Ansys

ADVANTAGE

EXCELLENCE IN ENGINEERING SIMULATION

ISSUE 4 / 2021

SIMULATE FOR SUSTAINABILITY

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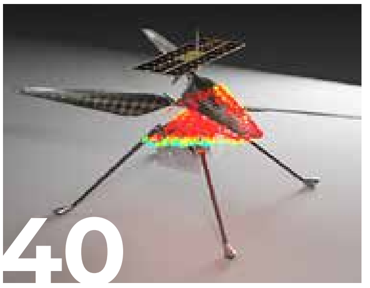

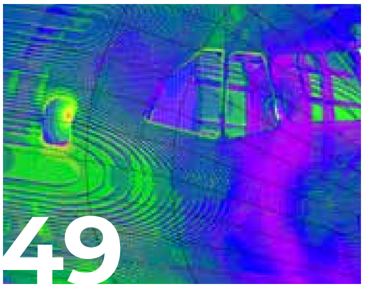

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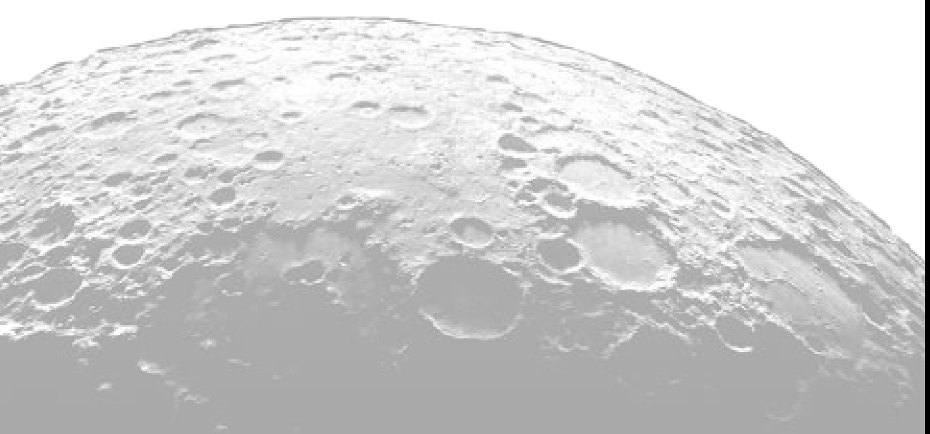

ADVANTAGE

Welcome to *Ansys Advantage*! We hope you enjoy this issue containing articles by Ansys customers, staff and partners.

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Ansys is the global leader in engineering simulation. We help the world's most innovative companies deliver radically better products to their customers. By offering the best and broadest portfolio of engineering simulation software, we help them solve the most complex design challenges and engineer products limited only by imagination.

The Impact of Materials on Sustainability

According to the U.S. Environmental Protection Agency, over 292.4 million tons of municipal solid waste were generated in the U.S. in 2018. Of this total, just 94 million tons, or about 32.1%, were recycled or composted. The remainder was sent to landfills.

While much of municipal solid waste is food, landfills are also crowded with discarded consumer and industrial products. The end-of life environmental impact of these products and increasing recycling rates are key areas of focus for the world's manufacturers.

Of course, engineers can also leverage materials to deliver positive environmental outcomes. Metal alloys and plastic composites have demonstrated their ability to make aircraft and cars lighter, increasing their fuel efficiency. Renewable energy sources, coupled with flexible energy storage systems (particularly battery technologies) show promise to displace fossil fuels and their associated carbon emissions. The reliable performance of solar-powered energy grids depends on optimizing the materials involved in energy collection and storage.

There can be no doubt that material and process engineering provides important parts of the solution for combating climate change.

Ansys Granta software provides powerful tools and extensive materials selection databases for intelligent decision making.

MATERIALS AND THE ENVIRONMENT: A COMPLEX ISSUE

According to Professors Michael Ashby and David Cebon — who co-founded Granta Design, the world's premier provider of materials information technology, in 1994 — assessing the overall sustainability of products over their entire lifespan is a complex task requiring comprehensive data for the environmental performance of materials and manufacturing processes.

Combating climate change requires material and process engineering.

With the integration of Granta's materials data management and selection capabilities into the Ansys product family in 2019, product developers can now more easily consider essential environmental issues.

"Integrating Granta's decades of material intelligence experience into the Ansys simulation portfolio gives engineers access to volumes of data on carbon and energy footprint, recyclability, biodegradability, and other relevant characteristics," says Cebon, an Ansys Fellow and mechanical engineering professor at Cambridge University. "Because every product has unique environmental implications, engineers need to consider a wide range of sustainability issues, including environmental footprint, current and pending environmental regulations, and the consequent supply risk. This requires comprehensive, high-quality data about materials, processes, coatings, substances, legislation, geopolitical factors, etc.

> ***"Sustainability, as it pertains to materials selection, can't be a consideration that's 'bolted on' at the last minute. It must be addressed from the earliest stages of design. Product developers should start with the biggest single consideration and then work from there."***
>
> *— David Cebon, Ansys Fellow and Mechanical Engineering Professor, Cambridge University*

"Is a material banned, or likely to be phased out, in certain markets in the future? What are the performance implications when you make a material substitution? And will a performance degradation due to substitution, such as lower fuel efficiency, result in an even larger negative impact?" Cebon asks. "Technology helps illuminate and address many of these questions, but engineers typically need to conduct rigorous analysis to make optimal design decisions."

Ashby, a research professor and principal investigator at Cambridge's Engineering Design Centre, agrees.

"There can be no doubt that the trade-offs are very sophisticated ones," says Ashby. "Many risks, such as government regulations, are time-dependent and difficult to predict in advance. And there is always new information emerging about the long-term impacts as materials break down. These are issues that product developers need to remain informed about."

TAKING A BROADER LOOK AT SUSTAINABILITY

Supporting sustainability via material and process selection doesn't end with understanding environmental impacts. "The definition of sustainability is 'the ability of an entity to continue operating effectively over the long term,'" notes Ashby. "And 'the long term' is a key phrase."

Ashby and Cebon argue that beyond environmental impacts, sustainability requires a materials supply chain that is stable, traceable and delivers positive social and economic outcomes. Engineers need to consider a host of factors, including community impact.

"As one example, historically the global mining industry hasn't had the best reputation for its impacts on employees, local communities, and land that has historical or cultural significance," says Cebon. "These kinds of social impacts need to be accessible — ideally quantified so that materials engineers can consider them, along with environmental performance and engineering properties."

Ashby emphasizes that product developers also have to support the economic success of the larger enterprise. "There's no quicker way for a company to become unsustainable than to go bankrupt," he states. "So much attention is focused on environmental issues like climate change, and rightfully so. But sustainability also involves economic considerations. Designers have a fiduciary obligation to stakeholders to make materials choices that support positive financial results."

Product development teams need to look at material and product costs, but also the long-term security of the material supply chain and the likelihood of disruption. Especially at a time when critical materials are being managed by some countries as a key geopolitical asset in what's termed 'resource imperialism.' Again, Ashby and Cebon point out that complex trade-offs are usually involved.

TACKLING THE SUSTAINABILITY CHALLENGE

Given the breadth and depth of the analysis required to choose materials and processes in a sustainable manner, what exactly are product designers supposed to do?

Both Cebon and Ashby agree that every product development team needs to have tools and a disciplined process in place for storing and applying materials data related to environmental, social, community, and financial impacts. As consumers become more aware of climate change and social responsibility, every company has to ensure due diligence on their material and process selection — or risk damaging both brand image and market share.

Landfills are crowded with discarded consumer and industrial products.

"Sustainability, as it pertains to materials selection, can't be a consideration that's 'bolted on' at the last minute," says Cebon. "It must be addressed from the earliest stages of design. Product developers should start with the biggest single consideration — for example, reducing a jet's fuel consumption — and then work from there. Later they might focus on how the parts of the plane could be recycled, or examine the end-to-end supply chain impacts, but the dominant factor is fuel consumption. Think about that first, and then move on to other sustainable design considerations."

Nuclear materials already have extensive traceability requirements. Cebon and Ashby want to see that extended to "critical" materials — those that are vital to the national economy but with supply chains that are not entirely secure. They believe that these materials should be carefully tracked and traced, creating a repository of readily available data about materials' provenance, impacts and characteristics. Until that happens, it's incumbent on individual designers to make carefully informed choices.

"One of the most important thing designers can do is gather and apply as much detailed information about their materials options as they can," concludes Ashby. "That means structural characteristics, thermal characteristics and weight, but it also means looking at the multi-layered global supply chain, regulatory guidelines, social and human impacts, and costs. Sustainability means expanding your perspective and thinking about the entire life cycle of the material, in all of its aspects."

Product designers and engineers can access Ansys Granta MI from their native Ansys Simulation tools. This offers instant access to a wide array of material properties in MaterialUniverse™ as well as embodied energy, CO_2 footprint, recyclability, and more. This insight into the material data for a particular component can then be used to understand the impact of its use on a product's sustainability, early in design, helping engineers make those complex trade-offs to select the right material.

Driving on Sunshine with Lightyear One

By Ansys Advantage Staff

Lightyear, an automotive company in Helmond, the Netherlands, is revolutionizing the concept of the eco-friendly automobile by constructing the roof out of solar cells, so you can recharge the batteries as you drive along during the day. It's almost like taking the charging station with you. The sun does all the work and tops off the batteries.

Lightyear, a member of the Ansys Startup Program, has been designing the Lightyear One from scratch — including the lightweight aluminum and carbon fiber chassis, the four in-wheel motors, the powertrain, and the solar roof — for maximum range and efficiency.

Lightyear engineers are using Ansys Mechanical, Ansys Fluent and Ansys HFSS to design the structure, aerodynamics, and electromagnetic and thermal properties of the five-seat Lightyear One solar car.

"Eco-conscious drivers are not worrying about how fast they can go from 0 to 100 kilometers per hour," says Andrea Carpi, structural lead engineer at Lightyear. "They are looking for efficiency — getting the most range from a clean power source without having to stop frequently to recharge."

Carpi and his fellow engineers are using Ansys Mechanical, Ansys Fluent and Ansys HFSS to design the structural, aerodynamic, electromagnetic and thermal properties of the five-seat Lightyear One so you can drive up to 725 km (450 miles) on one charge. The solar cells, which stretch from the top of the windshield to the back of the trunk, can add up to 12 km of range for every hour you drive in the sunshine. Lightyear One comes with a plug that fits into a regular wall outlet, but, depending on your driving habits and the amount of sunlight in your area, you may not have to use it much.

A WINNING DESIGN FROM THE START

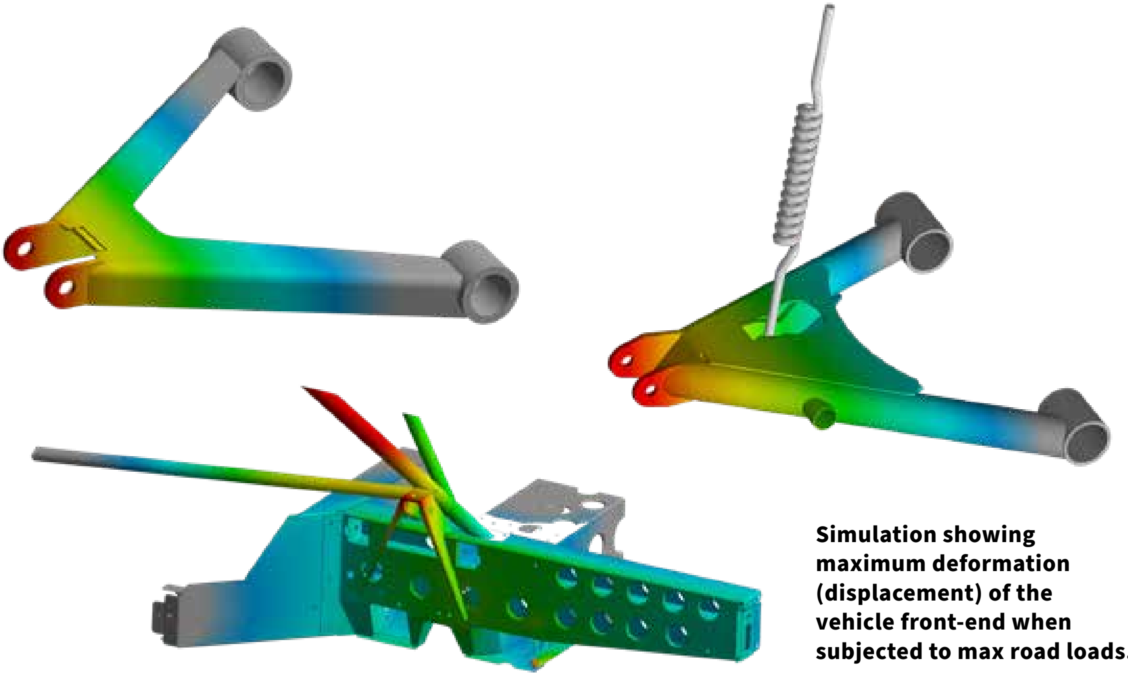
Though now a separate entity from the University of Eindhoven, Lightyear evolved from Solar Team Eindhoven, the student engineering team that won the Bridgestone World Solar Challenge four times in a row from 2013 through 2019 (the competition is held every other year, so they've won them all). Competing in the "cruiser" class of "practical solar vehicles," the team's Stellar Era solar–powered car completed the 3,020 km (1,876 mile) journey through the Australian outback, from Darwin to Adelaide, using only 71.24 kWH of power in October 2019.

Outstanding success like that can get you to thinking about commercializing your solar vehicle. In 2016, Lex Hoefsloot, a professor of engineering at the university and faculty leader of the team, along with cofounders Koen van Ham, Martijn Lammers, Arjo van der Ham, and Qurein Biewenga decided to do just that. The decision was based on the time-honored business formula of "We are going to regret this if we don't do it," Hoefsloot, now CEO of Lightyear, told *Forbes* magazine in November 2020.

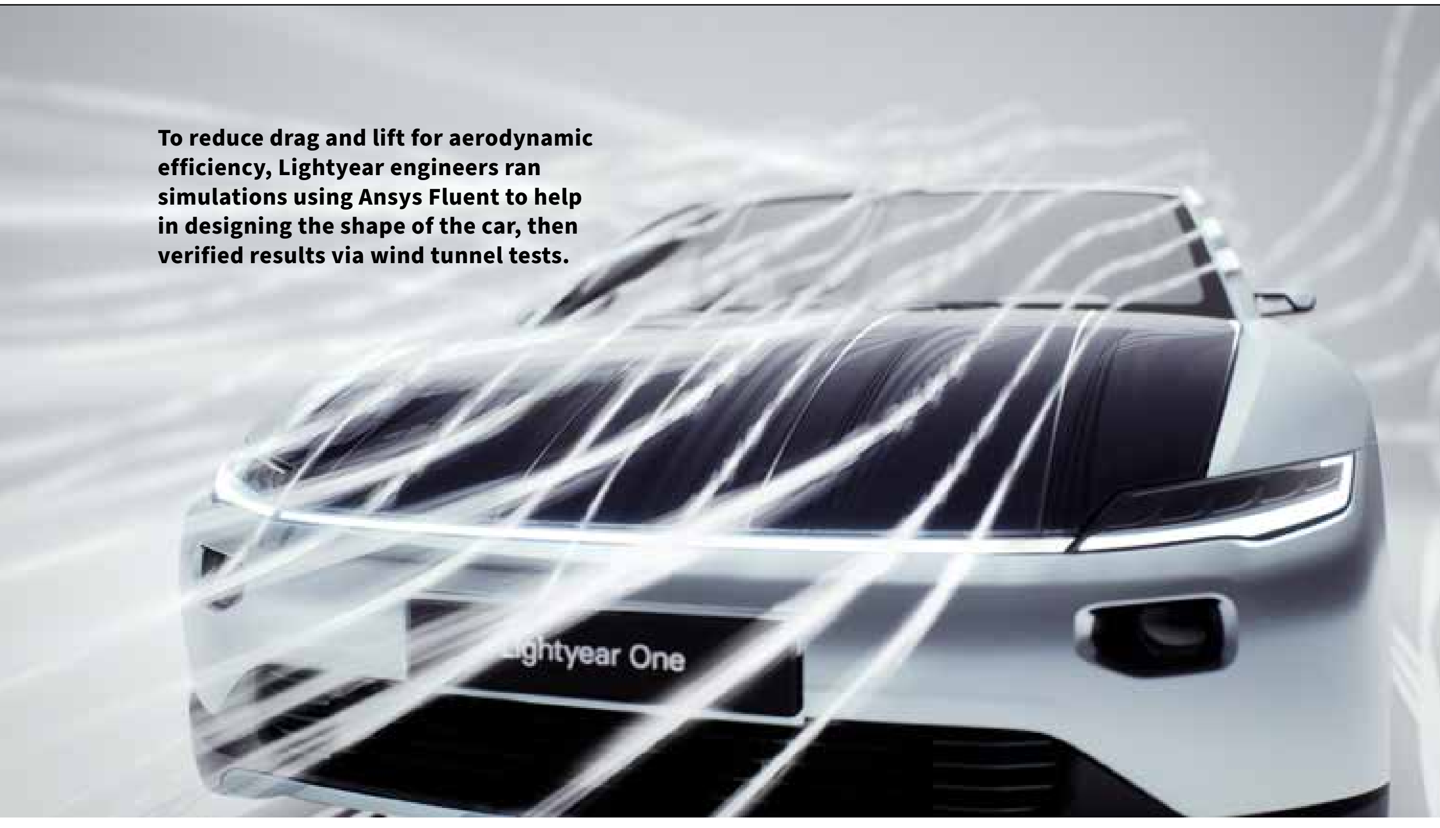
ENGINEERING EVERYTHING ALL OVER AGAIN

While they learned a lot from the Bridgestone World Solar Challenge, as a commercial company Lightyear had to rethink their design with the consumer in mind, which meant reducing cost and increasing efficiency and comfort. After all, while motivated college engineering students might be convinced to forgo air conditioning during a long road trip in Australia, your average consumer is less likely to put up with the discomfort.

