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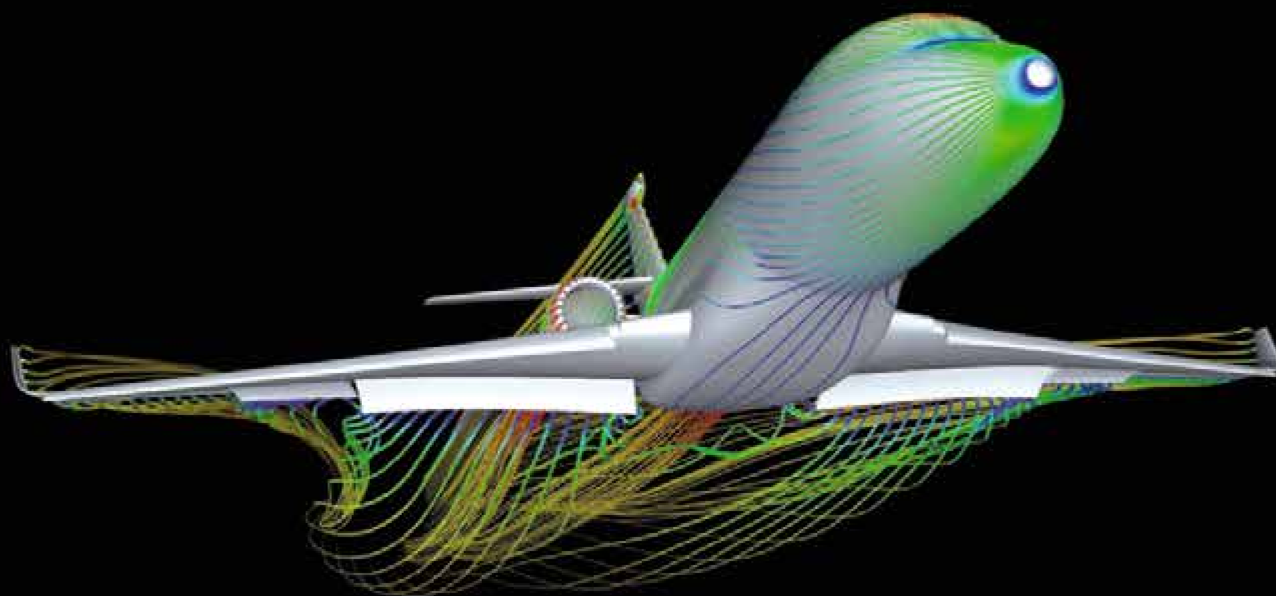
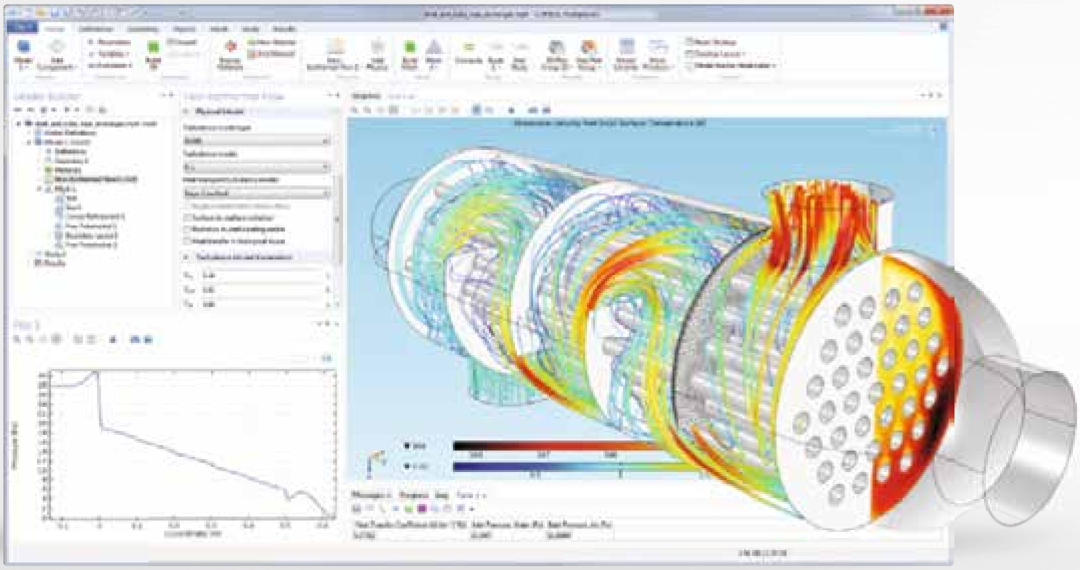


THE CHAMPIONS OF SIMULATION

HEAT EXCHANGER: Model of an air-filled shell and tube heat exchanger with water flowing through the inner tubes. Simulation results reveal flow velocity, temperature distribution, and pressure within the vessel.



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WAITING FOR BIG DATA...

AURÉLIE BARBAUX

Big data has received massive publicity and is mentioned at every conference and in every manufacturing or research project. In France, it is the only technology to be both one of French Minister for Industrial Renewal, Arnaud Montebourg's 34 Nouvelle France Industrielle (New Face of Industry in France) projects, and one of seven goals of the Innovation 2030 Commission, chaired by French businesswoman Anne Lauvergeon aimed at bringing to light national champions. And rightly so. According to researchers at the CNRS (French National Center for Scientific Research), big data has many industrial applications. It is defined using predictive mathematical models created from real data, which are more reliable than simulation. Are they really more reliable? That remains to be seen. For the time being, big data is used primarily by marketing experts trying to make sense of a data deluge not previously collected: the wealth of digital data generated by Internet users. In the future, billions of connected devices will be generating digital data. Hence the idea of predicting behavior patterns in digital data. This means using simulation, right? Not exactly. Big data extracts behavior patterns by taking sensor data rather than physics into account. Preconceived models are replaced by direct observation. "We're reinventing physics" say enthusiastic researchers. Well, almost. The experts nevertheless admit that, "Although big data enables us to predict what's going to happen, it doesn't explain why." Big data holds great promise for identifying optimum operating conditions in complex systems (airplanes in flight, industrial processes, vehicle traffic, etc.), but it is not expected to replace simulation. At any rate, not at our ten champions who have made this technology one of their key skills for industrial success. And not at some of the world's most successful research laboratories either, who are tackling ever more ambitious, giant-size research projects requiring more and more computing resources. At least, not right away. ■

Although big data enables us to predict what is going to happen, it does not explain why.

PASCAL GUITTET

Interview

«THE COMPUTING POWER RACE IS AHEAD OF US»

As the only European supercomputer manufacturer, Bull forms an essential link in the French simulation industry. **Philippe Vannier**, its CEO, promises increased computing power to meet industrial needs.

INTERVIEWED BY THIBAUT DE JAEGHER AND RIDHA LOUKIL

France has some simulation champions. Is there a specific national talent in this field?
Few countries in the world possess the concentration of talent required to master every aspect of the simulation industry. This first includes computer manufacturing, as well as modeling software, and supercomputer users. Only four countries have all these skills: the USA, Japan, China, and France. Since Bull has the ability to develop components and integrate them into computing systems, it plays an essential role in this ecosystem. To be relevant in this field, it's important to have strong proximity between supercomputer manufacturers, software vendors, and users. It's this proximity that enables you to progress. Creating a supercomputer on its own doesn't make sense. You design it in relation to a use or a simulation software program.

Do we owe this position to the quality of maths in France?
I think France is a country that has always been technologically innovative. And it's becoming virtually impossible to innovate without modeling. Our capacity to innovate has created a need for modeling, and the means for computing/simulation are now creating innovation. In a way, we have come full circle. Since there is strong proximity between simulation tool designers and users in our country, we have a virtuous cycle of innovation.

Are uses keeping up with this increased computing power?
Brute computing power is useless, except to say you have the world's most powerful computer. A computer must be calibrated to meet user needs at time T. User needs are currently increasing very quickly. We are following demand by supplying increasingly powerful computers. In this race, we are moving twice as fast as Moore's law. When you look at how supercomputer power has developed since 1993, it has multiplied by a factor of 8 every three years compared to a factor of 4 for Moore's law on processors. So there's a need for computing power. Things don't need to go any faster since you will never find users, but nevertheless the pace must be kept up.

What are the needs stated by users?
Needs differ according to the four main areas of use: industry, earth sciences, medicine, and image processing. The oil industry is one of the biggest consumers of simulation. At 10 petaflops, you can discover oil reservoirs that are barely suspected at 1 petaflop, and not at all at 50 teraflops. The most powerful computer in 2013 processes at a speed of 10 petaflops. The CEA (French Atomic Energy and Alternative Energies Commission) supercomputer processed at 1 petaflop in 2010 and 50 teraflops in 2005. One or two oil drilling operations are enough to finance a supercomputer.

Is this rapid development driving manufacturers to delay purchasing equipment, as with PCs among the general public?
There's a fundamental difference between personal and professional users. It would be no point you having a PC that is twice as powerful. You aren't going to type, read your emails or listen to music twice as quickly. Do you even know

the power of the processor in your iPad? This isn't the issue since you are the real limitation. But with supercomputers, if you provide manufacturers with a computer that is twice as powerful they will use it. The limitation today lies more in being able to do this within a given budget. Whether in aeronautics, the oil industry or weather forecasting, if it's possible to purchase a computer that is twice as powerful for the same cost then people will do so and will use it to full capacity.

Is simulation software keeping up with this power race?
You've put your finger on an important point. The whole chain needs to advance at the same speed. If you only have a computer operating twice as fast, it will be useless. The software chain must keep up. According to a 2011 study, over half of users questioned said they did not use more than 120 processor cores in parallel. The limitation comes from their modeling algorithms. It's here that we see a gap between the capacity of computer hardware and software.

What is putting the biggest brake on this development?
On the computer side, it's mainly power consumption. If someone was wealthy enough to purchase a computer from us that was 1,000 times more powerful than those we deliver

« Creating a supercomputer on its own doesn't make sense. You design it in relation to a use or a simulation software program. »

today, we would know how to make it. But we wouldn't know how to power it. In 2010, one petaflop consumed around 5 MW. If you intend to make a 1-exaflop computer, which is the world target for 2020, you can't multiply 5 MW by 1,000 since that would come to 5 GW, which is the power of three nuclear power stations. It's impossible. The issue here is increasing power a thousand-fold while ensuring that power consumption only increases fivefold. It's a very complicated target to achieve. The second issue is the number of processor cores to be managed in parallel. A computer from 2010 is in the 100,000 parallel cores category. A computer in 2020 will be in the 100 million parallel cores category, which presents a real software modeling issue.

What level of computing power do manufacturers equip themselves with today?
The average size of computers we sell to manufacturers today is typically around fifty teraflops and cost several million euros. In 2005, the CEA's computer was then the most powerful in Europe. The biggest CAC 40 manufacturers, such as Airbus and Total, now have petaflop computers and aim to acquire the exaflop category. But a significant minority of companies purchase computers in the generation just before. Meanwhile, the price of these computers has dropped by a factor of 10-15. This is because when things are moving twice as fast as Moore's law, the price stays the same.

« In the computing power race, we are moving twice as fast as Moore's microprocessor law. »

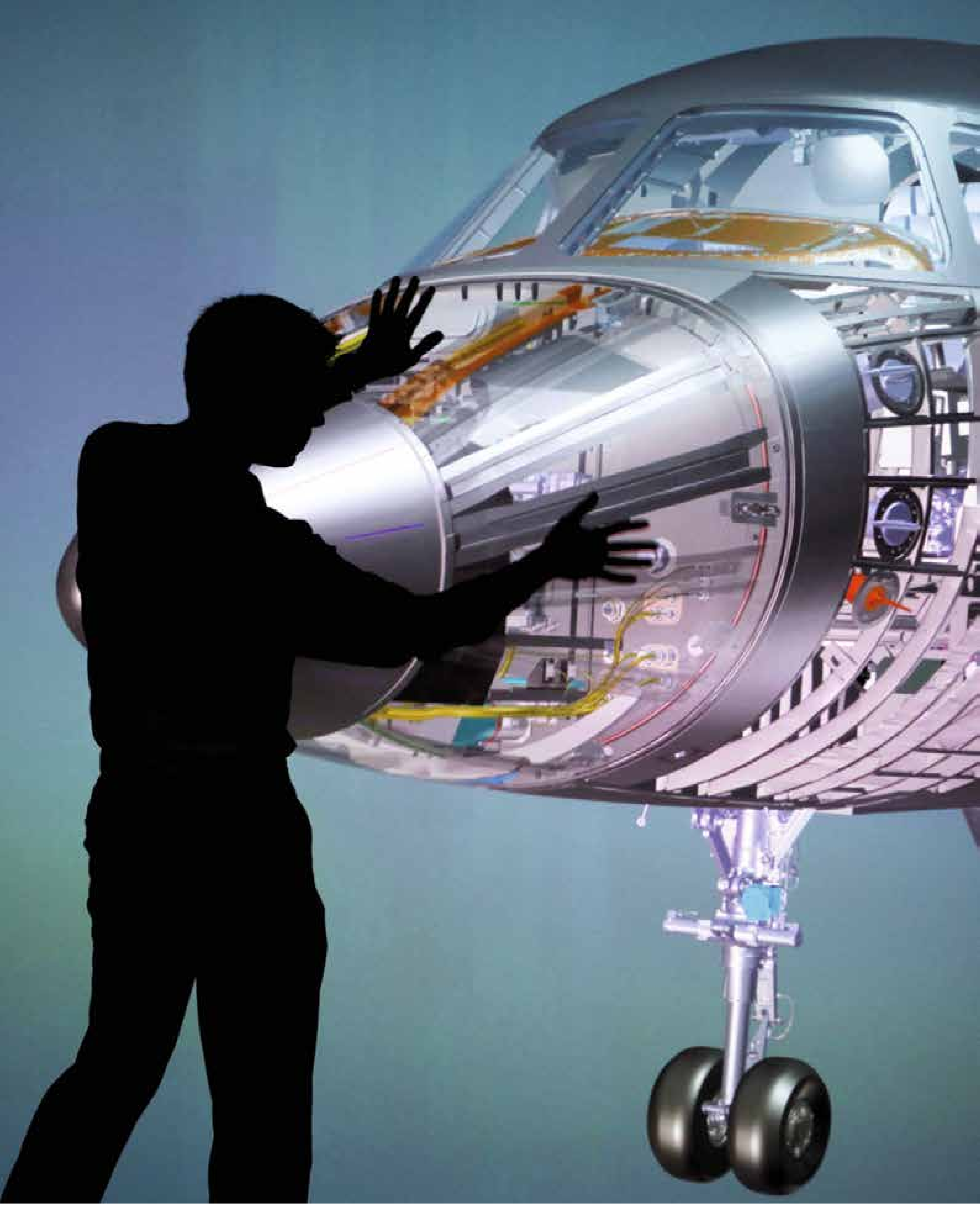
You have a cloud-based computing project. Is this a way of making high-performance computing more accessible?
We have a cloud-based computing solution, called Extreme Factory. SMEs use it for all their simulation needs and big groups for shedding load peaks; for example, when new products are being developed. This platform is meant to be an experimentation model. It will become an industrial model when a special purpose company, called NumInnov, is set up. Financial assistance from the French state, as part of the Investments for the Future plan, will make this possible. It's an important project and we really believe in it. We just need to launch it when it reaches maturity and not before,

since computers become obsolete very quickly. The market is ripe on massive data processing, but not yet on simulation.

Don't you see anything that could put a brake on this development?
No. Potential for infinite development lies ahead of us. Over the coming decades, needs will increase on a linear basis. I don't see this stopping. Making computers and software available will generate new uses. I'm certain of this.

The industry's high-performance computing plan aims to develop 'Made in France'. Is this possible?
I'm convinced that 'Made in France', or at least 'Designed in France' is important. For example, take our high-end Bullion server, it's the most powerful server in the world. To date, none of our competitors' products can supply more than half of its power. The key to this performance is a specific component we developed, which has made all the difference. As a result of this component, which acts like an orchestra leader, we can combine up to 16 sockets and 128 processor cores. These servers, launched in 2012, are essential for big data applications, large databases, and business intelligence. Put a software layer on top of it and you get a computer able to process enormous volumes of data. In 2013, sales rocketed by 70%. ■

« I'm convinced that 'Made in France', or at least 'Designed in France' is important. »



The Falcon 5 X was conceived and entirely simulated at Dassault's virtual reality centre.

