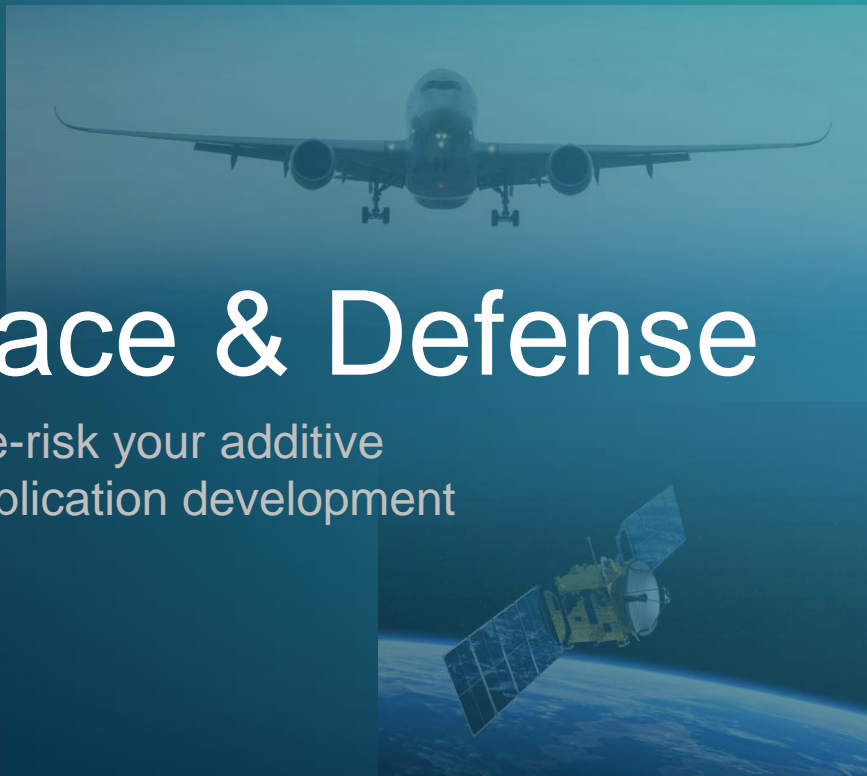


MM, DD, YYYY

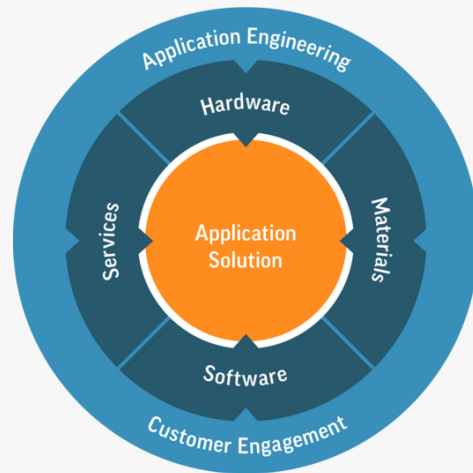
# Aerospace & Defense

Accelerate and de-risk your additive  
manufacturing application development

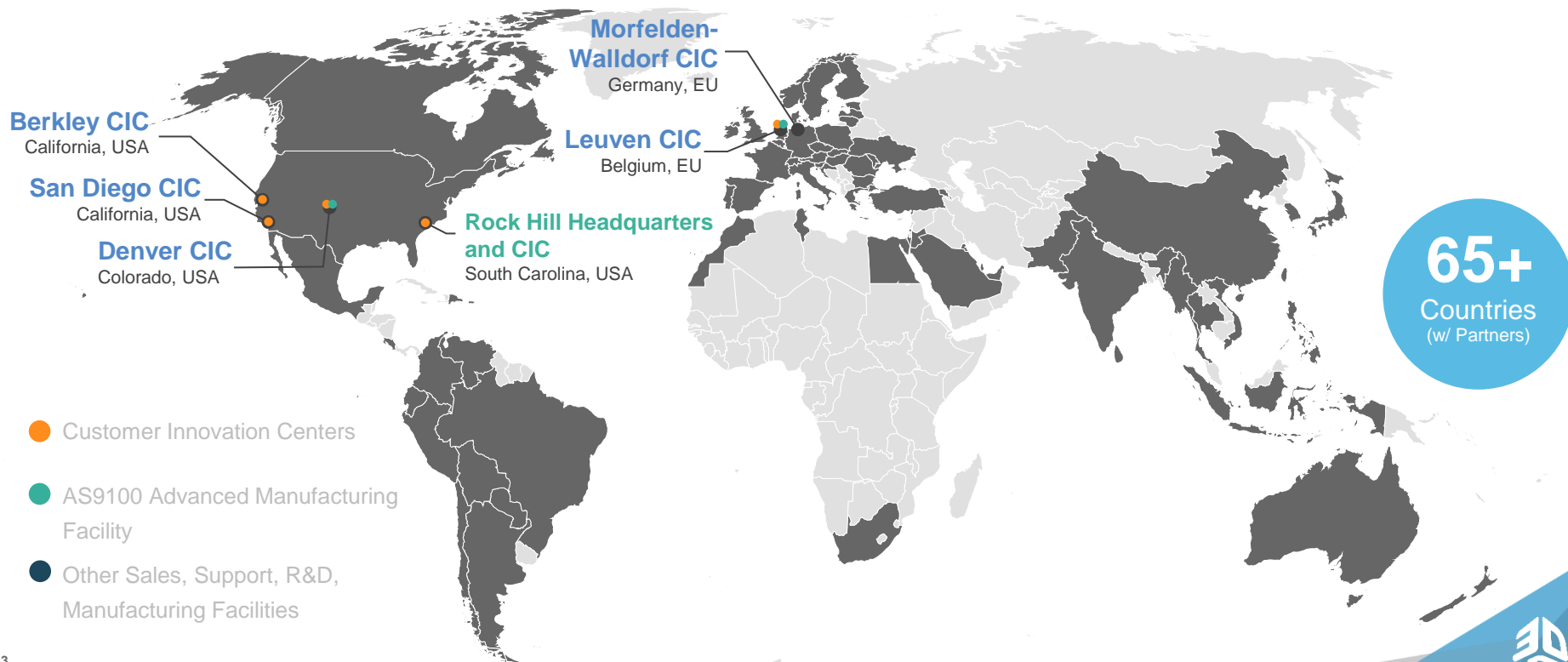


# 3D Systems

- Launched the additive manufacturing (AM) industry in 1986
- HQ: Rock Hill, SC (NYSE: DDD)
- ~2000 employees worldwide



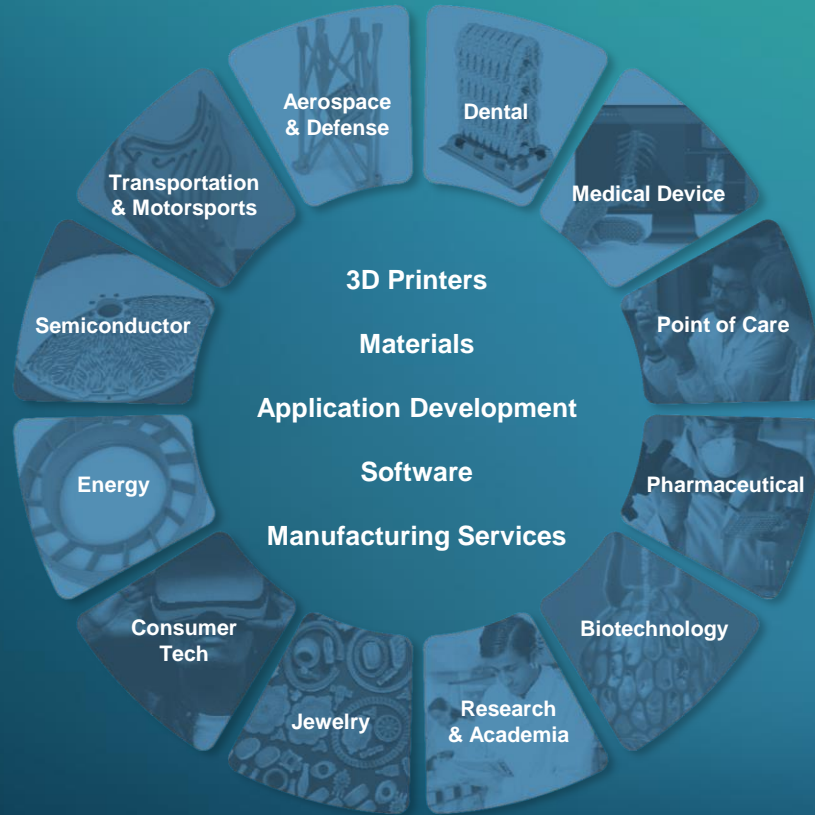
# Global Footprint



# AM Solutions Tailored to Applications that Demand High Reliability

Backed by an organizational  
commitment to engineering  
excellence

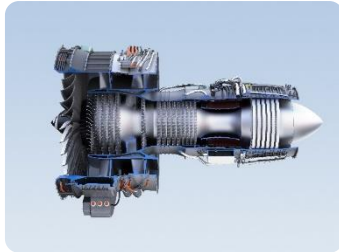
**35+** years of additive  
manufacturing expertise



