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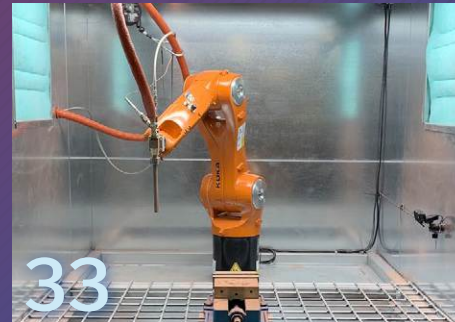
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Introduction

The need to solve the world's most critical social, environmental, and economic problems is an urgent one, and there's no shortage of great ideas. But those ideas have a better chance of becoming tangible solutions when collaboration is involved. When innovators team up with others, they're exposed to diverse perspectives and new ideas and information, and the ensuing explorations and iterations—and failure, lots of failure—can lead to powerful and often unexpected outcomes.

Innovation and collaboration are at the heart of the **Autodesk Technology Centers**, which provide a platform for exploring new possibilities of designing and making. With a global network of innovators from the industry, academic, and entrepreneurial communities, and physical workshops in San Francisco; Boston; Toronto; and Birmingham, UK, the technology centers provide support for residents as they seek new ways to design for impact.

The innovators in our programs—pioneers in architecture, engineering, and construction, and design and manufacturing—are all working in some way to connect designing and making, using our studios and workshops to experiment and leveraging our wide network of subject-matter experts and research and product teams. (Although the COVID-19 pandemic has caused our facilities to temporarily close, it's inspired us to reimagine our physical experiences for remote engagement.)

Earlier in my career, as an architect designing laboratories for research and learning, I sought to create places that fostered connections: between people, between ideas, between thinking and doing. I'm no longer a practicing architect, but I'm still fascinated by the way connection fosters innovation.

In these pages, learn how the architecture firm WZMH is installing smart technology into new buildings and retrofitting existing ones, creating safer and more sustainable structures. By consulting with others in the network, WZMH learned about new technologies, which it ultimately applied to its project. Collaborating with industry partners also helped four young architecture students explore solutions to the growing global problem of water scarcity. And, collaboration around cross-cultural design-and-make processes led The Okoa Project to new ideas for medical transportation in low-resource settings.

These are just a few of the stories of innovation happening every day through the Autodesk Technology Centers. In the following pages, you'll find more examples of ways our residents are helping to make the world a better place.

RICK RUNDELL

*Senior Director, Autodesk Technology Centers
Autodesk*



The Okoa Project's ambulance motorcycle attachment allows patients to access potentially lifesaving health care. Courtesy of The Okoa Project.

Boston-based nonprofit organization The Okoa Project has designed an ambulance trailer that attaches to a motorcycle, providing a safe way for patients to access health care.

THIS CLEVER MOTORCYCLE AMBULANCE SAVES LIVES IN TANZANIA

BY JEN CIRALDO

Globally, 1 billion people lack the transportation needed to access medical care. One of the most vulnerable populations? Expectant mothers.

In Tanzania, 5,000 women die every year from complications related to pregnancy and childbirth. Most live in remote areas, far from paved roads and health-care facilities. Thankfully, one organization is working to save lives using creative engineering, agile technology, and a community-centered approach to design.

The Okoa Project

NUMBER OF RESIDENTS: 5

LOCATION: Boston

LENGTH OF RESIDENCY: 1.5 years (ongoing)

GOAL: To use design feedback to build new prototypes of the team's ambulance trailer, to determine new areas for expansion, and to build location-specific prototypes at the technology centers.

“We’re a nonprofit focused on increasing access to health care with innovative technologies,” says Emily Young, executive director of **The Okoa Project**. The organization was born in the **MIT D-Lab**, where students design solutions to impact the lives of communities worldwide. In 2016, Young was in MIT’s Mechanical Engineering program when Deborah McCracken reached out to the D-Lab. As director of The Olive Branch for Children (**TOBFC**), an organization that serves more than 40 communities in the Mbarali District of Mbeya, Tanzania, McCracken wanted to find a way to transport rural residents to health-care providers. The team got to work designing an ambulance trailer that attaches to the back of any motorcycle, providing a safe way to transport people to lifesaving care.

What began as a student project for Young and two other women from MIT—Sade Nabahe, also a mechanical engineer, and Eva Boal, a computer scientist—soon evolved into a full-time nonprofit they named The Okoa Project after the Swahili word *okoa*, which means “to save.” They continued to work with McCracken to establish the ambulance program in Mbeya. Being a female-led organization has “allowed us to truly focus on the women-centered parts of design, more than other organizations or products do,” Young says. “One of



Building the ambulance motorcycle attachment prototype at the Autodesk Technology Center in Boston. Courtesy of The Okoa Project.

our biggest focuses is maternal health care and getting pregnant women to the hospital.”

In remote areas with poor road conditions, women commonly receive little or no prenatal medical attention, which could detect treatable complications like preeclampsia, a potentially fatal spike in blood pressure. In these regions, **less than half** of pregnant women have a skilled attendant present during labor and delivery, which could greatly increase their chance of survival if a problem arises.

Motorcycles are the primary mode of travel throughout East Africa, but taking a *boda boda* (motorcycle taxi) is expensive and uncomfortable, and it’s dangerous for pregnant women to travel on the back of the

motorcycle for hours on rough roads. To work within this existing transportation infrastructure, the team designed a universal attachment that “can turn any motorcycle into a lifesaving device.”

Community-Based Design

The Okoa Project uses a community-centered design approach to the ambulance. “We want to make sure that the community is involved in every step of the design process,” Young says. The team traveled to Mbeya early on and held focus groups with mothers, husbands, midwives, village leaders, health-care workers, and motorcycle drivers to get a wide range of perspectives on the safest, most comfortable way to transport people—especially pregnant women. “We’ve done over 500 interviews to inform our design,” Young says.

In remote areas with poor road conditions, women commonly receive little or no prenatal medical attention, which could detect treatable complications.

Young even brought an early prototype into the community for people to see and use. When the Okoa team talked with people about the design, “we realized that there were some big changes we needed to make, mostly in people feeling secure—having it be a private experience of going to the hospital,” Young says. Those changes included creating an enclosed ambulance for complete privacy, an onboard birthing kit, and an additional seat so a friend or family member can accompany



The Okoa Project staff traveled to Mbeya, Tanzania, to interview hundreds of people about the ambulance’s design. (above)

The Kubuni Centre and Collaborative innovation space in Mbeya houses The Okoa Project’s production operations. (left)

Courtesy of The Okoa Project.

the patient. There have been six prototypes so far, each iteration with improved safety and comfort based on community feedback.

The Okoa Project joined the residency program at the Autodesk Technology Center in Boston to improve upon its original design and manufacturing process; its production operations are based at the **Kubuni** Centre and Collaborative, an innovation space in Mbeya. “We train local technicians to build our ambulances in-country,” Young says.

The iterative design process has been a collaborative back-and-forth between Okoa’s engineers and the Tanzanian technicians, including apprentices, some of whom are youth forced to drop out of school early. “We also really focus on teaching and skill-building, as well as knowledge sharing across cultures,” Young says. “They showed us some of the ways to use motorcycle parts that were readily available and also make something attachable to the back of any motorcycle.”

Creating the Okoa ambulance has been a lesson in cross-cultural design thinking. Whereas the technicians design as they build, Young instead starts with an image. “I am a very visual communicator, and I like to draw things,” she says. “I really like CAD and engineering drawings.”

Despite the different approaches, the two methods are complementary, especially with Young’s portable design program. “We’ve been using [Autodesk] **Fusion 360** to coordinate the design,” she says. “Since it’s a lighter CAD product, we’ve been able to use it while we’ve been traveling.” The agile program has enabled The Okoa Project to explore generative-design possibilities in 2020 and has made field implementation more streamlined as the teams work together.

The ambulance is 60 inches wide by 64 inches long and costs \$1,200 to design and build. All materials are locally sourced, so it’s easy to make repairs. Okoa is currently working to improve the already robust suspension to create a smoother ride over the terrain.

Saving Lives and Creating Local Jobs

Once the motorcycles are ready to hit the road, they’re handed over to a motorcycle driver who’s been trained to transport patients. It’s another link in the sustainability of the design and completes the community-centered connection between people and medical care. “Our ambulances are built to save lives, but they also create local jobs and strengthen health-care systems that already exist,” Young says.

The Okoa Project team in Mbeya. Courtesy of The Okoa Project.



People in Mbeya are using the three ambulances currently in service. Young recently met Helena Boniface, who took one of the Okoa ambulances. “She was extremely sick,” Young says. “She couldn’t talk; she couldn’t eat. She was having extremely bad diarrhea and was really worried that her health would be compromised.” Boniface was also pregnant and worried about her baby. “Helena contacted the local ambulance dispatcher, Mama Rosie, and got to the hospital in time.” With mom and baby now doing well, Helena’s made a big decision. “She said she’d also take the ambulance to deliver.” It’s an anecdote that supports The Okoa Project’s mission: “Saving lives. One ride at a time.”

“Our ambulances are built to save lives, but they also create local jobs and strengthen health-care systems that already exist.”

—Emily Young, Executive Director, The Okoa Project

The three ambulances in Mbeya serve a population of 5,000 people. By the end of 2020, five will be operational in Ghana; Okoa is aiming for 25 ambulances by the end of 2021. Within the next **five years**, the team plans to build 250 more units to serve between 750,000 and 1.25 million people.

Young is already thinking of what’s next for The Okoa Project. “The last time we were in Tanzania, we helped customize a wheelchair for a man out in the communities we work in,” she says. “That sparked a lot of ideas about other ways we could help with innovative technologies.” 🇷🇺

See how Trexo Robotics developed a robotic gait trainer to help kids who suffer from cerebral palsy and limited mobility.



Smart-building technology is often an afterthought—but what if it's integrated from the beginning? One Toronto architecture firm is tackling this question with innovative prefab R&D.

HOW AN ARCHITECTURE FIRM IS INTEGRATING SMART-BUILDING TECHNOLOGY FROM BLOCK ONE

BY ZACH MORTICE



As smart-building technology filters down to the consumer level, it generally comes in the form of technology that's grafted into buildings piecemeal: a thermostat that adjusts temperatures based on which rooms are being used, or a washing machine that lets you start and stop cycles while you're away.

But one architecture firm is looking for ways to better integrate innovative technology systems into modular-building processes from the start—and to smarten existing structures.