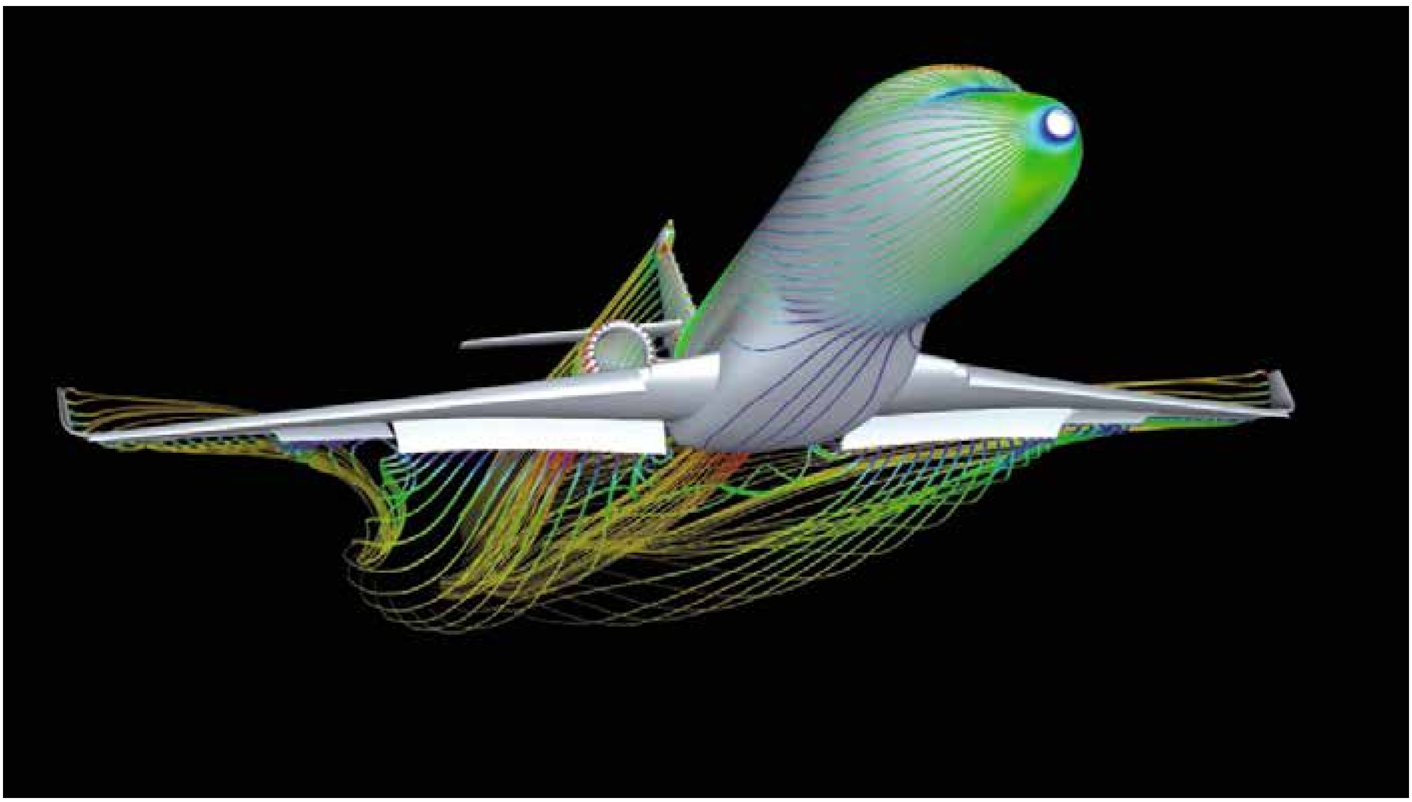
Technology

SIMULATION CHAMPIONS

Far from lagging behind in the innovation race, France has some aces up its sleeve. We demonstrate this using ten of its major manufacturers.

BY AURÉLIE BARBAUX

Could simulation be major French manufacturers' secret weapon? We are talking about innovative manufacturers, those successful on the international market, and who are leaders in their sector. Modeling physical phenomena is a French specialty, thanks chiefly to our high-performing public research and mathematics. Modeling is at the heart of these champions' R&D processes. And in every field, even the unexpected. This is because numerical simulation is increasingly moving beyond its preferred fields, such as metrology, mechanics, materials, and fluid flows, which are crucial in aeronautics, for example. Simulation is used in every area: chemistry, biology, telecommunications, natural resource networks and the transportation of power and people, even in real-time interaction with models of military and naval operations via augmented reality. It is no coincidence that L'Oreal, the world number one in beauty products, has become an international expert in skin and hair simulation. Or that Dassault Aviation is probably the first aircraft manufacturer able to fly a virtual plane under real flight conditions. Nor is it by chance that Alcatel-Lucent remains one of the world leaders in very high-speed communication systems, or that RTE enjoys the lead position in smart power networks. It is also no coincidence that Air Liquide is able to help its clients optimize their resources, and that Veolia Environnement is successfully exporting its water-network management expertise to build the smart cities of tomorrow in Singapore and Mexico. Thanks to its virtual and augmented reality expertise, DCNS is building the ships of the future. The same expertise is enabling the General Directorate for Armament to design ever-safer weapons and military operation systems. Not to mention Total and Méteo-France, who continue to invest in powerful computing centers to run increasingly audacious models, but which also require more and more resources. These are examples to keep a close eye on and (re) discover.



No more physical mock-ups, designing aircraft is now 100% digital. So too are test flights, as here with a Falcon 5X's virtual take-off

Aeronautics
DASSAULT AVIATION, VIRTUAL PILOT

This aircraft constructer has pioneered the transition to numerical simulation, and its teams are constantly developing applications for it.

You are in the cockpit, with the plane controls at your fingertips. Turning your head from left to right, the take-off runway stands out behind the windscreen. Perhaps you notice a last minute maintenance operation that needs to be done before the flight. Simply stretch out your arms, grab the faulty part but be careful not to bump into the wall. It is not unusual for users of this simulator in Dassault Aviation's immersive virtual reality center, at the group's head office in Saint-Cloud (Hauts-de-Seine), to lose their bearings. Engineers and technicians, wearing 3D glasses and rigged out with motion sensors all over their body, sit facing three giant screens in a comfortable room. They are checking the overall architecture of a life-size plane and the position of each aircraft part. The scene

DASSAULT AVIATION ; L'ORÉAL

is reminiscent of Tom Cruise's ballet of hand gestures in Minority Report. And like their hero, Dassault Aviation has a very clear vision of what does not yet exist.

A Reliable Predictive Model

Dassault Aviation's digital mock-up is at the heart of this process. It enables physical prototypes to be done away with and saves a great deal of time, from the design phase to the production phase. Dassault Aviation has been using it since 1990: for the Rafale, then the Falcon 2000 and 7X, the Neuron and now for the Falcon 5X, their new business jet. It has transformed the group into an experienced user of numerical simulation. "This mock-up is the exact virtual mathematical definition of an aircraft," explains an enthusiastic Jérôme Camps, technical manager at Dassault Aviation's design and engineering office. "It's a single database containing all the information needed to produce a plane." At Dassault Aviation, paper plans have not been used for ages. The hazing of new recruits involves asking them to find the paper plans for a given plane. Dassault Aviation's 12,000 staff owe this know-how to close collaboration with the group's other subsidiary, Dassault Systèmes.

This software vendor, set up in 1981, developed Catia, a computer-aided design program. Catia forms the basis of the digital mock-up, which has captured entire sectors of global industry, including the rail, car, and consumer goods industries. Dassault Aviation has been constantly improving this mock-up since it was first used, adding more and more functionalities. These include virtual tests of aerodynamic shape using air flow mathematical equations, numerical simulation tests derived from stress and force propagation calculations of plane structural performance, etc. "Test flights permit us to confirm calculations," summarizes Camps. "The mock-up has become a reliable predictive model." It is unbelievably realistic, even though a fighter aircraft or business jet comprises around 100,000 parts, 25 kilometers of cables and no less than 300,000 fasteners.

The mock-up has included life-cycle analysis software since the early 2000s, paving the way for a digital factory and anticipation of production processes prior to assembly. "This has halved the Falcon 7X's assembly time," says Camps. Another advantage is that the quality level previously associated with the 50th aircraft built in the series is now achieved immediately on the first plane leaving the production line. Setting up the virtual plateau has completely changed how the design and engineering office is organized: industrial partners for each aircraft project can

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now share mock-up data from their offices. "It's a 21st-century industry," says Camps, who views the mock-up as a crucial competitive advantage for Dassault Aviation against other aircraft manufacturers. What is the next stage? "We are turning our attention to overall virtual simulation of planes," replies Camps cryptically. "And the first results are promising." This apparently involves flying planes virtually, taking account of interactions between their equipment and under real flight conditions. But it is impossible to find out more about this. If the group attaches such importance to simulation, it is because global competition is very real too. ▮ OLIVIER JAMES

THE PROJECT TO KEEP AN EYE ON **Overall plane simulation, which will involve flying planes virtually, taking account of interactions between their equipment and under real flight conditions.**

Veolia is using the open-source software EPANET to optimize its water networks.

Sustainable Development

VEOLIA ENVIRONNEMENT PREPARES SMART CITIES

This French Group has been using simulation for water and waste water treatment for almost two decades. It is now addressing the issue of smart cities.

Singapore, Mexico and Lyon may be the first smart cities. At any rate, since 2013 they are the first to have ForCity (4CT), Veolia Environnement's urban modeling proof-of-concept demonstrator. This is an open, scalable platform interconnecting models of the urban ecosystem's various components: mobility, energy services, ground use, water, waste, buildings, environmental impacts, and resource shortages. This enables decision-makers to compare several urban planning options in 3D.

Simulation has been at the heart of the innovation process for a long time ; view from the control room.

In Nice, the three and a half year Réflexe (Response by Flexibility on Electricity) project, launched in 2011 is helping promote smarter energy management. The project is run by Dalkia, Veolia Environnement's subsidiary, and has a budget of 9 million euros. It is modeling energy production and consumption on about twenty service sector and industrial sites. The project has to assess system management solutions in order to test out real-time management of electricity production and consumption sites. "The idea is also to recover energy, so that public facilities such as municipal swimming pools can benefit from it," specifies Veolia Environnement.

If the group is at the leading edge of these forecasting projects, it is because simulation has been at the heart of its innovation processes for many years. "Water and waste water purification moved into the modeling era about twenty years ago. Today, we hardly ever sign contracts without incorporating simulation," explains Vincent Parez, head of networks and systems at Veolia Eau. This expertise is recognized internationally. The networks operated by Veolia in China include Shenzhen, for waste water treatment, and Dong for drinking water. In other words, over a thousand kilometres of networks. "In Prague, we were involved in flood crisis management and early warning systems. We inform the authorities if need be."

True real-time for tomorrow's world

For drinking water networks, Veolia works with Synergie and especially Epanet, an increasingly used open-source software package. The Infoworks suite is used for waste water treatment. "For most contracts, we already have a GIS (geographic information system) base. Retrieving information to model network specifications is facilitated by gateways," adds Vincent Parez.

VÉOLIA

Simulation was initially used as a tool for making better decisions about network requirements, and connections for new drinking water catchment areas. Today, simulation is interconnected with other tools and helps with management, cost reduction, leak location, reduction of network saturation and resource optimization. Water can also be bought from or sold to neighboring towns connected to a network. Things are more complicated for waste water treatment. You have to capture rainfall, prevent overflowing, interface the network and the environment, and study sea currents before pollution has time to impact.

"Computing power has progressed over the past twenty years. It is now much faster, enabling the right balance to be found between costs and the environment." What are the aims for the future? "To have more links with GISs and more real-time information. But we have not yet reached true real-time.» OLIVIER COGNASSE

THE PROJECT TO KEEP AN EYE ON The ForCity proof-of-concept demonstrator in Lyon's Gerland neighborhood. This project is run by EDF, Veolia Environnement, CMN Partners, and a start-up called The Cosmo Company.

Right: a lock of real hair. Left and center: a simulated lock, created from the first dynamic, parametrizable model of a head of hair.

Biotechnology

L'OREAL PRODUCTS: A MODEL OF REFINEMENT

The world number one in beauty care is stepping up its research on new molecules and aims to penetrate the mysteries of human tissue.

What do UV-absorbing sunscreen creams and electromagnetic wave-shielding paint for coating airplanes have in common? The same equations are used to understand their complex nature and predict how effective they will be. Twenty years after they hit on biology, now high-performance computing and 3D modeling are creating a revolution at L'Oreal. Designing tomorrow's innovations is no longer guided by chemical and physicochemical research. "This is a complete paradigm shift," says an enthusiastic Bernard Querleux, senior research assitant, responsable for the supercomputing at L'Oreal Research and Innovation. "Computers are now used to guide how new active ingredients are synthesized and create physicochemical formulae. By multiplying simulations we're exploring things never seen before."

Outsourced High-Tech Equipment

For several years now, L'Oreal's advanced research programs have given pride of place to digital technology. Purchasing a supercomputer and putting together a high-performance computing team in-house was not financially viable; L'Oreal therefore signed a partnership with the French Atomic Energy and Alternative Energies Commission (CEA) gaining access to high-tech equipment and expertise at their Research and Technology Computing Center (CCRT). "By replicating the behavior of skin and hair on computers, we are able to improve our understanding of these complex biological tissues, which have rarely been studied at a global level" explains Querleux. L'Oreal has taken the lead over its main competitors, the American company Procter&Gamble and the Anglo-Dutch company Unilever, who are also enthusiastic about simulation.

Until now, a head of hair, consisting of between 120,000 and 150,000 individual hairs of all types, was considered too complex to model. L'Oreal and the CNRS (French National Center for Scientific Research) took a set of relevant parameters and developed a static model describing the mechanical behavior of a single hair. They then worked with one of Inria's (French Institute for Research in Computer Science and Automation) laboratories specializing in representing complex scenes such as wheat fields to write hair-movement equations. In this way, the first dynamic, parametrizable model of a head of hair appeared in 2006. "This opened up incredible scope for our research teams to experiment on new product development. This is because modifying one of the model's parameters meant we understood how to change hair appearance," adds Querleux. L'Oreal has used this innovation on its shampoo lines, improving their smoothing and styling properties. Nevertheless, we still have to wait a few years before we can use the first entirely computer designed cosmetic product. GAËLLE FLEITOUR

THE PROJECT TO KEEP AN EYE ON Modeling will help fine-tune the assessment of product final performance, and predict how the color of foundation will be rendered on the skin.

RTE's National System Operation Centre ensures equilibrium between electricity generation and consumption.

Electricity Networks

ANTICIPATION IS RTE'S CREED

From electricity markets to electromagnetic transients, this electricity transmission system operator can't do without its simulators.

Simulation is everywhere at RTE (Réseau de Transport d'Électricité, the French electricity transmission system operator). "It's used in almost every line of our business," says Didier Zone, director of RTE's National Centre for Network Expertise. RTE operates, maintains and develops some 100,000 km of high and low-voltage power lines, and around 2,600 transforming stations located at intervals along them. The company is at the heart of the electricity system in a world of changing energy. Its business is based on anticipation. And simulation is its great asset.

Simulation enables RTE to ensure the smooth day-to-day running of this complex industrial machinery, which relies on synchronism between numerous rotating machines generating or consuming electricity. If an incident occurs, there is a risk of triggering a chain reaction leading to a breakdown of massive proportions: blackout. To avoid this, network management computers run continuously at RTE's eight control centres. They simulate incidents (power line cuts, generator breakdown, etc.) and check that the network remains stable in the face of these events. If this is not the case, more sophisticated simulation tools help operators find ways to counter the situation, such as distributing electricity flows differently or asking a power station to increase output. This is how the N-1 rule, the basis of network security, is implemented: a network must continue to work even after outage of a piece of equipment.

Homemade Software Suite

These network management tools were designed in-house by EDF and RTE. Their algorithms run on physical network electrical engineering models. "Our team of around 90 electricity system and equipment experts in Versailles and la Défense (Paris) is upgrading our simulators," says Zone. This set of simulators forms a software suite called Convergence, which RTE is also using to develop the network. Building an electricity network involves anticipation: a power station's impact, the contribution of a high-voltage power line or transforming station, etc. are all simulated. All the more so since, with the discussion and authorization phases, it can take between seven and ten years to build network infrastructures.

RTE also has more specialized software to study network dynamics (overvoltage, loss of synchronism, etc.). Electromagnetic transients are simulated down to the last millisecond using the powerful Eurostag algorithm. This program from EDF was co-developed by RTE and Tractebel (GDF Suez). RTE uses EMTP-RV, developed with Hydro-Québec and Powersys, to go below the millisecond level, software that simulates very fast transients, which may affect power electronics components.

Simulation does not stop with electrical engineering. Weather forecasts are integrated into models calculating electricity consumption and solar/wind electricity generation. Markets are simulated to anticipate how electricity trading will impact network flows. Everything at RTE is a matter of anticipation. In other words, everything is about simulation. MANUEL MORAGUES

THE PROJECT TO KEEP AN EYE ON **RTE is working on a serious game, an electricity networks SimCity, which will be used for in-house training. It is then expected to be released to the general public.**

Defense

WAR AS THOUGH YOU WERE IN THE THICK OF IT

The French General Directorate for Armament is counting on its simulation experts to speed up design work on future weapon systems.

Imagine that you are the commanding officer of a ship overseeing a commando landing operation. A large digital touch table has replaced the trusty old Ordnance Survey map in the control room. It shows a dynamic display of the tactical situation, the positions of targets and of the means at your disposal to achieve your objective. In the scenario envisaged, you are watching the progress of your troops in their dinghy as they rush towards the coast to overpower an enemy logistic unit. With a flick of his hand, an officer taps on the correct icon and video stream from a camera at the bow of the fast landing craft is displayed in a small window. By choosing the icon for the drone surveilling this zone, images taken from the sky begin to scroll by. In short, every video stream taken from different points of the battlefield is integrated into the touch table and can be seen instantly. Metadata for each stream specifies the images' source, point of focus, etc. If necessary, this information can be sent to central command via a satellite link in order to confirm a decision.

Focused on Centralized Streaming

For the past few months, this scene has ceased to be in the realm of science fiction. A handful of software experts at the DGA's Technical Operations Laboratory (LTO), located in Arcueil and on the Mourillon site in Toulon, have developed one such prototype. "After 'Opération Harmattan' in Libya, the operational naval forces said they needed to make better use of all the video information at their disposal. They asked us for a tool to centralize all the video streams, which would help them make the right decisions faster," explains Éric Bujon, head of simulation at the DGA. The French navy carried out sea tests of the prototype last summer. Their feedback will be valuable for eventually creating a version suitable for industrial production.

