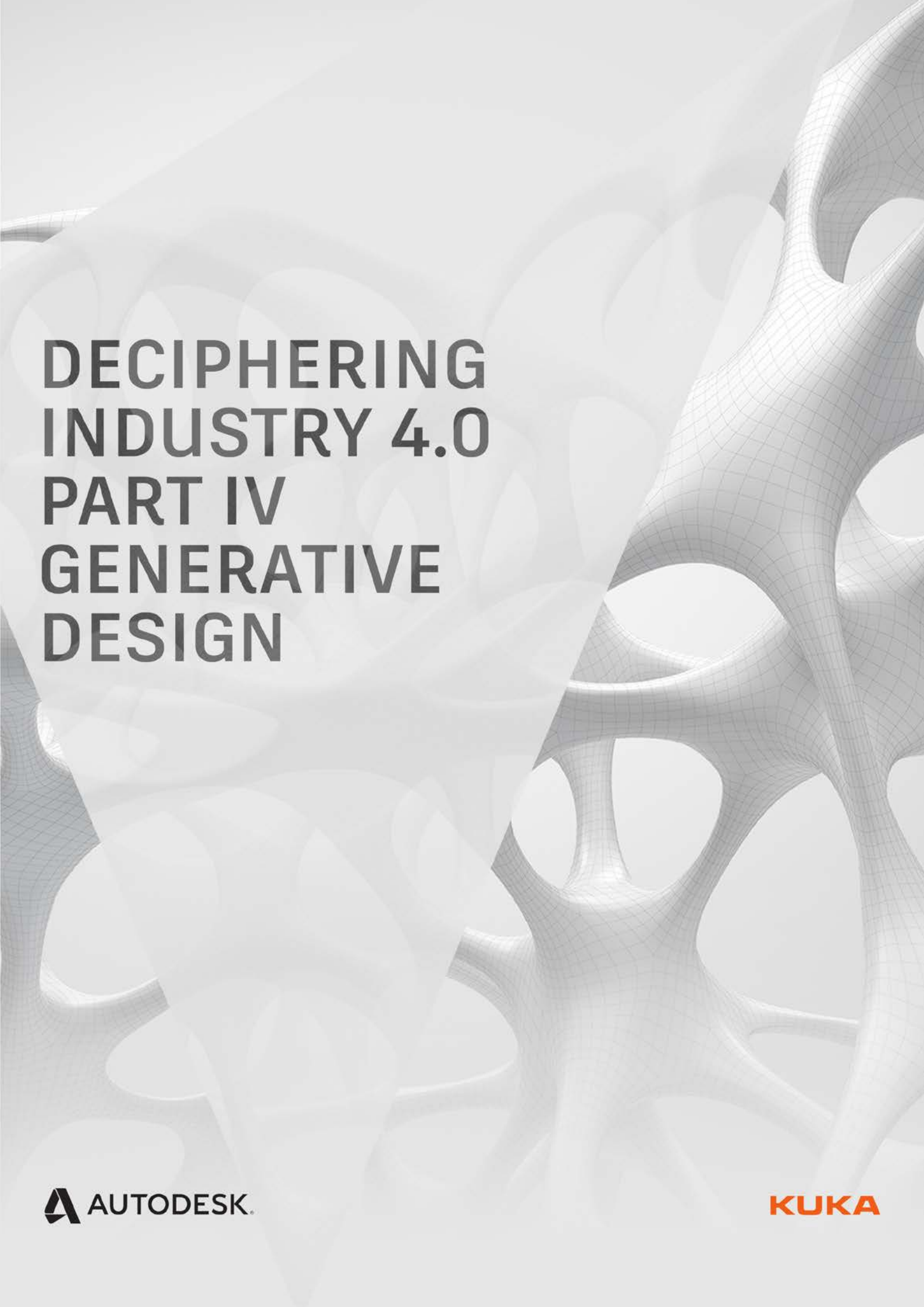
DECIPHERING INDUSTRY 4.0 PART IV GENERATIVE DESIGN



AUTODESK.

