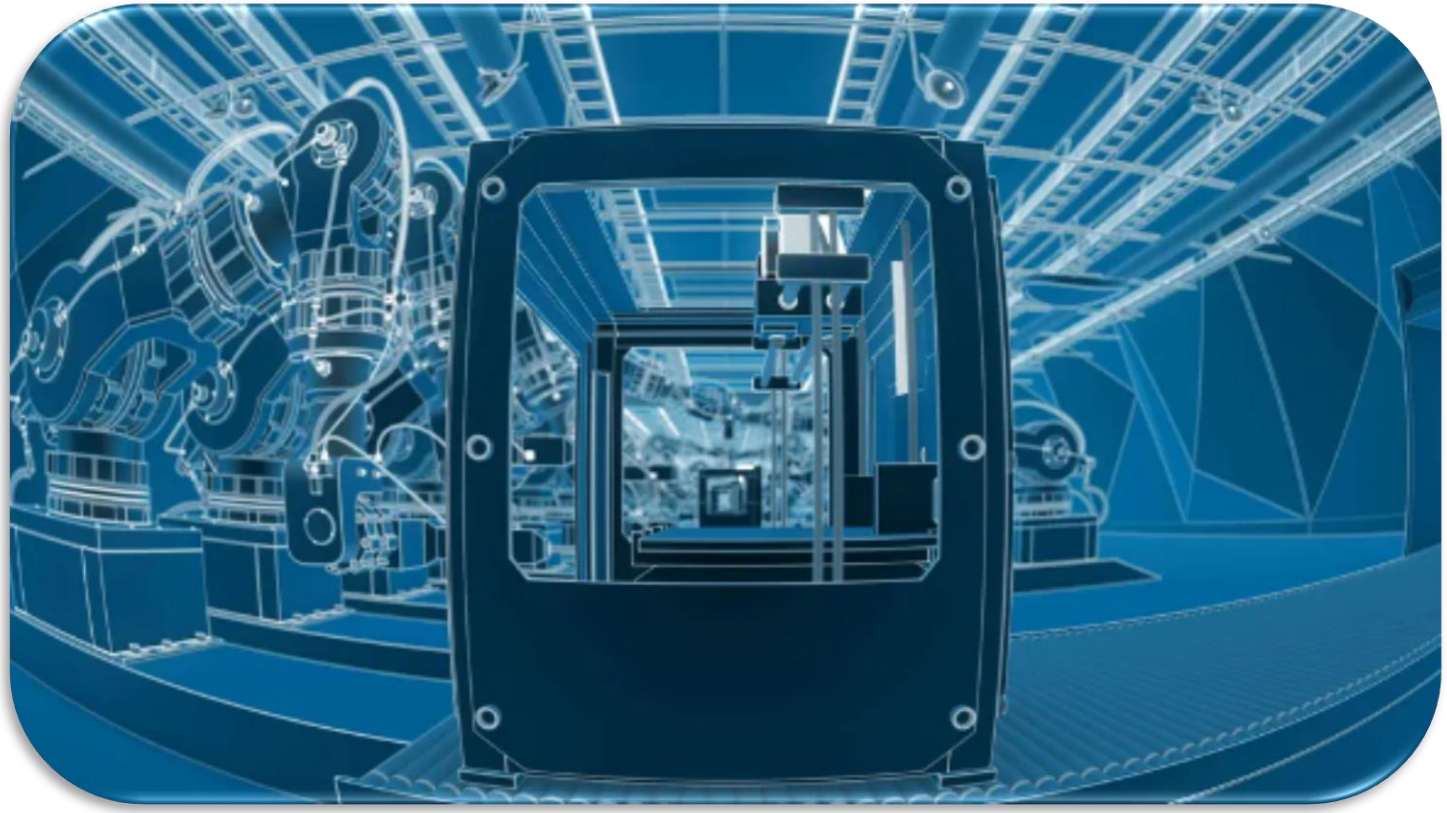
Introduction



What Is Additive Manufacturing?

- Additive manufacturing (AM) encompasses a range of technologies that allows physical components to be made, from **virtual 3D models** by building the component **layer-upon-layer** until the part is complete.