So they used what they had learned to redesign the solar car from scratch. The Ansys Startup Program enabled them to test structural, aerodynamic, and electronic designs virtually, without incurring the costs of physical prototyping and testing.



Simulation showing maximum deformation (displacement) of the vehicle front-end when subjected to max road loads.



To reduce drag and lift for aerodynamic efficiency, Lightyear engineers ran simulations using Ansys Fluent to help in designing the shape of the car, then verified results via wind tunnel tests.

"We definitely benefited from the low-cost simulation capabilities that Ansys offered us through their Startup Program," says Carpi. "You have to spend your investor's funds wisely to get the most out of it, and Ansys simulation software helped us to save time and money."

A unique structural problem in the case of Lightyear One is ensuring that the $5m^2$ of solar panels can withstand the bumps of the road and even a mild collision without complete destruction. Lightyear engineers used simulation to design a layered structure that includes safety glass on top of the solar cells, as well as support structures underneath, to add strength. Unlike standard solar panels that stop working if a single cell in the structure fails, the Lightyear One system keeps functioning if part of the panel becomes damaged.

To reduce drag and lift for aerodynamic efficiency, Lightyear engineers ran simulations using Fluent to help in designing the shape of the car. They then performed wind tunnel tests to verify the results of the simulations. With a flat bottom and a long, tapered top, Lightyear One's shape resembles an aircraft wing. By making the top longer with a gentle slope, the airflow remains attached to the car, reducing drag compared to a shorter body with a steeper slope. Novel wheel covers also direct the flow of air around the outside instead of into the wheel wells, which could cause more drag.

The Lightyear One interior will have a sleek, modern design.

The Lightyear team also used simulation to design the four independent in-wheel motors that provide power only where and when it is needed. They used Ansys electromagnetic simulations to ensure they are getting the most from their solar panels and battery management system (BMS) simulations to store and distribute power most efficiently.

Lightyear is now accepting reservations for orders for Lightyear One at a price of 150,000 euros for delivery to the EU, Norway and Switzerland, starting at the end of 2021. The rest of the world will have to wait until 2024 and 2025, when a second, more affordable model launches, to get their hands on one of these amazing solar-powered automobiles.

Making Waves in Sustainable Energy

By Ansys Advantage Staff

The United States, the United Kingdom, and many other countries have set ambitious goals for renewable energy to offset the well-documented impacts of climate change. Prime Minister Boris Johnson has stated that the U.K.'s energy industry will produce net zero emissions by 2050, and President Joe Biden has said he wants all electricity in the U.S. to be generated by renewable sources by 2035.

While solar- and wind-powered technology have begun to replace fossil fuels — and both represent fundamental alternatives in the global effort to combat climate change — they will not be enough to meet these ambitious goals. The world could embrace and exploit an enormous, yet overlooked, power source: the tides. By harnessing the power of natural oceanic flows, countries around the world can benefit from a clean, renewable, reliable, and predictable energy source with a relatively small physical footprint and minimal environmental impacts.

SETTING A COURSE FOR COMMERCIALIZATION

Tidal stream power generation is still an emerging renewable technology, primarily because it involves complex engineering challenges. These problems need to be addressed successfully before tidal power can be captured on the massive scale needed to support aggressive renewable energy targets.

Orbital was founded in Orkney, Scotland in 2002 with a straightforward goal: to bring together the engineering expertise to develop the advanced technologies needed to commercialize and install powerful, game-changing tidal turbines around the world.

Orbital's flagship solution, the O2, is a 74-meter-long turbine that is moored to the seabed by an anchoring system. When the O2 is positioned in a powerful tidal stream, large 1 MW twin underwater rotors capture this energy. The rotors' 10-meter blades provide more than 600 square meters of area to capture flowing tidal energy. Electricity is transferred from the turbine to the seabed via a dynamic cable, while a static cable running along the seabed carries the energy to an onshore distribution facility.

The O2 was designed by Orbital to address many of the historic obstacles to commercializing tidal turbines. Unlike seabed-mounted underwater turbines, its rotors are attached to legs that can be lifted to the water surface for maintenance and repair. This is a critical design feature, as oceanic conditions are harsh — and the difficulty and high costs of equipment maintenance have historically been viewed as significant obstacles to the broad commercialization of tidal turbines.

With its thoughtful design, the O2 is expected to have significantly lower production and maintenance costs than existing tidal turbine designs. Orbital hopes that the O2 will prove to be a key enabler in the widespread adoption of tidal-based energy generation.

INNOVATIVE DESIGN REQUIRES INNOVATIVE TOOLS

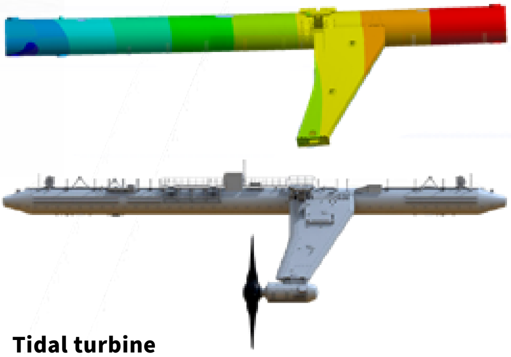
Since Orbital was founded nearly 20 years ago, its engineering team has adopted advanced solutions, including Ansys Mechanical, along with offshore test and demonstration programs to support the development of its tidal technology.

Supported locally by the U.K.'s Ansys Elite Channel Partner EDRMedeso, engineers at Orbital have used Ansys Mechanical to simulate the structural and environmental loadings on the entire turbine design, from the rotors to the anchors and chains, to ensure that it will successfully withstand harsh oceanic conditions, including extreme weather events.

Mechanical has enabled the Orbital team to study fatigue, vibration, stiffness, bending, and other issues at both the system level and the component level — including a rigorous analysis of the hundreds of individual connection points across the O2 design. Mechanical integrates seamlessly with other engineering tools used by Orbital's engineers, making it easy to collaborate and hand off design tasks.

By applying Mechanical to quickly model and verify its designs in a low-cost, risk-free virtual environment ahead of offshore testing, Orbital has been able to accelerate the initial design of the O2, cutting years from the development cycle.

Orbital engineers continue to use Mechanical to explore performance and cost improvements such as mass and weight reduction, improved manufacturability, and the use of alternative materials. Many members of the engineering team began using Mechanical while at university engineering programs, and it remains the industry standard today for fast, cost-effective, accurate structural analysis.



Tidal turbine

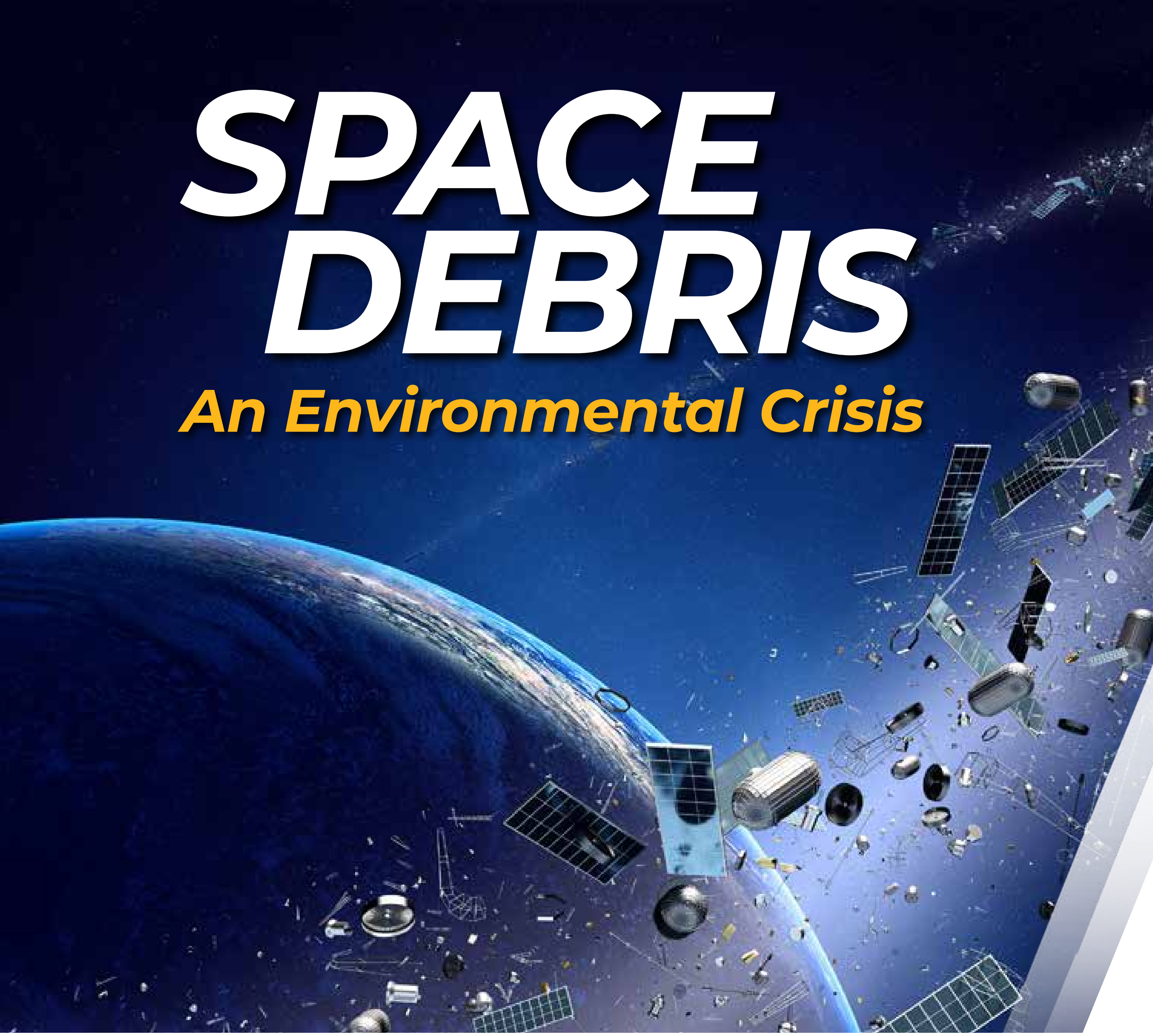
A SUCCESSFUL LAUNCH

Recently, Orbital completed installation of the O2 near its headquarters in Orkney, Scotland, which has some of the strongest tidal currents in the world.

Anchored in the Fall of Warness at the European Marine Energy Centre (EMEC), where tidal speeds can exceed three meters per second, the O2 is connected to the onshore electricity grid. The O2 can produce enough power for 2,000 homes, offsetting approximately 2,000 tons of CO_2 production annually that would otherwise be emitted from fossil fuel generation. To augment its positive environmental impact, the O2 project will shortly also provide power to EMEC's onshore electrolyzer, which generates green hydrogen to demonstrate how tidal energy can additionally supply predictable renewable energy to transport and heating sectors.

Building on the success of the O2, Orbital is now focused on broad commercialization of its technology by supplying multiple turbines to create tidal energy farms in regions of the world with strong tidal currents. As more and more O2 turbines are deployed, commercialization costs are projected to fall steeply from the product's rollout of the technology in Orkney, making tidal power an important component of the U.S., the U.K. and worldwide efforts to eliminate carbon emissions as fast as possible.

Looking ahead, Orbital will continue to leverage Mechanical — drawing on the technical support expertise offered by EDRMedeso — alongside other advanced engineering tools to constantly improve its product designs for both cost and performance. While tidal energy generation still lags behind wind and solar power, the ability to design, test and verify the performance of Orbital's tidal turbines in a virtual environment is essential in closing that gap — and fully realizing the potential of oceanic energy to turn the tide on climate change.



SPACE DEBRIS

An Environmental Crisis

By Ansys Advantage Staff

In August of 2021, the Intergovernmental Panel on Climate Change (IPCC) released its most significant report to date, identifying accumulating evidence of the climate crisis. It found there were 5.25 trillion macro and micro pieces of plastic in the ocean, and 8 million more are entering our oceans every day. However, not only has humanity polluted the oceans, we have also polluted our space environment. According to NASA, there are more than 27,000 pieces of space debris being tracked, but that is only a small amount of what is really out there.

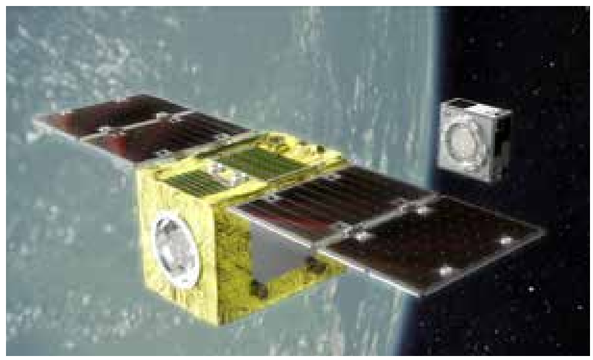
The impact of space debris poses a huge threat to the satellite services that have become an intrinsic part of our modern life, the growth of the space infrastructure and economy, and the future of space exploration. Most satellites and space debris are in low Earth orbit — between 800km and 2,000 km. The risk of collisions increases every time a satellite launches into space, where it could be destroyed into smaller pieces, adding to the problem. With several leading companies planning to build mega constellations of up to hundreds or thousands of satellites, this will pose serious challenges in the coming years.

Space is big, but Earth's orbits are finite, and they are becoming so crowded that satellite operators must burn expensive fuel meant to sustain the delivery of services and profits to instead move their satellites to safer or more advantageous orbits. The way we have operated in space until now has been bad for the space environment and bad for space business — but it's on this unsustainable foundation that we are trying to build a trillion-dollar space economy.

THE SOLUTION: REMOVAL AND PREVENTION

Astroscale is moving space to its next generation — to the space sustainability era — and is creating a sustainable foundation for growth of the space economy in the process. The company is developing innovative and scalable solutions across the spectrum of on-orbit servicing, including life extension, in situ space situational awareness, end of life, and active debris removal. Astroscale focuses on developing a global understanding that space is an extension of our environment on Earth and that preserving this environment is critical to the growth of the global space economy. By focusing on developing the technologies, informing the international polices, and building the economics for orbital sustainability, Astroscale is reorienting governments' and businesses' long-term decisions and building a sustainable space infrastructure in the process.

Astroscale is focusing on two key approaches to reduce the amount of space debris in our orbits. The first is mitigation. If satellite operators put docking plates on their satellites prior to launch, Astroscale can send a servicer satellite to remove any failed or defunct objects, reducing the risk to their services and other operators' spacecraft and maintaining a sustainable space environment. The second is remediation, which involves working with governments and national space agencies to locate and remove large pieces of debris, such as spent upper-stage rocket bodies. Removing these large pieces of debris presents a way to protect the orbital environment, ensure resiliency for space operations and enable a continued use of space for future generations.



Astroscale's ELSA program is a spacecraft retrieval service for satellite operators.

USING SIMULATION: IMPROVING THE MISSION

The role of simulation is increasingly integral to the development process of some of the world's most innovative technologies. Simulation is imitating the operation of real-world processes or systems with models over time.

Astroscale works with AGI, an Ansys company, to understand what is in our orbits. Space systems are particularly complex and dynamic — involving many moving parts — but AGI provides accurate simulations that analyze the variable conditions in space. This testing process reduces costs, accelerates development schedules, and enables Astroscale to learn about problems and issues that could arise in the future.

"We used AGI's Systems Tool Kit (STK) in our End-of-Life Services by Astroscale-demonstration (ELSA-d) mission for orbit design and analysis, as well as link budget and communication analysis," said Yuki Seto, GNC engineer at Astroscale. "STK proved to be a very user-friendly platform that allowed us to create any type of orbit ephemeris data, which was crucial in the early stages of our mission development."

CONCLUSION: THE TIME IS NOW

Measures have been put in place to tackle space debris — such as coating satellites with polymeric foam or charging annual fees — but its urgency requires a holistic solution to successfully address the issue. With the growing importance to create global awareness, Astroscale is taking the necessary steps and working with stakeholders around the world to reduce debris and support the long-term, sustainable use of space.

Vertical Farming

is Coming to a Store Near You

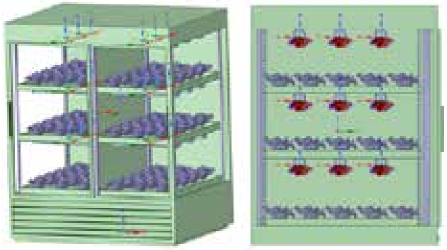
By **Julien Muller**, Senior Product Management, and **Maxime Cailler**, Application Engineer, Ansys

Inadequate consumption of fruits and vegetables is among the top 10 risk factors for our health. Eating fruits and vegetables daily helps prevent major diseases, ensures an adequate intake of most micronutrients and fibers, and can help displace foods high in saturated fats, sugar or salt.