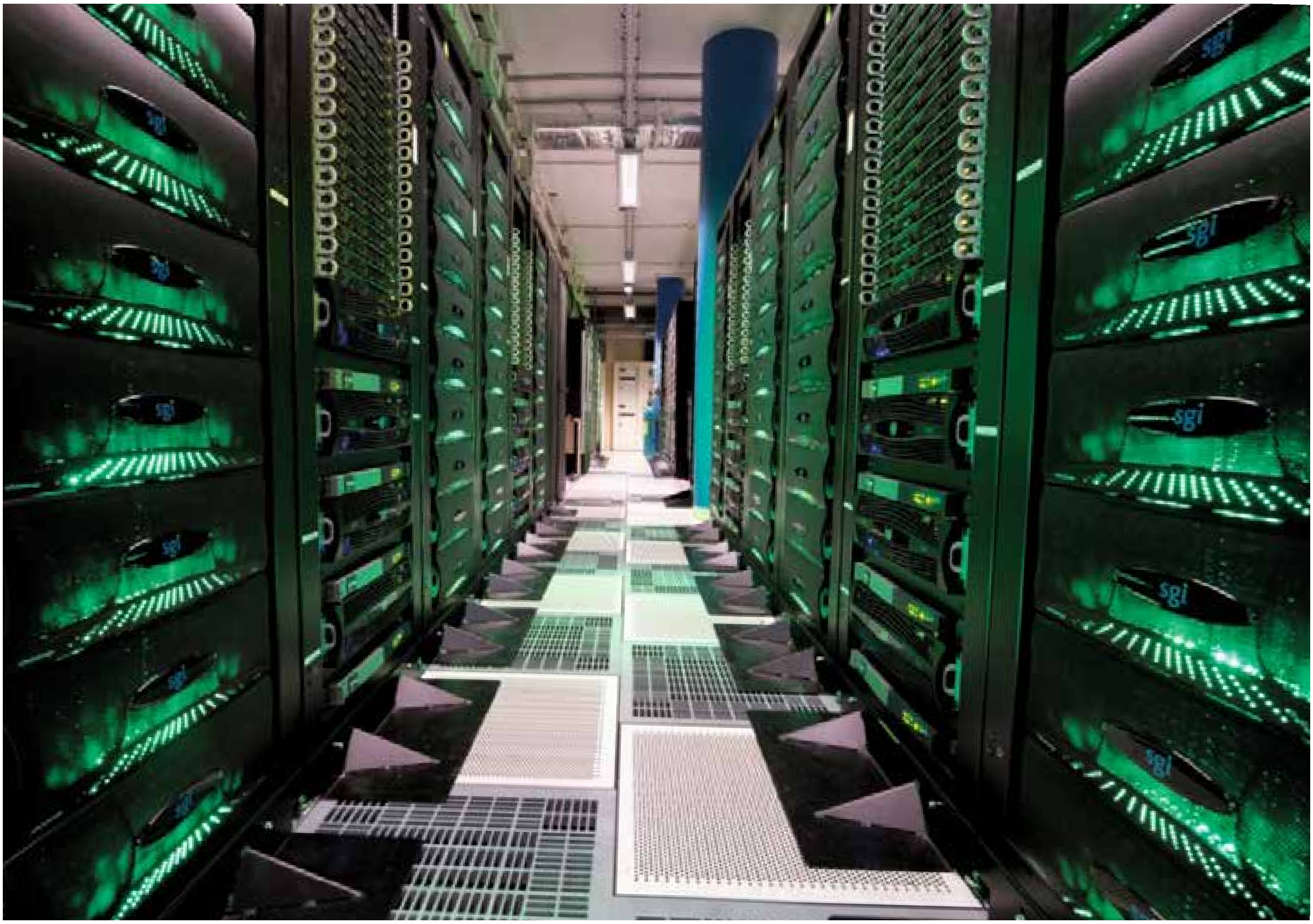
The laboratory has also been called on to validate other weapon concepts, in particular missile strikes made from armoured fighting vehicles with no direct sight of their target. Developers have used a serious game, immersing observers, decision-makers and missile gunners in a virtual world where they can test various strike scenarios. These simulations have helped establish the best distribution of roles among operational personnel. Beyond traditional simulators and training systems such as Rafale, the DGA is thus using simulation as a technical engineering tool. "Dialog between operational personnel, engineers and manufacturers is essential to design a new weapon system. It enables an operational need to be converted into specifications that will be used as a basis for the contract with a manufacturer. The contract will be realistic, both in terms of performance and development costs of future equipment," points out Bujon.

The DGA has made intense use of simulation technology for over twenty years. It now has 230 experts in this field, three times more than ten years ago. The DGA allocates an annual budget of several tens of millions of euros to simulation. "Despite the drop in resources, simulation remains a priority. In 2013, we set up a program to rationalize our activity. The way we operate needs to become more like an engineering company, with better pooling of resources and tools", concludes Bujon. **HASSAN MEDDAH**

Digital touch table, a hi-tech version of an Ordnance Survey map

THE PROJECT TO KEEP AN EYE ON The DGA and its suppliers have jointly formed the ADIS Association, with the aim to develop a shared simulation technology toolbox.

DGA ; LAURENT PASCAL



The Pangea supercomputer is fifteen times more powerful than its predecessor and cost Total 60 million euros.

Energy

TOTAL IS FUELED BY ALGORITHMS

The oil company Total uses supercomputers to model all areas of its industry: exploration, refining, and reservoir exploitation.

In a group as big as Total, hundreds of thousands, indeed millions, of euros are involved in successful, accurate numerical simulation. It is no surprise that the company has made this a key skill in every line of its business. First, data on seismic wave propagation in subsoil has to be converted into an image of the geological layers to discover hydrocarbon reservoirs. The volume of data to process can reach staggering heights: 170 terabytes for the biggest explorations.

Total then replicates multi-scale fluid dynamics, depicting how a hydrocarbon reservoir changes when it is exploited. This exercise is not easy since it involves simulating the migration of water, crude oil and gas in a complex environment, as well their interactions with the rock. But it is essential since decisions to carry out additional drilling or inject water to optimize exploitation depend on it. At the other end of the scale, Total uses the same principle to replicate chemical reactions, heat exchanges and polymerization occurring in major refining processes. “That’s what is the most complicated in multiphysic fluid mechanics,” explains Jean-François Minster, Total’s scientific director.

Overall Research Expertise

The group has also moved down to far more modest dimensions by modeling structures. This has become essential for the specialty chemicals business, which is run by subsidiaries such as Hutchinson. For example, making air duct seals for cars requires the entire car and its vibrations on roads to be replicated, to imitate how the product ages. Structural simulation also enables the casting of composite materials in molds to be assessed. Modeling continues down to the molecular level, where it aims to unravel macroscopic behavior using infinitely small scales. This is especially useful for researching glue.

As a result of designated staff and technical facilities, about a third of this research is carried out in-house. The rest is sub-contracted to specialist companies or universities, depending on the complexity and sensitivity of the research topics (industrial risks, environmental impact, etc.). Total has chosen to carry out part of this research in-house to retain control of its skills. “Since simulation is such a strategic issue, it is essential that we understand the calculations involved.

We can not content ourselves with the analysis of a service provider," explains Minster.

To achieve this, the group owns several supercomputers. Most importantly, since 2013 its hardware computer scientists, systems engineers, operators, mathematicians and geophysicists have had access to the powerful Pangea supercomputer, which was the world's ninth most powerful supercomputer when it was installed. Pangea is at the Centre Scientifique et Technique Jean-Fréger (Jean-Fréger Center for Science and Technology) in Pau (Pyrénées-Atlantiques). It has computing power of 2.3 petaflops and storage capacity of 7 petabytes. It has been so successful in making simulation easier and more accurate that it has repaid its 60 million euro investment in less than a year. This is a key factor for the petroleum industry, where only 15 to 30% of drilling is successful. Improving the success rate by a couple of points is enough to save millions of dollars. Simulation also saves a lot of time. Nine days of computing were required to analyze seismic data from the Kaombo project in Angola. It would have taken 4.5 months using the old supercomputer. **LUDOVIC DUPIN**

THE PROJECT TO KEEP AN EYE ON The multi-scale simulation and multi-phase polymerization project, launched in partnership with the Chinese Academy of Sciences in Peking. This project, a world first, has been made difficult due to similar density phases.

Climate

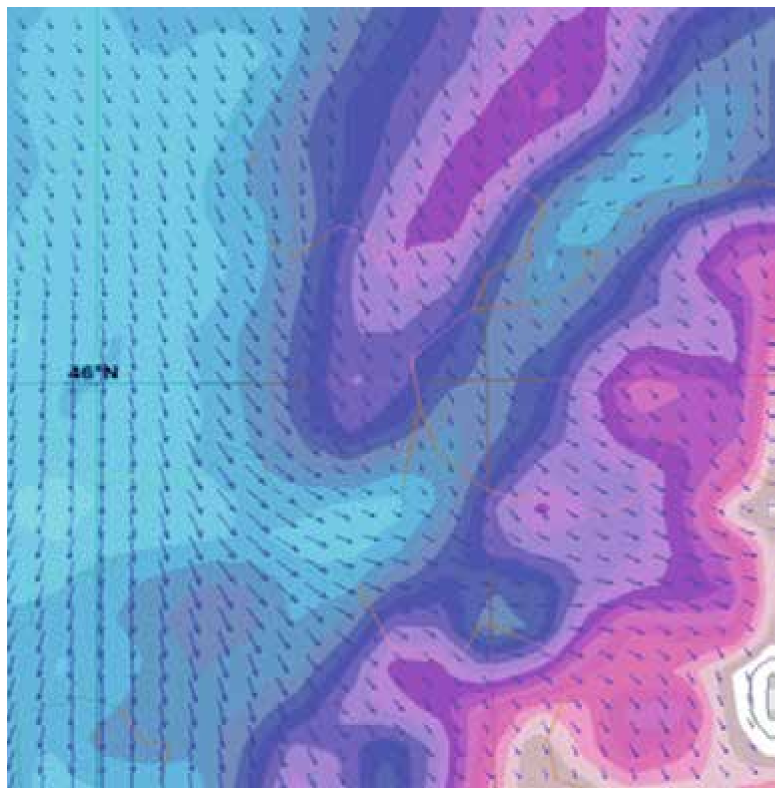
MÉTÉO-FRANCE SHARPENS FORECASTS

The French national meteorological service has increased its computing power in a bid to refine its atmospheric forecasting models.

In 2013, Météo-France installed two new supercomputers on its Toulouse site. Supplied by Bull, both supercomputers have over 500 teraflops of peak power each. In other words, twenty times more total power than the two NEC computers they replaced. One is for everyday forecasting, the other is for research. This is just one stage of a process: both computers will be upgraded in 2015-2016, which should increase their peak power fivefold. Overall, Météo-France expects the performance of its software to increase about thirtyfold. The first Bull supercomputer became operational in January. All the new computing equipment will be operational by May. And, thanks to a more efficient cooling system, without any increase in energy consumption.

Climate Change at Stake

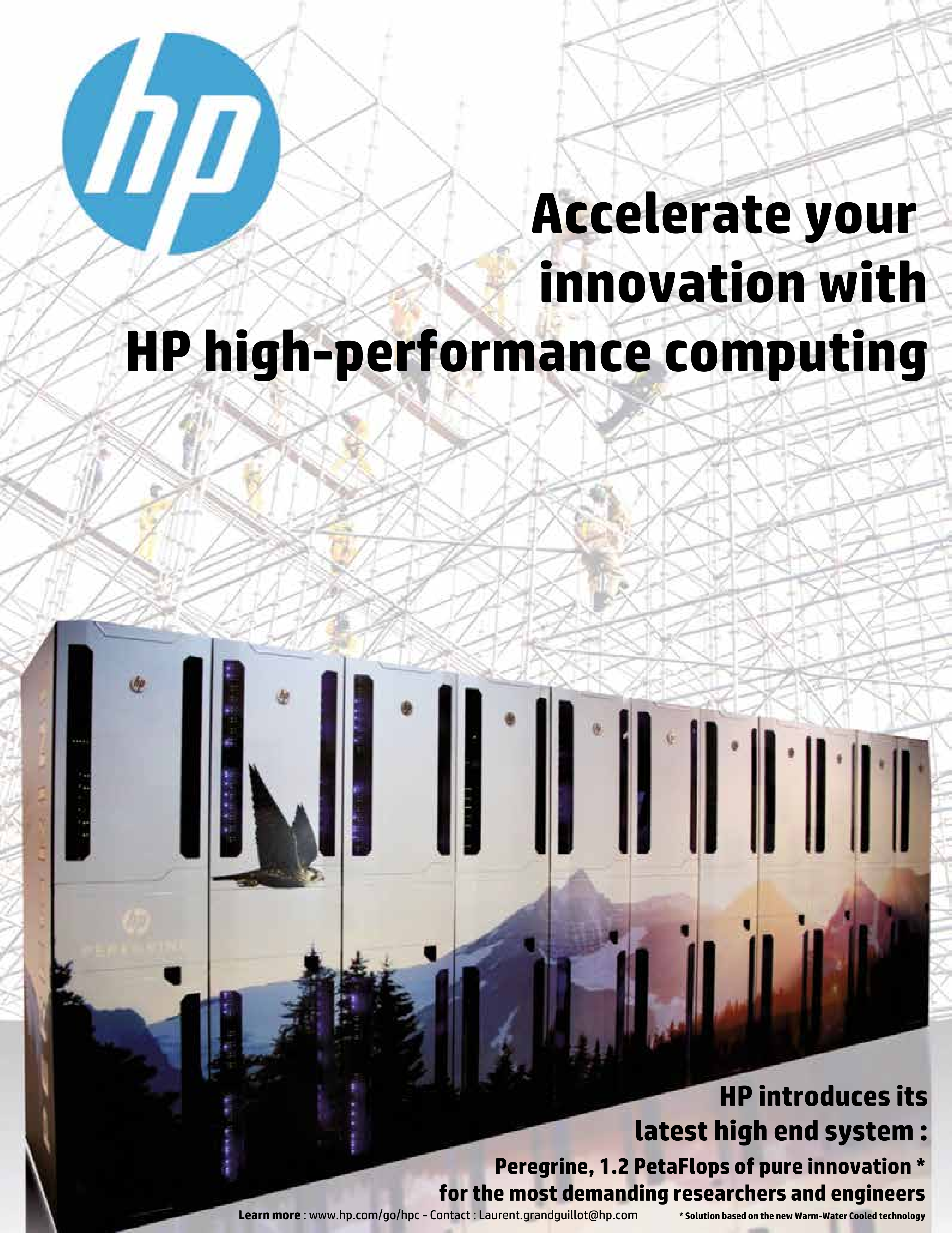
There is nothing surprising about this power ramp-up since weather forecasting has always made abundant use of computers. But the migration begun in 2013 is in answer to a specific forecasting improvement program. And it commits Météo-France to the huge task of revising its computational codes. "One of our goals is to make forecasts more accurate by reducing the mesh size of our atmospheric models," says Alain Beuraud, the project manager for high-performance computing at Météo France. The most refined model, Arome, providing local information in metropolitan France, currently operates with a mesh size of 2.5 km. This will be reduced to 1.3 km. Arome notably enables the forecast of potentially dangerous occurrences such as thunderstorms.



Météo-France aims at more accurate forecasts by reducing the mesh size of their models. The photo shows a temperature and wind map.

MÉTÉO FRANCE

Its use will be extended to French overseas territories. Another of Météo-France's simulation models, Arpege, is used for global-scale forecasting. It currently uses a mesh size of 15 km, which will be reduced to 7.5 km. But refined model meshing is not the only aim driving the creation of more powerful computers. The idea is also to run more simulations. For example, varying initial conditions on the same model to check or confirm the risk of a storm or dangerous occurrence. Or updating forecasts hourly, to respond to the specific needs of airports.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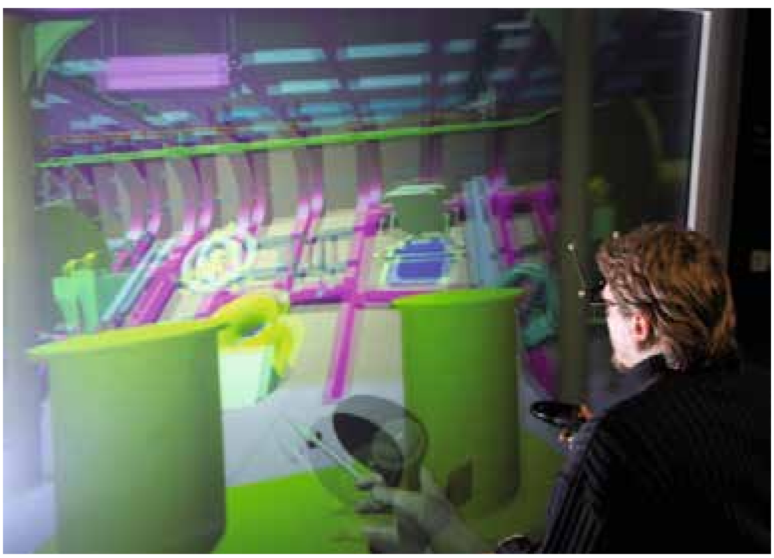
We should not forget that one of these two computers is for research purposes. Météo-France is heavily involved in studying climate change, and the Intergovernmental Panel on Climate Change (IPCC) recognizes one of the two French simulation models (a version of Arpege). The research computer will be used to prepare this panel's next global warming report.

But all this comes with some major IT challenges. Each of the two Bull supercomputers has 1,000 compute nodes and 24 Intel processor cores. They are completely unlike the previous generation of NEC supercomputers, with their ten vector processing nodes. Massive parallelization of computational codes is therefore required. "To reduce Arome's mesh size to 1.3 km, it will need to be run on thousands of processor cores," says Beuraud. Another key point: data input-output with a set of processors all working simultaneously. "This could be a sticking point; there's no point adding processors if this hasn't been sorted out," warns Beuraud. The research and production teams have joined forces to solve these problems, and there is enough to keep them busy for quite a while. At the same time, they are already preparing for the new leap forward in power – and in parallel computing – announced for the year 2016. THIERRY LUCAS

THE PROJECT TO KEEP AN EYE ON Adapting weather forecasting programs to the parallel architecture of new generations of supercomputers.


PASCAL GUITTET

Total immersion in the virtual reality room, where warship design bugs are tracked down.

Shipbuilding
DCNS, THE 3D SHIPBUILDER

DCNS is enthusiastic about virtual reality. It has extended it to the Fremm frigate program and is testing augmented reality in the production stage.

After donning 3D glasses, visitors to the virtual reality room find themselves deep inside a Fremm Aquitaine frigate displayed on the curved screen. This is the first ship of its type, delivered to the French Navy at the end of 2012 by DCNS the French naval defense company. The quarter-deck, central operations point, and command bridge, etc., "Every area has been closely examined with the client, right down to the location of electric sockets," explains Yann Bouju, DCNS's head of augmented and virtual reality, based in Lorient. The department counts about ten staff members for the whole group.

