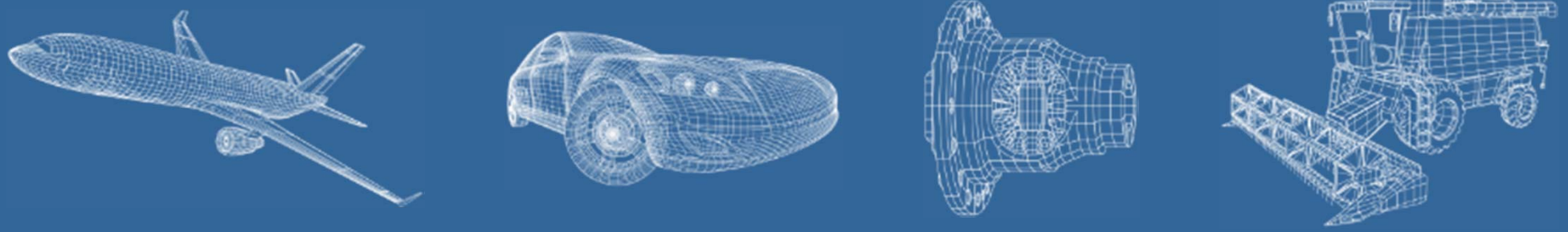


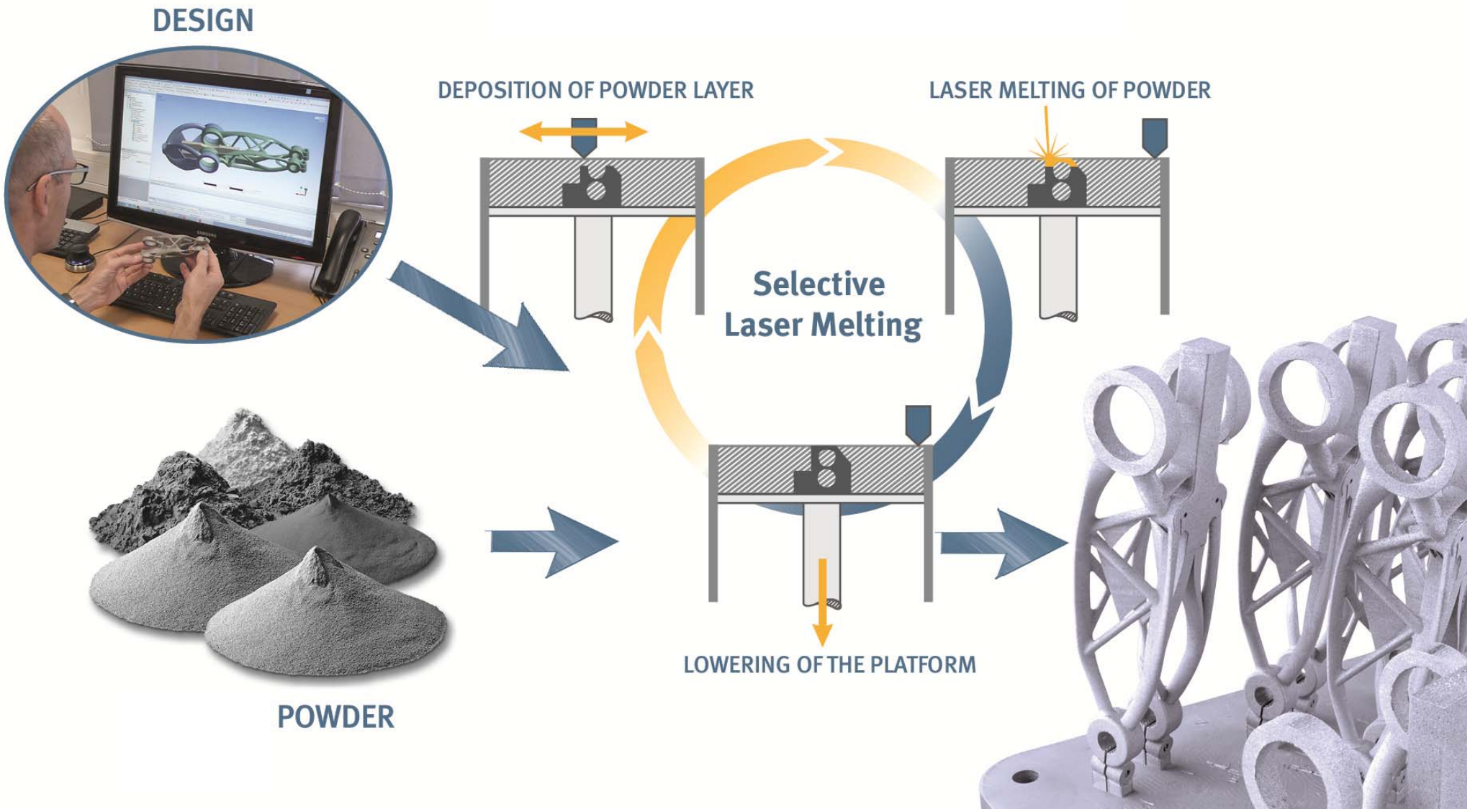
Net Shape Metal AM at GKN Powder Metallurgy

