



GE Additive

# For the ready.

Take to the skies with proven  
metal additive solutions.



Aerospace Solutions from GE Additive

# Take metal additive to full production.

Now is the time to leave molds and dies in the dust. To pave your path to full metal additive production—faster. Or risk falling behind.

Leaders in aerospace are already realizing their competitive advantage with metal additive. As your trusted partner with more than 10 years in metal additive industrialization, we'll help you realize your additive advantage and get to full production faster.

## Realize the potential for additive in aerospace

**Reduce material waste, long lead times and associated costs** of casting, milling and tooling.

**Print oversized airframe parts** on some of the world's largest 3D metal additive printers.

**Manufacture lighter, more durable parts** with titanium (Ti6Al4V), titanium aluminide (TiAl), cobalt chrome molybdenum (CoCrMo), nickel 718 (Ni 718) and other high-performance alloys.

**Produce low-volume replacement parts in-house**, streamlining the supply chain and reducing the time it takes to acquire spare parts for maintenance, repair and overhaul (MRO) and military outfits.

**Improve fuel efficiency** with lighter, consolidated components.

**Reach beyond the stars** with additive components built for space, satellites and unmanned aerial vehicles (UAVs).



# GO. Just say the word.

When you're ready to go from prototype to full metal additive production in aerospace, GE Additive has the products, solutions and expertise to help.



### Accelerate innovation

Leverage GE's global supply network of additive partners and diverse business experts to innovate at scale.



### Reduce risk

Lean on GE's experience with qualifying additively made parts in aerospace.



### Lower costs

Invest in additive with GE's easy, flexible pricing models while shortening the iterative process of making a metal additive part.



### Transform your business

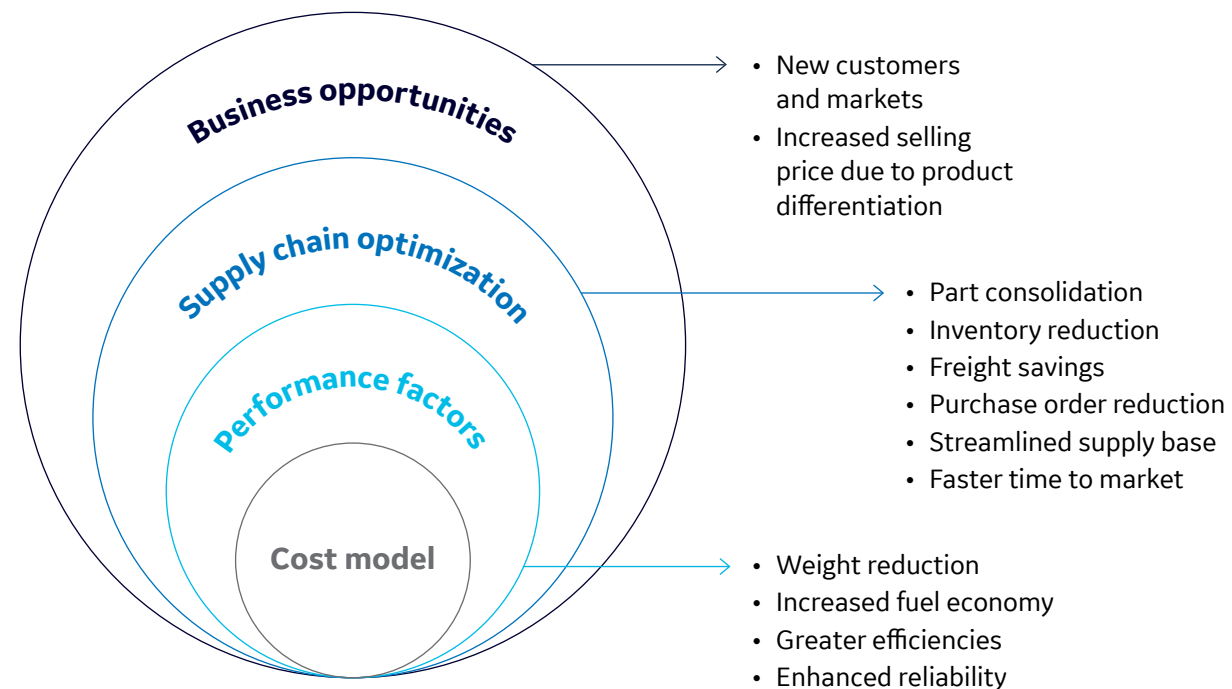
Take advantage of GE's unparalleled level of material science and application expertise to revolutionize aerospace and disrupt the supply chain.

