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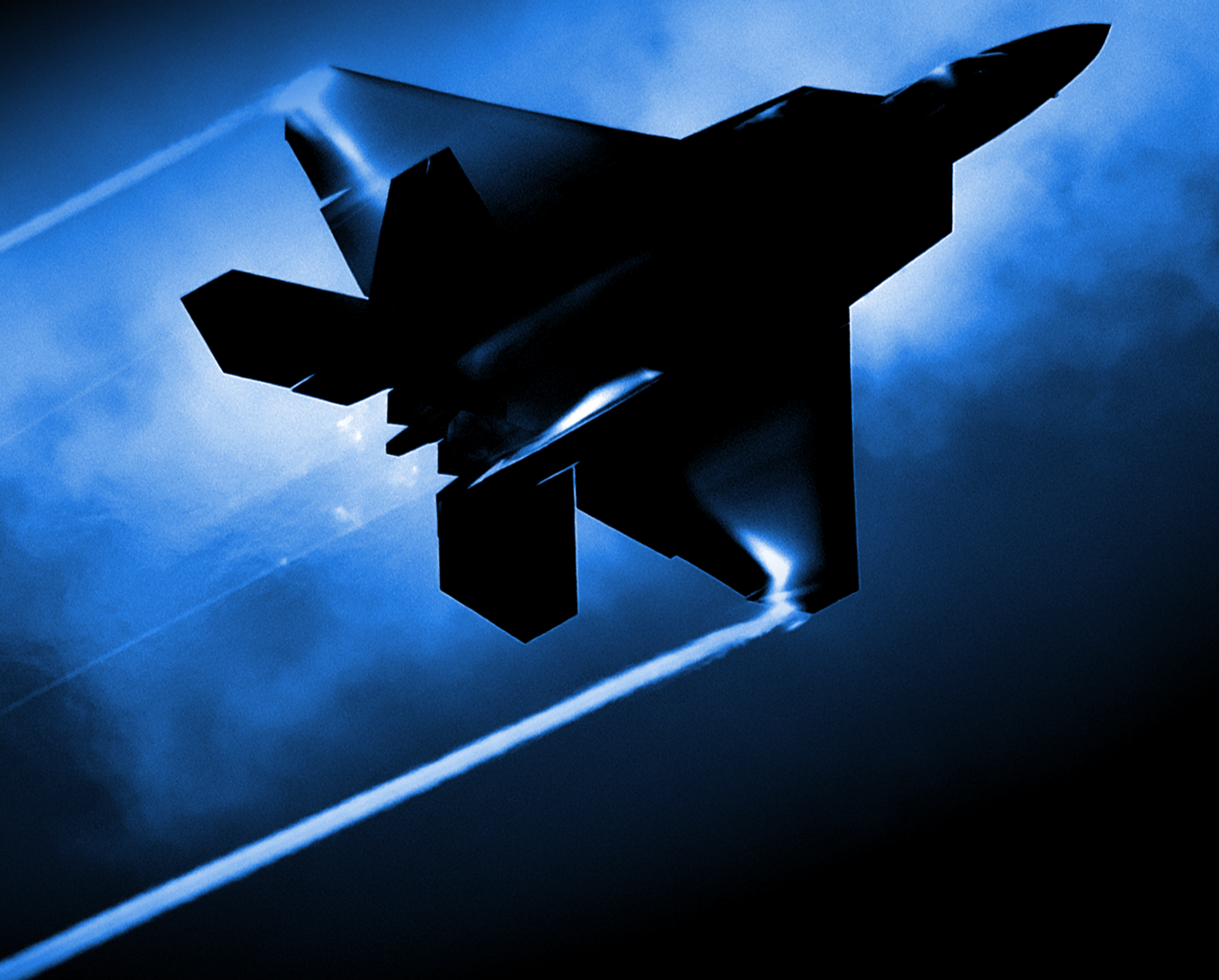

WHITEPAPER

Crawl, Walk, Run:

A Glimpse of the Phased Adoption of Additive Manufacturing in the Defense Industry

