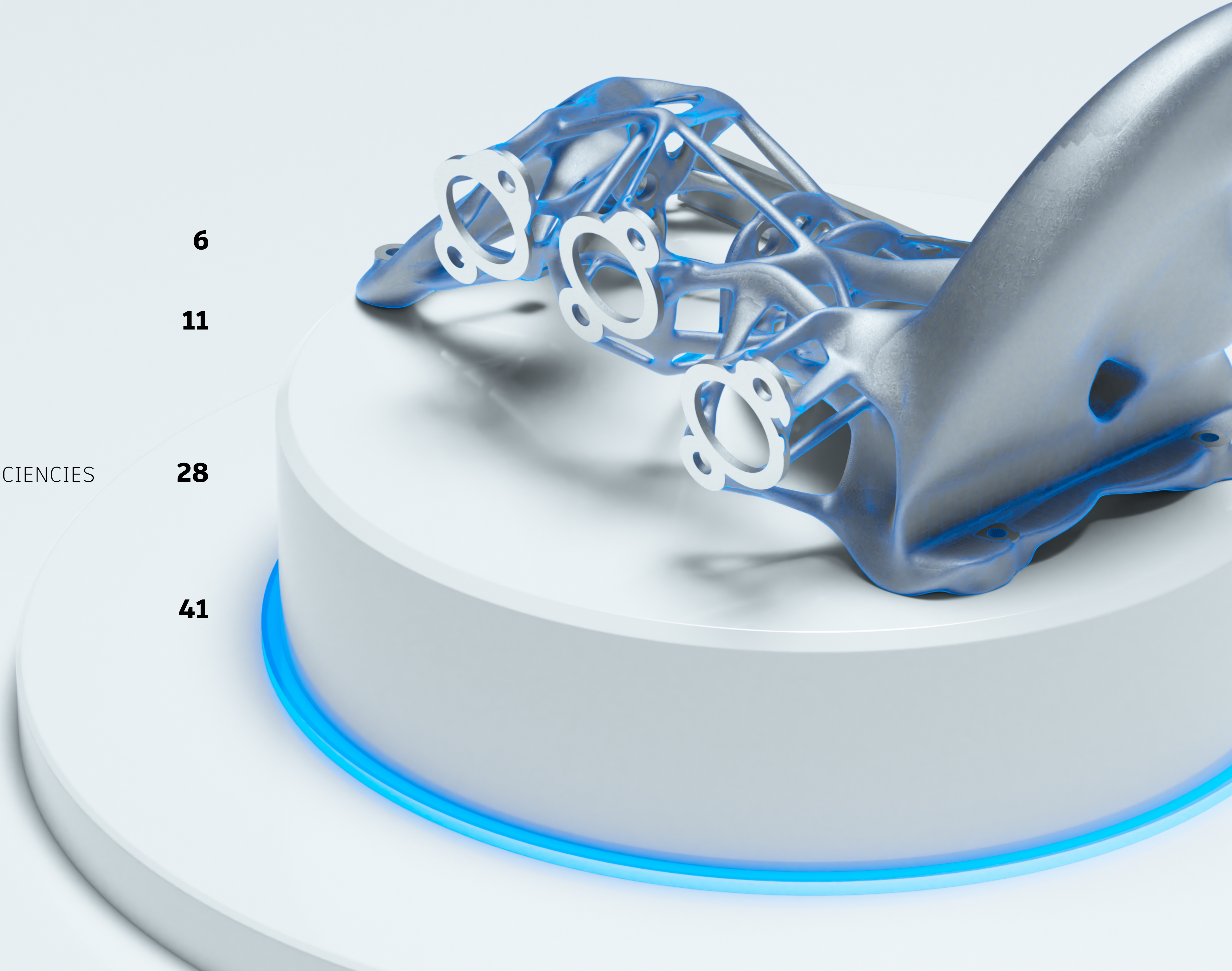
PRODUCT DESIGN & MANUFACTURING
SUMMER 2019

GENERATIVE DESIGN FOR MANUFACTURING

HOW TO ACCELERATE YOUR PRODUCT DEVELOPMENT PROCESS

AUTODESK. Make anything.



The Business Challenge

Engineers and designers are limited in time, resources, and energy that can be spent on a given design problem to fully explore both the design and manufacturing options that may be available.

Due to these constraints, they resort to heuristic, evolutionary, incremental improvements to previous design solutions created with proven, or in-use fabrication methods. As a result, components are often over-designed to meet performance criteria with minimal change to the status quo making innovation and differentiation difficult.

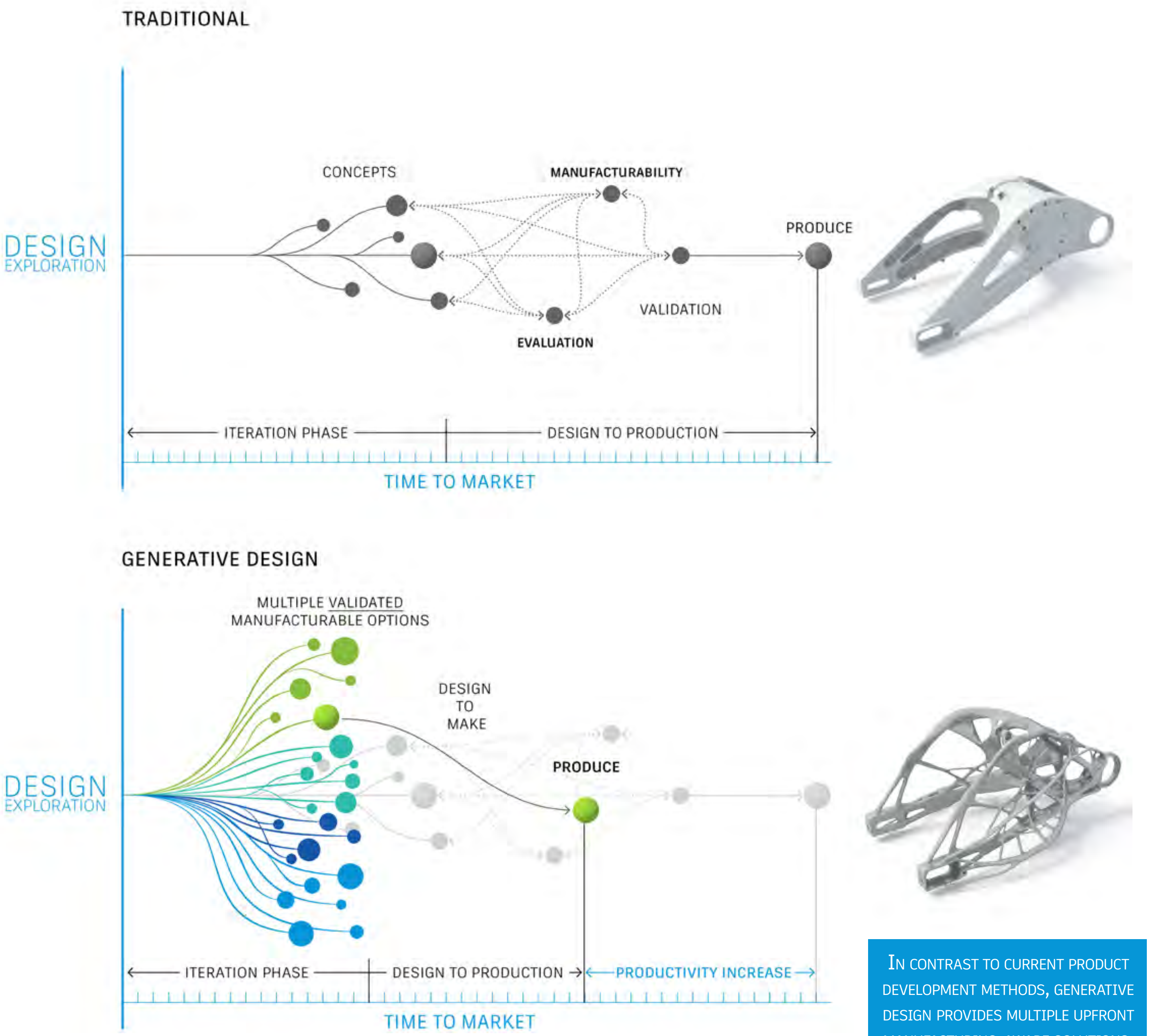
Generative design is a new, disruptive technology poised to upend the current state of design and engineering. No longer is the designer or engineer limited by their imagination, previous design history, or their past experience.

Generative design is a design exploration tool that simultaneously generates multiple solutions based on real-world design goals, product performance requirements, and manufacturing constraints.

