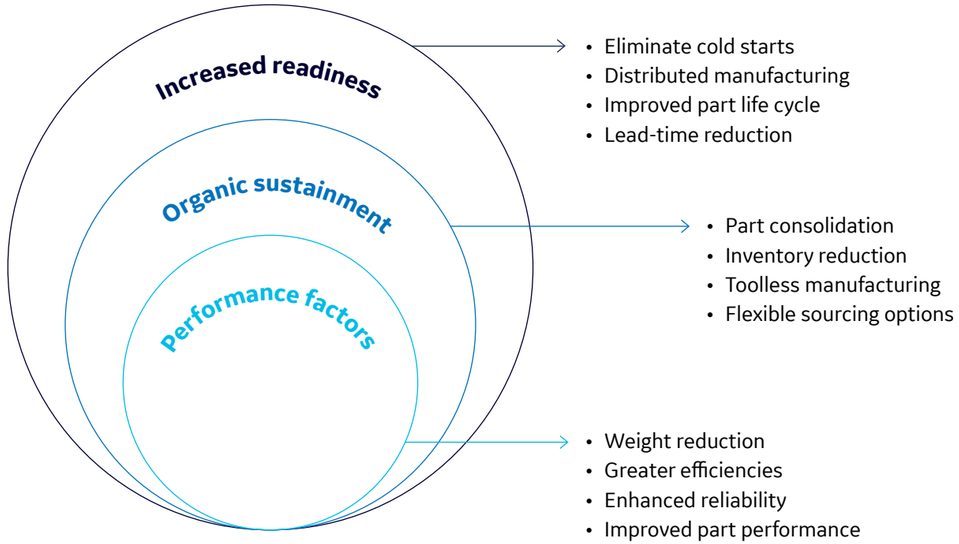
Military and Defense Solutions

Realize more benefits with metal additive.

An uncertain world with a complex threat matrix requires advanced platforms with modern supply chains. Whether on the ground or in the air, sea, or space, additive is the game-changing technology you need for more capable military products. Now, the ready are evaluating how additive can yield benefits like organic sustainment and increased fleet readiness.

Thinking through the bigger business case



- Eliminate cold starts
- Distributed manufacturing
- Improved part life cycle
- Lead-time reduction

- Part consolidation
- Inventory reduction
- Toolless manufacturing
- Flexible sourcing options

- Weight reduction
- Greater efficiencies
- Enhanced reliability
- Improved part performance

Where can metal additive take you?

Source legacy spare parts

A difficult-to-source WWII Mustang fighter aircraft exhaust stack redesigned to add advanced flow characteristics printed on the Concept Laser M2 using stainless steel powder.

From: 4 parts per exhaust stack
To: 1 part[1]

Speed time to market

General Atomics Aeronautical Systems, Inc (GA-ASI) NACA inlet for SkyGuardian™ drone, printed on the Concept Laser M2 in titanium Ti64I4V.

From: design to test flight in **6 months**
90% weight reduction
85% tooling reduction[5]

Maximize buy-to-fly ratio

GEnx jet engine's new power door opening system (PDOS) brackets using direct metal laser melting, printed on the Concept Laser M2 using cobalt chrome

≤90% reduction in scrap material waste[2]

Enhance part and cost efficiencies

GE Aviation's LEAP fuel nozzle

95% inventory reduction
30% cost-efficiency improvement
5x more durable with additive process[6]

Simplify sourcing

GE Aviation's Mid Frame Super Structure

300 to 1 part reduction
7 to 1 assembly reduction
50 to 1 source reduction[3]

Improved component and system performance

Air inlet for aerospace and defense optimized for airflow and integrated heating channels to avoid ice crystals, printed on the Concept Laser X Line 2000R using nickel alloy (In718)

10% weight reduction[3]
90% waste reduction

Reduce production lead time

GE Aviation's combustor test schedule reduced for the Catalyst engine

From: 12 months to test the combustor
To: 6 months[4]

OPPORTUNITIES FOR ADDITIVE

AM for repair and restoration

Precise repair and restoration are critical in the maintenance repair and overhaul (MRO) industry as it ensures end-of-life products are returned to operational condition. Traditional repair processes are manual and time-consuming.