# Realize ROI beyond the cost to make a part.

Now, the ready are evaluating beyond the part and considering how metal additive will benefit the entire system—from part cost to supply chain to potential new market opportunities.

As market leaders for additive in aerospace, GE Additive is here to help you discover your ROI potential with additive.

## Thinking through the bigger business case



## How much further can metal additive take you?

### Consolidate parts

GE Aviation's Servo HX, the first certified heat exchanger, printed on the Concept Laser M2 using aluminum powder

**From: 163 parts** per heat exchanger  
**To: 1 part<sup>1</sup>**

### Speed time to market

NASA's Pogo Z-baffle for RS-25 engine, printed on the Concept Laser M2

**From: 9 months** to manufacture the part  
**To: 9 days**  
**35% cost savings** compared to traditional methods<sup>5</sup>

### Unlock time and cost savings

Optisys LLC's radio frequency (RF) antenna for high-performance aerospace and defense applications, printed on a Concept Laser X Line 2000R

**75% reduction in non-recurring costs**  
**9-month reduction in lead time<sup>2</sup>**

### Enhance part and cost efficiencies

GE Aviation's LEAP fuel nozzle

**95% inventory reduction**  
**30% cost-efficiency improvement**  
**5x more durable** with additive process<sup>6</sup>

### Simplify supply chain

GE Aviation's Mid Frame Super Structure

**300 to 1** part reduction  
**7 to 1** assembly reduction  
**50 to 1** source reduction<sup>3</sup>

### Improve sustainability

Avio Aero's additively made low-pressure turbine blades for the GE9X engine, printed on the Arcam EBM A2X using titanium aluminide (TiAl)

**50% weight reduction**  
**10% lower fuel consumption**  
**10% decrease in emissions<sup>7</sup>**

### 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<sup>4</sup>**

### Maximize buy-to-fly ratio

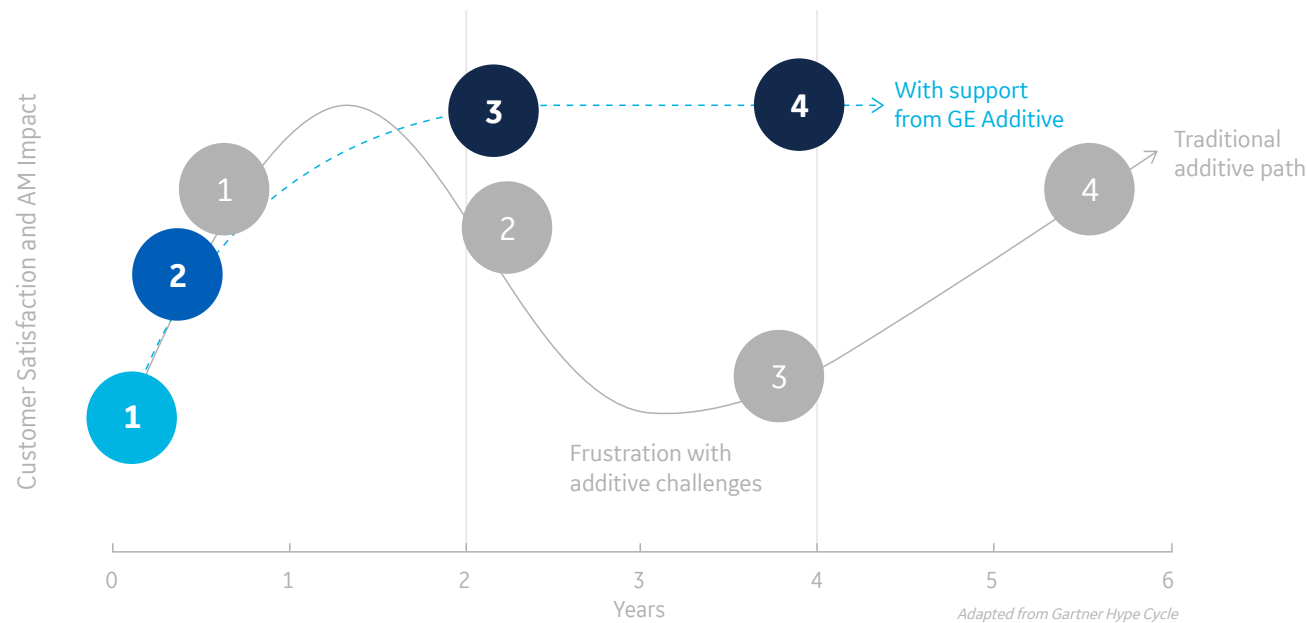
GENx jet engine's new power door opening system (PDOS) brackets using direct metal laser melting, printed on the Concept Laser M2 using cobalt chrome

