Additive Manufacturing – a structured approach to get started

March 2022

stratasys CONCEPTLASER a GE Additive company LITHOZ Artec 3D materialise

OBJECTIVE 3D
PRINTERS | PARTS | SCANNERS

What's the goal of our seminar

How to implement additive manufacturing successfully

- **Setting the scene – a brief history of AM**
  - Where it started, how it was used, materials, and technologies
- **What to be aware of when implementing AM**
  - What technologies are available, considering a cost model, AM as a complementary technology
  - Who's been successful and why
- **A stepwise approach to implementation**
  - Some use cases and a walk-through Objective 3D

First – a little About Objective3D

100% focused on Additive Manufacturing – its all we do

We supply 3D printers

What we offer:

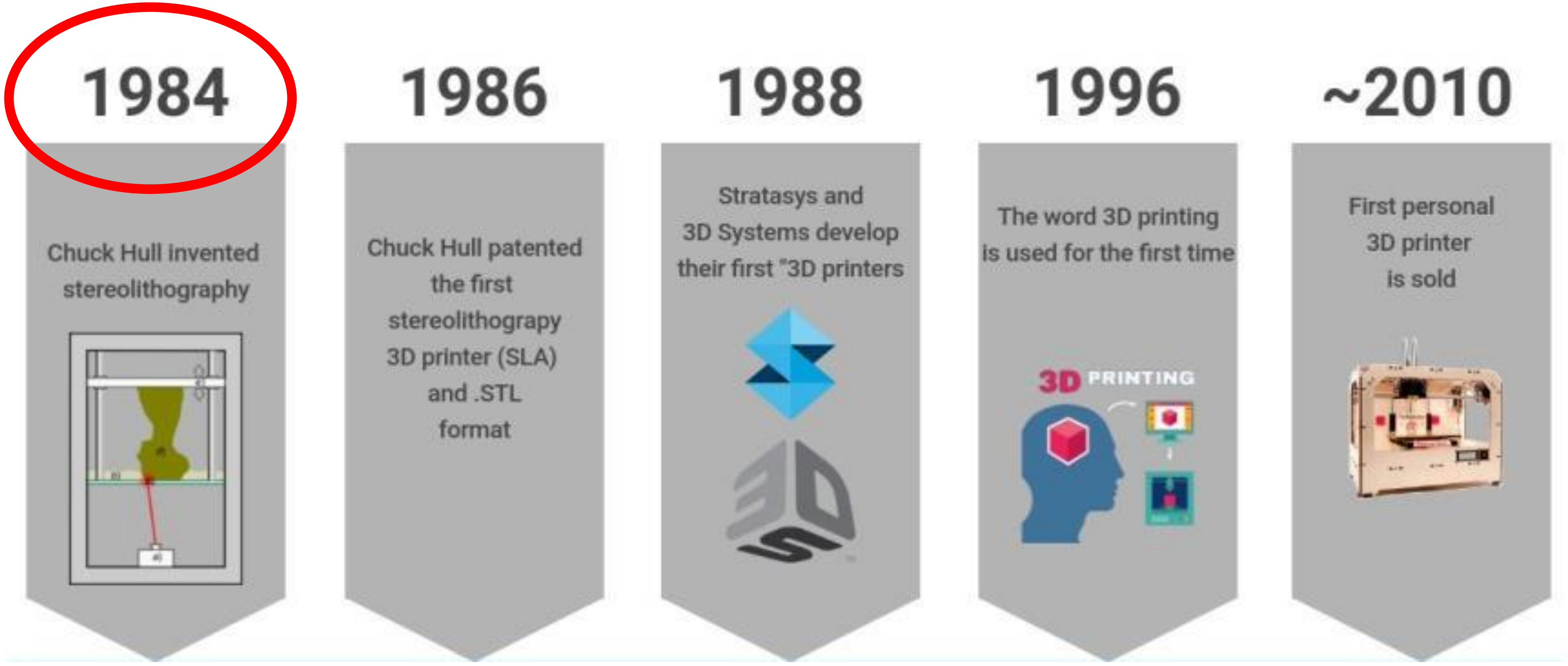
- Australia's Largest 3D Printing company
- Partnering with Stratasys
- 6 World Leading Technologies
- 14 years 3D printing experience
- Cover the widest range of industries
- Widest range of materials
- Expert backup and support
- Full range of materials and spare parts on site

We Print your 3D Parts

What we offer:

- 5 3D Printing technologies
- 3 dedicated engineering consultants
- 14 years 3D parts printing expertise
- 14+ commercial 3D Printers on-site, metal and plastic
- Concept models to production manufacturing
- In-house part finishing

3d printing is new – right?



3D printing history

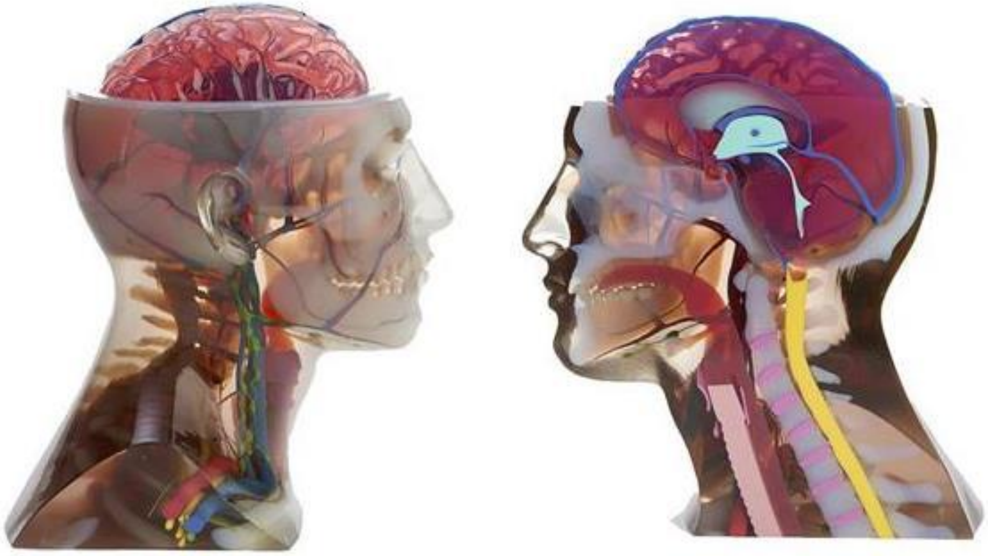
Technology overview - SLA

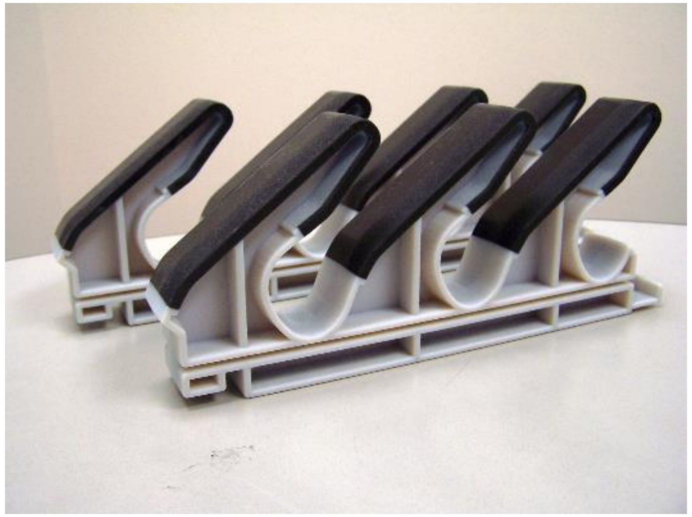
Fast printing with good surface finish.

Build complex parts with smooth finishes due to exceptional layer to layer scan repeatability.
SLA offers users the ability to produce parts for a range of different applications, requiring different properties, with one technology

Technology overview- Polyjet

Print in multiple materials and colours… ideal for overmoulded parts and product design applications





Technology overview- Polyjet

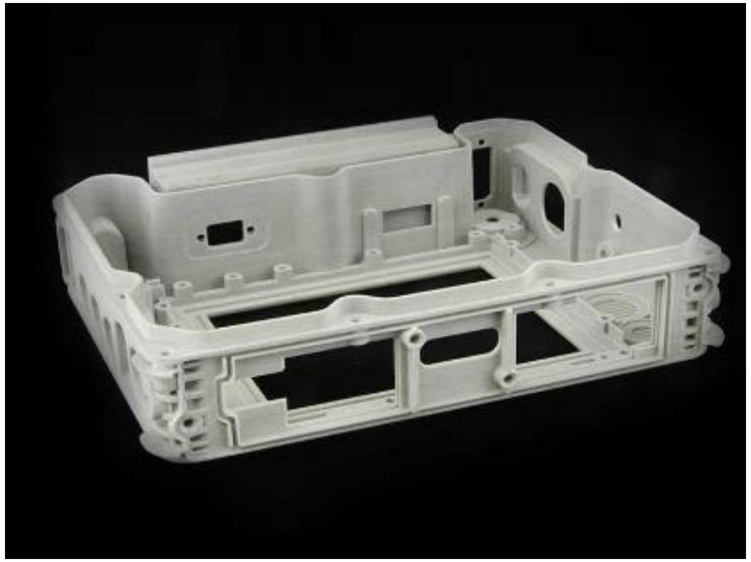
Print flexible rubber-like materials in a range of shore hardness's…
no need for PU tooling