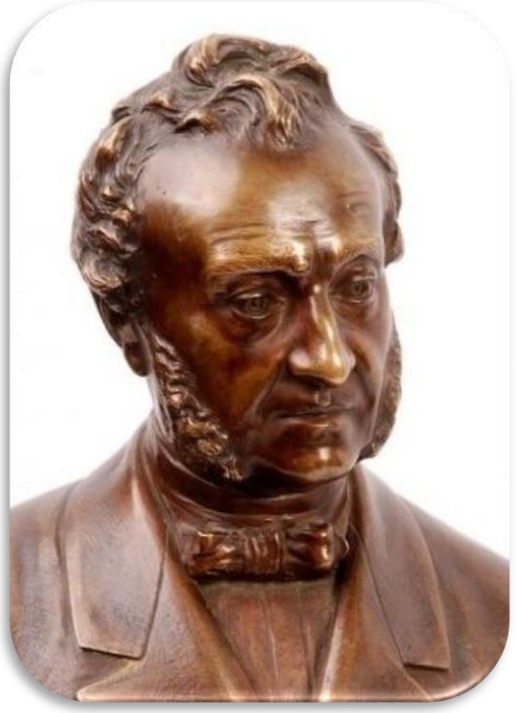
Subtractive manufacturing, where one builds a part by removing material from a block, versus additive manufacturing, in which one builds the part layer-upon-layer

A Brief History of AM (The Early Years)

- AM has a history that can be traced back to the **late 19th century** and **early 20th century** with the introduction of layer based **topographical maps**.
- In 1982, **Joseph E. Blanther** patented a manufacturing method to create contour relief maps.
- These maps were created by impressing topographical contour lines on a series of **wax plates**. The plates were then cut according to the contour lines and **stacked** on top of each other to create a three-dimensional model that represented the terrain.

A Brief History of AM (The Early Years)

- Around the same time in the **19th century**, photosculpture was also invented. In 1860, **Francois Willeme** simultaneously photographed an object with **24 equally spaced cameras** that were located around the circumference of a room. The silhouettes from these photos were then used to create a physical model by **carving out 1/24th of it at a time**.
- This was a very labor intensive method, so in **1904**, **Carlo Baese** patented a method that used photographs and graduated **light** to expose a **photosensitive gelatin**. The gelatin would expand in proportion to the light exposure to create the **physical model**.



François Willème

The Modern History of AM

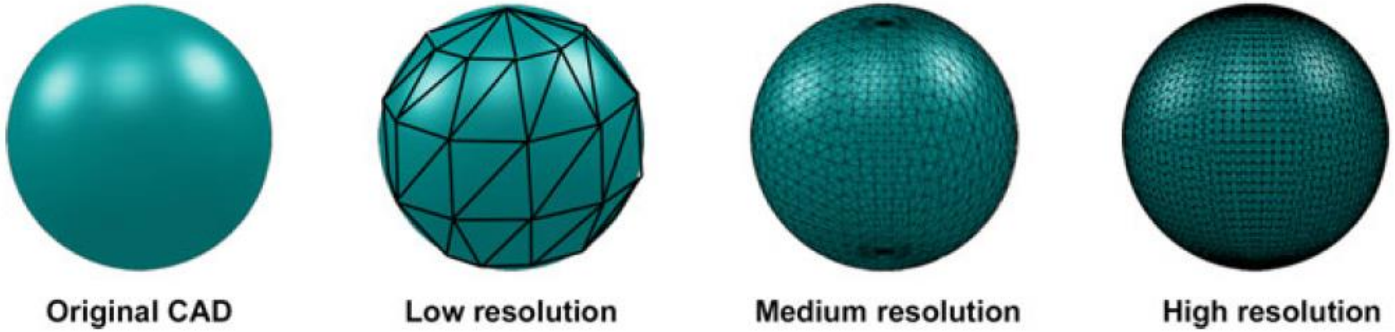
- Modern AM technology origins can be traced to a **stereolithography process** created by **Otto John Munz in 1951**. His process was essentially a series of layered 2D photographs printed on **photosensitive emulsion**.
- It was similar to the stereolithography machines we know today. Each layer was exposed individually and the build platform was lowered. However, **the drawback to his system** was that the 3D image of the object was contained within a clear cylinder after the process was completed. In order to get a final three-dimensional model, the image needed to be etched or carved out of the clear cylinder.

