Additive Manufacturing as a Sustainment Enabler

An Industry Perspective

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From an industry perspective, additive manufacturing (AM) has been a focus for more than 10 years, though rapid prototyping has actually been in practice for over 30 years with early emphasis and continued usage primarily during design and manufacturing of new systems.

However, AM recently received increased public focus in the Department of Defense (DoD) and the media, as well as in discussions within the Aerospace Industry Association (AIA) Product Support Committee. Over the last 2 years, increased awareness around the opportunity for AM as an enabler for sustainment has led industry to actively support the vision and begin to realize the benefits for the warfighter by aligning with new public-private partnership constructs, such as those enabled by the National Network for Manufacturing Innovation (NNMI). In support of this vision, America Makes, as the National Additive Manufacturing Innovation Institute, also expanded focus in 2015 to include application to maintenance and sustainment.

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The opportunities for AM in sustainment apply not only to replacement parts production and repair but also to tools and fixtures for repairs. As such, opportunities can apply to both industry- and government-operated repair depots in the United States and abroad. The application of AM in the deployed environment also provides a unique opportunity to seek industry digital data or thread in order to secure an AM-enabled distributed supply chain solution and rapid field-delivery of components. As part of the approach for obsolescence, many industry and government depots are evaluating capabilities for scanning, redesign for AM, and fabrication in the field of parts no longer available on long-lifetime fielded systems.

Incorporation of newly designed AM-produced components into planned modifications and upgrades is an additional post-production opportunity funded by sustainment budgets. Defining and implementing the business model and infrastructure for reimbursing the participants in the value chain for intellectual property, data as a service and actual AM of components is a current focus. There are opportunities for original equipment manufacturers and suppliers, including small business. This focus complements AIA's ongoing leadership in technical data management, industry standards and data rights as well as government and industry collaboration in Sustainment Business Model Wargames.

Current Applications/Capabilities

A look at current applications in industry of AM and supporting capabilities needs to go beyond the focus on parts. While AM with both polymers and metals provides a path from computer-aided design to finished part with minimum touch labor and time, today AM offers the capability to rapidly and affordably produce custom tooling and shop aids to improve maintenance efficiency. The photos provide examples of AM small tools citing

Left: A future leading-edge tool for a C-5 cargo plane. Right: Examples of 16 aircraft additive manufacturing tools that are up to 9-feet long when assembled.
Source: William Flite, "Large Scale Additive Manufacturing at Lockheed Martin," from briefing at the 2015 conference of Additive Manufacturing in Defense and Aerospace (AMDA), June 23, 2015. Used by permission of Lockheed Martin.

$225,000 cost savings over conventional methods and of large tools used in sustainment. As metal AM technologies mature and become more widespread, they likely will be used to produce replacement parts for legacy aircraft even when drawings and tooling no longer exist. AM integrates seamlessly with the "Digital Thread."

Success requires a team sport. Methods require not just the actual printing of the part by one of a number of technologies. Material science is key, as well as secondary processing operations to include heat treatment and surface finishing. Non-destructive inspection (NDI) approaches are also needed to support certification and accreditation of the parts. Design practices also need to change to have maximum leverage of the technology. In sustainment, additive repair processes provide options for addition to materials to parts that may have previously been considered "consumables" as opposed to "reparables." Culture also is important across the team, including design engineering, quality and airworthiness roles. A communication challenge is presented by the fact that the term "certification" means different things to each of these organizations.

When we look for specific successes in industry, the following is a short list of examples:

- Lockheed Martin parts obsolescence solutions for legacy platforms in depot operations
- Sikorsky cold spray repair applications
- Printing of specialty tools on demand rather than storing for years or deploying more support equipment, including indirect part tooling and castings
- Raytheon field grip refit for human factors considerations and personal customization
- Elevate Systems small business design service for reverse engineering and legacy part replacement (Source: Scott Gray, "Utilizing Additive Manufacturing For the B-52 Radar Blower Assembly," National Center for Manufacturing Sciences Technology Showcase, George Mason University, Nov. 3, 2015)

One additional benefit has been the reduction in number of mechanical parts to perform a function, resulting in less time in assembly and fewer connectors.