Michael Marucci

WORLD MATERIALS FORUM

ENGINEERING >THAT MOVES THE WORLD

Metal Additive Manufacturing



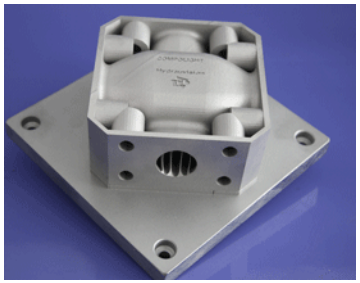
Design for Additive Manufacturing

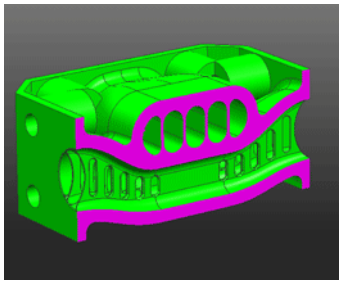
Source: WithinLab

Internal structures

Freeform

Bionic Design





Source: Fraunhofer IFAM

Monolithic Design

Source: Fraunhofer ILT

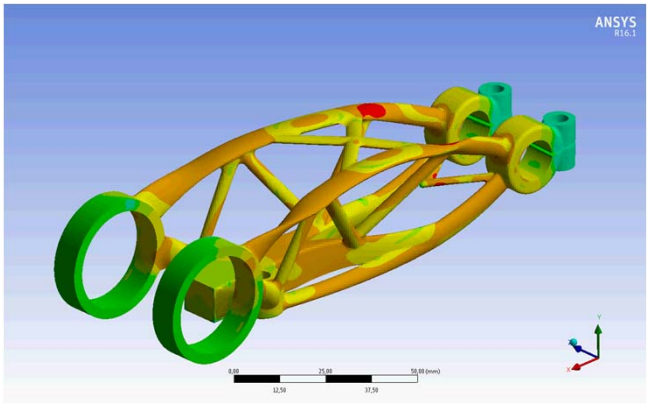
Speed and Design Freedom

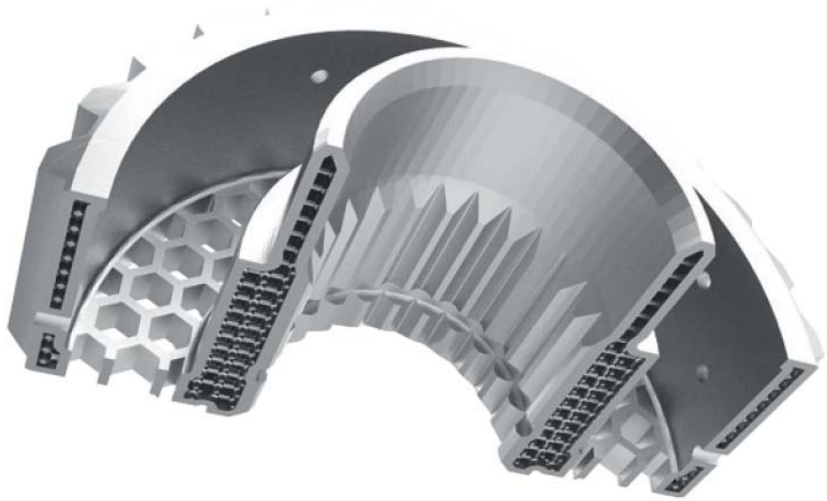
Rapid Prototyping – CAD to Part in Hours

