES) (Kadtke & Wells 2014). For each technology a structured overview is created including several indicators such as the readiness level, the possible uses (civilian and

[1] Mr. Ladetto is affiliated with armasuisse Science and Technology, which funded the writing of this work and it's publication by RAND Europe. The views and opinions expressed by Mr. Ladetto do not necessarily reflect those of RAND Europe.

military), the main challenges it faces together with its related fields and some recommendations.

If additive manufacturing (or 3D printing) is not really a new technology per se, the recent progresses in various connected areas, favoured by the publication of several patents, open new perspectives. These progresses gave birth to the "maker movement" where digital construction schemes are exchanged and turned into physical objects with the use of various 3D printing techniques.

For a country like Switzerland with military operations mainly inside its borders, the interest in such technology might be different or complementary to countries operating outside their borders. The following questions, considering opportunities and threats, are the main drivers for monitoring developments in additive manufacturing.

Remote untraceable developments but local consequences?

To print an object in 3D, two elements are necessary: the 3D model of the object and a printer that will transform the element into a physical tangible form. Except for some assembly knowledge, which could be described in a manual, complex items can be built by anybody having access to a printer. Today we have the example of printed guns, but could complex items such as improvised explosive devices (IED) be more easily built thanks to the progresses in additive manufacturing? (DEFTECH, 2015)

As 3D models marketplaces are already available on the Internet and on the dark-net (Hudson 2013), are there possibilities to assess the models that are being exchanged, to understand what do they represent, if they are a piece of a more complex system and, if yes, of what?

Are there new threats appearing, or new designs made possible by additive manufacturing that can render some detectors and systems ineffective?

New forms, new possibilities, new opportunities (and threats)?

Additive manufacturing allows the creation of forms and details that were not possible to realize with traditional machining processes which use a block of material and remove unnecessary excess to obtain the desired shape (i.e. subtractive manufacturing). For example, perfect cavities can be created within a structure, or material can be specifically added where mechanical efforts are maximal, therefore enhancing the resistivity of the element. As a consequence, common products with new shapes and new properties start to be available, which, in a security environment could raise the following concerns:

- How does this new design, material and form translate in terms of weight and resistance for the new equipment?
- Will it have an impact on the detectability of some dangerous and hazardous substances being carried inside the structure of other products?
- Are there new threats appearing, or new designs made possible by this technology that can render some detectors and systems ineffective?

Could additive manufacturing modify the inventory and the logistics of the military forces?

Could this technology modify the inventory and the logistics of the military forces?

When acquiring military systems, one main concern is to get the necessary spare parts to keep the systems operational for the planned period. This can represent a significant amount of money being tied-up over a long period. Could additive manufacturing help reducing the inventories, knowing that small batches can be produced on-demand at a constant cost compared to the cost of subtractive manufacturing?

What kind of military products would benefit from this technology?

Are there specific components in stored systems or ammunitions that are sensitive to ageing where having them built "on demand" would help reduce the cost of maintenance?

Given the size of Switzerland, would a strategic reserve of additive manufacturing capabilities be of benefit to the military?

Are there several key elements of additive manufacturing that need to be monitored more than others or some processes that once mastered, could present an advantage?

When discussing manufacturing, additive or subtractive, it implies automatically that industry, know-how and materials are involved. Mastering all components of the value chain might not be of equal strategic importance, which raises several questions:

- Which aspects of the technology could be sensitive? Is it the printers or the substrates?
- What kind of competences must be developed to gain as much independence as possible with respect to this technology?
- Are there military specificities that will make additive manufacturing different from the civilian use and that should, therefore, be developed specifically?

All these different questions, which will evolve with time, make additive manufacturing a technology worth considering when trying to understand the military technological landscape of tomorrow.

The challenge of obsolescence management and how additive manufacturing could be used to tackle this emerged in the discussion at the DEFTECH conference held at armasuisse in February 2015. Given the interest generated by this particular subject, armasuisse has commissioned RAND Europe to prepare a short perspectives paper to gather commentary on the issue of obsolescence management, defence and the potential for additive manufacturing.

The challenge of obsolescence management

Giacomo Persi Paoli and Jon Freeman – RAND Europe

What is obsolescence and why is it relevant for defence?

Obsolescence is the unavailability of materials, components, processes, skills and/or software that were previously available (IIOM 2015). It can occur at different stages of the equipment's life cycle (from the development, through design and production, to in-service) and it affects in particular those components that need to be maintained for several decades (IIOM 2015).

