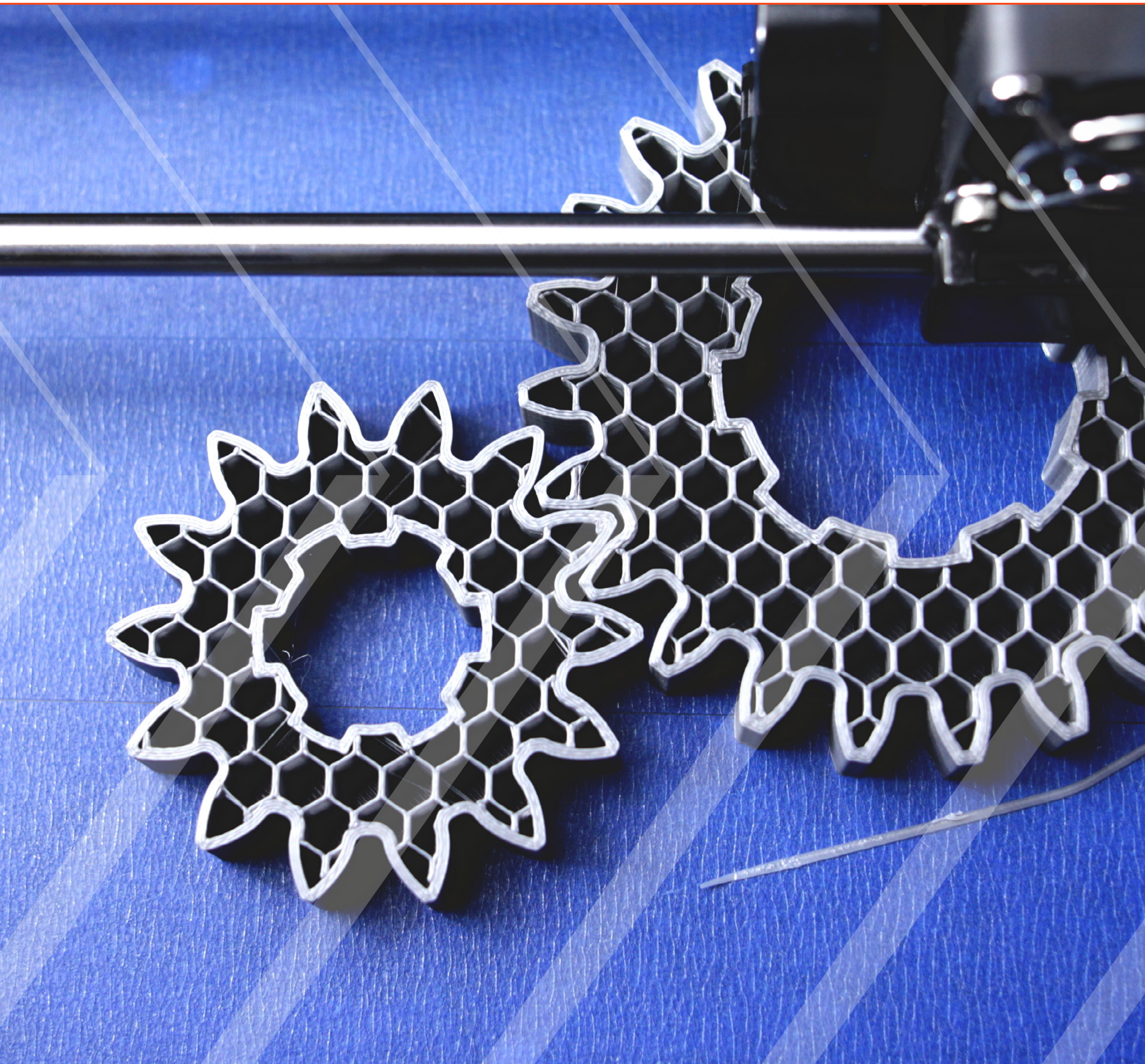
ALTAIR

GUIDE TO DEVELOPING AN ADDITIVE MANUFACTURING STRATEGY



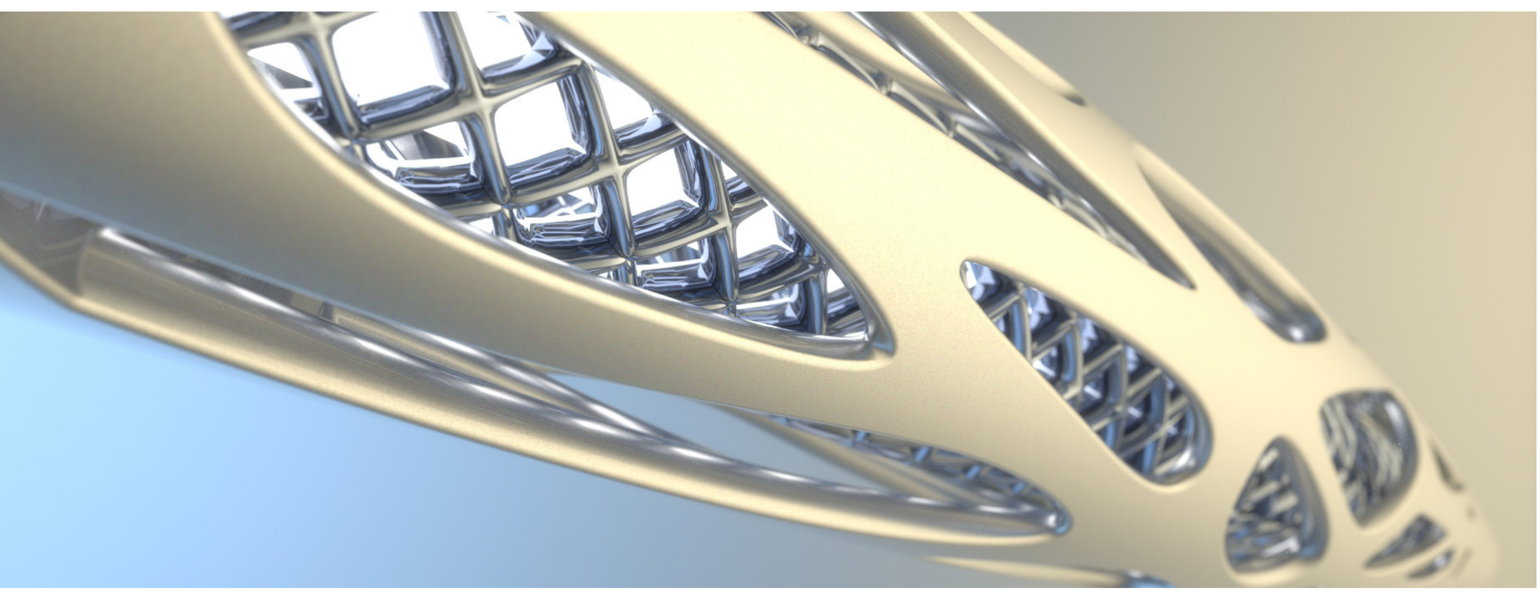
INTRODUCTION

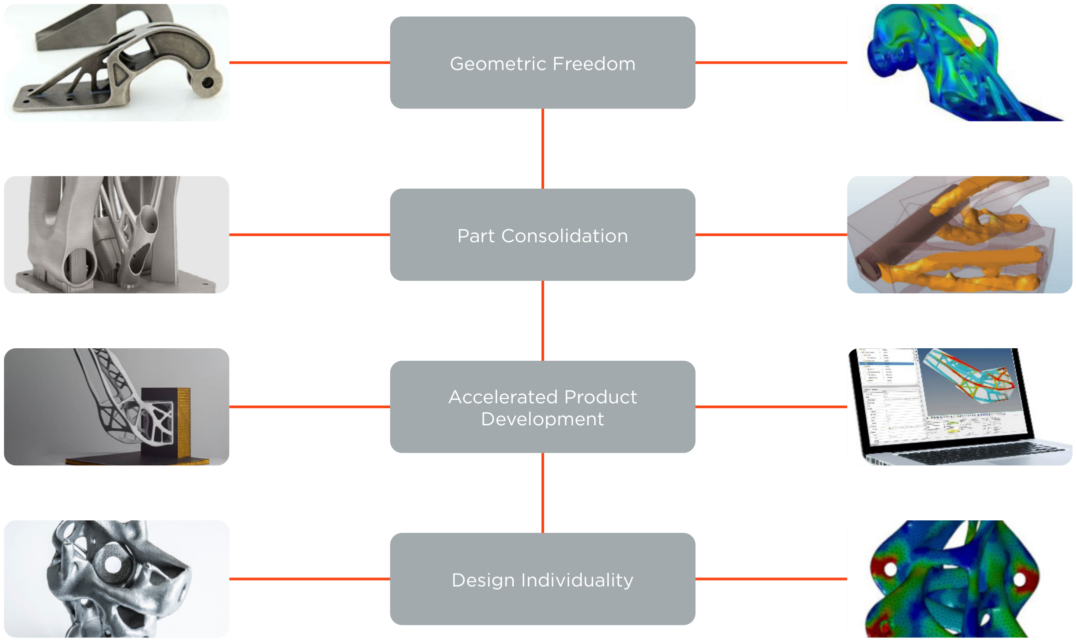
Just a few years ago, additive manufacturing was purely associated with rapid prototyping, research projects, and advanced engineering teams. Now, many organizations are looking to additive manufacturing as a production solution. To some this means the production of parts through an additive method, to others additive is essential for the creation of timely tooling. Either way the conversations involving additive manufacturing have changed from questions about technology capabilities and unique geometries, to discussions around manufacturing capacities and a robust toolchain to support design.

Significant lead time reduction, improved performance, and consolidation of parts are attractive opportunities offered by additive manufacturing and enabled by generative design. For prototypes – and some custom single-unit parts – topology optimized geometries can often be interpreted into additive parts in a very literal way. There are some important points to consider, however, when implementing additive manufacturing in production. At volume, additive manufactured parts must maintain dimensional consistency, meet cost targets, and achieve production schedules. When these considerations are met, additive manufacturing becomes an attractive application of generative design.

Additive Manufacturing to Production

How are leading companies approaching this? This guide walks you through the decision-making process to take additive manufacturing to production.





CAN SIMULATION SOFTWARE ENABLE COMPANIES TO PRINT RIGHT THE FIRST TIME

The short answer is yes!
Advanced engineering simulation has traditionally been employed as virtual testing of a mature design. A task performed late during product development, just before building a physical prototype. Organizations mature in their digital transformation use simulation technology early in the design process as part of concept design. To enable this shift, a new category of software has been created using the same physics as earlier designs but developed with a design audience in mind. Today, innovative companies are taking advantage of advanced simulation software to identify high value parts and business cases, where additive manufacturing offers a commercial considerable alternative to conventional manufacturing.