# Aerospace & Defense Segment

## Key Sub-Markets

- Civil Aviation
- Military Aviation
- Space
- Turbomachinery
- General Defense



# We Shape the Future of Additive Manufacturing

With more AM solutions than anyone in the industry



**1K+**

patents over  
the past decade

**2K+**

structural Ti or Al-alloy  
components for space  
flight since 2015

**15+**

satellites with 3D  
Systems produced flight  
hardware on board

**2M+**

medical devices  
manufactured

**200+**

passive RF flight parts  
since 2017 with high  
growth potential

**35+**

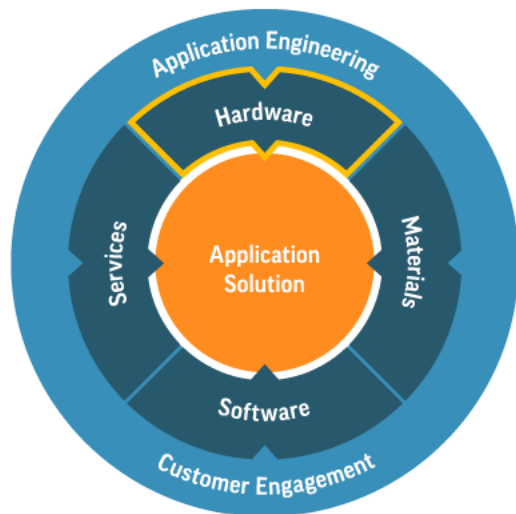
years of additive  
manufacturing  
innovation

**Additive  
Innovator**

end-to-end solutions  
for SLA, SLS, DMP,  
VPP, extrusion



# Hardware for Production AM Workflows



## Metals

Direct Metal Printing (DMP)

- Best in class structural titanium printing
- Lowest O<sub>2</sub> build environment (<25 ppm)
- Seamless printing with multi-laser productivity
- SupportFree™ printing parameters and strategies



## Plastics

SLS, SLA, VPP, Extrusion  
Production-grade plastics

- Comprehensive & consistent datasheets
- Long-term indoor & outdoor environmental stability
- Tested per industry standards



## Metal Casting/ Silicone Tooling

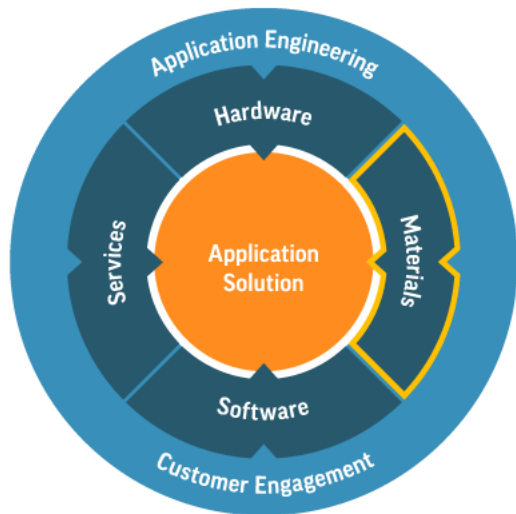
SLA, VPP, MJP for metals  
casting and flexible seals

- Cost savings, speed, flexibility, complexity, surface quality, efficiency, range of addressable materials
- Technologies to address different part volume and sizes





# Over 130 Materials for Diverse Applications



## Metals

Direct Metal Printing (DMP)

- Ti-6Al-4V
- AlSi10Mg, AlSi7Mg0.6, Scalmalloy, A6061-RAM2
- Ni 718, Ni 625
- 17-4PH, M789, 316L



## Plastics

SLS, SLA, VPP, Extrusion

- General and production-grade
- Rubber, durable, tough, and rigid material options
- Comprehensive portfolio of high-performance materials



## Metal Casting/ Silicone Tooling

SLA, VPP, MJP

- Lost wax and eggshell mold investment casting
- VisiJet® M2 ICast (MJP)
- Figure 4® EGG SHELL-AMB 10 (VPP)
- Accura® Fidelity (SLA)