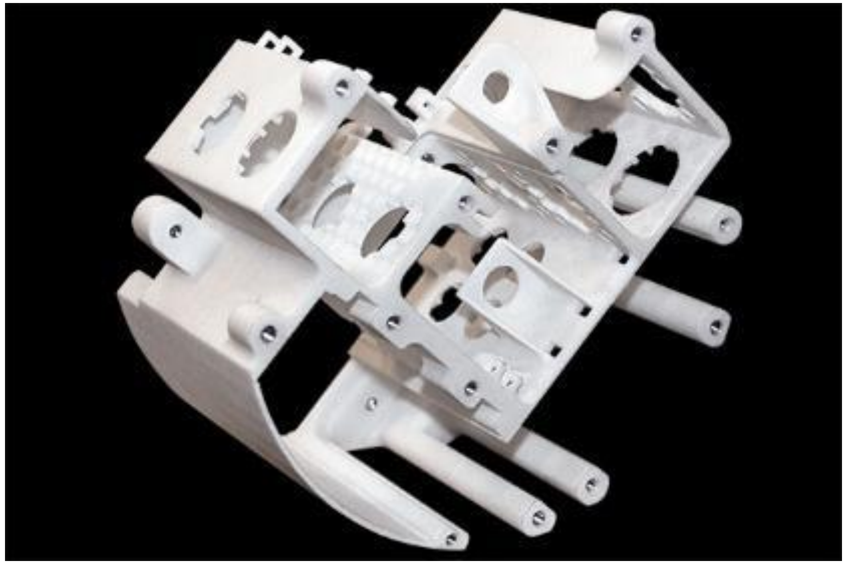


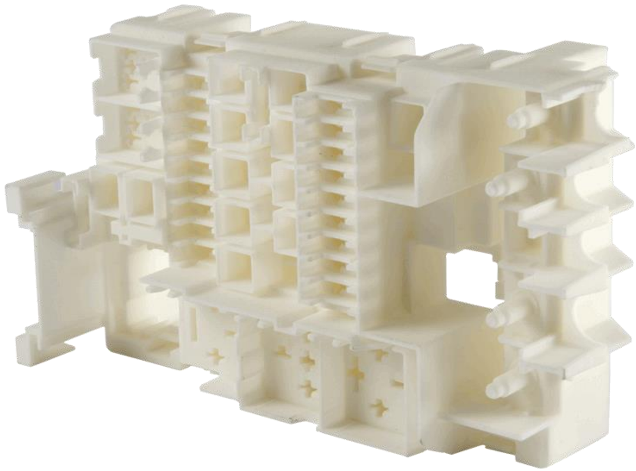



Process Selection – SLS / SAF

Fully functional production parts - **MANUFACTURING**

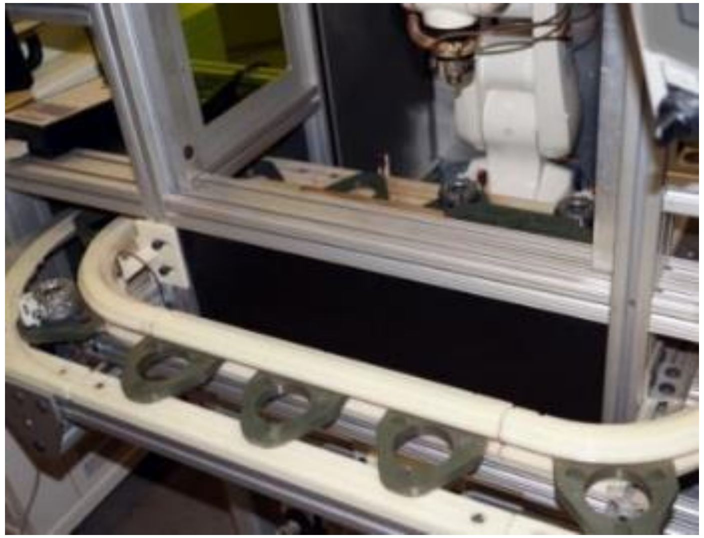
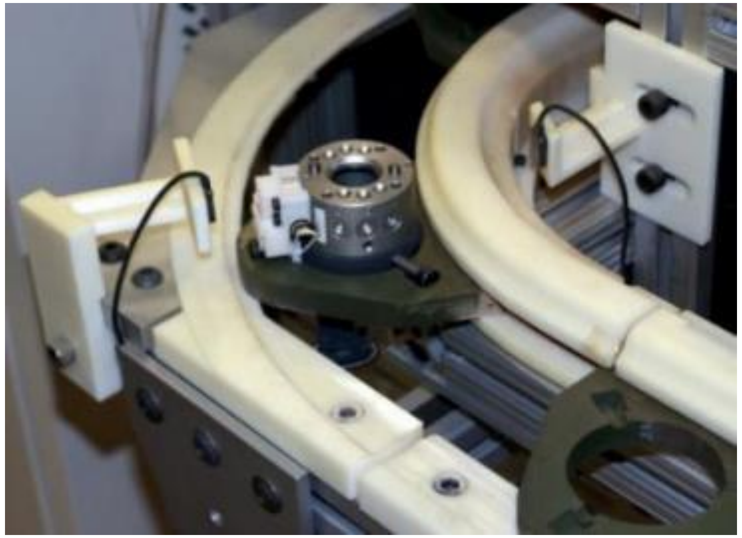


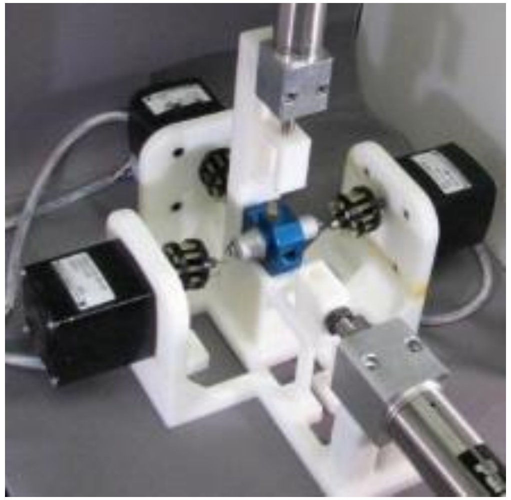
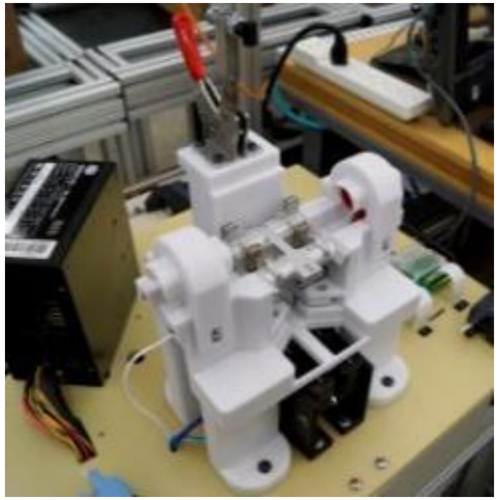




Technology Overview – FDM

Print in tough polymers that are suitable for production assembly & automation fixtures

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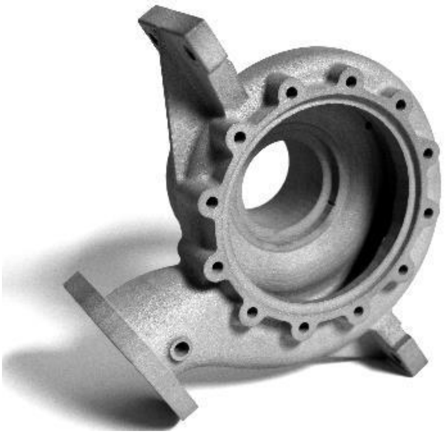
Technology overview – Metal Printing - DMLS



Early uses for 3d Printing

- **In less than one decade, three of the important 3d print technologies were born**
  - FDM or Fused deposition modelling
  - SLA – Stereolithography
  - SLS – Selective laser sintering
- **All of these technologies are still in use today**
- **Rapid prototyping was their first usage but as they become more productive, both SLS and FDM are used in the manufacturing domain**
  - Tough Nylon parts very much suited for end use (Orthotics, as an example) with SLS
  - Bespoke custom parts and printing in specific flight certified materials – such at Ultem 9085 or Anetero in the aerospace domain
  - Composite parts with carbon fibre reinforcement for lightweight robotic arms, end of arm tools, jigs and fixtures as well as end use parts.