The power of simulation to move additive manufacturing from an advanced capability to a production capacity with the power of simulation:

1 **Choose the best manufacturing process for the part.**
Companies interested in additive manufacturing often ask the question, “Is additive manufacturing the right manufacturing process to produce this part?” Recent developments of simulation software technologies are consolidating the decision making into a single environment. Design and manufacturing engineers are now able to assess and benchmark designs for different manufacturing processes efficiently, increasing the level of confidence in the selected method. Ultimately, they can create a unique design

of a particular part for each manufacturing process. The motorbike bracket example below shows six different designs, each of which was designed with the production process in mind.

The part that demonstrates the most value considering production volume and cost, material, lead time, tooling requirements, and post-processing is then selected for production.

Conventional Casting

Powder Bed Laser Melting

AM Sand Mold and Casting

Machining

Fused Metal Deposition

Metal Binder Jetting

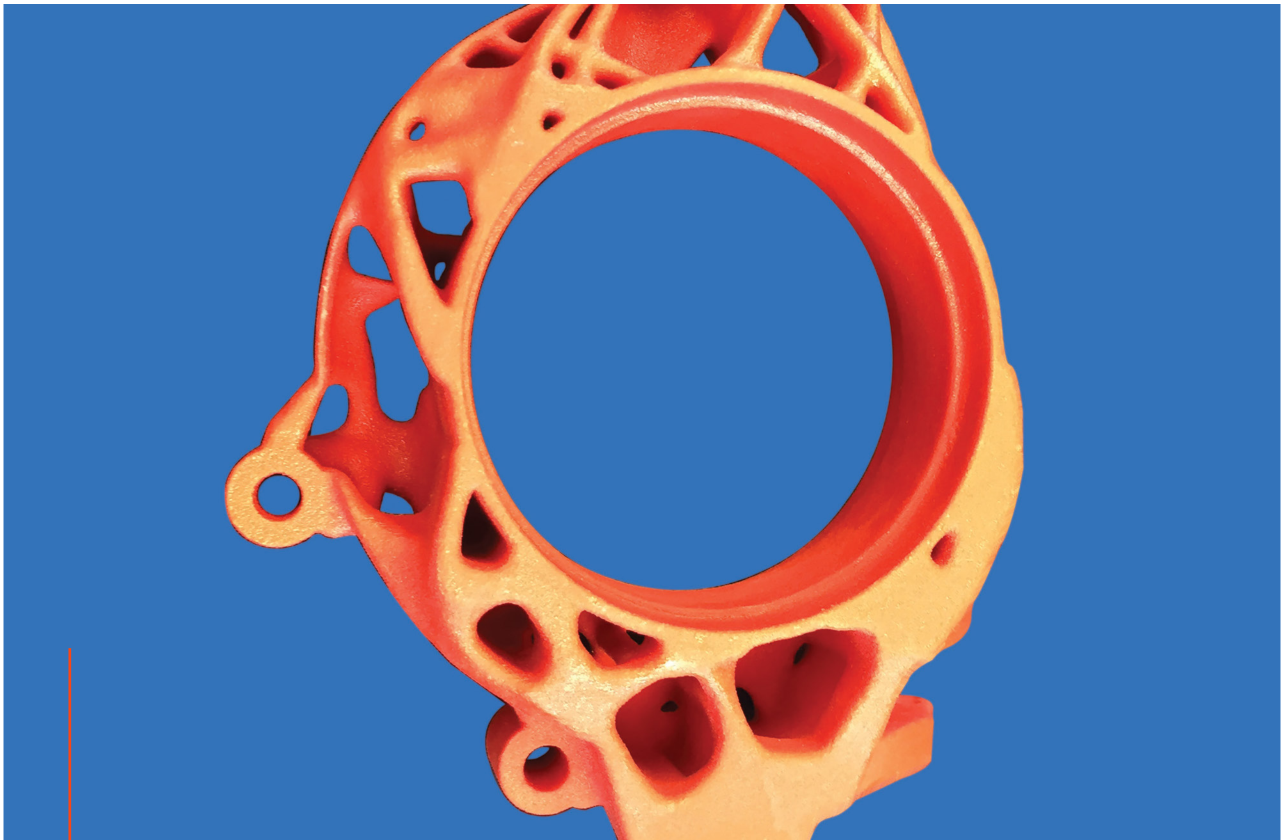
Watch the Demo

2

Print right the first time.
Simulation software enables manufacturing engineers to improve manufacturing efficiency and profitability. Engineers can quickly understand possible defects before printing and effectively influence changes to product design early in the process. It simplifies the identification and correction of potential deformation, delamination and excessive heating issues before building a part, reducing – and potentially eliminating – the physical process of trial-and-error testing.