Additive manufacturing allows for a more efficient repair capability of existing tools and parts, which leads to increased readiness, longer product lifetimes, and saving costs.

Additive advantages for MRO:

Increase efficiency while maintaining quality

AM produces a near-net-shape tool, greatly reducing material lead time and the machining workflow steps, which leads to shorter throughput time in the MRO shop and saves time and costs.

Save time and costs

Manufacturers can save significant time and costs by additively manufacturing parts which are traditionally sourced with long-lead times and high price tags.

Enable on-demand production

As a cost-effective method to repair and print parts, AM helps manufacturers achieve on-demand production and minimize downtime caused by broken parts.

CASE STUDY: SPARE PART READINESS

US Air Force to 3D print parts for fighter planes

Challenge:
Today, the US Air Force is searching for ways to procure parts, including crucial spare parts it needs for planes that have been in service for decades. GE's engineers are building a 3D-printed sump cover for the GE F110 engine. The sump is part of the oil lubrication system, and the sump cover is a key part of the engine.

Strategy:
The Air Force wanted to gain the capability and capacity of metal additive manufacturing as rapidly as possible to improve readiness and sustainability. GE has extensive experience qualifying and certifying additively manufactured metal components that require airworthiness certification and meet the commercial aviation sector's rigorous regulatory requirements. Sharing this knowledge helped the USAF explore how to quickly eliminate the associated risks with castings, and how metal additive might replace it for those parts that are either no longer in production, or where they need smaller production runs to keep platform.

Results:[8]

The US Air Force and GE settled on a program based on a "spiral development" model that increases in complexity and scale with each phase. In this program, complexity involves moving from simpler part identification, progressing to part and family of parts consolidation and eventually tackling complex components and systems.

OPPORTUNITIES FOR ADDITIVE

Supply chain robustness and resilience

Additive can help optimize manufacturing processes and streamline the larger supply chain. Shorten lead times and reduce costs by additively manufacturing hard-to-find, legacy, and low-volume parts on-demand.

Additive advantages for supply chain efficiencies:

Reduces lead time

End users can print low-volume parts organically, reducing the time to acquire replacement parts and streamlining the supply chain.

Lowers expenditures

With parts printed on-demand, additive reduces production downtime and eliminates the expense of high-volume replacement parts.

Enables mass customization

Freedom of design with additive enables manufacturers to customize tooling for mass production of bespoke parts.

Extends product life span

With optimized geometry and reduced welding and brazing, additive extends the life span of outdated or damaged parts.

Streamlines the supply chain

Additive enables more flexible inventory management, reducing inventory and the number of suppliers.

Smooth your supply chain. We're ready.

Challenge 1

Low-volume spare parts needed

Turn weeks of sourcing and repair into on-demand, organic production. Manufacture low-volume, spare parts in-house with additive technology.

Challenge 2

Long lead times

The ability to manufacture a part for a replace-vs.-repair scenario has a direct impact on turnaround time. Leverage additive to reduce the risk associated with MRO and a diminishing supplier base, removing the burden of accessing and sourcing hard-to-find parts by printing them in-house.

Challenge 3

Too many suppliers and costs

Freedom of design empowers manufacturers and end users to build unique structures, streamlining many parts from many suppliers into one additive part. The results are fewer purchase orders, less lead time and reduced costs.