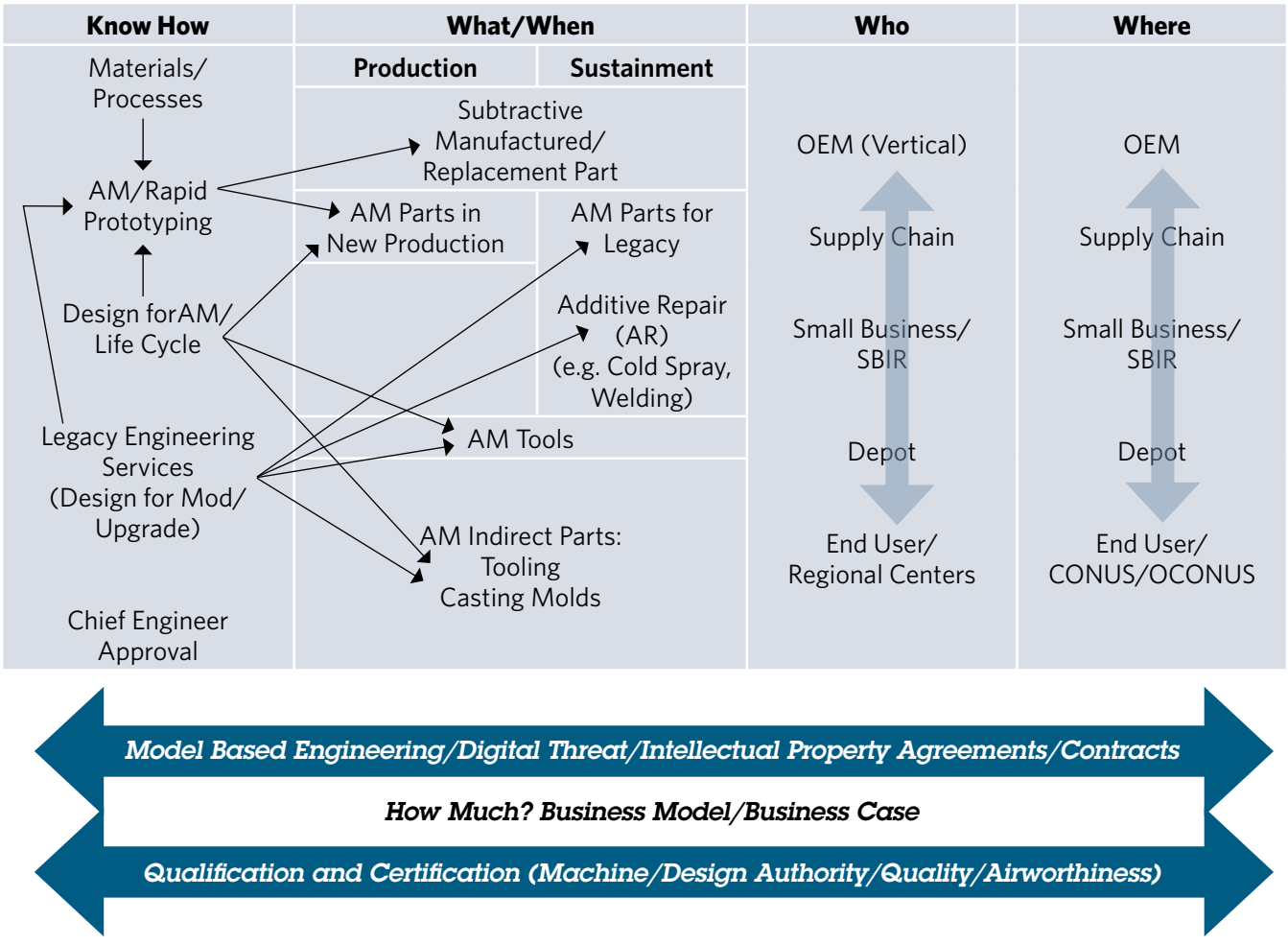
Challenges/Hurdles

Successful application of AM to sustainment requires partnership across an organization from manufacturing technology applications to the post-production stage. Putting together the solution relies on technical data management, application of industry standards for interoperability, and data rights considerations. In addition, cybersecurity risks for a distributed AM environment must be managed to safeguard the integrity of the three dimensional (3D) data inputs and the industrial control systems in the manufacturing/depot environment.

The large scale of aerospace and defense parts also provides challenges for the printing technology applied to initial structure production, as well as modifications and upgrades.

Figure 1. Additive Manufacturing for Sustainment Industry Use and Value Chain

Why? Faster, Lower Cost, Improved Readiness, Lower Inventory/Warehousing



Source: Diagram by author. Note: OEM=original equipment manufacturer; SBIR=Small Business Innovation Research; CONUS=continental United States; OCONUS=outside the continental United States.

Specific challenges surrounding adoption of AM technologies for rapid repair and rapid AM inspection continue to be a focus of America Makes projects. With three projects around rapid repair and AM inspection technologies now under way, additional work toward digital thread integration is a major focus for upcoming technology development investments. These three critical technology elements largely hinge upon the need for approved standards, schemas and protocols when creating parts through AM, with variants of these standards needed for original builds and for sustainment components. The unique needs of fielded AM repair systems make the need for rapid AM inspection and qualification a critical component in the overall life cycle's value chain, without which the customer adoption of AM for sustainment cannot be supported.

Figure 1 summarizes the multiple applications of AM to sustainment, synergy with issues for AM for new production, and management complexity of enablers of the entire process.

Considerations

