



GE Additive

For the ready.

Launch your additive manufacturing program with help from GE Additive.

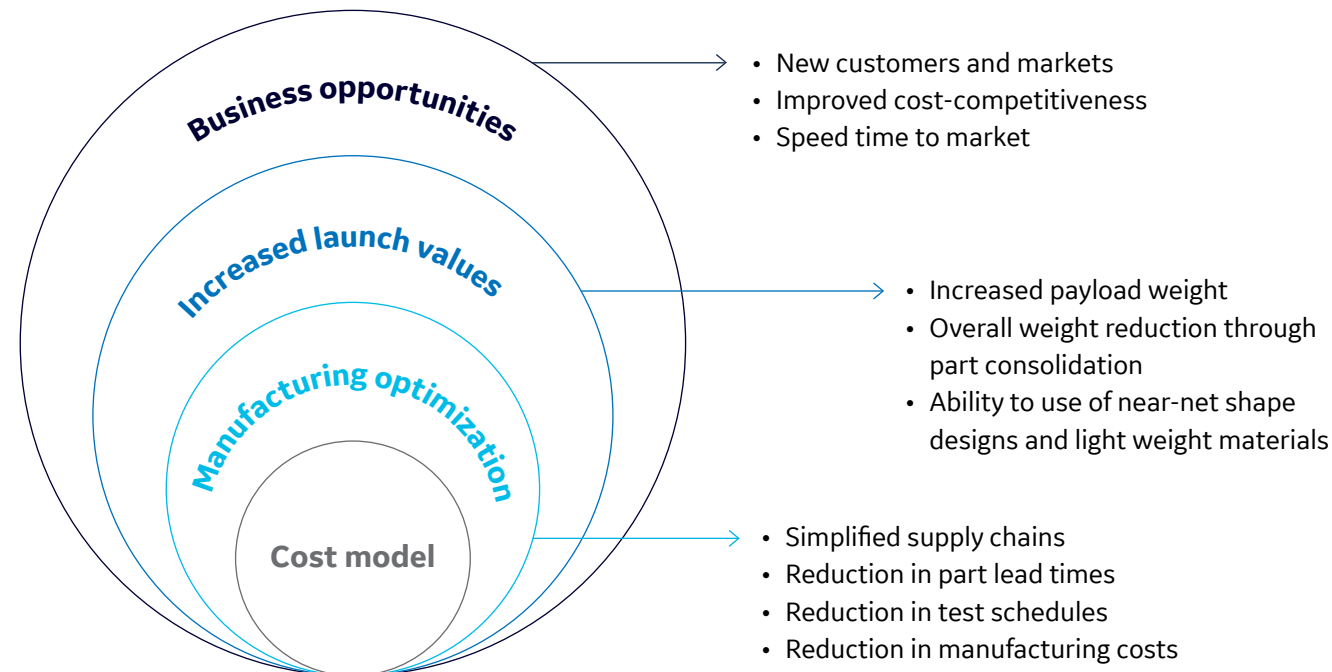


Space Solutions from GE Additive

Realize ROI beyond the cost to make a part.

To stay at the forefront of space exploration, you must radically change the way you design and build satellites, rockets, launch vehicles and more. Additive is the game-changing technology you need to reduce weight through 3D designs, digital analysis and optimization of parts produced exclusively for space applications. 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 generic space engine combustion chamber incorporates air ducts and free-form channels that eliminate the needs for welding, increasing productivity. Printed in Nickel alloy 718 on the Concept Laser X Line 2000R.

95% part reduction¹

High temperature stability

Unlock time and cost savings

Optisys LLC's radio frequency (RF) antenna for high-performance aerospace and space applications.

75% reduction in non-recurring costs

9-month reduction in lead time²

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 methods⁴

Enhance part and cost efficiencies

ThalesAlenia's Eutelsat's Konect satellite bracket demonstrates reproducible dynamic performance and higher performance capacity, printed in Aluminum on the Concept Laser X Line 2000R.

22% weight reduction

10% cost-efficiency improvement

2-month reduction in lead time⁵

Reduce production lead time

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

From: 12 months to test the combustor

To: 6 months³

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 emissions⁶



CASE STUDY

Optisys

Antennas are critical for conveying information across long distances. They are widely used in commercial and military aircraft, spacecraft and satellite communications. The complex radio frequency (RF) components that make up an antenna system can be large and heavy—characteristics that can impact mobility and performance. Optisys redesigned a large, multi-part antenna assembly into a palm-sized, lighter, one-piece, additive metal antenna. The antenna was printed in aluminum because of its surface conductivity, light weight, corrosion resistance and strength under shock and vibration.

How much further did additive take Optisys?

Business objective: Capture new revenue streams by creating a superior antenna that operates up to a 90-GHz frequency band.

Market obstacle: Traditional antenna manufacturing consists of complex systems that are large and heavy, which can lead to higher launch costs and inconsistent radio frequency (RF) performance at higher frequency bands.