KUKA

“The things that have limited us in the past – software, materials, manufacturing methods – no longer do so.”

Autodesk

OVERVIEW

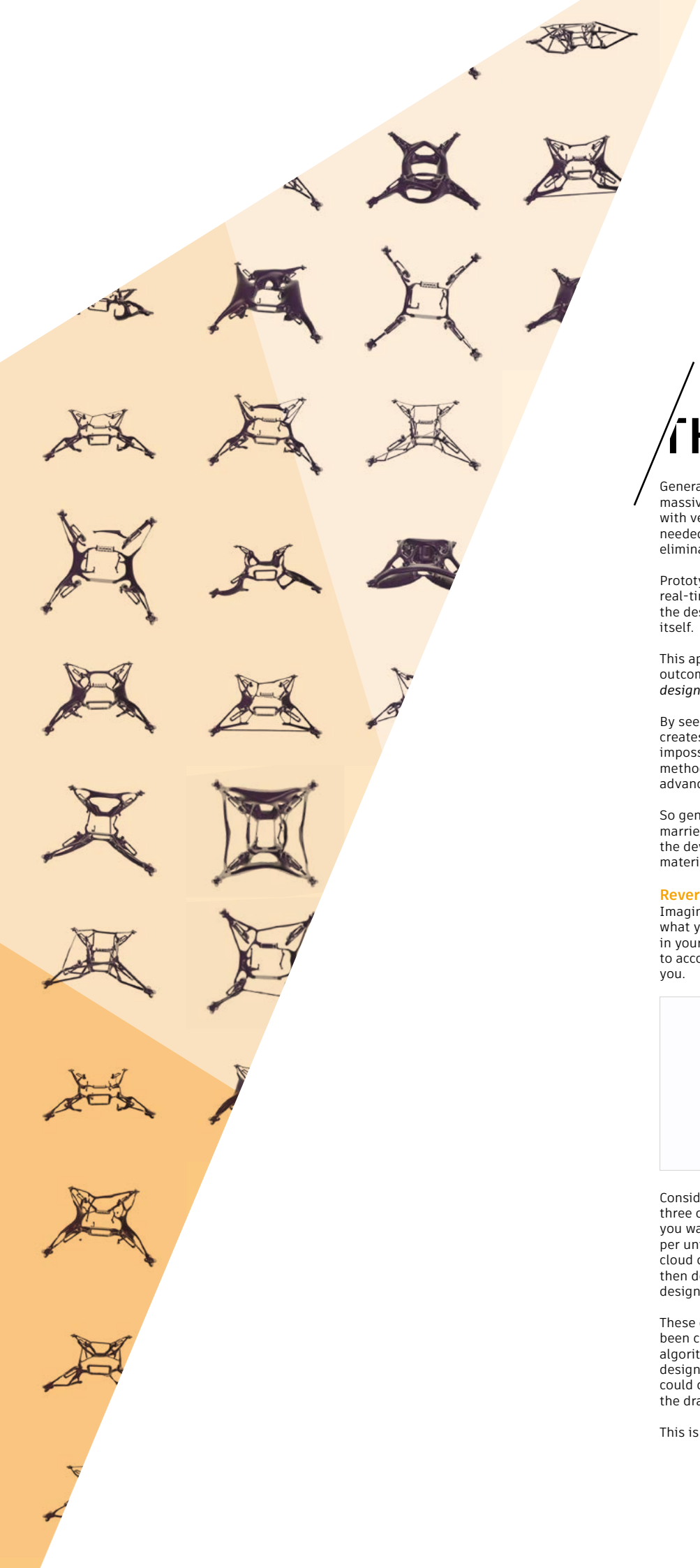
Engineers have traditionally designed a product that the market needs and then figured out how to manufacture it with the most suitable technologies. Sometimes the product would be easy to manufacture and profitable, sometimes difficult to manufacture and profitable and sometimes it would be neither easy nor profitable.