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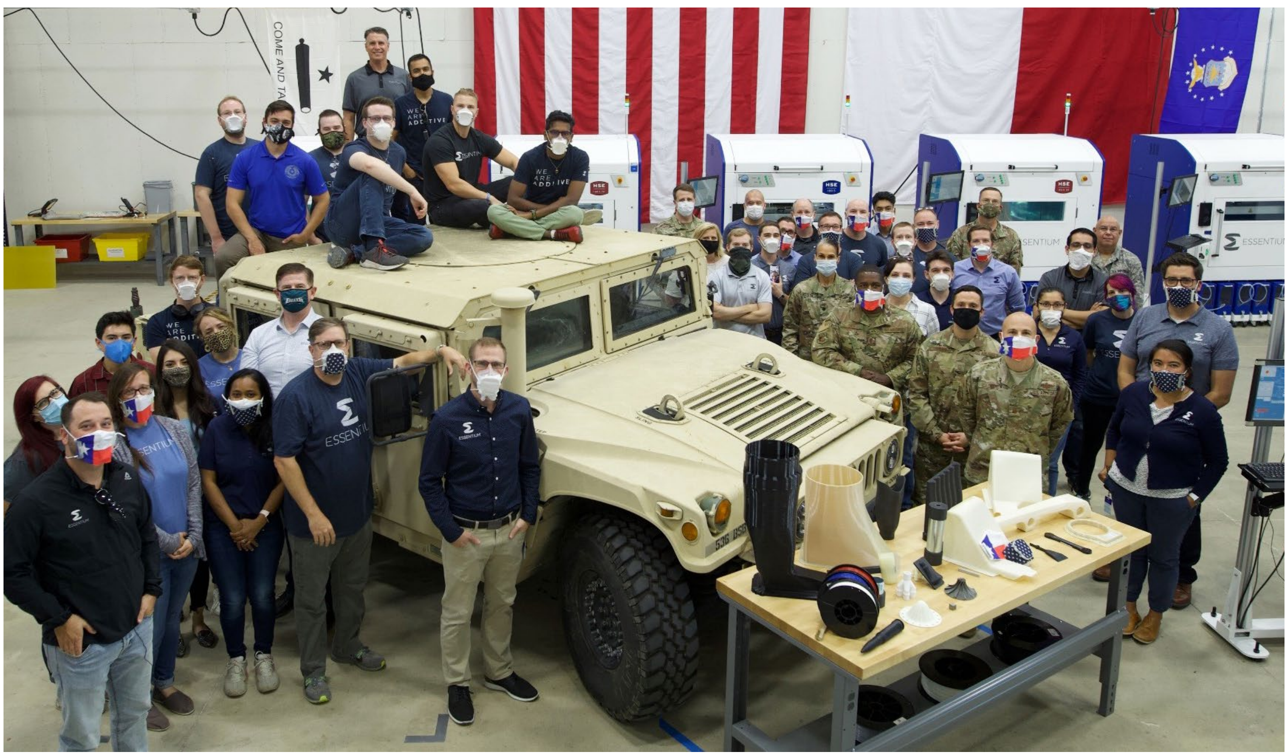
According to the National Defense Strategy published in 2018, the United States lists American technological innovation as a core tenet of its plan to “be prepared to defend the homeland, remain the preeminent military power in the world, ensure the balances of power remain in our favor, and advance an international order that is most conducive to our security and prosperity.” (United States Department of Defense, 2018) To reinforce this plan, defense innovation entities that permeate all branches of the military were formed. NavalX, Army Futures Command, RapidX, AFWERX, SPACEWERX, Defense Innovation Unit, Army Applications Laboratory, and Army Software Factory are among the most familiar groups.

Additive manufacturing (AM) is among the key technologies identified as critical to future defense efforts. However, for the defense industry to realize the full potential of AM technology, there must be greater emphasis on near-term AM exposure and education across all functional areas within the military on a much larger scale than is currently in place. The existing limited exposure to AM technology in specified fields and occupational specialties, such as maintenance and aviation, hinders the impact potential of 3D printing in the military.

Essentium Inc., in partnership with the National Guard Bureau and United States Air Force, had the opportunity to speak to service members of various ranks and occupational specialties about how AM could potentially scale across the military.

In one 60-minute brainstorm exercise, several Army National Guard motor transport operators were able to identify 12 polymer-based applications that would drastically improve quality of life and safety, reduce work hours, and streamline existing workflows. When signal corps soldiers answered the same set of questions, their desired materials and end-use applications varied wildly from the earlier group. Whereas transportation and maintenance soldiers focused on non-conductive customized tools, vehicle wheel chocks, and backlogged replacements for degraded rubber parts, signal corps soldiers focused on ESD safe-material applications, cable management, and maintenance trays. These observed variances occur across U.S. military components as well. Air National Guard members quickly pointed out polymer needs in flight boots and caps, custom FOD protection, and jigs and fixtures for advanced maintenance and machining needs.