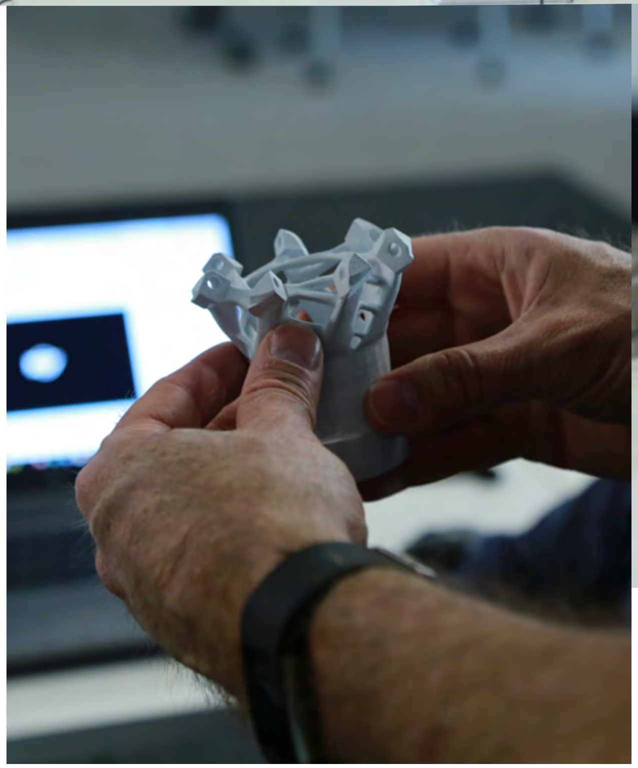
Generative design then delivers hundreds of design alternatives for consideration and trade-off studies in less time than a human can develop and evaluate 1 or 2 alternatives. The value of generative design is its ability to expose the design team to a greater number potential manufacturing-aware solutions to a specific set of design constraints, saving time and offering alternatives they wouldn't have otherwise imagined or considered.

According to Paul Magee, Director of Industrial Design at Crown Equipment, generative design has the potential to "… take the opinion out of early design, the ability to quickly solve complex engineering challenges, reducing the number of FEA iterations required, ultimately accelerating time to market and increasing product performance…". That said, it is still the domain of the engineer using his real-world experience to evaluate the design alternatives, to filter through the options, and to select the best solution based on the situation.

Generative design empowers teams to make informed trade-off decisions across a wider range of design alternatives to select the best outcomes. Perhaps it's as easy as a cost/weight analysis. But, in most cases,



IN CONTRAST TO CURRENT PRODUCT DEVELOPMENT METHODS, GENERATIVE DESIGN PROVIDES MULTIPLE UPFRONT MANUFACTURING-AWARE SOLUTIONS, HELPING YOU GET TO MARKET FASTER.



"...take the opinion out of early design and provides the ability to quickly solve complex engineering challenges, reducing the number of FEA iterations required, ultimately accelerating time to market and increasing product performance..."

PAUL MAGEE, DIRECTOR OF INDUSTRIAL DESIGN
CROWN EQUIPMENT

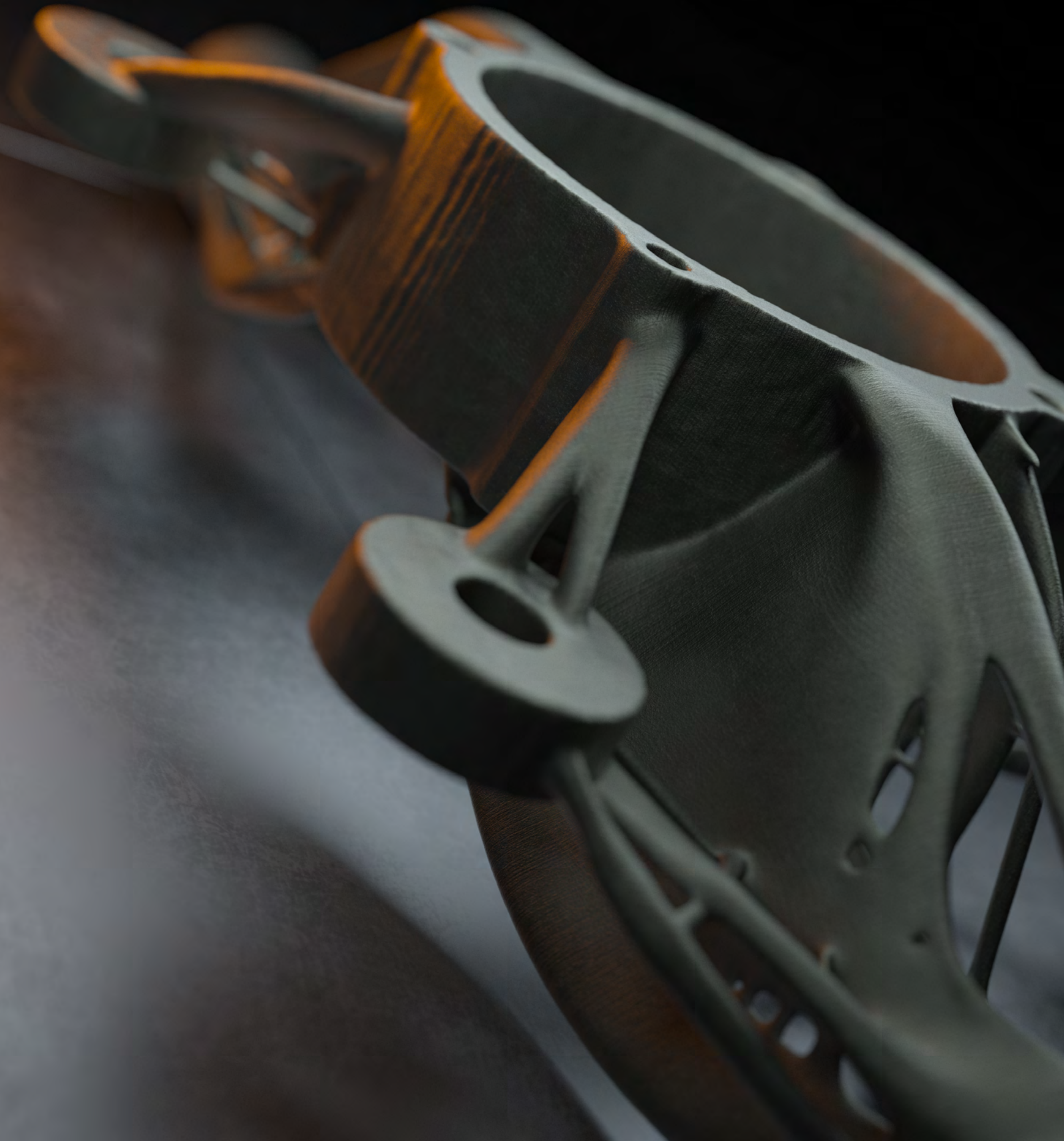
there are multiple variables to consider like machine production schedules, materials availability, or a combination of other factors that impact key business objectives.

With manufacturability integrated into the generative design process, selected design outcomes can be produced with existing additive or subtractive capabilities, eliminating the often time-consuming back and forth to manufacturing and enabling innovative design and engineering solutions in less time.

Generative design is much more than a new technology searching for its place in the engineer's toolbox. There are already proven applications with a path to production that have resulted in a significant *Return on Investment* for companies that have begun to explore its value.

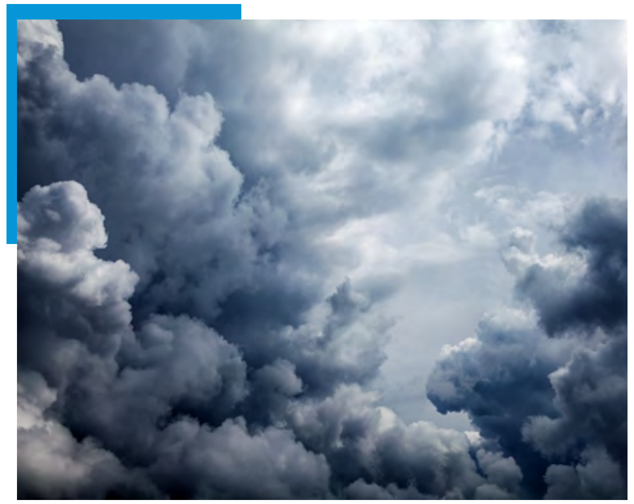
Potential Business Impact

Designers and engineers today are under pressure to evaluate a greater number of design alternatives in order to add new value, increase aesthetic appeal, improve the user experience, and/or reduce manufacturing costs. Existing processes to develop and validate design concepts typically limit exploration to only a handful of possible alternatives due to time constraints.



