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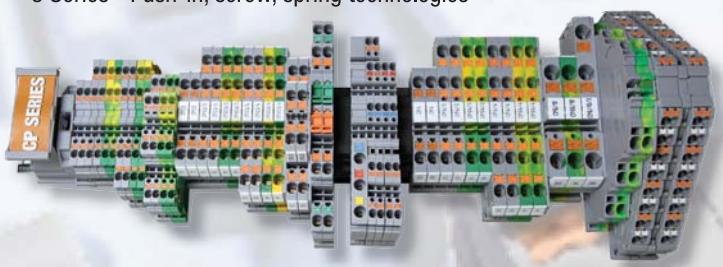

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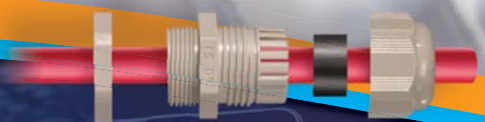

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From the Editor

By Rehana Begg, Editor-in-Chief

Inventive Problem Solving

WHEN I JOINED *Machine Design* three years ago, my No.1 goal was to expand my knowledge of engineering best practices and its relationship to the manufacturing industry. To succeed, I would need to lean on my teammates for guidance and embed myself in the industry by latching onto real-world engineering examples worthy of sharing with our audiences.

Today, with a healthy dose of humility, I proudly accepted the invitation to write the editor's note for *Machine Design*'s first issue of 2023. Those in my immediate sphere of influence know my commitment and hold the bulk of my gratitude.

My path to this moment is no fluke. The seeds were planted many years ago. As an MBA student, I took a course entirely devoted to The Theory of Inventive Problem Solving, or TRIZ. As a systematic approach, it provides a suite of tools for recognizing contradictions as they arise and solving them without compromise.

Students were asked to use TRIZ to solve engineering problems, such as designing a fan without blades (Dyson did that!) or redesigning a muffler to reduce noise. I learned that building off other ideas is a tried-and-true method of problem solving—and it inspires creativity. I was intrigued.

The notion of gaining access to others' ideas and connecting the right things to solve new problems has a storied history. Back in 1675, Sir Isaac Newton wrote his famed line, "If I have seen further it is by standing on the shoulders of giants." It was addressed to physicist Robert Hooke, with whom he had an intense correspondence about gravitation.

Contemporary concepts such as the metaverse and digital twins arguably can be equated to Newton's 17th Century imagined ideas of mass, gravity and velocity, which we now take for granted. The concept of digital twins (explored in "Digital Twins: Designing Virtual Replicas of Infrastructure Projects" on p. 24) is an example of an invention that is building on itself, with each digital simulation rendering a smarter version of a product or system that is greater than the sum of its parts.

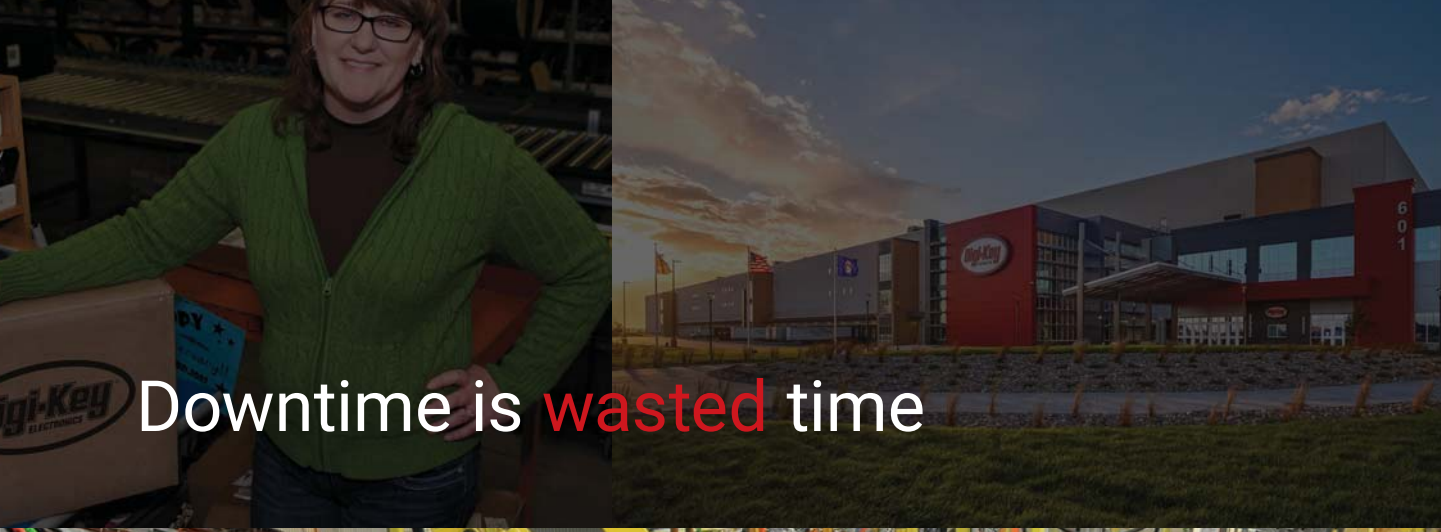
Building on past innovations to develop current technologies turned out to be a common thread among the articles curated for this issue. A spotlight on the space economy launches *Machine Design*'s exploration of questions and use cases on how aerospace, medical tech, semiconductor and other manufacturers are pursuing first-mover advantage in the private sector. SpaceRyde ("Engineering Sustainable Rocket Launches from a Balloon," p. 12) has designed a rocket system that uses a stratospheric balloon (not a new invention) to bypass 99% of the atmosphere before the rocket launches from a proprietary rocket carrier.

At the moment, the space economy generates most value by enabling activities on Earth. But thanks to greater access, lower costs and innovation—notably in computer-aided design and 3D printing, artificial intelligence and autonomous robotics—business and engineering services in orbit may be at the tipping point.

One notable effect of latching onto the many ways science and technologies are reshaping engineering is that it also amplifies our awareness of the societal effects. Turn to p. 8 for recent insights into an American Society of Mechanical Engineers (ASME) report on the general shift towards design for manufacturing, and how new workflows, roles and skills will foster Industry 4.0 business outcomes.

There is a lot to explore, and I hope this issue inspires and provokes.

Your feedback ensures our relevance. Reach me at rbegg@endeavorb2b.com. ■



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Transform Manufacturing Education to Boost Productivity

If the findings in a recent American Society of Mechanical Engineers (ASME) study hold sway, the manufacturing industry must inspire a unique mix of employees and skill sets in order to stay competitive in a changing market that demands intelligent and sustainable products.

According to the report, *Future of Manufacturing: New Workflows, Roles & Skills to Achieve Industry 4.0 Business Outcomes*, emerging technologies—including design for manufacturing (DfM), operations technology infrastructure, artificial intelligence/machine learning technologies such as generative design, integrated software platforms and centralized data management—will require new skills of mechanical and manufacturing engineers and machinists.

The research was conducted in partnership with Autodesk and is intended to provide guidance around advanced manufacturing in the future of work. The report pinpoints future workflows and skills needed for mechanical engineering, manufacturing engineering and CNC machinist roles over the next decade.

Ashley Huderson, Ph.D., director of Engineering Education and Outreach for ASME. *ASME*

The study's lead researcher, Ashley Huderson, PhD, who is also the director of Engineering Education and Outreach for ASME, said that each role will evolve separately, but that the necessary new skills applicable to all three of the roles will consist of "a combination of purposeful, common skills," including hard and soft skills, as well as interdisciplinary skills.

"We saw that there will be a shift in job function and skills around all three areas, and then there is a convergence around cloud and data platforms, generative design data analytics," Huderson told *Machine Design* during a WISE webinar.