Challenge 4

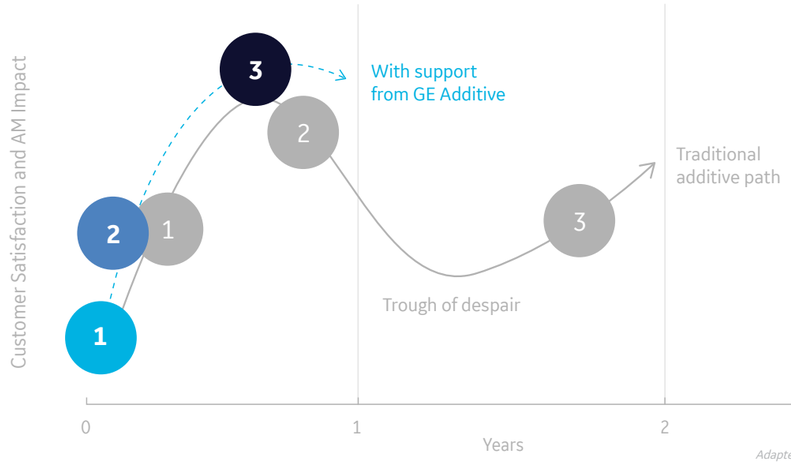
Sustainment and readiness of older equipment

Sustainment and readiness of older equipment. Keeping aged equipment operational is no small feat. Difficulties accessing and sourcing the necessary spare parts could represent a significant readiness challenge. But with additive enabling the production of on-demand parts, cold start time is greatly reduced.

Additive parts at scale? We're ready.

Our proven process helps you adopt additive—faster.

Path to Production for Non-Critical Parts



Adapted from Gartner Hype Cycle

What are the Application Sprints?

Fast-track your path to full production of additive parts when you leverage the Application Sprints from GE's AddWorks™*.

Comprehensive support—workshops and training, hands-on consulting and print services—to accelerate time to market

Extra expertise where you need it, whether in concept, development, qualification or full production

Key process steps and GE's AddWorks Application Sprints:

Concept Sprint	Development Sprint	Production Sprint
1. Identify a part.	2. Design the part for metal additive.	3. Qualify the part and enable full production.

*Trademark of General Electric Company

We are and will continue to be super users.

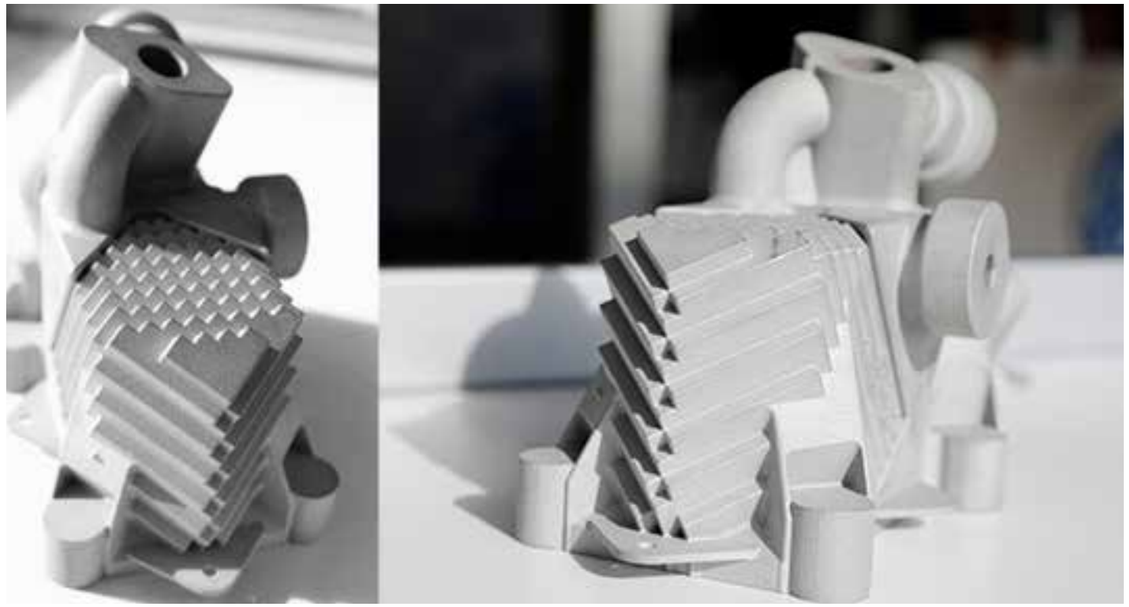
GE has been on the forefront of 3D printing for nearly four decades. As 'super-users' of additive equipment and with additive consultants around the globe, no one is better positioned to help customers on their additive journey than GE Additive.

