Taking stock: the evolution of simulation around the world pre- and post-Covid-19

From its earliest days through to future post-pandemic perspectives

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At this particular moment in time, the "Newsletter" editorial team wished to reflect on the evolution of CAE and simulation in an effort to present a big-picture view when most of us are daily dealing with all the devil in the details in every aspect of our lives. We approached some long-standing business friends in engineering simulation from various regions around the world to help us in this task.

The contributors come from different countries in Europe, the USA, Brazil, and Korea. Each had as different an early beginning as can be imagined considering the differences geographically, economically, technologically, and culturally. They all began their careers in technical roles as users of finite element simulation, after which their careers developed into management positions in various technical and consulting capacities that saw them involved in the deployment and application of the different generations of these advanced technologies over a period of thirty years.

This, therefore, provides an interesting snapshot of the evolution simulation has had and we hope it will stimulate further debate and thought as we move into the future.

As Roberto Gonella, Director of Corporate Strategic Initiatives at EnginSoft, explains, "Among friends we can allow ourselves to speak frankly, to compare and discuss the experiences and challenges that have seen us participating as protagonists for a long time, albeit in different cultural contexts. This background makes us, somehow, veterans of engineering simulation."

"The term veteran comes from Latin. In ancient Rome, the "veteranus" was a soldier who, after having served for a certain number of years, was retained in a special division (vexillum veteranorum) of the legion. He was released from regular service but obliged to fight in case of war, since the skills he had acquired were still necessary when important decisions had to be made that could potentially alter the outcome of a battle itself," he says.

"Inspired by the teachings of the ancients and with the intention of creating a type of virtual agorà (like the public square in Ancient Greece that welcomed public debate to reconcile the prospective vision of the future with past experiences), this feature will attempt to make a balanced comparison of the past, present, and future in different regions and try to glimpse the future of simulation on the horizon," states Gonella.

Looking back: the Asian dawn

Jinwook Shim, Ph.D, today is joint-CEO of South Korea-based CAE service provider TAE SUNG S&E (TSNE), but he first began his career in a shipbuilding company in 1984. One of the pioneering companies in Korea, Shim's employer used finite element method (FEM) to check the structural integrity and fatigue life of crude oil carriers and offshore drilling rigs. "It was the first time I came across the terms FEM and CAE," he notes. "At that time, FEM was a state-of-the-art technology only accessible to a few designers because the company did not have many computers or software. Designers could run small-sized models consisting of roughly several thousand elements and nodes which were manually constructed in a painfully time-consuming way on the mainframe computer in the computer room," Shim recalls. "And the postprocessing work, such as plotting stress contours and displacement contours, which looks so simple today when viewed on a monitor, was only possible on an A0-sized physical drawing that was printed by a big X-Y pen plotter on a roll of paper."

Contributors (in alphabetical order)

Dave Conover | Ansys
Chief Technologist for Mechanical Products (Retired), and Corporate Fellow

40-year veteran of FEA software development: elements, materials, nonlinear, dynamics, and additive manufacturing.

Markus Dutly | CADFEM (Suisse) AG
CEO

Achieved a bachelor's degree in mechanical engineering from ZHAW, then worked as calculation engineer at Maag Zahnräder (Zurich), after which he transitioned to support, consulting, training, and sales at CADFEM GmbH (Munich). He then became Managing Director of CADFEM Switzerland where he is also head of sales.

Roberto Gonella | EnginSoft
Director of Corporate Strategic Initiatives

With a degree in Aeronautical Engineering from Pisa, he worked at Italcae, where he participated in the development of the "Black Shark", a state-of-the-art heavy torpedo, the detailed design of the Arane 5 boosters, and the dynamic dimensioning of the powertrain system of the 8-cylinder Ferrari engine. Once Italcae was incorporated into EnginSoft, engineer Gonella, in the role of Director of Presales and special projects, is responsible for all the technical activities that govern the engineering software proposition within companies, and the management of special projects, including a nuclear site in Cadarache (France) and Castorone with Saipem.

Marco Perillo | EnginSoft
General Manager

Enamored with FEM since graduating in mechanical engineering in the mid-nineties. Follower of explicit time integration methods for dynamic high velocity problems, especially concerning composite structures. Devoted to discovering emerging methods and technologies to boost CAE application in industry.