Shifting Engineering Job Functions

As an example, she highlighted the role of the mechanical engineer, who is today primarily responsible for research, planning, design development and testing. "Most of them have at least a bachelor's degree, and some have an associate degree or no degree, in terms of hard skills," Huderson said. "We see that there's going to be this general shift towards design for manufacturing, including knowledge of the subsequent manufacturing processes, knowledge of coding, 3D modeling, data, analytics, prototyping, as well as engineering simulation. We're seeing this shift towards the incorporation of additional skill sets [for engineering technology] added to the basics of mechanical engineering."

According to the study, 60% of the industry believe interdisciplinary engineering knowledge will increase for mechanical engineers over the next five to 10 years. This finding was consistent across small, medium and large manufacturers.

Academia is conspicuous in embracing new technologies such as generative design (GD), AI/ML and augmented reality/virtual reality (AR/VR). The study showed that 80% of academics believe GD application will be an important skillset and 67% believe AI or ML will be an important product design skill over the next decade.

A similar picture unfolded for manufacturing engineers, who will blend skills with both mechanical engineers and CNC machinists. Within industry, 72% of respondents believe human-robotic interaction will increase and 74% believe automation will increase for this role, noted the report. Along with enhanced communication skills, manufacturing engineers will be expected to incorporate additive manufacturing and be adept at employing artificial intelligence/machine learning (AI/ML), digital twins and data analytics to improve throughput and efficiencies.

The role of the computer numerical control (CNC) machinist will undergo significant changes, as well. The report noted that the CNC operator role will evolve to that of an engineering technician who programs CNC machines. These technicians will likely take on additional manufacturing engineering functions as the work environment is transformed.

Cultivating Soft Skills

The data further revealed a growing focus on software tool functionality, data analytics, programming, and "smart" and sustainable design techniques is fostering an emphasis on soft skills such as problem solving and communication.

Huderson said that communication skills and other professional development skills are going to be critical in helping the upcoming workforce navigate their careers. "That includes your ability to communicate the work that you're doing and how you're doing it," she said. "We

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could do all this amazing work, but if you can't talk about it or write about it, it doesn't go anywhere. It's not shared with the field and doesn't benefit the rest of your constituents."

Certifications Over Degrees

The report, which is the culmination of surveys conducted with respondents in the U.S., Canada and UK, as well as an academic literature review and in-depth phone interviews, showed that 86% of academics not only embrace the idea that institutions should re-evaluate reliance on degrees, but they also favor specialized certifications in order to meet the changing industry demands. The majority of survey respondents (84%) noted that employers and academia should partner on new types of certification programs based on employer needs.

Across the board, the manufacturing industry is experiencing labor shortages that are expected to rise to about 2.1 million unfilled jobs by 2030, according to data compiled by Deloitte and The Manufacturing Institute.

Diversity, Equity and Inclusion

Huderson explained that some career trajectories don't require a four-year degree. "There are other valuable ways to get into the workforce and provide exposure and training into that skill set," she said.

On-ramps through certificates and technical training, said Huderson, will "allow individuals who normally may not have been at the table for various reasons, to come to the table with their solutions and their work."

She added that this is particularly relevant for women and other identities that have been excluded historically from engineering and science. "Obtaining a degree has at times been a barrier for exclusion," said Huderson. "Having financial and physical access to a four-year degree is not afforded to everyone."

Prompted to cast a diversity, equity and inclusion (DEI) lens over the data, Huderson explained that the study did not disaggregate the data around historically marginalized identities. "We don't speak to that in the data specifically, but those of us in this space understand the implications of this work," Huderson said.

In the grand scheme, Huderson said, the data highlights where the talent is and signals industry to consider community colleges, technical spaces and anywhere individuals from diverse socioeconomic backgrounds tend to gravitate.

Rehana Begg Named *Machine Design* Editor-in-Chief

The veteran journalist, who joined *MD* in 2019, will continue to spearhead the brand's content initiatives.

REHANA BEGG has been named editor-in-chief of *Machine Design*, effective immediately. With more than 20 years of media, content and publication experience, Begg joined *Machine Design* in 2019 as a senior editor. Since then, she has led a number of new editorial initiatives within both *Machine Design* and Endeavor Business Media.

"Rehana's skill, experience and enthusiasm makes her the ideal person to lead *Machine Design's* continuing content improvements online, in print, and across the digital landscape," said Bob Vavra, senior content director for *Machine Design*. "She is a respected voice in manufacturing, and I am thrilled to be able to amplify that voice for the benefit of our audience."

Since joining *Machine Design*, Begg has developed content across all platforms around topics such as automation, IIoT and Industry 4.0. For her efforts, she received the EBBIE award in 2020 as Endeavor Business Media's Editor of the Year. She also has led the Women in Science and Engineering (WISE) initiative, which compiles coverage on women and equity-seeking groups across STEM disciplines. Since 2015, she has been a juror for Bentley's Year in Infrastructure Awards, a global infrastructure and software implementation program that recognizes projects at the leading edge.

"Rehana's passion for the manufacturing and engineering community shines through in her work with the WISE initiative," said Michelle Kopier, group associate publisher of Endeavor's Design & Engineering Group. "Her dedication to offsetting bias and supporting diversity through elevation of unseen and unheard experts demonstrates her understanding of the long-term implications to the advancement of the industry without a diverse breadth of voices."

Prior to joining *Machine Design*, Begg spent six years with Annex Business Media in Canada as editor and content manager for the company's CanadianManufacturing.com website and *Machinery and Equipment MRO* magazine. She also worked for the *Plant Engineering & Maintenance* title at Annex Business Media. Prior to her work in manufacturing, Begg was editor of *Benefits Canada* magazine in Toronto, which received the 2013 Market Research Intelligence Association Public Policy Impact Award for a leading research initiative based on employer-sponsored pension plans.

Begg received her undergraduate degree in political science from York University in Toronto, with a post-graduate degree in journalism from Centennial College. She also holds a master's degree in journalism from Toronto Metropolitan (Ryerson) University and an MBA in project management from Aspen University.

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Engineering Sustainable ROCKET LAUNCHES from a BALLOON

How a Canadian startup has pioneered the space launch industry with its smart rocket services.

by **Rehana Begg,** Editor-in-Chief

NASA's announcement of three jump-start aerospace initiatives that would develop designs of space stations and other commercial space destinations signaled optimism for future projections to develop commercial activity in space.

Those initiatives—signed in December 2021 with Blue Origin in Kent, Wash., Nanoracks LLC of Houston and Northrop Grumman Systems Corporation in Dulles, Va.—are part of a broader plan intended to solidify U.S. commercial presence in low-Earth orbit by building the infrastructure to support development of independent space stations and to stimulate commercial activity.

Revenue generated from the global space market is expected to triple over the next 20 years to more than $1.1 trillion. As an investment theme, analysts at Morgan Stanley Research note that a burgeoning space economy is likely to impact a number of industries beyond Aerospace & Defense, including IT Hardware and Telecom sectors.

The combination of new technologies and the entry of private launch service providers is decreasing costs for launch and space hardware and is spawning a growing, quickly diversifying commercial startup scene.

AT A GLANCE:

- SpaceRyde, a Canadian startup, is building the future of space cargo transportation.
- SpaceRyde's rocket system uses a stratospheric balloon to bypass 99% of the atmosphere without depositing black particles into the ozone.
- The upper stage of the rocket, called Black Bay, will remain in orbit to fulfil future tasks, including refueling, space junk removal and de-orbiting.

By any standards across the globe, however, getting a rocket launch initiative off the ground requires a ton of resources, is bad for the environment and is costly. For companies based in Canada—which has about a 1.3% share of the global market and for the most part relies on other countries for rocket launches—crossing the threshold to join the commercial space race can be downright prohibitive.

That scenario could change with the ebullient innovations proposed by SpaceRyde, a rocket startup based in Concord, Ontario. Its intrepid founder, Sohrab Haghighat, has aspirations to realize a space transportation company that builds interplanetary logistics infrastructure.