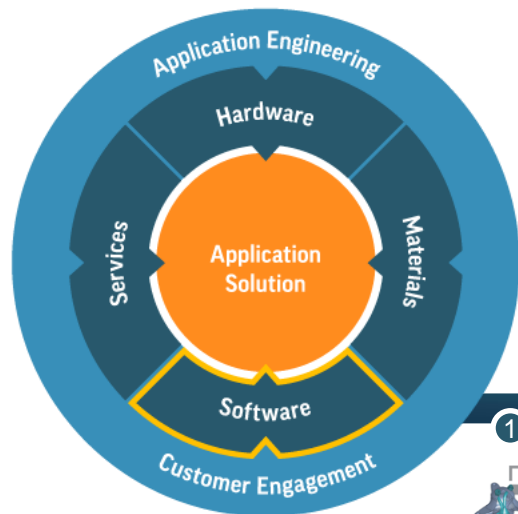


# Work Smarter with Integrated Software

A new category of production workflow automation software

 **3D SYSTEMS** + **OQTON**

New: Oqton Manufacturing Operating System



 **Geomagic Design X**

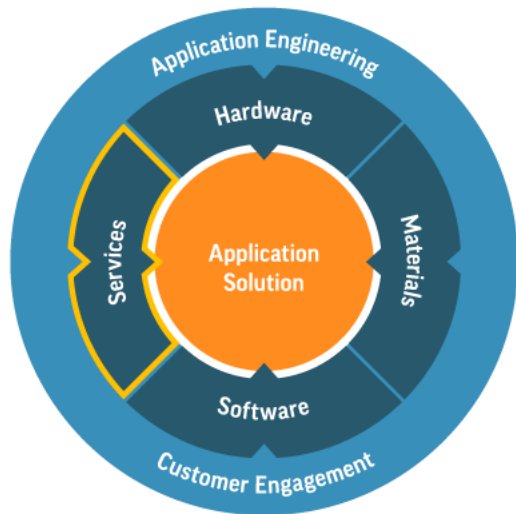


 **3DXpert**  **3D Sprint**



# Solve Your Most Advanced Design and Production Challenges

With a full range of additive manufacturing services



## Application Innovation Group

Consultative approach focused on your company's design and production challenges



## Technical Services

Team of service engineers to provide proactive and predictive support

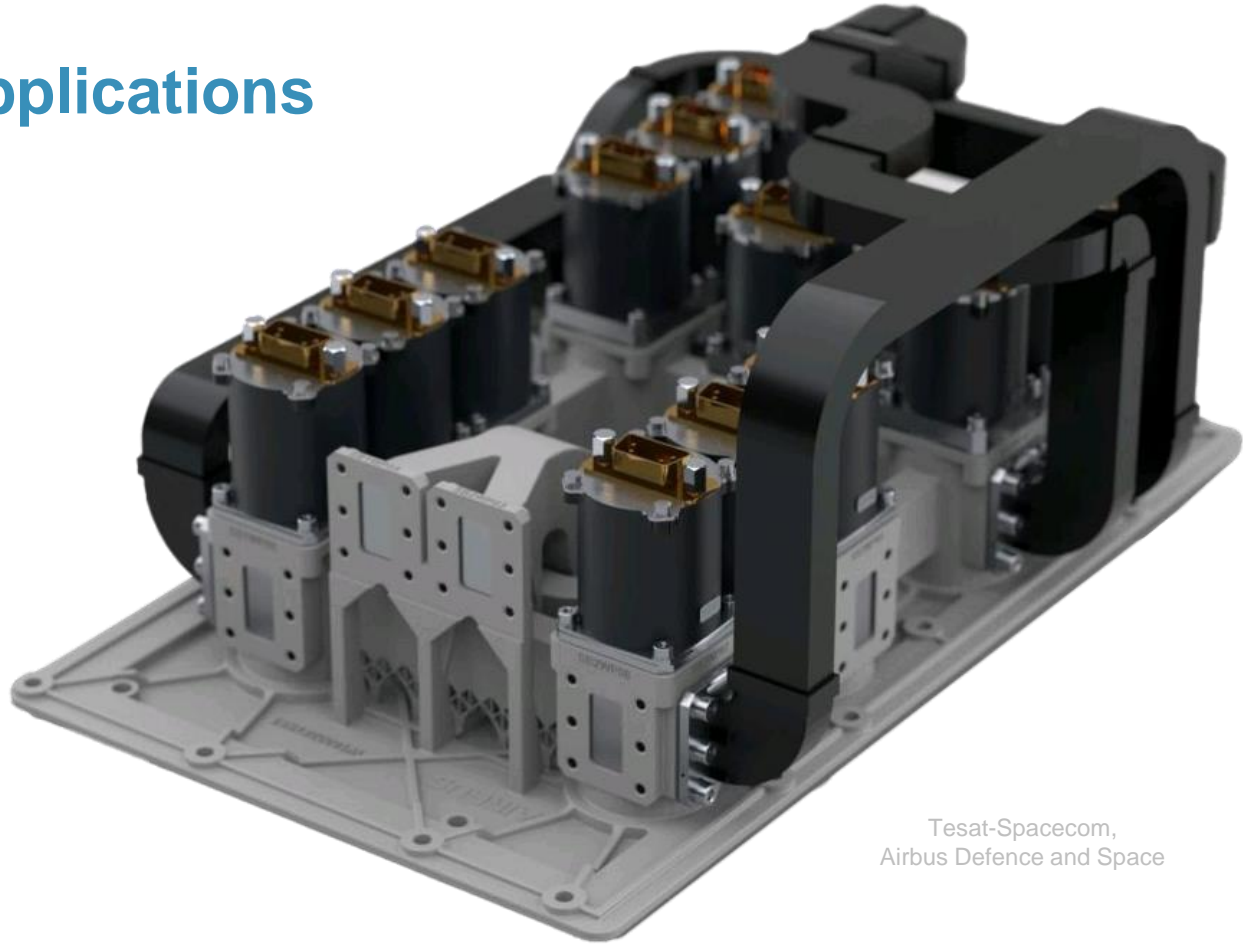


## Advanced Manufacturing

Bridge manufacturing facilities and services to scale production



# Satellite – Applications



Tesat-Spacecom,  
Airbus Defence and Space

# Why Partner with 3D Systems for AM Satellite Applications?

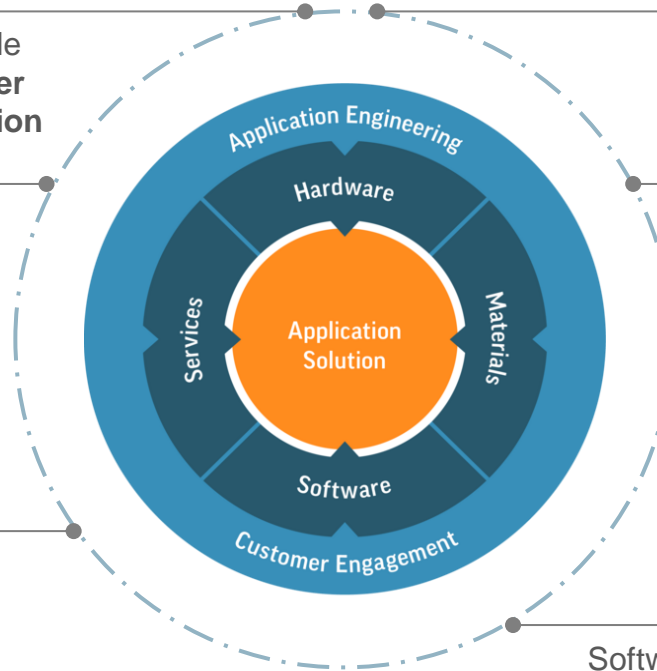
Vacuum chamber = best possible  
Al / Ti powder conditioning; **lower  
moisture, oxygen contamination**

Customers claim 3D Systems  
delivers **best-in-class quality**

- Airbus Defence and Space
- Thales Alenia Space
- APWorks

**Mature supply chain** for  
post-processing

- Etching, painting, mechanical  
testing, CNC machining



## Advanced build strategies

- Scanning strategies, part build orientation for part function

**LaserForm** Al and Ti-alloys  
already used for:

- Structure
- Feeds / horns (clusters)
- Waveguides / multi-blocks
- Switch assembly networks
- Filters
- Antennas / antenna circuits

Software-enabled 30µm /  
60µm layer thickness zones  
in-part for **cost-efficiency**



# Satellite – Applications



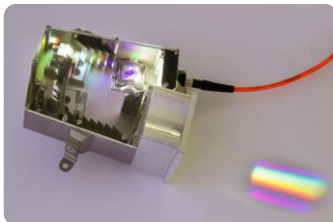
## Structural Brackets / Hold & Release

(Thales Alenia Space)



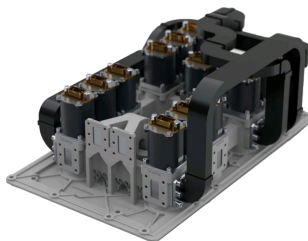
## Star Trackers / Scientific Instruments

(ESA funded Exomars spectrometer)



## Multi-Switch Blocks

(Tesat-Spacecom,  
Airbus Defence and Space)



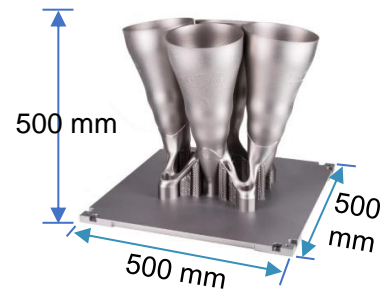
## Waveguides & Filters

(Airbus Defence and Space)



## Horn & Array Antennas

(Thales Aenia Space)



## Metasurface Antennas

(NASA Jet Propulsion Laboratory, Univ Rennes,  
CNRS, IETR - UMR 6164 )



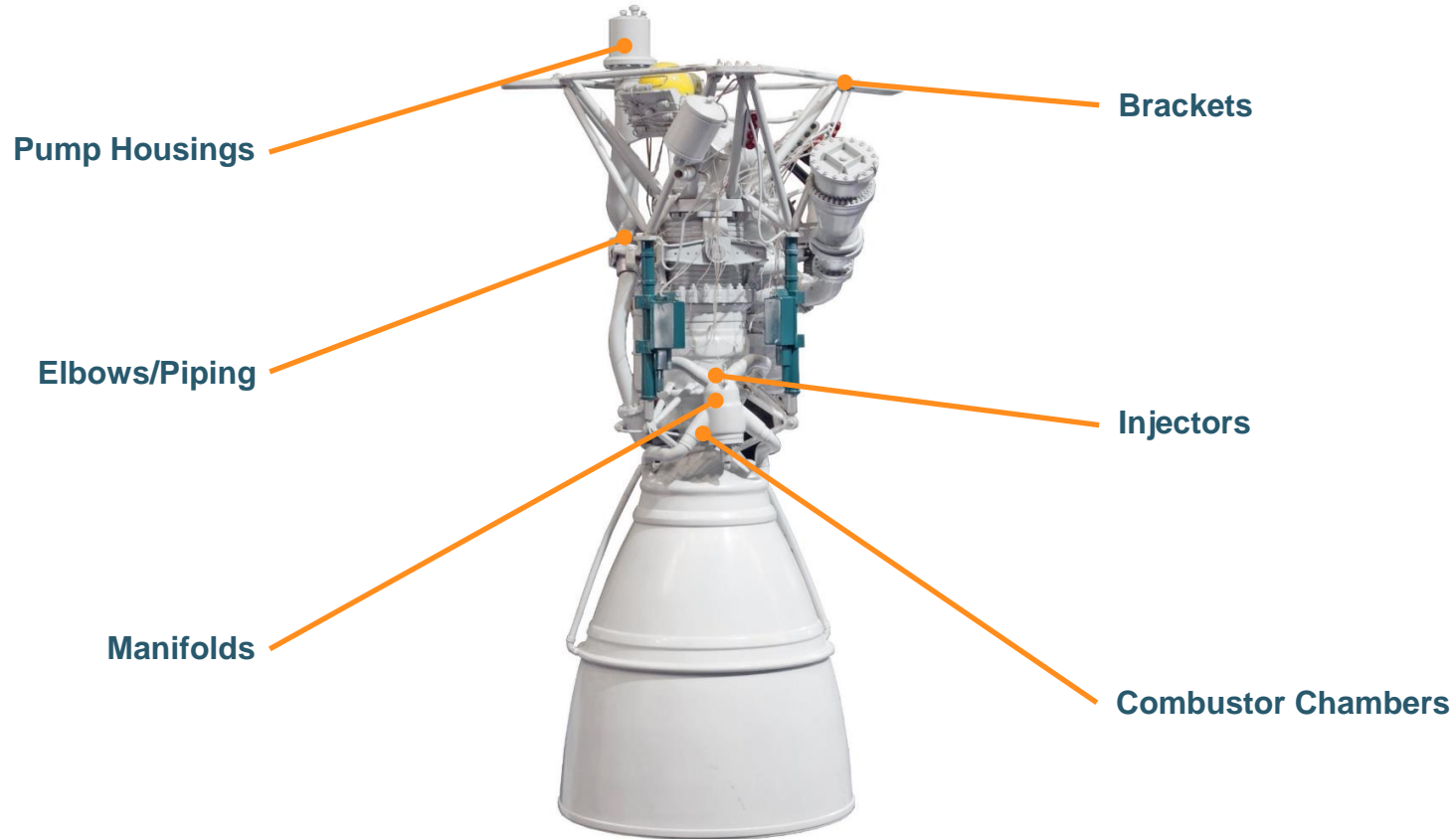
# Space Access / Space Propulsion – Applications



(Ursa Major Technologies: Showcase Thrust Chamber)