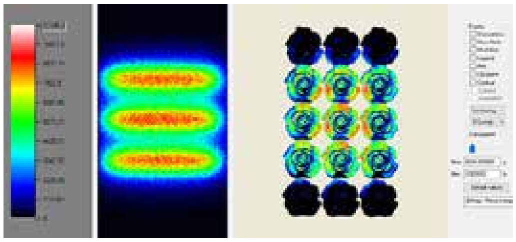
The health benefits of eating more produce can't be denied, but what about the old adage "fresh is best"? Locally grown fruits and vegetables have distinct advantages. The less time it takes to get to your plate, the better. Once vegetables are picked and harvested, they begin to lose their nutrients. Also, produce that is grown and sold locally has minimal transportation time, which translates to reduced fossil fuel emissions.

It may soon be common for anyone to pluck a farm-fresh tomato from the vine or choose their lettuce while it's still growing, even if they live in urban areas without gardens. Indoor farms, and even in-store farms, are fulfilling our need for more local vegetables. These semi-autonomous vertical farms offer fresh, healthy food options by bringing food production closer to consumers.

Vertical farms use state-of-the-art technologies, such as specialized LEDs, to help the vegetables grow. Simulation is used to strategically design and optimize indoor farm lighting to create an optimal environment that decreases growing times.



Vertical farm isometric (left) and side view.



Illuminance sensor (left) and 3D absorption (right) show room for improvement

VERTICAL FARMING LIGHTING CHALLENGES

Engineers designing in-store vertical farms must consider many optical aspects. First, for a row containing a certain type of plant, it is important to ensure the right illumination value. Different plants need varying amounts of light to grow, and that amount can vary during the growth cycle.

It is also important to ensure illumination homogeneity through a row so all the seeds grow at the same speed. This eases the burdens of plant care during production and allows growers to schedule harvests as needed.

Similarly, when it comes to the light spectrum, plants don't need all the wavelengths of natural light to grow. Plants respond best to just the red and blue wavelengths, so traditional lamps mimicking sunlight are a waste of energy. Careful optical design can help to optimize LED lighting to target only necessary wavelengths, saving energy in the process.

Lastly, the amount of light absorbed by the plants should be maximized. The less light plants reflect, the faster they grow, which reduces energy consumption.

VERTICAL FARMS GROW WITH SIMULATION

LED lights are the most efficient, effective and customer-friendly way to illuminate plants indoors. They use low energy, produce little heat and can be color-optimized for growth. To show how Ansys SPEOS can be used to design grow-light LED array solutions and simulate an indoor farm, we designed a generic light array with 90 LEDs. According to the literature, a diffuse purple spectrum (containing no green light) is optimal for plant growth. Plants reflect much of green visible light and absorb the rest of the spectrum. Consequently, the light array we created has 45 LEDs in the blue spectrum and 45 LEDs in the red spectrum, combining to make purple. Inside our farm, we first designed eight rows of 15 lettuce plants. Each row is illuminated by three of our purple spectrum light arrays.

To take the optical properties (light absorption and reflection) of the lettuce into account, we measured some leaf samples using Ansys' Portable Optical Measurement Device (OMD). The bidirectional reflectance distribution function (BRDF) obtained was applied to all of the lettuce plants in the geometry.

We then used light simulation to measure and visualize illuminance homogeneity, as well as the vegetables' light absorption.

We could see that the illumination was not homogeneous on the whole row. We then iterated on the LED array's position, the spectrum of the LED and the material of the walls of the vertical farm to produce the most efficient solution.

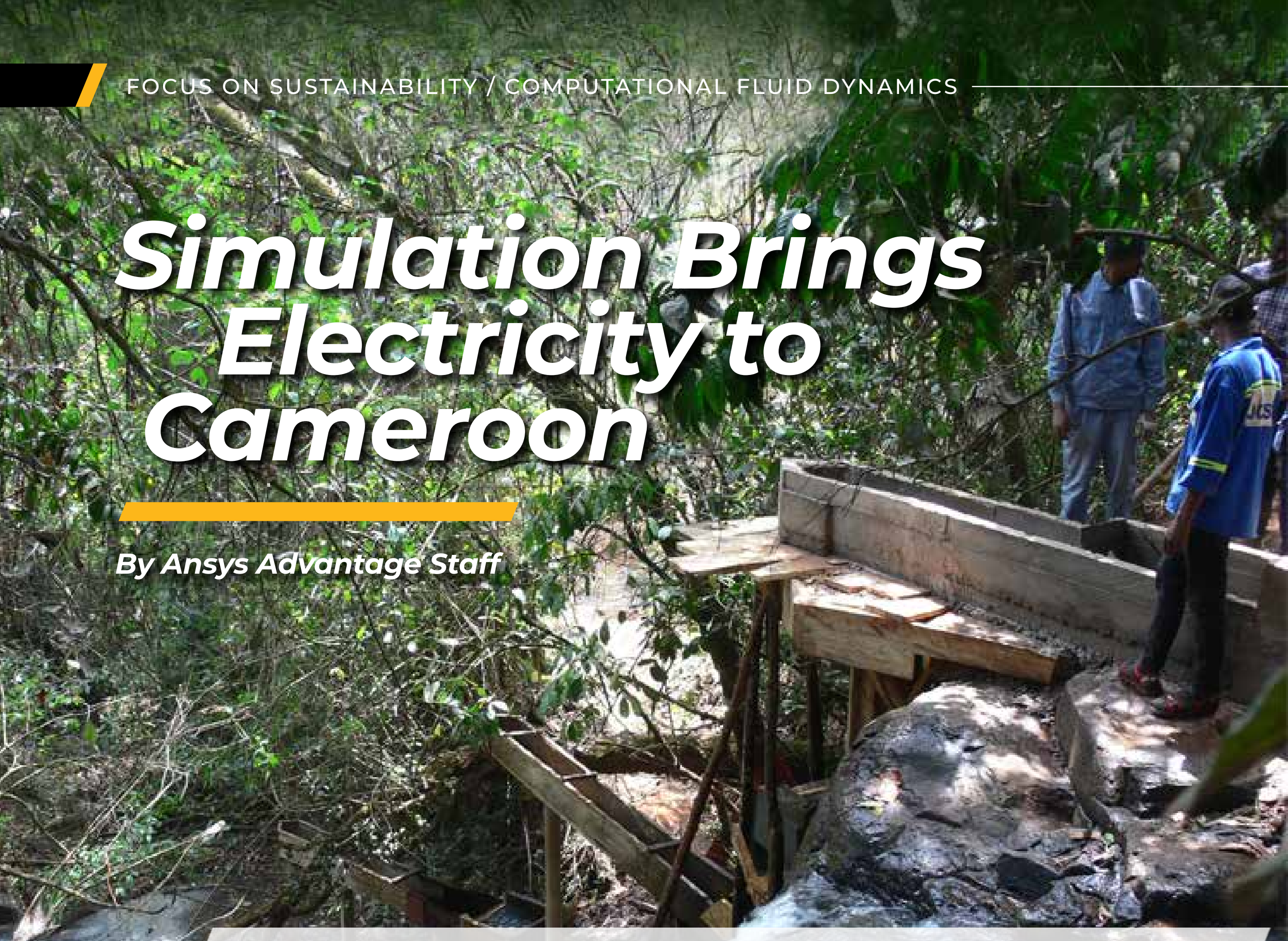
VERTICAL FARMING SIMULATION RESULTS ARE ILLUMINATING

We spaced the luminaires more evenly and gave more space between the LED arrays and lettuce plants. We also changed the materials on the sides and the back from transparent (absorbing) to white (diffusing). The front of the vertical farm was kept transparent so consumers could see the plants as they shopped.

Our next simulation showed that the illumination reaching the lettuce plants is more evenly distributed, producing a more uniform light absorption.

However, the lettuce plants in the front and back are a bit less illuminated, so they might not grow as well as the ones in the center. Because the simulation results are so visually striking, it's easy to determine where the vertical farming design could be improved. One idea for the front lettuce plants would be to apply a partially reflective coating on the inside face of the front glass to reflect more light toward them. The optimized system would then ensure both an optimal harvest yield and optimal energy consumption.

Vertical farming for in-store produce is an idea making its way to the mainstream. Optical simulation helps quantify and visualize the benefits of vertical farms, such as using less energy and water, and growing what is needed in small batches, which wastes less food.



Simulation Brings Electricity to Cameroon

By Ansys Advantage Staff

Cameroon is a central African country stretching from the Atlantic Ocean to Lake Chad, where approximately 26 million people live in mostly rural conditions, many without electricity. Ingenieure ohne Grenzen (Engineers Without Borders), a German not-for-profit group dedicated to improving living conditions for people in need through engineering, has used Ansys Fluent to develop a water-powered turbine to generate electricity in rural Cameroon. This not-for-profit organization was founded to solve major challenges in the less developed parts of the world using engineering. From its start in 2003, it has completed more than 160 projects worldwide.

"The special thing about Cameroon is that it is near the equator," says Maximillian Falk, a simulation engineer at Engineers Without Borders who has worked on the project. "There is a lot of hydropower potential — lots of rivers and waterfalls."

This abundance of flowing water, at least during the rainy season, inspired Engineers Without Borders to develop a Kaplan hydroelectric turbine to place in these flowing streams. The water turns an impeller that generates electricity. The concept is simple enough, but the social and environmental conditions in the country placed additional challenges in the engineers' way.

The Challenges of Engineering in Cameroon

When most of us think about a village, we envision a small number of houses grouped in close proximity. But in Cameroon there can be up to 3 or 4 kilometers (1.8 to 2.4 miles) between houses in what is considered a village.

"Based on these distances, what do you think is by far the most expensive part in the electrical grid we are trying to build?" Falk asks. "The wires by almost 50%."

> ***"The special thing about Cameroon is that it is near the equator, and there is a lot of hydropower potential — lots of rivers and waterfalls."***
>
> *— Maximillian Falk, Engineers Without Borders*

Considering that the turbine is usually about 500 meters to a kilometer (a third to two-thirds of a mile) away from the first house and the residual current device has to be connected with four wires, "in the best case you need at least 2 kilometers (more than a mile) of wire, which could completely destroy the budget," Falk says. So they have to design carefully.

Another problem with distance is planning an installation. If you need to buy a new screwdriver or some other tool, it's a two-day journey to the nearest big city.

Keeping the turbine design simple, with as few materials as possible, is important so they can be easily maintained. Here, Cameroon actually gives them a unique advantage in that it has a waterproof wood that can be used for the housing of the impeller hub.

"That's actually a very nice thing," Falk says, "because you can literally walk inside the jungle, chop a tree down and use it for several impellers."

An impeller needs to be replaced every two years, so this readily available material makes maintenance easy.

GENERATING ELECTRICITY IN THE DRY SEASONS

Cameroon experiences a short dry season from July to October and a long dry season from December to May. When the streams and waterfalls are drying up and supplying lower levels of water to the turbines, it can be hard to keep them generating electricity.

Initially, the engineers paid little attention to the design of the inlet basin of the turbine because it didn't seem important for a device that generates just 200 watts of power. The original design was just a wooden square at the inlet to direct water to the turbine.

"If the water level is low, there is a vortex behind the turbine that sucks in air, and this air increases cavitation inside the turbine and really degrades the material of the impeller," Falk says, "so we had to somehow circumvent this. At this point we didn't have a proper testing site in Germany."

The only way to gather data was to speak with someone in Cameroon who had access to a test unit there. By the time this man walked to the test unit, performed the analysis and sent results back to Germany, it took a week. Based on these results, the engineers would suggest a change and wait another week — hardly an efficient development process.

This situation improved greatly when Engineers Without Borders obtained Ansys

Fluent computational fluid dynamics (CFD) software and Ansys SpaceClaim, and when Falk found an old engineering paper about vortex cavitation in a Kaplan turbine in the literature. The paper suggested building a fin behind the cylinder in the inlet basin to decrease vortex shedding and make the flow more laminar throughout the turbine.

Using Fluent to simulate a sheet metal fin quickly revealed a flaw in this solution: The fin worked for air in exhaust stacks at chemical plants, but it didn't work for water flow.

Falk and his colleagues then began using SpaceClaim to change the position and length of the sheet metal fin and Fluent to determine the resulting water flow.

"We saw that this fin allowed us to direct the water flow behind the turbine," Falk says. The inlet water flow to the turbine comes from one direction, so parts of the turbine that are farther away from the inlet receive less water than the opening, leading to cavitation and inefficient electricity generation.

Using SpaceClaim and Fluent, they experimented with the angle at the end of the basin. By placing it at a 45-degree angle to the incoming water flow, it acted somewhat like a Venturi nozzle, increasing the water's speed. This change delivered a more constant stream of water to all parts of the turbine at once, reducing cavitation and making it run much more smoothly.

"We hadn't thought about changing the angle before — it simply resulted from the simulation," Falk says.

COVID LOCKDOWNS AND CIVIL WAR DELAY THE PROJECT

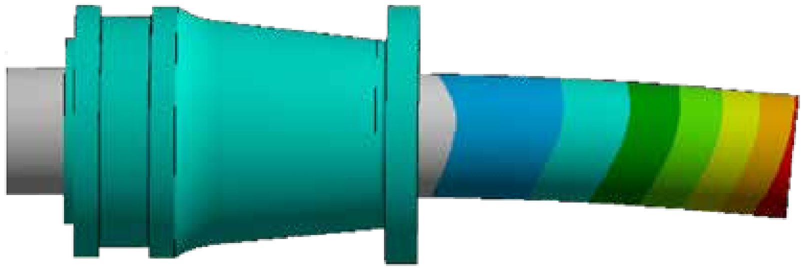
Engineers Without Borders managed to make one expedition to Cameroon before COVID hit, during which they installed four 200-watt turbine generators to supply electricity to rural villagers. The person in Cameroon responsible for keeping the turbines running is in COVID lockdown and Cameroon is also in the middle of a civil war, so it's been difficult to continue with the project onsite.

But with Ansys simulation software available in Germany where they work, the engineers have been continuing to make improvements to the hydroturbine design by running simulations that have increased the power output to 350 watts and have dealt with silt buildup problems in the turbine and other challenges.

Engineers Without Borders is funded solely by donations, so if you want to see other projects they are working on and contribute to their efforts, visit their website at www.ewb-usa.org. The organization also has chapters throughout the world.

Digital Engineering Reduces the Cost of Composite Pipe for Oil and Gas Operators

By **Steve Bell**, Analysis Manager at Magma Global, Portsmouth, UK



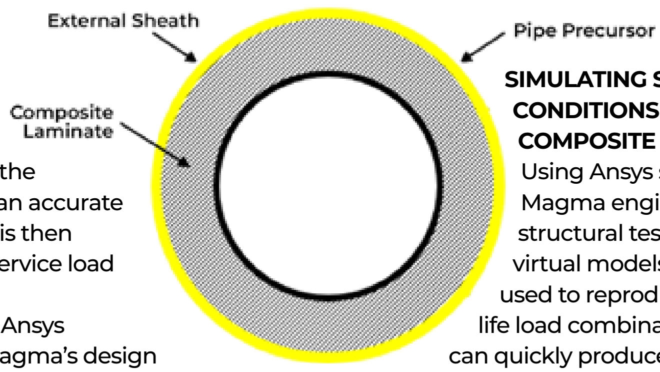
Magma Global is an innovative, fast-growing subsea technology company at the leading edge of carbon fiber composite development. Magma uses the most advanced materials and manufacturing science to deliver innovative solutions to the subsea oil and gas industry, with products deployed in some of the harshest conditions on the planet.

One of those products is m–pipe, which has been used for flowlines and jumpers, intervention systems and flying leads around the world, delivering hydrocarbon, water and gas. The flexibility of m–pipe defies its strength. It has a minimum bend radius that allows it to be delivered on standard reels, which, together with its light weight, makes it possible to deploy from smaller vessels.

The advanced engineering team at Magma are continuously refining the design of m–pipe laminate layers to optimize strength and minimize weight, while ensuring the polyether ether ketone (PEEK) and carbon fiber pipes are cost–effective to manufacture.

Minimizing the amount of thermoplastic composite within each new m–pipe reduces the consumption of fossil fuels used in the manufacturing process. Compared to traditional steel pipe installation, the lightweight nature of m–pipe minimizes installation costs and allows the use of smaller service vessels. M–pipe also requires fewer offshore trips, which further reduces the carbon footprint.

Ansys Workbench software has enabled the reduction of thermoplastics within m–pipe via realistic finite element analysis (FEA) simulations, which replicate actual test behavior in the structural response of an accurate numerical model. This is then used to reproduce in-service load combinations.



m-pipe cross-section

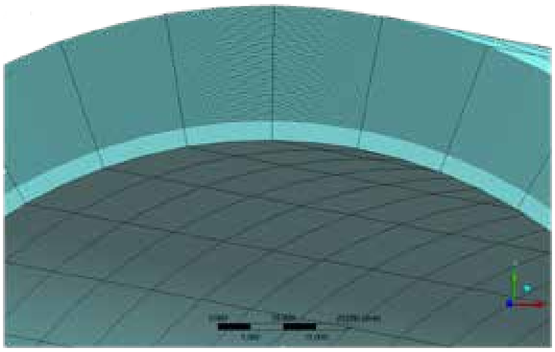
Prior to investing in Ansys simulation software, Magma's design process was like most in the industry. Engineers would develop a few designs for a particular customer's application and subject them to a series of physical tests, which can be costly and time–consuming.

The objective of simulation is to reduce the raw materials used while still delivering m-pipe in short lead times and satisfying DNV qualification requirements. DNV is an international accredited registrar and classification society.