Marcus Reiss | ESSS Brazil
Vice President

Marcus Reis was involved in various activities from his early days at ESSS (a Latin American pioneer in the field of numerical simulation). He started as a software developer, but soon migrated to CFD consulting. Over time, he has built a team of technical specialists working in various disciplines of computational modeling (CFD, FEA, EMAG, MDO, and DEM). He has participated in more than 100 projects for key customers from several industry segments, ranging from automotive, appliances, and aerospace, to mining and oil&gas. Concurrently, he also set up and developed the ESSS marketing and sales division with a key focus on Ansys software for LATAM and Iberia. More recently he has been responsible for the global business development of Rocky DEM software.

Jinwook Shim, PhD | TAE SUNG S&E (South Korea)
Ph.D, joint CEO

Studied marine engineering at Pusan National University and began his career at Daewoo Shipbuilding in South Korea. Deeply impressed by the beauty of CAE, he continued his studies earning master's and doctoral degrees. He began working for TSNE in 1997 as a support engineer, devoted to Ansys consulting and support for major companies in South Korea.

Erke Wang | CADFEM Germany
Managing Director

Joined CADFEM in 1988, my life is simulation.

Shim's company used CAE to decide the thickness of the steel to be used for the ship hulls. While the classification societies provided standard guidelines for scantling the hull thickness, shipbuilding companies used FEM software to determine the minimum thickness possible within the guideline criteria, or to cut down the overabundant safety margin: "Obviously, reducing the thickness was key to making more profits by saving on materials, manufacturing, dead weight and fuel, Shim says. In Korea, some government institutions, large enterprises, and first began using simulation software from the early Eighties, "OEM companies for shipbuilding, power plants, and the automotive and defense industries were the early adopters," he explains, "Later, those OEM companies began requiring their contractors to submit their simulation reports, which led to the expansion of CAE technology more widely into smaller companies."

"Since 2000, simulation technology has been widely used by electronics, electrical and semiconductor companies to investigate reasons for failures and to find solutions. Among end users, its use has expanded from a limited group of highly qualified experts to widespread use among normal designers and consequently the role of simulation has changed from merely assisting to improve designs or solve specific engineering problems to playing a key role as an adviser to enhance and maximize the performance of their products," Shim states.

The European beginnings

In Switzerland, when Markus Dutly, today CEO at CADFEM Suisse, started his career, simulation tools like Ansys were also only available on mainframe computers that were reached via a modem and client/server software, "This scenario is being duplicated now: today's cloud applications look very similar," he says, "Although the performance, speed and graphics are not comparable. Back then, my models contained a maximum of 5,000 elements. A job was sent in the evening and you hoped it would be processed by the next day. The costs were also remarkably high – around $500 per night," he explains. "For this reason, only large companies could simulate seriously."

Like in Korea, simulation was used mainly by professors and doctors and began in the established industries such as oil and gas, hydro power, nuclear power, and plant engineering with applications for generators, turbines, compressors, and pipelines. He states, "It was all about safety assessments and proof of standards. I estimate that there were less than 30 companies in Switzerland that used simulation in 1980."

When the first PCs came onto the market in 1990, smaller companies were able to enter the market, Dutly says, "Ansys PC LINEAR or Ansys FULL were popular products for small and medium-sized companies and design engineers were targeted for the first time in 1995. All the marketing and sales messages focused on the software having to be "easy to use", and, to this day, one can argue about what "easy to use" should be in engineering simulation. Some CAD manufacturers' marketing hammered the message that 'anyone can simulate' into

The Beginning of Simulation

Simulation method	FEA/FEM with hand-crafted node and element meshes
ICT environment	Mainframe computer with modems, terminals, line printers, and pen plotters
Users	Professors, PhDs, technical experts at state institutions and large enterprises
Industry sectors	Shipbuilding, oil&gas, power plants, aerospace, automotive and defense
Applications	Structural integrity, fatigue life, understanding failure or damage, assessment of standards, model parameter extraction
Model size	A few thousand elements

customers heads." But Dutly recalls, "John Swanson, the founder of Ansys, said at the time that he would never get into an aircraft that had been calculated by a designer who was simulating just 5% of his time."

Dutly states, "The recipe for the successful use of simulation is not the software alone, but its correct application: it takes a good engineer with good knowledge of numerics and physics and their practical relevance, and he must also be proficient in Ansys. These requirements have not changed since the beginning."