# Space Access / Space Propulsion – Applications





# Space Access / Space Propulsion – Applications

## Pump Housings

(SLA QuickCast Diamond Investment Casting)



## Elbows/ Piping

(Optimize fluid flow, weight, volume)



## Manifolds

(SLA QuickCast Diamond Investment Casting)



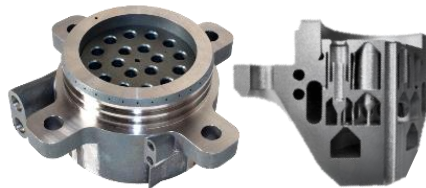
## Brackets

(Multiple casting or direct manufacturing workflows)



## Injectors

(\*DLR SMILE Project Fuel Injector)



## Combustion Chambers

(Vaya Space Star-3D Engine Combustion Chamber)



*\*This work is performed within the 'SMall Innovative Launcher for Europe' project. SMILE, coordinated by NLR, has received funding from the European Union's 'Horizon 2020 research and innovation program' under grant agreement No 687242.*

# Civil Aerospace – Applications



# Urban Air Mobility / eVTOL – Applications



# Urban Air Mobility / eVTOL – Applications

## Electric Motor Components

(DMP or QuickCast for Stators, Rotors, Cases)



## Heat Exchangers

(Direct Metal Printing)



## Structural Brackets

(ESA/ SABCA)



## Ducting

(SLS for Unitization of Complex Ducting)



## Interior Parts

(Vat Photopolymerization,  
FAR 23/25 Tested Options)

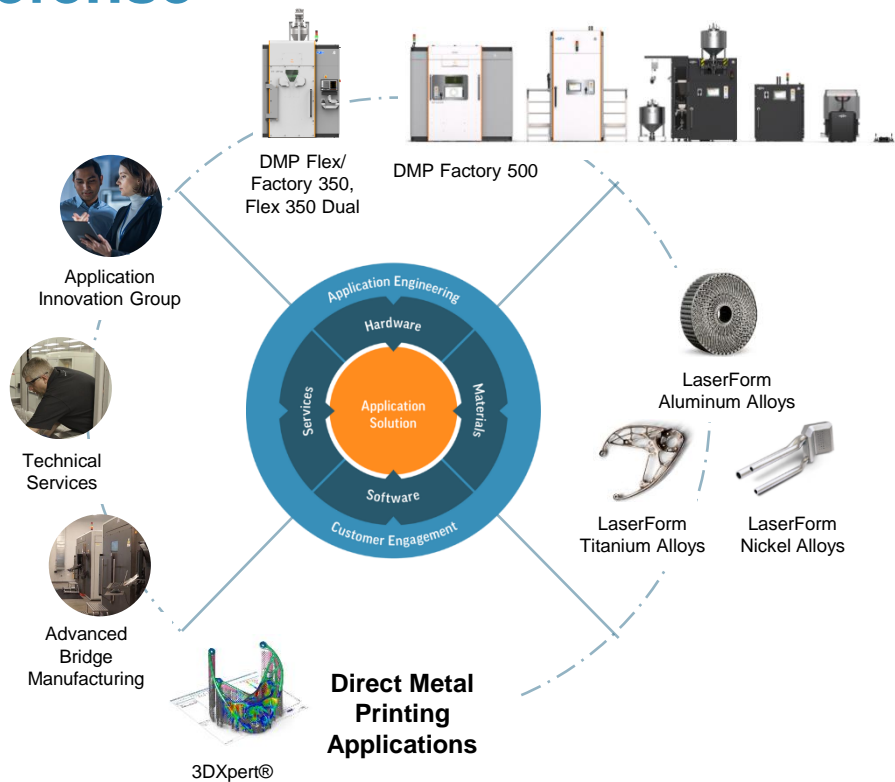


## Tooling for Composites

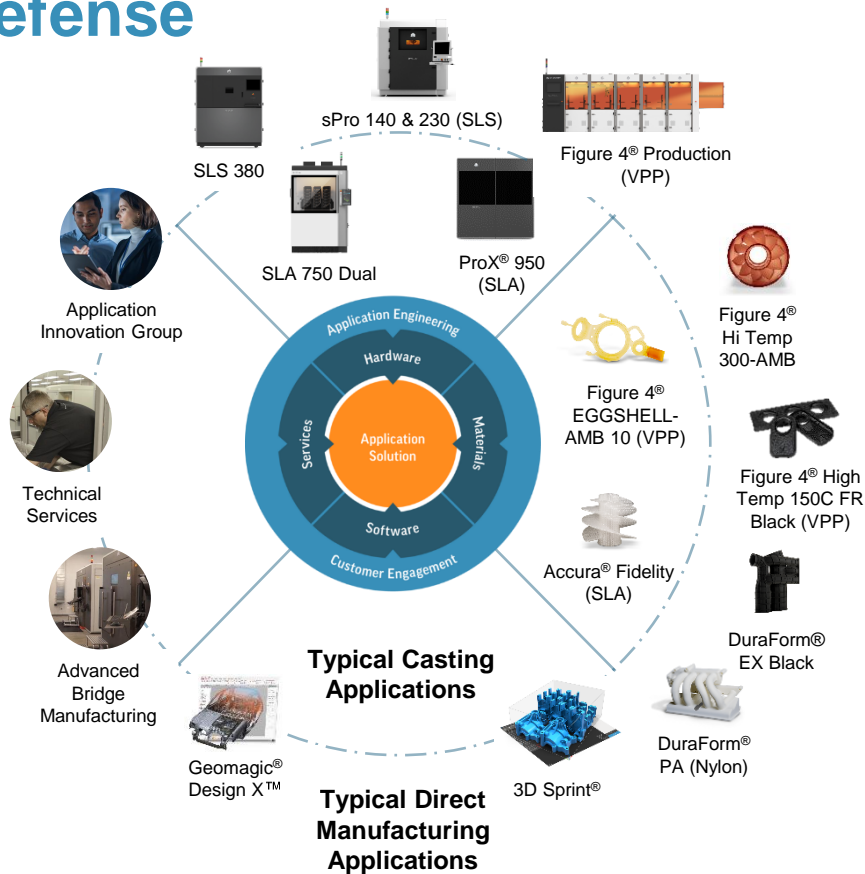
(Sacrificial Tooling for Carbon Fiber Parts)



# Solutions for Metal Applications in Aerospace & Defense



# Solutions for Polymer Applications in Aerospace & Defense

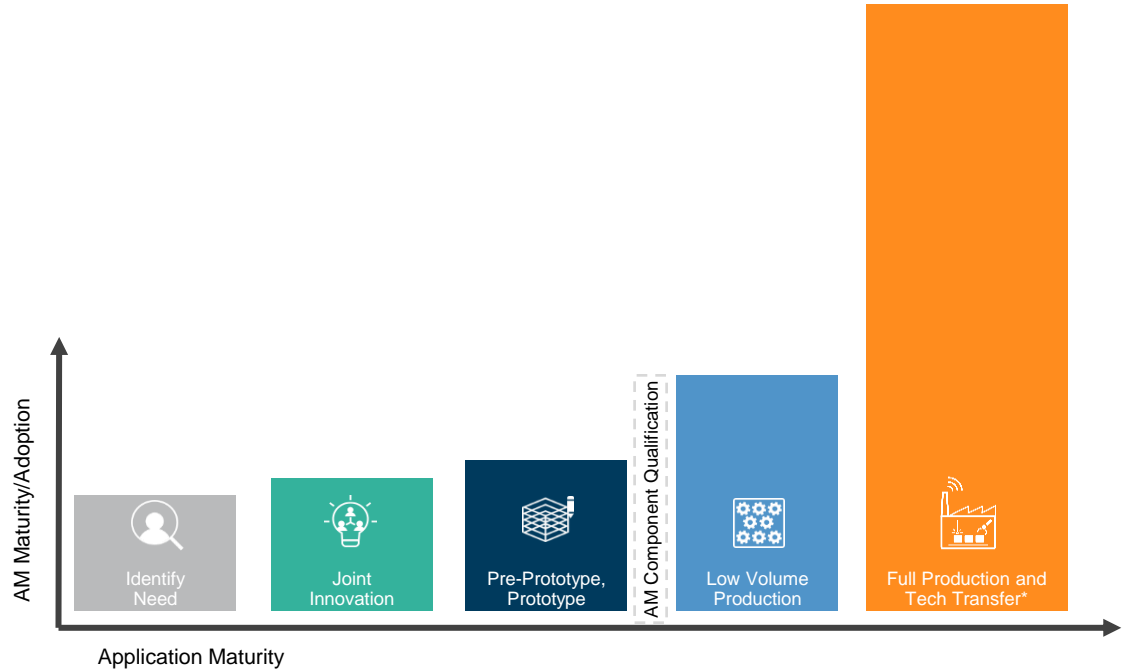


# How to Get Started?

## Application Innovation Group (AIG)

### Service Modules

1	Applications Screening	1 day
2	Design for Metal Additive Manufacturing Training	1 day
3	Custom Process-Material Development	1-6 months typ.
4	Application Development - Quality by Design	6-18 months typ.
5	Application Support	1-day modules
6	Gap Assessment for Validated Direct Metal Printing (DMP) Production	1 day on-site + final report 1-2 weeks
7	Validation and Qualification	5-18 months typ.
8	Technology Transfer	Customer + Application driven