WZMH's Intelligent Structural Panel integrates electrical, IT, security, audio-visual, HVAC, and other systems. Courtesy of WZMH.

WZMH Architects

NUMBER OF RESIDENTS: 6

LOCATION: Toronto

LENGTH OF RESIDENCY: 2 years (ongoing)

GOAL: To develop a smart modular-panel system called the Intelligent Structural Panel (ISP), to integrate smart-building devices such as sensors and mechanical and electrical devices, and to develop a BIM twin model to monitor the ISP panels.

Based in Toronto, **WZMH** Architects is a well-established firm that's developing a smart modular-panel system called the Intelligent Structural Panel (ISP). This work has earned WZMH the 2018 UPlift True Disruptor **Award** from the France Canada Chamber of Commerce, and earned WZMH R&D head Hiram Boujaoude a nomination for Innovator of the Year in Autodesk's 2019 AEC **Excellence Awards**.

The ISP system, currently in the prototype phase, is designed to integrate smart-building devices and network them with flexible hardware and a consumer-facing app. These panels are just two inches thick and have standard dimensions of 10-by-30 feet or 10-by-45 feet. Each panel is made of two steel plates and a perimeter, within which lies an intelligent highway. The panels, which were designed in Autodesk **Revit**, work as structural members. As a resident at the Autodesk Technology Centre in Toronto, WZMH has been working on constructing room-scaled functional prototypes.

"If you're going to do a floor panel off an assembly line," says WZMH partner and principal Zenon Radewych, who spearheaded



An ISP system panel prototype. Courtesy of WZMH.

the firm's smart-building research, "let's see what else we can put in the floor panel."

The smart devices that are compatible with the panel system include sensors (for motion, occupancy, temperature, and lighting) and mechanical and electrical devices (HVAC, window-shade rollers, cameras, and light fixtures)—with many combinations possible. The ISP is a cloud-based system that lets users program and monitor their smart devices through an app, using real-time analytics on both a local and cloud level.

A Common Intelligent Highway

Once sensors and devices are plugged into the system via a standard Ethernet connection that also supplies power, the individual elements are designed to react as a unified network. “That’s where you can create a true intelligent building: by having the different connected devices talk to each other because they’re going through this common intelligent highway,” Radewych says. A light sensor could trigger a window-shade roller to lower, for example. Train stations could use the ISP to tell passengers on a platform which approaching train cars are full. In a hospital, these systems could offer deeper levels of automated patient monitoring.

An effective shift to modular construction promises higher material efficiency, and ISPs offer similar gains. “This started with technology and prefab, but we’re seeing lots of benefits on the sustainability side,” Radewych says. “Not only do you get the benefits of the smarts, you get the benefits of less material used.”

Early studies indicate that a smart-panel system could reduce total building materials by 10%. By relying on power-over-Ethernet systems, ISPs can eliminate standard junction boxes and electrical conduits. “When you build a prefab component and include other materials and systems inside of it, you actually reduce the amount of materials you need compared to conventional work,” Radewych says. The ISP will also be able to harness waste energy generated by its smart components and dissipate it gradually as part of HVAC heating systems.



Building a prototype in the lab. Courtesy of WZMH.

While the panel system is intended for new construction, WZMH envisions using small black boxes (each measuring just a few inches) for retrofits and renovations that could be completed in only a few months. For example, standard light fixtures could be plugged into the ISP systems and interact with the network. These units act as both power converters (devices can be powered through Ethernet cables) and networked

switches that can tie each device’s essential functionality to the wider network. (WZMH is collaborating with Quasar Consulting Group, Stephenson Engineering, and C3PoE on the ISP and with Argentum Electronics for the black boxes.)

“Overnight, you basically have a smart building,” Radewych says. “Yes, we are building a lot of brand-new buildings every

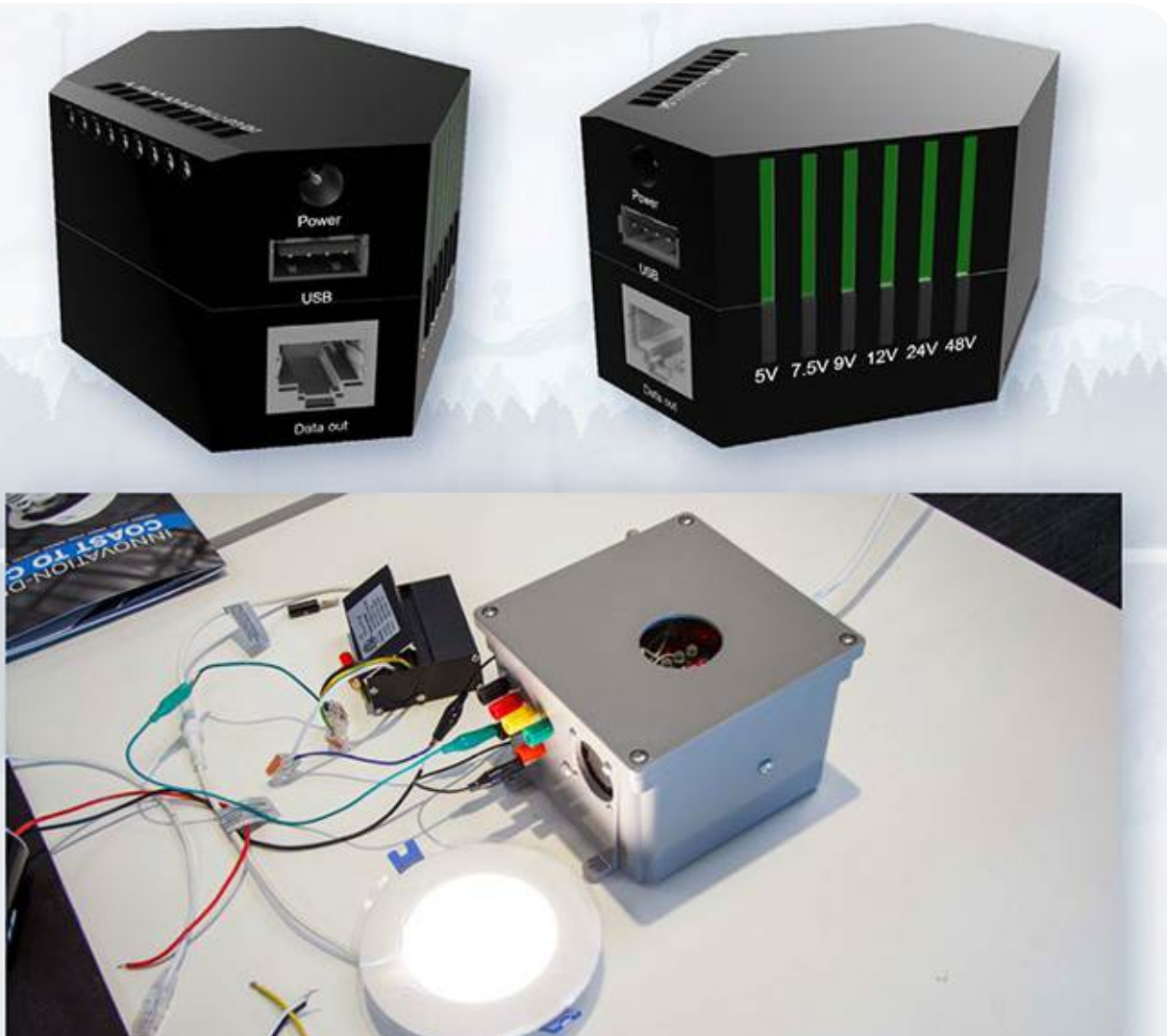
single day, but it doesn't mean we're tearing down the old buildings. They're still going to be around for 50, 60, 70 years or longer. The market potential is to convert existing buildings to make them smart. The black box is totally aligned with that idea."

While the panel system is intended for new construction, WZMH envisions using small black boxes for retrofits and renovations that could be completed in only a few months.

Actionable Data on Building Usage

Whether they're installed into new buildings or retrofitted into existing ones, the black boxes can supply building owners and tenants with actionable data on how the building is used. "Even if you plug in dumb devices, you can actually measure the amount of energy that is being used floor by floor and have spot renovations after that," Boujaoude says.

"Whatever you can pull from a device, the ISP will pull," Radewych says. "The really wonderful thing about this is that if you retrofit an older building, you suddenly have data on your day-to-day operations." To manage this data, WZMH is using Autodesk **Forge** to create a BIM (Building Information Modeling) twin of the panels and their devices.



This black box will allow off-the-shelf, low-voltage devices to be powered by Ethernet and talk to other devices. Courtesy of WZMH.

Learn how mass-timber construction is poised to elevate the way things are built—literally—with taller, stronger, carbon-sequestering structures.

The logo for Redshift by Autodesk, featuring a stylized red and white fan-like graphic to the left of the text "Redshift" in a bold, sans-serif font, with "by AUTODESK" in a smaller font below it.

Redshift
by AUTODESK



The hope is that building owners and tenants can gather this data for machine-learning routines or other artificial-intelligence applications to make buildings maximally efficient. (The WZMH team is also using machine learning to teach computers about humans' thermal-comfort thresholds.) This data can be mined for ways to trim energy expenditures, dynamically shutting off systems, rooms, and floors that aren't being used.

It could also be used to increase operational and maintenance efficiency. Occupancy and motion sensors could detect areas of the building that get the most traffic, which could be used to refine maintenance procedures and schedules accordingly. If it's a building type or program that will be repeated in a similar context, this data can be used to select more durable materials for the heavily trafficked areas.

In addition to significant material-efficiency savings, perhaps the greatest value of an off-the-shelf panel system that enables smart-building technology is that it can plug into a continual feedback loop for the steady refinement of the built environment. 📊



*A concrete deep beam created through generative design.
Courtesy of Dr. Sreekanta Das's Research Group.*

A Brazilian start-up is using generative-design principles to pioneer a new approach to forming sustainable concrete—starting with a humble footbridge.

CONCRETE FORMS GET STRONGER, LIGHTER, AND MORE SUSTAINABLE WITH GENERATIVE DESIGN

BY DREW TURNEY

Major breakthroughs in building methods don't come around very often. Some world-changing examples include the Great Pyramids of Giza, France's Pont Du Gard aqueduct, Le Corbusier's floating-slab design, and the Hoover Dam.

