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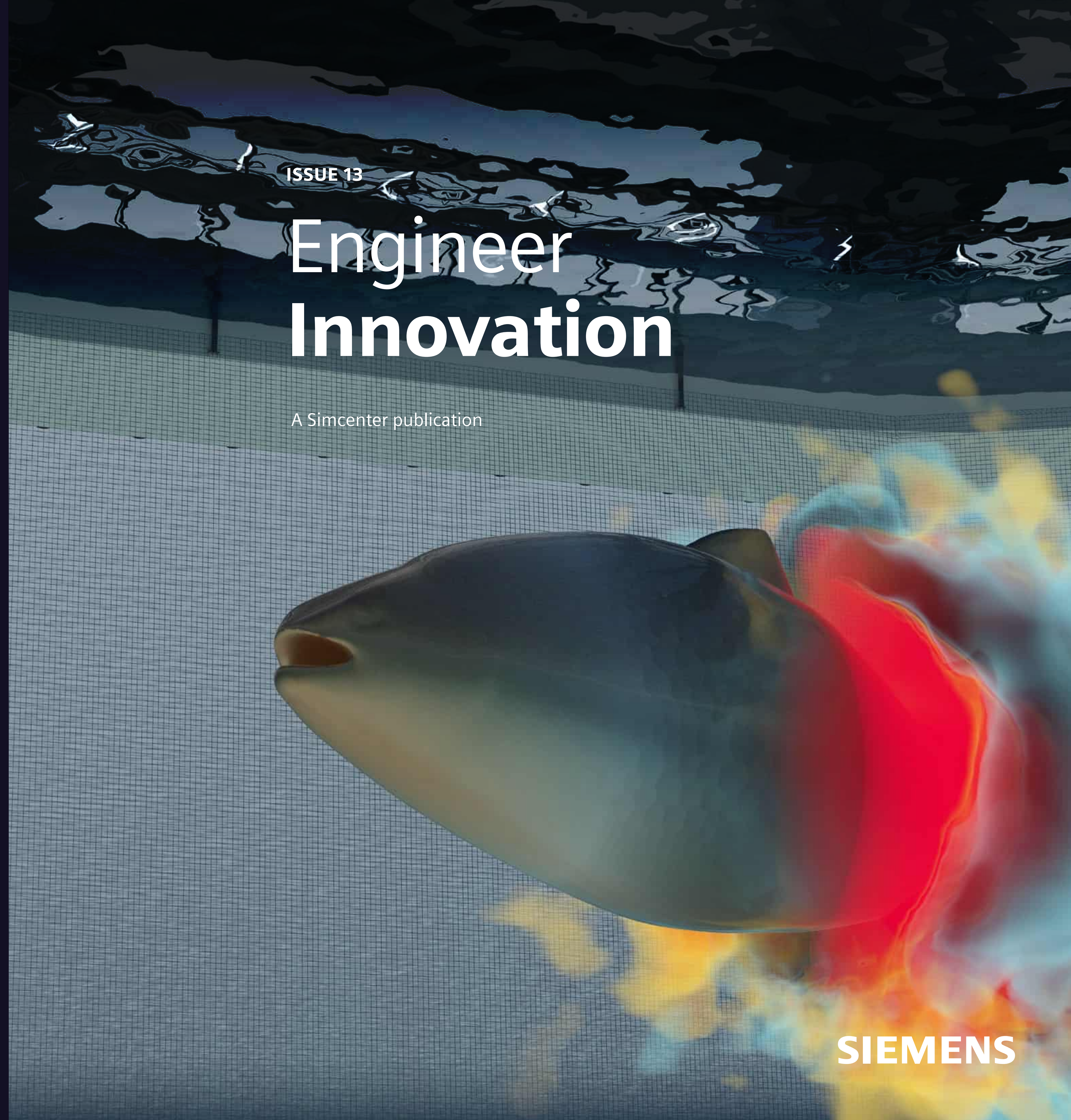


ISSUE 13

# Engineer **Innovation**

A Simcenter publication

SIEMENS

# A time of boundless possibilities

As I embark on this editorial journey, reminiscing about my early days in engineering when numerical simulation was just taking its first steps, I am amazed by the vast evolution it has undergone. From the clunky mechanisms of punch cards and dot matrix computers to the sophisticated systems we employ today, the trajectory has been nothing short of remarkable.

Who could have foreseen, over three decades ago, that I would stand here today, marveling at how engineering simulation is intricately woven into the design of open-water fish farms the size of the Colosseum? This edition of the Engineer Innovation Magazine encapsulates the transition "From Punch Cards to ChatGPT," delves into the historical nuances of our interaction with simulation software while prefiguring how Artificial Intelligence (AI) will permanently change our computational landscape.

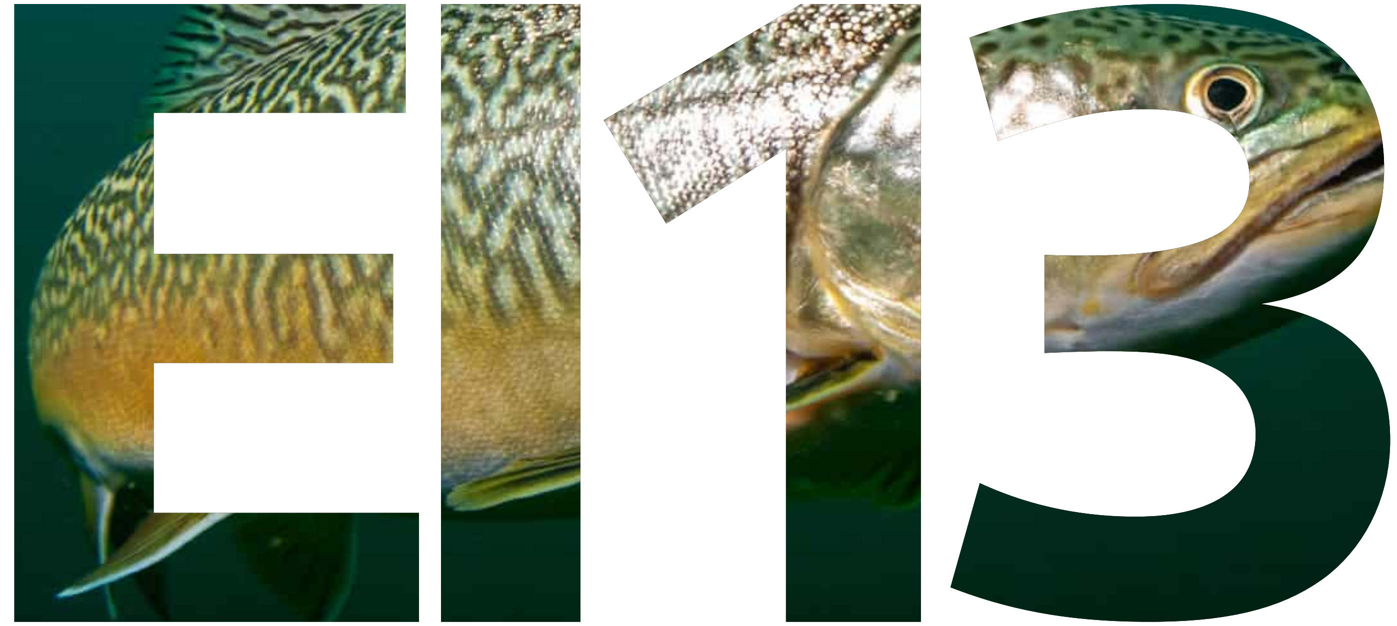
Our cover feature, "Fish First," embodies the fundamental role that Simcenter plays in advancing agricultural solutions in the inevitable perspective of climate change. As we face the imperative to sustainably nourish a global population of 10 billion, our reliance on simulation technologies becomes paramount in mitigating environmental degradation.

Furthermore, we step into the transformative impact of simulation on human welfare and explore how the concept of digital twin optimizes the storage and transportation of life-saving vaccines. These advancements characterize the convergence of technology and care, promising a future where healthcare is not just accessible but also efficient and resilient.

Of course, our journey wouldn't be complete without a glance towards the future of transportation - a domain busy with innovation and the relentless pursuit of electrification. From automobiles to aircraft, the electrification revolution is underway, propelling us towards a greener, more sustainable tomorrow.

It is an exciting time to be an engineer - a period defined by boundless possibilities and the promise of transformative change. As we engineer solutions to complex challenges, let us do so with a respect for the interrelation of all life on this precious planet we call home.

Savor the journey,
Jean-Claude

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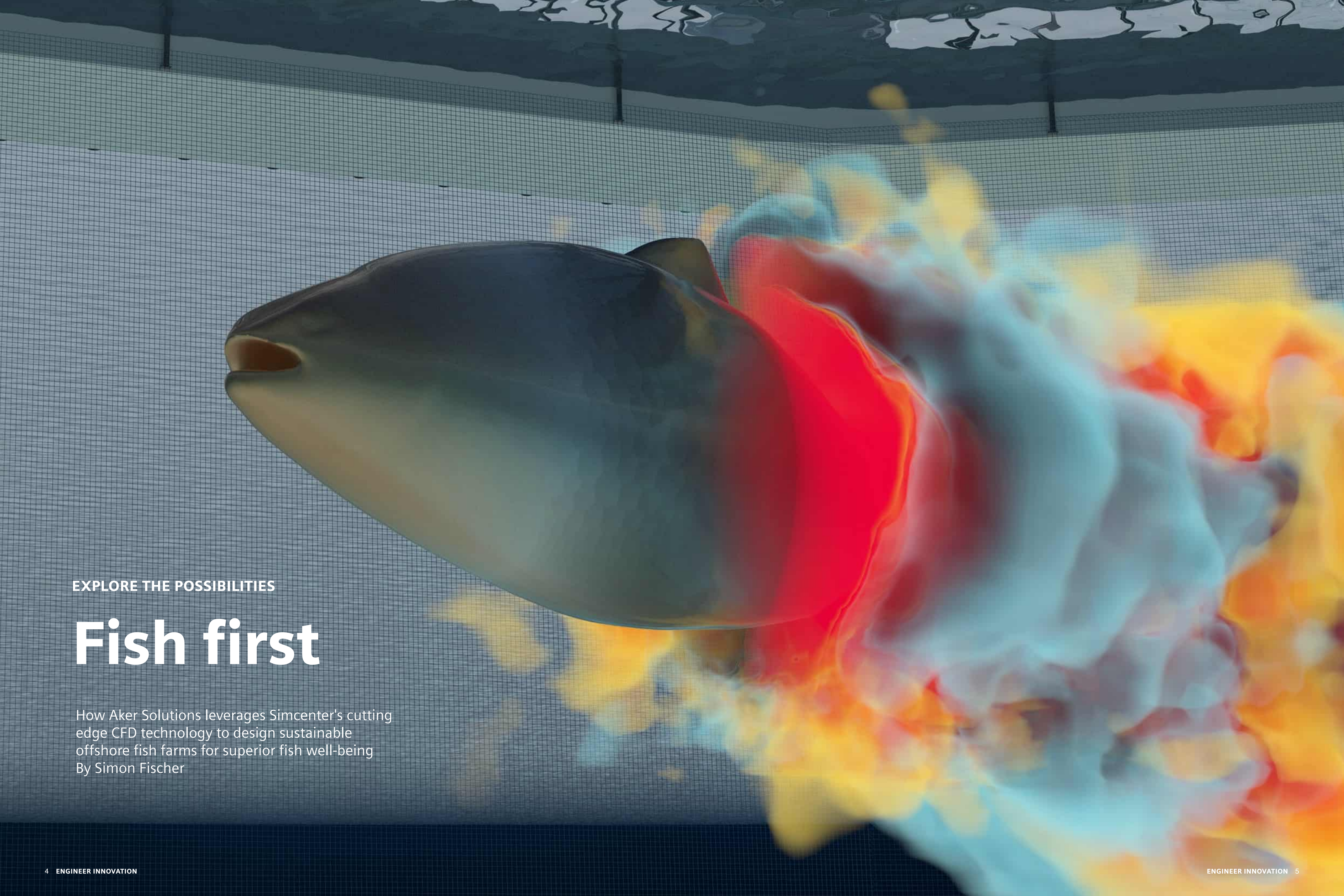


**EXPLORE THE POSSIBILITIES**

# Fish first

How Aker Solutions leverages Simcenter's cutting edge CFD technology to design sustainable offshore fish farms for superior fish well-being
By Simon Fischer

It has been said that fish have an attention span of nine seconds, one second above the average human. While this claim may be believed by some, it has long been revealed to be an urban myth stemming from scientifically questionable, fabricated data. However, the next time you order salmon in a restaurant, it may make you think; even if fish are only half as aware of their surroundings than once claimed, has this one been treated fairly? Did it have a good life? In fact, what does 'a good life' even mean for a fish? Are these questions I should even be worrying about?

By the time you reach this line, your attention span is presumably almost over, so let me tell you just one more thing before it's too late, the answer to many of these questions, lies in some extraordinary computational fluid dynamics simulations that will change the life of millions of fishes and human beings alike and for the better.

**Feeding the world**

But first thing's first. By 2050, ten billion people will live on this planet, it is estimated that feeding our species will require another 50% increase in food production. Currently, feeding the world accounts for one third of global greenhouse gas emissions (Food and Agricultural Organization of the United Nations, 2022), (Charles, 2021), (United Nations, 2023) and we cannot afford to further increase the impact of growing a resource needed to keep us all alive.

At the same time, an emerging sense and conscious awareness for animal welfare is conquering many societies and manifests itself in more stringent legislation for more ethical food production and higher food quality standards. Therefore, the implementation of sustainable methods to responsibly grow renewable proteins for a growing global population is of paramount importance. The question is: how?

**Utilizing the oceans' potential**

It is almost ironic. Because of how the earth looks from a distance - we call it the blue planet. When astronauts look down on our home base, what is prominent is the sea. 70% of the earth's surface is covered by water and yet today, only 2% of the food we eat stems from the ocean (Heidi K Alleyway 2019). Given that competition for land in the quest for energy, mobility, consumer goods and nutrition has made us squeeze every last drop out of our solid ground, gathering 2% of food mass from 70% of the earth's surface seems like a lost opportunity on a massive scale. "Then go and catch more fish" I hear you say. Well, it's no secret that despite the 2% we already consume, fish production from wild catches is already currently at its limit. Fish population in the world's lakes and oceans are already being exploited to the limit and we cannot push any further if we want to retain a sustainable source of food.

So, tell us the solution!

In the early days of homo sapiens, we survived by collecting, hunting and fishing. Cultivation of food production was the key disruptor to enable us to feed more people with less effort. It seemed relatively straight forward to increase productivity on soil. We understood that to gather more plant-based proteins per square meter, our strategy needed to move from collecting to growing and cultivating. Likewise, our ancient forefathers understood that a change in strategy from hunting wild animals to domesticating animals for meat was much more beneficial. At least on solid ground.

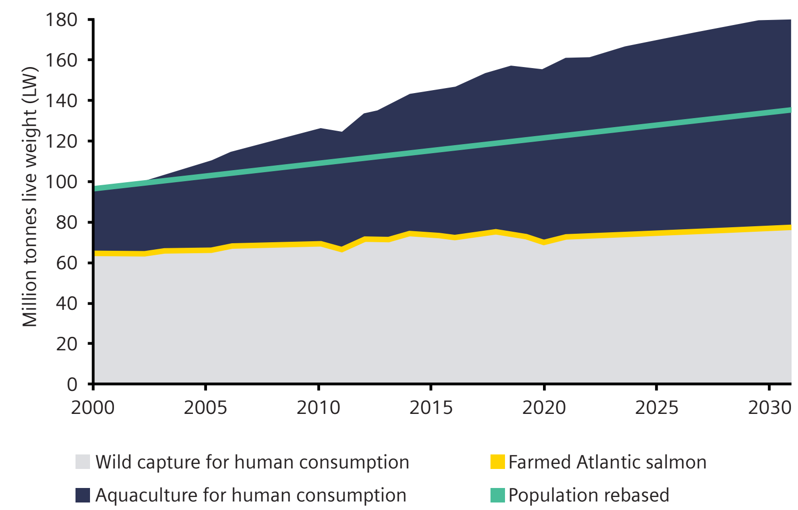
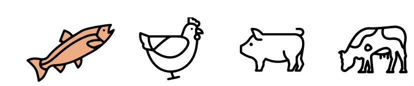



Figure 3 source: (Mowi, 2023)



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|---|---|---|---|---|
| **Carbon Footprint**<br>**kg CO2 / Kg edible meat** | **5.1kg** | **8.4kg** | **12.2kg** | **39.0kg** |
| **Water consumption**<br>**Litre / kg edible meat** | **2,000*** | **4,300** | **6,000** | **15,400** |

*Total water footprint for farmed salmonid fillets in Scotland, in relation to weight and content of calories, protein and fat.

Figure 4 source: (Mowi, 2023)

**Aquaculture - a fresh technology**

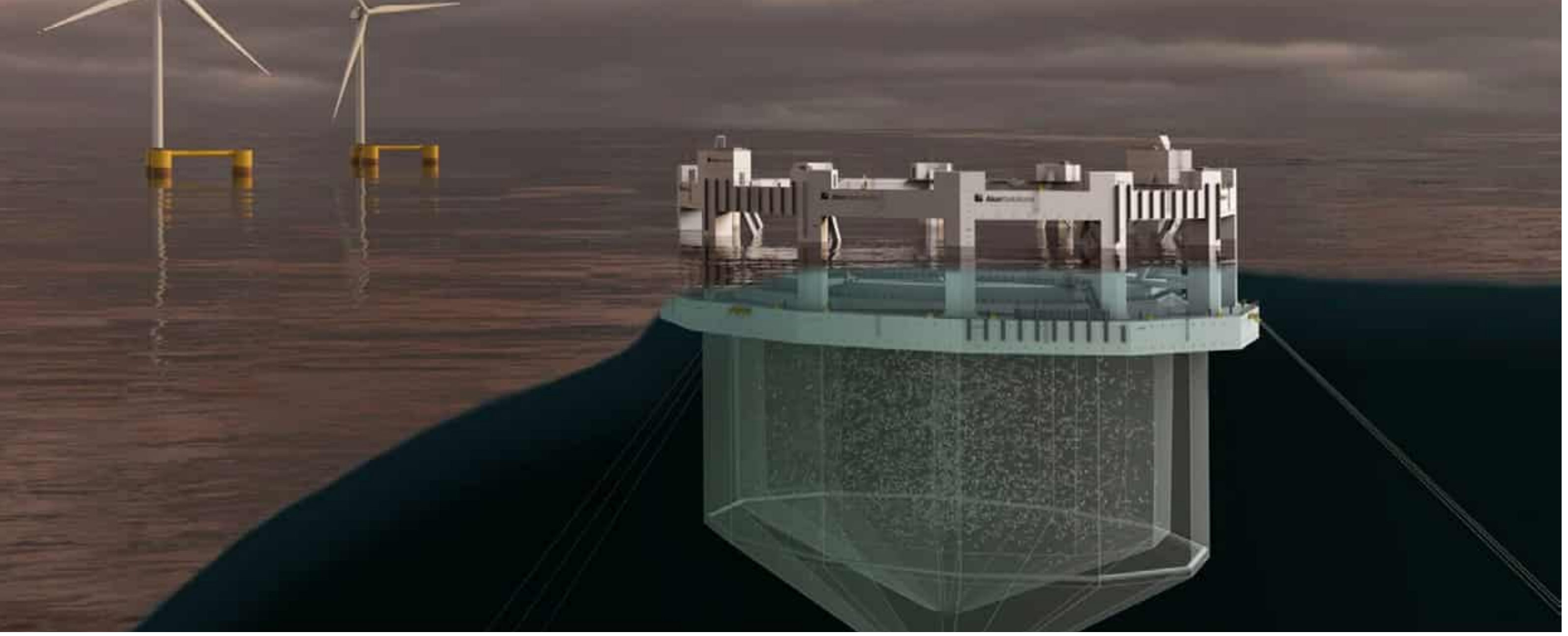
Compared to those ancient disruptive moves, turning our focus back to the oceans, the strategy of cultivation to supplement wild catch seems comparably young. As such, Aquaculture, i.e., the cultivation of fish population under controlled conditions, started to play a noticeable role in fish-based protein no sooner than the 1990s (Mowi, 2023).

However, just like for their land counterparts, the benefits of such cultivating technology in water are manifold and even superior. Aquaculture can happen either in seawater or freshwater. As fish are cold-blooded, there is no need for them to spend energy on heating and due to having a natural buoyancy by taking in air in the swim bladder, they have a significantly reduced need to fight gravity. This makes fish a very energy efficient species compared to land-living animals. And hence, farmed fish is an efficient protein source that when compared to meat-based land-grown proteins, is favorable from an environmental perspective. Food from farmed aquaculture even offers the highest protein output relative to feeding requirements, with a high level of nutrition stemming from healthy acids.

Given the natural limitations of traditional wild catch and this line-up of benefits, it seems like a no-brainer to leverage aquaculture as a key contributor to feeding a seemingly ever-increasing population in a more sustainable way. For these reasons, projections anticipate that fish production from aquaculture will soon overtake the stagnating numbers from wild catch, in terms of mass of fish produced.

At the same time, for numerous reasons, there is an increasing trend in the number of customers no longer accepting poorly grown food. This is true for plant-based, meat-based and likewise, fish-based-proteins. Consequently, regulations and the implementation of global quality standards demand an enhanced quality of farmed fish and of the conditions under which the fish are raised. These factors will support an ever-increasing acceptance of aquaculture and enable the industry to grow.

But it isn't that simple.



**Aquaculture at scale – it isn't that simple**

Just like on land there are major antagonistic forces at work when it comes to Aquaculture at scale. Despite astronauts confirming that 70 % of the earth's surface is covered by water, the first hurdle, astonishingly, is available space. The location criteria of 'traditional' fish farms are very specific. They need the right temperature range and sufficiently high-water quality and exchange, and on top of all that, they require protection from the wild open oceans and their harsh conditions, so the huge area of potential locations quickly shrinks to limited shorelines. Immediately you find yourself in competition with other industries, and interests - like recreational activities or just scenery, that claim that space. If you look at Norway's coastline the capacity for aquaculture is almost fully exploited.

The second caveat: environmental impact due to emissions. Like any other animal, fish produce waste and this waste needs to be taken care of, especially if you want to grow sustainable food at scale.

Thirdly, and tightly coupled to waste production, the fish's welfare is of paramount importance in aquaculture. Not just from an ethical perspective but also from a plain business perspective. Tightly packing in a swarm of fish is not acceptable. Keeping the water fresh and oxygenated in a fish farm and allowing for enough space not only serves the quality of the produced fish, it is simply a mandatory measure to keep mortality rates under control. Another fatal factor related to the living conditions is sea lice. This tiny little parasite has become the biggest threat, specifically to salmon and even more specifically to cultivated salmon. Not only does it cause a significant business impact, but it harms the fish's welfare in an ultimately irreversible fashion.

So, what's the solution to all those challenges? Does it even exist?

To answer that question the aquaculture team at Aker Solutions started from a very simple but bold idea.

**'Fish first'**

Based on this mantra, the team around Kristoffer Jakobsen, head of technology, aquaculture at Aker Solutions tried to answer the following questions: All constraints aside – if we were to design a fish farm that ensures fish welfare as the paramount condition, what would it look like? Where would it be? What would be required to build and operate it? And what would it produce at which cost?

The answer to all these questions brings us back to an equally disruptive thought:

'70% - the blue surface from outer space'

In other words, offshore fish farms. Moving all traditional concerns aside, the team at Aker Solutions, took well known research seriously and gave an already existing concept another thought. Moving aquaculture to the open waters offers higher fish welfare. Open water fish farms naturally offer a more continuous exchange of water, as such they reduce the risk of parasites and diseases and are expected to significantly reduce mortality. Furthermore, first trials indicate that offshore farms are also reducing the disturbance of wild populations.

With decades of experience in engineering offshore structures, Aker Solutions had all the know-how to come up with a first conceptual design for an offshore fish farm that would withstand the harshest conditions. And they went big, 70 - 120 meters in diameter, rivalling Rome's Colosseum, depending on the cage design. Offering a home for 3,000 and 6,000 tons of salmon, that is more than 0.5 to 1 million individuals, respectively, all while withstanding individual waves of up to 27 meters high.

**Design to accommodate for biology – leveraging a digital twin**

But obviously a large basin and structural integrity is not enough when 'Fish first' is your mantra. The team around Kristoffer also wanted to ensure a design that accommodated biology. Throughout each design phase the team's focus was targeted on a design that was good for the fish.

Kristoffer Jakobsen states: "Traditionally, in the design phase, there is little criteria you can use to manage fish health and welfare. This implies that biologists and vets typically evaluate fish performance after a system has been built and, any changes at this late stage can be very expensive, if not impossible. You basically design a structure to withstand the waves, and then you hope the fish will like it."

So how do you judge fish welfare when the structure you are about to design and build is so huge and expensive that you can't afford to just 'build and see'.

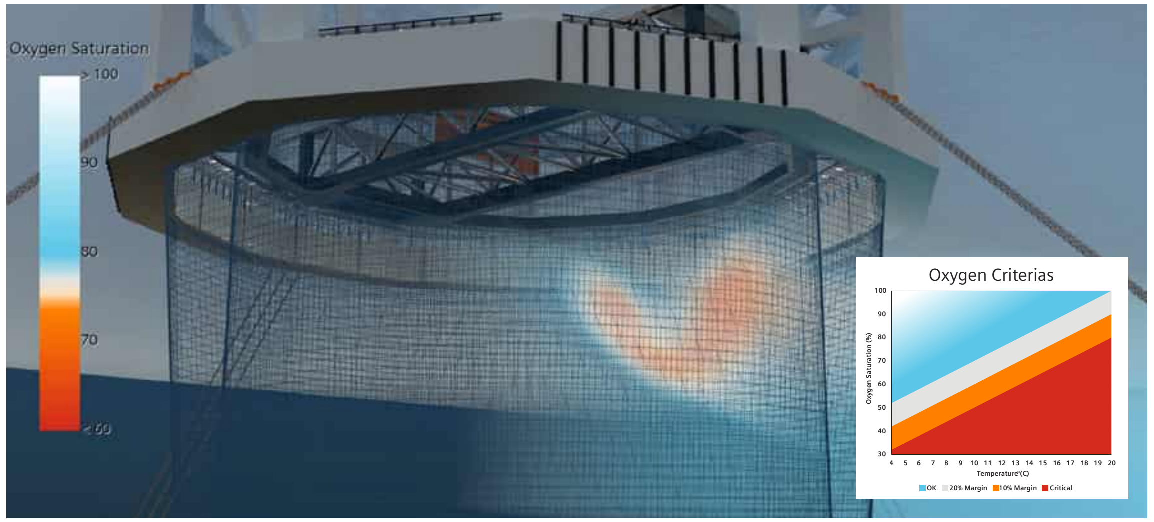
The first imminent answer for Aker Solutions was to tackle the challenge like it would tackle many other engineering challenges, by leveraging a digital twin. "We have worked on aquaculture projects before. While simulation technology has always been an intrinsic part of our offshore projects, to assess fish welfare based on simulation was not on our radar in these early days. And yet, these first projects indicated how important simulation really is." says Kristoffer.

**Computational Fluid Dynamics of an offshore fish farm**

Realizing the potential, Aker Solutions started to run computational fluid dynamics simulations to judge the flow conditions and make first assessments of how an offshore fish farm would perform in terms of water exchange. The methodology was initially based on air and water dynamics only. Yet it was quickly expanded to model the net-flow interactions. This already allowed the engineers at Aker Solutions to judge the effect of various net types including their interaction with the fish farm structure which jointly affected the flow conditions inside the cage and hence the water conditions for the fish.

"Reliably modeling the effect of net structures is not new to this industry and modeling a net alone can be done by many. But modeling the net interacting with a structure can only be done with a sophisticated CFD methodology. That has been done by few so far." says Joakim Hägglund, specialist CFD engineer at Aker Solutions. The challenge becomes even clearer if you remember that these nets, given the size of the offshore fishfarm, are huge. With a diameter of a farm about 100 m, a typical net circumference measures more than 300 m, so we are talking football fields of nets, millions of netting nodes etc. "The capabilities of Simcenter™ STAR-CCM+™ software really enabled us to resolve the impact of various net designs and their interaction with the structure to draw some valuable engineering conclusions." says Joakim.