SIMULATING SERVICE LIFE CONDITIONS FOR THERMOPLASTIC COMPOSITE PIPE (TCP)

Using Ansys simulation solutions, Magma engineers are simulating structural tests numerically through virtual models. The results are then used to reproduce actual service life load combinations. Magma Global can quickly produce a qualified product that exceeds customer requirements through the entire design cycle, including decommissioning.

Numerical simulation with Ansys Workbench enabled our computer–aided engineering (CAE) team to quickly consider different options through efficient scripts within Workbench. Numerous FEA iterations can be run to validate the structural integrity of the m-pipe. The number of physical tests has been dramatically reduced; now their sole



Example of pipe body composite laminate

purpose is to confirm the simulation results. Each physical test is also strain–gauged to correlate the results against the numerical model.

Estimating m–pipe service life using simulation gives our customers more confidence in our products. We not only share structural analysis results, including stress and strain plots, but we also interface with DNV to gain classification approval. Simulation helps us to produce some of the most robust thermoplastic composite pipe in the oil and gas sector. Using the least possible material, these pipes can still cope with the extreme operating conditions required of oil and gas components. This helps to keep product costs low so we can compete successfully with other suppliers.

MAGMA'S CAE PROCESS

Although the concept of a composite pipe appears relatively simple, in practice the numerical models are extremely complex. The laminate can comprise over 50 layers, with each layer oriented to optimize structural performance while remaining within manufacturing parameters. A metallic end fitting is secured at either end to provide a robust connection to third-party equipment. The analysis sequence simulates the service life of the product, which covers storage, transportation, testing, installation and operation.

The first step is usually an investigation using Orcaflex (dynamic analysis software tuned for subsea systems) to determine the system's global response. The local forces and moments are extracted and applied to the pipe body and end–fitting FEA models. Orcaflex is also used to simulate transpooling operations of the pipe around the Magma site as it comes off the manufacturing reels on to storage reels, or for lifting operations.

PIPE BODY FINITE ELEMENT ANALYSIS

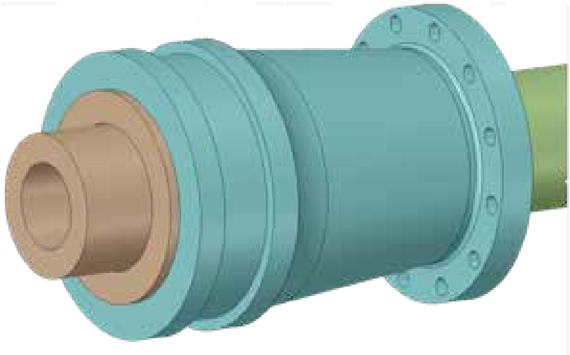
We have developed our own pipe body "Magma Ansys Pre and Post Processor" (MAPPS) interface, which is driven via a Microsoft Excel interface to create a parametric Ansys Parametric Design Language (APDL) script. MAPPS provides an easy–to–use design tool for all Magma engineers, even those without in–depth knowledge of Ansys software.

The following input parameters are required:
- Pipe geometry
- Element density
- Ply configuration: thickness and orientation
- Laminate build-up
- External loading (pressure, axial force, bending moment, etc.)

From the above data, a 3D FEA model is created using 20–node layered elements with quadratic behavior, which are required for modeling thick composites. MAPPS also allows the input of individual ply properties and the retrieval of stress and strain results.

Ply material properties are a key aspect of any composite model. We have completed extensive physical testing to derive this information, which forms the basis of our simulation models. Each simulation is run on a dedicated analytical server and takes seconds to complete, which allows laminate construction to be quickly optimized using our MAPPS results graphical interface.

The pipe body is designed in accordance with DNV–ST–F119 and DNV–ST–C501 using the limit state design method. This approach assesses the following three failure mechanisms:
1. Fiber dominated ply failure, based on total strain
2. Pipe body failure in response to axial loads
3. Pipe body collapse from elastic buckling



Example of end fitting CAD geometry

As m–pipe composite laminate is composed of numerous lamina at differing angles and material characteristics, assessing them individually ensures we don't exceed various failure criteria. Ansys Workbench has efficient post–processing tools to help with this, and they incorporate the following failure checks: max; strain, max; stress; Tsa-Wu; Tsai-Hill; Hashin; LaRC; and Cuntze.

We use the maximum strain failure criteria to carefully assess the fibers and matrix within each ply — both along the length of the pipe and through the laminate thickness. We also orient component results into the pipe system axis to determine axial, hoop and radial values.

END-FITTING FINITE ELEMENT ANALYSIS

The end–fitting assemblies are fabricated from super duplex stainless steel, which is used extensively for subsea equipment. It comprises an arrangement of concentric components that generate a radially compressive pressure that sandwiches the pipe body without the need for bolts or pinned connections, which would compromise laminate integrity.

The structural analysis is performed using an FEA assembly model created based on computer–aided design (CAD) geometry provided by the design team. Minor features, such as threads, non–critical holes and small blend radii, are then easily removed using Ansys SpaceClaim.

To allow the application of external loads, the end–fitting FEA model includes a section of the pipe body. This typically extends five times the pipe's outside diameter beyond the end–fitting interface to eliminate any end effects. Sensitivity studies ensure the element density is adequate in critical areas, e.g. stress concentrations. We check the element quality, which is the ratio of the volume to the edge length, to maintain a minimum value of 0.2.

The end-fitting is designed in accordance with Section F100 of DNV-OS-F101, which requires mechanical connectors be designed against ASME VIII Division 2. To verify the design of the end fitting, the following design checks are performed:

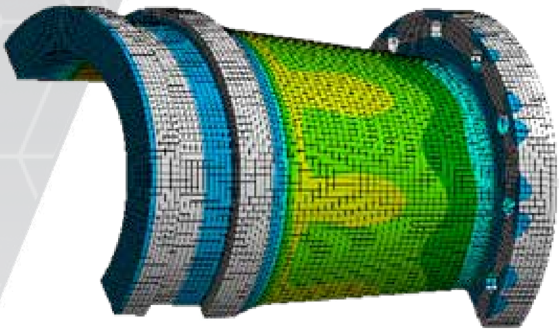
- Protection against plastic collapse
- Protection against local failure
- Protection against hydrogen-induced stress cracking (HISC) in accordance with DNV–RP–F112

To accurately simulate the load path through the end–fitting assembly, we determine contact between individual components, including the effect of friction. Stress–strain curves are defined for the super duplex material, including the effect of temperature. This, in combination with the contact, means the analyses include the effects of both nonlinear materials and geometry.

To represent each service condition, we apply a sequential loading combination to the FE model as a series of nonlinear steps. This can add up to 10 load steps, including thermal expansion, pressure, axial tension and bending moment.

Because operators are continuously developing the level of accuracy in the end–fitting FEA model, the complexity increases, escalating the solution time. To minimize this, operators optimize both the Ansys solver parameters and CPU cores.

As part of the detailed ASME integrity checks, operators extract component stresses and strains



Example of end fitting stress plot

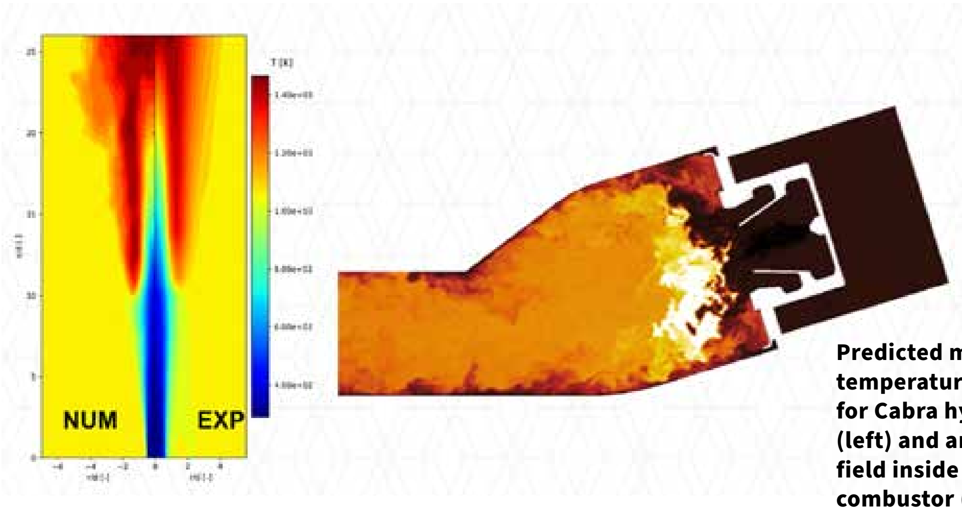
from the FEA model across all load combinations. This includes Von-Mises stress, equivalent plastic strain and the ratio of equivalent plastic strain to the triaxial strain. To assess protection against hydrogen induced stress cracking (HISC), operators carry out two further strain checks that include the use of the linearization technique within Workbench to extract an average strain value through the component wall thickness.

Presenting virtual results helps operators understand the behavior of m–pipe. Our analysis provides clear, concise information that all parties can easily interpret. The outcome is less risk, along with greater customer involvement and confidence.

WHAT IS IS M-PIPE?

M-pipe is made from two high–quality raw materials: carbon fiber and polyether ether ketone (PEEK). PEEK is the highest performing thermoplastic polymer available. PEEK has a long history of application for use in critical components due to its resistance to heat, common oilfield chemicals and permeation. The unidirectional carbon fiber and PEEK tape are fused by laser, layer by layer, in a fully automated robotic process to form a fully bonded structure with a smooth bore. The resulting m–pipe is not subject to degradation from oil field chemicals, such as hydrogen sulphide and carbon dioxide, which are prevalent in many oil field developments and prove challenging to both steel and flexible pipe. The use of PEEK also gives m–pipe high temperature capability and extremely low gas permeation.

Example of pipe body deformed shape



Predicted mean temperature distribution for Cabra hydrogen flame (left) and an aerothermal field inside an aero-engine combustor (right)

The Power of Hydrogen & Simulation:

Lowering Emissions & Accelerating Toward Net–Zero

Sunil Patil, Industry Lead for Turbomachinery and Propulsion, Ansys

Hydrogen is a significant part of the solution for carbon neutrality.

There are synergies among major industries like aerospace, energy and automotive to establish a sustainable infrastructure network for hydrogen. It provides many pathways toward sustainability — from energy storage to cleaner energy production and propulsion — while complementing other solutions, such as batteries.

Despite its potential as a "golden" fuel or energy carrier, burning hydrogen in engines poses several challenges, including flashback, acoustic instabilities, autoignition and flame holding inside the burner. Engineers can address these challenges with simulation.

GAS TURBINES: SIMULATION SAVES TIME AND COSTS

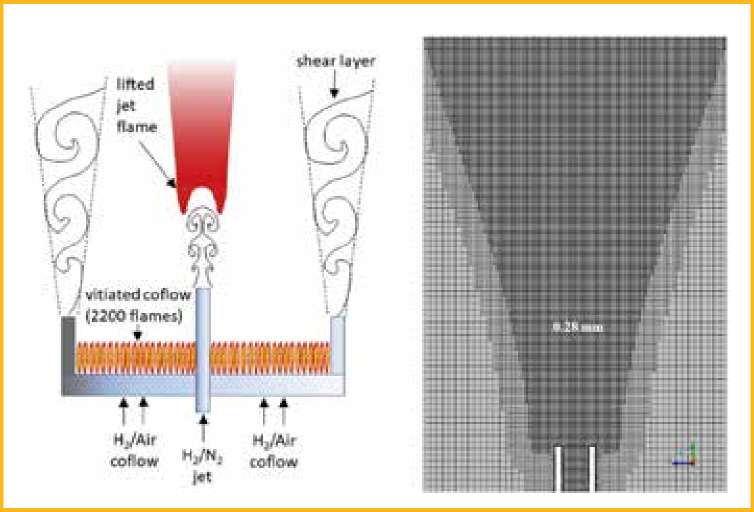
Rig testing does provide valuable information to help combat these challenges, but it is expensive and time consuming, and with 100% hydrogen, it can mean sacrificing the critical components and instrumentation of the rig. Numerical simulations can provide deeper characterization of many complex phenomena inside gas turbine combustion chambers. For example, Ansys Fluent enabled the use of computational fluid dynamics (CFD) to predict a complex aerothermal field inside an aero-engine combustor.

Accurate prediction of such complex phenomena and emissions inside gas turbine engines requires high fidelity and validated scale resolving turbulence models, combustion models, and fast transient numeric schemes. In one instance, a stress-blended eddy simulation (SBES) turbulence model was used in combination with Mosaic meshing technology from Ansys to resolve highly unsteady flow structures. Discrete phase modeling in a Eulerian–Lagrangian framework was used to model fuel spray while accounting for secondary breakup. Combustion was modeled with the flamelet–generated manifold (FGM) model, which represents thermo–chemistry by mixture fraction and reaction progress. This modeling strategy (SBES–FGM) has been validated for accurate prediction of flame behavior and emissions for jet engines, as well as land-based gas turbine combustors.

Modeling techniques with optional extensions have been proven to work for hydrogen-blend or pure-hydrogen fuels. Such extensions include modified definitions of reaction progress variables, and, in some cases, accounting for differential diffusion (different mass and thermal diffusivities for different species). A successful application of such a modeling framework for a hydrogen combustion is presented in the figure (below) on a Cabra case, which is a representative configuration of flame holding in a generic gas turbine premixing system.

The hydrogen fuel jet in the Cabra case is surrounded by a coaxial coflow of combustion products of 2,200 lean premixed hydrogen/air flames. Large eddy simulations (LES) were performed with the pressure-based solver in Fluent and the subgrid scales were modeled with the dynamic Smagorinky Lilly formulation. Combustion is modeled using FGM with a finite rate closure for the progress variable source term and an algebraic formulation for the progress variable (PV) and mixture fraction (Z) variances.

Simulation of LES–FGM also predicts the distribution of mixture fraction, temperature, and species in very close agreement with experimental data. Simulations also accurately reproduce the flame front thickness. Prediction of the flame at the leading edge is crucial for whole-flame prediction affecting the mixing downstream. The use of a diffusive flamelet approach allows more accurate reproduction of the flame anchoring, resulting in close agreement with the experimental data.



Cabra's case (left), Ansys poly-hexcore mesh in the zone of interest (right)

AVIATION INDUSTRY CAN USE HYDROGEN TO GET TO NET ZERO

The Paris Climate Agreement and aviation community's commitment to drastically lower emissions by 2050 are also driving hydrogen combustion research and development. One proposed roadmap for net–zero carbon for the aviation industry shows that only a sustainable fuel, such as hydrogen, provides a realistic path to net zero by 2050. It's important to note that electrification will continue to help reduce emissions, especially with short–haul flights, but more than 90% of emissions in the aviation sector are produced by mid- to long-range flights, according to the Air Transport Action Group.

Similar observations can be made for other sectors where hydrogen–based solutions must play a critical role alongside other important technologies — such as energy efficiency, batteries, and carbon capture — to achieve the net–zero goal.

"The decrease of the carbon content of power and the electrification of many economic activities (e.g. transportation or industry), benefiting from the strong decrease of renewable power costs, are key components of the roadmap for reaching the 1.5 C target by 2050," says Claude Heller, former director of group R&D programs for Air Liquide, now a senior advisor for the hydrogen economy. "In the so-called hard–to–abate sectors (e.g. steelmaking or aviation) indirect electrification is possible via hydrogen produced by water electrolysis with low carbon power (e.g. renewables or nuclear)."

THREE KEY CHALLENGES IN HYDROGEN DEMOCRATIZATION ACROSS INDUSTRIES

1. COST

The cost of green hydrogen production (hydrogen produced using renewable energy) is around $5 per kilogram, which has made it less competitive compared to carbon–heavy fuels such as natural gas or kerosene. The high cost is linked to the infrastructure investment and demand, which is now getting a boost because of regulations and proactive actions being taken by governments around the world.

Investment in green hydrogen now exceeds $1 billion per year. The biggest investment, globally, has come from the European Union, which accounts for more than half of hydrogen–based project investments in the early part of this decade. The U.S. Department of Energy (DOE) launched the Energy Earthshots Initiative in June 2021 for an accelerated energy transition. The first Energy Earthshot, called Hydrogen Shot, targets lowering the cost of green hydrogen to $1 per kg by the end of the decade.

2. INFRASTRUCTURE

With a significant investment in a hydrogen ecosystem, technical challenges related to hydrogen are back in focus. However, significant design challenges at each stage still exist — from its production to storage and transportation to its end use. One of the major challenges at all stages is the energy efficiency of the devices involved. Fuel cell efficiency currently ranges between 40% and 60%, while the average electrolyzer efficiency is 60%. Significant improvements in efficiency are possible, but time consuming in a traditional build–test–improve design environment.

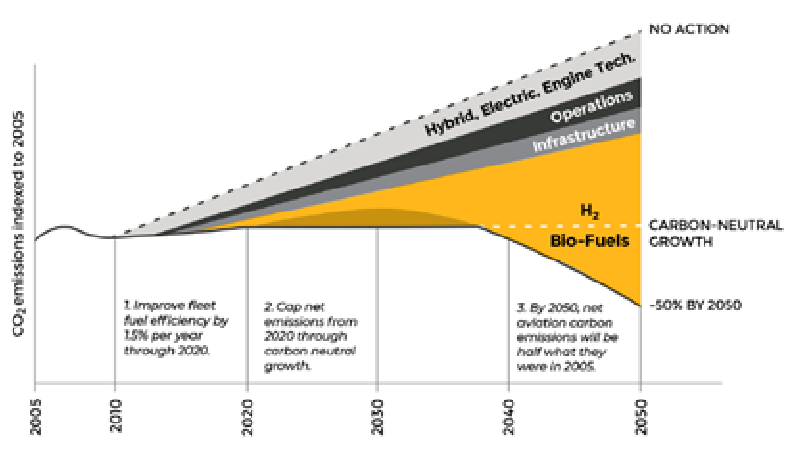
For example, hydrogen shows great promise in decarbonizing the aviation and power generation sectors with its end-use in gas turbines because of its high energy density and ability to burn lean. However, burning hydrogen in engines poses several technical challenges, including flashback, acoustic instabilities, autoignition and flame holding inside the burner.

