Engineer

INNOVATION

Issue 5

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Firsts and record breakers

Siemens PLM Software

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These are very difficult and strange times, and I wanted to extend my thoughts and well wishes to you and hope that you and your family are safe and well. I am fortunate in my role that I receive one of the first copies of Engineer Innovation, I need to read the stories to write this introduction. And what really struck me in this issue, is the firsts and record breakers showcasing their successes and how Simcenter has supported them along the way.

We kick off this issue with a record-breaking diesel engine from Wärtsilä, the most economical diesel engine ever built. CO_2 emissions from shipping contribute 3 percent to total global greenhouse gas emissions and growing; innovations like this become critical. Another record-breaker is the Daniel K Inouye Solar Telescope, the world's largest solar telescope, which has the opposite problem, too much energy in the form of heat to be dissipated.

Other notable firsts in this issue are Martin UAV who have launched a drone that can take off vertically and switch to flying horizontally, whilst carrying a payload of 16kilograms for eight hours. Clean Motion designed and built an electric tuk-tuk and then went further by designing a micro-factory to take manufacturing local. And ElectraMeccanica's SOLO which went from concept design to production in just eight months.

Engineers continuing to challenge the status-quo with innovations to deliver solutions to our everyday challenges, and quickly.

Lastly I was struck by the extraordinary parallels between the Apollo 13 mission and Team INEOS UK's America's Cup dreams. Separated by 50 years, and arguably 200,000 miles, the use of digital twins to simulate real situations whether they be unrealised or inaccessible shows the extent of human achievement. As ever the Simcenter team are incredibly proud to be part of our customers' success. ■

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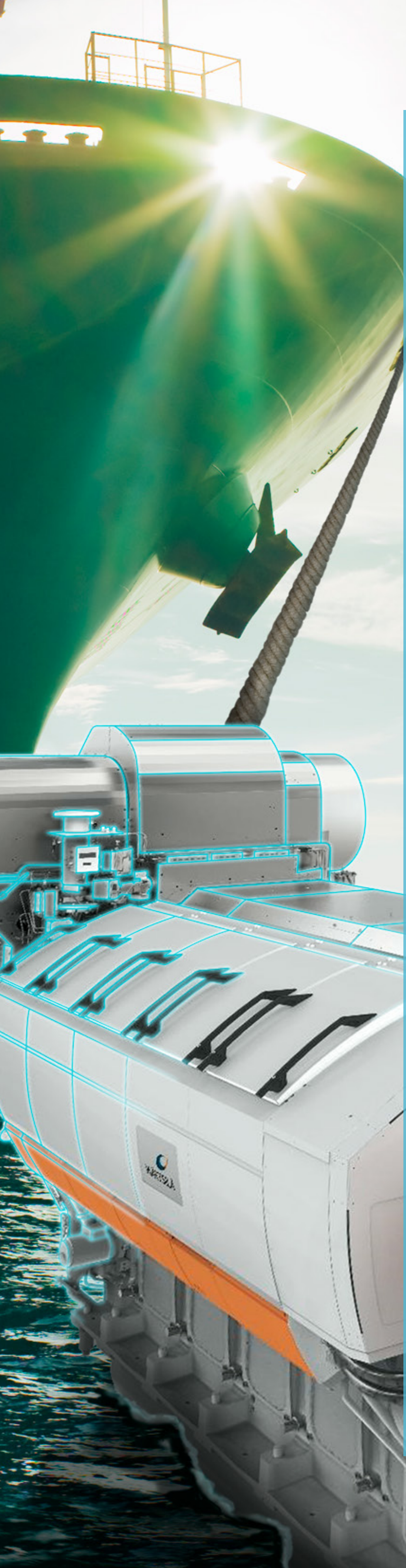
How Wärtsilä created the world's most efficient engine



The maritime industry is one of the mainstays of the global economy: around 90 percent of the world's trade involves shipping, while the cruise and leisure industry is a growing revenue generating stream across the globe. Shipping is recognized as the most efficient form of commercial transport, with the lowest CO_2 emissions per tonne of cargo transported. The enormous scale of the industry, however, means that it is still a significant contributor to the world's CO_2 emissions. The maritime industry is working hard to reduce its environmental impact, with new, stricter emission regulations coming into force in the coming years. Ship manufacturers and engine designers need to respond to these new rules and come up with new, efficient designs quickly. And if you want to reduce emissions then you start with the source: the engine. Wärtsilä is one of the biggest ship engine manufacturers and servicing agents in the world - one in three ships. To stay ahead of the competition they are always innovating and developing. They are committed to sustainability, with an overriding focus on ensuring profitability, providing environmentally sound products and services while ensuring responsible business conduct.

The Wärtsilä 31 diesel engine, released in 2015, has been awarded the accolade of Most Efficient Diesel Engine by the Guinness book of world records. This is due to its diesel fuel consumption being as low as 165 g/kWh, far lower than any other 4-stroke diesel engine currently available on the market. Its exceptional fuel efficiency is made possible through the use of new technologies, including 2-stage turbocharging, a high-pressure fuel injection system and adjustable valve actuation, with a next-generation engine control system. We sat down with Lars Ola Liavåg, manager of the Thermofluids & Simulations team to find out more about this amazing engine, and how multidisciplinary design simulation using Simcenter has helped Wärtsilä to create this innovative engine.

The Wärtsilä 31 (W31) is a medium speed 4-stroke engine, designed for use as either a main propulsion engine or an auxiliary engine. It can run as either a diesel, dual fuel or spark-ignited gas engine. Development took five years, starting in 2010, and Lars Ola and his team were involved from the earliest part of the engine design process. "We knew our customer requirements from internal stakeholders, so we aimed to make a new engine to replace existing models but also be of benefit to new customers". The new design had to be fuel efficient and meet all regulatory requirements. Wärtsilä also decided to use a modular design, making it easier to change parts and assemblies: small size modular engines have been in use for a while, but no other engine of this size uses this kind of modular approach.

Contribution of Simulation to engine design

The Thermofluids & Simulations team have used Simcenter software as part of the engine design process since the year 1999. Simcenter is used for both computational fluid dynamics (CFD) and internal combustion (ICE) analyses. This was the first time however that CFD had been used so early in the design process: Lars Ola and his team ran initial simulations on potential designs even before the W31 3D Computer aided design (CAD) was completed. "We looked at potential new system features for combustion on existing engine geometries. This gave us great freedom to try new things, as we could make mistakes virtually rather than creating expensive prototypes".

The scope of the CFD contribution to the project was not pre-defined. As the engine design evolved, CFD was used for analysis of more parts of the engine, including the complete charge air and exhaust manifold systems. Looking at the finished engine, Lars Ola comments "You can go round the whole engine and point out here we have simulated, here we have simulated, here we have simulated. CFD helped make many

Figure 1: The Wärtsilä 31 engine holds the Guinness World Record for the most efficient 4-stroke diesel engine

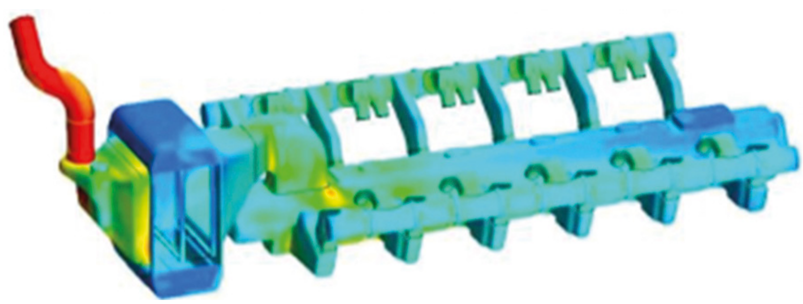


Figure 2: Simcenter STAR-CCM+ is being used to simulate transient gas dynamics in the complete charge air manifold design

small modifications, and these add up to a significant impact on the final engine design".

Lars Ola admits even he was surprised at how much they could simulate using Simcenter™ STAR-CCM+™: "I thought it was a joke when one of the guys proposed to model the complete charge air manifold system with transient fluctuations and all. Believe me, that is one big system!

But this is the kind of idea that comes out of using such an efficient software: the case used 70 million cells but is not even the biggest case we can run now". Thermal data from the complete charge air system was mapped on to solid models for stress analysis. As well as this the air cooler intake ducts were redesigned, which improved flow uniformity.

The wide variety of physical models available in Simcenter STAR-CCM+ meant that many different engine components could be analyzed. For example, the team simulated oil splashing within moving engine pistons, using the Volume of Fluid (VOF) model for the oil and overset meshes for the piston motion.

Conjugate heat transfer simulations provided thermal data which could be mapped on to solid models for stress analysis, and loose fluid/solid coupling was also used directly in Simcenter STAR-CCM+ to model the complete exhaust manifold. This approach enabled thermal analysis of different components such as bellows and fastening clamps.

The Thermofluids & Simulation team also used Simcenter software for the in-cylinder combustion analyses: these are vital to ensuring a safe, fuel efficient engine. Having worked with in-cylinder analysis for many years himself, Lars Ola considers Simcenter to be a powerful tool:

"Thanks to the strong support and collaboration with experts at Siemens, we can run a full engine cycle in one day with our power licensing." For the development of the Wärtsilä 31 engine, the team performed over 660 gas combustion simulations and way more than 1,200 diesel combustion simulations. These helped us optimize the piston geometries, fuel injector specifications and operating parameters for the engine.

This was the first time that a Wärtsilä engine family had been developed in both diesel, gas, and dual-fuel versions already from the outset, and these advanced CFD analyses helped ensure the design was optimized for both diesel and gas fuel operation. Inlet and exhaust ports were also optimized using CFD, and so were many critical components such as the prechambers of the gas engine version.

Cross-company collaboration

While the Thermofluids & Simulation team are the main users of CFD simulation, Lars Ola notes that use is becoming more widespread throughout the company. Engine design engineers are now using embedded CFD within NX, their CAD tool, to analyze flow through engine components from the very first design. Lars Ola supports this CAE democratization: “Involving basic CFD as part of the CAD design process means we receive fewer bad designs which we have to reject: it reduces the virtual scrap rate”. The Thermofluids & Simulation team also worked closely with the structural analysis team to create a thermal management analysis process based on conjugate heat transfer (CHT) simulations and in-cylinder CFD. As part of this project, also Finite Element (FE) engineers can now use Simcenter STAR-CCM+ to build some of their conjugate heat transfer models.

With this increased use of simulation software, efficient use of computing resources is a priority. Wärtsilä have one of the biggest computer clusters in Finland: this capacity is used for both FE

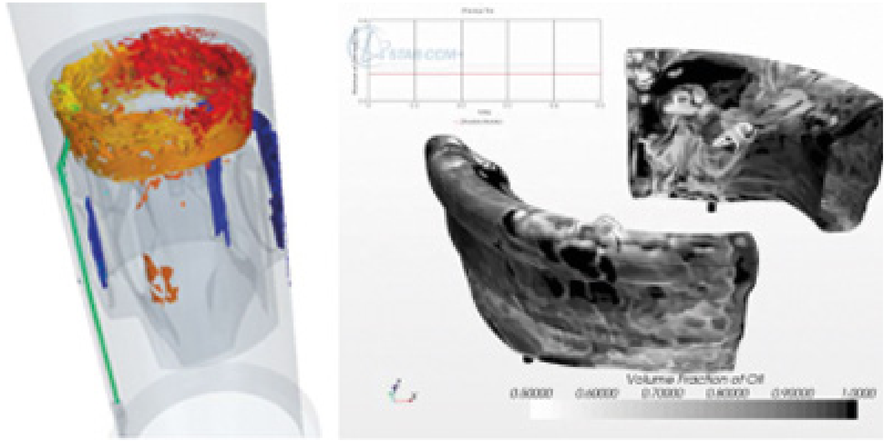


Figure 3: Complex physics like oil splashing with moving engine piston require sophisticated high fidelity modeling approaches, here Volume of Fluid method on overset moving mesh

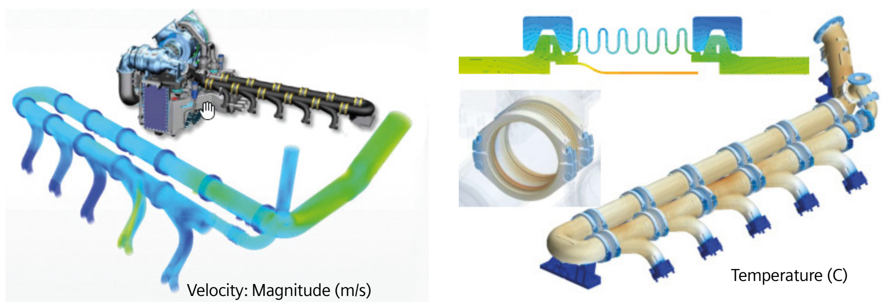


Figure 4: Fully embedded loose fluid/solid coupling approach for thermal analysis of e.g. the exhaust manifold

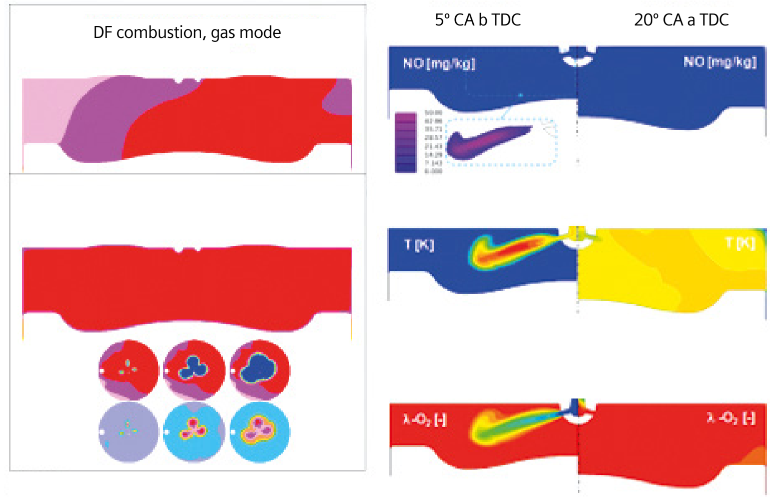


Figure 5: More than 660 Gas and 1200 Diesel combustion CFD simulations have been carried out to find an optimum combustion chamber and injector configuration and ideal engine operating conditions

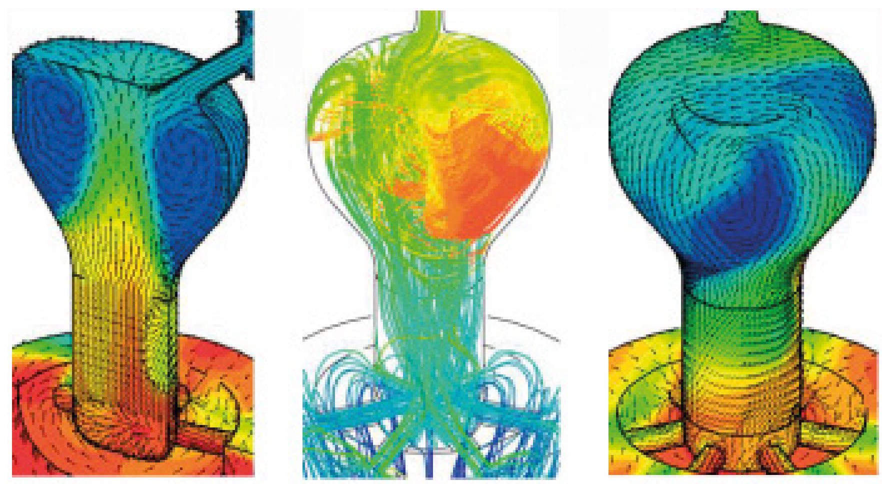


Figure 6: CFD simulation of the prechamber, one of the critical components for the gas powered engine

and CFD analysis. Simcenter STAR-CCM+'s power licensing scheme means the teams are not limited in their use of parallel cores, allowing them to meet their varying simulation needs. "The power licensing was a quantum leap forward in capability for us, as it allowed us to ride the wave of hardware capacity improvement. We can use our computing resources to their maximum capacity and run full engine cycle simulations in just one day".

Final design testing

Wärtsilä's use of CFD from early in the design process not only improved the design but also reduced the amount of engine rig testing required.

As a big bore engine can burn several tonnes of heavy fuel per hour, reducing the physical testing saves both time and energy, as well as reducing costs. As Lars Ola comments, "Our use of CFD meant we knew a lot better what to expect before we started the engine in the lab and allowed us to use our testing capacity in a much smarter way".

This way of working, with the use of simulation through ideation, concept and detailed design stages, meant that the final engine has exceeded the planned performance targets from the very first version. Instead of a prototype stage lasting several years, with subsequent release stages to fix later problems, the Wärtsilä 31 has already been optimized and rigorously tested via virtual validation. Looking back on the changes in the development process over the years, Lars Ola comments that "It is the way of working that is the real revolution. We are using the tools

Figure 8: Expensive test rig time can be significantly reduced thanks to the use of simulation through the complete development cycle from ideation, concept and detailed design stages

available to us to create the best possible product in a way that was not possible twenty years ago. We would not have been able to work this way without the modern CAE tools and high performance computing (HPC) systems".

Powering the ships of the future

All these different contributions from CFD to the design process can be seen in efficiency of the final engine, contributing to the reduction in CO_2 emissions compared to equivalent engines. Diesel fuel consumption can run as low as 165 g/kWh, while the total hydrocarbon emissions of the gas engine have been reduced by up to 50 percent. The engine has been optimized to comply with all existing and anticipated emission regulations and has an expected lifetime of 40 years.

From this discussion, it is clear to see that CFD simulation is embedded in the design process at Wärtsilä and has been instrumental in helping them to bring this new engine to market in just five years. The Wärtsilä 31 engine was officially unveiled at Nor-shipping 2015 and Wärtsilä have already fulfilled orders for both gas and diesel modes. As ship owners look to meet efficiency regulations, Wärtsilä are meeting that market demand, aided by their use of Simcenter and digital design. ■

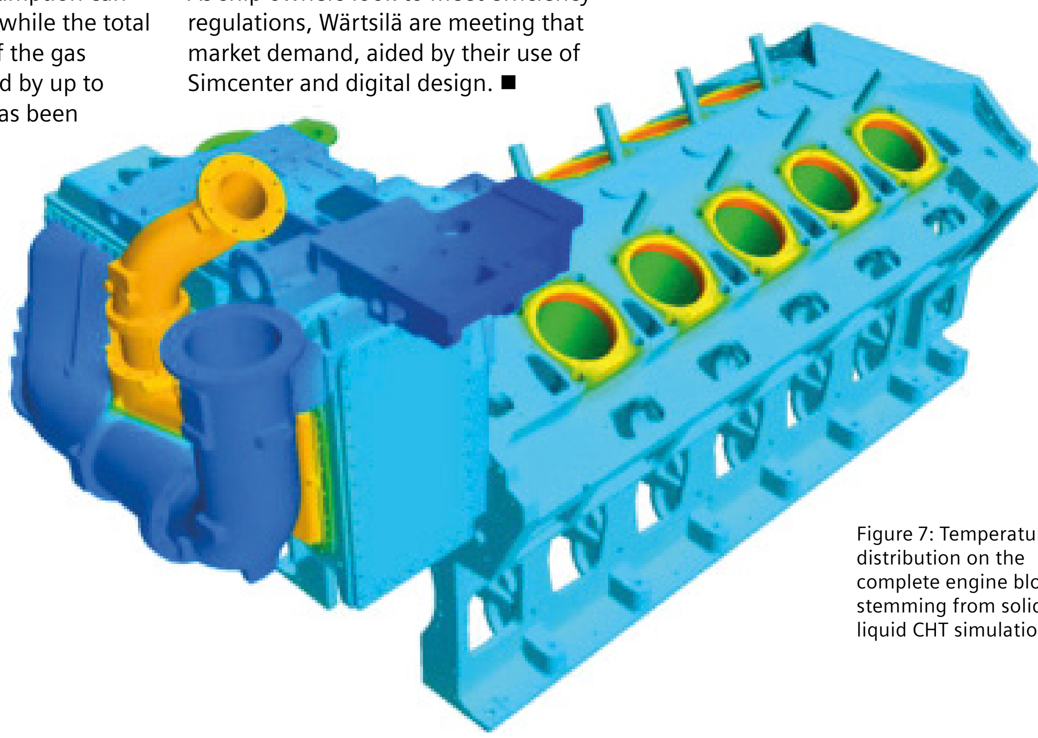
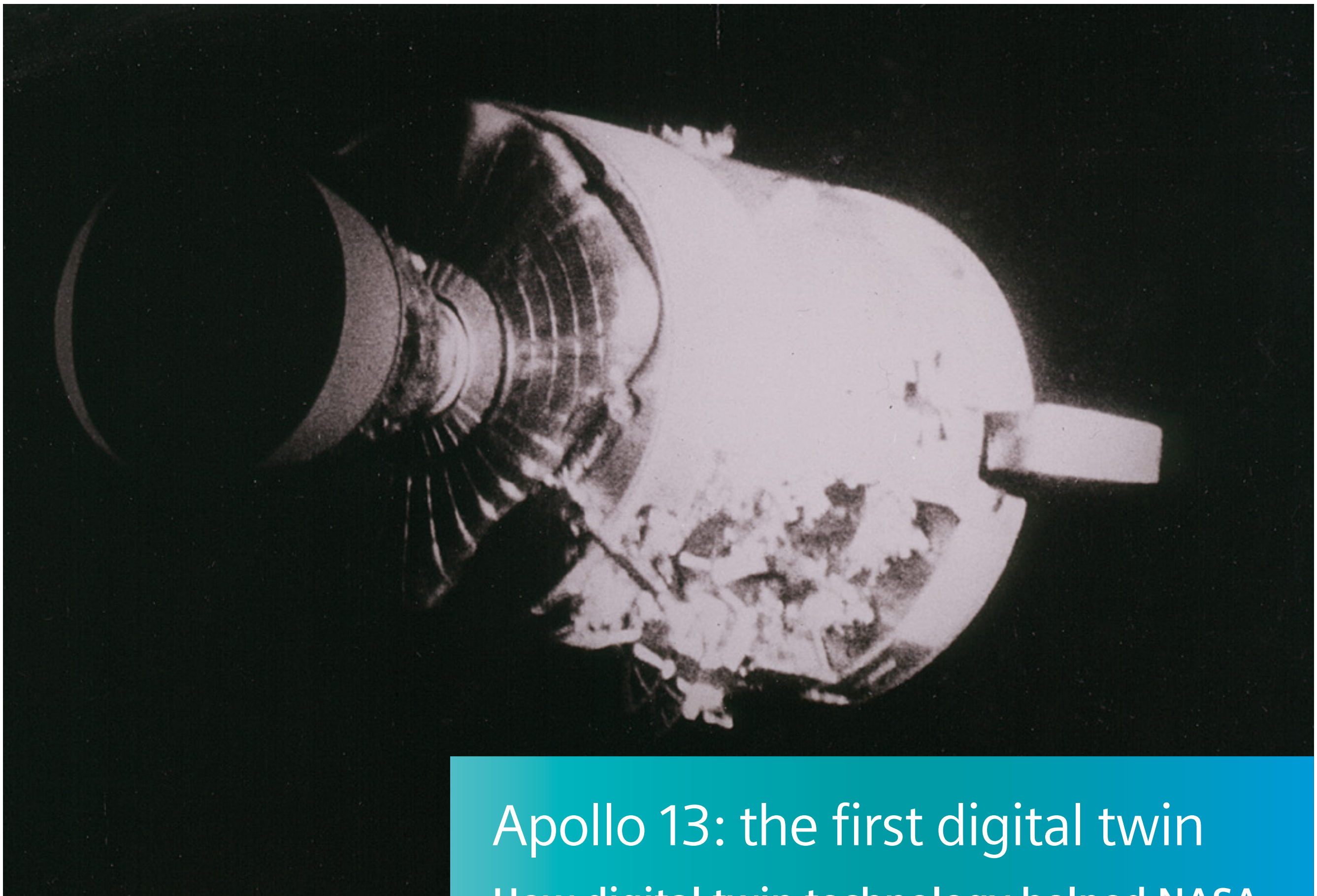


Figure 7: Temperature distribution on the complete engine block stemming from solid/liquid CHT simulations



This view of the severely damaged Apollo 13 Service Module was photographed from the Lunar Module/Command Module following the jettison of the Service Module. As seen here, an entire panel of the Service Module was blown away by the apparent explosion of oxygen tank number two located in Sector 4 of the Service Module. Image credit: NASA

Apollo 13: the first digital twin

How digital twin technology helped NASA enact the greatest rescue mission in history

By Stephen Ferguson, Siemens Digital Industries Software

Apollo 13 Mission Insignia - the motto reads "from the moon, science". Image Credit NASA

50 years ago, on April 14th, 1970, 55 hours and 55 minutes after launch, Apollo 13 suffered a catastrophic explosion in its service module.
Although the astronauts did not instantly recognize the severity of the problem (or even that fact that there had been an explosion). The damage this caused left the Apollo 13 venting oxygen, with a critically damaged main engine, and failing life support systems 200,000 miles away from earth. In the entire history of the human species, no-one had ever been in trouble so far from home.

This article is not the story of the Apollo 13 mission, plenty of others have done a much better job of telling that tale. Instead this is the untold story of the digital twins that helped Mission Control to overcome incredible odds and bring the astronauts home safely.

55:55:20
Commander Jim Lovell:
I believe we've had a problem here.

55:55:28
CAPCOM
This is Houston. Say again, please.

55:55:35
Commander Jim Lovell:
Houston, we've had a problem. We've had a MAIN B BUS UNDERVOLT.

55:55:42
CAPCOM
Roger. MAIN B UNDERVOLT.

55:55:57
CAPCOM
Okay, standby, 13. We're looking at it.

How do you look at, and solve, the problem of a failing physical asset that is 200,000 miles away and outside direct human intervention (other than from the three astronauts trapped inside who could not even see the damage that had been caused by the explosion)?

In the first moments after the explosion, Mission Control struggled just to keep the astronauts alive, conscious that any wrong decision might cause further terminal damage to the fragile spacecraft. Mission Control in Houston worked around the clock. To bring the astronauts home, they would have to work out how to maneuver and navigate a badly damaged spacecraft operating in an unusual configuration that was well outside of its design envelope. They would have to find innovative ways of conserving power, oxygen and water, while keeping astronauts and spacecraft systems alive. And finally, they would have to work out how to restart a command module that was never designed to be switched off in space.

Behind the scenes at NASA there were 15 simulators that were used to train astronauts and mission controllers in every aspect of the mission, including multiple failure scenarios (some of which came in useful in averting disaster in both Apollo 11 and 13). In his autobiography, Gene Kranz describes that Apollo simulators as "some of the most complex technology of the entire space program: the only real things in the simulation training were the crew, cockpit, and the mission control consoles, everything else was make-believe created by a bunch of computers, lots of formulas, and skilled technicians". There were three command module simulators, one in Houston (where Mission Control was located), and two in Cape Kennedy (the launch site). There were also two lunar module simulators, one at each location.

Although they obviously weren't called that at the time, my contention is that these simulators were perhaps the first real example of "digital twins". I'll explain in this article how these high-fidelity simulators and their associated computer systems were crucial to the success of the Apollo program, and how 50 years ago their flexibility and adaptability helped to bring three American astronauts safely home from deep space.

Apollo Simulators at Mission Control in Houston. The Lunar Module Simulator is in the foreground in green, the Command Module Simulator is at the rear of the photo in brown. Image credit: NASA

Of course, by itself a simulator is not a digital twin. What sets the Apollo 13 mission apart as probably the first use of digital twin, is the way that NASA mission controllers were able to rapidly adapt and modify the simulations, to match conditions on the real-life crippled spacecraft, so that they could research, reject, and perfect the strategies required to bring the astronauts home.

But before we explore the critical role these prototype "digital twins" played in the rescue of Apollo 13, it's worth examining how these simulators helped prevent disaster for both Apollo 11 and 13 even before the launch of either mission.

Use before launch

If you listen to the audio recordings of the flight controller loops immediately after the explosion, what strikes you most is the sense of controlled calm that is maintained throughout the incident. No-one panics, no-one loses

Apollo Command Module Mission Simulator showing Apollo 13 prime crew member Ken Mattingly in training. Mattingly was bumped from the crew a few days before launch because of exposure to the measles. Image credit: NASA

control, all that you can hear is calm reasoned decision making in the face of a terrible and potentially tragic unfolding situation.

This is because of the flight controllers, and the Apollo 13 crew, were well-rehearsed through simulation. Before launch, simulators were used to define, test, and refine “mission rules”, the instructions that determined the actions of mission controllers and astronauts in critical mission situations. Among the many simulators, the command module simulators and lunar module simulators occupied 80 percent of the Apollo training time of 29,967 hours.

Flight director, Gene Kranz’s, White Mission Control Team (one of three) had 11 days of simulation training to prepare for the landing of Apollo 11, seven of those with the actual crew, and four with simulated astronauts. As well as training both teams, the purpose of the sessions was to define a set of “mission rules” that would define any actions taken by both the crew and mission control these include “Go, No-go” decisions at critical stages of the spaceflight, and how decisions would be made in a crisis.

The various simulators were controlled by a network of digital computers, up to ten of them, which could be networked together to simulate a single large problem. There were four computers for the command module simulator, and three for the lunar module simulator. The computers could communicate using 256 kilobytes words of common memory, where information needed throughout the simulation could be stored.

There are at least two examples of simulated scenarios that directly influenced the successful resolution of problems on the actual missions (although there are likely hundreds more).

In the final simulation of the Apollo 11 mission, controllers wrongly aborted during the final stages of lunar landing when the guidance computer issued an "1201 alarm code" that the controllers had never seen before. After quickly determining that the error was indicating a computer overload that meant it might not be keeping up with its computing tasks, mission control called for the abort. This was the wrong decision, after conferring with the Massachusetts Institute of Technology (MIT) team that programmed the computer, guidance officer (GUIDO), Steve Bales later concluded that an "1201 code" was a warning rather than a critical error and rewrote the mission rules just nine days before the eventual landing. If the final simulation hadn't prompted him to do that, it's likely the actual Apollo 11 landing, the final minutes of which were plagued by a series of 1201 and similar 1202 alarms, would also have been aborted. The Eagle would not have landed.

During preparations for Apollo 10, mission controllers were tested in a simulation which involved the failure of the spacecraft's fuel cells as it approached lunar orbit, a scenario which is staggeringly similar to the Apollo 13 explosion. Controllers tried to evacuate the astronauts into the lunar module, using it as a "life raft", but did not manage to get it powered up in time, killing the virtual crew. Although many NASA insiders rejected the multiple failures of that scenario as "unrealistic" it inspired the controllers involved to develop procedures that would allow the lunar module to be used as a lifeboat, even with a crippled command module.

Although the simulators did not play a key role in the design of the spacecraft, they did play an essential role in defining its operating parameters. This illustrates one of the key purposes of the digital twin: to test the asset, and its systems and procedures, over a wide range of possible operating conditions.

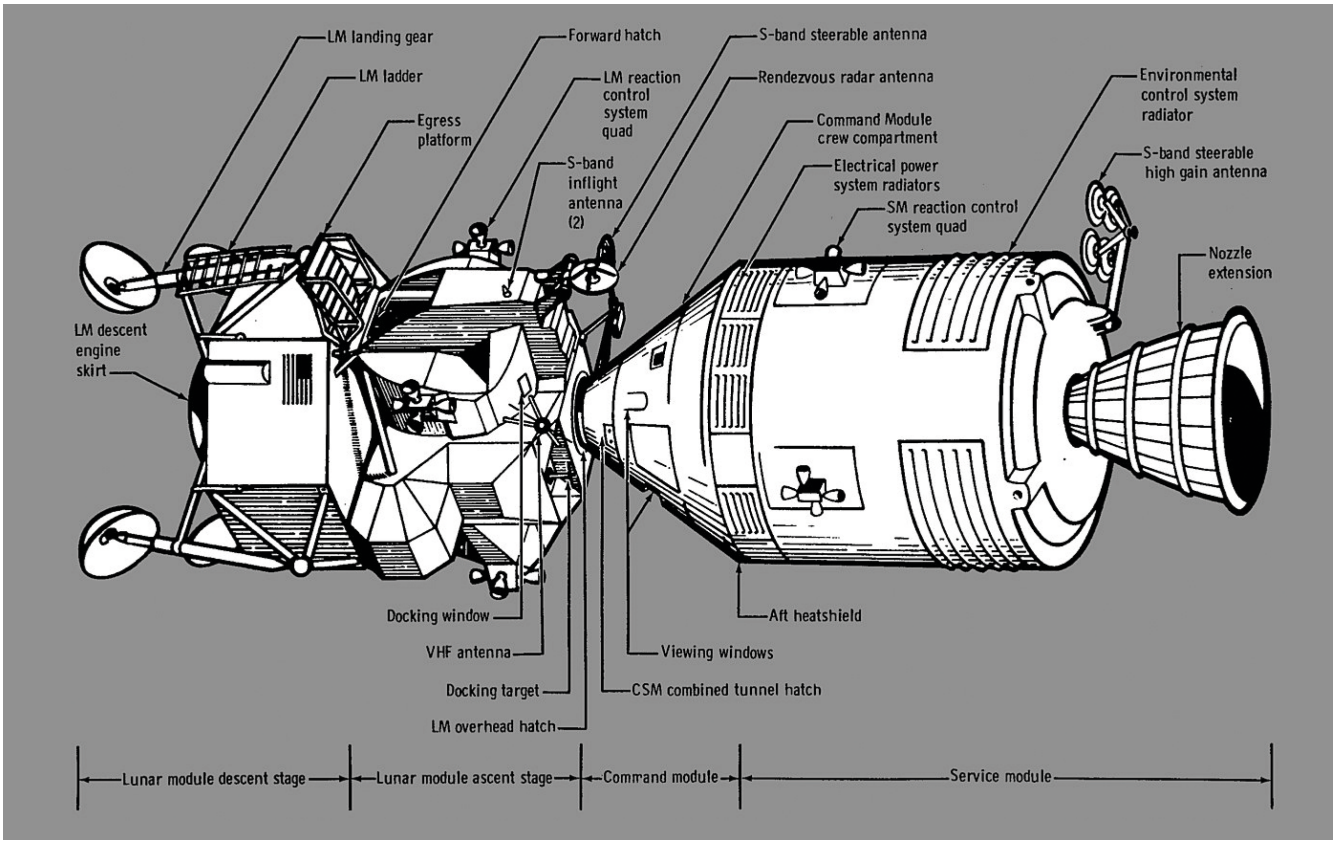
Connected twins

Most modern digital twins involve a remote physical asset which is connected to the digital model through a continuous stream of data. This connection is used to update the computer models in response to changes in the real-life object. Although Apollo 13 obviously didn't use "the Internet of Things", NASA did use state-of-the-art telecommunications technology to stay in touch with its spacecraft. That data was ultimately used to modify the simulators in order to reflect the condition of the crippled spacecraft.

Mission Control in Houston, moments before the explosion that would plunge the Apollo 13 mission into crisis. In the middle of the shot is White Team Leader, Flight Director Gene Kranz, whose team was responsible for defining the strategies to bring the crippled spacecraft safely home. Image credit: NASA

In the audio transcripts of the Apollo 13 flight controller loops, most of the immediate discussion is about maintaining data connections with the spacecraft (such as executing roll maneuvers to better align the main antenna array with ground tracking). One of the unsung heroes of the incident was the Integrated Communications Officer (INCO), Gary Scott who calmly kept the data communications stream running, while almost everything else was falling apart.

Although for some people the Apollo 13 story begins with commander Jim Lovell's ominous "Houston we have a problem" announcement (actually "Houston we've had a problem"), mission control was immediately aware that something had gone wrong through telemetry even before Lovell's voice report (delayed by 3 seconds by the transmission distance), as the guidance officer calmly announces "We've had a hardware restart. I don't know what it was", and then seconds



The Apollo spacecraft in docked configuration. The Lunar Module, on the left of the picture, was designed to take two men to the moon's surface and back before being jettisoned. For the Apollo 13 mission it provided a life raft and engine to bring the astronauts safely back to earth following an explosion in the service module. Image credit: NASA

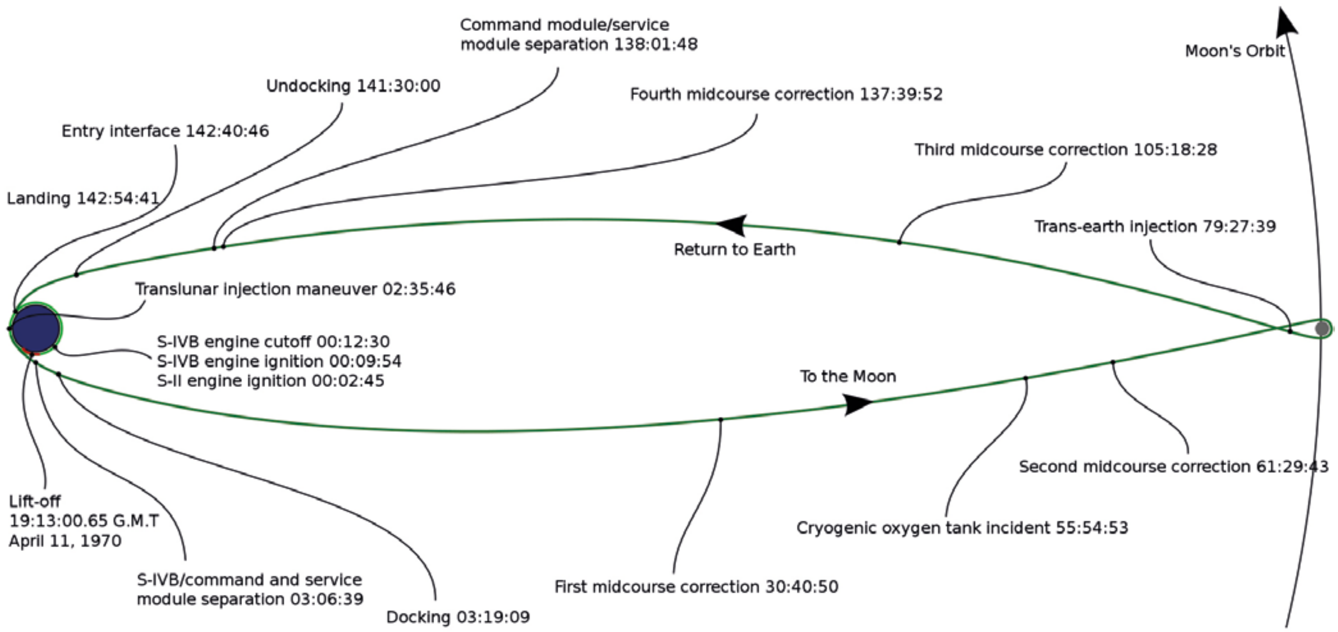
afterward the Electrical, environmental, and consumables manager (EECOM) controller announces, "we've got some instrumentation funnies, let me add them up...we may have had an instrumentation problem".