Obsolescence of components is common in sectors such as defence and aerospace where the equipment has long lead times and needs to be supported in-service for many decades, which combine to increase the problem of obsolescence. It is not unusual that 70–80 % of the electronic components become obsolescent before the system has been deployed (Sandborn 2013, 16).

Although the obsolescence problem is commonly associated with electronic components, it applies also to mechanical components, materials, software and media support, as well as tooling, test equipment, documentation and skills (Erkoyuncu & Roy 2015). Many interdependencies exist between these areas; therefore, there is a need to manage obsolescence in a holistic manner rather than treating each area independently.

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The cost of obsolescence

According to the British prime contractor for the Eurofighter project, obsolescence is the second-highest risk to the project and it is very expensive to design out obsolescence (Erkoyuncu & Roy 2015). While the cost of obsolescence may vary on a case-by-case, or country-by-country basis, evidence shows that obsolescence in many sectors is becoming very costly (Torresen & Lovland 2007). For instance, the total through-life obsolescence costs for the Nimrod MRA4, a maritime reconnaissance aircraft that never even entered service, were estimated to be £780m (Erkoyuncu & Roy 2015). Similarly, the US Navy estimates that obsolescence issues cost them up to $750 million annually (Erkoyuncu & Roy 2015).

From a military perspective, the real cost of obsolescence management is the reduced ability to safely field military equipment when it's required at a cost that supports a balanced equipment programme across the many competing demands on a finite budget.

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Managing obsolescence

In line with systems engineering principles, the life cycle of a defence system in the UK is divided into six phases: concept, assessment, demonstration, manufacture, in-service, and disposal (the so-called CADMID cycle). Obsolescence issues can arise at any stage of the life cycle and obsolescence management needs, therefore, to be considered from the early stages of any project (Romero Rojo et al. 2009).

There are two main approaches to obsolescence management: a proactive approach through mitigation and a reactive approach through resolution. In this context, the term 'mitigation' refers to the measures taken to minimise the impact or likelihood of having an obsolescence problem, while the term 'resolution' refers to the measures taken to tackle an obsolescence issue once it appears (Erkoyuncu & Roy 2015).

Obsolescence risk can be mitigated by taking actions in three main areas: supply chain (e.g. life-time buy and partnering agreements with suppliers), design (e.g. open system architecture, modularity, and use of multi-sourced components) and planning (e.g. an obsolescence management plan, technology roadmaps and monitoring tools). On the other hand, when an obsolescence issue arises, a resolution approach must be applied to address the problem. The different resolution approaches are broadly (Erkoyuncu & Roy 2015):

- Same component (e.g. last-time buy, cannibalisation)
- Form, fit and function (FFF) replacement (e.g. equivalent component)
- Emulation or redesign (e.g. use of state-of-the-art technologies to replicate or redesign the component).

Effective obsolescence management is based on the ability not only to mitigate (pro-active management) or resolve (reactive management) obsolescence issues, but also to conduct strategic management using obsolescence data, logistics data, technology forecasting, and business trending (demand forecasting) to enable strategic planning, life-cycle optimisation, and long-term business case development for system support (Sandborn 2013).

The obsolescence issues of commercial-off-the-shelf (COTS) in defence systems

The use of COTS products in defence systems is increasingly promoted by national authorities including the US government (Bil & Mo 2013). The life-cycle of a COTS product, typically five years or less, is different from the life-cycle of a defence system, typically more than 20 years (Bil & Mo 2013). This suggests that if a COTS system is managed through-life according to traditional defence approaches that obsolescence could be a significant problem. For COTS equipment there will need to be a different through-life support strategy which could include replacing equipment more often, on a timescale aligned with the COTS equipment life-cycle.

Innovative approaches to obsolescence management

Additive manufacturing could be applied to different parts of an obsolescence management approach. Supply chain mitigations could lead to manufacturers, suppliers or equipment users having

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partnering agreements to ensure components can be manufactured as needed using AM technologies.

Components could have their designs, specifications and materials retained in digital format to facilitate their subsequent remanufacture in later years. Even where it is not yet apparent that components are suited to AM, an obsolescence management plan could store their designs digitally against the possibility that AM techniques will evolve to include a greater range of products in the future.