**≤90% reduction in scrap material waste<sup>8</sup>**



# Shorten the time to production for additive parts with GE Additive's proven solutions for aerospace.

## Path to Production for Critical Parts



### What are the Application Sprints?

Work alongside GE's AddWorks™ experts. Get comprehensive support anywhere on your path to production: workshops and training, print services and hands-on consulting.

- End-to-end support—workshops and training, hands-on consulting and print services—to speed 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 Application Sprint	Development Application Sprint	Production Application Sprint
1. Build a business case and identify a part.	2. Design the part for metal additive.	3. Qualify the part and enable full production.
		4. Help you certify the part with a third party.

Wherever you're at on your path to full metal additive production, our team is ready to help you bring new innovation to market faster.

### With support from GE Additive

- Avoid missteps in creating a business case and selecting a part.
- Incorporate proven methodologies, material parameters and best practices for additive design.

### Without support

- Risk your business case and part decision failing during development.
- Undergo a steep, long learning curve for technical team with unanticipated expenses and obstacles.



“GE has learned by doing. These lessons learned are how **we help our customers succeed.**”

–Mark Shaw  
Director, Government Programs and Technology, GE Additive<sup>9</sup>

# Fast-track your path to production. We're ready.

As the world's leading power user of additive technologies in aerospace, we've seen firsthand how powerful this technology can be to an organization's top and bottom lines. Minimize your learning curve with GE Additive's proven solutions to common challenges.



## Challenge 1

### Identifying the Right Part for Additive

A business plan for metal additive can fall apart in the development phase when the team realizes the part they chose won't result in the ROI they envisioned.

**Fast track:** The best part for additive isn't always the costliest or most difficult to manufacture. Engineers must adopt an additive mindset and look beyond part-cost savings to find a part that works for metal additive in aerospace. Our experts can help your team achieve this and build a roadmap for development.

## Challenge 2

### Return on Investment

Sometimes manufacturers won't see a positive ROI of additive if they look only at the cost to make a part. A business case with a narrow scope means manufacturers lose out on larger ROI with additive while aerospace innovators forge ahead.

**Fast track:** Uncover all the opportunities for ROI that go beyond part cost and consolidation. GE Additive offers ways for you to invest with easy, flexible pricing models and proven solutions to build a successful business plan and get to production faster in aerospace.

## Challenge 3

### Gap in Resources, Talent or Experience

**"Lack of adequate skill sets is an industry issue,"** according to an estimated three in four business executives.

**Fast track:** Leverage GE Additive's technical expertise and material parameters, based on our own additive challenges and successes. Get consulting, training, hands-on support and more when your team partners with our engineers and specialists from GE's AddWorks.

## Challenge 4

### Repeatability and a Path to Serial Production

Achieving printing repeatability of high-quality parts can prove challenging, especially with extremely tight tolerance to meet aerospace certification requirements.