Haghighat's vision of a "rocket network" comes with big ambitions, beginning with SpaceRyde's three-stage small satellite launcher targeted for Earth and lunar orbit missions. The startup's objective is to build a network of smart rockets that will consume less fuel than conventional rockets, reduce the environmental impact and provide a cheaper, more efficient way to transport cargo to and from space.

Hoisted From a Balloon

Haghighat landed on the idea that using a stratospheric balloon to bypass the Earth's atmosphere could help solve a host of problems, not the least of which was to provide the ESG (environmental, social and corporate governance) benefits he touts as the keystone to his mission.

The idea that a rocket could be floated through the Earth's atmosphere via a stratospheric balloon filled with hydro-

SpaceRyde's rocket system. *Machine Design*

SpaceRyde co-founders Sohrab Haghighat and Saharnaz Safari are a husband-and-wife team. *SpaceRyde*

gen gas is not new, pointed out Saharnaz Safari, SpaceRyde's co-founder and COO, and Haghighat's wife. The use of "rockoons" dates back to the 1950s when they were used to deploy suborbital atmospheric-research flights. The method was abandoned due to its unreliability.

SpaceRyde's launch platform is deceivingly simple: A balloon system is designed to bypass 99% of the Earth's atmosphere before the rocket launches from a rocket carrier and jets off to complete its mission of carrying cargo to its intended destination.

Haghighat, who holds a PhD in aerospace, aeronautical and astronautical engineering from the University of Toronto, was under no illusion that launching a rocket from a balloon would require unique design modifications to the entire system, including an overhaul of the engines.

"From the get-go, the rocket starts operating in a vacuum condition," Haghighat explained. "With that comes vacuum-optimized engines. The performance of the rocket is improved. And since the rocket does not deal with high-speed travel through dense layers of the atmosphere, stress on the structure is reduced.

Saharnaz Safari, co-founder and COO, SpaceRyde, explained that the rocket carrier, called Flying Spider, was constructed from aluminum. This is only the second version of the design and can accommodate rockets with payloads of up to 150 kg.

"In a ground-launch rocket, the vacuum efficiency is only present in the upper stage," he continued. "For SpaceRyde's rocket it is present and available to all stages and results in a generally more efficient rocket. So, not only does this become a solution that addresses atmospheric and environmental concerns, it also brings a lot of benefits with it."

Path to Orbit

The cumulative effects of light-weighting the vessel are integral to the benefits. "We are not concerned with fast travel through dense layers of the atmosphere," said Haghighat. "You don't have to deal with loading on the structure. You don't have to deal with the concept of Max Q or aerodynamic loading on the structure of the rocket. This means that the structure can be simplified. As a result, it becomes lighter."

Max Q is shorthand for maximum dynamic pressure. It is the point at which the shuttle has reached the air pressure limit and undergoes maximum mechanical stress while passing through the atmosphere.

Since the balloon lifts the rocket through the atmosphere, drag and gravitational losses are close to zero. "Gravitational loss is something you incur when you are flying against gravity," explained Haghighat. "Because we launch at a very shallow path angle—pretty much horizontally—we incur very little gravitational loss. The rocket has to provide less energy to bring the payload to orbital speed. That means the rocket gets smaller."

Although the balloon's ascent through the atmosphere takes about an hour, the actual launch can be as quick as 10 to 15 min. "With a balloon, you're peacefully bringing the rocket up to three times as high as planes fly," explained Safari. "And

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once you get to that high altitude, where it's basically near vacuum conditions and the atmosphere is gone, that's when you launch the rocket. It doesn't create noise like rocket launchers do, it doesn't create emissions like rocket launchers, nor does it deposit black particles into the ozone layer like other rocket launchers do."

Flying Spider, Hidden AI

The rocket carrier is primarily an aluminum frame that attaches to the balloon. It was dubbed "Flying Spider" after the behavior of small spiders that release gossamer threads to catch the wind and become airborne across long distances. For Safari, the name is fitting for a structure she considers to be "the heart of the operation."

The first iteration of the rocket carrier was significantly over-designed and suboptimal for scaling the rocket. It has since been reengineered to accommodate bigger rockets with payloads up to 150 kg.

The rocket carrier is reclaimable, too, as engineers are able to safely steer the rocket carrier back to Earth—with the rocket aboard. "We don't know exactly where the balloon will take the rocket—the initial location is unknown," Safari said. "The carrier points the rocket, stabilizes it and becomes the launchpad midair."

An electronic circuit box affixed to the carrier houses an array of sensors, proprietary software and microcomputers, all of which control the trajectory of the rocket from the launch position.

Haghighat said the entire navigation system was designed with simplicity in mind, as it combines off-the-shelf components, GPS and other sensors with software and algorithms. "We take advantage of advanced filtering and data fusion algorithms to come up with a navigation system that is not on par but better than what is offered by speed-rated legacy hardware, at a fraction of the cost," he explained.

Haghighat comes by his navigation knowledge honestly. He previously worked for Cruise, an autonomous car technology company, where he pedaled his academic knowledge of working with software algorithms toward becoming an expert on navigation and control systems that move things (cars and trains) autonomously. "When I was doing my PhD, I showed that when aircrafts take advantage of active control systems, they can increase fuel efficiency, or they can increase endurance by up to 21%," he recalled.

Propulsion Engineering

Relatively small by industry standards, SpaceRyde's three-stage satellite launcher, named Ryder, is equipped with vacuum-optimized gimbaling hybrid engines that can provide significantly higher performance than rockets optimized to lift off the ground.

In its simplest form, a hybrid-propellant rocket system is composed of a solid propellant (fuel) housed in a combustion chamber and a liquid propellant (oxidizer). The two fuels are stored separately, but when the two fuels are combined, a strong exothermic reaction produces hot gas through a nozzle to propel the rocket.

SpaceRyde's Grolar engine is the only hybrid engine in the world with nozzle gimbaling capability, according to Haghighat. His team employed stress testing methods and analyses to reveal an optimized design that improved the structural integrity, as well as weight and manufacturability characteristics.

In gimbaled systems, the nozzle can be swiveled to control the direction of thrust or the trajectory the rocket takes. The combustion chamber in a typical liquid engine is relatively small, as it is optimized to move the whole engine. "In contrast, the combustion chambers in hybrid engines are big, making it impossible to move the combustion chamber. It would require huge actuators, which adds to the weight, along with other requirements that are just not worth the effort."

The "trick" was to move the nozzle. "In order to do so, you need a flexible seal that joins the nozzle to the combustion chamber," Haghighat explained. "It provides the means to gimbal the nozzle, while simultaneously sustaining the temperature and pressure of combustion and making sure that it is providing a seal."

Deep Space Logistics

With rapidly growing and changing public and private space endeavors come new sustainability questions. One aspect is the space junk, or debris, floating in lower orbit. Ranging from paint flakes and discarded hardware to rocket stages and defunct satellites, this detritus is the result of launching objects from Earth.

Space junk is not motionless and pose a risk to other satellites in low-Earth orbit. Debris orbits the Earth at speeds of about 15,700 miles per hour. (That's more than 10 times faster than the speed of a bullet.)

In September 2022 the Federal Communications Commission (FCC) issued new rules requiring satellite operators in low-Earth orbit to dispose of their

Machine Design

SpaceRyde's multi-disciplinary team of engineers line up for a photo opportunity with Canadian astronaut Chris Hadfield, who supports the project through the Creative Destruction Lab (CDL) startup program. *SpaceRyde*

satellites within five years of completing their missions.