There are limits to the abilities of AM techniques to reproduce components to the form, fit and functions that are required. It is not clear that all components, particularly electronic components, can be produced using AM. In the defence sector, an example of initiative launched to apply AM in obsolescence management is the US Navy Reverse Engineering: Science and Technology Obsolescence, Repair, and Evaluation (RESTORE) Lab (Fein 2015). The Lab uses the "SCAN to CAD to FAB" process of scanning a component with a 3D scanner, sending the image to a computer-aided design (CAD) program, and then fabricating a modern form, fit, and function replacement part, to support Life-Cycle-Extension Programs for legacy systems (Fein 2015).

Standards to support AM are already being developed by the International Organization for Standardization (ISO 2015), including a data file standard. To support obsolescence management it may be worth considering using these standards to record data for components even when appropriate AM techniques are not yet apparent.

Conclusions

The issue of obsolescence is particularly relevant for the defence sector which relies on systems that traditionally have long lead times and require support for several decades. As additive manufacturing is developed further in the defence sector, the opportunities it offers for obsolescence management need to be explored, for example the technical feasibility, the safety and performance of the components produced by AM and the true costs and the risks of adopting such an approach.

US DoD and US Army research into additive manufacturing and obsolescence management

Giuseppe L. Di Benedetto – U.S. Army Armament Research, Development and Engineering Center (ARDEC)

The world is on the cusp of a "Third Industrial Revolution" that will be driven by advancements in computer technology and additive manufacturing (AM). These advancements will establish a new set of methods for designing, prototyping, manufacturing and sustaining parts and products. These new methods can lead to the development and manufacturing of products with tremendously advanced capabilities, unique and functional geometries, and potentially lead to cost savings from the reduction of lead delivery times and raw material waste.

Though AM techniques, equipment and technology have been rapidly advancing in recent years, the maturity of many of the techniques and equipment are not sufficient enough for wide-spread, full rate manufacturing and reliability. The United States Department of Defense (DoD) and U.S. Army want to not only advance the AM techniques and technology, but also help to establish a domestic American AM industrial base. The DoD and U.S. Army understand that investment is needed in research and development in all aspects of AM to establish a domestic industrial base.

The DoD and U.S. Army have been investing and conducting research and development in AM in the areas of new materials and manufacturing techniques, conformal designs, better interior volume utilization, size and weight reduction, enhanced capabilities and versatility, rapid prototyping and training. However, one of the most important areas of research is in relation to obsolescence management of parts and components in legacy systems.

Aircraft repair and maintenance using AM

A major AM success story can be found at the Fleet Readiness Center East (FRCE) in Cherry Point, NC, USA. The key dilemma occurs when components from aging aircraft platforms such as the AV-8B Harrier are no longer available from the original equip-ment manufacturers (OEMs) or the OEM is no longer in business. When this happens, the U.S. Government has the right to either reverse-engineer or recreate parts from old drawings. In the case of some legacy aircraft, the OEMs are no longer producing spare parts. Robert "Yogi" Kestler, the Science & Technology lead at the U.S. Naval Air Systems Command (NAVAIR) FRCE, and his team have been using AM to solve this obsolescence issue by 3D printing tooling to make the replacement parts that were previously unavailable (COMFRC 2014). The FRCE team is utilizing 3D scanning technology to reverse-engineer legacy spare parts into a scanned solid CAD model or developing 3D solid models from drawings. This model allows them to utilize Fused Deposition Modeling (FDM) to make the correct size and shape tooling to produce the

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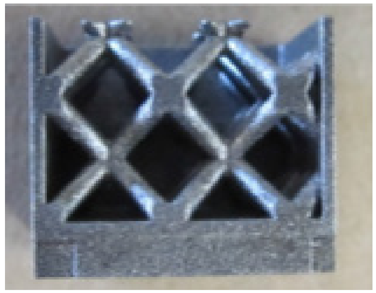
spare parts. The repairs and maintenance on these legacy aircraft are completed fully in-house at the different FRC installations (FRCSE 2015). Using these in-house AM capabilities, the FRC installations have been successfully repairing and replacing parts on the AV-8B Harrier, P-3 Orion, the F/A-18A-D Hornet, and other legacy aircraft systems (FRCSE 2015). Some of these repairs were made using AM over a few days, while using conventional methods could have taken three or more weeks (COMFRC 2014).

