# How 3D Scanning Speeds Up Reverse Engineering

Michael Alba | Subject Leader | Engineering.com | 11/29/2018


The FARO® 8-Axis Design ScanArm 2.5C features a rotary plate for faster, more accurate scans. (Image courtesy of FARO Technologies.)

As 3D scanning advances, new fields are finding applications for the technology, from more traditional metrology to product development, digital museum archiving and even design for the architecture, engineering and construction industry. Reverse engineering, in particular, has been completely revolutionized by the ability to capture data from the physical world and create 3D models from that information, which can then be manipulated and brought back into the physical world using modern fabrication technologies.

This application is experiencing growth in terms of widespread adoption. According to market research firm MarketsandMarkets, "The 3D metrology market for reverse engineering is expected to grow at a high rate between 2017 and 2023. Industries such as automotive, aerospace & defense, and manufacturing have started using 3D metrology for design modification of actual objects to produce customized cars, spare parts, and produce parts whose production had been discontinued. High precision, faster product analysis, and the ability to make changes in the original product are the major drivers of 3D metrology market for reverse engineering."

If 3D scanning is seeing increased adoption for reverse engineering, it's important to understand what the technology is and how it works in the real world. In this white paper, we take a look at 3D scanning in more detail, with a particular focus on how one company, Mammoth Machine + Design, deploys the technology to reverse engineer unique parts for large-scale manufacturing equipment. In one instance, the firm was able to use 3D scanning to supply a reverse engineered spare part to bring a mass production operation back online in just 24 hours.

## 3D Scanning: A Broad Overview

There are a variety of 3D scanning technologies on the market, ranging in terms of cost and capability. Photogrammetry is perhaps the most affordable option, but also the least precise, converting a series of photographs of an object or area into a 3D model via advanced software algorithms. While photogrammetry can reconstruct 3D data from photos, it lacks the precision seen with the two predominant methods used in the professional space: structured light and laser scanners.

A structured light 3D scanner projects patterned white light onto an object. (Images courtesy of Open Technologies.)

Structured light scanners project patterned blue or white LED light onto an object while additional sensors detect edges to determine the object's shape. Trigonometric triangulation is performed to determine the location of these features in space. Laser scanners similarly use trigonometric triangulation, projecting a laser line or multiple lines onto an object and calculating the lasers' reflection from the object using attached sensors.

Whereas structured light scanners are automated and can have higher resolution and accuracy, they are limited by the impact of ambient light and can potentially be more expensive. Laser line scanners, combined with an articulated arm, are less sensitive to lighting in the scan environment, are easy to use and can be more affordable.

Arm-mounted laser scanners are typically best for capturing smooth, organic geometry up to a certain level of detail. Further precision can be gained through the use of a hard probe, which can capture precise geometric features, as well as sharp machined lines.

Using the technology described above, designers in industries such as the automotive space can reverse engineer car parts to create custom components for aftermarket applications. With a laser or structured light scanner, one could scan a car door, for instance, and capture the more organic, molded aspects of the door. A touch probe could then be used to capture data associated with the door's machined parts. This information could ultimately be used to create products such as replacement components for a car that might be out of production, or items personalized specifically for the customer.

McKinsey & Company notes that the automotive aftermarket space is quickly evolving, in part driven by new digital technologies. "Digital-related revenues will triple to a share in sales of almost 20%," a 2017 report explains. The report goes on to note that "80% of players say they are currently not well prepared – mainly due to a lack of strategic focus and skills and insufficient digitization resources."

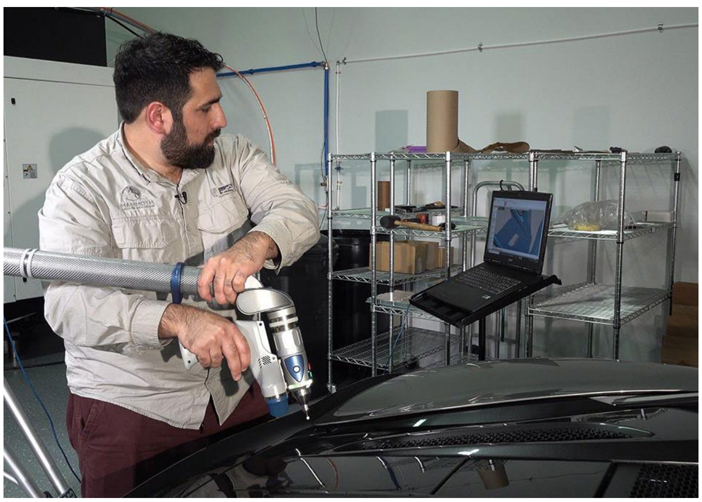

A laser scanner is used to capture data from an engine block, supported using a rotational plate. (Image courtesy of FARO Technologies.)