With several strong patents around additive heat exchangers, we are leaders in developing thermal management applications with additive. Our team has expertise in designing fuel-oil coolers, air-oil coolers, fuel heaters, air-air precoolers for ECS systems, and more.

Airworthy additive parts started here. Members of our team helped with the first additive FAA certification in 2015. We now have multiple part numbers certified, and over 20 parts in active certification projects. We also estimate that GE Aviation has 23,500+ flight quality additive parts produced to date.

We have materials expertise with a both range & depth of aerospace materials and experience working with external regulatory agencies for materials qualification. Several of our team members worked with GE's Aviation's fuel nozzle, including powder, parameters, production and qualification. We can provide access to our materials development engineers, parameter/theme developers, materials process engineers, and materials application engineers.

Photo: GE Aviation's Catalyst Engine, Heat Exchanger



GE Additive's end-to-end solutions, ready when you are.

See where our experts and offerings can support your company—from sustainment and legacy process improvements to making parts or molds with new metals.

Machines

Our specialty machines offer low machine-to-machine variance tomeet your industry requirements and scale production.

- Concept Laser M2 Series 5 (DMLM), enabling high productivity and quality
- Concept Laser X Line 2000R (DMLM), enables manufacturing of large additive parts with the largest build volume
- Arcam EBM Q10plus, saving costs with high-precision structures
- Spectra H, high-heat, crack-prone materials
- Binder Jet, superior results at mass production levels

Powders

We create certified, high-performing powders for every metal additive need, taking into account a variety of mechanical behavior design data and material science.

- Titanium alloys
- Nickel alloys
- Aluminum alloys
- Cobalt chromium
- Stainless steels alloys

Print Services

Ensure quality and speed to market when you send your part to GE for printing, no matter how complex or large the part. We serve you a printed part in one hand and a product roadmap in the other.

- Prototype and test articles
- Manufacturing technical data and development
- Large-format printing
- Design to print (AddWorks)
- Production printing

AddWorks from GE Additive

Our global team of 200-plus engineers and manufacturing specialists can support your team and accelerate additive adoption.

- Workshops and training
- Application Sprints
- Consulting services
- Engineering services

Customer Experience Centers

GE experts are ready to collaborate in person when you visit one of our two on-site locations, designed to help you from initial design to full production.

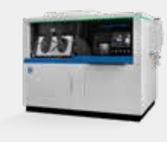
- Cincinnati, Ohio (USA)
- Munich, Germany (Europe)
- Mitsubishi Corporation Technos Co., Ltd.* (Japan)

*Sales partner in Japan

EBM AND LASER:

Which 3D printing technology is best for you?

Our experts will help you find the machine type fit for your application.