Haghighat's commitment to designing for future generations who will inherit the challenges of today is proving to be pre-emptive in heeding such regulatory realities. Ryder's upper stage (known as Black Bay) was purposefully designed to be reusable and multipurpose. "Once it completes the initial mission in space, it can remain operational and be put into other tasks and missions, such as lifting another satellite into higher orbit, or de-orbiting a malfunctioning satellite, or it can be refueled and transport something to the lunar orbit," Haghighat said.

"Not only are we are not contributing to space junk, but we are also over time building a network of rockets that are going to continuously go back and forth between the Earth and the Moon," he said. "That is the backbone of space transportation."

Cost to Innovate

In spite of all the advancements we see and hear about, technological progress in space is significantly slower than what we experience on the planet. Addressing the availability, affordability and frequency of space missions is one way to bridge the gap, Haghighat argued.

To that end, added Safari, the opportunities generated from going above the atmosphere to launch the rocket and developing multipurpose, reusable rocket systems can provide enormous cost advantages.

If SpaceRyde is to succeed at its business case, it will need to be both realistic and practical. While reducing the rocket's diameter reduces drag, the size and mass reduction dictates the optimal payload. But rather than view this as a negative constraint, Haghighat and Safari characterized it as an opportunity to focus on customers with smaller payloads, especially those that would otherwise be deterred by narrow launch schedules. The company has pegged its target price at $250,000 for a payload of 150 kg. "We're looking at an order of magnitude in driving down the cost of the launch of a rocket," Safari said.

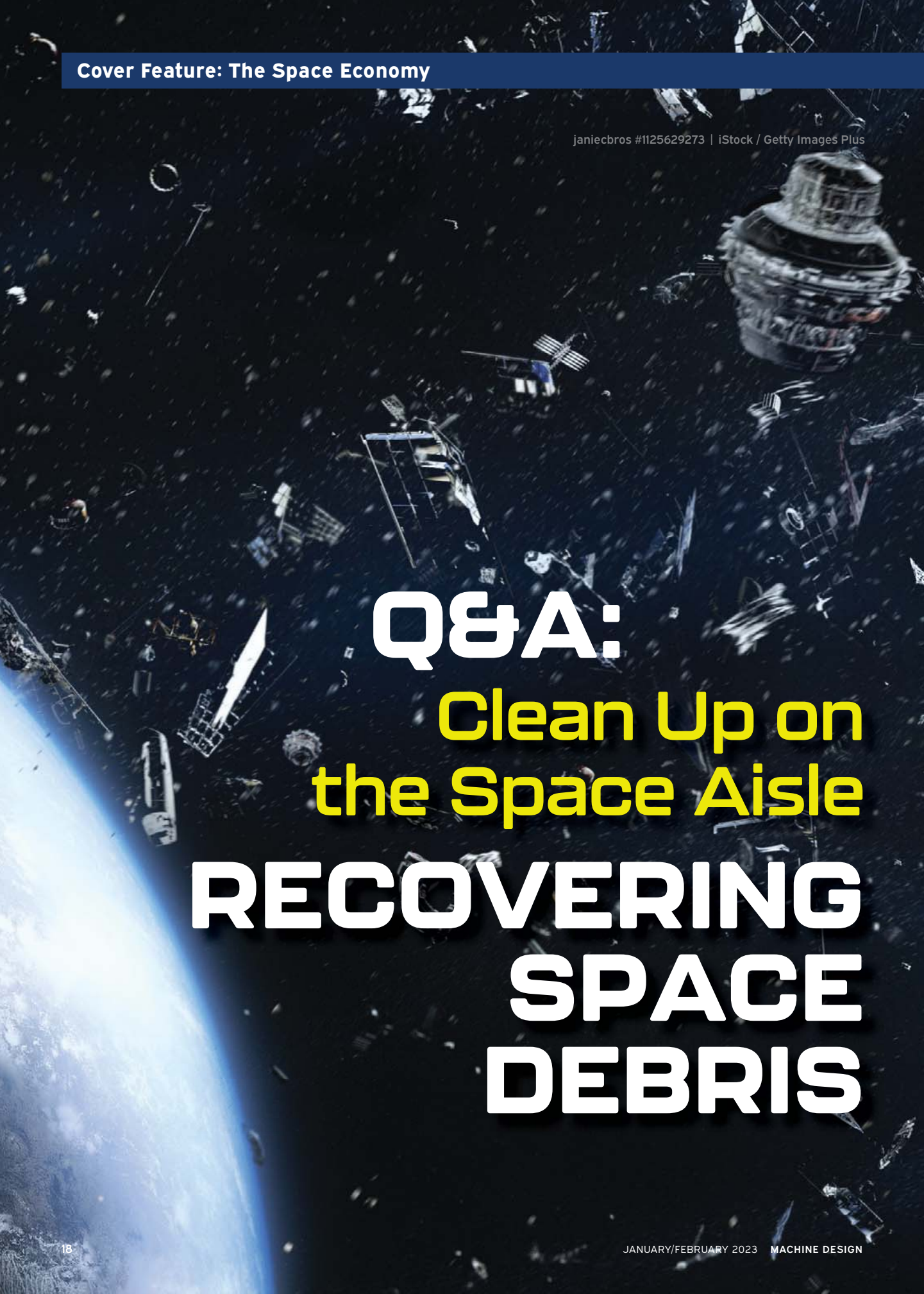
By Morgan Stanley estimates, the cost to launch a satellite has declined from $200 million to about $60 million as a result of reusable rockets, with a potential drop to as low as $5 million. Satellite mass production could shrink costs further from $500 million per satellite to $500,000.

SpaceRyde's success will be a multi-decade endeavor and the payoff will ultimately depend on scalability. To date, the company has raised about $10 million, with backing from both equity investors, including YCombinator, and government grants from the Canadian Space Agency, National Research Council Canada and Sustainable Development Technology Canada.

In November 2022, SpaceRyde shook hands on a deal to deliver on multiple launch agreements with ISILAUNCH, a Netherlands-based CubeSat and small satellite solutions provider. The MLA signified SpaceRyde's readiness to offer customizable rockets geared for precise orbits with price points starting at $250,000.

"Innovation is always risky," said Haghighat. "But when we can do that 10 times, or 20 times a year, then we come up with creative solutions that may or may not pan out. But through doing that, we come up with something that creates a paradigm shift. The fact that access is not yet on demand is what stops innovation or slows down innovation in space significantly."

Add to the space equation the moonshot demand to send polluting industries to outer space, and Hagighat remains unfazed. "Those factories would require tools, raw materials, and they need the product to be brought back to the planet," he said. "SpaceRyde is building the infrastructure to support this demand and wants to do so sustainably." ■



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Q&A: Clean Up on the Space Aisle

RECOVERING SPACE DEBRIS

A New Hampshire start-up is developing Orbital Robots (dubbed orbots) designed to safely discard space debris.

by Rehana Begg, Editor-in-Chief

Rogue Space Systems Corp. is on a mission to make a clean sweep of collecting debris in low-Earth orbit. The New Hampshire-based company is in the process of developing orbital robots (dubbed orbots) that will allow for the safe removal of space debris. Its main robot, Fred, is designed to move satellites and other assets to and from different orbits.

"With the acceleration of commercial space, one interesting fact is that in the year 2021 there was more mass sent to space in one year than all the previous 70 years of space exploration combined," said Jeromy Grimmett, founder and CEO of Rogue Space Systems Corporation.

He estimates that we've cataloged between 23,000 to 25,000 known objects. However, there are hundreds of thousands of objects that we can't see. "Nuts, bolts, astronaut gloves, Tic Tac cases…I mean there's all kinds of stuff that's floating around in space because of human presence."

Grimmett described how omnimagnets—in development through a partnership with the University of Utah—can be used to stop objects from tumbling to Earth. The technology will allow controllers to manipulate even non-magnetic objects in space and allow for six degrees of movement, he explained. Omnimagnet technology, which consists of electromagnets, create a magnetic field and synchronizes the orbit with the targeted piece of debris.