Fabrication and qualification of AM metal parts processing

While the DoD utilizes the current state-of-the-art FDM, SLA, SLS equipment from industry, a huge focus is also on the research and development of AM of commonly used metal materials found in many vehicle and weapon systems. Researchers at U.S. Army ARDEC have been working on the qualification of different metal alloys and their fabrication process with AM equipment and techniques. In order to achieve the reliability needed for qualification, there needs to be a better understanding of the consistency of the equipment performance from run-to-run, as well as a better understanding of the equipment parameter effects on the finished part or product. ARDEC engineers Elias Jelis and Matthew Clemente focus their research on qualifying the Direct Metal Laster Sintering (DMLS) fabrication process as well as the establishment of process parameters and the qualification of 4340 high strength low alloy (HSLA) steel for DMLS. The goal of the research is to understand the variability from build-to-build on the DMLS system, and to understand how DMLS process parameters must be adjusted in order to fabricate 4340 HSLA steel parts that match the mechanical properties found in typical wrought parts (Jelis, Clemente et al. 2015).

Figure 1. Photograph of 4340 steel lattice structure component produced by DMLS after bead blasting.



Source: Jelis, Sadangi et al., 2015

The DMLS process can build highly complex parts with mechanical properties comparable to wrought for approximately one dozen qualified materials. These complex parts and functional prototypes require little to no additional tooling after the DMLS manufacturing process. The DMLS equipment has many adjustable parameters, but Jelis and the ARDEC team chose to focus on a certain few. In each study, tensile tests were performed on fabricated 4340 steel specimens for a comparison to the typical wrought properties from literature. They investigated the influence of initial

Table 1. Tensile data of 1100oF (~593oC) stress-relieved laser sintering 4340 steel. DMLS Runs A and B 4340 steel met or surpassed the mechanical properties of Typical Wrought 4340 steel, as shown.

Material Condition	Modulus	Yield Strength	Tensile	Elongation
Typical wrought 4340 properties from ASM International	29000 ksi	183 ksi	199 ksi	15%
Run A: DMLS of virgin powder	31000 ksi	189-190 ksi	199 ksi	16-17%
Run B: DMLS after once recycled powder	31000 ksi	187-190 ksi	198 ksi	16-17%

Source: Jelis, Sadangi et al., 2015

particle size of the 4340 steel powder on the mechanical properties of the finished parts, and optimized the best particle size distribution for DMLS processing (Jelis, Sadangi et al. 2015). They also investigated the influence of the laser scan speed and the hatch distance while maintaining the optimal energy density range (113-163 J/mm3), and they were able to approach and match the mechanical properties of typical wrought 4340 steel (Jelis, Clemente et al. 2015). The table above shows results from some of these studies.

Figure 2. Photograph of 4340 steel tensile test specimens on the build plate following DMLS fabrication.

Source: U.S. Army ARDEC

The material and equipment qualification methods being established by Jelis and the ARDEC team will be used to qualify new DMLS and AM metal systems as well as additional materials for the DMLS and other metal AM processes. Once a material has been qualified, then a whole new family of replacement parts can be fabricated reliably and effectively using additive manufacturing.

Conclusions

These success stories are examples of the beginning of how AM can be used to alleviate the issue of part and component obsolescence. Since DoD parts and components must meet strict specifications to be used in fielded items, qualifying AM equipment, processes and materials represents the best strategy to expand AM for obsolescence management. Through these high standards and quality demands, the DoD will continue to push for the advancement of AM technology, techniques and materials in order to potentially achieve a future where there is minimal part or component obsolescence in the world.

Opportunities for additive manufacturing to address component obsolescence challenges

Dr. John Erkoyuncu, Prof. Rajkumar Roy, Prof. Stewart Williams, Dr. Paul Colegrove, Dr. Filomeno Martina, Alessandro Busachi – Manufacturing Department, Cranfield University

Background

Additive Manufacturing (AM) is offering opportunities in a number of areas; this article focuses on how AM can be utilised to replace or re-design components to handle obsolescence challenges in defence. If the time available to replace or re-design an alternative component is shorter than the window of opportunity to resolve the obsolescence issue then there is an obsolescence problem and a need for Obsolescence Management (OM).

One option to handle the obsolescence challenges is to expand the window of opportunity to mitigate and/or resolve obsolescence and the other option is to be more effective with the time available to replace a component. AM is an additional strategy that can assist with reducing the time it takes for replacement.

Additive Manufacturing applications

AM enables rapid conversion of computer-aided design (CAD) files into physical products by merging layer upon layer of heated material (Penny, Hellgren et al. 2013). Figure 2 presents an IDEF0 diagram that covers the input, output, control and mechanism for an AM based approach. IDEF0 offers a functional modelling language for the analysis, development, reengineering, and integration of information systems (US Department of Defense 2001).