But the insights from that initial study also raised a huge question. "Can we draw any meaningful conclusions on fish welfare from the flow field inside the cage, when we ignore the fish itself? And what does that even mean in engineering terms, fish welfare?" says Kristoffer.




**Fish welfare – in CFD engineering terms**
It was clear to the team at Aker Solutions that now was the time to take ‘fish first’ seriously and come up with a simulation methodology that was capable of judging if fish welfare is better or worse as a function of the aquaculture design under various flow conditions. “We were quite realistic in terms of what we could achieve,” says Joakim. “If your goal is to simulate the well-being of a fish swarm of a million individuals in the rough and highly transient conditions of the high seas, you need to set the right expectations. If we can judge whether design A is superior to design B with a high-level certainty, given the complex nature of the challenge at hand, that is a huge achievement and beyond anything this industry has seen so far.”

The team around Joakim was ready to do what it took to achieve that ambitious goal. In the next phase of the project, they looked at ways to quantify how fish welfare translated into accessible CFD simulation data. Many factors to foster healthy conditions in aquaculture are well understood in research. Above all is a sufficient exchange of wastewater with fresh water, connected to a certain level of flow velocity across the cage as well as the maintenance of optimum oxygen levels across the whole farm. While correlating such engineering numbers with a quantifiable real-life absolute ‘fish welfare index’ is hard, such indicators are a solid basis to compare two fish farm designs. “Being able to predict those factors will already allow to us to draw meaningful conclusions,” says Joakim.

Thanks to Simcenter STAR-CCM+, judging local velocity field conditions across a given fish farm design was straight forward. With the embedded design exploration tool, the Aker Solutions team could easily make simulation sweeps across various weather, i.e. wind, water stream and temperature conditions and correlate these with sensors delivering data from potential fish farm locations.

**The impact of a million fish**
But coming back to ‘fish first’ the big question was still: Is it good enough to neglect the presence of 6,000 tons of fish when the aim of the study was to understand exactly how those fish are doing under certain conditions? In engineering terms, does the fish swarm affect the flow field? And if yes, to what extent? Is it sufficient to neglect the fish impact on the flow entirely or are the simulation errors associated with such a crude approximation of a reality so big, that the entire methodology is meaningless? It was the usual simulation engineer’s set of questions that bubbled up. “If you don’t have any measurements available, which we did not at that stage,” says CFD engineer Philip Månsson. “There is only one way to find out, model the fish.”

Up until this point this would be quite the usual CFD simulation story, but with the decision to simulate a swarm of fish coupled to highly transient flows, Aker Solutions took the risk of opening a can of worms, in the hope for a good catch. Consequently, the team entered and explored entirely new territories of CFD.

**Discrete Element Modeling of a fish swarm**
3,000-6,000 tons of fish translates to around 1 million individuals. So, you soon realize that you cannot model each fish.

“This was the moment when Simcenter STAR-CCM+ really came in handy,” says Joakim. “We were quite certain modeling the swarm of fish must be tightly coupled to the flow field to add further value to our predictions, and we needed a tool that would seamlessly and computationally cater for such two-way coupled simulations with ease.”

Therefore, the fully integrated Discrete Element Method DEM seemed the way to go. By representing a local sub-swarm of 130 fish individuals with a representative particle, the simulation engineers reduced the total number of necessary ‘fish-representative particles’ to capture the whole swarm to a computationally reasonable number of around 10-20 thousand. This, in principle, enabled the simulation of the complete swarm moving inside the entire fish farm, some of which measure over 100 meters in diameter.

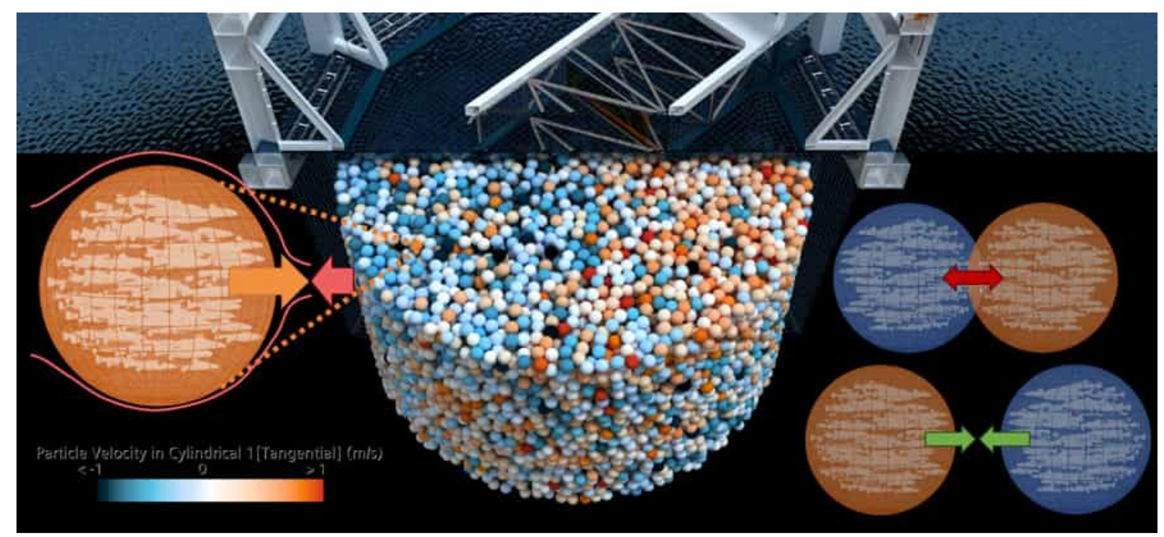
But that immediately brought several new challenges to the simulation engineers at Aker Solutions.

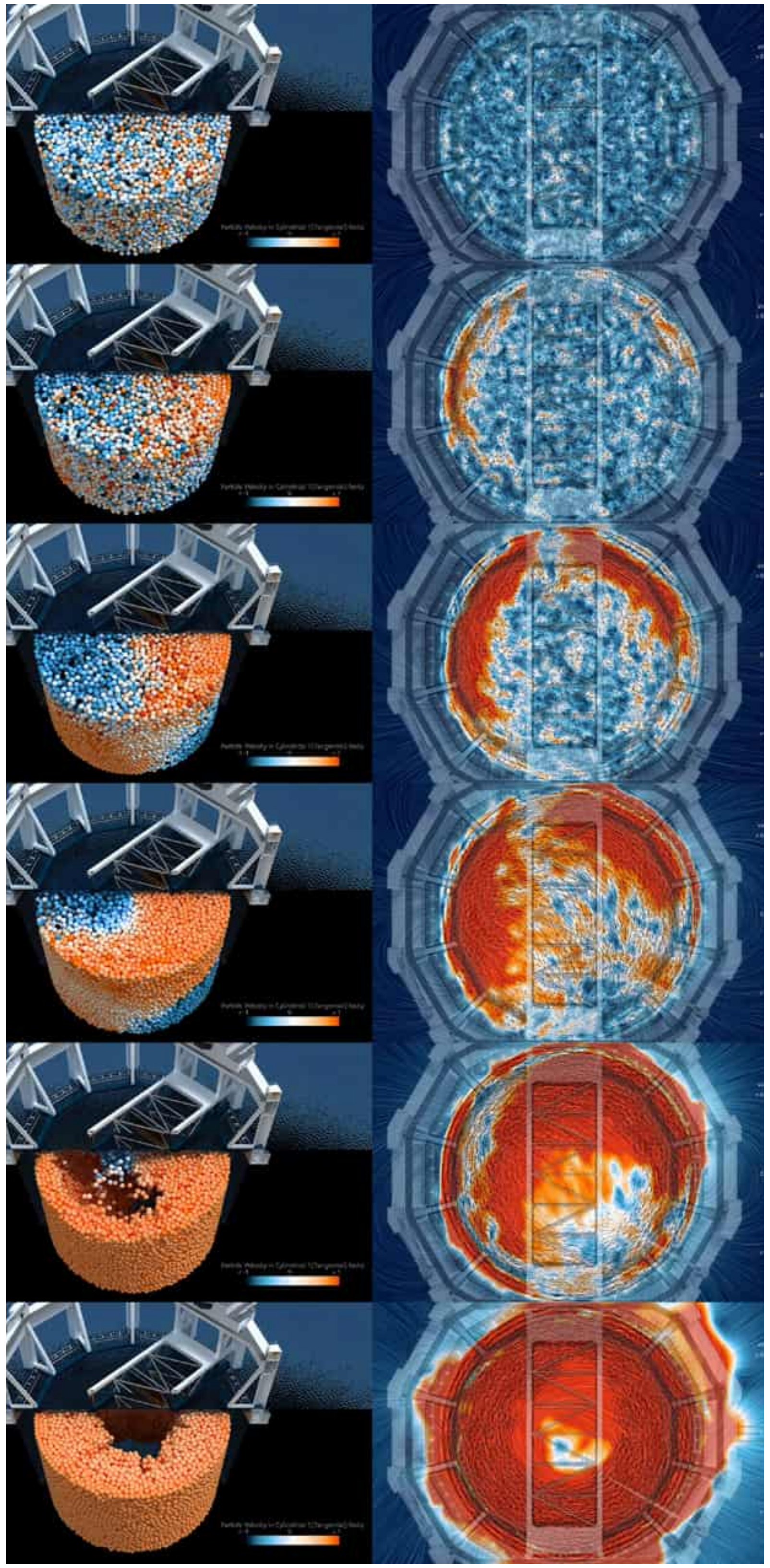
Firstly, if you want to simulate the overall swarm dynamics from the behavior of its individuals, or a representative cluster of such individuals, you must define the interaction forces between these representative sub-swarms in a meaningful way. Secondly, if you want to study the two-way coupled impact of a sub-swarm particle on the local flow field and vice versa, you must come up with meaningful drag and thrust force correlations for such an artificial cluster of fish.

The simulation team at Aker Solutions did not shy away from those challenges and instead, shifted gears, further pushing their innovative simulation method. “Leveraging Simcenter STAR-CCM+’s flexibility, we were able to implement customized physically motivated interaction force fields to precisely model the interaction between the fish sub-swarms,” explains Joakim. Whilst the CFD team is not disclosing all details, the model caters for an attraction force between sub swarms if they get close enough that turns into a retraction force if two sub-swarms overlap or collide.

**Simulating swarm dynamics**
“If you know a little bit about swarm dynamics, or ever watched a swarm of birds or fish for a few minutes, you will realize how those interaction functions between individuals or subsets of the swarm can trigger highly non-linear effects that lead to impressive, often beautiful pattern formations at times,” says Joakim. “It was an amazing moment to see our digital salmon swarm execute such exciting choreographies as if guided by some invisible hand, when we did our first digital experiments.”

At that stage, the simulation engineers leveraged Simcenter STAR-CCM+’s meshfree DEM that enabled them to run rapid swarm-only simulations to study the impact of and fine-tune their sub-swarm interaction model.





Yet the interaction between the local water conditions and a fish sub-swarm particle was still to be answered. Two forces act on a representative fish sub-swarm while it moves through the water. A thrust force drives the cluster of fish forward, representing the self-propelling motion of those fish in that cluster. Fish sub-swarms accelerate based on this thrust force until they either reach a certain goal velocity or (coming back to the intra-particle interaction forces) collide with another sub-swarm and decelerates.

At the same time the undisturbed sub-swarm experiences a decelerating drag force based on the effective slip velocity. These forces determine the two-way coupling between particles and fluid as the fish sub-swarms move through the water.

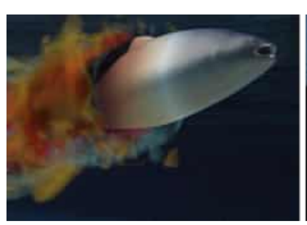
**Fish first CFD principles**

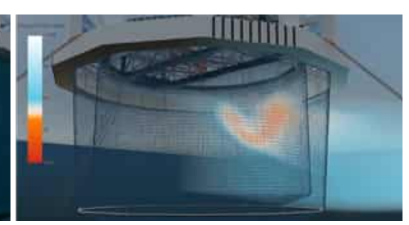
But it would not have been this ambitious simulation engineering team, had they not further stepped up their CFD-game to gather precise drag coefficients and thrust functions for the individual fish. And so, the team around Joakim created another highly sophisticated simulation model of an individual moving fish. "It felt like we were really pushing the edge of what Simcenter STAR-CCM+ had to offer. Morphing mesh, overset mesh, 6 degree-of-freedom fluid structure interaction. That fish will be moving as realistically as possible," says Philip.

"We could not have taken our initial project mantra 'fish first' any more literally," adds Joakim. "When we started this, I never thought we would end up simulating a moving fish with CFD."

**Designing better fish farms with cutting-edge CFD**

Ultimately the innovative CFD simulation method had been established, and each sub-step had undergone exhaustive sensitivity studies and plausibility checks. Now it was time to bring it all together to assess an offshore fish farm's performance with maximum simulation fidelity.





The two-way coupled DEM CFD method now considered fish movement, the fish-fish and fish-water interaction, external flow and net effects. This enabled the engineers at Aker Solutions to simulate local velocity fields and oxygen levels for an entire fish farm to ultimately determine fish welfare.

Meanwhile, Aker Solutions has managed to combine all the relevant physics in the toolbox of Simcenter STAR-CCM+ and all the learnings from the various models discussed. With the new CFD simulation method Aker Solutions has added a unique and powerful tool to its engineering toolbox to design offshore fish farms that not only withstand the roughest oceans but cater for more healthy living conditions. While there will be more validation and refinement work ahead of the team, the cutting-edge methodology brings Aker Solutions into the position to ultimately answer the much-discussed question on how the fish affect the water quality.

"In hindsight it seems almost ironic," says Joakim. "We started this ambitious engineering project with this one core idea of putting the fish at the center of all our efforts. Naturally, we started from the usual flow simulations, but we soon realized this isn't enough if you seriously want to judge fish swarm welfare. As we ventured down the rabbit hole of developing a valid simulation methodology, we realized we had to step-up our game with anything cutting-edge multiphysics CFD simulation had to offer. Highly transient flows, discrete element modeling with custom interaction functions, leading to highly nonlinear pattern formations, moving overset and morphing mesh and 6-DOF-fluid structure-interaction."

The amazing thing is, ultimately, our simulation methodology and the overarching project goal shared one fundamental idea:

'Fish first' - regardless of their attention span. Wait? Are you still here?

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MODEL THE COMPLEXITY

# Optimize refrigeration designs to protect life-saving vaccines

How B Medical Systems used advanced simulation to extend the shelf life of temperature sensitive medical products
By Nigel Ravenhill

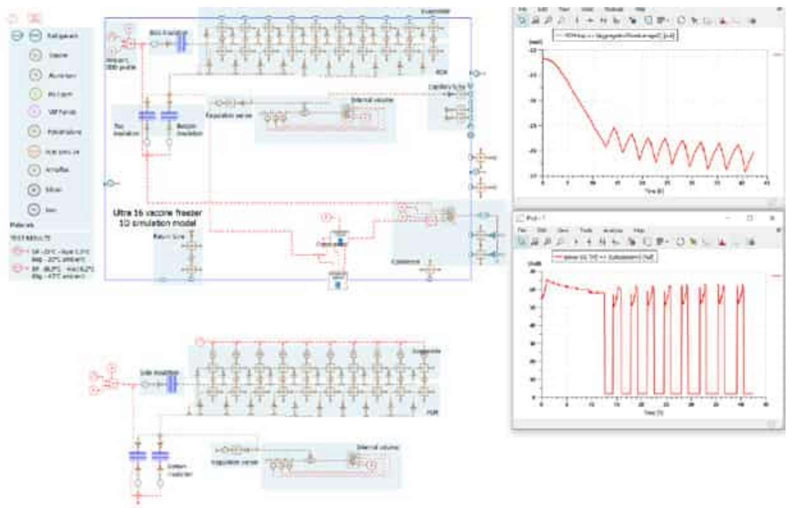
Without the ability to chill and freeze blood, vaccines, drugs and other medical supplies, some of the most important life-saving and prevention services provided by government agencies, non-governmental organizations (NGOs), hospitals and health clinics today would be impossible. Millions would die across the globe as otherwise preventable diseases spread unchecked or access to blood was impossible.

Fortunately, this almost dystopian reality is not our actual reality due to the innovation of companies such as B Medical Systems. In its fifth decade, the company develops and manufactures a wide range of medical refrigeration devices, including refrigerators, freezers and transport boxes. B Medical Systems' product portfolio includes vaccine transport systems with real-time monitoring solutions, medical refrigeration for ambient to -86°C temperatures, and blood management solutions.

While competitive, the medical refrigeration category wasn't, until recently, known to the general public. Providing reliable refrigeration from place of manufacture, collection or storage to point of distribution was, of course, critical to public health, but the average citizen was generally unaware of the travel details of a vaccine dose. Then COVID-19 happened.

The pandemic reminded the world that mass vaccination is a vital public health strategy to protect citizens from the worst consequences of preventable disease. With the COVID-19 virus spreading and mutating, governments, health organizations and the pharmaceutical industry began to collaborate on a massive public health project that ultimately coalesced medical research, pharmaceutical ingenuity, logistics expertise and product engineering.

As the pandemic raged throughout 2020, media coverage of the race to develop COVID vaccines offered an escape from lockdown restrictions. We learned of the promise of something called messenger RNA (mRNA). Pfizer, Moderna and others used the groundbreaking mRNA research (that won its creators the 2023 Nobel Prize in Physiology or Medicine) to develop their vaccines. As human trials took place and the most effective vaccines became more evident, journalists then began to educate us about the challenges of manufacturing and distributing mRNA vaccines.



## The Vaccine Cold Chain

Chief among them was the necessity of extreme refrigeration through the entire vaccine lifecycle, a temperature-controlled and monitored supply chain known as a vaccine cold chain. Transporting vaccines from manufacturing or storage facilities into a patient's body requires an uninterrupted cold chain; if not, vaccines break down, and their effectiveness either degrades or disappears entirely. Interrupted cold chains are extremely costly; The World Health Organization estimates that up to 50% of vaccines are wasted every year because the cold chain and ideal storage temperature is not maintained.

In the context of COVID, the cold chain challenge was even more extreme due to the effect of temperature on mRNA vaccine stability. While most flu vaccines can be stored at approximately 4 degrees Celsius,for example, long-term storage requirements (over 30 days) for Pfizer's and Moderna's original COVID vaccines were -70 and -20 degrees Celsius, respectively. As global health authorities began to plan how to distribute hundreds of millions of vaccine doses across the globe that needed to be transported at ultracold temperatures, they looked to medical refrigeration companies like B Medical Systems for solutions.

## Cold Chain Expertise

Vaccines save lives. So do blood and plasma transfusions and biological samples that lead to medical advancement. But none of them can be used to save lives if they are not appropriately stored and transported using the right equipment.

While the specific need in early 2021 was for ultracold refrigeration, B Medical Systems already had a global profile as a medical-grade refrigeration innovator with more than 500,000 units sold in 130-plus countries. In addition to vaccine refrigerators and freezers, the company also sells blood bank refrigerators, laboratory refrigerators and freezers, plasma and contact shock freezers, ultra-low freezers and transport systems. Within these categories are dozens of products; from ice-lined refrigerators and freezers for health centers with unreliable electricity, to solar-powered vaccine storage equipment, and robust transport systems for journeys of thousands of miles. What's common to all is the company's investment in design engineering.

## Simcenter™ Amesim™ Software

To ensure they continue to meet customer needs and the compliance requirements of the European Union Medical Device Regulation (EU MDR) and World Health Organization Performance, Quality and Safety (WHO PQS) standards, B Medical System's design engineering team has used Siemens' Simcenter™ Amesim™ Software, part of the Siemens Xcelerator business platform of software, hardware and services.

## Analyzing Ambience

B Medical Systems design engineers create system simulations in Simcenter Amesim to virtually assess and optimize product performance. An example is understanding and managing the absorption of refrigerant in the compressor oil because this is a requirement for effective cooling. The engineering team has used Simcenter Amesim to simulate the effects of decreasing the charge of a unit based on time and temperature. This helps improve design, including the system autonomy that ensures refrigerators can maintain the correct temperature of the stored contents such as blood bags and vaccine doses.

According to B Medical Systems Simulation Engineer Daniel Pires, a vital resource in this iterative process was support from Simcenter Engineering and Consulting Services.

"We didn't know creating these complex models was possible, but once we explained the challenges of our designs, Siemens Digital Industries Software showed us how we could simulate this with Simcenter Amesim." Pires recalls. "We can show exactly what will happen in specific conditions or different ambient temperatures, which helps us give clients full confidence in our products and their ability to protect the cold chain."

## Using Simulation to Manage the Supply Chain

Another critical application has been the ability to use simulation to help make procurement decisions. One of the biggest challenges the company faces is managing lead times from vendors that supply the various components that are assembled into finished refrigeration units. Component delays can lead to manufacturing delays and missed product launch dates so the cooling team regularly simulates different

components to make informed decisions that balance performance and other factors such as availability.

"Simulation is vital to keeping product development on track," says B Medical Systems' Head of Cooling Technology and Testing Vittorio Iormetti. "We need to be able to test different components to see how they affect overall performance. We know which components have shorter lead times and we can get their parameters from the suppliers, so we can try them out in Simcenter Amesim to see if they improve performance and if anything else needs to be changed to accommodate them."

**Optimizing Engineering Resources**
Resource planning and allocation is another major challenge that B Medical Systems—like almost all manufacturers—faces. With data showing that it can help reduce development and testing time by up to 80 percent, Simcenter Amesim has also saved vast amounts of engineering time that would otherwise have been spent in further development, testing and quality assurance.

"We can't afford to compromise on quality," says Iormetti. "But by using Simcenter Amesim, we're able to streamline testing, free up resources for other projects and save a significant amount of time. Now when we're ready to build a physical prototype, we're much closer to the optimum design."

This benefit is echoed by Pires, who adds: "We haven't found anything that does this as well as Simcenter Amesim. We can conduct the same amount of testing in one month that would normally take several months using physical prototypes. It's also a huge space saver as we don't have hundreds of rooms to carry out tests. Now we can carry out as many virtual tests as we like without worrying about where to conduct them."

**Demonstrating the value of simulation**
Simcenter Amesim's ease-of-use is a key feature for the engineering team.

"I can open a project file using Simcenter Amesim that someone else worked on a few years ago and understand everything within just a few minutes," Pires explains. "I can then make changes and simulate the results to help our design team with a new development – all in only two or three hours. Even if it was created in an older version, it just works. Simcenter Amesim is incredibly robust and reliable."

Computational speed is also an important performance metric to convince company management of the value of using simulation software. It helps Pires validate the vital contribution that Simcenter Amesim makes to his work.

"If it takes weeks or months to create detailed CFD models, management won't see the value in simulation," Pires notes. "They won't see any reason to change from existing test-based practices. Once I show them this can all be done in less than one week in a system simulation, it becomes something the business is much more interested in investing more in."

**Simulation for Non-Experts**
Simcenter Amesim's role at B Medical Systems is expanding; Pires' next goal is to help the mechanical (CAD) design team use the software without becoming simulation experts. The key is the flexibility of simulation models.

"It holds everything up if they need to keep coming to me to create simulations," Pires explains. "But I can create a Simcenter Amesim model whose parameters can be easily adjusted by the mechanical design team without my help. It will show them the results immediately."

This flexibility is crucial to the future success of the business, which is important because the medical refrigeration category is a very competitive market. While B Medical Systems is the leader in vaccine cold chain products, maintaining this leadership position requires continual innovation.

"There are always new standards to meet, new devices to be developed and engineering time to be optimized to create the best designs in the shortest time," concludes Iormetti. "The accuracy and ease of use of Simcenter Amesim plays a big role in making this possible."

National ministries of health, NGOs, hospitals, health clinics, research labs, pharmaceutical companies, and blood centers across the world rely on B Medical Systems. In the last 20 years, B Medical Systems vaccine cold chain equipment has helped vaccinate more than 300 million children in developing countries.

MODEL THE COMPLEXITY

# Building better batteries

Transforming the manufacturing process
By Jennifer Hand

As humans face global warming and climate change, over 140 countries around the world have set targets to reduce $CO_2$ emissions by 2050. With diesel and gas from vehicles accounting for a significant proportion of $CO_2$ released into the atmosphere, a transition to cleaner road transport is underway. Sales of electric vehicles are rising, which means that battery manufacturers are looking to scale up their output; but meeting an increase in demand is not the only difficulty facing the automotive industry.

Batteries are critical to the feasibility of electric cars, yet they embody some of the most environmentally damaging aspects of such vehicles: from the damage caused from mining of rare earth elements, to the amount of energy required in their production and disposal. Yes, we need batteries that are more powerful, more durable and lighter. However, at the same time, the process of manufacturing them also has to become more efficient and more sustainable. Does that present a challenge or an opportunity for battery machine manufacturers?

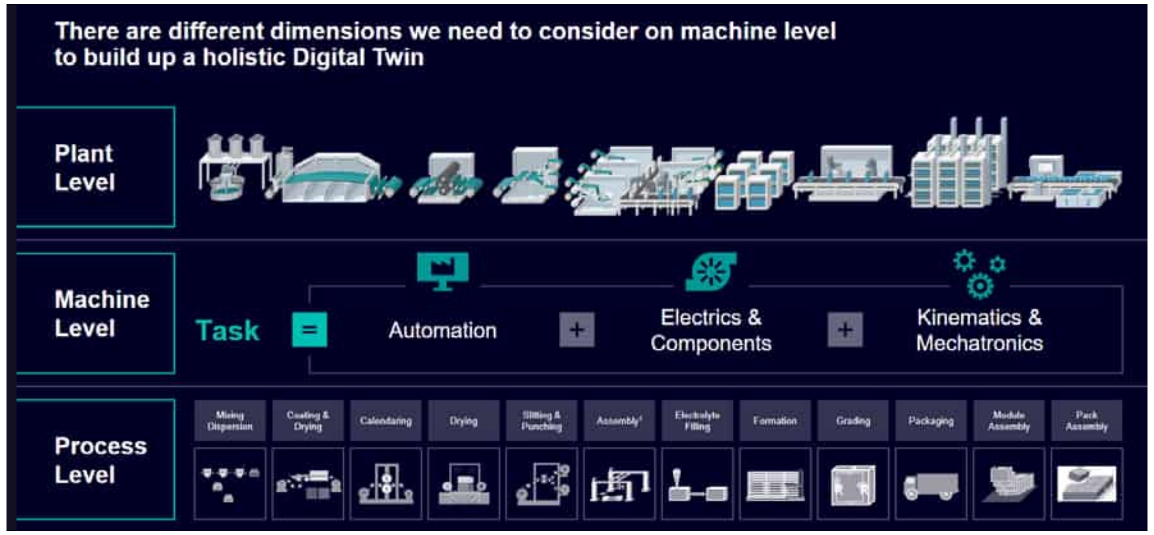
**A new approach**

Battery production involves a range of complex processes across several disciplines, such as machine engineering, automation, electrochemistry and materials science, yet everything is tightly interlinked. A minor amendment in one area can have a significant and sometimes hard-to-predict impact on another part of the design, engineering or production. Such changes need to be effectively monitored and managed. In addition, the need for adaptability, customization and collaboration will all become more important as demand increases and the market expands.

One thing is clear: document-based engineering with information kept in silos will make the challenges much greater. The scale and complexity of equipment development require a new approach, one that supports consistent communication with all stakeholders, ensuring accuracy and consistency.

The ideal scenario is for a network of systems to connect all domains and allow machine manufacturers to manage every aspect of the product development process from early concept and detailed design, through verification and manufacture to product support. At the design stage, team members would be able to select from a range of ready-to-use component models and simulations. Via multiple conceptual iterations, they would be able to define requirements and product architecture, explore subsystem interaction, assess overall performance, and identify viable solutions.

This is all possible when battery machine manufacturers adopt an integrated, multi-disciplinary approach. When they can capture




functional requirements and validate feasibility early in the development cycle, mechanical design and control logic of the equipment can be developed concurrently. This prevents delays caused by the late identification of problems. The result is an increase in machine safety, optimization of energy performance and a reduction in battery defect rates.

**Virtual validation comes first**

When the entire development process is mapped out virtually the benefits are substantial.

Engineering decisions accelerate by 40%. A thorough understanding of flow and mixing behavior can lead to a 54% reduction in blend time. Controls development time can be cut by 75%.