Could this approach be improved?

Product design methodology is changing rapidly. It is moving from a traditional system of single designer with a single computer using the modus operandi above, to a more collaborative method of design engineering that harnesses more processing power to design the best product based on constraints and criteria: think materials, load, cost and manufacturability.

This new paradigm for engineering design – known as Generative Design – is transforming how companies design and manufacture products and is a key element of the Fourth Industrial Revolution, 4IR or “Industry 4.0”.

Generative design will help both small and large companies broaden their design limitations, save money, reduce waste, and boost creativity. It is part of a suite of new digital technologies that are disrupting incumbent business models, and encouraging and empowering start-ups in engineering and manufacturing.



THE NEW WAY

Generative design is a new technology that uses massive amounts of computing power to create designs with very precise amounts of material only where its needed, achieving maximum performance while almost eliminating waste.

Prototypes can be fitted with sensors that capture real-time performance data that is looped back into the design process, so the product in effect co-designs itself.

This approach really is a way to produce multiple outcomes to a design problem, leading to the *"best design that is theoretically possible"*.

By seeking the optimal design, generative design creates complex forms that would otherwise be impossible to make using traditional manufacturing methods. But these are now possible with the advancement of new materials and metal 3D printing.

So generative design is technology that is perfectly married to 3D printing, in metals and polymers, and the development of new, lighter, stronger and better materials.

Reverse engineering

Imagine if instead of starting a CAD design based on what you think the customer wants or ideas that are in your head, you could tell a computer what you want to accomplish and then it helps produce the design for you.

Consider designing a chair. Instead of drawing two, three or even 10 options, you can tell the computer you want a chair that supports 110kg weight, costs $30 per unit, and uses 12kg material. The computer, using cloud computing to increase processing power, can then deliver hundreds of practical and manufacturable design options that all meet those criteria.

These designs will include some that could not have been conceived by the designer alone, because the algorithm is reaching possibilities based on math that a designer simply would not visualize. And the computer could create these ideas entirely on its own, without the drawing prowess of a human.

This is the power of generative design.

THE INGREDIENTS OF GENERATIVE DESIGN

Generative design is sophisticated software, far more powerful than normal CAD, and consequently needs access to huge computing power.

The ingredients for generative design are:

- A human operator
- Artificial intelligence algorithms
- Cloud computing power
- Strong link to manufacturing and process awareness

Artificial intelligence algorithms

GD is closely linked to artificial intelligence or AI, the technology that makes machines capable of calculating an appropriate response to a situation without prior programming.