3D Printing - Product Lifecycle – what works in manufacturing

Design | **Prototype** | **Test** | **Manufacture** | **Support**

Concept Models
Access Concept Validation
Assembly Simulation

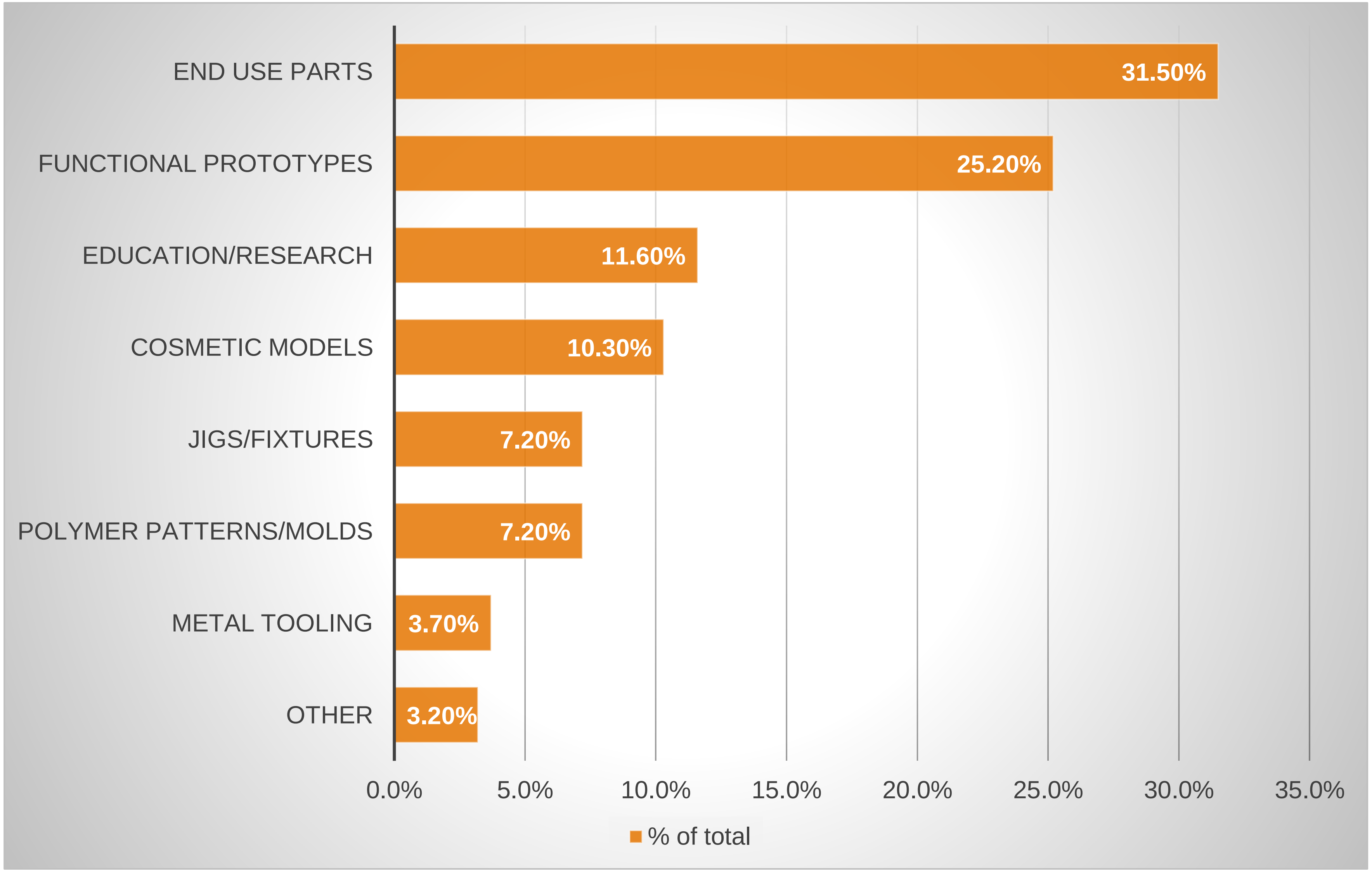
Prototypes Models

Specialized Interface Models
Functional Test Models
Pattern for Casting / mold

Pilot Production
Low and high volume production
Jigs & Fixtures
Digital Inventory

Repair Jigs & Fixtures
Remake of End-of-support production parts

Where are we today – the global picture



Source: Wohlers 2021 Report

What's new

As always, there's plenty of new things to talk about

- **Stratasys H350** – new SAF (selective adsorption fusion) technology
- Accurate **production** parts with best-in-class consistency
- Lower cost per part than similar technologies due to long life industrial print heads, higher nesting density
- Suitable for component parts, snap fits, connectors, housings, consumer electronics cases, etc

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What's new

- **Stratasys Origin1**
  - Programmable Photopolymerization (P3)
    - Vat photopolymerization technology (DLP)
  - Suitable for production parts and tooling
  - Quick and easy installation and setup
  - Repeatable, isotropic and accurate parts
  - Best in class materials from BASF, Henkel, and others
  - Injection moulded part quality

What's new

Lithoz Ceramics – CeraFab series

- Ceramic 3D printers for serial production
- S25, S65 and S230
- End use parts from a wide range of ceramics
    - Aluminia, Zirconia, Silicon Nitride to name a few
- CeraFab System allows for a (cascading) combination of up to 4 production units

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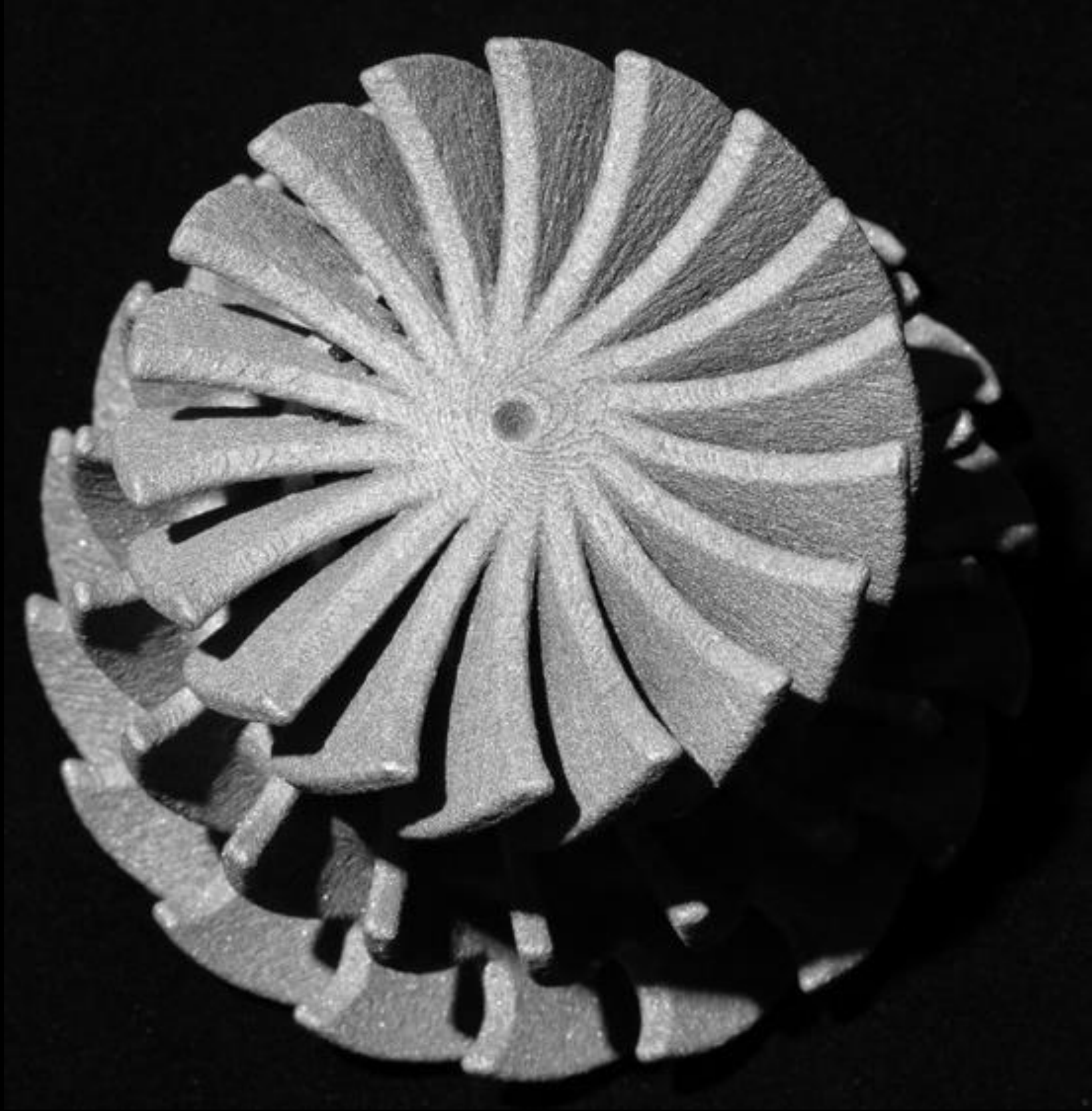
What's coming?

What's new on the AM horizon

- Materials - high performance materials continue to be released
  - High temp and high strength in DLP – with a move toward more production quality parts rather than prototyping
    - 300deg C materials with great surface finish
  - High strength alloys in metal – largely driven by aerospace, but interest from mining, and other sectors.
  - More composite materials in FDM.
- Multi material printing continues to develop in polyjet and ceramics printing
- More equipment focused on production, rather than prototyping

Technologies and materials



Session 2

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Session 2 – Technologies and materials

- **One size doesn't fit all – it could be that you may need different technologies for differing things you are producing.**
  - At the moment – the following types of technologies are being used in manufacturing for production
    - **FDM** – suitable for high end plastics in limited runs – an example are parts in aerospace with speciality resins that qualified for "fly away" parts. Jigs and fixtures for assembly is also very common
    - **SLS/SAF** – high quality nylon parts suitable for many industries. One good example is orthotics, many of which are already produced in Australia
    - **DLP** – limited run production of parts when traditional manufacturing that needs tooling will be too expensive (also applies to FDM / SAF)
    - **DMLS** – production of complex metal parts in one piece
    - **Binder Jetting** – volume production of small metal parts
    - **Ceramics** – parts for use in medical and aerospace applications