In the first 15 minutes after the explosion, flight director Gene Kranz became wrongly convinced that the problems that they were observing were a symptom of communication problems caused by an antenna glitch that they had been trying to resolve earlier, and which had been a frequent problem in the previous Apollo missions. In his autobiography, Kranz berates himself for this and wasting critical time in pursuing the wrong scenario, although to any outsider he seems to be following a calm and rational decision-making process during a rapidly unfolding crisis.

Kranz says "In mission control, you can't see, smell, or touch a crisis except through telemetry and the crew's voice reports". The crew trapped inside the command module could not see the damage, and other than the loud thud, which was not instantly recognized as an explosion, they also had to rely on the same telemetry as was being transmitted back to mission control. In the early stages of the crisis Kranz and the crew switch in and out different systems to try and work out what is working and what is broken.

Although the Apollo era data communications are crude by modern standards - they do highlight a common problem with modern digital twins: acquiring real-time data is one thing but processing that data into a form that can be easily used to make real-time decisions remains a challenge.

Even considering these limitations, mission control was able to quickly and accurately diagnose the problem and evacuate the astronauts into the lunar module before their oxygen supplies failed. They also made the sensible decision that the service module engine was damaged beyond repair. They were also able to use that data to modify their simulators to reflect the condition of the physical asset, another key quality of the digital twin.



Apollo 13 Mission Profile drawn to scale. Image Credit Andrew Buck.

Digital twin to the rescue
NASA faced many problems that all needed to be solved in order to bring the crew safely home, several of them solved only with the extensive use of the simulator digital twins.

One significant recurring problem was that of maneuvering the spacecraft, which was never designed to operate using the lunar module with crippled service and command modules attached for the whole return journey. With the guidance computer powered down to save energy, the crew had to manually align the spacecraft precisely to make three separate engine burns which required keeping the spacecraft on a free return trajectory to earth. In normal operation these maneuvers were performed by the onboard computer, but in this unusual configuration much of the work had to be performed manually. With limited fuel on board, any mistake could have been terminal, and left the vessel on a wrong trajectory.

The early signs were not promising, as the crew struggled to control the spacecraft "Why the hell are we maneuvering like this, are we still venting" exclaimed a frustrated Jim Lovell at one stage.

Mission Control immediately dispatched the backup crew to practice the maneuvers on the simulators that were being modified to reflect the unusual spacecraft configuration, which involved reprogramming the mainframes with information about the new spacecraft mass, center-of-gravity and engine thrust. Working together with the lunar module manufacturer, Northrop Grumman, the simulation team quickly worked out a new procedure in which the ship could be stabilized using autopilot and deploying the landing gear to get it out of the way of the descent engine. It worked and the crew were successfully able to perform the free return burn, greatly increasing their confidence.

A similar problem occurred two hours after Apollo 13's closest approach to the moon (the so called aspericynthion or PC for short), intended to speed up the return voyage by 12 hours, and bring their return just within the lifetime of their battery supplies. The problem this time was that the lunar module's guidance systems had been turned off to conserve power, forcing the astronauts to manually align the spacecraft using only visual cues. Ordinarily the crew could have navigated using the stars as a backup, but the large amount of debris surrounding the crippled spacecraft made it impossible for the astronauts to identify any constellations. In desperation, NASA once again turned to the simulators. After hours of trial and

Apollo 13 flight directors celebrate the successful splashdown and recovery of the Apollo 13 crew. From the left are Gerry Griffin, giving thumbs up, Gene Kranz and Glynn Lunney.
Credits: NASA

error, the simulator team came up with the ad-hoc process to align the tiny window of the lunar module with a quadrant of the sun. Before making the complicated alignment maneuver commander, Jim Lovell sought repeated assurance from mission control: "Had the backup crew configured the simulator properly with the lunar module in docked configuration? Had they had any trouble performing the maneuver?". He needn't have worried. Using the rapidly assembled procedure Lovell managed to align the spacecraft with the one-degree margin of error required to keep it on course.

The final problem was that in order to use the lunar module as a life-raft, the astronauts had to power down the command module, which they would ultimately return to for reentry. However, the command module was only ever designed to be powered-up on the launch pad, a complex process that took over two days, and no procedures existed for restarting in deep space, with almost exhausted power supplies. Under normal operation the lunar module drew about 70 amperes, however which would have exhausted the limited battery supplies. To conserve precious power supplies, mission control had shut-down non-essential systems (including crew heaters) to reduce the load to less than 12 amps (less than a domestic vacuum cleaner). But even still, as the time approached to power-up the command module less than two hours of power remained.

Behind the scenes EECOM, John Aaron worked around the clock to define a minimal power-up sequence, which everyone hoped would awake the command module before re-entry with the trickle of power left in the batteries. The exhausted and frozen crew were understandably anxious about correctly working their way through a long and complicated procedure that involved operating hundreds of switches in the correct order. Any mistake, any omission, would likely prove fatal, as turning the wrong system on would instantly deplete the small amount of remaining power. Astronaut, Ken Mattingly (who was bumped from the Apollo 13 crew a few days before launch), sealed himself in a dark command module simulator to rehearse and refine the switch on sequence before it was broadcast to the crew.

Is that really a digital twin?
I don't think it's much of a spoiler to tell you that, thanks to the round the clock work of hundreds of NASA engineers and controllers, the three astronauts were returned safely home. What could have been NASA's greatest disaster turned into its greatest triumph. Although the Apollo 13 mission happened 32 years before the coining of the term "digital twin", I do think that it remains one of the best real-life examples of a digital twin in action. I don't think the astronauts would have made it safely home without it.

Here are the characteristics of the Apollo simulators that I think defines them as perfect examples of a digital twin in action:

- Physical: Digital twins are most useful when they relate to physical assets that are (at least temporarily) out of reach of direct human intervention. Even though there were three

Apollo 13 crew arrive on the prime recovery ship U.S.S. Iwo Jima following the ocean landing and rescue in the South Pacific. Leaving the helicopter are (from left) Fred Haise, mission Commander James Lovell and John Swigert. Credit: NASA

astronauts on-board, Apollo 13 is a perfect example of this.

- Connected: Digital twins require constant feedback of data from the physical asset that can be used to update their condition, and then is used to inform engineering decisions: a key requirement of a digital twin. Modern digital twins typically use "the Internet of Things" to achieve this aim, NASA achieved the same purpose with advanced telecommunications which included two-way data transfer.
- Adaptable: Digital twins need to be flexible enough to react to changes in the physical asset. NASA were able to reconfigure their simulators in a matter of hours to reflect a configuration that had never been envisaged during their design and use those simulations to provide critical information to the crew.
- Threaded: There wasn't a single "digital twin" for the Apollo program; NASA used 15 different simulators to master the various aspects of the mission. The conception that modern digital twins need to be based around a single "grand unified model" that predicts every aspect of the physical device is also false. Contemporary digital twins consist of multiple interacting models that can be combined to account for different aspects of performance.
- Responsive: The events of Apollo 13 played out over just 3 and half days, during which incredible amount of adaptation and re-engineering occurred. I doubt whether many contemporary digital twins could have be deployed so quickly after critical damage to their physical asset.

Finally, if you are wondering what Siemens had to do with all of this: we made the incandescent lamps that illuminated the instrument panels of Apollo 13 with magical green light. Apparently, the lamps consumed almost no electricity, which is useful when you are stuck on a broken spacecraft 200,000 miles from home. ■

Hager Group

Simcenter FLOEFD: The Swiss army knife for the trunking system design team

By Stefan Spies (head of tool development), Bernd Trapp (tool design engineer), Thomas Szabó (product manager)

"The requirements on our tools in terms of quality, output capacity and cycle times are continuously increasing."

Stefan Spies,
head of tool development

The complex trunking structures are made of plastic materials, such as PVC, and produced in a continuous manufacturing process on modern extrusion lines. In addition to the detailed adjustment of the individual system components, a multiple strand extrusion tool is a core element of these complex systems. The multiple strand design ensures efficient, high output quantity. Modern design technologies, product complexity, material and color variations have lead the need to an increase in the number of special tools that are developed and put into operation every year.

The Hager Group, is a family owned leading supplier of solutions and services for electrical installations in residential, commercial and industrial buildings, employs around 11,500 employees. The sub-division Tehalit GmbH based in Heltersberg, Germany, has been a part of the Hager Group since 1996 and is the creator and European market leader for trunking systems with high flexibility for site and installation conditions, while maintaining high safety and reliability standards. The location in Heltersberg employs 740 employees and was founded in 1957.

Trunking systems bring electricity and data efficiently to varied locations within organizations resulting in the requirement for trunking solutions to be highly flexible to serve production, laboratories, practices and office spaces (Figure 2).

Hager Group and Siemens have been working together since the 1960s and today, Hager's varied product portfolio includes a wide range of systems from security systems to smart home devices and charging stations for electic vehicles.

Unlimited material, color and size variations

One of the strengths of the Hager Group's trunking division is their ability to manufacture and supply extrusion lines using a very high proportion of in-house manufacturing and development. Even though the external appearance of trunking systems has changed only slightly in recent years, the geometric and system complexity continued to increase, with size differences ranging from 4 x 4 millimeters (mm) to 380 x 120 mm (Figure 3). This is in addition to the number of material and color variants that are also constantly being created.

Unique competitive advantage through complex multiple strand tools

The complexity, functional requirements and quality demands on the extrusion tool increases, while cycle times shorten. In 2008 approximately 30 tools per year were developed, today there are more than 50 tools per year. Each tool is a special-purpose tool. Multiple four-strand tools were successfully put into operation in a shorter time with the help of Simcenter™ FLOEFD™ and provide a unique competitive advantage (Figure 4). 100 kilometers (km) of cable trunking is manufactured per day with no waste as the material is used again and again. One of the main targets is to achieve a uniform melt distribution at the tool outlet to maintain the product quality (Figure 5).

The Hager Group design engineers are responsible for the entire development process of their tools, starting from the basic digital concept up to the commissioning and final approval at the point where the tool is put into operation at the extrusion line. It is important to be able to work without any additional dependencies from others or external interfaces and thereby ensure an optimal development and design process.

Hager's approach to frontload their simulations

Hager Group engineers have been using Simcenter FLOEFD in their development process since 2008 and were able to use the results created in their initial training session resulting in a fast and productive implementation. With the assistance of

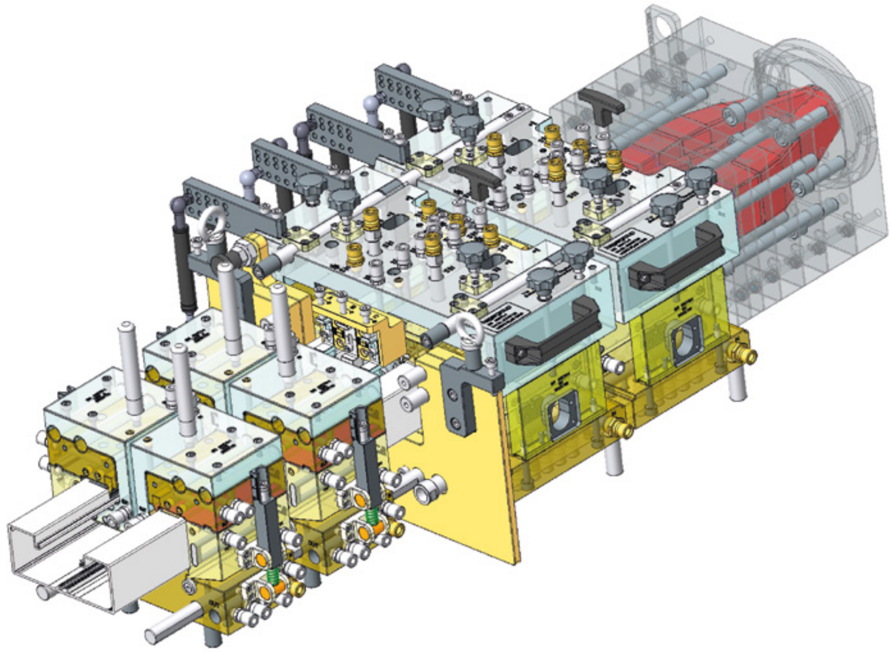


Figure 1: Extrusion tool and calibration

the technical support team, the continuous further development of the software and regular workshops, the knowledge was deepened even further. Besides the mold and tool design, the profile calibration as well as the layout of the cooling line are part of the simulations.

The existing experience of the Hager engineers in extrusion tool design has been extended over the years with further theoretical know-how, experience and knowledge about the material properties or physical conditions of non-Newtonian media and corresponding viscosity models. In addition, deeper insights were gained into the shear rate range that the new tools must cover. PVC, including multiple additives, is one of the most difficult material for the determination of the specific properties. At the same time, the material is often processed at the

Figure 2: High flexible trunking system tehalit.BR65

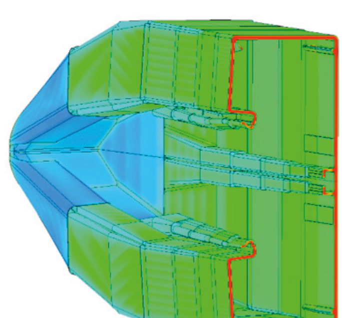


Figure 3: Size differences

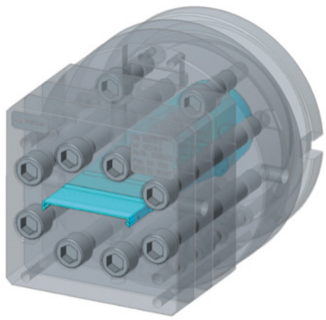


Figure 4a: Single strand tool

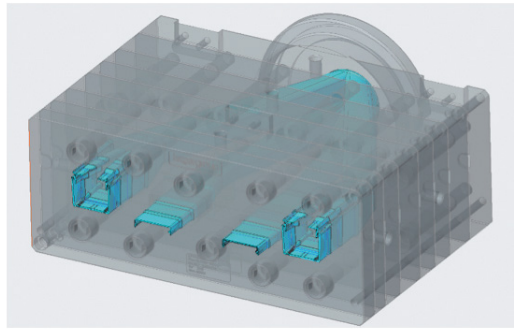


Figure 4b: Multi strand tool

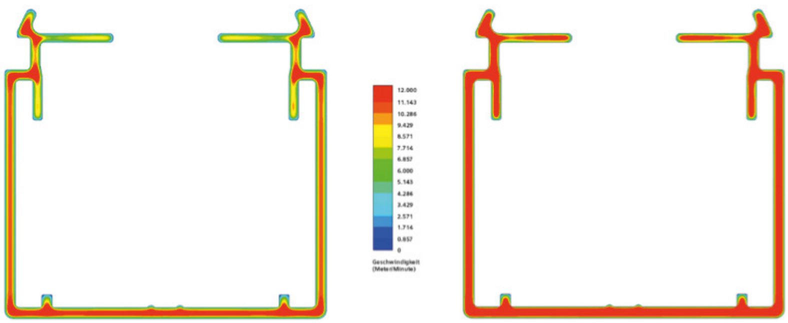


Figure 5: Optimized melt distribution in the right image (red areas).

temperature limits in the complex tool, which is impossible to be estimated without simulation. In particular, through the complete embedding of Simcenter FLOEFD in PTC Creo, in combination with the automatic mesh generation, more and faster optimization runs were made possible.

Extremely shortened development cycles with Simcenter FLOEFD

The extrusion tool development cycles were shortened dramatically and the use of Simcenter FLOEFD made it possible to integrate the computational fluid dynamics (CFD) simulation into the design process. The responsible design engineer can carry out and evaluate the simulation independently.

"While in 2008 we needed several days for the calculation, the flow analysis for our extrusion dies are already completed after a few hours and we then calculate models with up to 15 million cells, explains Bernd Trapp, design engineer for extrusion tools.

Each extrusion tool is unique, and is put into operation and adapted directly on the machine after development. For each project, a comparison is made between the simulation and the flow-part during commissioning at the extrusion line, so that findings are continuously incorporated into the simulation process. Figure 6 shows the first flow part sample between the extrusion tool and the calibration unit. The red areas in the top left image were identified and optimized with the help of the simulation. The bottom image shows the optimized configuration, which is appropriate to be passed through the calibration unit.

Extension of the application areas since 2008

The application areas of Simcenter FLOEFD are constantly extended. Initially, the flow behavior in the extrusion dies was optimized (Figure 7). In this case, the flow velocity, pressure, viscosity, shear rate, temperature, shear stress, and pressure distribution in the die were optimized.

Then the thermal design of the calibration tools was carried out with special consideration of the material properties. (Figure 7 a, b). Followed by cooling

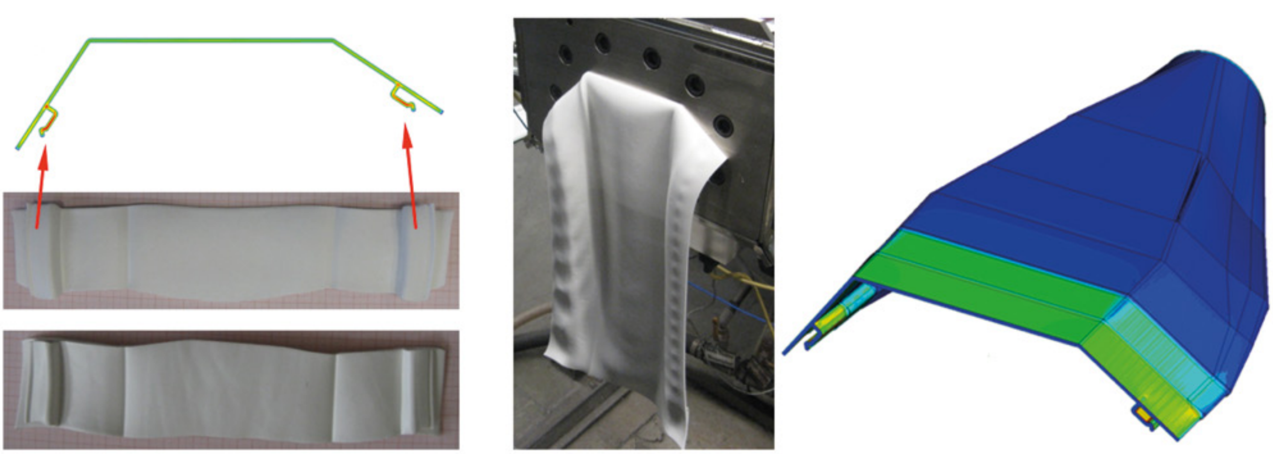
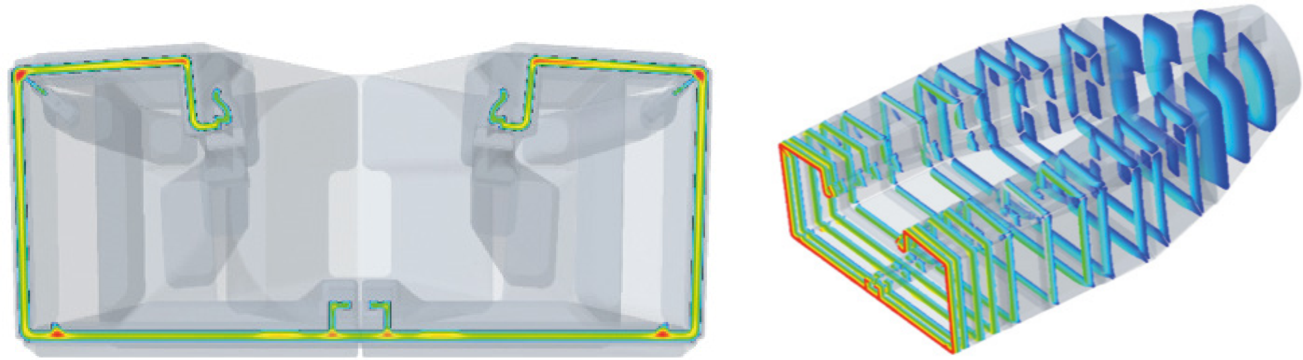


Figure 6: Simulation and flow-part samples which were taken during the commissioning



Figures 7 a, b: Extrusion die flow behavior analyses

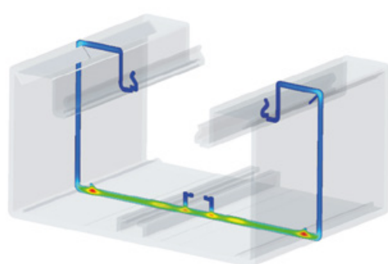


Figure 8a: Profile calibration

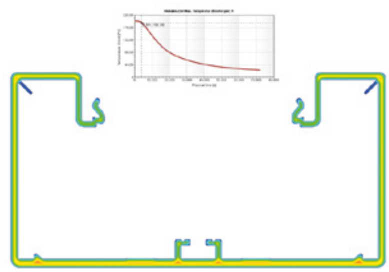


Figure 8b: Cooling behavior of the profile

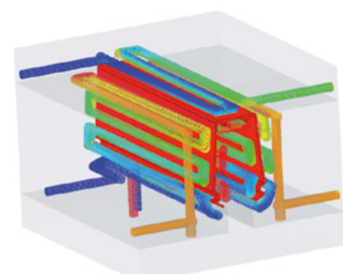


Figure 9: Cooling optimization

optimization for the calibrating tool (Figure 8). Particle studies were then carried out, while extracting systems at the extrusion line were analyzed (Figure 9). Finally the results are transferred to additional simulations, such as structural analyses. Since 2008, Simcenter FLOEFD is the tool of choice for many application areas, instead of using different tools for each area.

“When we started, we mainly focused on the flow velocity and shear stress of the non-Newtonian media. Meanwhile, the software has become also the tool of choice for many different applications. Our team uses Simcenter FLOEFD as a Swiss Army Knife around the tool development.”

“Regarding the flow conditions, our tools are now optimally designed from the very beginning through simulation. In combination with our experience around shrinkage and contraction we can design our ideal tools.” explains Bernd Trapp.

“Today, three to ten loops are simulated in advance for each tool, and modifications in the ramp-up process are also considered. The requirements on our tools in terms of quality, output capacity and cycle times are continuously increasing. At the same time, our trunking systems are becoming more complex. With Simcenter FLOEFD we cope with these challenges very well.” explains Stefan Spies, head of tool development.

“Our approach from 2008, was that each extrusion tool should optimized by the responsible design engineer with simulation during the design process, this has become a successful reality.” ■

Figure 10: Team Tool Design: Stefan Spies, Sascha Rollwa, Michael Riehmer, Bernd Trapp, Peter Wander, Tobias Seewald, Björn Schmitt

HASETRI keep the wheels of innovation turning

Preparing for an electrical vehicle future with Siemens Digital Industries Software testing solutions

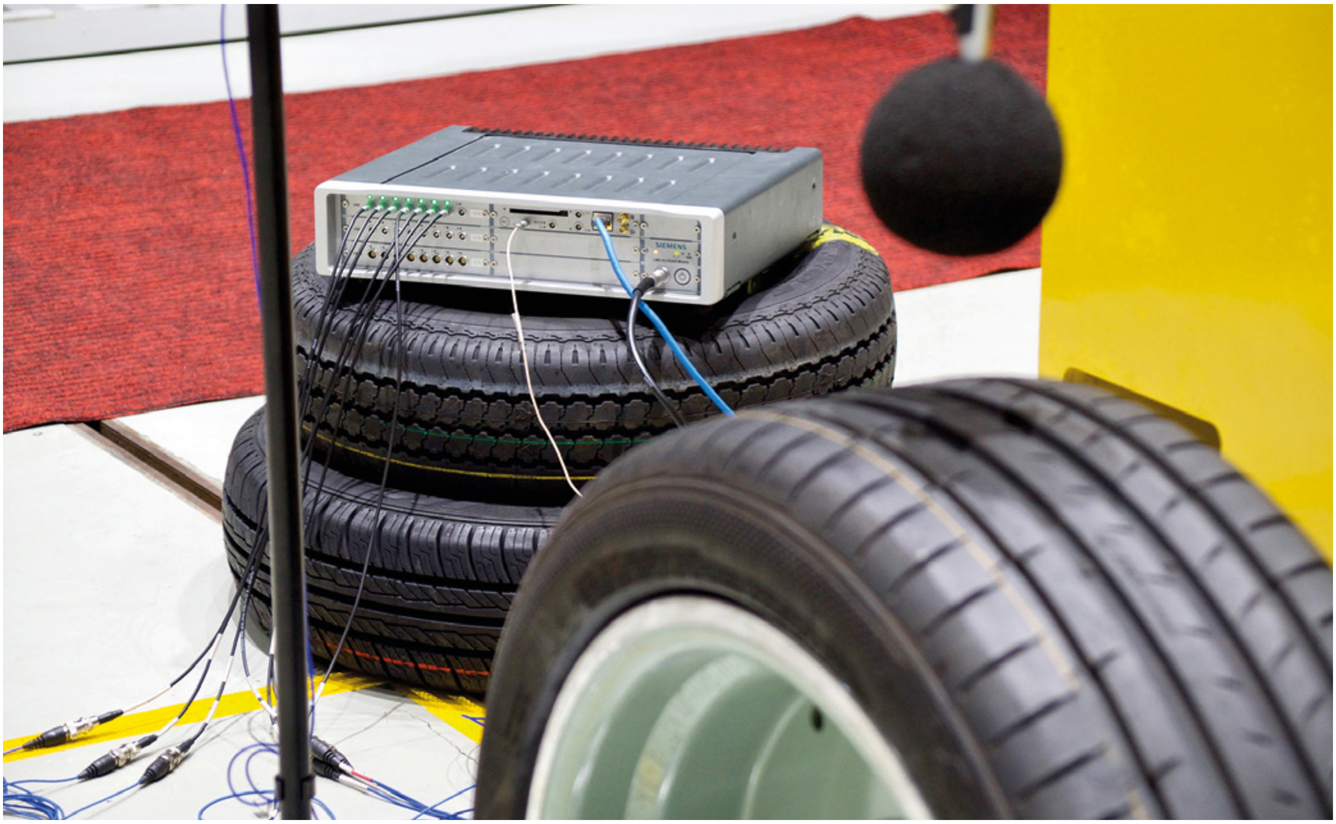
Driving research and development in rubber technology
The Hari Shankar Singhania Elastomer & Tyre Research Institute (HASETRI) in India is dedicated to the independent research and development (R&D) of new and improved technologies for elastomers and tires. HASETRI's primary goal is to foster the development and evolution of new technologies for the rubber and allied industries.

"Excellence comes not from words or procedures. It comes from an urge to strive and deliver the best," says Hari Shankar Singhania, founder, HASETRI. "A mindset that says, 'When it is good enough, improve it' is a way of thinking that comes only from a power within."

Established in 1991 as an independent research and testing laboratory, HASETRI broadens the scope of material and tire research to make products that meet unparalleled standards in quality and performance. They accomplish this through mechanical, chemical, and analytical testing, simulation, performance evaluation and product certification.

Tire importance
While engines and transmissions are believed to be a vehicle's most critical components, the development of the tire revolutionized road transportation. HASETRI's facilities host three rubber trees, which grow under the care of gardeners. Today, the institutes explore new ways to manufacture tires, use innovative materials and pioneer manufacturing methods.

HASETRI's research includes the development and testing of new materials, new aggregation methods, innovative shapes and designs. Each sample is tested using sophisticated laboratory equipment to predict the product's performance in real-life conditions that include structural durability, abrasion (wear), etc.



"We stand at a crossroads today," says Dr. Rabindra Mukhopadhyay, director and chief executive, HASETRI. "Resources on earth are limited and we need to re-invent mobility and develop more sustainable means of transportation, without which our existence is threatened. With our advanced research on tire technology, we strive to contribute to a better, more sustainable world and economy."

> *"We are confident that our existing and future expansion plans would be well supported by Siemens."*
>
> Dr. Prasenjit Ghosh
> Principal Scientist
> HASETRI

Electrified vehicles require different tire characteristics

HASETRI also assesses the acoustic properties of tire materials and designs. This is crucial as government and regulatory institutions continue to impose stricter limitations on a vehicle's acceptable noise levels, making the tire's noise performance critical. Tire noise, or the sound produced by the friction of tires on the road surface, is one contributor to a vehicle's noise level. Unlike internal combustion engine (ICE) cars, where the engine masks road noise, the road noise from electric cars becomes more apparent since electric cars, of course, do not feature a loud combustion engine. In addition, the battery in hybrid and electrical vehicles increases vehicle weight by 10 to 20 percent, which boosts instant torque generations in these vehicles and increases the demand on the tires.

To design tires with high noise levels at low vehicle speeds and low noise levels at high vehicle speeds, the HASETRI lab features extensive noise and vibration assessment and testing capabilities. Lingineni Madhav is a test engineer in HASETRI's Tire Mechanics Group, which deals with noise, vibration, harshness, (NVH) and handling properties of tires and related products. As a test engineer, Madhav ensures the smooth operation of different tests as per various national and international standards. He also develops new test methods to further

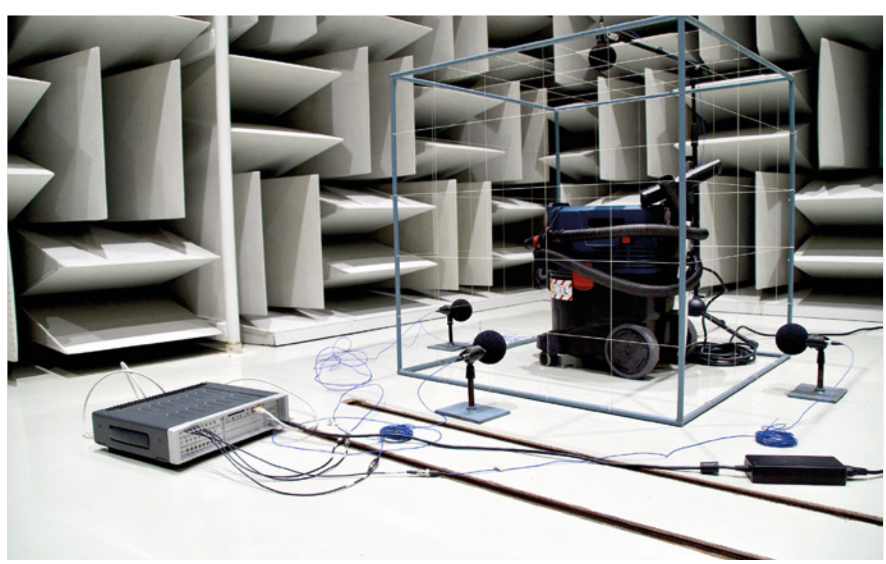
enhance the lab's capabilities and carry out noise, vibration, and harshness (NVH) studies, which contribute to providing noise abatement solutions at both the components and vehicle levels.

Through the use of Siemens Digital Industries Software solutions Simcenter™ Testlab™ software and Simcenter SCADAS™ hardware, the HASETRI tire mechanics department carries out various NVH-related tests, such as noise level measurements at constant speed, speed-sweep tests on the tire test rig located in a semi-anechoic chamber, in-cabin and external noise measurements on the vehicle level at designated test tracks across India as well as pass-by and coast-by noise measurements. The department engineer also performs modal testing on tires and other relevant industrial components.

"Simcenter testing solutions have expanded our existing tools and skills set to explore certain aspects of noise and vibration testing," says Madhav. "Simcenter tools have been critical in reducing the time needed for data acquisition and data processing. Another benefit Simcenter testing solutions provide is the ability to rapidly access different areas and domains during the testing process. The support and assistance from the Simcenter technical team to resolve hardware-related and technical and software-related queries have been extremely valuable."

Madhav continues, "The tests we conduct are important considering regulatory requirements, original specification (OE) specifications, and benchmarking. They are also vital as we strive to continuously improve our understanding of the NVH domain and move in a direction to contribute to NVH solutions both at the national and international levels."

Sound quality is an important criterion for the automobile industry. Moreover, new drive and fuel concepts, tightened ecological specifications, increase of vehicle classes and increasing diversification, challenge the acoustic engineers trying to create and preserve a pleasant cabin. Regulatory bodies are becoming more stringent in regard to NVH, especially in Europe. HASERTI believes it is important to provide accurate and reliable information on critical NVH matters during the initial design phase to meet these growing requirements and standards.



HASETRI's NVH section has ten highly skilled engineers who are involved in carrying out advanced NVH testing and research. In 2014, HASETRI partnered with Siemens to establish an anechoic chamber with the latest technology, including the chassis dyno in the very early stages. HASETRI operates a cutting-edge testing facility suitable for basic testing to advanced engineering projects that require a high-channel count and special hardware (for example, multi-reference transfer path analysis (TPA) and road noise). The Simcenter Testlab and Simcenter SCADAS hardware onsite is scalable and easily used for both the lab and mobile environments. HASERTI plans to use Siemens solutions for future projects.

"We are confident that our existing and future expansion plans would be well supported by Siemens," says Dr. Prasenjit Ghosh, Principal Scientist, HASETRI.

Increased testing efficiency

Besides using versatile testing solutions to provide customers with a wide range of possible NVH tests, HASETRI focuses on regular training of their engineers and customers to improve the quality of their delivered testing projects. "We are able to educate our customers through training by experts from Siemens," says Dr. Mukhopadhyay. "As a result of continuous interaction, we are able to improve the quality, reliability and repeatability of our testing, the interpretation of results and the testing times." ■

> *"Another benefit Simcenter testing solutions provide is the ability to rapidly access different areas and domains during the testing process."*
>
> Lingineni Madhav
> Test Engineer
> Tire Mechanics Group
> HASETRI

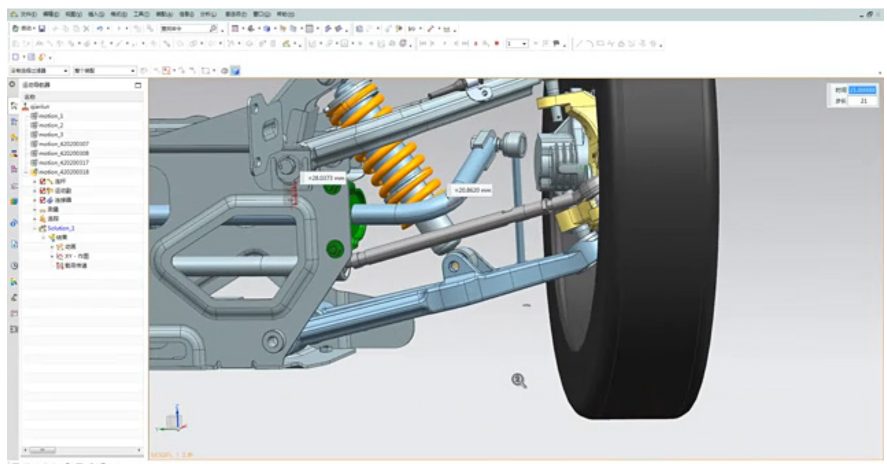
Interview

From Concept design to production in 8 months

Spotlight on ElectraMeccanica: ElectraMeccanica's SOLO has been lauded as one of the coolest cars of 2020 by Forbes Magazine. They use an ever expanding portfolio of tools including NX, Teamcenter and Simcenter

Tell us a bit about your company.
Henry Reisner: our past CEO, Jerry Kroll and I founded this company. I've known Jerry for over 20 years. Jerry is a very passionate environmentalist and even as far as 15 years ago was interested in electrification of transportation. At the time I wasn't sure that my customer base was moving in that direction. But about five or six years ago he brought the concept of a single passenger urban electric vehicle to me as something that he was interested in exploring. I really thought that this was an extremely exciting and potentially very strong niche that a small company could create. We identified some potential IP to acquire but upon visiting the company, we discovered that there was nothing to purchase. It was a disappointing turn of events but on our flight home Jerry and I discussed whether it would be possible to put together a team that could develop the IP and what kind of product we'd like to offer. This company is now at the culmination of that journey.