Erke Wang, Dutly's colleague at CADFEM Germany, where he is Managing Director today, elaborates, "Most companies used simulation to understand the reason for damage to a product after it had broken. The knowledge they gained from simulation helped them to improve the products. The time, costs and limitations of testing compared to simulation began to become obvious, so companies began realizing that using more simulation during the development process could save them on time and costs and help them better understand their products. So, while simulation was initially used for validation, it evolved into being used for simulation-driven product development."

According to Wang, the CAD interface and TET mesh features allowed simulation to become mainstream. "From 2D CAD to 3D CAD, companies realized that the value of the 3D model was in more than just its geometry, but that it could also be used for simulation. This is when the CAD-FEM interface became a business opportunity," he recalls, "The automatic TET mesh was the natural step to making the 3D CAD model available for simulation and this, simultaneously led to two important changes in simulation: it provided the experts with more time for advanced simulation and enabled non-experts to begin to use it," he states. "Another technological change that helped to expand the use of simulation was the move from the command-driven interface to the graphical user interface (GUI). Only dedicated experts were able to use the command-driven simulation software tools, whereas the GUI greatly increased the accessibility of the software, broadening the user community and making simulation an engineering tool for engineers too."

In Italy, the adoption of advanced simulation by industries was driven by technical expertise and a deep understanding of finite element methods from the late 1990s to the mid-2000s, according to Perillo. "An understanding of physical phenomena, governing equations and condition modeling, and FEM numerical techniques were necessary conditions to use engineering simulation software. While knowledge and familiarity with meshing capabilities, matrix generation options, and numerical techniques for solving systems of nonlinear equations all ensured stable solutions, accurate results, and a viable use of the expensive computational resources."

He adds, "Any design department that was incorporating CAE technologies for product development had to have an exceptional, respected technical expert on hand to direct the blinking cursor or the input decks with well-known procedures and precise commands."
"In the meantime, the reduction of product time to market in major industries drove the expansion of simulation to solve all physics by using huge, accurate models managed by the HPC systems available at that time. The principal supplementary problems to be solved by contemporary players in industry then were thermal, magnetic, acoustic, fluid dynamics, and crash issues - plus any combination of these," Perillo explains. "In those days, the constant refrain in the market was for CAD translation, defeaturing, and simplification, with automated meshing capabilities to create "single" multi-purpose simulation models. It certainly was the tech-driven era of CAE technologies."

Early forays across the pond

Marcus Reiss, today Vice President of ESSS in Brazil, recalls that in the early days in Brazil too, only super technical experts would deal with the few R&D users here and there, and with advanced product design groups. "Today's advances in both hardware and software, especially in usability, are leading to much greater adoption and a true democratization of physics-based 3D modeling and simulation," he says, "Today, the technology is no longer a 'nice to have' product. For most companies, it is a must-have if they want to remain competitive in their respective industries."

Dave Conover, Chief Technologist for Mechanical Products (retired) and Corporate Fellow at Ansys, says that in the USA, FEA was only used by the PhDs in the analysis departments of a few companies in aerospace, automotive and nuclear when he started at Ansys 40 years ago. "Today, it is used in almost all industries throughout the companies' engineering and design groups, and by engineers just starting out (who almost always encountered it in their undergraduate studies) as well as by the traditional FEA experts who now lead and guide these young engineers," he comments, "Certainly simulation is much more widespread today as a way of designing and validating design. While affordable compute power and software ease-of-use have contributed to this expansion, there has also been a thrust to solve increasingly complicated problems – more physics, more nonlinearities, more assembly models – rather than just simple part models. Industry has evolved from using FEA to augment testing to, in many cases, completely replacing testing; from "why did it fail?" to "the design is good, go to manufacturing"," Conover says.

The Covid-19 Tsunami

At the tail end of 2019 and the beginning of 2020, Covid-19 made its appearance on the world stage, totally disrupting every aspect of life around the world, not least work dynamics, and customer relations. Reiss explains that in Brazil they suddenly found themselves locked at home. Business development activities, which until then had been happening through face-to-face visits that resulted in heavily loaded travelling calendars, all moved online. "As a result, we had to significantly increase our digital presence, improve customer support, become more proactive, and really engage with our market and its priorities. From our customers' point of view, the inability to be on-site (in their factories and labs) helped to demonstrate how important modeling and simulation were to their processes," he says. "As a result, digital transformation has increased in pace even in this complex and difficult time." He adds, "It should not be forgotten that Latin America also has local territorial challenges, including unstable politics and high exchange-rate fluctuations, both of which usually make it much more difficult for companies to maintain the pace of their technology investments, meaning that it usually has to be a long-term strategy."