Materials - FDM

Material	Properties	Applications
ABS (ASA)	Most widely used. Tough, easy to finish. Uses soluble support (UV resistance is high)	Prototyping, some end use parts. Material often used in Injection molding
ABS-CF10	Mix of ABS and Chopped carbon fiber (10%) producing a strong stiff part	Jigs and fixtures, limited end use parts. Brackets etc.
Nylon 12CF	Mix of Nylon12 and Chopped carbon fiber (30%) producing a strong stiff part	Jigs and fixtures, end use parts.
Ultem 1010	Food safe and bio compatibility. High heat resistance. Strong and thermally stable	Custom medical devices, food production devices. Aerospace
Ultem 9085	High heat and chemical resistance. FST rates	Aerospace, transport, defence

Materials – SLS / SAF

Material	Properties	Applications
Nylon – PA 11	High ductility from renewable sources	Functional parts – such as parts with hinges
Nylon – PA 12	General purpose Nylon	General purpose functional parts
Aluminum Filled powder	Easy post-processing, good machinability, High temp performance, Thermal conductivity (limited), High stiffness	Applications with metallic finish Parts requiring machining Parts with thermal loads
Glass filled powder	Good heat resistance, 30% glass fiber and high reusability	Structural parts, fans, parts with high wear
TPU - Flexible	Soft elastic material – shore A hardness 80-85 (or 92) Good vibration dampening, heat and water resistant	Seals, washers, damping, protectors
Polystyrene	High Dimensional accuracy and low ash content when burned	Patterns for investment and vacuum casting

Materials – Metal

- **Many materials can be printed using DMLS machines. Some examples are:**
  - Stainless steel 316L. 17-4 PH, M300
  - Nickel Alloy 718 and 625
  - Various Titanium alloys (including Titanium aluminide
  - Various Aluminum alloys
  - Some powder manufacturers also have the ability to create custom powders such as:
    - Ti alloys
    - Ti-5Al-2.5Sn (Grade 6)
    - Nickel-titanium
    - Molybdenum alloys
    - Niobium alloys
    - Zirconium alloys

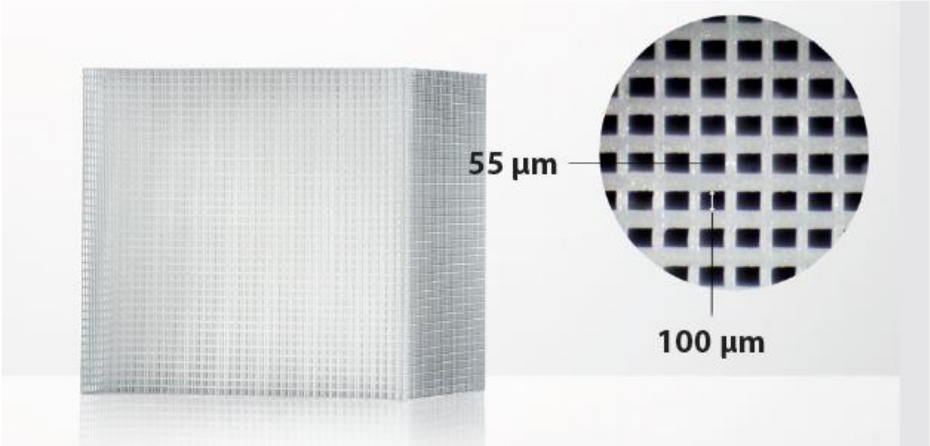
Materials – Binder jetting

- **Metal Binder jetting systems typically use MIM powders**
  - Widely available
  - However, QC is important to maintain part quality – not all powders are good enough in consistency
  - Parameters are not available for the full range of MIM powders and need to be tweaked if powder changes (even if it is the same material, but a different vendor)
  - The majority of binder jet materials are non-reactive at this point
    - Reactive powders require a high level of care in handling and storage.
    - Examples are aluminium, titanium

Impellor – BMW in 17-4 PH

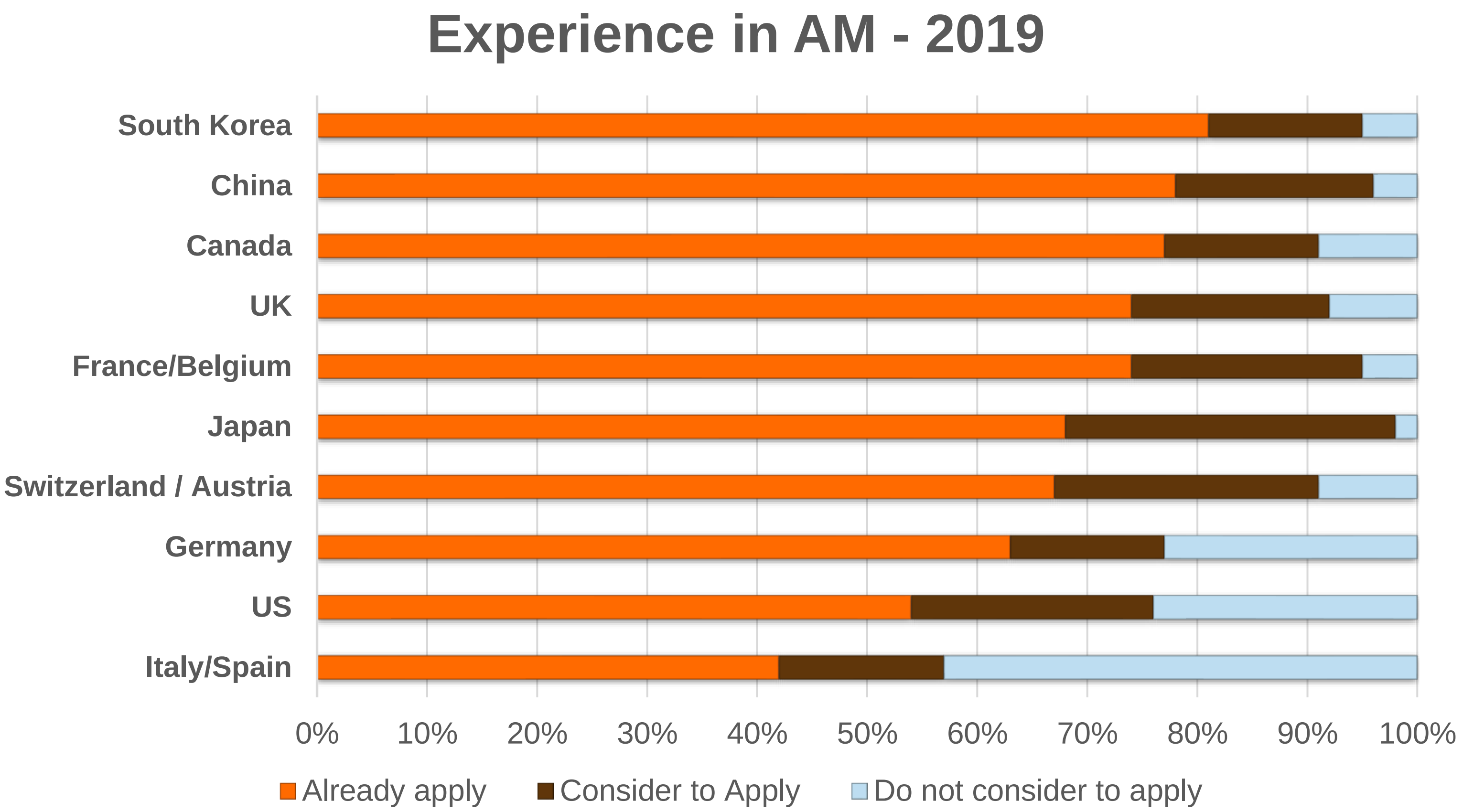
Materials – Ceramics

- Zirconia and Zirconia toughened alumina
- Alumninium Nitride. High performance material with high mechanical and thermal stability – suitable for industrial applications
- Silicon Nitride – used in applications such as impellers and medical inplants
- Piezoceramics – such as lead zirconate titanate – electrical components, sensors and actuators
- Alumina – very thin channels and bores.
- Silica/Alumina and zircon mix for casting cores and turbine plades
- Custom materials are possible



What’s happening in Australia

- **Little (or no) volume production – why?**
  - Lack of volume? If anything that’s a positive – smaller volumes tend to favour additive manufacturing!
  - No use cases? Not likely – there are everywhere else. Surely we are not that different
  - Don’t want to be the first mindset
  - We’ve always done it this way (the old way) mindset
  - There may be many reasons, but we have so many great use cases to highlight



Source: E&Y Global report on 3d Printing

Where is your company in the maturity matrix?

Maturity Level	Strategic direction	Organisation and processes	Technology	Value and performance management
Level 4 – Strategic application across company	- Application of 3DP embedded in company's strategy - C-level sponsorship	- 3DP embedded in relevant operational areas with clear orgnaisation and process	- Own or joint ventures – 3DP production locations - Own or JV 3DP research centres	- Embedded measurement of applying 3DP improves efficiency
Level 3. Application in "champion departments'	- Clear direction on application of 3DP in certain areas	- "Champion departments have integrated 3dP into operations	- Own systems from relevant technology - Established collaborations	- Measurable results within specific department or areas of application
Level 2. Experimenting and testing	- Department leaders start to invest, test and understand the technology	- Teams of enthusiasts test 3DP technology - No structured processes for application of 3DP	- Testing different technologies with services providers, research group or own cheap systems	- First own use cases with measurable results
Level 1. No experience	- Leadership has no or low awareness about 3DP and application in the company	- Eventually first evaluation and consideration of possibilities	- Eventually first evaluation and consideration of forms of applications (own system, cooperation)	- No own experience. Eventually review of experiences from other companies

Source - EY

What others have done!