Through centuries of design innovation, concrete has been a stalwart material for human-made structures. But old formulations and methods are evolving, as new technologies such as 3D printing and artificial intelligence (AI) promise to make concrete lighter, more durable, and—perhaps most important—more sustainable.

Hone Structures

NUMBER OF RESIDENTS: 2

LOCATION: Toronto

LENGTH OF RESIDENCY: 2 years (ongoing)

GOAL: To explore generative-design technology for placing rebar and lightweighting concrete structures.

Structural engineer Marcos Silveira and his team are spearheading a project called Hone Structures, which they hope will help advance sustainable concrete construction techniques. Hone Structures is applying generative design to reinforced concrete structures—starting with proof-of-concept concrete **deep beams**—to explore material savings and other potential benefits of the process.

Midway through his PhD at the University of São Paulo and the University of Windsor, Canada (under the supervision of Dr. Luís Bitencourt at the former and Dr. Sreekanta Das at the latter), Silveira and his teammate Gabriela Vivan attended the Generative Design for AEC Intensive Residency at the Autodesk Technology Centre in Toronto to develop concepts, then worked with robotics experts in Boston to build reinforced concrete and learn about 3D printing. Silveira says the project—a “living, breathing application” of his PhD thesis—“aims to reshape the design and construction process for reinforced concrete structures” using generative design, AI, and robotics.

Regarding traditional concrete design and construction, Silveira says, “It’s not a problem, exactly, but a limitation because it’s based on the designer’s experience and the limitations of the traditional



Marcos Silveira and teammate Gabriela Vivan print a prototype of their generative design-optimized part at the Autodesk Technology Centre in Toronto. Courtesy of Irene Kuan-Chung.

manufacturing process.” Instead, the Hone Structures approach observes how a concrete structure behaves by finite element analysis (**FEA**), then uses computation to reshape it and strengthen it in the right spots. “Basically, we divide the design load into a range of steps,” he says. “Instead of proposing and calculating an equivalent truss to represent the complex shape—a strut-and-tie approach—we analyze each load step, increasing it to understand the weakest points where reinforcement is needed.”

The team built several concrete forms in the structural lab at the University of Windsor, attached them to hydraulic frameworks to

apply pressure, and applied a digital image correlation (**DIC**) system using cameras to record the tests, which made it possible to later analyze the strain and stresses under certain conditions of force. The team then went back to the generative-design algorithm to come up with new lines of code in order to further improve the relationship between structural behavior and the material used for the next batch of elements.

Deep Beams, Deep Material Savings

The process translated directly to material savings. “It means the design process is based on the stress,” Silveira says. “Stress is force divided by area. If I increase the strength in terms of stress, I can reduce the area, and if I reduce the area, I can reduce the internal amount of material.”

That led to a truss characteristic of the atypical, irregular shapes generative-design

algorithms are known for: weird but optimal. Hone Structures produced 10 major designs for the piece, selected from more than 1,000 models generated by the algorithm. The team began using **topology optimization** as a trigger in the generative-design approach. In other words, the element was divided into small elements (FEA processes); understanding the behavior of—and stresses on—a given element yielded calculations that, when combined, informed the behavior of the entire piece. For each step of load, the algorithm analyzed which small elements could be excluded without compromising structural behavior of the entire set; after that, it ran again and again until it achieved the design goal.

The final result was a deep beam comprising just 55% of the material that would have been used in a traditional, human-driven design process. After proving the possibilities for reducing material, the next logical step is exploring better materials science, incorporating additive manufacturing, and making the whole process ever smarter (and greener).

Ultrahigh-performance **concrete**, used by the US Federal Highway Administration, is tougher and more expensive than traditional mixtures, but less of it is needed than regular concrete—and with the material savings that generative design offers, it becomes even more affordable. It also uses more sustainable formwork to construct, further saving money and materials.

Technologies such as 3D printing are changing the manufacturing process. Traditional formwork that constrains concrete to straight lines might be a thing of

A test set: The black box is the DAQ (data acquisition) system. Courtesy of Dr. Sreekantha Das's Research Group.



the past; research is continuing apace on 3D printing the steel rebar found inside concrete structures. At the same time, Silveira says that research by companies printing steel on a small scale is opening the doors to evermore-complicated rebar structures for concrete. Others are experimenting with making rebar from lighter and stronger carbon-fiber compounds.

A Bridge to New Design Technologies

As a proof of concept, Hone Structures is designing a reinforced concrete footbridge using generative-design algorithms and robot builders. Developing this structure will let the team work with shapes, forms, and sizes that are beyond the limits of current technology.

“In the future, the design of the rebar cage could be decided by the demands of the performance, not limited by current assembly technology.”

—Marcos Silveira, Hone Structures

“When we’re working with regular formwork, we’re limited to certain shapes, so we have to use those limitations in the design process,” Silveira says. “In the future, the design of the rebar cage could be decided by the demands of the performance, not limited by current assembly technology.”

He says a footbridge is the ideal application for everything Hone Structures has been working on, because the prestressed concrete emerging from the company’s research can be formed in very different shapes from those traditionally used in the built world. “This application could be a good opportunity to break some paradigms about additive manufacturing and generative design in the reinforced-concrete world,” he says.

The goal is to complete the project within two or three years. The bridge won’t only be a showcase for what’s possible; it will also be a teaching tool to demonstrate the limitations, opportunities, and peculiarities of the method.

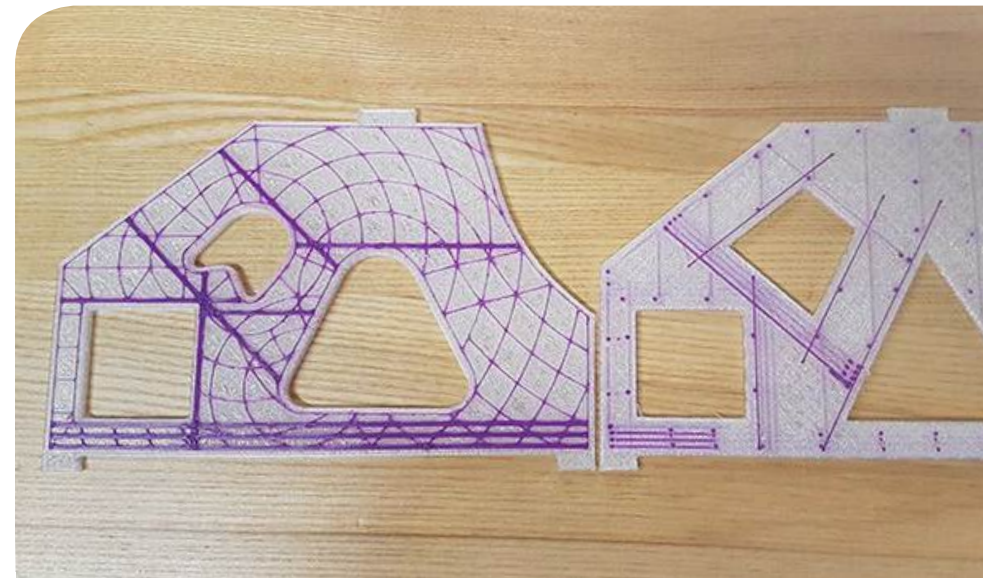
Silveira says these techniques can be applied to a variety of structures, anywhere in the world. “We’re aiming to produce entire buildings, tall buildings, metal buildings,” he says. “When you’re using artificial intelligence to design the position of the structural elements, you can go very far.”

These types of innovations could lead to a world that looks physically quite different, as the architecture will be driven partly by algorithms supplying choices that wouldn’t be possible through traditional design practices.

“In the future, we can use this approach to decide the architecture and the position of the elements, so the shape is going to be very different from today and the performance is going to be way better,” Silveira says. “Once we can work with thousands of solutions, we can find the points where we’re trying to improve the performance and decrease the amount of material.”

As 3D printing and robotics make construction faster, generative design will reduce materials and create new paradigms to make building components better. Projects such as Hone Structures are ticking all the boxes to give construction a new, sustainable lease on life. 🏗️

Small-scale deep-beam samples, designed with different constraints but using the same method. Courtesy of Hone Structures.



Many hurdles must be cleared for new technology to succeed—especially in traditional industries like construction. For 3D printing to disrupt housing, building codes have to get on board.

A BRAVE NEW WORLD OF CONSTRUCTION 3D PRINTING NEEDS BRAVE NEW BUILDING CODES

BY MATT ALDERTON

Building codes have a storied history and largely have been established only after tragic events such as the Great Fire of London, which destroyed swaths of the city in 1666. Since then, codes have been enacted to make buildings more fire resistant, for example, or to increase public safety in dense urban areas (something especially relevant during COVID-19).

In the United States, the first national building code was established in **1915**, and a winding path of municipal, state, and even international codes has persisted ever since.

Apis Cor 3D-printed wall structures for an administrative building in Dubai. Courtesy of Apis Cor.



Apis Cor

NUMBER OF RESIDENTS: 5

LOCATION: Boston

LENGTH OF RESIDENCY: 2 years (ongoing)

GOAL: To develop 3D-printed wall structures that are comparable to masonry to comply with building codes and to research how to 3D-print horizontal structures.

This dizzying world of building regulation now has a new challenge: assessing new technologies in the construction industry. With the promise to revolutionize building, 3D printing makes the process faster, cheaper, safer, and more sustainable—that is, if builders can successfully negotiate with building officials, whose most pressing concern is: How can we be confident that 3D-printed buildings are safe?

According to Anna Cheniuntai, founder and CEO of Boston-based **Apis Cor**, which manufactures specialized 3D printers for the construction industry: “3D-printing technology is very innovative and very disruptive, and the construction industry is a very conservative industry. Because of that, it’s hard to implement 3D printing in the real world. Our biggest challenge today is creating standards so that building officials and authorities can easily certify the process and issue building permits.”

Apis Cor and structural engineering firm **Thornton Tomasetti**—both residents at the Autodesk Technology Center in Boston—have partnered to create an industry standard for 3D-printed walls, which they hope will be the first step toward creating future-focused building codes.



Internal walls made using a 3D-printing process. Courtesy of Apis Cor.

Pursuing Precedent

Apis Cor has demonstrated the merits of 3D printing on a handful of projects since its inception. In 2016, for example, it completed what it says was the world’s first “on-site” 3D-printed **house**, built using a mobile concrete printer. Located in Stupino, Russia, the 400-square-foot circular home was erected in just 24 hours and cost approximately \$10,000 to build—a fraction of the approximate \$50,000 and eight months that Habitat for Humanity spends building a 1,050-square-foot, three-bedroom home.