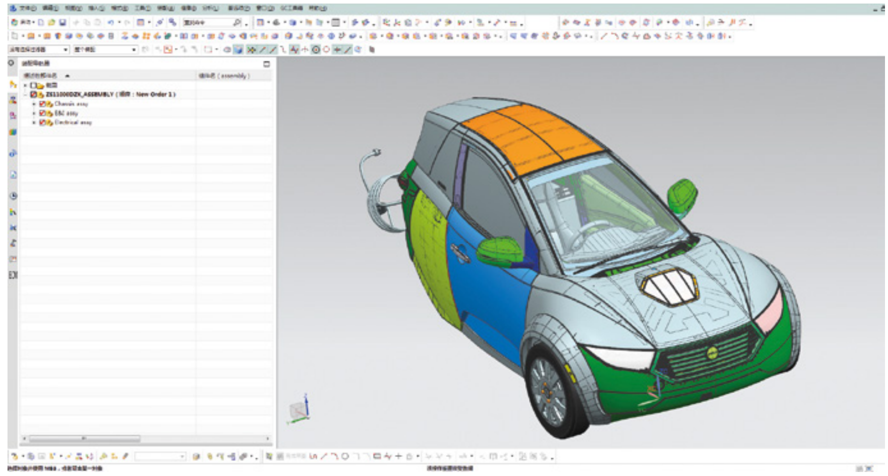
What makes your product unique?
Henry Reisner: Electric vehicles up to this point have been a fairly expensive product. We have a purpose-built product that delivers everything that you need for personal transportation on a daily basis. It has a high level of functionality that meets the daily needs of more than 70 percent of commuters. And we can do that at a sub $20,000 price point. **Bruce Gordon:** And that makes it that much more accessible to a significantly wider population. Now everybody can have a choice.

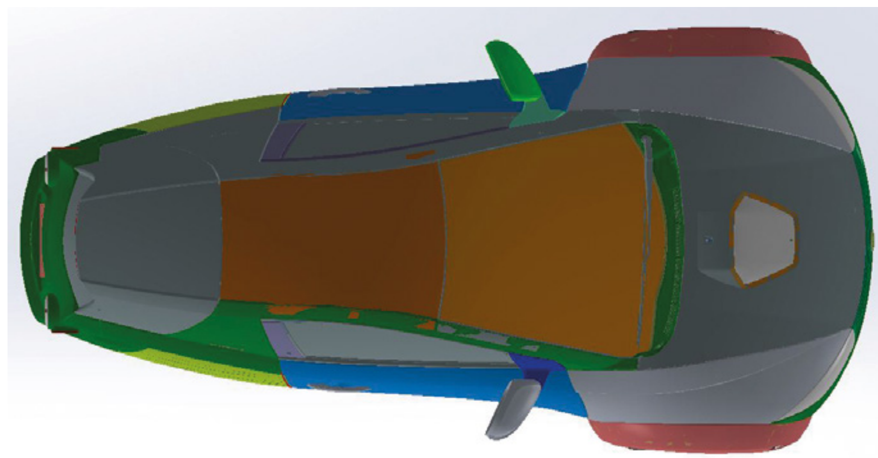


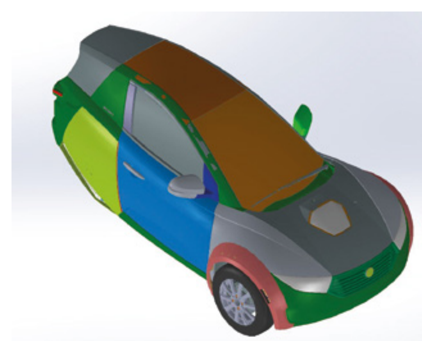
What are the challenges facing your team?
Henry Reisner: As a startup, we've had very good response from the financial market through both private and institutional investment backing. One of the things that we pride ourselves on is not having a capital intensive approach to this project. Therefore, we rely on partners for both development and manufacturing. There are also geopolitical issues that have influenced the way things are moving. No matter how good the plan might be, things always come in from the side. I'm proud to say that we are a committed, flexible and driven small team that is well supported by our executive team. So despite pandemics and political situations we will achieve our objective.

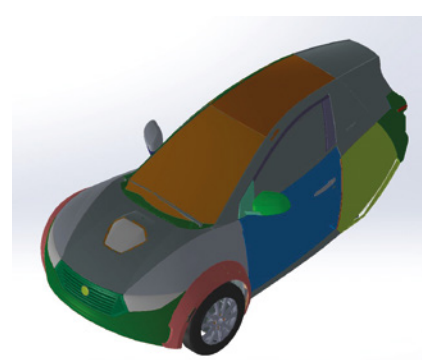
How do you achieve those objectives?
Bruce Gordon: We have a design team that is scattered around the globe – Detroit, Los Angeles, Vancouver and China. Our biggest challenge is to get everybody to contribute and have the channels of communication open so we can all give our best. **Henry Reisner:** As our team of engineers grows and the breadth of engineering partners grow, we all need to speak the same language and share the same data. That's why we rely on Siemens Digital Industries Software solutions. We are now in an expansion phase; therefore, we're adding more Siemens products as a part of our process to grow this company to the next level. As we push on our development, we can do a better job by having access to the same tools across the supply chain.

We have a strong, knowledgeable partner in Maya HTT, an engineering solution provider and Siemens Smart Certified Partner. Maya HTT's team understands our corporate DNA and our specific needs. As a small, nimble team, we have a very different way of thinking









and approaching problems, and their engineers know that. They have the expertise to support us at our stress points with the solutions and software we need to achieve engineering excellence.

How is Siemens Digital Industries Software solutions helping you?
Paul Rivera: Coming from a strong engineering background I know the importance of advanced software in the design of new vehicles and their components. We were very fortunate to have Siemens' support in the early development of our unique new single-seat SOLO and we'll continue to work with Siemens on future versions of the SOLO and other ElectraMeccanica vehicles for our growing global customer base.

Bruce Gordon: Our process relies on experts in various fields so we have to coordinate and share information effectively among the extended team. We have standardized on NX and look to Teamcenter to help us with some of the connectivity as well as accessibility of information challenges as well. We also use Simcenter finite element analysis (FEA) for stress, strain analysis as well as computational fluid dynamics (CFD) for fluid and thermal simulation as well as conduct crash studies. These types of software were new to us before we started working with Maya HTT and Siemens Digital Industries Software. These tools have allowed us to achieve engineering excellence. With Simcenter we now have a direct parametric link back to CAD data in one GUI, which makes it easy for us to analyze a design, make changes, go back to iterate on it and update the results. It's simply a much more streamlined and collaborative process.

The first generation car required about 18 months to go from a blank piece of paper to a driving prototype. Our latest model took eight months to go from concept generation to start production – this includes going from design through to manufacturing and production. We had already done a great deal of work to get from generation I to generation II so the groundwork was already in place for generation III. **Henry Reisner:** Paul Rivera, our CEO, joined us at the end of August 2019. He understood the potential pitfalls that could happen with early release of a product and identified areas for improvement. Bruce and I have been going through the lists with our engineering team and meeting deliverables.

Our engineers are inspired forward-thinkers. By working with comprehensive, ready-to-use software, they can unleash the potential of their engineering, not just to come up with ideas, but to find the best ways to bring those ideas to life. With Maya HTT and Siemens, we're moving faster to market with less error to deliver better value to SOLO drivers.

The improvements made to the latest model will make a significant difference to the user experience. We're comfortable and excited that we will be delivering a design like that we committed to Paul and getting the quality product that he wants on the ground in Los Angeles for distribution this summer. ■

Introducing system simulation for aircraft system development

Irkut Corporation uses Simcenter system simulation solutions to develop and integrate MC-21 airliner systems

"Few companies offer such a comprehensive simulation solution."

Yuri Logvin
Vice director for Design Data Management
Design Department
Irkut Corporation

In 2010, Irkut Corporation deployed Simcenter™ Amesim™ software from Siemens Digital Industries Software for MC-21 aircraft systems simulation. The concept design stage was near completion upon introducing Simcenter Amesim, but there were neither test benches nor a prototype. It is common practice to solve the challenges of integrating complex aircraft onboard systems at the detailed engineering phase while the fine-tuning and calibration are performed at the bench and flight test phases.

For the MC-21 airliner project, the designers had to define the systems' architecture and their key performance indicators, make design decisions based on analyses and study the physical phenomena occurring in the systems (hydraulic, fluid dynamics, thermal, mechanical, electrical, etc.). It was also required to analyze the systems' integration prior to installing them on the aircraft, to study how external factors affected system performance, and adjust each individual system operation. The systems had to be optimized as well.

At the test bench, ground and flight test phases, the key objectives were to identify the best physical test conditions, develop the test procedures and minimize the risk of equipment failure during the tests.

Irkut Corporation's management team decided to deploy Simcenter Amesim to address system integration challenges at the physical component interactions level using proven design tools based on the system energy distribution approach (system power balance.) A major benefit of Simcenter Amesim is it supports most aircraft system design procedures used by the company as well as its capabilities based on best global engineering practices.

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With the multiphysics system simulation models of the aircraft systems and components, engineers from Irkut Corporation's engineering center analyzed the aircraft systems' interactions at the physical level (thermal, hydraulic, fluid dynamics, electrical, mechanical, controls, etc.), at the pre-design phase and at the beginning of the detailed engineering stages.

"Simcenter Amesim enables easy system modeling with both standard library components and customized user-defined ones, then the system's behavior can be analyzed," says Sergey Gusarkin, design engineer, engineering analysis department, Irkut Corporation. "The standard validated Simcenter Amesim libraries are regularly updated. They help our engineers develop the aircraft systems without wasting time on creating component libraries. Compared to the legacy solution, Simcenter Amesim has accelerated complex model creation several fold."

Engineering aircraft systems using system simulation models

System simulation models have been used to design such systems as the landing gear extension/retraction system (LGERS), the fuel system (FS), the hydraulic system (HS), the integrated environment control system (IECS), the anti-icing system (AIS) and the power supply system (PSS).

The aforementioned system models were verified and validated as bench test data became available. Yevgeny Danilov, senior design engineer from the fuel systems department at Irkut Corporation, explains, "System simulation provides a clear picture of the fuel system's performance under different flight conditions taking into account the aircraft's altitude and load factors. The simulation results, validated with physical tests, have helped improve performance, reduce weight and the number of purchased system components."

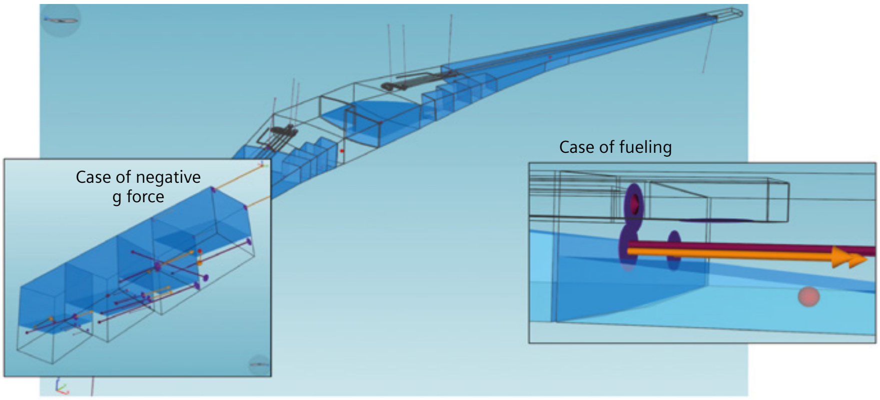
"As we mastered more and more engineering disciplines, the corporation established an engineering analysis department to develop a number of aircraft systems," says Anton Poplavsky, deputy head, engineering analysis department, Irkut Corporation. "The department operates in many disciplines. For example, the high lift devices department needed to analyze possible wing spar damage. Using the 2D mechanical library in Simcenter Amesim, we studied the issue and obtained the results that perfectly matched the data later provided by the supplier."

Yet another problem Simcenter Amesim solved was thermal analysis of the engine pylon. The MC-21 engine pylon carries a lot of hydraulic components close to the engine. The lower part of the pylon is exposed to the hot jet exhaust while its exterior is cooled with the compressor air. The engineers have successfully used Simcenter Amesim to analyze temperature distribution inside the pylon.

"Simcenter Amesim keeps improving in terms of usability," says Marina Grishina, engineer, engineering analysis department, Irkut Corporation. "Siemens Digital Industries Software provides excellent technical support. It is very easy to get all the information we need. We learn more through the training seminars conducted by the Siemens Digital Industries Software experts who teach us the best system simulation practices."

System integration

Analyzing the integrated systems' performance is a key aircraft design challenge. Irkut Corporation has used Simcenter Amesim to integrate the



Symmetrical tanks for negative g maneuvers

following systems: HS and LGERS; HS and the integrated flight control system (IFCS); HS and PSS; FS, power plant and IECS; LGERS, HS and the aircraft control system. A special task was the controls calibration for the aircraft control system.

The MC-21 system/equipment integration included the aircraft system performance and interaction analysis in emergency conditions, estimation of external factor effects on system operability and performance in the entire envelope, and system performance analysis for failures and accidents. A lot of work had been done to develop the system test procedures, as well as comparative parametric studies (analysis of design variants).

Mikhail Pylnev, head, engineering analysis department, Irkut Corporation, says, "Simcenter Amesim supports co-simulations when some connected subsystems are represented with simulation models created in third-party software. For instance, we have integrated a Simcenter Amesim aircraft hydraulic system model with the integrated flight control system model developed with MATLAB/Simulink. The integration process has enabled us to identify and analyze a lot of complicated effects and to make feasible design decisions for system operation and interaction. Virtual testing using simulation models has reduced the number of bench tests. For example, for the fuel system we have managed to remove 25 percent of the tests. In this way, system development for a new MC-21 configuration has been accelerated. Moreover, simulation with Simcenter Amesim is an efficient tool to monitor and manage the subcontractors."

The results have confirmed that implementing Simcenter Amesim as a system simulation tool for aircraft design was the correct decision.

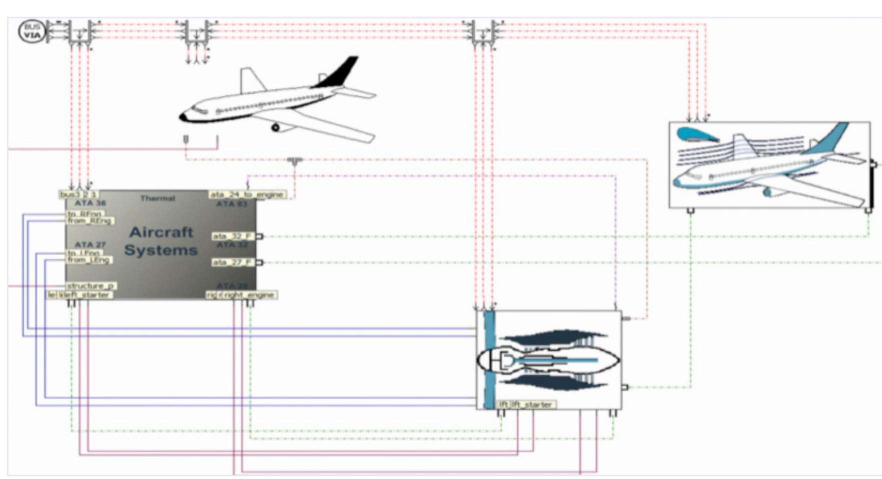
Developing a virtual integrated aircraft

The virtual integrated aircraft approach is aimed at integrated analysis and aircraft system optimization in flight. Simcenter Amesim can simulate the entire flight cycle: pre-departure operations, flight, and landing while analyzing the aircraft system interaction. Various environmental conditions and flight plans can be applied. Another important task is integrated aircraft thermal balance analysis. Conventionally, the thermal analysis department at Irkut Corporation is responsible for the thermal performance of the aircraft systems and serves other corporate divisions. Such analysis is done on an ad-hoc basis for typical system operating conditions. It does not provide the entire aircraft thermal profile for the entire flight. With dynamic models it is now possible to analyze system thermal performance in transient modes as well. Now there is a way to better identify any thermal load imbalance with an integrated aircraft thermal model.

Another issue is managing distributed aircraft system development by numerous engineers from the engineering center. Simcenter™ Sysdm software from Siemens Digital Industries Software is used to store and share the models. It has become an integrated tool-agnostic platform that stores simulation models, tracks their versions, and manages access rights. With this platform, it is possible to create complex simulation models of many systems and to refine the distributed product development and requirements verification with subcontractors as well as the system development departments at Irkut Corporation.

The company uses Simcenter™ System Synthesis software for virtual system integration. The solution helps create an integrated aircraft model from the subsystem models developed by various engineering center departments, specifying operating conditions and analyzing the results.

Yegor Mozhenkov, design engineer, engineering analysis department, Irkut Corporation, says, "System integration with Simcenter System Synthesis has changed the entire process, model storage requirements, database views for subsequent integration and other system development activities. We had to create a customized approach to use this technology. It results in a concise



Virtual integrated aircraft

aircraft system development process at every level: from the OEM suppliers to the entire aircraft performance analysis in various flight conditions."

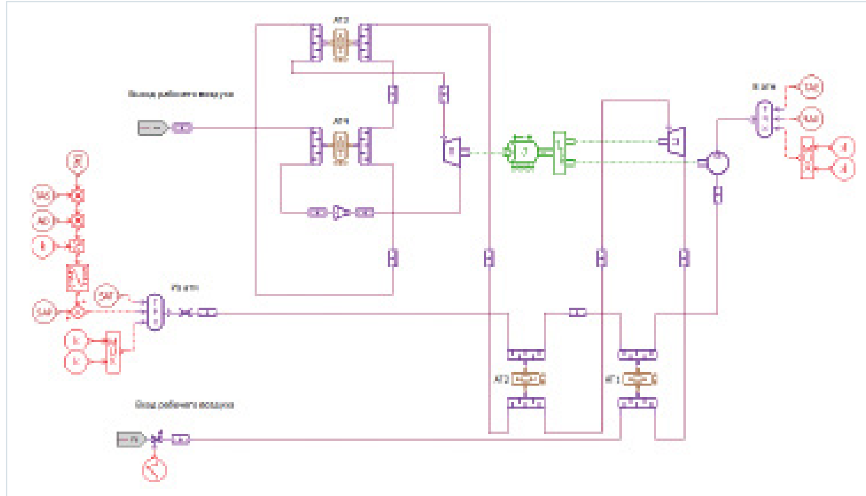
Test rig development and aircraft testing

Irkut Corporation has designed and built an "iron bird" of the landing gear extension/retraction system to validate the landing gear extension/retraction controls. After the controls strategies are verified and it is clear that expensive hardware will not be damaged, the virtual equipment is replaced with actual equipment for physical testing. The simulator is an efficient tool to optimize and refine the controls and to test new versions of controls strategies.

The LGERS iron bird identifies optimal test procedures and conditions and minimizes the risk of equipment damage. Moreover, it is possible to identify the root cause of failure or non-compliance with system requirements (for example, a design error or a broken cable) and to debug software (control logics).

Vladimir Oleynikov, deputy head, design procedures and training department, Irkut Corporation, says, "With the MIL-SIL-HIL technology, we developed the simulator in the shortest time possible. The simulator helps automatically test the aircraft control system functioning in all operating conditions.

"The control system logic is refined by concurrent operation of the hardware (control object) models and the control algorithms. In this way, design decisions are improved and control logic is



Air condition system modeling with Simcenter Amesim

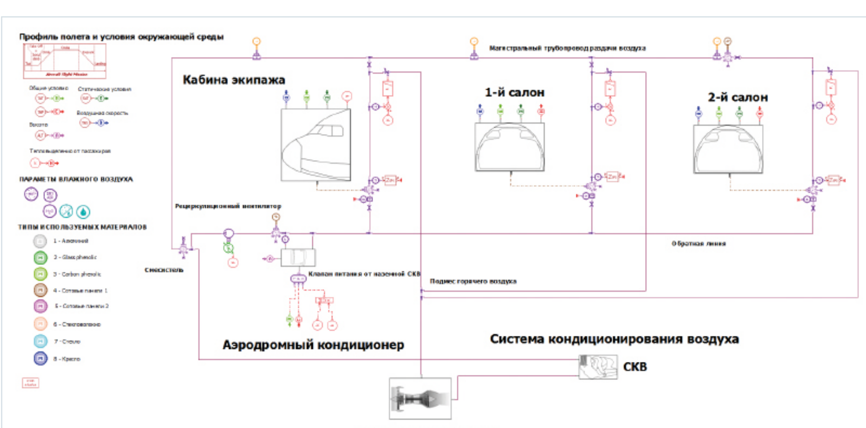
optimized at early development stages."

Future outlook

"Few companies offer such a comprehensive simulation solution," says Yuri Logvin, vice director for design data management, design department, Irkut Corporation. "System development with Simcenter Amesim has reduced errors identified through design review and has accelerated the design and some bench test activities. We can virtually assess change consequences for any aircraft system parameter without allocating too much money or personnel as would be required for physical testing. Our objective with this approach is to establish a coordinated procedure for simulation results recognition by the certification centers. We are striving to build a competitive aircraft while Siemens Digital Industries Software offers tools to address most of our challenges." ■

"We are striving to build a competitive aircraft while Siemens Digital Industries Software offers tools to address most of our challenges."

Yuri Logvin,
Vice director for Design Data Management
Design Department
Irkut Corporation



Multi-physics model of aircraft bays

Rise of the V-Bat

Drone maker, Martin UAV, uses Simcenter solutions to increase hover thrust and decrease cruise power

Rise of the V-BAT
Somewhere in a field in Plano, Texas the future of military surveillance and reconnaissance sits inconspicuously in the back of a pickup truck. It's an odd place to spot the next generation of tactical unmanned aerial systems (UAS) for the U.S. Army, U.S. Marine Corps and U.S. Navy. Then again, this is a unique drone. This is the V-BAT, the world's first true vertical takeoff and landing (VTOL) tailsitter (meaning it takes off and lands on its tail) unmanned aerial vehicle (UAV).

At first glance, it looks like an ingenious scientist just attached wings and blades on a larger than life lipstick. But the technology behind it is mighty impressive. The long-endurance V-BAT takes off vertically from small, confined areas and seamlessly switches to horizontal flight. This is quite a feat considering previous attempts to achieve a clean transition from vertical to horizontal flight have previously derailed many ambitious vehicle projects; or they have ended up being multi-copter hybrids or sounding like a flying lawnmower, neither of which fit military reconnaissance missions.

With the V-BAT, Plano-based Martin UAV has not only solved one of the hardest problems in transition flight, but delivered a UAS fit for the future – a true VTOL drone capable of taking off without a runway and flying for more than eight hours with a payload of more than eight pounds, top speed of just over 100 miles per hour (mph) and a range of 350 miles.

The UAV of the future is here (and it's in a box)
The V-BAT is currently in a race to replace the venerable Shadow, the Army's aptly named workhorse drone since 2004. As part of the U.S. Army's modernization efforts, the Future Vertical Lift (FVL) team is seeking a replacement for the long-standing Shadow. What the Army is looking for is a runway-independent UAS with improved ranges and greater endurance, which is easier to use and move around the battlefield, and systems that reduce acoustic signatures to avoid enemy detection.

Martin UAV's V-BAT, which comes in a transportable box, checks all these boxes, with the bonus of being quite safe because it has no exposed rotor blades.

The V-BAT can take off vertically from anywhere and can land repeatedly, precisely and autonomously in an area eight feet-by-eight feet from hovering several hundred feet above. It can even land in the back of a moving pickup truck.

The Army wants improved range, and with the ability to stay aloft for more than eight hours in horizontal flight, the V-BAT takes care of that.

It is also easy to maneuver around a battlefield. It fits inside a transportable case in the back of a pickup truck, providing equipment independence.

Users also cite the extremely reduced acoustic signatures in cruise flight due to the ducted propellers that minimize noise.

Figure 1: V-BAT being readied for launch

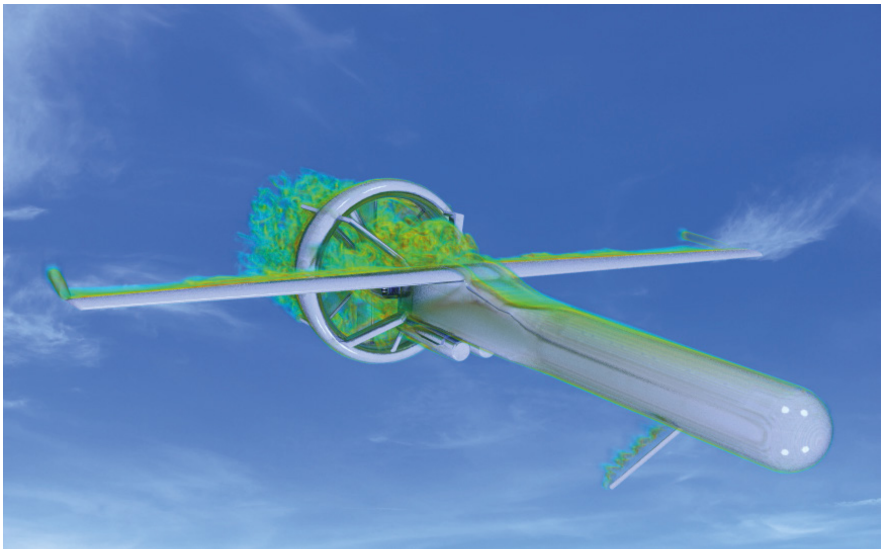


Figure 2: Simulation of the V-BAT aerodynamics with Simcenter STAR-CCM+

Any way you look at it, the V-BAT is easily meeting the expectations of UAS users.

Austin Howard, V-BAT's chief engineer, says, "Where others are stuck adapting existing platforms, the V-BAT is designed from scratch to be the safest, simplest and most tactical UAV in the Group 2/3 space."

Simulation in the V-BAT design
From the start, Martin UAV wanted to build a true vertical takeoff and landing (VTOL) system and not a hybrid. Hybrids spend a lot of electric power getting airborne – power that's lost when it comes to payload carrying capacity. A true VTOL system design has complex challenges, particularly designing for a high thrust for hover while also reducing drag for cruise. In simple terms, you are designing a helicopter and forward-flying aircraft in the same product, except the V-BAT cannot look like either.

Martin UAV's years of industry experience meant the first design was built from lower order tools, handbook methods and experience. The idea was simple – build, test and fly. And it worked, largely in-part due to the genius of the design. In fact, it worked so well the design was operation-test ready for customers.

Martin UAV had loftier goals to achieve the best design possible and turned to Siemens Digital Industry Software's Simcenter™ simulation and test suite of solutions.

Zach Hazen, aerodynamicist for the V-BAT, swears by digital simulation. "Our customers want more payload, more fuel carrying capacity and longer flight time. High-fidelity simulation is a way to stay ahead of their demands,", notes Hazen.

Duct, duct, choose
What makes the V-BAT work so well is the unique ducted-fan tailsitter configuration – the heart and soul of the drone. Ducted fans include a propeller (fan) and a duct, both connected to the fuselage by struts. Behind the rotating propeller lies a stator inside the duct and control surfaces outside that act as an aileron, a rudder and elevators.

Ducted fans are a boon for UAV applications. They can operate safely in closed confines and the environmental and noise footprint is minimal. The enclosed propeller blades act as a shield for noise and blade tip performance losses. Takeoff and hover performance are more efficient with a ducted fan configuration compared to open rotos. In horizontal flight, the ducted fan provides stability as a horizontal tail.

With its many benefits critical to the success of the V-BAT, it is no wonder that getting the V-BAT design right meant getting the duct design right. For Martin UAV, multiple objectives of the duct complicated matters. To achieve the best possible efficiency in vertical hover flight, the shrouded propellers needed a thick cross section to generate enough thrust. On the other hand, reducing the drag in horizontal cruise flight needed a thin propeller cross section to minimize the area of propeller facing air resistance.

How do you design something to be thin and thick at the same time? The answer: design optimization with Simcenter. In simple terms, Hazen needed to analyze hundreds of duct designs to choose the best compromise, something beyond the wildest dreams for any testing.

"When looking at designing a new duct, we looked at quite a few by hand by changing important duct parameters. This was very man-in-the-loop and we analyzed only a handful designs and were less sure of our optimum design," notes Hazen.

Finding the optimum duct design
Martin UAV turned to Simcenter to do this duct optimization. With Simcenter STAR-CCM+, the firm conducted a full computational fluid dynamics (CFD) analysis of the duct performance in hover and cruise conditions, including hover figure of merit and fixed-wing propulsive efficiency.

Hazen remembers the reason for choosing Simcenter STAR-CCM+™ software: "We invited a few companies to validate our product at a known design point and landed with Simcenter STAR-CCM+ because it won the competition. We weren't just looking at the quantitative answers, but also at how their engineers listened and gave answers. We were extremely impressed with the Simcenter support engineers."

In particular, the blade element method (BEM) capability let Martin UAV get a good approximation at a low computational cost by approximating rotor performance characteristics. For higher fidelity analysis of more promising designs, the rigid body motion (RBM) technology enabled analysis with rotating propellers for obtaining detailed, more accurate performance.

"I'm buying a software with an array of tools to give either fast answers covering a lot of the design space with assumptions or perform high-fidelity

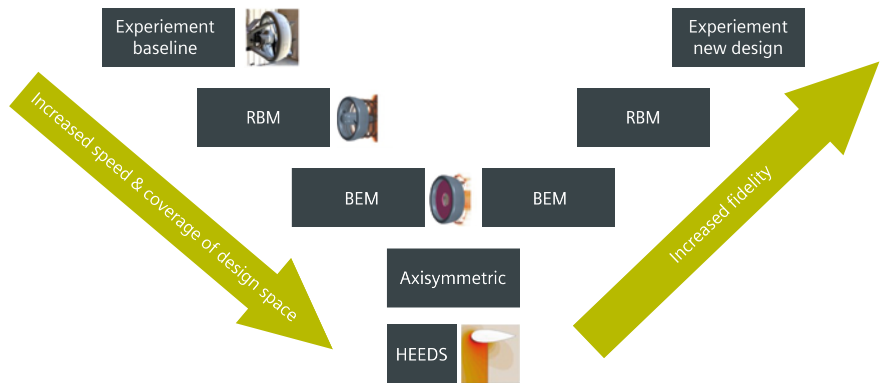


Figure 3: The design optimization process for the V-BAT duct

simulations for detailed answers," says Hazen.

Siemens Digital Industry Software's HEEDS™ software, an automated design exploration tool, was then used to run a full design optimization by changing the duct design to hundreds of configurations intelligently and running the CFD analysis on each. Martin UAV suddenly had the ability to design, analyze and automatically find the optimum duct design that satisfied their multiple objectives.

"With HEEDS, we could iterate through hundreds of designs for several runs of hover and cruise. I was pleasantly surprised at the kind of answers and insights we got," Hazen notes.

With digital duct optimization, Martin UAV found designs that increased the hover thrust by 5.8 percent yet decreased the cruise power by 3.8 percent, which meant there was more capacity for payload and fuel, and longer flight times were possible. The new design makes it all possible.

For a small company with lofty goals, using digital design optimization was a no-brainer and the only way to analyze thousands of duct designs before a single prototype was built.

Designing the future with digital twins

Today, designing a new product without using digital simulation and digital twins is akin to walking into a battlefield without armor or a weapon. Every industry is being disrupted by new business models and technology and engineering a revolutionary product is no different. For engineers and designers like Hazen, the pressure to get innovative products right the first time and provide fast results for customers means deploying digital simulation early and often in the design phase.

Martin UAV and Hazen bought into digital simulation early. The result: a true-VTOL UAV that may end up being a valuable reconnaissance asset for the Army. The V-BAT is already one of the finalists to replace the Shadow. Unsurprisingly, the V-BAT doesn't just have the Army and other military branches buzzing. Additional interest has been expressed for organizations conducting tactical reconnaissance, aerial mapping, shipboard operations, anti-piracy, farming and law enforcement – the applications for a versatile VTOL drone with a reasonable price tag are endless.

In the animal kingdom, bats are the only true flying mammals. Martin UAV's V-BAT is now staking the same claim in the drone kingdom. ■

"We weren't just looking at the quantitative answers, but also at how their engineers listened and gave answers. We were extremely impressed with the Simcenter support engineers."

Zach Hazen
Aerodynamicist
Martin UAV

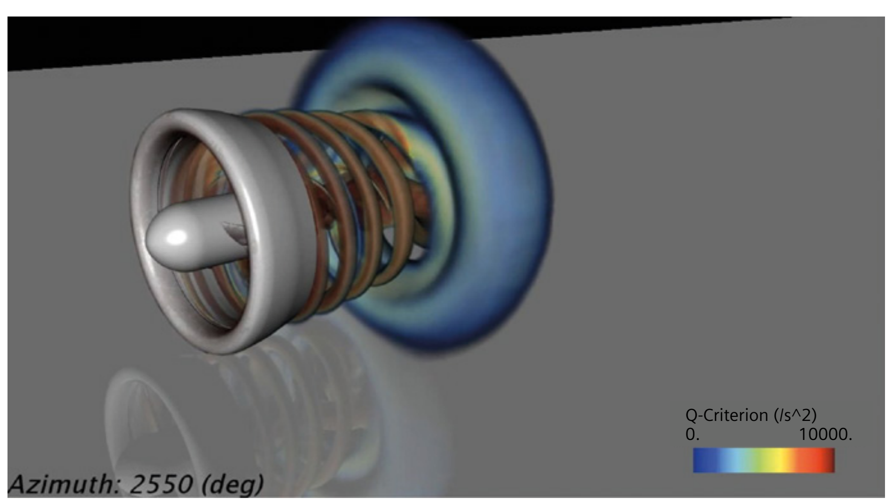
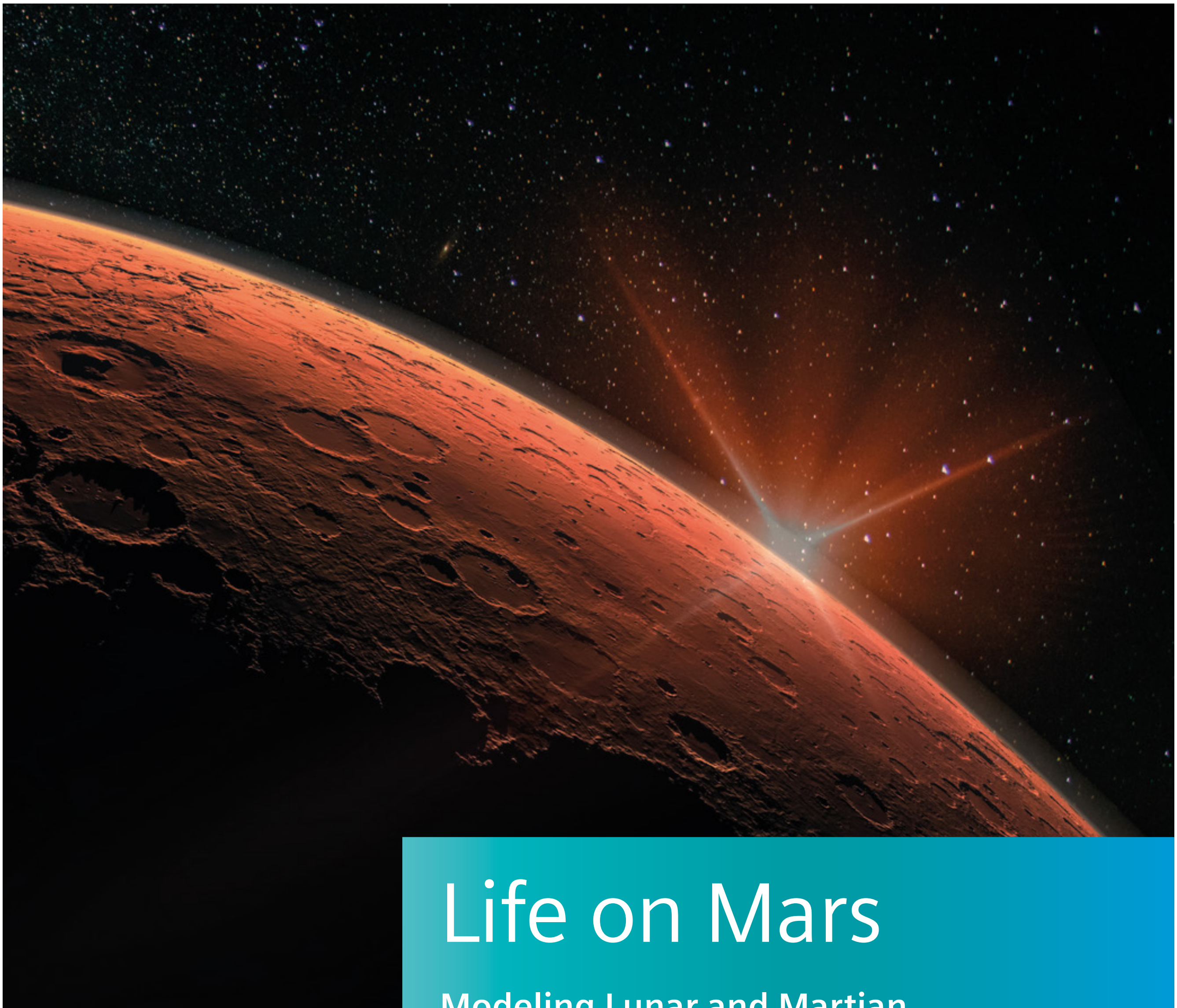


Figure 4: Simcenter STAR-CCM+ simulation showing vortices from one of the optimum duct designs



Life on Mars

Modeling Lunar and Martian Environments with Simcenter 3D Space Systems Thermal

Man hasn't set foot on the moon in almost 50 years but the quest to understand our near neighbors continues. Visiting the harsh environments of the lunar and Martian landscape provides several challenges – the biggest being the temperature differentials. If we are to explore the lunar and Martian surfaces then we need first to be able to design space vehicles capable of operating in these environments.

Many people see landing a person on Mars as the next big challenge for humanity. Returning to the Moon is seen as a precursor to this adventure because it provides opportunities to gain experience in living on other worlds and can potentially reduce the cost of a Mars mission by providing resources that are already outside of the Earth's gravitational pull. This focus means that there is increasing interest in modeling the thermal environments on the Moon and on Mars. In this article we look at the two thermal environments and investigate a number of approaches to modeling them using Simcenter from Siemens Digital Industries Software. Two different scenarios are considered, a lander or stationary rover on the surface and a moving rover.