Successful use cases

It started with 1 part …
the CFM LEAP fuel nozzle

Capabilities of full production
35,000 – 40,000 per year

30,000+
PARTS SHIPPED

20:1
PARTS

95%
INVENTORY REDUCTION

25%
WEIGHT REDUCTION

Source: GE Aviation

Boom Supersonic

United States

Challenges

- Long lead time for fabrication of Bleed Air Duct
- Material waste due to bulk of material being machined away
- Higher material costs

Solution

- Fortus 450mc™ using ULTEM™ 1010 resin
    - Produced ducts quickly and avoided typical machining backlog queue and machine setup
    - Material cost reduced with AM and used only amounted needed to build part
    - Eliminated design for manufacturability constraints inherent with machining

Impact

- Fabricate part in 14 hours vs. 7 weeks
- Total cost of per part $150 vs. $9,000 using conventional machining
- Total of 98% cost savings & 95% lead time savings

Learn More

Marchesini Group

Italy

"Having this on-demand production capability enables our engineers to take advantage of the greater design freedom enabled by 3D printing, which has empowered Marchesini Group to achieve higher quality results for our customers."

Challenges

- **Produce customized machinery parts with lower lead times and costs than traditional manufacturing**
- **Ensure customers' packaging machines continue to run efficiently after installation**

Solution

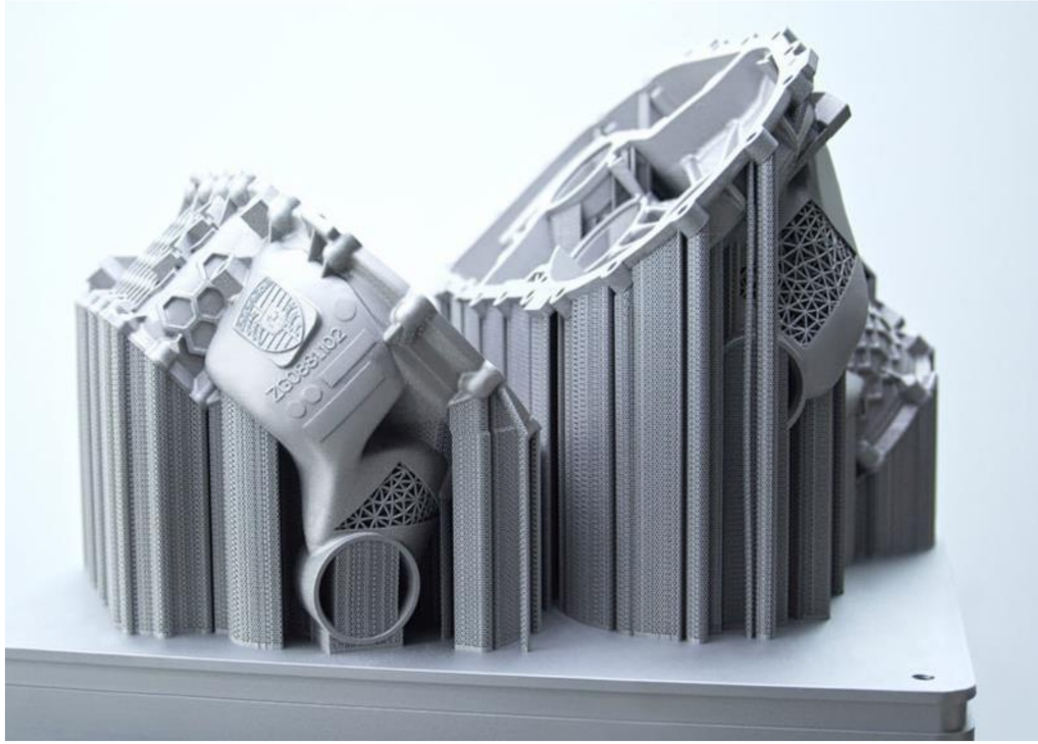
- **Fortus 450mc™, Stratasys F270™ using FDM Nylon 12CF and ULTEM™ 9085 resin**
  - Produce customized machine parts with no order minimum, as well as replacement parts on demand, eliminating the need to hold replacement inventory
  - Print geometrically complex parts in short time frames that would be unachievable with CNC machining

Impact

- **Part lead time reduced from several weeks to a few days**
- **Greater than 30% reduction in weight compared to traditionally metal parts**

Porsche

- “Lighter, more rigid, more compact: Porsche has produced its first complete housing for an electric drive using 3D printing. The engine-gearbox unit produced using the additive laser fusion process passed all the quality and stress tests without any problems”



Visual First

Netherlands

"Additive manufacturing offers significant opportunities to decrease spare-part inventory, reduce the supply chain and slash costs. The ability to print a spare parts on-demand offers manufacturers a rapid solution that ensures production continuity and, most importantly, help safeguard revenues."

Challenges

- **Prevent bottlenecks in packaging due to waiting for machine replacement parts**
- **Quickly produce replacement parts that won't jam or require human intervention**
- **Replacing customized machine parts via traditional manufacturing took over a month**

Solution

- **Fortus 450mc™ using Nylon 12CF**
  - The material's rigidity stood up to all machine tests and increased production once it replaced its metal counterpart
  - The ability to replace parts on demand reduces machine downtime

Impact

- **Receive replacement parts in less than 1 week vs. over 1 month**
- **Total of 60% cost savings on replacement parts**

Disruption is coming – are you ready?

ADDITIVE

SUBTRACTIVE

Implementing AM – a structured approach

Session 3

March 2022

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Session 3 – A structured approach

What we've covered so far:

- **We are aware of the technologies available**
- **We have seen some good use cases for integrating additive to your manufacturing**
- **What's to do now**
  - Consider how it may work for your companies!
  - Our thoughts on a stepwise approach
  - Some of the challenges to think about
  - Practising what we preach – a look at additive at Objective3D

Using AM for prototyping yields benefits, but the real breakthrough comes when companies apply AM for functional parts.

Why additive …

1 **Improves quality** … eliminates design trade offs; reduced defect opportunities, digital v. analog control, reduced anomaly size and frequency v. traditional castings

2 **Expands what is possible** … opens up new engineering capabilities and business opportunities to optimize part & system designs in a way we cannot with traditional manufacturing processes

3 **Simplifies systems** … more robust designs, reduced part counts, reduced braze/weld/rivet/bolted joints and assemblies; optimized systems

A structured approach to additive

A suggestion for a structured approach

1. **Evaluation** – Can additive work in your organization? Is it being used in pockets today? Identify challenges to adopt or grow (see the maturity matrix for details). Look outside Australia for success stories

2. **Business case** – Consider the entire supply chain – thinking about the entire product lifecycle associated with the use of AM

3. **Roadmap** – Create a realistic and achievable roadmap. Include a pilot in one targeted area before upscaling.

4. **Organisational shift** – You will need evangelists and a positive mindset through the oganisation.

Source: Deloitte: challenges to additive manufacturing with modifications

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Session 3 – A stepwise approach – Evaluation and business case