POTENTIAL BUSINESS IMPACT:

INCREASE INNOVATION CAPACITY



Leveraging artificial intelligence, advanced simulation, and cloud computing, generative design enables a new method of rapidly generating hundreds of potential design alternatives by simply specifying design, performance, and manufacturing constraints.

Based on design and engineering input, generative design returns a wide domain of validated design concepts for review. Quickly evaluate "what ifs" with these variables and analyze trade-offs with changes to materials and fabrication process to quickly iterate and converge on the most viable options for selection.

Generative design enables companies to rapidly accelerate the design pipeline, moving into production, and to market, at speeds that would be unimaginable, even with large teams of engineers.

One example is Claudius Peters, a company that produces process equipment for cement, coal, alumina, and gypsum plants. Their innovation goals were to reduce costs and to reduce the weight of process equipment components, and to accomplish these goals faster to reduce equipment lead times.

To realize their innovation goals and to compress engineering time, they turned to Scrum—an agile engineering practice leveraging focused, empowered teams—and to generative design. On the first project, the results surprised the team; generative design produced a result the team would never imagined. The design was between 20-60% lighter depending on the manufacturing method while meeting all performance constraints.

The other innovation goal was to reduce costs. The generative design topology was such that it could only be 3D printed, which at the volumes required would not be affordable. The generative design concept was used as a template to re-engineer the final design for more affordable conventional manufacturing processes. It required additional material for foundry processes. Even with added material, the final design was still 30% lighter, decreasing the cost of the component.

CUSTOMER SPOTLIGHT

CLAUDIUS PETERS

BUSINESS IMPACT

256 LBS

REDUCED WEIGHT PER UNIT

SMALL ASSEMBLY
(16 UNITS)
4,096 LBS (2 TONS) REDUCED

7 ASSEMBLIES PER YEAR =
28,672 LBS (14.3 TONS) REDUCED

LARGE ASSEMBLY
(65 UNITS)
16,640 LBS (8.3 TONS) REDUCED

7 ASSEMBLIES PER YEAR =
116,480 LBS (58.2 TONS) REDUCED

PHOTO Thomas Nagel

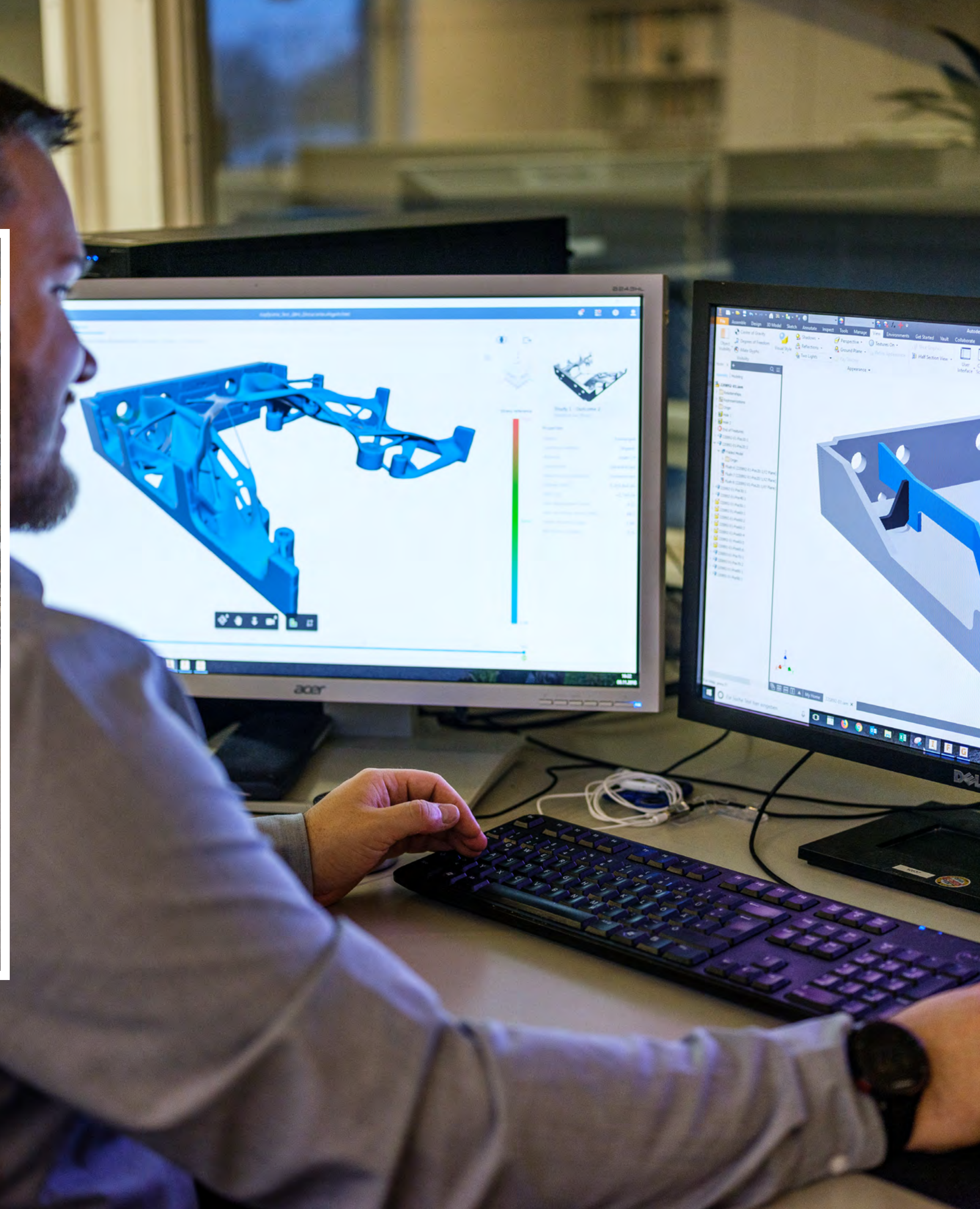
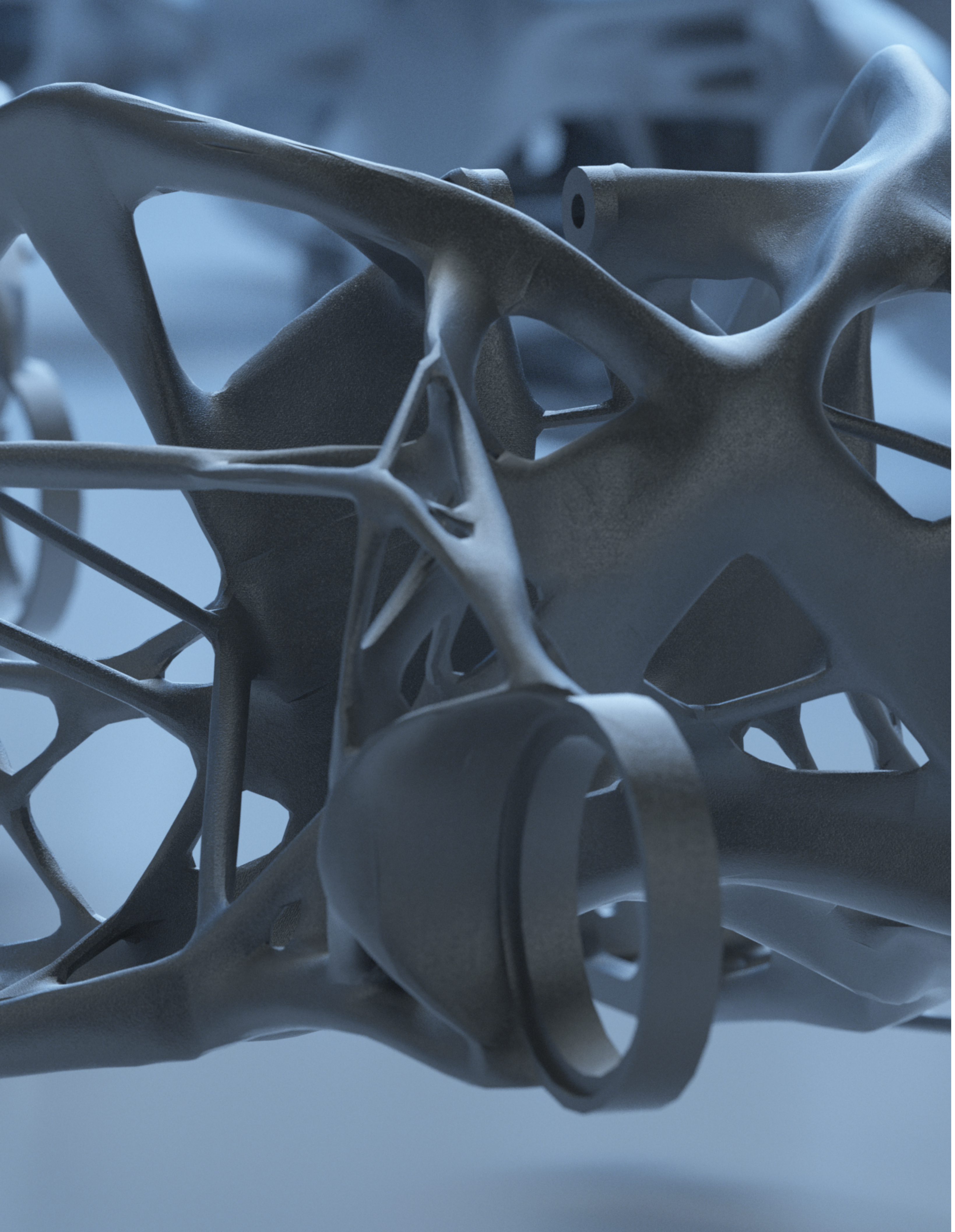