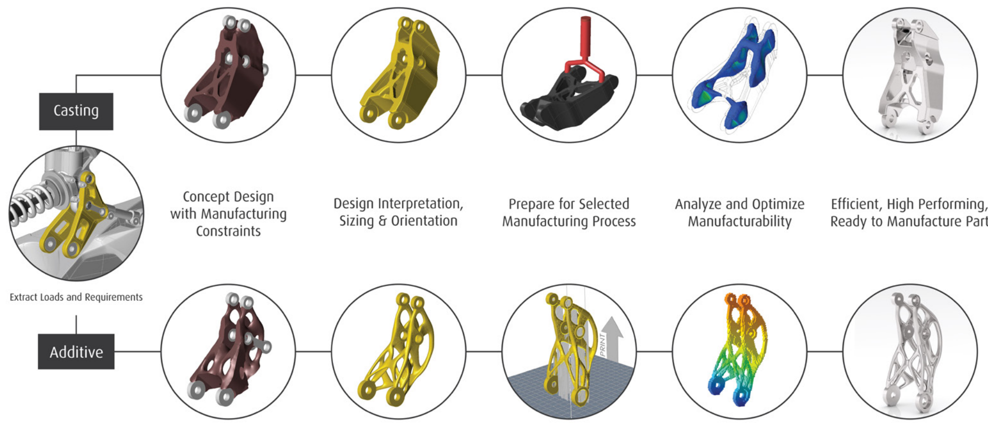
3

Explore design directions to design optimal parts.
The distinctive organic-looking parts that many consider a trademark of additive manufacturing aesthetic are created through a process called topology optimization. Software delivering this technology uses finite-element analysis (FEA) to create efficient geometries that meet design criteria for structural performance. During the concept stage of product development this enables designers to explore new possible design directions and understand the effect of changing the loads on the part or the design space it can inhabit. The geometry of the part and the support structure must be designed carefully, and this requires simulation of the design and the manufacturing process.



When simulation software is made available to design engineers, it enables an increased collaboration with the manufacturing engineers in the early stage of the design process.

Combining the insights of the design team with that of the manufacturing engineers to ensure that the design meets the functional requirements and is optimized for manufacturing.



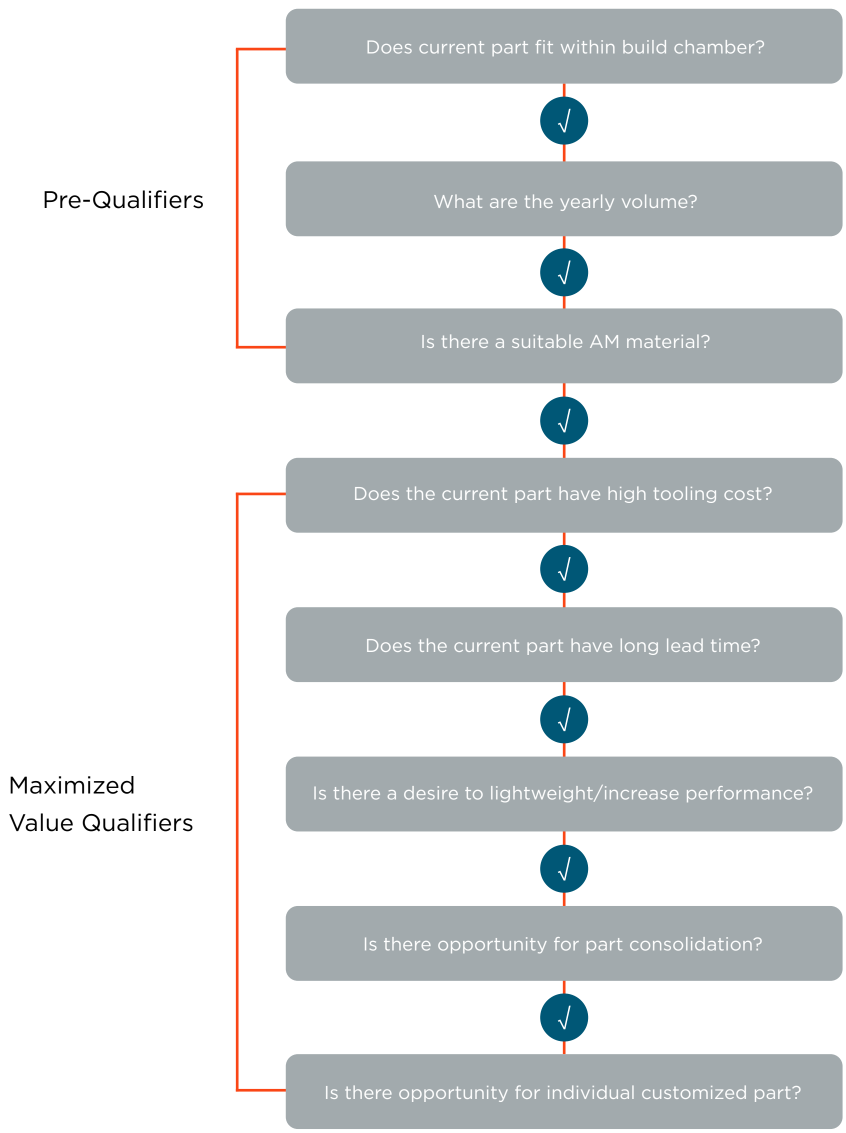
On average, the use of simulation can cut costs of low production volume parts by 50% to 75%.

STRATEGIC PART SELECTION

Part selection is a critical milestone when aligning any manufacturing process, even more so for additive manufacturing, especially if a company is just starting to investigate the technology. The outcome of the first project will set the expectations for management and determine further funding to support deeper investigations. Because of this, strategic part selection is critical.