Subsequently, in October 2019, Apis Cor completed 3D-printed walls for a two-story government building in **Dubai**; at 31 feet tall and more than 640 square feet in area, it is the largest 3D-printed building to date.

Proof of concept, however, is not the same as precedent. And precedent is what building officials require in order to sanction 3D printing at scale, says engineer Patrick Kenny, an associate at Thornton Tomasetti.

“Construction is different from manufacturing,” Kenny says. “With construction as it is today, you’re not building 1,000, 10,000, or one million of the same building like you would with manufacturing, where you can mess up the first 10 products and improve the process as you go. Each building is its own prototype, and that drives decision makers to be very conservative.”

That’s where building codes come in: By compelling builders to conform to universal standards, code officials make heterogenous buildings more homogenous. In so doing, they mitigate risk by turning completed buildings into precedents for future ones.

The challenge with new technology such as 3D printing is that there is no precedent. Or is there?

To make code officials more comfortable with 3D printing, Apis Cor is focusing exclusively on 3D-printed walls; its design mimics traditional concrete masonry unit (CMU) walls, complete with hollow cores

The dizzying world of building regulation now has a new challenge: assessing new technologies in the construction industry.

A 3D-printed structure takes shape. Courtesy of Apis Cor.





At 31 feet tall and more than 640 square feet in area, the government building in Dubai is the largest 3D-printed building to date. Courtesy of Apis Cor.

for rebar. Although 3D printing can enable radically new forms, Apis Cor believes the key to legitimizing new building methods is seeking common ground with traditional ones.

“We believe that if we can prove the structural similarity between our walls and masonry walls, it will simplify the permitting process because building officials will be able to look at the rules and building codes for masonry,” Cheniuntai says. She adds that Apis Cor’s approach allows builders to use their proven construction techniques for roofing, foundations, and so forth already in use for traditional masonry construction.

Thornton Tomasetti

NUMBER OF RESIDENTS: 3

LOCATION: Boston

LENGTH OF RESIDENCY: 2 years (ongoing)

GOAL: To experiment with milling or “sculpting” 3D-rendered images onto slate pieces that were saved during the renovation of the public library in Weston, MA; and to explore how this technique could be used to create custom detailed masonry and stone facades. (Thornton Tomasetti also partnered with Apis Cor on its 3D-printing project.)

Instead of envelope-pushing materials such as carbon fiber or bioplastic, Apis Cor veers toward familiar favorites such as concrete. Although regular concrete would not be suitable for 3D printing, the company has developed a proprietary recipe with the same ingredients—water, sand, and cement—plus a secret component that gives it high viscosity and a fast setting time.

“We understand that as a first step, we should be very familiar with the popular materials that are already used in construction,” Cheniuntai says. “Then, later on, we can introduce new materials.”

Cracking the Code

Of course, 3D-printed walls that look like masonry are only effective if they also perform like masonry. Apis Cor has been working with Briggs Engineering and Testing and the University of Connecticut to run its walls through the same battery of American Society for Testing and Materials International—certified **tests** that CMU blocks are subject

to, including evaluating strength, resistance, flexion, and compression.

“You can take a CMU block and crush it in a machine to measure how strong it is,” Kenny says. “A piece of 3D-printed wall that’s the exact same size receives the exact same test.” According to Kenny, Thornton Tomasetti is reviewing test results for Apis Cor and translating them into a document that can be shared with building officials. “What we’re trying to do is show that this new material meets all the requirements of an existing, very comparable building code, which is the CMU code,” he says.

Apis Cor plans to flex its empirical evidence on two upcoming demonstration projects. The first will be a 3D-printed two-story **home** in Jackson, LA. The second will be a 3D-printed affordable-housing **project** in Santa Barbara, CA, with the Housing Trust Fund of Santa Barbara County. Both projects will undergo the standard permitting process, showcasing both 3D-printing technology and its governance.

“What you want to do is win over a few people in a few locations, at which point there will be a precedent showing that you’ve built these buildings before,” Kenny says.



3D-printed wall structure. Courtesy of Apis Cor.

Although the promise of 3D-printed homes—fast, affordable housing—is compelling, the journey is difficult. Still, it’s vital.

Initial projects will be starkly simple. Over time, however, Apis Cor plans to introduce additional prototypes with more complex geometry—which will then have to win favor with building officials.

“Right now, we’re latching onto the CMU code, which is fairly rigid, because it’s easily understood and has very exact requirements,” Kenny says. “Eventually, though, I see 3D printing becoming part of the cast-in-place concrete code. Because while that code has a lot of requirements in it, it’s totally free-form. It doesn’t place any

restrictions on geometry, and that’s where you want to get to with 3D-printed concrete.”

Although the promise of 3D-printed homes—fast, affordable housing—is compelling, Apis Cor admits that the journey is difficult. Still, it’s vital.

“Our goal is to fill the affordable-housing gap, and we believe we can do that—but not until we figure out how to get approvals and permits,” Cheniuntai says. “When it comes to scaling this technology, that’s the most challenging part.” 📌



William Maluki works on creating his CNC pipe-bending machine in residence at the Autodesk Technology Center's fabrication workshop in San Francisco.

The Jua Kali of Kenya are craftspeople who, through improvisation and ingenuity, keep the country running. Will adding a simple machine help preserve these vital manufacturing jobs?

ONE MAN, HIS MACHINE, AND A MISSION TO TAKE KENYA'S MANUFACTURING JOBS TO THE NEXT LEVEL

BY KIMBERLY HOLLAND

In Kenyan towns large and small, an informal network of craftspeople, autoworkers, and small-scale manufacturers keeps the country's economy quietly humming.

These fixers and makers create and build whatever's needed, often with limited resources. Called the **Jua Kali**, this group of versatile artisans is a vital and growing element of the Kenyan economy, but mass producers and cheap goods from Europe and Asia are threatening their way of life.

William Maluki

NUMBER OF RESIDENTS: 1

LOCATION: San Francisco

LENGTH OF RESIDENCY: 6 months

GOAL: To create a working prototype of Maluki's pipe-bending machine for use by the Jua Kali informal manufacturing sector in Kenya.

However, if William Maluki has his way, the future of at least one Jua Kali group will be secured, perhaps bolstering Kenya's ad-hoc manufacturing jobs for years to come.

Maluki, head of engineering at makerspace **Gearbox** in Nairobi, Kenya, is pioneering a new CNC-based pipe bender. Designed for manufacturers of metal frames—think wheelbarrows; steel-tube furniture; or seats for *matatus*, Kenya's fleet of privately owned minibuses—this machine will allow makers to create identical frames in less time with precise and consistent output.

"The philosophy is, if the process quality is secured, then the product quality is guaranteed," Maluki says.

Jua Kali is Swahili for "fierce sun"—an homage to the fact that many of these tradespeople work along busy roadsides, often without a formal shop to shield them from the intense rays bearing down from above. A Jua Kali manufacturer can be one person or a small collective of people producing one-off or small-scale batches of products.

Many of the makers in the Jua Kali sector learn from hands-on experience earned through years of working alongside other makers

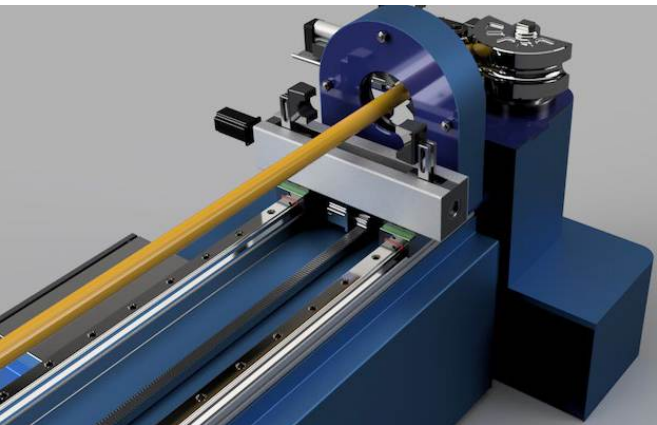
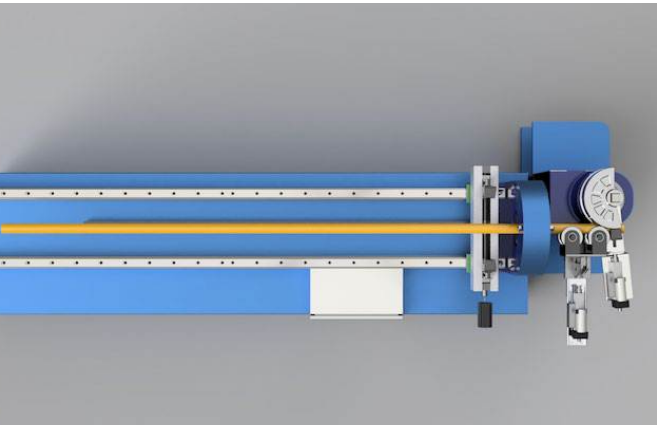
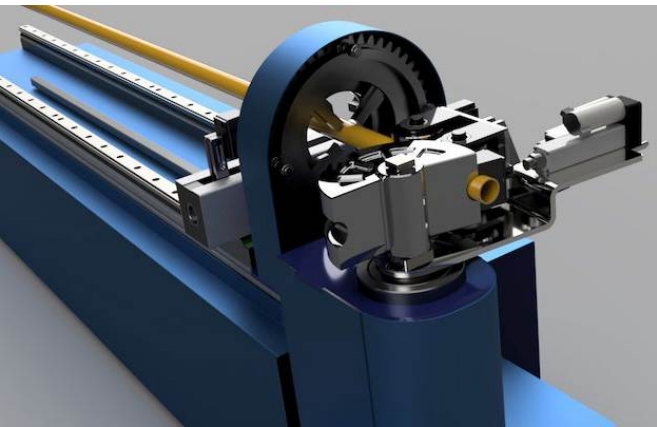


A Jua Kali worker in Kenya uses a homemade welder. Courtesy of Erik Hersman—CC by 2.0 license.

rather than from formal education or training. Their profit margins are small, but in a country of more than 48 million people, this group manages to make a modest living.

Better Equipment, Better Results

Many of the Jua Kali lack sophisticated equipment—a luxury few can afford. While not entirely rudimentary, the tools at their disposal are light-years away from the CNC machines, 3D printers, and Haas mills of Europe, Asia, and America. In turn, their products are often satisfactory and inexpensive but are sometimes seen as not only economical but



Unlike most pipe-bending machines today, Maluki's machine will be completely electric. Courtesy of William Maluki.

also of lower quality, and they can't always compete with imports.