The report highlights the importance of digital technologies, such as the Internet of Things, but neglects the potential that 3D printing has for reverse engineering and aftermarket applications. 3D scan data can be converted into a 3D model that can then be 3D printed as a part with an optimized strength-to-weight ratio or with a customer's monogram embedded into the object.

Moreover, the ability to 3D print an object from scan data can greatly improve turnaround time, as demonstrated by Mammoth Machine + Design in North Carolina. The company has shown that, not only can scan data be used to reverse engineer parts for customers in the business of large-scale manufacturing, but that it can do so quickly.

## Aiding Large-Scale Manufacturers

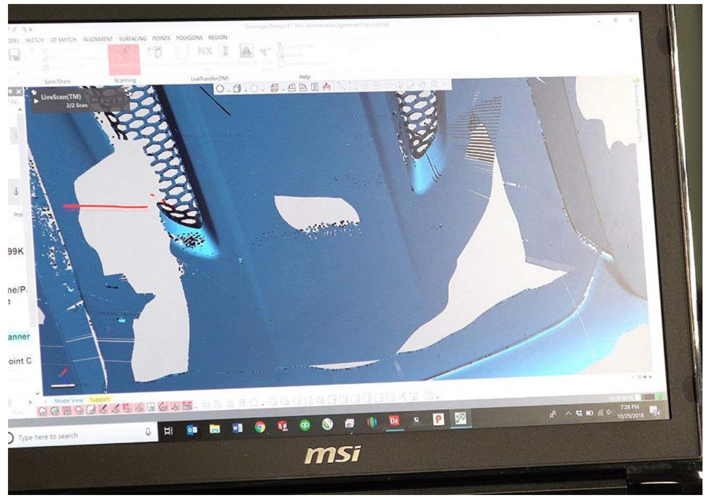
Mammoth Machine + Design services original equipment manufacturers (OEMs) that perform automation and large-scale manufacturing. To help customers repair or retrofit existing equipment, Mammoth uses a series of CNC machines and 3D printers, as well as a FARO® Edge ScanArm with HD Laser Line Probe for 3D scanning.



Mammoth CEO Ali Bahar 3D scanning the hood of a McLaren automobile.

"Our customers will come to us with obsolete parts or broken parts, or just parts that they need reverse engineered and recreated in a different material," Ali Bahar, Mammoth CEO, explained. "We've gone as quickly as six hours in reproducing parts, as part of our emergency response. When our customer has a component and the OEM simply cannot replace the part and their line is down, we'll use 3D scanning technology to reverse engineer the part with such high tolerances as to be able to repeat them on our precision machines."

Bahar described his firm's customers as some of the largest producers in their industries, such as plastic cup, plastic lid and cabling manufacturers—products that are essentially omnipresent in the modern world.




Scan data captured by Bahar during the McLaren scan.

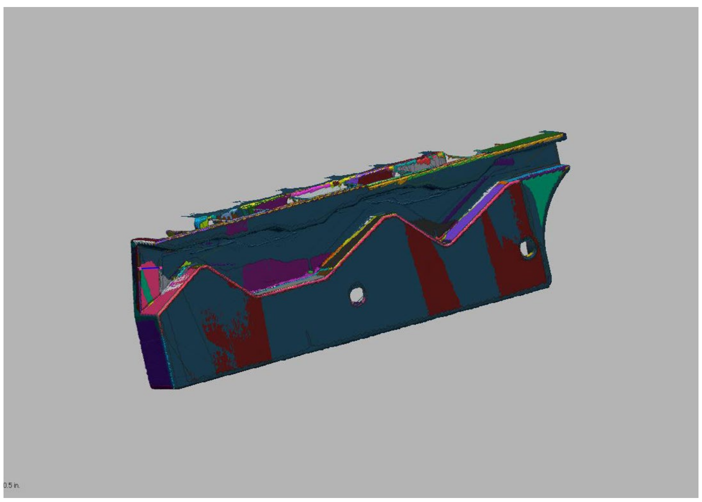
George Brinzey, head of sales for Mammoth, explained that the company began with the idea of aiding businesses with their product development. Along the way, however, the firm began to realize that large manufacturers simply didn't have the capability to service their own equipment.