- Current technology
- Stainless Steel, Tool Steels, Titanium, Aluminum

Design for AM

- Topology optimization – use only the metal needed
- Complete design freedom



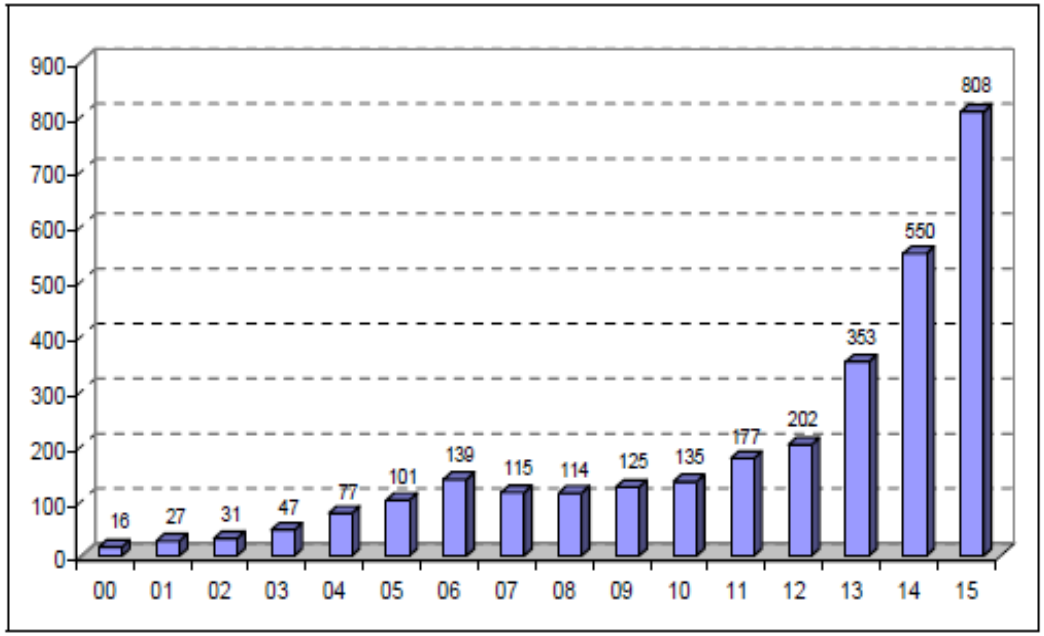


Metal AM Market

- Metal AM part revenue grew 81% in 2015 to $88M
- 808 metal AM machines were sold in 2015 a 47% increase over 2014
- The metal AM market is rapidly growing