Thermal effect	Moon	Mars
Direct solar	Yes	Yes
Diffuse (scattered) solar flux	No	Yes (during dust storm)
Atmospheric solar attenuation	No	Yes
Radiation to effective sky temperature	Yes, to deep space	Yes, time varying
Albedo	Yes	Yes
Surface vehicle interaction (radiation)	Yes	Yes
Convection	No	Yes

Table 1: Surface vehicle thermal effects

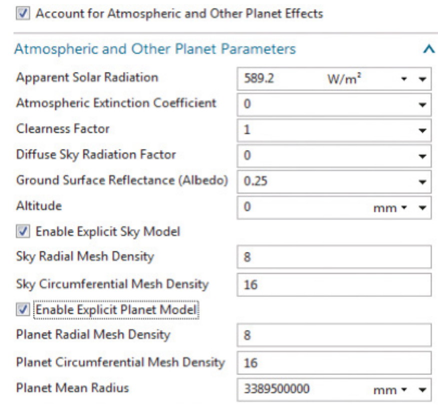


Figure 1: Atmospheric and planet surface form

The lunar environment has no atmosphere and the Martian atmosphere, compared to the Earth, has very low atmospheric pressure. The lack of atmosphere on the Moon results in a large temperature variation with latitude, at the equator this can be as high as 100 degrees Celsius (°C), down to -200°C at the poles. With the lunar day lasting 29.5 Earth days and a two-week night, any vehicle on the lunar surface will reach likely thermal equilibrium with its surroundings. The vehicle will cause shadowing which will result in local cooling of the surface to very low temperatures. Since the vehicle will be radiation cooled, these cold shadowed regions can result in lower vehicle temperatures.

Despite the low pressure in Mars' atmosphere it still has a significant impact on the thermal design of vehicles bound for Mars. This atmosphere results in some convection heat transfer from vehicle surfaces and, more significantly, results in dust storms that considerably change the transparency of the atmosphere. The results are a reduction in direct solar illumination, an increase in diffuse sky illumination and in sky temperature. The first effect will result in a decrease in vehicle temperature, the others lead to an increase in temperature. Detailed analysis is required to determine the overall effect. The Martian regolith is a better thermal conductor than the lunar regolith, but there is still significant interaction between a vehicle and the planet surface.

The surface vehicle thermal effects are shown in table 1.

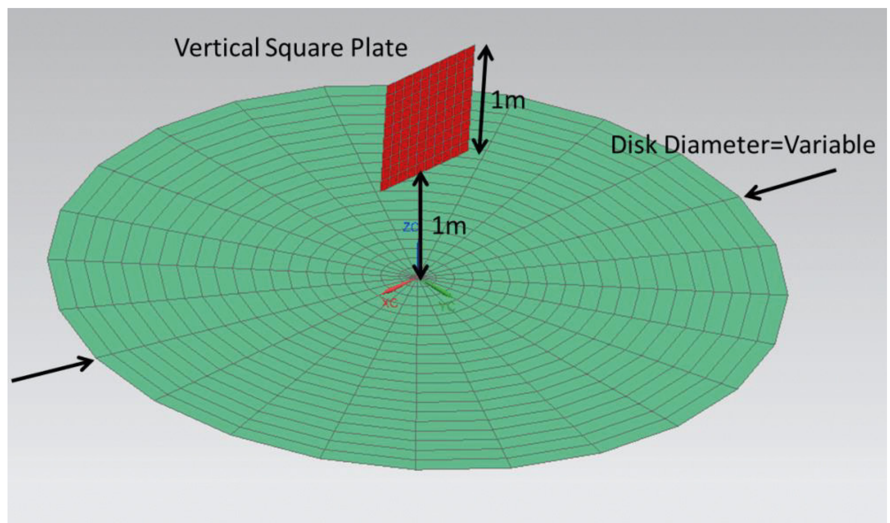


Figure 2: Simple plate over disk model

The presence of atmosphere on a planet also means that convective heat transfer may need to be addressed. For a terrestrial model, free convection and radiation are typically of similar order of magnitude. If the air is moving because of wind, for example, then convection begins to dominate the heat transfer. On Mars, radiation is typically the dominant mode of heat transfer but convection is still significant. The most accurate method of modeling convective heat transfer is with computation fluid dynamics (CFD). This can provide very accurate modeling of convection, but requires a very detailed model with a very fine mesh (compared to a typical spacecraft thermal model) and is typically overkill for a situation where convection is not the dominant mode of heat transfer. A simpler, and more practical, approach is to simply specify a heat transfer coefficient and atmospheric temperature for any

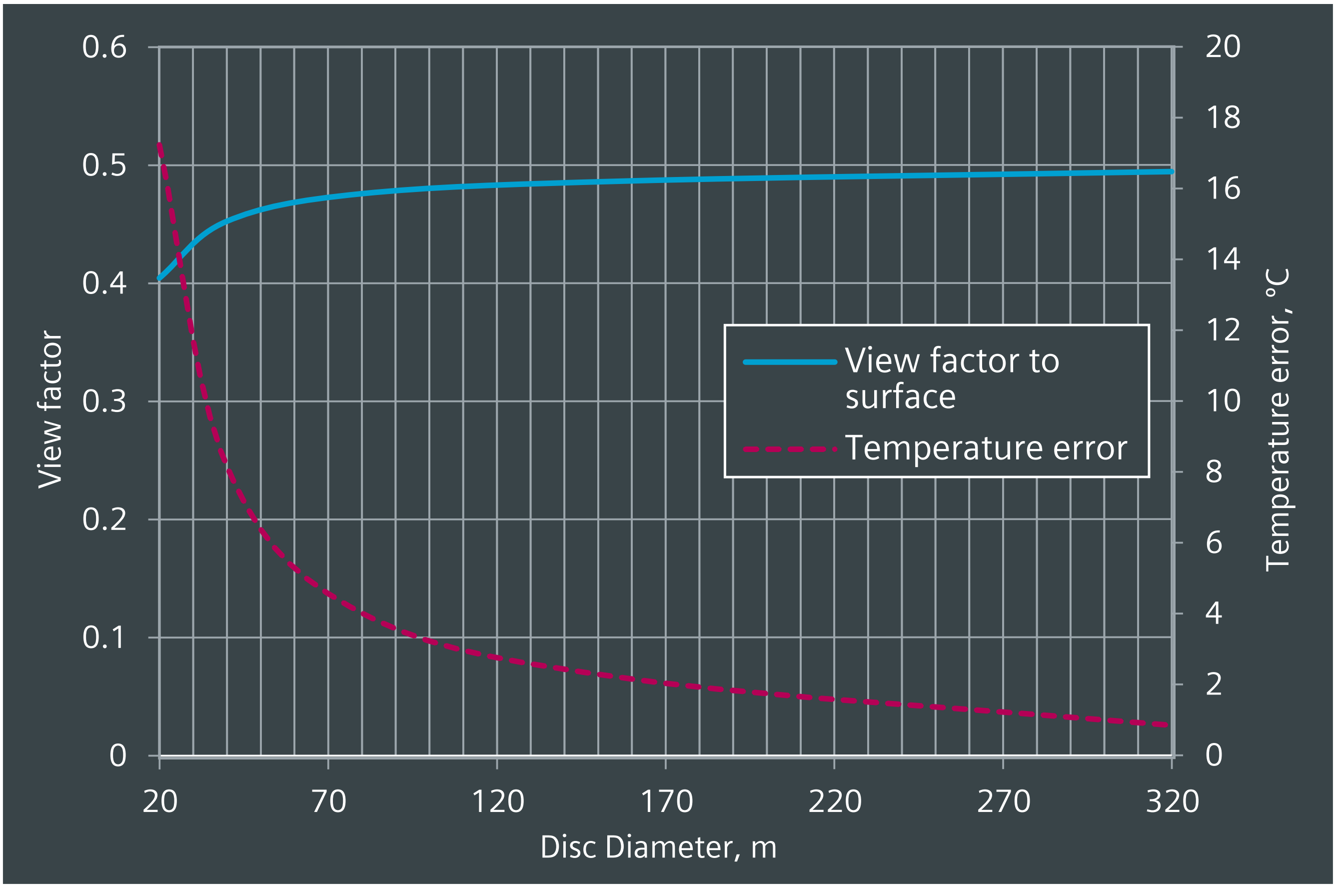


Figure 3: Effect of lunar surface disc diameter

	Initial Temperature (°C)				
Latitude	Fluff	Layer 1	Layer 2	Layer 3	Layer 4
0	-105	-42	-27	-27	-30
30	-111	-52	-37	-39	-40
45	-119	-62	-51	-51	-52
75	-146	-108	-101	-102	-102
85	-167	-142	-137	-137	-137

Table 2: Suggested initial temperatures for transient runs

exterior surface. A suitable heat transfer coefficient can be determined from published work or from hand calculations using empirical formulae.

Surface-vehicle interaction occurs because the vehicle shields part of the planet surface from the solar input and the Infrared (IR) emissions from the vehicle can cause local heating of the planet surface. On Earth, the atmosphere and moisture in the soil moderate these effects, but on a planet with no atmosphere and a low thermal conductivity regolith these effects can be significant.

Simcenter offers a space solution that includes a diurnal heating option that allows most of these effects to be included in a model. Selecting the planet fills in the form with reasonable values but these can be overridden when required. (Note that the moon is referred to as a planet in this article for convenience).

A simple model was built consisting of a one meter square, vertical plate over a horizontal disk. The plate was centered on the disk with the bottom edge one meter above the disk, see figure 2. Disk and plate were perfect black bodies which radiated to each other and the space environment. Using the exact view factor for a small plate level with a sphere, a one meter square vertical plate one meter above the surface of the moon will have a view factor to the lunar surface of 0.4993. If the lunar surface is at 400 kelvin (K), (typical maximum at the equator), the plate will be at 336.2K. The model was solved for various diameters of disk and the average plate temperature determined and used to calculate the view factor to the disk. The results are shown in figure 3. For the equatorial region a disk diameter of about

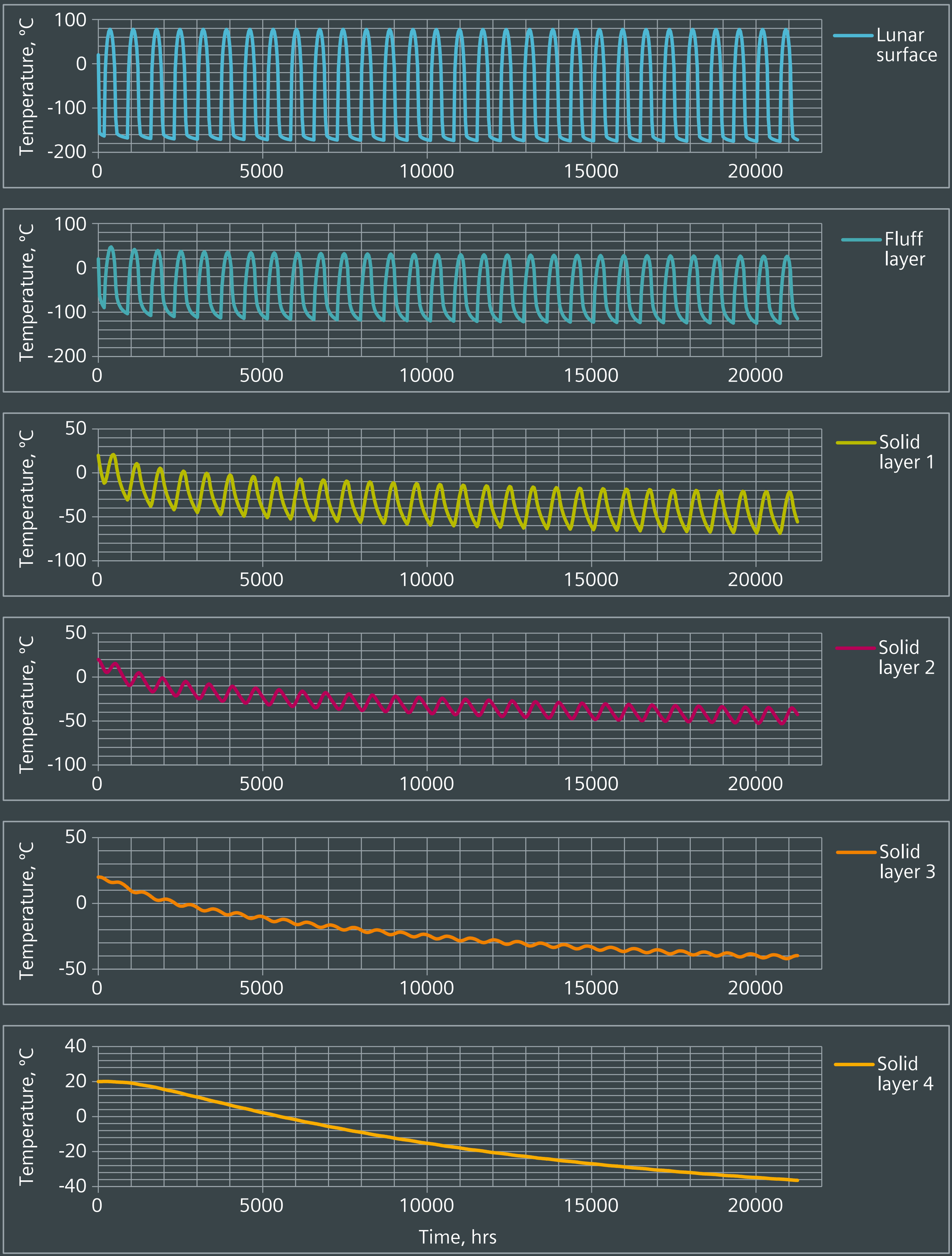


Figure 4: Lunar surface layer temperatures at 45° Latitude computed over 30 lunar days.

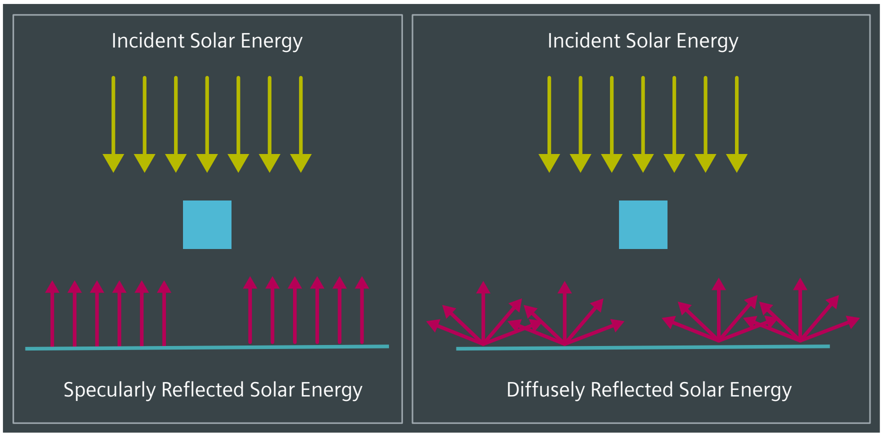


Figure 5: Specular and diffuse reflection onto bottom face

300 meters (m) is required to get within 1 K of the correct temperature. At higher latitudes, or at night, the disk size r equired for a given temperature error will be smaller as the cooler surfaces means that the difference between deep space and lunar surface temperatures is reduced.

To represent the lunar surface and its properties, there is a single layer of solid elements to represent the fluff layer and four layers of solid elements to represent the regolith. The regolith layers have increasing thickness with increasing depth. The thicknesses are: fluff, 20 millimeters (mm); regolith 60mm, 80mm, 160mm and 320mm to give the total of 620mm.

Whilst the model is very detailed, and the results correlate well with measured lunar temperatures, it does have some disadvantages:

1. For a steady-state analysis, the temperatures of the lower layers are not accurate. Given the relatively long lunar day, objects on the lunar surface are often very close to steady state equilibrium; therefore, steady state analysis is valid. The lowest layer included in the model is essentially isothermal throughout the lunar day and its temperature is determined by the average solar flux received at the top layer during a lunar day. In a steady state analysis there is either full sun or no sun and the resultant temperature will not be correct. This can be mitigated by fixing the temperature of the lower layer, but the problem still exists in the layers above, although to a lesser extent.
2. Transient runs require a long time to converge. Figure 5 shows the layer temperature from a transient analysis of a patch of lunar surface. The model was run for 30 lunar days (over two Earth years) and the lower layers are not at their final temperatures. This problem can be mitigated by assigning valid initial temperatures to each layer. Suggested initial temperatures for a number of different lunar latitudes are given in table 2.

From figure 5 it can be seen that the temperature of the lunar surface reaches its correct, periodic, temperature very quickly and does not appear to be significantly affected by the temperature of the lower layers. Since a vehicle on the surface will only interact with the surface layer, this suggests that it may not be necessary to model all the layers.

The lunar surface model was run in two additional configurations, with only the fluff and surface layers and with only the surface layer. Figure 6 shows the temperature of the lunar surface at 45° latitude when modeled in all three configurations. The daytime temperatures are not significantly affected by how many layers are used in the model, however, the night time temperatures do show significant variation. Modeling just the fluff and surface layers results in a lunar surface temperature that is 30°C below the temperature predicted by the full model. Modeling just the surface layer gives a lunar night temperature 100°C below that predicted by the full model. For a vehicle in operational mode where all surfaces are relatively warm, the changes in the much colder, surface temperatures from using the simpler model may not be significant and the model using just the fluff and surface layers would be acceptable. For a detailed, night survival analysis, it would be prudent to use the full model.

Demonstration of the calculation of the solar loads was performed with a simple model consisting of a one meter black cube, with its lowest face horizontal, one meter above the planet surface. For this case, the lunar surface was assumed to have a solar absorptivity of 0.8, a diffuse reflectivity of 0.1 and a specular reflectivity of 0.1. The simplest validation case was at a latitude of 0°. The values of the direct and reflected fluxes were compared with hand calculations where possible. It was found that the direct solar fluxes were being correctly calculated.

For validating the calculation of the reflected solar fluxes, the bottom face was examined. This face experiences only reflected solar energy with reflections being either diffuse or specular. The reflected solar fluxes were hand calculated, with some approximations, for comparison with the Simcenter results. Treating the lunar surface as a very large flat plane, figure 5 shows specular and diffuse reflections.

The direct solar loads are applicable to both lunar and Martian environments.

Simcenter space solutions were used to model lunar and Mars surface missions. A detailed model of the lunar surface was described and evaluated along with some variations. It was shown that for some mission analysis it is only necessary to model the surface and fluff layers (the top 20 mm) of the lunar surface, but for a detailed night survival analysis, the full model is recommended. Transient runs of the lunar surface model take considerable time for the temperatures of the lower layers to stabilize. This can be avoided by selecting appropriate initial temperatures. Suggested values are provided for a number of latitudes. The calculation of solar fluxes with and without atmospheric attenuation was demonstrated. A lunar surface model with a simple cube included specular reflection effects and a Mars model with a simple plate showed the impact of including atmospheric effects.

This article is a summary of the whitepaper:

Modeling Lunar and Martian Environments with Simcenter 3D Space Systems Thermal

Armin Veshkini[1], Kevin Lee[2], Chris Jackson[3], Christopher Pye[4], Maya HTT Ltd., Suite 400, 4999 St. Catherine W., Montreal, QC, H3Z 1T3 ■

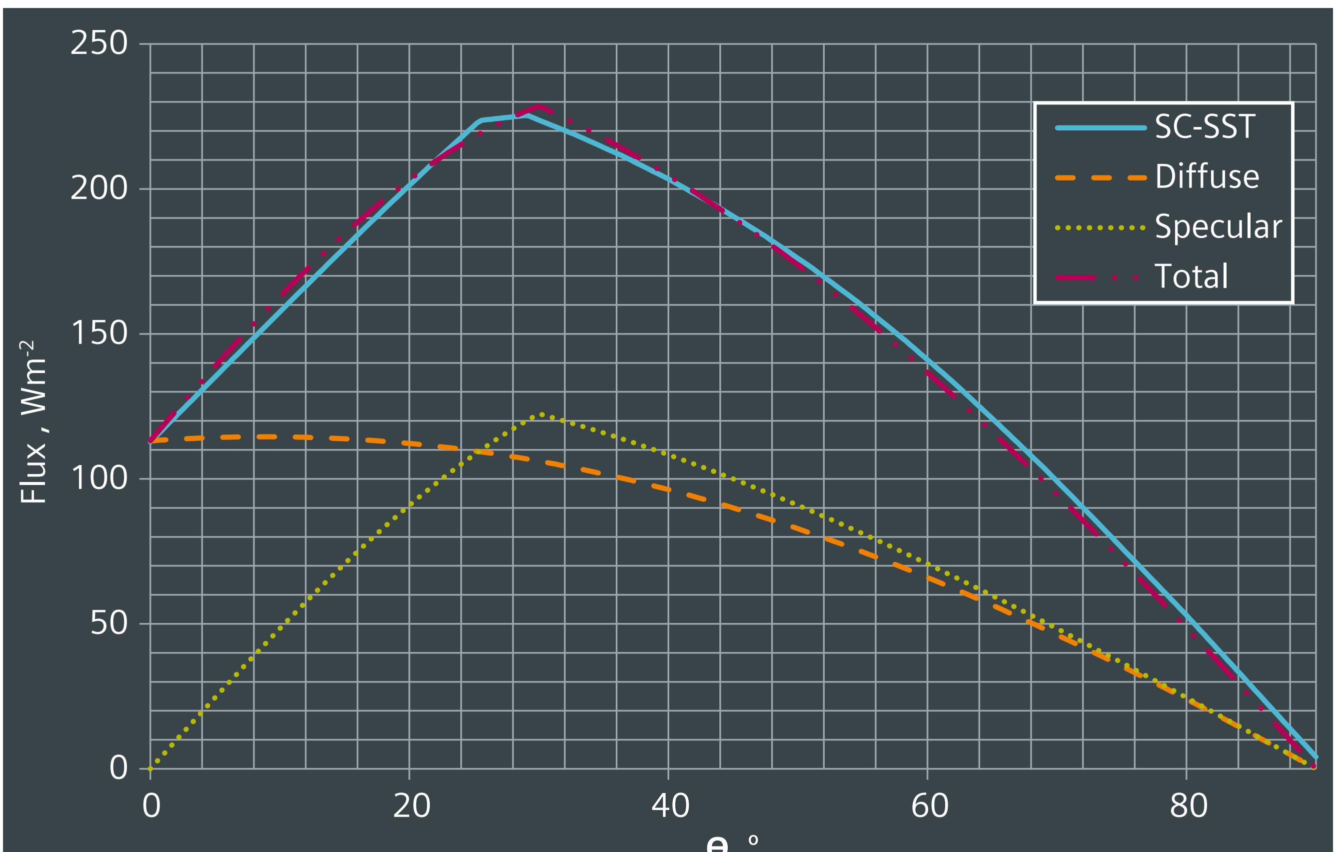


Figure 6: Lunar cube bottom face solar fluxes.

Efficient durability testing by Roush Industries Inc.

Global auto engineering company uses Siemens solutions for efficient durability testing

Roush opens new end-to-end testing possibilities with Simcenter solutions

Seeking solutions for durability testing
Detroit, Michigan-based Roush Industries, Inc. (Roush) provides engineering, testing, prototype development and manufacturing services to the mobility industry. The company also offers support services to the aerospace, defense, theme park, oil and gas, and motor sports industries.

In 2017, Roush completed their portfolio with durability testing capabilities by implementing Siemens Digital Industries Software's Simcenter™ SCADAS hardware to retain their market position and expand their offerings to their customers.

"Most of our work consists of consulting services and providing support to all big three U.S. automotive manufacturers as well as many other international OEMs," says Paul Riehle, vice president of CAE, NVH, Durability, and Additive Manufacturing at Roush. "Durability seemed like a logical area to expand. There is a shortage in terms of the capacity, which showed us that the investment of the MTS 329 rig made sense. And while we were doing that, it enabled us to expand to another durability-type test rig that we have been traditionally outsourcing to other companies. This brings everything into one location, all under Roush."

Roush is not a novice user of Simcenter solutions. In fact, the noise, vibration and harshness (NVH) team has extensive experience and knowledge using Simcenter™ Testlab™ software.

"Roush has been using Simcenter tools for about 30 years," says Riehle. "We have been very successful using Simcenter Testlab and experienced very good alignment with our large customers. And as the business grew, we started to use other Siemens products such as Simcenter Amesim, Teamcenter and Simcenter Nastran and added a lot of extensions of Simcenter Testlab. But not only the software, we also added a

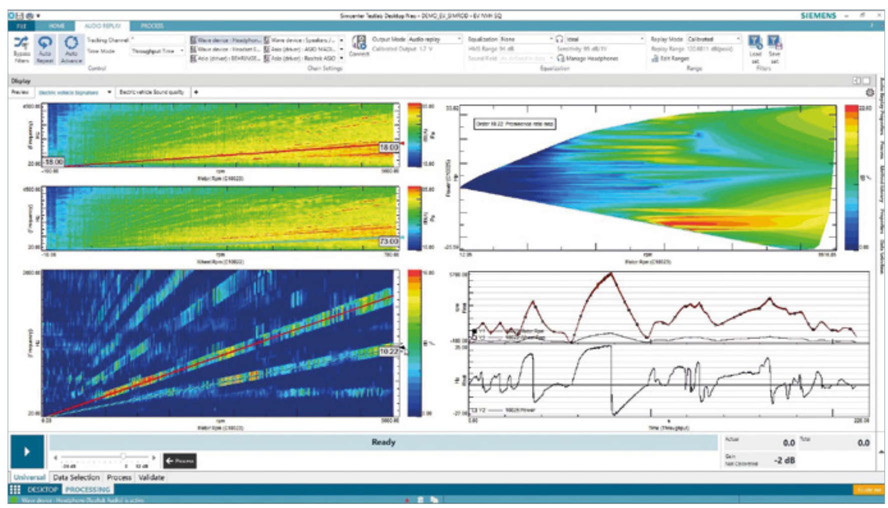
lot of hardware for data acquisition, which really allows us to streamline our processes and provide turnkey solutions for our customers."

Advanced durability testing facility
Roush recognizes the shifting requirements for durability testing as automotive manufacturers continue to lighten vehicle weight to achieve better energy efficiency while searching for durable materials to increase vehicle life expectancy. And at the same time, the electrification trend results in heavier cars due to battery weight.

"This is changing traditional designs by adding new stresses to the chassis and suspensions," says Gerald Roesser, Manager, Advanced Durability Lab, Roush. "Same as the autonomous vehicles, these are expected to take much higher duty cycles. There will be different durability challenges." In a rapidly evolving market, the demand for accelerated durability testing is increasing.

To help their customers, Roush deployed different durability testing systems to provide testing services on different levels: full vehicle, or component level, in all different development phases from prototype testing, production and validation.

"One of the critical advantages of this lab is that we are able to test the full vehicle on the proving ground condition much



earlier in the development cycle," says Roesser. "In fact, no running vehicle is needed. We can test either the full vehicle prototype or prototype chassis or suspension on a running vehicle. We collect those road loads, play them out on the rig and match that data."

All testing rigs at Roush, including the new Model 329 road simulator from the MTS corporation, work in conjunction with Simcenter SCADAS hardware and Simcenter Testlab with Simcenter Testlab Neo software. This testing platform provides complete end-to-end durability testing capabilities, from data acquisition to a detailed load data analysis. Simcenter Testlab Neo compiles advanced capabilities to gain valuable and precise insights to optimize the durability performance of the next

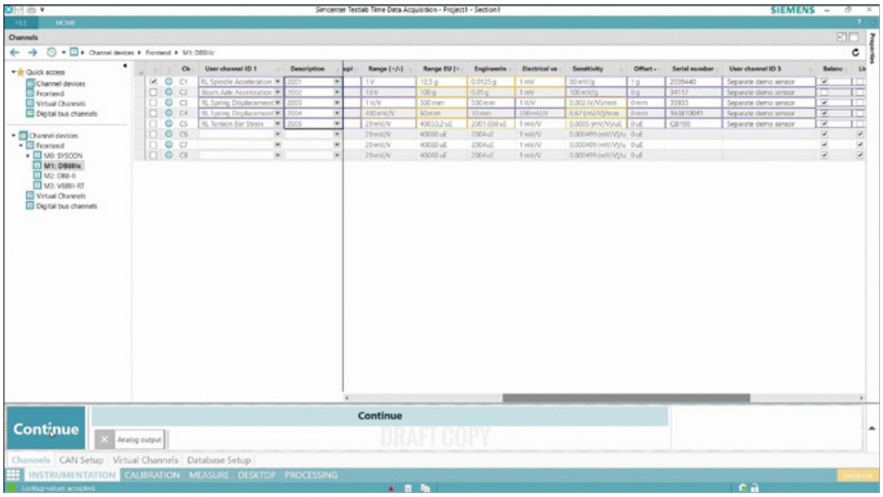
product generation designs. It also supports the damage equivalent creation and accelerated test profiles. And to boost the efficiency of the testing teams, this software embeds standardized procedure reports to ensure consistency and data quality.

"In this advanced durability lab, we also use Simcenter Testlab Neo and its time data acquisition module, which is very useful for us," says Roesser. "We can take the data systems in the field and use the software to set up the instrumentation and all the transducers. Upon completion, we can bring the very same format back into the lab and everything is ready to go. We don't need to reprogram any calibration or sensors. It's just plug-and-play."

Having this framework in place, Roush offers a turnkey solution for durability testing in earlier stages of vehicle development. "It's really about enabling our customers to gain more time to do durability testing, but perform each stage much faster," says Roesser."

One platform, multiple testing teams

Expanding the testing facility requires a strategic decision on the testing



platform. Management must evaluate the cost, expected integration and learning curve. To streamline and build upon the existing know-how and positive experience is a crucial factor in the decision-making process.

"We evaluated and owned many other systems for data acquisition and simulation tools," says Riehle. "Over time, it became apparent that it is much more efficient for us to operate under one setup of solution of software and data acquisition tools, such as Simcenter offers. It provided us a lot of benefits. Simcenter helped us gain operating efficiency and closer alliances with customers."

This approach allows Roush to benefit from easier consolidations, trainings and data transfer. Troy Bouman, NVH Project Manager Engineer, Roush, says, "One of the great benefits of Simcenter Testlab is the ability to leverage it across different teams. In our NVH group, where we have extensive experience, the durability team can easily approach us with questions, problems or new ways to process data. When we try to acquire data from hundreds of channels, they have a lot of knowledge in that room. We can leverage that knowledge base across the different teams to execute and bring new value to the customer."

The utilization of unified testing platforms enables easy hardware exchange. Bouman explains, "For example, if the durability colleagues need more channels, I can let them borrow our Simcenter SCADAS front-end hardware, or the other way around."

Software benefits for all teams
Bouman values the extensive functionality span of the software as it can be used for standard as well as complex new tests. "As an advanced user, I can read the technical documentation and understand exactly what the software is doing," says Bouman. "But in the same software I can write a pre-written simplified standard test the technician can follow. To have one software that can tackle both simple standard tests and complex tests is very valuable."

Other benefits of the software that both teams appreciate is its user-friendliness, ease of setup, data quality check and processing speed. With Simcenter Testlab Neo, both teams can efficiently cover the increasing demand for high channel-count testing.

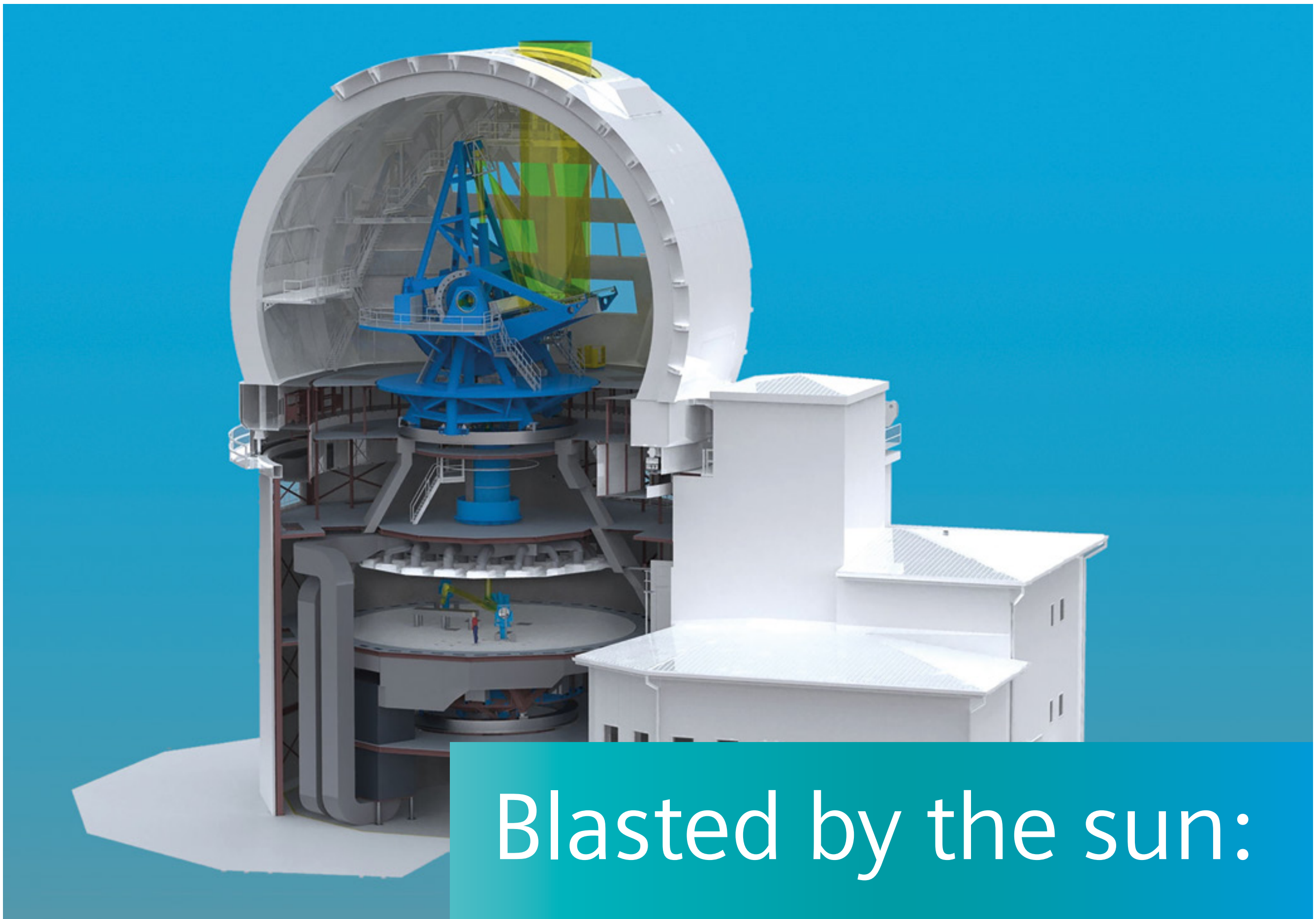
"When a test engineer needs to check and analyze hundreds of different channels, the ability to check the data with time domain in Simcenter Testlab Neo is a significant advantage," says Bouman.

Future outline of durability testing at Roush
Roush has a clear vision for their future plans. They intend to create a testing environment that leverages simulation to acquire road load data without going to the proving ground.

"One of our primary goals is to support hardware-in-the-loop testing," says Roesser. "The idea is to take a scan of the proving ground and plug it into the rig and collect those real-world responses." ■

"Simcenter helped us gain operating efficiency and closer alliances with customers."

Paul Riehle
Vice president of CAE, NVH, Durability, and Additive Manufacturing
Roush



Blasted by the sun:

Thermacore cools the world's largest solar telescope

by Stephen Ferguson, Siemens PLM Software

Currently under construction on the Pacific Island of Maui, the 41.5 m tall Daniel K. Inouye Solar Telescope (DKIST) will be the world's largest solar telescope. Once operational, the DKIST will be able to provide the sharpest views ever taken of the solar surface, which will allow scientists to learn even more about the sun and solar-terrestrial interactions. The DKIST will allow astronomers to resolve the extremely small, violently active, magnetic fields that control the temperature of the corona and the solar wind that produce flares and x-ray emissions, and help to improve prediction of the way these "space weather" phenomena influence the earth.

The telescope is currently being built atop the Haleakala volcano on the Pacific island of Maui, which was chosen from a list of 72 possible global locations after two years of monitoring daytime visibility conditions. Haleakala has the darkest, clearest skies, and its tropical location and elevation mean that the telescope sits above the turbulent inversion layer so there is little turbulence to blur its view or moisture to block the infrared spectrum.