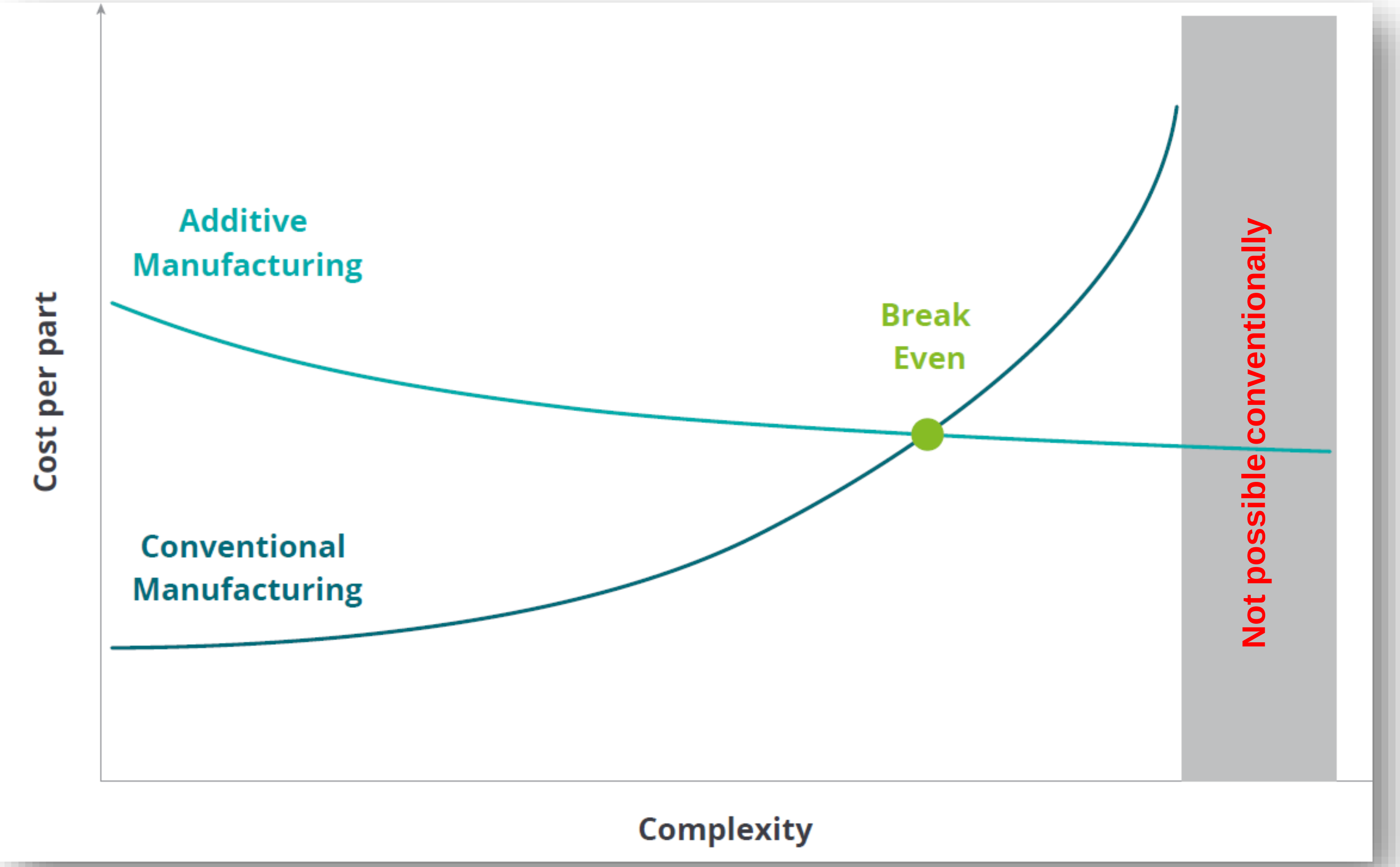
Our thoughts on how to proceed

- **Your Strategy - often the beginning of the end**
  - Many companies don't invest in understanding or developing their strategy (not just applying to AM)
  - Developing an AM strategy means understanding the environment you are in, both external and internal and also the vision or goal – only then can you develop plans on how to get there
    - Failure usually comes at the beginning, but not understanding the market, competition, economic environment etc and therefore not having the right plans to succeed.
    - Dominant personalities who "know it all" can derail what starts out as a well thought through project because it challenges their ideas (perhaps correctly!)
  - Having up-to-date data and financials in detail is really important when considering your approach.

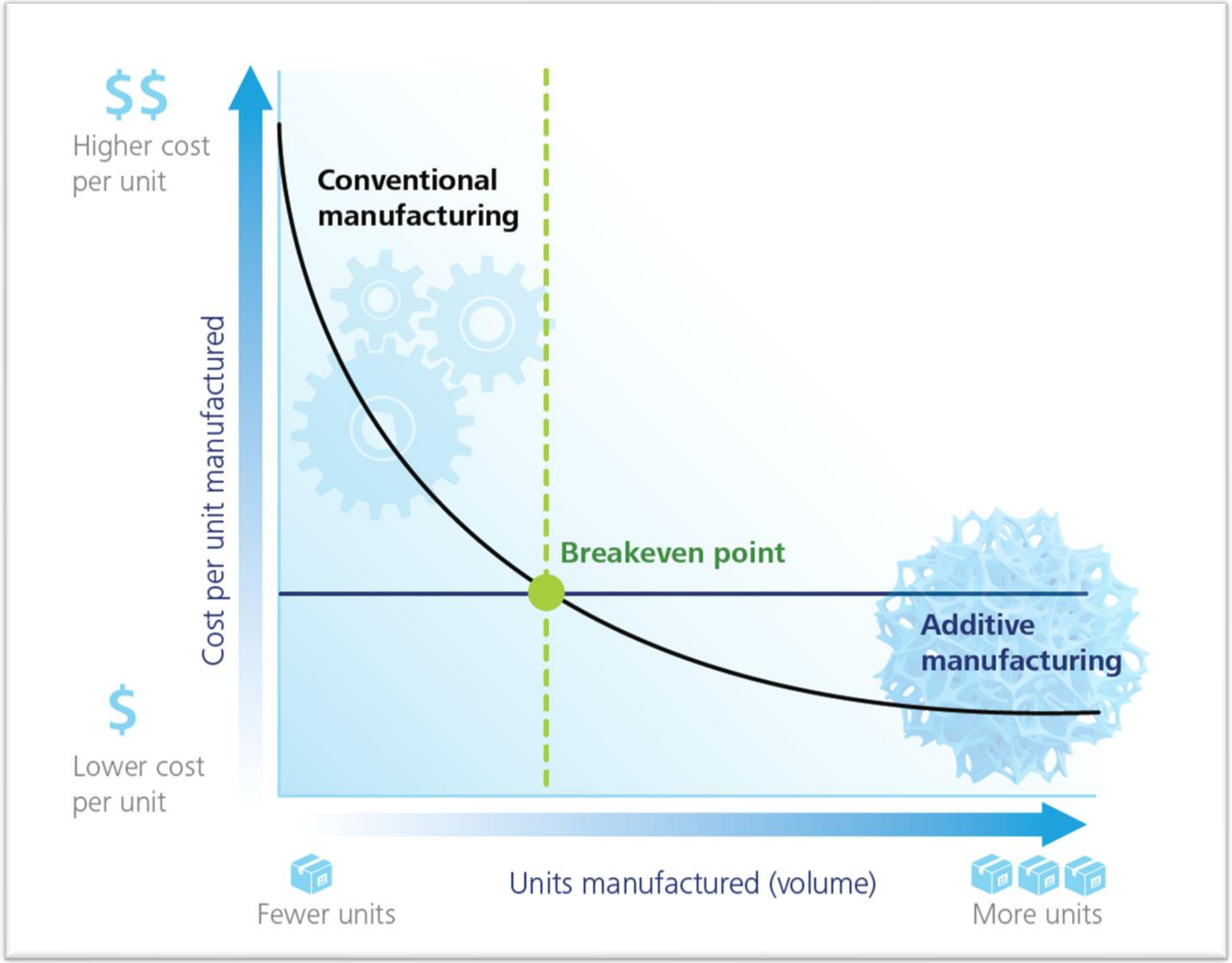
A stepwise approach to additive – business case

Break even point – 1 – complexity

- In this example the complexity of parts is the cost driver
- As parts become more complex, conventional costs increase as a comparison
- At the far right, there is no comparison as the part could not be made conventionally



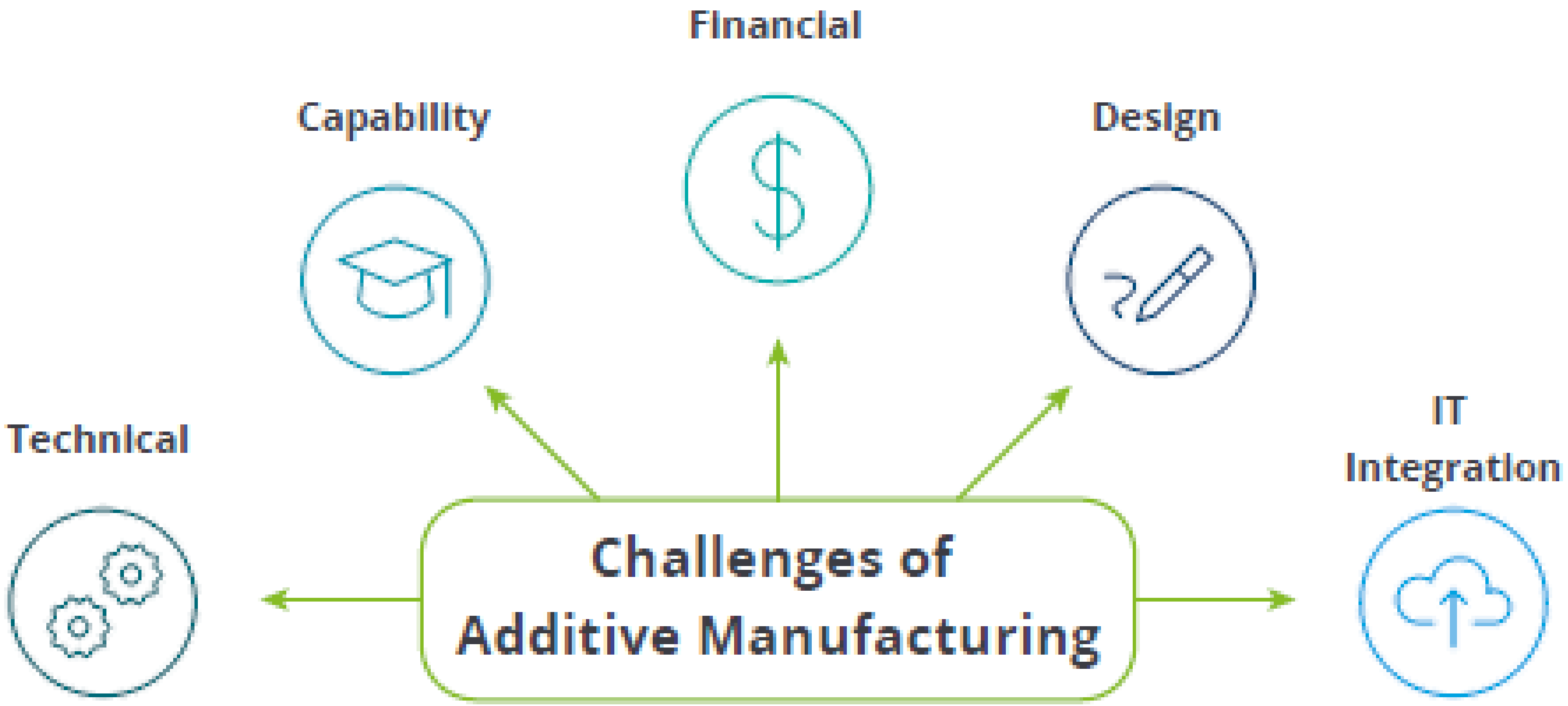
A stepwise approach to additive – business case



Break even point – 2

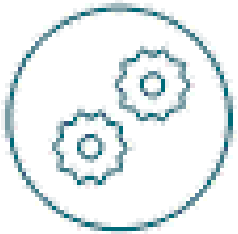
- In this case it is volume that is deriving the break even, not part complexity
- It is considering parts where an initial cost of tooling or makeready is contributing to every part made.