Because of its low molecular weight and density, storage of hydrogen in a compact space is also a big challenge. It needs to be heavily compressed or stored in cryogenic/liquid form. The storage tank design, whether it's flying in the sky on a plane or riding in the back of fuel cell vehicle on the ground, requires special consideration for embrittlement, leakage and associated safety risk.

3. SCALE

Finally, there are end-use challenges related to scaling hydrogen. The current system size and weight of fuel cells are large, especially for aerospace and automotive applications. Their durability and reliability need to be improved for most transportation applications. Thermal, water, and air management are also challenges when attempting to keep the size of the heat exchanger and overall system small.

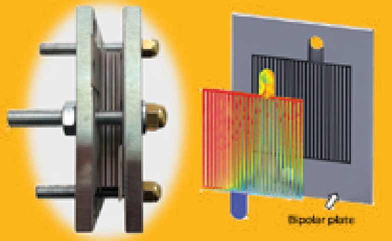
"Current hydrogen technologies (e.g. electrolysis or fuel cells) are mature enough to engage the hydrogen economy at scale for decreasing the costs," says Claude Heller, former director of group R&D programs for Air Liquide, now a senior advisor for the hydrogen economy. "In parallel, there is still a need to improve processes in order to decrease the costs beyond the size effect.



Aviation sector's commitment to net-zero (Source: IATA)

Ansys simulation technology is used for individual cell design, cost-effective and lightweight material selection, cell-stack optimization for energy efficiency, and thermal management of overall fuel cell and electrolysis system.

For that purpose, a better understanding and better modeling of electrochemical reactions at molecular scale and processes at system levels (e.g. cells or stacks) is essential."



A proton exchange membrane (PEM) water electrolysis stack for hydrogen production (left) with optimized cell design through Ansys simulation (right)

SIMULATION TECHNOLOGY ENABLES HYDROGEN ADOPTION

Ansys technology enables companies to overcome the challenges associated with hydrogen by improving performance at every phase of its ecosystem and accelerating new technology development to address the cost and scale conundrum. For example, ENHIGMA, a national project that involves different companies, as well as technological and research centers, used Ansys technology to manufacture low–cost, energy–efficient and durable proton–exchange–membrane–based electrolyzers (PEM) and fuel cells. As shown in the photos (right), Centro Nacional del Hidrógeno (CNH2) researchers optimized the PEM cell stacks using flow simulations in Ansys Fluent.

Ansys simulation technology is used for individual cell design, cost–effective and lightweight material selection, cell-stack optimization for energy efficiency and thermal management of overall fuel cell and electrolysis systems.

Cryogenic storage and transport are at the core of the hydrogen ecosystem. Ansys composites solutions can be used to design cryogenic vessels while closely mimicking its manufacturing process. The composite failure tool in Ansys Mechanical enables designers to evaluate potential failure modes and failure locations in-depth using advanced composite failure criteria, such as Tsai-Wu, Puck, and LaRC. It can further be used to understand the effect of embrittlement and crack initiation and propagation.

A typical hydrogen production system or hydrogen–based fuel cell plant contains many components. Most of these can be represented by a simplified model, but most critical parts — such as a fuel cell or PEM-cell stacks — can be represented by a ROM derived from Ansys 3D physics solvers. ROM creation for this digital twin is enabled by Ansys optiSLang, which automates the simulation toolchain and connects to algorithms for robust design optimization (RDO). With connection to live sensor data, this digital twin can monitor and optimize operations while enabling predictive maintenance.

By empowering engineers to explore more hydrogen design options faster and more affordably, simulation will help meet the top challenges related to increased hydrogen adoption. Being able to design and test hydrogen–related technologies in a virtual environment speeds time to market, which is critical as governments and industries rush to meet the 2050 net–zero carbon goals.

Hydrogen flame (mixture fraction) details captured by large eddy simulations

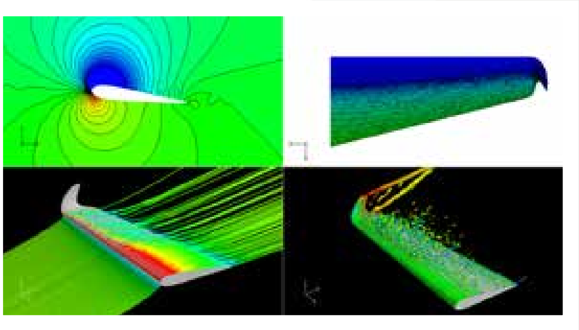
Toyota Simulates from Land to Air and Back Again

Collaboration among engineers often leads to innovation, but engineers at Toyota Motor Corp. have extended their knowledge of automotive aerodynamics by working with an air racing team. The unusual collaboration employed simulation to improve both airplane and automobile aerodynamics.

Yusuke Nakae, in charge of R&D of CAE technology at Toyota Motor Corp., has been working with Toyota's JSOL Corp. on fluid analysis using Ansys LS-DYNA to measure aerodynamic forces generated when a vehicle is in motion and how it affects vehicle stability. By using automotive simulation results to improve the air racing plane, and then learning from those results to improve Lexus vehicles, Nakae's team has found analyses that wouldn't have been possible using conventional methods.

FROM CONVENTIONAL TO EXPERIMENTAL AERODYNAMICS

The conventional method of testing vehicle aerodynamics involves applying wind to a car when it's stationary and then measuring what changes via experiments and calculations. Wondering how the air forces would be different when the car was moving vs. when it was stationary inspired Nakae's team to try to analyze a moving vehicle. Specifically, they wanted to simulate the aerodynamics of a car as it changed lanes using LS-DYNA.



Aerodynamic simulations of wings

The results obtained from normal analysis (where wind is applied when the car is stopped) were clearly different from the results when the car was driven. However, measuring the force of air when driving the car was still a challenge — even in a wind

“Analysis technology enables us to realize methods and performance that overturn conventional wisdom.”

— Yusuke Nakae, Toyota Motor Corp.

tunnel. Nakae’s team wanted to use simulations to quantitatively analyze the difference in aerodynamic forces. Because Toyota uses LS-DYNA as a standard tool for crash safety performance analysis, the team thought it could create an ideal environment for analyzing multiple physical properties with a single solver if they could add a fluid analysis function to it.

Lexus was sponsoring Yoshihide Muroya, who competes in the Red Bull Air Race World Championships. In 2017, Nakae’s team first tested their theory on airplane aerodynamics leading up to the race.

AIRPLANE AERODYNAMIC RESULTS BENEFIT CAR DESIGN

In the airplane world, aerodynamic analysis is usually done in a stationary state, so getting the air racing team to agree to applying the knowledge and expertise used in automotive simulations to airplane racing design was a challenge.

Part of the problem was the difference in air speed.

Airplanes are fast — propeller planes travel at 350 km per hour — while cars are slow, traveling at 100 km per hour. Moreover, airplanes are streamlined, but cars are not, so flows around their bodies are completely different. This means researchers couldn’t accurately calculate aerodynamic force unless they could reproduce their flow, especially in turbulent conditions.

Luckily, an abundance of experimental data on airplane wings already exists, so Nakae’s team could choose the right turbulence model for the airplane analysis.

Using different motions that would result in different aerodynamic forces, the team conducted simulations. High-performance computing was used to go through the complex calculations, compile the data, visualize it, and share it with the air racing team.

During air races, the team would test techniques, analyze the data they recorded and then test the updated techniques iteratively. A competitor even noticed that Muroya was flying in a bigger circle, yet their total time decreased.

AIR RACING RESULTS INSPIRE NEW LEXUS VEHICLE

Toyota/Lexus learned a lot from this experience.

“I learned how to control vortices, which should not be generated from the perspective of aerodynamic drag,” Nakae said. “I gained experience on how to control vortices by experimenting with different shapes of winglets and analyzing the simulation to find the one with the least aerodynamic drag.”

Turning to automobiles, the team knew that creating effective vortices around a car could improve its dynamic performance. And performance turned out to be as good as they hypothesized, leading to the release of the Lexus LC 500 Inspiration Series in January. This limited edition takes the 471-horsepower V8 grand-touring coupe to the next level. A big upgrade inspired by air racing is a carbon-fiber reinforced plastic rear spoiler modeled after an inverted aircraft wing with vortices at the wingtips that improve maneuverability and efficiency.

LOOKING TO THE FUTURE

While the Red Bull Air Race World Championships was deactivated in 2019, Nakae’s team will work to continue aerodynamic simulation research.

Looking at future automotive design, Toyota/Lexus will continue to use what they are learning by comparing the two different transportation methods and analyzing them to create new products.

As Nakae says, “Analysis technology enables us to realize methods and performance that overturn conventional wisdom.”

We Choose to Go Back to the MOON

Intuitive Machines is using multiphysics simulation to help land an unmanned vehicle on the moon in 2022.

By **Trent Martin** and **Marcel Bluth**, Intuitive Machines, Houston, Texas

NASA's plans to return humans to the Moon after an almost 50-year absence has challenged engineers to develop a spacecraft based on much more advanced technologies than those available in the 1960s. Before they send humans, they intend to send a series of commercial robotic missions.

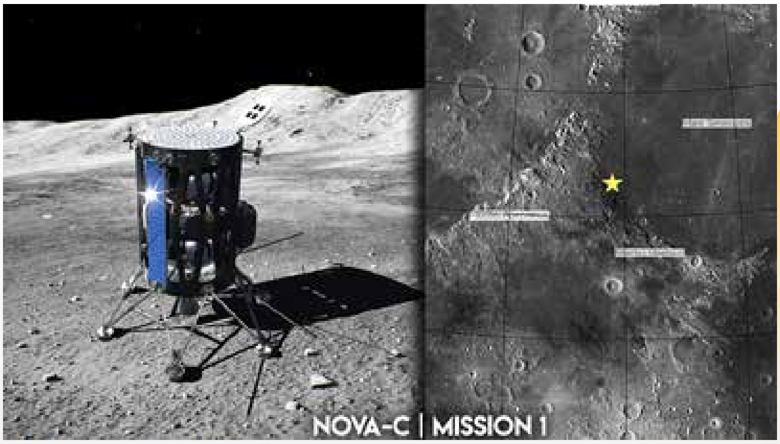
Intuitive Machines is one of two commercial companies that has won the right to deliver NASA payloads to the lunar surface. They are using multiphysics simulation to understand the properties and operating conditions of new fuels, composite materials, and cooling systems that will enable them to land an unmanned vehicle on the moon with little time for design and testing.

Vice President of Research and Development of Intuitive Machines Tim Crain, second from right, speaks with Thomas Zurbuchen, NASA Associate Administrator for the Science Mission Directorate, second from left, about the company's lunar lander on May 31, 2019, at Goddard Space Flight Center in Maryland. Intuitive Machines was one of three companies selected to provide the first lunar landers for the Artemis program's lunar surface exploration.
Image credit: NASA/Aubrey Gemignani

When U.S. President John F. Kennedy announced on Sept. 12, 1962, that "We choose to go to the moon," he set the goal as the end of the decade. This gave NASA engineers a little over seven years to overcome the many challenges involved in putting men on the moon and returning them safely to Earth. The successful Apollo 11 mission in July 1969 fulfilled Kennedy's vision and stands as a testament to human ingenuity and valor.

When Intuitive Machines of Houston, Texas, won the contract in 2019 to land five NASA payloads safely on the moon in 2021, they had a much shorter timeline of just two years. (These missions have now been delayed due to the COVID-19 pandemic.) Considering that lunar landings have until now been the "purview of superpowers," as Steve Altemus, one of the founders of Intuitive Machines likes to point out, and that no company has ever landed on the moon, this is quite a big challenge. With such a tight timeline, they will not have the luxury of building and testing multiple prototypes to incrementally work out the bugs. The first flight vehicle that Intuitive Machines builds will be the one that goes to the moon, greatly limiting their testing time.

The prototyping constraints make engineering simulation a key to achieving the goal. As part of the Ansys Startup Program, which gives fledgling companies access to Ansys simulation software at a fraction of the list price, Intuitive Machines engineers are using Ansys Fluent to solve liquid oxygen/methane heat transfer challenges in the main engine. This is the first time anyone has used methane as a fuel for in-space propulsion. They are also using Ansys Mechanical



Intuitive Machines' Nova-C will land near the Moon's equator.

to perform load analysis on all metallic components, as well as to reduce mass as much as possible while maintaining structural integrity under the high stress conditions of spaceflight. The engineers are performing multiphysics thermal and structural simulations, along with advanced materials simulations, to figure out how to keep electronics and cryogenics systems within temperature specifications in the wide temperature ranges the spacecraft will experience while in transit and when sitting on the moon's surface. And they have recently acquired Ansys HFSS to optimize low- and high-gain antennas that will be used for communicating with the lunar lander.

MOON LANDING MISSION DETAILS

To meet NASA's goal of landing payloads on the moon two to three times a year for 10 years following the first 2022 mission, Intuitive Machines engineers are designing the NOVA-C lunar lander using mostly composites to keep the weight down, with a liquid oxygen/methane engine, precision landing and hazard avoidance systems, and the capacity to transport 100-kg payloads from Earth to the moon for a soft landing on the surface. For the first mission, called IM-1, the NOVA-C will be boosted into orbit by a SpaceX Falcon 9 rocket and land a little north of the moon's equator six days later. For most of the flight, NOVA-C will be controlled remotely from Houston, but the final descent and landing will be completely autonomous. When given the "Go" command, NOVA-C will fire its own rockets, automatically determine the best landing site to ensure it doesn't land on a rock or a crater, and touch down within a 200-meter ellipse of the target landing site. The first landing will occur during daytime, so only visual cameras will be necessary for navigation and landing; the company will add lidar sensors for potential future nighttime landings. During 14 days on the moon, the payloads will carry out various experiments before NOVA-C enters the lunar night where the temperatures drop to levels so low that the vehicle electronics and batteries are unlikely to survive.

The second mission, called IM-2, will have as part of its payload Intuitive Machines' μNOVA (micro-NOVA) "hopper," which is a flying rover developed as an alternative to the dune buggy–type rovers that have been used on the moon and Mars. The μNOVA vehicle can fly to extreme environments, such as the bottoms of lunar craters, that are a challenge for a wheeled vehicle to navigate. The main purpose of the IM-2 will be to use NASA's PRIME-1 payload to drill into the surface of the cold South Pole to look for subsurface ice that scientists believe might be present. While that is going on, the μNOVA will be flying from one crater to another, a few 10s of yards at a hop, examining "permanently shadowed regions," which have never seen sunshine, taking data and sending it back to the NOVA-C for transmission to Earth.

COOLING ELECTRONICS IN A VACUUM

All electronics have a specified temperature range for optimal operation. For this project, the vacuum of outer space and the moon (which has no atmosphere) poses one type of challenge. Another will be adapting to the dramatic temperature variations the NOVA-C will experience between the in-transit and lunar surface phases of the mission. In transit, the lander will be extremely cold, so heaters keep electronic elements warm. Activating heaters is simple enough, but when sitting in the sunlight on the moon's surface, NOVA-C will get hot, and Intuitive Machines engineers must develop a way to keep the electronics from burning up.

With no atmosphere on the moon, heat cannot be dissipated by convection, and an active cooling mechanism like a fan would be useless because there is no air to move for cooling purposes. The main cooling mechanism is radiation, a passive mechanism that works even in a vacuum. Materials are key to passive radiation cooling. Intuitive Machines' engineers are using Ansys Mechanical to develop a system that has low mass, high conductivity and high emissivity — a measure of a material's effectiveness in emitting energy as thermal radiation — to exchange heat with the vacuum of space. They are investigating advanced materials for high thermal conductivity to use in thermal heat spreaders and thermal radiators to keep electronics cool. They are also simulating the effects of emissivity on different multilayer insulation architectures that are common on spacecraft. Using simulation to study the heat transport properties of laminated layers of composites, they are attempting to optimize the cooling properties of, for example, a composite radiator plate to keep the electronics within the specified temperature limits.

One area of concern is the avionics package, which controls the flight parameters for the mission and contains many integrated circuit chips, some of which generate significant amounts of heat. The engineers may have to dissipate anywhere from a few tenths of a watt to one or two watts of power from a chip to keep the temperature within specifications. But they can't put a thermal sensor on every chip. Instead, they use Ansys thermal simulations to map the temperature of the aluminum box that contains the printed circuit board on which the chips are mounted. By using the temperature data from specific points on the surface of the aluminum casing, they can perform thermal simulations to determine the temperature of the chip itself. With this information, they can add heat spreaders to transfer excess thermal energy to the chassis of the NOVA-C to either radiate the heat out into space or conduct it back into the lander for re-use.

Prior to adopting Ansys software as their standard, Intuitive Machines' engineers worked with separate thermal and mechanical simulation solutions from different vendors. They had to spend a lot of time mapping the temperatures from the thermal analyses onto the structural model because the grid layouts were not the same in the two software packages. With Ansys thermal and structural solvers working together with the same geometry, the mapping is easy and automatic, saving them time and money.