However, because of the unpredictable interaction of sub-systems, building a multi-domain automation system is challenging, even for software experts; and manufacturing equipment suppliers are often small to medium size, with limited inhouse expertise. One option is to implement a proven technology: a portfolio of software and hardware portfolio providing in-house simulation tools, all linked together in a product lifecycle management (PLM) system.

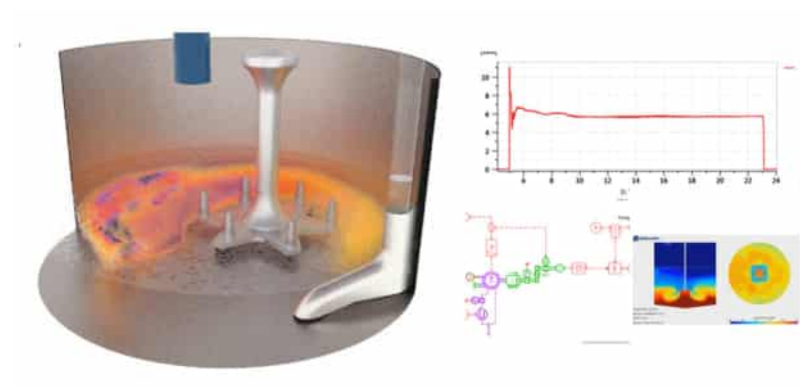
The Siemens Xelerator business platform of software, hardware and services is used by companies in every industry for virtual product development and the emerging battery manufacturing sector is now recognizing the potential benefits, particularly of Simcenter™ simulation software.

A comprehensive set of scalable and collaborative multiphysics tools, Simcenter is designed for ease of use. Linked via Teamcenter® software for PLM, Simcenter supports dynamic model-based performance engineering, enabling virtual development of a comprehensive digital twin - a holistic 3D model that provides complete product insight from concept design to certification. With consistent and accurate verification and validation throughout a product’s lifetime, machine performance, safety and energy efficiency can be optimized.

The digital twin exists within a single, integrated environment in which all verification processes, from simulation modeling to the physical test bench, are driven by requirements; planned and executed in the correct sequence; linked to the necessary resources; and conducted with full traceability. With such a clear overview, manufacturers can also adopt a modular approach, promoting the re-usability of parts and programs.

Using the digital twin, battery machine manufacturers and system integrators can address system challenges and engineer machine performance attributes much earlier on. Development of controls, for example, can be synchronized with development of the machine sub-system. Reach values can be maximized and potential errors such as the undersizing or oversizing of machinery can be avoided.





Because virtual validation and testing can be conducted before a physical build the machine can be optimized prior to commissioning. There is no need to go back and rebuild physical components. The implementation of testing solutions from the Simcenter portfolio has reduced test and data post-processing time by 30 percent.

**Perfecting key phases**

Using 3D computational fluid dynamics (CFD) in combination with system simulation allows manufacturers to perfect all stages of the electrode and battery cell production. In the manufacture of electrodes, mixing, coating and drying processes can all be improved.

Molecular and 3D CFD simulation can fine tune automatic programs and set operating parameters to improve mixing performance and the homogeneity of the final mix. Simulation can establish the correct thickness of coating, ensure uniformity of cover and minimize material waste. It can also select the best size of actuator and set the web tension and web speed of the converting machine.

For the calendaring and drying process, simulation ensures proper compaction and adhesion of the coating to the substrate, along with analysis of the compaction phenomenon. System simulation also allows for the design and sizing of the actuators that control the rollers. Through molecular modeling the solvent evaporation rate for best porosity can be calculated.

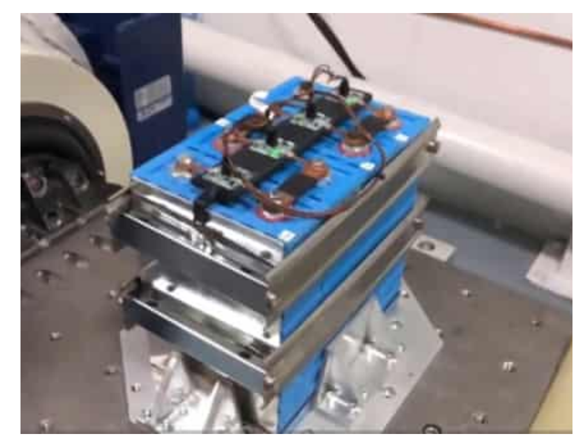
A detailed model of the converting mechanism for cell stacking can be created from the software and libraries within Simcenter™ Amesim™ software. Using this model, the controls and throughput mechanism can be optimized without damaging or wasting the material.

For fast and efficient electrolyte filling, a smooth flurry flow, full wetting of the porous cells and uniform cavity filling without bubble formation can be achieved through simulation of the nozzle flow and valve controls.

For gigafactory owners and integrators responsible for deploying the production line, the validation of the battery pack via realistic vibration testing is critical for assessment of durability and lifespan. Simcenter testing solutions enable engineers to consider customer use and reflect the range of environmental conditions expected during the life of the vehicle, such as road impact, terrain and battery-induced vibrations. The same tools can assist engineers to achieve balance; so that they do not run the risk of mechanical failure through not testing enough, yet also avoid unnecessary cost by testing too much.

**The digital win**

Electric vehicles running on battery power play a vital part in decarbonizing the transport industry and offer an unprecedented market opportunity for battery machine manufacturers who can exceed expectations for quality, timely delivery and cost effectiveness. Bringing all the production process strands together and performing automated, model-driven, safety and reliability analysis generates continual improvement. As a result, companies with interconnected systems working in unison to create a digital twin have seen their time-to-market reduce by 50 percent and their commissioning phase reduce by 25 percent.



# Using AI to electrify a luxury SUV

Hyundai look to the latest AI methodologies and Siemens' engineering design services to develop their next SUV
By Nigel Ravenhill

> Before this project, one requirement evaluation took two minutes to run in simulation. Using the neural network developed by Simcenter Engineering Services, this was reduced to one-tenth of a second."
>
> **Ilsoo Jeong,**
> Comfort Engineer,
> Hyundai Motor Group

Artificial intelligence (AI) is helping Hyundai Motor Group (HMG) develop electric versions of some of its most popular and critically acclaimed vehicles. To ensure the electrified versions wow and captivate when introduced, Hyundai looked to Siemens for engineering consulting, design and analysis software and the latest AI methodologies.

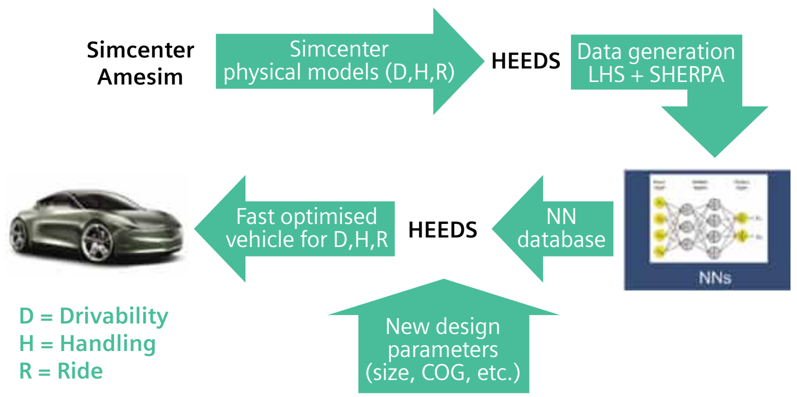
**It's not easy going green**
Electrifying an already excellent vehicle is a lengthy and extensive project. Replacing the internal combustion powerplant with an electric motor is just one of the challenges. There are hundreds of other challenges and choices, including optimizing chassis performance.

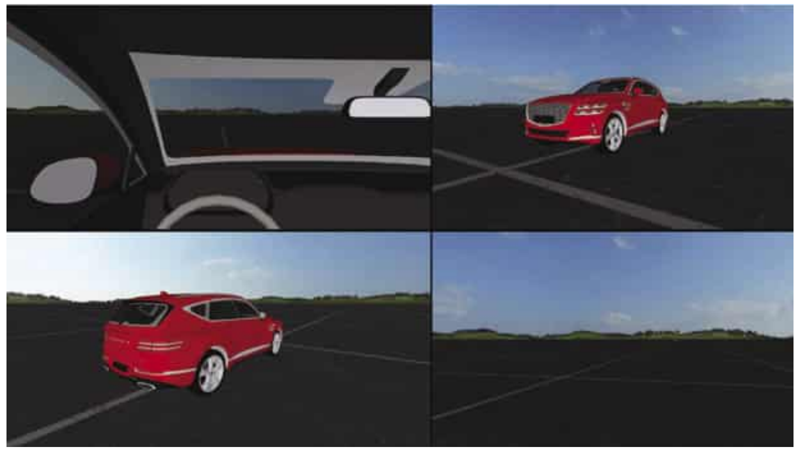
With every complicated engineering-driven project such as a car, the sooner you can test, analyze and prove or disprove theories and ideas, the lower your development costs. For companies that use a V-cycle approach to systems development lifecycle, making earlier analyses and decisions - so-called shift left testing - saves money, time and headaches down the road. Avoiding late-stage design changes, engineering teams can develop and finalize ready-for-production designs faster and cheaper.

**Shifting left using Artificial Intelligence (AI)**
Every transportation sector, from cars to giant cargo vessels, is pursuing a more sustainable future that replaces internal combustion engines (ICEs) with lower carbon propulsion. As the world transitions to a more sustainable future with electrification, AI has become a common enabling technology for engineering teams looking to do just this. An "enabled by AI" effort to shift left becomes more important and obvious.

Very few electric products are designed and developed from scratch. The vast majority of "green products" - think of the automotive industry for example - are evolutions of earlier designs, directions and fully realized products. Fortunately, Hyundai can leverage the enormous amounts of development and simulation data and models created while developing gasoline-powered vehicles to develop their new electric versions.

**Setting vehicle targets using neural networks**
What makes this exercise in mining existing and new data both possible and feasible is that engineers can now train neural networks to search terabytes of simulation data to help identify the ideal vehicle or component configuration. In 2023, HMG recognized the opportunity to use the capabilities of AI to enable a shift left to define architecture-driven requirements at the concept stage of electric vehicle development. A partnership with Simcenter™ Engineering and Consulting services (Simcenter Engineering services) to build the requisite neural networks was finalized.



Early in design, the left side of the V-cycle approach, engineering teams typically use requirement estimates of criteria such as mass, size, suspension technology, etc. These early ideas need to be explored and analyzed as efficiently as possible on what is an iterative path to the ideal design and configuration. Target setting for attributes such as optimal mass, kinematics, drivability, ride and handling gives engineering teams objective metrics or key performance indicators to hit. The earlier these targets can be met, the greater the gains in time and development cost.

**Balancing comfort and handling**

Comfort Engineer Ilsoo Jeong, is part of HMG's driving comfort virtual development team. He and his colleagues were tasked with setting targets for chassis development.

"Our goal was to achieve the best possible comfort and handling performance, so we had to consider hundreds of chassis parameters, such as mass distribution, suspension kinematics and the mounting system. We also needed to consider changes to designs and configurations from replacing the internal combustion engine," says Jeong. "We wanted the ability to perform sensitivity analyses to quickly understand how changes to the design of one component impacts the performance of others."

Jeong understood that the power of AI could both be used to do this analysis and evaluation much faster than before.

"Because Simcenter™ Amesim™ software is our preferred analysis tool, we partnered with Simcenter Engineering and Consulting Services to build these neural networks. They have vast expertise in vehicle development in general and neural networks in particular."

**Optimizing EV architecture**

The Simcenter Engineering Services team was also able to apply important learnings developed from a separate project with HMG using Simcenter Amesim software. That collaboration had developed a Simcenter Amesim architecture for evaluating vehicle maneuvers in which criteria could be separately weighted-up to 52 individual KPIs for each requirement - to generate an overall score.

Simcenter Engineering Services expanded the work for this electric vehicle chassis. Using the targets provided by HMG, Simcenter engineers generated over 200,000 simulation models in Simcenter Amesim, validating them against real vehicles. Simulation results were saved in a high-performance computing environment to enable faster computation in the future.

"Simcenter Amesim was the driving force behind our decision to select Siemens Digital Industries Software for this project," explains Jeong. "Only Simcenter Amesim had the capabilities to perform the number of simulations we needed, as well as the flexibility for attributes such as NVH frequency. Simcenter Amesim was also advantageous because it enabled us to work with our own templates rather than a prepackaged one. When it came to flexibility and simulation time, Simcenter Amesim was the best choice."



**Reduced Order Modeling**

Using Simcenter Reduced Order Modeling software, Simcenter Engineering Services also created and trained a neural network to deliver simulation results that enable direct model optimization. This neural network integrates with HEEDS™ software to assist HMG engineers in identifying the ideal vehicle configuration.

"If our targets or parameters change, we will no longer need to start the entire process from scratch," says Jeong. "We can now find the optimal parameter set very quickly by searching through the neural network built by Simcenter Engineering Services. The ability to easily retrieve these simulation results means we can give very quick feedback on the ideal configuration to each subsystem team. Later in development, we will also be able to use the benchmarking data retrieved by the neural network to efficiently compare the vehicle's driving performance to our targets."

**AI-enabled time savings: From a week to 15 minutes**

The Simcenter Engineering Services collaboration and Simcenter software have delivered significant process benefits to Jeong's team.

"Before this project, one requirement evaluation took two minutes to run in simulation," he says. "Using the neural network developed by Simcenter Engineering Services, this was reduced to one-tenth of a second. Similarly, our subsystem parameter optimization process used to take a week. With the help of Simcenter Engineering Services, this has been reduced to 15 minutes."

**Looking forward**

Progress is continuing; Jeong and the Simcenter Engineering Services team are aiming for more efficiency gains by integrating Teamcenter® Simulation software with the neutral network to fully link to and provide parameters and requirements traceability. This will enable non-specialists to enjoy the power and benefits of system simulation. For example, a program manager without any simulation knowledge will be able to directly input requirements and use parameters from a previous project to run online simulations and predict system performance or optimize parameter sets for subsystems.

"Siemens' Simcenter portfolio and Simcenter Engineering Services will continue to be a special development partner for HMG," concludes Jeong. "Our companies have a strong relationship and I look forward to collaborating on future projects."

MODEL THE COMPLEXITY

# Steering the way for tug boat design

Simulation brings the digital world closer to real life and speeds up tugboat design and certification
By Anna Wood

Designs for new tugs are being tested without putting a boat in the water. Naval architects Robert Allan Ltd (RAL) are simulating hydrodynamic forces to design the next generation of faster, safer, greener tugboats, and convinced marine authorities that computational fluid dynamics (CFD) is more reliable than real-life testing.

Marine traffic is growing, and since the Exxon Valdez oil spill in 1989 most ports have made it mandatory for tankers to be escorted by tugboats to be sure they can travel safely through confined waterways.

Tugboats are unusual because they need to perform with high escort forces whilst attached to a larger ship. This means that the design of the boats needs to consider the hydrodynamic lift and drag generated by the hull of the other vessel. At the same time, the boats' performances need to conform to the industry's stringent safety standards for tugs. Safety is paramount, especially for tankers that carry liquified natural gas and crude oil.

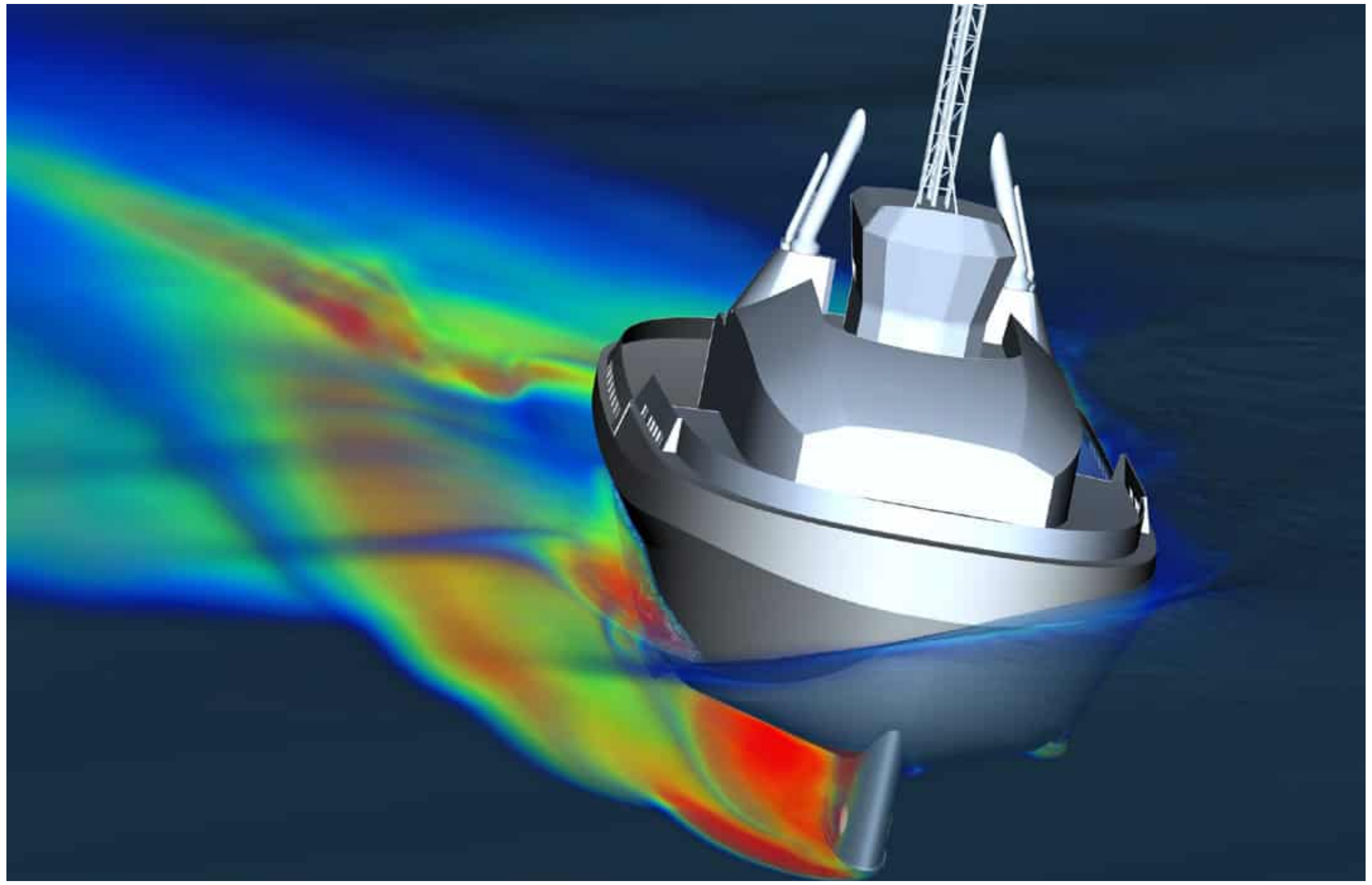
RAL's novel designs for tugboats are created by Brendan Smoker and his CFD team using Simcenter™ STAR-CCM+™ software to develop new designs and workflows. Smoker started with the company as an engineering student on a joint research project in 2007. That project used Simcenter STAR-CCM+, which is part of the Siemens Xcelerator business platform to study hydrodynamics with CFD. Their work with simulation has dramatically changed the design and certification of new tugboats.

**CFD**

CFD has become a central part of RAL's business and is changing the way they design tugs as the designers can test a concept at an earlier stage and then modify the design if needed. Smoker explains:

"We have a much larger CFD department and capability than some other naval architecture firms of our size. The ability to predict performance is a vital aspect of our development process, because it lets us know if our designs will meet requirements as early as possible." It also means that RAL can move away from building models and testing prototype boats in tanks. Smoker says: "In the past, designers used expensive physical testing with small models in towing tanks or full-scale tests at sea. With tanks and full-scale testing, it's difficult and costly to make design changes at that later stage if the trial identifies any design issues."

"Our engineers can use simulations to optimize designs faster, which is useful since towing tanks can be expensive and difficult to attain. Using Simcenter STAR-CCM+ we can speed up our processes and save money." Brendan Smoker,



Project Manager and Hydrodynamics Engineer, Robert Allan Ltd.

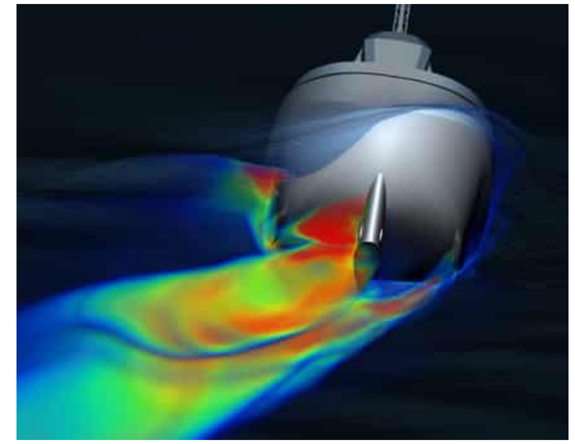
RAL's engineers use Simcenter STAR-CCM+ to carry out a series of full-scale resistance and escort studies for each tugboat design. These allow them to eliminate scaling errors and make separate calculations for pressure and shear force. This was useful for shortening the design process, but the greatest benefit was the commercial one. They were able to test several hull configurations and conditions without having to build multiple costly physical models.

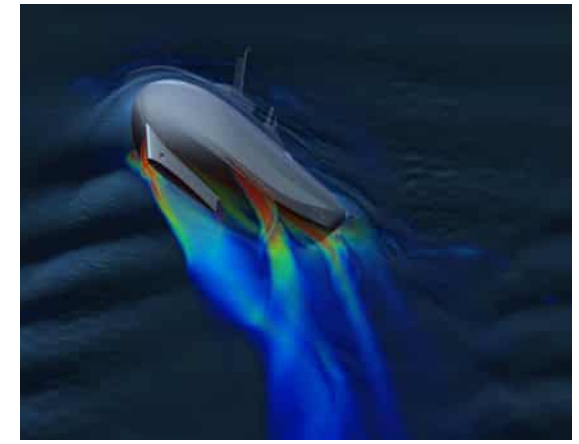
RAL is probably producing twice as many new design reports now than they could deliver with the traditional model and full-scale testing methods. "This is a huge boost to our competitiveness," says Smoker. "We use Simcenter STAR-CCM+ to turn projects around faster, which means that shipyards can add capacity and build more tugs. It is a boost for everyone."

**Learning about lift and drag**
Tugboats are different to other marine vessels. They need steering forces and braking forces at speeds of 6 to 12 knots combined with sufficient power and stability to counter the heeling movement created by the towline. Smoker explains how this works and how engineers can design tugs that take advantage of the indirect towing mode:

"Rather than relying only on the thrusters to produce a towline force, the escort tug attaches to the tanker's stern and uses the hydrodynamic lift and drag generated by its hull. This leverages the direct thrust available from the thrusters, so that at speeds above 6 knots, the escort tug can generate speeds and braking forces that are greater than its rated bollard pull." A design for a tugboat therefore must provide high escort forces and stay within the safety limits for stability. "Customers also want smaller boats with more power," he adds," and they can't compromise on safety."





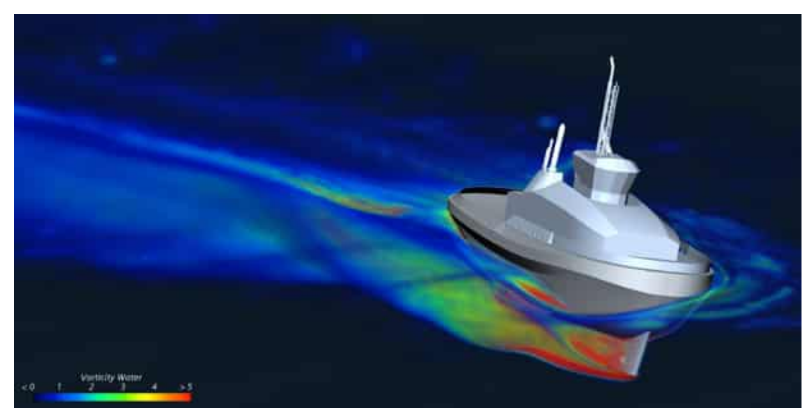


**It started with a student project**
RAL's customers were looking to the future and their list of new requirements presented some interesting engineering questions that the company wanted to understand better. Smoker explains:

"If the boats are shorter with more power, the design becomes more complex because you have a less streamlined boat, so essentially it becomes more like a bathtub that is shorter and fatter with more power. So it's really a challenge to figure out hydrodynamically how to design these boats so that they still work properly in quite a difficult length to beam ratio."

Boat owners were also starting to plan for de-carbonization, resulting in more design questions. What other power options are there for tugboats? What kind of electrification should there be on board?

RAL wanted to see how these changes might shape future designs, so they asked Smoker to analyze predictions of escort tug performance with CFD. Smoker explains:



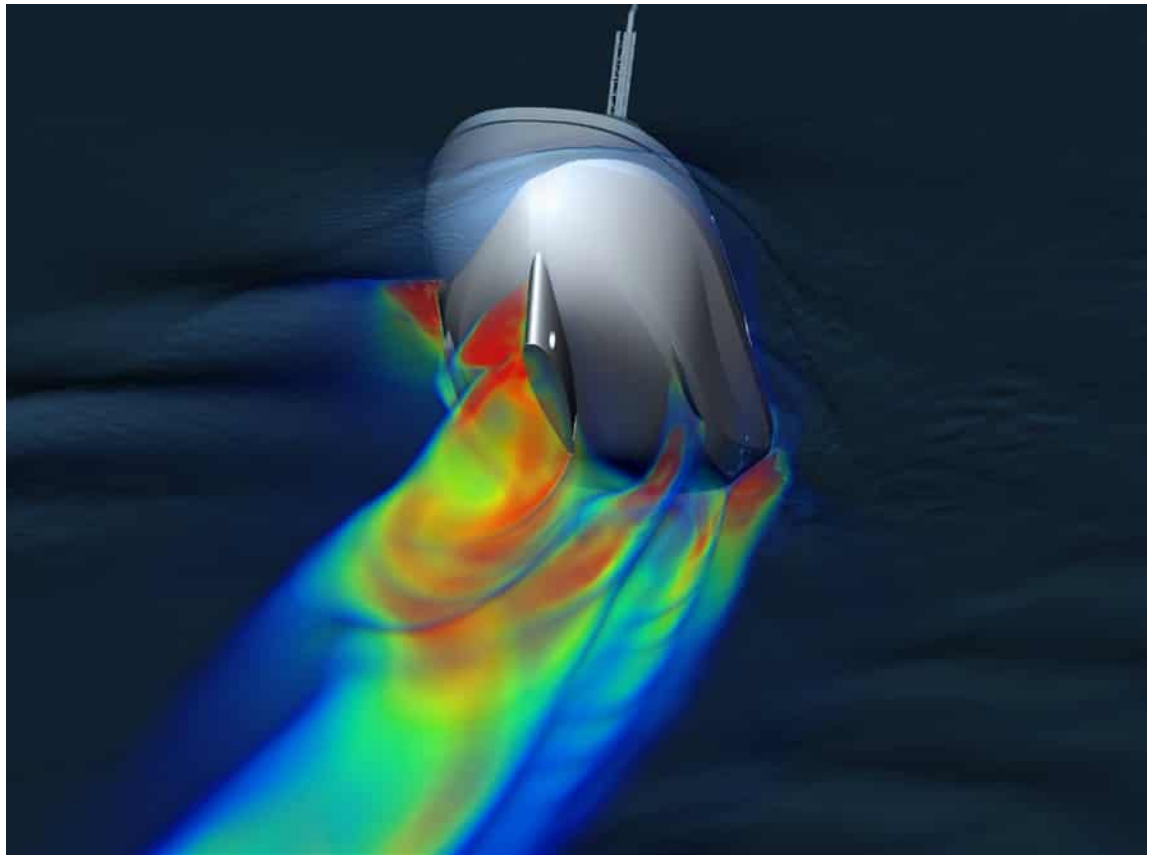
"We were trying to understand all that, for each geographic area and for each client, and to relate this to the likely cost of energy. Trying to figure all this out was using quite a bit of our time."

Smoker's work with Simcenter STAR-CCM+ resulted in a new methodology for analyzing the performance of escort boats. Smoker went on to gain his master's degree and joined the business where he now heads the CFD department.