**Fast track:** Engage GE Additive's team to use our pre-established process parameters for several key parts, materials and machines to shorten your development time. As you work toward qualifying and certifying parts, we'll help you create a locked-down process to prove repeatability and meet industry certification requirements around the world.

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

Optimize your path to metal additive success with our proven solutions for aerospace. See where our experts and offerings can support you, wherever you are on the path to full metal additive production.



## Machines

GE offers specialty machines with low machine-to-machine variance to meet your industry requirements and scale production. Our machines:

- Concept Laser, direct metal laser melting
- Arcam EBM, electron beam melting
- Binder Jet, powder-bed fusion with binding agents

## 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

## 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.

- Large-format printing
- Design to print
- Production printing

## AddWorks from GE Additive

From training to print services, our global team of 200 engineers and manufacturing specialists can support your team and accelerate additive adoption anywhere in the process.

- 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 three on-site locations, designed to help you from initial design to full production.

- Munich, Germany (Europe)
- Mitsubishi Corporation Technos Co., Ltd.\* (Japan)



EBM AND LASER:

# Which 3D printing technology is best for you?



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

Key Advantages

### Electron Beam Melting (EBM) machines

#### 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)

### Direct Metal Laser Melting (DMLM) machines

#### 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

Materials available for machines



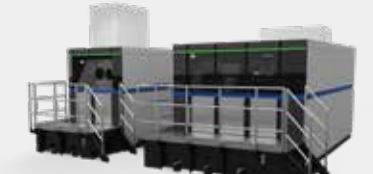
Q20plus

- Arcam EBM Ti6Al4V Grade 5, P-Material
- Arcam EBM Ti6Al4V Grade 23, P-Material



M2 Series 5

- 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



M Line Factory

- Cobalt CoCrMo
- Nickel 718 CL
- Aluminum A205



GE Additive

# Are you ready?

To turn a business case into a full-scale production.

To take metal additive further, faster.

To transform the way business is done.

To deliver innovation at the speed of today.

To look forward, not back.

When you're ready to turn complex into your competitive advantage, the pioneers in full metal additive production for aerospace are ready to help.

**Let's talk.**

[ge.com/additive/industry/aerospace](https://www.ge.com/additive/industry/aerospace)

<sup>1</sup>GE Additive Storyboard (accessed April 23, 2020).

<sup>2</sup>The additive journey: The time is now, Industry in 3D, [TBDURL.COM](https://www.ge.com/additive/industry/aerospace) (accessed April 23, 2020).

<sup>3</sup>GE Additive, "Aerospace\_Targeting.pdf" <https://ge.box.com/s/pbiqueefyox3i3e4p8f8lvjxz0w3rrgo> (accessed June 9, 2020).

<sup>4</sup>GE Additive, "Aerospace\_Targeting.pdf" <https://ge.box.com/s/pbiqueefyox3i3e4p8f8lvjxz0w3rrgo> (accessed June 9, 2020).

<sup>5</sup>GE Additive, "Aerospace\_Targeting.pdf" <https://ge.box.com/s/pbiqueefyox3i3e4p8f8lvjxz0w3rrgo> (accessed June 9, 2020).

<sup>6</sup>GE Additive, "Fuel Nozzle," [TBDURL.COM](https://www.ge.com/additive/industry/aerospace) (accessed June 26, 2020).

<sup>7</sup>GE Additive Production Playbook, November 2019, [TBDURL.COM](https://www.ge.com/additive/industry/aerospace) (accessed April 23, 2020).

<sup>8</sup>GE Additive Storyboard (accessed April 15, 2020).

<sup>9</sup>GE Additive, "GE Additive's Journey | Formnext 2019," <https://www.youtube.com/watch?v=J8JzqGvu26k> (accessed April 29, 2020).

<sup>10</sup>GE Additive, "GE Additive's Journey | Formnext 2019," <https://www.youtube.com/watch?v=J8JzqGvu26k> (accessed April 29, 2020).