But Rogue Space Systems has a long-term vision that encompasses much more than clearing space debris. Building tools to address the space junk problem is part of a strategic move as the company engages with the growing global space market. One goal, said Grimmett, is to become an interplanetary services company that encompasses everything from transport to communications transactions.

Fred, a 325-kilogram robot, will have four robotic arms. The orbot resembles a hornet, and is designed to move satellites and other objects to and from different orbits. *Rogue Space Systems Corp.*

The company seized on the opportunity to apply for state funding for space innovation and services in 2021, after General David D. Thompson, vice chief of Space Operations for the United States Space Force, stated that funding was available for commercial companies that can offer solutions to dealing with space debris mitigation.

Since 2010, the official policy in the U.S. has made clear the need to preserve the space environment and minimize the creation of human-made debris.

"We want to be the infrastructure that supports and enables the space economy," Grimmett said. "It's not going to happen overnight, but we're going to get there. As commercial business and U.S. national interest increase in space between the Moon and Mars, Rogue is going to be there."

In the following edited version of a three-part video interview with *Machine Design (https://machinedesign.com/21250142)*, Grimmett outlined why he believes space junk has become a "national security imperative" that should be dealt with.

Machine Design: **Jeromy, you're navigating a subset of the space industry that remains largely untapped. But you're changing all of that. Tell us about your work and the solutions that you provide.**

Jeromy Grimmett: We are building orbital robots to go and deal with space debris—primarily satellite servicing. When we first started Rogue, we had built the company around the idea of dealing with space debris and space junk. But what we quickly found out was that there was no market for it. No one was paying to solve that problem until late 2020, early 2021, when the vice chief of Space Operations, United States Space Force, General Thompson, stated that he would pay commercial companies to deal with space debris.

Now, this is a pretty big pivot from what was the norm over the course of the past several years, and through that we then re-pivoted. So, we started off with space junk; we pivoted to satellite servicing, which is analog to space junk or capturing and repairing satellites, refueling, power augmentation and things of that nature. We kind of re-pivoted back to space debris, so we never really stopped working on space debris. It just got brought to the forefront through the Space Force's request to industry that we try and get in there and start helping to solve that problem.

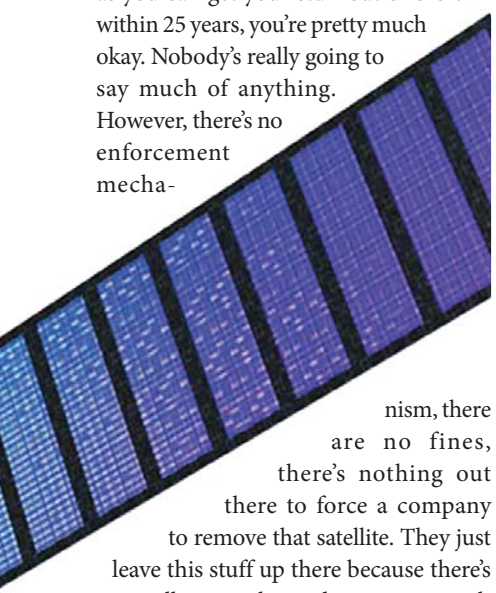
Rogue Space Systems aims to have Fred in space by the end of 2023 or early 2024. *Rogue Space Systems Corp.*

***MD:* For those who are less familiar with what is going on in the Earth's orbit, bring us into that space.**

JG: If you go to *https://sky.rogue.space* you'll see what it looks like in orbit around the Earth, and all the different objects that are out there…So there are all these things that we do know about and then there are all these other things that we don't know about, because our radar is not good enough and our ground-based measurement systems are not good enough to detect that stuff. We aggregate data from multiple sources in order to try and create the clear picture of what is out there.

***MD:* We're seeing this onslaught of commercial space traffic—I'm reading a lot more about it. How will more space activity exacerbate the problem?**

JG: Congress is trying to do things to improve the situation and, in this particular case, some government regulation would probably go a long way. Currently, the de-orbit lifetime is 25 years. So, as long as you can get your stuff out of orbit within 25 years, you're pretty much okay. Nobody's really going to say much of anything. However, there's no enforcement mechanism, there are no fines, there's nothing out there to force a company to remove that satellite. They just leave this stuff up there because there's not really a penalty, and it costs so much to get it down.



I'm pretty excited to see what the Administration and Congress do regarding space debris; they're trying to take some action. In my opinion, it's a national security imperative that we deal with. Because, with the acceleration of commercial space, one interesting fact is that in the year 2021 there was more mass sent to space in one year than all the previous 70 years of space exploration combined. That is a dangerous place to be.

Now we have Starship [a fully-reusable, super-heavy-lift launch vehicle under development by aerospace manufacturer SpaceX]. It's coming up, and guess what? That means tens of thousands of metric tons worth of cargo that they can payload, that they can deliver into space. SpaceX is on pace to launch, I think, 50 to 55 rockets this year. They are trending hard and they're putting more and more mass in space. It stands to reason that we will

> *"We had built the company around the idea of dealing with space debris and space junk. But what we quickly found out was that there was no market for it. No one was paying to solve that problem until late 2020, early 2021, when the vice chief of Space Operations, United States Space Force, General Thompson, stated that he would pay commercial companies to deal with space debris."*

outpace 2021 pretty heavily. And then, with Starship coming into service, it's only going to get worse.

***MD:* Tell us about the orbot program. Who is Fred? What is an orbot, and what are its capabilities?**

JG: An orbital robot is effectively a satellite that can go out autonomously and deal with the problem.

Now, right out of the gate, they're not going to be fully autonomous. However, that is the goal—to develop spacecraft that are fully autonomous, that can go and deal with space debris. It can go and attach something to increase the drag on a spacecraft that is decrepit, it can de-orbit it faster, it can go and inspect an object in space so that we can find out what's going on and what's wrong.

There's a series of orbots. The first one is called Barry; he's a very small little robot that is used to test and demonstrate some technology. Then you have Laura, who's an inspection and observation satellite spacecraft. Then you have Charlie, a robotic-enabled spacecraft, a little bit larger, about 150-200 kilograms.

And then, Fred, the one that you asked about, is a pretty sizable spacecraft at 325 kilograms. It has four robot arms. It kind of looks like a hornet whenever it's fully deployed. It's pretty cool-looking. And it's got an array of highly sophisticated sensors that we use to do a lot of detection and understand the environment that's around it.

***MD:* What will be Fred's objective once it is in orbit?**

JM: It will be able to transport the smaller orbots around the Earth and move them to locations where they might be needed to do inspections and observations or post them around something. Fred can also grab a hold of something, it can attach to something and move it, it can attach other things to another object, it has the ability to detumble an object in space.

Things in space are not static; they're not just sitting there. Given the Earth's influence and gravity and solar winds, they actually start spinning and moving in the various axes. That being said, you have to be able to de-tumble that stuff, and that's why we are exploring the omni-magnet technology with the University of Utah.

Laura is an orbot that is designed to perform diagnostics and operations on other objects or satellites in orbit. *Rogue Space Systems Corp.*

> *"Fred's purpose, basically, is to be the tow truck, the forklift, the mobile repair shop, because you can even change out tools at the end of those robot arms, depending upon the circumstances that you find yourself in."*

Fred's purpose, basically, is to be the tow truck, the forklift, the mobile repair shop, because you can even change out tools at the end of those robot arms, depending upon the circumstances that you find yourself in.

We're aggressively going after Fred, by trying to put that in space by the end of 2023, early 2024. It's a very aggressive timeline, but hey, it'll be a fun goal to see if we can pull it off.

***MD:* Can you talk a bit about the AI-enabled sensory observation technology platform?**

JG: In order to understand what's going on, you have to aggregate all of the sensors and all of the sensor inputs that the spacecraft is using. Everything from radar, to LiDAR, to range finding, to all the cameras. All of it has to get aggregated in order to clearly form a contextual picture of what's around it, what's moving, what's not moving and where it is in relation to the target. It's a highly complex problem that has to be solved.