"DCNS has been designing and manufacturing ships using digital mock-ups and 3D display since 1997. It started with the Charles-de-Gaulle nuclear-powered aircraft carrier," says Bouju. "We have extended this rationale to the forefront of the Fremm frigate project." Digital mock-ups are directly integrated into Etrave, a product life-cycle management (PLM) system developed in-house for the company's specific needs. With upward of a million parts, warships and submarines are complicated to manufacture. Upstream of the production stage, digital mock-ups enable feasibility checks and are used for preliminary studies with clients. "We work upstream on work station design and ergonomics," says Bouju. "The morphology of Malaysian seamen is nothing like their French counterparts. So we have to adapt the work stations." Using virtual reality during detailed studies enables many bugs to be de-risked. For example, from the command bridge of the Aquitaine, it was impossible to see the stern of the frigate where important operations take place such as launching dinghies for interventions. "So we added a wing to the side of the bridge," explains Bouju.

Extremely Profitable

A second room, called the tracking room, is next to the virtual reality room. The tracking room is for meetings focusing on more applied work. After putting on glasses topped by strange small antennae, digital mock-ups can be manipulated in every direction using a sort of joystick. There are identical rooms at Cherbourg-Octeville and Toulon. "For the past year and a half, we have also had a 'cellar' in Cherbourg-Octeville. This contains three screens and provides the opportunity for even greater immersion," explains Bouju. The 'cellar' is near the Barracuda nuclear submarine assembly line. "Welders come here in the morning to carry out feasibility checks for the afternoon's tasks," he continues. All this has been a considerable investment,

but DCNS is not disclosing any figures. We just know it is extremely profitable, in particular, because of savings made on later on-site alterations.

DCNS is also testing augmented reality devices on the sixth Fremm under construction. Picture a section of a ship at quay. Brendan Le Gallo, a business analyst, is in the future laundry room, carrying a case that has been dubbed 'Rapace' (bird of prey). Inside the case is an overhead projector coupled to a camera, both are connected to a laptop computer. The computer loads the digital mock-up, and the layout plan is projected into the room to see if the welded parts are placed correctly on the partitions. Most of them are, but one is jutting out by a few centimeters. "When the site is inspected, the production manager will decide if it needs to be moved or if it can be left as it is. In the latter case, it would be ideal if we could then alter the digital mock-up," explains Le Gallo. This may be the next step, after convincing team managers that the tool saves time. "We implemented the same shift of attitude when we moved from drawing boards to CAD," recalls Bouju. This is a minor revolution. PATRICK DÉNIEL

THE PROJECT TO KEEP AN EYE ON **Integrating augmented reality tools into the production stage, for on-site checking purposes.**

Chemistry

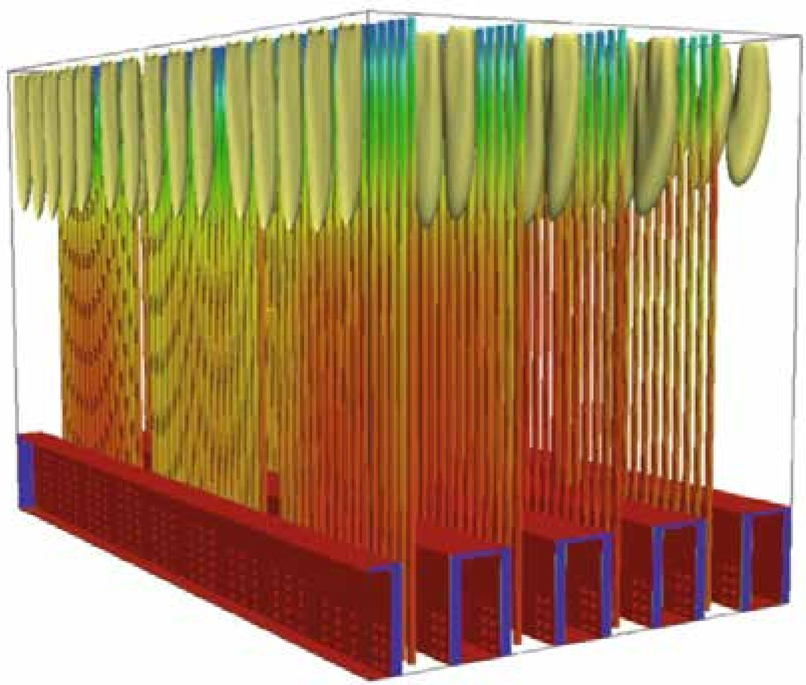
AIR LIQUIDE OPTIMIZES RESOURCES

This French group integrates simulation into all its projects, thereby improving the performance of its own and its clients' industrial equipment.

It is impossible to remain the world leader in medical and industrial gases without giving pride of place to innovation. At Air Liquide, (turnover of 15.3 million euros in 2012) research has traditionally made use of numerical simulation. As far back as twenty-five years ago, the group had computing and software experts able to model the furnace flames of their glassmaking clients. Today, "Numerical simulation and modeling are part of the nine key skills we have identified in R&D," observes Régis Réau, the group's senior scientific director. "Used in conjunction with other skills such as engineering processes, they have become almost essential tools for developing our projects."

Less energy-intensive production

No less than forty researchers in Europe and the United States – experts in fluid dynamics and molecular modeling – carry out simulation full-time. This is not counting the twenty some collaborations with major centers of excellence worldwide, such as the industrial chair in oxycombustion; set up in 2012 with the École Centrale Paris (French engineering school) and the CNRS (French National Center for Scientific Research). Simulation is so strategically important to Air Liquide because it optimizes every line of its business (healthcare, industrial merchant, large industry, and electronics), and every stage of its supply chain: gas production, transportation, storage, and delivery to clients. It is essential in the face of industry globalization and resource constraints, which the group's CEO, Benoît Potier, identified last December as among the main market trends for the future.



AIR LIQUIDE

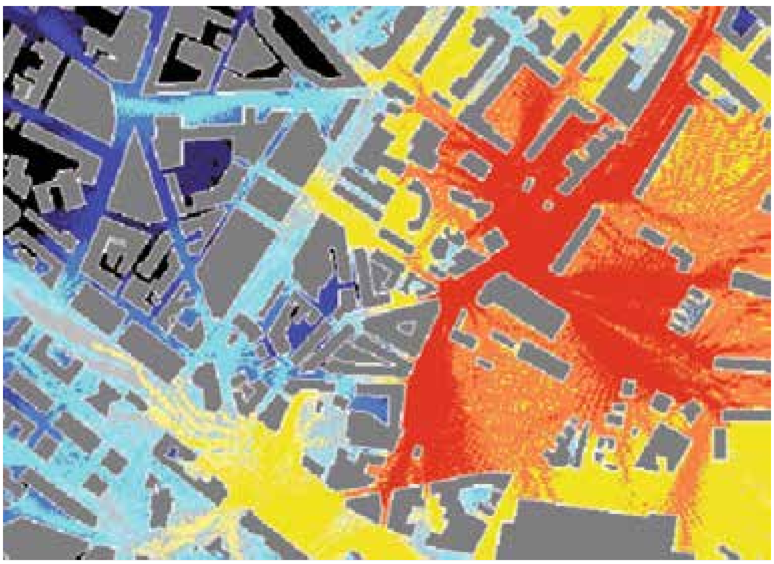
Simulating reforming furnaces reduces energy costs.

Simulation is invaluable for achieving less energy-intensive gas production. Computational fluid mechanics has enabled researchers to model the separation phases of different air gases. This has helped improve control of mass transfer and turbulence caused by the process of liquid converting to vapor. In combination with an automation process, modeling has reduced energy costs by 4% in the Air Liquide factories concerned. The same approach has been applied at Air Liquide's partners. "We bring value to our clients," insists Régis Réau, "developping personnalized solutions at the height of technology." At glass manufacturers, whom the group supplies with oxygen and burners for operating furnaces, simulation has enabled heat transfer distribution to be analyzed to optimize furnace design. In healthcare, which is an expanding sector for Air Liquide, simulation boosts innovation. A few years ago, Air Liquide researchers studied how sprays are absorbed by the bronchi, to help breathing in patients suffering from respiratory problems. "We used real data to construct a digital mock-up of bronchi,

and tried to understand the trajectory of gas particles to simulate how they are transported in airways," recounts Réau. "We discovered that a mixture of oxygen and helium, lighter and more viscous than air, facilitated breathing." This leap forward in technology was confirmed by in vitro and in silico tests.

What will the next challenge be? Big data. Having purchased a new supercomputer for its Île-de-France research center in Loges-en-Josas, Air Liquide intends to establish closer links with its neighbors, such as the CEA (French Atomic Energy and Alternative Energies Commission). **GAËLLE FLEITOUR**

THE PROJECT TO KEEP AN EYE ON Air Liquide and its partners are at the heart of the Paris-Saclay Consortium for Energy Efficiency. They are trying to envisage energy flow transfers between factories of the future and their ecosystems.



ALCATEL-LUCENT

Studying wave propagation in a neighborhood's fiber-optic network. The red zones are where traffic is fastest.

Network
MODELING, THE HEART OF ALCATEL-LUCENT

Researchers are simulating networks and wave propagation, and designing the software at Bell Labs, Alcatel-Lucent's R&D subsidiary.

Numerical simulation is second nature for Alcatel-Lucent. This equipment manufacturer uses it in every shape and form in its Bell Labs. "Modeling is used for almost 80% of our work," confirms Jean-Luc Beylat, the president of Alcatel-Lucent Bell Labs France. Alcatel-Lucent is without doubt the simulation champion. This telecommunications equipment manufacturer regards simulation as a means of innovation, as well as a way to reduce costs and innovation cycle times. To begin with, Alcatel-Lucent knows how to model all the layers of a telecommunications network (IP routing, optical transmission, etc.) and each of its components. This is essential to study how networks behave, optimize their configuration and test technology. Research teams at Bell Labs, which are multidisciplinary by nature, are developing their own modeling tools to meet their specific requirements. The work of these labs focuses on three main areas: the need to develop traffic and optimize information; analysing how equipment and the cloud have been used; components and quantum computing. Tools designed in-house are first and foremost, although not exclusively, used for this type of work. But they also facilitate the work of product design teams, and are sold to certain clients who want to reconfigure their network.

An Innovation Aid

The impressive amount of data generated by using Alcatel-Lucent's equipment is fed into its traffic modeling calculations. This modeling improves understanding of user reactions during complex communications, such as watching a streaming video. Or again, it helps study the behavior of small pressure transducers that only send a single piece of information per hour. With the constant growth of data flow and the proliferation of uses, being well-informed about traffic has become an essential telecommunications issue.

As an innovation and development aid, simulation sometimes gives Alcatel-Lucent a competitive advantage. In the field of optics, the company is proud of its ability to model wave propagation. "We aren't the only ones working on this topic," admits Jean-Luc Beylat, "but thanks to this skill, we were the first to offer a 100 Gbit/s coherent solution [Ed. note: very high-speed optical network]." Alcatel-Lucent is also venturing into thermal simulation. As Jean-Luc Beylat reminds us, "Network equipment follows Moore's law. The more powerful it becomes, the more transistors it has and the more heat it emits." Energy consumption is a major preoccupation for all economic players and telecommunications companies, Alcatel-Lucent's ideal clients, are no exception to this rule.

Alcatel-Lucent is also following the example of many manufacturers by using simulation for prototype development and tests. For example, simulation is ideal for experimenting with its very long-distance undersea optical cables before they are installed between two continents. **EMMANUELLE DELSOL**

THE PROJECT TO KEEP AN EYE ON Alcatel-Lucent is continuing its work on wave propagation in very high-speed landline and mobile optical networks.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INNOVATION BEGINS WITH AN ENCOUNTER
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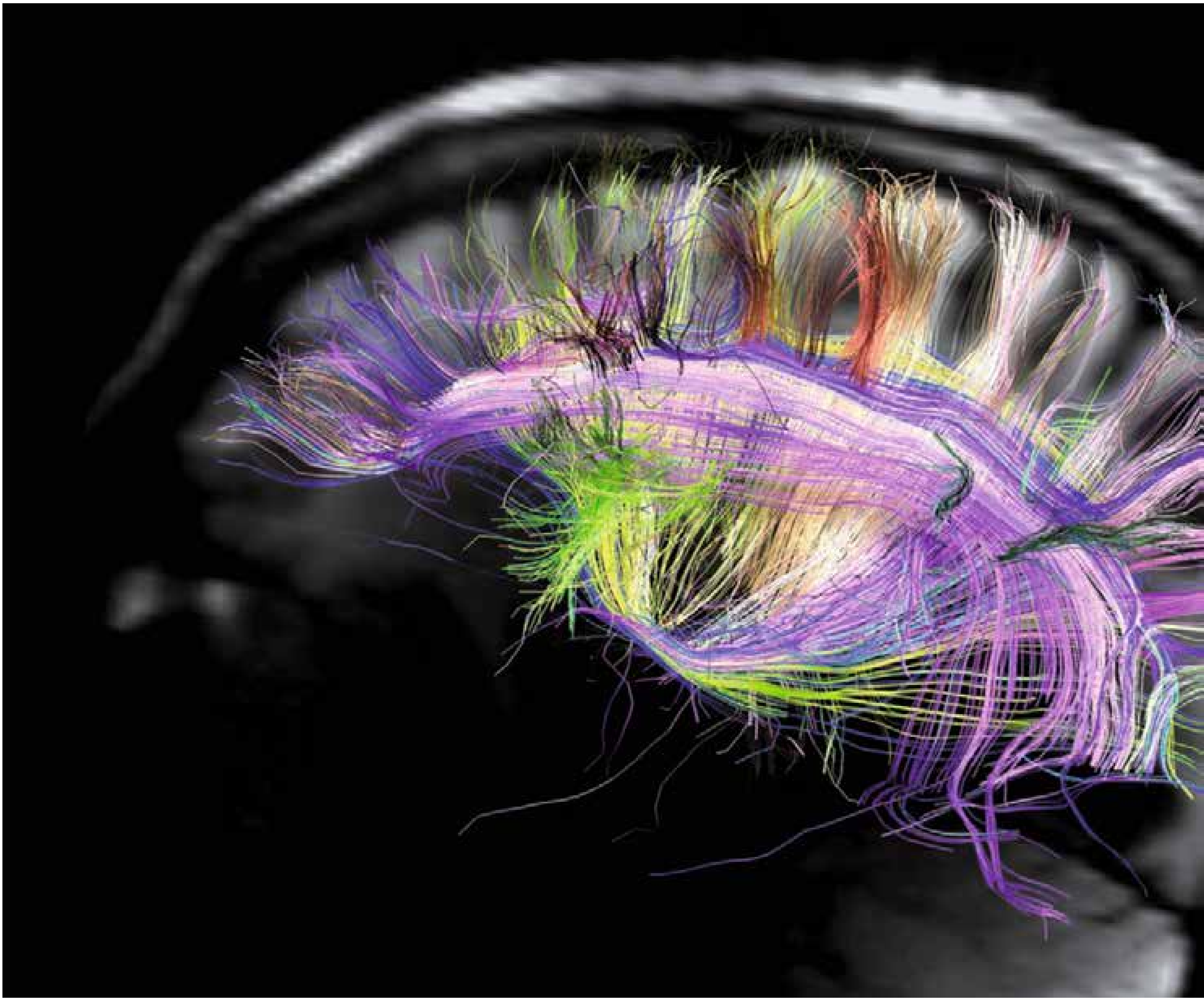


HÔPITAL GÉNÉRAL DU MASSACHUSETTS ; UIUC ; FRANÇOIS CAILLAUD SAGASCIENCE/CNRS

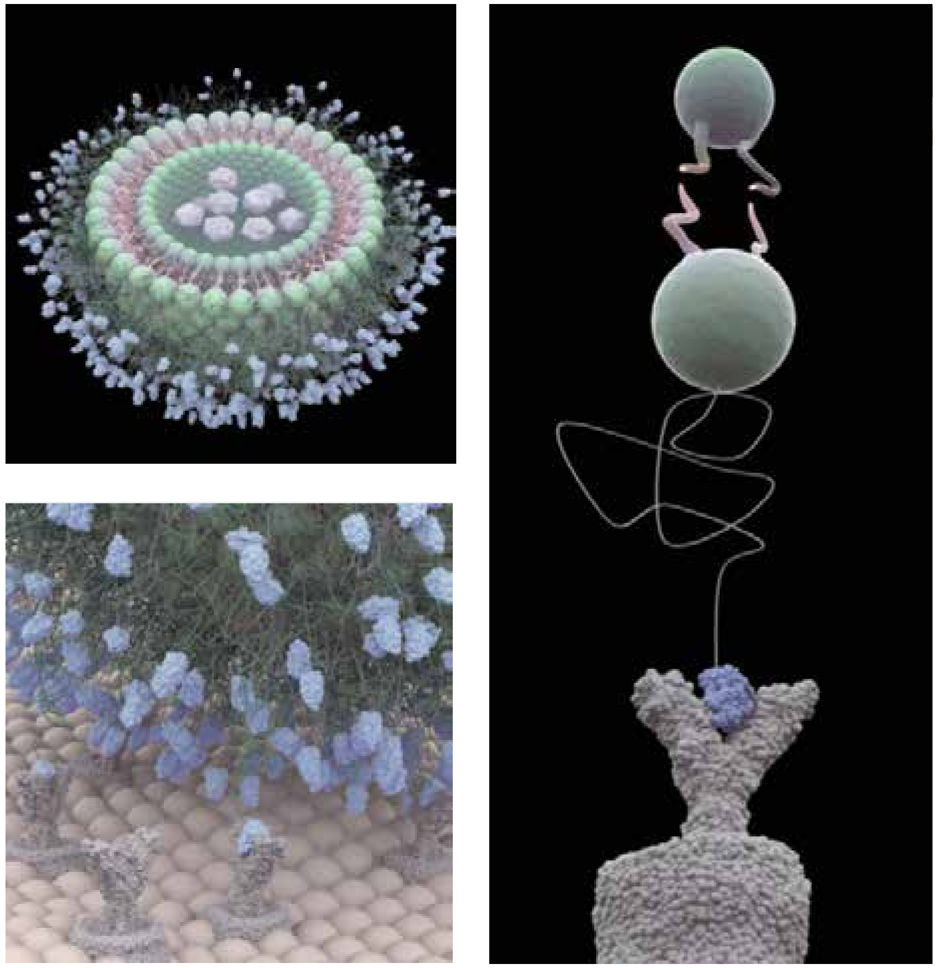
Portfolio

FROM EQUATION TO IMAGE

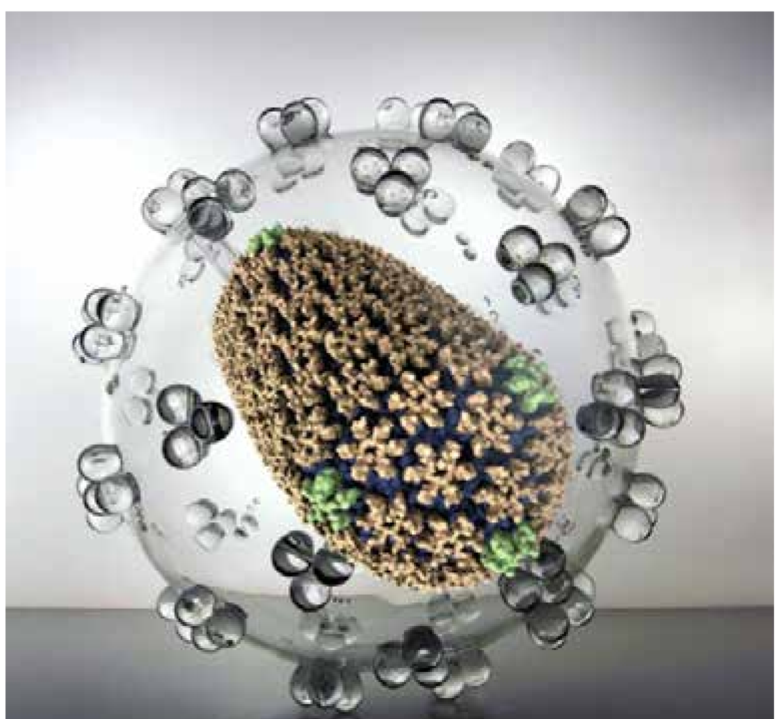
To the neophyte, simulated images may be misleading. To an expert, numerical images of physical or biological phenomena are often worth more than a thousand words.

