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The FlexCare Deployable Additive Manufacturing Printing Facility

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ABSTRACT

The key to vehicle survivability in a combat or otherwise hostile environment is the capability to quickly resupply critical parts. Rapid production of hard to obtain components within the theater of operations can significantly increase the availability of combat vehicles or other equipment. Additive manufacturing enables significant reduction in lead time for these components and thus offers an enhancement of combat capability. However, AM operations have specific environmental and support requirements in order to function. In partnership with CESI and CAPSA, AddUp has developed a unique concept of a "modular plant" called the Anywhere Additive Factory. The unit can be adjusted to meet the manufacturing requirements and volumes needed, while also being easily dismantled and moved to another location.

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1. INTRODUCTION

The ability to quickly replace or repair a part and have it back in operation is essential for ground system survivability. This is where the use of additive manufacturing can have several advantages. These can include reduced lead time, replacement of obsolete parts, and in some cases an improvement over the OEM part.

There are several barriers hindering the adoption of metal additive manufacturing for the military and defense network. One of these barriers is having the necessary facilities within an acceptable range to the warfighter in-theater. It requires significant infrastructure not only for the printing process itself, but also for the post-print operations.

In a traditional manufacturing environment, real estate is allocated to permanently install the additive machines and the auxiliary equipment for post processing. This space would include the necessary requirements for the process, such as temperature and humidity control, as well as controls for health and safety, like oxygen monitoring, fire suppression, and HEPA filtration. Permanent installations are fine for manufacturing plants, but not ideal for in-theater deployments.

The US military has strong initiatives to adopt additive manufacturing as it relates to the sustainment of ground systems. Such topics were presented at the Military Additive Manufacturing Summit in Tampa, FL this February. Among these initiatives discussed were "Modernizing supply chains through AM in support of the Warfighter", "Leveraging AM to enhance supply chains and improve material readiness for the Warfighter", "Operationalizing AM to enhance the material readiness of the US Army", "Leveraging 3D

printing to bolster material readiness across the US Air Force", and last but not least "Implementing 3D printing processes in support of the Army's ground and support systems". All of these initiatives can have a major impact on survivability; however, there is one major obstacle between metal AM and the warfighter, and it is access to proper facilities.

AddUp has recognized this problem in the industry and taken the initiative to solve it. It was realized there was a need for a deployable factory to produce parts with metal additive manufacturing. There are few opportunities to use an as-printed part directly off the machine. Often times there are several post processing steps involved such as heat treatment, machining, surface finishing, etc. Therefore, a factory with only additive equipment is not sufficient. This is why AddUp has engineered a turnkey factory, fully customizable to provide an end-to-end solution.

2. FACTORY OVERVIEW

The Anywhere Additive Factory is configurable to include one or more AM technologies; laser powder bed fusion and directed energy deposition. The design of the factory is based on standard 8'x20' shipping containers to allow for ease of transportation and installation. Due to this modular design, it is easy to add additional AM equipment or auxiliary equipment to support the process. The factory breaks down into individual containers with removable panels to seal off open walled areas during shipment. While the use of shipping containers for a deployable manufacturing facility is not a new concept, it has not been realized on this level, especially as it relates to metal AM. This concept has been achieved previously with polymer additive manufacturing. The issue when transitioning or adopting metal AM rather than polymers, is the associated health and safety requirements, as well as the post processing steps that accompany printing.

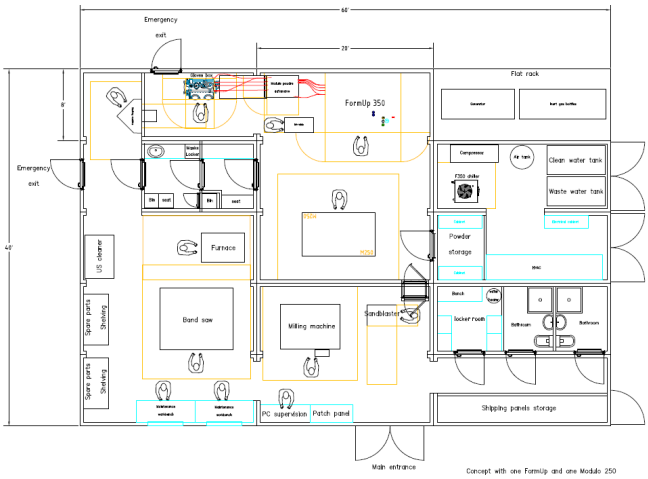

Figure 1: Conceptual layout of a full Anywhere Additive Factory with both LPBF and DED technologies.