REDUCING THE MASS OF THE NOVA-C

Keeping the mass of the lander as low as possible is key to this mission. Less mass in the lander means more room for customer payloads. Every extra kilogram built in to the lander costs Intuitive Machines a significant amount of money in lost business opportunities, so the engineers are planning to use topology optimization to reduce mass. Instead of looking first at the overall architecture of the NOVA-C, they will initially concentrate on internal details like inserts, fittings and joints that hold the lander together. Because these parts are used many times in the construction of the lander, saving a little mass on each piece quickly adds up. If the engineers can use topology optimization in Ansys Mechanical to save 100 grams on a particular fastener that is used at 20 places in the structures, that's a savings of 2 kilograms. While 2 kilograms may not sound like much, at an estimated payload price of ~$1 to $2 million per kilogram a few kilograms can add up quickly.

KEEPING SEALS SEALED

The NOVA-C consists mostly of composites to keep the weight down. The engineers include metals for the engine and various connecting points where they make more sense than composites. The interface between metals and composites is a point where the differing thermal expansion properties of the materials make it difficult to keep them in contact under extreme temperatures, particularly at the exit nozzle of the main engine.

To address that challenge, the engineers are taking a thermostructural multiphysics approach to design the exit nozzle connection. They are using Ansys Fluent to estimate temperatures, gas flow, heat conduction and heat load at the metal-composite seal and Ansys Mechanical to determine the effects of these temperatures on the expansion of the metal and the carbon-carbon composite. Multiphysics simulation is helping them to understand the dynamics of this section of the spacecraft and produce a design that will ensure that the nozzle stays sealed under all operating conditions.

THE LARGE ROLE OF SIMULATION

Intuitive Machines engineers consider simulation to be essential to the success of this project due to its many challenges and tight deadline.

For critical structural, thermal and fluid flow simulations, they trust Ansys simulation solutions to get them to the moon in less than two years. Success will make Intuitive Machines the first small, privately funded company ever to land on the moon. If anyone is racing to beat them to this distinction, they'd better hurry.

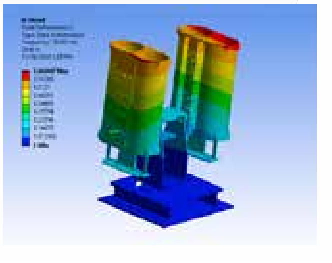
Shedding Light on a Shadowy Target

By Ansys Advantage Staff

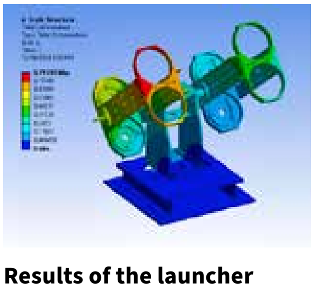
Could something as small and lightweight as a softball enable extended lunar missions and make the moon a launch pad for interplanetary travel?

A multidisciplinary team of undergrads and graduate students from the Arizona State University (ASU) Luminosity Lab hopes the configurable, multi-probe exploratory system they call VELOS may provide a giant leap in that direction.

VELOS, which is short for Variable Exploratory Lunar Observation System, is a finalist in NASA's Breakthrough, Innovative, and Game-changing (BIG) Idea Challenge. The annual competition gives grants to university teams to develop new approaches and technologies supporting the space agency's Artemis program, whose mission is to return humans to the moon.

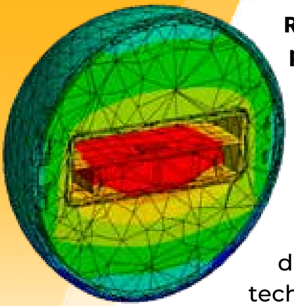


Results of the launcher shock and vibration simulation



Results of the launcher static structural simulation

The ASU team used Ansys Explicit, part of the Ansys Mechanical suite, to validate VELOS' moon-readiness ... Ansys Workbench's transient thermal analysis capabilities provided insight into how long the probes could reliably perform.



Results of the probe thermal simulation

For the 2020 challenge, students developed technology systems to explore one of the coldest and darkest places in our solar system: the largely uncharted permanently shadowed regions (PSRs) of the moon. Little is known about the area in and around the PSRs, making data collection important.

VELOS, one of eight finalists in the challenge, provides a means for data collection in a combination launcher/ probe system. Its catapult-like launcher assembly is capable of lofting four softball-sized, sensor-filled probes 100 meters (109 yards, roughly the length of a football field) on a preset trajectory into and around the PSRs. VELOS integrates with any Commercial Landing Payload Services (CLPS) lander, the payload delivery service to the moon.

VELOS system launching into a permanently shadowed region in VR environment

VELOS' probes can accommodate any sensor that fits, meaning the system could eventually be used for any number of science missions. However, for project purposes, the ASU team focused on a specific goal: understanding which elements are present in the regolith, the unconsolidated rocky material inside the PSRs. That includes detecting ice that could provide a water source for sustained lunar operations and even human habitation.

Probe subsystem

The ASU team used Ansys Explicit, part of the Ansys Mechanical suite, to validate VELOS' moon-readiness, including structural load testing, vibrations testing, and drop testing. Ansys Workbench's transient thermal analysis capabilities provided insight into how long the probes could reliably perform in the PSRs' ultra-cold environment.

THE FUTURE ON ICE

PSRs are located in craters at the moon's north and south polar regions, areas never exposed to direct sunlight. Temperatures there can be as low as 35 Kelvin (-394 degrees F). That is colder than Pluto, which averages a slightly less frigid 45 Kelvin (-378 degrees F). Both make the lowest temperature ever recorded on Earth — 184 Kelvin or -128 degrees F — seem like a sauna.

As forbidding as PSRs are, though, it appears they have one attribute essential to future deep-space missions: ice.

And where there's ice, there's typically water.

Launcher subsystem

ASU had less than a year to design, conduct proof-of-concept testing and validate VELOS. Meeting the timeline would have been impossible without rapid design iteration. And that was possible only by relying heavily on fast, accessible simulation.

Water stored as ice on the otherwise bone-dry moon could be revolutionary for science, space exploration and mankind itself. A source of water on the moon could sustain human life and supply hydrogen and oxygen, the building blocks of rocket fuel. That could provide a ready energy reserve for spacecraft going back and forth between the moon and Earth, as well as for those journeying to Mars.

The challenge, of course, is creating PSR exploration technology that can withstand harsh lunar conditions, not to mention the rigors of deep space travel.

That's a tough assignment under the best of circumstances. For ASU, doing the work on a compressed schedule — and during a global pandemic that shuttered many test facilities — made simulation even more important than normal.

From the time they received the challenge grant in February 2020, ASU had less than a year to design, conduct proof-of-concept testing and validate VELOS, plus prepare a presentation for NASA. Meeting the timeline would have been impossible without rapid design iteration. And that was possible only by relying heavily on fast, accessible simulation.

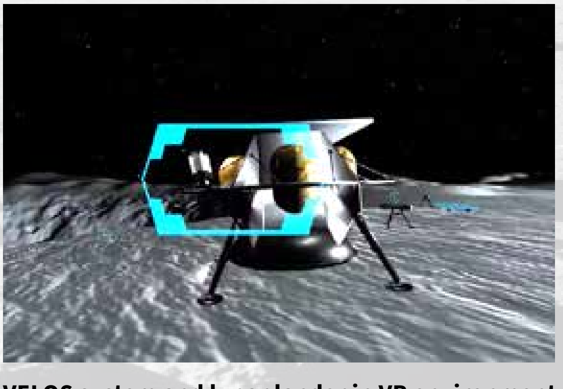
SIMULATING SHOCK, IMPACT AND BRUTAL COLD

The primary function of the VELOS probe is to collect data and transmit it to the launcher. But none of that is possible if its probes can't survive the shock of being launched, the impact of landing or the area's extreme thermal environment.

With help from Ansys channel partner PADT — and the support of advisors that include ASU's Jim Bell, the primary investigator on the Mars rover science camera — the team simulated turret structural integrity, probe drop testing and thermal response to PSR conditions in Ansys Explicit.

VELOS uses preloaded springs mounted to a rotating turret to launch the probes in an array that maximizes data collection potential. Once the CLPS lander's camera identifies a PSR, the turret swivels toward it then launches the four probes sequentially. The team performed structural and vibration analysis of the turret to help them understand the load placed on it during probe launching. This enabled a design that could withstand those forces while also ensuring launching wouldn't disturb the lander's sensitive equipment.

When it came to designing the probe's exterior, protecting the important electronics inside it was key. The probe's outer shell, which is made of HDPE and covered in an insulated blanket, and the internal energy absorption material — an aerospace-grade carbon foam — were designed to plastically deform during impact yet still protect the sensor electronics. To test the efficacy of their design, ASU chose a drop test velocity that represented a worst-case scenario: the probe impacting the regolith at 12.72 m/s without any angle of incidence.



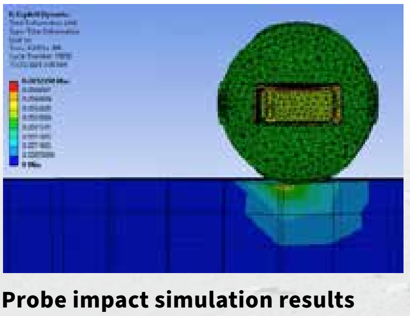
VELOS system and lunar lander in VR environment

The first simulation compared dropping the probe from a height of 1.67 meters (5.4 feet) onto a concrete surface and a sand-based surface. The resulting accelerations were used to run a structural analysis of how the probe shell would behave if it was launched onto a solid surface. The simulation indicated that the probe shell's performance was consistent with the design intent. It yielded and sustained damaged at the point of maximum stress while providing rigid protection for the electronics inside it.

Lunar lander in VR environment

Determining the lifespan of the probe's electronics at 35 Kelvin could have been done in a facility — if one had been readily available and not cost-prohibitive.

Instead, the ASU team performed partial vacuum testing using liquid nitrogen for cooling then validated the physical model, which assumed an initial probe temperature of 36 C (96.8 F) and an ambient temperature of -237.85 C (-396.13 F), in a transient thermal simulation using Ansys Explicit. The team determined that the probe's electronics should be able to operate continuously for five hours before temperature control is lost and the probe stops functioning.



Probe impact simulation results

A NOVEL, SCALABLE APPROACH

VELOS physical prototypes proved that it is more than just a wishful concept. During testing, the launcher successfully actuated, sending the probe more than 16.5 meters (54 feet) in Earth gravity, which is the same as the desired 100 meters in lunar gravity. Two probes launched at different distances and headings maintained operation.

What's next for VELOS is not certain, although it's not unreasonable to think the concept could be picked up by a commercial space provider.

In the meantime, the ASU Luminosity Lab team, a group accustomed to creating novel solutions to address some of the world's most pressing challenges, has developed an innovative, low-cost, reliable and scalable approach for exploring an unknown environment — something they would have been unable to do without Ansys simulation.

And who knows? Someday, their system might help scientists find water in the deep, dark crevices of the moon, allowing astronauts who travel there to become long–term visitors.

Simulation Deployed to Build the First Commercial Space Station

By Ansys Advantage Staff

The International Space Station (ISS), after 20 years of use by hundreds of astronauts, is only guaranteed funding to keep it running through 2024. Just as NASA opened the way for commercial entrepreneurs like SpaceX and Blue Origin to make the next generation of rocket boosters to lift people and payloads into orbit, it is now looking for entrepreneurs to take over the space station and build its replacement.

Axiom Space was founded in 2016 by Michael Suffredini, ISS program manager for NASA from 2005 to 2015, and Dr. Kam Ghaffarian, founder of Stinger Ghaffarian Technologies Inc., NASA's second-largest engineering services contractor. In early 2020, Axiom Space won the NASA contract to build the first commercial space station, initially attached to the forward Node of the ISS. There is a countdown on their website to the launch of Axiom Hub One, a space module that will travel to the ISS in roughly three years.

A rendering of an Axiom space station interior

"As a startup, you are always looking for deals because funding is limited in the early years. The Ansys Startup Program has proven to be a great deal for us."

— Matt Ondler, CTO, Axiom

Ansys stress analysis results are driving the design of the first Axiom module (AxH1).

Ansys will be helping them all along this timeline. Axiom engineers are trying to solve the toughest structural and fluid flow challenges they face using Ansys Mechanical and Ansys Fluent software obtained through the Ansys Startup Program.

"As a startup, you are always looking for deals because funding is limited in the early years," says Matt Ondler, chief technology officer of Axiom. "The Ansys Startup Program has proven to be a great deal for us."

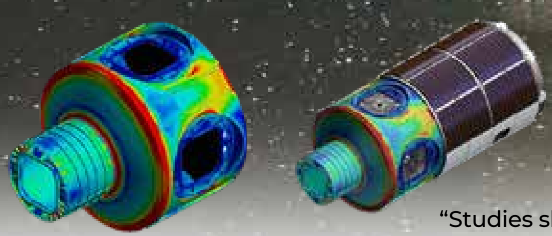
DESIGNING AND SIMULATING A UNIQUE THRUSTER

Axiom engineers are relying on an innovative thruster powered by oxygen and methane to propel Axiom Hub One to the ISS. They will get a boost into space from a SpaceX or Blue Origin launcher, then, once in orbit, they will depend on this new thruster to maneuver them to the ISS.

The oxygen-methane thruster solves two challenges: It replaces the toxic monomethyl hydrazine fuel that has traditionally been used to maneuver shuttle craft to date, and the methane fuel can be created throughout the mission from an unexpected source.

"We can make rocket fuel out of exhaled breath from the crew," Ondler says. Doing this relies on the Sabatier process, which uses a nickel catalyst to react hydrogen with carbon dioxide from the astronaut's breath to produce methane and water. It has already been tested and proven to work in ISS experiments.

> *"Our experience with Ansys Mechanical and Fluent has been very, very positive. The interface has been easy to learn and easy to use. The Ansys Startup Program has given us access to much–needed simulation tools."*
>
> *— Matt Ondler, CTO, Axiom*



"Studies show that with a crew of about six we can produce enough methane to meet all of our propellant needs," Ondler says. "The technology has long-term applications. There's a lot of CO_2 on Mars, so you could create the rocket fuel to bring you home from a Mars mission instead of carrying all that fuel with you."

But nobody has ever flown an oxygen–methane–powered spacecraft before, so they are using Ansys Fluent to help in the design. One of the challenges of the thruster is maximizing the efficiency, which is measured by a variable called the "specific impulse." This is just the total impulse (the average thrust force times the total firing duration) divided by the weight of the propellant used. The higher the specific impulse, the less fuel is consumed for a particular change of velocity.

One step in maximizing the specific impulse is to mix the methane and oxygen molecules as thoroughly as possible. An injector plate that causes the molecules to swirl and mix is an art and a science, according to Ondler. "So we run Ansys Fluent and get simulation results and we build that solution and test it to see how it works and then iterate between simulation and testing," he says.

"Maximizing the specific impulse of the thrusters trickles through the whole system — the more efficient the specific impulse, the smaller you can make the fuel tanks; the smaller you can make the tanks, the more margin you have on the vehicle itself, and it just propagates through the whole spacecraft."

SPACE STATION STRUCTURAL CONSIDERATIONS

An Axiom Hub, which will attach to the ISS and to any future commercial space station they build, is a living and research space for the astronauts who will occupy it. It is 60 feet long by 15 feet in diameter and weighs close to 60,000 pounds.

"These modules are massive pieces of hardware, and when you have pressure inside and vacuum outside they stretch and swell and bend," Ondler says. "We're using Ansys Mechanical to help us understand all those attributes: how it bends, where the stress points are, where we might need to change the design."

Structural loads will vary depending on whether the module is on the ground, being transported to the launch site, or experiencing the high forces of launch. Thermal loads can also cause major structural challenges in space because the side of the module facing the sun might be several hundred degrees hotter than the side facing away from it. Thermal expansion and contraction in cases like this could be enough to cause separation of the structure or buckling if the module is not designed correctly. Ansys Mechanical will help to make sure this doesn't happen.

"Our experience with Ansys Mechanical and Fluent has been very, very positive," Ondler says. "The interface has been easy to learn and easy to use. The Ansys Startup Program has given us access to much–needed simulation tools."

PRIVATE SPACE STATIONS ARE CRITICAL

Designing, manufacturing and flying the hubs to the ISS is the immediate goal. Ultimately, Axiom Space will separate from the ISS and become its own independent space station — the first fully commercial space station. After separation, Axiom will continue to add modules, some of which might be custom–built for specific space manufacturing or research customers. While some might question the need for another space station or even multiple stations with different functions, Ondler is sure we need space stations in both the near and distant future.

"The immediate use of our space station hubs will be to experiment with and manufacture products in microgravity that cannot be manufactured on the ground," he says. He cites some interesting, practical solutions that have been explored on the ISS:

- A fiber–optics cable that has 100 to 1,000 times the transmission length capability of current fiber optics.
- Perfect retinal and corneal implants that can be bio-printed in microgravity but would deform if made on Earth due to gravitational forces.
- Metal alloys whose components would settle out like oil and vinegar on Earth but that stay together in microgravity and create completely different metal characteristics and capabilities.
- Perfect protein crystals for faster and more efficient drug evaluations.

"And then there's a bigger, more existential need for space stations in the long run — pushing humanity beyond the Earth, "Ondler concludes. "It may be 100 or 1,000 years in the future, but to survive as a species we will have to populate multiple planets."