But with Maluki's pipe-bending machine, these small businesses might soon be more competitive with large-scale mass producers, making a profit and keeping an important economic aspect of Kenya alive.

"For somebody in the Jua Kali sector, when you're talking about minimum economic order quantities, it doesn't really apply," Maluki says. "They need a machine that allows them the flexibility to produce 10 pieces of an order of their making—at rather the same quality and cost as they would do if they were going to produce maybe 100 of them. I'm trying to give this Jua Kali sector of workers a means, an affordable means, to manufacture whatever it is that they manufacture in huge quantities, cheaply and in repeatable quality."

Jua Kali is Swahili for "fierce sun"—an homage to the fact that many of these tradespeople work along busy roadsides, often without a formal shop to shield them from the intense rays bearing down from above.

In 2018, Maluki spent four months designing and building his pipe-bending machine at the Autodesk Technology Center in San Francisco. There, he was able to take advantage of state-of-the-art prototyping equipment and collaborate with experienced staff and industry leaders through feedback sessions organized by the Technology Center and **Autodesk Foundation** management to hone and shape his pipe-bending prototype.

The machine, which will have CNC 3D-bending capability, takes in user parameters, including

various design measurements, and then outputs a real-time graphical render of the pipe as it will be bent. Most pipe-bending machines today are largely hydraulic and difficult to maintain, but Maluki's machine will be completely electric, which is important to fit into the Jua Kali business model.

"The hydraulic machines are also driven by electricity, but my goal is to build a completely electric pipe-bending machine," Maluki says. "Introducing hydraulics means additional maintenance, and that increases the complexity. I wanted to simply design and make a machine that is purely electric and mechanical."

Plus, to be an economically accessible option for the Jua Kali, who often work barely above profit margins, Maluki says his machine will charge by the bend, not by the batch of items.

"The ballpark figure is 50 shillings, which is about 5 cents US per bend," he says.

Maluki plans to harvest the data from the machine's computer to create the second generation of pipe-bending machines to help the Jua Kali and other makers produce more quickly and inexpensively. The data will also allow for customization so the artisans can produce products with even more speed and savings. (Since this article was first published, the pipe-bending machine has been made available for use as part of



A worker takes advantage of the advanced tools available at the Gearbox makerspace in Nairobi, Kenya. Courtesy of Gearbox.

Gearbox’s membership fee. Maluki is currently in the early stages of producing four new pipe-bending machines based on the original design.)

Success Means Building Trust and Creating Jobs

Back in Kenya, Maluki is one step closer to delivering his dream to the people he’s aiming to serve.

“They’re very creative and very resourceful people,” Maluki says of the Jua Kali. “Since a majority of them are youth—and I categorize myself as a youth, too—if these people are empowered, they are the best bet to actually drive this country ahead because they are the masses, so to speak.”

Success for Maluki won’t come when he gets his first pipe-bending machine up and running. It won’t come even when he’s placed 100 machines in shops.

Instead, he says, it will come when someone a lot like him—a creative thinker with a great idea—tries something unique and discovers an all-new way to use this machine that Maluki has spent so many hours thinking about, creating, and building.

“The longer impact that I hope this will have: People will start trusting the wares that are made by the Jua Kali sector a lot more,” he says. “Then, in the future, they will command a bigger market share in the economy and create the all-too important jobs.

“But real success for me will be for them to surpass or rather to invent new products that I did not even envision as a creator of this machine,” Maluki continues. “When they suddenly have access to a tool that can do wonderful things they’re not able to do with the tools they already have, because somebody sees the opportunity and creates new products to leverage the capacity of the machine—that will be success for me.”

Learn how Tarkka, a husband-and-wife engineering team, puts big-factory processes into the hands of small-to-midsize manufacturers and makers through distributed manufacturing.



Redshift
by AUTODESK

Courtesy of Gabriel Joffe.



The architecture industry is largely failing to address a growing global problem: water scarcity. See how the innovative work of four architecture students is bucking this trend.

FOUR ARCHITECTS ARE GOING AGAINST THE TIDE TO SEEK GLOBAL WATER SOLUTIONS

BY MATT ALDERTON

Water covers 70% of the Earth's surface, constitutes three-quarters of the human body, and is essential for everything from sanitation to agriculture. Water is critical—and it's in crisis.

According to global nonprofit Water.org, 844 million people **lack access** to safe water. Repercussions include higher disease and mortality rates in communities without sufficient water, poor education outcomes in communities where children miss school to collect water for their families, and increased poverty in communities where adults have to choose between finding work and finding water.

Institute for Advanced Architecture of Catalonia

NUMBER OF RESIDENTS: 4

LOCATION: Boston

LENGTH OF RESIDENCY: 1.5–2 months

GOAL: To produce architectural research projects that focus on global water solutions, discovering new ways to harness and protect this resource.

The problem is only **growing**, according to the World Resources Institute: As many as 3.5 billion people could experience water scarcity by 2025, due to increasing pollution and climate change. Global solutions are urgently needed, and architects have the unique opportunity to make a positive impact as built environments are intrinsically linked to water resources.

Four architecture students from the Institute for Advanced Architecture of Catalonia (**IaaC**) in Barcelona, Spain, are doing exactly that. As participants in the Residency Program at the Autodesk Technology Center in Boston, each fellow executed an architectural research project for which water was a major theme. Collectively, these future architects are showing new paths to harness and protect this invaluable resource.



Elliott Santos developed a novel cladding system that could be applied to building facades to provide passive wastewater treatment. Courtesy of Elliott Santos.

As many as 3.5 billion people could experience water scarcity by 2025, due to increasing pollution and climate change.



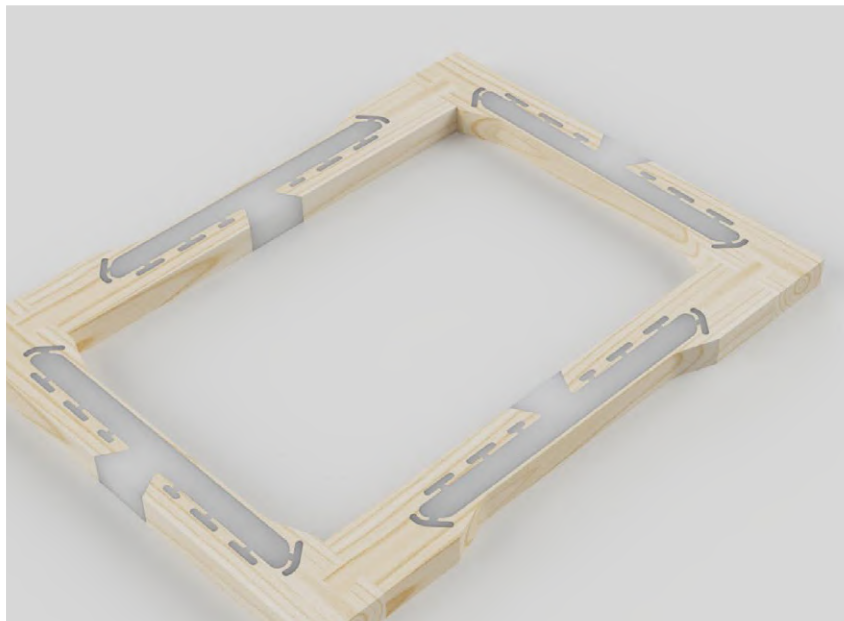
A Bridge to the Future

IaaC student Lars Erik Elseth has seen firsthand how new approaches in architecture can adapt to changing water needs. Originally from Scandinavia, Elseth grew up visiting his family's cabin in rural Norway. The inspiration for his research project was a decades-old footbridge that he and his family traversed to reach the cabin, crossing a river that swells each spring with snowmelt.

“Over the years, the bridge had been damaged from blocks of ice maneuvering their way downstream,” Elseth says. “The structural performance of the bridge decreased so much that it finally collapsed a couple of years ago.”

To replace it, Elseth conceived a flexible footbridge with soft silicone joints between dimensional lumber, which are assembled into an **auxetic** system: a system of joints that become wider when stretched and thinner when compressed, allowing the bridge to bend in response to rising water levels.

Elseth used Fusion 360 to simulate the joints' performance and improve his design, using a small prototype he constructed using a CNC machine. “Traditionally, water has been something you tried to escape or protect yourself against,” he says. “Instead of working with water, you'd isolate yourself from it or make everything waterproof. In my case, I'm using water as a force to generate the flexible movement in my bridge.”



Views of the flexible footbridge prototype: A bridge segment with structural cell units and other detailing. (above) A cell unit that can absorb horizontal forces. (left)

Courtesy of Lars Erik Elseth.

A Plastic Disaster Solution

More than eight million tons of plastic are **dumped** into the world's oceans every year, according to Plastic Oceans International. The Ocean Conservancy says this debris threatens marine life and can leach harmful chemicals into surrounding waters.

Gabriele Liuda Jureviciute is a Lithuanian IaaC student who designed a solution that encourages recycling plastic into architectural elements to improve livability in areas affected by mismanaged plastic waste. Her process begins with collecting, cleaning, and sorting plastic waste; then shredding it with a shredder from **Precious Plastic** (a global community that designs and builds open-source machines for plastic recycling); and finally, the plastic is melted and assembled by local communities. The approach intends to involve citizens in the recycling process, generating new value for the material as well as building social and environmental capital.

“What I found is that if you end up with a tile that’s at least one centimeter thick, it can withstand an amount of pressure higher than 900 kilopascals, allowing the design of a durable tile system for housing,” says Jureviciute, who spent her summer residency testing ways to manufacture and install the tiles. She’s applying her design toward emergency housing in Indonesia: sustainable shelters built with bamboo scaffolding, clad in recycled-plastic tiles. The shelters are low-cost, accessible, and secure, intended to house people displaced by natural disasters. Once they’ve served their temporary purpose, the tiles can be recycled again into architecture or other long-lasting items such as furniture. “Once you can afford a proper house, you can still use the tiles,” Jureviciute says.