PHOTO Claudius Peters Engineer



POTENTIAL BUSINESS IMPACT:

IMPROVE PRODUCT PERFORMANCE

Light weighting or material optimization can improve a product's performance profile and can reduce product costs by reducing the amount of materials used in the design. Light weighting initiatives are pervasive in the automotive and aerospace industries where even incremental reductions in mass can result in dramatic savings in fuel costs.

Typical light weighting initiatives start with an existing design. In a highly iterative process (manual or automated), it removes mass from non-critical areas then validates structural integrity and performance until satisfied with the results or running out of time.

The catch-22 is that this process may only be optimizing what was a sub-optimal design to begin with, instead of re-imagining the design from the ground up and exploring alternative design solutions not previously considered.

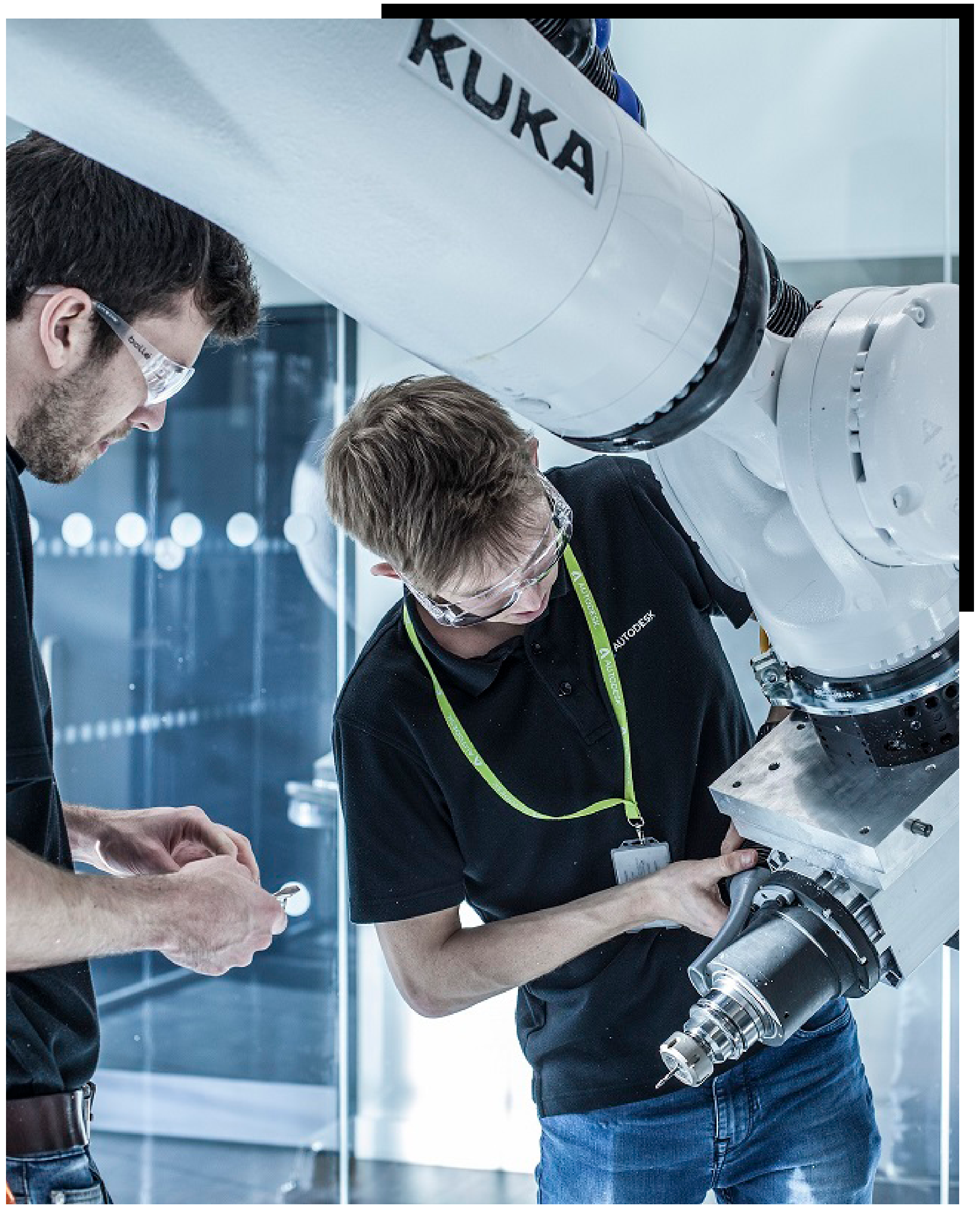


PHOTO AUTODESK TECHNOLOGY CENTER BIRMINGHAM, UK

DID YOU KNOW?
GENERATIVE DESIGN PROVIDES CONSTRAINTS FOR BOTH ADDITIVE AND SUBTRACTIVE MANUFACTURING.

Generative design enables a true clean sheet approach to development of design alternatives for evaluation.. Generative design returns hundreds of new design alternatives, all of which can meet the stated design and performance constraints. Just as important, designs constrained by additive manufacturing and traditional manufacturing methods can be compared.

Generative design provides constraints for both additive and subtractive manufacturing.The manufacturing process can be evaluated to determine if a design is better suited for additive manufacturing, providing weight reductions or performance benefits that may outweigh the lower costs of traditional manufacturing methods.

Stanley Black & Decker leveraged generative design to redesign a crimping tool attachment which is used to fix hanging electrical and telephones lines. The existing crimping tool attachment weighed 5.5 pounds, causing significant strain on workers during use. The design goal was to develop a lighter, more ergonomic version of the attachment.

Generative design returned 100 alternatives that met the design goals. The design selected weighed approximately two pounds, 60% lighter than the current crimping tool attachment. As an added benefit, it could be produced in 20-hours using additive manufacturing, compared to 45-hours of production time for the current design.