BY AURÉLIE BARBAUX

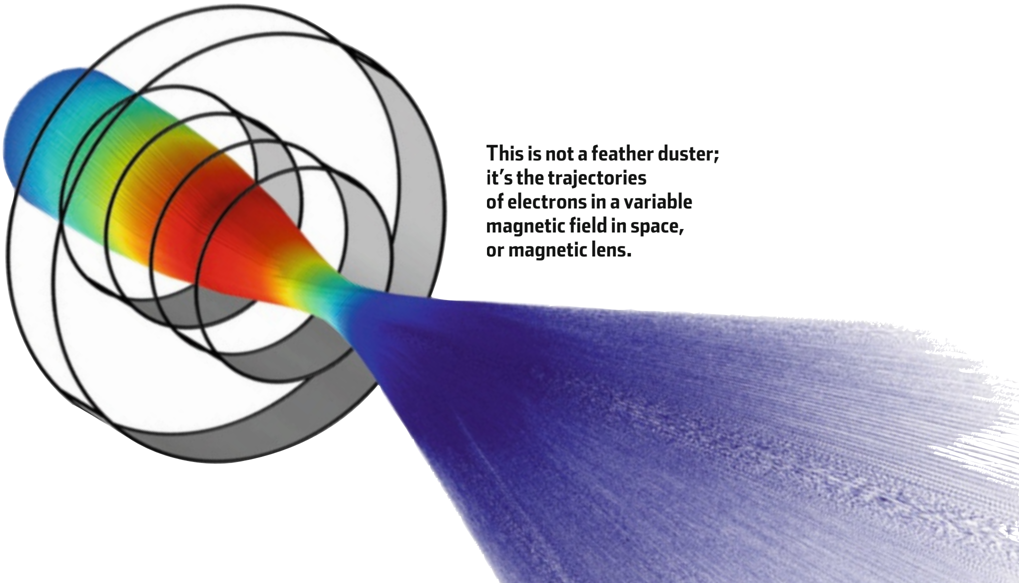
In fact, brain wiring is really quite tidy (University of Illinois).



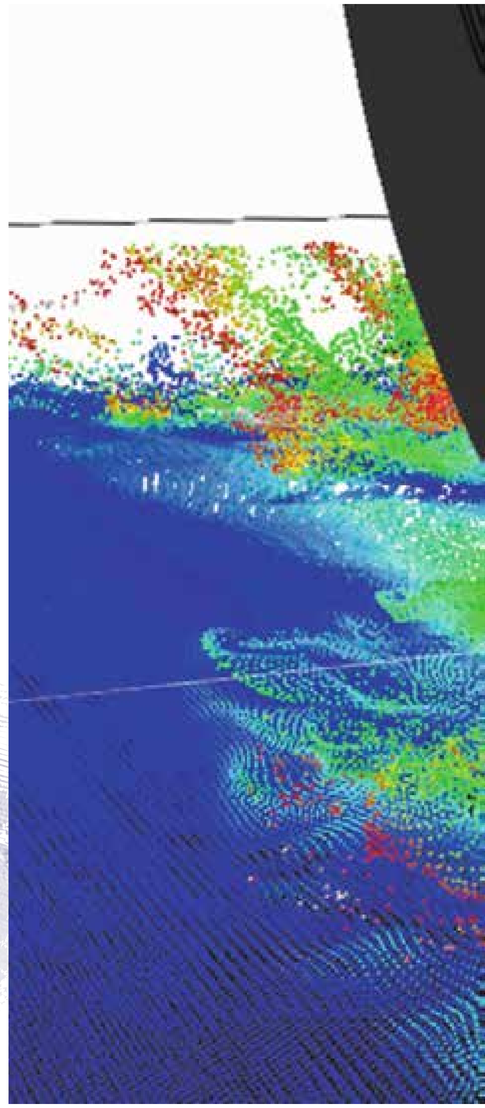
This is not a detail of a garden; it is views of a pegylated and decorated liposome (CNRS)



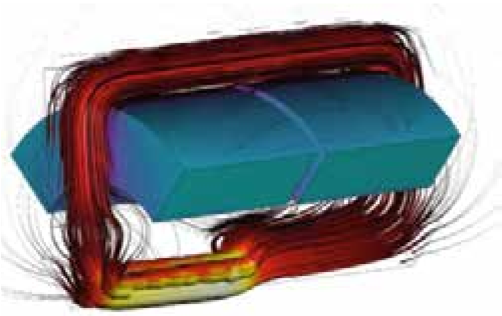
A capsid, the extremely protective transparent membrane that surrounds HIV, is not as fragile as it looks (Harvard Medical School).



This is not a feather duster; it's the trajectories of electrons in a variable magnetic field in space, or magnetic lens.

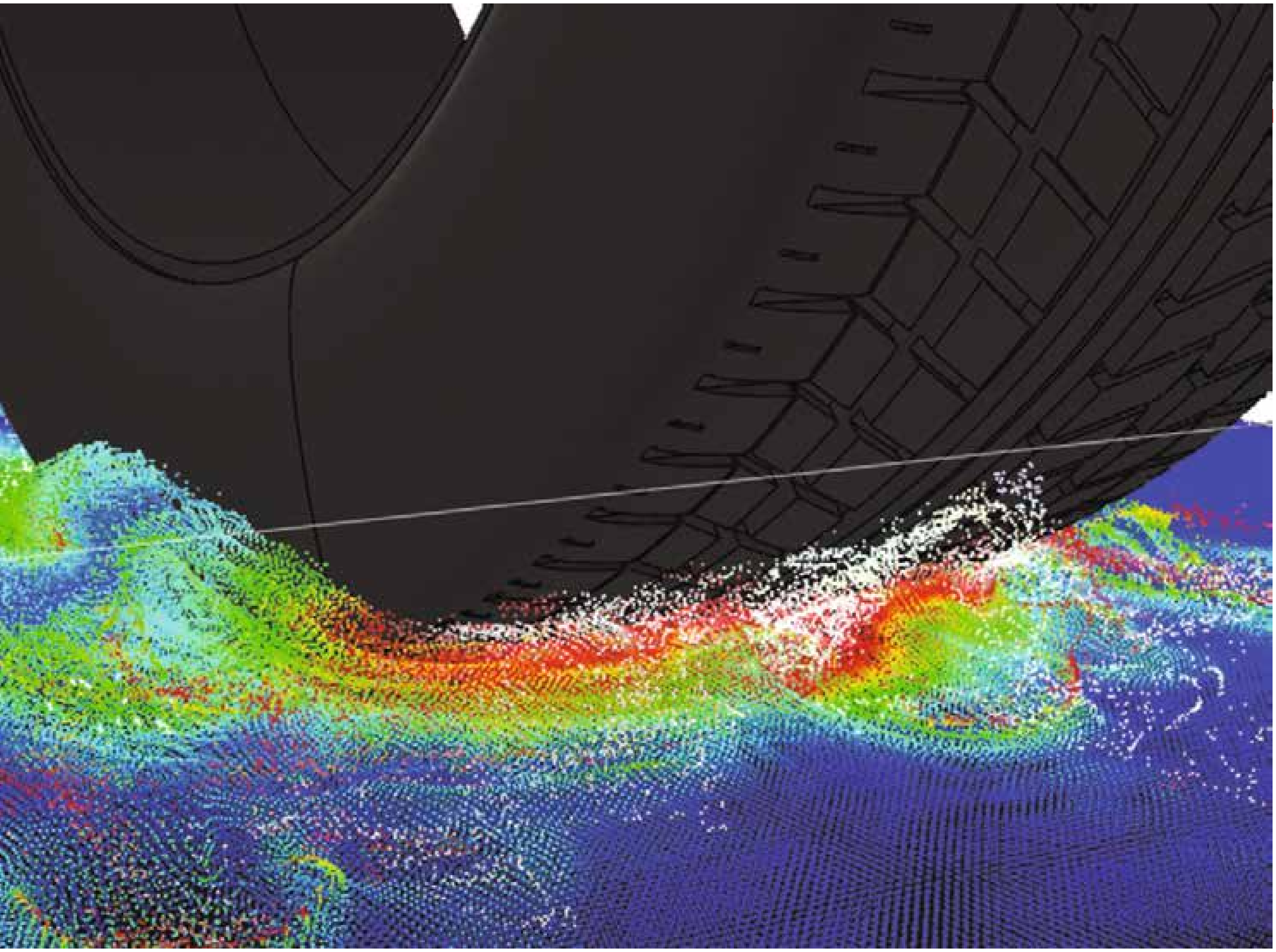


This is a study of a hydroplaning tire on a wet road (MSC Software).



Here's how temperature, produced by the alternating current in the stator coil and the induced currents in the fixation elements and rotor is distributed in an electric motor.

Never mind how they look, it's compared analysis of the near-surface flow velocity fields of existing and next generation goggles that counts (Speedo/Ansys).



MSC SOFTWARE; COMSOLS; ANSYS; V. BORRELLI, S. JABRANE, F. LAZARUS, B. THIBERT, D.ROHMER/CNRS

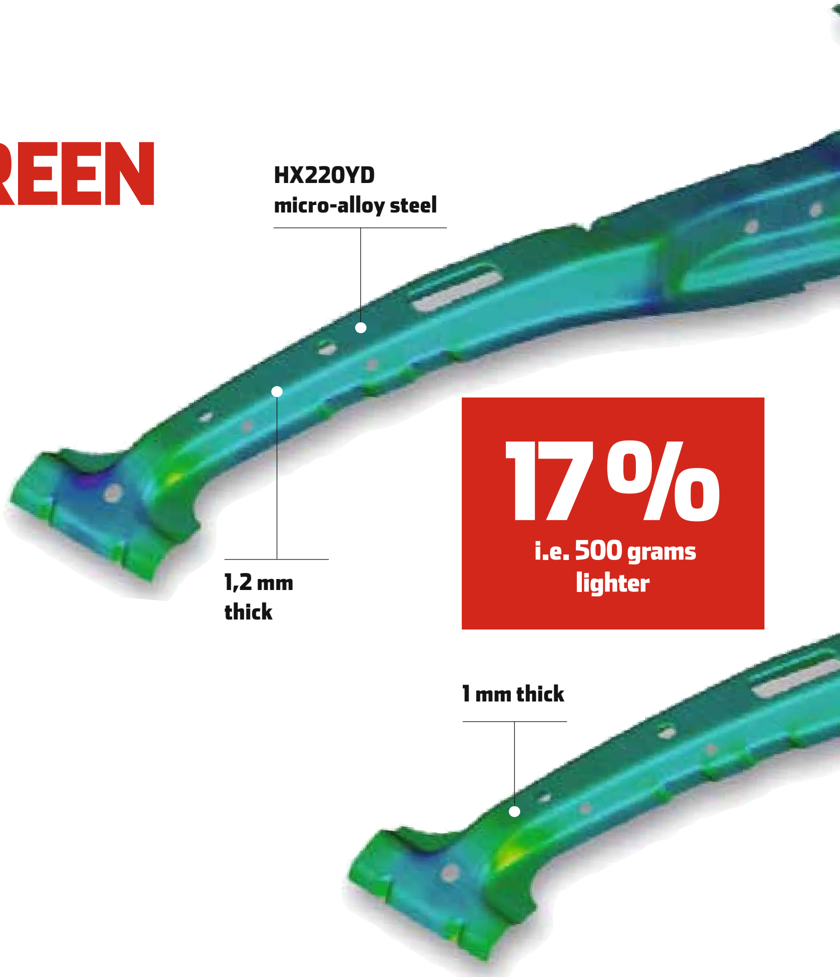
These undulating waves, called corrugations, correspond to internal and external views of the isometric extension of a 3D flat torus in ambient space. Also called smooth fractals (CNRS).

Production

MANUFACTURING PROCESSES GO GREEN

Most manufacturers are trying to limit the environmental impact of their manufacturing processes, offering a wonderful playground for numerical simulation.

BY JEAN-FRANÇOIS PREVÉRAUD



Whether constrained by regulations or cost issues, manufacturers are trying to limit the environmental impact of their manufacturing processes. They are increasingly turning to simulation to minimize the amount of raw materials used, limit scrap, reduce energy and fluid consumption, limit wear on tools, as well as take into account factors such as air conditioning, workshop lighting and odor or dust dispersion.

They are starting in the very heart of their factories. Manufacturing Executive System (MES) tools collect real production data, which is fed into numerical models used as a basis for simulation. This helps understand processes and explain occasional defects. In this way, the Italian manufacturer Tenaris has reduced the temperature for casting its petrol valve bodies by 15°C, resulting in a 15% reduction in water use and heating energy consumption.

Numerical factory software also helps to considerably reduce consumption. "Using a model of a production line enables us to know quickly every factor in the process and simulate overall optimization rather than an ad hoc juxtaposition of individual optimizations," says Hugues Drion, head of the Manufacturing Division at Autodesk France. A major German car manufacturer is also using its automated assembly line simulation software in this way to optimize consumption on its car assembly lines. "By adjusting the robots' speed so that they all complete their tasks at the same time, we have reduced rotation speed on most of the motors, thus reducing overall energy consumption on the assembly line by 50%," explains Hadrien Szigeti, a strategic analyst at Delmia.

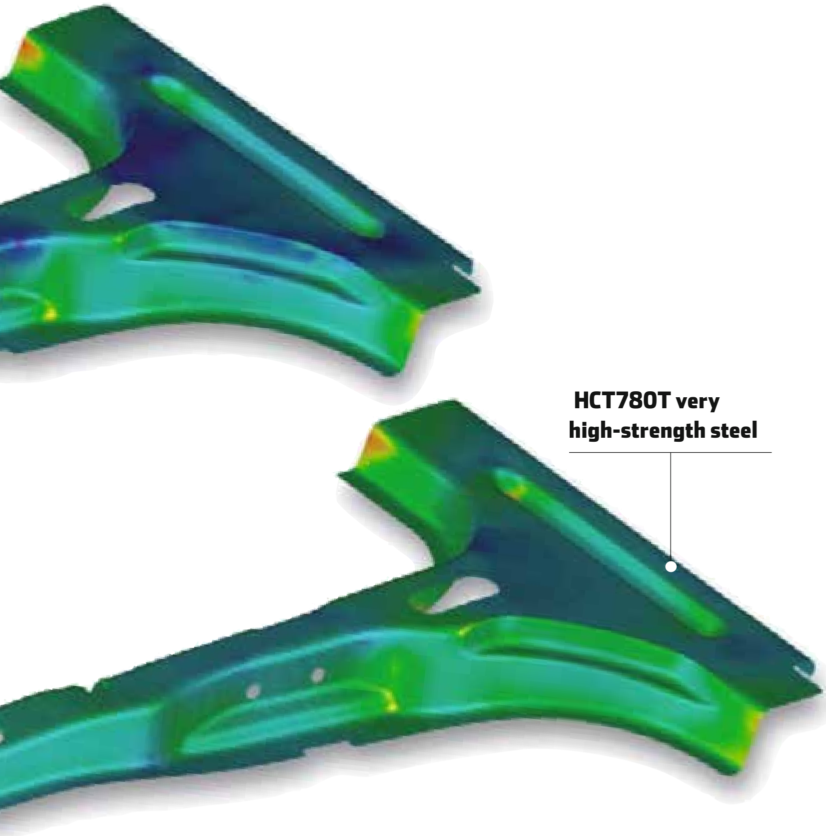
POTENTIAL SAVINGS ON…

- Energy
- Lighting
- Heating, ventilation
- Fluids (water, air, gas, etc.)
- Raw materials
- Scrap factor of finished parts
- Odors, dust
- Maintenance, dismantling work

AUTOFORM

An economically viable approach

In areas such as stamping, forging and casting, simulation is developing and improving the manufacturing processes at the same time as the parts are made. "All car manufacturers are making their vehicles lighter to ensure they achieve their targets for reducing CO_2 emissions. But they are using more effective high-strength steel or even very high-strength steel to ensure car safety," observes Vincent Chaillou, operations manager at ESI Group. Manufacturers are taking advantage of the high strength of these materials to create 'daring' parts. Hot stamping is then required, which changes the material's crystalline nature. "We are moving beyond the usual areas of work. Predicative simulation is the only economically viable means of understanding how materials behave in order to develop these new production processes," says Vincent Chaillou. Thanks to automotive constructors such as Peugeot and Volkswagen,



MAKING LIGHTER BUT NOT WEAKER

Car manufacturers are making their vehicles lighter to reduce their CO2 emissions. As here, simulation can help them validate a change of material and thickness for a body shell centre pillar, as well as the associated stamping process. Stronger materials can be thinner without the part becoming weaker.