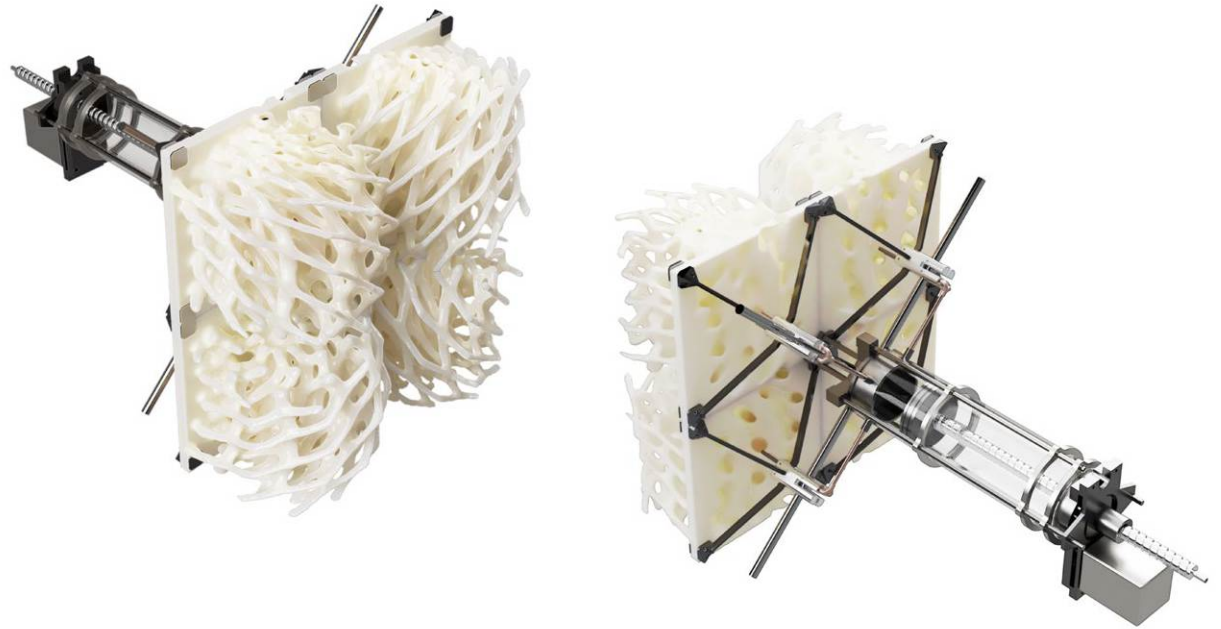
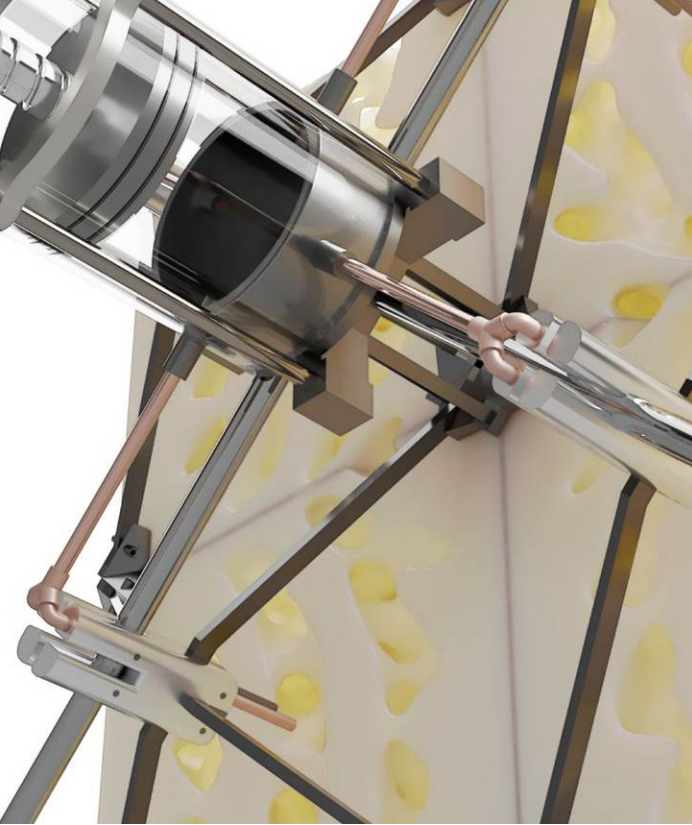


Tile mold, filled with shredded plastic. (above)

Furniture constructed with twice-recycled plastic. (right)

Courtesy of Gabriele Jureviciute.





Multiple views of a vascular-inspired lattice cladding system. Courtesy of Elliott Santos.

Wastewater for Biodiversity

The average person consumes—and wastes—a lot of water. (According to the USGS, in the United States, people use an average of **80 to 100 gallons** per day.) Consider the water that runs down your shower drain, washes your dishes and clothes, and irrigates your lawn. Although it ultimately ends up back in streams, rivers, lakes, and wetlands, it takes along harmful chemicals from soaps, detergents, fertilizers, and other pollutants.

During his residency, IaaC student Elliott Santos developed a novel cladding system that could be applied to building facades to provide passive wastewater treatment. “We don’t realize the things we’re actually putting into our water,” Santos says. “In places like Canada, where I’m from, our roads are salted so much during the winter that all the water runoff becomes super salty. That affects not only the water but also the soil.”

Santos’s solution is biological: He’s developed a vascular-inspired system of lattice structures that are 3D-printed with a biodegradable filament and then injected with a cellulose composite gel mixed with fungal spores. The resulting fungal growth naturally filters wastewater as it flows through the system from green roofs on buildings to waterways on the ground. And when the system eventually biodegrades, it becomes food for insects, which become food for birds, creating a chain of biodiversity—and cleaner waterways.

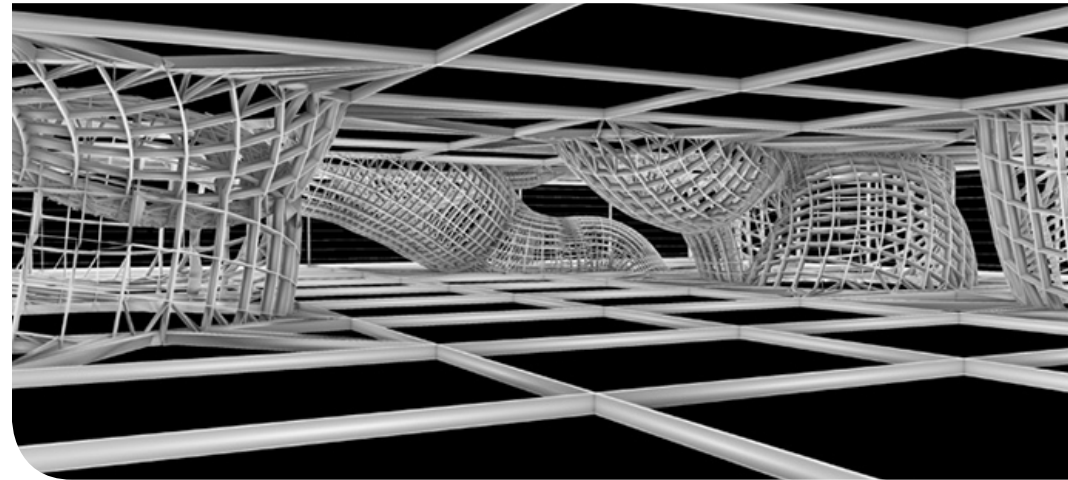
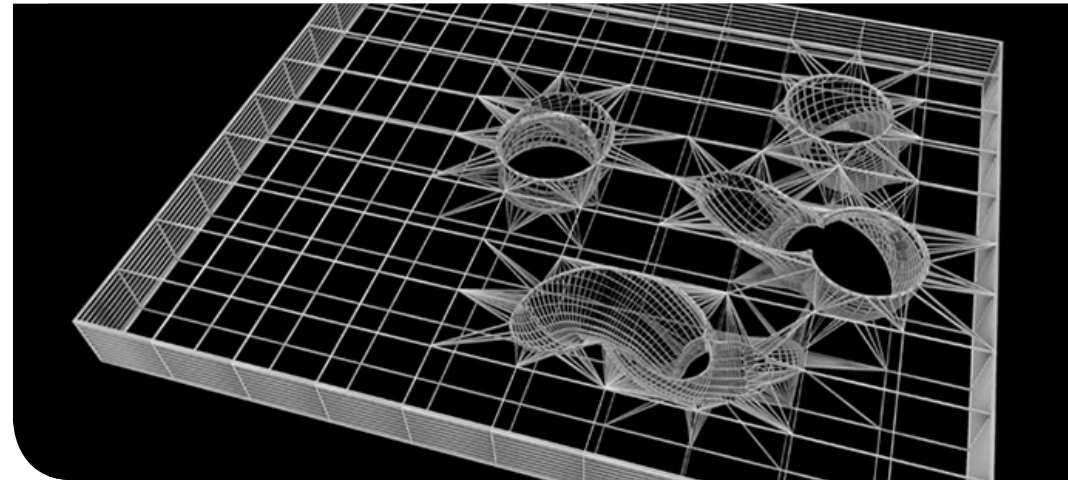
“In urban areas especially, there’s a huge gap of space and habitat for wildlife to thrive in,” Santos says. “My idea is to fill this gap by creating stepping stones that help species move through the city.”

Harvesting Blue Gold

IaaC scholar Yasmina El Helou is a Lebanese architecture student who grew up in the arid Middle East, where blue gold (water) is almost as precious as black gold (oil). “For me, water is very personal,” El Helou says. “Water scarcity is an issue I’ve lived with my whole life. It’s important to me that people understand it’s a real problem. Even if you don’t see it every day where you live, it’s happening. We cannot live without water.”

El Helou’s project was developed with dry urban landscapes in mind, focused on harvesting water in specific areas where it only exists as fog or mist. “I was inspired by the cactus and other plants that survive in dry environments,” El Helou says. Her vision is creating porous concrete tiles that can capture condensation from fog and funnel it into storage tanks for use in bathrooms and gardens. With help from the wind, water is driven from the tile to wires that will lead it to the building’s tanks.

Although she’s still experimenting with tile shapes and concrete blends, the project already has demonstrated what’s possible when architects think as much about function as they do about form. “Architecture now is about more than building a house or a mall,” El Helou says. “It’s about designing something for people that can help them in the long term. I’m not a scientist, but I have so many tools at my disposal that I can design something that helps scientists do scientific things. I believe that is our responsibility.” 🇩🇪



Two views of a sketch that demonstrates concrete tiles with channels. Courtesy of Yasmina El Helou.