A stepwise approach to additive - challenges



A stepwise approach to additive

Technical



Considering the challenges: Technical

- In many companies, AM is mainly used for prototyping. Why? Often it can be design constraints (more on that later)
- Are the materials you need available with the right specifications – cheap materials are often the downfall of forays into AM – you get what you pay for!
- Post processing and automating that part of production is now catching up
- When looking at recent developments, many are in the availability of new materials that companies require to make AM work. Consider if there is an alternative that will do the same job.
- Many challenges of today are temporary – and will diminish with the growth in investment in the AM industry.

A stepwise approach to additive

Capability

Considering the challenges: Capability

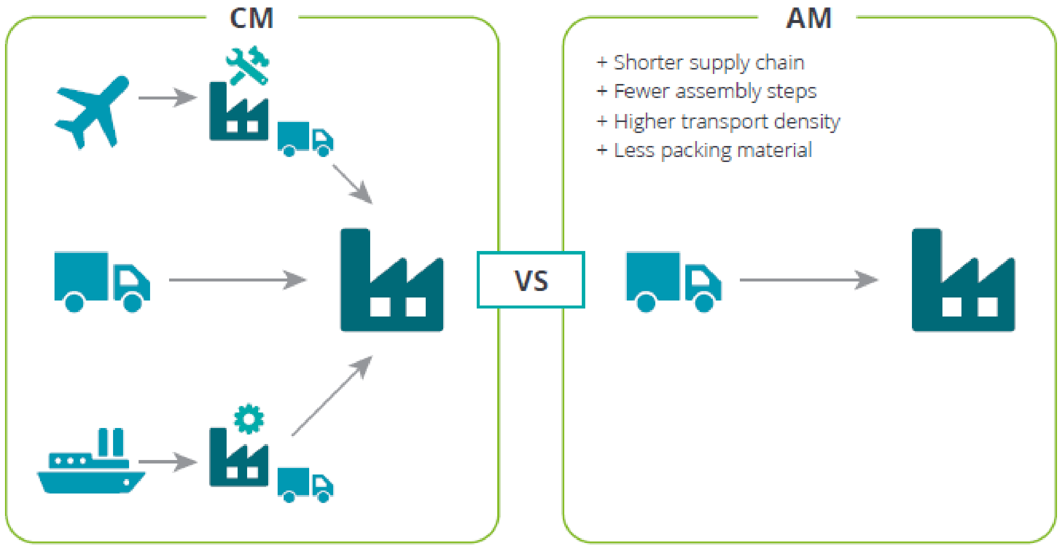
- Skill up. Build DfAM capabilities. This is one of the key areas. Potential benefits of AM production will be lost or never even started if you keep designing the way you do today
- Bring the whole team with you. There are opportunites to retrain people with great base skills to make the most of AM
- Look for graduate who have worked with AM and are ready to develop an holistic view (it’s not just engineering)
- Many universities have AM capabilities and are looking to engage with industry (UniSA is one great example!)
- Management mind set – needs to look further than the short and get up to speed with the possibilities and bring a vision to the table.

A stepwise approach to additive

Financial

Considering the challenges: Financial

- The business case needs careful thought. Additive is a workflow, and you need to consider the full impact, not just the cost of the machine.
- Remember, additive will impact the whole supply chain and product lifecycle (digital inventory is one example). Many failed attempts to implement AM don't look deep enough!
- AM may bring a positive environmental impact which is only good news today!
- AM brings the possibilities of mass customization, which are usually attractive to customers and increase demand and sales.

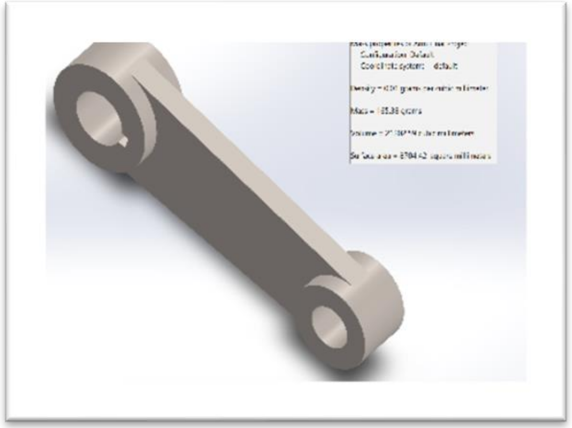


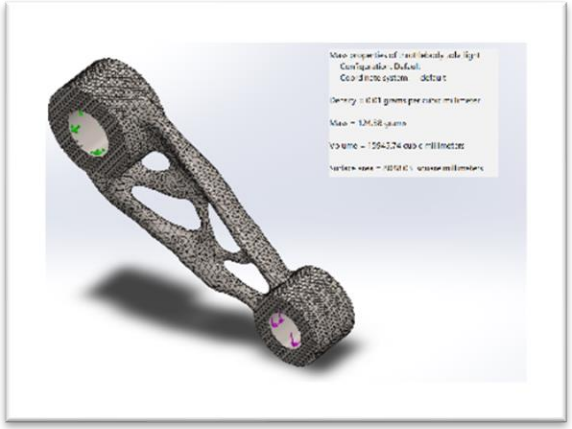
A stepwise approach to additive

Design

Considering the challenges: Design

- Product design are defined by customer requirements but the impact of how it is made will have a significant impact
- Reproducing a current design based on it being made another way is not a recipe for success – that mindset needs to change
- Designers need to consider how DfAM can help reduce weight, make the part stronger, etc. AM reframes the design process.
- The design process can be condensed, more collaborated and less linear.
- Products such as n-topology, and Live parts are becoming more widely used, helping advocate a new way of thinking.





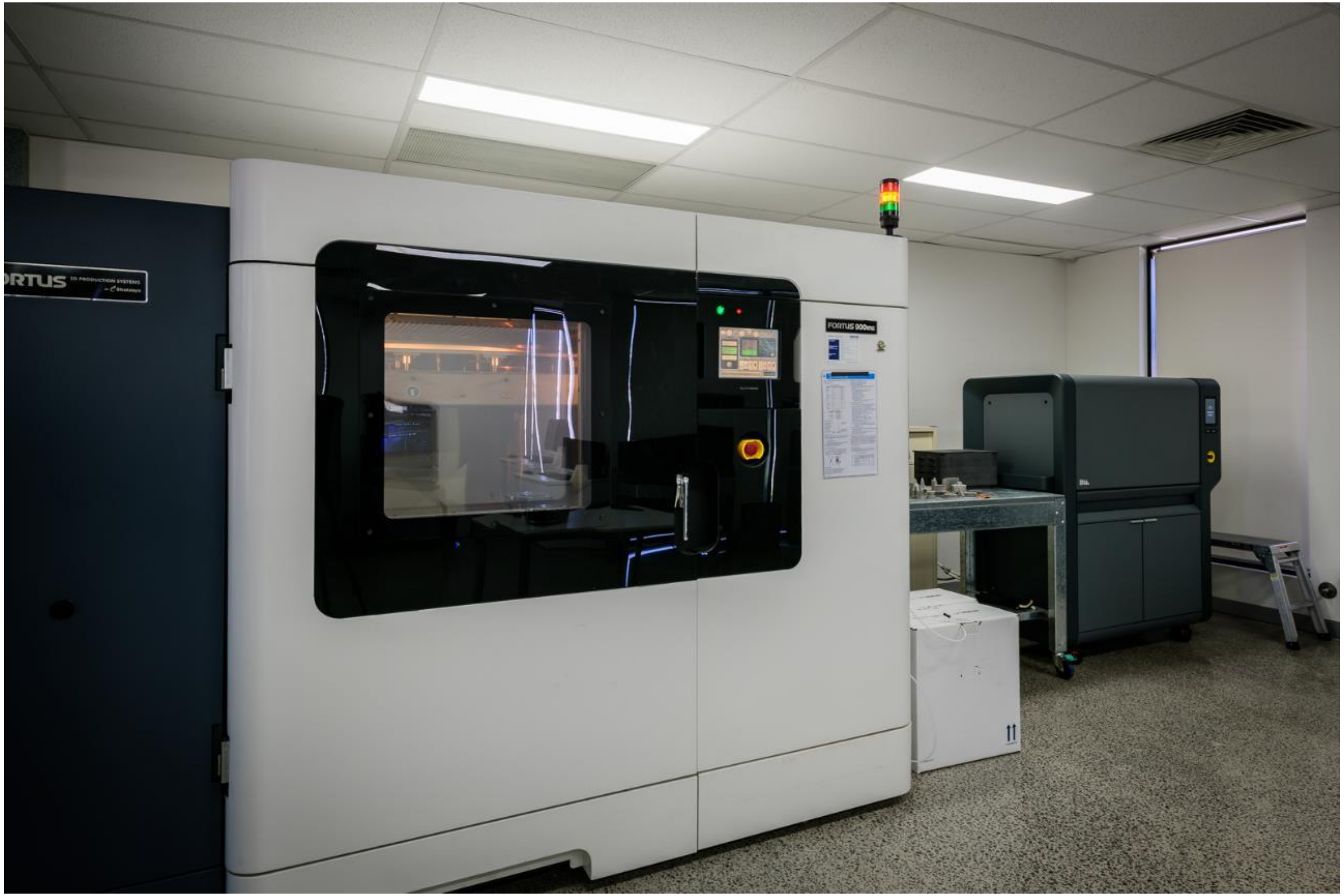
IT Integration

A stepwise approach to additive

Considering the challenges: IT Integration

- Depending on the size of production will define the size of this challenge.
- Not a big deal for prototyping, as an example however and not all factories are fully digitized today
- Not all ERP systems are designed for single part tracking, but rather batches.
- Standards such as using MTconnect are designed to integrate AM solutions (and many others) to the ERP system, which is a great start (www.mtconnect.org)
- Additionally, API's are more commonly available for the 3d Printer driver SW opening the door to more data becoming available for the ERP systems.
- The increasing digitization of manufacturing will drive connectivity and use of standards will only improve