At the heart of the telescope is a huge 13ft (4m) primary mirror which, when combined with adaptive optics technology that reduces the amount of blurring from earth's atmosphere, produces images

33 times sharper than those of common telescopes. The resolution of the DKIST is comparable with space telescopes, but at a much lower cost and with the benefit of greater accessibility. Unlike a

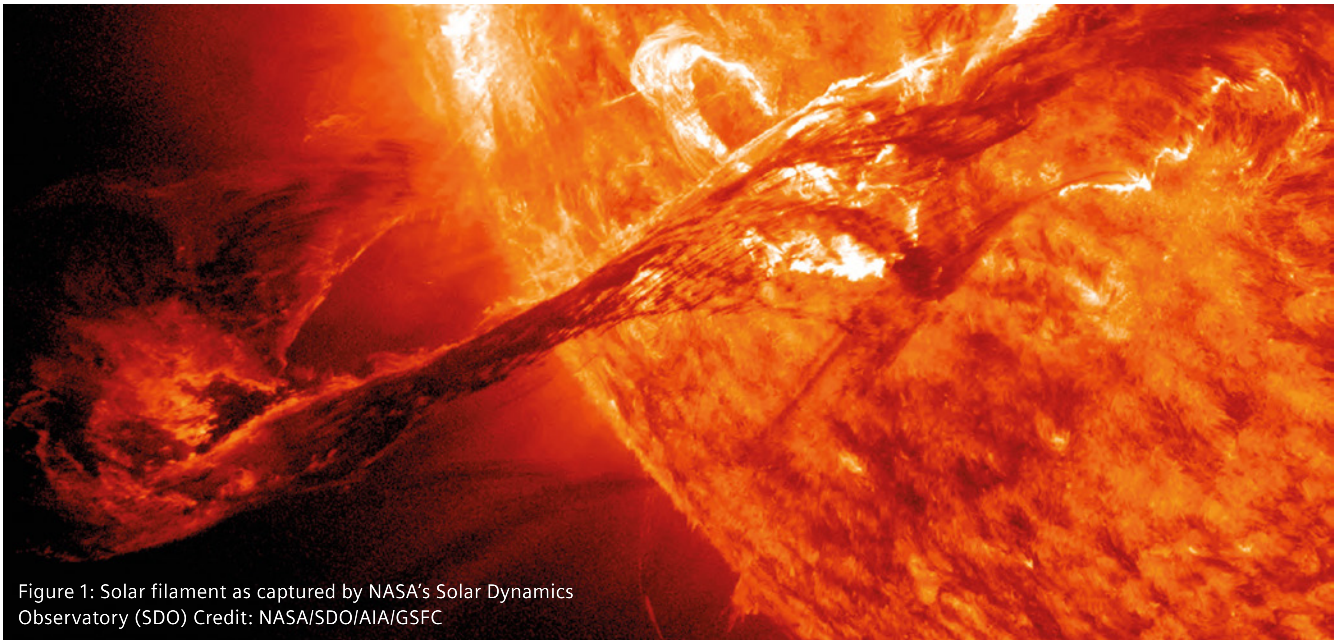


Figure 1: Solar filament as captured by NASA's Solar Dynamics Observatory (SDO) Credit: NASA/SDO/AIA/GSFC

space telescope, it will be relatively easy to upgrade the technology of the DKIST throughout its lifetime.

A solar telescope-specific problem is the heat generated by the tightly-focused sunlight. Unlike most large ground-based telescopes, which are used at nighttime to capture a small number of photons from distant astronomical bodies, the DKIST will spend its working life pointed directly at the sun, absorbing large quantities of focused light and heat energy.

A heat stop is an integral part of the design of solar telescopes, and represents one of its larger engineering challenges. It performs the role of what is called a "field stop" in a conventional telescope, limiting the field of vision to the area with minimal distortion. Located at the prime focus, the heat stop prevents unwanted solar disc light from heating and scattering on subsequent optics. In a solar telescope such as the DKIST, in addition to blocking light, the heat stop must also dissipate huge amounts of thermal energy.

For the upcoming DKIST, the heat load is 2.5 MW/m^2, reducing the heat load on subsequent optics from an enormous 12 kW to a minuscule 300 W (a reduction factor of 40). Designed by Thermacore, the heat stop assembly is actively cooled by an internal system of porous metal heat exchangers that dissipate

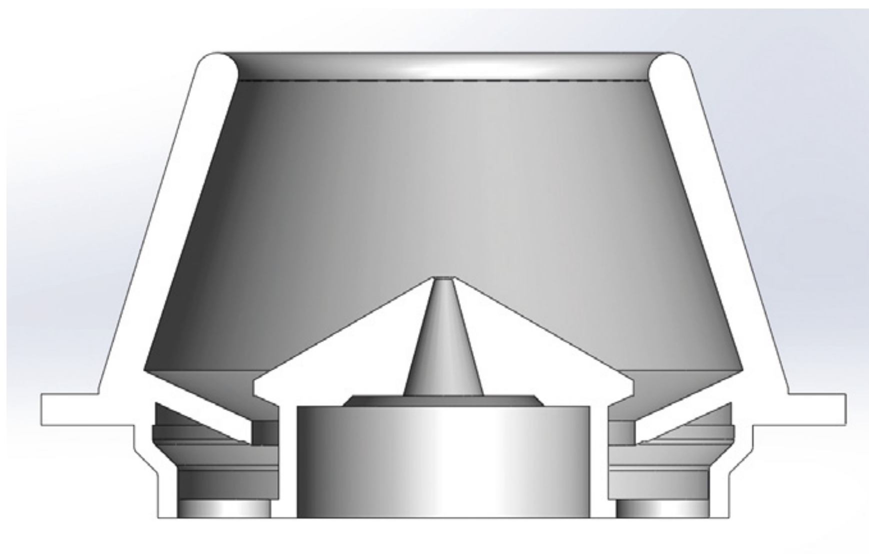


Figure 2: Located at the prime focus, the heat stop limits the field of vision of the telescope and absorbs large amounts of solar energy, preventing it from reaching subsequent optics.

approximately 1,700 W at peak operating load (see side box for a discussion of porous metal heat exchangers).

The heat stop must not only be able to survive this heat load (without cooling, the heat stop reflector would last only about 30 seconds before catastrophic failure), but also must remain cool enough not to induce any additional turbulence inside the telescope's dome.

One of the obstacles of ground-based astronomical observatories is a phenomenon known as "self-induced seeing." It consists of the degradation of image quality, mostly resulting in an

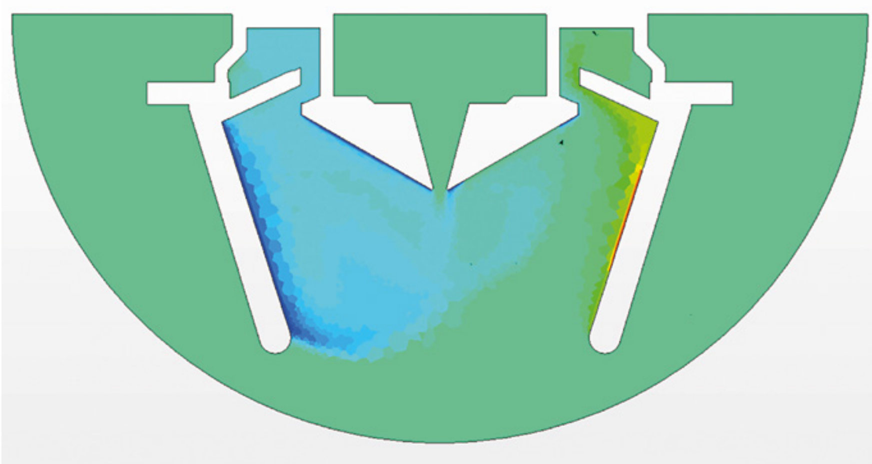


Figure 3: The heat stop must dissipate 1,700 W at peak operating load, without ever allowing the surface temperature to rise by more than 10˚C over ambient.

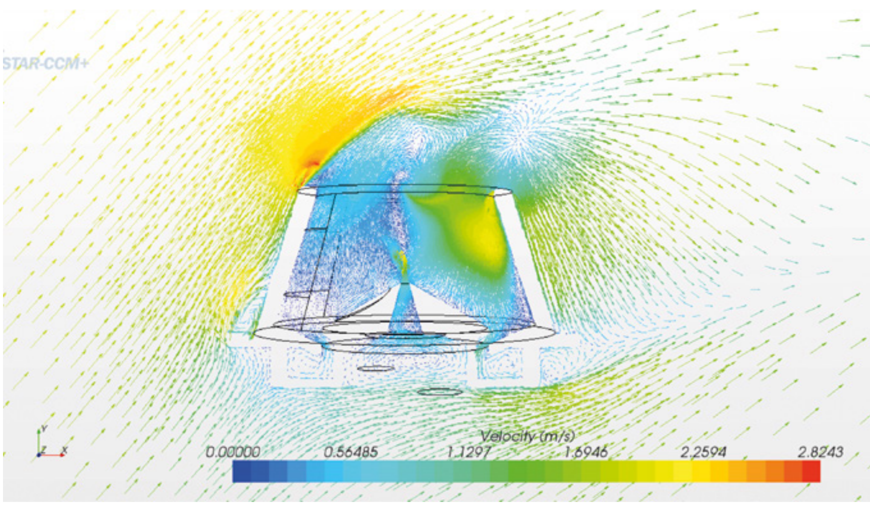


Figure 4: Limiting air disturbance, whether thermally generated or as a result of the wind, plays an important role in reducing "self-induced seeing".

increased blurring of objects and a reduction of contrast in long exposure images. This occurs when thermal and wind disturbances create fluctuating layers of refractive indices within the optical beam path. With this in mind, a small hot object in close proximity to the secondary mirror could have potentially disastrous consequences for the accuracy of the telescope. A key requirement for the system is that the surface temperature of the heat stop must never be more that 10°C higher than the temperature of the ambient air so as to prevent buoyancy-induced flows from creating turbulent disturbances that would result in "self-induced seeing."

As part of the design process, hermacore was required to demonstrate the efficacy and robustness of their heat stop cooling system across the full range of potential operating conditions, as well as in some "failure mode" scenarios in which the failure of some other component had resulted in the telescope being aligned outside of its design range.

The surface temperatures (and generated flow around the heat stop) depend on a number of interacting physical phenomena. In simulating the heat stop assembly, the Thermacore engineers had to take into account multiphase flow within the porous metal heat exchangers, conjugate heat transfer through the heat stop assembly and the interior wick structure, and both natural convection and radiation heat transfer around the heat stop.

Although some of these configurations provided lower direct thermal loading, Thermacore engineers needed to demonstrate that asymmetries in thermal loading would not lead to local "hot spots" that might generate additional buoyancy-driven flow patterns (the potential source of a "self-induced seeing" problem). Using Simcenter STAR-CCM+, the Thermacore engineers were not only able to fulfill the design criteria demonstrating that the surface temperature of the reflector could be kept below 10°C above ambient, but they also demonstrated that the criteria was sensible by visualizing the flow patterns generated within the enclosure as a result of natural convection.

The Thermacore team also examined the influence of various atmospheric wind loading scenarios, predicting flow patterns and heat transfer across a range of possible flow orientations, demonstrating that surface temperatures and turbulence levels would not exceed design criteria.

All about porous metal heat exchangers

The past decade has witnessed a significant growth in the number of applications for a new category of heat transfer device known as "porous metal heat exchangers." These devices, when used in conjunction with a pumped single-phase coolant or a pumped gas, employ a porous layer of a thermally conductive medium beneath the heat transfer surface to effect efficient heat transfer. In this device, convective heat transfer to the selected coolant combines with the "fin effect" produced by the large surface area of the conductive porous structure to produce efficient heat transfer. A porous media heat exchanger can be used to dissipate very large heat fluxes, such as those encountered in this solar telescope, or can be used to provide very efficient heat transfer at much lower heat fluxes.

The increased surface area, however, is obtained at the expense of increased flow resistance or pressure drop. To overcome the constricted flow paths, multiple closely-spaced inlets and outlets are used. For example, a section through the wall of a porous metal heat exchanger is illustrated schematically above. In a scale drawing, the circles, which represent grains of metal powder, would be many times smaller than shown. The pore sizes are sufficiently small to prevent a flow "short-circuit" near the walls. The thickness of the porous structure depicted below is typically on the order of 0.020-0.050mm.

A significant effort has been made in recent years to improve the fundamental understanding of convective forced flow heat transfer in porous metal heat exchangers, which has resulted in improved understanding of governing principles and has thus opened new applications for these devices such as cooling the DKIST solar telescope.

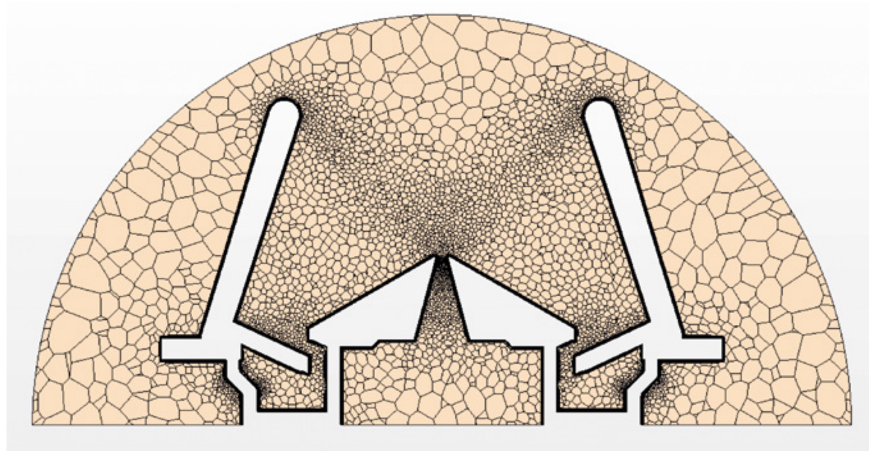


Figure 5: A polyhedral mesh (including fine prism layers) of the fluid space around the heat stop

About Thermacore

Founded in 1970, Thermacore specializes in the custom design, development and manufacturing of innovative, high performance thermal management and material solutions. Thermacore's thermal management solutions can be found at both the system and component levels for a variety of OEM applications in the military, aerospace, computer, communications, industrial, government and medical, test equipment markets. With intellectual property (over 100 patents), trade secrets and professional staff (over 50 engineers), Thermacore applies this know-how to solve complex thermal problems for their customers and help to enable their customers' products.

Thermacore has the industry's broadest collection of thermal management technologies, products and services, which include: k-Core encapsulated Annealed Pyrolytic Graphite (APG) based solid conduction heat spreader assemblies and thermal straps (all metal and k-Core based); passive two-phase devices such as heat pipe assemblies, vapor chamber assemblies, thermal ground planes, loop heat pipes, extreme temperature heat pipes, CCHP and VCHP Spacecraft heat pipes, and more; liquid cooled cold plates; aluminum vacuum brazed assemblies, cold plates, heat exchangers, chassis; pumped single and two-phase liquid systems; Intelligent Thermal Management Systems (iTMS); rugged liquid cooling systems (rLCS™); and enclosure heat exchangers. Other unique capabilities include the ability to develop custom refractory metal alloys, cryomilled aluminum and magnesium, and material characterization and testing services.

Thermacore brings unparalleled engineering design expertise and thermal management solution performance, quality, and reliability to help enable our customer's products and services. Thermacore employs more than 175 employees at six facilities located in the United States (Lancaster, Pennsylvania; Langhorne, Pennsylvania; Ronkonkoma, New York; Pittsburgh, Pennsylvania) and the United Kingdom (Ashington, Northumberland). Thermacore facilities are certified to the AS9100, ISO 9001 and ISO 14001 standards.

For information about Thermacore, visit www.thermacore.com

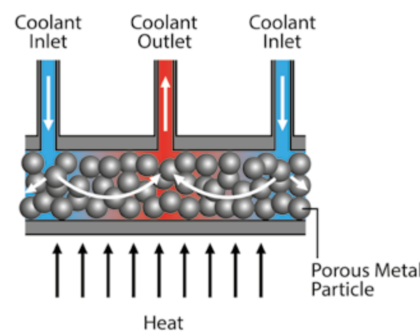


Figure 6: Section through the wall of a porous metal heat exchanger

Securing piping in the process industry against pressure surge

by Dr. Thomas Thiemeier, senior consultant, consilab GmbH and Marc Köbke, computational flow engineer, consilab GmbH

Many plant design engineers think there are no pressure surge problems in process plants, since pipes are short and thin compared to cross-country pipelines. But this is not true! Although incidents caused by pressure surge are not as frequently reported – they do occur. About 5 incidents are known within 10 years at Frankfurt-Höchst Industrial Park (damages, partly with release of substances). One such incident occurred on a system as depicted in figure 1 where the pipe partially left the rack bridge.

The 24", 65 m long pipe was being pumped with waste water via a pipe bridge. The high flow rate of nearly 3000 m^3/h resulted in a high flow velocity of 2.8 m/s. When the valve 1 downstream of the pump was closed, a negative pressure surge occurred causing a pressure impulse. The instrumentation measured a peak value of 8 barg – the real peak value probably was not detected, due to the slow scanning rate or placement of the sensor. The resulting forces on the pipe supports were strong enough to damage these and to push the line partially off the rack!

Experts at consilab GmbH have relied on Simcenter™ Flomaster™ for more than a decade to address this challenge. In this text, we will discuss the methodology utilized to screen the appropriate piping for surge analyses and assess appropriate techniques that can be conveniently deployed by customers to mitigate undesired pressure pulses in their systems.

consilab GmbH is a renowned consulting and laboratory company based in Frankfurt, Germany and working with multiple process companies in Europe on the following themes:

- Process safety: Obtaining safety relevant parameters for substances and chemical reactions
- Consulting: Expertise on safety concepts and safety assessment, incident investigations
- Safety relevant calculations: Pressure relief devices and general piping networks, consequences of release of hazardous substances, design of mitigation measures.

Pressure surge in process piping

If a liquid flows through a pipe with an initial flow velocity v0, and a valve closes, the flow velocity drops and pressure signals are initiated in both directions due to the liquid's inertia (figure 2). In upstream direction with positive sign, in downstream direction with negative sign. The low pressure is limited by the vapor pressure of the liquid. If this is reached, a vapor bubble will locally form (this is called "cavitation"). The maximum pressure increase that can be reached by a spontaneous flow velocity drop Δv can be calculated from the momentum (I) gradient as:

$$\Delta p_{Jouk.} = \frac{dI}{dt} \cdot \frac{1}{A_{pipe}} = \frac{\Delta v \cdot \left(\frac{dm}{dt}\right)_{affected}}{A_{pipe}} = \Delta v \cdot \rho \cdot a$$

"Joukowski-Shock"

Example (Figure 3): Liquid is pumped from one tank to another via a 3 km long pipe at 1.3 m/s. The valve at the target tank is closed within 3 seconds. The diagram in figure 3 shows the pressure time history directly upstream of the closing valve. It was obtained by simulation with Simcenter Flomaster.

It can be observed that the pressure rise doesn't occur instantaneously, but builds up during the valve is closing. A first maximum is reached when closure has completed. It is followed by a flatter rise (the so-called "line packing effect"), which is caused by the decreasing friction losses along the pipe length. After 9 s the reflection of the pressure wave arrives. It reversed its sign and direction at the other (open) end of the pipe. Therefore, it wipes out the initial pressure impulse. Since the pressure signal propagates with about 1 km/s, it takes a return time of 6 seconds to travel forth and back the 3 km long line. If the return time is shorter than the valve closing time, the reflected wave will cease the Joukowski shock before it has fully developed.

This attributes to the quality of physics implemented in Simcenter Flomaster. As

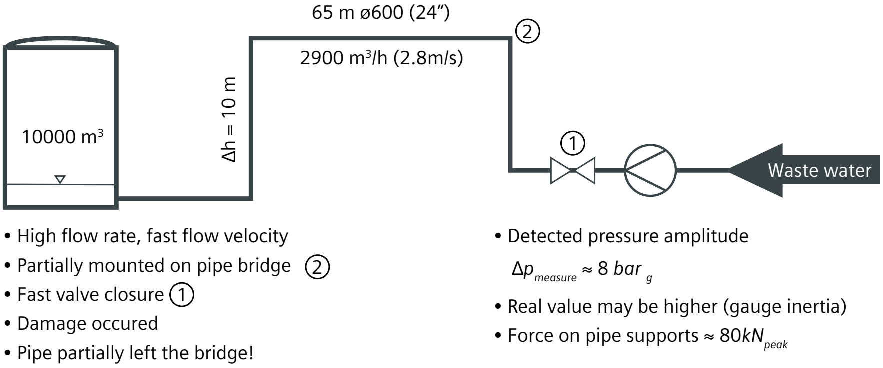


Figure 1: Real damage event in process industry

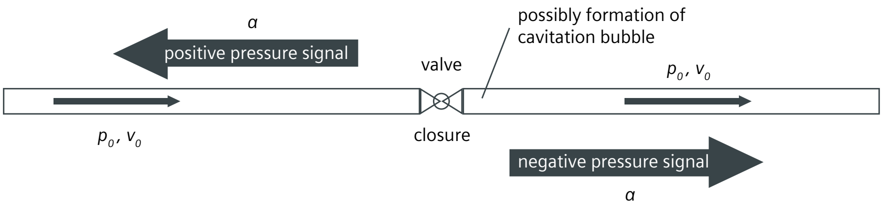


Figure 2: Pressure surge and cavitation phenomena

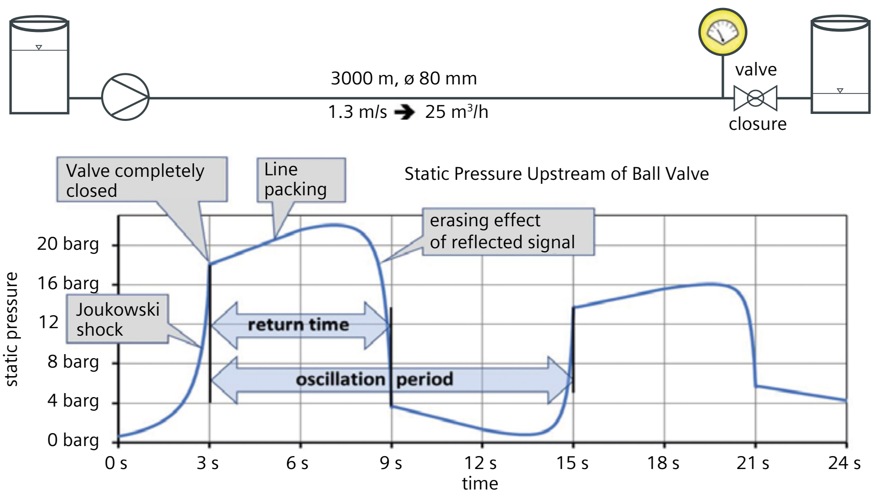


Figure 3: Pressure path for fully developed surge

such, the solver is stable for even highly complex networks and captures the relevant physical phenomena accurately. From a usability perspective, the models are easy to organize into projects and same models can be used for both steady and dynamic analyses. This allows for appropriate flow and velocity distribution to be calculated while accounting for multiple fittings. Accurate initial velocity distribution is critical to the accuracy of pressure surge calculation. For this reason any simplifications applied to the model may compromise the accuracy. Simcenter Flomaster allows the same model to be run in steady and transient simulations without any simplifications. Therefore, the user has full control to calibrate initial states and thereby ensure that the maximum possible accuracy from transient analyses is obtained.

Methodology to identify where pressure surge analysis is vital to safety

Process and pharma plants work with multiple fluids some of which may be supplied from external tank farms via long distance supply networks. There can be hundreds of such pipelines and high flow speeds can occur. To minimize effort, a more pragmatic approach is required to identify the components that are critical to safety and require detailed analyses. The practical approach used to do this is summarized below:

- Pipes containing gas or vapor are in general not as critical, with exceptions of condensing vapor, failure modes, reinforced pulsations, choking, etc.
- Short pipes within buildings are generally not critical. Exceptions can be fast closing valves or high flow speed lines.
- For each of the remaining set of pipes a systematic screening method is applied, by means of a spread sheet. First a reference peak pressure is obtained by adding the Joukowski shock to the normal operating pressure:

“Reference peak pressure“
$\hat{p}_{ref.} = p_{operation} + \Delta p_{Jouk.}$

This value is then compared to the acceptable pressure ("$p_{acceptable}$"), as defined by the pressure rating of the pipe. If $\hat{p}_{ref.} > p_{acceptable}$ further detailed investigation by dynamic simulation is required. If this condition is not true, further investigation may be avoided.

The flow chart in figure 4 describes the procedure from the screening down to detailed simulation. There are three exits, at which the path can be successfully left:

Exit 1: If the screening finds no critical reference peak pressure, no measure is required for this pipe.

Exit 2: If the reference peak pressure can be sufficiently reduced by simple means like throttling, reduced pump speed, or increased pipe diameter, the investigation is completed for this pipe.

Exit 3: At the last stage, a dynamic simulation is performed in order to get a less conservative prediction of the peak pressure. If this is still above the acceptable value, an investigation loop is started to assess multiple mitigating techniques like hydraulic damper, slower valve closing etc.

Case Study: Assessment of mitigation techniques for pressure surge

A tanker barge is filled with 60 m³/h methylene chloride through a 530 m long pipe PN16 via a pipe bridge, figure 5. The resulting flow velocity is 3 m/s. The wave propagation velocity is about 900 m/s, leading to a signal return time of 1.2 s. In case the ship begins to drift, a valve at the pier closes automatically within 1 second.

Exit 1 Criteria: Check qualitative maximum pressure expected

$\hat{p}_{ref.} = p_{operation} + \Delta p_{Jouk.}$

$\hat{p}_{ref.} = 77.6barg + \Delta v \cdot \rho \cdot a = 44.2barg$

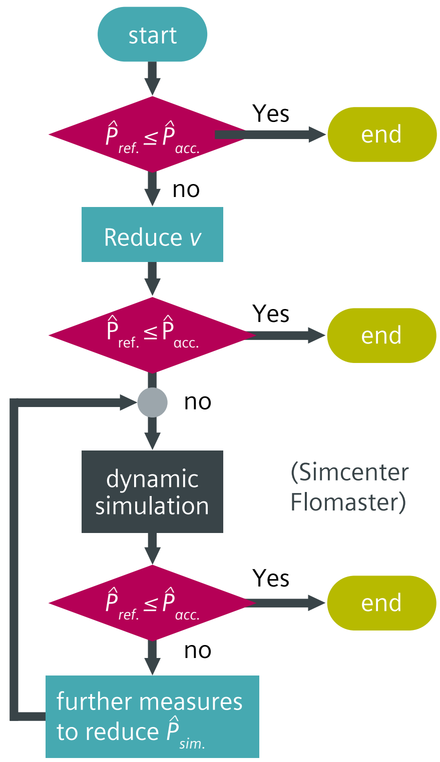
$p_{acceptable}$=16*bar* for a PN16 pipe. Since $\hat{p}_{ref.} > p_{acceptable}$, further investigation is needed.

Exit 2 Criteria: Check if peak pressure can be reduced by simple means

Analysing this is often a matter of practical concerns. The peak pressures could be reduced by lowering the flow velocities. To obtain this, either the pipe diameter is increased or the flow rate is limited to the required value. Pump speed can be varied but given the hydrostatic and friction head in the pipe, it is important to consider that the flow may slack if there isn't enough back-pressure maintained in the pipe. In this case, application of a throttling element (e.g. orifice) at the end of the line is favorable.

Exit 3 Criteria: Evaluate alternatives to mitigate high pressures

At this stage, it becomes necessary to have a detailed model set up in Simcenter Flomaster as shown in Figure 5 to evaluate mitigation techniques. We



class 1
no measure required

class 2
- limit flow (e.g. by orifice)
- reduce pump performance
- increase nominal diameter

Class 3 (only few cases)
- hydraulic damper
- slower valve closing
- venting valve (against cavitation)
- change of valve characteristics
- etc.

Figure 4: Practical approach flow chart

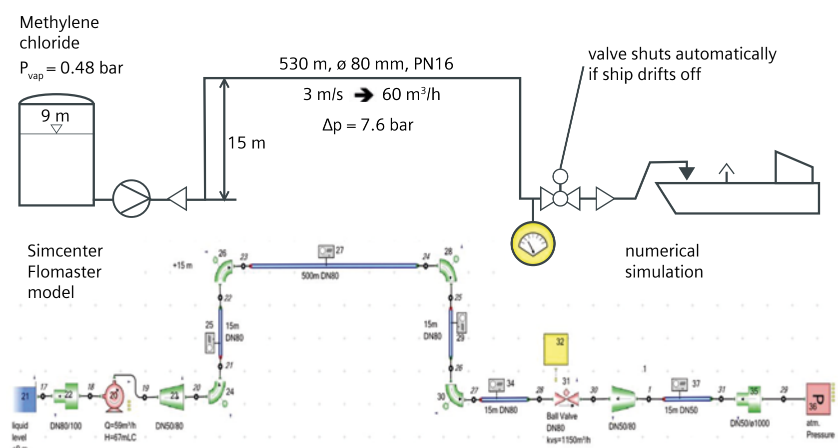


Figure 5: Case study – valve closure in ship loading line

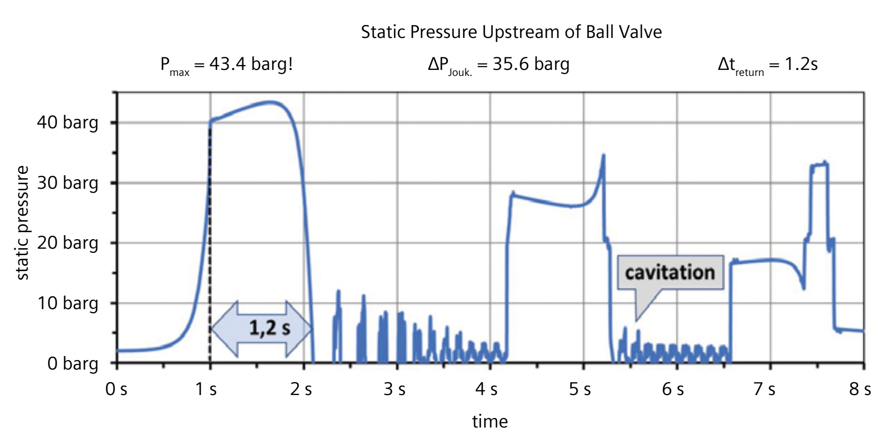


Figure 6: Status quo (valve closes uniformly in 1 second)

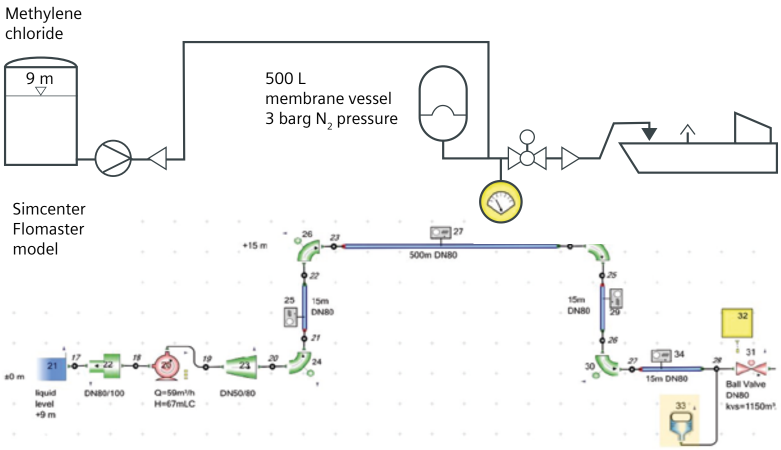


Figure 7: Application of hydraulic accumulator as damper

- Damper reduces P_{max} from 43.4 barg to 12.3 barg! (i.e. > 70 percent reduction)\
- Disadvantages: expensive and high maintenance requirements

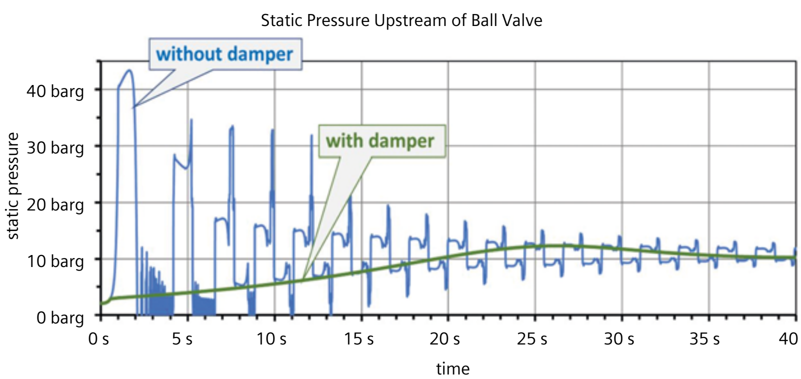


Figure 8: Results with and without damper

Closure time increased by x10 to 10s
P_{max} reduced by ÷1.5 (only...) to 20 barg

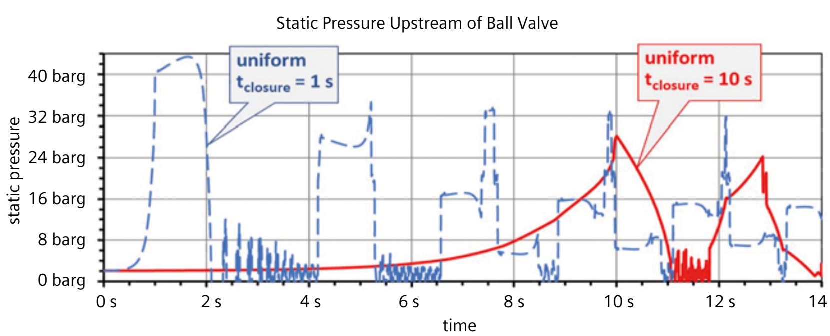


Figure 9: Impact of 10s uniform closure time

Ball valve characteristics in terms of "loss coefficient ζ"

Comparison of valve characteristics in terms of "flow coefficient K_v" (analogeous ro C_v)

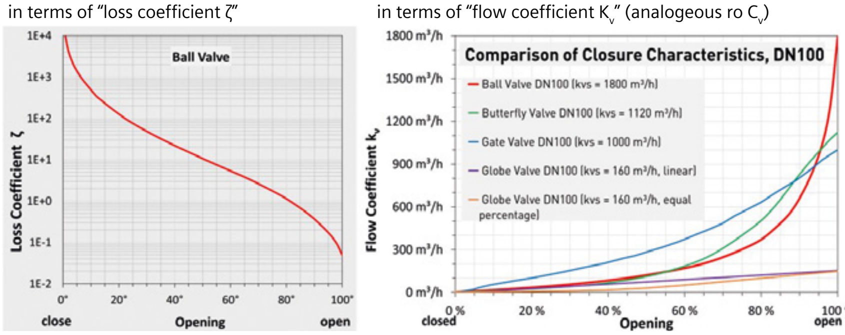


Figure 10: Non-linear valve characteristics

first assess the status quo i.e. where the valve shuts automatically in e. g. 1 s and observe the pressure behavior.

The simulation results for the status-quo as shown in figure 6 imply that:

- The Joukowski shock fully develops, since the valve is completely closed, when the signal reflection arrives.
- The negative reflection wave causes a pressure drop down to the vapour pressure of about 0.4 barg. This means, cavitation occurs.
- Multiple very sharp pressure peaks are caused by collapsing of the cavitation bubbles.
- The predicted overall maximum peak pressure is about 43 barg! This is high above the pipe's pressure rating of 16 barg.

One possibility to reduce the surge effect is to apply a hydraulic damper to the pipe. Therefore, to assess the impact of this technique, we add a 500 L membrane vessel pressurized with 3 barg of nitrogen to the model (figure 7).

The analysis time for such networks is typically less than a minute and quickly reveals some key insights into how this change impacts the transient pressure behaviour (figure 8).

The hydraulic damper clearly reduces the maximum pressures below acceptable limits and also effectively avoids cavitation. However, in practical terms, such dampers are often highly costly and require regular maintenance and inspections of the gas content and membrane condition.

As a next step, we attempt to assess the influence of slower valve closing profile and see whether this technique can be used to reduce maximum pressure below the acceptable limit and avoid the hydraulic damper. Therefore, we run a simulation with a closing time elongated from 1 s to 10 s (figure 9). The resulting maximum pressure does not reduce satisfactorily and still reaches 28 barg, considerably higher than the acceptable value.

At this stage, it is worth considering why the elongated closure was so ineffective. Frequently, the non-linear valve characteristic gets blamed for this. The left diagram in figure 10 shows the characteristic of a ball valve in terms of the dimensionless loss coefficient ζ. Due to the singularity of ζ at the completely closed state, the interpretation of the image is difficult.

Therefore, in the right diagram the same characteristic is shown, but in terms of the flow coefficient k_v (which is analogous to C_v in imperial units). Again, the red line represents the ball valve. In this diagram it gets clear, that the ball valve near the closed stat has a really smooth characteristic. So this does not explain the weak effect of the closing time elongation.

The behavior is completely different, when we look at the system "pipe + valve"(figure 11):

Figure 11 shows the flow rate versus the valve opening. The blue line represents the complete system for the case of the barge loading example. The dashed red line represents the ball valve alone (with the same pressure source). It can be observed now that the strongest effect of the valve closing occurs near the closed state, since during the first 80 percent of the valve closing, the capacity of the ball valve is still so high, that the pressure loss of the pipe strictly dominates.

With this information, we try another closing profile that also closes the valve in 10 seconds but in a phased manner as shown in figure 12.

The results for the status quo, staged closure and hydraulic damper are shown in figure 13. It can be observed that the objective can also be met with a slower valve closing, if the closing profile is optimised. Nevertheless, this is not in any case the best solution. For example, in case of line rupture due to ship drift, the amount of medium spilled during the valve closing process is of course higher compared to fast valve closure combined with a hydraulic damper.