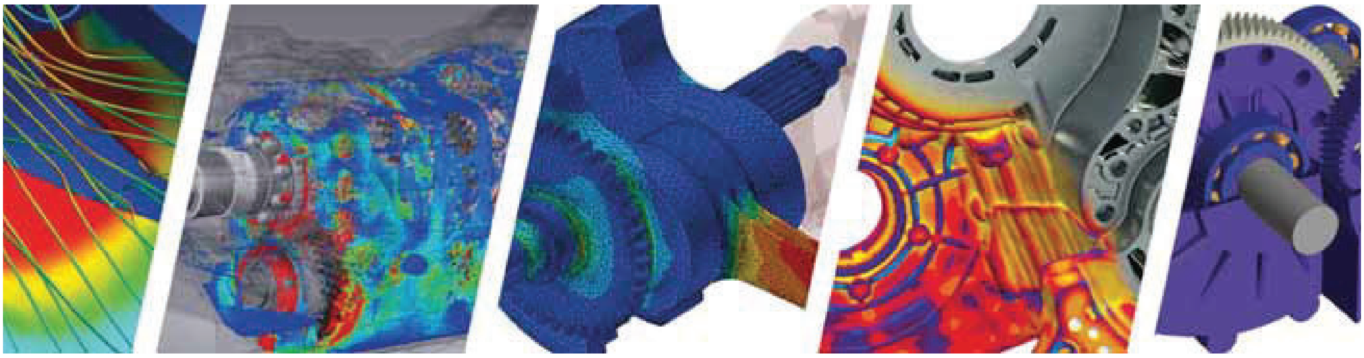
Conover agrees that online meetings in Zoom, Microsoft Teams, Google Meet and Cisco WebEx certainly enabled continued – and even more – interactions with clients both in the USA and overseas since time frames and travel became irrelevant constraints, while the ability to record and replay meetings and events also offers advantages.

Early Evolutions of Simulation

Simulation method	FEA from 2D and 3D CAD with TET meshing, CAD-FEM
ICT environment	PCs on Local Area Networks, limited HPCs
Users	Design engineers at large enterprises, but also medium-sized companies
Industry sectors	Shipbuilding, oil&gas, power plants, aerospace, automotive and defense
Applications	Product development, performance improvement, thermal, magnetic, acoustic, fluid dynamics, crash issues and combinations of these
Model size	10-100K elements

that this digitalization would also capture decision-makers' thinking, but that this unfortunately was rarely the case and that trial and error continues to be the greatest enemy.

"Today, we use Microsoft Teams and Zoom to see our clients. Our employees spend less time travelling and more time in front of a screen, but we no longer have a bottleneck in pre-sales activities because we can use our human resources more effectively. Our sales expenses have dropped dramatically, and we are questioning whether to revert back to the old model in the future," Dutly explains, "At the moment it is uncertain where 2021 will take us, but one thing is certain: simulation is necessary to produce high-tech products. Simulation will also become more important to save valuable resources and energy and to stop climate change, so there will definitely be more simulation in the future!"



However, he adds that they are not the best replacement for face-to-face interactions with customers, "Without body language and eye contact, it is difficult to know whether you have really connected with your audience – especially when so many in engineering are from different backgrounds and cultures. The difficulty in asking and answering questions is also somewhat limited in this virtual environment, so supporting users can be hard."

In Switzerland, Dutly says Covid-19 had a yo-yo effect throughout 2020: "First, business dynamics went steeply downhill, but, at the end of the year, there was an almost complete recovery. Fortunately, we were able to switch our seminars to online operation overnight and the software came from the cloud directly to the customer's home office. Nevertheless, there was a sharp downturn in the market because customers were on short-time work meaning that training had suddenly become too expensive." He says that it had been hoped

In Germany, however, Wang says that the transition to online business and the new work dynamic was seamless for his company as a result of their IT infrastructure: "Microsoft Office 365, softphone (VoIP telephony), a virtual private network (VPN) and our CADFEM Cloud enable us to work anywhere and we maintained communication with all our customers from day 1. We were also able to immediately offer our full training program online from day 1. The CADFEM cloud especially enables us to maintain the same quality of support for our customers. Digital communications have demonstrated their true value – our webinar attendance is up by 60% compared to 2019."