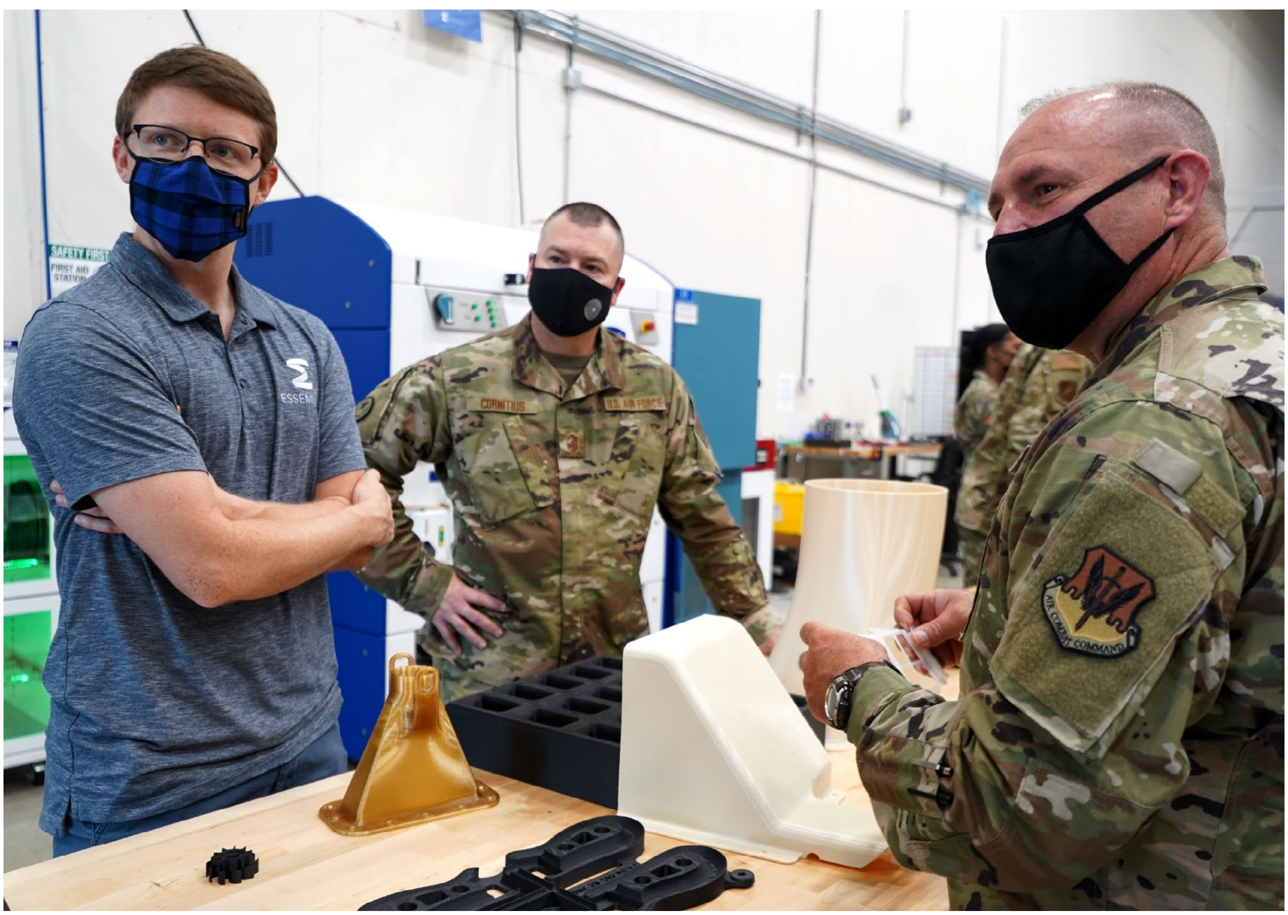
Based on these interactions, it is evident that with an increase of exposure and education of AM capabilities, other members of professional areas such as combat engineers, combat arms, medical, air defense, and artillery can find new ways in which rapid, customized polymer components can increase individual and unit readiness.