CUSTOMER SPOTLIGHT

STANLEY BLACK & DECKER

BUSINESS IMPACT

2 LBS

REDUCED WEIGHT PER UNIT

60% LIGHTER

THAN CURRENT PRODUCTION UNITS

PHOTO Harry Zhong, SB&D

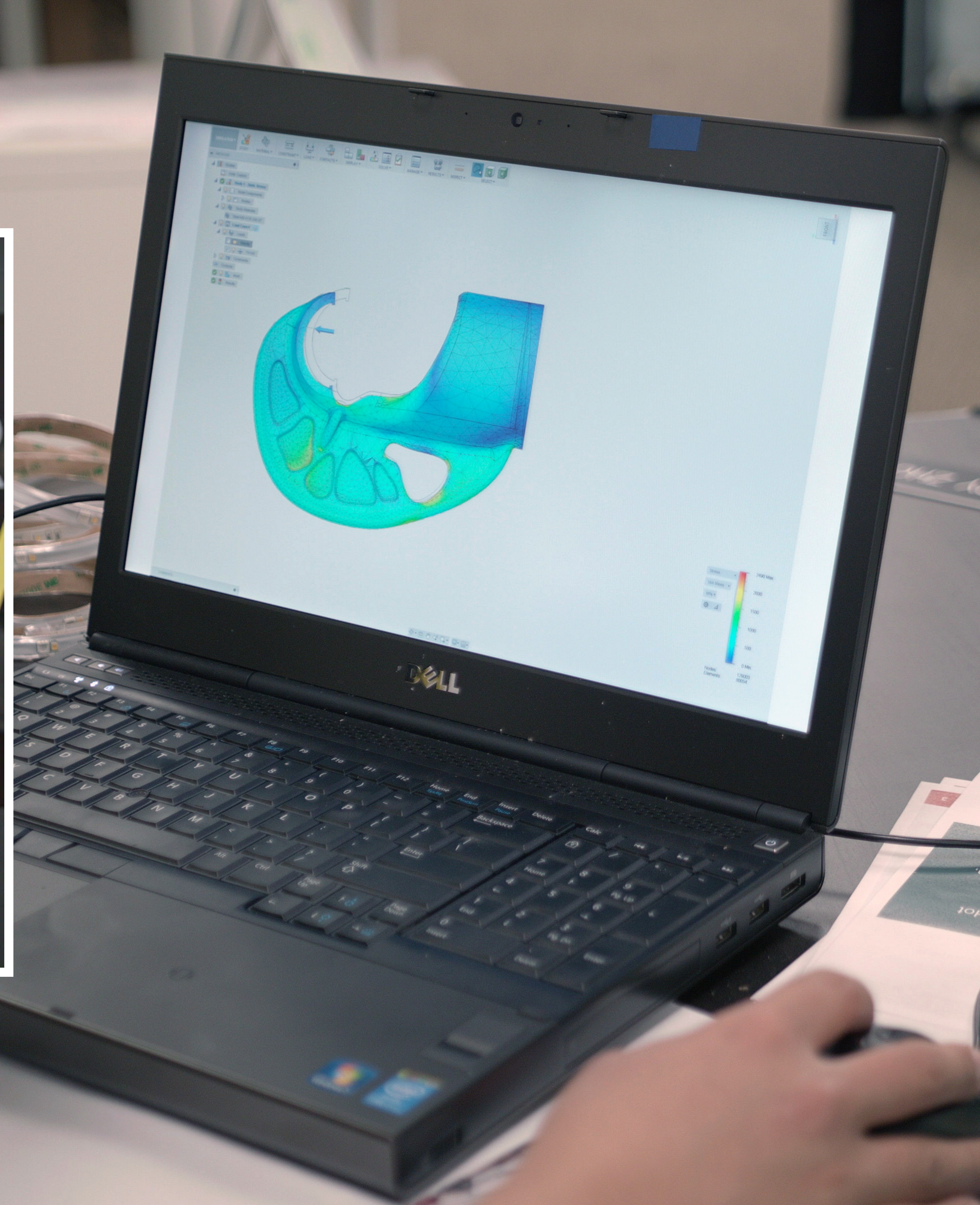


PHOTO Stanley Black & Decker HQ

POTENTIAL BUSINESS IMPACT:

WIN MORE BUSINESS WITH MASS CUSTOMIZATION

PHOTO Airplane Seat Casting Aristocast Factory

Across all industries, there are growing pressures and demand for customized products and services. Attempts to satisfy this demand have strained traditional manufacturing methods and has led to increased production costs and extended timelines.

A mass customization strategy combines the flexibility and personalization of bespoke, custom-made products with unit costs approaching that of mass production. Unfortunately, existing design and fabrication practices for mass production are too slow and cumbersome, hampering the ability to respond to customer requirements for customized products and limiting the capacity to scale.

Generative design methods simplify the design process, and will be essential for the next revolution in manufacturing to enable mass customization at scale. Instead of an engineer or designer fully defining each customized product in CAD, generative design enables designers to simply specify what the product should be as constraints, including use, function, performance, and space claim. Then the generative design engine automatically creates design options based on the input criteria. Further, additive manufacturing eliminates costs for tooling, tooling lead times, and time and cost associated with production change-over. Together, generative design and additive manufacturing will contribute to the transformation of industries where value is realized by product personalization and customization.

Recently, Perceptive Sensor Technologies employed generative design and additive manufacturing to support a mass customization strategy on a new product initiative. Perceptive Sensor Technologies is a developer and manufacturer of ultrasonic hardware devices for the detection, identification, verification, and measurement of fluids within closed environments.

Their technology is based on proven science—at any given temperature, every fluid has an individual acoustic signature as unique as any human fingerprint and a sound wave traveling through a contained fluid produces a unique, identifiable measurement. Their devices are known for precision, ease of use, and durability in the field. They are in use across a range of industries and government agencies.

They had a new requirement to scale down their technology to a reliable, customizable, hand-held device that would meet a wide range of niche applications, extending the company's business opportunities considerably. This hand-held device would be customized and produced in low volumes for specific industries. Key design criteria was ease of use, durability to withstand extreme environments, lightweight, and balanced to ensure proper stability for the technicians operating it in the field.

To develop the new customizable handheld device, Perceptive Sensor Technologies collaborated with Penumbra, a product development company that specializes in the use of generative design and additive manufacturing technologies. For this project, parameters that prioritized minimizing mass and equally balancing the weight of the device for ease of use and ergonomic benefit while maximizing stiffness to ensure durability were selected. Using generative design, the Penumbra team quickly explored all aspects of this complex challenge, running several studies to identify the design solutions that could be produced using additive manufacturing.

PERCEPTIVE
SENSOR TECHNOLOGIES

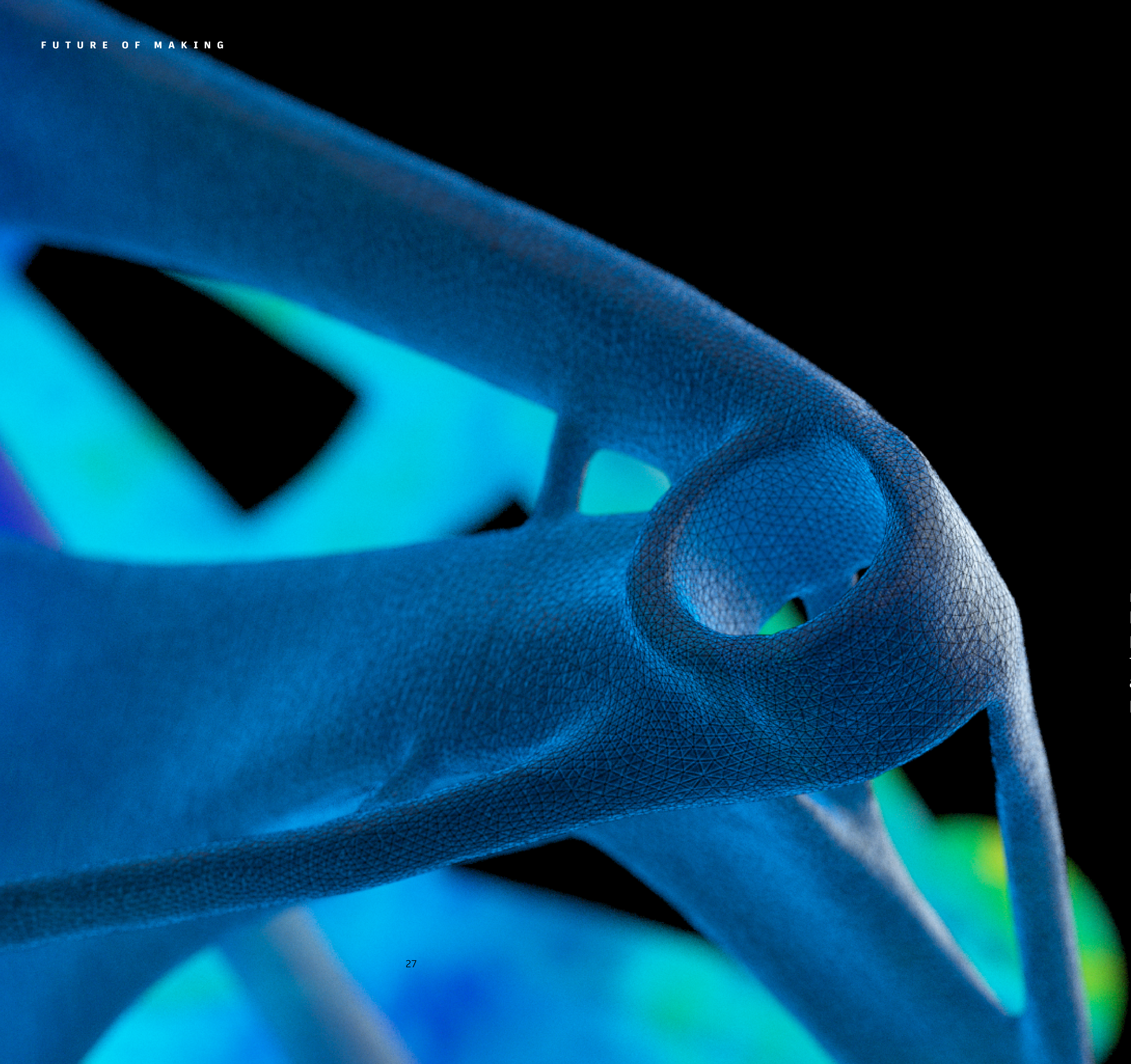
HANDHELD 3D PRINTED TRANSDUCER DEVICE

PRODUCT DESCRIPTION
Handheld acoustic measurement for easy identification and monitoring of stored liquids.