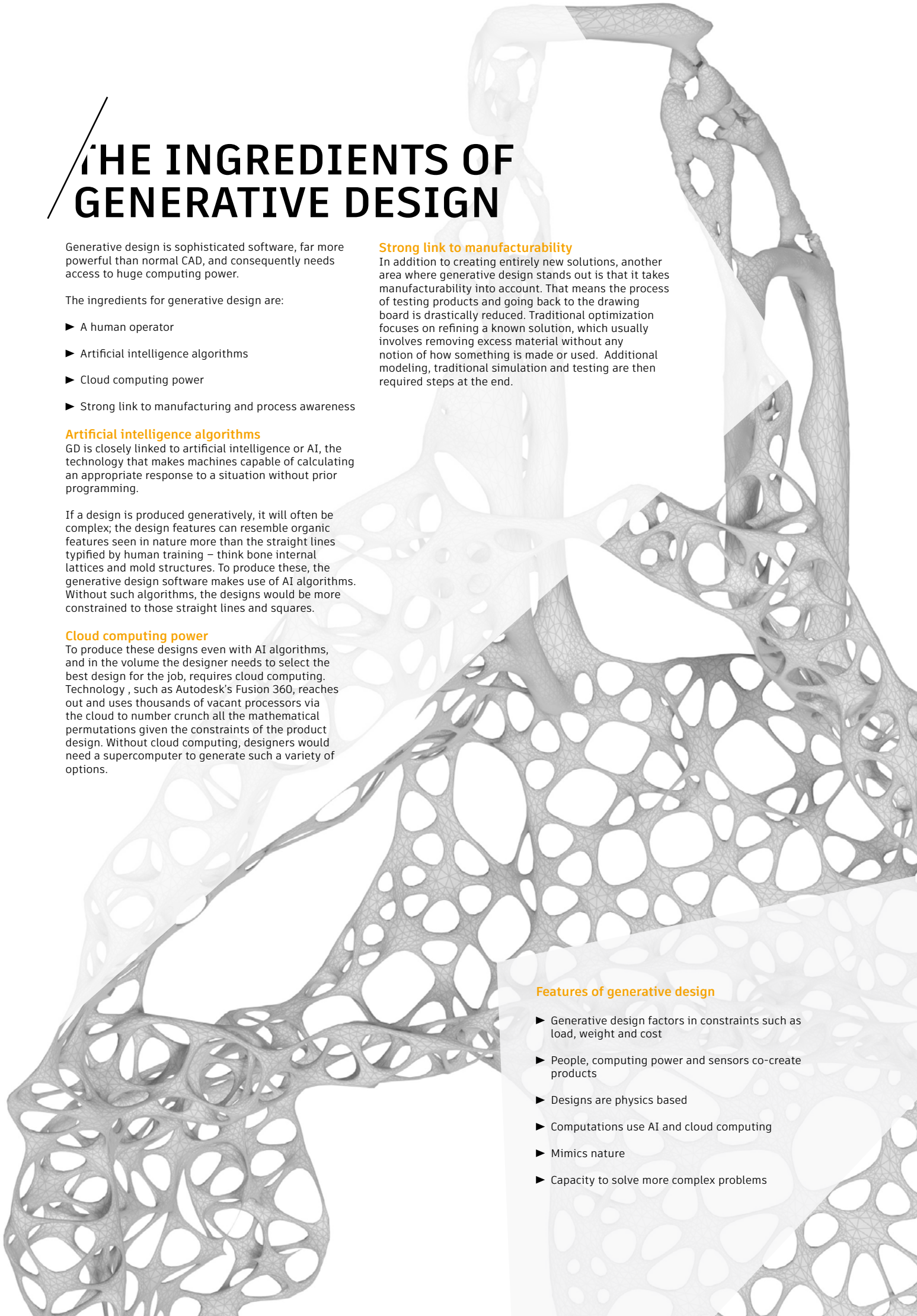
If a design is produced generatively, it will often be complex; the design features can resemble organic features seen in nature more than the straight lines typified by human training – think bone internal lattices and mold structures. To produce these, the generative design software makes use of AI algorithms. Without such algorithms, the designs would be more constrained to those straight lines and squares.

Cloud computing power

To produce these designs even with AI algorithms, and in the volume the designer needs to select the best design for the job, requires cloud computing. Technology , such as Autodesk's Fusion 360, reaches out and uses thousands of vacant processors via the cloud to number crunch all the mathematical permutations given the constraints of the product design. Without cloud computing, designers would need a supercomputer to generate such a variety of options.

Strong link to manufacturability

In addition to creating entirely new solutions, another area where generative design stands out is that it takes manufacturability into account. That means the process of testing products and going back to the drawing board is drastically reduced. Traditional optimization focuses on refining a known solution, which usually involves removing excess material without any notion of how something is made or used. Additional modeling, traditional simulation and testing are then required steps at the end.