Photo:metal-am.com – 6/18/2014

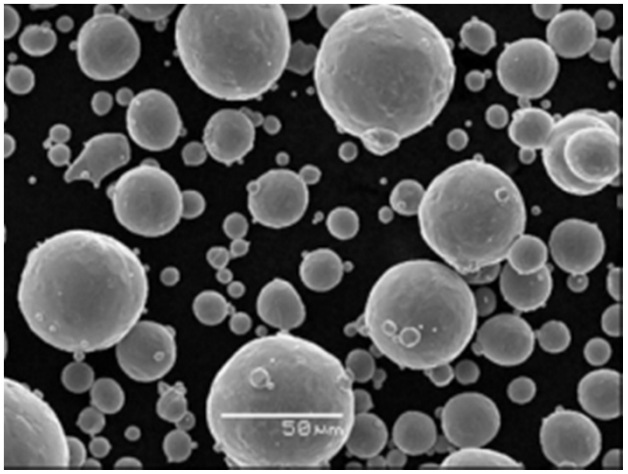
Metal AM Machines Delivered



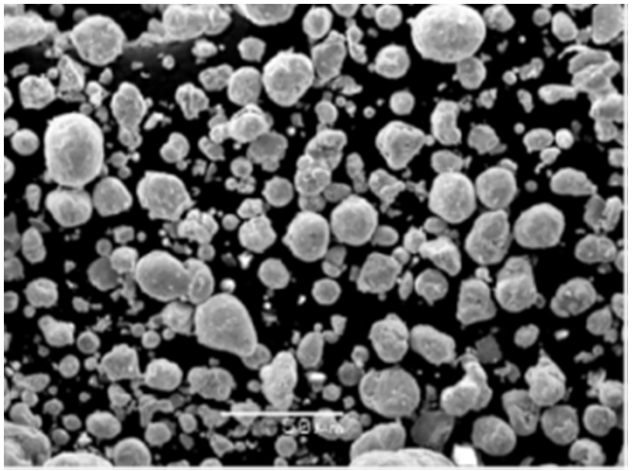
Source: Wohlers Associates, Inc.

AM Metal Powders

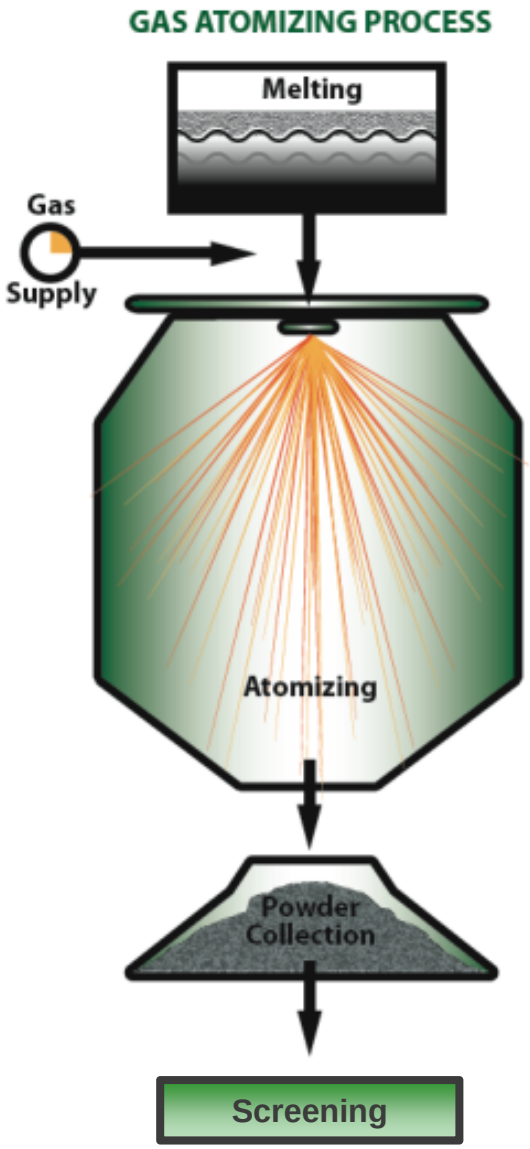
- Spherical gas atomized powders are most commonly used for AM
- Irregular water atomized powders can be used for some AM techniques
- All powders are screened, typically finer = more expensive



Gas Atomized Titanium



Water Atomized Tool Steel



AM Metal Powders

- Must be able to flow and spread evenly
- Particle size must be matched to AM process
- Chemical composition to meet requirement
- Purity to meet industry regulations
- Specify what is needed - over specification is expensive
- Some AM machine makers require powder qualification

Commercially Available AM Powders
Titanium Alloys
Stainless Steels
Tool Steels
Copper Alloys
Aluminum Alloys
Cobalt Alloys
Nickel Based Alloys
Some producers make custom alloys