Europe is leading the way. For casting, where the scrap factor on the most complex parts (cylinder heads, helicopter engine cases, etc.) can reach 15%, simulation is expected to bring this down quickly to less than 5%. Simulation is an economic, environmentally friendly approach. Recycling scrap also leads to additional expenditure on energy.

Simulating metal-cutting machining is also essential to reduce cycle times and ensure safe machining. "But customers are increasingly interested in reducing energy requirements. The Angel project, which we are running at Systematic with the help of manufacturers such as Airbus, Messier-Bugatti-Dowty and Snecma, is focusing on this issue," observes Gilles Battier, CEO of Spring Technologies. Simulation tools are also at the heart of businesses such as packaging. "One of our clients has used simulation to replace PET in its bottles with a biodegradable material based on corn starch. This client has successfully sized the bottles and developed the blowing/extrusion process to ensure a good balance between raw material quantity, product quality, mold lifespan, scrap reduction and lower energy requirements," explains Antoine Langlois, technical manager at MSC Software France.

But to get the best out of numerical modeling, the whole environment needs to be simulated. Optimizing a process should preferably take into account the building in which it is done as solar radiation can have adverse effects on a manufacturing process. "Aston Martin did this using Autodesk simulation tools to ensure the temperature on two aluminium panels is exactly the same when they are welded together, even though they come from different machines," explains Hugues Drion. Magna Steyr has carried out overall simulation in its car assembly factory for Minis to cut costs by 1% a year; this represents a saving of €40 million. "Simulation tools for stamping are used to work out the ideal process to obtain the best possible part while also minimizing costs. Let's not forget that raw materials represent around 80% of a part's cost. That's why manufacturers work on optimizing blanks and reducing scrap before thinking about cutting energy costs," observes Vincent Ferragu, CEO of AutoForm Engineering France.

Energy Optimization

Simulation tools currently on the market do not have a directly integrated energy optimization function. "But Comsol MVultiphysics includes a generic optimization module. This is a real toolbox, which our clients can use for energy optimization. In particular, one of our clients has used it to increase a fan's flow rate without changing its motor rotation speed. This was achieved by juggling with the blade geometry. You just have to maximize an objective function," explains Jean-Marc Petit, a manager at Comsol France. Jean-Pierre Roux, sales manager at Altair France, confirms this generic approach: "Our solutions can be used to optimize energy consumption on the production process if manufacturers have appropriate databases." Unfortunately, all too often these have not been put together. ▪

Moving towards more energy efficient buildings

The current emphasis in the building trade is on making constructions more energy efficient. "This has a major influence on our tools and working methods. Using 3D numerical models helps ensure consistency and that nothing is forgotten. It also means we can get everyone involved working at the same time rather than in sequence," explains Thierry Rampillon, an architect at Cr&On. "This enables us to cost out a project from the word go, ensuring a level of performance that we stick to. In the relatively near future, we will obviously also be able to simulate and optimize the environmental cost of a construction. We are already better at controlling the quantities of raw materials required, which limits waste." ▪

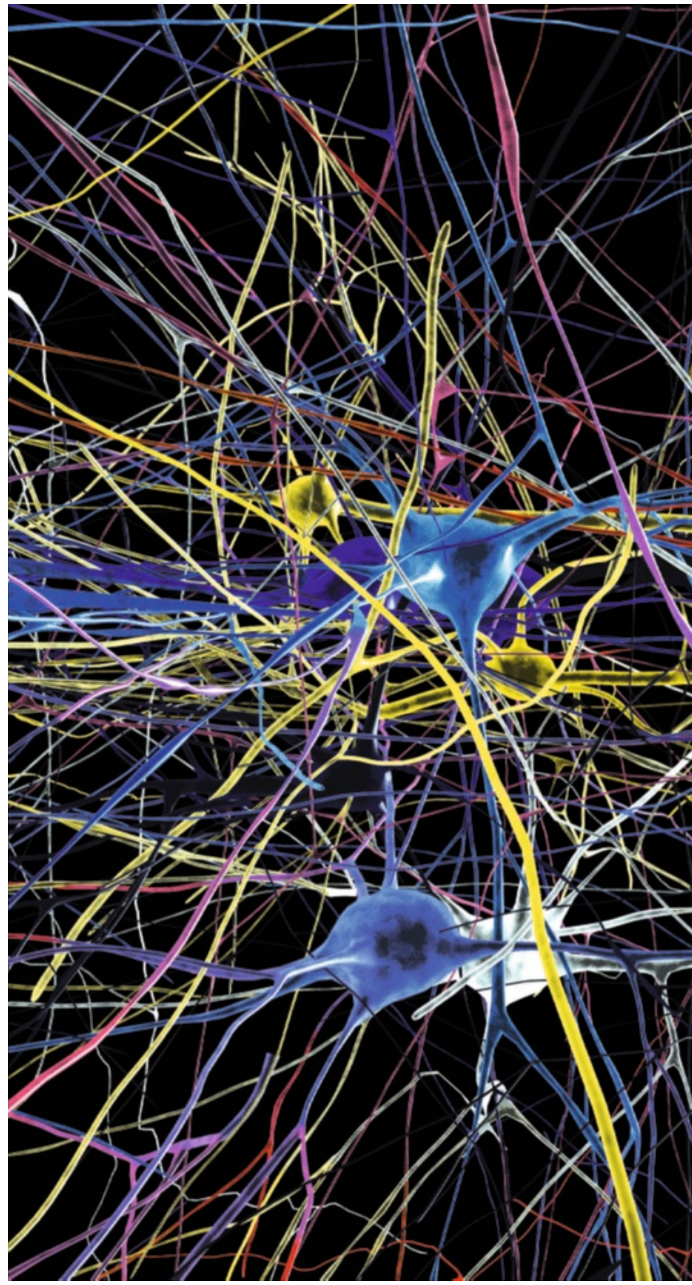
Research

GIANT-SIZE PROJECTS

Simulation is playing an increasingly important role in major scientific research projects, whether to elucidate abstract questions or provide answers to public health issues.

BY THIERRY LUCAS

People may wonder if running ultra-powerful computers to find out whether it is going to rain tomorrow is absolutely essential. But when it comes to predicting global warming, rising temperatures and their consequences for the world in the next century, few question their usefulness. The scale and stakes of this task justify mobilizing the world's most powerful supercomputers and hundreds of researchers. But weather and climate issues are not the only emblematic fields for mass scientific computing. Computer methods are used in many disciplines, often because simulation enables virtual experiments that would otherwise be difficult or impossible to perform. This is the case for the European Human Brain project, which relies on simulation to optimize treatments for neurological diseases. Developing the future ITER nuclear fusion reactor is requiring physicists to carry out intensive virtual physics while they wait for the prototype. And although astrophysicists using simulation to understand the structure of the universe are not working directly to make our life more comfortable in the future, their research is helping define the supercomputers of tomorrow's world.

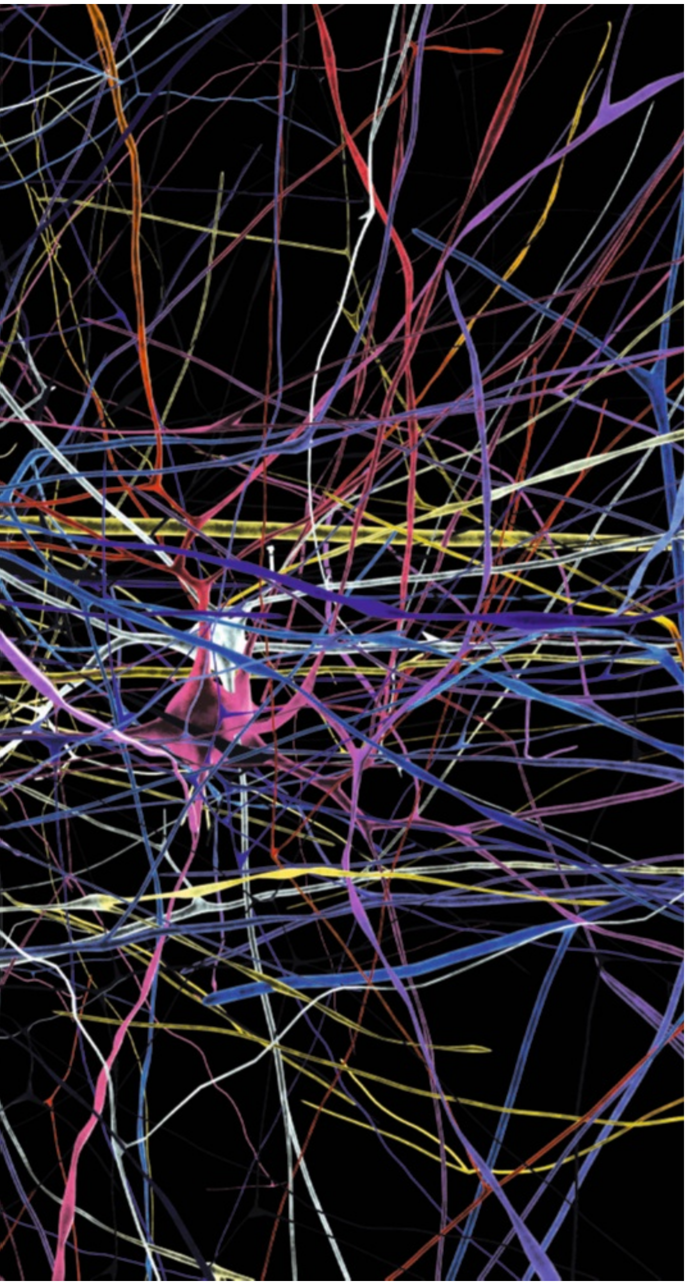


DEUS CONSORTIUM; DR

UNDERSTANDING BRAIN ACTIVITY

This is the most ambitious simulation project ever launched. It involves reproducing the complexity of the human brain on computers. Part of the Human Brain Project (HBP), with an allocation of 1 billion Euros over ten years, it is jointly managed by the École Polythechnique Fédérale de Lausanne (EPFL) (Swiss Federal Institute of Technology in Lausanne) and Heidelberg University in Germany. It aims to elucidate how our brain works, with implications expected in the fields of neuroscience, medicine and computer science. In silico experiments [Ed. note: 'using computer simulation'] will give neuro-researchers a deeper understanding of brain functions. Doctors will be able to use brain simulations to recreate diseases, research their causes and determine the right treatment. Computer science, which plays a key role in this research, is expected to benefit from new computer architecture, which should then enable currently impossible tasks to be carried out.

The HBP consortium (80 partners) has launched several sub-projects simultaneously to achieve all these advantages. The first involves gradually building a software platform by continuous integration of biological research data. The platform will use supercomputers to simulate the structure and behavior of a brain. It aims to identify the neurone architecture responsible for specific functions, and make the connection between these mechanisms and certain neurological and psychiatric illnesses. The HBP is not starting from scratch and follows in the footsteps of the Blue Brain project, run by the EPFL. In 2012, this project carried out a simulation involving one million neurones and one billion synapses. In other words, equivalent to the brain of a bee.

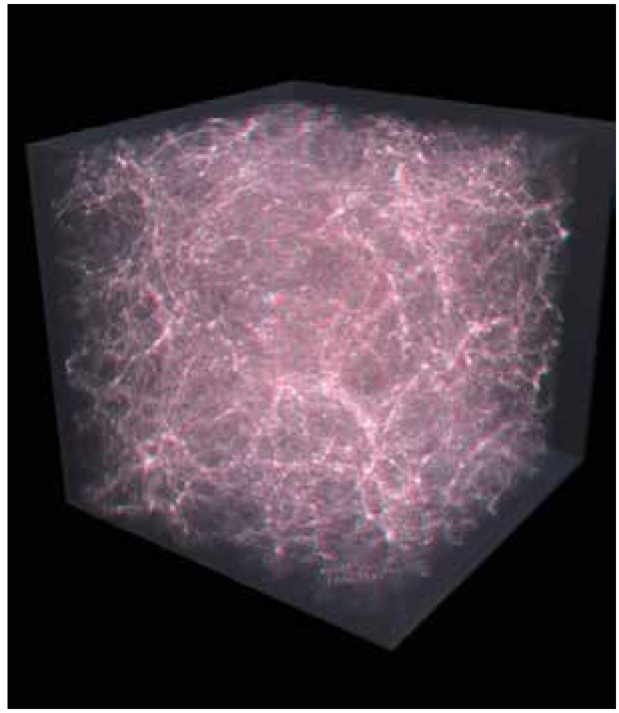


86 billion. That's now many neurones need to be modeled to reproduce the human brain.

The initial target for the new project is a rat's brain, i.e. 21 million neurones. Some 86 billion neurones will need to be modeled for a human brain. Initially, the HBP is expected to use supercomputers available in Europe, before building its own computing facilities at the Jülich Research Centre in Germany: 50 petaflops for 2017-2018, followed by an exaflop supercomputer (i.e. 1000 petaflops) planned for 2021-2022. The project's final aim is to design and build two 'neuromorphic' computers. These computers will operate completely unlike traditional computers, which consist of processors and memories. 'Neuromorphic' computers aim to produce a physical copy of neurone networks in the human brain.

CUTTING-EDGE LABORATORIES

IInstitute for Advanced Simulation, Jülich (Germany)
School of Computer Science, Manchester University (UK)
Kirchhoff-Institut für Physik, Heidelberg University (Germany)



A cube whose edges are 93 billion light-years long, to see the big bang.

UNRAVELLING THE STRUCTURE OF THE UNIVERSE

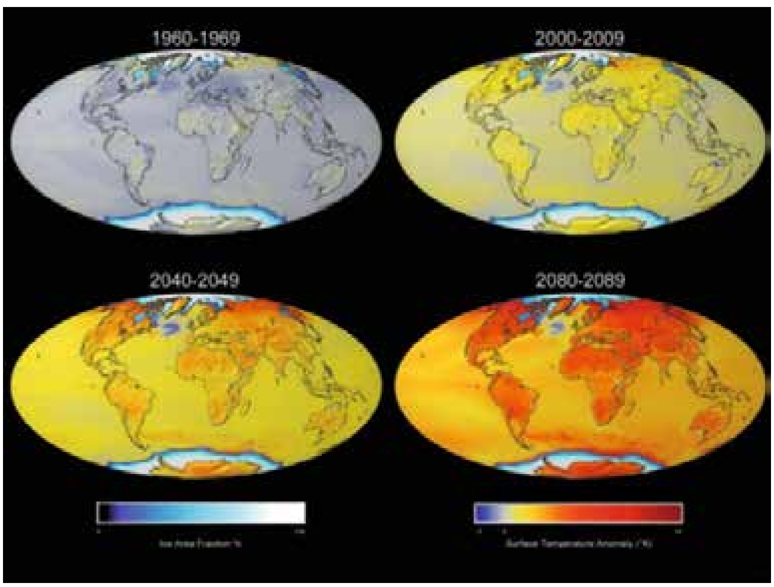
It would be difficult to go any further. The Dark Energy Universe Simulation-Full Universe Run (DEUS-FUR) project run by the Universe and Theories Laboratory (LUTH) at the Paris Observatory has simulated the entire observable universe, from the big bang to the present day. And the figures provide plenty to think about. The simulations carried out brought into play 550 billion particles, each with a mass equivalent to the mass of our galaxy, in a cube whose edges were 93 billion light-years long. The project aims to answer a fundamental question of cosmology: why is the expansion of the universe accelerating? According to this theory, 95% of the universe consists of invisible components, called dark matter and dark energy. This mysterious dark energy is said to be responsible for the accelerated expansion. Understanding dark energy would help us understand the structure of the universe (the distribution of galaxies), and vice versa.

Three simulations were carried out on the CEA's (French Alternative Energies and Atomic Energy Commission) Curie supercomputer, according to three different models. This generated a total of 1.5 petabytes of data, which now needs to be interpreted. Researchers want to know the best model for understanding dark energy, and what the consequences of this understanding would be for cosmology theory. This type of simulation has been carried out previously on a smaller scale by other laboratories, notably at the Korea Institute for Advanced Study and the Max Plank Institute for Astrophysics (Germany). In March 2013, six laboratories in the USA, managed by the Argonne National Laboratory, with the help of simulation on the most powerful computers available, launched a three-year project to track down dark energy.

The teams are determined to optimize computational codes, to adapt them to the computers that will be running them. "In projects like these, it isn't just about computing power: at the same time, you also need to worry about memory and data management, inputs-outputs, etc.," explains Jean-Michel Alimi, director of research at the CNRS, who is in charge of DEUS. But changing a code becomes very difficult when you want to change the physical modeling, or when the program needs to be adapted to new supercomputer architecture. When today's researchers design codes, they must be careful to keep modeling completely separate from specifically computer-related aspects. Furthermore, these simulation results need to be useful for space observation projects, which are also looking for dark energy. This applies whether the projects are carried out using land-based telescopes, like the Dark Energy Survey, an international project launched in Chili in September 2013, or satellites, like the European Space Agency's Elucid project, which is due to be launched in 2020 using a Soyuz space rocket. ∎

CUTTING-EDGE LABORATORIEST

Universe and Theories Laboratory (LUTH), Paris Observatory (France)
Argonne National Laboratory, Department of Energy (USA)
Max Planck Institute of Astrophysics (Germany)



CMIP5 refines meteorological forecasting software and makes it more reliable.

WORLD CLIMATE RESEARCH PROGRAM

PREDICTING CLIMATE CHANGE

In September 2013, the first part of the fifth Intergovernmental Panel on Climate Change (IPCC) report confirmed climate change predictions up to the end of this century. Depending on the scenario contemplated, temperatures could rise by 5°C and ocean levels may rise from 25 cm to almost 1 meter (the most pessimistic view). The report confirmed the significant impact of human activity on these changes. The conclusions are based on measurements and observations made worldwide, and on planet-scale numerical simulations. The stakes are high; around twenty research groups have risen to the challenge. Researchers are developing physical models of the various factors influencing climate: the atmosphere, continents, oceans, pack ice, etc. and, of course, humans, who cause the greenhouse effect and manufacture aerosols. These models are then assembled, coupled and assisted by supercomputers to produce data on changes in temperature, rainfall, etc. Although the development of different models has been disorganized (there are around forty of them), world experts have agreed on how to test them. The Coupled Model Intercomparison Project (CMIP5) has thus enabled results obtained using all these models to be compared on the same simulation 'exercises'.