Orbot servicing requires the aggregation of that. In order to formulate deci-

sions to conduct a safe operation in space, we don't always have real-time access to the spacecraft. If there's something that starts going wrong, the orbot needs to be able to say, "Hang on a minute, this is wrong. I need to back off." And then it can just disengage from that object.

***MD:* Can you elaborate on the omnimagnet concept and how the technology works?**

JG: It's some real Star Trek stuff. You may know this, but every metal is affected by magnetic waves. Some more than others. Iron, for example, that's really on the end of the spectrum, has a strong influence. Aluminum and copper, not so much, but there's still an effect. Omnimagnets project out magnetic fields and the Eddy currents that are generated through those magnetic fields pass through the metal within an object and can actually influence it over time.

And so, one of the dirty secrets of space debris and space debris removal that nobody wants to talk about—except for Rogue—is: How do you detumble an object without breaking it? If I fly up to a spacecraft, or I fly up to an object in space, and it's rotating and spinning around, I have to bring my orbot up to it, and then I try and maneuver and match all the spin so that I can safely approach and grab a hold of it. Well, that is very expensive from a fuel standpoint and it's almost impossible to do.

I can shoot it with a harpoon and then the mass of this object and the speed at which it's moving will just grab my orbot. I can twirl it around and then we have a disaster. If I shoot it with a net, I still have the same problem, except now I've probably broken off a few extra pieces and I'm getting dragged along with it.

Magnetic Eddy currents and omnimagnets solve that problem because we don't have to touch the object. We can stand off, we can project the magnetic fields, and over time, we can slow the spin in those six axes, so that we can safely approach, grab a hold of it, attach drag lines and attach drag streams to it, and then allow it to decay naturally into the upper atmosphere. That is a safe, sustainable, non-debris creating way of solving a problem.

> *"One of the dirty secrets of space debris and space debris removal that nobody wants to talk about—except for Rogue—is: How do you detumble an object without breaking it?"*

Rogue happens to be in partnership with the University of Utah to do that. It's already demonstrated in the lab. It does work. It's real. It's not science fiction, it's science fact. It's a beautiful, brilliant combination of physics and AI/machine learning and robotics. It's just really an elegant solution. ■

Digital Twins:
Designing Virtual Replicas of Infrastructure Projects

Bentley Systems' strategic priorities are framed around the advancement of digital twins that span the end-to-end lifecycle and value chains of infrastructure assets.

by Rehana Begg, Editor-in-Chief

Call it a superpower, but one of the greatest advantages of a digital twin is the ability to transform data into transformative information that map out future outcomes.

Keep in mind that the goal of using of digital twins differs with each application. The digital twins of every Tesla ever sold and the digital twin of professional NBA basketball player Carmelo Anthony, called "Digital Melo," are ground-breaking (yet vastly different) examples.

For testing autonomous driving capabilities, for example, the goal might be to focus on innovation, efficiency and rapid iteration, while improving safety and reducing costs compared to traditional testing methods.

Contrast this to a hyper-realistic human digital twin—whereby medical professionals track a patient's healthcare indicators, and both the intrinsic value and the potential of a digital twin extend beyond the deceptively superficial PR stunt of a celebrity avatar connecting with millions of viewers in their own language.

The level of sophistication that comes with interconnecting two or more digital twins, along with immersive reality, cloud-connected sensing, artificial intelligence (AI) and machine learning, allows every enterprise to harness virtual relationships for insights into entire systems of planes, factories or even cities. These relationships offer boundless opportunity, from up-to-date virtual simulations of machines and cradle-to-grave optimization to novel ways to scale a business.

Bentley Systems colleagues, Richard Irwin, senior manager, Digital Twins and Industry Marketing, and Alistair Stubbs, vice president, Asset Operations, discuss the value of developing digital twins during a press interview at the 2022 Going Digital Awards in Infrastructure in London. *Bentley Systems*

Infrastructure Digital Twins

Digital twins in infrastructure projects are no less impressive. Look to Singapore's digital twin for an example of an effort to steer an entire nation to improve sustainability and bolster efficiencies in energy consumption.

Based in Exton, Pa., Bentley Systems was a partner in enabling the Singapore project from the get-go by providing photogrammetry and scanning tools to capture the images of buildings and other landmarks. The infrastructure engineering company's ongoing experience with technologies that drive digital twins is rooted in years of continuous progression across enterprise systems that span the end-to-end lifecycle and value chain of infrastructure projects. About four years ago, the company set its strategic focus on digital twins with a series of open-source projects intended to develop cloud-native tools (called iTwin.js).

That focus is exemplified in Bentley's annual awards—The Year in Infrastructure and Going Digital Awards in Infrastructure—which invites Bentley Systems

users from around the globe to submit their design, construction and operations projects for review by a panel of independent industry experts. Finalists in the 2022 awards program were chosen from 12 categories, ranging from Process and Power Generation and Enterprise Engineering to Facilities, Campuses, and Cities and Rail and Transit.

As the name suggests, the annual event is as much a showcase for recognizing digital advancements in infrastructure projects as it is a study in the host's software applications. During his keynote at the 2022 awards event in London (Nov. 14-15), Keith Bentley, founder and CTO, Bentley Systems, noted that 42% of this year's finalists credited the use of the iTwin Platform, an engineering technology tool that provides capabilities for building interoperable Software as a Service (SaaS) solutions for engineering firms to employ in design, construction and operations workflows.

"It is clear to me that infrastructure digital twins are the future of our industry and our company," Bentley said.

The iTwin Platform is built on open APIs (application programming interface) that provide access to large-scale datasets and allow software components to communicate with each other. Digital twins of individual assets are synchronized and federated in their native formats while remaining accessible across complex user workflows. The platform's latest enhancements were purposely designed to augment (rather than replace) existing tools, so that engineers can build upon their workflows and processes and apply digital twin capabilities where it makes sense, Bentley explained.

Building on this platform, Bentley Systems rolled out iTwin Experience, a cloud-based product that empowers users to glean insights from critical infrastructure by visualizing and navigating digital twins. The solution is touted for accelerating "digital integrator" initiatives as it allows engineering firms to curate asset-specific digital twins by incorporating their proprietary machine learning, analytics and asset performance algorithms.

Keith Bentley, founder and CTO, Bentley Systems, said that infrastructure digital twins are the future of the AEC industry and the company.

AT A GLANCE:

- Bentley Systems hosted the 2022 Year in Infrastructure and Going Digital Awards in London (Nov. 14-15, 2022). The most advanced projects were those leveraging data to build better infrastructure.
- The extent to which Bentley Systems and its customers favor digital twin adoption for reengineering entire processes and experiences is a case study in optimizing performance.
- The annual event unveiled new digital twin technologies that help infrastructure companies synchronize and federate data of physical assets across complex user workflows.

Digital Maturity Takes Time

In practice, the digitalization journey towards developing infrastructure digital twins is more akin to a marathon than a sprint. This was evident not only in the varying levels of digital maturity of the projects submitted to Bentley Systems' awards program, but also in the fact that the projects had distinct goals and objectives.

A case in point is the three finalists in the Process and Power Generation category. "What we've seen are different types of ambitions," according to Alistair Stubbs, vice president, Asset Operations, Bentley Systems.

In an interview with *Machine Design*, he pointed first to OQ Upstream, the winner in this category. OQ Upstream is an integrated energy company located in Muscat, Oman, which operates and manages dozens of plants, thousands of assets and more than 4,500 km of pipeline across Oman. The OQ project focuses on establishing a centralized digital asset performance management (APM) system. The OQ team selected Bentley Systems' AssetWise software as their main asset data management platform for incorporating failure reporting and analysis, asset health indicators and digital inspection strategies to enable corrective maintenance management.