COVID-19 exposed cracks in global food systems—but food science and technology start-ups are on the case. Learn how rethinking old methods may finally bring agriculture into the 21st century.



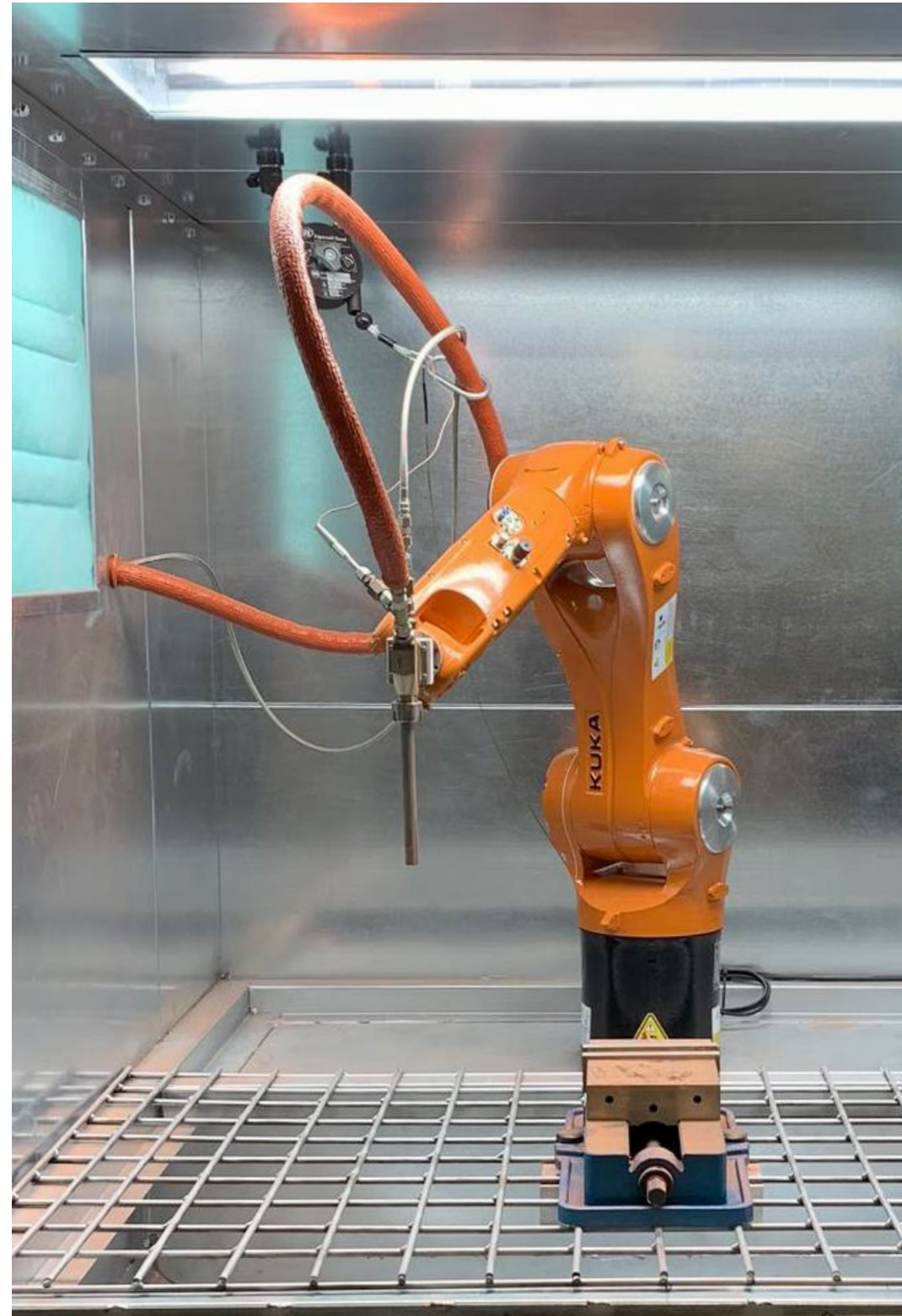
A San Francisco Bay Area start-up hopes to fulfill the promise of metal additive manufacturing with its cold-spray technology.

MANUFACTURING “LIVING METALS” WITH COLD-SPRAY TECHNOLOGY IS ROCKET SCIENCE

BY DREW TURNEY

The promise of metal additive manufacturing hasn't quite matched its initial hype. Costs are still high, and the tech remains best suited to fabricating low-volume, high-complexity parts. In short, it hasn't been the anticipated boon to industrial manufacturing yet—so using a rocket engine to spray and bond metal particles onto existing machine parts might seem a little like overkill.

The Tri-D Dynamics TerraForma machine uses a small rocket engine and heated nitrogen to project metal powder at supersonic speeds. Courtesy of Tri-D Dynamics.



Tri-D Dynamics

NUMBER OF RESIDENTS: 5

LOCATION: San Francisco

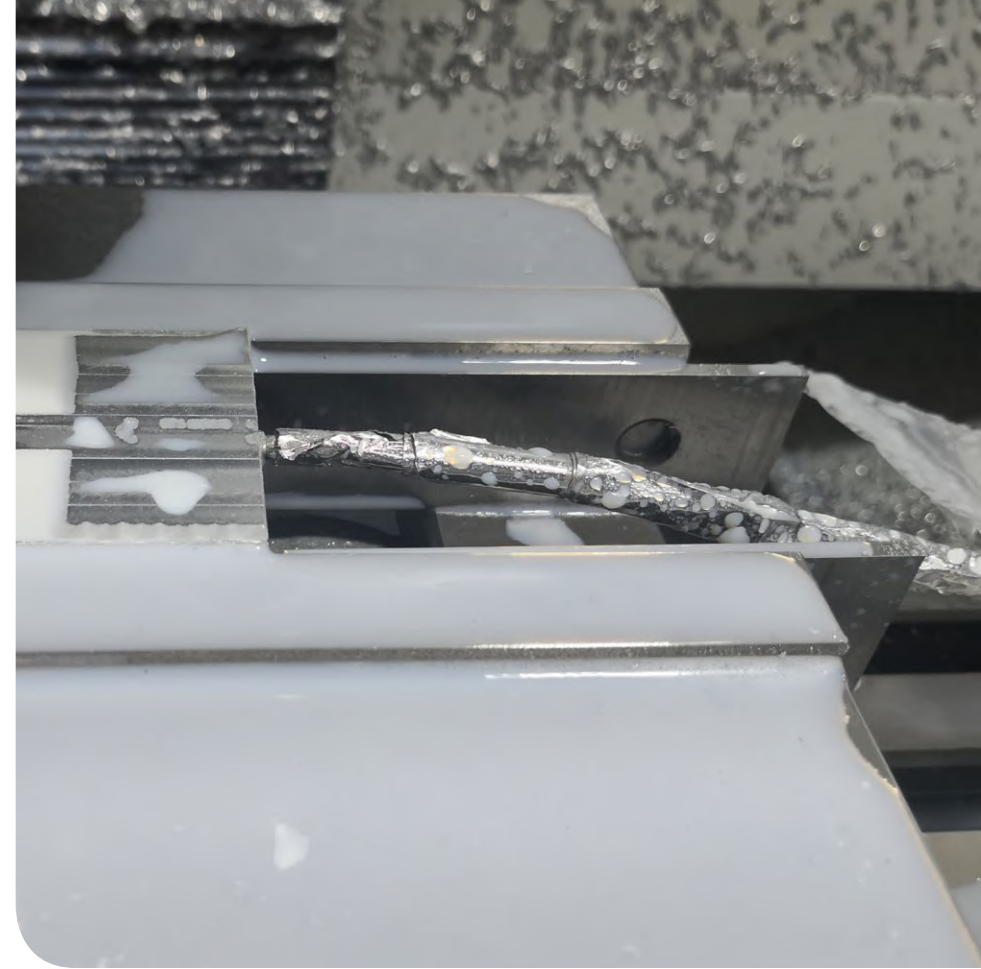
LENGTH OF RESIDENCY: 2 years (ongoing)

GOAL: To develop the Cold Metal Fusion 3D printer, using the workshop tools to prototype multiple iterations of the machine.

A Bay Area trio with a unique start-up idea may be changing all that. Cofounder engineers Deepak Atyam, Alex Finch, and Jesse Lang of **Tri-D Dynamics** have developed what they call “cold metal fusion,” which combines powder-based metallurgy with rocket science—and perhaps will open an untapped market in the process.

Tri-D Dynamics is developing a way to embed electronic sensors within metal machine parts, fortifying and protecting them from harsh environments by spraying the optimal material over them to prevent damage. Or as Finch puts it, “We can protect the electronics with a metal stronger than the metal from the part itself—getting more performance for a lower cost.” Seamlessly integrating structural hardware with the electronics required to activate them makes the parts “smart.”

The company does that through what it calls “augmented additive manufacturing”—building one metal on top of another and improving a machine part’s overall capabilities. Using cold metal fusion means the metal doesn’t need to be melted to be applied, so there’s no heating



Tri-D Dynamics' spray technology combines powder-based metallurgy with rocket science. Courtesy of Tri-D Dynamics.

damage to sensitive internal components like electronics. The whole process is also much faster. Essentially, Finch and Atyam are engaging in Internet-of-Things infrastructure, embedding sensors that report back on the performance of parts in real time. Cables, sensors, and chips are protected inside conduit spaces by using the cold metal fusion of other metals to cover, situate, and protect them. (Since this article was first published, Tri-D Dynamics has renamed its technology “smart metal fusion,” which encompasses the spray technology as well as other advanced manufacturing techniques.)

Tri-D's machine, the TerraForma, uses heated nitrogen to project metal powder through a small rocket engine and nozzle, accelerating the powder and spraying it at supersonic speeds directly onto the substrate. It bonds immediately and without having to heat or melt it for shaping. And the process is exponentially scalable—think of augmenting container ships, skyscrapers, shipyard cranes, and more.

Humans have long built machines to work in mines choked with dust, deep below the sea with saline corrosion and freezing temperatures, and in the radiation bombardment of space. Those are the kinds of places where breakdowns and failures can

be very expensive (if not dangerous) and where smart usage of equipment, informed by data, can save a lot of trouble in advance.

“If I want to drop the cost of operations, one of the biggest costs is tools breaking down and replacing them,” Finch says. “Maybe it’s only designed to operate in a certain temperature for a certain amount of time. If I don’t know the temperature of the part and its environment, I don’t really know if I’m getting close to its breaking point or not.”