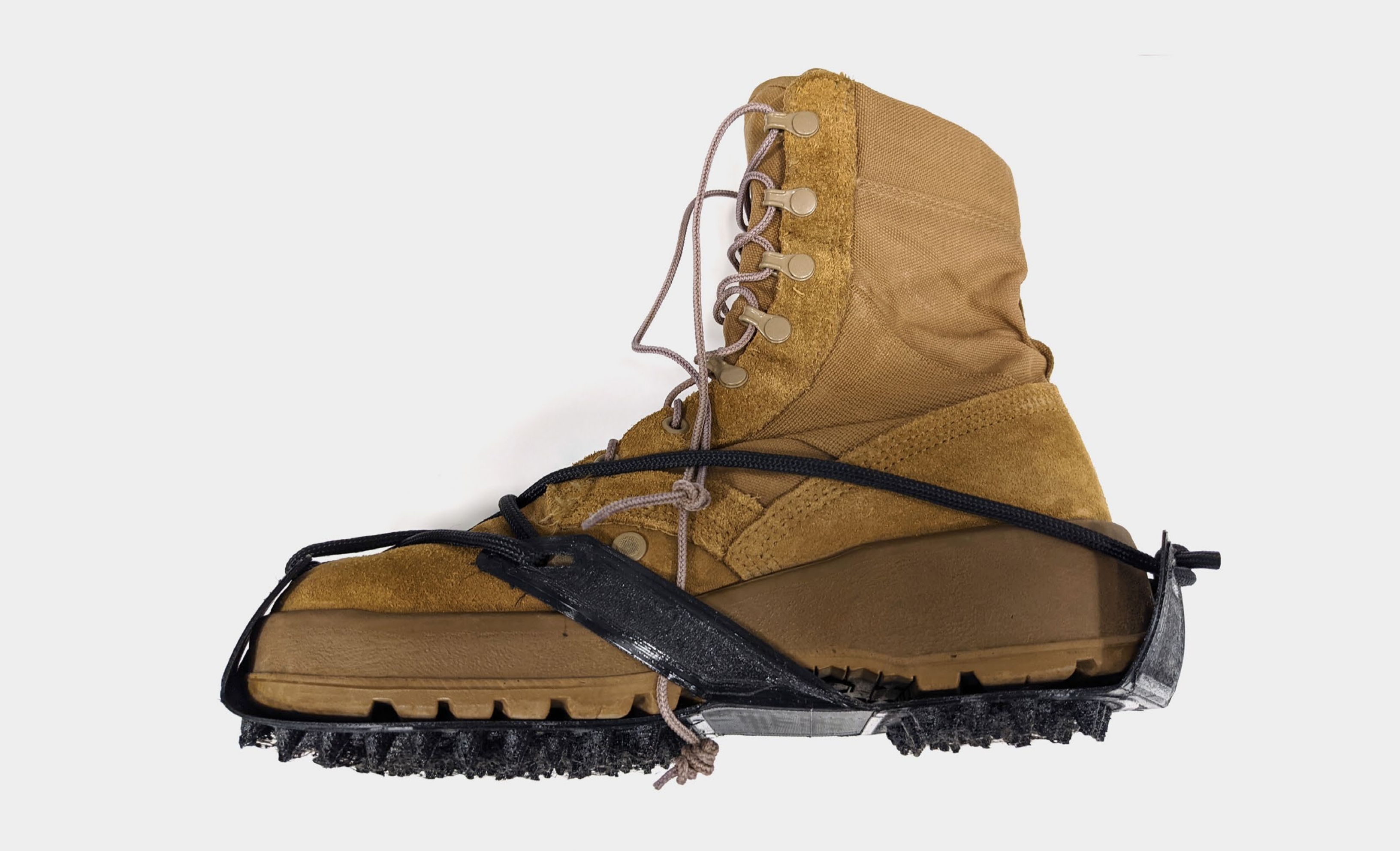
Stuck in the Crawling Phase

The common military phrase “crawl, walk, run,” used to support a phased approach to training, is becoming increasingly prevalent in the implementation of 3D printing. The Expeditionary Lab of the U.S. Army’s Rapid Equipping Force has used 3D printers in a deployed environment for over a decade and the Marine Corps began introducing desktop-based 3D printers to frontline units as early as 2016.

The experimentation of AM and 3D printing in military applications has been in the “crawl” phase for these groups for quite some time. On the other end of the spectrum, the Air Force and Navy adoption of industrial-strength AM at strategic depots is gaining momentum. These branches are “running” as they cater to advanced users who need access to engineering-grade materials for highly technical or demanding end products.

Essentium High Speed Extrusion provides the opportunity to bridge the gap between these two experience levels and “walk” the user through their skill development by supplying an all-inclusive toolset that can make a true impact within their formations.

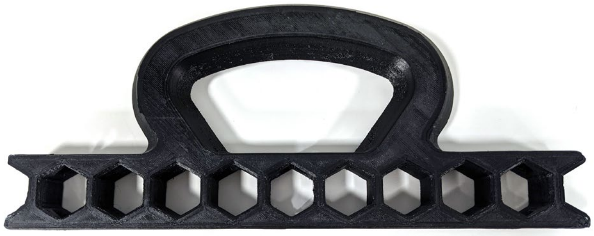




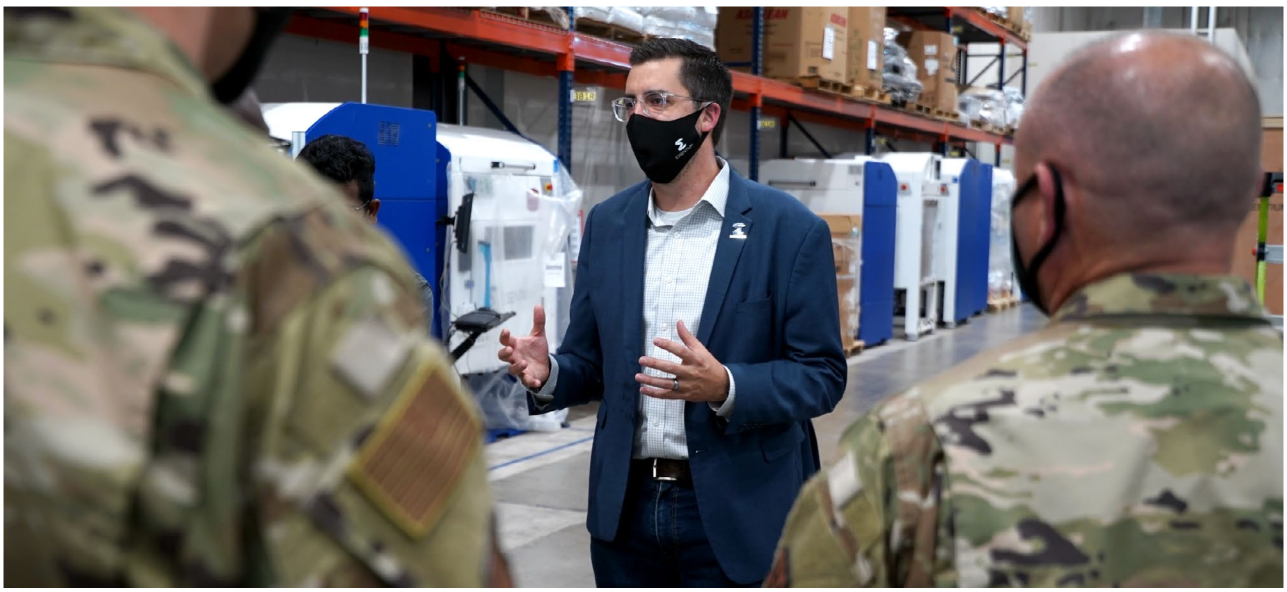
High Speed Extrusion in Action

Essentium applications engineers created two models to prove how rapidly scalable AM can impact the U.S. National Guard and military members operating in austere environments. The first was a traction cleat for frontline service members to illustrate how High Speed Extrusion can create rapid end-user equipment on demand. The need for this type of solution became more apparent as Texas experienced a severe winter storm that shut down supply chains and left first responders with inadequate winterized equipment when rescuing stranded motorists.