A significant opportunity for AM is around greater design flexibility and customisation. Also as the manufacturing can be localised, the overall time to market can be dramatically reduced (RAE 2013).

The American Society of Testing and Materials (ASTM) issued in 2013 a standard for alternative AM technologies (ASTM 2013).

The main differences between the methodologies include: the components of the machine, feed type and energy source applied. The most commonly applied approaches are (Martina, 2014): 'direct energy deposition' and 'powder bed fusion'. In order to identify the suitable technology various aspects such as material type,

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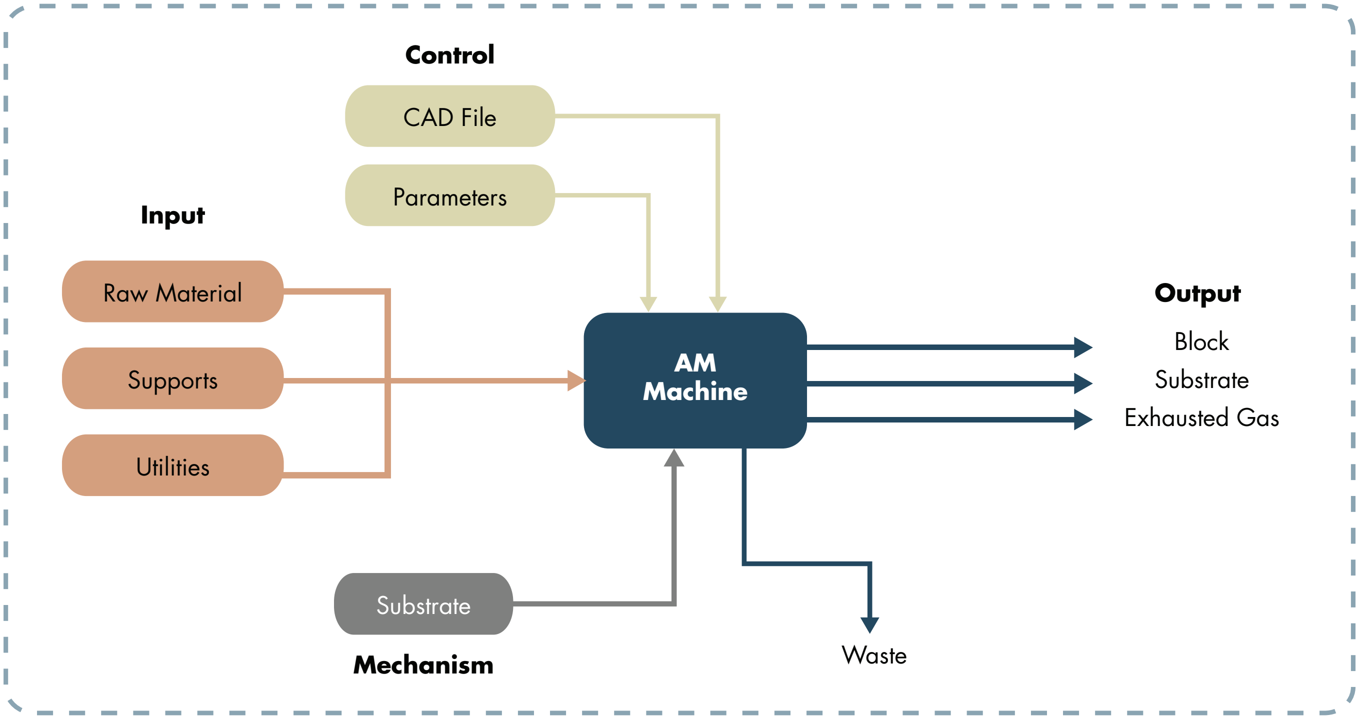
Figure 3. Additive Manufacturing IDEF0.



Source: Busachi, Erkoyuncu et al. (2015)

volume of part, accuracy required and minimum wall width has to be investigated. The limitations associated with AM methodologies influence the type of components that can be emulated.

Cost metrics for obsolescence

Parameters that affect the obsolescence cost metrics are: coupling level and package density (level of integration), type of platform and requalification. AM offers opportunities for emulation, where along with time based advantages it needs to be competitive in terms of cost compared to other resolution actions. A major challenge for the estimation of obsolescence costs is the development of accurate cost metrics. Table 2 offers an insight into the cost metrics, considering the resolution strategies based on an industry wide survey of costs (Romero Rojo 2011).