Altair has developed a methodology to help guide our clients to:
1. Review many parts down selecting to prime candidates;
2. Weigh those candidates against metrics that consider the complete footprint and;
3. Select a prime that would best demonstrate the value.

By simply answering a few questions the optimal parts will bubble to the top of the list.



FROM THE DESK OF DAVE COATES, ALTAIR CHIEF ENGINEER

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Dave Coates has more than 24 years of engineering experience in simulation-driven design. His early career focused on managing large, multidiscipline projects which entailed design, CAE (including component- and system-level CAE), multibody dynamics, and system testing. More recently Coates' focus has been on R&D projects combining advanced manufacturing technologies, such as additive manufacturing, coupled with advanced modeling and simulation techniques in developing optimized, lightweight components.

What competitive advantages does additive manufacturing offer more conventional processes?

1

Cost. With its reputation as expensive this may seem an odd place to start, but additive manufacturing offers a competitive alternative to other manufacturing processes for companies with low volume, high cost parts. Military parts are a great example where additive manufacturing is perceived as a true production solution. We recently redesigned a bracket for a military application, a very complicated and expensive part that cost around $8,000 to produce. The bracket was redesigned for metal 3D printing, is 11 pounds lighter and $4,000 cheaper to produce. Additive manufacturing offers a huge opportunity for parts that were developed a long time ago with older technologies, where there are often great prospects for improvements.

Cost-driven companies with high volume production might gain similar advantage in a few years when the additive manufacturing technologies mature to meet their production requirements.

2

Performance. Performance is another major driver for additive manufacturing especially in cases where it offers a competitive advantage. For instance, the recreational vehicle industry is driven by weight and performance. Reports are published annually evaluating vehicles based on power-to-weight ratio, hence manufacturers are always aiming to increase horsepower and decrease weight. Additive manufacturing enables the development of lighter parts without compromising performance.

For such applications, companies are willing to incur the incremental costs associated with additive manufacturing to achieve a competitive advantage and customers are willing to pay a premium for an advanced product. It's a perfect storm for additive.

3

Customization. Developing customized products is a market opportunity made easy by additive manufacturing. The medical industry is one of the first industries to embrace additive manufacturing as it realized the power of developing individualized parts in a short timeframe. Orthotics, orthopedic implants, dental restoration such as crowns, and external prosthetics are all examples of additively manufactured parts. The traditional way to make an orthosis for a child can be a lengthy and difficult process for the entire family, taking several months in some cases. Additive manufacturing enables the development of specifications tailored to each child and at a fraction of the time and cost compared to the existing alternatives.

In many cases, quick production turnarounds are not feasible with traditional manufacturing methods given the lead-times and change-over costs associated with tooling and fixtures.

What are the general characteristics of a good additive manufacturing candidate part?
Two key considerations that can help narrow down the direction between additive manufacturing for tooling or end part are the age of the part and the current manufacturing process used.

The first thing I would recommend is to look for old parts in the company's part bin. Additive manufacturing offers a huge opportunity for parts that were developed 40 years ago with 40-year-old technology. Part consolidation, weight reduction, and improved performance are some of the advantages that can be exploited to improve old parts.

Another place to start is with cast parts. A laser powder bed aligns itself very well with casting either as an alternative or complementary process. Companies can print the tool and get another level of geometry refinement to improve part weight and performance. Typical tooling lead times are months. Utilizing additive manufacturing can turn six months into six weeks. This is a great advantage to reach an optimal design for the end part through tooling.

Powder Bed
Laser Melting

AM Sand Mold
and Casting

In the injection molding industry, the conformal cooling loops are somewhat restricted in terms of the manufacturing process. Because of the limitations of the manufacturing process, the blind holes are drilled without the ability to optimize the flow through them. With additive manufacturing, you could almost print any geometry and be able to optimize the cooling loops to minimize part distortion.

How do I identify a specific candidate part?
Although there are relatively few additively manufactured parts in production, and often on specialty, high-end and low volume end products, as the technology matures, more parts will exploit the benefit of additive manufacturing. Until then, it is important for companies interested in additive manufacturing to put time into strategically selecting the right part.

Due to the additional cost of additive, high production capabilities reaching into the tens of thousands of dollars and above are often cost prohibitive. These increased costs can be worth it if there is a significant value-add such as the part being significantly lighter, stiffer, or offer some other compelling enhanced performance. As soon as production gets into the hundreds of thousands of dollars, it becomes 50 times more expensive. Additional costs are a driver that mass production companies won't be able to justify.

As stated earlier, companies would be willing to incur additional costs associated with additively manufactured high-volume parts if customization offers a competitive advantage and their end customers are willing to pay a premium.

We've seen some of the best results when customers employ an auditing process using simulation software, in particular topology optimization, to evaluate part candidates. This helps identify weight reduction opportunity, from there the redesigning process starts. After conducting this a few times, the team involved gains experience to strategically select the part easily using a combination of simulation and growing knowledge.

Is simulation important after the candidate selection?