The second was a personal fitness multi-grip built to enable frontline innovation and increase physical fitness readiness. By providing a multi-grip that service members can strap to any weighted object securely, Essentium demonstrated how similar production runs can improve readiness at scale. High Speed Extrusion gives service members the freedom to work and innovate without fear of damaging highly valuable or sensitive pieces of equipment. This same freedom allows them to adapt to a wider range of training environments more readily, through unparalleled access to items previously believed impractical or unattainable.

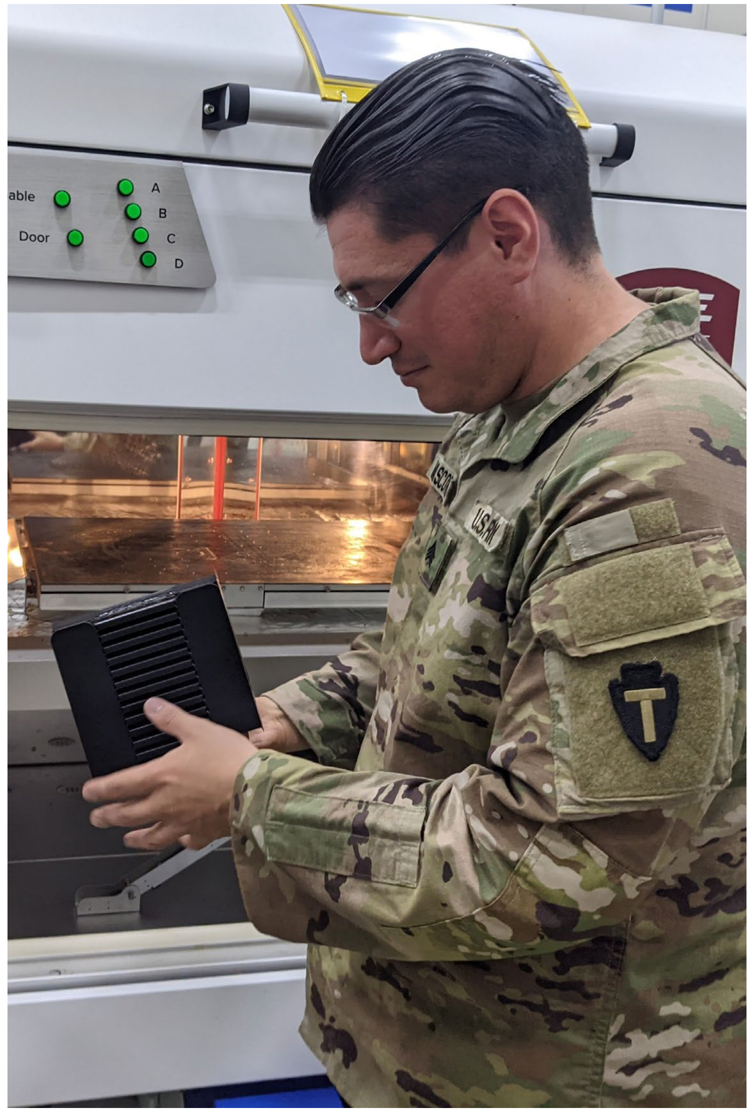


This access has further reinforced the advancements in AM technology through High Speed Extrusion. Reducing print time increases throughput in product, but most importantly, in experience and equipment access. Slower machines reduce this capability in military units, taking twice as long to produce any product, from simple training aids to complex end-use parts. Without the benefit of speed, one user may occupy a single printer for 10+ hours, filling a full duty day on one iteration. Additionally, any adjustments or mistakes extend time to part, causing the user to occupy a machine for days. This lengthy process has second and third effects that severely limit the capability of AM, as part printing must endure a filtration process of priority. The factor of speed also affects National Guard and Reserve forces who already endure tight schedules and compressed training days. These users need access to fast technology that allow them to conduct multiple iterations over the course of a weekend or two-week training period. Speed is crucial in part production, but more importantly, it grants broader access to AM technology.



It's difficult to imagine a modern fighting force without access to desktop and laptop computers. Technology permeates communication within modern society and has embedded itself throughout the military. The widespread use of various software and information applications currently enables users to engage in a wide array of mission-critical tasks ranging from annually required training modules to extremely sensitive intelligence operations. Computer skills, regardless of military occupation, are a necessity in the modern military. As Industry 4.0 begins to take shape in the modern world, the highly technical nature of design and print-on-demand capability will merge with advanced technologies such as machine learning and IoT. This continuous development of technological cocktails will drastically lower the barrier to entry for 3D printing and AM at an increasing rate. The near-term potential for AM to revolutionize hardware and equipment logistics echoes the historical impact that computers had on information and communication operations within the defense industry.