As a result of this exercise, we get all necessary information about the behavior of the system by simulating with Simcenter Flowmaster. Application of multiple mitigation techniques can easily be assessed concerning their effectiveness. Taking into account all the real life practical constraints, the solution that is most convenient for the customer can be obtained and delivered. ■

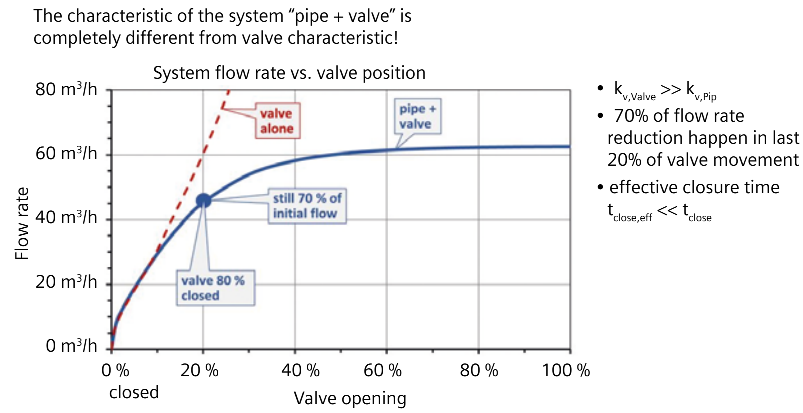


Figure 11: Comparison of characteristics of pipe + valve and valve alone

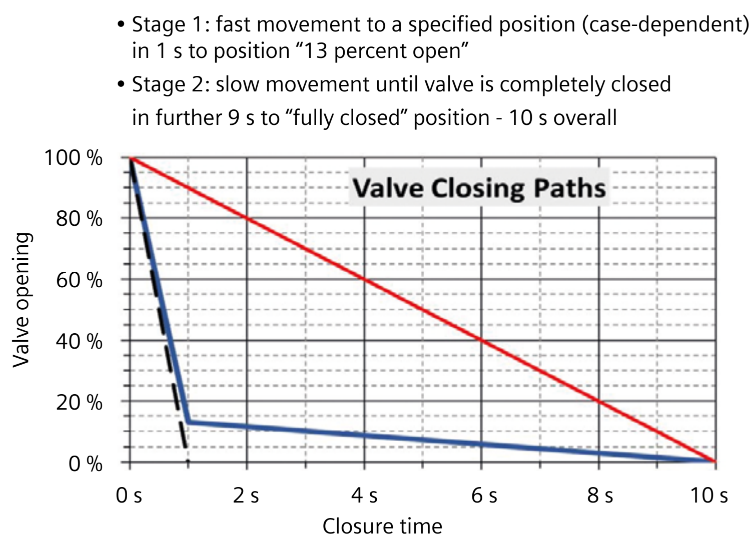


Figure 12: Two stage valve closure

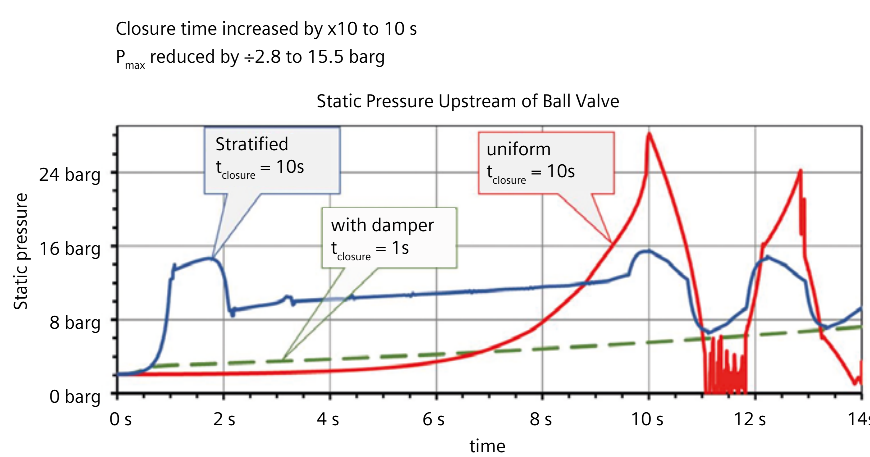


Figure 13: Comparison of different surge mitigation methods

A dramatically different design

INEOS TEAM UK uses Siemens Digital Industries Software to design America's Cup racing yacht

Class rules for the 36th America's Cup of 2021, announced at the end of March 2018, introduced a dramatic change in design. As Grant Simmer, chief executive of INEOS TEAM UK, observed: "This time around, boat designs are very large, powerful and complex with a completely new type of configuration." As a result, the team's first boat, launched in October 2019, is a foiling monohull that is over 20 meters long, weighs 7,800 kg and is made of 25,000 unique parts. The stock, fairing, wing, flaps and systems in each foil arm weigh 1,385 kg.

The technical challenge is extended by another new rule. Nick Holroyd, chief designer, explains: "Teams have got used to being able to change parts such as the foils and reconfigure boats according to the weather on race day. For the next America's Cup, we have a fixed configuration, which we are required to declare five days in advance. As racing is expected to last for ten days that means that we need to go for a rather general design which will sail well with any wind speed, both on the straight and going around corners."

A foil optimized for low speed in light wind is very different from one designed to withstand strong winds and high speed, so the team had to work around average wind speeds in Auckland, where the next race takes place in March 2021. The team weighted types of weather according to their likelihood at that time of year, then scoped a design around those parameters.

Simulation is key

From receiving the class rules in April 2018, the team spent five intense months focusing solely on design, with construction beginning in August that year. It took 90,000 design hours and 50,000 construction hours to get

the boat on the water. "We designed from scratch but we could draw on all the simulation tools and expertise that we already had in place," comments Holroyd. Those tools include NX™, Teamcenter® and Simcenter software from Siemens Digital Industries Software.

"We relied on our simulation environment whilst the first boat was being built," Holroyd continues. "One of the first requirements after the launch was therefore physical testing to validate what our simulation showed. We expect all our simulation to be within a two percent margin; even so, there's always a surprise and one of the fun aspects of the job is to turn such nuggets of information into an opportunity for our design."

Under race rules the team is limited to developing two boats with a maximum of three rigs, four rudders and three pairs of wings, so again the team needs to rely on simulation. "Because we cannot develop spares, the fidelity of our computational solutions is paramount," comments Holroyd.

Flying performance

"A racing yacht sits at the interface between two fluids, wind and water, deriving all its power from that dynamic by minimizing drag," says Holroyd. "However, we can't work with that in isolation. We have to consider structural and mechanical features, and for the boat to 'fly' we need to get the foils up to speed very quickly; but at high wind we quickly run into cavitation, when pressure reduces too much over the foil."

INEOS TEAM UK relies on Simcenter STAR-CCM+ software for computational fluid dynamics (CFD) to model the lift forces acting on the foil. Modeling shows how the flow is developing, changing, for example, from laminar to turbulent, and how it might separate, creating a drop in pressure and creating cavitation or a "boiling" effect in the water.

CFD engineer Max Starr spends 90 percent of his day using Simcenter STAR-CCM+. "When we receive a CAD file the geometry is pretty complex and often not the cleanest. We need to throw some mesh on before we can solve. We can very quickly facilitate meshing issues without having to fix the geometry manually and that means we achieve a very low failure rate." According to Starr, the team tends to run hundreds of short, one-hour simulations in parallel. "We gain much more from these than from one long simulation that takes weeks," he explains. "Simcenter STAR-CCM+ has a Design Manager feature which is very smart and handles changes really easily. Design Manager will manage all the parameters and present results as a table."

Automation and calculation
"We have established extensive automation within NX," comments Ollie Pendleton, design engineer with responsibility for managing the Siemens solution. "We have a lot of parameterized models on which we can change fundamental aspects and let NX update. This allows for speedy last-minute changes and is particularly helpful as deadlines mount and we start to see other boats. We can quickly adjust our own models in order to understand the approach adopted by other teams."

The design team also takes advantage of the automation and high-level scripting which it has built into Simcenter STAR-CCM+. As a result, non-CFD specialists can design a foil and define the matrix and test conditions.

Another rule is that teams are not allowed to test in any closed environment such as a wind tunnel, so the pressure is back on simulation. "The

> *"The rules and regulations push our research and development further into the digital world."*
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> Grant Simmer
> Chief executive
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"Because we cannot develop spares, the fidelity of our computational solutions is paramount."

Nick Holroyd
Chief Designer
INEOS TEAM UK

challenge is to work out the combined forces acting on the boat and calculate the loads on the foils, the hull and the crew," Holroyd says. "The calculations we gain from our software solution form the basis for waves and gusts introduced to a motion platform on which the sailors train, complete with virtual reality headsets and graphics."

The sailing team, which began using this simulator in 2018, are in continual dialog with the design team regarding the feel and behavior of the boat. Starr adds "We can gather feedback from over 100 different points on the boat to work out the pitch, roll and yaw then convert that data into a sensitivity reading, positive or negative, for each of the components."

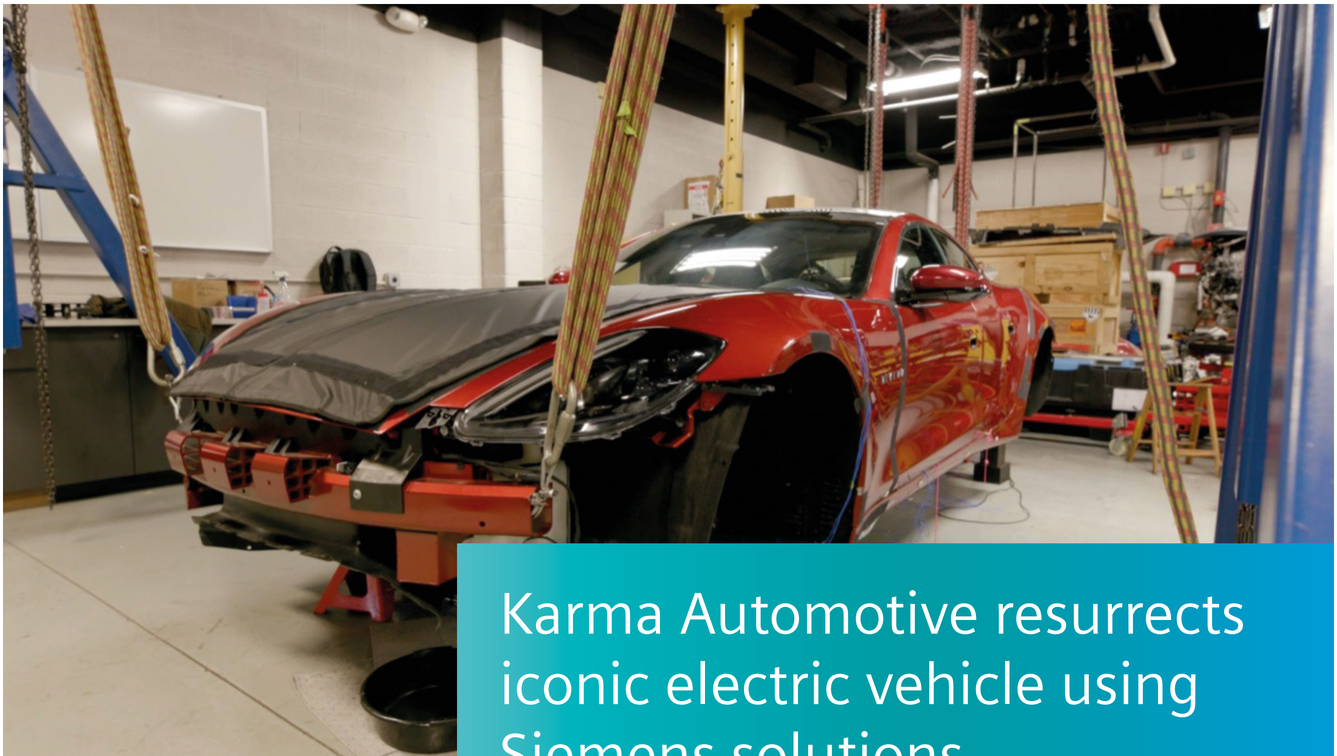
A team effort

"Teamcenter is essential for collaboration because everyone needs to see the absolute latest data," states Pendleton. "Teamcenter stores all assemblies and takes care of the release of models and drawings to suppliers. Within the Siemens suite we can integrate design and analysis with hydraulic and electrical schematics. That is very valuable to us as the design gradually evolves into digital manufacturing and the issue of files to suppliers. There's always pressure, especially as there might be 25,000 parts out for procurement, but the support we receive from Siemens is very hands-on. Our dedicated support engineers really understand our needs and our coding."

The team's second and final boat hits the water in the summer of 2020 and in early 2021 sailing begins in earnest. "The rules and regulations push our research and development further into the digital world and our success depends on what decisions we made at the start regarding our broad technical strategy and where to concentrate effort," comments Simmer. "To be competitive we are constantly balancing associated risk with performance reward and the resources that we can apply. Our use of the Siemens solution is fundamental to how we do that." ■

"The support we receive from Siemens is very hands-on. Our dedicated support engineers really understand our needs and our coding."

Ollie Pendleton
Design Engineering
INEOS TEAM UK



Karma Automotive resurrects iconic electric vehicle using Siemens solutions

Simcenter services, simulation and testing solutions help Karma Automotive go above and beyond NVH optimization

The emergence of EV sports cars
The time when electric cars were considered part of some distant, exotic future (due to our limited technological capacity or the perceived dominance of oil) is long gone. A little more than two decades ago, the iconic Toyota Prius seriously changed the game. Today, more than 12 million hybrid or electric cars have been sold worldwide and the numbers keep climbing: not only is electrification now considered one of the biggest revolutions of the automotive industry, humanity has begun to conceive a future without gasoline and combustion altogether.

Electric or hybrid cars aren't taking over the roads just yet for a number of reasons, including their elevated price tags and still limited autonomy. In addition, while many consider that the real beauty resides on the inside, a key differentiator for people who choose a new car remains its appearance. Tesla was the first to understand this when releasing its Model S onto the market in 2012. With it, Tesla managed to reach a distinct market segment that had previously been excluded to the game of electrification: customers who preferred a luxury, sporty design.

In the meantime, many OEMs have added at least one high-end, luxury hybrid or electric car to their fleets – examples include the Honda NSX, Lexus LC500h, BMW i8, Jaguar I-Pace and Porsche Panamera.

Many startups are trying their luck in this segment (Tesla also started small). While many companies failed or were acquired along the way, some emerged as new, respectable e-brands, ready to put their prototypes nose-to-nose with the establishment.

Karma Automotive - the story of a phoenix
One of these startups is Karma Automotive, a California-based carmaker that rose from the ashes (or rather assets) of Fisker Automotive in 2014. In the resurrection process, Karma managed to preserve the good and

overcome the bad: they retained the beautiful Italian design of their cars, which held a lot of appeal to their customers, but significantly upgraded the technology. The result is a luxury electric hybrid sedan that maintains much of the original exterior and interior of the Fisker Karma, but incorporates an A123 battery, charger and electrical controls. It is "the car you drive when you want to be seen," says Bob Kruse, chief technical officer of Karma Automotive.

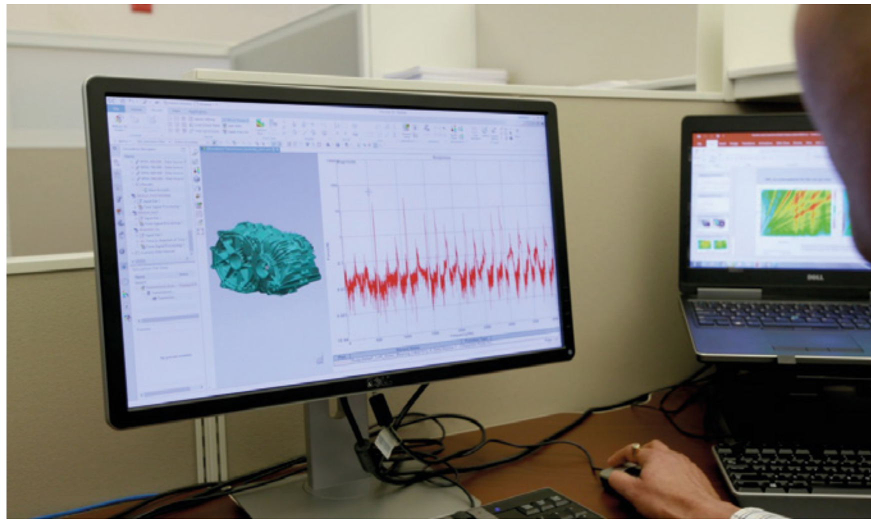
As a startup, Karma had to address some of the typical consequences of limited resources. For one, time is more expensive for startups than for established players. Also, there are hardly, if any, second chances. As a result, digitalization truly has become a matter of life and death. "It is now of more crucial importance than ever that models and analytics properly duplicate what happens in the physical world, so that when we do go back to the actual vehicle, the virtually obtained solutions fit with a high degree of confidence – and they actually are going to work," Kruse confirms.

A relentless pursuit of excellent NVH

With a hybrid-electric sports car, engine noise is a key performance attribute to manage throughout the entire development process. Engine noise needs to be brand-specific. This isn't an easy task, because "there is no history of what an electric sports car engine should sound like," says Jud Knittel, noise, vibration and harshness (NVH) lead engineer at Karma Automotive.

The main issue with hybrid-electric cars is that the lack of the noise-masking effect of a combustion engine makes a lot of other sounds more apparent, such as road or HVAC noise. Much more effort must be applied to reduce these noise sources than for traditional cars. In addition, efforts to optimize NVH can actually become counterproductive if they have a negative impact on other attributes such as such as weight, strength, durability and ride comfort.

Using testing and simulation (sometimes simultaneously) is essential in maintaining this balance. Karma understood this at the very beginning of the development project.



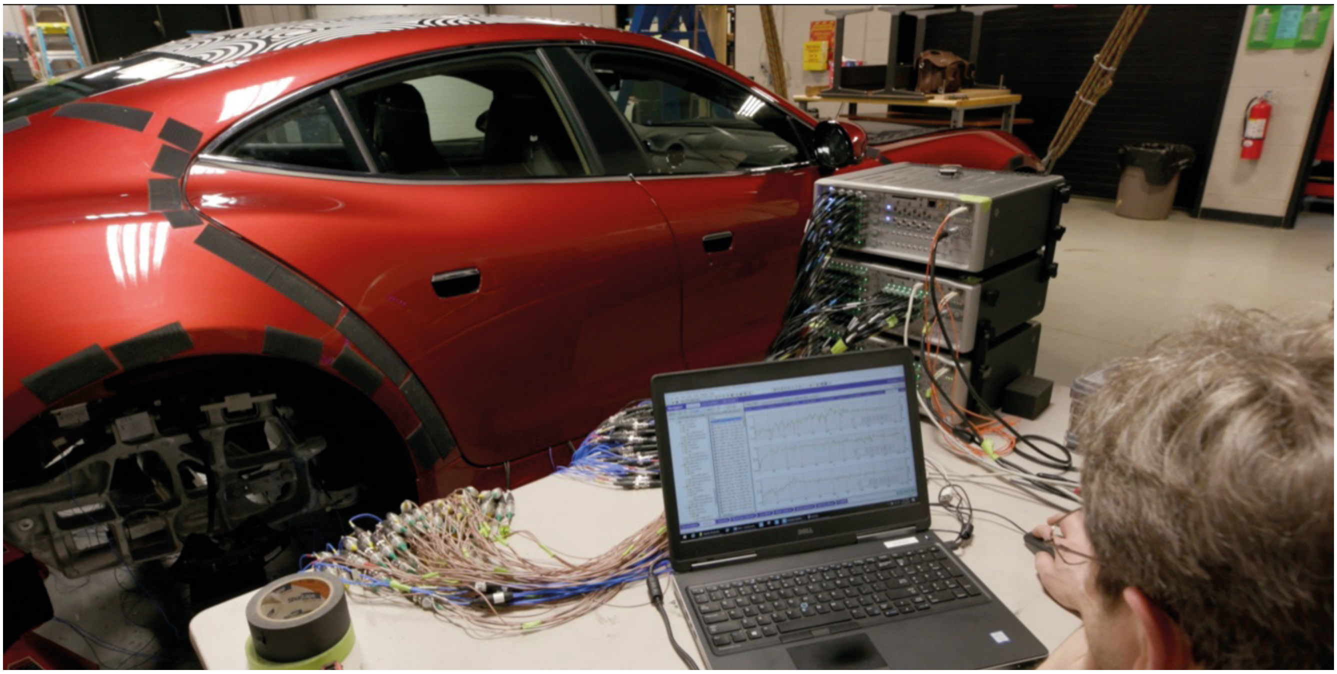
A well-oiled tandem of simulation and test

"When we took this project on, it wasn't only about the development of the product, but also of the process that we were building at Karma," explains Erik Keipper, director of vehicle integration at Karma Automotive. "The partnership we put together with Siemens really allowed seamless interaction from the program managers, engineers and technicians."

One of the keys to success for such an overarching vehicle development program – featuring not just product but also process – is to frontload the vehicle design definition phase as much as possible, such that last-minute, expensive corrections in the validation phase can be reduced to their absolute minimum or even avoided. Karma selected Simcenter 3D software for this task. Combining all the necessary high-end solutions and solvers, Simcenter 3D also allows for optimization of different attributes, with best-in-class computer-aided engineering (CAE) pre- and postprocessing capabilities and the software's unique CAD-integrated and managed environment. In particular, Karma used Simcenter 3D's hybrid modeling method to frontload the overall vehicle optimization effort across multiple performance attributes. In this approach, components under development are modeled with 3D CAE and existing ones with accurate reduced representations derived from tests results, such as frequency response functions (FRFs) and modes.

"Polarion is one tracking tool to cascade targets down from vehicle level all the way to component level, then goes back up to validate the car at each of the intermediate and full-vehicle levels.

Garren Salibian
Lead of Vehicle Integration
Karma Automotive



In addition to Simcenter 3D CAE software, Simcenter Testlab™ software and Simcenter™ SCADAS™ hardware were selected to carry out NVH testing. The seamless combination of these tools enables coverage of a wide range of testing capabilities such as experimental modal analysis, operational data collection and sound quality assessment. Besides fast and accurate data acquisition and test results, Simcenter Testlab software also provides a lot of engineering know-how and user guidance. Karma especially appreciated how the software's intelligent data viewing capabilities and displays allowed the company to look at the same data from multiple angles. "We have a huge number of functionalities we have to go through for the same dataset, and all of these are available at the click of a mouse in Simcenter Testlab," Knittel confirms.

Testing is not only important during the benchmarking, target setting and prototype performance validation phase; it also plays a crucial role in leveraging simulation to its fullest potential. Especially in cases like Karma's, where certain components are still under development and being explored in Simcenter 3D, and other parts already exist as prototypes, test-based validation through FRFs and modes in Simcenter Testlab is of paramount importance to the success of the larger vehicle development process, in terms of both speed and accuracy.

Like many OEMs, Karma realizes that simulation cannot replace physical testing entirely, but Karma staff are convinced that it helps them to achieve better NVH performance in less time. A proper combination of test and simulation allows engineers to determine whether a simulation model represents the reality as closely as possible. But it also yields more detailed insights, such as how to include damping in the model, or how to deal with so-called hybrid approaches.

Simcenter Engineering and Consulting services

The project involved development of process as much as product. For this reason, both Simcenter Software and Simcenter™ Engineering and Consulting services proved to be a perfect fit. Simcenter personnel were on site throughout most of the development, assisting with the benchmarking and target setting of the project, and with the analyses and validation of the targets through CAE and test. It was the specialized services that enabled Karma "to use math and science, as opposed to trial and error, to get it right with a minimum number of iterations," Kruse explains.

In addition to the technology and software, Karma appreciated the in-depth knowledge of Simcenter consultants. "They also supplied the know-how and expertise to allow Karma to continue the process and analysis by themselves," says Knittel. "They are the ones who not only facilitated seamless operation of the software involved, but also of interaction between the program managers and the technicians. They supplied the expertise we need, so that we can continue the processes and analyses ourselves in the future."

Expert knowledge, collaboration and technology transfer are the differentiating pillars upon which Simcenter engineering services were built and operate today. All three are vital in comprehensive vehicle development processes like Karma's.

The added perk of Polarion

Dealing with many software capabilities across multiple attributes, divisions and teams requires a powerful data tracking and management tool. Polarion ALM™ software, another solution in the extensive Siemens Digital Industries Software portfolio, addresses the challenge. "Polarion is one tracking tool to cascade targets down from vehicle level all the way to component level, then goes back up to validate the car at each of the intermediate and full-vehicle levels," says Garren Salibian, the lead of vehicle integration at Karma. "It has a lot more depth to it than a regular spreadsheet that ticks boxes. You can dive in on each level and get access to all the required data and analytics. Polarion enables you to have full control over your entire application lifecycle, without losing any of the agility that is often required within separate teams." As part of the larger Siemens software family, Polarion works seamlessly with the Simcenter software that was used for NVH optimization and multi-attribute balancing campaign by Karma.

Going above and beyond

"By using the Siemens consulting services and software tools, we were able to get it right with a minimum amount of iterations," Kruse says. "From a technical point of view the targets weren't only met, but beaten."

It may be bold but perhaps fair to say that Karma has succeeded where Fisker failed: on the hard business side of things. With the Karma Revero, superior design not only meets economics, but does so in an environmentally friendly and acoustically enjoyable way. These features are considered to be among the most important success parameters of the 21st century.

"By using the Siemens consulting services and software tools, we were able to get it right with a minimum amount of iterations."

Bob Kruse
Chief Technical Officer
Karma Automotive

Using the Simcenter tools and services for more than four years, Karma went beyond NVH optimization to optimize its overall development process. Combining both test and simulation in one platform uniquely enables collaboration among teams and divisions with streamlined data exchange.

"Now that we have a process in place at Karma, and we've successfully put our project on the market by utilizing this process, we're excited to take on the next challenge," Keipper concludes. "Soon, hopefully, a whole host of electric products and vehicles will fill the dealership." ■

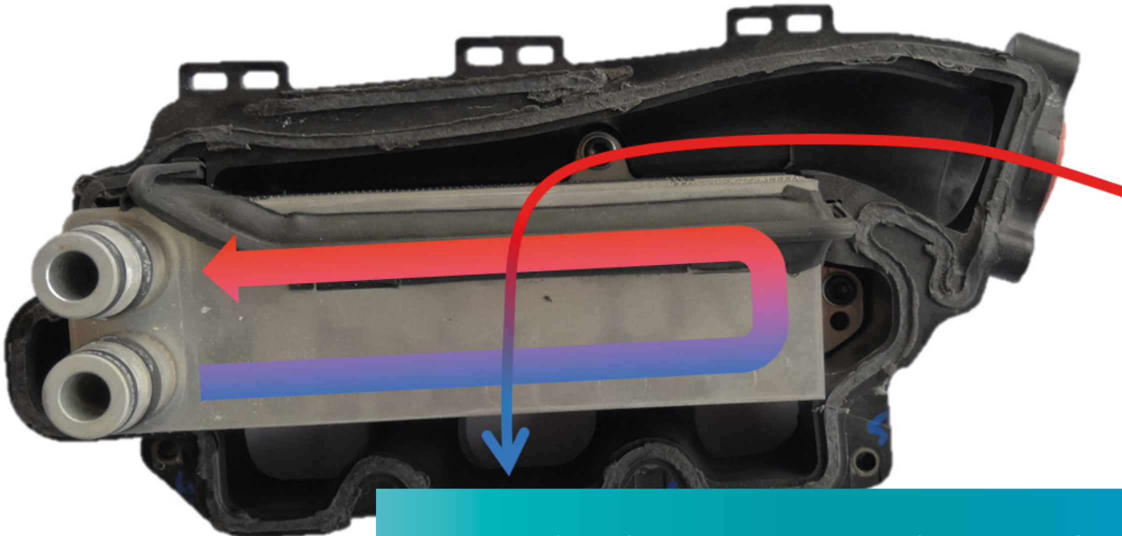
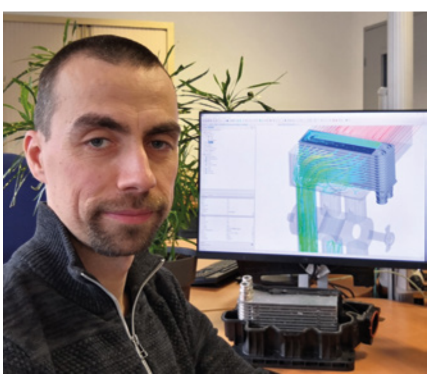


Figure 1: LCAC integrated in 3-cylinder air intake manifold

Predictive modeling of liquid-cooled charge-air cooler heat exchanges

By Arnaud Demange, CFD Engineer, Sogefi Air & Cooling SAS - Air & Cooling Business Unit



To reduce the impact on the environment, car manufacturers have been increasing their effort to improve fuel efficiency in turbocharged engines. The hot, charged air exiting the turbocharger at boosted pressure must be cooled before entering the combustion chamber via the air intake manifold to avoid a density downfall resulting in efficiency loss.

The core business at Sogefi Air & Cooling is the engineering and manufacture of advanced plastic automotive components such as air intake manifolds. Due to packaging constraints in specific applications, a liquid-cooled charge-air cooler (LCAC) may need to be integrated inside the air intake manifold plenum.

As this integration is so close to the cylinder heads, a very good prediction of the air temperature distribution at LCAC outlet and entering the cylinders is necessary. The simulation models traditionally used were not able to provide a refined modeling of the heat exchanges that was required so a new predictive simulation approach to model the heat transfer with an LCAC was introduced at Sogefi Air & Cooling.

This new methodology uses a hybrid modeling approach where the coolant is modeled as a fluid region and air /

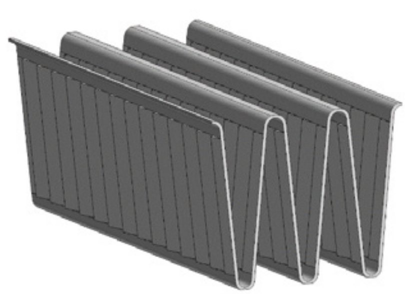


Figure 2: Details on 3 fins of the LCAC, air side

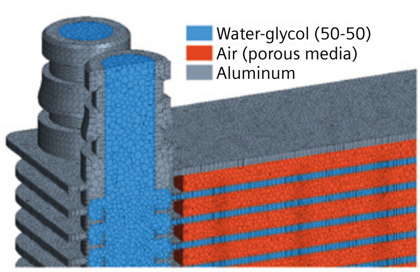


Figure 3: Representation of regions

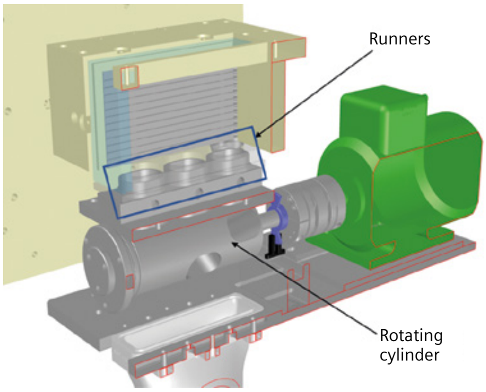


Figure 4: Unsteady assembly

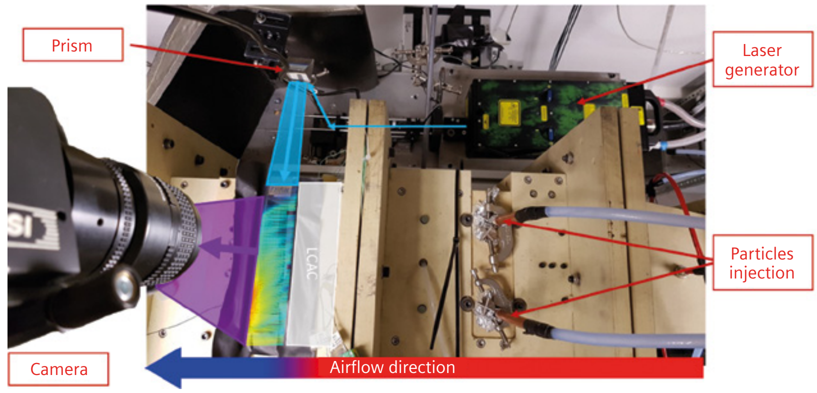


Figure 5: PIV system mounted on the stationary assembly

fins region modeled as phasic media addresses pressure drop as well as heat transfer without the need to model individual fins which would be impractical. Concurrently, test campaigns have been done to validate the methodology in terms of heat exchanges, temperature and velocities under steady and unsteady flow conditions.

The studied LCAC (figure 1), is a plate-fin hybrid flow heat exchanger where the air has a single pass while the liquid has two-passes. The global flow creates a counter flow heat exchanger, while each pass of liquid forms a crossflow heat exchanger.

On the air side, the fins are louvered (figure 2).

A fine detail model for heat flux and fluid flow

The meshing of the louvered fins for the entire LCAC is impossible because it would involve more than two billion cells. However, we need to accurately represent the heat exchanger geometry and the temperature distribution, whether the air flow is uniformly distributed at the inlet or not.

The aim is to keep the model as representative as possible by finding a specific treatment to the air/fins exchanges and to maintain the rest of the heat exchanger (aluminum and liquid volumes). Therefore, the actual liquid core and aluminum part are modeled, while the (air/fins) volumes are modeled by a phasic porous media, which will allow for the computation of the pressure drops and thermal exchanges (figure 3).

This methodology was made possible thanks to the phasic porous media model in Simcenter STAR-CCM+ which is able to resolve the energy equation in the solid part of the porous media.

With such a phasic porous media, the heat exchanges are possible between both phases (air and aluminum) inside each cell. This modeling needs two additional input parameters: the interaction area density that represents the exchange surface of one cubic meter of porous medium; and the heat transfer coefficient (HTC) that can be obtained empirically or with a detailed simulation.

For HTC, the latter method has been chosen: getting the heat transfer coefficient by modeling an elementary volume The goal was to describe the HTC in function of the geometry and the flow, by finding a relationship between the Nusselt, Reynolds and Prandtl numbers: HTC=f(Re,Pr).

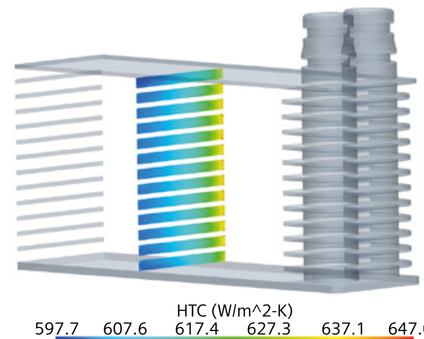


Figure 6: Heat transfer coefficient in the LCAC, air side

T_air at inlet 141°C	Heat exchanges [kW]	Air temperature at outlet [°C]
Tests bench	8.94	45.6
CFD model	8.95	45.4

Figure 7: Heat exchanges in stationary case

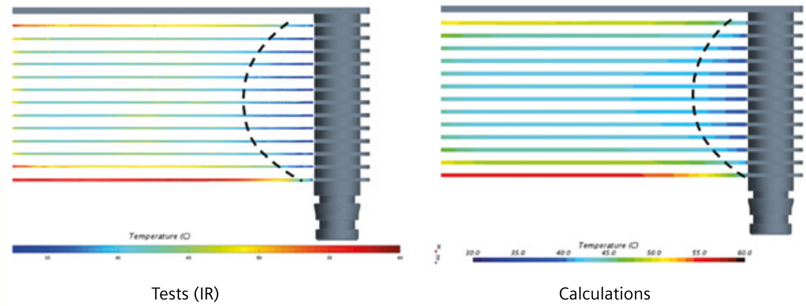


Figure 8: Temperature field on water tubes, air outlet side

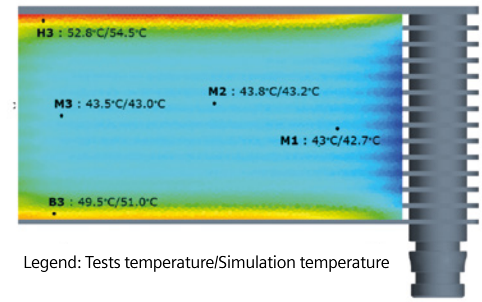


Figure 9: Air temperature at LCAC outlet

Configuration	P_air tests [kW]	Gain/steady	P_air CFD [kW]	Gap CFD/test
Steady	8.94	-	8.95	0%
1000RPM	9.15	2.3%	9.15	0%
3000RPM	9.27	3.7%	9.1	-1.8%

Figure 10: Heat exchanges under dynamic flow

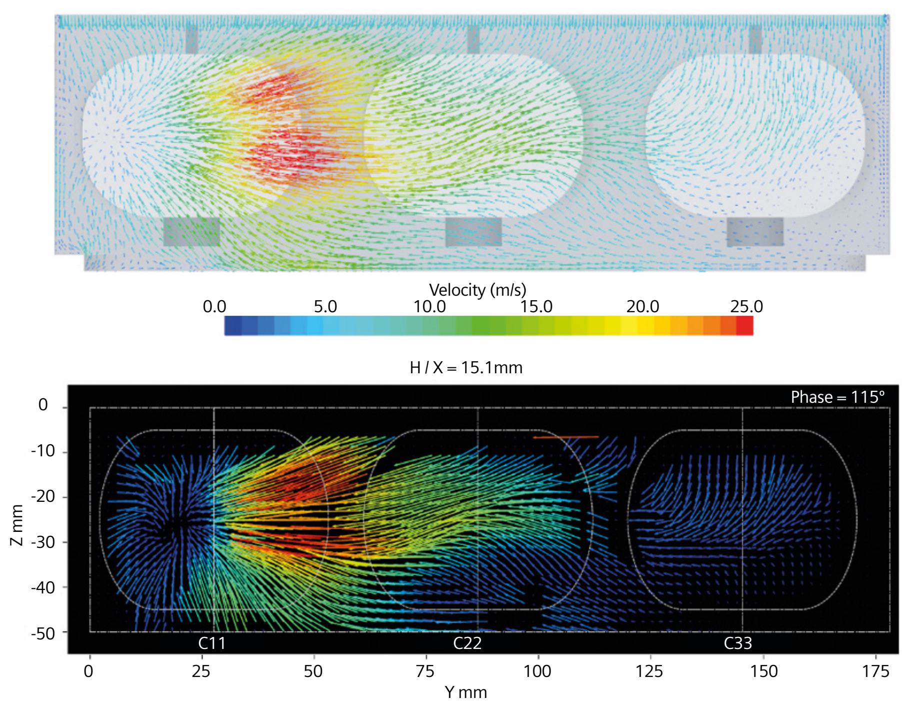


Figure 11: CFD vs. PIV: tangential components of the velocity in a horizontal plane at 3000RPM

Test means

The LCAC was tested in a straight channel for steady state correlation. The unsteady condition being a rotating cylinder with openings set up at the LCAC outlet (figure 4) allowing the sequential opening and closing of the three runners simulating the operation of a 3-cylinder engine.