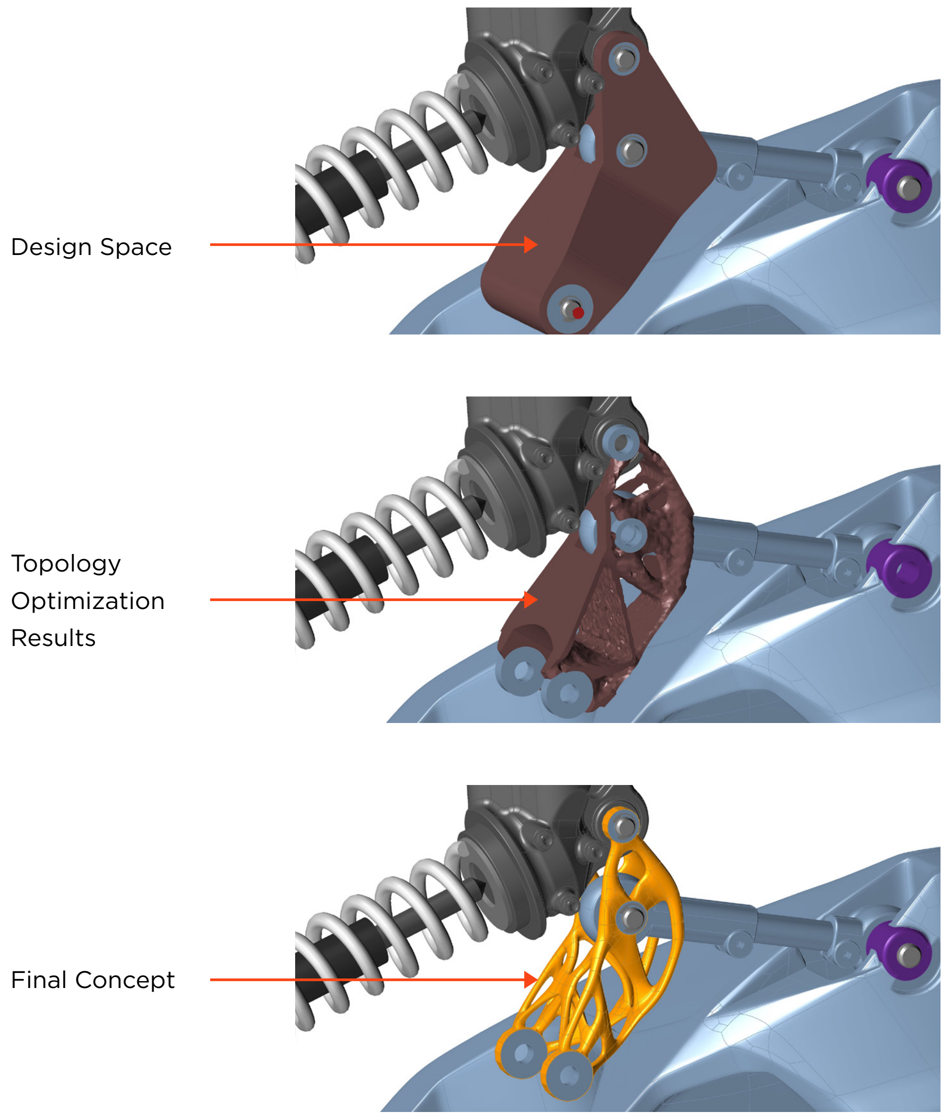
Leveraging simulation to evaluate manufacturability and predict part behavior can save a lot of money spent on trial and error. On average, the use of simulation can cut the costs of low production volume parts by 50% to 75%. I recall working with a client on redesigning a part for additive manufacturing where the client estimated the cost to be around $2,000 which seemed to be very high. When we asked why it cost $2,000, the answer was, "well, it only costs $500 to print one print, but I probably have to do it three, four or five times to get the right build parameters so that I can deliver a quality part to you." Simulation give companies the ability to print right the first time.

The availability of the advanced tools allows designers to design for efficiency regardless of the manufacturing constraints. Designers can explore the most optimal designs enabled by topology optimization technology, then decide on the manufacturing process that offers the best cost-weight metric.

Additive manufacturing offers a competitive alternative to other manufacturing processes for companies with low volume, high cost parts.

Analysis software is often thought of as virtual testing, but your examples are much more about answering design and business questions. Can you explain a little more about how simulation reduces cost and drives better decisions?

A good question to answer early on is, “what is the minimum amount of material needed to meet performance requirements?” Topology optimization is a type of generative design that enables the creation of an optimal design that can then be targeted towards a specific manufacturing process. When an optimal design is generated, it can be constrained and refined for any manufacturing process. Developing parts based on optimization results ensures efficient, cost effective, and smart manufacturing process. This creates an opportunity for a better performing part manufactured in a process that offers the best cost-weight metric. For instance, 10% to 15% of the weight of the car could be eliminated with this approach.



If I had my own company and I was considering additive or casting to manufacture a part, I'd start by evaluating weight performance for each design. Then I'd get cost information from manufacturers. That's everything I'd need to make a decision.

If you squeeze your eyes looking at the image below, you'll realize these parts look almost identical with minimal differences. This is an example of the great advantage of creating a concept design, ignoring the manufacturing constraints to reach optimal design. Then the design can be refined to meet the manufacturing requirements of any process.