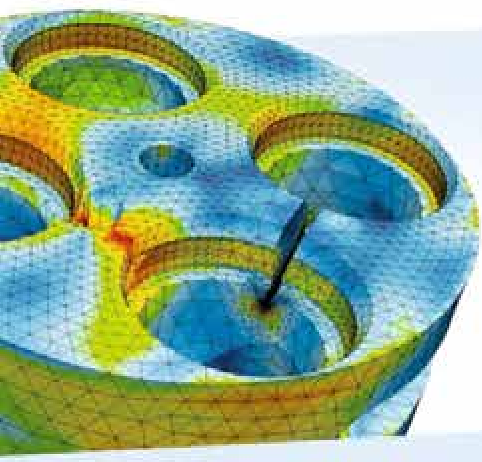
In France, two climate systems have been developed simultaneously: one by Météo France (French national meteorological service), and another by the Institut Pierre-Simon Laplace (IPSL) (Pierre-Simon Laplace Institute). The overall aim of comparative tests is to make simulation results more reliable and, in the long term, to converge the various models. This is currently being done for flow phenomena, which are governed by the laws of fluid mechanics. The difficulties – and disparities – are far more apparent when other factors (radiative transfer, chemistry, etc.) are modeled, or with what takes place on a smaller scale, below the chosen calculation mesh, which divides the atmosphere into units several tens of kilometers long. "Tests carried out as part of the CMIP5 are enabling some models considered inappropriate for a given phenomenon to be rejected, but not to determine the best model," points out Jean-Louis Dufresne, head of the IPSL's climate modeling center. All the teams are working to reduce the uncertainty hanging over simulation results, even though the chaotic nature of the climate means this cannot be completely eliminated. Furthermore, simulation programs themselves need to be updated to make the most of new massively parallel computer architecture. ∎

CUTTING-EDGE LABORATORIES

Institut Pierre-Simon Laplace (France)
Max Planck Institut für Meteorologie (Germany)
Hadley Center for Climate Prediction and Research (UK)
National Center for Atmospheric Research (USA)
Geophysical Fluid Dynamics Laboratory, Princeton (USA)

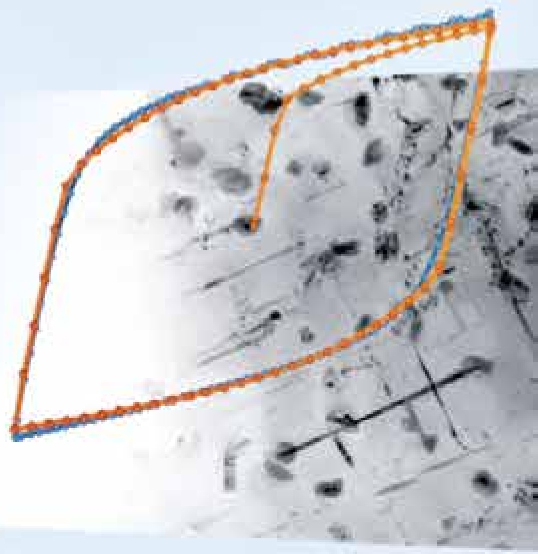
NONLINEAR MATERIAL MODELS IN **AUTOMOTIVE DESIGN** WITH Z-SET SOFTWARE

Automotive equipment and car manufacturers need robust estimations of the forces and deformations in critical parts. French automotive industry leaders **MONTUPET** and **Renault** use **Z-set** code in their advanced applications for material damage, aging or crack simulations.



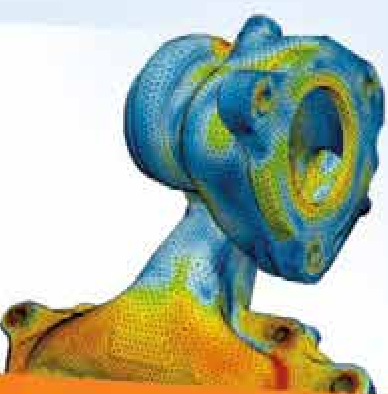
The thermal cycles applied to cylinder heads of car engines generate a plastic deformation field, which might induce crack initiation.

Renault and **MONTUPET** cooperated with **Z-set software** developers in order to create efficient simulation tools to predict crack formation, its propagation path and its possible arrest in presence of thermomechanical cyclic loading. These simulation tools are used at the industrial design stage.



Aluminum alloys constituting the cylinder heads undergo operating temperatures close to their initial heat treatment conditions.

The resulting changes in microstructure are reflected in a very significant decrease of the mechanical strength (up to 50% variation). This process is included in thermo-metallurgical models, which impact the regular non-linear mechanical behavior.

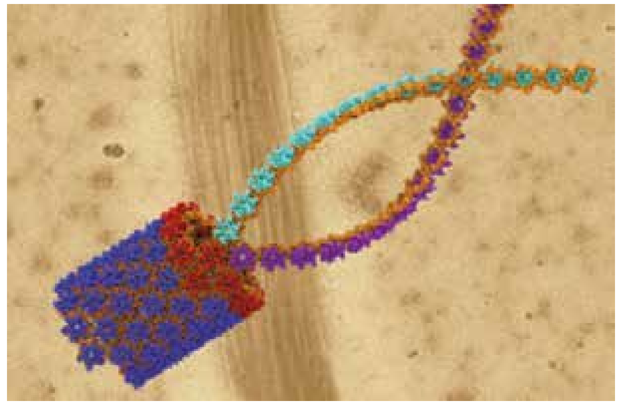


The **"downsizing"** process causes a significant increase of operating temperatures of the engine, so that the exhaust systems become sensitive parts.

They need therefore a more accurate lifecycle assessment, which involves cyclic plastic deformation. The lifetime is estimated using specialized models that simultaneously take into account the effect of cycles and dwell time.

www.zset-software.com Zset-software is developed at the **Center of Materials of Mines ParisTech** and **ONERA**, the **French Aerospace Lab**

ELUCIDATING A COMPONENT OF THE HIV VIRUS

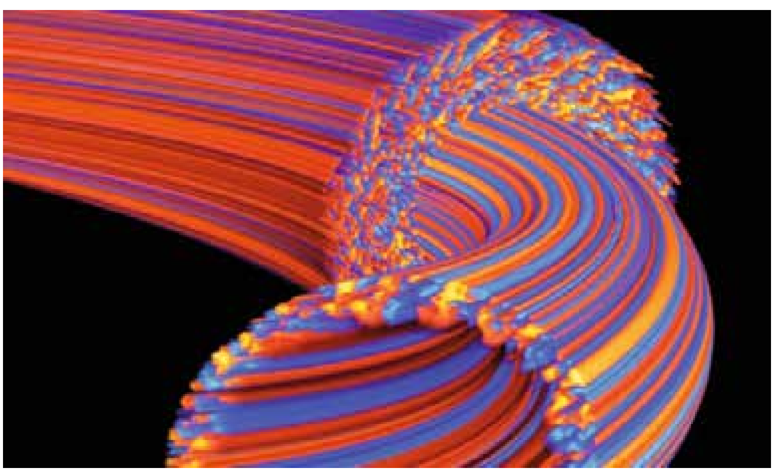


The chemical structure of the HIV virus capsid was determined using the Blue Waters supercomputer.

An advance in AIDS research — Researchers at the University of Illinois in Urbana-Champaign (UIUC) have fully reproduced the structure of the capsid, the protective shell for genetic material in the HIV virus that opens to release material into cells. This capsid is an assemblage of 1,300 proteins, representing 64 million atoms. It is one of biggest atom-level simulations ever carried out. All that was known of this capsid were the parts observed experimentally using tomography, nuclear magnetic resonance, etc. Elucidating its complete structure should help improve understanding of the mechanics of HIV virus action, and work out new techniques to fight it. But in order to achieve this, researchers had to wait for a generation of supercomputers possessing power in excess of petaflops, such as the Blue Waters supercomputer at the National Center for Supercomputing Applications (NCSA), which is one of the most powerful computers in the world. The American team designed a simulation using experimental data on capsid components to build the complete model. Previous research had shown that capsid proteins are organized into hexagons and pentagons. But researchers still had to determine the best structure to build a closed shell. Today's researchers will need greater computing power, especially to reproduce dynamic phenomena such as capsid formation and behavior. Researchers have so far only simulated for periods lasting a few microseconds, whereas the biological processes involved last several seconds or even minutes.

CUTTING-EDGE LABORATORIES

Department of Physics, UIUC (USA)
Department of Structural Biology, Pittsburgh University, with the National Center for Supercomputing Applications (USA)



Plasma reactions can be simulated using the Curie supercomputer.

PREPARING THE ENERGY OF THE FUTURE

A mixture of atomic nuclei and electrons, whose temperature reaches 150 million degrees in the center and contains vortices throughout-- A number of teams across the globe are working to model how this unusual plasma medium behaves. Plasma is needed to trigger the fusion reaction between deuterium and tritium, two isotopes of hydrogen. From 2040 onwards, this reaction may be a source of potentially unlimited energy. ITER, the future experimental nuclear fusion reactor, is already under construction in Cadarache (Bouches-du-Rhône). But physicists need to learn how to control the reaction medium. Experiments on tokamaks, the devices in which plasma is confined, have allowed them to make progress. Simulation has a role to play in getting ITER up and running. Its plasma chamber will be ten times bigger than the plasma chamber of the biggest tokamak currently in existence. In 2012, the French CEA-INRIA (Institute for Research in Computer Science and Automation) team, which uses the Gysela computational code, reproduced the turbulence in the plasma. This is a key factor in the future reactor's efficiency since turbulence is to blame for heat loss between the magma's core and edges. A world first achieved at the cost of making some simplifications, and with a plasma volume 25 times lower than in the ITER. The calculations were done on the Curie supercomputer at the CEA's Very Large Computing Center in Bruyères-le-Châtel. Research is now focusing on modeling plasma physics and on optimal use of supercomputer parallel architecture. It aims to remove the simplifications and model the entire ITER plasma chamber. Simulations carried out on 450,000 processor cores are already programed. Computers planned for 2020 should be able to align over 1 million simulations.

CUTTING-EDGE LABORATORIES

CEA-INRIA (France)
École Polytechnique Fédérale de Lausanne (Switzerland)
Max Planck Institute of Plasma Physics (Germany)

Success-story

OPTIS, THE HYPERREALIST

This French SME designs optical simulation tools that takes into account the physics of light and materials' surfaces.

PAR JEAN-FRANÇOIS PREVÉRAUD

Bentley Motors is using Optis software in its virtual reality center to create a real-time validation chain of the driver's immediate environment in its cars.

One of the most significant features of our media-dominated society is the power of images. A good image can swing a decision in favor of one project and spell the end of another equally viable one. "But these images still need to match reality. We use our software to make things look realistic rather than just pretty," explains Jacques Delacour, the founder and president of Optis, a software vendor in Toulon specializing in optical simulation. "When we create computer-generated images, we work on real renderings of the chosen materials under fixed lighting conditions. The real scene will look like a screen image. That's the secret of our success."

These simulations that come very close to reality are the fruit of almost three decades of research, initiated by Delacour. They are based on a simple premise: light is energy rather than mere geometrically propagated rays. To produce a realistic simulation, you need to take into account physics of both light itself, and of the surfaces of the objects it lights up.

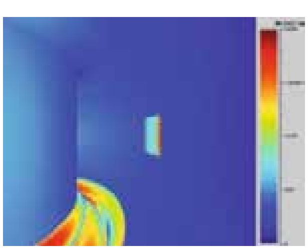
Delacour began by developing algorithms to simulate radiation using Monte Carlo methods [Ed. note: calculating a numerical value using probability techniques]. But he soon focused on studying light energy in optical systems, looking at radiation and spectrum, and including how light-energy reflecting surfaces behave. To do this, he used the bidirectional reflectance distribution function (BRDF), which describes the appearance of materials in terms of their interaction with light at each point on their surface. Other simulation software vendors wishing to simplify the calculations did not use this notion of energy.

These light/material interactions drove Optis engineers to become interested in geometric modeling of objects and hence in CAD. They then created computer-generated images to validate simulation results. This is how SPEOS software came to be launched on the market in 1994.

Prediction by Age Bracket

Studying light energy has also enabled development of a human vision model. Optis went back to Yves Le Grand's abacuses. According to the amount of light energy in a spectrum, these abacuses predict what, and with what degree of sensitivity, the human eye will see. Optis added a visual perception layer, which gives the image's spectral radiance.

Controlling ITER's light energy



OPTIS

The ITER program [see page 32] integrates optical simulation developed by Optis. Plasma circulating in the core of the ring-shaped magnetic containment vessel is a mixture of two hydrogen isotopes (deuterium and tritium), heated to temperatures in excess of 150 million degrees. This plasma emits very intense light, comparable to sunlight. It is reflected by the internal wall to prevent any absorption, which would cause fusion of the reactor shell. Optical cameras measure two pieces of information to control this reaction: light emitted by the plasma itself, i.e. the signal, and the plasma's reflection in the walls, which is called 'noise'. Using simulation to separate out these two pieces of information is easily done, and gives a better understanding of how the plasma will behave.

"The eye is sensitive to this magnitude. Depending on the spectrum of an image's pixel and its energy level, as well as the age of the person looking, there will be glare that changes how objects are perceived," explains Delacour. "In the car industry, for example, this is used to predict how well people in different age brackets will see and read light information according to its type, color, and illumination level, or to determine how much discomfort is created by a reflection."

In partnership with several business clusters, Optis has kept this technology at the heart of its R&D programs since 2005. The MARVEST project, run with the Mer Méditerranée innovation and business cluster, is a hyperrealistic, multi-sector ship-steering simulator, which evaluates users' reactions to glare or changing weather conditions. The second project, Virtu'ART, backed by Pôle Pégase (an aerospace cluster in Provence), Airbus Group and Airbus Helicopter, uses digital mock-ups to manipulate ultra-realistic, real-time visual renderings in an immersive virtual reality system. These projects have brought hyperrealistic, real-time simulation out of the laboratory, leading Optis to develop an industrial platform based on 3D animation technology produced by the SimplySim start-up, which Optis acquired in 2011.

Moving in this direction has boosted the company's growth: it has expanded from 40 to 120 people - mainly R&D engineers - in five years. Today, the car industry represents over half of its sales. All manufacturers in this sector use Optis software to design their vehicle headlights, signal lights, and dashboards. High-end car manufacturers use it to validate perceived quality, notably for evaluating gap and flush on bodywork that varies depending on the chosen paint color.

From Realistic to Real

In this field, Optis acquired the British software vendor Icona Solutions and its Aesthetica software at the end of 2013. This is specialist software for 3D visualization of the impact of manufacturing tolerances on the perceived quality of assembled end products. For example, the biggest car manufacturers (Nissan, GM Opel, Fiat, Chrysler, Porsche, and Bentley) use it to inspect gap and flush on their vehicles, a determining factor in car buying decisions. Since mastering the physical behavior of light and materials is integral to the Optis offer, they produce real 3D-model images, moving in real time and in complex environments, rather than merely realistic images. The software is also very popular in the electronics sector as it helps improve management of flat-screen backlighting energy and facilitates the transition to LED. In industry, the US Air Force uses the software to validate its pilots' anti-glare sunglasses by parasitic lasers. The CEA (French Atomic Energy and Alternative Energies Commission) uses it to establish what the optical control system will see of nuclear fusion in the ITER reactor core. "These applications are about to come out of design and engineering offices and go to end users. Thanks to configurators, it will be possible to use them with clients for visual validation of choices they make from among the numerous options they are offered. It won't matter whether we are dealing with aircraft, cars, or control rooms," predicts Delacour.

The boss who brings your projects to light

JACQUES DELACOUR,
founder, president, and CEO of Optis

An entrepreneur through and through, this engineer first developed photometric calculation software and then integrated it into CAD tools. Today, it is used everywhere to assess the perception and visual comfort of human-machine interfaces.

Luminous and radiant. Two terms that perfectly describe Jacques Delacour when he is talking about his passion: optical simulation. When in 1985 the fates of the entrance exams sent this son of an engineer to the Ecole Supérieure d'Optique de Paris (Paris Higher School of Optics) rather than Supélec (French graduate school of engineering), he was surprised by the paucity of existing optical software. So he sat down in his student room and designed – in between building synthesizers, laser harps, and other mixing consoles – more effective algorithms to monitor light-ray propagation in lenses. He continued this work in a junior enterprise (a non-profit organization managed by students, providing services for businesses whose activities are related to the students' field of study). This junior enterprise was studying the light flow received by an optical fiber sensor containing several emitters and a single receiver on behalf of Crouzet, an automation control component manufacturer. Delacour then became interested in 'energy photometry', which quantifies light energy emitted by a source, analyzes how it is carried through an optical system, and assesses the flow collected by a sensor. An entrepreneur through and through, as soon as he graduated in 1989, Delacour set up Optis to market the fruit of his first research on light energy in optical systems. Since light interacts with objects, Delacour soon made the leap from photon transport to computer-generated images, which for him must be an exact representation of how light reflects on 3D objects. They must also take the physical characteristics of light (radiation, spectrum, etc.) and the surfaces on which it impacts (reflection factor, etc.) into account. In 1994, this research resulted in the light simulation software SPEOS, which was integrated into the main CAD tools on the market. Delacour is passionate about research and remains at the heart of Optis' technology. A vintage car enthusiast and occasional airplane pilot, he knows how to delegate and trust his collaborators. His charisma, candor and open-mindedness as well as the human values he conveys have earned him the respect of his team.

Research Department

PROFITING FROM HIGH-PERFORMANCE COMPUTING

Numerical simulation can be a tool for SMEs to achieve competitive advantage. Although the transition is not easy, a network of experts is at hand to help them.