The Modern History of AM

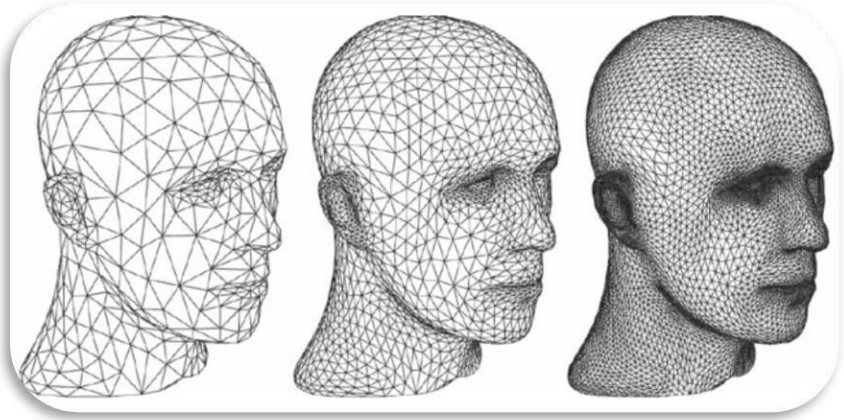
- The development of commercially available systems **did not occur until 1987**. It began with a patent originally **owned by UVP Inc.** and licensed to **Charles Hull**, a former employee. **Hull used the patent to form the company 3D Systems**.
- **3D Systems** introduced a process that solidified thin layers of **ultraviolet light-sensitive liquid polymer** using a laser. The **SLA-1** was the first commercially available AM system in the world.

The AM Process Chain

- The **CAD file** is converted into a file format that can be understood by the AM machine.
- Typically, today, the most commonly used file format is an **STL file** (standard triangle language, stereolithography, or standard tessellation language) which is a format that converts the original CAD file into a triangulated file.
- The higher the resolution of the STL file, the more triangles it contains, so the better the quality of the model.

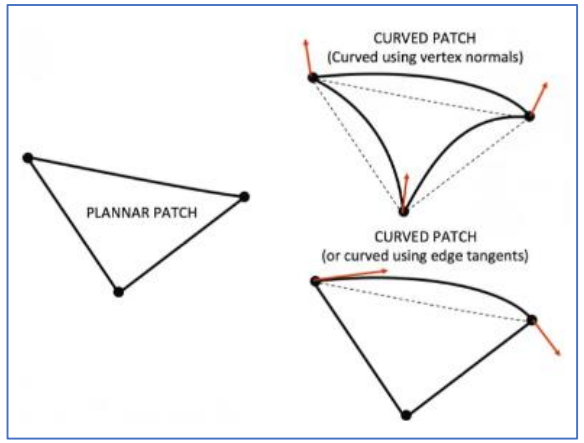


Examples of STL file resolution

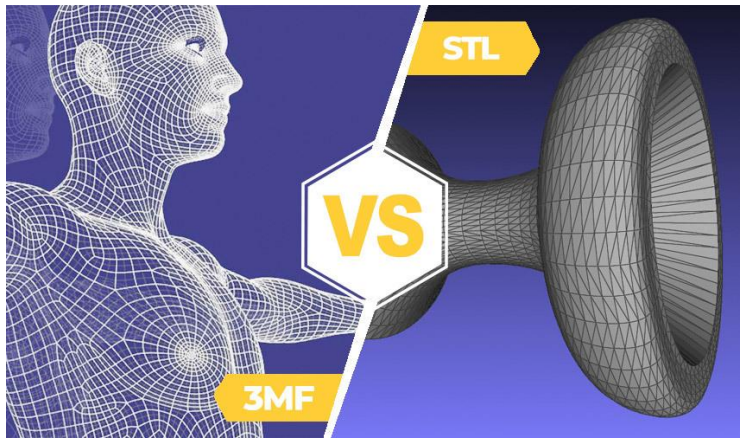


The AM Process Chain

- Some new additive manufacturing file formats, including **AMF** (Additive Manufacturing File Format) and **3MF** (3D Manufacturing Format), have recently been proposed which vastly improve the somewhat antiquated STL format, as they add more information to the file, **including colour and material**, and allows the **use of curved triangles to improve model quality**.
- At the time of publication, **3MF** appears to be gaining considerably more traction than the AMF format.