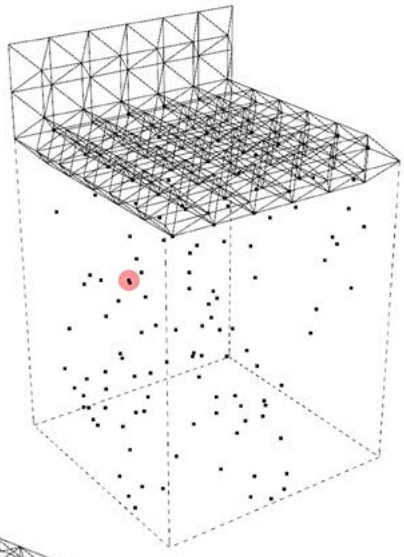


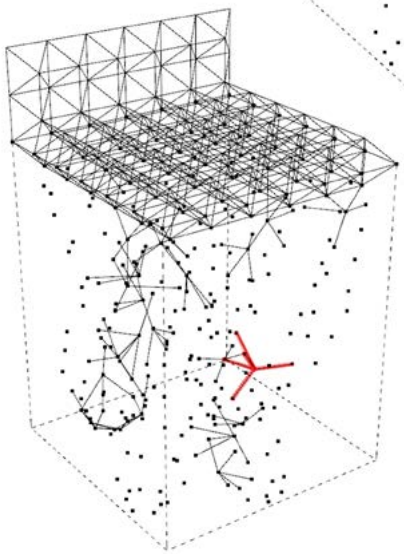
Features of generative design

- Generative design factors in constraints such as load, weight and cost
- People, computing power and sensors co-create products
- Designs are physics based
- Computations use AI and cloud computing
- Mimics nature
- Capacity to solve more complex problems

"With the generative approach I don't enter points and values in a CAD tool, I enter my goals."

Erin Bradner, Research Scientist at Autodesk





THE PROCESS AND BENEFITS OF GENERATIVE DESIGN

Generative design has a four-step process

1. Designer or engineer inputs design goals and constraints, using a generative-design system like Fusion 360. Human operator enters specifics such as material type, weight, strength and cost.
2. Computer uses algorithms and its own reasoning to generate different design options, creating process and performance aware solutions or outcomes.
3. Designer or engineer interrogates the options and modifies goals and constraints. Computer regenerates. Human intuition and computational artificial intelligence (AI) identifies the most relevant solution.
4. Designer or engineer then fabricates the prototype, by milling or 3D printing, and returns to step 3 as needed.

The core benefits of generative design are:

1. Explore a wider range of design options
2. Make impossible designs possible
3. Optimize designs for the choice of material, manufacturing method and cost
4. Save time and money
5. Reduce waste – the magnitude of waste reduction could be profound
6. Boost creativity

Compatible technologies

Generative design is very complimentary to these new manufacturing technologies:

- Additive manufacturing
- New material advancements
- Sensors embedded in prototypes
- Robots for repeatability

CASE STUDIES

Stanley Black & Decker

Application: Light weighting of crimping tool
Removing weight for a heavy cable-crimping tool was critical for power toolmaker Stanley Black & Decker. The handheld tool is frequently used when cutting or crimping electrical cables at altitude and it requires huge force, making light weighting and high strength desirable.

With an Autodesk generative design toolset, Stanley Black & Decker's Breakthrough Innovation team investigated up to 100 versions of the design. "The program itself filters by criteria, so if there were 100 potential ideas for this design, here are the 10 best," says Harry Zhong, Technical Lead at Stanley Black & Decker. "The design phase was an absolute success. We challenged ourselves, thought differently and we learned."

The pilot project yielded a crimping tool head that is 60% lighter and took 20-hours to 3D print, compared to 45-hours of fabrication for the current part.

Airbus

Application: Partition panel
How do you save more weight in an aircraft when its manufacturer devotes millions of dollars to reducing weight? Answer: Use generative design and print more components.

From 10,000-plus design options produced through generative design, Airbus's Emerging Technologies and Concept Group in Germany chose a small number to test comprehensively using simulation software. The result is a structurally sound yet lightweight "bionic" partition that can be printed by three additive-manufacturing systems. It is half as light and just as strong as the current panel.