GENERATIVE DESIGN
RUGGEDIZATION

The design produced by the Penumbra team exceeded expectations and resulted in a new state-of-the-art ultrasonic sensing device that provides the accuracy and durability customers expect.

Further, the additive manufacturing fabrication process required minimal upfront investment and provides flexibility to customize the sensing device to quickly address niche requirements of new customers.



Potential Operational Efficiencies

Every design project has a cost and manufacturability target that must be met in order to ensure product profitability. Come in less than the target cost and product gross margins are increased. Miss the target, and the product launch may result in a loss.

POTENTIAL OPERATIONAL EFFICIENCIES:

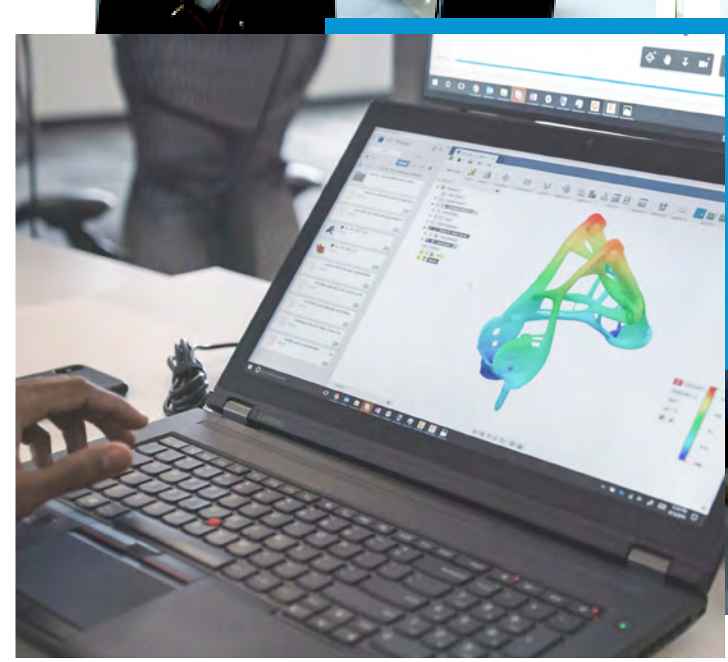
DESIGN FOR MANUFACTURING (DFM)

Due to the sequential nature of the product development process, decisions are often made in a vacuum. Decisions on manufacturability and fabrication are typically delayed until late in the design process after major aspects of the project are locked in, sometimes forcing production down a costly and less than desirable path.

Strategies to eliminate traditional serial processes that resulted in functional silos where each competency "threw the design over the wall" to the next function have been around since the early 1990s.

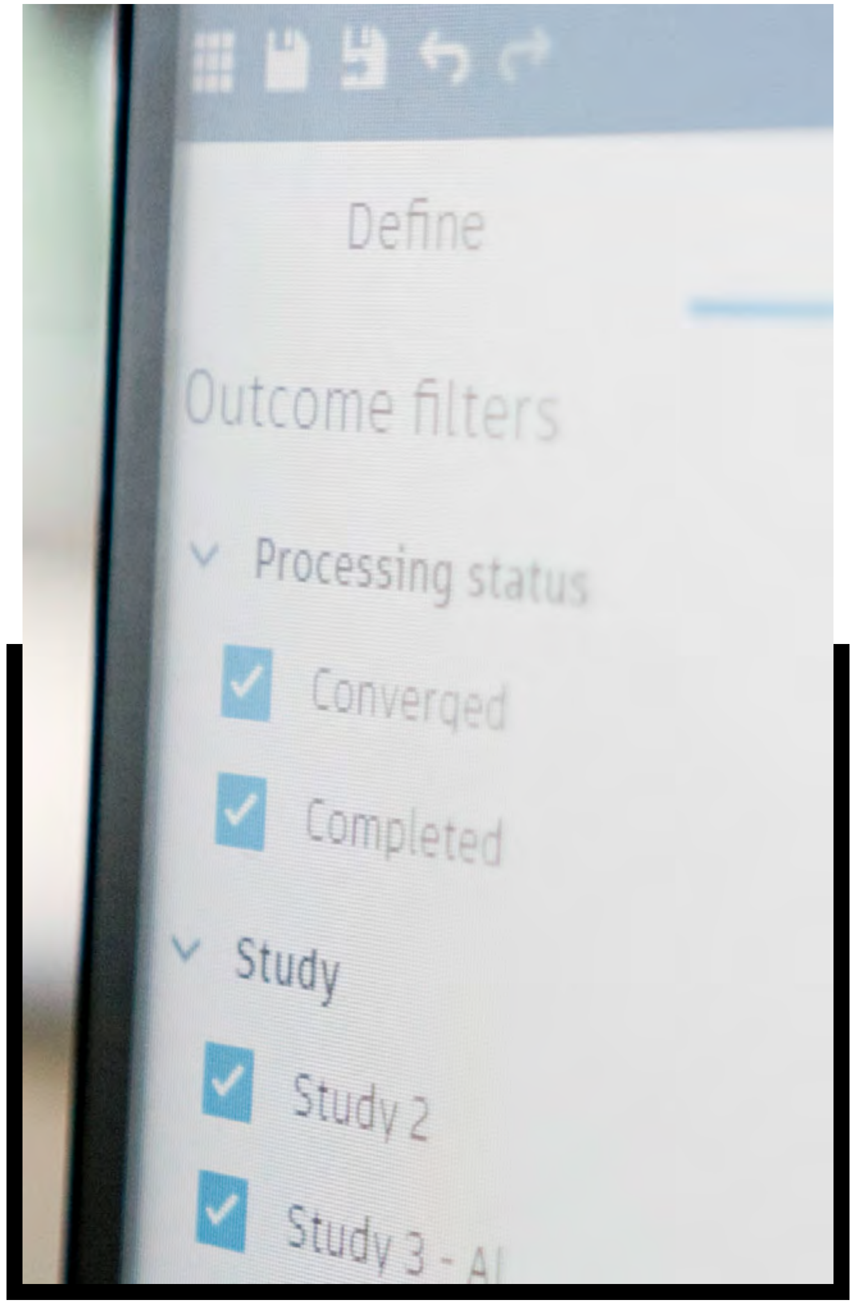
Whether it was called Concurrent Engineering or Design for Manufacturing, the focus is the same: consideration of the impact of design decisions on the manufacturing process to better manage the time and cost trade-offs.

Further, if these decisions can be moved up earlier in the product development process where the cost of change is minimal, it would raise the probability of hitting cost targets, lower the risk of delays, and result in earlier release to manufacturing.



RIGHT PHOTO Pier 9 Machinist

LEFT PHOTO Fusion 360 Simulation



New technologies were rolled out and new decision-making charts and process flows were mapped, but, as with any major shift, it's more than just technology and process. It also requires people to buy into what is a major culture change to adopt these strategies. Because of the amount of change, learning new systems, learning new processes, and new levels of interdepartmental collaboration and decision-making, culture change became the biggest hurdle to implementing Concurrent Engineering. When under pressure to deliver results, many companies that implemented this strategy defaulted back to what it knew best and backslid into existing sequential waterfall processes.

With the advent of generative design, culture change now becomes much less of an obstacle because much of the process and technology change that was required of people in the past has now been automated by artificial intelligence. Generative technology simplifies the DFM process down to the most basic requirements: specifying design goals and constraints that take into consideration existing manufacturing processes. Intelligent algorithms and massive computational power in the cloud handles the rest, returning hundreds of validated design options to review for more informed trade-off decisions early in the product development process.

Generative design breaks down the silos between product designers, mechanical engineers, and manufacturing engineers, bringing them together to develop required design and manufacturing constraints. Then when results are returned from the generative design engine, they can make informed trade-off decisions early in the design process as a team. Manufacturing constraints evaluate the feasibility of potential fabrication processes early in the cycle where this data can have the greatest impact on selecting the most viable path for production. The result: a faster, more agile product development process that increases innovation, accelerates time to market, decreases costs, and streamlines production.