# Electrical Thruster Mechanism (ETHM) for NEO Satellites

DMP Flex 350 | LaserForm Ti Gr 23 (A)

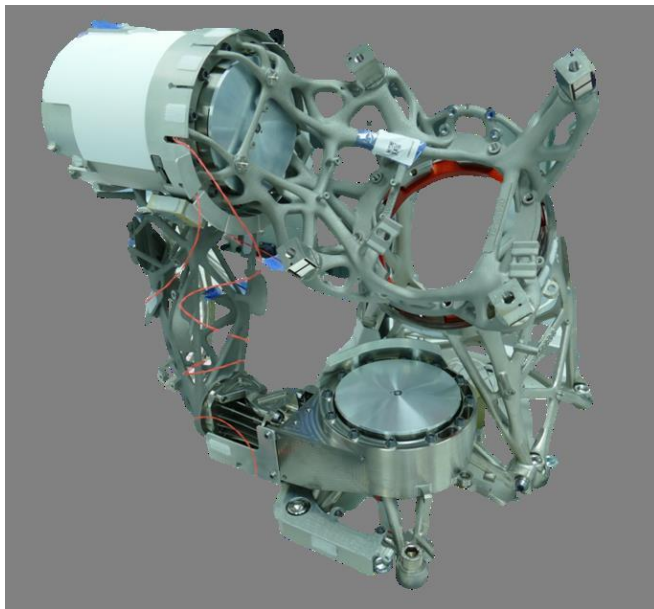


**7 structural  
Ti-6Al-4V parts  
in assembly**

**4 ETHM's per  
satellite**

**Up to 249  
CMM measurements  
in single bracket**

**0.1-deg.  
pointing accuracy  
for satellite  
propulsion**



## Compounding System Effects

**More Innovation**

**Lower cost solution**

**Improved fuel efficiency**

**Improved thrust efficiency**

**Lightweighting**

Thales Alenia Space Reference: <https://www.thalesgroup.com/en/worldwide/space/news/ethm-3d-printed-electrical-thruster-mechanism>



# Qualified Flight Part: Satellite Antenna Bracket

DMP Factory 500 | LaserForm Ti Gr 23 (A)

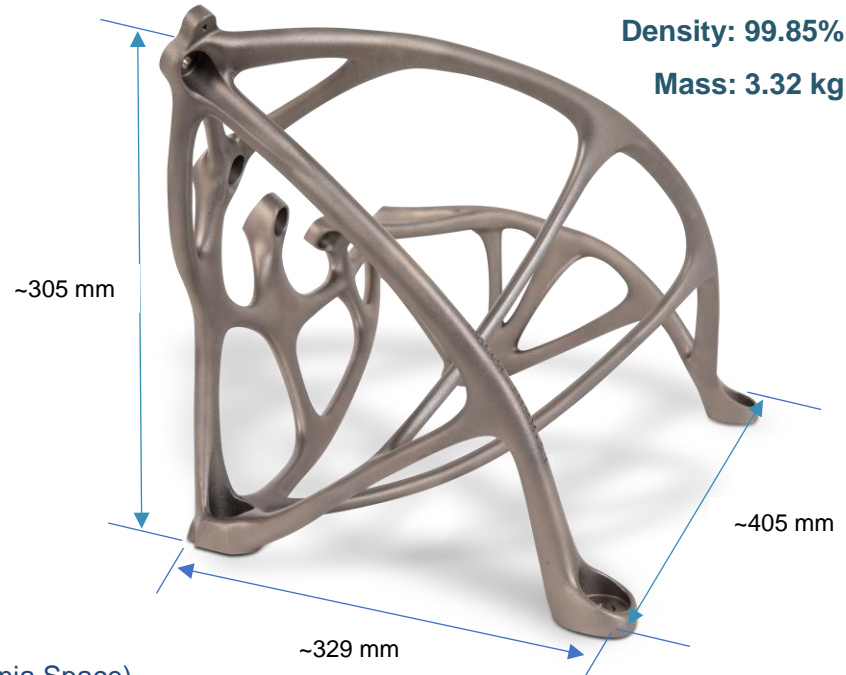


**First printed part is final flight part**

## Process:

- Print
- Vacuum stress relieve
- Remove platform
- Remove supports
- Manual finishing
- Optical scan
- CNC machining
- CT scan

(Part courtesy of Thales Alenia Space)



## Inspection:

- ✓ CMM interface position
- ✓ Optical scan surface
- ✓ Cross-section center point
- ✓ CT scan (material health)
- ✓ Tensile, metallography, fatigue coupons



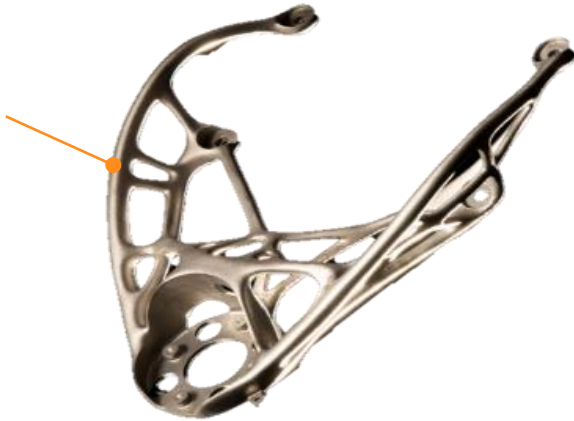
# Customized Lightweight Brackets for SES-17

DMP Factory 350 | LaserForm Ti Gr 23 (A)

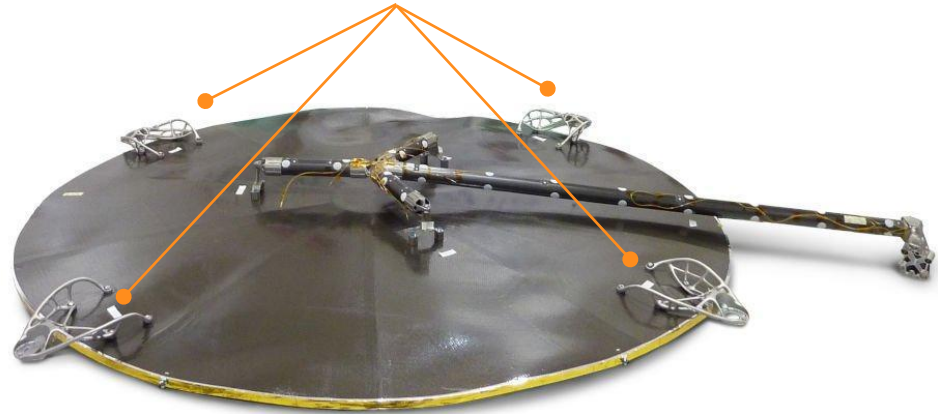


**50% reduced  
production time**

**25% lighter  
structure**



**Custom geometry by  
mounting location**



# Primary Structure Bracket

DMP Factory 350 Dual | LaserForm AlSi10Mg (A)

Flanges mounted onto CFRP panel with adhesive: no machining necessary on faces

Topology optimized for stiffness & redundancy

LaserForm AlSi10Mg (A) to minimize weight & cost

Build time reduction dual versus single laser  
Both layer thickness 30µm: 37%  
Both layer thickness 90µm: 30%

Layer thickness 90µm 68% faster than 30µm

3DXpert® Build Simulation  
minimizes deformation



Designed by SABCA & 3DSYSTEMS  
in ESA GSTP Program  
©SABCA Brussels



# Optical Mount with Integrated Flexure

DMP Flex 350 | LaserForm TiGr5(A)

Advanced kinematic  
flexures



Threaded features



Optimized strength-to-weight

Reduce vibration, hysteresis, and inertia

# 3DXpert - Generative Design

Aerospace Bracket



**Optimized weight and physical  
and functional properties  
through generative design**



**Post-processed using  
vibratory finishing**



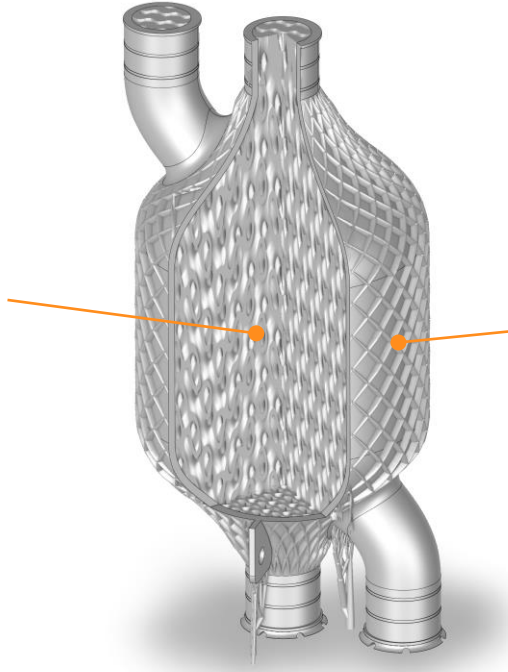


# 3DXpert - Implicit Modelling

Heat Exchanger



**Heat Exchanger with a variable double gyroid, creating two separate fluid domains, with baffles to preventing blending**