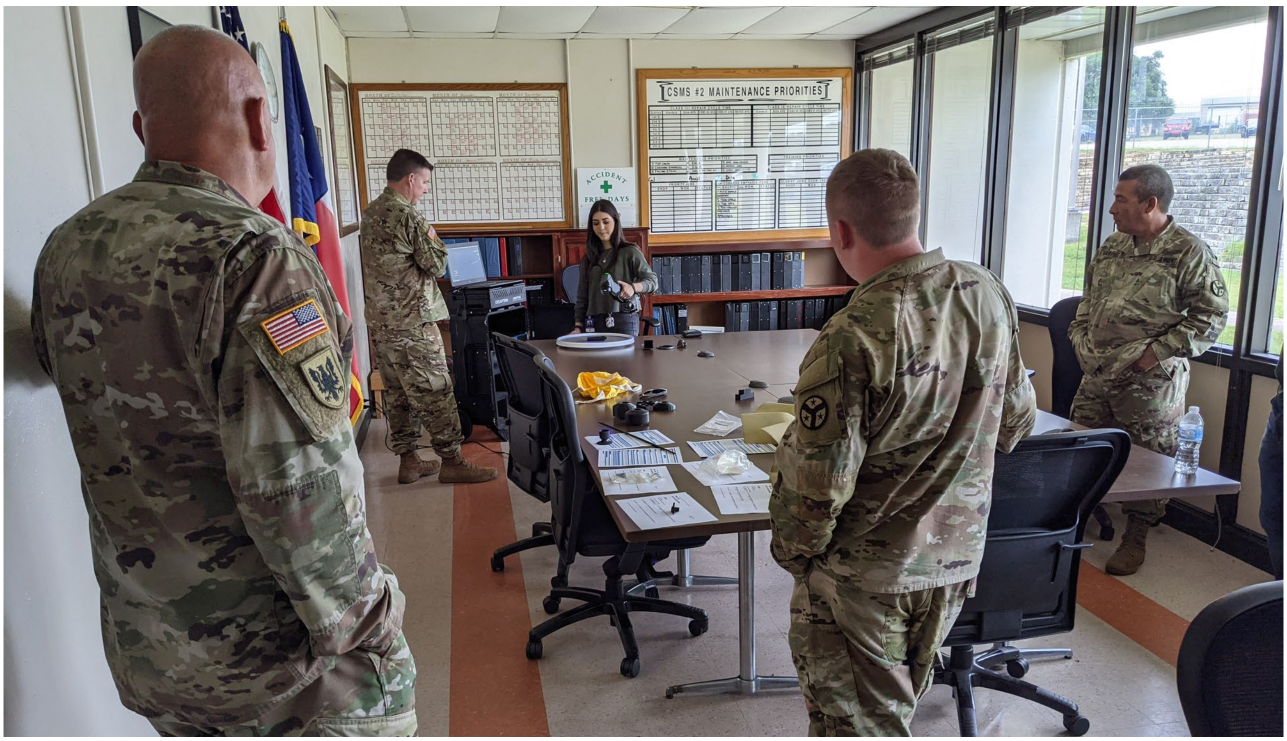
Hinderances in Adoption



The greatest hindrances to the scaled implementation of AM within the military are risk aversion, intellectual property concerns, and access to robust open platforms. Growing concerns over the capabilities and vulnerabilities of AM and 3D printing have surfaced. Of note is the potential for users to create or print unauthorized gear or items that could jeopardize the safety of service members or be exploited by adversaries engaged in cyberwarfare. The alteration of a 3D print file for a critical component in a weapon system could have terrifying repercussions on the battlefield, according to an audit conducted by the United States Inspector General in 2021. Again, this same concern mirrors the earlier implementation of computing technologies within military formations, yet it has now become commonplace and critical to mission success.

To combat these risks, the military has produced training programs that inform computer users how to avoid mishaps. There is an emphasis placed on end-user responsibility that is reinforced through training. Waiting for AM to be “perfect” before beginning wide-scale implementation forces it to tread the same ground as other technologies that have lagged significantly in the defense sector, such as small unmanned aerial systems (S-UAS). Like the S-UAS implementation, military end-users will be locked into “proven” systems that offer limited scope or capability, that become quickly outpaced by the more agile and competitive commercial market. The result is still being felt to this day; despite significant advancements and accessibility, American warfighters do not have common access to rapid, disposable unmanned systems. If risk aversion is again allowed to run rampant through the implementation of technology within the ranks, the commercial and private sector will begin to develop AM capabilities that far exceed that of the military, reducing their effectiveness in conventional and unconventional warfare.