**Standards and standardization**
Smoker's work has gone beyond designing new boats, he and his engineers have also used CFD simulation to develop a fully digital certification process. This had always been part of the plan. Smoker explains, "Robert Allan hired me to use this research in designs and justify our new approach to the classification bodies."

Tugboats are certified and classified to ensure that they are safe, and this traditionally relied on full-scale tests at sea. Smoker says: "You had to order a tanker to run a test that was incredibly expensive and offered limited reliability." Besides the difficulty of finding a tanker for trials, the process lacked consistency, "for example a tug operator might not drive the boat optimally to create the proper forces and behaviors. This meant that tugboats were certified for certain performances, but you'd need to explain that it was based on trials that varied widely in quality. Therefore, it was impossible to compare the performance of one tugboat with another."

Smoker explains the extent of the work needed to gain classification:



"When I started my research, the classification rules stated that the escort notation had to be verified by full scale trials. So you actually needed to get a tanker or some sort of massive ship, and you needed to get your tug after it was built and tether it up and fit it with instruments and run very time consuming and expensive tests to satisfy the notation.  You could also do it through model testing, which meant you would go to a towing tank and create a scale model of the tug, add test instruments and trial it in the towing tank. Those were the only ways to satisfy the notation, so that is what they used to do."

Now, simulation is speeding up the classification for new designs. Smoker adds: "Simulation is faster, which is useful since towing tanks can be expensive and difficult to obtain. We still use physical tests; however, it is becoming more common to use CFD validation."

**Worldwide classification**

Would the world's classification authorities accept the new digital route to certification? Smoker says:

"We proved that simulation software can simplify certification processes. Our results are more accurate than with physical models because we can analyze each boat consistently and compare the stability, safety and forces to get a reliable assessment of how each boat will perform."

Smoker had already published a PhD thesis recommending CFD certification. This led to a marine classification society, Bureau Veritas (BV) approaching him to develop his recommendations. Their co-operation helped to get an approval in principle (AIP) certificate, which stated that BV would accept the use of CFD in place of testing with full-scale trials or models.

"By working together, we were able to improve our methods and satisfy all their validation and certification requirements," he explains. The American Bureau of Shipping, Lloyd's Register and many other marine classification societies followed. "We spent a lot of time with numerous societies to make our reports into standards that everyone will accept," he adds.

Smoker points out that the ability to compare CFD data with data collected from earlier model tests helped to convince the authorities: "That allowed us to prove that our methods were just as good, if not better than the physical tests."

The fact that Simcenter STAR-CCM+ is well established in the industry may have made it easier to convince the world's classification societies to adopt it for certification. Many of them were already familiar with the software and understood the quality of the results. Smoker observes that, "proving our results with Simcenter STAR-CCM+ was much easier than if we had developed our own custom code and had to persuade them that it worked."

**Going beyond intuition**

While simulation is speeding up the process of designing boats and making certification consistent worldwide, it can actually generate new design ideas as well. There are cases where Simcenter STAR-CCM+ suggests approaches that the engineers would never have considered. This happened with a particular tugboat design for Australia. Simcenter STAR-CCM+ showed that the design would not meet all the client's performance specifications. The engineers had suspected that this would be the case, but Simcenter STAR-CCM+ also suggested a different approach to the skeg design which they had not thought of. Smoker's team explored this unexpected idea. He says: "We found an unconsidered, unintuitive change. We tried it, validated it with model testing and it did exactly what we needed. It performed well and the customer was impressed."

"We are working towards solutions that get closer to real life maneuvers," says Smoker. "If we could physically drive the boat in a CFD environment with all the physics around it, in real time, enabling us to capture the behavior in all types of conditions, we could simulate more variables and understand more unexpected situations."

**Simulation finds safety gaps**

RAL's CFD team has invested a lot of time in standardizing their CFD workflow for tugboat design and certification and they are viewed as experts in simulation for escort tug classification in the marine industry. Marine classification societies have accepted CFD as being a more accurate method than testing with physical models and this has helped the various agencies to harmonize the classification rules globally and, in some cases, to improve the certification process.

"We've had a big influence on the rules," says Smoker. "In some cases, we've pointed out gaps that our work highlights." This is an achievement but there is still more to do. "We're constantly pushing for even higher safety standards," he adds.

RAL remains a major force in naval engineering. In an industry where safety is the over-riding priority, they have attained a leading position, helping to shape even higher standards and they have helped to harmonize class rules across the various marine authorities. They have even advised on gaps in regulation revealed by simulations.

RAL's engineers are confident that the boats they design will meet their customers' performance requirements and satisfy the classification standards. Smoker sums this up: "Knowing that customers are not returning with issues is a great success for us."

> "Using Simcenter STAR-CCM+, we found an unconsidered, unintuitive change. We tried it, validated it with model testing and it did exactly what we needed. It performed well and impressed the customer."

**Brendan Smoker,** Project Manager and Hydrodynamics Engineer, Robert Allan Ltd.


STAY INTEGRATED

# **Breathing life** into the digital twin

How MxD uses digital twin to build next generation ventilator
By Stephen Ferguson

If you can bear to cast your minds back to the deepest, darkest days of the Covid pandemic, you might remember that there was a worldwide shortage of mechanical ventilators used to treat those patients with the most severe Covid-induced breathing difficulties. This led to doctors having to make some difficult choices to save lives.

I spoke to Daniel Reed, from MxD, the Digital Manufacturing and Cybersecurity Institute, who has worked extensively to apply digital twin technology to this problem.

“What was happening at the time, in the real world, doctors were having to make this difficult, impossible, kind of, triage decision to place more than one patient on a single ventilator,” he explains. “That is not an approved use. The machine was not designed for that. But when your patient is going to die if they don’t have a ventilator, obviously you’ve got to do something.”

To prevent these types of problems arising during the next pandemic (and there will be a next pandemic), the US Government made funding available through the CARES Act scheme to investigate the feasibility of safely using single ventilators on multiple patients.

“We originally called the project ‘rapid and secure deployment of medical devices and instrumentation’ but that’s a bit of a mouthful so we tend to call it 'Lungs in the Loop", says Reed.

The Lungs in the Loop project is a collaboration between MxD and Siemens, that uses Digital Twin technology to explore how ventilators might be employed to treat multiple patients more safely in the future.

“There were lots of unanswered questions that we wanted to address through the Lungs in the Loop project,” explains Reed. “Is it safe? And if so, when is it safe and when is it not safe? When is it okay for two people to be on the same machine, when is it not? For the machine to work effectively, the two patients need to be in similar conditions."

The project started with Polarion, Siemens’ requirements management system, that was used to create a design fork that described the difference between a ventilator operating in single or double patient configuration. This is the first step in building a digital twin of the machine than can operate in either configuration.

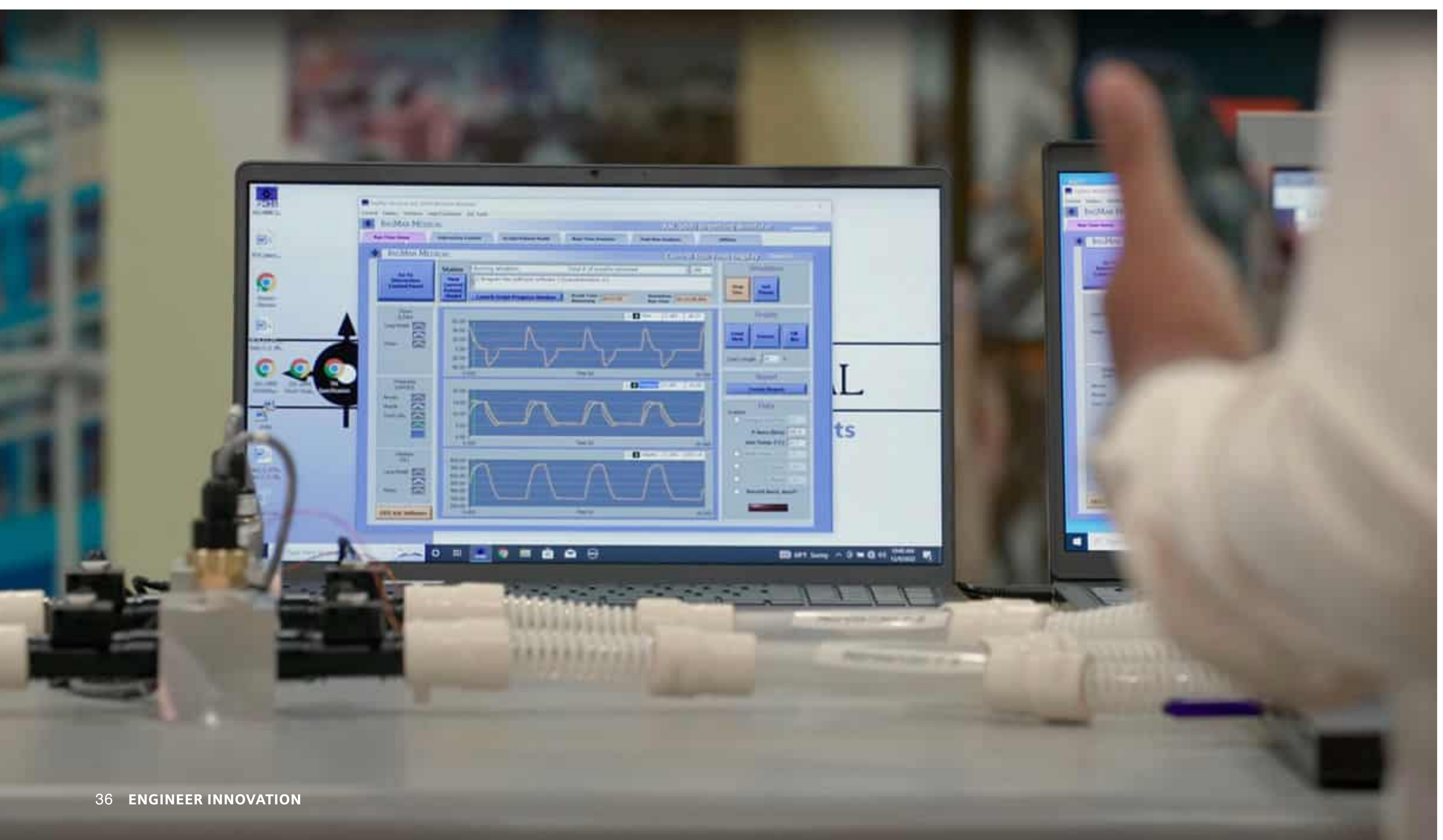
“Using Polarion, we were able to then prove; this is when it’s safe, this is how it’s safe. We could also detect some anomalies that were occurring or potential deterioration in the patients' heath. So, start to finish, basically a medical product redesign that shows exactly how you can use digital technology and the digital twin to accelerate a process, make it safer, and do it with better confidence.”

At the heart of the digital twin is a one-dimensional model of the ventilator, built using Simcenter™ Amesim™, that models the gas flow through the system. The model calculates what the tidal volume – how much breath is going into and out of – each patient, based on the operating conditions of the system.

“Because the ventilator is not designed to be used on two patients, it doesn’t have sensors built into it for two-patient operation,” says Reed. “When we built the physical prototype, the team put sensors in the operating line at critical points so that we would be able to see how much air was flowing past that point in real time.”

The benefit of the simulation model is that it can take data from the limited number of sensors and use that to work out what is going on at an almost infinite number of “virtual sensors” across the system. Although the full Simcenter Amesim model is complex, reduced order modeling is used to produce a smaller model that can provide almost instantaneous results, using an edge computer which is in the ventilator.

“So, you’ve got this simulation model that is downscaled to a smaller model that can run in real time. It is taking data off the real physical asset; it’s measuring airflow and then it’s comparing that to what it believes the airflow should be, based on on its directed operating conditions,” says Reed. “That is how it's able to detect that either, this is working how I expect, or not how I expect. Something may be wrong."



One possible problem is an air leak in the system that would leak pressurized air out into the environment, instead of reaching the patients’ lungs.

“We tested this by introducing a leak device that basically introduces a small leak into the line,” explains Reed. “The ventilator is pushing air, pulling air back in. Turns out that the ventilator can detect that leak because it knows how much is going out and coming in. Regardless of whether you’re running one patient or two patients, it knows that air is escaping from the system somewhere. And so, if we turn on the leak detector, within a few seconds, an alarm will go off on the ventilator saying, ‘Hey, there’s a leak.’”

Spotting leaks is important but also relatively trivial, a more demanding use case is detecting whether the ventilator is treating both patients adequately.

“Patients would typically be sedated at this point and they’re breathing in the same rhythm,” says Reed. “So, it’s the same volume of air that’s being split between two people. And that’s exactly where some of the most interesting learnings from this digital twin came from because there’s a lot of built-in safety systems in a ventilator but they are all tuned to single patient operation.”

And that is a potential problem, if the patients have different breathing capacities it can cause issues with the ventilator’s capacity to provide air to both.

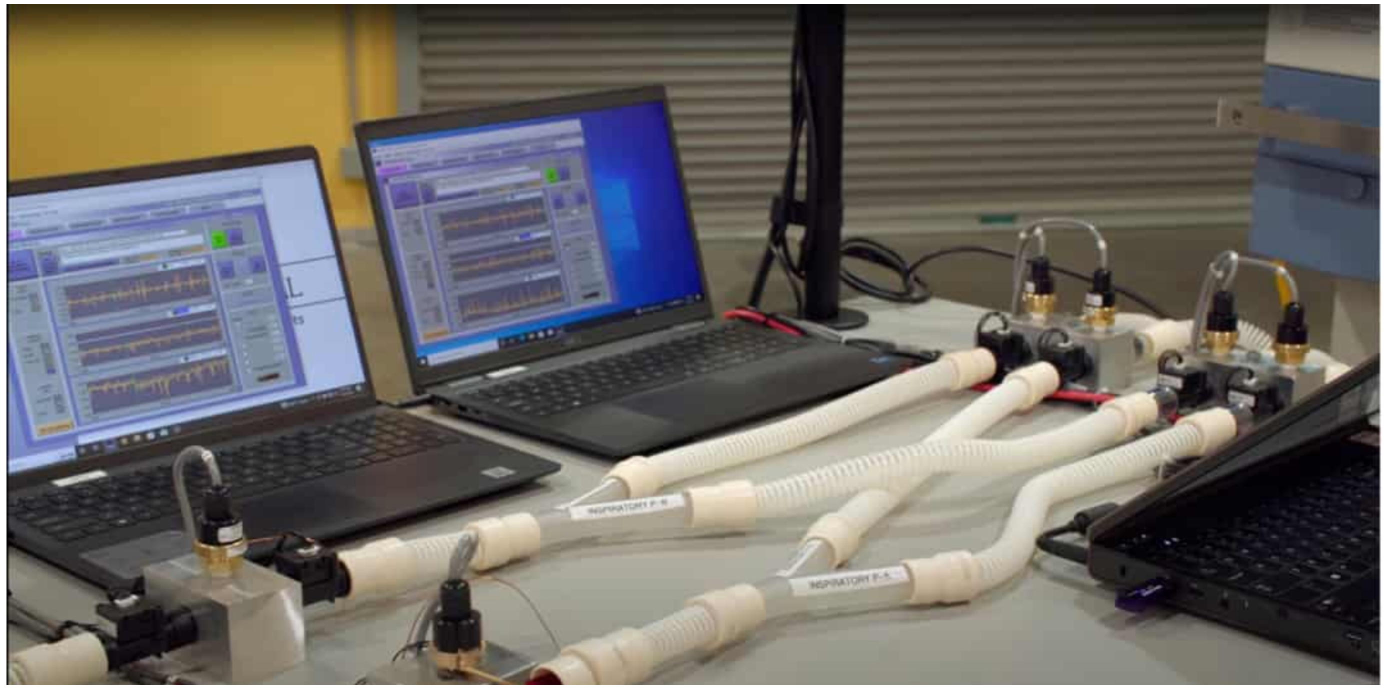
“One of the other things that has been learned from clinicians using these double-patient-ventilators in the field is that the patients must be ‘lung compliant’,” says Reed. “For both patients to be fed from the same machine, their lungs must be able to take in air at the same pressure, so they’re not pushing too much to one person or not enough to the other. We can simulate that too because we have lung simulators. So, we can simulate someone’s condition deteriorating, or them getting sicker.”

The Lungs-in-the-Loop digital twin not only validated the concept of “lung compliance” but it also learned how to spot when the lungs of the patients stopped being compliant.

“However, we noticed that if we simulate having one patient that is very sick with another that is less sick, the ventilator will never throw an alarm even though one of those patients is not getting enough air,” warns Reed. “The ventilator doesn’t recognize the issue because the ventilator wasn’t designed to work that way.”

However, because the digital twin has learned what “normal operation” looks like, through both simulation and real-world operation, it can spot that something is wrong and sound the alarm.

> A medical product redesign that shows exactly how you can use digital technology and the digital twin to accelerate a process, make it safer, and do it with better confidence."
>
> **Daniel Reed**



"So, it will notice the difference and throw an error that says, 'One of these two people doesn't look like they are getting enough air, you may not be able to put them on the same ventilator anymore'," explains Reed.

This digital twin is trained through the experiences of a single ventilator. It's difficult to imagine how much more learning and insight would be gained if this technology was installed on a fleet of ventilators.

"If you have the same digital twin, all ventilators kind of work the same but maybe a ventilator in for example, New Jersey, the ventilator's breaking down," says Reed. "you've got a digital twin that's deployed across your entire fleet of equipment, now you can start to learn things like, 'Okay, this is what it looks like before the machine breaks down. We can start doing predictive maintenance or predictive quality.' Or the machine designers can learn things from that data to say, 'Hey, we didn't design it for this condition. Or maybe we did, but something's happening that we didn't expect. Let's make an update, next version of this, maybe we make a design change.'"

However, before taking that step there are ethical obstacles to overcome.

"And that's a fascinating topic because the power of the data, potential of the data is huge, but there's also risk," warns Reed. "There's also danger associated with that. This is real people's data. This is real people's health information that we are collecting, and it's not okay for that not to be cyber secure. So, when you get into data in what we call a connected care setting, i.e. where the machinery, the care devices that are being used on a patient are connected into a digital framework, all kinds of concerns, reasonable concerns about how you can protect this data, how can we extract the value from it without putting individual patient privacy at risk?"

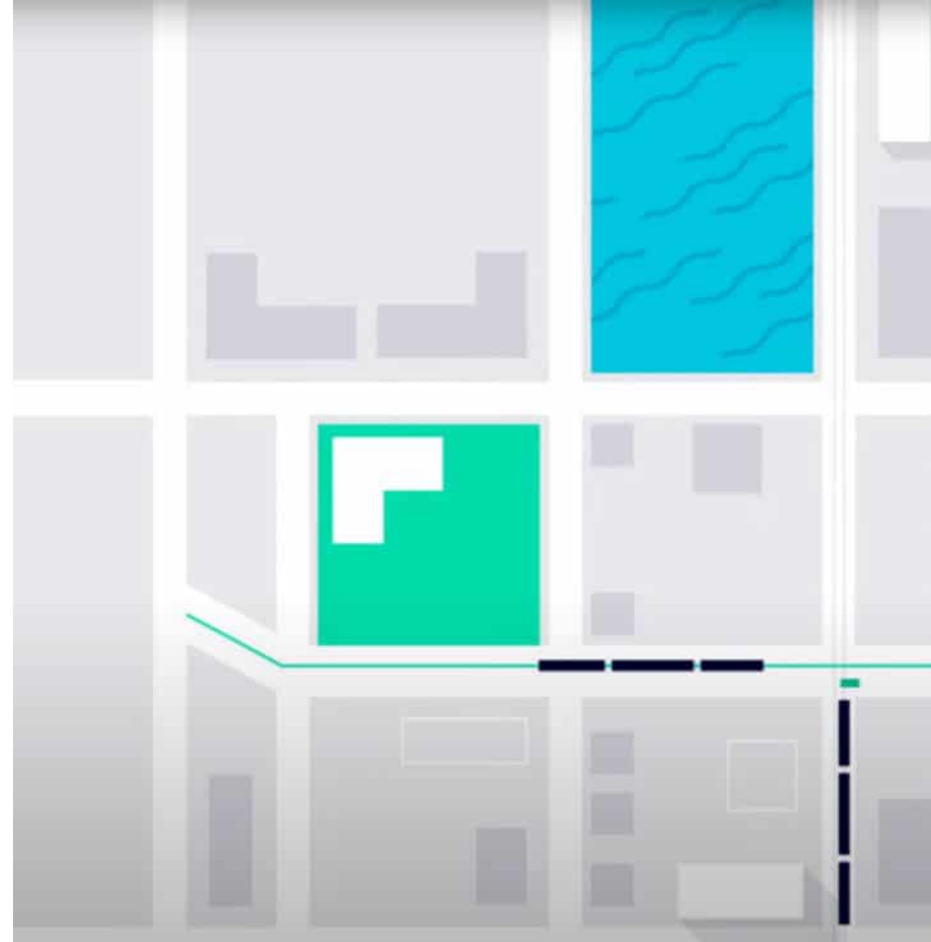
Although the Lungs-in-the-Loop project was remarkably successful, Daniel Reed and MxD are not quite finished with project yet:

"We are actually going to be extending it," he explains. "We're adding an active control device, so actually adding, not just sensors, but a control device that allows us to switch between different patient operating modes, and all of that will be incorporated into the digital twin."

You can hear more from Daniel Reed, as he talks about lungs-in-the-loop and the digital factory of the future in the Engineer Innovation Podcast.

Listen Now





# **xDT:** the Executable Digital Twin

Jane's Juices has a problem: its pasteurization machine is making its packaged orange juice too hot and causing it to spoil. Enter the Executable Digital Twin, or xDT. Simcenter™ Engineering Services helps companies build the Executable Digital Twin to improve machine efficiency, increase productivity and quality, and optimize production processes. After implementing the xDT with the support of Simcenter Engineering Services, Jane's Juices can now make smart usage of all data and information collected during production to optimize performance.

Watch now

Blog article: Five reasons why Executable Digital Twins are set to dominate engineering in 2023


STAY INTEGRATED

# **Navigating the AI frontier** at Realize Live

Rene Pronovost's insights on staying ahead
By Chad Ghalamzan

Realize LIVE, the annual user event by Siemens Digital Industries Software, is an exceptional hub for industry experts and enthusiasts worldwide. This unique gathering offers a platform for attendees to share and collaborate on innovative ideas, explore cutting-edge technologies, and network with like-minded professionals. As we look forward to Realize LIVE 2024, expectations are high for another year of groundbreaking discussions, presentations, and networking opportunities.

Artificial intelligence (AI) and machine learning (ML) look set to be hot topics for a second year. In 2023, the event took place just a few months after the first public release of OpenAI's ChatGPT platform, becoming an important milestone for AI/ML. Their Generative Pre-Transformer technology, which enabled natural language interaction, combined with the previous framework of AI technology, represented a monumental shift in functionality and interest.

AI capabilities surpassing human capacity is not a novel occurrence – it's happened before. However, there was a profound difference this time. The question had firmly become not 'can', but 'when will' machines think for, or out-think us? The impact is ongoing, and the unfolding AI era continues to bring about significant changes fueled by substantial interest and investment.

People, businesses and governments are still grappling with numerous questions and possibilities, attempting to navigate a course of action amid the challenging backdrop of a continually evolving playing field.

Rene Pronovost, the vice president of Services and Operations at Maya HTT, who presented on this topic at Realize Live 2023, has been at the forefront of navigating the changing AI landscape. He shared profound insights on the benefits of attending Realize Live and the pivotal role of AI in driving innovation and growth.

**What's the key benefit of attending the event?**
Realize LIVE provides a pause moment for attendees to step away from their day-to-day work and explore new perspectives. Unlike hour-long webinars, Realize LIVE offers an immersive experience where attendees can exchange ideas, learn from others, and discover emerging trends. AI-focused discussions and presentations at Realize LIVE offer invaluable insights into the latest technological innovations and their potential applications.

As an attendee, Realize LIVE provides valuable insights into the synergies of different solutions and broadens the digital perspective. It goes beyond day-to-day problem-solving, offering an opportunity to explore diverse ideas and


implementations and exchange perspectives with professionals. The event enhances the understanding of what is possible in the digital journey and fosters an environment where attendees discover more efficient ways of working.

**What role does Realize LIVE play in your engagement with customers?**
Realize LIVE serves as a crucial opportunity to stay connected with our customers, providing a platform to understand their challenges and needs. It's a valuable occasion to gather feedback, network, and gain insights into innovations and services that resonate with our customer-base. The event ensures Maya HTT remains aligned with industry demands and customer expectations.

**What discussions did you engage in with your customers last year?**
Last year's customer discussions were heavily focused on the substantial impact of cycle time, development, lead times on securing contracts, optimizing production, and enhancing responsiveness to shorter cycles, especially in the context of RFP responses. The emphasis on efficiency gains in processes, particularly with large teams handling repetitive tasks, underscored the need for automation to capture and leverage knowledge within specific workflows. The evolving dynamics of markets, staffing and knowledge prompted companies to show increased interest in documenting and streamlining workflows. Our commitment to automating portions of our customers' workflows aimed to deliver consistent and reliable results, offering reassurance in the effectiveness of their processes.

**You presented at Realize LIVE 2023. What was the focus of your talk?**
At Realize LIVE 2023, my focus was on exploring the potential of AI, particularly ChatGPT, within Siemens's portfolio. It was just a few months after the launch of the tool. We delved into its capabilities by running tests to determine its knowledge about Simcenter, NX, and custom developments in NX around Teamcenter—the initial presentation aimed to benchmark the out-of-the-box capabilities and understand their relevance for consulting with our customers.

We discussed the concept of augmenting models by providing additional context and documentation and testing the idea of creating a tailored copilot AI assistant. The presentation highlighted the evolving trends in leveraging large language models to develop private knowledge bases and databases, emphasizing the potential for creating a customized AI assistant to enhance engineers', consultants' and customers' access to information, ultimately supporting the successful adoption of Siemens technology.

**How do you stay current in the rapidly evolving AI landscape?**
Staying current in the AI landscape is a continuous process and requires a strategic approach. It's essential to have a thorough understanding of the latest advancements and their potential applications while also being mindful of the limitations and challenges of these tools.

Staying informed about tools for team efficiency is crucial. The fast-paced evolution of AI technology requires constant attention to stay caught up. Keeping abreast of developments and their readiness for implementation is vital for impacting business positively. Realize LIVE provides an excellent opportunity to stay informed about upcoming tools and innovations.

**Will you be attending Realize LIVE 2024, and what are your expectations?**
I plan on attending Realize Live 2024 to provide an update on our AI endeavors. I expect to share our continued experiments with ChatGPT and explore new takeaways. The event is an opportunity to showcase our progress and learn from other industry leaders' experiences and insights.

In addition to being an educational experience, Realize LIVE is undeniably a fun event. Whether engaging with colleagues or customers, the event's enjoyable atmosphere breaks down barriers. The more relaxed and fun setting fosters openness, providing an opportunity to connect more personally. Attending Realize LIVE is not just about learning; it's a chance to step away for a few days and enjoy quality time building strong relationships with industry, colleagues and partners.


In November 2023, we celebrated the first anniversary of ChatGPT's launch by exploring Artificial Intelligence (AI) and Machine Learning (ML). We published a series of thought-provoking content that delved into the current and future state of engineering.

We shared insights on cutting-edge ML capabilities, real-world applications, and the interdependent relationship between AI and human innovation. It's not just about adopting technology; it's about comprehending its profound impact on engineering, simulation, and the future.

To revisit the series and explore the latest content on this topic, visit Unleash innovation with AI/ML and Simcenter | Siemens Software


MODEL THE COMPLEXITY

# From punched cards to ChatGPT

A brief history of Computer Aided Engineering
By Stephen Ferguson

When we think about the history of Computer Aided Engineering, the focus is usually on the evolution of computer hardware and the development of the simulation tools themselves. We talk much less about the considerable changes that have occurred to the way that we communicate with those tools.

In this article, I am going to explore the history of how humans interact with computers, by splitting the last 60-or-so years of CAE into 3 eras, each of which has represented a step change in engineering productivity.

I do this because I think we're at the dawn of a new era, one which will make the current era of computer communication feel as clunky as the first era. Let's start with punched cards.

**Epoch 1: Punched Cards (1890 to 1980)**
In the beginning, data was physical. You could hold it in your hands. To change that data, you needed to manipulate it by physically punching holes in it.