A team at the Femto-st Institute implemented a particle imagery velocimetry (PIV) system (figure 5), infrared camera and hot wire anemometer in addition to other sensors to get detailed pictures of the flow and temperature distribution.

Simulating stationary conditions

The injection of the relationship HTC=f(Re,Pr) into the phasic porous media model resulted in a variation of the HTC inside the LCAC (figure 6) resulting in a non-uniform temperature distribution at the heat exchanger outlet.

The results have been compared to test, and the following conclusions have been made:

- The heat exchanges are the same (figure 7)
- The temperature profile of the external sides of the water channels look the same when comparing CFD calculations and the infrared camera image (figure 8).

The first and last fin rows have higher temperatures as a result of the contact with only one coolant plate and the parabolic shapes at the coolant inlet side (right side) are similar.

- The air temperature of five sensors at LCAC outlet are very close (figure 9)

The correlation is very good between tests and CFD calculations for steady flow.

Time-dependent conditions

For the simulation of dynamic behavior, the respective inlet mass flow rates and inlet temperatures of both fluids (air/coolant) have been kept the same as those in the steady condition study, while two rotating conditions have been considered corresponding to 1000 and 3000 engine revolutions per minute (RPM). The PIV system has been set up so that the flow can be observed between LCAC outlet and runners.

This test campaign reached the conclusion that:

- The flow dynamicity improves the exchanges in both cases (figure 10). In comparison with steady state, the heat exchanges during the tests have increased by 2.3 percent at 1000rpm and 3.7 percent at 3000rpm, while we obtained 2.2 percent and 1.7 percent in simulation respectively.
- From PIV analysis, a good correlation is achieved on the flow. The same flow structures are visible during tests and in CFD calculations (figures 11 and 12).

Conclusion

The comparison between test and CFD calculation validates the methodology: Sogefi Air & Cooling now has the means to predict the heat exchanges in a LCAC, whether it is integrated in to its manifolds or not. The fine accuracy of the temperature distribution calculation at LCAC outlet will allow an accurate prediction of the air temperature entering each cylinder in both steady and unsteady conditions.

■

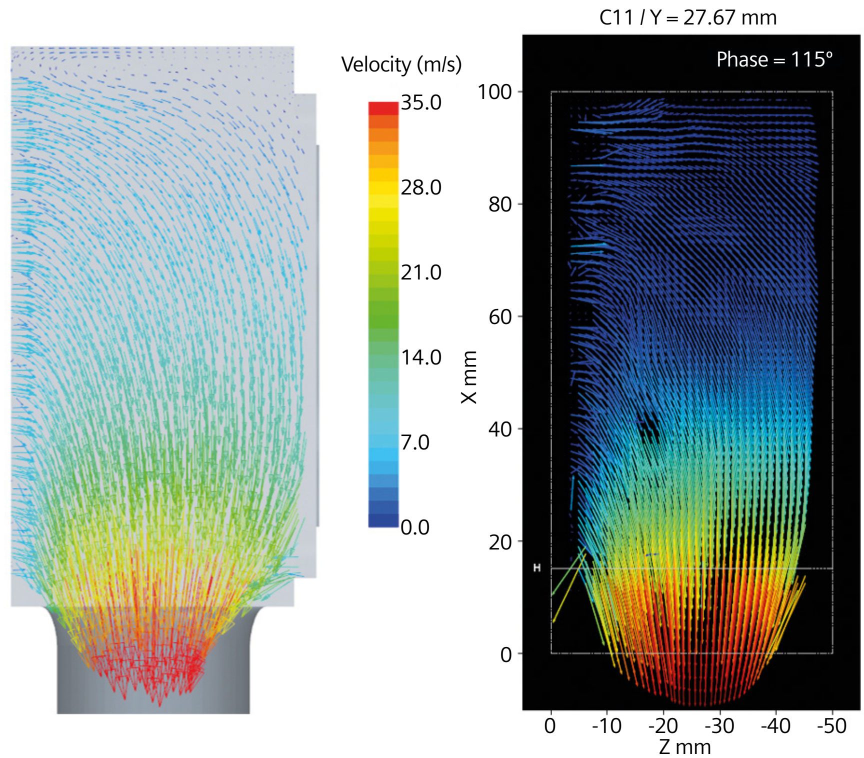


Figure 12: CFD vs PIV: tangential components of the velocity in a vertical plane at 3000RPM

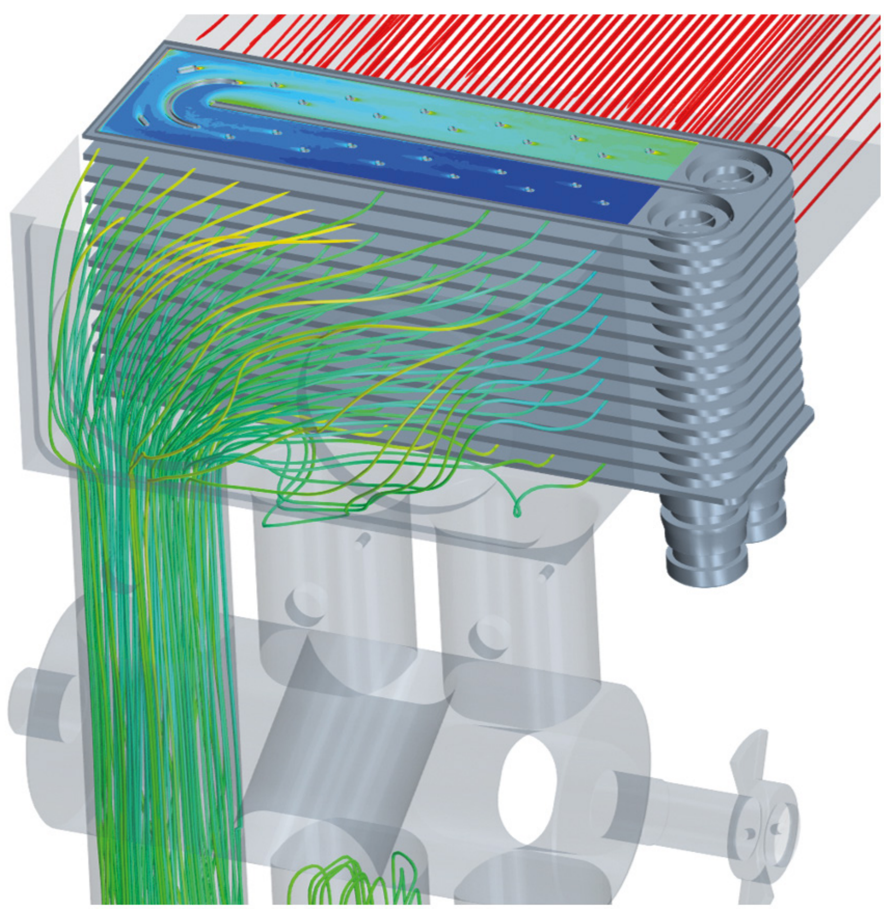


Figure 13: Air and liquid temperatures at 3000RPM

Clean Motion

The micro-factory business model that promotes social and economic empowerment

Inspiration strikes in the strangest places. Ask Göran Folkesson, the chief executive officer (CEO) of Clean Motion (Lerum, Sweden) and the visionary behind the electric composite pod, known as the Zbee. Years ago he took his kids to sailing lessons and watched them handle an Optimist dinghy, which resembles a floating bathtub. Its composite or fiberglass hull weighs only about 35 kilograms and is easy to operate, which is why the Optimist is pretty much the standard starter boat for sailors around the world. Made of composites, lightweight and easy-to-operate, Folkesson knew the Optimist provided clues to the mobility issue.

"When this all started, I had been thinking about creating something much more energy efficient than a traditional car," says Folkesson. "Then I took a couple of trips to Asia and realized three-wheelers are also an extremely important part of solving urban mobility requirements."

Originally post World-War II technology, the three-wheeler, popularly known as a "tuk-tuk" or auto rickshaw, can trace its roots to the 1948 Piaggio Ape (Ape means bee in Italian), the Italian answer to simple post-war transportation. At the time, it was an excellent transportation solution. It was sturdy and could carry a load of people or goods. It had a spare tire, was cheap to operate and relatively easy to repair.

Seventy years later, three-wheelers like the Piaggio Ape are still tooling around megacities throughout India and Southeast Asia. Unfortunately, many still have polluting and noisy two-stroke engines.

Folkesson knew that changing mobility wasn't a one-man task, so he started a small think tank of like-minded individuals from the automotive, engineering and product lifecycle management (PLM) worlds. Drawing inspiration from the Optimist and tuk-tuk, the founders of Clean Motion started their digital journey with the intention of injecting a healthy dose of disruptive innovation.

To start, the team tackled the obvious: how to make a three-wheeler lighter, cleaner and more energy efficient without losing the attributes that worked, liked simplicity, versatility and affordability. This was around 2010, years before electric vehicles were trendy. But the team moved forward with various design iterations and prototypes and by 2013, they had their first European Union (EU) approved vehicle type and validated digital twin. By late 2013, the Zbee, which comes with either a rear seat or a cargo space, was on the market.

Zbee arrives on the world stage

There are about 400 Zbees on the streets, including a successful taxi pool in Stockholm, Sweden and a growing fleet business in New Delhi, India. Today you can spot the Zbee practically everywhere, from Johannesburg, South Africa to Tromö, Norway. And many of these global daily users have already trimmed 4.5 tons of carbon dioxide (CO_2) pollution off their carbon footprint.

"From birth, we have been digital," says Folkesson. "This has been a core advantage. We could have never achieved this working in traditional ways."

The fact that many of the engineers on the team were digital natives impacted the entire Zbee design and development process. Coming from automotive and product lifecycle backgrounds, Folkesson and Niklas Ankarkrona, the chairman of Clean Motion, realized early on the advantages of centralizing the entire development process on Teamcenter® software and NX™ CAD software, part of the Siemens Digital Industries Software portfolio.

Some of the other engineers like Jesper Martaeng, chief technology officer (CTO)/technical director and Jörgen Johansson, global manufacturing manager, who had experience using Siemens tools at a major automotive original equipment manufacturer (OEM), knew they could take this much further than just creating a good NX CAD digital twin.

"We wanted to focus on creating an efficient product development process and digitalizing the manufacturing process, so we looked at existing solutions and saw Siemens and thought, 'Well, this is very interesting.'"

Lightweight and composites

One of the areas where Siemens digitalization tools made a difference was the weight of the Zbee. This critical design and analysis work was completed by a composites expert, Michael

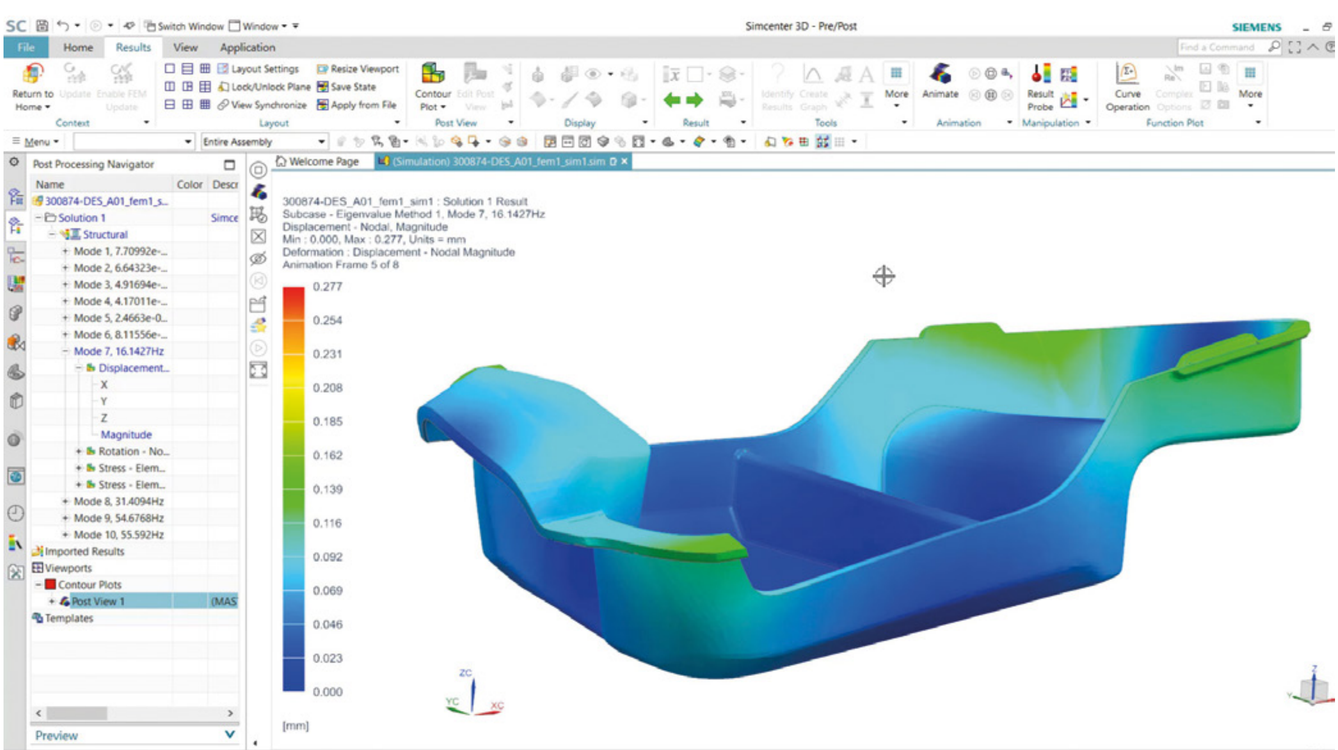
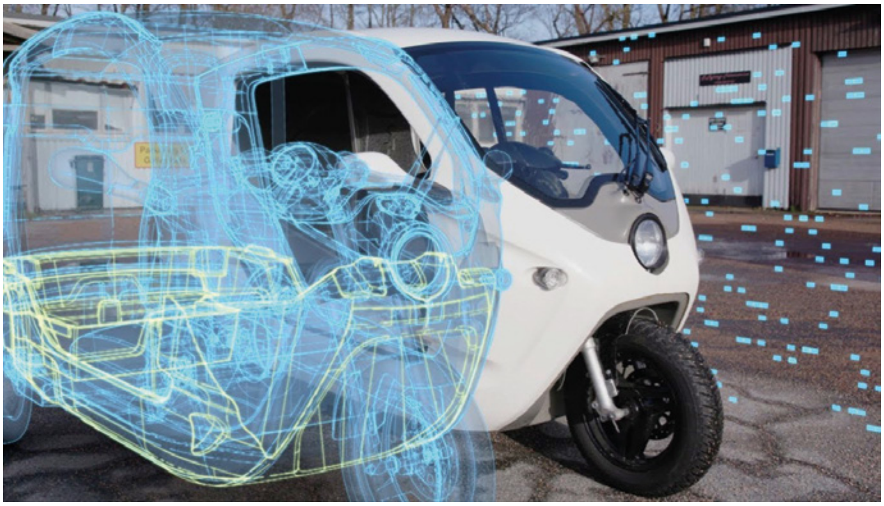
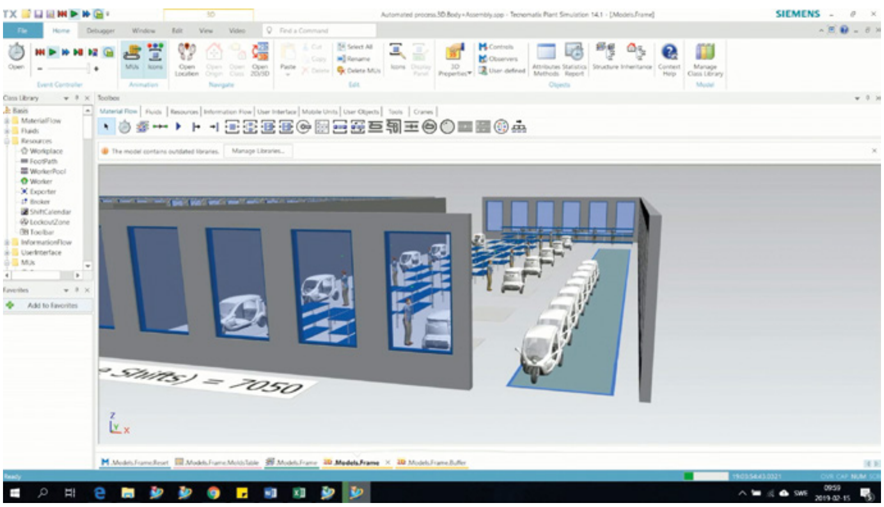


Figure 1: Simcenter 3D composite simulation tool





Inegbedion, who is an analysis and computer-aided design (CAD) engineer, using Simcenter™ 3D software along with the Fibersim™ portfolio, both Siemens products. He states, "Composite technology is one of the most effective measures for managing weight yet retaining even better stiffness properties than materials like aluminum and steel. You can go way down in the weight of your products. And sometimes it is a lot more beautiful."

"There is a seamless connection from your first design in NX to storing your data in Teamcenter to doing your analysis in Simcenter," says Inegbedion. "It looks like one software. You can change things directly in Simcenter 3D, your simulation software, yet you are working with your NX model. You don't have human interference like moving things around or converting from one format or another. You don't lose data intelligence.".

Working from an NX digital twin, the Zbee team used advanced engineering solutions to analyze ideas and optimize the final design. Inegbedion was able to strip the Zbee design down to its bare essentials. He analyzed his composite structure in detail – shaving precious grams where needed without sacrificing the structural integrity of the pod. (The Zbee weighs 280 kilograms, so there is minimal need for bulky, expensive and resource-demanding batteries.)

Sophisticated simplicity and the micro-factory

Another Zbee credo is an idea that the team likes to call "sophisticated simplicity." This is apparent in the Zbee's core design. With only 270 parts, the Zbee is not overdesigned, to say the least. Compared to traditional cars, which contain thousands of parts, the Zbee is designed to be easy to build and maintain while retaining its urban-hip looks and zippy performance.

Creating the Zbee was a lot of hard work, but when the team had the first working model, the next question was how to build it. Since the Zbee was based on composites and a simple design it pointed the team towards a new and different business model: the micro-factory.

"If you have a product that has only 270 parts, you could have a resource-efficient production facility," explains Christoffer Sveder, sales and marketing at Clean Motion. "And if the vehicle is an out-of-the-box solution, why couldn't the factory be like that as well?"

The Zbee digital factory

But going from a visionary business model to a digital factory to a physical factory required some simulation work from another young development engineer. Samuel Johansson 's job was to design a digital factory twin for Zbee production using Tecnomatix™ Plant Simulation software, NX Line Designer and Teamcenter Process Simulator, all part of the Siemens portfolio.

"I made some factory simulations to come up with the most optimal factory layout," says Johansson. "We tested over 100,000 different variants using the Tecnomatix Plant Simulation software. It is quite powerful and easy. We could have never tested all these variants using normal calculations.

"Siemens has a great training environment so with a little help I could figure this software out myself. It is a little bit like playing a strategy game on your computer. Sometimes you build a city. In this case, I am building a factory."

Thanks to Johansson's work, Clean Motion offers customers two digital twin micro-factory designs along with the digital twin plans for the Zbee. One plant digital twin, aimed at European and Western markets, contains more robotics and a slightly more sophisticated structure. A simpler more labor-intensive plant model is available for markets like India and Africa, where the micro-factory could be a sustainable investment, creating local employment and economic development. The Zbee team is currently working in India to get the first micro-factory up and running. A second site in Indonesia is in the works.

"It is a digital key to the future," adds Ankarkrona. "The Zbee is not only clean transportation. It is also a venue to self-sufficiency and economic and social empowerment."

The real Zbee micro-factory

Clean Motion runs a fully operational micro-factory in Trollhätten, Sweden at the former Saab site with a production capacity of approximately 250 vehicles annually. There a small team led by Jörgen Johansson, global manufacturing manager, which assembles and tests every Zbee prior to shipment.

"When I joined seven years ago, we produced one Zbee a month, mostly for prototyping purposes," explains Jörgen Johansson. "But we wanted to make production leaner. So early on, we came up with the idea of minimal parts and dedicated stations. We knew we needed to make it easy to assemble."

Today it only takes two days to make a Zbee. Nine body parts are glued together in the dedicated composite gluing room and the frame is moved from station to station to complete the systems, including brakes, steering, electrics and battery. Each Zbee runs through a quality test on the onsite test track. After passing the test, the team puts a green stamp on window and it is finished and delivered to the customer.

"We are increasing our volume quite a bit," adds Jörgen Johansson. "We need to automate. We need a robot to glue the body to get the quality we need."

Fleet and service models

Clean Motion is also taking the services model seriously. Working with partners, the company is investigating opportunities to sell prepackaged fleet franchises with the fleet management software and connectivity and apps to go with it. Especially in India, this type of business model could offer clean and sustainable transportation for short distances connecting fixed points like metro stations and malls and other local destinations.

"In the future, we won't have space for personal vehicles," says Folkesson. "If you look at most cars, they are used about one hour a day. They stand parked 96 percent of the time. This consumes too many resources. We need to look at shared mobility and mobility as a service, and mobility as a service does require connectivity to run electric vehicles efficiently."

The journey is just starting

Clean Motion has lots of ideas in the pipeline, including an energy-autonomous solar Zbee, which Folkesson calls a "killer product," and a standardized battery swapping program. Given the company's early success, don't bet against these ideas coming to fruition. ■

"There is a seamless connection from your first design in NX to storing your data in Teamcenter to doing your analysis in Simcenter. It looks like one software."

Michael Inegbedion
Analysis and CAD engineer
Clean Motion

Hilti

Construction tools manufacturer uses Simcenter testing solutions to enhance product durability and quality

Siemens Digital Industries Software solutions enable Hilti to reduce vibration, increasing permissible daily use by 300 percent

Mitigating the effects of vibration

The term vibration has a negative connotation because it is often associated with discomfort, loudness and even dysfunction or failure. When developing new products, equipment manufacturers seek to reduce vibrations as much as possible. However, in some situations, the vibration characteristics belong to the main properties of the product: It is designed to generate vibrations that fulfill a certain operating function.

Vibrations nevertheless affect the health and safety of operators using the hammer. They can also harm the environment due to the noise pollution they generate.

Hilti develops and manufactures construction equipment that meets the highest standards of quality and performance requirements. Since its establishment in 1941, Hilti has grown from a small family business into a worldwide enterprise. The Hilti Group supplies the worldwide construction and energy industries with technologically leading products, systems, software and services. In less than 80 years, it has become a worldwide player in fastening and demolition technology for construction professionals.

From its headquarters in Schaan, Liechtenstein, Hilti oversees production facilities and research and development (R&D) centers in Europe, Asia, North America and South America (Mexico). Close to 30,000 employees in more than 120 countries work to uphold the company's commitment to innovation, top quality and close customer relations.

The TE 3000-AVR

The TE 3000-AVR is Hilti's most powerful concrete demolition hammer that features low vibrations and a brushless motor. It offers impressive hammering impact energy for rapidly demolishing large concrete structures. It delivers exceptionally high breaking performance; up to six tons of concrete per hour. It is also versatile and easy to operate and transport as it doesn't require a compressor and is therefore easier to convey than any air tool. The demolition hammer features active vibration reduction (AVR), which makes the tool less tiring to use, increasing an operator's daily productivity.

Lengthy exposure to hand-arm vibrations can result in the hand-arm vibration syndrome (HAVS). The use of handheld power tools can cause damage to blood vessels, nerves in the fingers, bones and muscles. Susceptibility to this syndrome is influenced both by the duration of exposure and the magnitude of the vibrations transmitted to the operator.

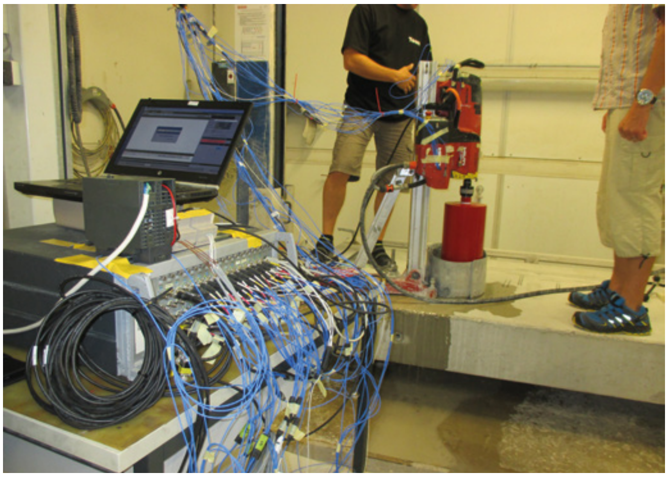
To preserve the health of operators, tools need to be certified according to relevant international standards. Hilti relies on the human body vibration filter add-in in Simcenter Testlab software, a powerful certification tool for analyzing vibrations transmitted to the human body according to internationally recognized standards. The application gives real-time feedback and clearly indicates limit values and/or violations as specified in the International Organization for Standardization (ISO) 2631, ISO 5349 and the European Normalization (EN) 60745 standards.

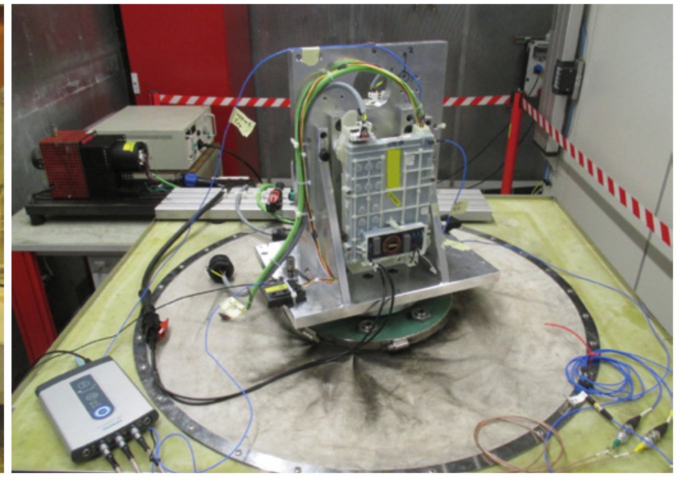
To meet the demanding requirements of the construction industry, Hilti provides AVR functionality, which allows operators to be less exposed to vibration, thus increasing permissible daily use of the tool. For example, a large hammer drill without any anti-vibration measures has a vibration level between 20 and 30 meters per second squared (m/s²). This means workers can use them for no longer than 30 minutes per day. The development of efficient vibration reduction technologies combined with extensive testing allows the user to reduce this level to below 10 m/s², thus increasing permitted use time to two hours per day, a 300 percent increase.

Testing the demolition hammer

The certification is not the only test the TE 3000-AVR is subjected to. Prior to the certification process, like other Hilti products the TE 3000 undergoes a series of comprehensive tests. These tests help shorten the product development cycle and answer market demand for longer product lifetime, enhanced reliability, high performance and low weight.

At the Hilti Competence Center for Health & Safety Technologies in Kaufering, Germany, group manager Lars Melzer and his team are tasked with challenging the performance of newly developed tools.





"Simcenter is necessary at every stage of component testing, especially during preparation to ensure high test quality."

Lars Melzer
Group Manager
Hilti Competence Center for Health & Safety Technologies

"There are two ways of qualifying new developments, the full system tests and the component tests," says Melzer. "We make use of the testing hardware and software offerings in the Simcenter portfolio to perform these tests in an efficient and reliable manner."

In a system test, a complete, functional power tool is tested according to its real-life applications. The test procedure reproduces simplified load cases collected on artificial work pieces. On the other hand, a component test focuses on a single component, such as a switch, electronic assembly, battery interface, motor, etc., which is isolated from the power tool. Component tests are performed on specific test rigs or a shaker.

Shake it before you build it

Component tests require shorter amounts of time, are less costly and can be executed even before the first prototype or tool is available. They can be performed in well-controlled conditions and allow for additional monitoring of environmental parameters (temperature, dust, etc.). To ensure the high quality, reliability and efficiency that characterizes the Hilti brand, shaker tests require a clear process.

It begins with acquiring data using Simcenter SCADAS hardware and Simcenter Testlab Spectral Testing software. The Hilti engineers perform an analysis on the data, using the Simcenter Testlab Signature acquisition capabilities to better understand the component's vibration behavior. Simcenter Testlab Impact Testing helps the team perform accurate shaker test setup. Simcenter Testlab Mission Synthesis is used throughout the shaker tests and validation. Finally, at the end of the process, the data is stored, managed and shared in an interactive graphical manner with the Simcenter Testlab Desktop application.

Matthias Patalong, development engineer on Melzer's team, comments: "Simcenter helps us set up quick and reliable component tests with minimal effort. All necessary functions are integrated within one software solution, making data conversion unnecessary."

A well-defined and harmonized test process

To get an understanding of the dynamic behavior of the system in the first phase the team relies on the broad range of structural testing and analysis capabilities available in Simcenter Testlab: impact testing, operational deflection shapes (ODS), experimental modal analysis (EMA) and operational modal analysis (OMA). These tests and analyses allow the Hilti team to identify potential damages and plan the mounting conditions of the device under test (DUT) or the test specimen on the shaker. Claudius Lein, development engineer, argues: "Under-standing the dynamic behavior of the system is mandatory for setting up high-quality shaker tests."

In the next step, the team performs vibration measurements. The engineers use Simcenter Testlab Signature Acquisition and Spectral Testing for defining and executing several tests corresponding to various applications and load cases. Simcenter SCADAS is used to acquire data that generates representative shaker profiles. The selected parameters for the load cases consist of a combination of tool, user, workpiece, insert (such as drill bit) and feed force.

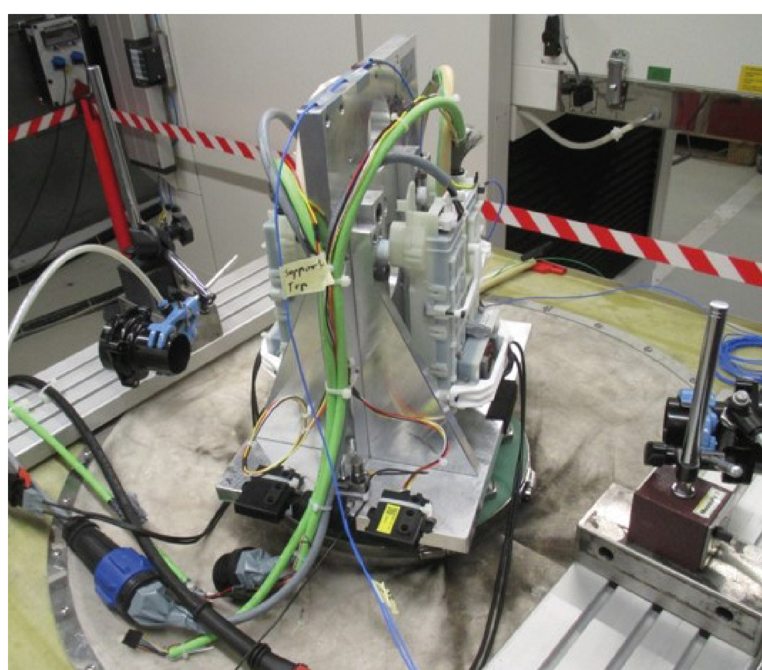
Perfect fixture design
"Adequately stiff shaker fixtures are essential for high-quality tests," adds Susann Nönnig, development engineer. For excellent fixture design, Hilti relies on tools from the Siemens Digital Industries Software portfolio, including the computer-aided design (CAD) module in NX software as well as numerical analysis and physical testing tools from the Simcenter portfolio.

The process starts with designing the fixture using NX CAD. From there, performing a numerical modal analysis using Simcenter 3D is only a step away. The fixture design is iterative and done in active collaboration between the design and simulation teams. The software suite available in the Siemens portfolio supports effective communication between the different teams. The iterative process ensures the fixture meets all set requirements prior to manufacturing.

Once the fixture is manufactured, the team performs the required physical tests and analyses to validate its design; namely, experimental modal analysis and ODS analysis. Once the fixture is validated, the physical component test is executed. The test item and its fixture are placed on the shaker and instrumented. The testing team feeds the defined test signal to the shaker, determines the frequency limit for the test and adapts the signals if required.

One of the main benefits of performing shaker component tests is that other conditions can be assessed simultaneously with the vibration tests. For example, a dust chamber can be placed on top of the shaker to simultaneously test sensitivity to concrete dust. Other test types may combine vibration with electrical load, climate, etc. Thanks to its well-defined procedures, Hilti engineering can ultimately save testing time while ensuring objects meet the requirements for superior quality and durability. The tests provide accurate results, delivering high-performance for a long lifetime in a tough environment while safeguarding operators and users.

Melzer concludes: "Simcenter is necessary at every stage of component testing, especially during preparation to ensure high test quality. We work closely with Simcenter Engineering and Consulting services to ensure best-practice workflows. Simcenter definitely makes our business more efficient." ■



Delivering control algorithms four times faster

Cerebrum-Ingénierie offers heavy equipment customers an alternative to the conventional hardware-in-the-loop (HiL) methodology using Simcenter Amesim

Figure 1: Mobile work platform

Avoiding recurrent prototyping to reduce risk

For heavy equipment manufacturers, customer requirements are usually so diverse and at the same time so specific that most machines are a limited series, if not unique editions. As a result there are lengthy development cycles that include a lot of trial-and-error and recurrent prototyping. Consequently, early virtual validation of various design aspects, including the machine concept and control strategies, is critical to save time and reduce risk. As well as this the development of information processing by the Controller Area Network (CAN) bus benefits enormously from such a simulation-based approach.

This is what French-based, Cerebrum-Ingénierie, has turned their focus to. Founded in 2015 from the Fluid Design Group, Cerebrum-Ingénierie engineers help manufacturers, particularly in the heavy equipment industry, to optimize and secure the development of mechatronic systems by bringing digital modeling into the design process. For this, they use Simcenter Amesim software from Siemens Digital Industries Software.

The first CAN bus was developed at Robert Bosch GmbH in the 1980s, as a response to the continuously growing number of distributed signals and interfaces in car passenger vehicles. The multiplexing of these systems had to be generalized and standardized. As today's requirements regarding energy efficiency, emissions, safety and comfort have led to an exponential increase of smart sensors and actuators, the CAN bus is becoming more complex, while at the same time more important than ever. The development time of algorithms inside the bus is largely determined by the required validation and fine-tuning calibration of the machine in operation.

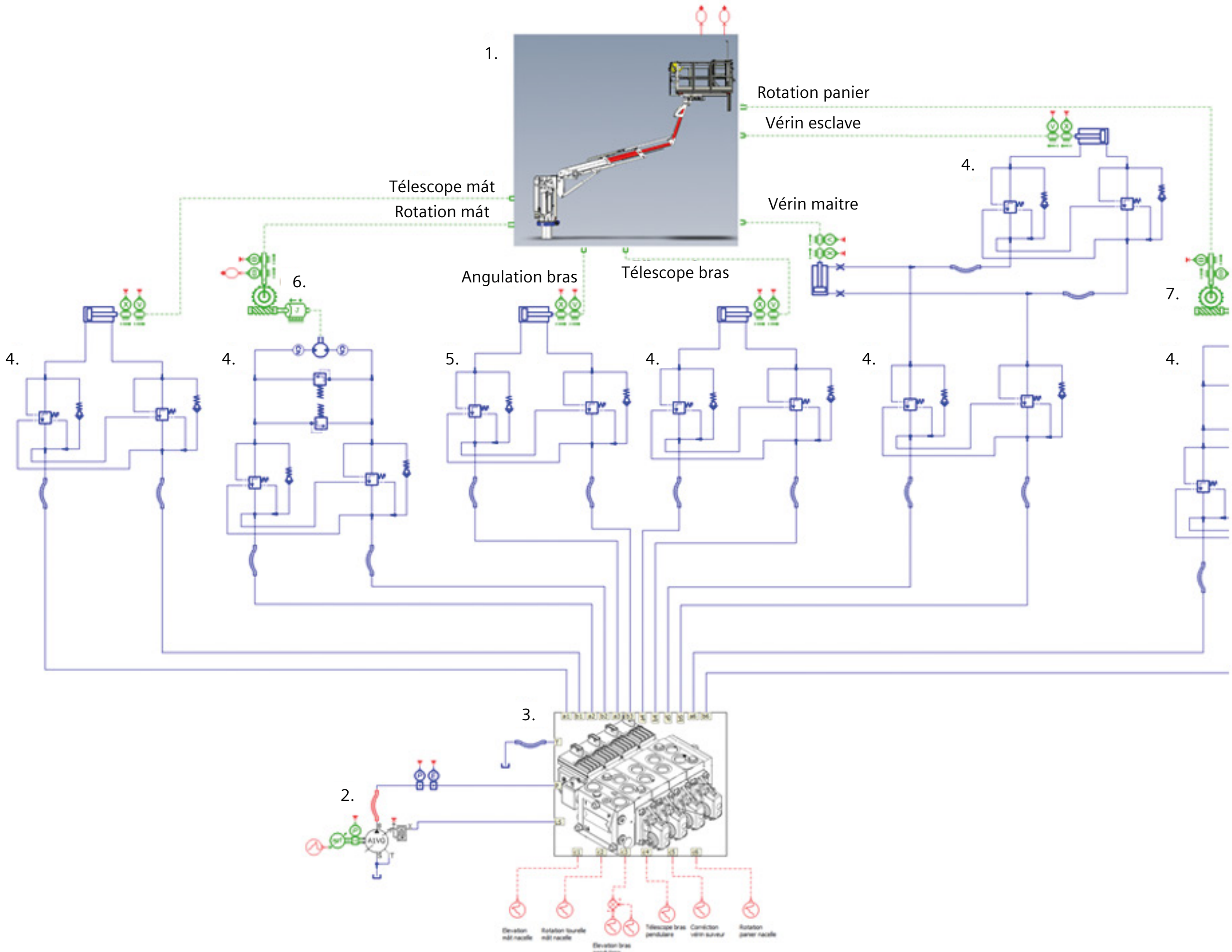


Figure 1: Machine Plant Model Using Simcenter Amesim

Following an entirely virtual approach with a plug-and-play CAN adapter
Mr. Michele Loizzo, systems engineer at Cerebrum-Ingénierie, and his colleagues offer their customers an alternative to the standard HIL methodology by adopting an entirely virtual approach. This includes the modeling of both the physical system (the so-called plant model) and its communication interface with the controller, all before any physical prototyping or HiL testing. Thanks to the universal serial bus (USB)/CAN interface they developed, they can connect the computer that runs the plant model directly with the real electronic control units (ECUs) to transcribe the numerical signals, without requiring a conventional HiL test bench, much earlier in the development process.