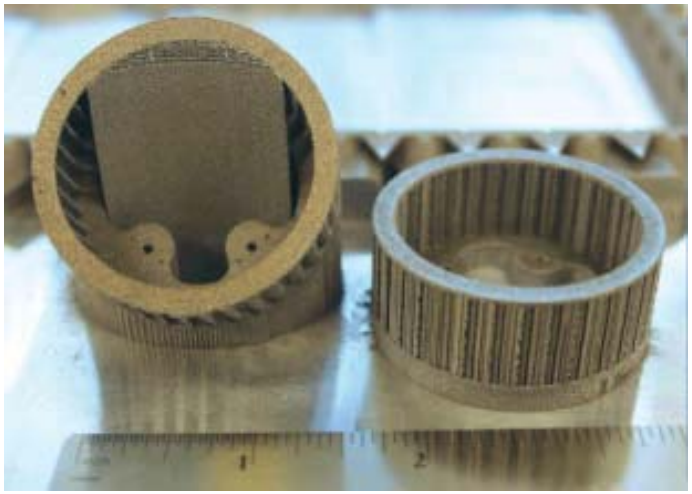
Challenges to Zero Waste – Metal Supports

Support Structures

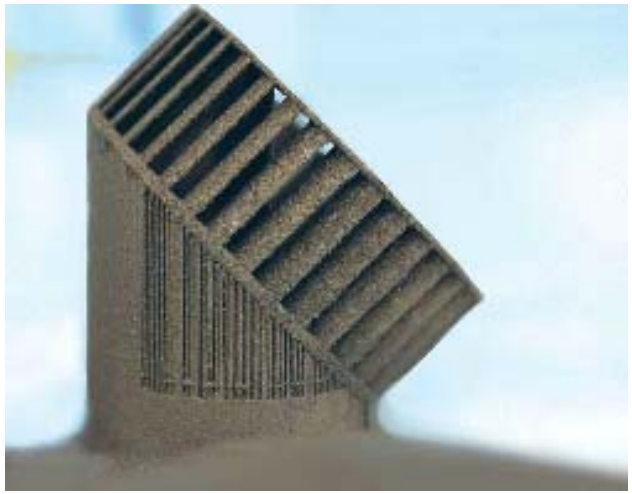
- Hold the part as it is grown
- Help heat transfer reducing distortion
- Changing part orientation can reduce the amount of supports needed

Waste Created from Supports

- Can equal 50% of build time
- Have to be cut away after the build
- Degrade surface finish
- Failed AM builds



Source: Article by P. Zelinski



Source: Metal AM Vol 2. No 1 – K. Hamilton

Challenges to Zero Waste – Powder Recycling

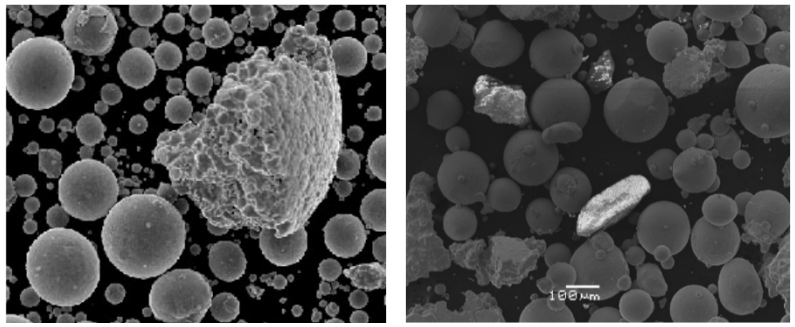
Powder Recyclability

- **AM powder is expensive and energy intensive to make**
- **Reuse of AM powder is sometimes not permitted or is difficult**

Powder Waste & Hazards

- **Fine metal powder trapped in AM dust filter – some not recoverable**
- **Yield loss from reclaim operations**
- **Contamination / shape changes**
- **Inhalation & explosion hazards**