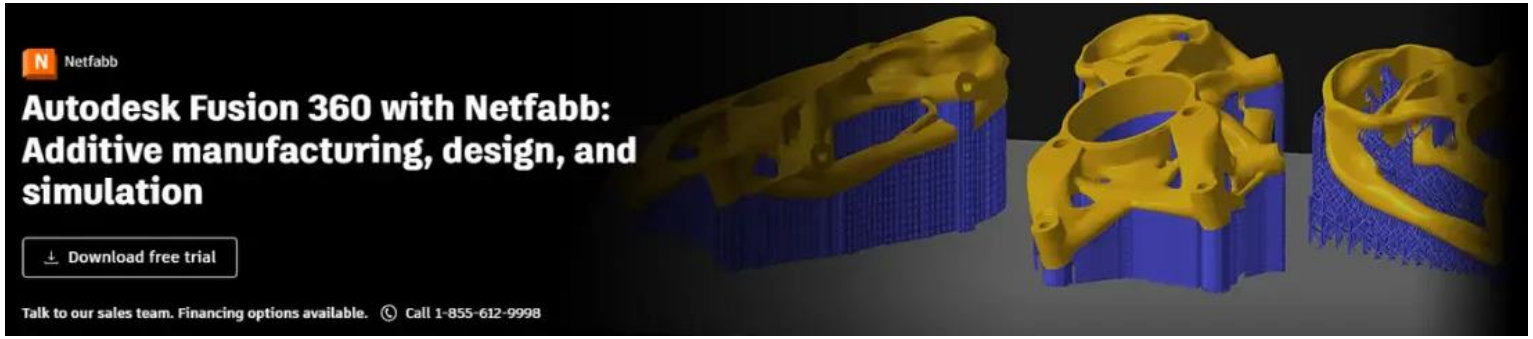


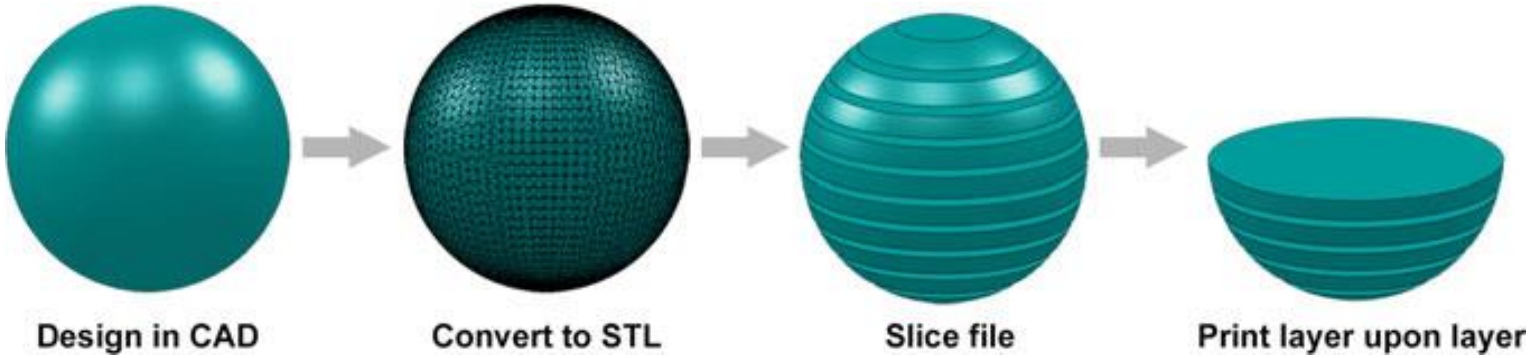
	STL	3MF
Creation	1987 by 3D Systems	2015 by the 3MF Consortium
Readable by Humans	No	Yes
Stored Info	Mesh (Polygons)	Units, textures, materials, colors, mesh, nesting, machine, thumbnail...
File Type	Mesh (RAW data)	Archive (Mesh + more info)
Size	Huge (thousands of polygons)	Light (code to express parameters & copies)



10 Best AM Software of 2023

1. Ansys
2. Autodesk Netfabb
3. 3dSystems
4. Siemens NX AM
5. Materialise Magics
6. Solid Edge
7. Amphyon
8. Genoa 3d Simulation
9. AdditiveLab
10. 3yourmind