Conventional Casting

Powder Bed
Laser Melting

AM Sand Mold
and Casting

Machining

Fused Metal
Deposition

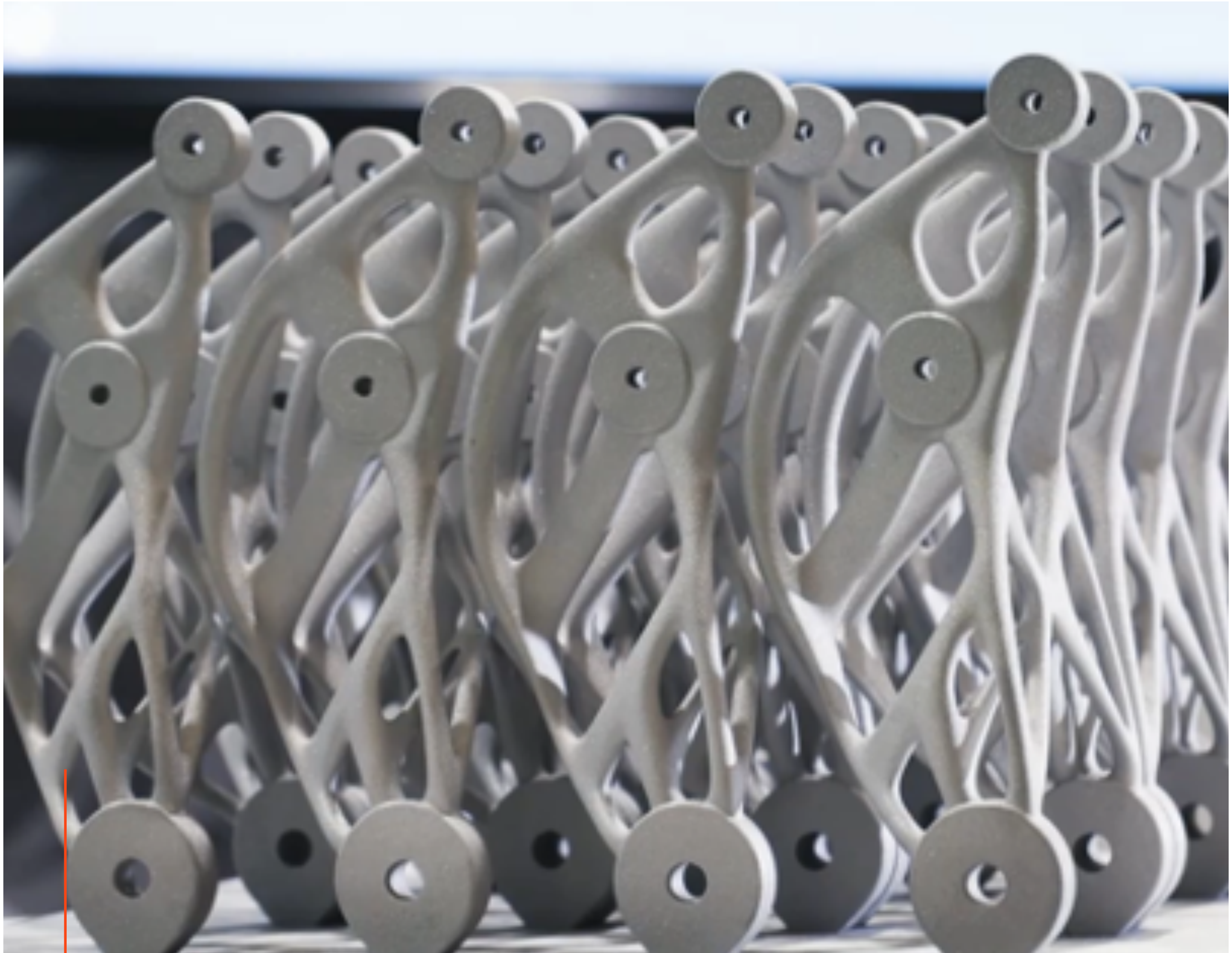
Metal Binder Jetting

You worked with customers in many different industries. Have you developed a standard workflow that translates across different organizations?

The first step to consider when designing for additive manufacturing is the manufacturing requirements. With the new paradigm shift, think about these requirements as a first step not fourth or fifth steps down the road. Traditionally, designers picked up the pencil and started designing based on historical part design or past experiences. Over time, designs get morphed to meet those requirements, and then released for production. The full understanding of the manufacturing requirements early in the process enables driving designs and influencing design directions, which eliminates inefficiencies in trial and error.

Then you move to the prequalifying questions the explore how big the part is, determining if it will fit in the bale chamber, and understanding if there is enough material to meet stress and stiffness requirements.

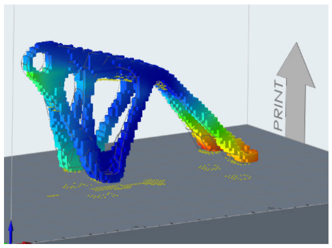
A lot of engineers and companies really struggle with this direction, thinking, "Why am I spending all this time up front like this when I should be picking up the pencil and making progress?" This is another aspect of the paradigm shift, understanding the system design. Even if redesigning the system is not considered, looking at the overall system helps identify opportunities to combine parts or eliminate joints.



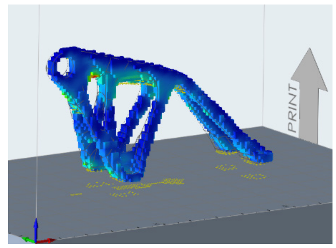
Print simulation is then utilized to ensure part distortion and certain quality metrics are met, which eliminates the need for physical testing.

Once you have a solid design you are now at the point where you know the material, requirements, and geometry. Then the design preparation is complete. Next would be preparing for the printing process that includes the orientation and support structure. The more thorough the virtual workflow, the more efficient the printing process becomes. Steps 6-9 in the workflow below doesn't change much regardless of the manufacturing process selected.