New space stations will be the steppingstones to these planets. Ansys simulation solutions will be there to help engineers solve their toughest challenges. Λ

How Simulation Is Helping Make History: The First Flight Attempt on Mars

By Ansys Advantage Staff

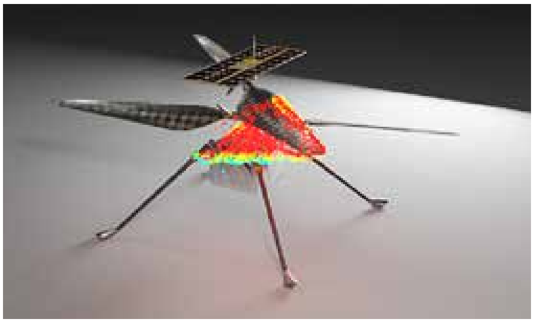
NASA's Perseverance Mars rover took a selfie with the Ingenuity helicopter. *Credit: NASA*

NASA is making history with a 4-pound (1.8 kg) helicopter named Ingenuity. Earlier this year, the world witnessed the first powered flight on another planet.

NASA's Perseverance rover, where Ingenuity was stored, touched down on Martian soil on February 18, 2021. In April, the Perseverance rover dropped Ingenuity onto the surface of the Red Planet to fend for itself. The helicopter took flight along the surface of the Jezero Crater with the first in a series of flights that would far exceed expectations for the tiny craft.

How could NASA be sure they had a helicopter that is going to make the trek to Mars and have a chance of flying? For one thing, they used Ansys Fluent to calculate the aerodynamic forces on the rotor blade.

Tracer particles are colored by velocity



Maximum velocity is red in color

It is difficult to anticipate the potential challenges of flying on Mars. Simulation and wind tunnels are critical to flight tests because they can replicate what an aircraft will experience. Accurate recreation of another planet's gravity and atmosphere on Earth is nearly impossible, so the keys to the successful flights were simulations that are truly out of this world.

THE CHALLENGES OF FLYING ON MARS

The main challenge to Mars flight is the thin atmosphere. The world altitude record for helicopter flight on Earth is held by Frenchman Frédéric North at 42,500 feet. The air at that stratospheric level is so thin that North's helicopter rotors could not lift him higher. On the surface of Mars, the atmospheric density is equivalent to Earth at 100,000 feet. The Ingenuity helicopter relied on a light design, large coaxial rotors, and the lower Martian gravity to fly in such extreme conditions.

The Martian flight environment is vastly different from Earth's:

- Density is 1% of Earth's
- 95% carbon dioxide
- Gravity is a third of Earth's
- Average temperature of -60 C (-76 F), with nights as cold as -90 C (-130 F) at Jezero Crater

Once Ingenuity leaves the ground, maintaining directional control in such a thin atmosphere is the big concern. To avoid crashing, continuous corrections are required to rotor pitch, roll, and angle of attack on a millisecond-by-millisecond basis. Simulation of the advanced flight control systems is the key to safe flights on Mars, but this requires accurate aerodynamic data.

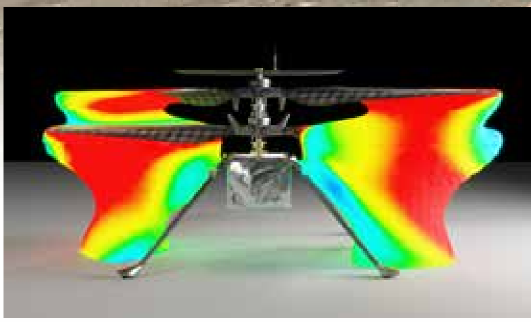
Before the mission, flight on Mars was theoretically possible, but engineers wondered if there would be enough control to let it succeed.

MAKING MARTIAN FLIGHT POSSIBLE WITH ANSYS FLUENT

How could NASA be sure they had a helicopter that was going to make the trek to Mars and have a chance of flying? For one thing, they used Ansys Fluent.

According to a research paper[1], Fluent was used to calculate the aerodynamic forces on the rotor blade. To predict these forces, the rotor blade was divided into many slices that included span, chord, twist, and sweep.

Coefficients of lift, drag, and pitch moment as a function of angle of attack and Mach number were then calculated. These values were tabulated and used for helicopter flight dynamics modeling at NASA.



An Ansys simulation showing zones of high pressure under the Ingenuity helicopter's rotors.

The simulations on the previous page show massless tracer particles that highlight the impact of the rotors as they slice through the atmosphere. The tracer particles are colored by velocity. We should see maximum velocity (red color) at the rotor and near the tips. We should see lower velocity as the particles make a spiral path to the ground plane. As the rotors pass by one another, we should not see the particles from the lower rotor being pulled up or disturbed by the upper rotor. We want to keep the interaction between the counter-rotating air currents pulled by the rotors to a minimum to ensure maximum lift for the helicopter.

WHY NOT A QUADCOPTER?

Ingenuity's rotors are arranged co-axially, which is not the popular quadcopter layout of many Earth-bound drones. Why is this? Coaxial rotors on Ingenuity increase efficiency.

The image above depicts zones of high pressure under the rotors. Pressure zones under the lower rotor are larger because the upper rotor has already compressed the thin Martian atmosphere. This phenomenon allows the lower rotor to provide more lift. A quadcopter, with its four independent rotors, does not have this advantage. Additionally, a quadcopter would be slightly heavier for the amount of thrust produced. Extra rotor supports and multiple motors add weight. Finally, a quadcopter would have difficulty being stowed and then unfolded from the belly of the Perseverance rover.

RECORDS ALREADY BROKEN

Ingenuity began as what is known as a technology demonstration — a project that seeks to test a new capability for the first time, with limited scope, according to NASA. It is the result of more than six years of work by engineers on the Ingenuity team.

Even if the copter would not have made such a successful series of flights, the team would have already demonstrated that it was theoretically possible to build an ultra-lightweight craft that could generate enough lift in Mars' thin atmosphere to take off from the ground and operate and survive autonomously in the challenging Martian environment. As NASA said before Ingenuity deployed: These accomplishments have already pushed the boundaries of flight.

"When NASA's Sojourner rover landed on Mars in 1997, it proved that roving the Red Planet was possible and completely redefined our approach to how we explore Mars. Similarly, we want to learn about the potential Ingenuity has for the future of science research," said Lori Glaze, director of the Planetary Science Division at NASA Headquarters via a press release before the first flight. "Aptly named, Ingenuity is a technology demonstration that aims to be the first powered flight on another world and, if successful, could further expand our horizons and broaden the scope of what is possible with Mars exploration."

After demonstrating that the technology works, Ingenuity took on a new mission. The Ingenuity experiment has entered into a new operations demonstration phase, exploring how aerial scouting and other functions could benefit future exploration of Mars and other worlds.

In fact, 16 flights later (as of press time), Ingenuity is still going strong. It has flown almost 3 kilometers and is now engaging with Perseverance on their joint objective to explore the Jezero Crater. Air on Earth can be 30 times denser than Martian Standard Temperature and Pressure. That makes piloting Ingenuity not just a first for aerodynamics, but a game-changer for offworld exploration.

BEYOND RECORDS

Ingenuity is now going into one of its most challenging flights to date.

The crossing of the Séítah region of Mars' Jezero Crater will take at least two flights, with a stop halfway across. This stop is necessary to reduce flight time, because of higher rotor RPMs, which means Ingenuity would need to fly faster to cover the same distance. Flying faster increases the navigation uncertainty built up during a flight, which means larger landing ellipses are required. By flying slower, Ingenuity can better target a landing site in South Séítah. Also, the terrain on the eastern side of South Séítah is more hazardous than the western side.

With two flights, Ingenuity can better target safe landing sites on the eastern side of Séítah, without excessive risk on landing.

During this flight, which is known as Flight 17, Ingenuity is expected to fly 187 meters at an altitude of 10 meters and be airborne for 117 seconds.

SIMULATION AND SCIENCE REDEFINE EXPLORATION

To date, Ingenuity has achieved astonishing success, and it hasn't abandoned Perseverance; it's been the perfect scout to lead the journey.

Together, they continue to explore Mars in an unprecedented way that could reveal if life ever existed on the red planet.

This is an exciting time to watch as simulation and science redefine planetary exploration.

Source:

1. "Flight Dynamics of a Mars Helicopter," H. F. Grip, W. Johnson, C. Malpica, D. P. Scharf, M. Mandić, L. Young, B. Allany, B. Mettlerz, and M. San Martin, 2017 (https://rotorcraft.arc.nasa.gov/Publications/files/ERF2017_final.pdf).

***Disclaimer:** The simulation images were created from a geometry Ansys redrew from the public domain model of the helicopter and were run and post processed by an Ansys engineer. NASA JPL was not involved in their creation.*

INGENUITY'S BIG MOMENTS

1. Perseverance and Ingenuity took a selfie together on April 6, sitting on the surface of the Jezero Crater.
2. Once deployed, Perseverance wasn't able to shield Ingenuity from frigid nights on Mars, which can dip to -130 F.
3. Without its faithful power supply, Ingenuity also had to charge itself using its solar panel.
4. On April 19, Ingenuity completed the first powered, controlled flight on another planet and safely landed back on the surface.
5. Ingenuity captured its first color image from 17 feet above the Martian surface on its second flight on April 22.
6. Ingenuity reached a height record of 39 feet in July.
7. Ingenuity survived unplanned swinging around the Martian atmosphere during its sixth flight when it endured pitch and roll motions of more than 20 degrees and spikes in power consumption. This proved Ingenuity's ability to tolerate errors without devolving into instability.
8. During its ninth flight, Ingenuity was airborne for 166.4 seconds — 2.8 minutes — and flew at a speed of 5 meters (16 feet) per second.

Reaching Low Earth Orbit on Short Notice with Aevum's Ravn X

By Ansys Advantage Staff

The Aevum Ravn X autonomous launch vehicle

Space missions typically have long lead times. If you want to launch a payload into low Earth orbit, you have to find a place on a rocket that is due to launch months or years in the future.

Aevum Inc., a member of the Ansys Startup Program, plans to change all that with low Earth orbit autonomous transport services that can be ready for takeoff in as little as three hours.

Jay Skylus, founder and CEO of Aevum, realized that there was no way to quickly respond to the need for supplies to cope with a natural disaster somewhere far away on Earth, or to rapidly deploy a surveillance satellite to better understand the dangers of a military situation anywhere around the globe. In these cases, waiting months or years to hitch a ride on a scheduled rocket simply isn't fast enough.

It was clear that limited access to space was stifling technologies that could save millions of lives. Spurred in part by having a brother in the military, Skylus resolved to democratize the access to space by founding Aevum in 2016. Four years later, on Dec. 3, 2020, Aevum unveiled the world's largest unmanned aircraft system (UAS) by weight, its Ravn X autonomous launch vehicle. Aevum has been selected by the U.S. Space Force for its Agile Small Launch Operational Normalizer 45 (ASLON 45) mission. ASLON 45, which is designed as a building block toward responsive launch and calls for the launching of multiple 3U and larger U.S. government CubeSats into low Earth orbit at a 45-degree inclination. Ravn X is designed to launch in as little as 180 minutes from the initial order.

Realizing early on that simulation would be needed to design the system, Skylus discovered the Ansys Startup Program through Ansys' Elite Channel Partner, Simutech.

"Being able to generate analysis results to justify the margins of safety for different components of Ravn X was very helpful," says Ovidiu Mihai, chief engineer at Aevum. "We would not have been able to do that without the Ansys Startup Program."

IT'S A PLANE, IT'S A ROCKET ... IT'S BOTH

The Ravn X autonomous drone looks like an airplane, and it can take off like one from a runway as short as 1 mile long. It can launch and land at many locations, making it versatile for quick deployment.

But this autonomous drone is only the first stage of a three-part system. It carries a two-stage rocket underneath it, which is activated in the air when the drone has reached a velocity of roughly 650 mph at an altitude of about 60,000 feet. The rocket drops away and ignites the kerosene–liquid oxygen engines of the second stage, while the 100%-reusable drone flies back to the landing strip and parks itself in the hangar, ready for reuse.

The second stage accelerates the rocket, then the third stage separates from the second, which is carrying a satellite or other

“Most of my experience has been doing mechanical simulations and checking them with hand calculations. With Ansys simulations, I get correlation of results within 5% all the time.”

— Ovidiu Mihai, Chief Engineer, Aevum

payload and fires its engines to reach escape velocity (over 17,000 mph) to put the payload into low Earth orbit. The third stage might contain a cargo module that carries 264 smaller drones for personalized delivery of supplies to areas on Earth.

DESIGNING THE RAVN X

Aevum’s design scheme from the start has included minimizing risk, maximizing flight efficiency, and leaving no space junk behind.

“By operating autonomously, there’s no risk to human life,” says Mihai. “The ignition of the rocket engines and the actual rocket flight happen far away from human beings, unlike traditional rockets that lift off from a launch pad on land.” And there are no humans onboard who might be at risk if something goes wrong in space.

Additionally, by removing a human pilot from the launch equation, Aevum can take full advantage of the laws of physics and optimum efficiency, which include significant fuel savings. Unlike other horizontal launches, where the plane acts like a carrier vehicle, Ravn X operates as a true first stage, contributing delta V to the rocket’s momentum. Delta V is the difference between the initial velocity and the final in-orbit velocity.

Ravn X is currently subsonic, though there are future plans for supersonic options. Finally, Aevum is determined to be a steward of the low Earth orbit environment.

“Our end goal is that every system of the Ravn X will be reusable,” Mihai says.

SIMULATING SPACE SOLUTIONS

A major initial challenge in designing multiple-stage rockets is determining the mass fractions for the different stages. The goal is to maximize the mass fraction, which is the ratio of the payload mass to the total vehicle mass.

“We make an effort to optimize fiber placement and fiber direction for all the structural components,” Mihai says. “We can’t get away with only composites — we’ll have some metallic structures as well — but even then, there’s always a way to make sure that

The autonomous drone is only the first stage of a three-part system. It carries a two-stage rocket underneath it.

we only carry the necessary structural weight.”

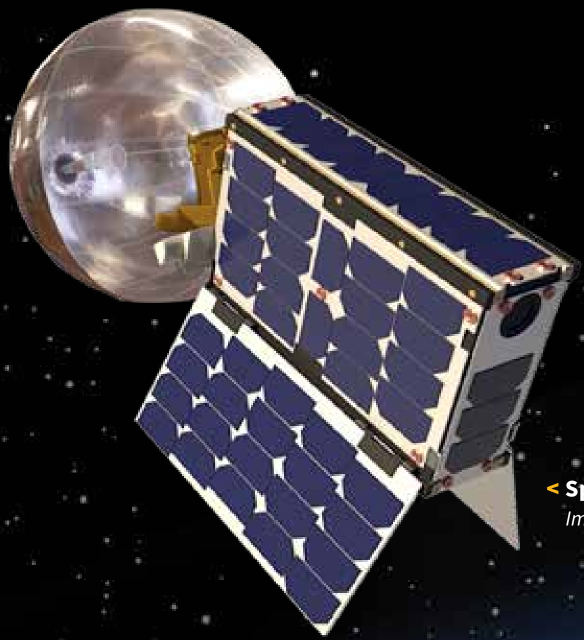
While investigating composites, he has used Ansys Mechanical ACP Prep-Post to predict the margins for failure criteria.

“Using the Tsai-Wu interaction constants is easy with Ansys Mechanical,” he says. “Setting up external data cloud points with pressure fields or other described loads is simple compared to other simulation products.” He also uses simulations to determine Hertzian contact stresses, which are localized stresses that develop as two curved surfaces come in contact and deform slightly under imposed loads.

Mihai has also used Mechanical to design Marman clamps, which hold two cylindrical objects together end-to-end with a ring clamp. Generally, a Marman clamp consists of a circular strap with an interior V-shaped groove. Tension is applied to the strap with a threaded bolt and nuts connecting to the ends. Mihai describes the design work as “normally very tedious,” but he got results quickly and easily using finite element analysis.

“Most of my experience has been doing mechanical simulations and checking them with hand calculations,” he says. “If you get similar results, it’s easier for upper management to say, ‘Go ahead and build a prototype and run a test.’ With Ansys simulations, I get correlation of results within 5% all the time.”

Mihai and his Aevum colleagues have done a lot in a short time — from the online unveiling of the Ravn X in December 2020 to the award of a patent for its technology on May 4, 2021, to its scheduled first commercial mission in 2022. But providing quick turnarounds is what Ravn X — and Ansys simulations — are built to do.



Spherical antenna prototype
Image courtesy of FreeFall Aerospace

Inflatable Space Antennas Improve Their Aim

by Ansys Advantage Staff

Transmitting data to and from space in the most efficient manner possible — minimizing weight, power, complexity, and cost — is and always has been one of the fundamental challenges facing the entire space industry.

FreeFall Aerospace, a Tucson, Arizona-based technology spinoff company from the University of Arizona, has developed a new type of antenna that promises to meet this challenge in a unique way. FreeFall uses an inflatable structure that can be packed inside a small satellite and deployed in space. This provides a large aperture that can transmit or receive vast amounts of data with very low mass and power compared to traditional antenna systems. The FreeFall antenna is essentially a balloon — half transparent and half metallized — that captures radio signals for efficient communication. Allowing the reflector to take a spherical rather than a parabolic shape results in very low-risk deployment since a sphere is the natural shape of most inflated objects. The resulting system has the potential to provide high data rate communication at a fraction of the size and cost of existing solutions.

FREEFALL AEROSPACE

FreeFall engineers have made extensive use of Ansys HFSS full–wave electronic simulations to analyze the performance of this system and develop detailed designs without the need for expensive and time-consuming hardware experiments.