Practicing what we preach – Objective 3D



Practicing what we preach – Objective 3D

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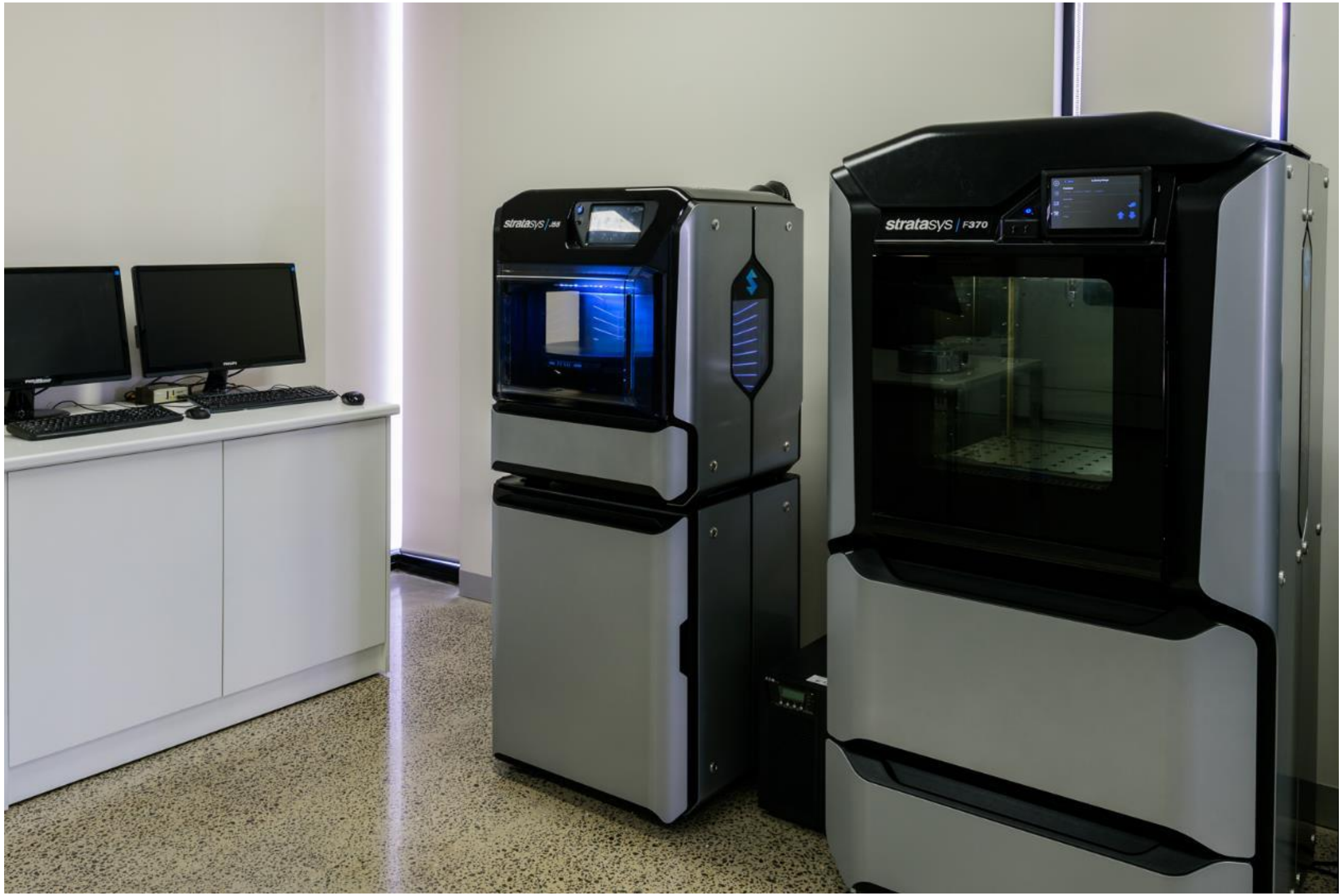
Practicing what we preach – Objective 3D



Practicing what we preach – Objective 3D

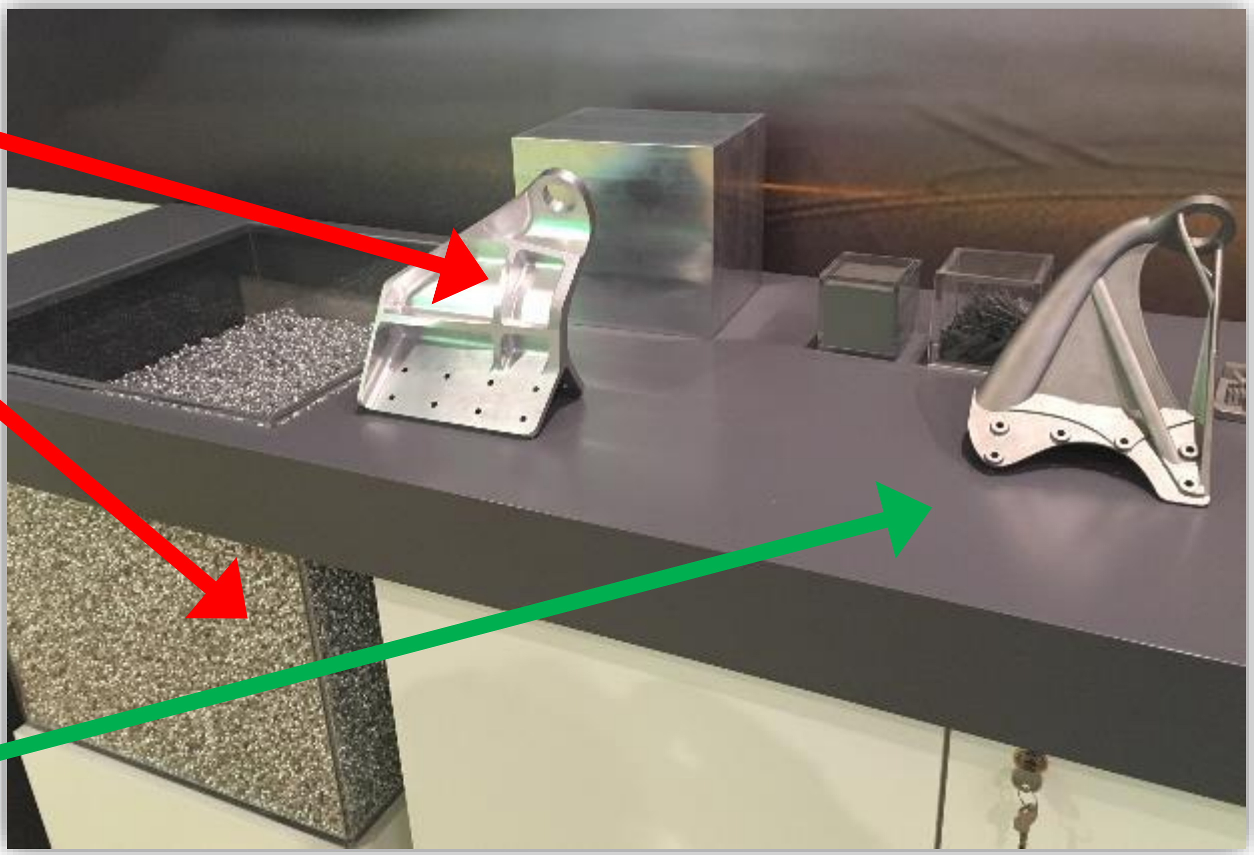
Practicing what we preach – Objective 3D

Practicing what we preach – Objective 3D

Food for thought as we finish . . .

On the left, a conventionally manufactured aluminum bracket

On the left of that, is the waste material from the billet of raw material . . . .



- On the right, the same bracket redesigned and optimized for additive manufacturing.
- Make of titanium, with almost no waste and increased strength and durability

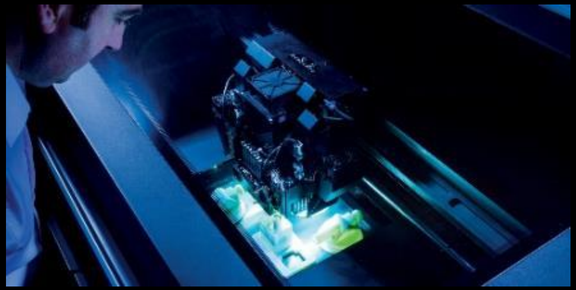
For more information

Thermoplastics (Stratasys) and Artec Scanners

- Sydney/QLD – Ash Bahl – ash@objective3d.com.au
- Vic/SA/WA – Grant Summers – grant@objective3d.com.au

Metal and ceramics

- All Australia and New Zealand – peter@objective3d.com.au



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