BY THIERRY LUCAS

Numerical simulation is not for us!» For many small and medium-sized enterprises, high-performance computing is synonymous with overcomplicated software and exorbitantly priced supercomputers that only the major groups can master and afford to purchase. Nevertheless, simulation helps speed up and improve product design, and can be a tool to achieve competitive advantage. For SMEs, however, this is a demanding, strategic commitment. The HPC-SME initiative run by the French National High-Performance Computing Organization (GENCI) and the French Institute for Research in Computer Science and Automation (INRIA), with financing by the French public investment bank Bpifrance, aims to give SME's easier access to high-performance computing (HPC).

1 DEFINING YOUR PROJECT AND IDENTIFYING THE ISSUES

In this little-known field, SMEs need help identifying their numerical simulation needs, as well as the financial, technical and human resources they can invest in it. This is the main role of the HPC-SME initiative. «There is a wide range of profiles, from business start-ups to companies already using HPC on a workstation. Our role is also to direct them to the right people,» says Brigitte Duême, in charge of HPC-SME at INRIA. The hpc-connexion.org website should make it easier to put businesses in touch with experts and researchers. Even 'initiated' users need to determine their project's issues.
For the Franco-Belgian engineering company GDTech, which employs 130 people, including around thirty in France, simulation is already part of the company's business. But this SME wants to draw up a HPC offer that is independent of its clients' computers (clients predominantly in aeronautics), using national and regional computing centers and its own resources. The strategic issue being diversifying its business beyond aeronautics. HydrOcean, an SME that is itself a fluid mechanics software vendor, wants to adapt its computational code to parallel computers based on graphics processing units (GPUs). «The idea is to divide computing time by five or ten and thereby convince new clients beyond our original maritime sector,» says Erwan Jacquin, HydrOcean's president. Using HPC may also be linked to setting up a business, as in the case of Q-Hedge Technologies. The company developed a financial consultancy website aimed to make decision-making tools hitherto reserved for experts available to the general public.

2 FINDING SKILLS

Defining a project may result in employing an expert. Generally speaking, the transition to HPC leads to hiring someone. Danielson Engineering, began using simulation several years ago to design car engines, hired a computer scientist. This was to create skills interfaces easily accessible to the company's engineers. Parallelization of HydrOcean's software also required hiring a new expert, even though the company employs 20 engineers. Some companies also use the HPC-SME network. For example, Entares (Nexio Group), an electromagnetism simulation (antennas, radar signatures, etc.) software vendor. «HPC-SME has opened up doors to us at IBM and Fujitsu for carrying out tests on machines. This would otherwise be impossible for an SME,» emphasizes Frédéric Amoros-Routié, Nexio's president. It is good to acquire skills, but even better to keep them. «Unlike a major group, we can't afford to lose an expert or two,» says Rui Da Silva, head of computational design at Danielson Engineering. So what should SMEs do? Avoid concentrating expertise in a given field in a single person and most importantly, entrust experts with real responsibilities so that they will want to stay.

3 CHOOSING HARDWARE AND SOFTWARE

Should you purchase a 'heavy duty' computer or rent power? There are many possible solutions, depending on the needs and financial resources of each SME. «Be careful though, using external equipment may be problematic for confidential contracts. And bandwidth for some remote computing may be expensive,» points out Rui Da Silva. But the key issue is software costs. «The price of large software packages, with a license fee dependent on how many computing cores are used, is completely unsuitable for an SME

THE HPC-SME PROGRAM

Le Genci, INTRIA and Bpifrance (ex-Oséo), together with the Aerospace Valley, Axelera, Systematic, Minalogic and Cap Digital business clusters, have launched the HPC-SME Initiative. Their aim, to give SMEs greater access to high-performance computing via innovative projects generating business competitiveness. Access available throughout their research work. The challenge is to engage SMEs in broaching the issue of high-performance computing. This will be achieved by helping them evaluate its relevance from the perspective of their growth model.
The program also aims to enlist support for SMEs from high-performance computing professionals, and help them put together their R&D programs.

JEAN-CLAUDE CHAUDY

As in the case of Danielson Engineering, the shift to HPC can be a marketing asset.

with two computing projects a year,» laments INRIA's Brigitte Duême. The solution is cloud computing software, charged on a pay-as-you-go basis. Entares is among the small software vendors who have started this. An offer developed with the Midi-Pyrénées Computing Center (CALMIP) is due to begin in 2014. But regular users such as GDTech must make do with licenses for large software packages, which are essential to work with major contractors. This Franco-Belgian company also uses open-source software, although only for R&D, and is co-developing certain specialized codes.

4 MAKING HPC INTO A STRATEGIC TOOL

Moving into numerical simulation costs time and money: there is no point in starting it for a one-off project. Nevertheless, HPC can become a real strategic tool. The diversified HPC offer set up by GDTech should help land more comprehensive engineering contracts, by transferring computing hitherto done by its clients. Danielson Engineering regards its simulation skills as a commercial argument and a development tool. «Our offer is enriched by every new task a client entrusts us with. This opens the door to other clients for us. That's the ideal scenario,» says Rui Da Silva. Success with this is quite rare among French SMEs. The second phase of the HPC-SME initiative, launched in 2013, aims to use major contractors to stimulate interest in high-performance computing among sub-contractors. In particular, this will be achieved via business clusters and other collaborative organizations. There is also a plan to set up 12 regional centers, to listen to what SMEs need.

Tools

EVERY AREA OF PHYSICS HAS ITS SOFTWARE

Remaining faithful to reality means respecting the laws of physics. And these are many, as are the number of computational codes. Here is an overview.

BY JEAN-FRANÇOIS PREVÉRAUD

Almost everything can be simulated. From pre-dimensioning in the preliminary project stage to end-of-life cycle dismantling. No other single tool covers such a wide range of uses. This explains the vast number of simulation tools and stakeholders on the market. As a consequence, a process of consolidation has been under way for some time. To make sense of all this, these tools can be divided into two main families: one for product-related aspects and the other for processes. Each can be classified by the main areas of physics dealt with. Furthermore, some software vendors are coupling tools from different fields, giving rise to what is called multiphysics simulation. The final category is open-source software, which is all the rage with academics and researchers.

COUPLING WITH CAD

All the main CAD software vendors include a computing and simulation option, of varying degrees of complexity, with their design offers. Some pre-dimensioning modules are integrated directly into design tools, with verification tools forming separate packages. These verification tools are very product-design focused: Simulia from Dassault Systèmes, NX Simulation from Siemens, Creo Simulate from PTC, and Simulation from Autodesk and SolidWorks. They include basic tools for structural and fluid mechanics, heat transfers, and composites. These offers are constantly changing as new technology is acquired.

Nevertheless, computing remains a specialist business. Experienced, general software vendors have extended their offers so that they are present in almost every field. Frequently, they have acquired small, specialized software vendors, taken over their technology and integrated it into their own software suites. Examples of this include Altair, Ansys, Comsol, ESI Group, and MSC Software, etc. Alongside these software vendors, there are a vast number of specialized software vendors, such as AutoForm Engineering for car-part stamping or Cedrat for electromagnetic simulation.

Segula Technologies would never have been able to design its hybrid vehicle prototype without a simulation tool.

TOOLS FOR PRODUCTS

We should mention a few software vendors and their products in this family, according to the area of physics dealt with. The software most used is for structural mechanics (Mechanical from Ansys; Abaqus from Dassault Systèmes; MSC Nastran; Creo Simulate from PTC; NX Simulation from Siemens, etc.); fluid mechanics (Fluent from Ansys; Star-CD from CD-adapco, etc.); heat transfers (Icepak from Ansys; MSC Sinda, etc.); dynamics (MSC Adams, etc.); acoustics and vibrations (MSC Actran; VA One from ESI, etc.); electrical engineering and electromagnetics (HFSS and Maxwell from Ansys; Flux 2 D/3 D from Cedrat; and CEM Solutions from ESI, etc.).

Many software packages deal with specific areas of physics, such as combustion (Forté, Energico and Chemkin from Ansys and Reaction Design; Fire from AVL, etc.); optics and visualization (Speos from Optis, etc.); fatigue (Castor Fatigue from Cetim; MSC Fatigue, etc.); control systems and mechatronics (Scade and Simplorer from Ansys; LMS Imagine.Lab; MapleSim from MapleSoft; MatLab and Simulink from MathWorks; MSC Easy5; MathCAD from PTC, etc.); and crash simulation (Pam-Crash from ESI, etc.).

Remaining faithful to reality sometimes means different solvers are required. For example, to study the effects of temperature or vibrations on a loaded structure. In this case, several areas of physics are used and multiphysics simulation comes into play. The leaders in this type of modeling are: HyperWorks from Altair; Multiphysics from Ansys; Comsol Multiphysics; Abaqus from Dassault Systèmes; Virtual Try-Out Space from ESI; and SimXpert from MSC.

The Curie supercomputer, at the French Atomic Energy and Alternative Energies Commission's site in Bruyères-le-Châtel, is serving SMEs.

TOOLS FOR PROCESSES

The second family of tools is for processes. Which apart from machining simulation – encompass milling, turning, drilling, grinding, and electrical discharge machining, on two to five or more axes, using software tools such as NCSimul from Spring Technologies or Vericut from CGTech – processes are the prerogative of specialized software vendors or specific modules in general offers. These deal with stamping and cutting (Stamping Adviser from AutoForm Engineering; Pam-Stamp from ESI, etc.); tube bending and hydroforming (Pam-Tube from ESI, etc.); casting (ProCast and QuickCast from ESI, etc.); hot- and cold-forming (Forge from Transvalor, etc.); welding (Weld Quality from ESI, etc.); composite materials (Pam-Form and Pam-RTM from ESI; e-Xstream Digimat from MSC, etc.); and plastics engineering (MoldFlow from Autodesk; Simpoe-Mold, etc.).

ELECTRONICS, BUILDING AND PUBLIC WORKS SECTOR

So far, we have looked at the types of simulation used in fields closely related to mechanical engineering. Electronics modeling is just as complex, and calls on design-tool software vendors with offers integrating analog, numerical, and mixed simulation, such as Cadence Design Systems, Mentor Graphics, and Synopsys. There are also a number of specialists in niche tools, which have a very short life cycle. The building and public works sector also has its own simulation tools, which deal with specific issues. For example, lowering loads between stories, or the use of materials such as reinforced concrete. An example is Advance Design software from Graitec. ■

TERATEC PUTS HPC WITHIN REACH

As part of a Supercomputer French industrial renewal project, Teratec intends to focus its attention on SMEs, helping them make use of high-performance computing and simulation.

After big companies, make way for SME's. "The Supercomputer project is one of 34 Nouvelle France Industrielle [New Face of Industry in France] projects, and has been entrusted to our president, Gérard Roucairol. Its main goals are to accelerate diversification in simulation use, disseminate it within French industry, and provide engineers with appropriate training. We will therefore be at the heart of structuring and guiding a community of industrial simulation users, especially SMEs, which are the fabric of French industry," explains Hervé Mouren, Teratec's director. Since its establishment in 2003, the Teratec Association has been managing a high-performance computing (HPC) ecosystem.

For the past ten years, Teratec has been working with large industrial users and technology sector SMEs offering hardware, software, and service solutions. In short, HPC aficionados. "It's now time for us to turn to SMEs, both current and future simulation users," says Mouren. This is an ambitious task since it concerns every sector of the economy. Transportation, of course, but also food-processing, chemistry, medicine, cosmetics, and materials, etc. Teratec intends to introduce SMEs to HPC, and provide support within their business context. How? "We will be relying on the big users, since it is in their interest for their industrial partners to acquire more skills in this area. We will also be turning to skills clusters and industrial technical centers connected with the main areas of industry, which also want to help their affiliates make progress. Furthermore, these centers are found everywhere, meaning we will be able to go into the regions and come right to these companies' doorstep." Support will be provided by setting up service facilities, for which Teratec could act first as a catalyst generating interest in HPC and then as a market place. ■

SOLIDWORKS; BULL

UTC

The University of Technology of Compiègne's Innovation Center cost 13 million euros and houses a virtual reality room.

Jobs

A LONG CHAIN OF SKILLS

Mathematicians, engineers and computer scientists are combining their expertise to design and use numerical simulation tools.

BY CÉCILE MAILLARD

In the beginning was the number. "Numerical simulation consists of studying how materials behave by means of equations." This is the definition given by François Costes of NAFEMS, an association providing support for manufacturers using simulation. A long chain of expertise is involved before a company receives answers to its questions about how a system behaves. Mathematics, physics and computer science are used in succession and in combination throughout this long, circuitous process. "The most important skill is knowing how to bring these various skills together," says Georges-Henri Cottet, director of AMIES, a labex supported by the CNRS (French National Center for Scientific Research) aiming to bring companies and mathematics closer together.

In the first stage scientists (physicists, biologists, geologists, etc.), set out their expectations. They may want to study a material, the planet or a core. Or perhaps simulate a structure's fatigue or optimize an object's weight. As in a laboratory, it is up to engineers, or graduates with masters in physics (sometimes PhDs) to provide the parameters and physical laws.

These expectations are then expressed as equations. This stage is pure mathematics. Complex modeling is carried out by mathematicians with a master's or PhD in scientific computing, or by engineers specializing in mathematics. Pure mathematicians are found widely in public laboratories. With the exception of a few R&D departments at the big groups, they are rarer in private companies.

It is only then that applied mathematicians get involved, converting this mathematical description of a material's behavior into numerical language. They are sometimes called scientific computing engineers or numerical analysts. At software vendors, IT services companies and the big groups, they are called development engineers when they make ongoing improvements to software packages. They obviously have IT skills, although computer scientists may take over from them in large organizations.

Mechanical Engineering, the best training option

These stages may be done by software vendors, who recruit mechanical engineers and computer scientists for development work. More rarely, they also recruit mathematicians for additional expert assistance on an occasional basis. Pierre Eliot is the senior technical sales manager at Simulia, Dassault Systèmes' range of software for realistic simulation. "To build the software itself, we enlist developers with strong skills in theoretical mathematics and computer science, as well as physicists. They are often PhD graduates. For customer contact work before and after making a sale, we mainly employ mechanical engineers. They tend to be generalists, with degrees from the Grandes Écoles (prestigious higher education establishments in France). The only highly technical staff we employ are those designing components or validating systems for our customers." Eliot himself is a mechanics and numerical mathematics graduate of the École Centrale de Lyon. At Altair, the HyperWorks suite software vendor, "We need people with a very good understanding of physics," explains Boris Royer, the technical manager. "When we recruit a mathematician for development work, he or she must be very good at physics."

The aeronautics entity of Sopra Group engineering, based in Toulouse, makes extensive use of simulation. "Our specific use is systems modeling," says François-Marie Lesaffre, the head of simulation. "We seek a balance between general engineers, automation engineers (who do modeling), and aeronautical engineers, who understand the underlying systems."

Simulation requires enormous computing capacity. IT systems engineers – or scientific computing design engineers – and high-performance computing project managers are needed for these computers; they run the supercomputers, choose their architecture and work on complex industrial projects.

Are any special skills required to use this software? "Simulation is becoming increasingly accessible and you would think it could be entrusted to technicians. But supercomputers are forever producing results. You need engineers to study them critically," says Professor Alain Rassineux of the Université de Technologie de Compiègne (UTC), who is head of the numerical mechanics team at the Roberval Laboratory (CNRS-UTC). He believes that manufacturers are very keen on mechanical engineers with a sound knowledge of mathematics. This skill enables them to handle simulation tools. But increasingly, companies need physicists. "Previously, some tasks could be entrusted to mathematicians or computer scientists. Due to the growing complexity of the physical phenomena studied, this is no longer possible."

Researchers, especially at the École Centrale de Nantes, are trying to develop models with simplified equations to obtain answers in real time. We are far from having explored the behavior of materials from every angle. Engineers recruited at Dassault Systèmes must know how to couple various areas of physics. There are many opportunities for physicists who are good at mathematics. Or for mathematicians who are good at physics.

« Building via simulation is magical! »

BILAL BENDJEFFAL,
aged 26, structural computing engineer at Altair

"I learnt my job by specializing during the third year of engineering school (ENIVL). Although I am not part of the software development team at Altair, I work on its use. I help clients validate their project before they buy software. Afterwards, I can provide further information if they come up against a difficulty, and can slightly change the software if need be. Sometimes you have to carry out a project for the client. In my team, we work in every sector but each with our own specializations. I am an optimization expert. For example, I look for what shape to give a part according to the various constraints and objectives. Increasingly mind-blowing computing facilities mean this job is changing all the time. I still find it magical to see an actual product that was built using simulation!"

THREE MAIN TRAINING ROUTES

● Engineering Degree
Grandes Écoles offering general mathematics and applied mathematics, or Grandes Écoles specializing in numerical mechanics or simulation (UTC, Eisti, Insa Lyon, Estaca, Ensimag, SupMeca, Enseirb-Matmeca...).

● Master's
Universities: applied mathematics, numerical simulation, modeling and scientific computing.
Engineering schools: École Centrale de Nantes, UTC, École Centrale de Paris.
Dual training: Paris-Saclay University.

● PhD
Simulation is one of the rare fields in which PhD graduates are highly prized by private companies. All engineering schools and specialized master's in simulation provide the opportunity to pursue PhD studies.

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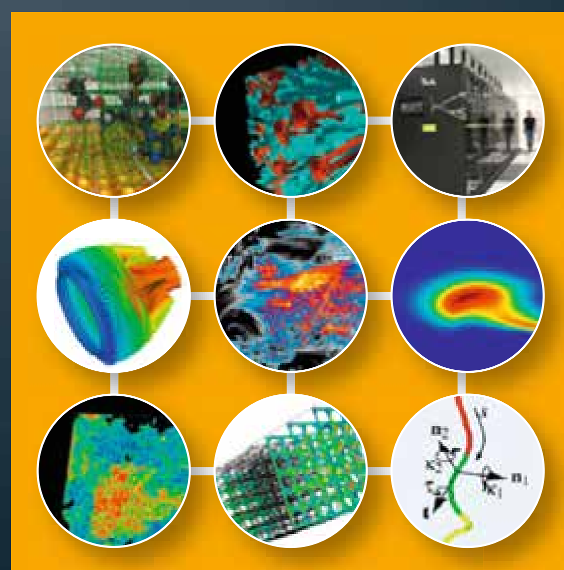

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