AM within a maintenance and sustainment environment presents a unique opportunity for public-private partnerships across the entire aerospace and defense supply chain. Selective investments are needed in the capital and operational knowhow to maintain the industrial base in partnership with the government-run depot and deployed forces. The business model for licensing, reimbursement and liabilities for access and/or use of technical data is just one example of many business considerations that need to be addressed parallel to technology development and qualification and/or accreditation. But more important, the business case needs to support use of AM where it makes sense in terms of cost and readiness outcomes, rather than just wanting the latest and greatest technical "toys" without justification.

Art of the Possible and the Future

Dan Cernoch, chairman of the Aerospace Industries Association's Product Support Committee, provides a good

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summary of the art of the possible: "Additive manufacturing is a disruptive technology that, when matured, will dramatically reshape sustainment, improving system availability and affordability through reduced cost and logistics footprint associated with distribution, stowage and management of spare part inventories. Additionally, mission readiness of needed warfighting capabilities will be improved by effectively eliminating logistics delays."

Changes are required, beginning at the university level, to prepare engineers for future industry openings. This includes design for AM as well as design for entire life-cycle sustainment. Fewer parts to remove and replace can impact life-cycle costs. Repairing parts with corrosion issues has focused on application of coatings, and welding technology has expanded the future for these industries.

The pull from the DoD customer is driving acceleration of AM adoption. This requires parallel planning for machine technology, manufacturing and sustainment processes, quality, and airworthiness to harvest the benefits and agility of these technologies while managing risk. This quickly becomes a systems issue, not just a parts challenge. The right "hybrid" blend of subtractive and additive technologies applied across parts, tools, and tooling and casting, combined with innovative qualification and certification technologies, will help move industry toward the future. However, this is not technology for the sake of technology; without a strong case and demonstrated best technology for the best value, our efforts to propel the diverse benefits of AM into our aerospace and defense industrial base cannot be supported by our government partners.

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