For about 90 years, punched cards were the principal mechanism by which engineers communicated with machines. Even before those machines were actually computers.

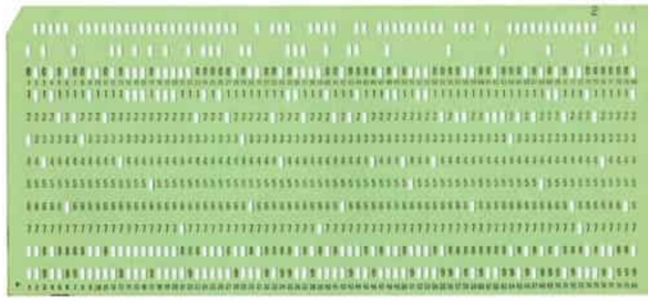
In 1890, Herman Hollerith invented a "tabulating machine" that used punched cards to count statistics from the US Census, which was able to process data at the incredible rate of 7000 cards a day. Hollerith's Tabulating Machine Company eventually became International Business Machines (or IBM), the company that standardized the punched card format as 80 columns, 12 rows with rectangular holes.

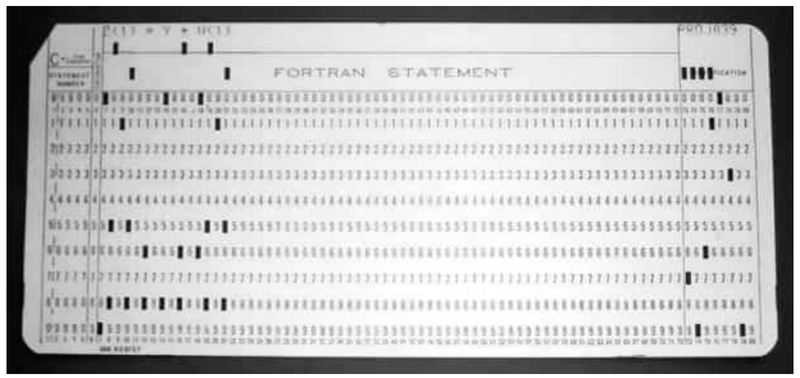
During the Second World War, the Enigma Research Section at Bletchley Park was getting through 2 million punch cards a week. Enough that if you put them in a pile, the stack would be as high as the Eiffel Tower.

By 1937, IBM was printing about 5 to 10 million punch cards a day. Each punched card could encode 80 characters of alphanumeric text.

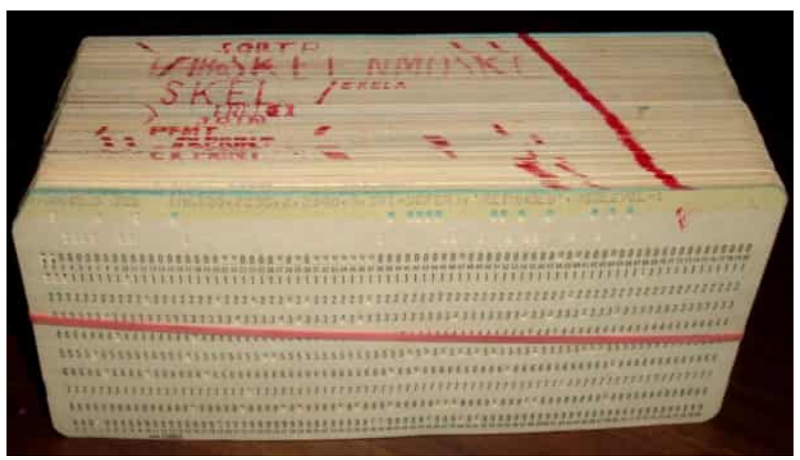
The whole arduous process is explained by Eduardo Grosclaude, who eloquently describes his experience programming computers at university in 1982:

1. Write your Fortran program in a coding sheet.
2. Purchase an adequate amount of new punch cards.




A punched card with the FORTRAN command "Z(1) = Y + W(1)"



A computer program written on punched cards and wrapped with a compulsory rubber band (courtesy of ArnoldReinhold – Own work, CC BY-SA 3.0 )

3. Fold your coding sheets, join them to the pack of cards, wrap the whole with a rubber band and deposit them in a card rack.
4. At a secret moment, a secret little truck would take our work to a secret place in Facultad de Ingeniería where our cards would be punched by secret little workers.
5. At a secret later time, our code and punched pack of cards would be returned along with a very long list of compiler errors. Guaranteed.
6. You would interpret said list of compiler errors to the best of your knowledge, rewrite your program on a new coding sheet, and rinse and repeat from step 2.

Coding (or typing) errors had to be corrected by re-punching the card that represented that line of text. Editing programs required reordering the cards and removing or adding cards to represent new lines of coding.

Until the advent of dot-matrix printers in the late 1960s output data would also be on punched cards – introducing another layer of decoding. Even then, the results were usually entirely numerical with no actual visualization capability for the model.

The commercial CAE software industry was born in the punched card era. The first commercial releases of Nastran and ANSYS both occurred in 1971.

**Epoch 2: The Keyboard (1980 to 1990)**
From the mid-1980s onwards, computer terminals with screens and keyboards quickly made punched cards obsolete. Engineers were now able to type their FORTRAN (or NASTRAN or whatever) commands directly into the computer's memory. This is my generation, I started university in 1990 and I've never seen a punch card in real life.

The keyboard era saw the birth of commercial CFD, with Phoenics released in 1981, Fluent in 1983 and STAR-CD in 1988. All of which were command-line driven.



In 1993 my first real-word CFD calculations were performed using STAR-CD v2.1 on a SUN Sparc Workstation (called cfd01). I talked to the simulations using the keyboard. Note how rudimentary an early 1990s computer mouse was (Image courtesy of the PC Museum website).

For engineers of that era, communicating with a simulation tool, typically meant learning a new language. In my case that language was proSTAR ("CSET NEWS VSET ANY"), the pre-and-post processor for the STAR-CD CFD code. At the same time, ANSYS introduced their "Parametric Design Language" (which still exists today) to replace punched card operation.

For my generation of engineers (in the early 90s) a computer mouse was mainly a way to navigate between windows, and not a direct input device to the CAE tool.

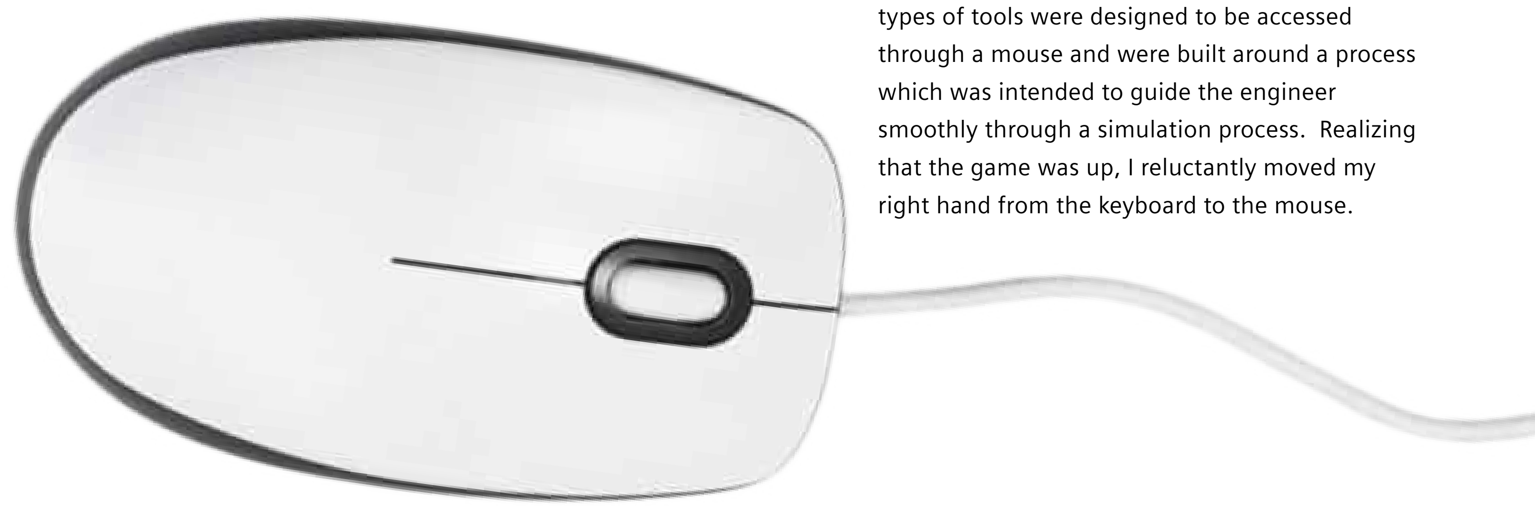
Computer operating systems moved from command line (DOS like) interfaces to ubiquitous windows type operating systems in the mid-1980s, The Apple Macintosh was released in 1984, Microsoft released Windows version 1 a year later. However, CAE tools were slow to follow and command lines persisted into the mid-1990s and beyond.

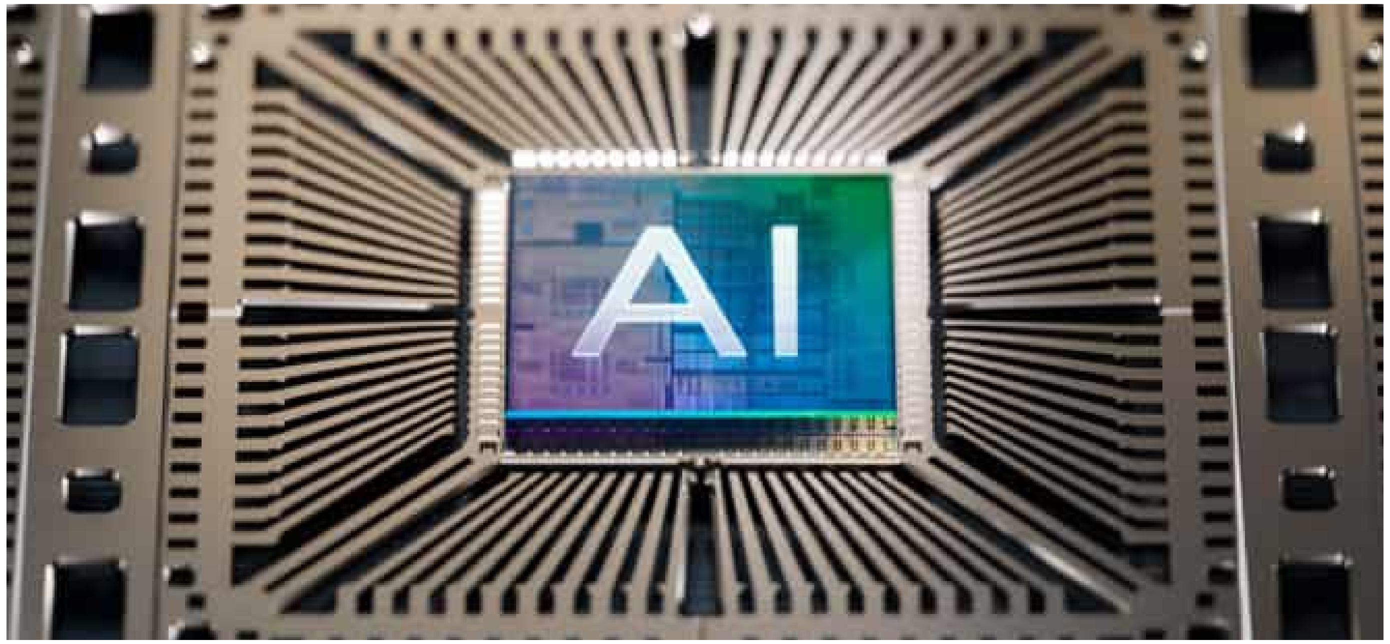
**Epoch 3: The Mouse (1990 to now)**
It shouldn't take too long to describe the mouse era, because we are now living at the end of it. Most engineers today spend more time with their fingers on their mouse than on a keyboard.

Most of the early point-and-click CAE tools simply placed a graphical user interface on top of the existing command line structure, with each click of the mouse generating a stream of commands in the background.

Freed from having to remember complicated command syntax, engineers would instead have to learn to navigate a (sometimes equally complex) menu system. These systems were easier to pick up for a new user of software, but not necessarily any more efficient to use for experienced users who had "learned the language".

I managed to style out my own career as a keyboard man in the mouse era until 2006 and the release of STAR-CCM+, which was a new generation CFD code, built from scratch. These types of tools were designed to be accessed through a mouse and were built around a process which was intended to guide the engineer smoothly through a simulation process. Realizing that the game was up, I reluctantly moved my right hand from the keyboard to the mouse.






Although each of these tools are individually marketed as being "easy to use", almost every CAE tool has a completely different interface. Being an expert in one tool doesn't really equip you to use any of the others, and the whole experience of trying to learn a new CAE interface can be soul destroying. Many of us build entire careers in becoming "jockeys" of a given tool (in my case STAR-CD and Simcenter™ STAR-CCM+™) and ignoring all of the others.

When it comes to automation, it's worth noting that most of us still revert to the keyboard, recording, writing or editing macros that can perform tasks in batch.

**Epoch 4: The Large Language Model (starting soon)**
Although the mouse era didn't end on November 30th 2022, something happened that I think will permanently change the way humans (and in particular engineers) interact with computers in the future.

I'm not suggesting that the computer mouse (or indeed the keyboard) is going to disappear from the engineering world like the punch card did, but I am very confident that Large Language Models will change the way that engineers interact with simulation tools forever.

Instead of having to interact with our tools by learning their language (as in the keyboard era) or learning to navigate their user interfaces (the mouse era), soon we'll simply be able to ask a Large Language Model to set up some, or all, of the simulation for us.

And, unlike in the mouse, keyboard or punched card era, we won't simply be issuing commands. Instead, we'll be having a two-way conversation with the simulation tool, building understanding and solving problems together.

I've already experienced this in my own engineering career. As a FORTRAN era programmer, I've generally struggled to learn how to use more modern languages like Python. Since the advent of ChatGPT, however, I don't have to worry about that anymore. I simply have a conversation with the LLM about what I want to achieve and it writes the code for me, we debug it together and it helps me to process whatever data it pumps out.

There are obstacles ahead, of course, at the moment LLMs tend to work best if their output has a slightly random element to it. Repeating the same prompt several times will produce different, but still intelligent answers. There are also unresolved questions about intellectual property and data privacy.

It will take some time for the major CAE vendors to resolve these problems and write interfaces between their tools and the most prominent LLM system(s) (which might or might not include ChatGPT), but that work is already underway.

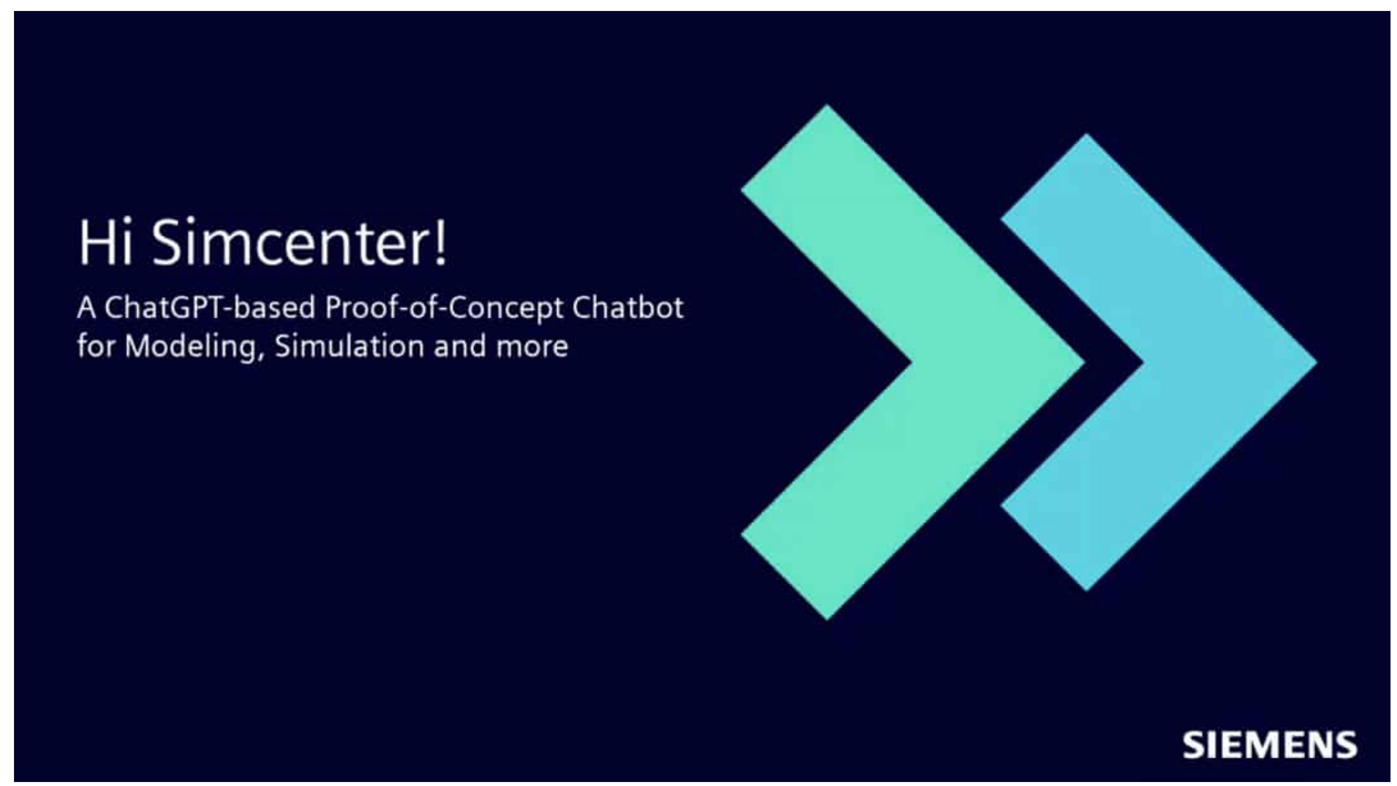
The "Hi Simcenter" proof of concept demonstrates how you can setup a complicated Simcenter™ Amesim™ software simulation using a simple ChatGPT prompt:

Hi Simcenter chatbot is a proof-of-concept that demonstrates how LLMs might be used to drive CAE in the future

For what it's worth, I think that LLMs will change the way we interact with everything and not just CAE tools. We've seen the start of this with Alexa and Siri, where it's generally quicker and easier to ask a virtual assistant to perform a simple command ("set an alarm", "play a podcast") than to do it yourself. The difference is that with LLMs, they have more ability to understand more complicated commands with context, and for the conversation to be two-way, which reduces the chance of misunderstanding.

What I want to be able to do is to ask my phone, "can you book me a taxi at 11pm to take me home from the pub? Let me know if the surge pricing increases that journey cost to more than £40 please" rather than having to click through

If you enjoyed reading this article, then you'll love the latest episode of the Engineer Innovation Podcast, in which I interview Kai Liu – the man who is responsible for implementing LLM technology into future generations of Simcenter products:

GO FASTER

# Plastic Omnium's fuel cell future **shines brightly with Siemens**

Hydrogen fuel cell innovator slashes development time 25% with Simcenter Amesim and Simcenter Reduced Order Modeling
By Nigel Ravenhill

In 1928, Henry Ford didn't need companies like Plastic Omnium. When the industrial icon opened the Ford River Rouge complex that year in Dearborn, Michigan, it was the largest vertically integrated factory in the world; iron ore and other raw materials entered at one end with ready-to-run cars and trucks rolling out the other end.

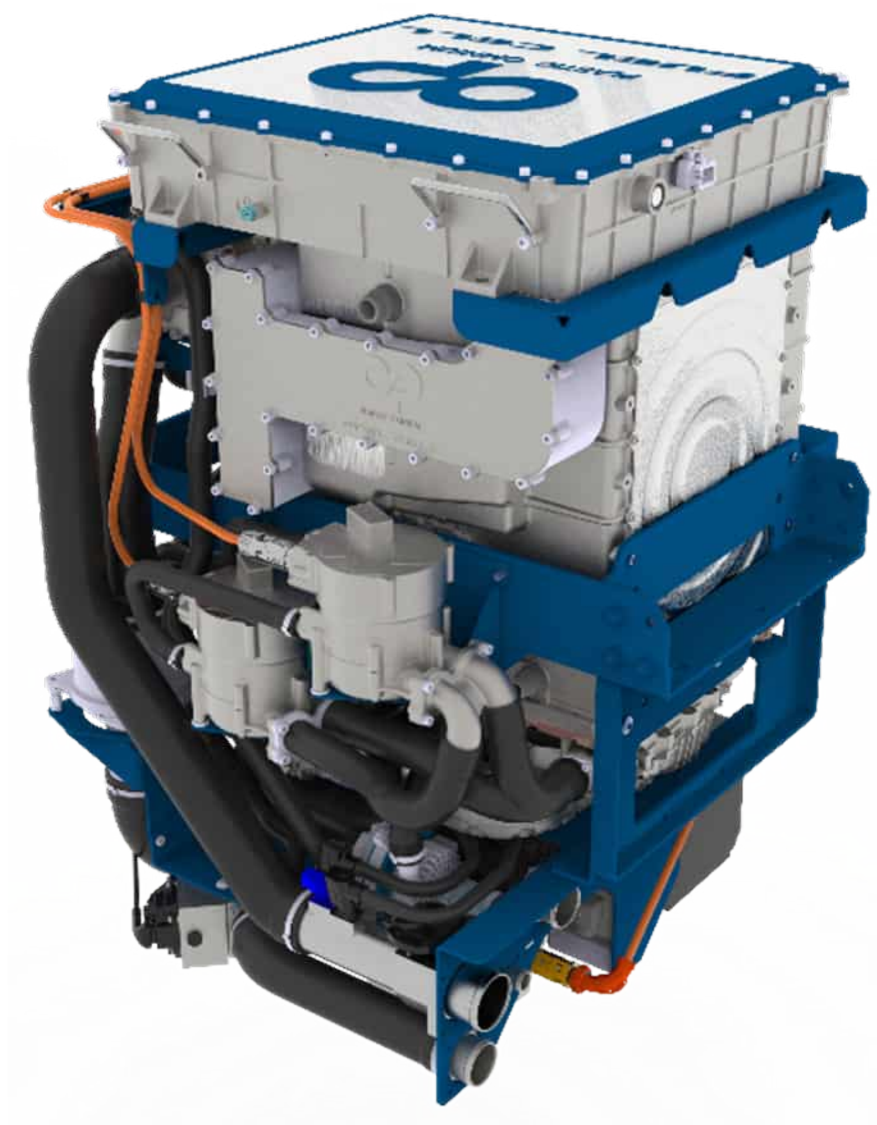
The auto industry has greatly evolved since then, most notably in supply chain management and technologies. Most factories are no longer even referred to as factories, they're called assembly plants. A century after vertical integration made sense, automakers now combine complex sub-assemblies sourced from companies like Plastic Omnium to produce the cars, trucks and vans that roll out of their plants.

Founded and still headquartered in the Paris metro region, Plastic Omnium has been supplying automakers with parts since 1946. As France started to rebuild its manufacturing strength after World War Two, company founder Pierre Burelle identified an opportunity to supply plastic-based vehicle components to customers like Renault. More contracts with other domestic and foreign manufacturers followed in the post-war boom as Plastic Omnium delivered on its promise of weight reduction and improved performance.

Fast forward 75 years: that culture of and commitment to innovation hasn't waned and annual revenues are close to €10 billion. Plastic Omnium has become one of the world's largest and most important suppliers of external plastic elements such as bumpers and energy absorption systems, fenders and front-end modules for cars. With the auto world shifting as quickly as possible, however, away from internal combustion engines to greener forms of propulsion, Plastic Omnium launched New Energies in 2022 as a new business unit to advance hydrogen mobility and help vehicle manufacturers pursue opportunities using fuel cell technology. Siemens Xcelerator business platform of software, hardware and services is an important resource and partner on this journey.

**Betting on the Future**

Since 2015, Plastic Omnium has invested €200 million to increase its expertise and capabilities across the entire hydrogen value chain. R&D centers have opened in Europe and China, while



several key acquisitions have added domain expertise, experienced personnel and vital intellectual property (IP). Plastic Omnium System Engineer Jurgen Dedeurwaerder explains:

“Plastic Omnium acquired companies already active in fuel cell system development and production but they worked mainly on demonstrators. We needed to adapt this for the automotive industry so the fuel cell systems could be mass-produced at high quality. To do this, we needed to master both our development and production processes.”

**A Hydrogen Fuel-Cell Primer**
Although a hydrogen fuel cell vehicle uses an electric motor, the energy doesn’t come from a heavy battery stack. Instead, compressed hydrogen is housed in a high pressure tank. When running, the hydrogen moves to a fuel cell stack where it passes through a membrane and combines with oxygen to produce electricity (and some water vapor). The electricity powers the motor which drives the wheels. (Some vehicles also have a small high-voltage low-capacity battery powered by fuel cell surplus or regenerative energy to help with acceleration).

**Partnering With Siemens for Simulation**
We’re in the very early days of developing fuel cell propulsion for passenger vehicles, light trucks, heavy trucks and buses, trains and even ships. There is much promise, but also many technological, design and manufacturing challenges (high-pressure storage tanks, fuel cell temperatures, tank safety and lifespan, etc.) to be solved. The necessity of cost management was therefore obvious according to Dedeurwaerder: “Simulation was essential from the start because we knew that it would improve our processes and help keep costs down.”

The obvious choice was Simcenter™ software, part of the Siemens Xcelerator business platform. Dedeurwaerder initially built a complete model of the fuel cell systems, including components, using Simcenter™ Amesim™ software. While his model was ideal for optimizing the architecture and production cost, the level of detail was so great that it would be unsuitable for exploring a wide range of design options.

**100 Times Faster**
To avoid the time-consuming analysis of complete models, yet still answer the team’s questions,



> We use Simcenter Amesim to look at different powertrain configurations, battery sizes, vessel sizes and fuel cell power levels. This allows us to interact with our customers to find the optimum design.
>
> **Jurgen Dedeurwaerder,**
> System Engineer, Plastic Omnium

Dedeurwaerder integrated Simcenter's Reduced Order Modeling software into their process.

“We trained the original model with a large range of variables such as the piloting of actuators and environmental conditions,” he says. “We used Simcenter Reduced Order Modeling to create the reduced order model with those training sets. The result was much faster simulations, probably 100 times faster than the original model.”

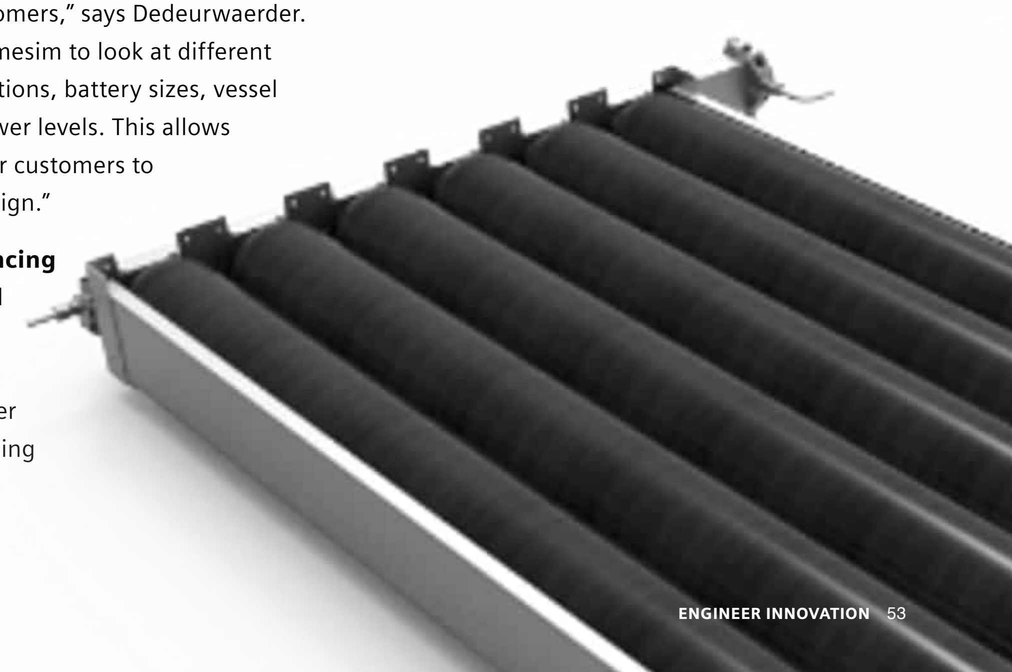
At this stage, this plant model is then converted to a black box model, which control and software engineers use to develop and test their algorithms. The same process is later used for hardware-in-the- loop (HiL) testing. It also serves as a fast and accurate model that customers can incorporate into their full vehicle models to test within their own environment.