POTENTIAL OPERATIONAL EFFICIENCIES:

COMPONENT CONSOLIDATION

PHOTO General Motors

Short run or custom components are often designed as a subassembly of welded or stamped components that are assembled with fasteners. Ideally, engineers would rather design one component that meets the design requirements rather than decompose it into separate parts that add complexity, must be validated, and need to be assembled.

The challenge is that tooling and production costs for processes that could simplify the component design as a single part such as forging, casting, or molding are not cost effective or justifiable at low volumes, not to mention the long lead times for tooling.

There are still hidden costs that may or may not have been considered. The trade-off is that initial cost savings for avoiding tooling are offset to some degree by the escalation in burdened cost of goods that result. This includes the increase in engineering time to decompose the subassembly into multiple components to achieve function; the increase in assembly required; costs for the increased number of parts; process costs for parts specification; sourcing and BOM; and increased parts inventory and maintenance costs.

As a general rule, most US companies plan for a rate of 9-15% burdened cost of goods on any given product produced.

In some cases, both the fabrication and assembly of these components are outsourced. This trend for companies to outsource component manufacturing and production has, at times, left the OEM manufacturer hostage to their supply chain, which can become complex and difficult to manage.

Further, the amount of time spent with suppliers upstream by design and engineering teams and downstream with other functional departments during the design and manufacturing process is significant, adding to the burdened cost of goods.

CUSTOMER SPOTLIGHT

GENERAL MOTORS

BUSINESS IMPACT

8

COMPONENTS TO ONE PART

3D PRINTED SEAT BRACKET

40%

LIGHTER

20%

STRONGER

IDENTIFYING NEW DESIGN SOLUTIONS THAT WOULD BE OTHERWISE IMPOSSIBLE FOR ENGINEERS TO IMAGINE

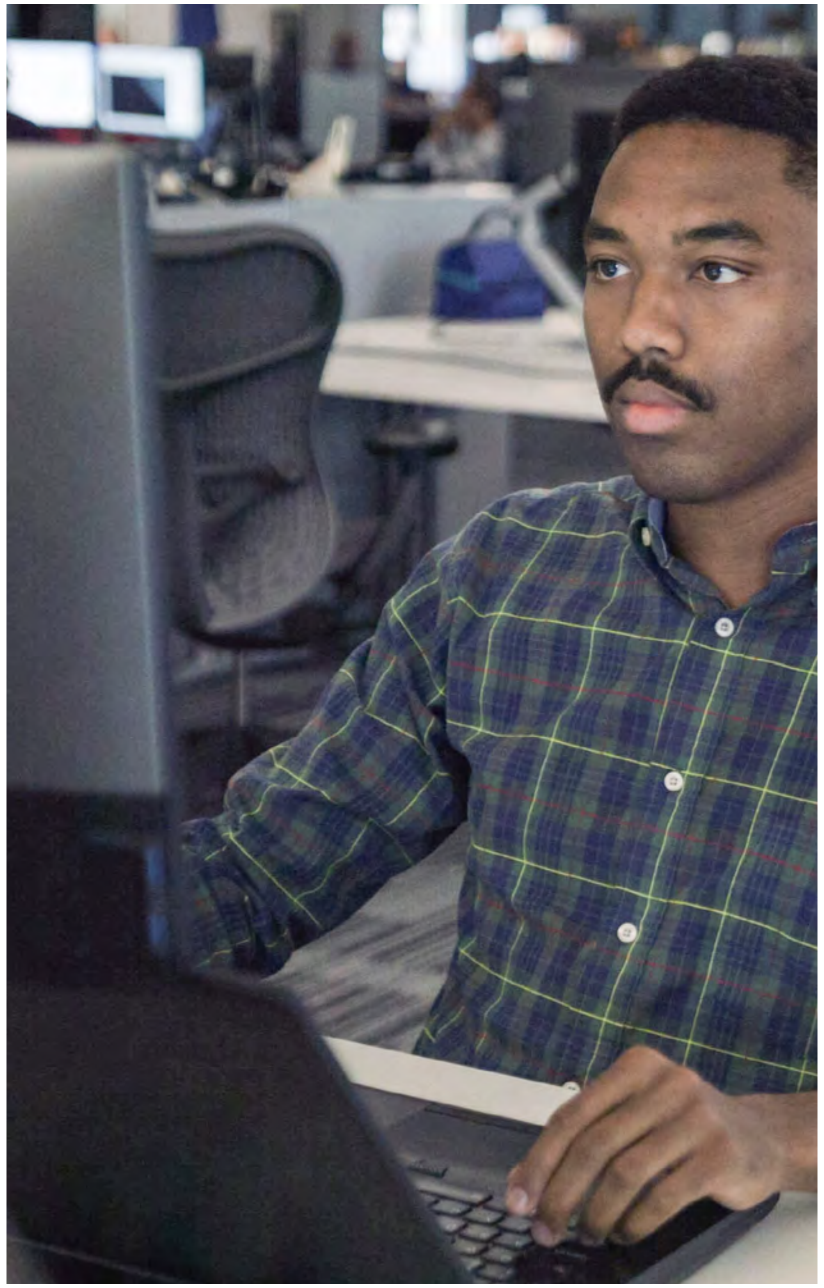


PHOTO GENERAL MOTORS ENGINEER

PHOTO GM Generative Design Part

POTENTIAL OPERATIONAL EFFICIENCIES:

REDUCE CNC MACHINING

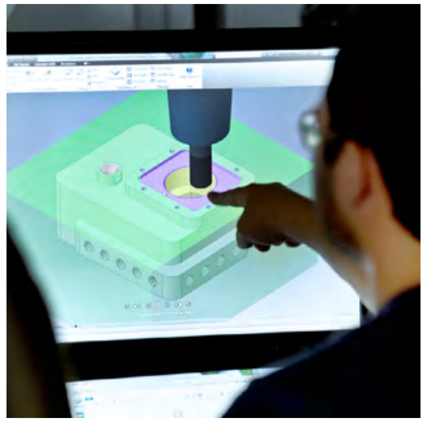
In the aerospace and medical industries, low volume parts are more cost effectively produced by CNC machining from expensive billets of high tech alloys than by forging, stamping, casting, or molding, despite the excessive waste material produced from this process.

Generative design and additive manufacturing methods can be leveraged to increase operational efficiencies for these applications. Generative design takes the efficient utilization of materials to another level by minimizing required topology, internal structure, and mass based on design and performance goals.

Additive manufacturing more efficiently utilizes raw materials during the fabrication process, resulting in significantly less material waste than CNC machining.

Additionally, engineers no longer need to think about designing component geometries within the context of the capabilities and limitations of the conventional processes and tools available.

Additive manufacturing enables the fabrication of near-net shape parts with features that cannot be easily machined, allowing increasing design complexity without inflating manufacturing costs. Lastly, additive manufacturing is more easily scalable, eliminating tooling and production setup steps required for CNC machining.