Metal additive manufacturing has different requirements than plastics, not only for the process, but in regard to operator safety as well. As a result, the facilities are more complex. The printing area of the factory is under negative pressure to prevent any loose powder from escaping into the rest of the facility. This protects the non-additive operators who would not be wearing the same PPE. The room is also temperature and humidity controlled to maintain the quality of the process. Several air changes are made per hour in order to keep fresh air in the room, and the evacuated air goes through a HEPA filter before exhausting to atmosphere. Because the process requires the use of inert gas (argon or nitrogen), oxygen monitors are installed in the room with alarms in case the oxygen level drops below a safe limit.

The required HVAC system is dependent on several factors. The total volume of the factory, i.e. how many containers, the total heat load from the machines, and the climate of the installation. These are all factors that can be designed around and easily modified. It is important to note that the rated tonnage of the HVAC system required has a direct impact on the overall cost of the factory.

All the necessary utilities are included. Electricity for the machines, lighting, HVAC, etc. can be supplied from a standard generator that meets the

total power requirements. Process gas can be supplied using a manifold of standard compressed gas cylinders, a bulk tank, or, in the case of nitrogen, a generator. Tanks are available for the supply of water as well as a recovery tank for waste water.

Because the factory is modular in design, it is easily adaptable to include various post-processing equipment. Depending on the needs of the facility, additional containers can be added to include furnaces for stress relieving and heat treatment, wire EDM or band saws for part removal from the build plate, bead blasting equipment for surface treatment, machining centers for support removal or to meet final feature tolerance, as well as metallurgical and metrology equipment to guarantee the quality of the print. All of these processes are taken into consideration when initially specifying the factory requirements.

3. PROOF OF CONCEPT

AddUp has successfully demonstrated this concept in collaboration with CESI in France. This modular factory includes a FormUp powder bed machine, a BeAM direct energy deposition machine, as well as post processing equipment such as a furnace, wire EDM, and a small machining center. For this installation, the primary factory area was designed around 40’ containers as there were not many shipping constraints. Smaller 20’ containers were used for the utilities and other areas that were not directly related to the printing process. This further demonstrates the modular capability of the system as it can be configured utilizing different combinations and sizes of containers.

Each section of the factory was built off-site and fully assembled prior to shipping. This included installing all of the printing and post processing equipment as well. Upon conclusion of factory acceptance testing, the factory was broken down into each subsection, and shipped directly to the customer site. The equipment remained inside the factory containers during shipment, reducing the installation time.

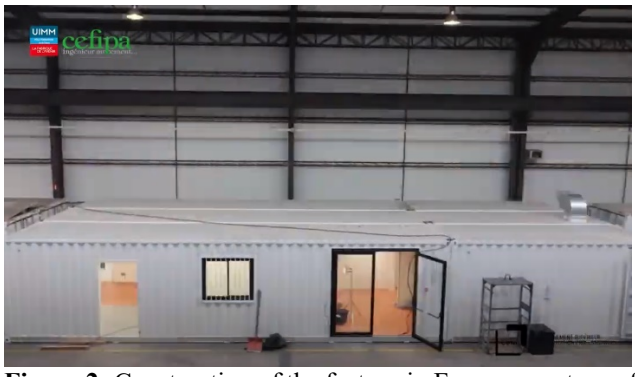

Figure 2: Construction of the factory in France, courtesy of CESI.

Once the factory was reassembled, there were still necessary checks that had to be done on the equipment to ensure and guarantee process stability. This includes such tasks as geometrical verification of the different axes, spatial calibration of the lasers, leak tests, etc. The shipping method as well as the geographical terrain during transport can have an effect on these systems, making it necessary to have final site acceptance criteria that match the original factory acceptance specifications.

Figure 3: Installation of the factory at customer site, courtesy of CESI.

Although the ultimate goal may be to get hands-on access to the warfighter on the front line, this concept shows that it is possible to get additive manufacturing within reach. This first installation

is a very important step forward as it proves it is possible to deploy and operate a modular additive factory.

4. CONCLUSION

As additive manufacturing becomes adopted as a normal part of ground vehicle sustainment, it will be absolutely necessary to ensure the proper facilities are accessible as close to the warfighter as possible. As discussed previously, having access to the printer alone will not be sufficient as many components will need some level of post-processing before they can be put into use. Consequently, some form of an "additive factory" will need to be realized, and AddUp has taken the initiative to forge this concept into reality.

By having these facilities near-theater, it will be possible to repair or replace OEM parts that are otherwise unattainable due to long lead times or obsolescence. The use of metal AM could cut lead times down from months to days depending on the application. This directly relates back to the initiatives discussed at the beginning as it pertains to leveraging additive manufacturing to enhance the supply chain, improve military readiness, and integrate AM into ground support systems. This is a critical need for the US Military as it relates to ground vehicle sustainment.