“We also carry out full vehicle simulations in-house for our customers,” says Dedeurwaerder. “We use Simcenter Amesim to look at different powertrain configurations, battery sizes, vessel sizes and fuel cell power levels. This allows us to interact with our customers to find the optimum design.”

**Optimization: Balancing Digital and Physical Testing**
Using Simcenter Amesim and Simcenter Reduced Order Modeling sharply decreases the amount of physical testing required to analyze the complete system.

“It’s not necessarily a reduction in the total amount of testing, but more oriented toward individual components,” he explains. “You can then build a model using components you’re confident about. With such an accurate model, much of the analysis previously done by full system testing can now be carried out with simulation.”

Dedeurwaerder also appreciates that the simulation can give him a better understanding of phenomena occurring inside the fuel system. Physical testing may not be able to explain, for example, a sudden and unexpected temperature drop. Simulation, however, might reveal that the cause is the presence of liquid water instead of vapor.



reduced order model that we integrate into our system model."

Having invested hundreds of millions of euros in R&D and an IP portfolio of more than 2,200 patents, Plastic Omnium is protective of its inventions. Dedeurwaerder notes that Simcenter Reduced Order Modeling allows Plastic Omnium to judiciously share models with customers and suppliers.

"We can allow them to see cell voltages and net power without viewing all the model details. It's always within our control. As we work more closely with partners, we can gradually disclose more details as the relationship progresses. And they can never see everything inside the system model or the specific algorithms we use."

Dedeurwaerder doesn't hesitate to rave about the value of Simcenter Reduced Order Modeling with those same partners: "We had a supplier who only worked with physical models. Integrating the physical model inside a complete vehicle model was too slow to run. So we showed them the benefits of using a reduced order model to explore complex boundary side effects and behave as a physical model would, but in a much shorter time. You end up with a better final product at a faster speed as you take all the boundary effects into account."

Simulation flexibility compared to physical testing is also valuable. "It's much easier to assess performance in different environments. Setting up test benches at certain altitudes or temperatures can be difficult. With simulation, we can choose any conditions we want. We now verify new components with simulation first. By the time we build the system, we've usually got it right, which saves a lot of time and money building further systems."

**Using Reduced Order Models to Protect Intellectual Property**

Reduced order models have also proved invaluable when full physics details of components are unavailable. "In some cases, the physics aren't fully understood, or the supplier can't disclose them due to IP rights," says Dedeurwaerder. "So we stress the component in all directions and record the variable data. This is used to train a

**Complexity Far Beyond Spreadsheets**

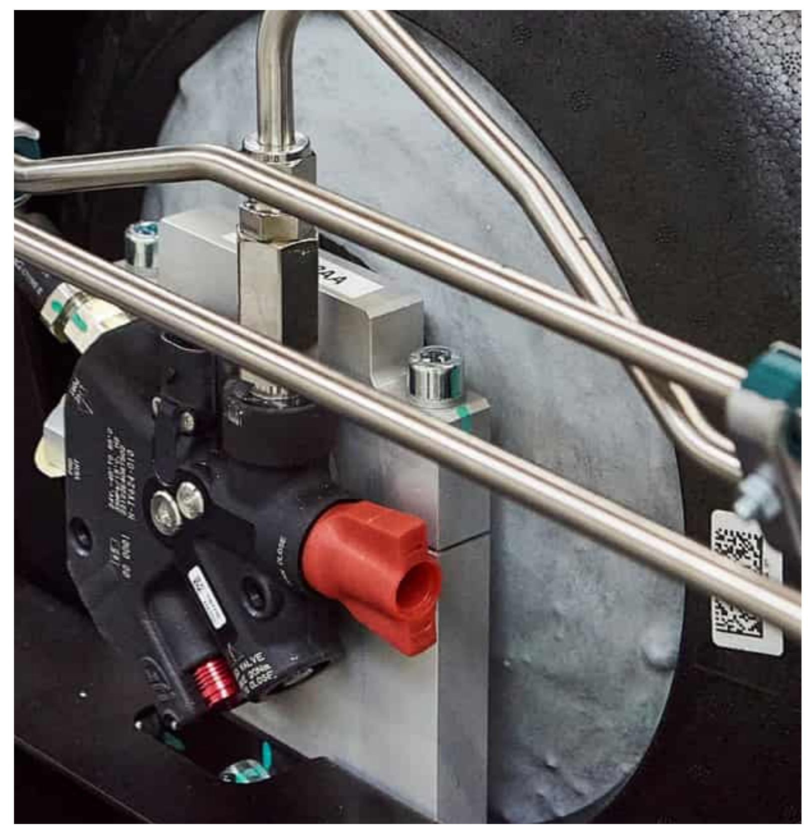
Before adopting Simcenter Amesim and Simcenter Reduced Order Modeling, Plastic Omnium often used a spreadsheet for calculations. Although it's possible to get limited results, they are typically inflexible static data. This spreadsheet method doesn't allow engineers to track gas or liquid properties, for example, that evolve with temperature and pressure. Changing a component requires a new analysis. In contrast, engineers using Simcenter Amesim and Simcenter Reduced Order Modeling can start with a simple model, progressively increasing complexity as their understanding develops.

"Simcenter products are easy to pick up, but you must learn how to generate the training data to be used in Simcenter Reduced Order Modeling. Being able to start simple has allowed us to easily integrate it with our processes and evolve our use as we get to know it better. Exporting and importing data to and from other systems is also easy. For instance, we're currently building a plant model with several reduced order models and circuitry around them. We set and test the conditions and then integrate it with the complete model using the Simulink interface. It all works well together."

**Overall Development Cycles Cut By 25%**

Dedeurwaerder believes that without simulation, addressing all the engineering challenges that Plastic Omnium must solve to enjoy commercial success in this business would be almost impossible. The company would have to conduct far more expensive physical testing and run the risk of making mistakes that would slow the development calendar while sharply increasing costs. Simulation addresses both areas with fewer resources.

"Simcenter Reduced Order Modeling reduces the overall development cycle by around 25 percent," reports Dedeurwaerder. "It lets us accelerate our simulation models to the point where a detailed fuel cell plant model runs significantly faster than real time with the same accuracy as a full system model. Activities such as model-in-the-loop controller development and testing are faster too. At the same time, it gives us a reliable, IP-protected and cost-effective way to distribute models to other teams, both internally and to our customers to augment the quality of their own products and processes. This results in better quality products being delivered to end users."



**Continuous Improvement from the digital twin**

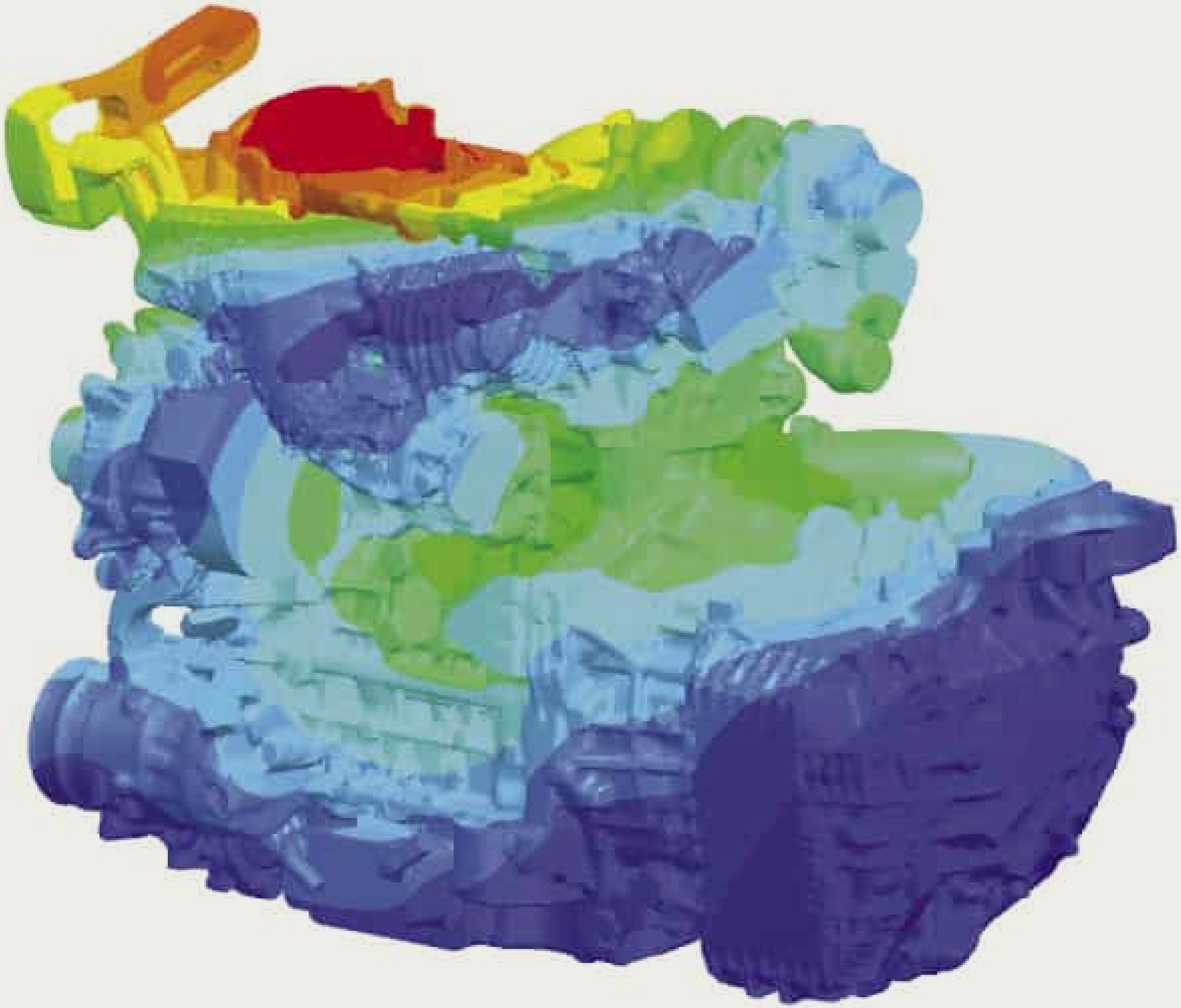
Every major automaker on the planet is working towards and investing in a future where vehicles powered by electric motors have replaced internal combustion engines. The close collaboration between Plastic Omnium's New Energies division and Siemens has already paid off by shortening the road between the ideas Dedeurwaerder tests and the test drives that prospective fuel cell vehicle buyers and drivers will make from a truck or car showroom.

"The digital twin is vital to maintain a competitive edge. That's why Simcenter Amesim and Simcenter Reduced Order Modeling are so important to us because they enable us to see inside our products and learn from real-time data to make improvements in future iterations. I expect to see more suppliers using this technology, which will help us all develop better products."

**A Henry Ford Postscript**

Remember Henry Ford's innovation in Dearborn, MI? Ford Motor Company still builds vehicles there. In fact, it opened a half-million square ft. electric vehicle manufacturing operation called the Rouge Electric Vehicle Center on the site of the historic Ford Rouge Center in 2021. The first production model is Ford's all-electric F-150 Lightning pickup truck, assembled using the kinds of component systems delivered from Plastic Omnium's own factories. In fact, Ford selected Plastic Omnium in 2022 to supply high-pressure tanks for the US Department of Energy's "Supertruck 3" program.

GO FASTER



# Supporting the **electric transition**

Efficient simulation enables NVH optimization across all engine types
By Luke Morris

Transition is fundamental to technological progress.

Sure, it would be great if, once a new technology is available, everything could be immediately switched over and all the old technology replaced. But that's not logistically or economically viable.

This is especially true when it comes to vehicle development. Electric powertrains are now available that can replace the internal combustion engine in many situations. Many, but not all. Whilst some consumers are eager to switch to electric, charging availability is a major factor in causing many to stick with the internal combustion engine.

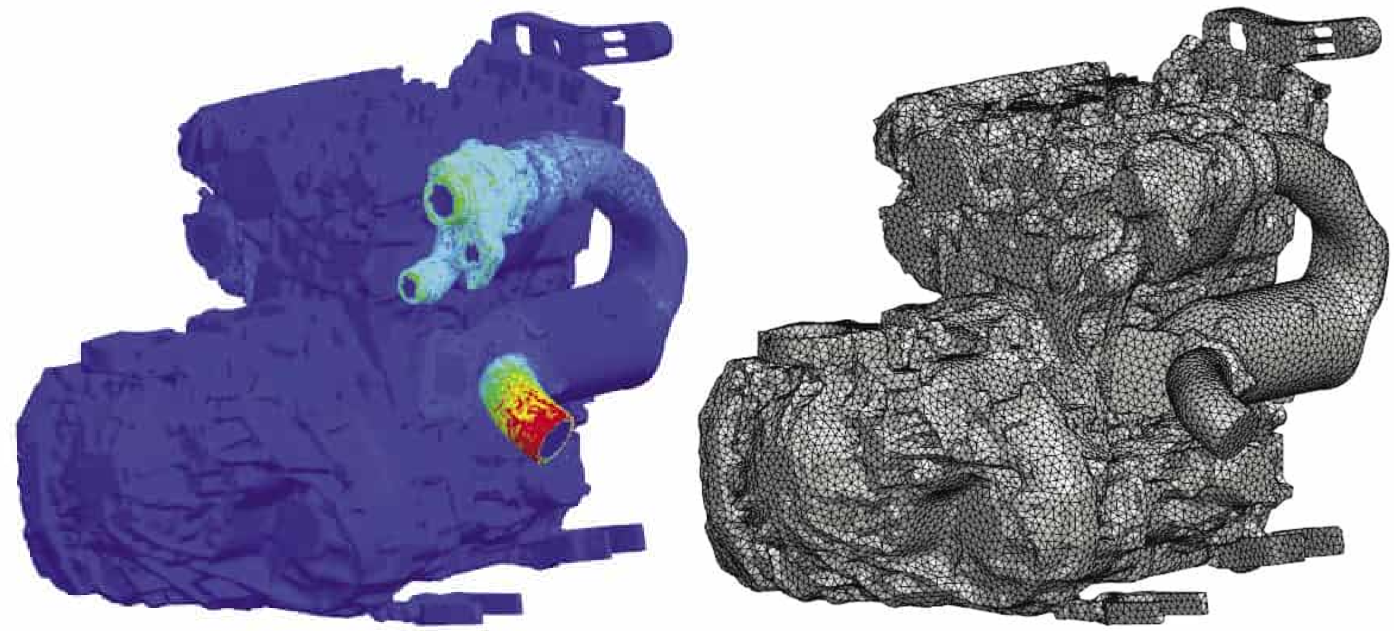
Most countries around the world plan to ban the sale of new internal combustion engine vehicles by 2040. But for now, the global automotive industry is very much in a transitional phase. It needs to ramp up production of electric vehicles while at the same time continuing to satisfy demand for fossil fuel powered vehicles.

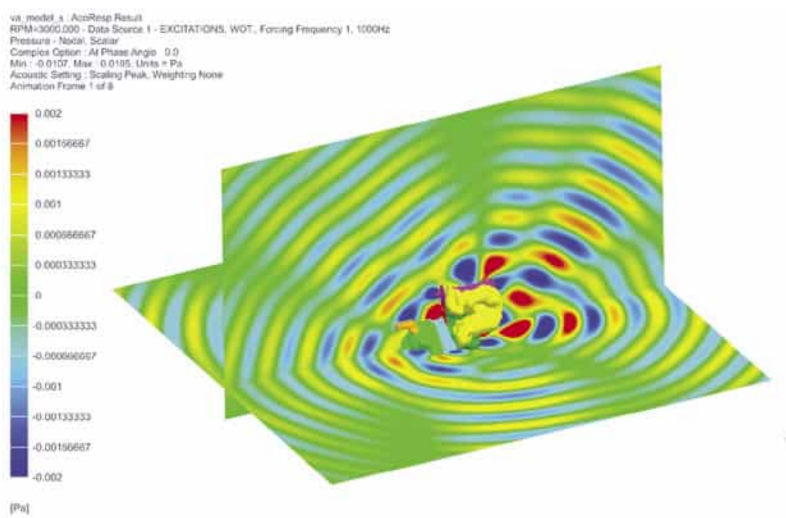
So, how can engine developers cater for both markets while remaining competitive?

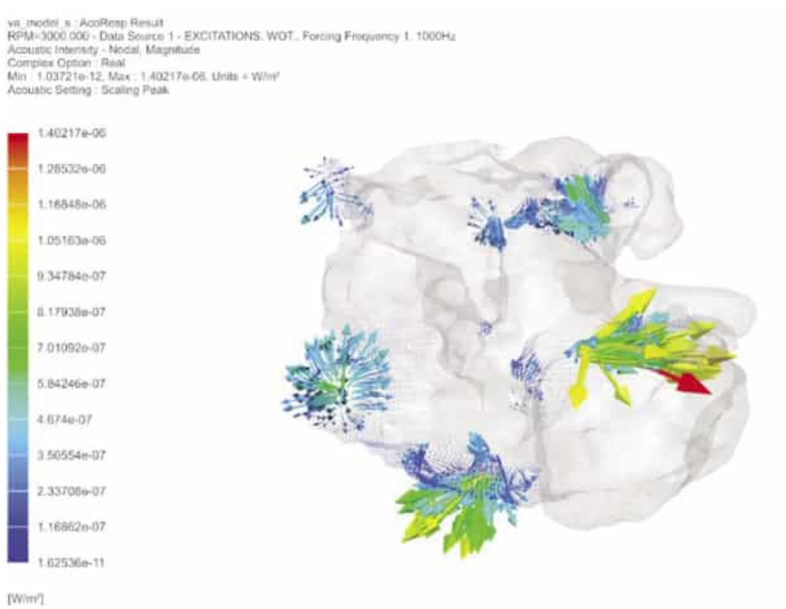
**Propulsion pioneers**

Aurobay, formerly part of Volvo Cars and Geely, is a pioneering supplier of propulsion technology that specializes in hybrid propulsion technology, development services and contract manufacturing with operations in Europe and Asia. To produce high performing hybrid engines, Aurobay have to be specialists in both internal combustion engines and electric motors. These two methods of propulsion and their unison into a hybrid would often require two different toolsets for development. This would mean not only investing twice in different software, but also training engineers on both – overall very expensive and time-consuming.

It simply wasn't financially viable, so the company knew it had to find a solution that could be used for both disciplines.







**Vibration prediction with Simcenter™ 3D software**

One of the key differences between developing internal combustion engines and electric motors comes in the prediction of vibrations. The former requires more extensive analysis of speed data (also known as Waterfall of Frequency Spectra Analysis), while the latter needs a greater focus on the analysis of ordered data. Most simulation software specializes in one or the other, hence the need for different tools, however, Simcenter 3D can perform both tasks at an equally high level, making it the ideal solution for Aurobay.

Technical leader Hans Johannesson also notes the open ecosystem as a significant factor in the decision. "We're able to use Simcenter 3D alongside our existing tools," he says. "This made it faster to integrate into the full toolchain and more affordable to implement."

**Saving time with reduced order models**

Measuring noise, vibration and harshness (NVH) requires calculation of the structural dynamics vibration caused by the engine. Previously, 21 full finite element runs were needed for each scenario to make accurate predictions. However, using Simcenter 3D, Aurobay engineers were able to create just one finite-element based reduced order model instead. This captures the acoustic sensitivity of the vibrations and can be quickly and easily re-used for different operating conditions.

Johanneson estimates that using Simcenter 3D in this way typically reduced the overall simulation time from over 2 hours to just 15 minutes. Consider that this is applied over multiple scenarios, and it adds up to a very significant saving.

The creation of the reduced order model by simulation experts allows the rest of the work to be delegated to less experienced engineers. They can build up their skillset while carrying out extensive analysis by adjusting the parameters of the loading conditions and using a linear solver – a valuable contribution to the overall project.

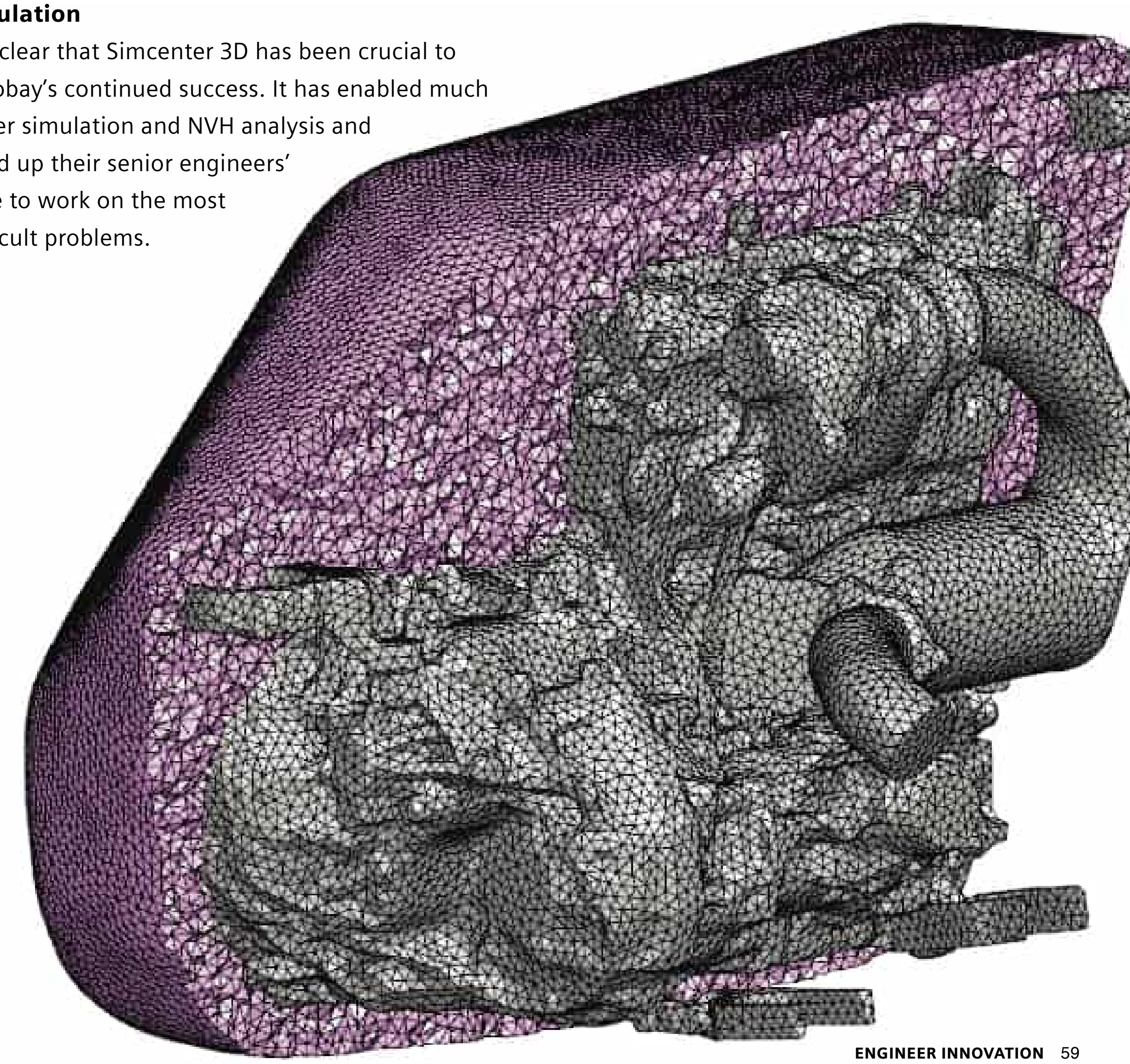
The postprocessing tools within Simcenter 3D also make it easy to search the vast amounts of data generated, which is then quickly shared across all the teams in the organization, better informing their design decisions and allowing them to complete projects sooner.

**Enhancing optimization with further simulation**

It is clear that Simcenter 3D has been crucial to Aurobay's continued success. It has enabled much faster simulation and NVH analysis and freed up their senior engineers' time to work on the most difficult problems.

Johanneson is keen to improve development further by adding more Simcenter solutions to combine simulations with physical testing. "We intend to use Simcenter™ STAR-CCM+™ software for input to Simcenter 3D Acoustics," he explains. "This will enable us to analyze flow and vibration acoustics. Simcenter STAR-CCM+ can give us data on things such as pressure on a duct, and then we can use Simcenter 3D to predict the noise this generates."

This would enable more extensive NVH performance evaluation, such as the noise inside the vehicle cabin, with a view to making the end products that Aurobay's engines are installed in even better and more comfortable for users.



The Rain Vortex at the Changi Jewel airport terminal
(Image courtesy of Supanut Arunoprayote.)

EXPLORE THE POSSIBILITIES

# Trains, planes and waterfalls

A new terminal in Singapore's Changi Jewell airport designed to challenge the standard expectations of airport terminals. By Stephen Ferguson

Modern airport terminals are usually functional buildings, with climate control settings carefully designed to accommodate passengers dressed for their destination rather than local surroundings.

If you travel often, it becomes difficult to tell airport terminals apart. The only real difference between them is the variety of retail experiences designed to extract the maximum cash from passengers as they wait for often delayed flights.

Not so in Singapore, where the newly opened Changi Jewel terminal has become an iconic leisure destination. At its centerpiece is the world's largest and tallest indoor waterfall: the seven-story-high "Rain Vortex" through which 10,000 gallons of harvested rainwater plummet every minute. Located inside a giant greenhouse atrium, surrounded by a terraced forest, the cascade of water is often accompanied by a spectacular display of choreographed lights and music.

However, in the hot and humid tropical climate of Singapore, managing the thermal comfort of occupants is always a challenge, even more so while trying to minimize energy consumption and greenhouse gas emissions.

Building the world's largest indoor waterfall inside a giant glass greenhouse in a tropical country while keeping the space comfortable for occupants was obviously a considerable engineering challenge. To complicate matters further, the atrium is penetrated by a passenger train service that has the potential to suck in warm air from the outside and expel cooled air back into it.

To address these complicated challenges, the architects responsible for designing the terminal appointed Atelier Ten Ltd to provide strategic environmental design, analytical consultancy and conceptual services engineering. Balancing the competing demands of abundant heat and light needed for plants and superior passenger thermal comfort for people was one of the project's key challenges. Atelier Ten produced detailed models of the thermal environment in the atrium, including using ray tracing technology to model the light entering through each triangular glass panes on the roof.

I spoke with Atelier Ten's Nikolai Artmann and Henry Woon about the challenges of designing the thermal environment of the Changi Jewel airport terminal.

**Waterfall engineering**

Their focus soon turned to the waterfall. Although one might naively assume that the waterfall would have a cooling effect, there was some concern that the vast mass of moving water might disrupt the thermal environment in the atrium.

"Although the architects originally hoped that there might be some evaporative cooling benefit, the real concern was the potential for de-stratifying the thermal environment inside the building," explained Henry Woon.

We all know that hot air rises. This thermal buoyancy effect means warmer air accumulates at the top of the atrium, from where it is extracted for air conditioning. Atelier Ten were keen to make sure that the warmer air at the top of the atrium wasn't entrained by the waterfall and dragged down to the lower occupied levels.

"The intention was to only expend energy in air-conditioning the occupied lower areas of the building, and the risk was that the waterfall would entrain warm air from further up and drag it down to the lower levels," said Woon. "We were concerned that the waterfall mixing up the air volume would harm the thermal comfort of occupants of the atrium."

A secondary concern was that moisture from the waterfall would add to the humidity of the air in the occupied space, adding load to the air conditioning system.

Engineers started by building models in a spreadsheet to try to understand the entrainment and evaporative cooling effect of the waterfall but soon concluded that more detailed engineering was required.

"One issue was that there was no literature on waterfall simulations that we could reference, apart from a few simulations of naturally occurring outdoor waterfalls that weren't very useful," said Nicolai Artmann, who led the indoor climate modeling on the project.

To answer these questions, Artmann built a detailed numerical model of the waterfall using Simcenter™ STAR-CCM+™ software.