"OQ Asset Reliability Digitalization emphasized a drive for increased productivity, increased availability and data maintenance," said Stubbs. "They've taken it deep through their asset cycle and they've [had] very credible metrics come out at the end."

Reducing asset failures and unplanned plant shutdowns has important preven-

tive implications in the oil and gas sector, where flaring is a serious environmental risk, noted Richard Irwin, senior manager, Digital Twins and Industry Marketing, Bentley Systems. Flaring is the burning of natural gas associated with oil extraction. It is a major environmental concern as it generates greenhouse gases, and it continues as long as the plant does not run efficiently.

At one compressor site, according to the OQ project description, "the APM digital solution saved 14.8% in total maintenance costs and reduced functional failures by 50% to achieve an annual operational reliability growth of 4.3%. Continuing to digitize, OQ is integrating APM as part of their efforts to develop a digital twin."

The winners in the Process and Power Generation category, OQ Upstream, were recognized for establishing a centralized digital asset performance management (APM) system. The OQ team operates and manages dozens of plants, thousands of assets and more than 4,500 km of pipeline across Oman.

Becoming a Digital Utility

Category finalist Sarawak Energy Berhad, a vertically integrated power utility and energy development company located in Malaysia, set a goal to become a digital utility by 2025. The company initiated a digital twin pilot project at its Bakun Hydroelectric Plant. Jurors commended Sarawak for generating high-resolution 3D reality models to achieve a reduction in the time to develop the as-built designs by 70%.

As part of its motivation to digitalize its processes, Sarawak noted that a lack of accurate as-built drawings and limited accessibility to generate intelligent 3D plant models were compounded by slow network speeds, large data files and incompatibility with third-party applications. They needed integrated, collaborative modeling technology to generate their digital twin. To achieve their 3D modeling milestone, Sarawak leveraged Bentley's PlantSight (the digital twin solution for process and plants) to the software used, in addition to ContextCapture (a set of tools for photogrammetry, laser scanning, meshing and GIS to develop 3D models) and MicroStation (CAD software for 2D and 3D design and drafting) solutions.

"The availability of digital twins is expected to reduce the travelling frequency of remotely stationed personnel to Bakun HEP by 40% or higher for on-site discussion, inspection, troubleshooting and supervision of minor maintenance work," emphasized Paul Kan Wilson Jetan, senior IT executive, Bakun Hydroelectric Plant.

Compared to OQ, Sarawak's digital twin journey progresses "diametrically the other way," said Stubbs. "Theirs is a horizontal expansion. Using PlantSight, they've aggregated information from multiple different disciplines that traditionally would have been more separate. They've worked on assets horizontally, which then encouraged the different types of collaboration amongst disciplines."

PlantSight is an open, cloud-based solution that was developed for the process industry in collaboration with Siemens. The solution allows a plant to collect, connect, contextualize and validate existing plant data.

Data Under the Sea

By all accounts, the project submitted by finalist Shell Projects and Technology is equally impressive. Shell's submission explores the extraction of oil and gas from beneath the deep waters in the Gulf of Mexico. A portfolio of projects in the region were earmarked for deploying their Deepwater Project Delivery Digital Platform with the goal of improving top-cost performance, while making gains on meeting net-zero carbon goals and improving cycle times for deep-water projects.

Without visual context, the impact and scale of this project is easily underappreciated. "There are a lot of installed assets spread out over a larger area," pointed out Stubbs. "It is only when you zoom in through a digital twin that you get to see the complexity and detail."

Fortunately, subsea tie-back projects that are currently using this digital platform are realizing how quickly concepts can be screened, said Stubbs, a veteran consultant on large assets for marine, road, rail, mining and energy sectors. The Shell project is located in a very challenging environment that integrates design information from many different sources into a searchable and scalable platform that fosters a single view of the truth. "In Shell's case, they've integrated disciplines that have never been seen on the same screen before," he said.

The Shell project can count having its risk management platform visible and accessible as one of its project outcomes. "We'll see Shell continue to aggregate information sources to truly give them a

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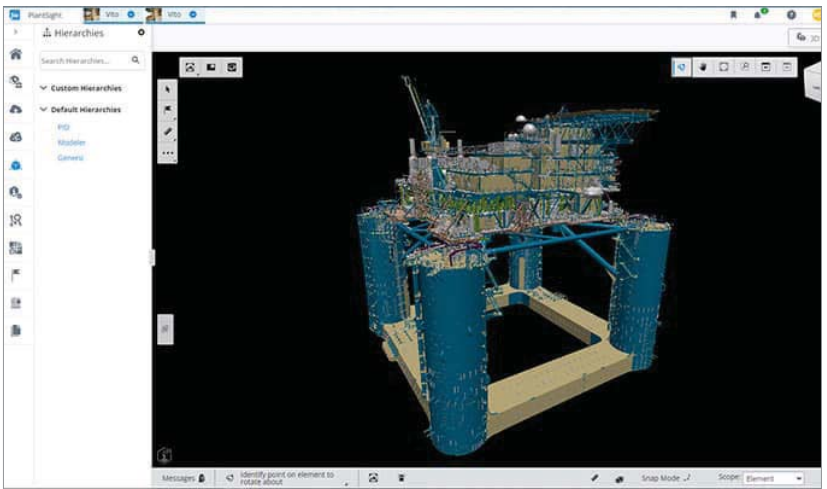

Shell's Deepwater Project Delivery Digital Platform explored the extraction of oil and gas from beneath the deep waters in the Gulf of Mexico. A subsea asset base is spread out over several kilometers. The project brought together subsea and above water disciplines for the first time. *Shell Projects and Technology/Bentley Systems*

single pane of glass mechanism to access all of their engineering data," explained Stubbs. "Of course, although they're drilling new subsurface wells, they're all tying back into brownfield assets. It's an interesting combination of brownfield and greenfield project work."

Open Systems, Collaboration and Compliance

From Bentley Systems' perspective, the collaborative digital environments demonstrated in the finalists' projects underpin the idea that it is no longer sufficient for infrastructure projects to innovate exclusively within an organization.

In addition, the current rate of innovation guarantees that systems can change significantly over short periods and open platforms provide a number of advantages to ecosystem adoption, said Stubbs.

"Consider what these systems will look like in five years' time; they don't even exist today," he said. "Unless you're open to accept data, open to give data, how can you take advantage of future systems that will come up with a new design, a new engineering system or a new version of SAP? We've got to be able to consume in an integrated environment and bring that information in. Trying to lock somebody into a single, closed vendor ecosystem for 40 or 50 years of an asset lifecycle is not practical."

Along with a demand to keep pace with innovation, Stubbs cited a parallel trend toward greater regulation. "Generically, the world is getting highly regulated," he said. "The digital environment will become an increasingly important way to demonstrate compliance. At one level, that's an understanding of what the asset condition is, or knowing what's going on. Another is the audit trail of how it ended up."

A montage of infrastructure projects that made it to the finals in the 2022 Year in Infrastructure and Going Digital Awards hosted by Bentley Systems.

Future-Proofing with Digital Twin Architecture

The extent to which Bentley and its customers favor digital twin adoption for reengineering entire processes and experiences provides a living history for enterprises looking to optimize performance and speed up time to market.

Yet, digitalization of workflows in the AEC landscape remains a pain point. "CIOs estimate that about 70% of the data that their organizations produce is never used, and in the infrastructure sector, we estimate that to be close to 95%," Nicholas Cumins, chief operating officer, Bentley Systems, said during a keynote.

"That means only 5% of the data generated by infrastructure organizations are used for analytics, or used to derive insights," Cumins continued. The net effect of the lack of insights and visibility, he said, is that decision-makers are potentially under-informed when making decisions on critical infrastructure. While the intelligence and solutions to make sense of data already exist, Cumins said, the key is to adopt a data-centric approach.