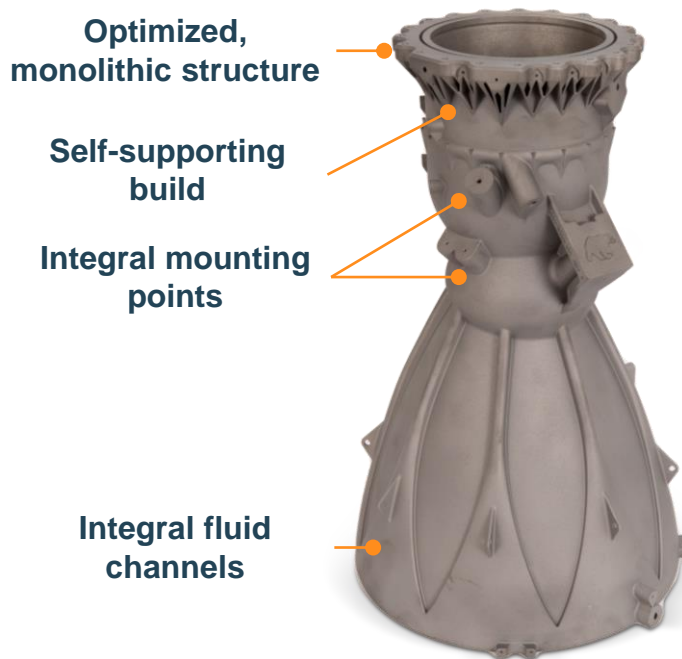


**External ribs, providing additional strength and protection**



# Ursa Major Technologies: Showcase Thrust Chamber

Direct Metal Printing (DMP) | LaserForm Ti Gr23 (A)



Representative thrust chamber for:

Reusable System

LOX/ Kerosene propellants

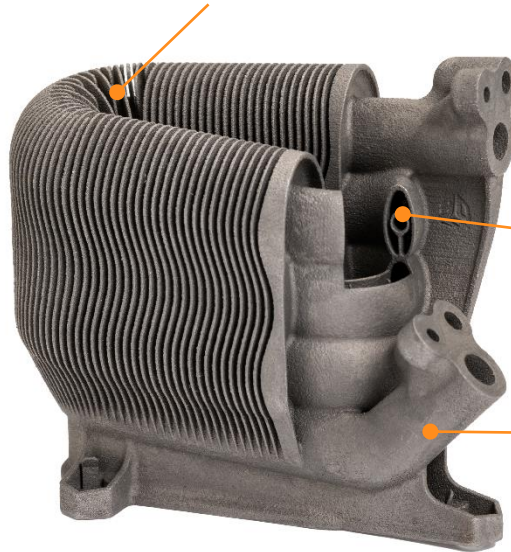
5,000 lbf thrust at sea level

LEO, GEO, in-space, and hypersonic applications

# Advanced Heat Exchanger

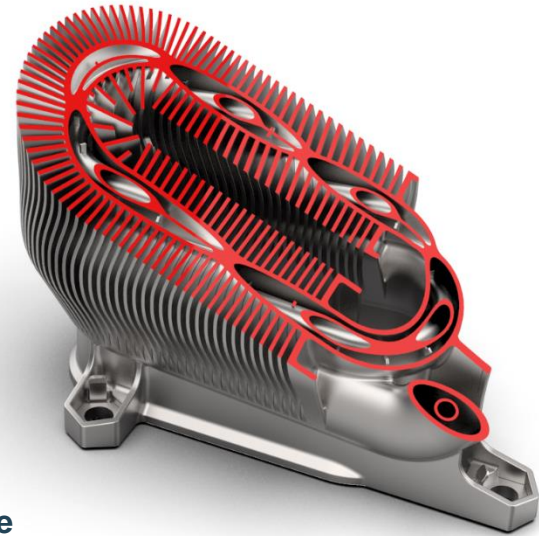
Direct Metal Printing with LaserForm 316L

0.6 mm fins for heat dissipation



Integrated Pipes

Increase performance  
from one part



# Throttle Manifold Lightweighting

DMP Factory 500 | LaserForm TiGr5(A)

Traditional Assembly

Direct Metal Printed Part



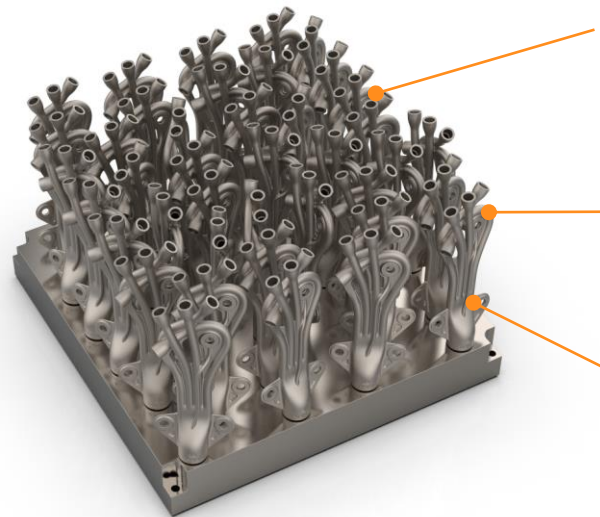
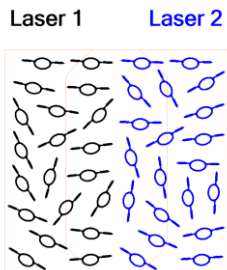
951g vs. 474g

**Up to 50% weight reduction**

# Cryogenic Manifold

DMP Flex 350 Dual | LaserForm Ti Gr23 (A)

**3DXpert® automates 2D nesting, maximizes the number of parts and respects minimal clearance for each part**



**Material efficient**

**Optimize fluid flow**

**Simplify Complex assemblies**

**Build time reduction dual versus single laser  
Both layer thickness 30µm: 43%**

# LOX Manifold

Direct Metal Printing | LaserForm TiGr23(A)

**Integral stiffeners**

**Large multi-laser  
seamless parts**

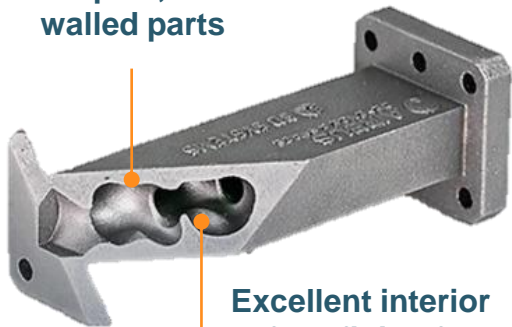
**50cm**



# Advantages in Waveguides and Filters: Airbus Defence and Space

DMP Factory 350 | LaserForm AlSi10Mg (A)

**Complex, thin-walled parts**



**Excellent interior surface finish from Semiconductor expertise**

**39:1 part reduction**

**50% weight reduction**

**Reduced assembly and integration**

**Schedule and cost reduction**

## USE CASE: AIRBUS DEFENCE AND SPACE

### First Air-Worthy Metal 3D Printed RF Filter Ready for Take-Off

Throughout 2016, Airbus Defence and Space worked with 3D Systems to achieve a major breakthrough: the first 3D printed radio frequency (RF) filter tested and validated for use in commercial telecommunications satellites. The project was built upon research funded by the European Space Agency<sup>1</sup>.

This redesigned RF filter delivers on the need for lighter weight parts by being 50% lighter than its traditionally-produced alternative. The design for additive approach enabled a part count reduction of 39 down to 1, with faster production times and a reduced cost of production. It has been in orbit since the end of 2017.