"We needed to work out how to segregate this warm air and reduce the impact to the core displacement ventilated condition space at low level," said Artmann. "But also, to calculate the evaporation rate of the waterfall and how much latent load it actually added into the system."


However, simulating a waterfall on this scale, including all the essential physics, provided its own challenge.

“These types of multi-phase simulations are computationally costly, so we exploited the rotational symmetry of the waterfall and simulated a single meter-wide slice at high resolution,” explained Artmann.

“We looked at the water droplet traveling down through this air-conditioned space and worked out the amount of water moisture released,” said Artmann. “But we also discussed whether there are some ways to estimate the amount of moisture released from droplets when they hit the bottom of the vortex. And how much water will turn into vapor, and then add onto the latent load into the air conditioning system.”

Having characterized the waterfall using detailed simulation, Atelier Ten engineers used that data to include source term models in their comprehensive model of thermal comfort in the atrium:

“We injected momentum sources to represent the air circulation created by the waterfall, focusing on how we disrupt our displacement ventilation, air conditioning strategies,” explained Woon. “I think the model, the software itself, was reasonably accurate in predicting the track of the waterfall. And then in terms of how it affects our air conditioning load as well.”

Of course, the real proof in any simulation is whether the predicted outcome is realized in the actual building once it is operational. Atelier Ten conducted significant post-implementation validation testing to check the veracity of their model.

“I would think that is reasonably well represented, based on my experience,” said Woon. “And we have been carrying out equipment and taking measurements in many spaces inside the dome. And multiple times as well, and we would always carry out site visits with our equipment, measuring temperature, et cetera. So, our simulation is generally quite aligned with site measured data I would say”.

If you visit the Changi Jewel (or look at photographs of it), you will see a one-meter-high balustrade around the Rain Vortex waterfall. This was not included in the original design and was introduced because of the simulation results.

“Early simulations showed air being dragged by the waterfall from the occupied areas into the pit in which the water is collected, the air will then rush upwards and carry quite a lot of water vapor with it” explained Artmann. “To prevent this water vapor entering air conditioned zones, we designed a one-meter-high solid glass balustrade that deflects the air upwards instead of sideways which would affect the visitors’ experience. This was a successful strategy based on our observation, that we would not have employed if not for the computational fluid dynamics simulation.”

**Driving trains at walls**

“In Singapore, it is summer all year round. That requires constant air-conditioning, and so there are stringent building codes concerning sustainability,” says Henry Woon. “Building regulations strictly prohibit the leaking of air-conditioning into the outside environment. Any opening without an automatic means of closing is deemed to be not complying with the regulations. You need to have effective automatic shutters, sliding doors or air curtains to be compliant.”

The issue here is that a train runs through the air-conditioned garden of the atrium.

Thanks to the engineering innovation of Atelier Ten, passengers have an uninterrupted view of the Rain Vortex waterfall as they pass through the air-conditioned atrium. Photo credit:Marvin Chandiary

“The original plan was to enclose the train line in a transparent glass tube, but the embedded carbon cost of building the tubes out of concrete, glass and steel began to look prohibitive,” says Woon. “They would also have blocked the view and been difficult to keep clean.”

“The first idea was to use a series of massive air curtains to create the vestibule,” continued Woon. “However, early simulations showed that it would require about a hundred cubic meters of air per second to create a useful curtain, which would cost too much in terms of fan energy. Then we looked at water-curtains before eventually settling on the idea of fast action doors that would open in front of the train and close behind it.”

To overcome objections from the regulator, Atelier Ten engineers had to demonstrate exactly how much air would leak during the train's passage through the tunnel.

“The Jewel project is of national interest; it’s the gateway to Singapore and the first thing that many international visitors will see, and so the regulators intensely scrutinized our design solutions,” said Woon. We submitted five times before we finally managed to persuade them - using simulation - that we could prevent significant leakage into the outside world.”

Atelier Ten solved this problem and optimized the performance of the system, using Simcenter™ STAR-CCM+™ to model the passage of the train moving into, though, and out of the atrium. This involved simulating the entire space of the massive atrium over the two minutes period which would take for the train to pass through it.

“We had to collaborate with Siemens for this, both in engineering expertise and supercomputing resources,” said Nicolai Artmann. “The action time on the doors is about 0.2 seconds, but the simulation had to run for over 500 times in order to cover that 2 mins period, and it took weeks of computing.”

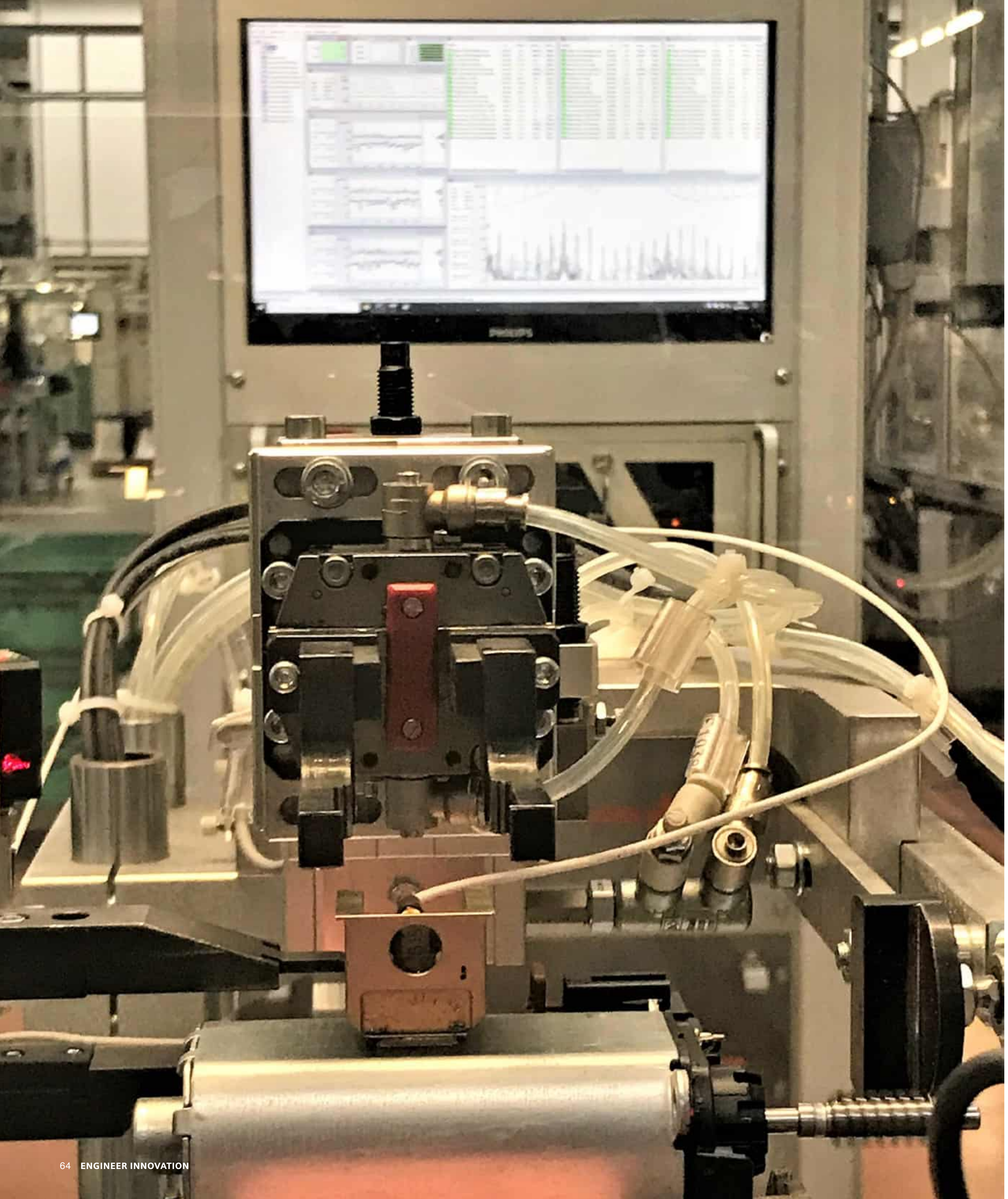
“One thing we had to consider was the piston effect of trains entering the space, sometimes two trains heading in opposite directions, and causing a piston effect that would force air out of pedestrian entrances on arrival, and suck it back out on departure,” said Artman. “The CFD simulation results convinced us that we had to reduce the speed of the trains in order to prevent piston effect.”

Using extensive simulation, Atelier Ten were able to convince regulators that their scheme would prevent the leakage of air-conditioned air, but had further work to do to convince them that the scheme was safe and would not impede train operations in the event of the failure of the moving door mechanisms.

“We had some fun installing a full-scale mock-up of the fast action doors in the car park, and then driving a forklift into them a full speed,” said Woon. “They are actually very lightweight and as you push against them, they automatically roll up, so there is no danger to passengers. In the event of power failure, the doors would automatically just roll up.”

Thanks to Simcenter, and their own engineering ingenuity, Atelier Ten were able to design a solution that not only reduced the carbon footprint of the building, but also offered more utility for users of the space.

The good news is that the system is working as designed. Air temperature monitors inside the tunnel confirm that air-conditioned air is not leaking into it. Passengers can enjoy an uninterrupted view of the atrium gardens and the Rain Vortex waterfall.





**MODEL THE COMPLEXITY**

# The challenge of change in end-of-line testing

Cebi Motors: Manufacturing the micromotors behind all those mod cons.
By Jenn Schlegel

As cars go electric and autonomous, discover the surprising answer one automotive supplier found to stay ahead in the NVH innovation game.

We don't think twice about all the mod cons (that's modern conveniences) that come with modern-day driving. Or all the electric motors and micromotors silently working behind the scenes to adjust your seats, roll down your windows, latch your trunk or open your sliding doors...

Luckily, this task is taken very seriously at Cebi Motors, a leader in the electric motor and micromotor component market. With 45 years of experience, Cebi is a go-to supply chain source when it comes to helping the global automotive industry make more comfortable cars. Cebi produces seat motors, power window regulators and many other components, sensors and solutions that contribute to better driving comfort, safety and performance.

Known for its commitment to innovation, the company customizes its products to precise design requirements rather than just offering a standard pick-your-product catalog. With all the personalized variants currently available in the automotive industry, this is certainly a tall order. And another bigger challenge has arrived with the increasing popularity of EVs and soon-to-arrive AVs: acoustic and electromagnetic compliance requirements.

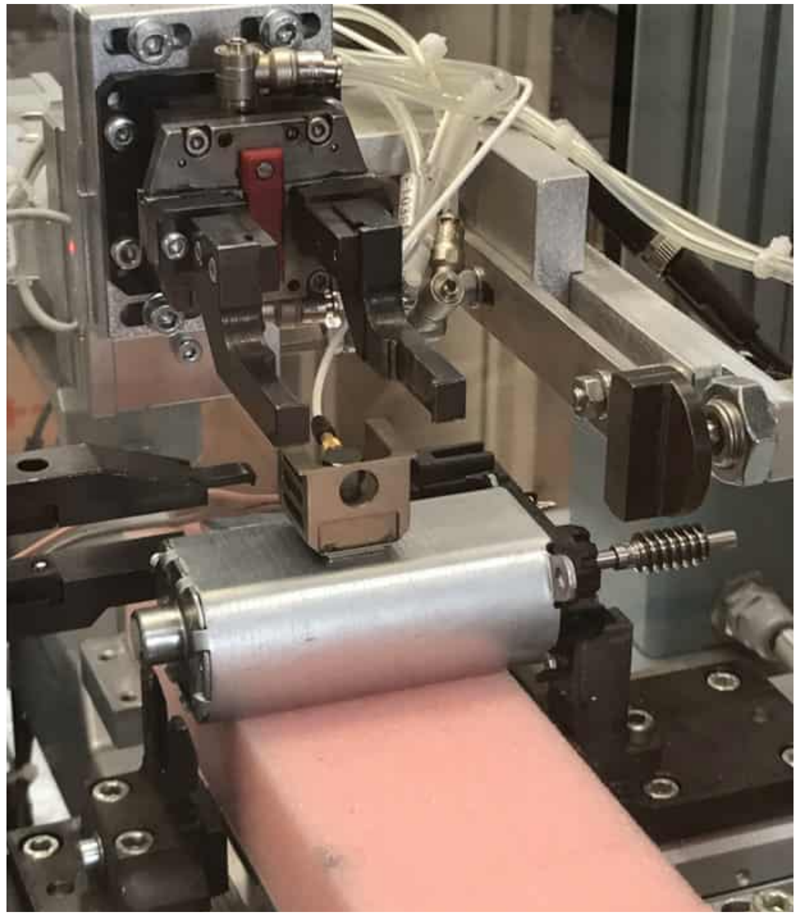
"The main challenges when building our products relate to noise and vibration and electromagnetic compliance," says Oscar Bertuzzo, laboratory manager at Cebi Motors in Veggiano, Italy, one of Cebi's 11 R&D and production sites.

**Driving a computer**

Our cars are packed with micromotors and electronics that can buzz, beep, rattle, resonate and hum – at times distracting the driver or causing possible safety issues. In the old days, the job of the noise, vibration and harshness (NVH) engineer was to make annoying sounds disappear. Techniques might include fine-tuning the structural resonances causing the interior noise, adjusting the engine sound signature, or adding damping material to block vibrations and unwanted sound.

Today, things have gotten a bit more complicated with the arrival of EVs and AVs. First, there is no longer a "noisy" combustion engine to cover up the cacophony of hums, whirls and churls. Secondly, there is the added possibility of unwanted electromagnetic interference and amplified resonances coming from the e-drives and other in-vehicle electric micromotors.

This is why most automotive OEMs and Tier 1 suppliers now require quieter and safer electric component motors. Under the 45 dBA range is a pretty standard stat to meet when it comes to OEM acoustic compliance requirements today.



"We strive to support our customers with maximum flexibility," says Oscar Bertuzzo. "We see that in the automotive market, there are many motor variants that need to be produced, while cost reduction has become a standard."

**Four motors just to adjust your seat?**

One example is adjustable seat motors, one of Cebi Motors' keystone products that account for approximately 85 percent of its business. Cebi offers four different motors for adjusting reclinable backrests, seat height, cushion position, and thigh support – adaptable to individual customer designs and requirements.

On top of this, Cebi continuously develops new motor concepts including differently sized, rare-earth magnet motors to meet the booming market for more powerful and even smaller, low-noise motors. This is especially relevant for future autonomous vehicles, where Cebi already sees OEMs requesting specific motors for smart seats that can rotate up to 180 degrees. This simple switch in design can require 20 to 30 percent more motor power, and certainly ups the potential for NVH issues.

**NVH continues to be a brand differentiator**

More than ever, NVH aspects, like overall acoustic and vibration comfort in your luxury EV, is seen as a key brand differentiator. To keep OEMs happy, suppliers, like Cebi, are hard at work to take the innovation lead in a very, very competitive market. One of the keys to innovation success is a tool that Cebi recently discovered and uses daily in its production process: Simcenter™ Anovis™ end-of-line testing hardware and software.

Typically, end-of-line testing is performed by a qualified operator to see whether the motors coming off the assembly line meet required customer standards. To maintain quality standards in the past, Cebi had multiple operators check each and every motor at end-of-the-line testing stations on each production line. Needless to say, this extremely subjective and repetitive step was a time-and-labor intensive, inefficient and flat-out expensive task.

Besides adding to production and overhead costs, their old quality control process was not statistically stable; it strongly depended on human perception and the overall batch quality, which could involve faulty raw materials or assembly issues as well.

**The challenge of change in end-of-line testing**

There were times when the R&D team saw that operators discarded "a good motor" from a batch just because they subjectively perceived it as "less good" than all the others. On the other hand, when analyzing a batch of motors with overall low NVH quality, operators would sort out only a small percentage, whereas the entire batch should have been under quality scrutiny. Unfortunately, these errors resulted in unnecessary product scrapping, excessive material waste and expensive customer recalls.

Knowing that they needed a better solution and fast, the team decided to switch to more objective NVH methods using a variety of in-house and external acoustic assessment solutions. But this approach brought its own issues. Microphones would pick up background noise from the production line during tests and, in most cases, processing the required results to extract the right parameters took even more time and effort.

"We felt the solution was to measure vibration only, but no software or hardware vendor wanted to take the risk to apply this idea in production," says Bertuzzo. "Siemens was the only one that took up the challenge to use vibration tests to extract metrics usable for acoustic troubleshooting."

Working together with their own production integrator and Siemens engineers, the Cebi team created and installed a modular and adaptable end-of-line testing solution based on Simcenter Anovis hardware and software. The best solution for an optimal production process was to start vibration measurements on multiple benches in an asynchronous way -- taking advantage of the parallel lines to save testing time and increase process efficiency to objectively characterize motors for NVH performance and overall batch quality.

There were many other reasons for Cebi's success, including Simcenter Anovis' baked-in, deep-order processing functionalities, specifically related to motor analysis, that helped create a straightforward workflow to analyze acoustic emissions based solely on vibration measurements. This method was easier, faster, and eliminated the background noise issue.

**Less waste equals better production processes**

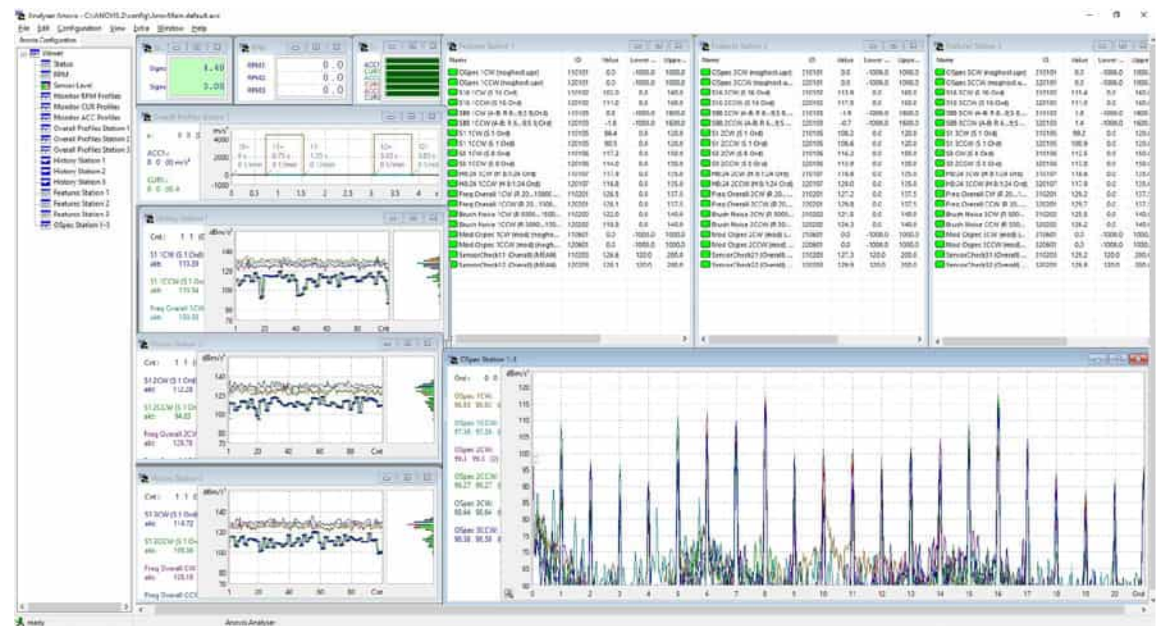
The advantages of the new Simcenter Anovis end-of-line testing solution are clear: fewer viable motors are scrapped by mistake and overall production costs are reduced. Plus, the end-of-line testing process is fully automated, drastically increasing the line's overall efficiency and eliminating repetitive manual labor.

"We can remove one operator per shift over three shifts, which is a huge cost advantage for the company," says Bertuzzo. "Our final goal is to avoid scraps and using Simcenter Anovis can help us achieve that."

Because Simcenter Anovis provides a detailed description of each tested motor's noise issues, the Cebi experts can trace the data back to a specific piece or point of the production process. The root cause can be identified in near real-time to provide immediate feedback to the operators on what to change in the assembly process to improve the acoustic performance on the fly.

"Siemens software is so complete in motor analysis that I envision using the output of the acoustic tests to monitor and adjust our product parameters during production," concludes Bertuzzo.

Cebi plans to deploy the Simcenter Anovis solution in new production lines and other plants throughout the company.




**EXPLORE THE POSSIBILITIES**

# The future of high-speed intercity travel?

Simcenter™ Madymo™ software proves that hyperloop can be safe for passengers
By Luke Morris


Affordable travel has changed the world in the last century. Today, the majority of people can journey to places they would only have dreamt of in the past. Passenger aircraft have opened up the furthest reaches of the globe, enabling people to absorb different cultures and expand their business markets.

But air travel is often inconvenient.

Getting to and from airports, waiting around before and after check-in, and then even the shortest flights take several hours.

Additionally, it's no secret that air travel is a significant contributor to $CO_2$ emissions.

What if there was an alternative that removed the hassle and the vast amounts of fossil fuels?

**Introducing hyperloop**
The modern hyperloop concept uses magnetic propulsion and low-pressure tubes to move pods through a tunnel at speeds of up to 900 kilometers per hour. Although this is similar to the speed of a commercial aircraft, there are two significant differences. First, acres of space are not required around the terminal for aircraft to take off and land – the hubs or stations could be built far closer to city centers, making them more easily accessible. Second, it is electrically powered, so it is a cleaner form of transport from the outset.

There is, of course, a long way to go before hyperloop travel can become a reality. But progress is being made, particularly in terms of proving passenger safety.

**From commercial competitions to government-funded research**
TUM Hyperloop is a team based at the Technical University of Munich that combines the experience of professionals and academic leaders with the passion, hard work and innovation of students.

The team had early success, developing pods which won all the SpaceX led competitions over a four-year period. Since then, it has embarked on its own research project funded by the Bavarian government.

The speed of the pods had been proven in the earlier competitions. To continue their development, TUM Hyperloop recently investigated the safety of Hyperloop passengers.

**Full-body simulation with Simcenter™ Madymo™ software**
Team member Natalia Roda undertook the task of developing a full-body simulation for her master's thesis. There were several objectives for the project:

- To analyze the dynamic behavior of a full-scale hyperloop prototype pod measuring eight meters long and weighing four tons.
- To evaluate human behavior in various scenarios, including acceleration, deceleration, and unexpected events.
- To contribute to the hyperloop certification process by documenting and presenting the simulation and assessment results.

Having evaluated several options, Roda chose Simcenter Madymo as the ideal solution. This is an award-winning, multiphysics CAE software for simulating vehicle occupant and road user safety which includes precisely correlating crash test dummies and human body models. It's ability to simulate validated human and dummy models extremely quickly, and the ease at which dummy positioning and user model parameters can be quickly adapted, were a clear advantage in this study which had a variety of dummies, simulations and load cases.

Full Hyperloop test rigs are extremely expensive and performing crash tests on humans is high risk, so simulation is the only viable option. The more information that can be acquired in simulation the lower the cost and risk to people of any future physical testing. "We need to understand how acceleration and braking will affect the human body," says Roda. "These models give us much more information as they include sensors that tell us if any injuries would occur during operation."

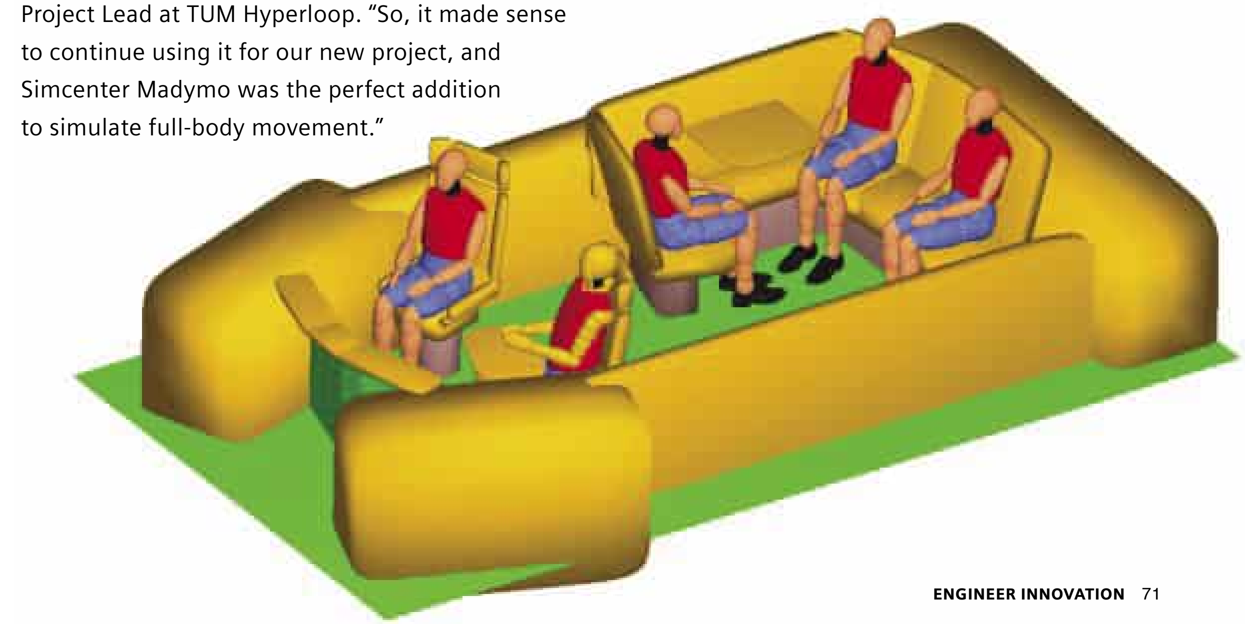
Roda worked closely with Claudio Santarelli, an academic business developer for the DACH region, to ensure that she could get the most out of both Simcenter Madymo and NX software for the project.

"We were already using NX as a CAD system for the SpaceX competitions since it could process larger models and was the best option in terms of licensing and support," explains Gabriele Semino, Project Lead at TUM Hyperloop. "So, it made sense to continue using it for our new project, and Simcenter Madymo was the perfect addition to simulate full-body movement."

**Certification and beyond**
The results of the simulations found that under normal operation, passengers would not suffer any severe injuries and only in rare occurrences would suffer minor injuries. The goal though, of course, was to limit injuries as much as possible and thanks to the models built within Simcenter Madymo, Roda was able to make adjustments to the pod design, such as adding elements to prevent passengers from falling out of their seats. With these modifications, the simulations showed that minor injuries would only be sustained in the absolute worst-case scenarios.

With the safety requirement satisfied, TUM Hyperloop was able to get certification from TUV SUD. the German-based authority that provides quality and safety testing across Europe, so they are now able to use the pod's design for future hyperloop tests with passengers. Semino believes this progress wouldn't have been possible without simulation. "Simcenter Madymo enabled us to demonstrate passenger safety without risking lives," he says. "Without it, it would be much harder to get this project off the ground as there would be too many unknowns. I am sure proving safety before building a physical prototype is a huge benefit for spurring innovation."

There's still a way to go before hyperloop travel becomes a reality, but thanks to the team at TUM Hyperloop, we're now a step closer. With safety concerns addressed, it will hopefully lead to more projects to further develop the infrastructure and analyze the feasibility of commercial hyperloop systems around the world.




**INTERVIEW**

# A Journey from Skyward Dreams to Groundbreaking Wind Turbines

We talk to Jesse Marcell from Airborne Motorworks (AMW) about turning a flying car into a form of power generation

It started with a concept in 2018 – Airborne Motorworks (AMW) co-founder and Chief Design Officer Jesse Marcell envisioned a unique flying vehicle for urban air mobility, utilizing electromagnetic propulsion.

Despite the challenges inherent in developing flying machines, Marcel's team made significant progress, culminating in gyroscopically stable electromagnetic propulsion prototypes. However, the regulatory landscape designed for certifying conventional aircraft presented a host of complexities that impacted the project's timely development and deployment.


So, a change in strategy was needed. While developing its flight prototypes, it became apparent that not only could AMW's technology be used for propulsion, but the reverse was also true: its propulsion technology could be used to generate energy.

AMW shifted its strategy to address a growing need across the planet – the increasing demand for a source of clean, efficient electricity generation. After considerable research into the best fit for its technology, AMW identified the growing microgrid market where it could provide a key component: a midrange wind turbine that could generate electricity in the 100kW to 500kW range.

Shifting focus required adapting their propulsion technology from a flying vehicle into a reconfigured power generation system.

