

Opening Remarks for House Energy and Commerce Subcommittee Hearing

Edward D. Herderick
Additive Technologies Leader
GE Corporate Supply Chain and Operations

████████████████████

Chairman Burgess, Vice Chairman Lance, Ranking Member Schakowsky and members of the Committee, it is a privilege to share GE's thoughts on 3D printing, which represents a larger digital industrial revolution happening in the US and globally. Today, a designer can create a computer-aided design model of a part and digitally transmit it to a 3D printer to be directly manufactured. Increasingly, new designs and processes like this are being connected and managed through a digital thread where the freedom of design and manufacturing seemingly has no limits. One of GE's engineering leaders appropriately captured it when she said, "Complexity is free."

My name is Ed Herderick, and I am the Additive Technologies Leader for GE helping to spread the application of additive technologies across GE's industrial portfolio. This portfolio spans across industries that build, move, power, transport and cure the world, from jet engines and power generation machines to locomotives, medical imaging systems and more.

The emergence of 3D printing and additive technologies in industry has been both sudden and disruptive. Recently, Boeing and Airbus conducted the first flight tests for their 737 MAX airplane and A320neo single aisle jets with GE LEAP engines. LEAP is the world's first jet engine to include 3D printed fuel nozzles, which as the engine's "fuel injector," mixing fuel and air in precise ways to achieve maximum fuel efficiency and lower emissions. Using metal printing, the fuel nozzles are more fuel efficient, lighter weight, and more durable compared to those made with conventional technologies.

The production of 3D printed metal parts in jet engines would have been almost unheard of even a decade ago. Today, we are asking what else can be printed in the engine to drive performance even higher. As it is, GE Aviation will be producing 35,000 printed fuel nozzles per year at the world's first mass additive production facility in Auburn, Alabama. By 2020, we will have produced more than 100,000 metal printed fuel nozzles. This success of

industrial implementation of additive technology in the aerospace industry is paving the way for broader applications in other industries.

GE's use of additive technologies in Aviation is only the tipping point of an exciting transformation underway across our 400+ factories. By 2025, we expect additive manufacturing methods will be used in the design and manufacture of more than 20% of GE's new product concepts. Our efforts in additive are part of a much broader initiative to build a digital thread through manufacturing that transform our factories into "Brilliant Factories." It is through the digital thread where additive technologies can truly emerge and realize their full potential for industries of all kinds.

Let me begin by introducing a bit of background on what I mean by additive manufacturing. For many additive manufacturing is synonymous with 3D printing. It's actually much more. Within GE, it involves a group of seven technologies that grow parts layer-by-layer from the bottom up from digital files. Processes such as cold spray, which spray metal powders at supersonic speeds, or direct write, which deposit liquid material through a stylus to print components like sensors, represent other ways of "building up" parts. Moreover, additive manufacturing itself is much more than just printing parts. GE uses additive throughout its manufacturing operations, from rapid prototyping and testing new designs to developing new tooling.

My testimony today is focused on one of those technologies, Laser Powder Bed Fusion, which is the most widely used of the metal printing technologies at GE. This technology uses powdered metal as the input material. The metal powder looks similar to silver colored metal flour and is engineered in both size and shape specifically for printing. The powder is encompassed in a box filled with an inert gas, such as nitrogen, and is melted in patterns to form parts using an industrial fiber laser. The parts are built on a metal plate in layers of 1 to 3 thousandths of an inch or about the thickness of a human hair. The machines themselves are about the size of two refrigerators side by side.

In many ways, the excitement and emphasis on additive manufacturing of metals and industrial materials is the product of a more than 20 year research odyssey. As early as 1993, researchers at GE Global Research demonstrated the feasibility for binderless sintering of metal powders. It's interesting to note the process and material advancement between then and now. In 1993 the laser used had 7.5 Watts of power, a scanning speed of 2 millimeters per second, and produced parts that were 30% dense. Today, we are using lasers with 200 to 1,000 Watts of power, scanning speeds of 1,000 millimeters per second, and produce parts that are greater than 99.9% density straight out of the box. Further, when implemented with care, the performance of additively produced metals parts today meets and even exceeds that of standard casting techniques. And this is a critical point.

I cannot emphasize enough the importance of understanding the physical metallurgy in order to produce this high quality, repeatable performance as the material properties are determined during the printing process. Manufacturers have had centuries to understand the physical properties of materials that traditionally have been milled or machined into the desired shape. With additive, and metals in particular, we have had only 20 years. Fortunately, GE, through its Global Research Center, is home to some of the world's foremost experts in materials and in additive techniques to help us make these evaluations.

As I mentioned, GE has expanded its thinking and application on where additive technologies can be applied across our businesses. I am excited to share a few more examples with you. In fact, one is part of an ongoing project we have with the Advanced Research Projects Agency for Energy (ARPA-E), where we have 3D printed a miniaturized version of a GE steam turbine rotor to test a new idea GE researchers have for reducing the cost of water desalination.. The rotor, roughly 6 inches long, is being used to demonstrate cost effective water and salt separation. In that case, metal printing empowered the team to design something that could not be made any other way and has the potential to dramatically improve the energy efficiency for water desalination. In order to accelerate new applications like this one, GE has built a new facility in Pittsburgh, Pennsylvania dedicated solely to 3D printing called the Center for Additive Technology Advancement.

We are also investing in small businesses through GE Ventures. One example where we have made a strategic investment is a company called Optomec based in Albuquerque, New Mexico. A key area of collaboration is 3D Sensors that are directly printed onto high-value components. Such tightly integrated sensors provide critical input to structural health and have the potential to substantially reduce the life cycle cost of complex mechanical systems

GE's initiatives with ARPA-E and through our Ventures business highlight the critical importance of building a robust ecosystem in additive technologies across the US. We're proud to be a partner of and applaud the America Makes Additive Innovation Institute in Youngstown, Ohio, which has been a leader in building this ecosystem of manufacturers, machine makers and other key stakeholders in the additive supply chain. GE also recently joined the 3MF Consortium. Based in Massachusetts, this Consortium is bringing big companies like GE and Microsoft together with machine makers such 3D Systems and Stratasys and design software makers such as Autodesk to standardize file formats around 3D printing. As we go forward, GE will continue to look for ways to strengthen the additive ecosystem here in the US.

In closing, additive manufacturing is a transformative technology that is opening up new frontiers in manufacturing and is an important tool in realizing GE's Brilliant Factory vision. It is and will have far reaching impacts that accelerate the introduction of new, high performance products that will support global infrastructure for years to come. Thank you, and I look forward to your questions.

###