Greater momentum to digital transformation

Perillo is more conservative regarding the situation in Italy, which was one of the countries worst affected by the Covid-19 pandemic, ranking in the top 10 countries worldwide both for total number of deaths and for number of deaths per 100,000 people[1]: "Gaining a reliable picture of the present is not easy. Certainly, the global pandemic is accelerating digital transformation trends in every area and consequently in CAE as well. Even before the pandemic, the need to bring to market Industry 4.0-ready solutions at competitive operational and production costs was generating an increasing demand for the creation of a systemic view within which to create virtual prototypes that both emulated functional and physical behaviors, and supported decision making in all product lifecycle scenarios. Regardless of developments around this disease, there is likely to be an increase in the demand for simulation to address novel product lifecycle management," he states.

"Hundreds of millions of people have had to live and work through the lockdowns. The pandemic is driving profound social and organizational changes and has normalized working from home, which will likely result in a "hybrid" approach to work in future. There is an opportunity for us to embrace the possibility of designing contactless processes to connect the work contributions of remote teams to greater value and outcomes for the remote customer. In this context, CAE remains a technology domain driven by humans using proven simulation methodologies combined with diverse connection technologies that are extended to any area and function of the organization. The ability to build on the lessons learned during this crisis to create a new ecosystem that appropriately leverages potential resources and saves money will be vital to successfully implementing new remote processes to design, plan, and manage next-generation contactless customer relationships," says Perillo.

In Korea, Shim agrees that Covid-19 accelerated digital transformation. But he believes the change was even more dramatic in Korea where working resources were centralized and face-to-face collaboration had been compulsory prior to the pandemic as opposed to the US situation where distributed working environments were more normal, "Koreans got a huge shock and didn't know what to do," he states. "They were asking questions like, "How can I run a big CFD simulation from home? How can I get Ansys training with practice? How can I provide enough technical support if I don't visit my customers? What can we replace our offline seminars and conferences with to generate leads?" Shim explains. He says that TSNE was fortunate because they had been developing their own cloud platform and e-learning/virtual class systems for the previous three years, "These played a tremendous role in preventing the disconnection of our communication with our customers. Currently remote support systems, web meetings, e-learning and virtual classes are believed to be compensating for most of the communication losses caused by social distancing and lock-downs."

Future Developments in Simulation

Simulation method	FEA (mixed with boundary elements, meshless methods, and other numerics) of complete assemblies and systems
ICT environment	Cloud-based, edge technologies, HPCs, IoT, Augmented Reality
Users	Designers, engineers, manufacturing
Industry sectors	All
Applications	Besides traditional mechanical parts, 5G sensors, autonomous platforms – robotics, vehicles, construction equipment
Model size	10M-100M elements

Shim says that the major markets for CAE business in Korea now are semi-conductor, HF antenna and automotive. "On the back of the exceptionally fast internet infrastructure, we expect to see exponential growth in three areas: education platform technologies based on VR/AR/MR; no-latency bi-directional communication technologies based on 5G/6G/mmWave; and technology convergence services based on the edge technology for the cloud. At TSNE, we have less direct contact with our customers, but we are getting more proficient in remote support, online training and digital content generation."

Looking to the future

Shim states, "Everyone has accepted by now that we will never go "back to normal" after the pandemic. The customers' desire for diverse experiences, infinite information sharing, the transition to an open society, and the revitalization of the sharing economy will lead us to find more efficient and shorter times to market, with differentiated and cost-effective production. Simulation technology will be an important part of analysis, decision making and control through feedback. Therefore, artificial intelligence (AI), machine learning (ML), and Big Data will not now be added to CAE but will instead be incorporated into CAE which will be developed as a "systems-based multi-physics CAE + service". Beyond the existing CAE space, we can expect multidisciplinary convergence technologies related to e-mobility, healthcare, telemedicine diagnostics, bio/health/beauty, wireless and mobile communications, and sensors to become the major drivers of next-generation CAE."

With regards to the Korean market, he says, "In the near future, the semiconductor business will grow faster in Korea and the demand for highly complex semiconductor simulation will increase. Companies are more likely to use cloud services without maintaining local computer servers. If cloud usage fees begin to decline, more companies will build servers in the cloud. As working from home and online support become normalized in the simulation services industry, sales and subscription support will increase. While the

References

[1] The Visual and Data Journalism Team. BBC News, "Covid map: Coronavirus cases, deaths, vaccinations by country," BBC News, 15-Mar-2021. [Online]. Available: https://www.bbc.com/news/world-51235105. [Accessed: 18-Mar-2021].

number of sales staff will probably decrease, there is likely to be an increase in paid support services offered by professional engineers and delivered over social networks."