The panel is an example of generative design mimicking nature. The algorithm for the partition frame was based on the growth patterns of slime mold, a single celled organism that connects multiple points with impressive efficiency. The algorithm for the structure within the partition frame was based on the grid structures of mammal bone growth, which are dense at points of stress but lighter elsewhere.

Image courtesy of Airbus

AI BUILD

If you thought that factory-scale robotic 3D printing of complex products using self-learning AI software is science fiction – think again.

Ai Build in Leyton, London is an exciting young company championing the factory of the future using industrial robots to 3D print furniture and ornate structures that are too big for normal 3D printers. The company also authors the software that controls the robots to produce these structures at high speed.

3D printing does not scale up well because of their dimensional limitations and [slow] speed, says Daghan Cam, founder and CEO. “We chose to work with industrial robots in order to make much larger structures.” Ai Build uses a KUKA KR30 L16 robot, with a reach of 3.1 metres, one of the longest reaches in the KUKA robot family.

Ai Build also authors the algorithms to control the robot movement to achieve the elaborate geometries of customers designs. “3D printing is all about optimising the tool path and making it more efficient,” says Daghan. “We do this at scale.”

The artificial intelligence in the company’s name comes from the algorithms it codes and the sensors and cameras in the robot end effector. The robot is able to see what it builds and, when a design feature does not work, learn from its mistakes.

Ai Build prints furniture, art and architectural installations. It printed multiple small scale, three-dimensional structures that form the decorative interior at retailer Bottletop’s flagship Regent Street branch.

A chair printed by Ai Build took 20 hours to print with a robot. Using a conventional 3D printer, the chair would have been printed in several parts and taken several days to print and assemble.

Generative design and large scale 3D printing is a very good match, says Cam. “The main advantage is that we can make very complex forms, that we could not have created before,” he says. “Our company is now focusing on making the method available for architecture and construction, offering new possibilities for 3D printing on a larger scale.” More architects are accessing this method now to achieve that they want to create.

One construction application is the 3D printing of form works for casting concrete. AI designs and prints exotic molds, and concrete is poured in to form the structure.