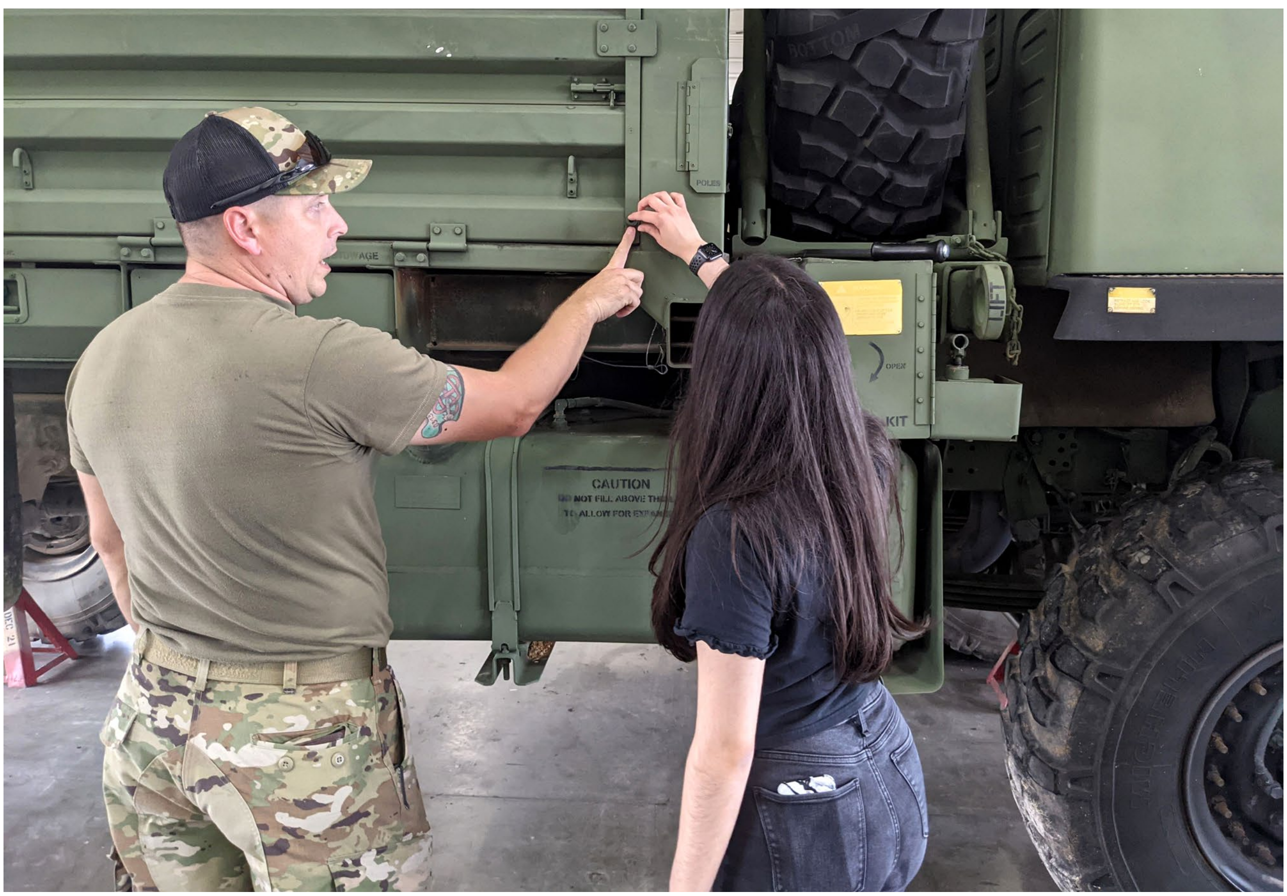
The second hindrance is that of intellectual property and the lack of clear guidance within formations. The capability to 3D scan physical objects is becoming increasingly accessible to the average user, with smartphones and like devices integrating LiDAR to enhance augmented reality programs. Developers have already built surprising powerful scanning applications that create files that can be printed. Hardware manufacturers are now facing a question almost identical to what the music industry with the rise of CD burners: what happens when user capability exceeds market availability or allows them to circumvent processes entirely? There is no shortage of proposed answers to this question. For example, prime military contractors can support the additive manufacturing process by adopting the technology organically to create parts on demand quickly or can transfer the responsibility of manufacturing directly to end-users with a reasonable percentage of part production.