"Through some interactions with some of the larger manufacturers, we noticed that tool rooms are disappearing," Brinzey said. "Businesses are not investing in top-notch equipment like they once were. Machinists are very difficult to find. It just seems like a dying market within larger manufacturing is having the ability to support precision manufacturing to support the actual machines that make their products."

## Tackling Mammoth Jobs with 3D Scanning

The first piece of equipment the company bought was a 3D scanner, which Bahar came to rely upon in his previous job at an engineering firm, where he would perform reverse engineering for such names as Lockheed Martin and Northrop Grumman. With the FARO ScanArm, Mammoth is able to recreate object details down to an accuracy of a few hundredths of a millimeter. The tool is used to capture free-form surfaces before a probe is used for higher precision details.

The 3D scanner not only helps with the design of replacement parts, but it also actually plays a role in aiding the initial job setup. If a large object needs to be placed on a table and oriented in a particular direction, Mammoth engineers will scan a portion of the object, such as the bottom surface. That rough data can then be used to model a fixture that can be 3D printed and hold the part in place while the main scanning job is performed.



A CAD model of a manufacturing component reconstructed via 3D scanning. (Image courtesy of Mammoth Machine + Design.)

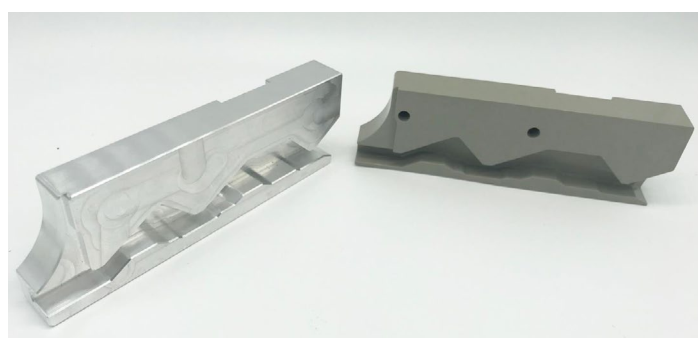
For Mammoth, the traditional 3D scanning workflow moves as follows: once a part is oriented on the firm's large granite table for scanning, Mammoth engineers will grab 3D data with the ScanArm before using the probe to capture the object's key features, such as hole locations. This data is brought into Geomagic Design X to recreate the part as a solid model. From there, the team will create engineering drawings and pursue traditional subtractive manufacturing or 3D printing as needed.

Once the part has been made, Mammoth can then scan the final component with the ScanArm and match it against the digital model or the original scan to qualify the part using Geomagic Control X. Items can be further qualified through first article inspection, in which a part is tested at each stage of the production process for the machine that Mammoth has repaired or retrofitted.

## A Mammoth Job in Record Time

It's during Mammoth's "emergency response" jobs that the benefits of 3D scanning are truly demonstrated. A particularly illustrative example arose when the firm was tasked with recreating a 150mm-diameter die for a large wire drawing station for Southwire Company.

Southwire is a leading producer of electrical wire and cable made from a variety of materials and for a variety of applications, as well as rod casting machinery and a number of other OEM products. Upon receiving a new piece of equipment, Southwire's crew realized that the die for the wire drawing station was undersized and unusable, after possible damage in transport. The machine's installer had already left for the day and wouldn't be able to return to the facility for months, leaving Southwire without production capabilities.



On the right, a plastic component that was too small for Southwire's operations. On the left, a machined aluminum equivalent that met the proper specs. (Image courtesy of Mammoth Machine + Design.)

To get a new die as quickly as possible, the company turned to Mammoth Machine + Design. Mammoth showed up at the facility and picked up the unusable die to transport the tool back to its headquarters.