The cost metrics allow the selection of the most cost effective solution and cost avoidance analysis assessment. It is clear from

Table 2. Cost metrics for obsolescence – requalification of air/safety critical components. The cost metrics represent the non-recurring costs of resolving an obsolescence issue using each of the resolution approaches. These non-recurring obsolescence costs are calculated, according to the parameters that characterise the obsolescence issue.

Obsolescence management approach	Integration level			
	Small	Medium	Large	Very large
Existing stock	£300	£300	£300	£300
Life time buy	£2,000	£2,000	£2,000	£2,000
Cannibalisation	£1,700	£2,500	£3,400	£4,500
Equivalent	£3,500	£3,500	£3,500	£3,500
Alternative	£10,100	£10,100	£15,200	£21,500
Authorised aftermarket	£13,000	£13,00	£19,800	£25,800
Emulation	£52,100	£193,000	£489,000	£2,690,000
Minor redesign	£50,100	£167,000	£244,000	£549,000
Major redesign	£250,000	£2,000,000	£3,400,000	£13,700,000

(Romero Rojo et al. 2012)

Table 2 that to enhance the implementation of AM, cost avoidance could be achieved by implementing AM more widely as an "emulation" and "equivalent" technology with the target of avoiding minor and major redesign challenges, especially with components very large integration level.

Potential role of AM for OM

Traditionally, contracting for the support of a sustainment-dominated system did not include the cost of resolving obsolescence issues. The prime contractor used to be in charge of resolving those problems and the customer used to pay for it separately. With the shift in ownership of obsolescence cost, there is an increasing need to accurately estimate the cost of obsolescence. As AM processes are relatively stable and the costs experienced are largely predictable; this offers a less uncertain obsolescence resolution option.

Obsolescence is externally driven but equipment sustainment is something that can be controlled (e.g. design for sustainment) and AM is offering further opportunities to enhance the ability to deliver sustainment oriented contracts.

This involves the use of AM to solve various obsolescence types such as mechanical components, tools, and testing equipment. A major source of obsolescence is experienced in electronic components, which requires further capability development in AM. Whilst mechanical AM technology is well established, interest in electronic components is emerging. In particular AM systems using the copper wire embedding technology are proving to be significantly promising (Solomon 2015).

The potential use of AM to deliver equipment sustainment, promotes the need to consider different types of contract structures and how these translate in to better product life cycle management. Furthermore, AM offers further options to consider design for sustainment. Mobile AM facilities can also offer opportunities to deliver sustainment contracts.For wider implementation of AM, it will be necessary to build the suitable legal infrastructure that allows the implementation of AM and avoids any IP infringements. Overall, AM is offering substantial opportunities to solve a number of types of obsolescence and the growing pace of technological developments is offering further optimism.

Conclusions

The cost of obsolescence is expected to continue to be a major cost driver in the future. Along these lines, additive manufacturing offers huge potential to resolve obsolescence in a timely and cost effective manner. The application of AM specifically to resolve obsolescence will grow as the cost-benefit can be justified. This will require further exploration of the boundaries of existing AM technologies, more confidence with the cost estimates associated to AM and further proactive behaviour to manage obsolescence so that cost effective strategies can be defined.

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About the DEFTECH workshops

The present report was stimulated during a discussion which took place during a DEFTECH Workshop (DEfence Future TECHnologies) dedicated to additive manufacturing and its impact on security applications, 11th February 2015 at armasuisse S+T in Thun, Switzerland. The scope of the DEFTECH workshops is to play the role of an eye-opener on how emerging technologies could be used in a military context. During one day, the workshop puts technology experts from industry and academia in direct contact with the military in order to generate ideas, to understand the real state-of-the-art possibilities and challenges faced in this area as well as informally exchange about that topic. The topics are selected based on relevance and potential as well as direct military requests. Topics covered in 2015 include exoskeleton, additive manufacturing, bionics and portable reusable energy.

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The Manufacturing Department at Cranfield University (Contact details for lead author Dr. John Ahmet Erkoyuncu: j.a.erkoyuncu@Cranfield.ac.uk) has vast experience in managing the impact on complex multi-stakeholder projects. The Manufacturing Department hosts the EPSRC Centre for Innovative Manufacturing in Through-life Engineering Services, which includes partners from across the value chain such as Rolls-Royce, BAE Systems, Ministry of Defence and Babcock International. The manufacturing department also hosts the Welding Engineering and Laser Processing Centre, which specialises in fundamental, strategic and applied research in the area of advanced fusion joining processes and high deposition rate additive built structures.

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