	Electron Beam Melting (EBM) machines	**Direct Metal Laser Melting (DMLM) machines**	**Binder Jet factory solution**
Key advantages	EBM machines create dimensionally accurate parts quickly and efficiently by utilizing a high-power electron beam. The process takes place in vacuum and at high temperatures, resulting in stress-relieved components with material properties better than cast and comparable to wrought material. **Design Freedom** • Allow for dense nesting of entire build tank and large, bulky parts without swelling • Easily create little to no supports on parts at low costs **High Productivity** • Achieve high productivity for large volumes • High process temperatures produce parts with no residual stress **Cost-Effectiveness** • Enable use of reactive and crack-prone materials (e.g., TiAl) at low costs • Reuse powder extracted from the Powder Recovery Station (PRS)	DMLM machines use lasers to melt layers of fine metal powder and create complex geometries with incredible precision directly from a CAD file. Several different machine envelope sizes — including the largest powder-bed metal additive system in the world — are available to meet the needs of any industry. **Design Freedom** • Allow for complex internal passages, thinner walled structures and undercuts • Create highly detailed and fine-feature parts directly from a CAD file **Surface Quality** • Achieve exceptional surface characteristics and minimal porosity • Deliver best-in-class repeatability, productivity and usability **Productivity and Safety** • Suited for highly regulated industries by providing superior part yield • Closed powder handling for less waste and operator exposure	The binder jet process spreads a thin layer of powder, with printheads strategically depositing droplets of binder into the powder bed. GE is actively partnering with select companies to bring this disruptive technology to market in 2021. **Design Freedom** • Provides the flexibility to scale without sacrificing quality • 99.9+% material density achievable **High Productivity** • No supports required, nest in 100% of the build box for maximum productivity • Superior green strength allows for automated production solution **Cost-Effectiveness** • Low cost powder and infinite powder reuse greatly reduces raw material cost • Extremely fast process creates tremendous throughput
Materials available for machines	 **Q20plus** Build volume 350 x 380 mm (Ø/H) • Arcam EBM Ti6Al4V Grade 5, P-Material • Arcam EBM Ti6Al4V Grade 23, P-Material	 **Spectra H** Build volume 250 x 430 mm (Ø/H) • Arcam EBM Ti6Al4V Grade 5, P-Material • Arcam EBM TiAl, D-Material • Arcam EBM Nickel alloy 718, D-Material • Arcam EBM Highly Alloyed Tool Steel, D-Material	 **M2 Series 5** Build volume 250 x 250 x 350 mm (x,y,z) • Stainless Steel 316L • Stainless Steel 17-4PH • Maraging Steel M300 • Aluminum AlSi10Mg • Aluminum AlSi7Mg • Nickel 718 • Nickel 625 • Titanium Ti6Al4V ELI Grade 23 • Cobalt CoCrMo	 **X Line 2000R** Build volume 800 x 400 x 500 mm (x,y,z) • Aluminum AlSi10Mg - Balanced • Aluminum AlSi10Mg - Productivity • Titanium Ti6AL4V Grade 23 • Nickel 718	**Coming 2021**  **Binder Jet** Build volume 500 x 500 x 500 mm (XYZ) • Stainless Steels 316L • Copper • Nickel based alloys • Others under development

GE Additive

Are you ready?

To rethink readiness and MRO efficiencies.

To accelerate production and shorten lead times.

To improve performance and reduce costs.

To look forward, not back.

When you're ready to optimize your business with metal additive, the people who pioneered its full production are ready to help.

Let's go. Talk to GE today.
ge.com/additive/military-defense

[1]Engineering.com, "Metal Additive Manufacturing Keeps Legend Flying, April 5, 2017, https://www.engineering.com/AdvancedManufacturing/ArticleID/14684/Metal-Additive-Manufacturing-Keeps-Legend-Flying.aspx

[2]GE Reports, "Readying the first additive manufactured part for the GEnx engines | GE Aviation," www.geaviation.com/press-release/genx-engine-family/readying-first-additive-manufactured-part-genx-engines (2018)

[3]Blair Clafin, "Cummins Takes Next Step in 3D Printing and the Future of Manufacturing," Cummins, March 7, 2019, https://www.cummins.com/news/2019/03/07/cummins-takes-next-step-3d-printing-and-future-manufacturing (accessed June 11, 2020).

[4]The additive journey: The Time Is Now, Industry in 3D (accessed May 14, 2020).

[5]GE Additive "GA-ASI completes first test flight with metal 3D-printed part," May 19, 2020, https://www.ge.com/additive/press-releases/ga-asi-completes-first-test-flight-metal-3d-printed-part

[6]Gplast, 3D Cooling/Additive Manufacturing, http://www.gplast.com/3d-cooling-or-additive-manufacturing.php (accessed May 20, 2020).

[7]GE Additive Aerospace Precision Targeting EXTERNAL (accessed May 19, 2020).

[8]GE Additive, "US Air Force and GE's collaboration on metal additive reaches first technology milestone with 3D printed sump cover for F110 engine," https://www.ge.com/additive/press-releases/us-air-force-and-ges-collaboration-metal-additive-reaches-first-technology-milestone (accessed June 11, 2020).