**50%**

LIGHTER THAN TRADITIONALLY PRODUCED ALTERNATIVES

**3D Printing Industry AWARDS 2021**

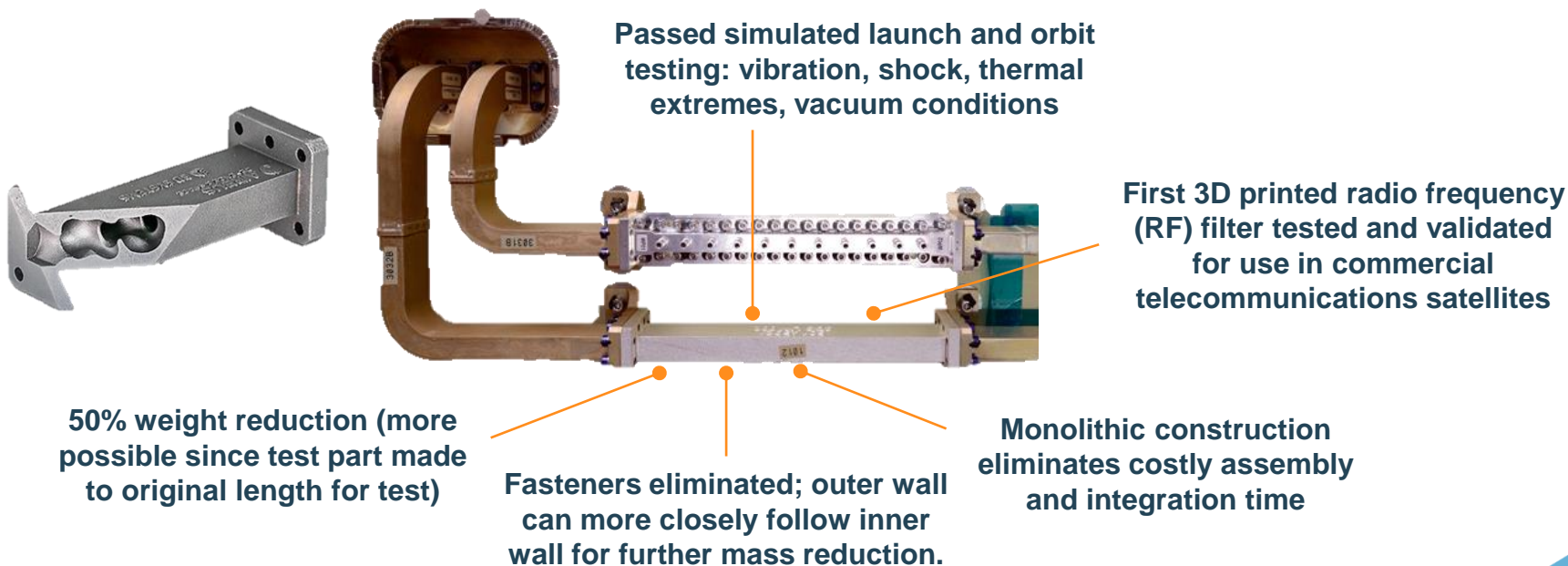
Images courtesy of Airbus Defence and Space





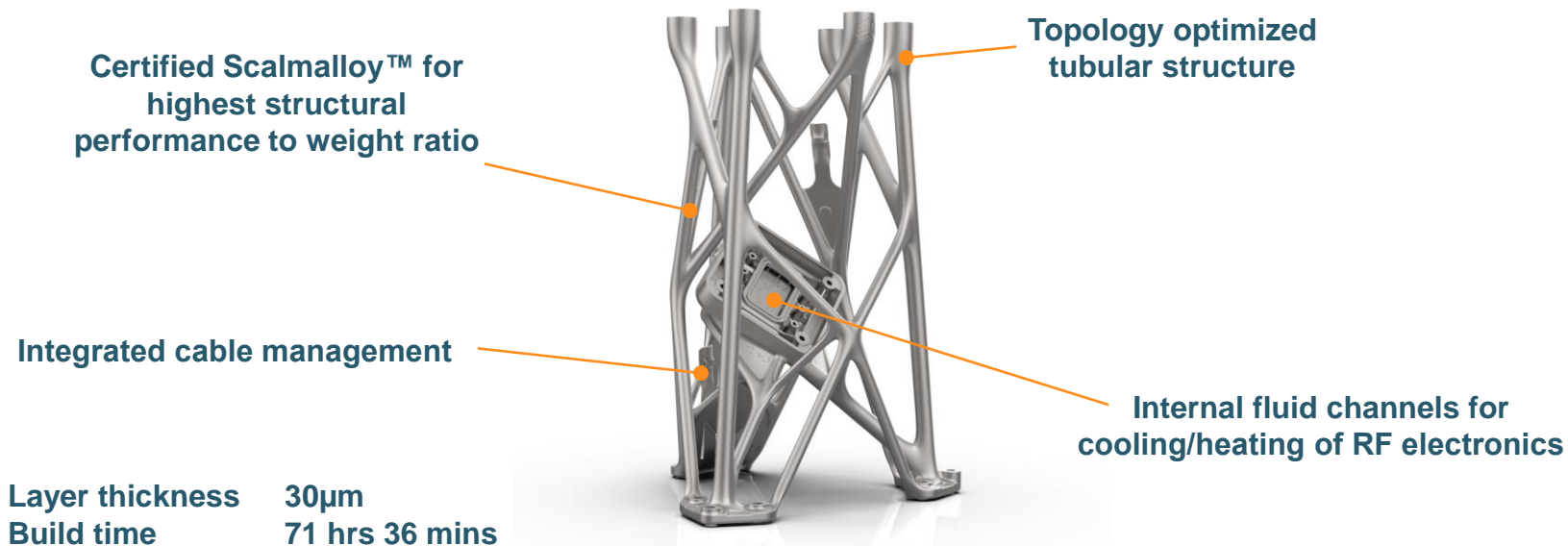
# Waveguide for radiofrequency (RF) filter: Airbus Defence and Space

Direct Metal Printing | LaserForm AlSi10Mg (A)



# Orbital Class RF Chassis

DMP Factory 350 | Certified Scalmalloy™



# Exomars Spectrometer Redesign Project

DMP Flex 350 | LaserForm Ti Gr23 (A)



## Project Objectives

Start with whole system design

Print mirrors with post-processed roughness of  $<5$  nm rms

Black-painted, printed baffles (hemi-reflectivity below 10% in 400-1000 nm wavelength spectrum)

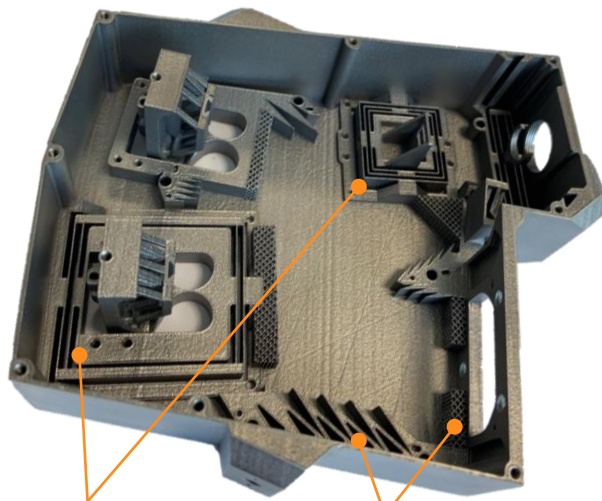
Reduce CTE mismatch by replacing CFRP with Ti Gr23

Integrate alignment features (flexures/ set screws)

Improve light trap concept

Work completed for ESA contract n°4000117719/16/NL/BJ/gp between The European Space Agency and Centre Spatial de Liège with Thales Alenia Space France, Thales Alenia Space Belgium, Safran Aero Booster, Lambda X and 3DS LayerWise as subcontractors.

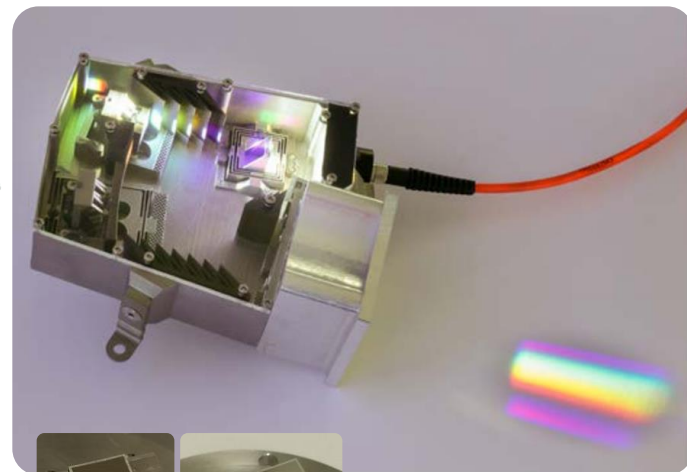
AM base component (~120 x 120mm)



Integral flexures & set screw points simplify alignment

Integral baffles & lattice reject stray light

Final assembly with dummy camera ( $>100$ g mass reduction vs. CFRP assy.)