The company obtained HFSS through the Ansys Startup Program, which makes simulation software available at significant discounts to startup companies. Ansys Elite Channel Partner Phoenix Analysis and Design Technologies (PADT) steered the FreeFall team to the Ansys Startup Program, which resulted in a FreeFall–Ansys partnership.

Inflatable space antennas improve their aim.
Image courtesy of FreeFall Aerospace

"I can't imagine how we or any similar company could have done this without tools like Ansys HFSS," says Doug Stetson, co–founder, president and CEO of FreeFall Aerospace. "I guess back in the day, you would build and test and test and test, but it would take a tremendous amount of time to build different antenna types, test them and tweak their designs physically to get the performance you want. We're able to do that all electronically now using HFSS, and it's a tremendous time and money saver — it's enabling for a company like ours."

SIMULATING SPHERICAL ANTENNAS

The symmetry of the spherical antenna is the key to FreeFall's technology.

"The symmetry gives a sphere essentially an infinite number of directions that you can aim the beam," says Terrance Pat, RF design engineer at FreeFall, who received his doctorate under Walker. The ability to efficiently steer the radio beam without the need to physically turn the spacecraft or antenna is one of the keys to FreeFall's approach. HFSS capabilities for rapid meshing and parametric adjustment of quantities, such as phase and amplitude, lead to a highly efficient process for antenna simulation and design.

"Ansys has made the process of determining the proper mesh more or less automated," Pat says. "So it's as easy as designing your antenna and defining the appropriate boundary conditions. About nine times out of 10, you can go with the default meshing, which is determined automatically."

Making Connections with Antennas

FreeFall Aerospace was founded in 2016 based on radio telescope innovations by Chris Walker, a professor of astronomy at the University of Arizona and co–founder of FreeFall. When it became obvious that Walker's research in terahertz radio astronomy could have major applications in communications satellite technology, Walker teamed up with Stetson, a 30-year veteran of NASA's Jet Propulsion Laboratory Propulsion Laboratory, to commercialize the technology.

"We strive to be experts in the science of connectivity, which is a major area of research throughout the space industry," Stetson says. "All of these applications rely on the ability to move large amounts of data from point to point, from person to person, through space, and around the Earth. Every bit of that data, at one point or another, goes through an antenna, so creating new high–efficient antenna systems is critical to the success of commercial and government programs alike."

"I guess back in the day, you would build and test and test and test, but it would take a tremendous amount of time to build different antenna types, test them and tweak their designs physically to get the performance you want. We're able to do that all electronically now using Ansys HFSS, and it's a tremendous time and money saver — it's enabling for a company like ours."

— Doug Stetson, Co–founder, President and CEO of FreeFall Aerospace

In simulating the antenna, Pat says he uses alternative computational methods to save time, such as the integral equation (IE) method, which solves massive equations using integrals instead of matrices, and the shooting–and–bouncing–ray (SBR) method, which is based on geometric optics.

"When you have a reflector that is electrically very large, you can approximate the field impinging on the reflector as geometric rays, which are almost parallel," Pat says. So you can use ray tracing to get back the scatter fields from the reflector. And the plus side of using SBR in those situations is that it's GPU friendly. You can use a graphics card to accelerate the computation, which really helps."

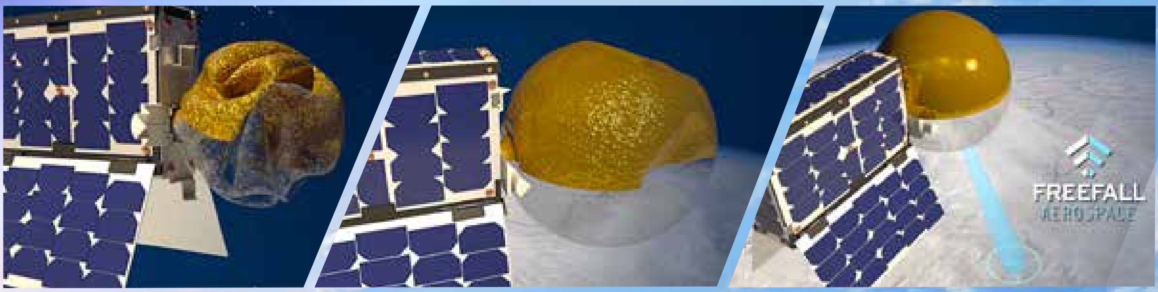
USING ANSYS HFSS FOR ENGINEERING AND SALES

Currently, the inflatable reflecting spherical antenna is in the prototype stage, with several interested potential customers monitoring the company's progress. Stetson has found that HFSS simulation results are key to keeping these potential customers informed.

"We use HFSS not only for our design but for communication with our customers," Stetson says. "They give us particular specifications on the type of radio beam output that they want to meet their needs. We have to show them that we have designed a system that will meet those specifications, so the output of HFSS is critical. We can show them in a graphical sense exactly what they're going to be getting from our design."

FreeFall Aerospace is working with Rincon Research in Tucson and students from the University of Arizona to develop the CatSat mission (named for the UA Wildcats). CatSat is a 6U CubeSat that was selected by the NASA CubeSat Launch Initiative mission and will fly in mid–2022. It is designed to demonstrate FreeFall's inflatable spherical reflector technology as well as perform a number of science experiments, all led by students and faculty of the University of Arizona.

"It's going to be very exciting," Stetson says. "We're proud to be part of this all-Arizona spaceflight mission and see our technology in action."



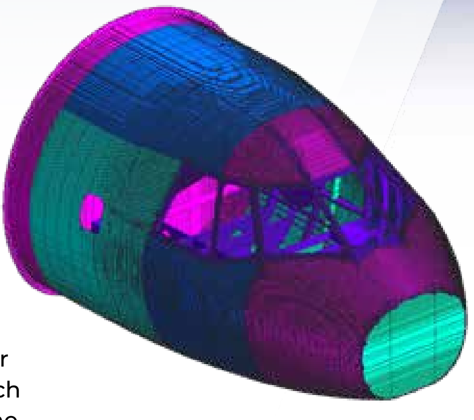
Three of the stages of spherical antenna deployment. *Images courtesy of FreeFall Aerospace.*

Lightning Simulation

Susceptibility Matches Field Results

By **Guadalupe Gutiérrez**, Airbus Defence and Space, Getafe, Spain

They say you never know when lightning will strike.



Cockpit meshed model

Though that expression is mostly used metaphorically to describe an innovative idea, lightning strikes are a very real concern for aircraft manufacturers and aviation regulators, especially considering that a commercial plane is likely to be struck by lightning once every 1,000 hours of flight time. Some aircraft manufacturers have their own innovative ideas on how to understand the effects of those strikes.

European aerospace pioneer Airbus recently used Ansys EMA3D and MHARNESS to simulate lightning susceptibility for a hybrid cockpit design made partially of metal, carbon fiber composite, and copper foil. The simulation was part of a research and technology project focused on developing the aircraft of the future: an ultra-green and highly cost-efficient air-transport system.

Specifically, Airbus engineers wanted to validate how well the model could predict the entire electromagnetic behavior of the cockpit's complex electronics and cabling system in response to induced transients. That would help them understand how closely simulation results matched the results of field testing.

Airbus has used Ansys EMA3D to understand lightning-induced electromagnetic compatibility (EMC) and support EMC certification for at least two decades.

A COMPLEMENT TO PHYSICAL TESTING

A single lightning strike can contain millions of volts or hundreds of kiloamps. When a force that powerful is injected into an airplane, it has the potential to cause tremendous damage. Lightning strikes can ignite flammable vapors, melt metallic parts, puncture and delaminate composite parts, and disturb the normal operation of safety- and mission-critical systems, including electrical and electronic equipment. At its worst, lightning has brought down commercial aircraft, although that's exceedingly rare. The last major incident was decades ago.

To promote overall flight safety, aircraft manufacturers design lightning protection into every plane.

Evaluating the effectiveness of those features generally centers on physical testing of parts and components — not the entire aircraft. This is mainly because full-threat physical testing of an entire aircraft is available only at a handful of facilities, and the process is difficult, destructive, and dangerous.

Cost and development delays also factor in to physical testing. For one thing, full physical testing of an aircraft under development requires manufacturing a prototype, which takes months and is expensive. If the aircraft fails the test at this point, redesign and retrofit costs can be in the millions of euros.

Electromagnetic model from the digital mock-up of the cockpit

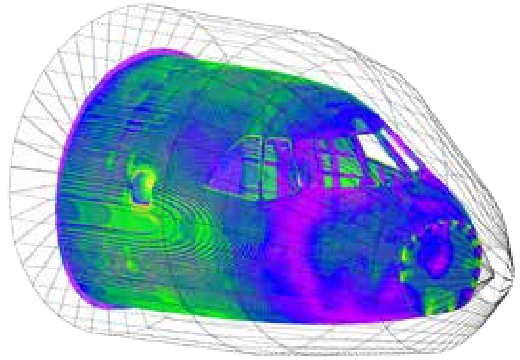
Fully testing an existing aircraft after changes to its lightning protection systems is also possible, but that process has its own challenges. Every day of testing an aircraft is a day it's not performing its intended function, flying passengers or cargo to their destinations. That's an expensive proposition as well. And, more than once, full-threat testing has caused enough damage to take an airplane out of service for an extended period.

Simulation avoids these challenges, but it is not meant to replace physical testing. Instead, it is an increasingly important tool that contributes to aircraft development as early as the proof-of-concept phase. In addition to helping produce robust designs, simulation also supports the qualification and certification process, as well as aircraft maintainability and modifications.

SIMPLE, LIGHT AND MANAGEABLE

Airbus has used Ansys EMA3D to understand lightning-induced electromagnetic compatibility (EMC) and support EMC certification for at least two decades. The solver allows engineers to model large aircraft while also resolving conductor pins no more than a millimeter — or less — in size.

In this case, Airbus compared Ansys EMA3D results to those produced by a complete lightning indirect effect (LIE) and high-intensity radiated field (HIRF) campaign (including low-level direct drive, low-level swept current and low-level swept fields) at its testing facilities in Getafe, Spain. The test cockpit was equipped with a realistic electrical installation, including several metal boxes as dummy equipment and over-braided harnesses with inner conductors.



Surface current distribution on the cockpit

Airbus then used a simple, light, and manageable EM model to perform the simulations. The Ansys EMA3D quasi-magnetic time step acceleration technique increased the permittivity of free space to accelerate the convergence of long transients, making it possible to reduce the speed of light without significantly affecting field values. In fact, EMA3D allowed engineers to select a time step several orders of magnitude higher than the one required by the Courant criterion for the real speed of the light. This is particularly useful in lightning simulations where engineers are interested not only in the peak amplitude but also in the energy content of the response or to solve slow waveforms.

Ultimately, the acceleration technique decreased the number of steps required to design the simulation, reducing simulation time by 90% and speeding the overall process.

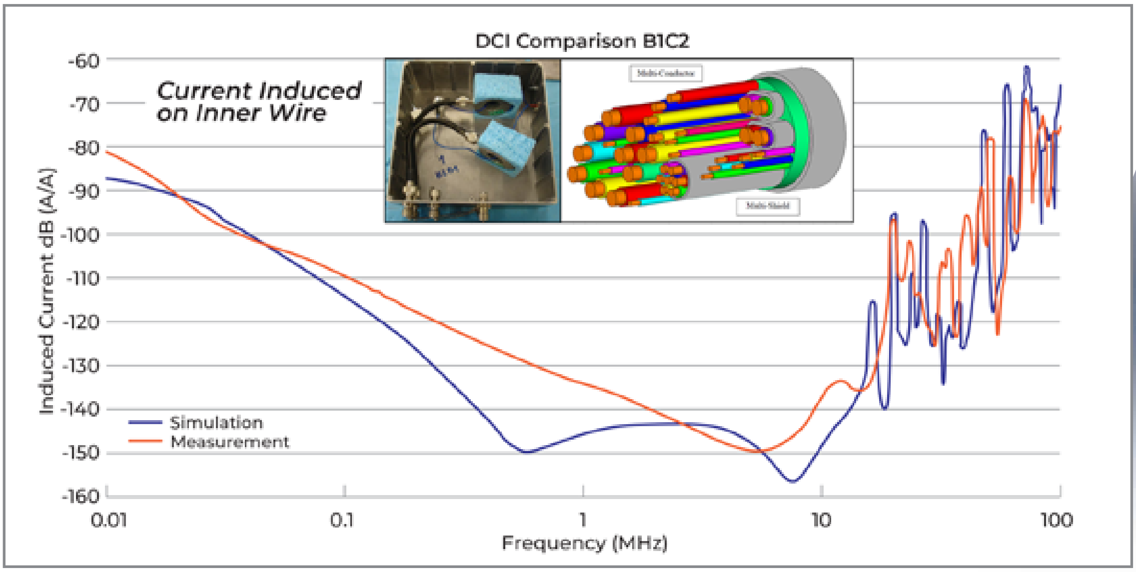
A SAFER PRODUCT

Airbus engineers found a high level of agreement between measured results and simulation. The simulation results were actually on the conservative side, making them useful not just for informing design decisions but also for meeting safety and certification criteria.

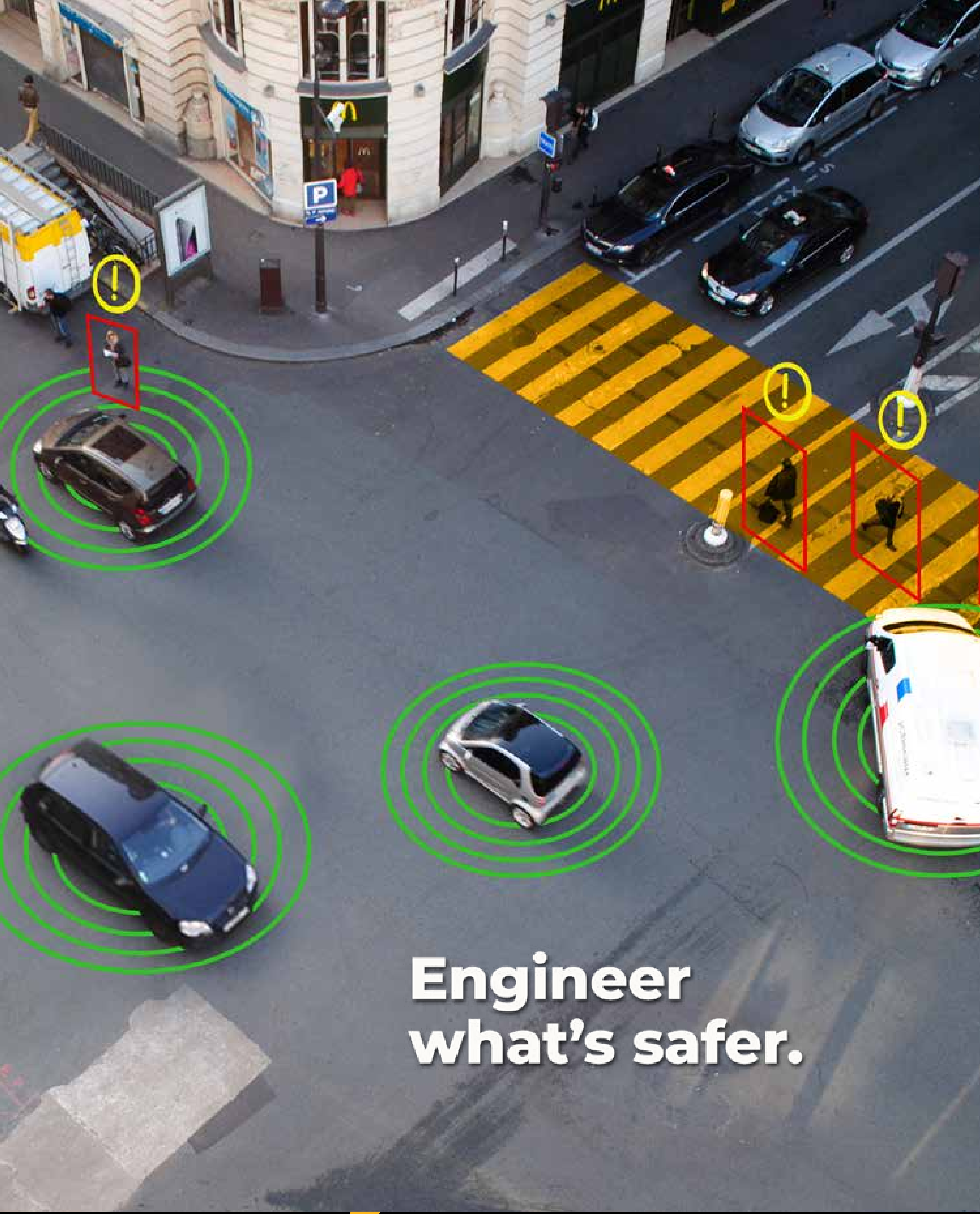
Using Ansys EMA3D, engineers did not have to tune the electromagnetic model to validate any of the different testing techniques. They were able to consider all of the relevant components, ensure the necessary contact between components and avoid unwanted connections.

In the end, the field study and simulation covered all of the main external threats that can affect an aircraft. The agreement between the two efforts proved the effectiveness of simulation and Ansys EMA3D's predictive capacity. Now, aircraft manufacturers can be more confident than ever in the ability of simulation to estimate transients induced in the aircraft at every stage in the product life cycle, from the beginning of the design process to qualification and certification, and also during ongoing maintenance.

As for the flying public, this means that if lightning ever does strike, they can rest assured knowing safety has been engineered into every inch of the aircraft.



The direct current simulation (blue) closely matched the test measurement (red).


Engineer
what's safer.