For Stubbs and Irwin, the infrastructure awards winners and finalists are proof positive that the most advanced projects were those leveraging data to build better infrastructure. And, they would argue, taking a page from Bentley Systems' open-source playbook would be a good place to start. ■

EDITOR'S NOTE: Rehana Begg was a juror in Bentley Systems' annual awards program.

Epoxy System Expands Bonding, Sealing Life

The Master Bond Supreme 42HT-2ND Black is a NASA low outgassing, electrically insulating, two-part epoxy system used for bonding, sealing and encapsulating. It passes 85°C/85% RH testing, which helps to determine the expected operating life for devices in many critical aerospace, optical, electronic and optoelectronic applications.

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Water-Cooled Motor Touts Improved Energy Efficiency

The Baldor-Reliance HydroCool XT motor offers a combination of flexible design, low maintenance and reliable performance in some of the toughest environments. This product line represents a new generation of water-cooled motors developed in response to market demands for improved technical features. HydroCool XT is available with induction or permanent magnet rotor technology. The motor can achieve the highest level (IE5) efficiency rating for energy savings. The motor's power-dense solution delivers more power in a smaller footprint than similarly sized totally enclosed, fan-cooled motors. Water-jacket cooling offers higher thermal conductivity than air cooling, helping to extend the motor life while eliminating the need for fans or air filters. HydroCool XT provides versatility for extreme marine duty; pulp and paper; water and wastewater pumping; mining; and aggregate applications, among others. The motor is available in four frame sizes from 60-1,250 horsepower (45-932 kW).

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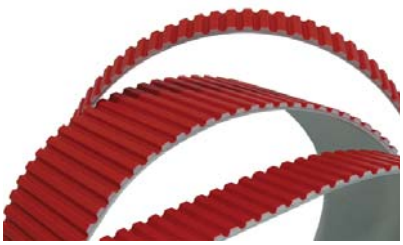

HED Timing Belt Improvements Offer Greater Strength, Durability

BRECO*flex* has expanded the *move*-series timing belt product line with the addition of AT8 MOV Open-Ended M for linear drives. Move-series timing belts are FEA optimized, laminate coated polyurethane timing belts with galvanized steel tension members. This re-engineering of the standard timing belt offers up to 75% greater stiffness and tensile strength with 30% more tooth shear strength, on average. For design engineers to end-users, making the switch from standard polyurethane timing belts to move-series allows for a decrease belt width while maintaining the same strength and safety factor for a more compact, quieter drive. The laminate coating and optimized tooth design also increases performance life. *Move*-series timing belts are available in open-ended for linear drives in AT8, AT10 and AT15 with standard widths of 25, 50, 75 and 100 mm. *Move*-series truly endless BFX for power transmission drives comes in AT8, AT10 and AT15 pitches in standard widths of 16, 25, 32, 50, 75 and 100.

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Spray Nozzle System Solves Common Industry Problems

The EXAIR 3/8 NPT HollowStream liquid atomizing spray nozzle provides a hollow cone spray pattern for pressurized liquids. They are applied to solve cooling, cleaning, foam breaking, rinsing and dust suppression applications for industry. The tangential flow design is vaneless, with wide open internal features to resist clogging and works well with liquids containing particulate. These liquid nozzles produce a uniform distribution of liquid in a ring pattern with medium to large droplets. Their right-angle design is compact and can fit in small areas. Liquid operating pressure is up to 250 PSI. HollowStream nozzles are CE compliant and available in a variety of flow rates. They complement EXAIR's large line of other 1/8, 1/4, 3/8 and 1/2 NPT liquid nozzles which are also available in a variety of liquid patterns and flow rates.

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Featured Products

Float Switches Work With Various Liquids

AutomationDirect has added ProSense float level switches, including the FLS-VM-800 float switch which has a ¾ in. PVC pipe fitting for use in HVAC condensate lines, and the FLS-VD series that includes a ¾ in. MNPT connection for mounting to most standard ¾ in. bungs in 55-gallon drums. A selection of top- and side-mount float switches, in medium and large sizes, has also been added with various material constructions for compatibility with a variety of liquid types, temperature ranges and system pressures. The ProSense float level switches are UL recognized, CE marked and RoHS compliant.

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Filter Series Offers Better Earth Conduction

SCHURTER's FMAB NEO single-phase filter series now has enhanced asymmetrical attenuation performance in higher frequencies, achieved by adding a ground line choke on the earth conductor. The new filter series offers a simple solution to filtering critical earth conductor currents generated by today's power conversion technologies, such as those using high-speed switching power supplies, frequency converters and motor drives. The FMAB NEO offers a second choke on the earth line to better address potential electromagnetic interference. The ground line choke is located between the filter input and output. With the two earth connections at the input and output, the earth connection at the main input is insulated from the housing. This ensures that possible high-frequency interference currents on the earth conductor cannot bypass the filter via the housing.

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Welding Systems Gain Control, Better Commissioning

The PRC7000 system from Bosch Rexroth features a dual-processor architecture for process control and communications, enabling high data transfer rates without affecting the welding process control. This enables automotive manufacturers and others using high-throughput automated welding systems to benefit from the highest-quality weld control and faster, more user-friendly commissioning. Weld Spot Analytics features:

- Machine learning-based analytics (for example, Nugget Size Prediction)
- Centralized data collection and dashboarding of all welding data
- Faster reaction time, thanks to its Smart Notification Engine
- A modern user interface with role-based authorization mechanism

BOSCH REXROTH

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Ad Index

ENDEAVOR BUSINESS MEDIA

Metal Tube Bending: Managing the Weld Seam

Pick the right technique for the right application.

by Marshall Arndt, Manufacturing Engineer, Sharpe Products

The two most common types of metal tubing used in custom tube bending and tube lasering are seamless and welded. The choice between the two is normally determined by application type, material availability and cost. Since welded tubing is more readily available and sometimes more economical than seamless tubing, many manufacturers specify this type of material for their projects.

Because the weld seam impacts the structural and physical properties of the tube, many fabricators use equipment with some form of weld seam detection, a technology that identifies the location of the weld seam on the tube so that it can be correctly placed in the machine prior to tube bending or tube laser cutting. This can be done either using sensors or manually and is quite important to figure into the overall process to achieve a quality result.

For tube bending, the weld seam must be oriented to the neutral, or zero, axis (top or bottom relative to bend plane) so that it is not exposed to stretching or contracting. For tight bends, this is especially critical as bending on a tight radius requires more torque, which can cause cracks along the seam. In some cases, where a seam would interfere with the aesthetics of the final product, the weld seam location will be called out in the drawing file or communicated to the fabricator.

The key to running accurate, consistent metal tube bending is to correctly orient the weld seam at the outset. *Sharpe Products*

In fiber optic tube laser cutting, weld seam detection is typically integrated with the machine, which uses a camera or sensor to identify the weld location. The machine then rotates the tube so that cuts are made (away from the seam) in the correct place on the material.

The standard rule of thumb for tube bending is to position the weld seam at the top or bottom of the material, close to the zero axis.

In fiber optic tube laser cutting, weld seam detection is typically integrated with the machine, which uses a camera or sensor to identify the weld location. The machine then rotates the tube so that cuts are made (away from the seam) in the correct place on the material. When laser cutting tubing, you want to stay away from the weld seam whenever possible.

Because not all stock material is created the same, operators must take care to check for consistency of the seam in each batch prior to loading the tubes for lasering or bending. On occasion, there can be inconsistency between batches and material must be checked to verify that the seam is in the same place for each of the tubes.

For both tube bending the tube laser cutting, it is important that the weld seam is correctly oriented at the start of the job. This allows the operator to run accurate, consistent batches without intervening, helping to streamline production and to stay focused on the overall quality of the work. ■

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