To scale up their electromagnetic motor from 15 inches to a 12-foot diameter wind turbine generator, AMW partnered with Maya HTT. The two teams worked collaboratively, utilizing the simulation capabilities of Siemens Simcenter to balance mass, power output, and rotational speed. The 700% increase in scale came with significant challenges, and the teams explored different materials to balance structural integrity and mass reduction.

John Shew, Simulation Services Director at Maya HTT, led the project with his team. "We started with the electromagnetics and designed the generator. You can't just scale that linearly."

The Maya HTT EMAG team scaled up the size while accounting for other changes required for the new machine and usage, using Simcenter E-machine Design. Additionally, they used HEEDS™ software for optimization studies on the sizing of the machine and the steel and magnet inside.

They selected a Halbach array, driven by its distinctive magnetic layout that concentrates a powerful magnetic field on one side while minimizing it on the other. By adopting this arrangement, AMW sought to gain better control over magnetic forces, ultimately leading to increased efficiency in energy conversion.

"From our end, it was entirely simulation-driven design. The Siemens portfolio helped us focus on the end goal," said Shew.

AMW's midrange wind turbine boasts a streamlined design that eliminates the need for gearboxes, standalone generators, and traditional cooling systems, thus reducing the high maintenance and operational costs associated with large, legacy wind turbines. The AMW turbine's ingenious integration of a shrouded duct acts as a static thrust multiplier while doubling down on functionality – from noise reduction to serving as a containment barrier and a safety shield.

The scalability of the AMW wind turbine allows users to tailor their power production to specific needs, seamlessly connecting multiple turbines and integrating alternative power sources. The compact size of the AMW wind turbine enables it to be installed in close proximity to end-users, thereby minimizing transmission line loss, making it a pivotal player in the future of sustainable and localized power generation.

"What differentiates AMW from other wind turbines is the radically different design that performs at uncommonly high efficiency, is low friction with high energy conversion rates, compact size for use in high-density areas, and can be mounted on a mast or atop a structure or building with the appropriate installation engineering. It has very low noise, vibration, and heat signatures with safety features that provide containment of moving parts and an

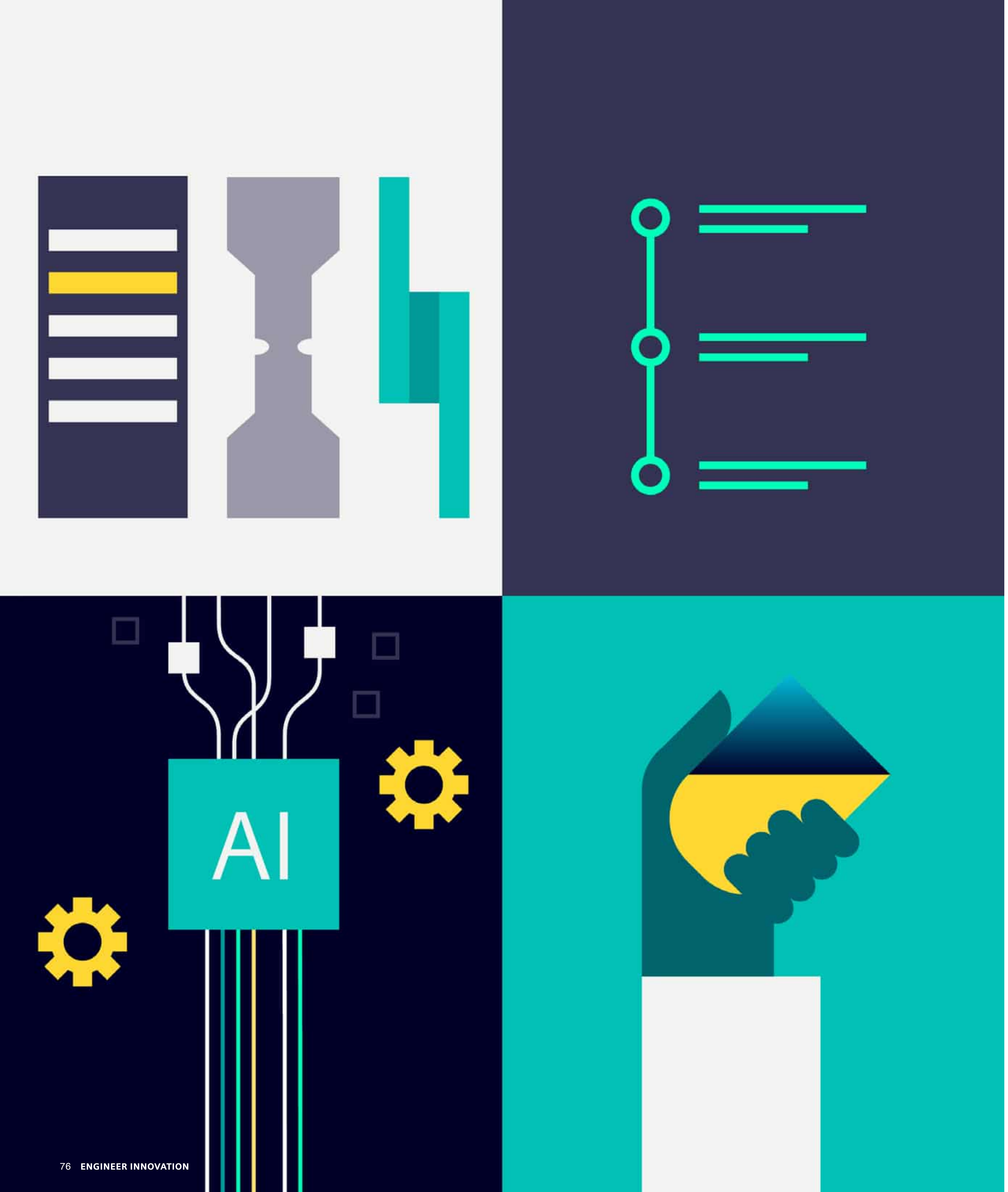
offset to wildlife contact." -- Jesse Marcel, Airborne Motorworks, Chief Design Officer

"The AMW design offers the advantages of substantially lower operating cost than legacy designed equipment. Due to its design and operating characteristics, it is adaptable to both new and retrofit installations. It is versatile in application as a primary or backup power source and managed with other power sources to maximize the operating efficiency of microgrids." -- Hugh McElroy, Airborne Motorworks, Executive Chairman and CEO

AMW is preparing to manufacture full-scale prototype wind turbines for field testing during 2024 at functioning industrial sites to assess their durability and installation construction. The goal is to launch a manufacturing production line in early 2025.

While Jesse Marcel's flying car remains a work in progress, AMW's midrange wind turbine design stands out for its streamlined, efficient and innovative features. The company's journey from concepts to groundbreaking wind turbines is a captivating tale of vision, adaptability and collaboration that promises to play a pivotal role in the future of sustainable and localized power generation.

> From our end, it was entirely simulation-driven design. The Siemens portfolio helped us focus on the end goal"
>
> **John Shew,**
> Simulation Services Director at Maya HTT




MODEL THE COMPLEXITY

# Advancements in predicting the fatigue lifetime of structural adhesive joints

Thanks to the convergence of Artificial Intelligence and Physics

By Adrien Scheuer, Stijn Donders and Vinicius Carrillo Beber
(Fraunhofer IFAM)

## The challenges of structural adhesives

In the realm of structural engineering, the behavior of structural adhesives stands as a pivotal yet complex enigma. These polymeric materials provide the cohesion and longevity of a wide array of engineered structures, from aircraft to automotive components. Their primary challenge lies in predicting their fatigue life, especially under the influence of cyclic loads. Such calculations are challenging and demanding in terms of precision and efficiency.

Structural adhesive joints are rather complex; they consist of an adhesive (typically a polymer) and two substrates, which can consist of metal, polymer or composite materials. As one can imagine, this inherent complexity makes it challenging to assess their fatigue performance, let alone to optimize it in a next step.

While physics-based models offer the highest accuracy for analyzing these joints, they require meticulous parameter calibration for every new adhesive. For example, consider a fatigue test on a structural adhesive joint with 10 million cycles at a frequency of 10 Hz. These tests are demanding and time-consuming, taking over 10 days to complete. Adding to the challenge is the need for numerous data points to construct a comprehensive fatigue design curve, a fundamental aspect of structural analysis. Given the need to optimize both efficiency and accuracy, engineers and researchers need and pursue innovative solutions.

One path to solution is the integration of Artificial Intelligence (AI) and Machine Learning (ML) into materials science. Recognized for its ability to address complex problems through learning from existing knowledge, AI provides a promising avenue for structural modeling by generating mathematical expressions that capture the

Figure 1 – Illustration of a structural adhesive joint, showcasing the complexity and diversity of materials and bonding characteristics in such connections. © Fraunhofer IFAM

interplay of various parameters. We expect that this rationale also applies to the structural modeling of the fatigue behavior of structural adhesive joints, which is the subject of our ongoing research.

However, the application of AI/ML in materials science often faces a practical challenge – the fact that in reality there is restricted availability of / access to data that is suitable to train the AI/ML algorithms. This challenge is partly being addressed by commendable initiatives to establish repositories and marketplaces for materials data, but in practice, the availability of comprehensive data remains constrained.

**The promise of hybrid models**

Towards achieving a solution for such complex challenges, researchers are already exploring the previously uncharted territory of hybrid models [1], which represent the synthesis of data-driven AI and physics-based methodologies. These models strategically leverage data from heterogeneous sources, including peer-reviewed articles, technical reports and material databases. By exploiting similarities in material behavior within specific categories, these hybrid models have the potential to provide an adequate understanding of the fatigue response of structural adhesive joints.

Hybrid models stand out for their capacity to integrate domain knowledge, guiding the selection of pertinent features and minimizing the risk of overfitting—a common pitfall where a model becomes too closely tailored to the training data, impeding its adaptability to new datasets. For example, Physics-informed neural networks (PINNs) harmonize established physics-based relationships with AI, achieving a delicate balance between "big data, small physics" and "small data, big physics." [3].

**Showcasing hybrid modeling on the DOME 4.0 platform**

In line with this innovative vision, Siemens Digital Industries Software and Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM are actively involved in the research project DOME 4.0 (Digital Open Marketplace Ecosystem 4.0). This project aims to establish a semantically enriched digital platform that seamlessly connects various materials data sources with numerous stakeholders, ensuring rigorous data transaction management to protect participant privacy. DOME 4.0 targets to revolutionize materials data exchange through efficient utilization of data for virtual materials engineering and product design, while fostering innovative business models rooted in cloud-based workflows. The technological innovations featured in this article are part of Showcase 4 within the DOME 4.0 project, which comprises a research collaboration between Fraunhofer IFAM, Siemens Digital Industries Software and Citrine Informatics.

This showcase exemplifies our commitment to revolutionizing materials selection and fatigue life prediction for adhesive joints. Leveraging the Citrine Platform [2], we seamlessly apply machine learning methods to integrate experimental datasets with physics-based modeling (based on stress concentration factors). This innovative approach not only significantly elevates the precision of fatigue predictions but also enables the precise selection of optimal adhesives for bonded structures, factoring in various material and geometrical properties, as well as usage conditions.



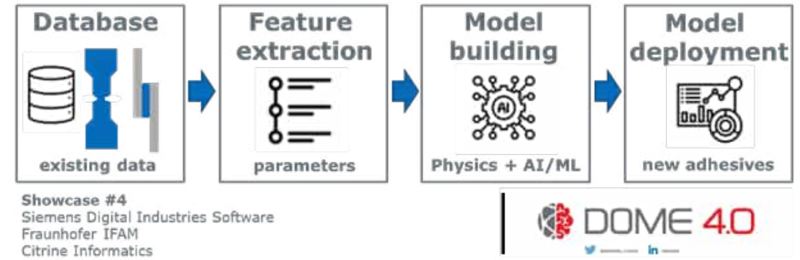



Figure 2 – Hybrid (physics + machine learning) approach to materials selection and fatigue life prediction for adhesive joints in place as showcase on the DOME 4.0 platform.

As ongoing research endeavors in this domain continue to evolve, it is evident that hybrid models have a promising future. Their potential is to blend empirical data-driven insights with the sound principles of physics, offering a path to better understand and fortify the behavior of complex structures, including structural adhesive joints. Engineers, scientists and industry professionals are all at the forefront of this new era, contributing to make such hybrid models fit-for-purpose for engineering design challenges now and in the future.

We hence invite all active on the tangent plane between materials science and engineering (and all those interested and curious about the potential) to be informed on the current status and to stay tuned for future advancements of hybrid modeling. And we hope that when you see a structural adhesive joint the next time, you'll see it with a revitalized appreciation for the science supporting its strength and reliability.

For additional insights, be sure to also explore the Simcenter blogpost "Materials informatics accelerates customer tailored composite material design" (covering Showcase 9 in the DOME 4.0 project, which is also enabled by the Citrine Platform).

**Acknowledgement**

Siemens Digital Industries Software (DI SW) and Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) acknowledge the support of the European Commission for the Horizon 2020 Research and Innovation project "DOME 4.0" (see https://dome40.eu/), with Grant Agreement No. 953163, coordinated by CMCL.

This article reports the technology innovation status of Fraunhofer IFAM, Siemens DI SW and Citrine Informatics for Showcase 4 "Structural adhesives: Fatigue behaviour" in DOME 4.0.

DOME 4.0 Grant Agreement 953163

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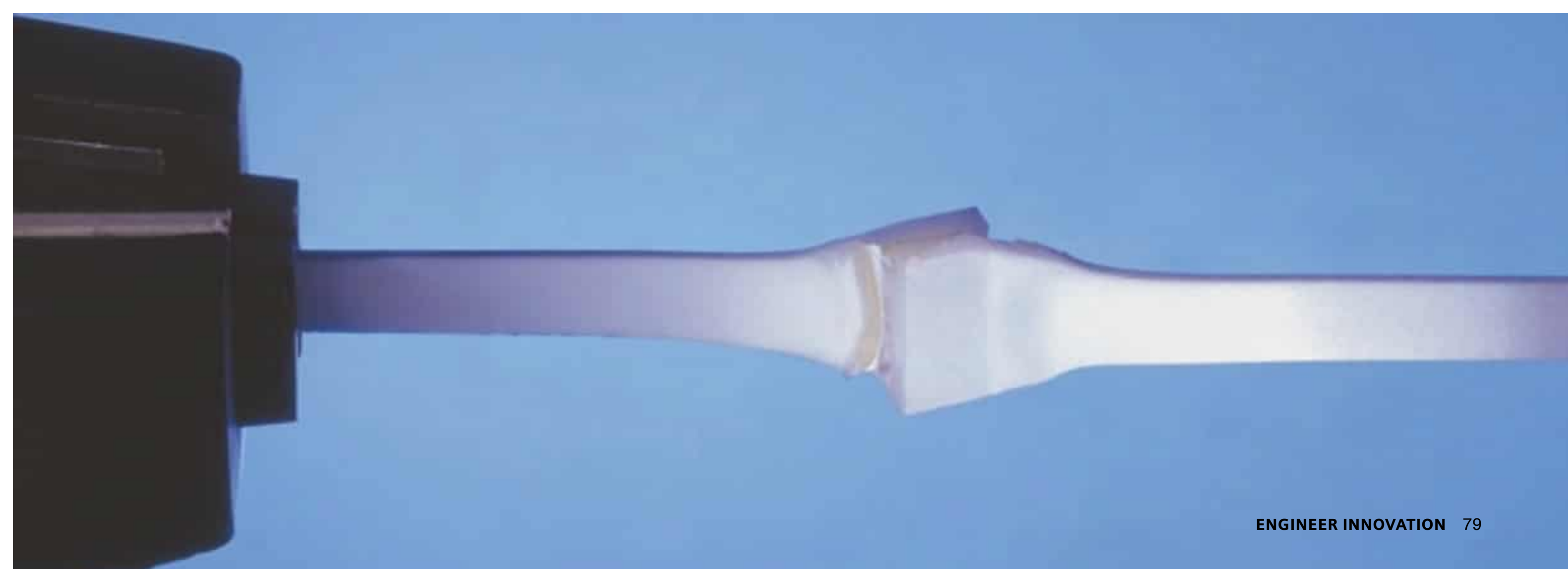


GEEK HUB

# Icing on a cake is great. **On a plane? Not so much**

Thankfully, simulation is evolving to help make aircraft safer than ever before

It's widely acknowledged that commercial airplanes are the safest form of transport in the world. In fact, according to the International Civil Aviation Organization (ICAO), air travel has become the first ultra-safe transportation system in history. This means that for every ten million flights, there is less than one catastrophic failure.

Recent figures show that in the United States there are just 0.035 fatalities per 100 million airmiles traveled. For every 100 million ground vehicle miles traveled, there are 1.13 fatalities. Or another way to look at it; the chances of dying in a car crash in the USA are a little over one in 100. The chances of dying in a plane crash in the USA are almost one in 10,000.

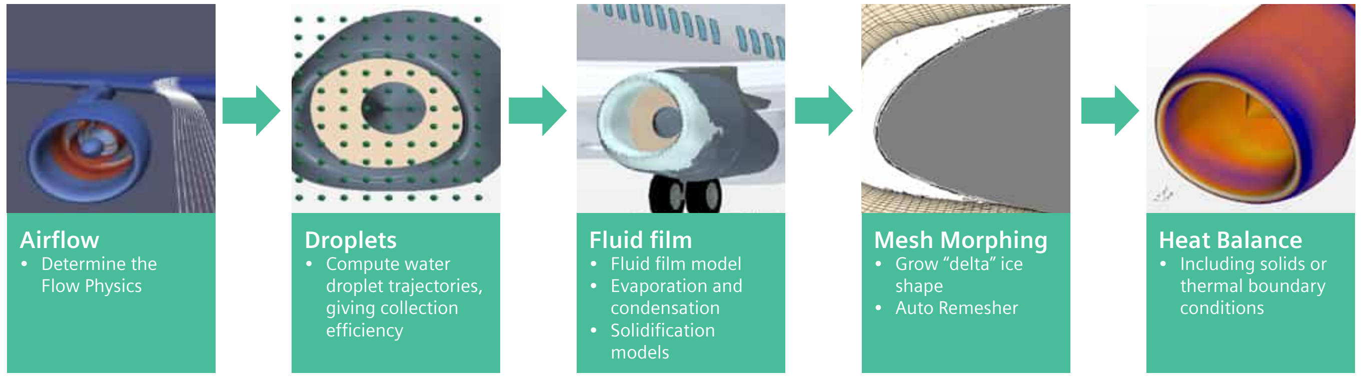
It makes sense when you consider all the checks that take place before and after flights. All the security within the airport. Not to mention the highly trained pilots with the skills to deal with any situation.

But accidents do still happen occasionally. And when they do, they're usually devastating. One accident is one too many and airlines are constantly striving to improve safety to give passengers peace of mind. This means that planes will be grounded in extreme weather conditions that could impact the flight. But very cold weather shouldn't be enough to prevent safe flying. Much of North America experiences sub-zero temperatures for significant periods of the year, so aircraft must be equipped to deal with this to provide a reliable service.

**Ice and aircraft are a bad combination**

In the winter months in areas where temperatures fall below freezing, icing on planes is a particular problem. If it's not dealt with, it can have terrible consequences.

"As ice builds on the wing, it creates what we call ice-horn development and scalloping," explains Solution Consultant, Scott Wilensky. "This effectively changes the shape of the wing, creating more drag and less lift. That's pretty problematic when it comes to keeping a plane in the air. As the aerodynamics degrade in this way it becomes far easier to stall the aircraft."




This phenomenon has indeed caused catastrophic accidents, such as Colgan Air Flight 3407 in 2009 which resulted in the deaths of all 49 people on board as well as one on the ground.

Obviously, adequate de-icing is a necessity for planes to fly safely in cold weather, but it's an extra cost to what is already a very expensive design and development process. Simulation is used in much of aircraft design, but, until recently, it hasn't been possible to fully simulate the effects of icing and the subsequent performance of a de-icing system.

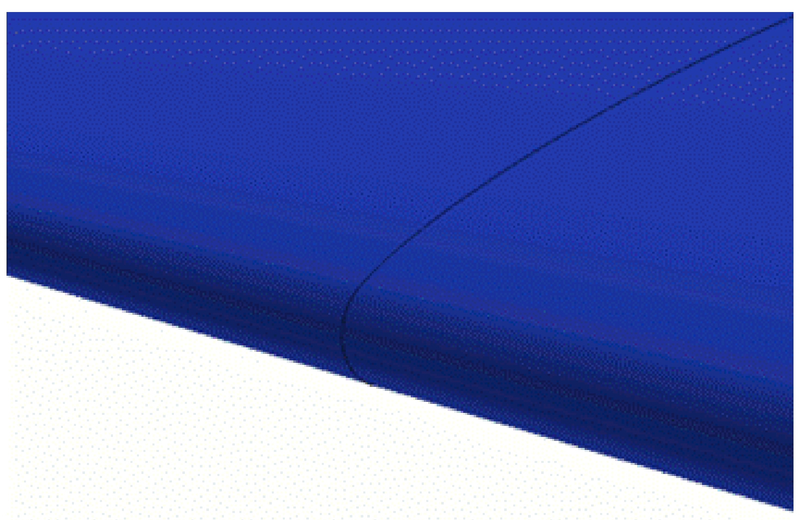
**Ice accretion involves complex multiphysics**
It is important to understand the complexity of icing simulation. First, there are three main types of ice formation that affect aircraft: rime ice, glaze ice and mixed ice. Rime ice is generally well understood – it occurs at temperatures below -20°C, is usually white like snow, freezes on impact and doesn't create horns. This means that it leaves smooth surfaces which don't affect the shape of wings. Glaze ice, typically observed at temperatures near to 0°C, is less well understood. It is much clearer in appearance and doesn't freeze on impact, leading to the development of ice horns and rough surfaces. Mixed ice, which occurs between 0°C and -20°C has characteristics of both, making the physics more complex.

Given that aircraft will operate across all these ranges of temperature, each type of icing needs to be accurately simulated to best understand how to overcome it. This requires the joining of multiple physics regimes: airflow, droplets, fluid film, mesh morphing and heat balance.

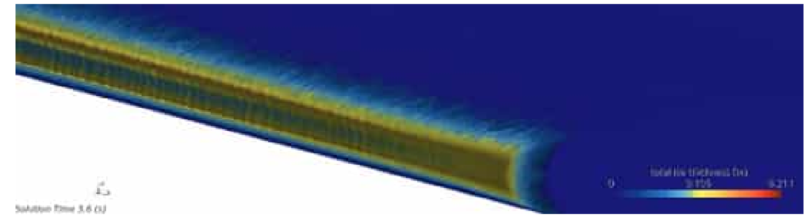
You can then predict the ice horn development and scalloping that change the shape of the wing.

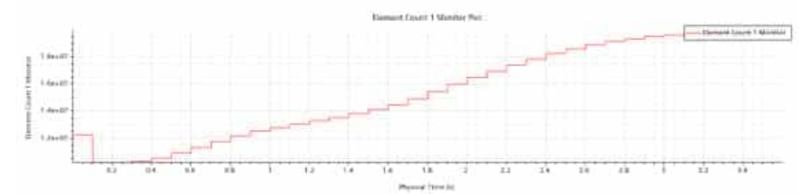
The fastest way to simulate this is with a single-shot steady solver where fluid flow is calculated once and is assumed to be unchanged throughout. This may also be relatively cheap, but it is not particularly accurate as the nature of ice accretion is that the fluid flow is constantly changing. A multi-shot steady solver updates fluid flow periodically as the ice accumulates but it is only as good as the number of intervals. The most accurate method is a fully coupled solver that is updated after each time-step in the accretion simulation. This, however, is an extremely time-consuming and expensive task.

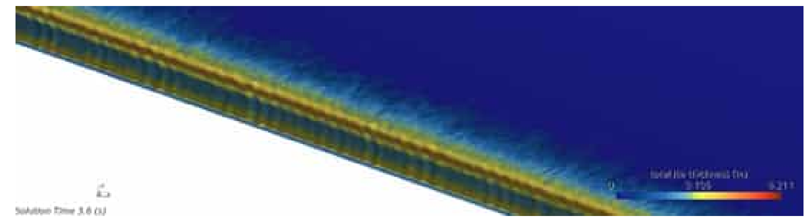
"The key is understanding exactly how the shape of the wing changes and simulating this correctly," says Scott. "As the shape alters, we need to change the shape of the grid. This involves stopping the simulation before it changes too much, redoing the mesh and redoing the grid. This takes an incredibly long time and simply isn't practical with how often the ice affects the shape of the wing."

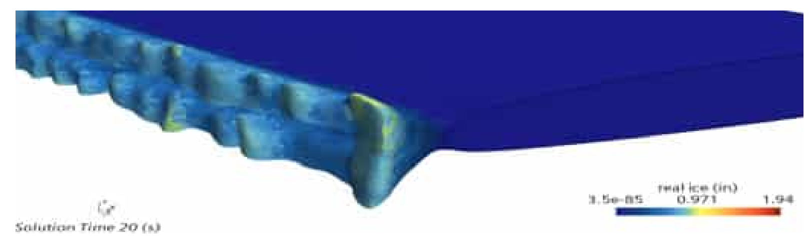













**Automated remeasure**
However, with the latest advancements in Simcenter™ STAR-CCM+™ software, Scott saw the potential for complete ice accretion modeling that aircraft manufacturers could rely on. "If we could automate the shape change due to ice accretion within the solver, that would give us the fully coupled solver that delivers the most accurate results," he says. "But at a fraction of the time and cost."

Scott worked with Chris Nelson, a technical specialist for aerospace, to develop a measure in the solver that looks ahead and calculates when the shape of the grid is going to change. Then it automatically carries out the remeshing and rebuilds the grid.

Now, the simulation gives an accurate prediction of the scalloping and the effect it has on drag and lift.

All that's left is to run the simulation again with thermal protection or de-icing applied to the wing, and you can see that it retains its shape.

"It's really cool that we can do this now with simulation," says Scott. "It saves a lot of time in design and development and, most importantly, it's helping to make aircraft even safer and keep passengers protected. We've got several customers now using this to test their de-icing systems and they're loving the results."

**Simulation never stands still**
So, next time you fly in freezing temperatures, rest assured that the aircraft builders will have analyzed all the potential problems caused by ice forming on the wings and installed appropriate measures to keep you safe.

This is just one aspect of simulation made possible by the newest advancements in Simcenter STAR-CCM+ and the hard work of engineers like Scott and Chris. Like the rest of the portfolio, Simcenter STAR-CCM+ is constantly being updated and improved to solve the toughest engineering simulation challenges. To keep up to date with the latest developments and see how they could aid your work be sure to follow the Simcenter blog page here.

And for a deeper dive into de-icing systems, check out this whitepaper that explores how simulation and testing play a crucial role in the development and certification process.

BROWNIAN MOTION

# The random musings of a Fluid Dynamicist

Can free will exist in a deterministic universe?

I am not writing this column because I chose to (or even because I was paid to). Neither are you reading these words through choice (instead of doing something more productive with your time).

That's because free will cannot exist in a deterministic universe.

Most engineers believe in determinism; that every physical event is caused by a series of prior events. As simulation engineers, we take the current state of those events, and predict what will happen in the near future, using the laws of physics to work out what will happen next.

A consequence of determinism is that the whole story of the universe was written at the moment of the Big Bang 13 billion years ago. The formation of matter, galaxies, stars, the solar system and life are all consequences of a series of deterministic processes that run all the way up to you reading this magazine article.

On Earth at least, the earliest that conscious life evolved was about 580 million years ago (with evolution of jellyfish neurons), although, in reality, the first conscious thought probably occurred much later. So that means that - even if you believe in free will - that for 95% of its life our local patch of the Universe was simply running on rails.

You might argue "what about randomness in all this?" However, in effect, randomness is an illusion of scale, so that apparently random processes - such as the collision of molecules that determine air pressure - are entirely deterministic too. If we had enough computing power (and enough information about initial conditions) we could in principle predict every future motion and collision.

I am not clever enough to argue about quantum effects, but even here there is a theory of "superdeterminism" that can be used to explain spooky things like quantum entanglement.

It is surprisingly difficult to argue against "pre-determination" even though it feels like our lives are directed by "free will" decisions taken by myself and others.

The most compelling argument against pre-determination comes from my wife, who refuses to believe that my dirty washing does not always find its way into the laundry basket because the "Big Bang made it do that".

She's probably right.