(~10x10 mm<sup>2</sup>)



(~10x30 mm<sup>2</sup>)

Curved AM mirrors within required performance

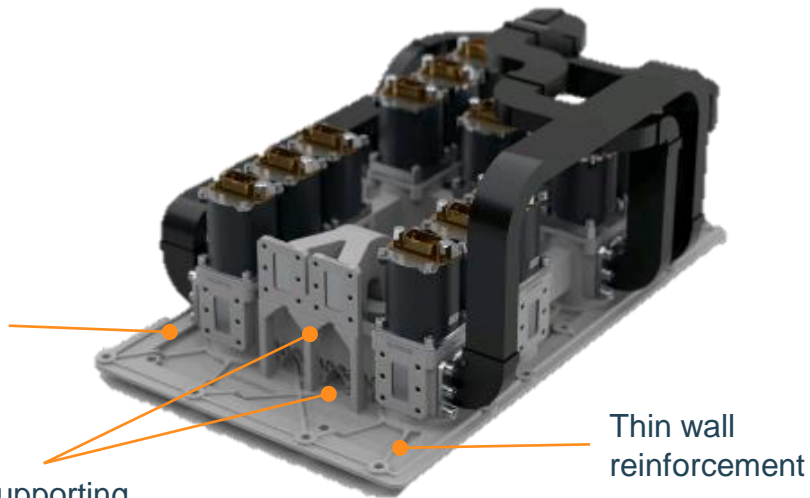
# Complex Multi-Switch Waveguides for Eurostar-Neo Spacecraft

DMP Factory 350 | LaserForm AlSi10Mg

**70 units** of this multi-switch assembly module provided for two satellites

Monolithic structure with reduced assembly interfaces

Self-supporting structures where possible



AM part space claim roughly 80 x 180 x 250 mm

Reduced footprint/ volume required to achieve function

Printed component weight approx. 1.5 kg

(Tesat-Spacecom, Airbus Defence and Space)

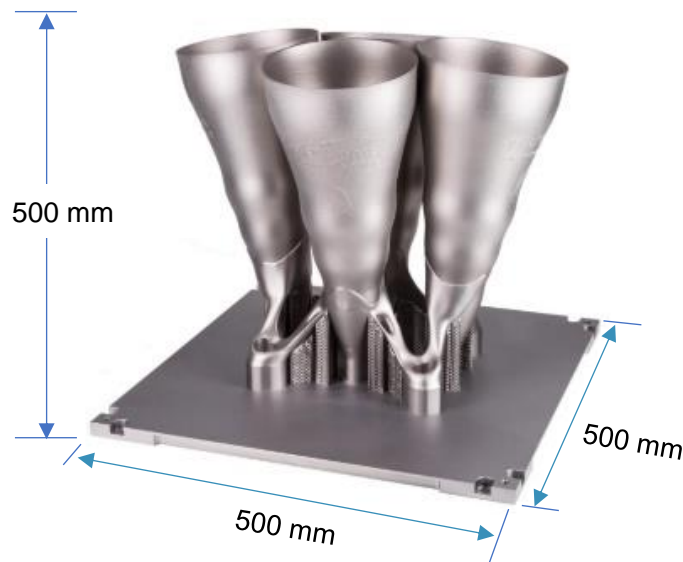


# Advantages in Horns and Phased Array Antennas

DMP Factory 500 | LaserForm AlSi10Mg

## Our Customer's AM Growth in Space

- **2K+** structural Ti or Al-alloy components for space flight since 2015
- **200+** passive RF flight parts since 2017
- **15+** satellites with 3D Systems produced flight hardware on board



(Thales Alenia Space)

## Our Unique Offering

- **Comprehensive Services:** Reliable support from concept to production and technology transfer
- **Hardware Productivity:** In-line, multi-laser system
- **Software Flexibility:** 3D-zoning of layer thickness, geometry-specific build parameters
- **Component Quality:** Seamless, full build area laser coverage



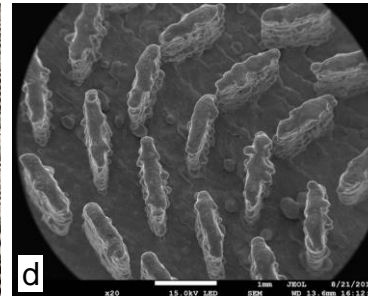
# AM is an Enabling Technology for Ka-band Antenna Applications

DMP Factory 350 | LaserForm AlSi10Mg

Several thousand  
elliptical cylinders  
on one base-plate

Macro view of 10 cm  
diam. antenna face

Zoom to central  
region in a)





# DYson conical Quad-Spiral Array (DYQSA)

DMP Factory 350 | LaserForm Ti Gr23

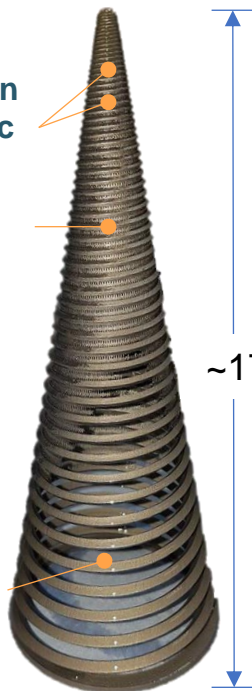


\*VGOS Radiotelescope in Yebes, Spain

Thin-walled supports maintain precise geometric control in the spiral

Proprietary etching removes fine supports while protecting geometry

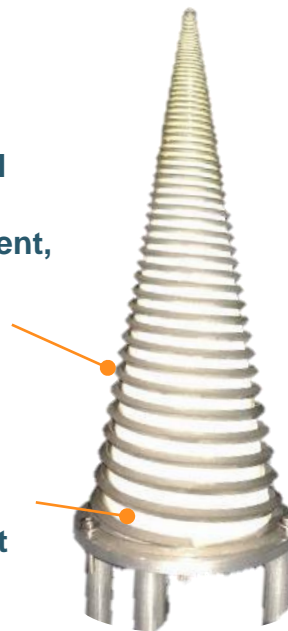
Manual support removal only possible in lower regions



~170 mm

Single conical log-spiral antenna element, silver coated

Nylon (SLS) dielectric inner support



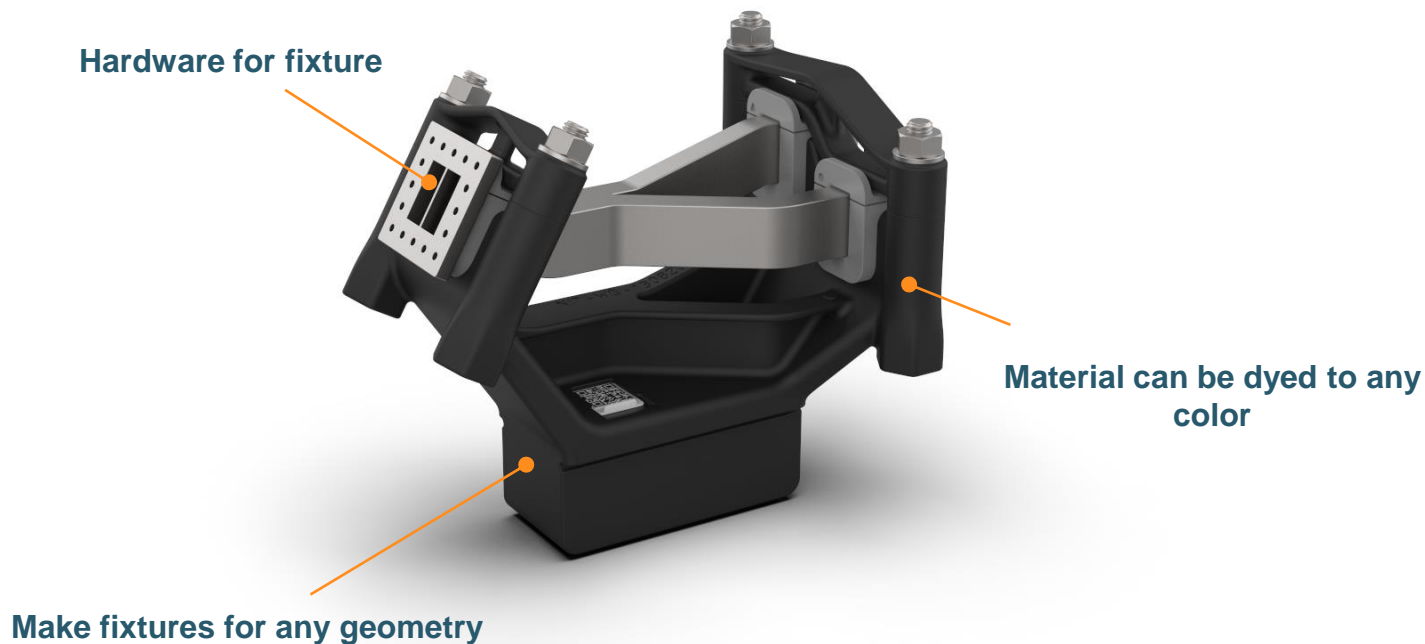
Reference: K. A. Abdalmalak et al., "Ultrawideband Conical Log-Spiral Circularly Polarized Feed for Radio Astronomy," in IEEE Transactions on Antennas and Propagation, vol. 68, no. 3, pp. 1995-2007, March 2020, doi: 10.1109/TAP.2019.2949700.



Testing the DYQSA

# Conformal, Normalized CNC Fixture

Selective Laser Sintering | DuraForm PA





# Mapping out Powder Reusability for Ti-6Al-4V DMP Process

## Powder Reuse: Critical for High-Cost Titanium Alloys

- Ti Gr 23 has USL of 0.13 wt. % Oxygen
- Using a simple top-up method cycled through a full lot of powder while tracking Oxygen content
- Results: **~126 reuse cycles** projected before exceeding 0.13 wt. % Oxygen specification
- This vastly exceeds typical user requirements