Researching Next-Gen Solutions

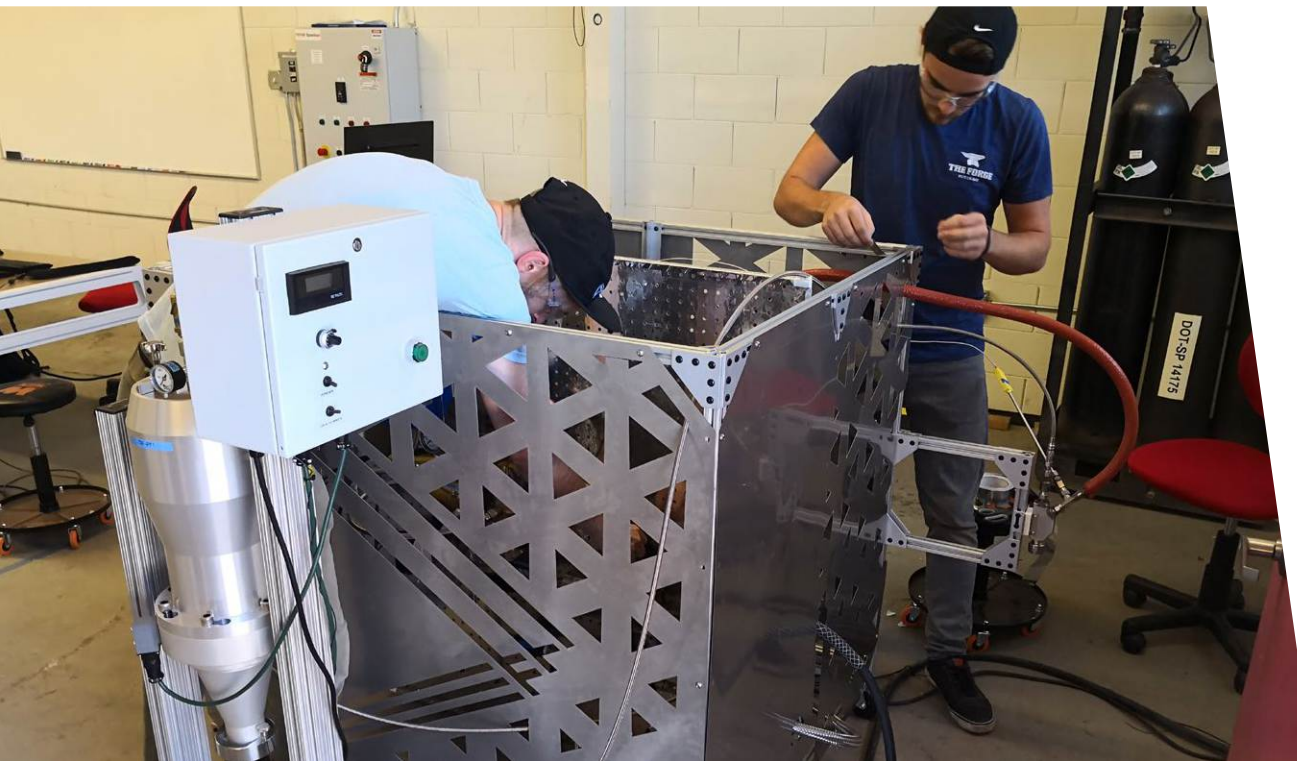
Finch's college thesis covered additively manufactured materials, and Atyam and Lang come from the aerospace-engineering world. After joining up at the University of California San Diego, Atyam and Finch were the first university team to accomplish the “impossible” task of a 3D-printed rocket engine test and flight. They got a lot of attention from the aerospace community when they succeeded.

Finch and Atyam then waded into the world of start-up capital, business plans, and market intelligence. The intended aerospace market didn't pan out, but they soon realized the potential of augmented additive manufacturing: rocket engines building things on other things by spraying powdered metal at high velocity.

Tri-D was part of the residency program at the Autodesk Technology Center in San Francisco, where Atyam (CEO), Finch (president), and Lang (VP of operations) had the opportunity to rapidly iterate and collect the data needed to build the best possible machines.

“We're looking at integrating sensing capabilities—your nerves, the ability to touch and feel and respond—into mechanical systems,” Atyam says. “How do you know what your robot or part is feeling? How do you know what your drill bit is feeling? If you can have the nervous system of each of these sensors tell a brain what's going on, you can adapt to the proper conditions.” He goes as far as calling this principle “living metals.”

Gas from a tank goes into the TerraForma, where it's heated in order to force powdered metals through the nozzle. Courtesy of Tri-D Dynamics.



The Future Is Meltless

It starts with tanks of a gas (currently nitrogen) and a supply of metal powder. They're fed into the relevant chambers of TerraForma, where the gas is heated, forcing the powdered particles through an aperture at high speed.

"You don't need to get it to melting temperature like in a lot of additive and general metal-fabrication technologies," Atyam says. "What you do is shoot the powder out at such a high speed that it deforms, flattening like a pancake and adhering to the substrate. It's the ductility and elasticity of metal particles rather than their melting point that counts."

Working with harder metals requires increasing the spray velocity to achieve the pancaking effect. Higher gas temperature—for higher pressure and a faster spray—is the only real cost variation. Each layer of sprayed material presses down and compacts the layer beneath, resulting in a very dense, strong material.

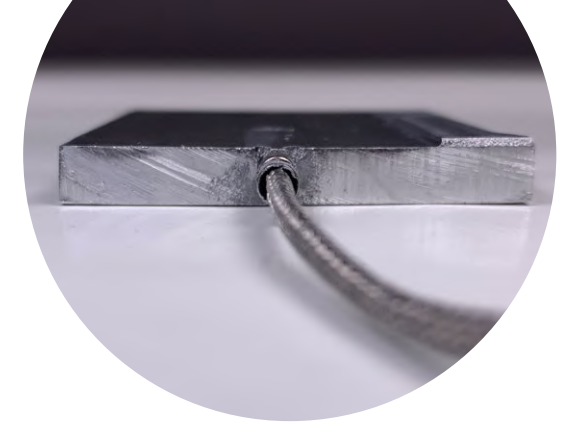
"We're looking at integrating sensing capabilities—your nerves, the ability to touch and feel and respond—into mechanical systems."

—Deepak Atyam, CEO, Tri-D Dynamics

It's scalable downward, as well, theoretically usable in a handheld mechanism. Similar in use to electroplating, only much faster, there are no toxic by-products or extreme temperatures. With negligible cooling, it's ready instantly, without the defects from heating and cooling that have plagued manufactured metals for hundreds of years.

With more funding, Atyam thinks the workability (and price) can come down. Currently, the gas is delivered in tanks from a commercial supplier—a cost that could be ameliorated with attached gas delivery in the system. The Tri-D team also moved to nitrogen from previous iterations that used helium, reducing costs to as little as a tenth of what they were. "Costs are driven by the material," Atyam says.

The end result of a sensor being embedded with cold metal fusion. Courtesy of Tri-D Dynamics.



"Harder metals like carbides are more expensive because you have to shoot them faster and use more gas and heat to do so."

The Sky's the Limit

So what's the future of rocket-aided additive manufacturing? Will Tri-D Dynamics provide parts across industries?

"We embed sensors in metal to protect them, which is best for industries that operate in harsh environments," Atyam says. "That's a starting point. From there, we want to make better sensors that are more suited to the process. We'd make parts that actually come with the full sensory network in them and provide the ability to control them."

Tri-D's three cofounders are also big proponents of smart cities, and as sensors in everything—roads, buildings, cars, trains—create vast new data sets, standing on the bleeding edge of smart technology will be crucial.

Building sensors and data technology into hard metal parts grew from a need Tri-D Dynamics tapped into organically; customers and research drove the technology. "We're trying to get real-time, critical data from the infrastructure back to the operators," Atyam says. "That's the idea of optimizing huge systems and reducing the wasted time, money, and environmental resources if they aren't."

And with huge energy production, aviation, and city systems all needing optimization to cut costs, save time, and create a smaller environmental footprint, there's no better time to shape the future by spraying metal particles through a rocket. 🚀

TAKEAWAYS

Innovative ideas have a better chance of becoming tangible solutions when collaboration is involved. Diverse perspectives, fresh ideas, and new information all help drive initial concepts to even greater outcomes. The work of the residents of the Autodesk Technology Centers is proof of how collaboration fosters innovation.

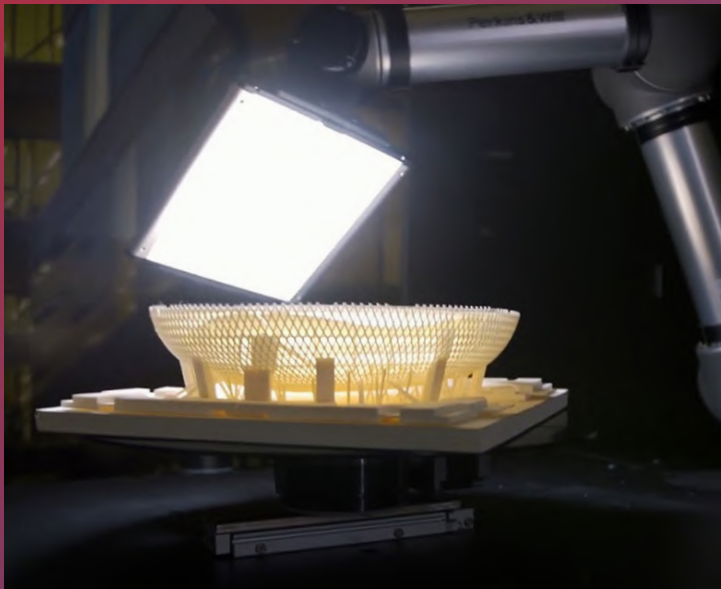
Autodesk residents—pioneers in architecture, engineering, and construction, and design and manufacturing—are working to solve the world’s most critical social, environmental, and economic problems.

They’re seeking new ways to design for impact, such as devising safer modes of medical transportation in low-resource settings, creating safer and more sustainable buildings, and exploring solutions to global water scarcity.

They collaborate with a wide network of innovators from the industry, academic, and entrepreneurial communities, as well as in-house research and product teams, to help them elevate and refine their ideas—and bring them to life.



Learn how Autodesk Technology Center residents are using robotics to help shape the future of architectural design—on Earth and beyond.



Merging Robotics and Architecture, MRAAD Will Change the Future of Building

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