For the ready.

Optimize your processes with proven metal additive solutions for military and defense.
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.

Realize more benefits with metal additive.

Thinking through the bigger business case

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

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

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

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

Maximize buy-to-fly ratio
GE/n 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

Simplify sourcing
GE Aviation’s Mid Frame Super Structure

- 300 to 1 part reduction
- 7 to 1 assembly reduction
- 50 to 1 source 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

Speed time to market
General Atomics Aeronautical Systems, Inc (GA-ASI) NACA inlet for SkyGuardian™ drone, printed on the Concept Laser M2 in titanium Ti64+V.

- From: design to test flight in 6 months
- 90% weight reduction
- 85% tooling reduction

Enhance part and cost efficiencies
GE Aviation’s LEAP fuel nozzle

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

Improved component and system performance
Airframe 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
- 90% waste reduction

Where can metal additive take you?

Where can metal additive take you?

- Source legacy spare parts
- Simplify sourcing
- Maximize buy-to-fly ratio
- Reduce production lead time
- Speed time to market
- Enhance part and cost efficiencies
- Improved component and system performance
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:
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.
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.

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.

For the ready.
Additive parts at scale? We’re ready. Our proven process helps you adopt additive—faster.

Path to Production for Non-Critical Parts

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:

<table>
<thead>
<tr>
<th>Concept Sprint</th>
<th>Development Sprint</th>
<th>Production Sprint</th>
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<tbody>
<tr>
<td>1. Identify a part.</td>
<td>2. Design the part for metal additive.</td>
<td>3. Qualify the part and enable full production.</td>
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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

*Trademark of General Electric Company
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 to meet your industry requirements and scale production.
- Concept Laser M2 Series S (DMLM), enabling high productivity and quality
- Concept Laser X Line 2000R (DMLM), enabling 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.

### Key advantages

#### Design Freedom
- Allows 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)

#### 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

### EBM machines

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.

### Direct Metal Laser Melting (DMLM) machines

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.

### Binder Jet factory solution

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.

### Materials available for machines

#### EBM machines

- Arcam EBM Ti6Al4V Grade 5, P-Material
- Arcam EBM Ti6Al4V Grade 23, P-Material
- Arcam EBM Ti6Al4V Grade 5, D-Material
- Arcam EBM Ti4Al
- Arcam EBM Nickel alloy 718, D-Material
- Arcam EBM Highly Alloyed Tool Steel, D-Material
- Stainless Steel 316L
- Stainless Steel 17-4PH
- Maraging Steel M300
- Aluminum AISI1050
- Aluminum AISI1050
- Nickel 718
- Nickel 625
- Titanium Ti6Al4V ELI Grade 23
- Cobalt CoCrMo
- Aluminum AISI120Mg - Balanced
- Aluminum AISI120Mg - Productivity
- Titanium Ti6Al4V Grade 23
- Nickel 718

#### DMLM machines

- Stainless Steels 316L
- Copper
- Nickel based alloys
- Others under development

### Build volume

- **Q20plus**
  - Build volume: 350 x 380 mm (Ø/H)

- **Spectra H**
  - Build volume: 250 x 250 x 350 mm (x,y,z)

- **M2 Series 5**
  - Build volume: 800 x 400 x 500 mm (x,y,z)

- **X Line 2000R**
  - Build volume: 500 x 500 x 500 mm (XYZ)

- **Binder Jet**
  - Build volume: 500 x 500 x 500 mm (XYZ)

**Coming 2021**

- Stainless Steels 316L
- Copper
- Nickel based alloys
- Others under development

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For the ready.

For the ready.
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