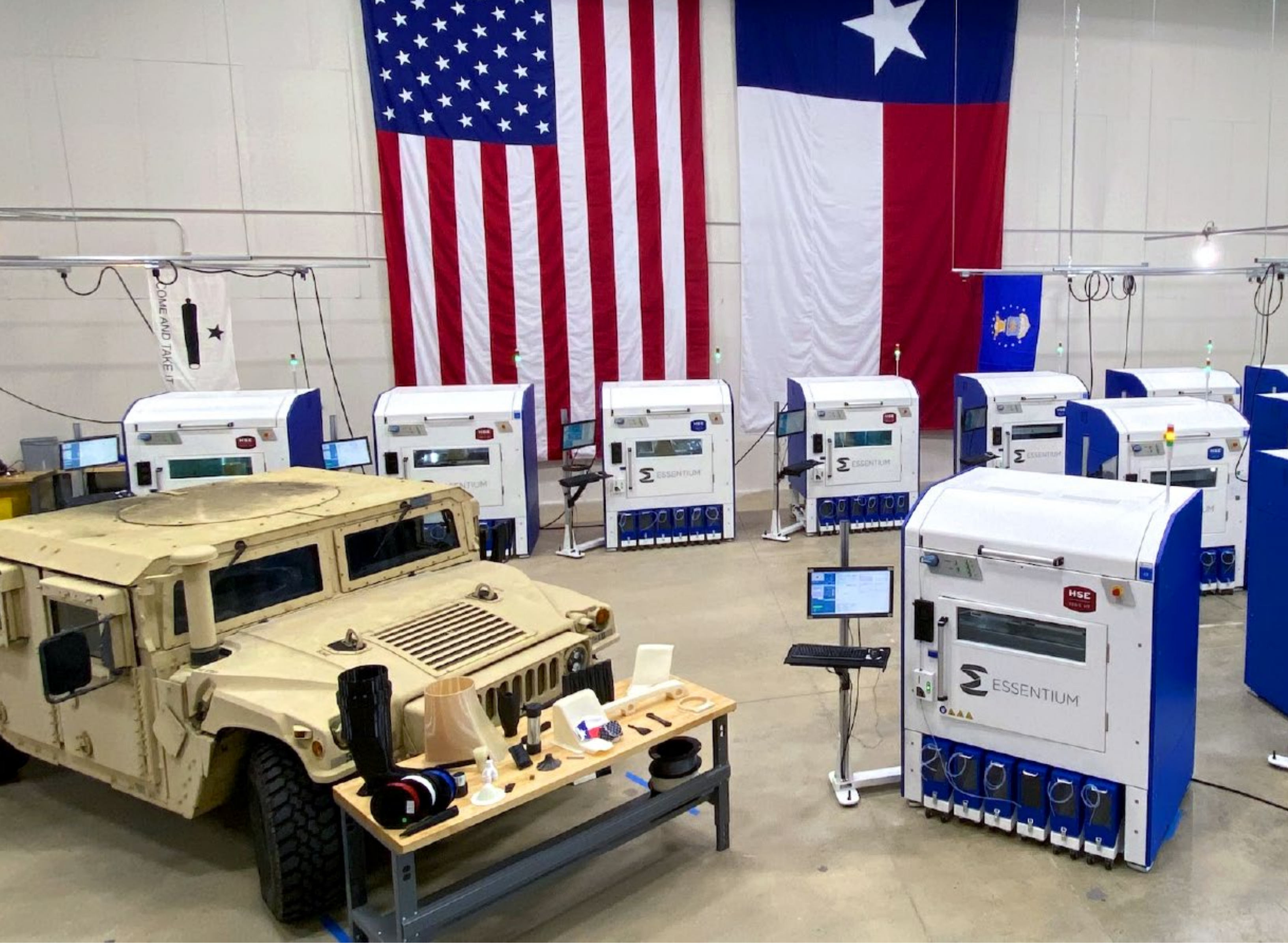


Former head of U.S. Army Materiel Command, Gen. Gus Perna said "I just need the rights to produce the capabilities for the equipment that we bought. It's for the execution of replacing these readiness drivers, not replacing the supply chain." This important concept has been a particular point of stagnation among progressing AM and is the subject of ongoing discussions between industry and defense professionals. When asked if they had placed any non-critical additive manufactured parts onto vehicles, a wheeled vehicle mechanic of the Texas National Guard simply shook his head and replied, "The part works great. I just don't know if I'm allowed to keep it on there." As 3D printing gains momentum from both sides, both strategic and end-user adoption, it becomes paramount to train a wide variety of military professions on the potential of additive manufacturing. This leads to the third hindrance to AM at scale.

The third hindrance to AM at scale is access to the target technology. Desktop 3D printers are decreasing in price and becoming more commonplace. However, the speed and material capabilities of these printers do not meet the needs of the warfighter. Conversely, industrial AM machines are traditionally more expensive, with closed platforms that provide little freedom to the user and lock them into brand-specific material portfolios. This heavily reduces mission capability and limits access to technology. In 2021, the United States Navy awarded a $20 million contract to buy advanced additive manufacturing capabilities to scale the technology.

The result was a purchase of 25 machines and included support material and training packages. While the purchase was a significant achievement for the additive manufacturing industry, it is worth noting that the United States Navy has approximately 80 bases inside and outside the continental United States. A similar purchase of $20 million in Essentium HSE 3D Printing Platforms would equate to over 85 280i HT HSE 3D Printers, support materials, training, and DryBox equipment for material storage. Considering the HSE 280i HT 3D Printer capability provides two completely independent print heads in one machine, this number rises to effectively double that capability available to the warfighter.





Conclusion

The military and defense industry are no strangers to 3D printing. However, historically the speed needed to make the technology applicable and useful to entire formations has been missing. Essentium continues to push boundaries and open capability pathways for a variety of industries. These breakthroughs have garnered the attention of professionals from across multiple industries. If the Department of Defense is focused on defying expectations and truly putting innovation in the hands of the warfighter, then scaling additive manufacturing capabilities across the entire force is a solid way to enter the next phase.

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