In Europe, Perillo believes that a five-year forecast could generate fragile, unreliable scenarios and suggests referencing the dimensions of Ansys' long-term technology strategy instead. "Focusing on our domestic market, Italian companies are mainly small and medium-sized manufacturing companies and, in 2019, the country still ranked seventh in the world for added value, fourth for production diversification and second for export competitiveness. It is quite clear that information and communication technologies will merge with industrial processes to meet the new challenges and they will play an active role in shaping both established and innovative technologies to permanently grow businesses and profits."

He adds, "CAE simulation technologies will evolve to continue to "aid" engineers to make the right choices at the request phase of the decision processes with sound and reliable background information and data. The synthesis of all the simulation models that combine to represent an entire product – both physically and functionally from a systemic, multidisciplinary perspective – in the real world must be fast, dynamic, and consistent with its alternative uses. An evolutionary execution of collaborative simulation models of differing scale and nature – connected to real-time edge data – will be the natural progression of today's Digital Twin concept to support either predictive operations or new pay-per-use models. This will be one of the characteristic elements of the business-driven new era for CAE technologies."

Dutly thinks that many European countries will have a similar approach: "The complexity of products is constantly increasing, and they are getting smarter. Electronics and embedded software are everywhere. In the past, it was linear statics of individual components; today, it's systems interacting with other domains, being controlled, and containing multiple physical effects. Teams are required to do this because the superhuman who understands it all is rarely found. Complexity can be mastered. That is positive. The question is: who masters the complexity? Only the big players? Is it worth it for an SME to provide that capacity? And that brings us back to EnginSoft and CADFEM. Today and five years from now, we can lead the customers to where they can get the maximum benefit. In the future, simulation will continue to be much more than just software," he concludes.

According to Wang, in the next five years, simulation will replace most of the testing that is used today. "Many companies currently only simulate single physics because Multiphysics simulation is still difficult for product engineers, yet products are becoming smarter and include more physical domains, so efficient process integration and design optimization (PIDO) will make product simulation available to more engineers. PIDO however generates much more data during product development. If that data is managed systematically, its value can be scaled across the enterprise. This will lead to simulation process and data management (SPDM) becoming the standard. Artificial intelligence will make simulation more accurate and create more innovation, while SPDM will increase the quality and use of

AI in simulation. Cloud computing will become cheaper and more powerful, making simulation available everywhere and even enabling in-product simulation. All of which, combined, will give more engineers, doctors, architects, designers, salespeople and managers access to simulation," he says.

Across in Brazil, Reiss too strongly believes that simulation will become more and more important, even for small to medium-sized businesses, "We share the vision that it will move out of R&D and product development and into large design groups, meaning that it will also move to earlier stages of product development," he states. "In terms of new applications, we see companies increasingly looking to improve the modeling and simulation of production and manufacturing processes (i.e., their production lines). In this regard, additive manufacturing has an obvious place in the future, and that goes hand in hand with the early application of simulation technology."

Conover says that using simulation for the full product lifecycle – from design (where it is now), to manufacturing (where it has some application), to product usage (think digital twin), to end-of-life (think disposal and recycling) – will become more the norm in engineering, "This will entail more physics, including chemical reactions, and more focus on materials," he states, and adds, "The second area of opportunity is inserting more of the human into the product design and usage. The use of AI to help define ergonomics, possible use cases (and abuse cases!), repairability, etc. will evolve quickly, particularly because the development of autonomous vehicles is pioneering this AI, human-centered approach!"

Constant evolution and broader application at a faster pace

For our industry veterans, it would seem that even in the post-pandemic world CAE and simulation technologies and techniques will continue to become easier to use and more widely available, and they will be applied across a broader spectrum of the business, not just to technical product design to assist companies to reduce costs, increase efficiency and useful life, but also to innovate new products and services to improve overall product longevity and business profitability, while improving staff and customer experiences and reducing environmental impact. To conclude with a literary reference, what has been one of the worst of times across the world, augurs to be the start of the best of times for the future of CAE and simulation.