"We have developed a library in Simcenter Amesim that allows us to send and receive CAN frames via a USB/CAN adapter," explains Loizzo. "We can then virtually validate the control laws and the data processing during the transfer between the real controllers (ECUs) and the virtual system (or plant model)."

Such an entirely virtual plug-and-play testing environment presents various advantages, as it allows direct communication between the Simcenter Amesim plant model and the code of the controller in the ECU. The engineers have tools available for both synchronous and asynchronous working modes, according to their needs. When in synchronous mode, a synchronization protocol keeps track of all dynamic/transient behavior, so that control commands can be fine-tuned without requiring the plant model to run in real time. The asynchronous mode on the other hand exists to process cases where the operator has to directly recalibrate the controller using a real-time plant model. Finally, the entire test setup can be managed by an interactive dashboard.

Effectively developing a controller that ensures safe machine operation
Loizzo and his colleagues successfully applied this methodology in an industrial project where they optimize the control algorithms of a complete maintenance platform train that replaces railway catenary consoles. For safety reasons, such a device has strict constraints in terms of stability. While the operator handles the platform using a joystick, the controls should help prevent the movement of the intervention arm exceeding the safety margins as a result of improper manipulation.

"First, we modeled the machine in Simcenter Amesim to size all components," explains Loizzo. "Then after completing the plant model, we could virtually identify potential failure cases and optimize the design accordingly. Finally, we simplified or reduced the model to virtually operate it in real time."

In parallel, the engineers developed the control algorithms. The real-time calculations in Simcenter Amesim enable direct exchange of signals between controller and model. "Simcenter Amesim can provide us, in real time, the component's position, acting as a virtual sensor," explains Loizzo. "Those virtual sensor signals are then introduced in a closed loop with the real ECU algorithms that adjust the position of the intervention arm in case the platform leaves the authorized intervention margins. As a precaution, the software can reduce the platform's movement speed when the boundaries are approached, or even stop it when exceeded. Using a 3D real-time animation of the model, we could interactively understand the system's behavior."

Frontloading up to 80 percent of the control strategy verification
This virtual testing approach allowed Cerebrum-Ingénierie to dramatically speed up the algorithm design and validation. "The catenary train control strategy definition took us only three

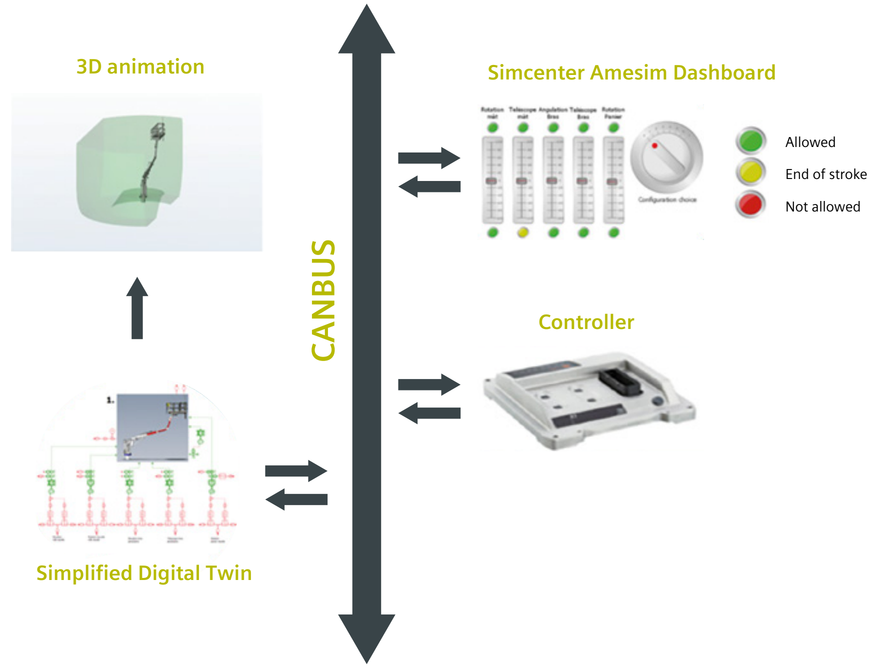


Figure 2: Processor-in-the-loop methodology steps

weeks of development, and just one week of further calibration at the customer," explains Loizzo. "Indeed, our processor-in-the-loop (PiL) methodology let us do 80% of the testing and validation virtually and upfront. That helped us reduce the time we had to spend with the customer fine-tuning the control laws for ultimate comfort improvement."

Mr. Frederic Lagors, technical director at Cerebrum-Ingénierie, put things in a wider perspective. He compares today's achievements with similar projects about five years ago and shares a remarkable statistic. "We assessed the effectiveness of the PiL methodology by comparing this platform train project with a similar one we delivered back in 2015," explains Lagors. "Five years ago, it took us four months to develop and validate the machine control algorithms. Now with the PiL method, we are at four weeks. So we can roughly say that the PiL approach allows us to deliver control algorithms four times faster. This is an enormous reduction of time, cost and risk." ■

Closing the loop

Mechanical qualification testing for space hardware

The mechanical environmental qualification is a requirement for all space hardware, from component to full space-craft. The type and level of excitation to which the hardware will be subjected to depends on a number of factors. For example, the spacecraft structure and equipment should be capable of withstanding the maximum expected launch vehicle ground and flight environments, and whether it can is determined by running tests.

Simcenter testing solutions provide a full suite for mechanical environmental testing for space hardware, consolidating years of expertise and end-users feedback from leading companies in the space industry.

Vibe Test
Simcenter Testlab Sine Control is a closed-loop control solution for swept sine vibration tests. Together with the Simcenter SCADAS hardware, it provides an integrated feature for force and moment limiting. Simcenter Testlab Sine Control enables to realistically notch spacecraft resonances and response limiting to protect the spacecraft structure and hardware from exceeding design strength capabilities. The solution also provides all necessary features to define and control a random vibration excitation that matches a predefined power spectral density profile. Among several safety features, this solution offers response limiting and sigma limiting. The implementation of a phase optimization algorithm for sigma limiting with no amplitude distortion and out-of-band noise is an added value, compared to traditional sigma clipping algorithms. Simcenter Testlab Shock Control is a

time-domain control solution that can use a previously measured pulse as reference waveform, a classical waveform such as a half sine pulse, or the result of a synthesis for control. Simcenter Testlab Shock Control offers a unique Shock Response Spectrum (SRS) limiting algorithm for test specimen protection and online SRS calculation with a wide range of post-test data analysis capabilities.

All closed-loop solutions have set trends in the industry for safety features. Since the first systems, installed over 20 years ago, when a smooth ramp-down of the voltage was used to reduce jolts in the amp-shaker system. Parameters have been added to the software to create the most flexible and safest vibration control system.

Pyroshock

A pyroshock is a very violent event characterized by its short duration (a few milliseconds) and a high magnitude with extreme acceleration levels. In the space industry, pyrotechnic devices such as explosive bolts are routinely used, for instance, in the release mechanisms employed for stage separation or payload release. The resulting pyroshock event may cause damage to the payload's electronics and may distort mechanical parts, such as bearings, gears and worm wheels.

Because of the criticality of this type of tests, its extremely short duration (milliseconds), and the high-frequency content (at least to 10kHz), the acquisition system must be reliable enough not to miss the event. It must sample high enough frequencies (200kHz is best practice) and it must process data very quickly to provide engineers all relevant information. Shock Response Spectrum must be available at all instances to enable engineers to perform the relevant engineering analysis. This type of data measurement and analysis can be done with the Simcenter Testlab data analysis software and the Simcenter SCADAS acquisition system.

Acoustic Testing

For satellites and components, the vibro-acoustic test is a milestone for the qualification campaign. In the space industry, these tests have been historically carried out in dedicated facilities called Reverberant Chambers. A digital controller in these chambers is needed to ensure that the acoustic level and the spectrum reach desired levels within the required tolerances. The dedicated solution, the Simcenter Testlab Acoustic Control, has been added to the environmental products family to supply a state-of-the art control system ready for critical tests. The Simcenter Testlab software offers flexibility together with extra safety options for engineers working in space labs. It has been designed and developed to consider all the necessary features for providing lab engineers and technicians with a comfortable system to carry out the

Figure 1: Instrumentation of satellite for vibration test: The Data Acquisition solution of Simcenter Testlab and SCADAS is engineered to acquire and process online data coming from hundreds of different sensors during vibe, pyro and acoustic tests.

Figure 2: Simcenter SCADAS and Testlab provide easy and clear high-channel count setup.

Figure 3: Simcenter solutions for vibration testing (sine, random and shock) for full satellite or space hardware components.

delicate job of qualifying the satellite to acoustic loading. Added features in the software, such as the definition of the reference profile in an excel-editable table format, a check-box to select which microphone should will be included in the loop for measurement or setting any abort parameters on both acoustic or vibration channels, give a peace of mind to the users. The control system can also work using multiple drives (multi-output) by simply setting the bandwidth (pass-band) of each drive so that each amplifier-modulator can be fed with an optimized drive with the desired crest factor value. The control system has been conceived to give full flexibility starting from a previous drive, for example, from a lower level test using the automatic control to adjust the drives for each octave being controlled; or by allowing the operator to run tests in full manual mode with a graphical equalizer to adjust the drive as desired. Once the test is over—as defined by the automatic or manual timer settings—the data in time and frequency (both narrow and octave bands) are ready and available to make the necessary engineering calls to continue testing.

In addition, over the past two decades or so, engineers and scientists have been exploring alternative test means to these otherwise costly, albeit proven, acoustic facilities. The use of commercially available loudspeakers has since then been regarded as a feasible alternative. Today's audio equipment, amps and speakers achieve the desired acoustic levels. At the same time, Simcenter Testlab provides Multi-Input-Multi-Output (MIMO) control schemes that ensure the necessary sound field uniformity around the test object. This technique, referred to as Direct Field Acoustic Noise (DFAN) currently has the attention of the space industry, especially where reverberant facilities are not available in-house and/or when the transportation of the test item is required.

Data Acquisition

If on the one hand there is a critical element in a vibration or acoustic test in controlling the input level to the exciter—be it a shaker, an acoustic modulator or a loudspeaker—, the very scope of a mechanical qualification test is to acquire and analyze the vibration response on the test item. In other words, the signals from hundreds of sensors (accelerometers, strain gauges, force sensors...) attached to the satellite need to be measured, recorded, processed and stored. This is where Siemens can provide the added value. Having equipped some of the biggest vibration test facilities in five continents, Siemens has collected a wealth of experience in hardware and software configuration to provide the most flexible and robust lab layout management. The acquisition cards to measure charge, IEPE/ICP, strain, and pressure sensors can be optimally distributed over several acquisition units.

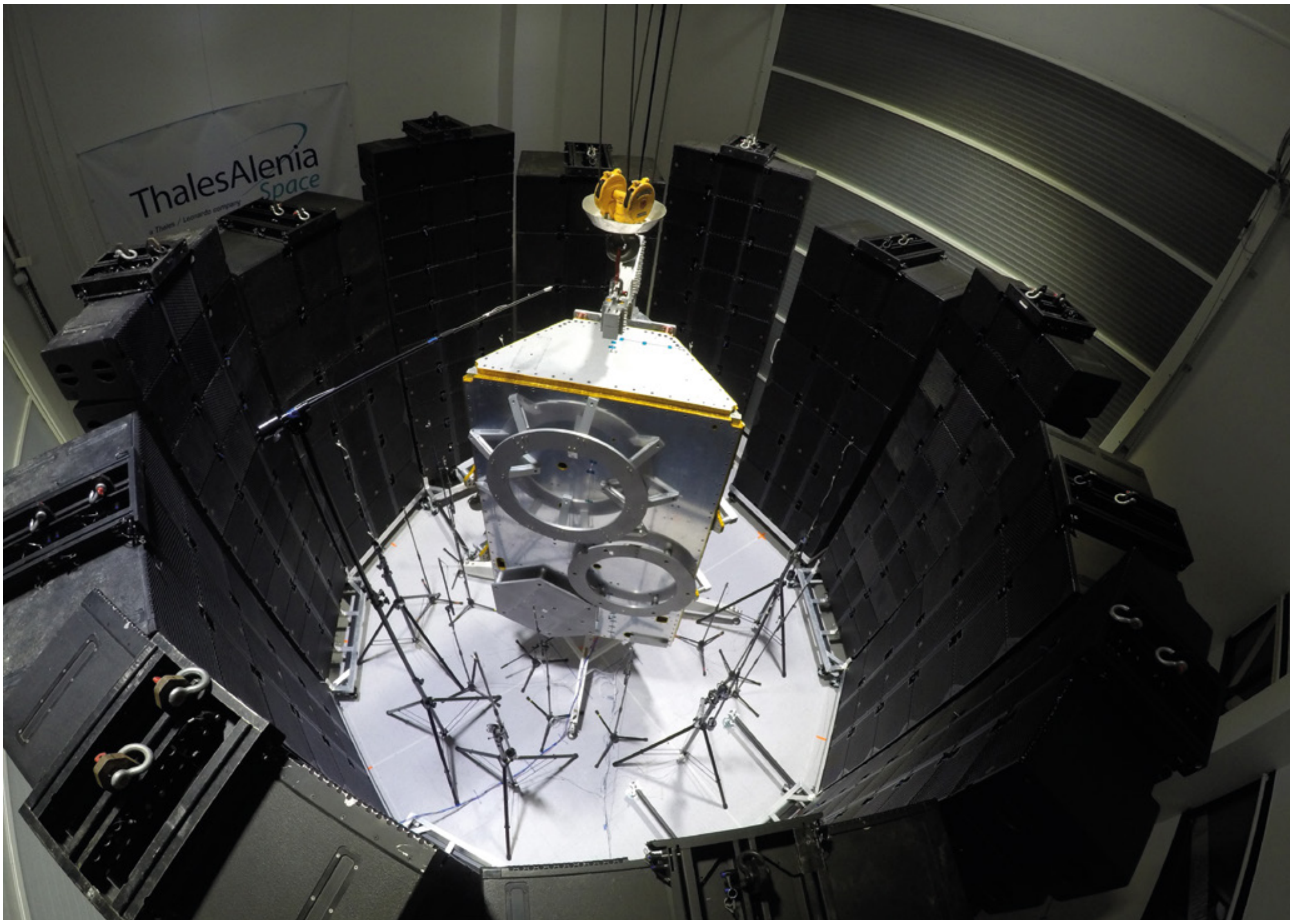


Figure 5: Simcenter also provides Multi-Input-Multi-Output control for Direct Field Acoustic Noise (DFAN) tests.

These can be work as stand-alone or clustered to provide measurement system of several hundred channels, and with a safe architecture that provides the safest risk mitigation against any possible data loss. Simcenter software is available to manage multiple acquisition stations centrally so that the systems can be started/stopped simultaneously, and all the data collected in a central repository. At the same time, the software gives lab engineers and customer a live view on critical data processed in frequency (narrow band and/or octave) for an immediate engineering feedback on vibration and acoustic response.

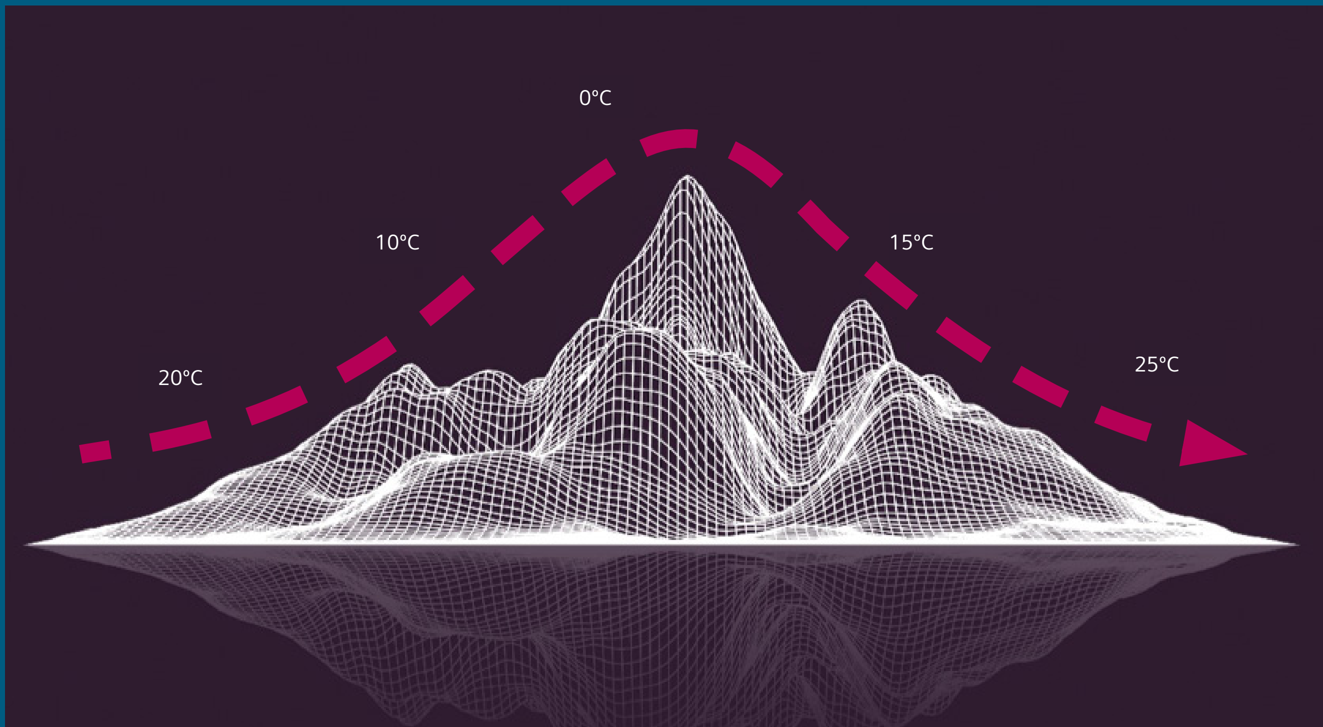
The combination of the Simcenter SCADAS hardware and the Simcenter Testlab software has been used to acquire data on hundreds of satellites over the past decades. This impressive track record gives the necessary confidence and peace of mind to lab engineers and managers to use Simcenter solutions for their most critical tests on multi-million-dollar objects.

Figure 4: Simcenter Testlab Acoustic Control is the solution for closed loop control in reverberant chambers.

With the addition of solutions for reverberant chamber control, direct field acoustic testing to the renowned vibe, pyro and data acquisition systems, Simcenter Testlab has closed the loop on providing all the necessary tools to complete a full mechanical qualification test campaign for all space hardware. ■

Geek Hub

Mountains aren't just funny, they're hills areas!



With the ski season fully underway, I thought this would be a good time to turn our attention to mountains, specifically the effects of weather in the Alps and what causes the warming and drying of air. This is something that skiers, snowboarders and residents of mountainous regions should be familiar with.

What I am talking about is the Foehn (Föhn) effect, which regularly impacts weather conditions, not just locally but often for hundreds of kilometres downwind. Simply, this is a change from wet and cold conditions on one side of a mountain to warmer and drier conditions on the other (leeward) side. This effect can often lead to massive temperature differences with the greatest being on the 14th January 1972 in Montana, USA. Within 24 hours the temperature changed from -48°C to 9°C, this is a temperature increase of 57°C!

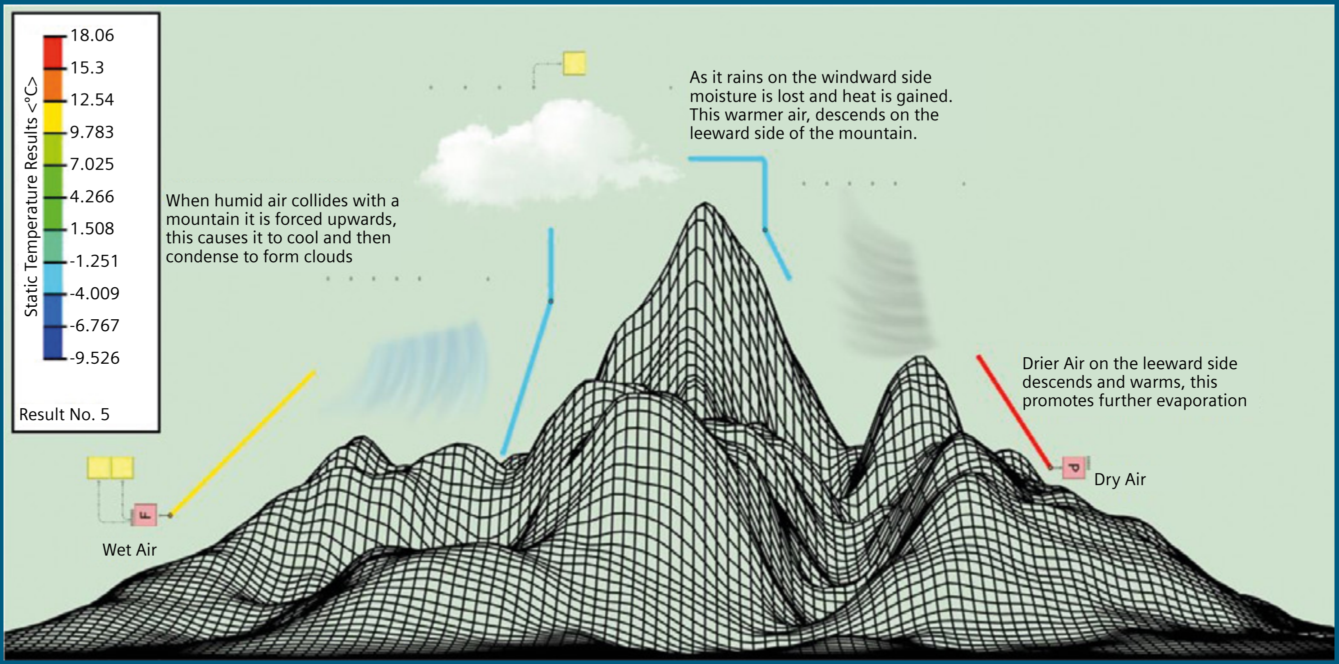
While we don't see extremes like this in the UK, the Foehn effect is most prevalent across the Scottish highlands where the high ground along the west coast results in wet weather. In contrast to this the lower ground across the east of Scotland enjoys warmer weather with more sunshine.

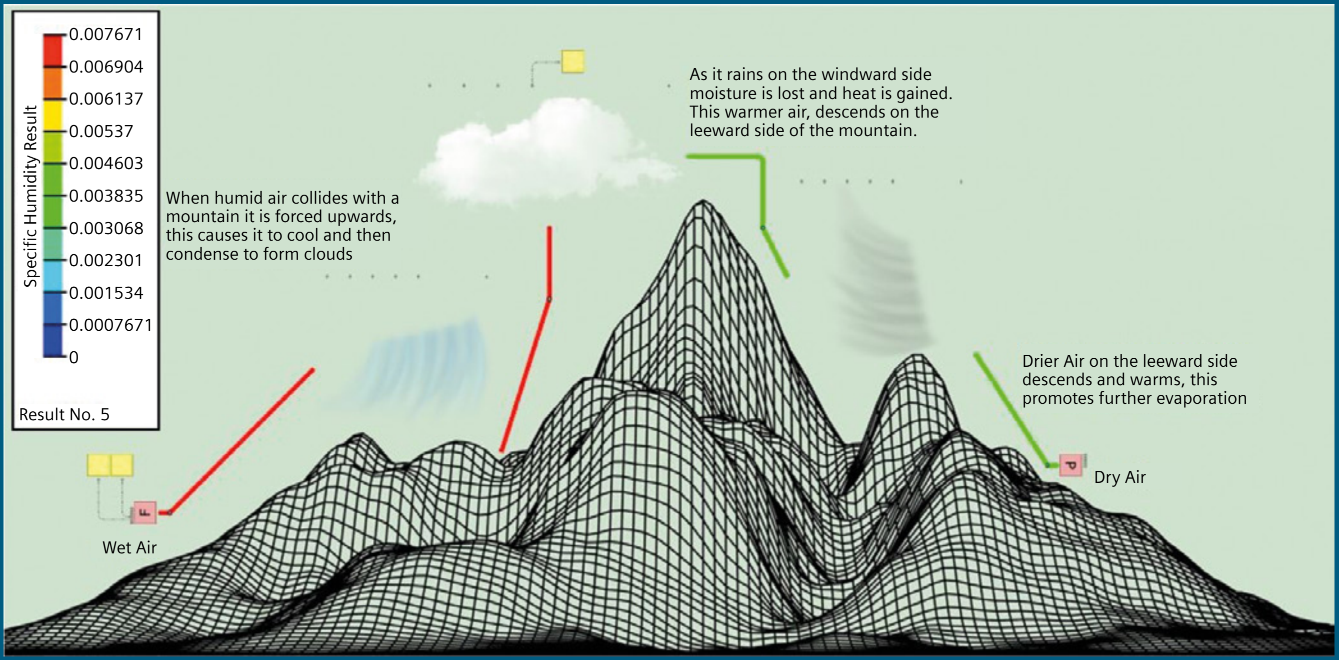
How does the Foehn effect work?
When air encounters a mountain it is forced upwards, as the pressure decreases with altitude this causes the air to expand and cool. As the colder air is less able to hold water vapour, the water condenses and forms clouds. These then release the water as rain or snow above the mountain.

This can enable us to draw two initial observations, firstly snow is only usually at the top of mountains and heavier on one side. Additionally you have probably observed a cloudless sky on a summer's day with only a few clouds forming around mountain peaks. These are both due to the pressure and temperature drop which result in cloud formation.

As the clouds form and then precipitate the fluid is changing from a vapor to a liquid state, this results in an irreversible heating effect due to the removal of moisture from the air. The flow of drier air passes over the mountain peak and down the leeward side which results in warm dry air. This is a great example of atmospheric thermodynamics and which can now be demonstrated in Simcenter™ Flomaster™.

The image above shows the wet air on the left (windward





side) that is forced up the mountain, this causes it to cool and then condense to form clouds. This then causes it to rain which results in moisture being lost and a gain in heat. This warmer air descends on the leeward side and promotes evaporation. This image only tells half the story though as we can't see the humidity change.

At the exit of the clouds the specific humidity is set to 100% on outflow. This means that any super-saturation is lost (as rain). The specific humidity reduces but relative humidity is 100%.

Now the air has no liquid water to condense, so the heat effect is nearly 10°C – leading to winds of 18°C.

Why is this important?
The Foehn effect can lead to a number of positive effects, mainly regions that experience this heating effect have drier climates which result in longer growing seasons. It does however have a number of negatives too. If we look back to skiing the warmth from the Foehn effect is good for tourism but it increases the risk of avalanches, it can also cause glacial melt and flooding

along with contributing to the loss of ice shelves in Polar Regions.

It also poses risks to climbers and can be a major contributing factor to the spread of wildfires. The combination of warm, dry air and high wind speeds promote the ignition and rapid spread of wildfires.

There are also claims of Foehnkrankenheit (Foehn sickness) among people in alpine regions which recent studies have suggested that there might be some truth in this as they have shown correlations with migraine occurrences.

This shows why complex physical phenomenon are very important to be able to understand fully and model accurately. We here at Siemens strive to understand these effects so that you can quickly model solutions with the highest levels of confidence and accuracy in the results. ■

“I bet you haven't seen the temperature change by 57°C in 24 hours before? The weather can do some weird things but we can understand these with advanced fluid modelling tools.”

Brownian Motion…

The random musings of a Fluid Dynamicist

Coughs and Sneezes Spread Diseases

Everyone sneezes, and as a hay fever sufferer, I sneeze more than most, especially at this time of year. At the best of times, coughing and sneezing in a social situation is awkward, but as the whole world is gripped in a COVID-19 pandemic, every cough, every sneeze, is seen as a potential transmission of the virus.

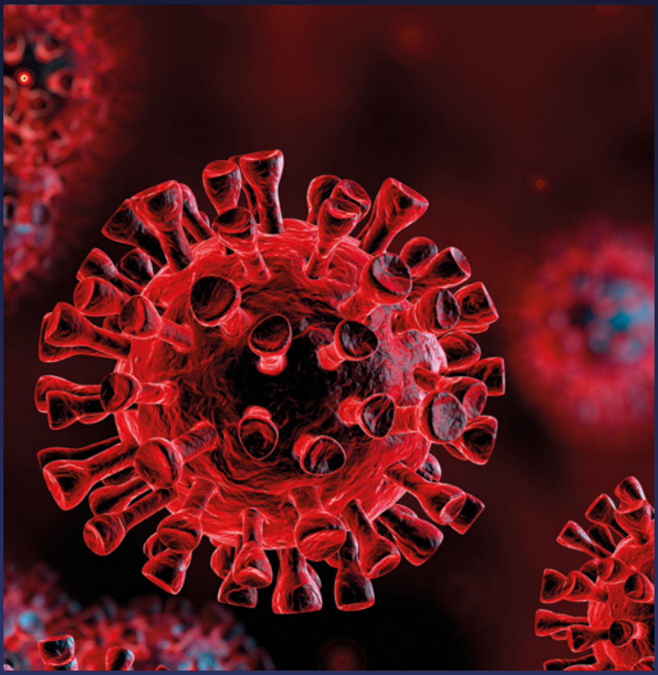
Coughing and sneezing are a biological mechanism for clearing foreign particles, including, microbes, mucus, and bacteria from the respiratory pathways of the body. Both involve high-pressure expulsions from the lungs. Unlike coughing - which is usually a conscious act, sneezing is a semi-autonomous convulsion, over which one has much less control. In both cases, viruses have evolved to hijack that mechanism to propel themselves over surprisingly large distances.

A 2012 paper in the Federation of American Societies for Experimental Biology described sneezing as a "natural reboot mechanism for your body," which is analogous to the famous Microsoft Windows "blue screen of death."

A 2002 study, which asked participants to record every sneeze in a diary, calculated that 95% of people sneeze less than four times per day (although in peak hay fever season I reckon easily I sneeze more than 40 times a day - that's a more reboot time than when trying to run CFD simulations on a temperamental Windows 95 computer). This study is somewhat validated by Peter Fletcher counted every sneeze for 3947 days on his riveting Sneeze Count Blog, racking up 5126 sneezes, about 1.3 a day, before the blog mysteriously stopped in May 2018. His conclusion from this mammoth scientific experiment? Sneezes only occur when you are awake, and that he sneezed more frequently in the morning than in the afternoon.

Do you ever feel the need to sneeze when you enter a sunny room? If so, you're not alone; 18 to 35% of the population suffers from "reflexive sneezing induced by sunlight," a condition that has the (best ever) acronym of ACHOOS (autosomal dominant compulsive helio-ophthalmic outbursts of sneezing). As a long-term sufferer of ACHOOS, and as a fluid dynamics geek, I had long ago contrived my own pet theory about buoyancy induced updrafts carrying particles of pollen and dust up my nostrils. However, that isn't a theory that has any scientific support.

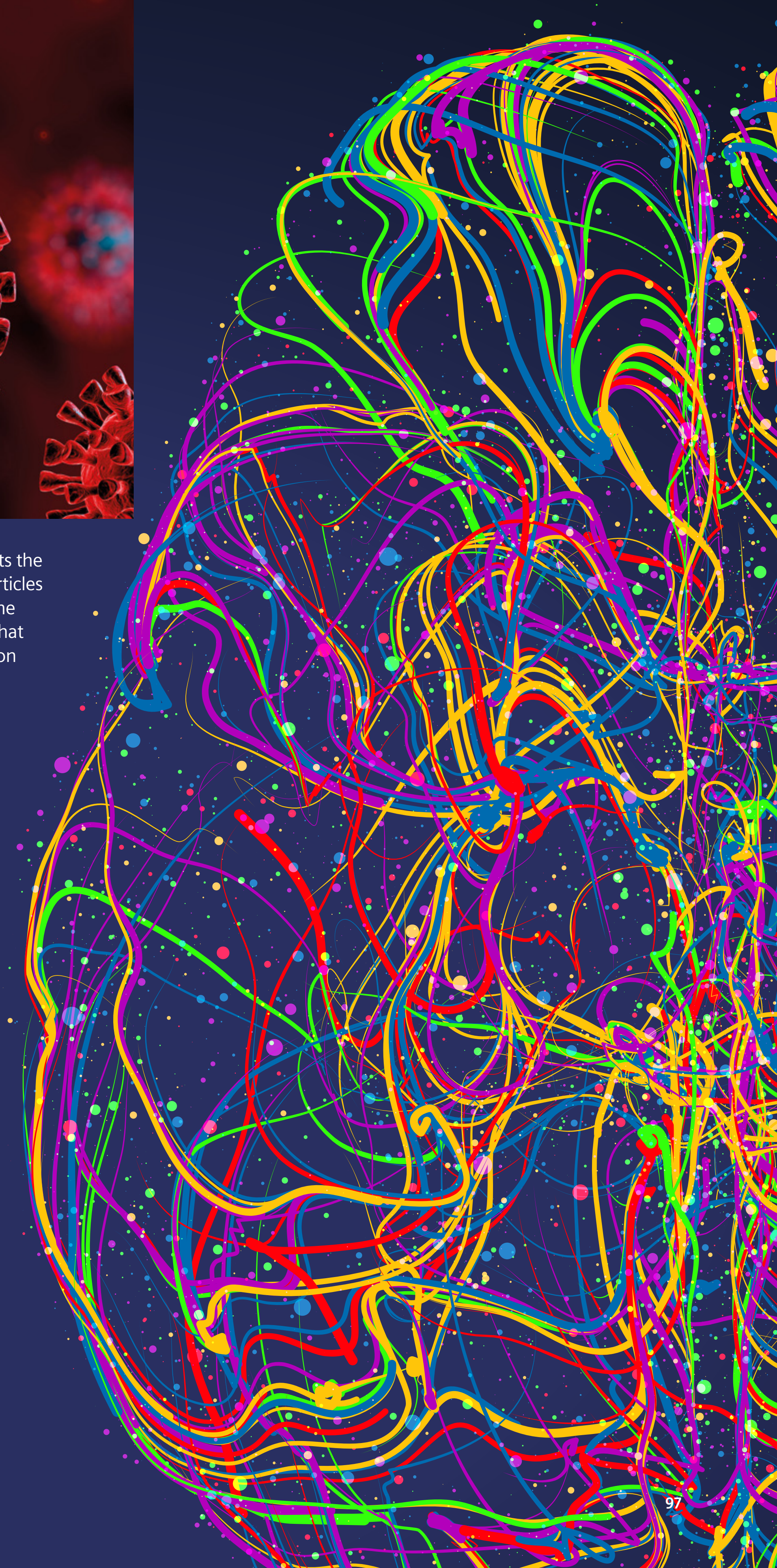
But of course, both coughing and sneezing involve multiphase fluid dynamics. The 2012 "reboot" paper described sneezing



this way: "When a sneeze works properly, it resets the environment within nasal passages, so "bad" particles breathed in through the nose can be trapped. The sneeze is accomplished by biochemical signals that regulate the beating of cilia (microscopic hairs) on the cells that line our nasal cavities."

The definitive study on the topic is a 2014 Journal of Fluid Mechanics paper from MIT entitled "Violent expiratory events: on coughing and sneezing," which explains how both events depend on a "multiphase turbulent buoyant cloud" erupting from a person's mouth, consisting of "hot and moist exhaled air," as well as drops of saliva. According to the study - which involved both numerical simulation and physical experiment, a typical sneeze consists of a cloud of up to 40,000 droplets traveling at peak velocities of over 200 miles an hour, which can project virus-laden mucus up to 25ft (7.5m). These droplets stay suspended in the air for up to 10 minutes!

All of which makes you think that wearing face masks in public whenever you are suffering from a cold, as is common in some Asian cultures, it probably a good idea if only to limit the velocity of one's mucus cloud. However, given that I've sneezed three times while writing this article, it would mean that my face would also be hidden behind a mask for much of the year. If you knew what I look like, you'd probably agree that that is a good idea too. ■



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