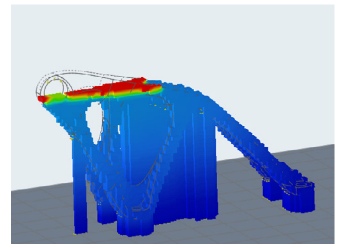
Displacement



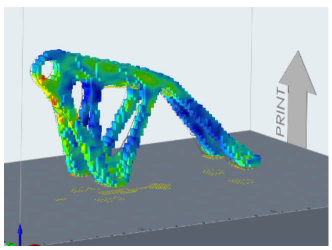
Plastic Strain



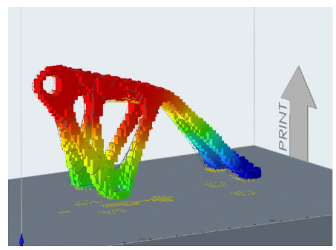
Temperature



von Mises Stress

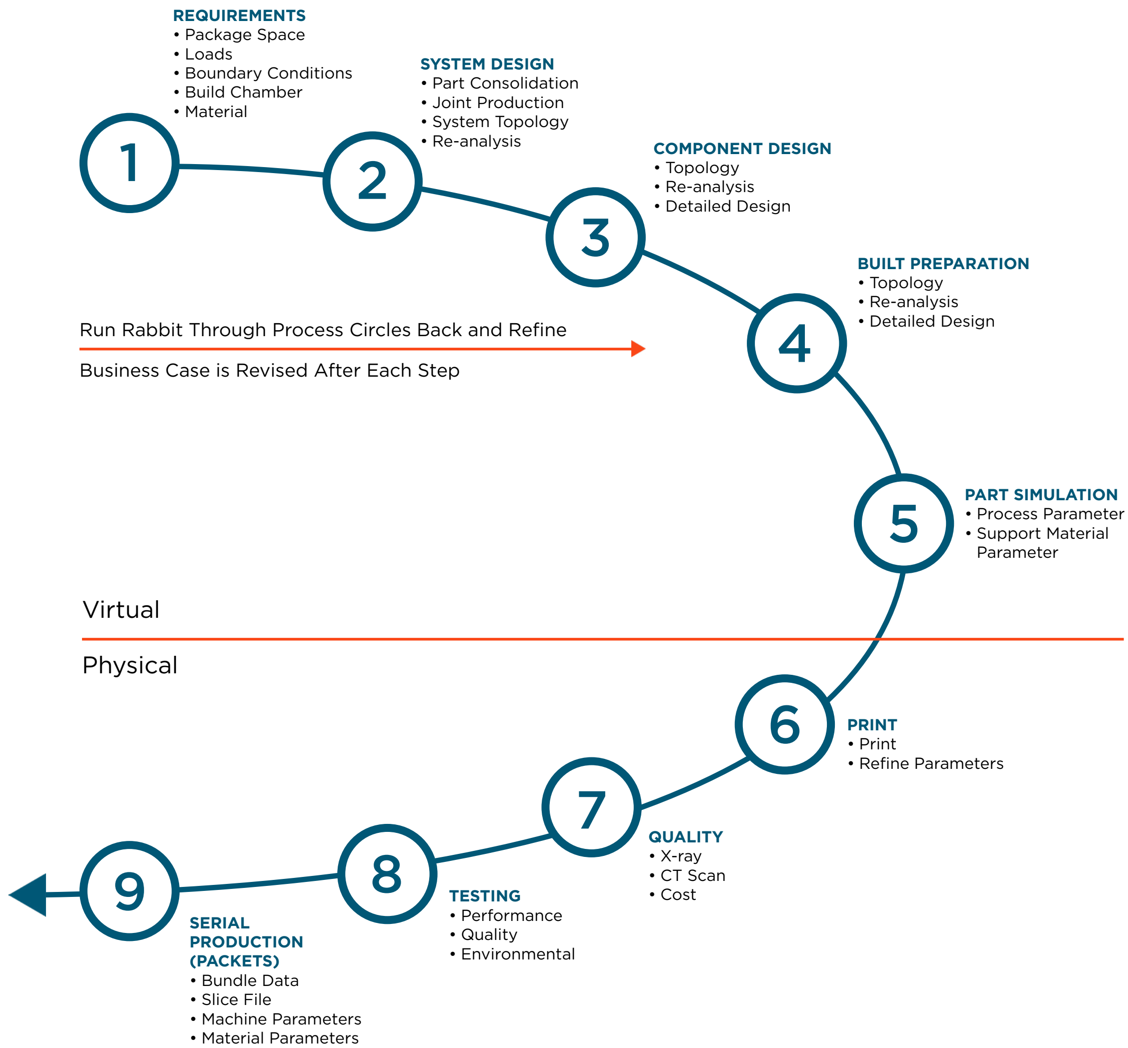


Nodal Temperature



The workflow below fully exploits the manufacturing process, demonstrating how to realize the potential of additive manufacturing early in the design process. For instance, the ability to of absorb functionality of different systems is explored in the second step of the workflow.

DFAM Optimization Work Flow



Altair is a global technology company that provides software and cloud solutions in the areas of product development, high performance computing (HPC) and data analytics. Altair enables organizations across broad industry segments to compete more effectively in a connected world while creating a more sustainable future.

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