"This was really a case of on-the-fly project management," Bahar recalled. "I was communicating with our engineers on the way back from the plant to get materials and prep the shop. It was a very dynamic shift in what we do from day to day. It was a fire drill, for sure. With an emergency response project like that, it's all hands on deck. Everyone pretty much drops their long-term projects and whoever is project lead starts to make the calls."


Bahar sitting with several manufactured parts and a FARO Edge ScanArm.

Once the die was at the Mammoth shop, it was 3D scanned using the FARO ScanArm, with the team capturing all of the key points necessary for mounting it to the new wire drawing equipment within hundredths of a millimeter. The die scan was then qualified with a Southwire engineer before he left the facility for the day.

Machining the die overnight "took every bit of 12 hours," according to Bahar. The following morning, the die was delivered to Southwire, where it was installed and tested, revealing the need to make a minor change. At this point, the die was brought back to Mammoth to make the adjustment, but the equipment was up and running by the end of the following day.

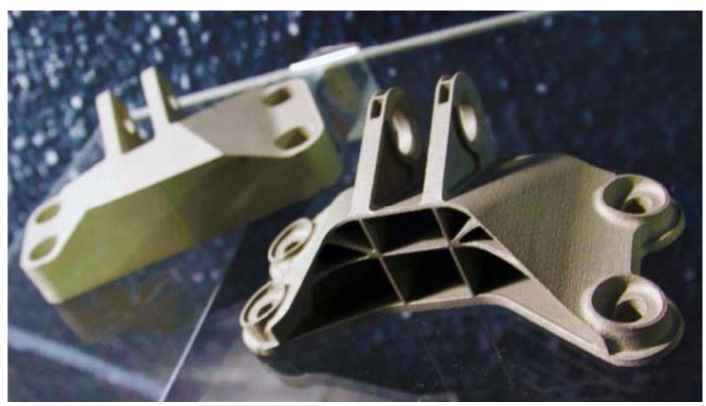
In total, Bahar estimated that the whole job took about 31 hours, including the revision. To scan all of the parts, however, took just one hour.

"I think it would have been impossible without the ScanArm. If we were to use a HandySCAN or off-the-shelf scanner, maybe it would have taken six or seven hours."

**Ali Bahar,**
CEO, Mammoth Machine + Design,

## The Future of Reverse Engineering

The power of 3D scanning and new manufacturing technologies is only just now beginning to be felt. In instances such as those demonstrated by Mammoth Machine + Design, those tools have shown they can deliver products and services in record time, but new design methods are also being developed that may introduce an entirely new range of benefits and capabilities to rapidly produce parts.



In the background, a metal aerospace bracket produced with traditional design and manufacturing processing. In the foreground, a topology optimized, 3D-printed part.

In particular, generative design and topology optimization are now possible with 3D printing. By selectively removing certain areas in a part, an engineer can reduce its overall weight while maintaining or even increasing its strength. Often, such methods of topology optimization can be based on organic geometries seen in nature, such as the microscopic porous structure found in bones.

Such features are clearly beneficial to industries such as aerospace and automotive, where light weighting is key to reducing costs and improving speed. However, topology optimization may also reduce material usage, and therefore costs, in any number of applications.

In order to determine the design with the best strength-to-weight ratio, a designer will most likely have to rely on some form of simulation software that will be able to calculate part stresses. Then, with generative design tools, it's possible to create a wide range of design iterations that meet the necessary criteria using artificial intelligence algorithms. After a series of choices have been created, the best option for the job can be selected.

Most geometries created with generative design and topology optimization cannot be fabricated using traditional manufacturing tools, such as injection molding or CNC machining. Due to the additive nature of 3D printing, in which material is deposited or fused layer by layer, it is generally the only technology capable of producing these unique shapes.

With this in mind, it's not difficult to imagine that these new design and manufacturing tools will be combined with ever-advancing 3D scanning technology to revolutionize reverse engineering. One can envision a firm like Mammoth not only 3D scanning and fabricating a replacement part for a customer, but also improving the strength-to-weight ratio of the component before 3D printing it.

3D scanning and other evolving technologies, then, coexist in a symbiotic relationship. As we see one improve, we'll naturally see others advance alongside it, ultimately improving the entire ecosystem overall.



FARO Technologies, Inc. | 250 Technology Park | Lake Mary, FL 32746





REV 04/01/2019