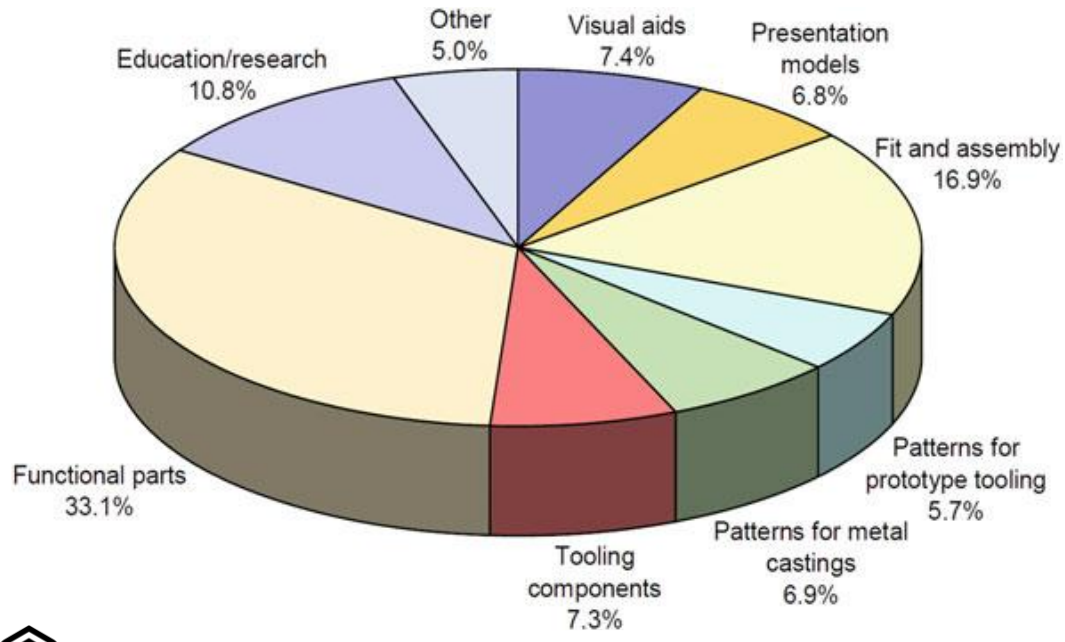




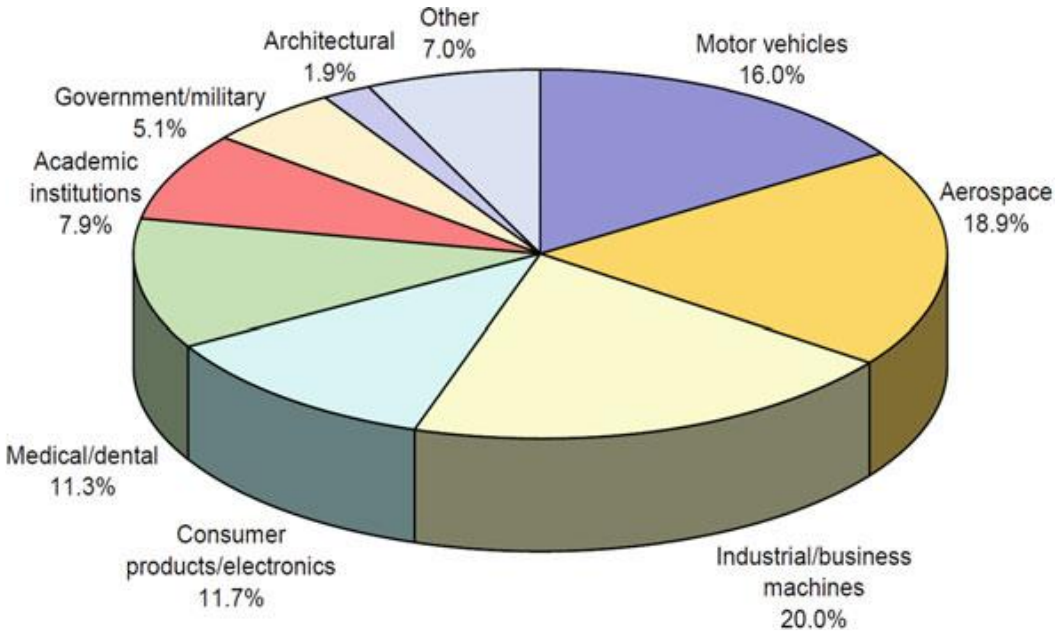
The additive manufacturing process chain