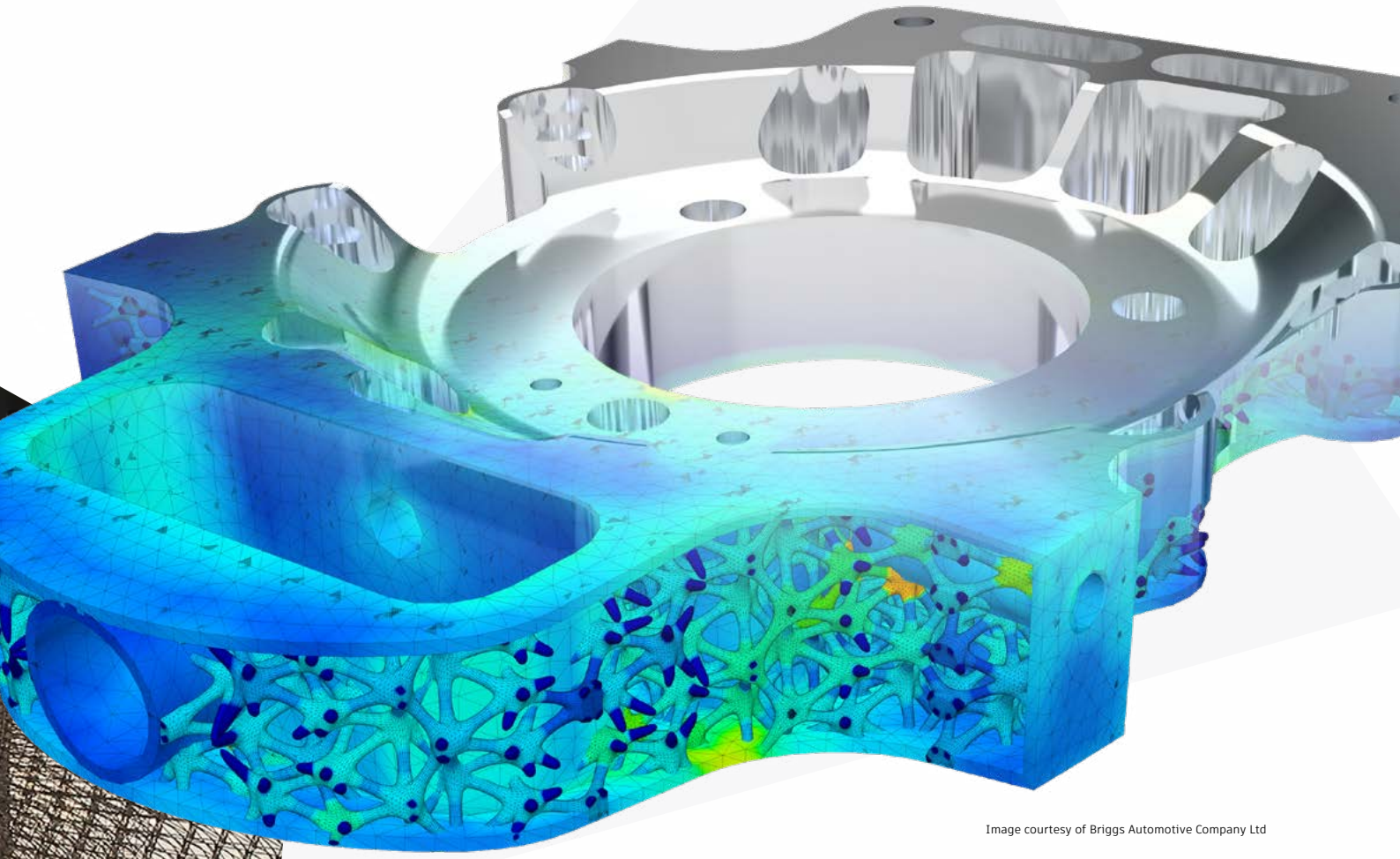


Image courtesy of Briggs Automotive Company Ltd

GENERATIVELY DESIGNED PRODUCTS

Here is a selection of products that have recently been designed with generative design software:

Customized automotive parts

The steering wheels on BAC Mono sports cars are customized to fit the driver's hands. The design of the structure is generative.

Furniture

The Elbo chair is a generatively designed chair fabricated from wood with a CNC router. It produces a stronger, lighter and more comfortable chair than one designed with CAD.

Footwear

Under Armour's Architech is the first 3D printed training shoe to market. It uses two printed interlace structures, one inside the other, which allows energy return to the wearer.

We hope you have found this white paper useful. Please get in touch with Autodesk and KUKA Robotics if you wish to discuss any aspect of this report further.

Reference links

- Defining generative design
  https://www.autodesk.com/solutions/generative-design

  https://www.autodesk.com/redshift/what-is-generative-design-2/

- How generative design is powered by machine learning
  https://www.autodesk.com/redshift/machine-learning/

- Stanley Black & Decker tool – generative design
  https://venturebeat.com/2017/06/22/autodesk-and-stanley-black-decker-use-algorithms-to-design-new-tool-for-electricians/

- Ai Build and zero waste shop
  https://www.kuka.com/en-gb/press/news/2017/12/ai-build-3d-project

- ExtruderBot at Autodesk University
  https://twitter.com/autodesk/status/798674789212655616?lang=en-gb

Videos

- Airbus “bionic” partition
  https://www.youtube.com/watch?v=IxF1FItQV4Y

- Under Armour Architech
  https://www.youtube.com/watch?v=4Ng76AyzI00

- Ai Build using KUKA robots
  https://www.youtube.com/watch?v=F_1zu6ZhmDk&t=217s

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