Recycling of powder need to be controlled to prevent changes



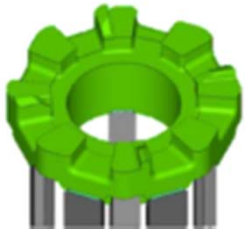
Photos: GKN Hoeganaes

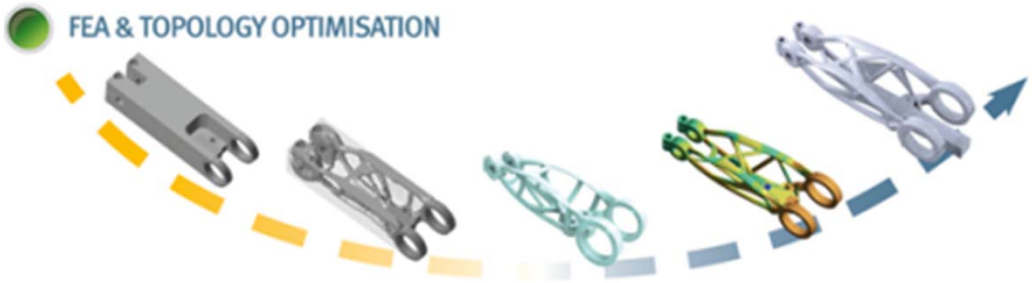
Photo Russell Finex

Photo Metal AM Vol 2. No 1 – Heidloff & Rieken

Tools Needed

Creative Designers & Applications





AM Design Optimization

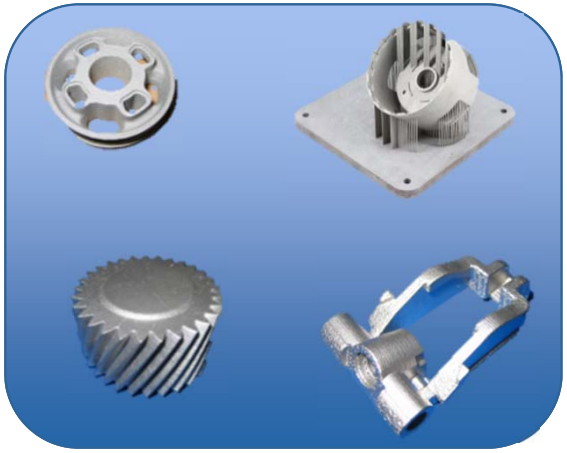
AM Equipment

Post Processing & Finishing

Prototyping to Serial Production

Prototyping
State of the Art

- Metal AM prototyping
- Small production runs
- Fast design changes
- Limited material options
- Low volume / high value



Serial Production
Development Targets

- Products with unique designs
- Larger production runs
- Fast design changes
- More material options
- Medium volume / medium value

Metal AM's Technical Journey

AM Software

- Capabilities for higher volume AM machines

AM Powders

- Efficiency
- More options
- Powder recycling

AM Equipment

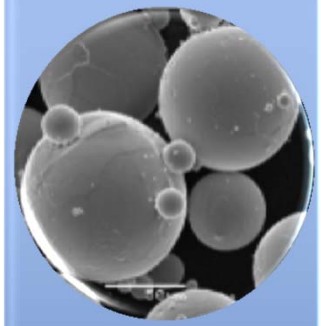
- Higher throughput
- Capital costs
- Fast obsolescence

Market

- Design for AM
- Qualification
- AM as a go to solution

Full Value Chain Needed

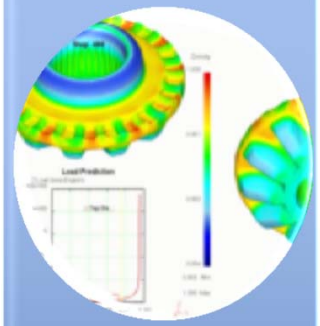
World Class Engineering



Powder Technology

Net Shape Design Expertise

AM Process Knowhow



Modeling Expertise

Market Access

The AM process is only a piece of the puzzle

Summary

- Metal AM is viable net shape / low waste technology
- Zero waste is not yet a reality
- Metal AM parts are entering production and the sector is in high growth
- The AM process is only part of the puzzle, design, powders, and process knowhow are essential
- Metal AM is focused on low volumes and high value applications
- Development continues to open up higher volume applications