Current Usage of AM

The 2018 Wohlers Report gives the data on areas of use for AM

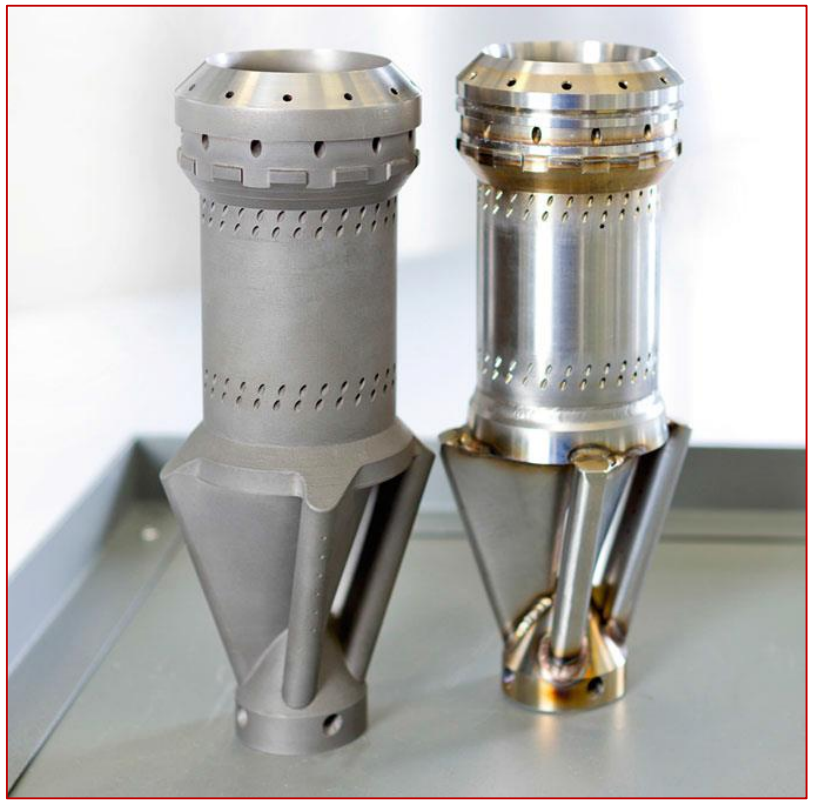


Industries using additive manufacturing (Wohlers Associates)



The Advantages of AM
1. Part Complexity

Examples of **geometrically complex forms** that would be hard, or impossible to make with traditional manufacturing



Siemens turbine burner

This part would be impossible to machine, or cast, as a single piece, but can be made through additive manufacturing.

The Siemens burner went from **13 machined parts joined together by 18 welds**, down to a **single AM part**.

The pilot gas feed was integrated into the structure this removing the need for an external pilot gas feed pipe.

Because of the improved cooling that AM allowed, it was also possible **to remove the need for a thermal barrier coating**.

The Advantages of AM
2. Instant Assemblies

- **Foldable guitar stand** that was printed using a **powder bed fusion technology**. The entire guitar stand is, however, manufactured in a single operation with no assembly whatsoever required. If the guitar stand were to be manufactured using traditional manufacturing methods, it would require, at least, **sixteen components and an assembly procedure** to attach all the separate components together.

The Advantages of AM
3. Part Consolidation

- This drone used part consolidation to manufacture the entire drone **with only six core components** (excluding the company labels).

The Advantages of AM
4. Mass Customization

- With additive manufacturing parts can be made on demand, as there is no longer a long lead-time to get tooling produced (**manufacturing-on-demand**).

This opens the door to mass customization in which, though mass-manufactured, each product can be customized to each individual customer.
This is already beginning to happen in industries including **hearing aids**, **dental crowns**, **implants**, **medical prostheses**, **customized orthotic shoe inserts**, and the high-end interior design and fashion industries.