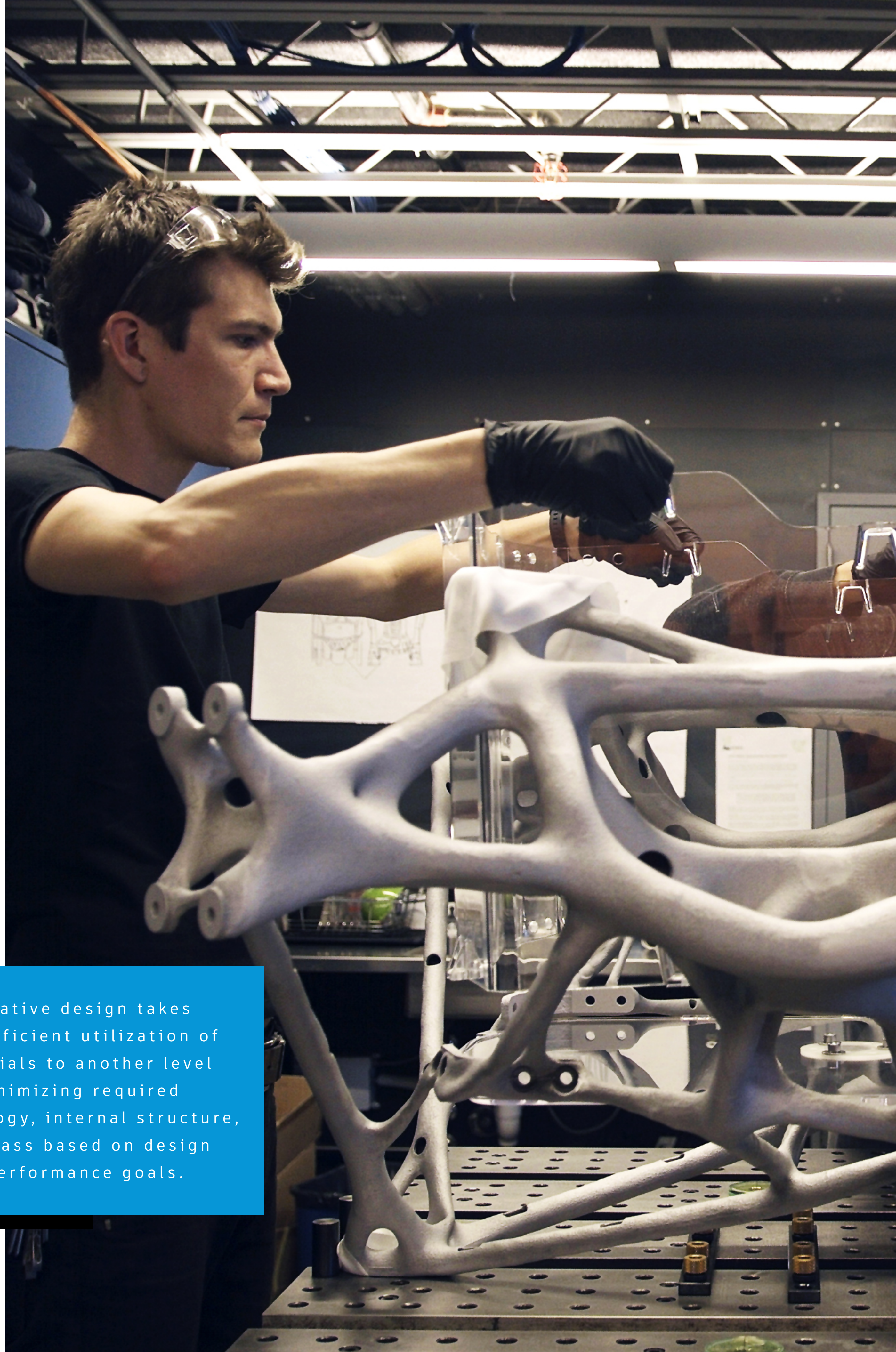

In the aerospace industry, several companies are testing the boundaries and rethinking rocket engine design using additive manufacturing. They are integrating lattice structures in the interior of an engine's shell, increasing heat dissipation and resulting in consistent cooling of the engine.

Relativity has developed a large-scale additive manufacturing system called Stargate, which is capable of creating parts that are up to 20 feet tall and 10 feet wide. Relativity states that Stargate will be able to fabricate 95 percent of the rocket they are fabricating called Terran 1.

The Stargate additive manufacturing system is cost effective because the build process can consolidate components and produce complex features that were expensive to traditionally manufacture, resulting in a rocket system with 100 times fewer components.

In addition, the fabrication process is much faster. Relativity claims to be able to build a rocket in as little as 60 days.

PHOTO Additive Rocket Corporation



Generative design takes the efficient utilization of materials to another level by minimizing required topology, internal structure, and mass based on design and performance goals.

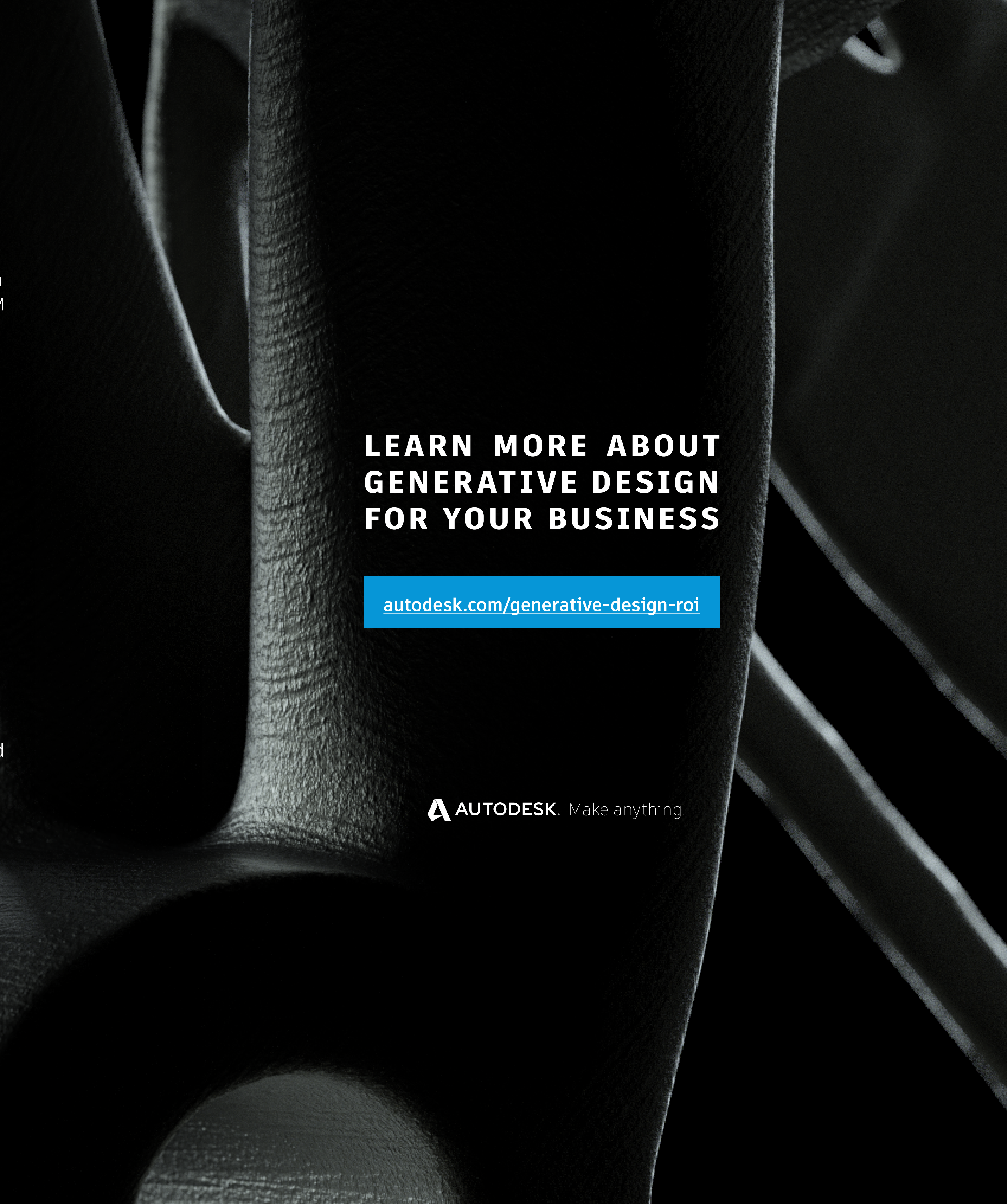
SUMMARY

Today there are many opportunities for generative design that have a quantifiable return on investment, enabling a viable path to production for low volume, short run, and custom components using additive manufacturing, CNC methods, or both. Additionally, generative design can be used as a starting point for companies that want the benefits of generative design without the cost of additive manufacturing. Claudius Peters demonstrates how generative design can be leveraged to inspire new and improved part shapes for high volume components that can then be reverse engineered to be produced using conventional manufacturing methods.

Autodesk generative design is making the convergence of design and manufacturing a reality. For the first time, Concurrent Engineering can truly be implemented as a technology-enhanced, automated process. Generative design provides your team the power to generate multiple, CAD-ready design options based on real-world manufacturing constraints. Autodesk generative design has both additive and subtractive constraints, and the output is an editable geometry readable by any CAD/CAM system.

Additive manufacturing time and costs continue their downward trajectory; as they fall below certain thresholds, new business models will become viable. At some point in the not too distant future, there will be an inflection point. Additive manufacturing costs for high volume production will not only become justifiable, it will also be necessary to remain competitive. As with any inflection point, the business environment will quickly evolve to manufacturers who disrupt the market and those whose business is disrupted.

It is incumbent upon today's forward-thinking companies to get out in front of this trend. By beginning to explore what is possible today and what the future may hold when the inflection point occurs, companies are ready, prepared, and have in place proven processes, methods, and practices to be successful with generative design and additive manufacturing.



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