Results:

Cost model:

- Optisys breaks even on machine acquisition just one year after purchasing its first metal additive machine
- 75% reduction in non-recurring costs

Performance factors:

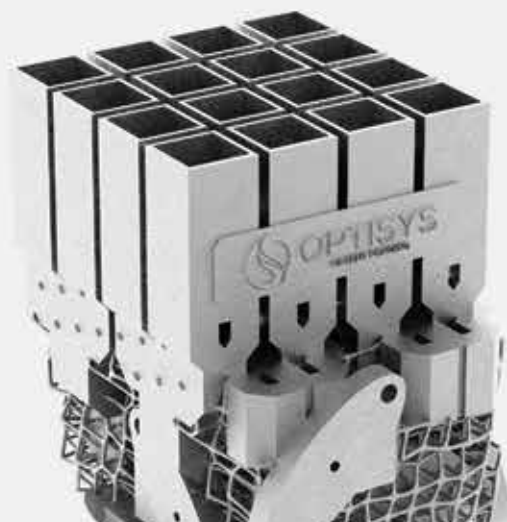
- 95% weight reduction
- 80% size reduction

Supply chain disruption:

- 100 parts with subtractive manufacturing to 1 part with additive
- Lead-time reduction: 11 months to 2 months

Business opportunities:

- Increase in sales: 30+ signed commercial contracts with \$34M in submitted proposals
- 2 patents awarded, with 10 provisional patents submitted and 20+ additional patents in preparation
- New market expansion: 5 product lines designed for AM



"It's easy to add features to an existing AM design, easier to assemble the finished components and, long-term, you have less testing, maintenance, and service when you have fewer parts."

– Rob Smith, COO at Optisys

"GE has learned by doing. These lessons learned are how we help our customers succeed."

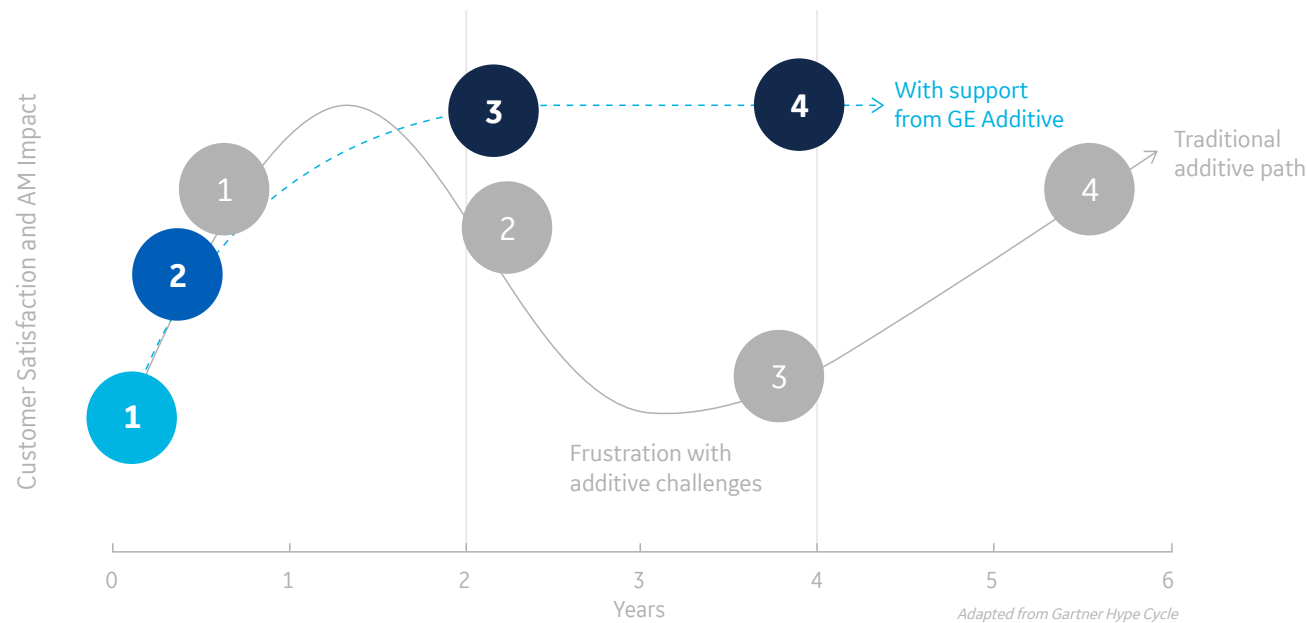
–Mark Shaw

Director, Government Programs and Technology, GE Additive⁸



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

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 are 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.



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

As the world's leading power user of additive technologies, 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 space. 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 EBW, Electron Beam Melting

Powders

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

- Nickel alloys
- Titanium
- Aluminums
- Copper
- Cobalt Chrome
- 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

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



Spectra 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

- 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

- Aluminum AlSi10Mg
- Titanium Ti6Al4V Grade 23
- Nickel 718
- Cobalt CoCrMo



GE Additive

Are you ready?

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

To take metal additive to a higher level.

To transform the way business is done.

To deliver innovation at rocket speed.

To look forward, not back.

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

Let's talk.

<https://www.ge.com/additive/space-industry-page>

¹GE Additive Storyboard (accessed April 23, 2020).

²The additive journey: The time is now, Industry in 3D (accessed April 23, 2020).

³GE Additive, "X Line product playbook" (accessed June 9, 2020).

⁴GE Additive, "X Line product playbook" (accessed June 9, 2020).

⁵GE Additive, "X Line product playbook" (accessed June 9, 2020).

⁶GE Additive, "X Line product playbook" (accessed June 9, 2020).

⁷Cision PR, <https://www.prweb.com/releases/2017/06/prweb14434835.htm> (June 20, 2017)

⁸The additive journey: The Time Is Now, Industry in 3D (accessed June 11, 2020).