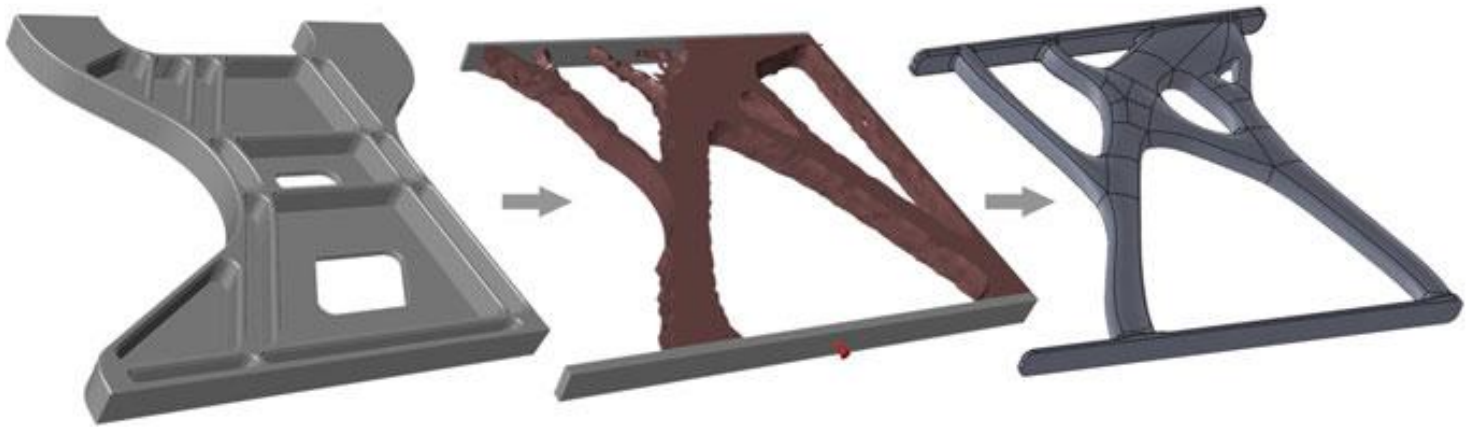
The Advantages of AM
5. Freedom of Design

- Most designers are quite accustomed to hearing the response of **"it cannot be made like that"** from **manufacturing engineers**.
- With additive manufacturing, complexity and geometry often no longer affect manufacturability.

Geometrically complex skull-shaped microphone. This products could not have been cost-effectively made using traditional manufacturing methods.

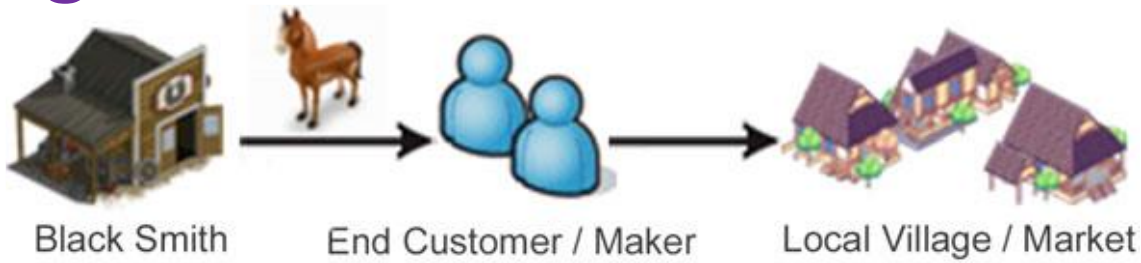
The Advantages of AM
6. Light-Weighting

- **Topology optimisation** is a method of removing as much material as possible from a part, while maintaining sufficient mechanical properties. It consists in performing a finite element analysis (FEA) and then iteratively removing unnecessary material.
- In the example of the **aircraft seat**, it would require a block weighing **16.2 kg** to be machined down into the finished product, weighing **4.1 kg**. In contrast, the topology optimised version weighs only **3.1 kg**.

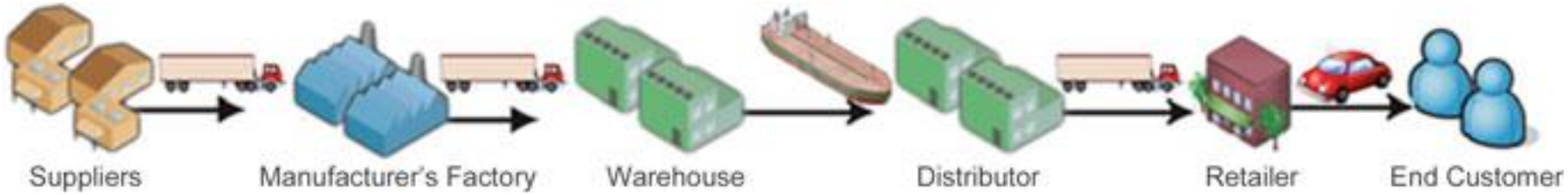


The Advantages of AM
7. On-Demand Manufacturing

The supply chain before the industrial revolution



The supply chain today



The supply chain of tomorrow